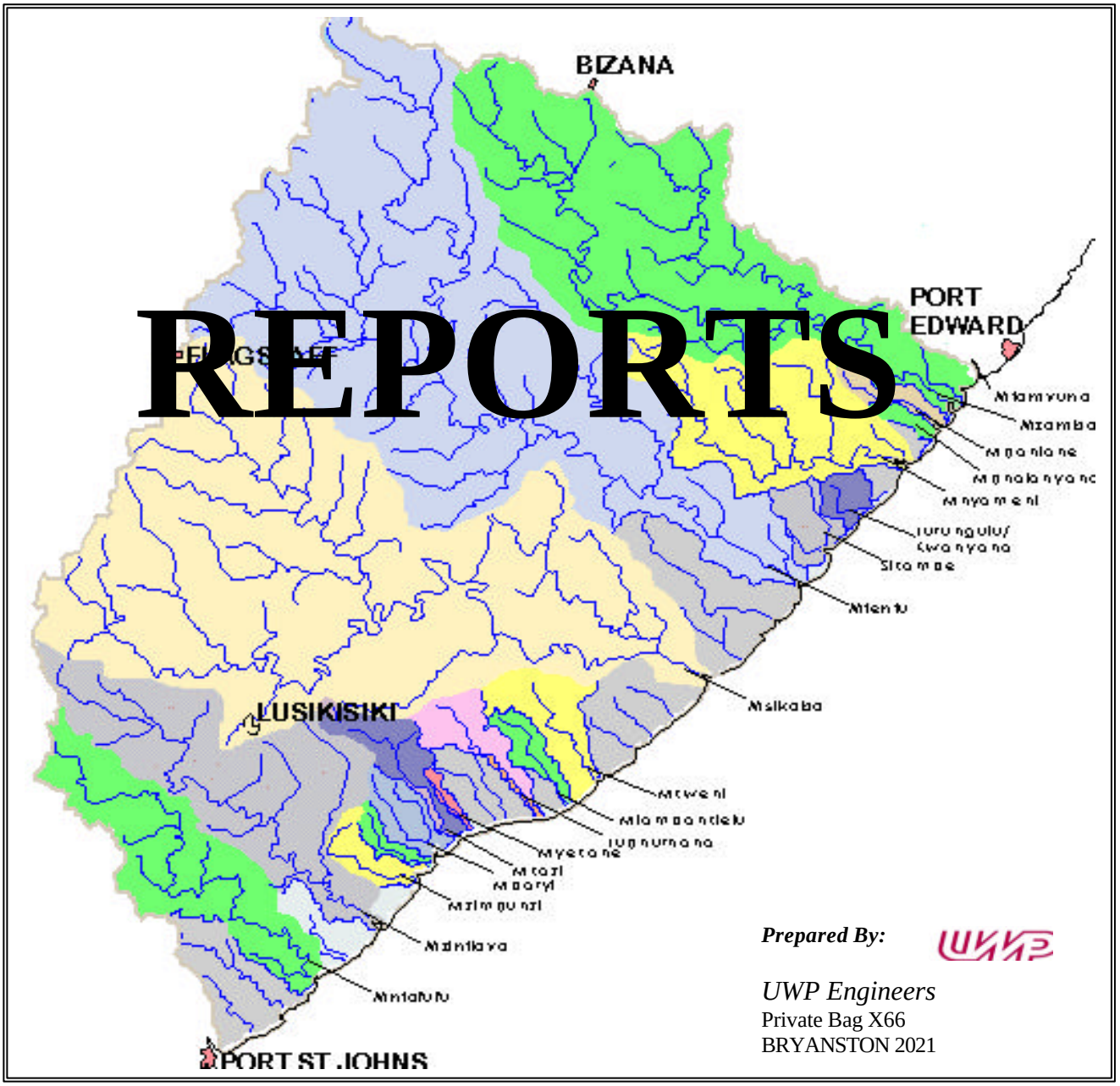
STEP 1. CLICK ON the "Show / Hide Navigation" icon on the toolbar.....

STEP 2. Click on "READ ME" for browsing instructions.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY

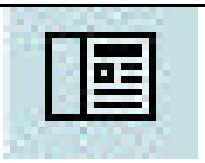


REPORTS

Prepared By:

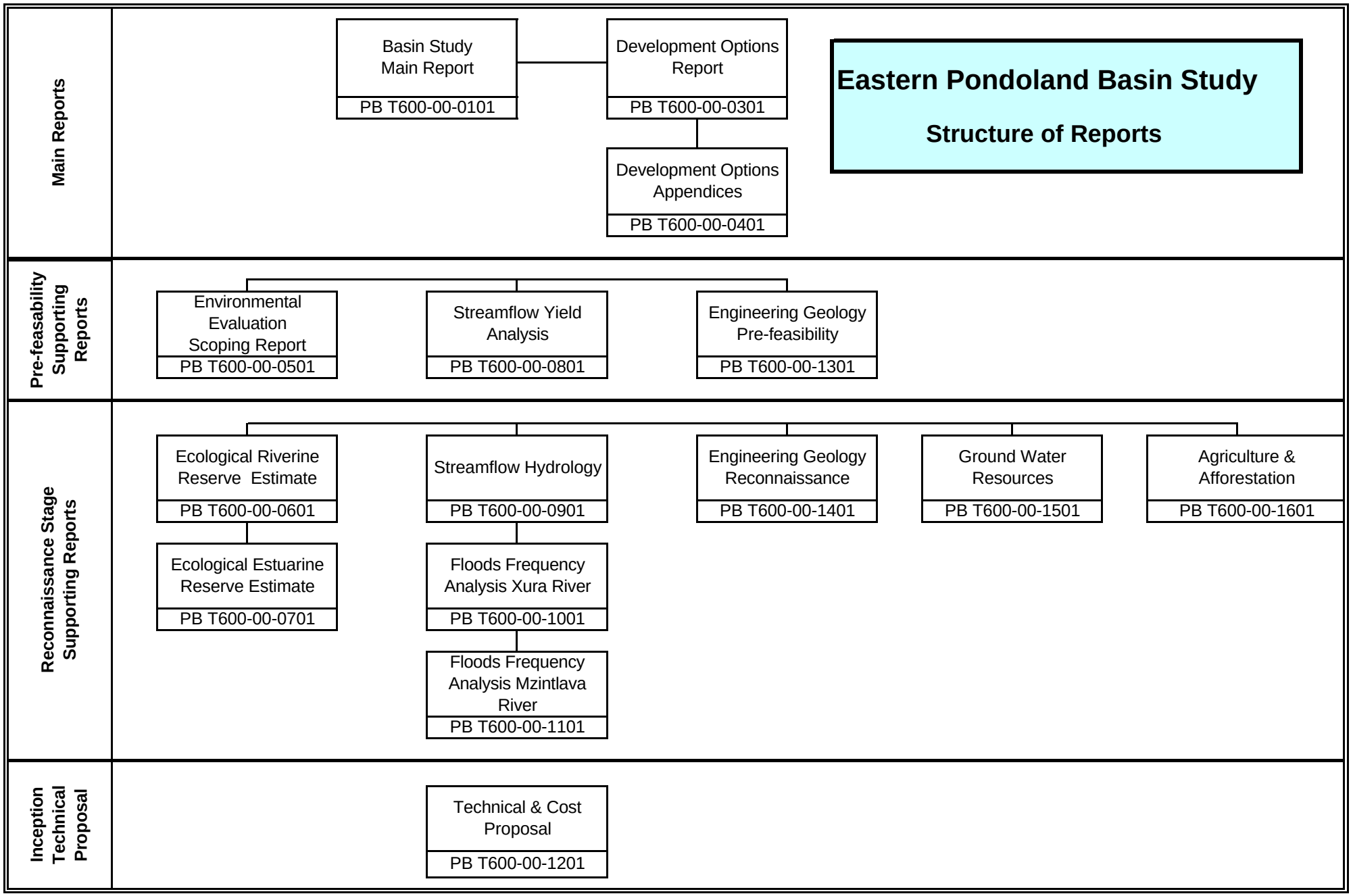
UWP Engineers
Private Bag X66
BRYANSTON 2021

READ ME

HOW TO SHOW NAVIGATION PANE	Click on the “show / hide navigation pane” icon on the tool bar. 
HOW TO BROWSE THROUGH REPORTS	The CD is set up so that it is possible to simply click with the mouse on the navigation pane on the left hand side across to the report, figure, appendices etc... you wish to look at. It is also possible to click on selected report sections from the contents page found in each report. The reports can also be accessed through the “Structure of reports” table.
HOW TO VIEW A CERTAIN REPORT	Simply click on the desired report title found on the navigation pane on the left hand side or on the “structure of reports” table.
HOW TO PRINT OUT A SINGLE REPORT	To print a single report – use the page numbering found on the bottom row of icons to help you select the pages you would like to print. 

Eastern Pondoland Basin Study

Structure of Reports

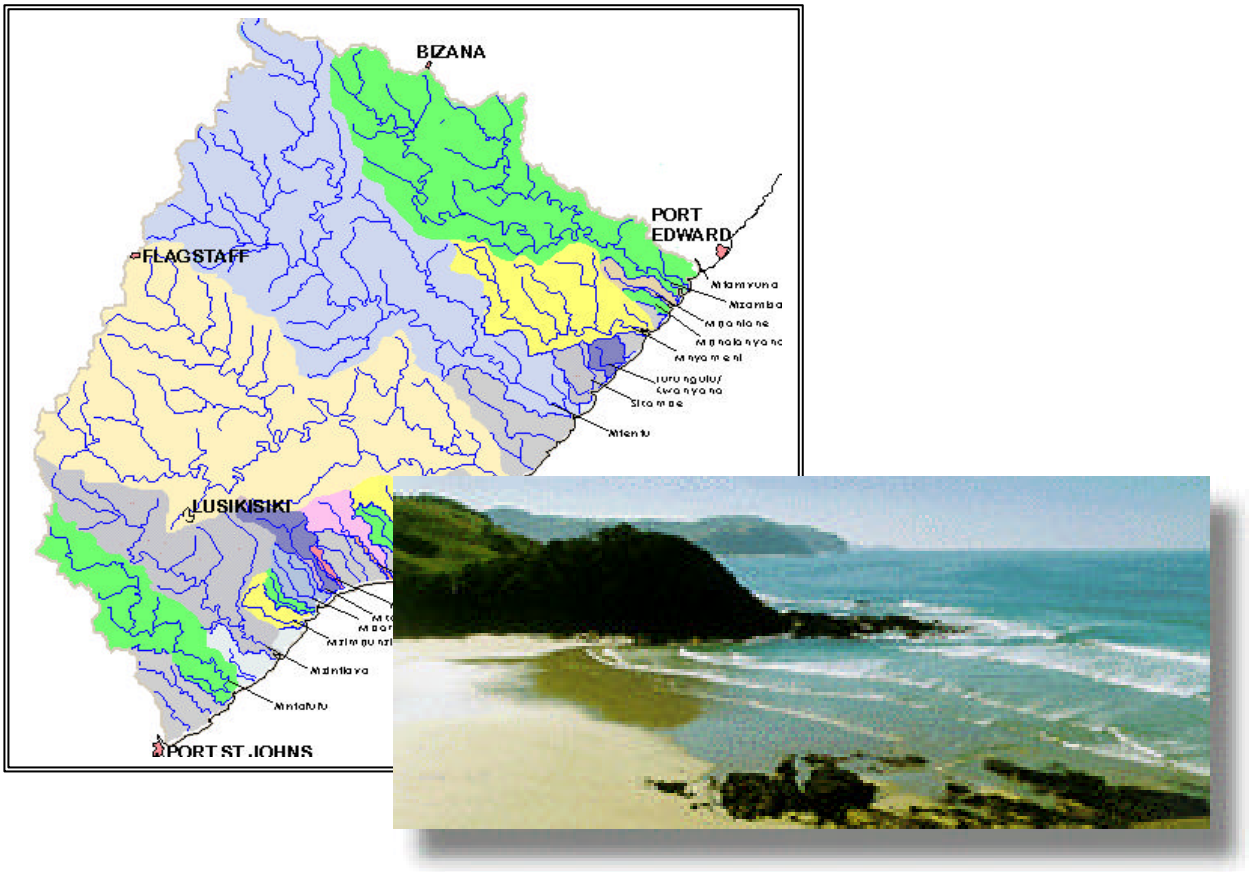


PB T600/00/0101

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



BASIN STUDY : MAIN REPORT

Final

June 2001

Prepared By:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Basin Study Main Report
AUTHOR	**:**	HV Doudenski
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-0101
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

ACKNOWLEDGEMENTS

UWP Engineers gratefully acknowledge the valuable contributions to this study provided by the following organisations (listed in alphabetical order):

Andre Roets & Associates
Anton Bok and Associates
Bosele Community Support Services
CSIR
Council for Geoscience: Geological Surveys
DWAF: Civil Design
DWAF: Eastern Cape Region
DWAF: Environmental Studies
DWAF: Hydrology
DWAF: Water Resources Planning
Kei Water Solutions
Pollution Control Technologies
Toens and Partners

EASTERN PONDOLAND BASIN STUDY

BASIN STUDY REPORT

EXECUTIVE SUMMARY

In January 1999, the Department of Water Affairs and Forestry (DWAF) commissioned the Eastern Pondoland Basin Study (EPBS) and appointed UWP Engineers as lead consultant to undertake the study. The scope of the study includes two main components:

- **River Basin Study:** to provide broad evaluation (at reconnaissance level of detail) of the current state of the water resources in the area, as well as of the potential for their development.
- **Development Options Study:** to identify, evaluate and select the best water source and conveyance system for the augmentation of the existing Lusikisiki Regional Water Supply Scheme (LRWSS) and its proposed extensions.

This main report covers the issues related to the basin study component of the project, and summarises the findings of a number of supporting reports. The structure of the study reports is shown schematically after the executive summary.

1. BASE INFORMATION

The Eastern Pondoland Coast is located in the Wild Coast District (1999 demarcation) of the Eastern Cape Province, and encompasses portions of the Lusikisiki, Flagstaff and Bizana Magisterial Districts (**Fig E1**). It borders the Mzimvubu River basin to the west and south-west, the Mtamvuna River basin to the north, and the Indian Ocean to the south-east.

The study area of about 3 700 km^2 includes the catchments of more than 25 relatively small coastal rivers between the Mzamba and Mtafufu Rivers (**Fig E2**). The area covers the T60 tertiary drainage region, and is sub-divided into 10 quaternary catchments. It includes about 330 rural settlements with a total estimated population of about 490 000 people. The main economic centres are the towns of Lusikisiki and Flagstaff.

The mean annual precipitation is high, and varies from 870 mm inland to 1 220 mm along the coast. All main rivers are perennial and flow in the south-easterly direction from the elevated inland plateau (maximum elevation 1 245 m) to the Indian Ocean. The Magwa dam (wall height of 25 m) on the Mkozi River is the only registered dam in the area, but regulates a very small catchment of approximately 5.5 km^2

The natural environment in the coastal belt of the study area is in pristine condition and has exceptionally high conservation value. Proposals have been tabled for the entire coastal area to be declared a National Conservation Park. The natural features of the inland areas have been largely modified and disturbed by the activities of man. The conservation value of these areas is therefore significantly lower than for the coastal areas.

The area has a high potential for the development of commercial forestry plantations, tourism and dry-land agriculture due to the favourable climatic and natural conditions.

The development of commercial irrigation in the area is not considered to be economically feasible. The high mean annual precipitation (above 900 mm) allows high yielding dry-

Eastern Pondoland Basin Study

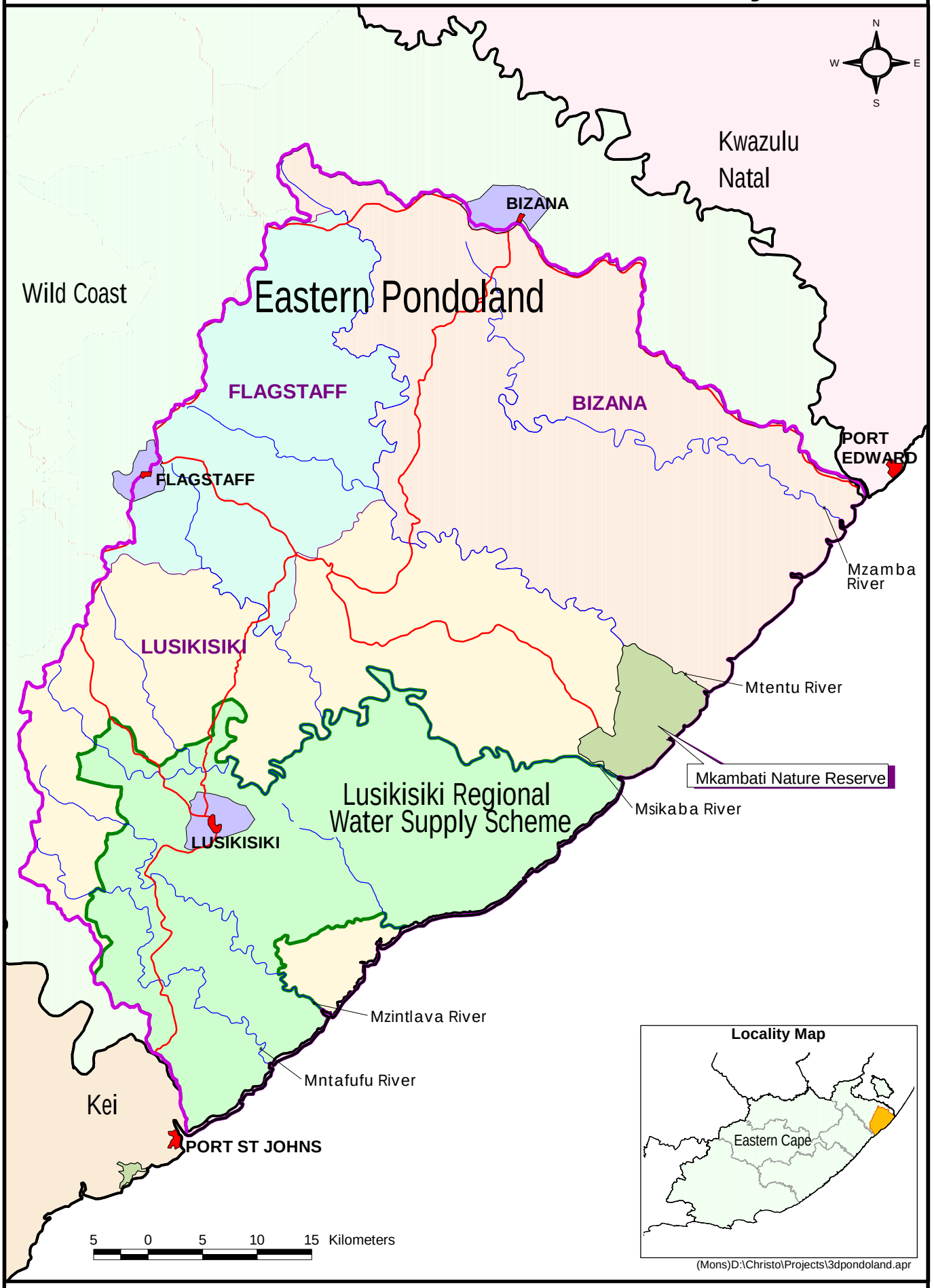
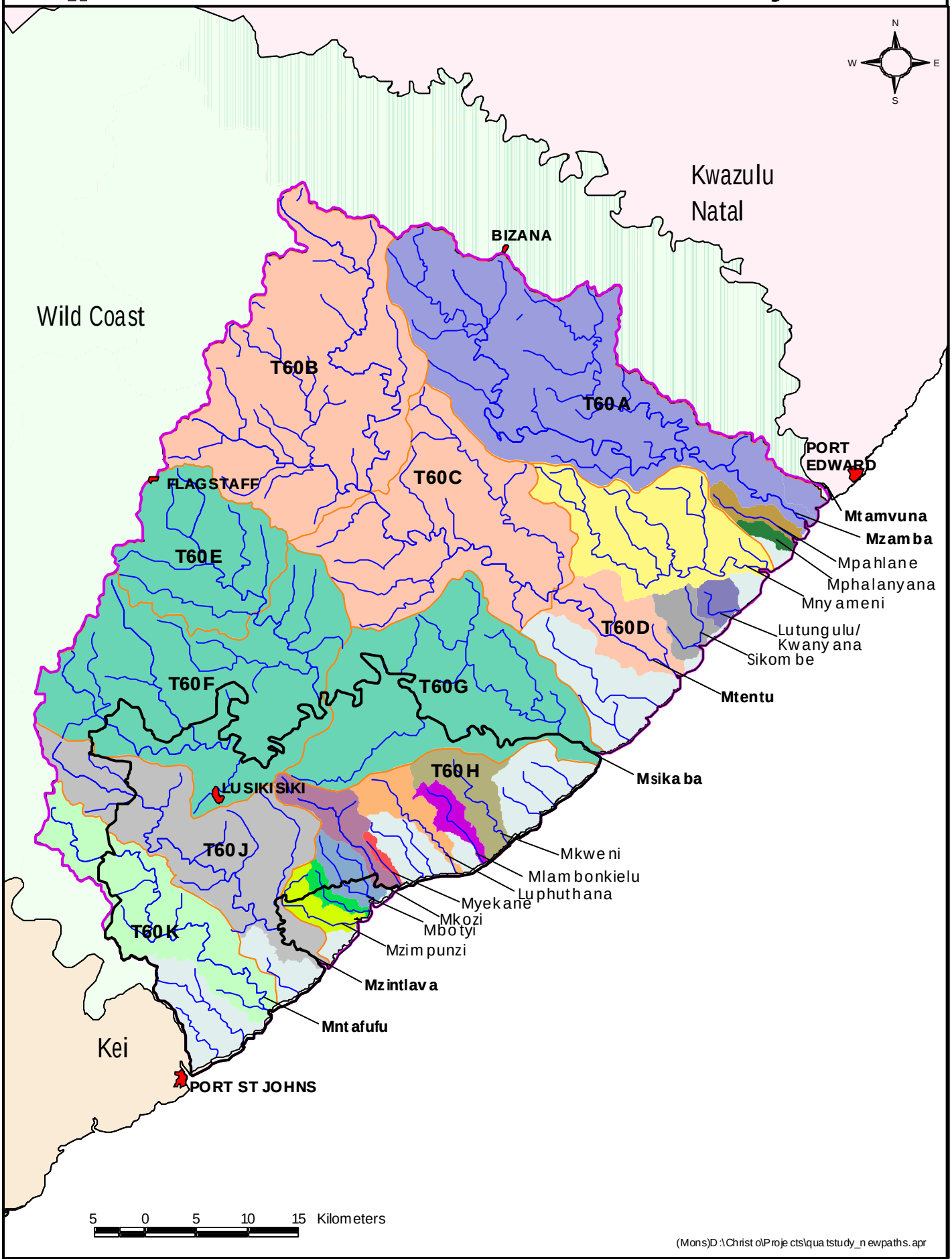


Fig E1 : Locality and Overview

UWP Engineers

Eastern Pondoland Basin Study



E2: River Catchments

UWP Engineers

land agriculture and will most probably not justify the high capital costs for development of irrigation infrastructure. The area is deeply incised by the main river basins, and the potential irrigable land is normally located in the alluvial flood plains within the river valleys. These valleys are usually not accessible by roads of satisfactory standards, which limits the access to potential markets. The development of irrigation on suitable areas on the plateau is severely restricted by the high pumping head requirements (100 to 500 m) and the associated costs for the water supply infrastructure.

The region is greatly underdeveloped and its infrastructure is generally in a poor state. The level of hardship with regards to water and sanitation services is high. Less than 20% of the population is supplied with water from nine existing water schemes, but mostly to service levels of sub-RDP standard. About 2% of the population enjoy sanitation facilities.

The Lusikisiki Regional Scheme is the largest water supply system in the area, and currently provides water services to approximately 52 000 people. Various options for the augmentation of the water source of this scheme have been investigated during the course of this study. Twelve water supply projects (R62 million, serving about 80 000 people) are currently being implemented and have reached various stages of completion.

From topographical and geological perspective the study area is not ideal for the construction of dams. The longitudinal slopes of the rivers are steep, the river sections are often noticeably asymmetrical, and the founding conditions are generally unfavourable.

The water quality in the upper and middle reaches of the main rivers (Xura, Mzintlava, Msikaba, Mtafufu and Mtentu) is good and is suitable for human consumption after treatment. A significant deterioration of the water quality has been observed in the lower reaches of the Msikaba River, resulting from the release of sub-standard effluent from the water treatment works of the town of Lusikisiki. The turbidity levels are generally low and no signs of erosion have been observed in the area. The sediment yields are expected to be generally low.

2. WATER REQUIREMENTS

The water requirements for the following uses have been estimated for each quaternary catchment and projected in 10 yearly intervals until 2030:

- **Consumptive use:** urban domestic and industrial, rural domestic, stock watering, irrigation, and afforestation requirements
- **Contributions to surface water:** Groundwater supplies and return flows
- **Non-consumptive use:** Riverine and Estuarine Ecological Reserve requirements

The DWAF: Water Services database (First Order Strategy) was used for estimation of the base year (1996) population numbers. The population growth rates were assumed to be 1% per annum for the rural and between 8% and 4% per annum for the urban population. The irrigation development potential in the area is low. It was estimated that less than 500 ha would be developed by 2030. The livestock numbers were estimated on the basis of reported average stocking rates. The afforestation development potential in the area is high. It was estimated that the areas covered by commercial forestry plantation would increase from 8 500 ha at present to 15 600 ha by year 2030. The ground water usage was

estimated on the basis of existing project data and the potential for development of additional sources. Allowance for return flows from urban treated effluent were made.

The total consumptive water requirements are low. The largest consumer at present is commercial forestry (50% of the total consumptive use), followed by the domestic and industrial requirements (24%). The domestic and industrial requirements are expected to increase to about 50% of the total water use by year 2030. A summary of the total consumptive water requirements per user sector is shown in the following table.

Table E1: Consumptive Water Requirements per User Sector

User Sector	Water Requirements ($10^6 m^3/a$)				Distribution, %	
	2000	2010	2020	2030	2000	2030
Urban domestic and industrial	1.2	2.6	5.0	8.1	6.5	15.6
Rural domestic	3.4	5.3	10.1	18.4	17.9	35.4
Stock watering	2.9	2.9	2.9	2.9	15.6	5.6
Irrigation	0.0	0.4	0.6	0.8	0.1	1.5
Afforestation	11.3	18.0	19.9	21.7	59.9	41.8
Total use	**18.8**	**29.3**	**38.5**	**51.9**	**100.0**	**100.0**
Return Flows	-0.4	-1.0	-2.0	-3.3	-2.1	-6.4
Groundwater supply	-0.1	-0.3	-1.2	-3.1	-0.6	-5.9
Total use from surface water	**18.3**	**28.0**	**35.3**	**45.5**	**97.3**	**87.7**

Note:

In January 2000, when the water requirements and the hydrological tasks of the basin study component were completed, the results from a comprehensive demographic study commissioned by DWAF (MarkData) became available. According to this study, due to the impacts of AIDS, migration and urbanisation the annual population growth rates in the study area are predicted to be significantly lower than previously expected. The recommended average growth rates for the rural population within this region will decline from plus 0.38 % for the period 1996 to 2000 to minus 0.75 % for the period 1996 to 2030. The urban population growth rates are predicted to vary between 1.29 % (1996 to 2000) and 0.51 % (1996 to 2030). Due to the small effect of the population numbers on the system hydrology, the project management team decided not to amend the results shown in the above table for the purposes of the basin study component. However, the more recent population growth rates were applied for sizing of the augmentation options for the Lusikisiki Regional Scheme, described in the **Development Options** report.

The ecological estuarine Reserve (EER) was determined as a desktop study, supplemented by a two-day specialist workshop. It was concluded that due to the exceptional ecological importance of the estuaries, the Reserve requirements would be very high. The total EER requirements are estimated to vary between 646 million m^3 (low estimate) and 751 million m^3 (high estimate), or between 82% and 96% of the naturalised MAR. This is by far the largest requirement imposed on the water resources in the area. For the purposes of this study it has been assumed that the lower estimate would be more appropriate, and this estimate has been used for reconciling the water requirements and supplies. More detailed studies are however required to confirm this statement.

The rapid estimates of the ecological riverine Reserve (ERR) for various sites have indicated that the riverine requirements will be in the range of 25% to 30% of the naturalised MAR.

The total water requirements (consumptive and non-consumptive) are estimated to be about 664 million m^3/a and 691 million m^3/a for years 2000 and 2030 respectively (for the low estimate of the ecological reserve).

3. WATER RESOURCES

The groundwater quality is good and is suitable for domestic supply. The groundwater harvest potential is estimated to be about 134 million m^3/a. However the low permeability of the aquifers, the low borehole yields and the inaccessibility of the terrain limit the groundwater development potential to about 13 million m^3/a. Groundwater resources can feasibly be implemented for the supply of small village schemes. Despite the high groundwater harvest potential, it is expected that the feasibility of utilising groundwater as a source for regional schemes will be limited by high operational costs.

The streamflow analysis was performed per quaternary catchment on the basis of the Water Resources Simulation Model (WRSM90). Due to the absence of reliable secondary observed flow data, no calibration of the model could be performed. The naturalised mean annual runoff form the entire study area is estimated to be 782 million m^3/a and the present day mean annual runoff is 764 million m^3/a. The total projected consumptive surface water usage by year 2030 is estimated to be less than 6% of the naturalised runoff.

Low flow analyses for eight weir sites were performed with the aim of assessing the applicability of supplying certain schemes (Lusikisiki and Mkambati) by run of river. "One-day" Flow Duration Curves (FDCs) were generated using a rapid method developed by Dr V Smakhtin (CSIR). It was concluded that due to the high ecological Reserve requirements and considerable seasonal variability of runoff, the available run of river yields with assurance levels of 98% are very low.

The potential maximum yield (hypothetical) from the surface water resources, calculated from the naturalised mean annual runoff (with no allowance for the release of the ecological component of the Reserve) is about 673 million m^3/a. The present unused potential yield is about 420 million m^3/a, and is expected to reduce to 392 million m^3/a by year 2030.

The surface water development potential (allowing for the release of the ecological estuarine Reserve requirements) is estimated to be 118 million m^3/a at present and 91 million m^3/a at year 2030. These estimates are valid for the low estimate of the estuarine Reserve. If the high estimate is considered, the surface water resources will experience deficits from around year 2015 onwards (deficit of about 14 million m^3/a by year 2030).

4. CONCLUSIONS AND RECOMMENDATIONS

(a) Ecological Reserve Requirements

The lower estimate for the ecological Reserve has been assumed to be more appropriate and has been used for reconciling the water requirements and availability.

It is recommended that a detailed Reserve determination study be commissioned as soon as possible by the DWAF for the Xura and Mtentu River catchments. If the updated estimates are substantially different than the desktop estimates, the water requirements part of the basin study should be revised.

(b) Population estimates

For the basin study component of the project, the domestic water requirements have been estimated conservatively.

It is recommended that the updated population numbers and growth rates, according to the recent study commissioned by DWAF (MarkData, 2000) be used in further planning activities. This is expected to result in a reduction of the domestic water requirement projections produced by this basin study.

(c) Stream gauging

Due to the absence of reliable observed streamflow data the water resources simulation model, used for the hydrological modelling of the system has not been calibrated.

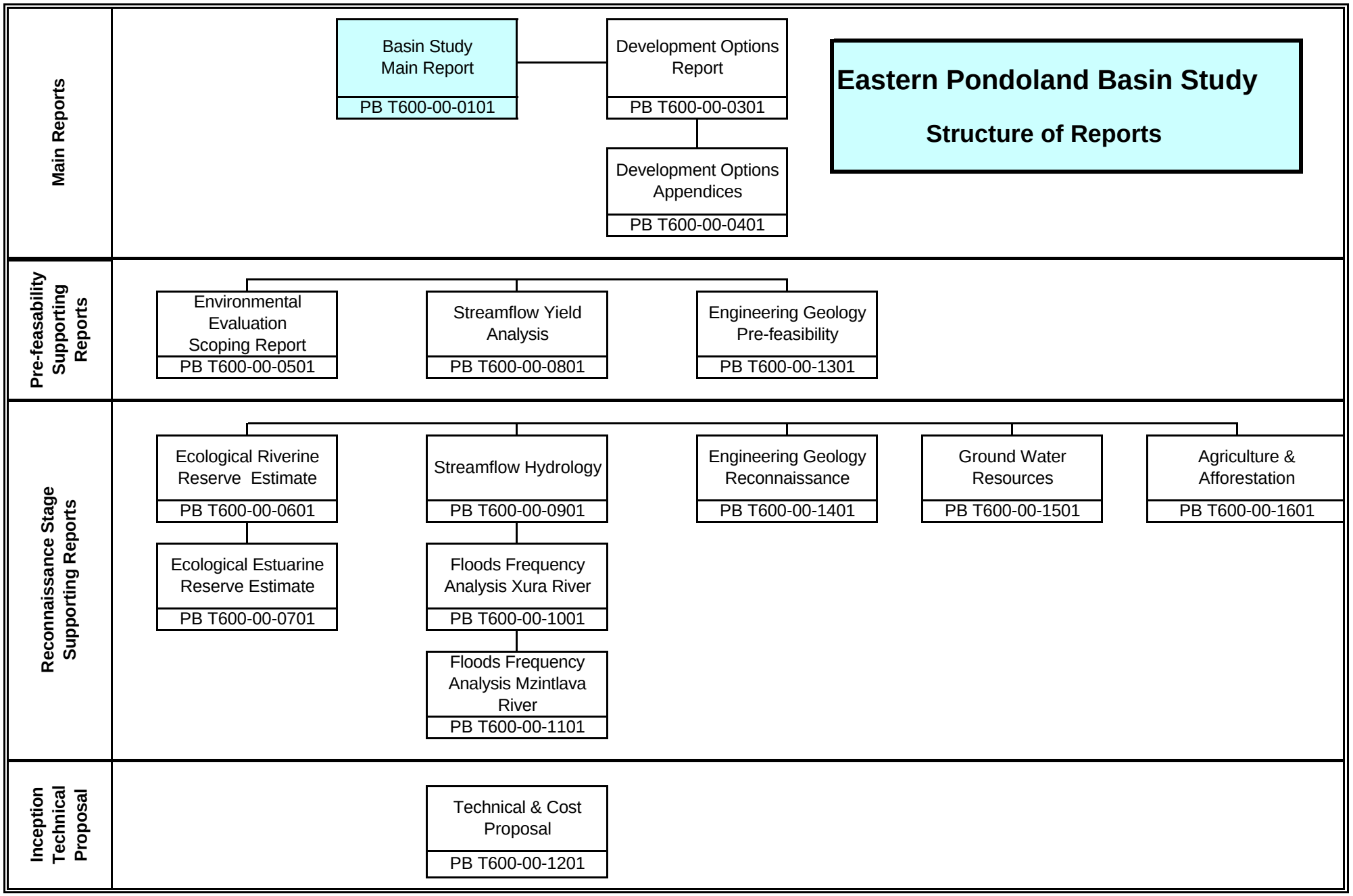
It is recommended that the reliability of the observed flow data records obtained since the revitalisation of the gauging stations on the Xura and Mtafufu Rivers be established by the DWAF and corrective measures be taken, if necessary. These records should be considered for calibration of the hydrological models during further studies in the area.

It is recommended that the DWAF consider the construction of a gauging station on the Mtentu River in view of possible future development projects in this area (Mkambati SDI water project).

(d) Water quality

It is recommended that regular collection and testing of water samples from specific locations on the main rivers in the study area be undertaken by the DWAF. The most likely rivers to be targeted for development during the next 30 years are the Xura/Msikaba, Mzintlava, Mtentu and Mzamba Rivers.

It is recommended that the water treatment works in the vicinity of Lusikisiki be inspected by the DWAF, and water quality samples from the discharged effluent be taken. If necessary, corrective measures should be taken.


Main Reports
Basin Study Main Report
PB T600-00-0101
Development Options Report
PB T600-00-0301
Development Options Appendices
PB T600-00-0401
Eastern Pondoland Basin Study
Structure of Reports
Pre-feasability Supporting Reports
Environmental Evaluation Scoping Report
PB T600-00-0501
Streamflow Yield Analysis
PB T600-00-0801
Engineering Geology Pre-feasibility
PB T600-00-1301
Reconnaissance Stage Supporting Reports
Ecological Riverine Reserve Estimate
PB T600-00-0601
Ecological Estuarine Reserve Estimate
PB T600-00-0701
Streamflow Hydrology
PB T600-00-0901
Floods Frequency Analysis Xura River
PB T600-00-1001
Floods Frequency Analysis Mzintlava River
PB T600-00-1101
Engineering Geology Reconnaissance
PB T600-00-1401
Ground Water Resources
PB T600-00-1501
Agriculture & Afforestation
PB T600-00-1601
Inception Technical Proposal
Technical & Cost Proposal
PB T600-00-1201

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE: WATER RESOURCES PLANNING

EASTERN PONDOLAND BASIN STUDY
BASIN STUDY REPORT

CONTENTS

Acknowledgements		i
Executive Summary		ii
Structure of Report for EPBS		vii
Table of Contents		a
1.	**INTRODUCTION**	1
2.	**BASE INFORMATION**	3
2.1	Overview of Study Area	3
2.2	Natural Characteristics	4
2.3	Demography and Socio-Economics	9
2.4	Spatial Development Initiative Projects (SDI)	10
3	**NATURAL ENVIRONMENT AND CONSERVATION VALUE**	11
3.1	Terrestrial Habitat	11
3.2	Aquatic Habitat	12
3.3	Proposed Extensions of the Conservation Areas	14
4.	**INFRASTRUCTURE AND PROJECTS**	15
4.1	General Infrastructure	15
4.2	Existing Water Supply and Sanitation Infrastructure	16
4.3	Water Supply Projects and Proposed Developments	19
5.	**WATER REQUIREMENTS**	24
5.1	Domestic and Industrial Water Requirements	24
5.2	Ground Water Usage and Return Flow	27
5.3	Irrigation Water Requirements	28
5.4	Stock Watering Requirements	29
5.5	Afforestation Requirements	30
5.6	Ecological Reserve Requirements	31
5.7	Summary of Consumptive Water Requirements	34

6. WATER RESOURCES 35

6.1 Ground Water 35
6.2 Surface Water Hydrology 37
6.3 Water Balance 40

7. FACTORS AFFECTING DEVELOPMENT 43

7.1 Topography 43
7.2 Geology Materials 44
7.3 Environmental Issues 44
7.4 Social Issues 45
7.5 Water Quality Issues 46
7.6 Sediment Yields 47
7.7 Institutional Arrangements for O&M 48
7.8 Catchment Management Agencies 49

8. SUMMARY OF FINDINGS 51

8.1 Base Information 51
8.2 Infrastructure 51
8.3 Water Requirements 52
8.4 Water Resources 52
8.5 Factors Affecting Development 53
8.6 Accuracy Limitations of Study Results and Additional Information Required. 54

9. RECOMMENDATIONS 55

APPENDICES

Appendix A : Reference List
Appendix B : Terms of Reference
Appendix C : Photographs and Plates
Appendix D : Existing Infrastructure
Appendix E : Water Requirements

LIST OF FIGURES

Figure 1	:	Locality Plan
Figure 2	:	Locality and Overview
Figure 3	:	Topography
Figure 4	:	Mean Annual Precipitation
Figure 5	:	River Catchments
Figure 5a	:	Geology of T60 Catchment
Figure 6a	:	Vegetation Types
Figure 6b	:	Vegetation Types
Figure 6	:	Land Use
Figure 7	:	Demography
Figure 8	:	Existing Infrastructure
Figure 9	:	Existing Infrastructure
Figure 10	:	Proposed Water Supply Projects
Figure 11	:	LRWSS: Dam Options
Figure 12	:	LRWSS: Weir Options
Figure 13	:	Mkambati Water Project: Dams and Weirs
Figure 14	:	Potential Irrigable Land
Figure 15	:	Ground Water Development Potential
Figure 16	:	Satellite Imagery
Figure 17	:	Exploration Drill Targets in the Vicinity of the LRWSS
Figure 18	:	Naturalised Mean Annual Runoff
Figure 19	:	LRWSS: Proposed Dam and Weir Sites
Figure 20	:	Surface Water Development Potential (2000)
Figure 21	:	Sediment Yields: Erodibility Indices

1. INTRODUCTION

The Eastern Pondoland Coast is located in the Wild Coast District Council (1999 demarcation) of the Eastern Cape Province. The area includes a number of small coastal river catchments located between the Mzamba and Mtafufu Rivers. The knowledge level regarding the water resources in the area (similar to many other former Transkei catchments) is very limited and needs to be brought in line with the level of information available for the rest of the catchments in South Africa.

The Lusikisiki Regional Water Supply Scheme, located in the area experiences severe water shortages and its water source needs to be urgently augmented. For these reasons, the Department of Water Affairs and Forestry (DWAF) commissioned in January 1999, the Eastern Pondoland Basin Study (EPBS) and appointed UWP Engineers as lead consultant to undertake the study. The scope of the study includes two main components:

River Basin Study: to provide broad evaluation (at reconnaissance level of detail) of the current state of the water resources in the area, as well as of the potential for their development in order to meet the requirements of all user sectors. This component of the study provides information and planning tools required to inform and guide the establishment of a catchment management strategy.

Development Options Study: to identify, evaluate and select the best water source and conveyance system for the augmentation of the existing Lusikisiki Regional Water Supply Scheme (LRWS) and its proposed extensions.

The Terms of Reference are attached in **Appendix A** This main report includes the issues related to the basin study components of the project, and summarises the findings of a number of supporting reports. The structure of the study reports is shown schematically after the executive summary. A separate main report (PB T600-00-0301) deals with the issues related to the feasibility assessment of various development options for the augmentation of the LRWS. The Basin Study Main Report is structured as outlined below:

Section 2 of this report provides a description of the location and natural characteristics of the study area (topography, climate, river catchments, geology, vegetation, land use). The existing and proposed infrastructure in the area is described in Section 3. An overview of the conservation value of the natural environment is provided in Section 4.

The present and projected water requirements for all user sectors within the study area have been estimated and projected until year 2030 and are described in Section 5. The base year (1996) population numbers have been assumed to be in accordance with the existing DWAF: Water Services (First Order Strategy) database.

An overview of the available water resources (surface and groundwater) is offered in Section 6. The streamflow hydrology has been derived on the basis of the WR90 model with the rainfall records extended to 1997. No observed flow data within the study area was available for the calibration of the model. The assessment of the groundwater resources was carried out as a desktop study, based on available information from previous reports, as well as on interpretation of satellite imageries. Limited field visits and verification of the information was undertaken. A first order water balance is provided in this section.

The factors affecting the feasibility of development of the water resources are described in Section 7. These include geology, topography, water quality, sedimentation, and environmental, social and institutional aspects.

The conclusions and recommendations are offered in Sections 8 and 9.

Eastern Pondoland Basin Study



N
W
E
S

100 0 100 200 300 400 500 Kilometers

(Mons)D:\Christo\Projects\3dpondoland.apr

Fig 1 : Locality Plan

UWP Engineers

2. BASE INFORMATION

2.1 OVERVIEW OF STUDY AREA

The Eastern Pondoland Coast (study area) is located along the Wild Coast in the Eastern Cape Province, between Port St. Johns and Port Edward and extends about 50 km inland (**Figures 1 and 2**). The study area of about 3700 km^2 includes the catchments of more than 25 relatively small coastal rivers between the Mzamba and Mtafufu Rivers. From hydrological perspective the area covers the T60 tertiary drainage region, and is sub-divided into 10 quaternary catchments – T60A to T60K. It borders the Mzimvubu River basin to the west and south-west, the Mtamvuna River basin to the north, and the Indian Ocean to the south-east.

The area falls under the jurisdiction of the Wild Coast District Council and encompasses portions of the Lusikisiki, Flagstaff and Bizana Magisterial Districts (1999 demarcation). The study area includes about 320 rural settlements with a total estimated population of about 500 000 people. The main economic centres are the towns of Lusikisiki and Flagstaff. The town of Bizana falls just outside of the study area.

Having been part of the former Transkei, the entire Eastern Pondoland region is greatly underdeveloped and its infrastructure is in a poor state. The provision of basic services (water, sanitation, roads, electricity, etc) is perceived to be a priority by government. Due to its favourable climatic and natural conditions, the study area has high potential for development of afforestation, tourism and dry land agriculture. Three nodes within the study area have been selected as potential economic growth centres and included in the Government's Spatial Development Initiative (SDI) programme: the Mkambati and Mbotyi tourism developments, and the extension of the Magwa Tee Estate. A number of afforestation developments are being considered by private companies.

The region can be accessed from Umtata via Port St. Johns on the main R61 tarred road. The R61 also provides a link between the towns of Lusikisiki, Flagstaff, Bizana and Port Edward. The secondary roads system, providing access to the villages within the area is in a poor state of repair. Many villages are inaccessible during wet conditions.

The level of hardship in the Eastern Pondoland region, with regards to water and sanitation services in the rural areas is high. Only about 20% of the population is presently served by formal water supply systems, but generally to standards lower than RDP. The water resources of this region are largely under-utilised and have high potential for development. This is somewhat limited by the exceptionally high ecological Reserve requirements for the coastal rivers.

The Lusikisiki Regional Water Supply Scheme is the largest existing scheme in the Eastern Pondoland Coast. The system was originally planned in 1979 and commissioned in July 1989. Only a portion (phase 1) of the originally planned larger scheme has been built to date. A weir on the Xura River, located some 7 km northwest of Lusikisiki, currently supplies the town of Lusikisiki (11 000 people) and 23 villages (41 000 people). Plans are underway for the extension and upgrading of the system including the augmentation of its water source.

Eastern Pondoland Basin Study

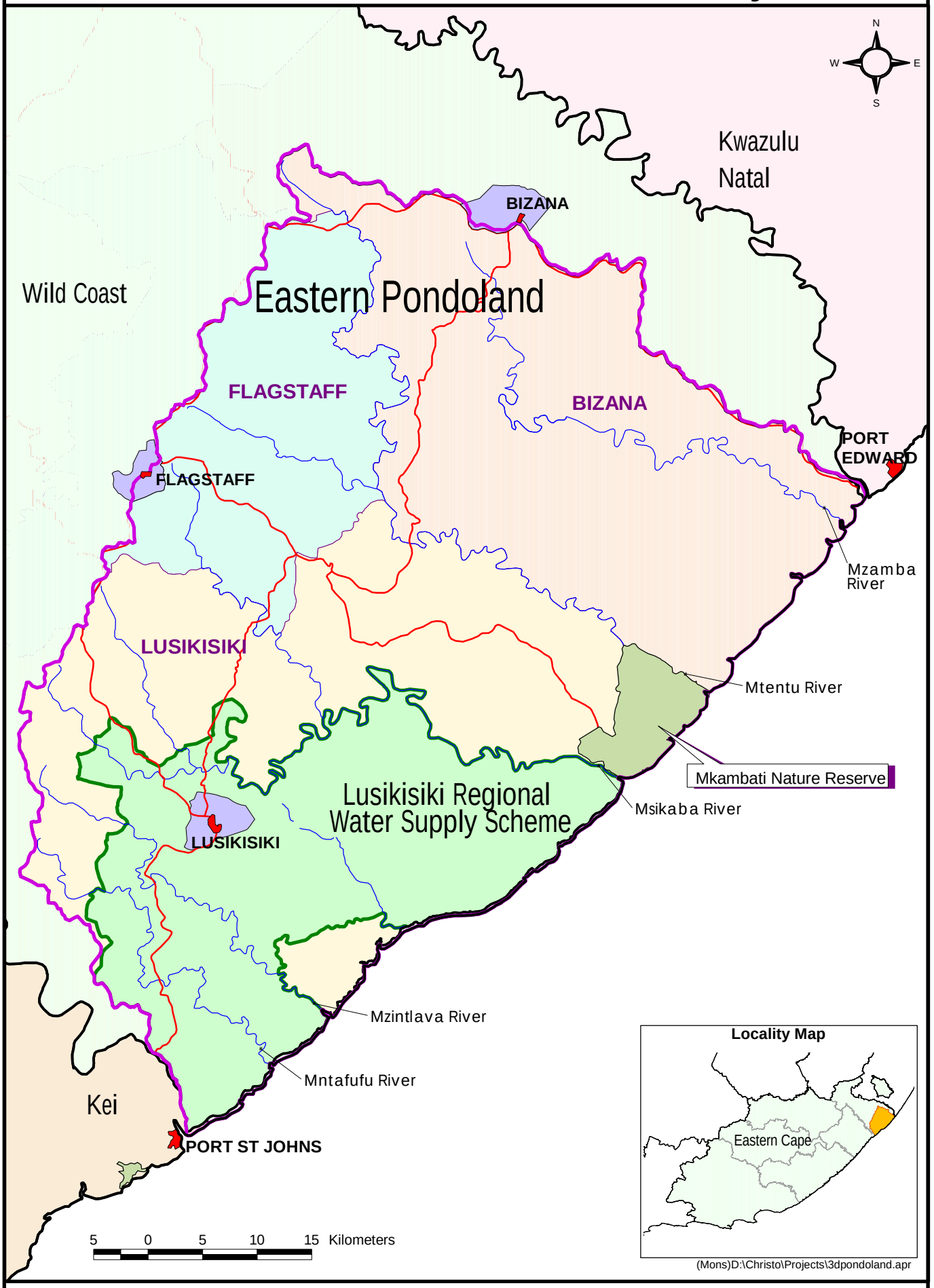


Fig 2 : Locality and Overview

UWP Engineers

2.2 NATURAL CHARACTERISTICS

2.2.1 Topography

The ground elevation within the study area rises in a series of 'steps' from the coastline to a maximum of 1 245 m above mean see level (msl) in the north-western corner (**Figure 3**).

There are two main physiographic regions within the Eastern Pondoland region, namely the coastal belt and the interior plateau. The coastal belt is generally between 20 and 30 km wide, varying in altitude between 0 and 650 m msl. The topography is typically flat, gently sloping towards the coast, but has been extensively incised by the main drainage systems of the Mtafufu, Msikaba, Mzintlava, Mtentu, and Mzamba Rivers. The inland plateau is characterised by an uneven, seaward-sloping surface, lying between 400 m and 1 100 m msl. The western and north-western portions of the study area are dominated by several mountain ranges.

The drainage channels are often linear and tend to follow the dominant fracture systems, especially the north west trend, as evident from the main river catchments in the region (see **Figure 5**). The region is underlain by sandstone of the Msikaba Formation and major steep sided gorges have been formed, often falling 300 to 500 m below the surrounding plateau.

2.2.2 Climate and Rainfall

The climate along the coast is warm to hot throughout the year, with humidity levels rising from December to March. Thunderstorms are frequent in summer. The inland climate is more temperate with warm summers and cool winters, although occasional colder spells may occur. Sea temperatures are moderate.

The region is characterised by a high annual precipitation. Higher annual rainfall values are associated with the coastline, and values decrease gradually toward the interior. Most of the rain falls in summer (October to March) and severe droughts have been observed during winter months. The study area falls within two rainfall zones, T6A and T6B, as defined by WR90. The mean annual precipitation for the quaternary catchments within the Eastern Pondoland Basin varies between 873 mm and 1 277 mm as illustrated in **Figure 4** and **Table 2.2.2**. The mean potential evaporation for the region (A-pan equivalent) varies between 1400 and 1800 mm.

Table 2.2.2: Mean Annual Precipitation

Rainfall Zone	Quaternary catchment	Area (km^2)	MAP (mm)
T6A	T60A	547	873
	T60B	528	896
	T60C	363	952
	T60D	415	1072
T6B	T60E	198	885
	T60F	464	940
	T60G	360	1116
	T60H	322	1277
	T60J	294	1101
	T60K	242	1075

Eastern Pondoland Basin Study

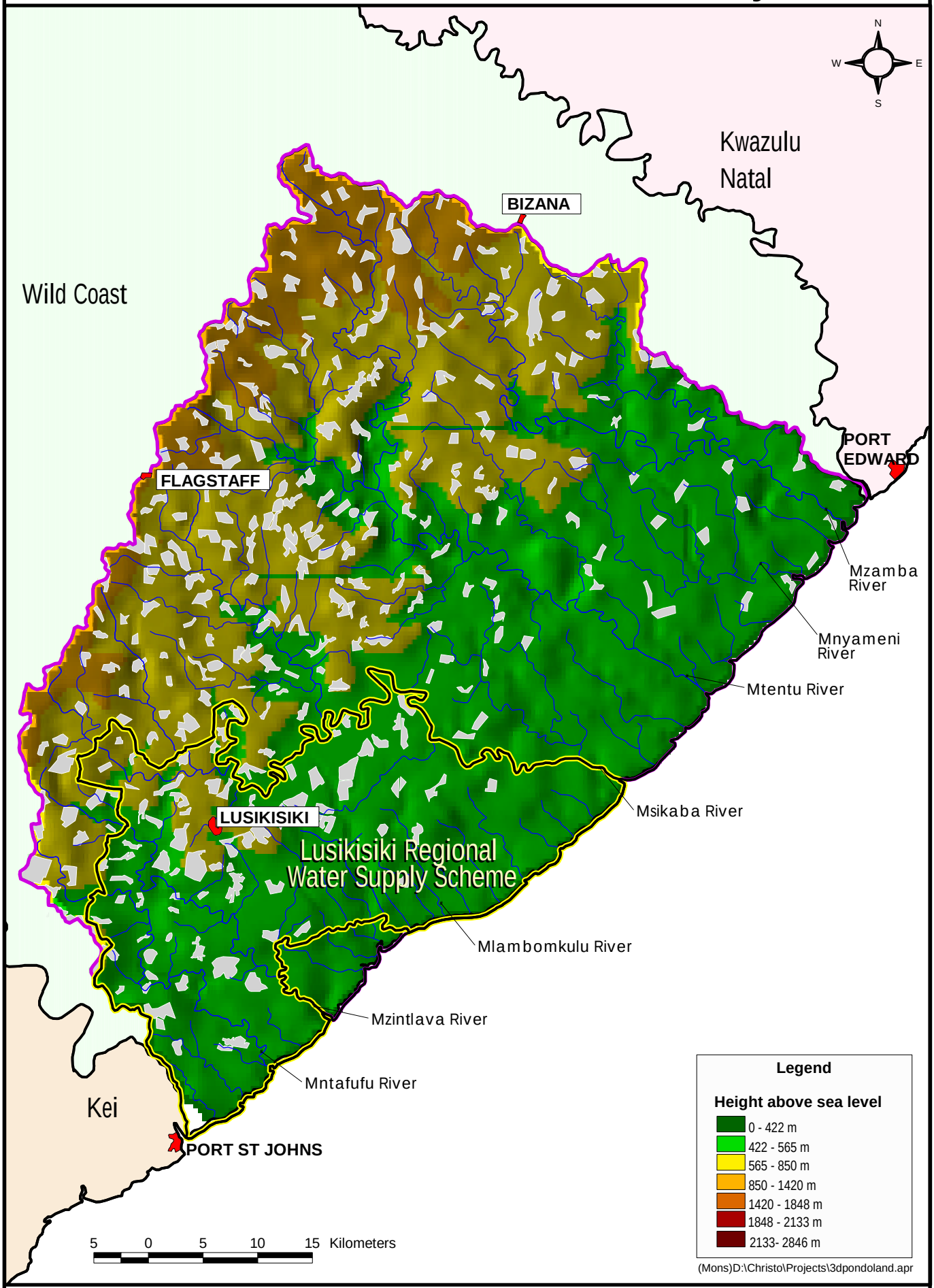


Fig 3 : Topography

UWP Engineers

Eastern Pondoland Basin Study

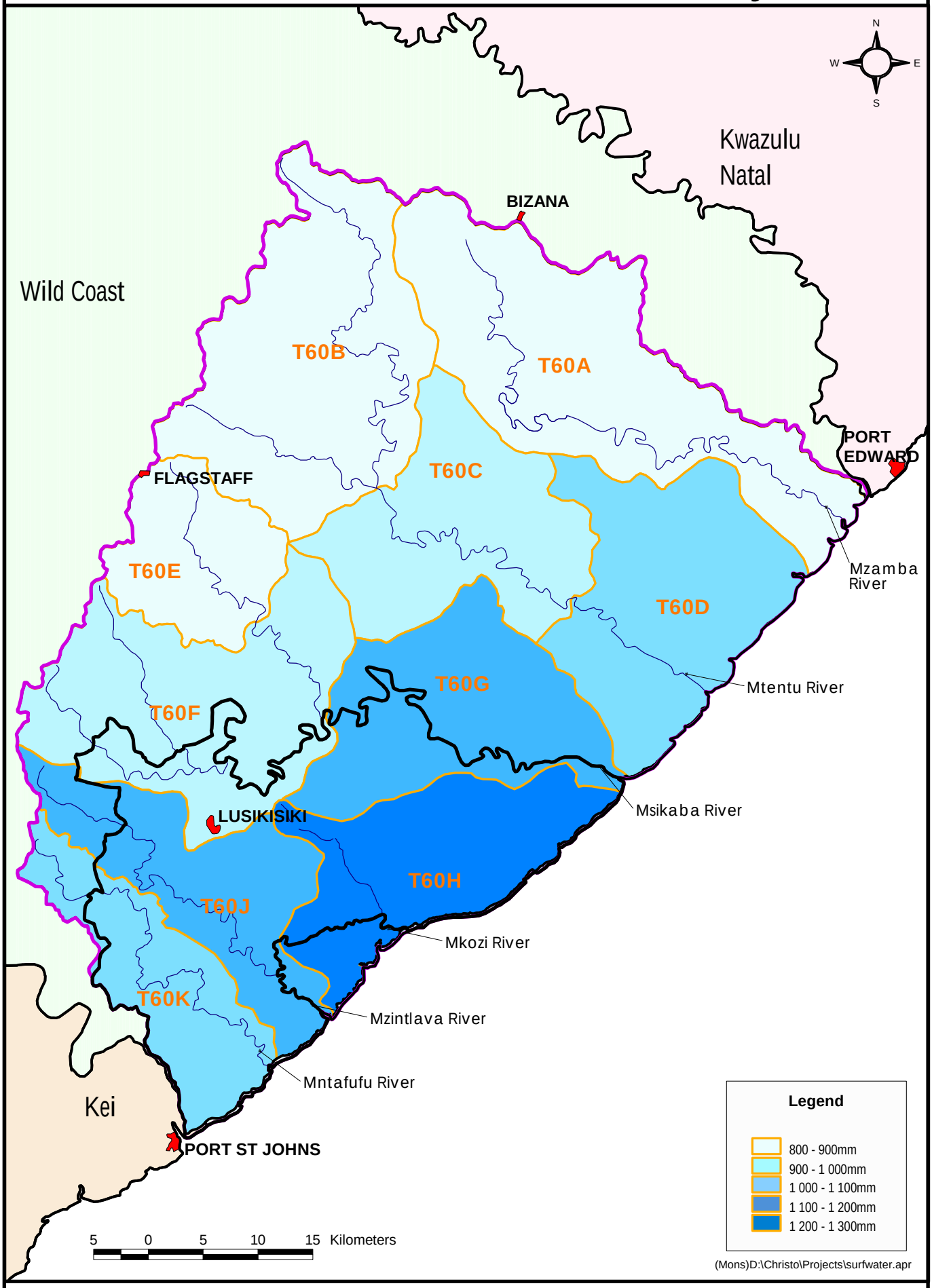


Fig 4 : Mean Annual Precipitation

UWP Engineers

2.2.3 Rivers and Drainage Regions

The rivers in the study area are presently largely under-utilised, and are not regulated by any dams of significant size. The main rivers draining the area are the Mtafufu, Mzintlava, Msikaba, Mtentu, and Mzamba. All main rivers are perennial and flow in the south-easterly direction from the elevated inland plateau to the Indian Ocean. The Magwa dam (wall height of 25 m) on the Mkozi River is the only registered dam in the area, but regulates a very small catchment of approximately 5.5 km^2. **Figure 5** illustrates the river catchments within the study area. **Table 2.2.3** offers a summary of the characteristics of the main rivers.

Table 2.2.3: Characteristics of the main rivers within the study area

River	Quaternary Catchment	Catchment Area km^2	Virgin MAR ($10^6 m^3/a$)
Mtafufu	T60K	186	45.8
Mzintlava	T60J	270	71.2
Mzimpunzi	T60H	24	9.3
Mbotyi (Kobenge)	T60H	29	11.2
Mkozi	T60H	43	16.7
Myekane	T60H	5	1.9
Luphuthana	T60H	20	7.8
Mkweni	T60H	48	18.6
Msikaba	T60G / E / F	1022	207.4
Mtentu	T60D / C / B	964	152.6
Sikombe	T60D	28	6.9
Lutungulu	T60D	16	3.9
Mnyameni	T60D	186	46.0
Mpahlane	T60A	20	2.6
Mpahlanyana	T60A	9	1.2
Mzamba	T60A	506	66.5

The Eastern Pondoland Coast, which constitutes the tertiary drainage region T60 is divided into ten quaternary sub-catchments – T60A to T60K, as illustrated in **Figures 4 and 5**.

2.2.4 Geology

The Eastern Pondoland region is underlain predominantly by sandstone of the Msikaba Formation, faulted Ecca shale, and Dwyka diamictite. Dolerite intrusions are almost exclusive to the Ecca and Beaufort sediments, but a number of dolerite dykes do transgress the Dwyka and Msikaba units. The Dwyka diamictite to the south of Lusikisiki have been intruded by a number of these sills. The lithostratigraphy of the study area is summarised in **Table 2.2.4** and illustrated in **Figure 5A**:

Eastern Pondoland Basin Study

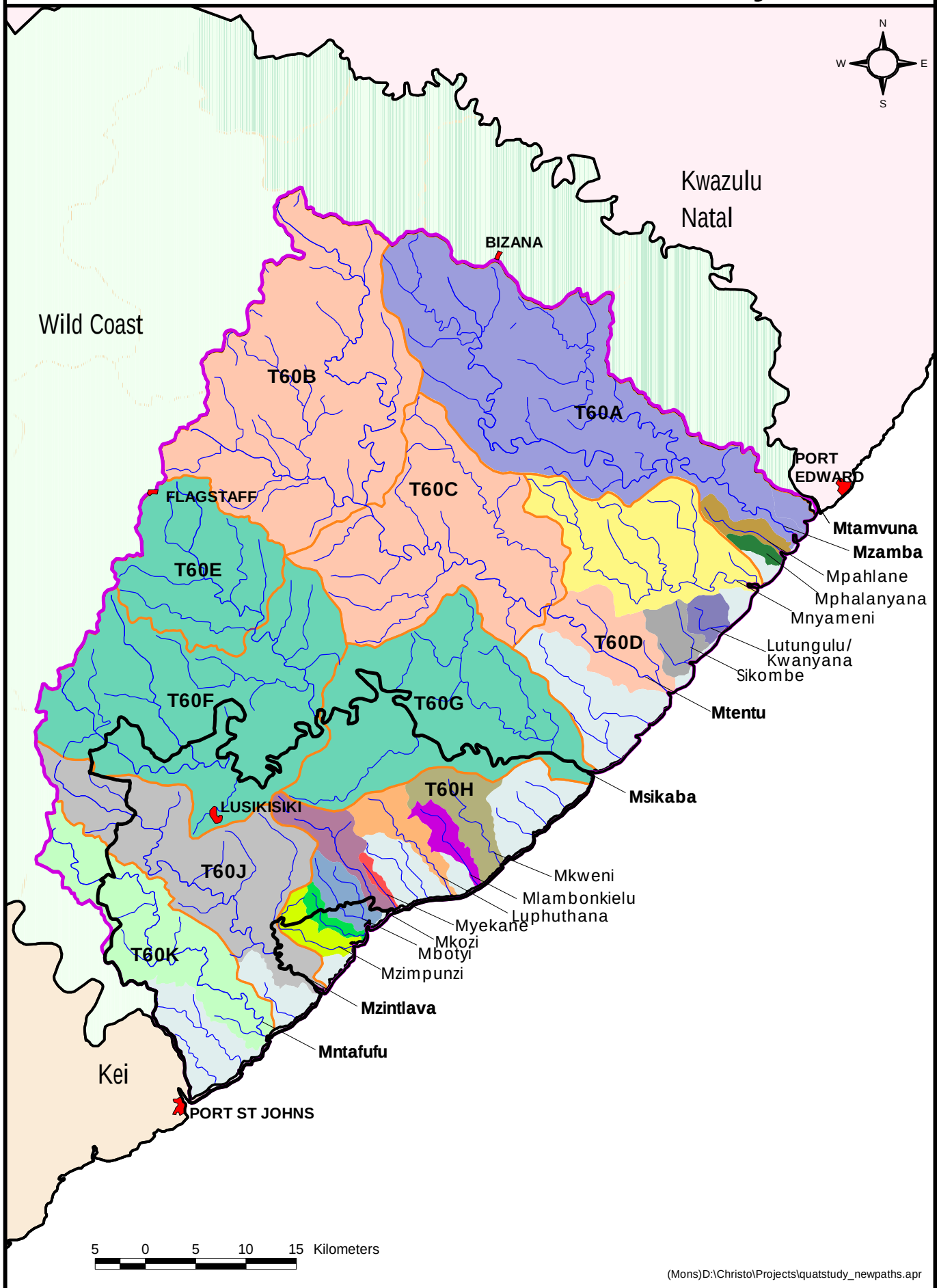


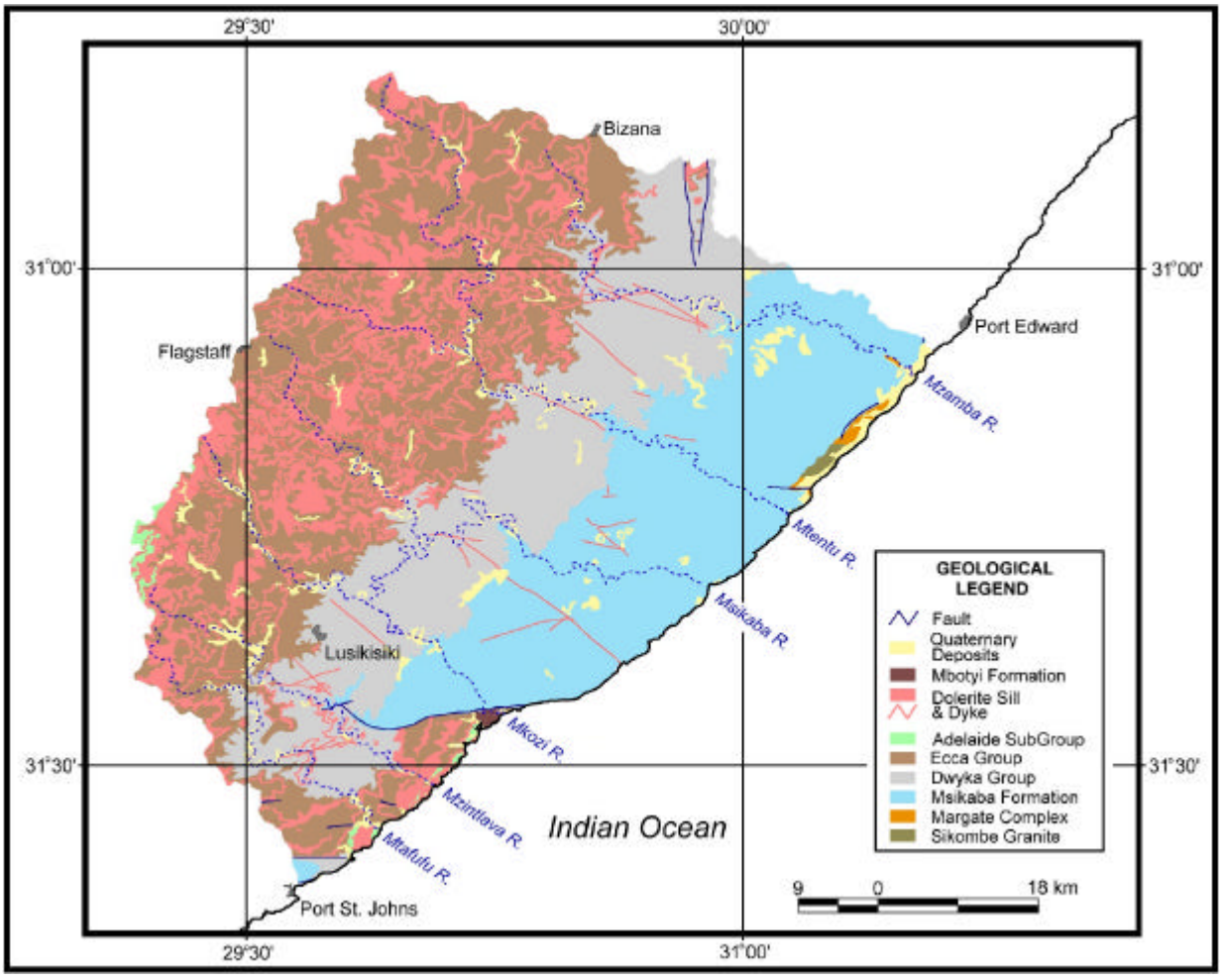
Fig 5 : River Catchments

UWP Engineers

Table 2.2.4: Geology of T60 drainage region

Group / Formation	Major Rock Type	Age
-	Unconsolidated alluvial, aeolian, estuarine and colluvial deposits. Minor travertine.	Quaternary
Mzamba Formation	Clay beds and fossiliferous shelly limestone.	Cretaceous
Mbotyi Formation	Greenish-grey conglomerates and subordinate coarse sandstone.	Cretaceous
Karoo Intrusives	Dolerite.	Jurassic
Beaufort Group	Green-grey to blue-grey, mudstone and sandstone.	Triassic
Ecca Group	Shale and minor sandstone.	Permian
Dwyka Group	Diamictite, minor shale.	Carboniferous
Msikaba Formation	Light, grey, quartzitic sandstone.	Devonian
Sikombe Granite – Margate Complex	Gneiss and granite.	Precambrian

Figure 5A: Geology of the T60 Catchment



Msikaba: This group underlies the Dwyka with a thickness of approximately 1 000 m. It consists mainly of quartz-arenites (70 to 96 % quartz).

Dwyka: This unit consists mainly of tillite or diamictite. It is massive with little jointing, but is stratified in places. The thickness of the Dwyka varies between 200 and 500 m. Thin dolerite sill intrusives are found in places.

Ecca: The Ecca consists of undifferentiated shales, which are heavily intruded by dolerite sills. The Ecca sediments cover the entire western and southern portion of the T60 catchment.

Quaternary: Estuarine, beach and aelion sands, as well as alluvial deposits occur. Alluvium deposits are found along the major rivers.

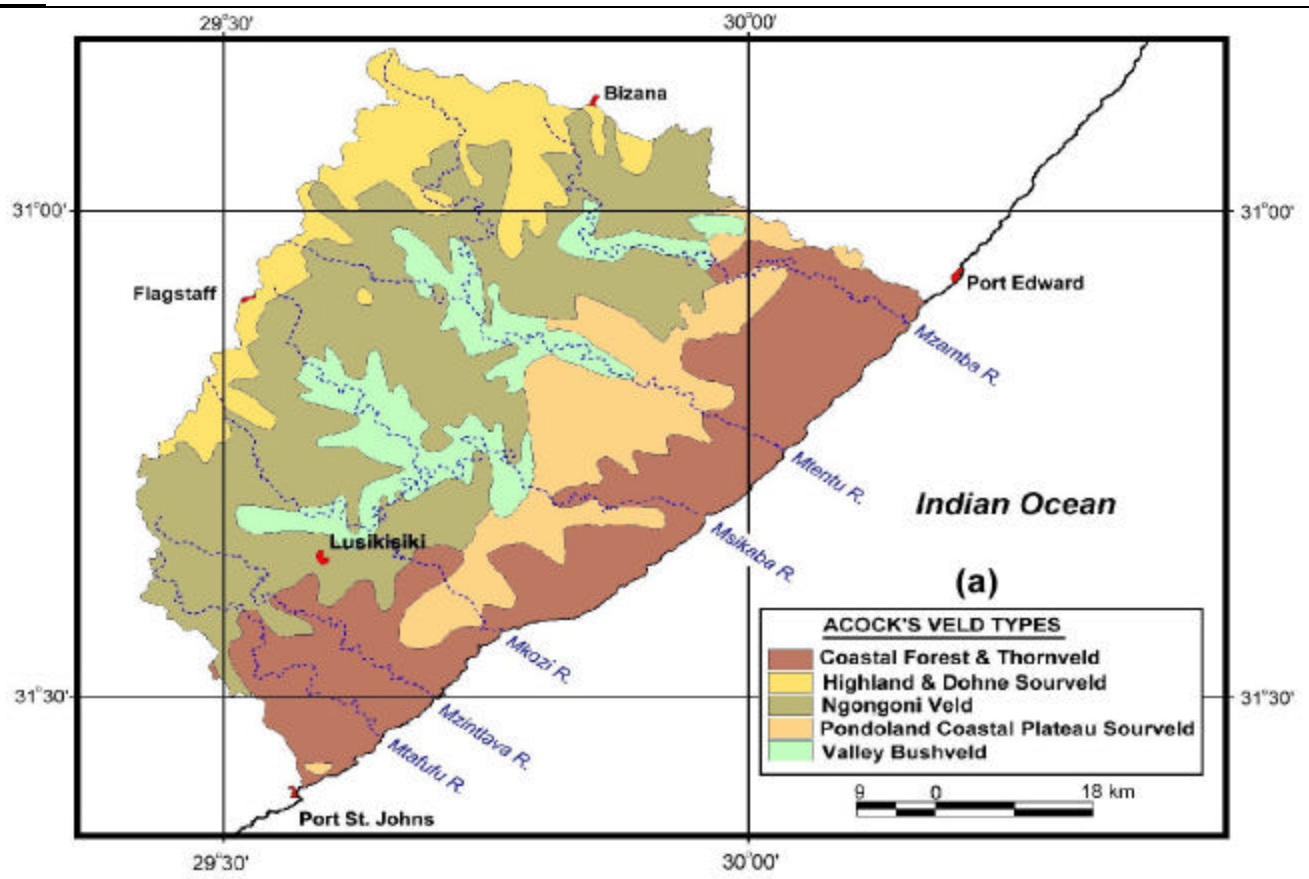
Dolerite: The density of dolerite intrusions varies from being very dense in the Ecca to less dense in the Dwyka and Msikaba units. No dolerite ring-complexes were found in this group. Dolerite sills are commonly 5 to 50 m thick, while the dykes are fairly thin varying between 2 and 10 m in thickness. The NW-WNW dykes are laterally persistent (10 to 20 km).

The geology of the study area was captured and compiled in a GIS from the Council for Geoscience's published 1:250 000 scale geological maps of Umtata (3128), Kokstad (3028) and Port Shepstone (3030). A more detailed description of the general geology is available in the supporting report **Groundwater Resources**.

Unfortunately no general soil map exists for the study area, or for any other part of the former Transkei. All previous reports on agricultural potential within the study area are rather vague when it comes to soil potential, and are largely based on reconnaissance visits. The Transkei Agricultural Development Study quotes Wood and van Schoor (1976) saying that the "the lack of proper profile description and analytical data makes it impossible to give anything but a very cursory description of the soils identified in Transkei". The climatic and soil conditions of the northern part of the coast are favourable for the cultivation of sugar cane and sugar beet. The north-eastern Coastal Forelands and Midlands are unsuitable for crop production due to poor soil conditions.

2.2.5 Vegetation

The major types of vegetation are forest and grassland, which form a mosaic in the landscape, contributing to the attractive visual contrasts of the Wild Coast. The vegetation of the north-eastern tablelands is of the Coast Belt Forest type, comprising of Coastal Forest and Thornveld. Grass species are similar to the Pondoland Coastal Sourveld, which occurs a few kilometres inland and is unique to Pondoland in the north-eastern sub-region. Further south, Eastern Province Thornveld is found adjacent to the Coastal Forests. The low mountains and river valleys are dominated by Valley Bushveld. A great variety of coastal forest types exhibit a very high degree of biodiversity. The forests are the region's most notable feature and are considered unique in South Africa and the world. There are dune forest and swamp forest, Pondoland coastal forest and mangrove forest. The Pondoland coastal forest is particularly diverse and rich in endemic species. The coastal grasslands are in good condition and constitute a valuable grazing resource. There are some 900 grassland and forest species of commercial medicinal and homeopathic value. The distribution of the major vegetation types in the T60 catchment are shown in **Figures 6(a)** and **6(b)**, after Acocks (1988) and Low-Rebello (1996) respectively.



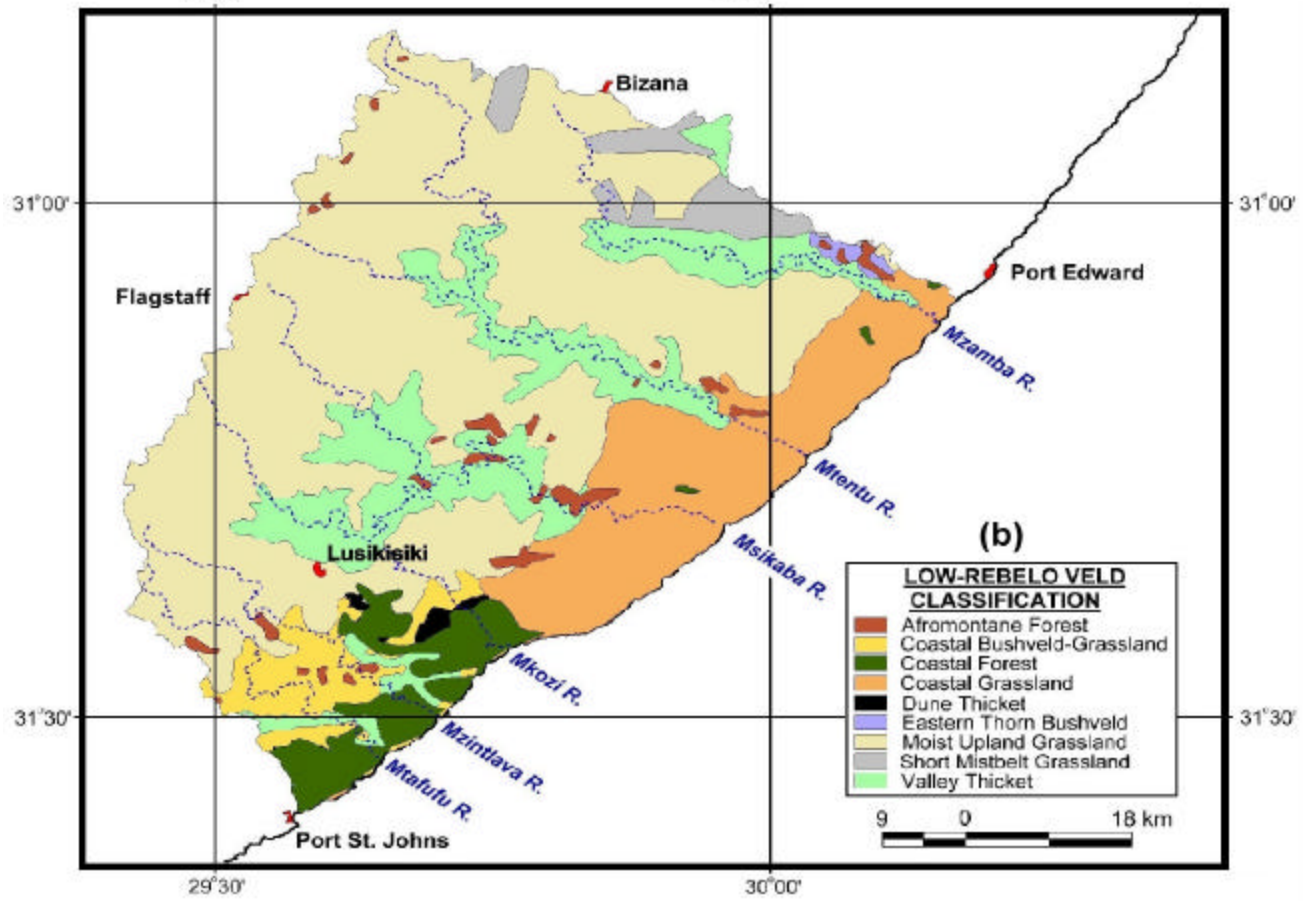


Fig6a and 6b : Vegetation Types

2.2.6 Land tenure and use

Land tenure

The dominant type of land tenure in the study area (about 92%) is the traditional/ communal tenure. The traditional land is further subdivided into the following categories:

- Residential land: (usually half a hectare per family), which may be in dispersed settlements or consolidated into betterment villages
- Arable land: allocated for every community member, which is normally used for subsistence farming
- Common grazing land

The right to utilise the land is determined by the tribal authority. Experience shows that individuals within a community are often resistant to allow land that has been allocated to them to be rezoned for other use (e.g. irrigation).

Other land tenures in the area include:

- Commercial forestry plantations: presently about 8 500 ha
- Conservation land: including indigenous forests and nature reserves. The Mkambati Nature Reserve located between the estuaries of the Msikaba and Mtentu Rivers extends over an area of 7 720 ha. About 1 600 ha of land on the southern bank of the Msikaba River estuary is proclaimed as indigenous forest reserve. Both reserves are under the management and control of the Eastern Cape Department of Economic Affairs, Environment and Tourism. Plans are presently underway to extend the area of the Mkambati Nature Reserve to about 30 000 ha.
- Intensive commercial agriculture: The Magwa Tea estate near Lusikisiki extends over an area of 2 955 ha, of which 1 800 ha are planted with tea. Additional 5 000 ha have been expropriated for the extension of the estate, but the extension plans have not materialised yet.

Land use

The land use information is presented in **Figure 6**. The high rainfall in the region facilitates dry land crop production, and there is no significant irrigated agriculture at present. A total of 8 500 ha of land potentially suitable for irrigation have been identified for the purposes of the Eastern Pondoland Basin Study. The feasibility of the development of irrigation is low due to the low incremental crop yield (irrigated minus dry land) and the high costs for the development of the irrigation infrastructure. It is anticipated that a total of 460 ha of irrigation will be developed by year 2030.

Large portions of the former Transkei are ideally suited for afforestation and much has already been done to develop this industry, which appears to be one of the fastest growing sectors of the economy in the region. Approximately 8 500 ha of afforestation have already been established within the Eastern Pondoland Region, which include eucalyptus, pine, wattle and indigenous plantations. The potential for expanding the afforestation is substantial (potential 35 000 ha), but may be limited by the associated reduction of runoff and the high environmental water requirements. The Wild Coast District Council's Land Development Objectives and Integrated Development Plan have as primary objectives the promotion of new investments in tourism, agriculture and forestry.

Eastern Pondoland Basin Study

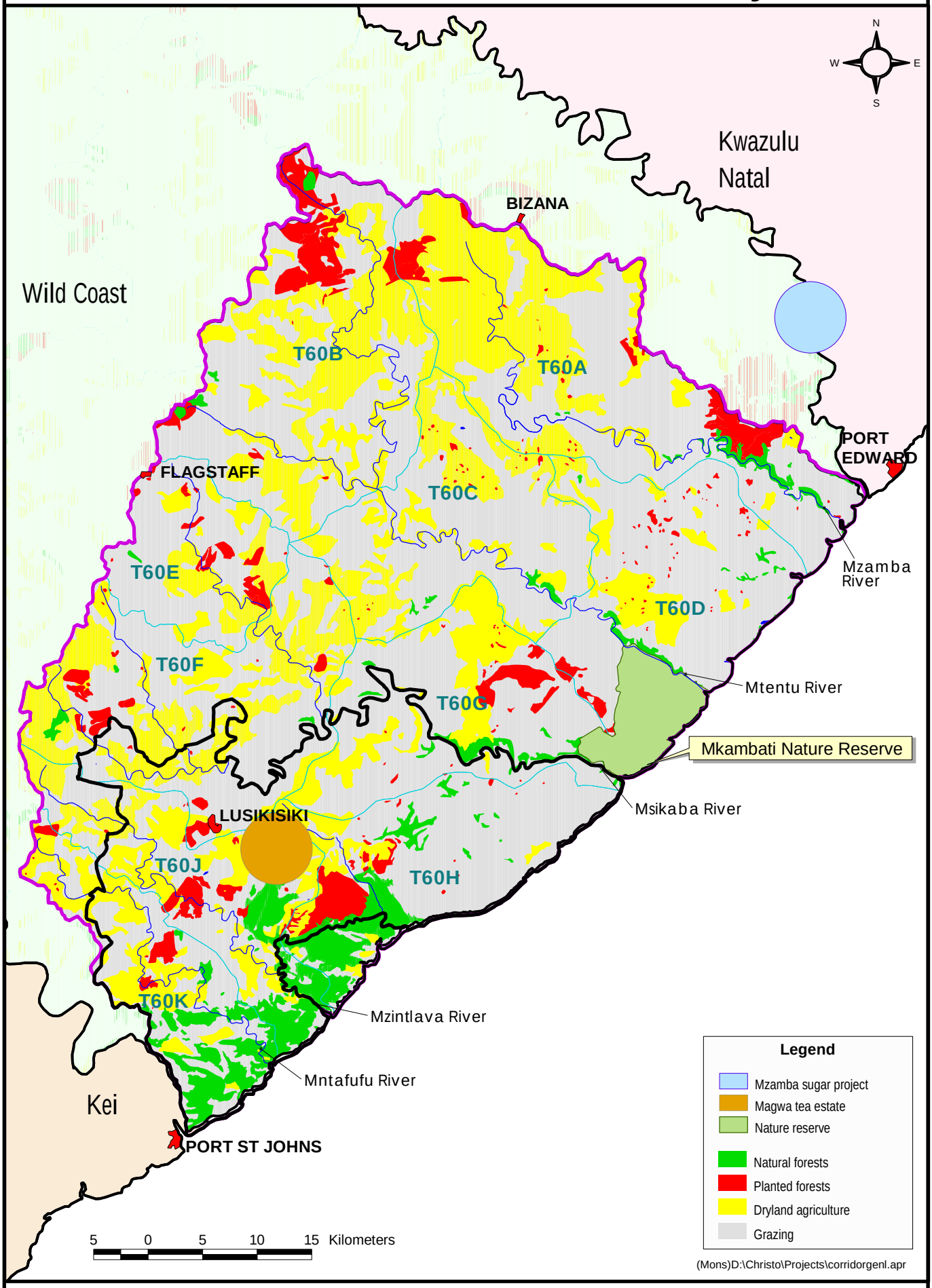


Fig 6 : Land Use

UWP Engineers

2.3 Demography and Socio-Economics

The population distribution within the study area is illustrated in **Figure 7**. The Eastern Pondoland is densely populated (an average of 0,75 people/ha) and most of the population reside in rural villages or dispersed settlements. The main economic centres in the area are the towns of Lusikisiki and Flagstaff, with Bizana, Port St. Johns and Port Edwards being just outside of the study area. The area is part of the Wild Coast District Council (1999 demarcation) and is divided between three magisterial districts (Lusikisiki, Flagstaff and Bizana), with the largest area falling within Lusikisiki district.

The study area includes 327 rural villages and two urban towns with a total population of approximately 489 000 (1996 base year) according to the DWAF: Water Services database (First Order Strategy). The settlement pattern in the majority of the coastal districts comprises of homesteads dispersed along ridges of the mountains and hills and sometimes in those valley bottoms that are fairly flat. In general, areas within a few kilometres of the coast are sparsely populated. Many of the villages have population numbers of less than 2 000 people.

The dependency rate (the percentage of the population under 15 or over 65 years of age) is high at 55 %, and the distribution of men and women in the study area is 44 % and 56 % respectively. Of the population in the region older than 18 years of age 43 % have no formal schooling qualification, 36 % have completed primary school, and only 4 % have their matric and/or a higher qualification. Industrial activity is limited and the main sources of income are subsistence farming and migrant remittance. Unemployment is very high - approximately 5 % of the total population in the area are formally employed.

The main economic and administrative centres in the study area are the towns of Lusikisiki, Flagstaff and Bizana.

The Magwa Tea Estate (2 995 ha), located to the east of Lusikisiki, currently employs about 1 700 permanent and 1 800 seasonal workers, with women making up almost 80 % of the labour force. The workers of the estate live in 14 agro-villages. The estate is managed by the Magwa Tea Corporation (MTC) and produces about 3000 tons of tea per annum, or 12 % of the tea consumed in South Africa.

The commercial forestry industry, which currently occupies about 8 500 ha of the study area provides permanent employment to about 800 people. The potential for growth of this industry is high.

A number of tourist developments of national importance are situated in the study area. The Wild Coast Sun hotel (800 beds, 3 000 day visitors), located between the Mzamba and Mtamvuna River estuaries, provides permanent employment to about 1 000 people. A number of small tourist developments at the Mkambati Nature Reserve can accommodate about 120 tourists. The Mbotyi hotel accommodates about 50 visitors.

Eastern Pondoland Basin Study

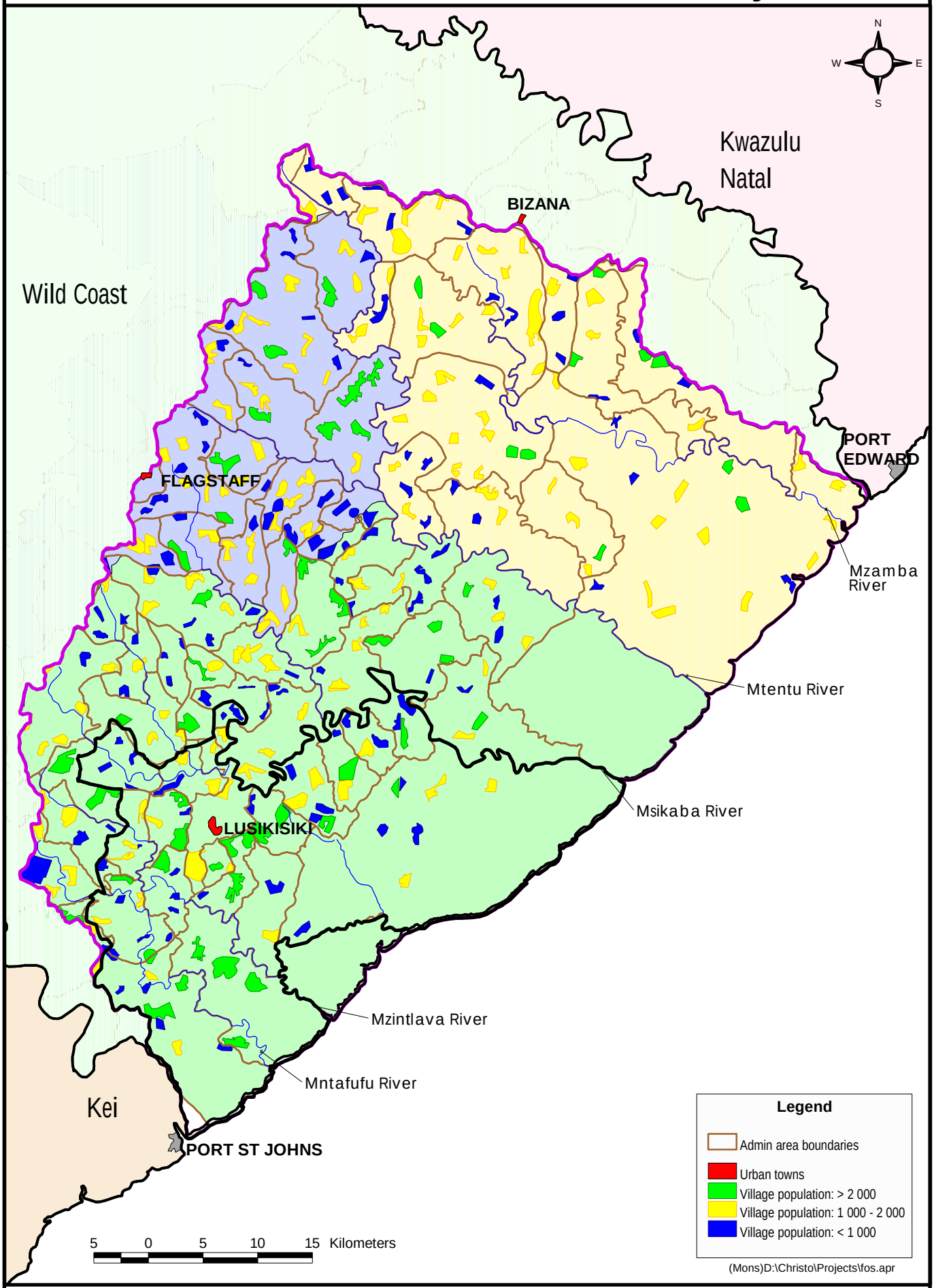


Fig 7 : Demography

UWP Engineers

2.4 Spatial Development Initiative (SDI) Projects

The Spatial Development Initiative (SDI) programme is a short-term investment strategy aiming to unlock inherent economic potential in specific spatial locations in Southern Africa. It uses public resources to leverage private sector investment in order to boost development in regions with high potential for economic growth. SDIs are the practical implementation of the government's economic strategy as set out in its Growth, Employment and Redistribution (GEAR) policy. The Mkambati, Mbotyi and Magwa nodal areas have been identified as three of six (Port St Johns, Coffee Bay and Dwesa/Cwebe being the others) potential economic growth centres within the Wild Coast SDI.

The Department of Trade and Industry is responsible for the funding, monitoring and implementation of all projects related to the Wild Coast SDI programme. The upgrading of the infrastructure and the provision of basic services (water, sanitation, roads, electricity, etc.) within the nodal areas is perceived to be an important prerequisite for attracting private investment and the associated success of the SDI programme. The responsibility for the development of the water supply infrastructure has been delegated to the Department of Water Affairs and Forestry.

The Mkambati nodal (980 km^2) area has been defined to include the nature reserve and the surrounding areas within an average 25 km radius. The Mkambati SDI project intends to develop the full tourist potential of the Mkambati Nature Reserve, which in turn is expected as a spin off to lead to agricultural developments and employment opportunities. The project includes the development of accommodation facilities for a total number of 300 tourists (from 120 presently available); the provision of water supply services to 41 villages (65 000 people) located in the surrounding areas; the development of 1 000 ha of dairy farming and possibly 500 ha of irrigation. A reconnaissance level feasibility study, which has identified an assessed various options for provision of water supply to the nodal area was undertaken by UWP Engineers in March 2000 [62].

The Magwa SDI project is intended to include the extension of the tea plantation by 1 000 ha, the upgrading and betterment of the processing factory, and the development of 4 000 ha of commercial forests.

The Mbotyi SDI project is intended to include the upgrading and extension of the tourist facilities at the Mbotyi River estuary from 50 visitors to 120 visitors, and the development 7 000 ha of commercial forests.

3. NATURAL ENVIRONMENT AND CONSERVATION VALUE

In considering the natural environment and the conservation value of a region, factors such as rarity and diversity of the biota and habitats, scenic richness and existing land use are regarded as important. When the study area is evaluated using these criteria, it is clearly apparent why this region is widely considered as having exceptionally high conservation value, particularly in the coastal areas.

3.1 Terrestrial Habitat

Vegetation

Eastern Pondoland falls within one of the seven centres of floral endemism in southern Africa, namely the Maputoland-Pondoland Region of Endemism, extending from southern Mozambique to about East London. The major portion of one of the two distinct foci for high floral endemism and diversity in the Maputoland-Pondoland Region, namely the Pondoland Centre of Endemism falls within the study area.

The Pondoland Centre of Endemism is largely confined to the quartzitic sandstone formation of the Natal Group, which occurs as surface outcrops in a belt of about 15 to 20 km wide along the coastal plateau from the Mtamvuna River to the Egoso fault at Mbotyi, just north of the Mzintlava River. The Pondoland Centre of Endemism contains at least 130 local endemic plant species. The most well known example is probably the highly localised and very rare Pondoland Coconut Palm (Mkambati Palm) *Jubaeopsis caffra*, which is found only on the north banks of the lower reaches of the Msikaba and Mtentu rivers. These trees have been declared a National Monument.

The Pondoland sandstone forests in the river gorges dissecting the coastal plateau have a rich variety of endemic or near-endemic plant species, many of which do not occur further south and only sporadically further north. There are at least 30 endemic/near endemic tree species in this area, most of which occur in the relatively inaccessible forests found in these deep, steep-sided gorges. These coastal sandstone areas have one endemic family (*Rhynchocalycaceae*) and 5 endemic/near endemic genera of plants, and are thus considered unique. In total, the Pondoland region has 33 taxa in the Red Data List of southern African Plants (rare, endangered or endemic), most of which are geophytic orchids, bulbs and large trees.

The relatively high plant diversity in this bio-diversity "hot-spot" is best illustrated by the fact that over 1 300 plant species have been recorded in the relatively well-studied Mtamvuna Nature Reserve, which falls within the Pondoland Centre. This compares favourably with the 1 400 species found in the whole of the Kruger National Park, which is more than 600 times the size of the Mtamvuna Nature Reserve.

Geology and Topography

The hard quartzitic rock of the Natal Group Sandstone form the coastal "Tablelands" in Eastern Pondoland, which are broad level areas with slopes of less than a 1:7 gradient. This coastal plateau has been deeply incised by numerous rivers and the erosive force of these rivers have created the spectacular forested gorges, making the coastal plateau possibly the most scenically dramatic landscape of the area. These gorges and rugged topography have largely prevented the construction of a coastal road in this region and subsequently large areas along the coast are relatively inaccessible.

The soils formed on the Natal Group sandstones are generally of low agricultural potential. This is because they are usually shallow, highly leached, sandy and acidic. In addition, many areas suffer from aluminium toxicity (Nicolson 1997). The poor soils combined with the rugged landscape, have contributed to the limited economic development and relatively low population density along the Pondoland coastal plain. This has created a situation where the natural environment is largely undisturbed and is presently in a relatively healthy state.

The geology of the study area changes markedly as one moves away from the coastal plateau into inland areas. Here the landscape consists of rolling hills and the soils are underlain by tillite, shale, mudstone and sandstone of the Karoo Sequence, with intrusions of igneous dolerite, gabbro and related intrusive rocks (Kaperta & Johnson 1979). In these areas the soils are generally of higher quality and the conditions are more suitable for agricultural development. These areas support higher population densities and more intensive land-use takes place. Consequently, the human-induced impacts on the natural environment are much higher in these areas.

3.2 Aquatic Habitat

There are more than 20 river systems of varying size that enter the sea between the Mtafufu and Mzamba rivers within the study area, 16 of which can be considered as "significant". These vary from small non-perennial rivers and streams with small catchments restricted to the coastal zone, to relatively large river systems, such as the Msikaba, Mtentu and the Mzamba, that originate further inland.

Ecological Status (Ecological Management Class) of Rivers in Study Area

The water resources in these rivers, in terms of the mean annual runoff, are presently utilized to a very limited extent. It has been estimated that less than 5% of the mean annual runoff (MAR) of the larger rivers, and even less of the MAR of the smaller rivers, is being abstracted at present. Human settlements in the catchments in Eastern Pondoland are largely rural in nature and there is little industrial development. Pollution levels in the rivers are therefore low, apart from domestic effluent inputs near larger towns such as Lusikisiki. The instream habitat integrity of most of the rivers in the Eastern Pondoland is therefore high, i.e. largely natural, with few modifications.

On the other hand, riparian habitats of many of the rivers in Eastern Pondoland, particularly in the more densely populated inland areas where the rivers are accessible and close to settlements, have been seriously impacted by man's activities. These man-induced impacts on the riparian zones include clearing and cultivation of the floodplain, overgrazing by goats and cattle, harvesting of hardwood trees for building materials and

firewood, trampling and destabilization of river banks by stock and destructive veld-burning practices.

There are very little data on the biota of the freshwater zones of these river systems as only a limited number of scientific surveys have been carried out in the ex-Transkei region. However, recent limited surveys of the fish populations in rivers within the study area, as well as in rivers in the ex Transkei to the south, have found a number of possibly new fish species (see Table 2). Indeed, it is likely that thorough surveys in the future will discover even more fish populations and species not yet known to science.

Little is known of the aquatic invertebrates in Eastern Pondoland, but it is likely that detailed studies will reveal a number of new species, particularly in the coastal rivers draining the Natal Sandstones, which have low pH and poorly-buffered water (de Moor, 2000). The same can be expected with regard to the amphibians, although a brief survey in 1996 indicated that the Mkambati Reserve might rank as one of the richest of the Eastern Cape's nature reserves in terms of herpetological diversity (Burger, 1996).

In a study by Ninham Shand (2000): *"The Eastern Cape Water Resources Situation Assessment"*, all quaternary catchments within the study area were designated as Class A default ecological management class (DEMC) – i.e. unique on a national scale and very sensitive to flow modifications. This was due to the very high ecological importance and sensitivity of the rivers in this region. However, further investigations undertaken for the purposes of the Eastern Pondoland Basin Study, taking into account the present ecological status of these rivers, gave the Eastern Pondoland quaternary catchments a Class B attainable ecological management class (AEMC). This was due to the fact that man-induced impacts on riverine habitats are widespread and that there has been a loss of natural habitats (i.e. present ecological status = B Class). This was mainly because of the wide-scale and sometimes serious loss of riparian habitats due to the man-induced impacts mentioned above.

The implication of an EMC of Class B for a river is that only water resource developments that have a small risk of modifying the natural biotic template and exceeding the resource base, are allowed (Kleynhans 1999). More detailed studies on specific reaches of the Xura tributary of the Msikaba River, the Mzintlava, and the Mtentu Rivers within the study area, gave attainable EMC classifications of B as well as C. Again, the main negative impacts on the river ecosystems investigated were associated with the destruction of the riparian habitat and bad catchment management (soil erosion) stemming from high population densities.

Ecological Status (Ecological Management Class) of Estuaries in Study Area

The Eastern Pondoland estuaries are in a relatively pristine state and are considered to be of significant conservation value. The region lies within the transitional zone between subtropical and warm-temperate zoogeographical zones, with many marine and estuarine species approaching the southern limit of their distribution (Wooldridge 1999). The estuaries are relatively small, usually less than about 5 km in length, and range from mangrove systems, shallow lagoons, to the deep (39 m) Msikaba estuary, which is the deepest estuary along the South African coast. The estuaries with mangrove communities, such as the Mntafufu and Mzintlava, are of particular importance and are very sensitive to any disturbances (such as reduced freshwater inflow), which may lead to mouth closure.

As detailed in the supporting report **Estuarine Reserve Estimate**, **(**see also **Section 5.5** of this report) the ecological management classes (EMCs) of the 16 significant estuaries in the study area were determined. In this study, both the Ecological Importance Rating and the Ecological Integrity were used to give the estuaries a (desired) EMC. Only 2 estuaries were given a Class B EMC status (Mbotyi and Mnyameni), while the remaining were given a Class A EMC status.

This preliminary investigation on the estuarine freshwater flow requirements, or estuarine Reserve (quantity), of the Eastern Pondoland estuaries, indicated that the freshwater requirement of the estuaries may well be much higher than those for the riverine zones. In addition, this study emphasised the importance of maintaining the natural base-flow component of river flows. These base-flows are considered essential in order to maintain the natural sediment dynamics, i.e. the natural open/closed mouth condition of these estuaries. This proposed restriction on abstracting base flows from these rivers may have significant implications for water supply schemes in the region.

3.3 Proposed Extensions of the Conservation Areas

It is evident from the overview given above that the natural environment of the Eastern Pondoland region has both exceptional conservation value as well as potentially significant socio-economic importance in the context of tourism development. There is an urgent need to conserve these natural attributes, particularly in the face of the rapidly increasing pressures from development projects. This realisation has resulted in a number of strongly motivated proposals for a large portion of Eastern Pondoland to be given formal conservation status (Nicolson 1997, Avery 2000).

The only formal nature reserve in Eastern Pondoland is the Mkambati Nature Reserve, under the jurisdiction of the Eastern Province Department of Economic Affairs, Environment and Tourism. This 7 720 ha reserve is located on the coastal plateau between the Mtentu and Msikaba rivers. In addition, there is 27 000 ha of demarcated indigenous state forest, as well as 10 000 of "headmen's" forest in the study area, which theoretically have some form of protection. There are, however, serious problems associated with the existing environmental management of this region. This is particularly true regarding the development of tourism and the limited benefit that the local people have gained from existing tourism developments.

There is a proposal by the Wildlife and Environment Society of Southern Africa (WESSA), supported by several Government and Provincial departments, to get the coastal plateau and adjacent areas between the Mtamvuna River in the north and the Mzimvubu River in the south, declared a National Park – the proposed "Pondoland Wild Coast National Park" (Nicolson, 1997; Avery 2000).

Poorly planned water resource developments on rivers can have major negative impacts on the ecological functioning of sensitive downstream reaches, including the estuaries. It is thus important that serious consideration be given to all the potential environmental impacts of proposed water supply projects in Eastern Pondoland. Only if measures are taken to ensure minimal impact on river ecosystems and the continued supply of high-quality fresh water to the estuaries, will these valuable natural assets be conserved and the development of the full tourism potential of Eastern Pondoland be possible.

4. INFRASTRUCTURE AND PROJECTS

4.1 GENERAL INFRASTRUCTURE

The existing general infrastructure within the Eastern Pondoland basin is illustrated in **Figure 8**. The region is underdeveloped and its infrastructure is generally in a poor state. The only north-south linkage through the region is provided by the N2 road, which connects Durban with East London via Kokstad, Umtata and Butterworth. This road follows the coastline from Durban to Port Shepstone, but then deviates some 60 to 80 km inland. Primary access from Port St. Johns is via the recently upgraded R61 between Port St. Johns and Umtata.

The main road within the study area is the R61, laid out along the catchment boundary from Port Edward to Port St. Johns via Bizana, Flagstaff and Lusikisiki. The greater part of this road is surfaced, except for a stretch of approximately 20 km between Port St. Johns and Lusikisiki, which is scheduled for upgrading during 2001. This road has recently been upgraded and is of a relatively good standard. Two main gravel roads intersect the study area linking Lusikisiki, Bizana, Flagstaff and the Mkambati Nature Reserve via Holy Cross. The secondary roads system, which provides access to the villages within the study area is in a poor state of repair and is inaccessible during wet conditions.

Rail access is limited to the East London-Umtata link. Umtata provides the nearest airport. Twice daily scheduled flights operate between Umtata and Johannesburg, and there is a possibility that the roster may be extended to include links to Durban and East London. There are four registered and four unregistered landing strips, almost all located along the coast. The strip at Port St. Johns is surfaced and is presently utilised by chartered and weekly scheduled flights. The hinterland towns provide essential commercial, social and economic services to surrounding rural areas.

The three towns, a limited number of villages and the tourist resorts are presently electrified. Eskom is however planning to gradually extend the coverage of the village electrification. The main power supply system (22 and 66 kV) is illustrated in **Figure 8**.

The telecommunication system is poorly developed, and presently covers only the main towns. Cellular telecommunication coverage is available along the R61 road, and occasionally in other areas.

Eastern Pondoland Basin Study

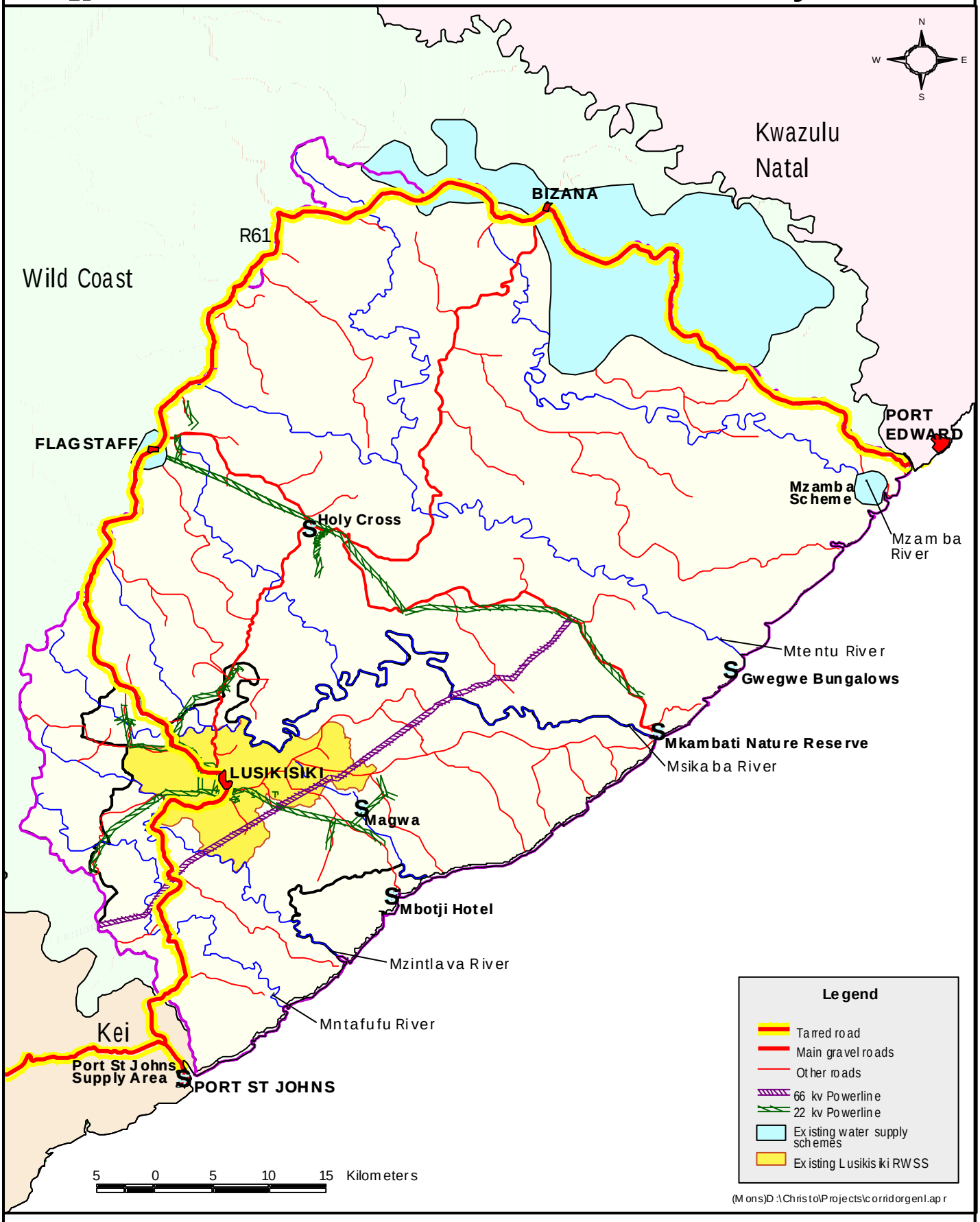


Fig 8 : Existing Infrastructure

UWP Engineers

4.2 EXISTING WATER SUPPLY AND SANITATION INFRASTRUCTURE

The location of the existing water supply schemes within the study area is illustrated in **Figure 8**. In general, the level of hardship for the local population with regards to water and sanitation services is high. Only the towns of Lusikisiki and Flagstaff have water born sanitation facilities. At present approximately 100 000 (20%) of the population within the study area is supplied with water from 9 schemes, but often to levels of service below RDP standard. The remaining 80 % of the population does not have access to water services. A summary description of the existing water supply schemes follows. More detailed information for selected schemes is available in **Appendix D**.

Lusikisiki Regional Water Supply Scheme

The layout of the existing system is shown on **Figure 9**. More detailed information about the existing and proposed infrastructure for this scheme is available in the **Development Options Report.**

The scheme was commissioned in July 1989 and currently supplies the town of Lusikisiki (11 000 people) and 21 rural villages (41 000 people). The town is provided with full water service - house connections and water born sanitation. The level of service for the villages is limited to bulk supply to village reservoirs.

The raw water is presently abstracted from a weir on the Xura River (Lo 29 31 43, La 31 19 40), located some 7 km northwest of Lusikisiki. The water is pumped to the water treatment works (WTW) situated close to the weir. The raw water pump station is equipped with two duty and one stand-by centrifugal pumps. The treatment process comprises chemical dosing, flocculation, sedimentation, slow sand filtration and chlorination. After treatment the water is pumped into the main storage reservoir (Reservoir A, 1 400 m^3) located at a command position, some 2 200 m away from the WTW. This reservoir then gravity feeds a further bulk reservoir (Reservoir B, 1 000 m^3). The secondary distribution system supplies by gravity some 24 village service reservoirs, varying in size between 20 and 90 m^3. All components of the bulk supply infrastructure have design capacities of 2 760 m^3/day (32 l/s gross).

A number of bulk users, including the town, draw water directly from the bulk main between reservoirs A and B. At present, the scheme appears to be unable to meet the water requirements of its consumers, and water shortages are frequently being experienced for the following reasons:

- Inadequate capacity and low assurance of supply of the water source
- Intermittent Eskom power failures and the inability of the bulk supply infrastructure to make up supply following a power failure (i.e. capacity of the infrastructure)
- The poor condition of the infrastructure (e.g. sand filters, pumps, pipelines and level control mechanisms in the village reservoirs)
- Operational procedures (possibly complicated by the poor condition of the infrastructure)
- Issues related to adequate water demand and water loss management for both the bulk and distribution systems

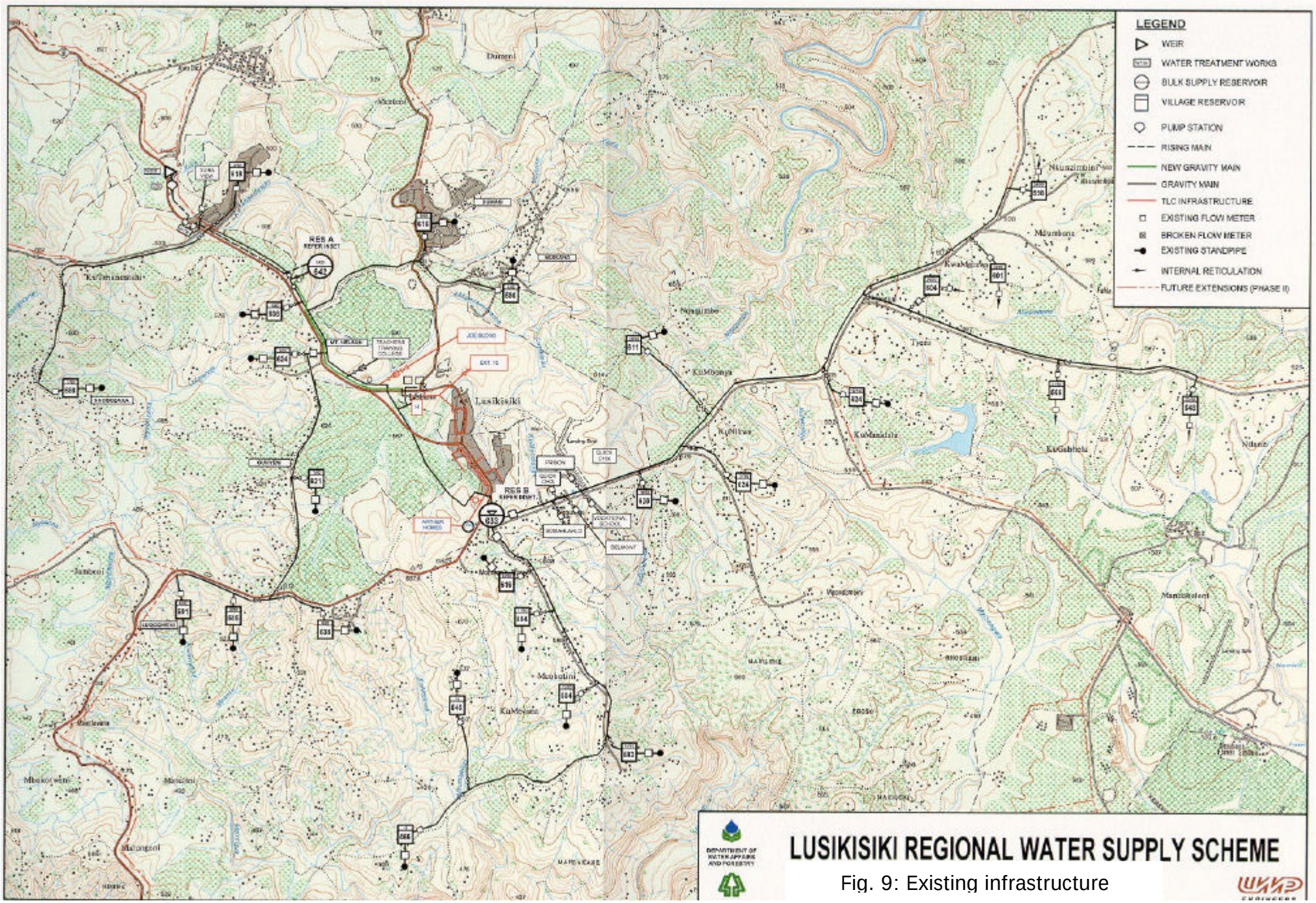


Fig. 9: Existing infrastructure

Magwa Tea Estate Water Scheme

The Magwa dam on the Mkozi River is the only registered dam in the study area. The dam has been constructed in the early 1970's and has the following main characteristics:

- Location of dam wall: Longitude: 29 39 15; Latitude: 31 22 56
- River bed level: 511.0 m msl, crest level 536.0 m msl
- Earth embankment wall, 25 m high to crest level, wall length 250 m, side channel spillway, crest width 4.0 m
- Full capacity: 1.33 x 10^3 m^3, surface area 0.19 km^2, catchment area 5.5 km^2

During a site inspection in July 1999 it was found that the dam wall is still in a fairly good condition. Seepage on the right flank was observed, but not considered to be serious. The outlet works and the bridge to the inlet tower are in a bad state of repair and require urgent attention.

The dam is used as a source of supply for the domestic and industrial requirements of the Tea Estate. In addition limited facilities are available at the estate for emergency irrigation in cases of extreme droughts. The water requirements are released from the dam into the Mkozi River and then abstracted from a weir located about 2 km downstream. The raw water is purified by a treatment plant, located next to the weir and then pumped to two command storage reservoirs with a total capacity of 420 m^3. The water is then distributed by gravity to the tea processing plant, about 50 staff houses (yard connections) and 14 agro-villages (communal stand pipe level of service) forming part of the estate. The scheme provides domestic supplies to about 5 000 people.

Flagstaff Local Water Supply Scheme

The scheme currently supplies the domestic and industrial requirements for the town of Flagstaff (300 houses) and the surrounding peri-urban areas, with a total estimated number of 5 300 people.

The scheme obtains raw water from four boreholes (total yield of 0.1 x $10^6 m^3/a$) and a diversion weir (1:50 assured yield of 0.11 x $10^6 m^3/a$) with a total available yield of about 0.21 x $10^6 m^3/a$. The raw water from the weir is being pumped to the water treatment works consisting of a settling tank and a pressure filter, with a capacity of 0.22 x $10^6 m^3/a$. The clear surface water and the borehole water are mixed into two bulk reservoirs located at command position. The water is then distributed to the consumers by gravity.

Mkambati Weir Scheme

The scheme supplies an existing clinic and staff (200 people) and the Main Camp at the nature reserve (44 beds). The Point cottages, with 6 beds, are situated near the coast, and obtain water from a tank that is replenished using a mobile water cart filled up at the Main Camp.

The scheme is approximately 50 years old. The concrete weir (31°15'40", 29°57'33") is located on the Mkambati River and is approximately 10 m long. The water is pumped at a rate of approximately 8l/s from the weir to two concrete reservoirs with a total capacity of

450 m^3. One duty and one standby pump hosted in a masonry pump house are powered by Lister diesel engines. One of the reservoirs is currently not operational and is in a poor state of repair. The water is dosed with chlorine after heavy rainfalls, but is not treated during dry periods. The water distributed by gravity from the reservoirs to the consumer nodes.

A separate small weir scheme, located about 7 km north-east from the main camp supplies about 50 consumers in Gwe Gwe resort with water. The existing HDPE distribution pipeline is in a poor state.

Mzamba Water Scheme

The Mzamba Scheme was built in 1983 to supply the requirements of the Wild Coast Sun Hotel, and was later upgraded and extended several times. The scheme presently supplies the Hotel complex (800 beds plus 3000 day visitors), the staff village (1000 people), the Mzamba police station, a small rural clinic and the Mzamba Curios Village.

A small earth embankment dam, 10 to 15 m in height, with a side channel spillway has been built on a small river within the property. A standby transfer scheme from the Mzamba River to the dam has been built to augment the system in times of emergency or severe droughts. The water is pumped by a raw water pump station (four electrical pumps and two standby diesel pumps) from the dam outlet to the water treatments works situated at a command position. The water treatment works have an operational capacity of 2 000 kl/d, and consist of coagulation and settlement tanks, pressure filters and electronic chlorination dosing equipment. The system includes three bulk reservoirs with a total storage capacity of 5,5 Ml.

Holy Cross Hospital Scheme (Taweni Village Scheme)

The Holy Cross Hospital is presently supplied from two small dams - Mcwesane (storage 11 000 m^3, yield 40 000 m^3/a) and Mketengeni (storage 30 000 m^3, yield 141 000 m^3/a). The estimated capacity of the scheme is 0,18 x $10^6 m^3$/a, supplying a total number of 1 500 people including patients and staff.

The raw water is being pumped from both water sources into the water treatment works. The works consist of sedimentation tank and slow sand filters with a capacity of 396 m^3/d. A total bulk storage capacity of 760 m^3 is available on the scheme. An extension of the scheme to supply nine villages in the surrounding area is being considered.

Bizana Regional Scheme

The town of Bizana and the surrounding villages are currently supplied with water from the Bizana Dam (30°48'S, 29°50'E) and a weir (30°50'S, 25°51'30"E). The water source, and the larger portion of the area supplied by this scheme fall beyond the boundaries of the EPBS study area. The total present capacity of the scheme is estimated to be 0.94 million m^3/a, supplying approximately 68 400 people. Fongoqa Skade Toyi and Associates (FST) and Africon are currently carrying out a feasibility investigation into the upgrading/extension of the scheme.

4.3 WATER SUPPLY PROJECTS AND PROPOSED DEVELOPMENTS

4.3.1 Implementation Projects

A number of water supply projects have been initiated and funded through the RDP programme of the DWAF, and have reached various stages of completion. These projects are listed in the following table (First Order Strategy study, DWAF, 2000) and illustrated in **Figure 10**.

Table 4.3A: RDP construction projects

Project No *[1]	Project name	Quarter-nary	Funding Allocation R 10^6	Water source *[1]	Beneficiaries Pop. (villages)
EC/01/001	Bizana Presidential Lead Project	T60A	6.26	S	15 500(10)0
EC/02/025	Lusikisiki RWS: village reticulation	T60F, G, H, J, K	39.7	S	78 000 (57)
EC/02/026	Lusikisiki RWS: bulk distribution system				
EC/03/037	Emergency Water Supply Project in Sipaqeni	T60E	1.3	G	3 400 (3)
EC/03/038	Group Water Scheme in Sipaqeni	T60E	1.5	G	4 000 (3)
EC/03/090	Ilinge Water Supply	T60E	1.1	S	850 (1)
EC/03/104	Xura Water Project	T60F	0.2	G	3 200 (2)
EC/04/045	Nkantolo A/A Water Supply	T60A	2.3	S&G	1000 (5)
EC/04/049	Siyaphambile Ndakeni Water Project	T60B	6.0	S&G	16 000 (9)
EC/04/048	Sipaqeni Water Supply	T60E	4.5	S&G	11 600 (8)
EC/04/092	Fama Domestic Water Supply	T60E	0.4	G	1 400 (1)
EC/04/111*[3]	Bizana Water Supply Extension	T60A	20.7	S	57 800 (38)

Notes:

*[1] Project Numbers: EC (Eastern Cape)/03 (RDP programme 3)/037 (Proj number)

*[2] Water Source: S (surface source), G (groundwater source), S&G (conjunctive surface and groundwater)

*[3] Project EC/04/111 falls only partially within the study area (T60)

4.3.2 Feasibility Studies for proposed projects

Three feasibility studies related to the development of the water resources and the water supply networks for proposed regional schemes were undertaken recently. Two of these studies (Lusikisiki RWSS, and Mkambati SDI) fall entirely within the study area. The third study (Bizana RWSS) has its water sources outside of the study area, but the distribution system supplies portions of the study area. The project areas are shown in **Figure 10**, and a brief project description follows:

Eastern Pondoland Basin Study

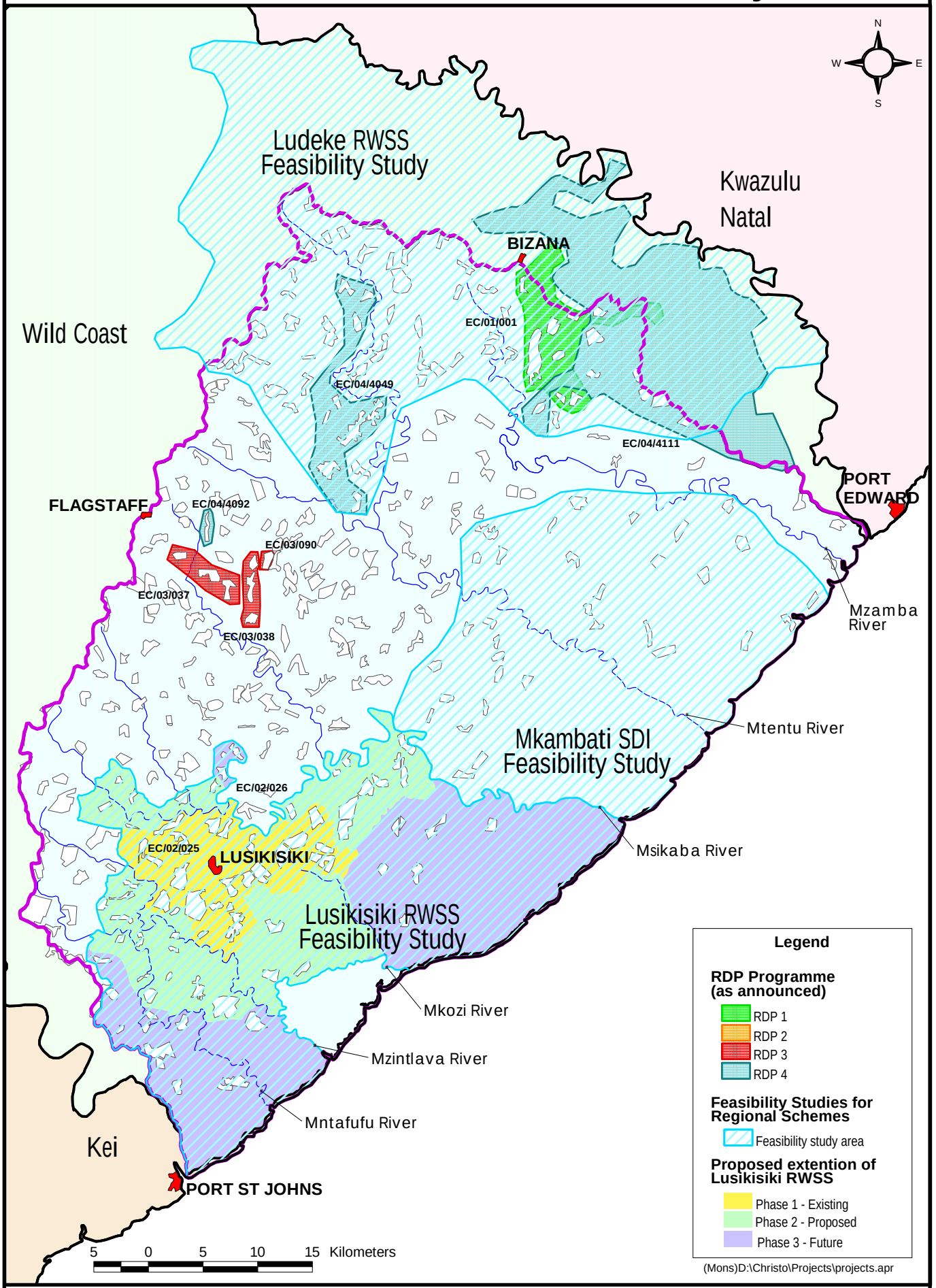


Fig 10 : Proposed Water Supply Projects

UWP Engineers

Lusikisiki Regional Water Supply Scheme (LRWSS)

A number of projects related to the upgrading of the standards of service as well as the extension of the supply area of the LRWSS scheme are being considered for implementation as part of the RDP programme. Due to the inadequate capacity of the existing water source (a weir on the Xura River) the implementation of these projects has been postponed until after the selection of an alternative source, capable to meet the increased water requirements.

The feasibility investigations into possible water sources for the augmentation of the LRWSS ware undertaken as part of this study, and are covered in detail in the **Development Options** report. A number of development options (**Table 4.3B**) based on various potential water sources were identified and evaluated:

- **Surface storage schemes:** five dams (stand alone schemes) on the Xura and Mzintlava Rivers and a number of conveyance scheme options for each dam were considered (**Figure 11**).
- **Surface water run of river scheme:** a system consisting of three weirs on the Xura and Mzintlava rivers, together with the associated infrastructure was evaluated (**Figure 12**).
- **Conjunctive use of surface and groundwater:** A number of options were considered to supplement the yield from the run of river scheme (described above) by groundwater during times of low river flows.

The weir scheme option can be considered if lower assurance of supply (80%) is acceptable. The conjunctive water scheme can be considered if lower capital cost combined with higher operation and maintenance costs are preferable.

The study concluded that the best option to augment the water source for the LRWSS would be the Zalu dam (D1B) with a capital cost of about R 50 million. This option provides the lowest unit reference value of water, reasonable flexibility with respect to future changes of the demand pattern, and less complicated institutional structure requirements. The upgrading of the existing primary conveyance infrastructure was recommended as the first phase of the proposed implementation.

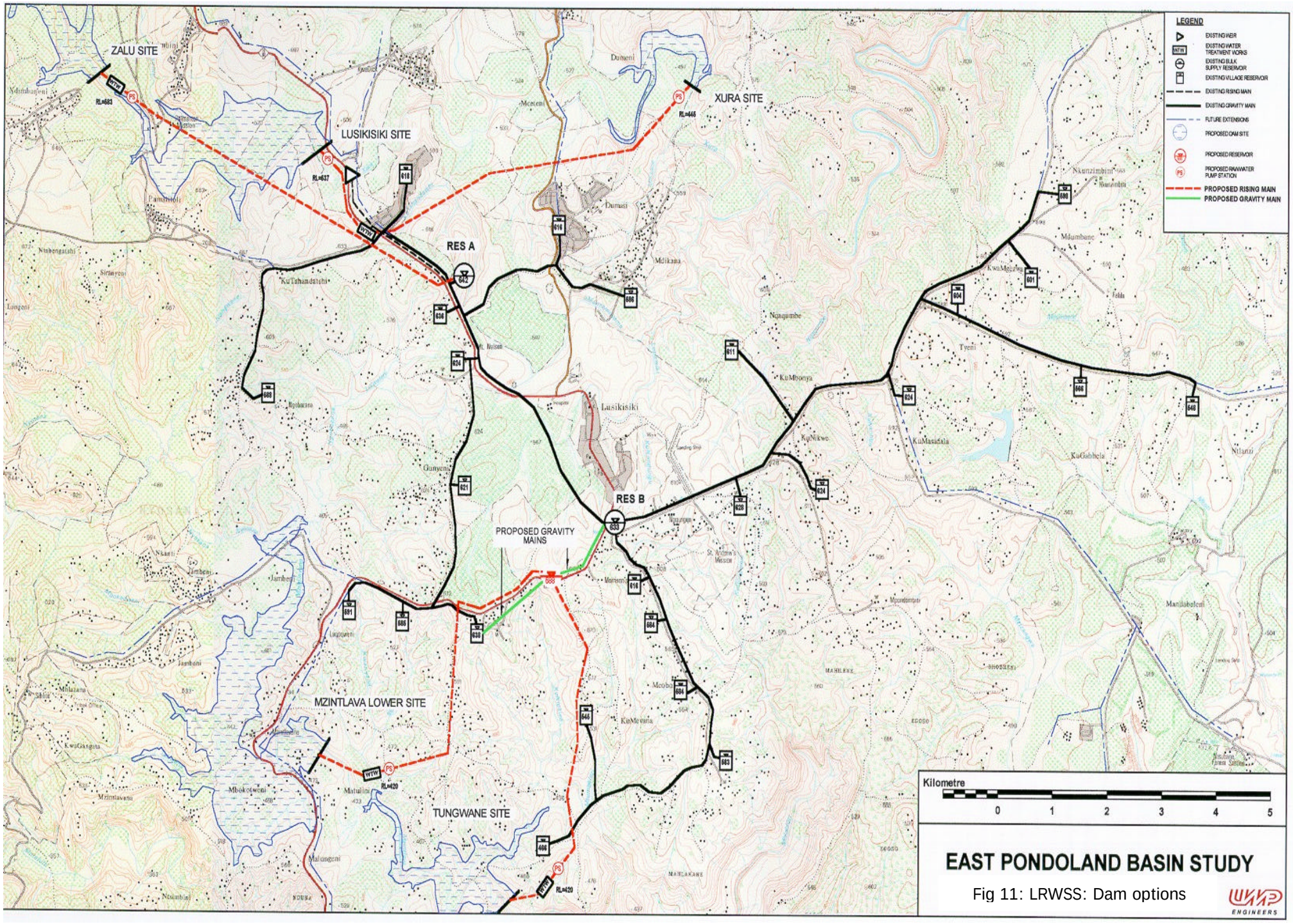


Fig 11: LRWSS: Dam options

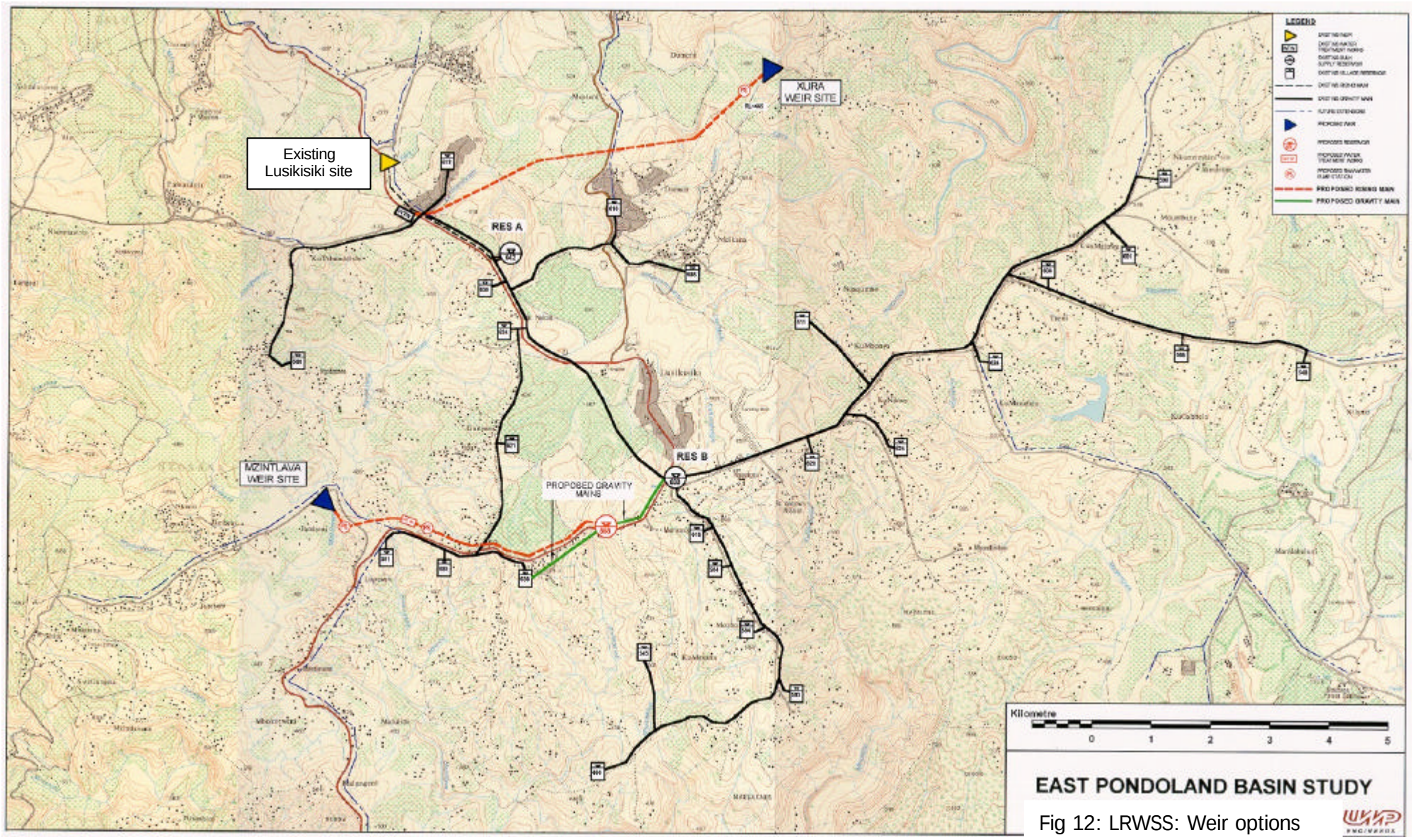


Fig 12: LRWSS: Weir options

Table 4.3B: Summary of Development Options: Augmentation of the Source for LRWSS

Option	Water Source	River	Assu-rance	Primary Conveyance system*
D1A	Zalu dam Conveyance: pumping from dam outlet Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPS -CWRM to Res. A -New reservoir adjacent to Reservoir A
D1B	Zalu dam Conveyance: release in river and pump from existing weir Surface water storage	Xura	98%	-Upgrade RWPS at existing weir site (72 l/s) -Upgrade RWRM to existing WTW -Upgrade WTW and CWPS -CWRM to Res. A -New reservoir adjacent to Reservoir A
D2A	Lusikisiki dam Conveyance: pumping from dam outlet Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPS -CWRM to Res. A -New reservoir adjacent to Reservoir A
D3	Xura dam Conveyance: pumping from dam outlet Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPS -CWRM to Res. A -New reservoir adjacent to Reservoir A
D4	Lower Mzintlava dam Conveyance: pumping from dam outlet Surface water storage	Mzintlava	98%	-RWGM to WTW (all components 72 l/s) -New WTW & CWPS -CWRM to reservoir -New reservoir 3 km west of Res. B -CWGM to Reservoir B
D5	Tungwane dam Conveyance: pumping from dam outlet Surface water storage	Mzintlava	98%	-RWGM to WTW (all components 72 l/s) -New WTW & CWPS -CWRM to reservoir -New reservoir 3 km west of Res. B -CWGM to Reservoir B
W1	-Lusikisiki weir -Xura weir -Mzintlava weir Non regulated, run of river	Xura Xura Mzintlava	80%	-Lusikisiki weir to existing WTW (72 l/s) -Xura weir to existing WTW (21 l/s) -Upgrade WTW and CWPS (72 l/s) -CWRM to Res A (72 l/s) -New reservoir close to reservoir A -RWPS at Mzintlava weir (19 l/s) -New WTW and CWPS and CWRM (19 l/s) -New reservoir 3 km west of Res. B -CWGM to Res B (19 l/s)
W1/G	-Lusikisiki weir -Xura weir -Mzintlava weir In conjunction with groundwater (40 l/s) Conjunctive water use	Xura Xura Mzintlava	90%	Surface water infrastructure same as above Groundwater infrastructure (total 40 l/s): -Pump, motor and pumphouse -CWRM to command location -Balancing reservoir
W2/G	-Lusikisiki weir In conjunction with groundwater (72 l/s) Conjunctive water use scheme	Xura	98%	-RWPS at weir (72 l/s) -RWRM to existing WTW (72 l/s) -Upgrade WTW and CWPS (72 l/s) -CWRM to Res. A (72 l/s) -New reservoir adjacent to Reservoir A -Groundwater infrastructure (total 72 l/s)
G1	Ground water (72 l.s)	-	98%	Groundwater infrastructure (total 72 l/s) -Pump, motor and pumphouse -CWRM to command location -Balancing reservoir
* Figures in brackets are the net design flows (for AADD) for sizing of the relevant infrastructure components				

Mkambati SDI Water Supply Scheme

A reconnaissance level feasibility study has been undertaken to determine the best development option for supplying water to the Mkambati Nodal Area of the Wild Coast Spatial Development Initiative (SDI) [UWP Engineers, Ref 62]. The Mkambati nodal area (980 km^2) has been defined to include the Mkambati Nature Reserve (situated between the Mtentu and Msikaba Rivers) and the surrounding area within an average 25 km radius (**Figure 13**). The planned scheme includes the provision of water to 41 villages (65 000 people), proposed tourist developments (about 300 beds) and certain agricultural developments - 500 ha of irrigation and 1 000 ha of dairy farming. A number of options with regards to potential water sources (**Table 4.3C**) were investigated and evaluated at reconnaissance level of detail:

- **Surface storage schemes:** Two dams on the Mtentu River and a number of conveyance scheme options for each dam were considered.
- **Surface water run of river scheme:** Three weirs on the Msikaba, Mtentu and Mzamba Rivers were considered as stand alone schemes or in combination
- **Conjunctive use of surface and groundwater:** Options to supply certain areas from groundwater in conjunction with surface water were considered and evaluated. The study concluded the following:

The best option to supply of the domestic water requirements for the rural villages is from run of river. Two schemes were recommended for final evaluation during further studies – the Spes Bona weir on Mtentu River or a combined scheme consisting of the Spes Bona and Mbongweni (Mzamba River) weirs. The total cost of the scheme, including the development of the water source, the primary and secondary conveyance systems, and the village reticulation is estimated to be in the order of R55 million.

The best option to supply the combined domestic and irrigation water requirements is from the Lusindisweni dam on Mtentu River. The total cost of this development was estimated to be about R 97 million. Due to the high incremental costs for the development of the water source to meet the irrigation requirements, irrigation developments were not recommended.

The best water source option to supply the tourist and dairy farming developments is from groundwater, at a total cost of about R8.7 million

Eastern Pondoland Basin Study

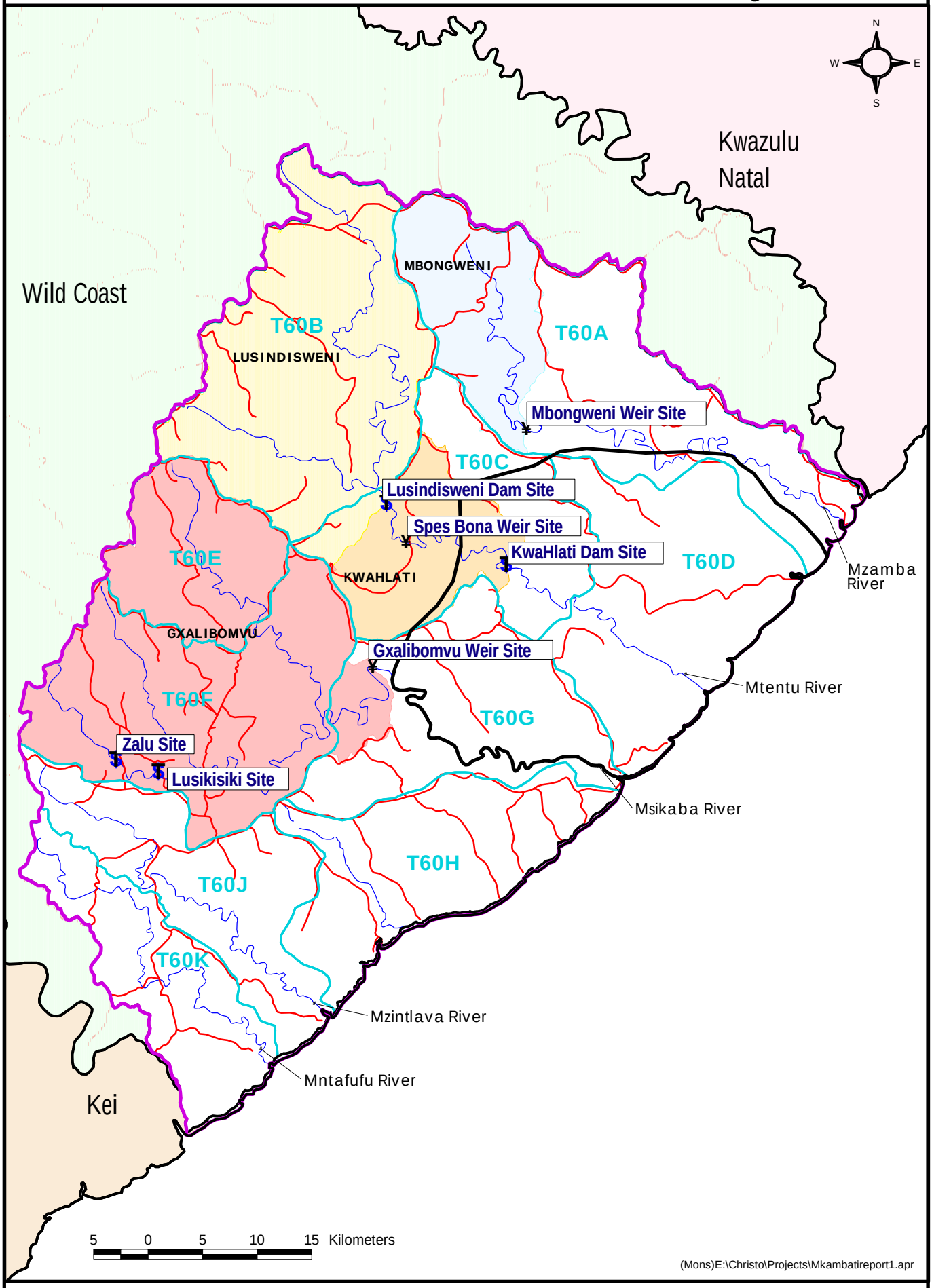


Fig13: Mkambati Water Project: Dams and Weirs

UWP Engineers

Table 4.3C: Mkambati SDI Water Project: Summary Development Options

Option	Source	Abstraction location	Conveyance System	Branch	Administrative Areas Served	Sizing Criteria	
						Yield ($10^6 m^3/a$)	Domestic SDD (l/s)
D1	Lusindisweni dam	Spes Bona weir	-Regional scheme. RWPS and WTW at weir -CWPS pumps into 2 branches to Res. A and B -Second stage (booster) pumps at each brunch -Village reservoirs fed by gravity from A and B -Reticulation system at each village	Reservoir A	Mtentu Ramsitter Hlabati Bontrand	4.377 domestic irrigation	32.89 for RWPS 12.15 for CWPS
				Reservoir B	Amadiba Amapisa Ama Kanyayo		17.76 for CWPS
W1	Spes Bona weir	Spes Bona weir	-Regional scheme. RWPS and WTW at weir -Off-channel storage – 7000 kl required -CWPS pumps into 2 branches to Res. A and B- -Second stage (booster) pumps at each brunch -Village reservoirs fed by gravity from A and B -Reticulation system at each village	Reservoir A	Mtentu Ramsitter Hlabati Bontrand	0.604 domestic only	32.89 for RWPS 12.15 for CWPS
				Reservoir B	Amadiba Amapisa Ama Kanyayo		17.76 for CWPS
D2	KwaHlati dam	Dam outlet	-Regional scheme. RWPS and WTW at weir -CWPS pumps into 2 branches to Res. A and B -Second stage (booster) pumps at each brunch -Village reservoirs fed by gravity from A and B -Reticulation system at each village	Reservoir A	Mtentu Ramsitter Hlabati Bontrand	4.377 domestic irrigation	32.89 for RWPS 12.15 for CWPS
				Reservoir B	Amadiba Amapisa Ama Kanyayo		17.76 for CWPS
W2/ W3	Spes Bona and Mbongweni weirs	Spes Bona weir and	-Group scheme. Separate RWPS and WTW at each weir -Off-channel storage – 1000 kl at Spes Bona -CWPS pumps in two stages to reservoir -Village reservoirs fed by gravity from A and C -Reticulation system at each village	Reservoir A Group 1	Mtentu Ramsitter Hlabati Bontrand	0.604 domestic	13.36 for RWPS 12.15 for CWPS
		Mbongweni weir		Reservoir C Group 2	Amadiba Amapisa Ama Kanyayo		19.53 for RWPS (from Mbongweni); 17.76 for CWPS
W4	KwaHlati weir	KwaHlati weir	-Regional scheme. RWPS and WTW weir -CWPS pumps into 2 branches to Res. A and C -Second stage (booster) pumps at each brunch -Village reservoirs fed by gravity from A and C -Reticulation system at each village	Reservoir A	Mtentu Ramsitter Hlabati Bontrand	0.604 domestic	32.89 for RWPS 12.15 for CWPS
				Reservoir B	Amadiba Amapisa Ama Kanyayo		17.76 for CWPS

5. WATER REQUIREMENTS

This section describes the methodology for estimating and projecting the water requirements per quaternary catchment within the study area, for the following consumer sectors:

- Domestic (rural and urban) and industrial
- Irrigation
- Stock watering
- Afforestation
- Ecological

The current and projected consumption from groundwater resources, as well as the return flows from the urban areas were also considered.

5.1 DOMESTIC AND INDUSTRIAL WATER REQUIREMENTS

Estimated Population Numbers and Growth Rates

No reliable historic population data is available for the study area. Therefore the DWAF: Water Services database (First Order Strategy) was used for estimation of the base year (1996) population numbers. According to this database the population number for the Eastern Pondoland Basin is approximately 489 000. Due to the fact that the domestic requirements are relatively small in comparison with other requirements (Ecological Reserve, Afforestation) it was decided that no detailed investigation would be required at this stage to verify the population number information. This database is more conservative than the 1996 Census results (weighted population of 387 350 people) by about 25%. The use of the DWAF database was selected for the following reasons:

- Its format provides convenience for planning purposes. The information is available per village.
- It has already been used for various other projects in the area and the relevant population numbers and village names will be consistent.
- It is more conservative, which will provide reasonable and needed safety in view of the overall uncertainties.

Based on the Census data for the period 1985 to 1996, the population growth rate in the Lusikisiki district of the study area is estimated to be about 4% pa for the rural areas, and 8% for the urbanised areas. The exceptionally high growth of the urban population can be attributed to the rapid institutional developments – new prison, teachers college, hospital, clinic, etc in the town of Lusikisiki. The RDP Rural Water Supply Design Criteria Guidelines (DWAF, October 1997) recommend the use of a 2.5 % rural population growth rate, if no reliable demographic information is available. It is anticipated that for the period until year 2030 the rural population growth rate would decline significantly, while the urban population growth rate will continue to be reasonably high due to the migration trends experienced in recent years. Growth rates of 1% for the rural areas and 8% decreasing to 4% for the urban areas were assumed for the purposes of the basin study.

Table 5.1A: Population Numbers per Quaternary Catchment

Quaternary sub-catchment	1996 (base)		2000		2010		2020		2030	
	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban
T60A	60267		62714	0	69275	0	76523	0	84529	0
T60B	101316		105430	0	116460	0	128644	0	142103	0
T60C	41642		43333	0	47866	0	52874	0	58406	0
T60D	20443		21273	0	23499	0	25957	0	28673	0
T60E	30728	5300	31976	7211	35321	15567	39016	27878	43098	41267
T60F	76541	4437	79649	6036	87982	13032	97187	23339	107355	34547
T60G	51828		53932	0	59575	0	65808	0	72693	0
T60H	9568		9956	0	10998	0	12149	0	13420	0
T60J	40421		42062	0	46463	0	51324	0	56694	0
T60K	46067		47938	0	52953	0	58493	0	64613	0
TOTAL	**478 821**	**9737**	**498 263**	**13 247**	**550 392**	**28 599**	**607 976**	**51 217**	**671 583**	**75 814**

Note:

In January 2000, when the water requirements and the hydrological tasks of the study were completed, the results from a comprehensive demographic study commissioned by DWAF (MarkData) became available. According to this study, due to the impacts of AIDS, migration and urbanisation the annual population growth rates in the study area are predicted to be significantly lower than previously expected. The recommended average growth rates for the rural population within this region will decline from plus 0.38 % for the period 1996 to 2000 to minus 0.75 % for the period 1996 to 2030. The urban population growth rates are predicted to vary between 1.29 % (1996 to 2000) and 0.51 % (1996 to 2030). Due to the small effect of the population numbers on the system hydrology, it was decided not to amend the results shown in the above table for the purposes of the basin study. However, the more recent population growth rates were applied for sizing of the augmentation options for the Lusikisiki Regional Scheme, described in the **Development Options** report.

Levels of service

The following per capita consumptions were assumed for the purposes of estimation of the projected domestic water requirements:

- **Rural population served by formal water supply schemes:** Net water requirements per person per day assumed to grow from 25 l/c/d (year 1996), to 30 l/c/d (2000), and to 80 l/c/d (year 2030) in accordance with the RDP Rural Water Supply Design Criteria Guidelines (DWAF, October 1997). A provision for certain institutional and unforeseen requirements (clinics, commuters from other areas, community halls, etc) and an allowance of 5l/c/d for scholars in the area has been made.
- **Rural population not served by formal scheme:** 15 l/c/d for year 2000 to 2030

- **Urban population:** house connections and water born sanitation: net daily requirements assumed to increase from 120 l/c/d (1996), to 160 l/c/d (2000), and to 240 l/c/d (2030).
- **Urban industrial and institutional requirements:** The metered present (1996) industrial/institutional water consumption for the towns of Lusikisiki (0.22 million m^3/a) and Flagstaff (0.16 million m^3/a) was assumed to grow at a rate of 4% per annum until year 2030.

Phasing of the water supply infrastructure development

It has been assumed that the population served by formal schemes will grow form 20% at present to 90% by year 2030. The proposed extensions of the Lusikisiki scheme and all projects already initiated were assumed to be completed by 2010. The development of water supply projects has been phased in for each quaternary catchment individually. The population supplied by the Bizana scheme (water source outside of the study area) has been excluded from the estimate of the water requirements for the study area.

The estimated urban and rural water requirements per quaternary catchment are shown in the tables below:

Table 5.1B: Estimated urban domestic and institutional water requirements

Quaternary Town	Projected Water Requirements ($10^6 m^3/a$)			
	2000	2010	2020	2030
T60E: Flagstaff	0.606	1.353	2.593	4.214
T60F: Lusikisiki	0.613	1.290	2.403	3.872
TOTAL	**1.219**	**2.643**	**4.996**	**8.087**

Table 5.1C: Estimated rural domestic water requirements

Quaternary Sub-catchment	Projected Water Usage ($10^6 m^3/a$)			
	2000	2010	2020	2030
T60A	0.230	0.251	0.604	1.078
T60B	0.655	0.942	1.984	4.011
T60C	0.292	0.315	0.816	1.730
T60D	0.161	0.169	0.409	0.852
T60E	0.210	0.338	0.793	1.276
T60F	0.998	2.856	4.631	7.538
T60G	0.317	0.227	0.516	1.127
T60H	0.052	0.021	0.012	0.004
T60J	0.151	0.064	0.072	0.211
T60K	0.311	0.125	0.232	0.536
TOTAL	**3.376**	**5.308**	**10.070**	**18.363**

5.2 GROUND WATER USAGE AND RETURN FLOWS

Groundwater Usage

The groundwater consumption has been estimated and projected in broad terms for each quaternary catchment, in accordance with the estimated existing groundwater usage and the potential for development of the groundwater resources in future.

Table 5.2B: Estimated usage of groundwater

Quaternary Sub-catchment	Projected Water Usage ($10^6 m^3/a$)			
	2000	2010	2020	2030
T60A	0.012	0.013	0.030	0.054
T60B	0.033	0.094	0.298	1.003
T60C	0.015	0.047	0.204	0.692
T60D	0.008	0.025	0.102	0.341
T60E	0.052	0.101	0.278	0.510
T60F	0.000	0.000	0.232	0.377
T60G	0.000	0.000	0.026	0.056
T60H	0.000	0.000	0.001	0.000
T60J	0.000	0.000	0.004	0.011
T60K	0.000	0.000	0.012	0.027
TOTAL	**0.119**	**0.281**	**1.185**	**3.071**

Return flows

The existing return water treatment plants in the study area are listed in the following table. The total presently installed effluent treatment capacity in the study area is about 0.28 million m^3/a (755 m^3/day).

Table 5.2A: Site sources of urban return flows and sewage treatment works

Water User	Catchment	Capacity	Treatment Facility
Lusikisiki Teachers Training College	Msikaba	90 m^3/day	Oxidation ponds
St Elizabeth's Hospital	Msikaba	120 m^3/day	Oxidation ponds
Lusikisiki Transitional Local Council	Msikaba	280 m^3/day	Septic tanks and managed wetlands
Lusikisiki - old prison	Msikaba	10 m^3/day	Oxidation ponds
- new prison	Msikaba	60 m^3/day	Oxidation ponds
Vocational School	Msikaba	20 m^3/day	Septic tank
Holy Cross Hospital	Msikaba	100 m^3/day	Oxidation ponds
Bambisana Hospital	Mtafufu	75 m^3/day	Activated sludge plant

For the purposes of this study it has been assumed that about 50% of the total urban water usage will return to the surface water system. It is not anticipated that water born sanitation will be installed in the rural areas. No return flows from these areas are therefore considered. The projected irrigation requirements are relative small and the potential return flows have been ignored.

5.3 IRRIGATION WATER REQUIREMENTS

The Department of Water Affairs and Forestry has initiated a programme for upgrading of the existing irrigation schemes in the former Transkei. Before any new large irrigation schemes are developed this programme will have to show significant success. Most of the planned irrigation development in the region will be small, community based projects supported by the Department of Public Works. These projects generally vary in size from 1 ha to 25 ha, with the majority below 10 ha.

In general, irrigation is not anticipated to be feasible in the study area. The high mean annual precipitation (above 900 mm) allows high yielding dry-land agriculture and will most probably not justify the high capital costs for development of irrigation infrastructure. The area is deeply incised by the main river basins, and the potential irrigable land is normally located in the alluvial flood plains within the river valleys. These valleys are usually not accessible by roads of satisfactory standards, which limits the access to potential markets. The development of irrigation on suitable areas on the plateau is severely restricted by the high pumping head requirements (100 to 300 m) and the associated costs for the water supply infrastructure.

The following criteria was used for estimating the potential irrigable land within the study area:

- Only land on the banks of rivers with a slope of less than 5 % was considered.
- The land considered was restricted to a maximum elevation of 40 m above the river.
- All land where the river could possibly be influenced by the tidal zone was ignored.
- Land in the upper 20 % of the catchment areas of the rivers was not considered since the yield of the rivers will not be sufficient to sustain irrigation, and the topography might not be suited to dam sites.

The total area potentially suitable for irrigation **(Figure 14)**, based on the aforementioned criteria is estimated to be about 8 500 ha. The irrigable land is distributed in small patches across the study area, largely adjacent to the major rivers. The existing and potential irrigation areas and the projected water requirements are shown in **Tables 5.3A and 5.3B** respectively. More information regarding the agricultural and irrigation potential of the study area is available in the supporting report **Agriculture and Afforestation**.

Eastern Pondoland Basin Study

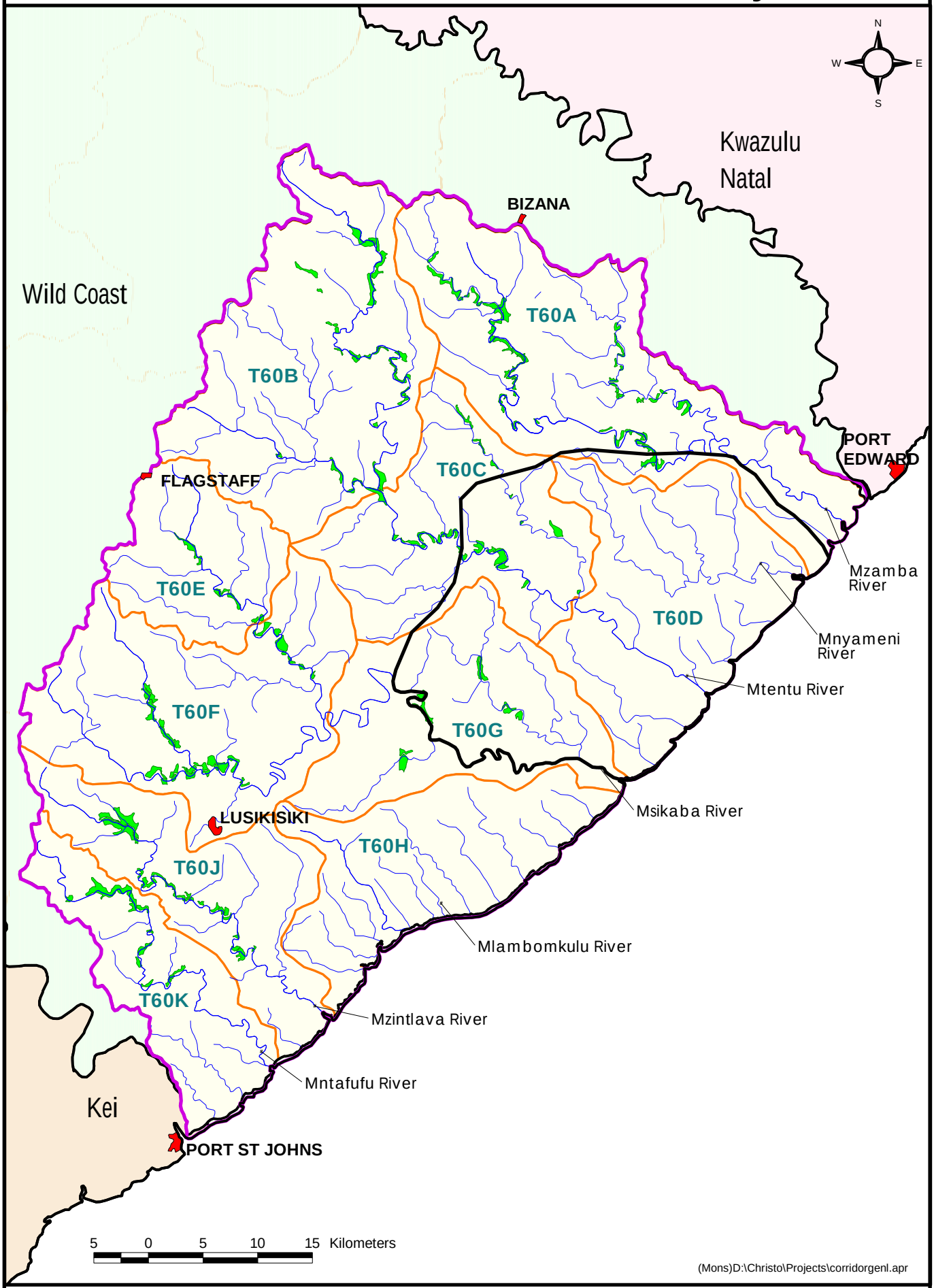


Fig 14 : Potential Irrigable Land

UWP Engineers

Table 5.3A: Existing and Potential Irrigation Areas (ha)

Quaternary sub-catchment	Irrigation Potential	Existing Irrigation	Projected Irrigation Areas (ha)		
			2010	2020	2030
T60A	1411	0	51	74	80
T60B	1130	0	29	46	59
T60C	698	0	4	12	18
T60D	1080	0	6	14	28
T60E	498	5	24	34	39
T60F	1745	1.5	76	115	148
T60G	444	0	7	13	17
T60H	0	0	0	0	0
T60J	906	0	17	29	39
T60K	605	7.5	23	30	37
TOTAL	**8517**	**14**	**237**	**367**	**465**

Table 5.3B: Estimated Irrigation Water Requirements ($10^6 m^3/a$)

Quaternary sub-catchment	Potential Demand	Projected Demand			
		2000	2010	2020	2030
T60A	2.567	0.000	0.097	0.141	0.160
T60B	2.276	0.000	0.058	0.092	0.117
T60C	0.892	0.000	0.004	0.014	0.023
T60D	1.507	0.000	0.008	0.020	0.039
T60E	1.009	0.010	0.049	0.067	0.080
T60F	3.270	0.003	0.139	0.210	0.270
T60G	0.490	0.000	0.008	0.013	0.019
T60H	0.000	0.000	0.000	0.000	0.000
T60J	1.102	0.000	0.019	0.032	0.045
T60K	0.776	0.006	0.025	0.035	0.044
TOTAL	**13.889**	**0.019**	**0.407**	**0.624**	**0.798**

5.4 STOCK WATERING REQUIREMENTS

The Transkei is well suited to livestock production, especially cattle, sheep and pigs. This has however resulted in high levels of overgrazing. There is little regulation on grazing and therefore almost no adherence to limitations of the carrying capacity of the region.

The available information regarding livestock numbers in the Eastern Pondoland Basin is very limited. An estimate of the livestock population in the region has been made on the basis of the "Revitalization of Agricultural Activities in the Transkei" report prepared by Kula and Nkonki Consortium (1996). The total number of livestock units was proportioned pro rata to the area of the quaternary catchments. An average stocking rate of 1.86 ha per LSU was utilised for the study area. Livestock requirements of 40 litres per large stock unit per day were used for the determination of the water requirements. Since the region is already overstocked it was assumed that the livestock population and water requirements would remain constant over the projection period.

Table 5.4: Livestock Numbers and Water Requirements

Quaternary Sub-catchment	Gross Area (km^2)	No. of LSU	Water demand ($10^6 m^3/a$)
T60A	547	29 409	0.429
T60B	528	28 387	0.414
T60C	363	19 516	0.285
T60D	415	22 312	0.326
T60E	198	10 645	0.155
T60F	464	24 946	0.364
T60G	360	19 355	0.283
T60H	322	17 312	0.253
T60J	294	15 806	0.231
T60K	242	13 011	0.190
T60	**3 733**	**200 699**	**2.930**

5.5 AFFORESTATION REQUIREMENTS

Large areas of the former Transkei are ideally suited for afforestation and much has already been done to develop this industry. This is one of the fastest growing sectors of the economy in the study area.

The existing and projected afforestation water requirements (reduction of runoff) have been taken into consideration for the determination of the mean annual runoff for all relevant catchments. The existing afforestation areas (CSIR, 1998 Wild Coast SDI Forestry Task Team Investigation) are shown in **Figure 6.** The reduction of runoff due to afforestation developments has been modelled using the Afforestek program and is described in more detail in the supporting report **Streamflow Hydrology**. More information regarding the existing and projected forestry developments is available in the supporting report **Agriculture and Afforestation**.

The existing and projected afforested areas as well as the associated reduction of run off per quaternary catchment are summarised in tables **Table 5.5A and B**.

Table 5.5A: Current and Projected Afforestation Areas (ha)

Quaternary Catchment	Afforestation areas (ha)			
	2000	**2010**	**2020**	**2030**
T60A	647	2 710	2 710	2 710
T60B	3 407	4 468	4 468	4 468
T60C	0	0	0	0
T60D	0	1 000	1 000	1 000
T60E	698	698	698	698
T60F	472	472	472	472
T60G	295	295	295	295
T60H	1 495	2 495	3 495	4 495
T60J	817	817	817	817
T60K	632	632	632	632
TOTAL	**8 463**	**13 587**	**14 587**	**15 587**

Table 5.5B: Estimated Reduction of Runoff due to Afforestation ($10^6 m^3/a$)

Quaternary Sub-catchment	Estimated water requirements (reduction of runoff)			
	2000	2010	2020	2030
T60A	0.70	2.85	2.85	2.85
T60B	3.70	4.90	4.90	4.90
T60C	0	0	0	0
T60D	0	1.67	1.67	1.67
T60E	0.78	0.78	0.78	0.78
T60F	0.58	0.58	0.58	0.58
T60G	0.49	0.49	0.49	0.49
T60H	2.81	4.50	6.40	8.21
T60J	1.27	1.27	1.27	1.27
T60K	0.96	0.96	0.96	0.96
TOTAL	**11.29**	**18.00**	**19.90**	**21.71**

5.6 ECOLOGICAL RESERVE WATER REQUIREMENTS

5.6.1 Ecological Estuarine Reserve Requirements

A desktop estimate of the ecological estuarine Reserve (EER) for the 16 largest rivers in the Eastern Pondoland region was carried out. The methodology applied involved a desktop study by various environmental experts, followed by a multidisciplinary two-day workshop, where the ecological management classes of the rivers were determined. This investigation has concluded that most of the estuaries in the study area are in pristine condition and are of high ecological and socio-economic importance. The estimated EERs for these rivers are therefore very high, and vary between 80 and 99% of the virgin MAR.

The total EER requirements for the study area are estimated to vary between 646 million m^3 (low estimate) and 751 million m^3 (high estimate), or between 82% and 96% of the naturalised MAR (see **Table 6.3C**). This is by far the largest requirement (although non-consumptive) imposed on the water resources in the area. At this stage it is considered that the lower estimate would be more appropriate, and it has been used for reconciling the water requirements and supplies.

Table 5.6.1 provides a summary of the estimated EER for the rivers within the study area. More detailed information is available in the supporting report **Ecological Estuarine Reserve Estimate**. The location of the estuaries is shown in **Figure 5**.

Table 5.6.1: Estimated Estuarine Reserve for Rivers within the LRWS Study Area

River Estuary	Quaternary Catchment	Nat. MAR ($10^6 m^3/a$)	Type of Estuary	EMC*	EER (% of MAR)	
Mtafufu	T60K	45.8	Open	A	80 - 95	Medium-large, permanently open barred, tidally dominated
Mzintlava	T60J	71.2	Open	A	80 - 95	Large, permanently open, barred (but lack of sediment?), tidally-dominated
Mzimpunzi	T60H	9.3	Closed	A	90 - 99	Small, open/closed system, barred, perched, river-dominated outlet, limited tidal inflows
Mbotyi	T60H	11.2	Closed	B	90 - 99	Small, open/closed system, barred, protected mouth, perched, river-dominated outlet
Mkozi	T60H	16.7	Closed	A	90 - 99	Small, open/closed system, barred, protected mouth, perched, river-dominated outlet
Myekane	T60H	1.9	Closed	A	90 - 99	Small, open/closed system, barred, perched, river-dominated outlet, limited tidal inflows
Luphuthana	T60H	7.8	Closed	A	80 - 95	Small, open/closed system, barred, perched, river-dominated outlet, limited tidal inflows
Mkweni	T60H	18.6	Closed	A	90 - 99	Small, open/closed system, barred, perched, river-dominated outlet, limited tidal inflows
Msikaba	T60G / E / F	207.4	Open	A	80 - 95	Large, permanently open, tidally dominated outlet, limited sediment at bar
Mtentu	T60D / C / B	152.6	Open	A	80 - 95	Large, permanently open, tidally dominated outlet, limited sediment at bar
Sikombe	T60D	6.9	Closed	A	90 – 99	Small, shallow, exposed to wave action, barred, river-dominated outlet
Lutungulu	T60D	3.9	Closed	A	90 – 99	Small, shallow, exposed mouth, barred, limited tidal prism, river-dominated outlet
Mnyameni	T60D	46.0	Closed	B	90 – 99	Medium-large, barred, tidally-dominated outlet, strong closing forces,
Mpahlanyana	T60A	1.2	Closed	A	90 – 99	Very small, exposed mouth, barred, perched, river-dominated, dependant on base flow
Mpahlane	T60A	2.6	Closed	A	90 – 99	Very small, exposed mouth, barred, perched, river-dominated, dependant on base flow
Mzamba	T60A	66.5	Open	A	90 – 99	Medium-large, barred, only partly protected, tidally dominated, could close in drought

** Ecological Management Class*

5.6.2 Ecological Riverine Reserve Requirements

The ecological riverine Reserve (ERR) (also known as instream flow requirements) was determined specifically for each of the proposed dam and weir sites within the study area. Five sites on the Msikaba (Xura) and Mzintlava River were investigated during this study for the purposes of augmentation of the water source for the LRWSS, and are shown in **Figure 19.** Five additional sites on the Mtentu and Mzamba Rivers were investigated during the course of the Mkambati SDI Water Project [62] and their positions are shown in **Figure 13.**

The estimates for the ERR were undertaken on the basis of the rapid methodology applying the Hughes DSS model (decision support system of Rhodes University's IWR). The ecological management classes, used as an input to the model, were assessed by a team of environmental specialists during a field trip in March 1999, and a workshop in August 1999. The results of the application of the Kleynhans method for the

determination of the "attainable" ecological management class (AEMC) for reaches of the Msikaba, Mzintlava, Mtentu and Mzamba Rivers are summarised in **Table 5.6.2A**. A summary of the estimated ERR for the various sites is offered in **Table 5.6.2B**. More detailed information including the assessment forms for the determination of ERR and the associated monthly rule curves, is provided in the supporting report **Ecological Riverine Reserve Estimate and in Report Ref. 62**. The rule curves have been used for the hydrological generation of present day monthly flows at each development site with provision for ERR releases.

Table 5.6.2A: Summary of Assessment of Ecological Management Classes

River	EISC*	DEMC*	DESC*	PESC*	AEMC*
Xura/Msikaba (Upper Reach)	High	B	B	C	C
Msikaba (Lower Reach)	High	B	B	C	B
Mzintlava (Upper Reach)	High	B	B	C	C
Mzintlava (Lower Reach)	High	B	B	B	B
Mzamba	Moderate	C	C	C	C
Mtentu	High	B	B	B	B

** EISC = ecological importance and sensitivity class; DEMC = default ecological management class; DESC = default ecological status class; PESC = present ecological status class; AEMC = attainable ecological management class*

The Kleynhans (1999) method does not allow for further differentiation of the EMC classes into a high or low sub-category (e.g. B class into AB or BC). A professional judgement of the river reaches in the study area gave an assessment of the AEMC for the various sites as indicated in **Table 5.6.2B**. Further studies are however required to increase the confidence in the initial assessments of the EMCs for the river reaches.

Table 5.6.2B: Estimated ERR (IFR) for the Proposed Development Sites

Site	River	AEMC	Naturalised MAR ($10^6m^3/a$)	ERR (IFR)	
				% of MAR	$10^6m^3/a$
Zalu	Xura/Msikaba	B/C	12.10	23.4	2.79
Lusikisiki	Xura/Msikaba	B/C	15.51	23.8	3.69
Xura	Msikaba	B	38.35	29.2	11.07
Lower Mzintlava	Mzintlava	B/C	17.06	24.6	4.20
Tungwane	Mzintlava	B	24.20	30.2	7.74
Lusindisweni	Mtentu	B/C	78.40	24.5	20.07
Spes Bona	Mtentu	B/C	81.52	24.5	20.88
KwaHlati	Mtentu	B/C	108.98	24.4	27.82
Mbongweni	Mzamba	B/C	26.28	24.8	6.81
Gxalibomvu	Msikaba	B	115.46	27.9	30.03

5.7 SUMMARY OF CONSUMPTIVE WATER REQUIREMENTS

The results of the estimates for the consumptive water requirements (domestic and industrial, irrigation, stock watering, afforestation) are summarised in **Tables 5.7A and B** per quaternary catchment and per user sector respectively. For the purposes of modelling of the surface water hydrology, the contributing factors – return flows and groundwater supply have been subtracted. The Ecological Reserve requirements are not included as these are specific for each development site. The naturalised incremental MAR per quaternary catchment is provided for reference.

As seen from the table below the total consumptive water requirements for the study area are estimated to be 18.8 million m^3 for the year 2000 and 51.9 million m^3 for the year 2030. Taking into consideration the estimated contributions form return flows and the supply from groundwater, the total requirements from the surface water resources would be 18.3 million m^3 for the year 2000 and 45.5 million m^3 for the year 2030.

Table 5.7A: Consumptive Surface Water Requirements per Quaternary

Quaternary Sub-catchment	Projected Water Requirements ($10^6 m^3/a$)				Naturalised MAR
	2000	2010	2020	2030	
T60A	1.348	3.615	3.994	4.463	71.9
T60B	4.737	6.220	7.093	8.440	75.5
T60C	0.562	0.557	0.911	1.346	62.7
T60D	0.478	2.147	2.322	2.546	102.7
T60E	1.498	2.034	3.017	4.188	28.0
T60F	2.383	4.778	7.041	10.735	79.1
T60G	1.089	1.007	1.276	1.862	100.3
T60H	3.115	4.774	6.664	8.466	124.7
T60J	1.652	1.584	1.602	1.747	77.6
T60K	1.466	1.300	1.405	1.704	59.7
TOTAL	**18.328**	**28.016**	**35.326**	**45.497**	**782.2**

Table 5.7B: Consumptive Water Requirements per User Sector

User Sector	Water Requirements ($10^6 m^3/a$)				Distribution, %	
	2000	2010	2020	2030	2000	2030
Urban domestic and industrial	1.219	2.643	4.996	8.087	6.5	15.6
Rural domestic	3.376	5.308	10.070	18.363	17.9	35.4
Stock watering	2.930	2.930	2.930	2.930	15.6	5.6
Irrigation	0.019	0.407	0.624	0.798	0.1	1.5
Afforestation	11.290	18.000	19.900	21.710	59.9	41.8
Total use	**18.834**	**29.288**	**38.520**	**51.888**	**100.0**	**100.0**
Return Flows	-0.387	-0.992	-2.010	-3.321	-2.1	-6.4
Groundwater supply	-0.119	-0.281	-1.185	-3.071	-0.6	-5.9
Total use from surface water	**18.328**	**28.016**	**35.326**	**45.497**	**97.3**	**87.7**

6. WATER RESOURCES

6.1 GROUNDWATER

Details regarding the results of the groundwater resources investigations undertaken for the Eastern Pondoland Basin Study are offered in the supporting report **Groundwater Resources**. The following paragraphs provide an overview and a brief summary of the results.

Regional perspective

The groundwater resources of the T60 drainage region are only being utilised at a fraction of their true potential, both actively via boreholes and passively from perennial springs or ephemeral seeps. The present groundwater consumption in the study area is estimated to be less than 1.0 million m^3 per annum. In general, the groundwater quality is good and is suitable for domestic water supply purposes, although local variability is anticipated. Local point source pollution of the groundwater is likely in densely populated areas, due to human activities, resulting in elevated nitrate levels and faecal bacterial counts.

The groundwater resources of the Eastern Pondoland Basin as indicated by the rainwater recharge potential are high, in the order of 280 million m^3 per annum. The groundwater harvest potential is estimated to be about 134 million m^3. Much of this groundwater is 'lost' as base-flow to the many perennial rivers draining the T60 catchment, particularly during the dry season. The low permeability of the shallow aquifers, the relatively low borehole yield potential, together with the inaccessibility of the terrain, limit the groundwater development potential of the T60 basin to between 12.5 and 23.5 million per annum. However, with the drilling of deeper (250 to 300 m), higher yielding production boreholes it may be possible to abstract between 50.0 and 90.0 million m^3 each year on a sustainable basis. The costs of exploring and developing such groundwater supply schemes will be considerably (five times) higher than the existing 'ad-hoc', low-yielding groundwater supply schemes. The distribution of the groundwater development potential for the Eastern Pondoland Basin is shown in **Figure 15**.

Groundwater resources can feasibly be implemented for the supply of small village schemes. Despite the favourable groundwater development potential of the study area the following factors limit the feasibility of utilising groundwater as a source for regional schemes (as compared to surface source):

- Cost considerations: pumps by diesel engines due to unavailability of electrical supply
- High O&M costs associated with multiple sources
- Generally lower assurance of supply compared to surface water

The cost of establishing and maintaining a groundwater supply scheme may, in certain parts of the T60 region, prove to be a factor limiting its development. The present groundwater development costs are relatively high in terms of the poor drilling success rates and low sustainable yields of the boreholes. The 'sustainability' of these water supplies are severely restricted by a lack of maintenance of the boreholes, pump equipment and reticulation networks.

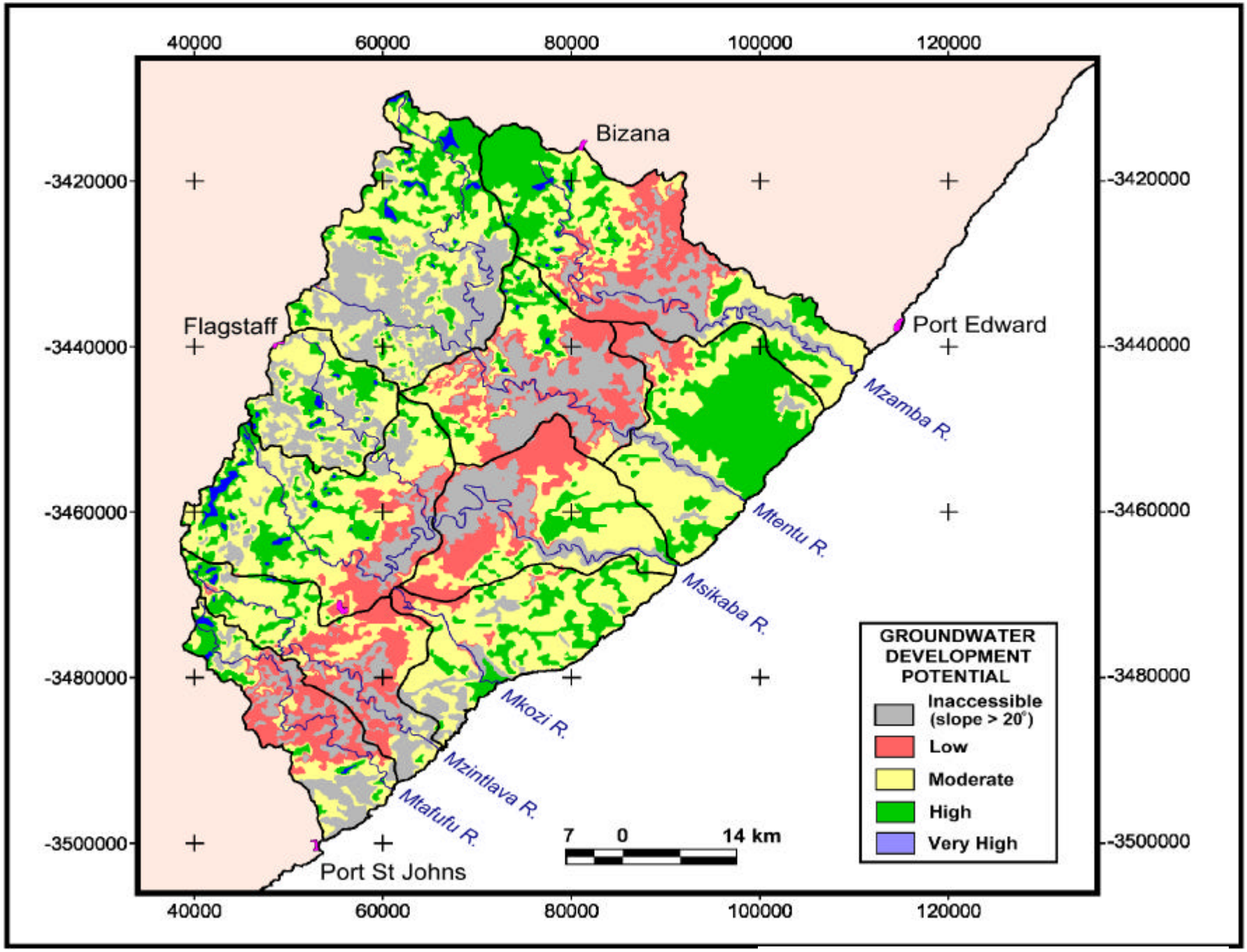


Fig 15: Ground water development potential

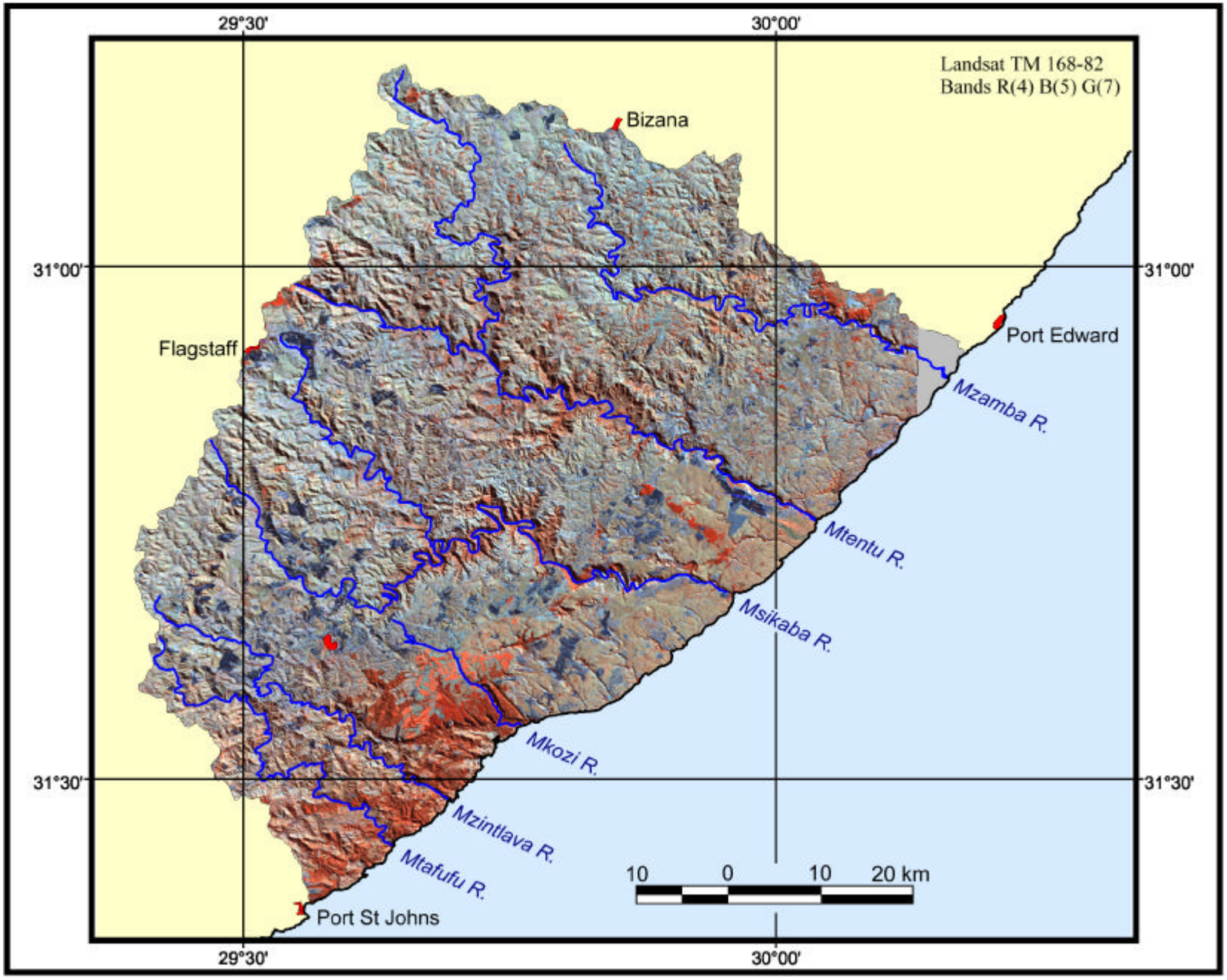


Fig 16: Satellite Imagery

Local perspective

At present, the LRWSS scheme study area is underdeveloped in terms of groundwater abstraction and only shallow aquifer systems have been utilised to a limited extend. Relatively high-yielding boreholes to a maximum of 5 l/s in isolated areas have been drilled in the past in the area. In the vicinity of the Nyosana Village, moderate borehole yields (2 l/s) were obtained along the contact of dolerite sills intruded into the Ecca shales. It is not known whether these boreholes are presently in production. In general, the weighted median yield of the boreholes drilled within the area varies in the range of 0,5 to 1,15 l/s.

Based on the density of the lineaments and the occurrences of favourable geological structures, taking into consideration the accessibility, a total of 61 potential exploration drill-sites were selected within "close" proximity (< 3 km) of the existing water supply infrastructure of the LRWS (**Figure 17**). The exploration drill-sites have been ranked according to their anticipated water-yielding potential in three categories, namely:

- Category A – Good (21 sites)
- Category B – Moderate (25 sites)
- Category C – Reasonable (15 sites)

Figure 17 indicates that the area to the south and south-east of Lusikisiki has the highest groundwater development potential. In some cases, more than one exploration site has been indicated along a regional geological structure, which results in the "clustering" of sites. This situation is ideal for the development of production "well-fields" (i.e. a number of closely-spaced boreholes). There are a number of operational and aquifer management advantages associated with such a production scheme.

As a first order estimate, the average yield of the production boreholes in the area covered by the Lusikisiki scheme is expected to be in the order of 1.0 to 2.0 l/s. Depths are expected to vary between 60 and 100 m and the success rates between 60% and 75%. However, it should be noted that no exploration drilling or testing of existing boreholes have taken place, therefore the confidence in the above numbers is low. It is recommended that detailed investigations be undertaken if groundwater is considered to be an acceptable source of supply.

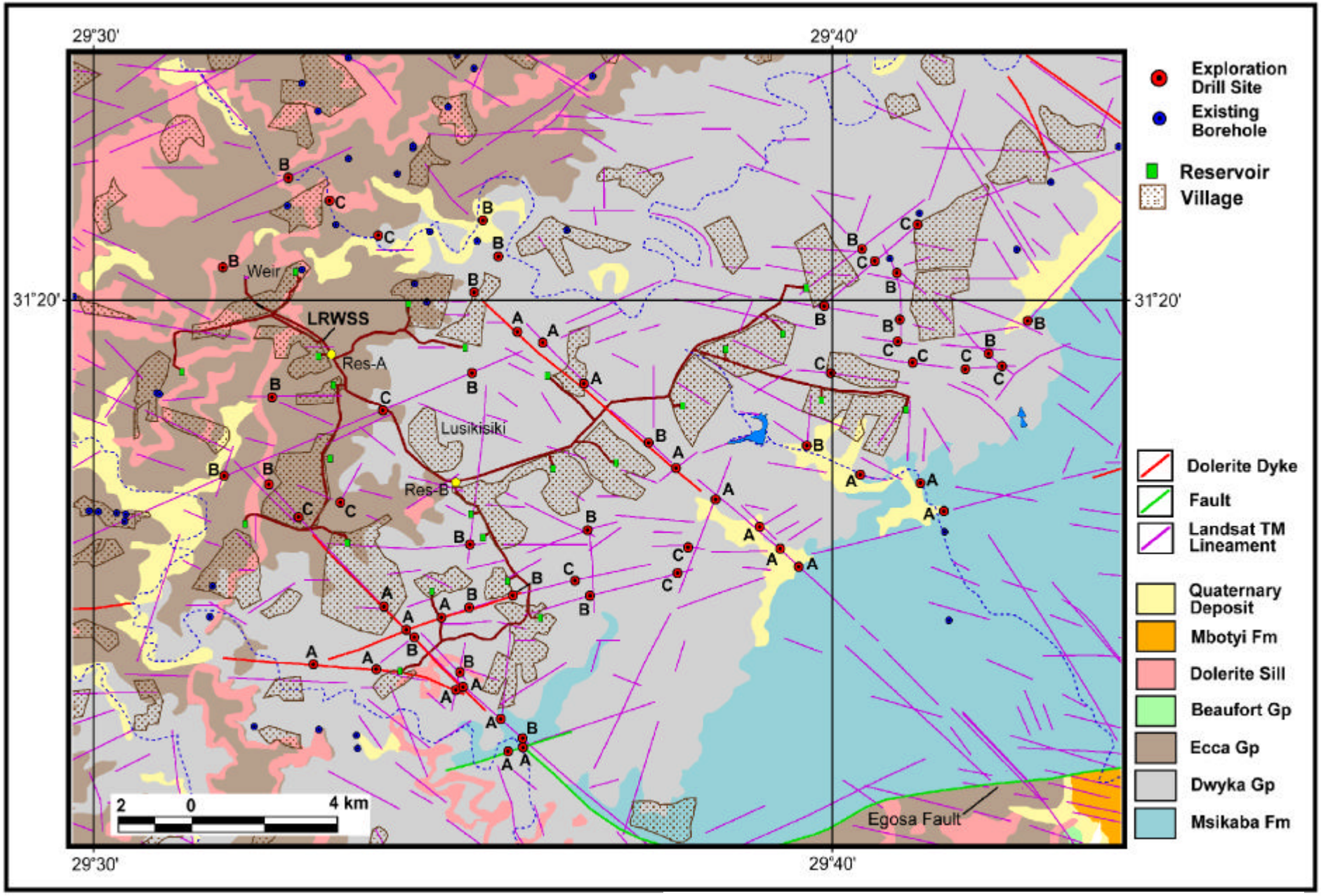


Fig 17: Exploration drill targets in the vicinity of the LRWSS

6.2 SURFACE WATER RESOURCES

6.2.1 Streamflow Hydrology for T60 Drainage Region

The streamflow analysis for the T60 drainage region has been undertaken on a quaternary catchment basis for the purposes of the Eastern Pondoland Basin Study. The results of these analyses are described in detail in the supporting report **Streamflow Hydrology**. This section outlines the findings related to possible development of the surface water resources.

The Water Research Commission publication "Surface Water Resources of South Africa, 1990" (WR90) [27] subdivides the study area into two rainfall zones and a number of functional rainfall gauging stations have been identified in each zone within the T60 region. The data from the majority of these stations contain gaps in their record, mostly for the period 1990 to 1997, but these were effectively patched. The hydrological analyses for the area have been based on the Water Resources Simulation Model (WRSM90) parameters and the rainfall input has been extended to include records until 1997.

An investigation of available hydrological and meteorological data revealed that only two flow-gauging stations exist in the Eastern Pondoland region (Xura and Mtafufu Rivers). Although certain observed stage records (time/height) are available, the reliability of the observed data has been found to be totally inadequate. No discharge tables for the time of observation are available to convert the primary records into secondary data (flows). In addition no similar catchments with reliable flow data records could be identified for cross correlation purposes, and therefore no calibration of the WRSM90 model was performed. The gauging stations have been revitalised since 1996, but the period of reliable observed data was too short for calibration purposes.

A summary of the results for the surface water runoff per quaternary catchment is provided in the following table and is illustrated in **Figure 18**.

Table 6.2.1: Surface Water Runoff per Quaternary Catchment

Quarter-nary	Catchm. Area	MAP	Natural. MAR	Natural. MAR	Surface Water Usage*		Incremental MAR	
					2000	2030	2000	2030
	(km^2)	(mm)	(mm)	($10^6m^3/a$)	($10^6m^3/a$)	($10^6m^3/a$)	($10^6m^3/a$)	($10^6m^3/a$)
T60A	547	873	129	71.9	1.3	4.5	70.6	67.6
T60B	528	896	134	75.5	4.7	8.4	70.8	67.2
T60C	363	952	171	62.7	0.6	1.3	62.1	61.4
T60D	415	1072	246	102.7	0.5	2.5	102.2	100.2
T60E	198	885	134	28.0	1.5	4.2	26.5	23.9
T60F	464	940	165	79.1	2.4	10.7	76.7	68.6
T60G	360	1116	276	100.3	1.1	1.9	99.2	98.5
T60H	322	1277	378	124.7	3.1	8.5	121.6	116.3
T60J	294	1101	258	77.6	1.7	1.7	75.9	75.8
T60K	242	1075	240	59.7	1.5	1.7	58.2	58.0
Total	**3733**			**782.2**	**18.3**	**45.5**	**763.9**	**737.5**

- Water usage includes all domestic, stock watering and afforestation requirements minus the return flows and the supply from groundwater. The irrigation and ecological requirements are excluded.

Eastern Pondoland Basin Study

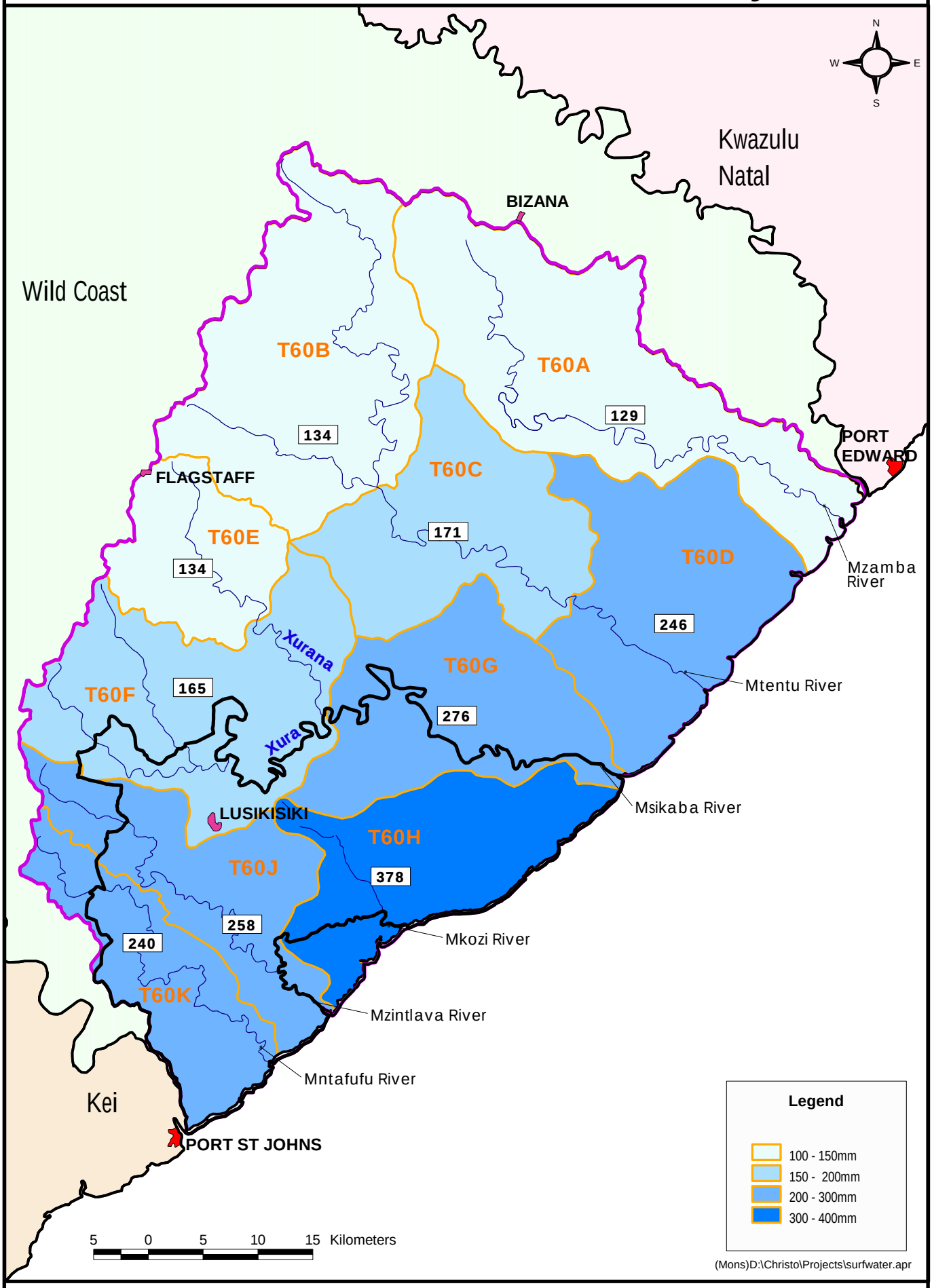


Fig 18 : Naturalised Mean Annual Runoff

UWP Engineers

The naturalised mean annual runoff form the entire study area is estimated to be 782 million m^3/a. Due to the activities of man the naturalised runoff is reduced by the present or projected water use from the surface water sources. The water usage was estimated on the basis of a methodology described in **Section 5,** and includes all consumptive requirements from the various user sectors (urban and rural domestic and institutional, stock watering, reduction of runoff due to afforestation). The contributions to the surface runoff, such as groundwater supplies and return flows were subtracted from the consumptive requirements. The irrigation requirements are negligible and have been excluded. The present day (2000) runoff from the study area is estimated to be 764 million m^3/a, while the runoff at year 2030 is projected to be 737 million m^3/a.

The total consumptive surface water usage (44.7 million m^3/a at year 2030) is estimated to be less than 6% of the naturalised runoff. It can be concluded that the available surface water resources have sufficient capacity to meet the water requirements.

6.2.2 Streamflow Hydrology for Selected Development Sites

Five dam sites and three weir sites on the Xura and Mzintlava Rivers have been investigated as potential sources for the augmentation of the Lusikisiki Regional Scheme as part of this study. Details are available in the **Development Options** Report and the position of the sites is shown in **Figure 19**. Five additional sites on the Mtentu, Mzamba and Msikaba Rivers were investigated during the course of the Mkambati SDI Water Project [62] and their positions are shown in **Figure 13.** A summary of the characteristics of the proposed development sites as well as the results of the hydrological simulation are offered in the following tables. Details regarding the methodology of simulation and the input/output data are available in the supporting report **Streamflow Hydrology**. The methodology for the determination of the Ecological Riverine Reserve (ERR) is outlined in **Section 5.6.2** of this report and is described in detail in the supporting report **Ecological Riverine Reserve Estimate.**

Table 6.2.2A: Catchment Areas for the Proposed Development Sites

Site name	River	Total Dam Catchment area (km^2)	Quaternary (km^2)		Quaternary area split by dam site (km^2)	
			No	Area	Up stream	Down stream
Zalu dam	Xura/Msikaba	71	T60F	464	71	393
Lusikisiki dam/weir	Xura/Msikaba	91	T60F	464	91	373
Xura dam/weir	Xura/Msikaba	225	T60F	464	225	239
Lower Mzintlava dam/weir	Mzintlava	98	T60J	294	98	196
Tungwane dam	Mzintlava	129	T60J	294	129	165
Lusindisweni dam	Mtentu	545	T60B,C	891	545	346
Spes Bona weir	Mtentu	563	T60B,C	891	563	328
KwaHlati dam	Mtentu	722	T60B,C	891	722	169
Mbongweni weir	Mzamba	200	T60A	547	200	347
Gxalibomvu weir	Msikaba	692	T60E,F,G	1022	692	330

Eastern Pondoland Basin Study

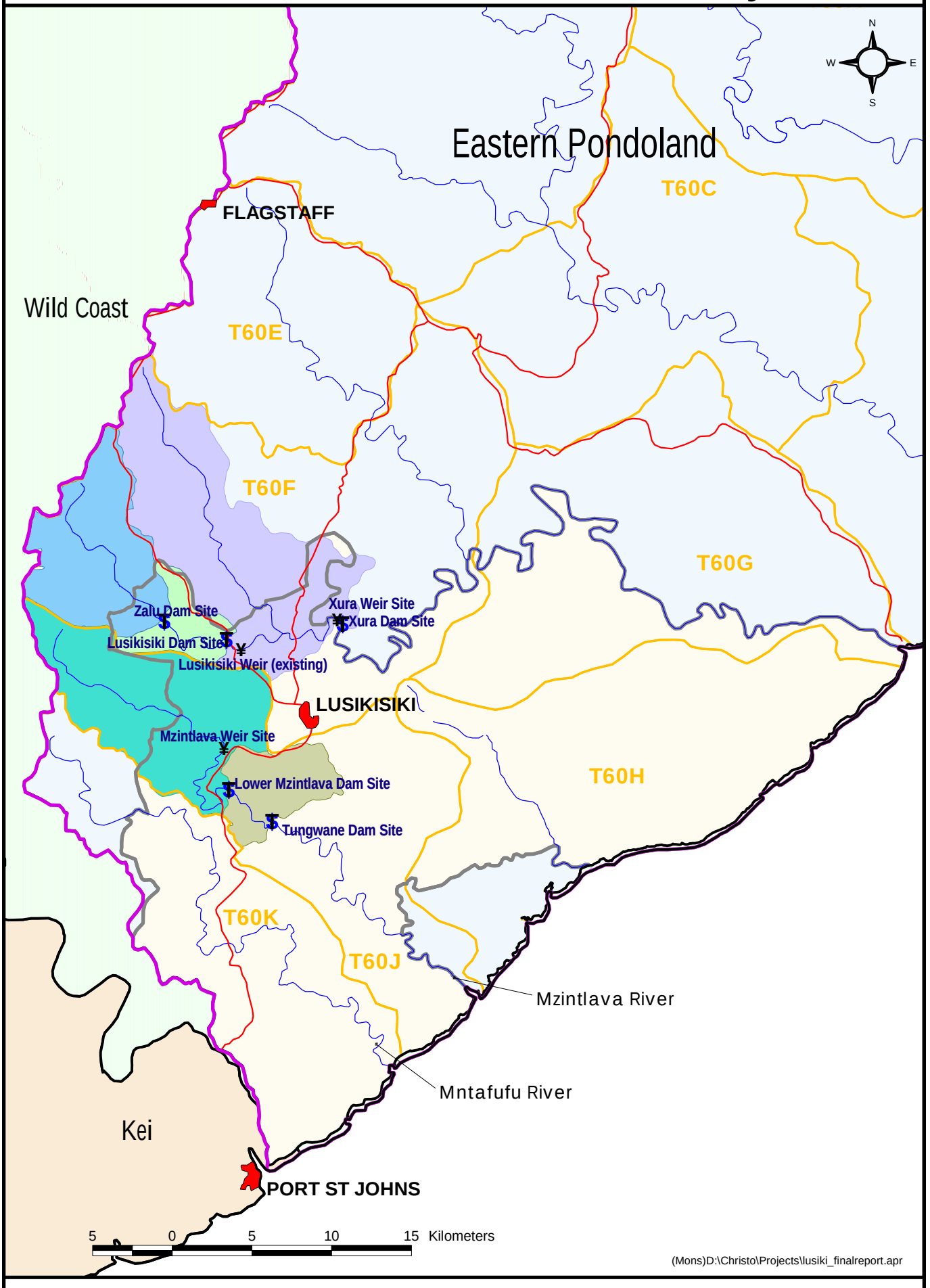


Fig 19 : Proposed Dam and Weir Sites

UWP Engineers

Table 6.2.2B: Surface Water Runoff for Proposed Development Sites

Site name	MAP upstream (mm)	MAP downstream (mm)	Natural MAR (10^6m^3)	Present MAR (10^6m^3)	ERR (10^6m^3)	Present MAR- ERR (10^6m^3)
Zalu dam	940	940	12.10	11.45	2.79	8.66
Lusikisiki dam/weir	940	940	15.51	14.76	3.69	11.07
Xura dam/weir	940	940	38.35	37.35	11.07	26.28
Lower Mzintlava dam/weir	975	1200	17.06	16.93	4.20	12.73
Tungwane dam	950	1177	24.20	23.44	7.74	15.70
Lusindisweni dam	898	898	78.40	73.69	20.07	53.64
Spes Bona weir	899	899	81.52	76.75	20.88	55.89
KwaHlati dam	911	911	108.98	103.97	27.82	76.17
Mbongweni weir	873	873	26.28	25.36	6.81	18.56
Gxalibomvu weir	932	932	115.46	111.63	30.03	81.63

6.2.3 Low Flow Yield Analyses for Proposed Weir Sites

Low flow analyses for proposed weir sites were performed with the aim of assessing the applicability of supplying certain schemes (Lusikisiki and Mkambati) by run of river (non-regulated) flows. The Lusikisiki, Xura and Mzintlava weirs were investigated during this study. The Spes Bona, Mbongweni and Gxalibomvu weirs were investigated as part of the Mkambati SDI Water Project [62]. Details regarding these investigations are available from the **Development Options** report and from report **Ref 62**. "One-day" Flow Duration Curves (FDCs) were generated using a rapid method developed by Dr V Smakhtin (CSIR). Applying certain assumptions, the model uses the simulated monthly flow series to generate daily flow sequences. The assurance of supply of various flows on monthly and on an annual basis is then estimated.

Due to the high ecological Reserve requirements and considerable seasonal variability of runoff, the available run of river yields with assurance levels of 98% are relatively low. The yields are very sensitive to variation of the ecological management class (EMC) of the river stretch and the associated Reserve requirements. Detailed environmental and Reserve determination studies are recommended to be commissioned prior to any developments.

A summary of the estimated low flows at the weir sites with and without provisions for ecological riverine Reserve (ERR), or as previously named instream flow requirements (IFR) is shown in the following table.

Table 6.2.3: Summary of estimated Low Flow (Run-of-River) Yields

Weir Site	Natural. MAR $10^6 m^3/a$	EMC	Provision for ERR	Yield (l/s) at Specific Assurance of Supply (%)				
				98%	95%	90%	80%	70%
Lusikisiki weir Xura River	91	B/C	No	30	42	56	85	114
			Yes	0	4	12.5	29	43
Xura weir * Xura River	225	B	No	80	111	146	217	287
			Yes	0	3	13	53	84
Mzintlava weir Mzintlava River	78	B/C	No	41	57	70	93	114
			Yes	0	13	24	39	51
Lusindisweni Mtentu River	545	B/C	No	157	229	291	430	578
			Yes	6	66	85	170	250
Spes Bona weir Mtentu river	563	B/C	No	166	240	300	459	595
			Yes	8	67	88	178	260
KwaHlati weir Mtentu River	722	B/C	No	212	312	398	597	784
			Yes	28	89	116	234	355
Mbongweni weir Mzamba River	200	B/C	No	60	87	107	161	209
			Yes	16	29	39	68	99
Gxalibomvu Msikaba river	692	B	No	212	311	403	627	850
			Yes	0	52	88	230	295

* The Xura weir site is situated downstream of the Lusikisiki weir. The catchment of the Xura weir (and the yields thereof) include the catchment of the Lusikisiki weir

6.3 RECONCILING WATER REQUIREMENTS AND AVAILABILITY

A theoretical method was used for a rough assessment of the water resources situation within the study area. The water requirements and the surface water availability were calculated incrementally at the downstream boundary of each quaternary catchment. The results are shown in **Tables 6.3A and B** for years 2000 and 2030 respectively, and the calculation methodology is described below.

The **Balance of Available Yield** (maximum potential yield minus the total water requirements) was used as an indication for the extent of utilisation of the surface water resources. Due to the exceptionally high Ecological Estuarine Reserve (EER) requirements (see **Section 5.6)**, only a fraction of the available yield can be used for further developments associated with consumptive water use. The term **Development Potential** was introduced as an indication of the further consumptive water use that can be supported by the surface water resources, provided that the EER requirements are met.

As seen from **Tables 6.3A and B** the water resources in the study area are largely under-utilised. The balance of available yield is estimated to be 420 million m^3 at present and 392 for the year 2030. The projected consumptive water use at year 2030 of 45,5 million m^3 is negligible when compared to the hypothetical yield that can be abstracted from the surface water resources. The development potential of the surface water resources is also reasonably high – 118 million m^3 at present and 91 million m^3 for the year 2030. This means that in 2030 the surface water resources will have sufficient capacity to support 3 times higher consumptive requirements than presently projected (45.5 million m^3), after the release of the EER requirements.

It should be noted that the above observations are based on the low estimate for the EER requirements, which at this stage are considered to be more appropriate, but this needs to be confirmed by undertaking a more detailed determination of the ecological Reserve. The total EER requirements for the study area are estimated to vary between 646 million m^3 (low estimate) and 751 million m^3 (high estimate), or between 82% and 96% of the naturalised MAR (see **Table 6.3C**). This is by far the largest requirement imposed on the water resources in the area. Should the high estimate be applied for calculation of the water balance, the surface water system would experience a deficit of 14.3 million m^3 at year 2030, or about 31% of the total consumptive water requirements.

The cumulative development potential (low EER estimate) per quaternary catchment is shown in **Figure 20**. The development potential is the lowest for T60A and E, and the highest in T60D and G.

The potential maximum yield was calculated as the incremental historical yield from a hypothetical dam with live storage of twice the present day MAR, assumed to be built at the downstream boundary of each quaternary. The potential maximum yields calculated during the Eastern Cape Situation Assessment Study [15] for the T60 drainage region were used.

The surface water usage per quaternary catchment has been estimated as described in **Section 5,** and includes all consumptive water use by the various user sectors (urban/rural domestic and institutional, irrigation, stock watering, and reduction of runoff due to afforestation). The estimated supplies from groundwater and the contributions to the surface runoff from return flows were subtracted form the consumptive requirements.

As described in **Section 5.6** The Ecological Riverine Reserve (ERR) requirements for various sites along the main rivers of the study area (Mzamba, Mtentu, Msikaba and Mzintlava) vary between 23% and 30% of the naturalised runoff. The more conservative value of 30% was used in the calculation for all quaternaries. The total water requirements were calculated as the sum of the surface water usage and the ERR requirements.

The balance of available yield is the difference between the potential maximum yield and the total water requirements. The development potential was calculated by subtracting the surface water use and the EER from the naturalised MAR. Both the development potential and the balance of available yield are calculated as cumulative values.

Table 6.3A: Requirements and Availability of Surface Water: Year 2000

Quaternary Catchment	Natural. MAR (10^6m^3)	Potential Maximum Yield (10^6m^3)	Surface Water Use (10^6m^3)	ERR (10^6m^3)	Total require-ments (10^6m^3)	Balance Available Yield (cum) (10^6m^3)	EER Low est. (10^6m^3)	Development Potential (Cumulative) (10^6m^3)
T60A	71.9	61.8	1.35	21.6	22.9	38.9	64.7	**5.8**
T60B	75.5	64.9	4.74	22.7	27.4	37.5	60.4	**10.4**
T60C	62.7	53.9	0.56	18.8	19.4	72.1	50.2	**22.3**
T60D	102.7	88.3	0.48	30.8	31.3	129.1	82.2	**42.4**
T60E	28.0	24.1	1.50	8.4	9.9	14.2	22.4	**4.1**
T60F	79.1	68.0	2.38	23.7	26.1	56.1	63.3	**17.5**
T60G	100.3	86.3	1.09	30.1	31.2	111.2	80.2	**36.5**
T60H	124.7	107.2	3.12	37.4	40.5	66.7	112.2	**9.4**
T60J	77.6	66.7	1.65	23.3	24.9	41.8	62.1	**13.9**
T60K	59.7	51.3	1.47	17.9	19.4	32.0	47.8	**10.5**
TOTAL	**782.2**	**672.7**	**18.3**	**234.7**	**253.0**	**419.70**	**645.4**	**118.5**

Table 6.3B: Requirements and Availability of Surface Water: Year 2030

Quaternary Catchment	Natural. MAR (10^6m^3)	Potential Maximum Yield (10^6m^3)	Surface Water Use (10^6m^3)	ERR (10^6m^3)	Total require-ments (10^6m^3)	Balance Available Yield (cum) (10^6m^3)	EER Low est. (10^6m^3)	Development Potential (Cumulative) (10^6m^3)
T60A	71.9	61.8	4.5	21.6	26.0	35.8	64.7	**2.7**
T60B	75.5	64.9	8.4	22.7	31.1	33.8	60.4	**6.7**
T60C	62.7	53.9	1.3	18.8	20.2	67.6	50.2	**17.9**
T60D	102.7	88.3	2.5	30.8	33.4	122.6	82.2	**35.8**
T60E	28.0	24.1	4.2	8.4	12.6	11.5	22.4	**1.4**
T60F	79.1	68.0	10.7	23.7	34.5	45.1	63.3	**6.5**
T60G	100.3	86.3	1.9	30.1	32.0	99.4	80.2	**24.7**
T60H	124.7	107.2	8.5	37.4	45.9	61.4	112.2	**4.0**
T60J	77.6	66.7	1.7	23.3	25.0	41.7	62.1	**13.8**
T60K	59.7	51.3	1.7	17.9	19.6	31.7	47.8	**10.2**
TOTAL	**782.2**	**672.7**	**45.5**	**234.7**	**280.2**	**392.5**	**645.4**	**91.3**

Table 6.3C: Estimates for the Ecological Estuarine Reserve per Quaternary

Quaternary Catchment	Naturalised MAR (10^6m^3)	EER (% of MAR)		EER (10^6 m^3/a)	
		Low estimate	High estimate	Low estimate	High estimate
T60A	71.9	90	99	64.7	71.2
T60B	75.5	80	95	60.4	71.7
T60C	62.7	80	95	50.2	59.6
T60D	102.7	80	95	82.2	97.6
T60E	28.0	80	95	22.4	26.6
T60F	79.1	80	95	63.3	75.1
T60G	100.3	80	95	80.2	95.3
T60H	124.7	90	99	112.2	123.5
T60J	77.6	80	95	62.1	73.7
T60K	59.7	80	95	47.8	56.7
TOTAL	**782.2**			**645.4**	**751.0**

Eastern Pondoland Basin Study

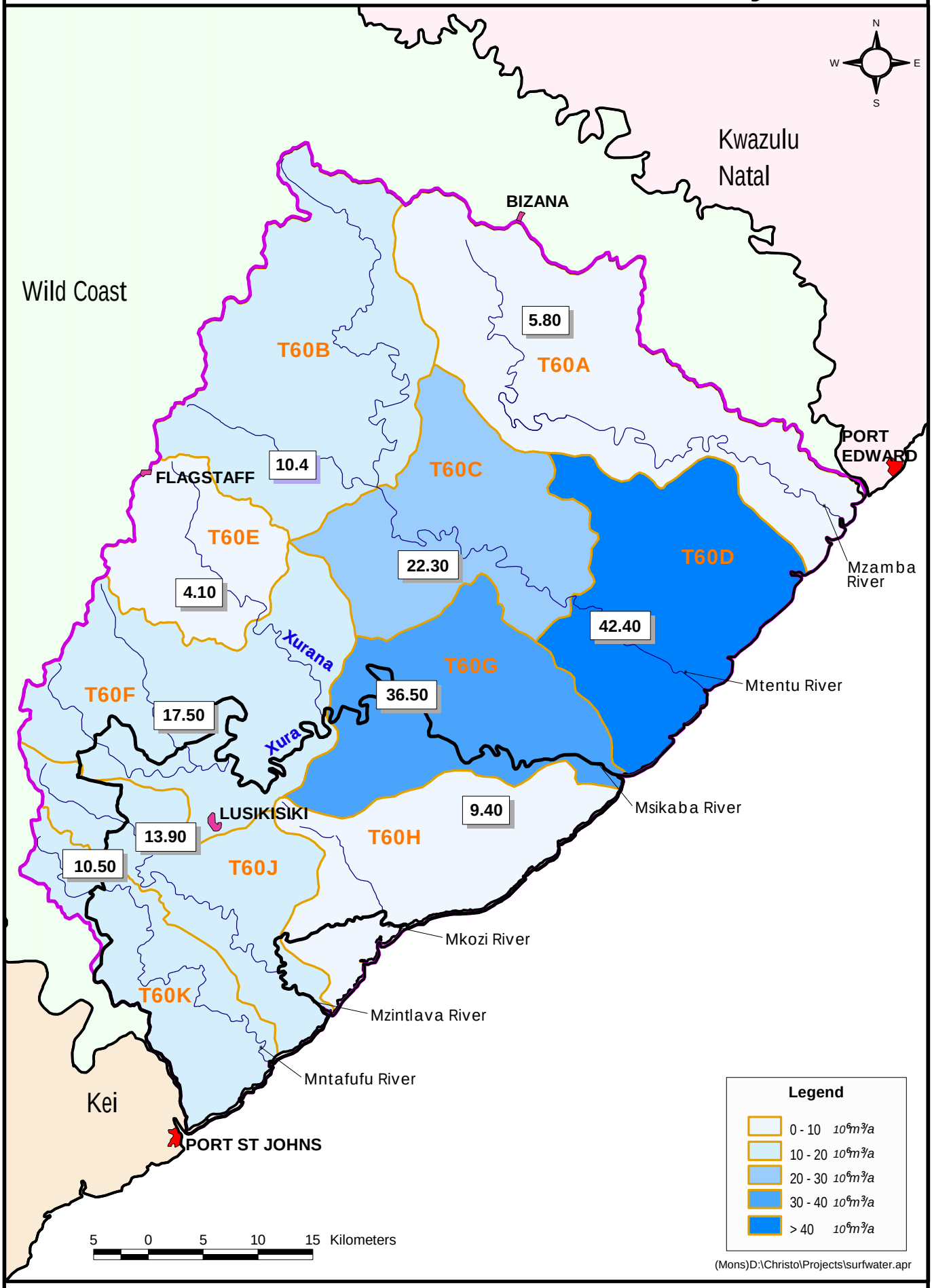


Fig 20: Surface Water Development Potential(2000)

UWP Engineers

7. FACTORS AFFECTING DEVELOPMENT

This section provides a brief summary of the information collected during the execution of the following two studies. More details can be obtained from the relevant study reports.

- This study: a number of development options for the augmentation of the Lusikisiki Regional scheme were evaluated. The investigations covered the upper and middle reaches of the Msikaba and Mzintlava Rivers. More detailed information is available in the **Development Options** supporting report.

- Mkambati SDI Water Supply Project [62]: Options for the supply of the Mkambati SDI nodal area. The investigations covered the middle reaches on the Mtentu and Mzamba Rivers, as well as the lower reach of the Msikaba River.

The factors affecting possible developments described in this section were investigated at a reconnaissance level, mainly on the basis of existing topographical, geological and environmental information, supplemented by site visits by specialists in all related disciplines (planning, conveyance, dams, geology, materials, environmental and social, water quality).

7.1 TOPOGRAPHY

All rivers in the study area flow in the south-easterly direction. The coastal belt is extensively incised by the main rivers, which have formed major steep-sided gorges, often falling 300 to 500 m. below the surrounding plateau. Water conveyance systems crossing these gorges will be impractical and expensive. At the same time most of the rural villages are located on or near the watersheds. Due to the high pumping heads required, the development of small individual village water schemes in these areas will be impractical. The development of regional schemes is recommended, where water is abstracted at higher elevations and then supplied by gravity along the watersheds. The inland plateau is characterised by uneven seaward sloping surfaces, where lesser pumping heads are required for the supply of the surrounding villages.

In general, the topography is not ideal for dam developments. The middle reaches of the largest rivers in the area (Msikaba, Mzintlava, Mtentu and Mzamba) were screened for suitable dam sites. It was concluded that the longitudinal slopes of the rivers are relatively steep, the river sections are asymmetrical, the geological conditions are seldom favourable, and the access is often problematic. Three reasonably suitable sites were identified on the Msikaba River [**Development Options** report] and one site on the Mtentu River [62]. No feasible dam sites are available in the middle reaches of the Mzintlava and Mzamba Rivers.

7.2 GEOLOGY AND MATERIALS

The study area is underlain by sedimentary strata of the lower Karoo Supergroup. This group comprises of mudrocks of the Ecca Group, and underlying tillite of the Dwyka Group. This sedimentary sequence has been intruded by younger dolerite dykes and sills, which comprise up to 40 % of the sequence within the Ecca mudrocks, but significantly less within the tillites. The strata are essentially sub-horizontal. No major regional-scale faults are recognized in the area and no economically important mineral deposits occur.

Except for the Zalu and Lusikisiki sites on the Msikaba River the founding conditions at all other investigated sites were poor. For all sites, sources of coarse aggregate/ rip-rap / crusher sand are available in the vicinity. Embankment fill material is expected to occur within the dam basins. No suitable natural sand reserves were identified at any of the sites and therefore crusher sand will have to be used.

Msikaba River sites: The geological founding conditions for the Zalu dam site were considered to be the most favourable of all sites investigated. The site is underlain by dolerite sills and weathered siltstone. The expected excavation depths will vary in the range of 1 to 5 m for a concrete structure. The Lusikisiki dam site is underlain by weathered siltstone, but extensive dolerite outcrops occur in the river section. The excavation depths are expected to vary between 5 and 15 m for a concrete structure. The Xura dam site is underlain by deeply weathered tillite, suggesting a composite dam structure. Excavation depths will vary between 2 and 5 m for an embankment structure.

Mzintlava River sites: Tungwane and Lower Mzintlava sites have poorer founding conditions than the Msikaba sites. The sites are markedly asymmetrical and are underlain by deeply weathered tillite, suggesting composites structures. Excavation depths will be up to 5 m for the embankment and 10 to 15 m for the concrete sections.

Mtentu River sites: Two dam sites were investigated during the Mkambati study- Lusindisweni and KwaHlati. The founding conditions at both sites are unfavourable. The sites are asymmetrical and are underlain by siltstone and tillite. Due to the relatively narrow sections a concrete structure will be the only option for dams. Excavation depths are expected to be in the range of 3 to 15 m.

7.3 ENVIRONMENTAL ISSUES

A detailed overview of the conservation status of the study area is provided in **Section 3.** The study area has an exceptionally high conservation value. Its coastal part is amongst the few regions in the country with its natural environment still preserved in pristine condition. For these reasons the Wildlife and Environment Society of Southern Africa (WESSA) has tabled a proposal for declaring a National Park within the coastal plateau between the Mtamvuna and Mzimvubu Rivers.

Due to the ecological importance of the estuaries, the estimated Ecological Estuarine Reserve requirements (**Section 5.6**) are exceptionally high. The smaller coastal rivers are considered to have higher estuarine requirements (90 to 99% of MAR) than the major rivers in the area – Mtafufu Msikaba, Mzintlava, and Mtentu (80 to 95% of MAR). Developments within the larger rivers are therefore preferred.

The natural features of the inland areas have been largely modified and disturbed by the activities of man, and their conservation value is lower than the coastal areas. A reconnaissance investigation was undertaken to assess the potential site-specific environmental impacts associated with proposed development options along the Mzintlava, Msikaba, Mtentu and Mzamba Rivers (**Environmental Evaluation: Scoping Report and Report ref. 62)**.

The natural riparian vegetation at all sites indicates a large to serious degree of degradation. No rare or endangered plant or terrestrial animal species were found. The apparent absence of any natural, cultural, or aesthetic features of outstanding value at any of the dam sites indicates that there will be no significant site-specific impacts as a result of the proposed developments. More significant potential negative impacts associated with water abstractions from the rivers in the area will be related to the sensitive and valuable ecosystems downstream of the proposed sites.

7.4 SOCIAL ISSUES

The potential social impacts associated with the development of the water resources should be carefully considered during feasibility investigations and planning studies. The following main social impacts need to be evaluated and appropriate impact management measures established (where applicable):

- Relocation of people due to inundation
- Loss of land (arable and grazing)
- Loss of access
- Loss of archaeological and historical sites
- Loss of religious and cultural sites
- Loss of natural resources
- Boost of regional economy due to inflow of capital
- Creation of employment opportunities
- Training and empowerment of labour force and local contractors
- Improvement of infrastructure and services (water, roads, electrical, telkom)
- Recreation and conservation opportunities

From social point of view the run of river abstractions are preferable to the construction of dams. The negative social impacts related to the development of conjunctive and ground water schemes are low. It should however be noted that the local population has had bad experience with groundwater developments in the past (low assurance, frequently malfunctioning, poor water quality, complicated operation and maintenance, etc). It is likely that groundwater options will not be favoured by the local population and may even be opposed

Any water resource developments should be accompanied by an extensive public participation and community involvement programme. A list of the interested and involved parties identified in the area is attached to the **Development Options** report.

7.5 WATER QUALITY ISSUES

The river systems of the Transkei basin have only been monitored on an ad hoc basis. The only available water quality records of note are for the Xura River (Lusikisiki weir), Msikaba River (Holy Cross Hospital) and Mtafufu River (Bambisana Hospital). The most comprehensive information is available for the period May 1998 to present. Special grab samples from the Xura and Mzintlava Rivers were collected in August 1999 for the purposes of this study. Samples from the Mtentu and the lower reaches of Msikaba (Gxalibomvu site) Rivers were taken in March 2000. Routine monthly water samples from the Lusikisiki weir have been obtained and used to provide an indication of seasonal variations in water quality parameters. The test results from water quality samples are provided in the **Development Options** Report.

Xura and Mzintlava Rivers

The water quality in the upper and middle reaches of the Xura and Mzintlava systems is good and shows little signs of pollution, with low nitrate, ammonia and phosphate concentration. At points adjacent to the Port St. Johns / Flagstaff road, there is little indication of human impacts on the rivers. Microbiologically the Mzintlava River is more impacted than the Xura River, but this may reflect the impacts of stock and game on the water, rather than catchment degradation.

There is little evidence of land surface erosion in the upper parts of the catchments. The turbidity values are lower than 25 NTU (Nephelometric Turbidity Units). Even after heavy rainfall events, no turbidity above 80 NTU has been recorded on the Xura River. The Mzintlava River is likely to have even lower turbidity. Dry weather particle loads are less than 4 g/m^3 and much of this is associated with biological debris.

The region adjacent to the Xura River between the Lusikisiki site and the Xura site is more urbanized than the upper catchment. A marked pollution impact on the water quality is evident downstream of the confluence of the Lusikisiki and Xura Rivers (downstream of the Xura dam site). Most of the water treatment works (see **Section 5.2**) of the town of Lusikisiki currently discharge effluent into the Lusikisiki River. The effluent does not comply with the standards, and is likely to cause severe impact on water quality during times of low river flows. Any further reduction of the flows due to increased abstractions from the Xura River may result in significant degradation of the water quality.

Mtafufu River

The observations are based on water samples taken in the upper reaches (Bambisana) since 1998. The water quality is good and the water is suitable for human consumption after treatment. The turbidity levels are very low.

Msikaba River

Based on a number of samples taken since 1998 it can be concluded that the water quality in the upper reaches (Holy Cross) is good and can be used for potable purposes after treatment. High turbidity levels (above 150 NTU) have been observed during floods.

A single sample was collected and tested in March 2000 from the lower reaches of the Msikaba River (Gxalibomvu site). The results should therefore be treated with caution. The water quality of the sample was significantly poorer than for the upper reaches of the river. This sample indicates high levels of nitrate, phosphate and suspended solids levels,

poor microbiological quality and high faecal contamination. This can be associated with pollution from the town of Lusikisiki and its peri-urban developments. The water is treatable, but care must be exercised when considering impoundments, as the higher nutrient, sediment and catchment pollution loads may result in eutrophication. Visual observation form the air indicated that the turbidity levels in the Msikaba River deteriorate downstream of the confluence with the Xura River. This was confirmed by the sample test results (turbidity of 50 NTU). The algal biomass was also high (6.7 μg/l Chlorophyll).

Mtentu River

There are no historical water quality data for the sites and the results from a single test need to be interpreted with care. No major sources of pollution are present in the upper catchment (Lusindisweni site) and the water quality is good, suitable for human consumption after treatment. The low suspended solids of 6 mg/l (measured during high flows) suggest low expected sediment yields. The algal biomass in the river was also low (3.4 μg/l Chlorophyll).

Similarly the water quality in the lower reaches (KwaHlati site) was good, potable after treatment. A slight increase in the turbidity and selected chemical and microbiological parameters was observed. These changes are normal with run-off-river sampling and may be attributed to direct impact of cattle (noticed close to the sampling point).

Proposed Locations of Water Quality Sampling Points

The regular collection and testing of water samples will contribute for obtaining of more reliable results from future investigations. For the Mzintlava River system sampling at the Port St John's/ Lusikisiki road bridge is adequate for determining instream water quality.

To evaluate the water quality for the proposed Zalu and Lusikisiki dam sites on the Xura River, the routine collection of raw water samples at the abstraction weir for the water treatment works will be adequate.

Regular collection and testing of water samples is recommended at the Spes Bona Bridge over the Mtentu River.

7.6 SEDIMENT YIELDS

Estimates for sediment yields were made incrementally for all quaternary catchments in the study area in accordance with the updated Rooseboom maps [32]. The area is located in the sediment yield region number 9, with erodibility indices ranging from high to low (**Figure 21**). The standardized average sediment yield within this region is 185 t/a.km^2 and the assumed sediment density is 1.35 kg/m^3 (0.74 m^3/t). The yields were estimated for the 50-year horizons at 80% confidence level. Based on the preliminary information and water quality samples (**Section 7.5**) for the study area it is considered that the values derived form the Rooseboom methodology are conservative, and the actual sediment yields may be lower. The distribution of areas with various erodibility indices per quaternary catchment is shown in **Table 7.6A**, and the results of the sediment yield calculations are shown in **Table 7.6B**.

Eastern Pondoland Basin Study

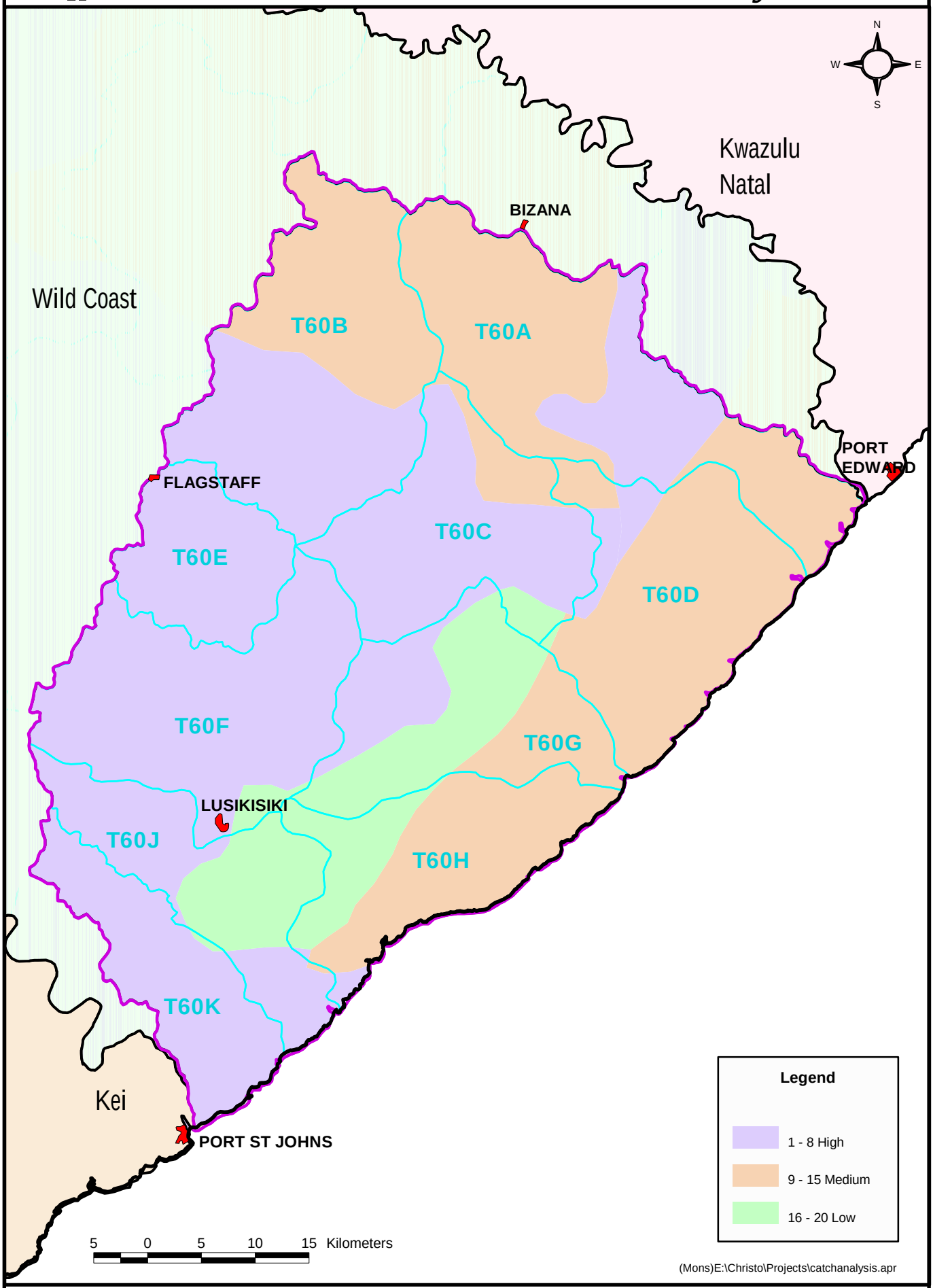


Fig21: Sediment Yields: Erodibility Indices

UWP Engineers

Table 7.6A: Areas with various erodibility indices (Rooseboom)

Quaternary Catchment	Area with erodibility index (km^2)			Total area (km^2)
	High 1-8	Medium 9-15	Low 16-20	
T60A	146	401		547
T60B	270	258		528
T60C	296	50	18	363
T60D	39	374		415
T60E	198			198
T60F	449		15	464
T60G	99	93	168	360
T60H	8	228	86	322
T60J	175	1	118	294
T60K	240		2	242
Total	**1 921**	**1 406**	**407**	**3 733**

Table 7.6B Estimated 50 year (80% confidence) Sediment Yields

Quaternary Catchment	Naturalised MAR ($10^6 m^3$)	Sediment Yield ($10^6 m^3$)
T60A	71.9	13.4
T60B	75.5	13.1
T60C	62.7	9.2
T60D	102.7	10.3
T60E	28.0	5.1
T60F	79.1	10.6
T60G	100.3	9.6
T60H	124.7	8.4
T60J	77.6	7.7
T60K	59.7	6.1
TOTAL	**782.2**	**93.4**

7.7 INSTITUTIONAL ARRANGEMENTS FOR O&M

The study area falls under the jurisdiction of the Wild Coast District Council (1999 demarcation) and includes portions of three magisterial districts – Lusikisiki, Flagstaff and Bizana (**Figure 2**). The town of Lusikisiki is the main economic centre in the area. The towns of Flagstaff and Bizana are located on the watershed and fall just outside the study area. Transitional Local Councils (TLC) have been established and are responsible for the management of all services in the relatively small urban and peri-urban areas surrounding the towns. Portions of the Flagstaff TLC are included in the study area, while the Bizana TLC borders with the study area. The predominant portion of the study area, the rural areas, falls under the jurisdictions of the Transitional Representative Councils (TRC) established in the three aforementioned magisterial districts.

Due to the lack of capacity within the local authorities the bulk supply portions of the two existing regional schemes in the area (Lusikisiki and Bizana) are managed by DWAF. The TLCs are responsible for the O&M of the distribution systems within their areas of

jurisdiction. According to the new legislation this situation is expected to change, and the local government will be expected in due time to take the full responsibility for the management of all schemes within the area.

The following characteristics of the study area should be taken into account when considering appropriate institutional structures for the operation and maintenance (O&M) of the water supply infrastructure.

- Remoteness: The area is located relatively far from main centres (Umtata, Kokstad, East London, Durban) providing technical expertise, supply of equipment and spare parts, etc
- Poor condition of supporting infrastructure: secondary roads not accessible during wet periods, telecommunication, electrical supply
- Lack of skills and technical capacity within the area
- Low income: only about 5% of the population is formally employed, and the area is amongst the poorest in the country. Appropriate schemes with low O&M costs should be selected in order to ensure affordability, O&M cost recovery, and thus sustainability

From institutional point of view preference should be given to the development of regional schemes. The primary infrastructure will be more compact in terms of location and number of major components (water source, treatment works, bulk supply system), requiring a less complex institutional structure and offering opportunities for the reduction of the operating costs.

The alternative, a large number of individual villages schemes (with the associated multiple water sources, treatment facilities, etc) will require a more complicated, decentralised institutional structure, which will result in higher O&M costs.

7.8 CATCHMENT MANAGEMENT AGENCIES

The National Water Act (Act 36 of 1998) sets out the framework for the management of water resources in South Africa. This framework provides for the establishment of water management institutions, which include catchment management agencies (CMAs) and water user associations (WUAs).

The CMAs are statutory bodies established to provide the second tier of the water management structure under Chapter 7 of the Act. They operate within the broader framework provided by the Minister of Water Affairs and Forestry and the National Water Resource Strategy. The core purpose of CMAs is to develop and implement a catchment management strategy for the water resources within their Water Management Area. The CMAs are governed by a board, which represents a broad stakeholder grouping together with experts. Local implementation of the catchment management strategy may be carried out through institutions to which the CMA may delegate functions.

The WUAs are statutory bodies established by the Minister under Section 92 of the Act to act as the third tier of the water management structure. WUAs are co-operative associations of individual water users, who wish to undertake water-related activities for their mutual benefit. The broad role of a WUA is to enable people within a community to pool their resources (money, human resources and expertise) in order to carry out effectively certain water related activities. The establishment of WUAs provides a

mechanism through which the CMA can devolve the implementation of certain aspects of the catchment management strategy to local levels.

South Africa has been divided into 19 catchment management areas as part of the progressive development of the National Water Resource Strategy. The Eastern Pondoland Basin falls into the proposed Umzimvubu to Keiskamma area. No catchment management strategy or agency for this area has yet been established. The DWAF is currently undertaking a pilot study for the development of a catchment management strategy for the Mtata River catchment. The study area includes all river basins between the Mbashe and Umzimvubu Rivers.

8. SUMMARY OF FINDINGS

8.1 Base Information

- The study area (3 700 km^2) is located between the Mzimvubu and Mtamvuna catchments, and covers the tertiary drainage region T60, which is divided into 10 quaternary catchments T60A to T60K.

- The area includes about 327 rural villages and the towns of Lusikisiki and Flagstaff, with a total estimated population of 489 000 people (1996 base year).

- Due to the favourable climatic and natural environmental conditions the area has high potential for the development of commercial forestry plantations, tourism and commercial dry-land agriculture. The development of irrigation in the area is not considered to be feasible.

- Three of the six nodal areas identified by the Wild Coast Special Development Initiative fall within the study area – the Mkambati, Magwa and Mbotyi nodal areas.

- The mean annual precipitation is high, varying between 870 mm and 1220 mm per annum. The study area includes more than 25 small to medium sized coastal rivers, located between the Mzamba and Mtafufu Rivers, the largest being the Msikaba (1022 km^2) and Mtentu (964 km^2).

8.2 Infrastructure

- The level of hardship with regards to water supply and sanitation services in the area is very high. Only about 20% of the population are presently supplied by nine existing schemes, but the levels of service are mostly of sub-RDP standard. About 2% of the population have sanitation facilities.

- The Lusikisiki Regional Scheme is the largest water supply system in the area, and currently provides water services to approximately 52 000 people. An extension of the supply area to serve additional population of about 68 000 people is being considered. Various options for the augmentation of the water source of this scheme have been investigated during the course of this study.

- Twelve water supply projects in the study area (capital costs R62 million, serving about 80 000 people) are currently being implemented and have reached various stages of completion.

- The Magwa dam on the Nkozi River is the only registered dam in the area (wall height 25 m, catchment area 5,5 km^2).

8.3 Water Requirements

- The water requirements were estimated for the consumptive users (domestic and industrial, agricultural and afforestation) and for the non-consumptive users (ecological riverine and estuarine Reserve).

- Due to the absence of more detailed and accurate information, the water requirements for the domestic and ecological use have been estimated conservatively.

- The total consumptive water requirements are estimated to be about 18 million m^3/a at present and 52 million m^3/a for the year 2030. These requirements are very low in relation to the mean annual runoff. The present consumptive water requirements are distributed as follows:

Urban domestic and industrial	6%
Rural domestic	18%
Stock watering	16%
Irrigation	0
Afforestation	60%

- Due to the high conservation value placed on the river estuaries, the ecological estuarine Reserve requirements were conservatively estimated by the estuarine specialists to be exceptionally high and vary between 80% and 95% of the naturalised mean annual runoff (MAR) for the larger rivers and between 90% and 99% of MAR for the smaller rivers (the first number in each set represent the low estimate and the second number the high estimate). The total ecological estuarine requirements amount to 646 million m^3/a or 82% of the MAR (low estimate) and 751 million m^3/a or 96% of the MAR (high estimate).

- The total present estimated water requirements (consumptive and non-consumptive) are estimated to be about 664 million m^3/a and 769 million m^3/a for the low and high estimate of the ecological Reserve respectively.

8.4 Water Resources

- The groundwater harvest potential for the study area is estimated to be 134 million m^3/a. The low permeability of the shallow aquifers, low average borehole yield, together with the inaccessibility of the terrain would limit the groundwater development potential to about 13 million m^3/a.

- Due to the high operation and maintenance costs the development of the groundwater resources would be feasible only for small, individual village schemes.

- It has been estimated that the groundwater usage is presently under 1 million m^3/a. In general the groundwater quality is good, suitable for human consumption.

- The naturalized surface water mean annual runoff from the study area is about 782 million m^3/a and the present day mean annual runoff is about 764 million m^3/a

- Due to the relatively high ecological riverine Reserve requirements and considerable seasonal variability of runoff, the available yields from run of river with 98% assurance levels are low. The run of river yields are very sensitive to the ecological Reserve requirements.

- The potential maximum yield (hypothetical historical yield) from the surface water resources, calculated from the naturalized mean annual runoff is about 673 million m^3/a. The present unused potential yield is about 420 million m^3/a if no allowance for the ecological Reserve is made.

- The present development potential of the surface water resources (allowing for the release of the low estimate of the ecological estuarine Reserve requirements) is 118 million m^3/a. The development potential is estimated to be 91 million m^3/a at year 2030. These estimates are valid for the low estimate of the estuarine Reserve. If the high estimate is considered, a deficit of about 14 million m^3/a can be expected by year 2030

8.5 Factors Affecting Development

- The study area is not ideal for the construction of dams. The longitudinal slopes of the rivers are steep, the river sections are often asymmetrical, and the founding conditions are generally unfavourable.

- The natural environment in the coastal belt of the study area is in pristine condition and has exceptionally high conservation value. Proposals have been tabled for the entire costal area to be declared a National Conservation Park. The Mkambati Nature Reserve is located in this area.

- The natural features of the inland areas have been largely modified and disturbed by the activities of man. The conservation value of the inland areas is significantly lower than for the coastal areas.

- The water quality in the upper and middle reaches of the main rivers (Xura, Mzintlava, Msikaba, Mtafufu and Mtentu) is good and is suitable for human consumption after treatments. A significant deterioration of the water quality has been observed in the lower reaches of the Msikaba River, resulting from the release of sub-standard effluent from the water treatment works of the town of Lusikisiki.

- The turbidity levels are generally low, except for the Msikaba River where high turbidity levels were recorded from single sampling (50 NTU). No signs of erosion in the area have been observed. The sediment yields are expected to be generally low.

8.6 Accuracy Limitations of Study Results and Additional Information Required

- The purpose of this study was to provide broad evaluation of the water resources at a reconnaissance level of detail. The study was therefore undertaken as a desktop study with limited site inspections and data verification.

- The domestic water requirements estimate has been based on the DWAF: Water Services (First Order Strategy) database, which is regarded to be conservative. According to this database the total population number for the study area is 489 000 (1996) people. According to the 1996 Census this number is 388 000. More accurate population counting techniques are recommended for further planning studies.

- Conservative projected population growth rates (1% for rural, and 4% for urban population) were applied in estimating the future domestic water requirements for the basin study component of the project. According to a recent study commissioned by DWAF (MarkData, 2000) the growth rates are predicted to be significantly lower than previously expected. These updated population growth rates were applied only for the development options component of the study.

- The total ecological estuarine Reserve is by far the largest requirement imposed on the water resources in the study area (82% to 96% of the MAR). The lower estimate for the Ecological Reserve has been assumed to be more appropriate and has been used for reconciling the water requirements and availability. A detailed Reserve determination study needs to be commissioned.

- Due to the absence of reliable observed streamflow data the water resources simulation model (WRSM90), used for the hydrological modelling of the system could not be calibrated. It is recommended that the streamflow data from the two revitalised gauging stations in the study area (Mtafufu and Xura Rivers) be recorded promptly. In view of the proposed water resources developments for the Mkambati Nodal Area, the establishment of a flow gauging station at the Spes Bona Bridge on the Mtentu River should be considered.

- Very little information on the actual present use of groundwater is available.

- Proper drilling target siting, based on satellite imagery, and exploration drilling is recommended in order to confirm the findings regarding the anticipated average yields and costs associated with groundwater development.

- Little confirmed information on the actual number of livestock is available

- The water quality data for the study area is very limited. Water quality sampling and testing at specified recommended locations on an ongoing basis is recommended.

- The effluent discharges from the several water treatment facilities in the vicinity of Lusikisiki should be monitored regularly. Compliance with the relevant standards should be imposed.

9. RECOMMENDATIONS

Based on the overall assessment of the water resources situation in the Eastern Pondoland area, and in view of the proposed water resources development projects, the following recommendations for actions are offered:

(a) Ecological Reserve Requirements

It is recommended that intermediate Reserve determination study be commissioned as soon as possible by the DWAF for the Xura and Mtentu River catchments.

If the updated estimates are substantially different than the desktop estimates, the water requirements part of the basin study should be revised. The more accurate Reserve requirements will also be used in further engineering planning activities for the proposed Lusikisiki and Mkambati Water projects.

(b) Population estimates

It is recommended that the updated population numbers and growth rates, according to the recent study commissioned by DWAF (MarkData, 2000) be used in further planning activities for the study area. This is expected to result in a reduction of the domestic water requirement projections produced during this study.

(c) Stream gauging

It is recommended that the reliability of the observed flow data records obtained since the revitalisation of the gauging stations on the Xura and Mtafufu Rivers be established by the DWAF and corrective measures be taken if necessary.

It is recommended that the DWAF consider the construction of a gauging station on the Mtentu River (position to be determined by DWAF: Hydrology), in view of possible future development projects in this area. These records will be used for calibration of the hydrological models during further studies in the area.

(d) Water quality

It is recommended that regular collection and testing of water samples from specific locations (Section 7.5) on the main rivers in the study area be undertaken by the DWAF.

It is recommended that the water treatment works in the vicinity of Lusikisiki be inspected by the DWAF, and water quality samples from the discharged effluent be taken. If necessary, corrective measures should be taken.

(e) Water resources development

The recommendations for the selection of the best development option for augmentation of the Lusikisiki Regional Scheme are given in the Development Options Report

APPENDIX A :

REFERENCE LIST

APPENDIX A

LUSIKISIKI BASIN STUDY: MAIN REPORT

REFERENCE LIST

Ref 1		HKS 1979 : Lusikisiki District Rural Water Supply Scheme
Ref 2		HKS 1987 : Lusikisiki Regional Water Supply Scheme : Outline of the major aspects of the scheme
Ref 3		HKS 1986 : Lusikisiki Regional Water Supply : Preliminary report
Ref 4		HKS, Feb 1995 : Lusikisiki Regional Water Supply Scheme : System Analysis
Ref 5		HKS 1980 : Lusikisiki District Bulk Water Supply Scheme : Zalu Dam – Report Volume 1 : Report, Vol 11 : drawings
Ref 6		HKS, Oct 1979 Lusikisiki Water Supply : Zulu dam site : Detailed geological and Materials investigation Vol 1 and 2
Ref 7		HKS, March 1979 Lusikisiki Water Supply, Zaludam Site, Foundation investigations, Tender document
Ref 8		Kula & Nkonki Consortium, 1996 Revitalization of Agricultural Activities in the Transkei, Prepared for PPT, Ministry of Agriculture and Land Affairs – EC
Ref 9		GMA, Nov 96 Addendum No 1 to Business Plan to Project No 26, Lusikisiki Regional Bulk Water Supply Scheme – Report on Low-Flow Yield Analysis
Ref 10		IWR, 1997. Assessment of the available water resources from the Xura River and the Lusikisiki Regional Bulk Water Supply Scheme
Ref 11		UWP, 1999 Lusikisiki Regional Water Scheme, Status Report, Revision 2, DWAF
Ref 12		UWP 1996, Lusikisiki village reticulation, Project Business Plan
Ref 13		GMA, 1996 Lusikisiki Regional Bulk Water Supply Scheme, Technical Report, Project No 26
Ref 14		GMA, 1996 Lusikisiki Regional Bulk Water Supply Scheme, Design Report
Ref 15		Ninham Shand, 1997. EC Situation Assessment First Draft – Main Report
Ref 16		Ninham Shand 1997. EC Situation Assessment First Draft – Appendices A and D to H
Ref 17		Ninham Shand 1997. EC Situation Assessment First Draft – Appendices B & C
Ref 18		GMA 1996, Lusikisiki Regional Bulk Water Supply scheme, Project Business Plan for the ECCWSS, Project 26
Ref 19		O'Connell, Manthe & Partners, Feb 1979. Proposed Regional Domestic Water Supply. Physical Survey and Planning of Supply Schemes
Ref 20		O'Connell, Manthe & Partners, Dec 1982, Republic of Transkei; Domestic Water Supply : Rural Areas
Ref 21		BKS & Ninham Shand. 1995b. Evaluation of Agricultural

		Developments : Reconnaissance Phase Draft Report. Prepared on behalf of the Department of Water Affairs and Forestry as part of the Orange River Development Project Replanning Study. Report no P Q000/00/0695.
Ref 22		Ninham Shand Inc. 1980. Hydro-Electric Development in Transkei. Prepared on behalf of the Department of Works and Energy, Transkei.
Ref 23		Vegter, JR 1994. Groundwater Resources of South Africa : An Explanation of a set of National Groundwater Maps. Prepared on behalf of the Water Research Commission. Report no TT74/95.
Ref 24		Consult 4. 1995. Main Report. Prepared on behalf of the Department of Water Affairs and Forestry as part of the Vaal Augmentation Planning Study, Mzimvubu Transfer Options : Reconnaissance Phase.
Ref 25		BKS & Ninham Shand. 1997b. (In preparation). Draft Report on System Analysis for Eastern Cape Rivers. Prepared on behalf of the Department of Water Affairs and Forestry as part of the Orange River Development Project Replanning Study.
Ref 26		DBSA. 1996. Population of South Africa : Updated Estimates Scenarios and Projections : 1990 – 2020.
Ref 27		DBSA. 1989. Transkei Development Information.
Ref 28		Department of Water Affairs and Forestry. 1997. White Paper on National Water Policy for South Africa.
Ref 29		Department of Agriculture and Land Affairs, Eastern Cape. 1996. Final Report of Proposed Transformation of Agricultural Parastatals and Some Major Agricultural Projects in the Eastern Cape.
Ref 30		Le Maitre, Scott & Fairbanks. 1995. Handy Reference Manual on Impacts of Timber Plantations on Runoff in South Africa. Prepared on behalf of the Department of Water Affairs and Forestry.
Ref 31		Midgley, Pitman & Middleton. 1994. Surface Water Resources of South Africa : 1990. Water Research Commission Report no 298/5.1/94.
Ref 32		Rooseboom, et al. 1992. The Development of the New Sediment Yield Map of Southern Africa. Water Research Commission Publication no 297/2/92.
Ref 33		Eksteen, v/d Walt & Nissan 1978. Report on general Hydrological Properties of the Transkei.
Ref 34		Amatole System Consulting Engineers. 1995a. Agricultural and Forestry Water Demand. Prepared on behalf of the Department of Water Affairs and Forestry as part of the Amatole Water Resource System Analysis Phase I. Report no P R000/00/0595.
Ref 35		Binnie & Partners; Ninham Shand. 1989. Mzimvubu Basin Development Study Stage 1. Prepared for the Department of Works and Energy, Transkei
Ref 36		BKS & Ninham Shand. 1995a. Social Overview – Eastern Cape Region : Reconnaissance Phase Draft Report. Prepared on behalf of

		the Department of Water Affairs and Forestry as part of the Orange River Development Project Replanning Study. Report no P Q 000/00/0895
Ref 37		BKS & Ninham Shand. 1996. Summary Report. Prepared on behalf of the Department of Water Affairs and Forestry as part of the Orange River Development Project Replanning Study : Reconnaissance Phase. Report no P Q000/00/1295.
Ref 38		BTS Consortium (Binnie & Partners, peter Thorburns & Associates & Ninham Shand) 1988 : Transkei Water Supply Prioritisation study. Prepared for Transkei DAF. Vol 1 : Report, Vol 2 : Data tables Proposed .Dam for Bizana to serve part of Lusikisiki
Ref 39		HKS, Nov 1978 : Lusikisiki bulk water supply : Preliminary Report
Ref 40	:	Midgley, Pitman & Middleton. 1994. Surface Water Resources of South Africa : 1990. Water Research Commission Report No 298/5.2/94.
Ref 41	:	Existing Water Supply Infrastructure. Transkei Department of Agriculture and Forestry, Engineering Services Branch. 1989. Annual Report 1985/86 – 1988/89.
Ref 42	:	BKS & Ninham Shand. 1997. Existing Water Infrastructure in the Eastern Cape Region and Water Demands of the Eastern Cape Region. Prepared on behalf of the Department of Water Affairs and Forestry as part of the Orange River Development Project Replanning Study : Reconnaissance Phase. Reports No. P Q000/00/0297 and P Q000/00/0397.
Ref 43		Data from Municipal Infrastructure Business Plans for ECDHLG
Ref 44	:	Department of Water Affairs. 1986. Management of the Water Resources of South Africa.
Ref 45	:	Stewart Scott. 1988. National Urbanisation Strategy Report 4, Volume 2 – Engineering Services. Prepared for Government of Transkei.
Ref 46	:	DBSA. 1989. Transkei Development Information. Section 9.
Ref 47		BKS & NS 1997 : Draft report on System Analysis for EC. Prepared for DWAF as part of Orange River Development Project Replanning Study
Ref 48		HKS, March 1979 Lusikisiki Water Purification Works, Preliminary Design Report, DAF Transkei
Ref 49		HKS, June 1979 Lusikisiki Water Purification Works, Revised Preliminary Design Report, DAF Transkei
Ref 50		HKS, Feb 1979 Lusikisiki Water Supply, Preliminary Geological and Soils Investigation, Lower Zalu Dam Site, DAF Transkei
Ref 51		HKS, March 1979 Zalu Dam Foundation Investigation, Tender Report

Ref 52		HKS, Jan 1990 Taweni Village Water Supply, Reconnaissance Report, DAF Transkei
Ref 53		SRK, July 1991: Northern Zone Village Water Supply Groundwater Programme: Transkei Department of Agriculture and Forestry, Engineering Services, Vol. 7, Report No. 174392/3
Ref 54		SRK, June 1991: Inventory of Formal Schemes 1990/1991, Vol. 1, Transkei Department of Agriculture and Forestry. Report No. 174392/2 (Draft)
Ref 55		SRK, July 1991: Northern Zone Village Water Supply Study Groundwater Programme 1990. Transkei Department of Agriculture and Forestry, Engineering Services, Vol. 1, Report No. 174392/3.
Ref 56		SRK, July 1991: The components and conditions of Registered Schemes in the Northern zone of the Transkei, Vol. 2. Department of Agriculture and Forestry, Report No. 174392/2.
Ref 57		SRK, July 1991: Northern Zone Village Water Supply Groundwater Programme 1990, Matatieze District Borehole data, Vol. 4. Transkei Department of Agriculture and Forestry, Engineering Services, Report No. 174392/3.
Ref 58		Borehole Database Report Indexed by Zones, Districts and Administration Areas, October 1992. Department of Agriculture and Forestry, Transkei National Groundwater Database.
Ref 59		SRK, July 1991: Qumbu District Borehole Data, Transkei Department of Agriculture and Forestry, Engineering Services, Report No. 174392/3, Vol. 2.
Ref 60		SRK, July 1991: Lusikisiki District Borehole Data. Transkei Department of Agriculture and Forestry, Engineering Services, Volume 6, Report No. 174392/3.
Ref 61		SRK, July 1991: Mount Fletcher District Borehole Data. Transkei Department of Agriculture and Forestry, Engineering Services, Vol. 3, Report No. 174392/3.
Ref 62		UWP Engineers, March 2000: Mkambati SDI Water Supply Scheme, Feasibility Study, Reconnaissance phase, Prepared for Amanz'Abantu Services and Department of Water Affairs and Forestry
Ref 63		Theart Mgijima & Associates, 2000, Flagstaff District: Land Development Objectives/Integrated Development Plan, prepared for the Wild Coast District Council
Ref 64		Theart Mgijima & Associates, 2000, Bizana District: Land Development Objectives/Integrated Development Plan, prepared for the Wild Coast District Council

Ref 65		Theart Mgijima & Associates, 2000, Lusikisiki District: Land Development Objectives/Integrated Development Plan, prepared for the Wild Coast District Council
Ref 66		Theart Mgijima & Associates, 2000, Wild Coast District: Land Development Objectives/Integrated Development Plan, prepared for the Wild Coast District Council
Ref 67		Wild Coast District Council, August 1999, Draft Water Services Development Plan – Discussion Document

APPENDIX B :

TERMS OF REFERENCE

APPENDIX B

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE OF WATER RESOURCES PLANNING

LUSIKISIKI BASIN STUDY

TERMS OF REFERENCE

LUSIKISIKI BASIN STUDY

TERMS OF REFERENCE

1. Background

Lusikisiki magisterial district is located in the most north-eastern, coastal part of the Wild Coast District of the Eastern Cape Province (formerly part of Transkei). This area is also known as the Pondoland coast and includes all river catchments between the Mntafufu and Mzamba Rivers (tertiary drainage region T600).

The introduction of the RDP water supply programme has resulted in the identification of the need in many instances for substantial augmentation of the domestic water supply schemes serving the large rural population in the region. In particular, water resources with adequate yield assurance are required for the upgrading of the water supply to the Lusikisiki magisterial district (213 000 people). The Wild Coast Spatial Development Programme has identified forestry and tourism as the drivers for economic development in the area. Agricultural developments for the production of sugar cane and tea may be viable. Furthermore, the riverine systems and the estuaries of the rivers in the area are in pristine condition. The Mkambati Nature Reserve (Msikaba River estuary) and the entire Pondoland coast are extremely environmentally sensitive. These are national assets and attractions for tourists.

The surface water resources in the area are largely under-utilised. Groundwater may have a potential for cost efficient water supply in certain areas of the district. Conjunctive use of run-of river and ground water may be economically viable in other areas. The economic viability of hydropower generation in the case of construction of dams in the area has not been investigated.

In general, the knowledge level about the water resources in the Pondoland area as well as many other Transkei catchments is very limited. In order to provide a planning tool for the sustainable development and efficient utilisation of the water resources in the area, it is recommended that a basin study be conducted. Such a study will further the aim of bringing the level of available information for the Transkei region in line with the rest of the catchments in South Africa. This study will also contribute valuable information for the establishment of a water management area and a catchment strategy as stipulated by the new Water Act.

The results of the study will be useful for other Government Departments and interested parties for the planning of various development initiatives.

2. Purpose of the Study

The study area is defined as the coastal river catchments between the Mntafufu and Mzamba Rivers (see attached locality map).

The study will provide a broad evaluation of the current state and the potential for development of the water resources in the area, as well as the present and potential water requirements for all user sectors. The Msikaba River catchment within which Lusikisiki lies will be given more detailed attention. Particular attention will be given to establishing the environmental water requirements for the Mkambati Nature Reserve which lies on the estuary of the Msikaba River.

A more specific output of the basin study will be a clear indication at a pre-feasibility level of detail, of a preferred source for augmentation of the domestic supply for the town of Lusikisiki and the surrounding rural areas as well as a recommendation for an implementation programme.

3. Proposed Scope of Work

The following activities are recommended to be undertaken during the course of this study (levels of detail – pre-feasibility for Msikaba River catchment and reconnaissance for the rest of the area) :

3.1 Background Information

- Assemble, collate and present in a suitable form existing information on the study area: climate, topography, demographics and socio-economic development, current and planned land use, institutional and legal aspects, natural resources, etc.
- Assessment of the accuracy and completeness of the existing information. Identification of gaps and further information required.
- Limited verification and patching of information, where necessary.

3.2 Domestic water supply situation

- Population and livestock distribution, present levels of service where this is known, existing projects and projects in process of implementation.
- Population growth and proposed future levels of service.
- Area planning and possible grouping of schemes.

3.3 Existing infrastructure

Existing road, rail and electricity infrastructure will be described. A description of the existing major water supply infrastructure, its operational condition and upgradability will be provided.

3.4 Agricultural developments and afforestation

- In general, this is to be limited to a broad overview of possible developments with reference to the effect of these developments on the runoff and water requirements. For the Msikaba catchment a more detailed assessment is required.
- Determine the extent of existing developments. Document all available information on development potential and identify information gaps. Study and review all development programmes proposed for the area (Wild Coast Spatial Development Initiative, for instance). Assess the feasibility of future developments taking into account available water resources, economic development potential and financial constraints. The assessment should include the effects of dryland farming, irrigation and commercial livestock farming as well as the effects of afforestation (planted forests) and invasive forests.

3.5 Water requirements

- Present and future water use by the various user sectors is to be assessed. Historical water use information should be presented where available and of use for future projections.
- Urban and industrial.
- Rural, domestic and livestock.
- Agricultural developments and afforestation.
- Hydropower generation (desktop evaluation of potential, feasibility and flows, only for proposed dams).
- Environmental and social requirements (the Reserve). IFR's are to be expressed as a percentage of natural annual flows.

3.6 Runoff hydrology, surface water resources and yield analysis

- In general the water resources assessments will be done primarily on the basis of WR90.
- In the case of the Msikaba River, the existing flow data collected by the former DAF of Transkei and by the DWAF prior to Transkei independence in 1968 will be reviewed, and if feasible will be used to determine more accurate Pitman Model parameters than obtainable from WR90. If flow records within the catchment are unsatisfactory then it may be necessary to calibrate a Pitman model for the catchment by making use of flow records for adjacent catchments and cross correlation.

Historical firm yield analysis will be applied for the calculation of the yields of proposed dams. Long term stochastic yield may be considered as an option.
- Floods for proposed dams and river abstractions will be estimated on the basis of TR137 for Msikaba River only.

3.7 Groundwater resources

- Studies for assessments of availability and assurance of groundwater resources will be undertaken on the basis of readily available information (borehole database) and previous experience in the area.
- A more detailed investigation may be required for the Lusikisiki water supply area only. The occurrence of aquifers, fractured rock and faults may have to be identified.

3.8 Reconciliation of supply and demand

- An assessment of the water balance in each catchment at 10 year intervals for the period until 2030 is to be undertaken and presented in a suitable form.

3.9 Water quality, sedimentation and return flows

- The river catchments of the study area are not presently included in any of the water quality monitoring systems and databases (HIS and POLMAN).
- Unless a monitoring programme is established by DWAF as a matter of priority then the consultant will be required to arrange that water samples from specific sites be tested during the course of the study and that the results be documented.
- Available sedimentation mapping and any other information on sedimentation such as the extent of erosion in the various catchments will be documented. This information will be used to predict the rate of sediment accumulation in new dams.
- The effect of return flows in the area is limited. Available information will be documented.

3.10 Development options for water supply to the Lusikisiki area

The various development options for the supply of water to Lusikisiki and surrounding villages are to be identified and described. This will involve:

- Review of previously identified schemes.
- Review, grouping and area planning.
- Shortlisting of options utilising all applicable criteria (technical feasibility, social and environmental acceptability, institutional and

operational viability, phased implementation, labour intensive construction, cost etc.)

3.11 Selection of preferred development option

- Conceptual design and sizing of competitive options, based on approved sizing criteria.
- Topographic surveys where required.
- Costing on the basis of cost models and cost functions agreed upon with the client. Recurrent annual costs will be calculated for each option.
- Economic evaluation will be done on the basis of discounted present cost and the unit reference value (URV) of water supplied by each option. The URV will be calculated for a period of time and discount rate as agreed with the client.
- A sensitivity analysis for various discount rates will be performed.

3.12 Environmental aspects

The purpose of this investigation will be to identify problematic areas and to provide a broad idea of the instream flow requirements for the rivers and the estuaries, to establish the river flows necessary to satisfy basic human needs and to provide a broad estimate of the Reserve. In the case of the Msikaba River a more detailed assessment of these water requirements is required. Results will be based on a desk study, existing information and limited site visits. No workshops are envisaged for this stage.

- Broad classification of rivers (possibly a group classification if rivers are similar).
- Broad estimate of the IFR for each river and estuary (based on D. Hughes planning estimate method) expressed as a percentage of the natural annual runoff.
- Assessment will be based on the Integrated Environmental Management (IEM) procedures as prescribed by the Environmental Conservation Act (1989) and more specifically the Regulations gazetted on 5 September 1998.
- More detailed assessment of the IFR and the Reserve for the Msikaba River (including its estuary) and the Mkambati Nature Reserve and of the impacts related to possible water resources developments for the Lusikisiki area will be undertaken. This could include assessment of the Preliminary Reserve as defined in the new Water Act and a scoping exercise to provide a broad assessment of the impacts of the more favourable dams identified.

3.13 Social aspects

For the schemes identified in the study the following will be established:

- Estimate number of people directly or indirectly affected by the developments.
- Estimate potential health and safety hazards.
- Estimate extent and value of physical assets that will be lost as a result of the development.
- Investigate and estimate the cost of mitigation measures.

3.14 Public involvement and community liaison

Public involvement and community liaison will be performed from the commencement of the study through the formation of a Stakeholders Liaison Committee. All affected communities and interested parties will be informed of the proposed developments and their inputs invited.

APPENDIX C :

PHOTOGRAPHS AND PLATES



PLATE 1: Lusindisweni dam site viewed upstream towards the dam basin (Mtentu River)



PLATE 2: KwaHlati site – with proposed dam wall on right of plate and the dam basin towards the left of the plate (Mtentu River)



PLATE 3: Spes Bona weir site viewed from upstream (Mtentu River)



PLATE 4: Gxalibomvu weir site (Msikaba River)



PLATE 5: Mbongweni weir site (Mzamba River)



PLATE 6: Zalu dam site viewed from the left flank (Xura Dam)



PLATE 7: Lusikisiki dam site viewed from upstream (Xura River)

APPENDIX D :

EXISTING INFRASTRUCTURE

EXISTING WATER INFRASTRUCTURE AUDIT

MAGWA TEA SITE VISIT

20 JUNE 2000 ASSESSMENT

CONTACT PERSONS

Mr. Mhlonga (Production Manager) 039-2531910
Mr. Dingiswayo (Assistant)
Mr. R. Ngomlomo (Maintenance Plumber)

1. EXISTING WATER INFRASTRUCTURE

Water is extracted using 2 No. 100 ϕ pipes from a weir. The weirs approximate dimensions are:

- 22m long, 0.95m thick and 1.1m deep.

Recent heavy flows have damaged the wall/weir as can be seen from the photo 2 & 3.

Little information was available regarding the dam upstream from the weir

The layout of the water treatment works (situated adjacent to the Weir) can be seen from figure 1

The Raw Water Pump Specifications follow:

Pump 1	KSB 287 ELBK 12/18/20 21 5 93	Motor 1	3 phase 50HZ Squirrel cage induction motor BP TEFC D100L 380A AD 6235/9 Duty SI CMR
Pump 2	6039 (unable to read Specs. of pump)	Pump 2	ASEA, 4kw, 2880r/m 50Khz, cat no. MK 14/001AB Cos ϕ : 0.9

The above pumps are connected in parallel and are used one at a time. Water is treated and then pumped to the main command reservoir with the following pumps connected in series

Pump 3	ETB 50.26 9986.2	Motor 3	BMM ser No. WD 7780/6 Kw Duty S1 CMR 380V 22.7A 2900RPM
Pump 4	KSM ETA 50.250 Serial No. 53233.431 Impellor F/S	Motor 4	RD 6520/19 2890 D160m

The rising main is a 160 dia PVC pipe which runs into 2 No. bulk reservoirs.

The reservoir sizes follow:

Reservoir 1 260kl (14.9m ϕ and 1.5m deep)	Reservoir 2 160kl (9m ϕ and 2.5m deep)

These command reservoirs feed approximately 20 other reservoirs.

An additional pump exists next to the weir. It is not in use but was originally intended for irrigation purposes.

Pump	ETA 100-50CA Serial No. 09235-431 Impelled 405/330	Motor	Hawker Siddeley Electric 1465rpm 37Kw (A73) Duty S No. 87312/161C IP55 Frame D2255

2. CURRENT CONSUMERS

Peak demands occur between September and June, caused by production cycles at the tea plantation. The following demands exist (there may be others)

2.1 Workers

The total labour force consists of approximately 3 500 workers, 1700 are permanent, whilst 1800 is migrant labour. The workers live in 13 compounds. There are approximately 10 standpipes per compound.

2.2 Ntsubana Forest

A village here draws from the scheme. The approximate population here varies between 100-300. This large variance is due to migrant labour.

2.3 Staff Houses

There are 50 staff houses. Each staff house has a yard connection.

3. ADDITIONAL DEVELOPMENT

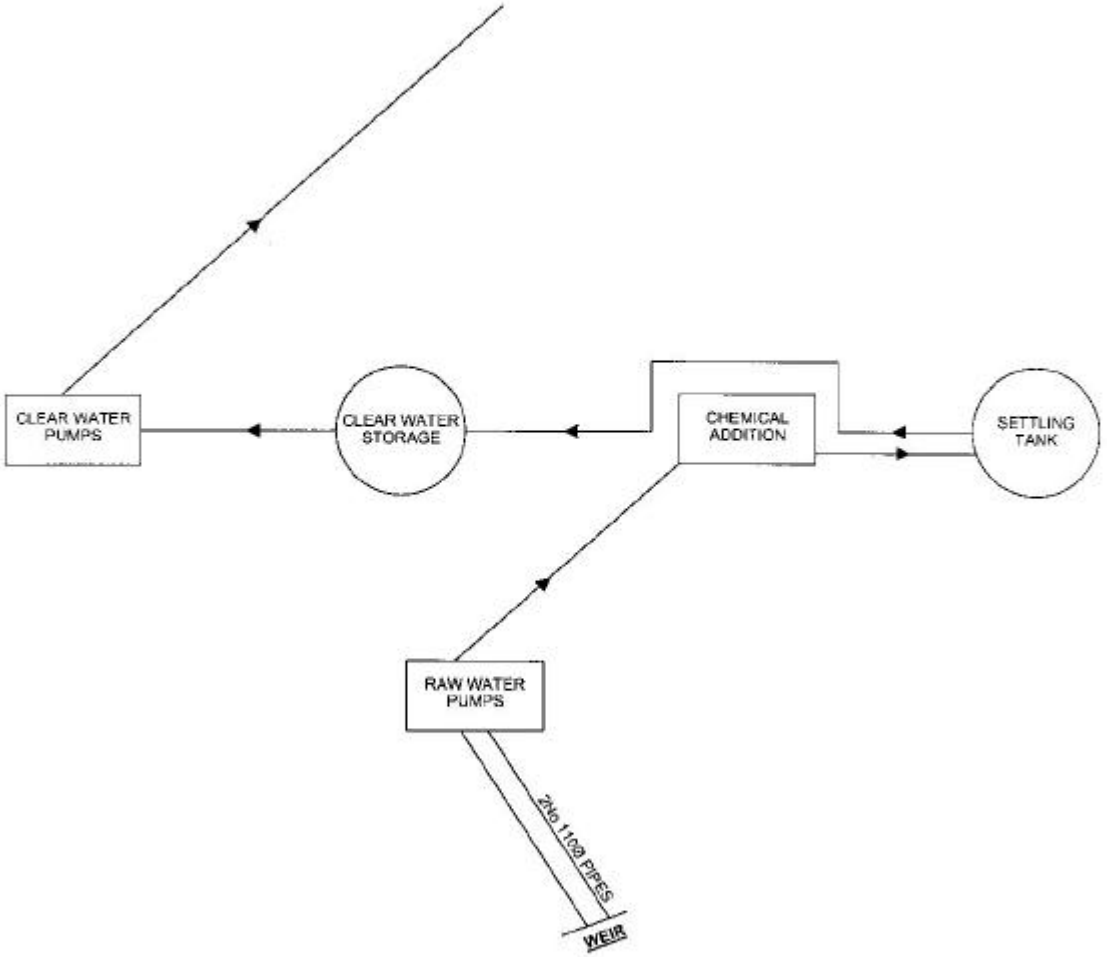
No development is being planned at this stage.

Ownership of the tea estate is currently being handed over to the locals.

APPENDIX D

DRAFT LAYOUT OF MAGWA TEA TREATMENT WORKS

FIGURE 1



FLAGSTAFF TLC SITE VISIT - WATER INFRASTRUCTURE AUDIT

20 JUNE 2000

CONTACT PERSONS

Mrs. Stofella	083 749 1422 (Town Clerk/Mayor)
	039 - 2520131
Mr. Gawulana	039 - 2520131 (Works Manager)

1. EXISTING WATER INFRASTRUCTURE

Water is extracted from a diversion weir and four boreholes. Only surface water is treated.

Specifications for the pump at the dam are as follows:

Pump	Orbit, type/302 P/R No. 3634 ROT (Contact tel : 011 8734007)	Motor	IIW 1450RPM 22.6A BP 0367450/15/50 3Ph 380V 50hz

The rising main from the dam consists of a 110PVC pipe. The pump is run for 8 hours each day and switched off at night.

One borehole was inspected. Borehole pump specifications are as follows :

Pump	Monopump MKJ Size 50mm Serial No. 23488	Motor	BP 4Kw 380v 50hz No. 0353420/03/5A 1425 rpm

A diesel lister motor is used as a standby motor. Borehole pumps are occasionally switched off for borehole recharge. Rising mains from boreholes consist of 110 ϕ pipes.

Two bulk reservoirs exist at the water treatment works (see figure 2):

Reservoir 1	200kl	Reservoir 2	275kl
(12.7m ϕ and	1.6m deep)	12.9m ϕ and	2.1m deep)

Reservoir 1 (higher up in photo) contains only borehole water while reservoir 2 holds both dam and reservoir water (reservoir 1 is linked to reservoir 2).

The outlet for the scheme draws at reservoir 2 with a 110 dia PVC pipe.

4. CURRENT CONSUMERS

Current consumers include :

- 2 funeral parlours,
- 1 clinic,
- 1 baker,
- Garages,
- 1 hotel,
- +/- 300 houses and informal settlement
- wholesalers.

A list of available flowmeter readings can be found in Appendix 1.

5. ADDITIONAL DEVELOPMENT

Additional development in the area includes the following :

2 150 low cost houses are planned to commence in July 2000. A reservoir is currently being constructed for the first 500 houses (phase I) and a 160 ϕ pipe from reservoir 2 is being laid. These houses will have yard connections.

300 medium cost houses are also planned. Land is being surveyed at present for these houses.

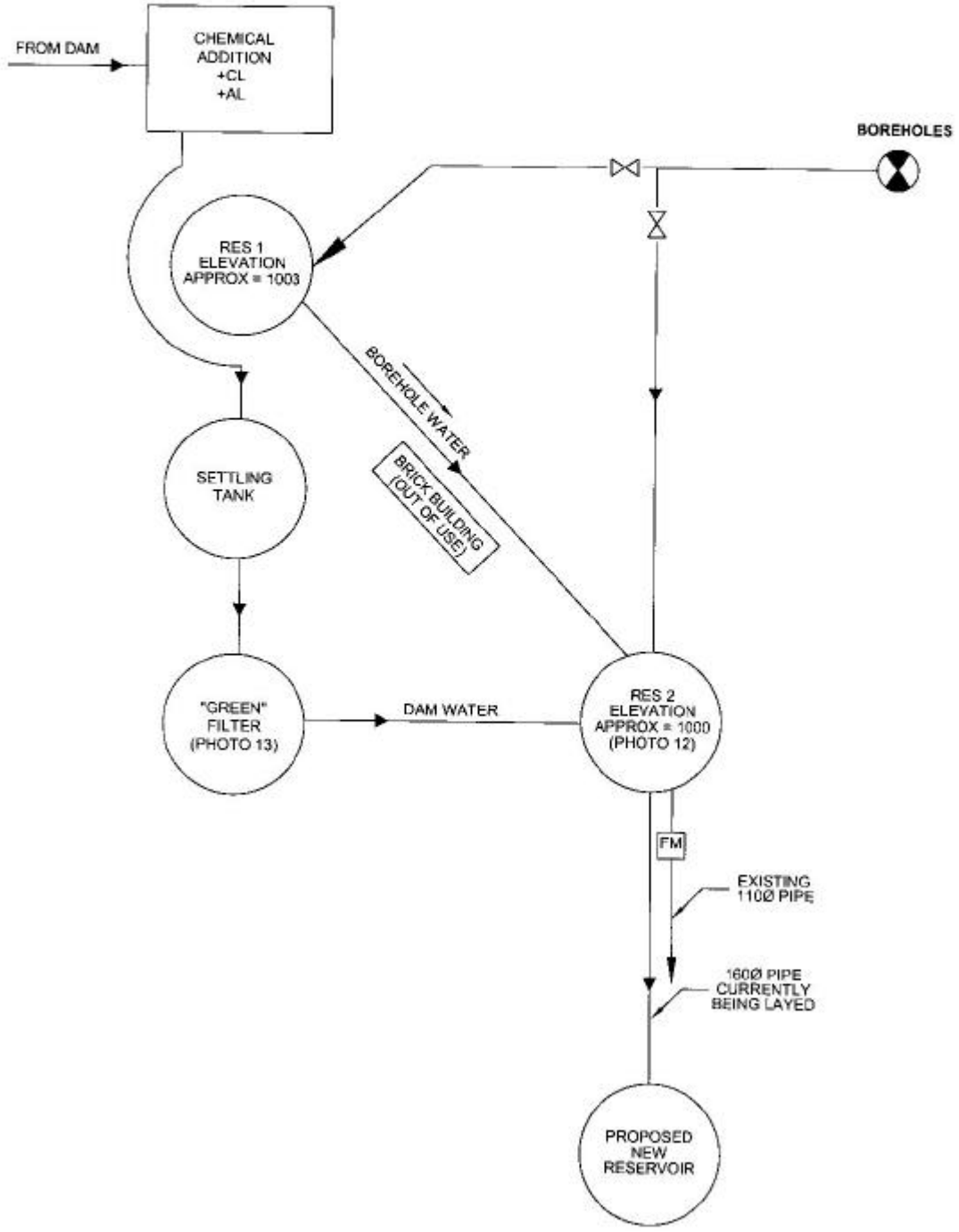
5 Industrial sites have been demarcated.

An informal settlement is currently being formalised in Flagstaff. The CMIP application for this has been approved.

Score (supermarket) are looking at spending R8 million on a shopping complex in Flagstaff.

DRAFT LAYOUT OF FLAGSTAFF WATER TREATMENT WORKS

FIGURE 2



MKAMBATI WEIR SCHEME

Existing infrastructure

1.1 Weir scheme

Raw water is pumped from a weir on the Mkambathi River directly to a reservoir. The scheme is old (approx. 50 years) and requires regular maintenance.

1.1.1 Location and specifications

The current infrastructure consists of 2 reservoirs (approx. 450kl) located at:

Latitude	31° 16' 23"
Longitude	29° 57' 20".
Height	240 m

The scheme operates from one reservoir. The second reservoir has been bypassed because of wall cracks.

Water is extracted from the Mkambathi River at the weir:

Latitude	31° 15' 40"
Longitude	29° 57' 33".
Height	220 m

Approximate dimensions of the weir are

Length	7m
Thickness	0.25m
Height	0.5m

The pump-house at the weir consists of two diesel driven pumps. The specifications of one of the pumps are given below. It is believed that the second pump is identical to the first.

Pump serial number	70327V18
Impellor size	250mm
Pump type	Salweir VEG40
Pump motor	Lister
Motor serial number	R107HR2A33
Power rating	21.6Kw
Motor speed	1500rpm

1.1.2 Water treatment

The water used is dosed with chlorine after heavy rainfall. It is not treated during dry periods.

1.1.3 Current consumers

Current consumers (see attached layout) include:

Location	No. Consumers
1. Staff & clinic	158
2. Main camp/lodge	44
Works for water (temporary)	70
Total	**272**

Note : Location of Works for water consumers uncertain.

1.2 Point cottage (South Sand Bluff) scheme

Point cottage contains 6 beds. It is situated on the coast near the cottages/lodge. A tank at this cottage is replenished using a mobile water cart.

1.3 Gwe Gwe/Riverside scheme

Gwe Gwe/Riverside is 7km away from the Main camp/lodge. A weir supplies Gwe Gwe. There are approximately 50 consumers here. The HDPE pipe from the weir is in a bad condition.

Mzamba Water Scheme

EXISTING INFRASTRUCTURE

The scheme has been initially built in 1983 to supply the requirements of the Wild Coast Sun hotel, and has later been upgraded and extended several times. The scheme presently supplies the hotel complex (800 beds, 3000 day visitors), the staff village (1000 people), Mzamba police station, a rural clinic and the Mzamba curios village.

A small earth embankment dam approximately 10 –15 m high with a side channel spillway has been built on a small river close to the resort. A stand by transfer scheme from Mzamba River to the dam has been built to augment the system in cases of emergency or severe droughts.

The water is pumped by a raw water pump station (4 electrical pumps and 2 stand-by diesel pumps and engines) at the toe of the dam to the water treatments works situated at a command position.

The water treatment works with present capacity of 2 000 kl/d consist of coagulation and settlement tanks, pressure filters and chlorination dosing equipment. The system includes 3 reservoirs with a total capacity of 5,5 Ml.



PHOTO 1 : Magwa weir

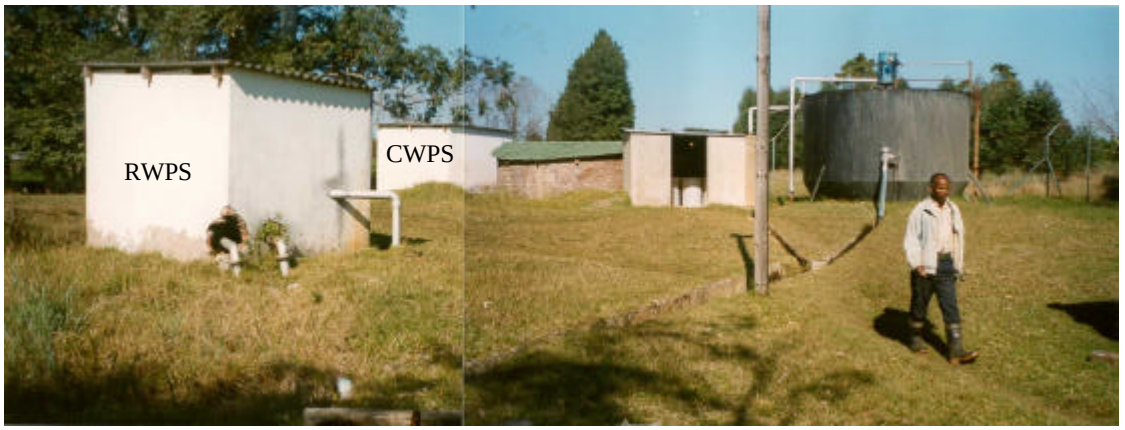


PHOTO 2 : Magwa WTW



PHOTO 3 : Flagstaff WTW



PHOTO 4 : Flagstaff WTW (sand filter)



PHOTO 5 : Existing weir on Mkambati River



PHOTO 6 : Access road to pumpstation at Mkambati weir

APPENDIX E :

WATER REQUIREMENTS

TABLE 1 : SUMMARY OF WATER REQUIREMENTS AND LAND USE PER QUATERNARY SUB-CATCHMENT

T60A

	2000	2030
Consumptive Domestic Use (Mm^3/a)	0.219	1.024
Urban Demands	0.000	0.000
Rural Demands	0.230	1.078
Livestock Demands (Mm^3/a)	0.429	0.429
Irrigation Demands (Mm^3/a)	0.000	0.160
Environmental Demands	56.718	56.718
Afforestation area (ha)	647	2710
Return flows	0.000	0.000
Groundwater supply	(0.012)	(0.054)
Total	58.066	61.181

T60B

	2000	2030
Consumptive Domestic Use (Mm^3/a)	0.622	3.008
Livestock Demands (Mm^3/a)	0.414	0.414
Irrigation Demands (Mm^3/a)	0.000	0.117
Afforestation area (ha)	3405	4468

T60C

	2000	2030
Consumptive Domestic Use (Mm^3/a)	0.277	1.038
Livestock Demands (Mm^3/a)	0.285	0.285
Irrigation Demands (Mm^3/a)	0.000	0.023
Afforestation area (ha)	0	0

T60D

	2000	2030
Consumptive Domestic Use (Mm^3/a)	0.153	0.511
Livestock Demands (Mm^3/a)	0.326	0.326
Irrigation Demands (Mm^3/a)	0.000	0.039
Afforestation area (ha)	0	1000

T60E

	2000	2030
Consumptive Domestic Use (Mm^3/a)	0.763	4.980
Livestock Demands (Mm^3/a)	0.155	0.155
Irrigation Demands (Mm^3/a)	0.010	0.080
Afforestation area (ha)	698	698

Note: Consumptive Domestic Use (Mm^3/a) is defined as the sum of the urban and rural domestic water requirements and bulk water requirements, less the groundwater supply and urban return flows. The return flow has been assumed to be equal to 50% of the urban domestic water requirement.

T60F

	2000	2030
Consumptive Domestic Use (Mm^3/a)	1.612	11.034
Urban Demands	0.613	3.872
Rural Demands	0.998	7.538
Livestock Demands (Mm^3/a)	0.364	0.364
Irrigation Demands (Mm^3/a)	0.003	0.270
Environmental Demands	63.424	63.424
Afforestation area (ha)	472	472
Return flows	-0.176	-1.513
Groundwater supply	0.000	(0.377)
Total	65.807	74.159

T60G

	2000	2030
Consumptive Domestic Use (Mm^3/a)	0.317	1.070
Livestock Demands (Mm^3/a)	0.283	0.283
Irrigation Demands (Mm^3/a)	0.000	0.019
Afforestation area (ha)	295	295

T60H

	2000	2030
Consumptive Domestic Use (Mm^3/a)	0.052	0.004
Livestock Demands (Mm^3/a)	0.253	0.253
Irrigation Demands (Mm^3/a)	0.000	0.000
Afforestation area (ha)	1495	4495

T60J

	2000	2030
Consumptive Domestic Use (Mm^3/a)	0.151	0.201
Livestock Demands (Mm^3/a)	0.231	0.231
Irrigation Demands (Mm^3/a)	0.000	0.045
Afforestation area (ha)	817	817

T60K

	2000	2030
Consumptive Domestic Use (Mm^3/a)	0.311	0.510
Livestock Demands (Mm^3/a)	0.190	0.190
Irrigation Demands (Mm^3/a)	0.006	0.044
Afforestation area (ha)	632	632

Summary T60

	2000	2030
Consumptive Domestic Use (Mm^3/a)	4.476	23.379
Livestock Demands (Mm^3/a)	2.930	2.930
Irrigation Demands (Mm^3/a)	0.019	0.798
Total (Dom. + LSU + Irrig.) (Mm^3/a)	7.425	27.108
Total (Afforestation) (ha)	8461	15587

SUMMARY OF WATER REQUIREMENTS PER USER SECTOR PER SUPPLY NODE (Mm^3/a)

with Environmental water requirements set to zero

T60A

	2000	2010	2020	2030
Urban Demands	0.000	0.000	0.000	0.000
Rural Demands	0.230	0.251	0.604	1.078
Stockwatering Demands	0.429	0.429	0.429	0.429
Irrigation Demands	0.000	0.097	0.141	0.160
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	0.700	2.850	2.850	2.850
Return flows	0.000	0.000	0.000	0.000
Groundwater supply	(0.012)	(0.013)	(0.030)	(0.054)
Total	1.348	3.615	3.994	4.463

T60B

	2000	2010	2020	2030
Urban Demands	0.000	0.000	0.000	0.000
Rural Demands	0.655	0.942	1.984	4.011
Stockwatering Demands	0.414	0.414	0.414	0.414
Irrigation Demands	0.000	0.058	0.092	0.117
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	3.700	4.900	4.900	4.900
Return flows	0.000	0.000	0.000	0.000
Groundwater supply	(0.033)	(0.094)	(0.298)	(1.003)
Total	4.737	6.220	7.093	8.440

T60C

	2000	2010	2020	2030
Urban Demands	0.000	0.000	0.000	0.000
Rural Demands	0.292	0.315	0.816	1.730
Stockwatering Demands	0.285	0.285	0.285	0.285
Irrigation Demands	0.000	0.004	0.014	0.023
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	0.000	0.000	0.000	0.000
Return flows	0.000	0.000	0.000	0.000
Groundwater supply	(0.015)	(0.047)	(0.204)	(0.692)
Total	0.562	0.557	0.911	1.346

T60D

	2000	2010	2020	2030
Urban Demands	0.000	0.000	0.000	0.000
Rural Demands	0.161	0.169	0.409	0.852
Stockwatering Demands	0.326	0.326	0.326	0.326
Irrigation Demands	0.000	0.008	0.020	0.039
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	0.000	1.670	1.670	1.670
Return flows	0.000	0.000	0.000	0.000
Groundwater supply	(0.008)	(0.025)	(0.102)	(0.341)
Total	0.478	2.147	2.322	2.546

T60E

	2000	2010	2020	2030
Urban Demands	0.606	1.353	2.593	4.214
Rural Demands	0.210	0.338	0.793	1.276
Stockwatering Demands	0.155	0.155	0.155	0.155
Irrigation Demands	0.010	0.049	0.067	0.080
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	0.780	0.780	0.780	0.780
Return flows	(0.211)	(0.540)	(1.094)	(1.807)
Groundwater supply	(0.052)	(0.101)	(0.278)	(0.510)
Total	1.498	2.034	3.017	4.188

T60F

	2000	2010	2020	2030
Urban Demands	0.613	1.290	2.403	3.872
Rural Demands	0.998	2.856	4.631	7.538
Stockwatering Demands	0.364	0.364	0.364	0.364
Irrigation Demands	0.003	0.139	0.210	0.270
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	0.580	0.580	0.580	0.580
Return flows	-0.176	-0.452	-0.916	-1.513
Groundwater supply	0.000	0.000	(0.232)	(0.377)
Total	2.383	4.778	7.041	10.735

T60G

	2000	2010	2020	2030
Urban Demands	0.000	0.000	0.000	0.000
Rural Demands	0.317	0.227	0.516	1.127
Stockwatering Demands	0.283	0.283	0.283	0.283
Irrigation Demands	0.000	0.008	0.013	0.019
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	0.490	0.490	0.490	0.490
Return flows	0.000	0.000	0.000	0.000
Groundwater supply	0.000	0.000	(0.026)	(0.056)
Total	1.089	1.007	1.276	1.862

T60H

	2000	2010	2020	2030
Urban Demands	0.000	0.000	0.000	0.000
Rural Demands	0.052	0.021	0.012	0.004
Stockwatering Demands	0.253	0.253	0.253	0.253
Irrigation Demands	0.000	0.000	0.000	0.000
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	2.810	4.500	6.400	8.210
Return flows	0.000	0.000	0.000	0.000
Groundwater supply	0.000	0.000	(0.001)	(0.000)
Total	3.115	4.774	6.664	8.466

T60J

	2000	2010	2020	2030
Urban Demands	0.000	0.000	0.000	0.000
Rural Demands	0.151	0.064	0.072	0.211
Stockwatering Demands	0.231	0.231	0.231	0.231
Irrigation Demands	0.000	0.019	0.032	0.045
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	1.270	1.270	1.270	1.270
Return flows	0.000	0.000	0.000	0.000
Groundwater supply	0.000	0.000	(0.004)	(0.011)
Total	1.652	1.584	1.602	1.747

T60K

	2000	2010	2020	2030
Urban Demands	0.000	0.000	0.000	0.000
Rural Demands	0.311	0.125	0.232	0.536
Stockwatering Demands	0.190	0.190	0.190	0.190
Irrigation Demands	0.006	0.025	0.035	0.044
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	0.960	0.960	0.960	0.960
Return flows	0.000	0.000	0.000	0.000
Groundwater supply	0.000	0.000	(0.012)	(0.027)
Total	1.466	1.300	1.405	1.704

	2000	2010	2020	2030
Total	18.328	28.016	35.326	45.497

SUMMARY OF WATER REQUIREMENTS PER USER SECTOR PER SUPPLY NODE (with Environmental & Afforestation demands = zero) (Mm3/a)

T60

	2000	2010	2020	2030
Urban Demands	1.219	2.643	4.996	8.087
Rural Demands	3.376	5.308	10.070	18.363
Stockwatering Demands	2.930	2.930	2.930	2.930
Irrigation Demands	0.019	0.407	0.624	0.798
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	0.000	0.000	0.000	0.000
Return Flows	(0.387)	(0.992)	(2.010)	(3.321)
Groundwater supply	(0.119)	(0.281)	(1.185)	(3.071)
Total	7.038	10.016	15.426	23.787

SUMMARY OF WATER REQUIREMENTS PER USER SECTOR PER SUPPLY NODE (with Environmental demands = zero) (Mm^3/a)

T60

	2000	2010	2020	2030
Urban Demands	1.219	2.643	4.996	8.087
Rural Demands	3.376	5.308	10.070	18.363
Stockwatering Demands	2.930	2.930	2.930	2.930
Irrigation Demands	0.019	0.407	0.624	0.798
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	11.290	18.000	19.900	21.710
Return Flows	(0.387)	(0.992)	(2.010)	(3.321)
Groundwater supply	(0.119)	(0.281)	(1.185)	(3.071)
Total	18.328	28.016	35.326	45.497

SUMMARY OF WATER REQUIREMENTS PER USER SECTOR PER SUPPLY NODE (with Environmental, afforestation and irrig demands = zero) (Mm^3/a)

Urban Demands

	3	5	10	18
Urban Demands	1.219	2.643	4.996	8.087
Rural Demands	3.376	5.308	10.070	18.363
Stockwatering Demands	2.930	2.930	2.930	2.930
Irrigation Demands	0.000	0.000	0.000	0.000
Environmental Demands	0.000	0.000	0.000	0.000
Afforestation	0.000	0.000	0.000	0.000
Return Flows	-0.387	-0.992	-2.010	-3.321
Groundwater supply	-0.119	-0.281	-1.185	-3.071
Total	7.019	9.609	14.801	22.989

Unit water requirements (l/c/d)

Consumer	Year	Low Estimate	Most Probable	High Estimate
Rural domestic connected to formal water supply	1996	25	30	30
	2000	25	30	30
	2010	30	45	60
	2020	40	60	90
	2030	50	80	120
Urban domestic	1996	120	120	200
	2000	120	160	225
	2010	140	190	250
	2020	160	215	275
	2030	180	240	300
Rural domestic **NOT** connected to formal water supply	1996	15	15	15
	2000	15	15	15
	2010	15	15	15
	2020	15	15	15
	2030	15	15	15

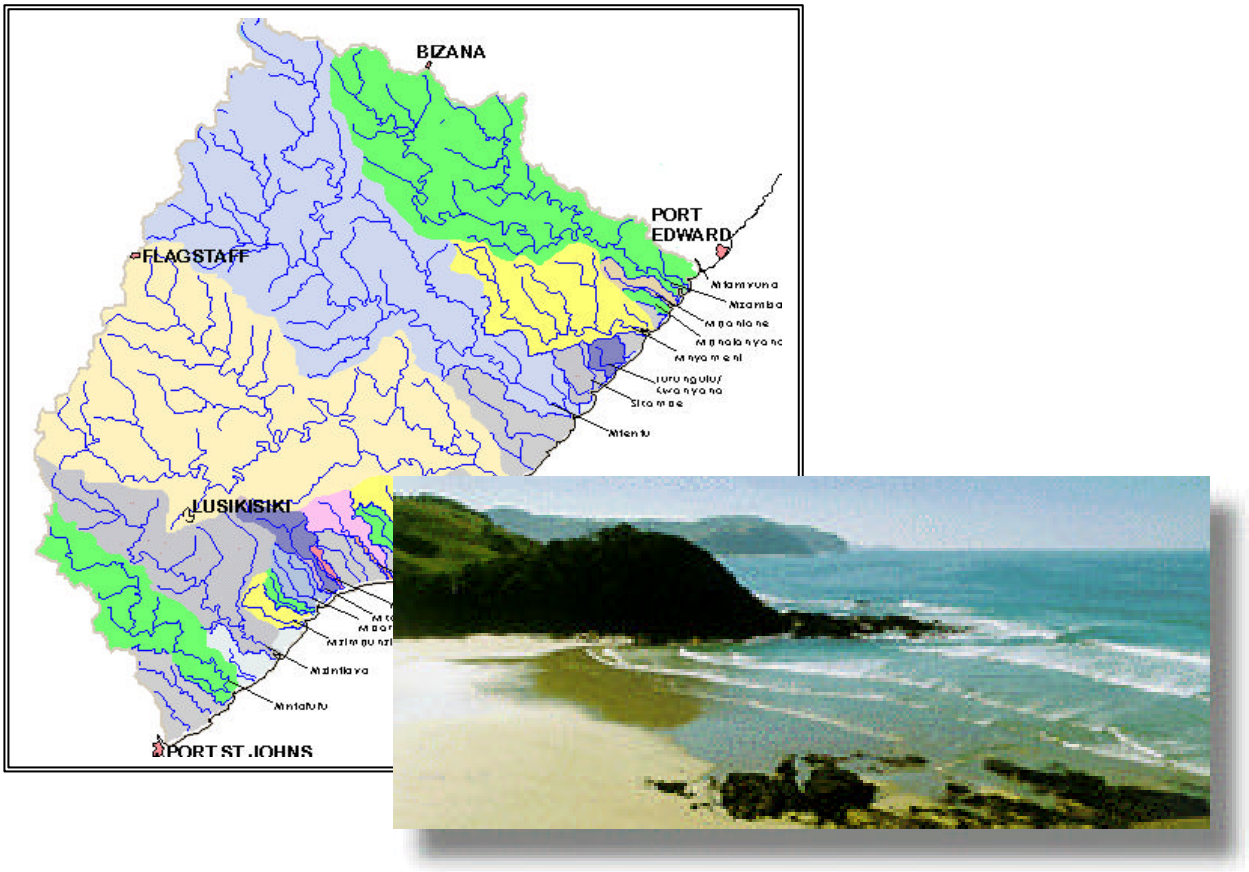
Livestock water requirements **40** litres/LSU/day

PB T600/00/0301

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



DEVELOPMENT OPTIONS

Volume 1 : Report

Final

June 2001

Prepared By:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Development Options, Volume 1: Report
AUTHOR	**:**	HV Doudenski
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-0301
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

ACKNOWLEDGEMENTS

UWP Engineers gratefully acknowledge the valuable contributions to this study provided by the following organisations (listed in alphabetical order):

Andre Roets & Associates
Anton Bok and Associates
Bosele Community Support Services
CSIR
Council for Geoscience: Geological Surveys
DWAF: Civil Design
DWAF: Eastern Cape Region
DWAF: Social and Environmental Studies
DWAF: Hydrology
DWAF: Water Resources Planning
Key Water Solutions
Pollution Control Technologies
Toens and Partners

EASTERN PONDOLAND BASIN STUDY

DEVELOPMENT OPTIONS REPORT

EXECUTIVE SUMMARY

E1. INTRODUCTION

At the request of the Eastern Cape Regional Office, the Directorate: Water Resources Planning of the Department of Water Affairs and Forestry commissioned the Eastern Pondoland Basin Study. The aim of the study was to investigate the water resources situation in the Eastern Pondoland region and in particular the Lusikisiki area, and to recommend solutions to the water supply problems, which were evident in that area at that time. The study therefore consisted of two main components – a basin study and a development options study. The structure of the study reports, including the Basin Study Reports is shown at the end of this chapter.

This report covers the investigations into possible development options for the augmentation of the bulk water source of the Lusikisiki Regional Water Supply Scheme (LRWSS). In accordance with the terms of reference, the scope of this study is limited to a reconnaissance level of detail. The study was therefore undertaken predominantly as a desktop study, with limited site investigation and verification.

The LRWSS (see **Figure E1**) currently supplies the town of Lusikisiki and 23 rural villages with a total population of approximately 52 000 people. Severe water shortages are currently experienced. A number of projects related to the upgrading of the standards of services (to RDP standards) as well as the extension of the supply area to include a total of 56 additional villages (68 000 people) are being considered. Due to the inadequate capacity of the existing water source (a weir on the Xura River) the implementation of these projects has been postponed until after the identification of a supplementary source, capable of meeting the increased water requirements. Other studies related to water demand management, leak detection and repair, and improvement of the operation procedures are currently being undertaken under separate assignments. The scheme is presently owned and operated by the DWAF Eastern Cape Office. In accordance with the Water Services Act it is envisaged that, after the upgrading, the scheme will be transferred to a Water Service Authority, i.e. the appropriate local authority (Oliver Tambo District Municipality).

Certain guidelines, listed below, for the development options investigated during this study were defined in consultation with the Eastern Cape Region (EC:R) early during the course of the study.

- Sizing to be done for a regional scheme, to supply the area covered by the existing scheme, and the proposed extensions, which are included in the RDP water supply programme.
- Sizing of the water source to be done for 98% assurance of supply.

Eastern Pondoland Basin Study

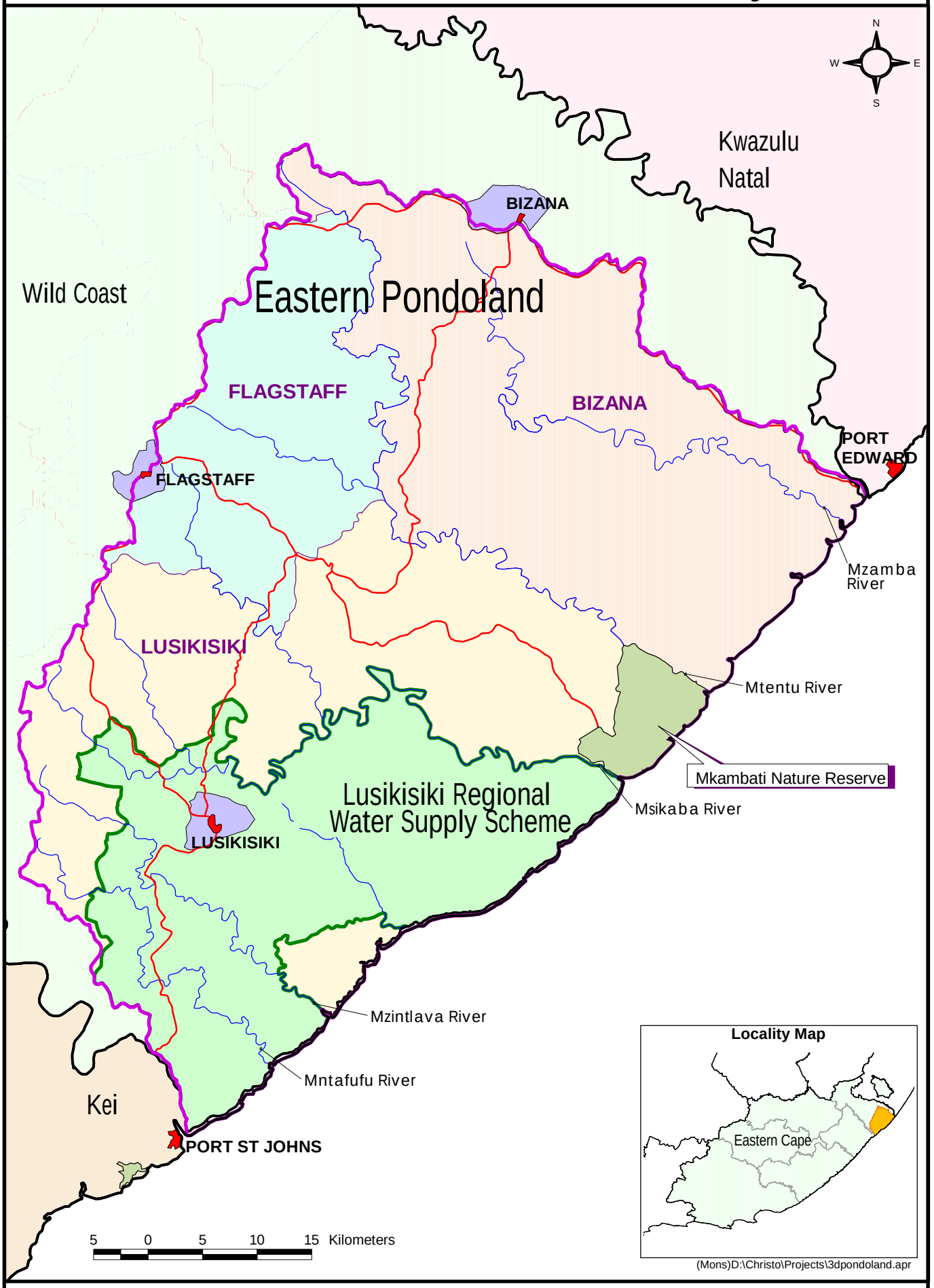


Fig E1 : Locality and Overview

UWP Engineers

- The levels of services to be provided by the scheme should be in accordance with the White Paper for water supply. The sizing criteria should be according to the latest Departmental guidelines for community water supply.
- Allowance for the release of the ecological Reserve should be made.
- If the technical and economical parameters for single and multiple water source options are equal, preference should be given to single source options, due to significant operation, maintenance and management advantages associated with such options.

E2. WATER REQUIREMENTS

Urban and rural domestic, industrial and institutional requirements

The present and projected domestic water requirements depend on the following factors: population numbers, growth rates, levels of service (per capita water use), growth in the industrial and institutional requirements, and phasing (timing of implementation) of the upgrading/extension of the existing infrastructure to supply additional areas. All these factors were investigated in detail, and where uncertainty existed, reasonable upper and lower estimates for each factor were made. Combinations of these estimates were then used to establish and assess various water requirements scenarios (high, medium, low and constant) for the scheme. These scenarios were evaluated and the most likely scenario was selected in consultation with the project management team and the EC: R and was used for sizing of the development options. The water requirements were estimated and projected in decades until year 2030, but all development options were sized for the year 2020 horizon.

Throughout this study, it has been assumed that the best water demand management and water loss control measures would be maintained during all times by the water service provider and the water service authority.

Present population numbers. All existing data sets regarding present population numbers (DWAF's 1st order strategy, Census 1996, Eskom (MegaSub), DWAF's recent demographic study (MarkData 2000)) were assessed in terms of accuracy and applicability for the purposes of this study. It was concluded that the information from the various sources compare reasonably well (±7% variation from average). It was decided that the DWAF 1st order strategy data would be used due to certain advantages in terms of spatial output required for the planning activities during this study. Year 1996 was selected as a base year for all demographic projections.

Population growth rates. An overview of available recent population information for the study area (Census data from 1970 to 1996) was undertaken in order to establish the historical variation of the population growth rates and possible future trends. The rural population in the study area has grown with a constant rate of about 2,5% per annum since 1970, while the urban population has grown with an average rate of about 6% during the same period. The results of the most recent demographic study commissioned by DWAF (MarkData, 2000) indicated that the rural population growth is expected to slow down considerably due to the impacts of AIDS, migration and urbanisation. As a result, the projected future growth rates (next 30 years) for the rural population across the country would be significantly lower than previously expected. Due to the uncertainties related to the population growth rates, two estimates were taken into consideration. The upper

estimate was determined on the basis of the historical information, modified with recent trends (1% for the rural population until year 2020). The lower estimate was based on the MarkData's study results (minus 0.5% for the rural population until year 2020).

Levels of service. The upper estimate for projected water use was established in accordance with the existing DWAF's rural water supply guidelines: rural 25 l/c/d (2000) to 60 l/c/d (2020) and urban 160 l/c/d (2000) to 240 l/c/d (2020). The lower estimate was established on the basis of experience with actual use at recently constructed projects in similar areas: rural 18 l/c/d (2000) to 36 l/c/d (2020) and urban 110 l/c/d (2000) to 200 l/c/d (2020). A provision for growth in the urban industrial and institutional water use at a constant rate of 1% per annum was made in accordance with the historical growth data. A provision for certain institutional requirements (clinics, commuters from other areas, community halls, etc) at 7% of the total net water consumption for rural areas was also made.

Phased implementation: The following most likely implementation programme for extension and upgrading of the regional scheme was adopted in consultation with the EC:R. These projects were included in the EC: RDP programme, but the implementation has been placed on hold due the inadequate capacity of the existing water source. The areas covered by the various phases are shown in **Figure 2** in the main body of the report.

- 2005: upgrade the existing bulk supply and commission the reticulation systems for the 23 villages included in the existing scheme: standpipe level of service
- 2010: commission the bulk supply and reticulation systems for 34 additional villages included in phase 2 of the scheme: stand pipe level of service
- 2015: commission the bulk supply and reticulation systems for 22 additional villages included in phase 3 of the scheme: stand pipe level of service

Total water requirement scenarios. The following projected water requirement scenarios were then established and evaluated. The results are shown in **Table E1.**

- **High scenario:** high estimate for projected population growth rates, and high estimate for levels of service (per capita water requirements)
- **Medium scenario:** low estimate for projected population growth rates, and high estimate for levels of service
- **Low scenario:** low estimate for projected population growth rates, and low estimate for levels of service
- **Constant scenario:** No change in rural population numbers (use year 2000 levels, with zero growth), low growth estimate for urban population, constant 25 l/d per capita water requirements for the rural population, and low estimate for urban service levels.

Table E1: Net Domestic and Industrial Water Requirements for various scenarios

Requirement Scenario	Net water requirements $10^6 m^3/a$		
	2000	2010	2020
High	1.177	2.996	5.635
Median	1.110	2.491	3.504
Low	1.020	1.766	2.285
Constant	1.043	1.807	2.238

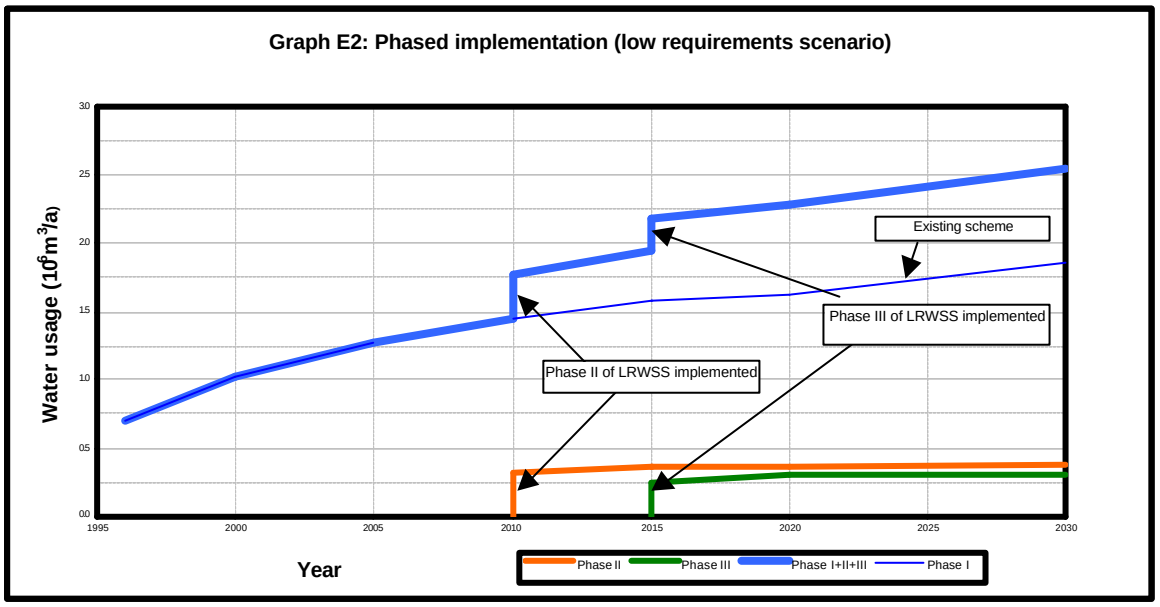
Selected water requirement scenario for sizing of the development options

In consultation with the Directorates of Water Resources Planning and the Eastern Cape Region it was decided that the Low Scenario would better represent the anticipated water use pattern in the study area. This scenario together with the year 2020 horizon was selected for sizing of the scheme components. The High and Medium scenarios were however used to assess the sensitivity of the various development options on variation of the projected water requirements.

The projected water requirements for the low scenario, per development phase of the scheme are illustrated in **Table E2 and Figure E2.** The development phase boundaries are illustrated in **Figure 2** (after page 3 in the main body of the report).

Table E2: Net urban and rural requirements for sizing (Low Scenario)

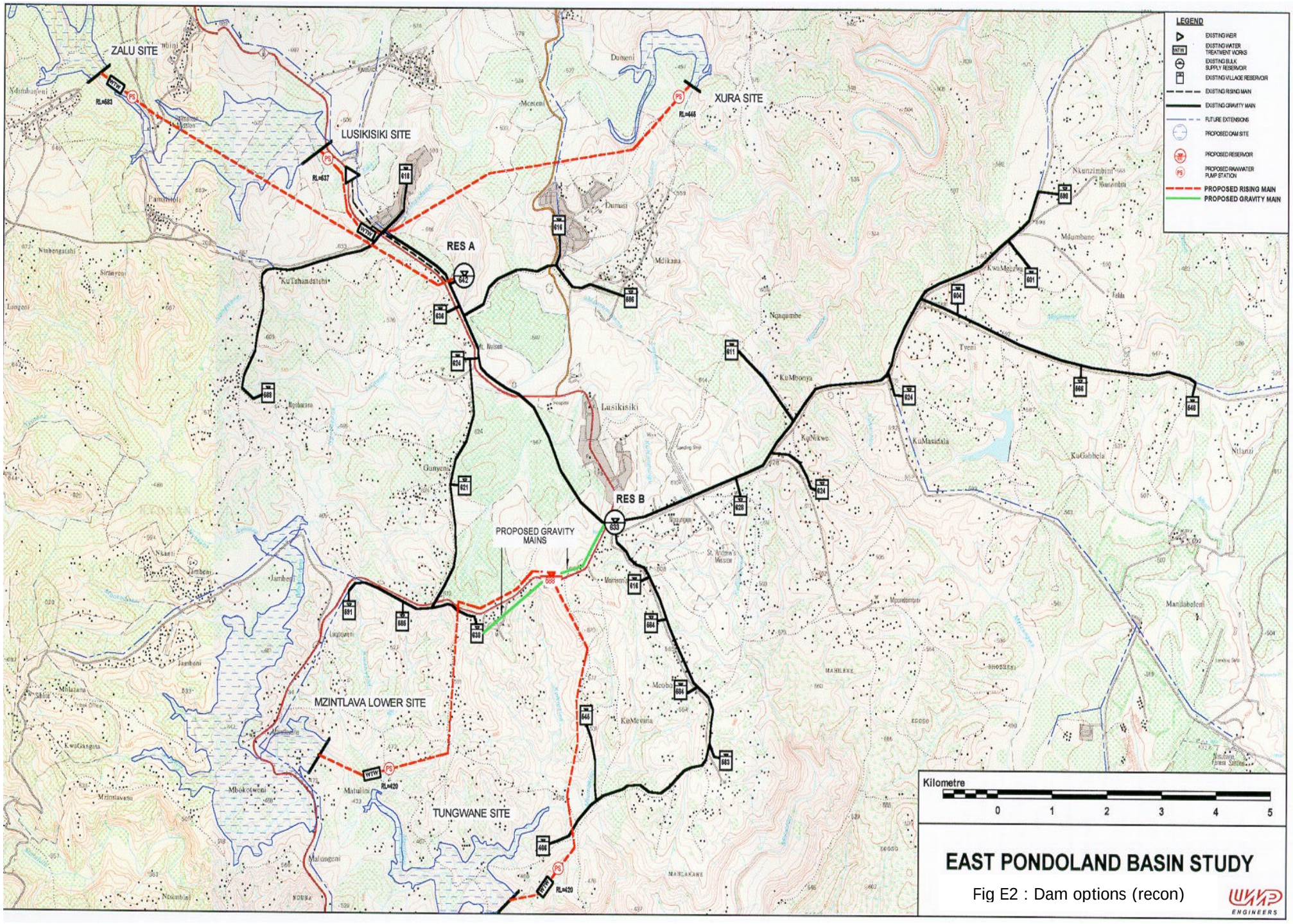
Development phase	Net water requirements x $10^6 m^3/a$		
	2000	**2010**	**2020**
Phase I (existing scheme)	1.020	1.443	1.628
Phase II (future extension)	-	0.323	0.361
Phase III (future extension)	-	-	0.296
Total	**1.020**	**1.766**	**2.285**



Other water requirements

The irrigation, stock watering and afforestation water requirements will not be supplied by the Lusikisiki Regional Scheme. These requirements were estimated for the purposes of the basin study and the results are available in the **Basin Study Main Report**.

The estuarine ecological Reserve requirements were estimated on the basis of the desktop method, as no rapid methodology was available. Owing to the extreme environmental sensitivity of the estuaries in the study area it was estimated that these requirements would be very high (80-95% of the MAR). However, the total scheme water requirements are less than 2% of the MAR of the most likely surface water source catchment (Msikaba River), and the high ecological requirements can be provided.


ZALU SITE
LUSIKISIKI SITE
XURA SITE
RES A
RES B
PROPOSED GRAVITY MAINS
MZINTLAVA LOWER SITE
TUNGWANE SITE
LEGEND
EXISTING WEIR
EXISTING WATER TREATMENT WORKS
EXISTING BULK SUPPLY RESERVOIR
EXISTING VILLAGE RESERVOIR
EXISTING RISING MAIN
EXISTING GRAVITY MAIN
FUTURE EXTENSIONS
PROPOSED DAM SITE
PROPOSED RESERVOIR
PROPOSED RAWWATER PUMP STATION
PROPOSED RISING MAIN
PROPOSED GRAVITY MAIN
Kilometre
0 1 2 3 4 5
EAST PONDOLAND BASIN STUDY
Fig E2 : Dam options (recon)
ENGINEERS

The riverine ecological Reserve for specific development sites was determined on the basis of the rapid method. The inland river stretches were found to be largely modified by the activities of man and are therefore not considered being of high ecological importance. The riverine ecological Reserve requirements would be moderate, at about 30% of MAR at the various potential development sites.

E3. EXISTING INFRASTRUCTURE OF THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME

The Lusikisiki Regional Water Supply Scheme was commissioned in July 1989 and currently supplies the town of Lusikisiki and 23 rural villages. The town is provided with full water service - house connections and water-born sanitation. The level of service for the villages is limited to bulk supply at village reservoirs. The construction of reticulation systems for all villages currently supplied by the scheme is being planned.

The existing bulk infrastructure is illustrated in **Figure E2**. The water source is a weir on the Xura River, situated about 7 km north west of Lusikisiki. The bulk supply system consists of a gravity concrete weir, row water pump station, water treatment works, clear water pump station, clear and raw water raising mains, and two main reservoirs (2 400 m^3) at a command location.

The bulk infrastructure has insufficient capacity to meet the present water requirements. All components of the bulk system have a gross capacity of 32 l/s (2 760 m^3/day), while the present water requirements are estimated at 42 l/s. The total static elevation between the weir and the command reservoirs is about 140 m.

The secondary distribution system supplying the rural villages is fed by gravity from the main reservoirs and includes 24 service reservoirs, varying in size between 20 and 90 m^3.

The scheme is being operated, maintained and managed by the DWAF: Eastern Cape Region. Due to the lack of capacity at local government levels, the DWAF currently performs the duties of a Water Service Authority and a Bulk Water Service Provider. The Lusikisiki TLC is however responsible for the water distribution within its area of jurisdiction.

E4. WATER RESOURCES

The basic information for the study area, which can affect the water resources developments (natural characteristics, demography, infrastructure, etc.) has been obtained from various sources, collated and, where possible, verified.

The information regarding the water resources in the study area (both surface and groundwater) is covered in more detail in the **Basin Study Report** and in the relevant **Supporting Reports:** Ground Water Resources, Streamflow Hydrology, Yield Analysis, and Flood Frequency Analysis. An abbreviated overview of selected information related to the assessment of the development options is provided in this chapter.

E4.1 GROUNDWATER

The groundwater investigations have been undertaken at a reconnaissance level of detail, mainly based on existing data and limited site verification. A satellite imagery interpretation has been undertaken. Firming up on the reconnaissance results will require considerable amount of exploration drilling and is expected to be costly and time consuming.

The groundwater resources of the T60 drainage region are only being utilised at a fraction of their true potential, both actively via boreholes and passively from perennial springs or ephemeral seeps. The present groundwater use in the study area is estimated to be less than 1.0 million m^3 per annum. In general, the groundwater quality is good and is suitable for domestic water supply purposes, although local variability is anticipated. Local point source pollution of the groundwater is likely in densely populated areas, due to human activities, resulting in elevated nitrate levels and faecal bacterial counts.

The groundwater resources of the Eastern Pondoland Basin as indicated by the rainwater recharge potential are high, in the order of 280 million m^3 per annum. Much of this groundwater is 'lost' as base-flow to the many perennial rivers, particularly during the dry season. The groundwater harvest potential is estimated to be about 134 million m^3/a. Practical problems with the low permeability of the shallow aquifers, the low borehole yield potential (about 1 to 1,5 l/s per borehole on average), the low success rate (about 60%), together with the inaccessibility of the terrain, limit the groundwater development potential to moderate levels of about 13 million m^3 per annum (through standard ground water schemes, with borehole depths of 60 to 100 m).

With the drilling of deeper (250 to 300 m), higher yielding production boreholes it may be possible to abstract about 70 million m^3 per year on a sustainable basis. The costs of exploring and developing such groundwater supply schemes will however be considerably (five times) higher than the standard low-yielding groundwater supply schemes. This is due to the high costs of siting, drilling, equipping and operating such schemes (total pumping heads expected to exceed 500 m).

E4.2 SURFACE WATER

The surface water resources in the study area have particularly high potential for development. The T60 drainage region is one of the few remaining areas in the country with vastly under-utilised surface water resources.

The streamflow analysis was performed per quaternary catchment using the Water Resources Simulation Model (WRSM90) based on 77 years of rainfall data records. Due to the absence of reliable secondary observed flow data, no calibration of the model could be performed. The naturalised mean annual runoff form the entire T60 drainage region is estimated to be 782 million m^3/a and the present day mean annual runoff is 764 million m^3/a. The total present consumptive surface water usage (18 million m^3/a) is 2,3% of the naturalised runoff. The potential maximum yield (hypothetical) from the surface water resources (with no allowance for the release of the ecological component of the Reserve) is about 673 million m^3/a. The surface water development potential (after allowing for the release of the ecological estuarine Reserve requirements) is estimated to be 118 million m^3/a at present and 91 million m^3/a at year 2030. Despite the high ecological Reserve the surface water resources will still have ample capacities to meat the water requirements.

The water quality of the surface water in the area is good and is suitable for human consumption after treatment. Certain negative impacts on the water quality are evident downstream of the Lusikisiki town, but these impacts are manageable. The turbidity levels are low, there is no sign of severe erosion, and the sediment yields will be relatively low.

The main rivers draining the study area (Lusikisiki Regional Scheme) are the Msikaba River (catchment area 1022 km^2, MAR 207 million m^3) with the Xura River as its main tributary, and the Mzintlava River (catchment area 270 km^2, MAR 71 million m^3). These rivers were identified as possible sources for surface water.

Low flow analyses

Three suitable weir sites were identified and investigated as possible run-of-river sources: the existing Lusikisiki weir on the Xura River (tributary to the Msikaba River), the Xura site, downstream on the same river, but after the confluence with another tributary, and the Mzintlava site on the Mzintlava River. "One-day" flow duration curves were generated using a rapid method developed by the WRC, which utilises the simulated monthly flow series to generate daily flow sequences with the associated assurance of supply. A summary of the estimated low flows at the weir sites with and without provisions for the ecological riverine Reserve (ERR) is shown in the following table.

Table E3: Summary of estimated Low Flow (Run-of-River) Yields

Weir Site	Provision for ERR	Yield (l/s) at Specific Assurance of Supply (%)						
		98%	95%	90%	80%	70%	60%	50%
Lusikisiki weir (existing source)	No	30	42	56	85	114	141	170
	Yes	0	4	12.5	29	43	57	79
Xura weir *	No	80	111	146	217	287	358	438
	Yes	0	4	13	53	84	108	163
Mzintlava weir	No	41	57	70	93	114	139	164
	Yes	0	13	24	39	51	60	74

The Xura weir site is situated downstream of the Lusikisiki weir. The yields at the Xura weir are cumulative and include these at the Lusikisiki weir.

E5. TIMING FOR AUGMENTATION

The peak water requirements for sizing of a non-regulated water source (run of river), taking into consideration the summer peak factors are as follows:

Table E4: Net urban and rural peal water requirements for sizing (Low Scenario)

Development phase	Instantaneous sizing water requirements, l/s		
	2000	2010	2020
Phase I (existing scheme)	42	59	67
Phase II (future extension)	-	13	15
Phase III (future extension)	-	-	12
Total	**42**	**73**	**94**

The following conclusions can be made on the basis of tables E3 and E4, and section E3:

- The capacity of the existing bulk supply infrastructure of 32 l/s is insufficient to meet the present water requirements of 42 l/s, and a shortage of about 30% is presently experienced. This infrastructure needs to be upgraded. However, the layout of the upgraded infrastructure would depend on the location of the future water source.

- The bulk water conveyance system should be upgraded irrespective of whether the supply area of the scheme is extended or not. The requirements of the proposed extensions are relatively low when compared with those of the existing scheme. The proposed future extensions may only influence to a limited extent the sizing parameters for upgrading of the bulk infrastructure, but not the decision to implement the upgrading.

- Despite the high MAR from the area, and due to considerable seasonal variability of runoff, the available run of river yields in and around the study area with assurance levels of 98% are low. The release of the ecological Reserve requirements further reduces the remaining low flows available for abstraction (zero at 98% assurance).

- If the ecological Reserve requirements must be released, the capacity of the existing water source (Lusikisiki weir) has to be augmented immediately. This source can supply the present and the year 2020 requirements with assurances of 70% and 50% respectively.

E6. DEVELOPMENT OPTIONS

The following categories of development options for the augmentation of the water source have been considered. A number of options for each category have been identified, sized and evaluated. All options were sized to supply the projected water requirements (low scenario) until year 2020, with an allowance for the release of the estimated ecological Reserve requirements.

- **Surface water storage schemes (Figure E2):** five dams (stand alone schemes) on the Xura and Mzintlava Rivers and a number of conveyance scheme options for each dam were considered.
- **Surface water run of river scheme (Figure E3):** a system consisting of three weirs on the Xura and Mzintlava rivers, together with the associated bulk supply infrastructure was evaluated. This scheme can only supply the design requirements with an assurance of 80% if the ecological Reserve is released.
- **Conjunctive use of surface and groundwater:** A number of options were considered to supplement the yield from the run of river scheme (described above and from the existing weir alone) by groundwater during times of low river flows.
- **Ground water stand-alone option (boreholes):** This option makes provision for the supply of the full scheme demands by groundwater only. The groundwater supply infrastructure (about 160 boreholes at year 2020) will consist of the following components at each borehole: a submersible pump driven by a diesel engine, a pump house, a rising main, a storage reservoir and an access road (track).

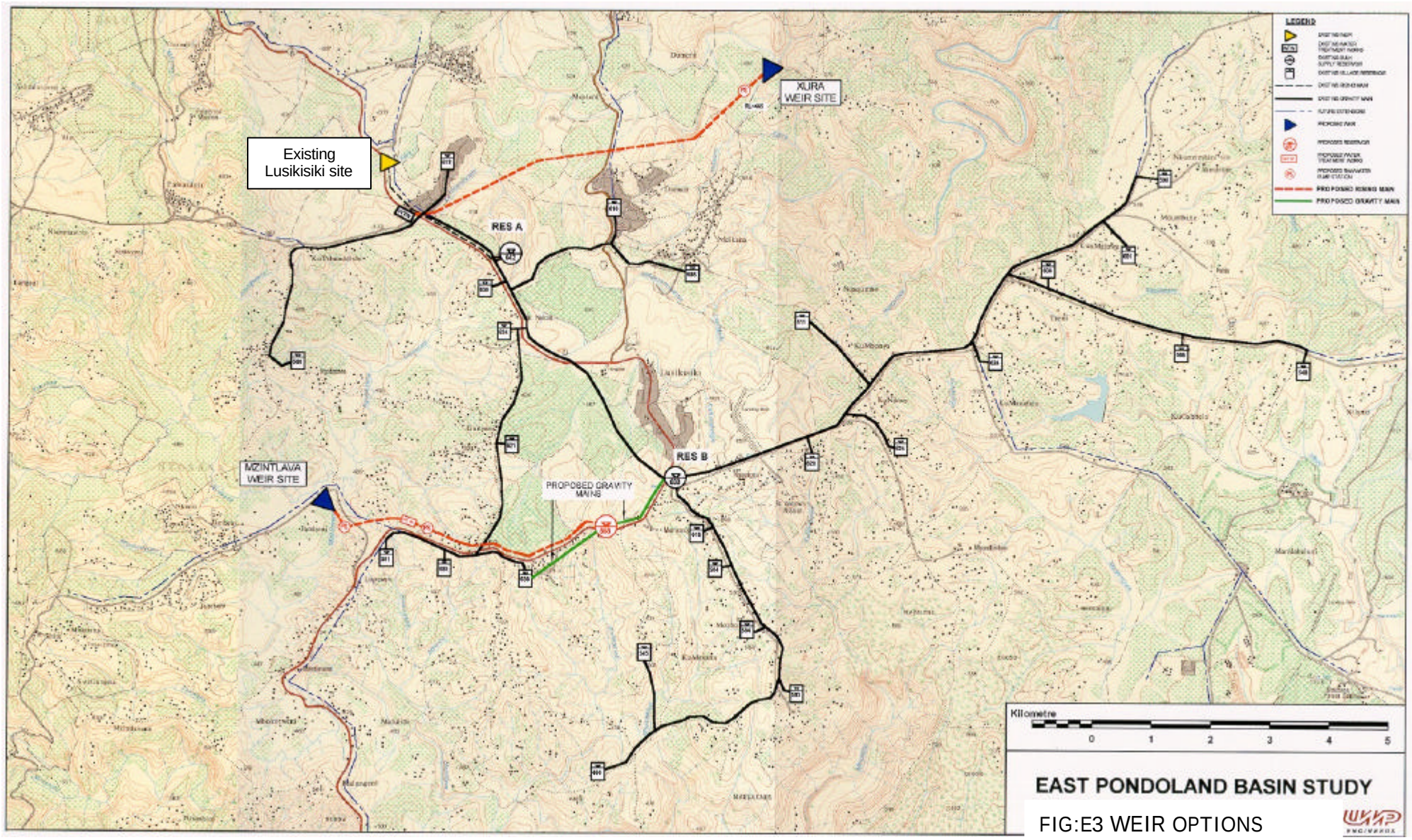
Each option includes the development of the water source and its specific bulk supply system, delivering to a common command reservoir. The bulk supply systems typically consist of pump stations, gravity and raising mains, water treatment works, and bulk storage reservoirs.

All options were sized at a reconnaissance level of detail, on the basis of available topographical and geological maps, supplemented by a multidisciplinary site inspection. The dam sizes were determined on the basis of the historical firm yield, taking into account the rapid estimates of ecological Reserve releases.

The environmental and social impact assessments were performed to a scoping level of detail. An assessment of all factors affecting the developments was undertaken: floods, sediment yields, water quality, geological conditions, materials, and institutional arrangements for operation and maintenance.

More detailed site investigations were undertaken only for two very competitive options (Zalu and Lusikisiki dams), which were difficult to isolate on the basis of the reconnaissance information. These studies included topographical surveys of the dam sites, aerial surveys of the dam basins, exploration drilling (Lusikisiki dam), stochastic yield analyses, conceptual designs and more detailed costing.

The sizing and costing for all options were done in accordance with the guidelines developed in previous DWAF studies (Vaal Augmentation Planning Study). The economic comparison was carried out on the basis of the unit reference value (URV) of water supplied by each option, taking into account the capital costs, the operation and maintenance costs, the residual values and the phasing of implementation.


Existing
Lusikisiki site
XURA
WEIR SITE
RES A
RES B
MZINTLAVA
WEIR SITE
PROPOSED GRAVITY
MAINS
LEGEND
Kilometre
0
1
2
3
4
5
EAST PONDOLAND BASIN STUDY
FIG:E3 WEIR OPTIONS

E.6.1 Evaluation of Development Options

The overall evaluation of the development options was undertaken on the basis of technical viability, economic feasibility, and ecological and social acceptability, taking into account other influencing factors such as geological uncertainties, operation and maintenance implications, institutional arrangement, employment opportunities, etc. A total number of thirteen options were investigated, and the best development option for each water source category was selected. Based on the findings of this study it can be concluded that the water source of the scheme can feasibly be augmented by one of the following development options:

Table E2: Summary of recommended schemes per source category

Water Source	Opt No.	Development Option	Assu-rance	Capital costs (10^6)			URV (R/m^3)
				Water Source	Conve - yance	Total	
Dam	D1B	**Zalu dam** (Conveyance from weir)	98%+	R38.14	R11.80	R49.94	3.21
RoR	W1	**Weir scheme** (Lusikisiki, Xura, Mzintl.)	80%	R4.68	R24.89	R29.57	1.78
Conjunctive	W2/G	**Conjunctive scheme** (Lusikisiki weir plus 160 boreholes supplying during low flows)	98%	R19.01	R43.07	R62.08	3.86
Groundwater	G1	**Groundwater** stand-alone scheme	98%	19.01	28.51	47.52	4.20

Surface water storage scheme (capital cost R49.94 million, URV R3.21)

This scheme would comprise the Zalu dam (option D1B), with water released down the river and abstracted again at the existing weir site on the Xura River. The option includes the upgrading of the existing bulk water conveyance infrastructure from the Lusikisiki weir to the command reservoirs. This option provides water at the highest assurance of supply (exceeding 98%) and the lowest cost (lowest URV of water). It provides reasonable and needed flexibility of supply - if the actual future water requirements are higher than previously projected the dam wall can be raised, which will result in increased yield. If no time for further studies is available this option can be recommended.

Surface water run of river scheme (capital cost R29.57 million, URV R1.78)

Option W1 includes the upgrading of the existing run of river scheme from the Lusikisiki weir, as well as the development of two additional weirs on the Xura and Mzintlava Rivers, together with the associated conveyance systems. Due to lower pumping costs, it was found that the optimal operation of this scheme can be achieved if the full water requirements are supplied from the Lusikisiki weir at times of high flows, and the other two wears are used for augmentation at times of low flows. In this case the capacity of the existing bulk supply infrastructure would need to be upgraded to convey the future water requirements. This is the most economical option, but supplies water at a lower assurance of supply. The maximum yield that can be abstracted, after the release of the ecological Reserve requirements, can meet the future water requirements with an assurance of 80%.

The abstracted yield can be increased to meet the projected water requirements at 98% assurance of supply only if the ecological Reserve requirements downstream of all three sites are relaxed. The relaxation of the ecological Reserve downstream of the Lusikisiki site will result in the environmental degradation of only about 3 km of river stretch (up to the next tributary) and can be justified. But, in the case of the other two weirs the impacts will be more severe, involving significantly longer river stretches, and are unlikely to be acceptable. Further studies will be required to confirm this statement.

The present water requirements can however be met with an assurance of about 95% from the existing weir alone if the ecological Reserve requirements are temporarily relaxed until further studies and final decisions are taken. In this case the existing balk water conveyance system needs to be upgraded.

Ground water stand-alone scheme (capital cost R47,62 million, URV R4.20)

This option involves the development of about 160 boreholes needed to meet the total projected water requirements of the system. This option is based on the development of a standard, shallow, low yielding groundwater scheme. The development of a deep, high yielding scheme is expected to be considerably more expensive due to the excessive costs for drilling, equipping and power supply. The URV of water supplied by this option is higher than for the other options due to the following reasons:

- High cost for developing and equipping of the boreholes: a large number of boreholes required due to low expected average yield (about 1,5 l/s) and low success rate (about 60%).
- High cost of power supply to boreholes: pumps to be driven by diesel engines due to unavailability of electrical supply. Even if reasonable electrical network to supply the villages is developed in future, it is estimated that due to the high costs for the required electrical extensions, the costs of electrically operated boreholes would be similar or higher when compared to these powered by diesel.
- Inaccessibility of sites: The road network in the region is underdeveloped and many areas are presently inaccessible, especially during poor weather conditions. The costs to provide reliable access roads to each borehole are expected to be high, especially when considering the rough topography of the study area.
- High operation and maintenance costs, and complicated institutional arrangements associated with multiple sources.

The assurance of supply from groundwater can only be ascertained on completion of extensive exploration drilling and long term monitoring studies.

In general, previous experience indicates that in cases of abundance of available surface water resources (as is the case in the study area), the surface water development options are more cost efficient than the stand-alone groundwater options. In many cases however, groundwater can be efficiently used in conjunction with surface water.

Conjunctive use of surface and groundwater (capital cost R62,08 mil., URV R3.86)

This option involves increased abstractions from the existing weir at times of high river flows, supplemented by groundwater supply from about 160 boreholes operating only at times of low surface flows. It includes the upgrading of the bulk supply system from the existing weir to the command reservoirs to convey the full year 2020 water requirements. Due to lower pumping heads and lower operation costs it would be more feasible to supply the system requirements from surface water at times of high run of river flows.

Due to the lower operation costs associated with the surface water abstractions, the overall URV of the water supplied by this option is lower than this for the stand-alone groundwater scheme option.

The provision for the ecological Reserve leaves no flows available for abstraction during droughts. The groundwater infrastructure had to be sized to supply the full projected water requirements in order to achieve the required assurance of supply of 98%.

The cost of this option can be reduced if the ecological Reserve is relaxed. The number of required boreholes will be reduced to from 160 to 95. This however needs to be confirmed by further environmental and groundwater studies.

E7. CONCLUSIONS

The findings of the reconnaissance investigations undertaken during the course of the Eastern Pondoland Basin Study indicate that the water shortages experienced at the LRWSS are due to the inadequate capacities of the two main components of the system – the water source, and the bulk supply infrastructure.

E7.1 Water source

- Without provision for the release of the ecological Reserve, the existing water source (a weir on the Xura River) can supply the present and future (2020) water requirements with assurances of 95% and 75% respectively.

- If provisions for the release of the ecological Reserve are made, the assurance of supply from the existing water source will be reduced to 70% and 50% for the present and future water requirements respectively.

- The above indicates that irrespective of the ecological Reserve requirements, the capacity of the existing water source is insufficient to meet the water requirements at the guideline limit of 98% assurance of supply, and the water source should be augmented.

- If the ecological Reserve must be released, the water source should be augmented immediately, there would be no time for further studies, and a decision should be taken on the basis of the reconnaissance study results. If the ecological Reserve can be relaxed, there would be more time for further studies to confirm the conclusions of the EPBS.

- The surface and the groundwater resources in the area have high potential for development and can be used for augmentation of the existing water source.

- Based on the results of the reconnaissance study, the following options for augmentation of the water source, capable of meeting the system's requirements at 98% assurance of supply, can be considered for implementation:

    - The most feasible storage scheme option is Zalu dam (URV R3,21). This option was found to be the most favourable amongst all options investigated during the course of the study. If there is no time for further studies, this option should be implemented.

- The conjunctive surface and groundwater use option (URV R3,86) includes abstractions from the existing weir, supplemented by the development of boreholes to be operated during times of low river flows. This option is feasible, but more detailed groundwater studies would be required before a consideration for implementation can be given.

- Despite the high MAR from the area, and due to the considerable seasonal variability of runoff, the run of river yields, available for abstraction in and around the study area with assurance levels of 98%, are low. The release of the ecological Reserve requirements reduces significantly the remaining low flows available for abstraction (zero at 98% assurance). Non-regulated, stand-alone run of river schemes (option W1) will not be capable of meeting the requirements as stand-alone augmentation options and can only be considered if a lower assurance of supply (80%) is acceptable. In order to meet the water requirements at 98% assurance of supply, a storage scheme would be required.

- The groundwater stand alone option (URV R4,20) considered during the course of the study was found to be less favourable than all other options investigated. This is due to the large number of boreholes (160) required to operate at all times, and the associated high costs for development, operation and maintenance of this source. It was proven that it would be more feasible to supply the system requirements form surface water at times of high flows, supplemented by groundwater (as per option W2/G), than to use groundwater alone. This option is therefore not recommended for further investigations.

E7.2 Bulk supply system

- The capacity of the existing bulk water conveyance infrastructure is insufficient to supply the present water requirements and a shortage of about 30% is presently experienced. This infrastructure needs to be upgraded urgently.

- The bulk water conveyance system should be upgraded irrespective of whether the supply area of the scheme is extended or not. The requirements for the areas covered by the proposed extensions are relatively low (28%) when compared with those for the full supply area. The proposed future extensions may only influence to a limited extent the sizing parameters for upgrading of the bulk infrastructure, but not the decision to implement the upgrading.

E7.3 Uncertainties and further studies

It should be noted that the EPBS study has been undertaken at a reconnaissance (desktop) level of detail and the above conclusions were made in the presence of a number of uncertainties. If time and resources could be made available, further studies should be undertaken to confirm the conclusions and refine the results of the reconnaissance study:

- Actual position and yield of the boreholes: certain assumptions based on the best available information have been made with regards to the average characteristics of the source and the conveyance infrastructure (yield, pumping head, access, conveyance length, storage). These assumptions can only be confirmed through

more detailed groundwater studies, including field investigations, exploration drilling and testing.

- Ecological Reserve requirements: these requirements were determined on the basis of the rapid methodology. The costs for the development of the surface water augmentation options are very sensitive to variations of the ecological Reserve estimates. Significant savings can be achieved if the ecological Reserve requirements are relaxed. More detailed environmental studies will be required.

- Reliable hydrological data (flow records) for the Xura River are available only from 1996. No proper calibration of the WRSM90 model could be done, as at least ten years of records would be required. The collection of observed flow data at the Lusikisiki weir site should continue. If the development of a surface water source (dam or weirs) is deferred for more than five years, the flow records should be used to update the catchment hydrology and to refine the design parameters of the proposed infrastructure.

- Water requirements: The population numbers were estimated on the basis of the 1996 Census results. The updated information from the 2001 Census will become available in 2003, and can be used to revisit the estimated water requirements.

The temporary relaxation of the ecological Reserve releases for the river stretch between the existing Lusikisiki weir and the confluence with the next major tributary (about 3 km) can make time available for firming up on the results of this study. At the same time the water supply situation can be significantly improved. This can be achieved by upgrading of the capacity of the existing bulk water conveyance infrastructure and by increasing the abstractions from the existing weir. The present water requirements can then be supplied with an assurance of 95% reducing to 93% by year 2005 and to 85% by year 2010.

E8. RECOMMENDATIONS

- Upgrade the existing bulk supply system from the Lusikisiki weir to the command reservoir to meet the projected water requirements up to the year 2020. This is a common component for all three favourable augmentation options considered and can be regarded as the first phase of the augmentation of the water source. The upgrading will allow increased abstractions from the existing weir at least at times of high river flow. This action, combined with the proposed relaxation of the ecological releases (see bullet below) will result in an immediate improvement of the water supply situation of the existing scheme and will increase the assurance of supply from 70% to 95%.

- Relax temporary the ecological Reserve releases into the Xura River, downstream of the existing weir. This may result in a temporary environmental impact on a river reach of approximately 3 km, which is presently largely modified. The ecological Reserve releases will be compromised only during low flow periods. During normal flow conditions, sufficient riverine flows will be available. After the augmentation of the water source is completed, the low flow ecological Reserve releases will be made and it is anticipated that the ecosystem in the affected river reach will recover.

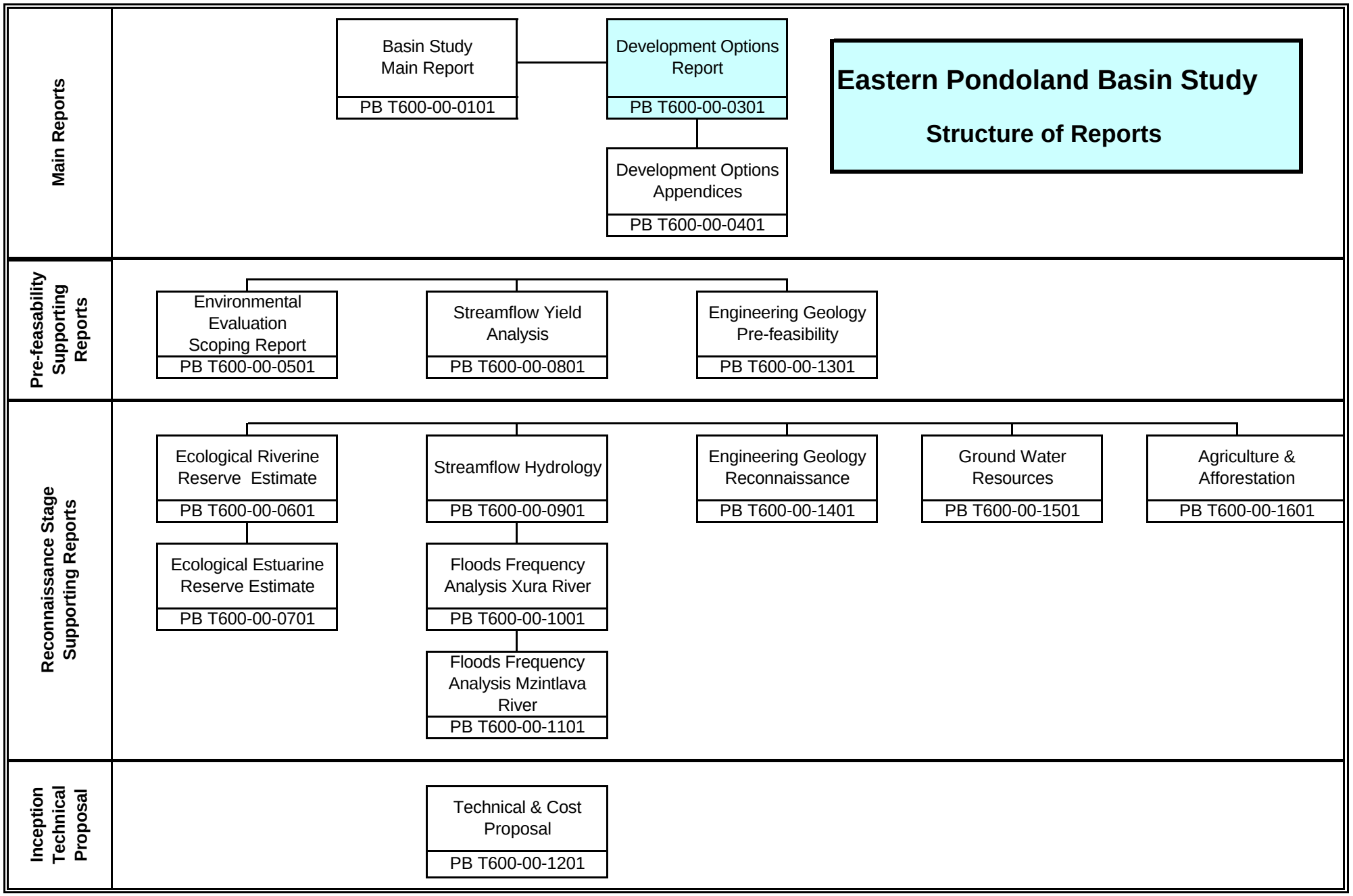
This will provide additional and needed time for further studies to confirm and finalise the results of the reconnaissance investigations undertaken during the course of the EPBS, and for implementing the selected option for augmentation of the water source. This action combined with the increase of the capacity of the bulk supply system will contribute for a speedy and notable improvement of the water supply situation within the existing scheme supply area.

- It is recommended that a more detailed feasibility study be commissioned in order to obtain more accurate information and to refine the results of the reconnaissance study. This study will allow the selection of the best development option with regards to the water source on the basis of updated information. The proposed feasibility study should include the following main components, and should address the uncertainties identified during the course of the reconnaissance study:
    - Groundwater resources aspects (hydro-census, follow up on remote sensing interpretations, exploration drilling and testing, report).
    - Ecological aspects (preliminary reserve determination, EIA associated with the proposed relaxation of the Reserve, detailed EIA report for approval of the proposed developments).
    - Engineering aspects and study co-ordination (guidance to specialist consultants, review hydrology and water requirements, review and reassess augmentation options, based on the updated information from the above studies, issue an overall study report).
- A drilling contractor may be required for the exploration drilling covered in the above section. The contractor will be supervised and managed by the groundwater consultant appointed for the aforementioned study. If successful boreholes are drilled at suitable positions they could be equipped and connected to the existing bulk supply system. This can be regarded as a bridging scheme, and could be used until the final augmentation option is selected and developed.

More information regarding the implementation strategy to augment the water source of the Lusikisiki Regional Water Supply Scheme is available form the report "Proposed Guidelines for Implementation (DWAF, March 2002, Report No. PB T600 – 00 – 1702).

Eastern Pondoland Basin Study

Structure of Reports



DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE: WATER RESOURCES PLANNING

EASTERN PONDOLAND BASIN STUDY

DEVELOPMENT OPTIONS

Volume 1 : Main Report

TABLE OF CONTENTS

Acknowledgements i

Executive Summary iii

Structure of report for the EPBS (diagram) ix

1. INTRODUCTION 1

SECTION A: BASE INFORMATION 3

2. BASE INFORMATION

2.1 Overview of Study Area 3
2.2 Physical Characteristics 4
2.3 Demography and Socio-Economics 6

3. INFRASTRUCTURE 7

3.1 General Infrastructure 7
3.2 Water Supply and Sanitation Infrastructure 7
3.3 The Lusikisiki Regional Water Supply Scheme (LRWS) 8

4. WATER REQUIREMENTS 11

4.1 Domestic and Industrial Water Requirements 11
4.2 Agricultural and Afforestation Requirements 18
4.3 Ecological Reserve Requirements 19
4.4 Summary of Water Requirements 20

5. WATER RESOURCES 21

5.1 Ground Water 21
5.2 Surface Water Hydrology 22

SECTION B: RECONNAISSANCE PHASE 25

6. IDENTIFICATION AND DEVELOPMENT OPTIONS 25

6.1 Outline of Planning Considerations 25
6.2 Water Source 26
6.3 Conveyance System 26
6.4 Identification of Dam and Weir Sites 28

7. YIELDS, FLOODS AND SEDIMENTATION 30

7.1 Yield Analysis For Proposed Dam Sites (RECON) 30
7.2 Low Flow Yield Analysis for Proposed Weir Sites 32
7.3 Flood Frequency Analysis 34
7.4 Sediment Yields 35

8. DESCRIPTION OF THE DEVELOPMENT OPTIONS 36

8.1 Surface Water Storage Schemes 36
8.2 Surface Water Run of River Schemes 38
8.3 Conjunctive Use of Surface and Ground Water Resources 40
8.4 Ground Water Stand Alone Option 40

9. FACTORS AFFECTING DEVELOPMENT 42

9.1 Geology and Materials 42
9.2 Environmental Impact Assessment of Development Sites 46
9.3 Social Impact Assessment 48
9.4 Water Quality Issues 50
9.5 Institutional Arrangements for O&M 52
9.6 Public Involvement Programme 52

10. RECONNAISSANCE SIZING AND COSTING 53

10.1 General Sizing Criteria: Design Capacities and Flows 53
10.2 Dams and Weirs 54
10.3 Ground Water Development 56
10.4 Primary Distribution System 58
10.5 Summary of Capital Costs 58

SECTION C: PRE-FEASIBILITY PHASE 59

11. PRE-FEASIBILITY INVESTIGATIONS FOR ZALU AND LUSIKISIKI DAMS 59

11.1 Topographical Surveys 59
11.2 Geological and Materials Investigations 59
11.3 Stochastic Yield Analysis 60

12. PRE-FEASIBILITY, CONCEPTUAL DESIGN AND COSTING 61

12.1 Dams 61
12.2 Primary Distribution System 63
12.3 Summary of Capital Costs 63

13. EVALUATION OF DEVELOPMENT OPTIONS 64

13.1 Economic Analysis Model 64
13.2 Evaluation of Development Options 67
13.3 Summary of Preferred Options 70

14. CONCLUSIONS 71

14.1 Development Options / Schemes 71
14.2 Water Source 72
14.3 Bulk Supply System 74
14.4 Uncertainties and Further Studies 74

15. RECOMMENDATIONS 75

16. REFERENCE LIST 77

LIST OF FIGURES

Figure 1 : Locality and overview
Figure 2 : Proposed Lusikisiki RWSS
Figure 3 : Topography
Figure 4 : Mean annual precipitation
Figure 5 : Rivers
Figure 6 : Land use
Figure 7 : Demography
Figure 8 : Existing infrastructure
Figure 9 : Proposed water supply projects
Figure 10 : LRWSS: Existing infrastructure
Figure 11 : Population No.: UWP and Mega sub
Figure 12 : Ground water development potential
Figure 13 : Exploration drilling targets in LRWSS
Figure 14 : Virgin mean annual run off
Figure 15 : Area planning
Figure 16 : Proposed dam and weir sites
Figure 17.1 : Dam option layouts
Figure 17.2 : Zalu dam site (D1)
Figure 17.3 : Lusikisiki dam site (D2)
Figure 17.4 : Xura dam site (D3)
Figure 17.5 : Lower Mzintlava dam site (D4)
Figure 17.6 : Tuugwane dam site (D5)
Figure 17.7 : Magwa dam (D6)
Figure 18 : Weir options
Figure 19 : Ground water options
Figure 20.1 : Zalu dam feasibility phase
Figure 20.2 : Zalu dam feasibility phase
Figure 20.3 : Lusikisiki dam feasibility phase
Figure 20.4 : Existing weir feasibility

APPENDICES INCLUDED IN THIS VOLUME (VOL 1)

Appendix A1 : Photographs and plates
Appendix A2 : Terms of reference
Appendix B : Population numbers and water requirements
Appendix C : Low flow analysis
Appendix D : Area – capacity relationships (reconnaissance phase)
Appendix E : Yield – capacity relationships (reconnaissance phase)
Appendix F : Social impact assessment (reconnaissance and pre-feasibility)
Appendix G : Water quality test results

APPENDICES INCLUDED IN VOLUME 2

Appendix H : Public participation programme
Appendix I : Sizing flow criteria
Appendix J : Costing and economic models reconnaissance phase
Appendix J1 : Summary capital costs
Appendix J2 : Cost models dams and weirs
Appendix J3 : Cost estimates: groundwater
Appendix J4 : Cost models: conveyance system
Appendix J5 : Economic models
Appendix K : Area – capacity relationships (pre-feasibility phase)
Appendix L1 : Sizing criteria dams (pre-feasibility phase)
Appendix L2 : Sizing criteria conveyance system (pre-feasibility phase)
Appendix M : Costing and economic models (pre-feasibility phase)
Appendix M1 : Summary capital costs
Appendix M2 : Cost models: dams
Appendix M3 : Cost models: conveyance system
Appendix M4 : Economic models
Appendix 2 : Dam layouts and typical details (Reconnaissance phase)
Appendix 3 : Conveyance systems sections (Reconnaissance phase)
Appendix 4 : Conceptual design: Zalu dam (pre-feasibility phase)
Appendix 5 : Conceptual design: Lusikisiki dam (pre-feasibility phase)
Appendix 6 : Conceptual design pump stations and pipelines (pre-feasibility phase)
Appendix 7 : Dam site cross sections (pre-feasibility phase)
Appendix 8 : Dam basin surveys (pre-feasibility phase)

1. INTRODUCTION

At the request of the Eastern Cape Regional Office, the Directorate: Water Resources Planning of the Department of Water Affairs and Forestry commissioned the Eastern Pondoland Basin Study. The aim of the study was to investigate the water resources situation in the Eastern Pondoland region and in particular the Lusikisiki area, and to recommend solutions to the water supply problems, which were evident in that area at that time. The study therefore consisted of two main components – a basin study and a development options study. The structure of the study reports, including the Basin Study Reports is shown at the end of this chapter.

This report covers the investigations into possible development options for the augmentation of the bulk water source of the Lusikisiki Regional Water Supply Scheme (LRWSS). In accordance with the terms of reference, the scope of this study is limited to a reconnaissance level of detail. The study was therefore undertaken predominantly as a desktop study, with limited site investigation and verification.

The LRWSS currently supplies the town of Lusikisiki and 23 rural villages with a total population of approximately 52 000 people. Severe water shortages are currently experienced. A number of projects related to the upgrading of the standards of services (to RDP standards) as well as the extension of the supply area to include a total of 56 additional villages (68 000 people) are being considered. Due to the inadequate capacity of the existing water source (a weir on the Xura River) the implementation of these projects has been postponed until after the identification of a supplementary source, capable of meeting the increased water requirements. Other studies related to water demand management, leak detection and repair, and improvement of the operation procedures are currently being undertaken under separate assignments. The scheme is presently owned and operated by the DWAF Eastern Cape Office. In accordance with the Water Services Act it is envisaged that, after the upgrading, the scheme will be transferred to a Water Service Authority, i.e. the appropriate local authority (Oliver Tambo District Municipality).

Certain guidelines, listed below, for the development options investigated during this study were defined in consultation with the Eastern Cape Region (EC:R) early during the course of the study.

- Sizing to be done for a regional scheme, to supply the area covered by the existing scheme, and the proposed extensions, which are included in the RDP water supply programme.
- Sizing of the water source to be done for 98% assurance of supply.
- The levels of services to be provided by the scheme should be in accordance with the White Paper for water supply. The sizing criteria should be according to the latest Departmental guidelines for community water supply.
- Allowance for the release of the ecological Reserve should be made.
- If the technical and economical parameters for single and multiple water source options are equal, preference should be given to single source options, due to

significant operation, maintenance and management advantages associated with such options.

This report describes the findings of the evaluation of various development options and the recommendations for the selection of the best option for the augmentation of the LRWS and its proposed extensions. The Terms of Reference for this project are attached in **Appendix A2**. In order to provide for a gradual increase in the level of detail of the investigations, and thus to achieve cost efficiency, the development options study was undertaken in two stages – reconnaissance and pre-feasibility. The report is structured in three main Sections, each comprising a number of sub-sections:

Section A provides a description of the base information used at both the reconnaissance and the pre-feasibility stages. It includes an overview of the study area, a description of the physical and geographic characteristics, the infrastructure, the estimates of the water requirements, and a general overview of the water resources.

Section B describes the investigations undertaken during the reconnaissance stage. This stage includes the identification of development options and the first order investigations undertaken on the basis of available topographical and geological maps, supplemented by a single multidisciplinary site inspection. The dam sizes were determined on the basis of the historical firm yield, taking into account the rapid estimates for ecological reserve releases. The yields for the proposed weir sites were determined on the basis of a rapid methodology. The environmental and social impact assessments were performed to a scoping level of detail. A first order sizing and costing was undertaken. Certain options requiring additional studies were carried forward to more detailed investigations in consultation with the client on presentation of the interim results.

Section C describes the more detailed pre-feasibility investigations undertaken for two dam development options (Zalu and Lusikisiki dams). The findings of the reconnaissance level studies were refined and upgraded on the basis of more accurate geological and topographical information. Exploration geological drilling was undertaken to refine the information regarding the foundation conditions at the proposed Lusikisiki dam site. Aerial surveys were performed for both Lusikisiki and Zalu dam basins and tachometric surveys were done at the dam sites. A stochastic yield analysis was undertaken for both options. The final evaluation was based on more detailed conceptual designs for each component of the scheme. This section also includes the overall study conclusions and recommendations.

The appendices referred to in this report are bound in two volumes:

- Appendices A to G are included in Volume 1 (this volume)
- Appendices H to M and 1 to 8 are included in Volume 2 (Appendices)

SECTION A: BASE INFORMATION

2. BASE INFORMATION

2.1 OVERVIEW OF STUDY AREA

The study area for the feasibility component of the project includes the area presently supplied by the Lusikisiki Regional Water Scheme (LRWS) as well as its proposed extensions. The area is located in the Eastern Pondoland Coastal region of the Eastern Cape, between Port St Johns and the Msikaba River estuary, and extends approximately 30 km inland (**Figure 1**). The study area of approximately 960 km^2 falls entirely within the Lusikisiki Magisterial District of the Wild Coast District Council (year 1999 demarcation). It includes the town of Lusikisiki and 79 rural settlements with a total estimated population of approximately 120 000 people, within 17 administrative areas **(Figure 2)**. The quaternary catchments included in the study area are shown in **Figure 4**.

The LRWS is the largest scheme in the Eastern Pondoland Coast. The system was originally planned in 1986 as a regional scheme to be supplied from a single node (a dam). Only a portion (phase 1) of the originally planned larger scheme has been built to date. A weir on the Xura River, located some 7 km northwest of Lusikisiki, currently supplies this scheme, but the original intention was to upgrade the water source (construct a dam) as soon as funds for extending the supply area were made available. The system presently experiences severe water shortages due to the inadequate capacity of the existing water source. For this reason the DWAF has decided to undertake a feasibility investigation into possible options for augmentation of the water source, which is described in this report.

The existing scheme (phase 1) supplies the town of Lusikisiki (11 000 people) and 23 villages (41 000 people). The town is currently provided with a full water service - house connections and water born sanitation. The level of service for the villages is limited to bulk supply to village reservoirs. The upgrading of this scheme to full standpipe level of service, including the installation of reticulation systems to all villages has been included in the RDP 2 programme and will be implemented as soon as the water source is augmented to provide for the increased requirements.

An extension of the existing scheme (Phase 2) to supply 34 additional villages (37 000 people) has been included in the RDP 4 programme and is planned for implementation soon.

A further extension (Phase 3) to supply 22 additional villages (31 000 people) is also planned for implementation, subject to the identification of a suitable water source.

The entire Eastern Pondoland region is greatly underdeveloped and its infrastructure is generally in a poor state. The town of Lusikisiki can be accessed by a tar road from either Port St Johns or Flagstaff, or by gravel road from Holy Cross. The secondary roads system, providing access to the villages within the area is in a poor state of repair. Many villages are inaccessible during wet conditions.

Eastern Pondoland Basin Study

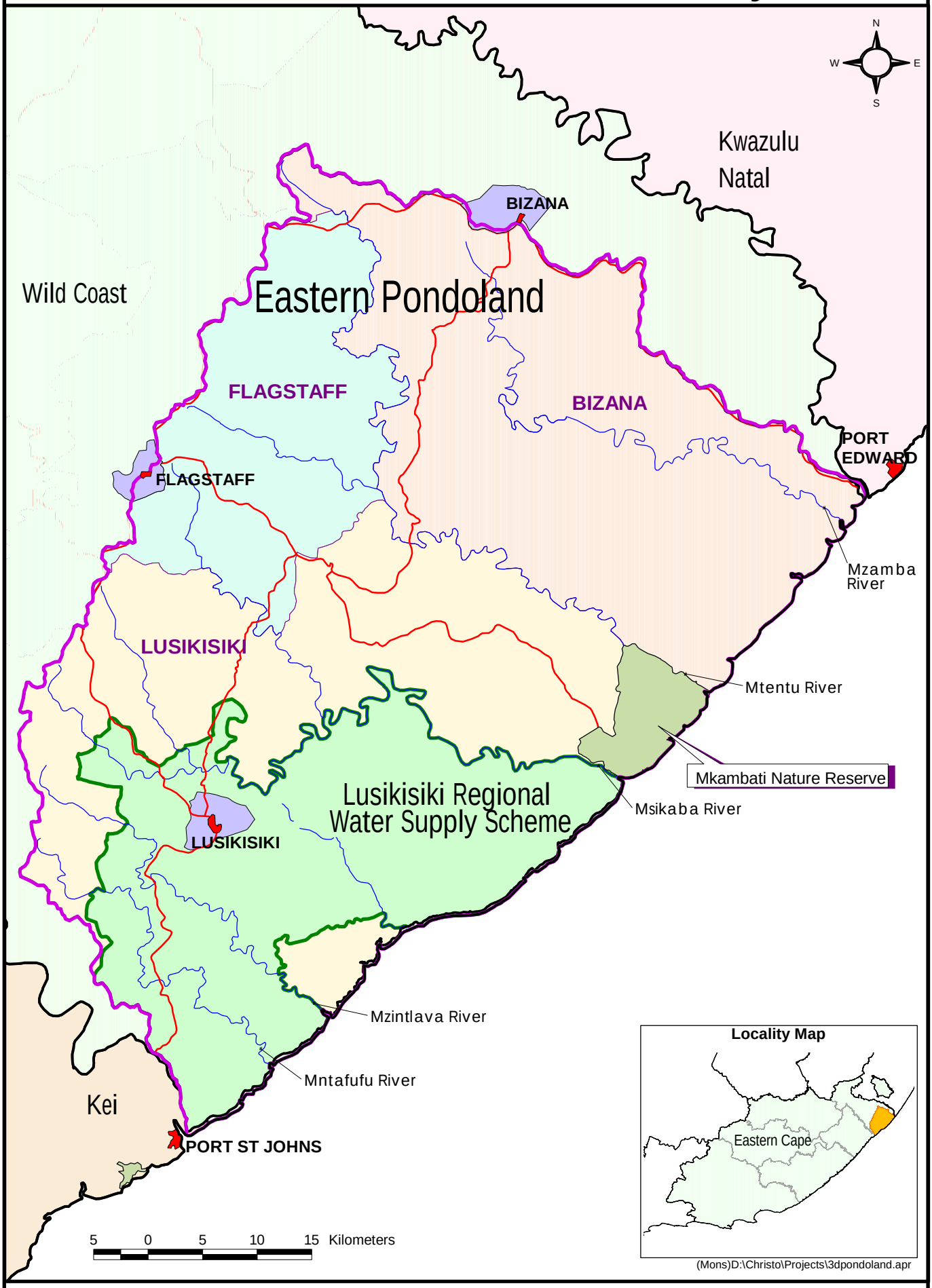


Fig 1 : Locality and Overview

UWP Engineers

Eastern Pondoland Basin Study

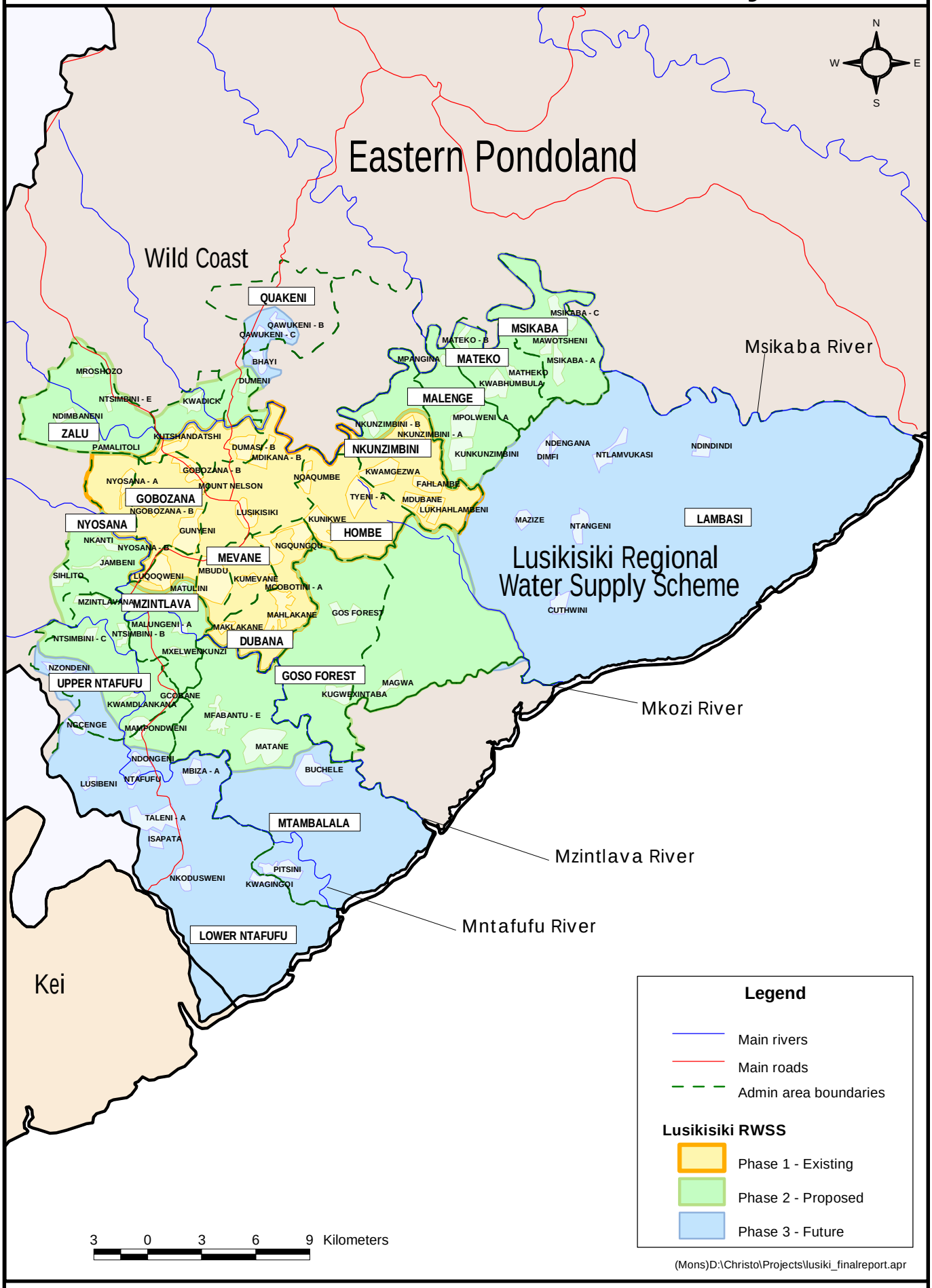


Fig 2 : Proposed Lusikisiki RWSS

UWP Engineers

Eastern Pondoland Basin Study

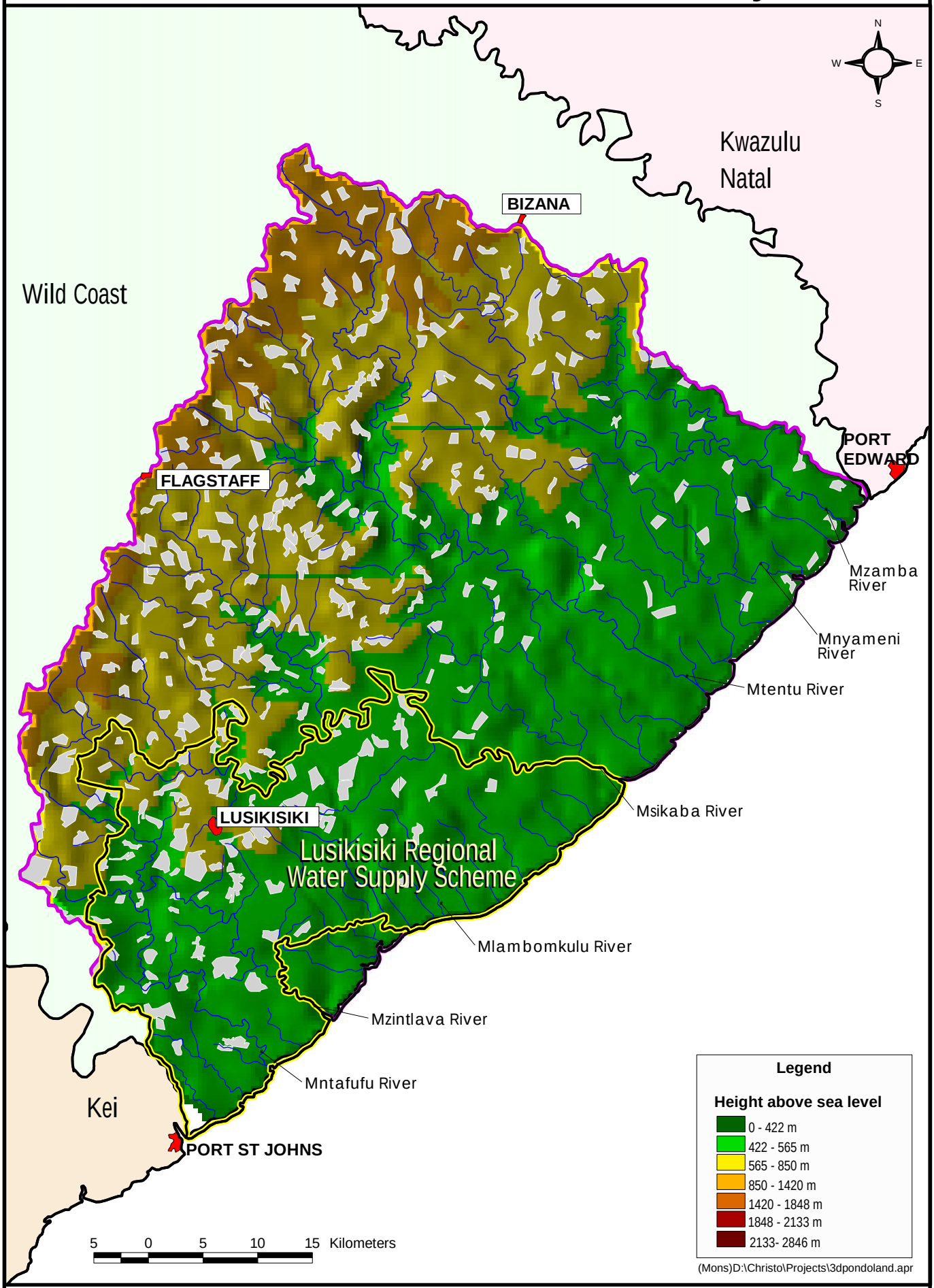


Fig 3 : Topography

UWP Engineers

Eastern Pondoland Basin Study

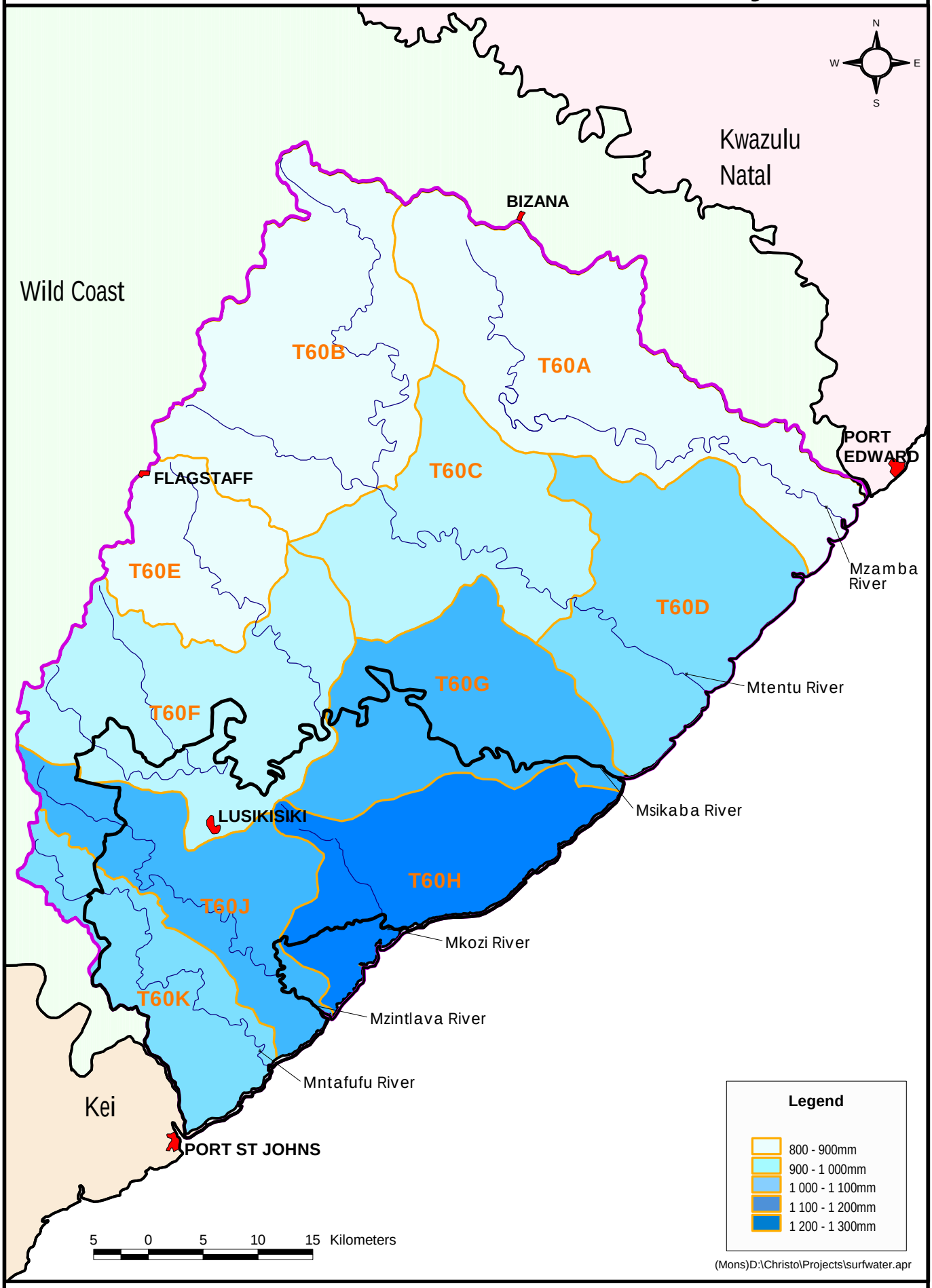


Fig 4 : Mean Annual Precipitation

UWP Engineers

The study area falls within T60 tertiary drainage region. The water resources of this region are largely under-utilised, having a high potential for development. This is somewhat limited by the exceptionally high ecological estuarine reserve flow requirements for the coastal rivers.

2.2 PHYSICAL CHARACTERISTICS

2.2.1 Topography

There are two main physiographic regions within the Eastern Pondoland region, namely the coastal belt and the interior plateau, as shown in **Figure 3**. The inland plateau is characterised by an uneven, seaward-sloping surface, lying between 400 m and 1100 m above mean sea level (msl). The coastal belt, within which most of the study area lies, is generally between 20 and 30 km wide, varying in altitude between 0 and 650 m msl.

The topography within the study area is incised by the main drainage systems of the Msikaba, Mzintlava, and Mtafufu Rivers. The drainage channels are often linear and tend to follow the dominant fracture systems (see **Figure 5**). The region is underlain by sandstone of the Msikaba Formation and major steep sided gorges have been formed, often falling 100 to 200 m below the surrounding plateau.

2.2.2 Climate and Rainfall

The climate along the coast is warm to hot throughout the year, with humidity levels rising from December to March. Thunderstorms are frequent in summer. The inland climate is temperate, with warm summers and cool winters, although occasional colder spells may occur. Sea temperatures are moderate.

The region is characterised by a high annual precipitation. Higher annual rainfall values are associated with the coastline, with the values decreasing gradually toward the interior. Most of the rain falls in summer (October to March) and severe droughts have been observed during winter months. The study area falls within T6B rainfall zone as defined by the WR90 report. The mean annual precipitation for quaternary catchments within the Eastern Pondoland Basin varies between 885 mm and 1 277 mm as illustrated in **Figure 4** and **Table 2.2.2**. Most of the LRWS study area however receives over 1 100 mm per annum.

The mean potential evaporation (A-pan equivalent) varies between 1400 and 1800 mm.

Table 2.2.2: Mean Annual Precipitation for the study area

Rainfall Zone	Quaternary catchment	Area (km^2)	MAP (mm)
T6B	**T60E**	198	885
	T60F	464	940
	T60G	360	1116
	T60H	322	1277
	T60J	294	1101
	T60K	242	1075

Eastern Pondoland Basin Study

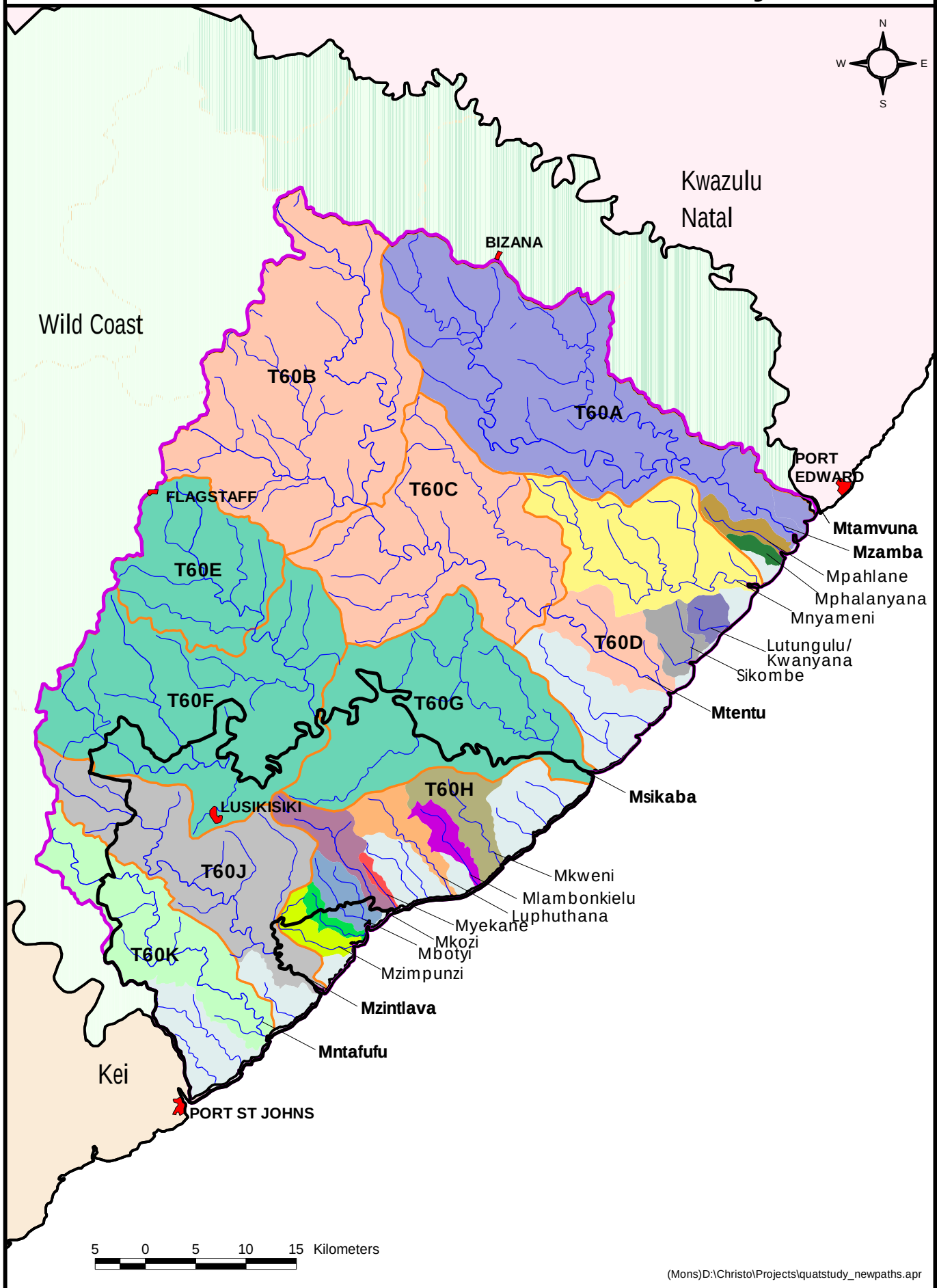


Fig 5 : River Catchments

UWP Engineers

The coefficient of variation (CV) of annual precipitation is an index of climatic risk, indicating the likelihood of fluctuations in reservoir storage, aquifer recharge etc. The higher the MAP the lower its inter-annual variability. The CV is less than 19% along the coastal plateau and increases inland to a maximum of 25% in the east and north-east of the study area.

2.2.3 Rivers and Drainage Regions

The rivers in this region are presently largely under-utilised, and are not regulated by any dams of significant size. The main rivers draining the LRWS study area are the Msikaba, with its main tributary the Xura River, the Mzintlava and the Mtafufu Rivers. Other rivers of significance (falling outside of the LRWS study area) within the Eastern Pondoland Coast are the Mtentu and Mzamba Rivers. All main rivers are perennial and flow in the south-easterly direction from the elevated inland plateau to the Indian Ocean. The Magwa dam (wall height of 25 m) on the Mkozi River is the only registered dam in the area, but regulates a very small catchment of approximately 6 km^2. **Figure 5** illustrates the river catchments within the study area. Table 2.2.3 offers a summary of the characteristics of the main rivers within the study area.

Table 2.2.3: Characteristics of the main rivers within the study area

River	Quaternary Catchment	Catchment Area km^2	Virgin MAR ($10^6 m^3/a$)
Mtafufu	T60K	186	45.8
Mzintlava	T60J	270	71.2
Mzimpunzi	T60H	24	9.3
Mbotyi (Kobenge)	T60H	29	11.2
Mkozi	T60H	43	16.7
Myekane	T60H	5	1.9
Luphuthana	T60H	20	7.8
Mkweni	T60H	48	18.6
Msikaba	T60G / E / F	1022	207.4
Mtentu	T60D / C / B	964	152.6

The Eastern Pondoland Coast, which constitutes the tertiary drainage region T60 is divided into ten quaternary catchments – T60A to T60K, as illustrated in **Figures 4 and 5**. The LRWS study area incorporates portions of quaternary catchments T60F to T60K.

2.2.4 Geology

The study area is situated predominantly on the coastal belt, which consists of a relatively flat, gentle seaward-sloping plain. The area is underlain predominantly by Dwyka diamictite, although portions of the scheme are underlain by sandstone of the Msikaba Formation and faulted Ecca shale. Dolerite intrusions are almost exclusive to the Ecca and Beaufort sediments, but a number of dolerite dykes do transgress the Dwyka and Msikaba units. The Dwyka diamictite to the south of Lusikisiki have been intruded by a number of these sills. The contact between these dolerite dykes and the regional geology would serve as primary groundwater exploration targets.

2.2.5 Vegetation and land use

The land use information is presented in **Figure 6.** No general soil map exists for the study area, or for any other part of the former Transkei. All previous reports on agricultural potential within the study area are rather vague, when it comes to soil potential, and are largely based on reconnaissance visits. The major types of natural vegetation are forest and grassland, which form a mosaic in the landscape, contributing to the attractive visual contrasts of the Wild Coast.

The high rainfall in the region facilitates dry land crop production. There is no irrigated agriculture at present. The potential for development of irrigation in future is low. The only relatively large agricultural project in the study area is the Magwa Tea Estate (1800 ha), which operates under dry land conditions. Limited facilities are available for emergency irrigation in case of extreme droughts. The climatic and soil conditions in the study area create good opportunities for development of afforestation. Approximately 8 500 ha of commercial forestry developments have already been established within the Eastern Pondoland, 3 700 ha of which falls within the catchments of the LRWS area.

The Mkambati Nature Reserve located in the coastal areas between the Mtentu and the Msikaba Rivers currently covers an area of 7 000 ha. The reserve is known for its biological diversity and the occurrence of very rare endemic species. Plans are underway for the expansion of the reserve area to about 30 000 ha.

The dominant type of land tenure within the rural communities is the traditional (communal) tenure. The right to utilise the land is determined by the tribal authority. Experience shows that individuals within a community are often resistant to allow land that has been allocated to them to be rezoned for other use (e.g. irrigation). Most of the population dwell in small rural villages scattered throughout the area, and land use in the area is mainly for subsistence farming.

2.3 Demography and Socio-Economics

The settlement distribution in the LRWS study area is illustrated in **Figures 2 and 7**. The area is densely populated and most of the population reside in rural villages or dispersed settlements. The main economic centre is the town of Lusikisiki. The study area includes 79 rural villages with a total population of approximately 120 000, living in 17 administrative areas, all forming part of the Lusikisiki magisterial district (1999 demarcation).

The settlement pattern in the majority of the coastal districts comprises homesteads dispersed along ridges of the mountains and hills, and sometimes in those valley bottoms that are fairly flat. In general, the area within a few kilometres of the coast is sparsely populated. The dependency rate (the percentage of the population under 15 or over 65 years of age) within the area of Lusikisiki scheme is high at 53 %, and the distribution of men and women is 45 % and 55 % respectively. Of the population in the study area older than 5 years of age, 43 % have no formal schooling qualification, 35 % have completed primary school, and only 5,5 % have their matric or a higher qualification.

Except for the town of Lusikisiki, the industrial activity is limited, and the main sources of income are subsistence farming and migrant remittance. Employment opportunities are limited. Only approximately 7% of the economically active population residing in the study area are formally employed.

Eastern Pondoland Basin Study

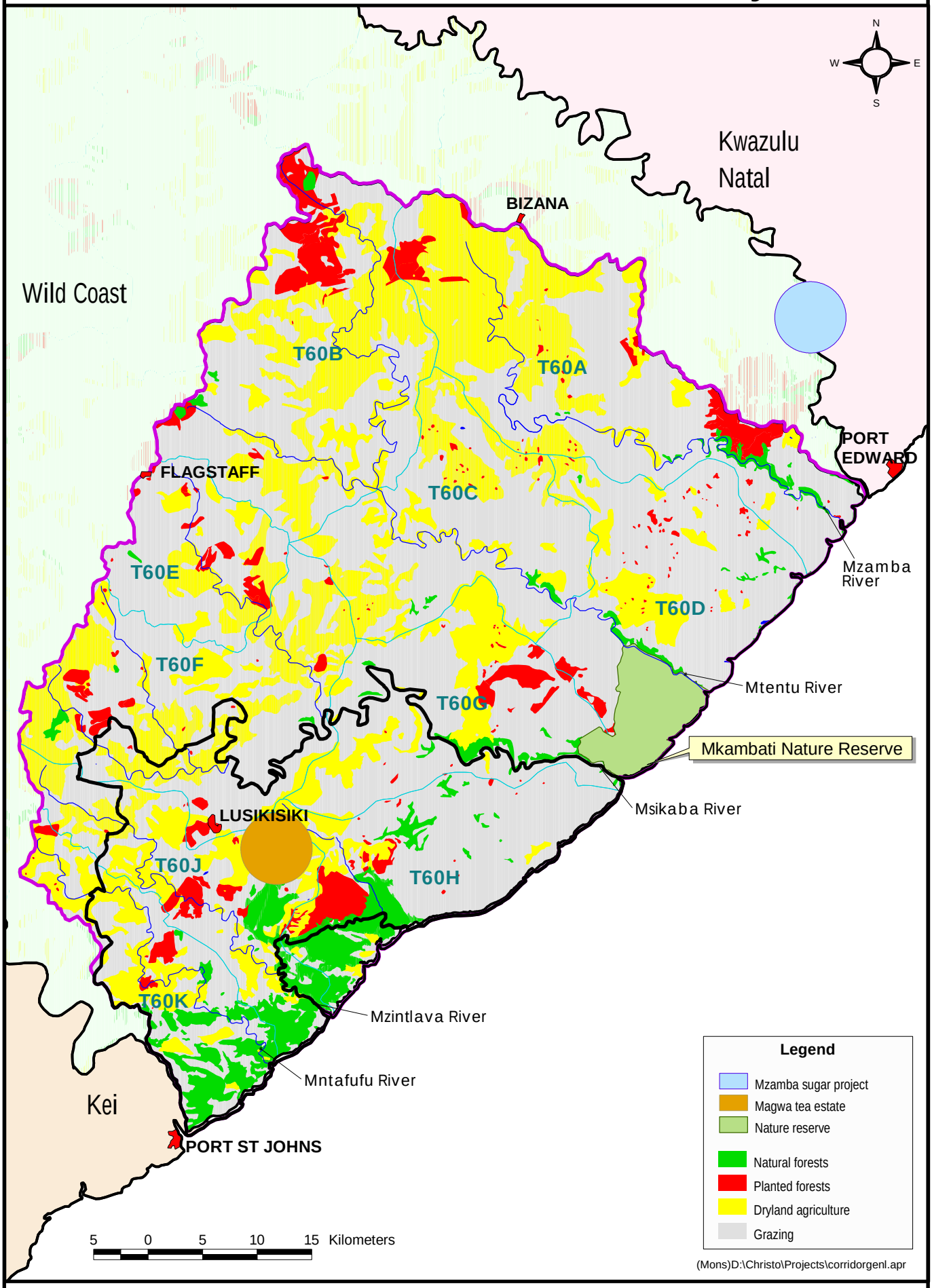


Fig 6 : Land Use

UWP Engineers

Eastern Pondoland Basin Study

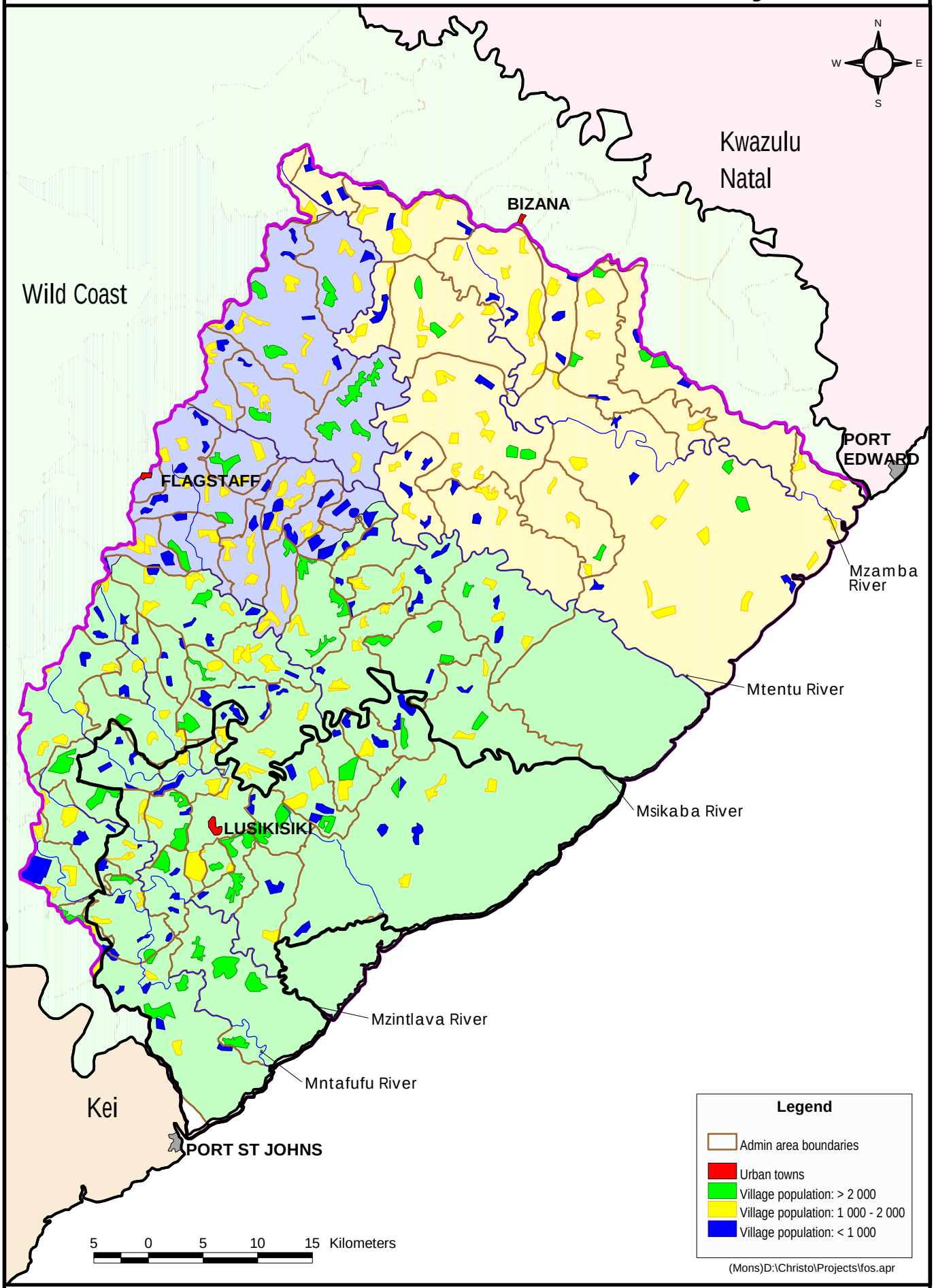


Fig 7 : Demography

UWP Engineers

3. INFRASTRUCTURE

3.1 GENERAL INFRASTRUCTURE

The existing infrastructure within the Eastern Pondoland is illustrated in **Figure 8**. The only north-south linkage through the region is provided by the N2 road, which connects Durban with East London via Kokstad, Umtata and Butterworth.

The main road in the Eastern Pondoland is the R61 from Port Edward to Port St Johns via Bizana, Flagstaff and Lusikisiki. The greater part of this road is surfaced, except for a stretch of approximately 20 km between Port St John's and Lusikisiki, which is scheduled for upgrading in 2001. This road has recently been upgraded and is of a relatively good standard.

Lusikisiki and a limited number of villages are presently electrified. Eskom is planning to gradually extend the coverage of the village electrification. The main power supply system (22 and 66 kV) is illustrated in **Figure 8**.

The telecommunication system is poorly developed, and presently covers only the main towns. Cellular telecommunication coverage is generally available along R61, and occasionally in other areas.

3.2 WATER SUPPLY AND SANITATION INFRASTRUCTURE

The existing water supply and sanitation infrastructure in the Eastern Pondoland is illustrated in **Figure 8**, while the proposed development projects are shown in **Figure 9**. In general, the level of hardship for the local population with regards to water and sanitation services is presently high. Approximately 18% of the population within the Eastern Pondoland Coastal region are currently supplied by 9 existing schemes, but mostly to levels of service below RDP standards. Except for the town of Lusikisiki, which has water born sanitation systems, no formal sanitation services are provided.

The existing infrastructure includes the Lusikisiki and Bizana regional schemes, and 7 relatively small schemes for the water supply of Flagstaff, Holy Cross, Magwa Tee Estate and the tourist developments at Mkambati, Gwe-Gwe, Mzamba and Mbotyi. A number of projects are currently being implemented as part of the RDP programme (**Figure 9**) and have reached various stages of completion. Two feasibility investigations into possible regional schemes to supply the Mkambati SDI nodal area and an extension to the Bizana scheme have recently been completed. The existing schemes and the proposed projects are described in detail in the **Main Basin Study Report.** None of these projects will however affect the decisions for the development options being investigated under this study.

Eastern Pondoland Basin Study

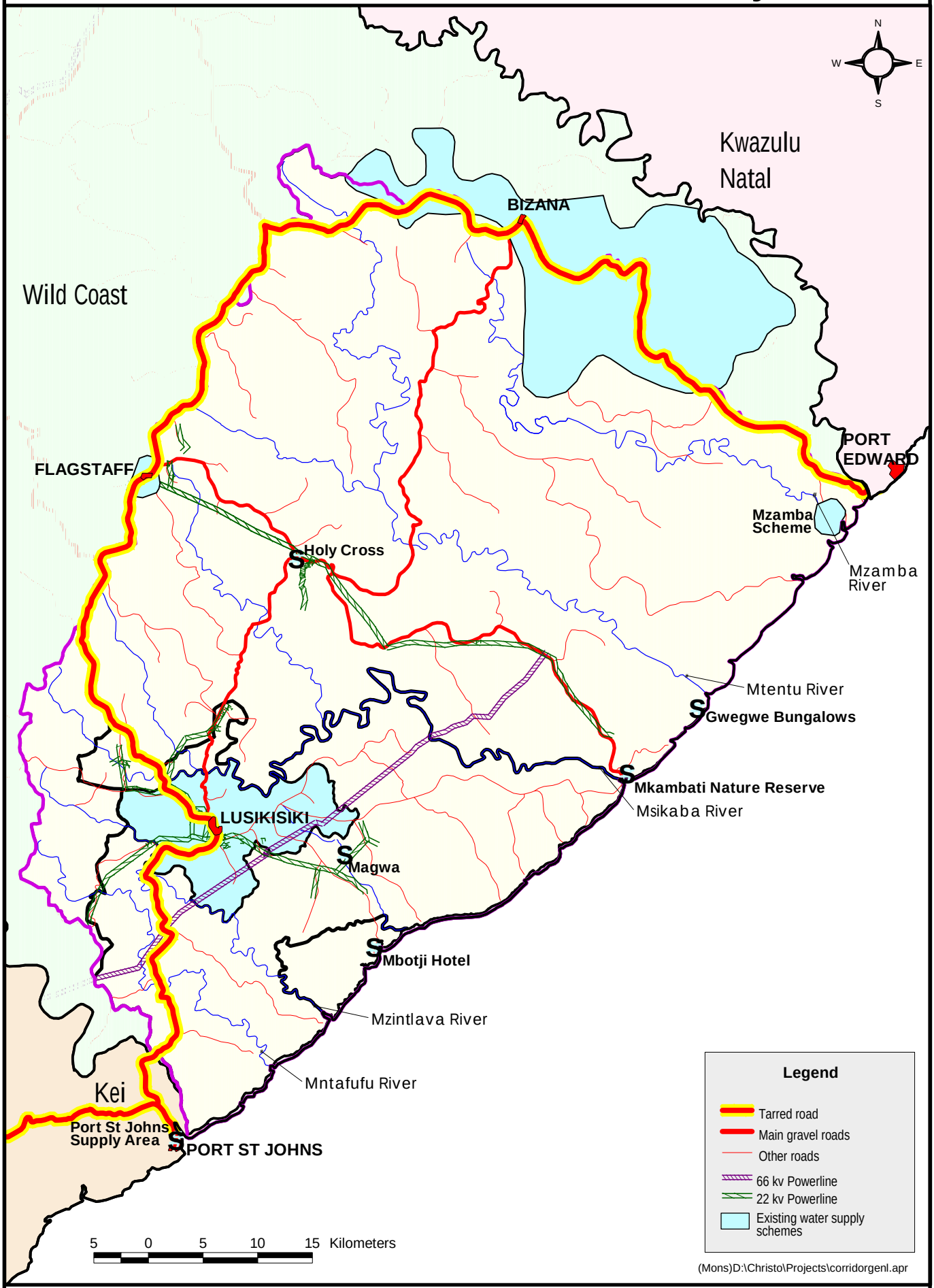


Fig 8 : Existing Infrastructure

UWP Engineers

Eastern Pondoland Basin Study

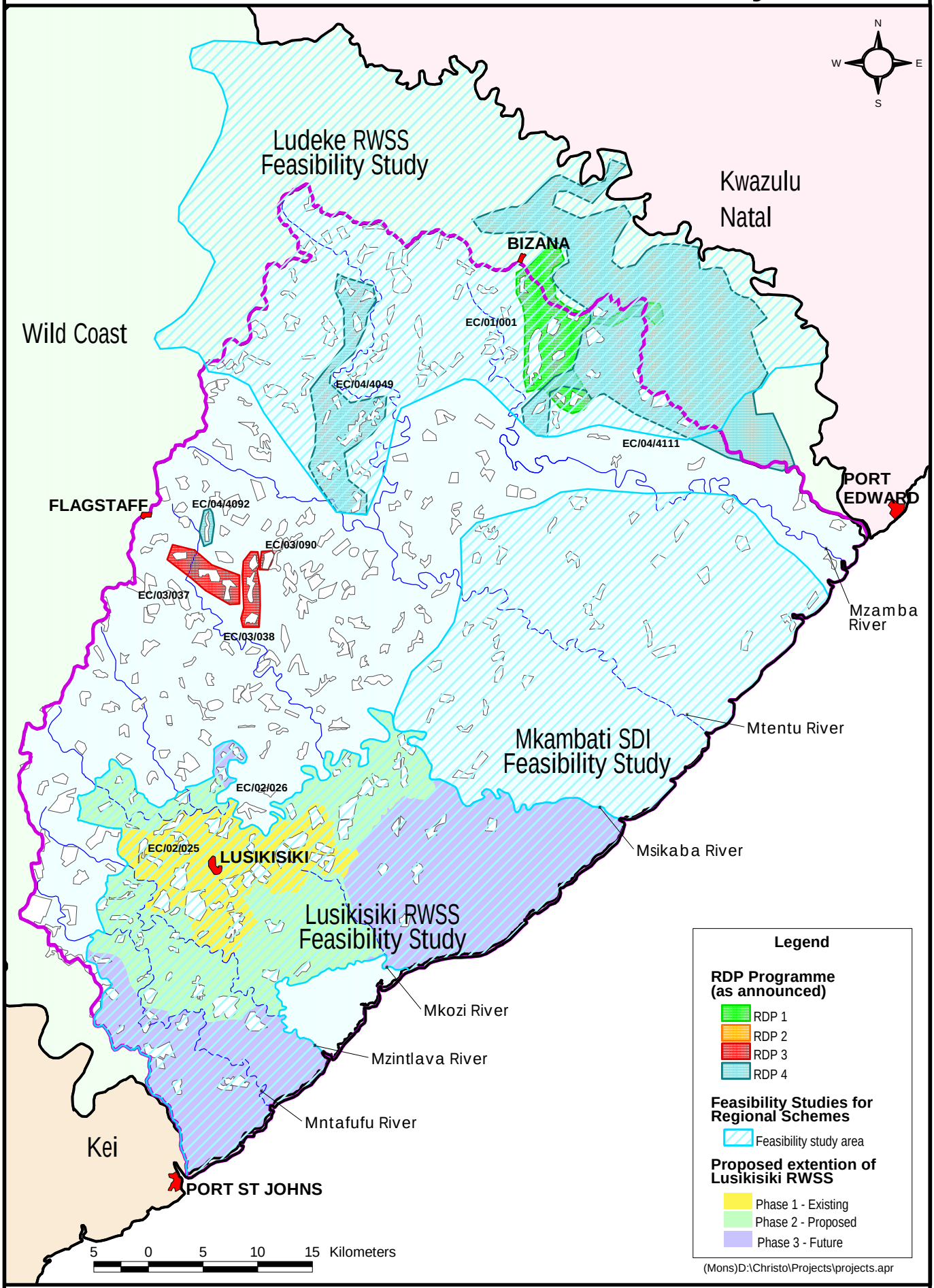


Fig 9 : Proposed Water Supply Projects

UWP Engineers

3.3 THE LUSIKISIKI REGIONAL WATER SUPPLY SCHEME (LRWS)

3.3.1 Historical overview and proposed developments

The LRWS (**Figure 1**) scheme was originally planned in 1978 [1] as a regional scheme to be supplied from a dam on the Xura River. The White Paper, proposing a programme for phased implementation was tabled for approval by the Transkei Government in 1979 [2]. Since then, a number of revisions of the implementation programme have been made [ref. 1 to 20].

To date, only phase 1 of the originally planned larger scheme has been implemented **(Figure 2)**. This scheme was commissioned in July 1989 and currently supplies the town of Lusikisiki (about 11 000 people) and 23 rural villages (about 41 000 people). The town is provided with full water service - house connections and water born sanitation. The level of service for the villages is limited to bulk supply to village reservoirs. As part of their Community Water Supply and Sanitation Programme, the Department of Water Affairs and Forestry has identified the following projects to upgrade the scheme, but the implementation has been postponed due to the need for upgrading of the water source to meat the increased requirements:

- Project 02 EC-025-Phase 1: Provision of full standpipe service to the 23 villages already connected to the scheme, including the installation of reticulation systems and upgrading of the village storage capacities.
- Project 02 EC-026: Upgrading of the existing bulk supply infrastructure to meet the increased requirements associated with the higher service levels within the existing scheme.
- Project 02 EC-025-Phase 2: An extension of the existing scheme (Phase 2) to supply 34 additional villages (37 000 people) including the extension of the bulk supply network, the provision of village reservoirs and reticulation systems.
- A further extension-Phase 3 to supply 22 additional villages (31 000 people) is planned for implementation, but has not yet been allocated a specific project number yet.

3.3.2 Description of the existing scheme

The existing water supply infrastructure for the LRWS is shown on **Figure 10**.

Water source

The raw water is presently abstracted at a weir on the Xura River, located under the bridge on the main road between Lusikisiki and Flagstaff, some 7 km northwest of Lusikisiki. Previous studies by GMA [14, 15], confirmed by the Institute of Water Research [18], have indicated the following present capacities of the water source:

Table 3.3.2: Estimated runoff at Lusikisiki weir (Xura River)

Flows	Flow rates at assurance of supply			
	98 % (1:50)	95 % (1: 20)	90 % (1:10)	80% (1:5)
Monthly: m^3/month	77 430	99 110	119 242	145 560
Daily: m^3/day	2 581	3 304	3 975	4 852
Instant: l/s	30	38	46	56

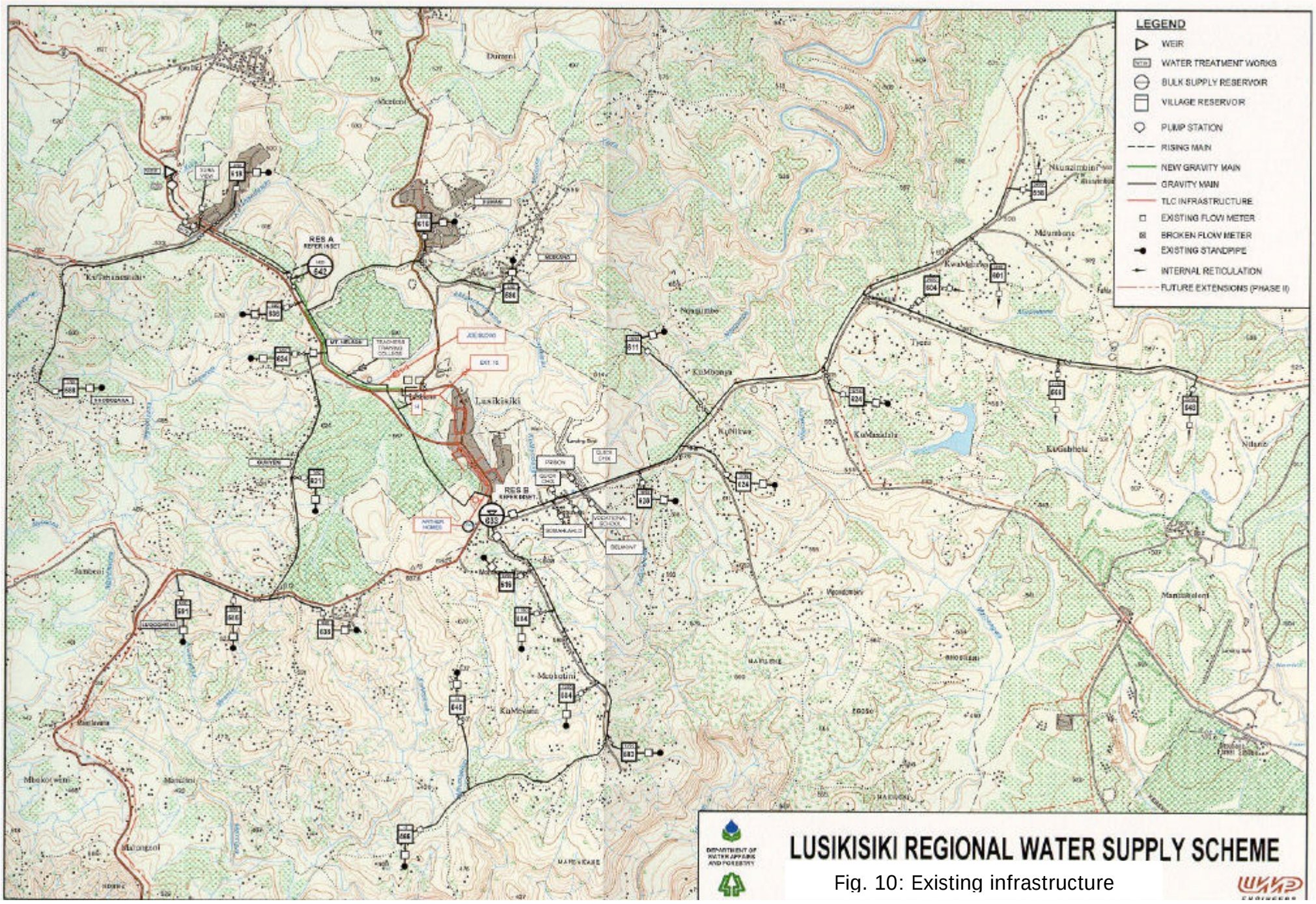


Fig. 10: Existing infrastructure

It should be noted that the above assessment has been undertaken at a reconnaissance level of detail, on the basis of WR90. No updating of the land use information for the upstream catchments has been done. No allowance for environmental releases has been made. It is therefore recommended that the above estimate should be treated with caution. More detailed assessments of the run of river yields at this site have been done for the purposes of this study and the results are offered in **Section 7.2**.

Bulk supply infrastructure

All components of the bulk supply infrastructure have design capacities of 2 760 m^3/day (32 l/s gross).

The water is pumped from the weir to the water treatment works through a raw water pump station located near the weir, through a 650 m long (ND 200 mm) raw water pumping main. The pump station is equipped with two duty and one stand-by centrifugal pumps (combined capacity of 32 l/s and design head of 60 m).

The water treatment works is situated just off the main road (R61) to Flagstaff. The treatment process comprises chemical dosing, flocculation, sedimentation, slow sand filtration and chlorination. The slow sand filtration system consists of three duty and one standby filter bays designed for a maximum head loss of 1,5 m and a total duty capacity of 32 l/s.

The clear water pump station located within the water treatment works consists of two duty and one standby pumps, with a total design duty capacity of 32 l/s and pumping head of 80 m. The clear water is conveyed by a 2 200 m long, 200 mm diameter AC rising main to the bulk storage reservoir (Reservoir A, 1 400 m^3). This reservoir then gravity feeds a further bulk reservoir (Reservoir B, 1 000 m^3) and 24 service reservoirs, varying in size between 20 and 90 m^3, supplying the rural villages.

A number of bulk users, including the town, draw water directly from the bulk main between reservoirs A and B, even though this pipeline has a limited conveyance capacity.

The level of service in the rural villages is below RDP standard. The villages have not been provided with internal reticulation and are serviced by banks of standpipes located near the village reservoirs. Furthermore, the storage capacity for some of the village reservoirs is inadequate.

3.3.3 Current Status of the Scheme

The scheme is being operated, maintained and managed by the DWAF: Eastern Cape. Due to the lack of capacity at local government levels, the DWAF currently performs the duties of a Water Service Authority and Bulk Water Service Provider. The Lusikisiki TLC is however responsible for the water distribution within its area of jurisdiction.

The actual water use of the scheme has been estimated [16] during the period 1993 to 1996, on the basis of bulk meter readings. The maximum recorded daily water use in 1996 amounted to about 1930 m^3/day. Approximately 40% increase in the water use has been recorded during the 3-year monitoring period. Further water balances have not been undertaken due to malfunctioning and insufficient numbers or inadequate location of bulk meters. A significant housing development (1 000 low cost houses) within the Lusikisiki area has been implemented during the last two years, which has noticeably increased the water use.

At present, the scheme appears to be unable to meet the water requirements, and water shortages are frequently being experienced. In fact, the main bulk reservoirs, Reservoirs A & B are seldom filled to over 25 % of their capacity. The low assurance of supply provided by the system can be attributed to the following reasons:

- Inadequate capacity and assurance of supply of the water source
- Intermittent Eskom power failures and the inability of the bulk supply infrastructure to make up supply following a power failure (i.e. capacity of the infrastructure)
- The poor condition of the infrastructure (e.g. sand filters, pumps, pipelines and level control mechanisms in the village reservoirs)
- Operational procedures (possibly complicated by the poor condition of the infrastructure) and the "uncontrolled" developments without prior consultations with DWAF regarding the ability of the system to meet increased requirements
- Issues related to adequate water demand and water loss management for both the bulk and distribution systems

The issue of augmentation of the existing water source is being discussed further in this report. All other issues listed above are presently being addressed by other projects commissioned by the DWAF and the Department of Local Government and Housing (DHLG).

4. WATER REQUIREMENTS

4.1 DOMESTIC AND INDUSTRIAL WATER REQUIREMENTS

The present and projected domestic water requirements depend on the following factors: population numbers, growth rates, levels of service (anticipated per capita water use), actual and anticipated growth in the industrial and institutional requirements, and phasing (timing of implementation) of the upgrading/extension of the existing infrastructure to supply additional areas. All these factors were investigated in detail, and where uncertainty existed, reasonable upper and lower estimates were made for each factor. Combinations of these estimates were then used to establish and assess various scenarios for the total scheme water requirements. The scenarios were evaluated and the most likely scenario was selected in consultation with the project management team and the EC: R and used for sizing of the development options. The water requirements were estimated and projected up to year 2020.

4.1.1 Population numbers

Historical overview

The population numbers and their projections have been estimated in a number of occasions since 1976 [1, 10, 13] by various consultants during the process of planning and re-planning of the LRWS scheme. A summary of the Census data for selected years is offered in the table below. According to the Census results, the total population within the study area has grown form 51 404 in 1970 to 112 700 in 1996, which matches very well with the projections made during the initial planning of the scheme in 1976 [1]. It has then been estimated that the total year 2000 population will be 115 000. Based on the Census data for the period 1985 to 1996, the population growth rate in the rural areas was estimated to be about 4% pa. The exceptionally high growth of the urban population of 7,8% for the same period can be attributed to a large extent to additional institutional developments – new prison, teachers college, hospital, clinic, etc. The results should however be treated with caution, since the area covered by the scheme (and the population served) may have been different during the previous assessments.

Table 4.1.1: Summary of historical census data for the LRWS scheme area

Town/Area	1970 Census		1985 Census		1996 Census	
	Pop Nos	Growth[1]	Pop Nos	Growth[2]	Pop Nos	Growth[2]
Lusikisiki Town	1 157	8.4%	1 938	3.5%	4 437	7.8%
Rural areas	50 247	2.4%	70 315	2.3%	108 263	4%
Total	51 404		72 253	2.3%	112 700	4%

[1] Estimated average annual growth rate used at the initial planning stage of the scheme

[2] Calculated average annual growth rate for the period, based on census figures

Base year population numbers

Due to the reasonable availability of information, year 1996 has been selected as the base year for population projections for this study. Population number estimates for this year have been undertaken for the purposes of various studies. A comparison between the information obtained from some of these sources is illustrated in the table below.

Table 4.1.2: Year 1996 population numbers estimated by various studies

Area	Source of information			
	DWAF: Water Services 1st order strategy	DWAF: MarkData	Eskom: Megasub	1996 Census
LRWS study area, including Lusikisiki	120 169	*	103 148	112 700
Lusikisiki town	11 350**	11 350**	2 118	4 437
Pondoland basin area	476 729	418 588	385 123	418 588

* Information available on the basis of magisterial district boundaries only.

** Includes a provision for the recent housing developments and all bulk users

The DWAF: Water Services first order strategy database has been compiled on the basis of the 1996 Census, but with some updating through actual population counts undertaken for the purposes of various water supply projects. This database is available in spatial format and includes population numbers per village, which is very convenient for planning purposes on a relatively small scale, as is the case for this project.

The most recent demographic study commissioned by DWAF (MarkData, 2000) provides a reconciled database at a magisterial district level. Disintegration of data to smaller areas, pro rata to the surface area will not be accurate. Database not available on village level. However, this study is based on the Census 1996 data.

The study commissioned by Eskom (Megasub, 1996) was conducted by means of hut counts from aerial photographic images, and is considered to be reasonably accurate for rural areas. The data is available in spatial format, per village. Due to significant discrepancies with the village names, direct comparison on village basis with the DWAF: WS database is not easily achievable. A comparison of the spatial data of the two databases is illustrated on **Figure 11**.

For comparison between the DWAF: WS and the 1996 Census databases the project area boundary was intersected with the 1996 Census enumeration area layout. The population numbers for enumeration zones falling entirely within the study area were summed and the prorata population for the intersected enumeration areas were added. It should be noted that according to the Census methodology the weighted population has been derived by multiplying the actual counted population by an estimated factor, specific for each enumerator zone, in order to make provision for undercounts. In this particular instance the average factor used for the study area was 1,93. This may be regarded as an indication of significant undercounts, and the associated inaccuracy of the census results.

As seen from **Table 4.1.2**, and taking into account the absence of detailed field investigations and the associated uncertainties, it is considered that the population numbers across the examined databases for the LRWS area compare reasonably well (±7% variation from average). It has been decided that the DWAF: WS database would be used for the purposes of this study due to the following reasons:

Eastern Pondoland Basin Study

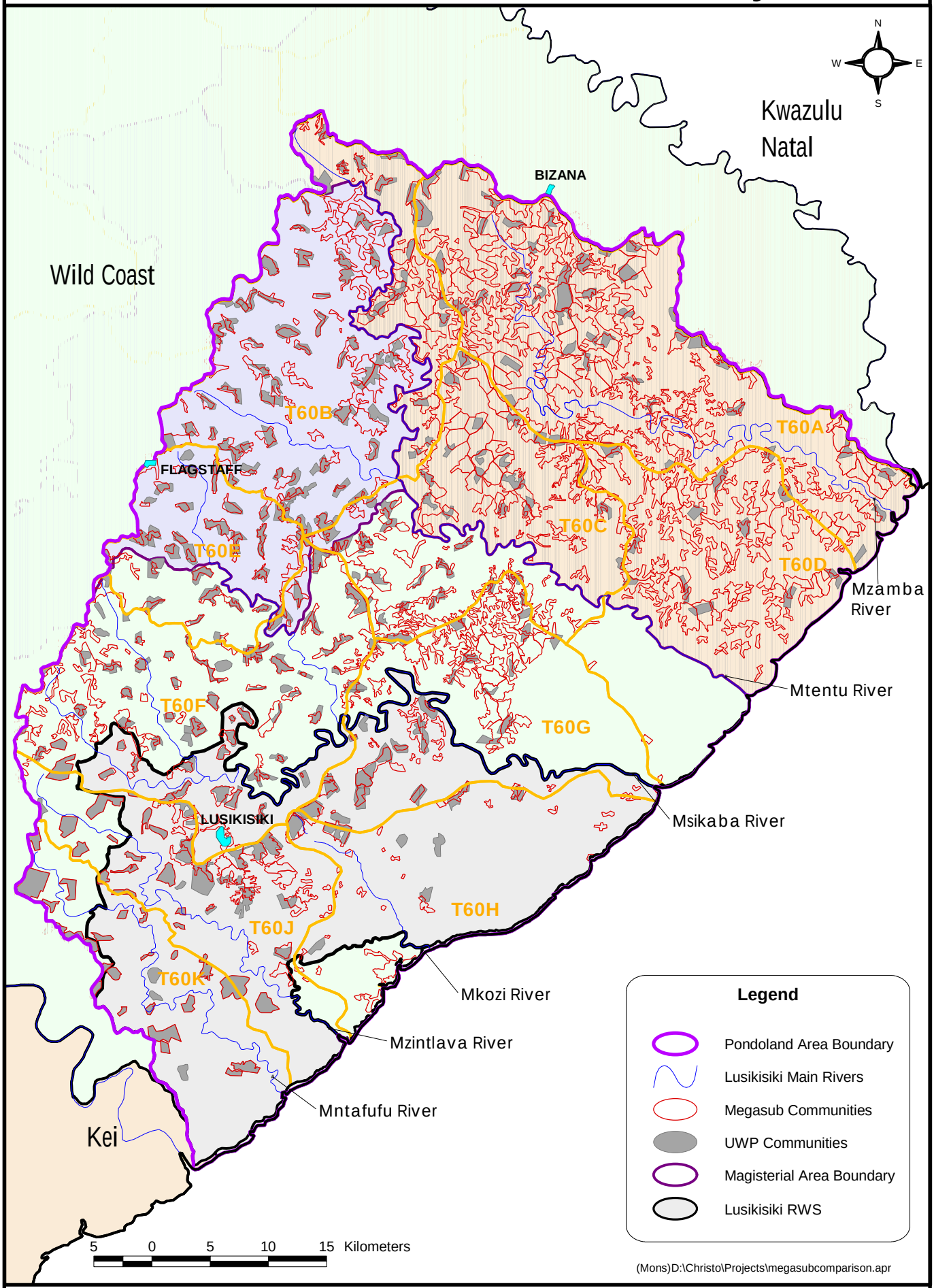


Fig 11 : Population numbers UWP and Megasub Data

UWP Engineers

- Its format provides convenience for planning purposes
- It has already been used for various other projects in the area and the relevant population numbers and village names will be consistent
- It is a bit more conservative than the other databases, which will provide reasonable and needed safety in view of the overall uncertainties.

4.1.2 Projected population growth rates

High estimate

The RDP Rural Water Supply Design Guidelines (DWAF, October, 1997) recommended a 2.5% pa growth rate for rural population for areas where no site specific and reliable information is available. However, recent studies have indicated that the rural population growth is expected to slow down considerably due to the impacts of AIDS, migration and urbanisation. As a result, the projected future growth rates (next 30 years) for the rural population across the country would be significantly lower than previously expected. In line with the available information at the beginning of the study, taking into account the historical growth rates and the trends for reduction of these rates in future, it was assumed that the rural population would grow at a constant rate of 1% to year 2030 and the urban population at 4% (1996 to 2020) and 3% (1996 to 2030).

Low estimate

During the course of the project, the results from the most recent demographic study commissioned by DWAF (MarkData, 2000) became available. According to this study it is projected that the average growth rate of the rural population within the study area will be between plus 0.38% (from 1996 to 2000) and minus 0.75% (from 1996 to 2030). The urban domestic growth rates will vary between 1.29% (from 1996 to 2000) and 0.51% (from 1996 to 2030). These projected growth rates were used as the low scenario for the sensitivity analysis described in Section 4.1.4 of this report.

The projected population numbers per phase of development of the LRWS using the high and low growth scenarios are shown in the following tables. The population numbers for the low scenario per village within the study area are shown in **Appendix B1**.

Table 4.1.2A : Population Number per Phase of Development (High growth scenario)

Area	1996	2000	2010	2020	2030
	Projected growth rate (given in % from 1996 base year)				
	Rural	1%	1%	1%	1%
	Urban	4%	4%	4%	3%
	Population numbers				
Lusikisiki town (urban)	11 350	13 278	19 655	29 094	31 007
Phase I (existing scheme)	40 758	42 413	46 850	51 752	57 166
Phase II (future extension)	37 363	38 880	42 948	47 441	52 404
Phase III (future extension)	30 698	31 944	35 287	38 978	43 056
Total	**120 169**	**126 515**	**144 739**	**167 265**	**183 634**

Table 4.1.2B : Population Number per Phase of Development (Low growth scenario)

Area	1996	2000	2010	2020	2030
	Projected growth rate (given in % from 1996 base year)				
	Rural	0.38%	-0.09%	-0.52%	-0.75%
	Urban	1.29%	0.76%	0.54%	0.51%
	Population numbers				
Lusikisiki town (urban)	11 350	11 946	12 624	12 907	13 479
Phase I (existing scheme)	40 758	41 384	40 242	35 930	31 510
Phase II (future extension)	37 363	37 937	36 890	32 937	28 886
Phase III (future extension)	30 698	31 170	30 309	27 061	23 733
Total	**120 169**	**122 437**	**120 065**	**108 835**	**97 609**

4.1.3 Water Requirement and Levels of Service

Historical overview of actual water use

A number of attempts to record the actual water use within the existing LRWS have been made since 1993. The maximum average daily water use recorded during the period 1993 to 1996 is illustrated in the table below. The figures quoted are gross and include operational and conveyance system losses.

Table 4.1.3A: Metered gross average daily water usage for the existing LRWS

User	Estimated population	Metered average daily water usage	Percent of total	Estimated per capita water usage
	No	m^3/day	%	l/c/d
Lusikisiki town	4 800	910	47	190
Bulk/institutional users		614	32	
Rural villages	40 758	399	21	10

As seen from the above table the town of Lusikisiki currently uses about 47% of the total water supplied by the scheme, or about 190 l/c/d. This however includes certain small businesses, commercial and municipal users. Due to the poor state of the existing system, the water losses are expected to be high, possibly in excess of 30% of the total water used. The issue of assessment and possible reduction of the water losses is currently being addressed through a separate project, commissioned by DWAF: ECR. Excluding the water losses as well as the estimated municipal and business usage, the estimated annual average net water usage per person is expected to be in the order of 110 l/c/d. The water usage by the bulk users, including the prison, the teacher's college, the hospital, the new housing developments, etc. account for 32% of the total demand.

The rural population uses about 21% of the total supply, or about 10 l/c/d. It should be noted that the level of service for the rural villages is below RDP standard with regards to the walking distance. If a full standpipe level of service is provided, the rural requirements are expected to increase.

The above-mentioned numbers should be treated with caution. The accuracy of the figures is somewhat questionable due to the poor condition of the meters, the inappropriate position of certain bulk meters, their inability to record low flows and the relatively long periods between meter readings.

Design per capita water requirements

The water requirements for the population in villages not provided with reticulation infrastructure, but supplied at village reservoir outlets were assumed to be 10 l/c/d in accordance with the historical water usage data. The requirements for the population supplied to RDP level of service were estimated as follows.

High estimate

The RDP Rural Water Supply Design Criteria Guidelines (DWAF, October 1997) recommend a minimum allowance of 25 litres per capita per day (l/c/d) for the case of standpipe level of service. In order to provide for growth in water requirements, the sizing of all components is recommended to be performed for 60 l/c/d for a 10-year population projection horizon. The urban requirements for the house connection level of services was assumed to grow from 160 l/c/d (MarkData estimate) to 240 l/c/d (years 2000 to 2030). These design criteria were used for estimation of the high water requirements scenario.

Low estimate

Information from various rural water supply schemes commissioned during recent years however reveals that the actual water use in rural schemes is considerably lower. A moderate increase of the levels of service for the rural population varying form 18 to 36 l/c/d for the period 2000 to 2030 has been used for the low water requirement scenario. The urban water requirements were assumed to vary between 110 to 200 l/c/d.

Constant estimate

In addition, a constant water use scenario at 25 l/c/d for the rural users throughout the design horizon was introduced. The design per capita water requirements, used for sensitivity analysis are illustrated in the following table.

Table 4.1.3B: Design Annual Average Daily Water Requirements

Demand estimate	Usage	Water requirements l/c/d			
		2000	2010	2020	2030
High	Urban	160	190	215	240
	Rural	30	45	60	80
Low	Urban	110	140	170	200
	Rural	18	24	30	36
Constant	Urban	110	140	170	200
	Rural	25	25	25	25

4.1.4 Total water requirements scenarios for the LRWS scheme

Based on the assumptions detailed in **sections 4.1.2 and 4.1.3** the following scenarios with regards to the total water requirements of the LRWS scheme have been established:

- **High requirements scenario:** high estimate projected population growth rates, and high estimate per capita water requirements
- **Medium requirements scenario:** low estimate projected population growth rates, and high estimate per capita water requirements
- **Low requirements scenario:** low estimate projected population growth rates, and low estimate per capita water requirements
- **Constant requirements scenario:** No change in rural population numbers (use year 2000 levels), low growth estimate for urban population, and constant estimate per capita water requirements

A constant 1% per annum growth rate has been allowed for the urban industrial and institutional requirements for all scenarios.

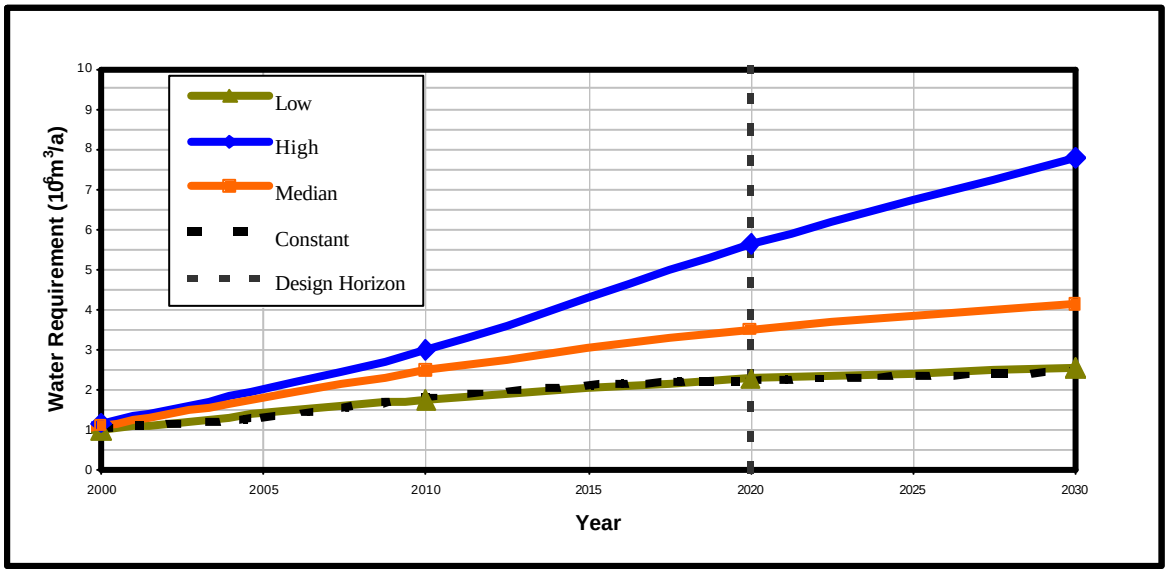
The total net water requirements estimated for each of the above scenarios are illustrated in **Table 4.1.4A** and **Graph 4.1.4.**

A provision for certain institutional requirements (clinics, commuters from other areas, community halls, etc) at 7 % of the total net water use for rural areas has been made. An allowance of 5 l/c/d for scholars in the area has been added.

Table 4.1.4A: Net Domestic and Industrial Water Requirements

Requirement Scenario	Net water requirements $10^6 m^3/a$			
	2000	2010	2020	2030
High	1.177	2.996	5.635	7.781
Median	1.110	2.491	3.504	4.130
Low	1.020	1.766	2.285	2.547
Constant	1.043	1.807	2.238	2.454

Graph 4.1.4A: Water Requirement Scenarios



As seen in the above graph the water requirements patterns for the low and constant scenarios are very similar.

Selected water requirement scenario for sizing of the development options

During presentations of the interim study results to the Directorates of Water Resources Planning and the Eastern Cape Region it was decided that the low scenario would better represent the anticipated water use pattern in the study area. This scenario together with the year 2020 horizon was selected for sizing of the scheme components. The High and Medium scenarios were however used for sensitivity analysis for the various development options discussed in this report.

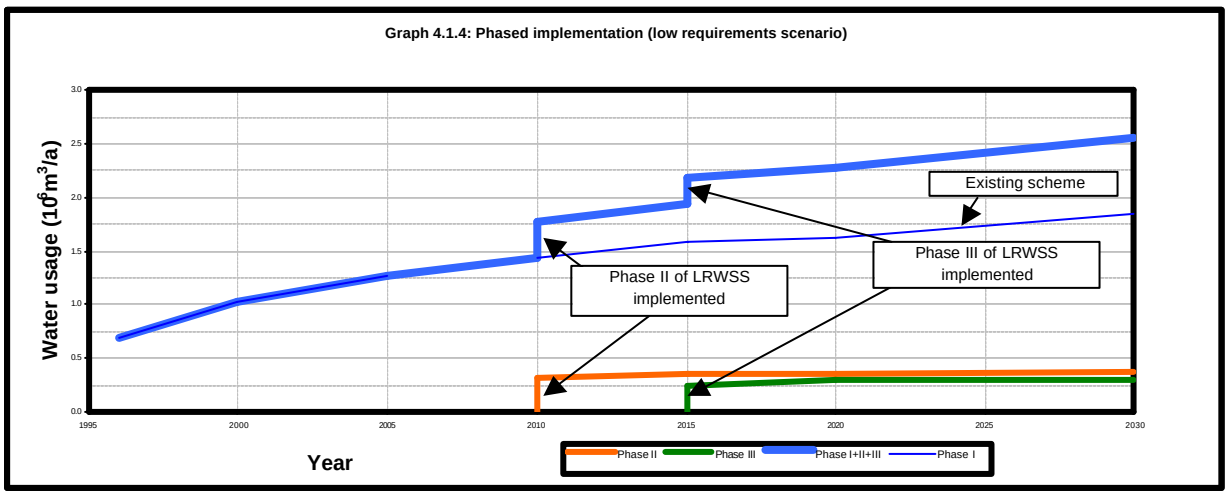
The projected water requirements for the selected scenario, per development phase of the scheme are illustrated in **Table 4.1.4B.** The development phase boundaries are illustrated in **Figure 2**.

Table 4.1.4B: Design Net Domestic and Institutional Requirements (Low Scenario)

Development phase	Net water requirements $10^6 m^3/a$			
	2000	2010	2020	2030
Phase I (existing scheme)	1.020	1.443	1.628	1.856
Phase II (future extension)	-	0.323	0.361	0.380
Phase III (future extension)	-	-	0.296	0.312
Total	**1.020**	**1.766**	**2.285**	**2.547**

The following scheme implementation programme as illustrated in the graph below, has been adopted for the purposes of estimation of the total scheme water requirements:

- 2005: commission the reticulation systems for the 23 villages included in the existing scheme and upgrade services provision to standpipe level (rural net demand will grow from 10 l/c/d to 18 l/c/d)
- 2010: commission reticulation systems for the 34 villages included in phase 2 of the scheme: stand pipe level of service
- 2015: commission reticulation systems for the 22 villages included in phase 3 of the scheme: stand pipe level of service



4.2 AGRICULTURAL AND AFFORESTATION REQUIREMENTS

More detailed information with regards to the agricultural and afforestation potential of the study area is available in the supporting report **Agricultural Developments and Afforestation**.

4.2.1 Irrigation

In general, irrigation is not anticipated to be feasible in the study area. The high mean annual precipitation (above 1 000 mm) allows high yielding dry land agriculture and will most probably not justify the high capital costs for source development and pumping. The area is deeply incised by the main river basins, and the irrigable land is normally located in the alluvial flood plains within the river valleys. These valleys are usually not accessible by roads of satisfactory standards. High pumping heads will be required (100 to 300 m) to irrigate larger portions of land on the plateau.

No existing irrigation projects are present in the area. The Magwa Tea Estate has limited infrastructure for the provision of emergency irrigation only. Limited projected irrigation requirements have been taken into account for determination of the mean annual runoff of the system, but no provision for irrigation supply infrastructure and water requirements has been made for the purposes of this feasibility study.

4.2.2 Stock Watering

The Lusikisiki RWS infrastructure will not provide for the stock watering requirements. Livestock requirements of 40 l/LSU/d have however been taken into account for the determination of the mean annual runoff for all catchments within the Eastern Pondoland region.

4.2.3 Afforestation

Existing and projected afforestation water requirements (reduction of runoff) have been taken into consideration for the determination of the mean annual runoff for all relevant catchments. The reduction of runoff due to afforestation developments has been modelled and is described in more detail in the supporting report **Streamflow Hydrology**. The reduction of runoff is therefore not taken into account as a direct water usage in order to avoid double counting.

4.3 ECOLOGICAL RESERVE REQUIREMENTS

4.3.1 Ecological Estuarine Reserve

A desktop estimate of the ecological estuarine Reserve (EER) for the 16 largest rivers in the Eastern Pondoland region has been carried out. The methodology applied involved a desktop study by various environmental experts, followed by a multidisciplinary two-day workshop, where the ecological management classes of the rivers were determined. This investigation has concluded that most of the estuaries in the study area are in pristine condition and are of high ecological and socio-economic importance. The estimated EERs for these rivers are therefore very high, and vary between 80 and 99% of the virgin MAR.

Table 4.3.1 provides a summary of the estimated EER for the rivers within the study area. More detailed information is available from the supporting report **Ecological Estuarine Reserve Estimate**. The location of the estuaries is shown in **Figure 5**.

Table 4.3.1: Estimated Estuarine Reserve for Rivers within the LRWS Study Area

River Estuary	Quaternary Catchment	Virgin MAR ($10^6 m^3/a$)	Type of Estuary	EMC*	EER (% of MAR)
Mtafufu	T60K	45.8	Open	A	80 - 95
Mzintlava	T60J	71.2	Open	A	80 - 95
Mzimpunzi	T60H	9.3	Closed	A	90 - 99
Mbotyi (Kobenge)	T60H	11.2	Closed	B	90 - 99
Mkozi	T60H	16.7	Closed	A	90 - 99
Myekane	T60H	1.9	Closed	A	90 - 99
Luphuthana	T60H	7.8	Closed	A	80 - 95
Mkweni	T60H	18.5	Closed	A	90 - 99
Msikaba	T60G / E / F	207.4	Open	A	80 - 95

* Ecological Management Class

4.3.2 Ecological Riverine Reserve

The ecological riverine reserve (ERR) (also known as instream flow requirements) was determined specifically for each of the proposed dam and weir sites. The selection of these sites is discussed in detail in **Section 6**, and the position of the sites is shown in **Figure 16**. The estimates for the ERR were undertaken on the basis of the rapid methodology applying the Hughes DSS model (decision support system of Rhodes University's IWR). The ecological management classes, used as an input to the model, were assessed by a team of environmental specialists during a field trip in March 1999, and a workshop in August 1999. The results of the application of the Kleynhans method for the determination of the "attainable" ecological management class (AEMC) for two reaches of the Msikaba and Mzintlava Rivers are summarised in **Table 4.3.2A**. A summary of the estimated ERR is offered in **Table 4.3.2B**. More detailed information including the assessment forms for the determination of ERR and the associated monthly rule curves, is provided in the supporting report **Rapid Ecological Riverine Reserve Estimate**. The rule curves have been used for the hydrological generation of present day monthly flows at each development site with provision for ERR releases (see detail in Section 5.2.2).

Table 4.3.2A: Summary of Assessment of Ecological Management Classes

River	EISC*	DEMC*	DESC*	PESC*	AEMC*
Xura/Msikaba (Upper Reach)	High	B	B	C	C
Msikaba (Lower Reach)	High	B	B	C	B
Mzintlava (Upper Reach)	High	B	B	C	C
Mzintlava (Lower Reach)	High	B	B	B	B

** (EISC = ecological importance and sensitivity class; DEMC = default ecological management class; DESC = default ecological status class; PESC = present ecological status class; AEMC = attainable ecological management class).*

The Kleynhans (1999) method does not allow for further differentiation of the EMC classes into a high or low sub-category (e.g. B class into AB or BC). A professional judgement of the two river reaches in the study area gave an assessment of the AEMC for the various sites on the Xura/Msikaba and Mzintlava Rivers as indicated in **Table 4.3.2B**. Further studies are however required to increase the confidence in the initial assessments of the EMCs for the river reaches.

Table 4.3.2B: Estimated ERR (IFR) for the Proposed Development Sites

Site	River	AEMC	Virgin MAR ($10^6m^3/a$)	ERR (IFR)	
				% of MAR	$10^6m^3/a$
Zalu	Xura/Msikaba	B/C	12.10	23.4	2.79
Lusikisiki	Xura/Msikaba	B/C	15.51	23.8	3.69
Xura	Msikaba	B	38.35	29.2	11.07
Lower Mzintlava	Mzintlava	B/C	17.06	24.6	4.20
Tungwane	Mzintlava	B	24.20	30.2	7.74

4.4 SUMMARY OF WATER REQUIREMENTS

Table 4.4: Summary of Net Water Requirements (Low Scenario)

USER	2000	2010	2020	2030
	$10^6m^3/a$			
Consumptive water requirements				
Urban domestic & industrial	0.741	0.933	1.119	1.336
Rural phase 1	0.280	0.434	0.437	0.454
Rural phase 2	-	0.398	0.400	0.416
Rural phase 3	-	-	0.329	0.342
Total consumptive water requirements	1.020	1.766	2.285	2.547
Non-consumptive water requirements (ERR) (Zalu)	2.793	2.793	2.793	2.793
Total water requirements, $10^6m^3/a$	**3.813**	**4.559**	**5.078**	**5.340**

Throughout this study, it has been assumed that the best water demand management and water loss control measures will be maintained during all times by the water service provider and the water service authority.

The total present day MAR at Zalu dam site, having the smallest catchment area of all dams investigated, is estimated to be 11.45 million m^3. It can be concluded that the total water requirements (consumptive and ecological) are less than 50% of the surface water available at this site. Therefore, the surface water resources in the study area have sufficient capacity to meet the requirements of the scheme, even after the release of the ecological reserve demands.

5. WATER RESOURCES

5.1 GROUNDWATER

Details regarding the results of the groundwater resources investigations undertaken for the Eastern Pondoland Basin Study are offered in the supporting report Groundwater Resources. The following paragraphs provide an overview and a brief summary of the results with specific reference to the development potential of the groundwater resources within the LRWS scheme study area.

Regional perspective

The groundwater resources of the T60 drainage region are only being utilised at a fraction of their true potential, both actively via boreholes and passively from perennial springs or ephemeral seeps. The present groundwater use in the study area is estimated to be less than 1.0 million m^3 per annum. In general, the groundwater quality is good and is suitable for domestic water supply purposes, although local variability is anticipated. Local point source pollution of the groundwater is likely in densely populated areas, due to human activities, resulting in elevated nitrate levels and faecal bacterial counts.

The groundwater resources of the Eastern Pondoland Basin as indicated by the rainwater recharge potential are high, in the order of 280 million m^3 per annum. Much of this groundwater is 'lost' as base-flow to the many perennial rivers draining the T60 catchment, particularly during the dry season. The low permeability of the shallow aquifers, the relatively low borehole yield potential, together with the inaccessibility of the terrain, limit the groundwater development potential of the T60 basin to between 12.5 and 23.5 million per annum. However, with the drilling of deeper (250 to 300 m), higher yielding production boreholes it may be possible to abstract between 50.0 and 90.0 million m^3 each year on a sustainable basis. The costs of exploring and developing such groundwater supply schemes will be considerably (five times) higher than the existing 'ad-hoc', low-yielding groundwater supply schemes. The distribution of the groundwater development potential for the Eastern Pondoland Basin is shown in **Figure 12**.

Despite the favourable groundwater development potential of the study area the following factors may limit the feasibility of utilising groundwater as a source for a regional scheme (as compared to surface source):

- Cost considerations: pumps to be powered by diesel engines due to unavailability of electrical supply
- High O&M costs associated with multiple sources
- Generally lower assurance of supply compared to surface water

The cost of establishing and maintaining a groundwater supply scheme may, in certain parts of the T60 region, prove to be a factor limiting its development. The present groundwater development costs are relatively high in terms of the poor drilling success rates and low sustainable yields of the boreholes. The 'sustainability' of these water supplies are severely restricted by a lack of maintenance of the boreholes, pump equipment and reticulation networks.

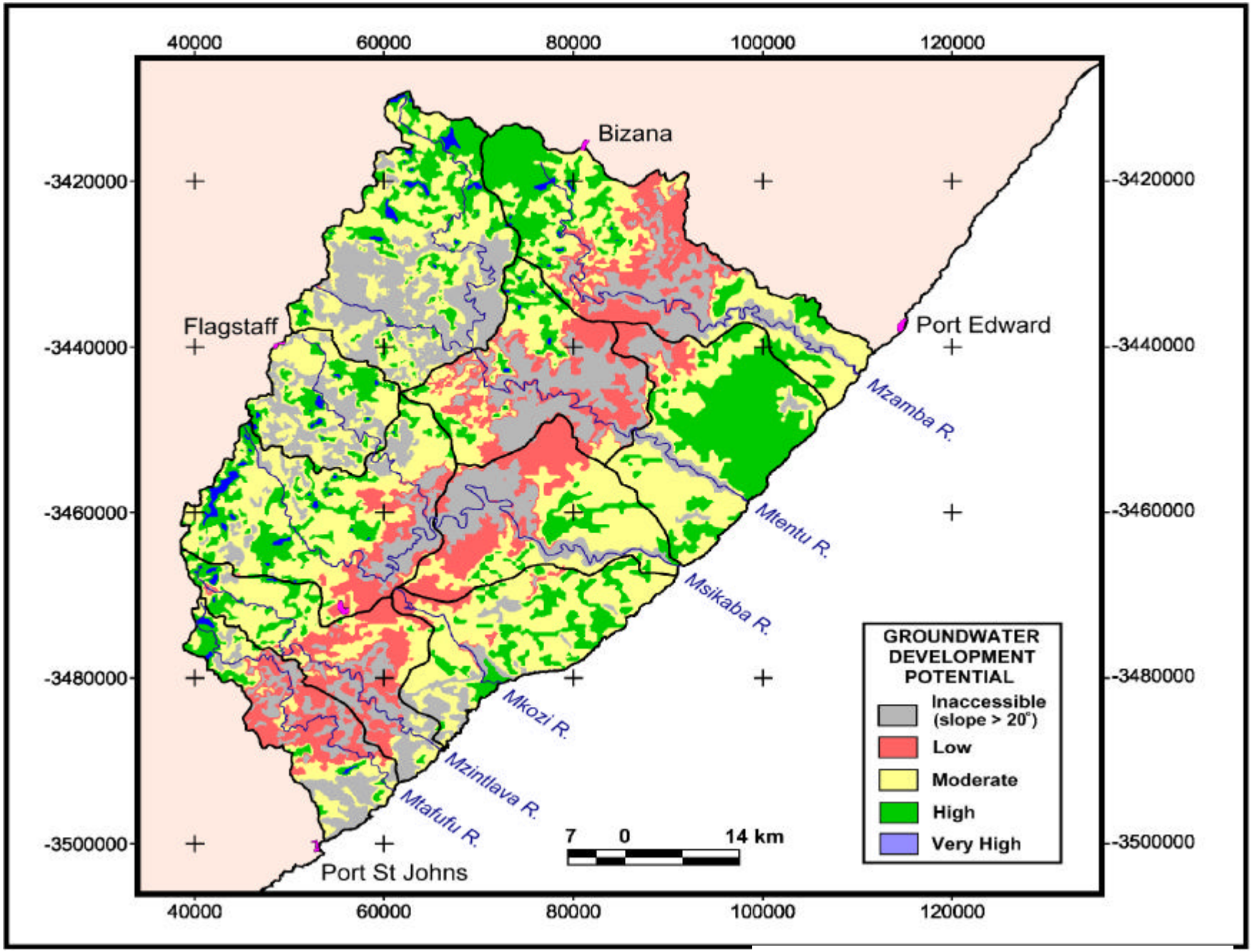


Fig 12: Ground water development potential

Local perspective

At present, the LRWS scheme study area is underdeveloped in terms of groundwater abstraction and only shallow aquifer systems have been utilised to a limited extend. Relatively high-yielding boreholes to a maximum of 5 l/s in isolated areas have been drilled in the past in the area. In the vicinity of the Nyosana Village, moderate borehole yields (2 l/s) were obtained along the contact of dolerite sills intruded into the Ecca shales. It is not known whether these boreholes are presently in production. In general, the weighted median yield of the boreholes drilled within the area varies in the range of 0,5 to 1,15 l/s.

Based on the density of the lineaments and the occurrences of favourable geological structures, taking into consideration the accessibility, a total of 61 potential exploration drill-sites were selected within "close" proximity (< 3 km) of the existing water supply infrastructure of the LRWS (**Figure 13**). The exploration drill-sites have been ranked according to their anticipated water-yielding potential in three categories, namely:

- Category A – Good (21 sites)
- Category B – Moderate (25 sites)
- Category C – Reasonable (15 sites)

Figure 13 indicates that the area to the south and south-east of Lusikisiki has the highest groundwater development potential. In some cases, more than one exploration site has been indicated along a regional geological structure, which results in the "clustering" of sites. This situation is ideal for the development of production "well-fields" (i.e. a number of closely-spaced boreholes). There are a number of operational and aquifer management advantages associated with such a production scheme.

As a first order estimate, the average yield of the production boreholes in the study area is expected to be in the order of 1.0 to 2.0 l/s. Depths are expected to vary between 60 and 100 m and the success rates between 60% to 75%. However, it should be noted that no exploration drilling or testing of existing boreholes have taken place, therefore the confidence in the above numbers is low. It is recommended that detailed investigations be undertaken if groundwater is considered to be an acceptable source of supply.

5.2 SURFACE WATER HYDROLOGY

5.2.1 Streamflow Hydrology for T60 Drainage Region

Regional perspective

The streamflow analysis for the T60 drainage region has been undertaken on a quaternary catchment basis for the purposes of the Eastern Pondoland Basin Study. The results of these analyses are described in detail in the supporting report **Streamflow Hydrology**. This section outlines the findings related to possible development of the surface water sources for the augmentation of the LRWS scheme.

The Water Research Commission publication "Surface Water Resources of South Africa, 1990" (WR90) [27] subdivides the study area into two rainfall zones and a number of functional rainfall gauging stations have been identified in each zone within T60 region.

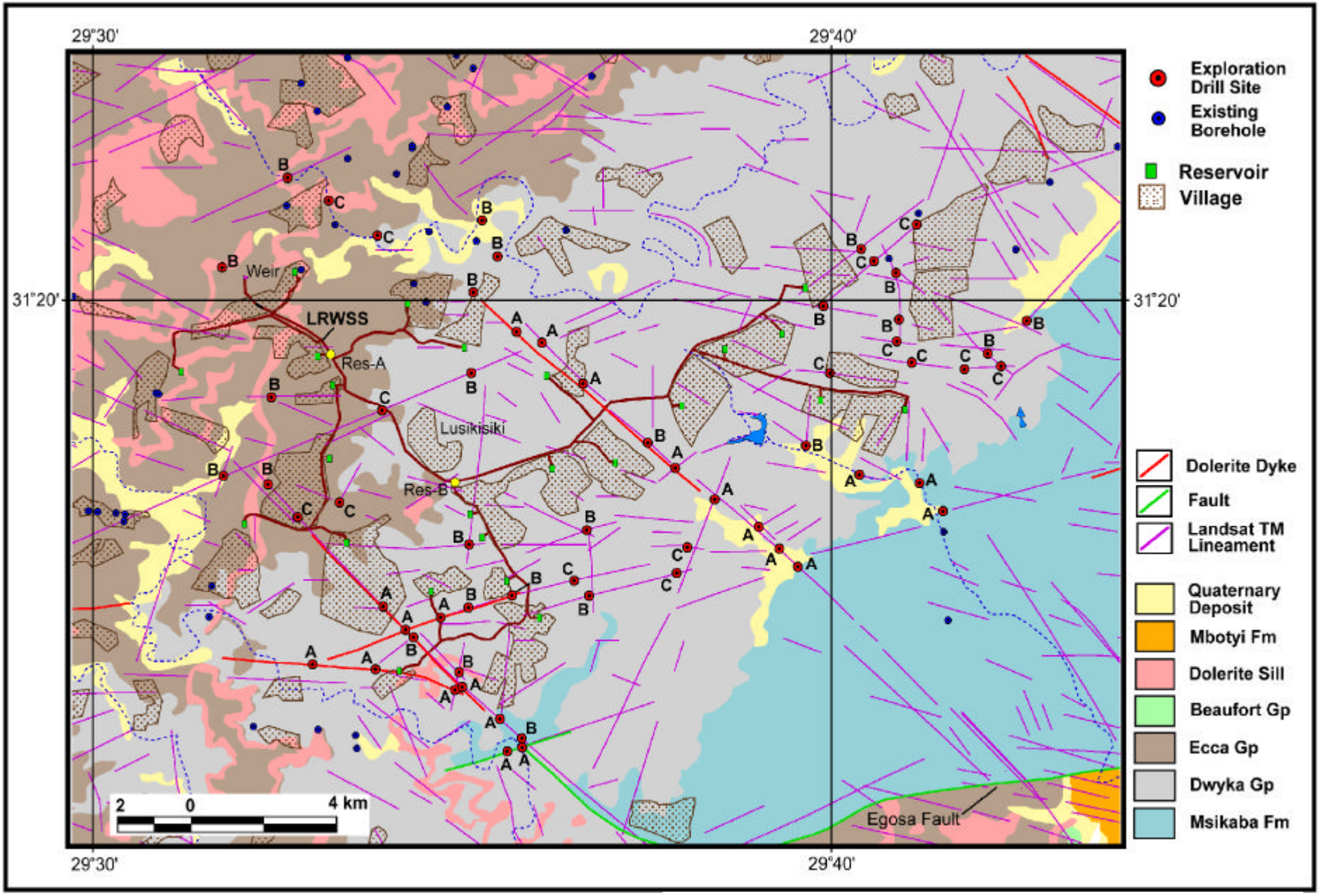


Fig 13: Exploration drill targets in the vicinity of the LRWSS

The data from the majority of these stations contain gaps in their record, mostly for the period 1990 to 1997, but these were effectively patched. The hydrological analyses for the area have been based on the Water Resources Simulation Model (WRSM90) parameters and the rainfall input has been extended to include records until 1997.

An investigation of available hydrological and meteorological data revealed that only two flow-gauging stations exist in the Eastern Pondoland region (Xura and Mtafufu Rivers). Although certain observed stage records (time/height) are available, the reliability of the observed data has been found to be totally inadequate. No discharge tables for the time of observation are available to convert the primary records into secondary data (flows). In addition no similar catchments with reliable flow data records could be identified for cross correlation purposes, and therefore no calibration of the WRSM90 model was performed.

A summary of the results for the surface water runoff per quaternary catchment and per river basin is provided in the following tables and is illustrated in **Figure 14**.

Table 5.2.1A: Surface Water Runoff per Quaternary Catchment

Quaternary Catchment	Catchment Area	MAP	Incremental MAR		
			Virgin	2000	2030
	(km^2)	(mm)	(10^3m^3)	(10^3m^3)	(10^3m^3)
T60A	547	873	71.9	70.5	67.6
T60B	528	896	75.5	70.7	67.1
T60C	363	952	62.7	62.1	61.4
T60D	415	1072	102.7	102.2	100.2
T60E	198	885	28.0	26.5	23.9
T60F	464	940	79.1	76.7	68.6
T60G	360	1116	100.3	99.2	98.5
T60H	322	1277	124.7	121.6	116.3
T60J	294	1101	77.6	75.9	75.8
T60K	242	1075	59.7	58.2	58.0
Total	**3733**		**782.2**	**763.9**	**737.4**

Table 5.2.1B: Surface Water Runoff for main Rivers within the LRWS area

River Estuary	Quaternary catchment	Catchment Area (km^2)	Virgin MAR ($10^6m^3/a$)
Mtafufu	T60K	186	45.8
Mzintlava	T60J	270	71.2
Mkozi	T60H	43	16.7
Mkweni	T60H	48	18.5
Msikaba	T60G / E / F	1022	207.4

Eastern Pondoland Basin Study

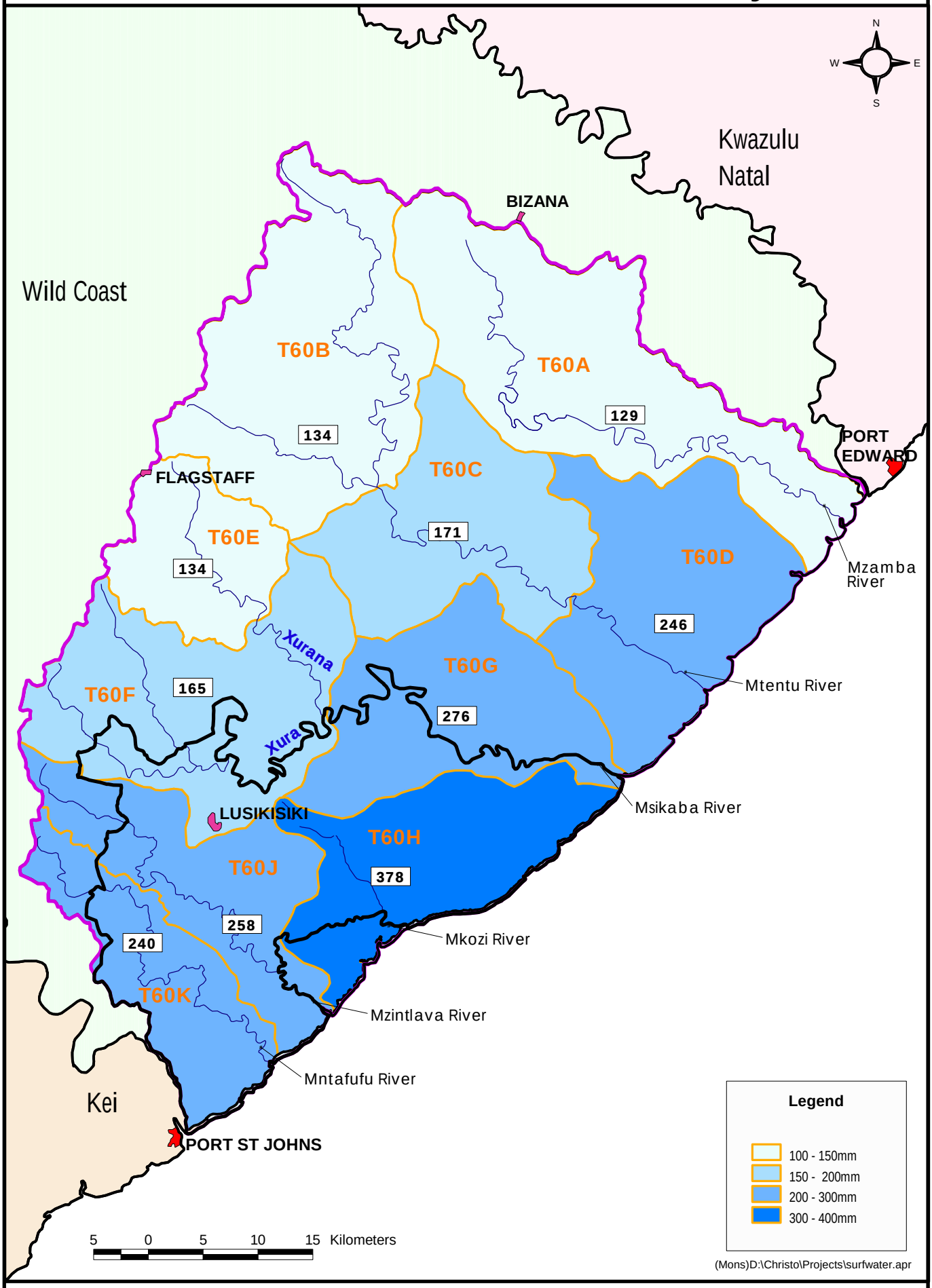


Fig 14 : Virgin Mean Annual Runoff

UWP Engineers

The LRWS scheme is located within parts of quaternary catchments T60 G, F, H, J and K, yielding a total combined incremental runoff of 420 million m^3/a (year 2030). The total projected consumptive water requirements for the LRWS scheme at year 2030 are estimated to be 2.5 million m^3/a (see **Section 4**). As seen from the above tables the available surface water runoff outranges the consumptive requirements by an order of magnitude (requirements are less than 2% of the runoff from the Msikaba River alone). It can be concluded that the available surface water resources have more than sufficient capacity for the augmentation of the LRWS scheme, even if a conservative approach regarding the ecological reserve requirements is applied.

5.2.2 Streamflow Hydrology for Selected Development Sites for the LRWS scheme

As described in detail in **Section 6**, five dam sites and three weir sites have been selected as possible surface water sources to supply the various development options of the LRWS scheme. The position of the selected sites and their catchment areas are illustrated in **Figure 16**. Summaries of the characteristics of the proposed development sites as well as the results of the hydrologic simulation are offered in the following tables. Details regarding the methodology of simulation and the input/output data are available in the supporting report **Streamflow Hydrology**. The methodology for the determination of the ecological riverine reserve (ERR) is outlined in **Section 4.3.2** of this report and is described in detail in the supporting report **Ecological Riverine Reserve Estimate.**

Table 5.2.2A: Catchment Areas for the Proposed Development Sites

Site name	River	Total Dam Catchment area (km^2)	Quaternary (km^2)		Quaternary area split by dam site (km^2)	
			No	Area	Up stream	Down stream
Zalu dam	Xura/Msikaba	71	T60F	464	71	393
Lusikisiki dam/weir	Xura/Msikaba	91	T60F	464	91	373
Xura dam/weir	Xura/Msikaba	225	T60F	464	225	239
Lower Mzintlava dam/weir	Mzintlava	98	T60J	294	98	196
Tungwane dam	Mzintlava	129	T60J	294	129	165

Table 5.2.2B: Hydrological Characteristics for Proposed Sites

Site name	MAP upstream (mm)	MAP downstream (mm)	Virgin MAR (10^6m^3)	Present MAR (10^6m^3)	ERR (10^6m^3)	Present MAR- ERR (10^6m^3)
Zalu dam	940	940	12.10	11.45	2.79	8.66
Lusikisiki dam/weir	940	940	15.51	14.76	3.69	11.07
Xura dam/weir	940	940	38.35	37.35	11.07	26.28
Lower Mzintlava dam/weir	975	1200	17.06	16.93	4.20	12.73
Tungwane dam	950	1177	24.20	23.44	7.74	15.70

As seen from the above table, the present day runoff from each proposed development site, after allowance for ecological reserve releases exceeds substantially the total estimated water requirements for the LRWS scheme (2.3 million m^3/a at year 2020).

SECTION B: RECONNAISSANCE PLANNING STUDY

6. IDENTIFICATION OF DEVELOPMENT OPTIONS

6.1 OUTLINE OF PLANNING CONSIDERATIONS

All development options described in this report have been sized to supply the "low demand scenario" (**Section 4.1.4**) for the entire study area (the existing scheme and its proposed extensions – phases 1, 2 and 3), as a regional scheme. However, the sensitivity of the results has been tested for variations demand scenarios.

The topography of the region allows the entire study area to be supplied by gravity from a single bulk reservoir located close to the town, between the Msikaba and Mzintlava rivers (Reservoir A or Reservoir B, **Figure 15**). The development of a regional scheme will be preferable from O&M point of view, considering the poor access in the study area as well as the lack of sufficient capacity within the local authorities. The augmentation of the bulk water supply for a regional scheme only has been investigated during this study, although multiple water sources have been considered for certain options.

The surface water resources in the area have ample capacity to supply the LRWS scheme. The area is drained by three main systems – the Msikaba, Mzintlava and Mntafufu rivers, any of which can be used as a surface water source for augmentation. This is however subject to the existence of feasible dam sites or sufficient assured yields from run of river. The largest portion of the proposed scheme (**Figure 15**), which includes the area presently supplied by the LRWSS as well as the existing infrastructure (treatment works and bulk reservoirs) falls between the Msikaba and Mzintlava rivers. Water sources located on these two rivers will allow shorter conveyance routes to the existing infrastructure and bulk reservoirs, and the schemes are likely to be more cost efficient. In addition, the riverbed elevations of the Msikaba and Mzintlava rivers are more favourable in terms of required pumping heads compared to the other rivers in the area such as the Mntafufu, Mkozi and all other smaller rivers in drainage region T60H (**Figure 5**).

Due to the high ecological reserve requirements and considerable seasonable variability of runoff, the available run of river yields (**Section 7.2**) from any one of the main rivers are insufficient to supply the demands of the study area at the required assurance levels (98%), through a single run of river scheme. The water requirements can however be met from either a single storage dam, or from a scheme comprising a number of run of river abstractions feeding the regional scheme.

The groundwater development potential of the study area is considered to be moderate. The feasibility of the development of groundwater may however be limited by problems related to accessibility, low average yields per borehole, deep water tables and O&M complications associated with multiple supply nodes. When considering the high surface water potential, groundwater would probably not be feasible as a stand-alone option for the supply of a regional scheme. Groundwater sources can however be efficiently used in conjunction with surface water sources.

Eastern Pondoland Basin Study

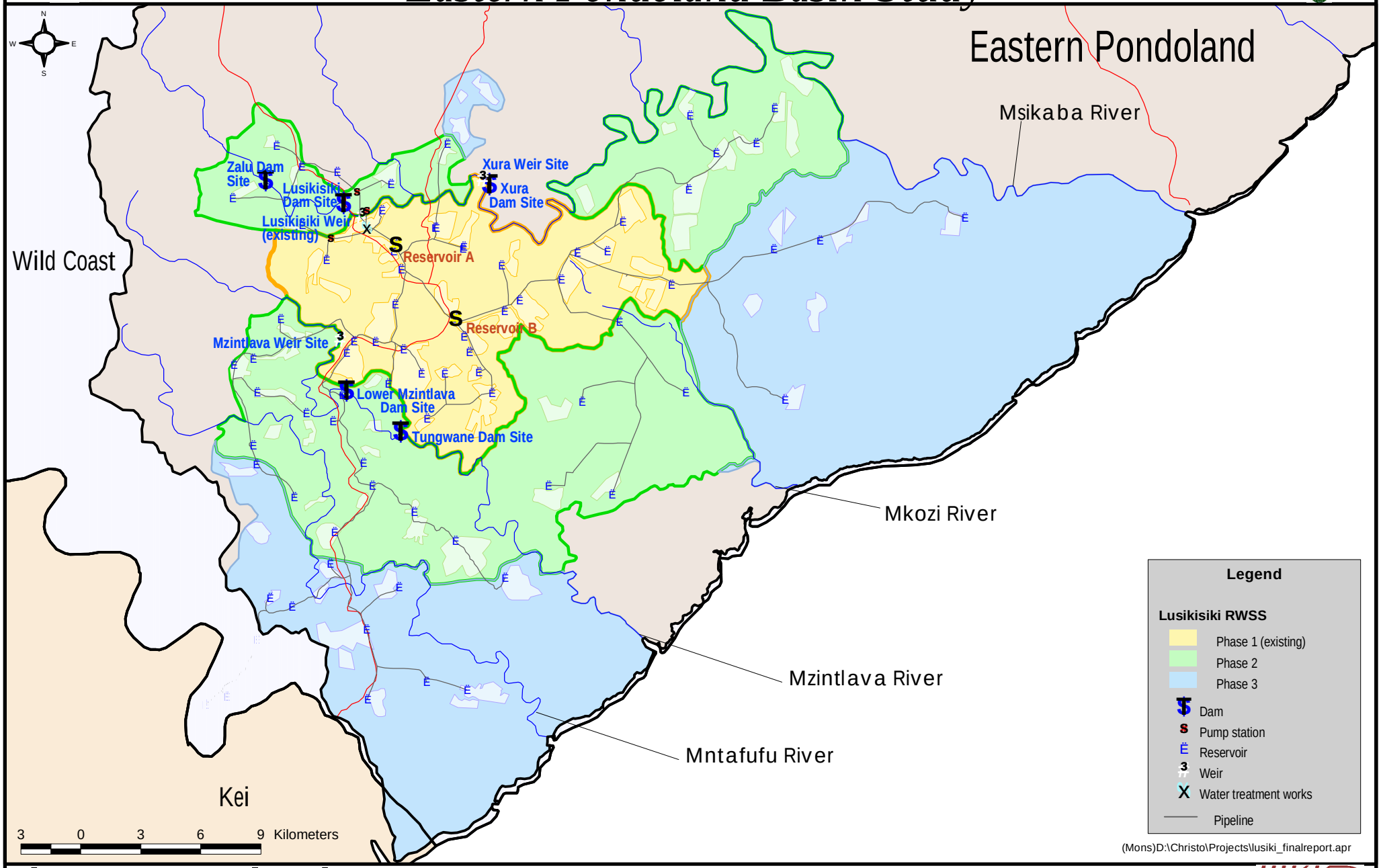


Fig 15 : Area Planning

UWP Engineers

6.2 WATER SOURCE

The following main categories of water source options have been investigated during this study. A number of sub-options for each category have been evaluated:

- **Surface storage (dams):** Five technically viable dam sites have been identified, investigated and evaluated. Each dam option will be able to supply the area as a stand-alone scheme from a single water source. The assurance of supply will in all cases be above the required minimum of 98%. These options have definite O&M advantages, but require significant initial capital investment.
- **Run of river (weirs):** Three weirs, combined into a single scheme to be implemented in phases, have been considered as an option for augmentation of the water supply. This option offers the advantage of phased development, but will have the disadvantage of higher O&M costs associated with a multiple water source scheme. As discussed further in the report, the total combined available yield can meet the design requirements only at 80% assurance of supply. This option can therefore only be considered for implementation, if lower assurance levels are acceptable.
- **Conjunctive water use (surface and groundwater source combination):** Groundwater developments can be used to supplement the supply from the run of river schemes at times of low flows and in this manner to increase the assurance of supply to acceptable levels. These options offer higher assurance of supply than the run of river schemes, but at higher capital and running cots.
- **Ground water stand alone (boreholes):** The capital requirements for this option can be phased in line with the increasing water requirements, resulting in lower initial capital costs, but the O&M costs are expected to be higher.

6.3 CONVEYANCE SYSTEM

In general, the conveyance system of the LRWS scheme comprises the following main components:

Primary bulk conveyance system

Depending on the water source option considered, the scheme will include all or some of the following components, delivering the abstracted water from the water source to the main system reservoirs (reservoirs A or B, **Figure 15**):

- Raw water pump station (RWPS)
- Raw water rising main (RWRM) or raw water gravity main (RWGM)
- Water treatment works (WTW)
- Clear water pump station (CWPS)
- Clear water rising main (CWRM)
- Main storage reservoirs (MSR)
- Clear water gravity main (CWGM), connecting the MSR to the secondary bulk conveyance system

Secondary bulk conveyance/distribution system

This system distributes the water stored at the main system reservoirs to the secondary storage reservoirs, close to the consumer nodes. The system comprises a network of secondary gravity mains and village reservoirs.

Tertiary distribution system (reticulation)

This system distributes the water from the village reservoirs, through a reticulation network to the user supply nodes - community standpipes in the case of villages, or house and bulk connections in the case of the Lusikisiki town.

Each development option considered in this study includes the relevant water source and the associated primary bulk conveyance system delivering to a main storage reservoir located in the vicinity of the existing reservoirs A or B. The layout of the primary conveyance is specific for each proposed water source development option. The costs associated with the development of the primary conveyance system will therefore affect the overall system cost and may have an influence on the selection of the preferred scheme. Where applicable, provision for the upgrading of the existing primary conveyance system and/or for the development of new infrastructure has been made.

In the case of the groundwater supply options, it has been assumed that the boreholes will discharge into small storage reservoirs positioned at command locations, and then connected to the secondary bulk conveyance system.

The costs associated with the upgrading and extensions of the secondary and tertiary distribution systems will not influence the selection of the source development options, and have therefore not been considered during this study.

6.4 IDENTIFICATION OF DAM AND WEIR SITES

In general, the area is not ideal for the development of dams. The longitudinal slopes of the rivers are relatively steep, the geological conditions are not always favourable, the access to sites is generally problematic and the area is environmentally sensitive.

The Xura and Mzintlava Rivers and their main tributaries in the vicinity of the study area were scanned for feasible dam sites using existing topographical maps (1:10 000 or 1:50 000). A number of potential sites were identified and evaluated using a rapid method on the basis of the following criteria: impoundment parameters, wall volume, distance to bulk reservoirs, required pumping heads, accessibility, etc. A digital elevation model in ArcView GIS together with a specialised sub-routine enabled the rapid determination of surface areas and inundated capacities for various dam wall heights. Approximately 30 sites within a 20 km radius of the existing main storage reservoirs were evaluated. Five dam sites Zalu, Lusikisiki and Xura on the Xura River, and Lower Mzintlava and Tungwane on the Mzintlava River were selected for further investigations.

The existing Magwa dam (capacity 2.6 million m^3), situated on the Mkozi River (T60H), was initially considered as a possible water source (**Figure 17.7**). This option was dropped from further considerations, taking into account that the dam has a catchment area of only 5.5 km^2 (low yield), that it is unfavourably located (in terms of distance and elevation in relation to the command reservoirs) and that its water is dedicated for emergency irrigation to the Magwa Tea Estate (the only major economic development node in the area).

Three weir sites on the Xura and Mzintlava Rivers were selected as possible run of river sources on the basis of catchment size/yield, topography and location in relation to the command nodes.

The position of the selected surface water source sites is shown on **Figures 16, 17.1 and 18,** and their technical parameters are offered in **Table 6.2.**

Eastern Pondoland Basin Study

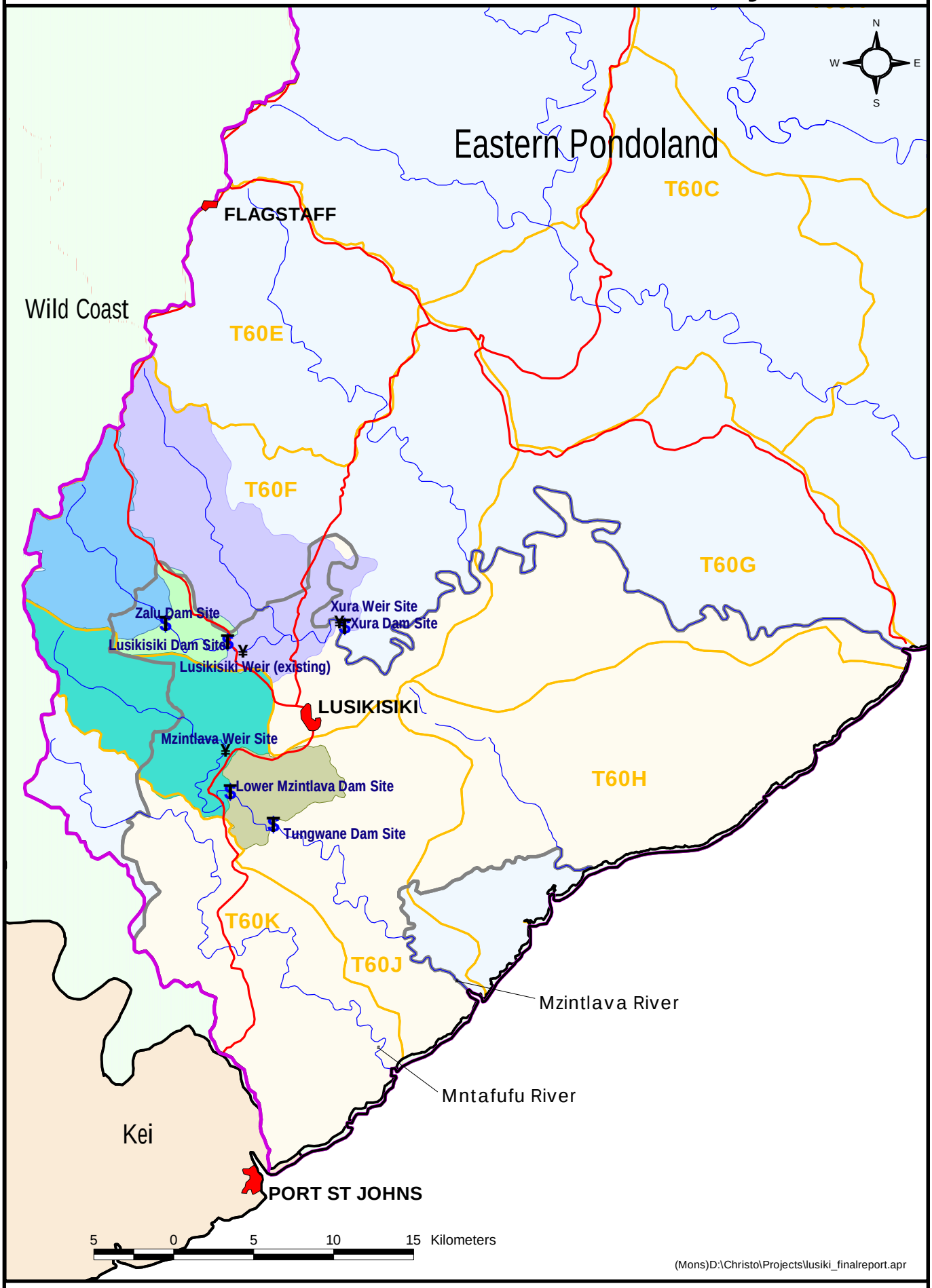


Fig 16 : Proposed Dam and Weir Sites

UWP Engineers

Table 6.4: Characteristics of Selected Dam and Weir Sites

Characteristic	Dam sites					Weir sites		
	Zalu	**Lusikisiki**	**Xura**	**Lower Mzintlava**	**Tungwane**	**Lusikisiki (existing)**	**Xura**	**Mzintlava**
Structure type (reconnaissance level)	Rollcrete concrete structure	Rollcrete concrete structure	Composite: embankment flanks	Composite: embankment flanks	Composite: concr. L flank; earth R flank	Mass concrete structure	Mass concrete structure	Mass concrete structure
Spillway type	Central concrete overspill	Central concrete overspill	Central concrete overtop chute	Central concrete overtop chute	Central concrete spillway	Central concrete overtop	Central concrete overtop	Central concrete overtop
Latitude	31°18'50"	31°19'25"	31°18'55"	31°24'25"	31°25'30"	31°19'39"	31°18'55"	31°22'58"
Longitude	29°28'40"	29°31'10"	29°35'35"	29°31'22"	29°33'30"	29°31'36"	29°35'35"	29°31'02"
River	Xura	Xura	Xura	Mzintlava	Mzintlava	Xura	Xura	Mzintlava
Catchment area (km^2)	71	91	225	98	129	92	225	78
Virgin MAR at dam site ($10^6 m^3/a$)	12.10	15.51	38.35	17.06	24.20	15.51	38.35	17.06
Present MAR at dam site ($10^6 m^3/a$)	11.45	14.76	37.35	16.93	23.44	14.76	37.35	16.93
Ecological riverine requirement $10^6 m^3/a$	2.79	3.69	11.07	4.20	7.74	3.69	11.07	4.20
Present MAR – IFR ($10^6 m^3/a$)	8.66	11.07	26.28	12.73	15.70	11.07	26.28	12.73
Regional maximum flood (m^3/s)	1090	1250	2520	1715	1955	1250	2520	1715
20-year sediment load (80% confidence) ($10^6 m^3$)	0.8	1.0	2.24	1.04	1.36	1.0	2.24	0.83
River bed level (msl)	586	535	449	409	358	530	449	454

7. YIELDS, FLOODS AND SEDIMENTATION

7.1 YIELD ANALYSIS FOR PROPOSED DAM SITES (RECON.)

Five dam sites have been identified for investigation during the reconnaissance phase of the study – Zalu, Lusikisiki, Xura, Lower Mzintlava and Tungwane. The first three sites are on the Xura River and the latter two on the Mzintlava River (**Figure 16**).

The yield analyses for the proposed dams were initially performed by means of the YIELD program without taking into consideration the ecological requirements. The selected range of yield requirements was then modelled with the Water Resources Yield Model (WRYM). The simulated historical inflow sequences for the present (2000) conditions were used. The analyses were undertaken for two options, with and without provision for ecological riverine reserve releases. Scenarios for accommodation of sediment yields with various return periods and design horizons (50 and 20 years) were considered. More details about the methodology applied during the analyses are offered in the supporting report **Streamflow Yield Analyses.**

The area capacity relationships for the proposed dam sites were derived from 1:10 000 maps (contour intervals of 5m) for all sites except Lusikisiki site. For a portion of the basin at the Lusikisiki site, the curve was extended utilising the 1:50 000 topographic maps, since more detailed maps were not available at the time of the reconnaissance investigations. More accurate area-capacity curves, based on aerial surveys of the dam basins for Zalu and Lusikisiki dams were produced during the pre-feasibility stage and are available in **Section C**. The area-capacity relationships used during the reconnaissance stage are offered in tabulated format in **Table 7.1A** and in graphical format in **Appendix D**. The yield-capacity relationships for each dam are provided in tabulated format in **Table 7.1B**. The yield-capacity curves for selected dams are shown in **Graph 8.1** and more detailed graphs are attached in **Appendix E**.

Table 7.1A: Area-capacity-elevation Relationships for Proposed Dam Sites (Recon)

Elevation (msl)	Area km^2	Capacity $10^6 m^3$	Elevation (msl)	Area km^2	Capacity $10^6 m^3$
Zalu Dam			**Lusikisiki Dam**		
620	1.430	16.500	567.0	1.517	15.271
615	1.010	10.300	560.5	1.150	7.541
610	0.690	6.100	555.5	0.579	3.218
605	0.480	3.300	550.5	0.245	1.160
600	0.280	1.300	545.5	0.085	0.335
595	0.130	0.300	540.5	0.021	0.070
590	0.050	0.100	535.5	0.005	0.010
586	River bed level		535.0	River bed level	

Elevation (msl)	Area km^2	Capacity 10^6m^3
Xura Dam		
470	1.413	10.595
465	0.756	5.172
460	0.442	2.178
455	0.141	0.720
450	0.049	0.245
449	River bed level	
Tungwane Dam		
395	6.733	15.754
385	3.502	7.254
380	1.590	4.279
375	0.628	2.154
370	0.213	0.874
365	0.036	0.242
360	0.014	0.014
358	River bed level	

Elevation (msl)	Area km^2	Capacity 10^6m^3
Lower Mzintlava Dam		
440	1.990	12.982
435	0.824	6.733
430	0.496	3.502
425	0.278	1.590
420	0.118	0.628
415	0.056	0.213
410	0.018	0.036
409	River bed level	

Table 7.1B: Yield capacity relationships (recon). No sediment load considered

Zalu Dam Site		
Capacity	**Yield**	
	No prov. for IFR	**With prov. for IFR**
10^6m^3	10^6m^3	10^6m^3
25.00	9.24	6.56
16.08	8.14	5.97
12.06	7.17	4.98
8.04	6.01	3.98
4.82	5.02	3.19
1.61	3.20	1.71
Xura Dam Site		
19.65	18.69	10.75
13.10	15.11	9.05
6.55	11.42	5.94
2.10	7.91	3.54
1.60	*	3.20
0.80	*	2.02
Tungwane Dam Site		
28.68	15.58	10.78
20.66	13.63	8.71
12.64	11.32	6.67
4.62	7.53	4.10
1.00	*	2.02

Lusikisiki Dam Site		
Capacity	**Yield**	
	No prov. for IFR	**With prov. for IFR**
10^6m^3	10^6m^3	10^6m^3
45.70	12.68	9.2
34.28	12.05	8.57
22.85	11.05	7.97
13.71	8.79	6.04
4.57	5.6	3.63
1.37	3.74	1.89
Lower Mzintlava Dam Site		
10.38	8.39	5.62
7.14	7.48	4.76
4.13	5.74	3.78
2.40	*	3.01
1.00	*	1.98

* Point not modeled

7.2 LOW FLOW YIELD ANALYSES FOR PROPOSED WEIR SITES

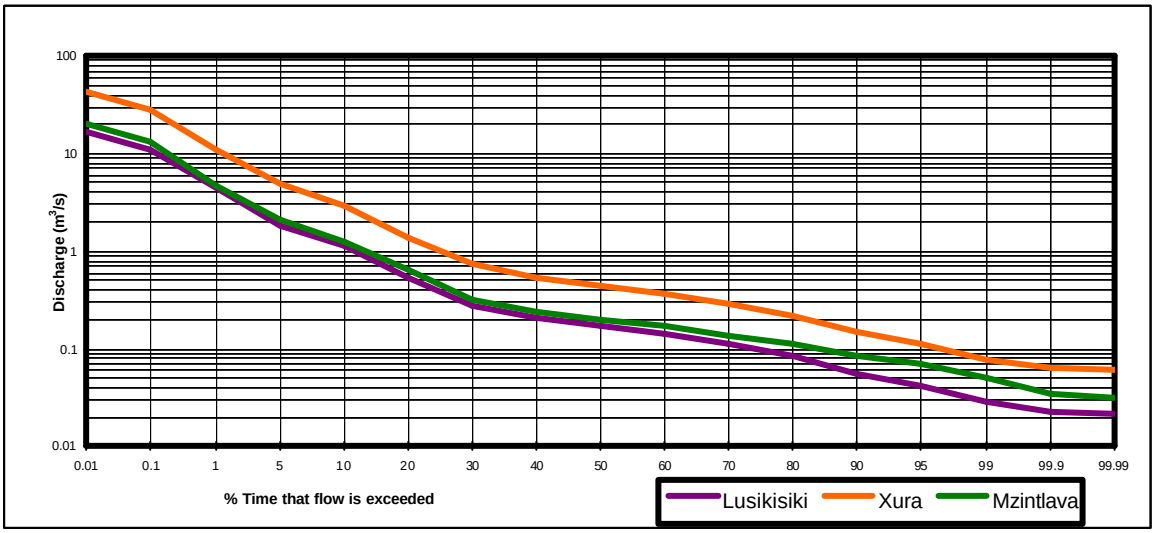
Low flow analyses for three proposed weir sites were performed with the aim of assessing the applicability of supplying the scheme by run of river (non-regulated) flows. "One-day" Flow Duration Curves (FDCs) were generated using a rapid method developed by Dr V Smakhtin (CSIR). Applying certain assumptions, the model uses the simulated monthly flow series to generate daily flow sequences. The assurance of supply of various flows on monthly and on an annual basis is then estimated. A detailed description of the methodology used, as well as the duration-discharge tables and graphs for each site are attached in **Appendix C.**

A summary of the estimated low flows at the three sites with and without provisions for ecological riverine Reserve (ERR) or as previously named instream flow requirements (IFR) is shown in the following table. The flow duration curves for the three weir sites are shown in the following graphs. The annual average daily requirements of the study area at year 2020 are estimated to be 72 l/s, while the summer peak requirements are 94 l/s.

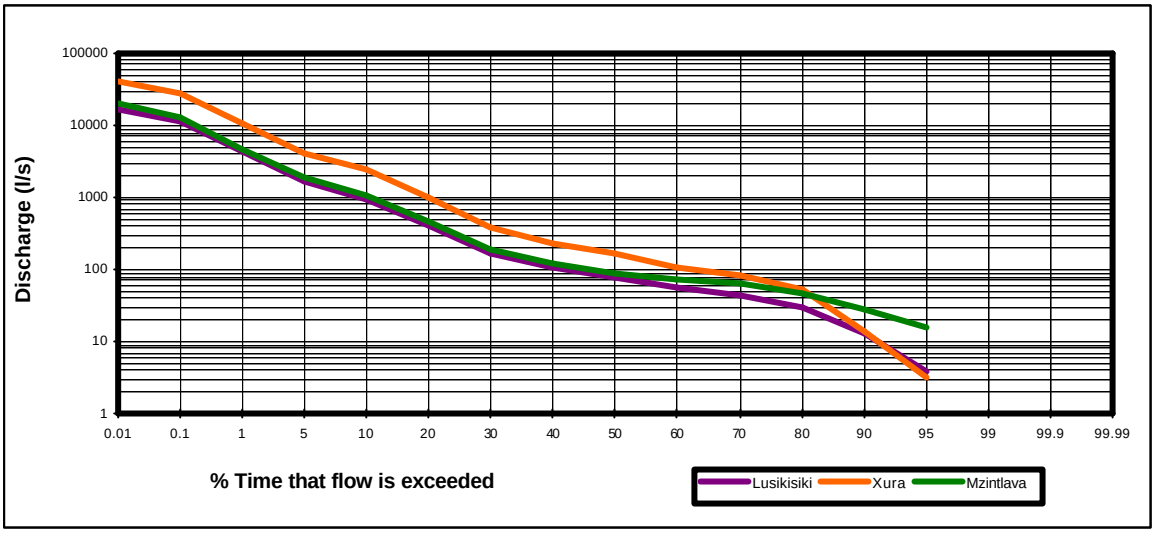
Table 7.2: Summary of estimated Low Flow (Run-of-River) Yields

Weir Site	Provision for ERR	Yield (l/s) at Specific Assurance of Supply (%)						
		98%	95%	90%	80%	70%	60%	50%
Lusikisiki weir (existing)	No	30	42	56	85	114	141	170
	Yes	0	4	12.5	29	43	57	79
Xura weir *	No	80	111	146	217	287	358	438
	Yes	0	4	13	53	84	108	163
Mzintlava weir	No	41	57	70	93	114	139	164
	Yes	0	13	24	39	51	60	74

* The Xura weir site is situated downstream of the Lusikisiki weir. The catchment of the Xura weirs (and the yields thereof) include the catchment of the Lusikisiki weir



Graph 7.2A: Flow Duration Curves, (No provision for ERR)



Graph 7.2B: Flow Duration Curves with Provision for ERR

7.2.1 TIMING FOR AUGMENTATION

The peak water requirements for sizing of a non-regulated water source (run of river), taking into consideration the summer peak factors are as follows:

Table 7.2.1: Net urban and rural peal water requirements for sizing (Low Scenario)

Development phase	Instantaneous sizing water requirements, l/s		
	2000	2010	2020
Phase I (existing scheme)	42	59	67
Phase II (future extension)	-	13	15
Phase III (future extension)	-	-	12
Total	**42**	**73**	**94**

The following conclusions can be made on the basis of tables 7.2 and 7.2.1

- The capacity of the existing bulk supply infrastructure of 32 l/s is insufficient to meet the present water requirements of 42 l/s, and a shortage of about 30% is presently experienced. This infrastructure needs to be upgraded. However, the layout of the upgraded infrastructure would depend on the location of the future water source.
- The bulk water conveyance system should be upgraded irrespective of whether the supply area of the scheme is extended or not. The requirements of the proposed extensions are relatively low when compared with those of the existing scheme. The proposed future extensions may only influence to a limited extent the sizing parameters for upgrading of the bulk infrastructure, but not the decision to implement the upgrading.
- Despite the high MAR from the area, and due to considerable seasonal variability of runoff, the available run of river yields in and around the study area with assurance levels of 98% are low. The release of the ecological Reserve requirements further reduces the remaining low flows available for abstraction (zero at 98% assurance).

- If the ecological Reserve requirements must be released, the capacity of the existing water source (Lusikisiki weir) has to be augmented immediately. This source can supply the present and the year 2020 requirements with assurances of 70% and 50% respectively.

7.3 FLOOD FREQUENCY ANALYSES

More detailed information regarding the floods hydrology for the main rivers in the region, Xura/Msikaba and Mzintlava is offered in two separate supporting reports - **Flood Frequency Analysis: Xura River** and **Mzintlava River** respectively. This section outlines the findings of the investigations.

Empirical and deterministic methods were used for estimation of the flood peaks with various probabilities for each proposed dam site. The relevant catchment parameters were established for each case - catchment area, the longest watercourse, the average catchment steepness, the time of concentration and the mean annual precipitation. The soils in the catchment are largely impermeable with the vegetation type consisting of forest, bush and grassland.

Empirical Methods

The empirical methods MIPI (Midgley and Pitman 1971), HRU 1/71 (Hydrological Research Unit), CAPA (Catchment Parameter), Roberts and TR 137 were used to calculate the flood peaks. The K_e value for the TR 137 method was determined for each site and the adjustment factors (f_{TR137}) were used to estimate the 50 years, 100 years and 200 years flood peaks.

Deterministic Methods

The deterministic methods utilised in the analysis include the Rational, DRH (Direct Runoff Hydrograph) and SUH (Synthetic Unit Hydrograph). Two rainfall stations with reliable data of sufficient length were used. The daily point rainfall values were obtained from the Hydrological Information System (HIS) rainfall database. The Thiessen Polygon method was used to determine the weighted contribution of each station to the average catchment rainfall. The RainCalc3 computer program was used to calculate aerial storm rainfall for the storm durations $^1/_2t_c$, t_c and $2t_c$, and for return periods of 2 to 200 years. The Detflo 99 computer program was then used to calculate flood peaks with the Rational, DRH and SUH methods.

The results derived by the various methods were analysed and the following flood peaks were recommended for sizing of the proposed dams.

Table 7.3: Recommended Design Flood Peaks for the Development Sites (m^3/s)

SITE	STORM DURATION (Hours)	PROBABILITY OF EXCEEDANCE (%)							
		50	20	10	5	2	1	0.5	RMF
Zalu	3.5	55	125	180	240	337	420	505	1 090
Lusikisiki	5.0	60	140	210	285	405	510	622	1 250
Xura	7.0	105	240	360	495	695	850	1060	2 520
L. Mzintlava	5.0	65	155	240	330	470	600	735	1 715
Tungwane	6.0	75	180	275	380	540	690	845	1 955

7.4 SEDIMENT YIELDS

The relative proximity of all the sites to the coastline and the sub tropical climate ensures that the catchments are well vegetated. There is little evidence of land surface erosion in the upper parts of the Lusikisiki catchment. This observation is supported by the available water quality data (**Section 9**), which indicates that the turbidity values are lower than 25 NTU (Nephelometric Turbidity Units). Even after heavy rainfall events no turbidity above 80 NTU has been recorded on the Xura River. The Mzintlava River is likely to have even lower turbidity. Dry weather particle loads are less than 4 g/m^3 and much of this is associated with biological debris.

Upper catchment records at Bambisana Hospital would suggest that even rainy periods generate little suspended material in the Mntafufu River. This may, in part, be attributed to the tendency for villages to be located on the ridges, away from the streams and rivers and the majority of the catchment being well vegetated.

Estimates for sediment yields were made for all proposed dam sites in accordance with the updated Rooseboom maps (WRC Report no. 297/1/92). The dam catchments are located in the sediment yield region number 9, with erodibility indices in the medium range. The standardized average sediment yield within this region is 185 $t/a.km^2$. The yields were estimated for the 20-year and 50-year horizons at various confidence levels. The 20-year horizon and the 80% confidence level were selected for sizing. Based on the preliminary information for the study area it is considered that the values used for sizing are conservative, and the actual sediment yields may be lower. The results are offered in the following table.

Table 7.4: Estimated Sediment Yields at Proposed Development Sites

Return period (confidence level)	Estimated Sediment Yields, $10^6 m^3$				
	Zalu	**Lusikisiki**	**Xura**	**Lower Mzintlava**	**Tungwane**
20-yr (80%)	**0.80**	**1.00**	**2.24**	**1.04**	**1.36**
20-yr (95%)	1.84	2.28	5.16	2.40	3.16
50-yr (80%)	2.00	2.50	5.60	2.60	3.40
50-yr (95%)	4.60	5.70	12.9	6.00	7.90

8. DESCRIPTION OF THE DEVELOPMENT OPTIONS

The planning considerations leading to the identification of the development options are summarised in **Section 6.1**. A summary description of the main components of the development options is offered in **Table 8.3.** The combined layouts of all surface water storage (dams) and run of river (weir) schemes are shown in **Figure 17.1** and **Figure 18** respectively. More detailed layouts for each individual dam scheme are offered in **Figures 17.2 to 17.6**. The existing infrastructure of the LRWS scheme is shown in **Figure 10**. The following sections describe the development schemes considered as options for possible augmentation of the water source for the LRWS. Each scheme consists of a water source (or an number thereof) and the corresponding primary conveyance system connecting the source to the existing distribution network.

8.1 SURFACE WATER STORAGE SCHEMES (DAMS)

All surface water storage options have been sized to meet the total water requirements of the study area as stand-alone schemes. Each option on the Xura/Msikaba River (Northern options) will include the upgrading of the existing water treatment works (WTW) and the clear water pump station (CWPS). In all cases the water will be pumped from the abstraction point to the WTW and then further to a new main storage reservoir located next to the existing reservoir A. The existing capacities of the primary conveyance infrastructure will be utilised and where necessary increased.

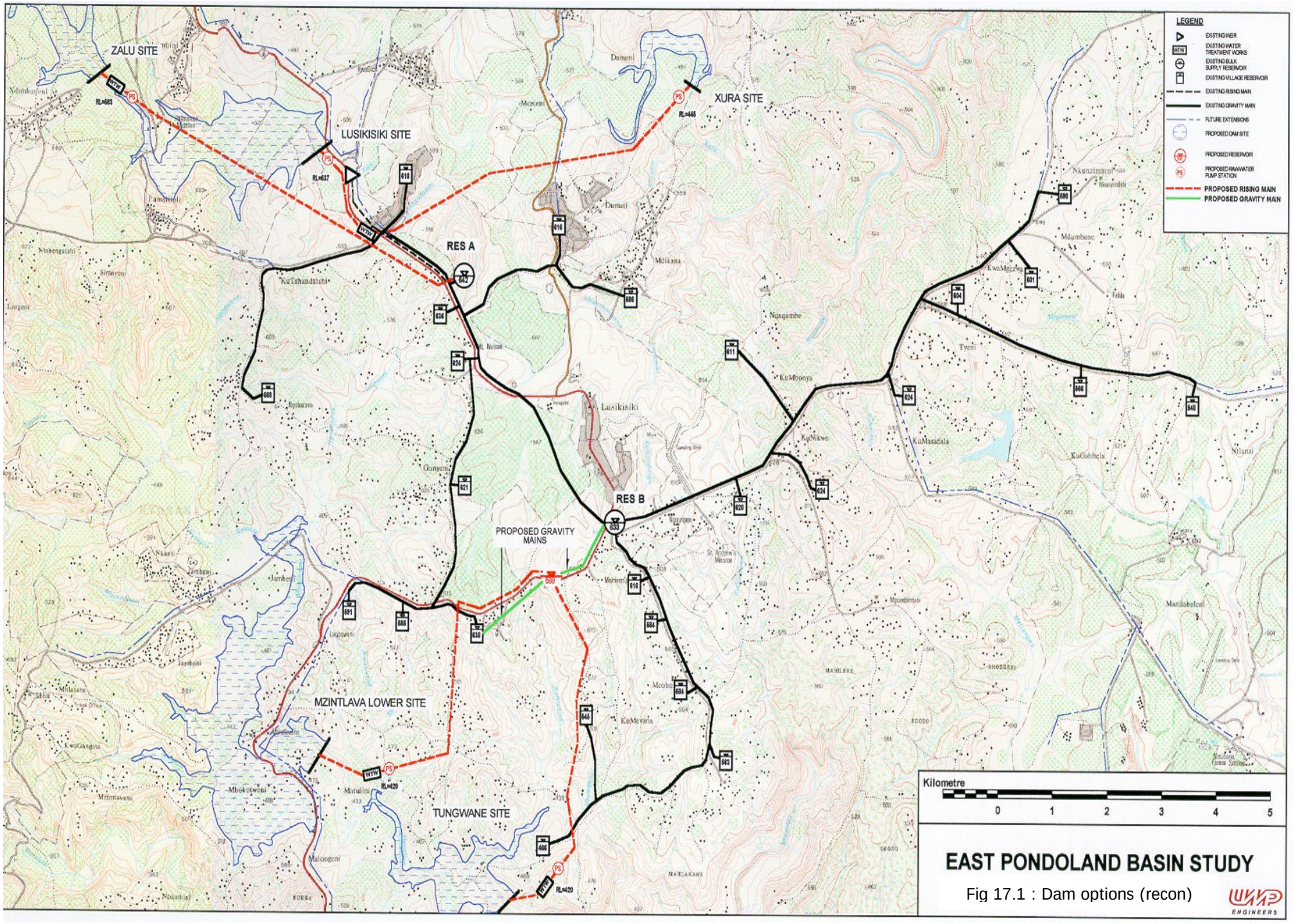
The primary conveyance system for the dam options on the Mzintlava River (Southern schemes) require new primary conveyance infrastructure. This will consist of new raw water pump stations, gravity and rising mains, new water treatment works and new clear water pump stations, all located at the abstraction point. For both options the primary conveyance systems will terminate at a new main storage reservoir, located approximately 3 000 m to the south west of the existing reservoir B. A new clear water gravity main will connect to the secondary conveyance system. In this case the existing primary infrastructure will not be used.

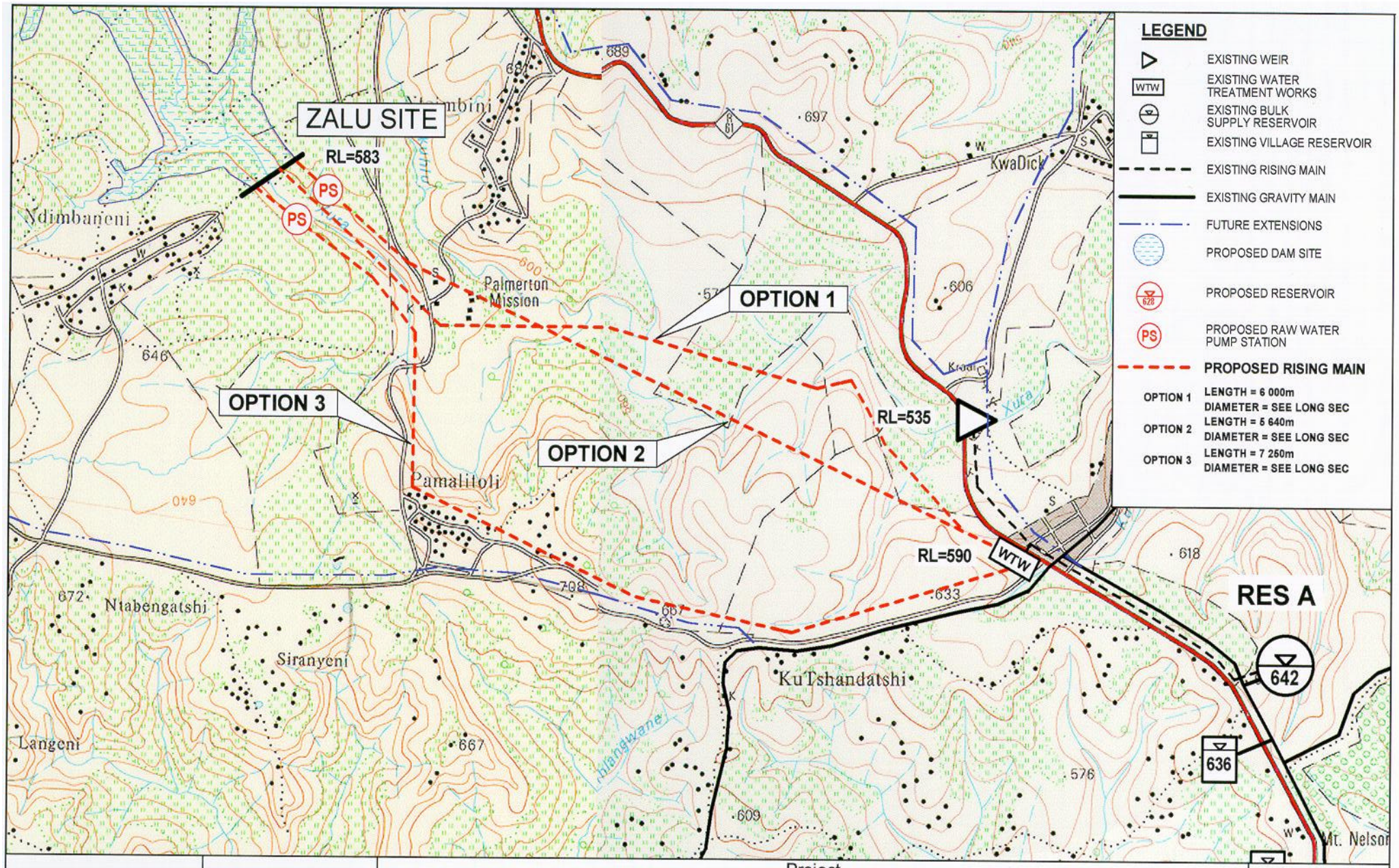
For each southern dam, an additional conveyance option to pump the raw water from the dam outlet to the existing water treatment works at the Xura River site (and thus utilise the capacities of the existing infrastructure) has been considered, but found to be not cost effective.

8.1.1 Options D1A and D1B: Zalu Dam, Xura River (Figure 17.2)

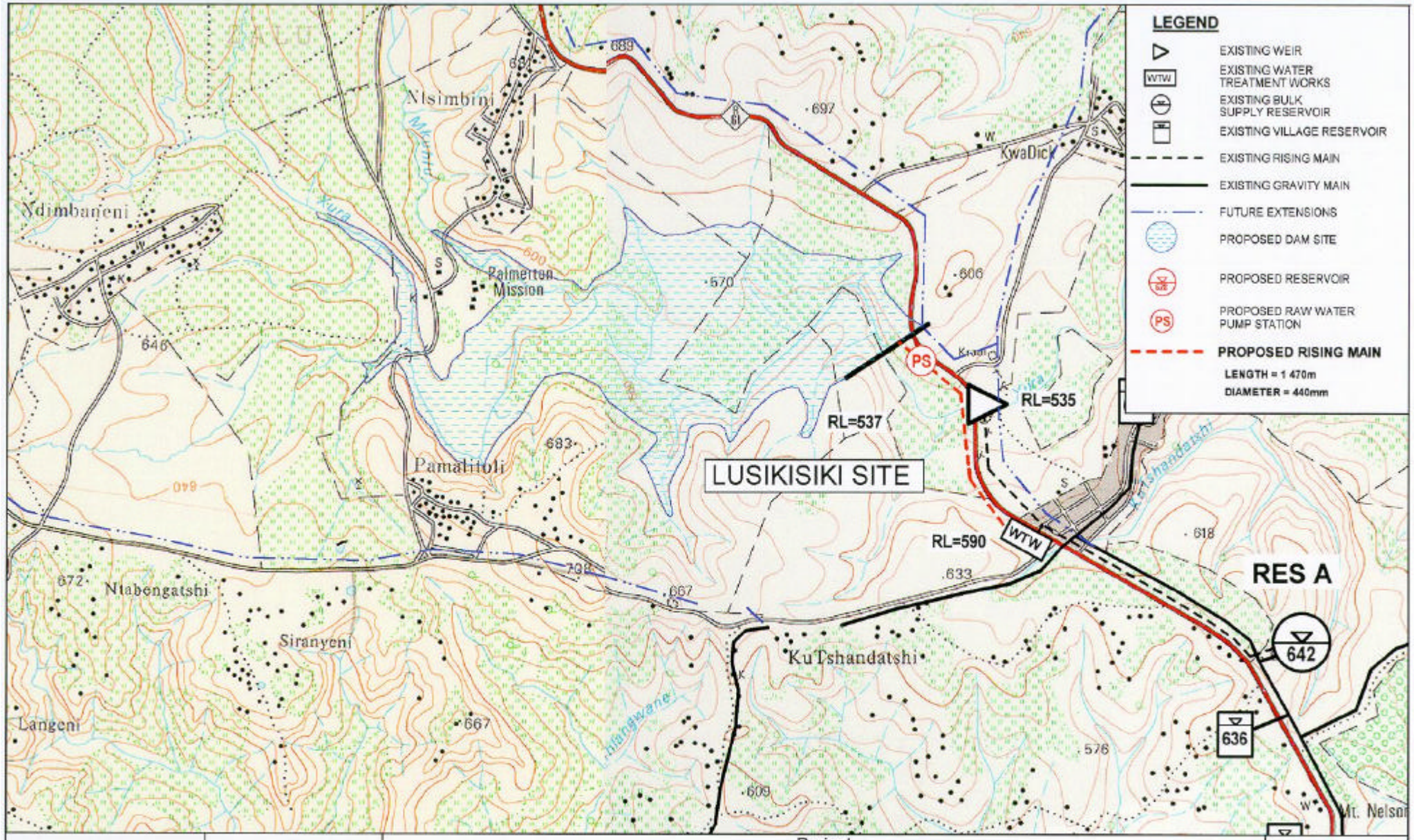
Due to the good founding conditions in the river section a rollcrete dam structure with a central ogee spillway is considered to be the most feasible option for the dam.

Two main options with regards to the conveyance system from the dam outlet to the water treatment works have been considered:

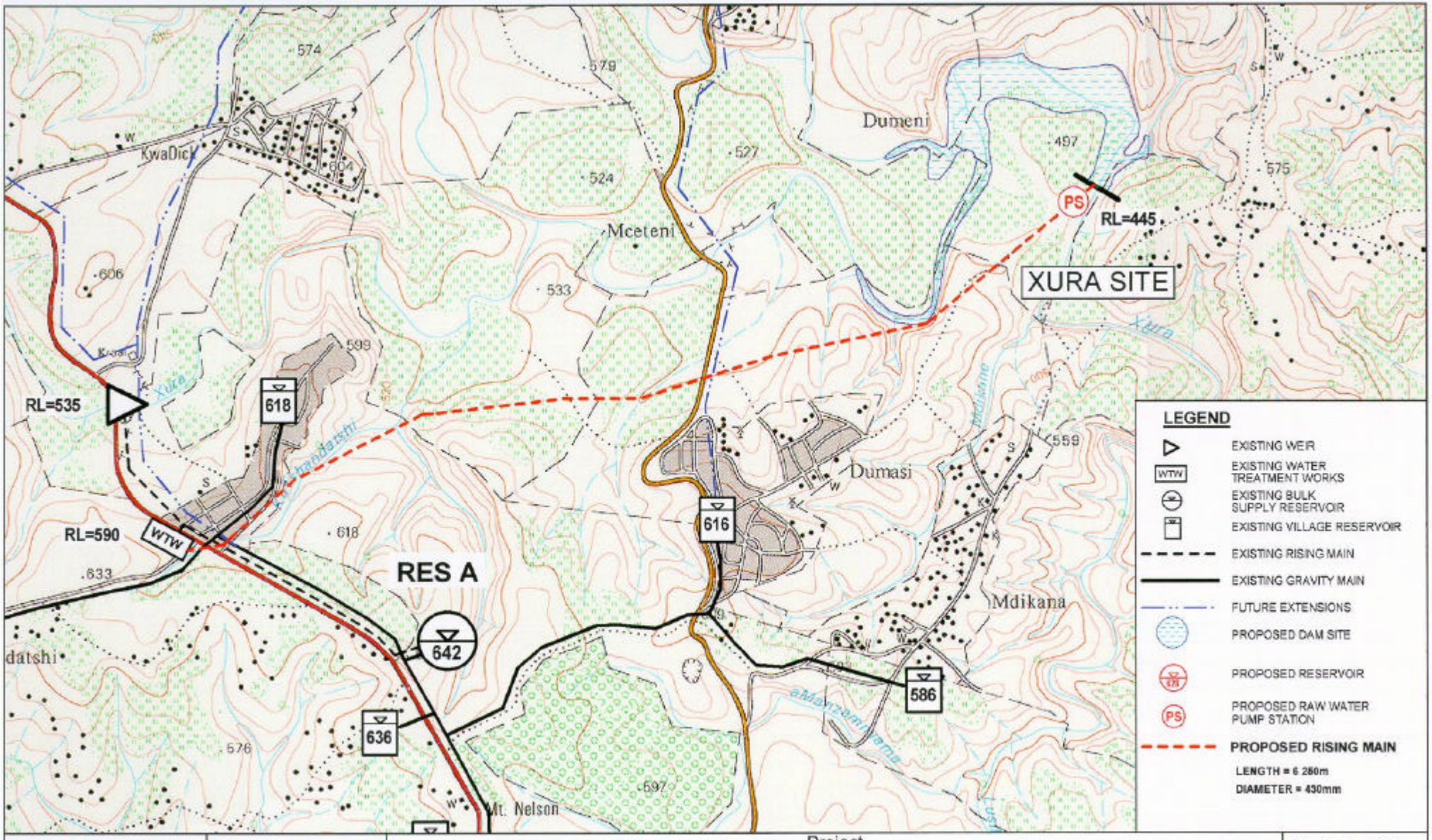

ZALU SITE
LUSIKISIKI SITE
XURA SITE
RES A
RES B
PROPOSED GRAVITY MAINS
MZINTLAVA LOWER SITE
TUNGWANE SITE
LEGEND
EXISTING WEIR
EXISTING WATER TREATMENT WORKS
EXISTING BULK SUPPLY RESERVOIR
EXISTING VILLAGE RESERVOIR
EXISTING RISING MAIN
EXISTING GRAVITY MAIN
FUTURE EXTENSIONS
PROPOSED DAM SITE
PROPOSED RESERVOIR
PROPOSED RAWWATER PUMP STATION
PROPOSED RISING MAIN
PROPOSED GRAVITY MAIN
Kilometre
0 1 2 3 4 5
EAST PONDOLAND BASIN STUDY
Fig 17.1 : Dam options (recon)
ENGINEERS



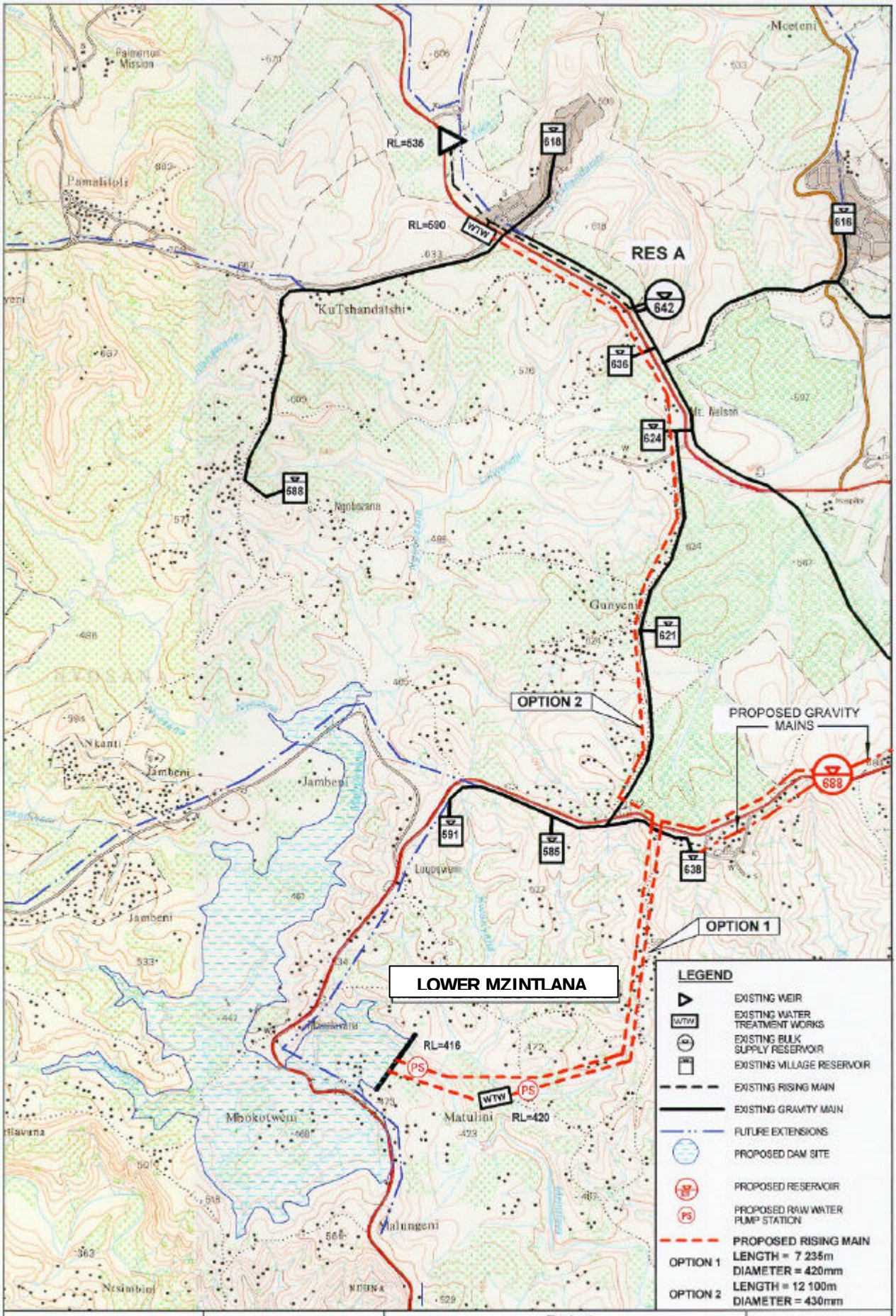
ENGINEERS	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: B.M.B.		Scale: N.T.S.
	Checked: W.S.K.	Description: ZALU DAM SITE (Option D1) PROPOSED BULK CONVEYANCE OPTIONS (Reconnaissance)	No. Fig. 17.2



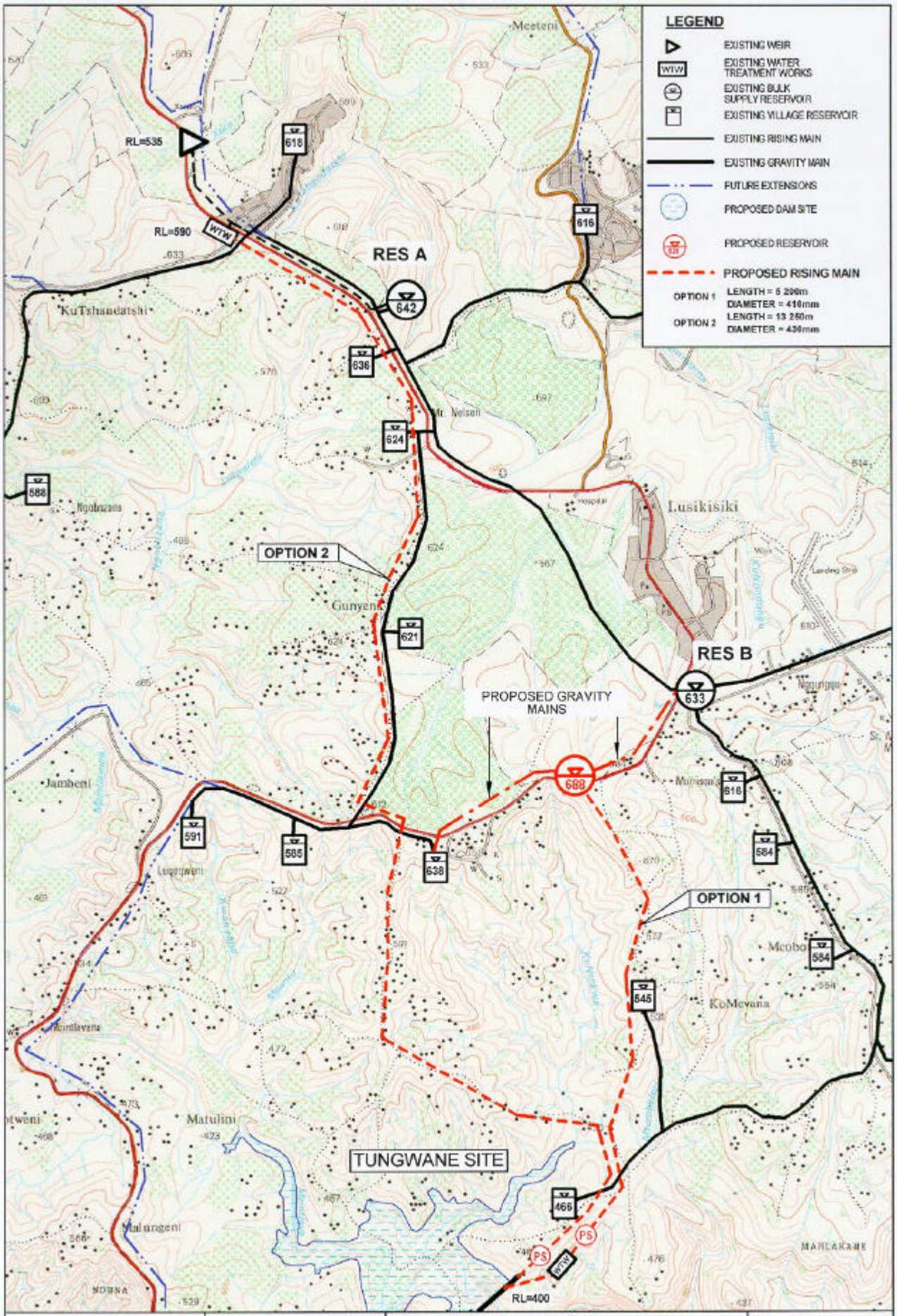
WRP ENGINEERS	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: B.M.B.		Scale: N.T.S.
	Checked: W.S.K.	Description: LUSIKISIKI DAM SITE (Option D2) PROPOSED BULK CONVEYANCE OPTION (Reconnaissance)	No Fig. 17.3



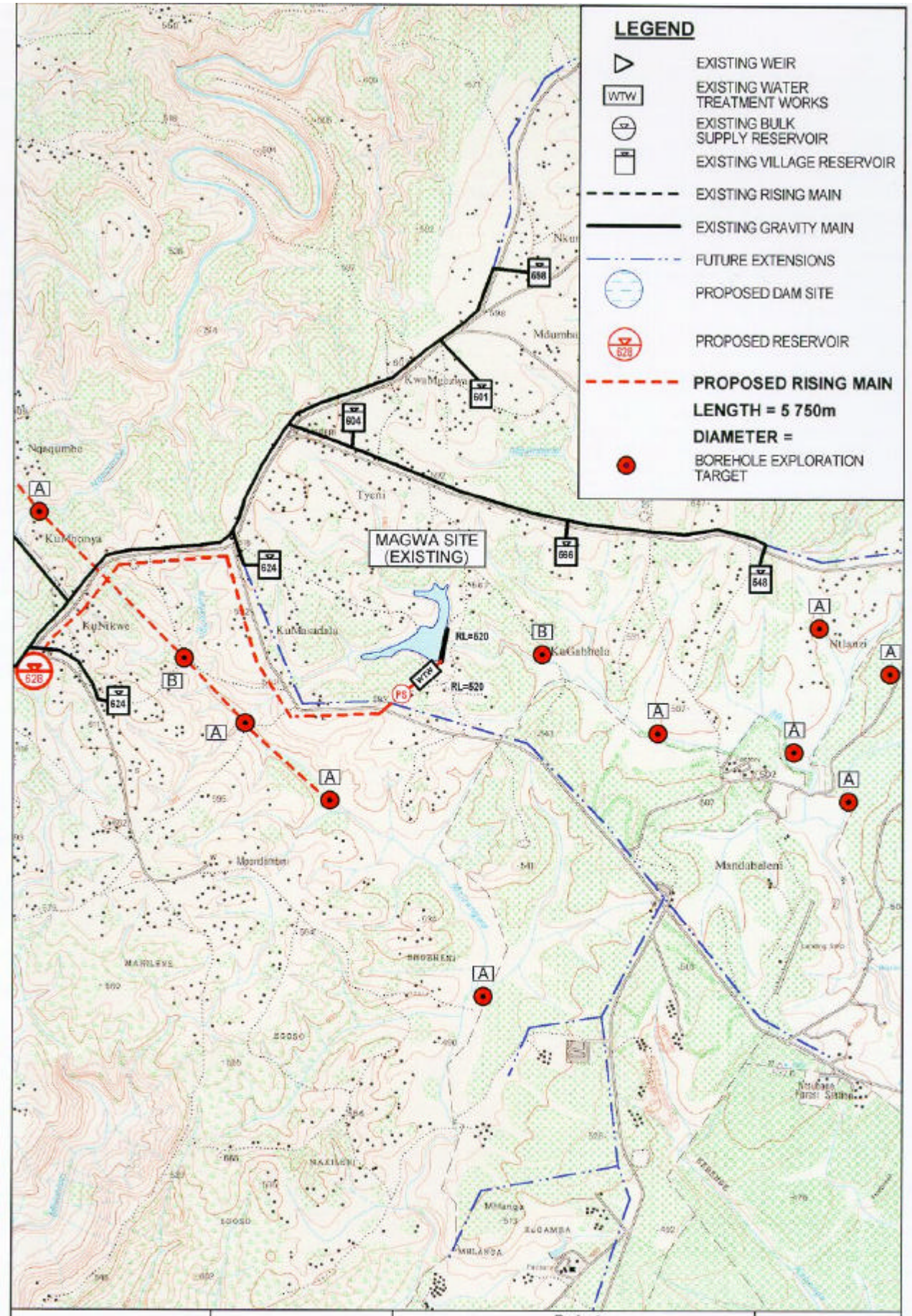
WRP ENGINEERS	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: B.M.B.		Scale: N.T.S.
	Checked: W.S.K.	Description: XURA DAM SITE (Option D3) PROPOSED BULK CONVEYANCE OPTION (Reconnaissance	No. Fig. 17.4



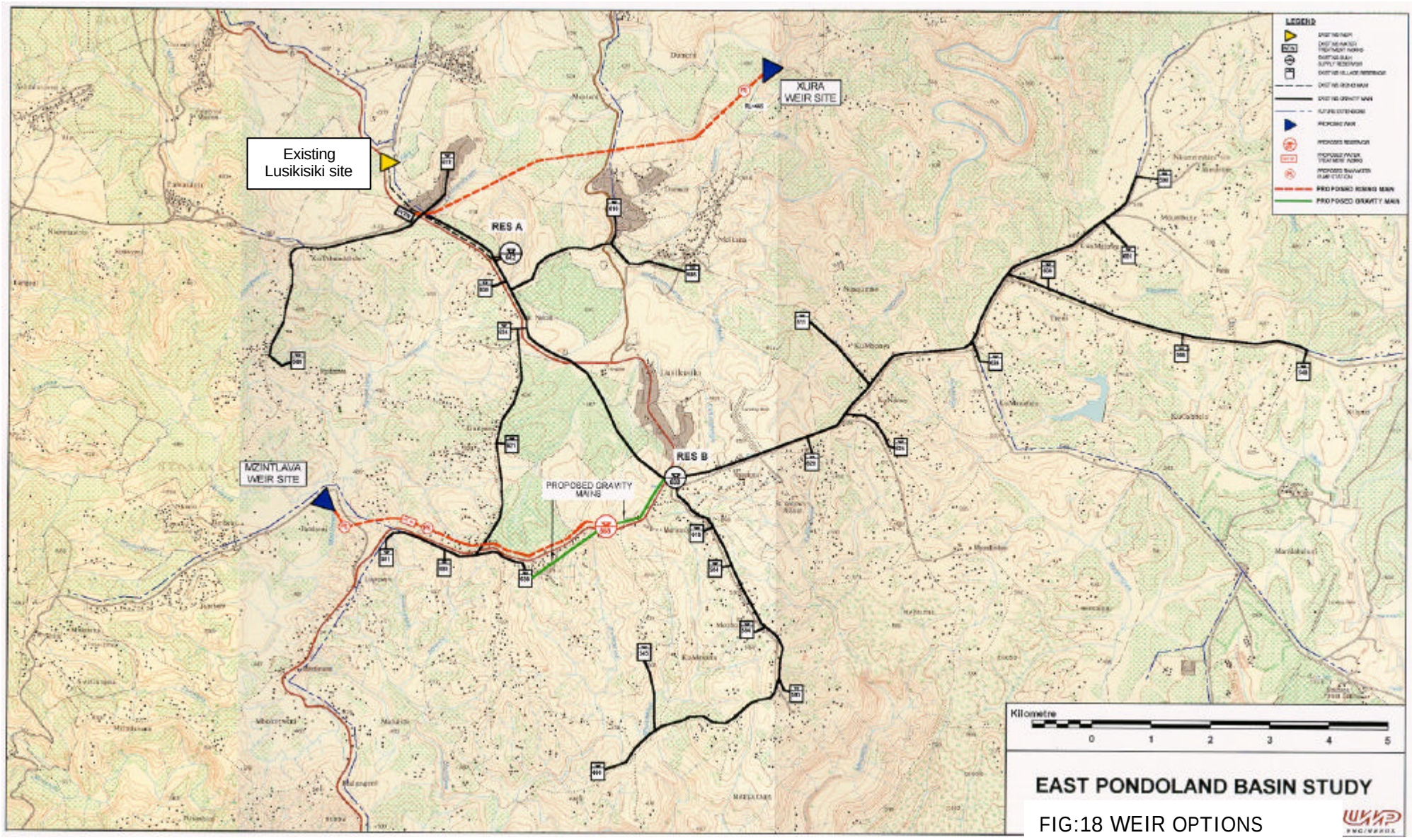
ENGINEERS	Designed: B.M.B.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: B.M.B.	Description: LOWER MZINTLANA DAM SITE (OPTION D) BULK CONVEYANCE OPTIONS (RECON)	Scale: N.T.S.
	Checked: W.S.K.		No. Fig. 17.5



WRP ENGINEERS	Designed: B.M.B.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: B.M.B.	Description: TUNGWANE DAM SITE (OPTION D 5) BULK CONVEYANCE OPTIONS (RECON)	Scale: N.T.S.
	Checked: W.S.K.		No Fig. 17.6



ENGINEERS	Designed: B.M.B.	Project EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: B.M.B.	Description MAGWA DAM SITE (OPTION D6) BULK CONVEYANCE OPTIONS (RECON)	Scale: N.T.S. No Fig. 17.7


Existing
Lusikisiki site
XURA
WEIR SITE
RES A
RES B
MZINTLAVA
WEIR SITE
PROPOSED GRAVITY
MAINS
LEGEND
Kilometre
0
1
2
3
4
5
EAST PONDOLAND BASIN STUDY
FIG:18 WEIR OPTIONS

- **D1A:** The water will be lifted by a new raw water pump station (static head – 6 m), located at the dam outlet works, through a 6 000 m long raw water rising main to the upgraded WTW. An option for conveyance under gravity was also investigated, but found to be unfavourable (due to the small elevation difference between the dam outlet and the WTW the costs associated with a required large-size gravity main are high). A number of possible conveyance routes were evaluated and the best route selected.

- **D1B:** The water will be released into the river and then abstracted at the existing weir site. The raw water will be lifted by the upgraded raw water pump station (static head 52 m) through a 650 m long raw water rising main to the WTW.

In both cases the water is pumped by an upgraded clear water pump station (static head 57 m) from the upgraded water treatment works to a new bulk storage reservoir, through a 2 120 m long clear water rising main.

Zalu dam has been investigated in the past by HKS (1980). Detailed geological and materials investigations have been undertaken, and it has been proposed that an embankment dam with a gross storage capacity of 13.69 million m^3 be constructed. The dam has been sized to supply the domestic requirements for the town of Lusikisiki and five administrative areas (Zalu, Ngobozana, Mevena, Dubana, Xura), as well as the irrigation requirements for an area of approximately 430 ha.

8.1.2 Option D2: Lusikisiki Dam, Xura River (Figure 17.3)

Depending on the height of the wall, the expected geological conditions will favour a composite dam (above 30 m) with concrete central spillway and left flank, and earth embankment right flank, or alternatively a mass concrete structure (below 30 m). This dam was sized as a rollcrete structure during the reconnaissance stage, for the purposes of obtaining first-order cost estimates. Based on more detailed geological information, this was revised during the pre-feasibility stage, and a composite structure was selected. A number of possible centre line locations were evaluated.

The water will be lifted by a new raw water pump station (static head 40 m), located at the dam outlet works, through a 1 470 m long new raw water rising main to the upgraded water treatment works. The conveyance system between the water treatment works and the new main reservoir is identical to this described for option D1.

8.1.3 Option D3: Xura Dam, Xura/Msikaba River (Figure 17.4)

The expected deeply weathered flanks and the good founding conditions in the river section would favour the construction of a composite dam. The dam has been sized for earthfill embankment flanks with a central concrete section with a horseshoe shaped chute spillway.

The water will be lifted by a raw water pump station (static head 141 m), located at the dam outlet works, trough a 6 250 m long raw water rising main to the upgraded water treatment works. The conveyance system between the water treatment works and the new main reservoir is identical to this described for option D1.

8.1.4 Option D4: Lower Mzintlava Dam, Mzintlava River (Figure 17.5)

The geology and the topography of the site favour the construction of a composite dam with embankment flanks, a central concrete section with a horseshoe shaped chute spillway.

The primary conveyance system consists of a raw water gravity main (1 450 m) delivering to the new water treatment works. From there, the water will be pumped by a clear water pump station (static head 268 m) through a clear water rising main (5 800 m) to the new main storage reservoir located to the south-west of the existing Reservoir B. The reservoir will be connected to the existing system by a clear water gravity main (3 000 m).

8.1.5 Option D5: Tungwane Dam, Mzintlava River (Figure 17.6)

The geology and the topography of the site favour the construction of a composite dam with an earth embankment right flank, and rollcrete central section and left flank, accommodating a central spillway.

The primary conveyance system consists of a raw water gravity main (1 400 m) delivering to the new water treatment works. From there the water will be pumped by a clear water pump station (static head 286 m) through a clear water rising main (3 800 m) to the new main storage reservoir located to the south-west of the existing Reservoir B. Similarly to option D4, the new reservoir will be connected to the existing system by a clear water gravity main (3 000) m.

8.2 SURFACE WATER RUN OF RIVER SCHEMES (WEIRS)

Option W1: Lusikisiki, Xura and Mzintlava Weirs (80% assurance) (Figure 18)

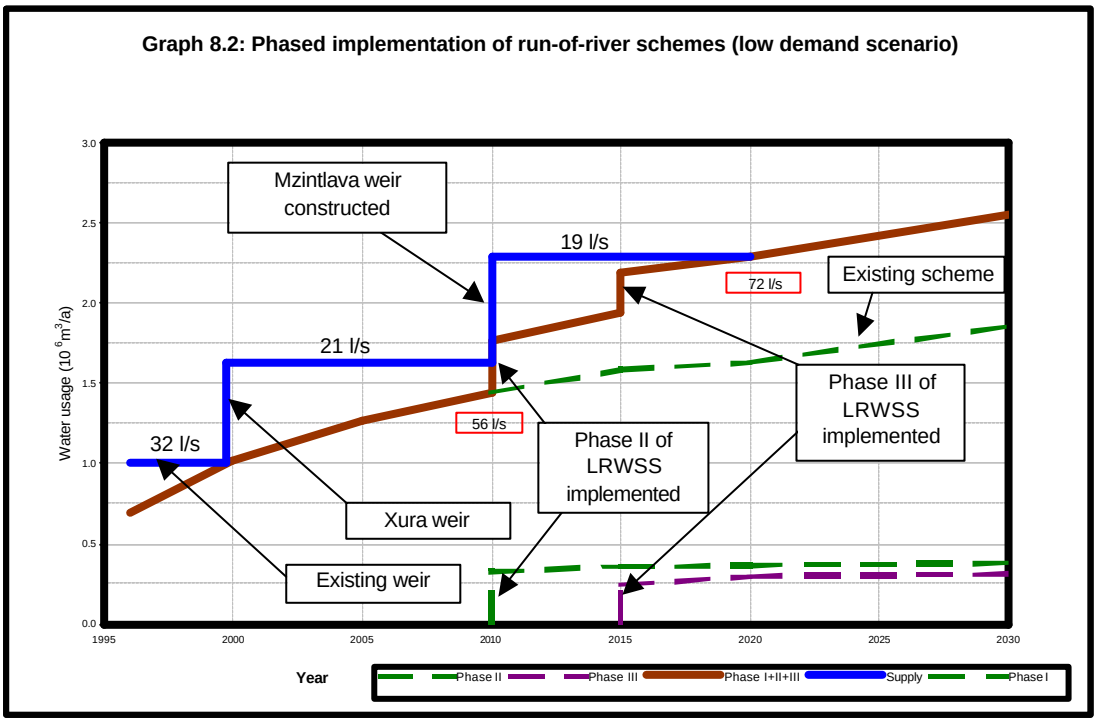
Three weir sites have been identified as possible run of river abstraction sources. The methodology used for low flow analysis and the yields associated with various assurance levels are discussed in **Section 7.2**. The total combined yield of the three schemes, after the release of the ecological reserve requirements is estimated to be 92 l/s (at 80% assurance) and 37 l/s (at 90 % assurance) and 0 at 98% assurance. The total water requirements of the scheme at year 2020 are estimated to be 72 l/s (annual average demand) and 94 l/s (summer peak demand). It is evident that none of the weir sites can meet the total requirements on their own, and that a scheme combining the yields of the three weirs can meet the requirements only with an assurance of 80%. This option can only be considered for implementation, if lower assurance levels are acceptable.

The implementation of the scheme can be phased to follow the projected demands curve, as shown on **Graph 8.2**. It is proposed that the Xura weir be built first, followed by the Mzintlava weir. The Lusikisiki (existing) weir alone will be able to meet the 2020 requirements approximately 50% of the time, while the combined yields of the Lusikisiki and Xura sites will meet these requirements approximately 70% of the time. The Mzintlava weir will be required to operate only about 30% of the time to supplement the yields of the other two weirs. In order to provide for a maximum utilisation of the existing infrastructure, as well as to reduce the O&M costs the primary conveyance system should be sized as follows:

Lusikisiki weir infrastructure (design flow 72 l/s net)**:** The existing raw water pump station (static head 52 m), raw water rising main (650 m), and the existing water treatment works, clear water pump station (static head 57 m) and clear water raising main (2 120 m) will be upgraded to convey the full scheme requirements. In this case the entire area can be supplied from one scheme during times of high flows (approximately 50% of the time).

Xura weir infrastructure (design flow 21 l/s net)**:** A new pump station (static head 141 m) and rising main (6 250 m) will be built at the Xura weir site to convey the raw water to the existing water treatment works. This infrastructure will be sized for the incremental yield of the Xura site (21 l/s net)

Mzintlava weir infrastructure (design flow 19 l/s net)**:** A new raw water pump station (static head 136 m) and rising main (1 050 m) will be built at the Mzintlava weir site to convey the raw water to the proposed new water treatment works. New clear water pump station (static head 90 m) and rising main (5 850 m) will convey the clear water to a new main storage reservoir. The reservoir will be connected to the existing secondary conveyance system through a new clear water gravity main (3 000 m). This infrastructure will be sized to supply the difference between the total scheme requirements and the combined yield available at the Lusikisiki and Xura weirs (19 l/s net).



Graph 8.2: Phased implementation of run of river schemes

8.3 CONJUNCTIVE USE OF SURFACE AND GROUNDWATER RESOURCES

Groundwater developments can be used to supplement the supply from run of river schemes at times of low flows and in this manner to increase the assurance of supply to acceptable levels. These options offer higher assurance of supply than the run of river schemes, but at higher capital and running costs.

8.3.1 Option W1/G: Lusikisiki, Xura and Mzintlava Weirs in conjunction with Groundwater (90% assurance of supply)

The run of river option W1 discussed in the previous section has been used as the basis for this scenario. In addition to the infrastructure described in **Section 8.2**, provision has been made for the development of ground water sources and conveyance infrastructure to supply 40 l/s net, being the difference between total scheme requirements (72 l/s net) and the run of river yield at 90% assurance (32 l/s net). In order to reduce the O&M costs associated with the groundwater supply, the surface water scheme has been sized to supply the full demand at times of high flows. The ground water sources will be used to provide the incremental demand only during drought periods.

The groundwater supply infrastructure will consist of the following components at each borehole (total net supply of 40 l/s): A submersible pump driven by a diesel engine, a pump house, a rising main, a storage reservoir and an access road (track). Due to the uncertainties with regards to the actual position and yield of the boreholes, certain assumptions have been made with regards to the average characteristics of the conveyance infrastructure per borehole (yield, pumping head, access, conveyance length, storage).

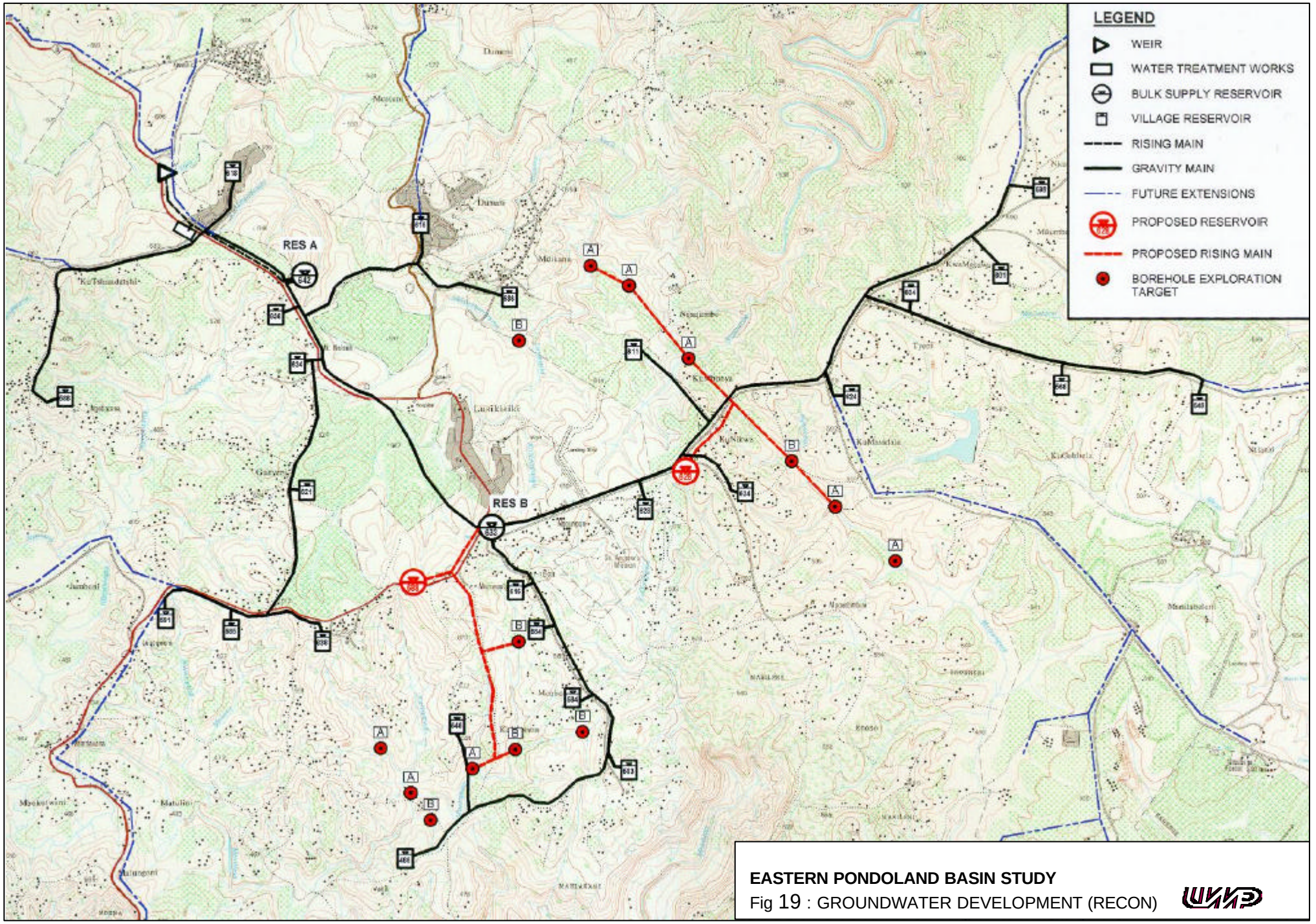
8.3.2 Option W2/G: Lusikisiki Weir in conjunction with Groundwater (98% assurance)

This option is similar to option W1/G, but the run of river scheme consists only of the existing Lusikisiki weir and its primary conveyance infrastructure. The existing surface water conveyance infrastructure (clear and raw water pump stations and rising mains, water treatment works, and main storage reservoirs) will be upgraded to supply the full scheme requirements (72 l/s net) at times of high flows. In addition, provision has been made for the development of ground water sources and conveyance infrastructure to supply 72 l/s net (the full demand, as no yield at 98% assurance is available at the weir).

The groundwater infrastructure will consist of components identical to the ones described for Option W1/G, but supplying a total flow of 72 l/s net.

8.4 GROUNDWATER STAND-ALONE OPTION (G1)

This option makes provision for the supply of the full scheme demands by groundwater only. The groundwater development infrastructure is assumed to be identical with the one described for Option W2/G (total supplied flows of 72 l/s net). A possible primary infrastructure system for the borehole scheme is illustrated in **Figure 19**. Due to the lack of site-specific information about the actual position of all boreholes needed to meet the demands of the scheme (more than 160 boreholes at year 2020), this option has been studied superficially.



EASTERN PONDOLAND BASIN STUDY

Fig 19 : GROUNDWATER DEVELOPMENT (RECON)

Table 8.4: Summary of Development Options

Option	Water Source	River	Assu-rance	Primary Conveyance system*
D1A	Zalu dam Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPS -CWRM to Res. A -New reservoir adjacent to Reservoir A
D1B	Zalu dam Surface water storage	Xura	98%	-Upgrade RWPS at existing weir site (72 l/s) -Upgrade RWRM to existing WTW -Upgrade WTW and CWPS -CWRM to Res. A -New reservoir adjacent to Reservoir A
D2	Lusikisiki dam Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPS -CWRM to Res. A -New reservoir adjacent to Reservoir A
D3	Xura dam Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPS -CWRM to Res. A -New reservoir adjacent to Reservoir A
D4	Lower Mzintlava dam Surface water storage	Mzintlava	98%	-RWGM to WTW (all components 72 l/s) -New WTW & CWPS -CWRM to reservoir -New reservoir 3 km west of Res. B -CWGM to Reservoir B
D5	Tungwane dam Surface water storage	Mzintlava	98%	-RWGM to WTW (all components 72 l/s) -New WTW & CWPS -CWRM to reservoir -New reservoir 3 km west of Res. B -CWGM to Reservoir B
W1	-Lusikisiki weir -Xura weir -Mzintlava weir Non regulated, run of river	Xura Xura Mzintlava	80%	-Lusikisiki weir to existing WTW (72 l/s) -Xura weir to existing WTW (21 l/s) -Upgrade WTW and CWPS (72 l/s) -CWRM to Res A (72 l/s) -New reservoir close to reservoir A -RWPS at Mzintlava weir (19 l/s) -New WTW and CWPS and CWRM (19 l/s) -New reservoir 3 km west of Res. B -CWGM to Res B (19 l/s)
W1/G	-Lusikisiki weir -Xura weir -Mzintlava weir In conjunction with groundwater (40 l/s) Conjunctive water use scheme	Xura Xura Mzintlava	90%	Surface water infrastructure same as above Groundwater infrastructure (total 40 l/s): -Pump, motor and pumphouse -CWRM to command location -Balancing reservoir
W2/G	-Lusikisiki weir In conjunction with groundwater (72 l/s) Conjunctive water use scheme	Xura	98%	-RWPS at weir (72 l/s) -RWRM to existing WTW (72 l/s) -Upgrade WTW and CWPS (72 l/s) -CWRM to Res. A (72 l/s) -New reservoir adjacent to Reservoir A -Groundwater infrastructure (total 72 l/s)
G1	Ground water (72 l.s)	-		Groundwater infrastructure (total 72 l/s) -Pump, motor and pumphouse -CWRM to command location -Balancing reservoir
* figures in brackets are the net design flows (for AADD) for sizing of the relevant infrastructure components				

9. FACTORS AFFECTING DEVELOPMENT

The reconnaissance level investigations were undertaken as a desktop study, mainly on the basis of existing topographical, geological and environmental information, supplemented by site visits by specialists in all related disciplines (planning, conveyance, dams, geology, materials, environmental and social, water quality). This section outlines the observations from the site visits. Selected photographs are attached in **Appendix A1**.

9.1 GEOLOGY AND MATERIALS

Detailed information regarding the engineering geological conditions and the availability of construction material for each proposed development site is offered in the supporting report **First Engineering Geological Reconnaissance Report**. The engineering geological and geotechnical appraisal for each of the proposed dam sites is summarised in **Table 9.1**.

The study area is underlain by sedimentary strata of the lower Karoo Supergroup. This group comprises of mudrocks of the Ecca Group, and underlying tillite of the Dwyka Group. This sedimentary sequence has been intruded by younger dolerite dykes and sills, which comprise up to 40 % of the sequence within the Ecca mudrocks, but significantly less within the tillites. The strata are essentially sub-horizontal. No major regional-scale faults are recognized in the area and no economically important mineral deposits occur.

9.1.1 Zalu Dam Site

The geological conditions at Zalu site have been investigated in the past Hill Kaplan Scott [8, 9], when 28 exploration boreholes were drilled and a detailed soil survey of potential borrow pit areas including laboratory testing was conducted. The confidence in the information available for this site is therefore substantially greater than for the other sites.

The site is located about 11 km north-west of Lusikisiki. It is asymmetrical; the left flank is relatively gently sloping (1:7), while the right flank is steeper (1:2,5). The river section is approximately 80 m wide, at an elevation of approximately 586 m above msl.

The site is underlain by dolerite sills. Within the river section the dolerite is at least 35 m thick, overlaid by alluvium layer of up to 5 m. The mid to lower left flank and most of the right flank are underlain by this dolerite sill, while the upper left flank is underlain by weathered siltstone. Soil cover is expected to be up to 5 m thick, although extensive dolerite outcrops occur on the lower right flank.

Founding conditions are suitable for a concrete gravity structure with a central spillway. Alternatively, the poorer founding conditions on the upper left flank might favour an embankment, with a concrete structure for the remainder of the section.

For a concrete structure, excavation depths are likely to vary between 5 m on the left flank (underlain by dolerite), 3 – 4 m in the river section and 1 - 4,5 m on the right flank (where underlain by dolerite). Deeper excavations will be necessary on the upper flank areas underlain by weathered siltstone (up to 15 m). Embankment cut-off depths are expected

to vary between 2 – 5 m on the left flank, 3 – 4 m in the river section, and 1 - 4,5 m on the right flank.

A source of coarse aggregate / rip-rap / crusher sand has not yet been investigated. No suitable natural sand reserves were identified. This is a problem common to all sites. In all likelihood, crusher sand will have to be used. Previous investigations identified the red clayey dolerite soils as a source of impervious core material, and fine-grained soils from siltstone and alluvium as semi-pervious transition material.

9.1.2 Lusikisiki Dam Site

This site is located about 7 km north-west of Lusikisiki, adjacent to road R61. The centreline is markedly asymmetrical. The river section is approximately 20 m wide. The steepness of the left flank at the Lusikisiki site is due to the intrusion of a dolerite sill. The flatter upper slopes are presumably underlain by weathered siltstone. Extensive dolerite outcrops occurs within the river section, although sill thickness is unknown. The gently sloping right flank is probably underlain by deeply weathered siltstone.

Expected founding conditions would favour a composite dam incorporating a concrete central section and left flank with an earth embankment right flank, or an earthfill embankment dam. However, if the dam wall is less than 25 m high a concrete structure can be considered, but will require deep excavations at the upper flanks (5 – 15 m deep).

Excavation depths between 0 - 2 m are expected for a concrete structure within the river section. Deeper excavation can be expected should this concrete section extend to the lower flanks. Embankment cut-off depths are likely to vary between 2 - 3 m on the left flank and 3 - 5 m on the gently sloping right flank.

The dolerite sill on the left flank represents the closest possible source of coarse aggregate/ rip-rap / crusher sand. Other suitable dolerite bodies are also expected, although probably not within the basin. Embankment fill material is expected to occur within the dam basin.

9.1.3 Xura Dam Site

The site is located about 6 km north-west of Lusikisiki. The site is roughly symmetrical, with side slopes in the order of 1:3. The river section is about 35 m wide. The proposed Xura site is underlain by tillite of the Dwyka Group. The flanks are expected to be deeply weathered, with soil cover varying between 1 - 2 m on the moderately steep left flank and possibly 2 - 3 m on the slightly flatter right flank. Scattered outcrop of unweathered tillite bedrock occurs within the river section. Alluvial cover is negligible. There is some evidence of past slope instability within the basin.

The expected deep weathering of the flanks would favour an embankment dam. Because of good founding conditions within the river section, a central concrete spillway section may, however, be considered.

Excavation depths for an embankment cut-off may be assumed to vary between 2 - 3 m on the left flank, and 3 - 5 m on the right flank. Cut-off excavations within the river section will be negligible, but for a concrete structure may be expected to vary up to 1 - 2 m.

A potential tillite quarry for coarse aggregate / rip-rap / crusher sand occurs roughly 500 m upstream of the centre-line, but appears deeply weathered. Embankment fill materials are likely to be located within the dam basin.

9.1.4 Lower Mzintlava Dam Site

The site is located about 8 km south-west of Lusikisiki. The site is asymmetrical and the river bed is narrow (15-20 m). The site is underlain by tillite, scattered outcrop of slightly weathered bedrock occurs within the river section and at the foot of the left flank slope. The flanks are expected to be deeply weathered. Colluvial soils at the flanks are expected to vary in depth between 2-5 m, with alluvium in the river section up to 2 - 3 m thick.

The deep weathering of the flanks favours an embankment dam. Cut-off depths might be expected to vary between 2 - 5 m on the flanks and up to 3 m within the river section. A central concrete spillway section might also be considered, but the river section is very narrow and deep excavations must be expected on the deeply weathered lower flanks (10 - 15 m, or greater).

Although no potential source of coarse aggregate / rip-rap / crusher sand was identified, major problems are not expected in this regard. A disused dolerite quarry is located roughly 2 km from the site. Embankment fill material may be expected to occur within the basin.

9.1.5 Tungwane Dam Site

The site is located about 7 km SSW of Lusikisiki. The site as markedly asymmetrical with a steep left flank (1:1 to 1:6) and a flat right flank (1:18 to 1:8) and is underlain by tillite, which is expected to be deeply weathered. Scattered outcrop is exposed at the foot of the steep left flank. Alluvial boulders cover the river section (thickness 2- 5m), but the underlying bedrock is expected to be unweathered.

The deep weathering of the flanks favours an earth embankment structure. The good founding conditions within the river section will suggest a central concrete section and spillway. Excavations for an embankment cut-off may be assumed to vary between 2 - 3 m, possibly deeper on the lower right flank.

Several areas of extensive tillite outcrop were identified adjacent to the river, which represent potential quarry sites. A disused dolerite quarry is located roughly 3 km from the site. Suitable embankment fill material probably occurs within the basin.

Table 9.1: Summary of Geological Characteristics at Dam Sites

	ZALU SITE	LUSIKISIKI SITE	XURA SITE	LOWER MZINTLAVA SITE	TUNGWANE SITE
Topography	Asymmetrical. Gently sloping left flank (1:2,5). River section approximately 80 m wide.	Markedly asymmetrical. Left flank moderately steep (1:3), right flank generally very gently sloping (1:33). River section approximately 20 m wide.	Roughly symmetrical. Left flank slightly steeper (1:2,5) than right (1:3). River section 30 – 35 m wide.	Asymmetrical. Left flank initially steep then flattens (1:1,5 to 1:2,5), right flank more gently sloping. River section 15 – 20 m wide.	Markedly asymmetrical. Left flank initially steep then flattens (1:1 bec 1:6), right flank gently sloping (1:18 steepening to 1:8). River section approximately 80 m wide.
Geology	Upper left flank underlain by weathered siltstone, mid- to lower slopes underlain by dolerite sill. Soil cover 2 –5 m. Alluvium in river section 5 m thick, overlying unweathered dolerite sill with minimum thickness 35 m. Right flank underlain by unweathered dolerite. Soil cover up to 5 m thick.	Steeper left flank underlain by dolerite sill, flatter upper slopes underlain by weathered siltstone. Extensive dolerite outcrop in river section. Right flank underlain by siltstone, presumably deeply weathered. Soil cover assumed 5 m thickness.	Shallow soils on left flank grade into underlying deeply weathered tillite. Outcrop of unweathered tillite exposed in river section. Negligible alluvium. Colluvial soils on right flank possibly 2 – 5 m, underlain by deeply weathered tillite.	Tillite underlying left flank expect deeply weathered, but slightly weathered outcrop at base of slope. Colluvial soil cover assume 2 – 5 m. Scattered tillite outcrop in river section, patchy alluvium (up to 2 – 3 m assumed) On right flank assume colluvial soils (2 – 5 m) underlain by deeply weathered tillite.	Left flank expect deeply weathered tillite, but slightly weathered bedrock exposed at foot of slop. Soil cover assume 2 – 5 m thick. River section covered with alluvial boulders (2 – 5 m thick) presumably underlain by unweathered tillite. Assume tillite underlying right flank to be deeply weathered. Soil cover up to 5 – 8 m likely, thinning to 2 – 3 m.
Dam type	Max height envisaged 35 m. Crest length 320 m. Suitable founding for concrete gravity dam, or composite structure with embankment left flank and concrete river section and right flank.	Max height envisaged 40 m. Crest length 740 m. Embankment dam favoured, or composite structure with central concrete spillway and embankment flanks.	Max height envisaged 30 m. Crest length 200 m. Deep weathering on flanks favours embankment dam, or composite structure with central concrete spillway.	Max height envisaged 39 m. Crest length 375 m. Deep weathering on flanks favours embankment dam. Central concrete section possible but width of river section limited.	Max height envisaged 50 m. Crest length 595 m. Deep weathering favours embankment dam, but central concrete spillway section also possible.
Likely excavation depths	For concrete structure, depths between 5 m on mid- to lower left flank, 3 – 4 m in river section, 1 – 4,5 m on right flank. Much deeper on upper flanks underlain by siltstone. Cut-off depth for embankment 2 – 5 m.	Concrete structure; depths between 0 – 2 m in river section, 2 – 5 m on lower left flank. Much deeper on right flank, upper left flank. Embankment cut-off; 2 – 3 m on left flank, 3 – 5 m on right flank.	Concrete structure; depths of 1 – 2 m in river section. Embankment cut-off; assume 2 – 3 m on left flank, 3 – 5 m on right. Negligible excavation within river section.	Embankment cut-off depths; assume 2 – 3 m on respective flanks, 2 – 3 m in river section.	Embankment cut-off depths to vary between 2 – 3 m, possibly up to 5 – 8 m on lower right flank. Central concrete section; 2 – 5 m in river section, possibly up to 5 – 8 m on lower flanks.
Construction material availability	Possible dolerite body for coarse aggregate, rip-rap, crusher sand. Previous investigations considered clayey dolerite soils for impervious core, soils from siltstone / alluvium for transition zones.	Dolerite sill on left flank possible source of coarse aggregate, rip-rap, crusher sand. Other dolerites further afield. Embankment materials likely within basin.	Tillite cliffs upstream of centre-line are possible source of coarse aggregate / rip-rap / crusher sand, but deeply weathered. Embankment fill materials likely within basin.	Either tillite or dolerite possible source of coarse aggregate / rip-rap / crusher sand, but potential site not yet identified. Disused quarry close to site. Embankment fill materials expected within basin.	Potential sites for tillite quarry evident (coarse aggregate / rip-rap / crusher sand). Disused dolerite quarry. Embankment material sources expected within basin.

9.2 ENVIRONMENTAL IMPACT ASSESSMENT OF DEVELOPMENT SITES

This section outlines the findings of the investigations related to the assessment of the potential site-specific environmental impacts (and their management) associated with the various dam development options. More detailed information is available in the supporting report **Environmental Evaluation: Scoping Report**, issued in terms of the Environmental Conservation Act, 1989. The proposed plan of study was submitted and approved by the Eastern Cape Department of Economic Affairs, Environment and Tourism (DEAET).

The investigations were based on available data and maps as well as on information obtained during two field visits. A specialist visit to the five proposed dam sites was carried out during the reconnaissance stage of the study. More detailed investigations, including a botanical survey were undertaken during the pre-feasibility phase for the two selected sites - Zalu and Lusikisiki.

Information was collected on the habitat integrity of both the riparian and instream components of the affected river reaches along the Xura and Mzintlava Rivers. The data was used to determine the ecological importance and sensitivity, as well as the present ecological status of the relevant reaches. These assessments allowed the determination of the ecological management classes of the river reaches within the study area as well as the conservation value of the inundated and affected areas.

The socio-cultural component of the investigation was limited to assessing the dependence of the population on the river and the associated natural resources as well as the cultural and historical value of the sites. Other aspects of possible social impacts are discussed in **Section 9.3**. The preliminary "socio-cultural" assessment indicated that dam construction at any of the proposed sites, except at Lower Mzintlava, will not result in significant social impacts.

It was found that the natural features at the various proposed dam sites have been largely modified by the activities of man. The natural riparian vegetation at all sites indicates a large to serious degree of degradation due to harvesting of firewood and building material, bush-clearing to create cultivated fields and destructive burning practices. No rare or endangered plant or terrestrial animal species were found at any of the sites. The degree of disturbance and habitat destruction makes it unlikely that any rare or endangered fauna, and possibly even flora, are present in these areas.

The apparent absence of any natural, cultural, or aesthetic features of outstanding value at any of the dam sites indicates that there will be no significant site-specific impacts as a result of the proposed developments. No "fatal flaws" were identified at any of the sites and there were also no distinct "preferred options" from the environmental point of view. A summary of the evaluation of the negative environmental impacts associated with the construction of dams at the proposed sites is provided in **Table 9.2**.

The other options (run of river, conjunctive and ground water) considered during this study, will result in negligible site specific environmental impacts.

More significant potential negative impacts associated with water abstractions (applicable to both dam and weir options) from the rivers in the area will be related to the sensitive and valuable ecosystems downstream of the proposed sites. The issues related to the determination of the ecological reserve (estuarine and instream flow requirements) are discussed in **Section 4.3**. These constraints will probably have a greater influence regarding the choice of a preferred option than any site-specific environmental considerations.

Table 9.2: Summary evaluation of negative environmental impacts associated with the construction of dams at five proposed sites.

L = low; M = medium; H = high; N = negligible; Mitig.= extent of impact with mitigation; ? = Uncertain, more data required.

ENVIRONMENTAL IMPACT DESCRIPTION	EVALUATION OF ENVIRONMENTAL IMPACT									
	Zalu Site		Lusikisiki Site		Xura Site		Mzintlava site		Tungwane Site	
	Extent	Mitig.	Extent	Mitig.	Extent	Mitig.	Extent	Mitig.	Extent	Mitig.
Loss of vegetation, particularly rare or endangered species, due to inundation	M?	M?	L to M?	L to M?	M?	L to M?	L?	L?	M?	L to M?
Loss of rare or endangered terrestrial fauna, due to inundation	L	L	L	L	L	L	L	L	L	L
Loss of rare or endangered aquatic fauna, due to inundation	M?	M?	M?	M?	M?	M?	M?	M?	M?	M?
Loss of valuable natural riparian resources used by locals, due to inundation	L	L to N	L	L to N	L	L to N	L	L to N	L	L to N
Loss of cultural or historic sites of value	L	L	L	L	L	L	L	L	L	L
Loss of special or spectacular natural features, aesthetically valuable areas	L	L	L	L	L	L	L	L	L	L
Potential impacts on valuable natural systems downstream (estuary, gorge)	M	L	M	L	L to M	L	M to H	L	M to H	L
Impacts of "associated development"	M	L to N	L to M	L to N	M	L to N	M	L to N	M	L to N
Socio-economic factors, e.g. inundation of cultivated lands, access roads and houses	L?	L?	L?	L?	L?	L?	M to H?	M?	L?	L?

9.3 SOCIAL IMPACT ASSESSMENT

The potential social impacts associated with the construction of dams were initially identified on the basis of desktop studies and literature reviews. The extent of inundation and possible loss of access were initially quantified on the basis of 1:10 000 topographical maps and recent aerial photographs. The information was later refined during field visits and interviews with various institutions and stakeholders with extensive local knowledge. The results of the investigations are summarised in the following paragraphs. More detailed information, including a socio-economic overview is attached in **Appendix F**.

Stakeholder interviews were conducted inter alia with the Transitional Representative Council (TRC), the Transitional Local Council (TLC) of Lusikisiki and the Project Steering Committee (PSC), consisting of representatives of all administrative districts affected by the developments. During the interviews the proposed scheme developments were explained in detail. Stakeholders were requested to comment on the acceptability of the options, and to put forward issues and concerns.

In addition, certain public participation and wider stakeholder involvement activities have taken place during the course of the study (section 9.6). The following main negative social impacts for each development option were evaluated.

- **Relocation of people due to inundation:** Considerable number of people (approximately 720) will need to be relocated in the case of the Lower Mzintlava dam option. The Tungwane Dam will necessitate the relocation of about 36 people, while the other dam options require no relocation.
- **Loss of land (arable and grazing):** The Zalu and Tungwane dams will lead to the lowest loss of land (about 100 ha each) followed by the Lusikisiki (140 ha), Lower Mzintlava (160 ha) and Zalu (180 ha) dams. However the loss of arable land in all cases is considered to be moderate, varying between 23 and 50 ha.
- **Loss of access:** The Lower Mzintlava and Xura dams will necessitate the relocation of important secondary access roads. In addition, the Lower Mzintlava dam will divide communities and will cause the greatest inconvenience to the population. The inundated area of the Tungwane dam will extend upstream beyond the new bridge on the Lusikisiki – Port St Johnes road, which may affect the stability of the road embankments and bridge abatements. The other dams will have low impact on access.
- **Loss of archaeological and historical sites:** No sites of importance were identified at any of the proposed development sites.
- **Loss of religious and cultural sites:** No sites of importance to the communities will be lost to inundation at any of the proposed developments.
- **Loss of natural resources:** It has been confirmed that the dependency of the population on natural resources within the inundated areas is insignificant for all options.

The positive impacts due to the proposed developments will be very similar for all options. These will include the following main benefits:

- Boost of regional economy due to inflow of capital
- Creation of employment opportunities
- Training and empowerment of labour force and local contractors
- Improvement of infrastructure and services (water, roads, electrical, telkom)
- Recreation and conservation opportunities

The results of the social impact assessment during the reconnaissance stage of the study are summarised in the following table.

Table 9.3A : Significance of negative social impacts due to dam developments

Dam site	Relocation of people	Loss of land	Loss of access	Loss of natural resources	Loss of historical and cultural sites
Zalu site Xura River	N/A	23 ha arable 5 ha grazing L	L	L	L
Lusikisiki site Xura River	N/A	22 ha arable 5 ha grazing L	L	L	L
Xura site Xura River	N/A	50 ha arable 20 ha grazing H	M	L	L
Lower Mzintlava Mzintlava River	720 p H	46 ha arable 15 ha grazing H	H	L	L
Tungwane Mzintlava River	36 p M	26 ha arable 16 ha grazing M	M	L	L

L – low, M – medium, H – high

In general, the negative social impacts related to the proposed dam developments are low to moderate and will most probably be less significant than the positive impacts. However, taking into account the most significant (from the community perspective) negative impacts, relocation, loss of land and loss of access, it appears that the Xura River options will be preferable from a social point of view.

The negative social impacts related to the development of the other options (run of river, conjunctive and ground water) will be even lower than the ones for the dam options. It should however be noted that the local population has had bad experience with groundwater developments in the past (low assurance, frequently malfunctioning, poor water quality, complicated operation and maintenance, etc). It is likely that groundwater options will not be favoured by the local population and may even be opposed.

More detailed investigations on the social impacts for the Zalu and Lusikisiki dams were undertaken during the pre-feasibility phase and have confirmed the reconnaissance stage results. More details are available in **Appendix F2**.

Table 9.3B: Summary of Negative Social Impacts for Zalu and Lusikisiki dam sites

Impact	Unit	Zalu	Lusikisiki
Relocation of households	no.	0	0
Relocation of roads and infrastructure	km/cost	0	0
Loss of arable (cultivated) land	ha	23	22
Loss of grazing land	ha	5	5
Loss of natural resources	L/M/H	Low	Low
Loss of specific religious or cultural sites	L/M/H	Low	Low
Loss of historical / archaeological sites	L/M/H	Low	Low
Graveyards and possible relocation	no.	0	0

9.4 WATER QUALITY ISSUES

The river systems of the Transkei basin have only been monitored on an ad hoc basis by engineers and developers on an as required basis. Discussions with the Department of Water Affairs and Forestry indicate that no water quality monitoring or routine hydrological data collection has taken place at most monitoring structures for many years.

The only available water quality records of note for the Lusikisiki area have been generated from samples tested by the Department of Health and the Department of Water Affairs and Forestry. The most comprehensive information spans the period January 1998 to present. Special grab samples of both the Xura and Mzintlava Rivers were collected in late August 1999 for the purposes of this study. Routine monthly water samples from the Lusikisiki water works' raw water intake have been obtained and used to provide an indication of seasonal variations in water quality parameters. The remaining detailed records (primarily from hospitals) are from sites located in adjacent catchments (the Mntafufu, Mtentu and Msikaba Rivers) and this information has been used to indicate the regional water quality. The test results from water quality samples are attached in **Appendix G**.

Broadly speaking, the water quality in both systems (Xura and Mzintlava) is similar with relatively clear streams. The water quality shows little signs of pollution with low nitrate, ammonia and phosphate concentration. At points adjacent to the Port St Johns / Flagstaff road, there is little indication of human impacts on the rivers. Microbiologically, the Mzintlava River is more impacted than the Xura River, but this may reflect the impacts of stock and game on the water rather than catchment degradation.

Upstream impacts

The upper catchments of both river systems are well vegetated and rural villages are generally confined to the hilltops. Village water resources are local springs and small catchment dams (earth). Little reliance is placed on groundwater as generally the yields are low (<0.2 l/s), and the boreholes are very deep. In areas where pools form in the rivers, cattle drink and village women congregate to wash clothes. On washdays soap and rinse water may extend for 200 – 300 m downstream, but the total impact on the system appears to be small. Competition for limited water resources (washing by the community and drinking water supplies for a hospital or clinic) has lead to disputes over the right to use the water.

Downstream Impacts

The region adjacent to the Xura River between the Lusikisiki site and the Xura site is more urbanized than the upper catchment. This region consists of the urban town of Lusikisiki and several satellite villages, but other than the abstraction of about 1million m^3/a of raw water from the abstraction weir at the Lusikisiki / Flagstaff road bridge, there are no additional impacts on the river. Return flow from the sludge pond at the water treatment works enters the river, discharging below the intake weir.

Downstream of the Xura dam site, the Lusikisiki River enters the Xura River and, at this point, there is a marked impact on the water quality in the Xura River as a result of urban runoff and a poorly operated sewage treatment works, which impact on the Lusikisiki River water quality. These works are listed in **Table 9.4**.

Table 9.4: Site sources of urban runoff and sewerage treatment works

Water User	Capacity	Treatment Facility
Lusikisiki Teachers Training College	90 m^3/day	Oxidation ponds
St Elizabeth's Hospital	120 m^3/day	Oxidation ponds
Lusikisiki Transitional Local Council	280 m^3/day	Septic tanks and managed wetlands
Lusikisiki - old prison	10 m^3/day	Oxidation ponds
- new prison	60 m^3/day	Oxidation ponds
Vocational School	20 m^3/day	Septic tank

With the exception of the Lusikisiki Teachers Training College, all works currently discharge effluent into the Lusikisiki River (small tributary of Xura to the north of, and adjacent to the town of Lusikisiki). The effluent does not comply with the general standard for effluent discharges and at low river flows there is likely to be a severe impact on water quality. Any further reduction of the existing downstream flows due to increased abstractions may result in significant degradation of the water quality.

Water Quality Concerns in the Impoundments

Many of the proposed impoundments are approximately 25 m in height at the dam wall and it is therefore likely that summer stratification of the reservoirs will take place. In the initial stages of development, this will probably lead to a de-oxygenated hypolimium as the residual vegetation rots. After stabilisation, the degree of de-oxygenation, if any, will depend on the response of the new reservoir to nutrient inputs and release of nutrients from the littoral areas. The available information suggests that the turbidity of the impounded water is likely to be low and as a result light penetration will be good. This will allow numerous algal species to take advantage of any nutrients present. In the initial development of any of the reservoirs there are likely to be severe algal blooms, but after stabilisation the system response will depend on adequate control of nutrients from diffuse runoff.

Proposed Locations of Water Quality Sampling Points

The regular collection and testing of water samples will contribute for obtaining of more reliable results from future investigations. For the Mzintlava River system sampling at the Port St John's/ Lusikisiki road bridge is adequate for determining instream water quality.

The Xura River is more complex. To evaluate the water quality for the proposed Zalu and Lusikisiki dam sites, the routine collection of raw water samples at the abstraction weir for the water treatment works will be adequate. The water quality at the Xura dam site will need to be determined at a point above the Xura / Lusikisiki River confluence.

The issues related to water turbidity and sediment yields are discussed in **Section 7.4**

9.5 INSTITUTIONAL ARRANGEMENTS FOR O&M

At present the scheme is managed by the DWAF. According to the new legislation this situation is expected to change, and the local government will be expected to act as a Water Services Authority. Due to the remoteness and the lack of capacity within the area it will be preferable to select a regional scheme. This may warrant the involvement of a specialised service provider, who will also provide support at village level.

Two Water Services Providers (WSP) are envisaged for this regional scheme. Although the WSPs may be responsible for their own respective portions of the scheme, there would be a need to develop a forum for communication between the respective WSPs. The WSA would need to have representation in this forum. It is envisaged that the two WSPs will be instituted to operate and maintain the regional scheme in the rural areas on the following two levels:

- **Bulk level:** Due to the complexity of the infrastructure to be installed, skilled operators with appropriate support are required to operate and maintain the scheme. It is therefore anticipated that on commissioning DWAF will transfer the scheme to the WSA. The WSA may elect to operate and maintain the scheme itself or it may instruct a Support Services Agent (SSA) to undertake this task on its behalf.
- **Village level:** It is envisaged that local Water Committees would be responsible for operation and maintenance of the reticulation network within the respective villages. The number and make-up of these committees would need to be finalised in conjunction with the respective communities and the WSA.

The dam options will be preferable from O&M point of view. The primary infrastructure will be compact in terms of location and number of major components (dam outlet, WTW and main reservoir), requiring less complex institutional structure and lower operating costs.

The weir options will need a more complex O&M structure, possibly leading to higher operational costs (3 abstraction points, 2 WTW and 2 main reservoirs).

The groundwater supply options will require the most complex institutional structure in order to ensure the sustainability and reliability of the scheme at the same level as for the other options. It is estimated that a total number of 230 boreholes will be required by the year 2020 (option G1). The operation and running costs for this option will be substantially higher than for the other options.

9.6 PUBLIC INVOLVEMENT PROGRAMME

The public involvement programme included the following activities:

- Public participation meeting held on 19 May 1999
- Newsletter issued in June 1999 in both Xhosa and English. 500 copies distributed through the Lusikisiki TLC and the previously established project steering committee (PSC)
- Public participation meeting held on 17 March 2001

Despite all organisational efforts the public meetings were not well attended. However, the most important affected parties participated (Lusikisiki TLC, TRC and PSC).

A list of the interested and affected parties as well as a copy of the newsletter and the invitation to the public participation meeting are attached in **Appendix H**.

10. RECONNAISSANCE SIZING AND COSTING

This section describes the methodology applied for the reconnaissance level of sizing and costing of the development options and should be read in conjunction with **Section 8**, which describes the infrastructure components for each development option. The layouts of the development options are shown in **Figures 17.1 to 17.6** and **18**.

Initially, all options identified in **Section 8** were evaluated in broad terms based on their technical and economic viability, taking into account the supporting factors affecting the developments (**Section 9**). It was established that the Lower Mzintlava and Tungwane Dam options (options D4 and D5 respectively) have considerable disadvantages, when compared to the other dams options, namely:

- Considerably higher pumping heads, leading to higher O&M costs
- Higher costs for dams and conveyance infrastructure (longer routes, inability to utilise the existing primary conveyance infrastructure)
- An unfavourable situation in relation of the area served by the existing scheme
- Unfavourable geological conditions at the dam sites
- More significant social impacts

Due to these reasons it was decided that these options should be excluded from further consideration. No detailed cost models were produced for these options.

All major components of the remaining options have been sized and their costs estimated at a reconnaissance level of detail, in accordance with the criteria specified below. The sizing has been done for the 2020 horizon for water requirements. No optimisation of the system components has been done at this stage.

A summary of the estimated capital costs for all options is provided in **Table 10.5**. The basic schedules of quantities and cost models are attached in **Appendix J**.

10.1 GENERAL SIZING CRITERIA: DESIGN CAPACITIES AND FLOWS

The sizing flows for the main infrastructure components are shown per development node in **Appendix I**. These flows have been established in accordance with the RDP Rural Water Supply Design Criteria Guidelines (DWAF, October 1997). The criteria used are summarised in the table below.

Table 10.1: Design capacities and flow rates for sizing of infrastructure components

System component	Demand definition	Sizing criteria
Sizing criteria		
Surface water source: dam	Gross Average Annual Daily Demand (GAADD)	AADD * (1+LFr)
Water treatment works & raw water pump station	Summer Daily Demand (SDD_{ww})	SPF * GAADD * (1+LFw)*24/Op Per.
Clear water bulk pipelines, run of river source	Summer Daily Demand (SDD_{pl})	SPF * GAADD
System reservoir storage		AADD * Hours
Borehole & clear water pump stations	Summer Daily Demand (SDD_{pu})	SPF * GAADD*24/BH operation period
Village reticulation	Design Peak Flow Rate (DPFR)	GAAD*SPF*DPF
Selected values		
Parameter	**Parameter**	**Selected values**
Conveyance loss	LFr	10 %
Water treatment loss	LFw	10 %
Summer Peak Factor	SPF	1.5
Operating period: WTW	Hours per day	20
Daily Peak Factor	DPF	2
Reservoir capacity: Single Source	Hours	48
Reservoir capacity: Multiple Source	Hours	36
Min flow per standpipe	Litres per minute	10
Operating period boreholes	Hours per day	12

10.2 DAMS WEIRS

Sizing

The dams ware sized and costed in accordance with the "Guidelines for Preliminary Sizing, Costing and Engineering Economic Evaluation of Planning Options" (DWAF, 1996) [33] established for the Vaal Augmentation Planning Study (VAPS). Each dam option was sized to meet the total water requirements of the study area at year 2020 design horizon **(Section 4).**

The type of dam for each option was selected on the basis of the geological conditions, topography, possible spillway arrangements and availability of construction material (**Section 8**). The Zalu and Lusikisiki dam walls were sized as mass concrete (rollcrete) structures. The other three dams were sized as composite structures. The Xura and Lower Mzintlava dams were sized for earth embankment flanks and central horseshoe shaped chute spillways. The Tungwane dam was sized as mass concrete left flank and central sections, and earth embankment right flank section. After initial evaluation the Lower Mzintlava and the Tungwane dam options were abandoned.

The weirs were sized as mass concrete structures to be founded on rock within the river section.

The cross section parameters were established in accordance with the VAPS guidelines. For concrete dam sections: crown width at non-overspill crest level (NOCL) 5,0 m, wet slope vertical, dry slope 1: 0,75. For earthfill dam sections: crown width 10 m, wet slope 1: 3, dry slope 1: 2,5. The typical sections for dams and weirs used for costing purposes during the reconnaissance stage of the study are shown in **Appendix 2**.

The excavation depths were determined according to the results of the geological investigations (**Section 9.1**). Allowances for aprons, intake and outlet works, and foundation drilling and grouting were provided for costing purposes in accordance with the VAPS guidelines.

In each case, the live storage was determined from the yield-capacity curves derived on the basis of the firm yield analysis **(Section 7.1)**. The total required storage was then established by adding the necessary sediment capacity (20 year sediment yield) and dead storage (10% of live storage). The full supply level (FSL) for each dam was determined from the area-capacity relationships.

The design floods for sizing of the spillways were established in accordance with the Guidelines on Safety in Relation to Floods (SANCOLD, Report 4, 1991). All dams were classified as Category III safety risk: medium size class (12 to 30 m) and high hazard rating, in accordance with Table 2.3. The recommended design discharge (RDD) was determined from Table 5.1 and the safety evaluation discharge (SED) from Tables 5.2 and 5.3. The design floods used for sizing of the spillways are shown in the following table.

Table 10.2A: Design and Extreme Floods for Sizing of Dam Spillways

Flood	Flood Description	Zalu	Lusikisiki	Xura	L Mzintlava*	Tungwane*
		m^3/s	m^3/s	m^3/s	m^3/s	m^3/s
Q_{50}	50 year flood peak discharge	337	405	695	470	540
Q_{100}	100 year flood peak discharge	420	510	850	600	690
Q_{200}	200 year flood peak discharge	505	622	1060	735	845
RMF	Regional Maximum Flood	1 090	1 250	2 520	1 715	1 955
RDD	Recom. Design Discharge	505	622	1 060	735	845
SED	Safety Evaluation Discharge	1 405	1 639	3 273	2 260	2 562

* Option abandoned, information provided for record

The spillway types were determined by site-specific geological and topographical conditions. The freeboards were sized in accordance with the VAPS guidelines, which specify the recommended design discharge (RDD) and safety evaluation flood (SED) to be used for sizing of the wet and total freeboard respectively. The Gorgen's formula was used to make a provision for the flood attenuation effects of the dam basins. The sizing parameters used for costing purposes are summarized in the table below.

Table 10.2B: Sizing Parameters for Dams (Net Demand 2,265 x $10^6 m^3$)

Parameter	Zalu	Lusikisiki	Xura	L Mzintlava*	Tungwane*
Type of dam	Concrete	Concrete	Composite	Composite	Composite
Type of spillway	Central	Central	Horseshoe Chute	Horseshoe Chute	Central
River	Xura	Xura	Xura	Mzintlava	Mzintlava
Catchment area (km^2)	71	91	225	98	129
Live storage ($10^6 m^3$)	3.13	2.46	1.14	1.93	1.86
Sediment yield/storage ($10^6 m^3$)	0.8	1.0	2.24	1.04	1.36
Dead storage ($10^6 m^3$)	0.31	0.25	0.11	0.19	0.19
Total storage ($10^6 m^3$)	4.24	3.71	3.49	3.16	3.41
Bed level (m above msl)	586.0	535.0	449.0	409	358
Free board (m)	3.5	4.6	6.0	5.8	5.9
FSL (m above msl)	606.7	556.1	462.2	429.1	377.9
NOCL (m above msl)	610.2	560.7	468.2	434.9	383.8
Depth to FSL (m)	20.7	21.1	13.2	20.1	19.9
Depth to NOCL (m)	24.2	25.7	19.2	25.9	25.8
Spillway length (m)	100	75	100	70	80

* Option not considered further, information provided for the record only

Capital Cost Estimates

The capital costs for dams and weirs have been estimated on the basis of the cost models established for VAPS [33]. The basic material quantities used in the models (excavation, drilling and grouting, volumes of concrete and earthfill, etc) have been determined in accordance with the sizing criteria described above. Allowances for mechanical items have been made.

The capital costs were estimated at March 1999 price levels. The unit rates provided in the VAPS models were escalated from April 1994 to March 1999 using the published consumer price indices. The cost models for the dams and weirs are attached in **Appendix J2**.

10.3 GROUNDWATER DEVELOPMENT

As described in **Sections 8.3 and 8.4**, groundwater resources are being considered for three development options – W1/G, W2/G (conjunctive use options) and G1 (stand alone groundwater option). The sizing parameters for the groundwater source development as well as for the associated infrastructure are specified in the above-mentioned sections.

Due to the uncertainties with regards to the actual positions and yield of the boreholes, certain assumptions have been made for the purposes of cost estimates. Based on the results of the geohydrological studies, it has been assumed that the boreholes in the area will have an average net yield of 1,5 l/s, borehole depth of 60 m, with recommended pumping time of 12 hours per day. The average siting and drilling success rate has been assumed to vary between 60% and 75%. The conveyance infrastructure has been assumed to include the following components at each borehole:

- A submersible positive displacement pump driven by a diesel engine, housed in a pump house
- 1,3 km of rising main connecting the borehole to the secondary conveyance system
- Balancing reservoir with a capacity of 30 m^3 at a command position
- 1,0 km of access tracks

The capital costs associated with the development of the boreholes have been estimated on the basis of information obtained from similar projects. The estimated costs for installation of equipment and conveyance systems have been added. Taking into consideration the sizing criteria (**Section 10.1**), the cost for the supply of 1 l/s of the AADD (72 l/s) by groundwater is estimated to be R660 000. A detailed description of the cost components and assumptions is provided in **Appendix J3**.

It should be noted that due to the absence of accurate exploration drilling and testing results, the confidence in the above cost estimates is relatively low.

10.4 PRIMARY DISTRIBUTION SYSTEM

Sizing

The layouts of the primary conveyance system associated with each development option are shown on **Figures 17 and 18.** The system components are described in detail in **Section 8**. Each option will include some or all of the following components:

- Raw water pump station (RWPS)
- Raw water rising main (RWRM) or raw water gravity main (RWGM)
- Water treatment works (WTW)
- Clear water pump station (CWPS)
- Clear water rising main (CWRM)
- Main storage reservoirs (MSR)
- Clear water gravity man (CWGM)

All components have been sized in accordance with the applicable design flow criteria shown in **Table 10.1**. A number of possible route locations for each development option have been investigated and the best route has been selected for sizing. The conceptual longitudinal profiles for selected pipeline routes are shown in **Appendix 3**.

The gravity mains have been sized on the basis of available head, while the pumping mains have been sized on the basis of optimal velocities (in the order of 2 m/s). No optimisation of the pipeline/pump system on economic principles has taken place during the reconnaissance phase. A provision for 50 % standby capacity at all pump stations has been made.

The position of the main storage reservoirs has been selected to be at command points (in terms of elevation) allowing the feeding of the secondary distribution system by gravity. The reservoirs have been sized for 24 hours of storage capacity.

Capital Cost Estimates

The water treatment process has been assumed to include flocculation, settling, sand filtration and chemical dosing.

The costing of all components has been done using cost models, based on all-in-one costs per metre of pipeline of specific type and size (gravity and rising mans), kW of installed power (pump stations), m^3 of treated water (WTW) and m^3 storage capacity (reservoirs). The cost models have been established on the basis of actual costs for projects implemented in similar areas and are considered to be reasonably accurate. The cost models are attached in **Appendix J4**.

10.5 SUMMARY OF CAPITAL COSTS

A summary of the estimated capital costs for the various development options is provided in the table below. More details are available in **Appendix J.** The capital costs have been estimated at March 1999 price levels and include provisions for P&G, contingencies, professional fees and VAT.

Table 10.5: Capital Cost Reconnaissance Phase

Opt No.	Development Option	Capital costs, R x 10^6 (March 99)		
		Water Source	Conveyance	Total
D1A	Zalu dam. Conveyance from outlet	R34.69	R21.53	R56.22
D1B	Zalu dam. Conveyance from weir	R34.69	R14.56	R49.25
D2	Lusikisiki dam	R34.93	R15.98	R50.91
D3	Xura dam	R42.24	R23.57	R65.81
W1	Weir scheme (80% assurance)	R4.68	R24.89	R29.57
W1/G	Conjunctive scheme (90% assurance)	R15.24	R40.37	R55.97
W2/G	Conjunctive scheme (98% assurance)	R19.01	R43.07	R62.08
G1	Groundwater stand alone scheme	R19.01	R28.51	R47.52

A sensitivity analysis of the capital costs for various demand scenarios (high and medium, **Section 4)** has been undertaken. This has confirmed that the cost rating of the options does not change.

The economic evaluation taking into account the operation and maintenance, running costs and residual values for all options is discussed in **Section 13**. The costs for the Zalu and Lusikisiki dams are very similar. Based on the available information it was not possible to make a decision on the preferred option. More detailed investigations for those dams were therefore undertaken, and are described in the following section.

SECTION C: PRE-FEASIBILITY PHASE

The costs (estimated at a reconnaissance level of detail) for the two viable surface storage options - Zalu and Lusikisiki (D1 and D2) are very similar. The difference in the capital costs is well within the margin of inaccuracy of the costing models. While the geology for Zalu dam site has been investigated in detail in the past, the information available for the Lusikisiki dam is very limited. Further geological investigations, topographical surveys, and more detailed conceptual design and costing will be required to facilitate a more accurate comparison between the two dam options. The additional studies undertaken for the Zalu and Lusikisiki dam options are discussed in this section.

11. PRE-FEASIBILITY INVESTIGATIONS FOR ZALU AND LUSIKISIKI DAMS

11.1 TOPOGRAPHICAL SURVEYS

A number of possible cross sections at both dam sites were surveyed to a scale of 1:1 000 and the survey plans are attached in **Appendix 7**. This has facilitated the selection of the best dam centreline for each option, and has allowed for more accurate measurement and costing.

Both dam basins were surveyed and maps to a scale of 1:5 000, with contour interval of 1 m were produced (**Appendix 8**). This has facilitated the refinement of the area-capacity relationships, which are attached in **Appendix K**.

11.2 GEOLOGICAL AND MATERIALS INVESTIGATIONS

Detailed geological information, based on extensive exploration drilling (26 boreholes), sampling and laboratory test analysis is available for the Zalu site. The Lusikisiki site was investigated to a limited extent during the course of this study and 7 exploration boreholes were drilled in order to provide for a meaningful comparison between the two sites. The results of the geological investigations are detailed in the supporting report **Engineering Geology: Pre-Feasibility Report.**

Both sites are asymmetric, although this is more pronounced for the Lusikisiki site. More importantly, the river section is significantly wider for the Zalu site (approximately 80 m) in comparison with the Lusikisiki site (only 30 m to 35 m in width). The narrow section at Lusikisiki site impacts on the optimisation of the spillway layout.

The founding conditions at the Zalu site are generally more favourable than at the Lusikisiki site, implying greater flexibility in terms of structure type and configuration. The founding conditions at the Zalu site are considered suitable for both embankment and concrete structures. In contrast, the poor founding conditions on the right flank of the proposed Lusikisiki dam site dictate that an embankment is more suitable than a concrete structure. As the prevailing founding conditions would be suitable for founding a concrete wall in the river section, extending onto the left flank, the favoured solution would

comprise a composite dam. While an embankment dam might also be considered at the Zalu site, with spillway options including a side-channel or morning glory and conduit combination, possible embankment spillway configurations at the Lusikisiki site are not as apparent.

The better founding conditions at the Zalu dam site are also reflected in the expected excavation depths. Within the river section, shallower excavation depths are expected at the Lusikisiki site (up to 1 m to 2 m), compared with expected depths between 3 m and 4 m at the Zalu site (which only comprises the removal of alluvium. Significantly shallower excavations may be assumed for the flanks of the Zalu site, compared to the Lusikisiki site. For the most part, excavation depths up to 5 m may be assumed for Zalu. At higher levels on the left flank, however, a concrete structure would require deeper excavation to ensure founding on unweathered dolerite. Areas underlain by weathered siltstone on the upper flanks would also require relatively deep excavation. For a concrete structure at the Lusikisiki site, on the other hand, excavation depths up to 9,5 m, increasing further in an up-slope direction, are expected on the left flank, while even deeper excavation will be necessary on the right flank. The excessive excavation depths on the right flank favour an embankment dam, for which cut-off depths of 3,5 m may be assumed at this stage.

In terms of construction material availability, conditions are more favourable for the Zalu site, although no hard rock quarry site for coarse aggregate / riprap has yet been proven. The abandoned dolerite quarry currently recognized as the most likely source is closer to the Zalu site than the Lusikisiki dam site (4 km, as opposed to 7 km). Furthermore, if an embankment dam is favoured at the Zalu site, together with a side-channel spillway, then these spillway excavations might produce suitable material. Sources of embankment construction materials have been identified at the Zalu dam site. While no investigations have been conducted in this regard at the Lusikisiki site, no major problems are envisaged.

11.3 STOCHASTIC YIELD ANALYSIS

The historic yield analyses for all proposed dam sites were performed during the reconnaissance phase of the study and the results are discussed in **Section 7.1**. Stochastic yield analysis for the Lusikisiki and Zalu sites were undertaken in order to confirm the levels of assurance associated with the supply of the yields, which are used for sizing of the dams. Detailed information regarding the methodology used and the results of the analysis is available in the supporting report **"Streamflow Yield Analysis"**.

For each dam, the stochastic yield analyses were performed for three different full supply capacities, and dead storage volumes. Two hundred and one flow sequences with a length of 77 years each were used for the stochastic runs. The results are represented by risk.

The analyses have confirmed that the capacities of the dams used for sizing (4.24 million m^3 and 3.71 million m^3 for Zalu and Lusikisiki dams respectively) will generate the required gross yield (2.51 million m^3) with assurance levels exceeding 98%. The results of the firm yield analysis are given in Tables 8.6 and 8.7 (**Section 8**). The yields calculated for the different capacities include the IFR releases.

12. PRE-FEASIBILITY CONCEPTUAL DESIGN AND COSTING

More detailed sizing and costing for the Zalu and Lusikisiki dam options were undertaken during the pre-feasibility stage. The layouts of the options are shown in **Figures 20.1 to 20.4**. More elaborated conceptual designs for all major components of the system were produced **(Appendices 4, 5 and 6).** Certain additional conveyance options were identified and investigated in order to provide a first-order optimisation of the system. The designs were undertaken on the basis of improved geological and topographical information.

12.1 DAMS

Sizing

Similarly to the reconnaissance phase, the dams ware sized and costed in accordance with the VAPS Guidelines for the 2020 requirements horizon. The required storage capacities (live, dead and sediment) determined during the reconnaissance stage were used. The corresponding dam levels were then refined using the improved area-capacity relationships.

The Zalu dam was sized as a mass roller compacted concrete (RCC) structure with a central spillway. The Lusikisiki dam was sized as a composite structure with RCC central section and left flank, and earth embankment right flank.

The cross section parameters recommended by the VAPS Guidelines [33] were used. For concrete dam sections the crown width at NOCL was accepted to be 6,0 m. The wet face - vertical and smooth, and the dry face sloping at 1: 0,75, stepped for the overflow section, but smooth for the NOC section.

The earth embankment section for the Lusikisiki dam was sized for a crown width of 6 m, and both wet and dry faces slopping at 1: 2.5. A central clay core was introduced, assuming that the available material for embankment will be semi-permeable. A tongue concrete wall provides the transition between the concrete and earth sections.

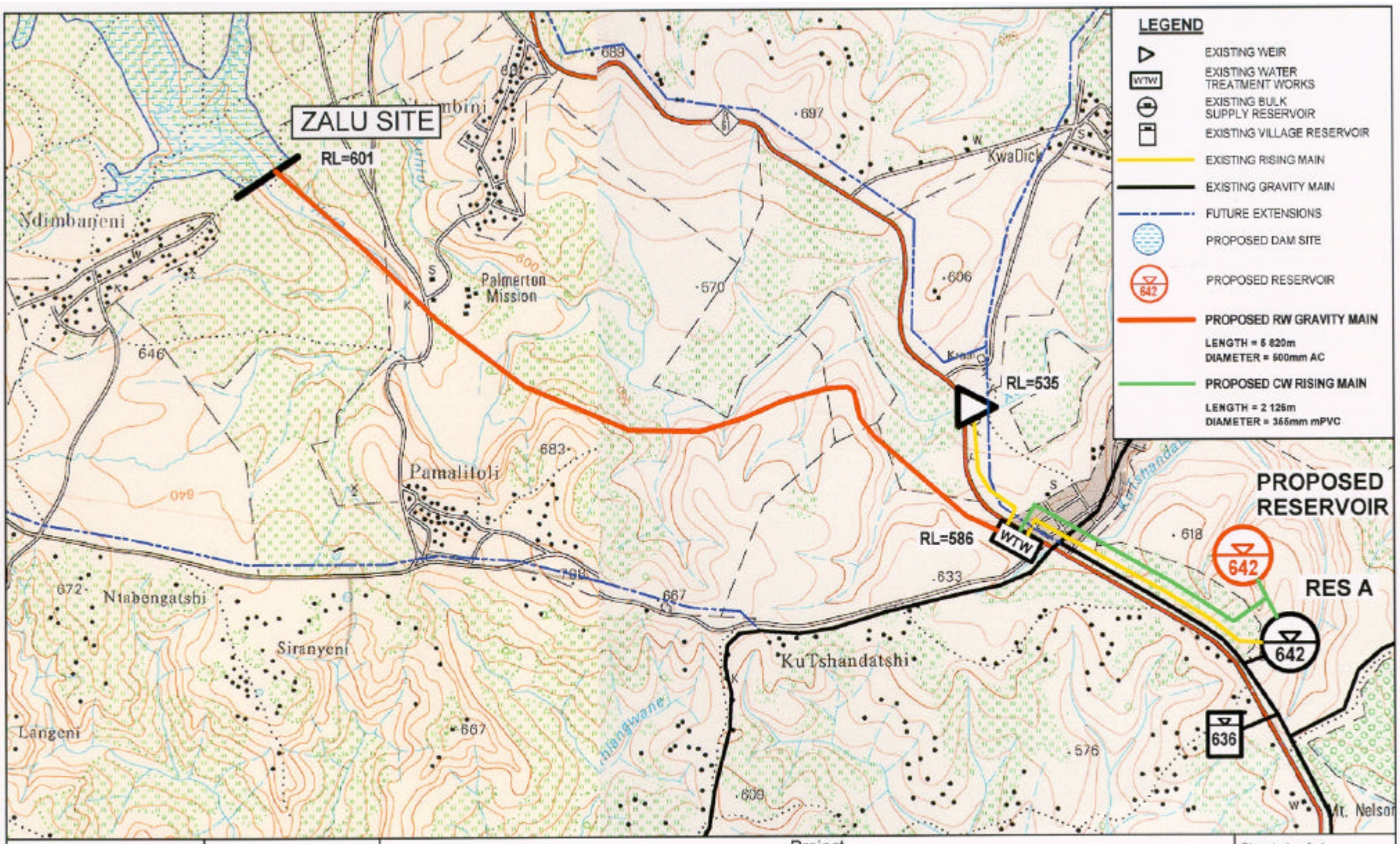
The excavation depths were adjusted according to the results of the more detailed geological investigations. Allowances for foundation drilling and grouting were provided for costing purposes in accordance with the VAPS guidelines.

The design floods for sizing of the spillways were established in accordance with the "Guidelines on Safety in Relation to Floods" (SANCOLD, Report 4, 1991) similarly to the procedure used during the reconnaissance stage. The dams were classified as follows:

- Zalu dam: Category II safety risk (medium size, significant hazard rating)
- Lusikisiki dam: Category III safety risk (large size, significant hazard rating)

The recommended flood peeks used for the determination of the RDD and SDD are shown in **Table 10.2**. The following design floods have been used for sizing of the spillways:

- Zalu: RDD of 420 m^3/s and SED of 1 090 m^3/s
- Lusikisiki: RDD of 622 m^3/s and SED of 1 639 m^3/s



ENGINEERS

Designed:	W.S.K.
Drawn:	B.M.B.
Checked:	W.S.K.

Project

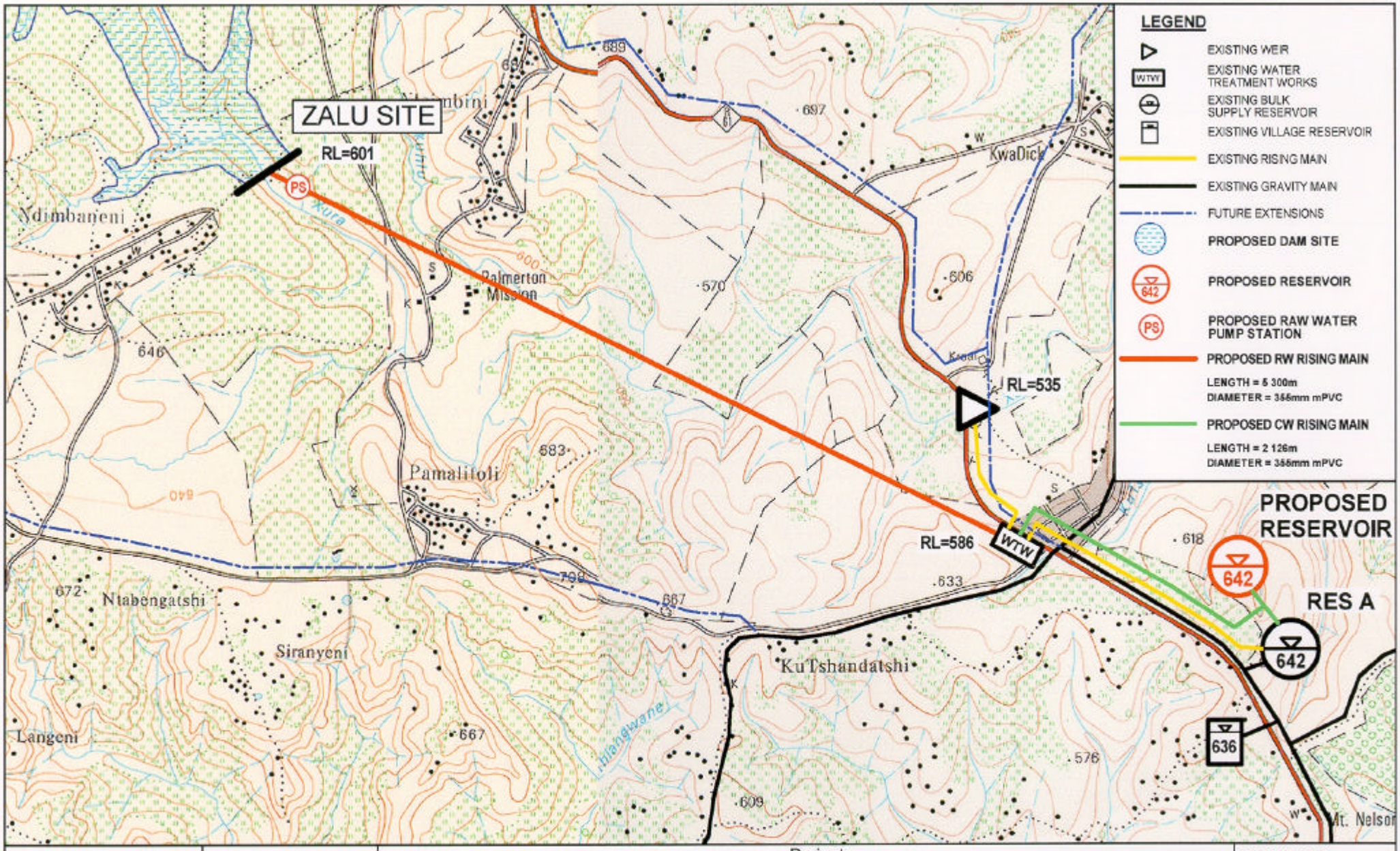
EAST PONDOLAND BASIN STUDY

Description

ZALU DAM SITE

PROPOSED BULK CONVEYANCE OPTIONS (No.3a)- GRAVITY FED (FEASIBILITY)

Sheet	1 of 1
Scale:	N.T.S.
Date:	31/07/2000
No.	Fig. 20.1



WRP ENGINEERS

Designed:	W.S.K.
Drawn:	B.M.B.
Checked:	W.S.K.

Project

EAST PONDOLAND BASIN STUDY

Description

ZALU DAM SITE

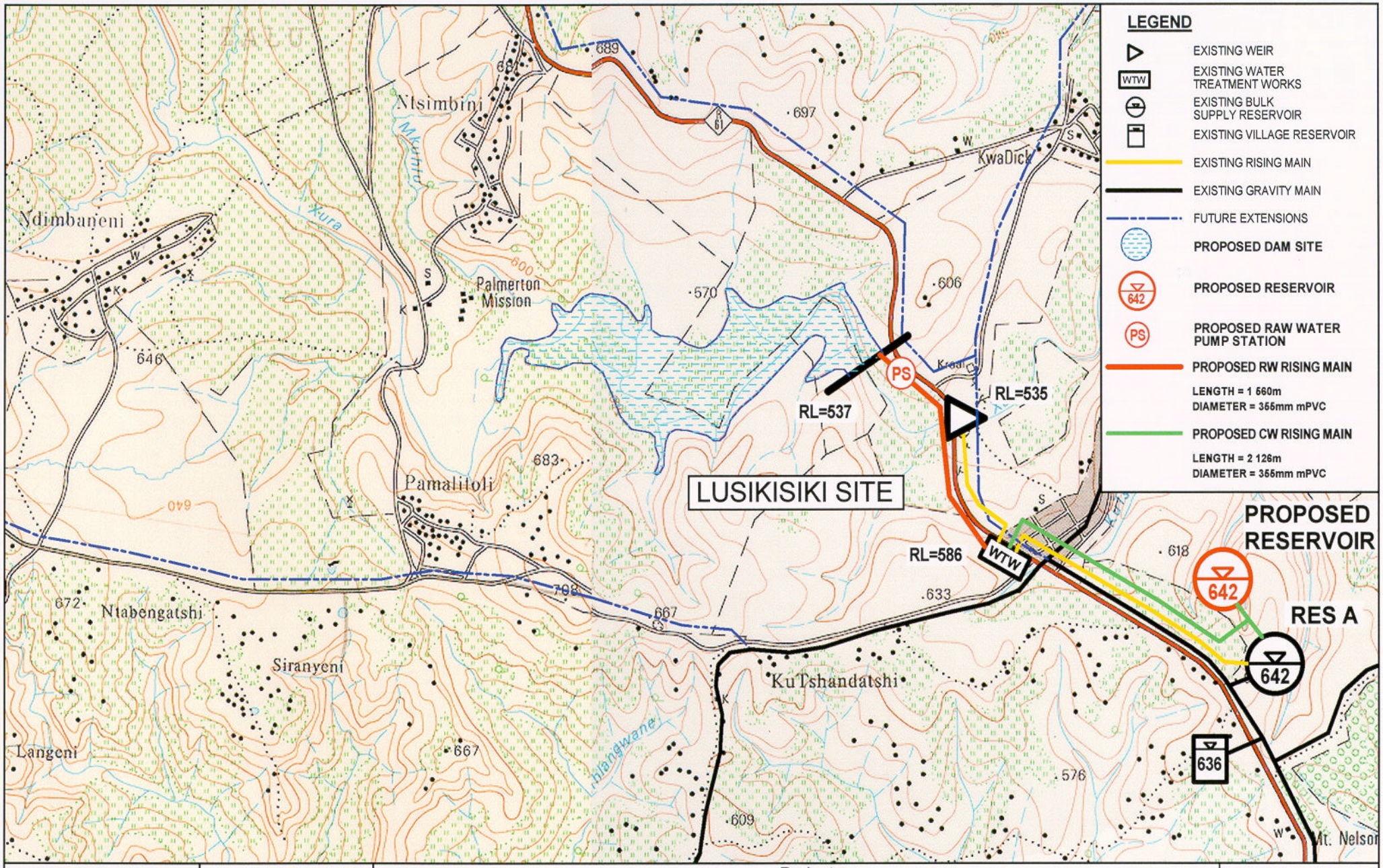
PROPOSED BULK CONVEYANCE OPTIONS (No.3b)- PUMPED (FEASIBILITY)

Sheet 1 of 1

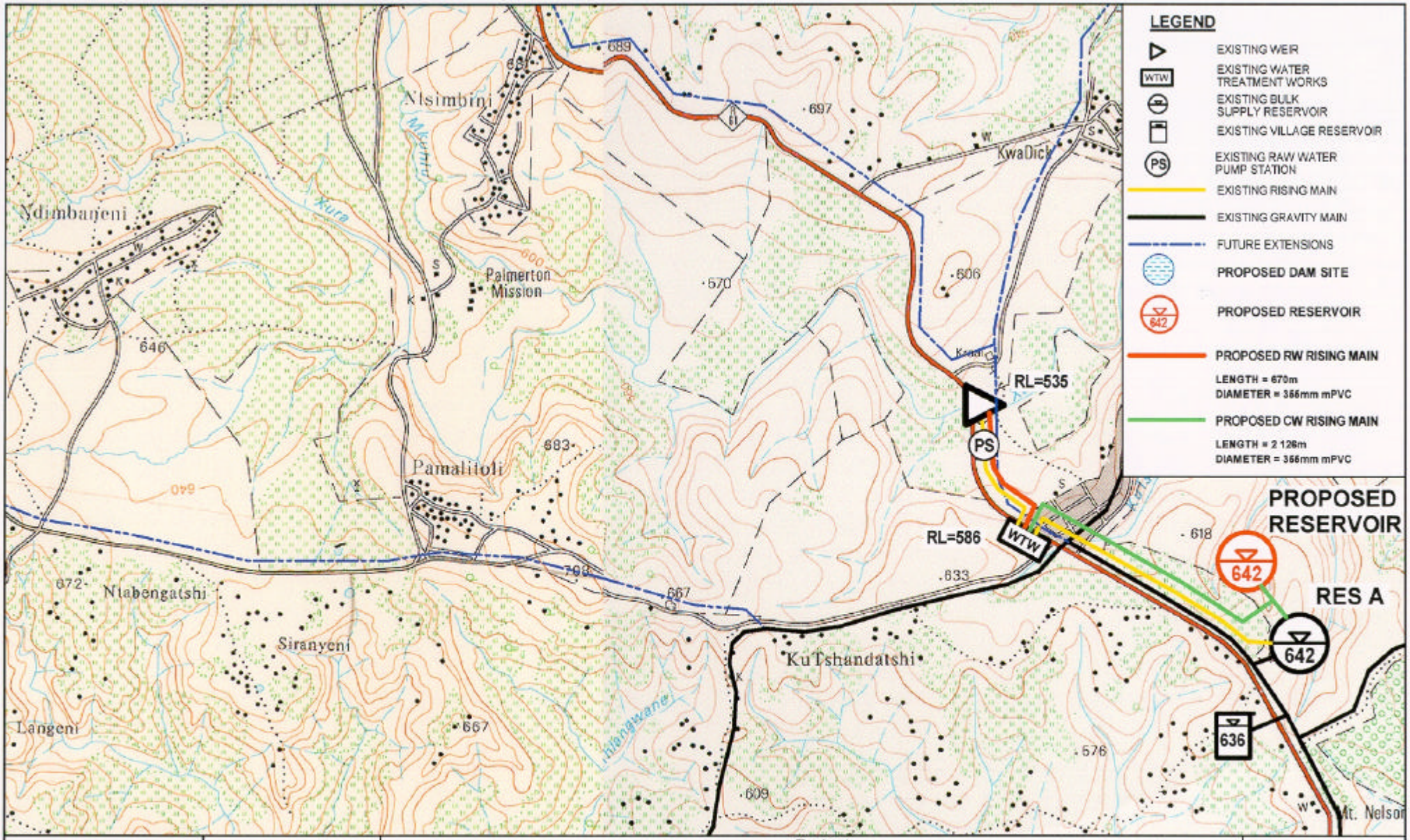
Scale: N.T.S.

Date: 31/07/2000

No Fig. 20.2



ENGINEERS	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: B.M.B.		Scale: N.T.S.
	Checked: W.S.K.	Description: **LUSIKISIKI DAM SITE** PROPOSED BULK CONVEYANCE OPTION (No.2)- PUMPED (FEASIBILITY)	Date: 31/07/2000
			No: Fig. 20.3



WWP ENGINEERS	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: B.M.B.		Scale: N.T.S.
	Checked: W.S.K.	Description: **EXISTING WEIR** PROPOSED BULK CONVEYANCE OPTION (No.1)- PUMPED (FEASIBILITY)	Date: 31/07/2000
			No. Fig. 20.4

All major structures related to the dams have been designed at conceptual level of detail: spillway and apron, gallery system, inlet and outlet works, dry well, control room, piping and valve arrangements, etc.

More detailed reports regarding the sizing of each dam are attached in **Appendix L** and the conceptual design plans are shown in **Appendices 4 and 5**. The sizing parameters are summarised in the following table.

Table 12.1: Sizing Parameters for Dams (pre-feasibility phase)

Parameter	Zalu	Lusikisiki
Type of dam	Concrete	Composite
Type of spillway	Central overflow	Central overflow
Live storage ($10^6 m^3$)	3.13	2.46
Sediment yield/storage ($10^6 m^3$)	0.80	1.00
Dead storage ($10^6 m^3$)	0.31	0.25
Total storage ($10^6 m^3$)	4.24	3.71
Bed level (m above msl)	585.5	533.0
Free board (m)	3.5	5.8
FSL (m above msl)	607.0	555.8
NOCL (m above msl)	610.5	561.6
Depth from bed to FSL (m)	21.5	22.8
Depth from bed to NOCL (m)	25.0	28.6
Depth from rock to NOCL (m)	26.5	32.6
NOC length	141	276
Spillway length (m)	90	60

Capital Cost Estimates

The capital costs have been estimated on the basis of the cost models established for VAPS. All quantities have been measured from the design plans. Allowances for mechanical items have been made. The cost models are attached in **Appendix M2**.

12.2 PRIMARY DISTRIBUTION SYSTEM

Sizing

A detailed report specifying the sizing considerations is attached in **Appendix L2** and the conceptual design plans are shown in **Appendix 6**.

The conveyance options D1A, D1B and D2 described in **Section 8.1,** as well as two additional options outlined below were sized and costed in more detail during the reconnaissance phase:

D1C: Zalu dam option, water supplied by gravity from the dam outlet works to the existing WTW

D2B: Lusikisiki dam option: similar to the Zalu option D1B, the water is released from the Lusikisiki outlet works and then pumped from the existing weir to the WTW

All system components have been sized in accordance with the applicable design flow criteria shown in **Table 10.1**. The costing has been based on the VAPS cost models, attached in **Appendix M3**.

12.3 SUMMARY OF CAPITAL COSTS

A summary of the estimated capital costs for the options studied during the pre-feasibility phase is provided in the table below. More details are available in **Appendix M.** The capital costs are estimated at March 1999 price levels and include provisions for P&G, contingencies, professional fees and VAT.

Table 12.3: Capital Cost Pre-Feasibility Phase (R million).

Opt No.	Development Option	Capital costs, R x 10^6		
		Water Source	Conveyance	Total
D1A	Zalu dam. Conveyance from outlet	R38.14	R16.16	R54.50
D1B	Zalu dam. Conveyance from weir	R38.14	R11.80	R49.94
D1C	Zalu dam: Gravity from site	R38.14	R20.16	R58.30
D2A	Lusikisiki dam: Conv. from outlet	R36.35	R12.85	R49.20
D2B	Lusikisiki dam: Conv. from weir	R36.35	R11.80	R48.15

13. EVALUATION OF DEVELOPMENT OPTIONS

13.1 ECONOMIC ANALYSIS MODEL

The most efficient scheme is not necessarily the one associated with the lowest capital costs. Running expenses, which influence the total project cost over the design life of the scheme, such as operation, maintenance and energy costs have to be taken into account. Furthermore the volume of water supplied also has to be weighted in the comparative evaluation of alternatives.

Two economic indicators of performance of the scheme have been employed in accordance with the VAPS guidelines and economic evaluation models:

- Net present cost (NPC)
- Net present value of water (NPV)

The economics model calculates the NPC at various discount rates, based on the capital costs, and the operational and maintenance costs. The NPV of water has been calculated by applying the same discount rates on the projected annual water supplies. The economic evaluation has been undertaken on the basis of the unit reference value of water (URV = NPC/NPV) established for each option. The economic analysis was performed for a 20-year horizon using the following parameters pertaining to the calculation of the operation, maintenance, energy and chemical costs:

- The following phased implementation of the scheme components has been assumed:
    - Dams, weirs and pipelines for surface water schemes: no phasing
    - Pump stations, treatment works and reservoirs: phased at 10 year intervals
    - Development of groundwater infrastructure: boreholes, pumps, pipelines etc. at 10 year intervals, following the demand curve
- A discount rate of 8 % was used, but sensitivity to variation of the rate was tested for 6 % and 10 %.
- The residual values at the end of evaluation period were established for each scheme component, on the basis of the following assumed design life:
    - 45 years for civil works
    - 30 years for M&E items and pipelines
    - 20 years for boreholes
    - 10 years for borehole pumps and diesel engines

- The annual operation and maintenance (O&M) costs were estimated as a percentage of the total capital costs. The following percentages were applied for the various types of schemes and components.

Table 13.1A: O&M costs as a percentage of the capital costs

Development Component	Single Source: Dams	Multiple Source: Weirs	Boreholes
Civil works	0.5 %	1%	1 %
M & E	4 %	8 %	10 %
Pipelines	1 %	1 %	2 %
Boreholes	-	-	3 %

- An estimate of the annual energy costs has been done, and the following rates:
  - Energy charge 6.93c / kWh
  - Demand charge R38.34 / kVA per month
  - Costs of chemicals 6c / kl

The calculated residual values, O&M costs, and energy costs for each option are provided in **Appendix J1**. The economics models, including the calculated NPC and URV are provided in **Appendix J5**. The following tables summarise the results of the economic analysis.

Table 13.1B: Results of the Economic Analysis (for reconnaissance phase)

Opt No	Description	Total Capital (R million)	Total Annual O&M (R million)	Residual Value (R million)	Max Energy (R million)	URV of Water, 8 % discount (R/kl)
D1A	Zalu dam (conv. from dam outlet)	R56.22	0.52	28.32	0.116	3.65
D1B	Zalu dam (conv. from weir)	R49.25	0.45	25.83	0.147	3.23
D2	Lusikisiki dam	R50.91	0.47	26.57	0.147	3.35
D3	Xura dam	R65.81	0.62	33.28	0.274	4.38
W1	Weir scheme (80% assurance)	R29.57	0.66	16.16	0.213	1.78
W1/G	Conjunc. (90%)	R55.97	1.54	26.42	0.456	3.03
W2/G	Conjunc. (98%)	R62.08	1.96	25.57	1.152	3.86
G1	Groundwater	R47.52	1.58	18.47	2.314	4.20

Table 13.1C: Results of the Economic Analysis (for pre-feasibility phase)

Opt No	Description	Total Capital (R mil.)	Total Annual O&M (R mil.)	Residual Value (R mil.)	Max Energy (R mil.)	URV of Water, 8 % discount (R/kl)
D1A	Zalu dam, pumping from outlet	R54.50	0.46	27.28	0.207	3.46
D1B	Zalu dam, pumping from weir	R49.94	0.42	25.77	0.281	3.21
D1C	Zalu dam, gravity from outlet	R58.30	0.49	28.49	0.159	3.69
D2	Lusikisiki dam, pumping from outlet	R49.20	0.42	25.15	0.250	3.16
D2B	Lusikisiki dam, pumping from weir	R48.15	0.40	24.81	0.281	3.10

13.2 EVALUATION OF DEVELOPMENT OPTIONS

The evaluation of the development options has been undertaken on the basis of technical viability, economic feasibility, and ecological and social acceptability, taking into consideration the other factors that may influence the developments such as geological uncertainties, employment opportunities, operation and maintenance implications and institutional arrangements. For convenience the estimated capital costs and the unit reference value (URV) of water supplied by each option, calculated at both the reconnaissance (**Tables 10.5 and 13.1B**) and pre-feasibility (**Tables 12.3 and 13.1C**) phases of the study, are combined into the following table. The top portion includes the results from the pre-feasibility phase and the bottom portion from the reconnaissance phase of the study. The costs, which were updated during the pre-feasibility phase, are excluded form the reconnaissance results.

Table 13.2: Summary capital costs and unit reference value of water

Phase	Water Source	Opt No.	Development Option	Capital costs, R x 10^6			URV of Water (R/m^3)
				Water Source	Conve - yance	Total	
Pre-feasibility phase	Dam	D1A	**Zalu dam**. Conveyance from outlet	38.14	16.16	54.50	3.46
		D1B	**Zalu dam**. Conveyance from weir	38.14	11.80	49.94	3.21
		D1C	**Zalu dam**: Gravity from site	38.14	20.16	58.30	3.69
		D2A	**Lusikisiki dam**: Conv. from outlet	36.35	12.85	49.20	3.16
		D2B	**Lusikisiki dam**: Conv. from weir	36.35	11.80	48.15	3.10
Reconnaissance phase		D3	**Xura dam**	42.24	23.57	65.81	4.38
	RoR	W1	**Weir** scheme (80% assurance)	4.68	24.89	29.57	1.78
	Conjunctive	W1/G	**Conjunctive scheme** (90% assur.)	15.24	40.37	55.97	3.03
		W2/G	**Conjunctive scheme** (98% assur.)	19.01	43.07	62.08	3.86
		G1	**Groundwater** stand alone scheme (98% assurance)	19.01	28.51	47.52	4.20

13.2.1 Surface Water Storage Schemes (Dam Options)

Selection of the best dam and associated conveyance system option

As described in **Section 10** it was concluded that the southern dam options (Lower Mzintlava and Tungwane dams on the Mzintlava river) are less favourable than the northern schemes (Zalu, Lusikisiki and Xura dams). This conclusion was based on an initial evaluation of the geological and topographic conditions, and social impacts. First order capital cost estimates confirmed that the southern options would be more expensive. Taking into account the higher pumping heads, it was concluded that these options would also have higher running costs. The southern dam options were therefore excluded from further consideration.

Amongst the northern dam options, the Xura dam appears to be less favourable. The geological conditions are poorer, and the construction of this dam will result in more significant social impacts. This option is also more expensive in terms of both capital costs (R65,81 million) and URV of water (R4,38/m^3) than the Zalu and Lusikisiki dam options. The Xura dam option can therefore be excluded from further consideration.

Even after the more detailed pre-feasibility investigations the costs for the Zalu (capital cost R49,94 million and URV R3,21/m^3) and Lusikisiki (capital cost R48,15 million and URV R3,10/m^3) dams remain very close. The difference in the costs (2.5%) is within the accuracy limits the costing models, and the costs can in fact be regarded to be identical. It is however considered that Zalu dam is preferable for the following reasons:

- The geological foundation conditions are notably more favourable. Exploration drilling has been undertaken in significant detail. The costs for future exploration drilling (if required at all) will therefore be relatively lower. All this points to less risk due to geological uncertainties than for the Lusikisiki dam.
- The topography at the dam site is more favourable and provides better dam raising opportunities in future. For higher demands, Lusikisiki dam is likely to become more expensive. Spillway conditions at Zalu dam are also preferable.
- Preferable from a social impact point of view

The best conveyance scheme option for Zalu dam is considered to be option D1B (water released from the dam outlet and abstracted at the existing Lusikisiki weir). This is the cheapest conveyance option, which also provides greater flexibility in terms of phasing of implementation. The implementation can start with the upgrading of the conveyance system from the existing weir to Reservoir A, resulting in an increased capacity of the existing scheme at times of high run of river flows. The dam can then be constructed during a follow up phase of the development. However, prior to the construction of the dam the assurance of supply from the upgraded existing scheme may be inadequate.

Based on the above considerations the Zalu dam (option D1B) is recommended for selection as the best water storage scheme option.

Summary of the advantages and disadvantages of the recommended Zalu dam option

When compared to the other water source options, the Zalu dam option has the following advantages and disadvantages:

Advantages

- The dam can be sized to supply water at the required 98% assurance of supply (or higher)
- The dam provides water at the lowest URV (R3,21) as compared to the other source options, which can be sized for the same high assurance levels (conjunctive option W2/G – R3.86, ground water stand alone option G1 – R4.20).
- Flexibility with respect initial development and to future changes in demand pattern. The incremental cost necessary to accommodate higher future demands (than projected during this study) will be lower than for any other source option.
- Less complicated institutional structures and cheaper operation and maintenance, resulting in potentially higher levels of sustainability.
- Potentially higher employment and recreation opportunities

Disadvantages

- Higher initial capital requirement, less phasing opportunities
- Marginally higher social impacts are possible

13.2.2 Run of River Scheme (Weirs, option W1)

This scheme was evaluated despite the fact that it can only be considered for implementation if a lower (80%) assurance of supply is acceptable. This option provides the lowest capital cost (R 29.57 million) and URV of water (R1.78). It should be noted that a direct comparison between options supplying at different assurance levels is not possible.

Advantages of the run of river option

- More flexible with regards to phasing of implementation. Can be implemented in three phases in line with the demand and availability of funds, i.e. upgrading of the existing primary infrastructure, followed by the construction of the two additional weirs and the associated conveyance systems.

Disadvantages of the run of river option

- Low assurance of supply. The assurance can be increased at the expense ecological flow releases (Reserve)
- Lack of flexibility to cater for change in water demand patterns. The maximum capacity is limited to the requirements of the low demand scenario. Should the demands be higher than currently projected, the assurance of supply will drop further to even more unacceptable levels.
- The operation of three abstraction points and two water treatment works will be more complicated and expensive than for the dam options.

Due to the lack of flow records of sufficient length, the confidence in the results of the low flow yield analysis used for sizing of this option is low. The feasibility of this option is very sensitive to the ecological flow releases. More detailed investigations will be required if this option is considered for implementation.

13.2.3 Conjunctive (run of river plus groundwater) and groundwater stand alone options (W1/G W2/G, and G1)

The conjunctive surface and groundwater source option W1/G (surface water supply from the Lusikisiki, Xura and Mzintlava weirs, supplemented by groundwater supply from about 90 boreholes at times of low surface flows) was sized to supply the requirements at an assurance of 90%. Although supplying at lower assurance, the economic parameters of this option (capital cost R55.97 million, and URV R3.03) are in the same range as the 98% assurance schemes (dam options). This option is therefore not favoured. An alternative to this option to supply water at 98% assurance was not investigated because it would obviously be more expensive than option W2/G discussed below.

Options W2/G (surface water supply from the Lusikisiki weir, supplemented by groundwater supply from about 160 boreholes at times of low surface flows) was sized for 98% assurance of supply. This option (URV R3.86) is more favourable than option G1 (stand alone groundwater scheme, based on the development of about 160 boreholes and the associated infrastructure, URV R4.20). Based on the aforementioned considerations the best conjunctive or groundwater scheme is considered to be option W2/G.

Advantages of conjunctive water schemes (W2/G)

- Opportunity for phased development. The existing primary infrastructure can be upgraded as a first phase, followed by the development of boreholes to be implemented in phases along with the growth of the demand on the system.

Disadvantages of conjunctive water schemes

- Higher URV of water (R3.86), when compared with the best dam option (R3.21)
- Based on previous experience, the local population does not favour and will probably not support a scheme based on groundwater supply (established during interviews with various involved parties)
- High operation and maintenance costs and complicated institutional structures will be required to ensure the sustainability of the scheme (160 boreholes)
- The confidence in the results of these options is lower than in the case of the dam options. No exploration drilling or testing of boreholes has been undertaken.

13.3 SUMMARY OF PREFERRED OPTIONS

Based on the comments in the previous sub-chapters, the following best development options for each category of water source are suggested:

Table 13.3: Summary of recommended schemes per source category

Water Source	Opt No.	Development Option	Assu-rance	Capital costs (10^6)			URV (R/m^3)
				Water Source	Conve - yance	Total	
Dam	D1B	**Zalu dam**. Conveyance from weir	98%+	R38.14	R11.80	R49.94	3.21
RoR	W1	**Weir** scheme (Lusikisiki, Xura, Mzintl.)	80%	R4.68	R24.89	R29.57	1.78
Conjunctive	W2/G	**Conjunctive scheme** (Lusikisiki weir plus 160 boreholes)	98%	R19.01	R43.07	R62.08	3.86

14. CONCLUSIONS

14.1 DEVELOPMENT OPTIONS/SCHEMES

The Lusikisiki Regional Water Supply Scheme (LRWS) currently serves about 52 000 people in the town of Lusikisiki and 23 surrounding villages, but the existing water source has insufficient assured yield to meet the water requirements. The augmentation of its water source is urgently required.

Various possible supplementary water sources have been considered – surface water storage schemes (dams), surface water run of river schemes (weirs), conjunctive use of surface and groundwater, and stand-alone ground water schemes. For each of these sources, a number of development options have been investigated, evaluated and the best options selected.

The capital cost of each option was estimated. This includes the development of the water source and the primary conveyance system (pump stations, bulk supply pipelines, water treatment works and storage reservoirs).

Based on the findings of this study it can be concluded that the water source of the LRWS scheme can feasibly be augmented by one of the following development options:

Surface storage scheme (capital cost R49.94 million, URV R3.21)

This scheme would comprise the Zalu dam (option D1B), with water released down the river and abstracted again at the existing weir on the Xura River. The option includes the upgrading of the existing primary conveyance infrastructure. This option provides the highest assurance of supply (exceeding 98%) at the lowest URV of water, and is considered to be the most favourable in comparison with all other options.

This option should be selected by the Department if:

- Assurance levels lower than 98% are not acceptable
- Possible future extension of the scheme is required or regarded as beneficial. This is the only feasible option if higher demand scenarios are anticipated
- Particular preference is given to lower operation and maintenance costs and less complicated institutional structures
- More employment and recreational opportunities are deemed important

Surface water run of river scheme (capital cost R29.57 million, URV R1.78, at 80% assurance)

Option W1 includes the upgrading of the existing run of river scheme from the Lusikisiki weir, as well as the development of two additional weirs on the Xura and Mzintlava Rivers, together with the associated conveyance systems. The maximum yield that can feasibly be abstracted, after the release of the ecological requirements, can meet the future water demands (low demand scenario only) at an assurance of 80%. Should the demands be higher than projected, the capacity of this option will not be adequate. Therefore, this option can only be considered if:

- Lower assurance of supply (80%) is acceptable, or alternatively if the ecological reserve requirements can be relaxed
- And, phased development is preferred
- And, a multiple source with the resulting operational complications and costs is acceptable
- And, no increase in the demand pattern is anticipated

Conjunctive use of surface and groundwater (capital cost R62,08 mil., URV R3.86)

Option W2/G (upgrading of the conveyance system from the Lusikisiki weir, supplemented by groundwater supply from about 160 boreholes at times of low surface flows) was identified as the best conjunctive scheme option. The implementation of this option can be considered if:

- Phased development (less initial capital) is of paramount importance
- And, higher operation and maintenance costs are acceptable
- And, the sustainability of the scheme can be guaranteed by the establishment of an adequate institutional structure required for the management of a reasonably complicated system
- And, rejection of borehole based schemes by local water users can be overcome

No specific preference for any of the development options can be given from an environmental point of view. From the social perspective the development of the Zalu dam involves the inundation of a small area of cultivated land and some loss of access, but this would probably be offset by positive impacts such as recreational opportunities, job creation, etc. The local population has expressed a definite preference for surface water supply.

14.2 WATER SOURCE

The findings of the reconnaissance investigations undertaken during the course of the Eastern Pondoland Basin Study indicate that the water shortages experienced at the LRWSS are due to the inadequate capacities of the two main components of the system – the water source, and the bulk supply infrastructure.

- Without provision for the release of the ecological Reserve, the existing water source (a weir on the Xura River) can supply the present and future (2020) water requirements with assurances of 95% and 75% respectively.

- If provisions for the release of the ecological Reserve are made, the assurance of supply from the existing water source will be reduced to 70% and 50% for the present and future water requirements respectively.
- The above indicates that irrespective of the ecological Reserve requirements, the capacity of the existing water source is insufficient to meet the water requirements at the guideline limit of 98% assurance of supply, and the water source should be augmented.
- If the ecological Reserve must be released, the water source should be augmented immediately, there would be no time for further studies, and a decision should be taken on the basis of the reconnaissance study results. If the ecological Reserve can be relaxed, there would be more time for further studies to confirm the conclusions of the EPBS.
- The surface and the groundwater resources in the area have high potential for development and can be used for augmentation of the existing water source.
- Based on the results of the reconnaissance study, the following options for augmentation of the water source, capable of meeting the system's requirements at 98% assurance of supply, can be considered for implementation:
  - The most feasible storage scheme option is Zalu dam (URV R3,21). This option was found to be the most favourable amongst all options investigated during the course of the study. If there is no time for further studies, this option should be implemented.
  - The conjunctive surface and groundwater use option (URV R3,86) includes abstractions from the existing weir, supplemented by the development of boreholes to be operated during times of low river flows. This option is feasible, but more detailed groundwater studies would be required before a consideration for implementation can be given.
- Despite the high MAR from the area, and due to the considerable seasonal variability of runoff, the run of river yields, available for abstraction in and around the study area with assurance levels of 98%, are low. The release of the ecological Reserve requirements reduces significantly the remaining low flows available for abstraction (zero at 98% assurance). Non-regulated, stand-alone run of river schemes (option W1) will not be capable of meeting the requirements as stand-alone augmentation options and can only be considered if a lower assurance of supply (80%) is acceptable. In order to meet the water requirements at 98% assurance of supply, a storage scheme would be required.
- The groundwater stand alone option (URV R4,20) considered during the course of the study was found to be less favourable than all other options investigated. This is due to the large number of boreholes (160) required to operate at all times, and the associated high costs for development, operation and maintenance of this source. It was proven that it would be more feasible to supply the system requirements form surface water at times of high flows, supplemented by groundwater (as per option W2/G), than to use groundwater alone. This option is therefore not recommended for further investigations.

14.3 BULK SUPPLY SYSTEM

- The capacity of the existing bulk water conveyance infrastructure is insufficient to supply the present water requirements and a shortage of about 30% is presently experienced. This infrastructure needs to be upgraded urgently.
- The bulk water conveyance system should be upgraded irrespective of whether the supply area of the scheme is extended or not. The requirements for the areas covered by the proposed extensions are relatively low (28%) when compared with those for the full supply area. The proposed future extensions may only influence to a limited extent the sizing parameters for upgrading of the bulk infrastructure, but not the decision to implement the upgrading.

14.4 UNCERTAINTIES AND FURTHER STUDIES

It should be noted that the EPBS study has been undertaken at a reconnaissance (desktop) level of detail and the above conclusions were made in the presence of a number of uncertainties. If time and resources could be made available, further studies should be undertaken to confirm the conclusions and refine the results of the reconnaissance study:

- Actual position and yield of the boreholes: certain assumptions based on the best available information have been made with regards to the average characteristics of the source and the conveyance infrastructure (yield, pumping head, access, conveyance length, storage). These assumptions can only be confirmed through more detailed groundwater studies, including field investigations, exploration drilling and testing.
- Ecological Reserve requirements: these requirements were determined on the basis of the rapid methodology. The costs for the development of the surface water augmentation options are very sensitive to variations of the ecological Reserve estimates. Significant savings can be achieved if the ecological Reserve requirements are relaxed. More detailed environmental studies will be required.
- Reliable hydrological data (flow records) for the Xura River are available only from 1996. No proper calibration of the WRSM90 model could be done, as at least ten years of records would be required. The collection of observed flow data at the Lusikisiki weir site should continue. If the development of a surface water source (dam or weirs) is deferred for more than five years, the flow records should be used to update the catchment hydrology and to refine the design parameters of the proposed infrastructure.
- Water requirements: The population numbers were estimated on the basis of the 1996 Census results. The updated information from the 2001 Census will become available in 2003, and can be used to revisit the estimated water requirements.

The temporary relaxation of the ecological Reserve releases for the river stretch between the existing Lusikisiki weir and the confluence with the next major tributary (about 3 km) can make time available for firming up on the results of this study. At the same time the water supply situation can be significantly improved. This can be achieved by upgrading of the capacity of the existing bulk water conveyance infrastructure and by increasing the abstractions from the existing weir. The present water requirements can then be supplied with an assurance of 95% reducing to 93% by year 2005 and to 85% by year 2010.

15. RECOMMENDATIONS

The following recommendations are offered:

- Upgrade the existing bulk supply system from the Lusikisiki weir to the command reservoir to meet the projected water requirements up to the year 2020. This is a common component for all three favourable augmentation options considered and can be regarded as the first phase of the augmentation of the water source. The upgrading will allow increased abstractions from the existing weir at least at times of high river flow. This action, combined with the proposed relaxation of the ecological releases (see bullet below) will result in an immediate improvement of the water supply situation of the existing scheme and will increase the assurance of supply from 70% to 95%.

- Relax temporary the ecological Reserve releases into the Xura River, downstream of the existing weir. This may result in a temporary environmental impact on a river reach of approximately 3 km, which is presently largely modified. The ecological Reserve releases will be compromised only during low flow periods. During normal flow conditions, sufficient riverine flows will be available. After the augmentation of the water source is completed, the low flow ecological Reserve releases will be made and it is anticipated that the ecosystem in the affected river reach will recover.

  This will provide additional and needed time for further studies to confirm and finalise the results of the reconnaissance investigations undertaken during the course of the EPBS, and for implementing the selected option for augmentation of the water source. This action combined with the increase of the capacity of the bulk supply system will contribute for a speedy and notable improvement of the water supply situation within the existing scheme supply area.

- It is recommended that a more detailed feasibility study be commissioned in order to obtain more accurate information and to refine the results of the reconnaissance study. This study will allow the selection of the best development option with regards to the water source on the basis of updated information. The proposed feasibility study should include the following main components, and should address the uncertainties identified during the course of the reconnaissance study:
  - Groundwater resources aspects (hydro-census, follow up on remote sensing interpretations, exploration drilling and testing, report).
  - Ecological aspects (preliminary reserve determination, EIA associated with the proposed relaxation of the Reserve, detailed EIA report for approval of the proposed developments).
  - Engineering aspects and study co-ordination (guidance to specialist consultants, review hydrology and water requirements, review and reassess augmentation options, based on the updated information from the above studies, issue an overall study report).

- A drilling contractor may be required for the exploration drilling covered in the above section. The contractor will be supervised and managed by the groundwater consultant appointed for the aforementioned study. If successful boreholes are drilled at suitable positions they could be equipped and connected to the existing bulk supply system. This can be regarded as a bridging scheme, and could be used until the final augmentation option is selected and developed.
- Take the final decision regarding the best development options for implementation on completion of the feasibility study.

More information regarding the implementation strategy to augment the water source of the Lusikisiki Regional Water Supply Scheme is available form the report "Proposed Guidelines for Implementation (DWAF, March 2002, Report No. PB T600 – 00 – 1702).

16. REFERENCE LIST

Reference No	Details
Ref 1	HKS, Nov 1978: Lusikisiki bulk water supply: Preliminary Report
Ref 2	Transkei Department of Agriculture and Forestry, 1979 : White Paper on the Proposed Lusikisiki District Rural Water Supply Scheme
Ref 3	HKS, Feb 1979 Lusikisiki Water Supply, Preliminary Geological and Soils Investigation, Lower Zalu Dam Site, DAF Transkei
Ref 4	HKS, March 1979 Lusikisiki Water Supply, Zalu Dam Site, Foundation investigations, Tender document
Ref 5	HKS, March 1979 Zalu Dam Foundation Investigation, Tender Document
Ref 6	HKS, March 1979 Lusikisiki Water Purification Works, Preliminary Design Report, DAF Transkei
Ref 7	HKS, June 1979 Lusikisiki Water Purification Works, Revised Preliminary Design Report, DAF Transkei
Ref 8	HKS, Oct 1979 Lusikisiki Water Supply : Zulu dam site : Detailed geological and Materials investigation Vol 1 and 2
Ref 9	HKS 1980: Lusikisiki District Bulk Water Supply Scheme : Zalu Dam – Report Volume 1 : Report, Vol 2: drawings
Ref 10	HKS 1986: Lusikisiki Regional Water Supply : Preliminary report
Ref 11	HKS 1987: Lusikisiki Regional Water Supply Scheme : Outline of the major aspects of the scheme
Ref 12	HKS, Jan 1990 Taweni Village Water Supply, Reconnaissance Report, DAF Transkei
Ref 13	HKS, Feb 1995: Lusikisiki Regional Water Supply Scheme: System Analysis
Ref 14	GMA 1996, Lusikisiki Regional Bulk Water Supply scheme, Project Business Plan for the ECCWSS, Project 26
Ref 15	GMA, Nov 96 Addendum No 1 to Business Plan to Project No 26, Lusikisiki Regional Bulk Water Supply Scheme – Report on Low-Flow Yield Analysis
Ref 16	GMA, 1996 Lusikisiki Regional Bulk Water Supply Scheme, Technical Report, Project No 26

Ref 17	GMA, 1996 Lusikisiki Regional Bulk Water Supply Scheme, Design Report
Ref 18	IWR, 1997. Assessment of the available water resources from the Xura River and the Lusikisiki Regional Bulk Water Supply Scheme
Ref 19	UWP, 1999 Lusikisiki Regional Water Scheme, Status Report, Revision 2, DWAF
Ref 20	UWP 1996, Lusikisiki village reticulation, Project Business Plan
Ref 21	O'Connell, Manthe & Partners, Feb 1979. Proposed Regional Domestic Water Supply. Physical Survey and Planning of Supply Schemes
Ref 22	O'Connell, Manthe & Partners, Dec 1982, Republic of Transkei; Domestic Water Supply : Rural Areas
Ref 23	Ninham Shand Inc. 1980. *Hydro-Electric Development in Transkei.* Prepared on behalf of the Department of Works and Energy, Transkei.
Ref 24	DBSA. 1996. *Population of South Africa : Updated Estimates Scenarios and Projections :* 1990 – 2020.
Ref 25	DBSA. 1989. *Transkei Development Information.*
Ref 26	Department of Water Affairs and Forestry. 1997. *White Paper on National Water Policy for South Africa*.
Ref 27	Midgley, Pitman & Middleton. 1994. *Surface Water Resources of South Africa : 1990*. Water Research Commission Report no 298/5.1/94.
Ref 28	Rooseboom, et al. 1992. *The Development of the New Sediment Yield Map of Southern Africa.* Water Research Commission Publication no 297/2/92.
Ref 29	BTS Consortium 1988 : Transkei Water Supply Prioritisation study, Proposed Dam for Bizana to serve part of Lusikisiki Vol 1 : Report, Vol 2 : Data tables
Ref 30	Data from Municipal Infrastructure Business Plans for ECDHLG
Ref 31	Stewart Scott. 1988. *National Urbanisation Strategy Report 4, Volume 2 – Engineering Services*. Prepared for Government of Transkei.
Ref 32	DBSA. 1989. *Transkei Development Information.* Section 9.
Ref 33	DWAF, 1996. Report No PC000/00/14394. VAPS: Guidelines for the preliminary sizing, costing and engineering economic evaluation of planning options.

APPENDIX A1 :

PHOTOGRAPHS AND PLATES



PLATE 1: Zalu dam site viewed from the left flank



PLATE 2: Zalu dam site at riverbed



PLATE 3: Lusikisiki dam site viewed from upstream



PLATE 4: Lusikisiki site: Scattered rock outcrops at riverbed



PLATE 5: Xura dam site viewed from upstream



PLATE 6: Tuugwane dam site viewed from upstream. Notably asymmetrical



PLATE 7: Lower Mzintlava dam site viewed from the right flank



PLATE 8: Lower Mzintlava Site viewed from downstream

APPENDIX A2 :

TERMS OF REFERENCE

APPENDIX A2

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE OF WATER RESOURCES PLANNING

LUSIKISIKI BASIN STUDY

TERMS OF REFERENCE

LUSIKISIKI BASIN STUDY

TERMS OF REFERENCE

1. Background

Lusikisiki magisterial district is located in the most north-eastern, coastal part of the Wild Coast District of the Eastern Cape Province (formerly part of Transkei). This area is also known as the Pondoland coast and includes all river catchments between the Mntafufu and Mzamba Rivers (tertiary drainage region T600).

The introduction of the RDP water supply programme has resulted in the identification of the need in many instances for substantial augmentation of the domestic water supply schemes serving the large rural population in the region. In particular, water resources with adequate yield assurance are required for the upgrading of the water supply to the Lusikisiki magisterial district (213 000 people). The Wild Coast Spatial Development Programme has identified forestry and tourism as the drivers for economic development in the area. Agricultural developments for the production of sugar cane and tea may be viable. Furthermore, the riverine systems and the estuaries of the rivers in the area are in pristine condition. The Mkambati Nature Reserve (Msikaba River estuary) and the entire Pondoland coast are extremely environmentally sensitive. These are national assets and attractions for tourists.

The surface water resources in the area are largely under-utilised. Groundwater may have a potential for cost efficient water supply in certain areas of the district. Conjunctive use of run-of river and ground water may be economically viable in other areas. The economic viability of hydropower generation in the case of construction of dams in the area has not been investigated.

In general, the knowledge level about the water resources in the Pondoland area as well as many other Transkei catchments is very limited. In order to provide a planning tool for the sustainable development and efficient utilisation of the water resources in the area, it is recommended that a basin study be conducted. Such a study will further the aim of bringing the level of available information for the Transkei region in line with the rest of the catchments in South Africa. This study will also contribute valuable information for the establishment of a water management area and a catchment strategy as stipulated by the new Water Act.

The results of the study will be useful for other Government Departments and interested parties for the planning of various development initiatives.

2. Purpose of the Study

The study area is defined as the coastal river catchments between the Mntafufu and Mzamba Rivers (see attached locality map).

The study will provide a broad evaluation of the current state and the potential for development of the water resources in the area, as well as the present and potential water requirements for all user sectors. The Msikaba River catchment within which Lusikisiki lies will be given more detailed attention. Particular attention will be given to establishing the environmental water requirements for the Mkambati Nature Reserve which lies on the estuary of the Msikaba River.

A more specific output of the basin study will be a clear indication at a pre-feasibility level of detail, of a preferred source for augmentation of the domestic supply for the town of Lusikisiki and the surrounding rural areas as well as a recommendation for an implementation programme.

3. Proposed Scope of Work

The following activities are recommended to be undertaken during the course of this study (levels of detail – pre-feasibility for Msikaba River catchment and reconnaissance for the rest of the area) :

3.1 Background Information

- Assemble, collate and present in a suitable form existing information on the study area: climate, topography, demographics and socio-economic development, current and planned land use, institutional and legal aspects, natural resources, etc.
- Assessment of the accuracy and completeness of the existing information. Identification of gaps and further information required.
- Limited verification and patching of information, where necessary.

3.2 Domestic water supply situation

- Population and livestock distribution, present levels of service where this is known, existing projects and projects in process of implementation.
- Population growth and proposed future levels of service.
- Area planning and possible grouping of schemes.

3.3 Existing infrastructure

Existing road, rail and electricity infrastructure will be described. A description of the existing major water supply infrastructure, its operational condition and upgradability will be provided.

3.4 Agricultural developments and afforestation

- In general, this is to be limited to a broad overview of possible developments with reference to the effect of these developments on the runoff and water requirements. For the Msikaba catchment a more detailed assessment is required.
- Determine the extent of existing developments. Document all available information on development potential and identify information gaps. Study and review all development programmes proposed for the area (Wild Coast Spatial Development Initiative, for instance). Assess the feasibility of future developments taking into account available water resources, economic development potential and financial constraints. The assessment should include the effects of dryland farming, irrigation and commercial livestock farming as well as the effects of afforestation (planted forests) and invasive forests.

3.5 Water requirements

- Present and future water use by the various user sectors is to be assessed. Historical water use information should be presented where available and of use for future projections.
- Urban and industrial.
- Rural, domestic and livestock.
- Agricultural developments and afforestation.
- Hydropower generation (desktop evaluation of potential, feasibility and flows, only for proposed dams).
- Environmental and social requirements (the Reserve). IFR's are to be expressed as a percentage of natural annual flows.

3.6 Runoff hydrology, surface water resources and yield analysis

- In general the water resources assessments will be done primarily on the basis of WR90.
- In the case of the Msikaba River, the existing flow data collected by the former DAF of Transkei and by the DWAF prior to Transkei independence in 1968 will be reviewed, and if feasible will be used to determine more accurate Pitman Model parameters than obtainable from WR90. If flow records within the catchment are unsatisfactory then it may be necessary to calibrate a Pitman model for the catchment by making use of flow records for adjacent catchments and cross correlation.

Historical firm yield analysis will be applied for the calculation of the yields of proposed dams. Long term stochastic yield may be considered as an option.
- Floods for proposed dams and river abstractions will be estimated on the basis of TR137 for Msikaba River only.

3.7 Groundwater resources

- Studies for assessments of availability and assurance of groundwater resources will be undertaken on the basis of readily available information (borehole database) and previous experience in the area.
- A more detailed investigation may be required for the Lusikisiki water supply area only. The occurrence of aquifers, fractured rock and faults may have to be identified.

3.8 Reconciliation of supply and demand

- An assessment of the water balance in each catchment at 10 year intervals for the period until 2030 is to be undertaken and presented in a suitable form.

3.9 Water quality, sedimentation and return flows

- The river catchments of the study area are not presently included in any of the water quality monitoring systems and databases (HIS and POLMAN).
- Unless a monitoring programme is established by DWAF as a matter of priority then the consultant will be required to arrange that water samples from specific sites be tested during the course of the study and that the results be documented.
- Available sedimentation mapping and any other information on sedimentation such as the extent of erosion in the various catchments will be documented. This information will be used to predict the rate of sediment accumulation in new dams.
- The effect of return flows in the area is limited. Available information will be documented.

3.10 Development options for water supply to the Lusikisiki area

The various development options for the supply of water to Lusikisiki and surrounding villages are to be identified and described. This will involve:

- Review of previously identified schemes.
- Review, grouping and area planning.
- Shortlisting of options utilising all applicable criteria (technical feasibility, social and environmental acceptability, institutional and

operational viability, phased implementation, labour intensive construction, cost etc.)

3.11 Selection of preferred development option

- Conceptual design and sizing of competitive options, based on approved sizing criteria.
- Topographic surveys where required.
- Costing on the basis of cost models and cost functions agreed upon with the client. Recurrent annual costs will be calculated for each option.
- Economic evaluation will be done on the basis of discounted present cost and the unit reference value (URV) of water supplied by each option. The URV will be calculated for a period of time and discount rate as agreed with the client.
- A sensitivity analysis for various discount rates will be performed.

3.12 Environmental aspects

The purpose of this investigation will be to identify problematic areas and to provide a broad idea of the instream flow requirements for the rivers and the estuaries, to establish the river flows necessary to satisfy basic human needs and to provide a broad estimate of the Reserve. In the case of the Msikaba River a more detailed assessment of these water requirements is required. Results will be based on a desk study, existing information and limited site visits. No workshops are envisaged for this stage.

- Broad classification of rivers (possibly a group classification if rivers are similar).
- Broad estimate of the IFR for each river and estuary (based on D. Hughes planning estimate method) expressed as a percentage of the natural annual runoff.
- Assessment will be based on the Integrated Environmental Management (IEM) procedures as prescribed by the Environmental Conservation Act (1989) and more specifically the Regulations gazetted on 5 September 1998.
- More detailed assessment of the IFR and the Reserve for the Msikaba River (including its estuary) and the Mkambati Nature Reserve and of the impacts related to possible water resources developments for the Lusikisiki area will be undertaken. This could include assessment of the Preliminary Reserve as defined in the new Water Act and a scoping exercise to provide a broad assessment of the impacts of the more favourable dams identified.

3.13 Social aspects

For the schemes identified in the study the following will be established:

- Estimate number of people directly or indirectly affected by the developments.
- Estimate potential health and safety hazards.
- Estimate extent and value of physical assets that will be lost as a result of the development.
- Investigate and estimate the cost of mitigation measures.

3.14 Public involvement and community liaison

Public involvement and community liaison will be performed from the commencement of the study through the formation of a Stakeholders Liaison Committee. All affected communities and interested parties will be informed of the proposed developments and their inputs invited.

APPENDIX B :

POPULATION NUMBERS AND
WATER REQUIREMENTS

Appendix B.1: Population numbers within certain Magesterial districts

Information based on reconcilliation of 1995 Census results (MarkData 2000)

EASTERN CAPE (EC) 1995

PROV	MGD	TOWNS / CC's AND RR PER MGD	F/URBAN	RR	TOTAL
EC	**BIZANA**	**BIZANA TOTAL DISTRICT**			**203 500**
EC	BIZANA	BIZANA	2 950		
EC	BIZANA	BIZANA RR		200 550	
EC	**FLAGSTAFF/SIPHAQUENI**	**FLAGSTAFF/SIPHAQUENI TOTAL DISTRICT**			**116 750**
EC	FLAGSTAFF/SIPHAQUENI	FLAGSTAFF	7 650		
EC	FLAGSTAFF/SIPHAQUENI	SIPHAQUENI / FLAGSTAFF RR		109 100	
EC	**LUSIKISIKI**	**LUSIKISIKI TOTAL DISTRICT**			**239 450**
EC	LUSIKISIKI	LUSIKISIKI	11 350		
EC	LUSIKISIKI	LUSIKISIKI RR		228 100	

PROV: Province
MGD: Magisterial District
CC: Consumption Centres
RR: Rural Remainder
F/URBAN: Functional Urban

Appendix B2: Population Numbers and Water Requirements per Village

Admin Area	Village Names	Population Numbers					Net Annual Demands ($10^6 m^3/a$)			
PHASE I (EXISTING SCHEME)										
		1996	**2000**	**2010**	**2020**	**2030**	**2000**	**2010**	**2020**	**2030**
Lusikisiki TLC	Lusikisiki: domestic	11 350	11 946	12 624	12 907	13 479	0.480	0.645	0.801	0.984
	Lusikisiki: institutional & industrial						0.261	0.288	0.318	0.352
Dubana	Maklakane; Ngibe	206	209	204	182	159	0.002	0.002	0.002	0.002
	Mcobotini - A	1 155	1 173	1 140	1 018	893	0.009	0.011	0.012	0.013
	Mahlakane	3 392	3 444	3 349	2 990	2 622	0.026	0.033	0.036	0.038
	Dlibona; Ngqunggqu; Ngqunggqushe	3 637	3 693	3 591	3 206	2 812	0.028	0.036	0.039	0.041
Xura	Dumasi	1 794	1 822	1 772	1 582	1 387	0.014	0.018	0.019	0.020
	KuTshandatatshi; Tshandatatshi	885	899	874	780	684	0.007	0.009	0.010	0.010
Lower Xura	Mdikana	1 324	1 344	1 307	1 167	1 023	0.010	0.013	0.014	0.015
Hombe	Tyeni-A; Tyeni	3 310	3 361	3 268	2 918	2 559	0.026	0.032	0.036	0.037
	Nqaqhumbe	406	412	401	358	314	0.003	0.004	0.004	0.005
	Kunikwe; Nikwe	2 667	2 708	2 634	2 351	2 062	0.021	0.026	0.029	0.030
Gobozana	Gunyeni	3 471	3 524	3 427	3 059	2 683	0.027	0.034	0.037	0.039
	Ngobozana-B; Ngobozana-C	1 128	1 145	1 113	994	872	0.009	0.011	0.012	0.013
	Gobozana - B	2 278	2 313	2 249	2 008	1 761	0.018	0.022	0.024	0.025
	Mount Nelson	886	900	875	781	685	0.007	0.009	0.010	0.010
Nkunzimbini	KwaMgezwa; Mgezwa	1 879	1 908	1 855	1 657	1 453	0.015	0.018	0.020	0.021
	Fahlambe	726	737	717	640	561	0.006	0.007	0.008	0.008
	Mdumbane; Mdubane;	347	352	343	306	268	0.003	0.003	0.004	0.004
	Nkunzimbini-A; Nkunzimbini	1 109	1 126	1 095	978	858	0.009	0.011	0.012	0.012
	Lukhahlambeni	2 216	2 250	2 188	1 953	1 713	0.017	0.022	0.024	0.025
Mbudu	Mbudu-A&B	1 158	1 176	1 143	1 021	895	0.009	0.011	0.012	0.013
Mzintlava	Luqhoqweni	2 395	2 431	2 364	2 111	1 851	0.019	0.023	0.026	0.027
Mevane	KuMevane; Mevana	3 219	3 268	3 178	2 838	2 489	0.025	0.032	0.035	0.036
Nyosana	Nyosana-A; Jambeni	1 170	1 188	1 155	1 031	905	0.009	0.011	0.013	0.013
Subtotal: Existing Phase I		**52 108**	**53 330**	**52 866**	**48 836**	**44 990**	**1.058**	**1.333**	**1.557**	**1.791**

PHASE II										
Malenge	Kunkunzimbini	1 743	1 770	1 721	1 536	1 347	0.014	0.017	0.019	0.019
	Mpolweni - A	2 057	2 089	2 031	1 814	1 590	0.016	0.020	0.022	0.023
Nkunzimbini	Nkunzimbini - B	193	196	190	170	149	0.002	0.002	0.002	0.002
Zalu	Pamalitoli	464	471	458	409	359	0.004	0.005	0.005	0.005
	Ndimbaneni	744	755	734	656	575	0.006	0.007	0.008	0.008
	Ntsimbini - E	605	614	597	533	468	0.005	0.006	0.007	0.007
	Mroshozo	694	704	685	612	536	0.005	0.007	0.007	0.008
Mateko	Mateko - B	299	303	295	263	231	0.002	0.003	0.003	0.003
	Kwabhumbula	1 015	1 031	1 003	895	785	0.008	0.010	0.011	0.011
	Matheko	704	715	695	621	545	0.005	0.007	0.008	0.008
Msikaba	Msikaba - A	2 958	3 003	2 920	2 607	2 286	0.023	0.029	0.032	0.033
	Msikaba - C	960	975	948	847	742	0.007	0.009	0.010	0.011
	Mawotsheni	743	754	734	655	574	0.006	0.007	0.008	0.008
Xura	Kwadick	1 090	1 106	1 076	960	842	0.008	0.011	0.012	0.012
Lower Xura	Dumeni	1 223	1 242	1 207	1 078	945	0.010	0.012	0.013	0.014
Malenge	Mpangina	411	418	406	363	318	0.003	0.004	0.004	0.005
Goso Forest	Kugwexintaba	1 382	1 404	1 365	1 219	1 069	0.011	0.014	0.015	0.015
	Gos Forest	165	167	162	145	127	0.001	0.002	0.002	0.002
	Magwa	70	71	69	62	54	0.001	0.001	0.001	0.001
Nyosana	Jambeni	1 289	1 309	1 273	1 137	997	0.010	0.013	0.014	0.014
	Nkanti	1 396	1 417	1 378	1 230	1 079	0.011	0.014	0.015	0.016
	Nyosana - B	43	43	42	38	33	0.000	0.000	0.000	0.000
Mzintlava	Malungeni - A	960	975	948	847	742	0.007	0.009	0.010	0.011
	Matulini	960	975	948	847	742	0.007	0.009	0.010	0.011
	Mxelwenkunzi	872	886	861	769	674	0.007	0.009	0.009	0.010
Mtambalala	Mfabantu - E	2 288	2 323	2 259	2 017	1 769	0.018	0.022	0.025	0.026
	Matane	3 209	3 259	3 169	2 829	2 481	0.025	0.031	0.034	0.036
Bomvini	Sihlito	982	997	969	865	759	0.008	0.010	0.011	0.011
Upper Ntafufu	Mzintlavana	2 485	2 523	2 454	2 191	1 921	0.019	0.024	0.027	0.028
	Mampondweni	2 235	2 269	2 207	1 970	1 728	0.017	0.022	0.024	0.025
	Kwamdlankana	165	168	163	146	128	0.001	0.002	0.002	0.002
	Gcobane	920	934	908	811	711	0.007	0.009	0.010	0.010
	Ntsimbini - C	920	934	908	811	711	0.007	0.009	0.010	0.010
	Ntsimbini - B	1 118	1 136	1 104	986	865	0.009	0.011	0.012	0.012
Subtotal: Phase II		**37 363**	**37 937**	**36 890**	**32 937**	**28 886**	**0.291**	**0.367**	**0.402**	**0.417**

PHASE III										
Upper Ntafufu	Ngcenge	954	969	942	841	737	0.007	0.009	0.010	0.011
	Nzondeni	1 525	1 549	1 506	1 344	1 179	0.012	0.015	0.016	0.017
Mtambalala	Buchele	3 911	3 971	3 862	3 448	3 024	0.030	0.038	0.042	0.044
	Pitsini	3 562	3 617	3 517	3 140	2 754	0.028	0.035	0.038	0.040
Lambasi	Ndengana	396	402	391	349	306	0.003	0.004	0.004	0.004
	Cuthwini	1 844	1 873	1 821	1 626	1 426	0.014	0.018	0.020	0.021
	Dimfi	2 051	2 082	2 025	1 808	1 585	0.016	0.020	0.022	0.023
	Ndindindi	1 571	1 595	1 551	1 385	1 214	0.012	0.015	0.017	0.018
	Ntlamvukasi	1 844	1 873	1 821	1 626	1 426	0.014	0.018	0.020	0.021
	Mazize	71	73	70	63	55	0.001	0.001	0.001	0.001
	Ntangeni	108	109	106	95	83	0.001	0.001	0.001	0.001
Quakeni	Qawukeni - B	363	368	358	320	280	0.003	0.004	0.004	0.004
	Qawukeni - C	99	100	97	87	76	0.001	0.001	0.001	0.001
Pumlo	Bhayi	1 234	1 253	1 218	1 088	954	0.010	0.012	0.013	0.014
Lower Ntafufu	Taleni - A	2 834	2 877	2 798	2 498	2 191	0.022	0.028	0.030	0.032
	Kwagingqi	627	636	619	552	484	0.005	0.006	0.007	0.007
	Ndongeni	1 868	1 896	1 844	1 646	1 444	0.015	0.018	0.020	0.021
	Lusibeni	199	202	196	175	154	0.002	0.002	0.002	0.002
	Ntafufu	501	509	495	442	388	0.004	0.005	0.005	0.006
	Nkondusweni	1 765	1 792	1 743	1 556	1 365	0.014	0.017	0.019	0.020
	Mbiza - A	2 693	2 735	2 659	2 374	2 082	0.021	0.026	0.029	0.030
	Isapata	679	689	670	598	525	0.005	0.007	0.007	0.008
Subtotal: Phase III		**30 698**	**31 170**	**30 309**	**27 061**	**23 733**	**0.239**	**0.301**	**0.330**	**0.343**
TOTAL										
Total: Rural phases I + II + III		**120 169**	**122 437**	**120 065**	**108 834**	**97 609**	**1.589**	**2.001**	**2.288**	**2.551**

APPENDIX C :

LOW FLOW ANALYSIS

Appendix C

ESTIMATION OF 1-day FLOW DURATION CURVES FROM MONTHLY STREAMFLOW DATA FOR EASTERN PONDOLAND BASIN STUDY

Smakhtin V. Y. CSIR : Environmentek, PO Box 395, Pretoria 0001

Background

The estimation of 1-day Flow Duration Curves (FDCs) is required for the following three sites in the T60 drainage region:

Lusikisiki site on the Xura River (existing weir)

Xura site on the Xura River

Mzintlava site on the Mzintlava River

The curves are required in tabular form for each of the 12 calendar months of the year. Annual curves were also required for the whole year for both natural catchment conditions and with the IFR subtracted at each site. The monthly step time series flow data for both scenarios for each of the three sites have been supplied by DWAF: Hydrology, who are involved with the hydrological component of the study.

Methodology

The method used to derive 1-day FDCs from the monthly streamflow time series assumes that for any site in a river, the variability of daily flows is higher than that of monthly flows. In high-flow months, maximum daily average discharges are higher than the monthly average. In low-flow months minimum daily average discharges may be much lower than the monthly average. The implication for FDCs is that the 1-day FDC generally has a larger slope than the 1-month FDC (**Fig 1**). Consequently daily discharges are higher than monthly discharges in the low probability of exceedance range, and lower than monthly discharges in the high probability range.

The method further assumes that it is possible to estimate two points on the 1-day FDC from monthly flow time series (which are usually available in South Africa) and then construct the entire 1-day curve by means of interpolation (and extrapolation). Smakhtin (2000) has developed the required formulae for two points on 1-day FDCs (1-day flow indices: one from the high-flow end of the curve, and one from the low-flow end). These relationships have been based on observed stationary flow records from 200 gauging stations obtained from different regions in South Africa. With a few exceptions, the areas of the catchments were less than 1 000 km^2, and were therefore similar to the range of catchment areas in this study.

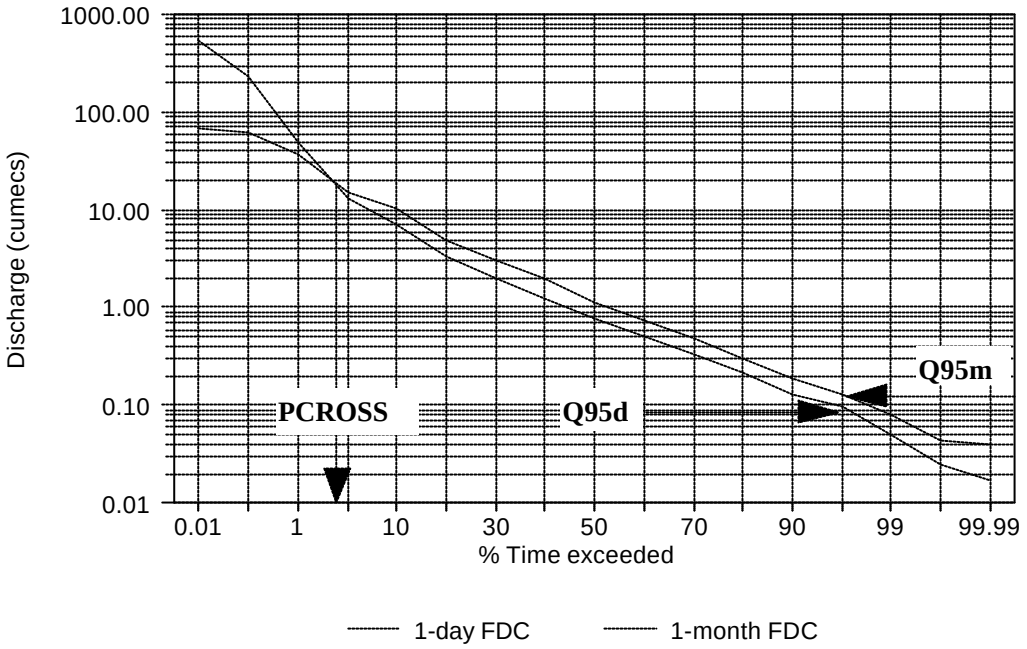


Figure 1. Example graph illustrating the differences between 1d and 1m FDCs for the same site and showing daily and monthly Q95 flow values and the percentage point at which two curves cross (PCROSS)

It has been found that the two curves (1-day and 1-month) usually cross between the 1% and 10% time exceedance points. With a few exceptions, this is valid for pairs of curves constructed for both the whole year and for individual calendar months. In the majority of cases studied the point where the two curves cross (PCROSS) may be approximated with a constant which is equal to 5%. The assumption of a constant PCROSS value has a convenient implication for the estimation of 1-day FDCs. It means that the first point for the 1-day FDC (at its high-flow end) may be read directly from the 1-month FDC at the 5% exceedance level.

The relationship suggested for the low-flow end of FDC differs for perennial and non-perennial rivers. For perennial rivers the flow exceeded 95% of the year (Q95, Figure 1) is used. The following relationship has been established :

$$Q95_d = 0.811 * Q95_m \quad (1)$$
$$(R^2 = 0.991; \quad SE = 0.006)$$

where $Q95_d$ and $Q95_m$ are flow values exceeded 95% of the time and estimated correspondingly from 1-day and 1-month annual FDCs.

The "low-flow" relationship for non-perennial rivers (which has a zero $Q95_m$ value) is represented by the percentage of time that zero-flow conditions occurred (T_0, %). For non-perennial rivers, the monthly T_0 is greater than 5%. The corresponding daily T_0 values are even larger as shown in **Figure 2** This is explained by the fact that in semi-arid and arid catchments a river may dry up completely for most of the low-flow month, while the average monthly discharge will remain non-zero. The established relationship between daily and monthly T_0 values is:

$$T_{0,daily} = 8.08 + 1.10 * T_{0,monthly} \quad (2)$$
($R^2 = 0.937$; SE = 5.81)

Once the required two points on the 1-day FDC for either perennial or non-perennial rivers are estimated as described by Eqs (1) or (2), the entire 1-day curve itself may be calculated by means of interpolation.

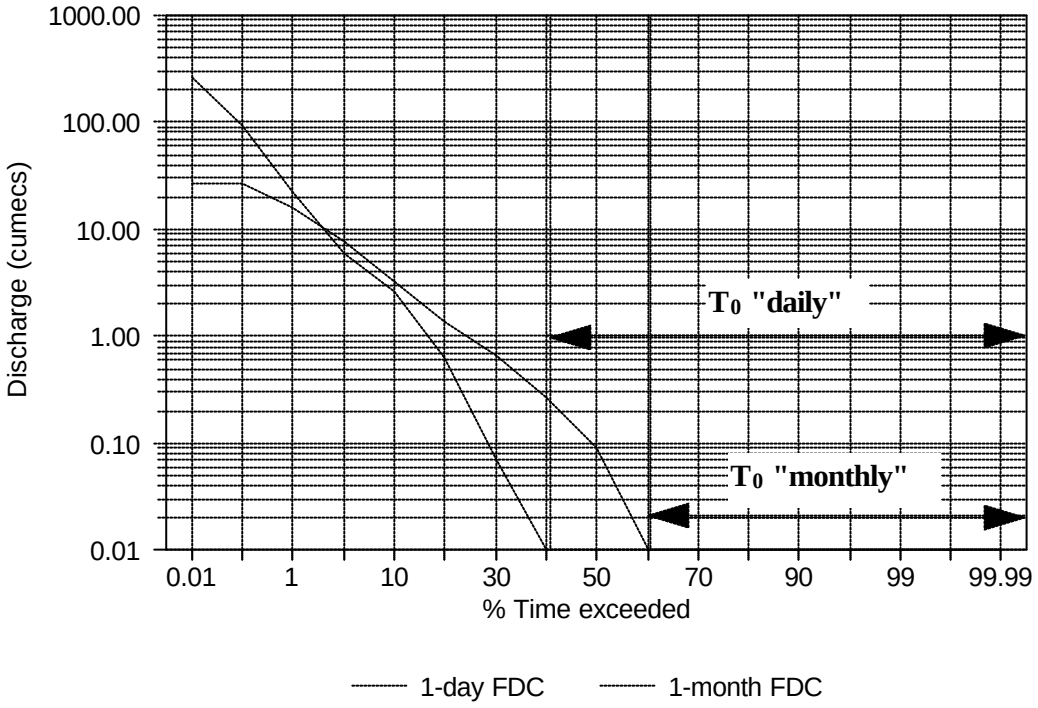


Figure 2. Example annual 1day and 1month FDCs for non-perennial river illustrating the differences between daily and monthly percentage time with zero flow conditions (T_0).

The HYMAS computer package has been used to perform all necessary calculations. In HYMAS (FDC construction procedure) the curves may be constructed from daily and monthly streamflow data for any of the 12 months of the year, or for the whole year. Traditionally HYMAS uses the 17 fixed percentage points on the curve (0.01, 0.1, 1, 5, 10, 20, 30, 40, 50, 60, 70, 80, 90, 95, 99, 99.9 and 99.99% time of exceedance) which together with corresponding flow rates represent a duration-discharge table (DDT). A DDT is a discrete representation of an FDC which may be printed or written to a file for further display, analysis or adjustment using a spreadsheet package.

Application

The approach for 1-day FDCs estimation was applied to three sites described in the beginning of this document using the following steps:

Construct a 1-month annual FDC and a FDC for each of the 12 calendar months of the year using the generated monthly flow time series for two scenarios (natural and future)

Estimate the $Q95_m$ flow value. If it is non-zero, use Eq. (1) to calculate the $Q95_d$ flow value. If the $Q95_m$ flow value is zero, estimate $T_{0,\,m.}$ Then use Eq. (2) to calculate $T_{0,\,d.}$. In both cases utilise the flow rate at PCROSS level of exceedence (5%). This should be read directly from the 1-month FDCs.

Use interpolation procedures described by Smakhtin (2000) to estimate the remaining of the 17 points on each 1-day FDC (for each month and for each scenario).

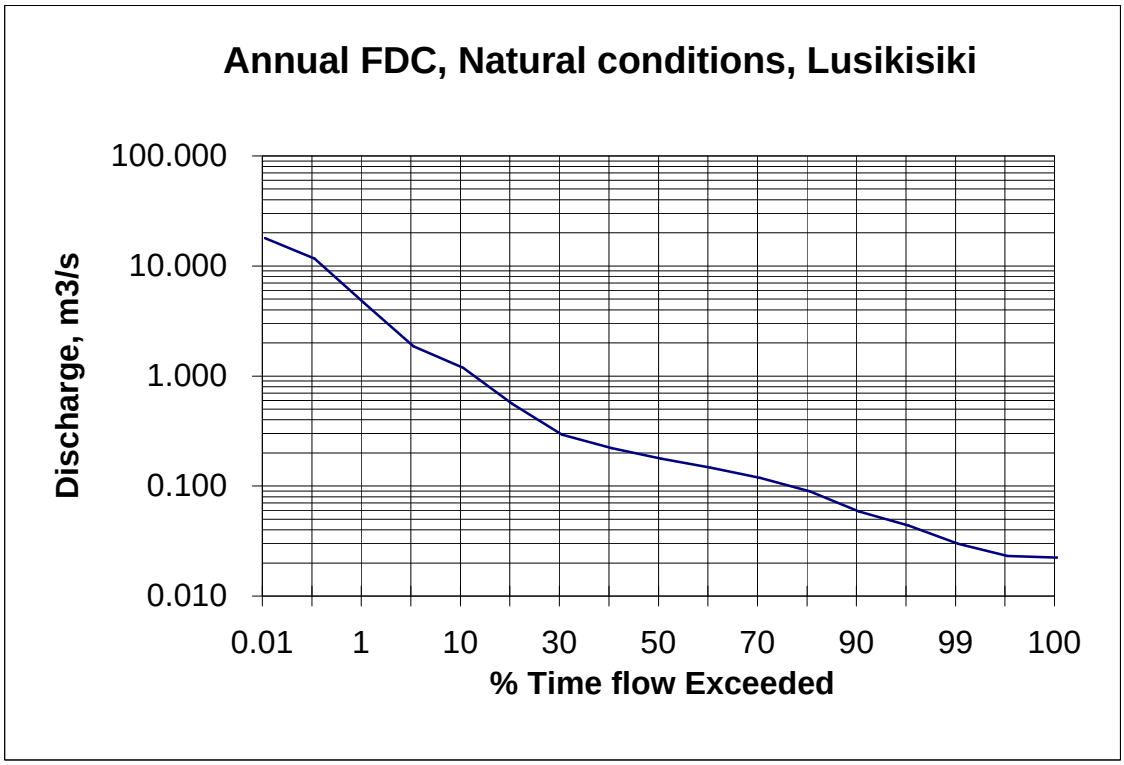
The DDT for 78 FDCs have been calculated (for three sites, for two scenarios and for each month, with one annual curve). The results are presented in the attached spreadsheet in tabular as well as in graphical format.

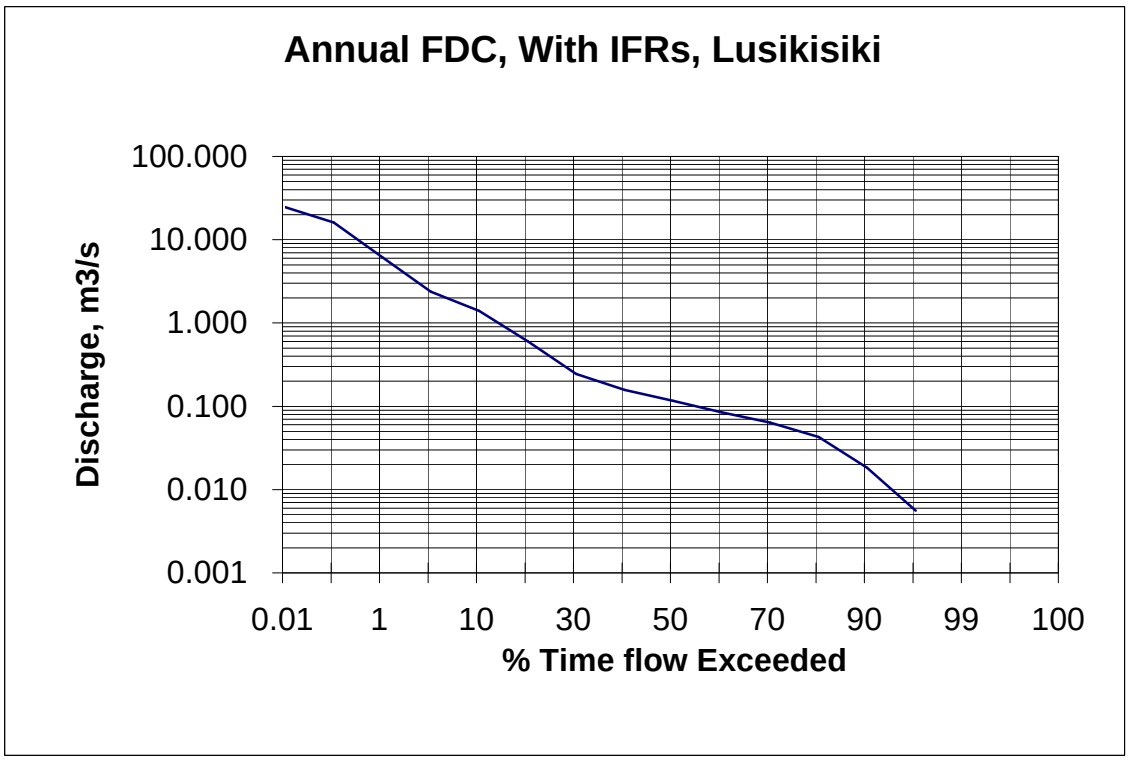
In this application, Eqs (1) and (2) have been used to establish both annual curves and curves for each calendar month. This approach is a pragmatic alternative in the absence of other techniques. It should be taken into account that the 1-month FDCs for some of the dry months (for "with IFR" scenario) demonstrate that Q95m is zero and T_o is consequently greater than 5%. In such cases Eq (2) has been used to derive a 1-day FDC from the 1-month FDC. Estimates of daily flow rates in such months should be treated as conservative (in the sense that "low flows" are likely to be underestimated).

Another problem which arises in the case of individual calendar month curves relates to the length of the record. When an annual 1-month FDC is constructed on the basis of 77 years of data (1920 – 1996), the number of months used equals 924. This is sufficient to calculate the extremes at 0.1 and 99.9% directly from the record. Flow values for the percentage points less than 0.1% and greater than 99.9% are calculated with an extrapolation procedure. Given possible extrapolation errors these estimates may not be accurate. This creates uncertainty at the level of annual FDCs. This problem is exacerbated when the sample is divided by 12. For example, to construct the FDC for January from a monthly flow record, which is 77 years long, only 77 values are available. This is just sufficient to define flows at 1 and 99% exceedance levels. The flows, which are exceeded less or more than these exceedence levels are calculated by means of extrapolation. Consequently, the accuracy of calculations reduces significantly at the level of estimation of 1-month FDC. This uncertainty is carried over to the procedure of deriving 1-day FDCs from 1-month FDCs for individual months. It is therefore recommended that the 1-day annual curves supplied in a spreadsheet are considered as the most reliable outcome of the completed exercise, while the curves for the individual months be treated as less reliable.

References:

Smakhtin V.U. (2000). Estimating daily flow duration curves from monthly streamflow data. Water SA 26(1): 13 – 18 (in press).


Annual FDC, Natural conditions, Lusikisiki
Discharge, m3/s
100.000
10.000
1.000
0.100
0.010
0.01
1
10
30
50
70
90
99
100
% Time flow Exceeded

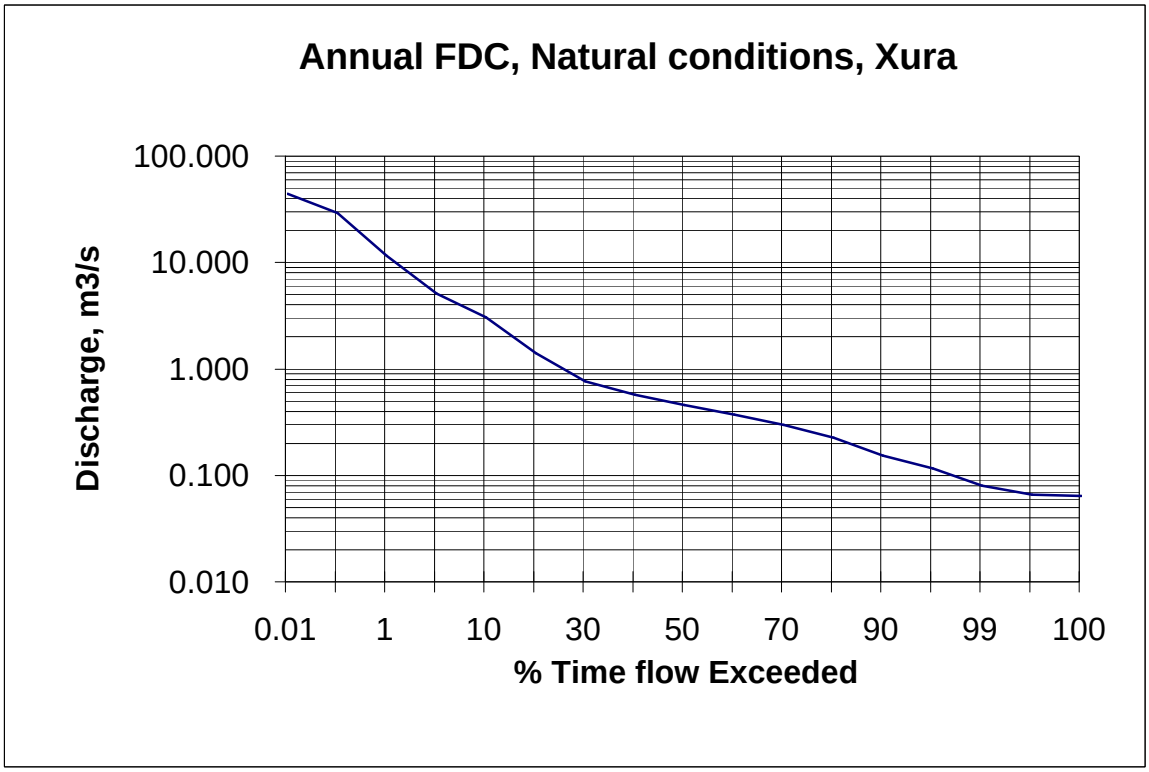

Annual FDC, With IFRs, Lusikisiki
Discharge, m3/s
100.000
10.000
1.000
0.100
0.010
0.001
0.01
1
10
30
50
70
90
99
100
% Time flow Exceeded

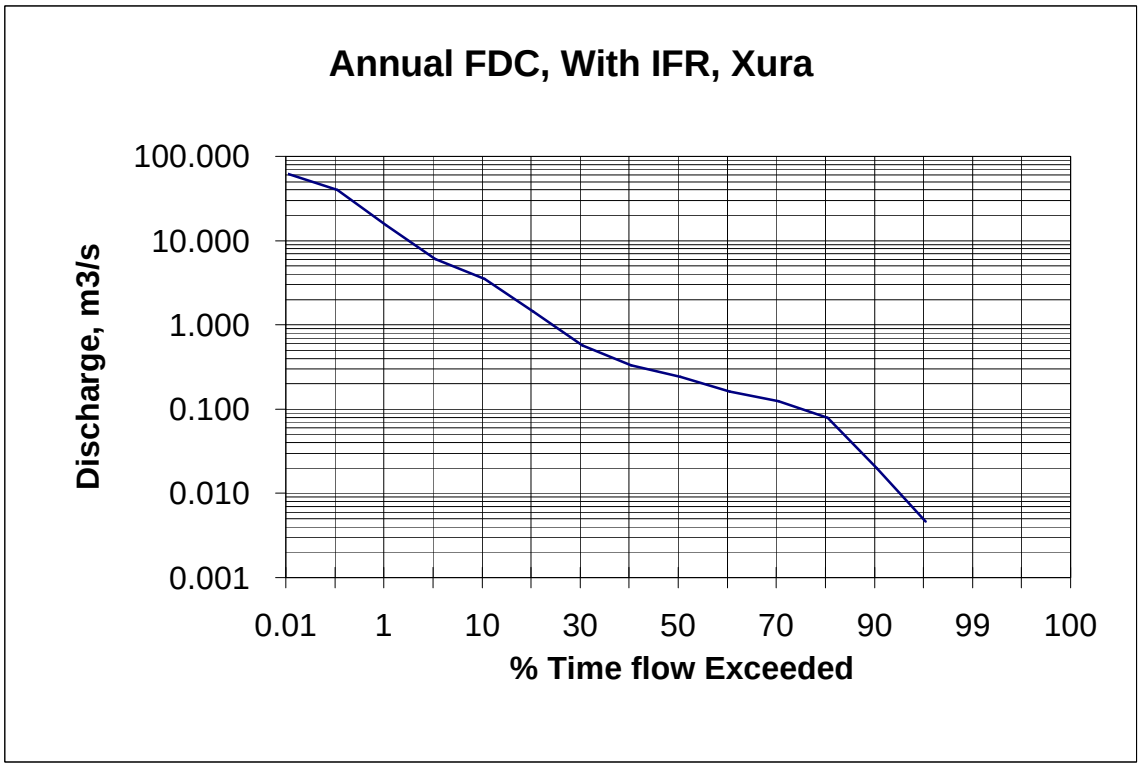
Duration-Discharge Table for Present Day Conditions for Lusikisiki Weir Site

% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exce	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s
January		**March**		**May**		**July**		**September**		**November**		**Annual**	**Lusikisiki**
0.01	5.009	0.01	12.239	0.01	5.088	0.01	33.754	0.01	31.893	0.01	8.697	0.01	17.130
0.1	4.150	0.1	10.170	0.1	4.298	0.1	26.194	0.1	24.777	0.1	7.303	0.1	11.183
1	2.770	1	6.989	1	3.487	1	9.085	1	8.687	1	5.576	1	4.434
5	1.533	5	2.820	5	1.246	5	1.177	5	1.072	5	3.267	5	1.789
10	1.149	10	1.769	10	0.745	10	0.785	10	0.488	10	2.373	10	1.140
20	0.534	20	0.908	20	0.387	20	0.244	20	0.230	20	1.191	20	0.536
30	0.308	30	0.556	30	0.216	30	0.156	30	0.163	30	0.928	30	0.281
40	0.243	40	0.333	40	0.172	40	0.135	40	0.137	40	0.469	40	0.212
50	0.206	50	0.233	50	0.139	50	0.108	50	0.114	50	0.310	50	0.170
60	0.175	60	0.200	60	0.111	60	0.071	60	0.100	60	0.213	60	0.141
70	0.160	70	0.158	70	0.095	70	0.055	70	0.085	70	0.186	70	0.114
80	0.143	80	0.131	80	0.080	80	0.044	80	0.069	80	0.157	80	0.086
90	0.115	90	0.088	90	0.063	90	0.036	90	0.053	90	0.137	90	0.056
95	0.076	95	0.067	95	0.049	95	0.032	95	0.045	95	0.112	95	0.042
99	0.051	99	0.051	99	0.034	99	0.023	99	0.023	99	0.073	99	0.029
99.9	0.047	99.9	0.047	99.9	0.031	99.9	0.022	99.9	0.022	99.9	0.062	99.9	0.022
99.99	0.046	99.99	0.046	99.99	0.031	99.99	0.022	99.99	0.022	99.99	0.061	99.99	0.022
February		**April**		**June**		**August**		**October**		**December**			
0.01	6.782	0.01	42.557	0.01	9.512	0.01	8.700	0.01	8.465	0.01	10.798		
0.1	5.692	0.1	33.233	0.1	7.850	0.1	6.922	0.1	7.027	0.1	8.889		
1	4.319	1	12.270	1	5.039	1	3.080	1	4.781	1	5.565		
5	2.013	5	1.865	5	1.550	5	0.684	5	2.450	5	2.591		
10	1.469	10	1.346	10	0.572	10	0.362	10	1.592	10	1.565		
20	0.755	20	0.678	20	0.272	20	0.215	20	0.538	20	0.844		
30	0.383	30	0.491	30	0.158	30	0.161	30	0.250	30	0.483		
40	0.239	40	0.249	40	0.134	40	0.118	40	0.208	40	0.365		
50	0.204	50	0.191	50	0.101	50	0.091	50	0.176	50	0.266		
60	0.174	60	0.154	60	0.081	60	0.076	60	0.143	60	0.231		
70	0.139	70	0.136	70	0.066	70	0.057	70	0.123	70	0.189		
80	0.118	80	0.115	80	0.055	80	0.044	80	0.099	80	0.161		
90	0.100	90	0.072	90	0.043	90	0.034	90	0.079	90	0.128		
95	0.094	95	0.042	95	0.034	95	0.029	95	0.065	95	0.103		
99	0.058	99	0.033	99	0.026	99	0.028	99	0.042	99	0.088		
99.9	0.047	99.9	0.031	99.9	0.025	99.9	0.028	99.9	0.032	99.9	0.078		
99.99	0.046	99.99	0.031	99.99	0.025	99.99	0.028	99.99	0.031	99.99	0.077		

Duration-Discharge Table with IFRs subtracted for Lusikisiki Weir Site

% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s
January		**March**		**May**		**July**		**September**		**November**		**Annual**	**Lusikisiki**
0.01	4.859	0.01	11.921	0.01	4.935	0.01	32.457	0.01	32.622	0.01	8.055	0.01	16.740
0.1	4.020	0.1	9.896	0.1	4.169	0.1	29.393	0.1	25.279	0.1	6.757	0.1	10.965
1	2.641	1	6.729	1	3.376	1	10.903	1	8.640	1	5.101	1	4.210
5	1.416	5	2.583	5	1.147	5	1.086	5	0.992	5	2.842	5	1.625
10	1.037	10	1.545	10	0.651	10	0.502	10	0.412	10	1.968	10	0.948
20	0.410	20	0.662	20	0.320	20	0.056	20	0.158	20	0.847	20	0.410
30	0.208	30	0.373	30	0.127	30	0.013	30	0.096	30	0.592	30	0.166
40	0.145	40	0.216	40	0.090	40	0.005	40	0.074	40	0.183	40	0.107
50	0.115	50	0.086	50	0.060	50	0.002	50	0.056	50	0.064	50	0.079
60	0.095	60	0.067	60	0.045	60	0.000	60	0.044	60	0.051	60	0.057
70	0.088	70	0.043	70	0.038	70	-	70	0.037	70	0.039	70	0.043
80	0.081	80	0.037	80	0.032	80	-	80	0.031	80	0.026	80	0.029
90	0.068	90	0.026	90	0.025	90	-	90	0.020	90	0.019	90	0.013
95	0.043	95	0.017	95	0.013	95	-	95	0.017	95	0.016	95	0.004
99	0.020	99	0.004	99	-	99	-	99	-	99	-	99	-
99.9	0.019	99.9	0.003	99.9	-	99.9	-	99.9	-	99.9	-	99.9	-
99.99	0.018	99.99	0.003	99.99	-	99.99	-	99.99	-	99.99	-	99.99	-
February		**April**		**June**		**August**		**October**		**December**			
0.01	6.571	0.01	37.209	0.01	9.402	0.01	7.534	0.01	8.288	0.01	10.616		
0.1	5.512	0.1	33.954	0.1	7.753	0.1	6.998	0.1	6.874	0.1	8.727		
1	4.162	1	13.593	1	4.935	1	3.344	1	4.635	1	5.381		
5	1.873	5	1.705	5	1.454	5	0.600	5	2.317	5	2.420		
10	1.335	10	0.946	10	0.482	10	0.225	10	1.465	10	1.402		
20	0.582	20	0.255	20	0.194	20	0.070	20	0.425	20	0.672		
30	0.276	30	0.065	30	0.080	30	0.027	30	0.141	30	0.406		
40	0.122	40	0.019	40	0.055	40	0.008	40	0.101	40	0.281		
50	0.092	50	0.007	50	0.030	50	0.003	50	0.079	50	0.157		
60	0.068	60	0.003	60	0.017	60	0.001	60	0.060	60	0.131		
70	0.059	70	0.002	70	0.013	70	0.000	70	0.052	70	0.106		
80	0.054	80	0.001	80	0.010	80	0.000	80	0.045	80	0.088		
90	0.049	90	-	90	0.007	90	-	90	0.035	90	0.072		
95	0.047	95	-	95	0.004	95	-	95	0.032	95	0.063		
99	0.020	99	-	99	-	99	-	99	0.007	99	0.050		
99.9	0.019	99.9	-	99.9	-	99.9	-	99.9	0.006	99.9	0.046		
99.99	0.018	99.99	-	99.99	-	99.99	-	99.99	0.006	99.99	0.046		


Annual FDC, Natural conditions, Xura
Discharge, m3/s
100.000
10.000
1.000
0.100
0.010
0.01
1
10
30
50
70
90
99
100
% Time flow Exceeded

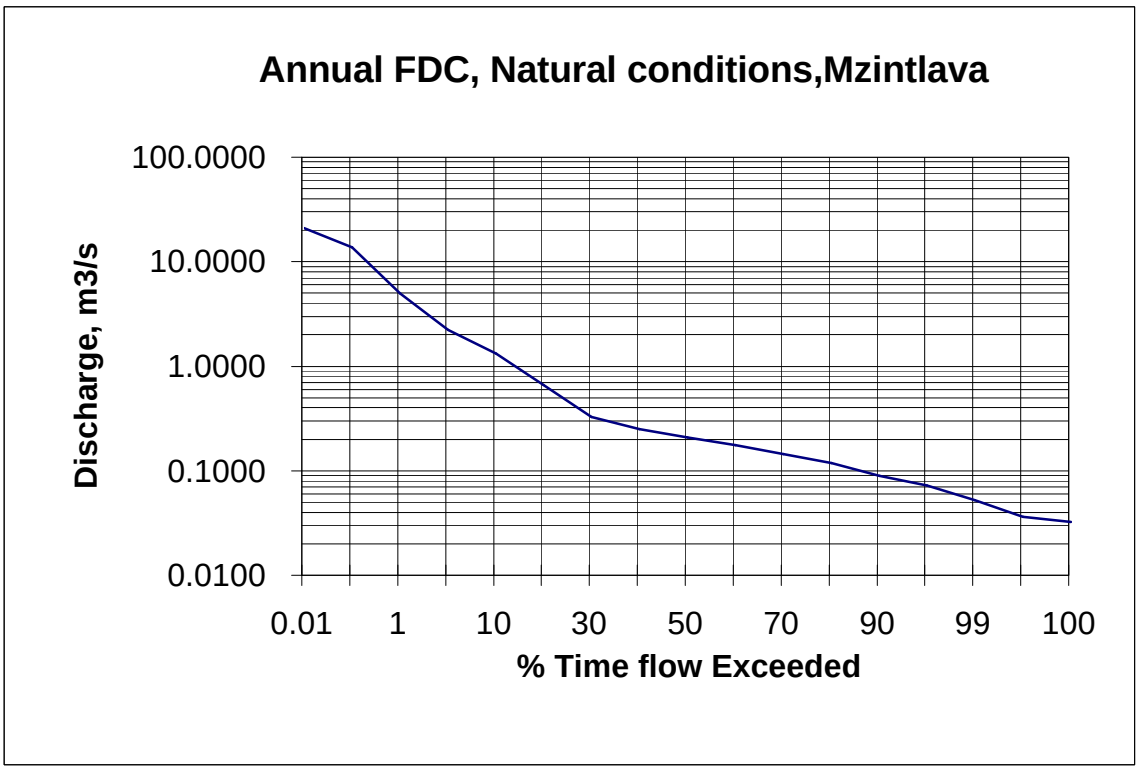

Annual FDC, With IFR, Xura
Discharge, m3/s
100.000
10.000
1.000
0.100
0.010
0.001
0.01
1
10
30
50
70
90
99
100
% Time flow Exceeded

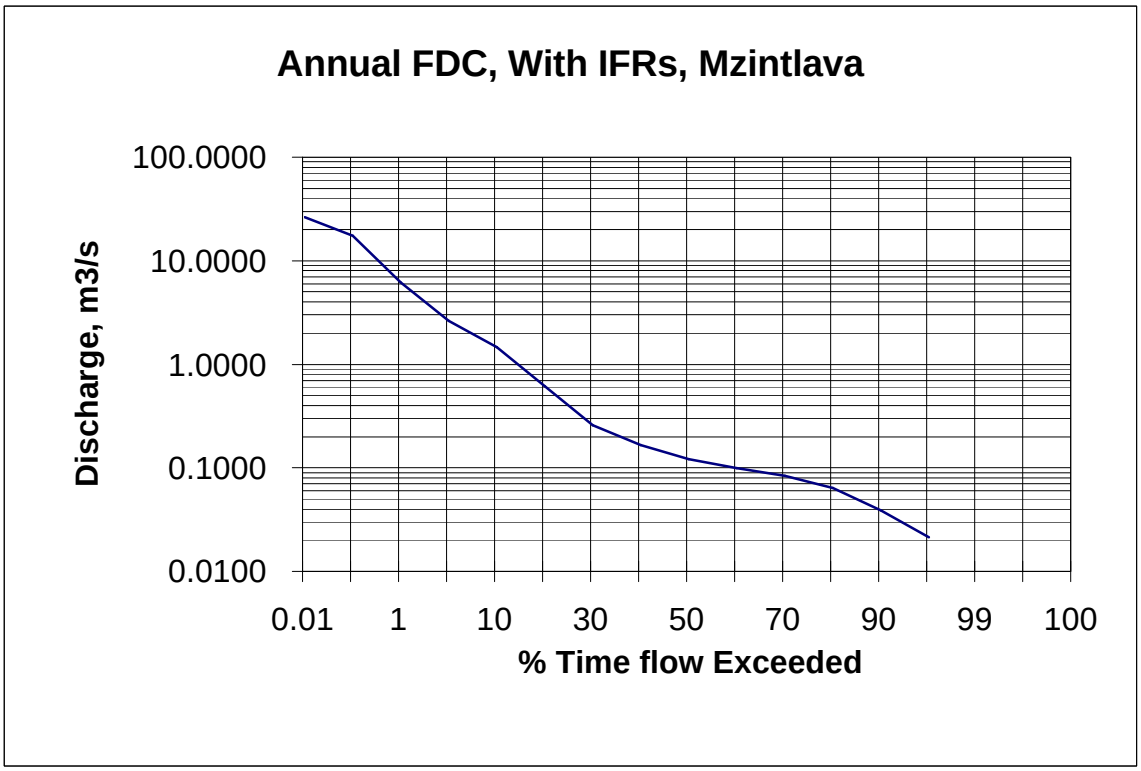
Duration-Discharge Table for Present Day Conditions for Xura Weir Site

% Exce	Q,m3/s	% Exceed	Q,m3/s	% Exce	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s
January		**March**		**May**		**July**		**September**		**November**		**Annual**	**Xura**
0.01	12.491	0.01	30.347	0.01	12.510	0.01	83.674	0.01	78.214	0.01	21.630	0.01	42.530
0.1	10.353	0.1	25.222	0.1	10.577	0.1	64.945	0.1	60.832	0.1	18.166	0.1	27.775
1	6.941	1	17.364	1	8.642	1	22.561	1	21.572	1	13.888	1	11.062
5	3.873	5	7.018	5	3.167	5	2.946	5	2.721	5	8.167	5	4.867
10	2.893	10	4.454	10	1.880	10	1.995	10	1.245	10	5.946	10	2.926
20	1.269	20	2.199	20	1.051	20	0.598	20	0.609	20	2.908	20	1.344
30	0.802	30	1.413	30	0.574	30	0.449	30	0.458	30	2.329	30	0.727
40	0.626	40	0.849	40	0.424	40	0.357	40	0.359	40	1.208	40	0.545
50	0.545	50	0.596	50	0.343	50	0.269	50	0.298	50	0.776	50	0.438
60	0.475	60	0.496	60	0.279	60	0.171	60	0.247	60	0.561	60	0.358
70	0.402	70	0.410	70	0.242	70	0.142	70	0.223	70	0.462	70	0.287
80	0.341	80	0.338	80	0.204	80	0.118	80	0.173	80	0.385	80	0.217
90	0.299	90	0.211	90	0.160	90	0.097	90	0.135	90	0.321	90	0.146
95	0.198	95	0.168	95	0.121	95	0.084	95	0.121	95	0.271	95	0.111
99	0.134	99	0.119	99	0.088	99	0.067	99	0.067	99	0.196	99	0.077
99.9	0.124	99.9	0.108	99.9	0.078	99.9	0.062	99.9	0.062	99.9	0.185	99.9	0.063
99.99	0.123	99.99	0.107	99.99	0.077	99.99	0.061	99.99	0.061	99.99	0.184	99.99	0.061
February		**April**		**June**		**August**		**October**		**December**			
0.01	16.897	0.01	104.768	0.01	23.616	0.01	21.176	0.01	21.026	0.01	26.765		
0.1	14.183	0.1	81.865	0.1	19.494	0.1	16.874	0.1	17.460	0.1	22.043		
1	10.779	1	30.412	1	12.538	1	7.623	1	11.922	1	13.857		
5	5.118	5	4.673	5	3.964	5	1.750	5	6.120	5	6.491		
10	3.721	10	3.372	10	1.447	10	0.905	10	4.030	10	3.927		
20	1.986	20	1.701	20	0.649	20	0.562	20	1.351	20	2.164		
30	1.084	30	0.993	30	0.425	30	0.391	30	0.649	30	1.259		
40	0.620	40	0.618	40	0.338	40	0.299	40	0.520	40	1.019		
50	0.520	50	0.479	50	0.264	50	0.230	50	0.432	50	0.720		
60	0.435	60	0.407	60	0.205	60	0.186	60	0.365	60	0.569		
70	0.361	70	0.347	70	0.165	70	0.158	70	0.310	70	0.490		
80	0.293	80	0.291	80	0.141	80	0.118	80	0.266	80	0.405		
90	0.265	90	0.189	90	0.113	90	0.097	90	0.199	90	0.331		
95	0.249	95	0.107	95	0.095	95	0.076	95	0.176	95	0.272		
99	0.150	99	0.088	99	0.073	99	0.064	99	0.119	99	0.242		
99.9	0.139	99.9	0.078	99.9	0.062	99.9	0.062	99.9	0.108	99.9	0.231		
99.99	0.138	99.99	0.077	99.99	0.061	99.99	0.061	99.99	0.107	99.99	0.230		

Duration-Discharge Table with IFRs subtracted for Xura Weir Site

% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s
January		**March**		**May**		**July**		**September**		**November**		**Annual**	**Xura**
0.01	12.039	0.01	29.382	0.01	12.051	0.01	80.124	0.01	80.275	0.01	18.221	0.01	41.336
0.1	9.960	0.1	24.389	0.1	10.187	0.1	72.543	0.1	62.250	0.1	17.889	0.1	27.117
1	6.553	1	16.576	1	8.310	1	26.848	1	21.429	1	14.886	1	10.236
5	3.520	5	6.299	5	2.871	5	2.675	5	2.486	5	6.891	5	4.046
10	2.557	10	3.774	10	1.597	10	1.262	10	1.021	10	3.448	10	2.371
20	0.995	20	1.597	20	0.706	20	0.132	20	0.383	20	0.693	20	0.961
30	0.470	30	0.895	30	0.300	30	0.029	30	0.200	30	0.258	30	0.382
40	0.313	40	0.355	40	0.186	40	0.011	40	0.154	40	0.035	40	0.224
50	0.237	50	0.135	50	0.109	50	0.003	50	0.115	50	0.005	50	0.163
60	0.206	60	0.102	60	0.089	60	0.000	60	0.093	60	0.002	60	0.108
70	0.192	70	0.076	70	0.077	70	-	70	0.084	70	-	70	0.084
80	0.181	80	0.054	80	0.069	80	-	80	0.072	80	-	80	0.053
90	0.171	90	0.039	90	0.062	90	-	90	0.055	90	-	90	0.013
95	0.105	95	0.033	95	0.037	95	-	95	0.043	95	-	95	0.003
99	0.057	99	0.013	99	0.010	99	-	99	-	99	-	99	-
99.9	0.047	99.9	0.012	99.9	0.009	99.9	-	99.9	-	99.9	-	99.9	-
99.99	0.046	99.99	0.012	99.99	0.009	99.99	-	99.99	-	99.99	-	99.99	-
February		**April**		**June**		**August**		**October**		**December**			
0.01	16.273	0.01	92.144	0.01	23.287	0.01	21.728	0.01	20.493	0.01	26.208		
0.1	13.651	0.1	84.077	0.1	19.204	0.1	17.227	0.1	17.000	0.1	21.545		
1	10.317	1	33.635	1	12.232	1	7.404	1	11.482	1	13.294		
5	4.704	5	4.190	5	3.679	5	1.504	5	5.721	5	5.971		
10	3.327	10	2.307	10	1.179	10	0.670	10	3.650	10	3.432		
20	1.603	20	0.600	20	0.427	20	0.336	20	1.007	20	1.695		
30	0.748	30	0.182	30	0.165	30	0.208	30	0.282	30	0.813		
40	0.251	40	0.037	40	0.116	40	0.099	40	0.200	40	0.658		
50	0.188	50	0.010	50	0.045	50	0.042	50	0.141	50	0.335		
60	0.152	60	0.005	60	0.026	60	0.024	60	0.109	60	0.273		
70	0.127	70	0.003	70	0.022	70	0.019	70	0.101	70	0.216		
80	0.110	80	0.001	80	0.013	80	0.016	80	0.094	80	0.199		
90	0.097	90	-	90	0.010	90	0.011	90	0.083	90	0.176		
95	0.088	95	-	95	0.007	95	0.007	95	0.078	95	0.161		
99	0.058	99	-	99	-	99	0.003	99	0.026	99	0.134		
99.9	0.047	99.9	-	99.9	-	99.9	0.003	99.9	0.025	99.9	0.124		
99.99	0.046	99.99	-	99.99	-	99.99	0.003	99.99	0.025	99.99	0.123		


Annual FDC, Natural conditions,Mzintlava
Discharge, m3/s
100.0000
10.0000
1.0000
0.1000
0.0100
0.01
1
10
30
50
70
90
99
100
% Time flow Exceeded


Annual FDC, With IFRs, Mzintlava
Discharge, m3/s
100.0000
10.0000
1.0000
0.1000
0.0100
0.01
1
10
30
50
70
90
99
100
% Time flow Exceeded

Duration-Discharge Table for Present Day Conditions for Mzintlava Weir Site

% Exce	Q,m3/s	% Exceed	Q,m3/s	% Exce	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s
January		**March**		**May**		**July**		**September**		**November**		**Annual**	**Mzintlava**
0.01	5.1639	0.01	13.8252	0.01	6.2482	0.01	36.1010	0.01	32.5799	0.01	8.6141	0.01	19.9476
0.1	4.2680	0.1	11.4995	0.1	5.2876	0.1	28.2290	0.1	25.5164	0.1	7.2333	0.1	13.1569
1	2.7791	1	7.9807	1	4.3611	1	10.5621	1	9.7007	1	5.5199	1	4.7394
5	1.3973	5	3.3662	5	2.0318	5	1.6876	5	1.2927	5	3.1175	5	2.1317
10	1.0380	10	2.1959	10	1.2681	10	1.1255	10	0.7340	10	2.1752	10	1.2681
20	0.3997	20	1.1313	20	0.6430	20	0.3231	20	0.2899	20	0.9801	20	0.6319
30	0.2610	30	0.7723	30	0.2997	30	0.2336	30	0.2139	30	0.6642	30	0.3112
40	0.2213	40	0.4650	40	0.2432	40	0.2093	40	0.1777	40	0.3696	40	0.2405
50	0.1881	50	0.2777	50	0.1891	50	0.1721	50	0.1551	50	0.2495	50	0.1993
60	0.1630	60	0.2409	60	0.1662	60	0.1167	60	0.1378	60	0.2055	60	0.1679
70	0.1380	70	0.1814	70	0.1418	70	0.0946	70	0.1233	70	0.1789	70	0.1383
80	0.1226	80	0.1566	80	0.1253	80	0.0813	80	0.1020	80	0.1538	80	0.1128
90	0.0993	90	0.1032	90	0.0976	90	0.0677	90	0.0813	90	0.1219	90	0.0859
95	0.0607	95	0.0761	95	0.0761	95	0.0609	95	0.0656	95	0.1015	95	0.0690
99	0.0419	99	0.0574	99	0.0574	99	0.0486	99	0.0359	99	0.0729	99	0.0497
99.9	0.0316	99.9	0.0470	99.9	0.0470	99.9	0.0462	99.9	0.0311	99.9	0.0624	99.9	0.0347
99.99	0.0308	99.99	0.0461	99.99	0.0461	99.99	0.0460	99.99	0.0307	99.99	0.0614	99.99	0.0310
February		**April**		**June**		**August**		**October**		**December**			
0.01	7.2088	0.01	45.5966	0.01	11.2358	0.01	7.9756	0.01	8.9468	0.01	11.3436		
0.1	6.0577	0.1	35.8419	0.1	9.3069	0.1	6.4615	0.1	7.4362	0.1	9.2938		
1	4.6564	1	14.1339	1	6.1956	1	3.4461	1	5.1223	1	5.5448		
5	2.2159	5	2.3889	5	2.3485	5	1.0067	5	2.5063	5	2.3555		
10	1.5969	10	1.6618	10	1.0717	10	0.5368	10	1.7117	10	1.3641		
20	0.7553	20	1.0128	20	0.4755	20	0.3059	20	0.5842	20	0.5622		
30	0.3833	30	0.6585	30	0.2336	30	0.2245	30	0.2888	30	0.4079		
40	0.2429	40	0.3317	40	0.2082	40	0.1755	40	0.2379	40	0.3141		
50	0.2113	50	0.2495	50	0.1636	50	0.1413	50	0.1991	50	0.2294		
60	0.1770	60	0.2058	60	0.1317	60	0.1211	60	0.1677	60	0.2034		
70	0.1417	70	0.1783	70	0.1140	70	0.0996	70	0.1418	70	0.1668		
80	0.1185	80	0.1587	80	0.0964	80	0.0788	80	0.1253	80	0.1350		
90	0.1022	90	0.0961	90	0.0764	90	0.0656	90	0.0943	90	0.1101		
95	0.0953	95	0.0609	95	0.0659	95	0.0576	95	0.0800	95	0.0885		
99	0.0575	99	0.0486	99	0.0514	99	0.0481	99	0.0574	99	0.0789		
99.9	0.0470	99.9	0.0462	99.9	0.0465	99.9	0.0462	99.9	0.0470	99.9	0.0769		
99.99	0.0461	99.99	0.0460	99.99	0.0460	99.99	0.0460	99.99	0.0461	99.99	0.0767		

Duration-Discharge Table with IFRs subtracted for Mzintlava Weir Site

% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s	% Exceed	Q,m3/s
January		**March**		**May**		**July**		**September**		**November**		**Annual**	**Mzintlava**
0.01	5.0320	0.01	12.0533	0.01	6.0417	0.01	36.8884	0.01	33.1584	0.01	8.2182	0.01	19.4495
0.1	4.1520	0.1	11.7143	0.1	5.1123	0.1	28.7681	0.1	25.9115	0.1	6.8962	0.1	12.8774
1	2.6589	1	8.8075	1	4.2121	1	10.4811	1	9.6330	1	5.2273	1	4.5556
5	1.2873	5	2.8541	5	1.8989	5	1.5728	5	1.1976	5	2.8555	5	1.9413
10	0.9311	10	1.2567	10	1.1417	10	1.0131	10	0.6433	10	1.9251	10	1.0878
20	0.3196	20	0.2999	20	0.4755	20	0.2199	20	0.2045	20	0.6778	20	0.4533
30	0.1622	30	0.0773	30	0.1828	30	0.1334	30	0.1333	30	0.4960	30	0.1897
40	0.1247	40	0.0161	40	0.1317	40	0.1179	40	0.1069	40	0.1569	40	0.1225
50	0.0981	50	0.0016	50	0.0934	50	0.0850	50	0.0874	50	0.0915	50	0.0901
60	0.0784	60	0.0003	60	0.0785	60	0.0424	60	0.0755	60	0.0752	60	0.0729
70	0.0708	70	-	70	0.0718	70	0.0316	70	0.0661	70	0.0672	70	0.0621
80	0.0641	80	-	80	0.0658	80	0.0285	80	0.0558	80	0.0585	80	0.0475
90	0.0511	90	-	90	0.0524	90	0.0254	90	0.0452	90	0.0483	90	0.0287
95	0.0290	95	-	95	0.0371	95	0.0230	95	0.0330	95	0.0345	95	0.0157
99	0.0104	99	-	99	0.0165	99	0.0159	99	0.0104	99	0.0128	99	-
99.9	0.0093	99.9	-	99.9	0.0154	99.9	0.0154	99.9	0.0093	99.9	0.0123	99.9	-
99.99	0.0092	99.99	-	99.99	0.0153	99.99	0.0153	99.99	0.0092	99.99	0.0123	99.99	-
February		**April**		**June**		**August**		**October**		**December**			
0.01	6.9781	0.01	46.6458	0.01	11.1989	0.01	7.9715	0.01	8.7458	0.01	11.1808		
0.1	5.8614	0.1	36.5543	0.1	9.2663	0.1	6.4399	0.1	7.2627	0.1	9.1437		
1	4.4866	1	13.9792	1	6.1022	1	3.3384	1	4.9589	1	5.3570		
5	2.0653	5	2.1906	5	2.2263	5	0.8998	5	2.3582	5	2.1808		
10	1.4524	10	1.4667	10	0.9559	10	0.4356	10	1.5709	10	1.1974		
20	0.6067	20	0.8220	20	0.3728	20	0.2113	20	0.4235	20	0.4268		
30	0.3176	30	0.3332	30	0.1333	30	0.1409	30	0.1653	30	0.2412		
40	0.1218	40	0.1831	40	0.1069	40	0.0880	40	0.1161	40	0.1831		
50	0.0872	50	0.0985	50	0.0720	50	0.0619	50	0.0862	50	0.1173		
60	0.0656	60	0.0776	60	0.0505	60	0.0500	60	0.0746	60	0.1020		
70	0.0581	70	0.0708	70	0.0430	70	0.0398	70	0.0683	70	0.0776		
80	0.0527	80	0.0646	80	0.0378	80	0.0315	80	0.0625	80	0.0685		
90	0.0478	90	0.0340	90	0.0332	90	0.0281	90	0.0519	90	0.0590		
95	0.0411	95	0.0076	95	0.0312	95	0.0198	95	0.0471	95	0.0511		
99	0.0227	99	0.0042	99	0.0165	99	0.0157	99	0.0226	99	0.0419		
99.9	0.0216	99.9	0.0032	99.9	0.0154	99.9	0.0154	99.9	0.0216	99.9	0.0316		
99.99	0.0215	99.99	0.0031	99.99	0.0153	99.99	0.0153	99.99	0.0215	99.99	0.0308		

APPENDIX D :

AREA: CAPACITY RELATIONSHIPS

RECONNAISSANCE PHASE

Tabulated Area-Capacity-Depth Data

Reconnaissance stage

Zalu Dam Site

Level (FSL)	Surface Area (km^2)	Capacity ($10^6 m^3$)
625	1.96	25.00
620	1.43	16.50
615	1.01	10.30
610	0.69	6.10
605	0.48	3.30
600	0.28	1.30
595	0.13	0.30
590	0.05	0.10
586	0.00	0.00

Lusikisiki Dam Site

Level (FSL)	Surface area (km^2)	Capacity ($10^6 m^3$)
577	2.35	34.63
567	1.52	15.27
560.5	1.15	7.54
555.5	0.58	3.22
550.5	0.25	1.16
545.5	0.09	0.34
540.5	0.02	0.07
535.5	0.01	0.01
535	0.00	0.00

Xura Dam Site

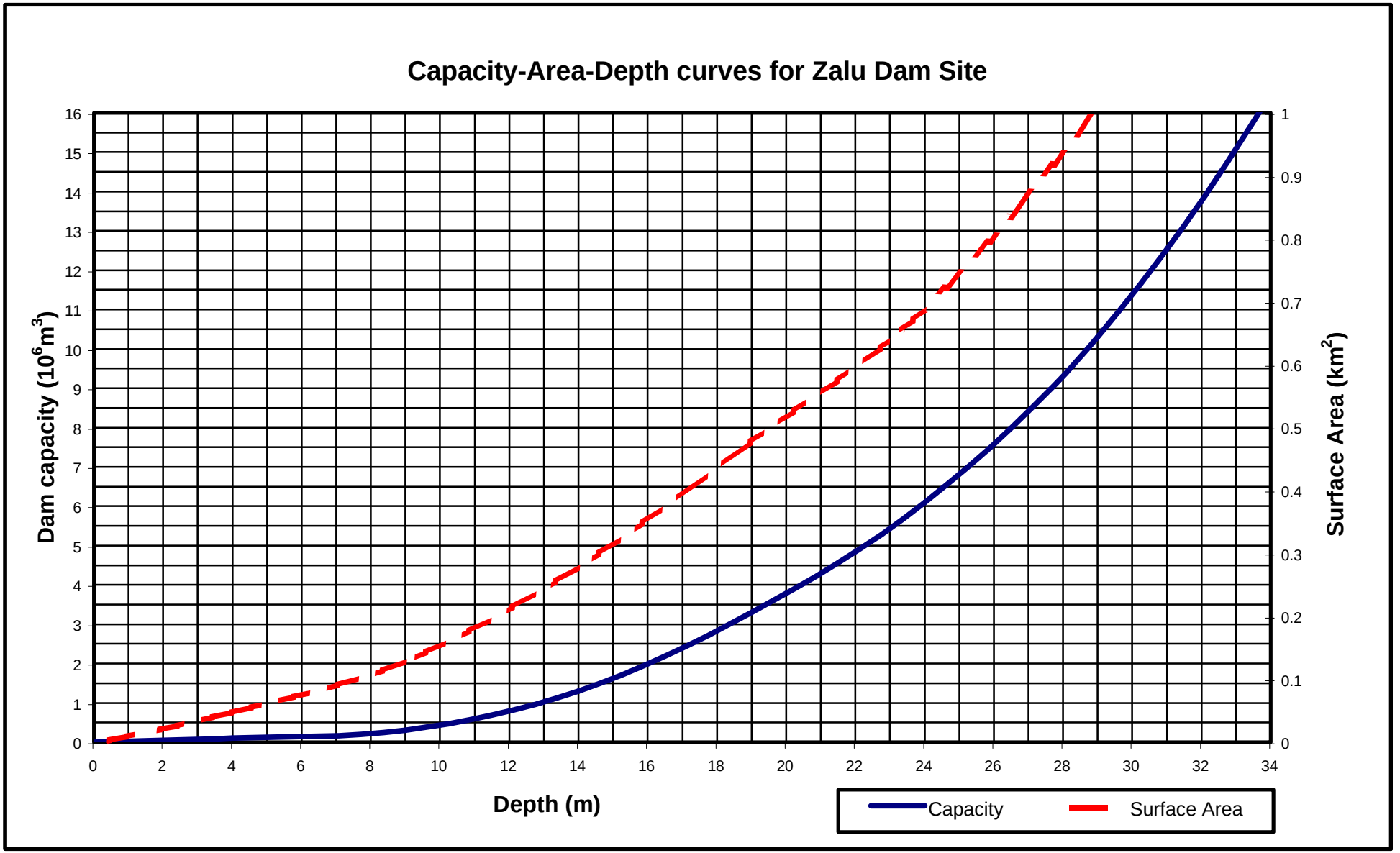
Level (ASL)	Surface area (km^2)	Capacity ($10^6 m^3$)
470	1.41	10.60
465	0.76	5.17
460	0.44	2.18
455	0.14	0.72
450	0.05	0.25
449	0.00	0.00

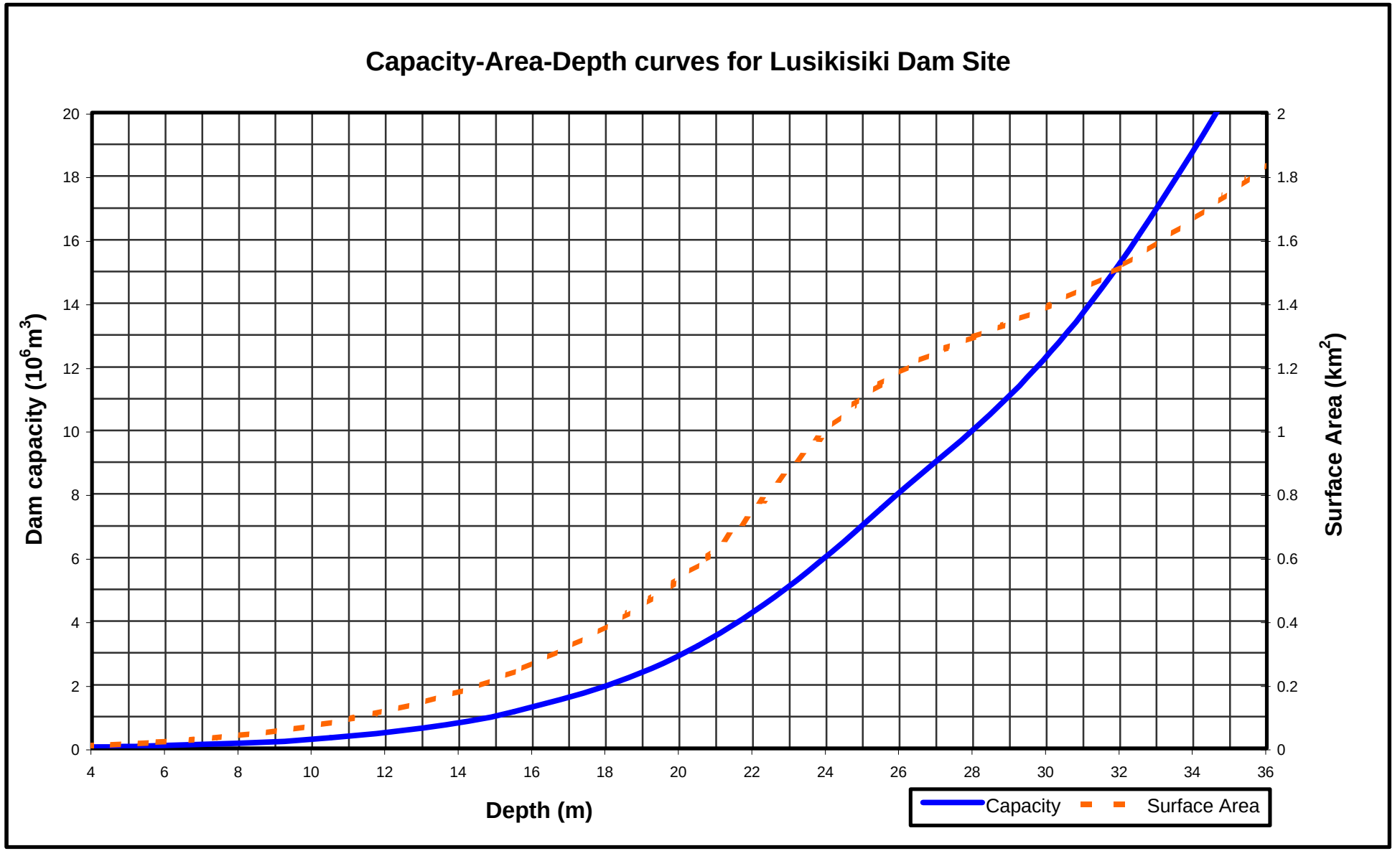
Lower Mzintlava Dam Site

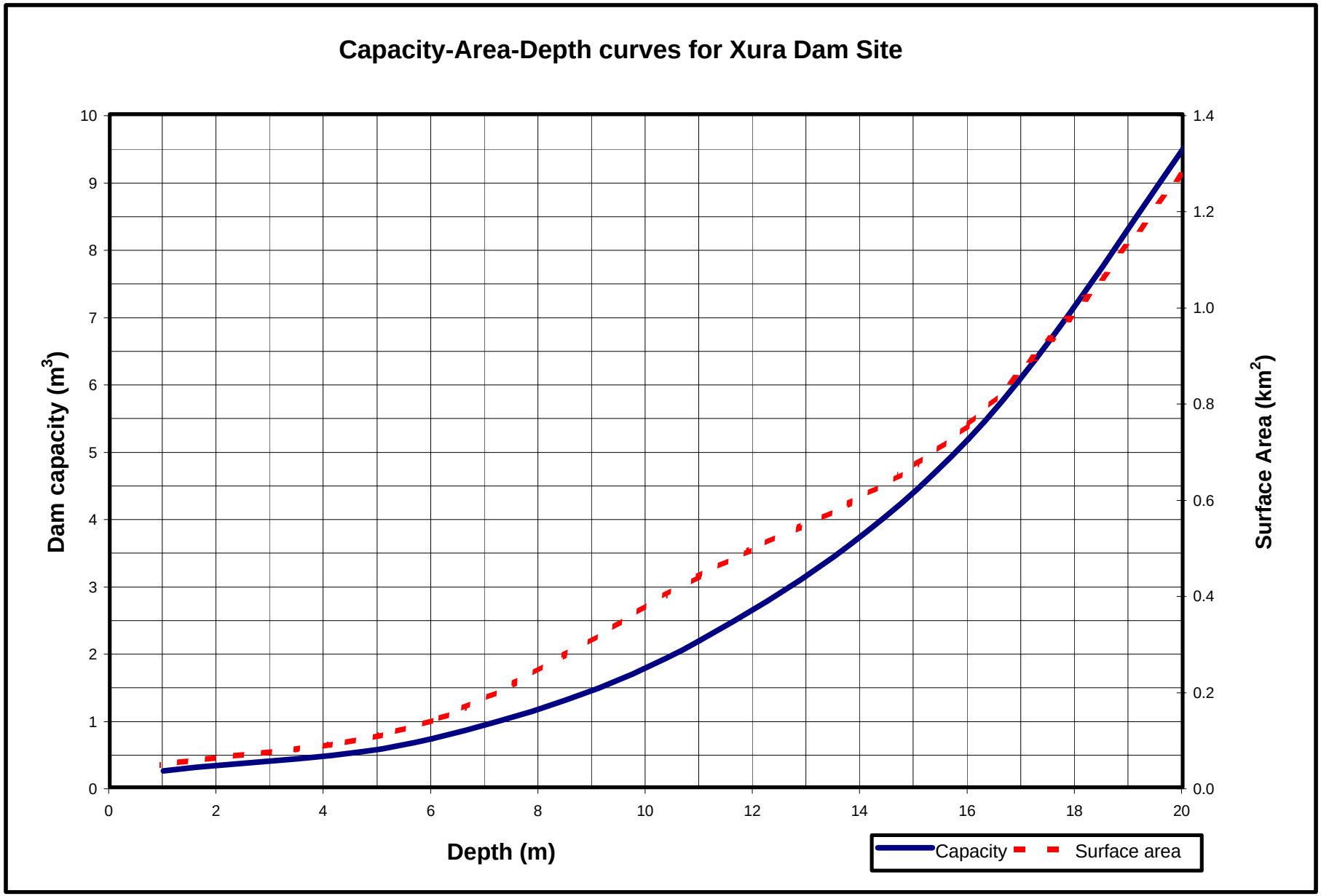
Level (FSL)	Surface Area (km^2)	Capacity ($10^6 m^3$)
409	0.00	0.00
410	0.02	0.04
415	0.06	0.21
420	0.12	0.63
425	0.28	1.59
430	0.50	3.50
435	0.82	6.73
440	1.99	12.98

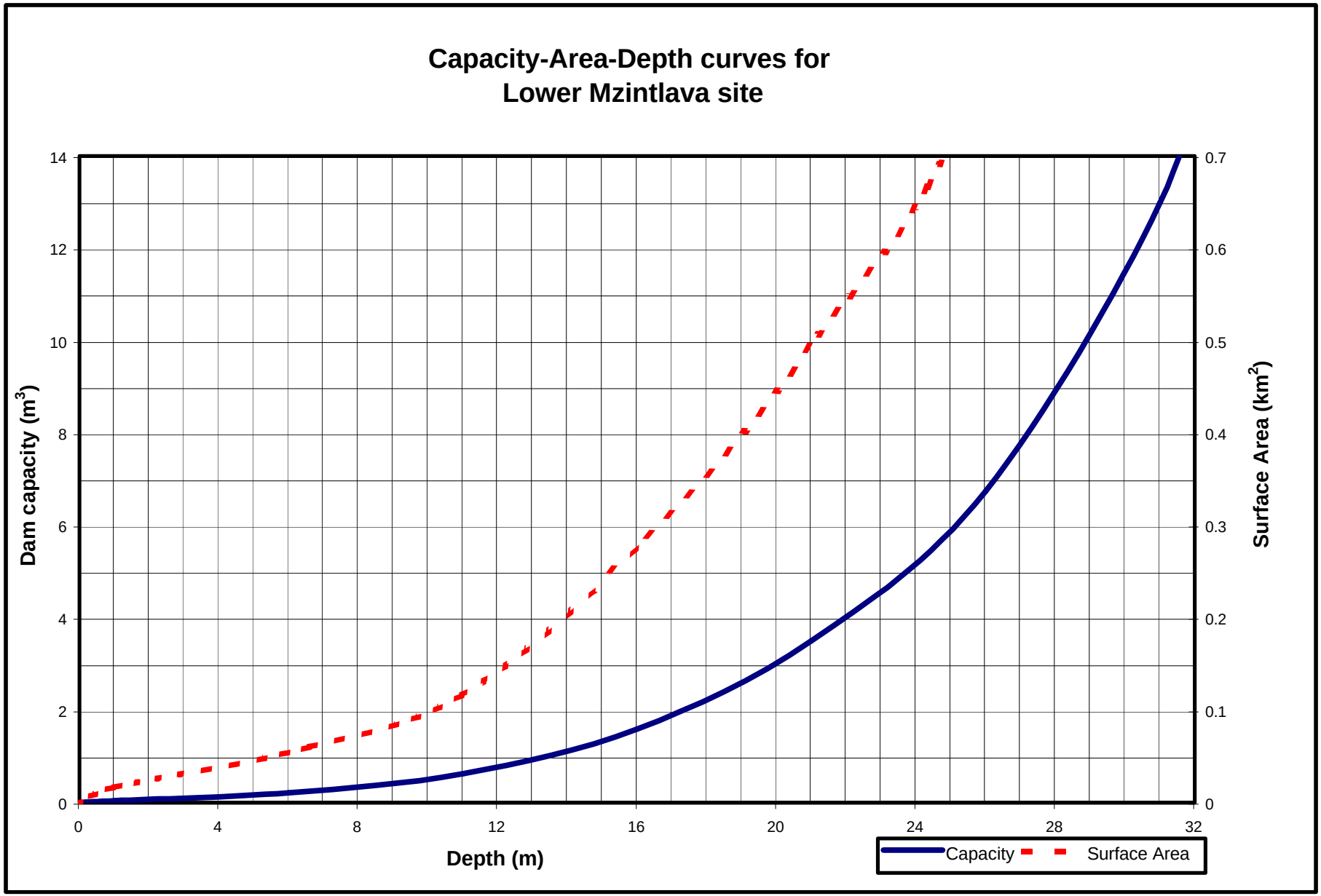
Tungwane Dam Site

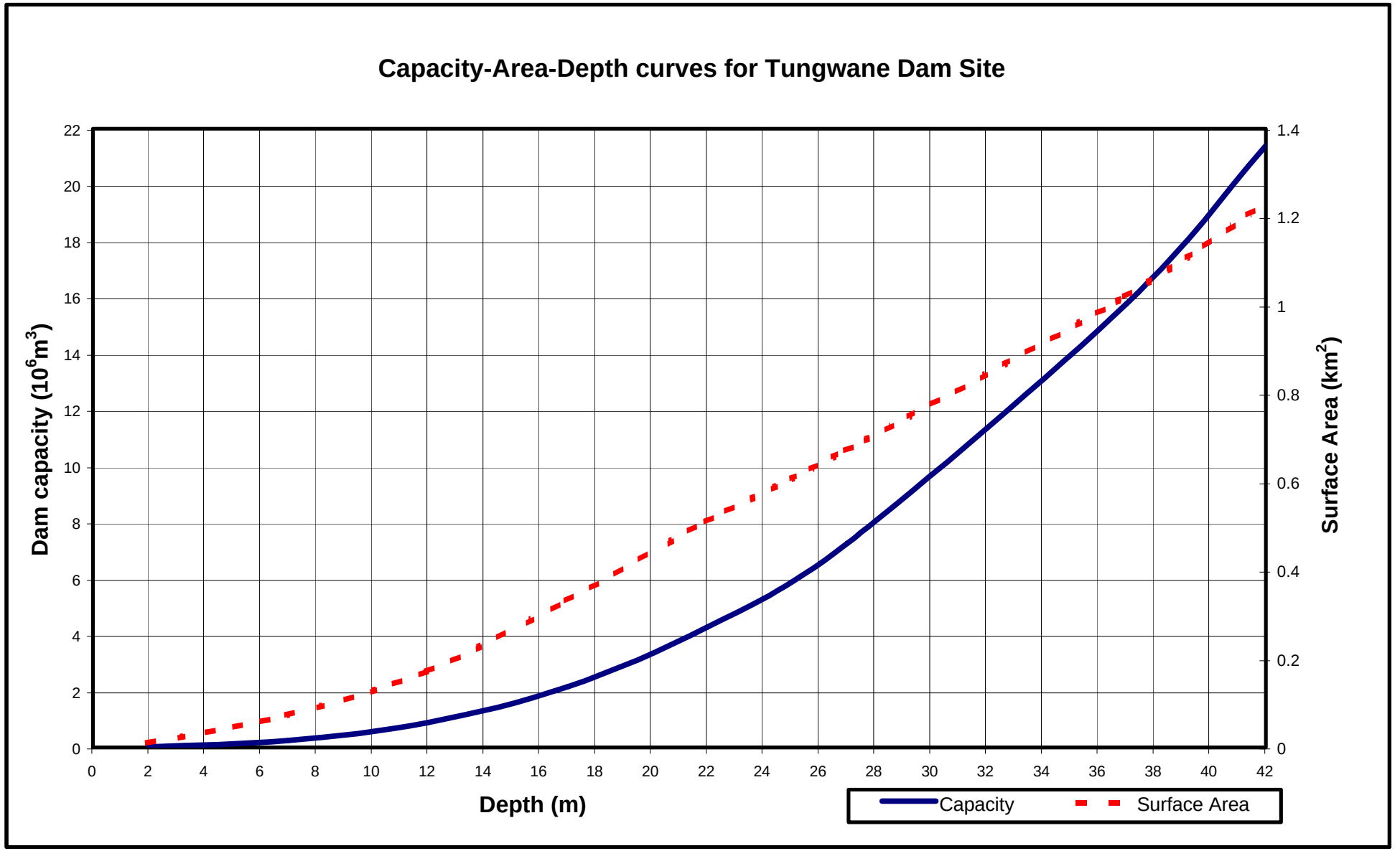
Level (FSL)	Surface Area (km^2)	Capacity ($10^6 m^3$)
358	0.00	0.00
360	0.01	0.01
365	0.08	0.24
370	0.18	0.87
375	0.34	2.15
380	0.51	4.28
385	0.68	7.25
395	1.02	15.75
400	1.23	21.40


Capacity-Area-Depth curves for Zalu Dam Site
Dam capacity (10^6 m^3)
Surface Area (km^2)
Depth (m)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
Capacity
Surface Area


Capacity-Area-Depth curves for Lusikisiki Dam Site
Dam capacity (10^6m^3)
Surface Area (km^2)
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Capacity
Surface Area


Capacity-Area-Depth curves for Xura Dam Site
Dam capacity (m3)
Surface Area (km2)
Depth (m)
0
1
2
3
4
5
6
7
8
9
10
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
0
2
4
6
8
10
12
14
16
18
20
Capacity
Surface area


Capacity-Area-Depth curves for
Lower Mzintlava site
Dam capacity (m3)
Surface Area (km2)
Depth (m)
0
2
4
6
8
10
12
14
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0
4
8
12
16
20
24
28
32
Capacity
Surface Area


Capacity-Area-Depth curves for Tungwane Dam Site
Dam capacity (10^6m^3)
Surface Area (km^2)
Depth (m)
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
0
0.2
0.4
0.6
0.8
1
1.2
1.4
Capacity
Surface Area

APPENDIX E :

YIELD: CAPACITY RELATIONSHIPS

RECONNAISSANCE PHASE

ZALU

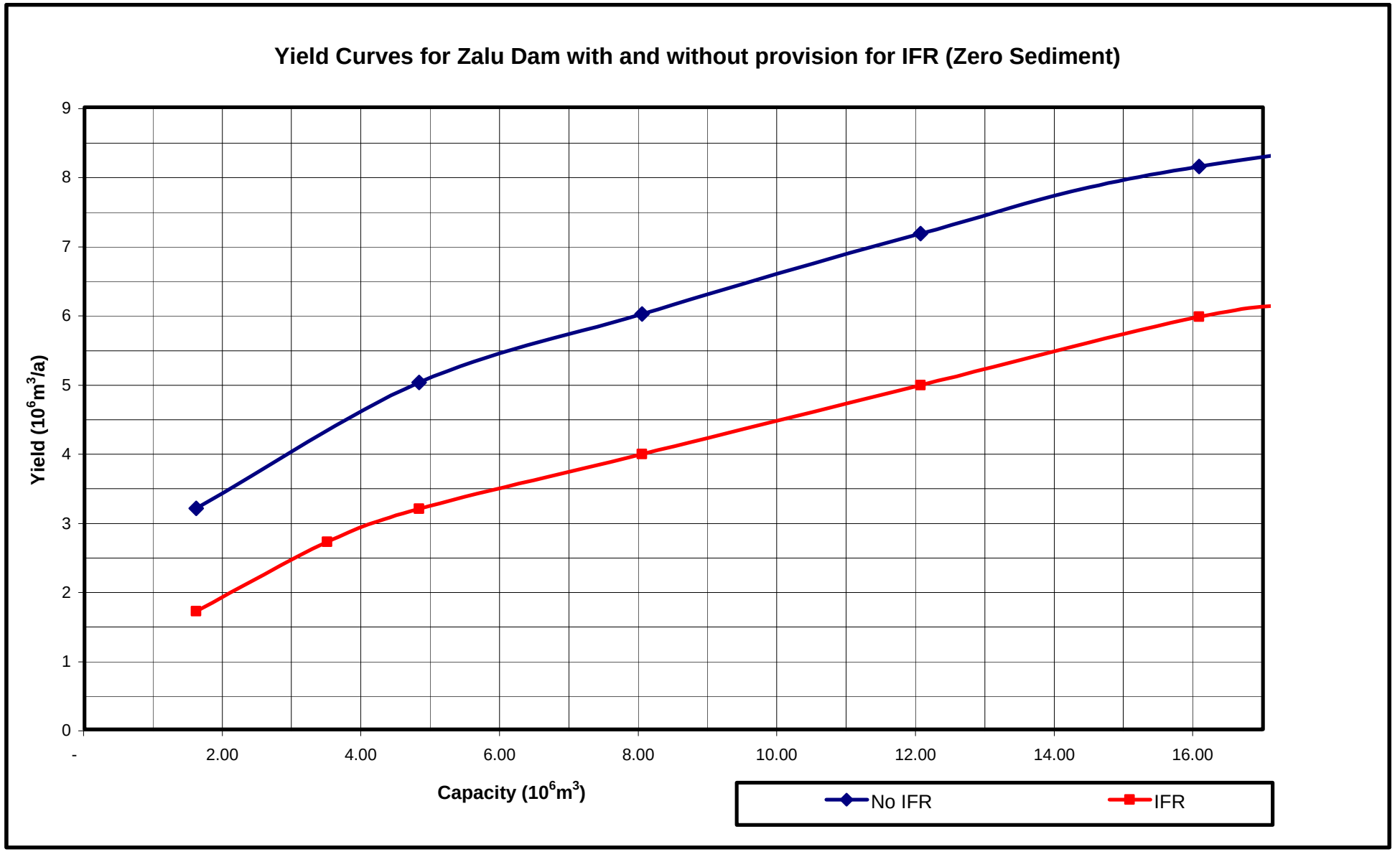
YIELD CAPACITY CURVES (RECONNAISSANCE)

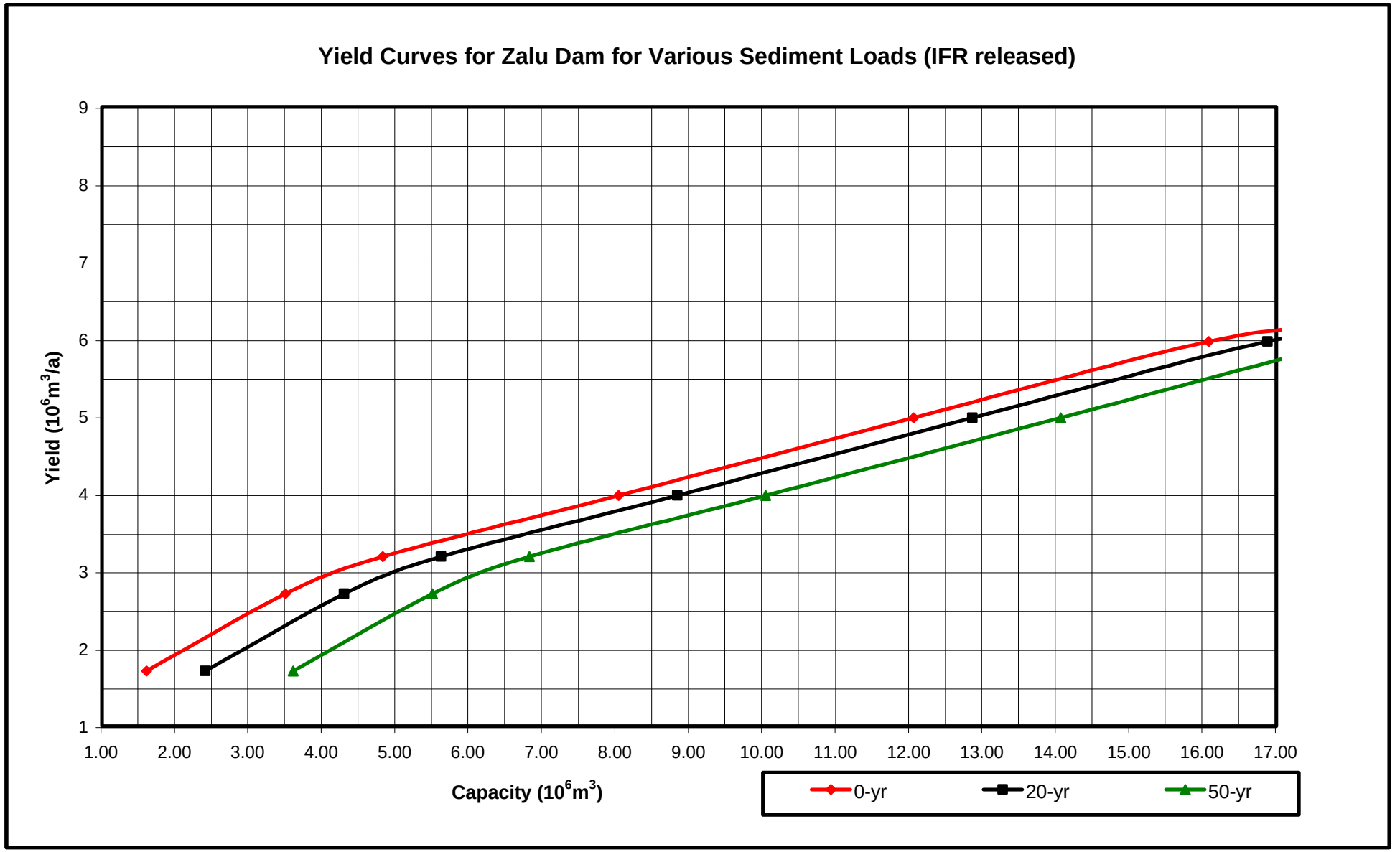
Capacity 10^6m^3	No sediment 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
25.00	0.0	9.24	6.56
23.00	0.0		6.44
18.00	0.0		6.18
16.08	0.0	8.14	5.97
12.06	0.0	7.17	4.98
8.04	0.0	6.01	3.98
4.82	0.0	5.02	3.19
3.50	0.0		2.71
1.61	0.0	3.20	1.71

Capacity 10^6m^3	20-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
25.80	0.8	9.24	6.56
23.80	0.8		6.44
18.80	0.8		6.18
16.88	0.8	8.14	5.97
12.86	0.8	7.17	4.98
8.84	0.8	6.01	3.98
5.62	0.8	5.02	3.19
4.30	0.8		2.71
2.41	0.8	3.20	1.71

Capacity 10^6m^3	50-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
27.00	2.0	9.24	6.56
25.00	2.0		6.44
20.00	2.0		6.18
18.08	2.0	8.14	5.97
14.06	2.0	7.17	4.98
10.04	2.0	6.01	3.98
6.82	2.0	5.02	3.19
5.50	2.0		2.71
3.61	2.0	3.20	1.71

Capacity 106m3	No sediment 106m3	No IFR 106m3	IFR 106m3
25.00	0.0	9.24	6.56
16.08	0.0	8.14	5.97
12.06	0.0	7.17	4.98
8.04	0.0	6.01	3.98
4.82	0.0	5.02	3.19
1.61	0.0	3.20	1.71


Yield Curves for Zalu Dam with and without provision for IFR (Zero Sediment)
Yield ($10^6 m^3/a$)
9
8
7
6
5
4
3
2
1
0
-
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
Capacity ($10^6 m^3$)
No IFR
IFR


Yield Curves for Zalu Dam for Various Sediment Loads (IFR released)
Yield ($10^6 m^3/a$)
9
8
7
6
5
4
3
2
1
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
16.00
17.00
Capacity ($10^6 m^3$)
0-yr
20-yr
50-yr

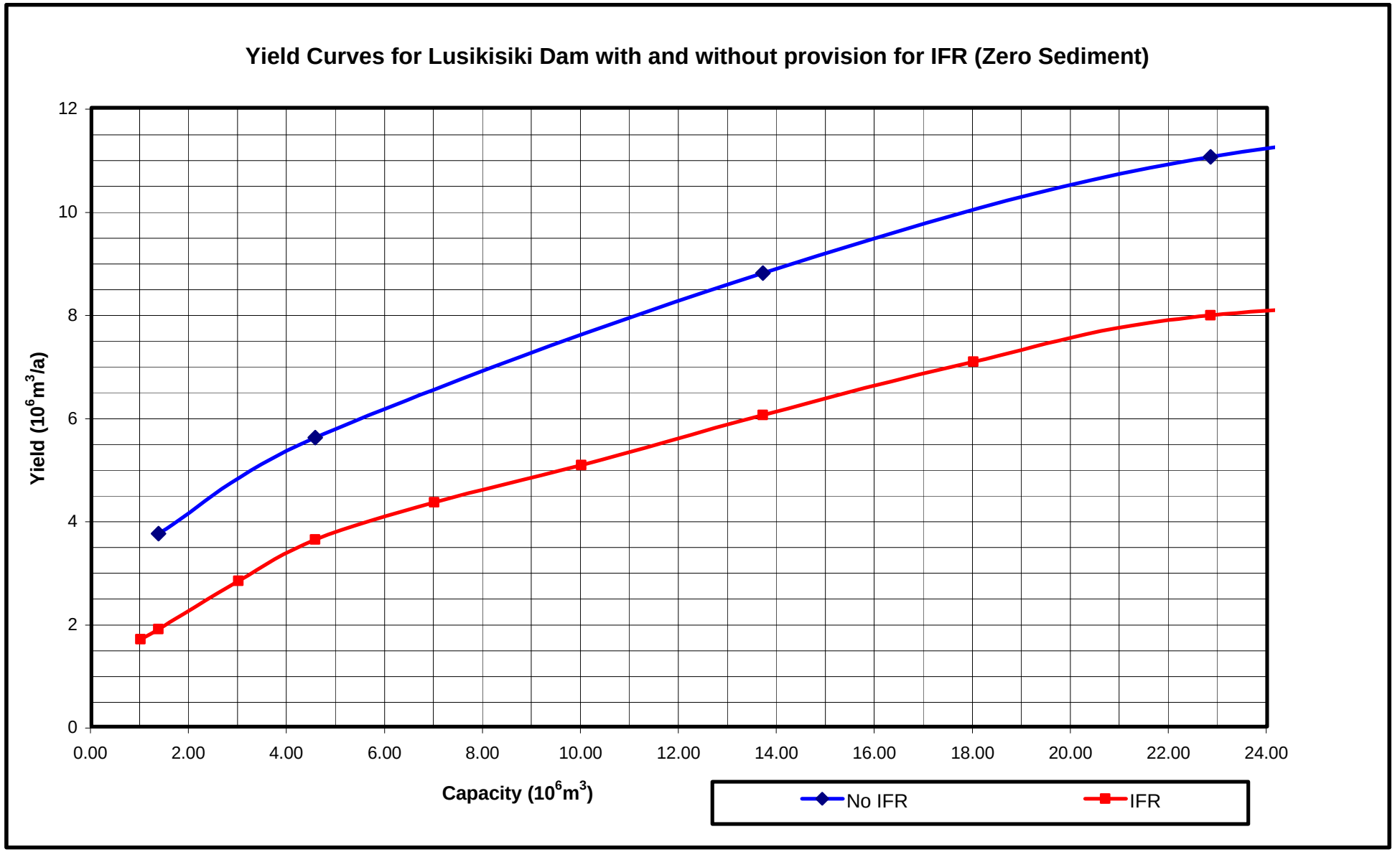
LUSIKISIKI

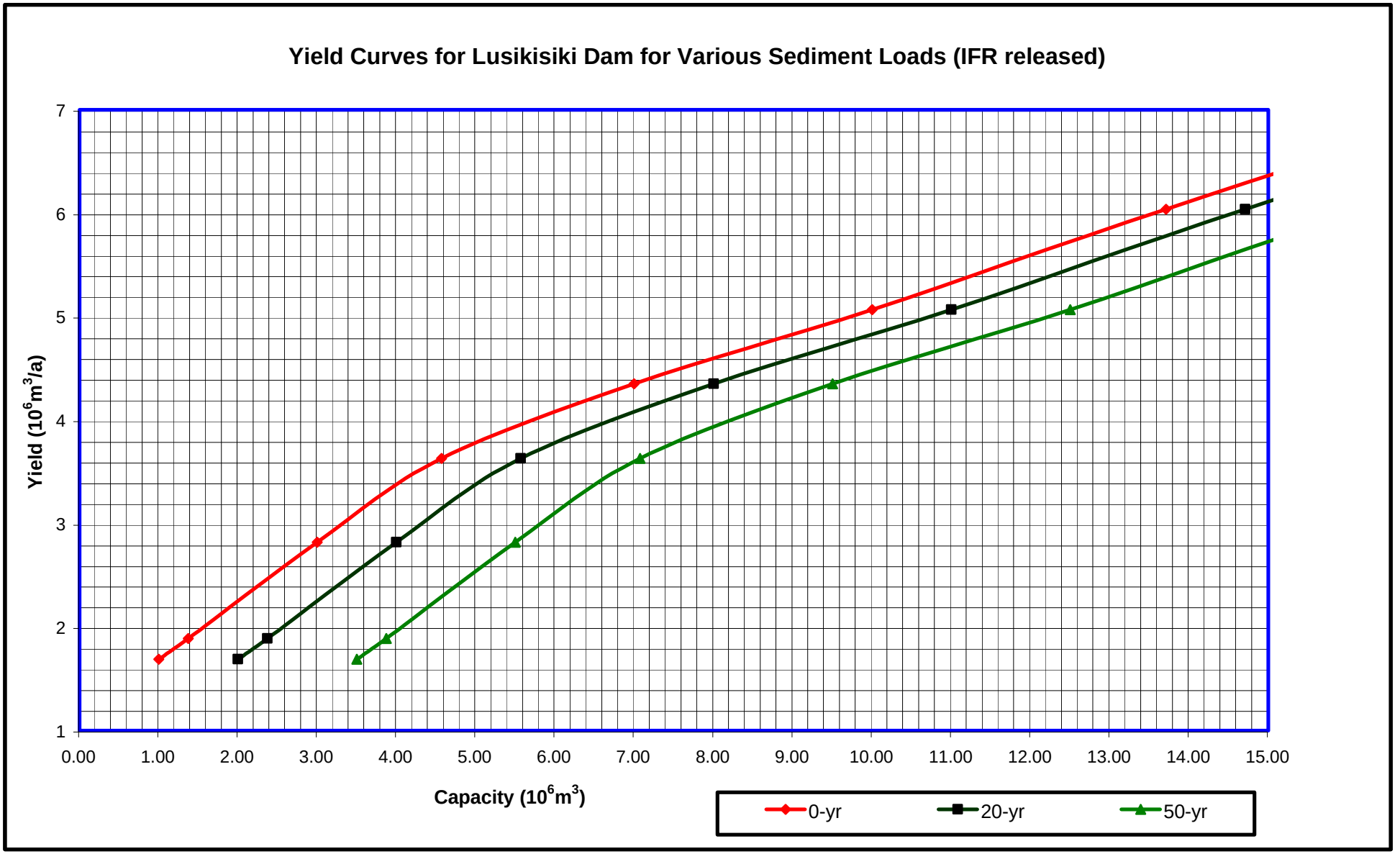
YIELD CAPACITY CURVES (RECONNAISSANCE)

Capacity 10^6m^3	No sediment 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
45.70	0.0	12.68	9.20
34.28	0.0	12.05	8.57
22.85	0.0	11.05	7.97
18.00	0.0		7.07
13.71	0.0	8.79	6.04
10.00	0.0		5.07
7.00	0.0		4.35
4.57	0.0	5.60	3.63
3.00	0.0		2.82
1.37	0.0	3.74	1.89
1.00	0.0		1.69

Capacity 10^6m^3	20-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
46.70	1	12.68	9.20
35.28	1	12.05	8.57
23.85	1	11.05	7.97
19.00	1		7.07
14.71	1	8.79	6.04
11.00	1		5.07
8.00	1		4.35
5.57	1	5.60	3.63
4.00	1		2.82
2.37	1	3.74	1.89
2.00	1		1.69

Capacity 10^6m^3	50-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
48.20	2.5	12.68	9.20
36.78	2.5	12.05	8.57
25.35	2.5	11.05	7.97
20.50	2.5		7.07
16.21	2.5	8.79	6.04
12.50	2.5		5.07
9.50	2.5		4.35
7.07	2.5	5.60	3.63
5.50	2.5		2.82
3.87	2.5	3.74	1.89
3.50	2.5		1.69


Yield Curves for Lusikisiki Dam with and without provision for IFR (Zero Sediment)
Yield (10^6m^3/a)
Capacity (10^6m^3)
0
2
4
6
8
10
12
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
22.00
24.00
No IFR
IFR


Yield Curves for Lusikisiki Dam for Various Sediment Loads (IFR released)
Yield ($10^6 m^3/a$)
7
6
5
4
3
2
1
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
13.00
14.00
15.00
Capacity ($10^6 m^3$)
0-yr
20-yr
50-yr

XURA

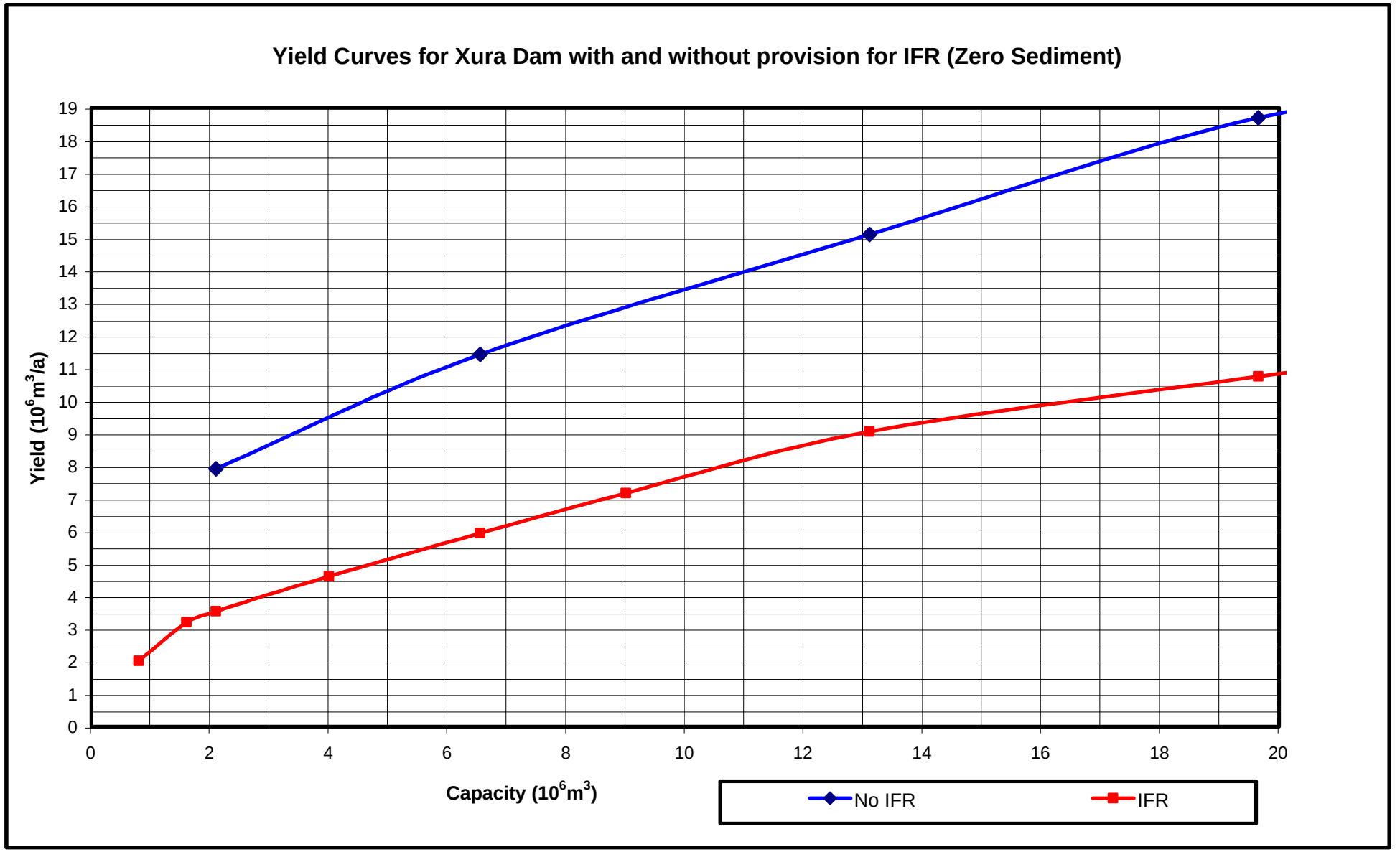
YIELD CAPACITY CURVES (RECONNAISSANCE)

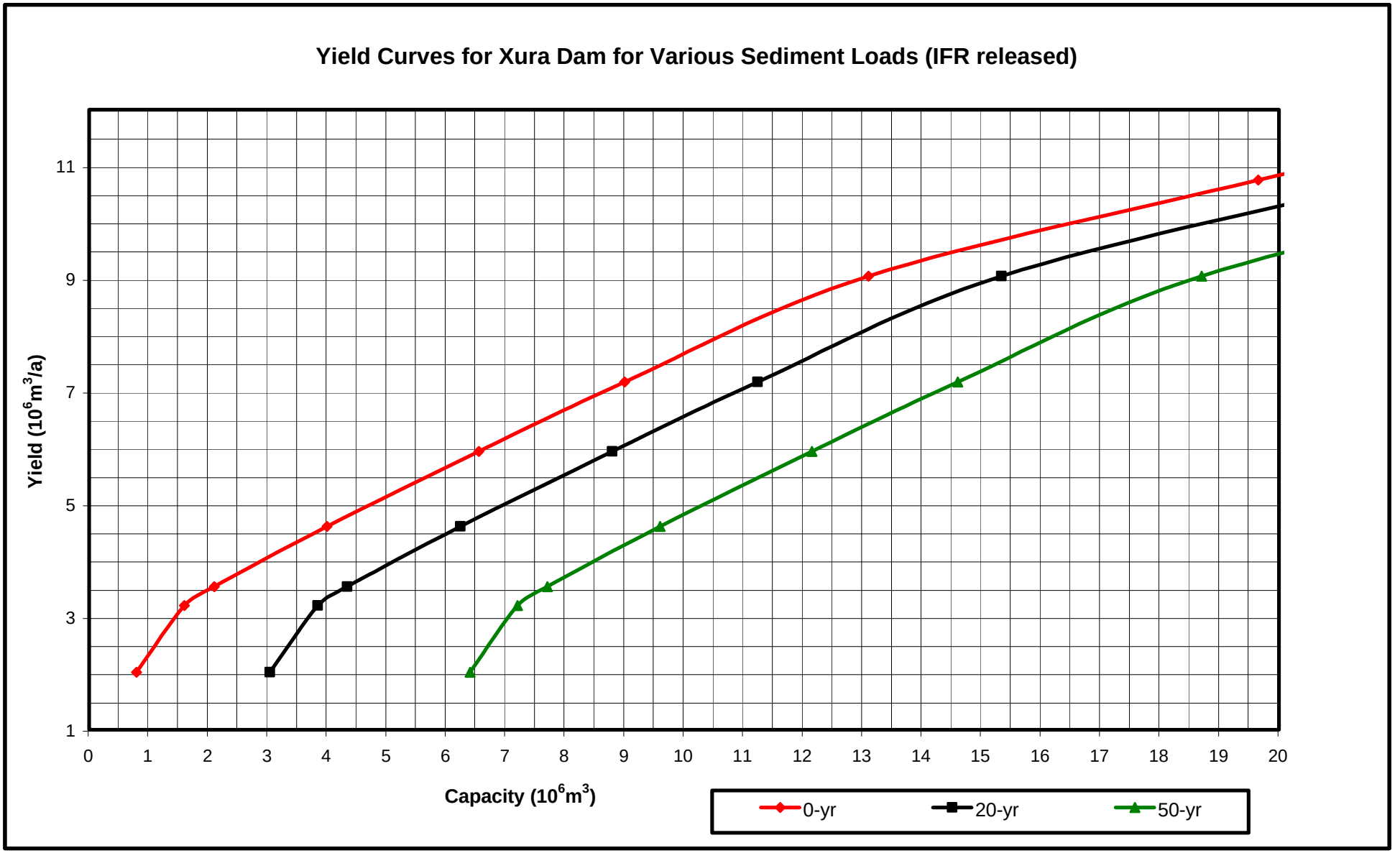
Capacity 10^6m^3	No sediment 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
26.20	0.0	20.50	12.36
19.65	0.0	18.69	10.75
13.10	0.0	15.11	9.05
9.00	0.0		7.17
6.55	0.0	11.42	5.94
4.00	0.0		4.61
2.10	0.0	7.91	3.54
1.60	0.0		3.20
0.80	0.0		2.02

Capacity 10^6m^3	20-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
28.44	2.24	20.50	12.36
21.89	2.24	18.69	10.75
15.34	2.24	15.11	9.05
11.24	2.24		7.17
8.79	2.24	11.42	5.94
6.24	2.24		4.61
4.34	2.24	7.91	3.54
3.84	2.24		3.20
3.04	2.24		2.02

Capacity 10^6m^3	50-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
31.80	5.6	20.50	12.36
25.25	5.6	18.69	10.75
18.70	5.6	15.11	9.05
14.60	5.6		7.17
12.15	5.6	11.42	5.94
9.60	5.6		4.61
7.70	5.6	7.91	3.54
7.20	5.6		3.20
6.40	5.6		2.02

Capacity 106m3	No sediment 106m3	No IFR 106m3	IFR 106m3
26.20	0.0	20.50	12.36
19.65	0.0	18.69	10.75
13.10	0.0	15.11	9.05
6.55	0.0	11.42	5.94
2.10	0.0	7.91	3.54
0.80	0.0		2.02


Yield Curves for Xura Dam with and without provision for IFR (Zero Sediment)
Yield ($10^6 m^3/a$)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
0
2
4
6
8
10
12
14
16
18
20
Capacity ($10^6 m^3$)
No IFR
IFR


Yield Curves for Xura Dam for Various Sediment Loads (IFR released)
Yield (10^6m^3/a)
Capacity (10^6m^3)
0-yr
20-yr
50-yr
1
3
5
7
9
11
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

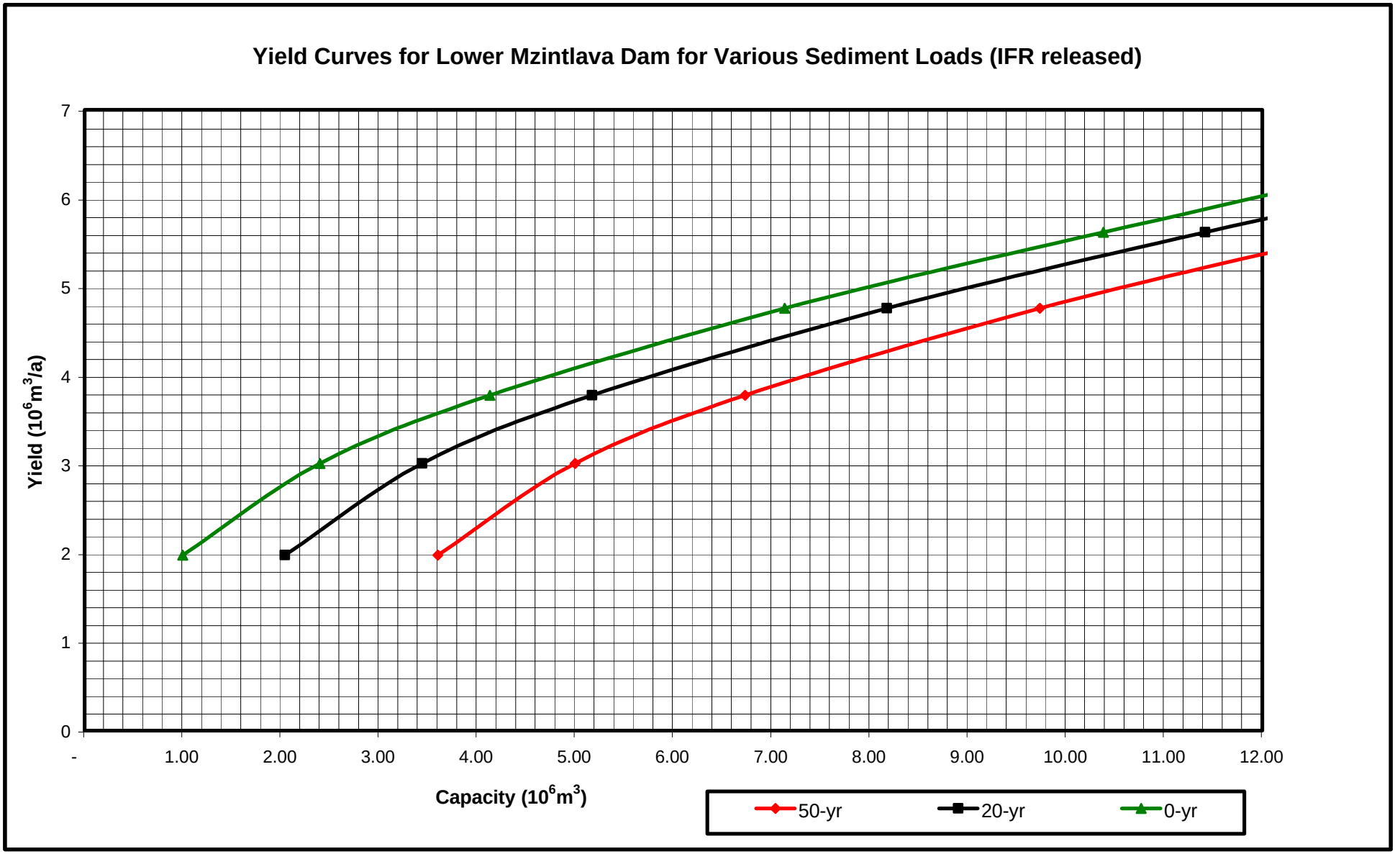
LOWER MZINTLAVA

YIELD CAPACITY CURVES (RECONNAISSANCE)

Capacity 10^6m^3	50-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
18.00	2.6		6.87
12.98	2.6	8.39	5.62
9.74	2.6	7.48	4.76
6.73	2.6	5.74	3.78
5.00	2.6		3.01
3.60	2.6		1.98

Capacity 10^6m^3	20-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
16.44	1.04		6.87
11.42	1.04	8.39	5.62
8.18	1.04	7.48	4.76
5.17	1.04	5.74	3.78
3.44	1.04		3.01
2.04	1.04		1.98

Capacity 10^6m^3	No sediment 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
15.40	0.0		6.87
10.38	0.0	8.39	5.62
7.14	0.0	7.48	4.76
4.13	0.0	5.74	3.78
2.40	0.0		3.01
1.00	0.0		1.98


Yield Curves for Lower Mzintlava Dam for Various Sediment Loads (IFR released)
Yield (10^6m^3/a)
Capacity (10^6m^3)
0
1
2
3
4
5
6
7
-
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
11.00
12.00
50-yr
20-yr
0-yr

TUNGWANE

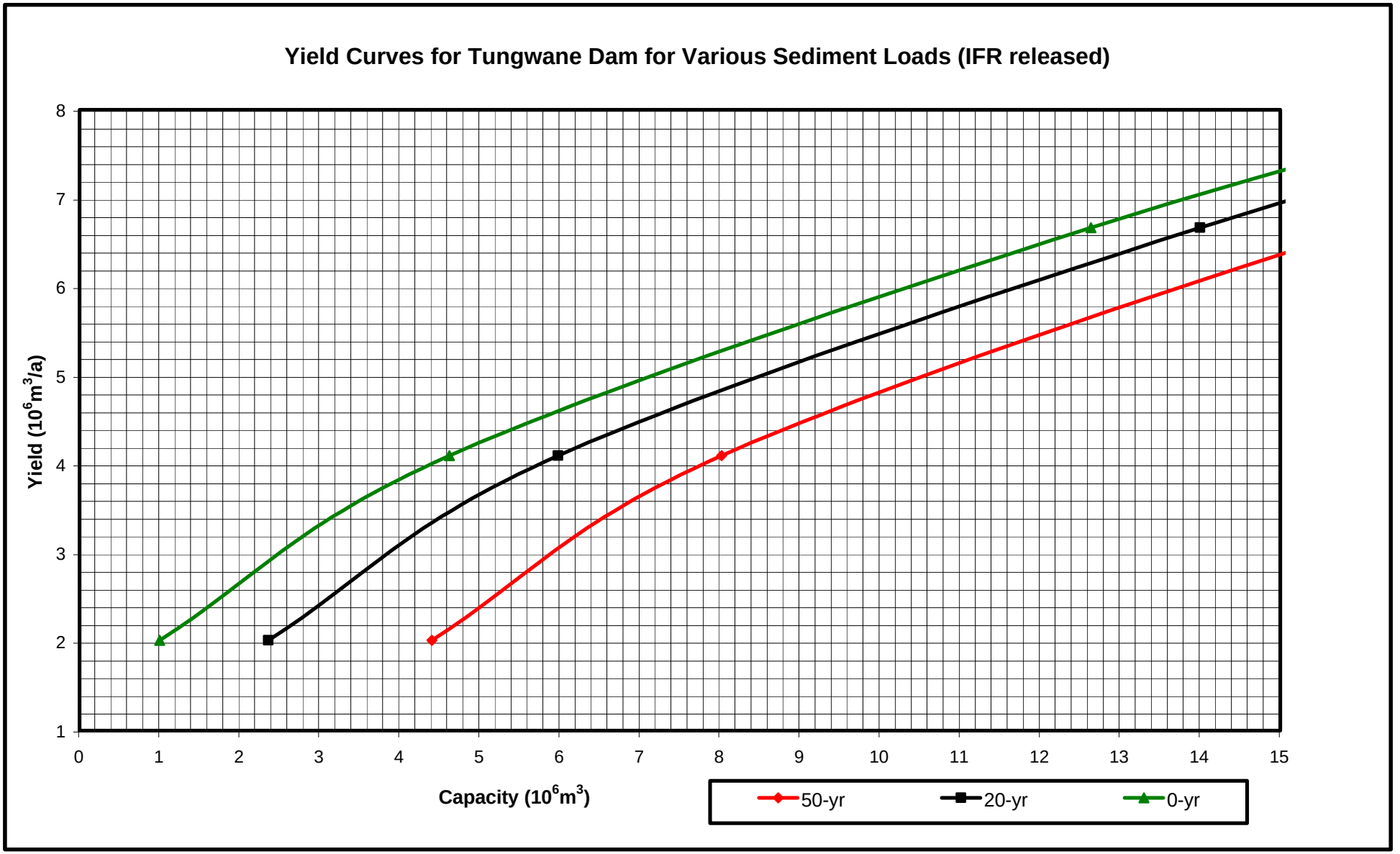
YIELD CAPACITY CURVES (RECONNAISSANCE)

Capacity 10^6m^3	50-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
32.08	3.4	15.58	10.78
24.06	3.4	13.63	8.71
16.04	3.4	11.32	6.67
8.02	3.4	7.53	4.10
4.40	3.4		2.02

Capacity 10^6m^3	20-yr Sediment Yield 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
30.04	1.36	15.58	10.78
22.02	1.36	13.63	8.71
14.00	1.36	11.32	6.67
5.98	1.36	7.53	4.10
2.36	1.36		2.02

Capacity 10^6m^3	No sediment 10^6m^3	No IFR 10^6m^3	IFR 10^6m^3
28.68	0.0	15.58	10.78
20.66	0.0	13.63	8.71
12.64	0.0	11.32	6.67
4.62	0.0	7.53	4.10
1.00	0.0		2.02

28.68	0.0	15.58	10.78
20.66	0.0	13.63	8.71
12.64	0.0	11.32	6.67
4.62	0.0	7.53	4.10
1.00	0.0		2.02


Yield Curves for Tungwane Dam for Various Sediment Loads (IFR released)
Yield ($10^6 m^3/a$)
Capacity ($10^6 m^3$)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
1
2
3
4
5
6
7
8
50-yr
20-yr
0-yr

APPENDIX F :

SOCIAL IMPACT ASSESSMENT

RECONNAISSANCE AND
PRE-FEASIBILITY

Appendix F1

SOCIAL IMPACT ASSESSMENT

1. SOCIO-ECONOMIC OVERVIEW

1.1 Historical Perspective

Pondoland region lies on the Transkei coast between the Mtamvuma and Umtata Rivers, bordering on Kwazulu Natal in the north and divided by Umzimvubu River into East and West Pondoland, each with its own chief. In 1894 Cecil Rhodes broke the power of the chiefs by annexing Pondoland to the Cape Colony. In East Pondoland the towns and districts are Lusikisiki, Flagstaff, Bizana and Tabankulu; in West Pondoland Port ST Johns, Libode and Ngqeleni. Qaukeni Great Place in Lusikisiki is the home of the Pondoland King Xolilizwe Sigcau, descendant of the great King Faku. The Pondoland region is the richest cattle country in the Transkei, and also the most fertile, although farming methods are very primitive. The agricultural potential is greater than that of any other part in the Transkei. The principal agricultural products are maize and dagga, the latter being cultivated and smuggled out.

The Pondoland region was marred by upheavals most notably the 1960 Pondoland revolt, which was cantered in dispute against the government and betterment policy. The first president of an independent Transkei Botha Sigcau was the King of East Pondoland. Oliver Reginald Tambo the then president of the ANC was also born in Pondoland, the district of Bizana.

1.2 Demographic Profile

The demographic statistics for the former Transkei are inadequate. The official growth estimates have been based on different rates. Apparently a rate of 2.9 % was used for some estimates during the 1980's and was close to the actual growth rate then. However, although the growth rate was expected to decrease to about 2.7% by 1995, a rate of 3% has been widely used. Some official estimates were apparently based on an annual growth rate of 5%. The development Bank of South Africa in 1988 reported that the growth rate for Umtata is 7% due to the rapid growth of the peri-urban areas. Whether at 2.5% or 3%, the population is growing rapidly and this implies high demand for jobs, housing, schooling, health and other services. The latest studies undertaken by the DWAF (MarkData, 2000) however reveal that the population growth rates will be significantly reduced during the following 30 years, due to the impacts of AIDS and migration. It is predicted that the population will decline by 0,5% by the year 2030.

Population density gives some indication of land pressure and potential labour supply as well as demand for services and service centres. The population density for the district of Lusikisiki based on the preliminary results of the 1991 Census is 114 people/km² (238 649 people in an area of 2 089 km²). Given the low levels of agricultural production, excessive stocking rates, the lack of non-agricultural

employment opportunities and almost non-existent rural infrastructure places considerable pressure on resources.

According to the 1991 census, the total number of immigrants from Transkei that year was 982 172. This has increased from 268 000 in 1970 and 308 000 in 1980. The majority of Transkei's rural immigrants (68%) worked in the Transvaal or Cape Province, whereas about 13% worked in Natal and 9% in the Orange Free State. About 75% of immigrants were employed as production or transport workers and labourers, while 12% were service workers and only 4% were in professional technical, administrative, managerial or clerical occupations. The passed 5 to 10 years has seen a sharp decline in migration. The reasons given by TEBA are the closing down of mines and the scaling down of work in mines that are still operating. According to TEBA in the 1980's they use to send about 7 000 people to the mines a year but recently they battle to send 1 000 a year. This means that the increase in numbers of unemployed migrant mineworkers has implications for the rural population. It might suggest that more people with no income. In the majority of cases widowed elderly women have the burden of supporting dependants from their meagre pensions. Retrenchments also increase the pressure on land for cultivation.

1.3 Socio Economic Status

The Transkei population is largely rural – 93.8% (Statistical Bulletin 1992). In 1982 a total of 50.3% of rural households earned an annual income of between R500 and R1000. Income from production accounted for 2.50% of the income earned, while 71.10% came from remittances, 14.30% from pensions and 12.10% from wages. The 1994 registered unemployed figures, however, indicate that the number of unemployed workers has increased, suggesting that migrant remittances have decreased. Salaries and wages accounted for 34.7% of the total annual income during 1990, while social welfare and pensions contributed 6% of the total income during the same period. In the 1990's there is evidence that on average, over 61% of the households are either receiving no income at all or are at the lowest income bracket (Mpambani, 1993: 26)

The inhabitants of rural Transkei are engaged in subsistence agriculture. Subsistence agriculture in this context is used to mean small-scale farming with the intention of producing enough to feed the household for the current season. A surplus may be produced to either sell for cash or to store for future household needs. Rural households are not able to farm successfully, one reason for the failure seems to be the ever-diminishing availability of land for cultivation. Betterment planning has been widely blamed for the land shortage. Some of those who have access to land do not have the cattle to plough with and cannot afford to hire tractors to plough for them.

Industries that exist in the Pondoland area of Lusikisiki, Bizana, Flagstaff and Tabankulu are the Magwa Tea plantation, sugar plantations, and the illegal cultivation of dagga. The Magwa Tea plantation in Lusikisiki was a major industry employing thousands of people. The sugar plantations are situated in Northern Pondoland in the Bizana district and are not contributing much to the economy of the region because of a variety of reasons. Amongst the reasons is the fact that the sugar plantations are not employing many people and the sugar production levels are low due to the unavailability of resources necessary to make sugar planting successful.

The planting of dagga is illegal, but has been the sole source of income for many households in the Pondoland region. Each household member has a piece of land in which he or she plants dagga for selling to buyers coming from as far as Cape Town, Johannesburg and Port Elizabeth.

The planting of dagga dates back to a long time and is regarded by the people of Pondoland as the only means available to them for making a living. It has also resulted in a high rate of illiteracy in the region, many generations never worried about going to school because every child that is born is allocated a piece of land to plant dagga. It is easy for the people to grow dagga because it grows without irrigation and fertilizers.

1.4 Institutional Structures

The administrative and institutional capacity of the former Transkei sub-region is extremely limited. Bureaucratic procedures are complicated and often futile, resources are scarce, particularly in the far-flung rural areas. The urban bias in resource distribution and the favouring of certain districts over others, are examples of the problematic administrative history of the sub region. These factors can also be attributed in part, to favours and privileges awarded to an emergent elite after independence. The majority of rural dwellers on the other hand, have remained poor, or become more impoverished over time.

Local government and administration in the former Transkei operates differently in urban and rural areas. An estimated 5% of the population of the sub-region lives in Transkei's 28 urban towns, which are administered under different legislation from that of rural areas. Towns (which were formally reserved for whites) act as seats of district magistracies. Until recently, towns have been administered by municipal councils in terms of the Municipalities Act of 1979. In terms of the transitional local government restructuring, statutory and non-statutory bodies now constitute transitional local councils, which are responsible for urban administration. The structure of rural local government is complicated, operating on a number of different levels- central, regional, district, tribal and local – it has suffered from shortages, poor administration of resources and limited infrastructure.

In rural Transkei, homesteads are grouped into villages, which fall under the authority of the sub-headmen who are generally nominated by village residents and not remunerated for their services. A number of such villages comprise an Administrative Area, which falls under the jurisdiction of a headman. This constitutes the smallest officially recognised administrative unit. The 940 Administrative Areas in the Transkei are administered by 182 Tribal Authorities, which are in turn responsible to district commissioners. These commissioners advice Tribal Authorities of their local government duties. The structure of Tribal Authorities is essentially based on traditional law and hence most positions are hereditary. Traditionally, administrative areas were headed by hereditary chiefs, but decision-making processes were consensual and chiefs were expected to provide patronage to their followers. Thus while the power to allocate land lay with chiefs, they were obliged to provide people living in the area under their jurisdiction with residential sites, arable allotments and access to grazing on communal commonages.

In the contested terrain of rural and urban local government in the sub-region, the South African National Civic Organisation (SANCO) has emerged with the objective of taking a leading role in community development. The 1995 local government elections ushered in the Transitional Representative Councils (TRC's). Each district is run by a TRC in so far as rural development is concerned. The TRC's are under the District Councils. The emergence of TRC's who in many cases are made up of SANCO members has resulted in confrontation between TRC's and the traditional authorities, and this has resulted in many development projects being unsuccessful. The best path to follow for any development programme to be successful is to make sure that it enjoys support from both the TRC's and the traditional authorities.

Local government and administrative structures in the Transkei sub-region are mostly rudimentary, unaccountable, fragmented and weak. Administration, control and allocation of land are entirely in the hands of chiefs, who have in some cases abused this role to the detriment of many rural people. There is an obvious and urgent need to democratise land-allocation procedures, and the implementation of any land reform programme in the Transkei needs to be based on a restructuring of the institutional and administrative framework. An essential component of rural local government restructuring must involve capacity building or human resource development including skills upgrading and assured access to training. Problems with institutional structures and a history of corruption in the region have undermined people's confidence in the system. Negative experiences of past dealings with bureaucracy have resulted in a general loss of faith in government structures and institutions, and the new government has not managed to alter this perception. Furthermore, institutions and structures, which have existed side by side, have often functioned in uncoordinated and sometimes contradictory ways.

1.5 Land Use and Tenure

The total area of the Transkei sub-region is 4 365 263 ha, but about 360 000 ha is mountainous and barely habitable. Of the total area, about 86% is rural land which is utilised according to traditional land use patterns namely:

- Residential land (usually half a hectare), which may be in dispersed settlements or consolidated into betterment villages.
- Arable land, which is normally used for summer crops (mainly maize)
- Common grazing land.

The rest of the land (14%) is used as follows:

- Forestry – hectares of commercial and semi–commercial plantations.
- Conservation, including indigenous forests, nature reserves, and government control areas.
- Intensive commercial agriculture, for example the Magwa Tea estate in Lusikisiki and the sugar cane plantation in Bizana.
- Farming on private farms.

Rural planning in the Transkei was based on Proclamation 116 of 1949, which enabled the demarcation of rural land into residential, arable, forestry and grazing, ostensibly for purposes of soil conservation and rational land use.

The tea plantations in Lusikisiki, which were run by Magwa Tea Corporation (MTC) encompass 2 955 ha. Tea was first planted in 1963, and in the late 1970's about 5 000 ha of land was expropriated for the expansion of the Magwa Estate. The displaced landholders were employed as labourers on the estate. The expansion plans never materialized due to unfavourable economic conditions. MTC has a commercial maize and beef farm on the remaining land, which is run in conjunction with TRACOR (under the Lambas, Farms company). MTC produces over 3 000 tons of tea per annum, which represents about 12,5% of the tea consumed in Southern Africa. MTC employs about 3000 permanent and 1 500 seasonal workers, with women making up almost 80% of the labour force. The workers at Magwa live in 14 agro-villages on the estate, with company subsidised transport. Holders of arable land (on average one to two ha plots) have been approached to grow tea on their land. Plants, inputs and initial assistance are provided by MTC.

Sugar is grown on about 1 500 ha in the Mankenkezi /Greenville area of the Bizana district. This estate is controlled by the North Pondoland Sugar Company (jointly managed by Tracor and Magwa Tea Corporation). The core estate employs 280 workers. In 1989/90, the last year for which figures are available, 49 500 tons of cane were harvested (a yield of about 45t per ha), with cane being milled at the Umzimkhulu Mill in Port Shepstone. In 1986 twenty small growers were allocated land for sugar cultivation. In 1991, there were 40 small holders growing sugar cane on plots of approximately 10 ha, as part of an outgrower scheme. After expansion, there were approximately 130 outgrowers in 1994. This expansion is based on the financial support of the DBSA and the SA Sugar Association's Small Grower's Fund (to plant the projected 4 000 ha). However there are reports of resistance from most of the local community to this scheme, as it means loss of grazing land and the implementation of top-down development planning. Unless land use planning involves a participatory process with the local community at the centre, there is a strong potential that further conflict and resistance to development programmes will occur.

There are two main categories of land tenure types – individual or freehold, and indigenous or communal. However, the differences between them are not always clear, since some individual forms of tenure resemble 'communal' tenure in practice, while communal tenure does allow long term and relatively secure occupancy of a site. The MTC and North Pondoland Sugar Estate were established on land held under communal tenure.

2. OUTLINE OF POSSIBLE SOCIAL IMPACTS

2.1 Relocation people and expropriation of land (negative impact)

The land tenure systems, together with population density govern the extent of social impact of development projects. For example, the severity of the impact of the relocation of people in over-populated; communally owned land is infinitely greater than the impact of the expropriation of landowners from privately held land. Moreover, in the latter case meaningful financial compensation to the affected people is possible, whereas in the former case it is virtually impossible, as the relocated cannot purchase community owned land.

A second important point, related to relocation and expropriation arising from development schemes, is the extreme dependence of the rural poor on the renewable natural resources of their immediate environment. Excision of the resources of the inundated dam basin from the available resource base can have major impacts on rural communities. In the Transkei most of the river valleys are used by local residents for the cultivation of subsistence crops, primarily maize. The loss of these soils to the local cultivators, who may reside outside the basin, may seriously impede their ability to provide security to their families.

Dam sites, which would necessitate the relocation of 100 or more families have been classing as having "serious" social impacts. "Moderate" impacts involve the relocation of 20 to 100 families and "minor" impacts less than 20 families. However, considerations other than financial include the permanent loss of arable land, grazing land, subsistence agricultural soils and of other natural resources.

2.2 Loss of access (negative impact)

The importance of pedestrian and stock access is not always self-evident and must be taken into account through public participation in the feasibility phase. In the rural area children walk long distances to schools, and even teachers normally commute to work everyday to reach rural schools. The loss of access to villages with schools, churches etc. may bring more hardship to the lives of the rural communities.

2.3 Loss of archaeological and historical sites (negative impact)

Surveys of proposed dam sites must be undertaken to locate threatened archaeological and historical sites and to make recommendations on how to deal with them. The historical importance of certain areas can be a 'fatal flow' for possible developments

.

2.4 Provision of domestic water (positive impact)

The proposed dams will create a major opportunity for the supply of domestic water to many rural residents in former Transkei districts.

2.5 Creation of employment opportunities (positive impact)

Due to high unemployment levels in the study area, employment opportunities, skills training and transfer, will be the key issues in the acceptability of the development.

2.6 Recreation opportunities (positive impact)

Carefully designed developments can enhance the value of the area by creating recreation, and eco-tourism opportunities.

2.7 Improved infrastructure and services (positive impact)

The infrastructure to be put in place should be designed to provide maximum post-construction benefit. A need analysis for the communities in and around the proposed dam sites will have to be undertaken to identify their priority needs.

3 QUANTIFICATION OF MAIN IMPACTS

3.1 Methodology

The potential social impacts associated with the construction of dams and conveyance systems for the augmentation of the LRWS scheme were initially identified on the basis desktop studies and literature reviews. The inundated areas and possible loss of access were quantified on the basis of 1:10 000 topographical maps and recent aerial photographs. The information was later refined during field visits and interviews with various institutions and stakeholders with extensive local knowledge.

The stakeholder interviews included the Transitional Representative Council (TRC), the Transitional Local Council (TLC) of Lusikisiki and the Project Steering Committee (PSC), consisting of representatives of all administrative districts affected by the developments. During the interviews the proposed scheme and was explained in detail. Stakeholders were requested to comment on the acceptability of various options, and to put forward issues and concerns.

In addition, a certain public participation and wider stakeholder involvement activities have taken place during the course of the study. These issues are discussed in Section 9.4 of the report.

Current Land Use

The land in the areas of possible inundation is currently used for the following purposes:

- Residential
- Arable
- Commonage

3.2 EVALUATION OF DAM SITES

All dam sites were evaluated in terms of the following issues: relocation of people, loss of land, loss of access, and loss of natural resources.

Zalu Site

The proposed dam site is situated to the north-west of Lusikisiki town. The total approximate inundated area due to the proposed dam basin is 1.0 km².

Relocation of people: No relocation of people will be required

Loss of access: Minor access roads between the villages of Ndimbaneni, Palmerton, Mroshozo, Ntsimbini and Mt Bleak will be inundated.

Loss of land: the dam will inundate 23 ha of arable allotments. Assuming that arable allotments are on average 1 hectare, then approximately 23 "farms" will be affected. If each family has 1 arable allotment then we may assume that 23 families will be affected by loss of arable land and the agricultural production associated therewith.

Loss of natural resources: No dependency on rivers and riparian resources

Lusikisiki Site

The proposed dam site is lying adjacent to the road joining the towns of Lusikisiki and Flagstaff. The total approximate area inundated by the dam is 1.4 km².

Relocation of people: No relocations of people will take place, although the area of inundation stretches closely around the Palmerton Mission School.

Loss of access: An access road linking Palmerton Mission School, the villages of Ntsimbini and Pamalitoli will be inundated.

Loss of land: The Lusikisiki dam site will inundate 22 ha of arable allotments. Assuming that arable allotments are on average 1 hectare, then approximately 22 "farms" will be affected. If each family has 1 arable allotment then we may assume that 22 families will be affected by loss of arable land and the agricultural production associated therewith.

Loss of natural resources: No dependency on rivers and riparian resources.

Xura Site

The proposed Xura dam site lies to the north of the Lusikisiki town. The total approximate area of inundation by the dam is 1.8 km².

Relocation of people: The Xura dam site will not affect residential settlements; therefore there won't be relocations.

Loss of access: The main road linking Lusikisiki town to the Qawukeni kraal of the Paramount Chief and areas lying towards Flagstaff and Holy Cross Mission will be inundated.

Loss of land: The Xura dam site will inundate approximately 50 ha of arable allotments. Assuming that arable allotments are on average 1 hectare, then approximately 50 "farms" will be affected. If each family has 1 arable allotment then we may assume that 50 families will be affected by the loss of arable land and the agricultural production associated therewith.

Loss of natural resources: No dependency on rivers and riparian resources.

Lower Mzintlava Site

The proposed Lower Mzintlava dam site is lying south of the Lusikisiki town. The total approximate inundated area by the dam is 1.6 km².

Relocation of people: The construction of the Lower Mzintlava dam will affect 120 households as the area of inundation stretches over the villages of Mbokothweni, Mzintlava, Jambeni and Matulini. It is estimated that 720 people will need to relocate.

Loss of land: The Mzintlava dam site will inundate 46 ha of arable allotments. Assuming that arable allotments are on average 1 hectare, then approximately 46 "farms" will be affected. If each family has 1 arable allotment then we may assume that 46 families will be affected by loss of arable land and the agricultural production associated therewith.

Loss of access: A secondary gravel road linking the Lusikisiki town to Port St Johns and is the route to Umtata will be inundated. The communities located around the dam basin will be isolated.

Loss of natural resources: It was found that there is no dependency on rivers for subsistence fishing, recreational use and there is not much use of riparian resources (plants).

Tungwane Site

The proposed Tungwane dam site is south of the town of Lusikisiki. The total approximate area of dam is 1.0 km².

Relocation of people: The construction of the dam will affect 6 households, and approximately 36 people will need to be relocated.

Loss of land: The Tungwane dam site will inundate 26 ha of arable allotments. Assuming that arable allotments are on average 1 hectare, then approximately 26 "farms" will be affected. If each family has 1 arable allotment then we may assume that 26 families will be affected by loss of arable land and the agricultural production associated therewith.

Loss of access: A secondary access road linking the village of Tungwane to the main road to Lusikisiki will be inundated.

Loss of natural resources: No dependency on rivers and riparian resources

4 Discussion of Negative and Positive Impacts

4.1 Negative Impacts

The loss of arable allotment can have adverse consequences for rural communities. Assuming that 1 ton of maize per hectare is produced in this part of the Transkei, the loss of I ha of arable land will result in a loss of income of about R3 000 per annum. It should however be noted that the agricultural potential of this area is high and under optimum farming conditions yields at between 4 and 6 tons of maize per hectare are not unrealistic. Such production levels would be equivalent to a loss of household income of between R12 000 to R18 000 per annum.

The inundation of major and minor access roads has a potential to distress people. Therefore, although, unavoidable, the inundation of infrastructure should be handled in a sensitive manner involving close consultation with affected people. While it is simpler to identify, quantify and make provision for vehicular access problems associated with dams, this is not always the case with pedestrian and stock access. All access problems associated with the dam sites will need to be investigated in depth and in consultation with local people during the further phases of the study. Specific attention should be given to inputs from transport operators and users during these investigations. Also, it should be noted that although roads can be realigned, the construction of new roads might lead to increase transport costs or even the loss of public transport services. These issues are usually dam specific and require investigation during later phases of the study.

Relocation of people is an extremely sensitive issue, which needs to be investigated in depth with the affected people. Comprehensive relocation strategies need to be formulated in close consultation with the affected people and surrounding communities, including those communities to which affected people may relocate. An overriding premise should be that all affected people are in a position that is better than prior to relocation. A carefully compiled relocation strategy with full public consultation is needed to ally fears as far as is possible.

The loss of grazing land is particularly important in the rural areas of the Transkei, where over stocking is already occurring. The loss of additional grazing land will place remaining grazing land under additional pressure.

4.2 Positive Impacts

The provision of bulk water for:

- Primary consumption
- Food plots

Public consultation on development spin-offs should be commenced during the feasibility phase. In this regard the proposed dams have tremendous potential to address local development needs.

There is potential for the development of conservation, recreational and tourist areas. Given assistance (for example, financial or via rural development programmes) it is feasible that local communities, previously excluded from enterprises of this nature, can participate in the development, management and ownership of eco-tourism ventures.

Other positive impacts include:

- Improved services: electricity, roads, telecommunications
- Short-term employment and contractual opportunities
- Long- term employment opportunities: operation and maintenance
- Skills transfer and training
- General economic boos due to major capital investment

5. Ranking of Options in Order of Preference

The ranking of the dam options is according to the level of hardship each dam site will bring to the local communities. It should be noted that the Transitional Representative Council (TRC) of Lusikisiki was consulted and afforded an opportunity to comment and rank options according to the order of preference. It is important to point out that they felt the need for water is a top priority in their district and as such they want the dams irrespective of the social costs associated with them. In their opinion the relocation of people is the most serious impact, which should be avoided if possible. They realise that the loss of arable and grazing land is unavoidable, but should be minimised. They don not consider the loss of access to be a very serious problem, because alternative routes can always be found.

The following is the ranking in order of preference by the TRC of Lusikisiki.

1. Xura
2. Zalu
3. Lusikisiki
4. Tungwane
5. Mzintlava

The following table lists the significance of the various impacts for all the dam sites considering all the major negative issues.

Impact significance is described in terms of:

Low - no influence on decision

Moderate - can influence decision

High - must influence decision

Table 1: Significance of negative social impacts due to dam developments

Dam site	Relocation of people	Loss of land	Loss of access	Loss of natural resources	Loss of historical and cultural sites
Zalu site Xura River	N/A	23 ha arable 5 ha grazing L	L	L	L
Lusikisiki site Xura River	N/A	22 ha arable 5 ha grazing L	L	L	L
Xura site Xura River	N/A	50 ha arable 20 ha grazing H	M	L	L
Lower Mzintlava Mzintlava River	720 p H	46 ha arable 15 ha grazing H	H	L	L
Tungwane Mzintlava River	36 p M	26 ha arable 16 ha grazing M	L	L	L

L – low, M – medium, H – high

Appendix F2

SOCIAL IMPACT ASSESSMENT: PRE-FEASIBILITY PHASE

During the pre-feasibility phase of the Eastern Pondoland Basin Study further social impact investigations have been undertaken. These included a summary and verification of the potential impacts determined during the reconnaissance phase. In addition to this a social impact study has been undertaken for the two dam sites investigated during the pre-feasibility phase of the project. Discussions were entered into with the Lusikisiki TRC with regards to the social impact of these proposed structures.

Potential Impacts of Proposed Zalu and Lusiksiki Dam Sites

The reconnaissance phase of the study involved the various supply options. These supply options had varying levels of assurance and included five dam sites, three weir sites and ground water and conjunctive use options. Two dam sites were selected for further analysis during the pre-feasibility phase of the project. These further investigations included geological drilling, basin surveys and further refinements on the design of the structure. No fatal flaws in terms of environmental or social issues were identified during the reconnaissance phase, and the positive and negative impacts identified during that phase have been reviewed in more detail for the proposed Zalu and Lusikisiki sites in the pre-feasibility phase.

The identification of impacts has been based on site inspections, data gathering and stakeholder interviews. The negative impacts at each of the dam sites include the loss of arable allotments and grazing lands. The total area of arable land to be inundated by each dam is less than 25 ha. The area of grazing land inundated by each dam is approximately 5 ha.

The permanent loss of arable land has serious consequences for the livelihood of the families that cultivated the land. The loss of arable land impacts negatively on the food self-efficiency of these families. The arable land that will be lost is at present utilised for the cultivation of subsistence crops, primarily maize. Although operating with the risk of flooding, the valley troughs are often used for cultivation because of the good quality of the alluvial soils, and the proximity of water. The loss of arable land should be viewed as a serious negative impact, which will require rural development initiatives in mitigation. The loss of grazing land is also important in rural areas where over-stocking is already occurring. The loss of further grazing land will place additional pressure on the remaining grazing land.

The positive development spin-offs for the people in the Lusikisiki district far outweigh the negative impacts that the construction of the dams will have. The selected dam will provide bulk treated water for primary consumption, at a high degree of assurance. In addition to the provision of water other positive impacts include:

- Improved related services (e.g. electricity);
- Short term employment and contractual opportunities;
- Long term operation and maintenance opportunities;
- Skills transfer and training.

It can be concluded that with appropriate mitigation measures negative impacts will be minimal in both dam sites. For both dam sites it can be stated that positive impacts outweigh negative impacts. The local communities, as stated by the stakeholders, are interested and enthusiastic about the positive impacts that the dams will bring to their area. The benefits of obtaining clean healthy water with the employment opportunities that will become available will fulfill the priorities of the area.

The order of preference of development sites was discussed with the Lusikisiki TRC. In their comments the TRC felt that because at both development sites people stand to loose more or less the same area of arable land the two dam sites are equally favourable. The only reason that may give the Zalu site preference over the Lusikisiki site from a social viewpoint is the fact that Zalu is further upstream while Lusikisiki is very close to the main road linking the Lusikisiki and Flagstaff towns.

Table 1 provides a summary of the negative social impacts associated with the Zalu and Lusikisiki dam sites.

Table 1: Summary of Negative Social Impacts for Zalu and Lusikisiki dam sites

Impact	Unit	Zalu	Lusikisiki
Relocation of households	no.	0	0
Relocation of roads and infrastructure	km/cost	0	0
Loss of arable (cultivated) land	ha.	23	22
Loss of grazing land	ha	5	5
Loss of access (estimated no. of people affected)	no.	0	0
Loss of natural resources	L/M/H	Low	Low
Loss of specific religious or cultural sites	L/M/H	Low	Low
Loss of historical / archaeological sites	L/M/H	Low	Low
Recreational importance of inundated portion of river	L/M/H	Low	Low
Graveyards and possible relocation	no.	0	0

Key: L/M/H - Low/Medium/High

Impacts, which must be considered in recommending a dam structure for development, are described briefly in a little more detail in the following paragraphs.

Relocation and Expropriation

In the Lusikisiki region where much of the land is communally owned, compensation for land occupied is a difficult. Many of the rural poor have a high dependence on the natural resources in their region. The loss of land or access to natural resources due to inundation may seriously impede several people's ability to provide security to their families. The severity of the social impact caused by the relocation or expropriation of families is a function of the number of families that are included in the relocation programme. When over 100 families are relocated the impact is termed serious.

As shown in **Table x** the number of people involved in relocation and loss of land render this impact as being low. These farmers will require compensation for the establishment of new land for subsistence agriculture. The increased ratio of people to land is not significant.

Access

Access to schools, churches, places of work, or other public meeting places is a potential social impact, especially due to the long distances that often need to be walked each day. The type of access may be for vehicles, pedestrians or stock.

There is a loss of a river crossing at the Zalu site, but an alternative crossing site may be utilized. No bus or taxi services will be interfered with since no tribal, farm or service roads will be inundated by the dam development. There will be increased traffic in the region during the construction phase.

The development of a dam will not result in an increase in medical and transport costs. There is however a risk of an increase in contagious diseases due to the influx of members of the construction team from other regions. Water-borne diseases will be more likely with the development of a dam, as will pollution, and these impacts will have to be managed and mitigated during construction.

Dependency on natural resources

The Lusikisiki TRC stated that there is no dependence of the local people on the natural environment in terms of fish, riparian plants, herbs or medicinal plants. The local people are not dependant on the proposed inundated area for firewood. The proposed dam developments will not create a major disruption of stock movement patterns or inundate dip, handling facilities or crush pens.

Archaeological and Historical Sites

Surveys of proposed dam sites must be undertaken to identify archaeological and historical sites. Recommendations on how to accommodate these sites must be addressed. The historical importance of some areas is often sufficient to exclude the proposed dam site from the development options.

There are no religious, culturally significant, historical or archaeological sites within the proposed inundated basin. No graveyards will be inundated by the development.

Domestic Water Supply

The proposed dams will supply domestic water to many rural villages surrounding Lusikisiki. The water will be supplied at RDP standards, and international drinking water standards. In addition to providing for the domestic requirements of the town and surrounding villages the dam has been sized for the supply of water for urban commerce and industry as well as rural institutions, schools and clinics. All of these factors will have a positive impact on the health and economic levels in the region. Improved water supply enables other activities such as tourism, educational and conservation developments.

In many rural regions where the irrigation potential is high, a dam can provide water at a higher level of assurance. The region surrounding Lusikisiki is not ideal for the development of the irrigation, and the proposed dams have therefore not been sized for the provision of water for agriculture. The structure has also not been sized for the provision of a livestock-watering system.

Employment

Due to high unemployment levels in parts of the study area, employment opportunities and skills training and transfer are key issues in the acceptability of the development of the Lusikisiki Basin. The employment opportunities range from short-term employment or contractual opportunities to long-term operation and maintenance opportunities. During the construction phase there will be an opportunity for skills training – both in the dam construction, and at a quarry. Additional employment opportunities through the importation of materials and equipment also exist.

Several local businesses, retail shops and informal trading stores will benefit during the construction phase of the project. The potential for the development of aquaculture in the region also exists. Where possible local labour and skills can be utilized in construction, and therefore limit the impact of migrant workers from other regions.

Recreation, Conservation and Resorts

There is an opportunity to enhance the value of the Lusikisiki Basin for recreation, conservation, resorts and eco-tourism. No portion of the river to be inundated has any existing recreational importance.

Improved Infrastructure and Services

The infrastructure making up the Lusikisiki RWS must be designed to provide the maximum post-construction benefit. A needs analysis for the communities in and around the dam sites will have to be undertaken to identify their priority needs in terms of supporting infrastructure. In addition to the provision of water and the associated services, additional infrastructure, such as better access roads, telephone services and electricity supply may result from the development. At the dam site additional infrastructure such as fencing, housing, food plots, toilets, refuse pits and standpipes will aid in the development of the area.

APPENDIX G :

WATER QUALITY TEST RESULTS

Raw water supplied to Lusikisiki Water Treatment Works from weir at Xura River

Samples collected at intake at Works
Source : DWAF tender with WSSA.

Name	Date	Sample type	pH	Conductivity	Turbidity	Alkalanity	Nitrate (as NO3)	Chloride (as Cl)	Sulphate (as S04)	Sodium (as Na)	Calcium (as Ca)	Magnesium (as Mg)	Potassium (as K)	Fluoride (as F)
				mS/m	NTU	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
LUSIKISIKI WTW	6-4-98	Raw water	6.93	23.6	15.0	83	0.1	19.3	14	20	16	18	1.1	0.5
LUSIKISIKI WTW	7-27-98	Raw water	7.13	28.0	10.3	93	0.3	25.0	6	17	18	17	0.9	0.1
LUSIKISIKI WTW	8-31-98	Raw water	8.12	26.3	44.6	78	0.1	26.8	17	24	12	15	1.1	0.2
LUSIKISIKI WTW	9-15-98	Raw water	7.31	31.6	13.6	99	0.1	24.8	5	23	15	22	0.9	0.2
LUSIKISIKI WTW	10-20-98	Raw water	7.35	31.7	16.7	99	0.1	25.2	4	23	11	17	0.9	0.2
LUSIKISIKI WTW	11-12-98	Raw water	7.87	32.1	8.4	104	0.1	23.9	29	22	19	16	0.5	0.1
LUSIKISIKI WTW	12-8-98	Raw water*	4.34	25.5	49.0	4	0.5	17.8	91	21	6	6	0.8	0.1
LUSIKISIKI WTW	1-14-99	Raw water	7.91	23.2	61.0	80	0.2	20.6	6	21	7	13	0.6	0.1
LUSIKISIKI WTW	2-10-99	Raw water	8.42	22.7	31.8	81	0.3	21.0	5	20	10	14	0.6	0.1
LUSIKISIKI WTW	4-28-99	Raw water	7.88	24.6	9.4	88	0.7	22.6	3	20	7	15	0.6	0.1
LUSIKISIKI WTW	5-24-99	Raw water	7.82	30.5	12.1	83	0.7	26.2	6	23	10	13	1.0	0.1
LUSIKISIKI WTW	6-9-99	Raw water	7.66	30.8	9.3	90	0.1	24.0	4	20	11	13	1.0	0.1
LUSIKISIKI WTW	7-12-99	Raw water	8.02	28.0	9.0	93	0.1	24.3	4	22	11	15	0.8	0.1
		Maximum	8.42	32.1	61.0	104	0.7	26.8	91	24	19	22	1.1	0.5
		Minimum	4.34	22.7	8.4	4	0.1	17.8	3	17	6	6	0.5	0.1
		Range	4.08	9.4	52.6	100	0.6	9.0	88	7	13	16	0.6	0.4
		Average		27.6	22.3	83	0.3	23.2	15	21	12	15	0.8	0.1
		Median	7.82	28.0	13.6	88	0.1	24.0	6	21	11	15	0.9	0.1

*Sampled after Alum Dosing

Median water quality values of raw water supplied to treatment works at each location (Period May 1998 to present)

	Holy Cross (Msikaba)	Lusikisiki (Xura)	Bambisana (Mntafufu)	Units
pH	7.17	7.82	6.74	
Conductivity	25.6	28.0	10.6	mS/m
Turbidity	197	14	2	NTU
Alkalinity	79	88	11	mg/l
Nitrate	0.6	0.1	0.7	mg/l
Ammonia	0.5		0.0	mg/l
Chloride	26	24	17	mg/l
Sulphate	40	6	4	mg/l
Sodium	24.4	21.0	10.2	mg/l
Calcium	11.9	11.0	4.3	mg/l
Magnesium	11.1	15.0	2.1	mg/l
Potassium	1.0	0.9	0.4	mg/l
Phosphate	0.02		0.01	mg/l
Fluoride	0.3	0.1	0.1	mg/l

Water Quality of selected effluent discharges in the Lusikisiki Basin

Location	Bambisana Hospital	St Elizabeths Hospital	Holy Cross Hospital	Lusikisiki TLC	Lusikisiki New Prison
Size (cubic metres per day)	75	120	100	280	160
Type	AS	OD	OD	ST	OD
Catchment	Mntafufu	Lusikisiki	Msikaba	Lusikisiki	Lusikisiki
pH	7	6.7	8.3	7.4	8.5
Conductivity (mS/m)	43	66		96	56
Total Suspended solids	40	65	40	36	15
Ammonia	9	20	3	31	2
Nitrate	3	1	1		
Chemical Oxygen Demand	102	160	84	105	72
Oxygen Absorbed	13	22	11	16	8
Number of samples	10	4	3	1	1

Note : All parameters are reported as mg/l unless otherwise stated.

Abbreviations

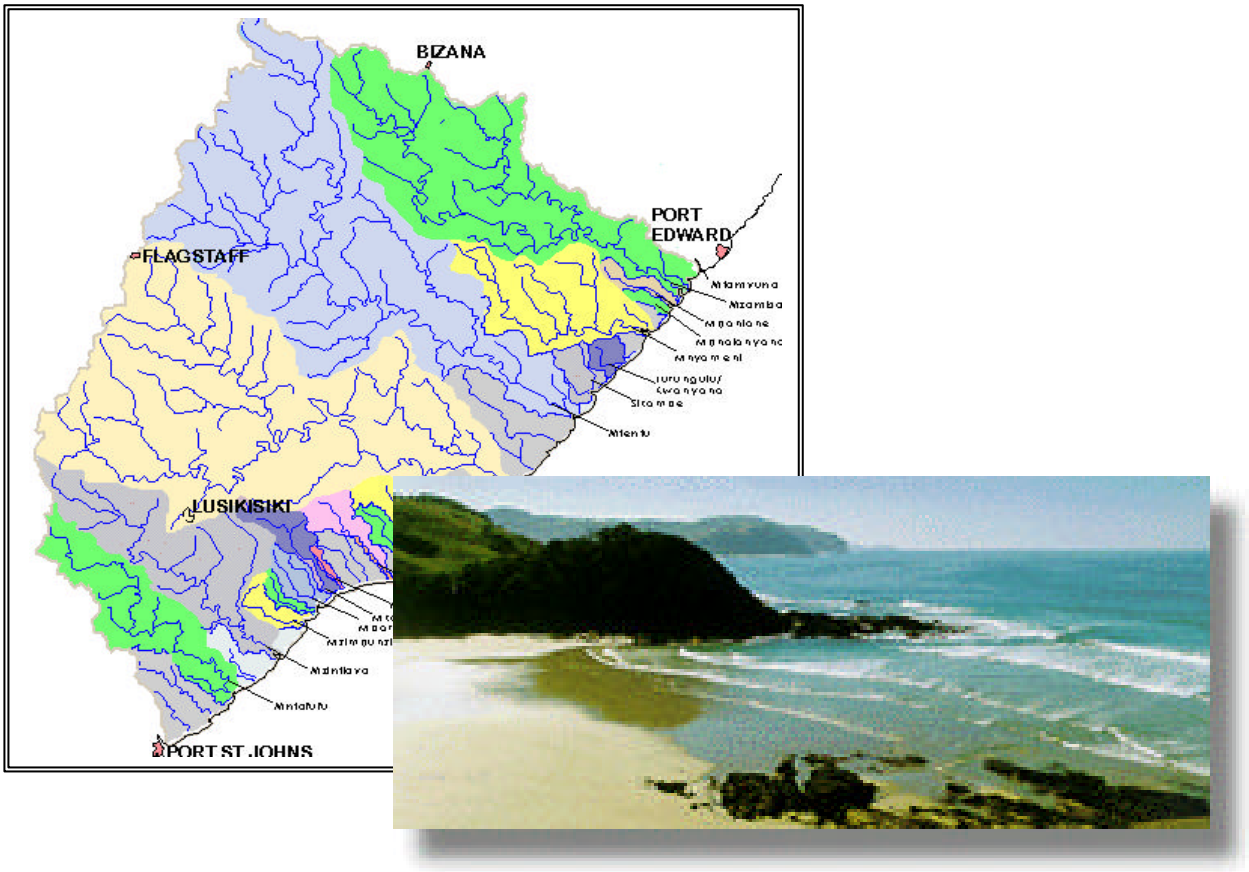
AS - Activated sludge Plant
OD - Oxidation pond system
ST - Septic tank systems

PB T600/00/0401

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



DEVELOPMENT OPTIONS

Volume 2 : Appendices

Final

June 2001

Prepared By:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Development Options, Volume 2: Appendices
AUTHOR	**:**	HV Doudenski
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-0401
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE: WATER RESOURCES PLANNING

EASTERN PONDOLAND BASIN STUDY

DEVELOPMENT OPTIONS

Volume 2 : Appendices

CONTENTS

APPENDICES INCLUDED IN VOLUME 1

Appendix A1 : Photographs and plates

Appendix A2 : Terms of reference

Appendix B : Population numbers and water requirements

Appendix C : Low flow analysis

Appendix D : Area – capacity relationships (reconnaissance phase)

Appendix E : Yield – capacity relationships (reconnaissance phase)

Appendix F : Social impact assessment (reconnaissance and pre-feasibility)

Appendix G : Water quality test results

APPENDICES INCLUDED IN THIS VOLUME (VOL 2)

Appendix H : Public participation programme

Appendix I : Sizing flow criteria

Appendix J : Costing and economic models reconnaissance phase

Appendix J1 : Summary capital costs

Appendix J2 : Cost models dams and weirs

Appendix J3 : Cost estimates: groundwater

Appendix J4 : Cost models: conveyance system

Appendix J5 : Economic models

Appendix K : Area – capacity relationships (pre-feasibility phase)

Appendix L : Sizing criteria dams and conveyance (pre-feasibility phase)

Appendix L1.1 : Zalu dam

Appendix L1.2 : Lusikisiki dam

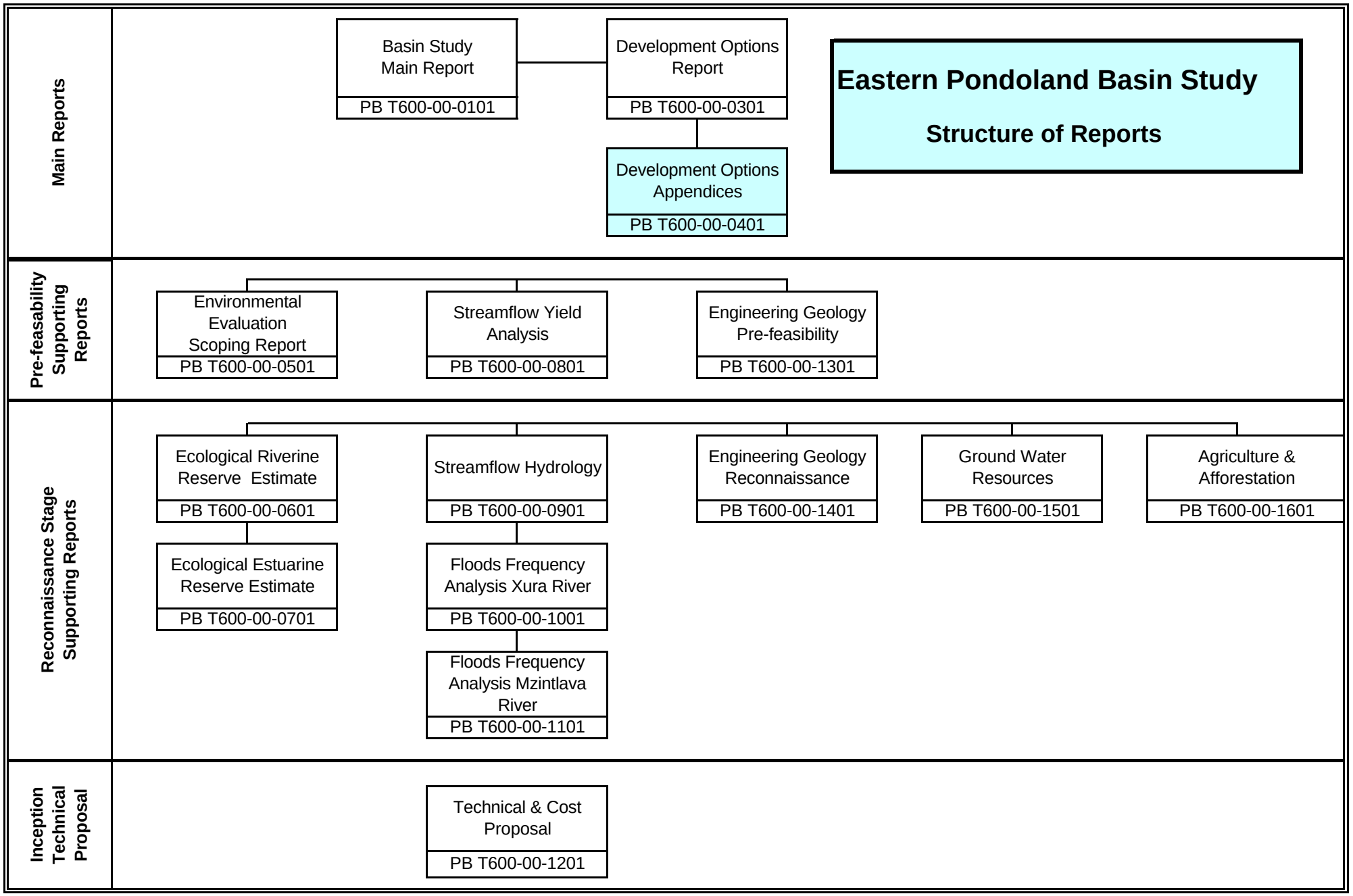
Appendix L2 : Conveyance system

Appendix M	:	Costing and economic models (pre-feasibility phase)
Appendix M1	:	Summary capital costs
Appendix M2	:	Cost models: dams
Appendix M3	:	Cost models: conveyance system

Appendix 2	:	Dam layouts and typical details (Reconnaissance phase)
Appendix 3	:	Conveyance systems sections (Reconnaissance phase)
Appendix 4	:	Conceptual design: Zalu dam (pre-feasibility phase)
Appendix 5	:	Conceptual design: Lusikisiki dam (pre-feasibility phase)
Appendix 6	:	Conceptual design pump stations and pipelines (pre-feasibility phase)
Appendix 7	:	Dam site cross sections (pre-feasibility phase)
Appendix 8	:	Dam basin surveys (pre-feasibility phase)

Eastern Pondoland Basin Study

Structure of Reports



APPENDIX H :

PUBLIC PARTICIPATION PROGRAMME

EASTERN PONDOLAND (LUSIKISIKI) BASIN STUDY

LIST OF INTERESTED AND AFFECTED PARTIES:

IMMEDIATE ROLE-PLAYERS: (other than DWAF)

NAME	ORGANISATION	TEL NO	FAX NO	CELL PHONE	POSTAL ADDRESS	PHYSICAL ADDRESS
1. Mr E Zellhuber	Wild Coast District Council	039 254-0320	039 254-0136	083 755-8077	Private Bag x511 Mount Ayliff 4735	Ntsizwa Street Mount Ayliff 4735
Mr A Naude	Stemele Bosch & Ass. (Water Services Dev. Plan Consultants)	039 743-4357	039 722-1731	083 283 6922	PO Box 11116 Southernwood 5213	3 Eton Street Southernwood 5201
Ms G Mgijima	Theart Mgijima & Associates (IDP Consultants)	043 743-7613	043 743-7627	082 823 5422	PO Box 18399 Quigney 5211	C/n no 17 Curry & Bonanza Streets On top of Kolaski Shop Quigney 5211
2. Mr Madlavuza	Lusikisiki PSC	039 252-0104	039 252-0155	083 765-3540	PO Box 271 Lusikisiki 4820	Tyeni Admistration Area Lusikisiki 4820
3. Mr Qhuba	Lusikisiki TRC	039 461-962	039 426-1126	-	Same as Physical address	TRC Office No 4, Lusikisiki 4820

IMMEDIATE ROLE-PLAYERS: (other than DWAF)

NAME	ORGANISATION	TEL NO	FAX NO	CELL PHONE	POSTAL ADDRESS	PHYSICAL ADDRESS
4. Ms E N Mazwi	Lusikisiki TLC	039 461-504	029 461-568	082 689 6492	P O Box 209 Lusikisiki	Erf 205 Mazolwuandle Drive Lusikisiki
5. Mr C Burger	Dept. Local Government and Housing					
6. Mr C Chimpelo	Goba Maohloli & Associates	031 266-9628	031 266-9808	082 894 9167	P O Box 439 Westville, Durban 3630	Suite 7 - 9 Prilefhe House 10 Church Rd, Westville, Durban 4001
7. Mr H Doudenski	UWP Engineers	011 709 8433	011 463 6176	083 441 3209	Private Bag x66 Bryanston 2021	Eton Office Park Harrison Avenue Bryanston 2021
8. Mr C Northwood	UWP Engineers	0431 430-186	0431 430-288	082 566 3646	PO Box 11170 Southernwood East London, 5213	22 Belgrave Rd, Belgravia East London 5201

OTHER INTERESTED PARTIES

NAME	ORGANISATION	TEL NO	FAX NO	CELL PHONE	POSTAL ADDRESS	PHYSICAL ADDRESS
1. Mrs N Mngoma	Wild Coast SDI	039 252-0091	039 252-0091	083 407 6281	PO Holy Cross Hospital Via Flagstaff 4811	Holy Cross Hospital Flagstaff No official street address
2. Mr Gwada	Correctional Services	039 461-241	039 461-527	-	Private Bag x1006 Lusikisiki 4820	5 km out of Lusikisiki Next to Ngugntufae Technical College No official street address
3. Dr Thomas	Dept. of Health	039 461-111	039 461-116	-	Private Bag x1007 Lusikisiki 4820	1 km out of Lusikisiki St Elizabeth Hospital No official street address
4. Mr Ndzoyiya	Dept. of Education (Rector of College)	039 46-1971	039 46-1979	082 254 9482 083 477 7243 (deputy)	Private Bag 1058 Lusikisiki 4820	Flagstaff Street Lusikisiki
5. Mr MV Lingesi	Dept. Economic Affairs, Environment & Tourism	037 727-3273	037 727-3257	082 659-8320	Private Bag x3513 Kokstad 4700	51 Hope Street Kokstad 4700
6. Mr Mpondombini	Traditional Leader ("King")	039 461-063	-	-	PO Box 2 Lusikisiki 4820	Qaukeni Great Place No official street address

OTHER INTERESTED PARTIES

NAME	ORGANISATION	TEL NO	FAX NO	CELL PHONE	POSTAL ADDRESS	PHYSICAL ADDRESS
7. Mr Ndlabi	Education	039 461-355	039 461-979			
8. Mr Kapps	Public Works	039 461-351	039 461-625			
9. Rev. Kiviet	Council of Churches	039 469-077				
10. Mr Lebenya	NGO's (Mvula Trust)	037 727-3349	037 727-3315	083 301-3266	PO Box 462 Kokstad 4700	C/n Main & Parker Streets First Floor Kokstad 4700
11. Mr W Selkirk	Pollution Control Technologies (Solid Waste Disposal Sites)	043 740-4735	043 740-2235	083 580-2766	PO Box 150 Gonubie 5256	13 Wilson Street Gonubie 5257

Departement van Waterwese en Bosbou
Hoofdirektoraat: Oos Kaap
Department of Water Affairs and Forestry
Chief Directorate: Eastern Cape

Private Bag X 5971
Umtata 5100

Faks · Fax (047) 531 4491
Internasionaal · International +27 47 531 4491

Faksboodskap / Fax Message

Navrae · Enquiries:(047) 531 4481

Faks · Fax no.:

Aan · To : **SEE DISTRIBUTION LIST**

Vir Aandag · For Attention:

Van · From : ***G S Mabunda***

Tel. no. : (047) 531 4481 Kamer · Room no.:

Cell : 083-631-5674

Getal bladsye, hierdie een ingesluit · Number of pages, including this one : ***5***

. .. .
Goedgekeur · Approved

.....
Datum · Date

NOTICE FOR A STAKEHOLDER COMMITTEE MEETING

EASTERN PONDOLAND (LUSIKIKISIKI) BASIN STUDY

EASTERN CAPE PROVINCE

DATE: 19 MAY 1999
TIME: 9:30 – 13:00
VENUE: LUSIKISIKI, UWP Engineers' offices, Roskruge Building, 399 Main St.

With reference to our previous notice, please find attached more detailed information about the meeting.

Purpose of meeting: Detailed information is attached
Convenor: DWAF: Directorates: Eastern Cape Region & Water Resources Planning
Costs: Please make own arrangements for travelling and time costs
Confirmation: Please complete and return the confirmation slip (attached to our previous fax) before 30 April 1999

DISTRIBUTION LIST

Attention	Institution	Fax Number
Mr T Balzer	DWAF: EC	043 642-1737
Mr D Coetzee / Mr N Lawry	DWAF: EC	043 642 1136
Mr Z H Keke / Mr T Geldenhuis	DWAF: EC	048 881 3545
Mr J A van Rooyen / Mr F Stoffberg	DWAF: WRP	012 338 8295
Mr G Mabunda	DWAF: EC	047 531 4491
Ms T Mbasa	DWAF: EC	043 642-1737
Mr G Mbambisa	DWAF: EC	047 532-6386
Ms J Evans	DWAF: ISD	012 323 3877
Mr C Northwood	UWP Engineers	0431 430-288
Mr J Gibson	UWP Engineers	#5013
Mr G Mpumza / Mr E Zellhuber	Wild Coast DC	039 254 0136
Mr R Barry	EC: Premier's office	040 635 1792
Mr M Lebenya	Mvula Trusts: Kokstat	037 727 3315
Mr C Burger	ECDHLG	040 636 4285
Mr A Naude	Stemele Bosch & Ass. (Water Services Dev. Plan Consultants)	039 722-1731
Ms G Mgijima	Theart Mgijima & Associates (IDP Consultants)	043 743-7627
Ms E N Mazwi	Lusikisiki TLC	039 461-568
Mr C Chimpelo	Goba Maohloli & Associates	031 266-9808
Dr Thomas	Department of Health	039 461-116
Mr Ndzoyiya	Dept. of Education (Rector of College)	039 46-1979
Mr Mpondombini	Traditional Leader	-
Mr Kapps	Public Works	039 461-625
Rev. Kiviet	Council of Churches	
Mr W Selkirk	Pollution Control Technologies (Solid Waste Disposal Sites)	043 740-2235
Mr Madlavuza **Could you please arrange delivery to the following people, whom we cannot reach**	Lusikisiki PSC	039 252-0155
Mr Gwada	Correctional Services	039 461-527
Mr MV Lingesi	Dept. Economic Affairs, Environment & Tourism	037 727-3257
Mr Ndlabi	Education	039 461-979
Mr Qhuba	Lusikisiki TRC	039 461 177/66
Mrs N Mngoma	Wild Coast SDI	039 252-0091
	Flagstaff TLC	
	Flagstaff TLC	
	Bizana TLC	
	Bizana TRC	

Mr

EASTERN PONDOLAND (LUSIKISIKI) BASIN STUDY

STAKEHOLDER MEETING 19 MAY 1999

AGENDA

10:00 – 10:10	Welcome and introduction of the project management team (Chairperson Mr D Coetzee)
10:10 – 10:20	Introduction of stakeholders and their fields of interest (Chairperson Mr D Coetzee)
10:20 – 11:00	Scope of services and methodology for the Eastern Pondoland Basin Study (UWP Engineers)
11:00 – 11:30	Co-ordination with other planning activities and initiatives currently underway (WCDC)
11:3 0 – 11:45	Break (cool drinks will be served)
11:45 – 12:15	Inputs and needs from interested and affected parties represented by the Stakeholders (plenary discussion)
12:15 – 12:30	Identification of sensitive issues related to the study area (plenary discussion)
12:30 – 12:45	Channels of further communication (Chairperson Mr D Coetzee)
12:45 – 13:00	Summary and general notes

EASTERN PONDOLAND (LUSIKISIKI) BASIN STUDY

INVITATION FOR A STAKEHOLDER MEETING

1. Background

As a result of the present shortage of water supply to, primarily, the Lusikisiki area, the Department of Water Affairs and Forestry have decided to commission a basin study (water resources planning study) for the Eastern Pondoland River catchments – the area between Mzamba and Mntafufu Rivers in the Pondoland Coast (a locality map is attached) and have appointed UWP Engineers to undertake the project.

The aim of the study is to set up a framework for the sustainable development and utilisation of the water resources in the study area. The project will provide a broad evaluation of the current state of the water resources as well as an assessment of the present and projected water requirements for all user sectors. This will include an assessment of the base conditions, hydrological and geohydrological studies, identification of potential agricultural and industrial developments, environmental and social studies and engineering evaluation of possible water resources development options. A number developments options for the augmentation of the bulk water supply to the Lusikisiki Regional Water Scheme will be identified and evaluated on the basis of technical viability, economic efficiency and environmental acceptability.

An important output of the study will be the selection of a specific water source (possibly a dam) and a conveyance system with sufficient yields, capable to meet the projected water demands in the Lusikisiki area.

For water resources studies such as this a Stakeholder Committee would normally be formed, comprising representatives of major Interested and Affected Parties (IAPs) – government departments, local authorities and various interest groups involved in the region. The Stakeholder Committee will serve as a forum to represent the IAPs, co-ordinate their inputs and express their needs through a transparent process.

Your organisation has been identified as one of the important stakeholders in the region and is therefore invited to designate a representative for the Stakeholder meeting scheduled to take place as follows:

Date and time: 19 May 1999 from 9:30 to 13:00
Venue: UWP Engineers offices, Roskruge Building, 399 Main Street, Lusikisiki

Please note that this is an organisational stakeholder forum - <u>not</u> a public involvement meeting and it is requested that participation be limited to <u>one</u> representative per organisation.

2. Purpose of this stakeholder meeting

Due to the multidisciplinary nature of the study, consultations with all stakeholders and co-ordination with other planning initiatives for the area (Wild Coast SDI, IDP, WSDP, etc.) is essential. The purpose of this meeting can be summarised as follows:

- To inform the stakeholders about the start of the study and to provide insight for the proposed scope of services, methodology and study programme to be applied
- To receive feedback from the stakeholders regarding possible inputs and specific needs
- To establish a co-ordination structure for all development planning initiatives taking place in the area
- To discuss the roles and responsibilities of the various stakeholders
- To identify possible sensitive issues within the region
- To establish channels for further communication during the course of the study

The goal of the meeting is to identify and mark the milestone issues, which will lead to finding technical solutions (during the course of the study) in harmony with the regional development objectives.

3. Proposed Agenda

9:30 – 10:00	Registration
10:00 – 10:10	Welcome and introduction of the project management team (Chairperson Mr D Coetzee)
10:10 – 10:20	Introduction of stakeholders and their fields of interest (Chairperson Mr D Coetzee)
10:20 – 11:00	Scope of services and methodology for the Eastern Pondoland Basin Study (UWP Engineers)
11:00 – 11:30	Co-ordination with other planning activities and initiatives currently underway (WCDC)
11:3 0 – 11:45	Break (cool drinks will be served)
11:45 – 12:15	Inputs and needs from interested and affected parties represented by the Stakeholders (plenary discussion)
12:15 – 12:30	Identification of sensitive issues related to the study area (plenary discussion)
12:30 – 12:45	Channels of further communication (Chairperson Mr D Coetzee)

12:45 – 13:00 Summary and general notes

FACSIMILE TRANSMISSION

To: Mr G Mabunda
Of: DWAF: EC: ISD
Fax No.: (047) 531 4491

Tel No.: (047) 531 4481

CONFIRMATION SLIP

FOR ATTENDING:

STAKEHOLDER COMMITTEE MEETING: EASTERN PONDOLAND BASIN STUDY

To be held on 19 May 1999 at Lusikisiki

Please return on or before 30 April 1999

From: _____ (name)

Organisation: _____

Position: _____

Fax No.: _____ Tel No.: _____

Date: _____

Postal address: _____

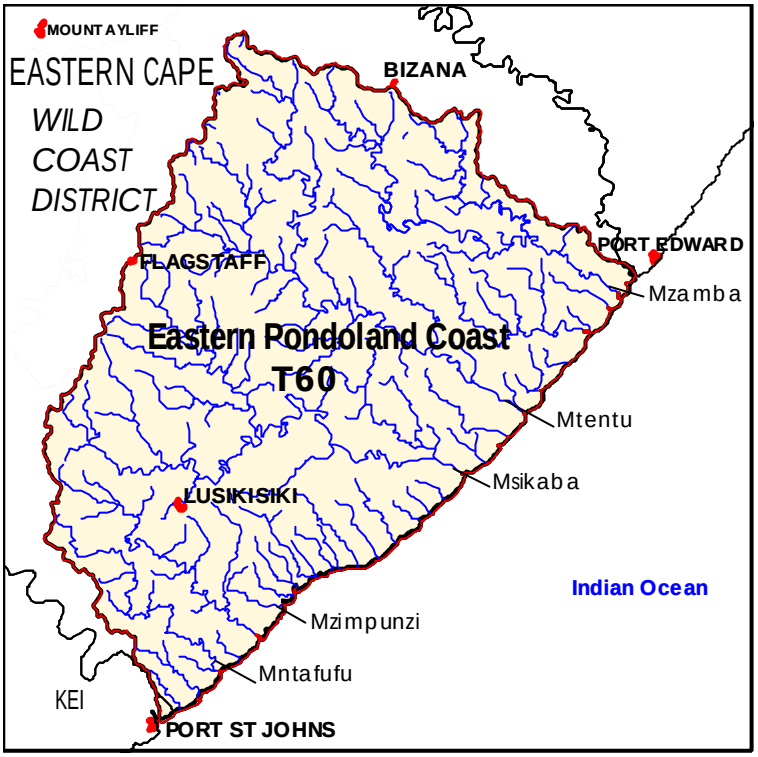
I confirm that the following member(s) of our organisation will attend the meeting:

No	Name	Designation/Office	Tel No.	Fax No.
1				
2				

EASTERN PONDOLAND BASIN STUDY – NEWSLETTER

The Department of Water Affairs and Forestry (DWAF), is currently undertaking a water resources planning study for the coastal region of the Eastern Cape Wild Coast District, also known as the Eastern Pondoland Coast. The study started in January 1999 and will be completed in July 2000. The study area includes parts of the Lusikisiki, Flagstaff and Bizana magisterial districts, between the Mntafutu and Mzamba Rivers as shown on the map below. No general water resource studies have been performed for the Eastern Pondoland coastal region in the past, and the surface water resources appear to be under-utilised. It is the aim of the study to bring the level of available information for this area to the same standard as for most of the other catchments in South Africa.

Demand for water in the study area has increased in recent years, especially for rural water supply. This has resulted in the need to determine how much, and with what reliability, water is available from the rivers and ground water resources in the study area. This water resources evaluation is necessary to ensure that the available water is apportioned and utilised in a sustainable manner. For proper allocation of resources it is necessary to determine the water requirements of all the different water use sectors in the region, such as domestic, industrial, forestry and livestock water usage, as well as those for the natural environment. The results of the study will be used by DWAF to make informed decisions about the development of water resources to meet the needs of the various users in the area.



This multidisciplinary reconnaissance study includes a number of components; such as agricultural, ground water, surface water hydrology, water quality, sedimentation, environmental, social and the investigation of various possible development options. An additional component of the study is to identify and select the best water source for the augmentation of the bulk water supply to the existing Lusikisiki Regional Water Supply Scheme. Groundwater would normally be the preferred option, but it does not appear to be adequate in this case. During June 1999 a site investigation was therefore undertaken to determine the suitability of several alternative dam sites in the Lusikisiki region. The planning of these options is still at an early stage. The reason for the investigation of a dam is to compare this option with other possible sources of supply, and to identify the most feasible source of supply for the Regional Scheme.

It is important that all parties interested in, or affected by, the study are kept informed and are given the opportunity to provide inputs to the process. For this reason a stakeholder meeting was held on 18 May 1999 in Lusikisiki and members of Wild Coast District Council, the various Transitional Rural Councils, the various Transitional Local Councils, various governmental departments and Non-Governmental Organisations were invited to inform them of progress and to discuss the way forward. The next stakeholder meeting will be held in April 2000.

Should there be any enquiries regarding the Eastern Pondoland Basin Study please contact the study leader Mr. Christo Doudenski of UWP Engineers, who were appointed by DWAF to undertake the study, at Tel. : 011-709-8422

APPENDIX I :

SIZING FLOWS PER NODE AND
TOTAL FOR SCHEME

Design/sizing equations & assumptions:-

Gross Average Annual Daily Demand (GAADD)	= AADD * (1+LFr):	Source development
Summer Daily Demand (SDDww)	= SPF * GAADD * (1+LFw):	Water treatment works & raw water pumps
Summer Daily Demand (SDDpl)	= SPF * GAADD:	Bulk pipelines
Summer Daily Demand (SDDpu)	= SPF * GAADD:	Borehole & clear water pumps
Design Peak Flow Rate (DPFR)	= GAAD*SPF*DPF	Village reticulation

LFr =	10%	Conveyance loss
LFw =	10%	Water treatment loss
SPF =	1.5	Summer Peak Factor
Operating period	20	Hours per day
DPF =	2	Daily Peak Factor
Storage	48	Hours * AADD : Pumped from Single Source
Storage	36	Hours * AADD : Pumped from Multiple Source
Min flow per standpipe	10	l per minute
Operating period boreholes	12	Hours per day
Provision for extenisons	1.3	Coefficient for reticulation

Appendix I: Sizing Flows Per Node and Total for Scheme
Design horizon: 2020

Administrative Area	Village Name	Population Number	Source	WTW	RWPS	CWPS	Bulk pipel.	Distr. Pipe.	BH pumps	BH pipes	Reservoirs		Reticulation
			GAADD	SDDww	SDDww	SDDpl	SDDpl	SDDpl	SDDpu	SDDpu	single s.	Multiple s.	DPFR
			l/s	l/s	l/s	l/s	l/s	l/s	l/s	l/s	kl	kl	l/s
Lusikisiki TLC	Lusikisiki: domestic	11350	27.93	55.31	55.31	50.28	50.28	41.90	83.80	83.80	2194	2194	108.95
	Lusikisiki: institutional & industrial	-	11.09	21.96	21.96	19.97	19.97	16.64	33.28	33.28	871	871	43.26
Dubana	Maklakane; Ngibe	206	0.08	0.15	0.15	0.14	0.14	0.12	0.23	0.23	6	6	0.30
	Mcobotini - A	1155	0.43	0.86	0.86	0.78	0.78	0.65	1.30	1.30	34	34	1.69
	Mahlakane	3392	1.27	2.52	2.52	2.29	2.29	1.91	3.81	3.81	100	100	4.96
	Dlibona; Ngqaqunggu; Ngqunggushe	3637	1.36	2.70	2.70	2.45	2.45	2.05	4.09	4.09	107	107	5.32
Xura	Dumasi	1794	0.67	1.33	1.33	1.21	1.21	1.01	2.02	2.02	53	53	2.62
	KuTshandatatshi; Tshandatatshi	885	0.33	0.66	0.66	0.60	0.60	0.50	1.00	1.00	26	26	1.29
Lower Xura	Mdikana	1324	0.50	0.98	0.98	0.89	0.89	0.74	1.49	1.49	39	39	1.93
Hombe	Tyeni-A; Tyeni	3310	1.24	2.46	2.46	2.23	2.23	1.86	3.72	3.72	97	97	4.84
	Nqaqhumbe	406	0.15	0.30	0.30	0.27	0.27	0.23	0.46	0.46	12	12	0.59
	Kunikwe; Nikwe	2667	1.00	1.98	1.98	1.80	1.80	1.50	3.00	3.00	79	79	3.90
Gobozana	Gunyeni	3471	1.30	2.58	2.58	2.34	2.34	1.95	3.90	3.90	102	102	5.07
	Ngobozana-B; Ngobozana-C	1128	0.42	0.84	0.84	0.76	0.76	0.63	1.27	1.27	33	33	1.65
	Gobozana - B	2278	0.85	1.69	1.69	1.54	1.54	1.28	2.56	2.56	67	67	3.33
	Mount Nelson	886	0.33	0.66	0.66	0.60	0.60	0.50	1.00	1.00	26	26	1.30
Nkunzimbini	KwaMgezwa; Mgezwa	1879	0.70	1.39	1.39	1.27	1.27	1.06	2.11	2.11	55	55	2.75
	Fahlambe	726	0.27	0.54	0.54	0.49	0.49	0.41	0.82	0.82	21	21	1.06
	Mdumbane; Mdubane	347	0.13	0.26	0.26	0.23	0.23	0.20	0.39	0.39	10	10	0.51
	Nkunzimbini-A; Nkunzimbini	1109	0.42	0.82	0.82	0.75	0.75	0.62	1.25	1.25	33	33	1.62
	Lukhahlambeni	2216	0.83	1.64	1.64	1.50	1.50	1.25	2.49	2.49	65	65	3.24
Mbudu	Mbudu-A&B	1158	0.43	0.86	0.86	0.78	0.78	0.65	1.30	1.30	34	34	1.69
Mzintlava	Luqhoqweni	2395	0.90	1.78	1.78	1.62	1.62	1.35	2.69	2.69	71	71	3.50
Mevane	KuMevane; Mevana	3219	1.21	2.39	2.39	2.17	2.17	1.81	3.62	3.62	95	95	4.71
Nyosana	Nyosana-A; Jambeni	1170	0.44	0.87	0.87	0.79	0.79	0.66	1.32	1.32	34	34	1.71
Malenge	Kunkunzimbini	1743	0.65	1.29	1.29	1.18	1.18	0.98	1.96	1.96	51	51	2.55
	Mpolweni - A	2057	0.77	1.53	1.53	1.39	1.39	1.16	2.31	2.31	61	61	3.01
Nkunzimbini	Nkunzimbini - B	193	0.07	0.14	0.14	0.13	0.13	0.11	0.22	0.22	6	6	0.28
Zalu	Pamalitoli	464	0.17	0.34	0.34	0.31	0.31	0.26	0.52	0.52	14	14	0.68
	Ndimbaneni	744	0.28	0.55	0.55	0.50	0.50	0.42	0.84	0.84	22	22	1.09
	Ntsimbini - E	605	0.23	0.45	0.45	0.41	0.41	0.34	0.68	0.68	18	18	0.88
	Mroshozo	694	0.26	0.51	0.51	0.47	0.47	0.39	0.78	0.78	20	20	1.01
Mateko	Mateko - B	299	0.11	0.22	0.22	0.20	0.20	0.17	0.34	0.34	9	9	0.44
	Kwabhumbula	1015	0.38	0.75	0.75	0.69	0.69	0.57	1.14	1.14	30	30	1.48
	Matheko	704	0.26	0.52	0.52	0.48	0.48	0.40	0.79	0.79	21	21	1.03
Msikaba	Msikaba - A	2958	1.11	2.20	2.20	2.00	2.00	1.66	3.33	3.33	87	87	4.32
	Msikaba - C	960	0.36	0.71	0.71	0.65	0.65	0.54	1.08	1.08	28	28	1.40
	Mawotsheni	743	0.28	0.55	0.55	0.50	0.50	0.42	0.84	0.84	22	22	1.09

Xura	Kwadick	1090	0.41	0.81	0.81	0.74	0.74	0.61	1.23	1.23	32	32	1.59
Lower Xura	Dumeni	1223	0.46	0.91	0.91	0.83	0.83	0.69	1.38	1.38	36	36	1.79
Malenge	Mpangina	411	0.15	0.31	0.31	0.28	0.28	0.23	0.46	0.46	12	12	0.60
Goso Forest	Kugwexintaba	1382	0.52	1.03	1.03	0.93	0.93	0.78	1.55	1.55	41	41	2.02
	Gos Forest	165	0.06	0.12	0.12	0.11	0.11	0.09	0.19	0.19	5	5	0.24
	Magwa	70	0.03	0.05	0.05	0.05	0.05	0.04	0.08	0.08	2	2	0.10
Nyosana	Jambeni	1289	0.48	0.96	0.96	0.87	0.87	0.73	1.45	1.45	38	38	1.89
	Nkanti	1396	0.52	1.04	1.04	0.94	0.94	0.78	1.57	1.57	41	41	2.04
	Nyosana - B	43	0.02	0.03	0.03	0.03	0.03	0.02	0.05	0.05	1	1	0.06
Mzintlava	Malungeni - A	960	0.36	0.71	0.71	0.65	0.65	0.54	1.08	1.08	28	28	1.40
	Matulini	960	0.36	0.71	0.71	0.65	0.65	0.54	1.08	1.08	28	28	1.40
	Mxelwenkunzi	872	0.33	0.65	0.65	0.59	0.59	0.49	0.98	0.98	26	26	1.28
Mtambalala	Mfabantu - E	2288	0.86	1.70	1.70	1.54	1.54	1.29	2.57	2.57	67	67	3.34
	Matane	3209	1.20	2.38	2.38	2.17	2.17	1.80	3.61	3.61	94	94	4.69
Bomvini	Sihlito	982	0.37	0.73	0.73	0.66	0.66	0.55	1.10	1.10	29	29	1.44
Upper Ntafufu	Mzintlavana	2485	0.93	1.84	1.84	1.68	1.68	1.40	2.79	2.79	73	73	3.63
	Mampondweni	2235	0.84	1.66	1.66	1.51	1.51	1.26	2.51	2.51	66	66	3.27
	Kwamdlankana	165	0.06	0.12	0.12	0.11	0.11	0.09	0.19	0.19	5	5	0.24
	Gcobane	920	0.34	0.68	0.68	0.62	0.62	0.52	1.03	1.03	27	27	1.34
	Ntsimbini - C	920	0.34	0.68	0.68	0.62	0.62	0.52	1.03	1.03	27	27	1.34
	Ntsimbini - B	1118	0.42	0.83	0.83	0.75	0.75	0.63	1.26	1.26	33	33	1.63
	Ngcenge	954	0.36	0.71	0.71	0.64	0.64	0.54	1.07	1.07	28	28	1.39
	Nzondeni	1525	0.57	1.13	1.13	1.03	1.03	0.86	1.72	1.72	45	45	2.23
Mtambalala	Buchele	3911	1.47	2.90	2.90	2.64	2.64	2.20	4.40	4.40	115	115	5.72
	Pitsini	3562	1.34	2.64	2.64	2.40	2.40	2.00	4.01	4.01	105	105	5.21
Lambasi	Ndengana	396	0.15	0.29	0.29	0.27	0.27	0.22	0.44	0.44	12	12	0.58
	Cuthwini	1844	0.69	1.37	1.37	1.24	1.24	1.04	2.07	2.07	54	54	2.70
	Dimfi	2051	0.77	1.52	1.52	1.38	1.38	1.15	2.31	2.31	60	60	3.00
	Ndindindi	1571	0.59	1.17	1.17	1.06	1.06	0.88	1.77	1.77	46	46	2.30
	Ntlamvukasi	1844	0.69	1.37	1.37	1.24	1.24	1.04	2.07	2.07	54	54	2.70
	Mazize	71	0.03	0.05	0.05	0.05	0.05	0.04	0.08	0.08	2	2	0.10
	Ntangeni	108	0.04	0.08	0.08	0.07	0.07	0.06	0.12	0.12	3	3	0.16
Quakeni	Qawukeni - B	363	0.14	0.27	0.27	0.24	0.24	0.20	0.41	0.41	11	11	0.53
	Qawukeni - C	99	0.04	0.07	0.07	0.07	0.07	0.06	0.11	0.11	3	3	0.14
Pumlo	Bhayi	1234	0.46	0.92	0.92	0.83	0.83	0.69	1.39	1.39	36	36	1.80
Lower Ntafufu	Taleni - A	2834	1.06	2.10	2.10	1.91	1.91	1.59	3.19	3.19	83	83	4.14
	Kwagingqi	627	0.23	0.47	0.47	0.42	0.42	0.35	0.70	0.70	18	18	0.92
	Ndongeni	1868	0.70	1.39	1.39	1.26	1.26	1.05	2.10	2.10	55	55	2.73
	Lusibeni	199	0.07	0.15	0.15	0.13	0.13	0.11	0.22	0.22	6	6	0.29
	Ntafufu	501	0.19	0.37	0.37	0.34	0.34	0.28	0.56	0.56	15	15	0.73
	Nkondusweni	1765	0.66	1.31	1.31	1.19	1.19	0.99	1.98	1.98	52	52	2.58
	Mbiza - A	2693	1.01	2.00	2.00	1.82	1.82	1.51	3.03	3.03	79	79	3.94
	Isapata	679	0.25	0.50	0.50	0.46	0.46	0.38	0.76	0.76	20	20	0.99
TOTAL FOR THE REGIONAL SCHEME		**120169**	**79.82**	**158.04**	**158.04**	**143.67**	**143.67**	**119.73**	**239.46**	**239.46**	**6269**	**6269**	**311.29**

APPENDIX J :

COSTING AND ECONOMIC MODELS
RECONNAISSANCE PHASE

APPENDIX J1 :

SUMMARY CAPITAL COSTS
RECONNAISSANCE PHASE

SUMMARY CAPITAL COSTS. 1999 PRICE LEVELS, R MILLION

LOW DEMAND - FULL SCHEME

All inclusive costs: include VAT, professional fees and disbursements

No.	DAM/OPTION	DAM/WEIR /BH	TOTAL CONVEYANCE	TOTAL Present cost
D1A	**Zalu full conveyance**	**R34.69**	**R21.53**	**R56.22**
D2	**Lusikisiki**	**R34.93**	**R15.98**	**R50.91**
D3	**Xura**	**R42.24**	**R23.57**	**R65.81**
D1B	**Zalu, from weir**	**R34.69**	**R14.56**	**R49.25**
W1	Weir scheme: Xura weir (21 l/s)	R2.55	R16.41	R18.96
	Existing weir-WTW	R0.00	R1.84	R1.84
	Mzintlava weir 19 l/s to res B	R2.13	R6.65	R8.78
W1	**Total weir scheme 80% assurance**	**R4.68**	**R24.89**	**R29.57**
W1G	Conjunctive use: Xura weir (21 l/s)	R2.55	R16.41	R18.96
	Existing weir-WTW	R0.00	R1.84	R1.84
	Mzintlava weir 19 l/s to res B	R2.13	R6.65	R8.78
	Boreholes 40 l/s	R10.56	R15.84	R26.40
W1G	**Total conjunctive use 90% assurance**	**R15.24**	**R40.73**	**R55.97**
W2G	Weir and BH	R0.00	R0.00	R0.00
	Existing weir-WTW	R0.00	R1.84	R1.84
	WTW to Res A	R0.00	R12.73	R12.73
	Boreholes 72 l/s	R19.01	R28.51	R47.52
W2G	**Total Weir and BH 98% assurance**	**R19.01**	**R43.07**	**R62.08**

LOW DEMAND - FULL SCHEME
INPUT DATA
Construction 2000, capital costs R million

Opt No	DAM/OPTION	DAM/WEIR /BH	RAW WATER PUMP STATION	RAW WATER RISING MAIN	WATER TREATMENT	CLEAR WATER PUMP STATION	CLEAR WATER RISING MAIN	STORAGE	CLEAR WATER GRAVITY MAINS	TOTAL
D1A	Zalu full conveyance	R26.68	R0.54	R5.79	R3.41	R0.85	R1.75	R2.07		R41.09
D2	Lusikisiki	R26.87	R0.80	R1.42	R3.41	R0.85	R1.75	R2.07		R37.16
D3	Xura	R32.49	R1.67	R6.03	R3.41	R0.85	R1.75	R2.07		R48.26
D1B	Zalu, from weir	R26.68	R0.79	R0.63	R3.41	R0.85	R1.75	R2.07		R36.17
W1	**Weir scheme**: Xura weir (21 l/s)	R1.96	R0.53	R2.30	R3.41	R0.85	R1.75	R2.07		R12.87
	Existing weir-WTW	R0.00	R0.79	R0.63						R1.41
	Mzintlava weir 19 l/s to res B	R0.00								R0.00
W1	**Total weir scheme 80% assurance**	**R1.96**	**R1.32**	**R2.93**	**R3.41**	**R0.85**	**R1.75**	**R2.07**	**R0.00**	**R14.28**
										R0.00
W1G	**Conjunctive use**: Xura weir (21 l/s)	R1.96	R0.53	R2.30	R3.41	R0.85	R1.75	R2.07		R12.87
	Existing weir-WTW	R0.00	R0.79	R0.63						R1.41
	Mzintlava weir 19 l/s to res B	R0.00								R0.00
	Boreholes 40 l/s	R8.12		R6.77		R2.71		R2.71		R20.31
W1G	**Total conjunctive use 90% assurance**	**R10.08**	**R1.32**	**R9.70**	**R3.41**	**R3.55**	**R1.75**	**R4.78**	**R0.00**	**R34.59**
										R0.00
W2G	**Weir and BH**									R0.00
	Existing weir-WTW	R0.00	R0.79	R0.63						R1.41
	WTW to Res A	R0.00			R3.41	R0.85	R1.75	R2.07		R8.08
	Boreholes 72 l/s	R14.62		R12.18		R4.87		R4.87		R36.55
W2G	**Total Weir and BH 98% assurance**	**R14.62**	**R0.79**	**R12.81**	**R3.41**	**R5.72**	**R1.75**	**R6.94**	**R0.00**	**R46.04**

All above costs exclude VAT (14%) and professional fees (16%). These are added into the summary tables

LOW DEMAND - FULL SCHEME
INPUT DATA
Construction 2010, capital costs R million

No.	DAM/OPTION	DAM/WEIR /BH	RAW WATER PUMP STATION	RAW WATER RISING MAIN	WATER TREATMENT	CLEAR WATER PUMP STATION	CLEAR WATER RISING MAIN	STORAGE	CLEAR WATER GRAVITY MAINS	TOTAL
D1A	**Zalu full conveyance**	R0.00	**R0.44**	**R0.00**	**R0.78**	**R0.34**	**R0.00**	**R0.59**		**R2.15**
D2	**Lusikisiki**	R0.00	**R0.29**	**R0.00**	**R0.78**	**R0.34**	**R0.00**	**R0.59**		**R2.00**
D3	**Xura**	R0.00	**R0.65**	**R0.00**	**R0.78**	**R0.34**	**R0.00**	**R0.59**		**R2.36**
D1B	**Zalu, from weir**	R0.00			**R0.78**	**R0.34**	**R0.00**	**R0.59**		**R1.71**
W1	Weir scheme: Xura weir (21 l/s)	R0.00			R0.78	R0.34	R0.00	R0.59		R1.71
	Existing weir-WTW	R0.00								R0.00
	Mzintlava weir 19 l/s to res B	R1.64	R0.42	R0.39	R1.50	R0.52	R1.23	R1.06		R6.75
W1	**Total weir scheme 80% assurance**	**R1.64**	**R0.42**	**R0.39**	**R2.28**	**R0.86**	**R1.23**	**R1.66**	**R0.00**	**R8.46**
W1G	Conjunctive use: Xura weir (21 l/s)	R0.00			R0.78	R0.34	R0.00	R0.59		R1.71
	Existing weir-WTW	R0.00								R0.00
	Mzintlava weir 19 l/s to res B	R1.64	R0.42	R0.39	R1.50	R0.52	R1.23	R1.06		R6.75
	Boreholes 40 l/s	R0.00								R0.00
W1G	**Total conjunctive use 90% assurance**	**R1.64**	**R0.42**	**R0.39**	**R2.28**	**R0.86**	**R1.23**	**R1.66**	**R0.00**	**R8.46**
W2G	Weir and BH									R0.00
	Existing weir-WTW	R0.00								R0.00
	WTW to Res A	R0.00			R0.78	R0.34	R0.00	R0.59		R1.71
	Boreholes 72 l/s	R0.00								R0.00
W2G	**Total Weir and BH 98% assurance**	**R0.00**	**R0.00**	**R0.00**	**R0.78**	**R0.34**	**R0.00**	**R0.59**	**R0.00**	**R1.71**

All above costs exclude VAT (14%) and professional fees (16%). These are added into the summary tables

LOW DEMAND - FULL SCHEME
Construction 2000, capital costs R million

No.	DAM/OPTION	DAM/WEIR /BH	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL
D1A	Zalu full conveyance	**R34.69**	**R1.81**	**R4.44**	**R2.69**	**R9.79**	**R53.42**
D2	Lusikisiki	**R34.93**	**R2.14**	**R4.44**	**R2.69**	**R4.12**	**R48.31**
D3	Xura	**R42.24**	**R3.27**	**R4.44**	**R2.69**	**R10.11**	**R62.74**
D1B	Zalu, from weir	**R34.69**	**R2.12**	**R4.44**	**R2.69**	**R3.09**	**R47.03**
W1	Weir scheme: Xura weir (21 l/s)	R2.55	R1.79	R4.44	R2.69	R5.27	R16.73
	Existing weir-WTW		R1.02	R0.00	R0.00	R0.81	R1.84
	Mzintlava weir 19 l/s to res B		R0.00	R0.00	R0.00	R0.00	R0.00
W1	**Total weir scheme 80% assurance**	**R2.55**	**R2.81**	**R4.44**	**R2.69**	**R6.08**	**R18.57**
W1G	Conjunctive use: Xura weir (21 l/s)	R2.55	R1.79	R4.44	R2.69	R5.27	R16.73
	Existing weir-WTW		R1.02	R0.00	R0.00	R0.81	R1.84
	Mzintlava weir 19 l/s to res B		R0.00	R0.00	R0.00	R0.00	R0.00
	Boreholes 40 l/s	R10.56	R3.52	R0.00	R3.52	R8.80	R26.40
W1G	**Total conjunctive use 90% assurance**	**R13.11**	**R6.33**	**R4.44**	**R6.21**	**R14.88**	**R44.97**
W2G	Weir and BH		R0.00	R0.00	R0.00	R0.00	R0.00
	Existing weir-WTW		R1.02	R0.00	R0.00	R0.81	R1.84
	WTW to Res A		R1.10	R4.44	R2.69	R2.27	R10.50
	Boreholes 72 l/s	R19.01	R6.34	R0.00	R6.34	R15.84	R47.52
W2G	**Total Weir and BH 98% assurance**	**R19.01**	**R8.46**	**R4.44**	**R9.02**	**R18.93**	**R59.86**

Construction 2000, annual O&M costs, R million

No.	DAM/OPTION	DAM	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPWELINES	TOTAL
	O&M Allowance Dams	0.68%	2.78%	1.73%	0.50%	1%	
	O&M Allowance Weirs	1.00%	5.56%	3.46%	0.50%	1%	
	O&M Allowance BH	3.00%	10.00%	7.00%	1.00%	2%	
D1A	**Zalu full conveyance**	**R0.23**	**R0.05**	**R0.08**	**R0.01**	**R0.10**	**R0.47**
D2	**Lusikisiki**	**R0.24**	**R0.06**	**R0.08**	**R0.01**	**R0.04**	**R0.43**
D3	**Xura**	**R0.29**	**R0.09**	**R0.08**	**R0.01**	**R0.10**	**R0.57**
D1B	**Zalu, from weir**	**R0.23**	**R0.06**	**R0.08**	**R0.01**	**R0.03**	**R0.41**
W1	Weir scheme: Xura weir (21 l/s)	R0.03	R0.10	R0.15	R0.01	R0.05	R0.34
	Existing weir-WTW	R0.00	R0.06	R0.00	R0.00	R0.01	R0.06
	Mzintlava weir 19 l/s to res B	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
W1	**Total weir scheme 80% assurance**	**R0.03**	**R0.16**	**R0.15**	**R0.01**	**R0.06**	**R0.41**
W1G	Conjunctive use: Xura weir (21 l/s)	R0.03	R0.10	R0.15	R0.01	R0.05	R0.34
	Existing weir-WTW	R0.00	R0.06	R0.00	R0.00	R0.01	R0.06
	Mzintlava weir 19 l/s to res B	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Boreholes 40 l/s	R0.32	R0.35	R0.00	R0.04	R0.18	R0.88
W1G	**Total conjunctive use 90% assurance**	**R0.34**	**R0.51**	**R0.15**	**R0.05**	**R0.24**	**R1.29**
W2G	Weir and BH	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Existing weir-WTW	R0.00	R0.06	R0.00	R0.00	R0.01	R0.06
	WTW to Res A	R0.00	R0.06	R0.15	R0.01	R0.02	R0.25
	Boreholes 72 l/s	R0.57	R0.63	R0.00	R0.06	R0.32	R1.58
W2G	**Total Weir and BH 98% assurance**	**R0.57**	**R0.75**	**R0.15**	**R0.08**	**R0.35**	**R1.90**

Residual values as at 2020, R million

No.	DAM/OPTION	DAM	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL
Residual values (@ 20 years): dams and weirs		54.00%	40.00%	47.00%	55.00%	33.00%	
Residual values BH		43.00%	25.00%	47.00%	55.00%	33.00%	
D1A	Zalu full conveyance	R18.73	R0.72	R2.09	R1.48	R3.23	**R26.25**
D2	Lusikisiki	R18.86	R0.86	R2.09	R1.48	R1.36	**R24.64**
D3	Xura	R22.81	R1.31	R2.09	R1.48	R3.34	**R31.02**
D1B	Zalu, from weir	R18.73	R0.85	R2.09	R1.48	R1.02	R24.17
W1	Weir scheme: Xura weir (21 l/s)	R1.38	R0.72	R2.09	R1.48	R1.74	R7.40
	Existing weir-WTW	R0.00	R0.41	R0.00	R0.00	R0.27	R0.68
	Mzintlava weir 19 l/s to res B	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
W1	**Total weir scheme 80% assurance**	**R1.38**	**R1.12**	**R2.09**	**R1.48**	**R2.01**	**R8.07**
W1G	Conjunctive use: Xura weir (21 l/s)	R1.38	R0.72	R2.09	R1.48	R1.74	R7.40
	Existing weir-WTW	R0.00	R0.41	R0.00	R0.00	R0.27	R0.68
	Mzintlava weir 19 l/s to res B	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Boreholes 40 l/s	R4.54	R0.88	R0.00	R1.94	R2.90	R10.26
W1G	**Total conjunctive use 90% assurance**	**R5.92**	**R2.00**	**R2.09**	**R3.41**	**R4.91**	**R18.33**
W2G	Weir and BH	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Existing weir-WTW	R0.00	R0.41	R0.00	R0.00	R0.27	R0.68
	WTW to Res A	R0.00	R0.44	R2.09	R1.48	R0.75	R4.76
	Boreholes 72 l/s	R8.17	R1.58	R0.00	R3.48	R5.23	R18.47
W2G	**Total Weir and BH 98% assurance**	**R8.17**	**R2.43**	**R2.09**	**R4.96**	**R6.25**	**R23.90**

LOW DEMAND - FULL SCHEME
Construction 2010, capital costs R million

No.	DAM/OPTION	DAM/WEIR /BH	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL
D1A	**Zalu full conveyance**		**R1.01**	**R1.02**	**R0.77**	**R0.00**	**R2.80**
D2	**Lusikisiki**		**R0.81**	**R1.02**	**R0.77**	**R0.00**	**R2.60**
D3	**Xura**		**R1.28**	**R1.02**	**R0.77**	**R0.00**	**R3.07**
D1B	**Zalu, from weir**		**R0.44**	**R1.02**	**R0.77**	**R0.00**	**R2.22**
W1	Weir scheme: Xura weir (21 l/s)		R0.44	R1.02	R0.77	R0.00	R2.22
	Existing weir-WTW		R0.00	R0.00	R0.00	R0.00	R0.00
	Mzintlava weir 19 l/s to res B	R2.13	R1.22	R1.95	R1.38	R2.10	R6.65
W1	**Total weir scheme 80% assurance**	**R2.13**	**R1.66**	**R2.96**	**R2.15**	**R2.10**	**R11.00**
W1G	Conjunctive use: Xura weir (21 l/s)		R0.44	R1.02	R0.77	R0.00	R2.22
	Existing weir-WTW		R0.00	R0.00	R0.00	R0.00	R0.00
	Mzintlava weir 19 l/s to res B	R2.13	R1.22	R1.95	R1.38	R2.10	R6.65
	Boreholes 40 l/s		R0.00	R0.00	R0.00	R0.00	R0.00
W1G	**Total conjunctive use 90% assurance**	**R2.13**	**R1.66**	**R2.96**	**R2.15**	**R2.10**	**R11.00**
W2G	Weir and BH		R0.00	R0.00	R0.00	R0.00	R0.00
	Existing weir-WTW		R0.00	R0.00	R0.00	R0.00	R0.00
	WTW to Res A		R0.44	R1.02	R0.77	R0.00	R2.22
	Boreholes 72 l/s		R0.00	R0.00	R0.00	R0.00	R0.00
W2G	**Total Weir and BH 98% assurance**		**R0.44**	**R1.02**	**R0.77**	**R0.00**	**R2.22**

Construction 2010, annual O&M costs, R million

No.	DAM/OPTION	DAM/WEIR /BH	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL
	O&M Allowance Dams	0.68%	2.78%	1.73%	0.50%	1%	
	O&M Allowance Weirs	1.35%	5.56%	3.46%	0.50%	1%	
	O&M Allowance BH	7.00%	7.00%	7.00%	1.00%	3%	
D1A	**Zalu full conveyance**	**R0.00**	**R0.03**	**R0.02**	**R0.00**	**R0.00**	**R0.05**
D2	**Lusikisiki**	**R0.00**	**R0.02**	**R0.02**	**R0.00**	**R0.00**	**R0.04**
D3	**Xura**	**R0.00**	**R0.04**	**R0.02**	**R0.00**	**R0.00**	**R0.06**
D1B	**Zalu, from weir**	**R0.00**	**R0.01**	**R0.02**	**R0.00**	**R0.00**	**R0.03**
W1	Weir scheme: Xura weir (21 l/s)	R0.00	R0.02	R0.04	R0.00	R0.00	R0.06
	Existing weir-WTW	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Mzintlava weir 19 l/s to res B	R0.03	R0.07	R0.07	R0.01	R0.02	R0.19
W1	**Total weir scheme 80% assurance**	**R0.03**	**R0.09**	**R0.10**	**R0.01**	**R0.02**	**R0.26**
W1G	Conjunctive use: Xura weir (21 l/s)	R0.00	R0.02	R0.04	R0.00	R0.00	R0.06
	Existing weir-WTW	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Mzintlava weir 19 l/s to res B	R0.03	R0.07	R0.07	R0.01	R0.02	R0.19
	Boreholes 40 l/s	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
W1G	**Total conjunctive use 90% assurance**	**R0.03**	**R0.09**	**R0.10**	**R0.01**	**R0.02**	**R0.26**
W2G	Weir and BH	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Existing weir-WTW	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	WTW to Res A	R0.00	R0.02	R0.04	R0.00	R0.00	R0.06
	Boreholes 72 l/s	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
W2G	**Total Weir and BH 98% assurance**	**R0.00**	**R0.02**	**R0.04**	**R0.00**	**R0.00**	**R0.06**

Residual values as at 2020, R million

No.	DAM/OPTION	DAM/WEIR /BH	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL
Residual values(10 years)		77.00%	70.00%	75.00%	78.00%	66.00%	
D1A	Zalu full conveyance	**R0.00**	**R0.71**	**R0.76**	**R0.60**	**R0.00**	**R2.07**
D2	Lusikisiki	**R0.00**	**R0.57**	**R0.76**	**R0.60**	**R0.00**	**R1.93**
D3	Xura	**R0.00**	**R0.90**	**R0.76**	**R0.60**	**R0.00**	**R2.26**
D1B	Zalu, from weir	**R0.00**	**R0.31**	**R0.76**	**R0.60**	**R0.00**	**R1.67**
W1	Weir scheme: Xura weir (21 l/s)	R0.00	R0.31	R0.76	R0.60	R0.00	R1.67
	Existing weir-WTW	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Mzintlava weir 19 l/s to res B	R1.64	R0.86	R1.46	R1.08	R1.38	R6.42
W1	**Total weir scheme 80% assurance**	**R1.64**	**R1.16**	**R2.22**	**R1.68**	**R1.38**	**R8.09**
W1G	Conjunctive use: Xura weir (21 l/s)	R0.00	R0.31	R0.76	R0.60	R0.00	R1.67
	Existing weir-WTW	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Mzintlava weir 19 l/s to res B	R1.64	R0.86	R1.46	R1.08	R1.38	R6.42
	Boreholes 40 l/s	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
W1G	**Total conjunctive use 90% assurance**	**R1.64**	**R1.16**	**R2.22**	**R1.68**	**R1.38**	**R8.09**
W2G	Weir and BH	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Existing weir-WTW	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	WTW to Res A	R0.00	R0.31	R0.76	R0.60	R0.00	R1.67
	Boreholes 72 l/s	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
W2G	**Total Weir and BH 98% assurance**	**R0.00**	**R0.31**	**R0.76**	**R0.60**	**R0.00**	**R1.67**

LOW DEMAND - FULL SCHEME
Total capital cost, R million

No.	DAM/OPTION	DAM/WEIR /BH	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL CONVEY	TOTAL
D1A	Zalu full conveyance	**R34.69**	**R2.82**	**R5.46**	**R3.46**	**R9.79**	**R21.53**	**R56.22**
D2	Lusikisiki	**R34.93**	**R2.95**	**R5.46**	**R3.46**	**R4.12**	**R15.98**	**R50.91**
D3	Xura	**R42.24**	**R4.55**	**R5.46**	**R3.46**	**R10.11**	**R23.57**	**R65.81**
D1B	Zalu, from weir	**R34.69**	**R2.56**	**R5.46**	**R3.46**	**R3.09**	**R14.56**	**R49.25**
W1	Weir scheme: Xura weir (21 l/s)	R2.55	R2.23	R5.46	R3.46	R5.27	R16.41	R18.96
	Existing weir-WTW	R0.00	R1.02	R0.00	R0.00	R0.81	R1.84	R1.84
	Mzintlava weir 19 l/s to res B	R2.13	R1.22	R1.95	R1.38	R2.10	R6.65	R8.78
W1	**Total weir scheme 80% assurance**	**R4.68**	**R4.47**	**R7.40**	**R4.84**	**R8.18**	**R24.89**	**R29.57**
W1G	Conjunctive use: Xura weir (21 l/s)	R2.55	R2.23	R5.46	R3.46	R5.27	R16.41	R18.96
	Existing weir-WTW	R0.00	R1.02	R0.00	R0.00	R0.81	R1.84	R1.84
	Mzintlava weir 19 l/s to res B	R2.13	R1.22	R1.95	R1.38	R2.10	R6.65	R8.78
	Boreholes 40 l/s	R10.56	R3.52	R0.00	R3.52	R8.80	R15.84	R26.40
W1G	**Total conjunctive use 90% assurance**	**R15.24**	**R7.99**	**R7.40**	**R8.36**	**R16.98**	**R40.73**	**R55.97**
W2G	Weir and BH	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Existing weir-WTW	R0.00	R1.02	R0.00	R0.00	R0.81	R1.84	R1.84
	WTW to Res A	R0.00	R1.54	R5.46	R3.46	R2.27	R12.73	R12.73
	Boreholes 72 l/s	R19.01	R6.34	R0.00	R6.34	R15.84	R28.51	R47.52
W2G	**Total Weir and BH 98% assurance**	**R19.01**	**R8.89**	**R5.46**	**R9.80**	**R18.93**	**R43.07**	**R62.08**

Total annual O&M costs, R million

No.	DAM/OPTION	DAM/WEIR /BH	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL CONVEY	TOTAL
D1A	**Zalu full conveyance**	**R0.23**	**R0.08**	**R0.09**	**R0.02**	**R0.10**	**R0.29**	**R0.52**
D2	**Lusikisiki**	**R0.24**	**R0.08**	**R0.09**	**R0.02**	**R0.04**	**R0.23**	**R0.47**
D3	**Xura**	**R0.29**	**R0.13**	**R0.09**	**R0.02**	**R0.10**	**R0.34**	**R0.62**
D1B	**Zalu, from weir**	**R0.23**	**R0.07**	**R0.09**	**R0.02**	**R0.03**	**R0.21**	**R0.45**
W1	Weir scheme: Xura weir (21 l/s)	R0.03	R0.12	R0.19	R0.02	R0.05	R0.38	R0.41
	Existing weir-WTW	R0.00	R0.06	R0.00	R0.00	R0.01	R0.06	R0.06
	Mzintlava weir 19 l/s to res B	R0.03	R0.07	R0.07	R0.01	R0.02	R0.16	R0.19
W1	**Total weir scheme 80% assurance**	**R0.05**	**R0.25**	**R0.26**	**R0.02**	**R0.08**	**R0.61**	**R0.66**
W1G	Conjunctive use: Xura weir (21 l/s)	R0.03	R0.12	R0.19	R0.02	R0.05	R0.38	R0.41
	Existing weir-WTW	R0.00	R0.06	R0.00	R0.00	R0.01	R0.06	R0.06
	Mzintlava weir 19 l/s to res B	R0.03	R0.07	R0.07	R0.01	R0.02	R0.16	R0.19
	Boreholes 40 l/s	R0.32	R0.35	R0.00	R0.04	R0.18	R0.56	R0.88
W1G	**Total conjunctive use 90% assurance**	**R0.37**	**R0.60**	**R0.26**	**R0.06**	**R0.26**	**R1.17**	**R1.54**
W2G	Weir and BH	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Existing weir-WTW	R0.00	R0.06	R0.00	R0.00	R0.01	R0.06	R0.06
	WTW to Res A	R0.00	R0.09	R0.19	R0.02	R0.02	R0.31	R0.31
	Boreholes 72 l/s	R0.57	R0.63	R0.00	R0.06	R0.32	R1.01	R1.58
W2G	**Total Weir and BH 98% assurance**	**R0.57**	**R0.78**	**R0.19**	**R0.08**	**R0.35**	**R1.39**	**R1.96**

Total residual values as at 2020, R million

No.	DAM/OPTION	DAM/WEIR /BH	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL CONVEY	TOTAL
D1A	**Zalu full conveyance**	**R18.73**	**R1.43**	**R2.85**	**R2.08**	**R3.23**	**R9.59**	**R28.32**
D2	**Lusikisiki**	**R18.86**	**R1.42**	**R2.85**	**R2.08**	**R1.36**	**R7.71**	**R26.57**
D3	**Xura**	**R22.81**	**R2.20**	**R2.85**	**R2.08**	**R3.34**	**R10.47**	**R33.28**
D1B	**Zalu, from weir**	**R18.73**	**R1.15**	**R2.85**	**R2.08**	**R1.02**	**R7.10**	**R25.83**
W1	Weir scheme: Xura weir (21 l/s)	R1.38	R1.02	R2.85	R2.08	R1.74	R7.69	R9.07
	Existing weir-WTW	R0.00	R0.41	R0.00	R0.00	R0.27	R0.68	R0.68
	Mzintlava weir 19 l/s to res B	R1.64	R0.86	R1.46	R1.08	R1.38	R4.78	R6.42
W1	**Total weir scheme 80% assurance**	**R3.02**	**R2.29**	**R4.31**	**R3.16**	**R3.39**	**R13.14**	**R16.16**
W1G	Conjunctive use: Xura weir (21 l/s)	R1.38	R1.02	R2.85	R2.08	R1.74	R7.69	R9.07
	Existing weir-WTW	R0.00	R0.41	R0.00	R0.00	R0.27	R0.68	R0.68
	Mzintlava weir 19 l/s to res B	R1.64	R0.86	R1.46	R1.08	R1.38	R4.78	R6.42
	Boreholes 40 l/s	R4.54	R0.88	R0.00	R1.94	R2.90	R5.72	R10.26
W1G	**Total conjunctive use 90% assurance**	**R7.56**	**R3.17**	**R4.31**	**R5.09**	**R6.29**	**R18.86**	**R26.42**
W2G	Weir and BH	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00
	Existing weir-WTW	R0.00	R0.41	R0.00	R0.00	R0.27	R0.68	R0.68
	WTW to Res A	R0.00	R0.75	R2.85	R2.08	R0.75	R6.43	R6.43
	Boreholes 72 l/s	R8.17	R1.58	R0.00	R3.48	R5.23	R10.30	R18.47
W2G	**Total Weir and BH 98% assurance**	**R8.17**	**R2.74**	**R2.85**	**R5.56**	**R6.25**	**R17.40**	**R25.57**

LOW DEMAND - FULL SCHEME

Annual Electricity charges and chemical costs

							W1: Weir scheme 80% assurance				W1/G: Conjunctive scheme 90% assurance					W2/G: Conjunctive scheme (98%)		
No	Component	Unit	Zalu D1A	Lusikisiki D2	Xura D3	Zalu dam D1B	Lusikisiki Weir	Xura Weir	Mzintlava Weir	Total Weirs 80%	Lusikisiki Weir	Xura Weir	Mzintl Weir	Ground water	Total Weirs 90%	Lusiki weir	Ground Water	Total Weir + BH
1	GAADD: min	l/s	35	35	35	35	16	10	9		16	10	9	9		35	35	
	: max	l/s	80	80	80	80	36	23	21		36	23	21	40		72	72	
2	Design SDD: min	l/s	64	64	64	64	28	19	17		28	19	17	17		64	64	
	max	l/s	144	144	144	144	64	42	38		64	42	38	68		130	130	
3	Static head	m	51	110	202	110	110	92	226		110	92	226	250		110	250	
4	Local losses	m	10	10	10	10	10	10	10		10	10	10	0		10	0	
5	Friction losses: min	m	7	6	14	6	4	12	38		4	12	38	60		6	60	
	max	m	55	27	63	27	20	51	168		20	51	168	60		27	60	
6	Total head: min	m	68	126	226	126	124	114	274		124	114	274	310		126	310	
	max	m	116	147	275	147	140	153	404		140	153	404	310		147	310	
7	Energy: min	kW	27	50	90	50	23	13	28		23	13	28	39		50	152	
	max	kW	106	134	251	134	57	40	97		57	40	97	174		121	313	
8	Installed capacity: min	kW	50	92	165	92	40	25	53		40	25	53	74		92	278	
	max	kW	191	241	452	241	102	73	175		102	73	175	295		218	565	
9	kVA Rating: min	kVA	125	174	321	174	74	51	119		74	51	119			161		
	max	kVA	198	252	471	252	106	76	182		106	76	182			227		
10	Energy unit cost	R/kwh	0.0693	0.0693	0.0693	0.0693	0.0693	0.0693	0.0693		0.0693	0.0693	0.0693	0.8807		0.0693	0.8807	
11	Demand unit cost	R/kwa/m	38.34	38.34	38.34	38.34	38.34	38.34	38.34		38.34	38.34	38.34			38.34		
12	Energy charge: min	R mil	0.030	0.056	0.100	0.056	0.024	0.015	0.032	0.071	0.024	0.015	0.032	0.114	0.185	0.056	0.644	0.699
	: max	R mil	0.116	0.147	0.274	0.147	0.062	0.044	0.106	0.213	0.062	0.044	0.106	0.456	0.669	0.132	1.307	1.439
13	Demand charge: min	R mil	0.058	0.080	0.148	0.080	0.034	0.023	0.055	0.112	0.034	0.023	0.055	-	0.112	0.074	-	
	max	R mil	0.091	0.116	0.216	0.116	0.049	0.035	0.084	0.168	0.049	0.035	0.084	-	0.168	0.104	-	
14	Chemicals unit cost	R/kl	0.06	0.06	0.06	0.06	0.06	0.06	0.06		0.06	0.06	0.06	-		0.06	-	
15	Total chem. cost: min	R mil	0.066	0.066	0.066	0.066	0.030	0.019	0.017	0.066	0.030	0.019	0.017	-	0.066	0.046	-	
	max	R mil	0.151	0.151	0.151	0.151	0.068	0.044	0.040	0.151	0.068	0.044	0.040	-	0.151	0.095	-	
16	Total electr & chemicals																	
	Min	R mil	0.154	0.202	0.314	0.202	0.088	0.057	0.104	0.250	0.088	0.057	0.104	0.114	0.364	0.176	0.644	0.820
	Max	R mil	0.358	0.414	0.642	0.414	0.179	0.123	0.230	0.532	0.179	0.123	0.230	0.456	0.988	0.332	1.307	1.639

Option G1: Groundwatrer stand alone scheme
INPUT DATA
Construction 2000, capital costs R million

No.	DAM/OPTION	SOURCE DEVELOPM.	RAW WATER PUMP STATION	RAW WATER RISING MAIN	WATER TREATMENT	CLEAR WATER PUMP STATION	CLEAR WATER RISING MAIN	STORAGE	CLEAR WATER GRAVITY MAINS	TOTAL
G1	**Groundwater stand alone scheme**									R0.00
	Boreholes 72 l/s	R14.62		R12.18		R4.87		R4.87		R36.55
G1	**Total G1**	**R14.62**	**R0.00**	**R12.18**	**R0.00**	**R4.87**	**R0.00**	**R4.87**	**R0.00**	**R36.55**

All above costs exclude VAT (14%) and professional fees (16%). These are added into the summary tables

OPTION G1: GROUNDWATER STAND ALONE SCHEME
Total capital cost, R million

No.	DAM/OPTION	SOURCE DEVELOPM.	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL CONVEY	TOTAL
G1	Groundwater stand alone scheme							
	Boreholes 72 l/s	R19.01	R6.34	R0.00	R6.34	R15.84	R28.51	R47.52
G1	**Total G1**	**R19.01**	**R6.34**	**R0.00**	**R6.34**	**R15.84**	**R28.51**	**R47.52**

Total annual O&M costs, R million

No.	DAM/OPTION	SOURCE DEVELOPM.	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL CONVEY	TOTAL
G1	Groundwater stand alone scheme	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00	**R0.00**
	Boreholes 72 l/s	R0.57	R0.63	R0.00	R0.06	R0.32	R1.01	**R1.58**
G1	**Total G1**	**R0.57**	**R0.63**	**R0.00**	**R0.06**	**R0.32**	**R1.01**	**R1.58**

Total residual values as at 2020, R million

No.	DAM/OPTION	SOURCE DEVELOPM.	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL CONVEY	TOTAL
G1	Groundwater stand alone scheme	R0.00	R0.00	R0.00	R0.00	R0.00	R0.00	**R0.00**
	Boreholes 72 l/s	R8.17	R1.58	R0.00	R3.48	R5.23	R10.30	**R18.47**
G1	**Total G1**	**R8.17**	**R1.58**	**R0.00**	**R3.48**	**R5.23**	**R10.30**	**R18.47**

LOW DEMAND - FULL SCHEME

Annual Electricity charges and chemical costs

			G1:Ground water scheme		
No	**Component**	**Unit**	**Lusiki weir**	**Ground Water**	**Total Weir + BH**
1	GAADD: min	l/s		35	
	: max	l/s		80	
2	Design SDD: min	l/s		64	
	max	l/s		144	
3	Static head	m		250	
4	Local losses	m		0	
5	Friction losses: min	m		60	
	max	m		60	
6	Total head: min	m		310	
	max	m		310	
7	Energy: min	kW		152	
	max	kW		348	
8	Installed capacity: min	kW		278	
	max	kW		626	
9	kVA Rating: min	kVA			
	max	kVA			
10	Energy unit cost	R/kwh		0.95	
11	Demand unit cost	R/kwa/m			
12	Energy charge: min	R mil		2.314	2.314
	: max	R mil		5.206	5.206
13	Demand charge: min	R mil		-	
	max	R mil		-	
14	Chemicals unit cost	R/kl		-	
15	Total chem. cost: min	R mil		-	
	max	R mil		-	
16	Total electr & chemicals				
	Min	R mil		2.314	2.314
	Max	R mil		5.206	5.206

APPENDIX J2 :

COST MODELS: DAMS AND WEIRS
RECONNAISSANCE PHASE

ZALU MASS CONCRETE DAM COST TABLE AADD 2.285

Reconnaissance

March 1999 price levels

No.	Pay ref.	Description	Unit	Rate	Quantity	Amount
1.	1.0	*Site and basin clearing*				
	1.1	(a) sparse	ha	2 125	0.6	R1 275
	1.2	(b) bush	ha	6 374	0.15	R956
	1.3	(c) trees	ha	10 623	0.15	R1 593
2.	2.0	*River diversion*	Sum		50 000	R50 000
3.	3.0	*Excavation*				
	3.4	(a) all materials	m^3	15	17 448	R264 778
	3.5	(b) extra over for rock	m^3	27	5 234	R142 980
	3.10	(c) Final foundation preparation	m^2	27	2 949	R80 558
4.	5.0	*Drilling & Grouting*				
		(a) curtain grouting	m drill	170	2 024	R343 967
		(b) consolidation grouting	m drill	170	0	R0
5.	6.0	*Formwork*				
	6.1	(a) Gang formed	m^2	76	5 905	R448 082
	6.2	(b) Intricate	m^2	121	656	R79 659
6.	7.0	*Concrete*				
	7.9	(a) mass	m^3	276	39 085	R10 795 283
	7.1	(b) structural	m^3	355	4 374	R1 553 350
7.	8.0	*Reinforcing*	t	3 794	206	R781 654
8.	10.0	*Mechanical items*				
	10.1	(a) Valves & gates	Sum	9%	Civil	R1 308 972
	10.2	(b) Cranes & hoists				
	10.3	(c) Structural steelwork				
9.	9.1.5	*Fencing*	km	10 623	1	R10 623
		SUB TOTAL				**R15 863 730**
10.	11.0	*Landscaping (% of 1 to 9)*	%	5		R793 187
11.	12.0	*Miscellaneous (% of 1 to 9)*	%	10		R1 586 373
		SUB TOTAL A				**R18 243 290**
12.	13.0	*Preliminary & General*	%	30		R5 472 987
		(% of sub total A)				
13.	14.0	*Preliminary works*				
	14.1	(a) Access road	km	90 000	3	R270 000
	14.2	(b) Electricity to site	Sum	50 000	1	R50 000
	14.3	(c) Water to site - Construction	Sum			R20 000
		(included in miscellaneous)				
	14.4	(d) Railhead & materials handling	Sum		miscellan.	R0

		(included in miscellaneous)				
14.	15.0	*Accommodation*	Sum		miscellan.	R0
		(included in miscellaneous)				
		SUB TOTAL B				**R24 056 276**
15.	17.0	*Contingencies (% of sub total B)*	%	10		R2 405 628
		SUB TOTAL C				**R26 461 904**
16	16.0	*Planning, design & supervision,*	%	15		R3 969 286
		fees, time, cost & transport				
		(% of sub total C)				
		SUB TOTAL D				**R30 431 190**
17.	18.0	*VAT (% of sub total D)*	%	14		R4 260 367
		NETT PROJECT COST				**R34 691 556**
18.	19.0	*Cost of relocations*	Sum			R0
19.	20.0	*Cost of land acquisition*	Sum			R0
		TOTAL PROJECT COST				**R34 691 556**

LUSIKISIKI MASS CONCRETE DAM COST TABLE AADD 2.285

Reconnaissance

March 1999 price levels

No.	Pay ref.	Description	Unit	Rate	Quantity	Amount
1.	1.0	*Site and basin clearing*				
	1.1	(a) sparse	ha	2 125	1.0	R2 125
	1.2	(b) bush	ha	6 374	0.30	R1 912
	1.3	(c) trees	ha	10 623	0.30	R3 187
2.	2.0	*River diversion*	Sum		50 000	R50 000
3.	3.0	*Excavation*				
	3.4	(a) all materials	m^3	15	27 660	R419 763
	3.5	(b) extra over for rock	m^3	27	8 298	R226 672
	3.10	(c) Final foundation preparation	m^2	27	2 907	R79 408
4.	5.0	*Drilling & Grouting*				
		(a) curtain grouting	m drill	170	1 802	R306 324
		(b) consolidation grouting	m drill	170	0	R0
5.	6.0	*Formwork*				
	6.1	(a) Gang formed	m^2	76	6 190	R469 667
	6.2	(b) Intricate	m^2	121	688	R83 496
6.	7.0	*Concrete*				
	7.9	(a) mass	m^3	276	38 300	R10 578 328
	7.1	(b) structural	m^3	355	4 585	R1 628 181
7.	8.0	*Reinforcing*	t	3 794	216	R819 309
8.	10.0	*Mechanical items*				
	10.1	(a) Valves & gates	Sum	9%	Civil	R1 320 153
	10.2	(b) Cranes & hoists				
	10.3	(c) Structural steelwork				
9.	9.1.5	*Fencing*	km	10 623	1	R10 623
		SUB TOTAL				**R15 999 148**
10.	11.0	*Landscaping (% of 1 to 9)*	%	5		R799 957
11.	12.0	*Miscellaneous (% of 1 to 9)*	%	10		R1 599 915
		SUB TOTAL A				**R18 399 020**
12.	13.0	*Preliminary & General*	%	30		R5 519 706
		(% of sub total A)				
13.	14.0	*Preliminary works*				
	14.1	(a) Access road	km	90 000	2	R180 000
	14.2	(b) Electricity to site	km	50 000	2	R100 000

	14.3	(c) Water to site - Construction	Sum			R20 000
		(included in miscellaneous)				
	14.4	(d) Railhead & materials handling	Sum		miscellan.	R0
		(included in miscellaneous)				
14.	15.0	*Accommodation*	Sum		miscellan.	R0
		(included in miscellaneous)				
		SUB TOTAL B				**R24 218 727**
15.	17.0	*Contingencies (% of sub total B)*	%	10		R2 421 873
		SUB TOTAL C				**R26 640 599**
16	16.0	*Planning, design & supervision,*	%	15		R3 996 090
		fees, time, cost & transport				
		(% of sub total C)				
		SUB TOTAL D				**R30 636 689**
17.	18.0	*VAT (% of sub total D)*	%	14		R4 289 136
		NETT PROJECT COST				**R34 925 826**
18.	19.0	*Cost of relocations*	Sum			R0
19.	20.0	*Cost of land acquisition*	Sum			R0
		TOTAL PROJECT COST				**R34 925 826**

XURA DAM COST MODEL AADD 2.285

Reconnaissance

March 1999 price levels

No.	Pay ref.	Description	Unit	Rate	Quantity	Amount
1.	1.0	*Site and basin clearing*				
	1.1	(a) sparse	ha	2 125	2.0	R4 249
	1.2	(b) bush	ha	6 374	1.00	R6 374
	1.3	(c) trees	ha	10 623	0.50	R5 311
2.	2.0	*River diversion*	Sum		50 000	R50 000
3.	3.0	*Excavation*				
		(a) Bulk				
	3.4	(i) all materials	m^3	15	22 520	R341 756
	3.5	(ii) extra over for rock	m^3	27	6 756	R184 548
		(b) Confined				
	3.4	(i) all materials	m^3	23	2 200	R50 080
	3.5	(ii) extra over for rock	m^3	38	660	R25 040
4.	3.10	*Preparation of solum*				
	3.4	(i) all materials	m^2	8	15 013	R113 919
	3.5	(ii) extra over for rock	m^2	8	4 504	R34 176
5.	5.0	*Drilling & Grouting*				
		(a) blanket grouting	m drill	170	0	R0
		(b) curtain grouting	m drill	170	1 295	R220 108
6.		*Embankment*				
		(a) Earthfill	m^3	18	70 820	R1 289 689
		(b) Filters	m^3	67	13 160	R878 732
		(c) Rip-rap	m^3	36	3 250	R118 356
		(d) Overhaul beyond 5km	m^3km	1.5	60 000	R91 054
7.		*Concrete Works*				
	6.0	(a) Formwork				
	6.1	(i) Gang formed	m^2	76	1 400	R106 400
	6.2	(ii) Intricate	m^2	121	200	R24 281
	7.0	(b) Concrete				
	7.9	(i) mass	m^3	276	28 411	R7 841 340
	7.1	(ii) structural	m^3	355	8 200	R2 911 000
	8.0	(c) Reinforcing	t	3 794	837	R3 174 787
8.	10.0	*Mechanical items*				
	10.1	(a) Valves & gates	Sum	8%	Civil	R1 346 310
	10.2	(b) Cranes & hoists				
	10.3	(c) Structural steelwork				
9.	9.1.5	*Fencing*	km	10 623	2	R21 246
		SUB TOTAL				**R18 838 755**
10.	11.0	*Landscaping (% of 1 to 9)*	%	5		R941 938
11.	12.0	*Miscellaneous (% of 1 to 9)*	%	10		R1 883 876
		SUB TOTAL A				**R21 664 568**

12.	13.0	*Preliminary & General*	%	30		R6 499 370
		(% of sub total A)				
13.	14.0	*Preliminary works*				
	14.1	(a) Access road	km	90 000	9	R810 000
	14.2	(b) Electricity to site	km	50 000	6	R300 000
	14.3	(c) Water to site - Construction	Sum			R20 000
		(included in miscellaneous)				
	14.4	(d) Railhead & materials handling	Sum		miscellan.	R0
		(included in miscellaneous)				
14.	15.0	*Accommodation*	Sum		miscellan.	R0
		(included in miscellaneous)				
		SUB TOTAL B				**R29 293 939**
15.	17.0	*Contingencies (% of sub total B)*	%	10		R2 929 394
		SUB TOTAL C				**R32 223 333**
16	16.0	*Planning, design & supervision,*	%	15		R4 833 500
		fees, time, cost & transport				
		(% of sub total C)				
		SUB TOTAL D				**R37 056 833**
17.	18.0	*VAT (% of sub total D)*	%	14		R5 187 957
		NETT PROJECT COST				**R42 244 789**
18.	19.0	*Cost of relocations*	Sum			R0
19.	20.0	*Cost of land acquisition*	Sum			R0
		TOTAL PROJECT COST				**R42 244 789**

WEIRS COST MODEL AADD 2.285

April 1999 price levels

	Xura	Mzintlava
Excavation depth (m)	4	4
Wall height	2	2
Top width	1	1
Wall section area (m^2)	16.5	16.5
Stilling basin length (m)	10	10
Stilling basin base thickness (m)	0.5	0.5
Stilling basin section area (m^2)	5	5
Toe depth (m)	4.5	4.5
Toe thickness (m)	1	1
Toe section area (m^2)	4.5	4.5
Total section area (m^2)	26	26
Length of weir structure (m)	61	50
Volume of weir structure (m^3)	**1586**	**1300**
Concrete cost per m^3	R 500	R 500
Structural concrete cost	**R 793 000**	**R 650 000**
Reinforcing, excavation, formwork,		
site clearing, etc	R 237 900	R 195 000
Mechanical	R 100 000	R 100 000
Sub-total	R 1 130 900	R 945 000
Landscaping	R 56 545	R 47 250
Miscellaneous	R 113 090	R 94 500
Sub-total	R 1 300 535	R 1 086 750
Preliminary & General	R 390 161	R 326 025
Sub-total	R 1 690 696	R 1 412 775
Contingencies	R 169 070	R 141 278
Sub-total	R 1 859 765	R 1 554 053
Planning, design & supervision	R 371 953	R 310 811
Sub-total	R 2 231 718	R 1 864 863
VAT	R 312 441	R 261 081
TOTAL	**R 2 544 159**	**R 2 125 944**

APPENDIX J3 :

COST ESTIMATES: GROUNDWATER SOURCE AND INFRASTRUCTURE

APPENDIX J3: ESTIMATED COSTS FOR DEVELOPMENT AND EQUIPPING OF BOREHOLES.

Assumptions:

Average yield per successful borehole: 1,5 l/s net

Average depth: 60 m

Success rates: 60 to 75%

Average recommended operating time 12 hr/day

1. Groundwater source development pr borehole, 1,5 l/s	**R/borehole**
Hydrocensus	R1 200
Exploration (siting, drilling & testing supervision)	R20 000
Drilling (contractor)	R41 500
Testing (contractor)	R17 500
Access tracks (1 km per borehole; 1 000 m x R15/m)	R15 000
Subtotal	**R95 200**
Contingencies (10%)	R10 000
VAT	R14 800
Total source development cost per successful borehole	**R120 000**

2. Equipment per borehole, 1,5 l/s net	R/borehole
Equipment (pump, motor, pump house) 1,5 l/s, 160 m head	R30 000
Pipelines (1.3 km of pipeline (Cl 20, ϕ 75) per BH at R55/m)	R71 000
Balancing reservoir	R25 000
Subtotal	R126 000
Contingencies	R12 600
VAT + 16 % professional fees	R41 400
Total cost for equipment per borehole	**R180 000**
Total cost: development and equipment per borehole	**R300 000**

In accordance with the RDP guidelines the groundwater need to be sized to supply the gross annual daily demand at summer peaks:

- Borehole operating period 12 hours per day
- Summer peak Factor (SPF) 1.5
- Gross annual average daily demand (GAADD) 1.1 AADD

Required yield = AADD x 1.1 x 1,5 x 24/12 = 3,3 x AADD

Assuming an average borehole yield of 1,5 l/s net, in can be concluded that a total of 2,2 boreholes will be required for the supply of 1 l/s net requirements (AADD).

The total costs for the establishment of groundwater supply for 1 l/s of the AADD are estimated to be R300 000 x 2,2 = R660 000. These costs can be split between the following components.

Drilling and Civil works	R264 000
Equipment / Pumps	R88 000
Pipelines	R220 000
Reservoirs	R88 000
Total	**R660 000**

APPENDIX J4 :

COST MODELS: CONVEYANCE SYSTEM RECONNAISSANCE PHASE

EAST PONDOLAND (LUSIKISIKI) BASIN STUDY

18-Jan-00

DESCRIPTION OF THE CONVEYANCE OPTIONS FOR THE RESPECTIVE DAM SI

LOW DEMAND, FULL SCHEME
ZALU DAM CONVEYANCE

Description : Pump to existing Water Treatment Works Site, pump to Reservoir A site, route option

COMPONENT

1 *Raw Water Pump Station*

2.1	Implement in year 2000 and sized for year 2010			
2.2	Upgrade in year 2010 and sized for year 2020			
2.3	Summer Daily Demand (SDDww - 2010)	123	l/s	
2.4	Summer Daily Demand (SDDww - 2020) - incremental increa	35	l/s	
2.5	Static Head	-6	m	
2.6	Total Head (2010)	33	m	
2.7	Total Head (2020)	55	m	
2.8	Required Power (2010)	58	kW	
2.9	Required Power (2020) - incremental increase	69	kW	
2.10	Unit Cost (2010)	R9 431.36	per kW	
2.11	Unit Cost (2020)	R6 438.01	per kW	
2.12	Installation Cost (2010)	R543 550.00		
2.13	Installation Cost (2020)	R442 100.00		
2.14	**Cost**			**R985 650.00**

2 *Raw Water Raising Main*

1.1	Summer Daily Demand (SDDww - 2020)	158	l/s	
1.2	Bottom Outlet Level (BOL)	596	m above MSL	
1.3	WTW Elevation	590	m	
1.4	Length	6000	m	
1.5	Total head	55	m	
1.6	Diameter (Steel)	325	mm	
1.7	Unit Cost	R964.26	per m	
1.8	**Cost**			**R5 785 550.00**

3. *Water Treatment Works*

3.1	Implement in year 2000 and sized for year 2010			
3.2	Upgrade in year 2010 and sized for year 2020			
3.3	Summer Daily Demand (SDDww - 2010)	123	l/s	
3.4	Summer Daily Demand (SDDww - 2020) - incremental increa	35	l/s	
3.5	Unit Cost (2010)	R27 836.45	per l/s	
3.6	Unit Cost (2020)	R22 268.03	per l/s	
3.7	Installation Cost (2010)	##########		

3.8	Installation Cost (2020)	R782 800.00		
3.9	**Cost**			**R4 197 150.00**

4. *Clear Water Pump Station*

4.1	Implement in year 2000 and sized for year 2010			
4.2	Upgrade in year 2010 and sized for year 2020			
4.3	Summer Daily Demand (SDDpl - 2010)	112	l/s	
4.4	Summer Daily Demand (SDDpl - 2020) - incremental increase	32	l/s	
4.5	Static Head	57	m	
4.6	Total Head (2010)	74	m	
4.7	Total Head (2020)	84	m	
4.8	Required Power (2010)	119	kW	
4.9	Required Power (2020) - incremental increase	55	kW	
4.10	Unit Cost (2010)	R7 123.87	per kW	
4.11	Unit Cost (2020)	R6 116.72	per kW	
4.12	Installation Cost (2010)	R847 050.00		
4.13	Installation Cost (2020)	R335 625.00		
4.14	**Cost**			**R1 182 675.00**

5. *Clear Water Rising Main*

5.1	Summer Daily Demand (SDDpl)	143	l/s	
5.2	Length	2 126	m	
5.3	Diameter - (steel)	300	mm	
5.4	Total Head	84	m	
5.5	Unit Cost	R822.20	per m	
5.6	**Cost**			**R1 748 000.00**

6. *Bulk Storage Reservoir*

6.1	Implement in year 2000 and sized for year 2010			
6.2	Upgrade in year 2010 and sized for year 2020			
6.3	Capacity (2010)	4866	kl	
6.4	Capacity (2020) - incremental increase	1395	kl	
6.5	Unit Cost (2010)	R425.02	per kl	
6.6	Unit Cost (2020)	R425.15	per kl	
6.7	Installation Cost (2010)	###########		
6.8	Installation Cost (2020)	R592 875.00		
6.9	**Cost**			**R2 660 925.00**

7. *Cost*

7.1	Installations Costs (2010)	**R14 406 550.00**
7.2	Istallation Costs (2020)	**R2 153 400.00**
7.3	Total Installation Cost	**R16 559 950.00**

EAST PONDOLAND (LUSIKISIKI) BASIN STUDY

18-Jan-00

DESCRIPTION OF THE CONVEYANCE OPTIONS FOR THE RESPECTIVE DAM SITES

LOW DEMAND, FULL SCHEME
Lusikisiki Dam

Description : Pump to existing Water Treatment Works Site, pump to Reservoir A site, route option 1

COMPONENT

1 *Raw Water Pump Station*

2.1	Implement in year 2000 and sized for year 2010			
2.2	Upgrade in year 2010 and sized for year 2020			
2.3	Summer Daily Demand (SDDww - 2010)	123	l/s	
2.4	Summer Daily Demand (SDDww - 2020) - incremental increase	35	l/s	
2.5	Static Head	49	m	
2.6	Total Head (2010)	58	m	
2.7	Total Head (2020)	64	m	
2.8	Required Power (2010)	103	kW	
2.9	Required Power (2020) - incremental increase	42	kW	
2.10	Unit Cost (2010)	R7 719.91	per kW	
2.11	Unit Cost (2020)	R6 823.49	per kW	
2.12	Installation Cost (2010)	R798 450.00		
2.13	Installation Cost (2020)	R289 450.00		
2.14	**Cost**			**R1 087 900.00**

2 *Raw Water Raising Main*

1.1	Summer Daily Demand (SDDww - 2020)	158	l/s	
1.2	Bottom Outlet Level (BOL)	541	m above MSL	
1.3	WTW Elevation	590	m	
1.4	Length	1470	m	
1.5	Total head	64	m	
1.6	Diameter (Steel)	325	mm	
1.7	Unit Cost	R964.29	per m	
1.8	**Cost**			**R1 417 500.00**

3. *Water Treatment Works*

3.1	Implement in year 2000 and sized for year 2010			
3.2	Upgrade in year 2010 and sized for year 2020			
3.3	Summer Daily Demand (SDDww - 2010)	123	l/s	
3.4	Summer Daily Demand (SDDww - 2020) - incremental increase	35	l/s	
3.5	Unit Cost (2010)	R27 836.45	per l/s	
3.6	Unit Cost (2020)	R22 268.03	per l/s	

3.7	Installation Cost (2010)	R3 414 350.00		
3.8	Installation Cost (2020)	R782 800.00		
3.9	**Cost**			**R4 197 150.00**

4. *Clear Water Pump Station*

4.1	Implement in year 2000 and sized for year 2010			
4.2	Upgrade in year 2010 and sized for year 2020			
4.3	Summer Daily Demand (SDDpl - 2010)	112	l/s	
4.4	Summer Daily Demand (SDDpl - 2020) - incremental increase	32	l/s	
4.5	Static Head	57	m	
4.6	Total Head (2010)	74	m	
4.7	Total Head (2020)	84	m	
4.8	Required Power (2010)	119	kW	
4.9	Required Power (2020) - incremental increase	55	kW	
4.10	Unit Cost (2010)	R7 123.87	per kW	
4.11	Unit Cost (2020)	R6 116.72	per kW	
4.12	Installation Cost (2010)	R847 050.00		
4.13	Installation Cost (2020)	R335 625.00		
4.14	**Cost**			**R1 182 675.00**

5. *Clear Water Rising Main*

5.1	Summer Daily Demand (SDDpl)	143	l/s	
5.2	Length	2 126	m	
5.3	Diameter - (steel)	300	mm	
5.4	Total Head	84	m	
5.5	Unit Cost	R822.20	per m	
5.6	**Cost**			**R1 748 000.00**

6. *Bulk Storage Reservoir*

6.1	Implement in year 2000 and sized for year 2010			
6.2	Upgrade in year 2010 and sized for year 2020			
6.3	Capacity (2010)	4866	kl	
6.4	Capacity (2020) - incremental increase	1395	kl	
6.5	Unit Cost (2010)	R425.02	per kl	
6.6	Unit Cost (2020)	R425.15	per kl	
6.7	Installation Cost (2010)	R2 068 050.00		
6.8	Installation Cost (2020)	R592 875.00		
6.9	**Cost**			**R2 660 925.00**

7. *Cost*

7.1	Installations Costs (2010)	**R10 293 400.00**
7.2	Istallation Costs (2020)	**R2 000 750.00**
7.3	Total Installation Cost	**R12 294 150.00**

EAST PONDOLAND (LUSIKISIKI) BASIN STUDY

18-Jan-00

DESCRIPTION OF THE CONVEYANCE OPTIONS FOR THE RESPECTIVE DAM SITES

LOW DEMAND, FULL SCHEME
Xura Dam

Description : Pump to existing Water Treatment Works Site, pump to Reservoir A site, route option 1

COMPONENT

1 *Raw Water Pump Station*

2.1	Implement in year 2000 and sized for year 2010			
2.2	Upgrade in year 2010 and sized for year 2020			
2.3	Summer Daily Demand (SDDww - 2010)	123	l/s	
2.4	Summer Daily Demand (SDDww - 2020) - incremental increase	35	l/s	
2.5	Static Head	141	m	
2.6	Total Head (2010)	181	m	
2.7	Total Head (2020)	205	m	
2.8	Required Power (2010)	321	kW	
2.9	Required Power (2020) - incremental increase	146	kW	
2.10	Unit Cost (2010)	R5 194.57	per kW	
2.11	Unit Cost (2020)	R4 452.56	per kW	
2.12	Installation Cost (2010)	R1 665 350.00		
2.13	Installation Cost (2020)	R651 000.00		
2.14	**Cost**			**R2 316 350.00**

2 *Raw Water Raising Main*

1.1	Summer Daily Demand (SDDww - 2020)	158	l/s	
1.2	Bottom Outlet Level (BOL)	449	m above MSL	
1.3	WTW Elevation	590	m	
1.4	Length	6250	m	
1.5	Total head	205	m	
1.6	Diameter (Steel)	325	mm	
1.7	Unit Cost	R964.26	per m	
1.8	**Cost**			**R6 026 600.00**

3. *Water Treatment Works*

3.1	Implement in year 2000 and sized for year 2010			
3.2	Upgrade in year 2010 and sized for year 2020			
3.3	Summer Daily Demand (SDDww - 2010)	123	l/s	
3.4	Summer Daily Demand (SDDww - 2020) - incremental increase	35	l/s	
3.5	Unit Cost (2010)	R27 836.45	per l/s	
3.6	Unit Cost (2020)	R22 268.03	per l/s	
3.7	Installation Cost (2010)	R3 414 350.00		

3.8	Installation Cost (2020)	R782 800.00		
3.9	**Cost**			**R4 197 150.00**

4. *Clear Water Pump Station*

4.1	Implement in year 2000 and sized for year 2010			
4.2	Upgrade in year 2010 and sized for year 2020			
4.3	Summer Daily Demand (SDDpl - 2010)	112	l/s	
4.4	Summer Daily Demand (SDDpl - 2020) - incremental increase	32	l/s	
4.5	Static Head	57	m	
4.6	Total Head (2010)	74	m	
4.7	Total Head (2020)	84	m	
4.8	Required Power (2010)	119	kW	
4.9	Required Power (2020) - incremental increase	55	kW	
4.10	Unit Cost (2010)	R7 123.87	per kW	
4.11	Unit Cost (2020)	R6 116.72	per kW	
4.12	Installation Cost (2010)	R847 050.00		
4.13	Installation Cost (2020)	R335 625.00		
4.14	**Cost**			**R1 182 675.00**

5. *Clear Water Rising Main*

5.1	Summer Daily Demand (SDDpl)	143	l/s	
5.2	Length	2 126	m	
5.3	Diameter - (steel)	300	mm	
5.4	Total Head	84	m	
5.5	Unit Cost	R822.20	per m	
5.6	**Cost**			**R1 748 000.00**

6. *Bulk Storage Reservoir*

6.1	Implement in year 2000 and sized for year 2010			
6.2	Upgrade in year 2010 and sized for year 2020			
6.3	Capacity (2010)	4866	kl	
6.4	Capacity (2020) - incremental increase	1395	kl	
6.5	Unit Cost (2010)	R425.02	per kl	
6.6	Unit Cost (2020)	R425.15	per kl	
6.7	Installation Cost (2010)	R2 068 050.00		
6.8	Installation Cost (2020)	R592 875.00		
6.9	**Cost**			**R2 660 925.00**

7. *Cost*

7.1	Installations Costs (2010)	**R15 769 400.00**
7.2	Istallation Costs (2020)	**R2 362 300.00**
7.3	Total Installation Cost	**R18 131 700.00**

DESCRIPTION OF THE CONVEYANCE OPTIONS FOR THE RESPECTIVE DAM SITES

LOW DEMAND, FULL SCHEME
ZALU DAM FROM WEIR

Description : Pump from existing weir to Water Treatment Works, pump to Reservoir A site

	COMPONENT			
1	***Raw Water Pump Station***			
2.1	Implement in year 2000 and sized for year 2010			
2.2	Upgrade in year 2010 and sized for year 2020			
2.3	Summer Daily Demand (SDDww - 2010)		l/s	
2.4	Summer Daily Demand (SDDww - 2020) - incremental increase	158	l/s	
2.5	Static Head	40	m	
2.6	Total Head (2010)		m	
2.7	Total Head (2020)	45	m	
2.8	Required Power (2010)	0	kW	
2.9	Required Power (2020) - incremental increase	102	kW	
2.10	Unit Cost (2010)	R7 700.00	per kW	
2.11	Unit Cost (2020)	R0.00	per kW	
2.12	Installation Cost (2010)	R788 861.58		
2.13	Installation Cost (2020)			
2.14	**Cost**			**R788 861.58**
2	***Raw Water Raising Main***			
1.1	Summer Daily Demand (SDDww - 2020)	158	l/s	
1.2	Bottom Outlet Level (BOL)		m above MSL	
1.3	WTW Elevation	590	m	
1.4	Length	650	m	
1.5	Total head	45	m	
1.6	Diameter (Steel)	325	mm	
1.7	Unit Cost	R964.00	per m	
1.8	**Cost**			**R626 600.00**
3.	***Water Treatment Works***			
3.1	Implement in year 2000 and sized for year 2010			
3.2	Upgrade in year 2010 and sized for year 2020			
3.3	Summer Daily Demand (SDDww - 2010)	123	l/s	
3.4	Summer Daily Demand (SDDww - 2020) - incremental increase	35	l/s	
3.5	Unit Cost (2010)	R27 836.45	per l/s	
3.6	Unit Cost (2020)	R22 268.03	per l/s	
3.7	Installation Cost (2010)	R3 414 350.00		
3.8	Installation Cost (2020)	R782 800.00		
3.9	**Cost**			**R4 197 150.00**

4. *Clear Water Pump Station*

4.1	Implement in year 2000 and sized for year 2010			
4.2	Upgrade in year 2010 and sized for year 2020			
4.3	Summer Daily Demand (SDDpl - 2010)	112	l/s	
4.4	Summer Daily Demand (SDDpl - 2020) - incremental increase	32	l/s	
4.5	Static Head	57	m	
4.6	Total Head (2010)	74	m	
4.7	Total Head (2020)	84	m	
4.8	Required Power (2010)	119	kW	
4.9	Required Power (2020) - incremental increase	55	kW	
4.10	Unit Cost (2010)	R7 123.87	per kW	
4.11	Unit Cost (2020)	R6 116.72	per kW	
4.12	Installation Cost (2010)	R847 050.00		
4.13	Installation Cost (2020)	R335 625.00		
4.14	**Cost**			**R1 182 675.00**

5. *Clear Water Rising Main*

5.1	Summer Daily Demand (SDDpl)	143	l/s	
5.2	Length	2 126	m	
5.3	Diameter - (steel)	300	mm	
5.4	Total Head	84	m	
5.5	Unit Cost	R822.20	per m	
5.6	**Cost**			**R1 748 000.00**

6. *Bulk Storage Reservoir*

6.1	Implement in year 2000 and sized for year 2010			
6.2	Upgrade in year 2010 and sized for year 2020			
6.3	Capacity (2010)	4866	kl	
6.4	Capacity (2020) - incremental increase	1395	kl	
6.5	Unit Cost (2010)	R425.02	per kl	
6.6	Unit Cost (2020)	R425.15	per kl	
6.7	Installation Cost (2010)	R2 068 050.00		
6.8	Installation Cost (2020)	R592 875.00		
6.9	**Cost**			**R2 660 925.00**

7. *Cost*

7.1	Installations Costs (2010)	**R9 492 911.58**
7.2	Istallation Costs (2020)	**R1 711 300.00**
7.3	Total Installation Cost	**R11 204 211.58**

EAST PONDOLAND (LUSIKISIKI) BASIN STUDY

18-Jan-00

DESCRIPTION OF THE CONVEYANCE OPTIONS FOR THE RESPECTIVE DAM SITES

LOW DEMAND, FULL SCHEME
Xura Weir 21 l/s

Description : Pump to existing Water Treatment Works Site, pump to Reservoir A site, route option 1 RWPS, RWPM sized for 21 l/s + factots. WTW, CWPS, Storage sized for combined use with existing wei

COMPONENT

1 *Raw Water Pump Station*

2.1	Implement in year 2000 and sized for year 2020			
2.2				
2.3	Summer Daily Demand (SDDww - 2020)		l/s	
2.4	Summer Daily Demand (SDDww - 2020)	38	l/s	
2.5	Static Head	141	m	
2.6			m	
2.7	Total Head (2020)	190	m	
2.8			kW	
2.9	Required Power (2020)	104	kW	
2.10			per kW	
2.11	Unit Cost (2020)	R0.00	per kW	
2.12	Installation Cost (2010)	R529 750.00		
2.13				
2.14	**Cost**			**R529 750.00**

2 *Raw Water Raising Main*

1.1	Summer Daily Demand (SDDww - 2020)	38	l/s	
1.2	Bottom Outlet Level (BOL)	449	m above MSL	
1.3	WTW Elevation	590	m	
1.4	Length	6250	m	
1.5	Total head	190	m	
1.6	Diameter (Steel)	200	mm	
1.7	Unit Cost	R368.42	per m	
1.8	**Cost**			**R2 302 650.00**

3. *Water Treatment Works*

3.1	Implement in year 2000 and sized for year 2010			
3.2	Upgrade in year 2010 and sized for year 2020			
3.3	Summer Daily Demand (SDDww - 2010)	123	l/s	
3.4	Summer Daily Demand (SDDww - 2020) - incremental increase	35	l/s	
3.5	Unit Cost (2010)	R27 836.45	per l/s	
3.6	Unit Cost (2020)	R22 268.03	per l/s	
3.7	Installation Cost (2010)	R3 414 350.00		
3.8	Installation Cost (2020)	R782 800.00		
3.9	**Cost**			**R4 197 150.00**

4. *Clear Water Pump Station*

4.1	Implement in year 2000 and sized for year 2010			
4.2	Upgrade in year 2010 and sized for year 2020			
4.3	Summer Daily Demand (SDDpl - 2010)	112	l/s	
4.4	Summer Daily Demand (SDDpl - 2020) - incremental increase	32	l/s	
4.5	Static Head	57	m	
4.6	Total Head (2010)	74	m	
4.7	Total Head (2020)	84	m	
4.8	Required Power (2010)	119	kW	
4.9	Required Power (2020) - incremental increase	55	kW	
4.10	Unit Cost (2010)	R7 115.67	per kW	
4.11	Unit Cost (2020)	R6 123.02	per kW	
4.12	Installation Cost (2010)	R847 050.00		
4.13	Installation Cost (2020)	R335 625.00		
4.14	**Cost**			**R1 182 675.00**

5. *Clear Water Rising Main*

5.1	Summer Daily Demand (SDDpl)	143	l/s	
5.2	Length	2 126	m	
5.3	Diameter - (steel)	300	mm	
5.4	Total Head	84	m	
5.5	Unit Cost	R822.20	per m	
5.6	**Cost**			**R1 748 000.00**

6. *Bulk Storage Reservoir*

6.1	Implement in year 2000 and sized for year 2010			
6.2	Upgrade in year 2010 and sized for year 2020			
6.3	Capacity (2010)	4866	kl	
6.4	Capacity (2020) - incremental increase	1395	kl	
6.5	Unit Cost (2010)	R425.02	per kl	
6.6	Unit Cost (2020)	R425.15	per kl	
6.7	Installation Cost (2010)	R2 068 050.00		
6.8	Installation Cost (2020)	R592 875.00		
6.9	**Cost**			**R2 660 925.00**

7. *Cost*

7.1	Installations Costs (2010)	**R10 909 850.00**
7.2	Istallation Costs (2020)	**R1 711 300.00**
7.3	Total Installation Cost	**R12 621 150.00**

EAST PONDOLAND (LUSIKISIKI) BASIN STUDY

18-Jan-00

DESCRIPTION OF THE CONVEYANCE OPTIONS FOR THE RESPECTIVE DAM SITES

LOW DEMAND, FULL SCHEME
Existing Weir to Water Treatment Works

Description : Pump from existing weir to Water Treatment Works. Sized for full demand - 72l/s plus fa

	COMPONENT			
1	***Raw Water Pump Station***			
1.1	Implement in year 2000 and sized for year 2010			
1.2	Upgrade in year 2010 and sized for year 2020			
1.3	Summer Daily Demand (SDDww - 2010)		l/s	
1.4	Summer Daily Demand (SDDww - 2020) - incremental increas	158	l/s	
1.5	Static Head	40	m	
1.6	Total Head (2010)		m	
1.7	Total Head (2020)	45	m	
1.8	Required Power (2010)	0	kW	
1.9	Required Power (2020) - incremental increase	102	kW	
1.1	Unit Cost (2010)	R7 700.00	per kW	
1.11	Unit Cost (2020)	R7 700.00	per kW	
1.12	Installation Cost (2010)			
1.13	Installation Cost (2020)	R788 861.58		
1.14	**Cost**			**R788 861.58**
2	***Raw Water Raising Main***			
2.1	Summer Daily Demand (SDDww - 2020)	158	l/s	
2.2	Bottom Outlet Level (BOL)		m above MSL	
2.3	WTW Elevation	590	m	
2.4	Length	650	m	
2.5	Total head	45	m	
2.6	Diameter (Steel)	325	mm	
2.7	Unit Cost	R964.00	per m	
2.8	**Cost**			**R626 600.00**
3	***Cost***			
3.1	Installations Costs (2010)			**R1 415 461.58**
3.2	Istallation Costs (2020)			**R0.00**
3.3	Total Installation Cost			**R1 415 461.58**

EAST PONDOLAND (LUSIKISIKI) BASIN STUDY

18-Jan-00

DESCRIPTION OF THE CONVEYANCE OPTIONS FOR THE RESPECTIVE DAM SITES

LOW DEMAND, FULL SCHEME
Conveyance from WTW to Res A

Description :WTW, pump to Reservoir A site, full capacity 72 l/s plus factors

COMPONENT

3. *Water Treatment Works*

3.1	Implement in year 2000 and sized for year 2010			
3.2	Upgrade in year 2010 and sized for year 2020			
3.3	Summer Daily Demand (SDDww - 2010)	123	l/s	
3.4	Summer Daily Demand (SDDww - 2020) - incremental increase	35	l/s	
3.5	Unit Cost (2010)	R27 836.45	per l/s	
3.6	Unit Cost (2020)	R22 268.03	per l/s	
3.7	Installation Cost (2010)	R3 414 350.00		
3.8	Installation Cost (2020)	R782 800.00		
3.9	**Cost**			**R4 197 150.00**

4. *Clear Water Pump Station*

4.1	Implement in year 2000 and sized for year 2010			
4.2	Upgrade in year 2010 and sized for year 2020			
4.3	Summer Daily Demand (SDDpl - 2010)	112	l/s	
4.4	Summer Daily Demand (SDDpl - 2020) - incremental increase	32	l/s	
4.5	Static Head	57	m	
4.6	Total Head (2010)	74	m	
4.7	Total Head (2020)	84	m	
4.8	Required Power (2010)	119	kW	
4.9	Required Power (2020) - incremental increase	55	kW	
4.10	Unit Cost (2010)	R7 115.67	per kW	
4.11	Unit Cost (2020)	R6 123.02	per kW	
4.12	Installation Cost (2010)	R847 050.00		
4.13	Installation Cost (2020)	R335 625.00		
4.14	**Cost**			**R1 182 675.00**

5. *Clear Water Rising Main*

5.1	Summer Daily Demand (SDDpl)	143	l/s	
5.2	Length	2 126	m	
5.3	Diameter - (steel)	300	mm	
5.4	Total Head	84	m	
5.5	Unit Cost	R822.20	per m	
5.6	**Cost**			**R1 748 000.00**

6. *Bulk Storage Reservoir*

6.1	Implement in year 2000 and sized for year 2010			
6.2	Upgrade in year 2010 and sized for year 2020			
6.3	Capacity (2010)	4866	kl	
6.4	Capacity (2020) - incremental increase	1395	kl	
6.5	Unit Cost (2010)	R425.02	per kl	
6.6	Unit Cost (2020)	R425.15	per kl	
6.7	Installation Cost (2010)	R2 068 050.00		
6.8	Installation Cost (2020)	R592 875.00		
6.9	**Cost**			**R2 660 925.00**

7. *Cost*

7.1	Installations Costs (2010)		**R8 077 450.00**
7.2	Istallation Costs (2020)		**R1 711 300.00**
7.3	Total Installation Cost		**R9 788 750.00**

EAST PONDOLAND (LUSIKISIKI) BASIN STUDY

18-Jan-00

DESCRIPTION OF THE CONVEYANCE OPTIONS FOR THE RESPECTIVE DAM SITES

LOW DEMAND, FULL SCHEME

Mzintlava Weir 19 l/s

Description : Pump to reservoir 40 site, Water Treatment Works Site, pump to Reservoir B site

All components sized for 19 l/s + factors.

COMPONENT

1 *Raw Water Pump Station*

2.1	Implement in year 2000 and sized for year 2020			
2.2				
2.3			l/s	
2.4	Summer Daily Demand (SDDww - 2020)	36	l/s	
2.5	Static Head	136	m	
2.6			m	
2.7	Total Head (2020)	143	m	
2.8			kW	
2.9	Required Power (2020)	74	kW	
2.10			per kW	
2.11	Unit Cost (2020)	R0.00	per kW	
2.12	Installation Cost (2020)	R418 960.00		
2.13				
2.14	**Cost**			**R418 960.00**

2 *Raw Water Raising Main*

1.1	Summer Daily Demand (SDDww - 2020)	36	l/s	
1.2	Bottom Outlet Level (BOL)	455	m above MSL	
1.3	WTW Elevation	591	m	
1.4	Length	1050	m	
1.5	Total head	143	m	
1.6	Diameter (Steel)	200	mm	
1.7	Unit Cost	R368.42	per m	
1.8	**Cost**			**R386 845.00**

3. *Water Treatment Works*

3.1	Implement in year 2000 and sized for year 2020			
3.2				
3.3			l/s	
3.4	Summer Daily Demand (SDDww - 2020) - incremental increase	36	l/s	
3.5			per l/s	
3.6	Unit Cost (2020)	R0.00	per l/s	
3.7	Installation Cost (2010)	R1 497 025.00		

3.8				
3.9	**Cost**			**R1 497 025.00**

4. *Clear Water Pump Station*

4.1	Implement in year 2000 and sized for year 2020			
4.2				
4.3			l/s	
4.4	Summer Daily Demand (SDDpl - 2020) - incremental increase	33	l/s	
4.5	Static Head	90	m	
4.6			m	
4.7	Total Head (2020)	232	m	
4.8			kW	
4.9	Required Power (2020) - incremental increase	111	kW	
4.10			per kW	
4.11	Unit Cost (2020)	R0.00	per kW	
4.12	Installation Cost (2010)	R523 190.00		
4.13	Installation Cost (2020)	R0.00		
4.14	**Cost**			**R523 190.00**

5. *Clear Water Rising Main*

5.1	Summer Daily Demand (SDDpl)	33	l/s	
5.2	Length	5 830	m	
5.3	Diameter - (steel)	150	mm	
5.4	Total Head	232	m	
5.5	Unit Cost	R210.24	per m	
5.6	**Cost**			**R1 225 720.00**

6. *Bulk Storage Reservoir*

6.1	Implement in year 2000 and sized for year 2010			
6.2	Upgrade in year 2010 and sized for year 2020			
6.3			kl	
6.4	Capacity (2020) - incremental increase	2500	kl	
6.5			per kl	
6.6	Unit Cost (2020)	R0.00	per kl	
6.7	Installation Cost (2010)	R1 062 500.00		
6.8	Installation Cost (2020)	R0.00		
6.9	**Cost**			**R1 062 500.00**

7. *Cost*

7.1	Installations Costs (2010)	**R5 114 240.00**
7.2	Istallation Costs (2020)	**R0.00**
7.3	Total Installation Cost	**R5 114 240.00**

APPENDIX J5 :

ECONOMIC MODELS: URV OF WATER RECONNAISSANCE PHASE

ECONOMICS MODEL

Low Demand Scenario
D1A: Zalu Dam Option

	0.47	0	0.03	0.058	0.066
	0.05		0.116	0.091	0.151

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	56.220						56.220	0.000	0.000	50.036	0.000	0.000	48.200	0.000	0.000	46.463	0.000	0.000
2002		0.470	0.000	0.030	0.058	0.066	0.000	0.536	0.088	0.000	0.450	0.074	0.000	0.425	0.070	0.000	0.403	0.066
2003		0.470	0.000	0.035	0.060	0.070	0.000	0.540	0.094	0.000	0.428	0.075	0.000	0.397	0.069	0.000	0.369	0.064
2004		0.470	0.000	0.039	0.061	0.075	0.000	0.545	0.101	0.000	0.407	0.075	0.000	0.371	0.068	0.000	0.338	0.062
2005		0.470	0.000	0.044	0.063	0.079	0.000	0.549	0.107	0.000	0.387	0.075	0.000	0.346	0.067	0.000	0.310	0.060
2006		0.470	0.000	0.048	0.065	0.084	0.000	0.554	0.113	0.000	0.368	0.075	0.000	0.323	0.066	0.000	0.284	0.058
2007		0.470	0.000	0.053	0.067	0.088	0.000	0.558	0.119	0.000	0.350	0.075	0.000	0.302	0.064	0.000	0.260	0.056
2008		0.470	0.000	0.057	0.068	0.093	0.000	0.563	0.126	0.000	0.333	0.074	0.000	0.282	0.063	0.000	0.239	0.053
2009		0.470	0.000	0.062	0.070	0.097	0.000	0.567	0.132	0.000	0.317	0.074	0.000	0.263	0.061	0.000	0.219	0.051
2010		0.470	0.000	0.066	0.072	0.102	0.000	0.572	0.138	0.000	0.301	0.073	0.000	0.245	0.059	0.000	0.200	0.048
2011	2.800	0.470	0.000	0.071	0.074	0.106	2.800	0.576	0.144	1.392	0.286	0.072	1.112	0.229	0.057	0.892	0.184	0.046
2012		0.520	0.000	0.075	0.075	0.111	0.000	0.631	0.151	0.000	0.296	0.071	0.000	0.232	0.055	0.000	0.183	0.044
2013		0.520	0.000	0.080	0.077	0.115	0.000	0.635	0.157	0.000	0.281	0.069	0.000	0.216	0.053	0.000	0.167	0.041
2014		0.520	0.000	0.084	0.079	0.120	0.000	0.640	0.163	0.000	0.267	0.068	0.000	0.202	0.051	0.000	0.153	0.039
2015		0.520	0.000	0.089	0.081	0.124	0.000	0.644	0.169	0.000	0.254	0.067	0.000	0.188	0.049	0.000	0.140	0.037
2016		0.520	0.000	0.093	0.082	0.129	0.000	0.649	0.176	0.000	0.241	0.065	0.000	0.175	0.047	0.000	0.128	0.035
2017		0.520	0.000	0.098	0.084	0.133	0.000	0.653	0.182	0.000	0.229	0.064	0.000	0.163	0.046	0.000	0.117	0.033
2018		0.520	0.000	0.102	0.086	0.138	0.000	0.658	0.188	0.000	0.217	0.062	0.000	0.152	0.044	0.000	0.108	0.031
2019		0.520	0.000	0.107	0.088	0.142	0.000	0.662	0.194	0.000	0.206	0.061	0.000	0.142	0.042	0.000	0.098	0.029
2020		0.520	0.000	0.111	0.089	0.147	0.000	0.667	0.201	0.000	0.196	0.059	0.000	0.132	0.040	0.000	0.090	0.027
2021	-28.320	0.520	0.000	0.116	0.091	0.151	-28.320	0.671	0.207	-7.859	0.186	0.057	-5.209	0.123	0.038	-3.479	0.082	0.025
TOTAL	**30.700**	**9.900**	**0.000**	**1.460**	**1.490**	**2.170**	**30.700**	**12.070**	**2.950**	**43.568**	**6.002**	**1.385**	**44.102**	**4.910**	**1.112**	**43.876**	**4.074**	**0.906**

	NPC	NPV water	URV, R/kl
AT 6%	**51.0**	**17.1**	**2.99**
AT 8%	**50.1**	**13.7**	**3.65**
AT 10%	**48.9**	**11.2**	**4.37**

17-Aug-01

ECONOMICS MODEL

Low Demand Scenario
D2: Lusikisiki Dam Option

0.43	0	0.056	0.08	0.066	
0.04		0.147	0.116	0.151	

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	50.910						50.910	0.000	0.000	45.310	0.000	0.000	43.647	0.000	0.000	42.074	0.000	0.000
2002		0.430	0.000	0.056	0.080	0.066	0.000	0.496	0.136	0.000	0.416	0.114	0.000	0.394	0.108	0.000	0.373	0.102
2003		0.430	0.000	0.061	0.082	0.070	0.000	0.500	0.143	0.000	0.396	0.113	0.000	0.368	0.105	0.000	0.342	0.097
2004		0.430	0.000	0.066	0.084	0.075	0.000	0.505	0.149	0.000	0.377	0.112	0.000	0.344	0.102	0.000	0.314	0.093
2005		0.430	0.000	0.070	0.086	0.079	0.000	0.509	0.156	0.000	0.359	0.110	0.000	0.321	0.098	0.000	0.288	0.088
2006		0.430	0.000	0.075	0.088	0.084	0.000	0.514	0.163	0.000	0.342	0.108	0.000	0.300	0.095	0.000	0.264	0.084
2007		0.430	0.000	0.080	0.089	0.088	0.000	0.518	0.169	0.000	0.325	0.106	0.000	0.280	0.092	0.000	0.242	0.079
2008		0.430	0.000	0.085	0.091	0.093	0.000	0.523	0.176	0.000	0.309	0.104	0.000	0.262	0.088	0.000	0.222	0.075
2009		0.430	0.000	0.090	0.093	0.097	0.000	0.527	0.183	0.000	0.294	0.102	0.000	0.244	0.085	0.000	0.203	0.070
2010		0.430	0.000	0.094	0.095	0.102	0.000	0.532	0.189	0.000	0.280	0.100	0.000	0.228	0.081	0.000	0.186	0.066
2011	2.600	0.430	0.000	0.099	0.097	0.106	2.600	0.536	0.196	1.292	0.267	0.097	1.032	0.213	0.078	0.828	0.171	0.063
2012		0.470	0.000	0.104	0.099	0.111	0.000	0.581	0.203	0.000	0.272	0.095	0.000	0.214	0.075	0.000	0.168	0.059
2013		0.470	0.000	0.109	0.101	0.115	0.000	0.585	0.210	0.000	0.259	0.093	0.000	0.199	0.071	0.000	0.154	0.055
2014		0.470	0.000	0.113	0.103	0.120	0.000	0.590	0.216	0.000	0.246	0.090	0.000	0.186	0.068	0.000	0.141	0.052
2015		0.470	0.000	0.118	0.105	0.124	0.000	0.594	0.223	0.000	0.234	0.088	0.000	0.173	0.065	0.000	0.129	0.049
2016		0.470	0.000	0.123	0.107	0.129	0.000	0.599	0.230	0.000	0.222	0.085	0.000	0.162	0.062	0.000	0.118	0.045
2017		0.470	0.000	0.128	0.108	0.133	0.000	0.603	0.236	0.000	0.211	0.083	0.000	0.151	0.059	0.000	0.108	0.042
2018		0.470	0.000	0.133	0.110	0.138	0.000	0.608	0.243	0.000	0.201	0.080	0.000	0.141	0.056	0.000	0.099	0.040
2019		0.470	0.000	0.137	0.112	0.142	0.000	0.612	0.250	0.000	0.191	0.078	0.000	0.131	0.054	0.000	0.091	0.037
2020		0.470	0.000	0.142	0.114	0.147	0.000	0.617	0.256	0.000	0.181	0.075	0.000	0.122	0.051	0.000	0.083	0.035
2021	-26.570	0.470	0.000	0.147	0.116	0.151	-26.570	0.621	0.263	-7.373	0.172	0.073	-4.887	0.114	0.048	-3.264	0.076	0.032
TOTAL	**26.940**	**9.000**	**0.000**	**2.030**	**1.960**	**2.170**	**26.940**	**11.170**	**3.990**	**39.229**	**5.557**	**1.907**	**39.792**	**4.547**	**1.541**	**39.639**	**3.773**	**1.263**

	NPC	NPV water	URV, R/kl
AT 6%	**46.7**	**17.1**	**2.74**
AT 8%	**45.9**	**13.7**	**3.35**
AT 10%	**44.7**	**11.2**	**3.99**

ECONOMICS MODEL

Low Demand Scenario

D3: Xura Dam Option

	0.57	0	0.1	0.148	0.066
	0.06		0.274	0.216	0.151

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	65.810						65.810	0.000	0.000	58.571	0.000	0.000	56.421	0.000	0.000	54.388	0.000	0.000
2002		0.570	0.000	0.100	0.148	0.066	0.000	0.636	0.248	0.000	0.534	0.208	0.000	0.505	0.197	0.000	0.478	0.186
2003		0.570	0.000	0.109	0.152	0.070	0.000	0.640	0.261	0.000	0.507	0.207	0.000	0.471	0.192	0.000	0.437	0.178
2004		0.570	0.000	0.118	0.155	0.075	0.000	0.645	0.273	0.000	0.482	0.204	0.000	0.439	0.186	0.000	0.400	0.170
2005		0.570	0.000	0.127	0.159	0.079	0.000	0.649	0.286	0.000	0.458	0.202	0.000	0.409	0.180	0.000	0.367	0.162
2006		0.570	0.000	0.137	0.162	0.084	0.000	0.654	0.299	0.000	0.435	0.199	0.000	0.382	0.174	0.000	0.336	0.153
2007		0.570	0.000	0.146	0.166	0.088	0.000	0.658	0.312	0.000	0.413	0.196	0.000	0.356	0.168	0.000	0.307	0.145
2008		0.570	0.000	0.155	0.169	0.093	0.000	0.663	0.324	0.000	0.392	0.192	0.000	0.332	0.162	0.000	0.281	0.138
2009		0.570	0.000	0.164	0.173	0.097	0.000	0.667	0.337	0.000	0.373	0.188	0.000	0.309	0.156	0.000	0.257	0.130
2010		0.570	0.000	0.173	0.177	0.102	0.000	0.672	0.350	0.000	0.354	0.184	0.000	0.288	0.150	0.000	0.235	0.123
2011	3.070	0.570	0.000	0.182	0.180	0.106	3.070	0.676	0.363	1.526	0.336	0.180	1.219	0.269	0.144	0.978	0.215	0.116
2012		0.630	0.000	0.192	0.184	0.111	0.000	0.741	0.375	0.000	0.347	0.176	0.000	0.272	0.138	0.000	0.215	0.109
2013		0.630	0.000	0.201	0.187	0.115	0.000	0.745	0.388	0.000	0.330	0.172	0.000	0.254	0.132	0.000	0.196	0.102
2014		0.630	0.000	0.210	0.191	0.120	0.000	0.750	0.401	0.000	0.313	0.167	0.000	0.236	0.126	0.000	0.179	0.096
2015		0.630	0.000	0.219	0.195	0.124	0.000	0.754	0.414	0.000	0.297	0.163	0.000	0.220	0.121	0.000	0.164	0.090
2016		0.630	0.000	0.228	0.198	0.129	0.000	0.759	0.426	0.000	0.282	0.158	0.000	0.205	0.115	0.000	0.150	0.084
2017		0.630	0.000	0.237	0.202	0.133	0.000	0.763	0.439	0.000	0.267	0.154	0.000	0.191	0.110	0.000	0.137	0.079
2018		0.630	0.000	0.247	0.205	0.138	0.000	0.768	0.452	0.000	0.254	0.149	0.000	0.178	0.105	0.000	0.126	0.074
2019		0.630	0.000	0.256	0.209	0.142	0.000	0.772	0.465	0.000	0.241	0.145	0.000	0.166	0.100	0.000	0.115	0.069
2020		0.630	0.000	0.265	0.212	0.147	0.000	0.777	0.477	0.000	0.228	0.140	0.000	0.154	0.095	0.000	0.105	0.064
2021	-33.280	0.630	0.000	0.274	0.216	0.151	-33.280	0.781	0.490	-9.235	0.217	0.136	-6.122	0.144	0.090	-4.088	0.096	0.060
TOTAL	**35.600**	**12.000**	**0.000**	**3.740**	**3.640**	**2.170**	**35.600**	**14.170**	**7.380**	**50.861**	**7.059**	**3.520**	**51.519**	**5.778**	**2.842**	**51.278**	**4.797**	**2.328**

	NPC	NPV water	URV, R/kl
AT 6%	**61.4**	**17.1**	**3.60**
AT 8%	**60.1**	**13.7**	**4.38**
AT 10%	**58.4**	**11.2**	**5.22**

ECONOMICS MODEL

Low Demand Scenario
D1B: Zalu Dam Option

0.41	0	0.056	0.08	0.066	
0.03		0.147	0.116	0.151	

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	49.250						49.250	0.000	0.000	43.832	0.000	0.000	42.224	0.000	0.000	40.702	0.000	0.000
2002		0.410	0.000	0.056	0.080	0.066	0.000	0.476	0.136	0.000	0.400	0.114	0.000	0.378	0.108	0.000	0.358	0.102
2003		0.410	0.000	0.061	0.082	0.070	0.000	0.480	0.143	0.000	0.381	0.113	0.000	0.353	0.105	0.000	0.328	0.097
2004		0.410	0.000	0.066	0.084	0.075	0.000	0.485	0.149	0.000	0.362	0.112	0.000	0.330	0.102	0.000	0.301	0.093
2005		0.410	0.000	0.070	0.086	0.079	0.000	0.489	0.156	0.000	0.345	0.110	0.000	0.308	0.098	0.000	0.276	0.088
2006		0.410	0.000	0.075	0.088	0.084	0.000	0.494	0.163	0.000	0.328	0.108	0.000	0.288	0.095	0.000	0.253	0.084
2007		0.410	0.000	0.080	0.089	0.088	0.000	0.498	0.169	0.000	0.313	0.106	0.000	0.269	0.092	0.000	0.232	0.079
2008		0.410	0.000	0.085	0.091	0.093	0.000	0.503	0.176	0.000	0.298	0.104	0.000	0.252	0.088	0.000	0.213	0.075
2009		0.410	0.000	0.090	0.093	0.097	0.000	0.507	0.183	0.000	0.283	0.102	0.000	0.235	0.085	0.000	0.196	0.070
2010		0.410	0.000	0.094	0.095	0.102	0.000	0.512	0.189	0.000	0.270	0.100	0.000	0.219	0.081	0.000	0.179	0.066
2011	2.220	0.410	0.000	0.099	0.097	0.106	2.220	0.516	0.196	1.103	0.257	0.097	0.882	0.205	0.078	0.707	0.164	0.063
2012		0.440	0.000	0.104	0.099	0.111	0.000	0.551	0.203	0.000	0.258	0.095	0.000	0.203	0.075	0.000	0.160	0.059
2013		0.440	0.000	0.109	0.101	0.115	0.000	0.555	0.210	0.000	0.246	0.093	0.000	0.189	0.071	0.000	0.146	0.055
2014		0.440	0.000	0.113	0.103	0.120	0.000	0.560	0.216	0.000	0.234	0.090	0.000	0.176	0.068	0.000	0.134	0.052
2015		0.440	0.000	0.118	0.105	0.124	0.000	0.564	0.223	0.000	0.222	0.088	0.000	0.165	0.065	0.000	0.123	0.049
2016		0.440	0.000	0.123	0.107	0.129	0.000	0.569	0.230	0.000	0.211	0.085	0.000	0.154	0.062	0.000	0.113	0.045
2017		0.440	0.000	0.128	0.108	0.133	0.000	0.573	0.236	0.000	0.201	0.083	0.000	0.143	0.059	0.000	0.103	0.042
2018		0.440	0.000	0.133	0.110	0.138	0.000	0.578	0.243	0.000	0.191	0.080	0.000	0.134	0.056	0.000	0.094	0.040
2019		0.440	0.000	0.137	0.112	0.142	0.000	0.582	0.250	0.000	0.181	0.078	0.000	0.125	0.054	0.000	0.087	0.037
2020		0.440	0.000	0.142	0.114	0.147	0.000	0.587	0.256	0.000	0.173	0.075	0.000	0.117	0.051	0.000	0.079	0.035
2021	-25.830	0.440	0.000	0.147	0.116	0.151	-25.830	0.591	0.263	-7.168	0.164	0.073	-4.751	0.109	0.048	-3.173	0.073	0.032
TOTAL	**25.640**	**8.500**	**0.000**	**2.030**	**1.960**	**2.170**	**25.640**	**10.670**	**3.990**	**37.768**	**5.316**	**1.907**	**38.354**	**4.352**	**1.541**	**38.237**	**3.613**	**1.263**

	NPC	NPV water	URV, R/kl
AT 6%	**45.0**	**17.1**	**2.64**
AT 8%	**44.2**	**13.7**	**3.23**
AT 10%	**43.1**	**11.2**	**3.85**

ECONOMICS MODEL

Low Demand Scenario
W1: Weir Scheme Option (80% assurance)

Weirs 80%	0.41	0	0.071	0.112	0.066
	0.26		0.213	0.168	0.151

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	18.570						18.570	0.000	0.000	16.527	0.000	0.000	15.921	0.000	0.000	15.347	0.000	0.000
2002		0.410	0.000	0.071	0.112	0.066	0.000	0.476	0.183	0.000	0.400	0.154	0.000	0.378	0.145	0.000	0.358	0.137
2003		0.410	0.000	0.078	0.115	0.070	0.000	0.480	0.193	0.000	0.381	0.153	0.000	0.353	0.142	0.000	0.328	0.132
2004		0.410	0.000	0.086	0.118	0.075	0.000	0.485	0.204	0.000	0.362	0.152	0.000	0.330	0.139	0.000	0.301	0.127
2005		0.410	0.000	0.093	0.121	0.079	0.000	0.489	0.214	0.000	0.345	0.151	0.000	0.308	0.135	0.000	0.276	0.121
2006		0.410	0.000	0.101	0.124	0.084	0.000	0.494	0.225	0.000	0.328	0.149	0.000	0.288	0.131	0.000	0.253	0.115
2007		0.410	0.000	0.108	0.127	0.088	0.000	0.498	0.235	0.000	0.313	0.148	0.000	0.269	0.127	0.000	0.232	0.110
2008		0.410	0.000	0.116	0.130	0.093	0.000	0.503	0.246	0.000	0.298	0.145	0.000	0.252	0.123	0.000	0.213	0.104
2009		0.410	0.000	0.123	0.133	0.097	0.000	0.507	0.256	0.000	0.283	0.143	0.000	0.235	0.119	0.000	0.196	0.099
2010		0.410	0.000	0.131	0.136	0.102	0.000	0.512	0.266	0.000	0.270	0.140	0.000	0.219	0.114	0.000	0.179	0.093
2011	11.000	0.410	0.000	0.138	0.139	0.106	11.000	0.516	0.277	5.467	0.257	0.138	4.368	0.205	0.110	3.505	0.164	0.088
2012		0.670	0.000	0.146	0.141	0.111	0.000	0.781	0.287	0.000	0.366	0.135	0.000	0.287	0.106	0.000	0.226	0.083
2013		0.670	0.000	0.153	0.144	0.115	0.000	0.785	0.298	0.000	0.347	0.132	0.000	0.267	0.101	0.000	0.207	0.078
2014		0.670	0.000	0.161	0.147	0.120	0.000	0.790	0.308	0.000	0.330	0.129	0.000	0.249	0.097	0.000	0.189	0.074
2015		0.670	0.000	0.168	0.150	0.124	0.000	0.794	0.318	0.000	0.313	0.125	0.000	0.232	0.093	0.000	0.173	0.069
2016		0.670	0.000	0.176	0.153	0.129	0.000	0.799	0.329	0.000	0.297	0.122	0.000	0.216	0.089	0.000	0.158	0.065
2017		0.670	0.000	0.183	0.156	0.133	0.000	0.803	0.339	0.000	0.281	0.119	0.000	0.201	0.085	0.000	0.144	0.061
2018		0.670	0.000	0.191	0.159	0.138	0.000	0.808	0.350	0.000	0.267	0.116	0.000	0.187	0.081	0.000	0.132	0.057
2019		0.670	0.000	0.198	0.162	0.142	0.000	0.812	0.360	0.000	0.253	0.112	0.000	0.174	0.077	0.000	0.121	0.054
2020		0.670	0.000	0.206	0.165	0.147	0.000	0.817	0.371	0.000	0.240	0.109	0.000	0.162	0.074	0.000	0.110	0.050
2021	-16.160	0.670	0.000	0.213	0.168	0.151	-16.160	0.821	0.381	-4.484	0.228	0.106	-2.972	0.151	0.070	-1.985	0.101	0.047
TOTAL	**13.410**	**10.800**	**0.000**	**2.840**	**2.800**	**2.170**	**13.410**	**12.970**	**5.640**	**17.509**	**6.157**	**2.677**	**17.317**	**4.965**	**2.158**	**16.867**	**4.063**	**1.765**

	NPC	NPV water	URV, R/kl
AT 6%	**26.3**	**17.1**	**1.54**
AT 8%	**24.4**	**13.7**	**1.78**
AT 10%	**22.7**	**11.2**	**2.03**

ECONOMICS MODEL

Low Demand Scenario

W1G: Conjunctive Weir and Groudwater (90% assurance)

0.41	0.33	0.185	0.112	0.066	
0.26	0.33	0.669	0.168	0.151	

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	18.570						18.570	0.000	0.000	16.527	0.000	0.000	15.921	0.000	0.000	15.347	0.000	0.000
2002	9.900	0.410	0.330	0.185	0.112	0.066	9.900	0.806	0.297	8.312	0.677	0.249	7.859	0.640	0.236	7.438	0.606	0.223
2003		0.410	0.330	0.210	0.115	0.070	0.000	0.810	0.325	0.000	0.642	0.258	0.000	0.596	0.239	0.000	0.554	0.222
2004		0.410	0.330	0.236	0.118	0.075	0.000	0.815	0.354	0.000	0.609	0.264	0.000	0.555	0.241	0.000	0.506	0.220
2005		0.410	0.330	0.261	0.121	0.079	0.000	0.819	0.382	0.000	0.578	0.269	0.000	0.516	0.241	0.000	0.463	0.216
2006		0.410	0.330	0.287	0.124	0.084	0.000	0.824	0.411	0.000	0.548	0.273	0.000	0.481	0.240	0.000	0.423	0.211
2007		0.410	0.330	0.312	0.127	0.088	0.000	0.828	0.439	0.000	0.520	0.276	0.000	0.448	0.237	0.000	0.386	0.205
2008		0.410	0.330	0.338	0.130	0.093	0.000	0.833	0.468	0.000	0.493	0.277	0.000	0.417	0.234	0.000	0.353	0.198
2009		0.410	0.330	0.363	0.133	0.097	0.000	0.837	0.496	0.000	0.468	0.277	0.000	0.388	0.230	0.000	0.323	0.191
2010		0.410	0.330	0.389	0.136	0.102	0.000	0.842	0.524	0.000	0.443	0.276	0.000	0.361	0.225	0.000	0.295	0.184
2011	11.000	0.410	0.660	0.414	0.139	0.106	11.000	1.176	0.553	5.467	0.585	0.275	4.368	0.467	0.220	3.505	0.375	0.176
2012	10.300	0.670	0.660	0.440	0.141	0.111	10.300	1.441	0.581	4.829	0.675	0.272	3.787	0.530	0.214	2.984	0.417	0.168
2013		0.670	0.660	0.465	0.144	0.115	0.000	1.445	0.610	0.000	0.639	0.270	0.000	0.492	0.208	0.000	0.381	0.161
2014		0.670	0.660	0.491	0.147	0.120	0.000	1.450	0.638	0.000	0.605	0.266	0.000	0.457	0.201	0.000	0.347	0.153
2015		0.670	0.660	0.516	0.150	0.124	0.000	1.454	0.666	0.000	0.572	0.262	0.000	0.424	0.195	0.000	0.316	0.145
2016		0.670	0.660	0.542	0.153	0.129	0.000	1.459	0.695	0.000	0.542	0.258	0.000	0.394	0.188	0.000	0.289	0.137
2017		0.670	0.660	0.567	0.156	0.133	0.000	1.463	0.723	0.000	0.513	0.253	0.000	0.366	0.181	0.000	0.263	0.130
2018		0.670	0.660	0.593	0.159	0.138	0.000	1.468	0.752	0.000	0.485	0.248	0.000	0.340	0.174	0.000	0.240	0.123
2019		0.670	0.660	0.618	0.162	0.142	0.000	1.472	0.780	0.000	0.459	0.243	0.000	0.316	0.167	0.000	0.219	0.116
2020	7.350	0.670	0.880	0.644	0.165	0.147	7.350	1.697	0.809	2.162	0.499	0.238	1.460	0.337	0.161	0.993	0.229	0.109
2021	-26.420	0.670	0.880	0.669	0.168	0.151	-26.420	1.701	0.837	-7.332	0.472	0.232	-4.860	0.313	0.154	-3.246	0.209	0.103
TOTAL	**30.700**	**10.800**	**10.670**	**8.540**	**2.800**	**2.170**	**30.700**	**23.640**	**11.340**	**29.966**	**11.023**	**5.238**	**28.536**	**8.837**	**4.183**	**27.021**	**7.193**	**3.391**

	NPC	NPV water	URV, R/kl
AT 6%	**46.2**	**17.1**	**2.71**
AT 8%	**41.6**	**13.7**	**3.03**
AT 10%	**37.6**	**11.2**	**3.36**

ECONOMICS MODEL

Low Demand Scenario

OPTION W2/G

0.37	0.67	0.699	0.074	0.046	
0	0.51	1.459	0.104	0.095	

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	O&M Weir	O&M BH	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	14.570						14.570	0.000	0.000	12.967	0.000	0.000	12.491	0.000	0.000	12.041	0.000	0.000
2002	21.100	0.370	0.670	0.699	0.074	0.046	21.100	1.086	0.773	17.716	0.912	0.649	16.750	0.862	0.614	15.853	0.816	0.581
2003		0.370	0.670	0.739	0.076	0.049	0.000	1.089	0.815	0.000	0.862	0.645	0.000	0.800	0.599	0.000	0.744	0.556
2004		0.370	0.670	0.779	0.077	0.051	0.000	1.091	0.856	0.000	0.815	0.640	0.000	0.743	0.583	0.000	0.678	0.532
2005		0.370	0.670	0.819	0.079	0.054	0.000	1.094	0.898	0.000	0.771	0.633	0.000	0.689	0.566	0.000	0.617	0.507
2006		0.370	0.670	0.859	0.080	0.056	0.000	1.096	0.939	0.000	0.729	0.625	0.000	0.640	0.548	0.000	0.563	0.482
2007		0.370	0.670	0.899	0.082	0.059	0.000	1.099	0.981	0.000	0.689	0.615	0.000	0.594	0.530	0.000	0.513	0.458
2008		0.370	0.670	0.939	0.083	0.061	0.000	1.101	1.022	0.000	0.652	0.605	0.000	0.551	0.511	0.000	0.467	0.434
2009		0.370	0.670	0.979	0.085	0.064	0.000	1.104	1.064	0.000	0.616	0.594	0.000	0.511	0.493	0.000	0.426	0.410
2010		0.370	0.670	1.019	0.087	0.067	0.000	1.107	1.106	0.000	0.583	0.582	0.000	0.475	0.474	0.000	0.388	0.388
2011		0.370	1.180	1.059	0.088	0.069	0.000	1.619	1.147	0.000	0.805	0.570	0.000	0.643	0.456	0.000	0.516	0.366
2012	16.000	0.370	1.180	1.099	0.090	0.072	16.000	1.622	1.189	7.501	0.760	0.557	5.883	0.596	0.437	4.635	0.470	0.344
2013		0.370	1.180	1.139	0.091	0.074	0.000	1.624	1.230	0.000	0.718	0.544	0.000	0.553	0.419	0.000	0.428	0.324
2014		0.370	1.180	1.179	0.093	0.077	0.000	1.627	1.272	0.000	0.679	0.531	0.000	0.513	0.401	0.000	0.389	0.304
2015		0.370	1.180	1.219	0.095	0.080	0.000	1.630	1.314	0.000	0.641	0.517	0.000	0.476	0.383	0.000	0.355	0.286
2016		0.370	1.180	1.259	0.096	0.082	0.000	1.632	1.355	0.000	0.606	0.503	0.000	0.441	0.366	0.000	0.323	0.268
2017		0.370	1.180	1.299	0.098	0.085	0.000	1.635	1.397	0.000	0.573	0.489	0.000	0.409	0.350	0.000	0.294	0.251
2018		0.370	1.180	1.339	0.099	0.087	0.000	1.637	1.438	0.000	0.541	0.475	0.000	0.379	0.333	0.000	0.268	0.235
2019		0.370	1.180	1.379	0.101	0.090	0.000	1.640	1.480	0.000	0.511	0.461	0.000	0.352	0.317	0.000	0.244	0.220
2020	12.600	0.370	1.580	1.419	0.102	0.092	12.600	2.042	1.521	3.706	0.601	0.448	2.503	0.406	0.302	1.703	0.276	0.206
2021	-25.570	0.370	1.580	1.459	0.104	0.095	-25.570	2.045	1.563	-7.096	0.567	0.434	-4.703	0.376	0.287	-3.141	0.251	0.192
TOTAL	**38.700**	**7.400**	**19.810**	**21.580**	**1.780**	**1.410**	**38.700**	**28.620**	**23.360**	**34.795**	**13.634**	**11.119**	**32.924**	**11.009**	**8.970**	**31.090**	**9.023**	**7.343**

	NPC	NPV water	URV, R/kl
AT 6%	**59.5**	**17.1**	**3.49**
AT 8%	**52.9**	**13.7**	**3.86**
AT 10%	**47.5**	**11.2**	**4.24**

ECONOMICS MODEL

Low Demand Scenario

OPTION G1: GROUNDWATER STAND ALONE SCHEME

0	0.67	2.314	0	0
0	0.51	5.206	0	0

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	O&M Weir	O&M BH	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001							0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2002	21.100	0.000	0.670	2.314	0.000	0.000	21.100	0.670	2.314	17.716	0.563	1.943	16.750	0.532	1.837	15.853	0.503	1.739
2003		0.000	0.670	2.466	0.000	0.000	0.000	0.670	2.466	0.000	0.531	1.953	0.000	0.492	1.813	0.000	0.458	1.684
2004		0.000	0.670	2.618	0.000	0.000	0.000	0.670	2.618	0.000	0.501	1.957	0.000	0.456	1.782	0.000	0.416	1.626
2005		0.000	0.670	2.771	0.000	0.000	0.000	0.670	2.771	0.000	0.472	1.953	0.000	0.422	1.746	0.000	0.378	1.564
2006		0.000	0.670	2.923	0.000	0.000	0.000	0.670	2.923	0.000	0.446	1.944	0.000	0.391	1.705	0.000	0.344	1.500
2007		0.000	0.670	3.075	0.000	0.000	0.000	0.670	3.075	0.000	0.420	1.929	0.000	0.362	1.661	0.000	0.313	1.435
2008		0.000	0.670	3.227	0.000	0.000	0.000	0.670	3.227	0.000	0.397	1.910	0.000	0.335	1.614	0.000	0.284	1.369
2009		0.000	0.670	3.379	0.000	0.000	0.000	0.670	3.379	0.000	0.374	1.887	0.000	0.310	1.565	0.000	0.258	1.303
2010		0.000	0.670	3.532	0.000	0.000	0.000	0.670	3.532	0.000	0.353	1.860	0.000	0.287	1.515	0.000	0.235	1.238
2011		0.000	1.180	3.684	0.000	0.000	0.000	1.180	3.684	0.000	0.586	1.831	0.000	0.469	1.463	0.000	0.376	1.174
2012	16.000	0.000	1.180	3.836	0.000	0.000	16.000	1.180	3.836	7.501	0.553	1.799	5.883	0.434	1.411	4.635	0.342	1.111
2013		0.000	1.180	3.988	0.000	0.000	0.000	1.180	3.988	0.000	0.522	1.764	0.000	0.402	1.358	0.000	0.311	1.050
2014		0.000	1.180	4.141	0.000	0.000	0.000	1.180	4.141	0.000	0.492	1.728	0.000	0.372	1.305	0.000	0.282	0.991
2015		0.000	1.180	4.293	0.000	0.000	0.000	1.180	4.293	0.000	0.465	1.690	0.000	0.344	1.253	0.000	0.257	0.934
2016		0.000	1.180	4.445	0.000	0.000	0.000	1.180	4.445	0.000	0.438	1.651	0.000	0.319	1.201	0.000	0.233	0.879
2017		0.000	1.180	4.597	0.000	0.000	0.000	1.180	4.597	0.000	0.413	1.611	0.000	0.295	1.150	0.000	0.212	0.827
2018		0.000	1.180	4.749	0.000	0.000	0.000	1.180	4.749	0.000	0.390	1.570	0.000	0.273	1.100	0.000	0.193	0.777
2019		0.000	1.180	4.902	0.000	0.000	0.000	1.180	4.902	0.000	0.368	1.528	0.000	0.253	1.052	0.000	0.175	0.729
2020	12.600	0.000	1.580	5.054	0.000	0.000	12.600	1.580	5.054	3.706	0.465	1.487	2.503	0.314	1.004	1.703	0.214	0.683
2021	-18.470	0.000	1.580	5.206	0.000	0.000	-18.470	1.580	5.206	-5.126	0.438	1.445	-3.397	0.291	0.958	-2.269	0.194	0.640
TOTAL	**31.230**	**0.000**	**19.810**	**75.200**	**0.000**	**0.000**	**31.230**	**19.810**	**75.200**	**23.798**	**9.187**	**35.439**	**21.739**	**7.354**	**28.494**	**19.921**	**5.978**	**23.251**

	NPC	NPV water	URV, R/kl
AT 6%	**68.4**	**17.1**	**4.01**
AT 8%	**57.6**	**13.7**	**4.20**
AT 10%	**49.2**	**11.2**	**4.39**

Low demand scenario

	35			
	80			
YEAR	**TOTAL SUPPLY (x1000 m3)**	**NPV of water supplied at 6% (x1000 m3)**	**NPV of water supplied at 8% (x1000 m3)**	**NPV of water supplied at 10% (x1000 m3)**
1999		0	0	0
2000		0	0	0
2001		0	0	0
2002	1.104	0.927	0.876	0.829
2003	1.178	0.933	0.866	0.805
2004	1.253	0.936	0.853	0.778
2005	1.328	0.936	0.837	0.750
2006	1.403	0.933	0.818	0.720
2007	1.477	0.927	0.798	0.689
2008	1.552	0.919	0.776	0.658
2009	1.627	0.908	0.753	0.627
2010	1.701	0.896	0.730	0.596
2011	1.776	0.883	0.705	0.566
2012	1.851	0.868	0.680	0.536
2013	1.925	0.852	0.656	0.507
2014	2.000	0.835	0.630	0.479
2015	2.075	0.817	0.606	0.452
2016	2.149	0.798	0.581	0.425
2017	2.224	0.779	0.557	0.400
2018	2.299	0.760	0.533	0.376
2019	2.373	0.740	0.509	0.353
2020	2.448	0.720	0.486	0.331
2021	2.523	0.700	0.464	0.310
TOTAL	**36.266**	**17.066**	**13.715**	**11.186**

APPENDIX K :

AREA-CAPACITY RELATIONSHIPS:
ZALU AND LUSIKISIKI DAMS

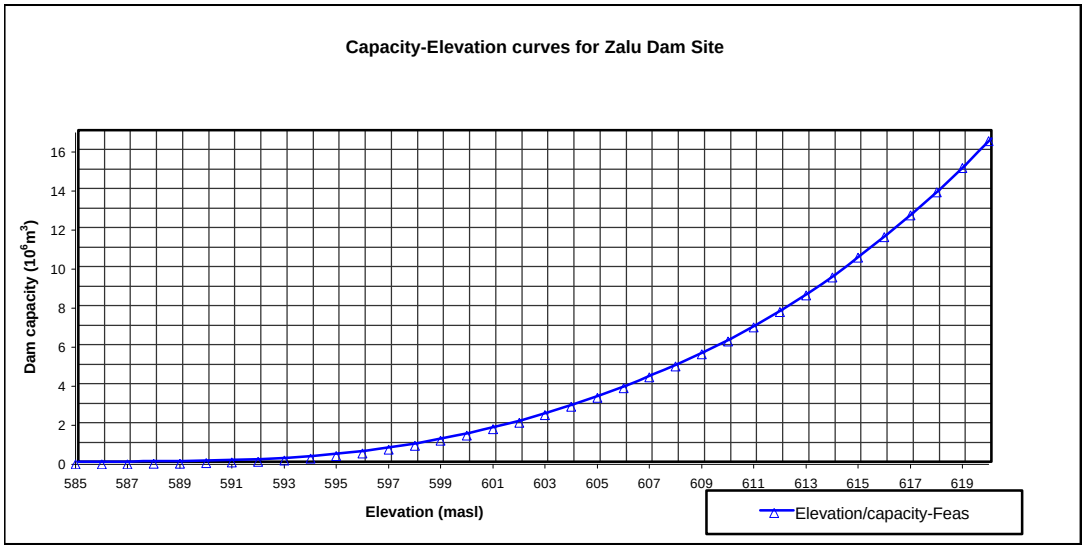
PRE-FEASIBILITY PHASE

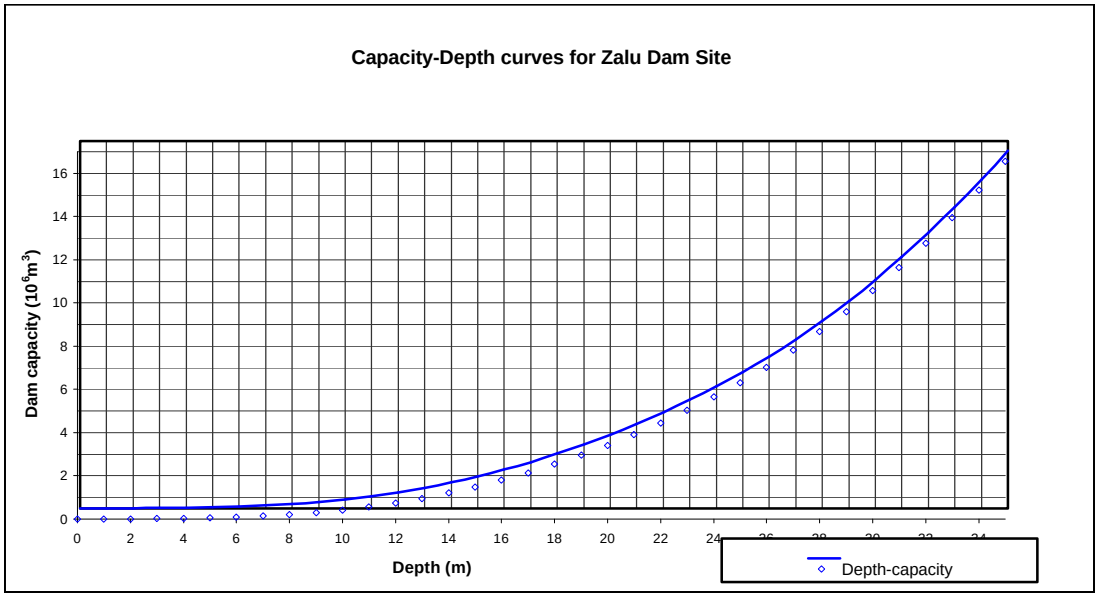
Area-capacity data for Zalu Dam

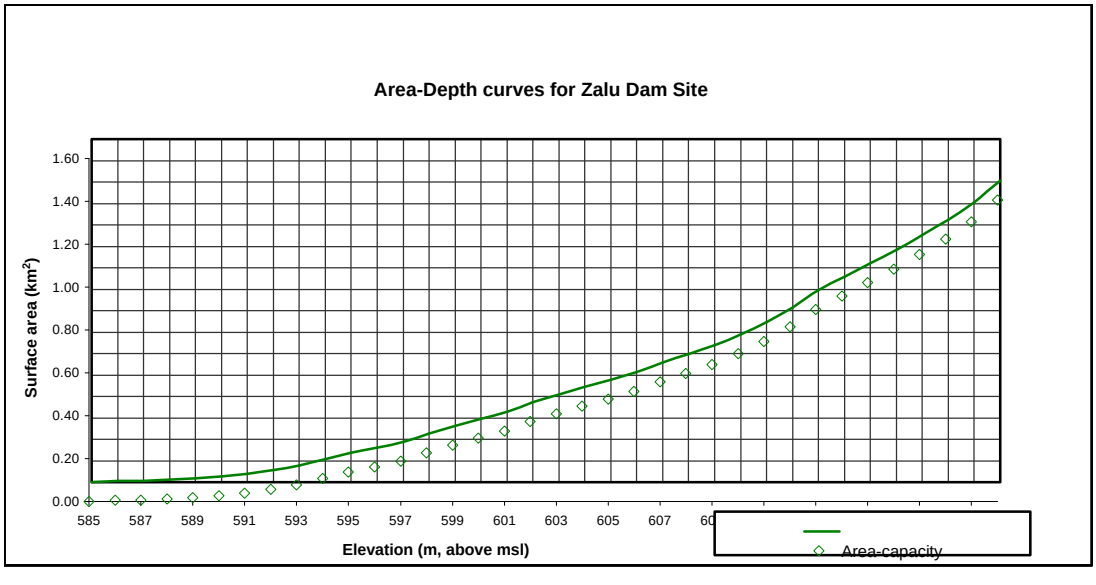
Based on aerial surveys

River bed level 585

Elevation (m, above msl)	Height (m, to FSL)	Surface area (km^2)	Capacity ($10^6 m^3$)
585	0	0.000	0.000
586	1	0.005	0.002
587	2	0.007	0.008
588	3	0.011	0.017
589	4	0.018	0.032
590	5	0.028	0.055
591	6	0.039	0.088
592	7	0.056	0.136
593	8	0.079	0.204
594	9	0.107	0.299
595	10	0.137	0.426
596	11	0.161	0.574
597	12	0.188	0.750
598	13	0.228	0.958
599	14	0.261	1.202
600	15	0.295	1.480
601	16	0.329	1.792
602	17	0.372	2.144
603	18	0.408	2.534
604	19	0.444	2.958
605	20	0.477	3.418
606	21	0.513	3.913
607	22	0.558	4.450
608	23	0.596	5.029
609	24	0.639	5.646
610	25	0.691	6.312
611	26	0.746	7.030
612	27	0.814	7.814
613	28	0.896	8.667
614	29	0.959	9.596
615	30	1.020	10.585
616	31	1.084	11.637
617	32	1.153	12.756
618	33	1.225	13.945
619	34	1.304	15.209
620	35	1.406	16.562


Capacity-Elevation curves for Zalu Dam Site
Dam capacity (10^6m^3)
0
2
4
6
8
10
12
14
16
585
587
589
591
593
595
597
599
601
603
605
607
609
611
613
615
617
619
Elevation (masl)
Elevation/capacity-Feas


Capacity-Depth curves for Zalu Dam Site
Dam capacity (10^6m^3)
0
2
4
6
8
10
12
14
16
0
2
4
6
8
10
12
14
16
18
20
22
Depth (m)
Depth-capacity

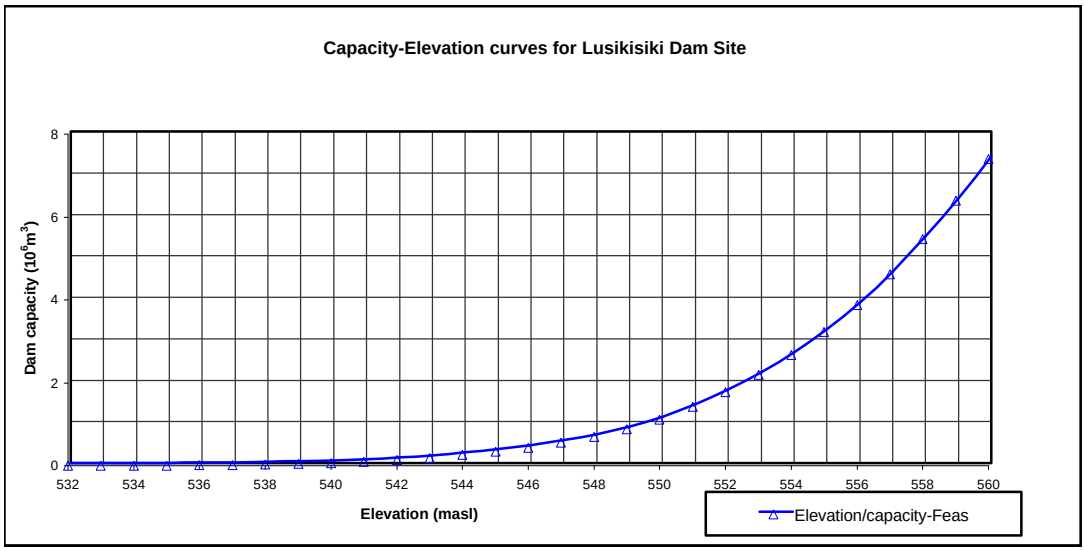

Area-Depth curves for Zalu Dam Site
Surface area (km^2)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
1.40
1.60
585
587
589
591
593
595
597
599
601
603
605
607
Elevation (m, above msl)
Area-capacity

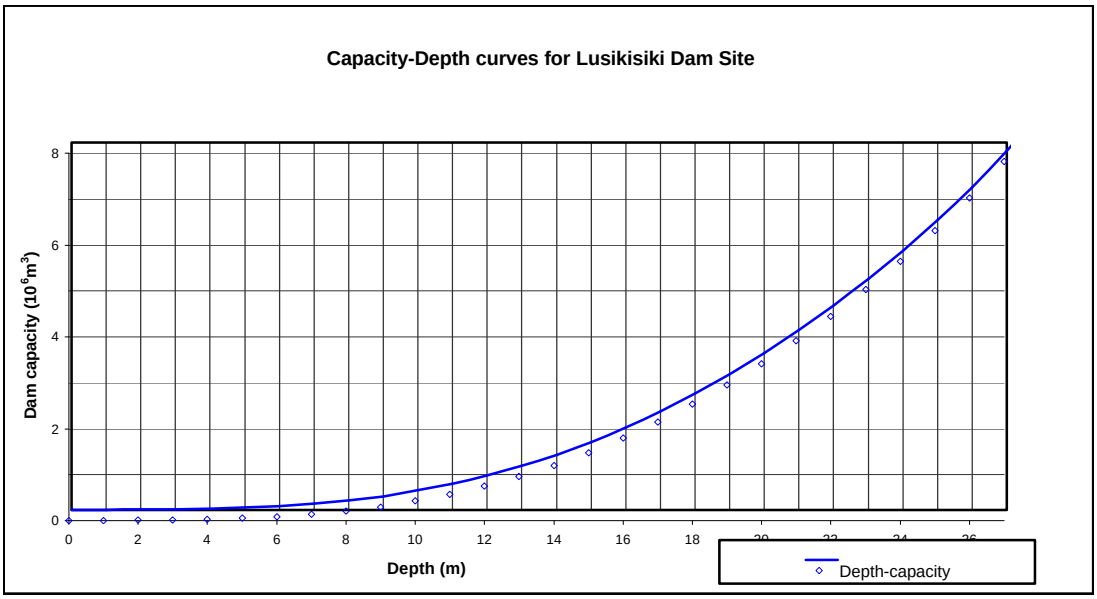
Area-capacity data for Lusikisiki Dam

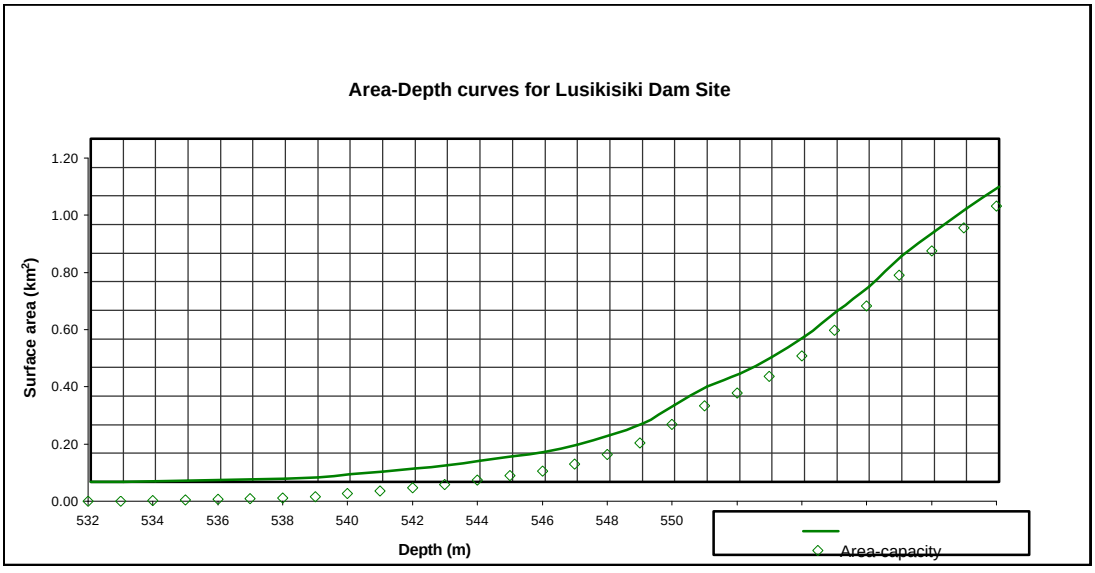
Based on aerial surveys

River bed level 533

Elevation (m, above msl)	Height (m, to FSL)	Surface area (km^2)	Capacity ($10^6 m^3$)
532	-1	0.001	0.000
533	0	0.001	0.001
534	1	0.002	0.002
535	2	0.005	0.005
536	3	0.007	0.011
537	4	0.009	0.018
538	5	0.012	0.028
539	6	0.015	0.042
540	7	0.027	0.064
541	8	0.037	0.096
542	9	0.047	0.137
543	10	0.058	0.190
544	11	0.075	0.258
545	12	0.090	0.339
546	13	0.106	0.436
547	14	0.130	0.551
548	15	0.162	0.697
549	16	0.203	0.879
550	17	0.268	1.112
551	18	0.333	1.417
552	19	0.378	1.775
553	20	0.436	2.187
554	21	0.507	2.665
555	22	0.597	3.224
556	23	0.683	3.870
557	24	0.791	4.620
558	25	0.875	5.462
559	26	0.957	6.391
560	27	1.033	7.399


Capacity-Elevation curves for Lusikisiki Dam Site
Dam capacity ($10^6 m^3$)
0
2
4
6
8
532
534
536
538
540
542
544
546
548
550
552
554
556
558
560
Elevation (masl)
Elevation/capacity-Feas


Capacity-Depth curves for Lusikisiki Dam Site
Dam capacity ($10^6 m^3$)
0
2
4
6
8
0
2
4
6
8
10
12
14
16
18
Depth (m)
Depth-capacity


Area-Depth curves for Lusikisiki Dam Site
Surface area (km^2)
0.00
0.20
0.40
0.60
0.80
1.00
1.20
532
534
536
538
540
542
544
546
548
550
Depth (m)
Area-capacity

APPENDIX L1 :

SIZING CRITERIA: DAMS

PRE-FEASIBILITY PHASE

Appendix L1.1

SIZING REPORT: ZALU DAM

PRE-FEASIBILITY PHASE

The Proposed Zalu Dam site is situated in the Xura River, approximately 11 km north west of the town of Lusikisiki, in the Eastern Cape province.

The dam will be a mass gravity structure with a central uncontrolled spillway constructed of Roller Compacted Concrete (RCC). The conceptual design plans are provided in Appendix 4.

The size of the catchment area is 71km^2.

The flood hydrology of the Zalu site has been analysed by the Directorate: Hydrology of the DWAF. The recommended flood peaks in **Table 1** below are obtained from the Flood Analysis Report (PB T600-00-1001, August 1999).

Table 1: Recommended flood peaks at Zalu Dam site (storm duration = 3,5h)

Return period (years)	Flood peak (m^3/s)
2	55
5	125
10	180
20	240
50	337
100	420
200	505
RMF	1 090

RMF = Regional Maximum Flood

Design Floods

The proposed Zalu Dam is classified as a Category II safety risk :

Size: Medium
Hazard Rating: Significant

The guidelines contained in "Safety in relation to Floods, SANCOLD, 1991" were used to estimate the Safety Evaluation Discharge (SED) and Recommended Design Discharge (RDD). According to this reference, the capacity of the spillway should be sufficient to pass the SED in such a way that although substantial damage may be sustained, the dam will not fail. The value of the SED recommended for dams of the above size class and hazard rating is as follows:

SED = RMF

where:

RMF = Regional Maximum Flood

It was therefore decided to adopt a SED of 1 090 m^3/s as the maximum flood for sizing of the dam spillway. The Recommended Design Discharge is the flood with a return period of 100 years, which is estimated as 420 m^3/s.

Floods for spillway sizing

The following results of the hydrological flood analyses are thus adopted for the design of the spillway capacity of Zalu Dam.

(i) Safety Evaluation Discharge (SED): 1 090 m^3/s
(ii) Recommended Design Discharge (RDD): 420 m^3/s

Dam Levels

The stage-area-capacity data at the proposed site were obtained from 1: 5 000 contour maps of the dam basin, surveyed for the purposes of this study (**Appendix K**). The FSL of the dam has been set at RL 607.0 m and the NOC at RL 610,50 m, resulting in a storage capacity of approximately $4,4x10^6$ m^3.

HYDRAULICS

Freeboard

The maximum total freeboard is 3,5 m, being the vertical distance between the normal full supply level (FSL at RL 607 m) and the non overflow crest level(NOC at RL 610,50 m).

The adequacy of the freeboard has been checked against the guidelines in "Interim Guidelines on freeboard for Dams; Sancold; Report no. 3; 1990" for two discharge conditions: the design discharge (Q_{100}) and the safety evaluation discharge (SED).

Design flood (Q_{100} = 420 m^3/s)

For the unattenuated design flood surcharge (1,79 m) and allowing for wind wave (0,36 m), the total required freeboard is 2,15 m. The available freeboard is therefore more than adequate.

Safety evaluation discharge

For this case, freeboard for flood surcharge only is required. The maximum overflow height for the unrouted SED of 1 090 m^3/s is 3,28 m. The freeboard requirement is therefore governed by the SED. The fact that the flood is not routed, as well as the provision of an additional 0, 22 m of freeboard, is regarded as a safety margin against potential future changes in hydrological conditions

Discharge capacity

The ogee shaped spillway section has a total length of 90 m with freeboard of 3,50 m. The ogee crest is shaped for a flood of 710 m^3/s (Hd = 2,50 m). This is done to limit the design head to approximately two thirds of the value of the maximum potential discharge head (Hmax = 3,28 m), in order to minimize the risk of cavitation at maximum discharge capacity.

The theoretical discharge capacity of the spillway:

$Q = 1,8554 \times L \times H^{1,5795}$
L = spillway length (m)

H = head above crest (m)
Q = total discharge (m^3/s)

The maximum theoretical discharge capacity is 1 208 m3/s, i.e. well in excess of the unrouted Safety Evaluation Discharge.

Energy dissipation and apron design

The downstream face of the spillway is stepped in order to assist with the hydraulic dissipation of energy; the extent of energy dissipation that will be achieved is however uncertain. Data on a number of stepped RCC spillways constructed in South Africa is listed in the paper "The design and construction of RCC dams in South Africa, JJ Geringer, 1996". Various dams already constructed in SA have design and maximum unit discharge rates larger than Zalu Dam (q_{100} = 4,7 $m^3/s/m$ and q_{max} = 12,1 $m^3/s/m$).

SEISMIC HAZARD

No site specific assessment of the seismic hazard has been made. However, the Zalu dam site is located in an area of low seismic activity.

DESIGN DETAIL OF THE CONCRETE SECTIONS

General

The feasibility layout of the dam was refined taking account the additional topographical information obtained during the course of the study (site cross section and dam basin surveys), Appendices 7 and 8

The dam is designed as a RCC structure with un-reinforced concrete facing, while the outlet works is designed as a conventional reinforced concrete structure. The excavation depths have been assumed in accordance with the recommendations of the geological investigations. Conventional mass concrete will therefore be placed on the uneven foundation levels to serve as a starting surface for the rollcrete.

The NOC sections and the upstream face of the spillway have smooth surfaces while the downstream face of the spillway is stepped.

Spillway and apron

The spillway section is 90 m long, with a smooth vertical upstream face, a conventional reinforced concrete ogee shaped cap, and a stepped downstream face with a slope of 1:0,75. All steps have dimensions of 1 m high by 0,75 m wide. The overspill section terminates on a reinforced concrete apron of 1,5 m average thickness. The apron is 15 m long and 101 m wide.

Non Overflow Section

The NOC consists of two flanks. The right is 51 m and the left is 86 m long. The downstream slope is vertical (RL 610.50 to RL 607.30) and has a slope of 1:0,75 below RL 607.30. The upstream face of the wall is vertical.

The crest width at the NOC is 6 m, which is wider than the minimum width recommended for effective rollcrete placing. Steel handrails are provided on the upstream and downstream crests of both walls.

Gallery system

The functions of the gallery system include provision of access between the intake tower and outlet control room, access for inspection and for drilling equipment (curtain grout holes, pressure relief holes and drainage holes to top) collection and drainage of seepage water and flow measurement of water discharging from the foundation drainage system. A single 3,0 m high by 2,5 m wide inspection gallery was designed through the spillway section and outlet structure.

OUTLET STRUCTURE

Sizing

The outlet works were sized to supply at least the maximum estimated required quantities for domestic use and to maintain the biophysical integrity of the Xura River downstream of the dam.

Bulk raw water for domestic purposes will be supplied directly from the outlet works. The ecological requirements will be supplied by means of river releases.

Design details

For design details of the outlet works, refer to sheets Appendix 4. The outlet works comprise an upstream intake structure and downstream control room as well as an intake control chamber.

The intake structure on the upstream side of the dam is 25 m high by 11 m wide. The upstream face of the intake structure is fitted with precast concrete coarse trash racks. Provision is made for fine screens. A dry well runs down the full height of the structure. A total of 4 intakes are connected to the two 600 mm nominal bore vertical service outlet pipes, which are encased in concrete. The upper 2 service intakes, of which the bottom one is situated at the lowest operating level, are staggered at 2,9 m intervals. The lowest two intakes, both at RL 594,00 m will serve three purposes, namely for scouring of silt from the area immediately surrounding the intake structure, for river diversion during construction and for rapid drawdown in case of emergency.

Each of the inlets is provided with a butterfly valve for level selection. The intakes can also be isolated individually by means of an emergency gate lowered in front of the intake pipes.

Control steel platforms are situated adjacent to each butterfly valve. Steel ladders provide access between the top and bottom sections of the intake structure. The outlet control room is accessible from the intake structure by means of a 2,5 m wide concrete gallery

The two vertical 600 mm diameter service outlet pipes are joined at RL 594,00 to the two horizontal scour pipes of the same diameter. The combined scour pipes /service outlets pass straight beneath the dam wall.

The outlet control room is situated at the downstream end of the main gallery, which also provides access to the intake tower. It has a plan dimension of 6,2 m by 5,0 m (from wall to wall) and is built at RL 595,30.

Three 400 mm diameter hooded sleeve valves are provided at the discharge point.

Five of the butterfly valves required for pipe selection control for the domestic offtakes are housed in the level below the outlet control room.

Maximum discharge capacity

The maximum discharges, through a single valve, with the flow velocity limited to 7 m/s, and the valve fully open, are:

400 mm valve:	FSL= RL 607,00m	1,4 m^3/s
	LDL= RL 597,90m	0,3 m^3/s

Appendix L1.2

SIZING CRITERIA LUSIKISIKI DAM

PRE-FEASIBILITY PHASE

The Proposed Lusikisiki Dam will be a composite earthfill-mass gravity structure with a central uncontrolled spillway constructed of Roller Compacted Concrete (RCC). The conceptual design plans are provided in Appendix 4. The size of the catchment area is 91km^2.

Floods

The flood hydrology of the Dam site has been analysed by the Directorate: Hydrology of the DWAF. The recommended flood peaks in **Table 1** below are in accordance with the results of the Flood Frequency Analysis undertaken for this site (Report no. PB T600-00-1001, August 1999).

Table 1: Recommended flood peaks at Lusikisiki Dam site (storm duration = 5,0h)

Return period (years)	Flood peak (m^3/s)
2	60
5	140
10	210
20	285
50	405
100	510
200	622
RMF	1 250

RMF = Regional Maximum Flood

Design Floods

The proposed Lusikisiki Dam is classified as a Category III safety risk :

Size: Large
Hazard Rating: Significant

The guidelines contained in "Safety in relation to Floods, SANCOLD, 1991" were used to estimate the Safety Evaluation Discharge (SED) and Recommended Design Discharge (RDD). According to this reference, the capacity of the spillway should be sufficient to pass the SED in such a way that although substantial damage may be sustained, the dam will not fail. The value of the SED recommended for dams of the above size class and hazard rating is as follows:

SED = RMF+D

where:

RMF = Regional Maximum Flood at a K value of the adjacent region numerically one step higher than the one in which the dam is situated.

K = Francou-Fodier Regional Coefficient

From Report no. Tr 137," Regional Maximum Flood Peaks in Southern Africa, DWAF, Directorate of Hydrology, 1988", the K values of the region in which the proposed Lusikisiki Dam is situated and than of the adjacent higher region are 5,2 and 5,4 respectively.

According to Technical report TR 137 the maximum expected increase in K value is 0,2. The appropriate K value for evaluation of the SED would therefore be 5,4.

It was therefore decided to adopt a SED of 1 640 m^3/s as the maximum flood for sizing of the dam spillway.

The Recommended Design Discharge is the flood with a return period of 200 years, which is estimated to be 622 m^3/s, from the data presented in Flood Hydrology Report no. T600-R000-9908-A.

Floods for spillway sizing

The following results of the hydrological flood analyses are thus adopted for the design of the spillway capacity of Lusikisiki Dam.

(i) Safety Evaluation Discharge (SED): 1 640 m^3/s
(ii) Recommended Design Discharge (RDD): 622 m^3/s

Dam Levels

The stage-area-capacity data at the proposed site were obtained from 1: 5 000 contour maps of the dam basin, surveyed for the purposes of this study (**Appendix K**). The FSL of the dam has been set at RL 555.80 m and the NOC at RL 661,60 m, resulting in a storage capacity of approximately $4,4x10^6$ m^3.

HYDRAULICS

Freeboard

The maximum total freeboard of 5,8 m, being the vertical distance between the normal full supply level (FSL at RL 555,8 m) and the non overflow crest (NOC at RL 561,6 m).

The adequacy of the freeboard has been checked against the guidelines in "Interim Guidelines on freeboard for Dams; Sancold; Report no. 3; 1990" for two discharge conditions: the design discharge (Q_{200}) and the safety evaluation discharge (SED).

Design flood (Q_{200} = 622 m^3/s)

For the unattenuated design flood surcharge (3,00 m) and allowing for wind wave (0,30 m), the total required freeboard is 3,30 m. The available freeboard is therefore more than adequate.

Safety evaluation discharge

For this case, freeboard for flood surcharge only is required. The maximum overflow height for the unrouted SED of 1 640 m^3/s is 5,50 m. The freeboard requirement is therefore governed by the SED. The fact that the flood is not routed, as well as the provision of an additional 0,30 m of freeboard, is regarded as a safety margin against potential future changes in hydrological conditions

Discharge capacity

The ogee shaped spillway section has a total length of 60 m with freeboard of 5,80 m. The ogee crest is shaped for a flood of 880 m^3/s (Hd = 3,70 m). This is done to limit the design head to approximately two thirds of the value of the maximum potential discharge head (Hmax = 5,50 m), in order to minimize the risk of cavitation at maximum discharge capacity.

The theoretical discharge capacity of the spillway:

$Q = 1,8554 \times L \times H^{1,5795}$
L = spillway length (m)
H = head above crest (m)
Q = total discharge (m^3/s)

The maximum theoretical discharge capacity is 1 788 m3/s, i.e. well in excess of the un-routed Safety Evaluation Discharge.

Energy dissipation and apron design

The downstream face of the spillway is stepped in order to assist with the hydraulic dissipation of energy. Data for a number of stepped RCC spillways constructed in South Africa is listed in the paper "The design and construction of RCC dams in South Africa, JJ Geringer, 1996". Various dams already constructed in SA have design and maximum unit discharge rates order bigger as Lusikisiki Dam (q_{200} = 10,4 $m^3/s/m$).

SEISMIC HAZARD

No site specific assessment of the seismic hazard has been made. However, the Lusikisiki Dam site is located in an area of low seismic activity.

EMBANKMENT DETAILS

Embankment slopes

A tongue wall is enveloped by embankment which is 185 m long, measured from the outer end of the tongue wall to the end of the embankment. The embankment is zoned, comprising a central clay core supported either side by zones of semi-previous materials. The upstream and downstream slopes of the outer shell zones are 1V:2,5H. The width of the crest is 6,0 m with a 2% slope towards the upstream edge. The width of the crest is 6 m.

DESIGN DETAIL OF THE CONCRETE SECTIONS

General

The reconnaissance sizing of the dam was refined taking into account the results of the additional topographical and geological investigations undertaken during the pre-feasibility phase.

The concrete dam section is designed as RCC structure with un-reinforced concrete facing, while the outlet works are designed as a conventional reinforced concrete structure. The excavation depths have been determined in accordance with the recommendations of the geological investigations (exploration drilling) . Conventional mass concrete will therefore be placed on the uneven foundation levels to serve as a starting surface for the rollcrete.

The NOC section and the upstream face of the spillway have smooth surfaces while the downstream face of the spillway is stepped.

Spillway and apron

The spillway section is 60 m long, with a smooth vertical upstream face a conventional reinforced concrete ogee shaped cap on top and a stepped downstream face with a slope of 1:0,75. All steps have dimensions of 1 m high by 0,75 m wide. The overspill section terminates on a reinforced concrete apron of 1,5 m average thickness. The apron is 17 m long and 71 m wide.

Non Overflow Section

The crest width at the NOC is 6 m, which is wider then minimum width for effective rollcrete placing. Steel handrails are provided on the upstream and downstream crests.

The downstream slope is vertical between RL 561,60 and RL 552,40 and has a slope of 1:0,75 below RL 552,40. The upstream slope is vertical.

Gallery system

The functions of the gallery system include provision of access between the intake tower and outlet control room, access for inspection and for drilling equipment (curtain grout holes, pressure relief holes and drainage holes to top) collection and drainage of seepage water and flow measurement of water discharging from the foundation drainage system. A single 3,0 m high by 2,5 m wide inspection gallery was designed through the spillway section and outlet structure.

OUTLET STRUCTURE

Sizing

The outlet works were sized to supply at least the maximum estimated required quantities for domestic use and to maintain the biophysical integrity of the Xura River downstream of the dam.

Bulk raw water for domestic purposes will be supplied directly from the outlet works via pipelines. The ecological requirements will be supplied by means of river releases.

Design details

For design details of the outlet works, refer to Appendix 5.

The outlet works comprise an upstream intake structure and downstream control room and an intake control chamber.

The intake structure on the upstream side of the dam is 25 m high by 11 m wide. The upstream face of the intake structure is fitted with precast concrete coarse trash racks. Provision is made for fine screens. A dry well runs down the full height of the structure. A total of 3 intakes are connected to the two 600 mm nominal bore vertical service outlet pipes, which are encased in concrete. The upper 2 service intakes, of which the bottom one is situated at lowest operating level, are staggered at 2,9 m intervals. The lowest two intakes, both at RL 543,50 m will serve three purposes, namely for scouring of silt from the area immediately surrounding the intake structure, for river diversion during construction and for rapid drawdown in case of emergency.

Each of the inlets is provided with a butterfly valve for level selection. The intakes can also be isolated individually by means of an emergency gate lowered in front of the intake pipes.

Control steel platforms are situated adjacent to each butterfly valve. Steel ladders provide access between the top and bottom sections of the intake structure. The outlet control room is accessible from the intake structure by means of a 2,5 m wide concrete gallery

The two vertical 600 mm diameter service outlet pipes are joined at RL 543,50 to the two horizontal scour pipes of the same diameter. The combined scour pipes /service outlets pass straight beneath the dam wall.

The outlet control room is situated at the downstream end of the main gallery, which also provides access to the intake tower. It has a plan dimension of 6,2 m by 5,0 m (from wall to wall).

Three 400 mm diameter hooded sleeve valves are provided at the discharge point.

Five of the butterfly valves required for pipe selection control for the domestic offtakes are housed in the level below the outlet control room (RL 544,80).

Maximum discharge capacity

The maximum discharges, through a single valve, with the flow velocity limited to 7 m/s, and the valve fully open, are:

400 mm valve:	FSL= RL 555,80m	1,5 m^3/s
	LDL= RL 546,40m	0,4 m^3/s

APPENDIX L2 :

SIZING CRITERIA:
CONVEYANCE SYSTEM

PRE-FEASIBILITY PHASE

Appendix L2

SIZING AND COSTING CRITERIA FOR THE CONVEYANCE SYSTEM

PRE-FEASIBILITY PHASE

1. DESCRIPTION OF CONVEYANCE OPTIONS

1.1 General

In all instances it is assumed that the existing infrastructure will be used as far as practically possible to facilitate phased implementation and possible cash flow constraints.

This implies that upgrading of the following existing components have been considered :

- Water Treatment Works
  - Upgrading of sand filters;
  - Upgrading of settling tank.

- Clear Water Pump Station
  - Use existing pump room;
  - Upgrading of suction and discharge manifolds;
  - Minor civils work i.e. building in pipes and construction of plinths.

- Raw Water Pump Station (Option No. 1 only)
  - Extend pump room;
  - Upgrade pumpsets and switch gear;
  - Upgrade suction and discharge manifolds.

All components will ultimately be sized for 2020 demands. All pipelines will be sized at the outset for 2020 demands. Other infrastructures will be upgraded as and when required by the implementation programme.

It should be noted that, due to the adopted growth rates (low demand scenario), the 2010 demands are not significantly larger than the 2020 demands. This implies that the incremental up-sizing of the infrastructure i.e. pump stations and reservoirs between 2010 to 2020 is small and may be impractical to implement.

1.2 CONVEYANCE OPTION No. 1: Abstraction from the Existing Weir (for development options D1B and D2B)

Requires pumping from the existing Weir to the existing Water Treatment works.

This option comprises the following :

i. Upgrade existing RWPS
ii. Install an additional RWRM
iii. Upgrade the existing WTW
iv. Upgrade the existing CWPS
v. Install an additional CWRM
vi. Provide additional bulk storage

1.3 CONV. OPTION No. 2 : Abstraction from the Proposed Lusikisiki Dam Site (D2A)

Requires pumping from the proposed Lusikisiki Dam to the existing Water Treatment Works

This option comprises the following :

i. Install a new RWPS
ii. Install a new RWRM
iii. Upgrade the existing WTW
iv. Upgrade the existing CWPS
v. Install an additional CWRM
vi. Provide additional bulk storage

1.4 CONV. OPTION No. 3a : Abstraction from the Proposed Zalu Dam Site (D1C)

The Water Treatment Works is gravity fed from the dam with downstream control at the WTW.

This option comprises the following :

i. Install a new RWGM
ii. Upgrade the existing WTW
iii. Upgrade the existing CWPS
iv. Install an additional CWRM
v. Provide additional bulk storage

1.5 CONV. OPTION No. 3b : Abstraction from the Proposed Zalu Dam Site (D1A)

Requires pumping from the dam to the existing water treatment works. (Straight line between dam and water treatment works i.e. shorter length of pipe but requires pumping due to hills between the dam and the WTW).

This option comprises the following :

i. Install a new RWRM
ii. Install a new RWPS
iii. Upgrade the existing WTW
iv. Upgrade the existing CWPS
v. Install an additional CWRM
vi. Provide additional bulk storage

2. BULK PIPELINES

2.1 Pipe Type and Material

- General : Consider AC and mPVC only
- Pumping Mains : mPVC pipe
- Gravity Mains : mPVC pipe D < 300mm
  AC D > 300mm

D = diameter of pipe

Allow for surge in the design of the pipe.

2.2 Internal Flow Velocities

- General : 1.0m/s to 2.5m/s
- Pumping Mains : 1.5m/s
- Gravity Mains : 2.0m/s

2.3 Installation Conditions

- See drawing 19278-PF-05 for the envisaged installation conditions

3. PUMP STATIONS

3.1 General

3.1.1 The existing CWPS can house approximately 6 No. pumps. More pumps will enable greater flexibility with implementation and operation. 4 No. duty pumps and 1 No. standby pump were selected. Pumps were therefore selected accordingly.

Raw pumps were also selected correspondingly to facilitate operation i.e. approx. balance of flows between raw and clear water flows.

3.1.2 Pump efficiency = 0.75

3.1.3 Motor efficiency = 0.9

3.1.4 Motor sized to 15% in excess of pump absorbed power

3.2 Piping Sizing Criteria

3.2.1 Suction manifold : Max flow velocity = 1.0m/s

3.2.2 Discharge manifold : Max flow velocity = 2.0m/s

4. OPERATION PHILOSOPHY

4.1 RWPS

- No permanent operator
- Start up (local)
- Shutdown (remote and local)
- Monitoring (remote and local)
- Emergency stop (local and remote)

5. COSTING MODEL

5.1 Cost breakdown

5.1.1	Civil	=	Generally 30% of the total cost for new infrastructure 55% or 70% of mechanical cost. Generally 7.5% of total cost for refurbishment of existing infrastructure or Generally 15% to 40% of the mechanical cost.
5.1.2	Mechanical	=	Generally 50% of the total cost
	5.1.2.1 Pumps and motor	=	60% of mechanical cost
	5.1.2.2 Valves	=	25% of mechanical cost
	5.1.2.3 Pipework	=	15% of mechanical cost
5.1.3	Electrical	=	Generally 20% of total cost or 30% to 50% of the total mechanical cost

5.2 Civil

5.2.1 Substructure

5.2.2 Superstructure

5.2.3 Loading bay

5.2.4 Control room/area

5.3 Mechanical

5.3.1 Pumpsets including standby capacity

5.3.2 Valves and pipework inside the pump room and outside to the start of the rising main. Excludes the raw water inlet pipes from the dam.

5.4 Electrical

5.4.1 High and low voltage equipment and cabling

5.4.2 Excludes Eskom transmission cables and transformers (No allowance made in cost model but generally +/- R65 000 per km).

6. RESERVOIRS

6.1 General

6.1.1 Only 1 command reservoir location has been considered (more than 1 reservoir may however be considered)

6.1.2 The reservoir(s) are to be circular in geometry

6.1.3 The reservoir(s) are to have the same height as existing reservoirs

6.1.4 All reservoirs are to be ground level reinforced concrete reservoirs.

6.2 Sizing Criteria

6.2.1 The command reservoir will provide 36 hours of AADD for the TLC and 24 hours of AADD for the rural areas.

7. WATER TREATMENT WORKS

7.1 General

7.1.1 The existing water treatment work is to be utilised and upgraded where required;

7.1.2 The following components are therefore to be upgraded :

- Settling tank (same type as existing)
- Sand filters
- Chemical dosing equipment

7.1.3 Self back washing filters have been considered and include the following :

- Electrical/Mechanical work
  - The drums/filters
  - Pipework and fittings
  - Pumps and motors
  - Switch gear
- Civil Work
  - Base for filters
  - Conversion of slow sand filters to balancing and backwashing tanks

APPENDIX M :

COSTING AND ECONOMIC MODELS

PRE-FEASIBILITY PHASE

APPENDIX M1 :

COST MODELS: SUMMARY

PRE-FEASIBILITY PHASE

FEASIBILITY PHASE
INPUT DATA
Construction 2000, capital costs R million

No.	DAM/OPTION	RWGM	RWPS	RRRM	WTW	CWPS	CWRM	RESERV	CWGM	TOTAL
D1C	Zalu dam: gravity from site	R9.77	R0.00	R0.00	R4.63	R0.57	R2.68	R2.52	R0.00	R20.16
D1A	Zalu dam: pumping from site	R0.00	R0.60	R5.36	R4.63	R0.57	R2.68	R2.52	R0.00	R16.36
D1B	Zalu dam: from weir	R0.00	R0.59	R0.81	R4.63	R0.57	R2.68	R2.52	R0.00	R11.80
D2A	Lusikisiki dam: pumping from site	R0.00	R0.59	R1.87	R4.63	R0.57	R2.68	R2.52	R0.00	R12.85
D2B	Lusikisiki dam: from weir	R0.00	R0.59	R0.81	R4.63	R0.57	R2.68	R2.52	R0.00	R11.80

Construction 2000, capital costs R million

No.	DAM/OPTION	DAM	PUMP STATIONS	WTW	RES	PIPELINES	TOTAL
D1C	Zalu dam: gravity from site	R38.14	R0.57	R4.63	R2.52	R12.44	R58.30
D1A	Zalu dam: pumping from site	R38.14	R1.17	R4.63	R2.52	R8.03	R54.50
D1B	Zalu dam: from weir	R38.14	R1.16	R4.63	R2.52	R3.49	R49.94
D2A	Lusikisiki dam: pumping from site	R36.35	R1.15	R4.63	R2.52	R4.54	R49.20
5	Lusikisiki dam: from weir	R36.35	R1.16	R4.63	R2.52	R3.49	R48.15

Construction 2000, annual O&M costs, R million

No.	DAM/OPTION	DAM	JMP STATIOI	WATER TREATMENT	RESERVOIRS	PIPWELINES	TOTAL
	O&M Allowance Dams	0.68%	2.78%	1.73%	0.50%	1%	
D1C	Zalu dam: gravity from site	R0.26	R0.02	R0.08	R0.01	R0.12	R0.49
D1A	Zalu dam: pumping from site	R0.26	R0.03	R0.08	R0.01	R0.08	R0.46
D1B	Zalu dam: from weir	R0.26	R0.03	R0.08	R0.01	R0.03	R0.42
D2A	Lusikisiki dam: pumping from site	R0.25	R0.03	R0.08	R0.01	R0.05	R0.42
D2B	Lusikisiki dam: from weir	R0.25	R0.03	R0.08	R0.01	R0.03	R0.40

Residual values as at 2020, R million

No.	DAM/OPTION	DAM	JMP STATIOI	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL
Residual values (@ 20 years): dams and		54.00%	40.00%	47.00%	55.00%	33.00%	
D1C	Zalu dam: gravity from site	R20.60	R0.23	R2.17	R1.39	R4.11	R28.49
D1A	Zalu dam: pumping from site	R20.60	R0.47	R2.17	R1.39	R2.65	R27.28
D1B	Zalu dam: from weir	R20.60	R0.46	R2.17	R1.39	R1.15	R25.77
D2A	Lusikisiki dam: pumping from site	R19.63	R0.46	R2.17	R1.39	R1.50	R25.15
D2B	Lusikisiki dam: from weir	R19.63	R0.46	R2.17	R1.39	R1.15	R24.81

FEASIBILITY PHASE
Total capital cost, R million

No.	DAM/OPTION	DAM	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL CONVEY	TOTAL
D1C	Zalu dam: gravity from site	R38.14	R0.57	R4.63	R2.52	R12.44	R20.16	R58.30
D1A	Zalu dam: pumping from site	R38.14	R1.17	R4.63	R2.52	R8.03	R16.36	R54.50
D1B	Zalu dam: from weir	R38.14	R1.16	R4.63	R2.52	R3.49	R11.80	R49.94
D2A	Lusikisiki dam: pumping from site	R36.35	R1.15	R4.63	R2.52	R4.54	R12.85	R49.20
5	Lusikisiki dam: from weir	R36.35	R1.16	R4.63	R2.52	R3.49	R11.80	R48.15

Total annual O&M costs, R million

No.	DAM/OPTION	DAM	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL CONVEY	TOTAL
D1C	Zalu dam: gravity from site	R0.26	R0.02	R0.08	R0.01	R0.12	R0.23	R0.49
D1A	Zalu dam: pumping from site	R0.26	R0.03	R0.08	R0.01	R0.08	R0.21	R0.46
D1B	Zalu dam: from weir	R0.26	R0.03	R0.08	R0.01	R0.03	R0.16	R0.42
D2A	Lusikisiki dam: pumping from site	R0.25	R0.03	R0.08	R0.01	R0.05	R0.17	R0.42
5	Lusikisiki dam: from weir	R0.25	R0.03	R0.08	R0.01	R0.03	R0.16	R0.40

Total residual values as at 2020, R million

No.	DAM/OPTION	DAM	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL CONVEY	TOTAL
D1C	Zalu dam: gravity from site	R20.60	R0.23	R2.17	R1.39	R4.11	R7.90	R28.49
D1A	Zalu dam: pumping from site	R20.60	R0.47	R2.17	R1.39	R2.65	R6.68	R27.28
D1B	Zalu dam: from weir	R20.60	R0.46	R2.17	R1.39	R1.15	R5.18	R25.77
D2A	Lusikisiki dam: pumping from site	R19.63	R0.46	R2.17	R1.39	R1.50	R5.52	R25.15
5	Lusikisiki dam: from weir	R19.63	R0.46	R2.17	R1.39	R1.15	R5.18	R24.81

HIGH DEMAND - FULL SCHEME
Annual Electricity charges and chemical costs

No	Component	Unit	Zalu gravity	Zalu from site	Zalu from weir	Lusikisiki from site	Lusikisiki from weir
1	GAADD: min	l/s	35	35	35	35	35
	: max	l/s	80	80	80	80	80
2	Design SDD: min	l/s	63	63	63	63	63
	max	l/s	144	144	144	144	144
3	Static head	m	61	61	112	97	112
4	Local losses	m	2	5	5	5	5
5	Friction losses: min	m	3	6	6	6	6
	max	m	26	50	40	38	40
6	Total head: min	m	66	72	123	108	123
	max	m	89	116	157	140	157
7	Energy: min	kW	26	29	49	43	49
	max	kW	81	106	143	128	143
8	Installed capacity: min	kW	47	52	88	78	88
	max	kW	146	191	258	230	258
9	kVA Rating: min	kVA	101	126	180	160	180
	max	kVA	152	198	269	240	269
10	Energy unit cost	R/kwh	0.0693	0.0693	0.0693	0.0693	0.0693
11	Demand unit cost	R/kwa/m	38.34	38.34	38.34	38.34	38.34
12	Energy charge: min	R mil	0.029	0.031	0.054	0.047	0.054
	: max	R mil	0.089	0.116	0.157	0.140	0.157
13	Demand charge: min	R mil	0.046	0.058	0.083	0.074	0.083
	max	R mil	0.070	0.091	0.124	0.110	0.124
14	Chemicals unit cost	R/kl	0.06	0.06	0.06	0.06	0.06
15	Total chem. cost: min	R mil	0.066	0.066	0.066	0.066	0.066
	max	R mil	0.151	0.151	0.151	0.151	0.151
16	Total electr & chemicals						
	Min	R mil	0.141	0.156	0.203	0.187	0.203
	Max	R mil	0.310	0.358	0.432	0.401	0.432

APPENDIX M2 :

COST MODELS: DAMS

PRE-FEASIBILITY PHASE

ESTIMATED COST FOR ZALU DAM

Rollcrete Dam
Wall height = 26,50m

March 1999 price levels

NO	DESCRIPTION	UNIT	RATE (Rand/Unit)	QUANTITY	AMOUNT (Rand)
1	**Site & basin clearing**				
	(a) Sparse	ha	2 125	0.50	1 063
	(b) Bush	ha	6 374	0.15	956
	(c) Trees	ha	10 623	0.15	1 593
2	**River diversion**	Sum			50 000
3	**Excavation**				
	(a) Soft Exkavation	m^3	15	19 500	292 500
	(b) Hard Excavation	m^3	27	6 830	184 410
	(c) Foundation Preparation	m^2	27	4 800	129 600
4	**Drilling and Grouting**				
	(a) Curtain Grouting	m	170	2 100	357 000
	(b) Consolidation Grouting	m	170	-	-
5	**Formwork**				
	(a) Straight	m^2	76	9 820	746 320
	(b) Curved	m^2	121	1 160	140 360
6	**Concrete**				
	(a) Rollcrete	m^3	245	34 570	8 469 650
	(b) Skin	m^3	300	6 100	1 830 000
	(c) Mass	m^3	276	2 240	618 240
	(d) Structural	m^3	355	6 240	2 215 200
7	**Reinforcing**	t	3 794	215	815 710
8	**Fencing**	km	10 623	1.00	10 623
9	**Mechanical Items**	%	10(Civil)		1 600 000
	SUB TOTAL				**17 463 225**
10	**Landscaping (% of 1-9)**	**%**	5		873 161
5	**Miscellaneous (% of 1-9)**	%	10		1 746 323
	SUB TOTAL A				**20 082 709**
6	**Preliminary & General** (% of Subtotal A)	%	30		6 024 813
7	**Preliminary Works**				
	(a) Access road	km	90 000	3.00	270 000
	(b) Electricity to Site	km	50 000	1.00	50 000
	(c) Water to site	sum			20 000

	(construction & potable)				
8	**Accomodation** (a) Permanent (b) Temporary		Included in P&G		
	SUB TOTAL B				**26 447 521**
9	**Contigencies** (% of Subtotal B)	%	10		2 644 752
	SUB TOTAL C				**29 092 274**
10	**Planning Design & Supervision, Fees, Time cost & Transport** (% of Subtotal C)	%	15		4 363 841
	SUB TOTAL D				**33 456 115**
11	**VAT** (% of Subtotal D)	%	14		**4 683 856**
	NET PROJECT COST				**38 139 971**
12	Cost of Relocations				-
13	Cost of Land Acquisition	m	0.00	750 000	-
	ESTIMATED TOTAL COST				**38 139 971**

ESTIMATED COST FOR LUSIKISIKI DAM

Pre Feasibility stage

Composite Dam

Wall height = 32,60m

March 1999 price levels

NO	DESCRIPTION	UNIT	RATE (Rand/Unit)	QUANTITY	AMOUNT (Rand)
1	**Site & basin clearing**				
	(a) Sparse	ha	2 125	1	2 125
	(b) Bush	ha	6 374	0.3	1 912
	(c) Trees	ha	10 623	0.3	3 187
2	**River diversion**	Sum			50 000
3	**Excavation**				
	(a) Soft Exkavation	m^3	15	26 150	392 250
	(b) Hard Excavation	m^3	27	9 150	247 050
	(c) Foundation Preparation	m^2	27	4 270	115 290
4	**Drilling and Grouting**				
	(a) Curtain Grouting	m	170	1 500	255 000
	(b) Consolidation Grouting	m	170	800	136 000
5	**Formwork**				
	(a) Straight	m^2	76	10 530	800 280
	(b) Curved	m^2	121	1 150	139 150
6	**Concrete**				
	(a) Rollcrete	m^3	245	26 600	6 517 000
	(b) Skin	m^3	300	4 800	1 440 000
	(c) Mass	m^3	276	2 450	676 200
	(d) Structural	m^3	355	6 750	2 396 250
7	**Embankment**				
	Earthfill	m^3	30	40 000	1 200 000
8	**Reinforcing**	t	3794	205	777 770
9	**Fencing**	km	10 623	1.0	10 623
10	**Mechanical Items**	%	10(Civil)		1 500 000
	SUB TOTAL				**16 660 087**
11	**Landscaping (% of 1-10)**	**%**	5		833 004
12	**Miscellaneous (% of 1-10)**	%	10		1 666 009
	SUB TOTAL A				**19 159 100**
13	**Preliminary & General** (% of Subtotal A)	%	30		5 747 730

14	**Preliminary Works**				
	(a) Access road	km	90 000	2	180 000
	(b) Electricity to Site	km	50 000	2	100 000
	(c) Water to site (construction & potable)	sum			20 000
15	**Accomodation**				-
	(a) Permanent		Included in P&G		
	(b) Temporary				
	SUB TOTAL B				**25 206 830**
16	**Contigencies** (% of Subtotal B)	%	10		2 520 683
	SUB TOTAL C				**27 727 513**
17	**Planning Design & Supervision, Fees, Time cost & Transport** (% of Subtotal C)	%	15		4 159 127
	SUB TOTAL D				**31 886 640**
18	**VAT** (% of Subtotal D)	%	14		**4 464 130**
	NET PROJECT COST				**36 350 770**
19	Cost of Relocations				-
20	Cost of Land Acquisition	m	0.00	1 200 000	-
	ESTIMATED TOTAL COST				**36 350 770**

APPENDIX M3 :

COST MODELS:
CONVEYANCE SYSTEM

PRE-FEASIBILITY PHASE

1. RAW WATER GRAVITY MAIN from Zalu dam outlet to WTW: Option D1C

Base Date April 1999

Raw water GRAVITY main from NEW ZALU Dam to existing WTW

No.	PAY REF	DESCRIPTION	UNIT	RATE	QUANTITY	TOTAL
1		**SITE CLEARANCE**				
		Clear and grub	ha	1400.00	5.8	R 8 148.00
		Transport materials to unspecified sites and dump	m³km	5.00	50.0	R 250.00
		Remove topsoil to nominal depth of 150mm and stockpile	m³	45.00	833.7	R 37 517.18
2		**EARTHWORKS (PIPE TRENCHES)**				
		Excavation in all materials , backfill & compaction				
		Exceeding 0 m but not exceeding 1.0 m	m	10.10	0.0	R 0.00
		Exceeding 1.0 m but not exceeding 2.0 m	m	20.10	5529.0	R 111 132.90
		Exceeding 2.0 m but not exceeding 3.0 m	m	26.00	291.0	R 7 566.00
		Excavation				
		Intermediate excavation	m³	60.00	7857.0	R 471 420.00
		Hard rock excavation	m³	120.00	523.8	R 62 856.00
		Excavate and dispose of unsuitable material from trench bottom (provisional)	m³	60.00	139.0	R 8 337.15
		Excavation Ancillaries				
		Make up deficiency in back-fill material (Provisional)	m³	22.50	500.2	R 11 255.15
		Opening up and closing down of designated borrow pit	No.	2000.00	6.0	R 12 000.00
		Compaction in road reserves	m³	15.00	25.8	R 386.78
		Finishing				
		Reinstate road surfaces	m²	20.00	86.0	R 1 719.00
3		**MEDIUM PRESSURE PIPELINES**				
		Supply, lay and bed pipes and bends complete with couplings				
		500 mm NB class 9 AC (COD) pipe	m	641.66	5820.0	###########
		500 mm NB class 12 AC (COD) pipe	m	0.00	0.0	R 0.00
		500 mm NB class 16 AC (COD) pipe	m	0.00	0.0	R 0.00
		Valves & chambers				
		50 mm air valve installation complete with chamber & manhole	No.	6000.00	12.0	R 72 000.00
		80 mm scour valve installation complete with chamber & manhole	No.	2750.00	12.0	R 33 000.00
		Install Anchor / Thrust blocks	No.	800.00	14.4	R 11 520.00
		Supply and install PI and route markers	No.	60.00	24.0	R 1 440.00
4		**BEDDING (PIPES)**				
		Provision of bedding				
		Selected fill material	m³	60.00	3620.3	R 217 218.18
		Concrete bedding (cradle)	m³	800.00	36.2	R 28 962.42
		SUB TOTAL (A)				###########
		MISCELANEOUS				
		(% of sub total)	%	10.00%		R 483 119.00
		PRELIMINARY & GENERAL				
		(% of sub total)	%	30.00%		###########
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0.1	R 10 000.00
		SUB-TOTAL B				###########
		CONTINGENCIES				
		(% of sub-total B)	%	10.00%		R 677 366.59
		SUB-TOTAL C				###########
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		###########
		SUB-TOTAL D				###########
		VAT (% of sub total D)	%	14.00%		###########
		NETT PROJECT COST				###########
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m²	10.00	34920	R 349 200.00

2. RAW WATER PUMP STATION at Zalu dam: Option D1A

Base Date April 1999

New RWPS at ZALU Dam Site

No.	PAY REF	DESCRIPTION	UNIT	RATE	QUANTITY	TOTAL
1		**MECHANICAL**				**R 142 400.00**
		Pumps & motors	sum	85440.00		R 85 440.00
		Valves & fittings	sum	35600.00		R 35 600.00
		Pipework	sum	21360.00		R 21 360.00
2		**ELECTRICAL**	sum	56960.00		**R 56 960.00**
3		**CIVILS**	sum	104426.67		**R 104 426.67**
		MISCELANEOUS				
		(% of items 1 to 3)	%	10.00%		R 30 378.67
		SUB-TOTAL A				**R 334 165.33**
		PRELIMINARY & GENERAL				
		(% of sub total A)	%	20.00%		R 66 833.07
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0	R 0.00
		SUB-TOTAL B				**R 400 998.40**
		CONTINGENCIES				
		(% of sub-total B)	%	15.00%		R 60 149.76
		SUB-TOTAL C				**R 461 148.16**
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		R 69 172.22
		SUB-TOTAL D				**R 530 320.38**
		VAT (% of sub total D)	%	14.00%		R 74 244.85
		NETT PROJECT COST				**R 604 565.24**
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m^2	10.00	225	R 2 250.00

3. RAW WATER PUMP STATION AT LUSIKISIKI WEIR: Options D1B, D2A, D2B

Base Date April 1999

Upgrade Existing RWPS

No.	PAY REF	DESCRIPTION	UNIT	RATE	QUANTITY	TOTAL
1		**MECHANICAL**				**R 165 733.33**
		Pumps & motors	sum	99440.00		R 99 440.00
		Valves & fittings	sum	41433.33		R 41 433.33
		Pipework	sum	24860.00		R 24 860.00
2		**ELECTRICAL**	sum	66293.33		**R 66 293.33**
3		**CIVILS**	sum	66293.33		**R 66 293.33**
		MISCELANEOUS				
		(% of items 1 to 3)	%	10.00%		R 29 832.00
		SUB-TOTAL A				**R 328 152.00**
		PRELIMINARY & GENERAL				
		(% of sub total A)	%	20.00%		R 65 630.40
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0	R 0.00
		SUB-TOTAL B				**R 393 782.40**
		CONTINGENCIES				
		(% of sub-total B)	%	15.00%		R 59 067.36
		SUB-TOTAL C				**R 452 849.76**
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		R 67 927.46
		SUB-TOTAL D				**R 520 777.22**
		VAT (% of sub total D)	%	14.00%		R 72 908.81
		NETT PROJECT COST				**R 593 686.04**
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m²	10.00	225	R 2 250.00

4. RAW WATER RISING MAIN from Zalu outlet to WTW: Option D1A

Base Date April 1999

Raw water RISING MAIN from NEW ZALU RWPS to existing WTW

No.	PAY REF	DESCRIPTION	UNIT	RATE	QUANTITY	TOTAL
1		**SITE CLEARANCE**				
		Clear and grub	ha	1400.00	5.3	R 7 420.00
		Transport materials to unspecified sites and dump	m^3km	5.00	50.0	R 250.00
		Remove topsoil to nominal depth of 150mm and stockpile	m^3	45.00	759.2	R 34 165.13
2		**EARTHWORKS (PIPE TRENCHES)**				
		Excavation in all materials , backfill & compaction				
		Exceeding 0 m but not exceeding 1.0 m	m	10.10	0.0	R 0.00
		Exceeding 1.0 m but not exceeding 2.0 m	m	20.10	5035.0	R 101 203.50
		Exceeding 2.0 m but not exceeding 3.0 m	m	26.00	265.0	R 6 890.00
		Excavation				
		Intermediate excavation	m^3	60.00	7155.0	R 429 300.00
		Hard rock excavation	m^3	120.00	477.0	R 57 240.00
		Excavate and dispose of unsuitable material from trench bottom (provisional)	m^3	60.00	126.5	R 7 592.25
		Excavation Ancillaries				
		Make up deficiency in back-fill material (Provisional)	m^3	22.50	455.5	R 10 249.54
		Opening up and closing down of designated borrow pit	No.	2000.00	6.0	R 12 000.00
		Compaction in road reserves	m^3	15.00	25.8	R 386.78
		Finishing				
		Reinstate road surfaces	m^2	20.00	86.0	R 1 719.00
3		**MEDIUM PRESSURE PIPELINES**				
		Supply, lay and bed pipes and bends complete with couplings for				
		315 mm NB class 9 mPVC pipe	m	261.00	1600.0	R 417 600.00
		315 mm NB class 9 mPVC pipe	m	332.00	3700.0	R 1 228 400.00
			m	0.00	0.0	R 0.00
		Valves & chambers				
		50 mm air valve installation complete with chamber & manhole	No.	6000.00	11.0	R 66 000.00
		80 mm scour valve installation complete with chamber &	No.	2750.00	11.0	R 30 250.00
		Install Anchor / Thrust blocks	No.	800.00	13.2	R 10 560.00
		Supply and install PI and route markers	No.	60.00	22.0	R 1 320.00
4		**BEDDING (PIPES)**				
		Provision of bedding				
		Selected fill material	m^3	60.00	3296.8	R 197 810.37
		Concrete bedding (cradle)	m^3	800.00	33.0	R 26 374.72
		SUB TOTAL (A)				**R 2 646 731.28**
		MISCELANEOUS				
		(% of sub total)	%	10.00%		R 264 673.13
		PRELIMINARY & GENERAL				
		(% of sub total)	%	30.00%		R 794 019.38
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0.1	R 10 000.00
		SUB-TOTAL B				**R 3 715 423.79**
		CONTINGENCIES				
		(% of sub-total B)	%	10.00%		R 371 542.38
		SUB-TOTAL C				**R 4 086 966.17**
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		R 613 044.92
		SUB-TOTAL D				**R 4 700 011.09**
		VAT (% of sub total D)	%	14.00%		R 658 001.55
		NETT PROJECT COST				**R 5 358 012.64**
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m^2	10.00	31800	R 318 000.00

5. RWRM: Options D1B, D2B from existing Lusikisiki weir to WTW

Base Date April 1999

No.	PAY REF	DESCRIPTION	UNIT	RATE	QUANTITY	TOTAL
1		**SITE CLEARANCE**				
		Clear and grub	ha	1400.00	0.7	R 938.00
		Transport materials to unspecified sites and dump	m³km	5.00	50.0	R 250.00
		Remove topsoil to nominal depth of 150mm and stockpile	m³	45.00	96.0	R 4 318.99
2		**EARTHWORKS (PIPE TRENCHES)**				
		Excavation in all materials , backfill & compaction				
		Exceeding 0 m but not exceeding 1.0 m	m	10.10	0.0	R 0.00
		Exceeding 1.0 m but not exceeding 2.0 m	m	20.10	636.5	R 12 793.65
		Exceeding 2.0 m but not exceeding 3.0 m	m	26.00	33.5	R 871.00
		Excavation				
		Intermediate excavation	m³	60.00	904.5	R 54 270.00
		Hard rock excavation	m³	120.00	60.3	R 7 236.00
		Excavate and dispose of unsuitable material from trench bottom (provisional)	m³	60.00	16.0	R 959.78
		Excavation Ancillaries				
		Make up deficiency in back-fill material (Provisional)	m³	22.50	57.6	R 1 295.70
		Opening up and closing down of designated borrow pit	No.	2000.00	1.0	R 2 000.00
		Compaction in road reserves	m³	15.00	25.8	R 386.78
		Finishing				
		Reinstate road surfaces	m²	20.00	86.0	R 1 719.00
3		**MEDIUM PRESSURE PIPELINES**				
		Supply, lay and bed pipes and bends complete with couplings for				
		355 mm NB class 9 mPVC pipe	m	332.00	275.0	R 91 300.00
		355 mm NB class 12 mPVC pipe	m	429.00	395.0	R 169 455.00
		355 mm NB class 16 mPVC pipe	m	542.00	0.0	R 0.00
		Valves & chambers				
		50 mm air valve installation complete with chamber & manhole	No.	6000.00	2.0	R 12 000.00
		80 mm scour valve installation complete with chamber &	No.	2750.00	2.0	R 5 500.00
		Install Anchor / Thrust blocks	No.	800.00	1.8	R 1 440.00
		Supply and install PI and route markers	No.	60.00	3.0	R 180.00
4		**BEDDING (PIPES)**				
		Provision of bedding				
		Selected fill material	m³	60.00	416.8	R 25 006.22
		Concrete bedding (cradle)	m³	800.00	4.2	R 3 334.16
		SUB TOTAL (A)				**R 395 254.26**
		MISCELANEOUS				
		(% of sub total)	%	10.00%		R 39 525.43
		PRELIMINARY & GENERAL				
		(% of sub total)	%	30.00%		R 118 576.28
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0.1	R 10 000.00
		SUB-TOTAL B				**R 563 355.97**
		CONTINGENCIES				
		(% of sub-total B)	%	10.00%		R 56 335.60
		SUB-TOTAL C				**R 619 691.56**
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		R 92 953.73
		SUB-TOTAL D				**R 712 645.30**
		VAT (% of sub total D)	%	14.00%		R 99 770.34
		NETT PROJECT COST				**R 812 415.64**
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m²	10.00	4020	R 40 200.00

6. RAW WATER RISING MAIN from Lusikisiki dam outlet to WTW: Option D2A

Base Date April 1999

Raw water RISING main from NEW RWPS to existing WTW

No.	PAY REF	DESCRIPTION	UNIT	RATE	QUANTITY	TOTAL
1		**SITE CLEARANCE**				
		Clear and grub	ha	1400.00	1.6	R 2 184.00
		Transport materials to unspecified sites and dump	m³km	5.00	50.0	R 250.00
		Remove topsoil to nominal depth of 150mm and stockpile	m³	45.00	223.5	R 10 056.15
2		**EARTHWORKS (PIPE TRENCHES)**				
		Excavation in all materials , backfill & compaction				
		Exceeding 0 m but not exceeding 1.0 m	m	10.10	0.0	R 0.00
		Exceeding 1.0 m but not exceeding 2.0 m	m	20.10	1482.0	R 29 788.20
		Exceeding 2.0 m but not exceeding 3.0 m	m	26.00	78.0	R 2 028.00
		Excavation				
		Intermediate excavation	m³	60.00	2106.0	R 126 360.00
		Hard rock excavation	m³	120.00	140.4	R 16 848.00
		Excavate and dispose of unsuitable material from trench bottom (provisional)	m³	60.00	37.2	R 2 234.70
		Excavation Ancillaries				
		Make up deficiency in back-fill material (Provisional)	m³	22.50	134.1	R 3 016.85
		Opening up and closing down of designated borrow pit	No.	2000.00	2.0	R 4 000.00
		Compaction in road reserves	m³	15.00	25.8	R 386.78
		Finishing				
		Reinstate road surfaces	m²	20.00	86.0	R 1 719.00
3		**MEDIUM PRESSURE PIPELINES**				
		Supply, lay and bed pipes and bends complete with couplings for				
		355 mm NB class 9 mPVC pipe	m	332.00	575.0	R 190 900.00
		355 mm NB class 12 mPVC pipe	m	429.00	985.0	R 422 565.00
		355 mm NB class 16 mPVC pipe	m	542.00	0.0	R 0.00
		Valves & chambers				
		50 mm air valve installation complete with chamber & manhole	No.	6000.00	4.0	R 24 000.00
		80 mm scour valve installation complete with chamber & manhole	No.	2750.00	4.0	R 11 000.00
		Install Anchor / Thrust blocks	No.	800.00	4.2	R 3 360.00
		Supply and install PI and route markers	No.	60.00	7.0	R 420.00
4		**BEDDING (PIPES)**				
		Provision of bedding				
		Selected fill material	m³	60.00	970.4	R 58 223.43
		Concrete bedding (cradle)	m³	800.00	9.7	R 7 763.12
		SUB TOTAL (A)				**R 917 103.22**
		MISCELANEOUS				
		(% of sub total)	%	10.00%		R 91 710.32
		PRELIMINARY & GENERAL				
		(% of sub total)	%	30.00%		R 275 130.97
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0.1	R 10 000.00
		SUB-TOTAL B				###########
		CONTINGENCIES				
		(% of sub-total B)	%	10.00%		R 129 394.45
		SUB-TOTAL C				###########
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		R 213 500.84
		SUB-TOTAL D				###########
		VAT (% of sub total D)	%	14.00%		R 229 157.57
		NETT PROJECT COST				###########
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m²	10.00	9360	R 93 600.00

7. WATER TREATMENT WORKS: All Options

Base Date April 1999

Refurbish Existing WTW - Sand Filters Only

Modifications Only i.e.only minor civils

No.	PAY REF	DESCRIPTION	UNIT	RATE	QUANTITY	TOTAL
1		**MECHANICAL**				**R 1 854 160.00**
		Filtration Plant	sum	1685600.00		R 1 685 600.00
		Pipework	sum	84280.00		R 84 280.00
		Pumps & motors	sum	84280.00		R 84 280.00
2		**ELECTRICAL**	sum	370832.00		**R 370 832.00**
3		**CIVILS**	sum	92708.00		**R 92 708.00**
		MISCELANEOUS				
		(% of items 1 to 3)	%	10.00%		R 231 770.00
		SUB-TOTAL A				**R 2 549 470.00**
		PRELIMINARY & GENERAL				
		(% of sub total A)	%	20.00%		R 509 894.00
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0.1	R 10 000.00
		SUB-TOTAL B				**R 3 069 364.00**
		CONTINGENCIES				
		(% of sub-total B)	%	15.00%		R 460 404.60
		SUB-TOTAL C				**R 3 529 768.60**
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		R 529 465.29
		SUB-TOTAL D				**R 4 059 233.89**
		VAT (% of sub total D)	%	14.00%		R 568 292.74
		NETT PROJECT COST				**R 4 627 526.63**
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m^2	10.00	0	R 0.00

8. CLEAR WATER PUMP STATION at WTW: All Options

Base Date April 1999

Existing Clear Water Pump Station (Refurbish)

No.	PAY REF	DESCRIPTION	UNIT	RATE	QUANTITY	TOTAL
1		**MECHANICAL**				**R 183 633.33**
		Pumps & motors	sum	110180.00		R 110 180.00
		Valves & fittings	sum	45908.33		R 45 908.33
		Pipework	sum	27545.00		R 27 545.00
2		**ELECTRICAL**	sum	73453.33		**R 73 453.33**
3		**CIVILS**	sum	27545.00		**R 27 545.00**
		MISCELANEOUS				
		(% of items 1 to 3)	%	10.00%		R 28 463.17
		SUB-TOTAL A				**R 313 094.83**
		PRELIMINARY & GENERAL				
		(% of sub total A)	%	20.00%		R 62 618.97
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0	R 0.00
		SUB-TOTAL B				**R 375 713.80**
		CONTINGENCIES				
		(% of sub-total B)	%	15.00%		R 56 357.07
		SUB-TOTAL C				**R 432 070.87**
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		R 64 810.63
		SUB-TOTAL D				**R 496 881.50**
		VAT (% of sub total D)	%	14.00%		R 69 563.41
		NETT PROJECT COST				**R 566 444.91**
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m²	10.00	225	R 2 250.00

9. CLEAR WATER RISING MAIN fron WTW to Reservoir A: All Options

Base Date April 1999

NEW Clear Water RISING Main from existing WTW to Reservoir A

No.	REF	DESCRIPTION	UNIT	RATE	QUANTITY	TOTAL
1		**SITE CLEARANCE**				
		Clear and grub	ha	1400.00	2.1	R 2 976.40
		Transport materials to unspecified sites and dump	m^3km	5.00	50.0	R 250.00
		Remove topsoil to nominal depth of 150mm and stockpile	m^3	45.00	304.5	R 13 704.73
2		**EARTHWORKS (PIPE TRENCHES)**				
		Excavation in all materials , backfill & compaction				
		Exceeding 0 m but not exceeding 1.0 m	m	10.10	0.0	R 0.00
		Exceeding 1.0 m but not exceeding 2.0 m	m	20.10	2019.7	R 40 595.97
		Exceeding 2.0 m but not exceeding 3.0 m	m	26.00	106.3	R 2 763.80
		Excavation				
		Intermediate excavation	m^3	60.00	2870.1	R 172 206.00
		Hard rock excavation	m^3	120.00	191.3	R 22 960.80
		Excavate and dispose of unsuitable material from trench bottom (provisional)	m^3	60.00	50.8	R 3 045.50
		Excavation Ancillaries				
		Make up deficiency in back-fill material (Provisional)	m^3	22.50	182.7	R 4 111.42
		Opening up and closing down of designated borrow pit	No.	2000.00	3.0	R 6 000.00
		Compaction in road reserves	m^3	15.00	25.8	R 386.78
		Finishing				
		Reinstate road surfaces	m^2	20.00	86.0	R 1 719.00
3		**MEDIUM PRESSURE PIPELINES**				
		Supply, lay and bed pipes and bends complete with couplings for				
		355 mm NB class 9 mPVC pipe	m	332.00	916.0	R 304 112.00
		355 mm NB class 12 mPVC pipe	m	429.00	450.0	R 193 050.00
		355 mm NB class 16 mPVC pipe	m	542.00	760.0	R 411 920.00
		Valves & chambers				
		50 mm air valve installation complete with chamber & manhole	No.	6000.00	5.0	R 30 000.00
		80 mm scour valve installation complete with chamber & manhole	No.	2750.00	5.0	R 13 750.00
		Install Anchor / Thrust blocks	No.	800.00	5.4	R 4 320.00
		Supply and install PI and route markers	No.	60.00	9.0	R 540.00
4		**BEDDING (PIPES)**				
		Provision of bedding				
		Selected fill material	m^3	60.00	1322.5	R 79 348.09
		Concrete bedding (cradle)	m^3	800.00	13.2	R 10 579.74
		SUB TOTAL (A)				**R 1 318 340.22**
		MISCELANEOUS				
		(% of sub total)	%	10.00%		R 131 834.02
		PRELIMINARY & GENERAL				
		(% of sub total)	%	30.00%		R 395 502.06
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0.1	R 10 000.00
		SUB-TOTAL B				**R 1 855 676.30**
		CONTINGENCIES				
		(% of sub-total B)	%	10.00%		R 185 567.63
		SUB-TOTAL C				**R 2 041 243.93**
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		R 306 186.59
		SUB-TOTAL D				**R 2 347 430.52**
		VAT (% of sub total D)	%	14.00%		R 328 640.27
		NETT PROJECT COST				**R 2 676 070.80**
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m^2	10.00	12756	R 127 560.00

10. RESERVOIR: All Options

A single reservoir in the vicinity of Reservoir A Apr-99

No.	Pay Ref	Description	Unit	Rate	Qty	Total
1		**SITE CLEARANCE**				
		Clear and grub	m²	R 0.70	1344.8	R 941.34
		Transport materials to unspecified sites	t.km	R 2.30	**50**	R 115.00
		Remove topsoil to 150mm & stockpile	m²	R 3.70	983.1	R 3 637.33
2		**EARTHWORKS**				
		Bulk Excavation				
		Exc. in all materials, use for backfill	m³	R 28.70	491.5	R 14 106.93
		E.O.				
		Intermediate excavation	m³	R 35.00	49.2	R 1 720.36
		Hard rock excavation	m³	R 149.80	24.6	R 3 681.56
		Restricted excavation				
		Exc. for restricted foundations, footings, chambers & trenches in all materials	m³	R 48.00	4.69	R 225.00
		E.O.				
		Intermediate excavation	m³	R 50.00	0.5	R 23.44
		Hard rock excavation	m³	R 149.80	0.2	R 35.11
		Extra exc.for working space	m²	R 28.70	27.8	R 797.48
		Importing of materials	m³	R 35.00	24.8	R 868.38
3		**CONCRETE (STRUCTURAL)**				
		FORMWORK				
		Rough vertical plane				
		for walls and slabs below ground level	m²	R 98.30	55.6	R 5 462.84
		Smooth vertical plane				
		for walls above ground	m²	R 58.30	1046.5	R 61 008.94
		Smooth horizontal plane				
		Slabs above ground level	m²	R 92.90	950.0	R 88 255.00
		Smooth narrow width (0-300m) curved	m	R 24.30	111.1	R 2 700.86
		Box out holes for specials	No.	R 71.30	**5**	R 356.50
		Box out holes for manhole covers	No.	R 118.80	*3*	R 356.40
		REINFORCEMENT				
		Mild steel bars	t	R 4 200.00	7.1	R 29 794.58
		High-tensile steel bars	t	R 4 200.00	63.8	R 268 151.20
		High tensile welded mesh	t	R 5 000.00	1.4	R 7 093.95
		CONCRETE				
		50mm blinding layer to res. & chambers	m³	R 50.00	49.5	R 2 476.55
		Strength concrete : 30MPa/20mm				
		kl Reservoir incl. chambers	m³	R 850.00	709.39	R 602 985.51
		UNFORMED SURFACE FINISHES				
		chamber floor slabs, horizontal joints	m²	R 3.00	990.6	R 2 971.86
		floor slabs and chamber roof slabs	m²	R 4.50	1975.2	R 8 888.29
		JOINTS				
		Horizontal joint at base with water stop	m	R 30.00	110.2	R 3 306.12
		intermediate level of reservoir wall	m	R 9.00	110.2	R 991.83
		MISCELLANEOUS				
		Build in pipes	No.	R 150.00	*5.0*	R 750.00
		Install valves in chambers	No.	R 1 800.00	3.0	R 5 400.00
		Water level indicator	No.	R 5 300.00	**1.0**	R 5 300.00
		Supply of Valves	No.	R 2 800.00	3.0	R 8 400.00
		Flow Meter	No.	R 4 500.00	1.0	R 4 500.00

		Strainer	No.	R 2 000.00	1.0	R 2 000.00
		LevelDex float valve	No.	R 13 000.00	1.0	R 13 000.00
		50 Micron PVC sheeting , in two layers on top of walls as a bond breaker to roof slabs	m	R 2.50	220.4	R 551.02
		75 Micron PVC sheeting placed as bond breaker between base and blinding	m²	R 4.00	983.1	R 3 932.24
		Manhole covers for :				
		a) Reservoirs	No.	R 600.00	1	R 600.00
		b) Chambers	No.	R 600.00	3	R 1 800.00
		Ladders : supply and install	No.	R 1 800.00	**1**	R 1 800.00
4		**MEDIUM PRESSURE PIPELINES**				
		Supply & place pipes and specials for :				
		Inlet pipe	No.	R 1 900.00	1	R 1 900.00
		Outlet pipe	No.	R 1 500.00	1	R 1 500.00
		Scour pipe	No.	R 700.00	1	R 700.00
		Ventilation pipe	No.	R 450.00	**4**	R 1 800.00
		Overflow pipe	No.	R 500.00	**4**	R 2 000.00
5		**BEDDING (PIPES)**				
		Provision of bedding	m³	R 30.00	**4**	R 120.00
6		**BRICKWORK**				
		Brickwork to all chambers	m²	R 157.00	12.7	R 1 987.62
7		**STERILEATION AND HYDROTESTING**	No.	R 1 000.00	1	R 1 000.00
		MISCELANEOUS				
		(% of items 1 to 7)	%	10.00%		R 116 999.32
		SUB-TOTAL A				**R 1 286 992.56**
		PRELIMINARY & GENERAL				
		(% of sub total A)	%	30.00%		R 386 097.77
		PRELIMINARY WORKS				
		(a) Acess road	km	100000	0	R 0.00
		SUB-TOTAL B				**R 1 673 090.32**
		CONTINGENCIES				
		(% of sub-total B)	%	15.00%		R 250 963.55
		SUB-TOTAL C				**R 1 924 053.87**
		PLANNING DESIGN & SUPERVISION				
		(% of sub total C)	%	15.00%		R 288 608.08
		SUB-TOTAL D				**R 2 212 661.95**
		VAT (% of sub total D)	%	14.00%		R 309 772.67
		NETT PROJECT COST				**R 2 522 434.63**
		Cost of relocations	Sum	0		R 0.00
		Cost of land acquisition	m²	10.00	1344.8	R 13 447.75

APPENDIX M4 :

ECONOMIC MODELS:

PRE-FEASIBILITY PHASE

ECONOMICS MODEL

Low Demand Scenario

D1A: Zalu Dam: Pumping from site

	0.46	0	0.031	0.058	0.066	
	0		0.116	0.091	0.151	

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	54.500						54.500	0.000	0.000	48.505	0.000	0.000	46.725	0.000	0.000	45.041	0.000	0.000
2002		0.460	0.000	0.031	0.058	0.066	0.000	0.526	0.089	0.000	0.442	0.075	0.000	0.418	0.071	0.000	0.395	0.067
2003		0.460	0.000	0.035	0.060	0.070	0.000	0.530	0.095	0.000	0.420	0.075	0.000	0.390	0.070	0.000	0.362	0.065
2004		0.460	0.000	0.040	0.061	0.075	0.000	0.535	0.101	0.000	0.400	0.076	0.000	0.364	0.069	0.000	0.332	0.063
2005		0.460	0.000	0.044	0.063	0.079	0.000	0.539	0.108	0.000	0.380	0.076	0.000	0.340	0.068	0.000	0.304	0.061
2006		0.460	0.000	0.049	0.065	0.084	0.000	0.544	0.114	0.000	0.362	0.076	0.000	0.317	0.066	0.000	0.279	0.058
2007		0.460	0.000	0.053	0.067	0.088	0.000	0.548	0.120	0.000	0.344	0.075	0.000	0.296	0.065	0.000	0.256	0.056
2008		0.460	0.000	0.058	0.068	0.093	0.000	0.553	0.126	0.000	0.327	0.075	0.000	0.277	0.063	0.000	0.234	0.054
2009		0.460	0.000	0.062	0.070	0.097	0.000	0.557	0.132	0.000	0.311	0.074	0.000	0.258	0.061	0.000	0.215	0.051
2010		0.460	0.000	0.067	0.072	0.102	0.000	0.562	0.139	0.000	0.296	0.073	0.000	0.241	0.059	0.000	0.197	0.049
2011	0.000	0.460	0.000	0.071	0.074	0.106	0.000	0.566	0.145	0.000	0.281	0.072	0.000	0.225	0.058	0.000	0.180	0.046
2012		0.460	0.000	0.076	0.075	0.111	0.000	0.571	0.151	0.000	0.268	0.071	0.000	0.210	0.056	0.000	0.165	0.044
2013		0.460	0.000	0.080	0.077	0.115	0.000	0.575	0.157	0.000	0.254	0.070	0.000	0.196	0.054	0.000	0.151	0.041
2014		0.460	0.000	0.085	0.079	0.120	0.000	0.580	0.164	0.000	0.242	0.068	0.000	0.183	0.052	0.000	0.139	0.039
2015		0.460	0.000	0.089	0.081	0.124	0.000	0.584	0.170	0.000	0.230	0.067	0.000	0.171	0.050	0.000	0.127	0.037
2016		0.460	0.000	0.094	0.082	0.129	0.000	0.589	0.176	0.000	0.219	0.065	0.000	0.159	0.048	0.000	0.116	0.035
2017		0.460	0.000	0.098	0.084	0.133	0.000	0.593	0.182	0.000	0.208	0.064	0.000	0.148	0.046	0.000	0.107	0.033
2018		0.460	0.000	0.103	0.086	0.138	0.000	0.598	0.188	0.000	0.198	0.062	0.000	0.138	0.044	0.000	0.098	0.031
2019		0.460	0.000	0.107	0.088	0.142	0.000	0.602	0.195	0.000	0.188	0.061	0.000	0.129	0.042	0.000	0.089	0.029
2020		0.460	0.000	0.112	0.089	0.147	0.000	0.607	0.201	0.000	0.178	0.059	0.000	0.120	0.040	0.000	0.082	0.027
2021	-27.280	0.460	0.000	0.116	0.091	0.151	-27.280	0.611	0.207	-7.570	0.170	0.057	-5.018	0.112	0.038	-3.351	0.075	0.025
TOTAL	**27.220**	**9.200**	**0.000**	**1.470**	**1.490**	**2.170**	**27.220**	**11.370**	**2.960**	**40.934**	**5.717**	**1.391**	**41.707**	**4.693**	**1.117**	**41.690**	**3.906**	**0.911**

	NPC	NPV water	URV, R/kl
AT 6%	**48.0**	**17.1**	**2.82**
AT 8%	**47.5**	**13.7**	**3.46**
AT 10%	**46.5**	**11.2**	**4.16**

ECONOMICS MODEL

Low Demand Scenario
D1B: Zalu Dam: From weir

0.42	0	0.054	0.083	0.066	
0		0.157	0.124	0.151	

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	49.940						49.940	0.000	0.000	44.446	0.000	0.000	42.816	0.000	0.000	41.273	0.000	0.000
2002		0.420	0.000	0.054	0.083	0.066	0.000	0.486	0.137	0.000	0.408	0.115	0.000	0.386	0.109	0.000	0.365	0.103
2003		0.420	0.000	0.059	0.085	0.070	0.000	0.490	0.145	0.000	0.389	0.115	0.000	0.361	0.106	0.000	0.335	0.099
2004		0.420	0.000	0.065	0.087	0.075	0.000	0.495	0.152	0.000	0.370	0.114	0.000	0.337	0.104	0.000	0.307	0.094
2005		0.420	0.000	0.070	0.089	0.079	0.000	0.499	0.160	0.000	0.352	0.113	0.000	0.315	0.101	0.000	0.282	0.090
2006		0.420	0.000	0.076	0.092	0.084	0.000	0.504	0.167	0.000	0.335	0.111	0.000	0.294	0.098	0.000	0.259	0.086
2007		0.420	0.000	0.081	0.094	0.088	0.000	0.508	0.175	0.000	0.319	0.110	0.000	0.275	0.094	0.000	0.237	0.082
2008		0.420	0.000	0.087	0.096	0.093	0.000	0.513	0.182	0.000	0.304	0.108	0.000	0.257	0.091	0.000	0.217	0.077
2009		0.420	0.000	0.092	0.098	0.097	0.000	0.517	0.190	0.000	0.289	0.106	0.000	0.240	0.088	0.000	0.199	0.073
2010		0.420	0.000	0.097	0.100	0.102	0.000	0.522	0.198	0.000	0.275	0.104	0.000	0.224	0.085	0.000	0.183	0.069
2011	0.000	0.420	0.000	0.103	0.102	0.106	0.000	0.526	0.205	0.000	0.262	0.102	0.000	0.209	0.081	0.000	0.168	0.065
2012		0.420	0.000	0.108	0.105	0.111	0.000	0.531	0.213	0.000	0.249	0.100	0.000	0.195	0.078	0.000	0.154	0.062
2013		0.420	0.000	0.114	0.107	0.115	0.000	0.535	0.220	0.000	0.237	0.097	0.000	0.182	0.075	0.000	0.141	0.058
2014		0.420	0.000	0.119	0.109	0.120	0.000	0.540	0.228	0.000	0.225	0.095	0.000	0.170	0.072	0.000	0.129	0.055
2015		0.420	0.000	0.124	0.111	0.124	0.000	0.544	0.236	0.000	0.214	0.093	0.000	0.159	0.069	0.000	0.118	0.051
2016		0.420	0.000	0.130	0.113	0.129	0.000	0.549	0.243	0.000	0.204	0.090	0.000	0.148	0.066	0.000	0.109	0.048
2017		0.420	0.000	0.135	0.115	0.133	0.000	0.553	0.251	0.000	0.194	0.088	0.000	0.138	0.063	0.000	0.099	0.045
2018		0.420	0.000	0.141	0.118	0.138	0.000	0.558	0.258	0.000	0.184	0.085	0.000	0.129	0.060	0.000	0.091	0.042
2019		0.420	0.000	0.146	0.120	0.142	0.000	0.562	0.266	0.000	0.175	0.083	0.000	0.121	0.057	0.000	0.084	0.040
2020		0.420	0.000	0.152	0.122	0.147	0.000	0.567	0.273	0.000	0.167	0.080	0.000	0.113	0.054	0.000	0.077	0.037
2021	-25.770	0.420	0.000	0.157	0.124	0.151	-25.770	0.571	0.281	-7.151	0.158	0.078	-4.740	0.105	0.052	-3.166	0.070	0.035
TOTAL	**24.170**	**8.400**	**0.000**	**2.110**	**2.070**	**2.170**	**24.170**	**10.570**	**4.180**	**37.295**	**5.308**	**1.987**	**38.075**	**4.356**	**1.602**	**38.107**	**3.624**	**1.311**

	NPC	NPV water	URV, R/kl
AT 6%	**44.6**	**17.1**	**2.61**
AT 8%	**44.0**	**13.7**	**3.21**
AT 10%	**43.0**	**11.2**	**3.85**

ECONOMICS MODEL

Low Demand Scenario
D1C: Zalu Dam: Gravity from site

	0.49	0	0.029	0.046	0.066	
	0		0.089	0.07	0.151	

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	58.300						58.300	0.000	0.000	51.887	0.000	0.000	49.983	0.000	0.000	48.182	0.000	0.000
2002		0.490	0.000	0.029	0.046	0.066	0.000	0.556	0.075	0.000	0.467	0.063	0.000	0.441	0.060	0.000	0.418	0.056
2003		0.490	0.000	0.032	0.047	0.070	0.000	0.560	0.079	0.000	0.444	0.063	0.000	0.412	0.058	0.000	0.383	0.054
2004		0.490	0.000	0.035	0.049	0.075	0.000	0.565	0.084	0.000	0.422	0.063	0.000	0.384	0.057	0.000	0.351	0.052
2005		0.490	0.000	0.038	0.050	0.079	0.000	0.569	0.088	0.000	0.401	0.062	0.000	0.359	0.056	0.000	0.321	0.050
2006		0.490	0.000	0.042	0.051	0.084	0.000	0.574	0.093	0.000	0.382	0.062	0.000	0.335	0.054	0.000	0.294	0.048
2007		0.490	0.000	0.045	0.052	0.088	0.000	0.578	0.097	0.000	0.363	0.061	0.000	0.312	0.052	0.000	0.270	0.045
2008		0.490	0.000	0.048	0.054	0.093	0.000	0.583	0.102	0.000	0.345	0.060	0.000	0.292	0.051	0.000	0.247	0.043
2009		0.490	0.000	0.051	0.055	0.097	0.000	0.587	0.106	0.000	0.328	0.059	0.000	0.272	0.049	0.000	0.226	0.041
2010		0.490	0.000	0.054	0.056	0.102	0.000	0.592	0.110	0.000	0.312	0.058	0.000	0.254	0.047	0.000	0.207	0.039
2011	0.000	0.490	0.000	0.057	0.057	0.106	0.000	0.596	0.115	0.000	0.296	0.057	0.000	0.237	0.046	0.000	0.190	0.037
2012		0.490	0.000	0.061	0.059	0.111	0.000	0.601	0.119	0.000	0.282	0.056	0.000	0.221	0.044	0.000	0.174	0.035
2013		0.490	0.000	0.064	0.060	0.115	0.000	0.605	0.124	0.000	0.268	0.055	0.000	0.206	0.042	0.000	0.159	0.033
2014		0.490	0.000	0.067	0.061	0.120	0.000	0.610	0.128	0.000	0.254	0.053	0.000	0.192	0.040	0.000	0.146	0.031
2015		0.490	0.000	0.070	0.062	0.124	0.000	0.614	0.132	0.000	0.242	0.052	0.000	0.179	0.039	0.000	0.134	0.029
2016		0.490	0.000	0.073	0.064	0.129	0.000	0.619	0.137	0.000	0.230	0.051	0.000	0.167	0.037	0.000	0.122	0.027
2017		0.490	0.000	0.076	0.065	0.133	0.000	0.623	0.141	0.000	0.218	0.050	0.000	0.156	0.035	0.000	0.112	0.025
2018		0.490	0.000	0.080	0.066	0.138	0.000	0.628	0.146	0.000	0.207	0.048	0.000	0.145	0.034	0.000	0.103	0.024
2019		0.490	0.000	0.083	0.067	0.142	0.000	0.632	0.150	0.000	0.197	0.047	0.000	0.136	0.032	0.000	0.094	0.022
2020		0.490	0.000	0.086	0.069	0.147	0.000	0.637	0.155	0.000	0.187	0.045	0.000	0.126	0.031	0.000	0.086	0.021
2021	-28.490	0.490	0.000	0.089	0.070	0.151	-28.490	0.641	0.159	-7.906	0.178	0.044	-5.240	0.118	0.029	-3.500	0.079	0.020
TOTAL	**29.810**	**9.800**	**0.000**	**1.180**	**1.160**	**2.170**	**29.810**	**11.970**	**2.340**	**43.981**	**6.023**	**1.109**	**44.742**	**4.945**	**0.893**	**44.682**	**4.117**	**0.730**

	NPC	NPV water	URV, R/kl
AT 6%	**51.1**	**17.1**	**2.99**
AT 8%	**50.6**	**13.7**	**3.69**
AT 10%	**49.5**	**11.2**	**4.43**

ECONOMICS MODEL

Low Demand Scenario

D2A: Lusikisiki Dam: From site

	0.42	0	0.047	0.074	0.066	
	0		0.14	0.11	0.151	

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	49.200						49.200	0.000	0.000	43.788	0.000	0.000	42.181	0.000	0.000	40.661	0.000	0.000
2002		0.420	0.000	0.047	0.074	0.066	0.000	0.486	0.121	0.000	0.408	0.102	0.000	0.386	0.096	0.000	0.365	0.091
2003		0.420	0.000	0.052	0.076	0.070	0.000	0.490	0.128	0.000	0.389	0.101	0.000	0.361	0.094	0.000	0.335	0.087
2004		0.420	0.000	0.057	0.078	0.075	0.000	0.495	0.135	0.000	0.370	0.101	0.000	0.337	0.092	0.000	0.307	0.084
2005		0.420	0.000	0.062	0.080	0.079	0.000	0.499	0.141	0.000	0.352	0.100	0.000	0.315	0.089	0.000	0.282	0.080
2006		0.420	0.000	0.067	0.082	0.084	0.000	0.504	0.148	0.000	0.335	0.099	0.000	0.294	0.086	0.000	0.259	0.076
2007		0.420	0.000	0.071	0.083	0.088	0.000	0.508	0.155	0.000	0.319	0.097	0.000	0.275	0.084	0.000	0.237	0.072
2008		0.420	0.000	0.076	0.085	0.093	0.000	0.513	0.162	0.000	0.304	0.096	0.000	0.257	0.081	0.000	0.217	0.069
2009		0.420	0.000	0.081	0.087	0.097	0.000	0.517	0.169	0.000	0.289	0.094	0.000	0.240	0.078	0.000	0.199	0.065
2010		0.420	0.000	0.086	0.089	0.102	0.000	0.522	0.175	0.000	0.275	0.092	0.000	0.224	0.075	0.000	0.183	0.061
2011	0.000	0.420	0.000	0.091	0.091	0.106	0.000	0.526	0.182	0.000	0.262	0.091	0.000	0.209	0.072	0.000	0.168	0.058
2012		0.420	0.000	0.096	0.093	0.111	0.000	0.531	0.189	0.000	0.249	0.089	0.000	0.195	0.069	0.000	0.154	0.055
2013		0.420	0.000	0.101	0.095	0.115	0.000	0.535	0.196	0.000	0.237	0.087	0.000	0.182	0.067	0.000	0.141	0.052
2014		0.420	0.000	0.106	0.097	0.120	0.000	0.540	0.202	0.000	0.225	0.084	0.000	0.170	0.064	0.000	0.129	0.048
2015		0.420	0.000	0.111	0.099	0.124	0.000	0.544	0.209	0.000	0.214	0.082	0.000	0.159	0.061	0.000	0.118	0.046
2016		0.420	0.000	0.116	0.101	0.129	0.000	0.549	0.216	0.000	0.204	0.080	0.000	0.148	0.058	0.000	0.109	0.043
2017		0.420	0.000	0.120	0.102	0.133	0.000	0.553	0.223	0.000	0.194	0.078	0.000	0.138	0.056	0.000	0.099	0.040
2018		0.420	0.000	0.125	0.104	0.138	0.000	0.558	0.230	0.000	0.184	0.076	0.000	0.129	0.053	0.000	0.091	0.038
2019		0.420	0.000	0.130	0.106	0.142	0.000	0.562	0.236	0.000	0.175	0.074	0.000	0.121	0.051	0.000	0.084	0.035
2020		0.420	0.000	0.135	0.108	0.147	0.000	0.567	0.243	0.000	0.167	0.072	0.000	0.113	0.048	0.000	0.077	0.033
2021	-25.150	0.420	0.000	0.140	0.110	0.151	-25.150	0.571	0.250	-6.979	0.158	0.069	-4.626	0.105	0.046	-3.090	0.070	0.031
TOTAL	**24.050**	**8.400**	**0.000**	**1.870**	**1.840**	**2.170**	**24.050**	**10.570**	**3.710**	**36.809**	**5.308**	**1.762**	**37.555**	**4.356**	**1.421**	**37.572**	**3.624**	**1.162**

	NPC	NPV water	URV, R/kl
AT 6%	**43.9**	**17.1**	**2.57**
AT 8%	**43.3**	**13.7**	**3.16**
AT 10%	**42.4**	**11.2**	**3.79**

ECONOMICS MODEL

Low Demand Scenario

D2B: Lusikisiki Dam: From weir

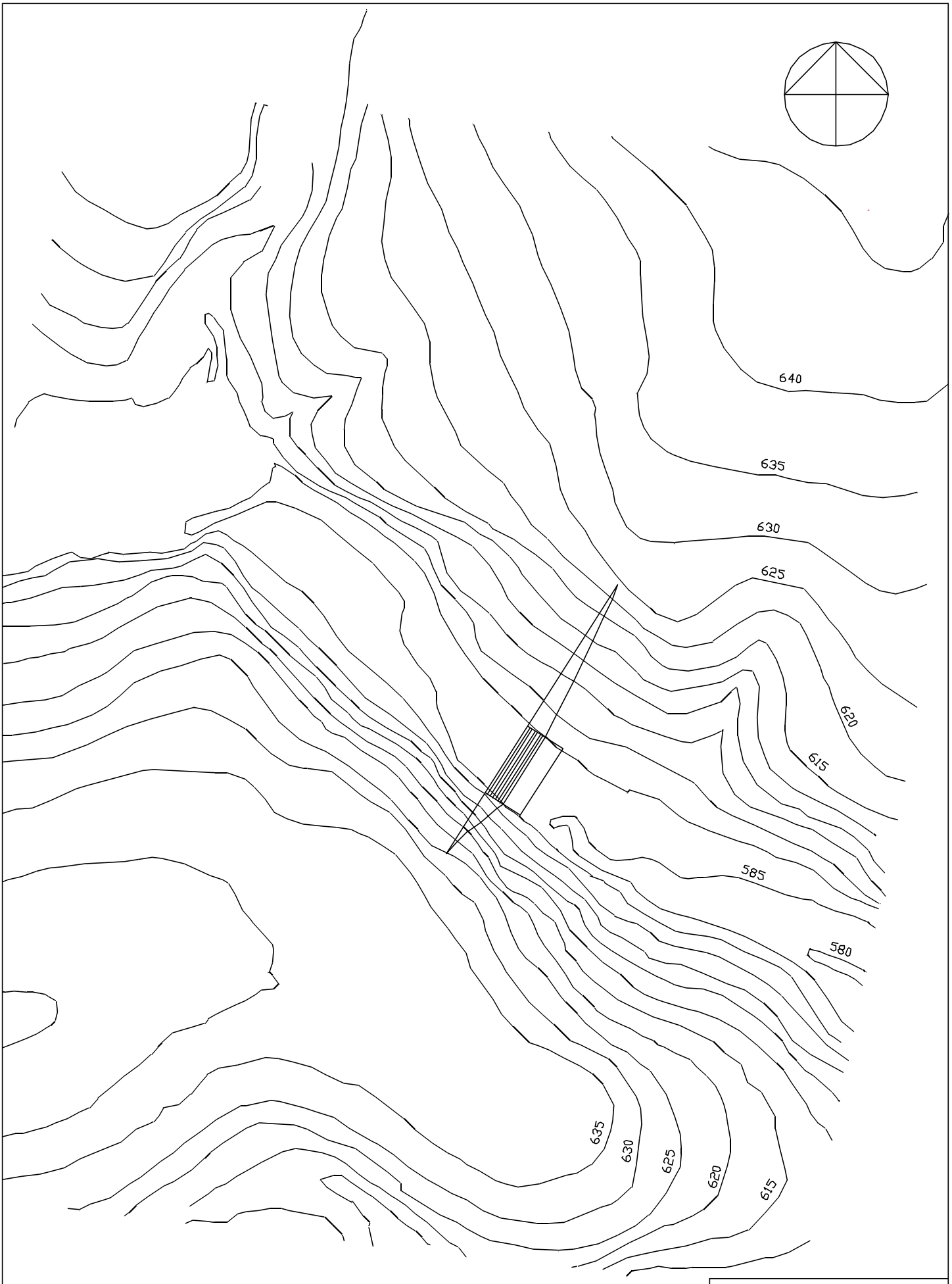
	0.4	0	0.054	0.083	0.066	
	0		0.157	0.124	0.151	

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%			NET PRESENT COST AT 10%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
1999							0	0	0	0	0	0	0	0	0	0	0	0
2000							0	0	0	0	0	0	0	0	0	0	0	0
2001	48.150						48.150	0.000	0.000	42.853	0.000	0.000	41.281	0.000	0.000	39.793	0.000	0.000
2002		0.400	0.000	0.054	0.083	0.066	0.000	0.466	0.137	0.000	0.391	0.115	0.000	0.370	0.109	0.000	0.350	0.103
2003		0.400	0.000	0.059	0.085	0.070	0.000	0.470	0.145	0.000	0.373	0.115	0.000	0.346	0.106	0.000	0.321	0.099
2004		0.400	0.000	0.065	0.087	0.075	0.000	0.475	0.152	0.000	0.355	0.114	0.000	0.323	0.104	0.000	0.295	0.094
2005		0.400	0.000	0.070	0.089	0.079	0.000	0.479	0.160	0.000	0.338	0.113	0.000	0.302	0.101	0.000	0.271	0.090
2006		0.400	0.000	0.076	0.092	0.084	0.000	0.484	0.167	0.000	0.322	0.111	0.000	0.282	0.098	0.000	0.248	0.086
2007		0.400	0.000	0.081	0.094	0.088	0.000	0.488	0.175	0.000	0.306	0.110	0.000	0.264	0.094	0.000	0.228	0.082
2008		0.400	0.000	0.087	0.096	0.093	0.000	0.493	0.182	0.000	0.292	0.108	0.000	0.247	0.091	0.000	0.209	0.077
2009		0.400	0.000	0.092	0.098	0.097	0.000	0.497	0.190	0.000	0.278	0.106	0.000	0.230	0.088	0.000	0.192	0.073
2010		0.400	0.000	0.097	0.100	0.102	0.000	0.502	0.198	0.000	0.264	0.104	0.000	0.215	0.085	0.000	0.176	0.069
2011	0.000	0.400	0.000	0.103	0.102	0.106	0.000	0.506	0.205	0.000	0.252	0.102	0.000	0.201	0.081	0.000	0.161	0.065
2012		0.400	0.000	0.108	0.105	0.111	0.000	0.511	0.213	0.000	0.239	0.100	0.000	0.188	0.078	0.000	0.148	0.062
2013		0.400	0.000	0.114	0.107	0.115	0.000	0.515	0.220	0.000	0.228	0.097	0.000	0.175	0.075	0.000	0.136	0.058
2014		0.400	0.000	0.119	0.109	0.120	0.000	0.520	0.228	0.000	0.217	0.095	0.000	0.164	0.072	0.000	0.124	0.055
2015		0.400	0.000	0.124	0.111	0.124	0.000	0.524	0.236	0.000	0.206	0.093	0.000	0.153	0.069	0.000	0.114	0.051
2016		0.400	0.000	0.130	0.113	0.129	0.000	0.529	0.243	0.000	0.196	0.090	0.000	0.143	0.066	0.000	0.105	0.048
2017		0.400	0.000	0.135	0.115	0.133	0.000	0.533	0.251	0.000	0.187	0.088	0.000	0.133	0.063	0.000	0.096	0.045
2018		0.400	0.000	0.141	0.118	0.138	0.000	0.538	0.258	0.000	0.178	0.085	0.000	0.125	0.060	0.000	0.088	0.042
2019		0.400	0.000	0.146	0.120	0.142	0.000	0.542	0.266	0.000	0.169	0.083	0.000	0.116	0.057	0.000	0.081	0.040
2020		0.400	0.000	0.152	0.122	0.147	0.000	0.547	0.273	0.000	0.161	0.080	0.000	0.109	0.054	0.000	0.074	0.037
2021	-24.810	0.400	0.000	0.157	0.124	0.151	-24.810	0.551	0.281	-6.885	0.153	0.078	-4.564	0.101	0.052	-3.048	0.068	0.035
TOTAL	**23.340**	**8.000**	**0.000**	**2.110**	**2.070**	**2.170**	**23.340**	**10.170**	**4.180**	**35.968**	**5.104**	**1.987**	**36.717**	**4.188**	**1.602**	**36.746**	**3.484**	**1.311**

	NPC	NPV water	URV, R/kl
AT 6%	**43.1**	**17.1**	**2.52**
AT 8%	**42.5**	**13.7**	**3.10**
AT 10%	**41.5**	**11.2**	**3.71**

APPENDIX 2 :

DAM LAYOUTS AND TYPICAL DETAIL
RECONNAISSANCE STAGE



ZALU DAM

FIGURE A 2.1

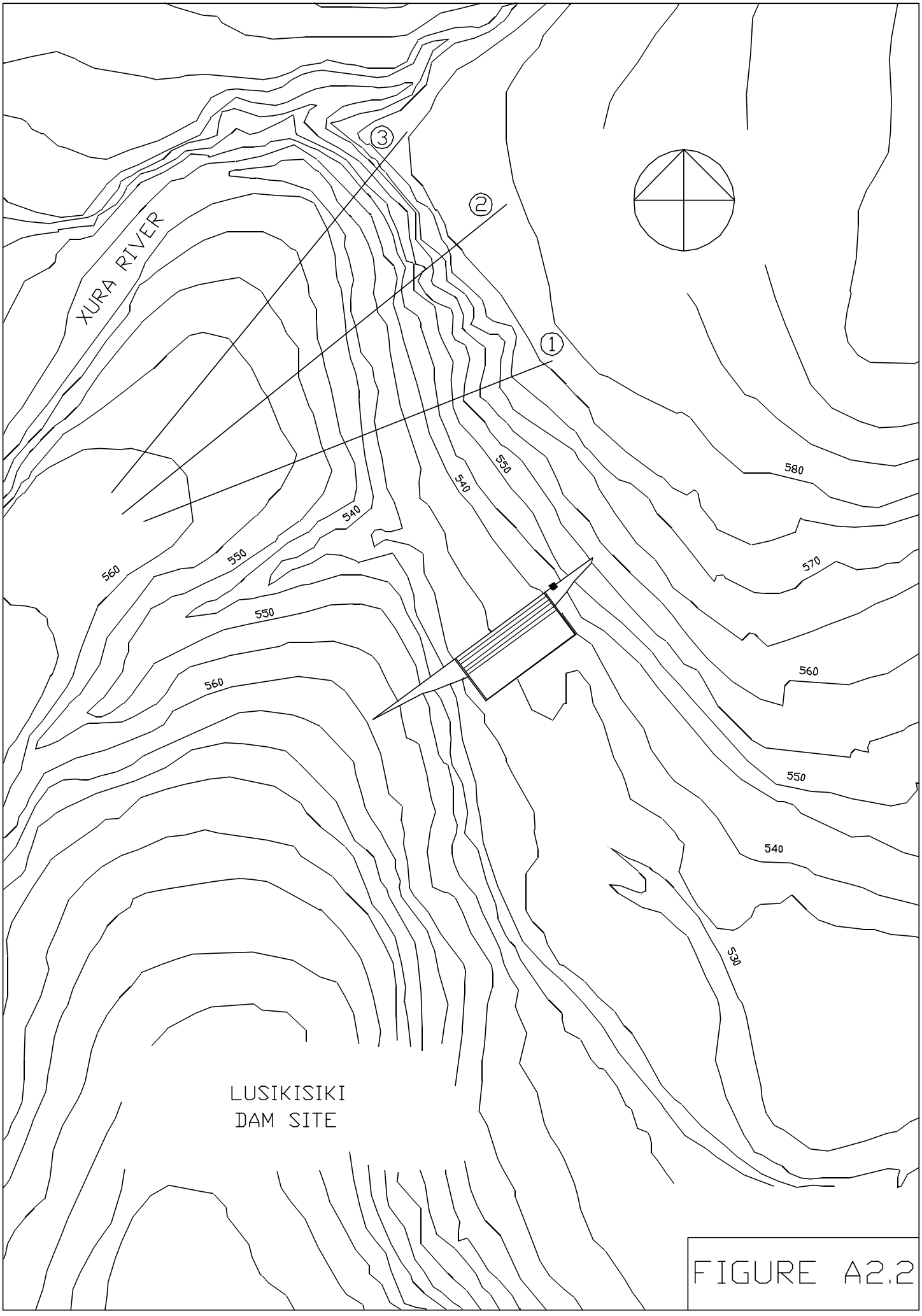
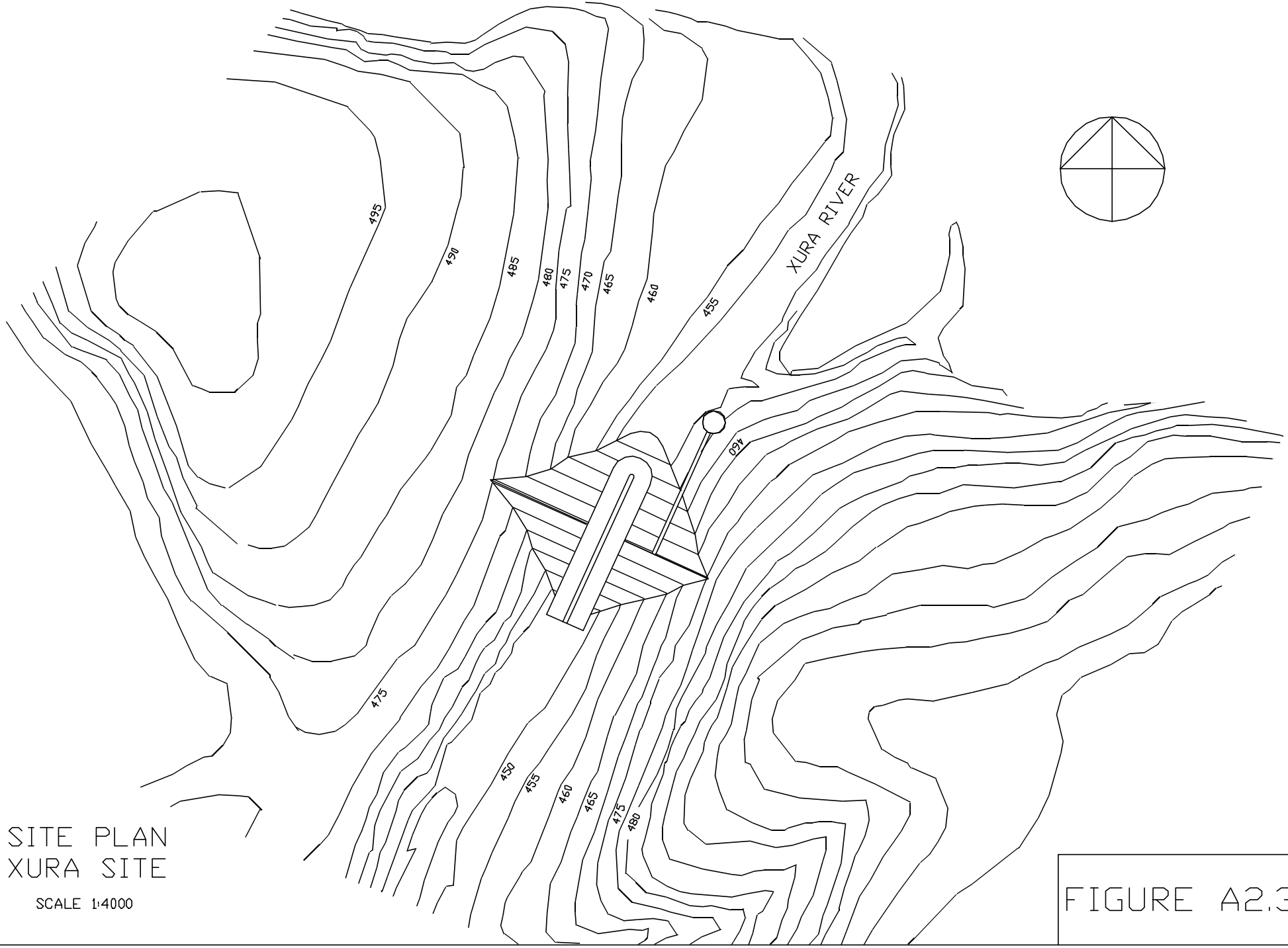


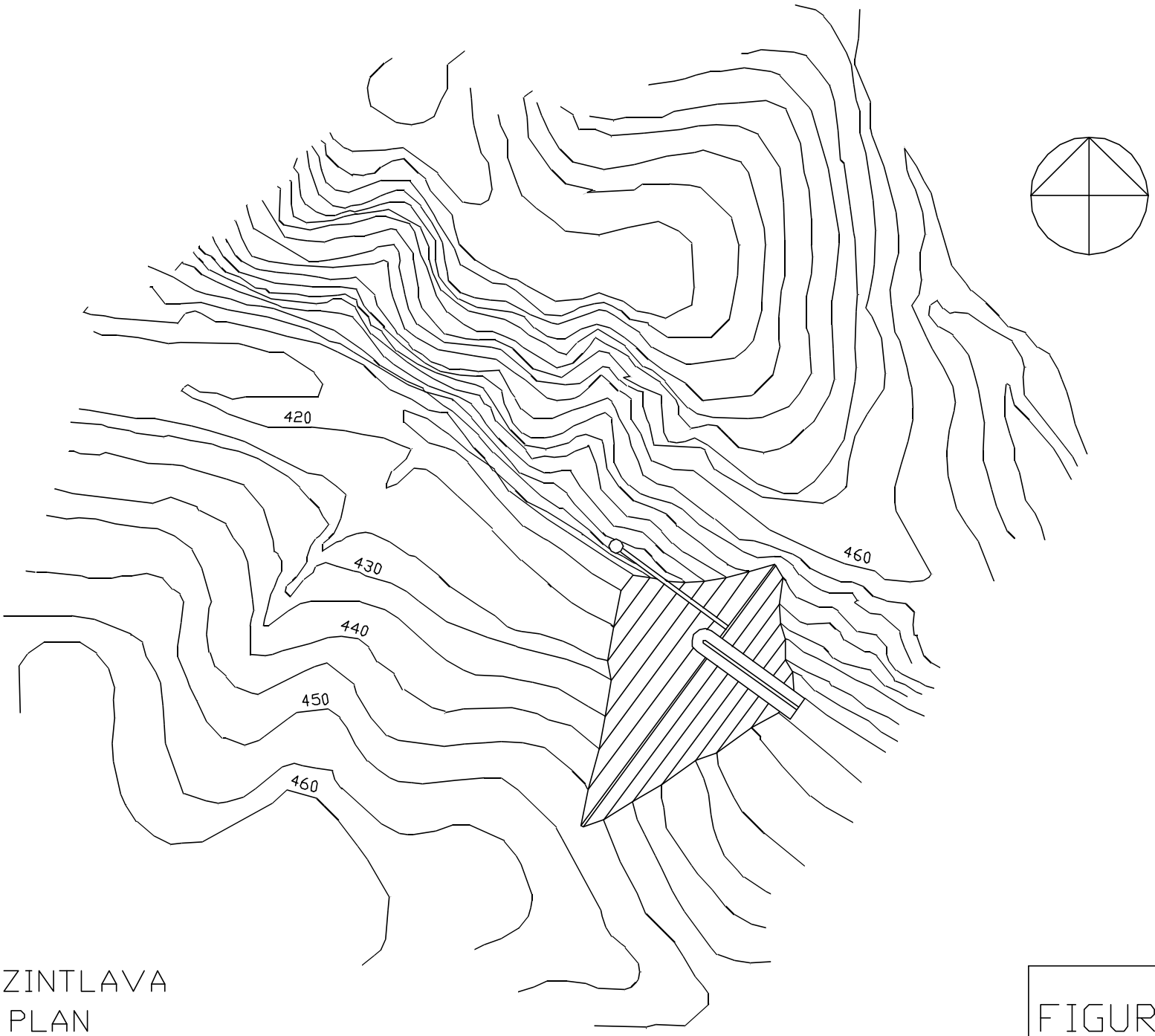
FIGURE A2.2



SITE PLAN
XURA SITE

SCALE 1:4000

FIGURE A2.3



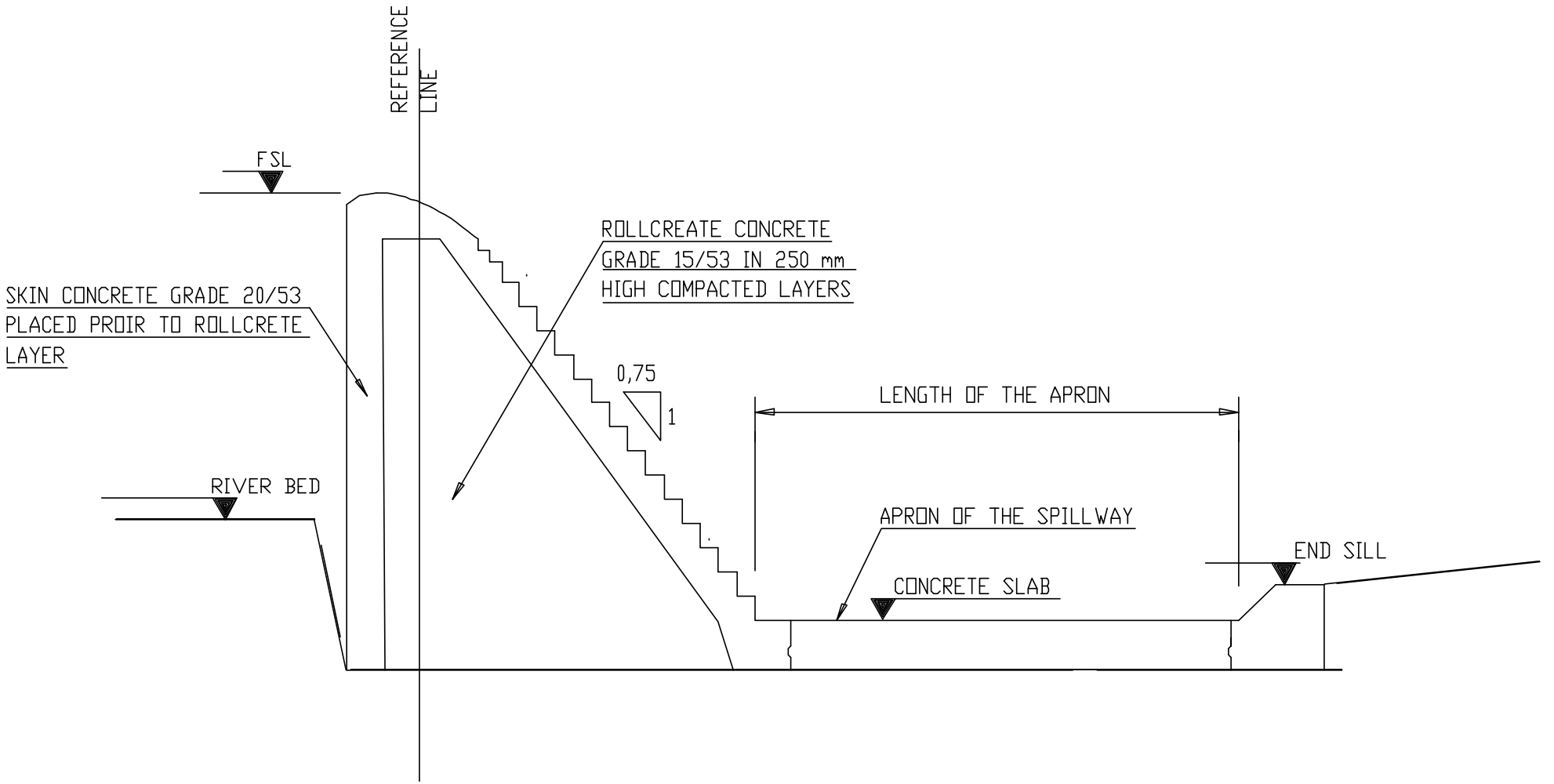
LOWER MZINTLAVA
SITE PLAN

FIGURE A2.4



TUNGWANE
SITE PLAN

FIGURE A2.5



TYPICAL SECTION THROUGH THE SPILLWAY

SCALE 1:250

SCALE 1:250

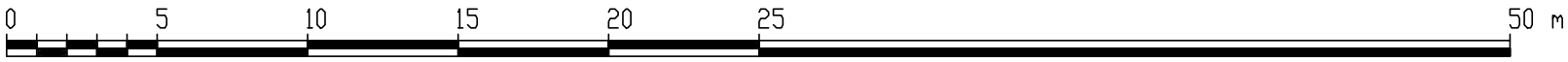
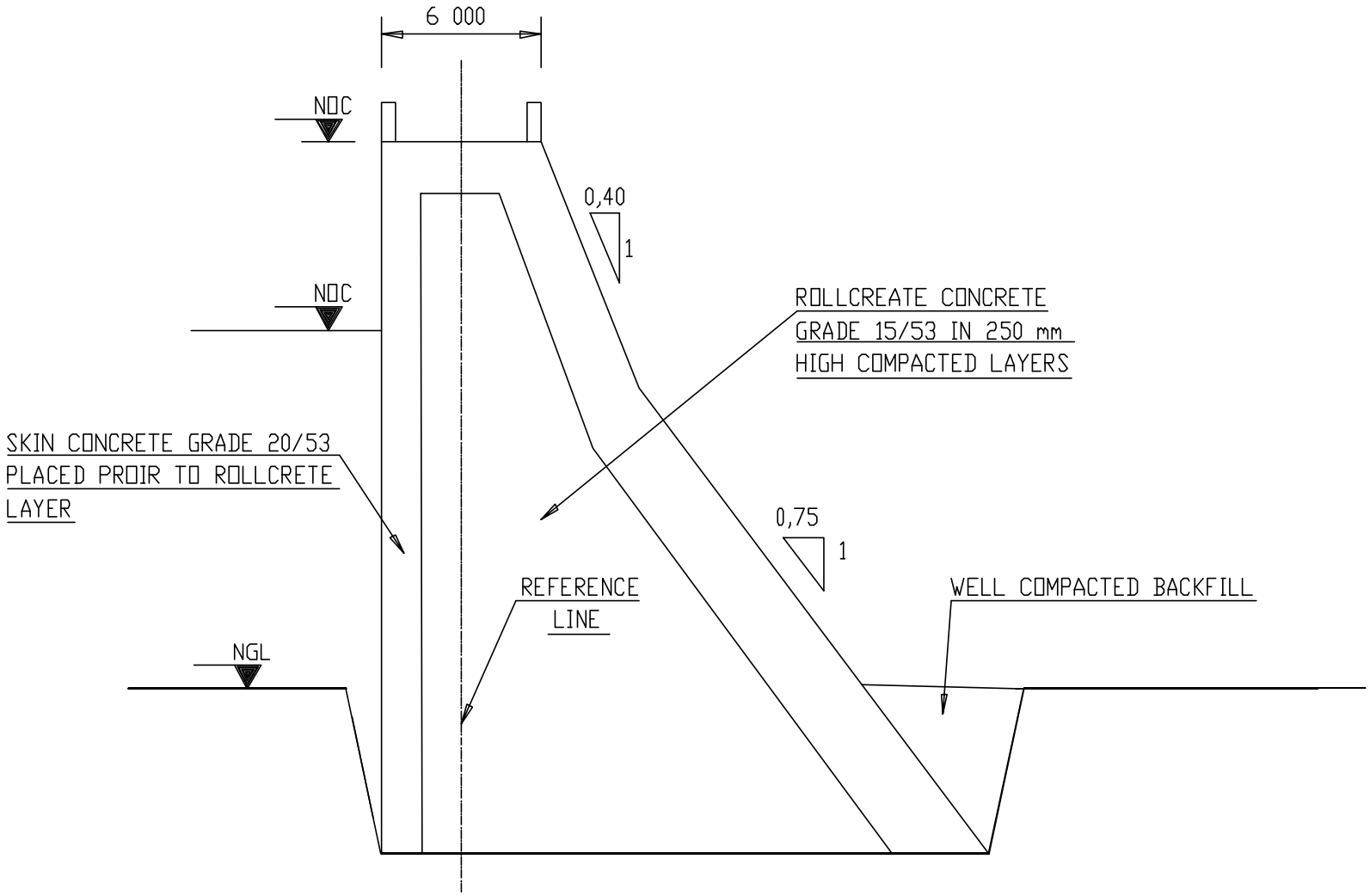


FIGURE A2.6



TYPICAL SECTION THROUGH THE NOC

SCALE 1:250

SCALE 1:250

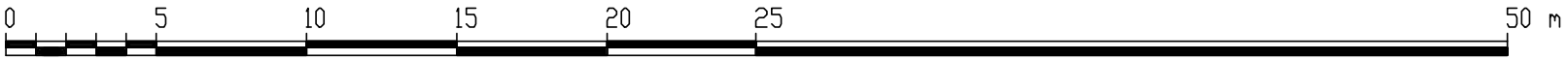
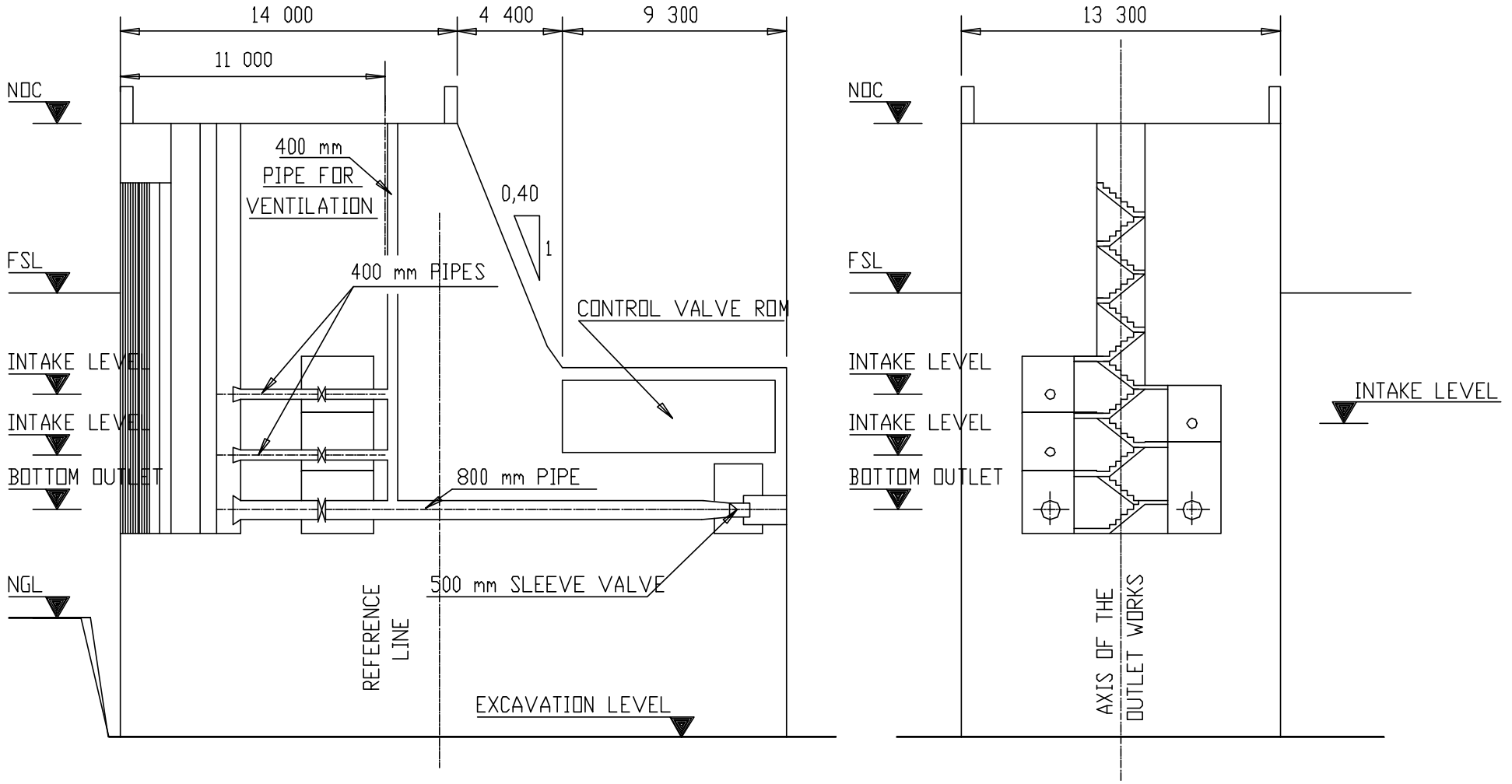


FIGURE A2.7



SECTIONS THROUGH THE OUTLET WORKS

SCALE 1:250

SCALE 1:250

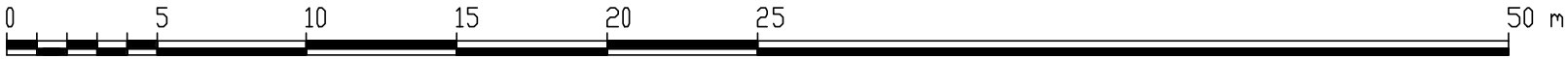
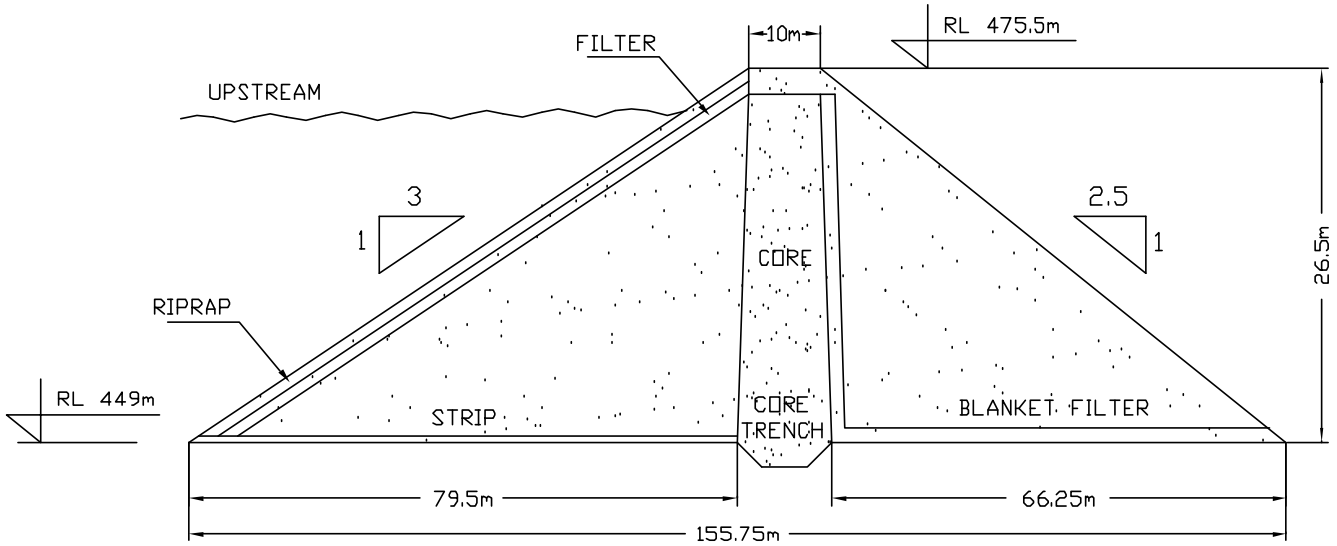


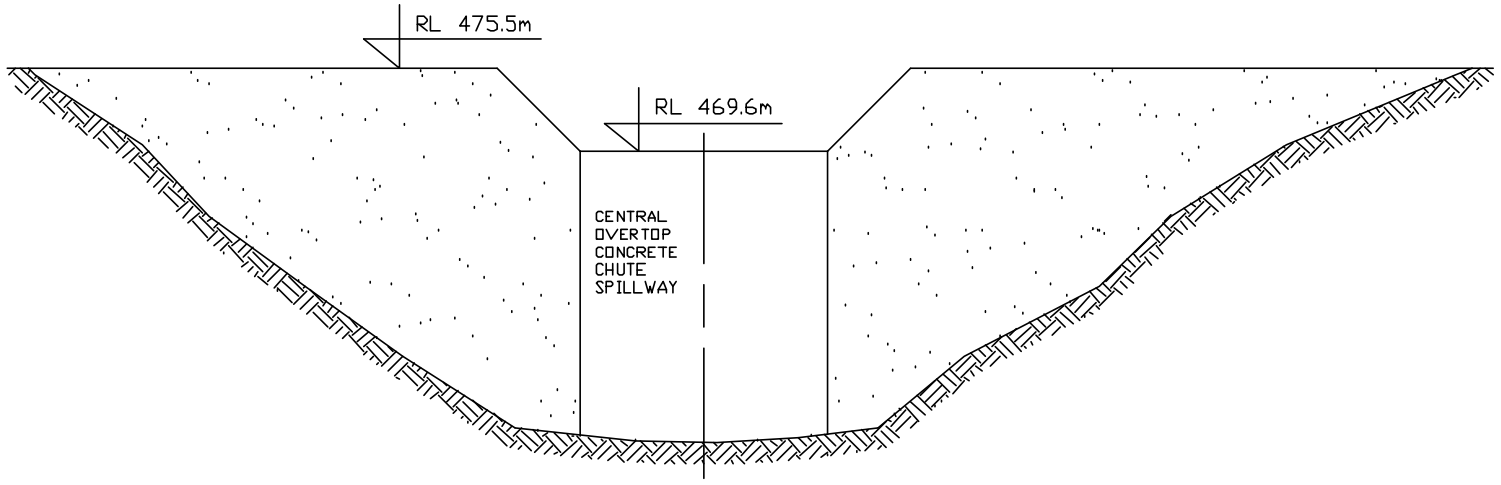
FIGURE A2.8



TYPICAL EMBANKMENT CROSS-SECTION : XURA DAM

VERT SCALE 1:500

HORIZ SCALE 1:1000

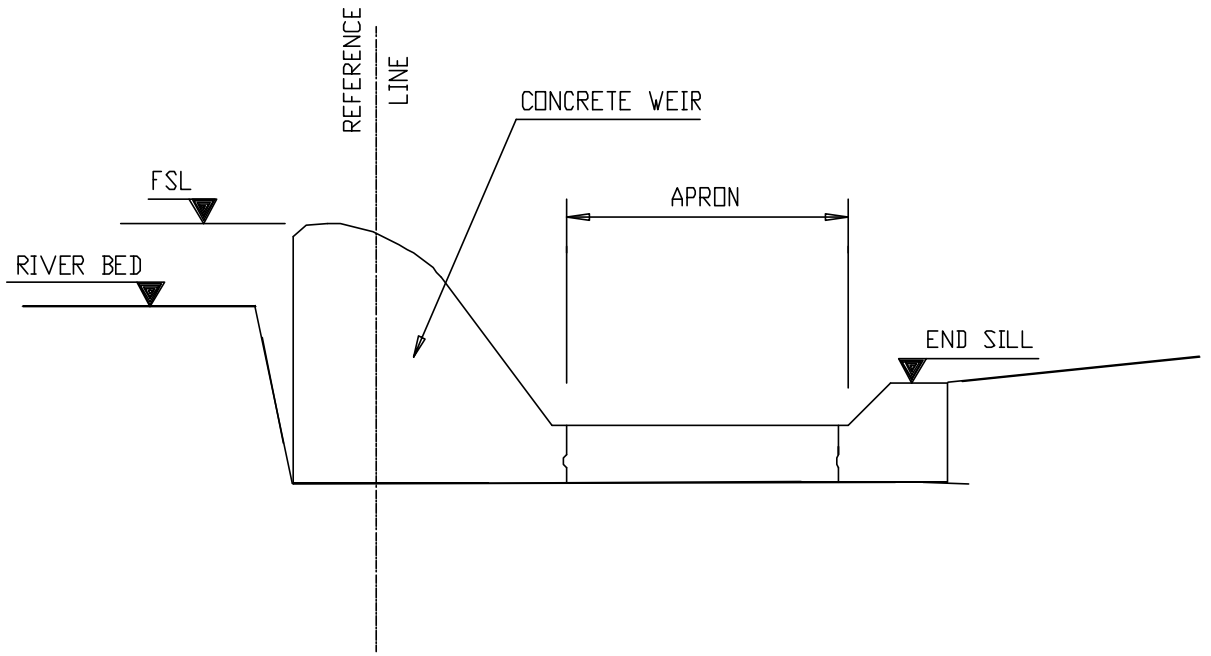


UPSTREAM ELEVATION : XURA DAM

VERT SCALE 1:500

HORIZ SCALE 1:1000

FIGURE A2.9



SECTION THROUGH A TYPICAL WEIR

SCALE 1:250

SCALE 1:250

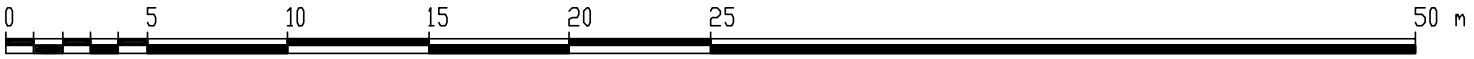
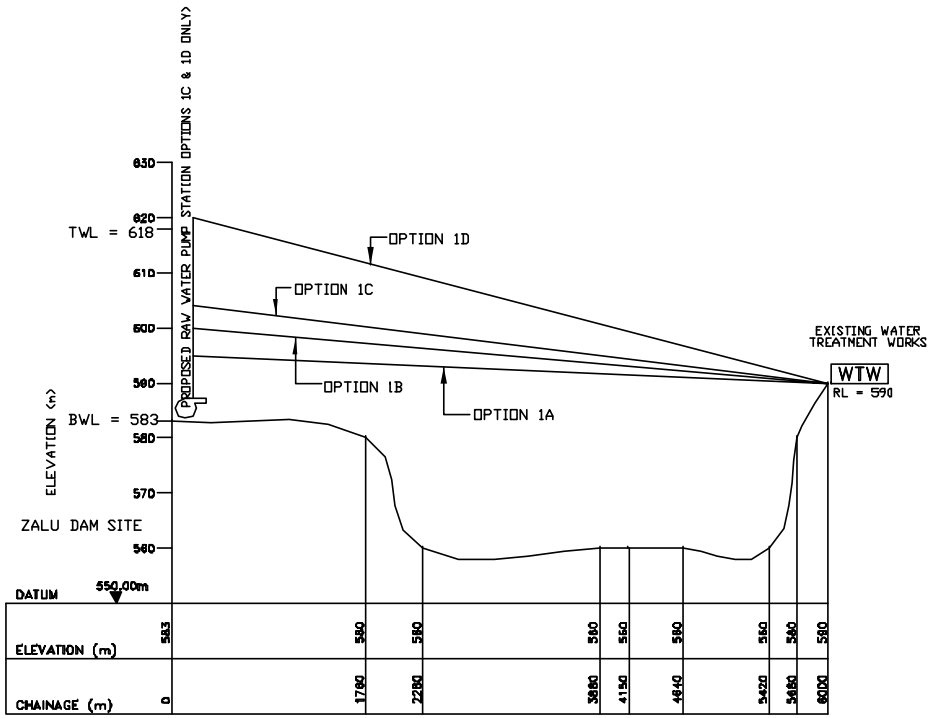


FIGURE A2.10

APPENDIX 3 :

BULK CONVEYANCE SYSTEM
SECTIONS
RECONNAISSANCE STAGE



LONGITUDINAL SECTION

HORIZONTAL : 1:50000
VERTICAL : 1:2000

YEAR 2000	Q = 65.4l/s
BWL	ø
595	595
600	600

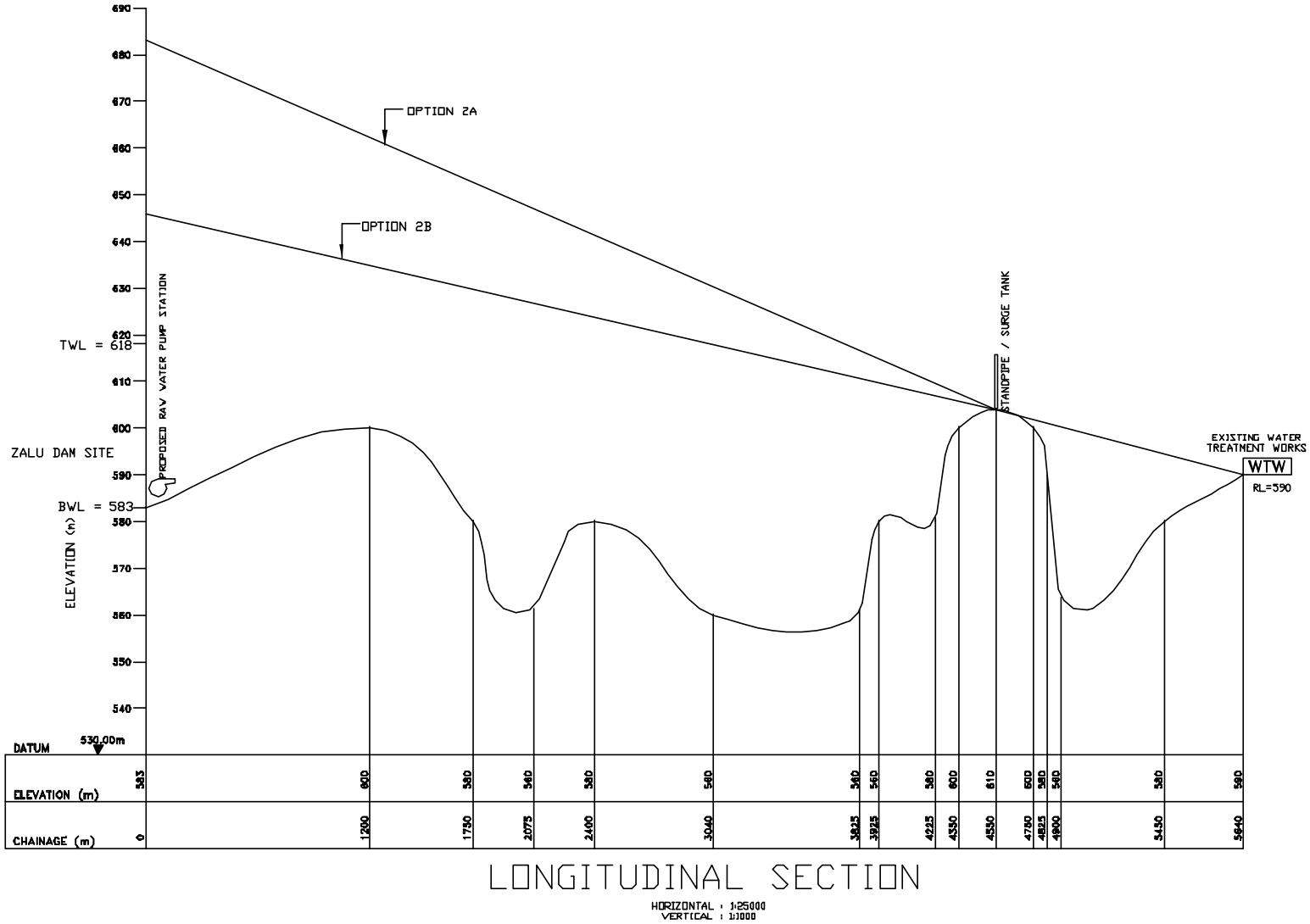
YEAR 2010	Q = 220l/s
BWL	ø
595	610
600	520

YEAR 2020	Q = 389l/s
BWL	ø
595	750
600	650

NOTES:

1. OPERATION
   a) GRAVITY FEED TO EXISTING WATER TREATMENT WORKS
   b) FEED INTO SYSTEM AS PER CURRENT OPERATION
2. NEW COMPONENTS
   a) GRAVITY RAW WATER MAIN TO WATER TREATMENT WORKS
3. EXISTING COMPONENTS TO BE UPGRADED
   a) WATER TREATMENT WORKS
   b) CLEAR WATER WELL
   c) CLEAR WATER PUMPS
   d) CLEAR WATER RISING MAIN
   e) STORAGE
   f) POSSIBLY MAIN BETWEEN RESERVOIR A & B
4. DAM PROPERTIES
   a) YIELD
   b) TWL 618m AMSL
   c) BWL 583m AMSL
5. PIPELINE PROPERTIES (GRAVITY MAIN) Q=389l/s (2020)
   a) LENGTH = 6 000m
   b) DIAMETER = SEE TABLE BELOW
   c) AVAILABLE HEAD 35m (BWL = 595m AMSL)
6. PIPELINE PROPERTIES (RISING MAIN)
   a) LENGTH = m
   b) DIAMETER = m N/A
   c) HEAD STATIC m
   d) HEAD TOTAL m
7. PUMPSTATION PROPERTIES
   a) POWER = Mw
      = Mw N/A
8. WATER TREATMENT WORKS
   a) CURRENT CAPACITY 12.7 Ml/day (1999)
   b) REQUIRED CAPACITY 19.0 Ml/day (2010)
      = 33.6 Ml/day (2020)
9. EXISTING CLEAR WATER RISING MAIN
   a) LENGTH = 2126m
   b) DIAMETER (EXISTING) 200mm AC (CLASSES D,E,F)

	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 3
	Drawn: M.K.		Scale: As shown
	Checked: W.S.K.	Description: ZALU DAM SITE PROPOSED BULK CONVEYANCE OPTION 1	No. Fig. A3.1



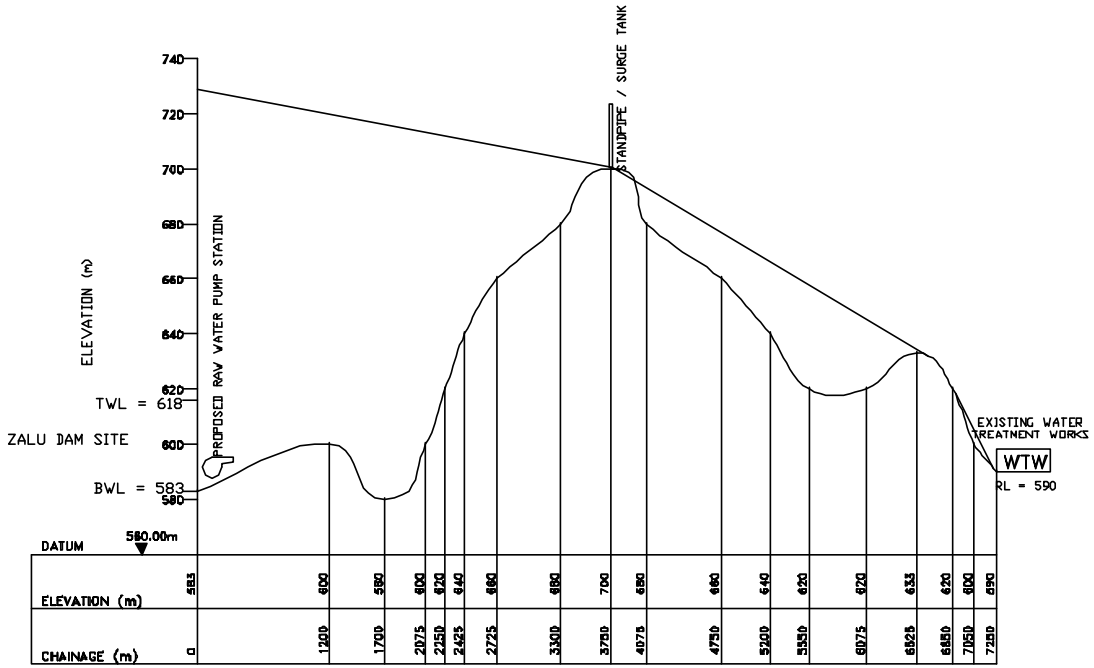
LONGITUDINAL SECTION

HORIZONTAL : 1:25000
VERTICAL : 1:1000

NOTES:

1. OPERATION
   a) PUMP TO EXISTING WATER TREATMENT WORKS
   b) FEED INTO SYSTEM AS PER CURRENT OPERATION
2. NEW COMPONENTS
   a) RAW WATER PUMP STATION
   b) RAW WATER RISING MAIN TO EXISTING WATER TREATMENT WORKS
3. EXISTING COMPONENTS TO BE UPGRADED
   a) WATER TREATMENT WORKS
   b) CLEAR WATER WELL
   c) CLEAR WATER PUMP STATION
   d) CLEAR WATER RISING MAIN
   e) STORAGE
   f) POSSIBLY MAIN BETWEEN RESERVOIRS A & B
4. DAM PROPERTIES
   a) YIELD
   b) TWL 618m AMSL
   c) BWL 583m AMSL
5. PIPELINE PROPERTIES (GRAVITY MAIN)
   a) LENGTH = m
   b) DIAMETER = m N/A
   c) AVAILABLE HEAD m
6. PIPELINE PROPERTIES (RISING MAIN) Q=389l/s (2020)
   a) LENGTH = 4 550m
   b) DIAMETER = 380mm (A) 440mm (B)
   c) HEAD STATIC 15m (A) 10m (B)
   d) HEAD TOTAL 87.8m (A) 45.7m (B)
7. PUMPSTATION PROPERTIES
   a) POWER = 0.14 Mw (2010)
      = 0.49 Mw (2020)
8. PIPELINE PROPERTIES (GRAVITY MAIN) Q=389l/s (2020)
   a) LENGTH = 1 090m
   b) DIAMETER = 400mm
   c) AVAILABLE HEAD 20m
9. WATER TREATMENT WORKS
   a) CURRENT CAPACITY 12.7 Ml/day (1999)
   b) REQUIRED CAPACITY 18.0 Ml/day (2010)
      = 33.6 Ml/day (2020)
10. EXISTING CLEAR WATER RISING MAIN
    a) LENGTH = 2126m
    b) DIAMETER (EXISTING) 200mm AC (CLASSES D,E,F)

	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 2 of 3
	Drawn: M.K.		Scale: As shown
	Checked: W.S.K.	Description: ZALU DAM SITE PROPOSED BULK CONVEYANCE OPTION 2	No. Fig. A3.2



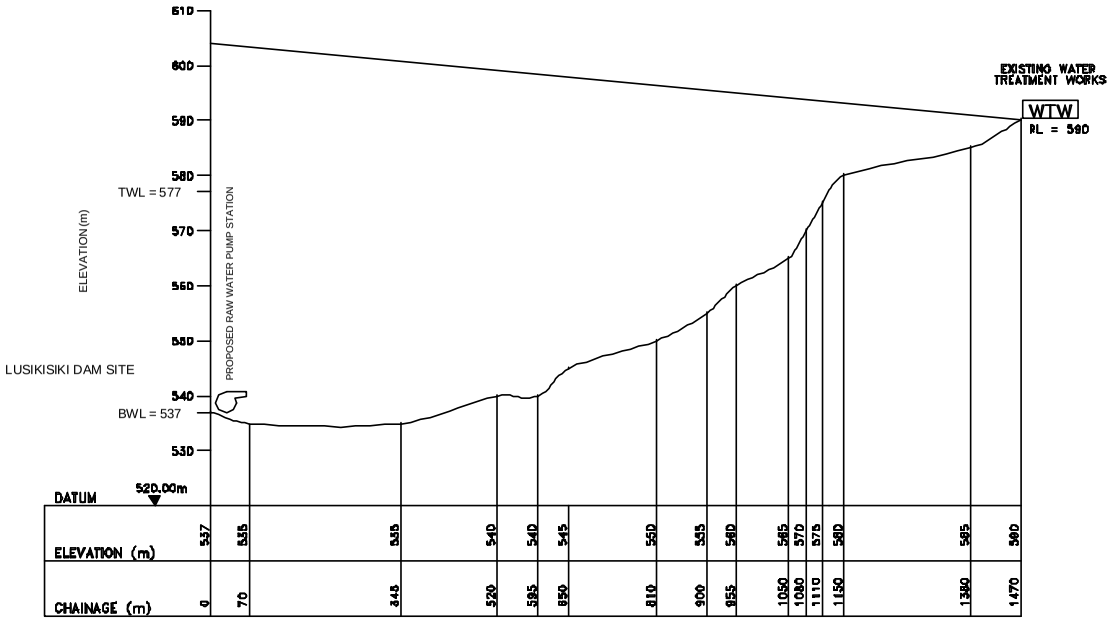
LONGITUDINAL SECTION

SCALES
HOR. 1:50000
VERT. 1:2000

NOTES:

1. OPERATION
   a) PUMP TO EXISTING WATER TREATMENT WORKS
   b) FEED INTO SYSTEM AS PER CURRENT OPERATION
2. NEW COMPONENTS
   a) GRAVITY MAIN TO RAW WATER PUMP STATION
   b) RAW WATER PUMP STATION
   c) RAW WATER RISING MAIN TO EXISTING WATER TREATMENT WORKS
3. EXISTING COMPONENTS TO BE UPGRADED
   a) WATER TREATMENT WORKS
   b) CLEAR WATER WELL
   c) CLEAR WATER PUMP STATION
   d) CLEAR WATER RISING MAIN
   e) STORAGE
   f) POSSIBLY MAIN BETWEEN RESERVOIRS A & B
4. DAM PROPERTIES
   a) YIELD
   b) TWL 618m AMSL
   c) BWL 583m AMSL
5. PIPELINE PROPERTIES (GRAVITY MAIN)
   a) LENGTH = m
   b) DIAMETER = m N/A
   c) AVAILABLE HEAD m
6. PIPELINE PROPERTIES (RISING MAIN) Q=389l/s (2020)
   a) LENGTH = 3 750m
   b) DIAMETER = 440mm
   c) HEAD STATIC 100m
   d) HEAD TOTAL 129.4m
7. PUMPSTATION PROPERTIES
   a) POWER = 0.29 Mw (2010)
      = 0.57 Mw (2020)
8. PIPELINE PROPERTIES (GRAVITY MAIN) Q=389l/s (2020)
   a) LENGTH = 3 500m
   b) DIAMETER = 360mm
   c) AVAILABLE HEAD 10m
9. WATER TREATMENT WORKS
   a) CURRENT CAPACITY 12.7 Ml/day (1999)
   b) REQUIRED CAPACITY 19.0 Ml/day (2010)
      = 33.6 Ml/day (2020)
10. EXISTING CLEAR WATER RISING MAIN
    a) LENGTH = 2126m
    b) DIAMETER (EXISTING) 200mm AC (CLASSES D,E,F)
11. NETT PRESENT VALUE OF INSTALLATION (R MILLION)
    a) PIPELINE = R 13.5
    b) PUMP STATION = R 8.5
    c) PUMPING COSTS = R 12.4
    d) TOTAL = R 34.4

Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY		Sheet 3 of 3
Drawn: M.K.			Scale: As shown
Checked: W.S.K.	Description: ZALU DAM SITE PROPOSED BULK CONVEYANCE OPTION 3		No. Fig. A3.3



LONGITUDINAL SECTION

SCALES
VERTICAL : 1:2000
HORIZONTAL : 1:50 000

NOTES:

1. OPERATION
   a) PUMP TO EXISTING WATER TREATMENT WORKS
   b) FEED INTO SYSTEM AS PER CURRENT OPERATION
2. NEW COMPONENTS
   a) RAW WATER PUMP STATION
   b) RISING RAW WATER MAIN TO EXISTING WATER TREATMENT WORKS
3. EXISTING COMPONENTS TO BE UPGRADED
   a) WATER TREATMENT WORKS
   b) CLEAR WATER RISING MAIN
   c) CLEAR WATER WELL
   d) CLEAR WATER PUMPS
   e) STORAGE
   f) CONVEYANCE BETWEEN RESERVOIRS (A) & (B)
4. DAM PROPERTIES
   a) YIELD ?
   b) TWL 475m AMSL
   c) BWL 445m AMSL
5. PIPELINE PROPERTIES (GRAVITY MAIN)
   a) LENGTH = m
   b) DIAMETER = mm N/A
   c) AVAILABLE HEAD m
6. PIPELINE PROPERTIES (RISING MAIN) Q=389l/s (2020)
   a) LENGTH = 1 470m
   b) DIAMETER = 440mm
   c) HEAD STATIC 53m
   d) HEAD TOTAL 66.6m
7. PUMPSTATION PROPERTIES
   a) POWER = 0.15 Mw (2010)
      = 0.30 Mw (2020)
8. WATER TREATMENT WORKS
   a) CURRENT CAPACITY 2.7 Ml/day (1999)
   b) REQUIRED CAPACITY 9.0 Ml/day (2010)
      = 33.6 Ml/day (2020)
9. EXISTING CLEAR WATER RISING MAIN
   a) LENGTH = 2126m
   b) DIAMETER (EXISTING) 200mm AC (CLASSES D,E,F)

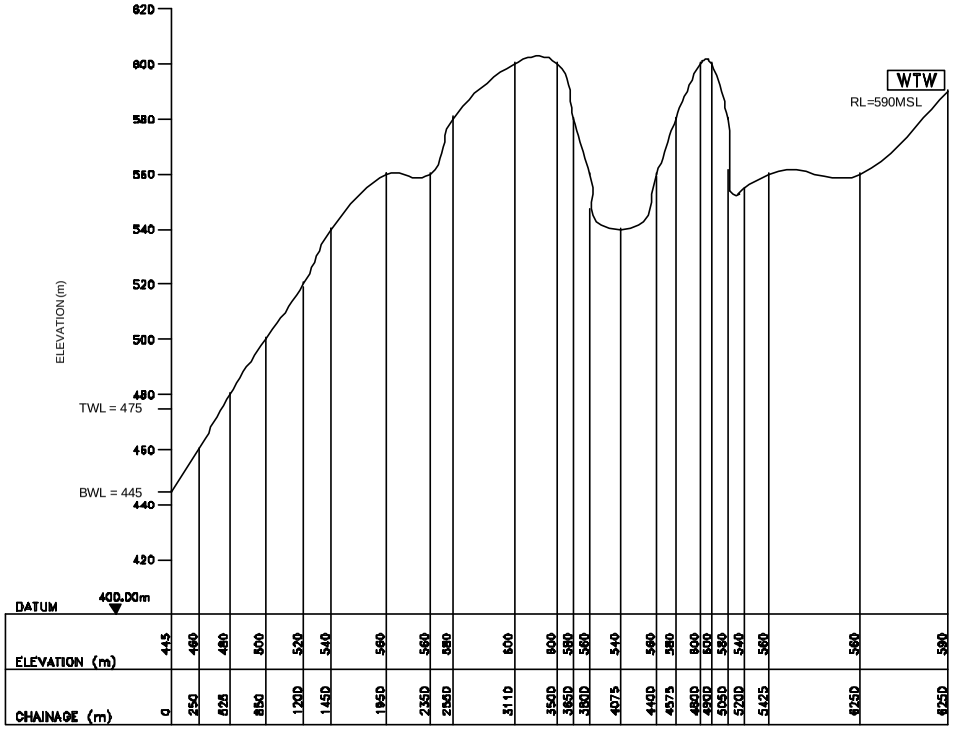
C:\BARRY\Logos\UWP5.jpg

Designed: W.S.K.
Drawn: M.K.
Checked: W.S.K.

Project
EAST PONDOLAND BASIN STUDY

Description
LUSIKISIKI DAM SITE
PROPOSED BULK CONVEYANCE

Sheet 1 of 1
Scale: As shown
No.
Fig. A3.4



LONGITUDINAL SECTION

SCALES
VERTICAL : 1:2000
HORIZONTAL : 1:50 000

NOTES:

1. OPERATION
   a) PUMP TO EXISTING WATER TREATMENT WORKS
   b) FEED INTO SYSTEM AS PER CURRENT OPERATION
2. NEW COMPONENTS
   a) GRAVITY RAW WATER MAIN TO PUMP STATION
   b) PUMP STATION
   c) RISING RAW WATER MAIN TO EXISTING WATER TREATMENT WORKS
3. EXISTING COMPONENTS TO BE UPGRADED
   a) WATER TREATMENT WORKS
   b) CLEAR WATER RISING MAIN
   c) CONVEYANCE BETWEEN RESERVOIR (A) & (B)
4. DAM PROPERTIES
   a) YIELD = x10/0
   b) TWL = m AMSL
   c) BWL = m AMSL
5. PIPELINE PROPERTIES (GRAVITY MAIN)
   a) LENGTH = m
   b) DIAMETER = m
   c) H STATIC = m
6. PIPELINE PROPERTIES (RISING MAIN)
   a) LENGTH = m
   b) DIAMETER = m
   c) H STATIC = m
   c) H TOTAL = m
7. PUMPSTATION PROPERTIES
   a) H = m
   b) Q = m
   c) eff = %
   c) POWER = kw
8. WATER TREATMENT WORKS
   a) CURRENT CAPACITY = 2760 kl/day
   b) REQUIRED CAPACITY = kl/day
9. CLEARWATER RISING MAIN
   a) L = 2126m
   b) øE = 200mm AC (CLASSES D,E,F)
   c) øR = mm

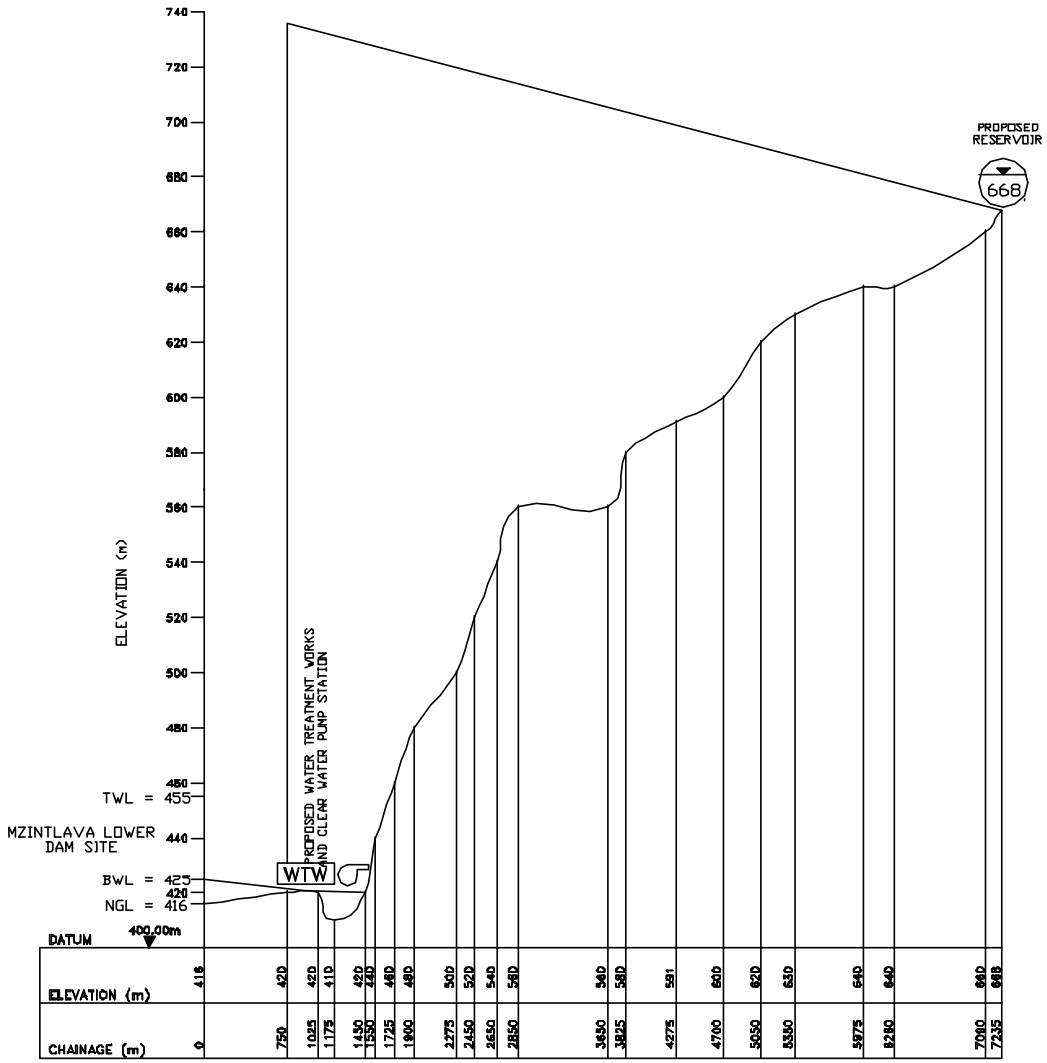
C:\BARRY\Logos\UWP5.bmp

Designed:	W.S.K.
Drawn:	M.K.
Checked:	W.S.K.

Project
EAST PONDOLAND BASIN STUDY

Description
XURA DAM SITE
PROPOSED BULK CONVEYANCE OPTION 1

Sheet 1 of 1
Scale: As shown
No. Fig A3.5



LONGITUDINAL SECTION

SCALES
VERTICAL : 1:2000
HORIZONTAL : 1:50 000

NOTES:

1. OPERATION
   a) NEW WATER TREATMENT WORKS
   b) CAN STILL USE EXISTING TREATMENT WORKS IF REQUIRED
   b) FEED INTO SYSTEM VIA PROPOSED NEW COMMAND RESERVOIR

2. NEW COMPONENTS
   a) GRAVITY RAW WATER MAIN
   b) WATER TREATMENT WORKS
   c) CLEAR WATER WELL
   d) CLEAR WATER PUMP STATION
   e) CLEAR WATER RISING MAIN
   f) COMMAND RESERVOIR
   g) 2 No. GRAVITY DISTRIBUTION MAINS

3. EXISTING COMPONENTS TO BE UPGRADED
   a) POSSIBLY MAIN FROM COMMAND RESERVOIR TO RESERVOIR A

4. DAM PROPERTIES
   a) YIELD
   b) TWL 455m AMSL
   c) BWL 425m AMSL

5. PIPELINE PROPERTIES (GRAVITY MAIN) Q=389l/s (2020)
   a) LENGTH = 1 450m
   b) DIAMETER = 490mm
   c) AVAILABLE HEAD 15m (min. WATER LEVEL = 425)

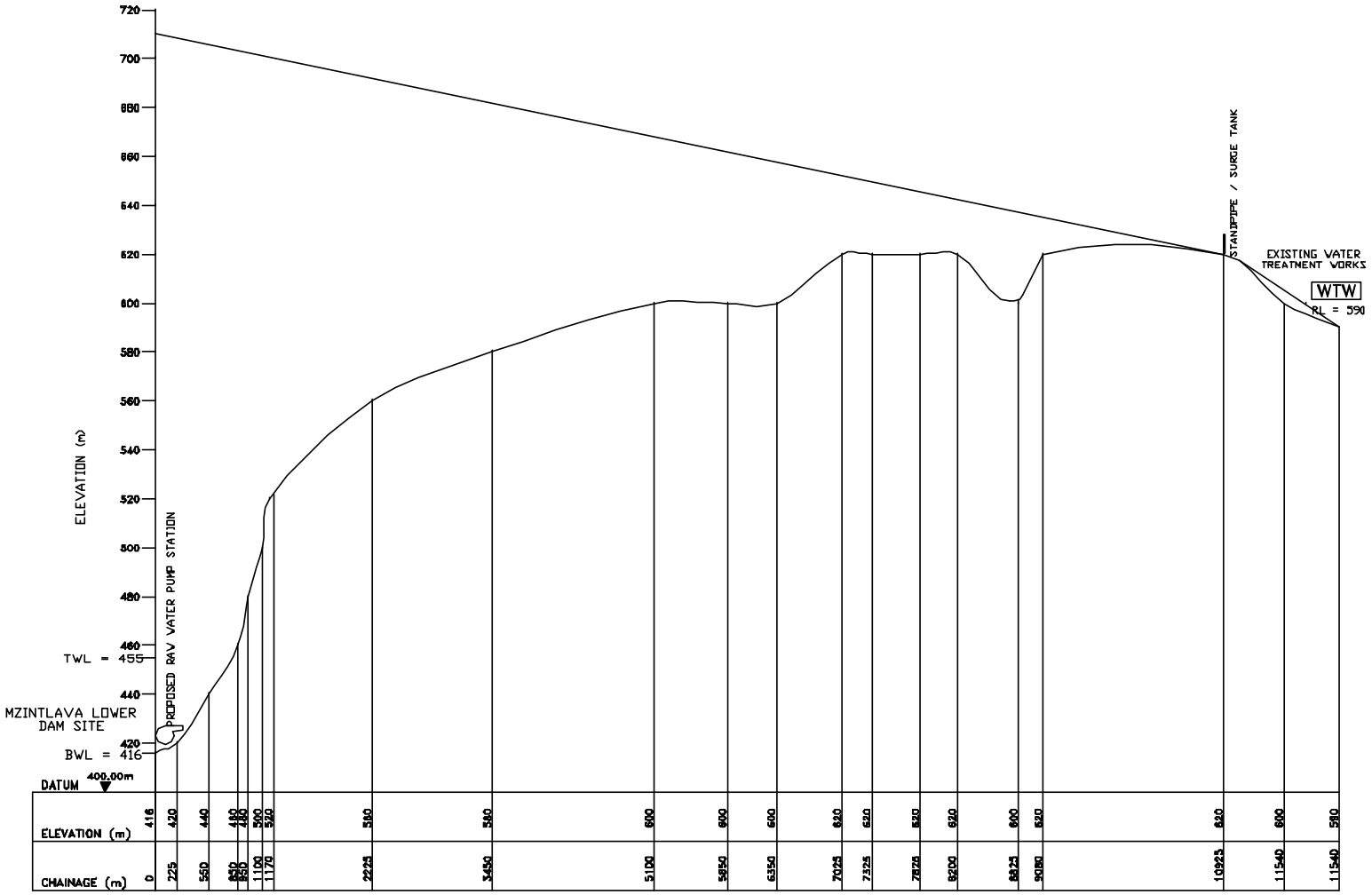
6. PIPELINE PROPERTIES (RISING MAIN) Q=354l/s (2020)
   a) LENGTH = 5 785m
   b) DIAMETER = 420mm
   c) HEAD STATIC 268m
   d) HEAD TOTAL 315.7m

7. PUMPSTATION PROPERTIES
   a) POWER = Mw (2010)
   = Mw (2020)

8. WATER TREATMENT WORKS
   a) CURRENT CAPACITY 12.7 Ml/day (1999)
   b) REQUIRED CAPACITY 19.0 Ml/day (2010)
   = 33.6 Ml/day (2020)

9. EXISTING CLEAR WATER RISING MAIN
   a) LENGTH = 2126m
   b) DIAMETER (EXISTING) 200mm AC (CLASSES D,E,F)

	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 2
	Drawn: M.K.		Scale: As shown
	Checked: W.S.K.	Description: MZINTLAVA LOWER DAM SITE PROPOSED BULK CONVEYANCE OPTION 1	No. Fig. A3.6



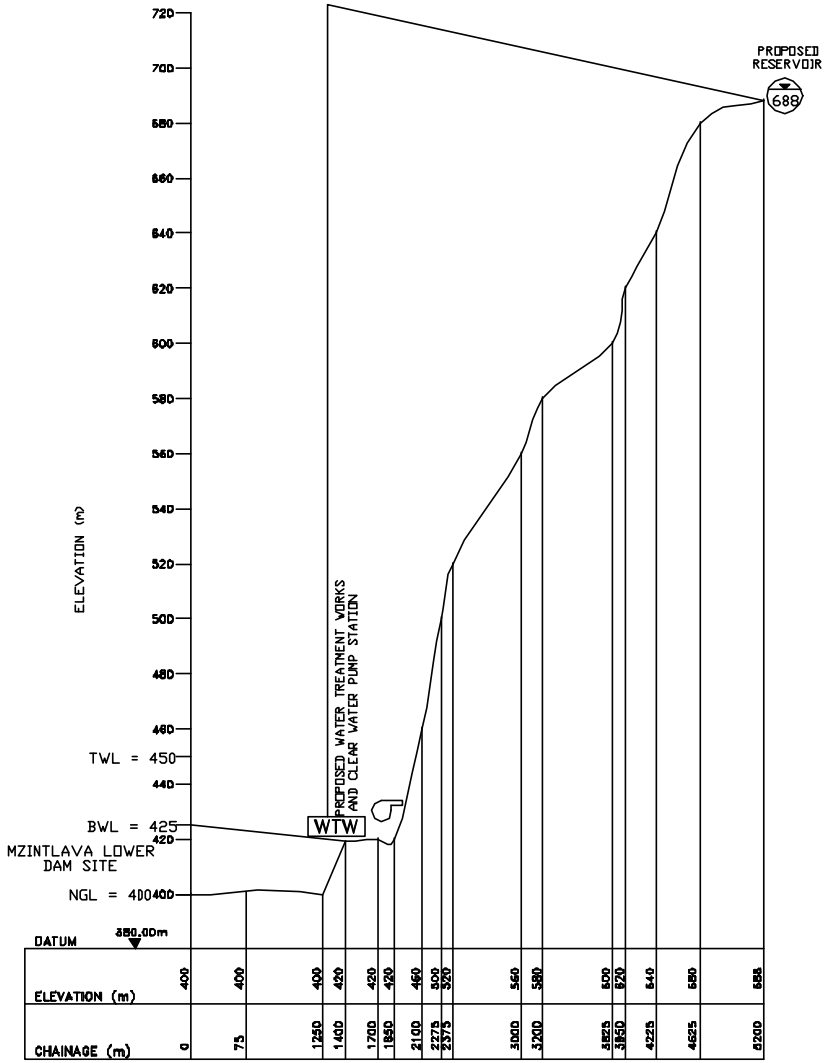
LONGITUDINAL SECTION

HORIZONTAL : 1:50000
VERTICAL : 1:2000

NOTES:

1. OPERATION
   a) NEW WATER TREATMENT WORKS
   b) CAN USE EXISTING TREATMENT WORKS
   c) FEED INTO SYSTEM VIA PROPOSED NEW COMMAND RESERVOIR
2. NEW COMPONENTS
   a) RAW WATER PUMP STATION
   b) RAW WATER RISING MAIN
3. EXISTING COMPONENTS TO BE UPGRADED
   a) WATER TREATMENT WORKS
   b) CLEAR WATER WELL
   c) CLEAR WATER PUMP STATION
   d) CLEAR WATER RISING MAIN TO RESERVOIR A
   e) STORAGE
   f) POSSIBLY CONVEYANCE BETWEEN RESERVOIRS A & B
4. DAM PROPERTIES
   a) YIELD
   b) TWL 455m AMSL
   c) BWL 416m AMSL
5. PIPELINE PROPERTIES (GRAVITY MAIN) Q=38l/s (2020)
   a) LENGTH = m
   b) DIAMETER = mm N/A
   c) AVAILABLE HEAD = m
6. PIPELINE PROPERTIES (RISING MAIN) Q=38l/s (2020)
   a) LENGTH = 10 925m
   b) DIAMETER = 430mm
   c) HEAD STATIC = 204m
   d) HEAD TOTAL = 294m
7. PUMPSTATION PROPERTIES
   a) POWER = 0.72 Mw (2010)
      = 1.18 Mw (2020)
8. PIPELINE PROPERTIES (GRAVITY MAIN) Q=38l/s (2020)
   a) LENGTH = 615m
   b) DIAMETER = 470mm
   c) AVAILABLE HEAD = 30m
9. WATER TREATMENT WORKS
   a) CURRENT CAPACITY = 2.7 Ml/day (1999)
   b) REQUIRED CAPACITY = 19.0 Ml/day (2010)
      = 33.6 Ml/day (2020)
10. EXISTING CLEAR WATER RISING MAIN
    a) LENGTH = 2126m
    b) DIAMETER (EXISTING) = 200mm AC (CLASSES D,E,F)

	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 2 of 2
	Drawn: M.K.		Scale: As shown
	Checked: W.S.K.	Description: MZINTLAVA LOWER DAM SITE PROPOSED BULK CONVEYANCE OPTION 2	No. Fig. A3.7



LONGITUDINAL SECTION

SCALES
VERTICAL : 1:2000
HORIZONTAL : 1:50 000

NOTES:

1. OPERATION
   a) NEW WATER TREATMENT WORKS
   b) CAN STILL USE EXISTING TREATMENT WORKS IF REQUIRED
   b) FEED INTO SYSTEM VIA NEW PROPOSED COMMAND RESERVOIR

2. NEW COMPONENTS
   a) GRAVITY RAW WATER MAIN
   b) WATER TREATMENT WORKS
   c) CLEAR WATER WELL
   d) CLEAR WATER PUMP STATION
   e) CLEAR WATER RISING MAIN
   f) COMMAND RESERVOIR
   g) 2 No. GRAVITY DISTRIBUTION MAINS

3. EXISTING COMPONENTS TO BE UPGRADED
   a) POSSIBLY MAIN FROM COMMAND RESERVOIR TO RESERVOIR A

4. DAM PROPERTIES
   a) YIELD ?
   b) TWL= 450m AMSL
   c) BWL= 400m AMSL

5. PIPELINE PROPERTIES (GRAVITY MAIN) Q=389l/s (2020)
   a) LENGTH = 1 400m
   b) DIAMETER = 570mm
   c) AVAILABLE HEAD = 5m (min. WATER LEVEL = 425)

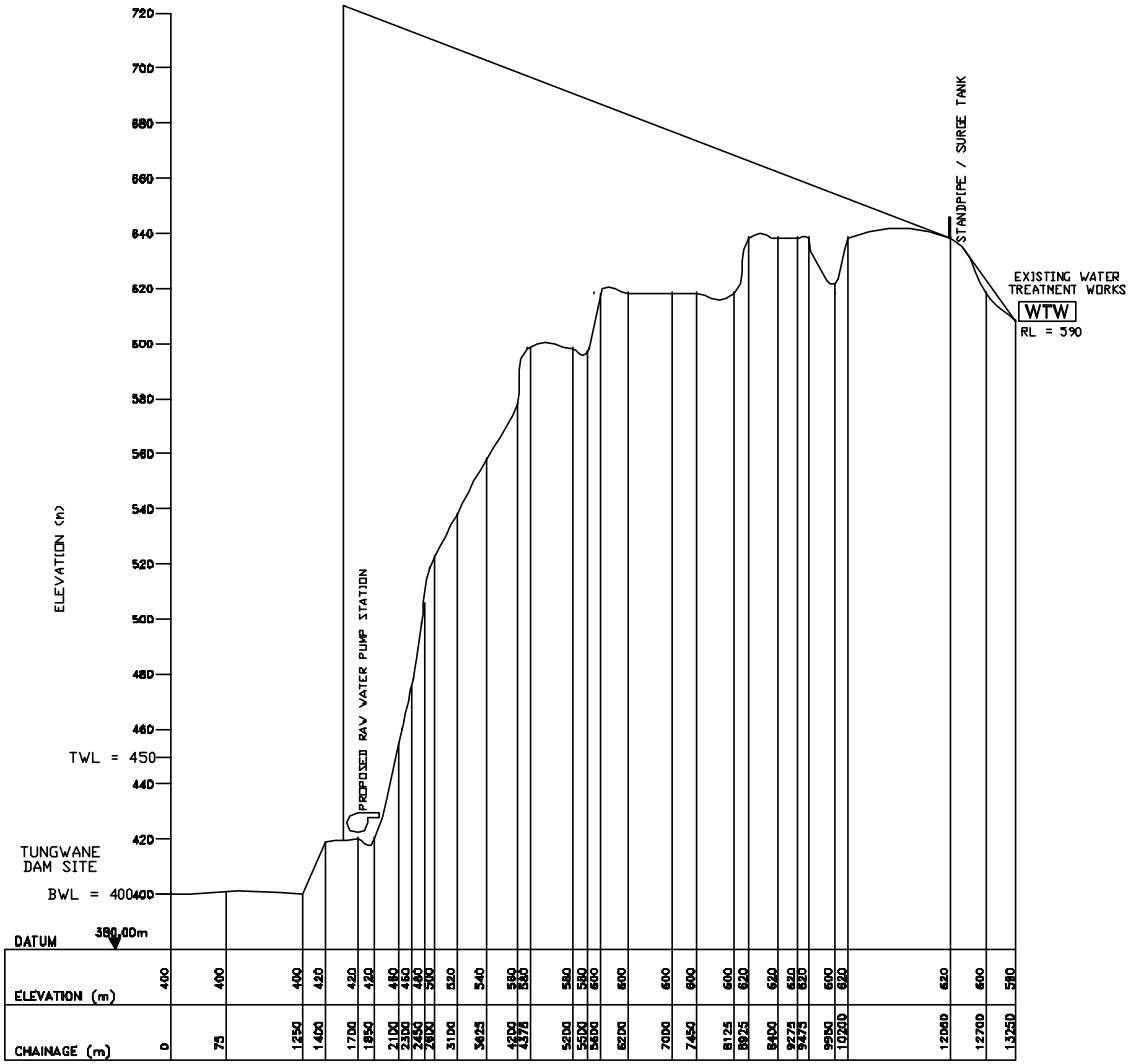
6. PIPELINE PROPERTIES (RISING MAIN) Q=354l/s (2020)
   a) LENGTH = 3 800m
   b) DIAMETER = 410mm
   c) HEAD STATIC = 268m
   d) HEAD TOTAL = 303m

7. PUMPSTATION PROPERTIES
   a) POWER = 0.68 Mw (2010)
   = 1.22 Mw (2020)

8. WATER TREATMENT WORKS
   a) CURRENT CAPACITY = 2.7 Ml/day (1999)
   b) REQUIRED CAPACITY = 19.0 Ml/day (2010)
   = 33.6 Ml/day (2020)

9. EXISTING CLEAR WATER RISING MAIN
   a) LENGTH = 2126m
   b) DIAMETER (EXISTING) = 200mm AC (CLASSES D,E,F)

	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 2
	Drawn: M.K.		Scale: As shown
	Checked: W.S.K.	Description: TUNGWANE DAM SITE PROPOSED BULK CONVEYANCE OPTION 1	No. Fig. A3.8



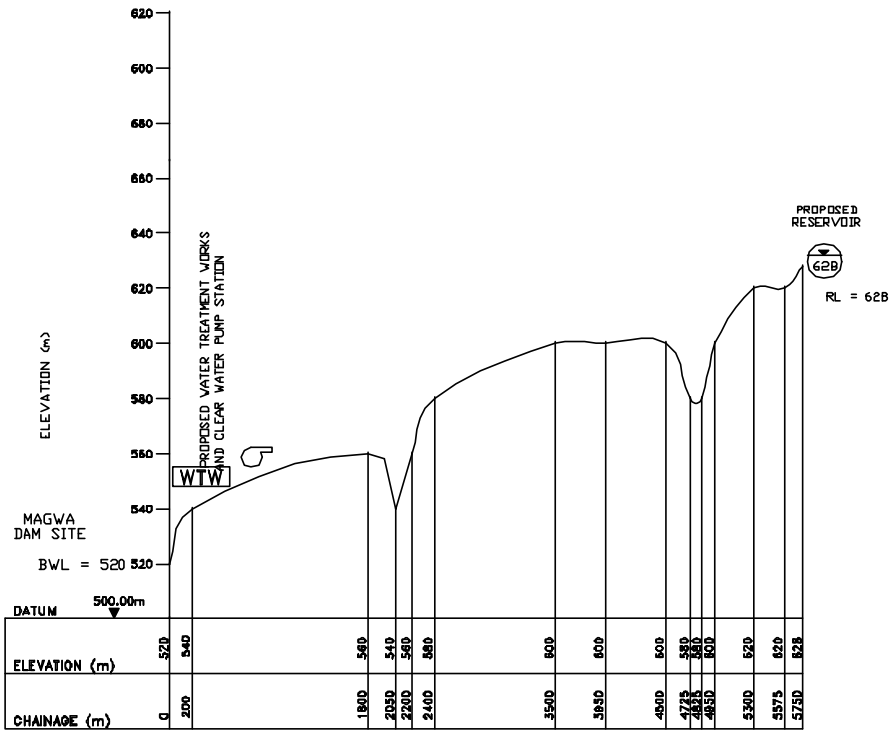
LONGITUDINAL SECTION

SCALES
VERTICAL : 1:2000
HORIZONTAL : 1:50 000

NOTES:

1. OPERATION
   a) PUMP TO EXISTING WATER TREATMENT WORKS
   b) FEED INTO SYSTEM AS PER CURRENT OPERATION
2. NEW COMPONENTS
   a) GRAVITY RAW WATER MAIN
   b) RAW WATER PUMP STATION
   c) RAW WATER RISING MAIN
3. EXISTING COMPONENTS TO BE UPGRADED
   a) WATER TREATMENT WORKS
   b) CLEAR WATER WELL
   c) CLEAR WATER PUMPS
   d) CLEAR WATER RISING MAIN TO RESERVOIR A
   e) CAPACITY OF RESERVOIR A
   f) POSSIBLY MAIN FROM COMMAND RESERVOIR TO RESERVOIR A
4. DAM PROPERTIES
   a) YIELD
   b) TWL 455m AMSL
   c) BWL 416m AMSL
5. PIPELINE PROPERTIES (GRAVITY MAIN) Q=389l/s (2020)
   a) LENGTH = 1 400m
   b) DIAMETER = 570mm
   c) AVAILABLE HEAD 5m (min. WATER LEVEL = 425)
6. PIPELINE PROPERTIES (RISING MAIN) Q=389l/s (2020)
   a) LENGTH = 11 850m
   b) DIAMETER = 430mm
   c) HEAD STATIC 200m
   d) HEAD TOTAL 277m
7. PUMPSTATION PROPERTIES
   a) POWER = 0.61 Mw (2010)
      = 1.23 Mw (2020)
8. PIPELINE PROPERTIES (GRAVITY MAIN) Q=389l/s (2020)
   a) LENGTH = 3 050m
   b) DIAMETER = 470mm
   c) AVAILABLE HEAD 30m
9. WATER TREATMENT WORKS
   a) CURRENT CAPACITY 2.7 Ml/day (1999)
   b) REQUIRED CAPACITY 9.0 Ml/day (2010)
      = 33.6 Ml/day (2020)
10. EXISTING CLEAR WATER RISING MAIN
    a) LENGTH = 2126m
    b) DIAMETER (EXISTING) 200mm AC (CLASSES D,E,F)

	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 2 of 2
	Drawn: M.K.		Scale: As shown
	Checked: W.S.K.	Description: TUNGWANE DAM SITE PROPOSED BULK CONVEYANCE OPTION 2	No. Fig. A3.9



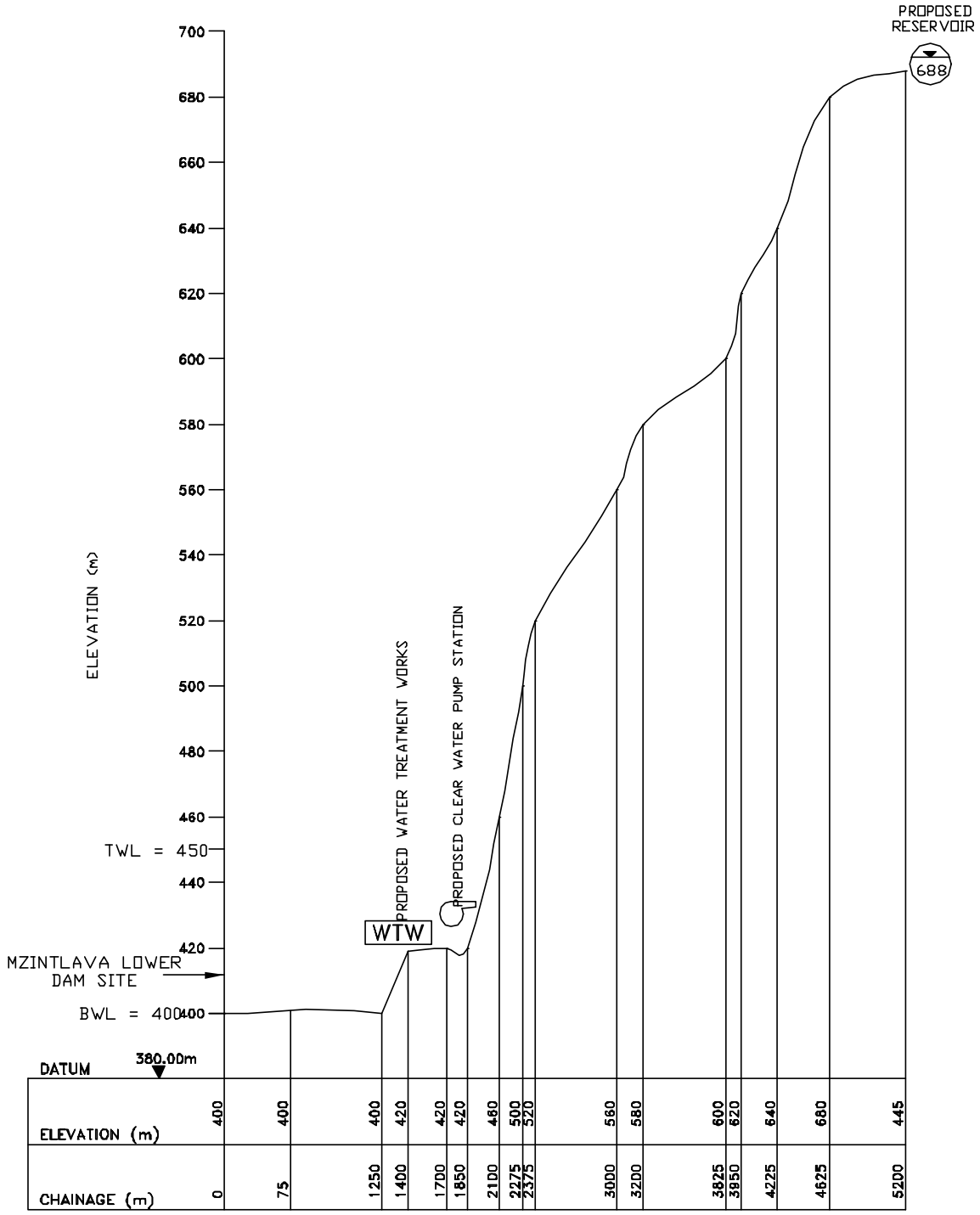
LONGITUDINAL SECTION

HORIZONTAL : 1:100000
VERTICAL : 1:2000

NOTES:

1. OPERATION
   a) NEW WATER TREATMENT WORKS
   b) CAN STILL USE EXISTING TREATMENT WORKS IF REQUIRED
   b) FEED INTO SYSTEM VIA PROPOSED NEW COMMAND RESERVOIR
2. NEW COMPONENTS
   a) WATER TREATMENT WORKS (PACKAGE)
   b) CLEAR WATER WELL
   c) CLEAR WATER PUMP STATION
   d) CLEAR WATER RISING MAIN
   e) COMMAND RESERVOIR
3. EXISTING COMPONENTS TO BE UPGRADED
   a) N/A
4. DAM PROPERTIES
   a) YIELD
   b) TWL m AMSL
   c) BWL 520m AMSL
5. PIPELINE PROPERTIES (GRAVITY MAIN)
   a) LENGTH = m
   b) DIAMETER = mm
   c) AVAILABLE HEAD m
6. PIPELINE PROPERTIES (RISING MAIN) Q=? l/s (2020)
   a) LENGTH = 5 750m
   b) DIAMETER = mm
   c) HEAD STATIC 108m
   d) HEAD TOTAL m
7. PUMPSTATION PROPERTIES
   a) POWER = Mw (2010)
   = Mw (2020)
8. WATER TREATMENT WORKS
   a) CURRENT CAPACITY 2.7 Ml/day (1999)
   b) REQUIRED CAPACITY 9.0 Ml/day (2010)
   = 33.6 Ml/day (2020)
9. EXISTING CLEAR WATER RISING MAIN
   a) LENGTH = 2126m
   b) DIAMETER (EXISTING) 200mm AC (CLASSES D,E,F)

	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: M.K.		Scale: As shown
	Checked: W.S.K.	Description: MAGWA DAM SITE PROPOSED BULK CONVEYANCE	No. Fig. A3.10



LONGITUDINAL SECTION

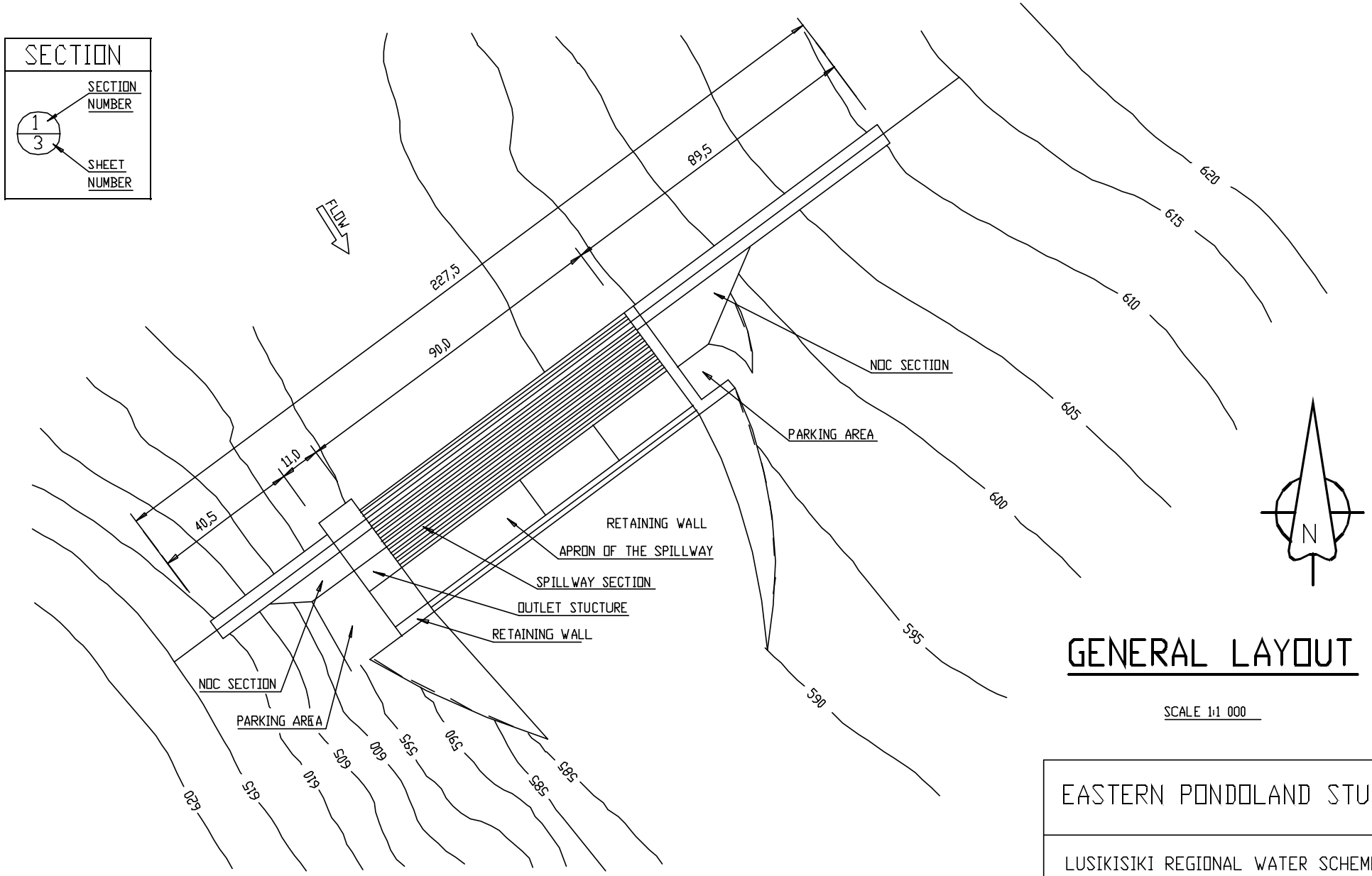
SCALES
VERTICAL : 1:2000
HORIZONTAL : 1:50 000

ENGINEERS	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: M.K.	Description: MAGWA DAM SITE BULK CONVEYANCE OPTION 1	Scale: As shown
	Checked: W.S.K.		No. ANNEXURE A3.11

APPENDIX 4 :

CONCEPTIONAL DESIGN ZALU DAM

PRE-FEASIBILITY STAGE



GENERAL LAYOUT

SCALE 1:1 000

SCALE 1:1 000

0 5 10 20 30 40 50 100 200 m

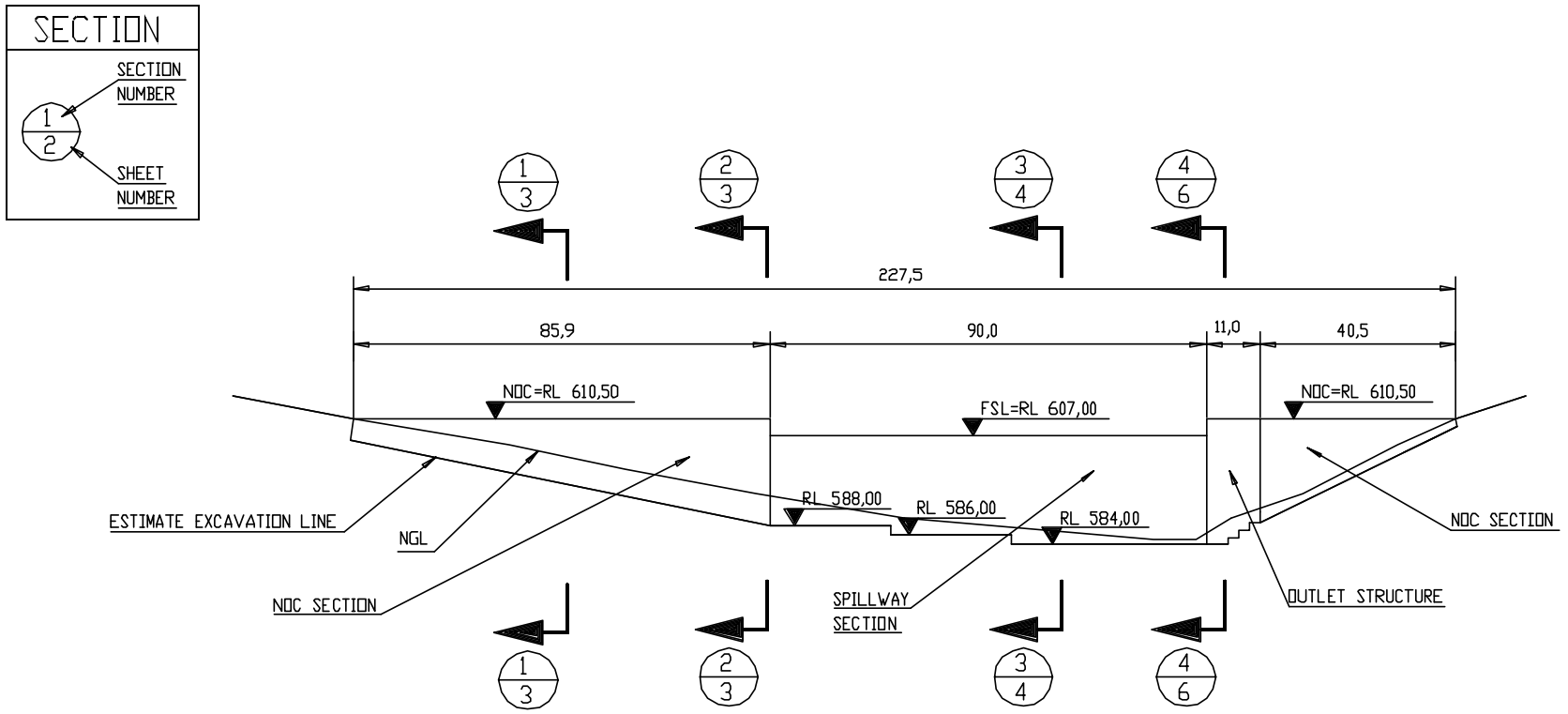
EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

ZALU DAM

SHEET 1/6

FIGURE No



UPSTREAM ELEVATION

SCALE 1:1 000

SCALE 1:1 000

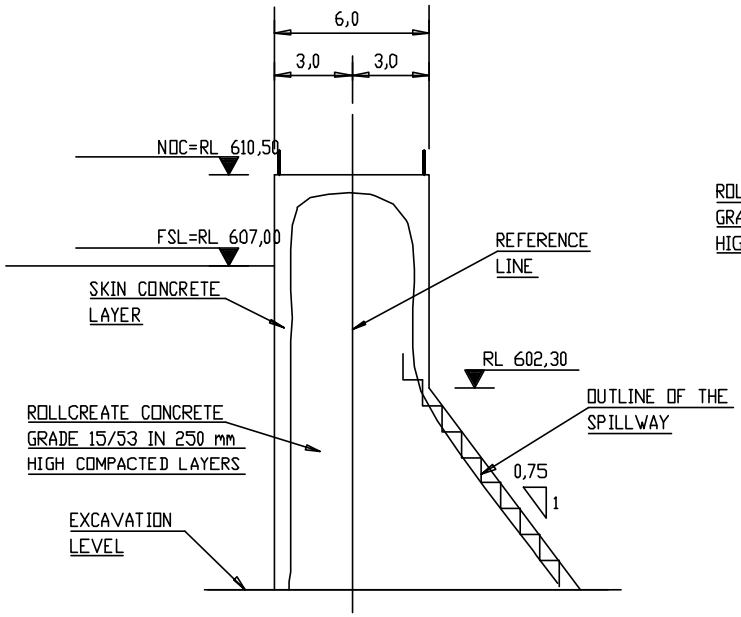
0 5 10 20 30 40 50 100 200 m

EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

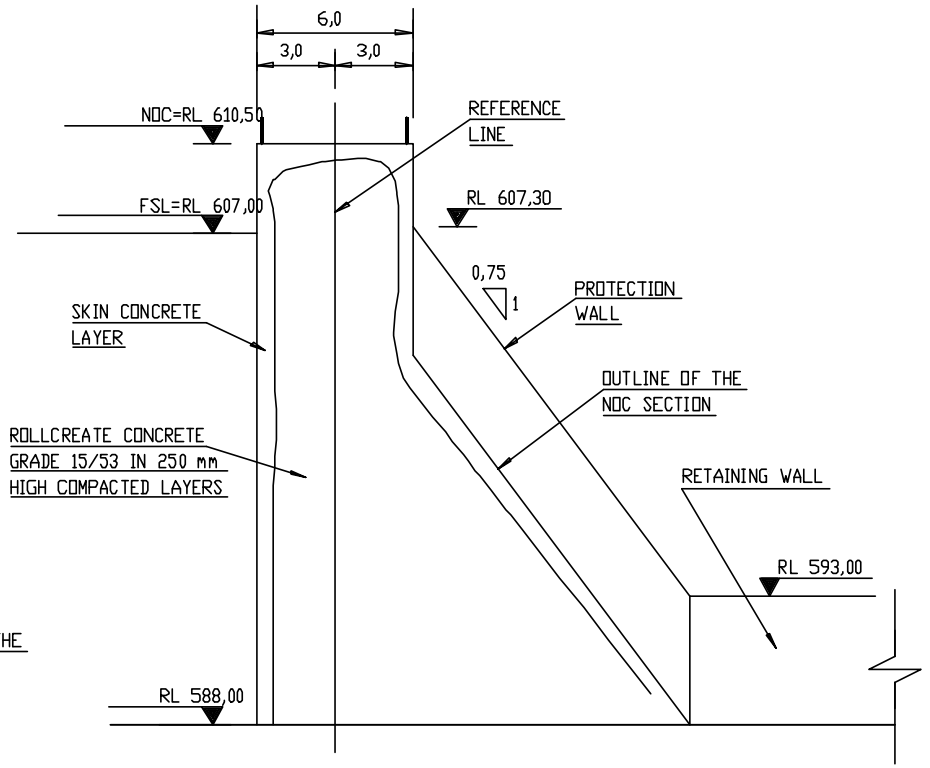
ZALU DAM

SHEET 2/6 FIGURE No



SECTION 1-1

SCALE 1:200



SECTION 2-2

SCALE 1:200

SCALE 1:200

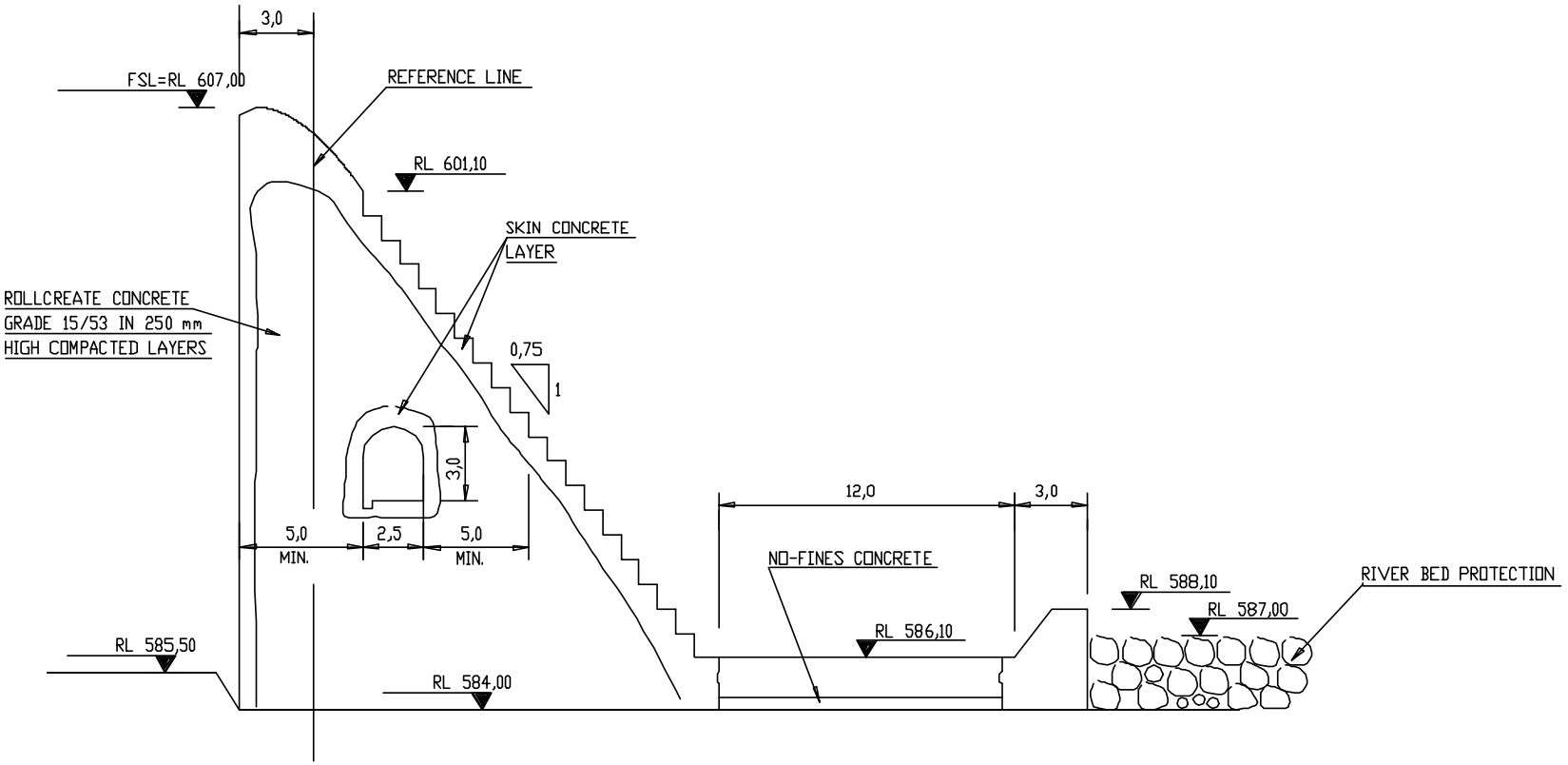
0 5 10 15 20 40 m

EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

ZALU DAM

SHEET 3/6 FIGURE No



SECTION 3-3

SCALE 1:200

SCALE 1:200

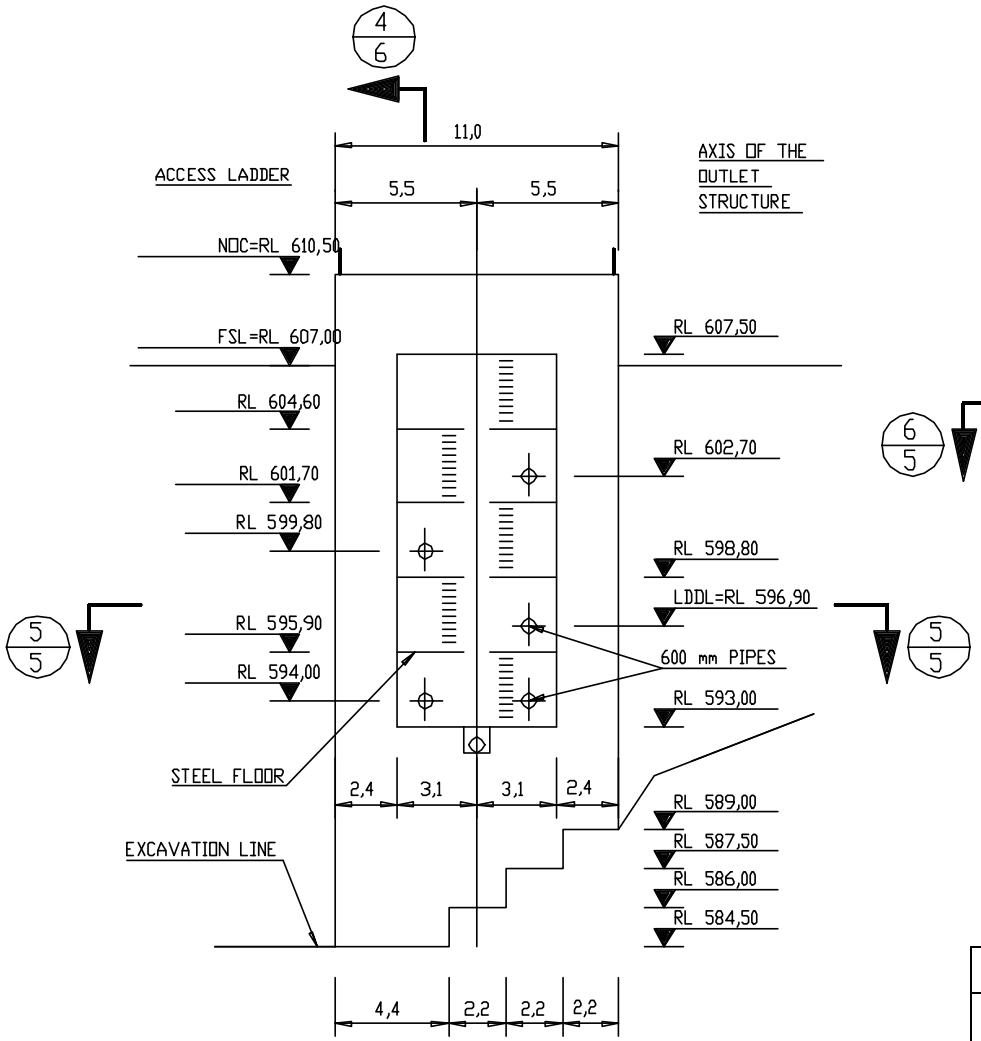
0 5 10 15 20 40 m

EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

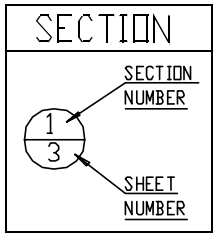
ZALU DAM

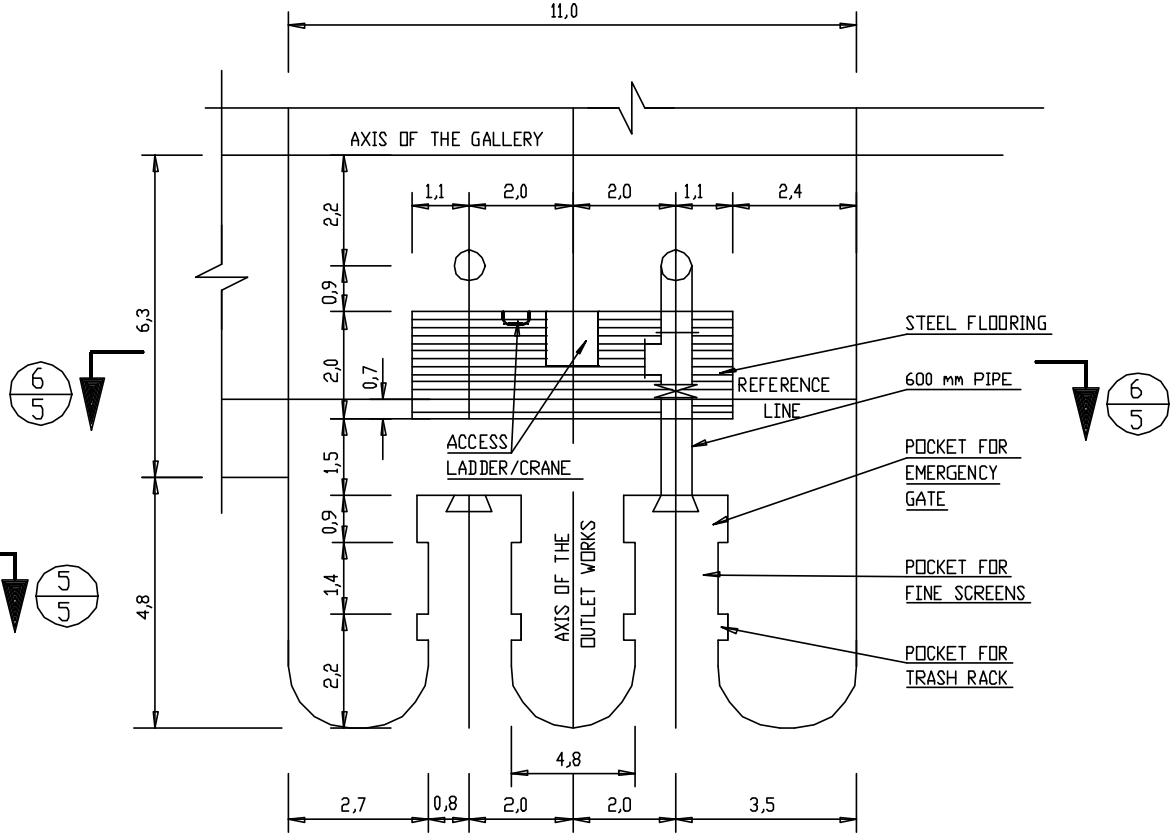
SHEET 4/6 FIGURE No



SECTION 6-6

SCALE 1:200





SECTION 5-5

SCALE 1:100

SCALE 1:100 0 1 2 3 4 5 10 20 m

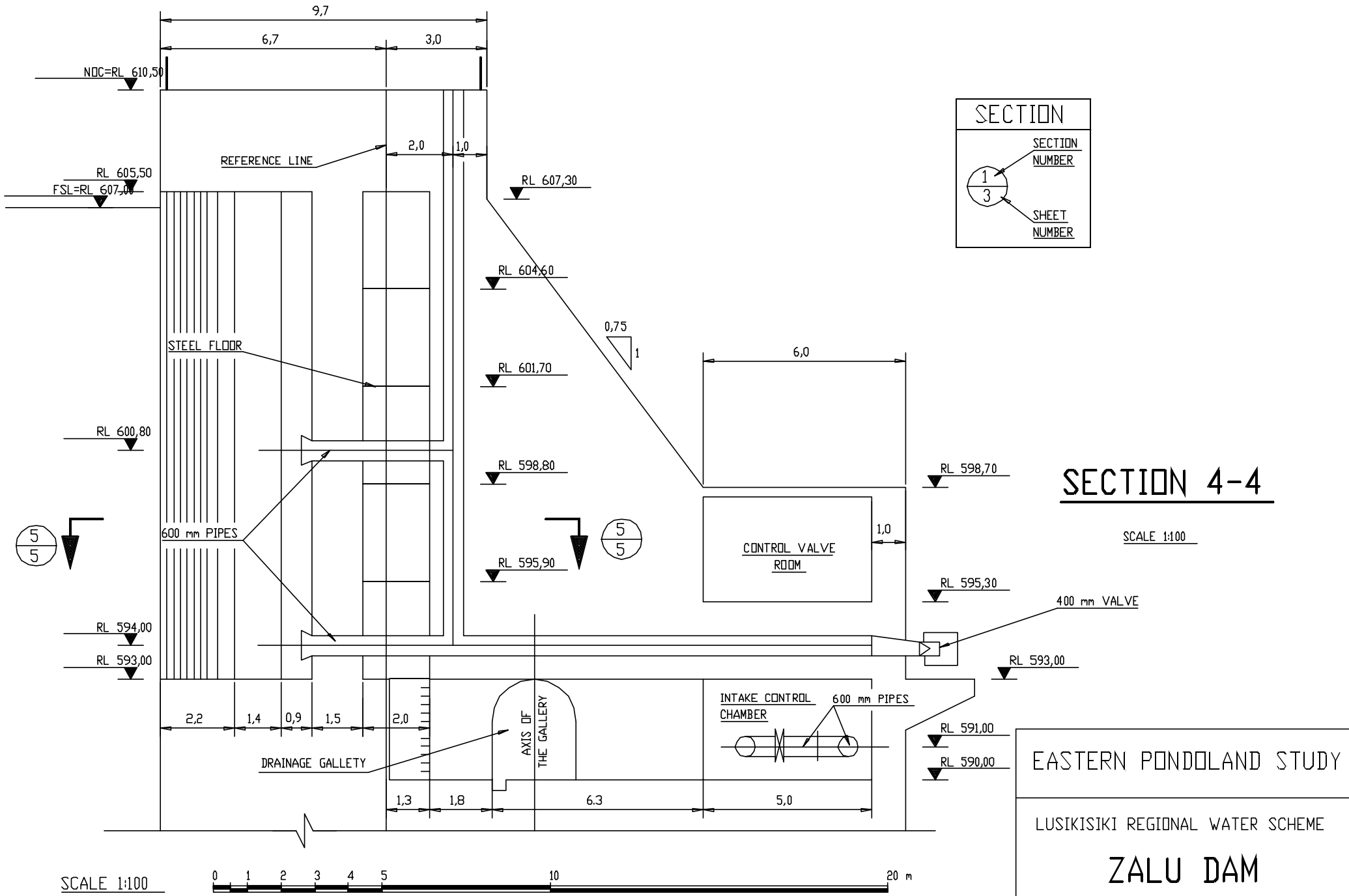
SCALE 1:200 0 5 10 15 20 40 m

EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

ZALU DAM

SHEET 5/6 FIGURE No



EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

ZALU DAM

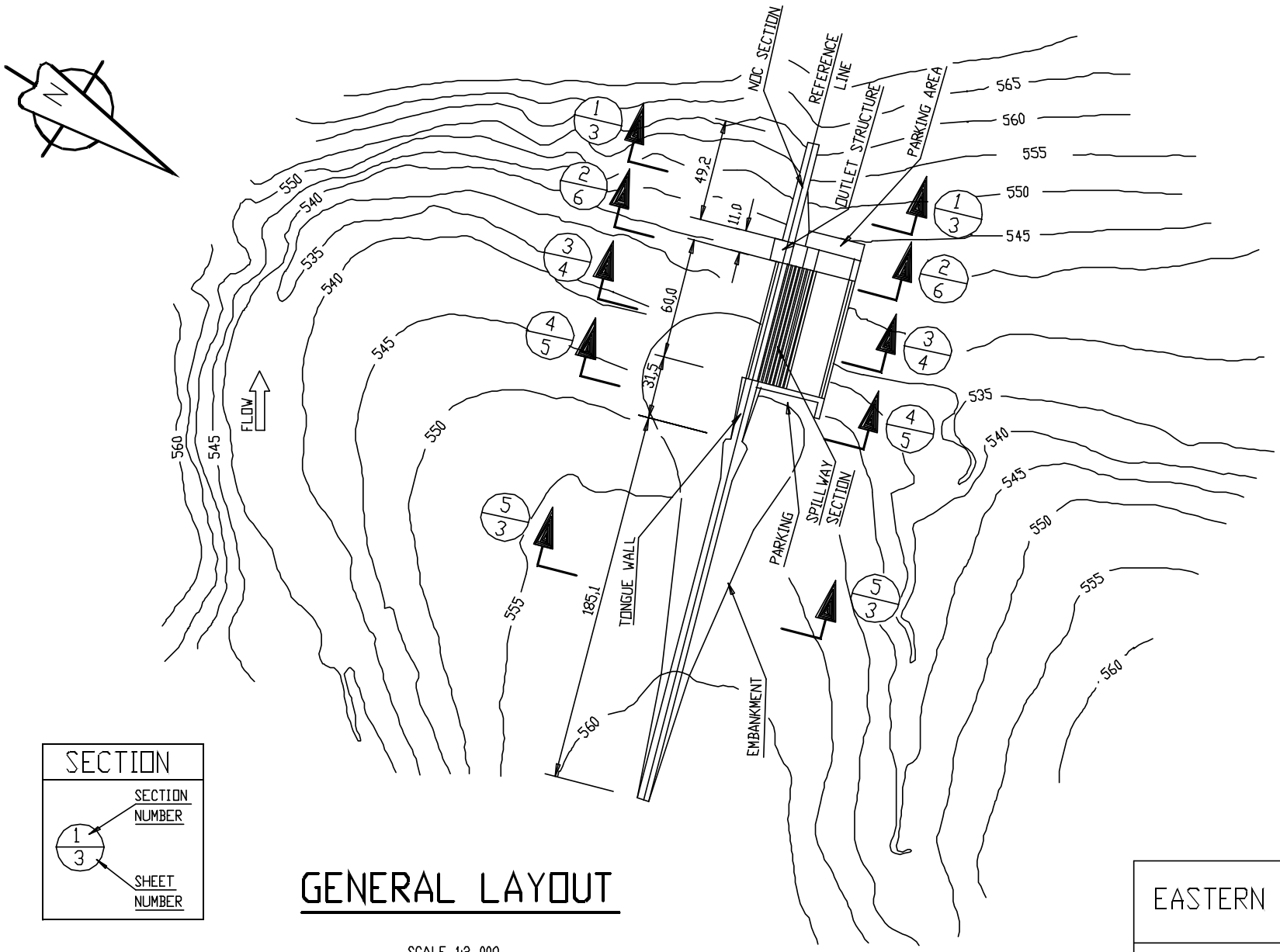
SHEET 6/6

FIGURE No

APPENDIX 5 :

CONCEPTIONAL DESIGN
LUSIKISIKI DAM

PRE-FEASIBILITY STAGE



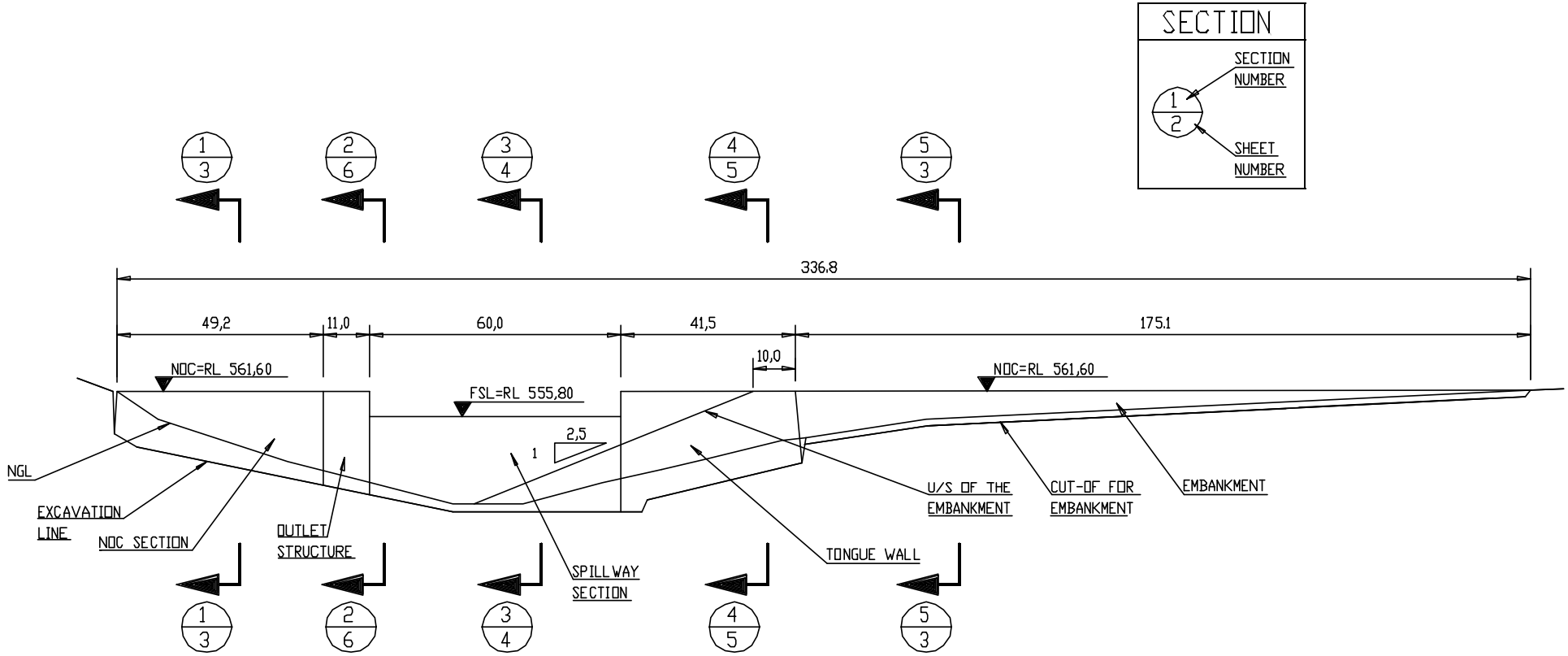
EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

LUSIKISIKI DAM

SHEET 1/6

FIGURE No



UPSTREAM ELEVATION

SCALE 1:1 000

SCALE 1:1 000

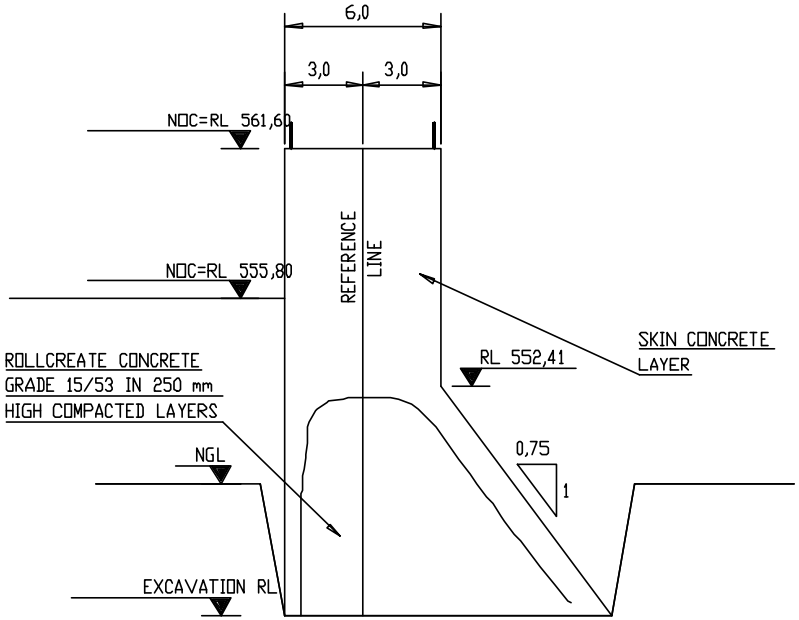
0 5 10 20 30 40 50 100 200 m

EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

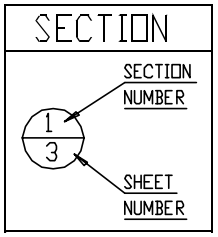
LUSIKISIKI DAM

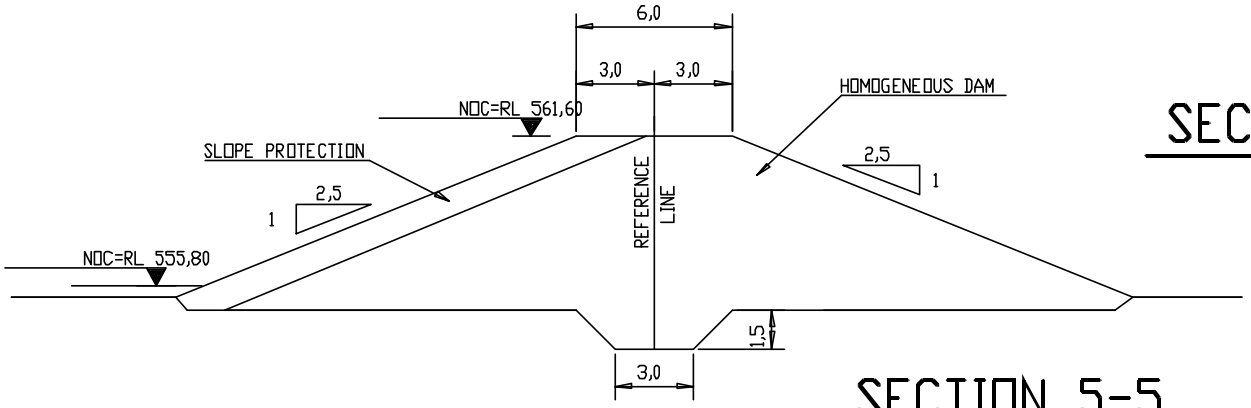
SHEET 2/6 FIGURE No



SECTION 1-1

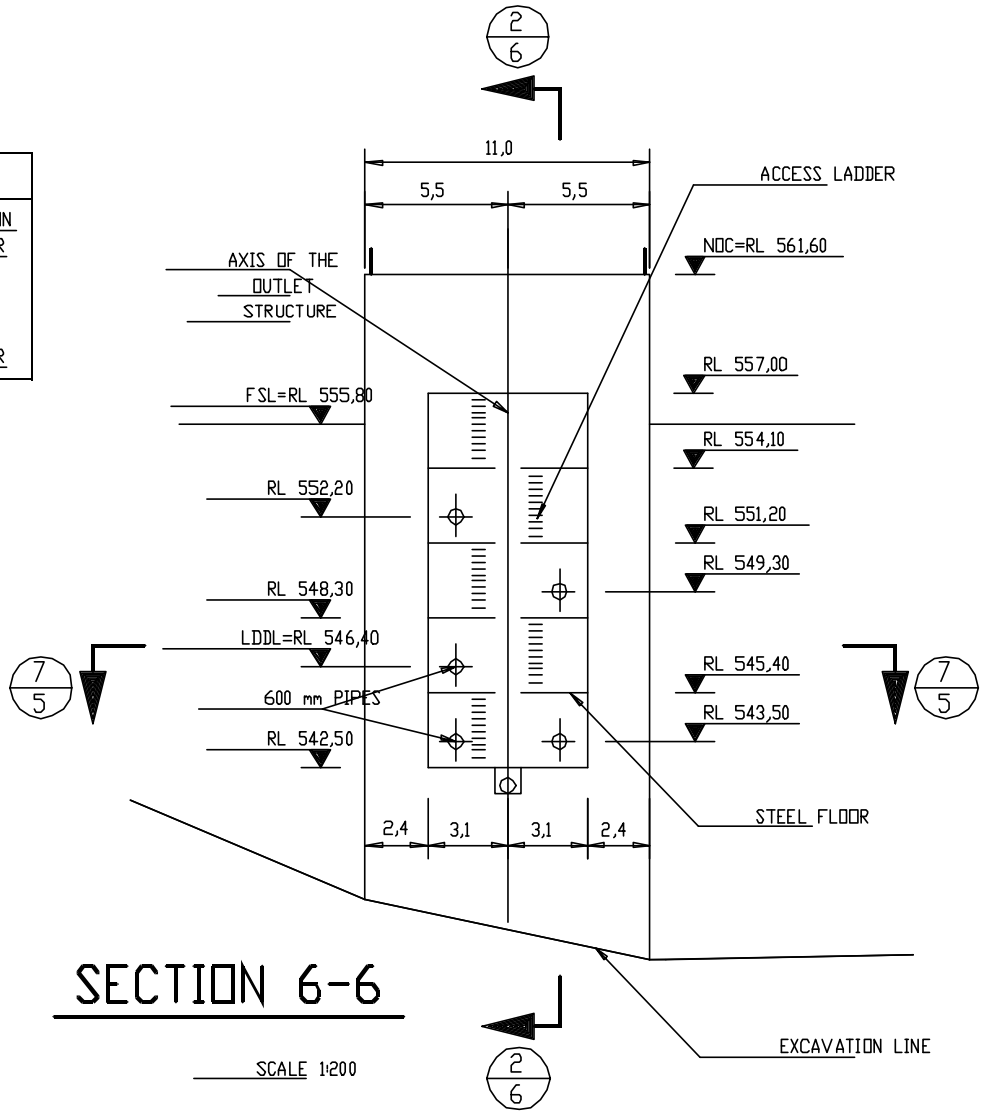
SCALE 1:200





SECTION 5-5

SCALE 1:200



SECTION 6-6

SCALE 1:200

SCALE 1:200

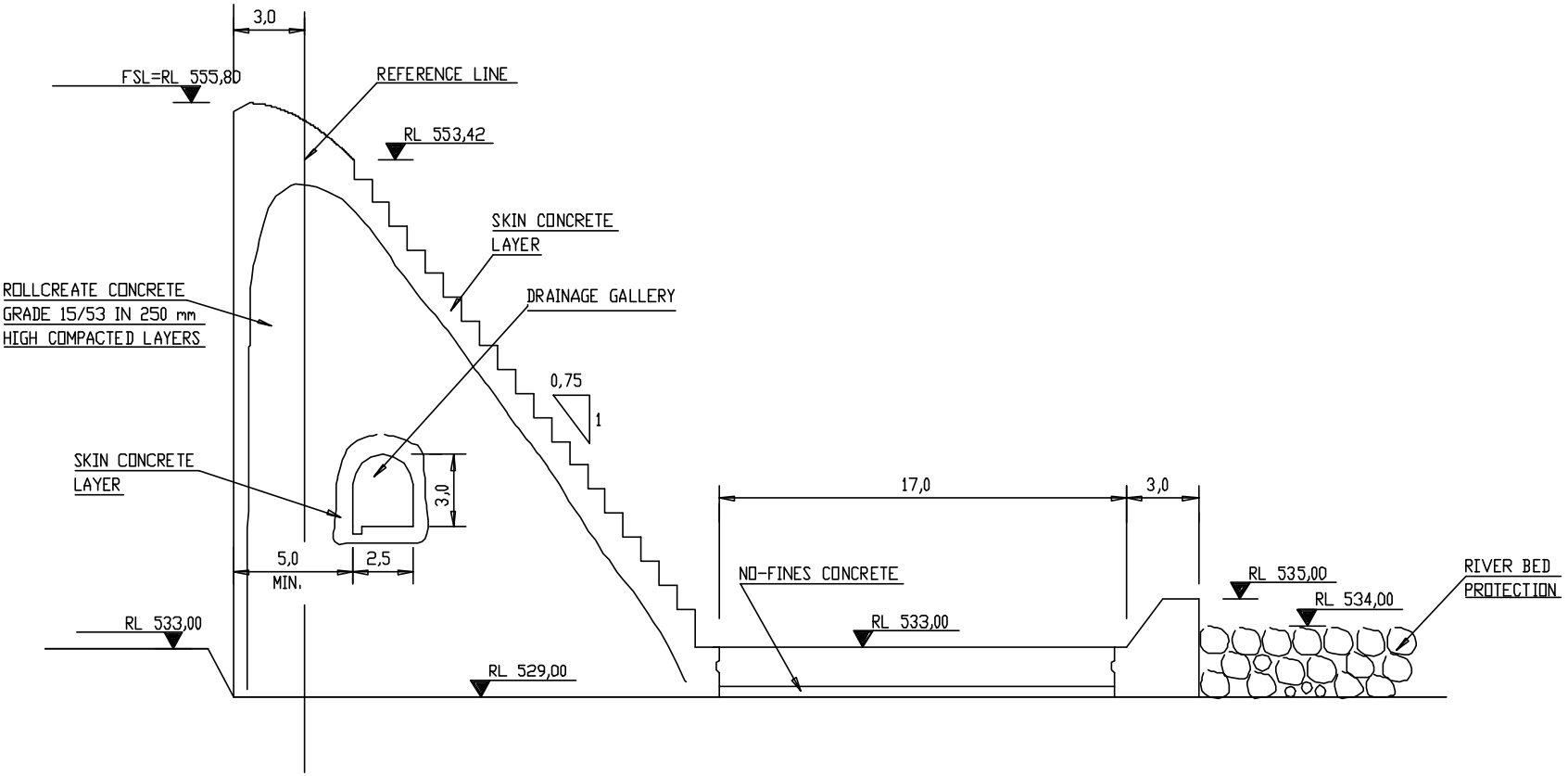
0 5 10 15 20 40 m

EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

LUSIKISIKI DAM

SHEET 3/6 FIGURE No



SECTION 3-3

SCALE 1:200

SCALE 1:200

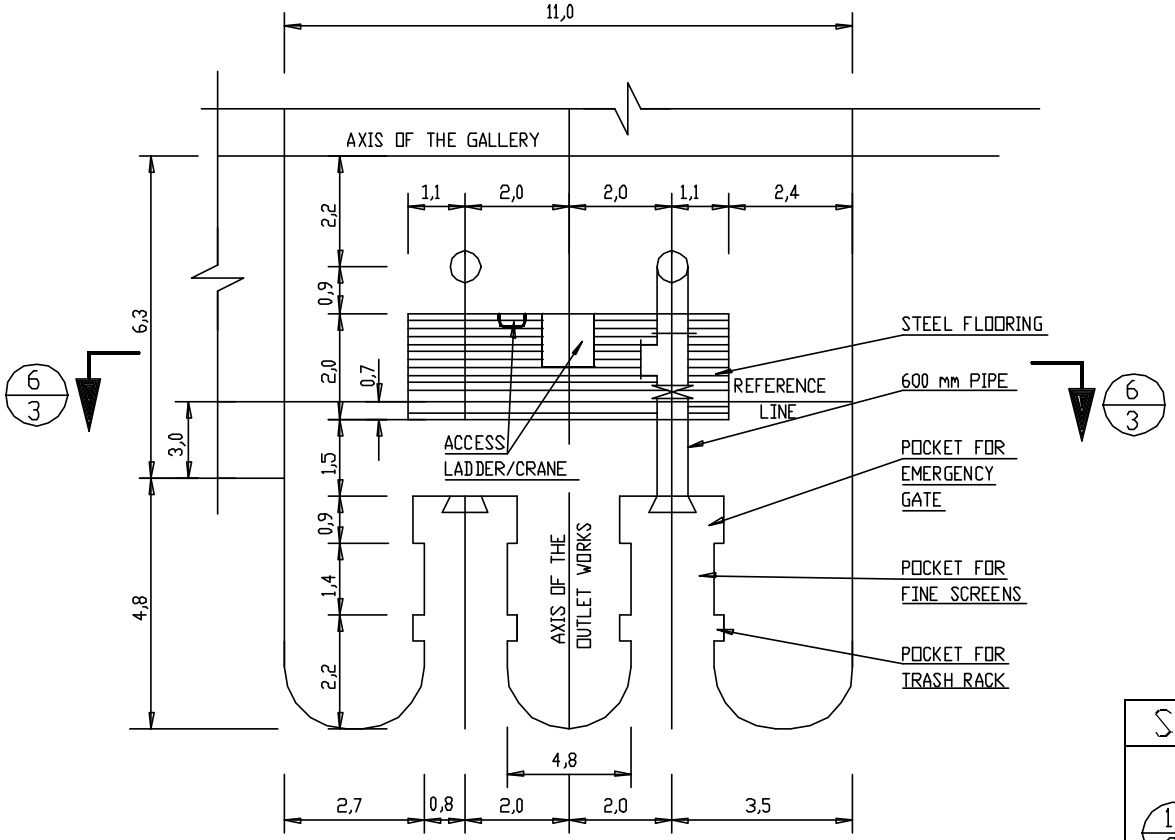
0 5 10 15 20 40 m

EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

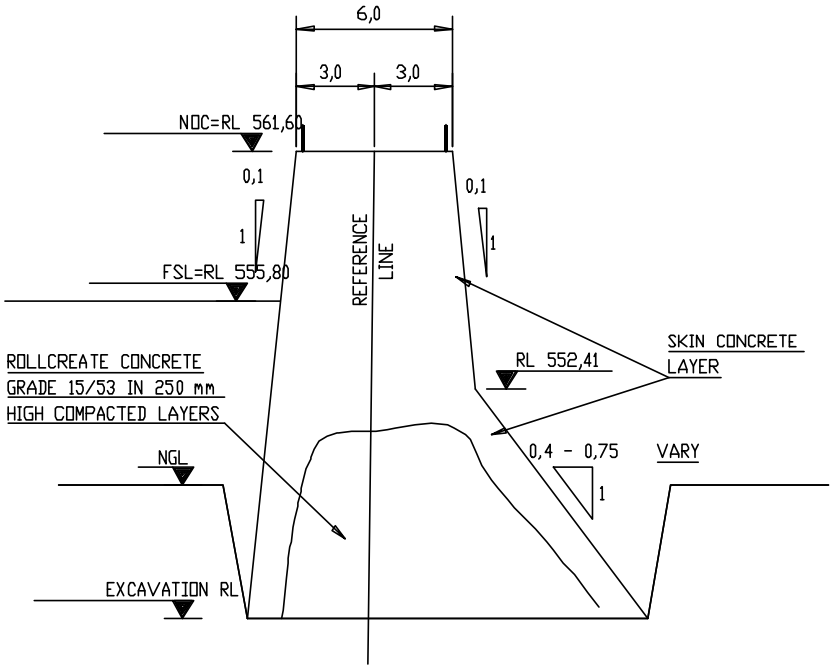
LUSIKISIKI DAM

SHEET 4/6 FIGURE No



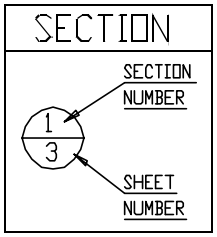
SECTION 7-7

SCALE 1:100



SECTION 4-4

SCALE 1:200



SCALE 1:100 0 1 2 3 4 5 10 20 m

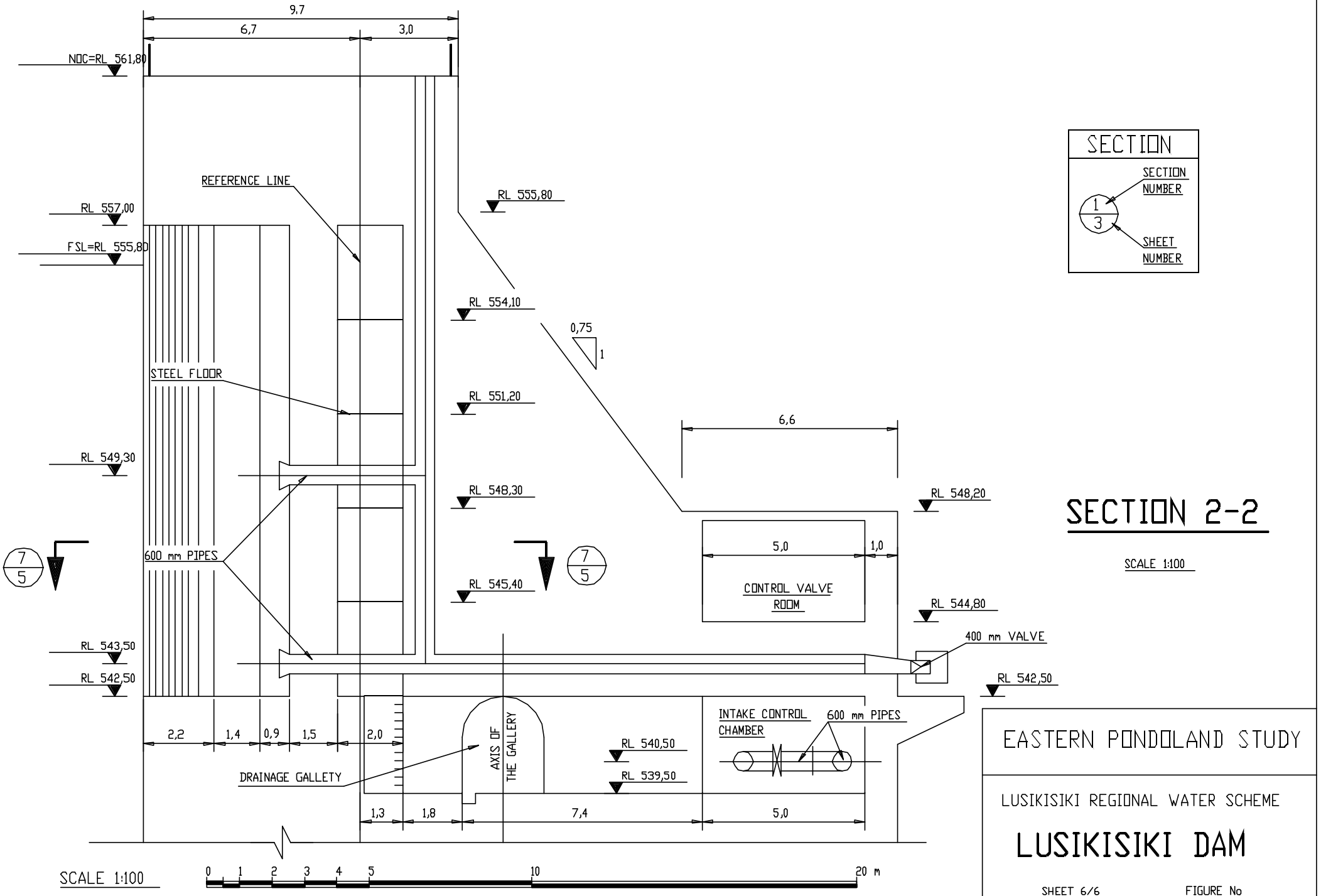
SCALE 1:200 0 5 10 15 20 40 m

EASTERN PONDOLAND STUDY

LUSIKISIKI REGIONAL WATER SCHEME

LUSIKISIKI DAM

SHEET 5/6 FIGURE No


9.7
6,7
3,0
NOC=RL 561,80
REFERENCE LINE
RL 555,80
RL 557,00
FSL=RL 555,80
RL 554,10
0,75
1
STEEL FLOOR
RL 551,20
6,6
RL 549,30
RL 548,30
RL 548,20
7
5
600 mm PIPES
7
5
5,0
1,0
CONTROL VALVE ROOM
RL 545,40
RL 544,80
400 mm VALVE
RL 543,50
RL 542,50
RL 542,50
2,2
1,4
0,9
1,5
2,0
AXIS OF THE GALLERY
INTAKE CONTROL CHAMBER
600 mm PIPES
RL 540,50
DRAINAGE GALLETY
RL 539,50
1,3
1,8
7,4
5,0
SCALE 1:100
0 1 2 3 4 5 10 20 m
SECTION
SECTION NUMBER
1
3
SHEET NUMBER
SECTION 2-2
SCALE 1:100
EASTERN PONDOLAND STUDY
LUSIKISIKI REGIONAL WATER SCHEME
LUSIKISIKI DAM
SHEET 6/6
FIGURE No

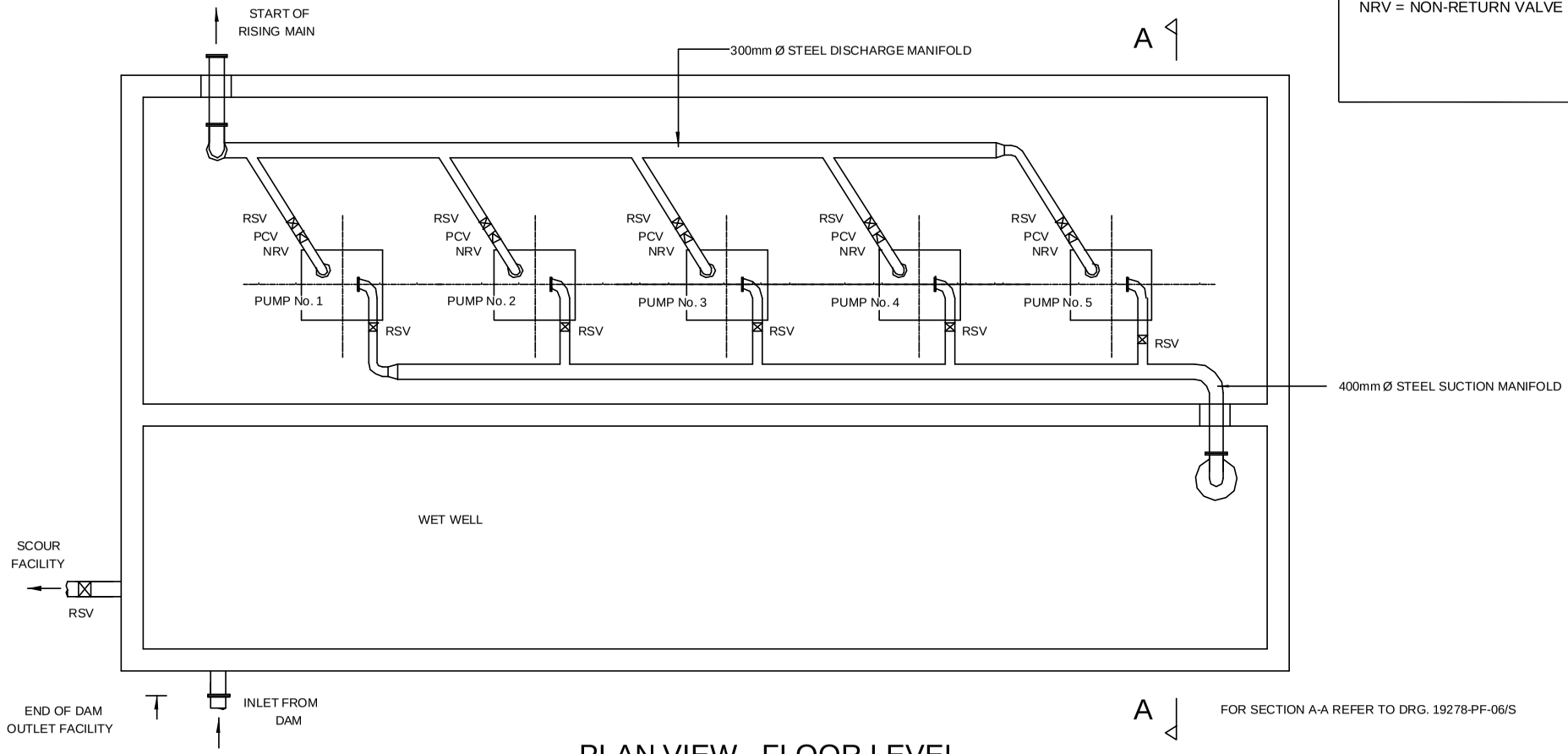
APPENDIX 6 :

CONCEPTIONAL DESIGN
PUMP STATIONS AND PIPELINES

PRE-FEASIBILITY STAGE

LEGEND:

RSV = RESILIENT SEAL ISOLATING VALVE
PCV = PUMP CONTROL VALVE
NRV = NON-RETURN VALVE



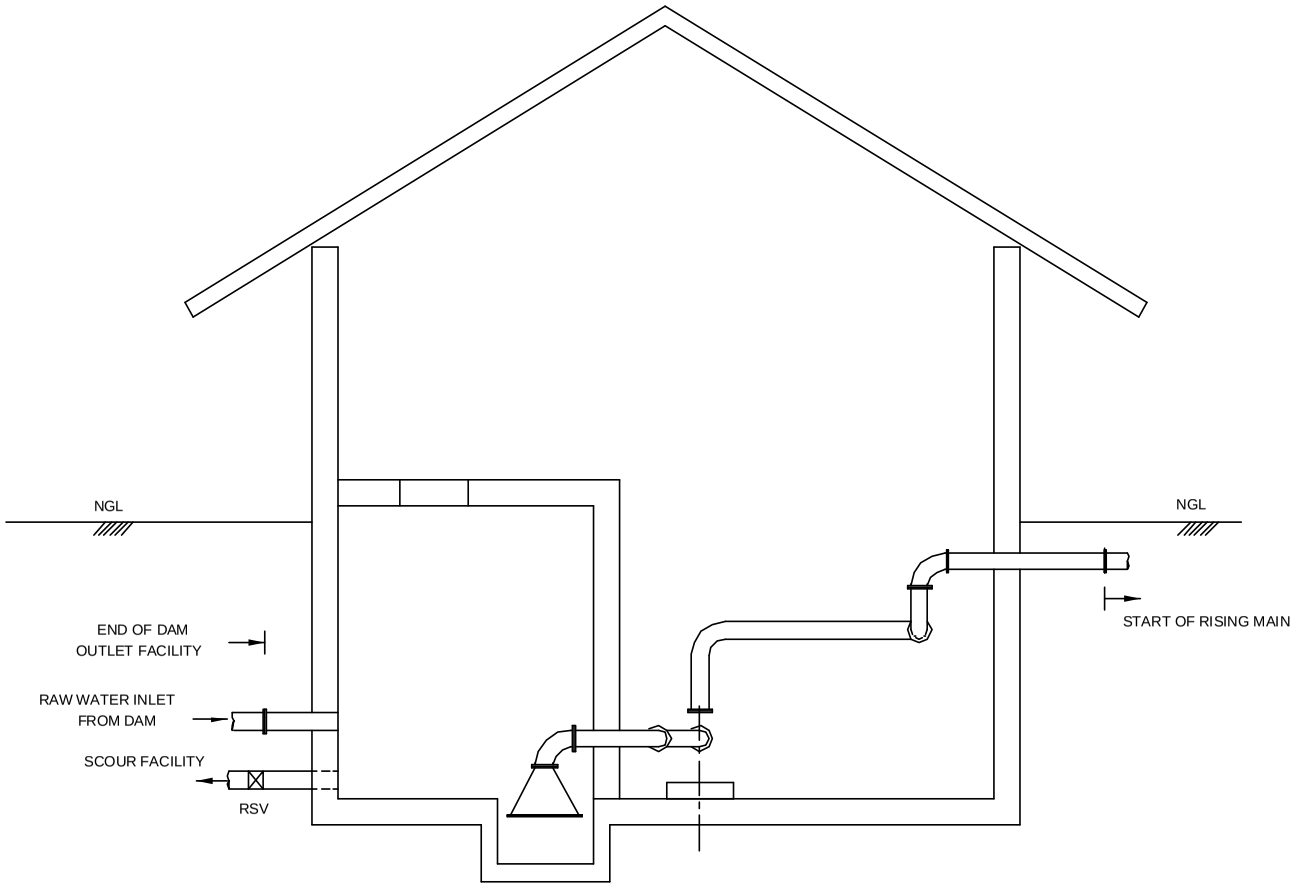
PLAN VIEW - FLOOR LEVEL

N.T.S.

Fig A6.1	Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: M.K.		Scale: As shown
	Checked: W.S.K.	Description: LAYOUT SCHEMATIC OF PROPOSED NEW RAW WATER PUMP STATION	Date: 31/07/2000
			No. 19278-PF-06/P

LEGEND:

RSV = RESILIENT SEAL ISOLATING VALVE



SECTION A-A

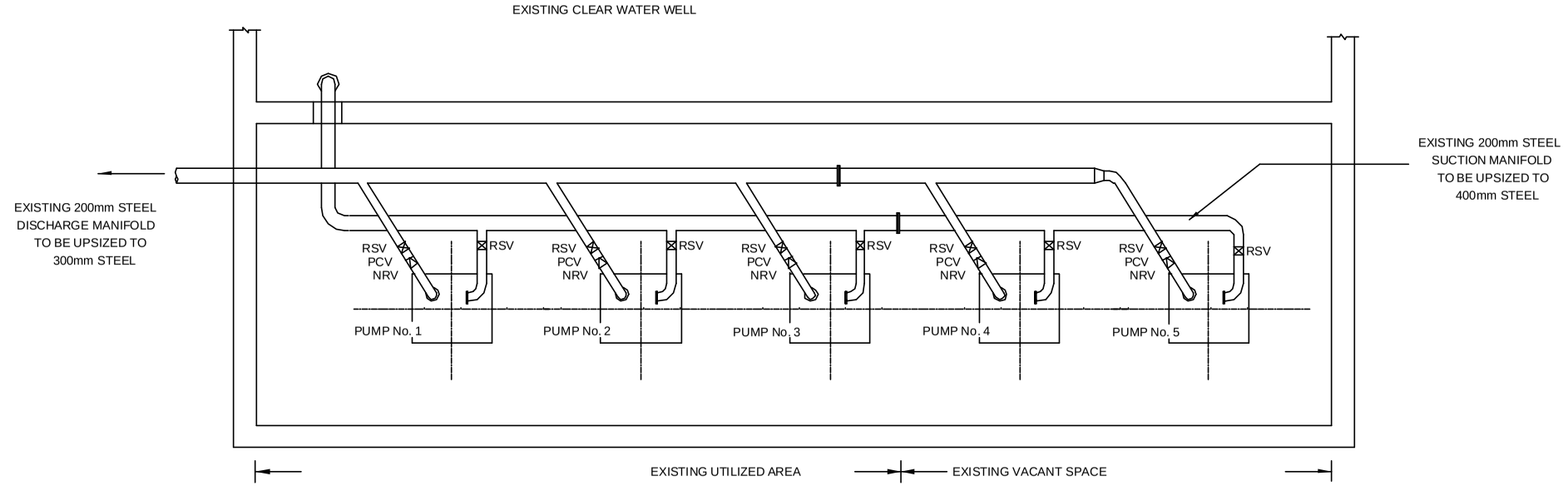
N.T.S.

Fig A6.2

Designed: W.S.K.	Project: EAST PONDOLAND BASIN STUDY		Sheet 1 of 1
Drawn: M.K.			Scale: As shown
Checked: W.S.K.	Description: LAYOUT SCHEMATIC OF PROPOSED NEW RAW WATER PUMP STATION		Date: 31/07/2000
			No. 19278-PF-06/S

LEGEND:

RSV = RESILIENT SEAL ISOLATING VALVE
PCV = PUMP CONTROL VALVE
NRV = NON-RETURN VALVE



PLAN

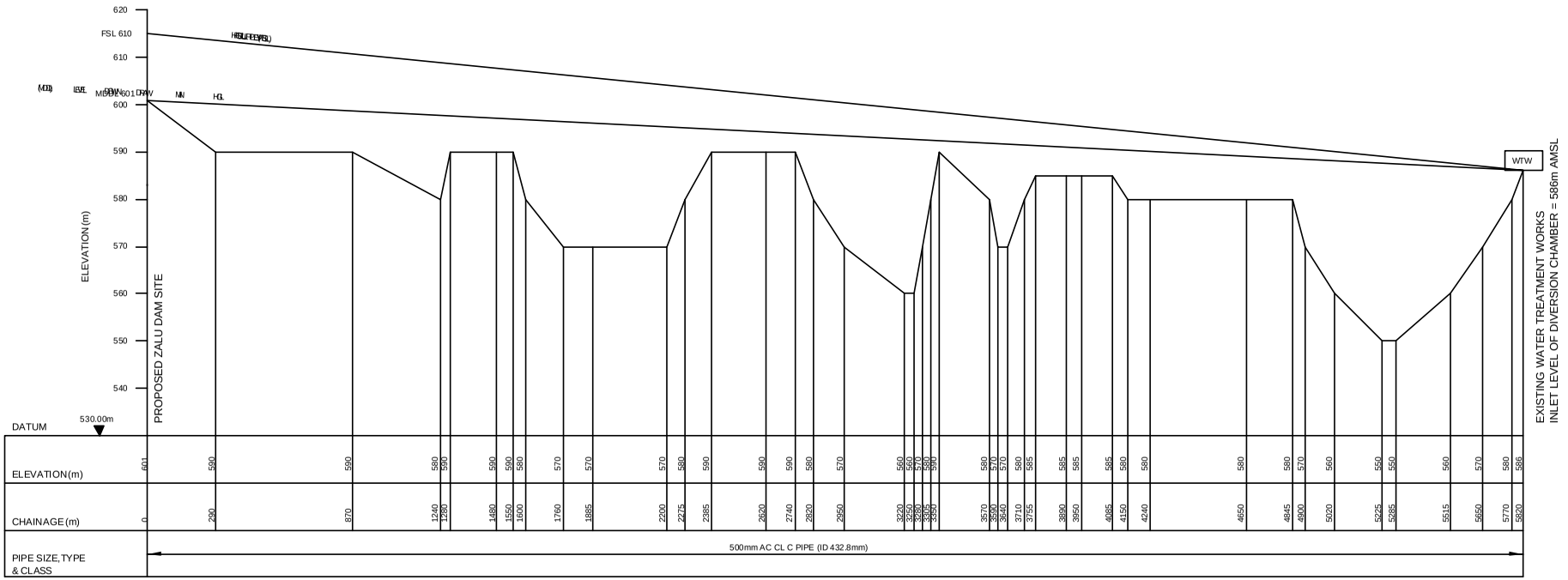
N.T.S.

Fig A6.3	Designed: W.S.K. Drawn: M.K. Checked: W.S.K.	**Project** EAST PONDOLAND BASIN STUDY **Description** LAYOUT SCHEMATIC OF PROPOSED LAYOUT OF THE EXISTING CLEAR WATER PUMP STATION	Sheet 1 of 1 Scale: As shown Date: 31/07/2000 No. 19278-PF-07/P

NOTES:

1. THE PIPE HAS BEEN SIZED TO DELIVER THE 2020 DESIGN FLOW RATE AT THE MDDL OF THE DAM.
2. FSL = FULL SUPPLY LEVEL
   MDDL = MINIMUM DRAW DOWN LEVEL

SUPPLY LEVEL	FLOW (l/s)
FSL	152
MDDL	196



LONGITUDINAL SECTION

HORIZONTAL : 1:20000
VERTICAL : 1:1000

Fig A6.4

Designed:	M.R.
Drawn:	B.M.B.
Checked:	W.S.K.

Project

EAST PONDOLAND BASIN STUDY

Description

ZALU DAM SITE (OPTION No.3a)
PROPOSED RAW WATER CONVEYANCE SYSTEM
PROPOSED DAM SITE TO EXISTING WTW

Sheet 1 of 1

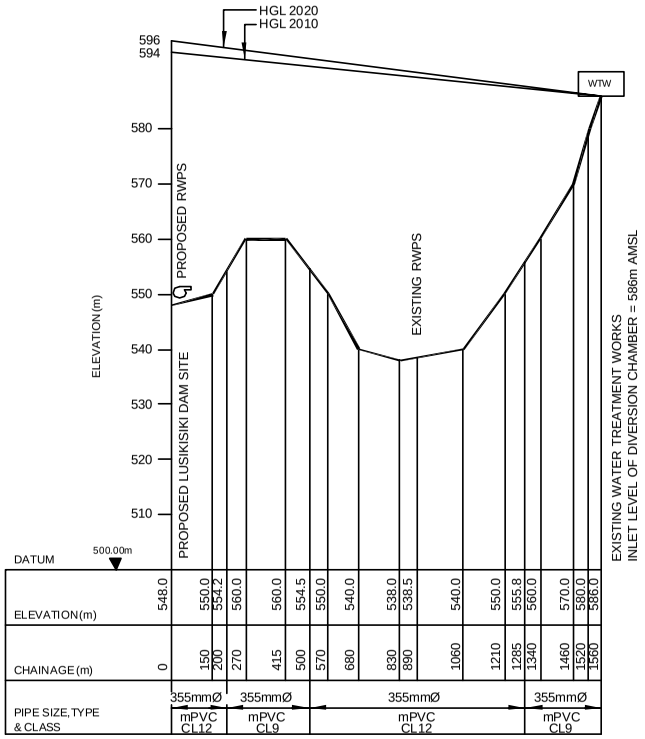
Scale: As shown

Date: 31/07/2000

No. 19278-PF-01/L

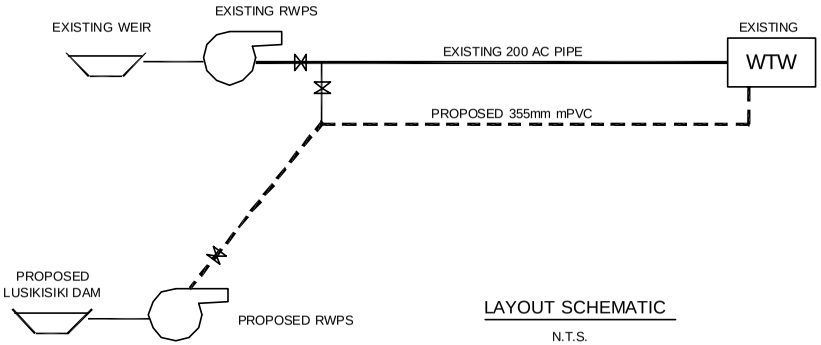
NOTES:

1. THE NEW PIPELINE HAS BEEN SIZED TO ACCOMMODATE THE 2020 DESIGN FLOW AT AN INTERNAL VELOCITY OF 1.5m/s.
2. SURGE ALLOWANCE OF 45m HAS BEEN INCORPORATED IN THE DESIGN OF THE NEW MAIN.



LONGITUDINAL SECTION
PROPOSED LUSIKISIKI DAM SITE TO EXISTING WATER TREATMENT WORKS

HORIZONTAL : 1:20000
VERTICAL : 1:1000



LAYOUT SCHEMATIC
N.T.S.

YEAR	FLOW (l/s)	TOTAL HEAD (m)
2010	120	46
2020	137	48

NOTE:

1. FIGURES GIVEN ABOVE ARE FOR THE "NEW" MAIN ONLY.
2. STATIC HEAD = 38.0m.

Fig A6.5

Designed:	M.R.
Drawn:	B.M.B.
Checked:	W.S.K.

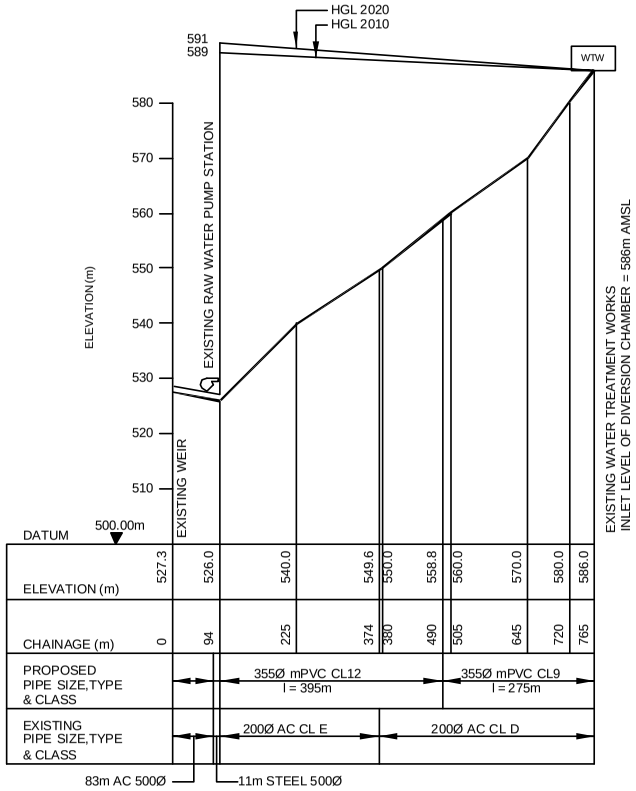
Project
EAST PONDOLAND BASIN STUDY

Description
LUSIKISIKI DAM SITE (OPTION No.2)
PROPOSED RAW WATER CONVEYANCE SYSTEM
PROPOSED DAM SITE TO EXISTING WTW

Sheet 1 of 1
Scale: As shown
Date: 31/07/2000
No. 19278-PF-02/L

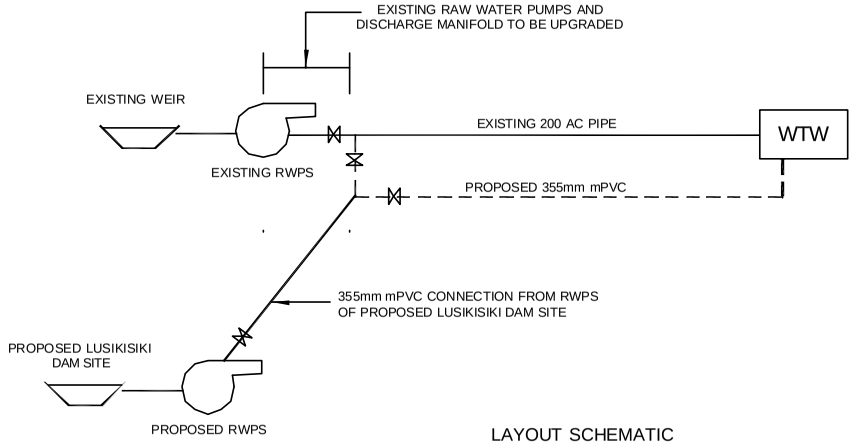
NOTES:

1. THE NEW PIPELINE HAS BEEN SIZED TO ACCOMMODATE THE 2020 DESIGN FLOW AT AN INTERNAL VELOCITY OF 1.5m/s.
2. THE EXISTING 200 AC PIPE NEED NOT BE ABANDONED BUT COULD BE USED FOR FLEXIBILITY OF SUPPLY.
3. THE BULK OF THE FLOW (89%) WILL BE THROUGH THE NEW PIPELINE IF BOTH PIPELINES ARE USED.
4. THE FLOW THROUGH THE EXISTING PIPELINE MUST BE REGULATED TO 32l/s WHEN USING ONLY THE OLD LINE WITH THE UPGRADED PUMPS.
5. SURGE ALLOWANCE OF 45m HAS BEEN INCORPORATED IN THE DESIGN OF THE NEW MAIN.



LONGITUDINAL SECTION
WEIR TO EXISTING WATER TREATMENT WORKS

HORIZONTAL : 1:10000
VERTICAL : 1:1000



LAYOUT SCHEMATIC

N.T.S.

YEAR	FLOW (l/s)	TOTAL HEAD (m)
2010	120	63
2020	137	65

NOTE:

1. FIGURES GIVEN ABOVE ARE FOR THE "NEW" MAIN ONLY.
2. STATIC HEAD = 60.0m.

Fig A6.6

Designed:	M.R.
Drawn:	B.M.B.
Checked:	W.S.K.

Project

EAST PONDOLAND BASIN STUDY

Description

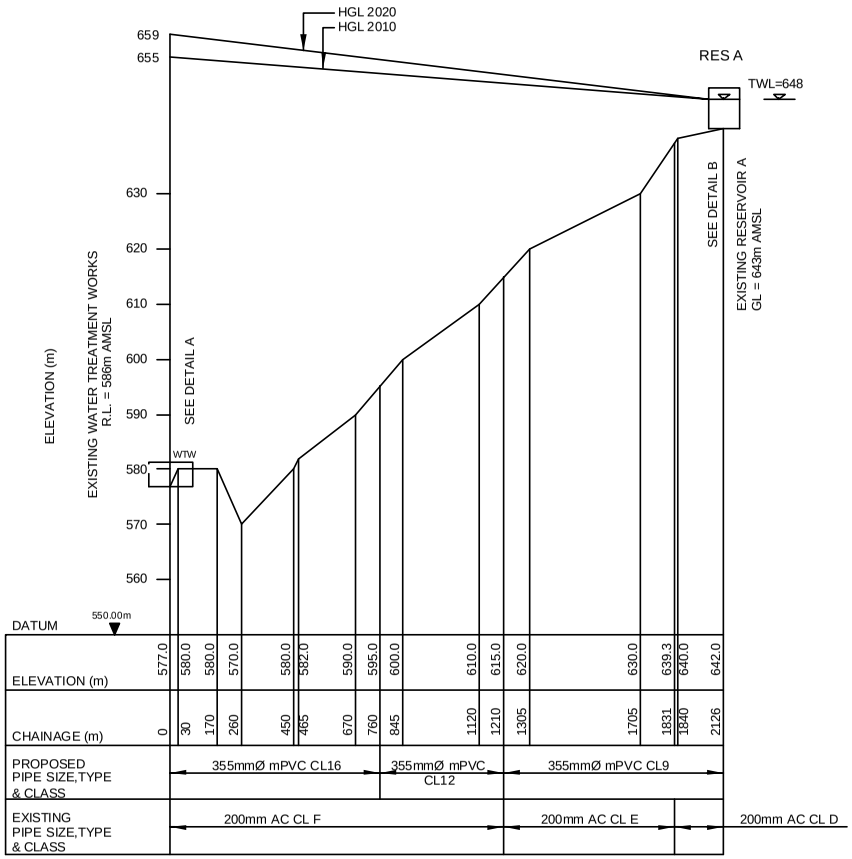
EXISTING WEIR (OPTION No.1)
PROPOSED RAW WATER CONVEYANCE SYSTEM
EXISTING RWPS TO EXISTING WTW

Sheet 1 of 1

Scale: As shown

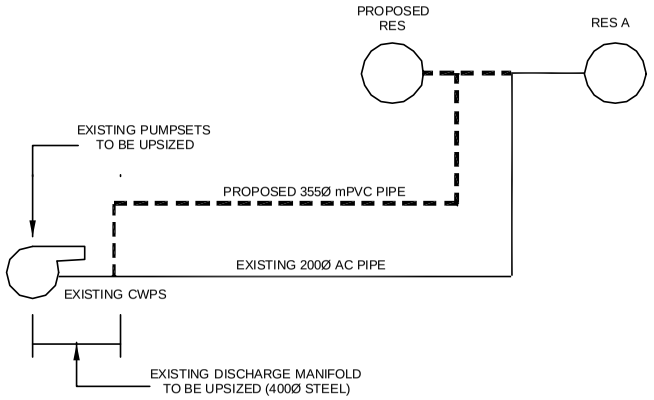
Date: 31/07/2000

No. 19278-PF-01/L



LONGITUDINAL SECTION
EXISTING WATER TREATMENT WORKS TO EXISTING RESERVOIR A

HORIZONTAL : 1:20000
VERTICAL : 1:1000



LAYOUT SCHEMATIC

N.T.S.

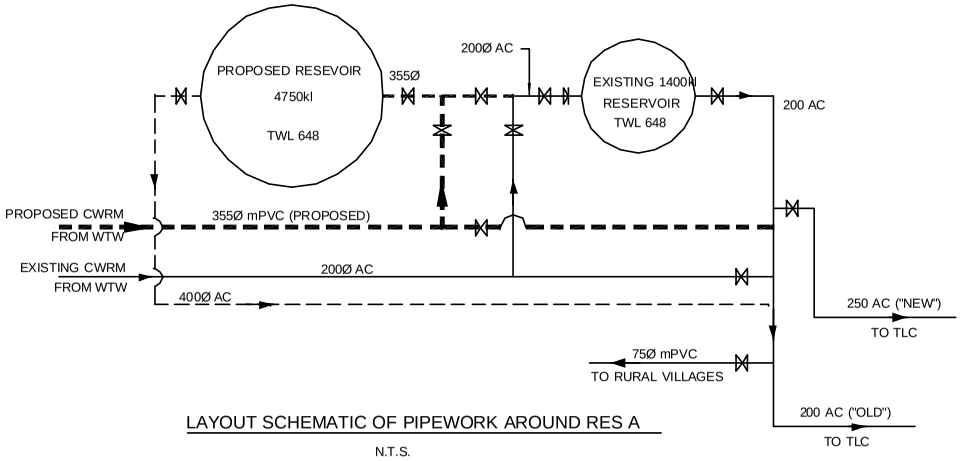
NOTES:

1. THE NEW PIPELINE HAS BEEN SIZED TO ACCOMMODATE THE 2020 DESIGN FLOW AT AN INTERNAL VELOCITY OF 1.5m/s.
2. EXISTING 200 AC RISING MAIN NEED NOT BE ABANDONED BUT COULD BE USED FOR FLEXIBILITY OF SUPPLY.
3. THE BULK OF THE FLOW (89%) WILL BE THROUGH THE NEW PIPELINE, IF BOTH PIPELINES ARE USED.
4. THE FLOW THROUGH THE EXISTING PIPE MUST BE REGULATED TO 32l/s WHEN ONLY THE OLD LINE IS USED WITH THE UPGRADED PUMPS.
5. SURGE ALLOWANCE OF 45m HAS BEEN ALLOWED FOR IN THE DESIGN OF THE NEW MAIN.

YEAR	FLOW (l/s)	TOTAL HEAD (m)
2010	100	78
2020	125	82

NOTE:

1. FIGURES GIVEN ABOVE ARE FOR THE "NEW" MAIN ONLY.
2. STATIC HEAD = 71.0m.



LAYOUT SCHEMATIC OF PIPEWORK AROUND RES A

N.T.S.

Fig A6.7

Designed:	M.R.
Drawn:	B.M.B.
Checked:	W.S.K.

Project

EAST PONDOLAND BASIN STUDY

Description

CLEAR WATER CONVEYANCE SYSTEM (ALL OPTIONS)
PROPOSED CLEAR WATER CONVEYANCE SYSTEM
EXISTING WATER TREATMENT WORKS TO COMMAND RESERVOIRS (RESERVOIRS A)

Sheet 1 of 1

Scale: As shown

Date: 31/07/2000

No. 19278-PF-04/L

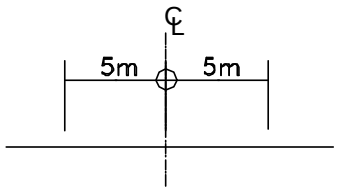
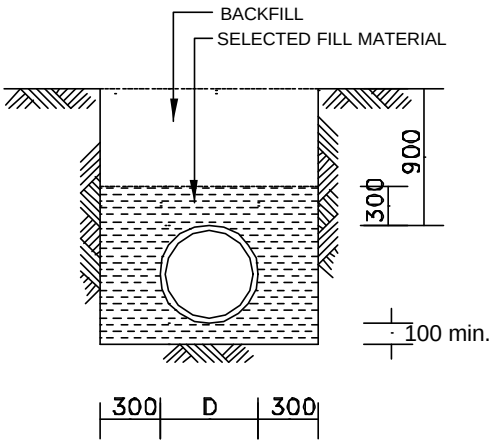
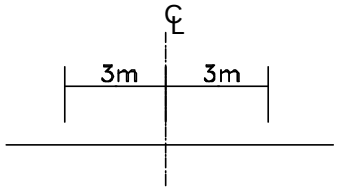
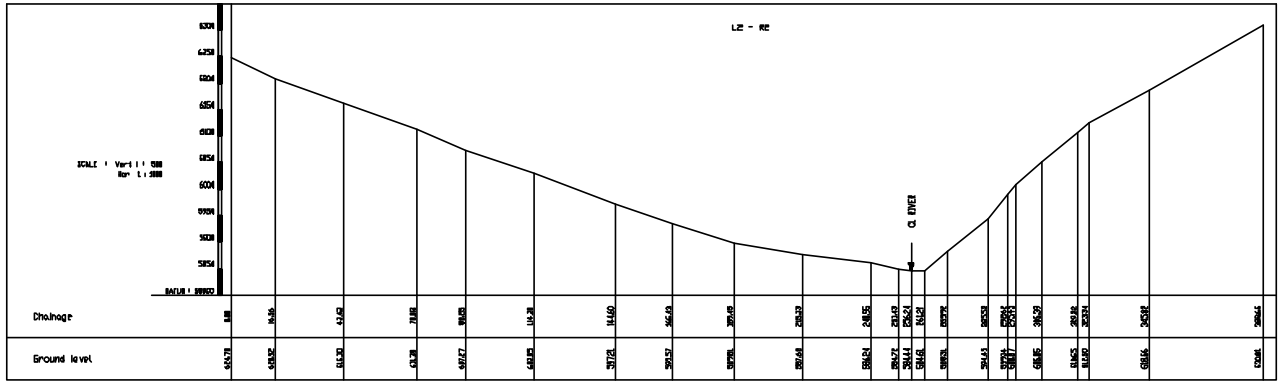
No.	DESCRIPTION	DIMENSIONS	APPLICABLE PAY ITEMS
1	WORKING AREA		CLEAR AND GRUB
2	TRENCH DIMENSIONS		TOP SOIL (150mm) TRENCH EXCAVATION EXTRA OVER MATERIALS BEDDING / SELECTED FILL ASSUMPTIONS: INTERMEDIATE EXCAVATION= 15% OF TOTAL EXCAVATION HARD EXCAVATION= 10% OF TOTAL EXCAVATION
3	VALVES & CHAMBERS		
3.1	AIR VALVES	50mm AIR VALVE COMPLETE WITH BRICK CHAMBER & MANHOLE EVERY 1.0km	
3.2	SCOUR VALVES	80mm SCOUR VALVE COMPLETE WITH BRICK CHAMBER & MANHOLE EVERY 1.0km	
3.3	ISOLATING VALVES	RSV ISOLATING VALVE COMPLETE WITH BRICK CHAMBER & MANHOLE EVERY 2.5km	
4	SERVITUDE	 PERMANENT SERVITUDE DIMENSIONS	LAND AQUISITION ASSUMPTION: NO COMPENSATION FOR WORKING SERVITUDE

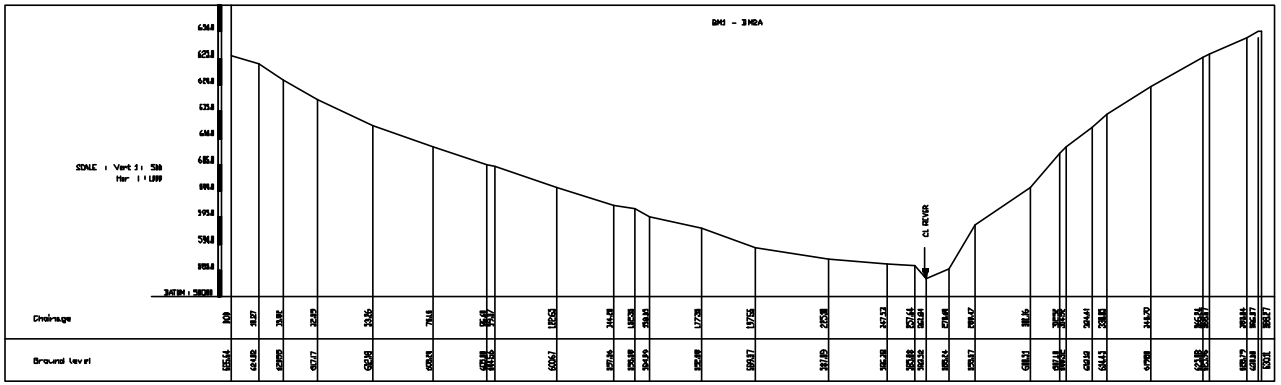
Fig A6.8	Designed: W.S.K.	Project EAST PONDOLAND BASIN STUDY	Sheet 1 of 1
	Drawn: B.M.B.		Scale: N.T.S.
	Checked: C.L.N.	Description BULK MAIN DETAILS	Date: 02/08/2000
			No. 19278-PF-05

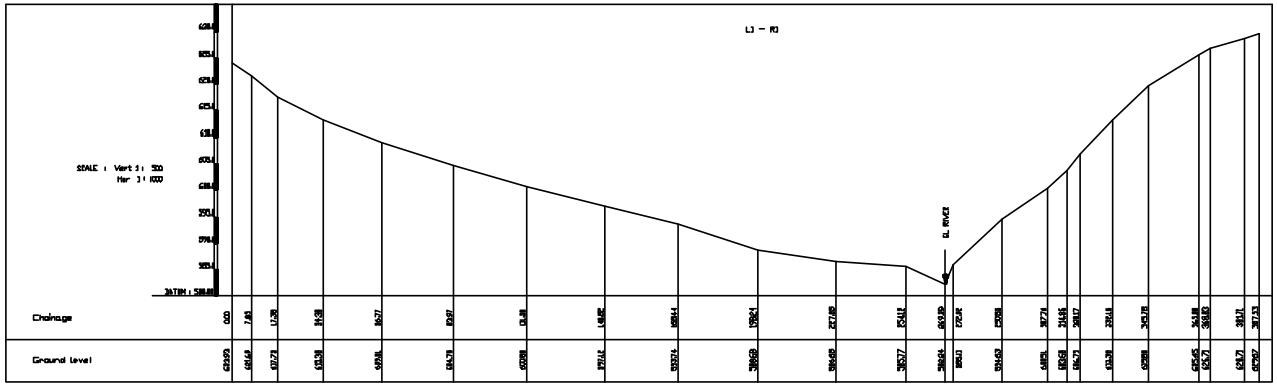
APPENDIX 7 :

DAM SITE CROSS-SECTION SURVEYS: ZALU AND LUSIKISIKI

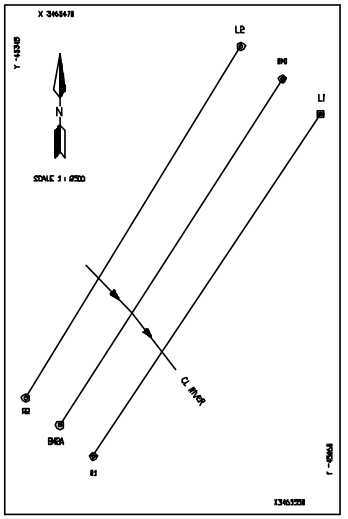
PRE-FEASIBILITY STAGE







SITE PLAN



KOORDINAATSTELSEL LO. 29			
HA. VANAF	TIS 6876	METERS IN REISKIEL	
STASIE	Y	X	HA.
◆ L1	-45 648.99	3 465 578.98	624.39
● L2	-45 364.88	3 465 599.95	624.70
◆ R1	-45 427.82	3 465 695.84	625.47
◆ R2	-45 364.30	3 465 844.78	626.58
◆ BM	-45 649.20	3 465 832.80	627.64
◆ 3824	-45 396.09	3 465 864.58	627.21

CO-ORDINATE SYSTEM LO. 29			
RL. FROM	TIS 6876	METRES ABOVE M.S.L.	
STATION	Y	X	RL.

VELLETJIE/SHEET LAYOUT

1

CROSS SECTIONS

VERT. SCALE 1 : 500

HOR. SCALE 1 : 2000

0 25 50 100 150 200 250 300

SITE PLAN SCALE 1:2500

INVENTORIAL ESTIMATING DIRECTORATE ESTIMATES

PRIVAATSAK X393 PRIVATE BAG

PRETORIA

0001

DRAWN TEKEN	EASTERN CAPE	1996	CHECKED NAGSIEN	EASTERN CAPE	1996
SUBMITTED INGEDIEN	EASTERN CAPE	1996	DIRECTORATE DIREKTORAAT		
APPROVED GOEDGEKEUR			DIRECTOR DIREKTEUR		

No/Nr.	REVISIONS / REVISIES	DATE/DATUM

REPUBLIEK VAN SUID-AFRIKA

DEPARTEMENT VAN WATERWESE EN BOSBOU

REPUBLIC OF SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

PONDOLAND OPVANGSGEBIED STUDIE

VOORGESTELDE ZALA DAMTERREIN

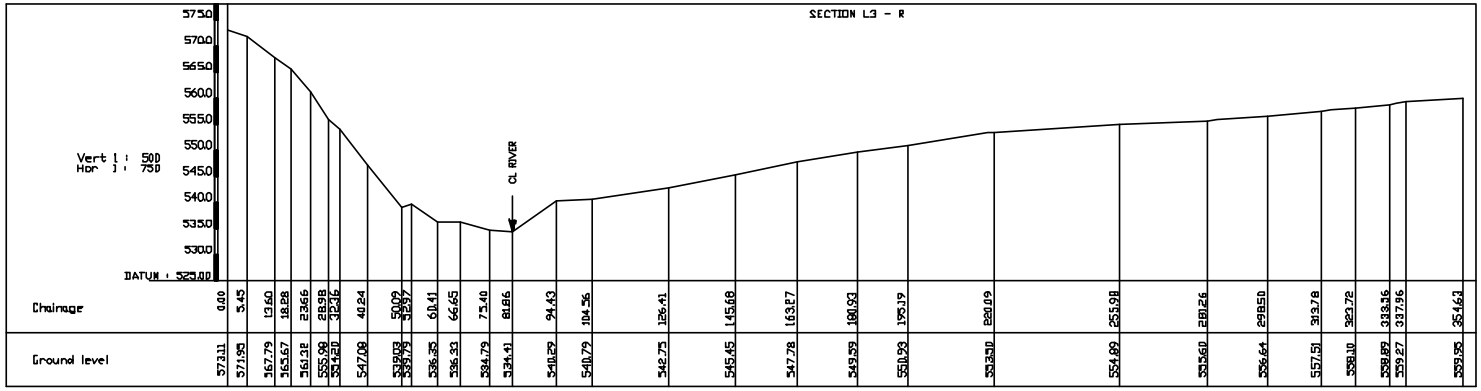
DWARSSNIT OPMETING

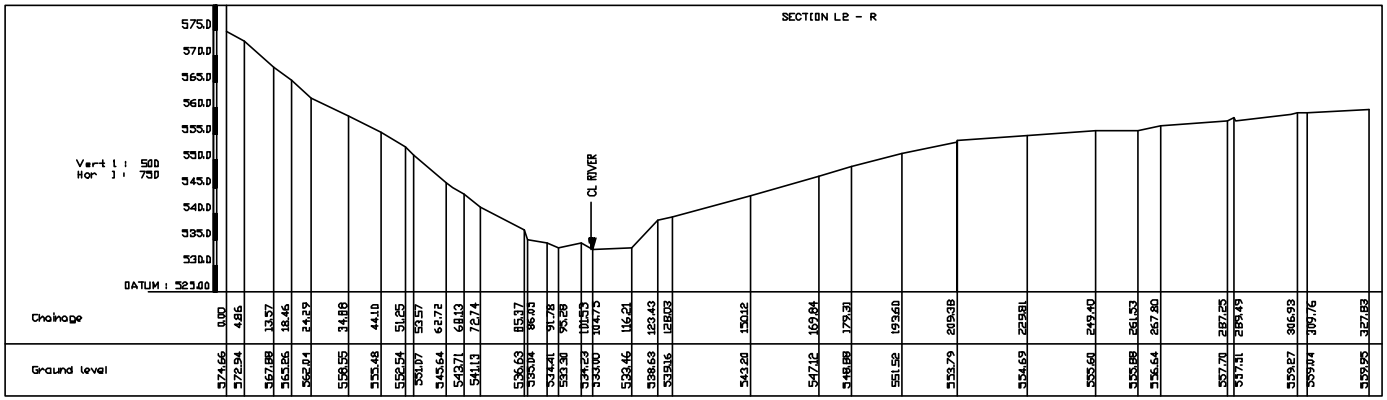
PONDOLAND BASIN STUDY

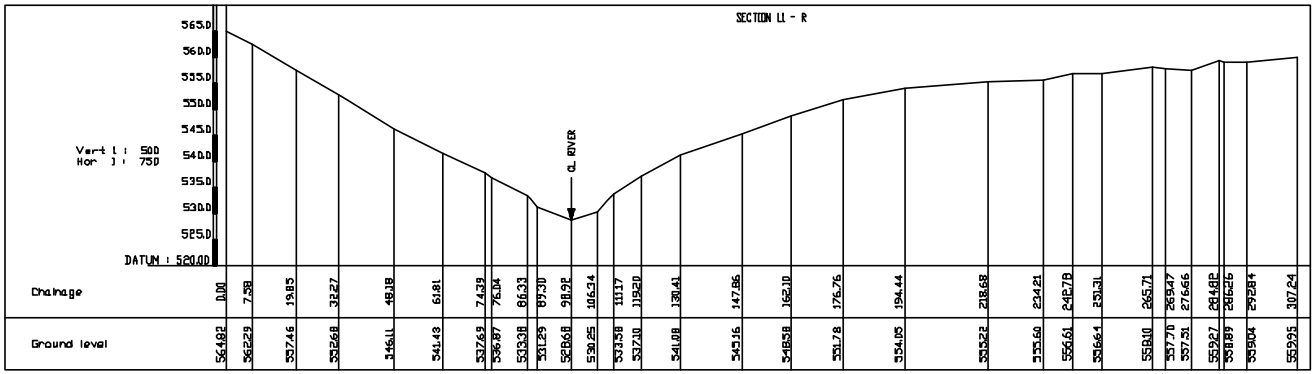
PROPOSED ZALU DAM SITE

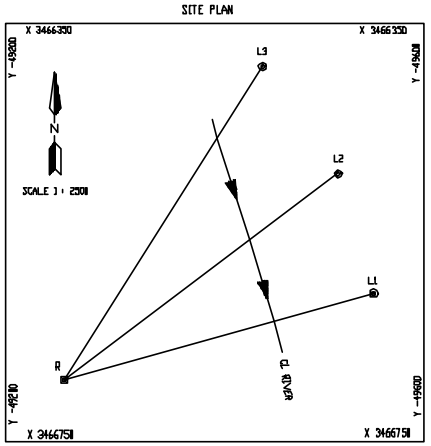
CROSS SECTIONS

DISTRIK DISTRICT	LOKASIE	VEL SHEET	LOK. NR/LOC. NO.	REG. NR/REG. NO.
UMTATA	KOKSTAD	1	T601	









KOORDINAATSTELSEL LO. 29

H.H. VANAF T15 687.6 METERS BO SEESPEEL "

STASIE	Y	X	H.H.
R	-49 82606	3 466 69848	55984
L1	-49 58199	3 466 60859	56486
L2	-49 58149	3 466 69449	57446
L3	-49 44582	3 466 59189	57510

CO-ORDINATE SYSTEM LO. 29

R.L. FROM T15 687.6 METRES ABOVE M.S.L.

STATION	Y	X	R.L.

VELUITLEG/SHEET LAYOUT

1

CROSS SECTIONS
VERT. SCALE 1 : 500
HOR. SCALE 1 : 750

0 25 50 100 150 200 250 300 350
SITE PLAN SCALE 1:2500

DIREKTORAAT GEOMATIKA DIRECTORATE GEOMATICS
PRIVAATSAK X313 PRIVATE BAG
PRETORIA
0001

OPMEET SURVEYED	EASTERN CAPE	RAND	MACLEAR RAND	EASTERN CAPE
SAAMGESTEL COMPILED	EASTERN CAPE	RAND	DEPARTEMENT WATERWESE DEPARTMENT OF WATER AFFAIRS	
TEKENAFTL DRAUGHTSMAN			KADASTRALE AFDELING CADASTRAL DIVISION	

No.	HERSIENING / REVISION	DATUM DATE

REPUBLIEK VAN SUID-AFRIKA
DEPARTEMENT VAN WATERWESE EN BOSBOU

REPUBLIC OF SOUTH AFRICA
DEPARTMENT OF WATER AFFAIRS & FORESTRY

PONDOLAND OPVANGSGEBIED STUDIE

VOORGESTELDE LUSIKISIKI DAMTERREIN DWARSSNIT OPMETING

PONDOLAND BASIN STUDY

PROPOSED LUSIKISIKI DAM SITE CROSS SECTIONS

DISTRIK DISTRICT: LUSIKISIKI
KODE CODE:
AFRIKA

VEL SHEET 1

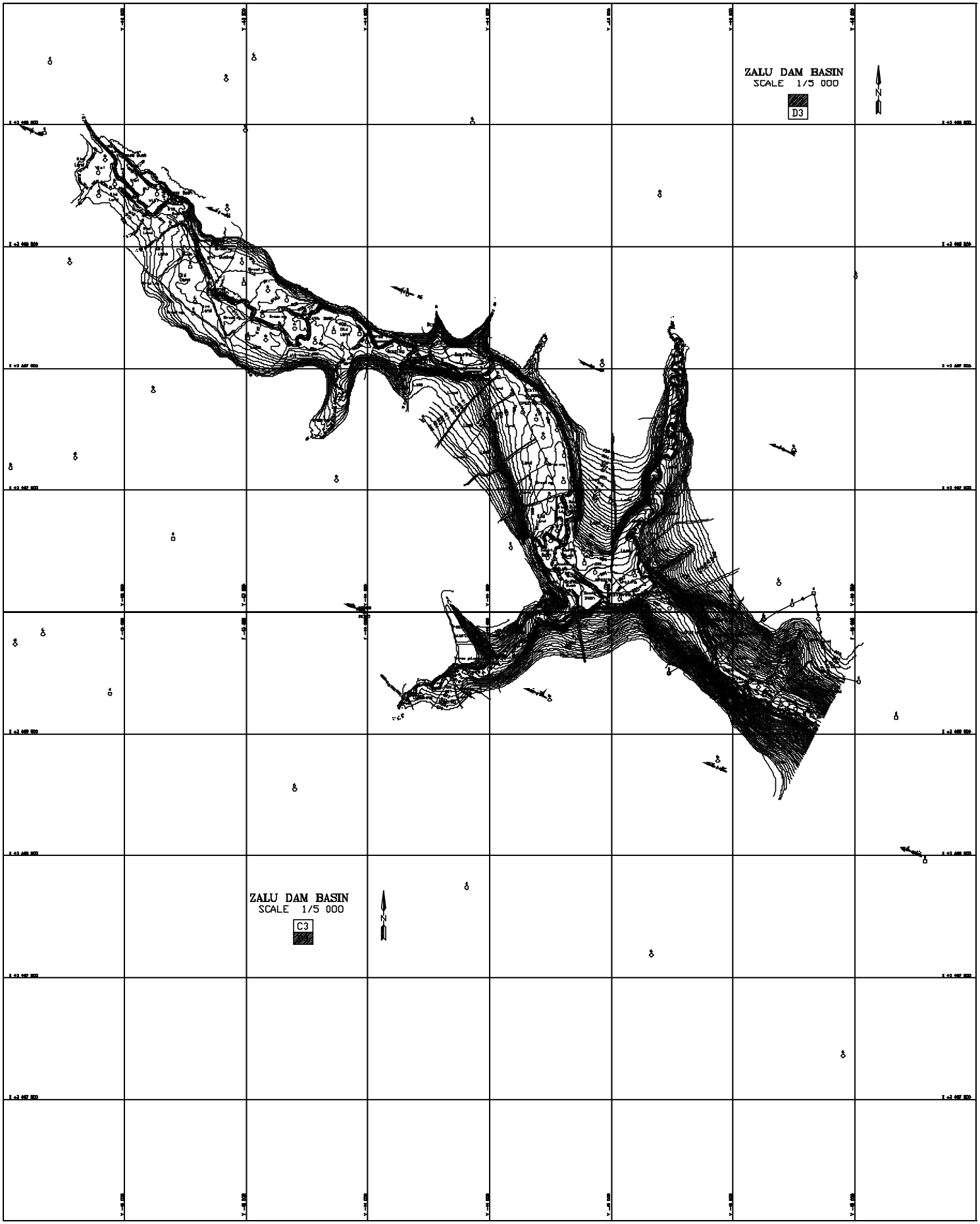
LOK. NR./LOC. NO. T601

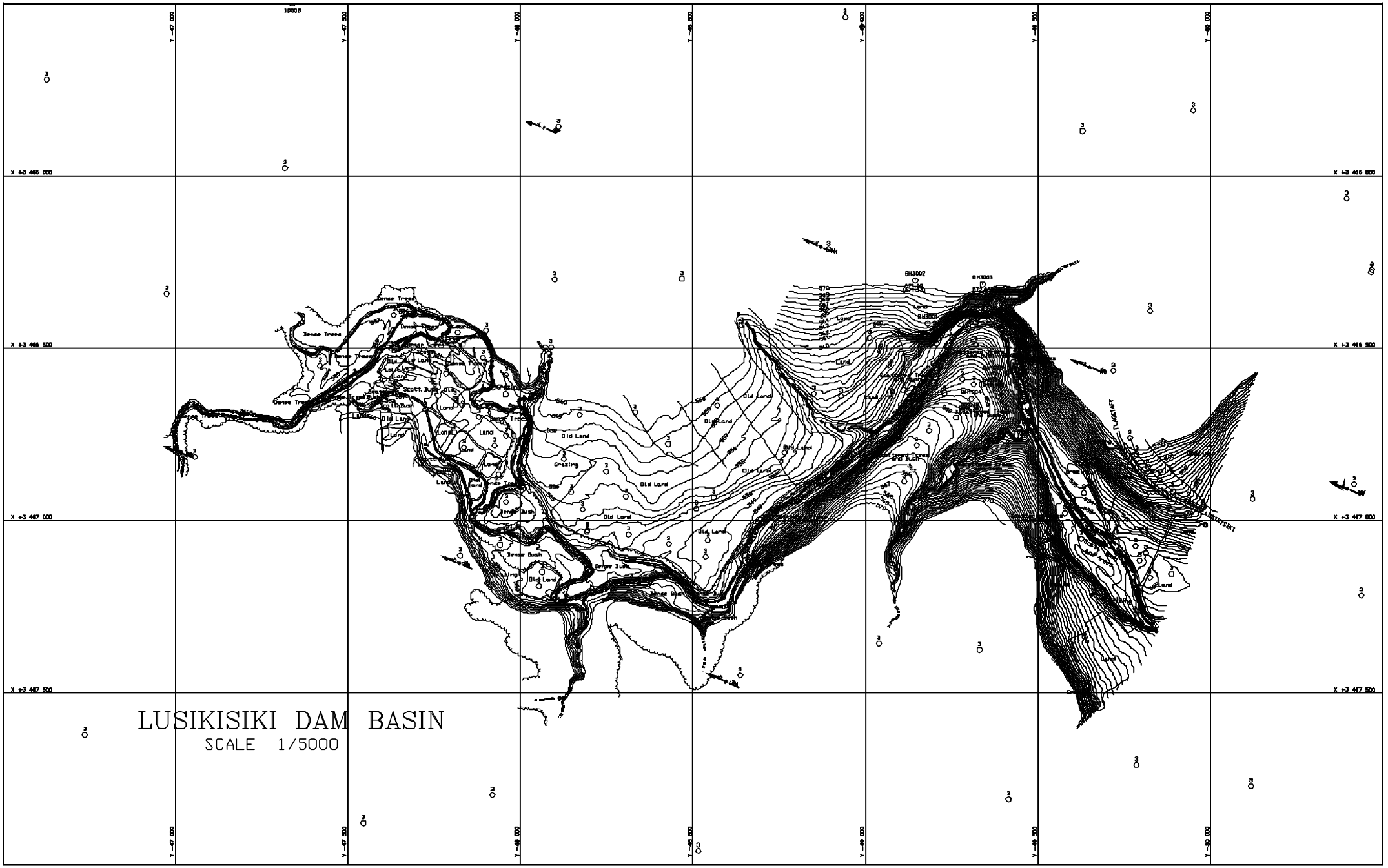
REG. NR./REG. NO.

APPENDIX 8 :

DAM BASIN SURVEYS:
ZALU AND LUSIKISIKI DAMS

PRE-FEASIBILITY STAGE


ZALU DAM BASIN
SCALE 1/5 000
D3
N
ZALU DAM BASIN
SCALE 1/5 000
C3
N

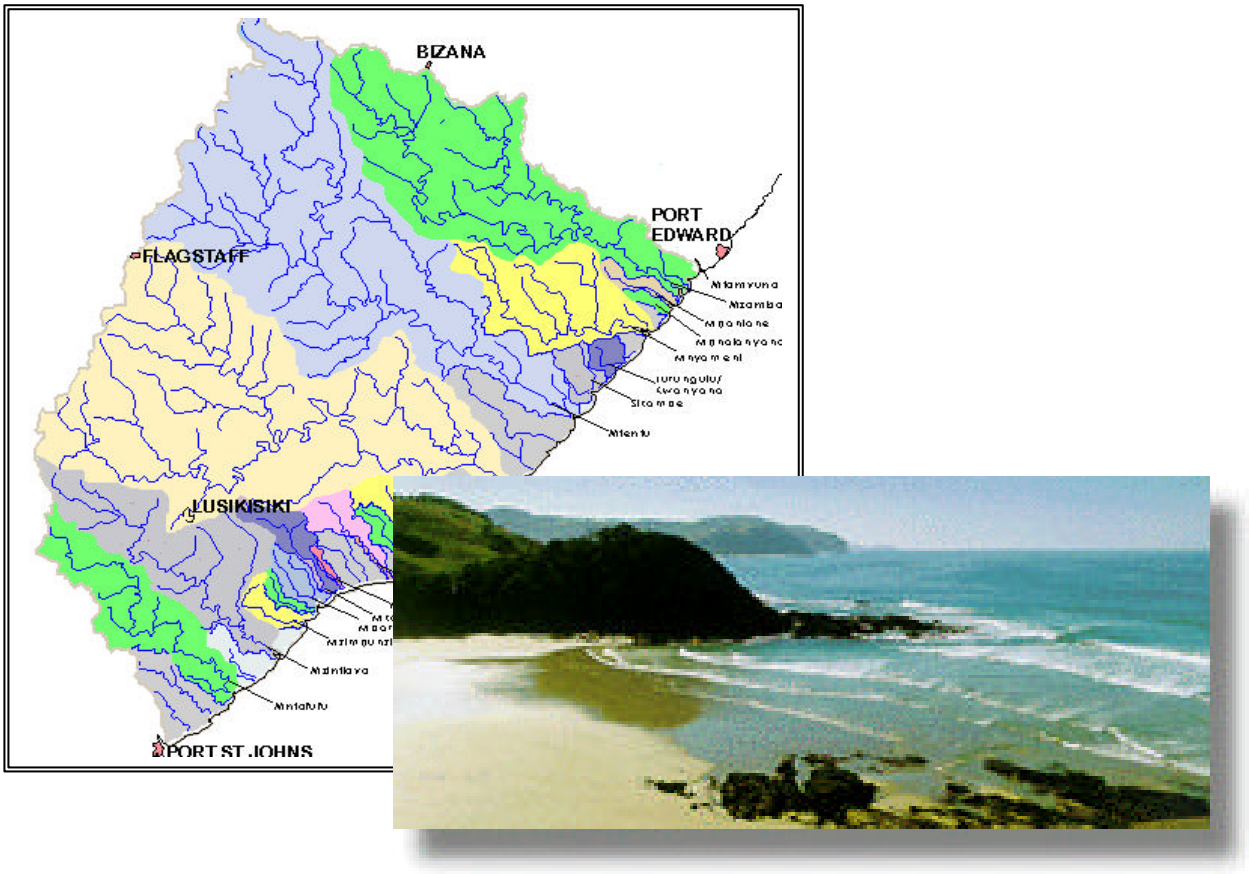

LUSIKISIKI DAM BASIN
SCALE 1/5000

PB T600/00/0501

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



ENVIROMENTAL EVALUATION OF PROPOSED DEVELOPMENT SITES

Scoping Report

Final

June 2001

Prepared By:

Anton Bok Aquatic Consultants CC
Port Elizabeth

ANTON BOK AQUATIC CONSULTANTS
Trading as ANTON BOK & ASSOCIATES

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Environmental Evaluation of Development Sites Scoping Report -
AUTHOR	**:**	A Bok
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-0501
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EXECUTIVE SUMMARY

The Department of Water Affairs and Forestry (DWAF) has initiated a project to augment the existing Lusikisiki Regional Bulk Water Supply Scheme, which includes the supply of piped water to surrounding villages. This water supply scheme is a component of a broader Eastern Pondoland Coast Basin Study, being undertaken by the consultants (UWP Engineers), and incorporates the construction of a dam (or dams) on the Xura tributary of the Msikaba River and/or the Mzintlava River.

The construction of any dam affecting the flow of a river is listed as a Schedule 1 activity in terms of the regulations (Section 21 (1), Government Gazette No. 18261, 5 September 1997), promulgated under the Environmental Conservation Act, 1989 (Act No. 73 of 1989). Most components of the Lusikisiki water supply project are still in the reconnaissance or pre-feasibility stage. However, discussions with officials from the Department of Economic Affairs, Environment and Tourism (DEAET), indicated that a scoping report in terms of the Environmental Conservation Act, 1989, would be necessary even at this early stage. A Plan of Study for scoping was thus submitted to the Kokstad office of DEAET in July 1999, in terms of these regulations. Verbal approval to proceed with the scoping report as outlined, was subsequently given.

This scoping report was prepared from data supplied from UWP Engineers and from information obtained during two field visits. The initial field visit to the 5 proposed dam sites was carried out during 28 to 30 June 1999, at which time , a preliminary vegetation survey on the areas to be inundated by the proposed dams was conducted by Mr B. Colloty (Botanist). A follow-up botanical survey was carried out in March 2000 by an experienced botanist, Ms Elize Cloete, familiar with the vegetation in Transkei. This second survey was undertaken to specifically survey the Zalu and Xura sites on the Xura River for rare and endangered plants, and was carried out during the summer flowering season.

In addition, information was collected on the habitat integrity of both the riparian and instream components of the river reaches into which the dam sites fell. These data were used to determine the ecological importance and sensitivity, as well as the present ecological status of the river reaches in the Xura and Mzintlava rivers, using recently-developed methodologies. These assessments allowed the ecological management classes of the various river reaches within the study areas to be determined, as well as to give an indication of the conservation value of the areas that would be affected by the proposed dams.

The socio-cultural component of the investigation was restricted to assessing the dependence of the local population, living in the vicinity of proposed dam sites, on the

river and associated natural resources. Aspects considered were the dependence in terms of the supply of clean water for domestic purposes, for stock-watering and the use of riparian vegetation for firewood, medicine and for building. The cultural and historical value of the sites were also considered.

This investigation found that the natural features of the various proposed dam sites have been largely modified due to the activities of man. The natural riparian vegetation at all of these sites showed a large to serious degree of degradation due to harvesting for firewood and building material, bush-clearing to create cultivated fields and destructive burning practices.

No rare or endangered plant or terrestrial animal species were found at any sites during these preliminary investigations. The degree of disturbance and habitat destruction by the local inhabitants makes it unlikely that any rare or endangered fauna, and possibly even flora, are present in these areas. Aquatic surveys were not undertaken due to time constraints. The preliminary "socio-cultural" assessment indicated that dam construction at any of the proposed sites would not have significant social impacts.

In short, the apparent absence of any natural, cultural, or aesthetic features of outstanding value at any of the sites, indicates that there should be no significant site-specific impacts due to the proposed developments. No "fatal flaws" were found at any of the sites and there were also no distinct "preferred options" from the environmental viewpoint.

The greatest potential for significant negative impacts due to dam construction (and subsequent water abstraction), appeared to be related to the sensitive and valuable ecosystems downstream. These constraints will probably have a greater influence regarding the choice of a preferred option than any site-specific environmental considerations.

This investigation therefore recommends that approval be given to the applicant (DWAF) to proceed with the next phase of this proposed development. However, a number of additional studies listed in the report, should be carried out as the project progresses, before any final decision on dam construction is taken.

Eastern Pondoland Basin Study

Structure of Reports

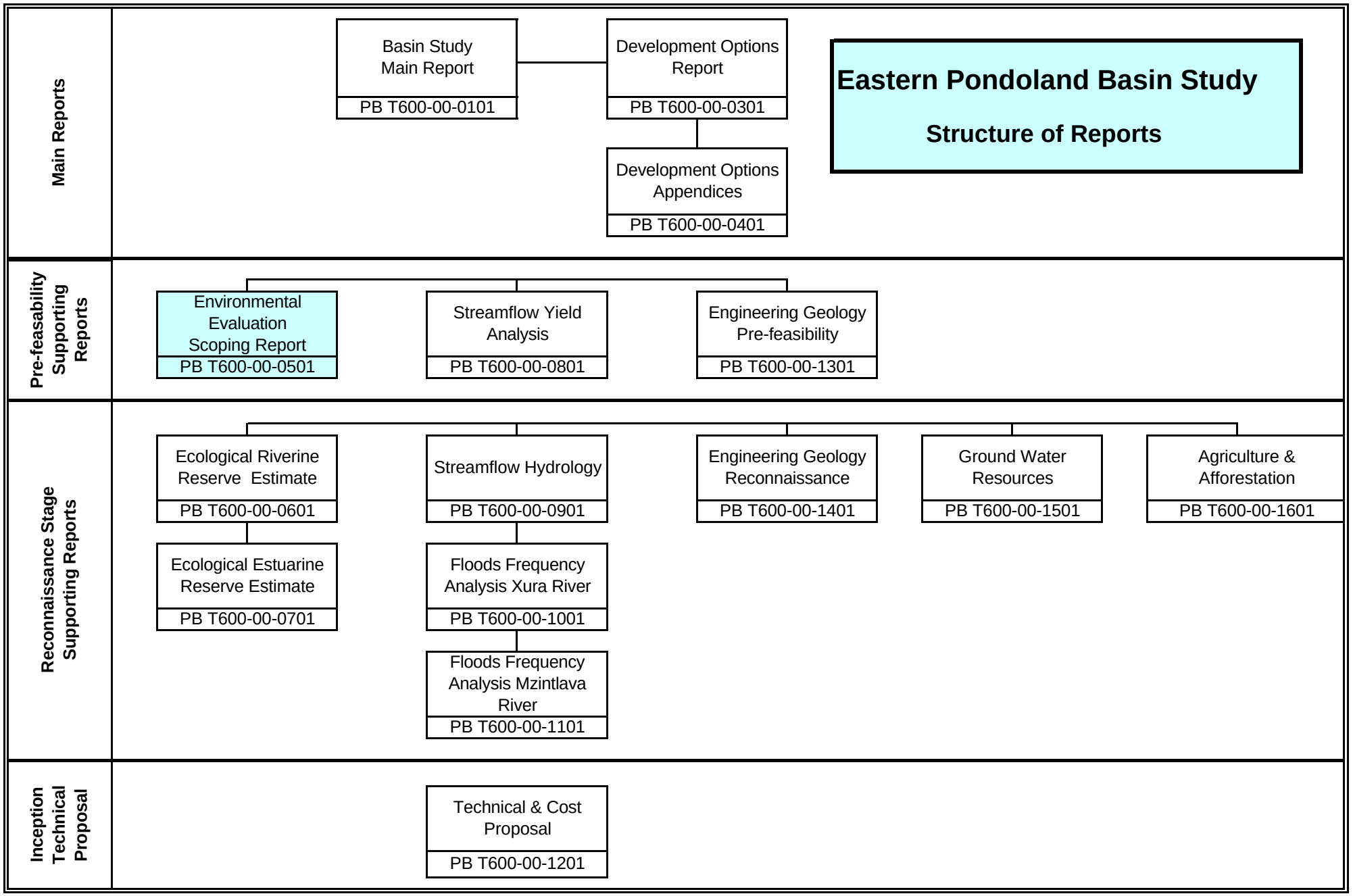


TABLE OF CONTENTS

			Page
Executive Summary			**i**
Table of Contents			**iii**
List of Plates, Figures, Tables, Appendices and Annexures			**v**
1.	**INTRODUCTION**		
	1.1	Background	1
	1.2	Environment Conservation Act, 1989.	1
	1.3	Terms of Reference for the Present Study	1
	1.4	Related Ecological Studies	2
		1.4.1 Eastern Cape Water Balance Desktop Estimate.	2
		1.4.2 Rapid Determination of the Ecological Reserve.	4
		1.4.3 Planning Estimate of the Estuarine Reserve for EPCBS Estuaries	4
	1.5	Report Preparation	5
2.	**DESCRIPTION OF THE FIVE PROPOSED DAM SITES**		
	2.1	Locality and Land Ownership of Sites	6
	2.2	Vegetation at Proposed Sites	6
		2.2.1 Vegetation Types	7
		2.2.2 Vegetation Description	7
	2.3	Preliminary Status Class of the River Reaches at the Proposed Dam Sites	8
	2.4	Description of Proposed Developments	11
		2.4.1 Construction Details	11

2.4.2 Associated Developments 11

3. ASSESSMENT OF ANTICIPATED IMPACTS

3.1 Site Specific Impacts 12

3.1.1 Terrestrial Impacts 12

3.1.2 Instream Impacts 12

3.1.3 Associated Impacts 12

3.1.4 Social Impacts 14

3.1.5 Downstream Impacts 15

4. CONCLUSIONS

4.1 Site-specific Impacts 15

4.2 Social Impacts 15

4.3 Downstream Impacts 16

5. RECOMMENDATIONS 16

6. REFERENCES 16

LIST OF PLATES

Plate 1. View of Zalu site looking downstream from left flank of Xura valley. 20

Plate 2. Zalu site showing eroded vehicle/pedestrian/cattle crossing over Xura River. 20

Plate 3. Xura R. at Zalu site looking upstream. 21

Plate 4. Lusikisiki Site looking downstream towards dam wall on Xura R. and Lusikisiki town in the background. 21

Plate 5. Xura R. at Xura Site looking downstream towards locality

of dam wall. 22

Plate 6. Xura R. at Zalu site showing riffle habitat and absence of riparian trees. 22

Plate 7. Mzintlava R. at Lower Mzintlava Site looking upstream of dam wall. 23

Plate 8. Mzintlava R. at Lower Mzintlava Site looking downstream. 23

Plate 9. Mzintlava R. at Lower Mzintlava Site. 24

Plate 10. Mzintlava R. looking downstream towards location of proposed Tungwane Site dam wall. 24

Plate 11. Mzintlava River at upstream end of Tungwane Site. 25

Plate 12. Mzintlava R. at Tangwane Site showing thick filamentous algae. 25

LIST OF FIGURES

Figure 1. Locality Map of 5 proposed dam sites for Lusikisiki Project. 19

Figure 2. Locality Map giving details of the proposed dam sites for Lusikisiki Water Supply Scheme. 19b

LIST OF TABLES

Table 1b. The status and management classes for EPCBS quaternary catchments as determined for the WBDE. 3

Table 1. Proposed Dam Sites for Lusikisiki Water Supply Scheme. 6

Table 2. Vegetation type, observed man-induced impacts and condition of vegetation found at the 5 proposed dam sites. 8

Table 3. Descriptive classes for the assessment of modifications to habitat integrity (from Kleynhans, 1996). 9

Table 4. Preliminary present status classes (from Kleynhans, 1996). 10

Table 5. The preliminary present status classes (PPSC) allocated to the various river reaches affected by the proposed dams. 10

Table 6. MAR values for the catchment areas upstream of the 5 proposed dams compared to the total MAR values of the two river systems. 11

Table 7. Potential associated impacts due to dam construction at the proposed sites. 13

Table 8. Summary evaluation of negative environmental impacts associated with the construction of dams at the proposed sites. 18

LIST OF APPENDICES

Appendix A. Determination of Preliminary Present Status Classes (PPSC) of the various river reaches affected by the proposed dam sites using the method of Kemper and Kleynhans, 1998). 26

Table A1. Evaluation of riparian zone impacts on Xura River dam sites. 27

*Figure A1***.** Relative Impact of Riparian Zone Modifications, Xura River. 27

Table A2. Weighted evaluation of riparian zone impacts on Xura River dam sites. 28

Figure A2.	Xura R. Riparian Zone Habitat Integrity.	28
Table A3.	Evaluation of instream modifications of Xura R. dam sites.	29
Figure A3.	Instream Modifications, Xura River: Zalu, Lusikisiki and Xura Dam Sites.	29
Table A4.	Weighted evaluation of instream modifications of Xura R. dam sites.	30
Figure A4.	Xura River Instream Habitat Integrity: Zalu, Lusikisiki and Xura sites.	30
Table A5.	Evaluation of instream zone modifications at Mzintlava R. dam sites.	31
Figure A5.	Relative Impact of Instream Modifications, Mzintlava River: Mzintlava lower and Tangwane sites (June 1999).	31
Table A6.	Weighted evaluation of instream modifications at Mzintlava dam sites.	32
Figure A6.	Mzintlava River Instream Habitat, Integrity, June 1999: Mzintlava lower and Tangwane sites.	32
Table A7.	Evaluation of riparian modifications at Mzintlava R. dam sites.	33
Figure A7.	Relative Impact of Riparian Zone Modifications, Mzintlava River, June 1999.	33
Table A8.	Weighted evaluation of riparian modifications at Mzintlava R. dam sites.	34
Figure A8.	Mzintlava River Riparian Zone Habitat Integrity:	

Mzintlava lower and Tangwane sites, June 1999. 34

Appendix B. Socio-cultural Evaluation: Xura River and Mzintlava River Dam Sites. 35

Table B1. Socio-cultural evaluation of the impact of Xura R. dams. 36

Figure B1. Socio-economic Importance of Proposed Dam Sites on Xura River. 36

Table B2. Socio-cultural evaluation of the impact of the Mzintlava R. 37

Figure B2. Socio-cultural Importance of Proposed Dam Sites on Mzintlava River. 37

LIST OF ANNEXURES

Annexure 1. Plan of Study for Scoping: Environmental Evaluation of 5 Proposed Dam Sites for the Lusikisiki Water Supply Scheme.

Annexure 2. Eastern Pondoland Basin Study – Newsletter

Annexure 3. Field Forms Used to Collect Relevant Data during Lusikisiki Site Visit: 28-30/06/1999

Annexure 4. Vegetation Survey Report for 5 Proposed Dam Sites: Brian Colloty.

Annexure 4B. Checklist of plant species at Zalu and Xura sites by Elize Cloete

Annexure 5. Draft Report on Construction Materials, Geology and Access for 5 Proposed Dam Sites.

SCOPING REPORT FOR UWP ENGINEERS (REVISED)

ENVIRONMENTAL EVALUATION OF 5 PROPOSED DAM SITES FOR AUGMENTING THE LUSIKISIKI BULK WATER SUPPLY SCHEME

1. INTRODUCTION

1.1 Background

UWP Engineers (UWP) have been appointed by the Directorate of Water Resources Planning (WRP) of the Department of Water Affairs and Forestry (DWAF) as lead consultants for the Eastern Pondoland Coast Basin Study (EPCBS). A major component of this study is the project to augment the existing Lusikisiki Regional Bulk Water Supply Scheme, including its planned extensions to supply surrounding rural villages.

When this basin study was initiated in January 1999, there was very limited information on the water resources of the so-called Eastern Pondoland coastal region, an area defined to include the river catchments between the Mntafufu and the Mzamba Rivers (see Figure 1). The potential environmental impacts resulting from the development of the water resources in this region are of particular concern for the EPCBS because of the relatively pristine condition of the river systems in this undeveloped area. The estuaries in eastern Pondoland, in particular, are considered to have a high conservation value.

1.2 Environment Conservation Act, 1989.

The construction or upgrading of dams, levees or weirs affecting the flow of a river is listed as a Schedule 1 activity in terms of the regulations (Section 21 (1), Government Gazette No. 18261, 5th September 1997) promulgated under the Environment Conservation Act, 1989 (Act No. 73 of 1989). Thus, regardless of the height of the dam or weir wall constructed or the volume of water impounded, the building of any structure affecting river flow is considered to be a listed activity and subject to the EIA regulations contained in sections 21, 22 and 26 of the above Act. In terms of this act, the applicant (i.e. individual or organisation applying for authorization to undertake such an activity) is required to appoint an independent consultant, who must on behalf of the applicant comply with the EIA regulations contained in the act, including the production of a Scoping Report.

1.3 Terms of Reference for the Present Study

It must be emphasised that the various studies being undertaken as part of the Lusikisiki Bulk Water Supply Scheme are still in the reconnaissance or pre-feasibility stage. More detailed studies of all aspects will only be conducted at a later stage.

The ToR of this study were to produce a scoping report in order to satisfy the requirements in terms of the Environmental Conservation Act, 1998. The investigation is therefore largely confined to an assessment of the potential site-specific impacts of the construction of the dams at the five proposed dam sites for the augmentation of the Lusikisiki water supply scheme.

An outline of the issues considered and the tasks undertaken in this study is given in the document "PLAN OF STUDY FOR SCOPING" (Annexure 1), submitted to the Kokstad office of the Department of Economic Affairs, Environment and Tourism, Directorate: Nature Conservation, in terms of the Environmental Conservation Act, 1989. Due to the early (reconnaissance) phase of most aspects of the study, public participation has been confined to a stakeholder meeting held on 18 May 1999 in Lusikisiki and the publication of a hand-out "Eastern Pondoland Basin Study – Newsletter" distributed among the affected communities (Annexure 2).

It is emphasised that only the site-specific impacts on the natural and social environments due to dam construction are considered in any detail in the present study. The possible environmental impacts downstream of the proposed dam sites have been or will be covered by the studies on the ecological reserve, both on the riverine, as well as estuarine zones downstream (see below).

In brief, the ToR for the study were thus to:

(a) Identify possible site-specific environmental impacts that may arise due to the construction of the proposed dams at the various sites;

(b) Assess the significance or magnitude of these impacts;

(c) Assess the feasibility of possible mitigatory measures that can be taken to obviate the identified potential impacts;

(d) Identify any "fatal flaws" that could rule out any of the options;

(e) Rank the various proposed dam site options according to the magnitude of the potential impacts.

1.4 Related Ecological Studies

Three recent studies concerned with the ecological freshwater flow requirements of the rivers within the EPCBS have relevance to the above-mentioned Lusikisiki bulk water augmentation scheme. These are:

1.4.1 Eastern Cape Water Balance Desktop Estimate.

The above study, commissioned by The Directorate: Project Planning of DWAF, forms part of a national water balance determination which is required in compliance with the provisions of the National Water Act. 1998. The purpose of this study is to determine a Level 1 or desktop estimate (DE), previously referred to as the "planning estimate", of

the ecological flow requirements or ecological reserve for all Eastern Cape rivers. This Eastern Cape water balance desktop estimate thus forms part of a country-wide study, referred to as the water balance desktop estimate or WBDE. The DE of the ecological reserve of all the quaternary catchments in the country will be used to develop the National Water Balance Model.

At a workshop held Grahamstown on 1 and 2 March 1999, the WBDE of all quaternary catchments in the Eastern Cape, including those catchments falling within the EPCBS area, were determined using the methodology developed by Kleynhans *et al* (1998). In this method, the ecological importance and sensitivity of the mainstream river per quaternary catchment as expected under unimpaired conditions, is assessed. At this workshop all the catchments within the EPCBS area were designated as Class A ecological management classes (EMCs) because of the high ecological importance and sensitivity of the rivers in this region.

At a subsequent workshop on 16 and 17 August 1999, these results of the March 1999 workshop were revisited in the light of changes or improvements to the original methodology (Kleynhans, June 1999). In addition, the present ecological status class (PESC) of the rivers within the quaternary catchments in the Eastern Cape were determined using this methodology. This review was necessitated by the new developments regarding the influence of the PESC on determining a realistic or attainable ecological management class, termed the AEMC (Kleynhans, June 1999).

During the August 1999 workshop described above, all of the quaternary catchments falling within the EPCBS area were considered to be "similar" and assessed as a single entity. The allocated classes given to the EPCBS catchments during this exercise are given in Table A below.

Table A. The status and management classes for the EPCBS quaternary catchments as determined for the WBDE (water balance desktop estimate).

CLASS DESCRIPTION	**CLASS SCORE**	**SCORE DESCRIPTION**
DEMC Default ecological management class derived from Ecological Importance and Sensitivity Class	A (Very High)	Unique on a national scale (mainly due to unique fish species), usually very sensitive to flow modifications and have only a small capacity for use
PESC Present ecological status class	B (High)	Largely natural with few modifications, but with some loss of natural habits, particularly riparian habitat
AEMC Attainable ecological management class	B (High)	Ecosystems modified mainly due to the destruction of riparian vegetation and poor stream bank condition and erosion

The relatively high AEMC for the rivers within the EPCBS indicates that the volumes of water required for the ecological flow requirements of the quaternary catchments in this region will be relatively high. The volumes (as a % of the MAR) of the WBDE of the Ecological Reserve for the various quaternary catchments have not yet been finalised, but it is anticipated that these data will be available in September 1999. This will be done by applying the methodology for determining the DE of the quantity component of the ecological reserve, recently developed by Professor Denis Hughs at the Institute for Water Research (IWR), Rhodes University (Hughs & Munster 1999). This computer-based decision support system (DSS) is based on hydrological extrapolation of past IFR workshop results.

1.4.2 Rapid Determination of the Ecological Reserve.

In addition to the above, further analyses of the ecological reserve of the two high priority rivers under consideration, namely the Xura tributary of the Msikaba River and the Mzintlava River, was carried out in a separate investigation. In this exercise, an upgrading of the DE, termed the Rapid Determination of the reserve (Level 2), was carried out in a one day work-session in Grahamstown on 31 August 1999. This work session was attended by Prof Denis Hughs, Prof. Jay O'keeffe and the author (Dr Anton Bok). The additional information used was mainly that collected during the EIA site inspection of the five proposed dam sites in the Lusikisiki area by the author in June 1999, as well as available physical, chemical and biological data relevant to this region.

The procedure involves data input via a user-interface facility available as part of the computer-based DSS developed by the Institute of Water Research Staff at Rhodes University mentioned in Section 1.4.1 above (Hughs & Munster 1999; Munster & Hughs, 1999). The user-interface facility of the above DSS enables the incorporation of additional habitat integrity, present ecological status as well as other bio-physical data into the model in order to "fine-tune" the setting of the Ecological Management Classes. In addition, "expert opinion" on ecological flow requirements pertaining to specific physical and biological factors in the river reach under consideration, can also be incorporated and used to modify the output (Munster and Hughs 1999).

The results from this exercise are given in detail in a separate internal report titled "Rapid Reserve Estimate of Xura and Mzintlava Rivers" to be submitted to UWP Engineers as part of the EPCBS programme. The IFR data in the above report are presented in terms of total IFR; maintenance lowflows; drought lowflows; maintenance highflows, both as a % of MAR and as monthly flow volumes.

1.4.3 Planning Estimate of the Estuarine Reserve for EPCBS Estuaries

The estuaries were not included in the above reserve determination studies as the methodology used to determine the DE of the riverine zones is not considered suitable for estuaries. The determination of the DE (previously termed Planning Estimate) of the EPCBS estuaries was carried out at a workshop held at the University of Port

Elizabeth on 13 and 14 May 1999. The proceedings of this workshop have been submitted to UWP Engineers as a draft internal report (Bok 1999).

In brief, the main findings of the above workshop were:

- The estuaries of the larger river systems in this region are thought to require between 80 to 95% of the natural MAR in order to maintain their present ecological status or management class (EMC);
- All of the natural base flows in the present distribution pattern (estimated to be 40 to 50% of MAR) are required for the estuarine reserve;
- Further studies are required to determine the amount of additional flow, particularly "flood" waters, required to maintain the existing sediment dynamics of the tidal inlets, i.e. mouth opening and closing, and thus maintain the present EMCs of the estuaries. Additional studies are thus required in order to determine the estuarine reserve (as % of MAR) more accurately;
- Further development of the methodology for the DE of the estuarine reserve will hopefully enable the results from the workshop to be revisited and estimates of monthly, as well as annual volumes of water required for the EFR to be made.

1.5 Report Preparation

A walk-over inspection of the five potential sites was carried out n 28 to 30 June 1999. During this field visit, special forms to collect appropriate data for the EIA Scoping Study, the Social Assessment and the Instream and Riparian Habitat Integrity were used (see Annexure 3).

A botanist (Mr Brian Colloty), familiar with riparian vegetation in this region, formed part of the June 1999 field survey team and conducted brief vegetation surveys of the various sites. In addition, Mr Wilton Madlavuza (a health inspector from the Department of Health and chairperson of the Lusikisiki RDP rural water supply committee) was present during 4 of the site visits. He facilitated discussions with local inhabitants and assisted with the gathering of information on the importance of the riverine habitat and natural resources for the local communities and possible social impacts of the proposed dams.

On 8 March 2000, a follow-up botanical survey of the two most likely dam sites, namely the Zalu and Xura sites on the Xura River, was undertaken. The purpose of this botanical survey was to determine the botanical importance of these two sites in terms of the presence of rare and endangered species. A local botanist familiar with the flora of the region, Ms Elize Cloete from UNITRA, undertook this survey which involved a walk-over survey of the areas to be inundated by the proposed dams at the two sites.

2 DESCRIPTION OF THE FIVE PROPOSED DAM SITES

Background information regarding the study area, including data on geology, climate, agricultural potential, climate and rainfall, streamflow hydrology, groundwater resources, water quality and sedimentation and social-economic aspects will be available from the other studies commissioned as part of the Eastern Pondoland Coast Basin Study (EPCBS). Only information directly relevant to this environmental study will therefore be presented in this report.

Photographs depicting various environmental aspects of the river reaches upstream of the 5 proposed dam sites, discussed in this report, are given in Plates 1 to 13.

2.1 Locality and Land Ownership of Sites

The locations (map co-ordinates) of the 5 proposed dam sites are given in Table 1 (below) and their relative positions on a 1:400 000 map given in Figure 1.

As shown, there are three sites on the Xura River (tributary of the Msikaba River) and two sites on the Mzintlava River. All sites and reaches of the rivers and adjacent land which will be inundated are situated on communal land which falls under the authority of the local headman or chief.

TABLE 1. PROPOSED DAM SITES FOR LUSIKISIKI WATER SUPPLY SCHEME

Proposed Site	Latitude	Longitude	Catchment area (km^2)	River	Max. dam wall height	1:50 000 map
Zalu site	31^0 18' 50"	29^0 28' 40"	71 km^2	Xuru	34m	3129AD
Lusikisiki site	31^0 19' 25"	29^0 31' 25"	91 km^2	Xura	46m	3129BC
Xura site	31^0 18' 55"	29^0 35' 35"	225 km^2	Xura	31m	3129BC
Tungwane site	31^0 25' 30"	29^0 33' 30"	129 km^2	Mzintlava	50m	3129BC
Mzintlava lower site	31^0 24' 25"	29^2 31' 22"	98 km^2	Mzintlava	39m	3129BC & AD

2.2 Vegetation at Proposed Sites

Details of the vegetation found at the various sites in June 1999 are given in the Vegetation Report by Brian Colloty (Annexure 4). In addition, a comprehensive checklist of plants found at the Zalu and Xura sites in March 2001 by Elize Cloete is given in Annexure 5. These findings are outlined below.

2.2.1 Vegetation Types

Four of the seven biomes present in South Africa are found in the Pondoland region according to Low and Rebelo (1996). A Biome is defined as "A broad ecological unit representing major life zones of large natural areas. In South Africa these are defined mainly by vegetation structure and climate". Remnants of all four biomes were found at most of the proposed dam sites. These biomes are:

(i) The Forest Biome (Coastal Forest and Afromontane Forest vegetation types);

(ii) The Thicket Biome (Valley Thicket vegetation type);

(iii) Savanna Biome (Eastern Thorn Bushveld vegetation type);

(iv) Grassland Biome (Moist Upland Grassland and Coastal Grassland vegetation types).

2.2.2 Vegetation Description

The vegetation at all of the sites was found to be significantly degraded and transformed due to the activities of man. This degradation of both the riparian vegetation and adjacent areas further away from the river, is considered to be mainly due to the following activities of the local inhabitants:

(i) cultivation on the floodplain (clearing and ploughing);

(ii) overgrazing by goats and cattle;

(iii) harvesting for fire-wood;

(iv) for use as building materials and medicinal purposes, and

(v) destructive veld burning practices.

A summary of the vegetation and the extent of the man-induced impacts at each proposed dam site is given in Table 2 above. A detailed description is provided in the Vegetation Report by Brian Colloty (Annexure 4).

No rare or endangered plant species were found during the initial vegetation survey in winter (June) 1999. Mr Colloty was of the opinion the high level of disturbance at all five sites would make the finding of Red Data species unlikely. A follow-up botanical survey of the Zalu and Xura sites was therefor undertaken in summer (March) 2000. This second survey took place during the flowering period, when many "difficult" and cryptic species such as endangered ground orchids (geophytes) or bulbs can more easily be identified. This follow-up survey by Elize Cloete, an experienced botanist very familiar with the area, did not reveal any Red Data species. These vegetation surveys support the proposal that it is unlikely that rare or endangered species are present in these highly disturbed areas.

Table 2. Vegetation type, observed man-induced impacts and condition of vegetation found at the 5 proposed dam sites. (*For description of impact class see Table 3 below.)

SITE NAME	VEGETATION TYPE	IMPACTS	CONDITION : *IMPACT CLASS	
			Riparian	Other
Zalu	Coastal grassland, Valley Thicket & riparian forest	Large-scale removal of hardwood species, cultivation on terraces	Large	Serious
Lusikisiki	Coastal grassland, Valley Thicket & riparian forest	Heavily disturbed, removal of hardwood species, cultivation on terraces	Serious	Serious
Xura	Valley Thicket & Coastal grassland	Overgrazing, removal, cultivation on terraces	Large	Serious
Tungwane	Coastal Forest & Coastal grassland	Removal of woody species, exotic invasions, cultivation on terraces	Large	Serious
Lower Mzintlava	Valley Thicket & Coastal Grassland	Removal of woody species, overgrazing, cultivation on terraces	Serious	Serious

2.3 Preliminary Status Class of the River Reaches at the Proposed Dam Sites

The procedure used to determine the present status of the various river reaches at the proposed dam sites on the Mzintlava and Xura Rivers was based upon that developed by Kleynhans (1996). However, the extensive field surveys normally used in this procedure, including the study of a continuous aerial video of the river taken at a low level from a helicopter, was not possible at this pre-feasibility stage. Therefore, the modified assessment techniques outlined for the determination of the preliminary present status (PPS) was closely followed (Kemper & Kleynhans 1998).

The technique is based on the qualitative assessment of a number of criteria which are thought to indicate the integrity of the instream and riparian habitats available for use by the riverine biota. The descriptive classes for the assessment of the various criteria are given in Table 3 below.

These criteria are then scored according to their assumed impact on or modification of the riverine habitat integrity. The scores of estimated impacts of all the criteria on the instream and riparian habitats are then summed and after some manipulation are used to place the habitat integrity of both in a specific descriptive habitat integrity or present

status class (see Kemper and Kleynhans 1998). These classes are described in Table 4.

Table 3. Descriptive classes for the assessment of modifications to habitat integrity (from Kleynhans, 1996).

IMPACT CLASS	DESCRIPTION	SCORE
None	No discernible impact, or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are also very small.	1 to 5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited.	6 to 10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.	11 to 15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	16 to 20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21 to 25

The details of the scores given to the impacts of the various criteria for the 5 proposed dam sites are given in Appendix A. Thus the final product of this exercise is an allocation of a present status class to both the instream and riparian components of the five river reaches in the study area. These data can be used :

a) To determine the conservation value of the river reach at each proposed dam site and thus the environmental "cost" of losing the area that will be inundated by the impounded water, and

b) As a necessary component in determining the ecological management class (EMC) of the river reach under consideration, which is a required component in the formulation of the ecological reserve.

Table 4. Preliminary present status classes (From Kleynhans, 1996).

CLASS	DESCRIPTION	SCORE (% OF TOTAL)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

A summary of these results of the determination of the present ecological status of the river reaches at the various dam sites are given in Table 5 (below).

Table 5. The preliminary present status classes (PPSC) allocated to the various river reaches affected by the proposed dams.

RIVER	DAM SITE	PRELIMINARY PRESENT STATUS CLASS (SCORE)	
		INSTREAM	**RIPARIAN**
Mzintlava	Mzintlava (lower)	B (87)	D (41)
	Tangwane	B (88)	C (63)
Xura	Zalu	B (89)	C (67)
	Lusikisiki	B (89)	B (74)
	Xura	C (77)	C (68)

2.4 Description of Proposed Developments

2.4.1 Construction Details

Due to the early stage (reconnaissance level) of this proposed development, there are no design details of the proposed dams available. However the estimated maximum dam wall heights at the various sites are given in Table 1. An indication of the size of the dam basins can be seen in the site map (Figure 2).

Table 6. MAR values for the catchment areas upstream of the 5 proposed dams compared to the total MAR values of the two river systems.

River **: Proposed Site**	**Dam MAR (Mm^3)**	**River MAR (Mm^3)**	**% of Total MAR (Mm^3)**
Msikaba: Zalu :	11.95	207.87	5.75
Msikaba: Lusikisiki	15.51	207.87	7.46
Msikaba: Xura	37.86	207.87	18.21
Mzintlava: Lower Mzintlava	25.85	71.15	36.33
Mzintlava: Tungwane	33.59	71.15	47.21

The Mean Annual Runoffs (MARs) into the various dams in relation to the total MAR of the river system involved (i.e. the Msikaba and Mzintlava rivers) are given in Table 6. As can be seen, the dams on the Mzintlava can potentially impound a far higher percentage of the MAR than those in the Xura tributary of the Msikaba River. Therefore, dams of comparable size could have a larger potential impact on downstream reaches, including the estuary, in the Mzintlava, compared to the Xura.

2.4.2 Associated Developments

A draft reconnaissance level report by UWP Engineers on the construction materials available, the geology of and access to the proposed sites is given in Annexure 5. This gives an indication of the necessity for developing quarries, building roads or extending electrical power supply-lines pertaining to the various sites. This preliminary information therefore allows an evaluation of the indirect environmental impacts that could be associated with the construction of the dams at the 5 proposed sites.

3. ASSESSMENT OF ANTICIPATED IMPACTS

3.1 Site Specific impacts

3.1.1 Terrestrial Impacts

This investigation showed that the natural attributes of the terrestrial areas to be inundated by the various proposed dams have been largely degraded and modified by man's actions. As shown in Table 2, the man-induced impacts on natural riparian vegetation at all 5 dam sites range from "large" to "serious". No rare or endangered plant species were found during the two vegetation surveys in June 19999 and March 2001.

The riparian zones have been further degraded by river bank erosion caused by removal of stabilizing vegetation binding the soil and erosion gullies formed by vehicle tracks and animal paths. This environmental degradation is reflected in the classification of the preliminary present status (PPS) given to the riparian component of the various river reaches under study, as either class C or D (Table 5 and Appendix A).

The impact of man on land adjacent to the riparian strip is also severe, mainly due to cultivation of maize crops, wood-cutting and intensive grazing. Although faunal surveys of the sites were not carried out, the high human pressure on these degraded ecosystems, including hunting with dogs and snares for the pot by local protein-hungry communities, suggests that few large indigenous animals remain.

3.1.2 Instream Impacts

The present man-induced impacts on the instream component at the various proposed dam sites are relatively small and this is reflected in the class B present status class given to all sites, except the Xura site (Table 5). There is relatively poor water quality in the vicinity of the Xura site which is situated downstream of the town of Lusikisiki, which is considered to be a source of a variety of organic pollutants (Bok 1996; Wayne Selkirk, pers. comm., September 1999). This is the main reason for this relatively low instream present status classification of the Xura site.

Details of the scoring of the various attributes in determining the present status of the Instream component at the various dams sites are given in Appendix A..

3.1.3 Associated Impacts

These are possible impacts due to developments "associated" with the construction of the proposed dams, and include:

(i) the development of new quarries or borrow pits for construction materials outside the dam basin, i.e. not covered by the impounded water;

(ii) the construction of new access roads to the dam sites and sources of building material, and

(iii) the erection of electrical power supply lines from the nearest Eskom distribution line.

Table 7. Potential associated impacts due to dam construction at the proposed sites.

Site	Potential Impact	Evaluation of Impact	With Mitigation
Zalu	Establishment of quarry for construction materials outside of dam basin may be necessary	Medium to high negative impact, long-term duration,	Reduced to low or negligible impact
	Upgrading of existing access roads	Medium positive impact, medium to long-term duration	Appropriate EMP methods required
Lusikisiki	Sand and stone source not within dam basin, establishment of new quarry	Medium negative, long-term impact	Reduced to low or negligible impact
	Construction of new access road of 1km to construction site	Low to medium, long-term negative impact	Reduced to low or negligible impact
	Electricity supply – extension of 500m	Medium, negative, short term impact	Reduced to low, short-term impact
Xura Site	Sand source not within dam basin, establishment of new quarry	Medium, negative, long-term impact	Reduced to low or negligible impact
	Construction of new 2.5 km gravel road	Low to medium, negative, long-term impact	Reduced to low or negligible impact
	Extension of Eskom electricity supply by about 3 km	Medium ,negative, short-term impact; low long-term impact	Reduced to low long-term impact
Lower Mzintlava	Suitable sand deposits likely to be a problem, but possible use of existing nearby quarry	Medium to low, negative long-term impact	Reduced to low or negligible impact
	Relocation of 3 km of gravel road and bridge	Medium to high, negative short-term impact, medium long-term impact	Medium short-term, low long-term impact
	Extension of Eskom electricity supply by either 8.5 or 4.5 km	Medium, short-term negative impact; low long-term impact	Low long-term impact

Table 7 (continued)

Site	Potential Impact	Evaluation of Impact	With Mitigation
Tungwane	Sand supply probably not available within dam basin, other construction material thought available	Low, short-tem negative impact	Low to negligible short-term impact
	Eskom extension of either 1 km or about 9.5 km	Low to medium negative short-term impact, low long-term impact	Low, long-term impact
	New access road of about 4.5 km required over hilly terrain	Medium to high negative, short-term impact, medium long-term impact	Medium short-term, low long-term impact

As can be seen in Table 7 (above) there are a number of potential medium to high negative impacts due to associated developments, but that appropriate mitigation can reduce these to medium or low severity impacts.

3.1.4 Social Impacts

A preliminary assessment of the social impact (or socio/cultural impact) of the construction of the various dams was undertaken following the method outlined by O'Keeffe (1998). This methodology is aimed at assessing the direct dependence of the population in the immediate catchment on a healthy riverine ecosystem and the cultural and historical value of the river. The determinants used and the various scores obtained using this socio-cultural evaluation, are given in Appendix B.

This assessment did not attempt to quantify factors such as the number of people living within the area of the potential dam basins, the area of cultivated land to be flooded or the number of access roads/paths that would be inundated. These factors were covered by a separate socio-economic study.

As can be seen in Appendix B, the main importance of the river to the local populations is the use of the water for the domestic purposes (washing of clothes, drinking, washing), drinking water for stock, and the riparian vegetation as a source of materials for fires, building and medicine. Of the dozen or so local people questioned, none felt that the construction of a large dam would have a significant negative impact on their lives. Most of the existing uses could probably take place on any future dam. The loss of riparian resources (thatching grass, firewood, vegetation for building and medicine) was not of great concern as the resources in the areas in question had already been largely depleted and they felt other areas could be utilised for this purpose. As a mitigation measure, important species could possibly be cultivated as compensation for any loss.

3.1.5 Downstream Impacts

As mentioned above, this report is mainly concerned with the site specific impacts on the environment of dam construction at the various proposed sites. Details of the environmental flow requirements of downstream areas will be covered in separate studies. However, it should be noted that the proposed dams on the Mzintlava River can potentially impound a far higher percentage of the MAR than those in the Xura tributary of the Mzikaba River. This has implications regarding potential negative downstream impacts. Other things being equal, dams of comparable size will have a larger potential impact on downstream reaches, including the estuary, in the Mzintlava, compared to those on the Xura.

Of particular concern is the freshwater requirements of the estuaries. The estuarine freshwater flow requirements (EFR's) of both the Mzintlava and Msikaba estuaries were estimated at a recent Planning Estimate workshop (Bok 1999) to be in the order of 80 to 95% of their MAR. This "conservative" estimate may be reduced as more data become available. However, it does appear that the construction of a dam on the Mzintlava River has the potential to cause a far greater negative impact on its estuary than a dam on the Xura tributary would have on the Msikaba estuary.

4. CONCLUSIONS

4.1 Site-specific Impacts

A summary of the potential impacts of dam construction at the various sites on both the Mzintlava and Xura rivers, is given in Table 8 (below). It can be seen that from a site-specific view-point, there appear to be no "fatal flaws" regarding the impact on the bio-physical environment. The value of the natural environment at all of the sites has been modified and degraded by man's activities to the extent that they have only moderate conservation value. In short, this investigation found no natural, cultural or aesthetic features of outstanding value at any of the proposed dam sites. In terms of the bio-physical features of the sites, there should be no significant impacts due to any of the proposed developments.

When the extent of potential site-specific environmental impacts at the 5 sites are compared, there are no major differences and thus no distinct "preferred option" for a proposed dam site.

4.2 *Social Impacts*

The "social" component of this preliminary investigation indicated there appear to be no serious concerns related to the social impacts (e.g. loss of resources) arising from dam construction at any of the proposed sites. An exception may possibly be at the Mzintlava lower site where a number of dwellings fall within the proposed dam basin. However, the full social assessment and quantification of this impact will be dealt with via a separate study.

4.3 Downstream Impacts

The extent of the downstream impacts of a dam at any of the proposed sites will naturally depend largely on the relative volume of water impounded, the design features of the dam and the operational management of the water releases. However, the greater environmental sensitivity to downstream impacts of the Mzintlava River compared to the Xura River, is an important constraint and could influence any decision regarding the preferred option for a dam site.

5. RECOMMENDATIONS

- As this scoping investigation did not find any significant impacts or "fatal flaws" at any of the proposed dam sites, it is recommended that authority be given to DWAF to proceed with the pre-feasibility phase of this development;
- More detailed site-specific environmental investigations will be required once additional information becomes available. This information should include details of dam design (wall height and design, dam capacity), exact area to be inundated, construction methods to be used and additional data on associated impacts (e.g. quarries, new roads, power lines, water pipelines, etc.);
- Further environmental work recommended includes a more detailed EIA investigation of the chosen dam site and the development of an Environmental Management Plan (EMP) for implementation during both the construction phase and subsequent dam management.
- The most significant potential impacts of the various dam options are considered to be those on the downstream reaches, particularly the estuaries. It is therefore essential (and a requirement of the National Water Act, 1998) that detailed studies on the Instream Flow Requirements (IFRs) for riverine areas and the Estuarine Flow Requirements (EFRs) be undertaken before any final decision on dam construction is taken

6. REFERENCES

BOK, A.. H. (1996). Survey of the freshwater biota, amphibians and reptiles of selected areas in ex-Transkei. Internal Report to Director of Nature Conservation, Department of Economic Affairs, Environment & Tourism. Eastern Cape Province.

BOK, A.. H. (1999). Eastern Pondoland Coastal Basin Study: Determination of the planning estimate of the estuarine reserve. Draft report to UWP- Engineers.

HUGHS, D.A. & MUNSTER, F (1999). A decision support system for an initial "low confidence" estimate of the quantity component of the reserve for rivers. Unpubl. Report, Institute for Water Research, Rhodes University. pp. 32.

KEMPER, N. & KLEYNHANS, C.J. (1998). Methodology for the preliminary present status of rivers. Unpubl. Report to DWAF.

KLEYNHANS, C.J., BRUWER, C.A., KILIAN, V., WESTON, B., VAN WYK, .N. & SELLICK, C. (1998). A procedure for the determination of the flow requirements of the ecological reserve for the purpose of the planning estimate. Internal Report to DWAF. pp. 22.

KLEYNHANS, C.J. (1996). A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo system, South Africa). Journal of Aquatic Ecosystem Health 5: 41-54.

KLEYNHANS, C.J. (1999). A procedure for the determination of the ecological reserve for the purpose of the national water balance model for South African rivers. Internal Report, IWQS, DWAF, Pretoria.. pp. 19.

LOW, A. B. & REBELO, A. (1996). *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environmental Affairs & Tourism, Pretoria.

MUNSTER, F. & HUGHS, D. A. (1999). Desktop estimate of the quantity component of the ecological reserve for rivers: potential for the inclusion of physical and biological factors into the reserve decision support system. Unpubl. Report. Institute for Water Research, Rhodes University, Grahamstown. pp. 39.

O'KEEFFE, J. (1998). Adding socio-economic and cultural criteria to the assessment of river importance for the reserve. Unpubl. Report to DWAF.

Table 8. Summary evaluation of negative environmental impacts associated with the construction of dams at the proposed sites. L = low; M = medium; H = high; N = negligible; Mitig.= extent of impact with mitigation; (data) = extra vegetation survey carried out over summer flowering seaaon; ? = uncertain, more data required.

ENVIRONMENTAL IMPACT DESCRIPTION	EVALUATION OF ENVIRONMENTAL IMPACT									
	Zalu Site		Lusikisiki Site		Xura Site		Mzintlava site		Tungwane Site	
	Extent	Mitig.	Extent	Mitig.	Extent	Mitig.	Extent	Mitig.	Extent	Mitig.
Loss of vegetation, particularly rare or endangered species, due to inundation	L to M (data)	L	L to M?	L to M?	L to M (data)	L	L?	L?	M?	L to M?
Loss of rare or endangered terrestrial fauna, due to inundation	L	L	L	L	L	L	L	L	L	L
Loss of rare or endangered aquatic fauna, due to inundation	M?	M?	M?	M?	M?	M?	M?	M?	M?	M?
Loss of valuable natural riparian resources used by locals, due to inundation	L	L to N	L	L to N	L	L to N	L	L to N	L	L to N
Loss of cultural or historic sites of value	L	L	L	L	L	L	L	L	L	L
Loss of special or spectacular natural features, aesthetically valuable areas	L	L	L	L	L	L	L	L	L	L
Potential impacts on valuable natural systems down-stream (estuary, gorge)	M	L	M	L	L to M	L	M to H	L	M to H	L
Impacts of “associated development” (see Table 7)	M	L to N	L to M	L to N	M	L to N	M	L to N	M	L to N
Socio-economic factors, e.g. inundation of cultivated lands, access roads and houses	L?	L?	L?	L?	L?	L?	M to H?	M?	L?	L?

Figure 1. Locality Map of 5 proposed dam sites for the Lusikisiki project.

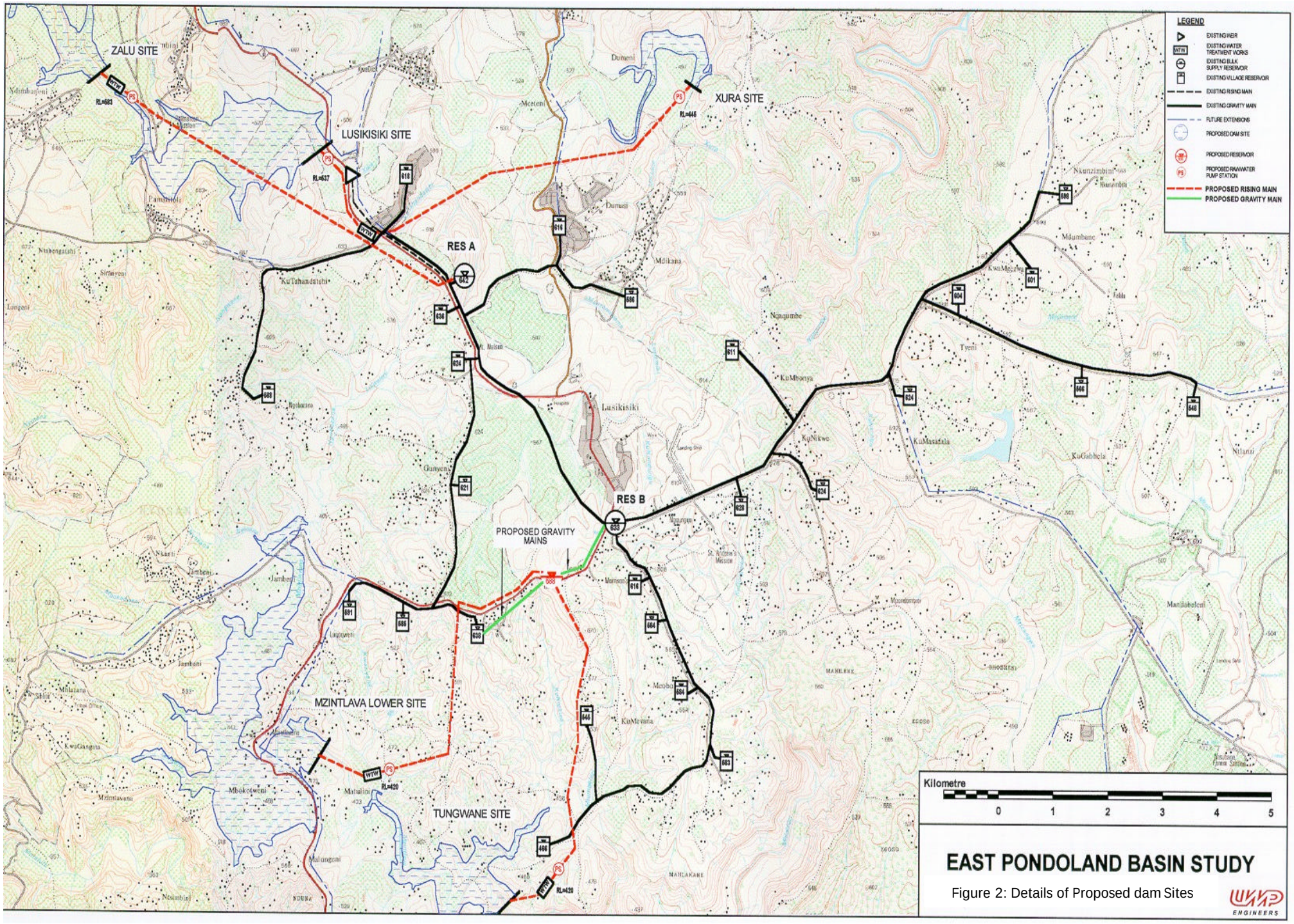


Figure 2: Details of Proposed dam Sites



Plate 1. View of Zalu site looking upstream from left flank of Xura valley. Note maize lands up to Xura River bank and sparse, denuded riparian vegetation.



Plate 2. Zalu site showing eroded vehicle/pedestrian/cattle crossing over Xura River .



Plate 3. Xura R. at Zalu site looking upstream. Note disturbed, stunted riparian vegetation.



Plate 4. Lusikisiki Site looking downstream towards dam wall on Xura R. and Lusikisiki town in the background.



Plate 5. Xura R. at Xura Site looking downstream towards locality of dam wall. Note sparse riparian vegetation and burn on right bank in distance.



Plate 6. Xura R. at Zalu site showing riffle habitat and absence of riparian trees.



Plate 7. Mzintlava R. at Lower Mzintlava Site looking upstream near location of dam wall. Note disturbed valley thicket vegetation on left bank, only grass on right bank.



Plate 8. Mzintlava R. at Lower Mzintlava Site looking downstream. Note bank erosion.



Plate 9. Mzintlava R. at Lower Mzintlava Site. Note filamentous algae on rocks.



Plate 10. Mzintlava R. looking downstream towards location of proposed Tungwane Site dam wall in valley behind tall gum tree.



Plate 11. Mzintlava River at upstream end of Tungwane Site. Note domestic use of river for washing clothes and bathing by local women.



Plate 12. Mzintlava R. at Tangwane Site showing thick filamentous algae in pool below popular clothes-washing locality.

APPENDIX A

Determination of Preliminary Present Status Classes (PPSC) of the various river reaches affected by the proposed dam sites using the method of Kemper and Kleynhans, 1998)

TABLE A1. Evaluation of riparian zone impacts on Xura River dam sites.

EVALUATION: **XURA** **RIVER**

RIPARIAN ZONE

SEGMENT/SITE	Zalu	Lusikisiki	Xura
VEGETATION REMOVAL	18	12	12
EXOTIC VEGETATION	5	8	8
BANK EROSION	2	5	4
CHANNEL MODIFICATION	2	2	4
WATER ABSTRACTION	2	2	8
INUNDATION	0	0	0
FLOW MODIFICATION	1	1	4
WATER QUALITY	4	4	8
TOTAL (OUT OF 200)	34	34	48

SCORE:
NONE = 0
SMALL = 1-5
MODERATE = 5-10
LARGE = 11-15
SERIOUS = 16-20
CRITICAL = 21-25

FIG. A1 RELATIVE IMPACT OF RIPARIAN ZONE MODIFICATIONS, XURA RIVER

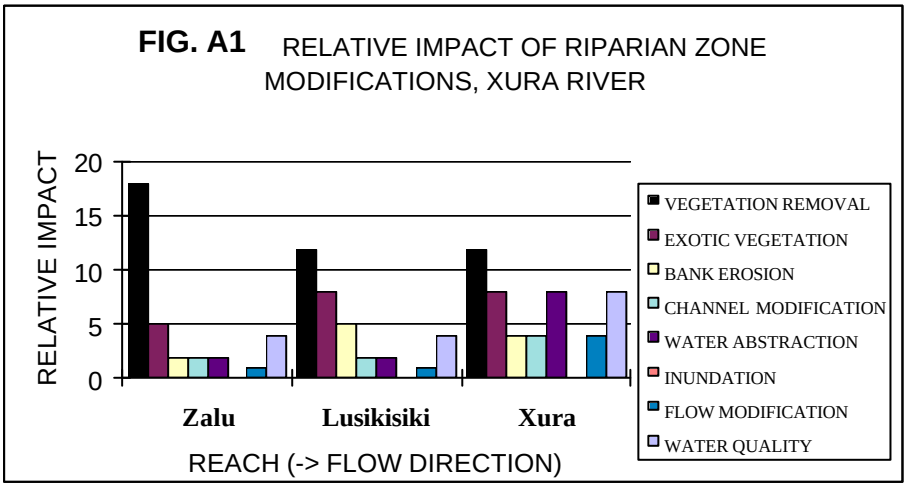


Table A2. Weighted evaluation of riparian zone impacts on Xura River dam sites.

WEIGHTED EVALUATION: **XURA RIVER**
RIPARIAN ZONE

SEGMENT/SITE	ZALU	LUSIKISIKI	XURA
VEGETATION REMOVAL	9	6	6
EXOTIC VEGETATION	2	4	4
BANK EROSION	1	3	2
CHANNEL MODIFICATION	1	1	2
WATER ABSTRACTION	1	1	4
INUNDATION	0	0	0
FLOW MODIFICATION	0	0	2
WATER QUALITY	2	2	4
TOTAL (OUT OF 100)	17	17	24
CONSERVATION STATUS	**82.56**	**82.56**	**75.52**
NEG.LOADS			
VEGETATION REMOVAL	18.36	10	10
EXOTIC VEGETATION	0	0	0
BANK EROSION	0	0	0
CHANNEL MODIFICATION	0	0	0
WATER ABSTRACTION	0	0	0
INUNDATION	0	0	0
FLOW MODIFICATION	0	0	0
WATER QUALITY	0	0	0
TOTAL NEG. LOAD	18	10	10
NEG. LOAD CONS STATUS	**67**	**74**	**68**

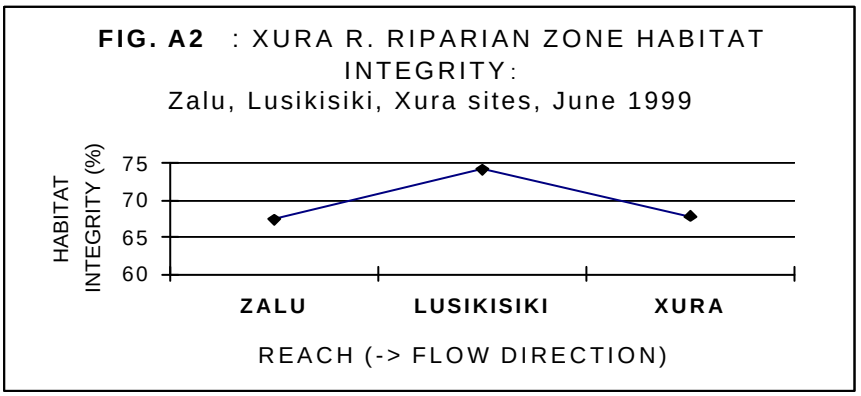


Table A3. Evaluation of instream modifications of Xura R. dam sites.

EVALUATION: **Xura River:**

Instream Zone

SEGMENT/SITE	Zalu	Lusikisiki	Xura
PRIMARY			
WATER ABSTRACTION	2	2	2
FLOW MODIFICATION	2	2	4
BED MODIFICATION	4	4	4
CHANNEL MODIFICATION	2	2	1
WATER QUALITY	10	10	16
INUNDATION	0	0	0
TOTAL (OUT OF 150)	20	20	27
SECONDARY			
EXOTIC MACROPHYTES	0	0	0
EXOTIC FAUNA	0	0	0
RUBBISH DUMPING	2	1	4
TOTAL (OUT OF 75)	2	1	4

SCORE:
NONE = 0
SMALL = 1-5
MODERATE =6-10
LARGE = 11-25
SERIOUS = 16-20
CRITICAL = 21-25

FIG A3

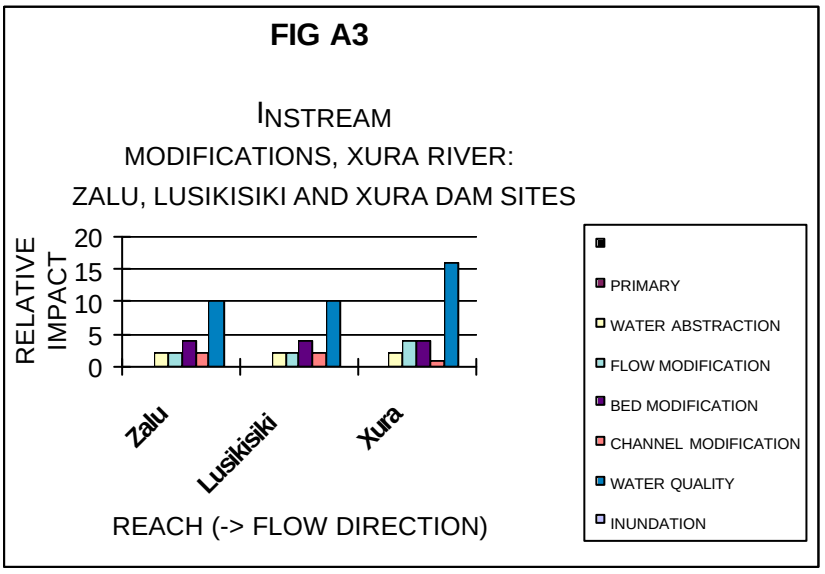


Table A4. Weighted evaluation of instream modifications of Xura R. dam sites.

WEIGHTED EVALUATION: **XURA RIVER:**
INSTREAM ZONE

SEGMENT/NAME	Zalu	Lusikisiki	Xura
PRIMARY			
WATER ABSTRACTION	1	1	1
FLOW MODIFICATION	1	1	2
BED MODIFICATION	2	2	2
CHANNEL MODIFICATION	1	1	1
WATER QUALITY	6	6	9
INUNDATION	0	0	0
TOTAL (OUT OF 77)	**11**	**11**	**15**
CONSERVATION STATUS(%)	**86**	**86**	**81**
SECONDARY			
EXOTIC MACROPHYTES	0	0	0
EXOTIC FAUNA	0	0	0
RUBBISH DUMPING	0	0	1
TOTAL (OUT OF 23)	0	0	1
CONSERVATION STATUS(%)	98	99	96
TOTAL CONSERVATION STATUS	**88.64**	**89**	**84**
PRIMARY			
WATER ABSTRACTION	0	0	0
FLOW MODIFICATION	0	0	0
BED MODIFICATION	0	0	0
CHANNEL MODIFICATION	0	0	0
WATER QUALITY	0	0	9
INUNDATION	0	0	0
TOTAL NEG. LOAD	0	0	9
LOAD CONS. STATUS	**89**	**89**	**77**

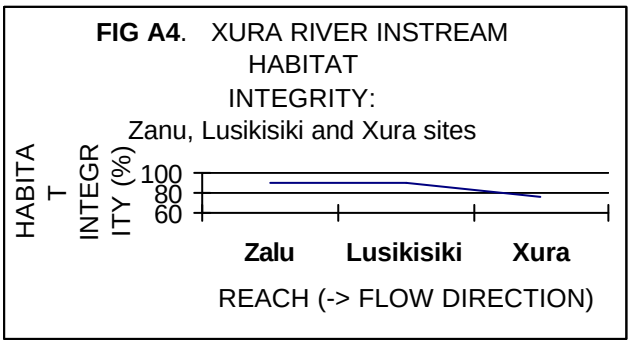


Table A5. Evaluation of instream zone modifications at Mzintlava R. dam sites.

EVALUATION: **Mzintlava River**

INSTREAM ZONE

SEGMENT/SITE	Mzintlava lower	Tangwane
PRIMARY		
WATER ABSTRACTION	2	2
FLOW MODIFICATION	2	2
BED MODIFICATION	6	4
CHANNEL MODIFICATION	2	2
WATER QUALITY	10	10
INUNDATION	0	0
TOTAL (OUT OF 150)	22	20
SECONDARY		
EXOTIC MACROPHYTES	0	0
EXOTIC FAUNA	0	0
RUBBISH DUMPING	4	4
TOTAL (OUT OF 75)	4	4

SCORE:
NONE =0
SMALL = 1-5
MODERATE =6-10
LARGE = 11-15
SERIOUS = 16-20
CRITICAL = 21-25

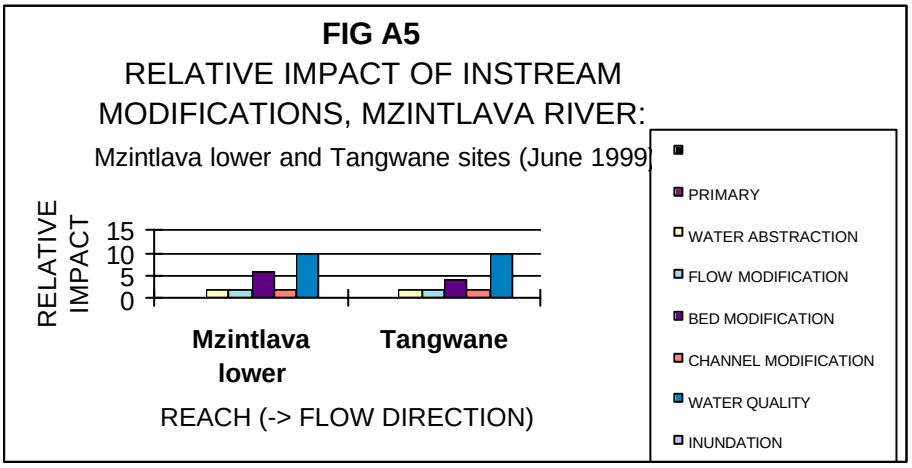


Table A6. Weighted evaluation of instream modifications at Mzintlava dam sites.

WEIGHTED EVALUATION: **MZINTLAVA RIVER**

INSTREAM ZONE

SEGMENT/SITE NAME	Mzintlava lower	Tangwane
WATER ABSTRACTION	1	1
FLOW MODIFICATION	1	1
BED MODIFICATION	3	2
CHANNEL MODIFICATION	1	1
WATER QUALITY	6	6
INUNDATION	0	0
TOTAL (OUT OF 77)	12	11
CONSERVATION STATUS(%)	85	86

EXOTIC MACROPHYTES	0	0
EXOTIC FAUNA	0	0
RUBBISH DUMPING	1	1
TOTAL (OUT OF 23)	1	1
CONSERVATION STATUS(%)	96	96
TOTAL CONSERVATION STATUS	**87.12**	**88**

WATER ABSTRACTION	0	0
FLOW MODIFICATION	0	0
BED MODIFICATION	0	0
CHANNEL MODIFICATION	0	0
WATER QUALITY	0	0
INUNDATION	0	0
TOTAL NEG.LOAD	0	0
LOAD CONS STATUS.	**87**	**88**

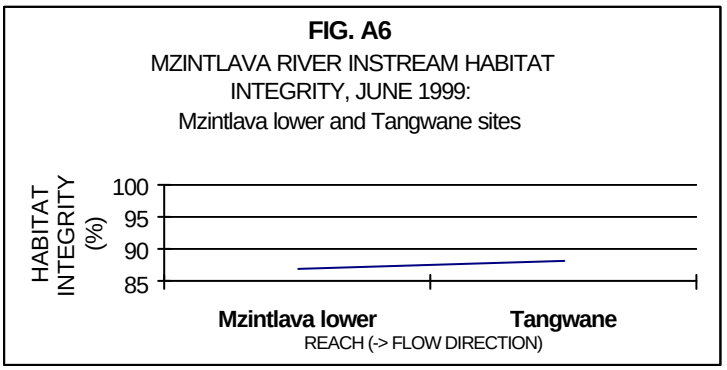


Table A7. Evaluation of riparian modifications at Mzintlava R. dam sites.

EVALUATION: **Mzintlava River:**

Riparian Zone

SEGMENT/ SITE	Mzintlava lower	Tangwane
VEGETATION REMOVAL	20	18
EXOTIC VEGETATION	10	10
BANK EROSION	18	4
CHANNEL MODIFICATION	8	4
WATER ABSTRACTION	2	2
INUNDATION	0	0
FLOW MODIFICATION	2	2
WATER QUALITY	5	4
TOTAL (OUT OF 200)	**65**	**44**

SCORE:
NONE = 0
SMALL =1-5
MODERATE = 6-10
LARGE = 11-15
SERIOUS =16-20
CRITICAL =21-25

FIG. A7
RELATIVE IMPACT OF RIPARIAN ZONE MODIFICATIONS, MZINTLAVA RIVER. JUNE 1999

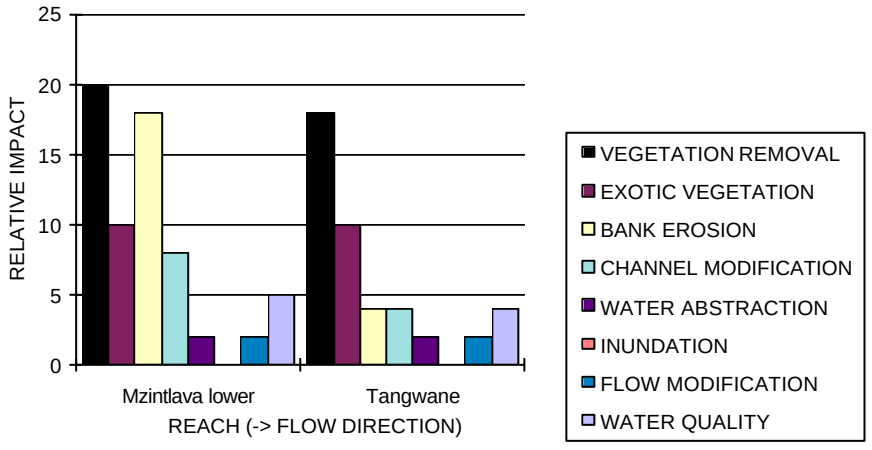


Table A8. Weighted evaluation of riparian modifications at Mzintlava R. dam sites.

WEIGHTED EVALUATION **Mzintlava River :**

Riparian Zone

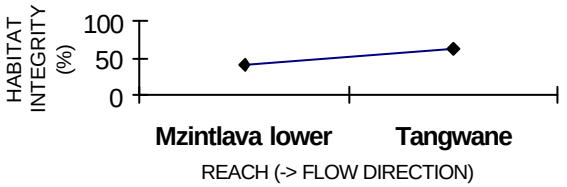
SEGMENT/SITE	Mzintlava lower	Tangwane
VEGETATION REMOVAL	10	9
EXOTIC VEGETATION	5	5
BANK EROSION	10	2
CHANNEL MODIFICATION	4	2
WATER ABSTRACTION	1	1
INUNDATION	0	0
FLOW MODIFICATION	1	1
WATER QUALITY	3	2
TOTAL (OUT OF 100)	34	22
CONSERVATION STATUS	**66**	**78**

NEGATIVE LOADS:

VEGETATION REMOVAL	19	18
EXOTIC VEGETATION	0	0
BANK EROSION	19	0
CHANNEL MODIFICATION	0	0
WATER ABSTRACTION	0	0
INUNDATION	0	0
FLOW MODIFICATION	0	0
WATER QUALITY	0	0
TOTAL NEG. LOAD	38	18
NEG. LOAD CONS STATUS	**41**	**63**

FIG. A8

MZINTLAVA RIVER RIPARIAN ZONE HABITAT INTEGRITY:
Mzintlva lower and Tangwane sites, June 1999



APPENDIX B

Socio-cultural Evaluation: Xura River and Mzintlava River Dam Sites

Table B1. Socio-cultural evaluation of the impact of Xura R. dams.

SOCIO-CULTURAL EVALUATION: XURA RIVER DAM SITES

Scoring system: none = 0; small = 1; moderate = 2; high = 3; very high = 4.

	SEGMENT/SITE:		
DETERMINANTS	**Zalu**	**Lusikisiki**	**Xura**
DOMESTIC, EFFLUENT, STOCK	3	3	3
RIPARIAN VEGETATION	3	2	2
SUBSISTENCE FISHING	1	1	1
RECREATION	2	2	2
RELIGIOUS/CULTURAL EVENTS	1	1	1
HISTORICAL/ARCHAEOLOGICAL	0	0	0
SPECIAL FEATURES	1	1	1
GENERAL AESTHETIC VALUE	2	2	1
TOTAL (OUT OF 32)	13	12	11
CULTURAL IMPORTANCE SCORE =	**1.625**	**1.5**	**1.375**
CULTURAL IMPORTANCE CLASS =	**MODERATE**	**MODERATE**	**MODERATE**

FIG. B1 . SOCIO-ECONOMIC IMPORTANCE OF PROPOSED DAM SITES ON ZURA RIVER

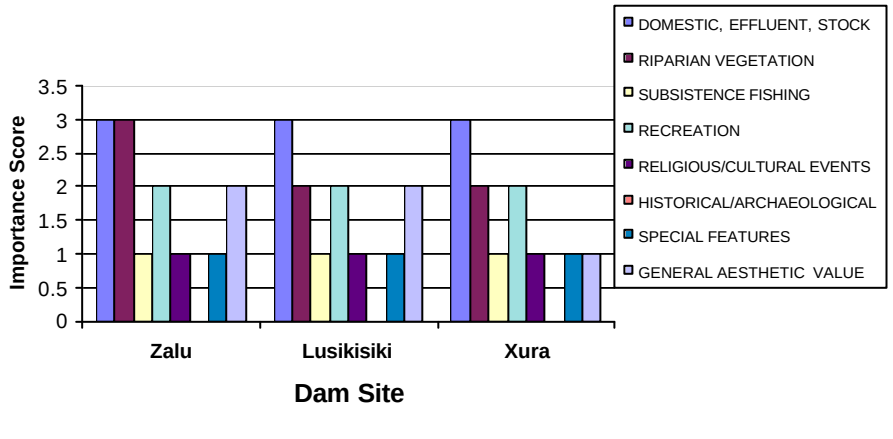


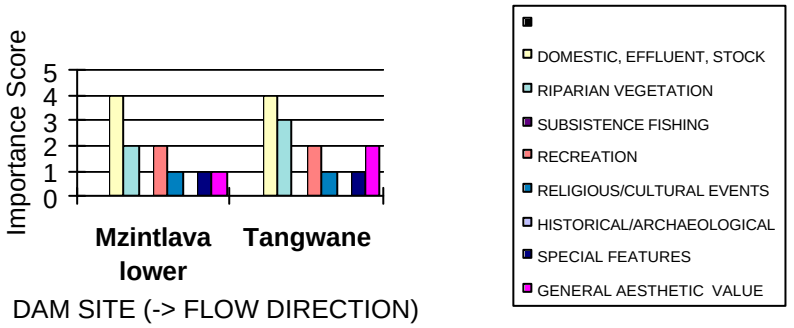
Table B2. Socio-cultural evaluation of the impact of the Mzintlava R. dams.

SOCIO-CULTURAL EVALUATION :
Mzintlava River

Scoring system: none = 0; small = 1; moderate = 2; high = 3; very high = 4.

SEGMENT/SITE	Mzintlava lower	Tangwane
DETERMINANTS		
DOMESTIC, EFFLUENT, STOCK	4	4
RIPARIAN VEGETATION	2	3
SUBSISTENCE FISHING	0	0
RECREATION	2	2
RELIGIOUS/CULTURAL EVENTS	1	1
HISTORICAL/ARCHAEOLOGICAL	0	0
SPECIAL FEATURES	1	1
GENERAL AESTHETIC VALUE	1	2
TOTAL (OUT OF 32)	11	13
CULTURAL IMPORTANCE SCORE	1.375	1.625
CULTURAL IMPORTANCE CLASS	**MODERATE**	**MODERATE**

FIG. B2
SOCIO-CULTURAL IMPORTANCE OF PROPOSED DAM SITES ON MZINTLAVA RIVER



ANNEXURE 1

Plan of study for scooping: Environmental Evaluation of 5 Proposed Dam Sites for the Lusikisiki Water Supply Scheme

PLAN OF STUDY FOR SCOPING:

ENVIRONMENTAL EVALUATION OF 5 PROPOSED DAM SITES FOR THE LUSIKISIKI WATER SUPPLY SCHEME

Consultant: Anton H Bok, Anton Bok Aquatic Consultants, 5 Young Lane, Mill Park, Port Elizabeth 6001 (Tel./fax: 041 – 3733 464)

1. Outline of development

The Directorate of Water Resources Planning (WRP) of the Department of Water Affairs and Forestry (DWAF) has appointed UWP Engineers (UWP) as lead consultants for the Eastern Pondoland Coast Basin Study. A major component of this study is the project to augment the bulk water supply for the Lusikisiki regional supply scheme. The reconnaissance and pre-feasibility phases of this scheme includes the selection of the preferred development options.

As part of the above exercise, the proposed scoping report will investigate the potential site-specific environmental impacts of 5 identified possible dam sites in the Lusikisiki District at the reconnaissance level. The locations of the 5 proposed sites on the two rivers to be impounded (the Xura tributary of the Msikaba River and the Mzintlava River), the catchment area upstream and the proposed maximum dam wall height, are given in Table 1 below. The relevant maps of the proposed dam sites as well as associated developments (roads, borrow-pits) will be included in the scoping report.

2. Outline of tasks to be performed

2.1 Site Inspection

The walk-over site inspection of the localities to be impacted by the proposed dams will investigate aspects such as:

- vegetation types and plant species to be affected
- the habitat integrity and conservation value of the river reach to be inundated
- the dependence of the local inhabitants on the natural riverine resources, both instream and riparian
- cultural, historical or archeological value of the area impacted
- aesthetical value of area
- social impacts of the development

2.2 Public Participation

The feelings and comments of the communities to be affected by the proposed developments will be assessed in a general manner at this early stage. A separate study involving the social aspects will be undertaken at the end of the reconnaissance phase, detailing social costs of the proposed developments. In addition, a project involving public participation and community liaison will be undertaken . The latter will include public meetings involving all the Interested and Affected Parties (I & AP's) at the end of the reconnaissance phase to inform all the stakeholders of the findings of the study. Additional opportunities will be afforded for public comment and objections during the next phase (pre-feasibility phase) of the development.

2.3 Other Related Studies

As mentioned above, the proposed Scoping Report will investigate and report on the site-specific environmental impacts of the proposed developments. The down-stream environmental impacts of the proposed dam construction and water abstraction on the particular river will be dealt with by means of separate studies as stipulated in the National Water Act, 1998. This will take the form of the assessment of the "Reserve" (both ecological and social) for both the river (IFR) and the estuary (EFR) at various levels of detail as the study progresses. These studies will determine how much water must be allowed to flow down the particular river under investigation to satisfy the ecological and social requirements of the river and associated estuary.

2.4 Time-table of Tasks

Reserve Determination: The planning estimate of the estuarine as well as riverine reserve has already been completed (June 1999). Both these estimates will be upgraded in August 1999. A preliminary or full reserve (more detailed reserve determination which has legal standing) will need to be carried during the feasibility phase of the development (in the year 2000).

EIA Scoping Report (reconnaissance level) on potential dam sites To be completed by end of August 1999

EIA Pre-feasibility Report on potential dam site(s). To be completed by December 1999.

TABLE 1. PROPOSED DAM SITES FOR LUSIKISIKI WATER SUPPLY SCHEME

Proposed Site	**Latitude**	**Longitude**	**Catchment area (km^2)**	**River**	**Maximum dam wall height**	**1:50 000 map**
Zalu site	31^0 18' 50"	29^0 28' 40"	71 km^2	Xuru	34m	3129AD
Lusikisiki site	31^0 19' 25"	29^0 31' 25"	91 km^2	Xura	46m	3129BC
Xura site	31^0 18' 55"	29^0 35' 35"	225 km^2	Xura	31m	3129BC
Tungwane site	31^0 25' 30"	29^0 33' 30"	129 km^2	Mzintlava	50m	3129BC
Mzintlava lower site	31^0 24' 25"	29^2 31' 22"	98 km^2	Mzintlava	39m	3129BC & AD

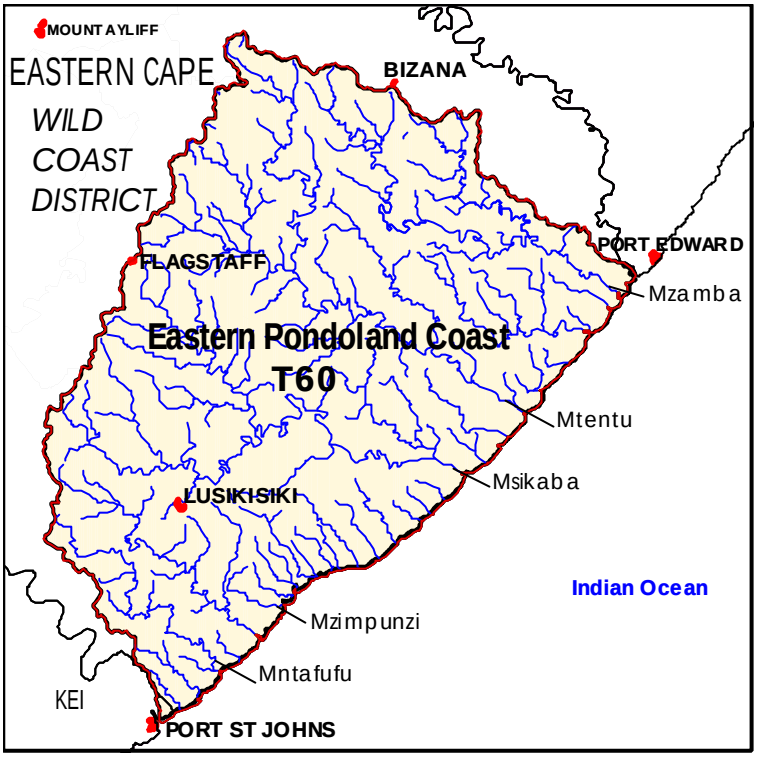
ANNEXURE 2

Eastern Pondoland Basin Study - Newsletter

EASTERN PONDOLAND BASIN STUDY – NEWSLETTER

The Department of Water Affairs and Forestry (DWAF), is currently undertaking a water resources planning study for the coastal region of the Eastern Cape Wild Coast District, also known as the Eastern Pondoland Coast. The study started in January 1999 and will be completed in July 2000. The study area includes parts of the Lusikisiki, Flagstaff and Bizana magisterial districts, between the Mntafutu and Mzamba Rivers as shown on the map below. No general water resource studies have been performed for the Eastern Pondoland coastal region in the past, and the surface water resources appear to be under-utilised. It is the aim of the study to bring the level of available information for this area to the same standard as for most of the other catchments in South Africa.

Demand for water in the study area has increased in recent years, especially for rural water supply. This has resulted in the need to determine how much, and with what reliability, water is available from the rivers and ground water resources in the study area. This water resources evaluation is necessary to ensure that the available water is apportioned and utilised in a sustainable manner. For proper allocation of resources it is necessary to determine the water requirements of all the different water use sectors in the region, such as domestic, industrial, forestry and livestock water usage, as well as those for the natural environment. The results of the study will be used by DWAF to make informed decisions about the development of water resources to meet the needs of the various users in the area.



This multidisciplinary reconnaissance study includes a number of components; such as agricultural, ground water, surface water hydrology, water quality, sedimentation, environmental, social and the investigation of various possible development options. An additional component of the study is to identify and select the best water source for the augmentation of the bulk water supply to the existing Lusikisiki Regional Water Supply Scheme. Groundwater would normally be the preferred option, but it does not appear to be adequate in this case. During June 1999 a site investigation was therefore undertaken to determine the suitability of several alternative dam sites in the Lusikisiki region. The planning of these options is still at an early stage. The reason for the investigation of a dam is to compare this option with other possible sources of supply, and to identify the most feasible source of supply for the Regional Scheme.

It is important that all parties interested in, or affected by, the study are kept informed and are given the opportunity to provide inputs to the process. For this reason a stakeholder meeting was held on 18 May 1999 in Lusikisiki and members of Wild Coast District Council, the various Transitional Rural Councils, the various Transitional Local Councils, various governmental departments and Non-Governmental Organisations were invited to inform them of progress and to discuss the way forward. The next stakeholder meeting will be held in April 2000.

Should there be any enquiries regarding the Eastern Pondoland Basin Study please contact the study leader Mr. Christo Doudenski of UWP Engineers, who were appointed by DWAF to undertake the study, at Tel. : 011-709-8422

ANNEXURE 3

Field Forms to Collect Relevant Data during Lusikisiki Site visit: 28-30/06/1999

EIA SITE SUMMARY TABLE **Scoping Report** *State of Environment* *Page*

PROJECT: …… *DATE* …… SITE NAME: ……

CATEGORY	CATEGORY DESCRIPTION/IMPACT	RATING
General Topography and description of site impacted		
Present land use of locality and population density		
Vegetation type(s) and conservation value		
Condition of vegetation/ impacts of man		
Physical modification to locality		
Conservation value of site itself – rare/endangered fauna or flora		
Conservation value of surrounds (near nature reserve, wilderness area?)		
General aesthetic value, naturalness or beauty		
TOTAL IMPACT/ CORE		

SCORE: **Minimum = 0; Maximum = 4**

REMARKS:

River System:_____ River: _____ Tributary: _____ Date:_____

+

Segment No.: _____ Segment Name:_____ Co-ordinates: _____

Description of Segment:

EVALUATION		NONE	SMALL	MODERATE	LARGE	SERIOUS	CRITICAL
RIPARIAN		(0)	(1-5)	(6-10)	(11-15)	(16-20)	(21-25)

	SCORE	REMARKS
VEGETATION REMOVAL		
EXOTIC VEGETATION		
BANK EROSION		
CHANNEL MODIFICATION		
WATER ABSTRACTION		
INUNDATION		
FLOW MODIFICATION		
WATER QUALITY		
TOTAL (OUT OF 200)	0	

Segment No/Name:_____ (Continued)

EVALUATION	NONE	SMALL	MODERATE	LARGE	SERIOUS	Critical
	(0)	(1-5)	(6-10)	(11-15)	(16-20)	(21-25)

INSTREAM	**Score**	**Remarks**
PRIMARY		
WATER ABSTRACTION		
FLOW MODIFICATION		
BED MODIFICATION		
CHANNEL MODIFICATION		
WATER QUALITY		
INUNDATION		
TOTAL (OUT OF 150)	0	
SECONDARY		
EXOTIC MACROPHYTES		
EXOTIC FAUNA		
RUBBISH DUMPING		
TOTAL (OUT OF 75)	0	

EIA SITE SUMMARY TABLE (Dam Construction)**:** **SOCIAL ASSESSMENT**

PROJECT: …… *DATE* …… SITE NAME: ……

CATEGORY	CATEGORY DESCRIPTION/IMPACT	RATING
Healthy water in river for drinking, domestic & stock use		
Use of riparian resources (plants) for building, medicine		
Dependence of river for subsistence fishing		
Recreational use of river and riparian zine		
Cultural Value (religious, spiritual) , sacred places		
Historical/Archeological sites (fossils, battles, disasters		
Special features/ beauty spots, gorges/deep pools, plants, etc		
General aesthetic value, naturalness or beauty		
TOTAL IMPACT/ CORE		

SCORE: **Minimum = 0; Maximum = 4**

REMARKS:

ANNEXURE 4

Vegetation Survey report for 5 Proposed Dam Sites: Brian Colloty

Preliminary site investigation of proposed dam sites for the Lusikisiki water supply scheme – Vegetation report.

Brian Colloty

Department of Botany

University of Port Elizabeth

PO Box 1600

Port Elizabeth, 6000

6 July 1999

Submitted to A. Bok & Associates

Phone: 041-5042-383

Email: btbbmc@upe.ac.za

Background

Location and land tenure

The Lusikisiki district is found in the south eastern Pondoland region in the former Transkei which is now included in the Eastern Cape Province. This district is characterised by a mixture of subsistence agriculture, commercial and residential areas. Formal agriculture in the form of tea production does occur in the coastal belt at Magwa, east of Lusikisiki (Figure 1).

Three major rivers systems flow through the Lusikisiki district, namely Msikaba, Mzintlava and Xura Rivers. The Xura River is a tributary to the Msikaba River, the latter forming the southern boundary of the Mkambati Nature Reserve (Figure 1). Both the Msikaba and Mzintlava have large estuarine mouths at the coast. These estuaries support important plant communities such as mangroves, reed beds and swamp forests.

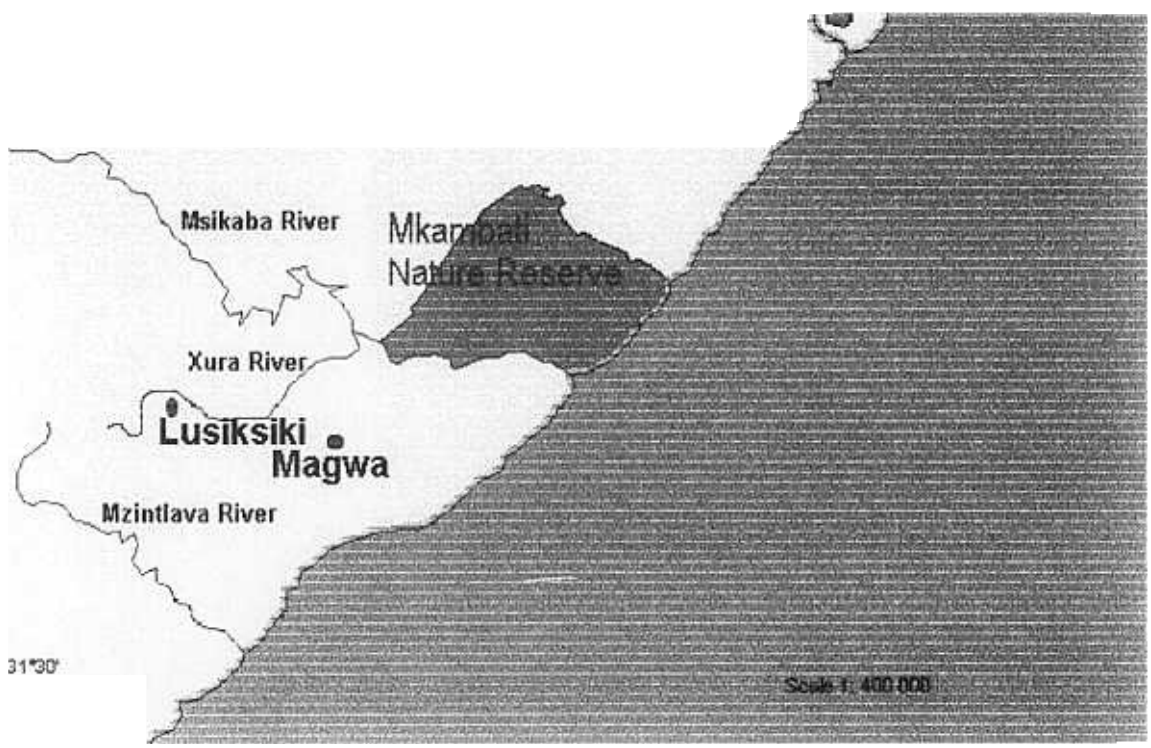


Figure 1: Map of the south eastern Pondoland region in the Eastern Cape Province.

Vegetation

The South African landscape has been divided into a series of vegetation units. These units have either been based on land use defined as veld types (Acocks 1988), or based on the climax plant community found within a particular region or geological sequence defined as a biome (Low & Rebelo 1998). The classification of vegetation into veld types as described by Acocks (1988) has become outdated, however it is useful to mention these veld types as they can describe more about the actual nature of the vegetation found in certain regions.

Seven biomes occur within South Africa, namely; Forest, Savanna, Grassland, Fynbos, Succulent Karoo, Nama Karoo and Thicket biomes (Low & Rebelo 1998). Each of these biomes can be divided into more specific vegetation types based on similarities with the climax plant community but vary in species composition due local conditions (Low & Rebelo 1998).

All seven biomes are found present in the Eastern Cape Province, with four occurring in the Pondoland region. These include the Forest, Thicket, Savanna, and Grassland biomes. The following is a description of the biomes and vegetation types found in the area being considered for development. These will also then be related to sites visited and used to determine the effects that construction of a dam would have on the surrounding vegetation.

Forest biome

The canopy cover of forests is continuous, comprising mostly evergreen trees, with multi-layered understories. It has been estimated that the Transkei coastal region and in particular the elevated region 500 m above mean seal level, that includes the Lusikisiki district, was once covered by a mixture of Coastal Forest and Afromontane forest. These forests were then interspersed by areas of savanna and grassland. Remnants of the forest vegetation still covers approximately 35 % of the area previously found (Johnson & Cawe 1987).

- Coastal forest

This has also been defined by Acocks (1988) as Tongoland-Pondoland Undifferentiated Forest or Transitional Coastal Forest. Coastal forest has affinities with both mature Afromontane forest such as that found at Knysna and the dune forests found the east coast of tropical Africa. The Pondoland region being the transitional zone for the two major forest types along the African coast (Lubke & McKenzie 1998).

Coastal forest develops were summer rainfall usually exceeds 700 mm per annum. The larger trees found in this vegetation type are utilised mainly for firewood and structural timber, however many species are used for traditional healing. This has resulted in large tracts of this vegetation type's transformation into grassland or open savanna. It is estimated that 43 % of South Africa's Coastal forest has already be transformed (Lubke & McKenzie 1998).

- Afromontane Forest

Acocks (1988) has also described this veld type as Knysna Forest, where trees can attain a maximum height of between 20 and 40 m. Forests of this nature require between 700 – 2000 mm of rainfall. The Afromontane forests in the Pondoland region seem transitional in nature and exhibit the highest number of plant species compared to forests found elsewhere in South Africa. Species thus found can be associated with true Afromontane Forest, Coastal Forest and Dune Thicket vegetation types. Trees found in these forests are used for timber, firewood and traditional healing. This has resulted in approximately 44 % of this vegetation type's transformation into grassland or savanna (Lubke & McKenzie 1998).

Thicket biome

- Valley Thicket

The thicket biome can be subdivided into an number of different vegetation types based not only on species composition but on water requirements (Lubke 1998). Previously this form of vegetation was termed Valley Bushveld (Acocks 1988), but this has recently been revised. The term now used is Valley Thicket and consists of a dense thicket of woody shrubs that occurs in river valleys. These are furthermore associated with the shales and clays of Dwyka and Ecca geological formations found in the Eastern Cape. Valley Thicket is economically important as the best area for angora and goat farming, but is under threat from poor farm management (Lubke 1998).

Savanna Biome

The Savanna Biome is the largest in southern Africa occupying 46 % of its area, and over one third of South Africa. It is characterised by a grassy ground layer and a distinct upper layer of woody plants. Most of the savanna vegetation types are used for grazing, but requires effective management and burning (Lubke & Bredenkamp 1998).

- Eastern Thorn Bushveld

In the Lusikisiki region Acocks (1988) defined this veld type as Acacia Savanna. This was due to the dominance of the upper woody layer by Sweet Thorn *Acacia karroo*. Eastern Thorn Bushveld dominates upper ridges on plateaus above Valley Thicket. With disturbance such as overgrazing, the grass understory is invaded by other woody species and is transformed into a dense impenetrable thicket (Lubke & Bredenkamp 1998).

Grassland Biome

The grassland biome is found on higher lying plateaus dominated by grass cover. The density of cover is dependant on grazing pressure and rainfall. Two grassland vegetation types are found in the Lusikisiki district; namely Moist Upland Grassland and Coastal Grassland (Bredenkamp *et al.* 1998).

- Moist Upland Grassland

The sour grassland is found at altitudes of between 600 and 1400 m above sea level. These receive high rainfall that exceeds 800 mm per annum and are associated with shallow rocky soils that have been leached. This vegetation type is used for grazing and if found near sources of water is transformed for subsistence agriculture. Moist Upland Grassland is sensitive to overgrazing and which leads to soil erosion (Bredenkamp *et al.* 1998).

- Coastal Grassland

Coastal Grassland extends along the Eastern Cape coastal region and found in areas that receive rainfall of up to a 1000 mm per year. Acocks (1988) defined this as a complex of thicket and grassland species, that exhibits affinities with the Coastal Forest vegetation type. This is due to the presence of a number of tree species. It is further thought that this vegetation should receive a high conservation status due to the high levels of endemic plant species found. Coastal Grassland is important for grazing in the Transkei region (Lubke *et al.* 1998).

Vegetation survey of proposed dam sites

Five proposed sites were visited during the period of 28 – 30 of June 1999. The vegetation was surveyed on the basis of how inundation would affect the surrounding vegetation at all five sites. Impacts considered were loss of rare or unique species and vegetation types. Possible loss of species that would affect surrounding inhabitants by reducing a source of plant material for, building, firewood, traditional remedies or their ability to perform ceremonies were also recorded.

Zalu site (31° 18 ' 50" S 29° 28' 40" E)

This site found on the Xura River showed affinities with the Coastal Grassland vegetation type (Grassland Biome -grass dominated). The higher lying reaches of this section were covered in monospecific stands of either Black Seed Bristle grass *Setaria nigrirostris* and Ngongoni Three-awn *Aristida stipitata.* These two species covered terraced fields on both sides of the valley. These fields were found left fallow and would not be inundated by the dam waters.

Lower lying areas of the river bank were dominated by remnants of riparian forest species namely; Common Guarii *Euclea undulata*, Buffalo-thorn *Ziziphus mucronata*, Small-leaved Trimeria, *Trimeria trinervis*. Most of these plants appeared to have sustained some form of removal for firewood, construction or had been grazed. The instream channel is occupied by plants associated with water. These included the Ruigtegras *Miscanthus capensis*, Cape Bulrush *Typha capensis*, Sedge *Schoenoplectus littoralis* and the Common Reed *Phragmites australis*. The remainder of the river bank was covered by the Wild Date Palm *Phoenix reclinata* and the Common Reed *Phragmites australis*. The palm can attain heights of up to 6m, however the palm found at this and the other four sites appeared stunted due to grazing.

Small reaches of the river bank were composed of rock and cliffs. Plants found on these formations included the Cape Aloe, *Aloe ferox*, *Aloe puridens*, Spekboom *Portulacaria afra*, Tree Euphorbia, *Euphorbia triangularis*, *Sisal spp.* and Giant Turpentine Grass *Cymbopogon validus*. Excluding the last mentioned sisal and grass species the remaining species indicate that this area could previously

covered by Valley Thicket, i.e. Aloes, Spekboom and Euphorbia's are a component of Valley Thicket.

Lusikisiki site (31° 19' 25" S 29° 31' 25" E)

This site showed affinities with Valley Thicket and the Grassland biome. Both heavily disturbed in the past. The Valley thicket found on both banks consisting of Cape Aloe, *Aloe ferox*, *Aloe puridens*, Spekboom *Portulacaria afra*, Tree Euphorbia, *Euphorbia triangularis* as well as Sweet Thorn *Acacia karroo*. These areas showed signs of disturbance with open gaps and erosion channels. At the time of the site visit Acacia karroo were being removed for fence poles.

The river banks were dominated by Forest Bush-willow *Combretum kraussii* and Ruigtegras *Miscanthus capensis*. These areas showed signs of over-utilisation due to the encroachment of the *Acacia karroo*. *Acacia karroo* is considered an invader of open gaps within the riparian forests in the Eastern Cape (Colloty 1996; Matoti 1999). The remainder of the river floodplain at this site consisted of fallow terraced fields. Grass in these fields included Black Seed Bristle Grass *Setaria nigrirostris*, Ngongoni Three-awn *Aristida stipitata*, Wire Grass *Elionurus muticus*, Cotton-wool Grass *Imperata cylindrica* and One Fingered Grass *Digitaria mondactyla*. The grass species as well as the Black Jack *Bidens pilosa* and *Sesbania bispinosa* found in these fields are indicators of past disturbance such as land cultivation or over-grazing.

A small area of coastal forest was found in the steep gorge, were the dam wall would be sited. Species found included Wild Banana *Strelitzia nicolai*, Boer Bean *Schotia spp.*, *Allophylus natalensis*, Fig *Ficus sur* and Coastal Cabbage Tree *Cussonia spictata*. However this had signs of disturbance due to the large proportion of cover by the Bug Tree *Solanum mauritianum*.

Xura site (31° 18' 55" S 29° 35' 35" E)

This site showed affinities with Valley Thicket and Grassland biome. The Valley thicket found on both banks consisting of Cape Aloe, *Aloe ferox*, Spekboom *Portulacaria afra*, Tree Euphorbia, *Euphorbia triangularis* as well as Sweet Thorn Acacia karroo showed signs of disturbance. Open gaps in these areas had been colonised by the invasive Bug Tree *Solanum mauritianum*.

The river bank were dominated by the Bulrush Typha capensis and the Ruigtegras *Miscanthus capensis*. Both these were being harvested at this site possibly for basket or mat weaving. The river floodplain at this site consisted of fallow terraced fields, however local woman were harvesting the Common Thatch Grass *Hyparrhenia hirta*. Grass in these fields included Black Seed Bristle Grass *Setaria nigrirostris*, Ngongoni Three-awn *Aristida stipitata*, Wire Grass *Elionurus muticus*, Common Carrot Seed *Tragus berternianus* and One Fingered Grass *Digitaria mondactyla*. These grass species are indicators of disturbance and overgrazing.

Tungwane site (31° 25' 30" S 29° 33' 30" E)

This site showed affinities with Coastal Forest and Grassland biomes. Species found included Wild Banana *Strelitzia nicolai*, Boer Bean *Schotia spp.*, *Allophylus natalensis*, Fig *Ficus sur* and Coastal Cabbage Tree *Cussonia spictata*.

The river banks were dominated by Common Guarii *Euclea undulata*, Buffalo-thorn *Ziziphus mucronata* and Small-leaved Trimeria *Trimeria trinervis*. Large areas where the riparian forest had been removed had been invaded by alien vegetation such as the Mauritius Thorn *Caesalpinia decapetala*, Peanut Butter Cassia *Senna didimobotrya*, Black Wattle *Acacia mearnsii* and the American Bramble *Rubus cuneifolius*.

Grasses in the fallow fields above the river bank included Black Seed Bristle Grass *Setaria nigrirostris*, Ngongoni Three-awn *Aristida stipitata*, Wire Grass *Elionurus muticus*, Common Carrot Seed *Tragus berternianus* and One Fingered Grass *Digitaria mondactyla*. These grass species are indicators of disturbance.

Lower Mzintlava site (31° 24' 25" S 29° 31' 22" E)

This site showed affinities with Valley Thicket and Grassland biomes. The Valley thicket found consisted of Cape Aloe, *Aloe puridens*, Spekboom *Portulacaria afra*, Tree Euphorbia *Euphorbia triangularis*. This area showed signs of being degraded and was invaded by the alien Bug Tree *Solanum mauritianum*.

The river bank were covered by Bulrush *Typha capensis* and Ruigtegras *Miscanthus capensis*. The remainder of the river floodplain at this site consisted of fallow terraced fields. Grasses in these fields included Black Seed Bristle Grass *Setaria nigrirostris*, Ngongoni Three-awn *Aristida stipitata*, Wire Grass *Elionurus muticus*, Common Carrot Seed *Tragus berternianus* and One Fingered Grass *Digitaria mondactyla*. Erosion of river bank was found leading to its collapse along most of this reach. This is as a result of the removal of riparian trees leading to instability of the river bank.

Social importance of vegetation

Four hundred species have been described in the Transkei region as being used for traditional healing or have other cultural uses. Most of the remaining hard wood species are also utilised for firewood or building material (Johnson & Cawe 1987). Some plant species found at the five site visited in this investigation could be listed as follows in terms of their use.

Building material

Of the hardwood species that remained (*Acacia karroo*, *Euclea undulata*, *Trimeria trinervis*) all were being utilised either for construction or for firewood.

The reeds and sedges (Bulrush, Ruigtegras and Common Reed) were being harvested from the river banks at all the sites. This material is used mostly in weaving of mats, ropes or baskets. The ropes are used in the roof thatching in which local thatch grass is used (*Hyparrhenia hirta*).

Medicinal value

The only species observed that could have any medical value were the Bulrush *Typha capensis and* Aloe species. A number of bulbs are known to also have a use (van Wyk *et al.* 1997), but were not observed as these would only be visible in spring.

Stock grazing

All the Grassland and Valley Thicket species recorded have a grazing value, however in all the sites visited these vegetation types had been degraded and the species that remained had a low nutritional value. With better veld management and burning practices these conditions could be improved.

Conservation importance of vegetation

Southern Africa has a remarkably rich flora of vascular plants, with 23 404 taxa. The number of endemic plant species is also high and is attributed to the diverse ecological conditions found in this region. This is not found to be uniform for the entire South Africa, but found in localised areas or 'hot spots'. Eight such 'hot spots' have been identified in which the Pondoland region is one (Cowling & Hilton-Taylor 1996). Based on Red Data book taxa, the Pondoland region has 33 rare, endangered or endemic taxa. Most of these species being the geophytic orchids, bulbs and large trees (Hilton-Taylor 1996).

With only seven percent of the Pondoland region receiving some form of conservation protection. The greatest threat to these plant species is land transformation, overgrazing, plant harvesting, veld burning and population growth (Davis & Heywood 1994). It is evident from the sites visited in this investigation that it is unlikely to find any of these species due to the high levels of disturbance that has already taken place. Most of the large trees have been removed and grasslands have been transformed into monospecific grass areas due to agriculture (overgrazing and land cultivation).

Conclusion

The vegetation that was found at the five sites included some of the more unique vegetation types found in the Eastern Cape, namely Coastal Forest and Valley Thicket. These including all the. other vegetation types found had been degraded or transformed. This had occurred to the extent that only remnants of the Afromontane Forest were found at any of the sites. No rare or endemic species were observed during the site visits. Plant species found to be of use for grazing, medicinal value or building material were indicated as not being important. Local inhabitants interviewed said sources of such material could be found elsewhere along the rivers. In these interviews it was also indicated that traditional uses for a number of plants have also been lost over time and have been replaced by more westernized medicines or materials.

From this preliminary investigation it could be established that construction of a dam at one of the five sites would not have any major effects on the vegetation of this district. It is however recommended that a more comprehensive vegetation survey be done once the final dam site has been selected. The field visits for this investigation were short and at a time of the year when most plants were not flowering or dormant underground and thus not visible. This is important in terms of the rare and endangered bulbs, ground orchids (geophytes) that have a known distribution in the Pondoland region (Cowling & Hilton Taylor 1996). The comprehensive survey should also include the affects of the dam on vegetation further down stream as well as the vegetation found in the associated estuaries.

References

Acocks, J.P.H. 1988. Veld types of South Africa. Memoirs of the Botanical Survey of South Africa No. 57. Department of Agriculture.

Bredenkamp, G.J., Granger, E., Lubke, R. & van Rooyen, N. 1998. Moist Upland Grassland. In: Low, A.B. & Rebelo, A.G. (eds) Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Colloty, B.M. 1996. Study of the riparian vegetation of the Keiskamma River and estuary. Unpublished M.Sc. Thesis. University of Port Elizabeth.

Cowling, R.M. & Hilton-Taylor, C. 1996. Patterns of plant diversity and endemism in Southern Africa: An overview. *Strelitzia 1*, 412pp.

Davis, S.D. & Heywood, V.H. (eds) 1994. Centres of plant diversity: A guide and strategy for their conservation. Oxford University Press.

Hilton-Taylor, C. 1996. Red data list of Southern African plants. *Strelitzia* 4, 117 pp.

Johnson, C.T. & Cawe, S. 1987. Analysis of tree taxa in the Transkei. *South African Journal of Botany* 53: 387-394.

Low, A.B. & Rebelo, A.G 1998. Biomes. In: Low, A.B. & Rebelo, A.G. (eds) Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Lubke, R. & Bredenkamp, G.J. 1998. Eastern Thorn Bushveld. In: Low, A.B. & Rebelo, A.G. (eds) Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Lubke, R. & McKenzie, B. 1998. Afromontane Forest. In: Low, A.B. & Rebelo, A.G. (eds) Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Lubke, R. & McKenzie, B. 1998. Coastal Forest. In: Low, A.B. & Rebelo, A.G. (eds) Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Lubke, R. 1998. Valley thicket. In: Low, A.B. & Rebelo, A.G. (eds) Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Lubke, R., Bredenkamp, G.J., Granger, E., & van Rooyen, N. 1998. Coastal Grassland. In: Low, A.B. & Rebelo, A.G. (eds) Vegetation of South Africa, Lesotho and Swaziland. Department of Environmental Affairs and Tourism, Pretoria.

Matoti, A. 1999. The role of riparian vegetation in reducing sediment loads of the Keiskamma River. Unpublished M.Sc. Thesis. University of Port Elizabeth.

van Wyk, B., van Oudtshoorn, B. & Gericke, N. 1997. Medicinal plants of South Africa. Briza publications, Pretoria.

Appendix – Species list

Grasses

Aristida stipitata	Ngongoni Three-awn
Cymbopogon validus	Giant Turpentine Grass
Digitaria mondactyla	One Fingered Grass
Elionurus muticus	Wire Grass
Hyparrhenia hirta	Common Thatch Grass
Imperata cylindrica	Cotton-wool Grass
Setaria nigrirostris	Black Bristle Grass
Tragus berternianus	Common Carrot Seed

Riparian vegetation

Acacia karroo	Common Sweet Thorn (invader)
Combretum kraussii	Forest Bush-willow
Euclea undulata	Common Guarii
Miscanthus capensis	Ruigtegras
Phoenix reclinata	Wild Date Palm
Phragmites australis	Common reed
Trimeria trinervis	Small leaved Trimeria
Typha capensis	Cape Bulrush
Ziziphus mucronata	Buffalo Thorn

Valley Thicket

Aloe ferox	Cape Aloe
Aloe puridens	
Euphorbia triangularis	Tree Euphorbia
Portulacaria afra	Spekboom

Coastal Forest

Allophylus natalensis	
Cussonia spictata	Coastal Cabbage Tree
Ficus sur	Fig
Schotia spp.	Boer Bean

Strelitzia nicolai	Wild Banana

Alien or invasive vegetation

Acacia mearnsii	Black Wattle
Bidens pilosa	Black Jack
Caesalpinia decapetala	Mauritius Thorn
Rubus cuneifolius	American Bramble
Senna didimobotrya	Peanut Butter Cassia
Sesbania bispinosa	Sesbania
Sisal spp.	Sisal
Solanum mauritianum	Bug Tree

ANNEXURE 4B

Vegetation Survey Checklist of Zalu and Xura Dam Sites

By

Elize Cloete

PLANTS COLLECTED AT ZALU, ON THE XURA RIVER, 8 MARCH 2000

Hyparrhenia filipendula
Paspalum dilatatum
Arundo donax
Maesa lanceolata
Pseudarthria hookeri
Berkheya sp. cf *decurrens*
Cyperus so. cf. *pulcher*
Asparagus plumosus
Mariscus sp. cf. *indecorus*
Diospyros lycioides
Ceratotheca triloba
Acacia ataxacantha
Felicia erigeroides

PLANTS COLLECTED ON THE XURA RIVER, LUSIKISIKI, 8 MARCH 2000

Digitaria eriantha
Paspalum dilatatum
Melinus repens
Hyparrhenia filipendula
Eleusine coracana subsp. *africana*
Plectranthus verticillatus
Clematis brachiata
Hippobromus pauciflorus
Tragia glabrata
Plectranthus laxiflorus
Coddia rudis
Grewia occidentalis
Helinus integrifolius
Maytenus nemorosa
Rumex sagitatus
Lobelia anceps
Desmodium hirsutum
Oxalis semiloba
Striga sp.
Chironia laxa
Syncolostemon densiflora
Kyllinga sp. cf. *erecta*
Fimbristylis sp.
Justicia sp. cf. *betonica*
Cyperus sp. cf. *pulcher*
Eucomis sp. cf. *comosa*
Scadoxus puniceus
Kniphofia sp.cf. *linearifolia*
Myrica serrata
Cyperus sp. cf. *pulcher*
Smodingium argutum
Clerodendrum glabrum
Cheilanther virides var. *virides*
Ziziphus mucronata subsp. *mucronata*
Chamaecrista mimosoides
Hibiscus trionum
Pavonia columella
Rhus sp. cf. *pentheri*
Rhus rehmanniana var. *glabrum*
Conyza scabrida
Trimeria grandifolia
Rubus rigidus
Leonotis dubia

Clutia puchella var. *obtusata*
Stephania abyssinica var. *tomentella*
Acacia ataxacantha
Dais cotinifolia
Combretum erythrophyllum
Euclea racemosa

ANNEXURE 5

Draft Report on Construction Material, Geology and Access for 5 proposed Dam Sites

NOTES FOR DEAE&T REPORT

1. ZALU SITE

Construction materials availability

Founding a quarry might be a problem. Earthfill material is available near the dam site. It is uncertain at this stage if a suitable borrow pit will be available in the dam basin, but this option willl be utilised if possible. There is also a possible borrow site downstream of the proposed dam site.

Geology

Geologically the site is suitable and various development options are available. The lower flanks adjacent to the river are of dolerite rock type. This site has been drilled extensively in the past.

Access

Access to the site is good and site establishment would not be problematic. Approximately 1 km of the existing road network would require upgrading from the main road to the right bank. The size of the bridge would need to be doubled and the road made large enough to accommodate two trucks (approximately 10 m wide). The Eskom power distribution lines pass near to the proposed site and electricity is therefore available on site.

2. LUSIKISIKI SITE

Construction materials availability

Earthfill material is available but sand and stone may have to be obtained commercially. At the position of the dam wall there is a rock face on the right bank, but this position is close to the river bend.

Access

The site is located favourably in close proximity to the Water Treatment Works. Access from the main road is available. The site has a desirable cross section. Although the proposed site is close to the main road a new gravel road of approximately 1 km will have to be built to the construction site. Electricity supply is available since the site is in close proximity to the network, and an extension of about 500 m will be necessary.

3. XURA SITE

Construction material availability

There is possibly earthfill and rockfill material in close proximity to the proposed site. The presence of sand for concrete is uncertain.

Geology

The banks are characterised by weathered Tillite material.

Access

Access to the site, and electricity supply are at present limitations to the development of the site. The Eskom electricity network requires extension by approximately 3km, and a new gravel road of about 2.5 km is required. The slope of this road would not promote erosion and the road will be retained after construction for access to the dam.

4. TUNGWANE SITE

Construction material availability

There is sufficient aggregate material available. Earthfill material may however be scarce. Sand may have to be obtained commercially. A borrow pit will be established in the inundated area if possible.

Geology

On the left bank is a steep tillite outcrop. At river bed level there is rock material which is covered to a large degree by boulders. The lower right flank is characterised by alluvial material, while the upper right flank has a soil layer overlying weathered tillite.

Access

A 66 kV power supply line passes approximately 1 km downstream of the proposed dam wall. This power line may be a bulk supply line and hence not available for connection. If so, connection to the 22 kV network at Lusikisiki would be necessary (about 9.5km). This will still be investigated. Access is a problem from upstream and the nearest access point downstream of the site should be investigated. The elevation of the new road and bridge will be investigated to ensure that they do not inhibit the maximum reservoir level. It is estimated that 4.5 km of new gravel road will be necessary in order to access the site.

5. LOWER MZINTLAVA DAM SITE

Site suitability

Several sites are available and could be feasible along the centreline of this proposed dam site. The one position reviewed yielded an open rock face on the steeper bank. Although the site is technically feasible it may be socially problematic. Fill material is generally available.

Geology

The site has a smaller cross section at the dam wall position than Tungwane dam site. The riverbed is rock and the sides of the channel are comprised of Tillite material. The Tillite appears to be deeply weathered.

Access

Should this site be selected it would be necessary to relocate about 3 km of the gravel road and the bridge. The site is in close proximity to the gravel road from Lusikisiki to Port St Johns. The Eskom network will require extension. This would occur from the 22 kV network along the main road from Lusikisiki, and be about 8.5km. If a connection can be made to the main 66 kV line this length would be reduced to 4.5 km.

Reconnaissance-level information on construction material availability

1. ZALU DAM SITE - Construction materials

No sources of coarse aggregate / rip-rap were investigated by drilling. A dolerite sill forming a hill-capping roughly 3,5 km north of the dam site was however identified as a potential quarry site. The report also mentions an existing quarry site located roughly 12 km from Lusikisiki, although doubts were expressed concerning available volumes and quality. Chances of locating a suitable quarry within the confines of the proposed dam basin appear rather remote. Should an embankment dam be favoured, excavations for a side-channel spillway within unweathered dolerite on the lower right flank might represent a potential source of rip-rap. A diversion tunnel through the right flank might similarly be considered a potential source of suitable material.

No suitable sand reserves were identified in the vicinity of the dam site. At the time of the investigation (1979), sand used in Lusikisiki was obtained from various sources located between 23 - 45 km away. Sands derived from the Karoo sedimentary strata are known to produce concrete with dimension problems. At this stage it may be assumed that fine aggregate will be obtained from crusher run.

Detailed investigations were conducted into potential sources of semi-pervious as well as impervious core material. Briefly; the red silty clays of dolerite origin between depths 0,5 - 3,0 m were considered most suitable for use as impervious core, while the finer grained material derived from siltstone and alluvium, respectively, was considered suitable shoulder material (Hill Kaplan Scott, 1979).

2. LUSIKISIKI DAM SITE - Construction materials

No detailed investigations into possible construction material sources have been conducted as yet. Some general comments can, however, be made.

The most obvious source of coarse aggregate / rip-rap is the dolerite sill on the left flank; providing the selected centre-line is sufficiently far removed, and overburden depths are not

excessive. While other dolerite sills can be expected to occur within a reasonable distance, these may not be within the dam basin.

The supply of suitable sand is an ubiquitous problem. The parent rocks in the area (Karoo mudrocks) typically produce very fine-grained sediments. Furthermore, concrete made with Karoo sand or sandstone displays excessive shrinkage properties. At this stage it may be assumed that sand will mainly have to be sourced from crusher run.

There appear to be vast areas within the proposed dam basin which might be considered potential sources of embankment fill materials, both for impervious core material as well as transition material. It is expected that these areas are underlain by weathered siltstone or alluvial / colluvial soils, and the materials comprise silty- / fine sandy soils with clay.

3. XURA DAM SITE - Construction materials

While the most obvious source of coarse aggregate / rip-rap / rock-fill would be an unweathered dolerite body, dolerite intrusions are not common within the Dwyka tillite. In the absence of dolerite in the immediate vicinity of the site, unweathered / slightly weathered tillite may be used. Cliffs of tillite located roughly 500 m upstream of the proposed centre-line represent a potential material source. The depth of weathering is however quite significant (estimate 10+ m) implying excessive overburden thickness. These weathering depths might be considered typical. A further consideration, depending on the properties of this material, would be utilization of this weathered rock in construction; either as rockfill or less durable transition material in the case of an earthfill embankment.

Location of natural sand deposits of acceptable quality is likely to present a problem. While crusher run represents the logical alternative, problems with excessive mortar shrinkage have been reported on the odd occasion.

The identification of suitable embankment fill materials should not present major difficulties. Deposits of fine-grained soils located within the basin, whether comprising alluvium or derived from the weathering of tillite, are likely candidates for impervious core materials, or possibly even semi-pervious transition materials. The unconsolidated deposit of previous landslide

material may also be suitable for use as transition material.

4. LOWER MZINTLAVA DAM SITE - Construction materials

Potential sources of coarse aggregate / rip-rap were not specifically identified in the immediate vicinity of the proposed dam site, although no major problems are foreseen in this regard. Either unweathered / slightly weathered tillite or an intrusive dolerite body represent potentially suitable sources. Note that a disused quarry is located roughly 2 km from the proposed dam site (Figure 1). This dolerite quarry may have been developed for the realignment of the Lusikisiki - Port St Johns road. The quality of the material is not known, nor are the available reserves.

Identification of suitable sand deposits is likely to present a problem. Natural or manufactures sands derived from Karoo sedimentary strata are known to produce mortar shrinkage, as is manufactured sand from tillite. At this stage the most obvious source of sand is crusher run from dolerite.

It is expected that reserves of suitable embankment materials occur within the proposed dam basin, or in the vicinity of the proposed dam site. The fine-grained soils derived from the weathering of the tillite or Karoo sediments are likely sources of impervious core or even transition materials.

5. TUNGWANE DAM SITE - Construction materials

A disused quarry in a dolerite body is located near a hilltop roughly 3 km from the site (Figure 2), although the road distance will be greater. It is likely this quarry was used to supply aggregate for the realigned Lusikisiki - Port St Johns road and bridge across the Mzintlava River. Rock quality and available volumes are not known at this stage. Other potential sources of coarse aggregate / rip-rap include several areas where unweathered / slightly weathered tillite outcrop occurs adjacent to the Mzintlava River. These areas will certainly fall within the proposed dam basin and are also much closer to the proposed site than the disused dolerite quarry.

As always, identification of suitable concrete / filter sand is likely to be a problem. Crusher run is the most obvious solution, although excessive mortar shrinkage has been recorded on rare occasions.

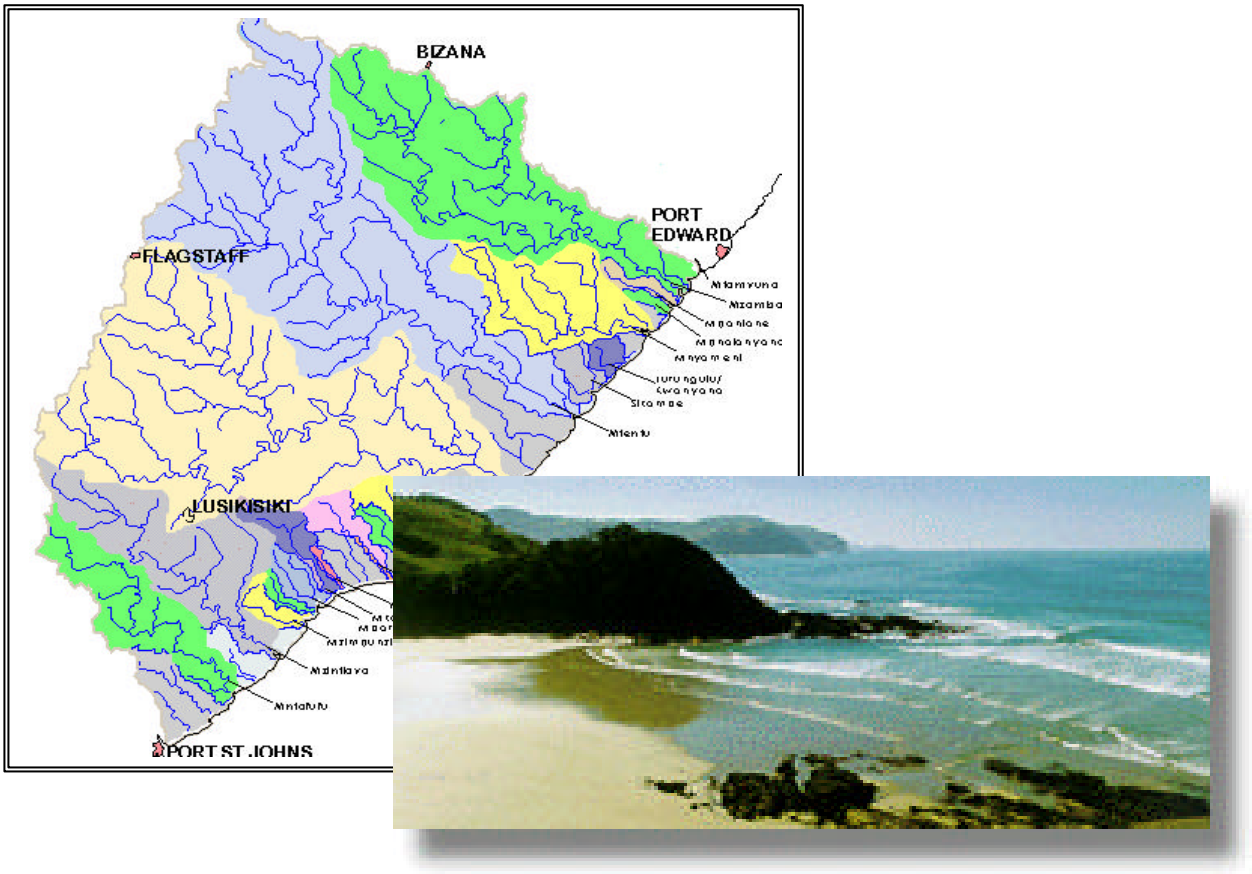
It is likely that sources of embankment materials occur within the basin. Deposits of fine-grained alluvial / colluvial soils occurring adjacent to the river represent potential sources of impervious or even semi-pervious material.

PB600/00/0601

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



ECOLOGICAL RIVERINE RESERVE ESTIMATE

Final

June 2001

Prepared By:

Anton Bok Aquatic Consultants CC
Port Elizabeth

ANTON BOK AQUATIC CONSULTANTS

Trading as ANTON BOK & ASSOCIATES

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Ecological Riverine Reserve Estimate
AUTHOR	**:**	A Bok
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-0601
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EASTERN PONDOLAND BASIN STUDY
ECOLOGICAL RIVERINE RESERVE ESTIMATE

EXECUTIVE SUMMARY

The estimation of the rapid Ecological Riverine Reserve (ERR) (previously termed instream flow requirements – IFR) of the sites within the study area was undertaken by "upgrading" or refining the low confidence desktop estimate (DE) using the computer based decision support system (DSS), developed at Rhodes University's Institute for Water Research (IWR) by Hughs and Munster (1999).

The procedures used to determine the DE, as well as the user-interface facility component of the DSS, which allows additional site-specific information to be incorporated into the programme, is described. The additional data needed to upgrade the DE of the Ecological Riverine Reserve for the five proposed dam sites for the Lusikisiki Water Supply Scheme, was collected during a field trip to the various sites in June 1999. Details of the various proposed dam sites on the Xura and Mzintlava rivers and data collected can be found in the report **Environmental Evaluation of Proposed Development Sites: Scoping Report**.

The site-specific data was incorporated into the decision support system model and the attainable ecological management classes (AEMCs) for the various river reaches within the study area, were determined. The ecological management class was fed into the DSS model to produce a reference ERR for the river reach under consideration.

In addition, a facility of the DSS model, allowed the influences of the specific ecological (physical and biological) characteristics found at the various sites to be used to modify the calculated ERR values. The final "refined" ERR values therefore take into account the hydrological, ecological and management class differences between the various proposed dam sites.

The ERR estimates for the 5 proposed dam sites are given in the report as a representative time series of monthly flow volumes recommended for the Ecological Reserve, as well as a percentage of the MAR for the four ERR components, namely maintenance and drought low flows, maintenance high flows and total ERR flows.

In addition, the ERR assurance rule curves for the 5 proposed dam sites are given, which indicates the percentage of time that certain flows should be equalled or exceeded in the modified flow regime.

In conclusion, the ERR values determined in this investigation, which ranged from 23,3 to 30,2 % of the MAR, are much lower than the 80 to 95% of the MAR estimated as the Ecological Estuarine Reserve requirements (EER) for the Mzintlava and Msikaba estuaries at a recent workshop (see report **Ecological Estuarine Reserve Estimate**). Further work on both the downstream freshwater reaches which appear to have greater ERR requirements, compared to the upper reaches, as well as the estuaries, will be required before long-term decisions of exploitations of the water resources of these two rivers, can be taken.

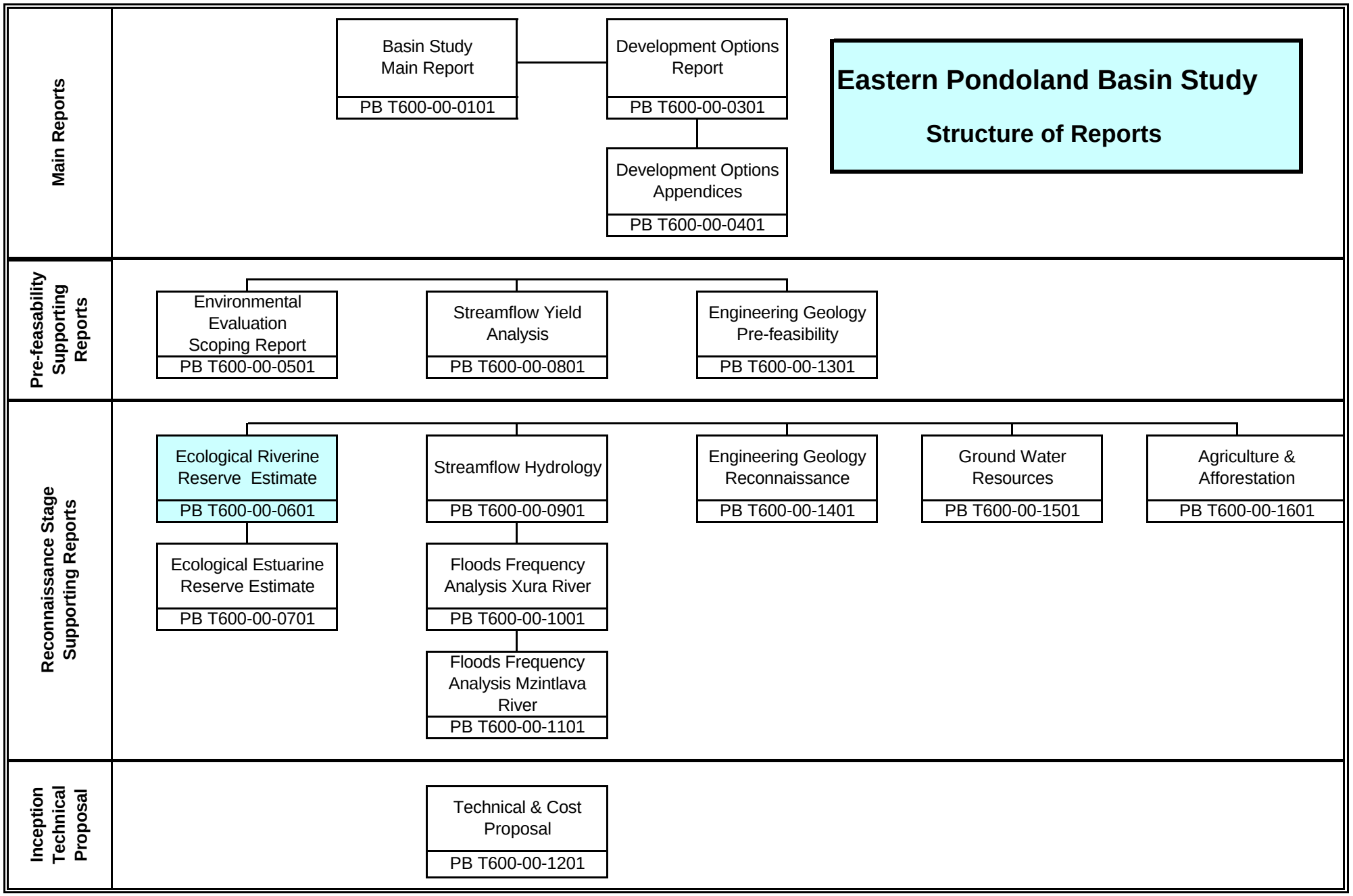

Main Reports
Basin Study Main Report
PB T600-00-0101
Development Options Report
PB T600-00-0301
Development Options Appendices
PB T600-00-0401
Eastern Pondoland Basin Study
Structure of Reports
Pre-feasability Supporting Reports
Environmental Evaluation Scoping Report
PB T600-00-0501
Streamflow Yield Analysis
PB T600-00-0801
Engineering Geology Pre-feasibility
PB T600-00-1301
Reconnaissance Stage Supporting Reports
Ecological Riverine Reserve Estimate
PB T600-00-0601
Ecological Estuarine Reserve Estimate
PB T600-00-0701
Streamflow Hydrology
PB T600-00-0901
Floods Frequency Analysis Xura River
PB T600-00-1001
Floods Frequency Analysis Mzintlava River
PB T600-00-1101
Engineering Geology Reconnaissance
PB T600-00-1401
Ground Water Resources
PB T600-00-1501
Agriculture & Afforestation
PB T600-00-1601
Inception Technical Proposal
Technical & Cost Proposal
PB T600-00-1201

TABLE OF CONTENTS

			Page
Executive Summary			**i**
Table of Contents			**ii**
List of Tables, Figures, Appendices and Annexures			**iii**
1.	**INTRODUCTION**		1
2.	**RAPID DETERMINATION OF THE ECOLOGICAL RESERVE (RER)**		
	2.1	Background	4
	2.2	Methods	5
		2.2.1 Details of Methods	5
		2.2.2 Field Data	5
		2.2.3 Hydrological Source Data	6
	2.3	Results	6
		2.3.1 Attainable Ecological Management Class	6
		2.3.2 Ecological Modifying Factors	6
		2.3.3 IFR Estimates	7
		2.3.4 IFR Assurance Rules	8
3.	**CONCLUSIONS**		9
4.	**REFERENCES**		9

LIST OF TABLES

Table 1. The DEMC, PESC and AEMCs for the EPCBS quaternary catchments as determined for the WBDE (water balance desktop estimate) in August 1999. 2

Table 2. Classification of the upper and lower reaches of the Xura and Mzintlava rivers using the methodology of Kleynhans, 1999. 6

Table 3. Summary of ecological factors scores for the various river reaches within the study area. 7

Table 4. Estimated Total IFR values for the 5 proposed dam sites. 8

LIST OF FIGURES

Figure 1. Outline of methodology for determination of Desktop Estimates (derived from Kleynhans *et al* 1998; Kleynhans 1999). 3

LIST OF APPENDICES

Appendix A. The virgin flow records for the 5 proposed dam sites for the Lusikisiki Bulk Water Supply Scheme. 10

Table A1. Virgin flow record for Zalu dam site. 11

Table A2. Virgin flow record for Lusikisiki dam site. 13

Table A3. Virgin flow record for Xura dam site. 15

Table A4. Virgin flow record for Lower Mzintlava. 17

Table A5. Virgin flow record for Tungwane dam site. 19

Appendix B. Details of the scores given to the determinants of riparian and instream habitats of river reaches in the study area using the protocol of Kleynhans (1999). 21

Table B1. Xura River: Upstream reach of river (Xura and Lusikisiki dam sites). 22

Table B2. Xura River (Reach downstream of Xurana R. junction): Inclusive of gorge zone in lower reaches. 24

Table B3. Mzintlava River: Upper catchment, excluding gorge zone (Lower Mzintlava site). 26

Table B4. Mzintlava River: Lower reaches, including lower gorge area. 28

Appendix C. The ecological modifying factors scores for the upper and lower reaches of the Xura and Mzintlava rivers using the ESCORE component of the IWR DSS system. 30

Table C1. Ecological factors scores for the upper reaches of the Xura and Mzintlava rivers. 31

Table C2. Ecological factor scores for the lower (gorge) reaches of the Xura and Mzintlava rivers. 33

Appendix D. Summary of IFR estimates for the 5 proposed dam sites for the Lusikisiki Bulk Water Supply Scheme. 35

Table D1. Summary of IFR estimates for the proposed Zalu dam site on Xura River. 36

Table D2. Summary of IFR estimates for the proposed Lusikisiki dam site on the Xura River. 37

Table D3. Summary of IFR estimates for the proposed Xura dam site on Xura River. 38

Table D4. Summary of IFR estimates for the proposed Lower Mzintlava dam site on Mzintlava River. 39

Table D5. Summary of IFR estimates for the proposed Tungwane dam site on Mzintlava River. 40

Appendix E. IFR Assurance Rule Curves for the 5 proposed dam sites for the Lusikisiki Bulk Water Supply Scheme. 41

Table E1. Summary of IFR rule curves for Zalu site, Xura R. 42

Table E2. Summary of IFR rule curves for Lusikisiki Site, Xura R. 43

Table E3. Summary of IFR rule curves for Xura Site, Xura R. 44

Table E4. Summary of IFR rule curves for lower Mzintlava dam site, Mzintlava R. 45

Table E5. Summary of IFR rule curves for Tungwane Site, Mzintlava R. 46

LIST OF ANNEXURES

Annexure 1. Copy of document by Kleynhans (1999) outlining the procedure to determine the desktop estimate (DE) of the ecological reserve for the National Water Balance Model for South Africa (WBDE).

RAPID ECOLOGICAL RESERVE ESTIMATE FOR XURA AND MZINTLAVA RIVERS

1. INTRODUCTION

The rapid estimate of the quantity component of the ecological Reserve (RER) is in essence an extension or upgrading of the low confidence "desktop estimate" (DE). A brief description of the DE, including techniques used to determine this Level 1 estimate of the ecological reserve, is therefore warranted.

The DE, previously referred to as the "planning estimate", was developed as a Level 1, low confidence estimate that could be rapidly applied to all the quaternary catchments in the country for input into the National Water Balance Model. The Directorate: Project Planning of DWAF has commissioned various consultants to undertake the determination of the DE of all quaternary catchments in South Africa. The results of the DE of the ecological reserve of the quaternary catchments falling within the study area of the EPCBS will therefore be made available via a separate study, and will not be considered in detail in this report.

The procedures used to determine the DE are given in detail in the report: "*A procedure for the determination of the ecological reserve for the purposes of the National Water Balance Model for South African Rivers*" by Kleynhans (1999). This document is attached to the present report as Annexure 1 and only an overview is given below.

In brief, the procedure involves the determination of the ecological importance and sensitivity class (EISC) of the mainstem river in the quaternary catchments being assessed. The EISC assessment is used as an indicator of the default ecological management class (DEMC). The DEMC relates to a default ecological status class (DESC), which is assigned to a resource (i.e. river or river reach) depending on the level of ecological importance and sensitivity.

The present ecological status class (PESC) is then assessed, i.e. the current condition or ecological integrity of the mainstem river(s) within the quaternary catchment(s) in question. If the PESC is the same as or higher than the DESC, then the PESC is taken as the attainable ecological management class (AEMC). If the PESC is lower than the the DESC, then the potential for improvement of PESC within 5 years in relation to flow or flow related aspects, is determined, i.e. the feasibility of restoring the river to a higher attainable EMC.

The final output of the process is thus the AEMC which is fed into the hydrological computer-based DSS model of Hughs and Munster (1999), developed at the IWR, Rhodes University, to give a low-confidence estimate of the ecological reserve

(quantity). This DSS is based on the relationships between the hydrology of the river in question, the IFR's estimated at previous workshops and the ecological management class (i.e. the AEMC) allocated to the river or river reach under consideration (Hughs and Munster 1999).

The procedure used is depicted graphically in Figure 1 (below).

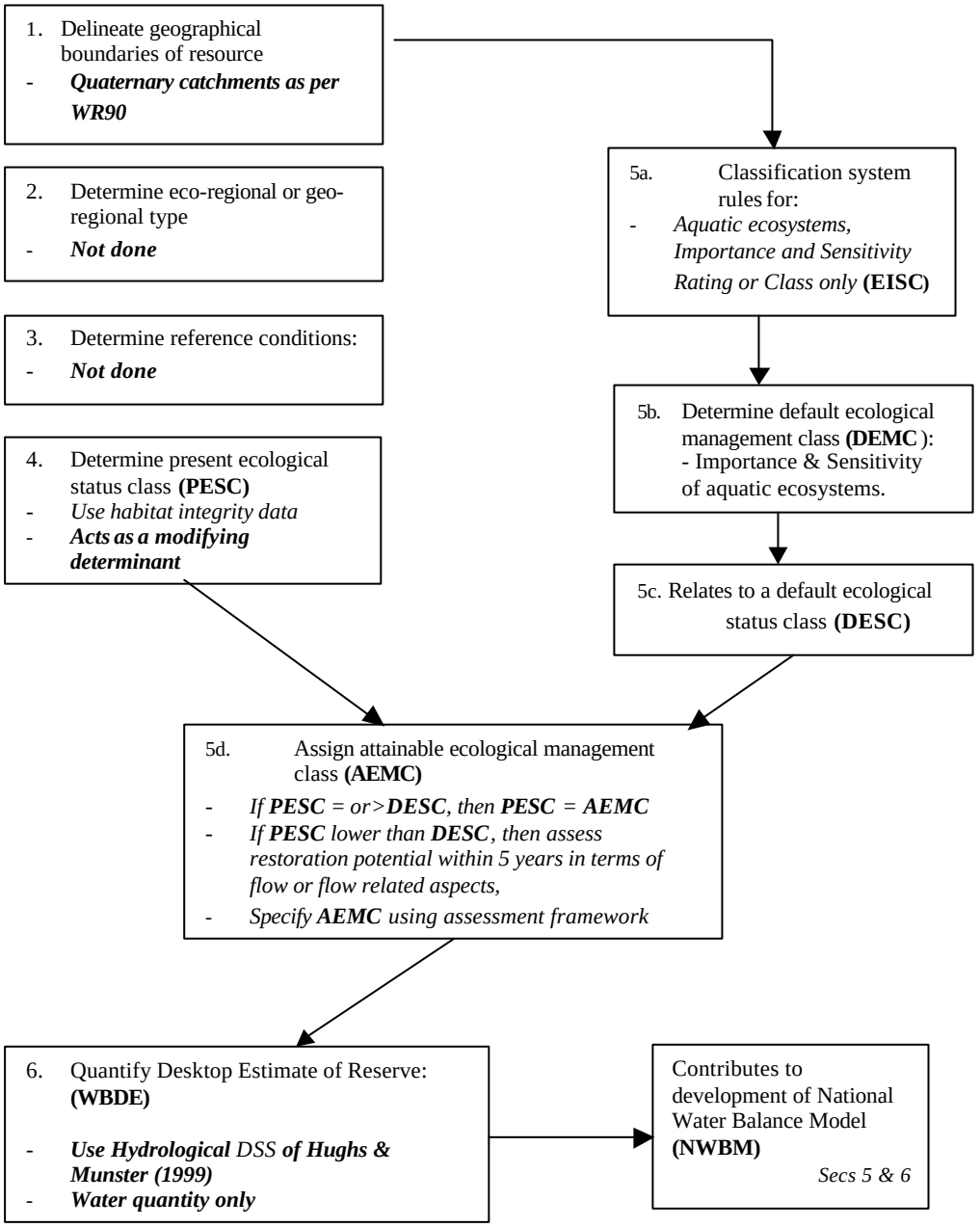
At a workshop held in Grahamstown on 16 and 17 August 1999, these results of an earlier (March 1999) exercise to assess the ecological importance and sensitivity class (EISC) of all Eastern Cape quaternary catchments, were revised using the latest updated methodology developed by (Kleynhans, June 1999). These latest methods were also applied to assess the present ecological status class (PESC) of the mainstem rivers within quaternary catchments in the Eastern Cape. The final step in the classification procedure was the allocation of the attainable ecological management class (AEMC) to the various quaternary catchments, depending on the restoration potential of the rivers concerned (see Figure1).

During the August 1999 workshop in Grahamstown to determine the AEMC for the national water balance model, all ten quaternary catchments falling within the EPCBS area were considered as being "similar". They were therefore assessed as a single entity by the workshop participants. The allocated classes given to the combined EPCBS quaternary catchments during this Grahamstown workshop are given in Table 1, below. The AEMC allocations will be used in the IWR DSS hydrological model to produce a low confidence (Level 1) DE of the ecological reserve for the National Water Balance Model. The results of this final step were not available to the author at the time of completion of the present report.

Table 1. The DEMC, PESC and AEMCs for the EPCBS quaternary catchments as determined for the WBDE (water balance desktop estimate) in August 1999.

CLASS DESCRIPTION	CLASS SCORE	SCORE DESCRIPTION
DEMC Default ecological management class derived from Ecological Importance and Sensitivity Class	**A** (Very High)	Unique on a national scale (mainly due to unique fish species), usually very sensitive to flow modifications and have only a small capacity for use
PESC Present ecological status class	**B** (High)	Largely natural with few modifications, but with some loss of natural habits, particularly riparian habitat
AEMC Attainable ecological management class	**B** (High)	Ecosystems modified mainly due to the destruction of riparian vegetation and poor stream bank condition and erosion

Figure 1. Outline of methodology for determination of Desktop Estimates (derived from Kleynhans *et al* 1998; Kleynhans 1999)



2. RAPID DETERMINATION OF THE ECOLOGICAL RESERVE (RER)

2.1 Background

The fundamental principle for determining the quantity component of the ecological reserve is that of relating ecological responses to changes in flow regime in the river under consideration. There is at present a reasonable understanding of the relationships between the hydrological characteristics of rivers and their IFR's. Therefore, hydrology forms the core component of the Hughs and Munster (1999) computer-based DSS. In essence, the DSS quantifies the relationships between the hydrological characteristics of the river under investigation with IFR's established at previous workshops (maintenance and drought low flows and maintenance high flows), and the predetermined future or attainable management class.

These authors designed their hydrological DSS with the idea that the Desktop Estimate (DE) should form the lower end of a continuum of approaches with the full or "Comprehensive" determination being the upper end (Level 4). The DSS therefore also incorporates the option of conducting more site specific estimations of the ecological reserve, particularly "at sites where additional information is available and where the results of the generic relationships could be modified to improve the confidence of a quick estimate" (Hughs and Munster 1999, pg. 2).

The procedure for the Level 2 or rapid estimation of the reserve (RER) determination using the computer based DSS, is described in detail in Hughs & Munster (1999). It basically involves data input via a user-interface facility available in the RESDSS component of the DSS computer model. The user-interface facility enables the incorporation of additional habitat integrity and present ecological status classification data into the model. This allows the user to "fine-tune" the setting of the Ecological Management Classes, as well as manually adjust certain of the estimated values .

In addition, a further facility (ECSCORE component) allows the influences of specific ecological (physical and biological) characteristics of the river reach under consideration, to be incorporated into the DSS model. These purely ecological factors can thus be used to modify the hydrological output (Munster and Hughs 1999).

The procedures to determine the influence of the various ecological modifying factors on the various components of the IFR (i.e. maintenance and drought low flows and maintenance low flows) were undertaken as far as available data allowed, during the work session on the 31 August 1999. Details of the physical and biological factors considered, as well as the methodology and underlying assumptions for this determination, can be found in the document: *"Potential for the inclusion of physical and biological factors into the reserve decision support system"* by Munster & Hughs (1999).

2.2 Methods

The collection of additional data on the two high priority rivers under consideration, namely the Xura River tributary of the Msikaba River and the Mzintlava River, therefore enabled the further application of the DSS model to be carried out. These data allowed the DE of the ecological reserve to be upgraded to Level 2, or the higher confidence rapid ecological reserve (RER). This determination of the RER of these two rivers was carried out in a one day work-session in Grahamstown on 31 August 1999, attended by Prof Denis Hughs, Prof. Jay O'keeffe and the author (Dr Anton Bok).

2.2.1 Details of Methods

For the purposes of this IFR investigation, the Xura and Mzintlava rivers were each divided into two distinct reaches. This division was based on the fact that both rivers have gorge-like lower reaches which are assumed to show some significant differences compared to the upper reaches. These differences include a higher conservation status and habitat integrity due to less human impact as a result of the rugged topography and inaccessibility. This was assumed to result in less disturbance of the riparian habitat, as well as a relatively lower sediment input due to less cultivation and human activity in or near the riparian zones. The lower sites in each river (Xura site in the Xura River and Tangwane site in Mzintlava River) were allocated the AEMC associated with the lower reach of each river system.

The most recent methodology (Kleynhans, June 1999) was used to determine the attainable ecological management class or AEMC for each proposed site, which was then used in the DSS model.

This input was then further refined by using available modifying ecological data collected by the author, as well as "expert opinion" generated by the workshop participants.

2.2.2 Field Data

The additional information used was mainly that collected during the EIA site inspection of the five proposed dam sites in the Lusikisiki area by the author and the sub-contracted botanical expert in June 1999. Details of the exact location of the five proposed dam sites and the data gathered from the various locations can be found in the report to UWP Engineers by the present author: "*Eastern Pondoland Coastal Basin Study: Environmental evaluation of 5 proposed dam sites for augmenting the Lusikisiki Bulk Water Supple Scheme"* (Bok, 1999a*)*.

At the workshop on 31 August, use was also made of photographs and slides taken of the river reaches in question by the author during the field visit in June 1999. In addition, consideration was given to available physical, chemical and biological data relevant to this region, which were obtained from a variety of scientific reports (see References).

2.2.3 Hydrological Source Data

The Hydrological data used in the DSS model were the monthly virgin flows calculated for the 77 years from 1920 to 1997, as supplied by DWAF Hydrological division. These data are given in full in Appendix A.

2.3 Results

2.3.1 Attainable Ecological Management Class

A summary of the results of the classification procedure carried out using the methodology of Kleynhans (1999), is given in Table 2, below. The relatively high man-induced negative environmental impacts on the riverine environment in the upper reaches of both rivers is clearly seen in the low score (class C) allocated to the present ecological status class (PESC).

As there is very little possibility of improving the present ecological status in terms of river flow in these upper reaches, the attainable ecological management class (AEMC) remains a class C. The present status of the lower Xura reach (Xura site), on the other hand, can theoretically be improved from a class C to a class B by modifying water abstraction volumes from the Lusikisiki take-off point, as well as reducing the input of pollutants from the town.

Table 2. Classification of the upper and lower reaches of the Xura and Mzintlava rivers using the methodology of Kleynhans, 1999.

RIVER REACH	EISC	DEMC	DESC	PESC	AEMC
Xura R. Upper Reach	High	B	B	C	C
Xura R. Lower Reach	High	B	B	C	B
Mzintlava R. Upper Reach	High	B	B	C	C
Mzintlava R. Lower Reach	High	B	B	B	B

The details of the scores given to the various components or determinants of the riparian and instream habitats of the river reaches under consideration, are given in Appendix B, as well as the reasons for allocating the various scores.

2.3.2 Ecological Modifying Factors

It must be stressed that the incorporation of ecological modifying factors into the IFR estimation was hindered by limited data. This exercise was nevertheless considered worthwhile and valuable within the constraints imposed by the rapid estimation procedure as described by Munster and Hughs (1999). The ecological conditions

(physical and biological) of the upper reaches of the Xura and Mzintlava rivers were considered to be very similar, thus allowing these reaches to be assessed together. Similarly, the more gorge-like reaches of the lower Xura and Mzintlava rivers were also considered similar enough to be assessed as one entity.

The scores given to the various ecological modifying factors by the ECSCORE component incorporated into the DSS model, is given in Appendix C. A summary of the IFR component scores used to modify the first DSS estimate of the IFR is given in Table 3 below.

Table 3. Summary of ecological factors scores for the various river reaches within the study area.

RIVER REACH	IFR COMPONENT	SCORE
Upper reaches of Xura and Mzintlava rivers	Maintenance low flow: Annual total	9.25
	Drought low flow: Annual Total	10.75
	Maintenance low flow: seasonal distribution	3.00
	Maintenance high flow: Annual total	2.50
Lower (gorge) reaches of Xura and Mzintlava rivers	Maintenance low flow: Annual total	10.5
	Drought low flow: Annual total	12.00
	Maintenance low flow: Seasonal Distribution	3.00
	Maintenance high flow: Annual total	5.00

The "eco-logical scores" given in Table 3 are the percentages by which the annual reference IFR should be modified. Incorporating this percentage adjustment for each component into the IFR, estimated by the RESDSS component of the DSS model, therefore results in a refined IFR which takes into account hydrological, ecological and management class differences between sites.

2.3.3 IFR Estimates

The results produced after running the DSS model are in the form of a representative time series of monthly flow volumes recommended for the ecological reserve for the five proposed dam sites (i.e. the RER, quantity). These data are in the same format as that used to represent the natural flow regime and are also given as a % of the

MAR. The modified IFR flows are given as the components of the IFR, namely drought and maintenance low flows, maintenance high flows and total flow.

Details of these data, determined for the five dam sites using the DSS model as described above, are given in Appendix D and a summary of total IFR values in Table 4.

Table 4. Estimated Total IFR values for the 5 proposed Dam sites

DAM SITE	MAR (M m^3)	TOTAL IFR (M m^3)	TOTAL IFR (% MAR)
Xura River: Zalu site	11.949	2.793	23.37
Xura River: Lusikisiki site	15.511	3.691	23.79
Xura River: Xura site	37.858	11.068	29.23
Mzintlava R.: L. Mzintlava site	25.858	6.361	24.61
Mzintlava R.: Tungwane site	33.590	10.149	30.22

2.3.4 IFR Assurance Rules

In order to be able to use the IFR data for water resource planning and management in a pragmatic way, it is necessary to have a basis for deciding when the high, maintenance and drought components of the recommended flows should apply. This is accomplished by means of so-called "Assurance Rules" which are basically a series of curves relating to the % of time that certain flows will be equalled or exceeded in the modified flow regime. These curves can be used with the natural time series and associated flow duration curves to generate representative time series of flows required to satisfy the Reserve requirements (Hughs and Munster 1999, page 5).

The IFR "rule curves" generated for the 5 proposed dam sites are given in Appendix E.

3. CONCLUSIONS

The IFR data in this report, estimated using techniques developed for the rapid estimate of the ecological reserve or RER (quantity), should be viewed with some caution. The available data on both the biological and physical components at the

various reaches under consideration were incomplete. This is particularly valid regarding data on instream biota, water quality and fluvial geomorphology of all reaches. In addition, assumptions were made regarding the ecological integrity of the lower, gorge-like reaches of both rivers that require confirmation by means of field surveys.

The planning estimates (now desktop estimate, DE) of the estuarine flow requirements (EFRs) for both the Mzintlava and Msikaba estuaries were determined at a recent workshop (Bok 1999b) to be in the order of 80% to 95% of their MAR. Although the above DE of the EFR is thought to be "conservative" due to the paucity of relevant data, it is very likely that the freshwater requirements of both the gorges in the downstream freshwater reaches and the estuaries of the Xura and Mzintlava rivers, will be critical in determining the ecological reserve for the two systems.

The IFR estimates given in this report therefore require considerable refining and upgrading before long-term, quantitative decisions on the exploitation of the water resources in these two rivers can be taken.

4. REFERENCES

BOK, A. H. (1999a). *Eastern Pondoland Coastal Basin Study: Environmental evaluation of 5 proposed dam sites for augmenting the Lusikisiki Bulk Water Supply Scheme.* Report to UWP Engineers.

BOK, A.. H. (1999b). *Eastern Pondoland Coastal Basin Study: Determination of the Planning Estimate of the Estuarine Reserve.* Report to UWP Engineers.

HUGHS, D. A. & MUNSTER, F. (1999). A decision support system for an initial "low-confidence" estimate of the quantity component of the reserve for rivers. Unpublished Report. IWR, Rhodes University, Grahamstown.

KLEYNHANS, C. J. (1999). A procedure for the determination of the ecological reserve for the purpose of the National Water Balance Model for South African rivers. Unpublished report, IWQS, DWAF.

MUNSTER, F. & HUGHS, D. A. (1999). Desktop estimate of the quantity component of the ecological reserve for rivers: potential for the inclusion of physical and biological factors into the reserve decision support system. Unpublished Report, IWR, Rhodes University, Grahamstown.

APPENDIX A

The virgin flow records for the 5 proposed dam sites for the Lusikisiki Bulk Water Supply Scheme

Table A1. Virgin flow record for Zalu dam site (Catchment area 71 km^2)

zalrq5.ans 1920 - 1996

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.16	0.34	0.67	0.61	0.53	0.67	0.64	0.42	0.21	0.12	0.08	0.13	4.58
1921	0.29	2.66	2.9	1.08	0.38	0.2	0.11	0.86	1.15	0.72	0.53	0.53	11.41
1922	2.36	5.92	2.11	4.83	6.66	3.43	0.9	0.26	0.16	3.2	1.48	0.34	31.65
1923	0.22	0.25	0.35	2.48	2.11	0.72	0.2	0.12	0.1	0.09	0.11	0.22	6.97
1924	0.37	0.53	1.04	0.7	0.51	2.89	1.4	0.45	0.26	0.19	0.15	0.24	8.73
1925	0.38	0.49	0.51	0.52	0.56	3.84	1.6	0.34	0.36	0.36	0.24	0.26	9.46
1926	0.49	1.57	1.08	0.57	0.38	5.63	2.17	0.23	0.12	0.09	0.09	0.14	12.56
1927	0.32	0.33	0.37	0.52	0.72	0.62	0.36	0.22	0.18	0.14	0.2	0.24	4.22
1928	0.29	0.45	0.5	0.45	0.37	0.49	0.44	0.29	2.28	1.75	0.88	2.3	10.49
1929	3.87	3.14	1.1	0.41	0.28	0.29	0.33	0.27	0.32	0.39	0.45	1.19	12.04
1930	0.85	0.53	0.44	2.83	2.74	4.25	1.61	0.33	0.17	12.45	4.59	0.44	31.23
1931	0.47	0.52	0.47	0.32	2.01	1.11	0.4	0.28	0.3	0.33	0.3	1.55	8.06
1932	1.44	7.38	5.67	1.36	0.29	0.35	0.31	0.2	0.14	0.12	0.1	0.1	17.46
1933	0.12	1.12	2.77	3.46	1.29	0.55	0.47	0.32	0.21	0.35	0.41	0.25	11.32
1934	0.19	0.39	1.96	1	0.34	0.37	1.58	2.93	4.97	1.87	0.64	0.54	16.78
1935	0.41	0.44	0.29	0.19	4.28	4.39	1.33	0.73	0.7	0.5	0.3	0.24	13.8
1936	0.51	10.02	3.68	0.36	1.1	1.52	0.75	0.29	0.16	0.15	0.17	0.18	18.89
1937	0.24	0.3	0.48	0.59	0.51	0.33	0.4	0.43	0.35	0.35	0.3	0.21	4.49
1938	0.2	0.38	0.56	0.62	1.93	1.05	0.47	0.4	0.35	0.36	0.43	3.47	10.22
1939	2.11	0.79	0.6	0.44	0.28	0.3	0.28	0.41	0.47	0.34	0.23	0.2	6.45
1940	0.21	0.48	0.61	0.43	0.23	0.17	0.17	0.13	0.11	0.12	0.13	0.15	2.94
1941	0.26	0.45	0.4	3.34	1.43	0.44	0.36	0.32	0.27	0.18	0.18	0.26	7.89
1942	0.4	6.71	4.82	1.27	0.39	0.5	2.02	1.04	0.44	0.35	0.53	0.65	19.12
1943	0.71	2.89	1.83	0.69	0.58	0.54	0.36	0.22	0.17	0.19	0.17	1.73	10.08
1944	1.18	0.63	0.33	0.32	0.49	0.6	0.46	0.28	0.2	0.16	0.13	0.17	4.95
1945	3.49	1.5	0.28	0.21	0.37	1.43	0.9	0.42	0.24	0.18	0.13	0.14	9.29
1946	0.22	0.57	0.63	0.5	0.46	1.31	2.13	1.02	1.24	0.87	0.44	0.31	9.7
1947	0.31	8.63	3.44	0.59	1.31	0.94	0.63	0.39	0.2	0.11	0.08	0.08	16.71
1948	0.38	0.62	0.57	0.44	4.25	2.01	0.7	0.45	0.23	0.14	0.13	0.16	10.08
1949	0.3	2.39	1.2	0.62	0.66	0.59	0.53	0.57	0.46	0.34	0.41	0.41	8.48
1950	0.45	0.41	2.42	1.28	0.52	0.5	0.42	0.25	0.17	0.15	0.17	0.26	7
1951	1.32	0.75	0.86	0.79	0.61	0.54	0.55	0.44	0.27	0.17	0.12	0.18	6.6
1952	0.26	0.29	0.29	0.27	0.32	0.34	0.32	0.24	0.15	0.11	0.12	0.29	3
1953	0.57	3.41	2.31	0.79	0.38	0.41	0.35	0.3	0.34	0.32	0.23	0.27	9.68
1954	6.09	2.52	0.49	1.75	3.03	1.37	0.56	0.34	0.22	0.16	0.11	0.2	16.84
1955	0.37	0.5	0.37	0.16	0.25	3.45	1.64	0.52	0.36	0.28	0.2	0.24	8.34
1956	0.53	5.84	9.37	3.03	0.68	2.16	2.59	1.02	0.37	0.27	0.24	0.37	26.47
1957	0.64	0.98	0.82	1.55	3.24	1.41	1.55	0.81	0.26	0.17	0.15	0.15	11.73
1958	0.21	0.49	0.66	0.44	0.35	0.38	0.38	6.07	2.42	0.49	0.55	0.54	12.98
1959	0.52	0.53	0.5	0.43	0.34	0.42	0.52	0.54	0.4	0.27	0.24	0.32	5.03
1960	0.38	0.54	1.88	1.1	0.57	0.53	5.27	2.21	0.47	0.39	0.35	0.28	13.97
1961	0.28	1.24	0.89	0.55	0.5	1.46	0.81	0.34	0.22	0.14	0.18	0.24	6.85
1962	0.45	2.67	1.29	2.73	1.25	7.76	2.97	0.42	0.29	1.98	1.07	0.36	23.24
1963	0.42	1.08	0.82	3.28	1.82	0.81	1.44	0.8	5.74	2.37	0.44	0.34	19.36
1964	1.58	0.89	0.35	0.3	0.28	0.18	0.11	0.14	3.17	1.65	0.78	0.72	10.15
1965	5.08	3.62	1.08	0.45	0.35	0.2	0.12	1.51	0.94	0.39	0.26	0.31	14.31

1966	0.34	0.34	0.37	0.52	0.58	4.78	3.59	1.05	0.36	0.49	0.52	0.32	13.26
1967	0.24	0.41	0.43	0.32	0.31	0.3	0.26	0.18	0.11	0.1	0.16	0.38	3.2
1968	0.58	0.87	0.72	0.4	0.6	2.95	1.31	1.98	1.06	0.42	0.3	0.26	11.45
1969	0.35	0.59	0.62	0.38	0.27	0.21	0.14	0.15	0.24	0.27	1.58	1.1	5.9
1970	5.53	3.04	0.87	0.5	0.46	0.42	0.4	2.61	1.25	0.59	1.9	1.1	18.67
1971	4.72	2.07	0.63	0.49	3.52	1.53	0.37	0.22	0.17	0.17	0.16	0.15	14.2
1972	0.15	0.43	0.64	0.53	0.39	0.37	0.5	0.42	0.22	0.13	0.18	0.39	4.35
1973	0.56	2.66	1.26	0.43	0.47	0.6	0.52	2.66	1.4	0.56	0.33	0.22	11.67
1974	0.22	0.39	0.59	0.53	0.42	0.39	0.34	0.24	0.16	0.13	0.13	2.4	5.94
1975	1.25	0.5	1.78	0.98	3.03	12.08	4.28	1.18	0.74	0.36	0.23	0.33	26.74
1976	8.3	3.18	0.4	0.35	1.1	0.77	0.39	0.2	0.15	0.16	0.22	0.36	15.58
1977	0.56	3.24	3.55	1.26	0.43	0.38	17.22	6.36	0.63	0.38	0.28	0.31	34.6
1978	1.79	1.21	0.62	0.38	0.3	0.43	0.43	0.28	0.18	0.31	0.48	0.51	6.92
1979	0.61	0.58	0.46	0.32	0.29	0.29	0.22	0.17	0.15	0.13	0.11	0.83	4.16
1980	0.77	2.23	1.2	0.66	0.57	0.39	0.21	0.3	0.36	0.27	0.32	0.36	7.64
1981	0.29	0.3	0.29	0.33	0.31	3.74	1.76	0.52	0.31	0.23	0.17	0.15	8.4
1982	0.3	0.38	0.26	0.17	0.16	0.14	0.12	0.1	0.08	2.19	1.2	0.49	5.59
1983	0.48	1.05	0.8	0.74	0.66	0.52	0.51	0.46	0.4	0.6	0.63	0.47	7.32
1984	0.42	1.96	1.1	0.53	7.79	2.96	0.34	0.17	0.12	0.11	0.09	0.08	15.67
1985	0.34	2.23	1.15	1.02	0.62	0.35	0.3	0.21	0.14	0.1	0.24	0.55	7.25
1986	2.25	1.28	0.56	0.44	0.3	0.33	0.35	0.25	0.19	0.15	0.2	12.06	18.36
1987	4.61	2.33	1.16	0.44	2.41	8.95	3.21	1.01	0.77	0.68	0.74	0.61	26.92
1988	0.55	2.69	5.43	1.82	3.7	1.69	1.54	0.85	0.39	0.31	0.21	0.18	19.36
1989	1.43	5.04	1.86	0.39	0.29	1.15	0.7	0.27	0.15	0.1	0.23	0.34	11.95
1990	0.47	0.48	0.36	0.39	0.59	0.54	0.3	0.17	0.14	0.12	0.13	0.22	3.91
1991	1.13	2.7	1.16	0.41	0.3	0.22	0.22	0.19	0.13	0.1	0.1	0.18	6.84
1992	0.32	0.4	0.43	0.38	0.28	0.17	0.13	0.11	0.09	0.07	0.09	0.25	2.72
1993	0.54	0.7	2.21	1.01	4.83	2.06	0.4	0.18	0.1	0.13	0.27	0.28	12.71
1994	0.23	0.21	0.5	0.54	0.33	1.61	3.89	1.56	0.63	0.61	0.37	0.27	10.75
1995	0.37	0.45	6.11	2.51	1.28	0.71	0.32	0.22	0.16	0.39	0.53	0.39	13.44
1996	0.49	6.78	2.68	0.6	1.83	1.02	3.02	1.37	8.53	3.45	0.65	0.51	30.93
month	82.09	138.9	106.26	70.42	90.35	115.5	90.9	56.21	51.82	49.63	31.97	47.95	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.12	0.21	0.26	0.16	0.16	0.14	0.11	0.1	0.08	0.07	0.08	0.08	2.72
max	8.3	10.02	9.37	4.83	7.79	12.08	17.22	6.36	8.53	12.45	4.59	12.06	34.6
median	0.45	0.79	0.72	0.53	0.52	0.6	0.47	0.34	0.26	0.27	0.24	0.31	10.22
mean	1.07	1.8	1.38	0.91	1.17	1.5	1.18	0.73	0.67	0.64	0.42	0.62	12.1

Sum of the monthly means = 12.10

s.d.	1.57	2.09	1.59	0.92	1.48	2.09	2.14	1.09	1.32	1.52	0.59	1.43	7.36
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.95	2.36	1.43	2.3	0.61

Table A2. Virgin flow record for Lusikisiki dam site (Catchment area 91 km^2)

lusrq5.ans 1920 - 1996

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.21	0.43	0.86	0.78	0.68	0.86	0.82	0.53	0.27	0.16	0.11	0.16	5.87
1921	0.37	3.41	3.72	1.39	0.48	0.26	0.14	1.11	1.47	0.92	0.68	0.68	14.63
1922	3.02	7.59	2.71	6.19	8.53	4.39	1.15	0.33	0.2	4.1	1.9	0.43	40.54
1923	0.28	0.32	0.44	3.18	2.7	0.93	0.26	0.15	0.13	0.12	0.14	0.28	8.93
1924	0.47	0.69	1.33	0.89	0.66	3.7	1.79	0.58	0.34	0.24	0.19	0.3	11.18
1925	0.49	0.63	0.66	0.67	0.72	4.92	2.05	0.43	0.46	0.46	0.31	0.33	12.13
1926	0.62	2.02	1.38	0.73	0.48	7.22	2.78	0.3	0.15	0.11	0.11	0.18	16.08
1927	0.41	0.42	0.48	0.67	0.93	0.79	0.46	0.28	0.23	0.18	0.26	0.31	5.42
1928	0.37	0.58	0.64	0.58	0.47	0.62	0.56	0.37	2.92	2.24	1.12	2.95	13.42
1929	4.96	4.03	1.42	0.53	0.36	0.37	0.43	0.35	0.41	0.5	0.57	1.53	15.46
1930	1.09	0.68	0.56	3.63	3.51	5.45	2.07	0.42	0.21	15.95	5.89	0.56	40.02
1931	0.6	0.67	0.6	0.41	2.57	1.43	0.51	0.36	0.38	0.42	0.38	1.98	10.31
1932	1.84	9.45	7.27	1.74	0.37	0.45	0.39	0.26	0.19	0.15	0.13	0.13	22.37
1933	0.16	1.44	3.55	4.43	1.66	0.7	0.6	0.41	0.26	0.45	0.53	0.33	14.52
1934	0.25	0.5	2.51	1.29	0.44	0.47	2.03	3.76	6.38	2.4	0.81	0.69	21.53
1935	0.53	0.56	0.37	0.24	5.48	5.62	1.7	0.94	0.9	0.64	0.39	0.31	17.68
1936	0.66	12.84	4.71	0.46	1.41	1.94	0.96	0.37	0.2	0.19	0.22	0.23	24.19
1937	0.3	0.38	0.62	0.75	0.66	0.43	0.52	0.55	0.45	0.44	0.39	0.26	5.75
1938	0.25	0.48	0.72	0.79	2.47	1.35	0.6	0.51	0.44	0.46	0.55	4.45	13.07
1939	2.7	1.01	0.77	0.56	0.36	0.38	0.36	0.52	0.6	0.43	0.29	0.25	8.23
1940	0.27	0.61	0.79	0.56	0.29	0.21	0.21	0.17	0.15	0.16	0.16	0.19	3.77
1941	0.33	0.57	0.51	4.28	1.84	0.56	0.46	0.41	0.35	0.23	0.23	0.33	10.1
1942	0.51	8.61	6.17	1.63	0.5	0.64	2.6	1.34	0.56	0.45	0.68	0.83	24.52
1943	0.91	3.7	2.35	0.88	0.74	0.69	0.47	0.29	0.22	0.24	0.22	2.22	12.93
1944	1.51	0.8	0.42	0.41	0.63	0.77	0.58	0.36	0.26	0.21	0.16	0.22	6.33
1945	4.48	1.92	0.36	0.27	0.47	1.83	1.16	0.54	0.31	0.23	0.17	0.17	11.91
1946	0.28	0.73	0.81	0.64	0.59	1.68	2.73	1.31	1.59	1.11	0.56	0.4	12.43
1947	0.4	11.07	4.41	0.76	1.68	1.21	0.81	0.5	0.25	0.15	0.11	0.1	21.45
1948	0.48	0.8	0.73	0.57	5.45	2.58	0.89	0.57	0.29	0.18	0.16	0.21	12.91
1949	0.38	3.06	1.54	0.79	0.84	0.76	0.69	0.73	0.59	0.44	0.52	0.52	10.86
1950	0.57	0.52	3.1	1.64	0.67	0.64	0.53	0.32	0.22	0.19	0.22	0.33	8.95
1951	1.69	0.97	1.1	1.01	0.79	0.69	0.71	0.57	0.35	0.22	0.15	0.23	8.48
1952	0.33	0.37	0.37	0.35	0.41	0.43	0.41	0.31	0.2	0.14	0.15	0.37	3.84
1953	0.73	4.37	2.96	1.01	0.49	0.53	0.45	0.38	0.43	0.41	0.29	0.35	12.4
1954	7.81	3.23	0.63	2.25	3.88	1.76	0.72	0.43	0.28	0.21	0.14	0.25	21.59
1955	0.47	0.64	0.47	0.2	0.32	4.42	2.11	0.67	0.46	0.35	0.25	0.31	10.67
1956	0.68	7.49	12.01	3.89	0.87	2.77	3.32	1.31	0.47	0.35	0.31	0.48	33.95
1957	0.81	1.26	1.05	1.99	4.15	1.81	1.99	1.04	0.34	0.22	0.19	0.2	15.05
1958	0.27	0.63	0.84	0.57	0.45	0.49	0.49	7.78	3.1	0.62	0.7	0.7	16.64
1959	0.66	0.68	0.64	0.55	0.44	0.54	0.67	0.69	0.52	0.34	0.31	0.41	6.45
1960	0.48	0.7	2.4	1.41	0.73	0.68	6.76	2.83	0.6	0.5	0.45	0.36	17.9
1961	0.36	1.59	1.15	0.7	0.65	1.87	1.03	0.43	0.28	0.17	0.22	0.31	8.76
1962	0.58	3.42	1.65	3.5	1.61	9.95	3.81	0.53	0.37	2.54	1.38	0.46	29.8
1963	0.54	1.38	1.05	4.2	2.33	1.03	1.85	1.02	7.35	3.04	0.56	0.43	24.78
1964	2.03	1.15	0.45	0.39	0.36	0.23	0.14	0.18	4.06	2.12	0.99	0.93	13.03
1965	6.51	4.64	1.38	0.58	0.45	0.26	0.15	1.94	1.21	0.5	0.34	0.39	18.35

1966	0.44	0.43	0.48	0.67	0.75	6.13	4.61	1.34	0.46	0.63	0.67	0.42	17.03
1967	0.31	0.53	0.56	0.41	0.39	0.38	0.33	0.23	0.15	0.12	0.2	0.49	4.1
1968	0.75	1.12	0.92	0.51	0.76	3.78	1.68	2.53	1.35	0.53	0.38	0.33	14.64
1969	0.45	0.76	0.79	0.49	0.35	0.27	0.19	0.19	0.3	0.34	2.02	1.41	7.56
1970	7.08	3.89	1.11	0.64	0.59	0.54	0.52	3.34	1.61	0.75	2.43	1.4	23.9
1971	6.05	2.65	0.81	0.63	4.51	1.96	0.47	0.29	0.22	0.22	0.21	0.19	18.21
1972	0.19	0.56	0.82	0.67	0.5	0.47	0.64	0.54	0.28	0.17	0.24	0.49	5.57
1973	0.72	3.41	1.61	0.55	0.61	0.77	0.67	3.41	1.79	0.72	0.42	0.28	14.96
1974	0.29	0.5	0.76	0.68	0.54	0.5	0.43	0.31	0.21	0.16	0.17	3.08	7.63
1975	1.6	0.65	2.29	1.25	3.88	15.48	5.48	1.51	0.94	0.46	0.3	0.42	34.26
1976	10.64	4.07	0.51	0.45	1.41	0.99	0.5	0.26	0.19	0.2	0.28	0.46	19.96
1977	0.72	4.15	4.55	1.62	0.56	0.49	22.07	8.15	0.81	0.49	0.36	0.4	44.37
1978	2.29	1.55	0.79	0.49	0.38	0.56	0.55	0.36	0.22	0.39	0.61	0.66	8.85
1979	0.78	0.75	0.59	0.41	0.37	0.37	0.28	0.22	0.19	0.16	0.15	1.07	5.34
1980	0.99	2.86	1.54	0.85	0.73	0.49	0.27	0.38	0.47	0.34	0.41	0.47	9.8
1981	0.37	0.38	0.37	0.42	0.4	4.79	2.25	0.67	0.4	0.29	0.21	0.19	10.74
1982	0.38	0.49	0.33	0.22	0.21	0.18	0.15	0.13	0.11	2.81	1.54	0.62	7.17
1983	0.62	1.35	1.02	0.95	0.84	0.67	0.66	0.59	0.51	0.77	0.8	0.6	9.38
1984	0.54	2.52	1.41	0.68	9.98	3.79	0.43	0.22	0.15	0.14	0.11	0.1	20.07
1985	0.44	2.86	1.47	1.31	0.8	0.45	0.38	0.27	0.18	0.13	0.3	0.7	9.29
1986	2.88	1.64	0.72	0.56	0.38	0.43	0.45	0.32	0.24	0.2	0.25	15.45	23.52
1987	5.91	2.98	1.49	0.56	3.08	11.48	4.11	1.29	0.99	0.87	0.95	0.78	34.49
1988	0.7	3.44	6.96	2.34	4.75	2.16	1.98	1.09	0.5	0.39	0.27	0.24	24.82
1989	1.83	6.45	2.39	0.5	0.38	1.47	0.9	0.34	0.19	0.13	0.29	0.44	15.31
1990	0.61	0.62	0.46	0.51	0.75	0.7	0.39	0.22	0.18	0.15	0.16	0.29	5.04
1991	1.45	3.46	1.49	0.52	0.38	0.28	0.29	0.24	0.16	0.12	0.13	0.23	8.75
1992	0.41	0.51	0.55	0.48	0.36	0.22	0.16	0.14	0.12	0.1	0.11	0.32	3.48
1993	0.7	0.9	2.83	1.29	6.19	2.65	0.52	0.22	0.13	0.17	0.35	0.36	16.31
1994	0.3	0.26	0.64	0.69	0.43	2.06	4.99	2	0.81	0.78	0.48	0.34	13.78
1995	0.47	0.58	7.83	3.22	1.64	0.91	0.41	0.29	0.2	0.5	0.68	0.5	17.23
1996	0.62	8.69	3.43	0.77	2.34	1.31	3.87	1.76	10.94	4.43	0.83	0.65	39.64
month	105.18	178.05	136.18	90.28	115.81	148.04	116.55	72.03	66.4	63.54	40.9	61.42	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.16	0.26	0.33	0.2	0.21	0.18	0.14	0.13	0.11	0.1	0.11	0.1	3.48
max	10.64	12.84	12.01	6.19	9.98	15.48	22.07	8.15	10.94	15.95	5.89	15.45	44.37
median	0.58	1.01	0.92	0.68	0.67	0.77	0.6	0.43	0.34	0.35	0.3	0.39	13.07
mean	1.37	2.31	1.77	1.17	1.5	1.92	1.51	0.94	0.86	0.83	0.53	0.8	15.51

Sum of the monthly means = 15.51

s.d.	2.01	2.68	2.04	1.18	1.9	2.68	2.74	1.39	1.69	1.95	0.76	1.84	9.43
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.96	2.36	1.43	2.3	0.61

Table A3. Virgin flow record for Xura dam site (Catchment area 225 km^2)

xurrq5.ans 1920 - 1996

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.52	1.06	2.14	1.93	1.67	2.13	2.03	1.32	0.67	0.39	0.26	0.41	14.53
1921	0.91	8.42	9.19	3.44	1.19	0.63	0.34	2.74	3.63	2.27	1.68	1.69	36.13
1922	7.47	18.77	6.7	15.3	21.1	10.87	2.84	0.82	0.5	10.13	4.69	1.07	100.26
1923	0.7	0.79	1.1	7.87	6.69	2.29	0.65	0.37	0.33	0.3	0.35	0.68	22.12
1924	1.16	1.69	3.28	2.21	1.63	9.16	4.43	1.44	0.83	0.59	0.46	0.75	27.63
1925	1.2	1.55	1.62	1.66	1.78	12.17	5.07	1.07	1.14	1.14	0.76	0.82	29.98
1926	1.54	4.98	3.42	1.81	1.2	17.85	6.88	0.74	0.38	0.27	0.27	0.44	39.78
1927	1.01	1.03	1.18	1.65	2.29	1.95	1.14	0.69	0.56	0.45	0.63	0.76	13.34
1928	0.92	1.43	1.58	1.44	1.16	1.54	1.39	0.92	7.22	5.55	2.77	7.29	33.21
1929	12.26	9.96	3.5	1.31	0.89	0.93	1.06	0.86	1.01	1.23	1.42	3.78	38.21
1930	2.69	1.68	1.4	8.98	8.69	13.47	5.11	1.05	0.53	39.45	14.56	1.38	98.99
1931	1.48	1.66	1.47	1.01	6.37	3.53	1.26	0.89	0.94	1.05	0.94	4.9	25.5
1932	4.56	23.37	17.97	4.3	0.91	1.12	0.97	0.65	0.46	0.37	0.32	0.33	55.33
1933	0.4	3.56	8.78	10.96	4.09	1.73	1.48	1.01	0.65	1.11	1.3	0.81	35.88
1934	0.62	1.23	6.2	3.18	1.09	1.16	5.01	9.29	15.77	5.94	2.01	1.72	53.22
1935	1.31	1.38	0.92	0.59	13.55	13.9	4.21	2.32	2.22	1.59	0.96	0.76	43.71
1936	1.63	31.75	11.65	1.13	3.48	4.81	2.37	0.91	0.5	0.47	0.54	0.57	59.81
1937	0.75	0.94	1.53	1.86	1.63	1.06	1.28	1.37	1.11	1.1	0.96	0.65	14.24
1938	0.62	1.2	1.79	1.96	6.1	3.34	1.49	1.27	1.1	1.14	1.36	11.01	32.38
1939	6.67	2.5	1.9	1.39	0.9	0.94	0.88	1.28	1.48	1.07	0.72	0.62	20.35
1940	0.67	1.52	1.94	1.37	0.72	0.52	0.53	0.43	0.36	0.38	0.41	0.47	9.32
1941	0.83	1.41	1.26	10.59	4.55	1.4	1.13	1.01	0.87	0.57	0.57	0.82	25.01
1942	1.27	21.28	15.26	4.03	1.23	1.59	6.42	3.3	1.39	1.11	1.67	2.06	60.61
1943	2.24	9.15	5.8	2.19	1.84	1.71	1.15	0.71	0.55	0.6	0.54	5.49	31.97
1944	3.74	1.98	1.05	1.02	1.55	1.9	1.45	0.9	0.63	0.51	0.4	0.54	15.67
1945	11.07	4.74	0.89	0.67	1.17	4.53	2.87	1.34	0.77	0.56	0.42	0.43	29.46
1946	0.69	1.81	2	1.58	1.46	4.16	6.74	3.24	3.94	2.74	1.39	0.98	30.73
1947	0.99	27.36	10.9	1.88	4.14	2.99	2	1.24	0.62	0.36	0.26	0.24	52.98
1948	1.19	1.97	1.81	1.4	13.48	6.37	2.21	1.42	0.72	0.44	0.4	0.52	31.93
1949	0.94	7.57	3.81	1.95	2.09	1.87	1.69	1.79	1.45	1.08	1.29	1.3	26.83
1950	1.41	1.3	7.68	4.06	1.64	1.59	1.32	0.8	0.55	0.46	0.54	0.82	22.17
1951	4.18	2.39	2.72	2.51	1.94	1.72	1.75	1.41	0.87	0.55	0.37	0.56	20.97
1952	0.82	0.92	0.91	0.86	1	1.08	1	0.76	0.49	0.34	0.38	0.91	9.47
1953	1.81	10.81	7.32	2.49	1.21	1.31	1.11	0.94	1.07	1.01	0.71	0.87	30.66
1954	19.3	7.98	1.56	5.55	9.6	4.35	1.78	1.07	0.7	0.52	0.35	0.62	53.38
1955	1.16	1.58	1.17	0.49	0.8	10.92	5.21	1.65	1.14	0.87	0.62	0.77	26.38
1956	1.67	18.51	29.69	9.61	2.14	6.85	8.21	3.23	1.17	0.87	0.75	1.18	83.88
1957	2.01	3.11	2.6	4.91	10.27	4.46	4.93	2.57	0.83	0.54	0.47	0.49	37.19
1958	0.66	1.55	2.08	1.4	1.11	1.21	1.21	19.23	7.67	1.54	1.74	1.73	41.13
1959	1.64	1.67	1.59	1.36	1.08	1.33	1.66	1.71	1.28	0.85	0.76	1.02	15.95
1960	1.19	1.72	5.94	3.48	1.8	1.69	16.7	6.99	1.48	1.23	1.11	0.9	44.23
1961	0.9	3.93	2.83	1.74	1.6	4.64	2.55	1.07	0.69	0.43	0.56	0.76	21.7
1962	1.42	8.46	4.07	8.66	3.97	24.6	9.42	1.32	0.91	6.28	3.41	1.13	73.65
1963	1.35	3.41	2.6	10.4	5.76	2.55	4.57	2.52	18.18	7.52	1.39	1.07	61.32
1964	5.01	2.83	1.12	0.96	0.89	0.57	0.33	0.44	10.04	5.23	2.46	2.29	32.17

1965	16.1	11.46	3.42	1.43	1.12	0.65	0.37	4.79	2.99	1.24	0.83	0.97	45.37
1966	1.08	1.06	1.18	1.66	1.85	15.15	11.39	3.32	1.14	1.56	1.65	1.03	42.07
1967	0.76	1.3	1.37	1.02	0.97	0.95	0.82	0.57	0.36	0.3	0.5	1.2	10.12
1968	1.85	2.77	2.27	1.27	1.89	9.34	4.15	6.26	3.35	1.32	0.94	0.82	36.23
1969	1.12	1.88	1.95	1.2	0.86	0.66	0.46	0.46	0.75	0.85	5	3.48	18.67
1970	17.51	9.62	2.74	1.58	1.46	1.34	1.28	8.26	3.97	1.86	6.01	3.47	59.1
1971	14.95	6.54	2.01	1.57	11.14	4.85	1.17	0.71	0.55	0.54	0.52	0.46	45.01
1972	0.46	1.37	2.03	1.67	1.23	1.16	1.58	1.34	0.7	0.41	0.59	1.22	13.76
1973	1.78	8.43	3.98	1.37	1.5	1.9	1.66	8.44	4.44	1.78	1.05	0.69	37.02
1974	0.71	1.23	1.87	1.69	1.34	1.23	1.06	0.77	0.51	0.4	0.41	7.62	18.84
1975	3.96	1.6	5.66	3.1	9.59	38.28	13.56	3.74	2.34	1.13	0.74	1.05	84.75
1976	26.31	10.06	1.25	1.12	3.47	2.44	1.23	0.63	0.47	0.49	0.7	1.14	49.31
1977	1.79	10.25	11.25	3.99	1.38	1.21	54.57	20.15	2	1.22	0.88	0.99	109.68
1978	5.67	3.82	1.96	1.22	0.94	1.37	1.36	0.88	0.56	0.97	1.51	1.62	21.88
1979	1.93	1.85	1.46	1.01	0.91	0.91	0.69	0.55	0.46	0.4	0.36	2.64	13.17
1980	2.44	7.07	3.8	2.09	1.81	1.22	0.67	0.94	1.15	0.85	1.02	1.15	24.21
1981	0.91	0.94	0.93	1.05	1	11.85	5.57	1.65	1	0.72	0.53	0.47	26.62
1982	0.94	1.2	0.81	0.55	0.52	0.44	0.37	0.32	0.26	6.95	3.81	1.54	17.71
1983	1.53	3.34	2.53	2.35	2.09	1.66	1.62	1.45	1.26	1.9	1.99	1.48	23.2
1984	1.33	6.22	3.48	1.67	24.67	9.37	1.06	0.55	0.37	0.34	0.28	0.25	49.59
1985	1.08	7.06	3.64	3.23	1.97	1.12	0.94	0.67	0.44	0.32	0.75	1.73	22.95
1986	7.12	4.05	1.77	1.39	0.95	1.06	1.12	0.79	0.59	0.48	0.63	38.21	58.16
1987	14.61	7.37	3.68	1.38	7.63	28.38	10.16	3.19	2.44	2.14	2.36	1.93	85.27
1988	1.73	8.51	17.2	5.78	11.74	5.35	4.88	2.7	1.23	0.97	0.67	0.58	61.34
1989	4.54	15.96	5.91	1.23	0.93	3.63	2.22	0.85	0.46	0.33	0.71	1.09	37.86
1990	1.51	1.53	1.13	1.25	1.86	1.72	0.96	0.55	0.44	0.37	0.4	0.71	12.43
1991	3.59	8.57	3.68	1.29	0.95	0.7	0.71	0.6	0.41	0.3	0.33	0.58	21.71
1992	1.01	1.26	1.37	1.19	0.88	0.55	0.4	0.35	0.28	0.24	0.28	0.79	8.6
1993	1.73	2.22	7	3.19	15.3	6.54	1.28	0.56	0.31	0.41	0.87	0.9	40.31
1994	0.74	0.65	1.58	1.7	1.05	5.09	12.34	4.94	2.01	1.94	1.18	0.84	34.06
1995	1.17	1.44	19.36	7.96	4.05	2.24	1.02	0.71	0.49	1.23	1.67	1.24	42.58
1996	1.54	21.47	8.49	1.89	5.8	3.25	9.56	4.36	27.05	10.94	2.05	1.6	98
month	260.1	440	336.7	223.2	286.3	366.1	288.1	178.2	164.2	157.1	101.2	151.9	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.4	0.65	0.81	0.49	0.52	0.44	0.33	0.32	0.26	0.24	0.26	0.24	8.6
max	26.31	31.75	29.69	15.3	24.67	38.28	54.57	20.15	27.05	39.45	14.56	38.21	109.68
median	1.42	2.5	2.27	1.67	1.64	1.9	1.49	1.07	0.83	0.87	0.75	0.97	32.38
mean	3.38	5.71	4.37	2.9	3.72	4.75	3.74	2.31	2.13	2.04	1.31	1.97	38.35

Sum of the monthly means= 38.35

s.d.	4.97	6.63	5.04	2.93	4.7	6.61	6.78	3.44	4.17	4.82	1.88	4.54	23.32
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.96	2.36	1.43	2.3	0.61

Table A4. Virgin flow record for Lower Mzintlava (Catchmentarea 98km^2)

lmzrq5.ans 1920 -1996

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.23	0.49	1.82	1.17	0.9	3.87	1.99	0.8	0.47	0.28	0.19	0.27	12.48
1921	0.53	5.2	5.29	1.79	0.61	0.38	0.24	4.94	4.5	1.6	0.9	0.96	26.94
1922	5.04	9.74	3.22	9.02	12.68	7.85	2.04	0.47	0.34	8.1	3.32	0.52	62.34
1923	0.33	0.35	0.5	5.51	5.31	1.62	0.36	0.26	0.26	0.23	0.26	0.46	15.45
1924	0.69	0.88	2.45	1.32	0.85	7.4	3.2	0.88	0.59	0.44	0.34	0.5	19.54
1925	0.71	0.8	0.77	0.85	1.45	9.03	3.47	0.64	0.82	0.84	0.56	0.56	20.5
1926	1.24	3.06	2.15	0.95	0.62	12.14	4.51	0.42	0.26	0.19	0.19	0.29	26.02
1927	0.59	0.52	0.57	1.05	3.05	1.62	0.68	0.49	0.44	0.35	0.47	0.53	10.36
1928	0.55	0.74	0.76	0.72	0.65	2.91	1.42	0.57	6.9	4.99	1.75	4.99	26.95
1929	6.85	4.93	1.59	0.59	0.46	0.61	0.78	0.69	0.84	1	1.24	4.32	23.9
1930	1.99	0.69	0.58	5.79	6.21	9.22	3.25	0.62	0.36	23.6	8.53	0.67	61.51
1931	0.73	0.77	0.66	0.46	5.43	2.57	0.76	0.64	0.74	0.83	0.72	5.09	19.4
1932	3.35	11.72	9.39	2.23	0.47	0.73	0.7	0.52	0.39	0.31	0.25	0.23	30.29
1933	0.23	2.96	5.1	6.56	2.37	1.88	1.18	0.68	0.49	1.48	1.07	0.49	24.49
1934	0.33	0.61	4.03	1.85	0.55	0.9	5.64	7.69	10.26	3.51	1.76	1.1	38.23
1935	0.63	0.62	0.38	0.26	9.14	9.76	2.78	3.94	2.06	0.89	0.58	0.46	31.5
1936	2.23	16.15	5.65	0.51	3.83	4.9	1.79	0.53	0.34	0.34	0.39	0.38	37.04
1937	0.44	0.47	1.04	1	0.89	0.66	2.14	1.3	0.77	0.8	0.7	0.45	10.66
1938	0.36	0.61	0.88	1.44	4.92	2.3	0.91	0.92	0.87	0.9	1.04	8.27	23.42
1939	4.44	1.17	0.8	0.63	0.47	0.61	0.65	2.49	1.48	0.69	0.48	0.4	14.31
1940	0.38	1.63	1.12	0.6	0.36	0.33	0.39	0.35	0.31	0.32	0.32	0.33	6.44
1941	0.5	0.73	0.6	6.85	2.78	0.83	0.78	0.79	0.72	0.47	0.44	0.57	16.06
1942	0.77	11.81	8.42	2.1	0.63	3.11	5.74	2.27	0.85	0.74	3.26	1.75	41.45
1943	1.59	4.45	3.12	1.14	2.45	1.39	0.69	0.5	0.43	0.47	0.41	5.33	21.97
1944	2.65	0.82	0.39	0.48	1.31	2.45	1.22	0.57	0.46	0.38	0.3	0.36	11.39
1945	7.42	2.86	0.33	0.29	0.9	5.01	2.36	0.82	0.54	0.41	0.31	0.29	21.54
1946	0.4	1.9	1.22	0.73	0.81	5.04	6.1	2.25	4.63	2.23	0.72	0.54	26.57
1947	0.52	14.69	6.11	1	4.01	3.68	1.54	0.73	0.42	0.26	0.19	0.16	33.31
1948	1.92	1.28	0.75	0.64	8.93	5.72	1.75	0.83	0.48	0.32	0.29	0.34	23.25
1949	0.55	4.81	2.13	1.95	1.59	1.11	1.3	2.38	1.3	0.71	0.89	0.85	19.57
1950	0.82	0.65	4.79	2.5	0.89	1.85	1.1	0.53	0.41	0.35	0.4	0.56	14.85
1951	3.91	1.66	1.78	2.25	1.22	1.31	1.6	1.06	0.62	0.41	0.27	0.37	16.46
1952	0.48	0.47	0.42	0.42	0.58	0.72	0.75	0.61	0.42	0.29	0.3	0.63	6.09
1953	1.99	5.86	4.03	1.3	0.62	1.13	0.83	0.7	0.86	0.8	0.55	0.6	19.27
1954	1.77	4.53	0.63	4.02	6.68	4.03	1.37	0.64	0.49	0.38	0.25	0.41	35.2
1955	0.69	0.81	0.54	0.21	0.48	8.76	4.17	1.09	0.76	0.62	0.44	0.51	19.08
1956	2.15	9.61	15.35	5.57	1.68	5.72	6.59	2.23	0.7	0.57	0.51	0.77	51.45
1957	2.36	1.77	1.36	3.33	6.86	2.94	5.01	2.12	0.47	0.34	0.31	0.31	27.18
1958	0.37	1.62	1.18	0.61	0.59	0.79	0.88	13.96	5.27	0.87	1.34	1.1	28.58
1959	0.88	0.8	0.73	0.66	0.6	1.57	1.46	1.43	0.98	0.61	0.55	0.68	10.95
1960	0.7	1.73	3.6	2.44	1.08	1.75	11.41	4.49	0.91	0.84	0.77	0.59	30.31
1961	0.52	2.91	1.62	0.82	0.89	5.3	2.27	0.64	0.48	0.31	0.4	0.51	16.67
1962	1.35	4.7	2.02	5.52	2.38	15.31	5.76	0.81	0.65	6.32	2.71	0.55	48.08
1963	0.68	2.24	1.37	6.38	4.67	3.22	4.4	1.82	11.97	4.7	0.72	0.59	42.76
1964	3.89	1.73	0.43	0.43	0.48	0.35	0.24	0.36	8.85	3.93	2.34	1.48	24.51

1965	8.94	5.9	1.55	0.66	0.6	0.4	0.27	6.13	2.75	0.68	0.49	0.59	28.96
1966	0.6	0.51	0.55	1.6	1.21	10.55	8.49	2.28	0.68	2.17	1.34	0.56	30.54
1967	0.39	0.63	0.63	0.49	0.55	0.63	0.61	0.46	0.31	0.25	0.39	0.95	6.29
1968	1.1	2.03	1.23	0.56	2.93	7.31	2.75	6.04	2.65	0.72	0.56	0.49	28.37
1969	0.63	1.43	1.02	0.52	0.46	0.41	0.34	0.38	0.63	0.69	5.81	2.76	15.08
1970	9.52	4.93	1.21	0.74	0.81	0.87	0.93	8.2	3.32	1.92	5.01	2.23	39.69
1971	8.22	3.38	0.85	0.73	7.73	3.18	0.7	0.5	0.43	0.43	0.4	0.32	26.87
1972	0.27	1.57	1.18	0.76	0.66	0.75	2.67	1.36	0.45	0.29	0.41	0.8	11.17
1973	1.05	5.01	2.14	0.62	1.26	2.53	1.37	7.42	3.32	1.02	0.63	0.41	26.78
1974	0.39	0.61	1.17	0.88	0.72	0.79	0.77	0.61	0.43	0.34	0.32	6.41	13.44
1975	2.72	0.66	3.33	1.68	6.8	22.12	8.49	4.38	1.9	0.6	0.44	0.63	53.75
1976	5.01	5.5	0.49	0.52	3.86	1.97	0.74	0.44	0.37	0.39	0.52	0.78	30.59
1977	1.71	5.63	6.02	2.06	0.72	0.77	32.45	12.61	1.34	0.7	0.55	0.61	65.17
1978	4.47	2.29	0.82	0.54	0.51	2.03	1.21	0.59	0.42	0.72	1.07	1.08	15.75
1979	1.6	1.03	0.62	0.46	0.5	0.6	0.51	0.44	0.4	0.33	0.29	3.86	10.64
1980	1.94	3.61	1.83	1.62	1.11	0.7	0.46	0.88	0.93	0.64	0.75	0.79	15.26
1981	0.55	0.47	0.42	0.53	0.57	9.1	4.5	1.13	0.64	0.5	0.37	0.31	19.09
1982	0.55	0.61	0.36	0.25	0.29	0.29	0.28	0.26	0.23	6.87	3	0.78	13.77
1983	0.77	2.19	1.33	2.26	1.43	0.98	1.93	1.25	0.92	3.84	1.9	0.74	19.54
1984	0.66	3.71	1.83	0.78	14.78	5.54	0.63	0.38	0.29	0.27	0.21	0.17	29.25
1985	1.22	4.05	1.81	2.75	1.36	0.64	0.65	0.52	0.36	0.27	0.57	2.61	16.81
1986	4.62	2.03	0.72	0.64	0.49	0.75	0.8	0.6	0.48	0.39	0.48	22.24	34.24
1987	8.23	3.74	1.76	0.62	5.91	17.1	5.87	4.53	2.22	2.32	2.18	1.15	55.63
1988	0.84	4.65	9.17	2.98	7.89	3.52	5.03	2.22	0.74	0.65	0.46	0.38	38.53
1989	4.03	8.48	2.82	0.57	0.49	4.73	2.09	0.49	0.31	0.23	0.51	0.73	25.48
1990	0.89	0.78	0.52	0.63	2.82	1.5	0.55	0.39	0.35	0.29	0.3	0.48	9.5
1991	3.61	4.74	1.68	0.58	0.5	0.44	0.53	0.49	0.35	0.25	0.26	0.4	13.83
1992	0.61	0.65	0.65	0.59	0.49	0.35	0.3	0.29	0.25	0.2	0.21	0.54	5.13
1993	1.86	1.31	3.93	1.69	9.81	4.23	0.79	0.36	0.23	0.31	0.64	0.62	25.78
1994	0.44	0.32	1.82	1.14	0.53	5.44	9.05	3.15	3.06	1.64	0.62	0.46	27.67
1995	0.62	0.7	10.66	4.46	3.71	1.67	0.61	0.51	0.39	2.72	1.56	0.66	28.27
1996	0.84	11.29	4.32	1.24	4.65	2.22	7.7	3.19	16.6	7.07	1.23	0.85	61.2
month	9.65	243	180.1	132.1	200.5	278.5	212.3	146	124.9	118.7	77.21	107.5	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.23	0.32	0.33	0.21	0.29	0.29	0.24	0.26	0.23	0.19	0.19	0.16	5.13
max	5.01	16.15	15.35	9.02	14.78	22.12	32.45	13.96	16.6	23.6	8.53	22.24	65.17
median	0.84	1.73	1.33	0.88	1.08	1.97	1.37	0.73	0.62	0.62	0.52	0.59	24.49
mean	2.2	3.16	2.34	1.72	2.6	3.62	2.76	1.9	1.62	1.54	1	1.4	25.85

Sum of the monthly means = 25.85

s.d.	2.89	3.45	2.71	1.85	3.08	4.15	4.22	2.63	2.81	3.07	1.35	2.85	14.05
c.v.	1.31	1.09	1.16	1.08	1.18	1.15	1.53	1.39	1.73	1.99	1.34	2.04	0.54

Table A5. Virgin flow record for Tungwane dam site (Catchment area 129 km^2)

tunrq5.ans 1920 - 1996

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.3	0.65	2.4	1.54	1.18	5.09	2.62	1.05	0.62	0.37	0.25	0.35	16.4
1921	0.7	6.84	6.96	2.36	0.8	0.5	0.32	6.5	5.93	2.11	1.19	1.26	35.5
1922	6.63	12.83	4.24	11.87	16.69	10.3	2.69	0.62	0.45	10.66	4.37	0.68	82.1
1923	0.43	0.46	0.66	7.26	7	2.13	0.47	0.34	0.34	0.3	0.34	0.61	20.3
1924	0.91	1.15	3.23	1.74	1.11	9.74	4.21	1.16	0.77	0.57	0.44	0.66	25.7
1925	0.94	1.05	1.02	1.12	1.91	11.9	4.57	0.85	1.08	1.11	0.73	0.73	27
1926	1.63	4.02	2.82	1.25	0.81	16	5.94	0.55	0.34	0.25	0.25	0.38	34.2
1927	0.77	0.69	0.74	1.38	4.01	2.14	0.89	0.65	0.58	0.46	0.63	0.7	13.6
1928	0.72	0.97	1	0.95	0.86	3.82	1.88	0.74	9.08	6.57	2.3	6.56	35.5
1929	9.02	6.49	2.1	0.78	0.61	0.8	1.03	0.91	1.11	1.32	1.64	5.68	31.5
1930	2.62	0.91	0.76	7.63	8.18	12.1	4.28	0.81	0.48	31.06	11.23	0.88	81
1931	0.96	1.01	0.86	0.61	7.14	3.38	1	0.84	0.98	1.09	0.95	6.7	25.5
1932	4.4	15.43	12.36	2.93	0.62	0.96	0.92	0.68	0.51	0.41	0.33	0.3	39.9
1933	0.31	3.89	6.71	8.64	3.12	2.48	1.55	0.89	0.65	1.95	1.41	0.64	32.2
1934	0.44	0.81	5.31	2.44	0.72	1.19	7.43	10.13	13.5	4.62	2.31	1.45	50.4
1935	0.82	0.82	0.51	0.35	12.03	12.8	3.66	5.18	2.71	1.18	0.76	0.6	41.5
1936	2.93	21.26	7.44	0.66	5.04	6.45	2.36	0.69	0.45	0.45	0.51	0.5	48.7
1937	0.58	0.62	1.37	1.32	1.17	0.87	2.82	1.71	1.01	1.05	0.92	0.59	14
1938	0.48	0.81	1.16	1.89	6.48	3.02	1.2	1.22	1.14	1.18	1.36	10.89	30.8
1939	5.84	1.54	1.06	0.83	0.62	0.81	0.85	3.28	1.95	0.91	0.63	0.53	18.9
1940	0.5	2.15	1.47	0.79	0.47	0.43	0.51	0.45	0.4	0.42	0.42	0.43	8.44
1941	0.65	0.97	0.78	9.02	3.66	1.09	1.03	1.03	0.95	0.61	0.59	0.76	21.1
1942	1.01	15.55	11.08	2.76	0.83	4.09	7.55	2.99	1.12	0.98	4.29	2.31	54.6
1943	2.09	5.86	4.11	1.51	3.23	1.83	0.9	0.66	0.57	0.62	0.54	7.02	28.9
1944	3.49	1.08	0.51	0.63	1.73	3.22	1.6	0.75	0.61	0.5	0.39	0.48	15
1945	9.76	3.77	0.44	0.38	1.18	6.59	3.11	1.07	0.71	0.54	0.41	0.38	28.3
1946	0.53	2.5	1.6	0.96	1.07	6.64	8.03	2.96	6.1	2.94	0.94	0.71	35
1947	0.68	19.34	8.04	1.31	5.28	4.84	2.02	0.96	0.56	0.34	0.24	0.21	43.8
1948	2.53	1.68	0.99	0.85	11.76	7.53	2.3	1.09	0.63	0.42	0.38	0.45	30.6
1949	0.73	6.34	2.8	2.56	2.09	1.46	1.71	3.13	1.71	0.94	1.17	1.12	25.8
1950	1.08	0.85	6.3	3.29	1.17	2.44	1.45	0.7	0.54	0.47	0.53	0.73	19.6
1951	5.14	2.18	2.34	2.96	1.61	1.72	2.11	1.39	0.82	0.54	0.35	0.49	21.7
1952	0.64	0.61	0.55	0.55	0.77	0.95	0.99	0.8	0.55	0.38	0.39	0.83	8.01
1953	2.62	7.71	5.3	1.71	0.82	1.48	1.09	0.92	1.13	1.06	0.73	0.8	25.4
1954	15.49	5.97	0.83	5.29	8.79	5.31	1.8	0.84	0.65	0.5	0.33	0.54	46.3
1955	0.91	1.07	0.71	0.28	0.63	11.5	5.49	1.43	0.99	0.81	0.58	0.67	25.1
1956	2.84	12.65	20.21	7.33	2.21	7.53	8.68	2.93	0.92	0.75	0.68	1.01	67.7
1957	3.1	2.33	1.79	4.38	9.03	3.88	6.59	2.79	0.62	0.45	0.41	0.4	35.8
1958	0.49	2.13	1.55	0.8	0.78	1.04	1.16	18.37	6.94	1.14	1.77	1.45	37.6
1959	1.15	1.06	0.96	0.87	0.79	2.07	1.92	1.88	1.29	0.81	0.72	0.9	14.4
1960	0.93	2.28	4.74	3.21	1.42	2.3	15.03	5.91	1.2	1.1	1.01	0.78	39.9
1961	0.68	3.84	2.14	1.07	1.17	6.98	2.99	0.84	0.63	0.41	0.53	0.68	22
1962	1.78	6.19	2.65	7.26	3.14	20.2	7.58	1.06	0.86	8.32	3.57	0.72	63.3
1963	0.9	2.95	1.8	8.4	6.15	4.24	5.8	2.4	15.76	6.19	0.95	0.78	56.3
1964	5.12	2.28	0.57	0.57	0.63	0.47	0.32	0.47	11.65	5.18	3.08	1.95	32.3

1965	11.77	7.77	2.05	0.86	0.79	0.52	0.35	8.06	3.62	0.89	0.65	0.78	38.1
1966	0.79	0.68	0.72	2.11	1.59	13.9	11.17	3	0.89	2.85	1.76	0.74	40.2
1967	0.51	0.83	0.83	0.64	0.72	0.82	0.8	0.61	0.41	0.33	0.51	1.25	8.26
1968	1.45	2.67	1.62	0.74	3.86	9.62	3.62	7.95	3.49	0.95	0.74	0.65	37.4
1969	0.83	1.89	1.34	0.68	0.6	0.54	0.44	0.5	0.83	0.91	7.65	3.64	19.9
1970	12.53	6.49	1.6	0.97	1.06	1.14	1.23	10.8	4.38	2.52	6.6	2.93	52.3
1971	10.82	4.45	1.11	0.96	10.17	4.19	0.93	0.66	0.57	0.56	0.52	0.42	35.4
1972	0.36	2.07	1.55	1	0.86	0.99	3.52	1.8	0.59	0.38	0.54	1.06	14.7
1973	1.38	6.6	2.81	0.82	1.66	3.34	1.81	9.77	4.38	1.34	0.83	0.54	35.3
1974	0.51	0.8	1.53	1.16	0.94	1.04	1.02	0.81	0.57	0.44	0.42	8.44	17.7
1975	3.59	0.86	4.39	2.22	8.95	29.1	11.18	5.77	2.5	0.79	0.57	0.83	70.8
1976	19.76	7.24	0.65	0.68	5.08	2.6	0.97	0.58	0.48	0.51	0.69	1.03	40.3
1977	2.26	7.41	7.93	2.71	0.95	1.01	42.72	16.6	1.76	0.93	0.72	0.81	85.8
1978	5.88	3.02	1.07	0.71	0.66	2.67	1.6	0.77	0.55	0.94	1.41	1.42	20.7
1979	2.11	1.35	0.82	0.6	0.66	0.79	0.67	0.58	0.52	0.44	0.38	5.08	14
1980	2.56	4.75	2.4	2.13	1.47	0.93	0.6	1.16	1.23	0.85	0.99	1.04	20.1
1981	0.72	0.62	0.56	0.7	0.75	12	5.92	1.49	0.84	0.66	0.48	0.41	25.1
1982	0.72	0.81	0.48	0.33	0.38	0.38	0.37	0.35	0.3	9.04	3.95	1.03	18.1
1983	1.02	2.88	1.75	2.98	1.88	1.29	2.54	1.65	1.21	5.05	2.5	0.97	25.7
1984	0.88	4.88	2.41	1.03	19.45	7.29	0.83	0.51	0.38	0.35	0.28	0.22	38.5
1985	1.6	5.33	2.38	3.62	1.78	0.85	0.86	0.68	0.48	0.35	0.75	3.43	22.1
1986	6.08	2.68	0.95	0.84	0.65	0.99	1.05	0.79	0.64	0.52	0.63	29.28	45.1
1987	10.84	4.92	2.32	0.82	7.78	22.5	7.73	5.97	2.92	3.06	2.87	1.51	73.3
1988	1.11	6.12	12.08	3.92	10.39	4.63	6.62	2.93	0.97	0.85	0.6	0.5	50.7
1989	5.3	11.16	3.71	0.75	0.65	6.23	2.75	0.64	0.41	0.31	0.67	0.96	33.5
1990	1.17	1.03	0.68	0.83	3.72	1.98	0.73	0.51	0.45	0.38	0.39	0.64	12.5
1991	4.75	6.24	2.22	0.77	0.66	0.58	0.69	0.64	0.46	0.34	0.34	0.53	18.2
1992	0.8	0.86	0.86	0.77	0.64	0.47	0.4	0.38	0.32	0.26	0.28	0.71	6.75
1993	2.45	1.73	5.17	2.23	12.91	5.56	1.04	0.47	0.3	0.4	0.84	0.81	33.9
1994	0.57	0.42	2.4	1.51	0.7	7.16	11.92	4.15	4.03	2.16	0.81	0.61	36.4
1995	0.82	0.92	14.03	5.87	4.88	2.2	0.8	0.66	0.51	3.58	2.05	0.87	37.2
1996	1.1	14.86	5.68	1.63	6.12	2.93	10.14	4.19	21.85	9.31	1.61	1.11	80.5
month	223.3	319.9	237.1	173.9	263.9	367	279.5	192.1	164.4	156.3	101.6	141.5	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.3	0.42	0.44	0.28	0.38	0.38	0.32	0.34	0.3	0.25	0.24	0.21	6.75
max	19.76	21.26	20.21	11.87	19.45	29.1	42.72	18.37	21.85	31.06	11.23	29.28	85.8
median	1.1	2.28	1.75	1.16	1.42	2.6	1.8	0.96	0.82	0.81	0.69	0.78	32.2
mean	2.9	4.15	3.08	2.26	3.43	4.76	3.63	2.49	2.14	2.03	1.32	1.84	34

Sum of the monthly means = 34.03

s.d.	3.8	4.54	3.57	2.44	4.05	5.46	5.55	3.46	3.7	4.04	1.77	3.75	18.5
c.v.	1.31	1.09	1.16	1.08	1.18	1.15	1.53	1.39	1.73	1.99	1.35	2.04	0.54

APPENDIX B

Details of the scores given to the determinants of riparian and instream habitats of river reaches in the study area using the protocol of Kleynhans (1999)

Table B1. Xura River: Upstream reach of river (Xura and Lusikisiki dam sites)

DETERMINANTS	SCORE	CONF.	COMMENTS
BIOTA (RIPARIAN & INSTREAM)		(1-4)	
Rare & endangered	3	1	Limited sampling data, but least one rare fish
Unique (endemic, isolated, etc.)	4	3	Possibly two unique fish, but requires verification
Intolerant (flow related)	3	2	Perennial system, flow for fish and invertebrates
Species/taxon richness	2	3	Rivers in region have relatively low diversity
RIPARIAN & INSTREAM HABITATS			
Diversity of types	2	3	Large pools, riffles, runs, waterfalls
Refugia value	2	3	Little human impact, large pools
Sensitivity to flow changes	3	3	Fairly small system, riffle habitat common
Sensitive to water quality changes	3	3	Moderately small system, low flows in spring
Migration route/corridor	1	3	Upper river reach, end of system
Conservation & natural areas	0	3	Lower gorge area relatively inaccessible, unspoiled
MEDIAN OF DETERMINANTS	2.50		

EC. IMP. & Sen. CLASS (EISC): **HIGH**

DEMC: SYSTEM **CLASS B: SMALL RISK ALLOWED**

DEMC:
PROF. OPINION (ENTER A, B, C, D) Class B
DESC: **CLASS B: LARGELY NATURAL**

PESC	SCORE	CONF.	COMMENTS
ASSESSMENT ATTRIBUTES (0 TO 5; 0=SERIOUS, 5=NATURAL)		(1-4)	
Flow modification	4	3	No dam or weirs, limited domestic and stock use
Inundation	4	3	No dams or weirs
Water quality modification	3	3	sediment, detergent, high population density
Introduced instream biota	5	1	None known
Bed modification	4	3	Possibly slight siltation
Riparian/bank condition	2	3	Largely modified riparian veg., some bank erosion
Mean	3.67		

PESC: ASSESSMENT SYSTEM **CLASS C: MODERATELY MODIFIED**

PESC: PROF. JUDGMENT (A -F) Class C/B

Table B1. Mzintlava River: Upper Catchment (excluding lower gorge section) (CONTINUED)

POT. FOR IMPROV. OF PESC SCORE WITHIN 5 YEARS	SCORE	CONF.	COMMENTS
(0 TO 5; 0=SERIOUS, 5=NATURAL)		(1-4)	
Flow modification	4		No potential for improvement
Inundation (automatic default)	4		No potential for improvement
Water quality modification	3		No potential for improvement
Instream biota (automatic default)	5		No potential for improvement
Bed modification	4		No potential for improvement
Riparian/bank condition	2		No potential for improvement
Mean	3.67		

BEST AEMC **CLASS C: MODERATELY MODIFIED**

SUMMARY:

EC. IMP. & SENS. CLASS (EISC)	HIGH
DEMC:	CLASS B: SMALL RISK ALLOWED
DESC:	CLASS B: LARGELY NATURAL
PESC: (ASSESSMENT SYSTEM)	CLASS C: MODERATELY MODIFIED

BEST (ATTAINABLE) AEMC **CLASS C: MODERATELY MODIFIED**

QUERIES

PESC=DESC?	NO
PESC>DESC?	NO
PESC<DESC?	YES
AEMC<DESC?	YES
AEMC=DESC?	NO
AEMC>DESC?	NO

AEMC FOR HYDRO. MODEL **CLASS C: MODERATELY MODIFIED**

Table B2. Xura River (Reach downstream of Xurana R. junction): Inclusive of gorge zone in lower reaches

DETERMINANTS	SCORE	CONF.	COMMENTS
BIOTA (RIPARIAN & INSTREAM)		(1-4)	
Rare & endangered	3	2	Limited sampling data, but least one rare fish
Unique (endemic, isolated, etc.)	4	3	Possibly two unique fish, but requires verification
Intolerant (flow related)	3	3	Perennial system, flow for fish and invertebrates
Species/taxon richness	2	3	Rivers in region have relatively low diversity
RIPARIAN & INSTREAM HABITATS			
Diversity of types	4	3	Large pools, riffles, runs, waterfalls
Refugia value	4	3	Little human impact, inaccessible, large pools
Sensitivity to flow changes	3	3	Fairly small system, riffle habitat common
Sensitive to water quality changes	3	3	Moderately small system, low flows in spring
Migration route/corridor	1	3	Same as upper section
Conservation & natural areas	3	3	Lower gorge area relatively inaccessible, unspoiled
MEDIAN OF DETERMINANTS	3.00		

EC. IMP. & Sen. CLASS (EISC): **HIGH**

DEMC: SYSTEM **CLASS B: SMALL RISK ALLOWED**

DEMC:
PROF. OPINION (ENTER A, B, C, D) Class B
DESC: **CLASS B: LARGELY NATURAL**

PESC	SCORE	CONF.	COMMENTS
ASSESSMENT ATTRIBUTES (0 TO 5; 0=SERIOUS, 5=NATURAL)		(1-4)	
Flow modification	2	3	Weir at Lusikisiki, most of low flow abstracted
Inundation	5	3	Only one weir
Water quality modification	2	3	Lusikisiki town -sewage effluent, detergents, etc.
Introduced instream biota	5	2	None known, limited sampling
Bed modification	4	3	Possibly slight siltation
Riparian/bank condition	3	3	Largely protected within gorge, rest impacted
Mean	3.50		

PESC: ASSESSMENT SYSTEM **CLASS C: MODERATELY MODIFIED**

PESC: PROF. JUDGMENT (A -F) Class C/B

Table B2 (cont.). Xura River (lower): Reach downstream of Xurana R. junction, including gorge zone

POT. FOR IMPROV. OF PESC SCORE WITHIN 5 YEARS	SCORE	CONF.	COMMENTS
(0 TO 5; 0=SERIOUS, 5=NATURAL)		(1-4)	
Flow modification	4		Dam releases, water abstraction management
Inundation (automatic default)	5		No potential for improvement
Water quality modification	3		Pollution control programme in Lusikisiki
Instream biota (automatic default)	5		No potential for improvement
Bed modification	4		No potential for improvement
Riparian/bank condition	3		No potential for improvement
Mean	4.00		

BEST AEMC **CLASS B: LARGELY NATURAL**

SUMMARY:

EC. IMP. & SENS. CLASS (EISC)	HIGH
DEMC:	CLASS B: SMALL RISK ALLOWED
DESC:	CLASS B: LARGELY NATURAL
PESC: (ASSESSMENT SYSTEM)	CLASS C: MODERATELY MODIFIED

BEST (ATTAINABLE) AEMC **CLASS B: LARGELY NATURAL**

QUERIES

PESC=DESC?	NO
PESC>DESC?	NO
PESC<DESC?	YES
AEMC<DESC?	YES
AEMC=DESC?	NO
AEMC>DESC?	NO

AEMC FOR HYDRO. MODEL **CLASS B: LARGELY NATURAL**

Table B3. Mzintlava River: Upper catchment, excluding gorge zone (Lower Mzintlava site)

DETERMINANTS	SCORE	CONF.	COMMENTS
BIOTA (RIPARIAN & INSTREAM)		(1-4)	
Rare & endangered	3	2	No data, but adjacent rivers have rare fish
Unique (endemic, isolated, etc.)	4	3	No data, but adjacent rivers have unique fish
Intolerant (flow related)	3	3	Perennial system, flow for fish and invertebrates
Species/taxon richness	2	3	Region and adjacent rivers have low diversity
RIPARIAN & INSTREAM HABITATS			
Diversity of types	2	3	Pool and riffles, odd small waterfall
Refugia value	2	2	No special attributes
Sensitivity to flow changes	3	3	Moderately small system, riffle habitat common
Sensitive to water quality changes	3	3	Moderately small system, low flows in spring
Migration route/corridor	1	3	Upper river reach, end of system
Conservation & natural areas	0	3	None present, high human pressure
MEDIAN OF DETERMINANTS	2.50		

EC. IMP. & Sen. CLASS (EISC) **HIGH**

DEMC: SYSTEM **CLASS B: SMALL RISK ALLOWED**

DEMC: Prof. Opinion (A-D) ***Class C to B***

DESC: **CLASS B: LARGELY NATURAL**

PESC	SCORE	CONF.	COMMENTS	
ASSESSMENT ATTRIBUTES				
(0 TO 5; 0=SERIOUS, 5=NATURAL)		(1-4)		
Flow modification	4	3	No dam or weirs, domestic and stock use only	
Inundation	5	2	No dam or weirs	
Water quality modification	3	3	some siltatio n, detergents, cattle,	
Introduced instream biota	5	2	None known	
Bed modification	3	3	Siltation, algal beds present on river bed	
Riparian/bank condition	2	3	Heavily utilised, modified, erosion gullies	
MEAN	3.67			3.5

PESC: ASSESSMENT SYS TEM **CLASS C: MODERATELY MODIFIED**

PESC*: Prof. Opinion (A -F)* ***Class C***

Table B3 (continued). Mzintlava River: Upper catchment, upstream of gorge zone

POT. FOR IMPROV. OF PESC: SCORE WITHIN 5 YEARS	**SCORE**	**CONF.**	**COMMENTS**
(0 TO 5; 0=SERIOUS, 5=NATURAL)		(1-4)	
Flow modification	4		No potential for improvement
Inundation (automatic default)	5	2	No potential for improvement
Water quality modification	3		No potential for improvement
Instream biota (automatic default)	5	2	No potential for improvement
Bed modification	3		No potential for improvement
Riparian/bank condition	2		No potential for improvement
Mean	3.67		

BEST AEMC	**CLASS C: MODERATELY MODIFIED**

SUMMARY:

EC. IMP. & SENS. CLASS (EISC)	HIGH
DEMC:	CLASS B: SMALL RISK ALLOWED
DESC:	CLASS B: LARGELY NATURAL
PESC: (ASSESSMENT SYSTEM)	CLASS C: MODERATELY MODIFIED
BEST (ATTAINABLE) AEMC	**CLASS C: MODERATELY MODIFIED**

QUERIES:

PESC=DESC?	NO
PESC>DESC?	NO
PESC<DESC?	YES
AEMC<DESC?	NO
AEMC=DESC?	YES
AEMC>DESC?	NO
AEMC FOR HYDRO. MODEL	**CLASS C: MODERATELY MODIFIED**

Table B4. Mzintlava River: Lower reaches, including lower gorge area.

DETERMINANTS	SCORE	CONF.	COMMENTS
BIOTA (RIPARIAN & INSTREAM)		(1-4)	
Rare & endangered	3	2	No data but adjacent rivers have rare fish
Unique (endemic, isolated, etc.)	4	3	No data but adjacent rivers have unique fish
Intolerant (flow related)	3	3	Perennial system, flow for fish and invertebrates
Species/taxon richness	2	3	Adjacent rivers low diversity
RIPARIAN & INSTREAM HABITATS			
Diversity of types	3	3	Large pools, riffles, runs, waterfalls
Refugia value	3	3	Little human impact, large pools
Sensitivity to flow changes	3	3	Fairly small system, riffle habitat common
Sensitive to water quality changes	3	3	Moderately small system, low flows in spring
Migration route/corridor	1	3	Upper river reach, end of system
Conservation & natural areas	3	3	Lower gorge area relatively inaccessible, unspoiled
MEDIAN OF DETERMINANTS	3.00		

EC. IMP. & Sen. CLASS (EISC) **HIGH**

DEMC: SYSTEM **CLASS B: SMALL RISK ALLOWED**

DEMC:
PROF. OPINION (ENTER A, B, C, D)
DESC: **CLASS B: LARGELY NATURAL**

PESC	SCORE	CONF.	COMMENTS
ASSESSMENT ATTRIBUTES (0 TO 5; 0=SERIOUS, 5=NATURAL)		(1-4)	
Flow modification	4	3	No dam or weirs, limited domestic and stock use
Inundation	5	3	No dams or weirs
Water quality modification	4	3	little sediment, limited human impact
Introduced instream biota	5	2	None known
Bed modification	4	3	Possibly slight siltation
Riparian/bank condition	4	3	Limited human impact, difficult access
Mean	4.33		

PESC: ASSESSMENT SYSTEM **CLASS B: LARGELY NATURAL**

PESC: PROF. JUDGMENT (A -F) Class B

Table B4 (continued). Mzintlava River: lower reaches, including gorge section.

POT.FOR IMPROV. OF PESC: SCORE WITHIN 5 YEARS	**SCORE**	**CONF.**	**COMMENTS**
(0 TO 5; 0=SERIOUS, 5=NATURAL)		(1-4)	
Flow modification	4		No potential for improvement
Inundation (automatic default)	5		No potential for improvement
Water quality modification	4		No potential for improvement
Instream biota (automatic default)	5		No potential for improvement
Bed modification	4		No potential for improvement
Riparian/bank condition	4		No potential for improvement
Mean	4.33		

BEST AEMC	**CLASS B: LARGELY NATURAL**

SUMMARY:

EC. IMP. & SENS. CLASS (EISC)	HIGH
DEMC:	CLASS B: SMALL RISK ALLOWED
DESC:	CLASS B: LARGELY NATURAL
PESC: (ASSESSMENT SYSTEM)	CLASS B: LARGELY NATURAL
BEST (ATTAINABLE) AEMC	**CLASS B: LARGELY NATURAL**

QUERIES

PESC=DESC?	YES
PESC>DESC?	NO
PESC<DESC?	NO
AEMC<DESC?	NO
AEMC=DESC?	YES
AEMC>DESC?	NO
AEMC FOR HYDRO. MODEL	**CLASS B: LARGELY NATURAL**

APPENDIX C

The ecological modifying factors scores for the upper and lower reaches of the Xura and Mzintlava rivers using the ESCORE component of the IWR DSS system.

Table C1. Ecological factors scores for the upper reaches of the Xura and Mzintlava rivers.

Summary of ecological factors scores for
Upstream Xura and Mzintlava

IFR Component and score	**Maint. Low Flow : Annual Total**			**9.25**
Temperature	: Weight =	3.00	Value =	0.00
Dry season in summer ?		No		
Shallow enough to affect temp. significantly ?		No		
Slow enough to affect temperature significantly ?		No		
Channel shaded in the summer ?		No		
Marginal Habitat	: Weight =	5.00 :	Value =	2.50
Marginal habitat an important biotope ?		: Yes		
Parabolic X-sectional channel shape ?		: Yes		
Multi-thread channel pattern ?		: No		
Perennial side channels present naturally ?		: No		
Instream Habitat	Weight =	5.00 :	Value =	1.25
Instream habitat an important biotope ?		: Yes		
Rectangular X-sectional channel shape ?		: No		
Single channel ?		: Yes		
Rough (cobble) channel bed ?		: Yes		
Steep gradient ?		: No		
Riparian Vegetation	Weight =	5.00 :	Value =	2.50
Significant riparian water requirement ?		: Yes		
Bedrock channel ?		: Yes		
Multi-thread channel ?		: No		
TSS Transport Capacity	: Weight =	4.00 :	Value =	3.00
Low flows significant for sediment transport ?		: Yes		
High catchment sediment yield ?		: Yes		
Coarse input sediment grain size ?		: No		
Low gradient ?		: No		
Low width:depth ratio (narrow & deep) ?		: No		
Cobble bed ?		: Yes		
IFR Component and score	**Drought Low Flow Annual Total**			**10.75**
Temperature	: Weight =	4.00 :	Value	
Dry season in summer ?		: Yes		
Shallow enough to affect temp. significantly ?		: Yes		
Slow enough to affect temperature significantly ?		: No		
Channel shaded in the summer ?		: No		
Marginal Habitat	: Weight =	5.00 :	Value =	
Marginal habitat an important biotope ?		: Yes		
Parabolic X-sectional channel shape ?		: Yes		
Multi-thread channel pattern ?		: No		
Perennial side channels present naturally ?		: No		
Temporary refuge areas available for biota ?		: Yes		
Instream Habitat	: Weight =	5.00 :	Value =	1.25
Instream habitat an important biotope ?		: Yes		
Rectangular X-sectional channel shape ?		: No		
Single channel ?		: Yes		
Rough (cobble) channel bed ?		: Yes		
Steep gradient ?		: No		
Temporary refuge areas available for biota ?		: Yes		
Riparian Vegetation	Weight =	6.00 :	Value =	3.00
Significant riparian water requirement ?		: Yes		
Bedrock channel ?		: Yes		
Multi-thread channel ?		: No		
IFR Component and score : Maint. Low Flow : Seasonal Dist				**3.00**

Table C1 (continued). Ecological factors scores for the upper reaches of the Xura and Mzintlava rivers.

Riparian Vegetation	: Weight =	10.00	: Value =		
Is year round water necessary for survival ?		: Yes			
Instream Habitat	: Weight =	6.00	Value =	0	
Large mammals and reptiles present ?		No			
Sediment Transport	: Weight =	10.00	: Value =	10.00	
Wet season flows facilitate transport of TSS ?		: Yes			
Migration	: Weight =	6.00	: Value =	3.00	
Wet season flows facilitate fish & eel migration ?		: Yes			
Secondary Channels/Distributaries	Weight =	6.00	: Value =	0.00	
Seasonal side channels ?		: No			
IFR Component and score Maint. High Flow : Annual Total				**2.50**	
Floodplain Inundation	Weight =	15.00	Value =	0.00	
Presence of flood plain ?		No			
Sediment Mobilisation	: Weight =	15.00	: Value =	0.00	
High sediment input ?		: Yes			
Activation of Seasonal Channels and Pools	: Weight =	5.00	Value =	0.00	
Presence of temporary pools and side channels ?		No			
Riparian Vegetation	: Weight =	5.00	: Value =	2.50	
Vegetation established on bedrock patches ?		: No			
Subsurface water and channel flow poorly connected ?		: Yes			

Table C2. Ecological factor scores for the lower (gorge) reaches of the Xura and Mzintlava rivers.

Summary of ecological factors scores for :
Gorge Xura and Mzintlava

IFR Component and score : Maint. Low Flow : Annual Total				**10.50**
Temperature	: Weight =	3.00	Value =	0.00
Dry season in summer ?				
Shallow enough to affect temp. significantly ?				
Slow enough to affect temperature significantly ?		No		
Channel shaded in the summer ?		No		
Marginal Habitat	: Weight =	5.00 :	Value =	2.50
Marginal habitat an important biotope ?		: Yes		
Parabolic X-sectional channel shape ?		: Yes		
Multi-thread channel pattern ?		: No		
Perennial side channels present naturally ?		: No		
Instream Habitat	: Weight =	5.00 :	Value =	2.50
Instream habitat an important biotope ?		: Yes		
Rectangular X-sectional channel shape ?		: No		
Single channel ?		: Yes		
Rough (cobble) channel bed ?		: Yes		
Steep gradient ?		: Yes		
Riparian Vegetation	: Weight =	5.00 :	Value =	2.50
Significant riparian water requirement ?		: Yes		
Bedrock channel ?		: Yes		
Multi-thread channel ?		: No		
TSS Transport Capacity	: Weight =	4.00	Value =	3.00
Low flows significant for sediment transport ?				
High catchment sediment yield ?		Yes		
Coarse input sediment grain size ?		No		
Low gradient ?		No		
Low width:depth ratio (narrow & deep) ?		No		
Cobble bed ?		Yes		
IFR Component and score : Drought Low Flow Annual Total				**12.00**
Temperature	: Weight =	4.00 :	Value =	4.00
Dry season in summer ?		: Yes		
Shallow enough to affect temp. significantly ?		: Yes		
Slow enough to affect temperature significantly ?		: No		
Channel shaded in the summer ?		: No		
Marginal Habitat	: Weight =	5.00 :	Value =	
Marginal habitat an important biotope ?		: Yes		
Parabolic X-sectional channel shape ?		: Yes		
Multi-thread channel pattern ?		: No		
Perennial side channels present naturally ?		: No		
Temporary refuge areas available for biota ?		: Yes		
Instream Habitat	: Weight =	5.00 :	Value =	2.50
Instream habitat an important biotope ?		: Yes		
Rectangular X-sectional channel shape ?		: No		
Single channel ?		: Yes		
Rough (cobble) channel bed ?		: Yes		
Steep gradient ?		: Yes		
Temporary refuge areas available for biota ?		: Yes		
Riparian Vegetation	Weight =	6.00 :	Value =	3.00
Significant riparian water requirement ?		: Yes		
Bedrock channel ?		: Yes		
Multi-thread channel ?		: No		
IFR Component and score : Maint. Low Flow Seasonal Dist.				**3.00**

Table C2 (continued). Ecological factor scores for the lower (gorge) reaches of the Xura and Mzintlava rivers.

Riparian Vegetation	: Weight =	10.00	: Value =	-10.00
Is year round water necessary for survival ?		: Yes		
Instream Habitat	: Weight =	6.00	: Value =	0.00
Large mammals and reptiles present ?		: No		
Sediment Transport	: Weight =	10.00	: Value =	10.00
Wet season flows facilitate transport of TSS ?		: Yes		
Migration	: Weight =	6.00	: Value =	3.00
Wet season flows facilitate fish & eel migration ?		: Yes		
Secondary Channels/Distributaries	Weight =	6.00	: Value =	0.00
Seasonal side channels ?		: No		
IFR Component and score Maint. High Flow : Annual Total				**5.00**
Floodplain Inundation	Weight =	15.00	Value =	
Presence of flood plain ?		No		
Sediment Mobilisation	: Weight =	15.00	: Value =	0.00
High sediment input ?		: Yes		
Activation of Seasonal Channels and Pools	: Weight =	5.00	Value =	0.00
Presence of temporary pools and side channels ?		No		
Riparian Vegetation	: Weight =	5.00	: Value =	5.00
Vegetation established on bedrock patches ?		: Yes		
Subsurface water and channel flow poorly connected ?		: Yes		

APPENDIX D

Summary of IFR estimates for the 5 proposed dam sites for the Lusikisiki Bulk Water Supply Scheme

Table D1. Summary of IFR estimates for the proposed Zalu dam site on Xura River.

Summary of IFR estimate for Quaternary Catchment Area
Total Runoff : REGION I Zalu

Annual Flows (Mill. cu. m or index values):

MAR	=	11.949
S.Dev.	=	7.437
CV	=	0.622
Q75	=	0.270
Q75/MMF	=	0.271
BFI Index	=	0.457
CV(JJA+JFM) Index	=	3.166

IFR Management Class = B/C

Total IFR	=	2.793	(23.37 %MAR)
Maint. Lowflow	=	2.040	(17.07 %MAR)
Drought Lowflow	=	0.958	(8.02 %MAR)
Maint. Highflow	=	0.753	(6.30 %MAR)

Monthly Distributions (Mill. cu. m.
Distribution Type : T Reg. Coast

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.052	1.562	1.484	0.155	0.074	0.075	0.231
Nov	1.781	2.090	1.173	0.219	0.100	0.303	0.522
Dec	1.362	1.588	1.165	0.197	0.091	0.058	0.255
Jan	0.903	0.923	1.022	0.155	0.074	0.047	0.202
Feb	1.158	1.480	1.278	0.150	0.072	0.089	0.240
Mar	1.481	2.081	1.405	0.210	0.096	0.116	0.326
Apr	1.165	2.130	1.828	0.211	0.097	0.065	0.276
May	0.721	1.083	1.503	0.167	0.079	0.000	0.167
Jun	0.664	1.309	1.970	0.158	0.075	0.000	0.158
Jul	0.636	1.514	2.379	0.153	0.073	0.000	0.153
Aug	0.410	0.592	1.445	0.139	0.067	0.000	0.139
Sep	0.615	1.425	2.318	0.125	0.061	0.000	0.125

Table D2. Summary of IFR estimates for the proposed Lusikisiki dam site on the Xura River

Summary of IFR estimate for Quaternary Catchment Area
Total Runoff : REGION I Lusik

Annual Flows (Mill. cu. m or index values)

MAR	=	15.511
S.Dev.	=	9.431
CV	=	0.608
Q75	=	0.350
Q75/MMF	=	0.271
BFI Index	=	0.464
CV(JJA+JFM) Index	=	3.139

IFR Management Class = B/C

Total IFR	=	3.691	(23.79 %MAR)
Maint. Lowflow	=	2.673	(17.23 %MAR)
Drought Lowflow	=	1.241	(8.00 %MAR)
Maint. Highflow	=	1.018	(6.56 %MAR)

Monthly Distributions (Mill. cu. m.
Distribution Type : T Reg. Coast

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.366	2.009	1.470	0.204	0.096	0.102	0.305
Nov	2.312	2.683	1.160	0.287	0.129	0.410	0.696
Dec	1.769	2.038	1.152	0.259	0.118	0.078	0.337
Jan	1.172	1.183	1.009	0.203	0.096	0.063	0.266
Feb	1.504	1.901	1.264	0.197	0.093	0.121	0.318
Mar	1.923	2.675	1.392	0.276	0.125	0.156	0.432
Apr	1.514	2.743	1.812	0.276	0.125	0.088	0.364
May	0.935	1.393	1.489	0.219	0.102	0.000	0.219
Jun	0.862	1.686	1.956	0.207	0.097	0.000	0.207
Jul	0.825	1.950	2.364	0.201	0.095	0.000	0.201
Aug	0.531	0.762	1.435	0.182	0.087	0.000	0.182
Sep	0.798	1.836	2.302	0.164	0.079	0.000	0.164

Table D3. Summary of IFR estimates for the proposed Xura dam site on Xura River.

Summary of IFR estimate for Quaternary Catchment Area
Total Runoff : REGION I Xura

Annual Flows (Mill. cu. m or index values):

MAR	=	37.858
S.Dev.	=	23.568
CV	=	0.623
Q75	=	0.850
Q75/MMF	=	0.269
BFI Index	=	0.456
CV(JJA+JFM) Index	=	3.169

IFR Management Class = B

Total IFR	=	11.068	(29.23 %MAR)
Maint. Lowflow	=	8.030	(21.21 %MAR)
Drought Lowflow	=	3.031	(8.01 %MAR)
Maint. Highflow	=	3.038	(8.02 %MAR)

Monthly Distributions (Mill. cu. m.)
Distribution Type : T Reg. Coast

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	3.334	4.948	1.484	0.610	0.234	0.304	0.913
Nov	5.641	6.621	1.174	0.868	0.316	1.222	2.090
Dec	4.316	5.031	1.165	0.781	0.288	0.233	1.015
Jan	2.862	2.925	1.022	0.608	0.233	0.189	0.797
Feb	3.671	4.689	1.278	0.589	0.227	0.361	0.950
Mar	4.694	6.594	1.405	0.834	0.305	0.467	1.301
Apr	3.693	6.752	1.828	0.836	0.306	0.262	1.098
May	2.284	3.431	1.502	0.657	0.249	0.000	0.657
Jun	2.105	4.150	1.972	0.620	0.237	0.000	0.620
Jul	2.014	4.798	2.382	0.601	0.231	0.000	0.601
Aug	1.297	1.878	1.448	0.541	0.212	0.000	0.541
Sep	1.947	4.517	2.319	0.485	0.194	0.000	0.485

Table D4. Summary of IFR estimates for the proposed Lower Mzintlava dam site on Mzintlava River.

Summary of IFR estimate for Quaternary Catchment Area :
Total Runoff : REGION I L.Mzi

Annual Flows (Mill. cu. m or index values):

MAR	=	25.849
S.Dev.	=	14.045
CV	=	0.543
Q75	=	0.510
Q75/MMF	=	0.237
BFI Index	=	0.439
CV(JJA+JFM) Index	=	2.826

IFR Management Class = B/C

Total IFR	=	6.361	(24.61 %MAR)
Maint. Lowflow	=	4.537	(17.55 %MAR)
Drought Lowflow	=	2.085	(8.07 %MAR)
Maint. Highflow	=	1.823	(7.05 %MAR)

Monthly Distributions (Mill. cu. m.)
Distribution Type : T Reg. Coast

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	2.203	2.887	1.310	0.334	0.156	0.179	0.513
Nov	3.156	3.449	1.093	0.412	0.187	0.288	0.700
Dec	2.339	2.709	1.158	0.366	0.169	0.144	0.510
Jan	1.715	1.852	1.080	0.313	0.148	0.101	0.414
Feb	2.604	3.080	1.183	0.339	0.158	0.229	0.568
Mar	3.617	4.150	1.148	0.505	0.224	0.708	1.212
Apr	2.757	4.216	1.529	0.494	0.220	0.175	0.668
May	1.895	2.628	1.386	0.421	0.191	0.000	0.421
Jun	1.622	2.810	1.732	0.377	0.173	0.000	0.377
Jul	1.542	3.073	1.993	0.364	0.168	0.000	0.364
Aug	1.003	1.348	1.344	0.330	0.155	0.000	0.330
Sep	1.396	2.845	2.038	0.283	0.136	0.000	0.283

Table D5. Summary of IFR estimates for the proposed Tungwane dam site on Mzintlava River.

Summary of IFR estimate for Quaternary Catchment Area
Total Runoff : REGION I Tungw

Annual Flows (Mill. cu. m or index values):

MAR	=	33.590
S.Dev.	=	18.771
CV	=	0.559
Q75	=	0.660
Q75/MMF	=	0.236
BFI Index	=	0.431
CV(JJA+JFM) Index	=	2.855

IFR Management Class = B

Total IFR	=	10.149	(30.22 %MAR)
Maint. Lowflow	=	7.254	(21.60 %MAR)
Drought Lowflow	=	2.677	(7.97 %MAR)
Maint. Highflow	=	2.895	(8.62 %MAR)

Monthly Distributions (Mill. cu. m.
Distribution Type : T Reg. Coast

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	2.863	3.790	1.324	0.531	0.200	0.285	0.816
Nov	4.102	4.536	1.106	0.661	0.241	0.457	1.118
Dec	3.039	3.561	1.171	0.585	0.217	0.228	0.814
Jan	2.229	2.436	1.093	0.496	0.190	0.161	0.657
Feb	3.383	4.046	1.196	0.539	0.203	0.363	0.903
Mar	4.700	5.454	1.160	0.814	0.288	1.124	1.938
Apr	3.583	5.530	1.543	0.796	0.282	0.277	1.074
May	2.462	3.448	1.401	0.675	0.245	0.000	0.675
Jun	2.108	3.682	1.747	0.602	0.222	0.000	0.602
Jul	2.004	4.025	2.009	0.581	0.216	0.000	0.581
Aug	1.302	1.770	1.359	0.525	0.198	0.000	0.525
Sep	1.815	3.727	2.054	0.447	0.174	0.000	0.447

APPENDIX E

IFR Assurance Rule Curves for the 5 proposed dam sites for the Lusikisiki Bulk Water Supply Scheme

Table E1. Summary of IFR rule curves for Zalu site, Xura R.

Total Runoff : REGION I Zalu

Regional Type : T Reg. Coast

EMC = B/C

Data are given in m^3 * 10^6 monthly flow volume

Month				%	**Points**					
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.268	0.267	0.263	0.255	0.241	0.215	0.179	0.137	0.1	0.083
Nov	0.85	0.771	0.703	0.642	0.581	0.479	0.411	0.313	0.203	0.133
Dec	0.348	0.333	0.319	0.304	0.287	0.256	0.226	0.181	0.13	0.098
Jan	0.237	0.236	0.234	0.23	0.222	0.208	0.183	0.147	0.106	0.079
Feb	0.278	0.277	0.274	0.269	0.259	0.24	0.21	0.165	0.114	0.082
Mar	0.476	0.446	0.418	0.392	0.364	0.316	0.276	0.217	0.151	0.11
Apr	0.323	0.321	0.317	0.308	0.291	0.261	0.218	0.168	0.125	0.104
May	0.2	0.199	0.196	0.191	0.182	0.165	0.142	0.114	0.09	0.079
Jun	0.189	0.188	0.185	0.181	0.171	0.156	0.134	0.108	0.086	0.076
Jul	0.183	0.182	0.18	0.175	0.166	0.151	0.129	0.105	0.083	0.07
Aug	0.166	0.165	0.163	0.159	0.151	0.137	0.118	0.096	0.077	0.068
Sep	0.149	0.149	0.147	0.143	0.136	0.124	0.107	0.087	0.07	0.062

Table E2. Summary of IFR rule curves for Lusikisiki Site, Xura R.

Total Runoff : REGION I Lusikisiki

Regional Type : T Reg. Coast

EMC = B/C

Data are given in m^3 * 10^6 monthly flow volume

Month					**%**		**Points**			
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.355	0.353	0.348	0.338	0.318	0.284	0.236	0.179	0.13	0.107
Nov	1.138	1.032	0.94	0.857	0.776	0.637	0.546	0.416	0.268	0.174
Dec	0.461	0.44	0.421	0.401	0.378	0.338	0.297	0.238	0.17	0.127
Jan	0.312	0.311	0.309	0.304	0.293	0.274	0.241	0.193	0.138	0.103
Feb	0.368	0.367	0.363	0.357	0.343	0.318	0.277	0.218	0.15	0.107
Mar	0.633	0.592	0.555	0.52	0.483	0.418	0.364	0.286	0.198	0.143
Apr	0.426	0.424	0.419	0.406	0.383	0.344	0.287	0.22	0.163	0.136
May	0.262	0.26	0.257	0.251	0.238	0.217	0.185	0.149	0.117	0.103
Jun	0.247	0.246	0.243	0.236	0.224	0.204	0.175	0.141	0.111	0.098
Jul	0.24	0.239	0.235	0.229	0.217	0.197	0.169	0.136	0.108	0.095
Aug	0.217	0.216	0.213	0.208	0.197	0.179	0.154	0.125	0.099	0.088
Sep	0.195	0.195	0.192	0.188	0.178	0.163	0.14	0.114	0.091	0.08

Table E3. Summary of IFR rule curves for Xura Site, Xura R.

Total Runoff : REGION I Xura

Regional Type : T Reg. Coast

EMC = B

Data are given in m^3 * 10^6 monthly flow volume

Month					**%**	**Points**				
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.061	1.055	1.039	1.006	0.943	0.836	0.681	0.499	0.342	0.269
Nov	3.411	3.094	2.818	2.569	2.32	1.72	1.55	1.207	0.743	0.449
Dec	1.387	1.325	1.266	1.205	1.132	1.004	0.871	0.678	0.457	0.317
Jan	0.933	0.931	0.923	0.906	0.872	0.809	0.703	0.548	0.37	0.256
Feb	1.099	1.095	1.085	1.063	1.019	0.941	0.81	0.622	0.406	0.268
Mar	1.903	1.78	1.669	1.563	1.446	1.245	1.071	0.822	0.538	0.359
Apr	1.285	1.278	1.26	1.22	1.144	1.016	0.831	0.613	0.425	0.33
May	0.785	0.781	0.771	0.749	0.706	0.634	0.529	0.407	0.301	0.252
Jun	0.74	0.736	0.726	0.704	0.663	0.595	0.497	0.383	0.285	0.24
Jul	0.718	0.713	0.703	0.681	0.64	0.56	0.47	0.37	0.277	0.234
Aug	0.647	0.643	0.634	0.615	0.58	0.521	0.436	0.338	0.254	0.215
Sep	0.579	0.577	0.569	0.553	0.523	0.471	0.396	0.308	0.232	0.197

Table E4. Summary of IFR rule curves for lower Mzintlava dam site, Mzintlava R.:

Total Runoff : REGION I Lower Mzintlava
Regional Type : T Reg. Coast
EMC = B/C

Data are given in m^3 * 10^6 monthly flow volume

Month				**%**	**Points**					
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.595	0.592	0.584	0.567	0.533	0.476	0.395	0.298	0.215	0.177
Nov	1.051	0.976	0.91	0.847	0.781	0.669	0.581	0.455	0.311	0.22
Dec	0.717	0.68	0.645	0.611	0.573	0.506	0.444	0.354	0.251	0.186
Jan	0.485	0.484	0.48	0.471	0.455	0.425	0.374	0.3	0.214	0.16
Feb	0.655	0.653	0.647	0.635	0.61	0.566	0.491	0.384	0.262	0.184
Mar	1.978	1.794	1.635	1.492	1.35	1.11	0.87	0.72	0.465	0.301
Apr	0.781	0.777	0.767	0.744	0.701	0.628	0.522	0.398	0.291	0.24
May	0.503	0.501	0.495	0.482	0.457	0.415	0.354	0.283	0.221	0.193
Jun	0.45	0.448	0.442	0.43	0.408	0.37	0.316	0.254	0.2	0.175
Jul	0.435	0.432	0.426	0.414	0.392	0.356	0.304	0.244	0.193	0.17
Aug	0.395	0.393	0.388	0.378	0.358	0.325	0.279	0.224	0.178	0.156
Sep	0.339	0.337	0.333	0.325	0.309	0.281	0.242	0.196	0.156	0.137

Table E5. Summary of IFR rule curves for Tungwane Site, Mzintlava R.:

Total Runoff : REGION I Tungwane

Regional Type : T Reg. Coast

EMC = B

Data are given in m^3 * 10^6 monthly flow volume

Month					**%**	**Points**				
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.946	0.941	0.927	0.897	0.84	0.744	0.604	0.441	0.299	0.233
Nov	1.677	1.557	1.451	1.35	1.242	1.058	0.907	0.692	0.447	0.292
Dec	1.143	1.083	1.027	0.971	0.908	0.797	0.689	0.534	0.357	0.244
Jan	0.769	0.767	0.76	0.746	0.718	0.665	0.578	0.45	0.303	0.209
Feb	1.042	1.038	1.028	1.007	0.966	0.89	0.765	0.584	0.376	0.244
Mar	3.155	2.864	2.61	2.38	2.151	1.761	1.09	0.95	0.58	0.38
Apr	1.255	1.248	1.229	1.19	1.115	0.988	0.804	0.589	0.403	0.316
May	0.807	0.803	0.792	0.769	0.724	0.648	0.539	0.411	0.3	0.249
Jun	0.719	0.715	0.705	0.684	0.643	0.575	0.479	0.367	0.27	0.225
Jul	0.694	0.689	0.679	0.657	0.617	0.552	0.459	0.352	0.261	0.219
Aug	0.627	0.624	0.615	0.597	0.562	0.503	0.42	0.323	0.24	0.201
Sep	0.535	0.532	0.525	0.51	0.481	0.433	0.363	0.281	0.21	0.177

ANNEXURE 1

Copy of document by Kleynhans (1999) outlining the procedure determine the desktop estimate (DE) of the ecological reserve for the National Water Balance Model for South Africa (WBDE)

PRELIMINARY

A PROCEDURE FOR THE DETERMINATION OF THE ECOLOGICAL RESERVE FOR THE PURPOSES OF THE NATIONAL WATER BALANCE MODEL FOR SOUTH AFRICAN RIVERS

C.J. Kleynhans

Institute for Water Quality Studies
DWAF

June 1999

INTRODUCTION

In terms of the South African Water Law, the reserve for all significant water resources must be determined. This consists of the reserve for basic human needs as well as the requirements of aquatic ecosystems. The latter is referred to as the ecological component of the Reserve and is the subject of this document.

The Directorate: Water Resources Planning requires a rough, desktop estimate (i.e. based on available information) of the ecological flow requirements of rivers for the purposes of the National Water Balance Model (NWBM). These requirements have been specified to be at the level of quaternary catchments as indicated in WR90 (Midgley *et al.* 1990). However, quaternary catchment delineations are not based on ecological principles. To provide some ecological basis for the desktop estimate (DE; previously referred to as the "planning estimate"), it was decided to base flow requirements on an index of the ecological importance and sensitivity (EISC; ecological importance and sensitivity class) of rivers in quaternary catchments. This index is then used as an indicator of the default ecological management class (DEMC) that can then be compared to the present ecological status class (PESC; i.e. current condition or ecological integrity status). The DEMC relates to a default ecological status class (DESC), which in theory, should be assigned to a resource, given an indicated level of ecological importance and sensitivity. The default EMC, in a comprehensive classification procedure, might be adjusted depending on additional information and stakeholder consultation, to a desired EMC.

The deviation of the PESC from the DESC can be assessed in terms of the practicality of restoring a system following an assessment of the changes that have occurred, to arrive at an attainable EMC (AEMC). In the context of this report, restoration is defined as "…reestablishment of the structure and function of an ecosystem, including its natural diversity" (Cairns 1988 in: Williams et al. 1997). Generally, structure is seen as the system's native or natural species diversity while function refers to its productivity (i.e. in terms of growth of plant biomass as the basis for food webs) and functions of hydrology, trophic structure and transport. Restoration is viewed as reversing the decline of ecosystem health and returning a degraded ecosystem towards its historic structure (Williams et al. 1997). In contrast, reclamation and rehabilitation are usually more local and site-specific. Habitat creation refers to establishment of new habitat without regard to historic conditions.

The total procedure followed to determine the AEMC is indicated in Figure 1.

It has been pointed out that integrity refers specifically to more natural ecological conditions, while health is viewed as referring to conditions default by humans but not necessarily natural (Karr 1996). It must be emphasised that cases where a river has been changed completely may represent situations where an alternative approach to the one described here will have to be followed. In such instances the health rather than the integrity of the system will need to be considered. Therefore, situations where a river ecosystem has been changed completely (i.e., through inundation or canalization) will have to be viewed from the ecosystem health perspective (and also habitat creation and rehabilitation) rather than

the ecological integrity perspective. This will involve an assessment of a diversity of factors (not only flow and water quantity) and also stakeholder participation to set desirable standards for ecosystem health. This will not be dealt with in the approach presented here.

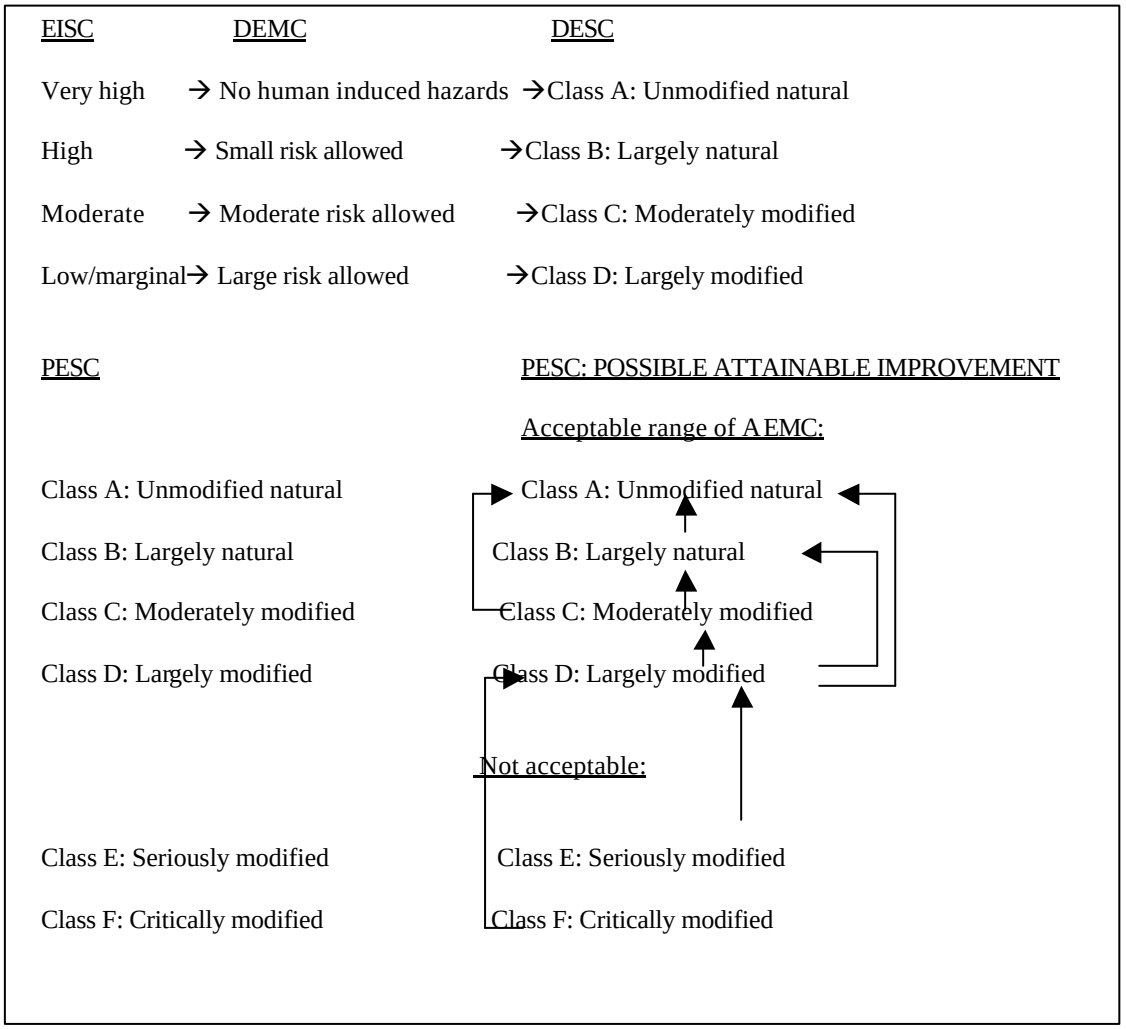


Figure 1: Procedure followed in the determination of the AEMC. →: indicates relationship, ⟶ : indicates possible direction of desirable change.

In addition to the needs of the desktop estimate for estimating the ecological flow component of the Reserve for the NWBM, a procedure is also required to derive the ecological management class of aquatic systems for the purpose of licensing as is required in terms of section 16 of the National Water Act (1998) (also see MacKay 1999). The purpose of such a procedure would be to expedite the process of issuing licenses. Such situations are expected to arise when *ad hoc* applications for limited water use in unstressed systems are made or where there is a need to substantiate the refusal of license applications in stressed systems (van Vliet pers.com. 1999). Essentially the same procedure as for the NWBM desktop estimate (referred to as the water balance desktop estimate, WBDE) can be envisaged for these situations. However, it can be expected and considered mandatory that the information required for the determination of the ecological component of the Reserve under these situations, should improve in confidence and detail compared to that of the WBDE, e.g. in all probability, information beyond desktop level will be required. This will be referred to as the rapid determination (MacKay pers. Com 1999) and will not be dealt with in this document.

This document is a follow-up of the report by Kleynhans et al. (1998) that proposed a procedure to derive the ecological importance and sensitivity of the main stem rivers in quaternary catchments and

then to equate this to the DEMC's. This procedure was followed during provincial workshops in 1998/99. However, it became apparent that the DEMC's alone are not sufficient for the purposes of the NWBM and that the present ecological status of the mainstem river in a quaternary catchment will also have to be considered to arrive at a more realistic estimate of the ecological management class, i.e. the AEMC. During the next round of provincial workshops, the ecological importance and sensitivity ratings will be revisited and reviewed based on the experience gained during the first series of workshops to arrive at an improved estimate of the DEMC. In addition, the PESC, restoration potential and AEMC will also be determined during the workshops.

Based on the principle that the estimated flow requirement for a quaternary catchment should be dependent on the EMC, the EMC would be associated with a particular proportion of the average flow or mean annual runoff. A modification of the Montana method was initially proposed for this purpose (Tennant 1976; Kleynhans *et al.* 1998). It has subsequently been decided by specialists at a workshop, to use a simulation method developed at the IWR of Rhodes University (Hughes & Münster 1999) and contributed to by various specialists at various institutions (i.e, Freshwater Research Unit, IWQS). However, water quality will only be accounted for to a limited context in this approach (i.e. flow related aspects such as water temperature and oxygen concentrations). This is considered sufficient for the purposes of the NWBM.

The following must be emphasised:

- For the purposes of the NWBM, the scale of the desktop estimate will be quaternary catchment level. The PESC will be estimated as indicated in this document. The intention of this procedure is that it should only be used for general planning purposes. Where the information requirements go beyond the general planning level (i.e. beyond desktop level), more detailed procedures should be followed.

- The decision framework being developed by O'Keeffe (1998), should be expanded and used as a guideline as to the procedure applicable to different situations where the ecological reserve needs to be determined.

- Fundamentally, the methodology proposed here is very conservative and based on a pre-cautionary approach.

METHODOLOGY

Acronyms used in this document:

EISC = ecological importance and sensitivity class
DEMC = default ecological management class
DESC = default ecological status class
PESC = present ecological management class
AEMC = attainable ecological management class
NWBM = national water balance model
WBDE = water balance desktop estimate

This methodology is based on the assumption that the ecological importance and sensitivity of a river would generally be closely associated with its default ecological management class, while its current ecological status and the restoration potential will determine the attainability of any ecological management class.

For the purposes of the WBDE, the procedure proposed here will be followed within the following limitations and considerations:

- Although the method is based on the assessment of the mainstem river in quaternary catchments, exceptions to this approach will be followed in the case of the Limpopo River. According to the WR90 maps, the Limpopo (and part of the Marico River) as an international border, does not form the mainstem river in quaternaries of the system. Consequently it was decided in collaboration with Mr. C. Sellick, not only to assess the quaternary catchments in this case but also to determine the DESC and PESC of the Limpopo River itself at the confluence with major South African tributaries such as the Matlabas, Mokolo, Lephalala, Sand, Nwanedzi, Nzhelele and Luvuvhu Rivers. The DESC, PESC and the AEMC for the Limpopo will be applicable to the river stretches downstream from such confluences. For the purposes of the NWBM, tributaries flowing into the Limpopo from Botswana and Mocambique were excluded. The same situation applies to the Orange River at the Namibia-South Africa border. However, in this case the tributaries flowing into the Orange do not contribute significantly to the flow of the Olifants and the EISC, DESC and AEMC will based on the Orange River itself.

- It concerns only lotic systems (i.e., streams and rivers and associated habitats such as lotic wetlands) and is not meant to be applied to lakes, pans, impoundments or estuaries. Although several of the components considered in this assessment can be expected to be generally applicable, the application of the procedure to systems other than rivers and streams has not been attempted.
- Where a quaternary catchment contains an estuary, this methodology should be applied only to the riverine part of the quaternary.
- Only the mainstem river in a quaternary should be considered in this assessment and not tributaries. The assessment of tributaries can be considered to be relevant at a sub-quaternary level which will not be addressed during this exercise. However, it must be realised that water-use where tributaries are involved should receive specific attention.
- In cases where a dam wall is present at or relatively close to the outlet of a quaternary, assessments for the determination of the AEMC for that quaternary will be based on the river upstream from the dam (i.e. upstream from the backwater effect of the dam) (Sellick pers.com. 1999).
- In cases where deterioration occurrs along certain sections of the mainstem of a quaternary, but where there are still substantial less disturbed sections, the determination of the AEMC should be based on these less disturbed areas. The intention of this is that the ecological flow requirements of these less disturbed sections should be catered for. Proper determination of the AEMC in such cases would require assessment at sub-quaternary level.
- Generally, the proportion of the MAR that will be generated by the method of Hughes and Münster (1999) will be applicable to the downstream border (outlet) of a quaternary catchment.
- The assessment should fundamentally be considered from an instream and riparian zone perspective. Although it is realised that the catchment in itself plays a major role in the condition and functioning of rivers, the purpose of this procedure is not a total assessment of catchments.
- The riparian zone should broadly be regarded as that part of the river bordering the river channel. Usually characteristic plants species and/or vegetation structure provides an indication of the delineation of the riparian zone.

The sequence of actions required to determine ecological management classes for input into the hydrological model (Hughes & Münster 1999) are indicated in Figure 2 and are elaborated on below.

The methodology provided here differs from the Kleynhans et al. (1998) approach in the sense that determinants are not separated into so-called primary and modifying determinants. What was previously considered as modifying determinants, are now treated as part of habitat determinants. This change is based on the evident over-estimation of the importance of modifying determinants in the previous version (Luger 1999b).

Ecological importance and sensitivity classes were assessed during the first round of provincial workshops in 1998/9. In most instances, the second round of provincial workshops will involve a general review of the ecological importance and sensitivity assessments of the first round. The second round of workshops is planned to be concerned primarily with assessing the PESC, restoration potential and the AEMC.

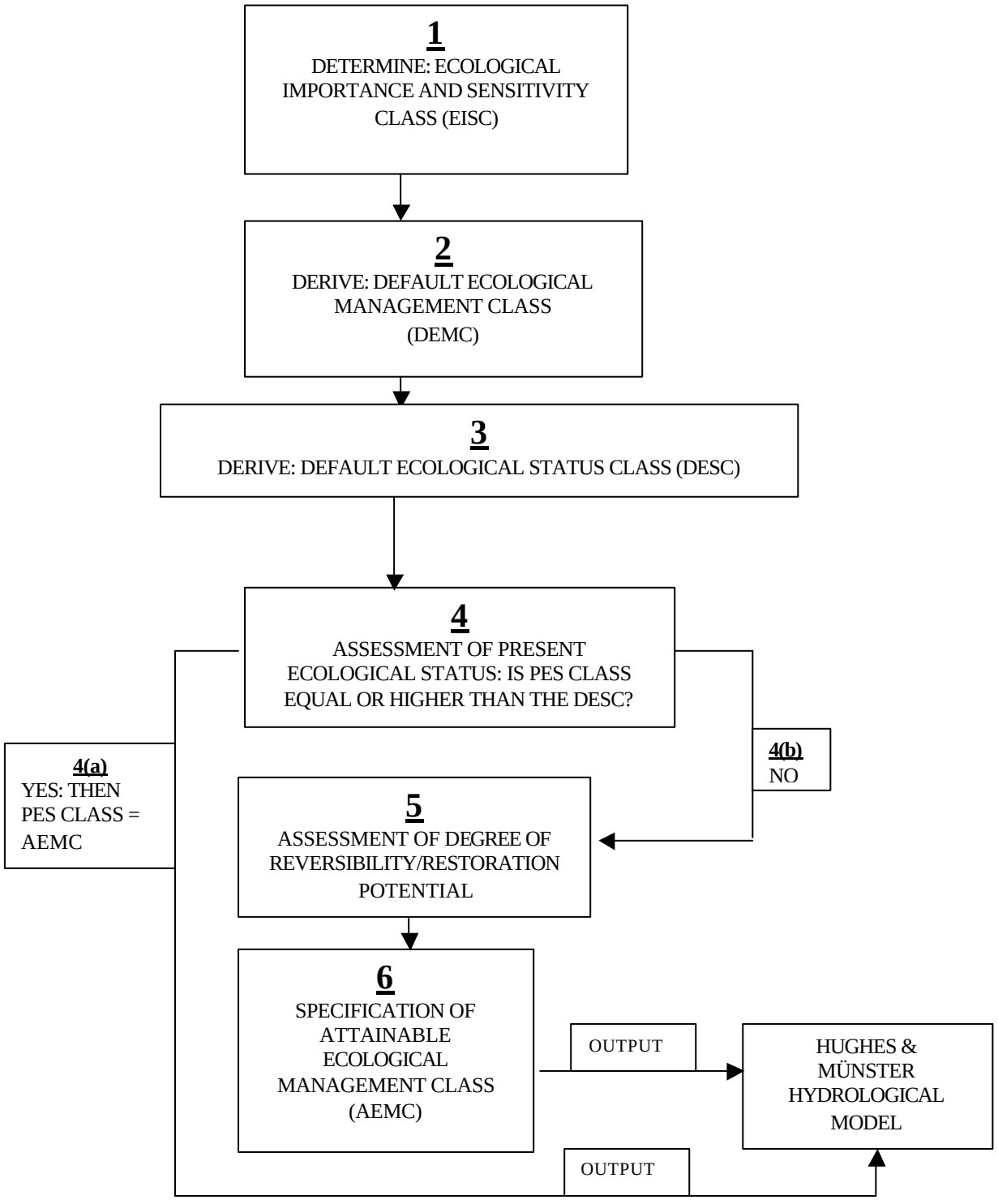


Figure 2: Flow diagram indicating the sequence of steps proposed for the determination of the attainable ecological management class in the determination of the WBDE.

ASSESSMENT OF ECOLOGICAL IMPORTANCE AND SENSITIVITY

Ecological importance of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience) (Resh *et al.* 1988; Milner 1994). Both abiotic and biotic components of the system are taken into consideration in the assessment of ecological importance and sensitivity (Figure 2, step 1).

In terms of this assessment, ecological importance and sensitivity is a general and unrefined estimation. It is strongly biased towards the potential importance and sensitivity of the mainstem river per quaternary as it would expected to be under unimpaired conditions. This means that the present ecological status or condition (PESC) should not be considered in determining the ecological importance and sensitivity *per se*.

This approach estimates and classifies the ecological importance and sensitivity of the streams in a catchment by considering a number of components surmised to be indicative of these characteristics. This procedure can be followed regardless of the fact that delineation of quaternary catchments is not based on ecological principles. However, it must be realised that the ecological sensitivity and reality of the approach may be low due to the omission of an ecological typing framework.

The first step is to estimate the ecological importance and sensitivity of streams in quaternary catchments. The following ecological aspects should be considered as the basis for the estimation of ecological importance and sensitivity:

- The presence of rare and endangered species, unique species (i.e. endemic or isolated populations) and communities, intolerant species and species diversity should be taken into account for both the instream and riparian components of the river.

- Habitat diversity should also be considered. This can include specific habitat types such as reaches with a high diversity of habitat types, i.e. pools, riffles, runs, rapids, waterfalls, riparian forests, etc.

- With reference to points 1 and 2, biodiversity in its general form (i.e., Noss 1990) should be taken into account as far as the available information allows.

- The importance of the particular river or stretch of river in providing connectivity between different sections of the river, i.e. whether it provides a migration route or corridor for species should be considered.

- The presence of conservation or relatively natural areas along the river section should also serve as an indication of ecological importance and sensitivity.

- The sensitivity (or fragility) of the system and its resilience (i.e. the ability to recover following disturbance) of the system to environmental changes should also be considered. Consideration of both the biotic and abiotic components is included here.

This system should be regarded as a guideline for the professional ecological judgement of individuals familiar with a particular area. The assessors will score a number of biotic and habitat determinants considered to be important for the determination of ecological importance and sensitivity (Tables 1, 2 & 3) . The median of these scores will be calculated to derive the ecological importance and sensitivity class. Assessors will then be required to compare this with their overall estimation of the ecological importance and sensitivity class (Table 1) of the mainstem river in a quaternary catchment.

It is advisable that assessors be able and required to substantiate and document their judgement to a reasonable degree for future revision. It is essential that this assessment be conducted by biologists familiar with the particular area in question or comparable areas.

There are 1946 quaternary catchments in South Africa (Schulze *et al*. 1997). In cases where there is a lack of information in a particular quaternary catchment, extrapolation of information from neigbouring catchments should be used. During the first round of provincial workshops it became apparent that it is often useful to group "like" quaternary catchments and in the Western Cape, only one quaternary catchment for each group was entered into the database. Where knowledge about riverine systems was low, the systems were compared to better known rivers and low confidence scorings were given (Luger 1999a). In some respects, the same approach was followed in the North West Province. This approach can be followed in other provinces where possible (especially where there is a lack of information). However, it was pointed out that in Kwazulu/Natal the large variation in river types provided little possibility of clumping quaternaries for purposes of assessing their classes (Chutter 1999).

Table 1: Ecological importance and sensitivity classes.

ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASSES	GENERAL DESCRIPTION
Very high	Quaternaries that are considered to be unique on a national or even international level based on unique biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually very sensitive to flow modifications and have no or only a small capacity for use.
High	Quaternaries that are considered to be unique on a national scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications but in some cases, may have a substantial capacity for use.
Moderate	Quaternaries that are considered to be unique on a provincial or local scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually not very sensitive to flow modifications and often have a substantial capacity for use.
Low/marginal	Quaternaries that are not unique at any scale. These rivers (in terms of biota and habitat) are generally not very sensitive to flow modifications and usually have a substantial capacity for use.

Determinants

Generally, a four point (1 to 4) scoring system is used to assess the various aspects of ecological importance and sensitivity. In some cases a five point (0 to 4) scoring system is used (Table 2). Determinants are assessed according to biological determinants (Table 2) and aquatic habitat determinants (Table 3).

Due to the uniqueness of the Fynbos Biome, it was decided to treat the Western Cape somewhat different with regard to some determinants in order to increase the applicability of the methodology in this part of the country (Luger 1999a & b). These modifications are indicated in the relevant tables.

Table 2: Biotic determinants (instream and riparian) for assessment of ecological importance and sensitivity.

DETERMINANT*	GUIDELINES AND DESCRIPTION[2]	SCORING GUIDELINES
Rare and[@] endangered biota	Biota can be rare or endangered on a local, Provincial and National scale. Useful sources for this information include the South African Red Data Books that are suitable for assessment on a National scale. However, species (or taxa in the case of invertebrates) can be rare or endangered on a Provincial or local scale but not on a National scale. Professional judgement needs to be utilised in such cases.	Very High - rating=4; One or more species/taxon judged as rare or endangered on a National scale (i.e. SA Red Data Books). High - rating=3; One or more species/taxon judged to be rare or endangered on a Provincial/regional scale. Moderate - rating=2; More than one species/taxon judged to be rare or endangered on a local scale. Marginal - rating=1; One species/taxon judged as rare or endangered at a local scale. None - rating=0; No rare or endangered species/taxon at any scale
Unique biota[@]	Endemic or uniquely isolated species populations (or taxa, i.e. in the case of invertebrates) that are not rare or endangered should be included here. This assessment should also consider local, Provincial and National scales and **should be treated separately from rare and endangered species (i.e. the same species should not be considered).** The assessment should be based on professional knowledge. Fynbos biome: Within this biome all the biota would be unique. The rivers were therefore assessed within the context of the biome for the Western Cape (Luger 1999a).	Very High - rating=4; One or more population (or taxon) unique on a National scale. For the Western Cape - rated on a biome scale. High - rating=3; One or more population (or taxon) judged to be unique on a Provincial/regional scale. For the Western Cape - rated on a sub-regional scale (i.e. northern, western, southern and karroid). Moderate - rating=2; More than one population (or taxon) judged to be unique on a local scale. Marginal - rating=1; One population (or taxon) judged to be unique at a local scale. None - rating=0; No population (or taxon) judged to be unique at any scale.
Intolerant biota	Intolerant biota includes those species (or taxa in the case of invertebrates) that are known (or derived or suspected) to be intolerant to decreased or increased flow conditions as well as changed physical habitat and altered water quality conditions related to decreased or increased flows. As little experimental information is available on the intolerance of indigenous biota, assessment should be based on professional judgement. Kwazulu/Natal: There is no quaternary without flow and everywhere that there is flow an invertebrate community dependent on flow develops. This would mean that every quaternary should be rated highly with respect to this criterion. The solution to the problem was to use only fish (Chutter 1999).	Very High - rating=4; A very high proportion of the biota is expected to be dependent on permanently flowing water during all phases of their life cycle. High - rating=3; A high proportion of the biota is expected to be dependent on permanently flowing water during all phases of their life cycle. Moderate - rating=2; A small proportion of the biota is expected to be dependent on permanently flowing water during some phases of their life cycle. Marginal - rating=1; A very low proportion of the biota is expected to be only temporarily dependent on flowing water for the completion of their life cycle. Sporadic and seasonal flow events expected to be sufficient. None - rating=0; Rarely if any biota expected with any dependence on flowing water.
Species/taxon richness	Species/taxon richness can be assessed on a comparative basis according to a local, Provincial or National scale. Strictly, this kind of assessment should be based on the grouping of ecologically similar rivers. However, such a system is still under development and assessment will again to have to be based on professional judgement.	Very High - rating=4; Rated on a National scale. For the Western Cape - rated on a biome scale. High - rating=3; Rated on a Provincial/regional scale. For the Western Cape - rated on a sub-regional scale (i.e. northern, western, southern and karroid). Moderate - rating=2; Rated on a local scale. Marginal/low - rating=1; Not significant at any scale. (a rating of none is not appropriate in this context)

*:The current guidelines will mostly be applicable to vertebrates and vascular plants for which information is more readily available than for other groups. In cases where expert knowledge allows for the assessment of biota other than vertebrates and vascular plants, such information should be included. The taxonomic groups on which the assessment is based should be indicated. In cases where invertebrates (in particular) and other plants are used as indicators, the relevant scoring system may have to be adapted by the relevant ecological experts.

[@]:In the case of rare and endangered and unqiue biota: the highest of the possible scores should be provided, i.e.:

- If a species is rare and endangered on a national scale, it should be scored as very high for this determinant.
- If a species is rare and endangered on a regional scale but it is very unique on a national scale, it should be scored as very high for this determinant.

Table 3: Habitat (instream and riparian) determinants for assessment of ecological importance and sensitivity.

DETERMINANT*	GUIDELINES AND DESCRIPTION	SCORING GUIDELINES
Diversity of aquatic habitat types or features	Diversity of habitat types in a river delineation should be assessed according to local, Provincial and National scales (riffles, rapids, runs, pools and backwaters and the associated marginal areas and substrate types, lotic wetlands (source sponges, floodplain habitat types) and the riparian zone). Assessment should again be based on professional judgement.	Very High - rating=4; Rated on a National scale. High - rating=3; Rated on a Provincial/regional scale. Moderate - rating=2; Rated on a local scale Marginal/low - rating=1; Not significant at any scale. (a rating of none is not appropriate in this context)
Refuge value of habitat types	The functionality of the habitat types present should be assessed in terms of their ability to provide refugia to biota during periods of environmental stress on a local, Provincial and National scale. Assessment is based on available information and expert judgement.	Very High - rating=4; Rated on a National scale. High - rating=3; Rated on a Provincial/regional scale. Moderate - rating=2; Rated on a local scale Marginal/low - rating=1; Not significant at any scale. (a rating of none is not appropriate in this context)
Sensitivity of habitat to flow changes	This assessment should essentially take into account the size of the stream as well as the habitat types available. The presumption is that only a limited decrease or increase in the flow (and the related depth and width) of certain rivers (often "smaller" streams) will result in particular physical habitat types (i.e. riffles), becoming unsuitable for biota as compared to "larger" streams. Assessment is based on available information and expert judgement.	Very High - rating=4; Streams of a particular size and with abundant habitat types highly sensitive to flow decreases or increases at all times High - rating=3; Streams of a particular size and with some habitat types being highly sensitive to flow decreases or decreases at all times. Moderate - rating=2; Streams of a particular size and with some habitat types being susceptible to flow decreases or increases during certain seasons. Marginal/low - rating=1; Streams of a particular size and with habitat types rarely sensitive to flow decreases or increases. (a rating of none is not appropriate in this context)
Sensitivity to flow related water quality changes	This assessment should also consider the size and flow of the stream in terms of its sensitivity to water quality changes. A decrease in the natural flow volume may, for example, result in a diminished assimilative capacity (in the situation where effluent forms part of the total flow volume) or may cause natural water quality variables (i.e. water temperature and oxygen) to reach levels detrimental for biota (also applicable to increases in flow). The assumption regarding the sensitivity of "smaller" streams is also applicable here. In terms of organic pollution load, it has been pointed out that slow flowing deep rivers would be impacted over greater distances than fast flowing shallow rivers where re-areation rates would be high (Chutter 1999). Assessment is based on available information and expert judgement.	Very High - rating=4; Streams of a particular size (usually "small") and with abundant habitat types highly sensitive to water quality changes related to flow decreases or increases at all times. High - rating=3; Streams of a particular size (usually "small") and with some habitat types being highly sensitive to water quality related changes related to flow decreases or increases at all times. Moderate - rating=2; Streams of a particular size (often "larger") and with some habitat types being sensitive to water quality related flow decreases or increases during certain seasons. Marginal/low - rating=1; Streams of a particular size (often "larger") and with habitat types rarely sensitive to water quality change related to flow decreases or increases. (a rating of none is not appropriate in this context)
Migration route/corridor for instream and riparian biota	The importance of a specific stream delineation in terms of the link it provides for the upstream and downstream biological functioning of other sections of the stream, is indicated here (i.e. connectivity). In essence the biological connectivity provided by a particular stream delineation can influence its ecological importance and result in an adapted (i.e. higher) rating than it would have had if was assessed only on its own. Assessments should be based on the results of ratings for individual stream network delineations, professional judgment and available information. The sensitivity of the migration route/corridor to modifications and disruptions form part of the assessment. Within this context, headwater quaternaries would not have an importance as a migration route /corridor (at a sub-quaternary scale, migration route/corridor may be important)	Very high - rating=4; The stream delineation is a critical link in terms of connectivity for the survival of biota upstream and downstream and is very sensitive to modification. High - rating=3; The stream delineation is an important link in terms of connectivity for the survival of biota upstream and downstream and is sensitive to modification. Moderate - rating=2; The stream delineation is a moderately important link in terms of connectivity for the survival of biota upstream and downstream and is moderately sensitive to modification. Marginal/Low - rating=1; The stream delineation is a marginally/low important link in terms of connectivity for the survival of biota upstream and downstream and has a marginal sensitivity to modification None – rating=0; The stream delineation is not of any importance in terms of connectivity for the survival of biota upstream and downstream.
National parks, Wilderness areas, Nature reserves Natural Heritage sites Natural areas	The presence of conservation (i.e. National Parks, Wilderness areas and Nature Reserves) and natural areas (i.e. unproclaimed, relatively unmodified/undisturbed areas) within a stream delineation will logically place an additional emphasis on the ecological importance and sensitivity of a stream. The importance of such areas for the conservation of the aquatic ecological diversity on different scales must be judged, i.e. the presence of a quaternary in a conservation or natural area does not automatically indicates a high score.	Very high - score=4; The stream delineation is present within an area very important for the conservation of ecological diversity on a National and even international scale. High - score=3; The stream delineation is present within an area important for the conservation of ecological diversity on a National scale. Moderate - score=2; The stream delineation is present within an area important for the conservation of ecological diversity on a provincial /regional scale. Marginal/Low - score=1; The stream delineation is present within an area important for the conservation of ecological diversity on a local scale. Very low - score=0; The stream delineation is not present within an area important for the conservation of ecological diversity on any scale.

*: The scoring system indicated here is mainly applicable to vertebrates. In cases where invertebrates (in particular) and plants are used as indicators, the relevant scoring system may have to be adapted by the relevant ecological experts.

DETERMINING THE ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)

In determining the ecological importance and sensitivity (Figure 2, step 1), no weighting of the relative importance of the various components of ecological importance and sensitivity is proposed at this stage. However, it is required that the relative confidence of each rating also be estimated based on a scale of four classes as indicated in Table 4. The possibility of using confidence ratings as indicators of the relative weights of various determinants is currently receiving attention.

The median score for the biotic and habitat determinants is interpreted as indicated in Table 5.

Table 4: Confidence ratings for biotic and habitat determinants.

CONFIDENCE RATING	CONFIDENCE SCORE
Very high confidence	4
High confidence	3
Moderate confidence	2
Marginal/Low confidence	1

Table 5: Ecological importance and sensitivity classes. Interpretation of median scores for biotic and habitat determinants.

ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS*	RANGE OF MEDIAN
Very high Quaternaries that are considered unique on a national or even international level based on unique biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually very sensitive to flow modifications and have no or only a small capacity for use.	>3 and <=4
High Quaternaries that are considered to be unique on a national scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications but may have a substantial capacity for use.	>2 and <=3
Moderate Quaternaries that are considered to be unique on a provincial or local scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually not very sensitive to flow modifications and often have a substantial capacity for use.	>1 and <=2
Low/marginal Quaternaries that are not unique at any scale. These rivers (in terms of biota and habitat) are generally not very sensitive to flow modifications and usually have a substantial capacity for use.	>0 and <=1

*: Quaternaries refer to the mainstem river in a quaternary.

DERIVING THE DEFAULT ECOLOGICAL MANAGEMENT CLASS (DEMC)

The four ecological importance and sensitivity classes can be regarded as equivalent to the four default ecological management classes (DEMC; A to D) proposed for the purposes of the National Water Act (Table 6), i.e. it is suggested that a very high ecological importance and sensitivity should justify the assignment of a very high ecological management class, etc. Default ecological management classes are defined in terms of the sensitivity of a system to disturbance and the risk of damaging the system (i.e. its capacity for sustainability and self-recovery) (Table 7) (Figure 2, step 2). Based on this, there would be desire to manage the system within particular risk ranges.

Table 6: Default ecological management classes for rivers (adapted from Kleynhans 1996 and Kleynhans et al. 1998).

DEFAULT ECOLOGICAL MANAGEMENT CLASSES	DESCRIPTION OF PERCEIVED CONDITIONS AND ALLOWABLE RISK
A **Highly sensitive systems:** **No human induced hazards**	Highly sensitive systems. The natural abiotic template should not be modified. The characteristics of the resource should be determined by unmodified natural disturbance regimes. There should be no human induced hazards to the abiotic and biotic maintenance of the resource.
B **Sensitive systems:** **Small risk allowed**	Sensitive systems. Only a small risk of modifying the natural abiotic template and exceeding the resource base should be allowed. Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.
C **Moderately sensitive systems: Moderate risk allowed**	Moderately sensitive systems. A moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well being and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least partly be mitigated by the presence of sufficient refuge areas.
D **Resilient systems:** **Large risk allowed**	Resilient systems. A large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by refuge areas.

Table 7: The relationship between ecological importance and sensitivity classes and default ecological management classes.

ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (cf. TABLE 5)	DEFAULT ECOLOGICAL MANAGEMENT CLASS (cf. TABLE 6)			
	A: No human induced hazards	B: Small risk allowed	C: Moderate risk allowed	D: Large risk allowed
Very High	X			
High		X		
Moderate			X	
Marginal/Low				X

DERIVING THE DEFAULT ECOLOGICAL STATUS CLASS (DESC)

The default ecological management class (DEMC) can be defined in terms of the default ecological status class (DESC; Table 8) (Table 9). In terms of this document, management (DEMC) would be based on the EISC with the end-point being the default status or condition of a class.

Table 8: Default ecological status classes (adapted from Kleynhans 1996).

DEFAULT ECOLOGICAL STATUS CLASS	DESCRIPTION OF GENERAL CONDITIONS
A	Unmodified, natural.
B	Largely natural with few modifications. A small change in natural habitats and biota can take place but the ecosystem functions should essentially be unchanged.
C	Moderately modified. A moderate change in natural habitat and biota can take place but the basic ecosystem functions should still predominantly be unchanged.
D	Largely modified. A large change in natural habitat, biota and basic ecosystem functions can occur.

Table 9: The relationship between default ecological management classes and default ecological status classes.

DEFAULT ECOLOGICAL STATUS CLASSES (cf. TABLE 8)	DEFAULT ECOLOGICAL MANAGEMENT CLASSES (cf. TABLE 6)			
	A: No human induced hazards	B: Small risk allowed	C: Moderate risk allowed	D: Large risk allowed
A: Unmodified, natural	X			
B: Largely natural		X		
C: Moderately modified			X	
D: Largely modified				X

ASSESSMENT OF PRESENT ECOLOGICAL STATUS CLASSES (PESC)

For the purpose of the WBDE, habitat integrity is considered as a broad preliminary indicator of present ecological status (PES) (i.e. ecological integrity, condition, naturalness) (Figure 2, step 4). Due to the detail required, it is not possible to use the complete index of habitat integrity (Kleynhans 1996) or the shortened method proposed for the preliminary reserve determination (Kemper and Kleynhans 1998). A much simplified approach is proposed that can be used for each quaternary and that is based on local expert knowledge. The attributes that should be considered within the context of the degree to which they modify instream and riparian habitat and impact on native biota are indicated in Table 10.

Table 11 provides scoring and rating guidelines for the estimation of the PESC. Each of the attributes is scored and the mean calculated. The mean is used to place the main river in the quaternary catchment in a particular present ecological status class. In cases where any of the attributes scores < 2 (i.e., it is considered to be seriously or critically modified) this score and not the mean taken into consideration . The latter approach is based on the assumption that extensive degradation of any of the river attributes may determine the PES. However, as is the case with the estimation of the ecological importance and sensitivity, the mean on which the assessment of the PES is based, should be regarded as a guideline and should also be tested against the opinion of local experts as guided by Table 11. Biological integrity is not directly estimated through this approach and it is acknowledged that in some systems or parts of systems, information on biological integrity is available. In such cases, the information on biological integrity can be used as a check of the PES assessment. The mean (or default low rating due to individual scores of serious or critical modification) is used to relate the river to a particular PES Class (Table 11).

Table 10: Attributes to be assessed for determination of present ecological status.

ASSESSMENT ATTRIBUTES	CONSIDERATIONS FOR ASSESSMENT OF ATTRIBUTES
Flow	Relative deviation from the expected natural - modification/ deterioration of habitat due to abstraction and/or flow regulation.
Inundation	Relative degree of inundation by weirs (or similar structures) and impoundments - loss of instream habitat and the riparian zone as well as the possible fragmentation effect on biological populations and communities.
Water quality	Water quality (relative degree of modification from the expected natural, and its perceived biological impact and significance).
Stream bed condition	Stream bed condition (relative degree of modification as caused by disturbances such as sedimentation, covering by excessive algal growth related to eutrophication, etc.).
Introduced instream biota	Species involved, their characteristics and severity of impact on native biota - i.e., impact on physical habitat and competition, predation.
Riparian or stream bank condition	Riparian or stream bank condition (relative deviation from the expected natural situation as indicated by disturbances such as removal of vegetation, invasive vegetation, erosion, etc.).

Table 11: Scoring and rating guidelines for present ecological status estimation (adapted from Kleynhans 1996).

SCORING GUIDELINES PER ATTRIBUTE*	RELATIVE CONFIDENCE OF SCORE OF ATTRIBUTE (APPLICABLE TO ALL ATTRIBUTES)	INTERPRETATION OF MEAN* OF SCORES FOR ALL ATTRIBUTES: RATING OF PRESENT ECOLOGICAL STATUS CLASS (PESC)
Natural, unmodified - score=5.	Very high confidence - score=4	WITHIN GENERAL ACCEPTABLE RANGE
		CLASS A >4; Unmodified, or approximates natural condition.
Largely natural - score=4.	High confidence - score=3	**CLASS B** >3 and <=4; Largely natural with few modifications, but with some loss of natural habitats.
Moderately modified- score=3.	Moderate confidence - score=2	**CLASS C** >2 and <=3; moderately modified, but with some loss of natural habitats.
Largely modified - score=2.	Marginal/Low confidence - score=1	**CLASS D** =2; largely modified. A large loss of natural habitats and basic ecosystem functions has occurred.
		OUTSIDE GENERAL ACCEPTABLE RANGE
Seriously modified - rating=1.		**CLASS E** >0 and <2; seriously modified. The losses of natural habitats and basic ecosystem functions are extensive.
Critically modified - rating=0.		**CLASS F** 0; critically modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat.

*: If any of the attributes are rated <2, then the lowest rating for the attribute should be taken as indicative of the PES class and not the mean.

ASSESSING THE REVERSIBILITY OF MODIFICATIONS AND SPECIFICATION OF THE AEMC

The PESC is compared with the DESC (Figure 2, step 4):

1. If it falls in the same class as the DESC or is higher than the DESC, the PESC is taken as the attainable ecological management class (AEMC) (Figure 2, step 4(a)).
2. If the PESC is lower than the DESC, the possibility of attaining the DESC has to be assessed (Figure 2, step 4(b)). Gonzalez (1996) proposes a system of four categories indicating distance from the "default future condition" (comparable to the DESC). In the context of the current approach, categories are formulated in terms of the PESC and DESC (adapted from Gonzalez 1996):

(a) Close; PESC>=DESC
(b) Moderate; PESC (for classes B-D) is 1 class lower than the DESC (for Classes A-C)
(c) Far; PESC (for classes C to D) is 2 classes lower than the DESC (for Classes A-B)
(d) Very far; PESC < class D when the acceptable range of the DESC can potentially vary from class A to class D (Table 6).

In general, it can be accepted that the farther the PESC is below the DESC, the more effort would be required to realise the DESC. However, the kind of change(s) that resulted in a particular PESC may vary in terms of the possibility of improving them in order to achieve restoration of the system up to the DESC. It follows that each of the attributes will have to be assessed in terms of the perceived possibility of restoring them to a condition where such an improvement will lead to an improvement of the PESC. Some changes may be practically irreversible within the limits of time and effort (including financial resources) required to achieve this. While five years is a commonly used time frame for many institutions and is considered a realistic period for attempting to estimate future conditions (Gonzalez 1996), it is difficult to put limits to what can be regarded as realistic efforts. Nevertheless, if three broad categories of threat to ecosystems are considered, it is possible to obtain some perception of the effort required to restore ecosystems (adapted from: Gonzalez 1996):

(a) Ecosystem degradation; occurs mainly through pollution, but could also be from selective removal of species (e.g., overfishing, overharvesting, etc.). Restoration potential is probably moderate to high.
(b) Ecosystem alteration; major physical changes (dredging, water diversion) and major removal of species (i.e., extinction). In terms of rivers, it is proposed that factors such as flow modification, water abstraction (i.e., indicators of physical habitat modification) would also be included here. Restoration potential is probably low to moderate.
(c) Ecosystem removal; the highest level of alteration (e.g., destruction of wetlands due to urbanisation, etc.). In terms of rivers, modifications such as inundation, canalisation and concreting, destruction of the riparian zone and the macro-geomorphological features of the river and its catchment could conceivably be included here. Restoration potential is probably low.

It must be emphasised that for the NWBM, the desktop estimate is required in order to estimate the ecological flow requirements. This means that the assessment of the possibility of improving the ecological conditions must be approached in terms of the flow situation, i.e. degradation of the system that occurred because of purely non-flow related changes should not be included as part of the estimation of the restoration potential of a river. Table 12 provides a framework for the assessment of the restoration potential of rivers and to estimate the AEMC.

Table 12: The assessment of the restoration potential of different modifications of the present ecological status class of rivers from which the AEMC is derived.

MODIFICATION	PRESENT DEGREE OF MODIFICATION: POSSIBLE SCORE (cf. TABLE 9)	CONFIDENCE*	ATTAINABLE IMPROVEMENT (FLOW OR FLOW RELATED) WITHIN 5 YEARS: POSSIBLE SCORE	CONFIDENCE*
Flow	0-5	1-4	0-5	1-4
Inundation	0-5	1-4	#	#
Water quality	0-5	1-4	0-5	1-4
Stream bed condition	0-5	1-4	0-5	1-4
Introduced instream biota	0-5	1-4	#	#
Riparian or stream bank condition	0-5	1-4	0-5	1-4
MEAN	PESC: 0-5		AEMC:0-5	
CLASS	PESC: A - F (possible)		AEMC: A -D (acceptable)	

*: 0=None; 1=Low; 2=Moderate; 3=High; 4=Very high. #: Modifications not likely to be improved by flow related improvements. The score for the present degree of modification is taken as a default.

The output of this process is the AEMC (Figure 2, steps 4(a) and 5; Table 12) which is used as an input into the hydrological model of Hughes and Münster (1999). As indicated in Table 11, only ecological management classes from A-D fall in the acceptable range. This means that regarding the AEMC, only classes A - D would be acceptable. When the assessment of the improvement indicates that a class better than E or F is not attainable in 5 years, the AEMC will have to be taken as class D as an input to the hydrological model. However, it must be realised that a class of E or F may indicate a practically irreversible change of the ecosystem. In such a case it would be appropriate to consider the ecological management class in terms of ecosystem health rather than integrity (Karr 1996; cf. Introduction) and desirable standards will have be set according to this. This is, however, not part of the WBDE.

ACKNOWLEDGEMENTS

The comments of the following persons on various as aspects of this document as well as earlier versions of it are appreciated:

Dr. H. van Vliet, Dr. H. MacKay, Mr. S. Jooste, Ms. L. Hill, Ms. C. Thirion, Prof. J. O'Keeffe, Ms. R. Tharme, Mr. C. Sellick, Dr. M. Chutter, Mr. M. Luger.

This methodology was tested on selected quaternaries of the Olifants River (Limpopo System) during a workshop in June 1999 at Lydenburg. Contributions and comments were provided by the following persons:

Dr. J.S. Engelbrecht, Ms. C. Thirion, Ms. L.Hill, Messrs. M. Angliss, A.Hoffman and F.Roux .

The remarks and contributions of all provincial experts during the first round of provincial workshops are also appreciated

LITERATURE

Boon, P.J. 1993. System for evaluating rivers for conservation. Unpublished document. Scotish Natural Heritage, Research and Advisory Services Directorate.

Chutter, M. 1999. Provincial water resources study: Kwazulu/Natal. Planning estimation of the present class by quaternary catchment. Interim report to DWAF on behalf of Knight Piesold.

Collier, K.J. & W.M. McColl. 1992. Assessing the natural value of New Zealand rivers. In P.J. Boon, P.Calow & G.E. Petts (eds.) River conservation and management. Wiley & Sons.

Gonzalez, O.T. 1996. Formulating an ecosystem approach to environmental protection. *Environmental Management* 20: 597-605.

Hughes, D.A. & F. Münster. 1999. A decision support system for an initial "low-confidence" estimate of the quantity component of the reserve for rivers. IWR, Rhodes University, Grahamstown. Version 1.

Karr, J.R. & D.R. Dudley. 1981. Ecological perspective on water quality goals. *Environmental Management*. 5:55-68.

Karr, J.R. 1996. Ecological integrity and ecological health are not the same. In: C. Schulze (ed.) *Engineering Within Ecological Constraints.* National Academy Press, Washington D.C. 97-109.

Kleynhans, C..J. 1996. A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo System, South Africa). *Journal of Aquatic Ecosystem Health* 5:41-54.

Kemper, N. & C.J. Kleynhans. 1998. Methodology for the preliminary present status of rivers. IWRE & IWQS. Unpublished report.

Kleynhans, C.J., C.A. Bruwer, V. Kilian, B. Weston, N. van Wyk and C. Sellick. 1998. A procedure for the determination of the flow requirements of the ecological reserve for the purpose of the desktop estimate. IWQS, DWAF. Internal Report.

Luger, M. 1999a. Western Cape water resources situation assessment. Workshop on ecological flow requirements: Notes on proceedings. Ninham Shand Environmental & Engineering Consultants. Report No. 2949/8331.

Luger, M. 1999b. Eastern Cape water resources situation assessment. Workshop on ecological flow requirements: Notes on proceedings. Ninham Shand Environmental & Engineering Consultants. Report No. 2948/8331.

MacKay, H. (editor). 1999. Resource-directed measures for protection of water resources. IWQS, DWAF. Report Number: N/0000/_/REH0299. Unofficial first draft.

Midgley, D. C., Pitman, W.V. & Middleton, B. J. 1994. Surface Water Resources of South Africa 1990. WRC, Pretoria.

Milner, A.M. 1994. System recovery. In, P.Calow & G.E. Petts (eds.): The rivers handbook. Vol. 2. Blackwell Scientific Publications. London.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4:355-364.

Resh, V.H., A.V. Brown, A.P. Covich, M.E. Gurtz, H.W. Li, G.W. Minshall, S.R. Reice, A.L. Sheldon, J.B. Wallace & R.C. Wissmar. 1988. The role of disturbance theory in stream ecology. *Journal of the North American Benthological Society.* 7: 433-455.

Schulze, R.E., M. Maharaj, S.D. Lynch, B.J. Howe & B. Melvil-Thomson. 1997. South African atlas of agrohydrology and -climatology. Water Research Commission, Pretoria, Report TT82/96.

Tennant, D.L. 1976. Instream flow regimes for fish, wildlife, recreation and related environmental resources. *Fisheries* 1: 6-10.

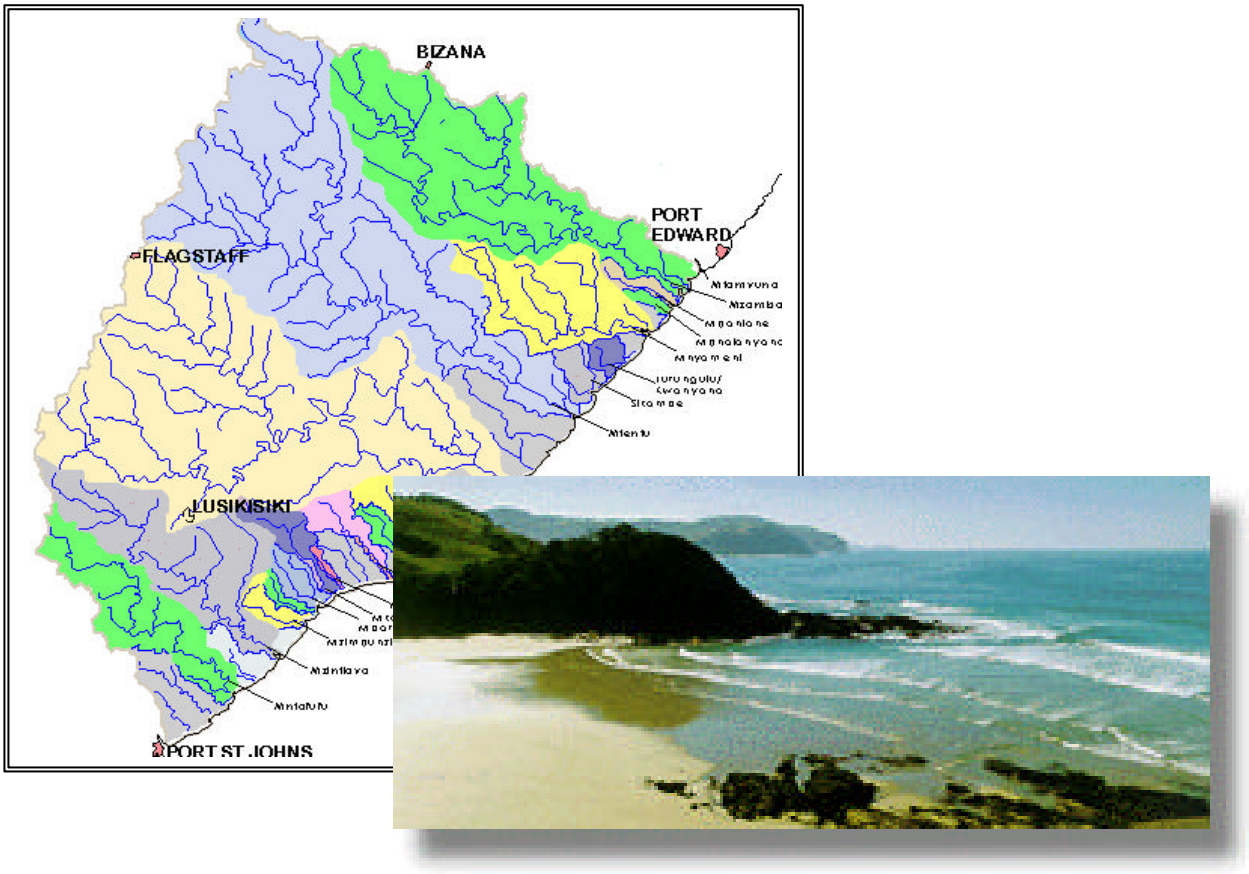
Williams, J.E., C.A. Woods and M.P. Dombeck. 1997. Understanding watershed-scale restoration. Pages 1-16 in: J.E. Williams, C.A. Wood and M.P. Dombeck (eds). Watershed restoration: principles and practices. American Fisheries Society, Bethesda, Maryland.

PB T600/00/0701

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



ECOLOGICAL ESTUARINE RESERVE ESTIMATE

Final

June 2001

Prepared By:

Anton Bok Aquatic Consultants CC
Port Elizabeth

ANTON BOK AQUATIC CONSULTANTS
Trading as **ANTON BOK & ASSOCIATES**

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Ecological Estuarine Reserve Estimate
AUTHOR	**:**	A Bok
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-0701
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EASTERN PONDOLAND BASIN STUDY
ECOLOGICAL ESTUARINE RESERVE ESTIMATE

EXECUTIVE SUMMARY

Introduction

The RDP rural water supply programme in the Eastern Pondoland Coast has necessitated a basin study in order to optimally use the surface water resources in this relatively undeveloped area. The pristine estuaries in the Eastern Pondoland region are widely regarded as having significant socio-economic importance in the context of tourism development in this region as well as having high conservation value. The biota in these sub-tropical estuaries, such as those making up the mangrove communities, are also known to be very sensitive to reductions in river flows. The freshwater requirements of the estuaries may well be higher than those for the riverine zones. It was therefore considered essential to determine the Ecological Estuarine Reserve (EER) (previously termed Estuarine Flow Requirements – EFR) of the rivers in the study area as part of the broader Eastern Pondoland Basin Study.

The methodology presently used for the determination of the desktop Ecological Reserve (Kleynhans et al 1998) is designed for the riverine zones and is not considered applicable for estuaries. It was therefore necessary to develop an appropriate methodology to determine the EER as well as to apply this methodology to all main river estuaries in the study area.

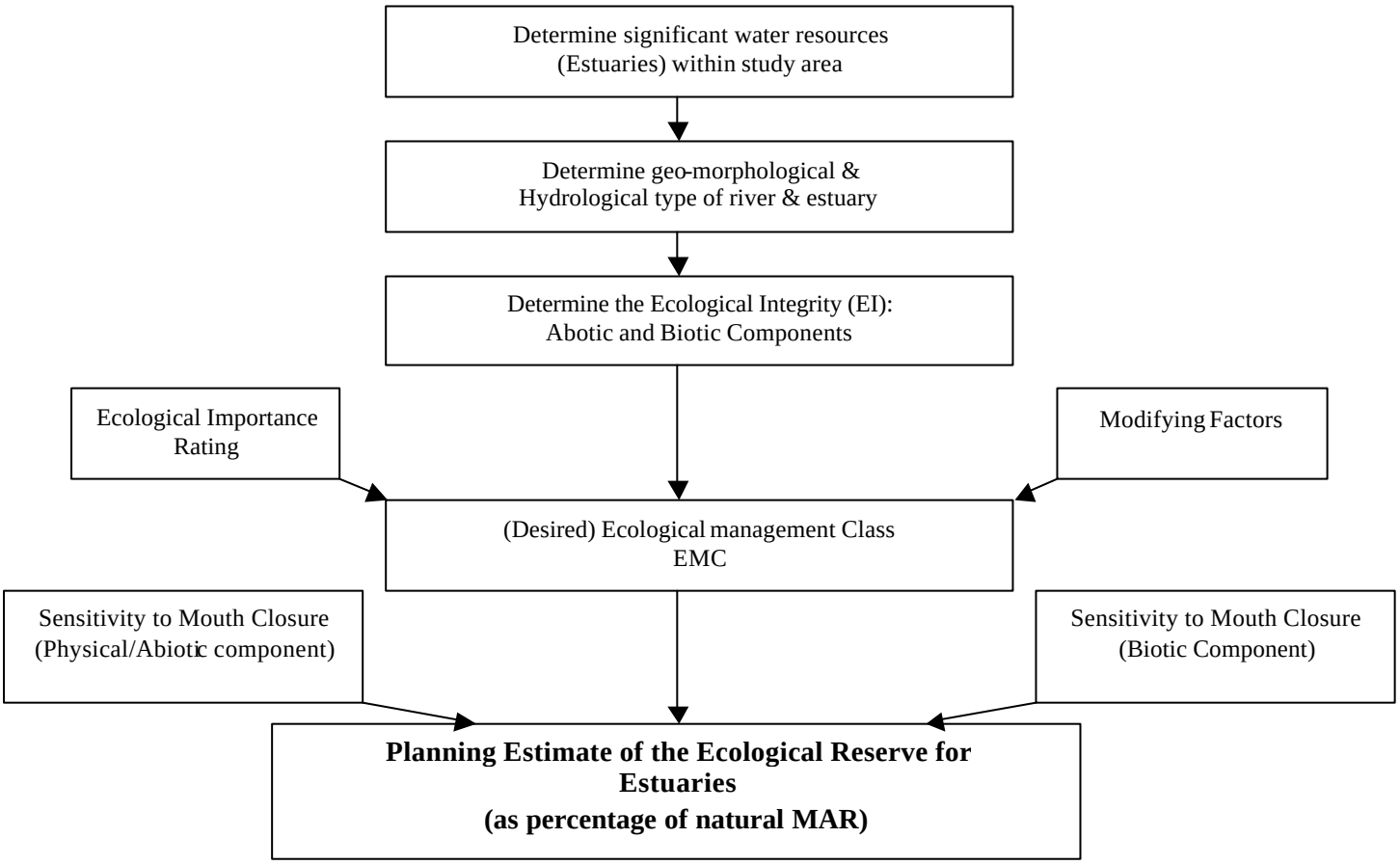
Methodology

The approach used in this investigation involved the combined efforts of a multi-disciplinary team in a workshop situation. As much information, both biotic and abiotic, was gathered by the various specialists before the workshop. In addition, recent photographic material (aerial photographs and slides) was available at the workshop. This visual material, together with the other data presented, enabled the authors to use professional judgment to give scores on a variety of abiotic and biotic factors

The methodology outlined in Figure A (see below) was used to place the 16 significant estuaries in the study area into Ecological Management Classes (EMC's). This method closely follows the generic methology for the determination of the Reserve in that the current ecological status (i.e. Ecological Integrity status -EI) was mainly used to determine the desired Ecological Management Class (EMC) for each estuary. . It is considered that the methodology applied for this study has yielded estimates with confidence levels higher than “desktop”, but lower than “rapid”.

The final step involved the designation of an estimated ecological Reserve, in terms of a percentage of the natural MAR, to each estuary. This volume of flow required for the Reserve depended on the designated EMC, as well as the sensitivity of the tidal inlet (i.e. estuary mouth) to closure due to a reduction in river flow.

Figure A: Method used to determine the EER estimates for the rivers in the study area



RESULTS AND DISCUSSION

The relativity pristine status of the Eastern Pondoland estuaries (i.e. high El ratings) ensured that of the 16 estuaries in the study area, 14 were given class A EMC status and only 2 (Mbotyi and Mnyameni) were given Class B EMC status. In only 3 instances (Mfafufu, Mzintlava and Msikaba estuaries) was the Importance rating higher than the El rating. In all three instances, however, the El rating put these estuaries in a Class A EMC. Again, only three instances were the El ratings slightly lower than the sensitivity ratings, namely in the A Class Mtafufu, Mtentu and Mzamba estuaries.

The desktop estimate of the EER for the estuaries in Eastern Pondoland varied between 80 to 95% of the natural MAR for the larger systems and 90 to 99% of the MAR for the smaller river systems. The main considerations used to arrive at these figures was the amount of river flow needed to:

a) ensure that the permanently open estuaries did not close, and

b) ensure that "the natural mouth condition (in terms of time periods of open/closed conditions in temporarily open systems) was maintained.

The above volumes for the EER are substantially higher than these estimated for the Ecological Riverine Reserve (ERR) of rivers in South Africa. Kleynhans et al (1998) estimated the ecological reserve for Class A rivers; to be 50 to 100% of the MAR and for Class B rivers, 50% of the MAR using a modified version of the Montana method (after Tennant 1976 vide Kleynhans et al 1998).

Important points arising from the workshop which could influence water resource development options included:

- The natural dynamic state of the tidal inlets of these estuaries is maintained to a large extent by river base-flow and thus it is important in all these estuaries to maintain all of the base-flow in the present annual distribution pattern.

- The base-flow in these rivers is estimated to be about 40 to 50% of the natural MAR.

- Floods are also important for estuarine functioning as they have a major influence on sediment dynamics and thus mouth condition. This factor is largely responsible for the higher Estuarine Ecological Reserve requirements compared to the Ecological Riverine Reserve requirements (see above).

- The present water usage in these 16 river systems in Eastern Pondoland is very low (from 1 to 4.3% of natural MAR) and all of these rivers are (theoretically) still perennial.

- Theoretically; if more that 6% of the natural MAR is removed from these rivers, flow will probably cease during the low-flow period and if more than 12% of natural MAR is removed, the rivers will stop flowing for 10% of the time.

- Further studies on the estuarine dynamics of individual estuaries, particularly factors effecting sediment dynamics and mouth condition (open and closure), would be required to determine the estuarine Reserve more accurately.

CONCLUSION

The much higher Ecological Estuarine Reserve requirements of these Pondoland estuaries, compared to the Ecological Riverine Reserve requirements the rivers, implies that the estuarine freshwater requirements would largely determine the upper limit to which the freshwater resources in this region will be able to be developed. The large volumes of river flow considered necessary to maintain the natural condition of the tidal inlets was a major reason for the relatively high estimate of the estuarine Reserve. This indicates that if maximum sustainable development (with minimum ecological impact) of the freshwater resources of these Pondoland rivers were desired, further studies to quantify the impact of river flow on mouth dynamics would be a prerequisite.

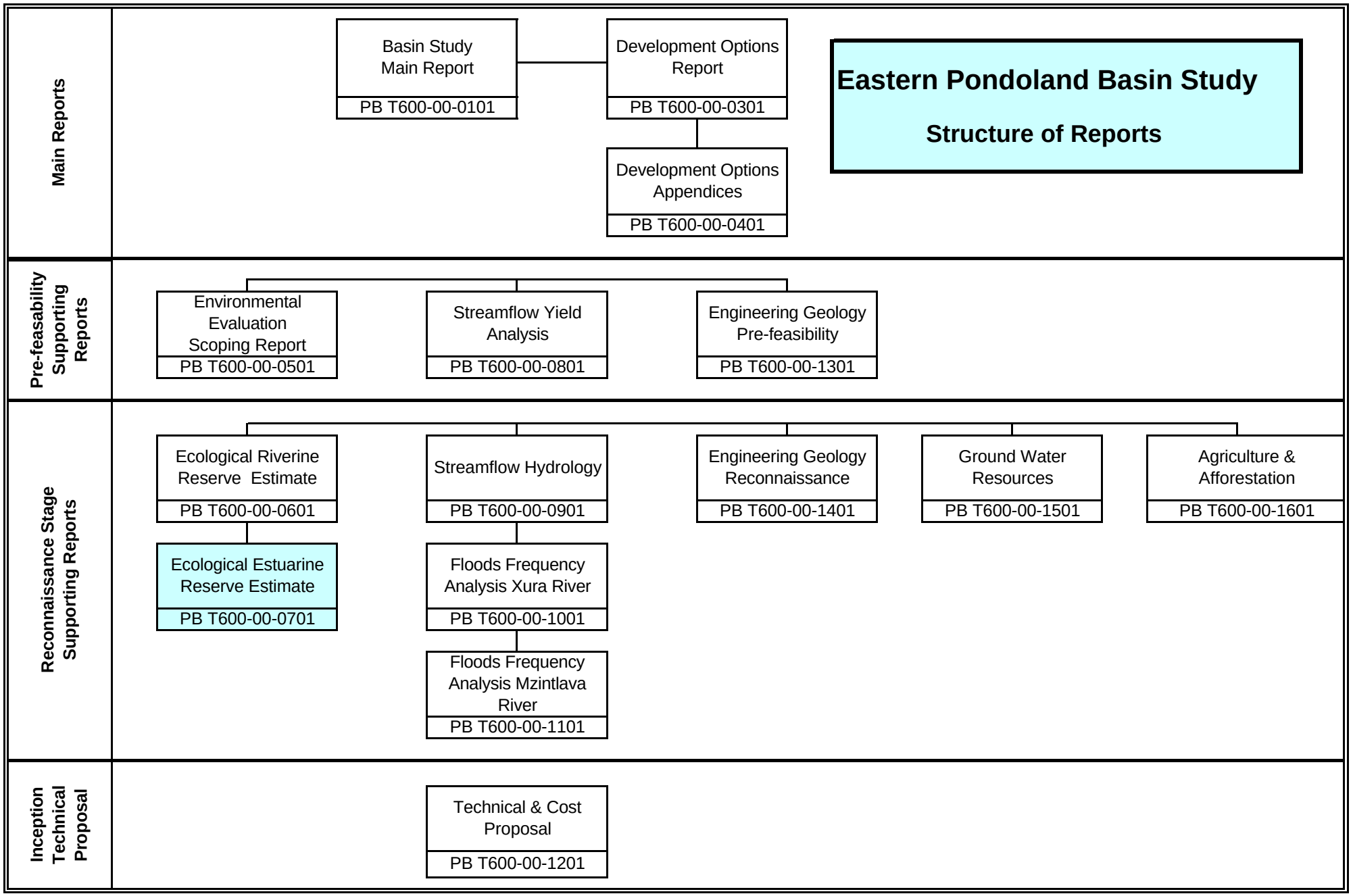

Main Reports
Basin Study Main Report
PB T600-00-0101
Development Options Report
PB T600-00-0301
Development Options Appendices
PB T600-00-0401
Eastern Pondoland Basin Study
Structure of Reports
Pre-feasability Supporting Reports
Environmental Evaluation Scoping Report
PB T600-00-0501
Streamflow Yield Analysis
PB T600-00-0801
Engineering Geology Pre-feasibility
PB T600-00-1301
Reconnaissance Stage Supporting Reports
Ecological Riverine Reserve Estimate
PB T600-00-0601
Ecological Estuarine Reserve Estimate
PB T600-00-0701
Streamflow Hydrology
PB T600-00-0901
Floods Frequency Analysis Xura River
PB T600-00-1001
Floods Frequency Analysis Mzintlava River
PB T600-00-1101
Engineering Geology Reconnaissance
PB T600-00-1401
Ground Water Resources
PB T600-00-1501
Agriculture & Afforestation
PB T600-00-1601
Inception Technical Proposal
Technical & Cost Proposal
PB T600-00-1201

TABLE OF CONTENTS

			Page
EXECUTIVE SUMMARY			
TABLE OF CONTENTS			iv
LIST OF FIGURES, TABLES AND ANNEXURES			v
1.	INTRODUCTION		
	1.1	Background to Investigation	1
	1.2	Planning Estimate of the Ecological Reserve	1
	1.3	Eastern Pondoland Basin Study	3
2.	METHODOLOGY		
	2.1	Existing Methods	3
	2.2	Approach Used	5
	2.3	Methodology for Determining the WBPE for the 16 Estuaries	5
		2.3.1 Determination of Significant Water Resources	6
		2.3.2 Determination of Ecological Integrity	6
		2.3.3 Determination of Ecological Importance	6
		2.3.4 Determination of Sensitivity	7
		2.3.5 Designation of Ecological Management Class (EMC)	7
		2.3.6 Estimation of the WBPE for the Estuaries	7
	2.4	Workshop Format	7
		2.4.1 Starter Documents and Prepared Contributions	10
3.	RESULTS		11
4.	DISCUSSION		
	4.1	Ecological Management Classes (EMC's)	31
	4.2	Planning Estimates of the Reserve (WBPE) for the Estuaries	31
	4.3	Comparison of Results with WBPE for Riverine Zones	32
	4.4	Important Considerations Influencing Development Options	32
5.	CONCLUSIONS		33
6.	REFERENCES		33

LIST OF FIGURES

Figure 1	Map of study area	2
Figure 2	Methodology for determination of Planning Estimates (After Kleynhans *et al* 1998)	4
Figure 3	Method used to determine the Planning Estimate of the Estuarine Reserve for Eastern Pondoland Estuaries	8
Figure 4	Generic Methodology for determination of the Reserve (DWAF 1998)	9

LIST OF TABLES

Table 1	Physical classification and sensitivity of estuarine classes to mouth closure.	11
Table 2.1	Mtafufu: Present Ecological Integrity (EI) Status of estuary	12
Table 3.1	Mtafufu: Importance Rating of estuary.	12
Table 4.1	Mtafufu: Sensitivity Rating of estuary.	12
Table 2.2	Mzintlava: Present Ecological Integrity (EI) Status of estuary.	13
Table 3.2	Mzintlava: Importance Rating of estuary.	13
Table 4.2	Mzintlava: Sensitivity Rating of estuary.	13
Table 2.3	Mzimpunzi: Present Ecological Integrity (EI) Status of estuary.	14
Table 3.3	Mzimpunzi: Importance Rating of estuary.	14
Table 4.3	Mzimpunzi: Sensitivity Rating of estuary.	14
Table 2.4	Mbotyi: Present Ecological Integrity (EI) Status of estuary.	15
Table 3.4	Mbotyi: Importance Rating of estuary.	15
Table 4.4	Mbotyi: Sensitivity Rating of estuary.	15
Table 2.5	Mkosi: Present Ecological Integrity (EI) Status of estuary.	16
Table 3.5	Mkosi: Importance Rating of estuary.	16
Table 4.5	Mkosi: Sensitivity Rating of estuary.	16
Table 2.6	Myekane: Present Ecological Integrity (EI) Status of estuary.	17
Table 3.6	Myekane: Importance Rating of estuary.	17
Table 4.6	Myekane: Sensitivity Rating of estuary.	17
Table 2.7	Lupatana: Present Ecological Integrity (EI) Status of estuary.	18
Table 3.7	Lupatana: Importance Rating of estuary.	18
Table 4.7	Lupatana: Sensitivity Rating of estuary.	18
Table 2.8	Mkweni: Present Ecological Integrity (EI) Status of estuary.	19
Table 3.8	Mkweni: Importance Rating of estuary.	19

Table 4.8	Mkweni: Sensitivity Rating of estuary.	19
Table 2.9	Msikaba: Present Ecological Integrity (EI) Status of estuary.	20
Table 3.9	Msikaba: Importance Rating of estuary.	20
Table 4.9	Msikaba: Sensitivity Rating of estuary.	20
Table 2.10	Mtentu: Present Ecological Integrity (EI) Status of estuary.	21
Table 3.10	Mtentu: Importance Rating of estuary.	21
Table 4.10	Mtentu: Sensitivity Rating of estuary.	21
Table 2.11	Sikombe: Present Ecological Integrity (EI) Status of estuary.	22
Table 3.11	Sikombe: Importance Rating of estuary.	22
Table 4.11	Sikombe: Sensitivity Rating of estuary.	22
Table 2.12	Lutungulu: Present Ecological Integrity (EI) Status of estuary.	23
Table 3.12	Lutungulu: Importance Rating of estuary.	23
Table 4.12	Lutungulu: Sensitivity Rating of estuary.	23
Table 2.13	Mnyameni: Present Ecological Integrity (EI) Status of estuary.	24
Table 3.13	Mnyameni: Importance Rating of estuary.	24
Table 4.13	Mnyameni: Sensitivity Rating of estuary.	24
Table 2.14	Mpahlanyana: Present Ecological Integrity (EI) Status of estuary.	25
Table 3.14	Mpahlanyana: Importance Rating of estuary.	25
Table 4.14	Mpahlanyana: Sensitivity Rating of estuary.	25
Table 2.15	Mpahlane: Present Ecological Integrity (EI) Status of estuary.	26
Table 3.15	Mpahlane: Importance Rating of estuary.	26
Table 4.15	Mpahlane: Sensitivity Rating of estuary.	26
Table 2.16	Mzamba: Present Ecological Integrity (EI) Status of estuary.	27
Table 3.16	Mzamba: Importance Rating of estuary.	27
Table 4.16	Mzamba: Sensitivity Rating of estuary.	27
Table 5	Current Ecological Integrity (EI) and Ecological Management Classes of the 16 Pondoland Estuaries.	28
Table 6	Conversion of various Ecological Management Classes (EMC's) to % of MAR.	29
Table 7	Summary table giving the WBPE of the 16 estuaries.	30

LIST OF ANNEXURES

Annexure 1	Eastern Pondoland Basin Study Draft Programme of Workshop.
Annexure 2	Objectives of Workshop on Eastern Pondoland Basin Study.
Annexure 3	Participant List of EPBS Workshop at UPE on 13 & 14 May 1999.

Annexure 4 Simulated MAR of 16 Pondoland Estuaries and Quatenary Catchment Sizes, MAP & MAR in study area.

Annexure 5 Estimated Present Annual Water Usage & Estimated Present Monthly Water Usage.

Annexure 6 Document: "Classification of Eastern Pondoland Estuaries".

Annexure 7 Figures and Charts showing Quatenary catchments, mean monthly flow distribution and standardised annual Flow Duration Curves for the 7 largest rivers, monthly water use in Mtafufu River and water use as % of MAR of 16 rivers in study area.

Annexure 8 Table giving monthly and annual average flows of the 16 significant rivers in both $Mm^3 m^3 s^{-1}$.

Annexure 9 Document: "Eastern Pondoland planning reserve estimate for sixteen Estuaries- Vegetation Report".

Annexure 10 Document: "Starter Document: Planning Estimates of the Estuarine Reserve of Eastern Pondoland Estuaries".

Annexure 11 Table A. Present-state categories based on ecosystem health/ ecological integrity (EI) status.

Table B. Criteria for determining the confidence levels for decisions taken.

Table C. (Future) Ecological Management Class (EMC) categories based on current ecological integrity status.

DETERMINATION OF THE PLANNING ESTIMATE OF THE ESTUARINE RESERVE FOR EASTERN PONDOLAND ESTUARIES

1 INTRODUCTION

1.1 Background to Investigation

The RDP water supply programme has identified a need for substantial augmentation of the domestic water supply schemes serving Lusikisiki and the rural populations in the eastern Pondoland coastal region. A map of the Eastern Pondoland Coastal Basin Study (EPCBS) area under investigation, which stretches from the Mtafufu River in the south to the Mzamba River in the north, is given in Figure 1 below. The lack of relevant information on these river systems, however, highlighted the need to undertake a basin study of all significant surface water resources of the region in order to provide a planning tool for sustainable development of these resources.

The natural scenic beauty and relatively unspoiled natural environment of the Pondoland coast has enormous tourist and hence socio-economic potential for this undeveloped region. The coastal zone, estuaries and adjacent terrestrial areas are national assets which are still in a relatively pristine condition. These ecosystems, however, are also extremely environmentally sensitive. It was therefore considered very important to give adequate attention to establishing the environmental water requirements of these river systems to ensure sustainable development of this region.

1.2 Planning Estimate of the Ecological Reserve

The Planning estimate of the ecological flow requirements for rivers is required by the Directorate: Project Planning of the Department of Water Affairs and Forestry (DWAF) for the purpose of the National Water Balance Model. This rough, largely desktop estimate of the "reserve" is referred to as the Water Balance Planning Estimate, or WBPE (Neels Kleynhans, pers. comm. May 1999). A procedure to determine the WBPE of the freshwater zones of rivers (i.e. excluding estuaries), based on an index of the ecological importance and sensitivity, has been developed by Kleynhans *et al* 1998 (see Figure 2).

In essence, the above method involves the determination of the desired Ecological Management Class (EMC) from the ecological importance and sensitivity data.

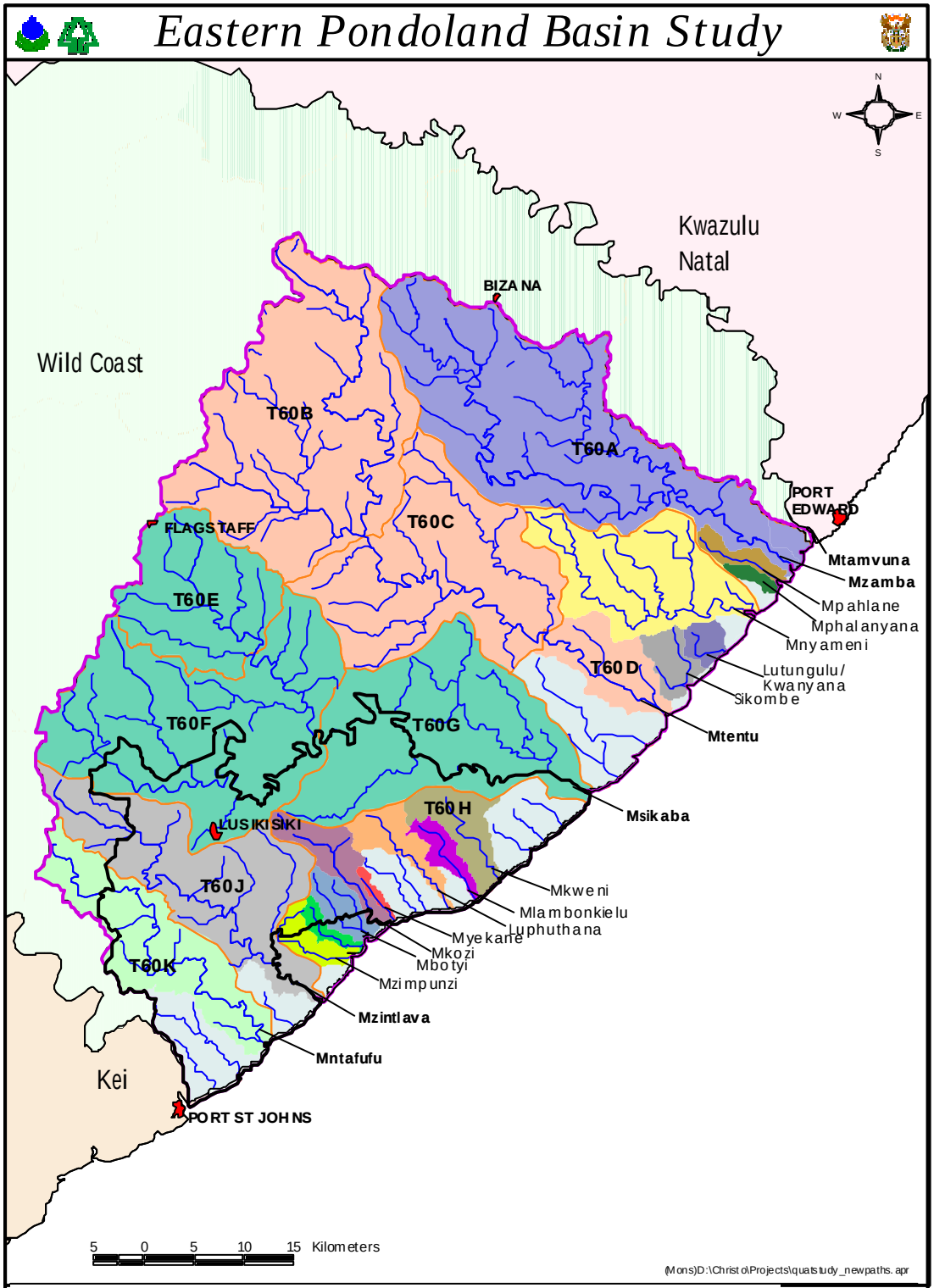


Fig 1: Map of Study Area

The river flow, given as a percentage of the MAR (note: unless specified, the term MAR refers to the natural MAR in this report), required to attain the particular desired (or future) EMC for the rivers in question, is then determined (see Figure 2). This is done (at present) using either a variation of the Montana or Tennant (1976) method or a method developed from the extrapolation of previous IFR's by Dennis Hughs of the IWR, Rhodes University. This above methodology has recently been applied to all quaternary catchments in the country as part of the National Water Balance Model study.

However, to date the estuarine freshwater flow requirements of the river systems have been largely ignored when determining the WBPE of the reserve during the above exercise. This may be a serious omission, as it is possible that in many instances the Estuarine Flow Requirements (EFRs) for certain types of estuaries may be higher than the freshwater Instream Flow Requirements (IFRs). In other words, the WBPE for the estuaries rather than the WBPE for the riverine zones, may well determine the amount of water available for the National Water Balance Model (i.e. water available for use by man) in many coastal rivers.

1.3 Eastern Pondoland Basin Study

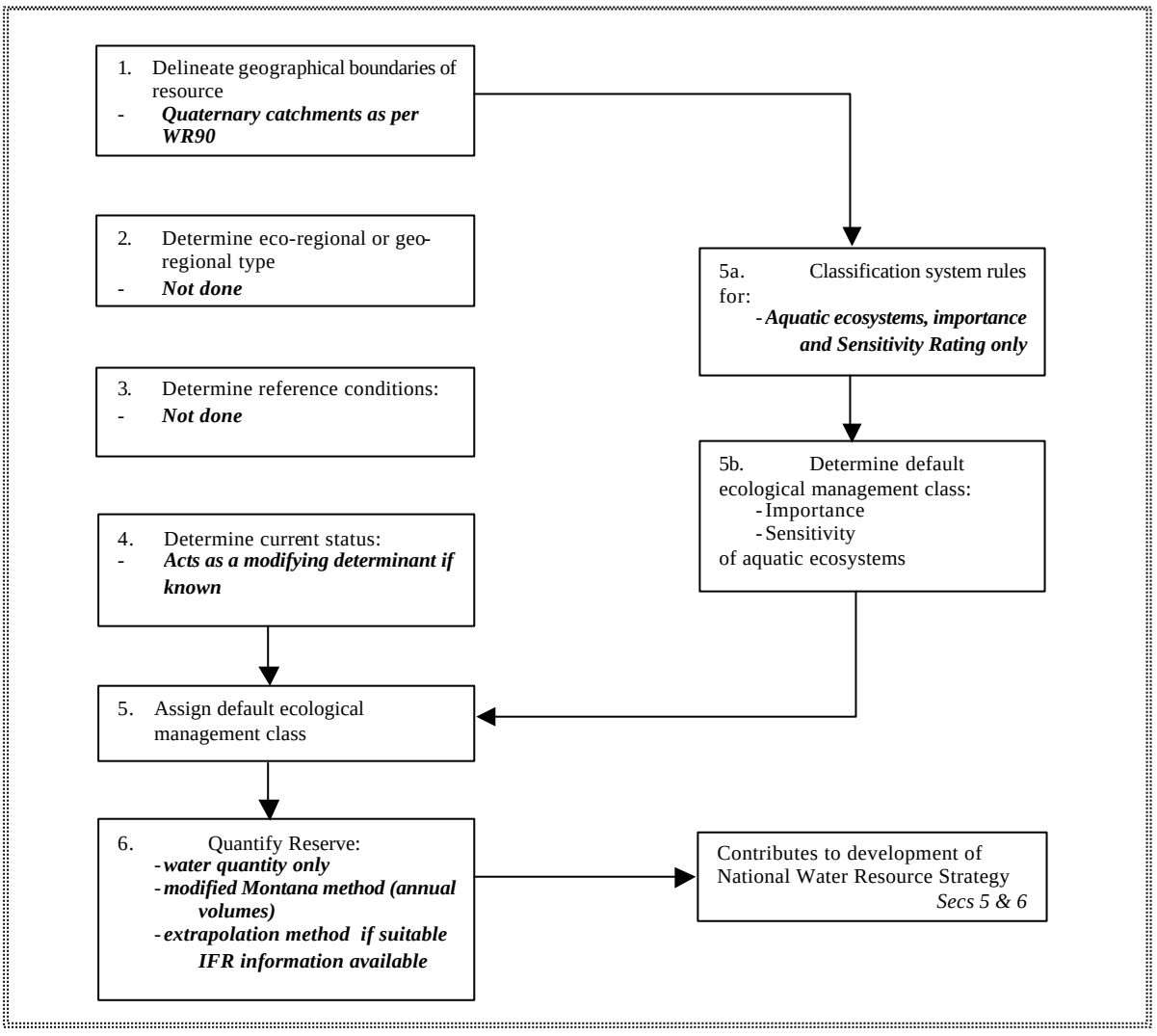
The estuaries in Pondoland are widely accepted as being among the most pristine in the country (if not in Africa) and are often less impacted by human activities than the riverine areas. In addition, many of these estuaries have valuable biota, such as mangroves, known to be very sensitive to changes (particularly reductions) to riverine inflow. It was therefore considered essential to determine the WBPE of these estuaries in some detail as part of the broader Eastern Pondoland Basin Study.

2. METHODOLOGY

2.1 Existing methods

At the time of preparation of this report (May 1999), an acceptable method for determining the planning estimate of the freshwater flow requirements (or ecological reserve) for estuaries was still in the developmental stage. However, it is widely accepted among estuarine scientists that the methodology developed by Kleynhans et al (1998) for riverine ecosystems is not directly applicable to estuaries. In addition, it is felt that estuaries are usually so different from each other and that enough information is available or can readily be obtained on each system, to ensure that each estuary should be treated individually rather than as part of a quaternary catchment.

Figure 2. Methodology for determination of Planning Estimates (After Kleynhans *et al* 1998)



It was therefore necessary to develop an appropriate methodology to determine the WBPE for estuaries as well as to apply this methodology to the estuaries included in the Eastern Pondoland Coastal Basin Study.

2.2 Approach Used

The approach used in this investigation involved the combined efforts of a multi-disciplinary team in a workshop situation. The workshop participants consisted of estuarine biologists familiar with these Pondoland estuaries, hydrologists (river flow) and experts in the field of estuarine hydrodynamics and coastal sedimentology. Details of this workshop (i.e. the starter documents, the delegates who attended, the objectives, the workshop programme and the results) are outlined below in the text and given in full in the annexures to this report.

In brief, this investigation involved the following steps:

a) A desktop study to determine the "significant estuaries" in the study area.

b) A desktop investigation to gather and analyse all available biotic and abiotic data on these estuaries and river systems by the various specialists. This included all known biological, hydrological and geo-morphological information, mouth dynamics (historical aerial photos, local records, etc.), human impact on the estuarine habitat and land use in riparian zones.

c) An up-to-date aerial photographic survey of the estuaries in the study area for the purpose of providing slides of each estuary for use at the workshop.

d) This recent as well as older photographic material of the estuaries, together with the data tabled at the workshop by the various specialists, enabled the delegates to use professional judgement to give scores on a variety on biotic and abiotic aspects – see below.

e) The application of the methodology (outlined below and shown as a flow chart in Figure 3) by the workshop delegates to generate a reasonably accurate estimate of the "ecological reserve" for each of the estuaries in the study area.

2.3 Methodology for Determining the WBPE for the 16 Estuaries

The methodology used to determine the WBPE for the estuaries investigated will not be presented in detail in this report. The development and refinement of a formal protocol to determine the WBPE of the estuarine reserve, applicable to all estuaries in South Africa, forms part of a separate Water Research Commission study, headed by Dr Janine Adams of UPE. A report setting out this methodology is in preparation and will be available to water resources managers (Janine

Adams, pers. comm. 1999). The methods developed and used to determine the WBPE for the estuaries in the eastern Pondoland coastal basin study at the workshop at UPE on 13 & 14th May 1999, formed part of this broader investigation.

In this regard, the methodology used in this study on the reserve for the Pondoland estuaries is more closely aligned to the "Generic Methodology for determination of the Reserve" presented in flow chart format in Figure 4 (after DWAF 1998) than the "Methodology for Determination of Planning Estimates" for rivers developed by Kleynhans *et al* 1998 (Figure 2).

An outline of the methodology used in this study is given in the flow chart in Figure 3. The application involved the following:

2.3.1 Determination of Significant Water Resources

The study area is bounded by the Mzamba River in the north and the Mtafufu in the south (see Figure 1). Within this area sixteen estuaries were judged to be "significant" (see Table 1). This choice was based on the basis of the volume of freshwater inflow into the estuary (i.e. size of the MAR of the river) and the presence of a functional estuary as recognised by estuarine scientists familiar with the area (Brian Colloty and Janine Adams, per. Comm. April 1999). A number of relatively large rivers in this region (e.g. Mlambonkielu and Mkambati rivers) do not form estuaries but plunge over the coastal escarpment into the sea. These systems were not included in this study

2.3.2 Determination of the Ecological Integrity

Unlike the method developed by Kleynhans (Figure 2), the main criteria used to determine the ecological management class (EMC) of the various estuaries was the present ecological status or present ecological integrity(EI) status. This was assessed in terms of the deviation of both biotic and abiotic components of the estuary (see Table 2) from the natural, un-impacted state. The EI status thus indicates the extent to which an estuary has been degraded by human impacts.

2.3.3 Determination of Ecological Importance

The ecological importance of an estuary (or river) is an expression of its importance in the maintenance of ecological diversity and functioning on local and wider scales (Kleynhans et al 1998). The various components used are listed in Table 3.

2.3.4 Determination of Sensitivity

Because of the major impact mouth dynamics has on estuarine systems, the sensitivity of the estuaries to more frequent mouth closure, resulting from reduced river flow, was assessed. The various biotic components included in this assessment are given in Table 4. These include the impact on fish and invertebrate species which breed in the sea or in estuaries and migrate through the estuaries into freshwater (catadromous species), as well as the impacts on the biota of lack of tidal fluctuations, increased water levels, etc.

2.3.5 Designation of Ecological Management Class (EMC)

The EMC (see Table C, Annexure 11) of each estuary was determined by assessing the current EI and the Importance rating scores (see Table 5). The EMC is determined by the higher of these values. Only one modifier was taken into account, namely the presence of designated conservation areas or nature reserves.

2.3.6 Estimation of the WBPE for the Estuaries

The final step in the process, involving the conversion of the EMC to a river flow value in terms of a percentage of the MAR for the various estuaries (see Figure 3), was more problematic. The sensitivity of the mouth to closure was the main consideration here and this varied for each system depending on variety of factors. These included catchment size (i.e. the MAR), the presence and availability of suitable sediment to form a bar at the mouth (or tidal inlet), the presence of rocky headlands providing protection from wave action and long-shore drift of sediment, the relationship between tidal currents and freshwater inflow in maintaining the mouth, whether the estuary was "perched" with little tidal ingress or had a large tidal prism, etc. etc.

2.4 Workshop Format

The workshop programme listing the contribution of the various speakers as well as the objectives (including steps undertaken to achieve these) and a list of all the workshop participants are given in Annexures 1 to 3 respectively. Only the results obtained from Day 1 will be given in this report as the proceedings of Day 2 will form part of a separate report by Dr Janine Adams.

FIGURE 3. METHOD USED TO DETERMINE THE PLANNING ESTIMATE OF THE ESTUARINE RESERVE FOR EASTERN PONDOLAND ESTUARIES

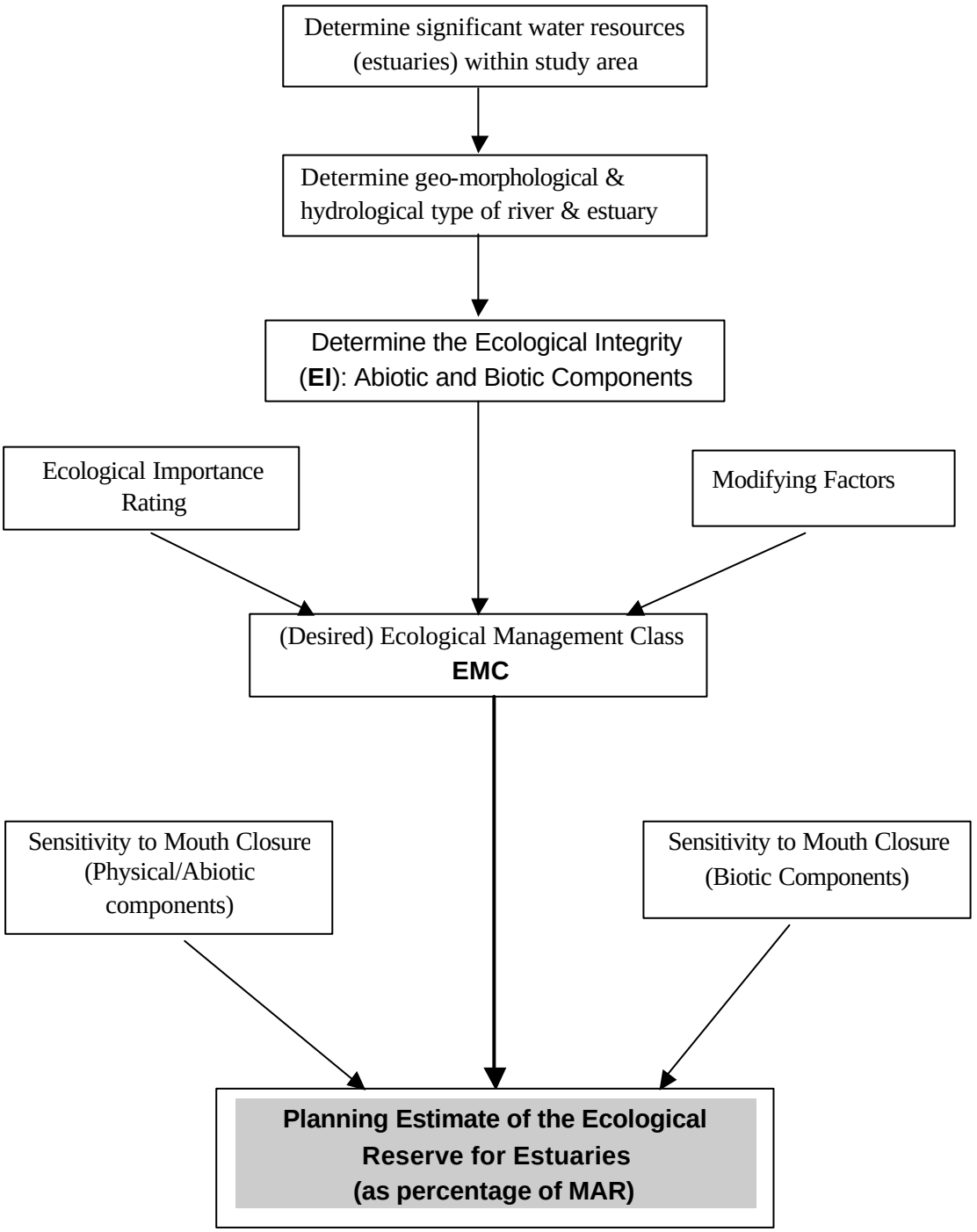
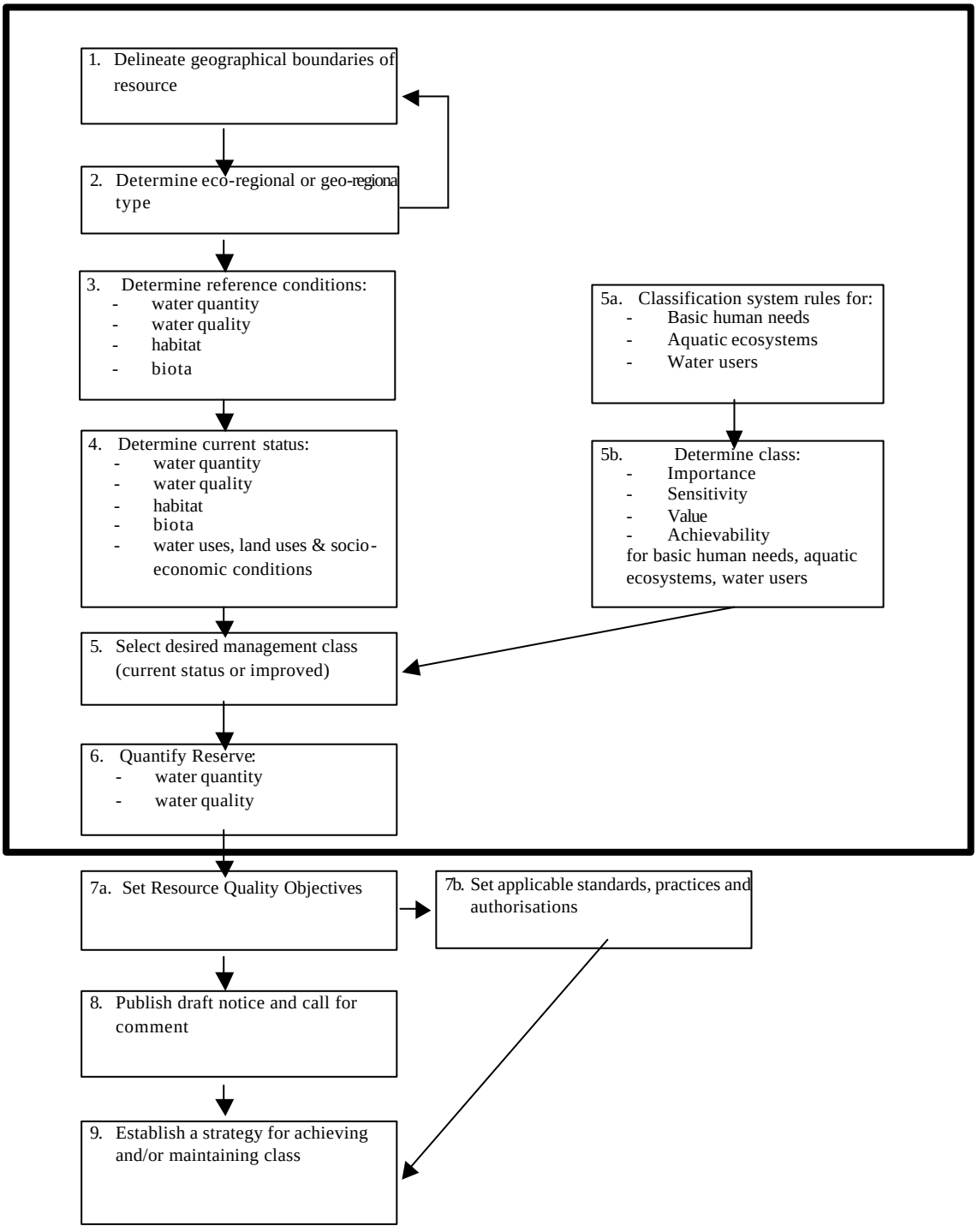


FIGURE 4. Generic Methodology for determination of the Reserve (DWAF 1998)



2.4.1 Starter Documents and Prepared Contributions

The format and content of Tables 1 to 7 for capturing the relevant data and expert opinions generated at the workshop were prepared by the author with input from Guy Bate and Janine Adams.

The starter documents and/or data presented by the various delegates for the workshop and attached to this report as Annexures are given below:

Author	**Document or data presented at workshop**	**Annexure Number**
P. Mtsweni	a) The size of the catchment areas and MAR's (10^6 m^3) of the 16 rivers in the study area based on simulated natural flow records from 1920/21 to 1996/97; b) Catchment area sizes, the MAP and MAR of each quaternary catchment area within the study area.	No 4 (1 pp.)
C. Doudenski	a) Estimated present annual water usage of the 16 rivers in the study area; b) Estimated present monthly water usage of the 16 rivers in the study area.	No 5 (2 pp.)
T. Harrison	Document: "Classification of Eastern Pondoland Estuaries".	No 6 (8 pp.)
V. Smakhtin	Figures and Charts showing Quaternary catchments, mean monthly flow distribution and standardised annual Flow Duration Curves for the 7 largest rivers, monthly water use in Mtafufu River and water use as % of MAR of 16 rivers in study area.	No 7 (5 pp.)
P. Huisenga	Table giving monthly and annual average flows of the 16 significant rivers both in Mm^3 and m^3s^{-1}.	No 8 (1 pp.)
B. Colloty (J. Adams & G. Bate)	Document: "Eastern Pondoland planning reserve estimate for sixteen estuaries- Vegetation Report".	No 9 (21 pp.)
T. Wooldridge	Document: " Starter Document: Planning Estimates of the Estuarine Reserve of Eastern Pondoland Estuaries".	No 10 (14 pp.
A. Bok	a) Table A - present-state categories based on Ecological Integrity (EI) status; b) Table B – Criteria for determining confidence levels for decision taken; c) Table C – Ecological Management Classes (EMC) categories based on current ecological integrity status.	No. 11 (2 pp.)

3. RESULTS

The proceedings of the workshop held at UPE on 13th May followed the steps as set out in the Workshop Objectives (see Annexure 2). Details of the results for all 16 estuaries are given in tabular format – see Tables nos. 1 to 7below.

Table 1. Physical classification (geo-morphological and hydrological) and sensitivity of the various estuarine classes to mouth closure due to reduced freshwater inflow (low, medium, high). For details of Geo-morphological classification see Annexure no. 6 .

ESTUARY	Geom. class	MAR (Mm^3)	Sensitivity to mouth closure	Explanation
Mtafufu	3a	45.81	Low	Medium-large, permanently open barred, tidally dominated
Mzintlava	3b	71.15	Low	Large, permanently open, barred (but lack of sediment?), tidally-dominated
Mzimpunzi	1a	9.10	High	Small, open/closed system, barred, perched, river-dominated outlet, limited tidal inflows
Mbotyi (Kobenge)	2	11.22	High	Small, open/closed system, barred, protected mouth, perched, river-dominated outlet
Mkozi	2	16.46	High	Small, open/closed system, barred, protected mouth, perched, river-dominated outlet
Myekane	1a	1.99	High	Small, open/closed system, barred, perched, river-dominated outlet, limited tidal inflows
Lupatana	1b	7.85	Low	Small, open/closed system, barred, perched, river-dominated outlet, limited tidal inflows
Mkweni	1a	18.45	Medium	Small, open/closed system, barred, perched, river-dominated outlet, limited tidal inflows
Msikaba	3b	207.87	Low	Large, permanently open, tidally dominated outlet, limited sediment at bar
Mtentu	3b	156.64	Low	Large, permanently open, tidally dominated outlet, limited sediment at bar
Sikombe	2	7.00	High	Small, shallow, exposed to wave action, barred, river-dominated outlet
Lutungulu/ Kwanyana	2	3.91	High	Small, shallow, exposed mouth, barred, limited tidal prism, river-dominated outlet
Mnyameni	3a	46.21	Medium	Medium-large, barred, tidally-dominated outlet, strong closing forces,
Mpahlan-yana	2	1.15	High	Very small, exposed mouth, barred, perched, river-dominated, dependant on base flow
Mpahlane	2	2.67	High	Very small, exposed mouth, barred, perched, river-dominated, dependant on base flow
Mzamba	3a	66.60	Medium	Medium-large, barred, only partly protected, tidally dominated, could close in drought

Table 2.1 Mtafufu: Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	**EI Status**	**Conf. Level**	**Remarks**
BIOTIC			
Fish	4	Med	
Invertebrates	4	Med	
Plants	3	High	Removal of reed and mangroves
MEAN	3.7		
ABIOTIC			
Water Quality	4	Med	
Condition: riparian	5	High	Photographs
Condition: instream	5	High	Photographs
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	High	Photographs, DWAF flow data
MEAN	4.8		
Combined = Ecological Integrity = (8.5 /2**) = 4.3**			

Table 3.1. Mtafufu: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	**IR Score**	**Conf. Level**	**Remarks**
Rare/endangered species	5	Med	Mangrove kingfisher, white-backed night heron
Unique biota	5	Med	Red mangrove stand
Diverse habitats	5	Med	
Unique habitats	5	Med	
Mean	**5**		

Table 4.1 Mtafufu: Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	**SR Score**	**Conf. level**	**Remarks**
Plants	5	High	Mangroves
Fish: Catadromous	5	High	Large catchment and freshwater habitat
Fish: Estuarine	4	Med	Large nursery area
Invertebrates: Cata	5	Med	Large catchment and freshwater habitat
Invertebrates: Est.	4	Med	Large nursery
Mean	**4.6**		

Table 2.2 Mzintlava: Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	-	-	
Invertebrates	-	-	
Plants	5	High	UPE Study
MEAN	5		
ABIOTIC			
Water Quality	-	-	
Condition: riparian	5	Med	Photographs
Condition: instream	5	Med	Photographs
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	High	Photographs, DWAF flow data
MEAN	5		
Combined = Ecological Integrity = (10/2) **= 5**			

Table 3.2. Mzintlava: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	-		
Unique biota	-		
Diverse habitats	5	Med	Mangroves, swamp forest
Unique habitats	-		
Mean	**5**		

Table 4.2. Mzintlava: Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. level	Remarks
Plants	5	High	Mangrove & swamp forest
Fish: Catadromous	5	High	Large catchment and freshwater habitat
Fish: Estuarine	4	Med	Large nursery area
Invertebrates: Cata	5	Med	Large catchment and freshwater habitat
Invertebrates: Es t.	4	Med	Large nursery area
(other)			
Mean	**4.6**		

Table 2.3 **Mzimpunzi:** Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	**EI Status**	**Conf. Level**	**Remarks**
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	4	High	UPE Study
MEAN	4		
ABIOTIC			
Water Quality	-		
Condition: riparian	3	Med	Photographs
Condition: instream	4	Med	Photographs
Freshwater inflow	5	Med	Photographs
Mouth condition	5	High	Photographs
MEAN	4.3		
Combined = Ecological Integrity = (8.3/2) **= 4.2**			

Table 3.3. Mzimpunzi: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	**IR Score**	**Conf. Level**	**Remarks**
Rare/endangered species	1	High	UPE study: Reed and sedges only
Unique biota	1	High	
Diverse habitats	1	High	
Unique habitats	1	High	
Mean	**1**		

Table 4.3. **Mzimpunzi:** Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure).

Component	**SR Score**	**Conf. level**	**Remarks**
Plants	2	Med	Reeds and sedges
Fish: Catadromous	3	Med	Small catchment, limited freshwater habitat
Fish: Estuarine	2	Med	Small system
Invertebrates: Cata	3	Med	Small catchment, limited freshwater habitat
Invertebrates: Est.	2	Med	Small system
Mean	**2.4**		

Table 2.4 **Mbotyi:** Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	**EI Status**	**Conf. Level**	**Remarks**
BIOTIC			
Fish	-		
Invertebrates	4	High	
Plants	4	High	UPE Study; increase in reeds
MEAN	4		
ABIOTIC			
Water Quality	-		Unknown
Condition: riparian	2	Low	Photographs: relatively high level of development
Condition: instream	2	Low	Photographs: causeway across estuary
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	High	Photographs, DWAF flow data
MEAN	3.5		
Combined = Ecological Integrity = (7.5/2) **= 3.8**			

Table 3.4. Mbotyi: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	**IR Score**	**Conf. Level**	**Remarks**
Rare/endangered species	1	Low	UPE study – plants only
Unique biota	1	Low	Only reeds and sedges
Diverse habitats	2	Med	Small swamp forest
Unique habitats	1	Med	
Mean	**1.3**		

Table 4.4. **Mbotyi:** Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	**SR Score**	**Conf. level**	**Remarks**
Plants	3		Small area of swamp forest present
Fish: Catadromous	3	Med	Small catchment, limited freshwater habitat
Fish: Estuarine	2	Med	Small nursery area
Invertebrates: Cata	3	Med	Small catchment, limited freshwater habitat
Invertebrates: Est.	2	Med	Small nursery area
Mean	**2.6**		

Table 2.5 **Mkosi:** Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	**EI Status**	**Conf. Level**	**Remarks**
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	5	High	UPE Study: no change over time
MEAN	5		
ABIOTIC			
Water Quality	-		
Condition: riparian	5	Med	Photographs
Condition: instream	5	Med	Photographs
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	Med	Photographs, DWAF flow data
MEAN	5		
Combined = Ecological Integrity = (10/2) **= 5**			

Table 3.5. Mkosi : Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	**IR Score**	**Conf. Level**	**Remarks**
Rare/endangered species	5	High	Mangrove species
Unique biota	-		
Diverse habitats	3	Med	
Unique habitats	4	Low	Mangroves
Mean	**4**		

Table 4.5. **Mkosi:** Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	**SR Score**	**Conf. level**	**Remarks**
Plants	5	High	Mangroves present
Fish: Catadromous	3	Med	
Fish: Estuarine	2	Med	
Invertebrates: Cata	3	Med	
Invertebrates: Est.	2	Med	
Mean	**3**		

Table 2.6 **Myekane:** Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	**EI Status**	**Conf. Level**	**Remarks**
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	5	High	UPE Study: no change over time
MEAN	5		
ABIOTIC			
Water Quality	-		
Condition: riparian	5	High	Photographs
Condition: instream	5	Med	Photographs
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	Med	Photographs, DWAF flow data
MEAN	5		
Combined = Ecological Integrity = (10/2) **= 5**			

Table 3.6. Myekane: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	**IR Score**	**Conf. Level**	**Remarks**
Rare/endangered species	1	High	Plants only
Unique biota	-		
Diverse habitats	3	Med	UPE studies
Unique habitats	1	Med	UPE studies
(other)			
Mean	**1.7**		

Table 4.6. **Myekane:** Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	**SR Score**	**Conf. level**	**Remarks**
Plants	1	High	UPE study: Reeds only, non-sensitive
Fish: Catadromous	3	Med	Small catchment; limited freshwater habitat
Fish: Estuarine	2		Limited nursery area
Invertebrates: Cata	3		Small catchment, limited freshwater habitats
Invertebrates: Est.	2		Limited nursery area
Mean	**2.2**		

Table 2.7 **Lupatana:** Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	4	High	UPE Study: loss of swamp forest
MEAN	4		
ABIOTIC			
Water Quality	-		
Condition: riparian	5	Med	Photographs
Condition: instream	5	Med	Photographs
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	Med	Photographs, DWAF flow data
MEAN	5		
Combined = Ecological Integrity = (9/2) **= 4.5**			

Table 3.7. Lupatana: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	1	High	UPE study: plants only
Unique biota	-		
Diverse habitats	3	Med	UPE study: reeds and swamp forest
Unique habitats	1	Med	
Mean	**1.7**		

Table 4.7. Lupatana: Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. level	Remarks
Plants	2	Med	UPE study: small swamp forest
Fish: Catadromous	1	Med	Small catchment. Waterfall barrier near estuary
Fish: Estuarine	1	Med	Very small system
Invertebrates: Cata	1	Med	Small catchment, waterfall barrier near estuary
Invertebrates: Est.	1	Med	
Mean	**1.2**		

Table 2.8 **Mkweni:** Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	5	High	UPE Study: no change in plants over time
MEAN	5		
ABIOTIC			
Water Quality	-		
Condition: riparian	5	Med	Photographs, no disturbance apparent
Condition: instream	5	Low	Photographs
Freshwater inflow			DWAF flow data
Mouth condition			Photographs, DWAF flow data
MEAN	5		
Combined = Ecological Integrity = (10/2) **= 5**			

Table 3.8 **Mkweni:** Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	1	High	UPE study: none found (plants only)
Unique biota	-		
Diverse habitats	3	Med	UPE study: Swamp forest and reeds
Unique habitats	1	Med	
Mean	**1.7**		

Table 4.8 **Mkweni:** Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. Level	Remarks
Plants	3	High	Swamp forest
Fish: Catadromous	3	Med	Small catchment, limited freshwater habitat
Fish: Estuarine	2	Med	Limited nursery area
Invertebrates: Cata	3	Med	Small catchment, limited freshwater habitat
Invertebrates: Est.	2	Med	Limited nursery area
Mean	**2.6**		

Table 2.9 **Msikaba:** Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	4	Med	Difficult to sample
Invertebrates	5	Med	Data from 1970's
Plants	3	High	UPE Study; reeds
MEAN	4		
ABIOTIC			
Water Quality	4	Med	Disturbed with high sediment in floods
Condition: riparian	5	Med	Photographs: very limited disturbance seen
Condition: instream	5	Med	Photographs: no disturbance seen
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	High	Photographs, DWAF flow data
MEAN	4.8		
Combined = Ecological Integrity = (8.8/2) **= 4.4**			

Table 3.9 **Msikaba:** Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	1	Med	Fish and plants
Unique biota	-		
Diverse habitats	3	Med	Rockfaces
Unique habitats	4	Med	Vertical walls, very deep holes
Mean	**2.7**		

Table 4.9 **Msikaba:** Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. level	Remarks
Plants	3	Med	Steep sides, limited area for plants
Fish: Catadromous	5	Med	Large catchment, large freshwater habitat
Fish: Estuarine	4	Med	Large system
Invertebrates: Cata	5	Med	Large catchment, large freshwater habitat
Invertebrates: Est.	4	Med	Large system
Mean	**4.2**		

Table 2.10 Mtentu: Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	4	Med	Moderate number of species
Invertebrates	4	Med	1970 survey data only
Plants	4	High	UPE study: increase in swamp forest and mangroves
MEAN	4		
ABIOTIC			
Water Quality	4	Med	CSIR Study, high E-Coli count
Condition: riparian	5	Med	Photographs: no development or disturbances
Condition: instream	5	Med	Photographs
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	Med	Photographs, DWAF flow data
MEAN	4.8		
Combined = Ecological Integrity = (8.8/2) = **4.4**			

Table 3.10 Mtentu: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5).

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	4	Med	Mud-skipper, mangrove kingfisher
Unique biota	-		
Diverse habitats	5	Med	Rocky ledges, deep channels
Unique habitats	5	High	Mangroves near freshwater waterfall
Mean	**4.7**		

Table 4.10 Mtentu: Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. level	Remarks
Plants	5	High	UPE study: mangroves and swamp forest
Fish: Catadromous	5	Med	Large catchment and freshwater habitat
Fish: Estuarine	4	Med	Relatively large estuary
Invertebrates: Cata	5	Med	Large catchment and hence freshwater habitat
Invertebrates: Est.	4	Med	Relatively large estuary
Mean	**4.6**		

Table 2.11 Sikombe: Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	5	H	UPE Study: no change in vegetation with time
MEAN	5		
ABIOTIC			
Water Quality	-		
Condition: riparian	5	Med	Photographs
Condition: instream	5	Med	Photographs
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	High	Photographs, DWAF flow data
MEAN	5		
Combined = Ecological Integrity = (10/2) **= 5**			

Table 3.11 Sikombe: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	1	Med	Plants only known
Unique biota	-		
Diverse habitats	3	Med	Swamp Forest
Unique habitats	1	High	
Mean	**2**		

Table 4.11. Sikombe: Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. level	Remarks
Plants	2	Med	Swamp forest
Fish: Catadromous	3	Med	Small catchment, limited freshwater habitat
Fish: Estuarine	2	Med	Small nursery area
Invertebrates: Cata	3	Med	Small catchment, limited freswater habitat
Invertebrates: Est.	2	Med	Small nursery area
Mean	**2.4**		

Table 2.12 **Lutungulu:** Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	4	High	UPE Study: reeds increasing
MEAN	4		
ABIOTIC			
Water Quality	-		
Condition: riparian	5	Med	Photographs
Condition: instream	5	Med	Photographs
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	Med	Photographs, DWAF flow data
MEAN	5		
Combined = Ecological Integrity = (9/2) = **4.5**			

Table 3.12 **Lutungulu:** Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	1	Med	Plants only
Unique biota			
Diverse habitats	3	Med	Swamp forest, reed beds
Mean	**2.7**		

Table 4.12 **Lutungulu:** Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. level	Remarks
Plants	1	High	UPE study: reeds only
Fish: Catadromous	3	Med	Small catchment, limited freshwater habitat
Fish: Estuarine	2	Med	Small system and nursery area
Invertebrates: Cata	3	Med	Small catchment and limited freshwater habit
Invertebrates: Est.	2	Med	Small estuary and nursery area
Mean	**2.2**		

Table 2.13 Mnyameni: Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	3	High	UPE Study: loss of mangroves over time
MEAN	3		
ABIOTIC			
Water Quality	-		
Condition: riparian	4	Med	Photographs – bush clearing and grazing
Condition: instream	3	Low	Photographs – damaged riparian zone, banks
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	Med	Photographs, DWAF flow data
MEAN	4.3		
Combined = Ecological Integrity = (7.3/2) **=3.7**			

Table 3.13 Mnyameni: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	1	High	Plants only
Unique biota			
Diverse habitats	3	Med	Swamp forest, reeds
Unique habitats	1	High	
Mean	**1.7**		

Table 4.13 Mnyameni: Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. level	Remarks
Plants	2	Med	Small swamp forest
Fish: Catadromous	4	Med	Medium size catchment
Fish: Estuarine	3	Med	Medium size estuary
Invertebrates: Cata	4	Med	Medium size catchement
Invertebrates: Est.	3	Med	Medium size estuary
Mean	**3.2**		

Table 2.14 Mpahlanyana : Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	5	High	UPE Study: no change over time
MEAN	5		
ABIOTIC			
Water Quality	-		
Condition: riparian	4	low	Photographs: settlement
Condition: instream	5	Low	Photographs
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	Med	Photographs, DWAF flow data
MEAN	4.8		
Combined = Ecological Integrity = (9.8/2) **= 4.9**			

Table 3.14 Mpahlanyana: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	1	High	Plants only (UPE)
Unique biota	-		
Diverse habitats	3	Med	Swamp forest, reeds and sedge, no mangroves
Unique habitats	1	High	
Mean	**1.7**		

Table 4.14 Mpahlanyana: Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. level	Remarks
Plants	1	High	UPE: reeds only
Fish: Catadromous	3	Med	Small catchment, limited freshwater habitat
Fish: Estuarine	2	Med	Small estuary, limited nursery area
Invertebrates: Cata	3	Med	Small catchment, limited freshwater habitat
Invertebrates: Est.	2	Med	Small estuary
Mean	**2.2**		

Table 2.15 **Mpahlane:** Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of various biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	**EI Status**	**Conf. Level**	**Remarks**
BIOTIC			
Fish	-		
Invertebrates	-		
Plants	5	4	UPE Study: no change over time
MEAN	5		
ABIOTIC			
Water Quality	-		
Condition: riparian	4	Med	Photographs: bush-clearing
Condition: instream	5	Low	Photographs
Freshwater inflow			DWAF flow data
Mouth condition			Photographs, DWAF flow data
MEAN	4.5		
Combined = Ecological Integrity = (9.5/2) = **4.8**			

Table 3.15 Mpahlane: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	**IR Score**	**Conf. Level**	**Remarks**
Rare/endangered species	1	High	Plants only
Unique biota	-		
Diverse habitats	1	High	
Unique habitats	1	low	Limited knowledge
Mean	**1**		

Table 4.15 **Mpahlane:** Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	**SR Score**	**Conf. level**	**Remarks**
Plants	1	High	UPE study: reeds only
Fish: Catadromous	3	Med	Small catchment, limited freshwater habitat
Fish: Estuarine	2	Med	Small system
Invertebrates: Cata	3	Med	Small catchment, limited freshwater habitat
Invertebrates: Est.	2	Med	Small estuary
Mean	**2.2**		

Table 2.16 Mzamba: Present Ecological Integrity (EI) Status (low = 0-1; medium = 2-3; high = 4-5) of biotic and abiotic components of estuary compared to undisturbed or natural condition.

Component	EI Status	Conf. Level	Remarks
BIOTIC			
Fish	4	Low	Moderate diversity of fish species
Invertebrates	-		
Plants	4	High	UPE Study: some loss of swamp forest and mangroves
MEAN	4		
ABIOTIC			
Water Quality	2	Med	High E-coli, high phosphate, low DO
Condition: riparian	4	Med	Photographs: some disturbance
Condition: instream	4	Med	Photographs: some disturbance
Freshwater inflow	5	High	DWAF flow data
Mouth condition	5	Med	Photographs, DWAF flow data
MEAN	4		
Combined = Ecological Integrity = (8/2) **= 4**			

Table 3.16. Mzamba: Importance Rating of estuary (low = 0-1; medium = 2-3; high = 4-5)

Component	IR Score	Conf. Level	Remarks
Rare/endangered species	1	High	Plants only
Unique biota	-		
Diverse habitats	4	Med	Swamp forest, reeds, sedges and mangroves
Unique habitats	4	Med	Mangroves
Mean	**3**		

Table 4.16 Mzamba: Sensitivity Rating (SR) of estuary (low = 0-1; medium – 2-3; high = 4-5) to reduced flow (i.e. more frequent mouth closure)

Component	SR Score	Conf. level	Remarks
Plants	3	Med	Small swamp forest and mangroves
Fish: Catadromous	5		Large catchment, large freshwater habitat
Fish: Estuarine	4		Fairly large system, suitable nursery areas
Invertebrates: Cata	5		Large catchment, suitable freshwater habitat
Invertebrates: Est.	4		Fairly large nursery area
Mean	**4.2**		

Table 5. Current Ecological Integrity (EI) compared to the "natural", undisturbed state; importance rating as well as future (desired) Ecological Management Classes (EMCs) of the 16 significant Eastern Pondoland estuaries. Class A = 4 - 5; Class B = 3 - 3.9; Class C = 2 - 2.9; Class D = 1 - 1.9. For description of EMC's see Table C.

Estuary	EI Rating	Imp. Rating	Modifier	EMC	Remarks
Mtafufu	4.3	5.0	-	A	
Mzintlava	5.0	5.0	-	A	
Mzimpunzi	4.2	1.0	-	A	
Mbotyi (Kobenge)	3.8	1.3	-	B	
Mkozi	5.0	4.0	-	A	
Myekane	5.0	1.7	-	A	
Lupatana	4.5	1.7	-	A	
Mkweni	5.0	1.7	-	A	
Msikaba	4.8	2.7	Provincial Reserve	A	Mkambati Nature Reserve on L. bank
Mtentu	4.4	4.7	Provincial Reserve	A	Mkambati Nature Reserve on R. bank
Sikombe	5.0	2.0	-	A	
Lutungulu	4.5	2.7	-	A	
Mnyameni	3.7	1.7	-	B	
Mpahlanyana	4.9	1.7	-	A	
Mpahlane	4.8	1.0	-	A	
Mzamba	4.0	3.0	-	A	

Table 6. Conversion of various Ecological Management Classes (EMC's) to % of MAR required for prevent measurable adverse effects on the (hypothetical) estuary (i.e. maintain designated EMC). Sensitivity to mouth closure determined by interaction of physical forces, i.e. geo-morphological (sediment dynamics) and hydrological (related to the size of MAR) (see text and Table 1).

EMC	Sensitivity to mouth closure	% of MAR	Remarks
A	High	90 - 99	Small MAR, open/closed system, barred, protected mouth, perched, river-dominated outlet, base-flow needed to keep mouth open (e.g: Mkosi).
	Medium	90-99	Small MAR, open/closed system, barred, not perched, river-dominated outlet, limited tidal inflows (e.g. Mkweni).
	Low	80-95	1) MAR large enough to maintain mouth, permanently open, tidally dominated outlet, limited sediment at bar, but base flow also important (e.g. Msikaba). 2) Small, open/closed system, protected, limited sediment for bar, perched, river-dominated outlet, limited tidal inflows (e.g. Lupatana).
B	High	90-99	Small MAR, open/closed system, barred, perched, river-dominated outlet, limited tidal inflows (e.g. Mbotyi).
	Medium	90-99	Medium-large MAR, barred, tidally-dominated outlet, exposed to strong closing forces (sediment and wave action (e.g. Mnyameni).
	Low	80-95	?

Table 7. Summary table giving the WBPE of the 16 estuaries (i.e. estimate of the percentage of the MAR required to maintain the designated EMC's and prevent measurable adverse effects). (Open = permanently or near-permanently open; Closed = closed/open or temporary open systems. Biotic sensitivity to closure scores: Class D = 0 - 1.9; Class C = 2 - 2.9; Class B = 3 – 3.9; Class A = 4 – 5).

Estuary	Class (geom./Hydro	Sensitivity to closure		EMC	MAR (Mm^3)	Percentage of MAR
		Abiotic	Biotic			
Mtafufu	Open	LOW	4.6	A	45.81	80-95
Mzintlava	Open	LOW	4.6	A	71.15	80-95
Mzimpunzi	Closed	HIGH	2.4	A	9.10	90-99
Mbotyi (Kobenge)	Closed	HIGH	2.6	B	11.22	90-99
Mkozi	Closed	HIGH	3.0	A	16.46	90-99
Myekane	Closed	HIGH	2.2	A	1.99	90-99
Lupatana	Closed	LOW	1.2	A	7.85	80-95
Mkweni	Closed	MED	2.6	A	18.45	90-99
Msikaba	Open	LOW	4.2	A	207.87	80-95
Mtentu	Open	LOW	4.6	A	156.64	80-95
Sikombe	Closed	HIGH	2.4	A	7.00	90-99
Lutungulu	Closed	HIGH	2.2	A	3.91	90-99
Mnyameni	Closed	MED	3.2	B	46.21	90-99
Mpahlanyana	Closed	HIGH	2.2	A	1.15	90-99
Mpahlane	Closed	HIGH	2.2	A	2.67	90-99
Mzamba	Open	MED	4.2	A	66.6	80-95

4. DISCUSSION

4.1 Ecological Management Classes (EMC's)

The relatively pristine status of these eastern Pondoland estuaries is shown by the 14 Class A and 2 Class B ecological management classes (EMC's) designated to the 16 estuaries at the workshop, based on their present Ecological Integrity (Table 7). In only 3 estuaries, namely the Mtafufu, Mzintlava and Msikaba, were the Importance ratings higher than the EI ratings. In all three instances, however, the EI ratings ensured that these estuaries were in a Class A EMC. Again in only three instances were the EI ratings slightly lower than the Sensitivity ratings, namely in the A Class Mtafufu, Mtentu and Mzamba estuaries (Table 7). In both cases where a modifier came into effect (Mkambati Nature Reserve adjoining the Msikaba and Mtentu estuaries), both estuaries were already placed in a Class A category.

4.2 Planning Estimates of the Reserve (WBPE) for the Estuaries

The estimated volumes of river flow, in terms of a percentage of the MAR required to maintain the designated EMC's (i.e. the ecological reserve) in these estuaries was linked to sensitivity to mouth closure. The main consideration used to estimate the reserve was therefore the river flow into the estuary required to maintain the natural functioning of the tidal inlet. In other words, the WBPE for these Class A and Class B estuaries was taken as the river flow needed to ensure that:

a) permanently open estuaries do not close, and
b) for temporary open/closed systems, the natural periods of the opening and closing of the tidal inlet be maintained.

Due to lack of hard data on sediment dynamics of these Pondoland estuaries, the "sensitivity to mouth closure" was closely linked to the size of the natural MAR of these rivers. The smaller the MAR the more sensitive to mouth closure. Other factors known to influence mouth closure (such as size/volume of estuary, wave action at the mouth, availability of sediment in the adjacent marine environment, presence of protective headlands, beach slope, etc.) were also taken into account, when known.

As shown in Table 7, the estimated WBPE for these 16 estuaries in the study area varied between:

a) 80 to 95% of the MAR for the "larger" systems (>100 Mm^3) and "medium" systems (10 –100 Mm^3), and

b) (90 to 99% of the MAR for "smaller" systems (<50 Mm^3).

4.3 Comparison of Results with WBPE for Riverine Zones

Kleynhans *et al* (1998), using a modification of the Montana method linked to various EMC's, recommended that for Class A rivers the instream flow requirements (i.e. reserve) should vary between 50-100% of the MAR and for Class B rivers the reserve was estimated at about 40% of the MAR. This is considerably lower than the > 80% of the MAR as recommended for the estuarine reserve at this workshop.

4.4 Important Considerations Influencing Development Options

- The natural dynamic state of the tidal inlets of these estuaries is maintained to a large extent by river base-flow, which is particularly important for ensuring that permanently open estuaries do not close.
- It is important in all these estuaries to maintain all of the base-flow in the present annual distribution pattern.
- The base-flow in these rivers is estimated to be about 40 to 50% of the MAR.
- Floods are also important for estuarine functioning as they have a major influence on sediment dynamics and thus mouth condition. It is postulated that 1 in 5 year floods and greater are particularly important regarding sediment dynamics and hence maintaining mouth condition. This largely explains the greater Estuarine Flow Requirements (EFR's) compared to the Instream Flow Requirements (IFR's) (see above).
- The present water usage in these 16 river systems in eastern Pondoland is very low (from <1 to 4.3% of natural MAR) and all of these rivers are (theoretically) still perennial (Annexure 7).
- Theoretically, if more that 6% of the natural MAR is removed from these rivers, flow will probably cease during the low-flow period and if more than 12% of MAR is removed, the rivers will stop flowing for 10% of the time (Annexure 7).
- Further studies on the estuarine dynamics of individual estuaries, particularly factors affecting sediment dynamics and mouth condition (open and closure), were required to determine the estuarine reserve more accurately.
- In estuaries where the utilization of the upstream water resources is seriously considered, it is recommended that a water level recorder be installed. The data obtained from such a recorder are required to facilitate the determination

of an accurate estimate of the estuarine flow requirements, i.e. the preliminary or full estimate of the ecological reserve for the estuary.

5. CONCLUSIONS

The results from this study indicate that in many instances the higher ecological flow requirements of these Pondoland estuaries would over-ride that of the IFR of the rivers. In terms of this basin study, this implies that the estuarine freshwater requirements would largely determine the upper limit to which the freshwater resources in this region will be able to be developed.

The substantially higher estuarine flow requirements are largely related to the fact that 100% of the base flow as well as "most" of the larger floods are required to maintain the "natural" mouth condition. The lack of quantitative data on the effect of the size of floods on sediment dynamics at the various tidal inlets was highlighted as a major unknown factor, resulting in a conservative (i.e. high) estimate of the estuarine reserve. This indicates that if maximum sustainable development (with minimum ecological impact) of the freshwater resources of these Pondoland rivers is desired, further studies to quantify the impact of river flow on mouth dynamics will be a prerequisite.

6. REFERENCES

DWAF (1998). Generic Metholodogy for Determination of the Reserve. Unpublished Report.

KLEYNHANS, C.J., BRUWER, C.A., KILIAN, V., WESTON, B., VAN WYK, N. AND SELLICK, C. (1998). A procedure for the determination of the flow requirements for the ecological reserve for the purpose of the planning estimate. DWAF, Unpublished Report. 22 pp.

ANNEXURE 1

Eastern Pondoland Basin Study Draft Programme of Workshop

EASTERN PONDOLAND BASIN STUDY

DRAFT PROGRAMME:

WORKSHOP TO DETERMINE THE PLANNING ESTIMATES OF THE ESTUARINE RESERVE OF 16 EASTERN PONDOLAND ESTUARIES

Venue: Kraal Conference Room, UPE, Port Elizabeth
Date: 13th May 1999
Time: 09:00 (for 09:30) to 16:30

09:30- 09:35	*Anton Bok* Welcome and Introduction
09:35– 09:45	*Frans Stoffberg* Planning Estimates: Purpose and use
09:45-09:55	*Barbara Weston* Planning Estimates: Existing methodology
09:55-10:15	*Guy Bate* Introduction, workshops objectives, protocols and procedures
10:15-10:30	Slide/video show of study area (Trevor Harrison & others)
10:30-10:40	*Trevor Harrison* Geomorphological Classification and EHI of Eastern Pondoland (EP) estuaries
10:40:10:55	*Vladimir Smakhtin* Hydrological classification of EP Rivers
10:55-11:10	*Piet Huizinga* Estuarine dynamics and sand budget of EP estuaries
11:10-11:25	*Janine Adams (and Brian Colloty)* Botanical Classification of EP estuaries and correlation with geomorphological classification
11:25-11:40	*Tris Wooldridge* Biological classification (invertebrates) of EP estuaries
11:40-12:00	TEA
12:00-13:00	*Guy Bate & Group* Placement of 16 EP estuaries into Future Management Classes (FMC's)
13:00- 13:30	LUNCH
13:30-15:00	*Guy Bate & Group* Finalise placement of 16 EP estuaries into FMC's; emphasis placed on Msikaba estuary
15:00-15:40	*Guy Bate and Group* Correlate FMC's with % of MAR's for Planning Estimate of Estuarine Reserve
15:40-16:00	TEA
16:00-16:30	*Guy Bate and Group*: Summary and Recommendations

DAY 2

Date: 14th May 1999
Time: 08:30 to 15:30

Day 2 will be funded from the Estuarine Reserve project.

The objective of the workshop will be to use the proceedings from Day 1 to develop a planning reserve estimate method for estuaries.

A planning method for estuaries is required as the planning estimate for rivers may not be adequate for estuaries.

Enquiries related to Day 2 must be addressed to Janine Adams (e-mail: btajba@upe.ac.za).

ANNEXURE 2

Objectives of Workshop on Eastern Pondoland Basin Study

WORKSHOP TO DETERMINE THE PLANNING ESTIMATES OF THE ESTUARINE RESERVE OF EASTERN PONDOLAND ESTUARIES TO BE HELD AT UPE, 13 & 14 MAY 1999

Objectives of workshop

It can be assumed that the general ecological information and principles used to determine the riverine planning estimate of the reserve will be used to determine the planning estimate of the estuarine reserve. It is therefore important that as much available data and expert opinions are captured during the workshop in a format that will enable the estimate of the estuarine reserve to be updated and refined as the methodology evolves and is improved.

Therefore, the objectives of the proposed workshop are to gather all available ecological (biotic and abiotic) information on the estuaries of Eastern Pondoland (EP) estuaries in question at the appropriate level of detail in order to:

(i) Classify the estuaries into geo-morphological classes and hydrological classes according to pre-determined criteria;

(ii) Use expert opinion and available knowledge of mouth opening and closure as well as available sand-budget data, in order to estimate the potential for mouth closure of the various estuaries and correlate with geo-morphological and hydrological classification;

(iii) Use available data and expert opinions of estuarine scientists from a number of disciplines at the workshop to determine the present ecological integrity (EI) status of the various estuaries;

(iv) Use available data and expert opinion as above to determine the importance and sensitivity rating of the various estuaries;

(v) The confidence levels for all decisions taken should be listed;

(vi) Determine the EMC's of each estuary using both the ecological integrity status and importance and sensitivity rating ;

(vii) Estimate the % of the MAR required to maintain the various EMC's as defined using the sensitivity to mouth closure derived from previously determined estuarine classification;

(viii) Determine the % of the MAR required to prevent measurable adverse effects on each estuary. This is done using estimates previously made for the various EMC's in the previous step.

During Day 2, the above methods used to determine the planning estimate of the reserve for the Pondoland estuaries will be further developed and refined. This will enable the results of Day 1 to be revisited and upgraded.

ANNEXURE 3

Participant List of EPBS Workshop at UPE on 13 & 14 May 1999

PARTICIPANT LIST: **EASTERN PONDOLAND BASIN STUDY (EPBS) WORKSHOP ON PLANNING ESTIMATE OF ESTUARINE RESERVE. *VENUE*: , UPE; *DATE*: 13 & 14 MAY 1999**

PARTICIPANT	REPRESENTING	ADDRESS	SPECIALITY/ROLE	CONTACT DETAILS
PROF GUY BATE	INSTITUTE FOR COASTAL RESOURCES	UNIVERSITY OF PE P O BOX 1600 PORT ELIZABETH. 6000	FACILITATOR: SPECIALIST: PHYTOPLANKTON MICRO ALGAE	TEL: (041) 504 2396 FAX: (041) 532 317 E.MAIL: btagcb@upe.ac.za
DR JANINE ADAMS	INSTITUTE FOR COASTAL RESOURCES	UNIVERSITY OF PE P O BOX 1600 PORT ELIZABETH. 6000	SPECIALIST: MACROPHYTES	TEL: (041) 504 2429 FAX: (041) 532 317 E.MAIL: btajba@upe.ac.za
DR ALAN WHITFIELD	JLB SMITH INSTITUTE OF ICHTHYOLOGY	P O BOX 1015 GRAHAMSTOWN. 6140	SPECIALIST: ICHTHYOLOGY	TEL: (046) 636 1002 FAX: (046) 622 2403 E.MAIL: ihaw@giraffe.ru.ac.za
DR PIET HUIZINGA	CSIR STELLENBOSCH	P.O.BOX 320 STELLENBOSCH. 7599	SPECIALIST: HYDRODYNAMICS	TEL: (021) 888 2495 FAX: (021) 888 2693 E.MAIL: phuizing@csir.co.za
MS SUSAN TALJAARD	CSIR, STELLENBOSCH	P.O.BOX 320 STELLENBOSCH. 7599	SPECIALIST: ESTUARINE DYNAMICS	TEL: (021) 888 2494 FAX: (021) 888 2693 E.MAIL: staljaar@csir.co.za
MR TREVOR HARRISON	CSIR DURBAN	P.O.BOX 17001 CONGELLA. 4013	SPECIALIST: ICHTHYOLOGY	TEL: (031) 261 8161 FAX: (031) 261 2509 E.MAIL: tharrison@csir.co.za
PROF TRIS WOOLDRIDGE	INSTITUTE FOR COASTAL RESOURCES	UNIVERSITY OF PE P O BOX 1600 PORT ELIZABETH. 6000	SPECIALIST: MACRO BENTHOS ZOOPLANKTON	TEL: (041) 504 2425 FAX: (041) 504 2317 E.MAIL: zlathw@zoo.upe.ac.za
MR BRIAN COLLOTY	INSTITUTE OF COASTAL RESEARCH	UNIVERSITY OF PE P O BOX 1600 PORT ELIZABETH. 6000	STUDENT: ESTUARINE BOTANIST	TEL. (041) 504 2383 FAX (041) 504 2317 E-MAIL:btbbmc@upe.ac.za
DR VLADIMIR SMAKHTIN	INSTITUTE FOR WATER RESEARCH	RHODES UNIVERSITY P O BOX 94 GRAHAMSTOWN. 6140	SPECIALIST: HYDROLOGIST/ ESTUARINE	TEL: (046) 622 4014 FAX: (046) 622 4014 E.MAIL: smakhtin@iwr.ru.ac.za
MS BARBARA WESTON	SOCIAL & ECOLOGICAL SERVICES	DWAF PRIVATE BAG X313 PRETORIA. 0001	ESTUARINE MANAGEMENT	TEL: (012) 338 8221 FAX: (012) 338 8678 E.MAIL: ded@dwaf.pwv.gov.za

DR DIRK VAN DRIEL	IWQS	DWAF P/B X313 PRETORIA,0001	ESTUARINE MANAGEMENT	TEL: (012) 808 0374 FAX: (012) 808 0338 E.MAIL: eeu@dwaf-hri.pwv.gov.za
MR CHRISTO DOUDENSKI	UWP-ENGINEERS	JOHANNESBURG	PROJECT LEADER	TEL: (011) 709 8433 FAX: (011) 463 6176
DR ANTON BOK	AQUATIC ENVIRONMENTAL CONSULTANT	5 YOUNG LANE, MILL PARK, PORT ELIZABETH, 6001	PROJECT CO-ORDINATOR	TEL: (041) 3733 464 FAX: (041) 3733 464 E-MAIL: antonbok@iafrica.com
MR ALAN BROWN	DWAF	PRETORIA	CHIEF ENGINEER DIRECTORATE OF WATER RESOURCES PLANNING (CLIENT)	TEL: (012) 338 8319 FAX: (012) 3388295
MR DENNIS BEHRMANN	DWAF	PRETORIA	ENGINEER DIRECTORATE OF WATER RESOURCES PLANNING (CLIENT)	TEL: (012) 338 8195 FAX: (012) 338 8295
MR THEO GELDENHYS	DWAF	REGIONAL OFFICE CRADOCK	CHIEF ENGINEER	TEL: (048) 81 3005 FAX: (048) 81 3545
MS ZANELE MABASO	DWAF	REGIONAL OFFICE CRADOCK	GEOGRAPHER T	TEL: (048) 881 3545 FAX: (048) 881 3005
MR PATRICK MTSWENI	DWAF:HYDROOGY	PRETORIA	HYDROLOGIST	TEL: (012) 338 7901

ANNEXURE 4

Simulated MAR of 16 Pondoland Estuaries and Quatenary Catchment Sizes, MAP & MAR in study area

MAR based on simulated natural flow records by P. Mtsweni over the record period 1920/21 to 1996/97

River name	Quatenary	Catch. Area (km^2)	Sim. MAR 10^6 m^3
Mtafufu	T60K	185.87	45.81
Mzintlava	T60J	270.00	71.15
Mzimpunzi	T60H	23.57	9.10
Mbotyi	T60H	28.85	11.22
Mkozi	T60H	42.54	16.46
Myekane	T60H	5.19	1.99
Lupatana	T60H	20.13	7.85
Mkweni	T60H	47.70	18.45
Msikaba	T60G	1022.00	207.87
Mtentu	T60D	964.10	156.64
Sikombe	T60D	28.22	7.00
Lutungulu	T60D	15.83	3.91
Mnyameni	T60D	186.13	46.21
Mpahlanyane	T60A	8.78	1.15
Mzamba	T60A	505.47	66.6
Mpahlane	T60A	20.20	2.67

Quatenary	Catch Area (km^2)	MAP (mm)	MAR 10^6 m^3
T60A	547	873	72.08
T60B	528	896	75.68
T60C	363	952	62.86
T60D	415	1072	102.93
T60E	198	885	28.09
T60F	464	940	79.28
T60G	360	1116	100.51
T60H	322	1277	124.66
T60J	294	1101	77.50
T60K	242	1075	59.60

ANNEXURE 5

Estimated Present Annual Water Usage & Estimated Present Monthly Water Usage

TABLE 1: ESTIMATED PRESENT ANNUAL WATER USAGE

River subcatchment	Quoternary	PRESENT ANNUAL WATER USAGE In Ml (10^3 m^3) or Mm^3 (10^6 m^3) as indicated					
		Domestic & industrial usage Ml	Livestock watering Ml	Irrigation Ml	Afforestation Ml	Total annual Ml	Total annual Mm3
Mpahlanyana	T60A-2	1	6		-	7	0.01
Mpahlane		2	14		-	16	
Mzamba		215	397		1,911		
Mtentu	T60B, T60C, T60D-1	1,270	763				
Sikombe	T60D-3	3	22		-		
Lutungulu		12	12		-		
Mnyameni		125	153		-		
Msikaba	T60E, T60F, T60G	2,263	807	13	4,526		
	T60H-2	2	18		-		
		3	22		-		
		4	33		-		
		0	4		-		
		3	30		-		
		2	16		-		
		34	41		-		
		116	212		2,014		
		297	144	7			
Total for above catchments		4,352	2,696	20	14,500	21,568	21.57

TABLE 2: ESTTIMATED PRESENT MONTHLY WATER USAGE

River subcatchment	Quaternary drainage region	Total annual water usage Ml/a	PRESENT MONTHLY WATER USAGE											
			OCT Ml	NOV Ml	DEC Ml	JAN Ml	FEB Ml	MAR Ml	APR Ml	MAY Ml	JUN Ml	JUL Ml	AUG Ml	SEP Ml
Mpahlanyana	T60A-2	7	1	1	1	1	1	1	1	1	0	0	0	1
Mpahlane	T60A-3	16	1	1	2	2	2	1	1	1	1	1	1	1
Mzamba	T60A-4	2,536	178	186	226	246	210	236	216	215	206	179	224	214
Mtentu	T60B, T60C, T60D-1	8,538	467	488	586	635	550	610	557	549	523	456	568	549
Sikombe	T60D-3	24	2	2	2	3	2	2	2	2	2	1	2	2
Lutungulu	T60D-4	25	2	2	2	3	2	2	2	2	2	1	2	2
Mnyameni	T60D-6	278	23	25	28	30	28	25	23	21	19	16	19	21
Msikaba	T60E, T60F, T60G	7,596	555	585	692	749	656	707	645	629	594	519	639	629
Mzinpunzi	T60H-2	20	2	2	2	2	2	2	2	2	1	1	1	2
Mbotyi	T60H-4	25	2	2	2	3	2	2	2	2	2	1	2	2
Mkozi	T60H-5	37	3	3	4	4	4	3	3	3	2	2	2	3
Myekane	T60H-6	5	0	0	0	1	0	0	0	0	0	0	0	0
Luphuthana	T60H-8	34	3	3	3	4	3	3	3	3	2	2	2	3
Mlambonkulu	T60H-10	18	1	2	2	2	2	2	1	1	1	1	1	1
Mkweni	T60H-11	75	6	7	8	8	8	7	6	6	5	4	5	6
Mzintlava	T60J-3	2,342	160	165	204	221	188	219	201	202	195	170	215	202
Mntafufu	T60K-2	1,993	139	145	177	192	164	196	170	169	163	142	178	169
Total for above catchments		21,568	1,545	1,621	1,942	2,103	1,824	2,009	1,835	1,805	1,718	1,499	1,862	1,805

ANNEXURE 6

Document: "Classification of Eastern Pondoland Estuaries"

Classification of Eastern Pondoland Estuaries

T.D. Harrison

Division of Water, Environment and Forestry Technology, CSIR

P.O. Box 17001, Congella, 4013

Introduction

The Pondoland coast, from Port St Johns to Port Edward has some 45 outlets to the sea. These range from large tidal estuaries to small coastal streams and in some cases, waterfalls which plunge directly into the ocean.

As part of an exercise to determine the estuarine reserve of 16 selected systems along this coast, one of the objectives is to classify these systems into similar groups based on their morphology. However, given the paucity of data available, an attempt has been made here to arrange these estuaries based on their similarities to a preliminary classification of 43 Transkei estuaries undertaken by Dr Andrew Cooper (Harrison *et al*., 1999).

Estuary Classification

The classification of 43 selected Transkei estuaries was based upon a number of geomorphological parameters obtained from a combination of field observations and measurements, historical references, and analysis of aerial photographs and topographical map sheets. Parameters used in the classification included: salinity, mouth condition, barrier type, floodplain dimensions, channel dimensions, the presence of tidal flow, and mean annual runoff (MAR). These data were reduced to an ordinal scale and subjected to cluster analysis. The resultant groupings were then tested against field observations and a series of iterations enabled the establishment of a geomorphologically acceptable classification.

The results of the classification resulted in four basic groups of estuaries being identified:

Group 1. This comprised a relatively large assemblage of small systems with variable characteristics but which are temporarily open due either to a small river catchment and/or a small tidal prism. These systems close either due to an inability to overcome onshore/alongshore sand transport by freshwater discharge, or due to extreme marine influences which may close the outlet. They vary from brackish to fresh in salinity characteristics. Further detailed investigations may reveal this group to be quite variable, but for the time being these systems have been grouped mainly on the basis of their small size. For the purposes of this exercise these systems are referred to as small, temporarily open, barred estuaries. Although not part of the scope of this exercise, two Pondoland estuaries (Ntlupeni and Butsha) were classified in this group.

Within Group 1, a sub-group of small systems which are believed to be nearly permanently open were also recognised. These appear to produce mainly seaward discharge through a shallow channel maintained by the beach water table. Some marine input to these systems may take place via barrier overwashing but this is reduced compared to other systems in the group. Although these estuaries have been described as a sub-group of Group 1 estuaries, their lack of a substantial barrier, near-permanent mouth condition and frequent marine input suggests that they may comprise a discrete group. For this reason these systems are described as small, open, non-barred estuaries.

Group 2. These were moderately sized systems with temporarily open mouths. Many are perched slightly above sea level and water levels fall by a small amount when they open. The relatively low elevation of most of the coastal barriers of these systems may be attributed to high wave energy which also promotes barrier overwashing and the introduction of sea water even during closed phases. In these systems periodic breaching appears to rely on increased river discharge. When open, the systems may experience tidal inflow but the tidal prisms thus induced are insufficient to generate tidal flows capable of maintaining the inlet for prolonged periods against marine processes. Although quite diverse, no sub-divisions were recognised in this group which can be described as moderate, temporarily open, barred systems. The

Mtentwana, just south of Port Edward, was the only Pondoland estuary which fell into this group.

Group 3. This group of estuaries have near-permanent inlets with regular tidal exchange. They usually well-developed flood-tidal deltas produce shallow sandy areas around the estuary mouth and the system becomes deeper n its middle reaches. At the upper reaches such systems typically contain a fluvial delta that marks the downstream limit of fluvial coarse grained sedimentation. It is important to note that the gradual advance of these deltas together with lateral sedimentation may cause such systems to eventually move toward a river-dominated condition.

Although three sub-groups were identified, they can essentially be divided into tidally-dominated, barred estuaries and tidally-dominated estuaries with no barrier.

In tidally-dominated barred estuaries it is the large tidal prisms that maintain the inlets. This implies that the volume of water that enters the estuary on each rising tide generates tidal currents sufficiently strong to maintain the inlet against littoral drift and cross-shore wave-induced sediment transport processes which may act to close the inlet. Such systems may close due to enhanced marine influences (e.g. during storms) rather than as a result of reduced freshwater flow. At these times, increased river discharge or human intervention may be necessary to breach the barrier and reinstate the tidal inlet. Two Pondoland estuaries, the Mntafufu and Mzamba, fell into this category.

Two estuaries, the Msikaba and Mtentu were classified as tidally-dominated estuaries with no barrier. Their main characteristic is their lack of a barrier and barrier-associated sediment bodies. This morphological difference is further reflected in the substrate type (mud and boulders). Its most important consequence is that these estuaries cannot close due to a lack of available barrier sediment.

Group 4. These systems are considered to be estuaries dominated by river flow and exhibit minimal tidal influence. Such river-dominated estuaries rely on a large freshwater discharge to maintain a connection with the sea; their tidal prism alone is insufficient to maintain an inlet against marine-processes that act to close the tidal inlet. The consequences for such systems of changes in discharge are likely to be much more profound than for tidally dominated estuaries. The Mzimvubu estuary at Port St Johns is an example of this type of system.

In an attempt to classify the 16 Pondoland estuaries, each system was grouped according to its relative size, the predominant mouth condition, the presence or absence of a barrier, and the predominant process of maintaining an outlet. These results are presented in Table 1.

Table 1. Morphological classification of 16 Pondoland estuaries.

Estuary	Size	Mouth	Barrier	Outlet	Estuary type
Mntafufu	large	open	present	tidal	open, tidally-dominated, barred
Mzintlava	large	open	absent?	tidal	open, tidally-dominated, non barred
Mzimpunzi	small	open/closed	present	river	small, temporarily open, barred
Mbotyi	moderate	open/closed	present	river	moderate, temporarily open, barred
Mkosi	moderate	open/closed	present	river	moderate, temporarily open, barred
Myekane	small	open/closed	present?	river	small, temporarily open, barred
Lupatana	small	open	absent	river/tidal	small, open, non barred
Mkweni	small	open/closed	present	river	small, temporarily open, barred
Msikaba	large	open	absent	tidal	open, tidally-dominated, non barred
Mtentu	large	open	absent	tidal	open, tidally-dominated, non barred
Sikombe	moderate	open/closed	present	river	moderate, temporarily open, barred
Kwanyana	moderate	open/closed	present	river	moderate, temporarily open, barred
Mnyameni	large	open	present	tidal	open, tidally-dominated, barred
Mpahlanyana	moderate	open/closed	present	river	moderate, temporarily open, barred
Mpahlane	moderate	open/closed	present	river	moderate, temporarily open, barred
Mzamba	large	open	present	tidal	open, tidally-dominated, barred

Of the 16 selected Pondoland estuaries, six were classified as near-permanently open estuaries. Of these, the Mntafufu, Mnyameni and Mzamba appear to be systems in which tidal currents are responsible for maintaining an inlet against sediment transport processes which may act to close the mouth. Such systems may close as a result of marine storm events rather than reduced freshwater flow and at these times, increased river discharge or human intervention may be necessary to reinstate the tidal inlet. The remaining three near-permanently open estuaries (Mzintlava, Msikaba, and Mtentu) appear to lack a barrier and barrier-associated sediment bodies. These systems appear to be confined to narrow valleys and contain fairly well developed flood-tidal deltas in their lower reaches. The implications of a lack of a significant barrier at the mouth this is that reduced freshwater flow will not result in these estuaries closing due to a lack of available barrier sediment. Although reduced freshwater input may not have a

significant impact on the mouth condition of these estuaries, it may have some ecological consequences particularly with regard to maintaining estuarine salinity gradients necessary to maintain certain biota.

Six estuaries in the region (Mbotyi, Mkosi, Sikombe, Kwanyana, Mpahlanyana, Mpahlane) were classified as moderately sized systems with temporarily open mouths. In these systems periodic breaching appears to rely on increased river discharge. When open, the systems may experience tidal inflow but this is not sufficient to maintain an inlet for prolonged periods. A reduction in freshwater flow into these systems will result in prolonged mouth closure. Although barrier overwashing may introduce sea water into these estuaries during closed phases, many organisms which utilise estuaries require an open mouth for at least part of the year.

The remaining four estuaries were small systems. The Mzimpunzi, Myekane and Mkweni all appear to have sand barriers while the Lupatana opens to the sea over a pebble/shingle beach and appears to be permanently open. A reduction in freshwater input into these systems will result in prolonged mouth closure, however, given their small size this may even lead to these systems drying up completely.

In summary, six of the 16 selected Pondoland estuaries are large, open, tidal estuaries in which a reduction in freshwater inflow is unlikely to have an effect on their mouth condition. The remaining 10 estuaries are small to moderately sized systems in which a reduction of freshwater input may have a significant effect on their mouth dynamics and consequently their ecology.

References

HARRISON, T. D., COOPER, J. A. G., RAMM, A. E. L. & SINGH, R. A. 1999. *Application of the Estuarine Health Index to South Africa's estuaries, Transkei. Technical Report.* East Coast Programme, CSIR, Durban. Submitted to Department of Environmental Affairs.

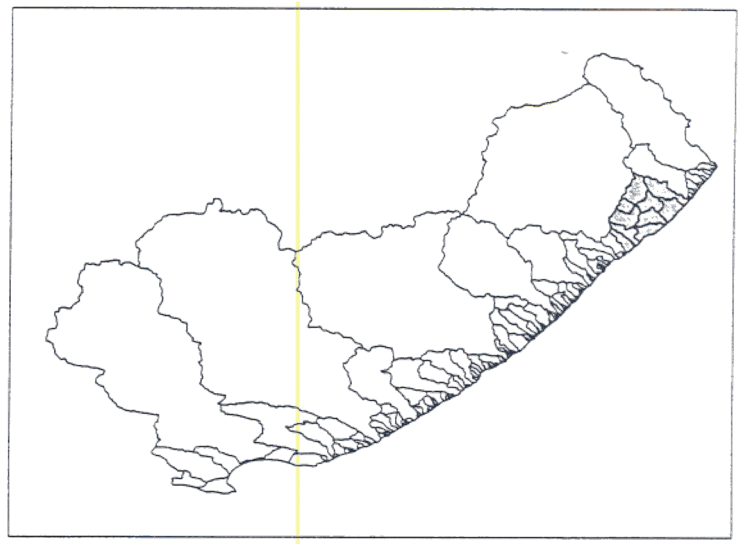
Technical Report. East Coast Programme, CSIR, Durban. Submitted to Department of Environmental Affairs.

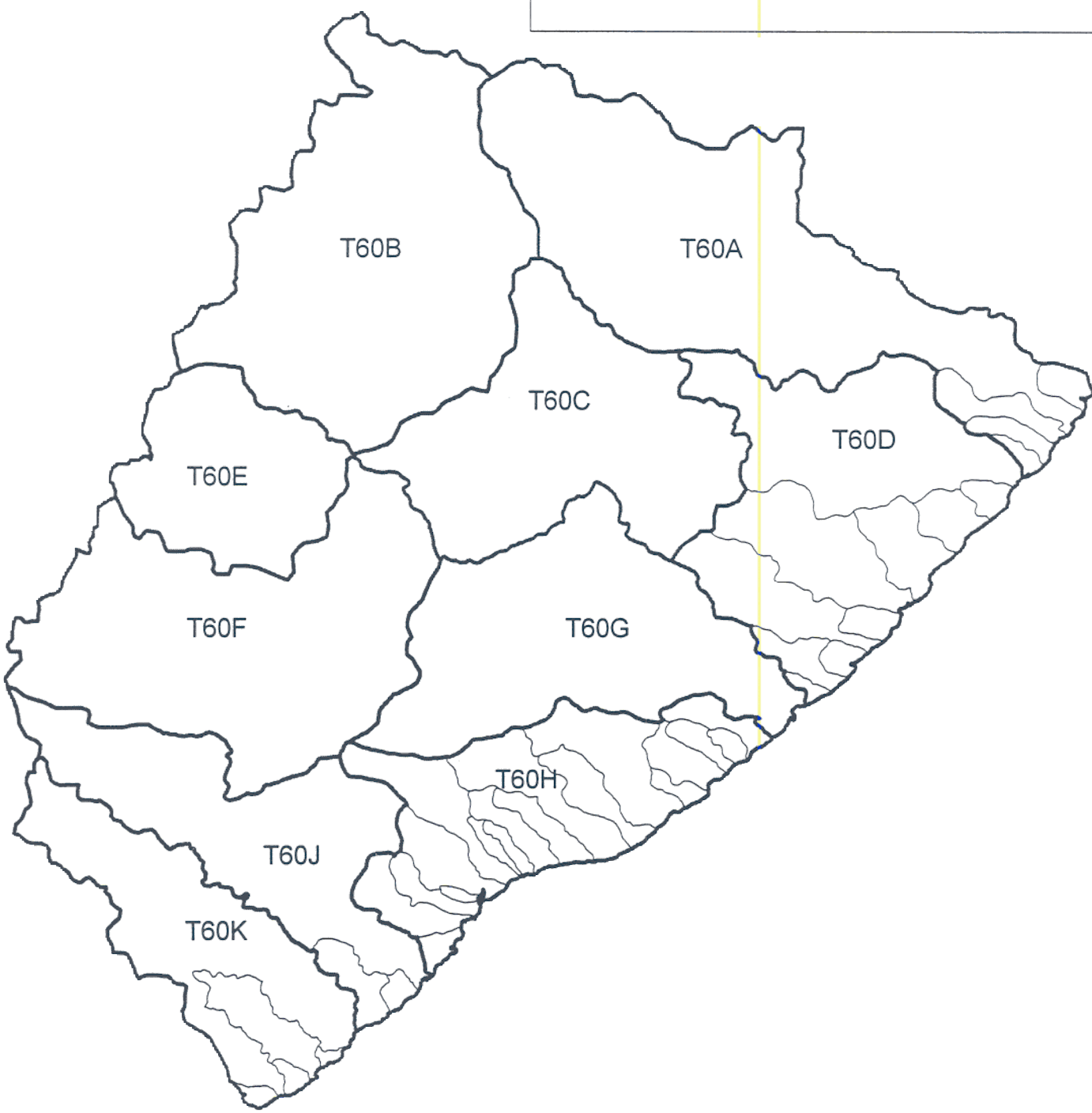
C ass cati on o Pondo and Es uar e

Estuary	Size	Mouth	Barrier	Outlet
Mntafufu	L	O	√	tide
Mzintlava	L	O	x?	tide
Mzimpunzi	S	O/C	√	river
Mbotyi	M	O/C	√	river
Mkosi	M	O/C	√	river
Myekane	S	O/C	√?	river
Lupatana	S	O	x	river/tide
Mkweni	S	O/C	√	river
Msikaba	L	O	x	tide
Mtentu	L	O	x	tide
Sikombe	M	O/C	√	river
Kwanyana	M	O/C	√	river
Mnyameni	L	O	√	tide
Mpahlanyana	M	O/C	√	river
Mpahlane	M	O/C	√	river
Mzamba	L	O	√	tide

ANNEXURE 7

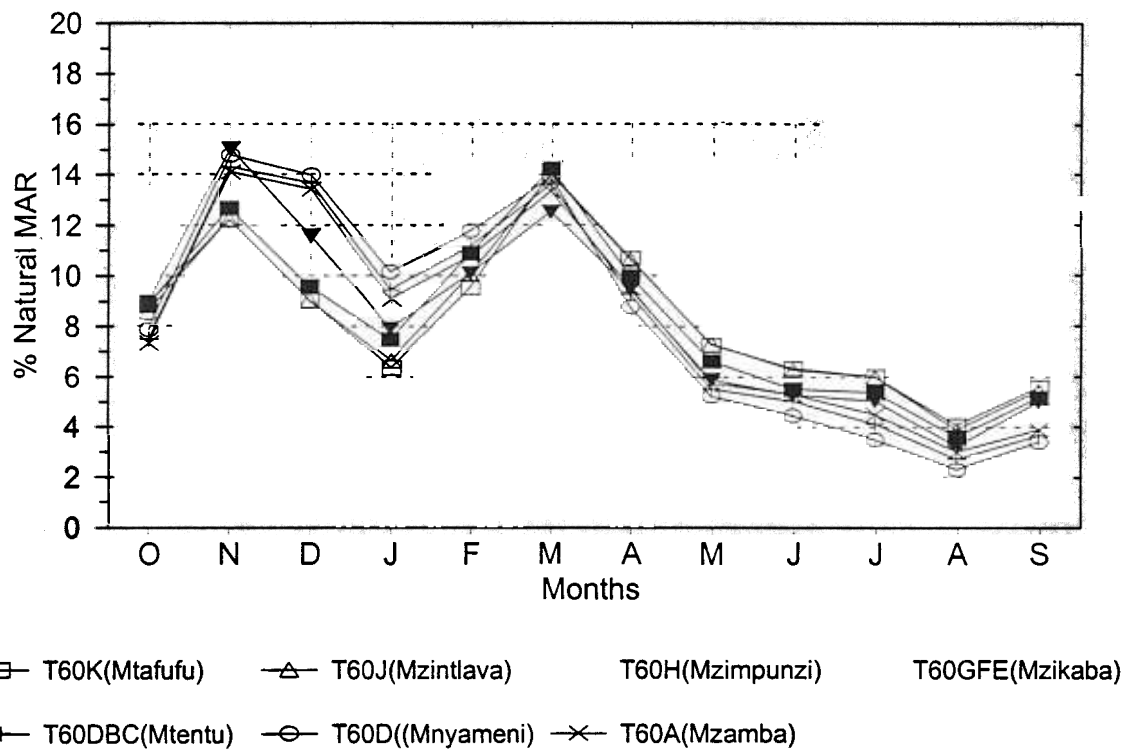
Figures and Charts showing Quatenary catchments, mean monthly flow distribution and standardised annual Flow Duration Curves for the 7 largest rivers, monthly water use in Mtafufu River and water use as % of MAR of 16 rivers in study area




T60B
T60A
T60C
T60D
T60E
T60F
T60G
T60H
T60J
T60K

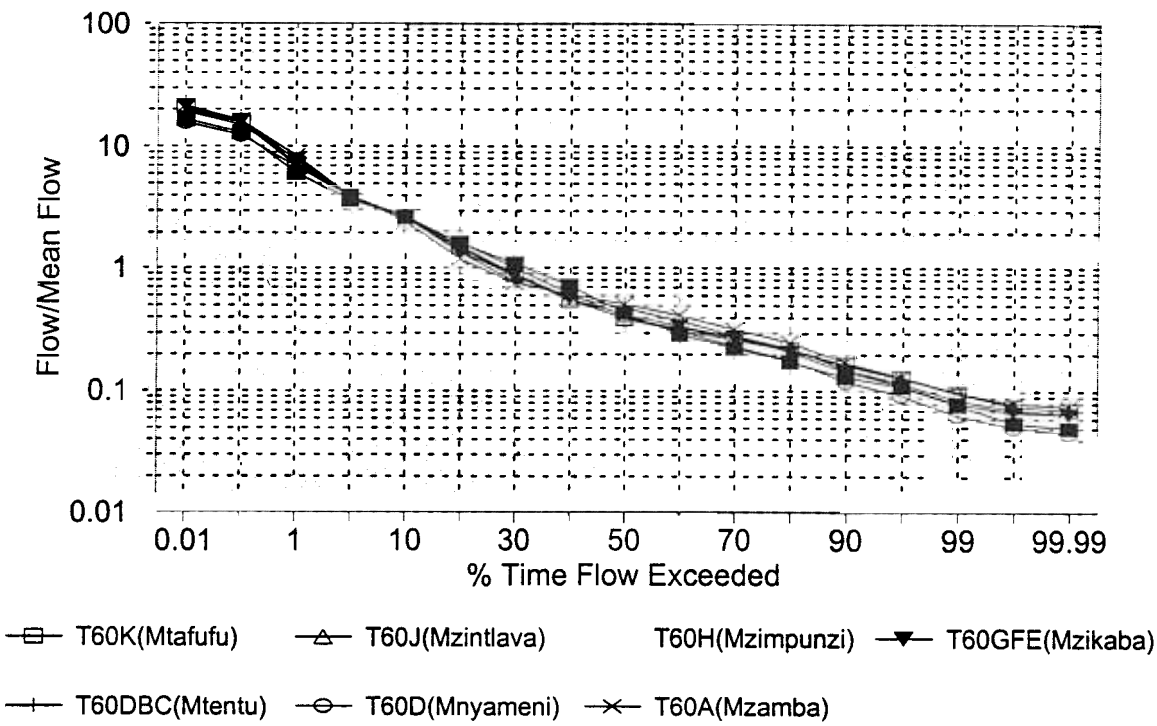
Mean Monthly Flow Distribution

Quaternary Catchments in Pondola



Standardised annual FDCs

Quaternary catchments in Pondola

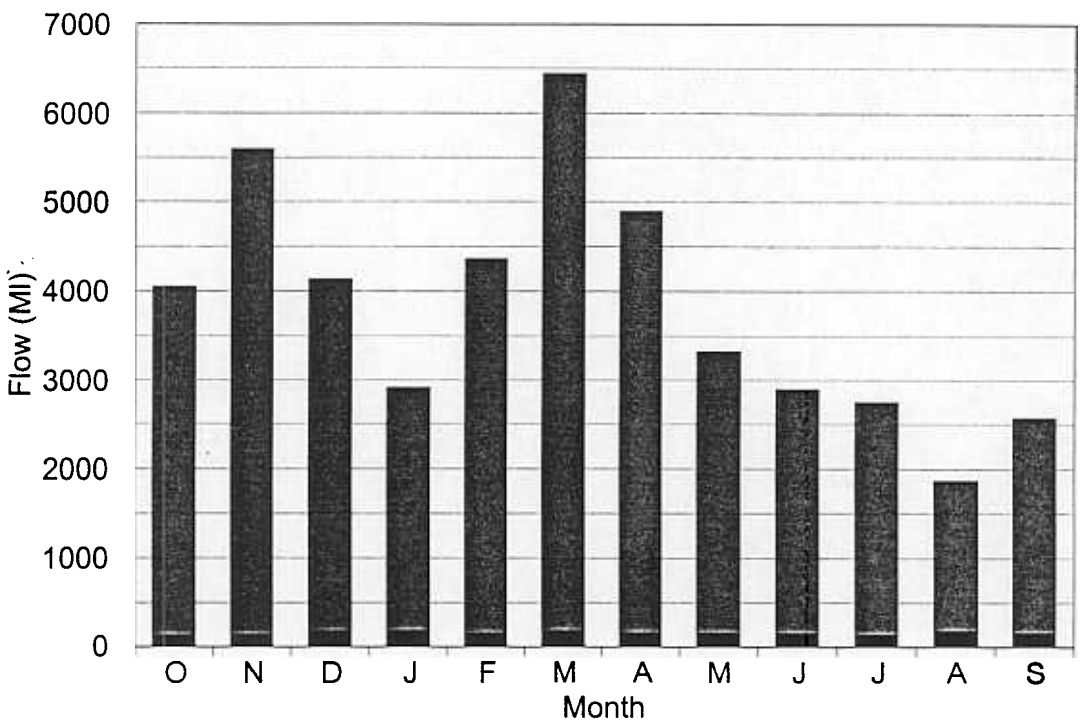


The water use in the 16 "significant" rivers in the EPCBS (after V. Smakhtin, May 1999)

Estuary	Mouth type	Cat area (km^2)	MAR (1929-1997) in M m^3	Water Use (M $m^{3)}$	Water Use % MAR
Mtafufu	O	186	45.8	1.99	**4.3**
Mzintlava	O	270	71.2	2.32	**3.26**
Mzimpunzi	O/C	24	9.1	0.02	**0.22**
Mbotyi	O/C	29	11.2	0.02	**0.22**
Mkozi	O/C	43	16.5	0.037	**0.22**
Myekane	O/C	5.2	1.99	0.005	**0.25**
Lupatana	O/C	20.1	7.85	0.034	**0.43**
Mkweni	O/C	47.7	18.45	0.075	**0.4**
Msikaba	O	1022	207.9	7.6	**3.65**
Mtentu	O	964	156.6	6.54	**4.17**
Sikombe	O/C	28.2	7	0.024	**0.34**
Lutungulu	O/C	15.8	3.91	0.025	**0.64**
Mnyameni	O/C	186	46.2	0.278	**0.6**
Mpahlanyana	O/C	8.78	1.15	0.007	**0.61**
Mpahlane	O/C	20.2	2.67	0.016	**0.6**
Mzamba	O	506	66.6	2.54	**3.81**

Mtafufu water use

MAR = 45.8 MCM, Use = 1.99 MCM (4.3%)



ANNEXURE 8

Table giving monthly and annual average flows of the 16 significant rivers in both Mm^3 m^3s^{-1}

MONTHLY AND ANNUAL AVARAGE FLOWS IN Mm^3 AND m^3s^{-1}

Number	River name	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Ann Mean	Units
1	**Mtafufu**	4.05	5.60	4.13	2.91	4.37	6.44	4.90	3.32	2.90	2.75	1.87	2.56	45.81	Mm^3
		1.512	2.160	1.542	1.086	1.790	2.404	1.890	1.240	1.119	1.027	0.698	0.988	1.452	m^3/s
2	**Mzintlava**	6.11	8.69	6.44	4.72	7.15	9.94	7.56	5.20	4.47	4.25	2.77	3.86	71.15	Mm^3
		2.281	3.353	2.404	1.762	2.929	3.711	2.917	1.941	1.725	1.587	1.034	1.489	2.255	m^3/s
3	**Mzimpunzi**	0.81	1.15	0.87	0.68	0.99	1.30	0.91	0.60	0.50	0.49	0.33	0.47	9.10	Mm^3
		0.302	0.444	0.325	0.254	0.406	0.485	0.351	0.224	0.193	0.183	0.123	0.181	0.288	m^3/s
4	**Mbotyi**	0.99	1.42	1.08	0.84	1.22	1.60	1.12	0.74	0.62	0.60	0.40	0.58	11.22	Mm^3
		0.370	0.548	0.403	0.314	0.500	0.597	0.432	0.276	0.239	0.224	0.149	0.224	0.356	m^3/s
5	**Mkozi**	1.46	2.09	1.58	1.23	1.79	2.34	1.64	1.09	0.91	0.88	0.59	0.85	16.46	Mm^3
		0.545	0.806	0.590	0.459	0.733	0.874	0.633	0.407	0.351	0.329	0.220	0.328	0.522	m^3/s
6	**Myekane**	0.18	0.25	0.19	0.15	0.22	0.28	0.20	0.13	0.11	0.11	0.07	0.10	1.99	Mm^3
		0.067	0.096	0.071	0.056	0.090	0.105	0.077	0.049	0.042	0.041	0.026	0.039	0.063	m^3/s
7	**Lupatana**	0.70	1.00	0.75	0.59	0.85	1.12	0.79	0.52	0.43	0.42	0.28	0.40	7.85	Mm^3
		0.261	0.386	0.280	0.220	0.348	0.418	0.305	0.194	0.166	0.157	0.105	0.154	0.249	m^3/s
8	**Mkweni**	1.63	2.34	1.77	1.38	2.01	2.63	1.84	1.22	1.02	0.99	0.66	0.95	18.45	Mm^3
		0.609	0.903	0.661	0.515	0.824	0.982	0.710	0.455	0.394	0.370	0.246	0.367	0.585	m^3/s
9	**Msikaba**	18.65	31.20	24.08	16.46	20.98	26.02	19.69	12.24	10.98	10.48	6.74	10.37	207.87	Mm^3
		6.963	12.037	8.990	6.145	8.596	9.715	7.596	4.570	4.236	3.913	2.516	4.001	6.587	m^3/s
10	**Mtentu**	11.75	22.39	21.37	14.80	17.49	21.29	14.54	8.65	7.86	6.48	4.27	5.75	156.64	Mm^3
		4.387	8.638	7.979	5.526	7.166	7.949	5.610	3.230	3.032	2.419	1.594	2.218	4.964	m^3/s
11	**Sikombe**	0.55	1.03	0.98	0.71	0.82	0.97	0.61	0.36	0.31	0.25	0.16	0.24	7.00	Mm^3
		0.205	0.397	0.366	0.265	0.336	0.362	0.235	0.134	0.120	0.093	0.060	0.093	0.222	m^3/s
12	**Lutungulu**	0.31	0.58	0.55	0.40	0.46	0.54	0.34	0.20	0.17	0.14	0.09	0.13	3.91	Mm^3
		0.116	0.224	0.205	0.149	0.188	0.202	0.131	0.075	0.066	0.052	0.034	0.050	0.124	m^3/s
13	**Mnyameni**	3.63	6.82	6.45	4.69	5.43	6.41	4.06	2.41	2.06	1.62	1.07	1.57	46.21	Mm^3
		1.355	2.631	2.408	1.751	2.225	2.393	1.566	0.900	0.795	0.605	0.399	0.606	1.464	m^3/s
14	**Mpahlanyane**	0.08	0.16	0.15	0.10	0.12	0.15	0.11	0.07	0.06	0.05	0.03	0.05	1.15	Mm^3
		0.030	0.062	0.056	0.037	0.049	0.056	0.042	0.026	0.023	0.019	0.011	0.019	0.036	m^3/s
15	**Mzamba**	4.89	9.38	8.94	6.06	7.16	8.87	6.35	3.83	3.53	2.99	2.01	2.60	66.60	Mm^3
		1.826	3.619	3.338	2.263	2.933	3.312	2.450	1.430	1.362	1.116	0.750	1.003	2.110	m^3/s
16	**Mpahlane**	0.20	0.38	0.36	0.24	0.29	0.36	0.25	0.15	0.14	0.12	0.08	0.10	2.67	Mm^3
		0.075	0.147	0.134	0.090	0.119	0.134	0.096	0.056	0.054	0.045	0.030	0.039	0.085	m^3/s

ANNEXURE 9

Document: "Eastern Pondoland planning reserve estimate for sixteen Estuaries – Vegetation Report"

Eastern Pondoland planning reserve estimate for sixteen estuaries - Vegetation report

B.M. Colloty *, Dr. J.B. Adams & Prof. G.C. Bate

Department of Botany, University of Port Elizabeth

PO Box 1600, Port Elizabeth, 6001

Phone: 041-5042-383

Fax: 041-583-2317

*Email: btbbmc@upe.ac.za

April 1999

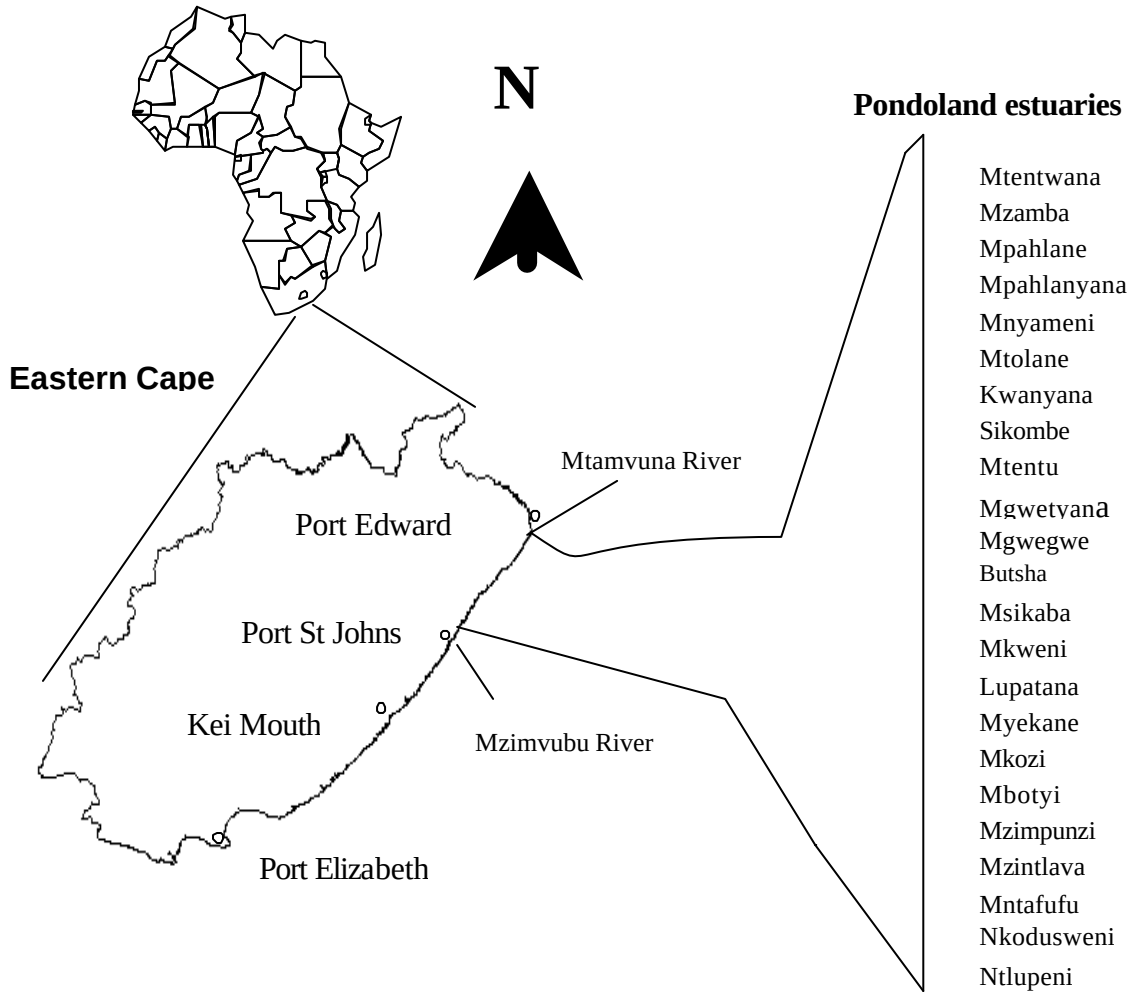
Table of contents

1 Study area 3
2 Estuarine classification. 4
3 Botanical surveys 6
4 Botanical importance of Pondoland estuaries 7
4.1 Botanical importance rating 7
4.2 Regional botanical importance 8
4.3 National botanical importance 8
4.4 Change in botanical importance over time 10
5 Botanical rarity of Pondoland estuaries 12
6 Available literature and information on the Pondoland region 18
7 Estuarine database (Appendix) 21

1 Study area

The Transkei wild coast is a rugged and undeveloped region extending 270 km from the Great Kei River to the boundary between the Eastern Cape and Kwazulu-Natal provinces (Mtamvuna River). The region has numerous rivers and bays and is characterised by rocky shores (41 % wave cut platforms and 18 % rocky headlands) and sandy beaches (34 %) (Avis *et al*. 1998). The southern portion of this region is made of low hills and meandering rivers. Further north, rivers flowing through deep valleys plunge straight into the sea at several places. About half the coastline is covered by indigenous coastal forest that has a high biodiversity of approximately 400 different plant taxa. This region can be further subdivided into the northern Transkei coast known as Pondoland that stretches from the Mntafufu River in the south to the Mtamvuna River in the north (Figure 1).

Figure 1: Locality map of estuaries in the Pondoland region in the Eastern Cape Province



2 Estuarine classification.

Fourty five rivers occur along the 150 km Pondoland coast, of these twenty three are considered estuaries. Whitfield (1995) has described these estuaries as either temporarily closed (18) or permanently open (5) (Table 1). Harrison *et al.* (1999) developed a geomorphological classification system for these estuaries. In their system estuaries are classified based on similarity in physical condition, morphology, catchment size and mouth condition. Estuaries that have been classified in the Pondoland region include; Ntlupeni, Butsha, Mgwegwe, Mgwetyana, Mtentwana, Mntafufu, Mzamba, Msikaba and Mtentu (Table 1) (Harrison *et al.* (1999). The remaining fourteen Pondoland estuaries have for the purposes of this report been compared to the above mentioned systems and have been placed in the classification groups based on similar characteristics (Table 1).

Summary of geomorphological classification group characteristics Harrison *et al.* (1999)

Group 1A – This group consists of small systems (surface area < 5 ha) with variable characteristics. They are temporarily open due to either a small catchment or a small tidal prism. These systems remain closed as a result of an inability to overcome local sediment transport regimes or due to extreme marine influences that may close the inlet. The salinity within these systems is dominated by fresh to brackish conditions (0.03 – 12 g l^{-1}).

Group 1B –These estuaries are located in narrow sinuous river valleys and are mostly permanently open. Freshwater inflow maintains the open inlets as a result of large catchment areas combined with steep valley formations. Freshwater tends to flow straight out to sea and these estuaries are characterised by low salinity (< 15 ppt).

Group 2 – This group of estuaries are moderately sized (surface area 5–15 ha) with temporarily open mouths. Many are perched slightly above sea level and water levels fall by insignificant amounts when open. The perched barriers of these estuaries are attributed to high wave energy conditions that also promote over-topping. Breaching of such systems only occurs during high rainfall events. These systems experience tidal inflow but the tidal prism is too small to maintain an open mouth.

Group 3A – These near permanently open estuaries have regular tidal exchange (salinity range 0 – 36 g l^{-1}). Flood tidal deltas have developed in the mouth region and the systems become deeper in the middle reaches (up to 3 m). Large tidal prisms dominate these estuaries and maintain the inlets. This implies that the volume of water that enters the estuary on each flood tide generates enough energy to keep the inlet open. These systems have been known to close for short periods due to extended heavy sea conditions rather than as a result of reduced freshwater input.

Group 3B - The Mngazana the only estuary in this group and not found in the Pondoland region has the most extensive floodplain of any estuary in the Transkei. The floodplain is up to 1500 m wide and is traversed by a sinuous channel with several tributaries. The channel sections of the estuary are deep (1.5–2.5 m) while the upper reaches are rocky.

Group 3C – These systems have been grouped together due to similarities with near permanent open inlets, large tidal prisms and lack of barrier and barrier associated sediment bodies. This

morphological difference is further reflected in the substrate type (mud and boulders), consequently the Mtentu and Msikaba estuaries cannot close due to lack of available barrier sediment.

Table 1: Twenty three estuaries occur along the Pondoland coast and have been classified by Whitfield (1995) and Harrison *et al.* (1999). Estuaries have been listed in order of occurrence from west to east. Permanently open estuaries are highlighted in bold

Estuary	Whitfield classification	Geomorphological classification
Ntlupeni	Temporarily closed	1A
Nkodusweni	Temporarily closed	1B
Mntafufu	Permanently open	3A
Mzintlava	Permanently open	3A
Mzimpunzi	Temporarily closed	2
Mbotyi	Temporarily closed	2
Mkozi	Temporarily closed	1A
Myekane	Temporarily closed	1A
Lupatana	Temporarily closed	1A
Mkweni	Temporarily closed	1B
Msikaba	Permanently open	3C
Butsha	Temporarily closed	1A
Mgwegwe	Temporarily closed	2
Mgwetyana	Temporarily closed	2
Mtentu	Permanently open	3C
Sikombe	Temporarily closed	2
Kwanyana	Temporarily closed	1B
Mtolane	Temporarily closed	1A
Mnyameni	Temporarily closed	2
Mpahlanyana	Temporarily closed	1A
Mpahlane	Temporarily closed	1A
Mzamba	Permanently open	3A
Mtentwana	Temporarily closed	2

3 Botanical surveys

Botanical surveys were conducted within all twenty three systems (February 1998) in the Pondoland region as part of a Water Research Commission funded project held in the Department of Botany, University of Port Elizabeth. This project aims to determine the botanical importance of estuaries in the Transkei region in relation to other South African estuaries. Plant community types were identified as well as species composition. This information was used to calculate past and present cover for all estuaries using aerial photographs. Physical conditions (salinity, temperature, depth and secchi depth) were also measured in the survey. Fourteen plant species were found in the Pondoland estuaries (Table 2) and were representative of three of the seven possible estuarine macrophytic community types namely; mangroves (4 species), reeds and sedges (8 species) and lagoon swamp forest (2 species). Phytoplankton (measured as water surface area) and benthic microalgae (measured as exposed sand and mud banks) were found in all systems.

The area covered by the different plant community types (ha) was measured using 1:50 000 topographic maps and aerial photographs and converting these into scaled digital images (Hewlett-Packard Scanner 4C). The digital images were then calibrated and the area covered by the plant community types was measured using the image analysis software (analySIS 3.0). These measurements were verified with field measurements.

Table 2: List of plant species found in the estuaries of the Pondoland region

Species	Family	Plant community type
Acrostichum aureum L.	Adiantaceae	Mangrove
Avicennia marina Forssk. Vierh.	Verbenaceae	Mangrove
Bruguiera gymnorrhiza (L.) Lam.	Rhizophoraceae	Mangrove
Cyperus textilis Thunb.	Cyperaceae	Reeds and sedges
Juncus kraussii Hochst	Juncaceae	Reeds and sedges
Phragmites australis (Cav.) Steud.	Poaceae	Reeds and sedges
Phragmites mauritianus Kunth.	Poaceae	Reeds and sedges
Prionium serratum (L. f.) Dreg ex Mey.	Juncaceae	Reeds and sedges
Rhizophora mucronata Lam.	Rhizophoraceae	Mangrove
Sporobolus virginicus (L.) Kunth.	Poaceae	Reeds and sedges
Stenotaphrum secundatum (Walt.) Kuntze	Poaceae	Reeds and sedges
Strelitzia nicolai Regel & Koern.	Strelitziaceae	Lagoon swamp forest
Typha capensis (Rhorb.) N.E. Br.	Typhaceae	Reeds and sedges
Hibiscus tiliaceus L.	Malvaceae	Lagoon swamp forest

The total estuarine surface area for Pondoland was approximately 342.7 ha. Reeds and sedges (15.2 %), phytoplankton measured as water surface area (61 %) and benthic microalgae measured as intertidal sand and mudflats (10.9 %) were dominant in the Pondoland estuaries. The remaining plant community types mangroves and lagoon swamp forest covered 5.5 % and 6.3 % respectively. Further analysis of the species composition of the Pondoland estuaries has shown that plant species are mostly related to freshwater dominated systems. This is as a result of the higher mean annual runoff and changes in geomorphology that occur within this region as compared to the southern Transkei region.

4 Botanical importance of Pondoland estuaries

4.1 Botanical importance rating

A botanical importance rating system has been developed to summarize the botanical importance of an estuary (Coetzee 1997; Colloty 1998). Botanical importance is defined as the contribution of the flora to the conservation status of an estuary. The formula can be applied to all estuaries to calculate their present importance or show the effects of human activities on the estuarine flora over time. The formula is based on area covered by the different plant community types and their contribution in the form of energy input to higher trophic levels (i.e. average primary productivity). The formula may be written as follows:

$$\mathbf{BIR = a(Area_{sup}) + b(Area_{int}) + c(Area_{sub}) + d(Area_{ree}) + e(Area_{man}) + f(Area_{ben}) + g(Area_{phy}) + h(Area_{macro}) + I(Area_{swamp})}$$

Where: **a, b, c, d, e, f, & g** = average primary productivity for the community type (based on available literature).

$Area_{sup}$ = area in ha covered by supratidal marsh and where a = 836 g m^{-2} y^{-1}

$Area_{int}$ = area in ha covered by intertidal marsh and where b = 651 g m^{-2} y^{-1}

$Area_{sub}$ = area in ha covered by submerged macrophytes and where c = 1316 g m^{-2} y^{-1}

$Area_{ree}$ = area in ha covered by reeds and sedges and where d = 1385 g m^{-2} y^{-1}

$Area_{man}$ = area in ha covered by mangroves and where e = 1811 g m^{-2} y^{-1}

$Area_{ben}$ = area in ha covered by intertidal benthic microalgae and where f = 124 g m^{-2} y^{-1}

$Area_{phy}$ = area in ha covered by phytoplankton and where g = 163 g m^{-2} y^{-1}

$Area_{macro}$ = area in ha covered by macroalgae and where h = 196 g m^{-2} y^{-1}

$Area_{swamp}$ = area in ha covered by lagoon swamp forest and where i = 1890 g m^{-2} y^{-1}

4.2 Regional botanical importance

The botanical importance of estuaries can be compared on a regional basis. Estuaries of the Pondoland region were thus rated using the botanical importance formula. The permanently open estuaries have the highest botanical importance scores (Table 3). This is also reflected in the higher community richness scores (number of plant community types present). The smaller closed estuaries have less available habitat and this coupled to the lack of tidal exchange results in low plant community richness. An exception is the Msikaba estuary, a large permanently open system (15 ha), due to its steep valley formation there is little available habitat for estuarine plant colonisation hence the low botanical importance score. Further exceptions are the Mbotyi and Mnyameni estuaries that have been classified as temporarily open systems. These estuaries have high botanical importance scores as the large delta areas at their mouths are colonized by reeds.

4.3 National botanical importance

Estuaries can also be rated on a national basis using the botanical importance rating formula. Comparisons can thus be made between estuaries along the South African coastline in order to gain a better perspective on the importance of an estuary. A number of systems were selected form the Cape and Kwazulu-Natal regions (Table 4). Estuaries showed a decrease in botanical importance and community richness as their size decreased. The Pondoland estuaries showed lower botanical importance and community richness compared to other regions with importance scores between 0 and 12 This is possibly as a result of the surrounding geomorphology of this region that limits the formation of large intertidal areas suitable for estuarine plant community types.

Table 3: Present (1998) community richness and botanical importance rating of estuaries found in the Pondoland region. BIS = Botanical importance rating score. Estuaries are ranked in decreasing order of botanical importance. Permanently open estuaries are shown in bold.

Estuary	Community richness	BIS	Normalised score
Mzamba	5	49468	100
Mntafufu	5	29116.46	59
Mtentu	5	22889	46
Mbotyi	4	17169.6	35
Mnyameni	4	14815.09	30
Mzintlava	5	11833.38	24
Nkodusweni	3	10842.7	22
Mgwegwe	4	9270.02	19
Msikaba	3	4492.41	9
Sikombe	4	4244.89	9
Butsha	3	3903.75	8
Mkweni	4	3830.27	8
Mkozi	4	3385.87	7
Mzimpunzi	3	2527.66	5
Kwanyana	3	2025.1	4
Mtentwana	2	1815.51	4
Lupatana	4	1618.79	3
Mpahlanyana	3	1527.93	3
Mpahlane	3	1434.17	3
Ntlupeni	3	865.71	2
Mgwetyana	3	842.74	2
Myekane	3	660.45	1
Mtolane	2	204.81	0

Table 4: The community richness and botanical importance of estuaries being to compared to some selected estuaries found along the South African coastline. BIS = Botanical importance rating score and estuaries are ranked in decreasing order of importance. Pondoland estuaries are shown in bold.

Estuary	Community richness	BIS	Normalised score
Olifants	6	413357	100
Mngazana	6	329685	80
Kromme	6	222781	54
Swartkops	6	182666	44
Umlalazi	7	128816	31
Mhlanga	3	102808	25
Bree	5	87174	21
Zinkwazi	3	79351	19
Mzamba	5	49468	**12**
Mntafufu	5	29116	**7**
Mtentu	5	22889	**6**
Mnyameni	4	14815	**5**
Mbotyi	4	17169	**4**
Mzintlava	5	11833	**3**
Nkodusweni	3	10846	**3**
Mgwegwe	4	9270	**2**
Msikaba	3	4492	**1**
Sikombe	4	4244	**1**
Butsha	3	3903	**1**
Mkweni	4	3830	**1**
Mkozi	4	3385	**1**
Mzimpunzi	3	2527	**1**
Kwanyana	3	2025	**0**
Mtentwana	2	1815	**0**
Lupatana	4	1618	**0**
Mpahlanyana	3	1527	**0**
Mpahlane	3	1434	**0**
Ntlupeni	3	866	**0**
Mgwetyana	3	842	**0**
Myekane	3	660	**0**
Mtolane	2	204	**0**

4.4 Change in botanical importance over time

The change in botanical importance for estuaries was calculated by comparing past aerial photographs. Photographs were available for the Pondoland region taken in 1961 and showed that for 52 % of the estuaries botanical importance has not changed over the last 33 years (Table 5). Twenty percent of the estuaries have shown an increase in botanical importance (i.e. an increase in cover). The remaining 28 % of estuaries showed a decrease in botanical importance due to the loss of mangrove or reed cover. This decrease was however not as great as those systems subjected to higher levels of anthropogenic disturbances such as in the Cape and Kwazulu-Natal regions (e.g. Swartkops, Nhlabane and Umlalazi estuaries). The exception being the Mtentwana estuary where reed cover has been lost due to the construction of a small dam and golf course at the head of the estuary. The Pondoland region on a national basis (Table 5) has a high conservation status with a greater percentage of estuaries either showing an increase in botanical importance or remaining unchanged.

Table 5: The past (1961) and present (1998) botanical importance scores of selected estuaries found along the South African coastline. BIS = Botanical importance rating score and estuaries are ranked in decreasing order of importance. The normalised scores are calculated for each estuary in order to calculate the change in botanical importance as a percentage. Pondoland estuaries are shown in bold.

Estuary	Past BIS	Present BIS	Normalised score	% change
Mgwegwe	1710	9270	18	**82**
Msikaba	2810	4492	62	**38**
Kwanyana	1665	2025	82	**18**
Mtentu	19268	22889	84	**16**
Mbotyi	14807	17169	86	**14**
Zinkwazi	72115	79351	90	10
Mzintlava	11833	11833	100	**0**
Sikombe	4244	4244	100	**0**
Mkweni	3830	3830	100	**0**
Mkozi	3385	3385	100	**0**
Mzimpunzi	2527	2527	100	**0**
Mpahlane	1434	1434	100	**0**
Mpahlanyana	1527	1527	100	**0**
Mgwetyana	842	842	100	**0**
Myekane	660	660	100	**0**
Nkodusweni	10843	10843	100	**0**
Ntlupeni	866	866	100	**0**
Mtolane	204	204	100	**0**
Mngazana	329685	329680	99	**- 1**
Mzamba	50827	49468	97	**- 3**
Lupatana	1562	1618	96	**- 4**
Mntafufu	38134	29116	76	**- 24**
Mnyameni	20248	14815	73	**- 27**
Butsha	6096	3903	64	**-36**
Swartkops	280357	182666	65	- 37
Umlalazi	224042	128816	57	- 43
Mtentwana	4253	1815	42	**- 58**
Nhlabane	120585	13666	11	- 89

5 Botanical rarity of Pondoland estuaries

It is important to highlight estuaries that have unique features or species composition. The Mkozi estuary is small but is the only estuary in the Eastern Cape Province where the mangrove fern *Acrostichum aureum* occurs. The Mtentu and Msikaba estuaries have unique geomorphology, and are also the only two South African estuaries where the rare Mkambati palm, *Jubaeopsis caffra* is found. Although not considered part of the estuarine flora, due to the steep sided banks of these estuaries, these palms are only a few metres from the high water mark.

The mangrove physiognomy is unique to the Pondoland region. This is due to the surrounding geomorphology that results in limited areas for mangrove colonisation in the permanently open estuaries. The mangrove stands found in these estuaries are usually a double row or in some cases a single row of mangrove trees. In Australia and Japan where these rare stands occur, these types of mangroves have been termed fringe mangrove forests. Mangroves found elsewhere along the South African coast have developed into large complex communities with a large number of associated species. These larger communities are found to be more resilient to disturbance, whereas fringe mangrove forest exhibits lower juvenile recruitment rates and are more susceptible to disturbance. Thus these Pondoland systems would require a greater degree of protection as has been shown in Australia and Japan (Clough *et al.* 1981).

6 Estuarine planning estimate workshop

6.1 Determination of the Ecological Management Class (EMC)

In Table 5 the botanical importance of the Pondoland estuaries are shown as a percentage change over time. This reflects how the present ecological integrity of an estuary has been altered from the natural condition. The results of Table 5 are then used to determine to deviation from natural for each estuary and used to calculate the EMC using the ranges shown below Table 6. Estuaries that have shown no change over time in their botanical importance have kept their ecological integrity. These receive an ecological management class A. Estuaries can also show an increase in plant cover over time and this is shown as a positive percentage change in BIS over time (Table 5 & 6). These estuaries are still awarded ecological management classes based on the ranges shown in Table 6, but are highlighted due to the increase in plant cover. Estuaries in which this has occurred in the Pondoland region include the Mbotyi, Msikaba, Mtentu and Kwanyana estuaries (Table 6). With the exception of the Mtentu estuary, all increases were due to an increase in reed cover over time. The increase in reed cover has occurred into the adjacent floodplain areas and not reducing the areas of other estuarine plant community types found. The Mtentu has shown an increase in mangroves and lagoon swamp forest plant communities types.

Table 6: Present Ecological Integrity (EI) status = % change in botanical importance over time. BIS = Botanical importance score and past is measured from aerial photographs (1961) and compared to the present plant community type cover (1998). EMC = Ecological Management Class and is calculated using the ranges below and the estuaries' deviation from natural (100). Estuaries with an increase in plant cover (+ % change) are shown in bold.

Estuary	1961 BIS	1998 BIS	% Change	Deviation from natural	EMC	EI Status	Remarks
Mntafufu	38134	29116	-24	76	C	High – 4	Loss of reed and Lagoon swamp forest
Mzintlava	11833	11833	0	100	A	High – 5	No change over time
Mzimpunzi	2527	2527	0	100	A	High – 4	No change over time
Mbotyi	**14807**	**17169**	**+14**	**86**	**B**	**High – 4**	**Increase in reed cover**
Mkozi	3385	3385	0	100	A	High – 5	No change over time
Myekane	660	660	0	100	A	High – 5	No change over time
Lupatana	1562	1618	-4	96	B	High – 4	Loss of Lagoon swamp forest
Mkweni	3830	3830	0	100	A	High – 5	No change over time
Msikaba	**2810**	**4492**	**+38**	**62**	**B**	**Medium – 3**	**Increase in reed cover**
Mtentu	**19268**	**22889**	**+16**	**84**	**B**	**High – 4**	**Increase in mangrove and lagoon swamp forest**
Sikombe	4244	4244	0	100	A	High – 5	No change over time
Kwanyana	**1665**	**2025**	**+18**	**82**	**B**	**High – 4**	**Increase in reed cover**
Mnyameni	20248	14815	-27	73	C	Medium – 3	Loss of mangroves
Mpahlanyana	1527	1527	0	100	A	High – 5	No change over time
Mpahlane	1434	1434	0	100	A	High – 5	No change over time
Mzamba	50827	49468	-3	97	B	High – 4	Loss of lagoon swamp forest and mangroves

Ranges for EMC calculation

Class A	100 %	**Class B**	81 – 99 %	**Class C**	61 – 80 %
Class D	41 – 60 %	**Class E**	21 – 40 %	**Class F**	0 – 20 %

Example : Lupatana estuary showed a small loss of swamp forest caused by an access road between Mbotyi and Port Grosvener. This resulted in a 4 % loss in botanical importance over time.

Therefore EMC = (100 – 4%) = 96 %, Substituted into the above ranges equals Class B

The high, medium and low ecological integrity are based on the following ranges:

Deviation from natural - 76 – 100 (3 –4) = High

50 – 75 (2 – 3) = Medium

< 50 (0 –10) = Low

7 Importance , species rarity and habitat diversity calculations

7. 1 National botanical importance rating

This has been discussed in a previous section (4.3 page 9) but included here are the values converted into high medium and low categories (Table 7a). This allows for the comparison between botanical importance and the other components of Table 7a.

Example: Lupatana estuary has national botanical importance score of 0. This applied to the ranges in Table 7a equals a **LOW** botanical importance of between **0 -24**. This is as a result of the small area covered by the estuary and low plant community richness consisting of phytoplankton, benthic microalgae, reeds and sedges and lagoon swamp forest.

7.3 Plant species rarity

The percentage of plant species present in each estuary was calculated. Twenty of the Pondoland estuaries contained reed and sedges species, while only twelve had lagoon swamp forest. The rarest species were the mangroves in particular the red mangrove *Rhizophora mucronata* and the mangrove fern, *Acrostichum aureum* found in the Mntafufu and Mkozi estuaries respectively (Table 7a).

Example: Lagoon swamp forest, reeds and sedges, phytoplankton and benthic microalgae are present in the Lupatana estuary. All the species found in the Lupatana estuary occur in 50 % or more of the Pondoland systems. This is substituted in the ranges in Table 7a and equals a **LOW** plant rarity, i.e. species found present occur in **more than 50 %** of the estuaries in a region.

7.4 Diverse plant habitats

The number of plant community types is recorded for each estuary as community richness (Table 5). These values are then applied to the ranges described in Table 7a to determine the habitat diversity. The larger the estuary the more habitats are available the higher its importance and habitat diversity. The permanently open systems usually have the highest values (eg. Mntafufu, Mzintlava, Mtentu and Mzamba estuaries) (Table 7a). The Msikaba estuary is an exception, due to its unique geomorphology it has limited areas for colonisation by estuarine plants.

Example: The Lupatana estuary contains four of the nine possible estuarine plant community types. This value of four is substituted in to the ranges in Table 7a. Therefore 4 plant community types falls into the **Medium** range **3 – 4**.

7.5 Unique habitats

Unique habitats were measured based on the plant community types presence or absence. This is converted into a proportion of estuaries in which they occur. This proportion of plant community type uniqueness is then applied to the set of ranges shown below Table 7a. The twenty three estuaries found in the Pondoland range region all have the reeds and sedges, while only five estuaries have mangroves and twelve have lagoon swamp forests. Of these only four have both lagoon swamp forest and mangroves present.

Example: The Lupatana estuary with its small area of swamp forest habitat uniqueness is calculated as follows: Swamp forest occurs is twelve Pondoland estuaries (52%) and applied to the ranges in Table 7a the Lupatana has a **LOW** habitat uniqueness, i.e. the least common of the plant community types within the estuary occurs in between **50 and 100 %** of the other estuaries.

7.6 Summary

This characterisation of estuaries has highlighted similarities between systems, i.e. permanently open systems have the highest botanical importance and habitat diversity, but it has also indicated the value of the smaller systems. For example the Mkozi estuary is the third smallest estuary (4.01 ha) in the Pondoland region, however is the only estuary in which *A. aureum* is found.

Table 7a – Importance rating of estuaries based on national botanical importance, rarity and uniqueness of species and habitat found in each estuary.

Estuary	Nat. BIR	Rare Species	Diverse habitats	Unique habitats	Sum of ranges	Conf. levels
Mntafufu	Low 1	High 5	High 5	High 5	16	> 60
Mzintlava	Low 1	Low 1	High 5	High 5	12	> 60
Mzimpunzi	Low 1	Low 1	Medium 3	Low 1	6	> 60
Mbotyi	Low 1	Low 1	Medium 3	Low 1	6	> 60
Mkozi	Low 1	High 5	Medium 3	High 5	14	> 60
Myekane	Low 1	Low 1	Medium 3	Low 1	6	> 60
Lupatana	Low 1	Low 1	Medium 3	Low 1	6	> 60
Mkweni	Low 1	Low 1	Medium 3	Low 1	6	> 60
Msikaba	Low 1	Low 1	Medium 3	Low 1	6	> 60
Mtentu	Low 1	Medium 3	High 5	High 5	17	> 60
Sikombe	Low 1	Low 1	Medium 3	Low 1	6	> 60
Kwanyana	Low 1	Low 1	Medium 3	Low 1	6	> 60
Mnyameni	Low 1	Low 1	Medium 3	Low 1	6	> 60
Mpahlanyana	Low 1	Low 1	Medium 3	Low 1	6	> 60
Mpahlane	Low 1	Low 1	Medium 3	Low 1	6	> 60
Mzamba	Low 1	Low 1	High 4	Low 1	7	> 60

Ranges for National BIR

	Ranges
High = 50 – 100 %	4 - 5
Medium = 25 – 49 %	2 - 3
Low = 0 – 24	0 - 1

Ranges for rare species (% OF ESTUARIES IN WHICH SPECIES ARE PRESENT)

	Ranges
High = 1 – 25 %	4 - 5Ranges
Medium = 26 - 50	2 - 3
Low = >50%	0 - 1

Ranges for diverse habitats (COMMUNITY RICHNESS)

	Ranges
High = .> 5 plant community types	4 - 5
Medium = 3 – 4 Plant community types	2 - 3
Low = 1 – 2	0 - 1

Ranges for unique habitats (PROPORTION OF ESTUARIES IN WHICH PCT IS FOUND)

	Ranges
High = 1 – 25 %	4 - 5
Medium = 26 – 50 %	2 - 3
Low = 51 – 100	0 - 1

8 Calculation of sensitivity to mouth closure using the botanical components

The presence or absence of species or communities is as a result of the surrounding physical conditions. Each of these species or communities have a specific sensitivity to change in the surrounding conditions for example mouth closure and lack of tidal exchange. The plant community types found in estuaries can be ranked according to their sensitivity to mouth closure (Table 7b). These values are then summed for each plant community type in each estuary and summed for each plant community type (Table 7b).

Example: The Lupatana estuary has four plant community types present. Each of these is given the weights assigned in Table 7b and summed.

Therefore Lupatana estuary - Intertidal benthic microalgae - 7

Phytoplankton - 6
Lagoon Swamp forest – 5
Reeds and sedges – 2

The sum of the weights equals 20 and applied to the ranges in Table 7b shows that the Lupatana has a medium sensitivity to mouth closure (19- 29).

Table 7b – Sensitivity of estuary to mouth closure, where SS = sensitivity score as calculated below.

Estuary	SS	Impact	Range scores	Conf. levels
Mntafufu	29	High	5	> 60
Mzintlava	29	High	5	> 60
Mzimpunzi	20	Medium	2	> 60
Mbotyi	20	Medium	3	> 60
Mkozi	29	High	5	> 60
Myekane	15	Low	1	> 60
Lupatana	20	Medium	2	> 60
Mkweni	20	Medium	3	> 60
Msikaba	20	Medium	3	> 60
Mtentu	29	High	5	> 60
Sikombe	15	Low	1	> 60
Kwanyana	15	Low	1	> 60
Mnyameni	15	Low	1	> 60
Mpahlanyana	15	Low	1	> 60
Mpahlane	15	Low	1	> 60
Mzamba	20	Medium	3	> 60

Sensitivity formula:
S = Sum of Plant community type found present x sensitivity to closure weighting
Plant community type weights.
1 Mangroves = 9
2 Intertidal salt marsh = 8
3 Benthic microalgae = 7
4 Phytoplankton = 6
5 Lagoon swamp forest = 5
6 Submerged macrophytes = 4
7 Macroalage = 3
8 Reeds = 2
9 Supratidal salt marsh = 1

Ranges = High 29 – 36 (4 –5)
Medium 20 – 28 (2 3)
Low 13 – 19 (0 – 1)

9 Total score

Table 8: Summation of all ranges ecological integrity, importance and sensitivity to mouth closure, ranked in decreasing order of scores.

Estuary	Ecological integrity	Importance	Sensitivity	Total
Mtentu	4	17	5	26
Mntafufu	4	16	5	25
Mkozi	5	14	5	24
Mzintlava	5	12	5	22
Mkweni	5	6	3	14
Mzamba	4	7	3	14
Mbotyi	4	6	3	13
Mzimpunzi	4	6	2	12
Myekane	5	6	1	12
Lupatana	4	6	2	12
Msikaba	3	6	3	12
Sikombe	5	6	1	12
Mpahlanyana	5	6	1	12
Mpahlane	5	6	1	12
Kwanyana	4	6	1	11
Mnyameni	3	6	1	10

10 Available literature and information on the Pondoland region

Avis, T.J., Christopher, J., Hosking, S., Lubke, R., McGwynne, L.E. and Nicholson, G. 1998. Garden Route region, Western District Region, Border-Kei region, Wild coast Region. In: Characterisation and Assessment of South African Coast. Coastal Management Policy Programme, Cape Town.

Connell, A.D. 1988. Mysidacea of the Mtentu River estuary. Zoologica Africana 9: 147-159

Harrison, T.D., Cooper, J.A.G. and Singh, R.A. 1997. Application of the estuarine health index to South Africa's estuaries, Old Woman's - Great Kei. CSIR (Water, Environment and Forestry technology) Technical Report.

Harrison, T.D., Cooper, J.A.G. and Singh, R.A. 1999. Application of the estuarine health index to South Africa's estuaries, Transkei. CSIR (Water, Environment and Forestry technology) Technical Report.

McNae, W. 1963. Mangrove swamps in South Africa. Journal of Ecology 51: 1-25.

Ward, C.J. and Steinke, T.D. 1982. A note on the distribution and approximate areas of mangroves in South Africa. South African Journal of Botany 1:51-53.

Whitfield, A.K. 1992. A characterisation of southern African estuarine systems. South African Journal of Aquatic Sciences. 18: 89-103

Whitfield, A.K. 1995. Available scientific information on individual South African estuarine systems. Water research Commission Report no. 577/1/95 Pretoria.

Steinke, T.D. 1972. Further observations on the distribution of mangroves in the Eastern Cape Province. J. S. Afr. Bot. 38: 165-178.

Ward, C.J. & Steinke, T.D. 1982. A note on the distribution and approximate areas of mangroves in South Africa. S. Afr. J. Bot. 3: 51-53.

West, O. 1944. Distribution of mangroves in the Eastern Cape Province. S.A. J. Sci. 41: 238-242.

11 Literature cited

Clough, B.F. & Andrews, T.J. 1981. Some ecophysiological aspects of primary production in mangroves in north Queensland. Wetlands 1: 6-7.

Coetzee, J.C., Adams, J.B. & Bate, G.C. 1997. A botanical importance rating of selected Cape estuaries. Water SA 23:81-93.

Colloty, B.M., Adams, J.B. & Bate, G.C. 1998. The botanical importance of estuaries in the former Ciskei and Transkei region. Progress Report to the Water Research Commission.

12 Estuarine database (Appendix)

List of information:

Page 1

1. Estuary name.
2. DWAF river code.
3. Geomorphological classification group code (Harrison *et al*.)
4. Province (Transkei and Ciskei are still kept separate from the Eastern Cape Province to aid rapid searches).
5. Region – marine biogeographic region in which the estuary is located.
6. Classification - Whitfield estuary mouth condition classification
7. Available information – available scientific information (Whitfield 1995).
8. Whitfield page # - If any scientific information is available then a reference is made to the page number in the South African estuary database (Whitfield 1995) to locate further available literature.
9. Impacts or activities – a short summary of any impacts or activities that might influence the structure or function of the estuary seen in field surveys.
10. Comments – summary of any available physical data or interesting facts on the estuary.
11. Photograph

Page 2

The first six points are repeated on the second page of each estuary to aid database searches and interpretation of the botanical importance scores.

7. Past plant community type cover and botanical importance rating score – each plant community is shown separately to aid interpretation of score.
8. Present plant community type cover and botanical importance rating score – each plant community is shown separately to aid interpretation of score.
9. Remarks – a short note on how the cover values were obtained.

ANNEXURE 10

Document: "Starter Document: Planning Estimates of the Estuarine Reserve of Eastern Pondoland Estuaries"

STARTER DOCUMENT: PLANNING ESTIMATES OF THE ESTUARINE RESERVE OF EASTERN PONDOLAND ESTUARIES

T. Wooldridge

Introduction

The rugged nature of the eastern Pondoland coast is unique to South Africa. Rivers have gouged deep and narrow valleys and many patches of well-preserved coastal forest remain. The region represents the start of the transitional zone between subtropical and warn temperate zoogeographical zones, with many marine and estuarine faunal species approaching their southern limit of distribution. Estuaries are relatively small (<5 km in length) and are largely in the natural state. These range from mangrove systems, shallow lagoons to the deepest estuary on the South African coast (Msikaba has a maximum depth of 39 m). Some work has been carried out on invertebrates, but is limited to a few systems only. Published information includes research by Wooldridge (1970's), Blaber, Hill & Forbes (1970's) and Connell (1970's). Begg (1986) undertook a preliminary investigation on the Mzamba estuary, but the report was not available at the time of writing this report. Some information is also available on exploited estuarine resources of Transkei estuaries (Fielding *et al.* 1994), but of the sixteen estuaries under present study, basic information is limited to the Mbotyi and Mzamba systems. Future potential status assumes a reduction in freshwater supply to the estuaries discussed below.

Available information on Invertebrates

1. Ntafufu estuary

Present status

The estuary is navigable for about 4-5 km, with an average depth 3-5 m over much of this length. Salinity stratification appears to be characteristic. with vertical salinity differences of about 15, 10 and 5 in the upper, middle and lower estuarine reaches respectively (Plumstead *et al.*1991). Surface salinity in the upper estuary (navigable reach) regularly falls below 10, while near the mouth salinity remains mostly around 30.

Although not documented by MacNae (1963), Ntafufu estuary 11 km north of Port St Johns supports a healthy and dense mangrove forest. This is probably the largest mangrove stand on the Pondoland coast and the estuary has a rich and unique faunal community. Crabs species (such as *Sesarma* and *Uca*) characterise the mangrove macrofauna and all species require a marine phase of development during their larval stages. Zooplankton is also rich and abundant. with mysid shrimps contributing 75% to biomass in summer. *Mesopodopsis africana* was most abundant in the middle estuary and *Rhopalophthalmus terranatalis* in the upper reaches (Wooldridge 1977).

The inlet channel is about 70 m long and 15 m wide with a mimimum low spring tide depth of about 0.5 m (depth measured in November 1972, pers. obs.). The mouth

has never closed in historical times (at least since 1924, verbal communication), although the mouth is becoming shallower according to holiday cottage owners.

Future potential status
Mangroves are intolerant of mouth closure and the survival of the specialised community requires a permanently open tidal inlet. Although occasional flooods occur, salinity in subsurface waters in the middle and lower estuary is likely to remain close to that of seawater (suggested by the presence of a healty mangrove flora).

In his review on available scientific information on individual estuaries, Whitfield (1995) remarked that the 'wide variety of habitats makes this a valuable estuary'. The catchment is small (178 km^2) and present runoff is probably just sufficient to maintain the marine-estuary link. The mouth channel is long and shallow and even a small reduction in river runoff (10-15%) probably has the potential to lead to mouth closure. The effect would change the present high conservation value of the estuary and the loss of a specialised community. These include mangrove crabs and rare bird species such as the Mangrove Kingfisher. The White-backed Night Heron also occurs here – the status of both species is listed as indeterminate in the Red Data book on birds (1984).

2. Mbotyi estuary
Present status
Mbotyi estuary is a small temporary closed system a short distance south of Waterfall Bluff. The catchment (25 km^2) in the coastal escarpment is largely covered in dense indigenous forest that produces good water quality. The river enters the estuary at a cement causeway. The lower half of the estuary forms a shallow lagoon (500 m x 400 m) with an average depth of about 1 m. During times when the inlet is closed, water level in the lagoon may increase by up to 1 m. Substrate in the lagoon is mostly soft mud, grading into beach sand near the inlet channel (about 100 m in length). Three other minor streams enter the middle and lower estuary, but their combined water volume is probably only important during floods.

Average annual rainfall at Ntsubane Forest station on the escarpment above the estuary (Tables 1A and 1B, Fig. 1) is 1441 mm per annum (1942-1973). These data were taken directly from records kept at the forest ranger's office. Between May 1972 and April 1973 rainfall was below average and only 965 mm was recorded (Table 2 and Fig. 2). Further inland at Lusikiiki village rainfall was 713 mm during the same period.

Mbotyi estuary was sampled for zooplankton on eight occasions between May 1972 and April 1973. Sampling times and state of the tidal inlet is shown in Fig. 3. The water column is well mixed and salinity in the estuary tends to be higher in winter during the lower rainfall months (above or below 15 in winter or summer respectively). Maximum salinity was 29 (August) and the lowest 9 (November – March).

Zooplankton was rich and abundant, with seventy-four species recorded in samples. These include *Upogebia africana* and *Palaemon perengui* larvae. Relatively large

populations of *Upogebia africana* and *Callianassa* kraussi were present in the estuary. The former species requires a marine phase of development, while the latter breeds in the marine nearshore, utilizing estuaries (and rocky shore pools) as nursery areas. *Callianassa kraussi* undergoes its entire life cycle in estuaries, but requires a salinity exceeding 20 during the breeding season.

Future potential status

Biological data suggest that Mbotyi estuary frequently opens to the sea, particularly in summer. (indicated by the presence of healthy populations of *Upogebia* and *Callianassa* in 1972-1973). Salinity is higher in winter and this provides suitable conditions for *Callianassa* to breed. In this estuary, periodic wave overtopping is probably important in elevating salinity values. Thus, frequency and intensity of mouth opening is an important mechanism in maintaining a suitably low beach profile in order for overtopping to occur.

The year during the study period (May 1972-April 1973) experienced below average rainfall (approximately 33%). Frequency and duration of an open mouth was probably less frequent compared to higher rainfall years. Although *Upogebia africana* could be used as an indicator, the potential negative effect of reduced marine influence would not be immediately apparent on population density (impact on larval exchange and subsequent recruitment). Such impacts would become apparent in longer-term studies.

It is important to adopt a conservative approach when considering the amount of freshwater that could be abstracted from the river. Insufficient data are available for Mbotyi (or other temporarily closed systems that have a similar biological community) that may guide opinion, but it is probable that that a sustained reduction of even 20% in river runoff would have a negative effect on the estuary in the longer term.

3. Msikaba estuary

Present status

The Msikaba catchment is approximately 1100 km^2 in area and near the coast, runs through deep gorges and steep, forest-covered slopes. The estuary is 3.3 km in length. The margins of the estuary are characterized by rocky cliffs (up to 100 m in height) and outcrops of rock that descend vertically into the depths of the estuary. Water depth varies from 1 to 5 m in the upper half, to 39 m at the narrowest point (15 m). This point probably represented a waterfall prior to present sea level.
The estuary shallows to 5 m at the edge of the sandbar near the mouth. A small stand of mangroves occurs on the western bank near the mouth. Mudprawn (*Upogebia africana*) occur on exposed mudbanks in the vicinity of mangroves.

The narrow mouth channel is consistently changing in configuration. In July 1972, the inlet was 5 m wide on average. Maximum depth was 0.5 m at normal high tide. At the same locality in summer of 1972 and in 1973, the channel was considerably wider and approximately 2.5 m deep.

Msikaba is characterised by a permanent halocline throughout the estuary, shown for November 1972 (Fig. 4) and July 1973 (Fig. 5). Zooplankton was sampled on

eight occasions between May 1972 and March 1973 (Wooldridge 1976). Although about 70 species were recorded, population numbers were low. Below the halocline, a marine associated fauna was present in addition to typical estuarine species.

Future potential status

Msikaba estuary is unique among South African estuaries due to its exceptional water depth and spectacular scenery adjacent to the estuary. However, from an invertebrate point of view, the species assemblage is not distinctive. This is coupled to the generally low biomass of the organisms present.

The potential for mouth closure presents the greatest concern. Available data suggests that the inlet is very dynamic and even under present conditions, comes close to closing during dry periods (e.g. winter). In a study on the animals attached to the vertical rock face near the deepest part of the estuary, Blaber *et al* (1974) recorded oxygen values declining to less than 5% in January and October 1973 below 12 m water depth. On the two other occasions when the estuary was sampled, O_2 values fell to 20% and 60% of saturation below the same depth (April and June 1973, respectively). Tidal induced mixing of the water column is probably the main mechanism providing O_2 to deeper water and it is probable that the estuary would become deoxygenated and sterile should the mouth close. Further, the estuary may not recover immediately upon inlet opening. This would present a barrier for recolonization and for those species moving through the estuary into freshwater.

The conclusion is that even a small reduction in freshwater suppply (10-20% of present runoff in any year experiencing below average rainfall) is likely to have serious implications for the functioning of the estuary. However, management options may be able to address such negative impacts.

4. Mtentu estuary

Present status

The Mtentu estuary has a catchment area of about 2000 km^2. Length of the estuary is 3 km; maximum width is 150 m and water depth does not exceed 7 m. The tidal inlet remains permanently open and mangroves are present. The mudprawn *Upogebia africana*, occurs on gently sloping mudbanks below the middle reaches. High cliffs flank the upper estuary that give way to steep slopes covered in grass or forest.

Connell (1974) sampled the estuary for mysids on eight occasions between February 1971 and March 1972. Salinity stratification was always evident, with botton salinity exceeding 30 on all occasions. Surface salinity ranged between 10 and 20 at most stations during the study period.

Mysids were represented by four species and high numbers were recorded on occasions.

Future potential status

Mtentu estuary has physico-chemical characteristics similar to Msikaba estuary, although maximum water depth is considerably less. The presence of mangroves and mudprawns indicate a permanently open tidal inlet. However, insufficient data are available to comment on the potential for mouth closure, although basic information provided by Connell (1974) suggests that the inlet would probably be less prone to closure when compared to Msikaba estuary.

References

Begg, G. A preliminary interpretation of the ecology of the Mzambe estuary in the Transkei. Unpublished report, Chris Mulder Associates Inc., Overport.

Blaber, S.J.M., Hill, B.J. & Forbes, A.T. 1974. Infratidal zonation in a deep South African estuary. Mar. Biol. **28**: 333-337.

Fielding, P.J., Robertson, W.D. Dye, A.H. Tomalin, B.J., van der Elst, R.P., Beckley, L.E. Mann B. Q., Birnie, S. Schleyer, M.H. & Lasiak, T.A. 1994. Transkei Coastal Fisheries Resources. Special Publication No. 3, Oceanographic Research Institute, Durban. 175 pp.

MacNae, W. 1973. Mangrove swamps in South Africa. J. Ecol. **51**: 1-15.

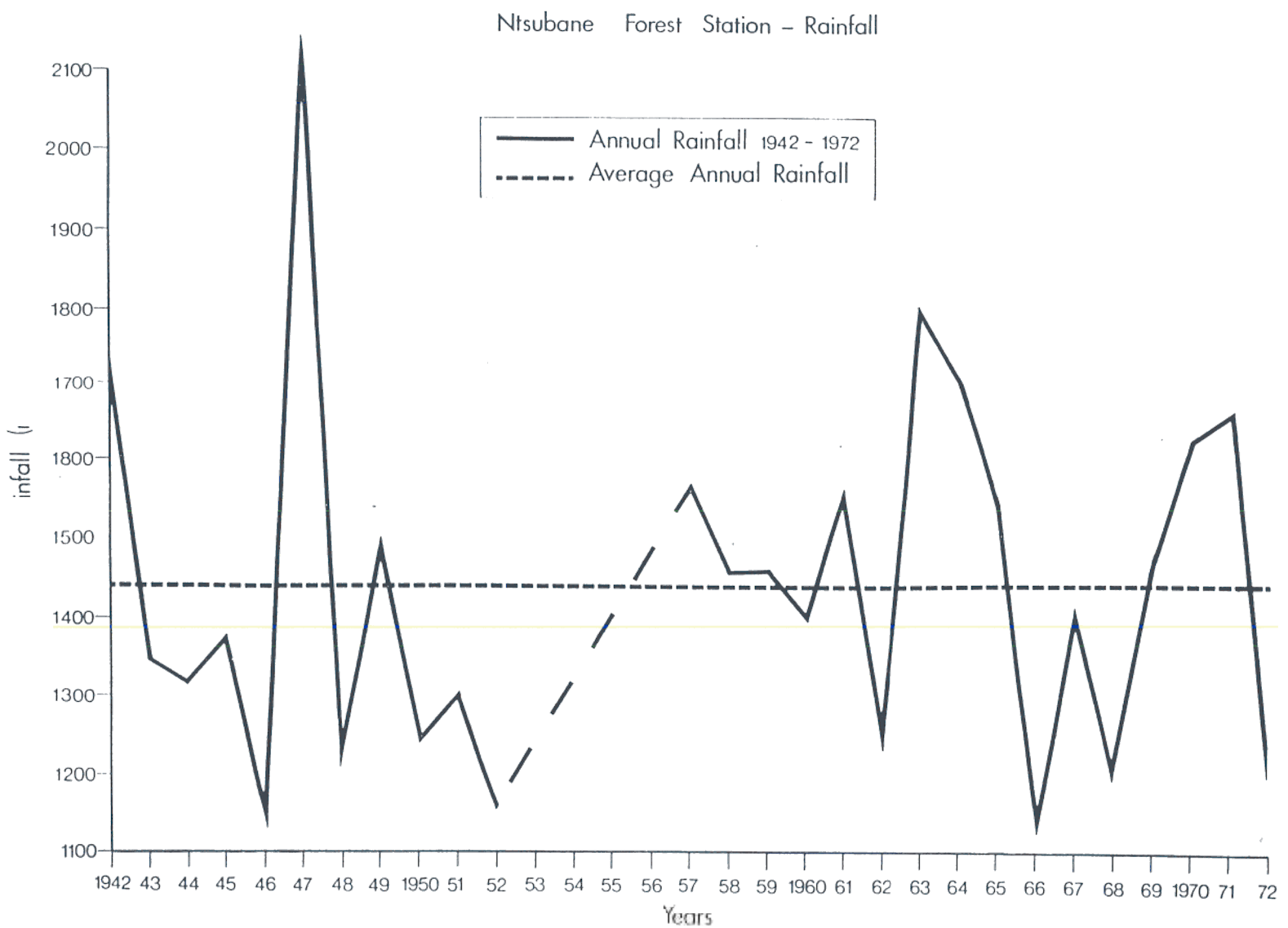
Plumstead, E.E., Prinsloo, J.F. & Schoonbee, H.J. 1991. A survey of the fisf fauna of Transkei estuaries Part Four: The Mntafufu and Mzamba river estuaries. S. Afr. J. Zool. **26**: 153-163.

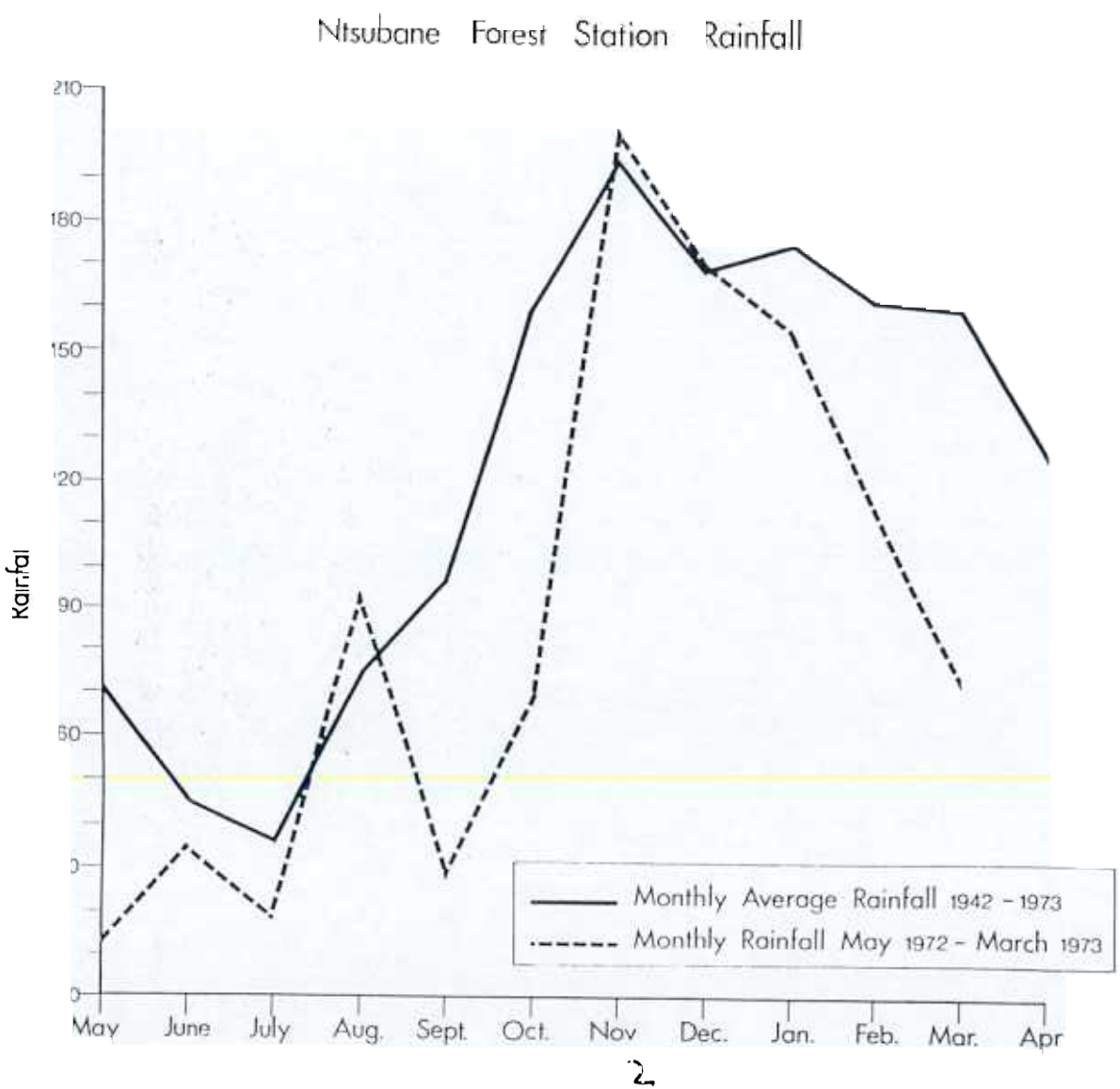
Whitfield, A.K. 1995. Available scientific information on individual South African estuarine systems. Water Research Commission Report No.5771/1/95.

Wooldridge, T.H. 1976. The zooplankton of Msikaba estuary. Zool. Afr. **11**: 23-44.

Wooldridge, T.H. 1977. The zooplankton of Mgazana, a mangrove estuary in Transkei, South Africa. Zool. Afr. **12**: 307-322.

Wooldridge, T.H. 1999. Estuarine zooplankton community structure and dynamics. In: Allanson, B.R. & Baird, D. (eds). Estuaries of South Africa. Cambridge University Press, UK. Pp. 141-166.


Ntsubane Forest Station – Rainfall
Annual Rainfall 1942 - 1972
Average Annual Rainfall
2100
2000
1900
1800
1700
1800
1500
1400
1300
1200
1100
infall (
1942 43 44 45 46 47 48 49 1950 51 52 53 54 55 56 57 58 59 1960 61 62 63 64 65 66 67 68 69 1970 71 72
Years

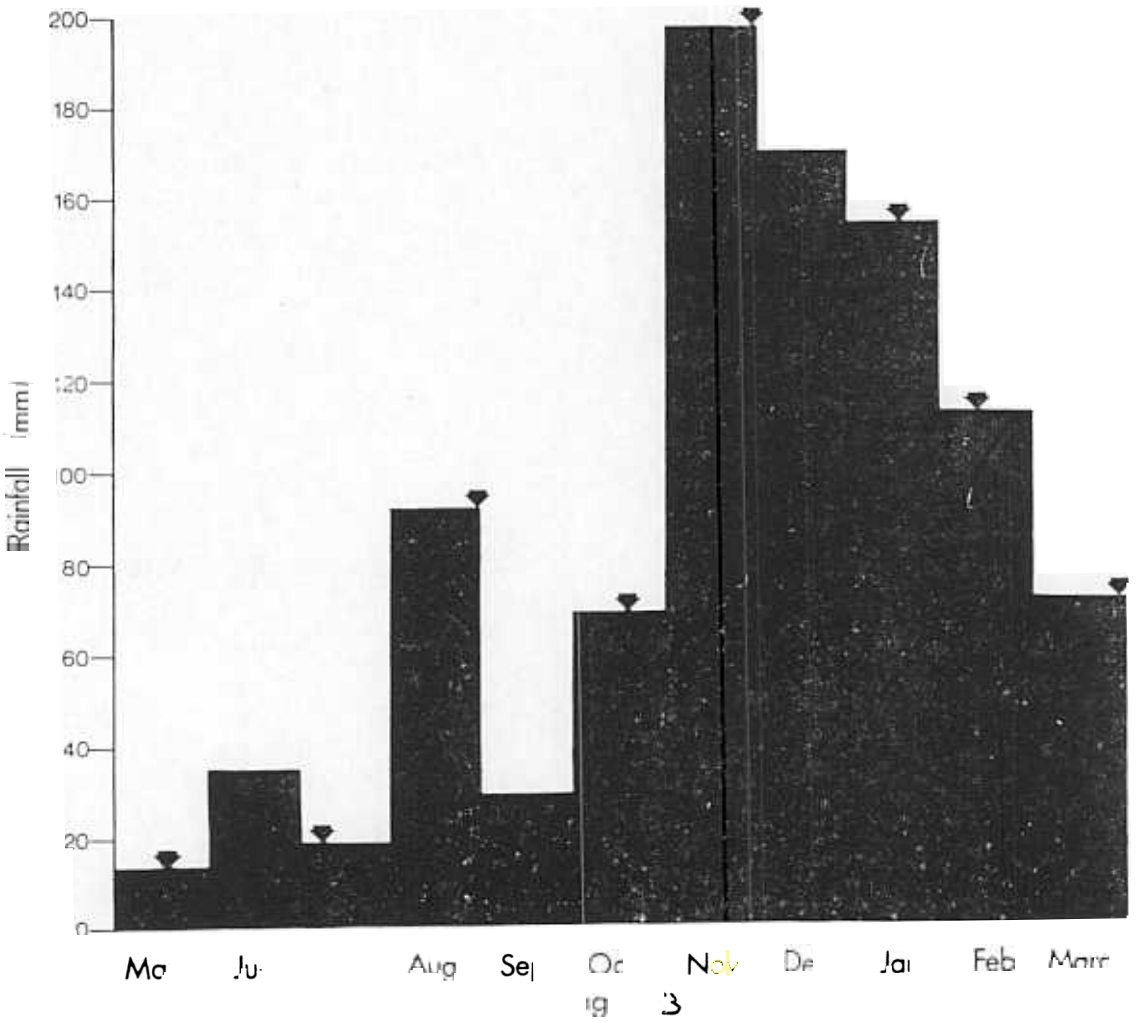

Ntsubane Forest Station Rainfall
Rainfal
210
180
150
120
90
60
0
0
May
June
July
Aug.
Sept.
Oct.
Nov
Dec.
Jan.
Feb.
Mar.
Apr
Monthly Average Rainfall 1942 - 1973
Monthly Rainfall May 1972 - March 1973

MON HI AINFAL NTSUBAN OR 'A ION

May 1972 March 19?3

tuary Mouth Open C ⋈C

Sampling Dat



Msikaba Estuary Vertical Salinity and Temperature Distribution

30th November, 1972

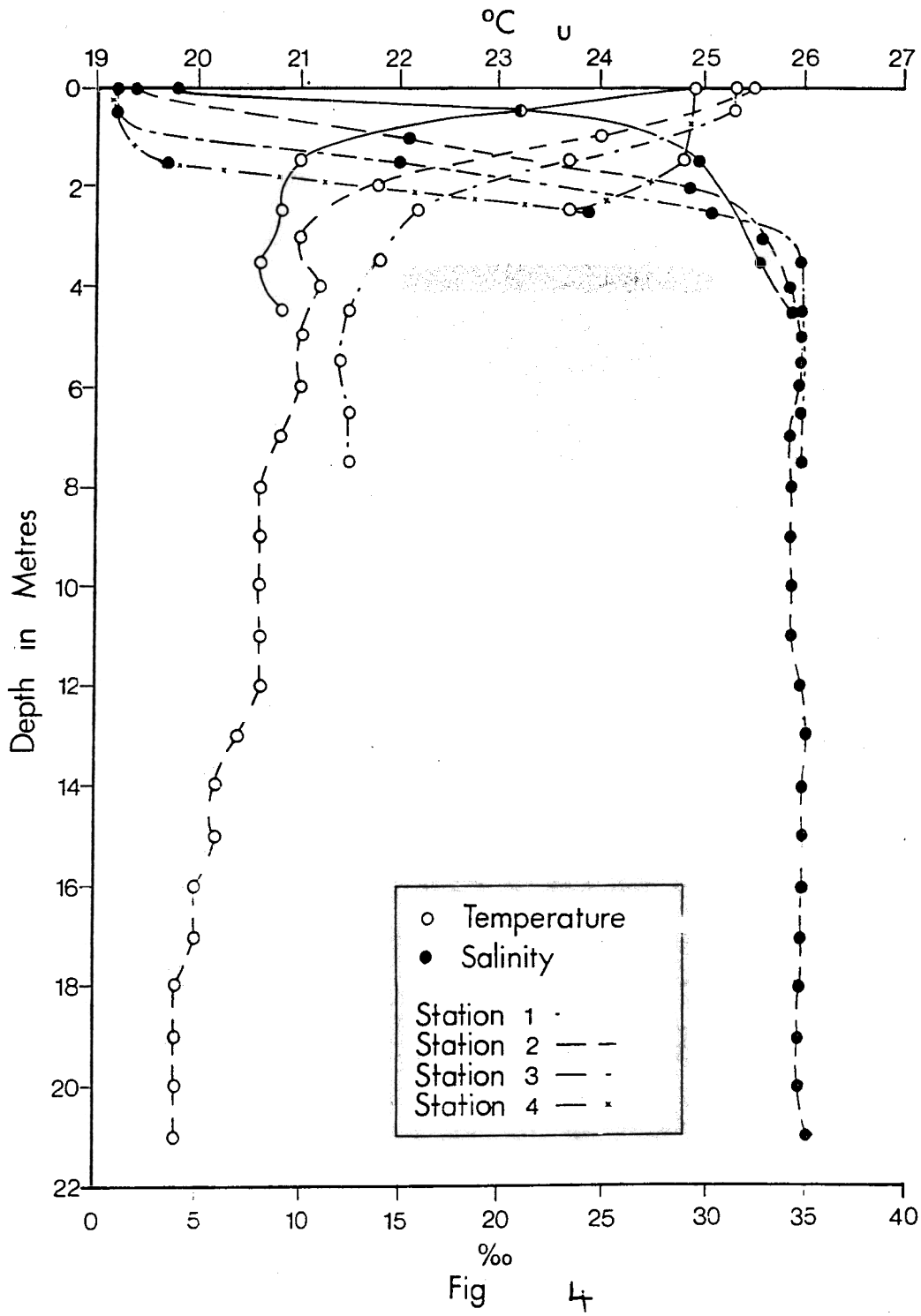


Fig 4

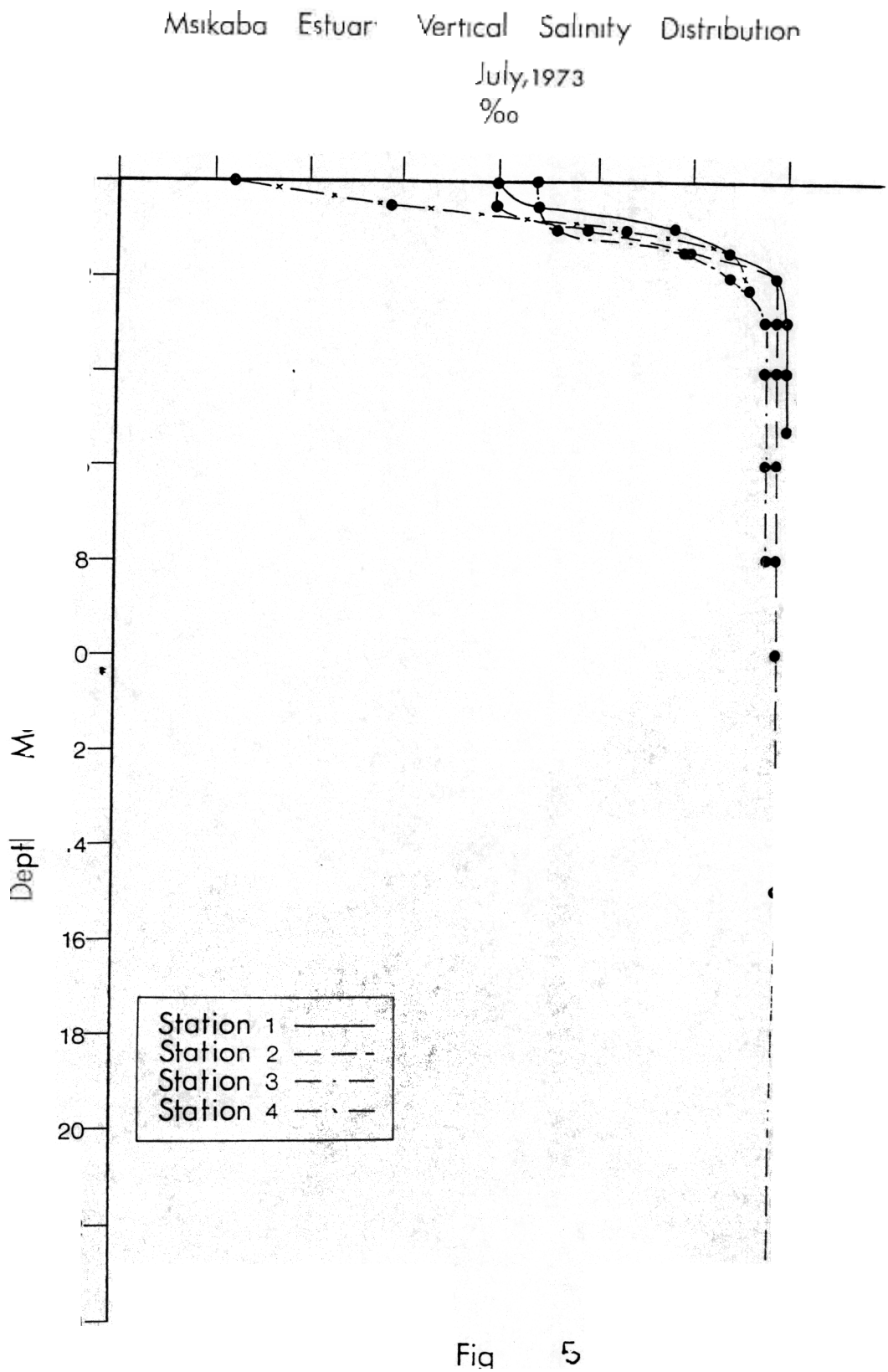

Msikaba Estuar Vertical Salinity Distribution
July, 1973
‰
Depth M
8
0
2
4
16
18
20
Station 1
Station 2
Station 3
Station 4

Fig 5

TABLE 9

MONTHLY AN ANN L RAINFALL FIGURES - NTSUBANE FOREST STATION, JANUARY 1942 - MARCH 1973

											96				Av
ry	218,5										96				174,8
ebru	101,5														161,8
	139,5														160,0
Ap	378,4														126,8
	46,5														70,8
	8,0														45,3
	100,2														36,3
Augus	11,6	85													74,0
Septem	73,5														97,2
Oc	93,0														158,9
lovemb	226,5														193,3
ecem	157,6														168,7
Total amount	1554,8												99	Av	

TABLE B

MONTHLY AND ANNUAL RAINFALL FIGURES - NTSUBANE, FOREST STATION

JANUARY 1942 - MARCH 1973

	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	960
January	328,4	108,0	147,6	212,3	166,6	133,6	143,8	118,9	200,9	248,4	250,7	193,8				176,0	207,0	94,5	148,7
February	93,2	100,8	189,7	202,9	149,1	160,0	201,2	321,6	153,4	100,6	89,4	119,1				160,3	251,4	146,5	103,0
March	134,1	202,7	97,8	170,2	178,8	204,5	188,0	204,7	99,1	128,0	166,9	270,5				202,8	135,5	89,5	192,0
April	83,3	193,3	66,8	59,2	111,8	443,7	98,0	90,2	73,7	40,4	93,5	198,6				240,0	212,6	81,0	105,5
May	110,0	38,1	24,4	52,3	17,5	42,4	1,0	6,6	73,2	15,7	24,1	47,0			-	26,5	0,1	383,0	68,5
June	Nil	66,5	68,3	9,9	13,7	160,8	6,6	Nil	Nil	22,6	7,6	21,6			64,0	54,5	Nil	7,8	Nil
July	Nil	17,0	45,2	15,7	1,5	26,4	Nil	10,7	46,2	3,6	11,9	Nil			4,0	12,3	30,5	77,0	19,2
August	89,4	182,4	8,9	11,7	5,6	18,0	15,5	40,4	60,5	61,5	Nil	155,4			14,0	54,5	41,4	130,2	60,0
September	75,7	51,8	364,5	126,7	68,6	104,4	37,6	124,4	49,3	87,4	150,6	192,8			164,0	103,0	84,6	87,4	141,6
October	142,7	156,7	156,5	385,1	107,0	91,7	239,5	121,9	180,3	238,8	83,3	-		-	179,1	127,2	90,5	86,5	113,0
November	475,2	194,6	89,7	17,8	224,3	552,7	148,8	307,8	36,3	12,2	184,2	-			418,0	103,6	276,0	139,3	194,5
December	195,1	136,4	58,7	111,8	103,9	200,7	146,8	138,4	271,8	342,1	101,3	-			400,5	304,0	129,8	138,6	254,0
Total annual	= 1727,1	1348,3	1318,1	1375,6	1145,4											1564,7	1434,4	1461,5	1400,0

TABLE 2

Ntsubane Forest Station, daily rainfall data (mm) : May1972 - March 1973

Days / Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Tot.
1972 May						-	5,6				3,5	4,0																			-	13,0
Jun	30,5					-	4,5											-	-	-						-	-	-	-	-	-	35,0
July																		19,0	-	-						-	-	-	-	-	-	19,0
Aug	-	-	-	-	-	-	-	-	-	-								88,0	33,0	-	-	-	-	-	-	-	5,5	4,0	5,0	6,5	-	92,0
Sep	-	-	-	6,5	-	-	-	-	-	-		-	-	11,5	-	-			-	-	-	-	5,0	6,0	-	-	-	-	-	-	-	29,0
Oct	-	3,0	7,5	1,5	-	-	-	3,0	2,5	2,5		1,5	11,5	-	-	-	-	-	4,0	-	3,0	5,5	-	-	-	-	-	23,5	-	-	-	69,0
Nov	7,0	9,0	51,0	4,0	-	4,0	-	9,5	-	-		-	-	-	22,5	-	-	-	-	-	-	-	44,0	29,0	2,5	-	-	10,0	-	-	-	198,5
Dec	-	-	-	7,0	-	-	10,0	28,5	-	6,0		2,0	-	33,0	-	-	27,5	-	-	2,5	26,5	14,5	-	-	-	-	2,0	-	8,5	2,0	-	170,0
1973 Jan	-	-	-	-	18,5	-		11,0	8,0		2,5	17,0	-					-	34,0	2,0	-		-	4,5	5,5	-	-	-	14,0	36,0	2,5	155,5
Feb	-	-	-	-	-	-		1,0	-		-	6,0	5,0					7,0	63,0	-	2,5						-	6,0	-	-	-	111,4
	5,0	11,5	-	-	-	-		3,5	12,0						11,0	4,5		-	12,5	-	-		10,5				-	-	-	-	-	72,5

2965 mm

TABLE 3

Lusikisiki village, daily rainfall data (mm) : May 1972 - March 1973.

Days / Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Tot.
1972 May						8,0	-				4,0	1,8								2,0							-	2,0	-		-	17,8
Jun	15,0	-		-			2,0						1,0	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-	-	38,0
Jul	-	-	-	-	-	-	-	-	-				-	-	-	-		10,0	-	-	-	-	-	0,4	-	-	-	-	-	-	10,4
Aug	3,0	-	-	-	-	-	-	-	-				-	-	-	-		7,5	2,5	-	-	-	-	-	-	-	-	5,0	-	-	-	18,5
Sep	-	-	6,0	-	-	-	-	-	-				-	2,5	-	-		-	-	-	-	-	-	10,5	-	-	-	-	-	-	-	19,0
Oct	-	3,5	5,0	5,0	-	-	-	1,3	-	-	-		11,5	-	-	-		-	-	2,5	-	8,4	-	-	-	-	-	15,5	-	-	8,5	61,2
Nov	-	10,5	36,0	-	4,5	2,5	-	3,5	-	-	-		-	-	5	17,0		-	-	-	-	-	44,0	14,6	8,0	0,3	-	-	-	-	-	146,4
Dec	-	-	-	1,0	-	-	9,0	29,0	-	4,5	1,5		-	26,0	-	19,0		-	-	-	12,0	4,0	-	-	-	-	-	6,5	3,5	-	-	116,0
1973 Jan	-	-	-		-	16,0	-	6,7	-	-	6,5			-	-	-	-	-	12,0	-	1,4		-	3,3	5,5		-	-	15,0	28,3	3,0	97,7
Feb	-	-	-		-	-	-	-	-	-	10,0	-	1,6	-	-	-	-	25,0	40,0	0,6	-		-	11,5	-		-	10,0	-	-	-	98,7
Mar	10,0	7,5	3,0		-	-	-	3,0	5,0	-		-	-	-	11,0	2,5	-	-	-	-	-		-	11,3	-		-	-	10,0	25,5	-	88,8

≤ 713 mm

ANNEXURE 11

Table A. Present-state categories based on ecosystem health/ecological integrity (EI) status

Table B. Criteria for determining the confidence levels for decisions taken

Table C. (Future) Ecological Management Class (EMC) categories based on current ecological integrity status

Table A. Present-state categories based on ecosystem health/ecological integrity ***(EI***) status.

CAT.	DESCRIPTION
A	· Unmodified, natural; · The resource base has not been decreased; · The resource capability has not been exploited.
B	· Largely natural with few modification; · The resource base has been decreased to a small extent; · A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	· Moderately modified; · The resource base has been decreased to a moderate extent; · A change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	· Largely modified; · The resource base has been decreased to a large extent; · Large changes in natural habitat, biota and basic ecosystem functions have occurred.
E	· Seriously modified · The resource base has significantly decreased; · The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	· Critically modified; · The resource base has been critically decreased; · Modifications have reached a critical level and the resource has been modified completely with an almost total loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Table B. Criteria for determining the confidence levels for decision taken.

Not enough information or understanding to determine a reliable estimate (less than 40 % sure of the assessment)	Some information exits, but needs to be confirmed. Moderately certain of the estimate (between 40 % and 60 % certain of the estimate)	Information and/or understanding allows a relatively confident assessment (more than 60 % sure of the assessment)
LOW (< 40 %)	**MEDIUM (40 % to 60 %)**	**HIGH (> 60 %)**

Table C. Ecological Management Class (***EMC***) categories based on current ecological integrity status.

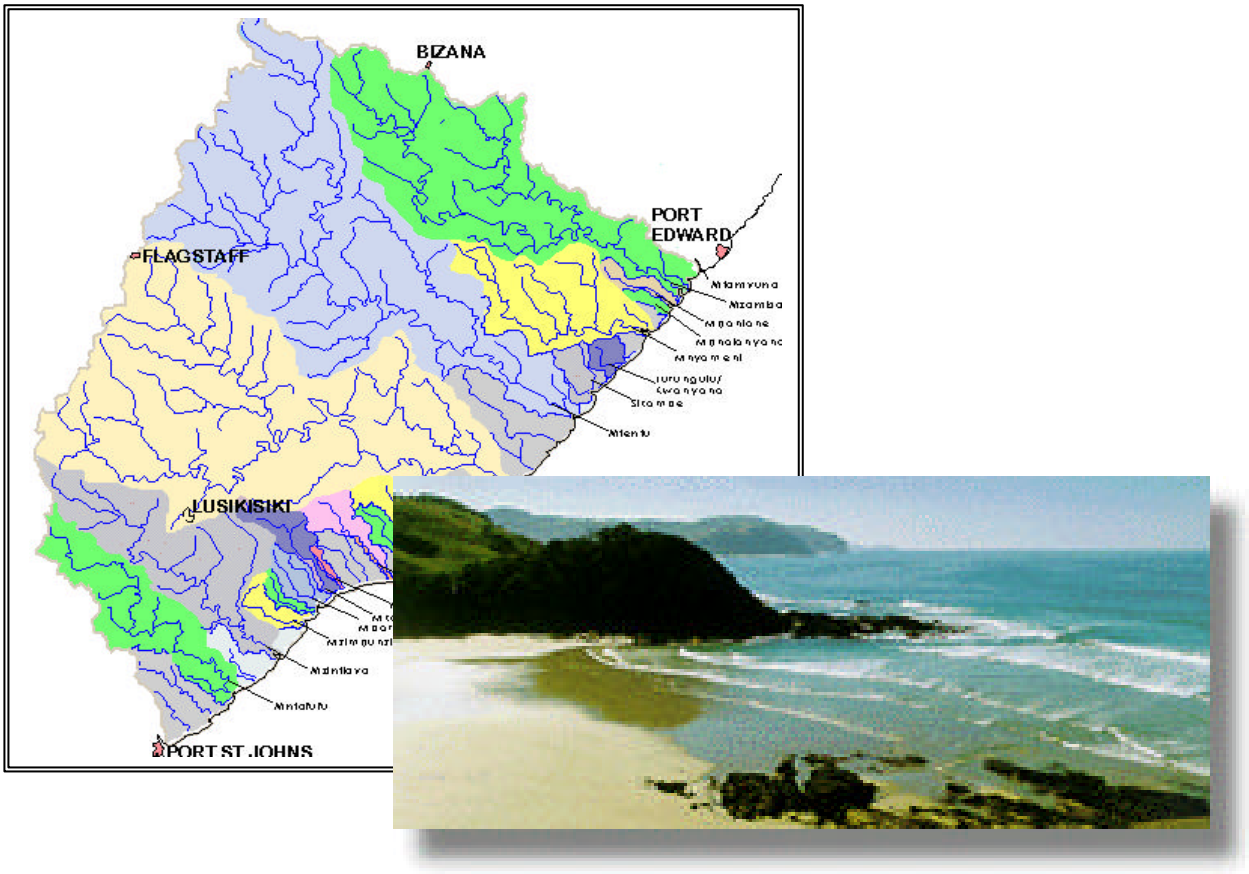
CAT.	DESCRIPTION
A	· Unmodified, natural - the natural abiotic template should not be modified; · The characteristics of the resource should be completely determined by unmodified natural disturbance regimes; · There should be no human induced risks to the abiotic and biotic maintenance of the resource.
B	· Largely natural with few modification - only a small risk of modifying the natural abiotic template and exceeding the resource base should be allowed; · The risk to the well-being and survival of intolerant biota (depending on the nature of the disturbance) many be slightly higher than expected under natural conditions.
C	· Moderately modified - a moderate risk of modifying the abiotic template may be allowed. Risks to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities.
D	· Largely modified - a large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may generally be allowed to increase substantially with resulting low abundances and frequency of occurrence.

PB T600/00/0801

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



STREAMFLOW YIELD ANALYSIS

Final

June 2001

Prepared By:

Department of Water Affairs and Forestry
Directorate: Hydrology
Water Resources
Private Bag X313, Pretoria, 0001

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Streamflow Yield Analysis
AUTHOR	**:**	E Nel and P Mtsweni
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-0801
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EASTERN PONDOLAND BASIN STUDY
STREAMFLOW YIELD ANALYSIS

EXECUTIVE SUMMARY

1. INTRODUCTION

The Directorate: Water Resources Planning commissioned the Eastern Pondoland Basin Study (EPBS) in collaboration with the Eastern Cape Regional Office, to provide a broad evaluation of the state of the water resource availability and utilization in the study area, and to identify a suitable water source for the augmentation of the Lusikisiki Regional Water Scheme.

This **Streamflow Yield Analysis** report covers supporting work done as part of the EPBS to estimate the yields of storage facilities at the following dam sites, identified as possible sources:

- Five sites identified as potential sources for augmentation of the Lusikisiki Regional Scheme: Zalu, Lusikisiki and Xura dam sites on the Xura River, Lower Mzintlava and Tungwane dam sites on the Mzintlava River
- Two sites identified as potential water sources for the supply of the proposed Mkambati SDI water project (a separate study undertaken concurrently with the EPBS): Lusindisweni and KwaHlathi dam sites on the Mtentu River

2. METHODOLOGY

Dams for the Augmentation of the Lusikisiki Regional Scheme

Historic yield analyses were initially performed by means of the YIELD program without taking into consideration the ecological Reserve requirements in order to test the range of dam capacities required to meet the demands.

Historic firm yield analyses were then performed using the Water Resources Yield Model (WRYM). The simulated historical inflow sequences for the present (2000) conditions were used. The analyses were undertaken for two options, with and without provision for the riverine ecological Reserve. Options for accommodation of sediment yields with various confidence levels and design horizons were modelled.

The study resulted in the production of yield-capacity relationships for each dam, as well as variations such as including and excluding releases of the riverine ecological Reserve, including and excluding evaporation losses, variation of dead storage, etc.

The reliabilities of the firm yields for two selected dams (Lusikisiki and Zalu) were tested using the WRYM. For each dam, the stochastic yield analyses were performed for three different full supply capacities, and dead storage volumes. Two hundred and one stochastically generated flow sequences with a length of 77 years each were used.

The analyses have confirmed that the dams can be sized to supply the required yields with the necessary assurance levels (98%).

Dams for the supply of the Mkambati SDI water project

Lusindisweni and KwaHlathi dams were investigated at a lower level of detail. A historic yield analysis was performed with the YIELD program using the present day simulated flow sequences. The analyses were undertaken for two options, with and without provision for the riverine ecological Reserve. The results were produced in the form of yield-capacity relationships for each dam.

CONTENTS

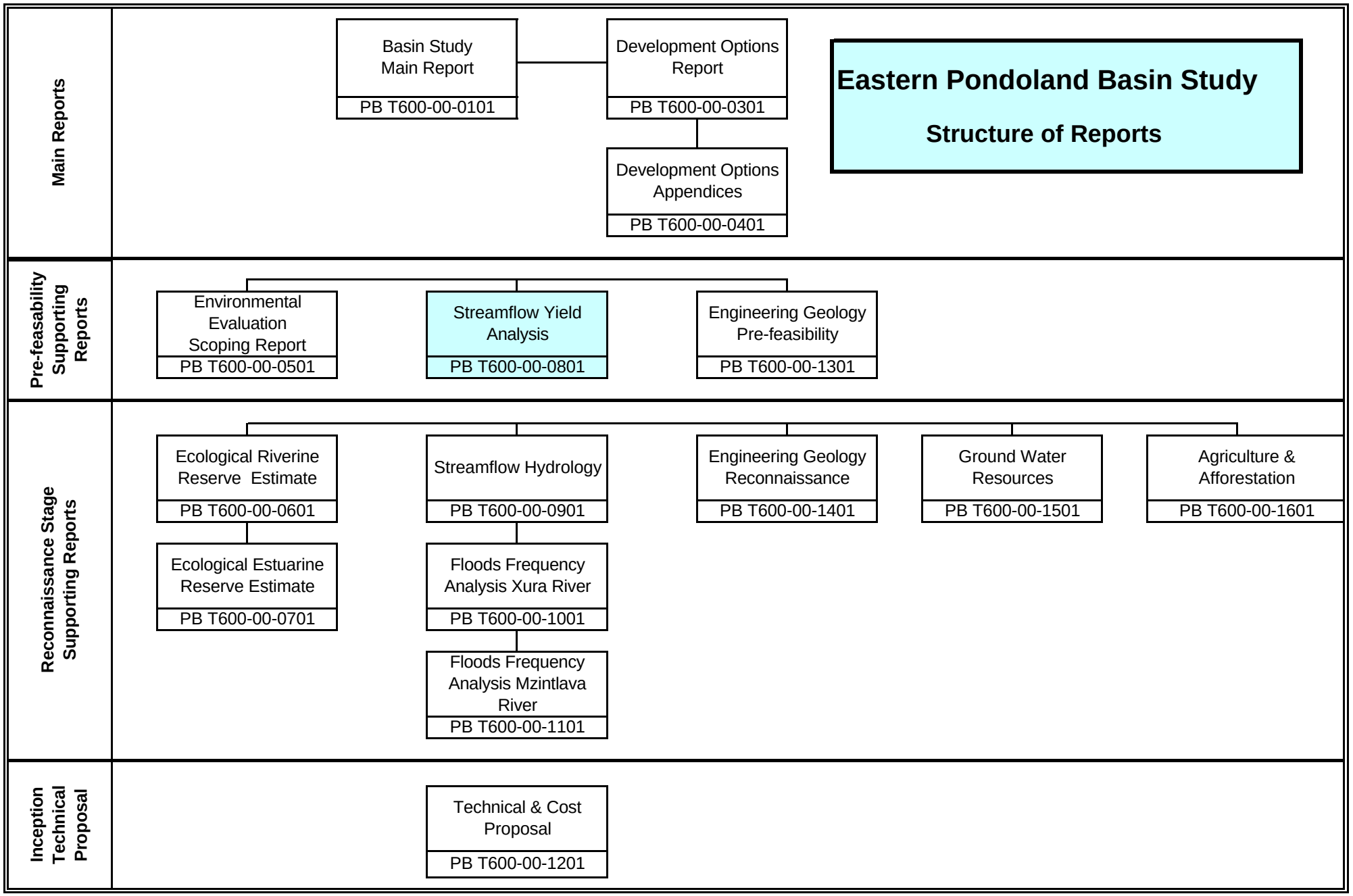
1.	**INTRODUCTION**		1
2.	**SCHEMATIC DIAGRAMS OF THE FIVE PROPOSED DAMS SYSTEMS**		2
	2.1	Schematic diagram of the proposed Zalu, Xura and Lusikisiki Dams Systems	2
	2.2	Schematic diagram of the proposed Tungwane and Lower Mzintlava Dams Systems	2
3.	**REQUIRED INFORMATION**		3
	3.1	Data required for systems analysis with the WRYM	3
	3.1.1	Natural flow sequences	3
	3.1.2	Point rainfall sequences	3
	3.1.3	Irrigation water requirement sequences	3
	3.1.4	Afforestation runoff reduction sequences	4
	3.2	Nodes with storage	4
	3.2.1	Area-capacity relationship for dams	4
	3.2.2	Gross evaporation	4
4.	**YIELD ANALYSIS WITH THE YIELD PROGRAMME**		5
	4.1	Data requirement for the yield programme	5
	4.2	Output from the yield programme	6
	4.3	Yield analysis of the other two proposed dams	8
5.	**METHODOLOGY OF WRYM ANALYSIS**		10
6.	**STOCHASTIC FLOW SEQUENCES**		11
	6.1	Generation of stochastic natural flow sequences	11
	6.2	Evaluation of stochastic natural flow	11
	6.2.1	Monthly and yearly averages and standard deviations	11
	6.2.2	Minimum run sums	11
	6.2.3	Maximum deficits and duration of deficits	12
	6.2.4	Yield-capacity plots	12
7.	**ECOLOGICAL RESERVE RELEASES**		13
	7.1	Methodology	13
8.	**RESULTS OF YIELD ANALYSES**		13
	8.1	Introduction	13
	8.2	Results of the historic yield analysis	13
	8.3	Results of the yield analyses for Zalu and Lusikisiki	17
9.	**SUMMARY**		18
10.	**REFERENCES**		18

LIST OF APPENDICES

#	Description	Appendix
1	Map showing the position of the proposed dams	1
2	Schematic diagrams for WRYM	2
3	Natural flow sequences	3
4	Point rainfall sequences	4
5	Afforestation sequences	5
6	Area-capacity tables	6
7	Yield-capacity graphs	7
8	WRYM data files	8
9	Paramk5.dat files	9
10	Monthly and yearly averages and standard deviations (Lusikisiki Dam)	10.1
11	Monthly and yearly averages and standard deviations (Zalu Dam)	10.2
12	Sampled cumulative distributions (Lusikisiki Dam)	11.1
13	Sampled cumulative distributions (Zalu Dam)	11.2
14	Minimum run sums, maximum deficits and deficits duration (Lusikisiki Dam)	12.1
15	Minimum run sums, maximum deficits and deficits duration (Zalu Dam)	12.2
16	Yield-capacity plots (Lusikisiki Dam)	13.1
17	Yield-capacity plots (Zalu Dam)	13.2
18	IFR (Instreaam Flow Requirements sequences	14
19	Risk Yield Curves (Zalu Dam, HFY = 2.29, 2.51, 3.51)	15.1
20	Risk Yield Curves (Lusikisiki Dam, HFY = 2.29, 2.51, 3.51)	15.2

Eastern Pondoland Basin Study

Structure of Reports



1. INTRODUCTION

This report has been prepared by Sub-Directorate: Water Resources Studies of the Directorate: Hydrology in the Department of Water Affairs and Forestry, as part of the Eastern Pondoland Basin Study. The report outlines the methodology applied and offers the results of the yield analysis for the following proposed dam sites located in tertiary drainage region T60:

Zalu, Lusikisiki and Xura sites on the Xura River (a tributary of the Msikaba River) and Lower Mzintlava and Tungwane sites on the Mzintlava River, investigated as options for the augmentation of the water source for the Lusikisiki Regional Water Supply Scheme. Lusindisweni and Kwa-Hlati sites on the Mtentu River investigated as water source options for the proposed Mkambati SDI Regional Water Scheme. A historic yield analysis was undertaken for all above sites including and excluding IFR. In addition, two sites - Lusikisiki and Zalu were selected for more detailed investigations and a stochastic analysis including and excluding IFR was performed for them.

More details on the hydrological characteristics of the study catchment are given in the report titled "Eastern Pondoland Hydrology Report".

The aim of the stochastic yield analyses is to attach risks of failure to target drafts set for the above mentioned dams. For all the scenarios, flow sequences of 75 years each in length were generated. The results of the stochastic simulations were used to plot families of long-term risk-yield curves.

In section 2 the schematic diagrams of the Zalu, Xura, Lusikisiki, Lower Mzintlava and Tungwane Dams are discussed. For the discussion of the schematic diagrams for Lusindisweni and Kwa-Hlati dams refer to the Hydrology Report[1]

Natural flow, point rainfall, irrigation requirement and afforestation water consumption sequences needed for the system analysis are discussed in section 3.

Yield analyses with the Yield programme is discussed in section 4 with the results of the seven proposed dams.

The methodology of the Water Resources Yield Model (WRYM) analysis is discussed in section 5 for the five proposed dams excluding Lusindisweni and Kwa-Hlati dams.

The generation and evaluation of stochastic flow sequences are discussed in section 6.

The methodology of the ecological reserve releases is discussed in section 7.

The results of the historic and stochastic yield analysis with the WRYM programme are discussed in section 8.

The summary of this report is given in section 9.

2. SCHEMATIC DIAGRAMS OF THE PROPOSED DAMS.

Seven sites were identified as potential sites for the dams. A WRYM system was set up for each site excluding Lusindisweni and Kwa-Hlati to evaluate the yield potential for each dam. The Zalu, Xura and Lusikisiki Dam systems are similar as well as the Tungwane and Lower Mzintlava Dam systems. Zalu, Xura and Lusikisiki Dams are discussed in section 2.1; Tungwane and Lower Mzintlava Dams are discussed in section to 2.2. Lusindisweni and Kwa-Hlati schematic diagrams are discussed in the Hydrology Report[1]. The catchments of the three dams consist of three quaternary catchments each. The catchment areas and mean annual precipitation are given in Table 2.1. Appendix 1, Figure 1 is a map showing the position of all the proposed dams sites as well as the quaternary catchments.

Table 2.1: The Catchment areas and MAPs for the proposed and existing dams.

Name of the proposed dam	Quaternary Catchment where the dam is located	Catchment Area (km^2)	MAP at the dam (mm)	MAP of the Quaternary Catchment (mm)
Zalu Dam	T60F	71	940	940
Xura Dam	T60F	225	940	940
Lusikisiki Dam	T60F	91	940	940
Tungwane Dam	T60J	129	975	1101
Lower Mzintlava Dam	T60J	98	950	1101
Lusindisweni Dam	T60C	545	898	952
Kwa-Hlati Dam	T60C	722	911	952

2.1 Schematic diagram of the proposed Zalu, Xura and Lusikisiki Dams Systems

A schematic representation of the Zalu, Xura and Lusikisiki Dam systems for modelling with the WRYM is attached as Appendix 2. A short discussion of the schematic representation is given for clarity.

The proposed dam is represented by node 3 with three outflow channels, namely, 13 - yield channel, 26 - the IFR release channel and 17 - the spill channel. The circles 1, 2, 4, 5, 6, 7, 8, 9 and 24 represent nodes without storage. The IFR release channel 26 is an inflow channel to node 24. The domestic and livestock demands within the system are indicated with the channels 11, 15, 21 and 22. The incoming curled arrows represent natural inflows to the system. No river losses were modelled.

2.2 Schematic diagram of the proposed Tungwane and Lower Mzintlava Dams systems

A schematic representation of the Tungwane and Lower Mzintlava Dam system for modelling with the WRYM is attached as Appendix 2. A short discussion of the schematic representation is given for clarity.

Node 3 represents the proposed dam with three outflow channels namely, 13 - yield channel, 9 - spill channel and 15 - IFR release channel. The five circles 1, 2, 4, 5, 14 represent nodes without storage. The IFR release channel 15 is an inflow channel to node 14. The domestic and livestock demands within the system are indicated with the channels 7 and 11. The incoming arched arrows represent natural inflows in the system. No river losses were modelled.

3. REQUIRED INFORMATION

3.1 Data sets required for system analysis with the WRYM

The complete system for the proposed dams Zalu, Xura and Lusikisiki, consists of three quaternary catchments, namely T60E, T60F and T60G. T60F has been split into two parts, namely, the upper and the lower part to accommodate the proposed dam. Each system thus has a total of four incremental catchments.

For the other two dams, Tungwane and Lower Mzintlava, a complete system for each dam consists of one quaternary catchment T60J. The quaternary catchment has been split into two parts, above and below the dam.

For each incremental catchment, a set of four sequences is required:

- a natural flow sequence (in $10^6 m^3$)
- a point rainfall sequence (in mm)
- an irrigation requirement sequence (in 10^6 m^3)
- an afforestation runoff reduction sequence (in 10^6 m^3)

The four required sequences for the incremental catchments are discussed in sections 3.1.1 to 3.1.5.

3.1.1 Natural flow sequences

The natural flow sequences for the incremental catchments are attached in Appendix 3. These sequences were obtained by simulation with the WRSM90 model for the period 1920/21 – 1996/97. For more details refer to the Hydrology Report[1]. The mean annual natural runoffs (MAR) at the dams are given in Table 3.1

3.1.2 Point rainfall sequences

Point rainfall sequences are required to model the net evaporation losses from the surface of the dams.
A point rainfall sequence for a specific dam is calculated by multiplying the representative percentage rainfall sequence by the MAP (mm) at the dam. The point rainfall sequences for the proposed dams are attached in Appendix 4.

3.1.3 Irrigation water requirement sequences

The irrigation requirements for all the incremental catchments are zero. For more details, refer to the Hydrology Report[1].

3.1.4 Afforestation runoff reduction sequences

Afforestation runoff reduction sequences (in 10^6 m^3) for present (2000) conditions for the incremental catchments have been simulated with the WRSM90 model and are attached as Appendix 5. The mean annual reduction in runoff by present (2000) afforestation is listed in Table 3.1.

Table 3.1: Mean annual natural runoff, present (2000) afforestation areas and mean annual runoff reduction by present day afforestation.

Name of the proposed dam	Natural MAR (Mm^3/a)	Afforestation Area (km^2)	Mean afforestation runoff reduction (Mm^3/a)
Zalu Dam	12.10	3.98	0.48
Xura Dam	38.35	4.64	0.57
Lusikisiki Dam	15.51	4.02	0.49
Tungwane Dam	24.20	4.97	0.60
Lower Mzintlava Dam	17.06	0	0
Lusindisweni Dam	78.40	34.07	3.69
Kwa-Hlati Dam	108.98	34.07	3.69

3.2 Nodes with storage

3.2.1 Area-capacity relationship for dams

The area-capacity tables for the proposed dams have been supplied by UWP Consulting Engineers. Appendix 6 gives the area-capacity tables for the proposed dams.

3.2.2 Gross evaporation

Pan-to-dam factors were used to convert mean monthly gross S-pan evaporation to mean monthly gross dam evaporation. The relevant evaporations are listed in Table 3.2. For a complete discussion of the S-pan evaporation refer to the Hydrology Report[1].

Table 3.2: Mean monthly gross dam evaporation for the proposed dams.

Month	Pan-to-dam Factors	Zalu, Xura, Lusikisiki, Lusindisweni and Kwa-Hlati Dams		Tungwane and Lower Mzintlava Dams	
		Mean S-pan Evaporation (mm)	Mean Dam Evaporation (mm)	Mean S-pan Evaporation (mm)	Mean Dam Evaporation (mm)
Oct	0.81	100	81	116	94
Nov	0.82	101	83	124	102
Dec	0.83	129	107	145	120
Jan	0.84	138	116	145	122
Feb	0.88	120	105	117	103
Mar	0.88	114	101	103	91
Apr	0.88	89	78	78	69
May	0.87	73	59	59	48
Jun	0.85	55	46	44	37
Jul	0.83	60	50	51	42
Aug	0.81	83	67	75	61
Sep	0.81	89	72	97	78
Total		1151	965	1154	967

4. YIELD ANALYSIS WITH THE YIELD PROGRAMME

A programme called YIELD was used to produce gross and net yield-capacity curves for the seven proposed dams. Gross and net yields are the yields excluding and including evaporation losses from the dams.

4.1 Data requirements for the Yield programme

For each dam the following data served as input for the Yield programme: -

- present day inflow sequence at the dam
- point rainfall sequence at the dam
- pan-to-dam factors
- water abstraction pattern
- twelve monthly mean S-pan evaporations
- area-capacity relationship

Table 4.1 gives the abstraction pattern used for all the dams.

Table 4.1: Percentage Water Abstraction Pattern

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
8.33	9.17	10.00	10.83	10.00	9.17	8.33	7.50	6.67	5.83	6.67	7.50	100

4.2 Output from the Yield programme

The output of the Yield programme giving the yields and the gross and net dam capacities are given in Tables 4.2 to 4.4. These values are used to plot yield-capacity graphs shown in Appendix 7. The yields corresponding with gross and net dam capacities are the gross and net yields respectively.

Table 4.2: Yield, Gross and Net capacities of Lusikisiki and Zalu Dams (NO IFR).

Lusikisiki Dam			**Zalu Dam**		
Yield (Mm^3/a)	**Gross capacity (Mm^3)**	**Net capacity (Mm^3)**	**Yield (Mm^3/a)**	**Gross capacity (Mm^3)**	**Net capacity (Mm^3)**
0.74	2.50	2.54	0.57	2.00	2.03
1.48	2.55	2.60	1.14	2.03	2.07
2.21	2.86	2.98	1.72	2.26	2.36
2.95	3.25	3.41	2.29	2.56	2.69
3.69	3.74	4.07	2.86	2.94	3.21
4.42	4.92	5.28	3.43	3.85	4.15
5.16	6.20	6.58	4.01	4.83	5.17
5.90	7.47	7.88	4.58	5.82	6.18
6.64	8.74	9.18	5.15	6.81	7.19
7.38	10.13	11.00	5.72	7.87	8.59
8.11	12.86	13.97	6.30	10.01	10.80
8.85	15.67	16.94	6.87	12.19	13.05
9.59	18.51	19.90	7.44	14.40	15.31
10.32	21.39	22.87	8.01	16.63	17.60
11.06	24.26	25.83	5.59	18.86	19.90
11.80	29.63	33.80	9.16	23.06	25.73

Table 4.3: Yield, Gross and Net capacities of Xura and Lower Mzintlava Dams (NO IFR).

Xura Dam			Lower Mzintlava		
Yield (Mm^3/a)	**Gross capacity (Mm^3)**	**Net capacity (Mm^3)**	**Yield (Mm^3/a)**	**Gross capacity (Mm^3)**	**Net capacity (Mm^3)**
1.87	5.60	5.68	0.85	2.60	2.64
3.73	5.69	5.78	1.69	2.65	2.69
5.60	6.37	6.60	2.54	2.88	2.99
7.47	7.35	7.64	3.39	3.41	3.53
9.34	8.51	9.09	4.23	3.94	4.06
11.20	11.44	12.10	5.08	5.06	5.34
13.07	14.64	15.36	5.93	6.50	6.81
14.94	17.86	18.64	6.77	7.96	8.31
16.81	21.08	21.91	7.62	9.42	10.11
18.67	24.30	25.44	8.47	12.25	13.11
20.54	30.76	32.18	9.31	15.14	16.18
22.41	37.87	39.39	10.16	18.11	19.37
24.28	45.06	46.66	11.00	21.24	22.69
26.14	52.35	54.03	11.85	24.61	26.30
28.01	59.63	61.41	12.70	28.09	30.07
29.88	72.13	74.46	13.54	35.67	39.05

Table 4.4: Yield, Gross and Net capacities of Tungwane Dam (NO IFR).

Tungwane Dam		
Yield (Mm^3/a)	**Gross capacity (Mm^3)**	**Net capacity (Mm^3)**
1.17	3.40	3.44
2.34	3.47	3.51
3.52	3.85	3.95
4.69	4.58	4.69
5.86	5.31	5.43
7.03	6.95	7.17
8.20	8.97	9.19
9.38	10.99	11.23
10.55	13.02	13.33
11.72	16.90	17.28
12.89	20.95	21.34
14.06	25.07	25.49
15.24	29.24	29.63
16.41	33.81	34.21
17.58	38.38	38.83
18.75	48.44	47.43

4.3 Yield analysis of the other two proposed dams.

Since the Yield programme cannot accommodate IFR releases from a dam, IFR demands were subtracted from the dam's present day inflow record.

The present day MARs at the dams, excluding and including IFR demands, are given in Table 4.5. The yields and the gross and net dam capacities are given in Tables 4.6 and 4.7.

For more information on the two proposed dams (Lusindisweni and Kwa-Hlati) refer to the Hydrology Report[1].

Table 4.5: Present day MAR at the dams excluding and including IFR demands.

Dam name	Annual IFR demand (Mm^3)	Present day MAR excluding IFR demand (Mm^3)	Present day MAR including IFR demand (Mm^3)
Lusindisweni	20.1	73.7	53.6
Kwa-Hlati	27.8	104.0	76.2

Table 4.6: Yield, Gross and Net capacities of Lusindisweni Dam excluding and including class B/C IFR releases.

Excluding IFR			**Including IFR**		
Yield (Mm^3/a)	**Gross capacity (Mm^3)**	**Net capacity (Mm^3)**	**Yield (Mm^3/a)**	**Gross capacity (Mm^3)**	**Net capacity (Mm^3)**
3.68	4.70	4.78	2.68	4.95	5.04
7.37	4.88	4.98	5.36	5.47	5.68
11.05	5.46	5.60	8.04	7.01	7.44
14.74	6.44	6.66	10.73	10.64	11.22
18.42	8.93	9.31	13.41	14.33	15.43
22.10	12.52	13.11	16.09	21.37	22.78
25.79	17.04	17.78	18.77	28.58	30.17
29.47	22.33	23.79	21.45	35.80	37.56
33.16	31.58	33.23	24.13	46.57	49.62
36.84	40.82	42.66	26.82	59.97	63.34
40.52	52.27	55.57	29.50	73.38	77.01
44.21	70.32	73.98	32.18	86.91	90.83
47.89	88.43	92.39	34.86	101.60	105.88
51.58	106.85	111.10	37.54	116.42	120.96
55.26	125.27	129.79	40.22	152.67	162.45
58.94	144.21	151.19	42.90	199.39	210.24

Table 4.7: Yield, Gross and Net capacities of Kwa-Hlati Dam excluding and including class B/C IFR releases.

Excluding IFR			Including IFR		
Yield (Mm^3/a)	**Gross capacity (Mm^3)**	**Net capacity (Mm^3)**	**Yield (Mm^3/a)**	**Gross capacity (Mm^3)**	**Net capacity (Mm^3)**
5.20	5.90	6.02	3.81	6.25	6.37
10.40	6.19	6.34	7.62	7.05	7.34
15.59	7.04	7.28	11.43	9.36	9.96
20.79	8.49	8.83	15.23	14.60	15.26
25.99	11.94	12.41	19.04	19.92	20.69
31.19	17.28	17.95	22.85	28.85	30.24
36.39	23.75	24.56	26.66	39.10	40.66
41.58	30.42	31.71	30.47	49.35	51.06
46.78	43.28	44.93	34.28	64.71	67.51
51.98	56.32	58.14	38.08	83.71	86.81
57.18	73.31	76.42	41.89	102.76	106.15
62.38	98.63	102.07	45.70	121.80	125.47
67.57	124.26	128.05	49.51	141.99	146.07
72.77	150.25	154.39	53.32	163.10	167.44
77.97	176.24	180.70	57.13	199.93	207.56
83.17	202.51	207.46	60.94	266.29	275.07

5. METHODOLOGY OF WRYM (WATER RESOURCES YIELD MODEL) ANALYSIS

A historic yield analysis for all the five proposed dams was initially carried out to check the correctness of the fourteen WRYM files (Appendix 8) and to verify the operating rules for the systems. Thereafter 201 stochastic natural flow sequences for Zalu and Lusikisiki Dam systems were generated and evaluated with several tests. The results of the stochastic yield analysis are represented by risk-yield curves.

6. STOCHASTIC FLOW SEQUENCES

6.1 Generation of stochastic natural flow sequences

For each incremental catchment 201 stochastic natural flow sequences of 77 years each were generated based on the historic long term natural flow sequences for all the incremental catchments based on the so called ARMA (0,0) model. The statistical characteristics of the historic long term flow sequences that were used for generating the stochastic natural flow sequences are given in Appendices 9 (file name Paramk5.dat).

6.2 Evaluation of stochastic natural flow sequences

Before the stochastically generated sets of natural flow sequences can be used for yield analysis, a critical evaluation of the stochastic generated flow sequences is necessary. It is necessary to verify that the statistical properties of the historic natural flow sequence are satisfactorily preserved in the stochastic sequences. For this purpose so called "box plot" representations were used to evaluate the monthly and yearly averages and standard deviations of the stochastic sequences. In this way the spread of the statistics for the stochastic flow sequences could be compared with those of the historic flow sequences. Similar comparisons were made with respect to the N-month run sums, the maximum deficits, the duration of maximum deficits and the duration of maximum depletion.

Finally the stochastic flow sequences were compared with the historic flow sequence with respect to gross yield curves. The tests carried out are briefly discussed in the following subsections.

6.2.1 Monthly and yearly averages and standard deviations

The monthly and yearly averages of the 201 stochastic flow sequences were compared with the corresponding statistics of the historic flow sequence for each incremental catchment. The results are represented by so called "box plots". The historic values for the mentioned statistics are indicated by arrow points and must preferably lie between the 25 th and the 75 th percentiles of the stochastic flow sequences. It is the case for all the yearly averages and standard deviations and for most of the monthly statistics.
The "box plots" appear in Appendix 10.

6.2.2 Minimum run sums

So called "minimum run sums" are usually calculated for a specific time period e.g. 6 months, 12 months, 18 months etc. The 12 months (say) minimum run sum for a given flow sequence is the lowest flow that occurred for 12 consecutive months as calculated over the whole duration of the flow sequence.
Box plot representations of the calculated "minimum N-month run sums" for the historic flow sequence and the 201 stochastic flow sequences are attached in Appendix 11 for all the incremental catchments.

6.2.3 Maximum deficits and duration of deficits

The maximum deficit and deficit duration tests are validation tests where a given draft expressed as percentage of the MAR is applied to a semi-infinite reservoir starting full. Three tests are undertaken, the maximum deficit test, the duration of maximum deficit test and the duration of longest depletion test.
The test for maximum deficits gives an indication of the minimum reservoir capacity that is required for each flow sequence in order to meet the target yields of 40%, 50%, 60%, 70% and 80% of the historic MAR.

The test for the duration of the maximum deficit gives an indication of the duration in months of the drought that causes the maximum deficit. The duration of the drought is the time from when the dam is full until the maximum deficit is reached and back to full supply capacity.

A third test, duration of longest depletion, involves the calculation of the duration (in months) of the longest period to empty the dam.

Box plot representations of the above mentioned three tests are attached as Appendix 12. With a few exceptions, the historic values lie between the 25 th and the 75 th percentiles. The stochastic sequences were therefore accepted.

6.2.4 Yield – capacity plots

Finally the gross yield curves of the stochastic natural flow sequences are compared with those of the historic natural flow sequences.

The yield capacity test indicates the minimum net reservoir capacity that is necessary to satisfy a given yield for each of the 201 stochastic flow sequences. The results are expressed in terms of the historic natural MAR and yields and capacities are expressed as percentages of the MAR. No evaporation losses from the dam surface are taken into account, therefore the reference to gross yield curves.

The gross yield curves for the incremental catchments are attached in Appendix 13. Inspection of the curves shows that the median and average yield curves as derived from the 41 stochastic flow sequences lie above the historic yield curve for all the incremental catchments.

7. ECOLOGICAL RESERVE RELEASES

7.1 Methodology

Professor Denis Hughes of Rhodes University was supplied with the natural inflow sequences of all the dams (Zalu, Xura, Lusikisiki, Tungwane, Lower Mzintlava, Lusindisweni and Kwa-Hlati Dams). He used the "Desktop Estimate" to create sequences of instream flow requirements (IFR). The ecological Reserve requirement sequences are given in Appendix 14.

8. RESULTS OF YIELD ANALYSES

8.1 Introduction

Historic firm yields based on present (2000) development conditions in the catchments of the dams were calculated for the five proposed dams with the WRYM Model. These yields exclude and include IFR (Instream Flow Requirements) releases. The results are given in section 8.2

After the historic yield analyses Zalu and Lusikisiki Dams were chosen for further historic and stochastic yield analyses. The results are given in section 8.3.

8.2 Results of the Historic Yield Analysis

UWP Consulting Engineers provided various live storages, dead storages and silt volumes. The gross full supply capacities of the dams were then calculated. The yields excluding and including IFR releases are given in Tables 8.1 to 8.5.

Table 8.1: Historic firm yields for Zalu Dam.

Gross FSC (%)	Gross Full Supply Capacity (Mm^3)	Silt volume (Mm^3)	Yield (WRYM)			Annual IFR Demand (Mm^3)	Present MAR at dam site (Mm^3)	Present MAR (zero storage) at estuary (Mm^3)	Natural MAR at estuary (Mm^3)	Present MAR (with IFR) at estuary (Mm^3)	Present MAR as a % of Natural MAR
			Yield without IFR (Mm^3)	Yield with class B/C IFR (Mm^3)	Yield with IFR as a % of yield without IFR						
155	25.000	0	9.24	6.56	71.00	2.74	11.46	203.26	207.43	196.70	94.83
100	16.080		8.14	5.97	73.34					197.30	95.12
75	12.060		7.17	4.98	69.46					198.31	95.60
50	8.040		6.01	3.98	66.22					199.45	96.20
30	4.824		5.02	3.19	63.55					200.11	96.15
10	1.608		3.20	1.71	53.44					201.62	96.47
50	8.040	0.800	5.92	3.77	63.68					199.54	97.20

Table 8.2: Historic firm yields for Tungwane Dam.

Gross FSC (%)	Gross Full Supply Capacity (Mm^3)	Silt volume (Mm^3)	Yield (WRYM)			Annual IFR Demand (Mm^3)	Present MAR at dam site (Mm^3)	Present MAR (zero storage) at estuary (Mm^3)	Natural MAR at estuary (Mm^3)	Present MAR (with IFR) at estuary (Mm^3)	Present MAR as a % of Natural MAR
			Yield without IFR (Mm^3)	Yield with class B IFR (Mm^3)	Yield with IFR as a % of yield without IFR						
100	32.075	3.40	15.58	10.78	69.19	6.87	23.42	77.34	78.86	66.71	84.59
75	24.056		13.63	8.71	63.90					68.80	87.24
50	16.038		11.32	6.67	58.92					70.78	89.75
25	8.019		7.53	4.10	54.45					73.34	93.00

Table 8.3: Historic firm yields for Xura Dam.

Gross FSC (%)	Gross Full Supply Capacity (Mm^3)	Silt volume (Mm^3)	Yield (WRYM)			Annual IFR Demand (Mm^3)	Present MAR at dam site (Mm^3)	Present MAR (zero storage) at estuary (Mm^3)	Natural MAR at estuary (Mm^3)	Present MAR (with IFR) at estuary (Mm^3)	Present MAR as a % of Natural MAR
			Yield without IFR (Mm^3)	Yield with class B IFR (Mm^3)	Yield with IFR as a % of yield without IFR						
100	26.20	0	20.50	12.36	60.29	10.57	37.33	203.36	203.43	191.05	92.10
75	19.65		18.69	10.75	57.52					192.63	92.87
50	13.10		15.69	9.05	59.89					194.33	93.68
25	6.55		15.11	5.94	52.01					197.43	95.18
8	2.10		7.91	3.54	44.75					199.79	96.32
25	6.55	2.24	10.01	4.68	46.75					198.69	95.79
10	2.60		4.65	0.89	19.14					202.44	97.59
100	26.20	5.60	18.87	10.92	57.87					192.47	92.79
75	19.65		15.52	9.24	59.54					194.14	93.59
50	13.10		11.84	6.32	53.38					197.05	95.00
25	6.55		5.56	1.92	34.53					201.43	97.11

Table 8.4: Historic firm yields for Lusikisiki Dam.

Gross FSC (%)	Gross Full Supply Capacity (Mm^3)	Silt volume (Mm^3)	Yield (WRYM)			Annual IFR Demand (Mm^3)	Present MAR at dam site (Mm^3)	Present MAR (zero storage) at estuary (Mm^3)	Natural MAR at estuary (Mm^3)	Present MAR (with IFR) at estuary (Mm^3)	Present MAR as a % of Natural MAR
			Yield without IFR (Mm^3)	Yield with class B/C IFR (Mm^3)	Yield with IFR as a % of yield without IFR						
100	45.700	0	12.68	9.20	72.56	3.57	14.83	203.33	207.43	194.08	93.56
75	34.275		12.05	5.57	71.12					194.71	93.87
50	22.850		11.05	7.97	72.13					195.34	94.17
30	13.710		8.79	6.04	68.71					197.30	95.12
10	4.570		5.60	3.63	64.82					199.73	96.29
3	1.370		3.74	1.89	50.53					201.50	97.14
10	4.57	1.000	5.00	3.09	50.17					200.30	96.56
4	1.80		2.93	1.47	50.53					201.91	97.34
100	45.700	2.50	12.50	9.05	72.40					194.21	93.63
75	34.275		11.91	8.42	70.70					194.87	93.94
50	22.850		1038	7.60	73.22					195.69	94.34
30	13.710		8.12	5.36	66.01					197.96	95.43
10	4.570		4.09	2.23	54.52					201.15	96.97

Table 8.5: Historic firm yields for Lower Mzintlava Dam.

Gross FSC (%)	Gross Full Supply Capacity (Mm^3)	Silt volume (Mm^3)	Yield (WRYM)			Annual IFR Demand (Mm^3)	Present MAR at dam site (Mm^3)	Present MAR (zero storage) at estuary (Mm^3)	Natural MAR at estuary (Mm^3)	Present MAR (with IFR) at estuary (Mm^3)	Present MAR as a % of Natural MAR
			Yield without IFR (Mm^3)	Yield with class B/C IFR (Mm^3)	Yield with IFR as a % of yield without IFR						
100	12.980	2.60	8.39	5.62	66.98	4.10	16.91	77.10	78.82	71.51	90.73
75	9.735		7.48	4.76	63.64					72.36	91.80
50	6.730		5.74	3.78	65.85					73.34	93.05

8.3 Results of the yield analysis for Zalu and Lusikisiki dams

The historic and stochastic yield analyses were done for three different gross full supply capacities and sediment deposits. Two hundred and one flow sequences with a length of 77 years each were used for the stochastic runs. The results are presented with risk yield curves shown in Appendix 15. From these curves different yields corresponding to various risks of failure, expressed as recurrence intervals, are obtained.

The results of the yield analysis are given in tables 8.6 and 8.7. The yields calculated for the different capacities include the IFR releases.

Table 8.6 Historic Firm and Stochastic Yields for Zalu Dam

Zalu Dam					
Sediment Volume = 1.07 Mm^3		**Sediment volume = 1.22** Mm^3		**Sediment volume = 1.38** Mm^3	
Gross FSC = 3.52 Mm^3		**Gross FSC = 4.08** Mm^3		**Gross FSC = 6.94** Mm^3	
HFY = 2.29 Mm^3/a		**HFY = 2.51** Mm^3/a		**HFY = 3.51** Mm^3/a	
Return Period (years)	Yield (Mm^3/a)	Return Period (years)	Yield (Mm^3/a)	Return Period (years)	Yield (Mm^3/a)
200	2.30	200	2.50	200	3.50
100	2.40	100	2.60	100	3.70
50	2.60	50	2.80	50	4.00
20	2.90	20	3.10	20	4.30

Table 8.7 Historic Firm and Stochastic Yields for Lusikisiki Dam

Lusikisiki Dam					
Sediment Volume = 1.19 Mm^3		**Sediment Volume = 1.31** Mm^3		**Sediment Volume = 1.43** Mm^3	
Gross FSC = 3.33 Mm^3		**Gross FSC = 3.85** Mm^3		**Gross FSC = 5.83** Mm^3	
HFY = 2.29 Mm^3/a		**HFY = 2.51** Mm^3/a		**HFY = 3.51** Mm^3/a	
Return Period (years)	Yield (Mm^3/a)	Return Period (years)	Yield (Mm^3/a)	Return Period (years)	Yield (Mm^3/a)
200	2.30	200	2.50	200	3.50
100	2.40	100	2.60	100	3.70
50	2.60	50	2.80	50	4.00
20	2.90	20	3.10	20	4.30

HFY: Historic Firm Yield
FSC: Full Supply Capacity

9. Summary

Yield analysis was done using the Yield programme, yield-capacity curves were plotted excluding IFR releases for the first five proposed dams and for the other two proposed dams, yield-capacity curves excluding and including IFR releases were plotted.

Further analysis, the WRYM system was set up for the five proposed dams, yields including and excluding IFR releases were calculated for all the dams. UWP Consulting Engineers supplied different siltation volumes and desired yields then associated live storages were calculated for all the dams.

The five proposed sites were thoroughly investigated and finally two sites were selected for a detailed study. Zalu and Lusikisiki were the most favorable among the five sites and then stochastic runs were performed and risk-yield curves plotted.

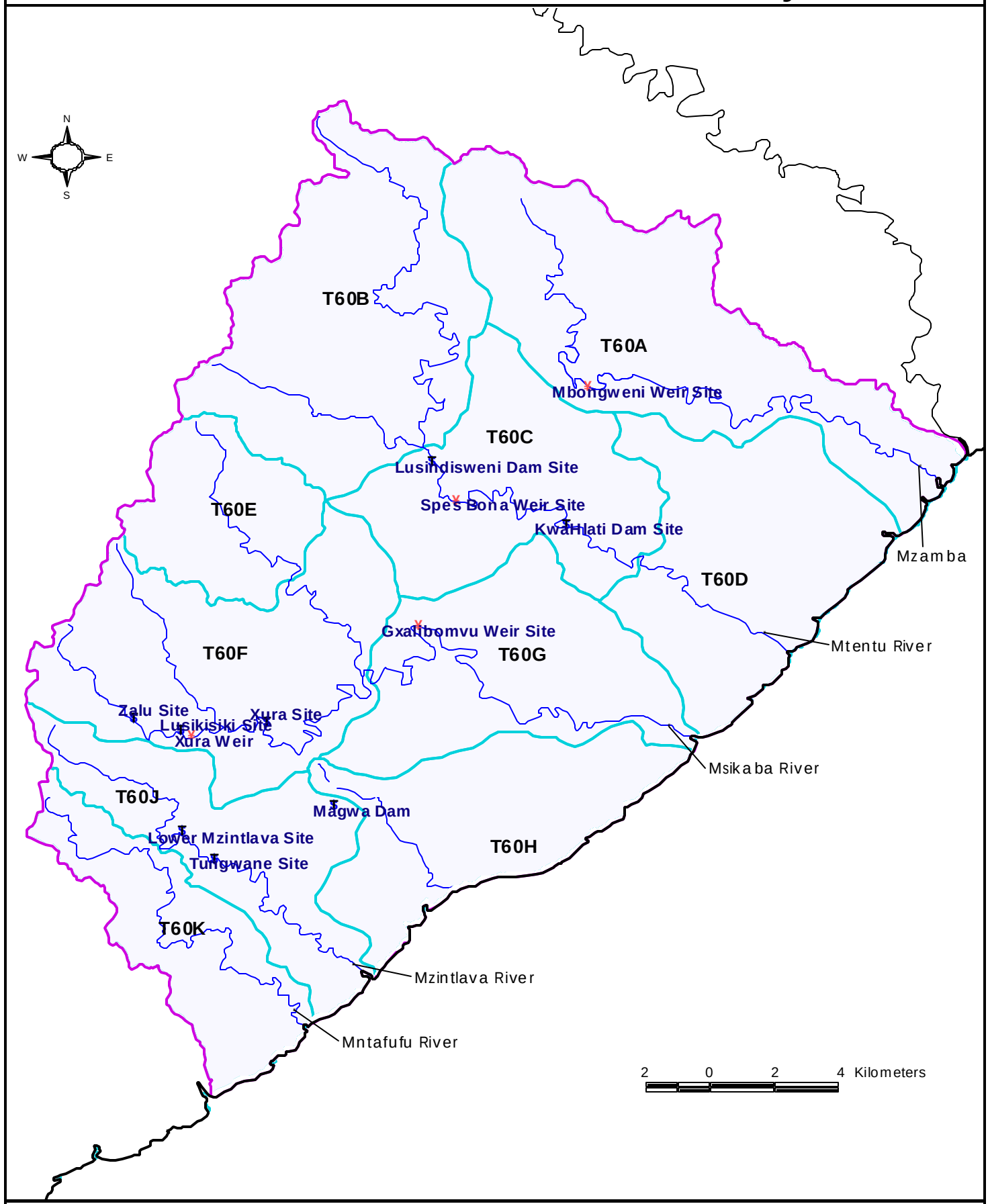
10. References

1. Eastern Pondoland Hydrology Report

APPENDICES

APPENDIX 1
Figure 1.
Map showing the position of proposed dams as well as quaternary catchmets

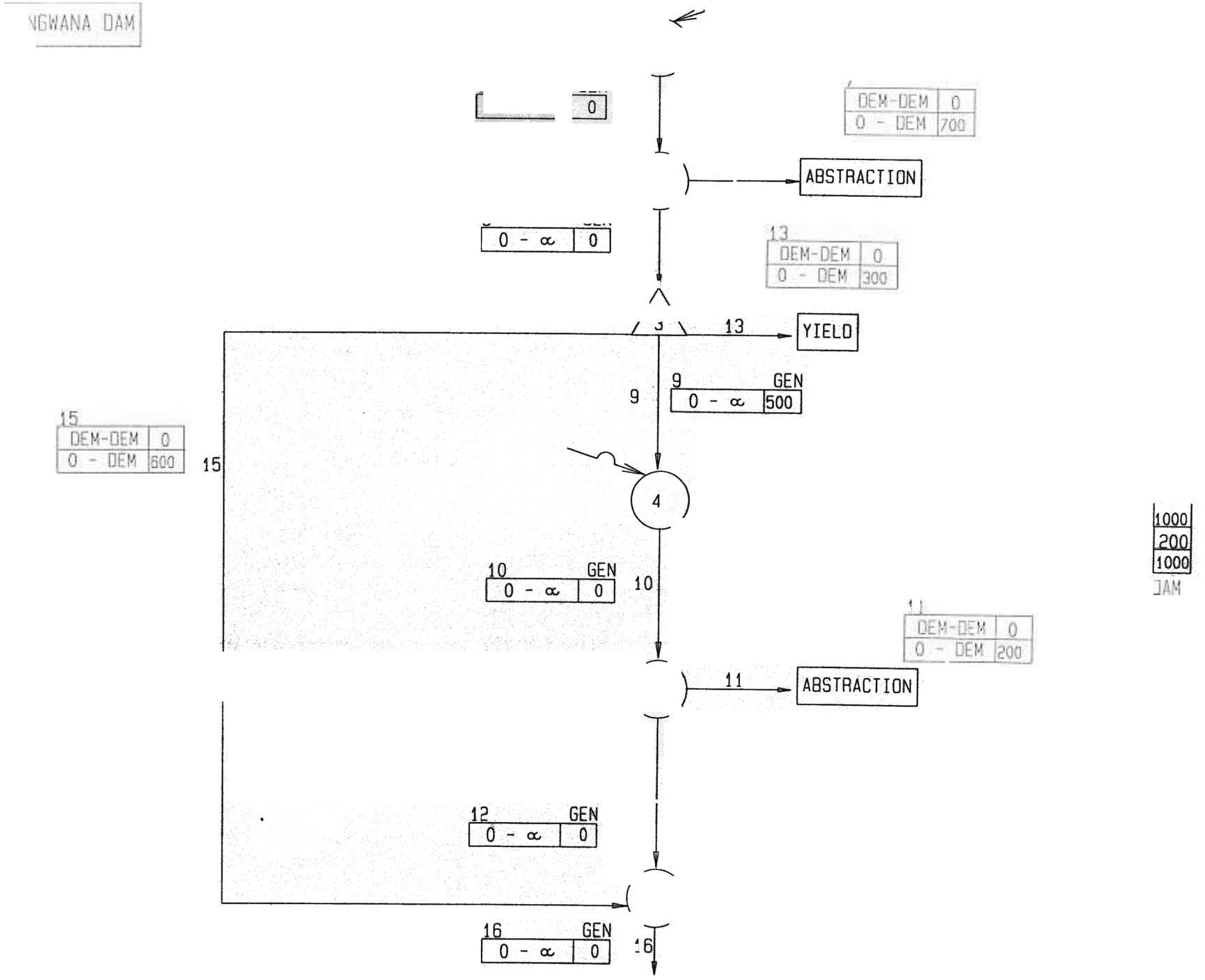
Eastern Pondoland Basin Study

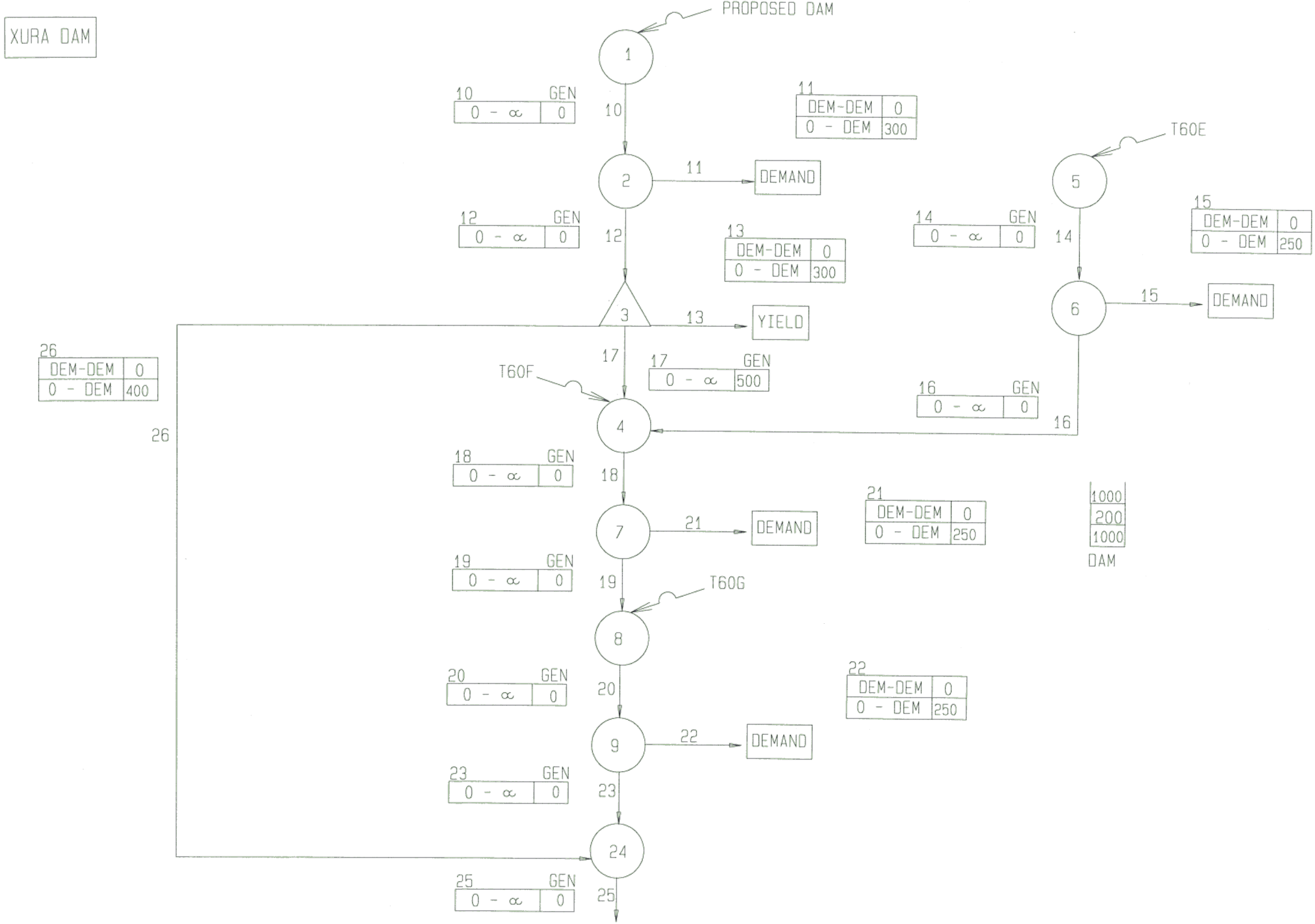


Dam and Weir Sites

(Mons) E:\Christo\Projects\catchanalysis.apr

APPENDIX 2
SCHEMATIC DIAGRAMS FOR WRYM


NGWANA DAM
0
DEM-DEM 0
0 - DEM 700
ABSTRACTION
0 - α 0
13
DEM-DEM 0
0 - DEM 300
3
13
YIELD
9
9 GEN
0 - α 500
15
DEM-DEM 0
0 - DEM 600
15
4
10 GEN
0 - α 0
10
1000
200
1000
JAM
11
DEM-DEM 0
0 - DEM 200
11
ABSTRACTION
12 GEN
0 - α 0
16 GEN
0 - α 0
16


XURA DAM
PROPOSED DAM
1
10
GEN
0 - ∝
0
11
DEM-DEM
0
0 - DEM
300
2
11
DEMAND
12
GEN
0 - ∝
0
13
DEM-DEM
0
0 - DEM
300
12
3
13
YIELD
26
DEM-DEM
0
0 - DEM
400
26
17
17
GEN
0 - ∝
500
T60F
4
16
GEN
0 - ∝
0
16
T60E
5
14
GEN
0 - ∝
0
14
15
DEM-DEM
0
0 - DEM
250
6
15
DEMAND
18
GEN
0 - ∝
0
18
7
21
DEMAND
21
DEM-DEM
0
0 - DEM
250
1000
200
1000
DAM
19
GEN
0 - ∝
0
19
T60G
8
20
GEN
0 - ∝
0
20
22
DEM-DEM
0
0 - DEM
250
9
22
DEMAND
23
GEN
0 - ∝
0
23
24
25
GEN
0 - ∝
0
25

APPENDIX 3
NATURAL FLOW SEQUENCES

APPENDIX 3.1
ZALU DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.16	0.34	0.67	0.61	0.53	0.67	0.64	0.42	0.21	0.12	0.08	0.13	4.58
1921	0.29	2.66	2.90	1.08	0.38	0.20	0.11	0.86	1.15	0.72	0.53	0.53	11.41
1922	2.36	5.92	2.11	4.83	6.66	3.43	0.90	0.26	0.16	3.20	1.48	0.34	31.65
1923	0.22	0.25	0.35	2.48	2.11	0.72	0.20	0.12	0.10	0.09	0.11	0.22	6.97
1924	0.37	0.53	1.04	0.70	0.51	2.89	1.40	0.45	0.26	0.19	0.15	0.24	8.73
1925	0.38	0.49	0.51	0.52	0.56	3.84	1.60	0.34	0.36	0.36	0.24	0.26	9.46
1926	0.49	1.57	1.08	0.57	0.38	5.63	2.17	0.23	0.12	0.09	0.09	0.14	12.56
1927	0.32	0.33	0.37	0.52	0.72	0.62	0.36	0.22	0.18	0.14	0.20	0.24	4.22
1928	0.29	0.45	0.50	0.45	0.37	0.49	0.44	0.29	2.28	1.75	0.88	2.30	10.49
1929	3.87	3.14	1.10	0.41	0.28	0.29	0.33	0.27	0.32	0.39	0.45	1.19	12.04
1930	0.85	0.53	0.44	2.83	2.74	4.25	1.61	0.33	0.17	12.45	4.59	0.44	31.23
1931	0.47	0.52	0.47	0.32	2.01	1.11	0.40	0.28	0.30	0.33	0.30	1.55	8.06
1932	1.44	7.38	5.67	1.36	0.29	0.35	0.31	0.20	0.14	0.12	0.10	0.10	17.46
1933	0.12	1.12	2.77	3.46	1.29	0.55	0.47	0.32	0.21	0.35	0.41	0.25	11.32
1934	0.19	0.39	1.96	1.00	0.34	0.37	1.58	2.93	4.97	1.87	0.64	0.54	16.78
1935	0.41	0.44	0.29	0.19	4.28	4.39	1.33	0.73	0.70	0.50	0.30	0.24	13.80
1936	0.51	10.02	3.68	0.36	1.10	1.52	0.75	0.29	0.16	0.15	0.17	0.18	18.89
1937	0.24	0.30	0.48	0.59	0.51	0.33	0.40	0.43	0.35	0.35	0.30	0.21	4.49
1938	0.20	0.38	0.56	0.62	1.93	1.05	0.47	0.40	0.35	0.36	0.43	3.47	10.22
1939	2.11	0.79	0.60	0.44	0.28	0.30	0.28	0.41	0.47	0.34	0.23	0.20	6.45
1940	0.21	0.48	0.61	0.43	0.23	0.17	0.17	0.13	0.11	0.12	0.13	0.15	2.94
1941	0.26	0.45	0.40	3.34	1.43	0.44	0.36	0.32	0.27	0.18	0.18	0.26	7.89
1942	0.40	6.71	4.82	1.27	0.39	0.50	2.02	1.04	0.44	0.35	0.53	0.65	19.12
1943	0.71	2.89	1.83	0.69	0.58	0.54	0.36	0.22	0.17	0.19	0.17	1.73	10.08
1944	1.18	0.63	0.33	0.32	0.49	0.60	0.46	0.28	0.20	0.16	0.13	0.17	4.95
1945	3.49	1.50	0.28	0.21	0.37	1.43	0.90	0.42	0.24	0.18	0.13	0.14	9.29
1946	0.22	0.57	0.63	0.50	0.46	1.31	2.13	1.02	1.24	0.87	0.44	0.31	9.70
1947	0.31	8.63	3.44	0.59	1.31	0.94	0.63	0.39	0.20	0.11	0.08	0.08	16.71
1948	0.38	0.62	0.57	0.44	4.25	2.01	0.70	0.45	0.23	0.14	0.13	0.16	10.08
1949	0.30	2.39	1.20	0.62	0.66	0.59	0.53	0.57	0.46	0.34	0.41	0.41	8.48
1950	0.45	0.41	2.42	1.28	0.52	0.50	0.42	0.25	0.17	0.15	0.17	0.26	7.00
1951	1.32	0.75	0.86	0.79	0.61	0.54	0.55	0.44	0.27	0.17	0.12	0.18	6.60
1952	0.26	0.29	0.29	0.27	0.32	0.34	0.32	0.24	0.15	0.11	0.12	0.29	3.00
1953	0.57	3.41	2.31	0.79	0.38	0.41	0.35	0.30	0.34	0.32	0.23	0.27	9.68
1954	6.09	2.52	0.49	1.75	3.03	1.37	0.56	0.34	0.22	0.16	0.11	0.20	16.84
1955	0.37	0.50	0.37	0.16	0.25	3.45	1.64	0.52	0.36	0.28	0.20	0.24	8.34
1956	0.53	5.84	9.37	3.03	0.68	2.16	2.59	1.02	0.37	0.27	0.24	0.37	26.47
1957	0.64	0.98	0.82	1.55	3.24	1.41	1.55	0.81	0.26	0.17	0.15	0.15	11.73
1958	0.21	0.49	0.66	0.44	0.35	0.38	0.38	6.07	2.42	0.49	0.55	0.54	12.98
1959	0.52	0.53	0.50	0.43	0.34	0.42	0.52	0.54	0.40	0.27	0.24	0.32	5.03
1960	0.38	0.54	1.88	1.10	0.57	0.53	5.27	2.21	0.47	0.39	0.35	0.28	13.97
1961	0.28	1.24	0.89	0.55	0.50	1.46	0.81	0.34	0.22	0.14	0.18	0.24	6.85
1962	0.45	2.67	1.29	2.73	1.25	7.76	2.97	0.42	0.29	1.98	1.07	0.36	23.24
1963	0.42	1.08	0.82	3.28	1.82	0.81	1.44	0.80	5.74	2.37	0.44	0.34	19.36
1964	1.58	0.89	0.35	0.30	0.28	0.18	0.11	0.14	3.17	1.65	0.78	0.72	10.15
1965	5.08	3.62	1.08	0.45	0.35	0.20	0.12	1.51	0.94	0.39	0.26	0.31	14.31
1966	0.34	0.34	0.37	0.52	0.58	4.78	3.59	1.05	0.36	0.49	0.52	0.32	13.26
1967	0.24	0.41	0.43	0.32	0.31	0.30	0.26	0.18	0.11	0.10	0.16	0.38	3.20
1968	0.58	0.87	0.72	0.40	0.60	2.95	1.31	1.98	1.06	0.42	0.30	0.26	11.45
1969	0.35	0.59	0.62	0.38	0.27	0.21	0.14	0.15	0.24	0.27	1.58	1.10	5.90
1970	5.53	3.04	0.87	0.50	0.46	0.42	0.40	2.61	1.25	0.59	1.90	1.10	18.67
1971	4.72	2.07	0.63	0.49	3.52	1.53	0.37	0.22	0.17	0.17	0.16	0.15	14.20
1972	0.15	0.43	0.64	0.53	0.39	0.37	0.50	0.42	0.22	0.13	0.18	0.39	4.35
1973	0.56	2.66	1.26	0.43	0.47	0.60	0.52	2.66	1.40	0.56	0.33	0.22	11.67
1974	0.22	0.39	0.59	0.53	0.42	0.39	0.34	0.24	0.16	0.13	0.13	2.40	5.94
1975	1.25	0.50	1.78	0.98	3.03	12.08	4.28	1.18	0.74	0.36	0.23	0.33	26.74
1976	8.30	3.18	0.40	0.35	1.10	0.77	0.39	0.20	0.15	0.16	0.22	0.36	15.58
1977	0.56	3.24	3.55	1.26	0.43	0.38	17.22	6.36	0.63	0.38	0.28	0.31	34.60
1978	1.79	1.21	0.62	0.38	0.30	0.43	0.43	0.28	0.18	0.31	0.48	0.51	6.92
1979	0.61	0.58	0.46	0.32	0.29	0.29	0.22	0.17	0.15	0.13	0.11	0.83	4.16
1980	0.77	2.23	1.20	0.66	0.57	0.39	0.21	0.30	0.36	0.27	0.32	0.36	7.64
1981	0.29	0.30	0.29	0.33	0.31	3.74	1.76	0.52	0.31	0.23	0.17	0.15	8.40
1982	0.30	0.38	0.26	0.17	0.16	0.14	0.12	0.10	0.08	2.19	1.20	0.49	5.59
1983	0.48	1.05	0.80	0.74	0.66	0.52	0.51	0.46	0.40	0.60	0.63	0.47	7.32
1984	0.42	1.96	1.10	0.53	7.79	2.96	0.34	0.17	0.12	0.11	0.09	0.08	15.67
1985	0.34	2.23	1.15	1.02	0.62	0.35	0.30	0.21	0.14	0.10	0.24	0.55	7.25
1986	2.25	1.28	0.56	0.44	0.30	0.33	0.35	0.25	0.19	0.15	0.20	12.06	18.36
1987	4.61	2.33	1.16	0.44	2.41	8.95	3.21	1.01	0.77	0.68	0.74	0.61	26.92
1988	0.55	2.69	5.43	1.82	3.70	1.69	1.54	0.85	0.39	0.31	0.21	0.18	19.36
1989	1.43	5.04	1.86	0.39	0.29	1.15	0.70	0.27	0.15	0.10	0.23	0.34	11.95
1990	0.47	0.48	0.36	0.39	0.59	0.54	0.30	0.17	0.14	0.12	0.13	0.22	3.91
1991	1.13	2.70	1.16	0.41	0.30	0.22	0.22	0.19	0.13	0.10	0.10	0.18	6.84
1992	0.32	0.40	0.43	0.38	0.28	0.17	0.13	0.11	0.09	0.07	0.09	0.25	2.72
1993	0.54	0.70	2.21	1.01	4.83	2.06	0.40	0.18	0.10	0.13	0.27	0.28	12.71
1994	0.23	0.21	0.50	0.54	0.33	1.61	3.89	1.56	0.63	0.61	0.37	0.27	10.75
1995	0.37	0.45	6.11	2.51	1.28	0.71	0.32	0.22	0.16	0.39	0.53	0.39	13.44
1996	0.49	6.78	2.68	0.60	1.83	1.02	3.02	1.37	8.53	3.45	0.65	0.51	30.93
month	82.09	138.90	106.26	70.42	90.35	115.50	90.90	56.21	51.82	49.63	31.97	47.95	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.12	0.21	0.26	0.16	0.16	0.14	0.11	0.10	0.08	0.07	0.08	0.08	2.72
max	8.30	10.02	9.37	4.83	7.79	12.08	17.22	6.36	8.53	12.45	4.59	12.06	34.60
median	0.45	0.79	0.72	0.53	0.52	0.60	0.47	0.34	0.26	0.27	0.24	0.31	10.22
mean	1.07	1.80	1.38	0.91	1.17	1.50	1.18	0.73	0.67	0.64	0.42	0.62	12.10
Sum of the monthly means = 12.10													
s.d.	1.57	2.09	1.59	0.92	1.48	2.09	2.14	1.09	1.32	1.52	0.59	1.43	7.36
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.95	2.36	1.43	2.30	0.61

APPENDIX 3.2
XURA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.52	1.06	2.14	1.93	1.67	2.13	2.03	1.32	0.67	0.39	0.26	0.41	14.53
1921	0.91	8.42	9.19	3.44	1.19	0.63	0.34	2.74	3.63	2.27	1.68	1.69	36.13
1922	7.47	18.77	6.70	15.30	21.10	10.87	2.84	0.82	0.50	10.13	4.69	1.07	100.26
1923	0.70	0.79	1.10	7.87	6.69	2.29	0.65	0.37	0.33	0.30	0.35	0.68	22.12
1924	1.16	1.69	3.28	2.21	1.63	9.16	4.43	1.44	0.83	0.59	0.46	0.75	27.63
1925	1.20	1.55	1.62	1.66	1.78	12.17	5.07	1.07	1.14	1.14	0.76	0.82	29.98
1926	1.54	4.98	3.42	1.81	1.20	17.85	6.88	0.74	0.38	0.27	0.27	0.44	39.78
1927	1.01	1.03	1.18	1.65	2.29	1.95	1.14	0.69	0.56	0.45	0.63	0.76	13.34
1928	0.92	1.43	1.58	1.44	1.16	1.54	1.39	0.92	7.22	5.55	2.77	7.29	33.21
1929	12.26	9.96	3.50	1.31	0.89	0.93	1.06	0.86	1.01	1.23	1.42	3.78	38.21
1930	2.69	1.68	1.40	8.98	8.69	13.47	5.11	1.05	0.53	39.45	14.56	1.38	98.99
1931	1.48	1.66	1.47	1.01	6.37	3.53	1.26	0.89	0.94	1.05	0.94	4.90	25.50
1932	4.56	23.37	17.97	4.30	0.91	1.12	0.97	0.65	0.46	0.37	0.32	0.33	55.33
1933	0.40	3.56	8.78	10.96	4.09	1.73	1.48	1.01	0.65	1.11	1.30	0.81	35.88
1934	0.62	1.23	6.20	3.18	1.09	1.16	5.01	9.29	15.77	5.94	2.01	1.72	53.22
1935	1.31	1.38	0.92	0.59	13.55	13.90	4.21	2.32	2.22	1.59	0.96	0.76	43.71
1936	1.63	31.75	11.65	1.13	3.48	4.81	2.37	0.91	0.50	0.47	0.54	0.57	59.81
1937	0.75	0.94	1.53	1.86	1.63	1.06	1.28	1.37	1.11	1.10	0.96	0.65	14.24
1938	0.62	1.20	1.79	1.96	6.10	3.34	1.49	1.27	1.10	1.14	1.36	11.01	32.38
1939	6.67	2.50	1.90	1.39	0.90	0.94	0.88	1.28	1.48	1.07	0.72	0.62	20.35
1940	0.67	1.52	1.94	1.37	0.72	0.52	0.53	0.43	0.36	0.38	0.41	0.47	9.32
1941	0.83	1.41	1.26	10.59	4.55	1.40	1.13	1.01	0.87	0.57	0.57	0.82	25.01
1942	1.27	21.28	15.26	4.03	1.23	1.59	6.42	3.30	1.39	1.11	1.67	2.06	60.61
1943	2.24	9.15	5.80	2.19	1.84	1.71	1.15	0.71	0.55	0.60	0.54	5.49	31.97
1944	3.74	1.98	1.05	1.02	1.55	1.90	1.45	0.90	0.63	0.51	0.40	0.54	15.67
1945	11.07	4.74	0.89	0.67	1.17	4.53	2.87	1.34	0.77	0.56	0.42	0.43	29.46
1946	0.69	1.81	2.00	1.58	1.46	4.16	6.74	3.24	3.94	2.74	1.39	0.98	30.73
1947	0.99	27.36	10.90	1.88	4.14	2.99	2.00	1.24	0.62	0.36	0.26	0.24	52.98
1948	1.19	1.97	1.81	1.40	13.48	6.37	2.21	1.42	0.72	0.44	0.40	0.52	31.93
1949	0.94	7.57	3.81	1.95	2.09	1.87	1.69	1.79	1.45	1.08	1.29	1.30	26.83
1950	1.41	1.30	7.68	4.06	1.64	1.59	1.32	0.80	0.55	0.46	0.54	0.82	22.17
1951	4.18	2.39	2.72	2.51	1.94	1.72	1.75	1.41	0.87	0.55	0.37	0.56	20.97
1952	0.82	0.92	0.91	0.86	1.00	1.08	1.00	0.76	0.49	0.34	0.38	0.91	9.47
1953	1.81	10.81	7.32	2.49	1.21	1.31	1.11	0.94	1.07	1.01	0.71	0.87	30.66
1954	19.30	7.98	1.56	5.55	9.60	4.35	1.78	1.07	0.70	0.52	0.35	0.62	53.38
1955	1.16	1.58	1.17	0.49	0.80	10.92	5.21	1.65	1.14	0.87	0.62	0.77	26.38
1956	1.67	18.51	29.69	9.61	2.14	6.85	8.21	3.23	1.17	0.87	0.75	1.18	83.88
1957	2.01	3.11	2.60	4.91	10.27	4.46	4.93	2.57	0.83	0.54	0.47	0.49	37.19
1958	0.66	1.55	2.08	1.40	1.11	1.21	1.21	19.23	7.67	1.54	1.74	1.73	41.13
1959	1.64	1.67	1.59	1.36	1.08	1.33	1.66	1.71	1.28	0.85	0.76	1.02	15.95
1960	1.19	1.72	5.94	3.48	1.80	1.69	16.70	6.99	1.48	1.23	1.11	0.90	44.23
1961	0.90	3.93	2.83	1.74	1.60	4.64	2.55	1.07	0.69	0.43	0.56	0.76	21.70
1962	1.42	8.46	4.07	8.66	3.97	24.60	9.42	1.32	0.91	6.28	3.41	1.13	73.65
1963	1.35	3.41	2.60	10.40	5.76	2.55	4.57	2.52	18.18	7.52	1.39	1.07	61.32
1964	5.01	2.83	1.12	0.96	0.89	0.57	0.33	0.44	10.04	5.23	2.46	2.29	32.17
1965	16.10	11.46	3.42	1.43	1.12	0.65	0.37	4.79	2.99	1.24	0.83	0.97	45.37
1966	1.08	1.06	1.18	1.66	1.85	15.15	11.39	3.32	1.14	1.56	1.65	1.03	42.07
1967	0.76	1.30	1.37	1.02	0.97	0.95	0.82	0.57	0.36	0.30	0.50	1.20	10.12
1968	1.85	2.77	2.27	1.27	1.89	9.34	4.15	6.26	3.35	1.32	0.94	0.82	36.23
1969	1.12	1.88	1.95	1.20	0.86	0.66	0.46	0.46	0.75	0.85	5.00	3.48	18.67
1970	17.51	9.62	2.74	1.58	1.46	1.34	1.28	8.26	3.97	1.86	6.01	3.47	59.10
1971	14.95	6.54	2.01	1.57	11.14	4.85	1.17	0.71	0.55	0.54	0.52	0.46	45.01
1972	0.46	1.37	2.03	1.67	1.23	1.16	1.58	1.34	0.70	0.41	0.59	1.22	13.76
1973	1.78	8.43	3.98	1.37	1.50	1.90	1.66	8.44	4.44	1.78	1.05	0.69	37.02
1974	0.71	1.23	1.87	1.69	1.34	1.23	1.06	0.77	0.51	0.40	0.41	7.62	18.84
1975	3.96	1.60	5.66	3.10	9.59	38.28	13.56	3.74	2.34	1.13	0.74	1.05	84.75
1976	26.31	10.06	1.25	1.12	3.47	2.44	1.23	0.63	0.47	0.49	0.70	1.14	49.31
1977	1.79	10.25	11.25	3.99	1.38	1.21	54.57	20.15	2.00	1.22	0.88	0.99	109.68
1978	5.67	3.82	1.96	1.22	0.94	1.37	1.36	0.88	0.56	0.97	1.51	1.62	21.88
1979	1.93	1.85	1.46	1.01	0.91	0.91	0.69	0.55	0.46	0.40	0.36	2.64	13.17
1980	2.44	7.07	3.80	2.09	1.81	1.22	0.67	0.94	1.15	0.85	1.02	1.15	24.21
1981	0.91	0.94	0.93	1.05	1.00	11.85	5.57	1.65	1.00	0.72	0.53	0.47	26.62
1982	0.94	1.20	0.81	0.55	0.52	0.44	0.37	0.32	0.26	6.95	3.81	1.54	17.71
1983	1.53	3.34	2.53	2.35	2.09	1.66	1.62	1.45	1.26	1.90	1.99	1.48	23.20
1984	1.33	6.22	3.48	1.67	24.67	9.37	1.06	0.55	0.37	0.34	0.28	0.25	49.59
1985	1.08	7.06	3.64	3.23	1.97	1.12	0.94	0.67	0.44	0.32	0.75	1.73	22.95
1986	7.12	4.05	1.77	1.39	0.95	1.06	1.12	0.79	0.59	0.48	0.63	38.21	58.16
1987	14.61	7.37	3.68	1.38	7.63	28.38	10.16	3.19	2.44	2.14	2.36	1.93	85.27
1988	1.73	8.51	17.20	5.78	11.74	5.35	4.88	2.70	1.23	0.97	0.67	0.58	61.34
1989	4.54	15.96	5.91	1.23	0.93	3.63	2.22	0.85	0.46	0.33	0.71	1.09	37.86
1990	1.51	1.53	1.13	1.25	1.86	1.72	0.96	0.55	0.44	0.37	0.40	0.71	12.43
1991	3.59	8.57	3.68	1.29	0.95	0.70	0.71	0.60	0.41	0.30	0.33	0.58	21.71
1992	1.01	1.26	1.37	1.19	0.88	0.55	0.40	0.35	0.28	0.24	0.28	0.79	8.60
1993	1.73	2.22	7.00	3.19	15.30	6.54	1.28	0.56	0.31	0.41	0.87	0.90	40.31
1994	0.74	0.65	1.58	1.70	1.05	5.09	12.34	4.94	2.01	1.94	1.18	0.84	34.06
1995	1.17	1.44	19.36	7.96	4.05	2.24	1.02	0.71	0.49	1.23	1.67	1.24	42.58
1996	1.54	21.47	8.49	1.89	5.80	3.25	9.56	4.36	27.05	10.94	2.05	1.60	98.00
month	260.08	440.01	336.68	223.23	286.30	366.10	288.06	178.15	164.18	157.10	101.15	151.90	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.40	0.65	0.81	0.49	0.52	0.44	0.33	0.32	0.26	0.24	0.26	0.24	8.60
max	26.31	31.75	29.69	15.30	24.67	38.28	54.57	20.15	27.05	39.45	14.56	38.21	109.68
median	1.42	2.50	2.27	1.67	1.64	1.90	1.49	1.07	0.83	0.87	0.75	0.97	32.38
mean	3.38	5.71	4.37	2.90	3.72	4.75	3.74	2.31	2.13	2.04	1.31	1.97	38.35
Sum of the monthly means =				38.35									
s.d.	4.97	6.63	5.04	2.93	4.70	6.61	6.78	3.44	4.17	4.82	1.88	4.54	23.32
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.96	2.36	1.43	2.30	0.61

APPENDIX 3.3
LUSIKISIKI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.21	0.43	0.86	0.78	0.68	0.86	0.82	0.53	0.27	0.16	0.11	0.16	5.87
1921	0.37	3.41	3.72	1.39	0.48	0.26	0.14	1.11	1.47	0.92	0.68	0.68	14.63
1922	3.02	7.59	2.71	6.19	8.53	4.39	1.15	0.33	0.20	4.10	1.90	0.43	40.54
1923	0.28	0.32	0.44	3.18	2.70	0.93	0.26	0.15	0.13	0.12	0.14	0.28	8.93
1924	0.47	0.69	1.33	0.89	0.66	3.70	1.79	0.58	0.34	0.24	0.19	0.30	11.18
1925	0.49	0.63	0.66	0.67	0.72	4.92	2.05	0.43	0.46	0.46	0.31	0.33	12.13
1926	0.62	2.02	1.38	0.73	0.48	7.22	2.78	0.30	0.15	0.11	0.11	0.18	16.08
1927	0.41	0.42	0.48	0.67	0.93	0.79	0.46	0.28	0.23	0.18	0.26	0.31	5.42
1928	0.37	0.58	0.64	0.58	0.47	0.62	0.56	0.37	2.92	2.24	1.12	2.95	13.42
1929	4.96	4.03	1.42	0.53	0.36	0.37	0.43	0.35	0.41	0.50	0.57	1.53	15.46
1930	1.09	0.68	0.56	3.63	3.51	5.45	2.07	0.42	0.21	15.95	5.89	0.56	40.02
1931	0.60	0.67	0.60	0.41	2.57	1.43	0.51	0.36	0.38	0.42	0.38	1.98	10.31
1932	1.84	9.45	7.27	1.74	0.37	0.45	0.39	0.26	0.19	0.15	0.13	0.13	22.37
1933	0.16	1.44	3.55	4.43	1.66	0.70	0.60	0.41	0.26	0.45	0.53	0.33	14.52
1934	0.25	0.50	2.51	1.29	0.44	0.47	2.03	3.76	6.38	2.40	0.81	0.69	21.53
1935	0.53	0.56	0.37	0.24	5.48	5.62	1.70	0.94	0.90	0.64	0.39	0.31	17.68
1936	0.66	12.84	4.71	0.46	1.41	1.94	0.96	0.37	0.20	0.19	0.22	0.23	24.19
1937	0.30	0.38	0.62	0.75	0.66	0.43	0.52	0.55	0.45	0.44	0.39	0.26	5.75
1938	0.25	0.48	0.72	0.79	2.47	1.35	0.60	0.51	0.44	0.46	0.55	4.45	13.07
1939	2.70	1.01	0.77	0.56	0.36	0.38	0.36	0.52	0.60	0.43	0.29	0.25	8.23
1940	0.27	0.61	0.79	0.56	0.29	0.21	0.21	0.17	0.15	0.16	0.16	0.19	3.77
1941	0.33	0.57	0.51	4.28	1.84	0.56	0.46	0.41	0.35	0.23	0.23	0.33	10.10
1942	0.51	8.61	6.17	1.63	0.50	0.64	2.60	1.34	0.56	0.45	0.68	0.83	24.52
1943	0.91	3.70	2.35	0.88	0.74	0.69	0.47	0.29	0.22	0.24	0.22	2.22	12.93
1944	1.51	0.80	0.42	0.41	0.63	0.77	0.58	0.36	0.26	0.21	0.16	0.22	6.33
1945	4.48	1.92	0.36	0.27	0.47	1.83	1.16	0.54	0.31	0.23	0.17	0.17	11.91
1946	0.28	0.73	0.81	0.64	0.59	1.68	2.73	1.31	1.59	1.11	0.56	0.40	12.43
1947	0.40	11.07	4.41	0.76	1.68	1.21	0.81	0.50	0.25	0.15	0.11	0.10	21.45
1948	0.48	0.80	0.73	0.57	5.45	2.58	0.89	0.57	0.29	0.18	0.16	0.21	12.91
1949	0.38	3.06	1.54	0.79	0.84	0.76	0.69	0.73	0.59	0.44	0.52	0.52	10.86
1950	0.57	0.52	3.10	1.64	0.67	0.64	0.53	0.32	0.22	0.19	0.22	0.33	8.95
1951	1.69	0.97	1.10	1.01	0.79	0.69	0.71	0.57	0.35	0.22	0.15	0.23	8.48
1952	0.33	0.37	0.37	0.35	0.41	0.43	0.41	0.31	0.20	0.14	0.15	0.37	3.84
1953	0.73	4.37	2.96	1.01	0.49	0.53	0.45	0.38	0.43	0.41	0.29	0.35	12.40
1954	7.81	3.23	0.63	2.25	3.88	1.76	0.72	0.43	0.28	0.21	0.14	0.25	21.59
1955	0.47	0.64	0.47	0.20	0.32	4.42	2.11	0.67	0.46	0.35	0.25	0.31	10.67
1956	0.68	7.49	12.01	3.89	0.87	2.77	3.32	1.31	0.47	0.35	0.31	0.48	33.95
1957	0.81	1.26	1.05	1.99	4.15	1.81	1.99	1.04	0.34	0.22	0.19	0.20	15.05
1958	0.27	0.63	0.84	0.57	0.45	0.49	0.49	7.78	3.10	0.62	0.70	0.70	16.64
1959	0.66	0.68	0.64	0.55	0.44	0.54	0.67	0.69	0.52	0.34	0.31	0.41	6.45
1960	0.48	0.70	2.40	1.41	0.73	0.68	6.76	2.83	0.60	0.50	0.45	0.36	17.90
1961	0.36	1.59	1.15	0.70	0.65	1.87	1.03	0.43	0.28	0.17	0.22	0.31	8.76
1962	0.58	3.42	1.65	3.50	1.61	9.95	3.81	0.53	0.37	2.54	1.38	0.46	29.80
1963	0.54	1.38	1.05	4.20	2.33	1.03	1.85	1.02	7.35	3.04	0.56	0.43	24.78
1964	2.03	1.15	0.45	0.39	0.36	0.23	0.14	0.18	4.06	2.12	0.99	0.93	13.03
1965	6.51	4.64	1.38	0.58	0.45	0.26	0.15	1.94	1.21	0.50	0.34	0.39	18.35
1966	0.44	0.43	0.48	0.67	0.75	6.13	4.61	1.34	0.46	0.63	0.67	0.42	17.03
1967	0.31	0.53	0.56	0.41	0.39	0.38	0.33	0.23	0.15	0.12	0.20	0.49	4.10
1968	0.75	1.12	0.92	0.51	0.76	3.78	1.68	2.53	1.35	0.53	0.38	0.33	14.64
1969	0.45	0.76	0.79	0.49	0.35	0.27	0.19	0.19	0.30	0.34	2.02	1.41	7.56
1970	7.08	3.89	1.11	0.64	0.59	0.54	0.52	3.34	1.61	0.75	2.43	1.40	23.90
1971	6.05	2.65	0.81	0.63	4.51	1.96	0.47	0.29	0.22	0.22	0.21	0.19	18.21
1972	0.19	0.56	0.82	0.67	0.50	0.47	0.64	0.54	0.28	0.17	0.24	0.49	5.57
1973	0.72	3.41	1.61	0.55	0.61	0.77	0.67	3.41	1.79	0.72	0.42	0.28	14.96
1974	0.29	0.50	0.76	0.68	0.54	0.50	0.43	0.31	0.21	0.16	0.17	3.08	7.63
1975	1.60	0.65	2.29	1.25	3.88	15.48	5.48	1.51	0.94	0.46	0.30	0.42	34.26
1976	10.64	4.07	0.51	0.45	1.41	0.99	0.50	0.26	0.19	0.20	0.28	0.46	19.96
1977	0.72	4.15	4.55	1.62	0.56	0.49	22.07	8.15	0.81	0.49	0.36	0.40	44.37
1978	2.29	1.55	0.79	0.49	0.38	0.56	0.55	0.36	0.22	0.39	0.61	0.66	8.85
1979	0.78	0.75	0.59	0.41	0.37	0.37	0.28	0.22	0.19	0.16	0.15	1.07	5.34
1980	0.99	2.86	1.54	0.85	0.73	0.49	0.27	0.38	0.47	0.34	0.41	0.47	9.80
1981	0.37	0.38	0.37	0.42	0.40	4.79	2.25	0.67	0.40	0.29	0.21	0.19	10.74
1982	0.38	0.49	0.33	0.22	0.21	0.18	0.15	0.13	0.11	2.81	1.54	0.62	7.17
1983	0.62	1.35	1.02	0.95	0.84	0.67	0.66	0.59	0.51	0.77	0.80	0.60	9.38
1984	0.54	2.52	1.41	0.68	9.98	3.79	0.43	0.22	0.15	0.14	0.11	0.10	20.07
1985	0.44	2.86	1.47	1.31	0.80	0.45	0.38	0.27	0.18	0.13	0.30	0.70	9.29
1986	2.88	1.64	0.72	0.56	0.38	0.43	0.45	0.32	0.24	0.20	0.25	15.45	23.52
1987	5.91	2.98	1.49	0.56	3.08	11.48	4.11	1.29	0.99	0.87	0.95	0.78	34.49
1988	0.70	3.44	6.96	2.34	4.75	2.16	1.98	1.09	0.50	0.39	0.27	0.24	24.82
1989	1.83	6.45	2.39	0.50	0.38	1.47	0.90	0.34	0.19	0.13	0.29	0.44	15.31
1990	0.61	0.62	0.46	0.51	0.75	0.70	0.39	0.22	0.18	0.15	0.16	0.29	5.04
1991	1.45	3.46	1.49	0.52	0.38	0.28	0.29	0.24	0.16	0.12	0.13	0.23	8.75
1992	0.41	0.51	0.55	0.48	0.36	0.22	0.16	0.14	0.12	0.10	0.11	0.32	3.48
1993	0.70	0.90	2.83	1.29	6.19	2.65	0.52	0.22	0.13	0.17	0.35	0.36	16.31
1994	0.30	0.26	0.64	0.69	0.43	2.06	4.99	2.00	0.81	0.78	0.48	0.34	13.78
1995	0.47	0.58	7.83	3.22	1.64	0.91	0.41	0.29	0.20	0.50	0.68	0.50	17.23
1996	0.62	8.69	3.43	0.77	2.34	1.31	3.87	1.76	10.94	4.43	0.83	0.65	39.64
month	105.18	178.05	136.18	90.28	115.81	148.04	116.55	72.03	66.40	63.54	40.90	61.42	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.16	0.26	0.33	0.20	0.21	0.18	0.14	0.13	0.11	0.10	0.11	0.10	3.48
max	10.64	12.84	12.01	6.19	9.98	15.48	22.07	8.15	10.94	15.95	5.89	15.45	44.37
median	0.58	1.01	0.92	0.68	0.67	0.77	0.60	0.43	0.34	0.35	0.30	0.39	13.07
mean	1.37	2.31	1.77	1.17	1.50	1.92	1.51	0.94	0.86	0.83	0.53	0.80	15.51
Sum of the monthly means = 15.51													
s.d.	2.01	2.68	2.04	1.18	1.90	2.68	2.74	1.39	1.69	1.95	0.76	1.84	9.43
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.96	2.36	1.43	2.30	0.61

APPENDIX 3.4
TUNGWANE DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.28	0.52	0.92	0.94	0.94	2.46	1.69	0.95	0.56	0.34	0.23	0.30	10.13
1921	0.56	3.99	4.18	1.66	0.67	0.40	0.26	3.89	4.16	1.80	1.10	1.10	23.77
1922	4.26	9.67	3.39	8.46	12.85	7.76	2.11	0.59	0.41	8.17	3.52	0.66	61.85
1923	0.39	0.38	0.49	3.91	4.20	1.55	0.45	0.31	0.30	0.27	0.30	0.50	13.05
1924	0.72	0.88	1.08	0.97	0.94	6.74	3.15	1.04	0.69	0.51	0.39	0.55	17.66
1925	0.75	0.81	0.75	0.80	0.97	8.48	3.49	0.78	0.92	0.94	0.63	0.61	19.93
1926	0.95	1.84	1.44	0.92	0.67	11.97	4.59	0.53	0.32	0.24	0.23	0.33	24.03
1927	0.62	0.54	0.55	0.81	1.48	1.27	0.79	0.55	0.50	0.40	0.52	0.57	8.60
1928	0.58	0.74	0.74	0.68	0.61	1.16	0.99	0.69	6.72	4.95	1.97	4.76	24.59
1929	6.74	4.36	1.51	0.65	0.47	0.60	0.77	0.70	0.86	1.04	1.14	3.56	22.40
1930	1.91	0.80	0.61	4.42	5.36	9.32	3.49	0.75	0.44	25.92	9.49	0.84	63.35
1931	0.83	0.82	0.66	0.45	3.92	2.22	0.88	0.71	0.81	0.89	0.78	4.20	17.17
1932	2.50	12.24	9.21	2.18	0.52	0.74	0.71	0.53	0.42	0.34	0.28	0.26	29.93
1933	0.26	1.43	4.03	5.95	2.35	1.13	1.07	0.81	0.58	0.92	1.05	0.62	20.20
1934	0.40	0.64	2.41	1.41	0.61	0.76	4.93	7.82	11.24	4.01	1.33	1.12	36.68
1935	0.78	0.69	0.40	0.26	8.29	9.50	2.94	3.45	2.10	1.10	0.70	0.53	30.74
1936	0.96	17.12	6.23	0.56	2.32	4.04	1.83	0.65	0.42	0.40	0.45	0.43	35.41
1937	0.47	0.48	0.73	0.91	0.88	0.65	0.92	1.08	0.95	0.94	0.80	0.51	9.32
1938	0.40	0.63	0.85	0.96	3.72	2.10	1.04	1.00	0.94	0.97	1.11	7.83	21.55
1939	3.75	1.12	0.88	0.64	0.46	0.59	0.63	1.01	1.19	0.88	0.60	0.47	12.22
1940	0.43	0.79	0.93	0.64	0.36	0.33	0.39	0.35	0.33	0.34	0.35	0.36	5.60
1941	0.52	0.73	0.58	5.54	2.46	0.91	0.82	0.82	0.76	0.51	0.49	0.61	14.75
1942	0.79	11.47	7.77	2.03	0.69	1.67	5.20	2.44	1.03	0.88	2.47	1.66	38.10
1943	1.22	3.81	2.15	1.01	1.22	1.10	0.80	0.56	0.49	0.52	0.46	4.48	17.82
1944	2.50	0.96	0.44	0.47	0.85	1.20	1.02	0.72	0.56	0.46	0.35	0.41	9.94
1945	6.85	2.78	0.39	0.29	0.65	3.92	2.20	0.97	0.63	0.48	0.36	0.33	19.85
1946	0.44	0.86	0.97	0.78	0.80	3.68	5.55	2.41	4.52	2.39	0.91	0.64	23.95
1947	0.58	15.00	5.92	0.98	2.76	2.67	1.51	0.88	0.51	0.32	0.23	0.19	31.55
1948	0.73	1.04	0.85	0.65	8.12	4.89	1.75	1.02	0.59	0.39	0.34	0.39	20.76
1949	0.59	3.48	1.79	1.00	1.16	1.18	1.21	1.50	1.21	0.90	1.03	0.95	16.00
1950	0.88	0.68	3.29	1.93	0.94	1.04	0.95	0.65	0.49	0.42	0.46	0.61	12.34
1951	2.70	1.37	0.85	1.18	1.12	1.11	1.26	1.12	0.76	0.50	0.33	0.42	12.72
1952	0.52	0.48	0.41	0.40	0.54	0.68	0.73	0.61	0.44	0.32	0.33	0.66	6.12
1953	1.11	5.22	3.06	1.12	0.68	0.86	0.80	0.76	0.92	0.87	0.61	0.65	16.66
1954	11.70	4.64	0.71	2.47	5.94	3.36	1.33	0.77	0.58	0.45	0.30	0.46	32.71
1955	0.72	0.82	0.53	0.21	0.45	7.70	3.60	1.19	0.93	0.74	0.53	0.57	17.99
1956	1.03	9.71	16.17	5.29	1.24	5.35	6.45	2.39	0.86	0.69	0.60	0.84	50.62
1957	1.23	1.32	1.20	2.17	6.28	2.86	4.76	2.20	0.61	0.43	0.38	0.36	23.80
1958	0.41	0.81	0.99	0.65	0.59	0.76	0.87	14.21	5.55	1.07	1.25	1.19	28.35
1959	0.99	0.85	0.73	0.63	0.57	0.84	1.18	1.34	1.09	0.75	0.64	0.76	10.37
1960	0.75	0.94	2.37	1.62	1.03	1.09	12.01	4.97	1.10	0.97	0.87	0.67	28.39
1961	0.56	1.42	1.24	0.87	0.88	3.98	1.98	0.78	0.57	0.38	0.46	0.56	13.68
1962	0.88	3.83	1.89	4.50	2.16	16.09	6.16	0.96	0.75	6.07	2.81	0.69	46.79
1963	0.76	1.14	1.12	5.49	3.66	2.41	4.05	1.95	13.01	5.24	0.91	0.70	40.44
1964	2.88	1.51	0.50	0.44	0.47	0.34	0.24	0.37	8.41	3.98	2.01	1.54	22.69
1965	9.05	5.31	1.46	0.71	0.60	0.40	0.27	5.18	2.64	0.86	0.61	0.67	27.76
1966	0.66	0.54	0.54	0.81	1.01	10.26	8.36	2.45	0.84	1.42	1.27	0.71	28.87
1967	0.46	0.66	0.63	0.47	0.52	0.59	0.59	0.47	0.33	0.28	0.42	0.86	6.28
1968	1.13	1.20	1.05	0.61	1.32	6.77	2.91	5.95	2.81	0.91	0.69	0.57	25.92
1969	0.68	0.96	0.91	0.54	0.45	0.40	0.33	0.39	0.64	0.72	5.10	2.72	13.84
1970	9.69	4.22	1.08	0.79	0.80	0.85	0.92	7.54	3.30	1.45	5.00	2.47	38.11
1971	8.22	3.50	0.93	0.73	6.69	2.98	0.82	0.57	0.49	0.48	0.44	0.36	26.21
1972	0.30	0.72	0.98	0.80	0.65	0.73	1.08	1.00	0.59	0.37	0.48	0.87	8.57
1973	1.10	3.78	1.83	0.68	0.84	1.23	1.14	7.47	3.55	1.24	0.77	0.49	24.12
1974	0.44	0.63	0.89	0.81	0.71	0.77	0.76	0.62	0.45	0.37	0.35	5.75	12.55
1975	2.66	0.76	1.85	1.29	6.10	24.10	8.70	4.28	2.12	0.78	0.55	0.71	53.90
1976	15.62	5.82	0.56	0.52	2.19	1.57	0.85	0.51	0.42	0.44	0.57	0.82	29.89
1977	1.10	4.90	5.32	1.99	0.78	0.78	35.37	13.46	1.50	0.89	0.67	0.70	67.46
1978	3.46	2.05	0.92	0.57	0.50	0.88	0.97	0.71	0.50	0.81	1.20	1.18	13.75
1979	1.19	0.97	0.67	0.45	0.48	0.57	0.50	0.45	0.42	0.36	0.32	2.73	9.11
1980	1.73	2.65	1.61	1.07	1.00	0.76	0.48	0.75	0.98	0.74	0.83	0.86	13.46
1981	0.59	0.48	0.42	0.50	0.53	8.30	3.83	1.19	0.82	0.62	0.45	0.36	18.09
1982	0.59	0.63	0.36	0.24	0.27	0.28	0.27	0.27	0.24	6.23	2.99	0.95	13.32
1983	0.86	1.09	1.08	1.11	1.18	1.09	1.18	1.16	1.09	3.31	1.91	0.91	15.97
1984	0.76	2.42	1.51	0.84	14.86	5.70	0.74	0.44	0.33	0.31	0.25	0.20	28.36
1985	0.67	3.11	1.67	1.33	0.98	0.73	0.69	0.55	0.40	0.30	0.61	1.29	12.33
1986	4.00	2.12	0.81	0.64	0.48	0.67	0.80	0.63	0.52	0.43	0.52	24.04	35.66
1987	9.00	2.75	1.52	0.68	4.76	18.15	6.52	4.15	2.29	1.91	1.74	1.23	54.70
1988	0.99	3.63	8.75	3.04	7.42	3.40	4.73	2.30	0.91	0.77	0.54	0.43	36.91
1989	2.92	8.14	2.93	0.61	0.50	3.34	1.77	0.61	0.39	0.29	0.56	0.78	22.84
1990	0.92	0.79	0.51	0.59	1.03	1.08	0.68	0.45	0.40	0.33	0.34	0.52	7.64
1991	2.34	3.80	1.62	0.64	0.51	0.44	0.52	0.49	0.37	0.28	0.29	0.43	11.73
1992	0.63	0.66	0.63	0.55	0.46	0.34	0.30	0.30	0.26	0.22	0.24	0.56	5.15
1993	1.05	1.15	2.63	1.34	9.52	4.11	0.89	0.44	0.28	0.36	0.69	0.67	23.13
1994	0.47	0.34	0.70	0.86	0.58	4.28	9.01	3.45	2.64	1.69	0.79	0.56	25.37
1995	0.69	0.73	9.98	4.16	2.77	1.50	0.71	0.57	0.44	1.67	1.40	0.82	25.44
1996	0.90	11.33	4.44	0.96	3.63	2.07	7.48	3.28	18.38	7.44	1.35	1.02	62.28
month	154.75	217.20	158.70	110.83	171.97	252.58	207.72	145.86	132.57	123.38	80.04	107.69	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.26	0.34	0.36	0.21	0.27	0.28	0.24	0.27	0.24	0.22	0.23	0.19	5.15
max	15.62	17.12	16.17	8.46	14.86	24.10	35.37	14.21	18.38	25.92	9.49	24.04	67.46
median	0.86	1.14	0.99	0.81	0.94	1.23	1.07	0.81	0.69	0.74	0.61	0.67	22.40
mean	2.01	2.82	2.06	1.44	2.23	3.28	2.70	1.89	1.72	1.60	1.04	1.40	24.20
Sum of the monthly means =					24.20								
s.d.	2.89	3.51	2.66	1.57	2.90	4.32	4.51	2.63	2.99	3.27	1.36	2.93	14.56
c.v.	1.44	1.25	1.29	1.09	1.30	1.32	1.67	1.39	1.74	2.04	1.31	2.09	0.60

APPENDIX 3.5
LOWER MZINTLAVA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.21	0.38	0.65	0.67	0.66	1.45	1.13	0.71	0.42	0.26	0.17	0.22	6.93
1921	0.41	2.60	2.76	1.16	0.49	0.29	0.19	2.57	2.89	1.32	0.83	0.81	16.32
1922	2.88	6.87	2.45	6.00	9.21	5.49	1.51	0.44	0.31	5.81	2.54	0.50	44.01
1923	0.29	0.28	0.35	2.48	2.78	1.09	0.34	0.23	0.22	0.20	0.22	0.36	8.84
1924	0.52	0.63	0.77	0.69	0.66	4.65	2.23	0.77	0.51	0.38	0.29	0.40	12.50
1925	0.54	0.58	0.54	0.57	0.68	5.86	2.46	0.58	0.68	0.69	0.46	0.45	14.09
1926	0.69	1.03	0.96	0.67	0.48	8.47	3.28	0.40	0.24	0.18	0.17	0.24	16.81
1927	0.45	0.39	0.39	0.57	0.83	0.88	0.60	0.41	0.37	0.30	0.38	0.42	5.99
1928	0.42	0.53	0.53	0.48	0.43	0.70	0.70	0.53	4.86	3.55	1.45	3.33	17.51
1929	4.77	2.99	1.06	0.47	0.34	0.43	0.55	0.50	0.62	0.75	0.83	2.33	15.64
1930	1.32	0.59	0.44	2.87	3.64	6.66	2.53	0.56	0.33	18.92	6.95	0.63	45.44
1931	0.61	0.59	0.47	0.32	2.50	1.51	0.65	0.52	0.59	0.65	0.57	2.82	11.80
1932	1.73	8.97	6.61	1.56	0.38	0.53	0.51	0.39	0.30	0.25	0.21	0.19	21.63
1933	0.19	0.73	2.65	4.10	1.67	0.83	0.77	0.59	0.42	0.67	0.76	0.45	13.83
1934	0.29	0.46	1.40	0.92	0.45	0.55	3.30	5.56	8.20	2.96	0.99	0.83	25.91
1935	0.57	0.50	0.29	0.18	5.71	6.71	2.13	2.36	1.50	0.83	0.53	0.40	21.71
1936	0.71	12.53	4.56	0.41	1.36	2.70	1.31	0.49	0.31	0.30	0.33	0.32	25.33
1937	0.34	0.35	0.52	0.64	0.62	0.46	0.65	0.77	0.69	0.68	0.58	0.37	6.67
1938	0.29	0.45	0.61	0.68	2.34	1.42	0.77	0.73	0.69	0.71	0.80	5.49	14.98
1939	2.60	0.83	0.66	0.46	0.33	0.42	0.45	0.73	0.89	0.66	0.45	0.35	8.83
1940	0.31	0.57	0.66	0.46	0.26	0.23	0.28	0.25	0.24	0.25	0.25	0.26	4.02
1941	0.37	0.53	0.41	3.68	1.68	0.67	0.60	0.60	0.55	0.37	0.36	0.45	10.27
1942	0.57	8.10	5.40	1.43	0.51	0.92	3.60	1.77	0.77	0.65	1.61	1.17	26.50
1943	0.90	2.51	1.48	0.73	0.78	0.80	0.60	0.42	0.36	0.39	0.34	3.03	12.34
1944	1.76	0.71	0.32	0.33	0.60	0.85	0.73	0.51	0.40	0.33	0.26	0.30	7.10
1945	4.74	1.96	0.29	0.21	0.46	2.51	1.51	0.72	0.47	0.36	0.27	0.24	13.74
1946	0.32	0.62	0.69	0.55	0.57	2.33	3.89	1.77	3.19	1.73	0.68	0.48	16.82
1947	0.43	10.75	4.26	0.71	1.68	1.70	1.07	0.65	0.38	0.24	0.17	0.14	22.18
1948	0.53	0.75	0.61	0.46	5.58	3.31	1.25	0.76	0.44	0.29	0.25	0.29	14.52
1949	0.43	2.23	1.22	0.72	0.83	0.84	0.86	1.01	0.89	0.68	0.77	0.70	11.18
1950	0.64	0.49	2.06	1.30	0.68	0.74	0.68	0.47	0.36	0.30	0.34	0.44	8.50
1951	1.69	0.92	0.62	0.84	0.80	0.79	0.90	0.80	0.55	0.37	0.24	0.31	8.83
1952	0.38	0.35	0.30	0.28	0.38	0.48	0.52	0.44	0.32	0.23	0.24	0.48	4.40
1953	0.80	3.49	1.94	0.76	0.50	0.62	0.58	0.55	0.66	0.63	0.44	0.47	11.44
1954	8.32	3.33	0.52	1.47	4.08	2.26	0.94	0.58	0.43	0.33	0.22	0.33	22.81
1955	0.52	0.59	0.38	0.15	0.32	5.28	2.53	0.88	0.69	0.55	0.39	0.42	12.70
1956	0.74	6.80	11.60	3.83	0.90	3.66	4.54	1.73	0.65	0.52	0.45	0.61	36.03
1957	0.89	0.95	0.85	1.21	4.38	2.07	3.27	1.56	0.46	0.33	0.28	0.27	16.52
1958	0.30	0.58	0.71	0.46	0.42	0.54	0.62	10.16	4.00	0.80	0.93	0.87	20.39
1959	0.72	0.61	0.52	0.45	0.40	0.60	0.84	0.96	0.79	0.54	0.47	0.55	7.45
1960	0.55	0.67	1.37	1.07	0.75	0.79	8.53	3.57	0.82	0.72	0.64	0.49	19.97
1961	0.41	0.73	0.81	0.64	0.63	2.57	1.36	0.58	0.42	0.28	0.34	0.41	9.18
1962	0.63	2.47	1.28	3.00	1.49	11.61	4.47	0.71	0.56	4.25	2.01	0.52	33.00
1963	0.56	0.83	0.80	3.64	2.39	1.56	2.81	1.41	9.47	3.84	0.69	0.52	28.52
1964	1.86	1.04	0.37	0.32	0.33	0.24	0.18	0.26	5.90	2.85	1.34	1.10	15.79
1965	6.46	3.67	1.02	0.52	0.43	0.28	0.20	3.50	1.86	0.65	0.46	0.50	19.55
1966	0.48	0.39	0.38	0.58	0.71	7.18	5.90	1.77	0.63	0.87	0.90	0.54	20.33
1967	0.34	0.48	0.45	0.33	0.37	0.42	0.42	0.34	0.24	0.20	0.30	0.62	4.51
1968	0.82	0.86	0.74	0.43	0.60	4.71	2.10	4.21	2.03	0.69	0.51	0.42	18.12
1969	0.49	0.69	0.65	0.39	0.32	0.29	0.24	0.28	0.46	0.52	3.48	1.93	9.74
1970	6.93	3.01	0.80	0.59	0.58	0.61	0.66	5.24	2.35	0.94	3.56	1.80	27.07
1971	5.85	2.52	0.68	0.52	4.55	2.07	0.60	0.42	0.36	0.35	0.33	0.26	18.51
1972	0.22	0.52	0.70	0.57	0.46	0.52	0.80	0.75	0.44	0.28	0.36	0.64	6.26
1973	0.79	2.45	1.24	0.50	0.60	0.87	0.85	5.33	2.57	0.93	0.57	0.36	17.06
1974	0.32	0.45	0.63	0.57	0.50	0.55	0.54	0.45	0.33	0.27	0.26	3.95	8.82
1975	1.87	0.56	1.04	0.85	4.19	17.55	6.29	3.14	1.59	0.59	0.41	0.53	38.61
1976	11.24	4.21	0.42	0.37	1.25	1.04	0.63	0.37	0.31	0.32	0.42	0.60	21.18
1977	0.79	3.26	3.60	1.40	0.57	0.56	25.76	9.75	1.10	0.67	0.50	0.52	48.48
1978	2.28	1.42	0.67	0.41	0.35	0.63	0.69	0.51	0.36	0.58	0.86	0.85	9.61
1979	0.86	0.69	0.48	0.32	0.34	0.41	0.35	0.32	0.30	0.26	0.23	1.73	6.29
1980	1.19	1.70	1.10	0.78	0.71	0.54	0.35	0.54	0.70	0.53	0.60	0.62	9.36
1981	0.43	0.35	0.30	0.35	0.37	5.73	2.71	0.88	0.60	0.46	0.33	0.27	12.78
1982	0.43	0.45	0.26	0.17	0.19	0.20	0.20	0.19	0.18	4.31	2.12	0.71	9.41
1983	0.64	0.79	0.77	0.79	0.84	0.77	0.84	0.83	0.78	2.17	1.33	0.68	11.23
1984	0.56	1.48	1.01	0.61	10.61	4.10	0.55	0.33	0.24	0.23	0.18	0.15	20.05
1985	0.48	1.94	1.12	0.79	0.69	0.55	0.51	0.41	0.29	0.22	0.44	0.88	8.32
1986	2.84	1.54	0.59	0.46	0.34	0.48	0.57	0.46	0.38	0.32	0.38	17.47	25.83
1987	6.56	1.77	1.04	0.50	3.16	13.13	4.78	2.87	1.64	1.28	1.25	0.93	38.91
1988	0.74	2.41	6.15	2.18	5.17	2.42	3.25	1.63	0.69	0.57	0.40	0.32	25.93
1989	1.87	5.73	2.11	0.45	0.36	2.11	1.20	0.46	0.29	0.22	0.41	0.57	15.78
1990	0.67	0.57	0.36	0.42	0.73	0.76	0.49	0.33	0.29	0.24	0.25	0.38	5.49
1991	1.42	2.53	1.14	0.47	0.36	0.31	0.37	0.36	0.27	0.21	0.21	0.31	7.96
1992	0.46	0.47	0.45	0.39	0.32	0.24	0.21	0.21	0.19	0.16	0.17	0.41	3.68
1993	0.76	0.83	1.56	0.87	6.73	2.94	0.66	0.33	0.21	0.26	0.51	0.49	16.15
1994	0.34	0.24	0.50	0.61	0.41	2.78	6.39	2.52	1.80	1.21	0.60	0.42	17.82
1995	0.50	0.52	6.98	2.95	1.75	1.02	0.53	0.42	0.32	0.99	0.97	0.62	17.57
1996	0.66	8.03	3.17	0.70	2.31	1.41	5.28	2.36	13.44	5.39	1.01	0.78	44.54
month	109.49	151.39	110.25	76.44	117.83	176.25	148.14	104.47	96.05	88.79	57.80	77.02	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.19	0.24	0.26	0.15	0.19	0.20	0.18	0.19	0.18	0.16	0.17	0.14	3.68
max	11.24	12.53	11.60	6.00	10.61	17.55	25.76	10.16	13.44	18.92	6.95	17.47	48.48
median	0.63	0.79	0.71	0.59	0.66	0.87	0.77	0.59	0.51	0.54	0.45	0.49	15.64
mean	1.42	1.97	1.43	0.99	1.53	2.29	1.92	1.36	1.25	1.15	0.75	1.00	17.06
Sum of the monthly means =				17.06									
s.d.	2.06	2.52	1.88	1.08	2.03	3.10	3.26	1.87	2.17	2.37	0.97	2.11	10.43
c.v.	1.45	1.28	1.31	1.08	1.33	1.36	1.69	1.38	1.74	2.06	1.29	2.11	0.61

APPENDIX 4
POINT RAINFALL SEQUENCES

APPENDIX 4.1
ZALU DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	47.25	116.28	132.57	95.13	104.85	122.13	63.36	8.28	0.00	2.97	1.08	70.38	764.28
1921	78.21	165.51	146.79	90.27	59.04	26.01	26.10	163.35	67.05	0.00	75.60	46.98	944.91
1922	137.61	186.66	63.36	241.02	204.93	131.94	15.12	20.52	8.10	186.57	1.98	19.17	1216.98
1923	41.22	75.15	106.92	187.74	131.40	23.40	18.45	24.57	13.05	3.87	39.69	70.74	736.20
1924	72.18	101.88	131.58	89.73	108.45	167.13	64.44	19.71	5.85	20.52	6.48	90.63	878.58
1925	59.76	95.40	93.51	121.59	103.41	184.59	29.25	33.57	65.88	1.89	13.86	74.07	876.78
1926	96.21	120.87	118.44	81.09	76.05	245.79	3.78	13.68	0.36	6.57	24.30	55.44	842.58
1927	91.89	25.83	132.21	122.04	124.38	74.52	15.66	38.16	13.05	3.87	70.74	21.15	733.50
1928	75.51	99.18	90.63	103.95	67.68	132.84	15.75	42.57	147.51	62.19	43.47	119.16	1000.44
1929	131.31	125.64	75.69	90.72	54.36	100.35	54.54	20.34	71.10	23.22	67.86	105.12	920.25
1930	49.50	68.94	92.52	195.57	141.66	173.07	41.94	5.22	2.97	363.87	17.19	28.35	1180.80
1931	95.76	67.23	93.06	60.21	191.88	82.26	13.59	60.93	31.50	39.51	17.01	146.88	899.82
1932	86.13	224.73	170.37	27.45	107.91	88.11	27.99	23.67	7.20	11.88	10.17	35.19	820.80
1933	35.82	171.81	153.81	170.64	78.03	107.91	40.77	26.46	6.03	96.66	4.32	15.48	907.74
1934	49.86	122.40	153.27	85.41	51.39	119.25	127.71	115.38	133.29	13.14	79.74	22.41	1073.25
1935	57.69	87.84	17.01	98.46	237.51	155.88	20.43	122.58	29.07	18.72	2.16	57.60	904.95
1936	121.59	275.49	54.18	89.37	160.56	122.40	30.24	8.91	9.09	32.49	26.01	37.17	967.50
1937	63.63	66.96	140.49	107.91	85.41	38.25	118.17	18.00	40.50	33.39	19.71	14.76	747.18
1938	59.49	112.32	113.85	119.52	147.06	85.14	42.84	62.91	11.79	57.69	47.70	158.31	1018.62
1939	86.49	62.28	121.68	58.86	74.25	90.00	34.20	102.96	14.58	9.72	20.61	38.97	714.60
1940	45.18	142.11	87.39	73.71	36.72	70.92	40.41	8.91	24.48	14.58	25.74	38.16	608.31
1941	82.44	96.03	57.33	221.85	54.99	104.58	26.46	65.61	0.00	3.06	53.64	52.92	818.91
1942	83.88	235.44	155.97	88.56	65.88	137.97	119.34	27.18	38.43	14.58	109.17	43.47	1119.87
1943	95.67	137.70	124.92	84.42	132.66	62.10	39.60	14.31	29.52	26.19	9.81	168.48	925.38
1944	75.06	50.67	42.12	137.25	111.15	103.77	23.04	34.29	8.64	16.74	6.93	67.32	676.98
1945	186.93	16.02	69.48	83.79	133.20	136.53	63.45	11.16	12.87	15.75	4.23	48.87	782.28
1946	63.99	135.99	90.54	97.65	101.07	140.49	116.10	37.44	99.72	19.80	7.20	55.17	965.16
1947	49.50	295.65	110.88	90.36	148.95	106.83	58.41	4.77	1.71	0.72	9.72	21.87	899.37
1948	152.28	70.38	99.81	86.58	217.53	108.54	71.55	6.12	0.54	13.41	23.13	51.39	901.26
1949	80.82	158.94	80.91	141.75	101.43	85.32	74.16	70.38	2.52	37.08	67.68	28.98	929.97
1950	85.86	41.76	192.42	114.75	69.75	113.67	24.93	20.97	17.01	10.26	48.60	58.50	798.48
1951	133.83	17.46	164.61	125.82	83.43	98.10	77.31	22.05	6.30	7.92	0.90	81.81	819.54
1952	40.05	73.44	75.87	90.27	98.46	71.28	56.25	10.89	8.46	2.61	40.95	93.96	662.49
1953	92.97	153.09	130.68	82.44	74.16	109.62	16.92	66.51	36.54	16.29	8.37	84.06	871.65
1954	219.60	66.60	74.61	178.92	155.34	104.49	40.77	18.09	21.33	0.45	4.50	91.17	975.87
1955	67.32	93.69	36.45	33.12	148.14	184.68	74.79	23.49	31.32	9.54	14.49	74.79	791.82
1956	109.71	197.28	253.17	118.53	104.76	144.72	119.88	15.03	32.04	8.91	39.51	88.29	1231.83
1957	94.32	99.99	115.92	144.00	162.63	88.29	120.24	2.70	0.00	25.65	11.70	44.73	910.17
1958	55.62	137.34	99.36	56.52	107.82	79.20	63.45	218.61	1.17	53.91	64.53	45.27	982.80
1959	69.21	81.63	95.49	94.23	71.28	116.55	73.44	59.04	1.62	19.98	38.52	70.02	791.01
1960	48.15	127.26	141.75	122.85	76.23	108.27	194.22	44.55	10.89	50.76	17.73	42.21	984.87
1961	53.19	148.77	101.52	96.57	105.48	139.59	30.60	34.38	0.45	1.17	66.42	35.64	813.78
1962	112.77	140.76	83.70	186.57	71.73	276.30	40.50	37.53	13.86	142.74	9.27	19.08	1134.81
1963	110.52	112.41	102.24	186.93	120.24	107.19	106.83	15.12	204.84	10.98	16.11	59.40	1152.81
1964	134.19	39.06	72.00	103.77	65.07	24.39	30.87	58.32	173.34	40.14	67.41	58.50	867.06
1965	176.67	121.86	78.57	99.90	70.74	15.84	40.95	169.38	12.78	3.69	34.11	67.14	891.63
1966	41.94	71.73	101.25	138.78	93.06	205.65	119.88	10.44	36.27	81.54	16.47	14.22	931.23
1967	54.36	116.01	64.44	87.12	90.27	64.80	47.61	2.43	10.62	10.08	63.81	91.89	703.44
1968	74.88	108.54	97.02	49.59	161.91	155.25	37.62	136.71	12.87	16.56	29.34	39.69	919.98
1969	84.78	112.59	87.30	55.26	91.44	30.78	40.05	38.61	59.94	4.14	146.88	63.36	815.13
1970	178.56	107.37	87.84	103.41	95.49	75.42	69.57	145.44	5.22	79.83	96.30	46.89	1091.34
1971	175.59	80.01	100.71	92.61	197.46	61.56	39.33	13.14	30.60	14.85	25.74	20.70	852.30
1972	42.84	149.31	98.37	90.63	77.40	87.84	99.00	0.09	0.54	10.62	64.44	85.32	806.40
1973	73.80	146.70	77.76	93.24	120.15	104.85	45.54	148.77	42.30	11.52	6.93	37.35	908.91
1974	51.30	111.24	120.60	85.23	88.92	79.83	47.16	17.91	6.12	16.02	26.37	180.99	831.69
1975	34.11	80.28	160.83	94.86	180.54	317.79	74.43	91.71	5.58	8.10	25.83	87.66	1161.72
1976	254.43	42.03	74.97	113.04	148.77	77.04	22.95	8.46	31.95	15.30	61.11	69.12	919.17
1977	92.61	151.56	156.87	94.32	75.15	87.12	447.75	53.37	19.53	4.95	39.78	59.49	1282.50
1978	138.51	95.94	76.23	79.47	80.55	122.85	31.50	22.14	6.30	91.62	45.54	61.38	852.03
1979	86.85	62.46	88.74	68.04	94.68	64.62	26.37	36.81	5.58	16.02	15.30	156.33	721.80
1980	48.51	143.46	102.96	125.37	83.16	50.04	18.45	102.51	9.54	8.82	80.64	26.37	799.83
1981	37.26	81.27	69.66	117.72	60.93	215.10	75.96	18.72	16.11	17.55	5.31	43.92	759.51
1982	93.69	55.89	43.29	82.26	62.37	42.84	35.91	14.49	7.02	180.81	18.54	51.57	688.68
1983	73.71	121.14	99.00	136.35	97.38	75.33	87.48	29.07	47.34	84.69	21.15	46.71	919.35
1984	62.64	148.95	94.41	100.35	278.64	54.99	26.64	6.12	18.00	11.43	1.71	26.64	830.52
1985	140.49	131.94	85.32	150.21	54.27	79.38	47.16	9.72	10.35	1.35	101.34	88.74	900.27
1986	114.39	91.35	63.00	117.90	29.70	126.81	32.40	22.59	21.87	3.24	64.62	346.14	1034.01
1987	56.07	134.91	88.47	78.66	185.40	260.28	56.70	101.70	29.25	67.50	60.84	32.76	1152.54
1988	81.63	148.50	198.45	47.07	221.85	84.87	120.78	20.07	31.68	18.09	2.79	52.02	1027.80
1989	150.57	174.33	47.16	117.99	43.47	171.36	21.24	10.53	7.29	3.06	95.49	36.54	879.03
1990	95.13	51.21	76.32	128.25	125.82	59.76	12.06	33.48	8.91	7.11	37.80	69.75	705.60
1991	129.60	130.77	65.34	102.51	55.26	60.03	62.55	4.68	11.79	0.72	37.35	60.75	721.35
1992	74.07	71.19	103.77	79.74	66.15	28.53	45.81	12.69	7.47	2.70	34.29	96.21	622.62
1993	95.40	89.64	151.56	64.53	236.07	85.14	5.76	5.58	10.44	42.93	73.26	4.68	864.99
1994	54.72	40.41	169.20	83.61	47.79	179.28	147.87	30.42	84.78	9.72	5.31	54.18	907.29
1995	80.37	73.80	250.65	112.32	132.66	45.72	49.77	17.91	8.82	117.27	16.29	37.08	942.66
1996	103.50	223.11	84.60	128.88	144.09	85.14	151.74	26.82	249.84	43.20	21.06	66.96	1328.94
month	6933.15	8711.37	8125.74	8197.11	8519.85	8350.20	4695.84	3221.73	2322.27	2556.99	2731.68	4974.57	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	34.11	16.02	17.01	27.45	29.70	15.84	3.78	0.09	0.00	0.00	0.90	4.68	608.31
max	254.43	295.65	253.17	241.02	278.64	317.79	447.75	218.61	249.84	363.87	146.88	346.14	1328.94
median	81.63	111.24	97.02	96.57	98.46	100.35	42.84	23.49	12.87	14.85	25.74	55.17	899.37
mean	90.04	113.13	105.53	106.46	110.65	108.44	60.98	41.84	30.16	33.21	35.48	64.60	900.53

Sum of the monthly means = 900.53

s.d.	44.06	54.80	43.72	40.04	52.54	58.98	59.13	45.66	46.26	54.20	30.67	48.61	154.20
c.v.	0.49	0.48	0.41	0.38	0.47	0.54	0.97	1.09	1.53	1.63	0.86	0.75	0.17

APPENDIX 4.2
XURA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	52.50	129.20	147.30	105.70	116.50	135.70	70.40	9.20	0.00	3.30	1.20	78.20	849.20
1921	86.90	183.90	163.10	100.30	65.60	28.90	29.00	181.50	74.50	0.00	84.00	52.20	1049.90
1922	152.90	207.40	70.40	267.80	227.70	146.60	16.80	22.80	9.00	207.30	2.20	21.30	1352.20
1923	45.80	83.50	118.80	208.60	146.00	26.00	20.50	27.30	14.50	4.30	44.10	78.60	818.00
1924	80.20	113.20	146.20	99.70	120.50	185.70	71.60	21.90	6.50	22.80	7.20	100.70	976.20
1925	66.40	106.00	103.90	135.10	114.90	205.10	32.50	37.30	73.20	2.10	15.40	82.30	974.20
1926	106.90	134.30	131.60	90.10	84.50	273.10	4.20	15.20	0.40	7.30	27.00	61.60	936.20
1927	102.10	28.70	146.90	135.60	138.20	82.80	17.40	42.40	14.50	4.30	78.60	23.50	815.00
1928	83.90	110.20	100.70	115.50	75.20	147.60	17.50	47.30	163.90	69.10	48.30	132.40	1111.60
1929	145.90	139.60	84.10	100.80	60.40	111.50	60.60	22.60	79.00	25.80	75.40	116.80	1022.50
1930	55.00	76.60	102.80	217.30	157.40	192.30	46.60	5.80	3.30	404.30	19.10	31.50	1312.00
1931	106.40	74.70	103.40	66.90	213.20	91.40	15.10	67.70	35.00	43.90	18.90	163.20	999.80
1932	95.70	249.70	189.30	30.50	119.90	97.90	31.10	26.30	8.00	13.20	11.30	39.10	912.00
1933	39.80	190.90	170.90	189.60	86.70	119.90	45.30	29.40	6.70	107.40	4.80	17.20	1008.60
1934	55.40	136.00	170.30	94.90	57.10	132.50	141.90	128.20	148.10	14.60	88.60	24.90	1192.50
1935	64.10	97.60	18.90	109.40	263.90	173.20	22.70	136.20	32.30	20.80	2.40	64.00	1005.50
1936	135.10	306.10	60.20	99.30	178.40	136.00	33.60	9.90	10.10	36.10	28.90	41.30	1075.00
1937	70.70	74.40	156.10	119.90	94.90	42.50	131.30	20.00	45.00	37.10	21.90	16.40	830.20
1938	66.10	124.80	126.50	132.80	163.40	94.60	47.60	69.90	13.10	64.10	53.00	175.90	1131.80
1939	96.10	69.20	135.20	65.40	82.50	100.00	38.00	114.40	16.20	10.80	22.90	43.30	794.00
1940	50.20	157.90	97.10	81.90	40.80	78.80	44.90	9.90	27.20	16.20	28.60	42.40	675.90
1941	91.60	106.70	63.70	246.50	61.10	116.20	29.40	72.90	0.00	3.40	59.60	58.80	909.90
1942	93.20	261.60	173.30	98.40	73.20	153.30	132.60	30.20	42.70	16.20	121.30	48.30	1244.30
1943	106.30	153.00	138.80	93.80	147.40	69.00	44.00	15.90	32.80	29.10	10.90	187.20	1028.20
1944	83.40	56.30	46.80	152.50	123.50	115.30	25.60	38.10	9.60	18.60	7.70	74.80	752.20
1945	207.70	17.80	77.20	93.10	148.00	151.70	70.50	12.40	14.30	17.50	4.70	54.30	869.20
1946	71.10	151.10	100.60	108.50	112.30	156.10	129.00	41.60	110.80	22.00	8.00	61.30	1072.40
1947	55.00	328.50	123.20	100.40	165.50	118.70	64.90	5.30	1.90	0.80	10.80	24.30	999.30
1948	169.20	78.20	110.90	96.20	241.70	120.60	79.50	6.80	0.60	14.90	25.70	57.10	1001.40
1949	89.80	176.60	89.90	157.50	112.70	94.80	82.40	78.20	2.80	41.20	75.20	32.20	1033.30
1950	95.40	46.40	213.80	127.50	77.50	126.30	27.70	23.30	18.90	11.40	54.00	65.00	887.20
1951	148.70	19.40	182.90	139.80	92.70	109.00	85.90	24.50	7.00	8.80	1.00	90.90	910.60
1952	44.50	81.60	84.30	100.30	109.40	79.20	62.50	12.10	9.40	2.90	45.50	104.40	736.10
1953	103.30	170.10	145.20	91.60	82.40	121.80	18.80	73.90	40.60	18.10	9.30	93.40	968.50
1954	244.00	74.00	82.90	198.80	172.60	116.10	45.30	20.10	23.70	0.50	5.00	101.30	1084.30
1955	74.80	104.10	40.50	36.80	164.60	205.20	83.10	26.10	34.80	10.60	16.10	83.10	879.80
1956	121.90	219.20	281.30	131.70	116.40	160.80	133.20	16.70	35.60	9.90	43.90	98.10	1368.70
1957	104.80	111.10	128.80	160.00	180.70	98.10	133.60	3.00	0.00	28.50	13.00	49.70	1011.30
1958	61.80	152.60	110.40	62.80	119.80	88.00	70.50	242.90	1.30	59.90	71.70	50.30	1092.00
1959	76.90	90.70	106.10	104.70	79.20	129.50	81.60	65.60	1.80	22.20	42.80	77.80	878.90
1960	53.50	141.40	157.50	136.50	84.70	120.30	215.80	49.50	12.10	56.40	19.70	46.90	1094.30
1961	59.10	165.30	112.80	107.30	117.20	155.10	34.00	38.20	0.50	1.30	73.80	39.60	904.20
1962	125.30	156.40	93.00	207.30	79.70	307.00	45.00	41.70	15.40	158.60	10.30	21.20	1260.90
1963	122.80	124.90	113.60	207.70	133.60	119.10	118.70	16.80	227.60	12.20	17.90	66.00	1280.90
1964	149.10	43.40	80.00	115.30	72.30	27.10	34.30	64.80	192.60	44.60	74.90	65.00	963.40
1965	196.30	135.40	87.30	111.00	78.60	17.60	45.50	188.20	14.20	4.10	37.90	74.60	990.70
1966	46.60	79.70	112.50	154.20	103.40	228.50	133.20	11.60	40.30	90.60	18.30	15.80	1034.70
1967	60.40	128.90	71.60	96.80	100.30	72.00	52.90	2.70	11.80	11.20	70.90	102.10	781.60
1968	83.20	120.60	107.80	55.10	179.90	172.50	41.80	151.90	14.30	18.40	32.60	44.10	1022.20
1969	94.20	125.10	97.00	61.40	101.60	34.20	44.50	42.90	66.60	4.60	163.20	70.40	905.70
1970	198.40	119.30	97.60	114.90	106.10	83.80	77.30	161.60	5.80	88.70	107.00	52.10	1212.60
1971	195.10	88.90	111.90	102.90	219.40	68.40	43.70	14.60	34.00	16.50	28.60	23.00	947.00
1972	47.60	165.90	109.30	100.70	86.00	97.60	110.00	0.10	0.60	11.80	71.60	94.80	896.00
1973	82.00	163.00	86.40	103.60	133.50	116.50	50.60	165.30	47.00	12.80	7.70	41.50	1009.90
1974	57.00	123.60	134.00	94.70	98.80	88.70	52.40	19.90	6.80	17.80	29.30	201.10	924.10
1975	37.90	89.20	178.70	105.40	200.60	353.10	82.70	101.90	6.20	9.00	28.70	97.40	1290.80
1976	282.70	46.70	83.30	125.60	165.30	85.60	25.50	9.40	35.50	17.00	67.90	76.80	1021.30
1977	102.90	168.40	174.30	104.80	83.50	96.80	497.50	59.30	21.70	5.50	44.20	66.10	1425.00
1978	153.90	106.60	84.70	88.30	89.50	136.50	35.00	24.60	7.00	101.80	50.60	68.20	946.70
1979	96.50	69.40	98.60	75.60	105.20	71.80	29.30	40.90	6.20	17.80	17.00	173.70	802.00
1980	53.90	159.40	114.40	139.30	92.40	55.60	20.50	113.90	10.60	9.80	89.60	29.30	888.70
1981	41.40	90.30	77.40	130.80	67.70	239.00	84.40	20.80	17.90	19.50	5.90	48.80	843.90
1982	104.10	62.10	48.10	91.40	69.30	47.60	39.90	16.10	7.80	200.90	20.60	57.30	765.20
1983	81.90	134.60	110.00	151.50	108.20	83.70	97.20	32.30	52.60	94.10	23.50	51.90	1021.50
1984	69.60	165.50	104.90	111.50	309.60	61.10	29.60	6.80	20.00	12.70	1.90	29.60	922.80
1985	156.10	146.60	94.80	166.90	60.30	88.20	52.40	10.80	11.50	1.50	112.60	98.60	1000.30
1986	127.10	101.50	70.00	131.00	33.00	140.90	36.00	25.10	24.30	3.60	71.80	384.60	1148.90
1987	62.30	149.90	98.30	87.40	206.00	289.20	63.00	113.00	32.50	75.00	67.60	36.40	1280.60
1988	90.70	165.00	220.50	52.30	246.50	94.30	134.20	22.30	35.20	20.10	3.10	57.80	1142.00
1989	167.30	193.70	52.40	131.10	48.30	190.40	23.60	11.70	8.10	3.40	106.10	40.60	976.70
1990	105.70	56.90	84.80	142.50	139.80	66.40	13.40	37.20	9.90	7.90	42.00	77.50	784.00
1991	144.00	145.30	72.60	113.90	61.40	66.70	69.50	5.20	13.10	0.80	41.50	67.50	801.50
1992	82.30	79.10	115.30	88.60	73.50	31.70	50.90	14.10	8.30	3.00	38.10	106.90	691.80
1993	106.00	99.60	168.40	71.70	262.30	94.60	6.40	6.20	11.60	47.70	81.40	5.20	961.10
1994	60.80	44.90	188.00	92.90	53.10	199.20	164.30	33.80	94.20	10.80	5.90	60.20	1008.10
1995	89.30	82.00	278.50	124.80	147.40	50.80	55.30	19.90	9.80	130.30	18.10	41.20	1047.40
1996	115.00	247.90	94.00	143.20	160.10	94.60	168.60	29.80	277.60	48.00	23.40	74.40	1476.60
month	7703.50	9679.30	9028.60	9107.90	9466.50	9278.00	5217.60	3579.70	2580.30	2841.10	3035.20	5527.30	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	37.90	17.80	18.90	30.50	33.00	17.60	4.20	0.10	0.00	0.00	1.00	5.20	675.90
max	282.70	328.50	281.30	267.80	309.60	353.10	497.50	242.90	277.60	404.30	163.20	384.60	1476.60
median	90.70	123.60	107.80	107.30	109.40	111.50	47.60	26.10	14.30	16.50	28.60	61.30	999.30
mean	100.05	125.71	117.25	118.28	122.94	120.49	67.76	46.49	33.51	36.90	39.42	71.78	1000.58

Sum of the monthly means = 1000.58

s.d.	48.95	60.89	48.58	44.49	58.38	65.53	65.70	50.73	51.40	60.22	34.08	54.01	171.34
c.v.	0.49	0.48	0.41	0.38	0.47	0.54	0.97	1.09	1.53	1.63	0.86	0.75	0.17

APPENDIX 4.3
LUSIKISIKI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	47.25	116.28	132.57	95.13	104.85	122.13	63.36	8.28	0.00	2.97	1.08	70.38	764.28
1921	78.21	165.51	146.79	90.27	59.04	26.01	26.10	163.35	67.05	0.00	75.60	46.98	944.91
1922	137.61	186.66	63.36	241.02	204.93	131.94	15.12	20.52	8.10	186.57	1.98	19.17	1216.98
1923	41.22	75.15	106.92	187.74	131.40	23.40	18.45	24.57	13.05	3.87	39.69	70.74	736.20
1924	72.18	101.88	131.58	89.73	108.45	167.13	64.44	19.71	5.85	20.52	6.48	90.63	878.58
1925	59.76	95.40	93.51	121.59	103.41	184.59	29.25	33.57	65.88	1.89	13.86	74.07	876.78
1926	96.21	120.87	118.44	81.09	76.05	245.79	3.78	13.68	0.36	6.57	24.30	55.44	842.58
1927	91.89	25.83	132.21	122.04	124.38	74.52	15.66	38.16	13.05	3.87	70.74	21.15	733.50
1928	75.51	99.18	90.63	103.95	67.68	132.84	15.75	42.57	147.51	62.19	43.47	119.16	1000.44
1929	131.31	125.64	75.69	90.72	54.36	100.35	54.54	20.34	71.10	23.22	67.86	105.12	920.25
1930	49.50	68.94	92.52	195.57	141.66	173.07	41.94	5.22	2.97	363.87	17.19	28.35	1180.80
1931	95.76	67.23	93.06	60.21	191.88	82.26	13.59	60.93	31.50	39.51	17.01	146.88	899.82
1932	86.13	224.73	170.37	27.45	107.91	88.11	27.99	23.67	7.20	11.88	10.17	35.19	820.80
1933	35.82	171.81	153.81	170.64	78.03	107.91	40.77	26.46	6.03	96.66	4.32	15.48	907.74
1934	49.86	122.40	153.27	85.41	51.39	119.25	127.71	115.38	133.29	13.14	79.74	22.41	1073.25
1935	57.69	87.84	17.01	98.46	237.51	155.88	20.43	122.58	29.07	18.72	2.16	57.60	904.95
1936	121.59	275.49	54.18	89.37	160.56	122.40	30.24	8.91	9.09	32.49	26.01	37.17	967.50
1937	63.63	66.96	140.49	107.91	85.41	38.25	118.17	18.00	40.50	33.39	19.71	14.76	747.18
1938	59.49	112.32	113.85	119.52	147.06	85.14	42.84	62.91	11.79	57.69	47.70	158.31	1018.62
1939	86.49	62.28	121.68	58.86	74.25	90.00	34.20	102.96	14.58	9.72	20.61	38.97	714.60
1940	45.18	142.11	87.39	73.71	36.72	70.92	40.41	8.91	24.48	14.58	25.74	38.16	608.31
1941	82.44	96.03	57.33	221.85	54.99	104.58	26.46	65.61	0.00	3.06	53.64	52.92	818.91
1942	83.88	235.44	155.97	88.56	65.88	137.97	119.34	27.18	38.43	14.58	109.17	43.47	1119.87
1943	95.67	137.70	124.92	84.42	132.66	62.10	39.60	14.31	29.52	26.19	9.81	168.48	925.38
1944	75.06	50.67	42.12	137.25	111.15	103.77	23.04	34.29	8.64	16.74	6.93	67.32	676.98
1945	186.93	16.02	69.48	83.79	133.20	136.53	63.45	11.16	12.87	15.75	4.23	48.87	782.28
1946	63.99	135.99	90.54	97.65	101.07	140.49	116.10	37.44	99.72	19.80	7.20	55.17	965.16
1947	49.50	295.65	110.88	90.36	148.95	106.83	58.41	4.77	1.71	0.72	9.72	21.87	899.37
1948	152.28	70.38	99.81	86.58	217.53	108.54	71.55	6.12	0.54	13.41	23.13	51.39	901.26
1949	80.82	158.94	80.91	141.75	101.43	85.32	74.16	70.38	2.52	37.08	67.68	28.98	929.97
1950	85.86	41.76	192.42	114.75	69.75	113.67	24.93	20.97	17.01	10.26	48.60	58.50	798.48
1951	133.83	17.46	164.61	125.82	83.43	98.10	77.31	22.05	6.30	7.92	0.90	81.81	819.54
1952	40.05	73.44	75.87	90.27	98.46	71.28	56.25	10.89	8.46	2.61	40.95	93.96	662.49
1953	92.97	153.09	130.68	82.44	74.16	109.62	16.92	66.51	36.54	16.29	8.37	84.06	871.65
1954	219.60	66.60	74.61	178.92	155.34	104.49	40.77	18.09	21.33	0.45	4.50	91.17	975.87
1955	67.32	93.69	36.45	33.12	148.14	184.68	74.79	23.49	31.32	9.54	14.49	74.79	791.82
1956	109.71	197.28	253.17	118.53	104.76	144.72	119.88	15.03	32.04	8.91	39.51	88.29	1231.83
1957	94.32	99.99	115.92	144.00	162.63	88.29	120.24	2.70	0.00	25.65	11.70	44.73	910.17
1958	55.62	137.34	99.36	56.52	107.82	79.20	63.45	218.61	1.17	53.91	64.53	45.27	982.80
1959	69.21	81.63	95.49	94.23	71.28	116.55	73.44	59.04	1.62	19.98	38.52	70.02	791.01
1960	48.15	127.26	141.75	122.85	76.23	108.27	194.22	44.55	10.89	50.76	17.73	42.21	984.87
1961	53.19	148.77	101.52	96.57	105.48	139.59	30.60	34.38	0.45	1.17	66.42	35.64	813.78
1962	112.77	140.76	83.70	186.57	71.73	276.30	40.50	37.53	13.86	142.74	9.27	19.08	1134.81
1963	110.52	112.41	102.24	186.93	120.24	107.19	106.83	15.12	204.84	10.98	16.11	59.40	1152.81
1964	134.19	39.06	72.00	103.77	65.07	24.39	30.87	58.32	173.34	40.14	67.41	58.50	867.06
1965	176.67	121.86	78.57	99.90	70.74	15.84	40.95	169.38	12.78	3.69	34.11	67.14	891.63
1966	41.94	71.73	101.25	138.78	93.06	205.65	119.88	10.44	36.27	81.54	16.47	14.22	931.23
1967	54.36	116.01	64.44	87.12	90.27	64.80	47.61	2.43	10.62	10.08	63.81	91.89	703.44
1968	74.88	108.54	97.02	49.59	161.91	155.25	37.62	136.71	12.87	16.56	29.34	39.69	919.98
1969	84.78	112.59	87.30	55.26	91.44	30.78	40.05	38.61	59.94	4.14	146.88	63.36	815.13
1970	178.56	107.37	87.84	103.41	95.49	75.42	69.57	145.44	5.22	79.83	96.30	46.89	1091.34
1971	175.59	80.01	100.71	92.61	197.46	61.56	39.33	13.14	30.60	14.85	25.74	20.70	852.30
1972	42.84	149.31	98.37	90.63	77.40	87.84	99.00	0.09	0.54	10.62	64.44	85.32	806.40
1973	73.80	146.70	77.76	93.24	120.15	104.85	45.54	148.77	42.30	11.52	6.93	37.35	908.91
1974	51.30	111.24	120.60	85.23	88.92	79.83	47.16	17.91	6.12	16.02	26.37	180.99	831.69
1975	34.11	80.28	160.83	94.86	180.54	317.79	74.43	91.71	5.58	8.10	25.83	87.66	1161.72
1976	254.43	42.03	74.97	113.04	148.77	77.04	22.95	8.46	31.95	15.30	61.11	69.12	919.17
1977	92.61	151.56	156.87	94.32	75.15	87.12	447.75	53.37	19.53	4.95	39.78	59.49	1282.50
1978	138.51	95.94	76.23	79.47	80.55	122.85	31.50	22.14	6.30	91.62	45.54	61.38	852.03
1979	86.85	62.46	88.74	68.04	94.68	64.62	26.37	36.81	5.58	16.02	15.30	156.33	721.80
1980	48.51	143.46	102.96	125.37	83.16	50.04	18.45	102.51	9.54	8.82	80.64	26.37	799.83
1981	37.26	81.27	69.66	117.72	60.93	215.10	75.96	18.72	16.11	17.55	5.31	43.92	759.51
1982	93.69	55.89	43.29	82.26	62.37	42.84	35.91	14.49	7.02	180.81	18.54	51.57	688.68
1983	73.71	121.14	99.00	136.35	97.38	75.33	87.48	29.07	47.34	84.69	21.15	46.71	919.35
1984	62.64	148.95	94.41	100.35	278.64	54.99	26.64	6.12	18.00	11.43	1.71	26.64	830.52
1985	140.49	131.94	85.32	150.21	54.27	79.38	47.16	9.72	10.35	1.35	101.34	88.74	900.27
1986	114.39	91.35	63.00	117.90	29.70	126.81	32.40	22.59	21.87	3.24	64.62	346.14	1034.01
1987	56.07	134.91	88.47	78.66	185.40	260.28	56.70	101.70	29.25	67.50	60.84	32.76	1152.54
1988	81.63	148.50	198.45	47.07	221.85	84.87	120.78	20.07	31.68	18.09	2.79	52.02	1027.80
1989	150.57	174.33	47.16	117.99	43.47	171.36	21.24	10.53	7.29	3.06	95.49	36.54	879.03
1990	95.13	51.21	76.32	128.25	125.82	59.76	12.06	33.48	8.91	7.11	37.80	69.75	705.60
1991	129.60	130.77	65.34	102.51	55.26	60.03	62.55	4.68	11.79	0.72	37.35	60.75	721.35
1992	74.07	71.19	103.77	79.74	66.15	28.53	45.81	12.69	7.47	2.70	34.29	96.21	622.62
1993	95.40	89.64	151.56	64.53	236.07	85.14	5.76	5.58	10.44	42.93	73.26	4.68	864.99
1994	54.72	40.41	169.20	83.61	47.79	179.28	147.87	30.42	84.78	9.72	5.31	54.18	907.29
1995	80.37	73.80	250.65	112.32	132.66	45.72	49.77	17.91	8.82	117.27	16.29	37.08	942.66
1996	103.50	223.11	84.60	128.88	144.09	85.14	151.74	26.82	249.84	43.20	21.06	66.96	1328.94
month	6933.15	8711.37	8125.74	8197.11	8519.85	8350.20	4695.84	3221.73	2322.27	2556.99	2731.68	4974.57	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	34.11	16.02	17.01	27.45	29.70	15.84	3.78	0.09	0.00	0.00	0.90	4.68	608.31
max	254.43	295.65	253.17	241.02	278.64	317.79	447.75	218.61	249.84	363.87	146.88	346.14	1328.94
median	81.63	111.24	97.02	96.57	98.46	100.35	42.84	23.49	12.87	14.85	25.74	55.17	899.37
mean	90.04	113.13	105.53	106.46	110.65	108.44	60.98	41.84	30.16	33.21	35.48	64.60	900.53
Sum of the monthly means = 900.53													
s.d.	44.06	54.80	43.72	40.04	52.54	58.98	59.13	45.66	46.26	54.20	30.67	48.61	154.20
c.v.	0.49	0.48	0.41	0.38	0.47	0.54	0.97	1.09	1.53	1.63	0.86	0.75	0.17

APPENDIX 4.4
TUNGWANA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	57.75	142.12	162.03	116.27	128.15	149.27	77.44	10.12	0.00	3.63	1.32	86.02	934.12
1921	95.59	202.29	179.41	110.33	72.16	31.79	31.90	199.65	81.95	0.00	92.40	57.42	1154.89
1922	168.19	228.14	77.44	294.58	250.47	161.26	18.48	25.08	9.90	228.03	2.42	23.43	1487.42
1923	50.38	91.85	130.68	229.46	160.60	28.60	22.55	30.03	15.95	4.73	48.51	86.46	899.80
1924	88.22	124.52	160.82	109.67	132.55	204.27	78.76	24.09	7.15	25.08	7.92	110.77	1073.82
1925	73.04	116.60	114.29	148.61	126.39	225.61	35.75	41.03	80.52	2.31	16.94	90.53	1071.62
1926	117.59	147.73	144.76	99.11	92.95	300.41	4.62	16.72	0.44	8.03	29.70	67.76	1029.82
1927	112.31	31.57	161.59	149.16	152.02	91.08	19.14	46.64	15.95	4.73	86.46	25.85	896.50
1928	92.29	121.22	110.77	127.05	82.72	162.36	19.25	52.03	180.29	76.01	53.13	145.64	1222.76
1929	160.49	153.56	92.51	110.88	66.44	122.65	66.66	24.86	86.90	28.38	82.94	128.48	1124.75
1930	60.50	84.26	113.08	239.03	173.14	211.53	51.26	6.38	3.63	444.73	21.01	34.65	1443.20
1931	117.04	82.17	113.74	73.59	234.52	100.54	16.61	74.47	38.50	48.29	20.79	179.52	1099.78
1932	105.27	274.67	208.23	33.55	131.89	107.69	34.21	28.93	8.80	14.52	12.43	43.01	1003.20
1933	43.78	209.99	187.99	208.56	95.37	131.89	49.83	32.34	7.37	118.14	5.28	18.92	1109.46
1934	60.94	149.60	187.33	104.39	62.81	145.75	156.09	141.02	162.91	16.06	97.46	27.39	1311.75
1935	70.51	107.36	20.79	120.34	290.29	190.52	24.97	149.82	35.53	22.88	2.64	70.40	1106.05
1936	148.61	336.71	66.22	109.23	196.24	149.60	36.96	10.89	11.11	39.71	31.79	45.43	1182.50
1937	77.77	81.84	171.71	131.89	104.39	46.75	144.43	22.00	49.50	40.81	24.09	18.04	913.22
1938	72.71	137.28	139.15	146.08	179.74	104.06	52.36	76.89	14.41	70.51	58.30	193.49	1244.98
1939	105.71	76.12	148.72	71.94	90.75	110.00	41.80	125.84	17.82	11.88	25.19	47.63	873.40
1940	55.22	173.69	106.81	90.09	44.88	86.68	49.39	10.89	29.92	17.82	31.46	46.64	743.49
1941	100.76	117.37	70.07	271.15	67.21	127.82	32.34	80.19	0.00	3.74	65.56	64.68	1000.89
1942	102.52	287.76	190.63	108.24	80.52	168.63	145.86	33.22	46.97	17.82	133.43	53.13	1368.73
1943	116.93	168.30	152.68	103.18	162.14	75.90	48.40	17.49	36.08	32.01	11.99	205.92	1131.02
1944	91.74	61.93	51.48	167.75	135.85	126.83	28.16	41.91	10.56	20.46	8.47	82.28	827.42
1945	228.47	19.58	84.92	102.41	162.80	166.87	77.55	13.64	15.73	19.25	5.17	59.73	956.12
1946	78.21	166.21	110.66	119.35	123.53	171.71	141.90	45.76	121.88	24.20	8.80	67.43	1179.64
1947	60.50	361.35	135.52	110.44	182.05	130.57	71.39	5.83	2.09	0.88	11.88	26.73	1099.23
1948	186.12	86.02	121.99	105.82	265.87	132.66	87.45	7.48	0.66	16.39	28.27	62.81	1101.54
1949	98.78	194.26	98.89	173.25	123.97	104.28	90.64	86.02	3.08	45.32	82.72	35.42	1136.63
1950	104.94	51.04	235.18	140.25	85.25	138.93	30.47	25.63	20.79	12.54	59.40	71.50	975.92
1951	163.57	21.34	201.19	153.78	101.97	119.90	94.49	26.95	7.70	9.68	1.10	99.99	1001.66
1952	48.95	89.76	92.73	110.33	120.34	87.12	68.75	13.31	10.34	3.19	50.05	114.84	809.71
1953	113.63	187.11	159.72	100.76	90.64	133.98	20.68	81.29	44.66	19.91	10.23	102.74	1065.35
1954	268.40	81.40	91.19	218.68	189.86	127.71	49.83	22.11	26.07	0.55	5.50	111.43	1192.73
1955	82.28	114.51	44.55	40.48	181.06	225.72	91.41	28.71	38.28	11.66	17.71	91.41	967.78
1956	134.09	241.12	309.43	144.87	128.04	176.88	146.52	18.37	39.16	10.89	48.29	107.91	1505.57
1957	115.28	122.21	141.68	176.00	198.77	107.91	146.96	3.30	0.00	31.35	14.30	54.67	1112.43
1958	67.98	167.86	121.44	69.08	131.78	96.80	77.55	267.19	1.43	65.89	78.87	55.33	1201.20
1959	84.59	99.77	116.71	115.17	87.12	142.45	89.76	72.16	1.98	24.42	47.08	85.58	966.79
1960	58.85	155.54	173.25	150.15	93.17	132.33	237.38	54.45	13.31	62.04	21.67	51.59	1203.73
1961	65.01	181.83	124.08	118.03	128.92	170.61	37.40	42.02	0.55	1.43	81.18	43.56	994.62
1962	137.83	172.04	102.30	228.03	87.67	337.70	49.50	45.87	16.94	174.46	11.33	23.32	1386.99
1963	135.08	137.39	124.96	228.47	146.96	131.01	130.57	18.48	250.36	13.42	19.69	72.60	1408.99
1964	164.01	47.74	88.00	126.83	79.53	29.81	37.73	71.28	211.86	49.06	82.39	71.50	1059.74
1965	215.93	148.94	96.03	122.10	86.46	19.36	50.05	207.02	15.62	4.51	41.69	82.06	1089.77
1966	51.26	87.67	123.75	169.62	113.74	251.35	146.52	12.76	44.33	99.66	20.13	17.38	1138.17
1967	66.44	141.79	78.76	106.48	110.33	79.20	58.19	2.97	12.98	12.32	77.99	112.31	859.76
1968	91.52	132.66	118.58	60.61	197.89	189.75	45.98	167.09	15.73	20.24	35.86	48.51	1124.42
1969	103.62	137.61	106.70	67.54	111.76	37.62	48.95	47.19	73.26	5.06	179.52	77.44	996.27
1970	218.24	131.23	107.36	126.39	116.71	92.18	85.03	177.76	6.38	97.57	117.70	57.31	1333.86
1971	214.61	97.79	123.09	113.19	241.34	75.24	48.07	16.06	37.40	18.15	31.46	25.30	1041.70
1972	52.36	182.49	120.23	110.77	94.60	107.36	121.00	0.11	0.66	12.98	78.76	104.28	985.60
1973	90.20	179.30	95.04	113.96	146.85	128.15	55.66	181.83	51.70	14.08	8.47	45.65	1110.89
1974	62.70	135.96	147.40	104.17	108.68	97.57	57.64	21.89	7.48	19.58	32.23	221.21	1016.51
1975	41.69	98.12	196.57	115.94	220.66	388.41	90.97	112.09	6.82	9.90	31.57	107.14	1419.88
1976	310.97	51.37	91.63	138.16	181.83	94.16	28.05	10.34	39.05	18.70	74.69	84.48	1123.43
1977	113.19	185.24	191.73	115.28	91.85	106.48	547.25	65.23	23.87	6.05	48.62	72.71	1567.50
1978	169.29	117.26	93.17	97.13	98.45	150.15	38.50	27.06	7.70	111.98	55.66	75.02	1041.37
1979	106.15	76.34	108.46	83.16	115.72	78.98	32.23	44.99	6.82	19.58	18.70	191.07	882.20
1980	59.29	175.34	125.84	153.23	101.64	61.16	22.55	125.29	11.66	10.78	98.56	32.23	977.57
1981	45.54	99.33	85.14	143.88	74.47	262.90	92.84	22.88	19.69	21.45	6.49	53.68	928.29
1982	114.51	68.31	52.91	100.54	76.23	52.36	43.89	17.71	8.58	220.99	22.66	63.03	841.72
1983	90.09	148.06	121.00	166.65	119.02	92.07	106.92	35.53	57.86	103.51	25.85	57.09	1123.65
1984	76.56	182.05	115.39	122.65	340.56	67.21	32.56	7.48	22.00	13.97	2.09	32.56	1015.08
1985	171.71	161.26	104.28	183.59	66.33	97.02	57.64	11.88	12.65	1.65	123.86	108.46	1100.33
1986	139.81	111.65	77.00	144.10	36.30	154.99	39.60	27.61	26.73	3.96	78.98	423.06	1263.79
1987	68.53	164.89	108.13	96.14	226.60	318.12	69.30	124.30	35.75	82.50	74.36	40.04	1408.66
1988	99.77	181.50	242.55	57.53	271.15	103.73	147.62	24.53	38.72	22.11	3.41	63.58	1256.20
1989	184.03	213.07	57.64	144.21	53.13	209.44	25.96	12.87	8.91	3.74	116.71	44.66	1074.37
1990	116.27	62.59	93.28	156.75	153.78	73.04	14.74	40.92	10.89	8.69	46.20	85.25	862.40
1991	158.40	159.83	79.86	125.29	67.54	73.37	76.45	5.72	14.41	0.88	45.65	74.25	881.65
1992	90.53	87.01	126.83	97.46	80.85	34.87	55.99	15.51	9.13	3.30	41.91	117.59	760.98
1993	116.60	109.56	185.24	78.87	288.53	104.06	7.04	6.82	12.76	52.47	89.54	5.72	1057.21
1994	66.88	49.39	206.80	102.19	58.41	219.12	180.73	37.18	103.62	11.88	6.49	66.22	1108.91
1995	98.23	90.20	306.35	137.28	162.14	55.88	60.83	21.89	10.78	143.33	19.91	45.32	1152.14
1996	126.50	272.69	103.40	157.52	176.11	104.06	185.46	32.78	305.36	52.80	25.74	81.84	1624.26
month	8473.85	10647.23	9931.46	10018.69	10413.15	10205.80	5739.36	3937.67	2838.33	3125.21	3338.72	6080.03	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	41.69	19.58	20.79	33.55	36.30	19.36	4.62	0.11	0.00	0.00	1.10	5.72	743.49
max	310.97	361.35	309.43	294.58	340.56	388.41	547.25	267.19	305.36	444.73	179.52	423.06	1624.26
median	99.77	135.96	118.58	118.03	120.34	122.65	52.36	28.71	15.73	18.15	31.46	67.43	1099.23
mean	110.05	138.28	128.98	130.11	135.24	132.54	74.54	51.14	36.86	40.59	43.36	78.96	1100.64
Sum of the monthly means = 1100.64													
s.d.	53.85	66.98	53.43	48.94	64.22	72.09	72.27	55.80	56.54	66.24	37.49	59.41	188.47
c.v.	0.49	0.48	0.41	0.38	0.47	0.54	0.97	1.09	1.53	1.63	0.86	0.75	0.17

APPENDIX 4.5
LOWER MZINTLAVA

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	52.50	129.20	147.30	105.70	116.50	135.70	70.40	9.20	0.00	3.30	1.20	78.20	849.20
1921	86.90	183.90	163.10	100.30	65.60	28.90	29.00	181.50	74.50	0.00	84.00	52.20	1049.90
1922	152.90	207.40	70.40	267.80	227.70	146.60	16.80	22.80	9.00	207.30	2.20	21.30	1352.20
1923	45.80	83.50	118.80	208.60	146.00	26.00	20.50	27.30	14.50	4.30	44.10	78.60	818.00
1924	80.20	113.20	146.20	99.70	120.50	185.70	71.60	21.90	6.50	22.80	7.20	100.70	976.20
1925	66.40	106.00	103.90	135.10	114.90	205.10	32.50	37.30	73.20	2.10	15.40	82.30	974.20
1926	106.90	134.30	131.60	90.10	84.50	273.10	4.20	15.20	0.40	7.30	27.00	61.60	936.20
1927	102.10	28.70	146.90	135.60	138.20	82.80	17.40	42.40	14.50	4.30	78.60	23.50	815.00
1928	83.90	110.20	100.70	115.50	75.20	147.60	17.50	47.30	163.90	69.10	48.30	132.40	1111.60
1929	145.90	139.60	84.10	100.80	60.40	111.50	60.60	22.60	79.00	25.80	75.40	116.80	1022.50
1930	55.00	76.60	102.80	217.30	157.40	192.30	46.60	5.80	3.30	404.30	19.10	31.50	1312.00
1931	106.40	74.70	103.40	66.90	213.20	91.40	15.10	67.70	35.00	43.90	18.90	163.20	999.80
1932	95.70	249.70	189.30	30.50	119.90	97.90	31.10	26.30	8.00	13.20	11.30	39.10	912.00
1933	39.80	190.90	170.90	189.60	86.70	119.90	45.30	29.40	6.70	107.40	4.80	17.20	1008.60
1934	55.40	136.00	170.30	94.90	57.10	132.50	141.90	128.20	148.10	14.60	88.60	24.90	1192.50
1935	64.10	97.60	18.90	109.40	263.90	173.20	22.70	136.20	32.30	20.80	2.40	64.00	1005.50
1936	135.10	306.10	60.20	99.30	178.40	136.00	33.60	9.90	10.10	36.10	28.90	41.30	1075.00
1937	70.70	74.40	156.10	119.90	94.90	42.50	131.30	20.00	45.00	37.10	21.90	16.40	830.20
1938	66.10	124.80	126.50	132.80	163.40	94.60	47.60	69.90	13.10	64.10	53.00	175.90	1131.80
1939	96.10	69.20	135.20	65.40	82.50	100.00	38.00	114.40	16.20	10.80	22.90	43.30	794.00
1940	50.20	157.90	97.10	81.90	40.80	78.80	44.90	9.90	27.20	16.20	28.60	42.40	675.90
1941	91.60	106.70	63.70	246.50	61.10	116.20	29.40	72.90	0.00	3.40	59.60	58.80	909.90
1942	93.20	261.60	173.30	98.40	73.20	153.30	132.60	30.20	42.70	16.20	121.30	48.30	1244.30
1943	106.30	153.00	138.80	93.80	147.40	69.00	44.00	15.90	32.80	29.10	10.90	187.20	1028.20
1944	83.40	56.30	46.80	152.50	123.50	115.30	25.60	38.10	9.60	18.60	7.70	74.80	752.20
1945	207.70	17.80	77.20	93.10	148.00	151.70	70.50	12.40	14.30	17.50	4.70	54.30	869.20
1946	71.10	151.10	100.60	108.50	112.30	156.10	129.00	41.60	110.80	22.00	8.00	61.30	1072.40
1947	55.00	328.50	123.20	100.40	165.50	118.70	64.90	5.30	1.90	0.80	10.80	24.30	999.30
1948	169.20	78.20	110.90	96.20	241.70	120.60	79.50	6.80	0.60	14.90	25.70	57.10	1001.40
1949	89.80	176.60	89.90	157.50	112.70	94.80	82.40	78.20	2.80	41.20	75.20	32.20	1033.30
1950	95.40	46.40	213.80	127.50	77.50	126.30	27.70	23.30	18.90	11.40	54.00	65.00	887.20
1951	148.70	19.40	182.90	139.80	92.70	109.00	85.90	24.50	7.00	8.80	1.00	90.90	910.60
1952	44.50	81.60	84.30	100.30	109.40	79.20	62.50	12.10	9.40	2.90	45.50	104.40	736.10
1953	103.30	170.10	145.20	91.60	82.40	121.80	18.80	73.90	40.60	18.10	9.30	93.40	968.50
1954	244.00	74.00	82.90	198.80	172.60	116.10	45.30	20.10	23.70	0.50	5.00	101.30	1084.30
1955	74.80	104.10	40.50	36.80	164.60	205.20	83.10	26.10	34.80	10.60	16.10	83.10	879.80
1956	121.90	219.20	281.30	131.70	116.40	160.80	133.20	16.70	35.60	9.90	43.90	98.10	1368.70
1957	104.80	111.10	128.80	160.00	180.70	98.10	133.60	3.00	0.00	28.50	13.00	49.70	1011.30
1958	61.80	152.60	110.40	62.80	119.80	88.00	70.50	242.90	1.30	59.90	71.70	50.30	1092.00
1959	76.90	90.70	106.10	104.70	79.20	129.50	81.60	65.60	1.80	22.20	42.80	77.80	878.90
1960	53.50	141.40	157.50	136.50	84.70	120.30	215.80	49.50	12.10	56.40	19.70	46.90	1094.30
1961	59.10	165.30	112.80	107.30	117.20	155.10	34.00	38.20	0.50	1.30	73.80	39.60	904.20
1962	125.30	156.40	93.00	207.30	79.70	307.00	45.00	41.70	15.40	158.60	10.30	21.20	1260.90
1963	122.80	124.90	113.60	207.70	133.60	119.10	118.70	16.80	227.60	12.20	17.90	66.00	1280.90
1964	149.10	43.40	80.00	115.30	72.30	27.10	34.30	64.80	192.60	44.60	74.90	65.00	963.40
1965	196.30	135.40	87.30	111.00	78.60	17.60	45.50	188.20	14.20	4.10	37.90	74.60	990.70
1966	46.60	79.70	112.50	154.20	103.40	228.50	133.20	11.60	40.30	90.60	18.30	15.80	1034.70
1967	60.40	128.90	71.60	96.80	100.30	72.00	52.90	2.70	11.80	11.20	70.90	102.10	781.60
1968	83.20	120.60	107.80	55.10	179.90	172.50	41.80	151.90	14.30	18.40	32.60	44.10	1022.20
1969	94.20	125.10	97.00	61.40	101.60	34.20	44.50	42.90	66.60	4.60	163.20	70.40	905.70
1970	198.40	119.30	97.60	114.90	106.10	83.80	77.30	161.60	5.80	88.70	107.00	52.10	1212.60
1971	195.10	88.90	111.90	102.90	219.40	68.40	43.70	14.60	34.00	16.50	28.60	23.00	947.00
1972	47.60	165.90	109.30	100.70	86.00	97.60	110.00	0.10	0.60	11.80	71.60	94.80	896.00
1973	82.00	163.00	86.40	103.60	133.50	116.50	50.60	165.30	47.00	12.80	7.70	41.50	1009.90
1974	57.00	123.60	134.00	94.70	98.80	88.70	52.40	19.90	6.80	17.80	29.30	201.10	924.10
1975	37.90	89.20	178.70	105.40	200.60	353.10	82.70	101.90	6.20	9.00	28.70	97.40	1290.80
1976	282.70	46.70	83.30	125.60	165.30	85.60	25.50	9.40	35.50	17.00	67.90	76.80	1021.30
1977	102.90	168.40	174.30	104.80	83.50	96.80	497.50	59.30	21.70	5.50	44.20	66.10	1425.00
1978	153.90	106.60	84.70	88.30	89.50	136.50	35.00	24.60	7.00	101.80	50.60	68.20	946.70
1979	96.50	69.40	98.60	75.60	105.20	71.80	29.30	40.90	6.20	17.80	17.00	173.70	802.00
1980	53.90	159.40	114.40	139.30	92.40	55.60	20.50	113.90	10.60	9.80	89.60	29.30	888.70
1981	41.40	90.30	77.40	130.80	67.70	239.00	84.40	20.80	17.90	19.50	5.90	48.80	843.90
1982	104.10	62.10	48.10	91.40	69.30	47.60	39.90	16.10	7.80	200.90	20.60	57.30	765.20
1983	81.90	134.60	110.00	151.50	108.20	83.70	97.20	32.30	52.60	94.10	23.50	51.90	1021.50
1984	69.60	165.50	104.90	111.50	309.60	61.10	29.60	6.80	20.00	12.70	1.90	29.60	922.80
1985	156.10	146.60	94.80	166.90	60.30	88.20	52.40	10.80	11.50	1.50	112.60	98.60	1000.30
1986	127.10	101.50	70.00	131.00	33.00	140.90	36.00	25.10	24.30	3.60	71.80	384.60	1148.90
1987	62.30	149.90	98.30	87.40	206.00	289.20	63.00	113.00	32.50	75.00	67.60	36.40	1280.60
1988	90.70	165.00	220.50	52.30	246.50	94.30	134.20	22.30	35.20	20.10	3.10	57.80	1142.00
1989	167.30	193.70	52.40	131.10	48.30	190.40	23.60	11.70	8.10	3.40	106.10	40.60	976.70
1990	105.70	56.90	84.80	142.50	139.80	66.40	13.40	37.20	9.90	7.90	42.00	77.50	784.00
1991	144.00	145.30	72.60	113.90	61.40	66.70	69.50	5.20	13.10	0.80	41.50	67.50	801.50
1992	82.30	79.10	115.30	88.60	73.50	31.70	50.90	14.10	8.30	3.00	38.10	106.90	691.80
1993	106.00	99.60	168.40	71.70	262.30	94.60	6.40	6.20	11.60	47.70	81.40	5.20	961.10
1994	60.80	44.90	188.00	92.90	53.10	199.20	164.30	33.80	94.20	10.80	5.90	60.20	1008.10
1995	89.30	82.00	278.50	124.80	147.40	50.80	55.30	19.90	9.80	130.30	18.10	41.20	1047.40
1996	115.00	247.90	94.00	143.20	160.10	94.60	168.60	29.80	277.60	48.00	23.40	74.40	1476.60
month	7703.50	9679.30	9028.60	9107.90	9466.50	9278.00	5217.60	3579.70	2580.30	2841.10	3035.20	5527.30	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	37.90	17.80	18.90	30.50	33.00	17.60	4.20	0.10	0.00	0.00	1.00	5.20	675.90
max	282.70	328.50	281.30	267.80	309.60	353.10	497.50	242.90	277.60	404.30	163.20	384.60	1476.60
median	90.70	123.60	107.80	107.30	109.40	111.50	47.60	26.10	14.30	16.50	28.60	61.30	999.30
mean	100.05	125.71	117.25	118.28	122.94	120.49	67.76	46.49	33.51	36.90	39.42	71.78	1000.58

Sum of the monthly means = 1000.58

s.d.	48.95	60.89	48.58	44.49	58.38	65.53	65.70	50.73	51.40	60.22	34.08	54.01	171.34
c.v.	0.49	0.48	0.41	0.38	0.47	0.54	0.97	1.09	1.53	1.63	0.86	0.75	0.17

APPENDIX 4.6
LUSINDISWENI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	56.16	107.46	128.34	98.10	90.09	131.94	62.37	8.28	2.52	0.90	5.31	54.09	745.56
1921	86.31	178.02	173.43	102.51	76.41	26.46	13.86	164.34	79.02	0.90	65.25	22.23	988.74
1922	100.62	169.29	76.77	163.80	229.59	147.15	8.19	18.18	7.92	207.45	5.76	17.01	1151.73
1923	34.83	56.70	107.73	236.88	147.33	32.94	16.11	26.37	12.15	0.27	33.03	52.83	757.17
1924	84.60	112.05	148.95	45.54	76.14	172.89	56.34	20.34	0.00	11.79	0.36	43.92	772.92
1925	81.90	114.57	85.86	131.04	75.69	196.20	16.47	36.18	60.66	0.99	9.90	76.68	886.14
1926	99.54	93.06	124.38	77.49	80.19	242.01	4.68	17.10	0.36	14.76	36.90	37.44	827.91
1927	90.54	34.02	169.38	183.78	118.89	64.98	13.95	27.72	11.25	3.69	53.01	26.55	797.76
1928	73.62	82.08	69.48	87.39	54.72	151.83	25.11	33.48	128.07	49.14	25.47	117.27	897.66
1929	94.59	99.27	83.70	121.50	74.16	124.74	54.63	13.23	68.58	9.54	71.82	78.75	894.51
1930	59.31	73.89	142.83	190.62	124.38	186.75	28.26	3.78	1.80	253.35	15.12	18.00	1098.09
1931	88.92	64.44	84.24	76.14	179.82	67.95	11.43	48.78	31.59	41.22	13.32	112.86	820.71
1932	85.32	212.13	177.12	35.28	59.40	106.92	38.25	18.72	7.20	14.13	10.80	19.08	784.35
1933	31.23	194.58	167.94	145.53	88.02	88.02	55.53	22.59	3.51	71.55	2.52	28.71	899.73
1934	52.29	111.15	166.50	81.90	82.53	90.36	132.93	120.87	109.44	5.22	72.99	17.19	1043.37
1935	53.64	85.05	11.43	102.33	217.35	139.50	8.91	121.05	19.26	16.20	1.17	54.36	830.25
1936	108.18	296.82	74.61	132.48	196.74	96.03	26.73	6.12	10.98	15.57	16.47	27.09	1007.82
1937	67.86	78.57	114.48	99.72	126.81	41.76	98.82	14.76	32.31	27.90	26.28	18.72	747.99
1938	64.35	101.70	138.06	98.64	161.73	65.70	40.68	53.19	9.00	45.36	33.21	150.84	962.46
1939	80.73	88.29	129.06	72.36	82.62	90.00	46.80	124.38	23.67	6.66	11.25	40.23	796.05
1940	54.45	138.15	130.14	65.97	48.69	91.26	39.87	5.22	14.67	14.40	26.91	42.30	672.03
1941	77.85	79.29	72.00	183.78	86.22	118.35	43.83	48.24	0.63	3.51	47.61	48.06	809.37
1942	95.58	201.33	183.06	100.98	72.99	162.81	122.31	33.12	41.76	26.28	106.20	39.69	1186.11
1943	116.64	157.23	145.35	83.16	138.06	74.88	33.30	27.09	24.93	24.57	8.82	141.57	975.60
1944	71.10	45.99	38.07	139.41	105.39	125.28	15.48	36.99	5.85	12.69	4.95	48.78	649.98
1945	158.13	20.07	63.36	89.73	135.81	145.35	54.00	15.12	9.09	13.86	5.67	49.68	759.87
1946	67.05	126.00	95.31	107.64	130.68	135.63	94.77	28.89	119.88	19.44	11.07	49.41	985.77
1947	56.70	281.16	115.47	121.77	144.54	114.66	62.55	5.49	0.63	0.81	10.17	18.63	932.58
1948	147.15	69.57	109.80	111.06	152.28	92.34	75.51	6.48	0.45	15.84	19.17	38.61	838.26
1949	87.21	141.30	73.62	167.94	102.33	99.45	64.44	68.58	2.34	40.59	75.51	28.17	951.48
1950	71.19	52.47	208.44	99.54	78.66	125.37	22.14	22.50	14.22	9.72	51.21	60.21	815.67
1951	123.12	22.32	146.16	123.39	110.88	80.91	94.68	21.69	6.30	8.91	2.61	69.21	810.18
1952	34.92	74.52	79.11	90.81	105.30	69.93	55.62	9.45	7.56	2.70	38.70	79.20	647.82
1953	97.65	131.31	145.35	92.34	99.00	98.10	16.56	73.53	31.32	12.96	7.56	77.13	882.81
1954	210.69	69.48	76.59	186.21	186.66	103.68	51.93	19.26	20.88	1.17	4.77	80.28	1011.60
1955	69.84	97.47	45.54	28.35	151.11	180.81	91.08	25.29	27.45	9.72	16.65	60.57	803.88
1956	110.70	168.93	240.48	120.87	112.14	154.26	105.30	15.84	27.09	10.98	41.04	105.84	1213.47
1957	102.15	123.12	84.24	149.49	165.69	82.71	110.70	3.60	0.45	19.35	7.02	44.73	893.25
1958	56.16	141.30	109.44	84.42	107.37	85.59	69.57	226.26	0.00	44.10	53.19	38.16	1015.56
1959	71.28	95.94	101.07	94.23	90.72	109.62	69.84	45.63	2.61	14.31	34.11	63.99	793.35
1960	54.09	129.15	150.84	133.83	75.33	128.70	184.77	31.41	8.91	27.81	10.53	43.02	978.39
1961	48.33	145.80	98.64	119.16	141.30	130.14	26.19	36.54	1.71	0.72	56.70	29.07	834.30
1962	113.40	148.41	103.86	191.43	80.37	277.74	45.18	20.52	12.96	129.24	11.16	20.43	1154.70
1963	117.18	137.70	139.86	182.97	102.51	103.86	106.11	11.97	202.59	11.25	16.11	59.94	1192.05
1964	165.69	34.02	94.05	111.60	84.33	30.78	36.27	49.77	158.49	50.13	67.86	58.59	941.58
1965	149.49	128.34	78.84	114.39	69.93	21.06	42.57	178.38	11.25	2.70	35.82	62.73	895.50
1966	51.57	83.52	109.98	131.22	108.36	224.19	97.65	13.41	38.61	66.15	11.88	11.07	947.61
1967	63.18	122.22	64.26	96.66	87.12	79.47	52.65	2.97	5.04	8.91	65.97	81.27	729.72
1968	79.38	98.82	99.72	50.76	162.00	156.51	33.21	100.08	6.30	15.93	32.67	41.49	876.87
1969	89.19	106.20	98.91	70.20	85.41	33.84	31.32	50.76	48.24	3.15	92.61	67.05	776.88
1970	160.02	95.40	120.78	115.29	98.28	83.61	59.40	116.55	5.49	62.82	98.37	46.80	1062.81
1971	173.34	74.07	95.85	123.03	163.62	77.40	27.81	12.42	30.69	11.25	10.98	24.66	825.12
1972	48.33	152.19	87.21	94.59	99.99	93.51	55.44	1.08	0.00	9.36	55.44	76.32	773.46
1973	70.47	133.11	78.57	128.97	126.81	139.50	46.08	119.16	36.90	5.40	3.42	30.24	918.63
1974	60.57	125.10	129.87	107.55	121.59	94.23	36.54	5.94	5.31	6.12	19.89	140.31	853.02
1975	40.59	83.61	191.70	146.16	164.16	281.52	63.99	73.08	3.33	4.14	17.91	82.98	1153.17
1976	179.01	60.03	113.85	105.48	106.56	81.72	26.01	11.25	22.41	10.08	32.13	64.44	812.97
1977	124.74	131.67	140.22	120.87	92.16	99.09	368.82	42.66	7.92	0.81	40.41	66.33	1235.70
1978	118.89	117.90	105.66	84.51	96.93	110.34	36.45	2.97	5.94	71.19	28.53	43.02	822.33
1979	80.82	73.44	99.81	71.64	77.94	77.94	20.61	30.24	0.72	7.02	12.15	158.13	710.46
1980	53.46	162.63	118.44	127.53	112.05	65.07	19.89	65.34	4.59	2.79	70.20	32.76	834.75
1981	32.67	78.30	78.84	143.28	77.40	145.26	74.07	16.92	17.46	12.42	1.26	44.10	721.98
1982	109.17	40.59	65.52	87.75	68.58	50.76	46.80	20.25	2.25	42.12	19.89	44.91	598.59
1983	75.51	125.82	111.87	164.25	135.27	114.30	111.51	20.34	26.82	48.96	23.04	38.16	995.85
1984	63.36	121.14	124.38	124.56	241.02	56.43	24.75	2.61	20.52	4.50	0.45	22.23	805.95
1985	193.32	107.28	131.04	114.30	77.94	60.75	29.34	4.50	15.03	1.35	118.35	58.05	911.25
1986	123.39	130.95	81.90	127.80	68.85	117.09	36.00	18.18	11.70	0.00	82.53	263.88	1062.27
1987	65.61	129.69	171.27	91.71	210.15	245.43	62.46	91.80	39.51	60.12	56.70	43.29	1267.74
1988	72.00	143.82	164.52	80.10	242.28	64.08	101.61	17.73	31.59	14.58	0.36	39.42	972.09
1989	146.70	245.52	83.07	111.51	53.91	178.56	39.87	8.82	3.87	2.25	98.01	28.62	1000.71
1990	115.20	58.77	95.94	150.21	108.72	60.93	1.71	25.20	4.59	0.00	24.75	69.75	715.77
1991	164.79	109.17	79.20	104.04	80.46	88.47	39.78	4.14	2.79	0.45	27.27	38.25	738.81
1992	72.09	124.38	121.59	95.67	113.13	39.42	49.14	0.00	2.16	0.00	27.81	114.75	760.14
1993	154.26	92.16	166.41	94.41	159.84	150.12	15.21	1.17	15.21	53.19	27.90	2.07	931.95
1994	45.27	51.48	89.82	120.87	47.34	182.79	88.74	32.67	57.78	0.00	0.00	50.94	767.70
1995	80.01	110.88	292.23	134.55	178.92	91.53	12.42	8.01	1.71	83.43	12.51	41.58	1047.78
1996	84.78	188.55	106.56	151.83	124.02	108.18	138.96	27.36	198.36	36.45	30.96	51.21	1247.22
month	7013.97	8791.92	8921.97	8848.80	8911.71	8659.44	4342.86	2913.93	2046.15	1969.29	2425.41	4389.93	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	31.23	20.07	11.43	28.35	47.34	21.06	1.71	0.00	0.00	0.00	0.00	2.07	598.59
max	210.69	296.82	292.23	236.88	242.28	281.52	368.82	226.26	202.59	253.35	118.35	263.88	1267.74
median	80.82	110.88	109.44	111.51	105.39	99.45	45.18	21.69	11.25	11.79	24.75	46.80	882.81
mean	91.09	114.18	115.87	114.92	115.74	112.46	56.40	37.84	26.57	25.58	31.50	57.01	899.16
Sum of the monthly means = 899.16													
s.d.	40.54	52.91	45.27	37.95	45.91	55.48	50.83	44.22	41.87	41.52	28.68	40.30	153.83
c.v.	0.45	0.46	0.39	0.33	0.40	0.49	0.90	1.17	1.58	1.62	0.91	0.71	0.17

APPENDIX 4.7
KWAHLATHI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	59.28	113.43	135.47	103.55	95.10	139.27	65.84	8.74	2.66	0.95	5.61	57.10	787.00
1921	91.10	187.91	183.06	108.20	80.65	27.93	14.63	173.47	83.41	0.95	68.88	23.47	1043.66
1922	106.21	178.70	81.04	172.90	242.35	155.32	8.65	19.19	8.36	218.97	6.08	17.95	1215.72
1923	36.77	59.85	113.72	250.04	155.51	34.77	17.01	27.83	12.82	0.28	34.86	55.77	799.23
1924	89.30	118.27	157.22	48.07	80.37	182.49	59.47	21.47	0.00	12.44	0.38	46.36	815.84
1925	86.45	120.93	90.63	138.32	79.90	207.10	17.39	38.19	64.03	1.05	10.45	80.94	935.38
1926	105.07	98.23	131.29	81.80	84.65	255.46	4.94	18.05	0.38	15.58	38.95	39.52	873.92
1927	95.57	35.91	178.79	193.99	125.50	68.59	14.72	29.26	11.88	3.90	55.96	28.02	842.09
1928	77.71	86.64	73.34	92.25	57.76	160.26	26.50	35.34	135.19	51.87	26.89	123.78	947.53
1929	99.85	104.79	88.35	128.25	78.28	131.67	57.66	13.96	72.39	10.07	75.81	83.13	944.21
1930	62.60	78.00	150.76	201.21	131.29	197.13	29.83	3.99	1.90	267.42	15.96	19.00	1159.09
1931	93.86	68.02	88.92	80.37	189.81	71.73	12.07	51.49	33.34	43.51	14.06	119.13	866.31
1932	90.06	223.92	186.96	37.24	62.70	112.86	40.37	19.76	7.60	14.92	11.40	20.14	827.93
1933	32.97	205.39	177.27	153.62	92.91	92.91	58.61	23.84	3.70	75.53	2.66	30.31	949.72
1934	55.20	117.32	175.75	86.45	87.12	95.38	140.32	127.58	115.52	5.51	77.04	18.14	1101.33
1935	56.62	89.78	12.07	108.01	229.42	147.25	9.40	127.78	20.33	17.10	1.24	57.38	876.38
1936	114.19	313.31	78.75	139.84	207.67	101.37	28.22	6.46	11.59	16.44	17.39	28.59	1063.82
1937	71.63	82.93	120.84	105.26	133.86	44.08	104.31	15.58	34.10	29.45	27.74	19.76	789.54
1938	67.93	107.35	145.73	104.12	170.72	69.35	42.94	56.15	9.50	47.88	35.05	159.22	1015.94
1939	85.22	93.19	136.23	76.38	87.21	95.00	49.40	131.29	24.99	7.03	11.88	42.47	840.29
1940	57.48	145.82	137.37	69.64	51.40	96.33	42.09	5.51	15.48	15.20	28.41	44.65	709.38
1941	82.17	83.70	76.00	193.99	91.01	124.92	46.26	50.92	0.67	3.70	50.26	50.73	854.33
1942	100.89	212.51	193.23	106.59	77.04	171.85	129.10	34.96	44.08	27.74	112.10	41.90	1251.99
1943	123.12	165.97	153.43	87.78	145.73	79.04	35.15	28.59	26.31	25.93	9.31	149.44	1029.80
1944	75.05	48.55	40.19	147.16	111.25	132.24	16.34	39.04	6.17	13.40	5.22	51.49	686.10
1945	166.91	21.19	66.88	94.71	143.35	153.43	57.00	15.96	9.60	14.63	5.99	52.44	802.09
1946	70.78	133.00	100.60	113.62	137.94	143.17	100.04	30.50	126.54	20.52	11.68	52.15	1040.54
1947	59.85	296.78	121.88	128.53	152.57	121.03	66.03	5.79	0.67	0.86	10.73	19.67	984.39
1948	155.32	73.44	115.90	117.23	160.74	97.47	79.70	6.84	0.48	16.72	20.24	40.75	884.83
1949	92.06	149.15	77.71	177.27	108.01	104.98	68.02	72.39	2.47	42.85	79.70	29.74	1004.35
1950	75.14	55.39	220.02	105.07	83.03	132.33	23.37	23.75	15.01	10.26	54.06	63.56	860.99
1951	129.96	23.56	154.28	130.25	117.04	85.41	99.94	22.89	6.65	9.40	2.76	73.06	855.20
1952	36.86	78.66	83.50	95.86	111.15	73.81	58.71	9.97	7.98	2.85	40.85	83.60	683.80
1953	103.07	138.60	153.43	97.47	104.50	103.55	17.48	77.62	33.06	13.68	7.98	81.41	931.85
1954	222.39	73.34	80.84	196.55	197.03	109.44	54.81	20.33	22.04	1.24	5.03	84.74	1067.78
1955	73.72	102.89	48.07	29.93	159.51	190.86	96.14	26.69	28.97	10.26	17.58	63.94	848.56
1956	116.85	178.31	253.84	127.58	118.37	162.83	111.15	16.72	28.59	11.59	43.32	111.72	1280.87
1957	107.83	129.96	88.92	157.79	174.90	87.31	116.85	3.80	0.48	20.43	7.41	47.21	942.89
1958	59.28	149.15	115.52	89.11	113.34	90.34	73.44	238.83	0.00	46.55	56.15	40.28	1071.99
1959	75.24	101.27	106.68	99.46	95.76	115.71	73.72	48.17	2.76	15.11	36.01	67.55	837.44
1960	57.10	136.33	159.22	141.26	79.52	135.85	195.03	33.16	9.40	29.35	11.12	45.41	1032.75
1961	51.02	153.90	104.12	125.78	149.15	137.37	27.64	38.57	1.81	0.76	59.85	30.69	880.66
1962	119.70	156.65	109.63	202.06	84.83	293.17	47.69	21.66	13.68	136.42	11.78	21.57	1218.84
1963	123.69	145.35	147.63	193.13	108.20	109.63	112.00	12.63	213.85	11.88	17.01	63.27	1258.27
1964	174.90	35.91	99.28	117.80	89.02	32.49	38.28	52.53	167.30	52.91	71.63	61.85	993.90
1965	157.79	135.47	83.22	120.75	73.81	22.23	44.94	188.29	11.88	2.85	37.81	66.22	945.26
1966	54.44	88.16	116.09	138.51	114.38	236.65	103.07	14.15	40.75	69.82	12.54	11.68	1000.24
1967	66.69	129.01	67.83	102.03	91.96	83.89	55.58	3.13	5.32	9.40	69.64	85.79	770.27
1968	83.79	104.31	105.26	53.58	171.00	165.21	35.05	105.64	6.65	16.82	34.48	43.79	925.58
1969	94.14	112.10	104.41	74.10	90.16	35.72	33.06	53.58	50.92	3.33	97.75	70.78	820.05
1970	168.91	100.70	127.49	121.69	103.74	88.25	62.70	123.03	5.79	66.31	103.83	49.40	1121.84
1971	182.97	78.18	101.17	129.87	172.71	81.70	29.35	13.11	32.40	11.88	11.59	26.03	870.96
1972	51.02	160.64	92.06	99.85	105.54	98.71	58.52	1.14	0.00	9.88	58.52	80.56	816.44
1973	74.38	140.50	82.93	136.13	133.86	147.25	48.64	125.78	38.95	5.70	3.61	31.92	969.65
1974	63.94	132.05	137.08	113.52	128.34	99.46	38.57	6.27	5.61	6.46	21.00	148.11	900.41
1975	42.85	88.25	202.35	154.28	173.28	297.16	67.55	77.14	3.51	4.37	18.90	87.59	1217.23
1976	188.95	63.36	120.18	111.34	112.48	86.26	27.45	11.88	23.66	10.64	33.91	68.02	858.13
1977	131.67	138.99	148.01	127.58	97.28	104.59	389.31	45.03	8.36	0.86	42.65	70.02	1304.35
1978	125.50	124.45	111.53	89.20	102.32	116.47	38.48	3.13	6.27	75.14	30.12	45.41	868.02
1979	85.31	77.52	105.36	75.62	82.27	82.27	21.76	31.92	0.76	7.41	12.82	166.91	749.93
1980	56.43	171.67	125.02	134.61	118.27	68.69	21.00	68.97	4.85	2.94	74.10	34.58	881.13
1981	34.48	82.65	83.22	151.24	81.70	153.33	78.18	17.86	18.43	13.11	1.33	46.55	762.08
1982	115.24	42.85	69.16	92.63	72.39	53.58	49.40	21.38	2.38	44.46	21.00	47.40	631.87
1983	79.70	132.81	118.08	173.37	142.79	120.65	117.71	21.47	28.31	51.68	24.32	40.28	1051.17
1984	66.88	127.87	131.29	131.48	254.41	59.56	26.12	2.76	21.66	4.75	0.48	23.47	850.73
1985	204.06	113.24	138.32	120.65	82.27	64.12	30.97	4.75	15.87	1.43	124.92	61.27	961.87
1986	130.25	138.23	86.45	134.90	72.68	123.60	38.00	19.19	12.35	0.00	87.12	278.54	1121.31
1987	69.25	136.90	180.78	96.81	221.82	259.06	65.93	96.90	41.71	63.46	59.85	45.69	1338.16
1988	76.00	151.81	173.66	84.55	255.74	67.64	107.25	18.71	33.34	15.39	0.38	41.61	1026.08
1989	154.85	259.16	87.68	117.71	56.90	188.48	42.09	9.31	4.08	2.38	103.46	30.21	1056.31
1990	121.60	62.03	101.27	158.55	114.76	64.31	1.81	26.60	4.85	0.00	26.12	73.63	755.53
1991	173.95	115.24	83.60	109.82	84.93	93.38	41.99	4.37	2.94	0.48	28.78	40.37	779.85
1992	76.09	131.29	128.34	100.99	119.42	41.61	51.87	0.00	2.28	0.00	29.35	121.13	802.37
1993	162.83	97.28	175.66	99.66	168.72	158.46	16.05	1.24	16.05	56.15	29.45	2.19	983.74
1994	47.79	54.34	94.81	127.58	49.97	192.95	93.67	34.48	60.99	0.00	0.00	53.77	810.35
1995	84.46	117.04	308.46	142.02	188.86	96.62	13.11	8.46	1.81	88.07	13.20	43.89	1106.00
1996	89.49	199.03	112.48	160.26	130.91	114.19	146.68	28.88	209.38	38.48	32.68	54.06	1316.52
month	7403.67	9280.38	9417.61	9340.37	9406.84	9140.53	4584.12	3075.79	2159.85	2078.74	2560.18	4633.87	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	32.97	21.19	12.07	29.93	49.97	22.23	1.81	0.00	0.00	0.00	0.00	2.19	631.87
max	222.39	313.31	308.46	250.04	255.74	297.16	389.31	238.83	213.85	267.42	124.92	278.54	1338.16
median	85.31	117.04	115.52	117.71	111.25	104.98	47.69	22.89	11.88	12.44	26.12	49.40	931.85
mean	96.15	120.52	122.31	121.30	122.17	118.71	59.53	39.95	28.05	27.00	33.25	60.18	949.12

Sum of the monthly means = 949.12

s.d.	42.79	55.85	47.78	40.06	48.46	58.56	53.65	46.68	44.20	43.82	30.28	42.53	162.37
c.v.	0.45	0.46	0.39	0.33	0.40	0.49	0.90	1.17	1.58	1.62	0.91	0.71	0.17

APPENDIX 5
AFFORESTATION SEQUENCES

APPENDIX 5.1
LUSIKISIKI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.01	0.09	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.14
1921	0.01	0.20	0.17	0.04	0.00	0.01	0.01	0.22	0.14	0.02	0.01	0.01	0.84
1922	0.14	0.14	0.04	0.15	0.16	0.13	0.04	0.00	0.00	0.19	0.07	0.00	1.06
1923	0.00	0.01	0.01	0.20	0.17	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.44
1924	0.02	0.03	0.17	0.05	0.01	0.16	0.06	0.00	0.01	0.01	0.01	0.01	0.54
1925	0.02	0.02	0.02	0.01	0.02	0.16	0.05	0.00	0.01	0.01	0.01	0.01	0.34
1926	0.02	0.17	0.10	0.00	0.00	0.12	0.04	0.00	0.00	0.00	0.00	0.01	0.46
1927	0.02	0.02	0.02	0.02	0.09	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.19
1928	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.19	0.12	0.02	0.11	0.55
1929	0.12	0.12	0.04	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.16	0.55
1930	0.06	0.01	0.01	0.18	0.16	0.14	0.04	0.00	0.00	0.07	0.03	0.00	0.70
1931	0.01	0.01	0.02	0.01	0.20	0.08	0.00	0.01	0.01	0.01	0.01	0.18	0.55
1932	0.13	0.12	0.14	0.04	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.49
1933	0.01	0.22	0.18	0.15	0.05	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.68
1934	0.01	0.02	0.19	0.07	0.01	0.01	0.18	0.14	0.11	0.03	0.00	0.00	0.77
1935	0.01	0.01	0.00	0.01	0.24	0.18	0.03	0.13	0.05	0.00	0.00	0.01	0.67
1936	0.02	0.17	0.06	0.01	0.18	0.15	0.04	0.00	0.00	0.00	0.01	0.01	0.65
1937	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.15
1938	0.01	0.01	0.02	0.02	0.16	0.05	0.00	0.01	0.00	0.01	0.01	0.18	0.48
1939	0.13	0.03	0.01	0.00	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.26
1940	0.01	0.02	0.02	0.02	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.11
1941	0.01	0.02	0.01	0.21	0.07	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.38
1942	0.01	0.20	0.12	0.02	0.01	0.01	0.16	0.06	0.00	0.01	0.02	0.01	0.63
1943	0.02	0.12	0.14	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.20	0.56
1944	0.07	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.17
1945	0.22	0.08	0.00	0.01	0.01	0.19	0.06	0.00	0.00	0.01	0.00	0.00	0.58
1946	0.01	0.09	0.01	0.00	0.00	0.13	0.14	0.03	0.10	0.04	0.00	0.01	0.56
1947	0.01	0.19	0.06	0.00	0.06	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.37
1948	0.02	0.02	0.01	0.02	0.20	0.16	0.03	0.00	0.00	0.00	0.00	0.01	0.47
1949	0.01	0.20	0.07	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.39
1950	0.01	0.01	0.19	0.07	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.34
1951	0.20	0.07	0.14	0.05	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.52
1952	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.01	0.13
1953	0.02	0.17	0.15	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.46
1954	0.20	0.07	0.01	0.17	0.16	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.67
1955	0.01	0.02	0.01	0.01	0.01	0.24	0.08	0.01	0.00	0.00	0.00	0.01	0.40
1956	0.02	0.17	0.16	0.05	0.01	0.13	0.14	0.04	0.00	0.00	0.01	0.01	0.74
1957	0.01	0.14	0.04	0.12	0.15	0.05	0.11	0.04	0.01	0.00	0.00	0.01	0.68
1958	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.20	0.06	0.00	0.00	0.01	0.39
1959	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.01	0.01	0.15
1960	0.01	0.00	0.00	0.00	0.01	0.01	0.16	0.06	0.00	0.01	0.01	0.00	0.27
1961	0.01	0.19	0.07	0.00	0.02	0.15	0.05	0.00	0.01	0.00	0.00	0.01	0.51
1962	0.02	0.18	0.06	0.14	0.06	0.15	0.05	0.00	0.01	0.16	0.06	0.00	0.89
1963	0.01	0.14	0.05	0.13	0.15	0.04	0.10	0.03	0.12	0.04	0.00	0.00	0.81
1964	0.16	0.06	0.00	0.01	0.01	0.01	0.01	0.01	0.25	0.09	0.00	0.01	0.62
1965	0.12	0.14	0.03	0.01	0.01	0.00	0.00	0.23	0.07	0.00	0.01	0.00	0.62
1966	0.01	0.01	0.02	0.02	0.02	0.17	0.15	0.03	0.00	0.01	0.01	0.01	0.46
1967	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.13
1968	0.02	0.15	0.05	0.00	0.17	0.11	0.02	0.13	0.04	0.00	0.00	0.00	0.69
1969	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.20	0.07	0.39
1970	0.10	0.12	0.03	0.01	0.01	0.01	0.02	0.18	0.06	0.00	0.11	0.03	0.68
1971	0.11	0.04	0.01	0.01	0.18	0.06	0.00	0.01	0.00	0.01	0.01	0.01	0.45
1972	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.14
1973	0.02	0.17	0.06	0.00	0.02	0.02	0.01	0.16	0.05	0.00	0.00	0.00	0.51
1974	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.21	0.34
1975	0.07	0.01	0.15	0.05	0.15	0.15	0.04	0.09	0.03	0.00	0.00	0.01	0.75
1976	0.18	0.06	0.01	0.01	0.18	0.06	0.01	0.01	0.00	0.00	0.01	0.02	0.55
1977	0.02	0.17	0.16	0.05	0.01	0.01	0.18	0.06	0.00	0.00	0.01	0.01	0.68
1978	0.17	0.10	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.01	0.02	0.02	0.36
1979	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.21	0.33
1980	0.07	0.12	0.05	0.01	0.01	0.00	0.00	0.01	0.02	0.01	0.01	0.02	0.33
1981	0.01	0.01	0.01	0.01	0.01	0.22	0.08	0.01	0.00	0.00	0.00	0.00	0.36
1982	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08	0.03	0.00	0.21
1983	0.01	0.14	0.05	0.12	0.04	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.44
1984	0.01	0.17	0.06	0.01	0.16	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.46
1985	0.02	0.19	0.06	0.14	0.05	0.01	0.01	0.00	0.01	0.00	0.01	0.02	0.52
1986	0.16	0.06	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.21	0.53
1987	0.07	0.11	0.04	0.01	0.17	0.17	0.04	0.11	0.04	0.01	0.00	0.00	0.77
1988	0.01	0.14	0.15	0.04	0.18	0.06	0.12	0.04	0.00	0.00	0.00	0.01	0.75
1989	0.18	0.15	0.04	0.01	0.01	0.20	0.07	0.00	0.01	0.00	0.01	0.01	0.69
1990	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.00	0.01	0.01	0.00	0.01	0.15
1991	0.20	0.16	0.04	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.44
1992	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.11
1993	0.03	0.03	0.16	0.06	0.16	0.06	0.01	0.00	0.01	0.01	0.01	0.01	0.55
1994	0.01	0.00	0.08	0.00	0.00	0.14	0.14	0.04	0.01	0.00	0.00	0.00	0.42
1995	0.01	0.01	0.18	0.07	0.12	0.05	0.00	0.01	0.00	0.02	0.02	0.01	0.50
1996	0.01	0.18	0.06	0.02	0.14	0.05	0.13	0.04	0.13	0.05	0.00	0.01	0.82
month	3.59	6.15	4.32	2.95	4.47	4.57	2.96	2.41	1.79	1.22	0.92	2.09	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
max	0.22	0.22	0.19	0.21	0.24	0.24	0.18	0.23	0.25	0.19	0.20	0.21	1.06
median	0.02	0.06	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.49
mean	0.05	0.08	0.06	0.04	0.06	0.06	0.04	0.03	0.02	0.02	0.01	0.03	0.49

Sum of the monthly means = 0.49

s.d.	0.06	0.07	0.06	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.06	0.21
c.v.	1.31	0.89	1.04	1.37	1.22	1.11	1.29	1.73	1.94	2.14	2.28	2.03	0.43

APPENDIX 5.2
ZALU DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.08	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.15
1921	0.02	0.20	0.17	0.03	0.01	0.01	0.01	0.21	0.14	0.02	0.00	0.01	0.83
1922	0.14	0.14	0.03	0.15	0.16	0.14	0.04	0.00	0.01	0.18	0.06	0.00	1.05
1923	0.00	0.01	0.02	0.20	0.17	0.03	0.00	0.01	0.00	0.00	0.00	0.02	0.46
1924	0.02	0.02	0.17	0.06	0.01	0.16	0.06	0.00	0.00	0.01	0.01	0.01	0.53
1925	0.01	0.02	0.01	0.01	0.02	0.16	0.05	0.00	0.01	0.01	0.01	0.01	0.32
1926	0.02	0.16	0.09	0.00	0.00	0.13	0.05	0.00	0.00	0.00	0.01	0.01	0.47
1927	0.02	0.02	0.01	0.02	0.07	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.17
1928	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.19	0.12	0.03	0.10	0.56
1929	0.12	0.12	0.03	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.16	0.52
1930	0.05	0.01	0.01	0.17	0.16	0.14	0.03	0.00	0.01	0.08	0.02	0.00	0.68
1931	0.01	0.01	0.02	0.01	0.21	0.07	0.01	0.01	0.01	0.01	0.01	0.19	0.57
1932	0.13	0.12	0.13	0.04	0.01	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.47
1933	0.00	0.21	0.18	0.15	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.64
1934	0.00	0.02	0.19	0.06	0.00	0.02	0.17	0.14	0.10	0.02	0.01	0.00	0.73
1935	0.00	0.01	0.01	0.01	0.25	0.19	0.04	0.12	0.04	0.00	0.00	0.01	0.68
1936	0.01	0.17	0.06	0.01	0.18	0.16	0.04	0.01	0.00	0.00	0.00	0.01	0.65
1937	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.15
1938	0.01	0.02	0.02	0.02	0.16	0.05	0.01	0.01	0.01	0.01	0.01	0.17	0.50
1939	0.14	0.03	0.01	0.01	0.00	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.29
1940	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.11
1941	0.01	0.03	0.02	0.21	0.07	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.40
1942	0.02	0.19	0.14	0.03	0.01	0.01	0.15	0.05	0.00	0.00	0.02	0.01	0.63
1943	0.02	0.13	0.13	0.04	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.20	0.55
1944	0.07	0.01	0.00	0.01	0.02	0.02	0.02	0.00	0.01	0.00	0.01	0.01	0.18
1945	0.22	0.08	0.00	0.01	0.02	0.19	0.06	0.00	0.00	0.01	0.00	0.01	0.60
1946	0.01	0.07	0.01	0.00	0.00	0.14	0.14	0.03	0.10	0.04	0.00	0.01	0.55
1947	0.00	0.18	0.06	0.00	0.08	0.03	0.00	0.00	0.01	0.00	0.00	0.01	0.37
1948	0.02	0.02	0.01	0.01	0.20	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.38
1949	0.02	0.20	0.07	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.41
1950	0.02	0.01	0.19	0.07	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.35
1951	0.20	0.06	0.14	0.05	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.49
1952	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.01	0.02	0.14
1953	0.02	0.17	0.15	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.46
1954	0.20	0.07	0.00	0.16	0.16	0.04	0.00	0.01	0.00	0.00	0.00	0.01	0.65
1955	0.02	0.02	0.01	0.01	0.01	0.23	0.07	0.00	0.00	0.01	0.01	0.01	0.40
1956	0.02	0.17	0.16	0.04	0.01	0.13	0.14	0.03	0.00	0.00	0.01	0.01	0.72
1957	0.02	0.13	0.05	0.12	0.15	0.04	0.11	0.04	0.00	0.00	0.00	0.00	0.66
1958	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.19	0.06	0.01	0.01	0.00	0.36
1959	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.14
1960	0.02	0.00	0.01	0.01	0.01	0.01	0.15	0.06	0.01	0.01	0.01	0.00	0.30
1961	0.01	0.18	0.06	0.01	0.01	0.15	0.06	0.01	0.01	0.01	0.01	0.01	0.53
1962	0.02	0.18	0.07	0.14	0.05	0.14	0.05	0.01	0.01	0.16	0.05	0.01	0.89
1963	0.01	0.14	0.05	0.14	0.15	0.04	0.10	0.04	0.13	0.04	0.00	0.01	0.85
1964	0.16	0.05	0.00	0.01	0.01	0.01	0.01	0.01	0.25	0.08	0.01	0.00	0.60
1965	0.12	0.13	0.04	0.01	0.01	0.00	0.01	0.22	0.07	0.00	0.00	0.01	0.62
1966	0.01	0.02	0.01	0.02	0.01	0.17	0.14	0.03	0.00	0.01	0.01	0.00	0.43
1967	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.02	0.15
1968	0.02	0.15	0.06	0.00	0.12	0.00	0.00	0.14	0.05	0.01	0.01	0.01	0.57
1969	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.02	0.02	0.20	0.07	0.40
1970	0.11	0.12	0.04	0.01	0.01	0.01	0.01	0.18	0.06	0.01	0.11	0.04	0.71
1971	0.11	0.05	0.01	0.00	0.18	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.43
1972	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.02	0.16
1973	0.02	0.17	0.06	0.01	0.01	0.02	0.01	0.16	0.06	0.00	0.00	0.01	0.53
1974	0.00	0.02	0.02	0.01	0.01	0.02	0.02	0.00	0.00	0.01	0.01	0.21	0.33
1975	0.07	0.00	0.15	0.06	0.15	0.16	0.04	0.09	0.03	0.00	0.00	0.01	0.76
1976	0.18	0.07	0.01	0.01	0.18	0.06	0.01	0.00	0.01	0.01	0.01	0.02	0.57
1977	0.02	0.17	0.16	0.04	0.00	0.01	0.18	0.07	0.00	0.00	0.01	0.01	0.67
1978	0.17	0.09	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.36
1979	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.20	0.33
1980	0.07	0.12	0.05	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.33
1981	0.01	0.02	0.01	0.02	0.01	0.23	0.08	0.00	0.00	0.01	0.01	0.01	0.41
1982	0.02	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.12	0.04	0.01	0.26
1983	0.01	0.14	0.05	0.07	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.01	0.34
1984	0.01	0.16	0.06	0.01	0.16	0.06	0.01	0.00	0.01	0.00	0.00	0.00	0.48
1985	0.02	0.19	0.07	0.13	0.04	0.00	0.01	0.00	0.01	0.00	0.01	0.02	0.50
1986	0.17	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.21	0.52
1987	0.07	0.11	0.04	0.01	0.18	0.16	0.04	0.11	0.04	0.01	0.00	0.01	0.78
1988	0.01	0.15	0.15	0.03	0.17	0.07	0.12	0.04	0.00	0.01	0.00	0.00	0.75
1989	0.19	0.16	0.03	0.01	0.01	0.20	0.06	0.00	0.01	0.00	0.01	0.01	0.69
1990	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.10
1991	0.20	0.16	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.47
1992	0.02	0.02	0.01	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.12
1993	0.02	0.02	0.16	0.06	0.16	0.05	0.00	0.01	0.00	0.01	0.01	0.01	0.51
1994	0.01	0.01	0.07	0.01	0.00	0.15	0.14	0.04	0.01	0.01	0.00	0.01	0.46
1995	0.01	0.01	0.18	0.06	0.12	0.04	0.00	0.00	0.01	0.02	0.02	0.01	0.48
1996	0.02	0.17	0.06	0.01	0.14	0.05	0.13	0.04	0.12	0.04	0.00	0.01	0.79
month	3.62	6.09	4.29	2.86	4.36	4.45	2.85	2.36	1.77	1.34	1.00	2.16	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
max	0.22	0.21	0.19	0.21	0.25	0.23	0.18	0.22	0.25	0.18	0.20	0.21	1.05
median	0.02	0.05	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.48
mean	0.05	0.08	0.06	0.04	0.06	0.06	0.04	0.03	0.02	0.02	0.01	0.03	0.48
Sum of the monthly means =				0.48									
s.d.	0.06	0.07	0.06	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.05	0.21
c.v.	1.32	0.88	1.04	1.37	1.26	1.15	1.31	1.73	1.96	1.95	2.05	1.93	0.43

APPENDIX 5.3
XURA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.01	0.20	0.07	0.01	0.16	0.05	0.01	0.00	0.00	0.00	0.01	0.52
1921	0.02	0.23	0.20	0.05	0.00	0.00	0.00	0.25	0.15	0.02	0.01	0.01	0.94
1922	0.16	0.16	0.04	0.17	0.18	0.16	0.04	0.00	0.01	0.22	0.07	0.00	1.21
1923	0.01	0.01	0.02	0.23	0.20	0.04	0.01	0.00	0.00	0.01	0.01	0.01	0.55
1924	0.02	0.02	0.19	0.07	0.01	0.19	0.07	0.00	0.00	0.01	0.00	0.01	0.59
1925	0.01	0.02	0.02	0.02	0.02	0.18	0.06	0.00	0.01	0.01	0.01	0.01	0.37
1926	0.02	0.18	0.16	0.04	0.01	0.20	0.07	0.00	0.00	0.00	0.00	0.00	0.68
1927	0.02	0.01	0.02	0.02	0.18	0.06	0.01	0.00	0.00	0.01	0.01	0.01	0.35
1928	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.22	0.14	0.02	0.12	0.63
1929	0.13	0.14	0.04	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.19	0.62
1930	0.06	0.01	0.02	0.20	0.19	0.16	0.04	0.01	0.00	0.01	0.00	0.00	0.70
1931	0.01	0.01	0.01	0.01	0.24	0.09	0.00	0.01	0.01	0.01	0.01	0.21	0.62
1932	0.16	0.14	0.16	0.04	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.59
1933	0.01	0.25	0.21	0.18	0.05	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.77
1934	0.01	0.02	0.21	0.07	0.01	0.01	0.20	0.16	0.13	0.04	0.00	0.01	0.87
1935	0.00	0.01	0.00	0.01	0.28	0.21	0.04	0.14	0.05	0.00	0.00	0.01	0.75
1936	0.02	0.19	0.07	0.00	0.21	0.18	0.04	0.00	0.00	0.00	0.01	0.01	0.73
1937	0.01	0.02	0.03	0.03	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.19
1938	0.01	0.02	0.03	0.02	0.18	0.06	0.01	0.01	0.01	0.01	0.01	0.21	0.58
1939	0.15	0.03	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.00	0.31
1940	0.01	0.03	0.02	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.12
1941	0.02	0.02	0.01	0.24	0.09	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.46
1942	0.02	0.22	0.18	0.04	0.01	0.02	0.18	0.06	0.00	0.01	0.01	0.01	0.76
1943	0.01	0.14	0.16	0.04	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.23	0.62
1944	0.08	0.00	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.20
1945	0.25	0.08	0.00	0.01	0.02	0.22	0.08	0.00	0.01	0.00	0.00	0.00	0.67
1946	0.01	0.22	0.08	0.01	0.01	0.18	0.17	0.04	0.13	0.04	0.01	0.00	0.90
1947	0.00	0.21	0.05	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.28
1948	0.02	0.02	0.01	0.01	0.23	0.18	0.04	0.01	0.01	0.00	0.00	0.01	0.54
1949	0.01	0.24	0.08	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.44
1950	0.01	0.02	0.22	0.08	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.39
1951	0.23	0.08	0.17	0.07	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.62
1952	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.00	0.01	0.01	0.14
1953	0.02	0.19	0.17	0.04	0.01	0.01	0.02	0.01	0.01	0.02	0.00	0.01	0.51
1954	0.22	0.08	0.01	0.19	0.19	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.74
1955	0.01	0.02	0.01	0.00	0.02	0.27	0.09	0.00	0.00	0.00	0.00	0.01	0.43
1956	0.02	0.19	0.18	0.05	0.01	0.16	0.16	0.04	0.01	0.01	0.00	0.01	0.84
1957	0.02	0.15	0.05	0.13	0.18	0.05	0.14	0.05	0.00	0.00	0.00	0.01	0.78
1958	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.22	0.07	0.01	0.01	0.01	0.44
1959	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.18
1960	0.01	0.00	0.00	0.00	0.01	0.02	0.17	0.06	0.00	0.00	0.01	0.01	0.29
1961	0.01	0.22	0.07	0.01	0.02	0.18	0.06	0.00	0.01	0.00	0.01	0.01	0.60
1962	0.02	0.21	0.07	0.17	0.06	0.17	0.06	0.01	0.00	0.19	0.07	0.00	1.03
1963	0.02	0.16	0.06	0.16	0.17	0.04	0.12	0.04	0.14	0.05	0.00	0.01	0.97
1964	0.18	0.06	0.00	0.01	0.01	0.01	0.00	0.01	0.28	0.10	0.01	0.01	0.68
1965	0.14	0.15	0.04	0.01	0.01	0.01	0.00	0.25	0.08	0.00	0.00	0.01	0.70
1966	0.01	0.01	0.01	0.02	0.02	0.19	0.17	0.03	0.00	0.01	0.01	0.01	0.49
1967	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.02	0.13
1968	0.03	0.18	0.06	0.00	0.20	0.18	0.04	0.15	0.06	0.01	0.00	0.01	0.92
1969	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.23	0.08	0.44
1970	0.12	0.14	0.03	0.01	0.02	0.01	0.02	0.21	0.07	0.00	0.13	0.04	0.80
1971	0.13	0.04	0.01	0.01	0.20	0.07	0.01	0.01	0.01	0.00	0.01	0.01	0.51
1972	0.00	0.02	0.03	0.02	0.01	0.01	0.02	0.01	0.01	0.00	0.01	0.02	0.16
1973	0.02	0.20	0.07	0.01	0.01	0.02	0.01	0.19	0.07	0.00	0.01	0.00	0.61
1974	0.01	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.24	0.40
1975	0.09	0.01	0.18	0.06	0.17	0.18	0.05	0.11	0.04	0.00	0.00	0.01	0.90
1976	0.21	0.07	0.00	0.01	0.20	0.07	0.01	0.00	0.01	0.00	0.01	0.02	0.61
1977	0.03	0.19	0.19	0.04	0.01	0.01	0.21	0.07	0.00	0.01	0.00	0.01	0.77
1978	0.20	0.15	0.04	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.53
1979	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.23	0.34
1980	0.08	0.14	0.05	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.36
1981	0.01	0.01	0.02	0.02	0.02	0.26	0.09	0.00	0.01	0.01	0.01	0.00	0.46
1982	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.10
1983	0.01	0.16	0.06	0.14	0.05	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.52
1984	0.01	0.19	0.07	0.01	0.18	0.06	0.00	0.01	0.01	0.00	0.00	0.00	0.54
1985	0.02	0.22	0.07	0.15	0.05	0.01	0.01	0.00	0.01	0.00	0.01	0.02	0.57
1986	0.19	0.07	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.24	0.60
1987	0.08	0.13	0.05	0.01	0.21	0.20	0.04	0.13	0.04	0.00	0.01	0.00	0.90
1988	0.01	0.17	0.17	0.04	0.21	0.08	0.13	0.05	0.00	0.00	0.00	0.00	0.86
1989	0.22	0.18	0.04	0.01	0.01	0.23	0.07	0.01	0.00	0.00	0.01	0.01	0.79
1990	0.02	0.02	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.13
1991	0.23	0.19	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.53
1992	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.13
1993	0.03	0.03	0.18	0.07	0.18	0.06	0.00	0.01	0.00	0.01	0.01	0.01	0.59
1994	0.01	0.01	0.24	0.08	0.00	0.21	0.18	0.04	0.01	0.01	0.00	0.00	0.79
1995	0.01	0.02	0.21	0.08	0.14	0.05	0.00	0.01	0.00	0.02	0.02	0.01	0.57
1996	0.02	0.19	0.07	0.01	0.17	0.06	0.15	0.06	0.15	0.05	0.00	0.00	0.93
month	4.09	7.10	5.37	3.57	5.20	5.64	3.46	2.79	2.04	1.26	0.98	2.38	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
max	0.25	0.25	0.24	0.24	0.28	0.27	0.21	0.25	0.28	0.22	0.23	0.24	1.21
median	0.02	0.06	0.04	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.59
mean	0.05	0.09	0.07	0.05	0.07	0.07	0.04	0.04	0.03	0.02	0.01	0.03	0.57

Sum of the monthly means = 0.57

s.d.	0.07	0.08	0.07	0.06	0.08	0.08	0.06	0.06	0.05	0.04	0.03	0.06	0.25
c.v.	1.34	0.90	1.04	1.28	1.24	1.09	1.28	1.68	1.96	2.30	2.43	2.04	0.43

APPENDIX 5.4
TUNGWANA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.01	0.03	0.02	0.03	0.19	0.07	0.01	0.00	0.00	0.00	0.00	0.36
1921	0.01	0.25	0.22	0.05	0.00	0.01	0.01	0.26	0.17	0.02	0.00	0.01	1.01
1922	0.16	0.18	0.05	0.10	0.17	0.18	0.04	0.00	0.00	0.21	0.07	0.01	1.17
1923	0.00	0.01	0.01	0.27	0.22	0.05	0.01	0.01	0.01	0.01	0.01	0.02	0.63
1924	0.02	0.02	0.02	0.02	0.02	0.20	0.07	0.00	0.01	0.01	0.00	0.01	0.40
1925	0.02	0.02	0.02	0.02	0.03	0.21	0.07	0.01	0.01	0.01	0.01	0.01	0.44
1926	0.02	0.18	0.06	0.00	0.01	0.22	0.07	0.00	0.00	0.00	0.00	0.01	0.57
1927	0.02	0.02	0.02	0.02	0.21	0.07	0.00	0.00	0.01	0.01	0.01	0.01	0.40
1928	0.01	0.02	0.02	0.02	0.02	0.23	0.08	0.00	0.10	0.10	0.02	0.13	0.75
1929	0.15	0.16	0.04	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.18	0.67
1930	0.06	0.01	0.02	0.24	0.22	0.17	0.04	0.00	0.00	0.07	0.02	0.00	0.85
1931	0.01	0.02	0.02	0.02	0.28	0.10	0.01	0.01	0.01	0.01	0.01	0.20	0.70
1932	0.11	0.00	0.02	0.03	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.26
1933	0.01	0.26	0.23	0.20	0.06	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.84
1934	0.01	0.02	0.23	0.08	0.01	0.01	0.21	0.17	0.13	0.03	0.01	0.00	0.91
1935	0.01	0.01	0.00	0.01	0.32	0.23	0.04	0.16	0.06	0.00	0.00	0.00	0.84
1936	0.01	0.00	0.00	0.01	0.24	0.20	0.05	0.00	0.01	0.00	0.01	0.01	0.54
1937	0.01	0.01	0.03	0.02	0.02	0.01	0.03	0.02	0.01	0.01	0.01	0.00	0.18
1938	0.01	0.02	0.02	0.02	0.21	0.07	0.01	0.01	0.01	0.01	0.02	0.17	0.58
1939	0.15	0.03	0.01	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.26
1940	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.15
1941	0.02	0.02	0.01	0.28	0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.50
1942	0.01	0.23	0.21	0.05	0.00	0.20	0.17	0.03	0.00	0.01	0.15	0.05	1.11
1943	0.01	0.15	0.06	0.01	0.18	0.06	0.01	0.00	0.01	0.00	0.01	0.23	0.73
1944	0.08	0.01	0.01	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.23
1945	0.26	0.08	0.00	0.01	0.02	0.25	0.09	0.01	0.00	0.00	0.00	0.01	0.73
1946	0.02	0.02	0.02	0.01	0.02	0.22	0.12	0.01	0.12	0.04	0.01	0.00	0.61
1947	0.00	0.22	0.08	0.01	0.19	0.18	0.04	0.01	0.00	0.00	0.00	0.00	0.73
1948	0.02	0.02	0.01	0.01	0.26	0.20	0.04	0.01	0.00	0.00	0.00	0.01	0.58
1949	0.02	0.24	0.08	0.02	0.01	0.01	0.02	0.13	0.04	0.00	0.01	0.00	0.58
1950	0.01	0.01	0.23	0.09	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.44
1951	0.22	0.08	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.41
1952	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.17
1953	0.02	0.20	0.19	0.05	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.57
1954	0.21	0.07	0.01	0.22	0.21	0.16	0.04	0.00	0.00	0.00	0.00	0.01	0.93
1955	0.02	0.02	0.01	0.01	0.02	0.28	0.10	0.00	0.00	0.00	0.01	0.01	0.48
1956	0.02	0.20	0.20	0.06	0.02	0.09	0.13	0.04	0.00	0.00	0.00	0.02	0.78
1957	0.02	0.02	0.02	0.17	0.18	0.05	0.14	0.04	0.00	0.00	0.00	0.01	0.65
1958	0.01	0.03	0.02	0.01	0.02	0.02	0.02	0.23	0.08	0.01	0.01	0.01	0.47
1959	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.18
1960	0.01	0.02	0.19	0.07	0.01	0.01	0.17	0.07	0.00	0.00	0.00	0.01	0.56
1961	0.01	0.21	0.08	0.01	0.02	0.20	0.06	0.01	0.01	0.01	0.01	0.01	0.64
1962	0.03	0.21	0.07	0.19	0.07	0.18	0.06	0.01	0.01	0.19	0.06	0.00	1.08
1963	0.01	0.02	0.02	0.20	0.19	0.15	0.15	0.04	0.15	0.05	0.00	0.01	0.99
1964	0.18	0.06	0.01	0.01	0.02	0.01	0.00	0.02	0.28	0.10	0.09	0.03	0.81
1965	0.14	0.17	0.04	0.01	0.01	0.01	0.00	0.28	0.10	0.00	0.00	0.01	0.77
1966	0.02	0.01	0.02	0.02	0.02	0.21	0.18	0.04	0.00	0.13	0.04	0.00	0.69
1967	0.00	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.03	0.18
1968	0.02	0.02	0.02	0.01	0.23	0.20	0.04	0.15	0.06	0.00	0.01	0.00	0.76
1969	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.23	0.08	0.48
1970	0.13	0.09	0.00	0.00	0.00	0.01	0.01	0.19	0.06	0.11	0.12	0.04	0.76
1971	0.14	0.06	0.01	0.01	0.24	0.09	0.01	0.01	0.01	0.01	0.00	0.01	0.60
1972	0.01	0.02	0.03	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.13
1973	0.02	0.18	0.06	0.01	0.02	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.33
1974	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.00	0.01	0.00	0.25	0.41
1975	0.09	0.01	0.20	0.07	0.19	0.19	0.14	0.13	0.03	0.00	0.01	0.01	1.07
1976	0.21	0.07	0.00	0.01	0.24	0.09	0.00	0.01	0.01	0.01	0.01	0.02	0.68
1977	0.02	0.20	0.20	0.06	0.01	0.01	0.12	0.10	0.02	0.00	0.00	0.01	0.75
1978	0.19	0.07	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.43
1979	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.24	0.41
1980	0.09	0.16	0.06	0.01	0.02	0.01	0.00	0.01	0.02	0.02	0.01	0.02	0.43
1981	0.01	0.01	0.01	0.02	0.02	0.29	0.10	0.00	0.01	0.01	0.00	0.00	0.48
1982	0.02	0.02	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.07	0.03	0.01	0.22
1983	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.15	0.05	0.01	0.37
1984	0.01	0.20	0.07	0.01	0.21	0.07	0.01	0.00	0.00	0.01	0.00	0.01	0.60
1985	0.02	0.22	0.08	0.17	0.06	0.01	0.01	0.01	0.01	0.00	0.02	0.09	0.70
1986	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.24	0.33
1987	0.08	0.14	0.05	0.01	0.23	0.21	0.04	0.13	0.05	0.09	0.04	0.00	1.07
1988	0.00	0.12	0.18	0.04	0.23	0.08	0.14	0.05	0.00	0.00	0.00	0.00	0.84
1989	0.22	0.20	0.04	0.01	0.02	0.25	0.08	0.01	0.01	0.00	0.01	0.01	0.86
1990	0.02	0.01	0.01	0.02	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.16
1991	0.23	0.20	0.05	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.57
1992	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.16
1993	0.02	0.02	0.19	0.06	0.20	0.07	0.01	0.00	0.00	0.01	0.01	0.02	0.61
1994	0.01	0.01	0.03	0.02	0.01	0.25	0.21	0.04	0.11	0.04	0.00	0.00	0.73
1995	0.01	0.02	0.23	0.08	0.16	0.05	0.00	0.01	0.01	0.20	0.07	0.00	0.84
1996	0.01	0.19	0.07	0.01	0.19	0.07	0.14	0.05	0.14	0.11	0.02	0.00	1.00
month	3.86	5.97	4.46	3.55	6.30	7.03	3.74	2.82	2.14	2.08	1.44	2.50	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.13
max	0.26	0.26	0.23	0.28	0.32	0.29	0.21	0.28	0.28	0.21	0.23	0.25	1.17
median	0.02	0.02	0.02	0.02	0.02	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.60
mean	0.05	0.08	0.06	0.05	0.08	0.09	0.05	0.04	0.03	0.03	0.02	0.03	0.60

Sum of the monthly means = 0.60

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
s.d.	0.07	0.08	0.07	0.07	0.09	0.09	0.06	0.06	0.05	0.05	0.04	0.06	0.26
c.v.	1.38	1.08	1.23	1.45	1.16	0.99	1.14	1.70	1.76	1.79	1.91	1.92	0.44

APPENDIX 5.5
LUSINDISWENI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.03	0.10	0.16	0.14	0.11	0.16	0.14	0.07	0.03	0.02	0.01	0.03	1.00
1921	0.10	1.84	1.45	0.32	0.06	0.04	0.03	0.16	1.36	0.44	0.03	0.04	5.87
1922	0.09	1.07	0.38	1.18	1.32	1.20	0.31	0.01	0.01	0.34	0.12	0.02	6.05
1923	0.03	0.05	0.10	1.97	1.56	0.32	0.02	0.02	0.02	0.02	0.02	0.05	4.18
1924	0.12	0.19	1.52	0.50	0.05	1.64	0.57	0.03	0.02	0.02	0.01	0.02	4.69
1925	0.08	0.16	0.15	0.16	0.12	1.65	0.56	0.02	0.06	0.07	0.04	0.07	3.14
1926	0.14	0.17	0.16	0.11	0.09	1.62	0.54	0.01	0.01	0.01	0.03	0.05	2.94
1927	0.11	0.11	0.18	1.29	0.47	0.06	0.04	0.03	0.03	0.03	0.04	0.06	2.45
1928	0.09	0.14	0.12	0.10	0.08	0.18	0.15	0.09	1.59	0.55	0.03	0.95	4.07
1929	0.96	0.25	0.05	0.09	0.09	0.13	0.12	0.07	0.08	0.09	0.10	0.14	2.17
1930	0.13	0.11	0.15	1.31	1.25	1.14	0.31	0.02	0.01	0.32	0.12	0.02	4.89
1931	0.06	0.09	0.10	0.09	1.78	0.61	0.03	0.04	0.05	0.08	0.07	0.13	3.13
1932	0.18	1.40	1.31	0.30	0.03	0.09	0.11	0.08	0.04	0.04	0.03	0.03	3.64
1933	0.03	1.89	1.26	1.09	0.33	0.07	0.08	0.06	0.04	0.07	0.07	0.05	5.04
1934	0.06	0.14	1.69	0.58	0.06	0.10	1.47	1.18	0.86	0.21	0.04	0.05	6.44
1935	0.05	0.08	0.06	0.07	2.07	1.56	0.29	0.08	0.08	0.06	0.03	0.04	4.47
1936	0.12	1.61	0.55	0.09	1.28	0.46	0.04	0.03	0.02	0.02	0.03	0.03	4.28
1937	0.07	0.11	0.16	0.15	0.18	0.12	0.12	0.10	0.07	0.08	0.07	0.05	1.28
1938	0.08	0.13	0.19	0.15	1.45	0.49	0.04	0.06	0.06	0.07	0.08	1.61	4.41
1939	0.56	0.06	0.35	0.00	0.00	0.05	0.07	0.15	0.14	0.08	0.04	0.04	1.54
1940	0.07	0.17	1.38	0.47	0.03	0.07	0.09	0.06	0.03	0.04	0.04	0.05	2.50
1941	0.11	0.14	0.12	1.77	0.62	0.09	0.08	0.07	0.05	0.03	0.04	0.07	3.19
1942	0.13	1.64	1.40	0.33	0.06	1.41	1.26	0.28	0.03	0.05	0.11	0.10	6.80
1943	1.12	1.14	1.12	0.31	0.10	0.11	0.07	0.05	0.05	0.05	0.05	0.15	4.32
1944	0.17	0.11	0.06	0.11	0.16	0.19	0.12	0.07	0.05	0.04	0.03	0.04	1.15
1945	1.74	0.58	0.03	0.07	0.15	1.65	0.56	0.02	0.02	0.02	0.02	0.03	4.89
1946	0.08	0.17	0.17	0.14	0.16	1.33	0.47	0.04	1.03	0.35	0.02	0.03	3.99
1947	0.06	1.56	0.56	0.08	1.08	0.40	0.06	0.03	0.01	0.01	0.01	0.01	3.87
1948	0.13	0.16	0.15	0.14	1.45	0.50	0.06	0.05	0.02	0.02	0.02	0.03	2.73
1949	0.10	1.66	0.57	1.21	0.45	0.08	0.08	0.09	0.07	0.06	0.10	0.10	4.57
1950	0.10	0.09	1.70	0.60	0.06	0.12	0.09	0.05	0.04	0.04	0.05	0.09	3.03
1951	0.19	0.14	0.14	0.16	0.15	0.11	0.12	0.09	0.05	0.03	0.02	0.05	1.25
1952	0.07	0.09	0.10	0.11	0.14	0.14	0.12	0.08	0.04	0.02	0.04	0.09	1.04
1953	0.17	1.53	1.35	0.32	0.08	0.11	0.08	0.08	0.10	0.08	0.05	0.07	4.02
1954	1.70	0.59	0.05	1.40	1.37	0.34	0.05	0.04	0.03	0.02	0.02	0.05	5.66
1955	0.11	0.16	0.11	0.06	0.12	1.95	0.68	0.04	0.03	0.03	0.02	0.05	3.36
1956	0.14	1.49	1.38	0.35	0.08	1.16	1.10	0.25	0.02	0.03	0.04	0.12	6.16
1957	1.28	1.17	0.28	0.10	1.23	0.44	0.09	0.06	0.03	0.02	0.02	0.03	4.75
1958	0.07	0.18	0.19	0.12	0.12	0.12	0.12	1.58	0.53	0.03	0.06	0.07	3.19
1959	0.09	0.12	0.13	0.11	0.11	0.14	0.14	0.11	0.07	0.04	0.05	0.08	1.19
1960	0.10	0.18	1.47	0.61	0.00	0.00	0.87	0.31	0.02	0.03	0.03	0.04	3.66
1961	0.06	0.16	0.17	0.15	1.32	1.25	0.29	0.03	0.02	0.02	0.04	0.05	3.56
1962	0.13	1.61	0.56	1.18	0.42	1.22	0.43	0.03	0.03	0.74	0.06	0.00	6.41
1963	0.01	1.01	1.17	1.26	0.38	0.08	0.18	0.00	0.47	0.18	0.02	0.04	4.80
1964	1.43	0.48	0.05	0.10	0.11	0.08	0.05	0.06	1.94	0.66	0.04	0.05	5.05
1965	0.95	1.10	0.29	0.08	0.09	0.06	0.04	1.90	0.64	0.01	0.02	0.06	5.24
1966	0.08	0.11	0.14	0.16	0.16	1.42	1.16	0.24	0.03	0.07	0.07	0.04	3.68
1967	0.05	0.14	0.12	0.11	0.11	0.12	0.11	0.07	0.03	0.02	0.06	0.13	1.07
1968	0.17	0.17	0.14	0.08	0.16	1.53	0.51	0.08	0.06	0.04	0.04	0.05	3.03
1969	0.11	0.16	0.15	0.10	0.10	0.08	0.05	0.06	0.10	0.09	0.13	0.16	1.29
1970	1.51	0.53	0.07	0.09	0.08	0.09	0.09	0.43	0.01	0.00	0.55	0.20	3.65
1971	0.94	0.34	0.06	0.10	1.38	0.48	0.04	0.02	0.03	0.03	0.03	0.03	3.48
1972	0.05	0.17	0.17	0.13	0.13	0.13	0.12	0.06	0.03	0.02	0.04	0.10	1.15
1973	0.15	1.53	0.52	0.09	0.13	1.21	0.41	1.01	0.35	0.02	0.01	0.01	5.44
1974	0.06	0.14	0.18	0.15	0.13	0.12	0.08	0.04	0.03	0.01	0.02	0.13	1.09
1975	0.15	0.13	1.59	1.41	1.25	1.22	0.33	0.07	0.05	0.02	0.02	0.07	6.31
1976	1.69	0.58	0.07	0.10	0.12	0.11	0.08	0.04	0.04	0.04	0.04	0.08	2.99
1977	0.19	1.51	1.32	0.33	0.07	0.10	1.39	0.48	0.03	0.02	0.02	0.07	5.53
1978	0.16	1.28	0.45	0.06	0.08	0.13	0.10	0.06	0.02	0.07	0.09	0.08	2.58
1979	0.12	0.14	0.14	0.10	0.10	0.11	0.08	0.06	0.04	0.02	0.02	0.15	1.08
1980	0.18	1.48	0.52	0.08	0.10	0.07	0.05	0.06	0.06	0.04	0.06	0.09	2.79
1981	0.07	0.09	0.11	0.16	0.16	0.82	0.11	0.00	0.00	0.00	0.00	0.02	1.54
1982	0.10	0.12	0.09	0.09	0.10	0.09	0.07	0.07	0.05	0.05	0.06	0.07	0.96
1983	0.12	0.19	0.19	1.40	1.31	0.34	0.86	0.29	0.03	0.05	0.06	0.06	4.90
1984	0.08	0.15	0.18	0.15	1.30	0.45	0.03	0.02	0.02	0.02	0.02	0.02	2.44
1985	1.78	1.31	1.03	0.31	0.07	0.07	0.05	0.03	0.02	0.02	0.10	0.16	4.95
1986	1.46	1.26	0.29	0.09	0.08	0.13	0.10	0.07	0.04	0.03	0.06	1.76	5.37
1987	0.61	0.91	0.92	0.24	1.35	1.36	0.34	0.08	0.08	0.08	0.08	0.07	6.12
1988	0.08	1.27	1.33	0.33	1.28	0.46	0.08	0.07	0.06	0.05	0.03	0.03	5.07
1989	0.15	1.57	0.54	0.08	0.07	1.58	0.54	0.02	0.01	0.01	0.07	0.09	4.73
1990	0.15	0.14	0.12	0.16	0.16	0.10	0.05	0.03	0.03	0.02	0.02	0.06	1.04
1991	1.86	1.33	0.27	0.06	0.09	0.10	0.10	0.05	0.03	0.02	0.02	0.04	3.97
1992	0.09	0.17	0.20	0.14	0.14	0.09	0.06	0.04	0.02	0.01	0.02	0.10	1.08
1993	1.78	0.62	1.01	0.37	1.20	1.29	0.30	0.01	0.01	0.04	0.06	0.04	6.73
1994	0.04	0.06	0.09	0.15	0.11	1.89	0.66	0.04	0.06	0.05	0.03	0.04	3.22
1995	0.09	0.15	1.58	1.37	1.16	0.33	0.03	0.01	0.01	0.03	0.04	0.05	4.85
1996	0.09	1.72	0.61	1.05	0.83	0.00	0.22	0.10	1.04	0.36	0.03	0.04	6.09
month	27.56	46.60	38.99	30.27	35.93	40.86	20.54	11.49	12.42	6.62	3.93	9.07	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.01	0.05	0.03	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.96
max	1.86	1.89	1.70	1.97	2.07	1.95	1.47	1.90	1.94	0.74	0.55	1.76	6.80
median	0.11	0.17	0.19	0.15	0.13	0.14	0.11	0.06	0.04	0.04	0.04	0.05	3.68
mean	0.36	0.61	0.51	0.39	0.47	0.53	0.27	0.15	0.16	0.09	0.05	0.12	3.69

Sum of the monthly means = 3.69

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
s.d.	0.54	0.61	0.53	0.48	0.56	0.59	0.34	0.32	0.37	0.14	0.06	0.28	1.70
c.v.	1.51	1.02	1.05	1.23	1.21	1.12	1.26	2.15	2.27	1.68	1.26	2.38	0.46

APPENDIX 5.6
KWAHLATHI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.03	0.10	0.16	0.14	0.12	0.16	0.14	0.07	0.03	0.01	0.01	0.03	1.00
1921	0.10	1.84	1.45	0.32	0.07	0.05	0.03	0.16	1.36	0.44	0.04	0.04	5.90
1922	0.09	1.07	0.38	1.18	1.32	1.21	0.31	0.01	0.01	0.33	0.12	0.01	6.04
1923	0.03	0.05	0.10	1.97	1.56	0.31	0.02	0.02	0.03	0.02	0.03	0.06	4.20
1924	0.12	0.18	1.51	0.50	0.05	1.64	0.57	0.03	0.02	0.01	0.01	0.02	4.66
1925	0.09	0.17	0.15	0.16	0.13	1.65	0.55	0.03	0.06	0.07	0.04	0.06	3.16
1926	0.15	0.16	0.15	0.11	0.09	1.62	0.55	0.01	0.02	0.01	0.03	0.05	2.95
1927	0.11	0.10	0.18	1.29	0.47	0.06	0.04	0.04	0.03	0.03	0.04	0.06	2.45
1928	0.09	0.13	0.12	0.11	0.09	0.18	0.15	0.08	1.60	0.54	0.02	0.95	4.06
1929	0.95	0.25	0.05	0.08	0.09	0.13	0.12	0.08	0.08	0.08	0.10	0.13	2.14
1930	0.13	0.12	0.15	1.32	1.24	1.13	0.30	0.02	0.01	0.32	0.12	0.02	4.88
1931	0.06	0.09	0.10	0.09	1.78	0.62	0.03	0.04	0.05	0.08	0.07	0.13	3.14
1932	0.18	1.39	1.31	0.30	0.04	0.10	0.10	0.07	0.05	0.03	0.03	0.03	3.63
1933	0.03	1.89	1.26	1.10	0.33	0.07	0.08	0.06	0.04	0.07	0.07	0.06	5.06
1934	0.06	0.13	1.69	0.58	0.07	0.09	1.48	1.18	0.87	0.21	0.04	0.05	6.45
1935	0.05	0.09	0.07	0.06	2.07	1.55	0.29	0.08	0.09	0.05	0.04	0.04	4.48
1936	0.13	1.61	0.56	0.09	1.28	0.46	0.04	0.03	0.02	0.02	0.02	0.03	4.29
1937	0.07	0.11	0.16	0.15	0.17	0.12	0.13	0.10	0.08	0.07	0.07	0.05	1.28
1938	0.07	0.13	0.19	0.15	1.45	0.49	0.04	0.06	0.06	0.06	0.08	1.61	4.39
1939	0.56	0.05	0.35	0.00	0.00	0.05	0.08	0.16	0.15	0.08	0.04	0.04	1.56
1940	0.07	0.16	1.38	0.46	0.04	0.07	0.09	0.06	0.03	0.03	0.04	0.06	2.49
1941	0.11	0.14	0.13	1.76	0.62	0.09	0.08	0.07	0.05	0.03	0.04	0.07	3.19
1942	0.13	1.64	1.40	0.33	0.07	1.40	1.26	0.28	0.04	0.05	0.11	0.10	6.81
1943	1.12	1.14	1.11	0.32	0.10	0.10	0.07	0.05	0.05	0.06	0.05	0.14	4.31
1944	0.18	0.11	0.06	0.11	0.16	0.18	0.11	0.07	0.05	0.03	0.02	0.04	1.12
1945	1.75	0.59	0.03	0.07	0.15	1.65	0.56	0.03	0.02	0.02	0.02	0.03	4.92
1946	0.08	0.17	0.17	0.14	0.16	1.33	0.47	0.04	1.03	0.35	0.02	0.03	3.99
1947	0.06	1.56	0.57	0.08	1.09	0.40	0.06	0.03	0.01	0.00	0.01	0.02	3.89
1948	0.12	0.16	0.15	0.13	1.45	0.51	0.06	0.04	0.02	0.02	0.02	0.04	2.72
1949	0.10	1.66	0.57	1.21	0.45	0.07	0.08	0.09	0.07	0.05	0.10	0.10	4.55
1950	0.10	0.09	1.70	0.60	0.07	0.12	0.09	0.05	0.04	0.03	0.05	0.09	3.03
1951	0.19	0.14	0.15	0.16	0.14	0.12	0.12	0.09	0.04	0.03	0.02	0.04	1.24
1952	0.07	0.10	0.10	0.11	0.14	0.14	0.11	0.07	0.05	0.02	0.03	0.09	1.03
1953	0.17	1.53	1.35	0.32	0.08	0.11	0.07	0.08	0.10	0.08	0.05	0.08	4.02
1954	1.69	0.59	0.05	1.40	1.36	0.34	0.06	0.04	0.04	0.03	0.02	0.05	5.67
1955	0.11	0.15	0.11	0.05	0.12	1.95	0.68	0.04	0.04	0.04	0.03	0.06	3.38
1956	0.14	1.49	1.38	0.35	0.09	1.15	1.10	0.25	0.02	0.03	0.04	0.12	6.16
1957	1.28	1.17	0.28	0.10	1.23	0.43	0.09	0.06	0.02	0.02	0.02	0.04	4.74
1958	0.07	0.17	0.19	0.13	0.12	0.13	0.12	1.58	0.53	0.03	0.06	0.07	3.20
1959	0.09	0.12	0.13	0.12	0.12	0.14	0.14	0.11	0.07	0.04	0.05	0.08	1.21
1960	0.11	0.18	1.46	0.61	0.00	0.00	0.87	0.31	0.02	0.02	0.03	0.04	3.65
1961	0.07	0.17	0.17	0.15	1.32	1.25	0.29	0.03	0.02	0.02	0.04	0.05	3.58
1962	0.13	1.61	0.56	1.18	0.42	1.22	0.42	0.03	0.02	0.75	0.06	0.00	6.40
1963	0.01	1.01	1.17	1.26	0.37	0.08	0.18	0.00	0.48	0.18	0.02	0.05	4.81
1964	1.42	0.49	0.06	0.10	0.12	0.08	0.05	0.07	1.93	0.66	0.04	0.05	5.07
1965	0.95	1.09	0.29	0.08	0.09	0.06	0.05	1.89	0.65	0.01	0.02	0.06	5.24
1966	0.08	0.11	0.14	0.16	0.15	1.42	1.17	0.25	0.03	0.07	0.07	0.04	3.69
1967	0.05	0.14	0.13	0.10	0.12	0.12	0.11	0.07	0.04	0.02	0.06	0.12	1.08
1968	0.16	0.18	0.15	0.08	0.15	1.53	0.51	0.08	0.07	0.05	0.04	0.06	3.06
1969	0.11	0.16	0.15	0.10	0.10	0.07	0.05	0.07	0.10	0.09	0.12	0.16	1.28
1970	1.50	0.53	0.07	0.08	0.09	0.09	0.09	0.43	0.01	0.00	0.55	0.20	3.64
1971	0.94	0.34	0.06	0.10	1.38	0.48	0.03	0.03	0.03	0.04	0.03	0.03	3.49
1972	0.05	0.17	0.18	0.13	0.13	0.14	0.12	0.07	0.03	0.02	0.04	0.11	1.19
1973	0.15	1.53	0.52	0.09	0.13	1.21	0.42	1.01	0.35	0.02	0.02	0.02	5.47
1974	0.06	0.14	0.18	0.14	0.14	0.12	0.08	0.04	0.02	0.01	0.01	0.13	1.07
1975	0.15	0.13	1.59	1.41	1.24	1.23	0.34	0.07	0.05	0.02	0.02	0.06	6.31
1976	1.69	0.58	0.08	0.10	0.12	0.12	0.08	0.04	0.03	0.04	0.04	0.08	3.00
1977	0.19	1.51	1.32	0.33	0.07	0.09	1.39	0.49	0.03	0.01	0.02	0.07	5.52
1978	0.16	1.28	0.45	0.06	0.09	0.13	0.10	0.06	0.03	0.06	0.09	0.09	2.60
1979	0.12	0.13	0.13	0.11	0.10	0.11	0.08	0.06	0.05	0.02	0.03	0.15	1.09
1980	0.18	1.48	0.53	0.08	0.09	0.07	0.05	0.06	0.07	0.04	0.06	0.08	2.79
1981	0.07	0.09	0.10	0.16	0.15	0.82	0.10	0.00	0.00	0.00	0.00	0.02	1.51
1982	0.11	0.11	0.08	0.09	0.10	0.09	0.08	0.06	0.04	0.05	0.06	0.07	0.94
1983	0.11	0.19	0.19	1.39	1.31	0.33	0.85	0.29	0.02	0.05	0.06	0.06	4.85
1984	0.08	0.15	0.18	0.15	1.30	0.45	0.03	0.02	0.02	0.02	0.02	0.01	2.43
1985	1.78	1.31	1.03	0.31	0.07	0.06	0.06	0.03	0.02	0.02	0.10	0.15	4.94
1986	1.47	1.26	0.29	0.08	0.09	0.13	0.10	0.06	0.04	0.03	0.07	1.76	5.38
1987	0.61	0.91	0.91	0.24	1.34	1.36	0.34	0.07	0.07	0.08	0.08	0.07	6.08
1988	0.09	1.27	1.33	0.33	1.28	0.45	0.08	0.07	0.05	0.05	0.03	0.04	5.07
1989	0.16	1.57	0.54	0.08	0.07	1.59	0.54	0.02	0.02	0.01	0.06	0.09	4.75
1990	0.15	0.14	0.11	0.16	0.15	0.10	0.05	0.03	0.02	0.02	0.02	0.06	1.01
1991	1.86	1.33	0.26	0.07	0.09	0.11	0.09	0.06	0.02	0.01	0.02	0.04	3.96
1992	0.09	0.17	0.20	0.14	0.14	0.10	0.07	0.04	0.03	0.01	0.02	0.11	1.12
1993	1.78	0.61	1.02	0.37	1.20	1.29	0.30	0.01	0.01	0.05	0.07	0.05	6.76
1994	0.04	0.06	0.09	0.15	0.12	1.89	0.66	0.04	0.05	0.05	0.03	0.04	3.22
1995	0.09	0.15	1.57	1.37	1.16	0.33	0.03	0.02	0.01	0.03	0.04	0.05	4.85
1996	0.09	1.71	0.61	1.04	0.82	0.00	0.22	0.10	1.04	0.37	0.03	0.05	6.08
month	27.59	46.53	39.00	30.23	35.99	40.84	20.55	11.54	12.50	6.52	3.94	9.14	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.01	0.05	0.03	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.94
max	1.86	1.89	1.70	1.97	2.07	1.95	1.48	1.89	1.93	0.75	0.55	1.76	6.81
median	0.11	0.17	0.19	0.15	0.14	0.14	0.10	0.06	0.04	0.03	0.04	0.06	3.69
mean	0.36	0.60	0.51	0.39	0.47	0.53	0.27	0.15	0.16	0.08	0.05	0.12	3.69

Sum of the monthly means = 3.69

s.d.	0.54	0.61	0.53	0.48	0.56	0.59	0.34	0.32	0.37	0.14	0.06	0.28	1.70
c.v.	1.51	1.02	1.05	1.23	1.20	1.12	1.27	2.14	2.26	1.71	1.25	2.35	0.46

APPENDIX 6
AREA-CAPACITY TABLES

APPENDIX 6.1

Table 6.1: Area-capacity table for Lusikisiki and Zalu Dam.

Lusikisiki Dam			Zalu Dam		
Elevation (m)	Capacity (Mm^3)	Surface Area (km^2)	Elevation (m)	Capacity (Mm^3)	Surface Area (km^2)
42.00	34.626	2.354	39.00	25.00	1.96
32.00	15.271	1.517	34.00	16.50	1.43
25.50	7.541	1.150	29.00	10.30	1.01
20.50	3.218	0.579	24.00	6.10	0.69
15.50	1.160	0.245	19.00	3.30	0.48
10.50	0.335	0.085	14.00	1.30	0.28
5.50	0.070	0.021	9.00	0.30	0.13
0.50	0.010	0.005	4.00	0.10	0.05

Table 6.2: Area-capacity tables for Xura and Lower Mzintlava Dam.

Xura Dam			Lower Mzintlava Dam		
Elevation (m)	Capacity (Mm^3)	Surface Area (km^2)	Elevation (m)	Capacity (Mm^3)	Surface Area (km^2)
475.00	26.20	2.160	442.00	18.00	-
472.00	20.10	1.860	440.00	12.982	1.990
469.00	14.80	1.580	435.00	6.733	0.824
466.00	10.60	1.330	430.00	3.502	0.496
463.00	7.08	1.060	425.00	1.590	0.278
460.00	4.26	0.705	420.00	0.628	0.118
457.00	2.48	0.427	415.00	0.213	0.056
454.00	1.33	0.329	410.00	0.036	0.018
451.00	0.62	0.208	409.00	0.000	0.000
448.00	0.17	0.098			
445.00	0	0			

PPENDIX 6.2

Table 6.3: Area-capacity table for Tungwana Dam.

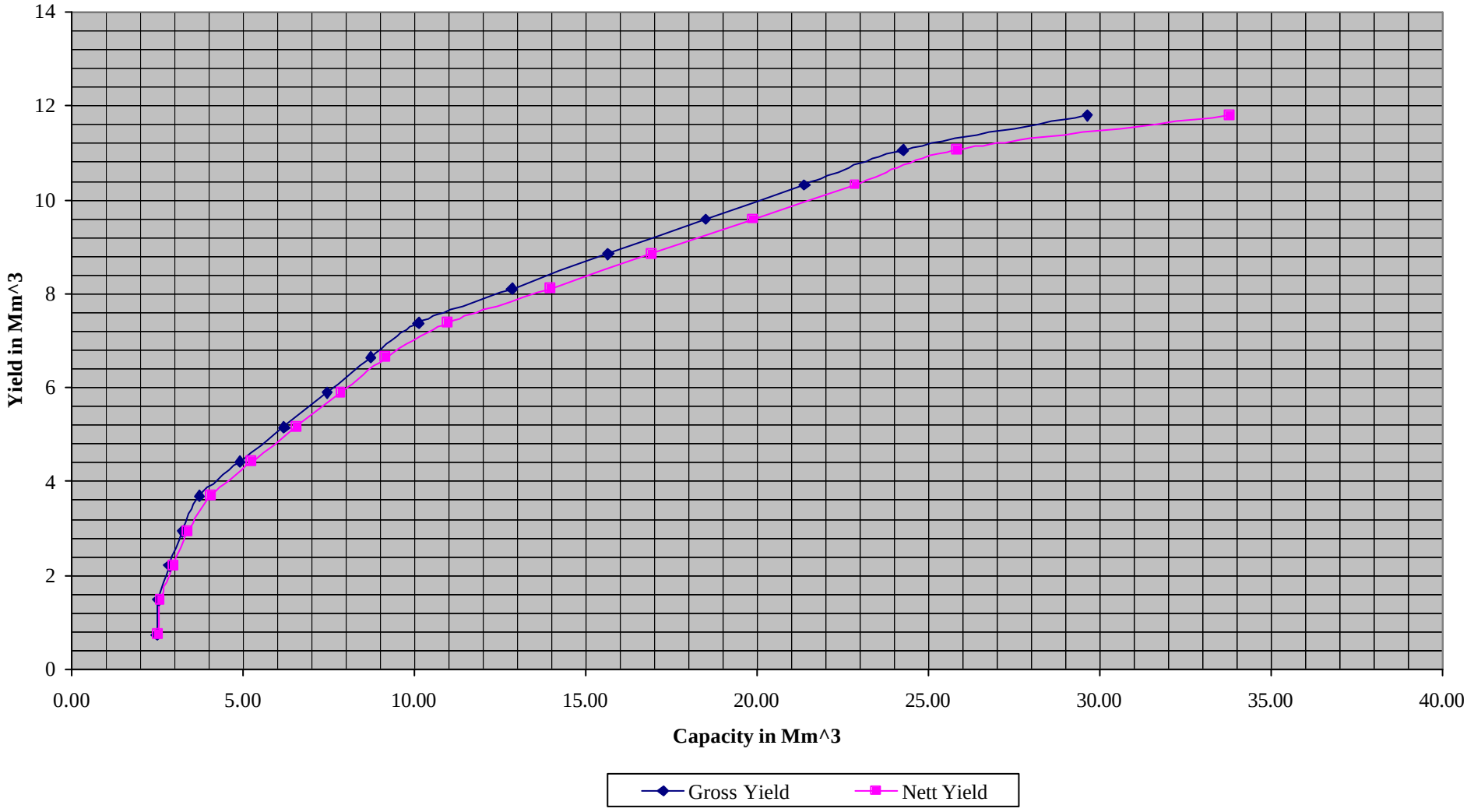
Tungwana Dam		
Elevation (m)	Capacity (Mm^3)	Surface Area (km^2)
50.00	32.08	1.423
46.00	26.66	1.286
42.00	21.79	1.151
38.00	17.45	1.019
34.00	13.63	0.889
30.00	10.33	0.764
26.00	7.52	0.641
24.00	6.30	0.582
22.00	5.19	0.523
20.00	4.20	0.466
18.00	3.33	0.410
16.00	2.56	0.355
12.00	1.36	0.250
6.00	0.29	0.107
2.00	0.03	0.028

Table 6.4: Area-capacity tables for Lusindisweni and KwaHlathi Dam.

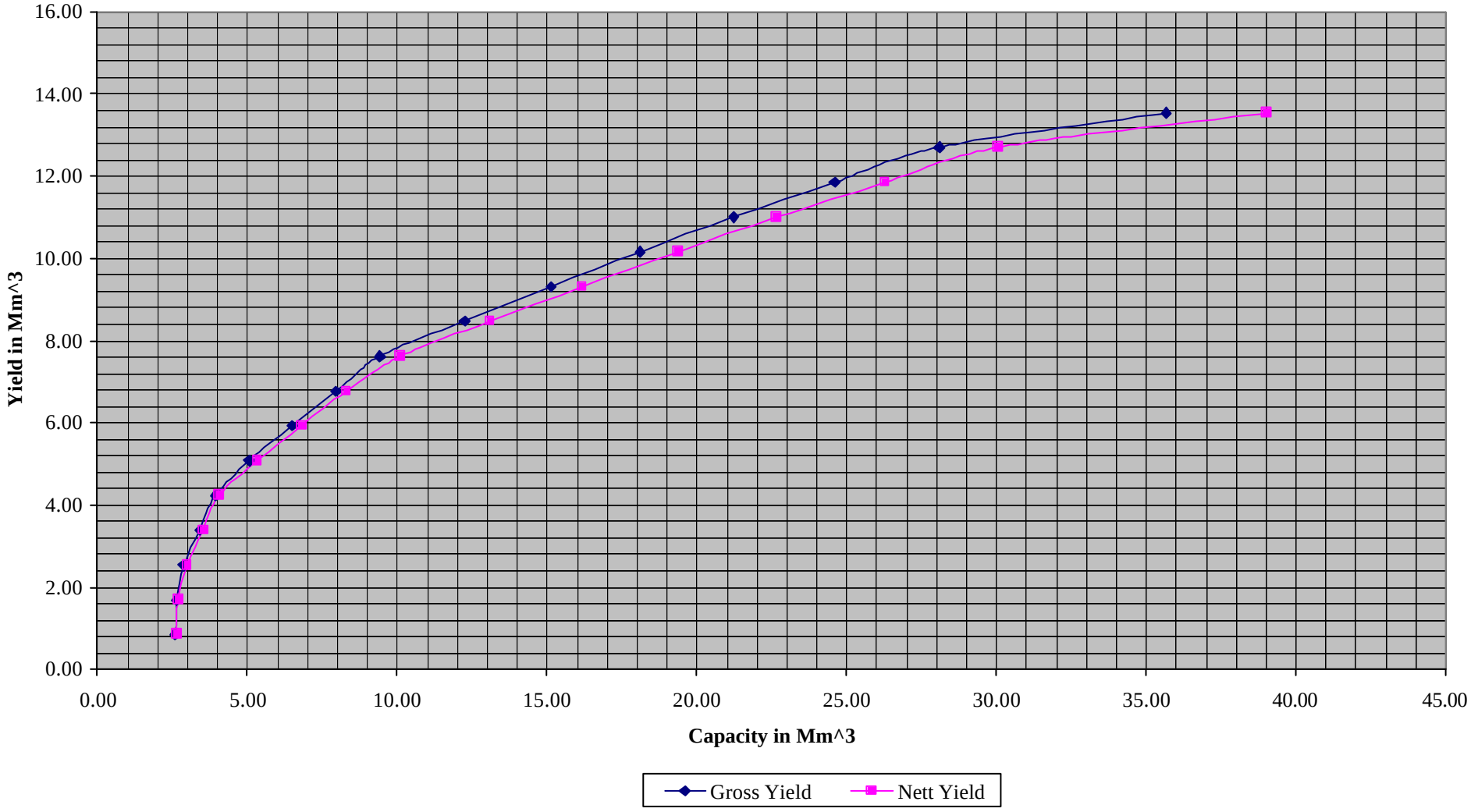
Lusindisweni Dam			KwaHlathi Dam		
Elevation (m)	Capacity (Mm^3)	Surface Area (km^2)	Elevation (m)	Capacity (Mm^3)	Surface Area (km^2)
41.45	72.414	3.943	34.98	64.296	5.598
36.45	53.841	3.422	29.96	47.764	3.038
31.45	37.960	2.949	24.98	34.014	2.449
26.45	24.738	2.213	19.98	23.014	1.999
21.45	14.969	1.697	14.98	13.827	1.648
16.45	7.992	1.139	9.98	6.324	1.261
1.45	3.315	0.709	4.98	0.992	0.483
6.45	0.872	0.299			
1.45	0.028	0.029			

APPENDIX 7
YIELD-CAPACITY GRAPHS

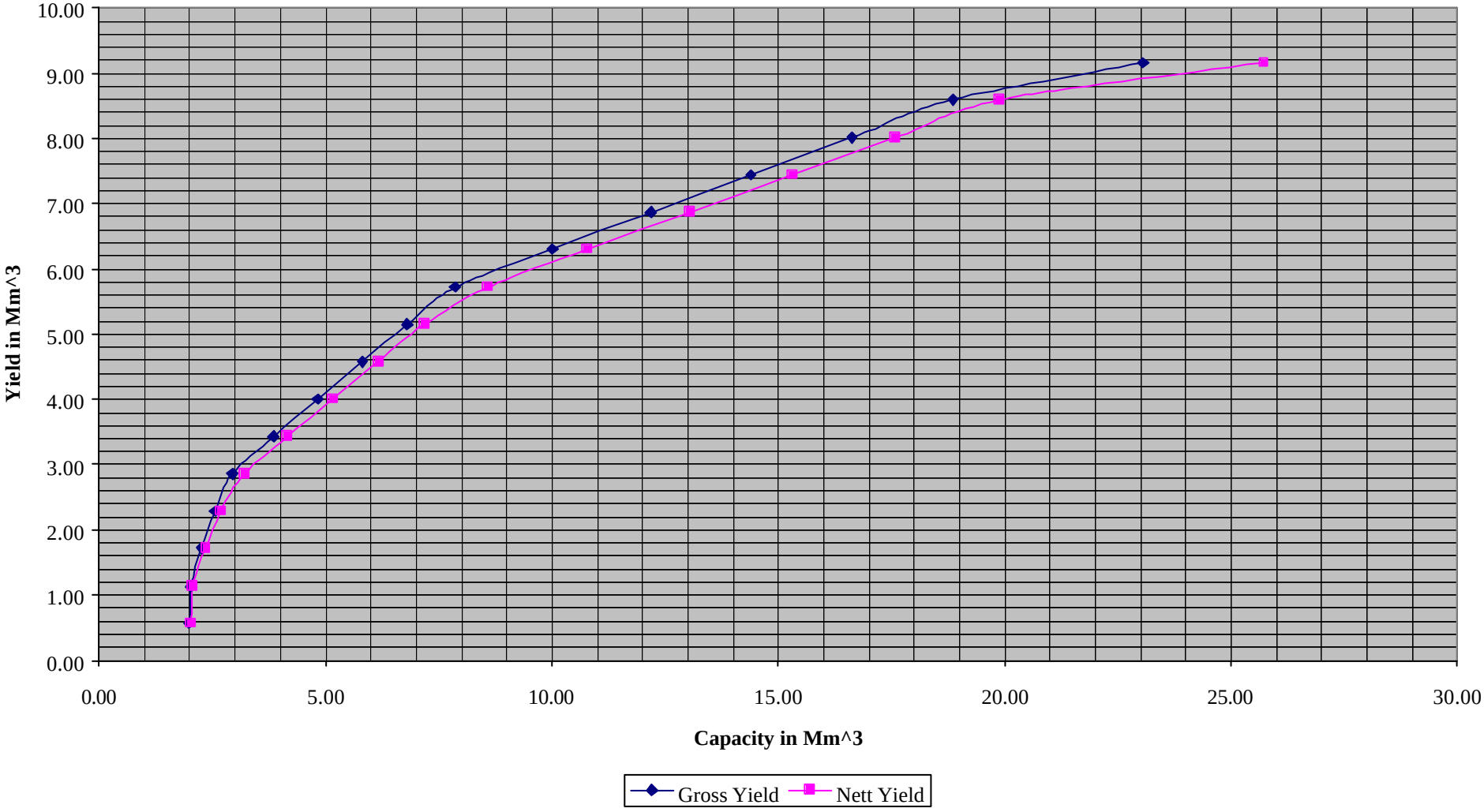
Lusikisiki Yield Curves (Present day: 2000)



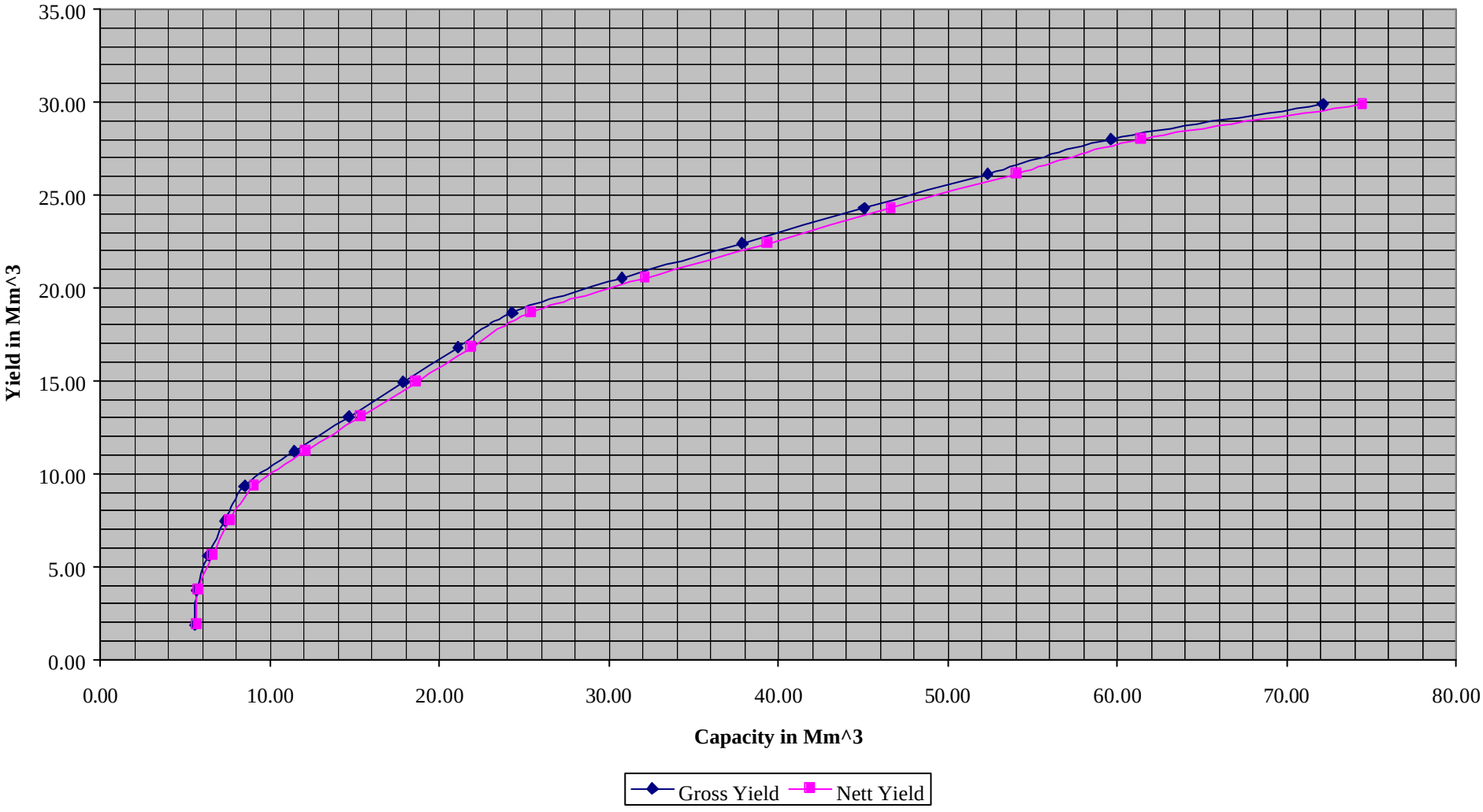
Lower Mzintlava Yield Curves (Present day: 2000)



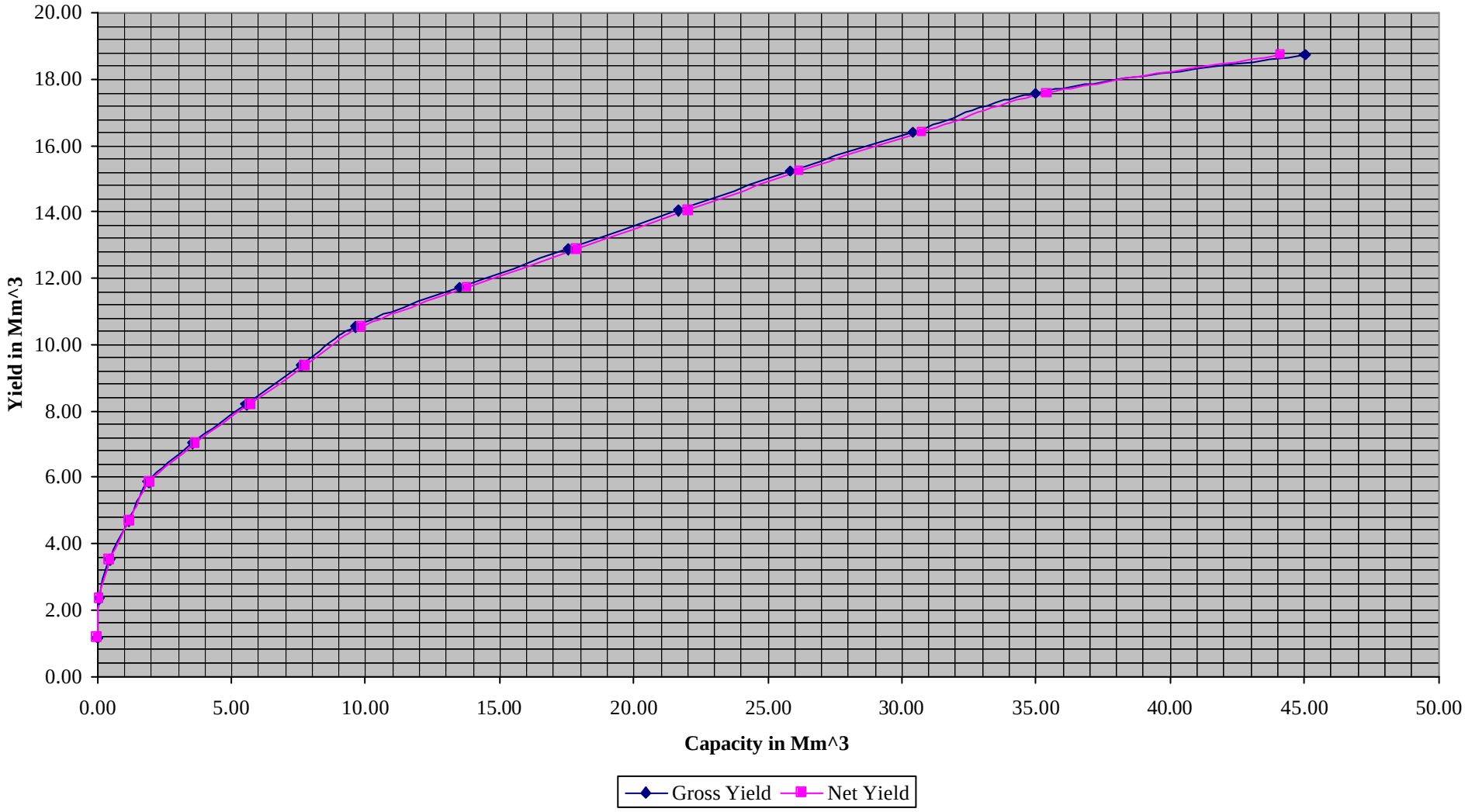
Zalu Yield Curves (Present day: 2000)



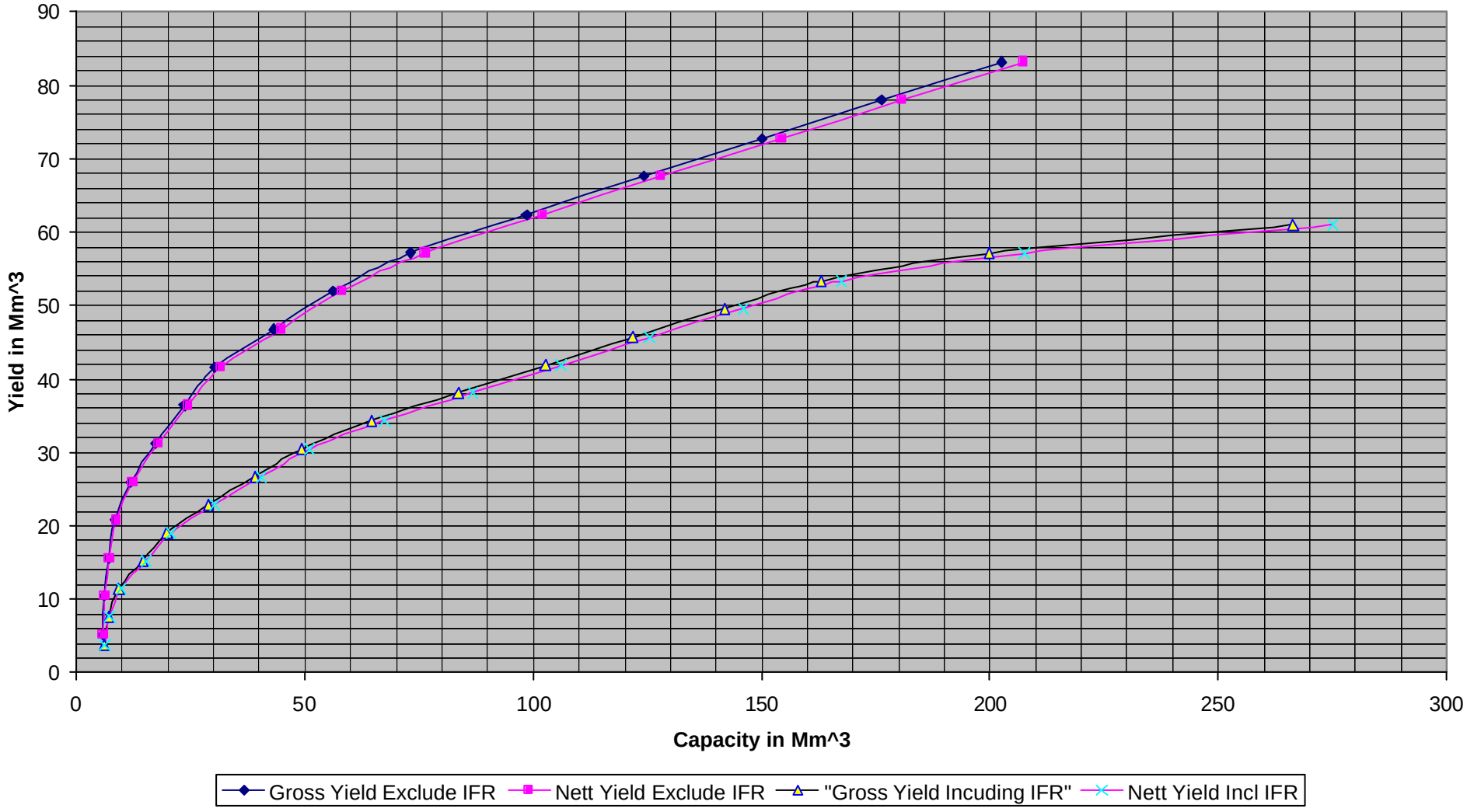
Xura Yield Curves (Present day: 2000)



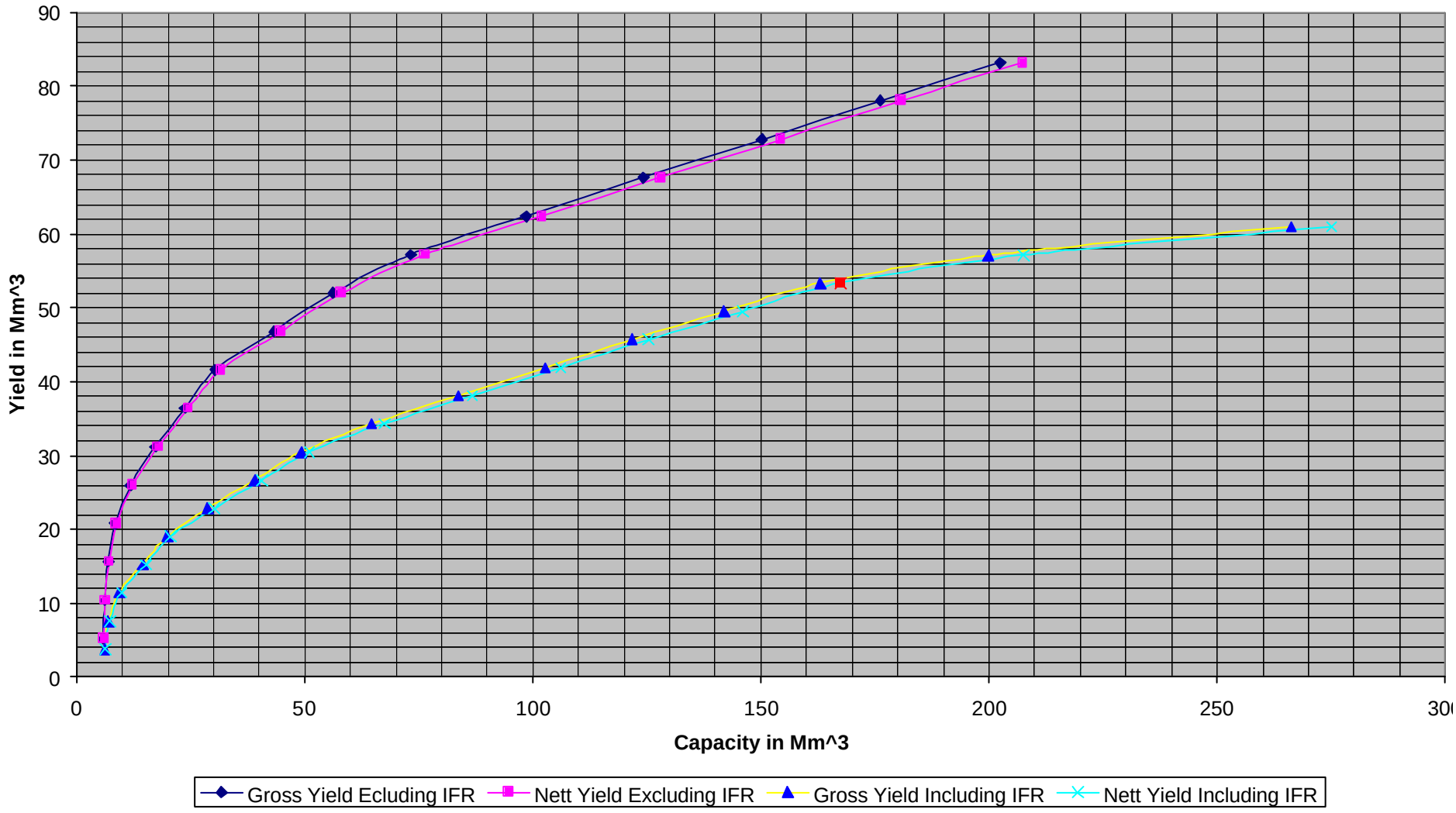
Tungwane Dam Yield Curve (Present day, 2000)



Yield-capacity curves for KwaHlathi Dam Excluding and Including IFR



KwaHlathi Dam Yield Curves Excluding and Including IFR releases



APPENDIX 8
WRYM DATA FILES

APPENDIX 8.1
ZALU, XURA AND LUSIKISIKI DAMS

```
File:  Lusf01.dat             (Lusikisiki Dam)

(This file is the for Zalu, Xura and Lusikisiki)

Lusikisiki dam systems analysis
One dam (Record period 77 years :1920-1996)
Yield on channel 23(September 1998)
924     1  1920     1   924    -3     2     1     0     1     N     0
0     1     0
OCT   NOV   DEC   JAN   FEB   MAR   APR   MAY   JUN   JUL   AUG   SEP
31.00 30.00 31.00 31.00 28.25 31.00 30.00 31.00 30.00 31.00 31.00
30.00
77     1     2     1     H     1
D:\Lusik\WRYM\lusik\hydro\Paramk5.dat
1
21.80  0.01
21.80  0.01
0.0
```

```
File:  Lusf02.dat             (Lusikisiki Dam)

(This file is unique for each dam)

 5  MCM
Lusikisiki dam                          Y    3    1    8
   0.00      0.00      0.00    1.0062     0.000    1
0
535.000   540.000   545.000   549.100   550.000   554.480  555.000
559.379
 0.0100    0.0700    0.3350    1.0000    1.1600    3.0000   3.2180
7.0000
0.00500   0.02100   0.08500   0.21210   0.24500   0.54363  0.57900
1.00620
  81.04     82.61    106.71    116.11    105.35    100.70    78.03
  59.06     46.33     50.02     67.25     72.00
Inc catch T60F (Node 4)                 Y    4    0    0       1.0
1.0      0.00
0.000     0.000    3
0
Inc catch T60E (Node 5)                 Y    5    0    0       1.0
1.0      0.00
0.000     0.000    2
0
Inc catch T60G (Node 8)                 Y    8    0    0       1.0
1.0      0.00
0.000     0.000    4
0
Inc catch Upzalu (Node 1)               Y    1    0    0       1.0
1.0      0.00
0.000     0.000    1
0
```

File: Xurf02.dat (Xura Dam)

```
5  MCM
Xura dam                                  Y    3    1   11
  0.00      0.00      0.00
 1.207     0.000    1
     0
445.00    448.00    451.00    451.77    454.00    454.71    456.38
457.00    460.00    462.44    464.64
 0.002     0.170     0.617     0.800     1.330     1.600     2.240
 2.480     4.260     6.550     9.000
 0.001     0.098     0.208     0.239     0.329     0.352     0.407
 0.427     0.705     0.993     1.207
 81.04     82.61    106.71    116.11    105.35    100.70     78.03
 59.06     46.33     50.02     67.25     72.00
Inc catch T60F (Node 4)                   Y    4    0    0
   1.0       1.0      0.00
 0.000     0.000    2
     0
Inc catch T60E (Node 5)                   Y    5    0    0
   1.0       1.0      0.00
 0.000     0.000    3
     0
Inc catch T60G (Node 8)                   Y    8    0    0
   1.0       1.0      0.00
 0.000     0.000    4
     0
Inc catch Upzalu (Node 1)                 Y    1    0    0
   1.0       1.0      0.00
 0.000     0.000    1
    0
```

```
File:  Zalf02.dat             (Zalu Dam)


5  MCM
Zalu dam                                  Y    3    1   13
  0.00      0.00      0.00
1.8351    0.000    1
     0
 0.000     4.000     9.000    14.000    14.696    19.000    24.000
24.999    29.000    34.000    34.883    37.824    39.000
 0.000     0.100     0.300     1.070     1.380     3.300     6.100
6.939    10.300    16.500    18.000    23.000    25.000
0.0000    0.0500    0.1300    0.2460    0.2880    0.4800    0.6900
0.7539    1.0100    1.4300    1.5230    1.8351    1.9600
 81.04     82.61    106.71    116.11    105.35    100.70     78.03
59.06     46.33     50.02     67.25     72.00
Inc catch T60F (Node 4)                   Y    4    0    0
   1.0       1.0      0.00
 0.000     0.000    2
     0
Inc catch T60E (Node 5)                   Y    5    0    0
   1.0       1.0      0.00
 0.000     0.000    3
     0
Inc catch T60G (Node 8)                   Y    8    0    0
   1.0       1.0      0.00
 0.000     0.000    4
     0
Inc catch Upzalu (Node 1)                 Y    1    0    0
   1.0       1.0      0.00
 0.000     0.000    1
    0
```

File: Lusf03.dat (Lusikisiki Dam)

(This file is the same for Zalu, Xura and Lusikisiki Dams)

```
    7
    1    1   20
    2    1    0
    3    2    0       300
    4    2    0       250
    5    1  500
    6    2    0       400
    7    2    0       500
    1                                  /Yield channel
   13    3    0    3    W
    0                                  /Power channel
    0                                  /Irrigation channel
    0                                  /Diversion channel
    0                                  /Min-channel
    0                                  /Loss channel
    4                                  /Min-max
   11    2    0    3
   15    6    0    4
   21    7    0    4
   22    9    0    4
    0                                  /Pumping channel
    0                                  /Specified inflow channel
    1                                  /Specified demand channel
   26    3   24    6    1    HD:\LUSIK\WRYM\LUSIK\HYDRO\LUSIK.IFR
   10                                  /General flow channel
   10    1    2    2
   12    2    3    2
   17    3    4    5
   14    5    6    2
   16    6    4    2
   18    4    7    2
   19    7    8    2
   20    8    9    2
   23    9   24    2
   25   24    0    2
   16    1
   13  Y  Yield Chnl -13
   10  Y  Flow Chnl -10
   11  Y  Uplusik abstraction -11
   12  Y  Inflow Chnl -12
   14  Y  Flow Chnl -14
   15  Y  T60e Abstraction -15
   16  Y  Flow Chnl -16
   17  Y  Spill Chnl -17
   18  Y  Flow Chnl -18
   19  Y  Flow Chnl -19
   20  Y  Flow Chnl -20
   21  Y  T60f abstrac -21
   22  Y  T60g Abstraction -22
   23  Y  To IFR inflow -23
   25  Y  River Outlet -25
   26  Y  IFR Channel -26
```

File: Lusf05.dat (Lusikisiki Dam)

(This file is unique for each dam)

```
    3    1    1
    SURCHG    3    1    1      1000
    DRDWN     3    1    1       200
    DSL       3    1    1      1000
    3    1         0   559.379   535.000   535.000    /Lusiki dam
    0
```

File: Xurf05.dat (Xura Dam)

```
    3    1    1
    SURCHG    3    1    1      1000
    DRDWN     3    1    1       200
    DSL       3    1    1      1000
    3    1         0    464.64    445.00    445.00    /Xura dam
    0
```

File: Zalf05.dat (Zalu Dam)

```
    3    1    1
    SURCHG    3    1    1      1000
    DRDWN     3    1    1       200
    DSL       3    1    1      1000
    3    1         0    37.824    00.000    00.000     /Zalu dam
    0
```

File: Lusf06.dat (Lusikisiki Dam)

(This file is unique for each dam)

```
 3  559.379
 0         0
```

File: Xurf06.dat (Xura Dam)

```
 3   464.64
 0        0
```

File: Zalf07.dat (Zalu Dam)

```
 3   37.824
 0        0
```

File:	Lusf04.dat	Xurf04.dat	Zalf04.dat
	Lusf07.dat	Xurf07.dat	Zalf07.dat
	Lusf08.dat	Xurf08.dat	Zalf08.dat
	Lusf09.dat	Xurf09.dat	Zalf09.dat
	Lusf10.dat	Xurf10.dat	Zalf10.dat
	Lusf11.dat	Xurf11.dat	Zalf11.dat

(The files above were not needed for proposed dam systems and were left empty).

File: Lusf12.dat (lusikisiki dat)

(This file is unique for each system)

```
11 - UpLusik Abstraction  11
0.00750.00770.00750.00750.00820.00750.00770.00370.00390.00370.00370.0
039
0.00750.00770.00750.00750.00820.00750.00770.00370.00390.00370.00370.0
039
15 - T60e Abstraction  15
0.02240.02310.02610.02990.02870.02240.02310.01870.01930.01490.01870.0
193
0.02240.02310.02610.02990.02870.02240.02310.01870.01930.01490.01870.0
193
21 - T60f Abstraction  21
0.02240.00270.02610.02990.02870.02610.02310.01870.01930.01490.01870.0
193
0.02240.00270.02610.02990.02870.02610.02310.01870.01930.01490.01870.0
193
22 - T60g Abstraction  22
0.01870.02310.02240.02610.02460.02240.01930.01870.01540.01490.01490.0
193
0.01870.02310.02240.02610.02460.02240.01930.01870.01540.01490.01490.0
193
```

File: Xurf12.dat (Xura Dam)

```
11 - UpXura Abstraction  11
0.01490.01540.01490.01870.01640.01490.01540.01120.01160.01120.01120.0
116
0.01490.01540.01490.01870.01640.01490.01540.01120.01160.01120.01120.0
116
15 - T60e Abstraction  15
0.02240.02310.02610.02990.02870.02240.02310.01870.01930.01490.01870.0
193
0.02240.02310.02610.02990.02870.02240.02310.01870.01930.01490.01870.0
193
21 - T60f Abstraction  21
0.01490.01540.01870.01870.02050.01490.01540.01490.01160.01120.01120.0
154
0.01490.01540.01870.01870.02050.01490.01540.01490.01160.01120.01120.0
154
22 - T60g Abstraction  22
0.01870.02310.02240.02610.02460.02240.01930.01870.01540.01490.01490.0
193
0.01870.02310.02240.02610.02460.02240.01930.01870.01540.01490.01490.0
193
```

File: Zalf12.dat (Zalu dam)

11 - Upzalu Abstraction 11
0.00370.00770.00750.00750.00820.00750.00390.00370.00390.00370.00370.0
039
0.00370.00770.00750.00750.00820.00750.00390.00370.00390.00370.00370.0
039
15 - T60e Abstraction 15
0.02240.02310.02610.02990.02870.02240.02310.01870.01930.01490.01870.0
193
0.02240.02310.02610.02990.02870.02240.02310.01870.01930.01490.01870.0
193
21 - T60f Abstraction 21
0.02240.02700.02610.02990.02870.02610.02310.02240.01930.01490.01870.0
231
0.02240.02700.02610.02990.02870.02610.02310.02240.01930.01490.01870.0
231
22 - T60g Abstraction 22
0.01870.02310.02240.02610.02460.02240.01930.01870.01540.01490.01490.0
193
0.01870.02310.02240.02610.02460.02240.01930.01870.01540.01490.01490.0
193

File: Lusf13.dat (Lusikisiki Dam)

(This file is the same for Zalu, Xura and Lusikisiki Dams)

Water yield control chanel 13

1.00 1.10 1.20 1.30 1.20 1.10 1.00 0.90 0.80 0.70 0.80 0.90

File Lusf14.dat (Lusikisiki dam)

(This file is unique for each system)

```
 1
 26 1 0 7
 1
 0.00 0.00  0.00 0.00  0.00 0.00  0.00 0.00  0.00 0.00   0.00  0.00
           0.0   0.00  0.00 0.00  0.00 0.00  0.00 0.00   0.00  0.00
            0.00 0.00
 0.06 0.04  0.10 0.07  0.12 0.05  0.07 0.04  0.09 0.05   0.07 0.05
            0.07 0.06  0.05 0.04  0.04 0.04  0.04 0.04   0.04 0.03
            0.04 0.03
 0.11 0.06  0.20 0.13  0.18 0.07  0.17 0.06  0.16 0.07   0.14 0.07
            0.14 0.08  0.09 0.05  0.07 0.05  0.06 0.05   0.05 0.04
            0.07 0.04
 0.15 0.08  0.26 0.22  0.21 0.09  0.19 0.08  0.17 0.09   0.18 0.11
            0.17 0.10  0.12 0.07  0.08 0.06  0.07 0.06   0.06 0.05
            0.09 0.05
 0.18 0.10  0.74 0.33  0.38 0.14  0.21 0.10  0.19 0.11   0.21 0.15
            0.19 0.12  0.14 0.08  0.10 0.08  0.08 0.07   0.09 0.06
            0.12 0.06
 0.21 0.12  1.25 0.37  0.60 0.16  0.25 0.11  0.22 0.13   0.96 0.22
            0.21 0.14  0.15 0.09  0.14 0.09  0.11 0.08   0.10 0.07
            0.13 0.07
79.45 0.13 99.07 0.43 89.68 0.17 46.22 0.12 81.78 0.15 115.59 0.23
          170.29 0.16 60.86 0.10 84.41 0.10 119.10 0.09 43.98 0.08
          119.21 0.08
```

File: Xurf14.dat (Xura Dam)

```
0
```

File: Zalf14.dat (Zalu Dam)

```
1
26 1 0 18
1
0.0  0.00  0.00 0.00  0.00 0.00  0.00 0.00  0.00 0.00  0.00 0.00
           0.0  0.00  0.00 0.00  0.00 0.00  0.00 0.00  0.00 0.00
           0.00 0.00
0.04 0.03  0.08 0.05  0.12 0.04  0.08 0.03  0.07 0.03  0.08 0.05
           0.05 0.04  0.06 0.03  0.05 0.03  0.04 0.03  0.04 0.03
           0.07 0.03
0.09 0.04  0.13 0.08  0.13 0.05  0.08 0.03  0.10 0.04  0.11 0.06
           0.08 0.05  0.06 0.03  0.06 0.04  0.05 0.04  0.04 0.03
           0.09 0.04
0.09 0.04  0.15 0.10  0.15 0.06  0.12 0.04  0.10 0.04  0.12 0.07
           0.12 0.06  0.06 0.03  0.06 0.04  0.05 0.04  0.04 0.03
           0.09 0.04
0.09 0.04  0.16 0.11  0.18 0.07  0.12 0.04  0.11 0.05  0.13 0.08
           0.13 0.07  0.06 0.03  0.06 0.04  0.05 0.04  0.04 0.03
           0.09 0.04
0.10 0.05  0.19 0.16  0.19 0.08  0.13 0.05  0.11 0.05  0.14 0.09
           0.13 0.07  0.06 0.03  0.06 0.04  0.05 0.04  0.04 0.03
           0.11 0.05
0.10 0.05  0.20 0.17  0.23 0.09  0.15 0.06  0.12 0.06  0.15 0.10
           0.14 0.08  0.08 0.04  0.06 0.04  0.05 0.04  0.06 0.04
           0.11 0.05
0.10 0.05  0.21 0.18  0.27 0.10  0.15 0.06  0.12 0.06  0.16 0.11
           0.15 0.09  0.08 0.04  0.07 0.05  0.06 0.05  0.06 0.04
           0.11 0.05
0.11 0.06  0.24 0.19  0.27 0.10  0.15 0.06  0.14 0.08  0.20 0.12
           0.15 0.09  0.08 0.04  0.07 0.05  0.06 0.05  0.06 0.04
           0.11 0.05
0.11 0.06  0.34 0.22  0.27 0.10  0.16 0.07  0.14 0.08 0.23 0.13
           0.15 0.09  0.08 0.04  0.07 0.05  0.06 0.05  0.06 0.04
           0.11 0.05
0.12 0.07  0.38 0.23  0.27 0.10  0.16 0.07  0.16 0.09  0.23 0.13
           0.15 0.09  0.08 0.04  0.07 0.05  0.06 0.05  0.06 0.04
           0.11 0.05
0.12 0.07  0.48 0.24  0.27 0.10  0.16 0.07  0.16 0.09  0.30 0.14
           0.17 0.10  0.09 0.05  0.07 0.05  0.06 0.05  0.06 0.04
           0.11 0.05
0.12 0.07  0.61 0.25  0.40 0.11  0.16 0.07  0.16 0.09  0.53 0.15
           0.17 0.10  0.09 0.05  0.07 0.05  0.13 0.06  0.08 0.05
           0.11 0.05
0.14 0.08  0.97 0.27  0.40 0.11  0.21 0.08  0.16 0.09  0.81 0.16
           0.17 0.10  0.09 0.05  0.09 0.06  0.13 0.06  0.08 0.05
           0.11 0.05
0.14 0.08  1.03 0.28  0.40 0.11  0.21 0.08  0.16 0.09  0.81 0.16
           0.20 0.11  0.12 0.06  0.09 0.06  0.13 0.06  0.08 0.05
           0.11 0.05
0.14 0.08  0.21 0.30  0.90 0.12  0.21 0.08  0.20 0.10  0.81 0.16
           0.20 0.11  0.12 0.06  0.09 0.06  0.13 0.06  0.08 0.05
           0.11 0.05
0.15 0.09  0.40 0.31  0.90 0.12  0.21 0.08  0.20 0.10  1.29 0.17
           0.20 0.11  0.12 0.06  0.09 0.06  0.13 0.06  0.08 0.05
           0.11 0.05
61.98 0.10 77.31 0.32 69.97 0.13 36.07 0.09 63.83 0.11 90.20 0.18
          132.87 0.12 47.49 0.07 65.82 0.07 92.97 0.07 99.27 0.06
          93.06 0.06
```

APPENDIX 8.2
TUNGWANA AND LOWER MZINTLAVA DAMS

File: Tunf01.dat   (Tungwana Dam)

(This file is the same for both Tungwana and Lower Mzintlava dams)

```
Tungwane dam systems analysis.
One dam (Record period 77 years :1920-1996)
Yield on channel 23(September 1998)
924     1  1920     1   924    -3     2     1     0     1     N     0
0     1     0
OCT   NOV   DEC   JAN   FEB   MAR   APR   MAY   JUN   JUL   AUG   SEP
31.00 30.00 31.00 31.00 28.25 31.00 30.00 31.00 30.00 31.00 31.00
30.00
77     1     2     1     H     1
D:\Lusik\WRYM\tung\Hydro\Paramk5.dat
     1
 20.00  00.01
 20.00  00.01
   0.0
```

File: Tunf03.dat (Tungwana Dam)

(This file is the same for both Tungwana and Lower Mzintlava dams)

```
    7
    1    1    0
    2    1   20
    3    2    0       300
    4    2    0       200
    5    1  500
    6    2    0       600
    7    2    0       700
    1                                  /Tungwane Yield channel
   13    3    0    3    W
    0                                  /Power channel
    0                                  /Irrigation channel
    0                                  /Diversion channel
    0                                  /Min-channel
    0                                  /Loss channel
    2                                  /Min-max
    7    2   0     7
   11    5   0     4
    0                                  /Pumping channel
    0                                  /Specified inflow channel
    1                                  /Specified demand channel
   15    3   14    6    1    D:\lusik\wrym\tung\hydro\tung.ifr
    6                                  /General flow channel
    6    1    2    1
    8    2    3    1
    9    3    4    5
   10    4    5    1
   12    5   14    1
   16   14    0    1
   10    1
   13  Y  Yield Chnl -13
    6  Y  Flow Chnl -6
    7  Y  UpTungwane Abstr -7
    8  Y  Flow Chnl -8
    9  Y  Spill Chn -9
   10  Y  Flow Chnl -10
   11  Y  DnLmzi Chn -11
   12  Y  River Outlet -12
   15  Y  IFR Chnl -15
   16  Y  River Outlet -16
```

File:	Tunf04.dat	Lmzf04.dat
	Tunf07.dat	Lmzf07.dat
	Tunf08.dat	Lmzf08.dat
	Tunf09.dat	Lmzf04.dat
	Tunf10.dat	Lmzf10.dat

(The files above were not needed for proposed dams systems and were left empty).

File: Tunf05.dat (Tungwana Dam)

(This file is unique to each dam)

```
    3    1    1
    SURCHG    3    1    1      1000
    DRDWN     3    1    1       200
    DSL       3    1    1      1000
    3    1         0     20.39     18.17   2.00    /Tungwane dam
    0
```

File Lmzf05.dat (Lower Mzintlava Dam)

```
   3    1    1
    SURCHG    3    1    1      1000
    DRDWN     3    1    1       200
    DSL       3    1    1      1000
    3    1         0   432.323    427.65  410.00    /L.Mzintlava dam
    0
```

File: Tunf06.dat (Tungwana Dam)

(This file is unique to each dam)

```
 3    20.39
 0       0
```

File: Lmzf06.dat (Lower Mzintlava Dam)

```
 3  432.323
 0       0
```

File: Tunlf12.dat (Tungwana dam)

07 - Up Tugwane 7
0.00370.00770.00750.00750.00820.00750.00390.00370.00390.00370.00370.0
039
0.00370.00770.00750.00750.00820.00750.00390.00370.00390.00370.00370.0
039
11 - Dn Tungwane 11
0.00750.00770.00750.00750.00820.00750.00770.00750.00390.00370.00370.0
077
0.00750.00770.00750.00750.00820.00750.00770.00750.00390.00370.00370.0
077

File: Lmzf12.dat (Lower Mzintlava dam)

07 - Up Lower Mzintlava 7
0.00370.00390.00370.00750.00410.00370.00390.00370.00390.00370.00370.0
039
0.00370.00390.00370.00750.00410.00370.00390.00370.00390.00370.00370.0
039
11 - Dn Lower Mzintlava 11
0.00750.00770.00750.01120.00820.00750.00770.00750.00770.00750.00750.0
077
0.00750.00770.00750.01120.00820.00750.00770.00750.00770.00750.00750.0
077

File: Tunf13.dat (Tungwana Dam)

(This file is the same for both Tungwana and Lower
 Mzintlava dams)

Water yield control chanel 13
1.00 1.10 1.20 1.30 1.20 1.10 1.00 0.90 0.80 0.70 0.80
0.90

```
File:  Tunf14.dat             (Tungwana Dam)
       Lmzf14.dat             (Lower Mzintlava Dam)
0
```

APPENDIX 9
PARAMK5.DAT FILES

APPENDIX 9.1
LOWER MZINTLAVA DAM

```
2  THE PARAMETER FILE FOR ANSMK5

2 1 2

d:\lusik\wrym\lmzi\hydro\mzintla
          77           20      1.8887      1.8887      0.3400
0.3400
 1           -4.4317394           1.6648441           1.0000000
0.0000000
     0.00000     1.00000     0.00000     0.00000     0.00000
0.00000     0.00000   0
    17.06390    10.36607    79.05333    79.05333

d:\lusik\wrym\lmzi\hydro\mevana
          77           20      1.7106      2.0661     -0.0597
0.3599
 3            1.8925514           1.4428850         265.5675202
0.0000000
     0.00000     1.00000     0.75133     0.00000     0.81688
0.15738     0.00000   0
    61.78805    31.33980    77.40300    79.05333

 B - THE SQUARE-ROOT OF THE LAG-ZERO DISPERSION MATRIX G0
 -1.00000000  0.00000000
 -0.95245235  0.00000000

 B0 - THE SQUARE-ROOT OF THE LAG-ZERO STARTING MATRIX H0
  0.00000000  0.00000000
  0.00000000 -0.14671629

 B1 - THE SQUARE-ROOT OF THE LAG-ONE STARTING MATRIX H1
  0.00000000  0.00000000
  0.00000000 -0.30468757

 A - THE COEFFICIENT MATRIX OF Z(-1) IN CALCULATING Z(0)
  0.00000000  0.00000000
  0.00000000 -0.85213899

 C - THE COEFFICIENT MATRIX OF A(-1) IN CALCULATING Z(0)
  0.00000000  0.00000000
  0.00000000 -0.91768899
```

APPENDIX 9.2
LUSIKISIKI DAM

```
4  THE PARAMETER FILE FOR ANSMK5

4 1 2 3 4

D:\lusik\wrym\lusik\hydro\lusik
          77           20      1.5847      1.8552      0.1581
0.4654
 1           -4.2817238           1.6677789           1.0000000
0.0044072
     0.00000     1.00000     0.75039     0.00000     0.82138
0.15416     0.00000   0
    15.51143     9.36914    77.43444    79.05333

D:\lusik\wrym\lusik\hydro\flags
          77           20      1.5754      1.8317      0.1768
0.4762
 1           -4.4642640           1.4734645           1.0000000
2.2022668
     0.00000     1.00000     0.75322     0.00000     0.82759
0.14824     0.00000   0
    28.00961    17.62267    77.61392    79.05333

D:\lusik\wrym\lusik\hydro\bomvi
          77           20      1.5851      1.8556      0.1565
0.4641
 1           -6.6374245           1.6683663           1.0000000
0.0017054
     0.00000     1.00000     0.75021     0.00000     0.82212
0.15345     0.00000   0
    63.57857    38.39956    77.42477    79.05333

D:\lusik\wrym\lusik\hydro\lmsika
          77           20      1.7584      1.7584      0.3914
0.3914
 3            1.4516093           1.0720834         338.8138693
19.1258782
    -0.04772     1.15277     0.00000     0.00000     0.00000
0.00000     0.00000   0
   100.32792    52.05256    79.05333    79.05333

 B - THE SQUARE-ROOT OF THE LAG-ZERO DISPERSION MATRIX G0
 -0.95172547  0.00000000  0.00162589  0.02018933
 -0.95168935  0.00000000  0.00001807 -0.04196979
 -0.95172264  0.00000000 -0.00164449  0.01950201
 -0.99999798  0.00000000  0.00000046  0.00201050

 B0 - THE SQUARE-ROOT OF THE LAG-ZERO STARTING MATRIX H0
 -0.14059764 -0.00051452  0.00291126  0.00000000
 -0.13513425 -0.00000584 -0.00595466  0.00000000
 -0.14057242  0.00052022  0.00281252  0.00000000
  0.00000000  0.00000000  0.00000000  0.00000000

 B1 - THE SQUARE-ROOT OF THE LAG-ONE STARTING MATRIX H1
 -0.30620723 -0.00067165  0.00671313  0.00000000
 -0.30389497 -0.00001194 -0.01318168  0.00000000
 -0.30626781  0.00068336  0.00636775  0.00000000
  0.00000000  0.00000000  0.00000000  0.00000000

 A - THE COEFFICIENT MATRIX OF Z(-1) IN CALCULATING Z(0)
```

```
 0.20325983 -1.24917925  0.17795025  0.00000000
 0.62144910 -2.06338886  0.57474532  0.00000000
 0.20789470 -1.25775551  0.18235583  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000

C - THE COEFFICIENT MATRIX OF A(-1) IN CALCULATING Z(0)
 0.13226983 -1.24917925  0.17795025  0.00000000
 0.62144910 -2.13775886  0.57474532  0.00000000
 0.20789470 -1.25775551  0.11044583  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000
```

APPENDIX 9.3
TUNGWANE DAM

```
2  THE PARAMETER FILE FOR ANSMK5

2 1 2

d:\lusik\wrym\tung\hydro\tung
          77           20      1.8682      1.8682      0.3712
0.3712
 1           -5.0398147           1.6719728           1.0000000
0.0000000
     0.00000     1.00000     0.00000     0.00000     0.00000
0.00000     0.00000   0
    24.19857    14.46576    79.05333    79.05333

d:\lusik\wrym\tung\hydro\mziza
          77           20      2.0747      2.0747      0.3611
0.3611
 3            1.8657826           1.4557798         230.3428766
0.0000000
     0.00000     1.00000     0.00000     0.00000     0.00000
0.00000     0.00000   0
    54.66247    27.27342    79.05333    79.05333

 B - THE SQUARE-ROOT OF THE LAG-ZERO DISPERSION MATRIX G0
  0.07901744  0.99687323
 -0.07901744  0.99687323

 B0 - THE SQUARE-ROOT OF THE LAG-ZERO STARTING MATRIX H0
  0.00000000  0.00000000
  0.00000000  0.00000000

 B1 - THE SQUARE-ROOT OF THE LAG-ONE STARTING MATRIX H1
  0.00000000  0.00000000
  0.00000000  0.00000000

 A - THE COEFFICIENT MATRIX OF Z(-1) IN CALCULATING Z(0)
  0.00000000  0.00000000
  0.00000000  0.00000000

 C - THE COEFFICIENT MATRIX OF A(-1) IN CALCULATING Z(0)
  0.00000000  0.00000000
  0.00000000  0.00000000
```

APPENDIX 9.4
XURA DAM

```
4  THE PARAMETER FILE FOR ANSMK5

4 1 2 3 4

d:\lusik\wrym\xura\hydro\xura
          77           20      1.5836      1.8550      0.1561
0.4646
 1           -5.7925664           1.6679588           1.0000000
0.0000000
     0.00000     1.00000     0.74901     0.00000     0.82033
0.15406     0.00000   0
    38.34987    23.16435    77.48278    79.05333

d:\lusik\wrym\xura\hydro\lusik
          77           20      1.5846      1.8555      0.1560
0.4639
 1           -5.8940914           1.6681864           1.0000000
0.0000000
     0.00000     1.00000     0.74992     0.00000     0.82152
0.15407     0.00000   0
    40.73584    24.60446    77.42684    79.05333

d:\lusik\wrym\xura\hydro\flags
          77           20      1.6781      1.9108      0.1873
0.4566
 1           -5.2334286           1.6602492           1.0000000
0.0000000
     0.00000     1.00000     0.76277     0.00000     0.83354
0.14339     0.00000   0
    28.00961    17.62267    77.89361    79.05333

d:\lusik\wrym\xura\hydro\lmsika
          77           20      2.0241      2.0241      0.3829
0.3829
 3            2.0147692           1.4453644         457.3190188
0.0000000
     0.00000     1.00000     0.00000     0.00000     0.00000
0.00000     0.00000   0
   100.32792    52.05256    79.05333    79.05333

 B - THE SQUARE-ROOT OF THE LAG-ZERO DISPERSION MATRIX G0
 -0.95190357  0.00000000  0.00000000  0.01938380
 -0.95163189  0.00000000  0.00000000  0.01967210
 -0.95332692  0.00000000  0.00000000 -0.04218698
 -0.99999599  0.00000000  0.00000000  0.00283150

 B0 - THE SQUARE-ROOT OF THE LAG-ZERO STARTING MATRIX H0
 -0.14273998 -0.00013161 -0.00265807  0.00000000
 -0.14274593  0.00013101 -0.00269822  0.00000000
 -0.13297723  0.00000064  0.00574965  0.00000000
  0.00000000  0.00000000  0.00000000  0.00000000

 B1 - THE SQUARE-ROOT OF THE LAG-ONE STARTING MATRIX H1
 -0.30570570 -0.00022385 -0.00691593  0.00000000
 -0.30653781  0.00022625 -0.00665342  0.00000000
 -0.29865464 -0.00000308  0.01390824  0.00000000
  0.00000000  0.00000000  0.00000000  0.00000000

 A - THE COEFFICIENT MATRIX OF Z(-1) IN CALCULATING Z(0)
```

```
-0.23521173 -0.23805068 -0.39128711  0.00000000
-0.23161219 -0.23462802 -0.40148209  0.00000000
 0.17984638  0.16140537 -1.21478771  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000

C - THE COEFFICIENT MATRIX OF A(-1) IN CALCULATING Z(0)
-0.30653173 -0.23805068 -0.39128711  0.00000000
-0.23161219 -0.30622802 -0.40148209  0.00000000
 0.17984638  0.16140537 -1.28555771  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000
```

APPENDIX 9.5
ZALU DAM

```
4  THE PARAMETER FILE FOR ANSMK5

4 1 2 3 4

d:\lusik\wrym\zalu\hydro\zalu
          77           20      1.5835      1.8556      0.1556
0.4647
 1           -3.8719333           1.6689761           1.0000000
-0.0018403
     0.00000     1.00000     0.74980     0.00000     0.82133
0.15412     0.00000   0
    12.10390     7.30949    77.42208    79.05333

d:\lusik\wrym\zalu\hydro\lusik
          77           20      1.5843      1.8555      0.1560
0.4642
 1           -6.7262224           1.6686595           1.0000000
-0.0145686
     0.00000     1.00000     0.75002     0.00000     0.82167
0.15386     0.00000   0
    66.98623    40.46017    77.42831    79.05333

d:\lusik\wrym\zalu\hydro\flags
          77           20      1.5754      1.8317      0.1768
0.4762
 1           -4.4642640           1.4734645           1.0000000
2.2022668
     0.00000     1.00000     0.75322     0.00000     0.82759
0.14824     0.00000   0
    28.00961    17.62267    77.61392    79.05333

d:\lusik\wrym\zalu\hydro\lmsika
          77           20      1.7584      1.7584      0.3914
0.3914
 3            1.4516093           1.0720834         338.8138693
19.1258782
    -0.04772     1.15277     0.00000     0.00000     0.00000
0.00000     0.00000   0
   100.32792    52.05256    79.05333    79.05333

 B - THE SQUARE-ROOT OF THE LAG-ZERO DISPERSION MATRIX G0
 -0.95166939  0.00000000  0.00293992 -0.01889743
 -0.95166758  0.00000000 -0.00288367 -0.02014906
 -0.95171746  0.00000000 -0.00006148  0.04132753
 -0.99999797  0.00000000  0.00000461 -0.00201590

 B0 - THE SQUARE-ROOT OF THE LAG-ZERO STARTING MATRIX H0
 -0.14083332  0.00092728  0.00271134  0.00000000
 -0.14075543 -0.00090709  0.00291079  0.00000000
 -0.13520705 -0.00002155 -0.00585441  0.00000000
  0.00000000  0.00000000  0.00000000  0.00000000

 B1 - THE SQUARE-ROOT OF THE LAG-ONE STARTING MATRIX H1
 -0.30646319 -0.00095746 -0.00624546  0.00000000
 -0.30638176  0.00093932 -0.00662221  0.00000000
 -0.30390390  0.00001854  0.01297425  0.00000000
  0.00000000  0.00000000  0.00000000  0.00000000

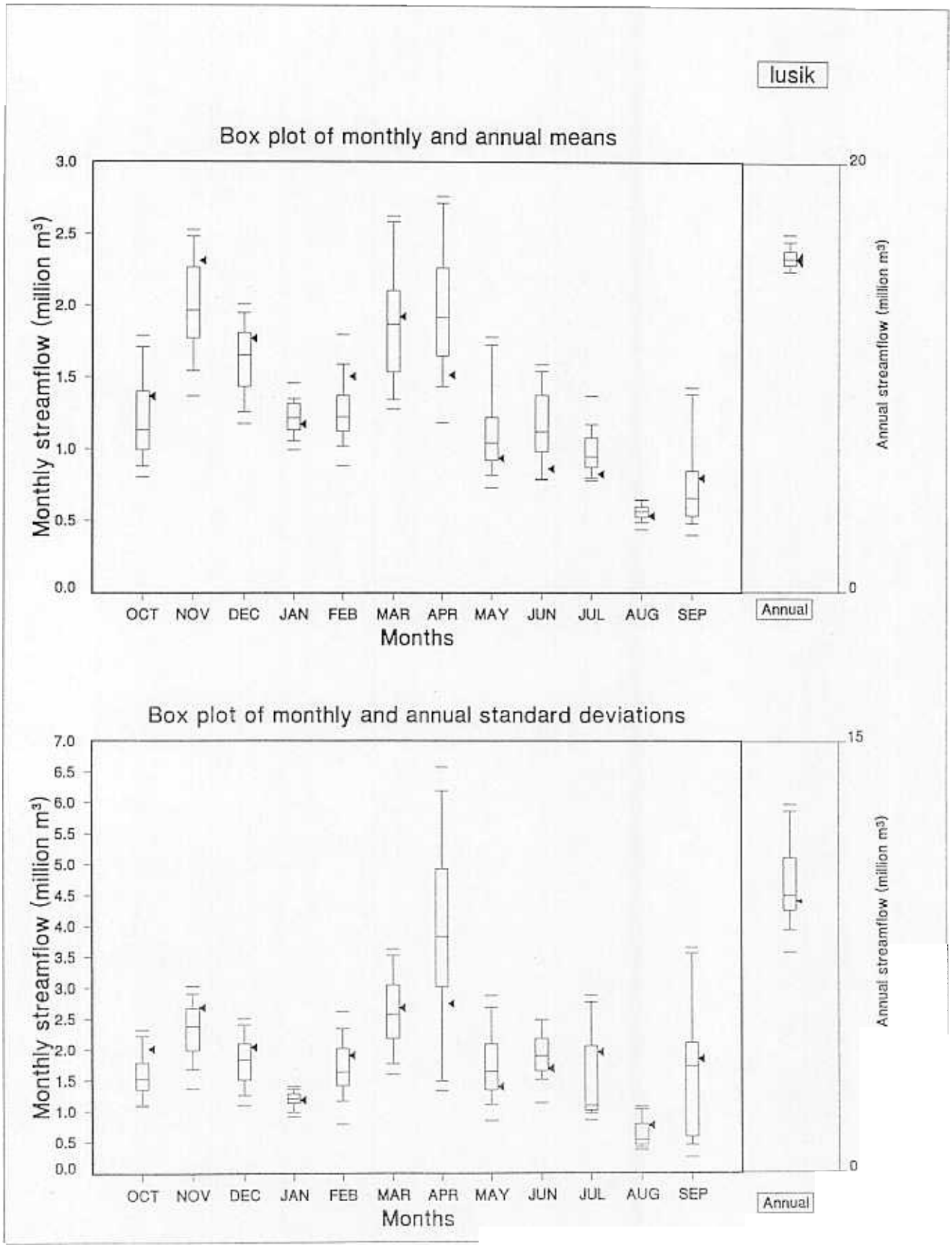
 A - THE COEFFICIENT MATRIX OF Z(-1) IN CALCULATING Z(0)
```

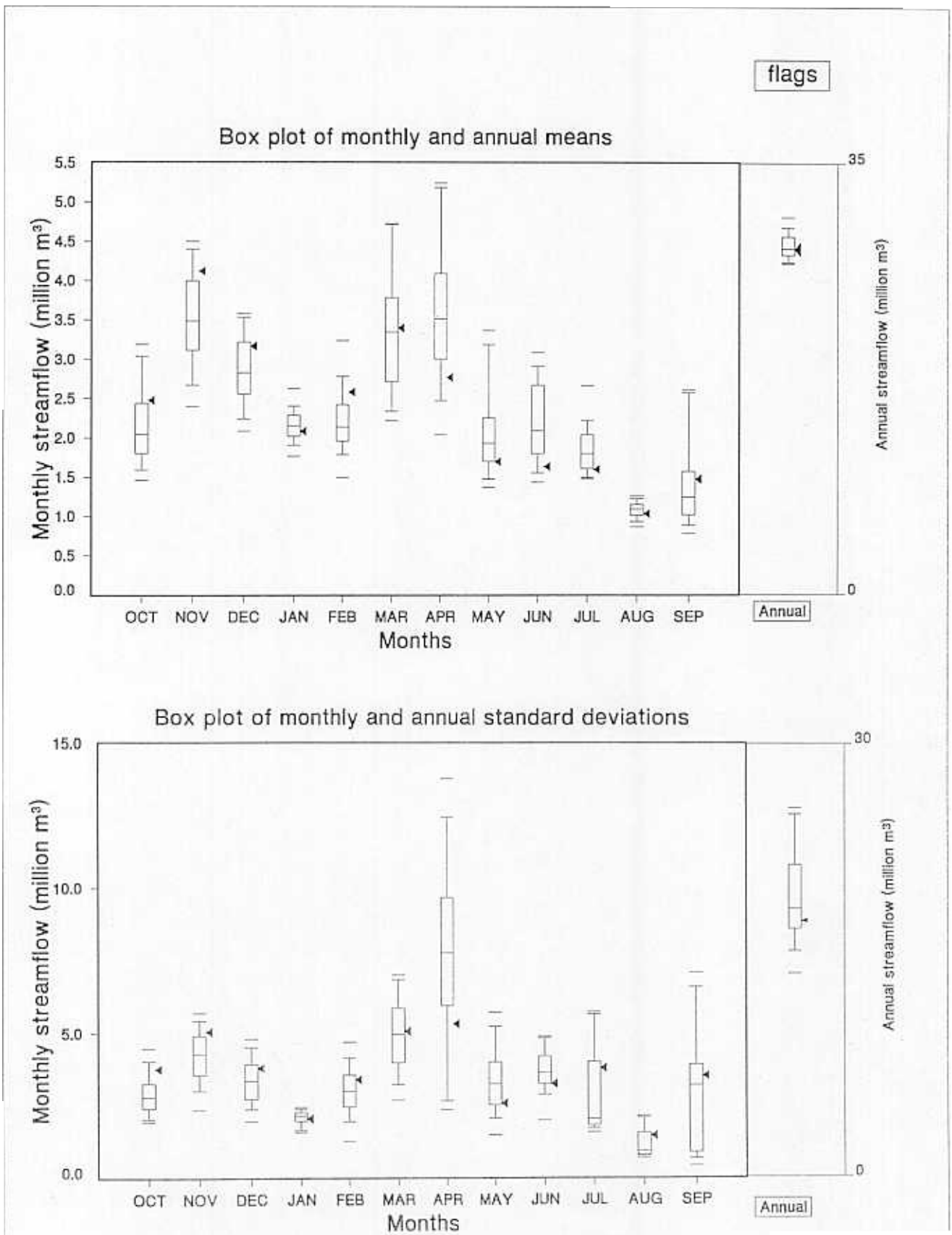
```
 0.18479012  0.21336341 -1.26655165  0.00000000
 0.17564700  0.20366544 -1.24739104  0.00000000
 0.57266952  0.62449962 -2.06515024  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000

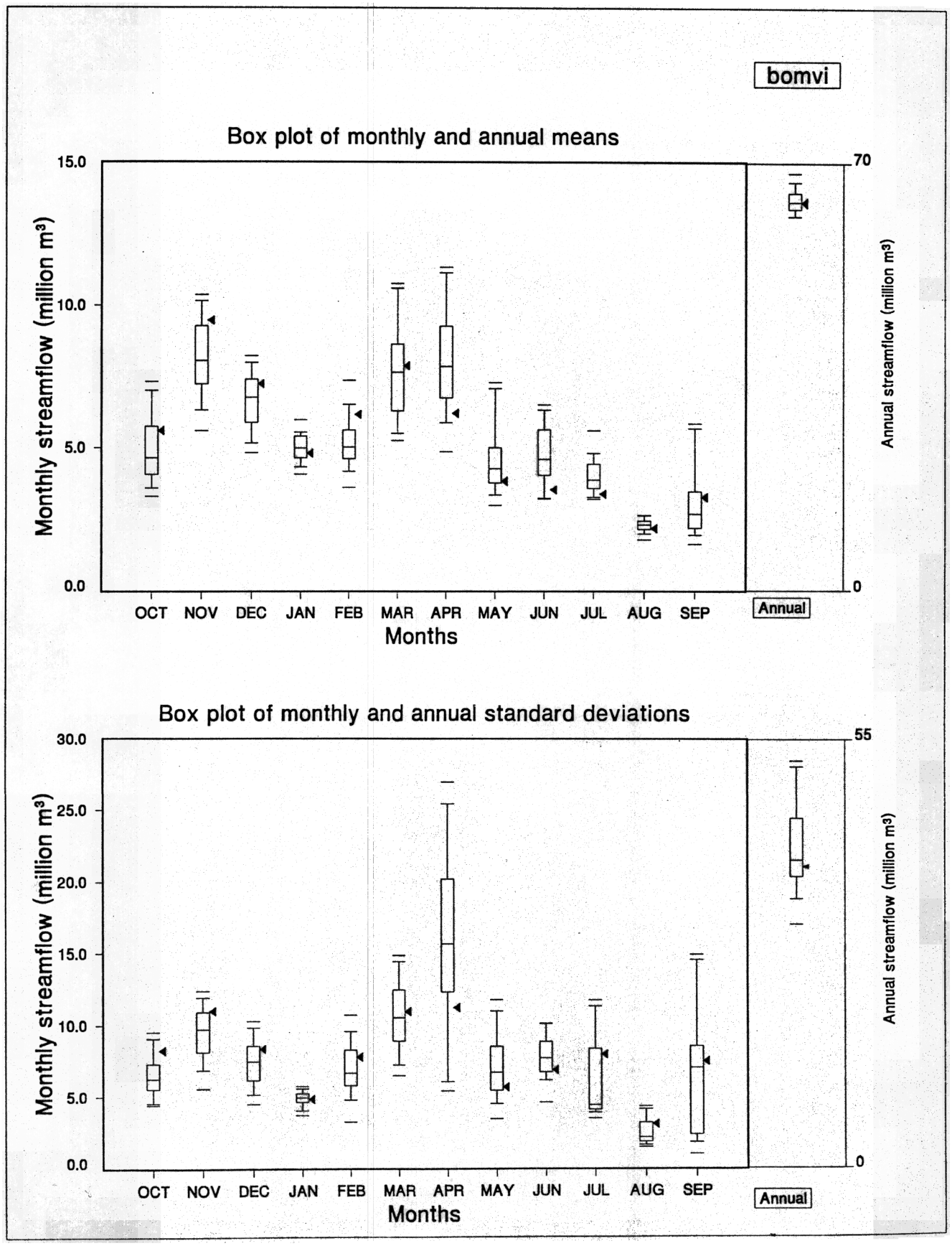
C - THE COEFFICIENT MATRIX OF A(-1) IN CALCULATING Z(0)
 0.11326012  0.21336341 -1.26655165  0.00000000
 0.17564700  0.13201544 -1.24739104  0.00000000
 0.57266952  0.62449962 -2.13952024  0.00000000
 0.00000000  0.00000000  0.00000000  0.00000000
```

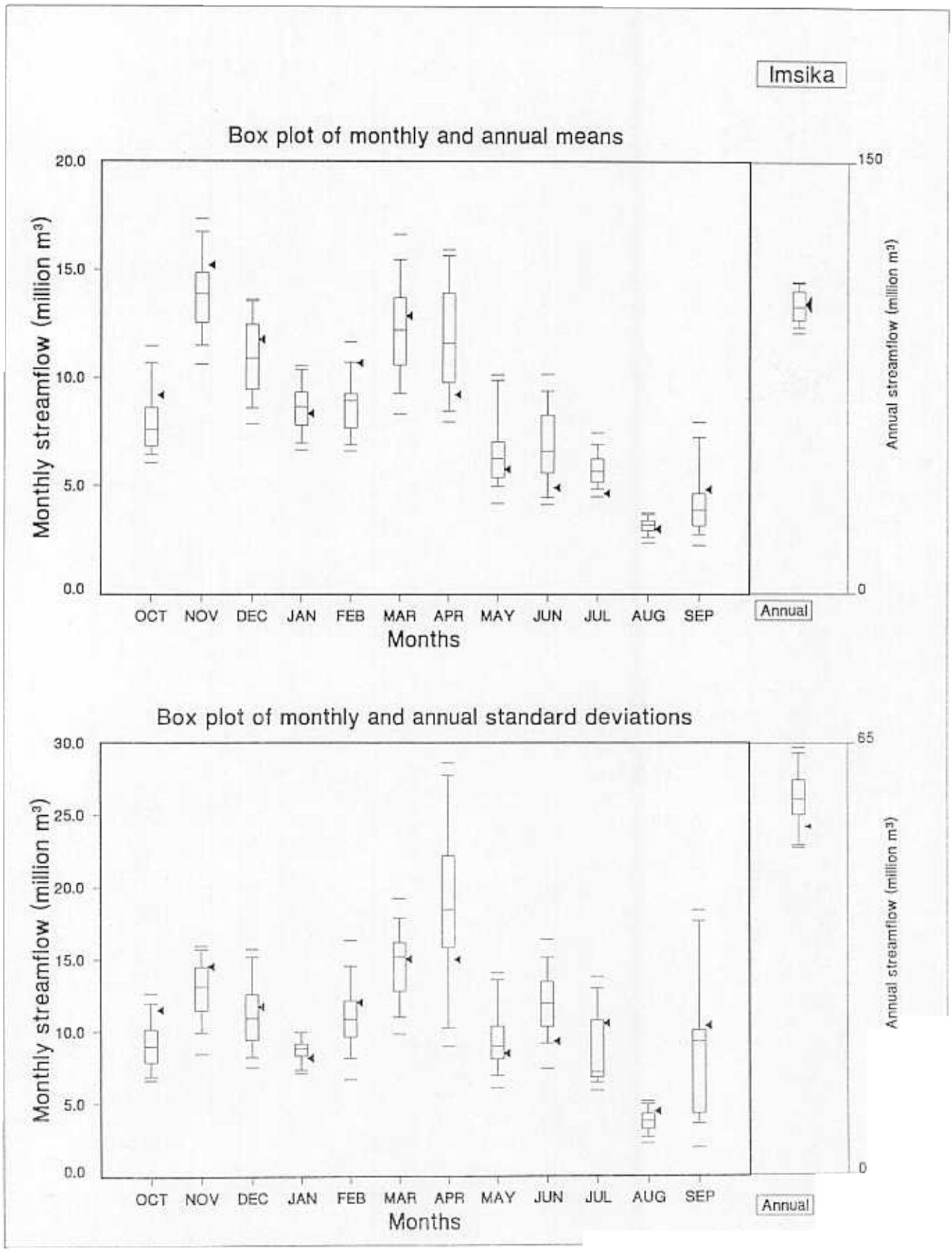
APPENDIX 10.1
MONTHLY AND YEARLY AVERAGES AND STANDARD DEVIATIONS

LUSIKISIKI DAM SYSTEM


lusik
Box plot of monthly and annual means
Monthly streamflow (million m³)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Months
20
0
Annual streamflow (million m³)
Annual
Box plot of monthly and annual standard deviations
Monthly streamflow (million m³)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Months
15
0
Annual streamflow (million m³)
Annual


flags
Box plot of monthly and annual means
Monthly streamflow (million m³)
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Months
35
0
Annual streamflow (million m³)
Annual
Box plot of monthly and annual standard deviations
Monthly streamflow (million m³)
15.0
10.0
5.0
0.0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Months
30
0
Annual streamflow (million m³)
Annual


bomvi
Box plot of monthly and annual means
Monthly streamflow (million m³)
15.0
10.0
5.0
0.0
70
0
Annual streamflow (million m3)
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Annual
Months
Box plot of monthly and annual standard deviations
Monthly streamflow (million m³)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
55
0
Annual streamflow (million m3)
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Annual
Months

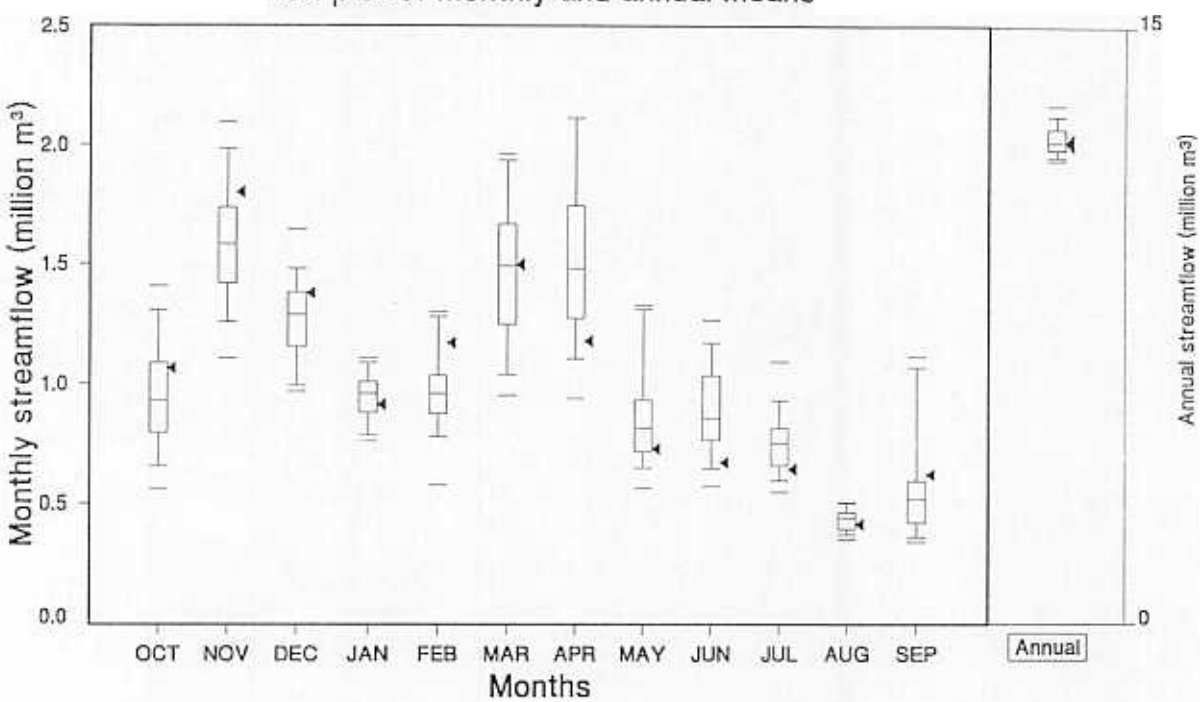

Imsika
Box plot of monthly and annual means
Monthly streamflow (million m³)
20.0
15.0
10.0
5.0
0.0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Months
150
0
Annual streamflow (million m³)
Annual
Box plot of monthly and annual standard deviations
Monthly streamflow (million m³)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
Months
65
0
Annual streamflow (million m³)
Annual

APPENDIX 10.2
MONTHLY AND YEARLY AVERAGES AND STANDARD DEVIATIONS

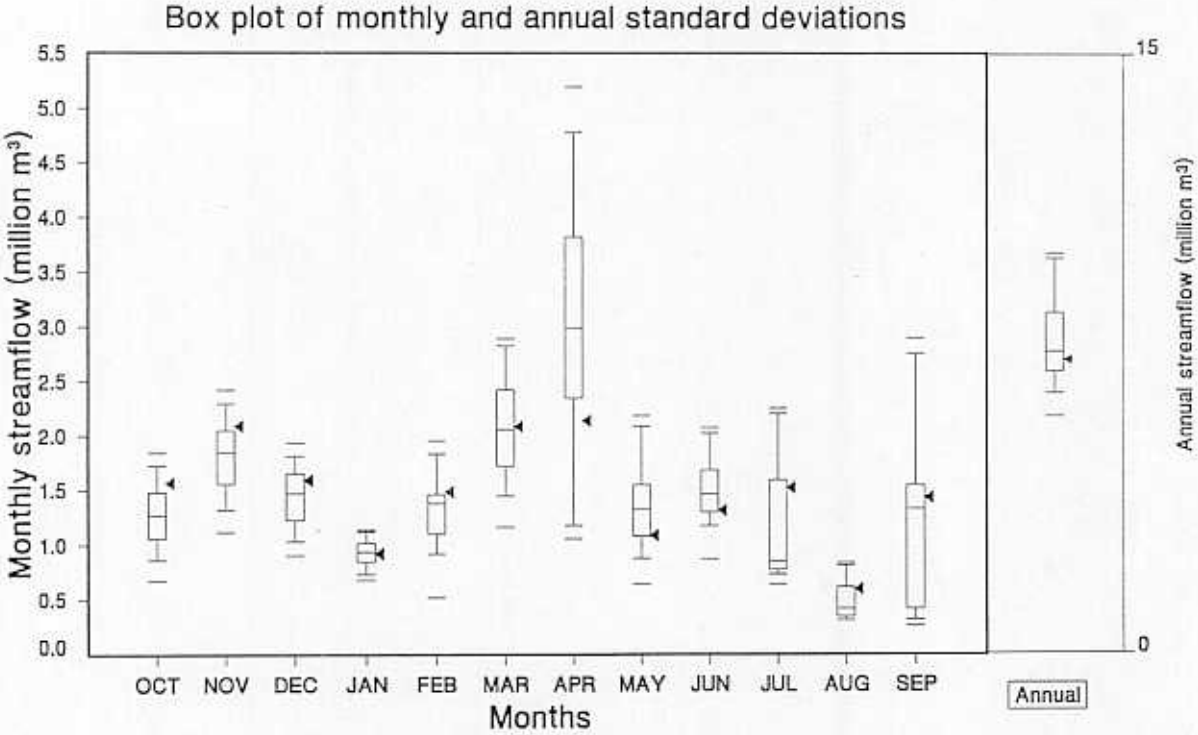
ZALU DAM SYSTEM

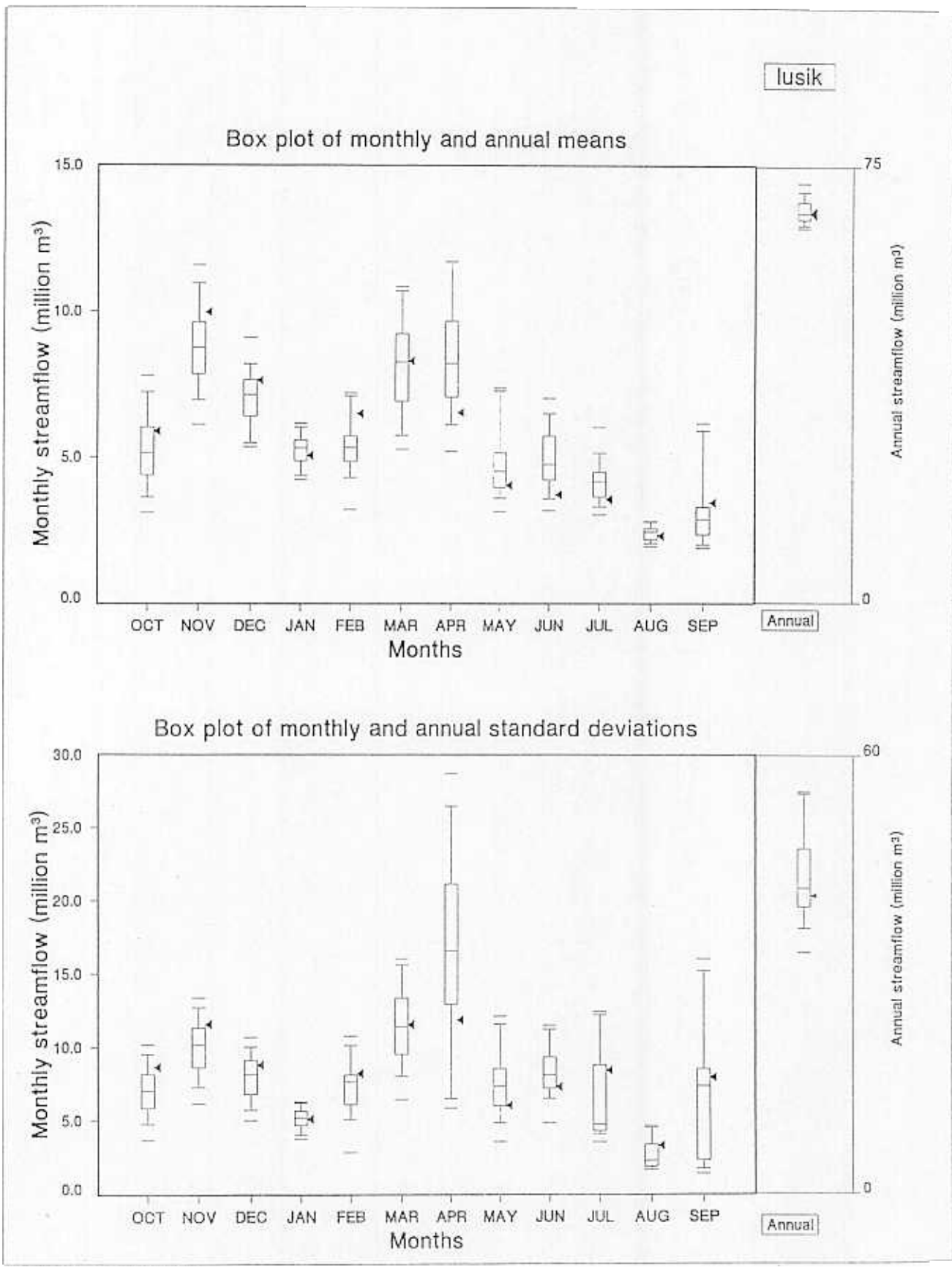
zaltu

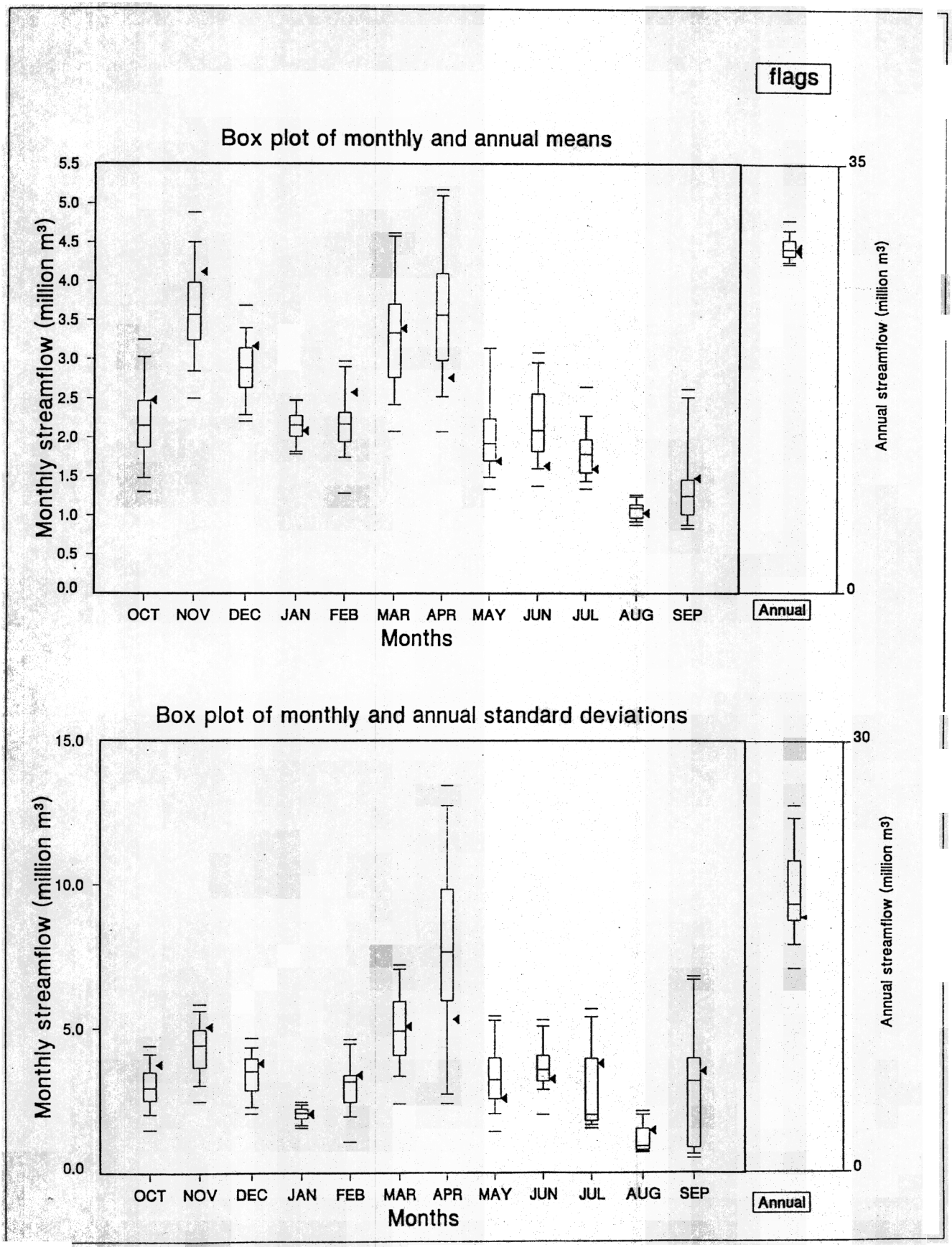
Box plot of monthly and annual means



Box plot of monthly and annual standard deviations

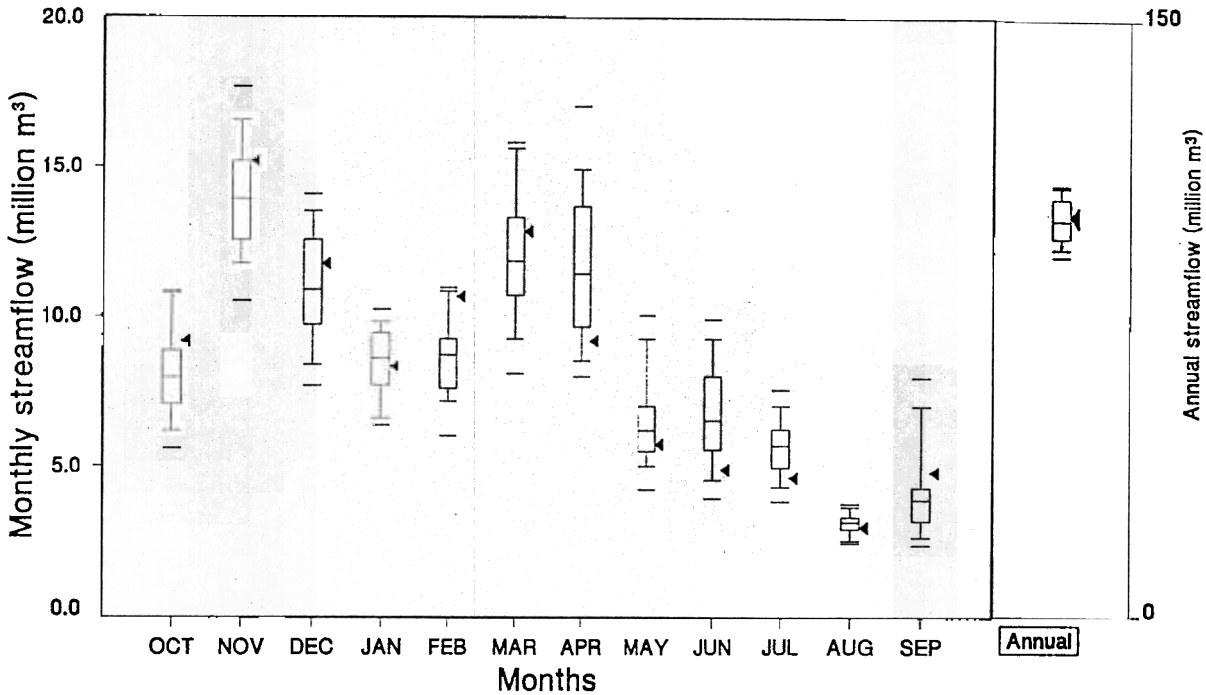



Iusik
Box plot of monthly and annual means
Monthly streamflow (million m³)
15.0
10.0
5.0
0.0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Months
75
0
Annual streamflow (million m³)
Annual
Box plot of monthly and annual standard deviations
Monthly streamflow (million m³)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Months
60
0
Annual streamflow (million m³)
Annual

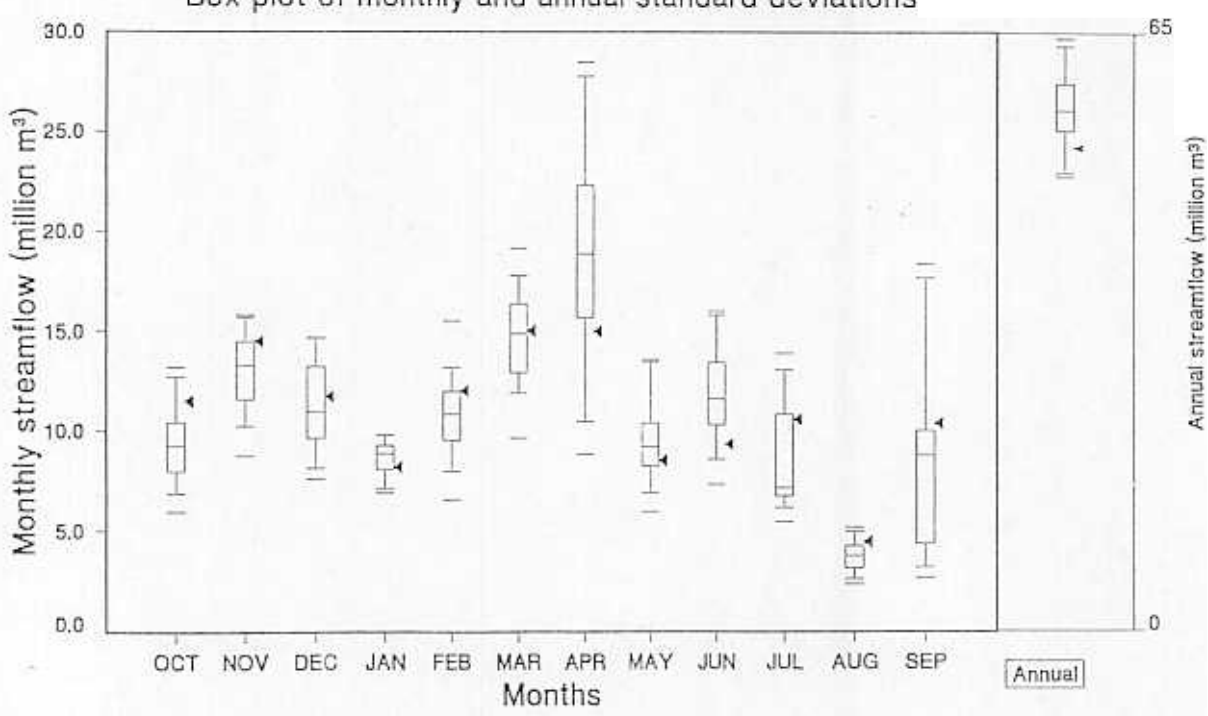

flags
Box plot of monthly and annual means
Monthly streamflow (million m³)
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Months
35
0
Annual streamflow (million m3)
Annual
Box plot of monthly and annual standard deviations
Monthly streamflow (million m³)
15.0
10.0
5.0
0.0
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
Months
30
0
Annual streamflow (million m3)
Annual

Imsika

Box plot of monthly and annual means



Box plot of monthly and annual standard deviations

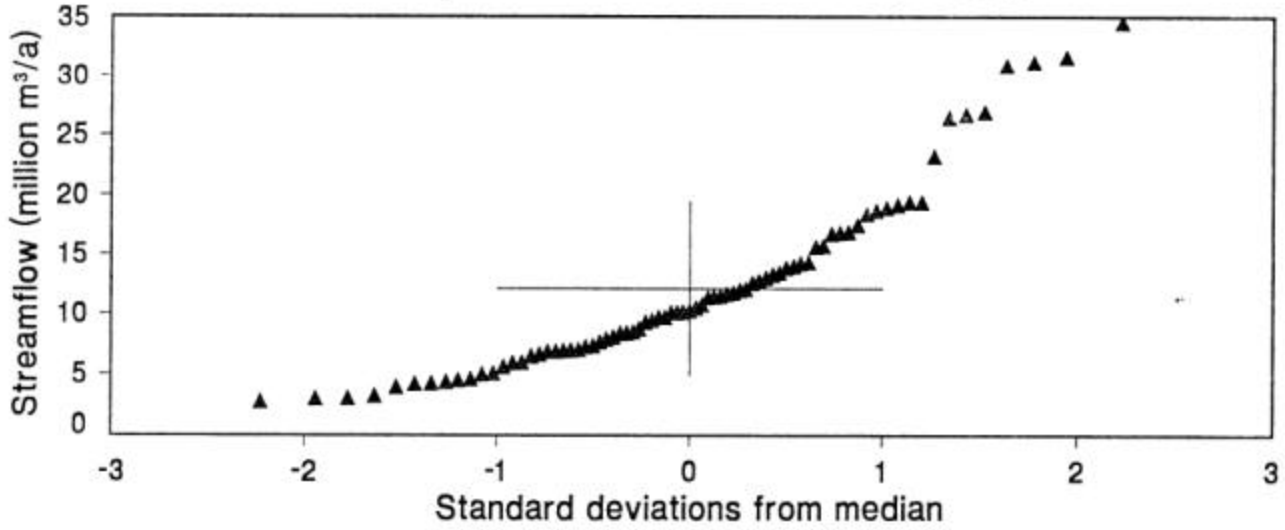


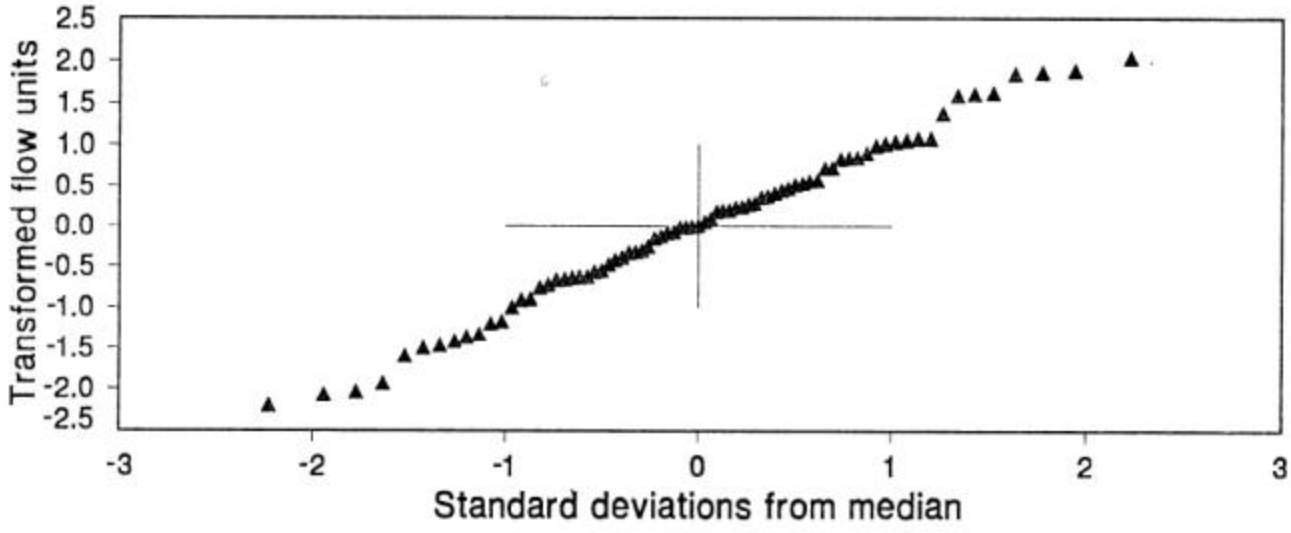
APPENDIX 11.1
SAMPLED CUMULATIVE DISTRIBUTIONS

LUSIKISIKI DAM SYSTEM

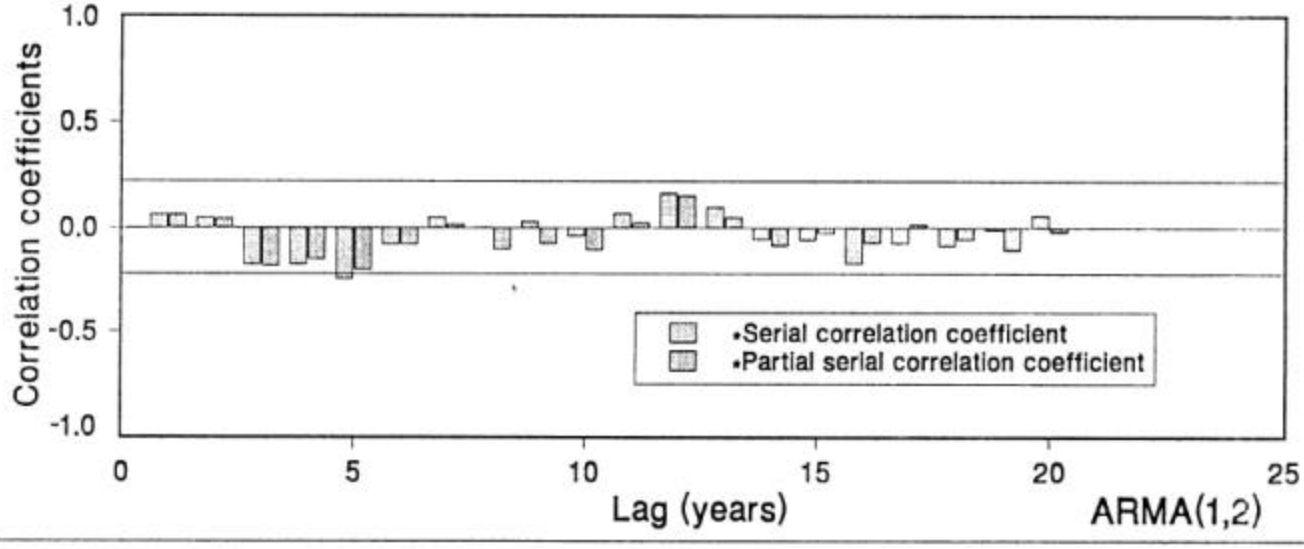
ZALU

Sampled Cumulative Distributions



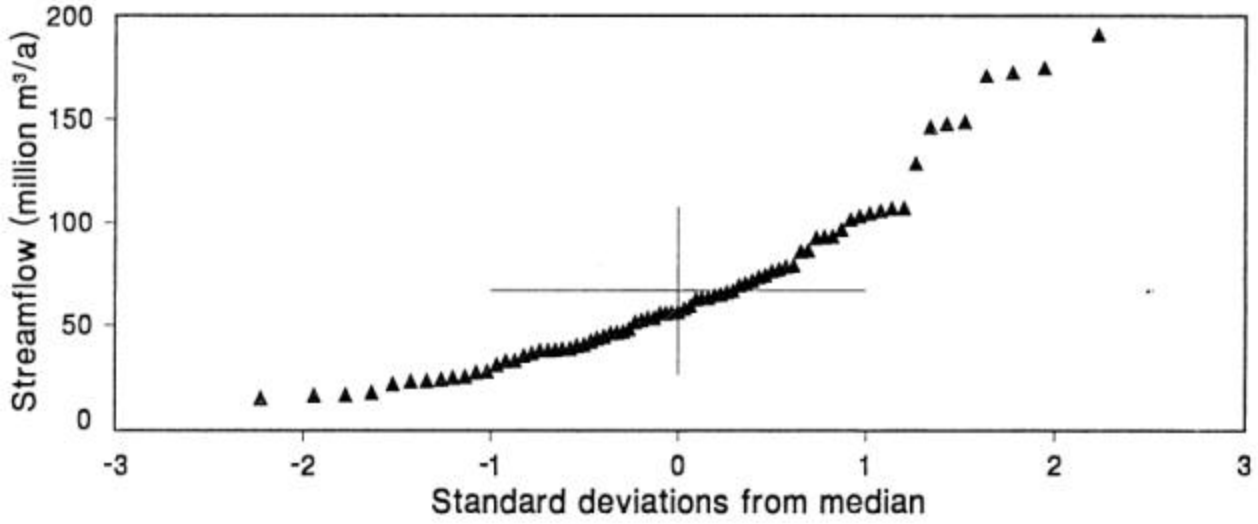


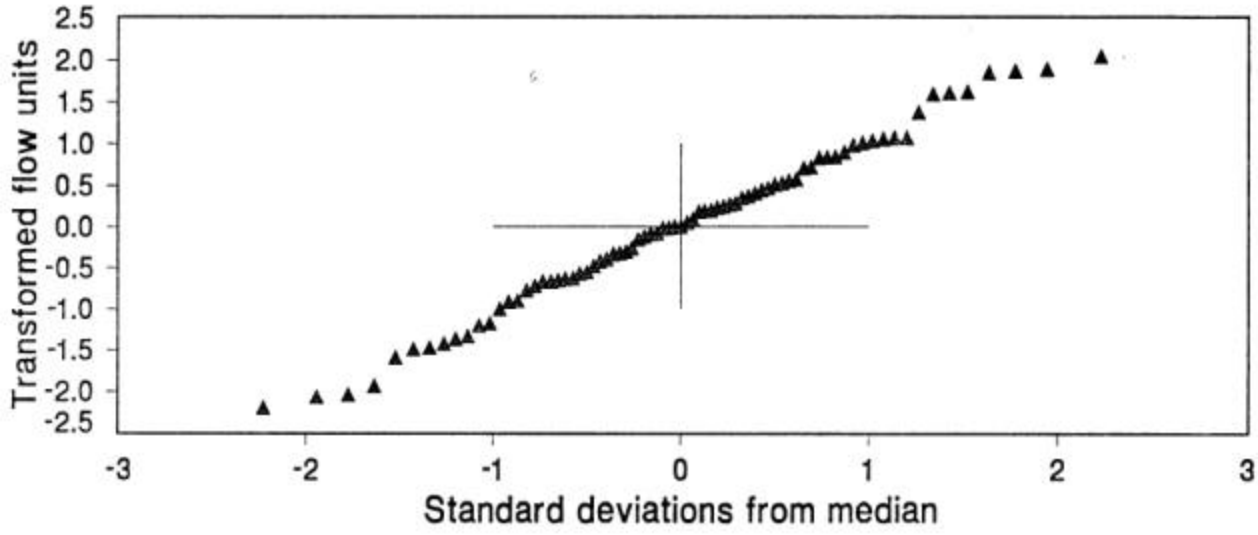
Correlogram of normalized annual streamflow



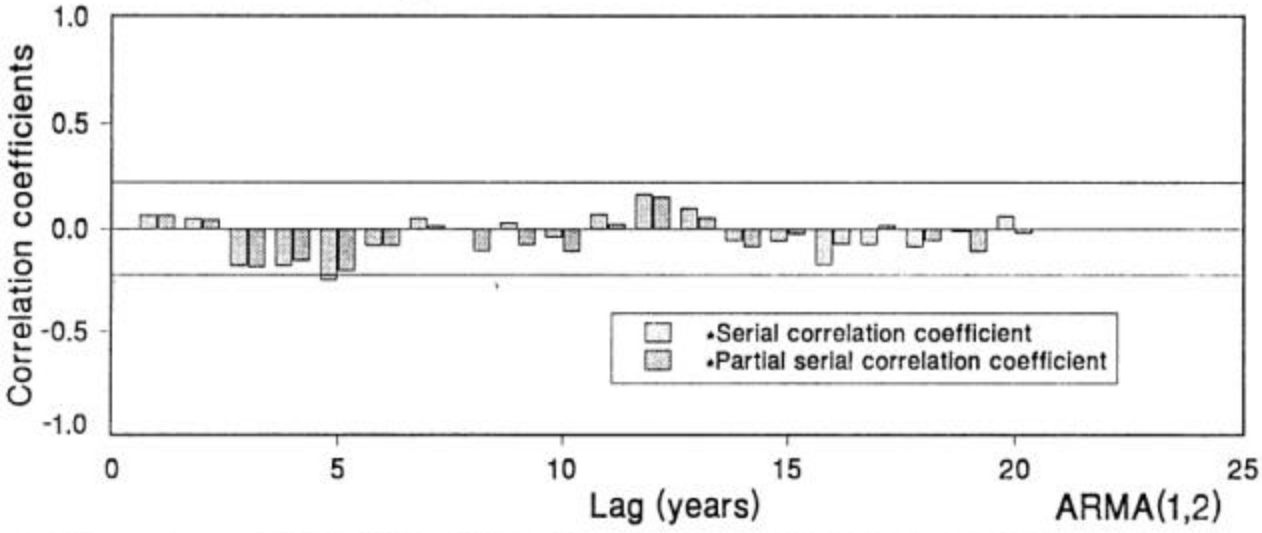
LUSIK

Sampled Cumulative Distributions



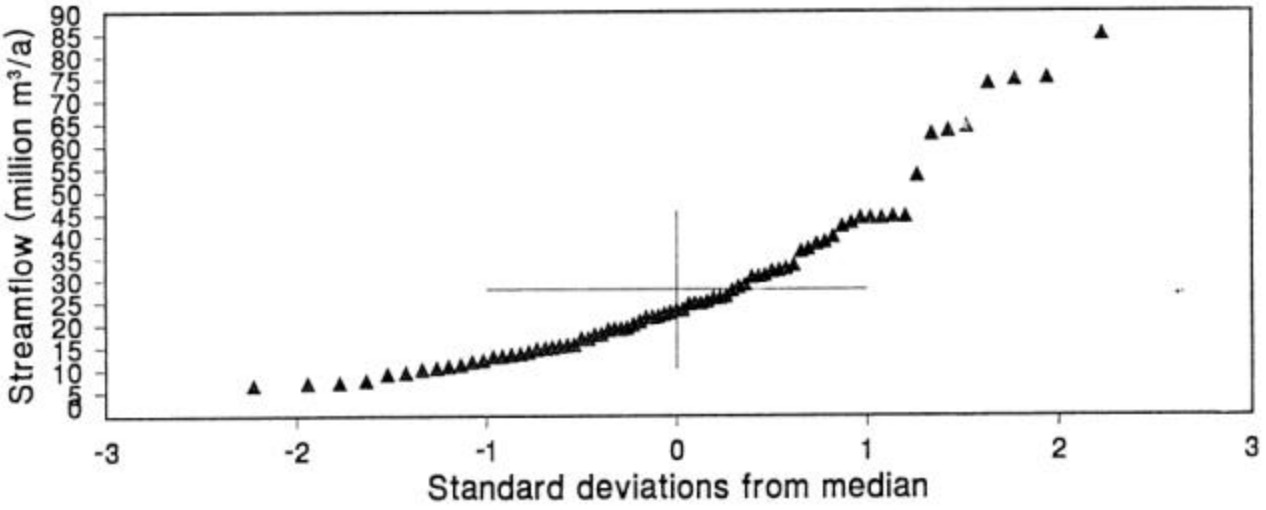


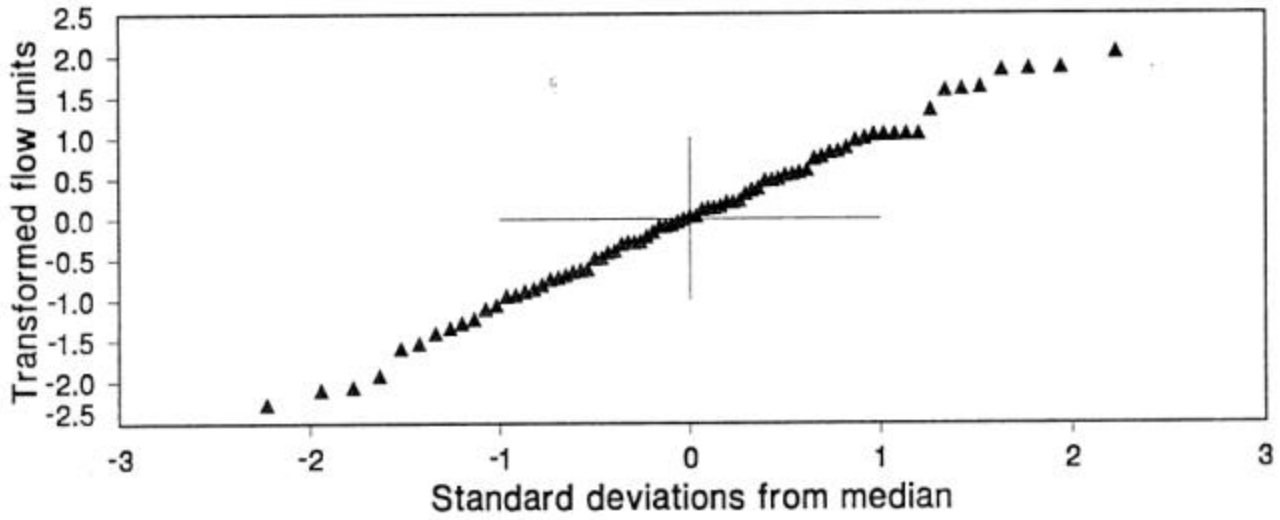
Correlogram of normalized annual streamflow



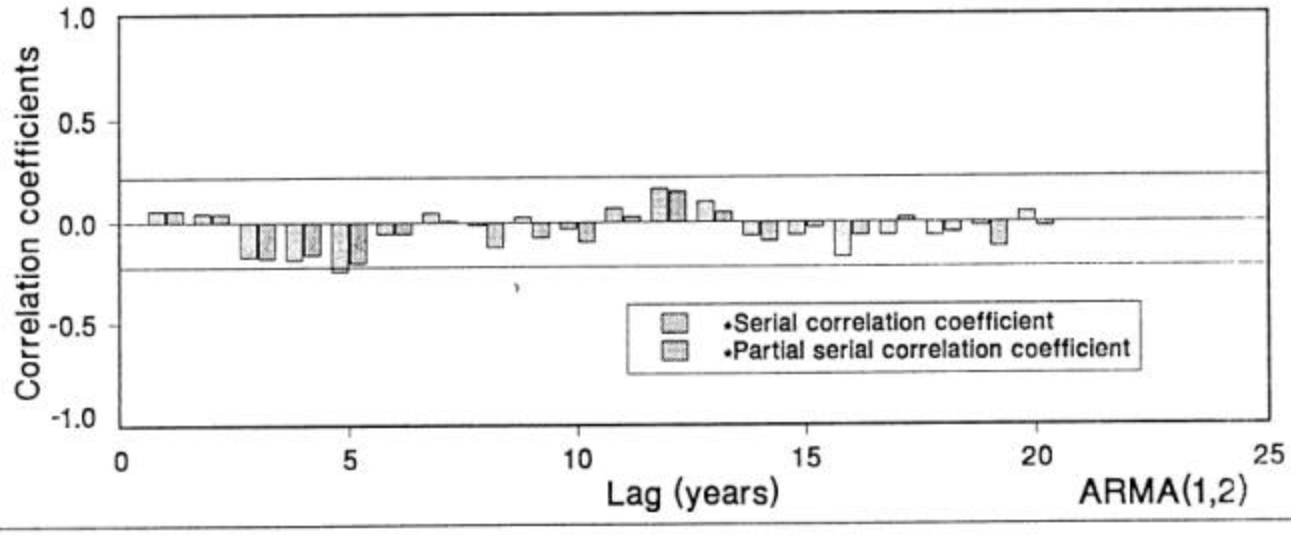
FLAGS

Sampled Cumulative Distributions



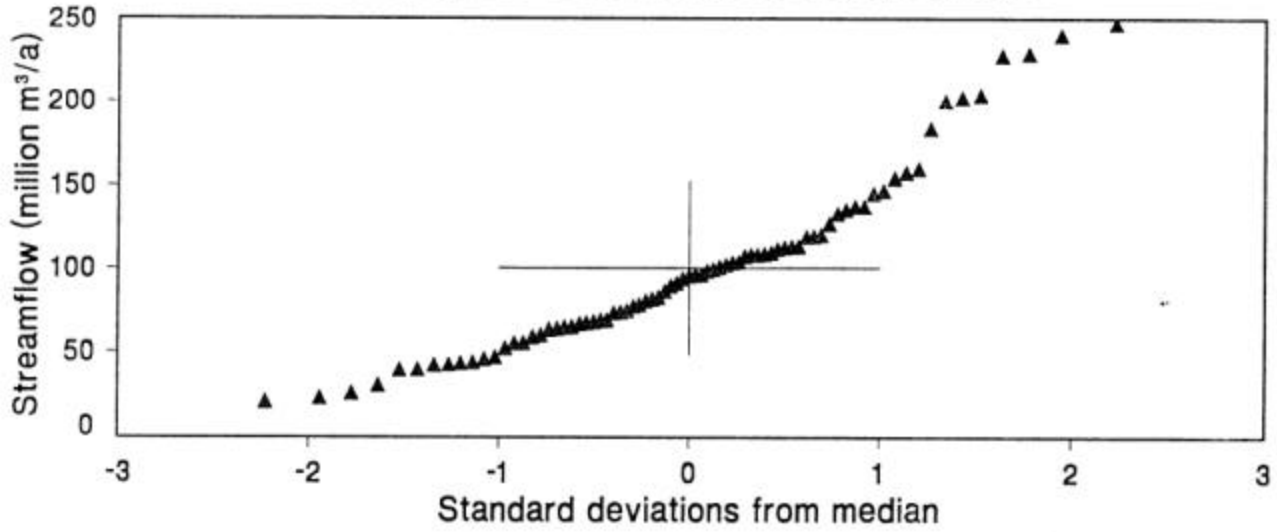


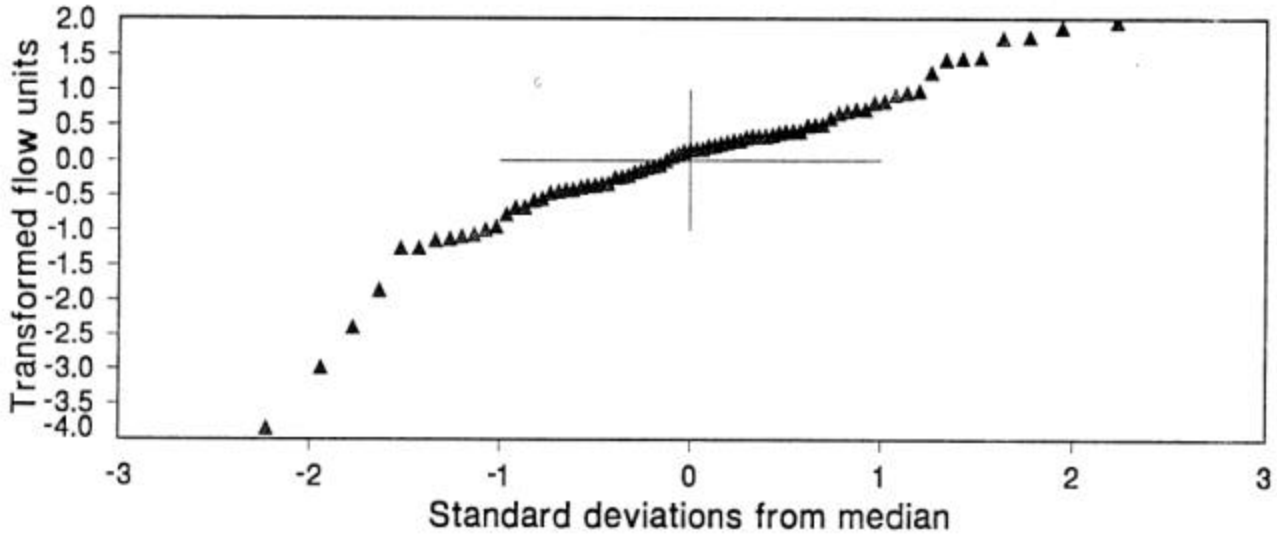
Correlogram of normalized annual streamflow



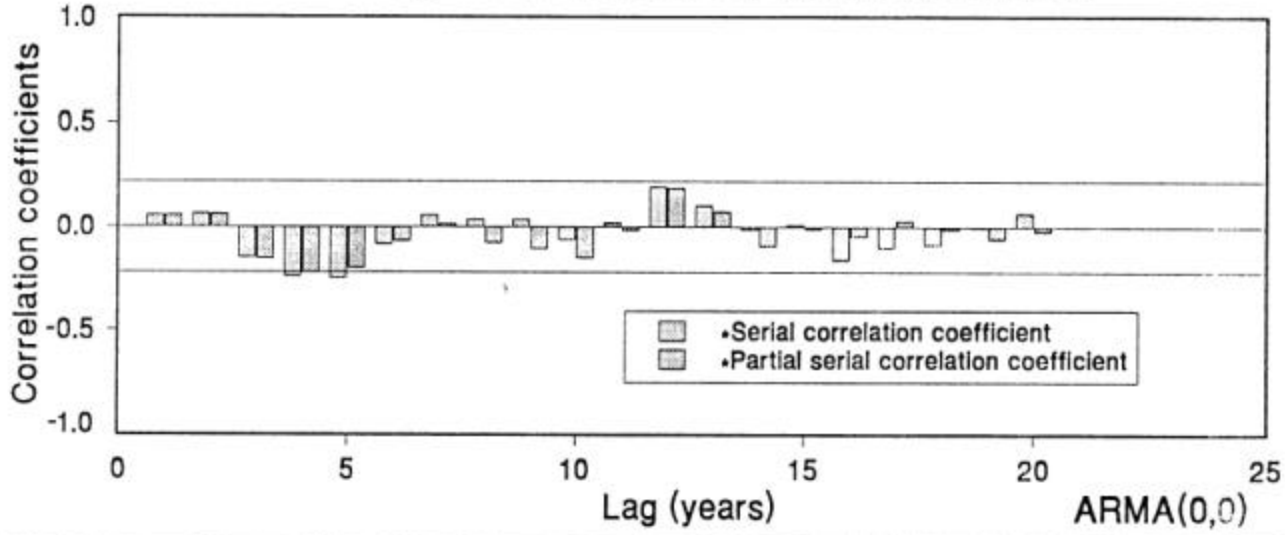
LMSIKA

Sampled Cumulative Distributions





Correlogram of normalized annual streamflow

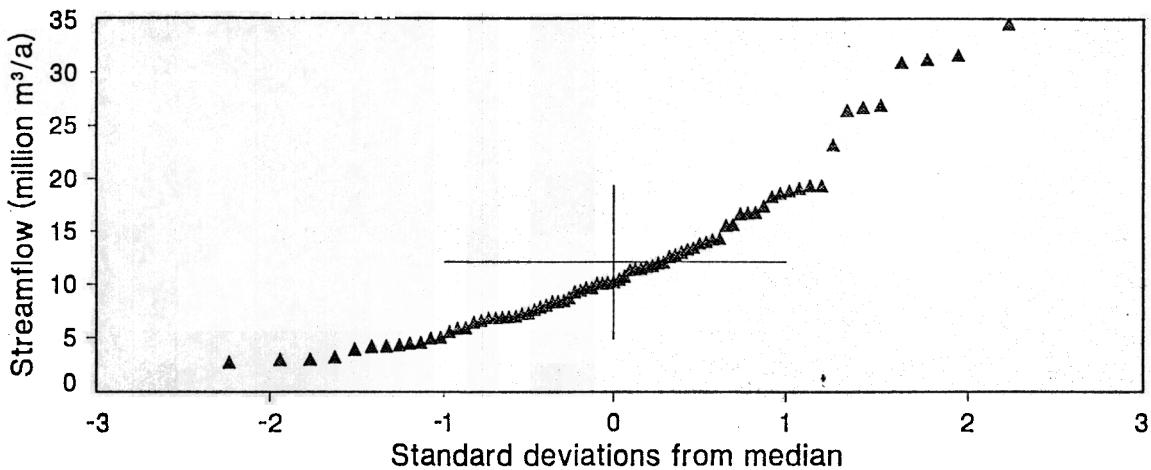


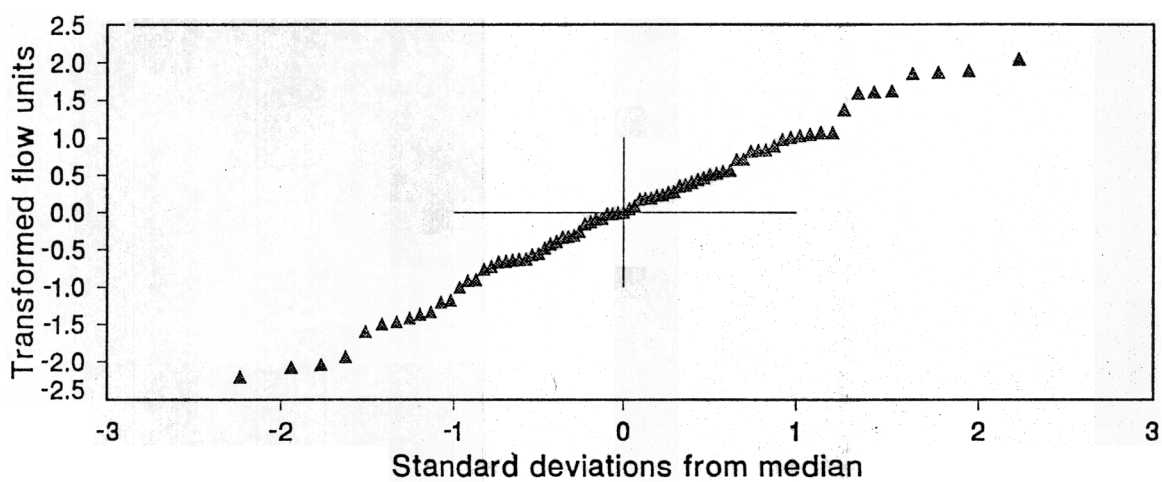
APPENDIX 11.2
SAMPLED CUMULATIVE DISTRIBUTIONS

ZALU DAM SYSTEM

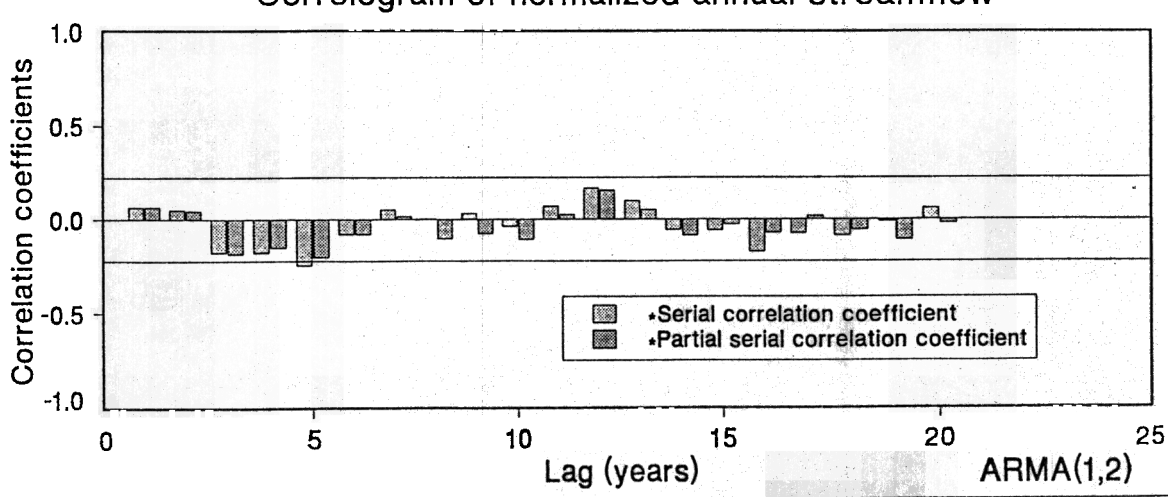
ZALU

Sampled Cumulative Distributions



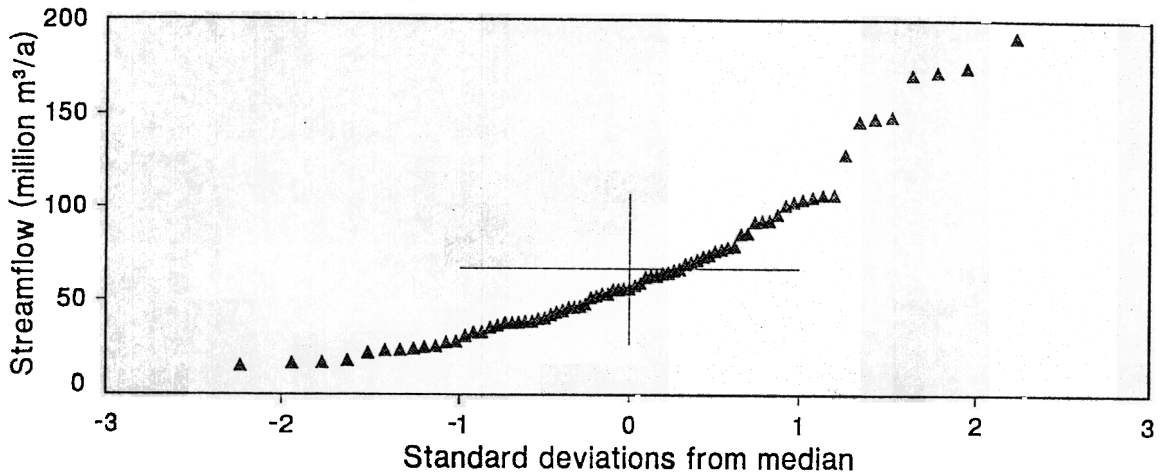


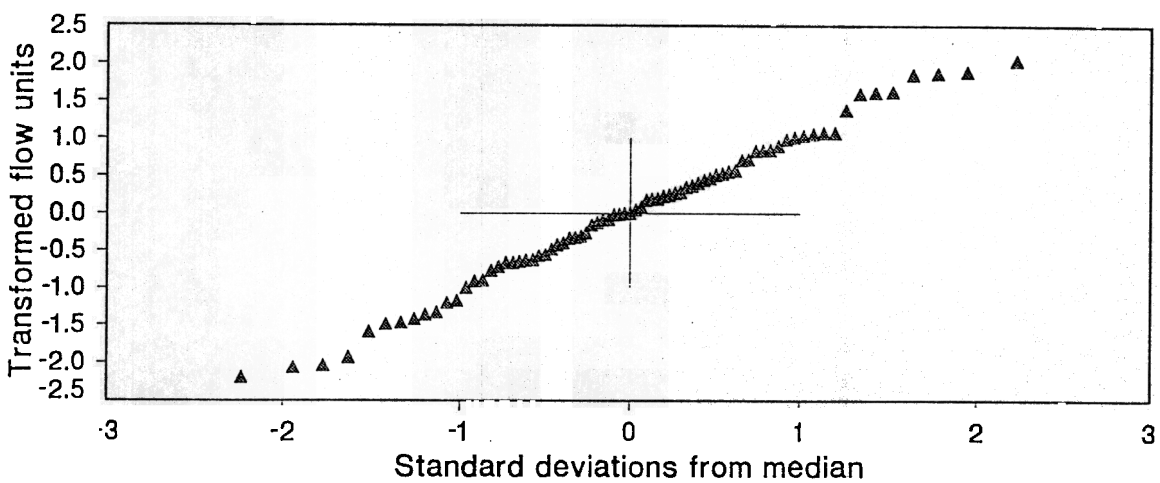
Correlogram of normalized annual streamflow



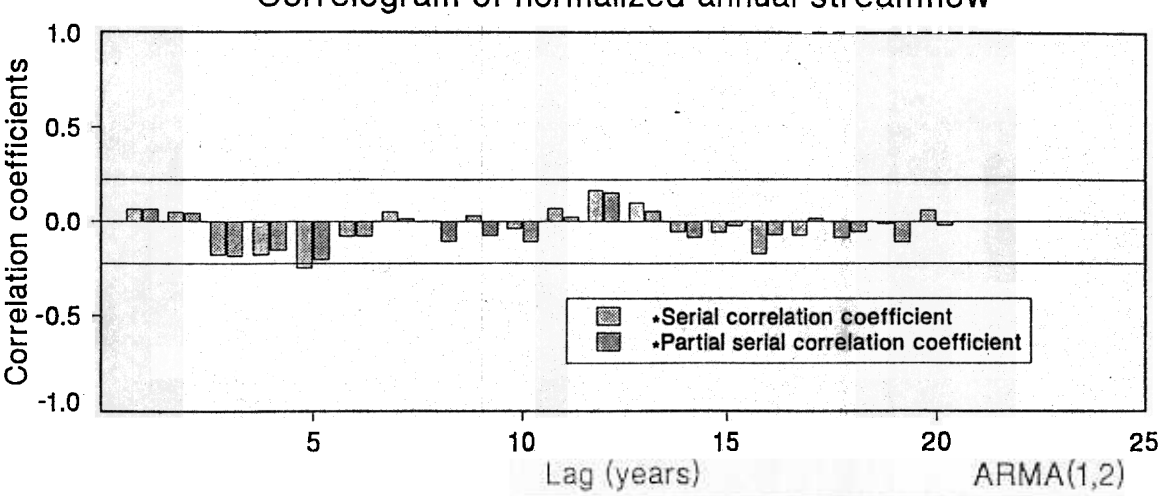
LUSIK

Sampled Cumulative Distributions



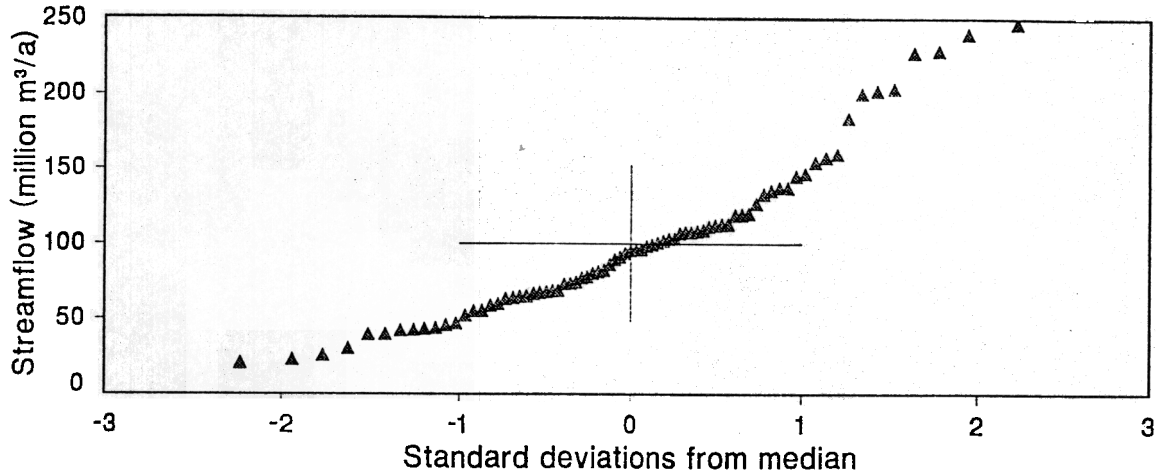


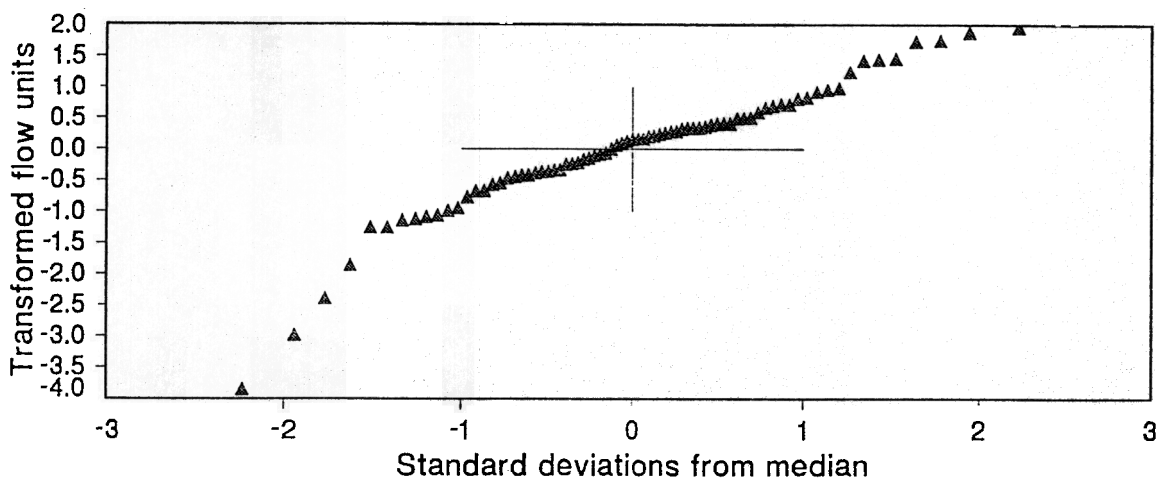
Correlogram of normalized annual streamflow



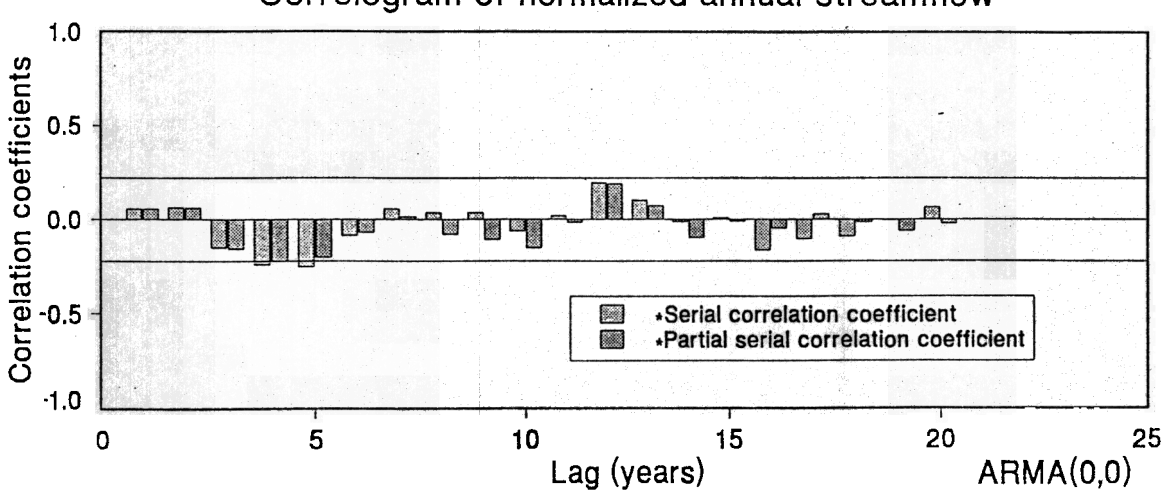
LMSIKA

Sampled Cumulative Distributions



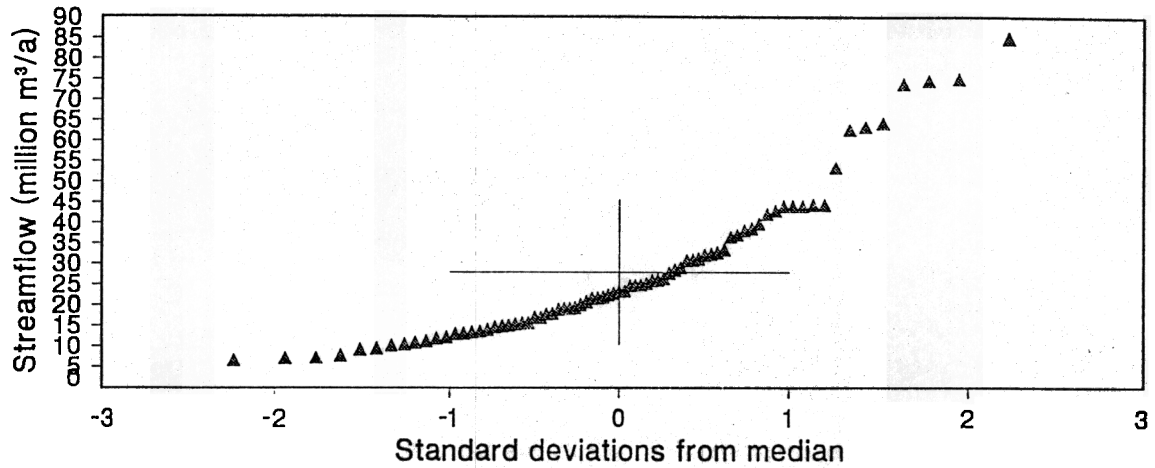


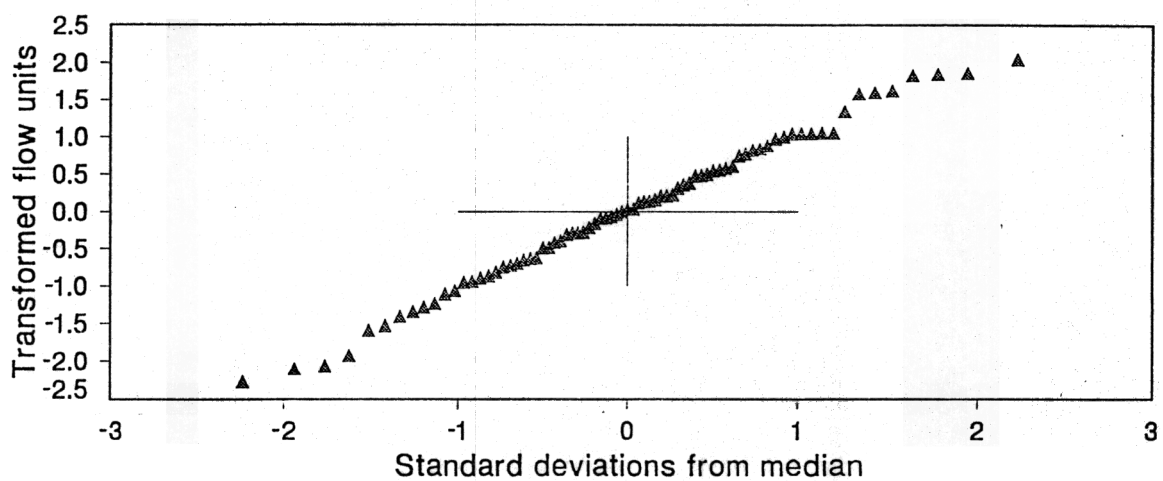
Correlogram of normalized annual streamflow



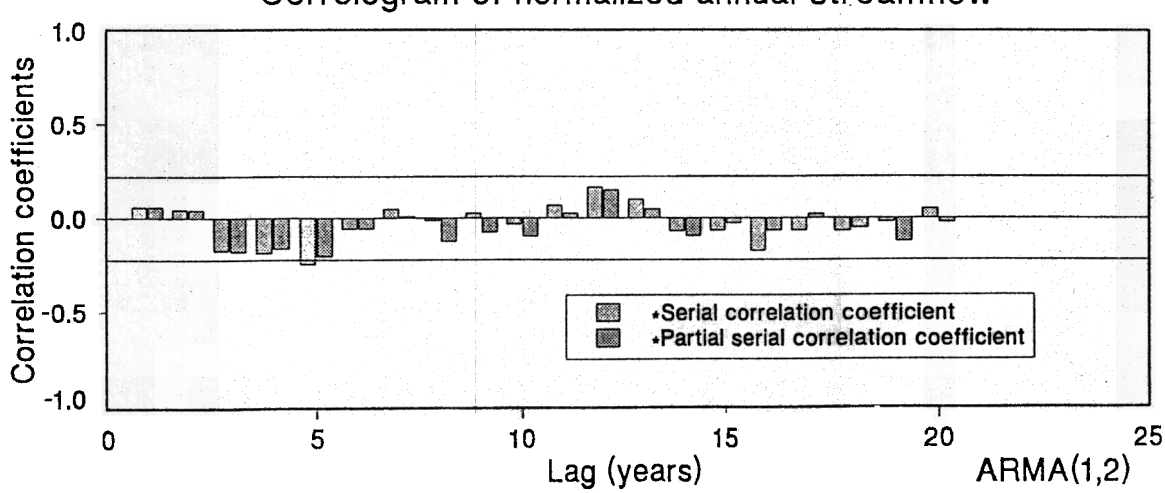
FLAGS

Sampled Cumulative Distributions



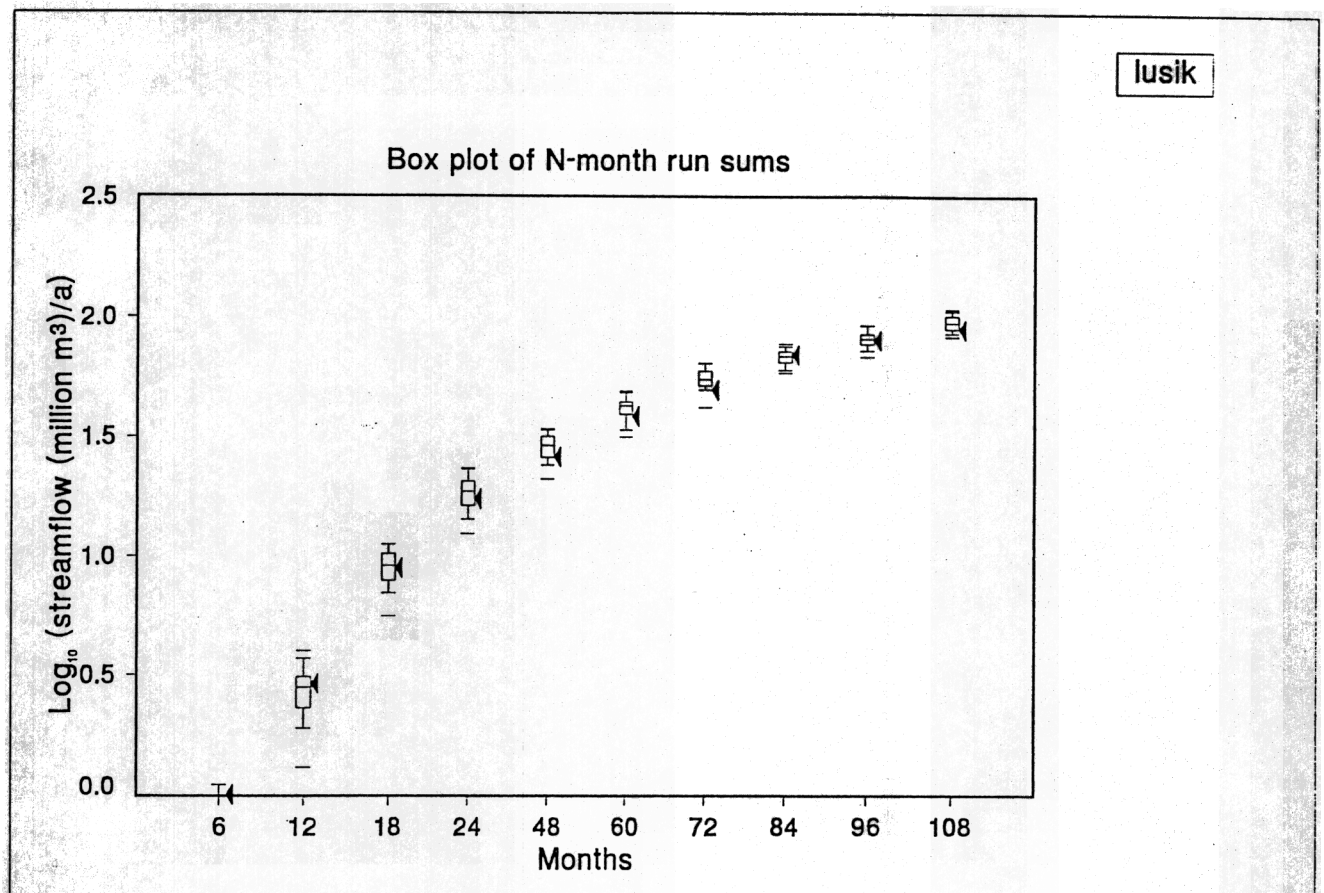


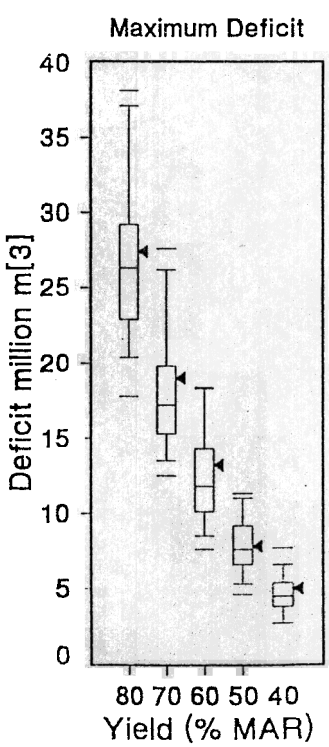
Correlogram of normalized annual streamflow

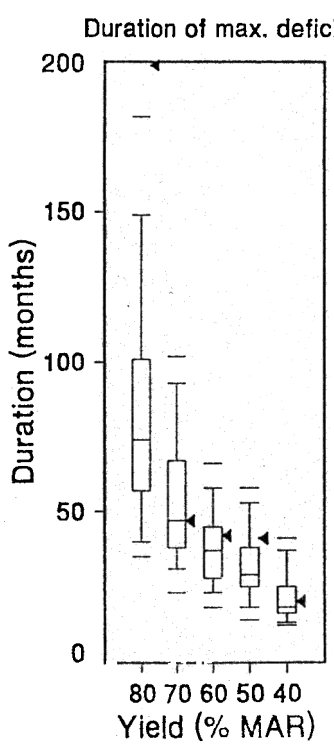


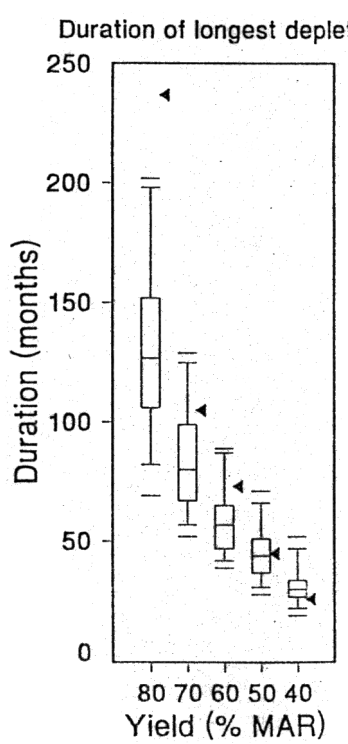
APPENDIX 12.1
MINIMUM RUN SUMS, MAXIMUM DEFICITS AND DEFICIT DURATIONS

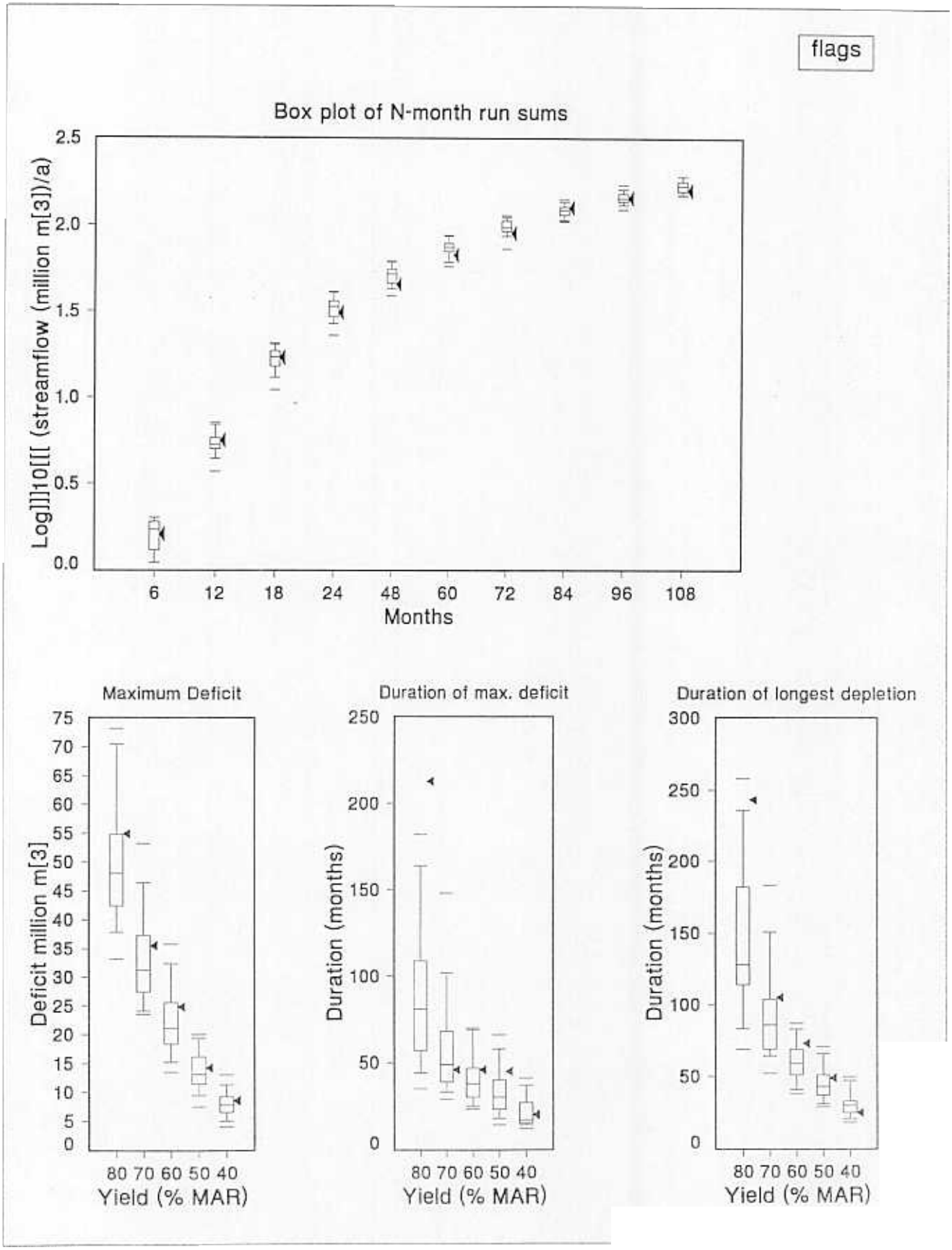
LUSIKISIKI DAM SYSTEM


Iusik
Box plot of N-month run sums
Log10 (streamflow (million m3)/a)
2.5
2.0
1.5
1.0
0.5
0.0
6
12
18
24
48
60
72
84
96
108
Months

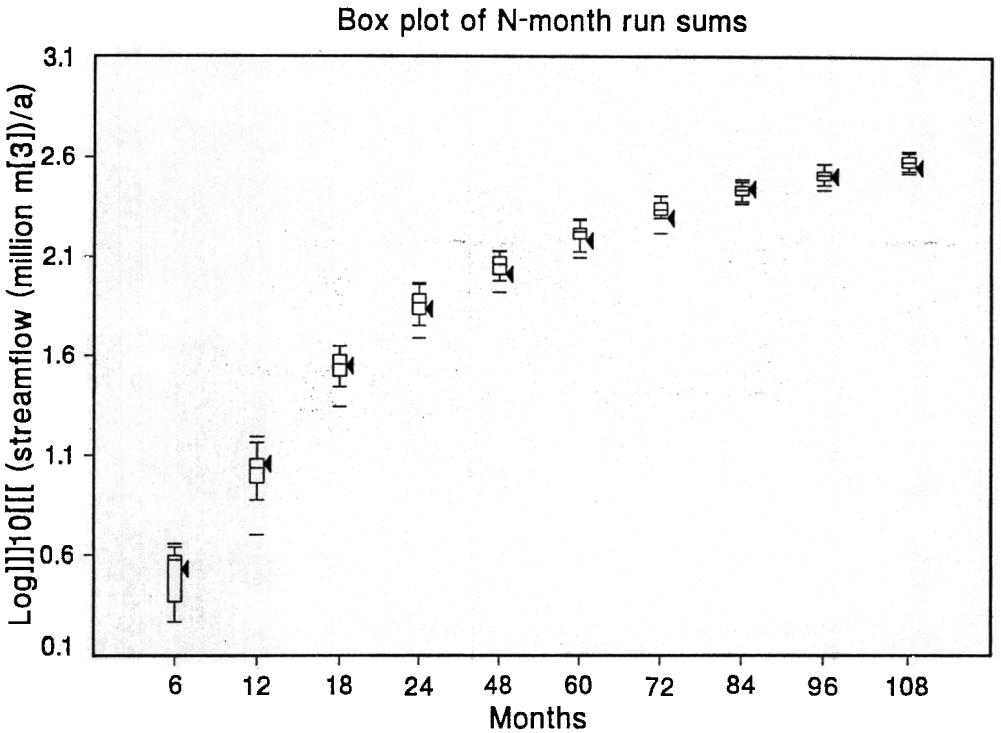

Maximum Deficit
Deficit million m[3]
40
35
30
25
20
15
10
5
0
80 70 60 50 40
Yield (% MAR)

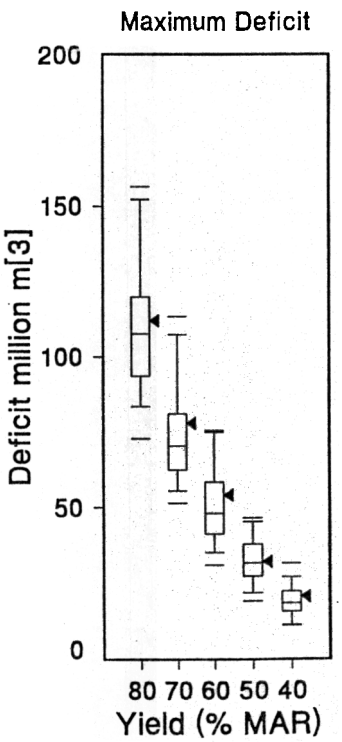

Duration of max. deficit
Duration (months)
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

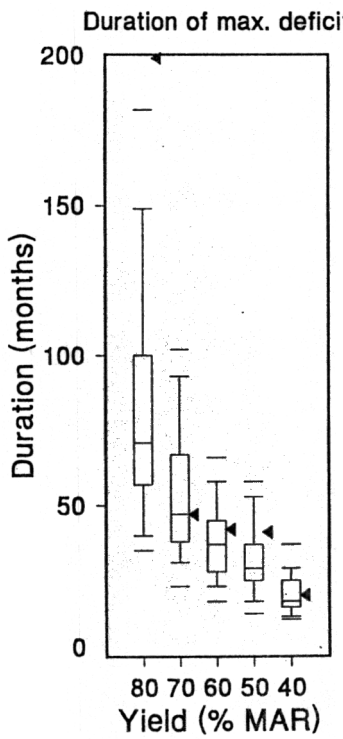

Duration of longest depletion
Duration (months)
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

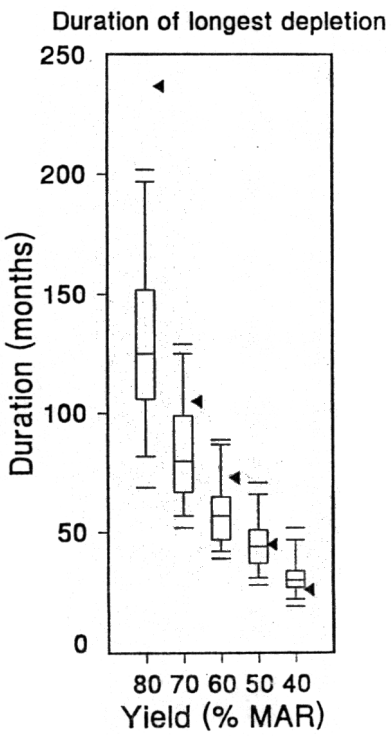

flags
Box plot of N-month run sums
Log]]]10[[[(streamflow (million m[3])/a)
2.5
2.0
1.5
1.0
0.5
0.0
6
12
18
24
48
60
72
84
96
108
Months
Maximum Deficit
Deficit million m[3]
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
80 70 60 50 40
Yield (% MAR)
Duration of max. deficit
Duration (months)
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)
Duration of longest depletion
Duration (months)
300
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

bomvi

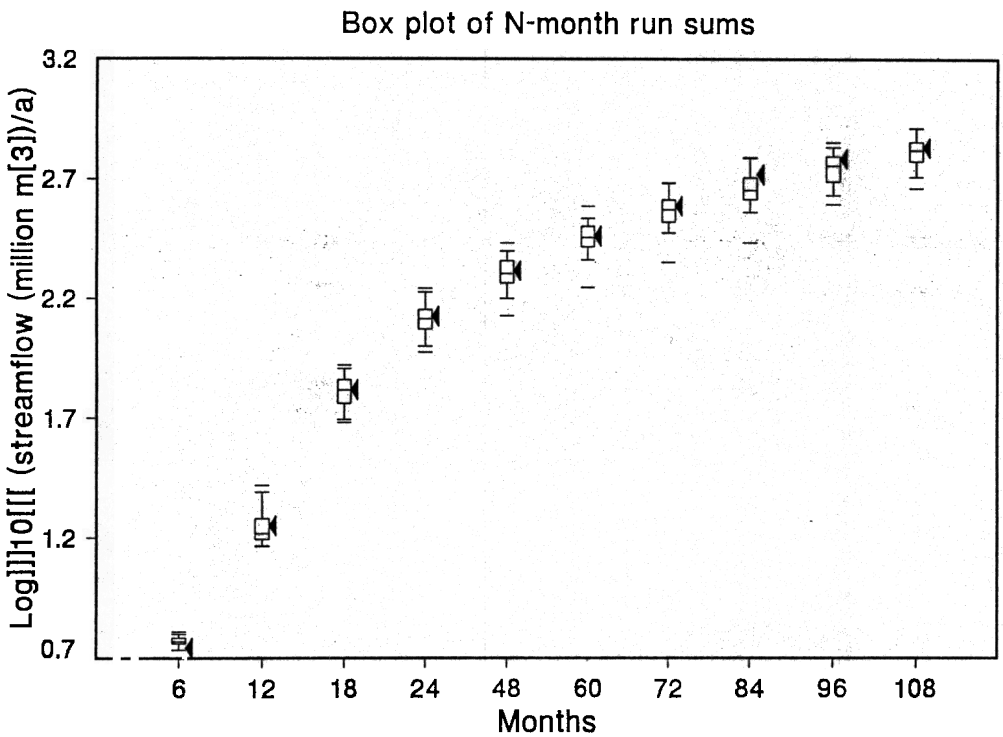

Box plot of N-month run sums
Log]]]10[[[(streamflow (million m[3])/a)
3.1
2.6
2.1
1.6
1.1
0.6
0.1
6
12
18
24
48
60
72
84
96
108
Months

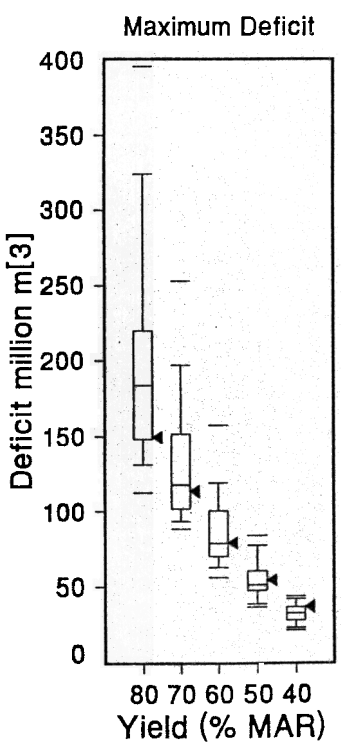

Maximum Deficit
Deficit million m[3]
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

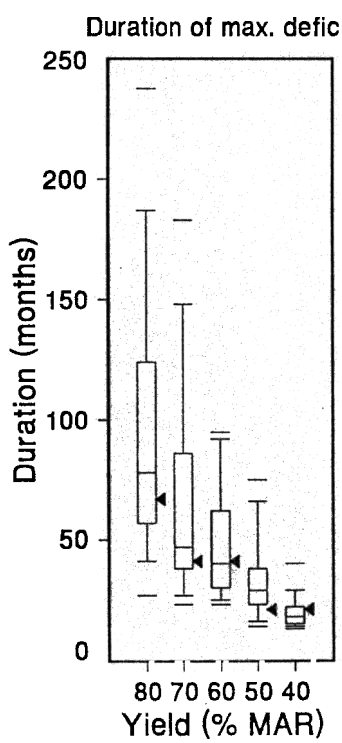

Duration of max. deficit
Duration (months)
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

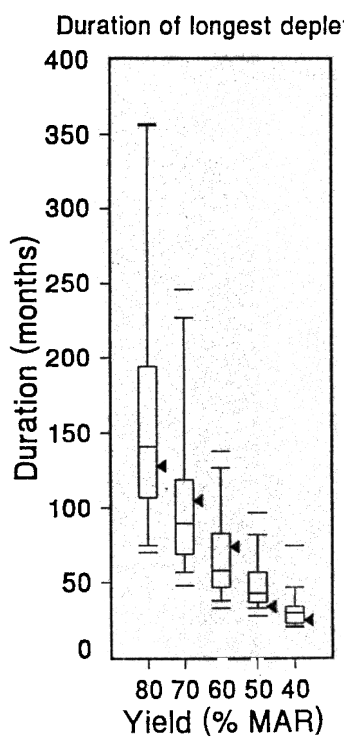

Duration of longest depletion
Duration (months)
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

Imsika


Box plot of N-month run sums
Log[]]]10[[[(streamflow (million m[3])/a)
3.2
2.7
2.2
1.7
1.2
0.7
6
12
18
24
48
60
72
84
96
108
Months


Maximum Deficit
Deficit million m[3]
400
350
300
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

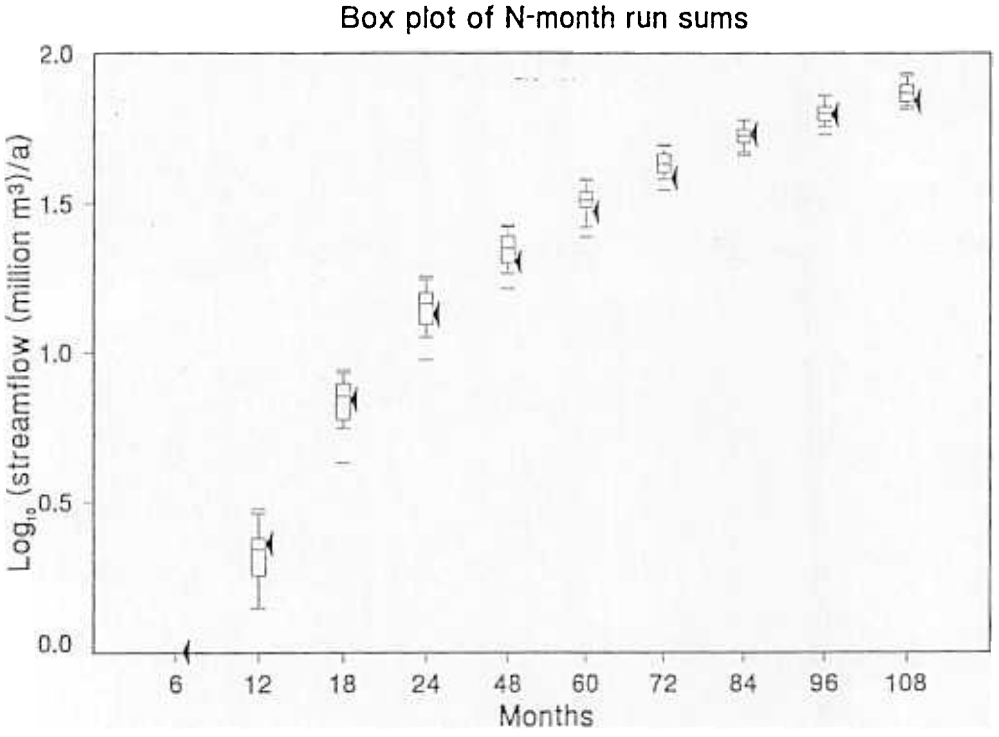

Duration of max. deficit
Duration (months)
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

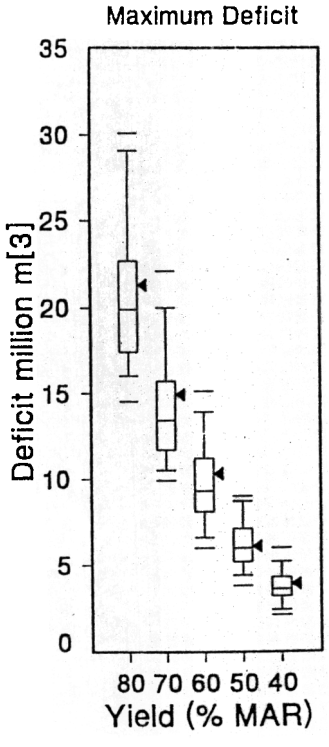

Duration of longest depletion
Duration (months)
400
350
300
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

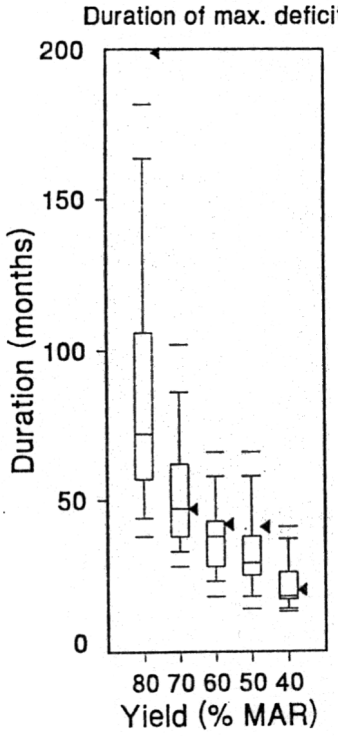
APPENDIX 12.2
MINIMUM RUN SUMS, MAXIMUM DEFICITS AND DEFICIT DURATIONS

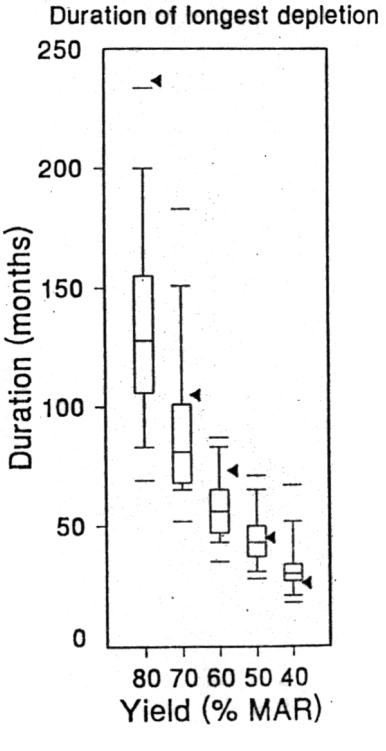
ZALU DAM SYSTEM

zalu

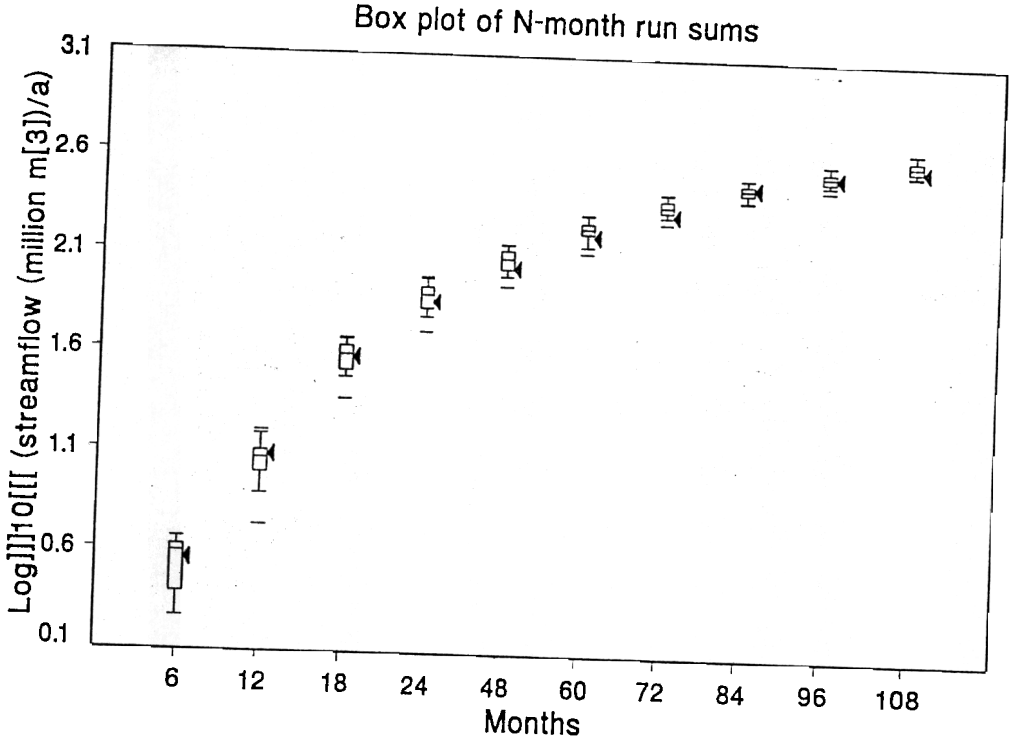

Box plot of N-month run sums
Log10 (streamflow (million m3)/a)
2.0
1.5
1.0
0.5
0.0
6
12
18
24
48
60
72
84
96
108
Months

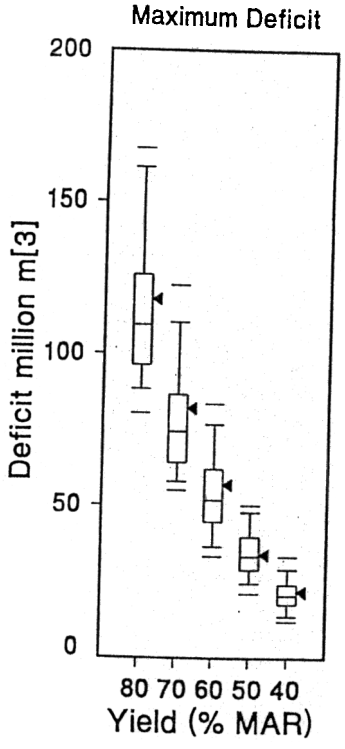

Maximum Deficit
Deficit million m[3]
35
30
25
20
15
10
5
0
80 70 60 50 40
Yield (% MAR)

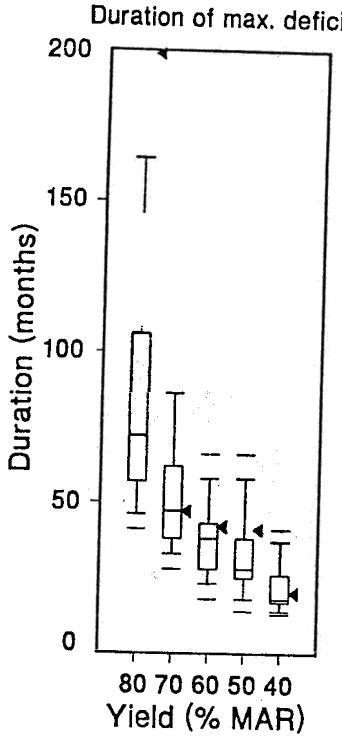

Duration of max. deficit
Duration (months)
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

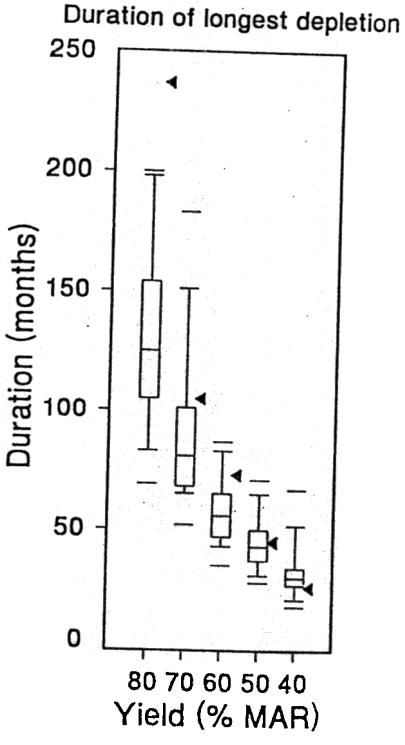

Duration of longest depletion
Duration (months)
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

lusik

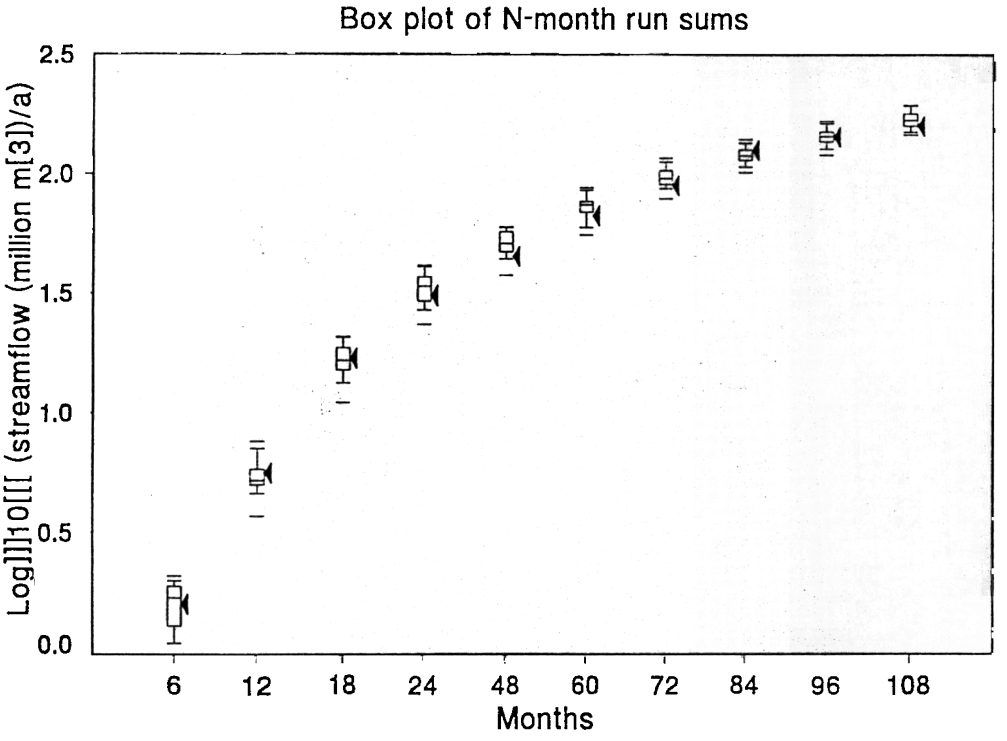

Box plot of N-month run sums
Log]]]10[[[(streamflow (million m[3])/a)
3.1
2.6
2.1
1.6
1.1
0.6
0.1
6
12
18
24
48
60
72
84
96
108
Months

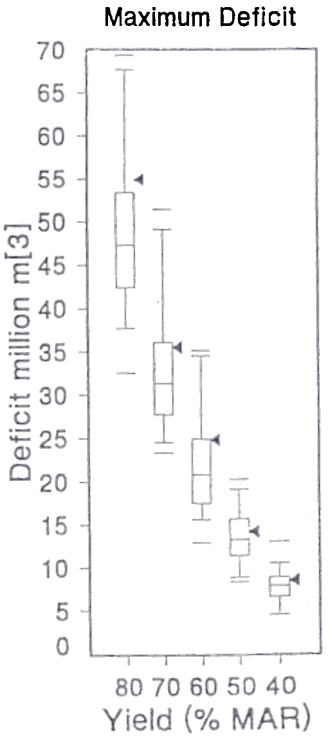

Maximum Deficit
Deficit million m[3]
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

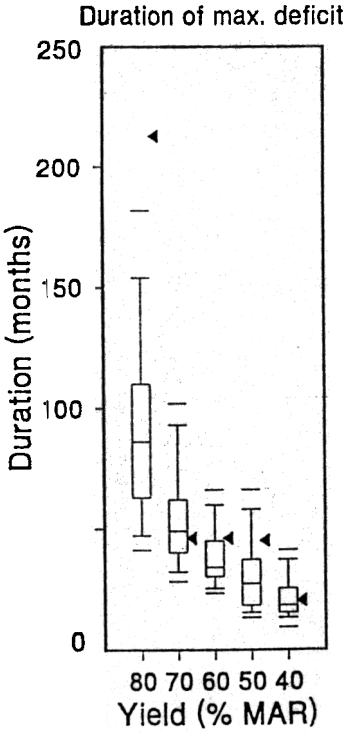

Duration of max. deficit
Duration (months)
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

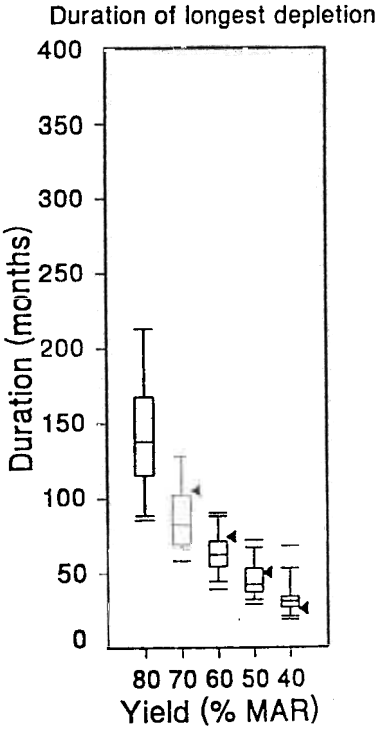

Duration of longest depletion
Duration (months)
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

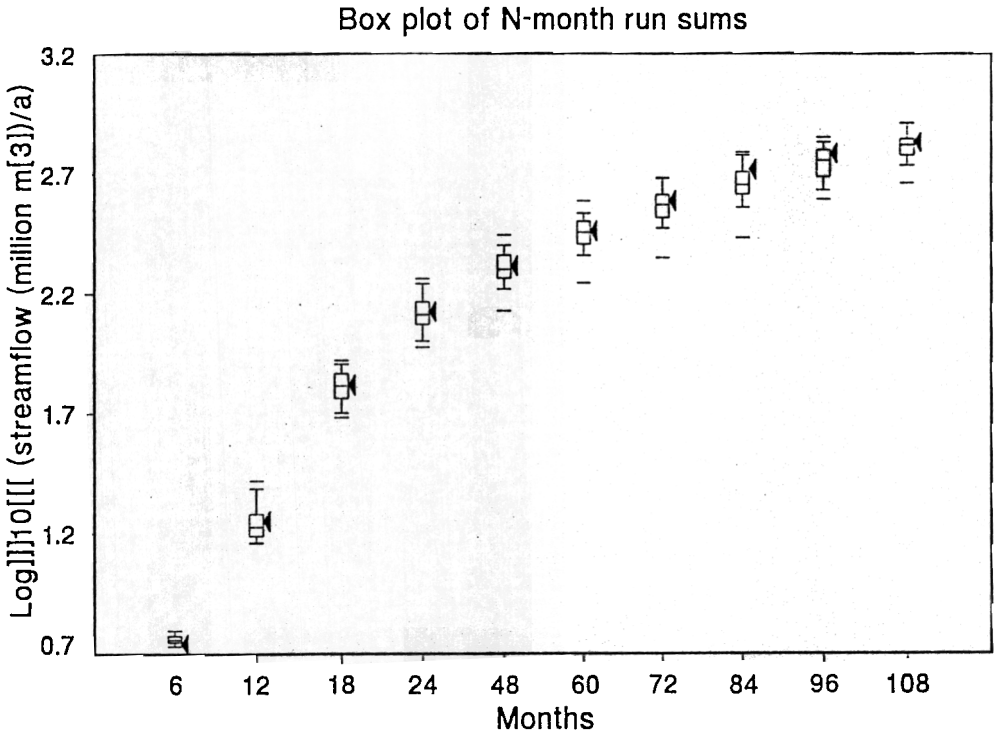
flags

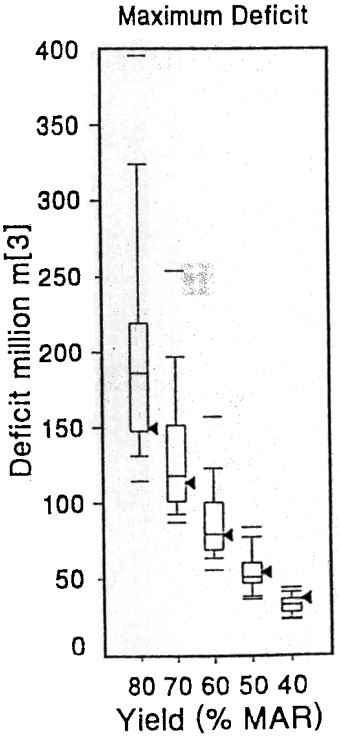

Box plot of N-month run sums
Log]]]10[[[(streamflow (million m[3])/a)
2.5
2.0
1.5
1.0
0.5
0.0
6
12
18
24
48
60
72
84
96
108
Months

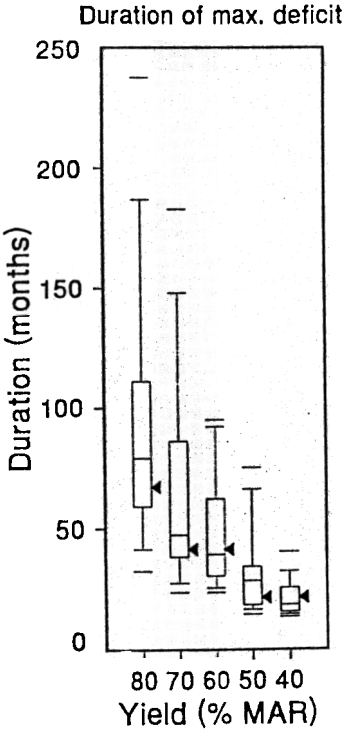

Maximum Deficit
Deficit million m[3]
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
80 70 60 50 40
Yield (% MAR)

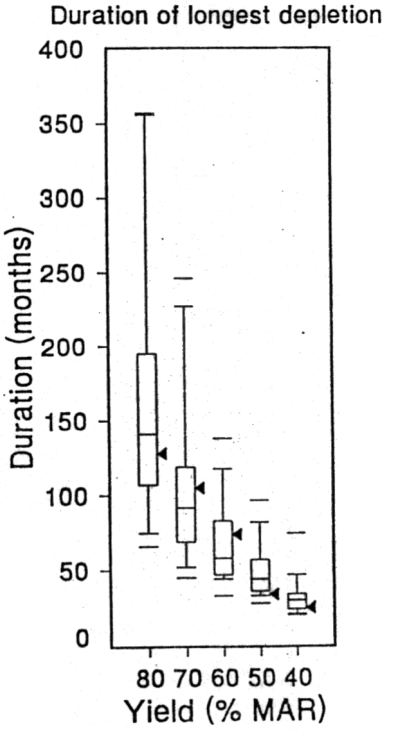

Duration of max. deficit
Duration (months)
250
200
150
100
0
80 70 60 50 40
Yield (% MAR)


Duration of longest depletion
Duration (months)
400
350
300
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)


Box plot of N-month run sums
Log]]]10[[[(streamflow (million m[3])/a)
3.2
2.7
2.2
1.7
1.2
0.7
6
12
18
24
48
60
72
84
96
108
Months


Maximum Deficit
Deficit million m[3]
400
350
300
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

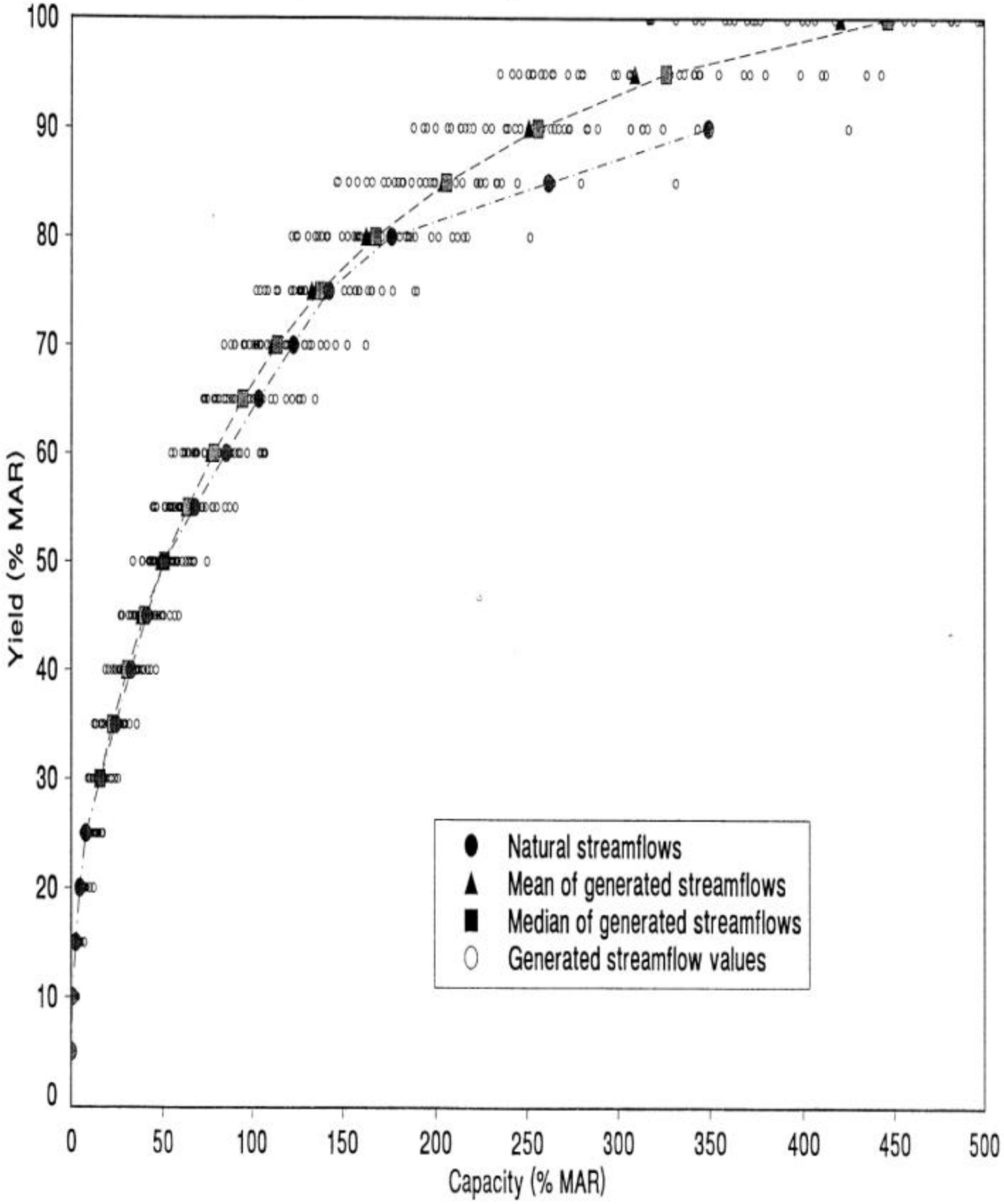

Duration of max. deficit
Duration (months)
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

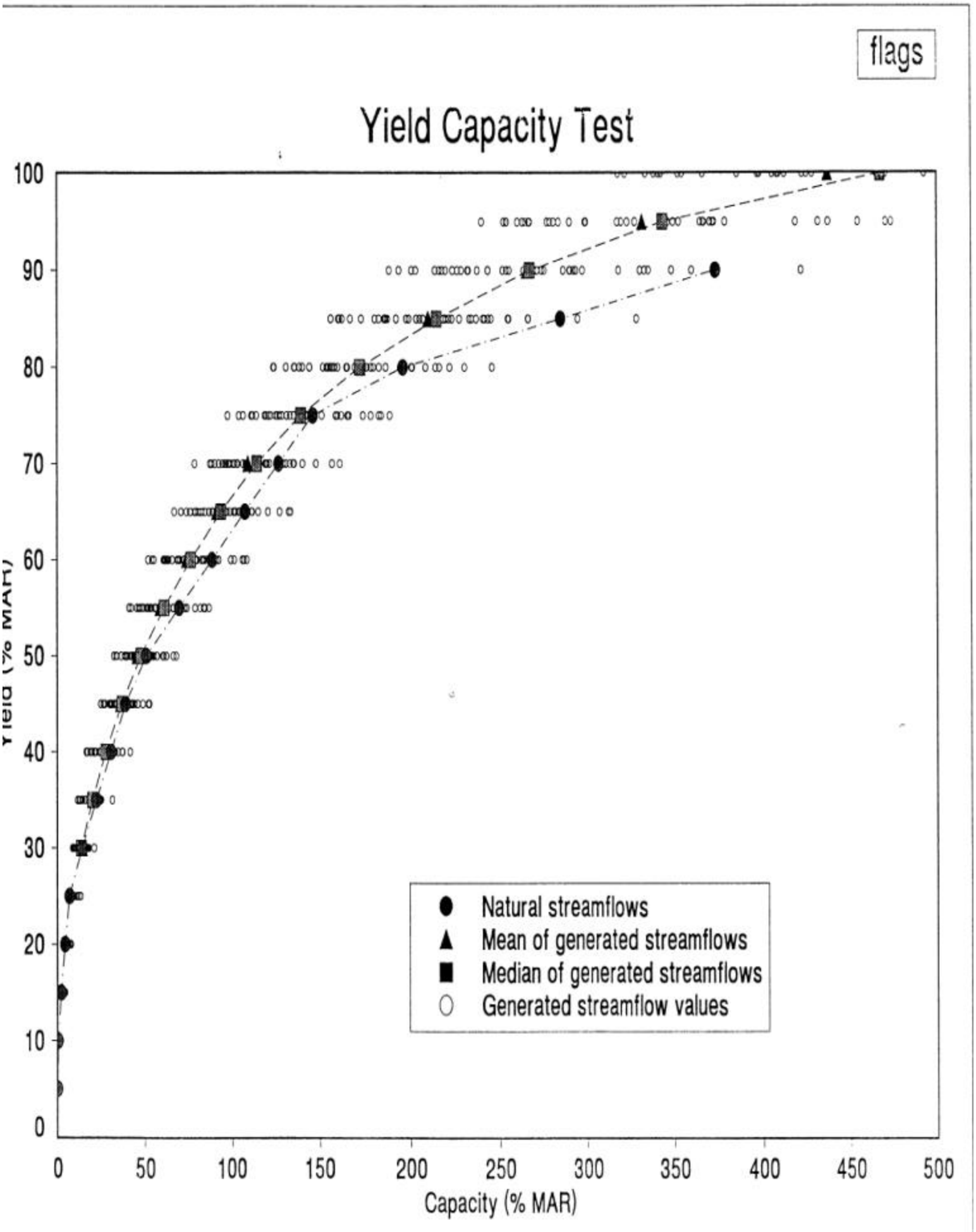

Duration of longest depletion
Duration (months)
400
350
300
250
200
150
100
50
0
80 70 60 50 40
Yield (% MAR)

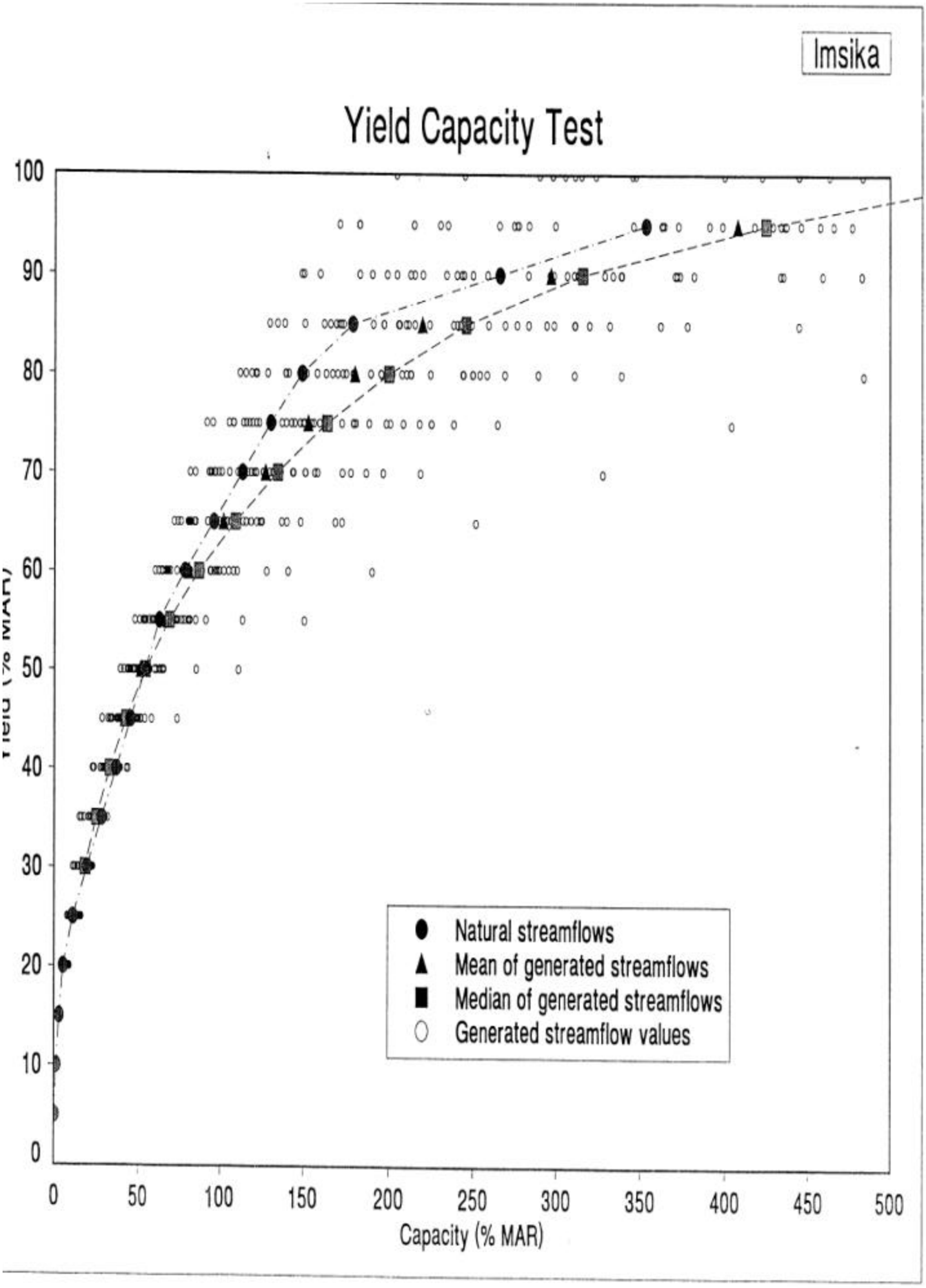
APPENDIX 13.1
YIELD-CAPACITY PLOTS

LUSIKISIKI DAM SYSTEM

Yield Capacity Test

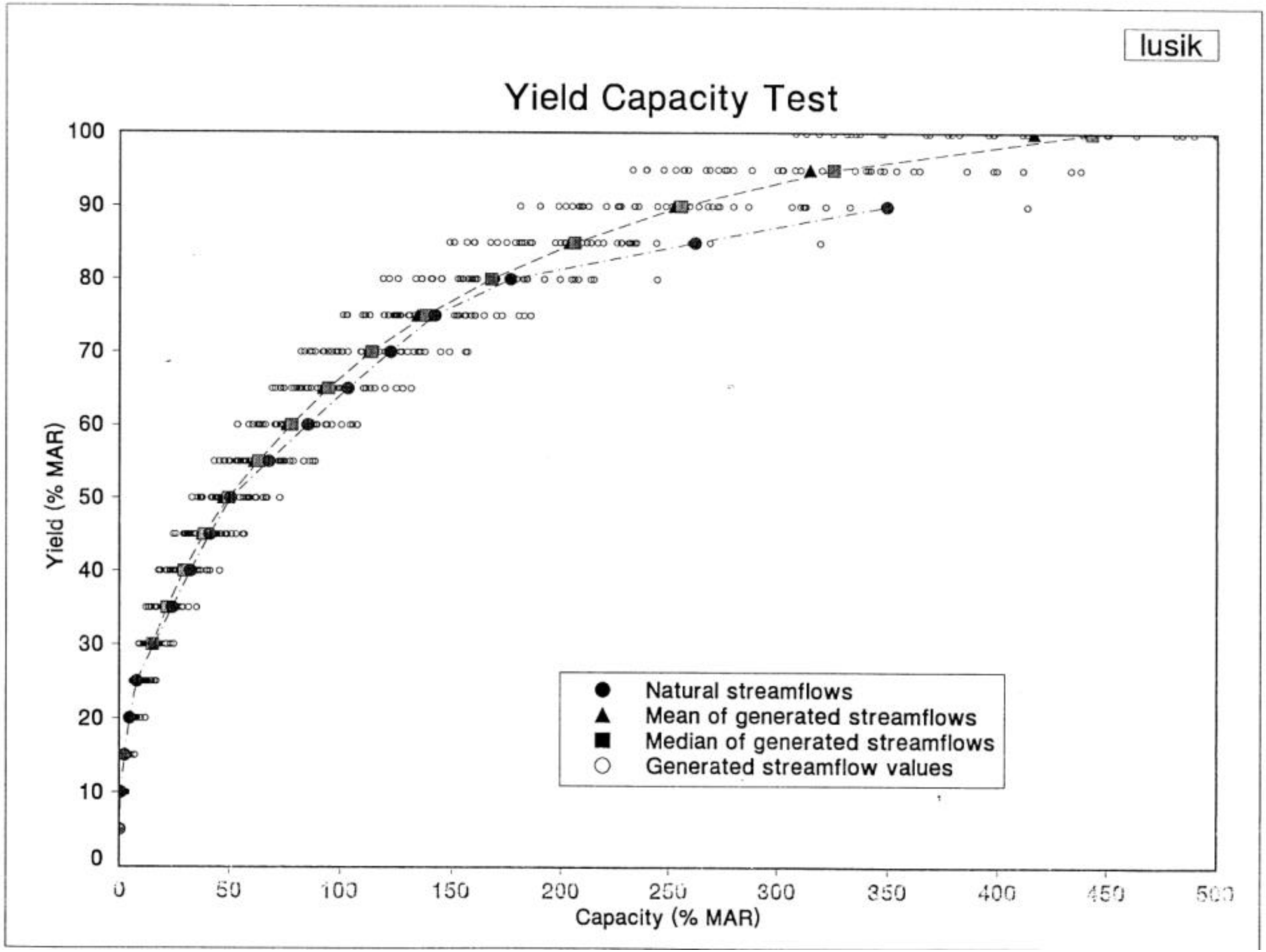


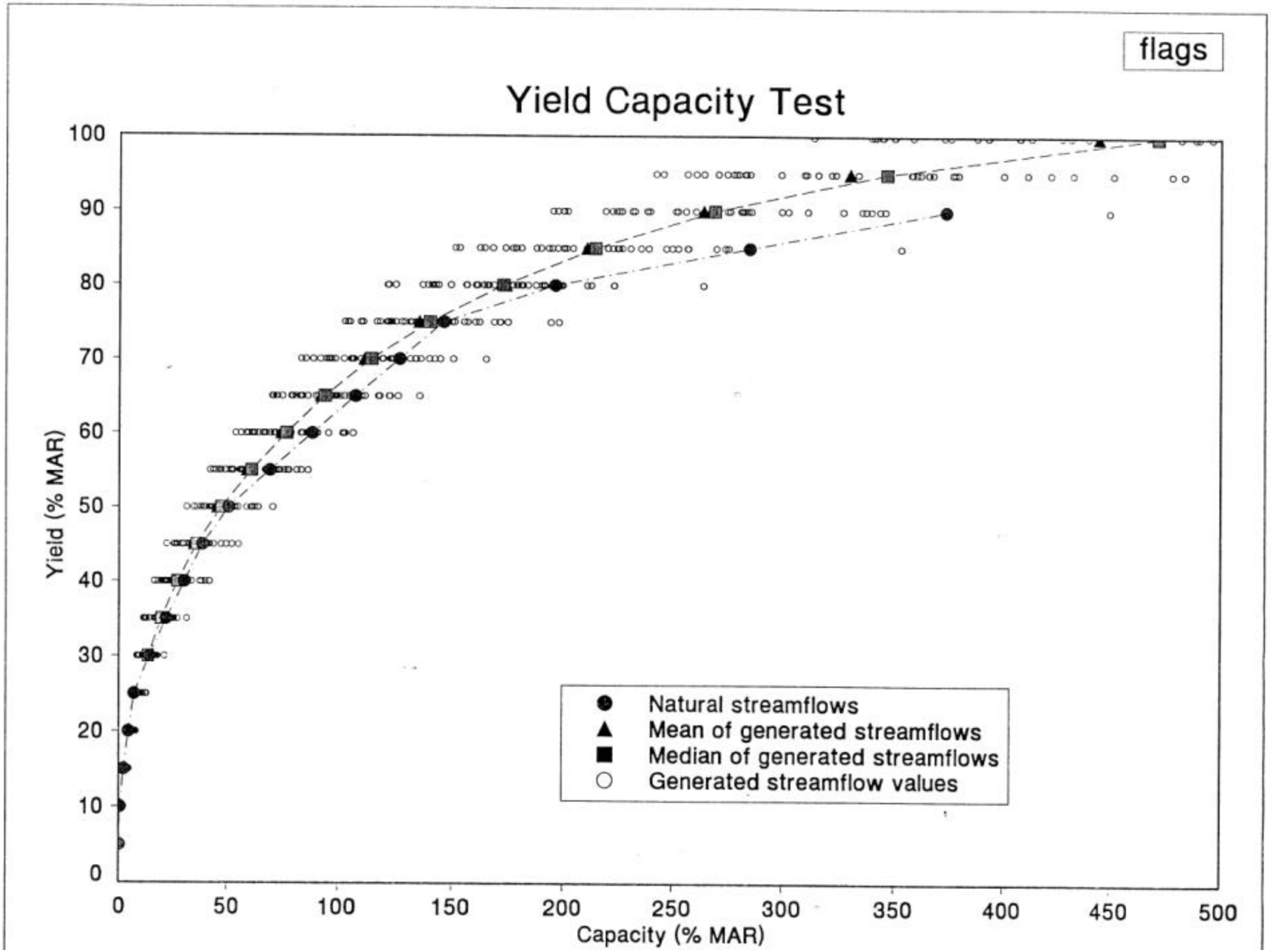

flags
Yield Capacity Test
Yield (% MAR)
Capacity (% MAR)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
Natural streamflows
Mean of generated streamflows
Median of generated streamflows
Generated streamflow values

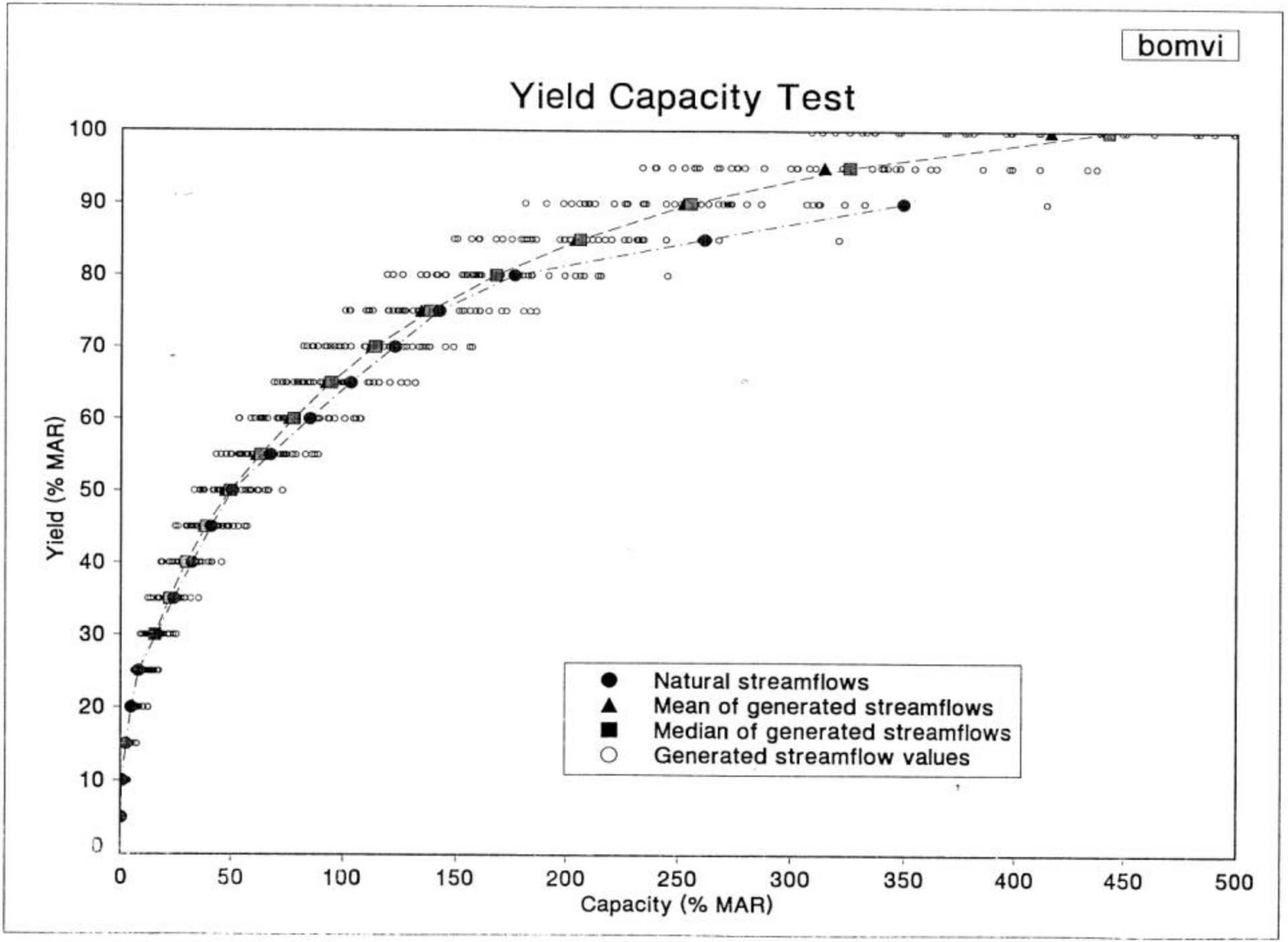

Imsika
Yield Capacity Test
Yield (% MAR)
Capacity (% MAR)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
Natural streamflows
Mean of generated streamflows
Median of generated streamflows
Generated streamflow values

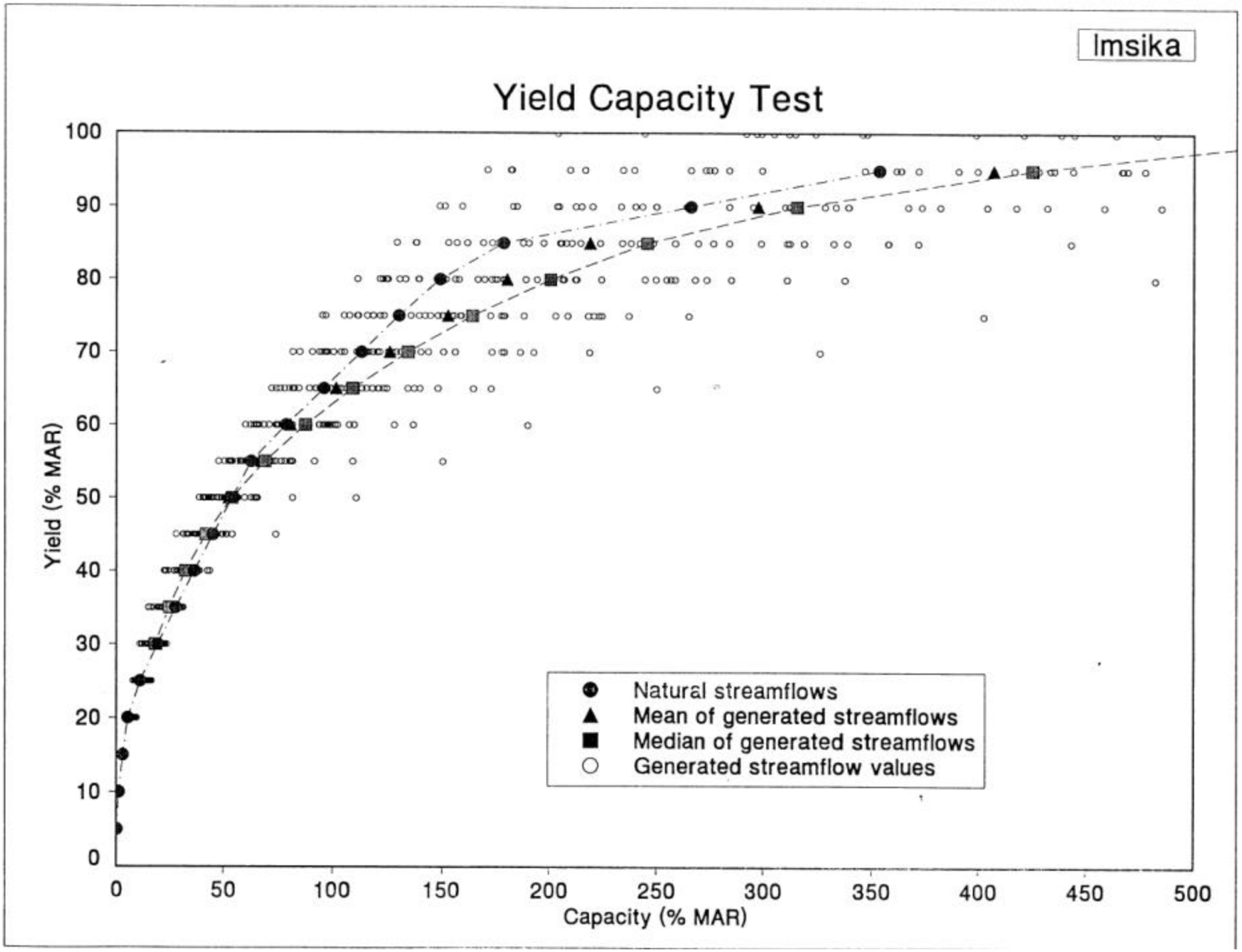
APPENDIX 13.2
YIELD-CAPACITY PLOTS

ZALU DAM SYSTEM


lusik
Yield Capacity Test
Yield (% MAR)
Capacity (% MAR)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
Natural streamflows
Mean of generated streamflows
Median of generated streamflows
Generated streamflow values


flags
Yield Capacity Test
Yield (% MAR)
Capacity (% MAR)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
Natural streamflows
Mean of generated streamflows
Median of generated streamflows
Generated streamflow values


bomvi
Yield Capacity Test
Yield (% MAR)
Capacity (% MAR)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
Natural streamflows
Mean of generated streamflows
Median of generated streamflows
Generated streamflow values


Imsika
Yield Capacity Test
Yield (% MAR)
Capacity (% MAR)
0
10
20
30
40
50
60
70
80
90
100
0
50
100
150
200
250
300
350
400
450
500
Natural streamflows
Mean of generated streamflows
Median of generated streamflows
Generated streamflow values

APPENDIX 14
IFR (INSTREAM FLOW REQUIREMENT SEQUENCES)

APPENDIX 14.1
LOWER MZINTLAVA IFR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.11	0.17	0.32	0.28	0.37	1.00	0.52	0.33	0.27	0.17	0.11	0.10	3.75
1921	0.19	0.62	0.45	0.29	0.32	0.25	0.16	0.34	0.32	0.31	0.28	0.25	3.78
1922	0.39	0.69	0.45	0.29	0.40	1.30	0.52	0.23	0.18	0.31	0.28	0.22	5.26
1923	0.12	0.14	0.15	0.29	0.40	0.94	0.20	0.13	0.13	0.12	0.12	0.16	2.90
1924	0.30	0.42	0.37	0.28	0.37	1.25	0.53	0.33	0.29	0.25	0.17	0.18	4.74
1925	0.31	0.37	0.28	0.27	0.38	1.34	0.53	0.31	0.31	0.30	0.25	0.20	4.85
1926	0.36	0.55	0.39	0.28	0.31	1.34	0.54	0.19	0.13	0.12	0.11	0.11	4.43
1927	0.24	0.17	0.19	0.27	0.39	0.88	0.36	0.19	0.24	0.20	0.22	0.19	3.54
1928	0.21	0.33	0.28	0.24	0.27	0.70	0.45	0.28	0.32	0.31	0.28	0.25	3.92
1929	0.39	0.64	0.40	0.23	0.16	0.38	0.31	0.27	0.31	0.30	0.28	0.25	3.92
1930	0.38	0.41	0.22	0.29	0.40	1.34	0.53	0.30	0.20	0.31	0.28	0.24	4.90
1931	0.34	0.41	0.23	0.13	0.40	1.00	0.42	0.28	0.30	0.29	0.27	0.25	4.32
1932	0.39	0.69	0.46	0.29	0.23	0.50	0.27	0.18	0.17	0.15	0.12	0.10	3.55
1933	0.11	0.46	0.45	0.29	0.40	0.83	0.47	0.31	0.27	0.30	0.27	0.20	4.36
1934	0.12	0.24	0.42	0.29	0.29	0.55	0.54	0.35	0.32	0.31	0.28	0.25	3.96
1935	0.32	0.29	0.12	0.10	0.40	1.34	0.53	0.34	0.32	0.30	0.27	0.18	4.51
1936	0.36	0.69	0.46	0.18	0.39	1.15	0.52	0.26	0.18	0.20	0.20	0.14	4.73
1937	0.16	0.15	0.27	0.28	0.36	0.41	0.42	0.33	0.31	0.30	0.27	0.16	3.42
1938	0.12	0.20	0.30	0.28	0.40	1.00	0.47	0.33	0.31	0.30	0.28	0.25	4.24
1939	0.39	0.51	0.32	0.22	0.14	0.34	0.24	0.33	0.32	0.29	0.25	0.15	3.50
1940	0.13	0.36	0.32	0.22	0.11	0.19	0.18	0.14	0.13	0.15	0.15	0.11	2.19
1941	0.17	0.33	0.20	0.29	0.40	0.67	0.36	0.31	0.29	0.25	0.22	0.20	3.69
1942	0.32	0.69	0.46	0.29	0.33	0.91	0.54	0.34	0.32	0.29	0.28	0.25	5.02
1943	0.38	0.61	0.43	0.29	0.39	0.78	0.36	0.21	0.23	0.25	0.20	0.25	4.38
1944	0.39	0.45	0.14	0.13	0.35	0.85	0.46	0.27	0.26	0.24	0.16	0.12	3.82
1945	0.39	0.58	0.12	0.10	0.30	1.13	0.52	0.33	0.28	0.25	0.16	0.11	4.27
1946	0.14	0.42	0.34	0.26	0.34	1.10	0.54	0.34	0.32	0.31	0.27	0.22	4.60
1947	0.22	0.69	0.46	0.28	0.40	1.02	0.51	0.32	0.25	0.14	0.11	0.10	4.50
1948	0.31	0.47	0.30	0.22	0.40	1.19	0.52	0.33	0.27	0.19	0.15	0.12	4.47
1949	0.22	0.59	0.42	0.29	0.39	0.84	0.49	0.34	0.32	0.30	0.27	0.24	4.71
1950	0.35	0.28	0.44	0.29	0.38	0.73	0.44	0.25	0.23	0.20	0.20	0.20	3.99
1951	0.39	0.52	0.31	0.29	0.39	0.77	0.49	0.34	0.29	0.25	0.14	0.13	4.31
1952	0.18	0.15	0.13	0.12	0.23	0.43	0.28	0.23	0.19	0.13	0.14	0.22	2.43
1953	0.38	0.67	0.44	0.29	0.33	0.62	0.34	0.29	0.31	0.29	0.25	0.21	4.42
1954	0.39	0.66	0.27	0.29	0.40	1.08	0.50	0.31	0.27	0.24	0.12	0.14	4.67
1955	0.30	0.41	0.17	0.10	0.12	1.28	0.53	0.34	0.31	0.28	0.23	0.19	4.26
1956	0.37	0.69	0.46	0.29	0.39	1.21	0.54	0.34	0.31	0.27	0.25	0.24	5.36
1957	0.38	0.53	0.38	0.29	0.40	1.04	0.54	0.34	0.27	0.24	0.17	0.11	4.69
1958	0.13	0.37	0.35	0.22	0.26	0.52	0.40	0.35	0.32	0.30	0.28	0.25	3.75
1959	0.37	0.41	0.27	0.20	0.25	0.60	0.49	0.34	0.32	0.28	0.26	0.24	4.03
1960	0.31	0.43	0.42	0.29	0.39	0.77	0.54	0.35	0.32	0.30	0.27	0.22	4.61
1961	0.19	0.46	0.37	0.28	0.36	1.15	0.52	0.31	0.27	0.18	0.20	0.18	4.47
1962	0.34	0.61	0.42	0.29	0.40	1.34	0.54	0.33	0.30	0.31	0.28	0.23	5.39
1963	0.32	0.51	0.37	0.29	0.40	1.01	0.53	0.34	0.32	0.31	0.27	0.23	4.90
1964	0.39	0.55	0.16	0.13	0.14	0.22	0.16	0.14	0.32	0.31	0.28	0.25	3.05
1965	0.39	0.67	0.40	0.26	0.27	0.24	0.17	0.35	0.32	0.29	0.25	0.22	3.83
1966	0.27	0.17	0.17	0.27	0.38	1.34	0.54	0.34	0.31	0.30	0.28	0.23	4.60
1967	0.16	0.26	0.22	0.13	0.21	0.34	0.23	0.16	0.13	0.12	0.18	0.24	2.38
1968	0.38	0.51	0.36	0.19	0.35	1.26	0.53	0.35	0.32	0.30	0.26	0.19	5.00
1969	0.28	0.44	0.32	0.17	0.12	0.25	0.18	0.14	0.27	0.27	0.28	0.25	2.97
1970	0.39	0.64	0.37	0.27	0.35	0.61	0.43	0.35	0.32	0.30	0.28	0.25	4.56
1971	0.39	0.61	0.33	0.26	0.40	1.04	0.36	0.21	0.23	0.24	0.20	0.11	4.38
1972	0.11	0.32	0.34	0.27	0.30	0.48	0.48	0.33	0.27	0.18	0.22	0.24	3.54
1973	0.38	0.61	0.42	0.25	0.35	0.87	0.49	0.35	0.32	0.30	0.27	0.16	4.77
1974	0.14	0.20	0.31	0.27	0.33	0.55	0.30	0.24	0.20	0.18	0.16	0.25	3.13
1975	0.39	0.36	0.40	0.29	0.40	1.34	0.54	0.35	0.32	0.28	0.24	0.23	5.14
1976	0.39	0.67	0.20	0.15	0.39	0.93	0.41	0.17	0.18	0.21	0.24	0.24	4.18
1977	0.38	0.65	0.46	0.29	0.34	0.56	0.54	0.35	0.32	0.30	0.26	0.23	4.68
1978	0.39	0.56	0.33	0.18	0.18	0.63	0.44	0.27	0.23	0.28	0.28	0.25	4.02
1979	0.38	0.44	0.24	0.13	0.16	0.30	0.20	0.15	0.17	0.17	0.13	0.25	2.72
1980	0.38	0.57	0.41	0.29	0.38	0.52	0.20	0.29	0.32	0.27	0.27	0.24	4.14
1981	0.22	0.15	0.13	0.14	0.21	1.33	0.53	0.34	0.30	0.26	0.20	0.11	3.92
1982	0.22	0.20	0.12	0.10	0.11	0.19	0.17	0.13	0.12	0.31	0.28	0.24	2.19
1983	0.35	0.49	0.37	0.29	0.39	0.74	0.49	0.34	0.32	0.31	0.28	0.24	4.61
1984	0.32	0.56	0.40	0.27	0.40	1.23	0.31	0.15	0.13	0.13	0.11	0.10	4.11
1985	0.27	0.58	0.41	0.29	0.38	0.55	0.27	0.19	0.16	0.13	0.25	0.25	3.73
1986	0.39	0.56	0.30	0.22	0.16	0.43	0.33	0.24	0.25	0.21	0.22	0.25	3.56
1987	0.39	0.57	0.40	0.25	0.40	1.34	0.54	0.35	0.32	0.31	0.28	0.25	5.40
1988	0.37	0.61	0.46	0.29	0.40	1.12	0.54	0.34	0.31	0.28	0.23	0.14	5.09
1989	0.39	0.69	0.44	0.20	0.19	1.05	0.52	0.24	0.16	0.13	0.24	0.24	4.49
1990	0.35	0.36	0.15	0.19	0.38	0.73	0.26	0.15	0.16	0.14	0.15	0.17	3.19
1991	0.38	0.61	0.41	0.23	0.19	0.26	0.21	0.17	0.14	0.13	0.12	0.13	2.98
1992	0.26	0.25	0.22	0.17	0.12	0.22	0.17	0.13	0.12	0.12	0.11	0.18	2.07
1993	0.37	0.51	0.43	0.29	0.40	1.17	0.43	0.15	0.13	0.17	0.26	0.22	4.53
1994	0.16	0.14	0.25	0.27	0.26	1.16	0.54	0.34	0.32	0.31	0.27	0.19	4.21
1995	0.29	0.32	0.46	0.29	0.40	0.93	0.29	0.21	0.19	0.31	0.28	0.24	4.21
1996	0.35	0.69	0.46	0.28	0.40	0.99	0.54	0.34	0.32	0.31	0.28	0.24	5.20
month	23.05	35.56	25.37	18.54	24.73	63.99	32.03	21.35	19.90	18.95	17.26	15.36	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.11	0.14	0.12	0.10	0.11	0.19	0.16	0.13	0.12	0.12	0.11	0.10	2.07
max	0.39	0.69	0.46	0.29	0.40	1.34	0.54	0.35	0.32	0.31	0.28	0.25	5.40
median	0.34	0.49	0.35	0.27	0.37	0.87	0.47	0.31	0.29	0.28	0.25	0.22	4.26
mean	0.30	0.46	0.33	0.24	0.32	0.83	0.42	0.28	0.26	0.25	0.22	0.20	4.11
Sum of the monthly means =				4.11									
s.d.	0.10	0.17	0.11	0.06	0.09	0.36	0.13	0.08	0.07	0.07	0.06	0.05	0.79
c.v.	0.33	0.37	0.33	0.26	0.29	0.44	0.31	0.27	0.27	0.27	0.26	0.26	0.19

APPENDIX 14.2
LUSIKISIKI IFR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.11	0.23	0.34	0.30	0.34	0.48	0.40	0.25	0.20	0.14	0.09	0.09	2.97
1921	0.19	0.96	0.45	0.31	0.28	0.16	0.13	0.26	0.25	0.24	0.22	0.21	3.66
1922	0.35	1.12	0.43	0.31	0.37	0.61	0.41	0.19	0.14	0.24	0.22	0.20	4.59
1923	0.13	0.17	0.16	0.31	0.36	0.49	0.16	0.10	0.10	0.10	0.10	0.13	2.31
1924	0.26	0.60	0.39	0.30	0.34	0.60	0.41	0.25	0.22	0.20	0.14	0.14	3.85
1925	0.29	0.54	0.30	0.29	0.35	0.62	0.42	0.24	0.24	0.23	0.20	0.17	3.89
1926	0.32	0.86	0.40	0.30	0.28	0.62	0.42	0.16	0.11	0.10	0.09	0.09	3.75
1927	0.23	0.22	0.20	0.29	0.36	0.48	0.28	0.15	0.18	0.15	0.18	0.15	2.87
1928	0.19	0.47	0.29	0.26	0.28	0.40	0.35	0.21	0.25	0.24	0.22	0.21	3.37
1929	0.35	1.06	0.40	0.22	0.13	0.20	0.25	0.20	0.23	0.23	0.21	0.21	3.69
1930	0.35	0.59	0.23	0.31	0.37	0.62	0.42	0.23	0.15	0.24	0.22	0.21	3.94
1931	0.32	0.58	0.25	0.14	0.36	0.52	0.33	0.20	0.23	0.22	0.21	0.21	3.57
1932	0.35	1.12	0.45	0.31	0.15	0.28	0.22	0.14	0.12	0.12	0.10	0.09	3.45
1933	0.11	0.82	0.45	0.31	0.36	0.43	0.36	0.23	0.19	0.23	0.21	0.17	3.87
1934	0.11	0.33	0.43	0.31	0.24	0.30	0.42	0.26	0.25	0.24	0.22	0.21	3.32
1935	0.30	0.41	0.14	0.11	0.37	0.62	0.41	0.26	0.24	0.24	0.21	0.15	3.46
1936	0.33	1.12	0.45	0.17	0.36	0.56	0.41	0.21	0.14	0.16	0.15	0.11	4.17
1937	0.15	0.19	0.26	0.30	0.34	0.27	0.34	0.25	0.24	0.23	0.21	0.13	2.91
1938	0.11	0.26	0.32	0.30	0.36	0.52	0.36	0.25	0.23	0.23	0.21	0.21	3.36
1939	0.35	0.72	0.33	0.24	0.13	0.23	0.20	0.25	0.24	0.23	0.19	0.12	3.23
1940	0.12	0.51	0.33	0.24	0.11	0.14	0.15	0.11	0.11	0.14	0.12	0.10	2.18
1941	0.16	0.44	0.21	0.31	0.36	0.39	0.28	0.23	0.22	0.20	0.17	0.17	3.14
1942	0.29	1.12	0.45	0.31	0.30	0.41	0.42	0.26	0.24	0.23	0.22	0.21	4.46
1943	0.35	1.01	0.42	0.30	0.35	0.42	0.29	0.16	0.17	0.20	0.15	0.21	4.03
1944	0.35	0.65	0.15	0.14	0.33	0.47	0.36	0.20	0.19	0.18	0.12	0.11	3.25
1945	0.35	0.85	0.13	0.11	0.28	0.55	0.41	0.25	0.21	0.20	0.13	0.09	3.56
1946	0.13	0.63	0.34	0.28	0.32	0.54	0.42	0.26	0.25	0.24	0.21	0.19	3.81
1947	0.22	1.12	0.45	0.30	0.36	0.51	0.40	0.24	0.19	0.12	0.09	0.09	4.09
1948	0.28	0.65	0.32	0.26	0.37	0.58	0.40	0.25	0.21	0.15	0.12	0.10	3.69
1949	0.20	0.93	0.41	0.30	0.36	0.47	0.38	0.26	0.24	0.23	0.21	0.21	4.20
1950	0.31	0.35	0.44	0.31	0.34	0.41	0.34	0.18	0.17	0.16	0.15	0.17	3.33
1951	0.35	0.71	0.38	0.31	0.36	0.42	0.39	0.25	0.22	0.18	0.11	0.11	3.79
1952	0.16	0.19	0.14	0.13	0.22	0.27	0.23	0.17	0.14	0.11	0.11	0.18	2.05
1953	0.34	1.08	0.44	0.31	0.29	0.36	0.27	0.22	0.23	0.22	0.19	0.18	4.13
1954	0.35	0.95	0.28	0.31	0.37	0.54	0.39	0.24	0.20	0.18	0.10	0.12	4.03
1955	0.26	0.55	0.18	0.10	0.11	0.61	0.42	0.25	0.24	0.22	0.18	0.15	3.27
1956	0.34	1.12	0.45	0.31	0.36	0.58	0.42	0.26	0.24	0.22	0.20	0.20	4.70
1957	0.35	0.79	0.37	0.31	0.37	0.55	0.42	0.26	0.22	0.18	0.14	0.10	4.06
1958	0.12	0.54	0.34	0.26	0.25	0.32	0.32	0.26	0.25	0.24	0.22	0.21	3.33
1959	0.33	0.59	0.29	0.23	0.24	0.37	0.38	0.26	0.24	0.21	0.20	0.19	3.53
1960	0.28	0.61	0.43	0.31	0.35	0.42	0.42	0.26	0.24	0.23	0.21	0.18	3.94
1961	0.18	0.84	0.38	0.29	0.33	0.55	0.41	0.24	0.20	0.14	0.15	0.15	3.86
1962	0.31	0.96	0.42	0.31	0.36	0.62	0.42	0.25	0.23	0.24	0.22	0.20	4.54
1963	0.30	0.81	0.37	0.31	0.36	0.50	0.42	0.26	0.25	0.24	0.21	0.20	4.23
1964	0.35	0.77	0.16	0.13	0.13	0.15	0.13	0.11	0.25	0.24	0.22	0.21	2.85
1965	0.35	1.08	0.40	0.26	0.25	0.16	0.14	0.26	0.24	0.23	0.20	0.19	3.76
1966	0.25	0.23	0.20	0.29	0.35	0.62	0.42	0.26	0.24	0.24	0.22	0.19	3.51
1967	0.15	0.37	0.23	0.14	0.20	0.23	0.18	0.12	0.11	0.10	0.14	0.20	2.17
1968	0.34	0.76	0.36	0.21	0.35	0.60	0.41	0.26	0.25	0.24	0.21	0.17	4.16
1969	0.25	0.64	0.33	0.19	0.12	0.17	0.15	0.11	0.21	0.21	0.22	0.21	2.81
1970	0.35	1.04	0.38	0.28	0.32	0.37	0.34	0.26	0.25	0.24	0.22	0.21	4.26
1971	0.35	0.89	0.34	0.27	0.37	0.56	0.29	0.16	0.17	0.18	0.15	0.10	3.83
1972	0.11	0.41	0.34	0.29	0.30	0.30	0.38	0.25	0.20	0.14	0.17	0.20	3.09
1973	0.34	0.96	0.42	0.23	0.32	0.47	0.38	0.26	0.25	0.24	0.21	0.13	4.21
1974	0.14	0.33	0.33	0.29	0.31	0.33	0.25	0.17	0.15	0.14	0.13	0.21	2.78
1975	0.35	0.56	0.42	0.31	0.37	0.62	0.42	0.26	0.24	0.23	0.19	0.19	4.16
1976	0.35	1.06	0.21	0.16	0.36	0.49	0.32	0.14	0.12	0.17	0.19	0.20	3.77
1977	0.34	1.07	0.45	0.31	0.31	0.32	0.42	0.26	0.24	0.23	0.20	0.19	4.34
1978	0.35	0.84	0.33	0.19	0.18	0.39	0.35	0.20	0.17	0.22	0.21	0.21	3.64
1979	0.34	0.63	0.25	0.14	0.15	0.20	0.16	0.12	0.12	0.14	0.11	0.21	2.57
1980	0.35	0.91	0.41	0.30	0.35	0.32	0.16	0.22	0.24	0.21	0.21	0.20	3.88
1981	0.19	0.19	0.14	0.14	0.22	0.62	0.42	0.25	0.23	0.21	0.15	0.10	2.86
1982	0.20	0.29	0.13	0.10	0.11	0.14	0.14	0.10	0.10	0.24	0.22	0.21	1.98
1983	0.32	0.80	0.37	0.31	0.36	0.41	0.38	0.25	0.24	0.24	0.22	0.21	4.11
1984	0.30	0.88	0.40	0.29	0.37	0.60	0.25	0.12	0.11	0.11	0.09	0.09	3.61
1985	0.25	0.91	0.40	0.31	0.36	0.28	0.21	0.14	0.12	0.10	0.19	0.21	3.48
1986	0.35	0.84	0.32	0.24	0.18	0.27	0.27	0.18	0.19	0.17	0.18	0.21	3.40
1987	0.35	0.92	0.41	0.24	0.36	0.62	0.42	0.26	0.24	0.24	0.22	0.21	4.49
1988	0.34	0.97	0.45	0.31	0.37	0.57	0.42	0.26	0.24	0.22	0.18	0.12	4.45
1989	0.35	1.12	0.43	0.20	0.18	0.53	0.40	0.19	0.12	0.10	0.19	0.20	4.01
1990	0.32	0.52	0.17	0.21	0.35	0.43	0.22	0.12	0.12	0.12	0.12	0.14	2.84
1991	0.35	0.97	0.41	0.21	0.18	0.17	0.17	0.13	0.11	0.10	0.10	0.11	3.01
1992	0.23	0.34	0.23	0.18	0.13	0.15	0.14	0.10	0.10	0.10	0.09	0.16	1.95
1993	0.34	0.69	0.44	0.31	0.37	0.58	0.34	0.12	0.10	0.14	0.20	0.18	3.81
1994	0.15	0.17	0.29	0.29	0.24	0.56	0.42	0.26	0.24	0.24	0.21	0.18	3.25
1995	0.26	0.47	0.45	0.31	0.36	0.49	0.23	0.16	0.14	0.23	0.22	0.20	3.52
1996	0.32	1.12	0.45	0.30	0.36	0.52	0.42	0.26	0.25	0.24	0.22	0.21	4.67
month	21.01	54.12	25.84	19.68	22.82	33.25	25.21	16.19	15.15	14.87	13.53	12.99	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.11	0.17	0.13	0.10	0.11	0.14	0.13	0.10	0.10	0.10	0.09	0.09	1.95
max	0.35	1.12	0.45	0.31	0.37	0.62	0.42	0.26	0.25	0.24	0.22	0.21	4.70
median	0.31	0.72	0.36	0.29	0.34	0.47	0.36	0.24	0.22	0.22	0.19	0.19	3.66
mean	0.27	0.70	0.34	0.26	0.30	0.43	0.33	0.21	0.20	0.19	0.18	0.17	3.57
Sum of the monthly means =				3.57									
s.d.	0.09	0.30	0.10	0.07	0.08	0.15	0.10	0.06	0.05	0.05	0.04	0.04	0.65
c.v.	0.31	0.42	0.30	0.26	0.29	0.35	0.30	0.26	0.27	0.26	0.26	0.26	0.18

APPENDIX 14.3
TUNGWANE IFR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.17	0.26	0.55	0.49	0.65	1.78	0.88	0.54	0.42	0.22	0.15	0.15	6.26
1921	0.31	1.09	0.78	0.50	0.55	0.39	0.24	0.58	0.54	0.51	0.46	0.41	6.36
1922	0.67	1.20	0.77	0.50	0.70	2.26	0.89	0.36	0.26	0.51	0.46	0.36	8.94
1923	0.18	0.21	0.24	0.50	0.70	1.55	0.29	0.19	0.18	0.17	0.18	0.25	4.64
1924	0.51	0.72	0.63	0.49	0.65	2.20	0.91	0.56	0.47	0.41	0.27	0.28	8.10
1925	0.52	0.67	0.48	0.46	0.66	2.35	0.91	0.50	0.52	0.50	0.42	0.33	8.32
1926	0.62	0.96	0.67	0.48	0.55	2.35	0.92	0.28	0.19	0.17	0.15	0.16	7.50
1927	0.41	0.27	0.30	0.46	0.69	1.27	0.57	0.30	0.38	0.31	0.37	0.31	5.64
1928	0.35	0.56	0.47	0.42	0.47	1.16	0.77	0.44	0.54	0.51	0.46	0.41	6.56
1929	0.67	1.12	0.69	0.39	0.24	0.60	0.53	0.45	0.51	0.50	0.46	0.41	6.57
1930	0.66	0.64	0.35	0.50	0.70	2.35	0.91	0.48	0.32	0.51	0.46	0.40	8.28
1931	0.57	0.70	0.39	0.20	0.70	1.75	0.70	0.46	0.50	0.49	0.45	0.41	7.32
1932	0.66	1.20	0.80	0.50	0.37	0.74	0.43	0.28	0.28	0.22	0.17	0.14	5.79
1933	0.17	0.91	0.78	0.50	0.70	1.13	0.81	0.52	0.43	0.50	0.46	0.34	7.25
1934	0.18	0.39	0.74	0.50	0.47	0.76	0.92	0.58	0.54	0.51	0.46	0.41	6.46
1935	0.54	0.49	0.18	0.15	0.70	2.35	0.90	0.58	0.54	0.51	0.44	0.27	7.65
1936	0.62	1.20	0.80	0.29	0.69	2.02	0.89	0.41	0.28	0.31	0.31	0.22	8.04
1937	0.25	0.23	0.46	0.48	0.63	0.65	0.73	0.56	0.52	0.50	0.45	0.25	5.71
1938	0.18	0.32	0.52	0.49	0.70	1.73	0.80	0.55	0.52	0.50	0.46	0.41	7.18
1939	0.67	0.86	0.53	0.38	0.21	0.59	0.38	0.55	0.53	0.49	0.41	0.23	5.83
1940	0.21	0.62	0.56	0.38	0.17	0.30	0.28	0.19	0.19	0.22	0.24	0.16	3.52
1941	0.29	0.54	0.33	0.50	0.70	0.91	0.62	0.52	0.49	0.41	0.35	0.33	5.99
1942	0.55	1.20	0.80	0.50	0.57	1.65	0.92	0.58	0.53	0.49	0.46	0.41	8.66
1943	0.65	1.07	0.74	0.49	0.69	1.10	0.59	0.32	0.36	0.41	0.32	0.41	7.15
1944	0.66	0.75	0.21	0.20	0.62	1.20	0.78	0.47	0.42	0.38	0.24	0.19	6.12
1945	0.67	1.00	0.17	0.16	0.52	2.00	0.89	0.55	0.45	0.39	0.25	0.16	7.21
1946	0.21	0.72	0.58	0.45	0.60	1.97	0.92	0.58	0.54	0.51	0.45	0.35	7.88
1947	0.35	1.20	0.80	0.49	0.70	1.80	0.87	0.53	0.39	0.20	0.15	0.14	7.62
1948	0.51	0.81	0.52	0.39	0.70	2.09	0.89	0.55	0.44	0.30	0.22	0.18	7.60
1949	0.36	1.03	0.71	0.49	0.68	1.18	0.84	0.57	0.53	0.49	0.46	0.41	7.75
1950	0.59	0.47	0.76	0.50	0.65	1.04	0.74	0.41	0.36	0.33	0.32	0.33	6.50
1951	0.66	0.90	0.52	0.50	0.68	1.11	0.84	0.56	0.49	0.40	0.20	0.20	7.06
1952	0.29	0.23	0.19	0.19	0.41	0.68	0.46	0.38	0.32	0.20	0.20	0.36	3.91
1953	0.64	1.17	0.76	0.50	0.57	0.86	0.59	0.49	0.52	0.48	0.42	0.36	7.36
1954	0.67	1.14	0.43	0.50	0.70	1.92	0.85	0.50	0.43	0.37	0.18	0.23	7.92
1955	0.51	0.70	0.27	0.14	0.19	2.25	0.91	0.56	0.52	0.46	0.37	0.31	7.19
1956	0.64	1.20	0.80	0.50	0.69	2.13	0.92	0.58	0.51	0.45	0.41	0.40	9.23
1957	0.65	0.90	0.64	0.50	0.70	1.83	0.92	0.57	0.44	0.34	0.26	0.16	7.91
1958	0.19	0.67	0.59	0.39	0.45	0.76	0.69	0.58	0.54	0.51	0.46	0.41	6.24
1959	0.63	0.71	0.46	0.34	0.43	0.84	0.83	0.57	0.53	0.46	0.42	0.39	6.61
1960	0.52	0.74	0.74	0.50	0.67	1.09	0.92	0.58	0.53	0.50	0.45	0.37	7.61
1961	0.31	0.91	0.65	0.48	0.63	2.01	0.89	0.50	0.43	0.29	0.32	0.30	7.72
1962	0.59	1.07	0.73	0.50	0.69	2.35	0.92	0.55	0.48	0.51	0.46	0.38	9.23
1963	0.53	0.87	0.63	0.50	0.70	1.77	0.91	0.57	0.54	0.51	0.45	0.38	8.36
1964	0.66	0.92	0.24	0.20	0.24	0.34	0.24	0.20	0.54	0.51	0.46	0.41	4.96
1965	0.67	1.17	0.68	0.43	0.46	0.39	0.25	0.58	0.54	0.48	0.42	0.37	6.44
1966	0.46	0.27	0.29	0.46	0.66	2.35	0.92	0.58	0.51	0.51	0.46	0.38	7.85
1967	0.24	0.43	0.37	0.20	0.37	0.59	0.35	0.24	0.19	0.17	0.29	0.40	3.84
1968	0.65	0.88	0.63	0.32	0.69	2.20	0.90	0.58	0.54	0.49	0.44	0.31	8.63
1969	0.48	0.75	0.55	0.27	0.19	0.39	0.26	0.21	0.45	0.45	0.46	0.41	4.87
1970	0.67	1.11	0.63	0.46	0.60	0.85	0.73	0.58	0.54	0.51	0.46	0.41	7.55
1971	0.67	1.03	0.56	0.44	0.70	1.85	0.62	0.34	0.36	0.39	0.31	0.16	7.43
1972	0.17	0.53	0.59	0.46	0.52	0.73	0.82	0.55	0.44	0.28	0.35	0.40	5.84
1973	0.64	1.07	0.72	0.42	0.62	1.23	0.83	0.58	0.54	0.51	0.45	0.24	7.85
1974	0.21	0.32	0.54	0.46	0.58	0.77	0.50	0.39	0.33	0.28	0.24	0.41	5.03
1975	0.66	0.58	0.72	0.50	0.70	2.35	0.92	0.58	0.54	0.46	0.38	0.38	8.77
1976	0.67	1.17	0.31	0.24	0.69	1.57	0.67	0.27	0.28	0.36	0.39	0.40	7.02
1977	0.64	1.15	0.80	0.50	0.60	0.78	0.92	0.58	0.54	0.49	0.43	0.38	7.81
1978	0.66	0.96	0.55	0.30	0.32	0.88	0.76	0.46	0.38	0.47	0.46	0.41	6.61
1979	0.65	0.76	0.40	0.20	0.26	0.50	0.31	0.22	0.28	0.26	0.20	0.41	4.45
1980	0.66	0.99	0.70	0.50	0.66	0.76	0.30	0.48	0.53	0.46	0.45	0.40	6.89
1981	0.36	0.23	0.20	0.23	0.40	2.33	0.91	0.56	0.50	0.43	0.31	0.16	6.62
1982	0.36	0.32	0.17	0.14	0.17	0.28	0.25	0.19	0.18	0.51	0.46	0.41	3.44
1983	0.58	0.84	0.63	0.50	0.68	1.09	0.83	0.56	0.53	0.51	0.46	0.41	7.62
1984	0.53	0.98	0.69	0.47	0.70	2.15	0.48	0.22	0.19	0.19	0.16	0.14	6.90
1985	0.47	1.01	0.70	0.50	0.66	0.73	0.42	0.30	0.24	0.19	0.42	0.41	6.05
1986	0.67	0.97	0.50	0.38	0.26	0.67	0.59	0.40	0.41	0.34	0.37	0.41	5.97
1987	0.67	0.99	0.69	0.42	0.70	2.35	0.92	0.58	0.54	0.51	0.46	0.41	9.24
1988	0.63	1.05	0.80	0.50	0.70	1.93	0.92	0.58	0.52	0.46	0.38	0.22	8.69
1989	0.66	1.20	0.75	0.32	0.32	1.92	0.89	0.38	0.23	0.18	0.39	0.39	7.63
1990	0.61	0.62	0.25	0.31	0.67	1.08	0.41	0.22	0.24	0.21	0.22	0.26	5.10
1991	0.66	1.07	0.70	0.38	0.34	0.41	0.32	0.25	0.21	0.17	0.18	0.22	4.91
1992	0.43	0.43	0.37	0.28	0.21	0.34	0.26	0.19	0.18	0.17	0.16	0.30	3.32
1993	0.64	0.88	0.75	0.50	0.70	2.02	0.70	0.22	0.18	0.26	0.44	0.37	7.66
1994	0.25	0.21	0.42	0.47	0.44	2.04	0.92	0.58	0.54	0.51	0.45	0.30	7.13
1995	0.49	0.54	0.80	0.50	0.70	1.50	0.43	0.34	0.32	0.51	0.46	0.40	6.99
1996	0.60	1.20	0.79	0.49	0.70	1.72	0.92	0.58	0.54	0.51	0.46	0.41	8.92
month	38.86	61.25	43.21	31.52	43.05	105.91	53.84	35.00	32.53	30.70	27.94	24.97	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.17	0.21	0.17	0.14	0.17	0.28	0.24	0.19	0.18	0.17	0.15	0.14	3.32
max	0.67	1.20	0.80	0.50	0.70	2.35	0.92	0.58	0.54	0.51	0.46	0.41	9.24
median	0.58	0.87	0.59	0.46	0.65	1.23	0.81	0.52	0.47	0.46	0.42	0.37	7.15
mean	0.50	0.80	0.56	0.41	0.56	1.38	0.70	0.45	0.42	0.40	0.36	0.32	6.87
Sum of the monthly means =				6.87									
s.d.	0.18	0.31	0.20	0.11	0.17	0.68	0.24	0.14	0.13	0.12	0.11	0.09	1.43
c.v.	0.35	0.39	0.35	0.28	0.31	0.50	0.34	0.30	0.30	0.31	0.30	0.29	0.21

APPENDIX 14.4
XURA IFR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.29	0.73	1.07	0.90	1.02	1.45	1.21	0.74	0.59	0.35	0.22	0.23	8.80
1921	0.54	2.89	1.35	0.92	0.84	0.47	0.34	0.77	0.74	0.71	0.64	0.62	10.83
1922	1.05	3.36	1.31	0.93	1.09	1.82	1.23	0.55	0.43	0.71	0.65	0.59	13.72
1923	0.35	0.48	0.44	0.93	1.09	1.47	0.42	0.26	0.26	0.24	0.25	0.39	6.58
1924	0.77	1.69	1.18	0.91	1.01	1.80	1.25	0.75	0.66	0.58	0.38	0.42	11.40
1925	0.84	1.55	0.87	0.86	1.04	1.88	1.26	0.70	0.71	0.69	0.58	0.50	11.48
1926	0.97	2.63	1.19	0.88	0.85	1.88	1.27	0.48	0.28	0.24	0.22	0.24	11.13
1927	0.68	0.69	0.54	0.86	1.07	1.43	0.84	0.40	0.50	0.45	0.52	0.43	8.41
1928	0.58	1.37	0.86	0.80	0.81	1.21	1.07	0.63	0.74	0.71	0.65	0.62	10.05
1929	1.05	3.19	1.22	0.65	0.39	0.64	0.70	0.57	0.69	0.70	0.64	0.62	11.06
1930	1.04	1.68	0.70	0.93	1.09	1.88	1.26	0.69	0.47	0.71	0.65	0.61	11.71
1931	0.95	1.66	0.76	0.37	1.09	1.59	0.98	0.60	0.68	0.67	0.61	0.62	10.58
1932	1.05	3.36	1.37	0.93	0.43	0.81	0.61	0.38	0.35	0.31	0.24	0.22	10.06
1933	0.27	2.47	1.35	0.93	1.08	1.32	1.12	0.67	0.58	0.68	0.63	0.49	11.59
1934	0.32	0.93	1.31	0.92	0.72	0.92	1.26	0.78	0.74	0.71	0.64	0.62	9.87
1935	0.89	1.22	0.35	0.28	1.09	1.88	1.24	0.77	0.73	0.71	0.62	0.43	10.21
1936	0.99	3.36	1.37	0.49	1.08	1.68	1.23	0.63	0.43	0.47	0.45	0.32	12.50
1937	0.41	0.55	0.81	0.89	1.01	0.76	1.00	0.75	0.70	0.68	0.62	0.37	8.55
1938	0.32	0.89	0.93	0.90	1.09	1.57	1.13	0.73	0.70	0.69	0.64	0.62	10.21
1939	1.05	2.29	0.98	0.74	0.40	0.65	0.57	0.73	0.73	0.67	0.56	0.35	9.72
1940	0.33	1.52	0.99	0.70	0.29	0.39	0.39	0.27	0.27	0.33	0.34	0.25	6.07
1941	0.46	1.31	0.60	0.93	1.09	1.16	0.83	0.67	0.67	0.57	0.49	0.50	9.28
1942	0.87	3.36	1.37	0.93	0.89	1.23	1.27	0.78	0.72	0.68	0.64	0.62	13.36
1943	1.04	3.11	1.28	0.91	1.05	1.30	0.86	0.46	0.49	0.58	0.45	0.62	12.15
1944	1.05	1.98	0.42	0.39	0.99	1.42	1.11	0.62	0.56	0.51	0.33	0.29	9.67
1945	1.05	2.61	0.34	0.30	0.82	1.64	1.23	0.74	0.63	0.56	0.35	0.24	10.51
1946	0.34	1.81	1.01	0.84	0.96	1.62	1.27	0.78	0.74	0.71	0.64	0.56	11.28
1947	0.65	3.36	1.37	0.89	1.08	1.54	1.20	0.73	0.55	0.30	0.22	0.21	12.10
1948	0.83	1.97	0.94	0.76	1.09	1.75	1.22	0.75	0.61	0.43	0.33	0.28	10.96
1949	0.60	2.80	1.25	0.90	1.07	1.41	1.16	0.77	0.73	0.67	0.63	0.61	12.60
1950	0.93	1.06	1.33	0.93	1.01	1.23	1.03	0.53	0.49	0.46	0.45	0.50	9.95
1951	1.05	2.23	1.15	0.92	1.06	1.31	1.17	0.75	0.67	0.55	0.29	0.31	11.46
1952	0.45	0.52	0.35	0.34	0.62	0.77	0.64	0.50	0.38	0.28	0.30	0.54	5.69
1953	1.02	3.24	1.32	0.92	0.86	1.11	0.80	0.64	0.70	0.66	0.56	0.52	12.35
1954	1.05	2.84	0.84	0.93	1.09	1.63	1.17	0.70	0.60	0.52	0.25	0.35	11.97
1955	0.77	1.58	0.53	0.26	0.30	1.82	1.26	0.76	0.71	0.64	0.51	0.45	9.59
1956	1.00	3.36	1.37	0.93	1.07	1.76	1.27	0.78	0.71	0.64	0.58	0.60	14.07
1957	1.03	2.39	1.14	0.93	1.09	1.64	1.26	0.77	0.66	0.53	0.39	0.26	12.09
1958	0.33	1.55	1.04	0.76	0.74	1.02	0.93	0.78	0.74	0.71	0.64	0.62	9.86
1959	0.99	1.67	0.86	0.69	0.71	1.12	1.15	0.76	0.72	0.63	0.58	0.57	10.45
1960	0.83	1.72	1.29	0.92	1.04	1.29	1.27	0.78	0.73	0.70	0.63	0.53	11.73
1961	0.50	2.53	1.15	0.88	1.00	1.66	1.23	0.70	0.60	0.42	0.47	0.43	11.57
1962	0.94	2.93	1.25	0.93	1.08	1.88	1.27	0.74	0.67	0.71	0.65	0.60	13.65
1963	0.90	2.44	1.14	0.93	1.09	1.49	1.25	0.77	0.74	0.71	0.64	0.59	12.69
1964	1.05	2.34	0.45	0.36	0.39	0.42	0.33	0.28	0.74	0.71	0.65	0.62	8.34
1965	1.05	3.25	1.19	0.79	0.76	0.49	0.35	0.78	0.73	0.70	0.59	0.56	11.24
1966	0.72	0.73	0.54	0.86	1.05	1.88	1.27	0.78	0.71	0.71	0.64	0.58	10.47
1967	0.41	1.06	0.67	0.39	0.57	0.66	0.54	0.34	0.27	0.24	0.41	0.60	6.16
1968	1.02	2.33	1.12	0.62	1.06	1.80	1.24	0.78	0.73	0.70	0.61	0.50	12.51
1969	0.75	1.88	0.99	0.53	0.36	0.50	0.38	0.28	0.63	0.63	0.65	0.62	8.20
1970	1.05	3.16	1.15	0.84	0.96	1.12	1.00	0.78	0.74	0.71	0.65	0.62	12.78
1971	1.05	2.73	1.02	0.84	1.09	1.69	0.88	0.46	0.49	0.53	0.43	0.24	11.45
1972	0.28	1.19	1.03	0.87	0.89	0.92	1.14	0.74	0.60	0.38	0.50	0.60	9.14
1973	1.02	2.90	1.25	0.70	0.97	1.42	1.15	0.78	0.74	0.71	0.62	0.39	12.65
1974	0.37	0.93	0.96	0.87	0.92	1.06	0.70	0.51	0.44	0.37	0.34	0.62	8.09
1975	1.05	1.60	1.27	0.92	1.09	1.88	1.27	0.78	0.73	0.69	0.57	0.58	12.43
1976	1.05	3.20	0.59	0.49	1.08	1.48	0.95	0.37	0.36	0.49	0.55	0.60	11.21
1977	1.02	3.22	1.37	0.93	0.94	1.02	1.27	0.78	0.73	0.70	0.60	0.56	13.14
1978	1.05	2.51	1.00	0.55	0.51	1.14	1.05	0.59	0.50	0.65	0.64	0.61	10.80
1979	1.03	1.85	0.75	0.37	0.43	0.63	0.47	0.30	0.35	0.37	0.27	0.62	7.44
1980	1.04	2.76	1.25	0.91	1.04	1.04	0.44	0.64	0.71	0.63	0.62	0.60	11.68
1981	0.54	0.55	0.36	0.44	0.62	1.86	1.26	0.76	0.68	0.60	0.44	0.25	8.36
1982	0.60	0.89	0.31	0.27	0.27	0.35	0.35	0.25	0.24	0.71	0.65	0.61	5.50
1983	0.96	2.43	1.13	0.91	1.07	1.27	1.15	0.76	0.72	0.71	0.64	0.61	12.36
1984	0.90	2.71	1.21	0.87	1.09	1.80	0.70	0.30	0.28	0.28	0.23	0.21	10.58
1985	0.72	2.76	1.23	0.92	1.06	0.81	0.59	0.39	0.32	0.26	0.58	0.62	10.26
1986	1.05	2.54	0.93	0.74	0.53	0.76	0.82	0.53	0.53	0.48	0.52	0.62	10.05
1987	1.05	2.78	1.23	0.72	1.09	1.88	1.27	0.77	0.73	0.71	0.65	0.62	13.50
1988	1.01	2.98	1.37	0.93	1.09	1.71	1.26	0.77	0.72	0.65	0.54	0.33	13.36
1989	1.05	3.36	1.29	0.56	0.50	1.59	1.22	0.57	0.35	0.27	0.56	0.59	11.91
1990	0.96	1.53	0.47	0.59	1.05	1.31	0.60	0.30	0.32	0.31	0.33	0.40	8.17
1991	1.05	3.05	1.23	0.63	0.53	0.53	0.49	0.36	0.30	0.24	0.25	0.33	8.99
1992	0.68	0.98	0.67	0.53	0.38	0.40	0.36	0.26	0.24	0.23	0.23	0.47	5.43
1993	1.01	2.14	1.32	0.92	1.09	1.75	1.00	0.32	0.25	0.38	0.60	0.53	11.31
1994	0.40	0.44	0.86	0.87	0.67	1.70	1.27	0.78	0.73	0.71	0.63	0.51	9.57
1995	0.79	1.39	1.37	0.93	1.08	1.46	0.66	0.46	0.38	0.70	0.64	0.61	10.47
1996	0.97	3.36	1.34	0.90	1.09	1.56	1.27	0.78	0.74	0.71	0.64	0.61	13.97
month	62.17	162.41	77.21	58.41	67.70	100.19	74.93	47.44	44.53	43.05	39.24	37.80	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.27	0.44	0.31	0.26	0.27	0.35	0.33	0.25	0.24	0.23	0.22	0.21	5.43
max	1.05	3.36	1.37	0.93	1.09	1.88	1.27	0.78	0.74	0.71	0.65	0.62	14.07
median	0.94	2.29	1.12	0.87	1.01	1.42	1.13	0.70	0.66	0.64	0.58	0.56	10.83
mean	0.81	2.11	1.00	0.76	0.88	1.30	0.97	0.62	0.58	0.56	0.51	0.49	10.59
Sum of the monthly means =				10.59									
s.d.	0.27	0.91	0.32	0.21	0.26	0.46	0.32	0.18	0.17	0.17	0.15	0.14	2.07
c.v.	0.33	0.43	0.32	0.28	0.30	0.36	0.33	0.29	0.29	0.30	0.29	0.28	0.20

APPENDIX 14.5
ZALU IFR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.09	0.20	0.27	0.23	0.26	0.37	0.31	0.19	0.16	0.09	0.07	0.07	2.31
1921	0.15	0.72	0.34	0.23	0.22	0.14	0.10	0.20	0.19	0.18	0.17	0.16	2.80
1922	0.27	0.84	0.33	0.24	0.28	0.46	0.31	0.15	0.12	0.18	0.17	0.15	3.50
1923	0.10	0.14	0.13	0.24	0.28	0.37	0.12	0.08	0.08	0.08	0.08	0.11	1.81
1924	0.20	0.45	0.30	0.23	0.26	0.45	0.32	0.19	0.17	0.15	0.11	0.11	2.94
1925	0.21	0.40	0.23	0.22	0.26	0.47	0.32	0.18	0.18	0.18	0.15	0.13	2.93
1926	0.25	0.66	0.30	0.23	0.22	0.47	0.32	0.13	0.09	0.08	0.07	0.07	2.89
1927	0.18	0.19	0.15	0.22	0.27	0.36	0.22	0.13	0.14	0.12	0.14	0.11	2.23
1928	0.15	0.35	0.22	0.21	0.21	0.31	0.27	0.16	0.19	0.18	0.17	0.16	2.58
1929	0.27	0.79	0.31	0.17	0.11	0.17	0.19	0.15	0.18	0.18	0.16	0.16	2.84
1930	0.26	0.45	0.18	0.24	0.28	0.47	0.32	0.18	0.13	0.18	0.17	0.16	3.02
1931	0.24	0.44	0.20	0.11	0.28	0.40	0.26	0.16	0.18	0.17	0.16	0.16	2.76
1932	0.27	0.84	0.34	0.24	0.14	0.21	0.17	0.11	0.09	0.09	0.07	0.07	2.64
1933	0.08	0.62	0.34	0.24	0.27	0.34	0.29	0.17	0.16	0.17	0.16	0.13	2.97
1934	0.09	0.25	0.33	0.23	0.19	0.24	0.32	0.20	0.19	0.18	0.17	0.16	2.55
1935	0.23	0.33	0.11	0.09	0.28	0.47	0.31	0.20	0.19	0.18	0.16	0.11	2.66
1936	0.25	0.84	0.34	0.14	0.27	0.42	0.31	0.16	0.12	0.13	0.12	0.09	3.19
1937	0.12	0.16	0.21	0.23	0.26	0.20	0.26	0.19	0.18	0.17	0.16	0.10	2.24
1938	0.10	0.24	0.24	0.23	0.28	0.39	0.29	0.19	0.18	0.18	0.16	0.16	2.64
1939	0.27	0.57	0.25	0.20	0.11	0.18	0.16	0.19	0.19	0.17	0.15	0.10	2.54
1940	0.10	0.39	0.25	0.18	0.09	0.12	0.12	0.08	0.08	0.09	0.10	0.07	1.67
1941	0.13	0.35	0.17	0.24	0.27	0.30	0.22	0.17	0.17	0.15	0.13	0.13	2.43
1942	0.22	0.84	0.34	0.24	0.23	0.31	0.32	0.20	0.19	0.17	0.17	0.16	3.39
1943	0.26	0.77	0.32	0.23	0.27	0.33	0.22	0.13	0.13	0.15	0.12	0.16	3.09
1944	0.27	0.51	0.12	0.11	0.25	0.36	0.28	0.16	0.15	0.14	0.10	0.09	2.54
1945	0.27	0.65	0.10	0.09	0.21	0.41	0.31	0.19	0.16	0.15	0.10	0.07	2.71
1946	0.10	0.48	0.26	0.22	0.25	0.41	0.32	0.20	0.19	0.18	0.16	0.15	2.92
1947	0.17	0.84	0.34	0.23	0.27	0.39	0.30	0.19	0.15	0.08	0.07	0.07	3.10
1948	0.21	0.50	0.24	0.20	0.28	0.44	0.31	0.19	0.16	0.12	0.10	0.08	2.83
1949	0.16	0.70	0.32	0.23	0.27	0.35	0.29	0.20	0.19	0.17	0.16	0.16	3.20
1950	0.24	0.28	0.33	0.24	0.26	0.31	0.27	0.14	0.13	0.13	0.12	0.13	2.58
1951	0.27	0.56	0.29	0.23	0.27	0.33	0.30	0.19	0.17	0.14	0.08	0.09	2.92
1952	0.13	0.15	0.11	0.10	0.17	0.21	0.18	0.14	0.11	0.08	0.08	0.14	1.60
1953	0.26	0.81	0.33	0.23	0.22	0.28	0.22	0.17	0.18	0.17	0.15	0.14	3.16
1954	0.27	0.71	0.22	0.24	0.28	0.41	0.30	0.18	0.16	0.14	0.08	0.10	3.09
1955	0.20	0.41	0.15	0.08	0.09	0.46	0.32	0.20	0.18	0.17	0.14	0.11	2.51
1956	0.25	0.84	0.34	0.24	0.27	0.44	0.32	0.20	0.18	0.17	0.15	0.16	3.56
1957	0.26	0.60	0.29	0.24	0.28	0.41	0.32	0.20	0.17	0.14	0.11	0.07	3.09
1958	0.10	0.40	0.27	0.20	0.19	0.26	0.24	0.20	0.19	0.18	0.17	0.16	2.56
1959	0.25	0.45	0.22	0.18	0.19	0.29	0.29	0.20	0.19	0.17	0.15	0.15	2.73
1960	0.21	0.47	0.33	0.23	0.26	0.33	0.32	0.20	0.19	0.18	0.16	0.14	3.02
1961	0.14	0.63	0.29	0.22	0.25	0.42	0.31	0.18	0.16	0.12	0.13	0.11	2.96
1962	0.24	0.73	0.32	0.24	0.27	0.47	0.32	0.19	0.17	0.18	0.17	0.16	3.46
1963	0.23	0.61	0.29	0.24	0.28	0.38	0.32	0.20	0.19	0.18	0.16	0.15	3.23
1964	0.27	0.59	0.13	0.10	0.11	0.12	0.10	0.09	0.19	0.18	0.17	0.16	2.21
1965	0.27	0.81	0.30	0.21	0.19	0.14	0.11	0.20	0.19	0.18	0.15	0.15	2.90
1966	0.19	0.20	0.15	0.22	0.27	0.47	0.32	0.20	0.18	0.18	0.17	0.15	2.70
1967	0.12	0.28	0.18	0.11	0.16	0.18	0.15	0.10	0.08	0.08	0.11	0.16	1.71
1968	0.26	0.58	0.28	0.16	0.27	0.45	0.31	0.20	0.19	0.18	0.16	0.13	3.17
1969	0.19	0.49	0.26	0.15	0.11	0.14	0.11	0.09	0.16	0.17	0.17	0.16	2.20
1970	0.27	0.79	0.29	0.22	0.25	0.29	0.26	0.20	0.19	0.18	0.17	0.16	3.27
1971	0.27	0.68	0.26	0.21	0.28	0.42	0.23	0.13	0.13	0.14	0.11	0.07	2.93
1972	0.09	0.31	0.26	0.22	0.23	0.24	0.29	0.19	0.16	0.10	0.13	0.16	2.38
1973	0.26	0.72	0.32	0.18	0.25	0.36	0.29	0.20	0.19	0.18	0.16	0.11	3.22
1974	0.10	0.25	0.25	0.22	0.24	0.27	0.20	0.14	0.12	0.10	0.10	0.16	2.15
1975	0.27	0.41	0.32	0.23	0.28	0.47	0.32	0.20	0.19	0.18	0.15	0.15	3.17
1976	0.27	0.80	0.17	0.13	0.27	0.37	0.25	0.11	0.11	0.14	0.14	0.16	2.92
1977	0.26	0.80	0.34	0.24	0.24	0.26	0.32	0.20	0.19	0.18	0.16	0.15	3.34
1978	0.27	0.63	0.26	0.15	0.15	0.29	0.27	0.16	0.14	0.17	0.17	0.16	2.82
1979	0.26	0.49	0.19	0.11	0.14	0.17	0.14	0.09	0.11	0.10	0.08	0.16	2.04
1980	0.26	0.69	0.32	0.23	0.26	0.27	0.13	0.17	0.18	0.17	0.16	0.16	3.00
1981	0.15	0.16	0.11	0.12	0.16	0.47	0.32	0.20	0.18	0.16	0.12	0.07	2.22
1982	0.16	0.24	0.10	0.08	0.08	0.11	0.11	0.08	0.08	0.18	0.17	0.16	1.55
1983	0.25	0.61	0.29	0.23	0.27	0.32	0.29	0.19	0.19	0.18	0.17	0.16	3.15
1984	0.23	0.68	0.31	0.22	0.28	0.45	0.20	0.09	0.09	0.08	0.07	0.07	2.77
1985	0.19	0.69	0.31	0.23	0.27	0.21	0.16	0.11	0.09	0.08	0.15	0.16	2.65
1986	0.27	0.64	0.24	0.20	0.15	0.20	0.22	0.14	0.14	0.13	0.14	0.16	2.63
1987	0.27	0.69	0.31	0.20	0.28	0.47	0.32	0.20	0.19	0.18	0.17	0.16	3.44
1988	0.26	0.75	0.34	0.24	0.28	0.43	0.32	0.20	0.18	0.17	0.14	0.09	3.40
1989	0.27	0.84	0.32	0.16	0.14	0.40	0.31	0.15	0.11	0.08	0.15	0.15	3.08
1990	0.24	0.39	0.14	0.16	0.27	0.33	0.16	0.09	0.09	0.09	0.10	0.11	2.17
1991	0.27	0.76	0.31	0.17	0.15	0.15	0.14	0.10	0.09	0.08	0.07	0.09	2.38
1992	0.18	0.26	0.18	0.15	0.11	0.12	0.11	0.08	0.08	0.07	0.07	0.13	1.54
1993	0.26	0.54	0.33	0.23	0.28	0.44	0.26	0.10	0.08	0.10	0.16	0.14	2.92
1994	0.11	0.13	0.22	0.22	0.18	0.43	0.32	0.20	0.19	0.18	0.16	0.14	2.48
1995	0.20	0.35	0.34	0.24	0.27	0.37	0.18	0.13	0.12	0.18	0.17	0.16	2.71
1996	0.25	0.84	0.34	0.23	0.28	0.39	0.32	0.20	0.19	0.18	0.17	0.16	3.55
month	16.16	41.25	19.83	15.22	17.55	25.51	19.43	12.54	11.84	11.32	10.47	10.04	

Statistics Period = 77 years

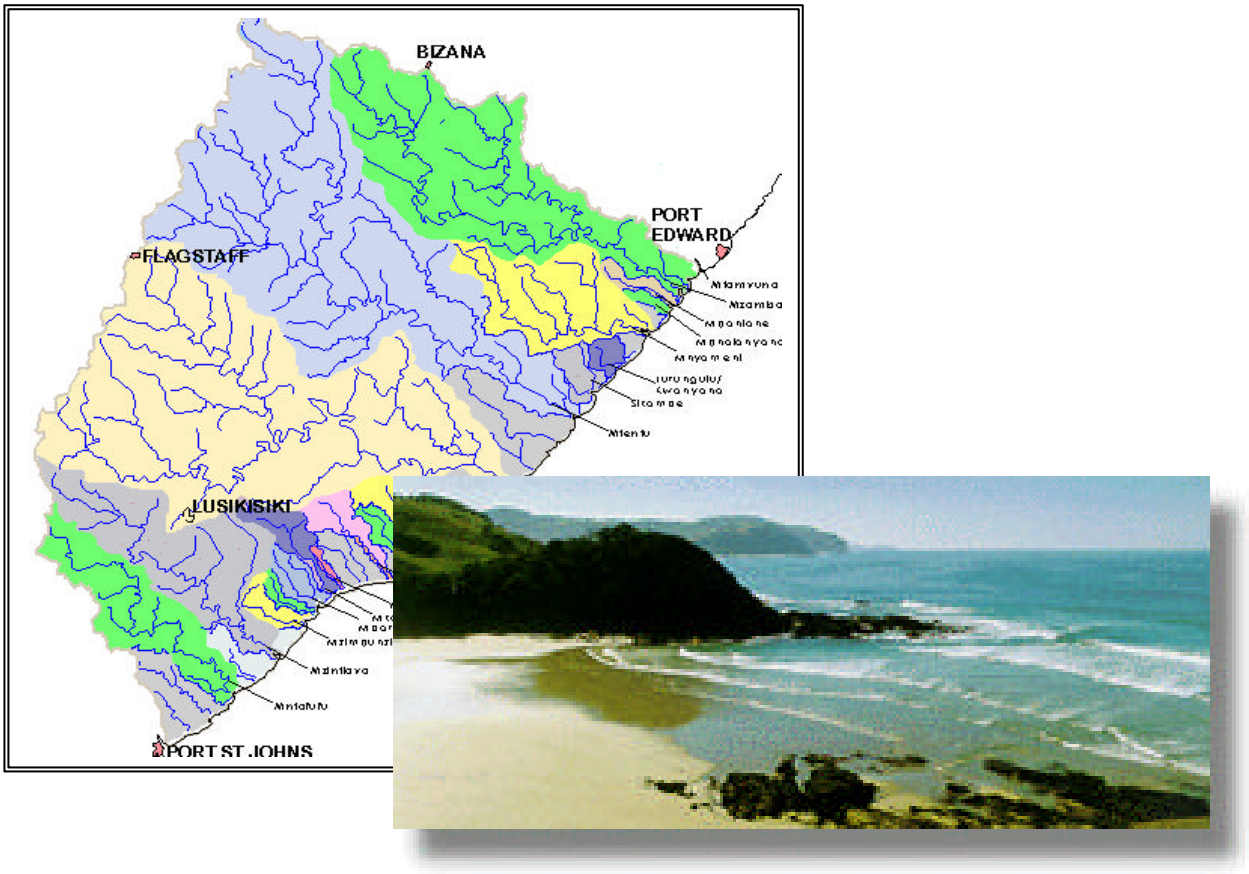
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.08	0.13	0.10	0.08	0.08	0.11	0.10	0.08	0.08	0.07	0.07	0.07	1.54
max	0.27	0.84	0.34	0.24	0.28	0.47	0.32	0.20	0.19	0.18	0.17	0.16	3.56
median	0.24	0.57	0.28	0.22	0.26	0.36	0.29	0.18	0.17	0.17	0.15	0.15	2.82
mean	0.21	0.54	0.26	0.20	0.23	0.33	0.25	0.16	0.15	0.15	0.14	0.13	2.74
Sum of the monthly means =				2.74									
s.d.	0.06	0.22	0.07	0.05	0.06	0.11	0.07	0.04	0.04	0.04	0.03	0.03	0.49
c.v.	0.30	0.41	0.29	0.25	0.27	0.33	0.29	0.25	0.25	0.26	0.25	0.25	0.18

PB T600/00/0901

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



STREAMFLOW HYDROLOGY

Final

June 2001

Prepared By:

Department of Water Affairs and Forestry
Directorate: Hydrology
Water Resources
Private Bag X313, Pretoria, 0001

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Streamflow Hydrology
AUTHOR	**:**	E Nel and P Mtsweni
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-0901
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EASTERN PONDOLAND BASIN STUDY
STREAMFLOW HYDROLOGY

EXECUTIVE SUMMARY

1. INTRODUCTION

The Directorate: Water Resources Planning commissioned the Eastern Pondoland Basin Study (EPBS) in collaboration with the Eastern Cape Regional Office, to provide a broad evaluation of the state of the water resource availability and utilization in the study area, and to identify a suitable water source for the augmentation of the Lusikisiki Regional Water Scheme.

This **Streamflow Hydrology** report is one of the supporting reports issued as part of the EPBS set of reports. Because of the limited streamflow data available in the Pondoland area, simulated monthly flow sequences had to be generated as follows:

- General hydrology for ten quaternary catchments included in the study area, i.e. T60A to T60K. The results were required for a broad evaluation of the development potential of the surface water resources in each quaternary catchment. Monthly flows were simulated for natural, present and future conditions.
- Specific streamflow data for the ten potentially feasible dam/weir development sites located on the Xura, Msikaba, Mzintlava, Mtentu and Mzamba Rivers. The results were required for the determination of the yields as well as for the determination of the riverine ecological Reserve below these sites.
- General hydrology for the entire catchments of the sixteen largest rivers in the study area. The results were required for the determination of estuarine ecological Reserves.

2. METHODOLOGY

The land use information taken into account included present and projected afforestation and irrigation areas, domestic, industrial and stock water use, existing farm dams, etc. The reduction of runoff due to afforestation was modelled using the WRSM90 programme. Due to the insignificance of the extent of present and projected irrigation developments in the area, the irrigation water requirements were ignored.

A standard rainfall-runoff model, the PITMAN or the Water Resources Simulation Model was used to generate 77 years of monthly flow sequences. Due to the absence of reliable observed flow records the model could not be directly calibrated, and the regional parameters recommended by the Water Research Commission's publication "Surface Water Resources of South Africa, 1990" (WR90) were used.

WR90 subdivides the study area into two rainfall zones. A number of functional rainfall gauging stations were identified in each zone within the T60 region. The data from the majority of these stations contained gaps in their records, but these were effectively patched. WR90 evaporation data was used.

3. SUMMARY OF RESULT

Table 3.1: Surface Water Runoff per Quaternary Catchment

Quaternary Catchment	Catchment Area	MAP	Incremental MAR		
			Naturalised	2000	2030
	(km^2)	(mm)	(10^6m^3)	(10^6m^3)	(10^6m^3)
T60A	547	873	71.9	70.5	67.6
T60B	528	896	75.5	70.7	67.1
T60C	363	952	62.7	62.1	61.4
T60D	415	1072	102.7	102.2	100.2
T60E	198	885	28.0	26.5	23.9
T60F	464	940	79.1	76.7	68.6
T60G	360	1116	100.3	99.2	98.5
T60H	322	1277	124.7	121.6	116.3
T60J	294	1101	77.6	75.9	75.8
T60K	242	1075	59.7	58.2	58.0
Total	**3733**		**782.2**	**763.9**	**737.7**

Table 3.2: Surface Water Runoff for each possible Development Site

Site Name	Quaternary Catchment	Catchment Area upstream of site	Incremental MAR	
			Naturalised	2000
		(km^2)	(10^6m^3)	(10^6m^3)
Xura	T60F	225	38.35	37.35
Zalu	T60F	71	12.10	11.45
Lusikisiki	T60F	91	15.51	14.84
Tungwane	T60J	129	24.20	23.44
Lower Mzintlava	T60J	98	17.06	16.93
Lusindisweni Dam	T60C	17	78.40	73.70
KwaHlathi Dam	T60C	194	109.00	104.00
Mbongweni Weir	T60A	200	26.30	25.40
Gxalibomvu Weir	T60G	30	115.50	111.60
Spes Bona Weir	T60C	35	81.50	76.80

Table 3.3: Surface Water Runoff per River Catchment

River	Quaternary Catchment	Catchment Area (km^2)	Naturalised MAR (10^6m^3)
Mtafufu	T60K	186	45.8
Mzintlava	T60J	270	71.2
Mzimpunzi	T60H	24	9.3
Mbotyi (Kobenge)	T60H	29	11.2
Mkozi	T60H	43	16.7
Myekane	T60H	5	1.9
Luphuthana	T60H	20	7.8
Mkweni	T60H	48	18.6
Msikaba	T60G / E / F	1022	207.4
Mtentu	T60D / C / B	964	152.6
Sikombe	T60D	28	6.9
Lutungulu	T60D	16	3.9
Mnyameni	T60D	186	46.0
Mpahlane	T60A	20	2.6
Mpahlanyana	T60A	9	1.2
Mzamba	T60A	506	66.5

CONTENTS

		PAGE
1.	**INTRODUCTION**	4
1.1.	Purpose of the Study	4
1.2.	Catchment Description	5
2.	**CLIMATOLOGY**	5
2.1.	Rainfall	5
2.1.1	Introduction	5
2.1.2	Selection and evaluation of rainfall stations	5
2.1.3	Patching of rainfall records	6
2.1.4	Catchment rainfall	8
2.1.5	Catchment Mean Average Precipitation (MAP)	9
2.2	Evaporation	10
2.2.1	Introduction	10
2.2.2	Source of evaporation	10
2.2.3	Pan-to-dam factors	11
3.	**LAND AND WATER USE**	12
3.1.	Afforestation	12
3.2.	Irrigation	12
3.3.	Water use	12
4.	**WRSM90 FLOW SIMULATION**	15
4.1.	Methodology	15
4.1.1	Observed Flow data	15
4.1.2	Natural Flow Simulation	15
4.1.3	Simulated Flow Sequences for Present (2000) and Future (2030) conditions	17
4.1.4	WRSM90 System Diagrams	17
5.	**PROPOSED DAMS**	20
5.1.	Introduction	20
5.2.	Description and Location of the Dam Sites	20
5.2.1	Lusikisiki Dam Site	20
5.2.2	Zalu Dam Site	20
5.2.3	Xura Dam Site	20
5.2.4	Tungwana Dam site	20
5.2.5	Lower Mzintlava Dam Site	20
5.3.	Natural and Present day flow Simulation for Proposed Dam Sites	21
5.4	WRSM90 System Diagrams	23
5.4.1	Lower Mzintlava and Tungwana Dam Catchments	23
5.4.2	Xura, Lusikisiki and Zalu Dam Catchments	23
6.	**WEIRS AND TWO OTHER PROPOSED DAMS**	24
6.1.	WRSM90 System Diagrams	25
6.2	Lusindisweni Dam, KwaHlathi Dam and Spes Bona Weir Catchments	25
6.3	Mbongweni Weir Catchment	25
6.4	Gxalibomvu Weir Catchment	25

7. FLOW SIMULATION AT ESTUARIES 26
7.1 WRSM90 System Diagram 26
7.2 Mtentu and Msikaba River Catchments 26
7.3 Other River Catchments (fourteen rivers) 26

8. RECOMMENDATION 27

9. CONCLUSION 27

10. REFERENCES 28

LIST OF APPENDICES

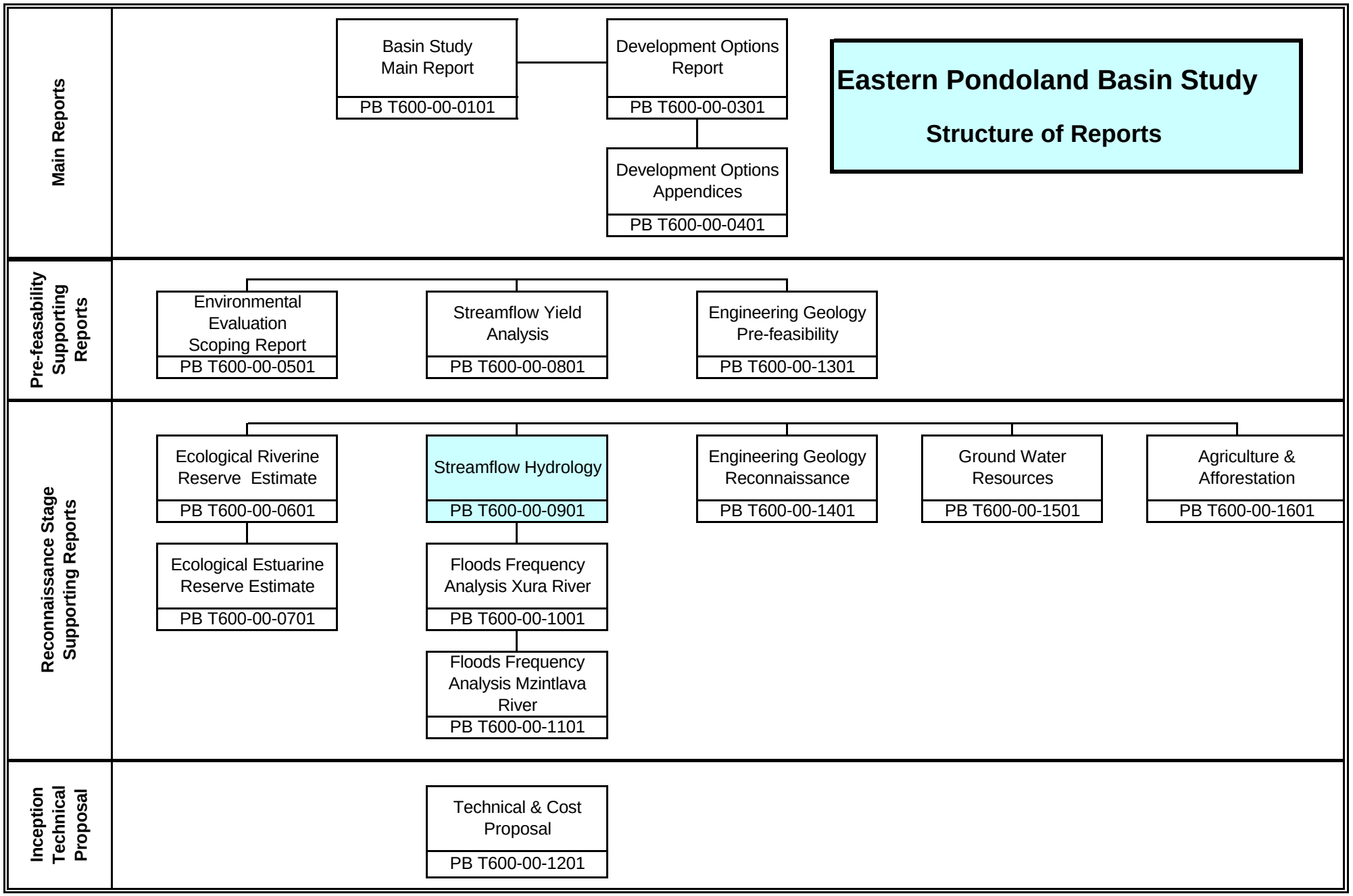
DESCRIPTION	APPENDIX
ZONAL CTCHMENT RAINFALL	1
NATURAL FLOW RECORDS FOR QUATERNARY CATCHMENTS	2
NATURAL INFLOW RECORDS FOR PROPOSED DAM SITES	3
NATURAL INFLOW RECORDS FOR WEIRS AND OTHER PROPOSED DAMS	4
NATURAL FLOW RECORDS FOR ESTUARIES	5
PRESENT DAY FLOW RECORDS FOR QUATERNARY CATCHMENTS (2000)	6
FUTURE FLOW RECORDS FOR QUATERNARY CATCHMENTS (2030)	7
PRESENT DAY FLOW RECORDS FOR PROPOSED DAM SITES (2000)	8
FUTURE FLOW RECORDS FOR PROPOSED DAM SITES (2030)	9
PRESENT DAY FLOW RECORDS FOR WEIRS AND OTHER PROPOSED DAMS	10
AFFORESTATION RUNOFF REDUCTION FOR QUATERNARY CATCHMENTS (2000)	11
AFFORESTATION RUNOFF REDUCTION FOR QUATERNARY CATCHMENTS (2030)	12
AFFORESTATION RUNOFF REDUCTION FOR PROPOSED DAM SITES (2000)	13
AFFORESTATION RUNOFF REDUCTION FOR PROPOSED DAM SITES (2030)	14
WRSM90 MODEL DIAGRAMS	15
MAPS	16

LIST OF FIGURES

Figure 1 - Map showing the distribution of rainfall stations.
Figure 2 - Map showing the afforested areas (2000).
Figure 3 - Map showing the afforested areas (2030).
Figure 4 - Map showing the potential irrigation areas.
Figure 5 - Map showing the position of all the proposed and weirs.
Figure 6 - Map showing all the estuary rivers.

Eastern Pondoland Basin Study

Structure of Reports



1. INTRODUCTION

The study area is located in the most northeastern, coastal part of the Wild Coast District of the Eastern Cape Province (formerly part of Transkei). This area is also known as the Eastern Pondoland and includes all catchments from the Mtafufu to the Mzamba Rivers (tertiary drainage region T600).

The introduction of the RDP water supply programme has resulted in the identification of the need in many instances for substantial augmentation of the domestic water supply schemes serving the large rural population in the region. In particular, water resources with adequate yield assurance are required for the upgrading of the water supply to the Lusikisiki Regional Water Supply scheme (120 000 people). The Wild Coast Spatial Development Program has identified forestry and tourism as the drivers for economic development in the area. Agricultural developments for the production of sugar cane and tea may be viable. Furthermore, the riverine systems and the estuaries of the rivers in the area are in pristine condition. The Mkambati Nature Reserve (Msikaba River estuary) and the entire Pondoland coast are extremely environmentally sensitive. These are national assets and attractions for tourists.

The surface water resources in the area are largely under-utilized. Groundwater may have a potential for cost efficient water supply in certain areas of the district. Conjunctive use of run-of river and ground water may be economically viable in other areas. The economic viability of hydropower generation in the construction of dams in the area has not been investigated.

In general, the knowledge level about the water resources in the Pondoland area as well as many other Transkei catchments is very limited. In order to provide a planning tool for the sustainable development and efficient utilization of the water resources in the area, it was recommended that a basin study be conducted. Such a study will further the aim of bringing the level of available information for the Transkei region in line with the rest of the catchments in South Africa. This study will also contribute valuable information for the establishment of a water management area and a catchment strategy as stipulated by the new Water Act.

In section 2 the climatology of the region is discussed. This mainly involves the selection and evaluation of rainfall stations, the patching of rainfall records and calculation of the zonal catchment rainfall record.

Section 2.2 discusses the availability of evaporation data. This involves the calculation of the S-pan evaporation data and the use of the conversion equation to calculate the A-pan evaporation.

The land and water use requirements are discussed in section 3. Section 4 discusses the simulation of long term flow sequences for the quaternary catchments while the simulation of inflow sequences for the proposed dams is discussed in section 5.

Three weirs and two other proposed dams are discussed in section 6. This involves the simulation of long term natural and present day inflow records to the dams and through the weirs. For a more detailed study on the yields of the dams refer to a report titled 'Eastern Pondoland Yield Analysis Report'

Section 7 discusses the estuaries, this involves the simulation of natural flow records at the estuaries of the sixteen rivers.

The recommendation and conclusion are discussed in section 8 and 9 respectively. Finally section 10 gives the references.

The results of this study will be useful for other Government Departments and interested parties for the planning of various development initiatives.

1.1 Purpose of this study

The study will provide a broad evaluation of the current state and the potential for development of the water resources in the area, as well as the present and potential water requirements for all user sectors. The Msikaba River catchment within which Lusikisiki lies will be given more detailed attention.

A more specific output of the basin study will be a clear indication at a pre-feasibility level of detail, of a preferred source for augmentation of the domestic supply for the town of Lusikisiki, and the surrounding rural areas as well as a recommendation for an implementation programme.

1.2 Catchment description

The total catchment area (T600) is approximately 3733 km^2. The coastal part of the catchment is a high rainfall area as compared to the inland where rainfall decreases. It is a hilly catchment; the rainfall run-off response is very quick. A number of minor dams and weirs exist in the catchment.

2. CLIMATOLOGY

2.1. RAINFALL

2.1.1 Introduction

Rainfall data influences the accuracy of any catchment study, particularly in the generation of stream flow sequences. Hence it is desirable to obtain rainfall gauging stations with good spatial coverage of the catchment area, spanning sufficiently long record periods and having high stationarity levels.

Not all rainfall records are complete, hence it is necessary to patch missing data. Sections 2.1.2 and 2.1.3 reviews the techniques and methods implemented to accomplish this task. Once the records were patched, further measures were implemented to ensure that the patched values were of an acceptable standard.

Once all the rainfall records were patched, percentage catchment rainfall records were calculated.

2.1.2 Selection and evaluation of rainfall stations

The records of rain gauges in the study area as well as those gauges in neighboring catchments, were retrieved from the rainfall data bank of the Department of Water of Affairs and Forestry (RDBF). The Weather Bureau publication Caelum[3] – A history of Notable Weather Events in South Africa: 1500 – 1994 was used to verify large rainfall events, which occurred in the study area.

The record length and missing data for each rainfall record were examined. Records of stations which ended before 1920 as well as stations with short record periods ($\leq$ 15 years) and stations with too many years of missing data (i.e. unsuitable to patch) were automatically rejected.

The record of each station was then subjected to the Wilcox stationarity test. Graphs of cumulative rainfall vs. time (mass plots) were also plotted to test for stationarity. Patched stations with non-stationary records were rejected. Stations that had large sections of missing data in the middle of the record periods were separated to form two rainfall records spanning different time periods. If these time periods were too

short, they were rejected. Large sections of missing data at either the beginning or the end of a rainfall record were also deleted. This avoided patching of long sequences of missing data.

The records of rainfall stations lying relatively close together were compared to each other for any possible unrealistic outliers. These outliers were then flagged as missing data.

2.1.3 Patching of rainfall records

Stations were initially grouped together for patching on the principles of closeness and comparable MAP. The grouping was refined by using the CLASSR program. Gaps in the monthly rainfall records were patched by the PATCHR program. Rainfall records were not extended.

Once all the stations were patched, each patched station was tested for stationarity. A number of stations showed poor stationarity and hence the patching process was redone for these stations, grouping them in different combinations. Stations that still showed unfavorable stationarity were then rejected.

A number of status levels were introduced to indicate the reliability level of each station; for example an acceptable station has a status of 0 whereas a station with insufficient intact years of data, has a status of 3. All the rainfall stations in and near the study area are listed in Table 2.1. Figure 1 in Appendix 16 shows the distribution of the rainfall stations inside and outside the study catchment.

Table 2.1: Rainfall Stations

Station number	Station name	Status*	Latitude	Longitude	Period of record (Hydrological years)
0181166	NDINDINDI – BOS	0	30^{0}46’	29^{0}36’	1926 to 1997
0181379	LUDEKE – MISSION	0	30^{0}49’	29^{0}43’	1925 to 1950
0181561	BIZANA – BOS	0	30^{0}51’	29^{0}49’	1914 to 1994
0180712	TONTI – BOS	1	30^{0}52’	29^{0}24’	1914 to 1994
0181054	EMFUNDISWENI	0	30^{0}54’	29^{0}32’	1919 to 1941
0180537	TABANKULU – TNK	1	30^{0}57’	29^{0}18’	1898 to 1997
0182450	EMOYENI	1	31^{0}00’	30^{0}15’	1934 to 1953
0153631	TABANKULU – BOS	1	31^{0}01’	29^{0}22’	1916 to 1997
0154151	MALONGWANA	3	31^{0}01’	29^{0}36’	1953 to 1968
0153875	FLAGSTAF – TNK	0	31^{0}05’	29^{0}30’	1900 to 1997
0153518	MTUKUKAZI	1	31^{0}08’	29^{0}18’	1957 to 1968
0154279	HOLLY CROSS MISSION	0	31^{0}09’	29^{0}40’	1942 to 1974
0153820	BUKAZI	2	31^{0}10’	29^{0}28’	1958 to 1975
0154796	MKAMBATHI	0	31^{0}16’	29^{0}57’	1925 to 1997
0154142	LUSIKISIKI – TNK	0	31^{0}22’	29^{0}35’	1909 to 1995
0154354	NTSUBANE – BOS	0	31^{0}24’	29^{0}42’	1914 to 1997
0153570	MAJOLA	2	31^{0}30’	29^{0}19’	1939 to 1953
0129007	PORTSTJOHNS – BOS	2	31^{0}37’	29^{0}31’	1923 to 1997
0129068A	CAPE HERMES – VRT	0	31^{0}38’	29^{0}33’	1887 to 1997

*Status	Description
0	Accepted
1	Only employed to patch
2	Unacceptable stationarity
3	Record too short

2.1.4 Catchment rainfall

The study area consists of ten quaternary catchments with two rainfall zones, each associated with a number of quaternary catchments. The WR90 quaternary catchments that fall within each rainfall zone are as follows:

Zone T6A:	T60A, T60B, T60C and T60D.
Zone T6B:	T60E, T60F, T60G, T60H, T60J and T60K.

The objective was to create a catchment rainfall record for each of the zones which is representative of the average rainfall over the zone. For each rainfall zone, a group of rainfall stations was selected as listed in Table 2.2. The zonal catchment rainfall records were then calculated using the HDYP08 program. This program converts each monthly rainfall value in a selected record to a percentage of that record's MAP. The percentages are then averaged among stations chosen for a particular zone in order to obtain a record of mean monthly percentages for the zone.

The rainfall gauges selected for calculating the zonal catchment rainfall are given in Table 2.2 and the zonal monthly catchment rainfall records for the record period 1920/21 to 1996/97 are given in Appendix 1.

Table 2.2: Rainfall Stations used for generating catchment rainfall records.

RAINFALL ZONE T6A					
Station number	**Period of Record**	**Record Length (years)**	**MAP (mm)**	**Latitude**	**Longitude**
0181166	1957 – 1996	39	1176	$30^0$46’	$29^0$36’
0181379	1925 – 1949	25	793	$30^0$49’	$29^0$43’
0181561	1928 – 1993	65	814	$30^0$51’	$29^0$49’
0153875	1920 – 1996	76	848	$31^0$05’	$29^0$30’
0154279	1942 – 1972	30	923	$31^0$09’	$29^0$40’
0154796	1925 – 1991	66	1233	$31^0$16’	$29^0$57’
0181054	1920 – 1940	20	776	$30^0$54’	$29^0$32’
RAINFALL ZONE T6B					
0153875	1920 – 1996	76	848	$31^0$05’	$29^0$30’
0154279	1942 – 1972	30	923	$31^0$09’	$29^0$40’
0154142	1920 – 1976	56	985	$31^0$22’	$29^0$35’
0154796	1925 – 1996	71	1233	$31^0$16’	$29^0$57’
0129068	1959 – 1996	37	1039	$31^0$38’	$29^0$33’
0154354	1924 – 1996	72	1467	$31^0$24’	$29^0$42’

2.1.5 Catchment Mean Average Precipitation (MAP)

The WRSM90 model calculates a catchment rainfall record in mm by multiplying the catchment percentage rainfall record with the catchment MAP in mm. Table 2.3 gives the rainfall zones, corresponding quaternary catchments, quaternary catchment areas and MAPs as obtained from the WR90[1] publication.

Table 2.3: Catchment Areas and MAPs

Rainfall zone	Quaternary catchment	Catchment area (km^2)	MAP (mm)
T6A	T60A	547	873
	T60B	528	896
	T60C	363	952
	T60D	415	1072
T6B	T60E	198	885
	T60F	464	940
	T60G	360	1116
	T60H	322	1277
	T60J	294	1101
	T60K	242	1075
	Total	3733	1004

2.2. EVAPORATION

2.2.1 Introduction

Evaporation data is required for the modelling of evaporation losses by the WRSM90 rainfall run-off model, the determination of net evaporation losses from dam surfaces and for the calculation of evapotranspiration from irrigated crops.

Two types of evaporation pans are commonly used to measure evaporation, namely the Symons pan (S-pan) and the American Class 'A' pan (A-pan). The evaporation values from these two types of pans differ significantly. The A-pan evaporation is generally 1.1 to 1.3 times higher than that of the S-pan, depending on the locality of the pan. A-pan evaporation is required for the assessment of irrigation requirements as the so called "crop factors" relate to A-pan evaporation. S-pan evaporation on the other hand, is used for estimating evaporation losses from free water surfaces.

2.2.2 Source of Evaporation data

The report "Surface Water Resources of South Africa 1990" (WR90[1]) by DC Midgley, WV Pitman and BT Middleton is the only source of evaporation data since no observed evaporation records are available.

According to WR90[1] the study area lies in evaporation zones 29B and 30C. The mean monthly gross Symons pan (S-pan) evaporation as a percentage of the mean annual gross evaporation, for these zones is given in Table 2.4.

Table 2.4: Mean Monthly Gross S-pan Evaporation Percentages.

Evapor-ation Zone	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
29B	10.06	10.82	12.60	12.62	10.20	8.97	6.82	4.77	3.82	4.43	6.49	8.40
30C	8.70	8.76	11.18	12.02	10.41	9.95	7.71	6.34	4.74	5.24	7.22	7.73

The monthly distribution pattern in Table 2.4 and the mean annual gross evaporation for quaternary catchments as found in WR90[1] were then used to calculate the mean monthly gross S-pan evaporation in mm. These values are listed in Table 2.5.

The mean monthly gross S-pan evaporation was converted to mean monthly gross A-pan evaporation using the formula of Bosman in WR90[1]. The Bosman formula is:

$$\text{A-pan} = 26.3622 + 1.0786 \times \text{S-pan}$$

The A-pan evaporations are listed in Table 2.5.

Table 2.5: Mean monthly gross S-pan and A-pan Evaporation (mm).

Quaternary catchments T60A-G													
Pan type	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual Total
S-pan (mm)	100	101	129	138	120	114	89	73	55	60	83	89	1151
A-pan (mm)	134	135	165	176	156	150	122	105	85	91	116	122	1557
Quaternary catchments T60H-K													
S-pan (mm)	116	124	145	145	117	103	78	59	44	51	75	97	1154
A-pan (mm)	151	161	183	183	153	138	111	86	74	81	107	131	1559

2.2.3 Pan–to-dam Factors

Evaporation from the free water surface is usually less than the evaporation measured using evaporation pans. Pan conversion factors are applied to the S-pan values to estimate the dam evaporation. It should be noted that these factors relate to S-pan evaporation only and the adjusted S-pan evaporation is commonly referred to as "lake" evaporation.

The pan-to-dam factors as calculated by Chapman[2], are given in Table 2.6.

Table 2.6: Pan-to-Dam Factors

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.81	0.82	0.83	0.84	0.88	0.88	0.88	0.87	0.85	0.83	0.81	0.81

3. LAND AND WATER USE

3.1 Afforestation

Climate is a dominant limiting factor in afforestation development. A MAP of 800 mm and higher is generally considered ideal. According to the MAP values in the study area, the whole catchment can sustain afforestation. Quaternary catchments T60A, T60B and T60H have significantly more afforestation than the other quaternary catchments. The total afforestation area for the year 2000 scenario is approximately 84.61 km^2, accounting for 2.27% of the total catchment area. For the year 2030 scenario it is about 155.87 km^2, accounting for 4.18 % of the total catchment area. Table 3.1 gives a summary of afforestation areas as supplied by UWP Consulting Engineers. Figures 2 and 3 in Appendix 16 are maps showing existing (2000) and projected (2030) afforested areas in the study area.

Table 3.1: Present and Projected Afforestation areas

Quaternary Catchment	2000	2030
	Afforestation Area (km^2)	Afforestation Area (km^2)
T60A	6.47	27.10
T60B	34.05	44.68
T60C	0	0
T60D	0	10.00
T60E	6.98	6.98
T60F	4.72	4.72
T60G	2.95	2.95
T60H	14.95	44.95
T60J	8.17	8.17
T60K	6.32	6.32
TOTAL	84.61	155.87

3.2 Irrigation

There is very little commercial farming (irrigation) taking place in the entire catchment. The irrigation requirement is less than one percent of the natural MAR, which is insignificant. It was then decided that it should be ignored for the simulation of both the 2000 and the 2030 scenarios. Figure 4 in Appendix 16 is a map showing potential irrigation areas.

3.3 Water use

Water use refers to domestic and livestock water requirements. The two consumers are modelled as a combined abstraction for both the 2000 and the 2030 scenarios. Table 3.2 gives a summary of land and water use on a quaternary basis for the 2000 and the 2030 scenarios as supplied by UWP Consulting Engineers.

Table 3.2: Summary of irrigation and water use for years 2000 and 2030 per quaternary catchment

Quatenary Catchment	Catchment Area (km^2)	2000		2030	
		Irrigation Demand (Mm^3/a)	Domestic + Livestock (Mm^3/a)	Irrigation Demand ($Mm^{3/}/a$)	Domestic + Livestock (Mm^3/a)
T60A	547	0	0.63	0.16	1.46
T60B	528	0	1.03	0.12	3.43
T60C	363	0	0.57	0.02	1.33
T60D	415	0	0.48	0.04	0.84
T60E	198	0.01	0.70	0.08	3.33
T60F	464	0	1.77	0.27	9.89
T60G	360	0	0.63	0.02	1.35
T60H	322	0	0.31	0	0.26
T60J	294	0	0.40	0.05	0.44
T60K	242	0.01	0.50	0.04	0.70
TOTAL	3733	0.02	7.02	0.80	23.03

Tables 3.4 and 3.5 give the monthly domestic and livestock water consumption as calculated using the annual demand figures multiplied by the monthly abstraction pattern (%) given in Table 3.3 (supplied by UWP Consulting Engineers). The monthly domestic and livestock water consumption are given for both the present (2000) and future (2030) scenarios.

Table 3.3 Abstraction Pattern (%)

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
8.33	9.17	10.00	10.83	10.00	9.17	8.33	7.50	6.67	5.83	6.67	7.50

Table 3.4: Monthly domestic and livestock water consumption (Mm^3) for quaternary catchments (2000)

Quaternary Catchment	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
T60A	0.05	0.06	0.06	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.05	0.63
T60B	0.09	0.09	0.10	0.10	0.06	0.09	0.09	0.08	0.07	0.06	0.07	0.08	1.03
T60C	0.05	0.05	0.06	0.06	0.06	0.05	0.05	0.04	0.04	0.03	0.04	0.04	0.57
T60D	0.04	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.48
T60E	0.06	0.06	0.07	0.08	0.07	0.06	0.06	0.05	0.05	0.04	0.05	0.05	0.70
T60F	0.15	0.16	0.18	0.19	0.18	0.16	0.15	0.13	0.12	0.10	0.12	0.13	1.77
T60G	0.05	0.06	0.06	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.05	0.63
T60H	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.31
T60J	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.03	0.03	0.40
T60K	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.04	0.50

Table 3.5: Monthly domestic and livestock water consumption (Mm^3) for quaternary catchments (2030)

Quaternary Catchment	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
T60A	0.12	0.13	0.15	0.16	0.15	0.13	0.12	0.11	0.10	0.08	0.10	0.11	1.46
T60B	0.29	0.31	0.34	0.37	0.34	0.31	0.29	0.26	0.23	0.20	0.23	0.26	3.43
T60C	0.11	0.12	0.13	0.14	0.13	0.12	0.11	0.10	0.09	0.08	0.09	0.10	1.33
T60D	0.07	0.08	0.08	0.09	0.08	0.08	0.07	0.06	0.06	0.05	0.06	0.06	0.84
T60E	0.28	0.30	0.33	0.36	0.33	0.30	0.28	0.25	0.22	0.19	0.22	0.25	3.33
T60F	0.82	0.91	0.99	1.07	0.99	0.91	0.82	0.74	0.66	0.58	0.66	0.74	9.89
T60G	0.11	0.12	0.14	0.15	0.14	0.12	0.11	0.10	0.09	0.08	0.09	0.10	1.35
T60H	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.26
T60J	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.44
T60K	0.06	0.06	0.07	0.08	0.07	0.06	0.06	0.05	0.05	0.04	0.05	0.05	0.70

4. WRSM90 FLOW SIMULATION

4.1. Methodology

4.1.1 Observed flow data

A number of gauging stations of the Department of Water affairs and Forestry (DWAF) were identified as possible locations for rainfall-runoff calibration using the WRSM90 model. The sub-directorate Data Quality determined the accuracy and reliability of each individual station and verified the data at these stations.

Although certain observed stage records (time/height) are available, the reliability of the observed data has been found to be totally inadequate. No discharge tables for the period of observation are available to convert the primary records into secondary data (flows). No similar catchments with reliable flow data records could be identified for cross correlation purposes. In this case no calibration of the WRSM90 model could be performed because of the unavailability of observed flow records. The following has been reported on each individual flow gauging station.

- **T6H001** *(Mtafufu River at Mtafufu Location 35)*
  This station has an observed time/height record (primary data) covering the period 29/7/1969 to 22/8/1979. There is no discharge table (DT) available for the aforementioned period and consequently no flow rate/volumetric (secondary data) is available. This station can therefore not be used for WRSM90 calibration purpose.

- **T6H002** *(Msikaba River and Msikaba Road Bridge)*
  This station is only a water quality sampling point and flow is not recorded.

- **T6H003** *(Mtentu River at Spes Bona Road Bridge)*
  This station is only a water quality sampling point and flow is not recorded.

- **T6H004** *(Xura River at Lusikisiki)*
  Although some recorder charts (time/height) are available the reliability thereof is totally inadequate to derive secondary data. Rhodes University also confirmed this when they tried to use this data. This station has recently been made operational again and was equipped with an electronic data logger. Recent data (approx. 2 months) are insufficient to be useful.

4.1.2 Natural Flow Simulation

Natural stream flow simulation was done for all quaternary catchments, viz. T60A, T60B, T60C, T60D, T60E, T60F, T60G, T60H, T60J and T60K. Natural flow is a flow that would have been expected if there were no man made influences on the catchment. Input data for the WRSM90 model for natural flow simulation are as follows: -

- catchment area (quaternary catchment)
- quaternary catchment MAP
- mean monthly evaporation (S-pan)
- period of simulation
- regional Pitman parameter set
- monthly rainfall sequence as a percentage of the MAP (1920/21-1996/97)

No model calibration could be done due to the unavailability of observed flow records. The WR90 regional parameters were therefore used to simulate natural flows for the quaternary catchments. These parameters are the same for all the quaternary catchments and are given in Table 4.1.

Table 4.1: WR90 Regional Parameters

POW	SL	ST	FT	GW/FT	ZMIN	ZMAX	PI	TL	GL	R
3.0	0.0	200	15.0	0.00	999	999	1.5	0.25	0.0	0.5

The abbreviations of the eleven WR90 parameters are as follows:

POW - power of soil moisture / subsurface flow equation
SL - soil moisture state when subsurface flow is zero in mm
ST - soil moisture capacity in mm
FT - subsurface flow at soil moisture capacity in mm/month
GW - maximum groundwater flow in mm/month
ZMIN - minimum catchment absorption in mm/month
ZMAX - maximum catchment absorption in mm/month
PI - interception storage in mm
TL - lag of flow (excluding groundwater) in months
GL - lag of groundwater flow in months
R - coefficient of evaporation / soil moisture equation

The natural flow records simulated are given in Appendix 2. The MARs and coefficients of variance of the simulated flows were compared to those of the WR90. The comparisons are tabulated in Table 4.2 below.

Table 4.2: Comparison of Natural MARs and coefficients of variance: simulated vs. WR90

Quatenary Catchment	MAR in Mm^3 (WR90) 1920-1989	MAR in Mm^3 (simulated) 1920-1989	MAR in Mm^3 (simulated) 1920-1997	CV (WR90) 1920-1989	CV (simulated) 1920-1989	CV (simulated) 1920-1997
T60A	73.3	71.7	71.9	0.616	0.610	0.620
T60B	76.9	75.3	75.5	0.607	0.600	0.610
T60C	64.1	62.5	62.7	0.579	0.570	0.580
T60D	104.6	102.5	102.7	0.522	0.510	0.520
T60E	28.7	28.0	28.0	0.625	0.620	0.630
T60F	80.6	79.4	79.1	0.562	0.590	0.610
T60G	101.6	100.8	100.3	0.528	0.510	0.520
T60H	125.6	125.4	124.7	0.478	0.450	0.470
T60J	78.3	78.0	77.6	0.544	0.530	0.540
T60K	60.4	60.1	59.7	0.555	0.550	0.560

4.1.3 Simulated Flow sequences for present (2000) and future (2030) conditions.

Two scenarios were considered, the present (2000) and the future (2030). The present scenario (2000) reflects the current state of a catchment, the future scenario (2030) reflects the future developments of the catchment. UWP Consulting Engineers supplied the data.

With the WR90 regional parameters, present day flow records were simulated for all ten quaternary catchments. Present day flow takes into account the present day development of the catchment i.e. a catchment with man made influences such as commercial afforestation, irrigation, interbasin transfers, water abstractions and farm dams. Section 4.1.4 explains the WRSM90 system diagrams.

4.1.4 WRSM90 System Diagrams

The system diagrams for the quaternary catchments as drawn up for the WRSM90 model are shown in Appendix 15.1. Figure 4 in Appendix 16 gives a map showing the all the quaternary catchments.

T60A, H, J and K: These quaternary catchments have similar system diagrams. The RU1 module represents natural runoff from a particular quaternary catchment, CR2 represents a river channel reach and Dem1 is a water demand placed on the river.

T60B, C and D: RU1, RU2, and RU3 represent natural runoff from quaternary catchments T60B, T60C and T60D respectively. Dem1, Dem2 and Dem3 represent total water demand in quaternary catchments T60B, T60C and T60D respectively.

T60E, F and G: RU1, RU2, and RU3 represent natural runoff from quaternary catchments T60E, T60F and T60G respectively. Dem1, Dem2 and Dem3 represent total water demand in quaternary catchments T60E, T60F and T60G respectively.

The MARs as simulated by the WRSM90 model on quaternary basis for both natural and present day/future conditions are given in Table 4.3 (2000 scenario) and Table 4.4 (2030 scenario). Natural flow records for the quaternaries are given in Appendix 2.

Table 4.3: Natural and Present Day MARs for year 2000 scenario

2000									
Quaternary Catchment	Catchment area (km^2)	MAP (mm)	Natural MAR (Mm^3/a)	Present day MAR with Afforestation (Mm^3/a)	Present day **accumulative** MAR with Afforestation and Abstractions (Mm^3/a)	Afforestation Area (km^2)	Mean Afforestation Runoff Reduction (Mm^3/a)	Domestic + Livestock	
								Demand (Mm^3/a)	Supply (Mm^3/a)
T60A	547	873	71.9	71.2	70.6	6.47	0.70	0.63	0.63
T60B	528	896	75.5	71.8		34.05	3.70	1.03	1.03
T60C	363	952	62.7	62.7		0.00	0.00	0.57	0.57
T60D	415	1072	102.7	102.7	235.1	0.00	0.00	0.48	0.48
T60E	198	885	28.0	27.3		6.98	0.78	0.70	0.70
T60F	464	940	79.1	78.6		4.72	0.58	1.77	1.77
T60G	360	1116	100.3	99.8	202.5	2.95	0.49	0.63	0.63
T60H	322	1277	124.7	121.9	121.6	14.95	2.81	0.31	0.31
T60J	294	1101	77.6	76.3	75.9	8.17	1.27	0.40	0.40
T60K	242	1075	59.7	58.7	58.2	6.32	0.96	0.50	0.50
TOTAL	3733		782.2	771.0	763.9	84.61	11.29	7.02	7.02

Table 4.4: Natural and Future MARs for year 2030 scenario.

2030									
Quaternary Catchment	Catchment area (km^2)	MAP (mm)	Natural MAR (Mm^3/a)	Future MAR with Afforestation (Mm^3/a)	Future **accumulative** MAR with Afforestation and Abstractions (Mm^3/a)	Afforestation area (km^2)	Mean Afforestation runoff reduction (Mm^3/a)	Domestic + Livestock	
								Demand (Mm^3/a)	Supply (Mm^3/a)
T60A	547	873	71.9	69.1	67.6	27.10	2.85	1.46	1.46
T60B	528	896	75.5	70.6		44.68	4.90	3.43	3.43
T60C	363	952	62.7	62.7		0.00	0.00	1.33	1.32
T60D	415	1072	102.7	101.1	228.8	10.00	1.67	0.84	0.84
T60E	198	885	28.0	27.3		6.98	0.78	3.33	3.31
T60F	464	940	79.1	78.6		4.72	0.58	9.89	9.89
T60G	360	1116	100.3	99.8	191.1	2.95	0.49	1.35	1.35
T60H	322	1277	124.7	116.5	116.3	44.95	8.21	0.26	0.26
T60J	294	1101	77.6	76.3	75.9	8.17	1.27	0.44	0.44
T60K	242	1075	59.7	58.7	58.0	6.32	0.96	0.70	0.70
TOTAL	3733		782.2	760.7	737.7	155.87	21.71	23.03	22.99

5. PROPOSED DAMS

5.1 Introduction

One of the main measures for satisfying the increasing demands on the water resource is the provision of sufficient storage to optimally regulate the surface water runoff. In order to reach this objective a number of suitable dam sites in the region, having potential for development, have to be evaluated. The approach for evaluation of dams is to determine the impact of present and future development on the yield of the dams and to compare yield characteristics of the dams. The following five dam sites were identified for further evaluation and Figure 5 shows the position of all the proposed dams.

1. Lusikisiki
2. Zalu
3. Xura
4. Tungwana
5. Lower Mzintlava

5.2. Description and Location of the sites

5.2.1 Lusikisiki dam site

The dam site is situated in the T60F quaternary catchment on the Xura River which is a tributary of the Msikaba River. The total T60E quaternary catchment also contributes to the runoff at the dam site.

5.2.2 Zalu dam site

The dam site is situated on the Xura River in the T60F quaternary catchment upstream of the Lusikisiki dam site.

5.2.3 Xura dam site

The dam site is situated in the T60F quaternary catchment on the Msikaba River downstream of the Lusikisiki dam site.

5.2.4 Tungwana dam site

The dam site is situated on the Mzintlava River downstream of the Lower Mzintlava dam site in the T60J quaternary catchment.

5.2.5 Lower Mzintlava

The dam site is situated on the Mzintlava River in the T60J quaternary catchment. Lower Mzintlava is located upstream of Tungwana dam site.

The names of the proposed dams, catchment areas, MAP and location are given in Table 5.1.

Table 5.1: Catchment Area, MAP and Location of Proposed Dams

Proposed dam Name	Quaternary Catchment	Catchment area (km^2)	Catchment MAP (mm)	Location	
				Latitude	Longitude
Lusikisiki	T60F	91	940	$31^0$19’25’’	$29^0$31’10’’
Zalu	T60F	71	940	$31^0$18’50’’	$29^0$28’40’’
Xura	T60F	225	940	$31^0$18’55’’	$29^0$35'35’’
Lower Mzintlava	T60J	98	950	$31^0$24’25’’	$29^0$31’22’’
Tungwana	T60J	129	975	$31^0$19’29’’	$29^0$31’10’’

5.3 Natural and present day flow simulation for proposed dam sites

Natural and present day flow simulations were done with the dams in place for all the proposed dam sites. The dams were modelled individually, not as a system. A quaternary catchment is split into two sub-catchments, upstream and downstream of the dam. Within the specific quaternary in which the dam is situated MAP adjustment is done for the two sub-catchments with the weighted MAP giving the original MAP of the quaternary catchment.

For the present day flow simulation, landuse data and water use requirements were also split by UWP Consulting Engineers into upstream and downstream demands depending on their locations in the quaternary catchment. The data used as input into the WRSM90 model is the same as for the quaternary catchments except for the splits of the catchments to accommodate the newly formed sub-catchments, associated catchment areas, land and water use and readjusted MAP values. Two scenarios were considered, namely the 2000 and the 2030 scenarios. Table 5.2 gives a summary of land and water use demands for the present (2000) and future (2030) scenarios as supplied by UWP Consulting Engineers.

Table 5.2: Summary of land and water use demands.

Dam Name	Upstream of Dam Site		Downstream of Dam Site		Quaternary Catchment	
Xura Dam (T60F)	2000	2030	2000	2030	2000	2030
Domestic + livestock demands (Mm^3/a)	0.445	0.328	0.476	0.296	0.920	0.623
Irrigation demand (Mm^3/a)	0	0	0.003	0.270	0.003	0.270
Afforested area (km^2)	464	464	8	8	472	472
Catchment area (km^2)	225		239		464	
TUNGWANE DAM (T60J)						
Domestic + livestock demands (Mm^3/a)	0.172	0.157	0.210	0.148	0.382	0.305
Irrigation demand (Mm^3/a)	0	0	0	0.045	0	0.045
Afforested area (km^2)	497	497	320	320	817	817
Catchment area (km^2)	129		165		294	
LOWER MZINTLAVA (T60J)						
Domestic + livestock demands (Mm^3/a)	0.148	0.133	0.234	0.172	0.382	0.305
Irrigation demand (Mm^3/a)	0	0	0	0.045	0	0.045
Afforested area (km^2)	0	0	817	817	817	817
Catchment area (km^2)	98		196		294	
LUSIKISIKI DAM (T60F)						
Domestic + livestock demands (Mm^3/a)	0.190	0.210	0.730	0.413	0.920	0.623
Irrigation demand (Mm^3/a)	0	0	0.003	0.270	0.003	0.270
Afforested area (km^2)	402	402	70	70	472	472
Catchment area (km^2)	91		373		464	
ZALU DAM (T60F)						
Domestic + livestock demands (Mm^3/a)	0.175	0.185	0.745	0.438	0.920	0.623
Irrigation demand (Mm^3/a)	0	0	0.003	0.270	0.003	0.270
Afforested area (km^2)	398	398	74	74	472	472
Catchment area (km^2)	71		393		464	

5.4 WRSM90 System diagram

The system diagrams for the proposed dams as drawn up for the WRSM90 model are shown Appendix 15.2.

5.4.1 Lower Mzintlava and Tungwana dam catchments

The system diagrams for the Lower Mzintlava and Tungwana dam sites are similar to each other. RU1 represents the natural runoff from the dam catchment, Dem1 is the water demand placed on the river before the dam site. RV3 represents a dam with route 8 as a spill channel. RU5 is natural runoff from a sub-catchment downstream of the dam and Dem2 is the water demand on the river downstream of the dam. It is estimated that 33 percent of the runoff generated in T60J is available as an inflow into the proposed Lower Mzintlava dam and 44 percent into the proposed Tungwana dam.

5.4.2 Xura, Lusikisiki, and Zalu dam catchments

The system diagrams for these dam sites are similar to each other. RU1 represents the natural runoff into the dam catchment in T60F (upstream). RU2, RU3 and RU4 represent natural runoff from quaternary catchments T60E, T60F and T60G respectively. RU3 (downstream of dam) is a sub-catchment downstream of the dam. Dem1 and Dem3 are water demands upstream and downstream of the dam. RV11 represents the proposed dam with route 17 as the spill channel. It is estimated that 49, 20 and 15 percent of quaternary catchment's T60F runoff is routed into Xura, Lusikisiki and Zalu respectively.

Table 5.3 gives the natural, present day (2000) and future (2030) MARs for the proposed dams. The simulated runoff records are further used in a detailed study of the proposed dams. Appendix 3 gives the natural inflow records to the dams and Appendices 8 and 9 gives the inflow records to the dams for present and future scenarios.

Table 5.3: Natural and Present Day (2000) and future (2030) MARs at proposed dams

Proposed Dam Name	Quaternary Catchment	Catchment Area of Dam (km^2)	MAP Upstream Of Dam (mm)	MAP Downstream of Dam (mm)	Natural MAR (Mm^3)	Present and Future MAR (Mm^3)	
						2000	2030
Xura	T60F	225	940	940	38.35	37.35	37.47
Zalu	T60F	71	940	940	12.10	11.45	11.43
Lusikisiki	T60F	91	940	940	15.51	14.84	14.82
Tungwana	T60J	129	975	1200	24.20	23.44	23.46
Lower Mzintlava	T60J	98	950	1177	17.06	16.93	16.94

The afforestation runoff reduction for proposed dams is given in Table 5.4 for both present (2000) and future (2030) scenarios.

Table 5.4: Afforestation Runoff Reduction for Present (2000) and Future (2030) conditions.

Proposed Dam Site	Afforestation Runoff Reduction (Mm^3)	
	2000	2030
Xura Dam	0.57	0.57
Zalu Dam	0.48	0.48
Lusikisiki Dam	0.49	0.49
Tungwana Dam	0.60	0.60
Lower Mzintlava Dam	0	0

6. WEIRS AND TWO OTHER PROPOSED DAMS

Two other dams were proposed and three weirs exist in the catchment. The impact of this minor dams and weirs is insignificant on quaternary catchments, so these were modelled separately on a special request and not included in the modelling of quaternary catchments. Natural and present day flows were simulated using the same approach as for the proposed dam sites as discussed in section 5. During the simulation of the present day flow, only one scenario was considered, namely the 2000 scenario that represents the current state of the catchment. The simulated flow records were further used in a detailed study of these dams; the details are given in the yield analysis report. Section 6.1 explains the WRSM90 system diagrams for the existing dams and weirs. See Figure 5 in Appendix 16 for the location of the proposed dams and weirs.

Table 6.1 gives the split of quaternary catchments for the existing dams and weirs as supplied by UWP Consulting Engineers. A recommendation was made that the land and water use information as summarized in Tables 3.1 and 3.2 for present (2000) scenario be used as follows: -

T60C Proportion pro rata to catchment areas.
T60G All afforestation to be considered downstream of site, other demands to be proportioned.
T60A All afforestation to be considered upstream of site, other demands to be proportioned.

Table 6.1: Split of catchment areas per site

Site Name	Total Catchment area split				Downstream part of Quaternary Catchment	
	Full Quaternary		Upstream Part of Quaternary Catchment			
		Area (km^2)		Area (km^2)		Area (km^2)
Lusindisweni dam	T60B	528	T60C	17	T60C	346
KwaHlati dam	T60B	528	T60C	194	T60C	169
Mbongweni weir	0	0	T60A	200	T60A	347
Gxalibomvu weir	T60E + F	662	T60G	30	T60G	330
Spes Bona weir	T60B	528	T60C	35	T60C	328

6.1 WRSM90 SYSTEM DIAGRAM

The diagrams for the incremental catchments of the proposed dams and weirs, as drawn up for the WRSM90 model are shown in Appendix 15.3.

6.2 Lusindisweni Dam, KwaHlathi Dam and Spes Bona Weir Catchments

These dams and weirs have similar systems diagrams. RU1 and RU4 represent the natural runoff from quaternary catchments T60B and T60D respectively. RU2 represents natural runoff from sub-catchment T60C upstream of the dam and RU3 represents natural runoff from sub-catchment T60C downstream of the dam. Dem1 represents water demand in the quaternary catchment T60B, Dem2 represents water demand upstream of the dam and Dem3 represents water demand downstream of the dam. Route 18 is the spill of the dam and route 24 is the estuary mouth of the river.

Lusindisweni Dam: The catchment areas for T60C upstream and downstream of the dam are 17 km^2 and 346 km^2 respectively. It is estimated that 5 percent of the runoff generated in T60C and 100 percent of the runoff generated in T60B are routed into the dam.

KwaHlathi Dam: The catchment areas for T60C upstream and downstream of the dam are 194 km^2 and 169 km^2 respectively. It is estimated that 53 percent of the runoff generated in T60C and 100 percent of the runoff generated in T60B are routed into the dam.

Spes Bona Weir: The catchment areas for T60C upstream and downstream of the weir are 35 km^2 and 328 km^2 respectively. It is estimated that 10 percent of the runoff generated in T60C and 100 percent of the runoff generated in T60B are routed through the weir.

6.3 Mbongweni Weir Catchment

RU1 represents the natural runoff from sub-catchment of T60A upstream of the weir with Dem1 a water demand placed on the river upstream of the weir. RU2 represents the natural runoff from sub-catchment of T60A downstream of the weir with Dem2 a water demand placed on this sub-catchment. The catchment area upstream of the weir is 200 km^2. It is estimated that 37 percent of the runoff generated in T60A is routed through the weir.

6.4 Gxalibomvu Weir Catchment

RU1 and RU2 represent the natural runoff from quaternary catchments T60E and T60F respectively. RU3 and RU4 represent the natural runoff from quaternary catchment T60G upstream and downstream of the weir respectively. Dem1 represents water demand in the quaternary catchment T60E, Dem2 represents water demand in T60F and Dem3 represents water demand in T60G upstream of the weir. RU4 represents the natural runoff from quaternary catchment T60G downstream of the weir and Dem4 is the water demand downstream of the weir in T60G. The catchment area of T60G upstream of the weir is 30 km^2. It is estimated that 8 percent of the runoff generated in T60G and 100 percent of the runoffs generated in T60E and T60F are routed through the weir.

Table 6.2 gives a summary (name of the dam/weir, the location, catchment area, MAP, natural MAR and present day MAR) of the dams and weirs. Appendices 4 and 10 give the natural and present day flow records for the proposed dams and weirs respectively.

Table 6.2: Proposed dams and existing weirs.

Name of Dam/Weir	Catchment Area (km^2)	Catchment MAP (mm)	Natural MAR (Mm^3)	Present Day MAR (Mm^3)	Co-ordinates	
					Latitude	Longitude
Lusindisweni Dam	545	898	78.4	73.7	$31^0$05'53''	$29^0$43'53''
KwaHlathi Dam	722	911	109.0	104.0	$31^0$08'49''	$29^0$50'54''
Mbongweni Weir	200	873	26.3	25.4	$31^0$01'59''	$29^0$51'51''
Gxalibomvu Weir	692	932	115.5	111.6	$31^0$13'58''	$29^0$43'21''
Spes bona Weir	563	899	81.5	76.8	$31^0$07'44''	$29^0$45'05''

7. FLOW SIMULATION AT ESTUARIES

Sixteen rivers were identified whose estuarine flows were required for environmental purposes. Natural stream flow records were simulated for these rivers. No present day stream flows could be simulated, as there were no land and water use data available for the different river catchments.

7.1 WRSM90 System diagram

The system diagrams for the incremental catchments of the sixteen rivers, as drawn up for the WRSM90 model, are shown in Appendix 15.4. Msikaba and Mtentu Rivers have similar system diagrams. The fourteen remaining rivers have simple and similar system diagrams. All the catchment areas for the different rivers were planimetered on a 1: 50 000 map. See Figure 6 in Appendix 16 for location of the estuary rivers.

7.2 Mtentu and Msikaba River Catchments

Mtentu River: RU1, RU2 and RU3 represent the natural runoff from the quaternary catchments T60B, T60C and T60D respectively. It is estimated that 100 percent of the runoff generated in T60B and T60C is available to the river. The catchment area of the part of Mtentu River in T60D is 73 km^2 and that makes a contribution of only 18 percent of the runoff generated in T60D.

Msikaba River: RU1, RU2 and RU3 represent the natural runoff from quaternary catchments T60E, T60F and T60G. It was estimated that 100 percent of the runoff generated in each quaternary catchment is available to the river.

7.3 Other river catchments (fourteen rivers)

The fourteen remaining rivers have similar system diagrams. RU1 represents natural runoff from the catchment of a particular river.

The river name, catchment area and natural MAR of the estuaries are given in Table 7.1 Natural flow records for the estuaries are given in Appendix 5.

Table 7.1: Natural MARs at Estuaries

Name of River	Quaternary Catchment at River Mouth	Catchment Area (km^2)	Natural MAR at Estuary (Mm^3)
Mtafufu River	T60K	186	45.8
Mzintlava River	T60J	270	71.2
Mzimpunzi River	T60H	24	9.3
Mbotyi River	T60H	29	11.2
Mkozi River	T60H	43	16.7
Myekane River	T60H	5	1.9
Lupatana River	T60H	20	7.8
Mkweni River	T60H	48	18.6
Msikaba River	T60G	1022	207.4
Mtentu River	T60D	964	152.6
Sikombe River	T60D	28	6.9
Lutungulu River	T60D	16	4.0
Mnyameni River	T60D	186	46.0
Mpahlane River	T60A	20	2.6
Mpahlanyane River	T60A	9	1.2
Mzamba River	T60A	506	66.5

8. RECOMMENDATION

An action plan has to be in place to maintain existing or erect new gauging stations in order to strengthen the flow-gauging network. This would help improve the availability of observed flow data in and around the study area.

9. CONCLUSION

The results of this study should be treated with caution, as the reliability is not satisfactory. This is due to fact that the WRSM90 model could not be calibrated because there was no observed flow data available.

10. REFERENCES

1. Surface Water Resources of Southern Africa 1990 by Midgley, WV Pitman and BJ Middleton (1994)
2. Pan Coefficients for Estimating Evaporation from South African Reservoirs, RA Chapman (1991).
3. Caeleum, A history of Notable Weather Events in South Africa: 1500 – 1994

APPENDIX 1

ZONAL CATCHMENT RAINFALL

APPENDIX 1.1
ZONE T6A CATCHMENT RAINFALL

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	6.24	11.94	14.26	10.90	10.01	14.66	6.93	0.92	0.28	0.10	0.59	6.01	82.84
1921	9.59	19.78	19.27	11.39	8.49	2.94	1.54	18.26	8.78	0.10	7.25	2.47	109.86
1922	11.18	18.81	8.53	18.20	25.51	16.35	0.91	2.02	0.88	23.05	0.64	1.89	127.97
1923	3.87	6.30	11.97	26.32	16.37	3.66	1.79	2.93	1.35	0.03	3.67	5.87	84.13
1924	9.40	12.45	16.55	5.06	8.46	19.21	6.26	2.26	0.00	1.31	0.04	4.88	85.88
1925	9.10	12.73	9.54	14.56	8.41	21.80	1.83	4.02	6.74	0.11	1.10	8.52	98.46
1926	11.06	10.34	13.82	8.61	8.91	26.89	0.52	1.90	0.04	1.64	4.10	4.16	91.99
1927	10.06	3.78	18.82	20.42	13.21	7.22	1.55	3.08	1.25	0.41	5.89	2.95	88.64
1928	8.18	9.12	7.72	9.71	6.08	16.87	2.79	3.72	14.23	5.46	2.83	13.03	99.74
1929	10.51	11.03	9.30	13.50	8.24	13.86	6.07	1.47	7.62	1.06	7.98	8.75	99.39
1930	6.59	8.21	15.87	21.18	13.82	20.75	3.14	0.42	0.20	28.15	1.68	2.00	122.01
1931	9.88	7.16	9.36	8.46	19.98	7.55	1.27	5.42	3.51	4.58	1.48	12.54	91.19
1932	9.48	23.57	19.68	3.92	6.60	11.88	4.25	2.08	0.80	1.57	1.20	2.12	87.15
1933	3.47	21.62	18.66	16.17	9.78	9.78	6.17	2.51	0.39	7.95	0.28	3.19	99.97
1934	5.81	12.35	18.50	9.10	9.17	10.04	14.77	13.43	12.16	0.58	8.11	1.91	115.93
1935	5.96	9.45	1.27	11.37	24.15	15.50	0.99	13.45	2.14	1.80	0.13	6.04	92.25
1936	12.02	32.98	8.29	14.72	21.86	10.67	2.97	0.68	1.22	1.73	1.83	3.01	111.98
1937	7.54	8.73	12.72	11.08	14.09	4.64	10.98	1.64	3.59	3.10	2.92	2.08	83.11
1938	7.15	11.30	15.34	10.96	17.97	7.30	4.52	5.91	1.00	5.04	3.69	16.76	106.94
1939	8.97	9.81	14.34	8.04	9.18	10.00	5.20	13.82	2.63	0.74	1.25	4.47	88.45
1940	6.05	15.35	14.46	7.33	5.41	10.14	4.43	0.58	1.63	1.60	2.99	4.70	74.67
1941	8.65	8.81	8.00	20.42	9.58	13.15	4.87	5.36	0.07	0.39	5.29	5.34	89.93
1942	10.62	22.37	20.34	11.22	8.11	18.09	13.59	3.68	4.64	2.92	11.80	4.41	131.79
1943	12.96	17.47	16.15	9.24	15.34	8.32	3.70	3.01	2.77	2.73	0.98	15.73	108.40
1944	7.90	5.11	4.23	15.49	11.71	13.92	1.72	4.11	0.65	1.41	0.55	5.42	72.22
1945	17.57	2.23	7.04	9.97	15.09	16.15	6.00	1.68	1.01	1.54	0.63	5.52	84.43
1946	7.45	14.00	10.59	11.96	14.52	15.07	10.53	3.21	13.32	2.16	1.23	5.49	109.53
1947	6.30	31.24	12.83	13.53	16.06	12.74	6.95	0.61	0.07	0.09	1.13	2.07	103.62
1948	16.35	7.73	12.20	12.34	16.92	10.26	8.39	0.72	0.05	1.76	2.13	4.29	93.14
1949	9.69	15.70	8.18	18.66	11.37	11.05	7.16	7.62	0.26	4.51	8.39	3.13	105.72
1950	7.91	5.83	23.16	11.06	8.74	13.93	2.46	2.50	1.58	1.08	5.69	6.69	90.63
1951	13.68	2.48	16.24	13.71	12.32	8.99	10.52	2.41	0.70	0.99	0.29	7.69	90.02
1952	3.88	8.28	8.79	10.09	11.70	7.77	6.18	1.05	0.84	0.30	4.30	8.80	71.98
1953	10.85	14.59	16.15	10.26	11.00	10.90	1.84	8.17	3.48	1.44	0.84	8.57	98.09
1954	23.41	7.72	8.51	20.69	20.74	11.52	5.77	2.14	2.32	0.13	0.53	8.92	112.40
1955	7.76	10.83	5.06	3.15	16.79	20.09	10.12	2.81	3.05	1.08	1.85	6.73	89.32
1956	12.30	18.77	26.72	13.43	12.46	17.14	11.70	1.76	3.01	1.22	4.56	11.76	134.83
1957	11.35	13.68	9.36	16.61	18.41	9.19	12.30	0.40	0.05	2.15	0.78	4.97	99.25
1958	6.24	15.70	12.16	9.38	11.93	9.51	7.73	25.14	0.00	4.90	5.91	4.24	112.84
1959	7.92	10.66	11.23	10.47	10.08	12.18	7.76	5.07	0.29	1.59	3.79	7.11	88.15
1960	6.01	14.35	16.76	14.87	8.37	14.30	20.53	3.49	0.99	3.09	1.17	4.78	108.71
1961	5.37	16.20	10.96	13.24	15.70	14.46	2.91	4.06	0.19	0.08	6.30	3.23	92.70
1962	12.60	16.49	11.54	21.27	8.93	30.86	5.02	2.28	1.44	14.36	1.24	2.27	128.30
1963	13.02	15.30	15.54	20.33	11.39	11.54	11.79	1.33	22.51	1.25	1.79	6.66	132.45
1964	18.41	3.78	10.45	12.40	9.37	3.42	4.03	5.53	17.61	5.57	7.54	6.51	104.62
1965	16.61	14.26	8.76	12.71	7.77	2.34	4.73	19.82	1.25	0.30	3.98	6.97	99.50
1966	5.73	9.28	12.22	14.58	12.04	24.91	10.85	1.49	4.29	7.35	1.32	1.23	105.29
1967	7.02	13.58	7.14	10.74	9.68	8.83	5.85	0.33	0.56	0.99	7.33	9.03	81.08
1968	8.82	10.98	11.08	5.64	18.00	17.39	3.69	11.12	0.70	1.77	3.63	4.61	97.43
1969	9.91	11.80	10.99	7.80	9.49	3.76	3.48	5.64	5.36	0.35	10.29	7.45	86.32
1970	17.78	10.60	13.42	12.81	10.92	9.29	6.60	12.95	0.61	6.98	10.93	5.20	118.09
1971	19.26	8.23	10.65	13.67	18.18	8.60	3.09	1.38	3.41	1.25	1.22	2.74	91.68
1972	5.37	16.91	9.69	10.51	11.11	10.39	6.16	0.12	0.00	1.04	6.16	8.48	85.94
1973	7.83	14.79	8.73	14.33	14.09	15.50	5.12	13.24	4.10	0.60	0.38	3.36	102.07
1974	6.73	13.90	14.43	11.95	13.51	10.47	4.06	0.66	0.59	0.68	2.21	15.59	94.78
1975	4.51	9.29	21.30	16.24	18.24	31.28	7.11	8.12	0.37	0.46	1.99	9.22	128.13
1976	19.89	6.67	12.65	11.72	11.84	9.08	2.89	1.25	2.49	1.12	3.57	7.16	90.33
1977	13.86	14.63	15.58	13.43	10.24	11.01	40.98	4.74	0.88	0.09	4.49	7.37	137.30
1978	13.21	13.10	11.74	9.39	10.77	12.26	4.05	0.33	0.66	7.91	3.17	4.78	91.37
1979	8.98	8.16	11.09	7.96	8.66	8.66	2.29	3.36	0.08	0.78	1.35	17.57	78.94
1980	5.94	18.07	13.16	14.17	12.45	7.23	2.21	7.26	0.51	0.31	7.80	3.64	92.75
1981	3.63	8.70	8.76	15.92	8.60	16.14	8.23	1.88	1.94	1.38	0.14	4.90	80.22
1982	12.13	4.51	7.28	9.75	7.62	5.64	5.20	2.25	0.25	4.68	2.21	4.99	66.51
1983	8.39	13.98	12.43	18.25	15.03	12.70	12.39	2.26	2.98	5.44	2.56	4.24	110.65
1984	7.04	13.46	13.82	13.84	26.78	6.27	2.75	0.29	2.28	0.50	0.05	2.47	89.55
1985	21.48	11.92	14.56	12.70	8.66	6.75	3.26	0.50	1.67	0.15	13.15	6.45	101.25
1986	13.71	14.55	9.10	14.20	7.65	13.01	4.00	2.02	1.30	0.00	9.17	29.32	118.03
1987	7.29	14.41	19.03	10.19	23.35	27.27	6.94	10.20	4.39	6.68	6.30	4.81	140.86
1988	8.00	15.98	18.28	8.90	26.92	7.12	11.29	1.97	3.51	1.62	0.04	4.38	108.01
1989	16.30	27.28	9.23	12.39	5.99	19.84	4.43	0.98	0.43	0.25	10.89	3.18	111.19
1990	12.80	6.53	10.66	16.69	12.08	6.77	0.19	2.80	0.51	0.00	2.75	7.75	79.53
1991	18.31	12.13	8.80	11.56	8.94	9.83	4.42	0.46	0.31	0.05	3.03	4.25	82.09
1992	8.01	13.82	13.51	10.63	12.57	4.38	5.46	0.00	0.24	0.00	3.09	12.75	84.46
1993	17.14	10.24	18.49	10.49	17.76	16.68	1.69	0.13	1.69	5.91	3.10	0.23	103.55
1994	5.03	5.72	9.98	13.43	5.26	20.31	9.86	3.63	6.42	0.00	0.00	5.66	85.30
1995	8.89	12.32	32.47	14.95	19.88	10.17	1.38	0.89	0.19	9.27	1.39	4.62	116.42
1996	9.42	20.95	11.84	16.87	13.78	12.02	15.44	3.04	22.04	4.05	3.44	5.69	138.58
month	779.33	976.88	991.33	983.20	990.19	962.16	482.54	323.77	227.35	218.81	269.49	487.77	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	3.47	2.23	1.27	3.15	5.26	2.34	0.19	0.00	0.00	0.00	0.00	0.23	66.51
max	23.41	32.98	32.47	26.32	26.92	31.28	40.98	25.14	22.51	28.15	13.15	29.32	140.86
median	8.98	12.32	12.16	12.39	11.71	11.05	5.02	2.41	1.25	1.31	2.75	5.20	98.09
mean	10.12	12.69	12.87	12.77	12.86	12.50	6.27	4.20	2.95	2.84	3.50	6.33	99.91
Sum of the monthly means = 99.91													
s.d.	4.50	5.88	5.03	4.22	5.10	6.16	5.65	4.91	4.65	4.61	3.19	4.48	17.09
c.v.	0.45	0.46	0.39	0.33	0.40	0.49	0.90	1.17	1.58	1.62	0.91	0.71	0.17

The Wilcox (first order stationarity) factor is : 0.34

APPENDIX 1.2
ZONE T6B CATCHMENT RAINFALL

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	5.25	12.92	14.73	10.57	11.65	13.57	7.04	0.92	0.00	0.33	0.12	7.82	84.92
1921	8.69	18.39	16.31	10.03	6.56	2.89	2.90	18.15	7.45	0.00	8.40	5.22	104.99
1922	15.29	20.74	7.04	26.78	22.77	14.66	1.68	2.28	0.90	20.73	0.22	2.13	135.22
1923	4.58	8.35	11.88	20.86	14.60	2.60	2.05	2.73	1.45	0.43	4.41	7.86	81.80
1924	8.02	11.32	14.62	9.97	12.05	18.57	7.16	2.19	0.65	2.28	0.72	10.07	97.62
1925	6.64	10.60	10.39	13.51	11.49	20.51	3.25	3.73	7.32	0.21	1.54	8.23	97.42
1926	10.69	13.43	13.16	9.01	8.45	27.31	0.42	1.52	0.04	0.73	2.70	6.16	93.62
1927	10.21	2.87	14.69	13.56	13.82	8.28	1.74	4.24	1.45	0.43	7.86	2.35	81.50
1928	8.39	11.02	10.07	11.55	7.52	14.76	1.75	4.73	16.39	6.91	4.83	13.24	111.16
1929	14.59	13.96	8.41	10.08	6.04	11.15	6.06	2.26	7.90	2.58	7.54	11.68	102.25
1930	5.50	7.66	10.28	21.73	15.74	19.23	4.66	0.58	0.33	40.43	1.91	3.15	131.20
1931	10.64	7.47	10.34	6.69	21.32	9.14	1.51	6.77	3.50	4.39	1.89	16.32	99.98
1932	9.57	24.97	18.93	3.05	11.99	9.79	3.11	2.63	0.80	1.32	1.13	3.91	91.20
1933	3.98	19.09	17.09	18.96	8.67	11.99	4.53	2.94	0.67	10.74	0.48	1.72	100.86
1934	5.54	13.60	17.03	9.49	5.71	13.25	14.19	12.82	14.81	1.46	8.86	2.49	119.25
1935	6.41	9.76	1.89	10.94	26.39	17.32	2.27	13.62	3.23	2.08	0.24	6.40	100.55
1936	13.51	30.61	6.02	9.93	17.84	13.60	3.36	0.99	1.01	3.61	2.89	4.13	107.50
1937	7.07	7.44	15.61	11.99	9.49	4.25	13.13	2.00	4.50	3.71	2.19	1.64	83.02
1938	6.61	12.48	12.65	13.28	16.34	9.46	4.76	6.99	1.31	6.41	5.30	17.59	113.18
1939	9.61	6.92	13.52	6.54	8.25	10.00	3.80	11.44	1.62	1.08	2.29	4.33	79.40
1940	5.02	15.79	9.71	8.19	4.08	7.88	4.49	0.99	2.72	1.62	2.86	4.24	67.59
1941	9.16	10.67	6.37	24.65	6.11	11.62	2.94	7.29	0.00	0.34	5.96	5.88	90.99
1942	9.32	26.16	17.33	9.84	7.32	15.33	13.26	3.02	4.27	1.62	12.13	4.83	124.43
1943	10.63	15.30	13.88	9.38	14.74	6.90	4.40	1.59	3.28	2.91	1.09	18.72	102.82
1944	8.34	5.63	4.68	15.25	12.35	11.53	2.56	3.81	0.96	1.86	0.77	7.48	75.22
1945	20.77	1.78	7.72	9.31	14.80	15.17	7.05	1.24	1.43	1.75	0.47	5.43	86.92
1946	7.11	15.11	10.06	10.85	11.23	15.61	12.90	4.16	11.08	2.20	0.80	6.13	107.24
1947	5.50	32.85	12.32	10.04	16.55	11.87	6.49	0.53	0.19	0.08	1.08	2.43	99.93
1948	16.92	7.82	11.09	9.62	24.17	12.06	7.95	0.68	0.06	1.49	2.57	5.71	100.14
1949	8.98	17.66	8.99	15.75	11.27	9.48	8.24	7.82	0.28	4.12	7.52	3.22	103.33
1950	9.54	4.64	21.38	12.75	7.75	12.63	2.77	2.33	1.89	1.14	5.40	6.50	88.72
1951	14.87	1.94	18.29	13.98	9.27	10.90	8.59	2.45	0.70	0.88	0.10	9.09	91.06
1952	4.45	8.16	8.43	10.03	10.94	7.92	6.25	1.21	0.94	0.29	4.55	10.44	73.61
1953	10.33	17.01	14.52	9.16	8.24	12.18	1.88	7.39	4.06	1.81	0.93	9.34	96.85
1954	24.40	7.40	8.29	19.88	17.26	11.61	4.53	2.01	2.37	0.05	0.50	10.13	108.43
1955	7.48	10.41	4.05	3.68	16.46	20.52	8.31	2.61	3.48	1.06	1.61	8.31	87.98
1956	12.19	21.92	28.13	13.17	11.64	16.08	13.32	1.67	3.56	0.99	4.39	9.81	136.87
1957	10.48	11.11	12.88	16.00	18.07	9.81	13.36	0.30	0.00	2.85	1.30	4.97	101.13
1958	6.18	15.26	11.04	6.28	11.98	8.80	7.05	24.29	0.13	5.99	7.17	5.03	109.20
1959	7.69	9.07	10.61	10.47	7.92	12.95	8.16	6.56	0.18	2.22	4.28	7.78	87.89
1960	5.35	14.14	15.75	13.65	8.47	12.03	21.58	4.95	1.21	5.64	1.97	4.69	109.43
1961	5.91	16.53	11.28	10.73	11.72	15.51	3.40	3.82	0.05	0.13	7.38	3.96	90.42
1962	12.53	15.64	9.30	20.73	7.97	30.70	4.50	4.17	1.54	15.86	1.03	2.12	126.09
1963	12.28	12.49	11.36	20.77	13.36	11.91	11.87	1.68	22.76	1.22	1.79	6.60	128.09
1964	14.91	4.34	8.00	11.53	7.23	2.71	3.43	6.48	19.26	4.46	7.49	6.50	96.34
1965	19.63	13.54	8.73	11.10	7.86	1.76	4.55	18.82	1.42	0.41	3.79	7.46	99.07
1966	4.66	7.97	11.25	15.42	10.34	22.85	13.32	1.16	4.03	9.06	1.83	1.58	103.47
1967	6.04	12.89	7.16	9.68	10.03	7.20	5.29	0.27	1.18	1.12	7.09	10.21	78.16
1968	8.32	12.06	10.78	5.51	17.99	17.25	4.18	15.19	1.43	1.84	3.26	4.41	102.22
1969	9.42	12.51	9.70	6.14	10.16	3.42	4.45	4.29	6.66	0.46	16.32	7.04	90.57
1970	19.84	11.93	9.76	11.49	10.61	8.38	7.73	16.16	0.58	8.87	10.70	5.21	121.26
1971	19.51	8.89	11.19	10.29	21.94	6.84	4.37	1.46	3.40	1.65	2.86	2.30	94.70
1972	4.76	16.59	10.93	10.07	8.60	9.76	11.00	0.01	0.06	1.18	7.16	9.48	89.60
1973	8.20	16.30	8.64	10.36	13.35	11.65	5.06	16.53	4.70	1.28	0.77	4.15	100.99
1974	5.70	12.36	13.40	9.47	9.88	8.87	5.24	1.99	0.68	1.78	2.93	20.11	92.41
1975	3.79	8.92	17.87	10.54	20.06	35.31	8.27	10.19	0.62	0.90	2.87	9.74	129.08
1976	28.27	4.67	8.33	12.56	16.53	8.56	2.55	0.94	3.55	1.70	6.79	7.68	102.13
1977	10.29	16.84	17.43	10.48	8.35	9.68	49.75	5.93	2.17	0.55	4.42	6.61	142.50
1978	15.39	10.66	8.47	8.83	8.95	13.65	3.50	2.46	0.70	10.18	5.06	6.82	94.67
1979	9.65	6.94	9.86	7.56	10.52	7.18	2.93	4.09	0.62	1.78	1.70	17.37	80.20
1980	5.39	15.94	11.44	13.93	9.24	5.56	2.05	11.39	1.06	0.98	8.96	2.93	88.87
1981	4.14	9.03	7.74	13.08	6.77	23.90	8.44	2.08	1.79	1.95	0.59	4.88	84.39
1982	10.41	6.21	4.81	9.14	6.93	4.76	3.99	1.61	0.78	20.09	2.06	5.73	76.52
1983	8.19	13.46	11.00	15.15	10.82	8.37	9.72	3.23	5.26	9.41	2.35	5.19	102.15
1984	6.96	16.55	10.49	11.15	30.96	6.11	2.96	0.68	2.00	1.27	0.19	2.96	92.28
1985	15.61	14.66	9.48	16.69	6.03	8.82	5.24	1.08	1.15	0.15	11.26	9.86	100.03
1986	12.71	10.15	7.00	13.10	3.30	14.09	3.60	2.51	2.43	0.36	7.18	38.46	114.89
1987	6.23	14.99	9.83	8.74	20.60	28.92	6.30	11.30	3.25	7.50	6.76	3.64	128.06
1988	9.07	16.50	22.05	5.23	24.65	9.43	13.42	2.23	3.52	2.01	0.31	5.78	114.20
1989	16.73	19.37	5.24	13.11	4.83	19.04	2.36	1.17	0.81	0.34	10.61	4.06	97.67
1990	10.57	5.69	8.48	14.25	13.98	6.64	1.34	3.72	0.99	0.79	4.20	7.75	78.40
1991	14.40	14.53	7.26	11.39	6.14	6.67	6.95	0.52	1.31	0.08	4.15	6.75	80.15
1992	8.23	7.91	11.53	8.86	7.35	3.17	5.09	1.41	0.83	0.30	3.81	10.69	69.18
1993	10.60	9.96	16.84	7.17	26.23	9.46	0.64	0.62	1.16	4.77	8.14	0.52	96.11
1994	6.08	4.49	18.80	9.29	5.31	19.92	16.43	3.38	9.42	1.08	0.59	6.02	100.81
1995	8.93	8.20	27.85	12.48	14.74	5.08	5.53	1.99	0.98	13.03	1.81	4.12	104.74
1996	11.50	24.79	9.40	14.32	16.01	9.46	16.86	2.98	27.76	4.80	2.34	7.44	147.66
month	770.35	967.93	902.86	910.79	946.65	927.80	521.76	357.97	258.03	284.11	303.52	552.73	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	3.79	1.78	1.89	3.05	3.30	1.76	0.42	0.01	0.00	0.00	0.10	0.52	67.59
max	28.27	32.85	28.13	26.78	30.96	35.31	49.75	24.29	27.76	40.43	16.32	38.46	147.66
median	9.07	12.36	10.78	10.73	10.94	11.15	4.76	2.61	1.43	1.65	2.86	6.13	99.93
mean	10.00	12.57	11.73	11.83	12.29	12.05	6.78	4.65	3.35	3.69	3.94	7.18	100.06
Sum of the monthly means = 100.06													
s.d.	4.90	6.09	4.86	4.45	5.84	6.55	6.57	5.07	5.14	6.02	3.41	5.40	17.13
c.v.	0.49	0.48	0.41	0.38	0.47	0.54	0.97	1.09	1.53	1.63	0.86	0.75	0.17

The Wilcox (first order stationarity) factor is : 0.96

APPENDIX 2

NATURAL FLOW RECORDS FOR QUATERNARY CATCHMENTS

APPENDIX 2.1
T60A

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.35	2.33	3.78	3.78	3.12	3.92	4.24	2.85	1.50	0.89	0.62	0.77	29.15
1921	1.75	18.03	26.79	10.25	3.30	1.85	0.86	2.86	9.71	6.27	3.72	2.96	88.35
1922	3.28	22.88	10.44	5.80	42.55	28.95	7.43	1.78	1.03	25.39	11.77	2.66	163.96
1923	1.57	1.36	1.80	26.54	21.36	6.55	1.68	0.93	0.79	0.68	0.70	1.07	65.03
1924	2.06	3.65	9.63	4.99	1.88	5.83	5.13	3.05	1.70	1.09	0.77	0.76	40.54
1925	1.52	3.17	3.55	3.59	3.22	20.41	9.09	2.23	2.26	2.23	1.48	1.65	54.40
1926	3.24	4.44	4.86	3.73	2.53	33.95	13.57	1.80	0.96	0.74	0.88	1.11	71.81
1927	1.99	2.12	3.42	21.32	10.85	4.23	2.31	1.26	0.96	0.79	0.99	1.22	51.46
1928	1.67	2.39	2.25	1.79	1.37	2.67	2.98	2.04	3.86	5.87	4.86	7.25	39.00
1929	9.53	6.94	4.65	3.73	3.05	3.46	3.57	2.45	2.29	2.41	2.67	3.71	48.46
1930	4.06	3.59	4.25	23.38	11.58	29.24	12.02	2.10	1.02	40.36	17.09	3.02	151.71
1931	2.67	2.94	2.54	1.90	5.98	4.89	2.42	1.51	1.58	1.93	1.81	2.85	33.02
1932	4.66	42.16	36.40	9.61	1.53	1.69	1.90	1.44	0.99	0.83	0.73	0.63	102.57
1933	0.64	7.86	22.08	13.63	5.54	3.61	2.96	2.17	1.40	1.76	1.91	1.38	64.94
1934	1.34	2.40	10.79	6.16	2.82	2.57	4.88	19.16	25.29	9.93	4.11	3.26	92.71
1935	2.41	2.53	1.66	1.09	16.87	17.92	6.46	3.71	4.14	3.08	1.84	1.46	63.17
1936	2.82	69.14	26.10	3.98	26.08	12.15	3.47	1.76	0.99	0.84	0.80	0.77	148.90
1937	1.18	1.88	2.66	2.86	3.49	2.94	2.78	2.53	1.94	1.83	1.72	1.35	27.16
1938	1.44	2.44	4.04	4.10	10.40	6.10	2.73	2.16	1.84	1.82	1.99	10.55	49.61
1939	8.01	5.63	5.37	3.93	2.57	2.41	2.25	3.78	4.59	3.26	1.90	1.41	45.11
1940	1.57	3.33	5.09	3.81	1.93	1.60	1.63	1.17	0.80	0.75	0.82	1.02	23.52
1941	1.73	2.50	2.32	5.69	4.90	4.34	3.72	2.83	2.00	1.26	1.20	1.57	34.06
1942	2.68	31.70	35.07	11.50	3.20	7.59	14.78	7.43	3.52	2.99	4.21	4.71	129.38
1943	7.38	25.58	18.82	6.44	4.08	4.00	2.73	1.72	1.38	1.39	1.20	2.96	77.68
1944	4.95	3.98	1.99	1.94	2.89	4.11	3.34	2.01	1.38	1.06	0.81	0.87	29.33
1945	4.88	4.20	2.04	1.43	2.50	8.23	5.72	2.87	1.63	1.16	0.89	0.93	36.48
1946	1.53	3.23	3.97	3.49	3.99	9.06	6.99	4.55	10.90	7.12	3.37	2.27	60.47
1947	2.25	52.62	21.72	5.12	9.55	6.99	4.82	2.98	1.49	0.86	0.62	0.54	109.56
1948	2.30	3.80	3.75	3.52	7.06	5.65	4.28	2.92	1.54	1.00	0.89	0.96	37.67
1949	1.77	5.30	4.58	6.41	5.37	4.40	3.83	3.68	2.92	2.29	2.99	3.05	46.59
1950	2.85	2.55	17.92	9.03	3.30	3.58	3.07	1.83	1.22	1.00	1.19	1.82	49.36
1951	3.88	3.73	3.55	4.25	4.44	3.90	3.92	3.35	2.08	1.32	0.89	1.12	36.43
1952	1.46	1.68	1.78	1.72	2.13	2.29	2.09	1.55	1.00	0.73	0.79	1.60	18.82
1953	3.28	10.17	13.77	6.55	3.41	3.38	2.49	2.12	2.38	2.10	1.45	1.66	52.76
1954	32.90	14.63	3.60	10.25	28.85	12.53	4.20	2.66	1.74	1.26	0.85	1.24	114.71
1955	2.24	3.23	2.57	1.12	1.67	17.46	9.95	4.40	2.89	2.06	1.46	1.53	50.58
1956	3.13	24.25	52.95	18.94	4.85	15.08	11.02	5.00	2.68	1.91	1.69	3.01	144.51
1957	5.91	12.98	6.96	4.49	19.01	9.32	4.90	3.88	2.00	1.22	0.96	0.95	72.58
1958	1.33	3.25	4.61	3.64	3.07	3.08	3.02	43.93	17.65	3.36	3.24	2.96	93.14
1959	2.90	3.51	3.69	3.09	2.65	3.11	3.46	3.15	2.25	1.50	1.32	1.75	32.38
1960	2.22	3.66	12.00	7.74	4.29	4.23	33.88	14.27	2.96	2.04	1.57	1.34	90.20
1961	1.48	3.35	4.46	4.12	5.67	9.68	5.32	2.40	1.55	1.00	1.12	1.37	41.52
1962	2.62	14.86	8.43	20.58	9.51	53.29	20.72	2.88	1.72	3.64	4.56	2.84	145.65
1963	3.28	13.89	13.19	22.83	10.22	4.55	5.14	4.15	36.52	15.66	3.30	2.46	135.19
1964	18.46	8.87	2.82	2.62	2.60	1.77	1.06	1.11	12.53	8.91	6.13	5.43	72.31
1965	22.91	20.88	7.64	3.44	2.70	1.54	0.90	10.13	6.71	2.92	1.92	2.11	83.80
1966	2.40	2.65	3.08	3.72	4.13	37.82	16.98	4.39	2.80	3.23	3.07	1.85	86.12
1967	1.53	2.92	3.07	2.32	2.14	2.20	2.08	1.48	0.88	0.66	1.09	2.33	22.70
1968	3.59	4.40	4.23	2.61	3.21	17.11	8.19	3.97	3.67	2.49	1.87	1.75	57.09
1969	2.50	3.90	4.14	2.87	2.06	1.46	0.94	1.00	1.56	1.64	2.36	3.61	28.04
1970	23.94	12.10	5.55	4.81	4.08	3.47	2.93	4.27	4.38	3.85	6.55	5.73	81.66
1971	29.63	13.30	4.09	3.66	12.70	7.16	2.87	1.55	1.16	1.13	0.94	0.78	78.97
1972	0.93	2.94	4.00	3.17	2.81	3.02	2.84	1.88	1.00	0.68	0.97	1.96	26.20
1973	2.95	5.81	4.75	3.77	4.44	11.38	6.43	6.45	5.74	3.78	2.08	1.28	58.86
1974	1.41	2.93	4.63	4.54	4.42	4.37	3.25	1.82	1.00	0.72	0.66	2.49	32.24
1975	3.76	3.46	18.81	13.62	19.94	68.77	24.76	4.64	3.52	2.09	1.32	1.79	166.48
1976	23.77	11.27	4.03	3.55	3.46	3.28	2.32	1.32	0.95	0.90	0.94	1.44	57.23
1977	3.58	14.72	13.47	6.66	4.19	3.76	95.34	35.60	3.69	2.04	1.52	1.98	186.55
1978	3.98	10.44	6.82	3.65	2.84	3.30	2.95	1.73	0.94	1.39	1.96	1.93	41.93
1979	2.46	2.95	2.96	2.28	1.75	1.76	1.42	1.05	0.82	0.65	0.57	2.73	21.40
1980	4.56	19.69	10.32	5.19	4.89	3.81	2.20	1.77	1.66	1.19	1.46	1.85	58.59
1981	1.62	1.71	1.84	2.70	3.00	4.15	4.93	3.59	2.15	1.52	1.06	0.93	29.20
1982	2.20	2.64	1.83	1.43	1.36	1.17	1.07	0.98	0.77	0.90	1.10	1.23	16.68
1983	1.87	3.67	4.71	11.75	11.00	6.68	9.66	5.73	2.81	2.62	2.49	2.02	65.01
1984	2.08	3.44	4.76	4.91	43.95	17.16	2.37	1.17	0.78	0.71	0.55	0.47	82.35
1985	8.96	9.77	7.86	5.36	3.65	2.48	1.60	0.96	0.67	0.59	1.83	3.36	47.09
1986	8.91	16.98	7.92	3.84	3.12	3.22	2.91	1.89	1.22	0.88	1.42	54.35	106.66
1987	22.47	12.36	23.51	9.64	26.71	59.02	20.45	5.04	5.02	4.98	5.01	4.20	198.41
1988	3.71	11.24	21.06	8.62	35.23	14.52	4.07	3.41	2.41	1.92	1.32	1.01	108.52
1989	3.15	56.88	22.03	3.66	2.51	8.33	5.55	2.43	1.27	0.81	1.63	2.30	110.55
1990	3.51	3.93	3.22	3.87	4.59	3.62	1.87	0.94	0.70	0.56	0.55	1.07	28.43
1991	12.17	11.04	5.43	3.22	2.60	2.50	2.16	1.39	0.80	0.56	0.56	0.77	43.20
1992	1.38	3.11	4.55	4.04	3.66	2.72	1.75	1.14	0.68	0.48	0.51	1.82	25.84
1993	19.44	10.63	18.17	8.64	9.57	18.21	7.57	1.76	0.92	1.23	1.61	1.22	98.97
1994	0.97	1.05	1.31	2.01	1.85	6.79	6.35	4.46	3.70	2.98	1.72	1.28	34.47
1995	2.00	3.48	59.94	24.86	24.32	11.14	3.08	1.43	0.76	1.42	1.91	1.68	136.02
1996	2.28	24.00	11.67	7.69	6.30	5.49	18.45	8.85	39.15	17.20	4.55	3.36	148.99
month	406.79	779.02	740.11	502.58	594.41	739.97	529.05	318.63	291.86	248.31	166.98	216.48	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.64	1.05	1.31	1.09	1.36	1.17	0.86	0.93	0.67	0.48	0.51	0.47	16.68
max	32.90	69.14	59.94	26.54	43.95	68.77	95.34	43.93	39.15	40.36	17.09	54.35	198.41
median	2.67	3.93	4.65	4.04	3.99	4.34	3.47	2.43	1.70	1.50	1.46	1.75	58.59
mean	5.28	10.12	9.61	6.53	7.72	9.61	6.87	4.14	3.79	3.22	2.17	2.81	71.87
Sum of the monthly means = 71.87													
s.d.	6.97	12.80	11.06	5.89	9.24	12.80	11.80	6.55	6.77	5.81	2.45	6.16	44.24
c.v.	1.32	1.27	1.15	0.90	1.20	1.33	1.72	1.58	1.79	1.80	1.13	2.19	0.62

APPENDIX 2.2
T60B

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.33	2.35	3.86	3.89	3.23	4.06	4.38	2.92	1.52	0.90	0.61	0.77	29.82
1921	1.78	19.79	28.30	10.52	3.31	1.88	0.88	2.94	11.45	6.73	3.63	2.92	94.13
1922	3.29	24.15	10.80	7.37	43.84	30.11	7.66	1.73	1.01	26.59	12.07	2.58	171.20
1923	1.54	1.36	1.83	28.58	23.02	6.81	1.64	0.92	0.79	0.67	0.69	1.08	68.93
1924	2.09	3.73	11.60	5.59	1.87	7.61	5.65	3.01	1.68	1.07	0.76	0.75	45.41
1925	1.53	3.23	3.65	3.71	3.34	22.50	9.70	2.18	2.25	2.22	1.47	1.66	57.44
1926	3.29	4.53	4.99	3.85	2.62	35.47	13.99	1.75	0.93	0.73	0.86	1.11	74.12
1927	2.01	2.15	3.52	23.19	11.43	4.24	2.33	1.27	0.97	0.79	0.99	1.23	54.12
1928	1.69	2.44	2.31	1.85	1.42	2.77	3.08	2.10	5.57	6.32	4.77	8.39	42.71
1929	10.53	7.08	4.64	3.79	3.14	3.57	3.68	2.51	2.34	2.45	2.70	3.78	50.21
1930	4.13	3.66	4.37	25.20	13.14	30.35	12.21	2.05	1.00	41.46	17.36	2.95	157.88
1931	2.65	2.96	2.59	1.96	8.03	5.51	2.39	1.51	1.58	1.94	1.82	2.89	35.83
1932	4.75	43.81	37.86	9.86	1.51	1.72	1.95	1.46	1.00	0.83	0.73	0.63	106.11
1933	0.64	9.58	23.30	14.90	5.84	3.61	3.00	2.20	1.41	1.78	1.92	1.39	69.57
1934	1.35	2.45	12.75	6.76	2.82	2.62	6.70	20.06	25.79	9.94	4.02	3.23	98.49
1935	2.41	2.55	1.69	1.12	18.94	19.52	6.69	3.68	4.15	3.08	1.84	1.46	67.13
1936	2.86	70.54	26.51	4.00	27.58	12.59	3.45	1.76	0.98	0.83	0.79	0.77	152.66
1937	1.19	1.91	2.74	2.96	3.62	3.04	2.87	2.59	1.97	1.86	1.74	1.36	27.85
1938	1.45	2.48	4.15	4.24	12.52	6.73	2.71	2.17	1.84	1.83	2.00	12.09	54.21
1939	8.44	5.60	5.71	3.95	2.54	2.44	2.30	3.87	4.69	3.31	1.91	1.42	46.18
1940	1.58	3.40	7.02	4.39	1.92	1.62	1.67	1.19	0.81	0.75	0.82	1.02	26.19
1941	1.75	2.55	2.37	7.76	5.54	4.36	3.77	2.87	2.03	1.27	1.20	1.58	37.05
1942	2.72	33.40	36.54	11.76	3.21	9.38	16.11	7.58	3.46	2.96	4.23	4.75	136.10
1943	8.90	26.76	20.00	6.72	4.12	4.09	2.79	1.75	1.40	1.40	1.20	3.01	82.14
1944	5.05	4.05	2.03	2.00	2.99	4.26	3.45	2.06	1.40	1.07	0.81	0.87	30.04
1945	6.51	4.67	2.00	1.44	2.58	10.27	6.32	2.82	1.61	1.15	0.88	0.93	41.18
1946	1.54	3.29	4.08	3.60	4.14	11.17	7.61	4.52	12.15	7.43	3.28	2.23	65.04
1947	2.24	53.97	22.13	5.17	11.44	7.56	4.82	3.00	1.49	0.85	0.62	0.53	113.82
1948	2.34	3.88	3.85	3.63	9.16	6.29	4.27	2.94	1.54	0.99	0.89	0.96	40.74
1949	1.79	7.03	5.10	7.97	5.85	4.42	3.89	3.74	2.97	2.32	3.03	3.09	51.20
1950	2.89	2.60	19.83	9.62	3.31	3.66	3.14	1.86	1.23	1.00	1.20	1.84	52.18
1951	3.95	3.81	3.65	4.39	4.60	4.03	4.05	3.44	2.12	1.33	0.89	1.12	37.38
1952	1.47	1.71	1.82	1.78	2.21	2.38	2.15	1.59	1.02	0.73	0.79	1.61	19.26
1953	3.35	11.97	15.32	6.82	3.43	3.45	2.54	2.16	2.42	2.13	1.46	1.67	56.72
1954	34.43	15.07	3.58	12.08	30.35	12.78	4.20	2.67	1.74	1.26	0.84	1.24	120.24
1955	2.27	3.29	2.63	1.15	1.73	19.59	10.59	4.36	2.88	2.05	1.46	1.53	53.53
1956	3.18	25.99	54.25	19.15	4.90	16.93	12.38	5.16	2.61	1.88	1.67	3.03	151.13
1957	7.46	14.25	7.16	4.52	20.93	9.90	4.91	3.91	2.00	1.22	0.95	0.95	78.16
1958	1.34	3.32	4.74	3.76	3.18	3.19	3.12	45.60	18.10	3.28	3.20	2.95	95.78
1959	2.92	3.56	3.78	3.18	2.75	3.22	3.57	3.24	2.30	1.52	1.33	1.77	33.14
1960	2.25	3.75	14.00	8.44	4.18	4.19	35.32	14.66	2.89	2.00	1.55	1.33	94.56
1961	1.48	3.42	4.58	4.26	7.75	11.27	5.55	2.35	1.53	0.99	1.11	1.37	45.66
1962	2.66	16.63	8.96	22.18	10.00	54.52	21.06	2.84	1.70	4.29	4.54	2.67	152.05
1963	3.22	15.30	14.62	24.17	10.52	4.57	5.30	4.10	37.16	15.78	3.21	2.43	140.38
1964	19.81	9.24	2.80	2.66	2.67	1.82	1.09	1.13	14.23	9.36	6.05	5.41	76.27
1965	24.25	22.08	7.83	3.45	2.75	1.58	0.92	11.92	7.20	2.83	1.88	2.09	88.78
1966	2.41	2.69	3.15	3.84	4.28	39.85	18.41	4.56	2.73	3.20	3.06	1.85	90.03
1967	1.53	2.97	3.14	2.39	2.22	2.27	2.15	1.52	0.89	0.67	1.10	2.36	23.21
1968	3.66	4.50	4.34	2.69	3.33	19.27	8.83	3.94	3.68	2.49	1.87	1.75	60.35
1969	2.53	3.98	4.25	2.96	2.14	1.51	0.96	1.03	1.59	1.66	2.40	3.67	28.68
1970	25.23	12.46	5.56	4.91	4.20	3.58	3.02	4.68	4.37	3.73	7.54	5.97	85.25
1971	30.52	13.54	4.08	3.73	14.71	7.76	2.84	1.54	1.15	1.12	0.93	0.78	82.70
1972	0.93	3.01	4.11	3.27	2.91	3.13	2.93	1.93	1.01	0.68	0.97	1.98	26.86
1973	3.01	7.56	5.27	3.79	4.55	13.38	7.01	7.57	6.01	3.69	2.03	1.25	65.12
1974	1.41	2.97	4.75	4.68	4.57	4.53	3.35	1.86	1.01	0.72	0.66	2.53	33.04
1975	3.83	3.53	20.76	15.33	21.24	69.58	24.86	4.62	3.52	2.08	1.31	1.80	172.46
1976	25.32	11.71	4.02	3.62	3.56	3.38	2.39	1.35	0.96	0.90	0.95	1.45	59.61
1977	3.65	16.56	15.03	6.94	4.21	3.84	96.59	35.93	3.63	2.01	1.50	1.98	191.87
1978	4.04	12.19	7.35	3.65	2.90	3.40	3.04	1.77	0.95	1.41	1.99	1.95	44.64
1979	2.50	3.01	3.03	2.36	1.81	1.82	1.46	1.07	0.83	0.65	0.56	2.78	21.88
1980	4.66	21.46	10.86	5.23	5.00	3.92	2.26	1.81	1.69	1.20	1.47	1.87	61.43
1981	1.64	1.74	1.88	2.80	3.11	4.92	5.04	3.50	2.11	1.50	1.04	0.92	30.20
1982	2.22	2.68	1.87	1.48	1.41	1.21	1.10	1.01	0.78	0.91	1.11	1.24	17.02
1983	1.90	3.75	4.84	13.88	12.67	6.96	10.99	6.08	2.74	2.59	2.48	2.02	70.90
1984	2.10	3.50	4.89	5.07	45.98	17.76	2.34	1.16	0.77	0.70	0.55	0.46	85.28
1985	10.54	11.07	9.06	5.63	3.66	2.52	1.63	0.98	0.68	0.59	1.85	3.42	51.63
1986	10.57	18.27	8.11	3.86	3.19	3.31	3.00	1.93	1.24	0.89	1.43	55.68	111.48
1987	22.83	13.55	24.53	9.80	28.24	60.16	20.59	5.02	5.04	5.02	5.05	4.24	204.07
1988	3.75	12.95	22.56	8.89	36.68	14.95	4.07	3.43	2.43	1.92	1.32	1.01	113.96
1989	3.21	58.45	22.50	3.68	2.56	10.26	6.12	2.38	1.24	0.80	1.63	2.32	115.15
1990	3.56	4.00	3.29	4.00	4.75	3.75	1.93	0.96	0.70	0.56	0.54	1.08	29.12
1991	13.81	12.36	5.62	3.22	2.66	2.57	2.22	1.42	0.81	0.56	0.56	0.77	46.58
1992	1.40	3.18	4.68	4.17	3.79	2.81	1.81	1.16	0.69	0.48	0.51	1.85	26.53
1993	21.11	11.11	19.60	9.08	11.13	19.62	7.79	1.71	0.90	1.22	1.61	1.22	106.10
1994	0.96	1.06	1.34	2.08	1.92	8.84	6.96	4.43	3.70	2.99	1.71	1.27	37.26
1995	2.02	3.55	61.67	26.50	25.24	11.28	3.06	1.43	0.76	1.42	1.92	1.69	140.54
1996	2.31	25.74	12.20	9.28	7.22	5.45	19.33	9.08	39.86	17.33	4.46	3.33	155.59
month	429.46	824.44	780.18	536.15	635.81	785.24	549.93	327.00	301.38	252.86	167.88	220.93	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.64	1.06	1.34	1.12	1.41	1.21	0.88	0.92	0.68	0.48	0.51	0.46	17.02
max	34.43	70.54	61.67	28.58	45.98	69.58	96.59	45.60	39.86	41.46	17.36	55.68	204.07
median	2.66	4.00	4.84	4.24	4.12	4.42	3.57	2.38	1.69	1.50	1.47	1.75	61.43
mean	5.58	10.71	10.13	6.96	8.26	10.20	7.14	4.25	3.91	3.28	2.18	2.87	75.47
Sum of the monthly means = 75.47													
s.d.	7.39	13.26	11.49	6.37	9.75	13.17	12.02	6.77	6.97	5.99	2.51	6.34	45.69
c.v.	1.32	1.24	1.13	0.91	1.18	1.29	1.68	1.59	1.78	1.82	1.15	2.21	0.61

APPENDIX 2.3
T60C

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.95	1.78	3.04	3.11	2.61	4.63	3.70	2.13	1.11	0.65	0.44	0.57	24.72
1921	1.36	17.62	23.55	8.28	2.49	1.45	0.68	4.53	9.30	4.83	2.57	2.12	78.78
1922	2.48	20.64	8.84	8.10	34.80	24.36	6.09	1.21	0.72	21.78	9.49	1.81	140.32
1923	1.10	1.01	1.42	24.33	19.78	5.52	1.17	0.67	0.58	0.49	0.50	0.81	57.38
1924	1.61	2.94	11.94	5.17	1.37	8.61	5.08	2.17	1.22	0.77	0.54	0.55	41.97
1925	1.17	2.53	2.89	2.99	2.70	19.92	8.15	1.55	1.66	1.66	1.09	1.25	47.56
1926	2.55	3.55	5.46	3.36	1.96	29.25	11.25	1.23	0.66	0.52	0.63	0.82	61.24
1927	1.54	1.67	5.27	19.11	9.84	3.34	1.65	0.92	0.71	0.58	0.74	0.92	46.29
1928	1.29	1.90	1.82	1.48	1.15	2.26	2.48	1.66	6.94	5.45	3.41	8.13	37.97
1929	9.51	6.41	3.57	2.82	2.44	2.84	2.93	1.98	1.82	1.89	2.08	2.93	41.22
1930	3.22	2.86	5.79	20.72	11.77	24.45	9.42	1.45	0.71	32.26	13.23	2.08	127.96
1931	1.95	2.25	2.01	1.56	9.39	5.14	1.73	1.12	1.19	1.47	1.37	2.23	31.41
1932	3.83	34.56	30.33	7.77	1.10	1.34	1.53	1.14	0.77	0.62	0.54	0.47	84.00
1933	0.48	9.97	19.84	13.36	4.86	2.70	2.31	1.70	1.08	1.36	1.47	1.05	60.18
1934	1.03	1.91	12.78	6.05	2.11	2.05	8.01	16.86	20.17	7.45	2.86	2.36	83.64
1935	1.79	1.95	1.31	0.89	17.55	17.20	5.37	2.71	3.12	2.31	1.36	1.09	56.65
1936	2.21	54.88	20.44	3.04	23.65	10.33	2.55	1.31	0.72	0.61	0.58	0.57	120.89
1937	0.90	1.48	2.17	2.39	2.94	2.46	2.31	2.06	1.54	1.43	1.33	1.03	22.04
1938	1.11	1.94	5.01	3.71	11.88	5.78	1.98	1.63	1.39	1.38	1.51	11.54	48.86
1939	7.52	4.16	6.44	3.61	1.89	1.90	1.81	5.14	3.99	2.27	1.33	1.01	41.07
1940	1.17	3.16	7.39	3.84	1.41	1.26	1.31	0.92	0.61	0.56	0.61	0.77	23.01
1941	1.35	1.99	1.88	9.21	5.19	3.30	2.92	2.23	1.56	0.95	0.90	1.20	32.68
1942	2.11	27.70	29.64	9.19	2.41	9.96	14.21	5.92	2.47	2.16	4.07	3.69	113.53
1943	8.29	21.61	16.86	5.46	3.77	3.23	2.06	1.31	1.05	1.06	0.90	2.66	68.26
1944	3.85	3.01	1.54	1.59	2.42	4.73	2.99	1.48	1.02	0.78	0.59	0.64	24.64
1945	7.46	4.22	1.44	1.11	2.07	11.08	5.72	2.03	1.17	0.83	0.63	0.68	38.44
1946	1.17	2.58	3.24	2.90	4.28	10.73	6.92	3.37	10.36	5.81	2.30	1.60	55.26
1947	1.67	42.45	18.32	4.10	10.93	7.70	3.80	2.09	1.05	0.60	0.43	0.38	93.52
1948	1.81	3.04	3.05	2.92	10.33	5.75	3.19	2.22	1.15	0.73	0.65	0.71	35.55
1949	1.38	8.12	4.67	8.55	5.17	3.34	3.01	2.92	2.30	1.77	2.33	2.38	45.94
1950	2.23	2.02	17.94	8.16	2.49	2.87	2.48	1.45	0.94	0.76	0.91	1.41	43.66
1951	5.21	3.39	2.66	3.41	3.66	3.23	3.24	2.72	1.64	1.01	0.67	0.85	31.69
1952	1.12	1.32	1.44	1.43	1.80	1.93	1.74	1.26	0.79	0.55	0.59	1.24	15.21
1953	2.62	11.92	13.98	5.54	2.59	2.71	2.00	1.70	1.89	1.64	1.11	1.28	48.98
1954	28.17	11.95	2.64	12.04	25.09	9.94	3.12	2.01	1.31	0.94	0.62	0.94	98.77
1955	1.75	2.58	2.08	0.91	1.41	17.87	9.07	3.15	2.04	1.47	1.05	1.13	44.51
1956	2.45	22.19	42.56	14.63	3.74	15.47	11.41	4.12	1.84	1.34	1.22	2.31	123.28
1957	8.15	12.71	5.66	5.47	16.99	7.52	5.24	3.26	1.35	0.84	0.67	0.69	68.55
1958	1.00	3.31	3.78	2.86	2.51	2.55	2.49	36.67	14.21	2.32	2.33	2.19	76.22
1959	2.21	2.76	2.98	2.55	2.22	2.61	2.88	2.58	1.80	1.16	1.01	1.35	26.11
1960	1.74	3.61	12.71	8.68	3.61	3.29	27.96	11.31	2.05	1.44	1.12	0.98	78.50
1961	1.11	4.15	3.84	3.20	8.83	10.89	4.51	1.67	1.11	0.71	0.81	1.03	41.86
1962	2.05	15.11	7.50	18.92	8.18	42.65	16.27	2.05	1.24	5.38	3.95	1.87	125.17
1963	2.40	13.82	13.28	19.97	8.25	3.45	6.66	3.81	28.86	11.99	2.25	1.76	116.50
1964	16.99	7.51	2.05	2.07	2.13	1.46	0.87	0.89	13.39	7.72	4.39	4.03	63.50
1965	20.28	18.42	6.16	2.60	2.16	1.25	0.72	11.80	6.17	1.98	1.33	1.54	74.41
1966	1.82	2.07	2.49	3.10	3.47	33.04	16.09	3.68	1.93	2.35	2.28	1.37	73.69
1967	1.15	2.32	2.48	1.92	1.80	1.84	1.73	1.20	0.69	0.50	0.83	1.83	18.29
1968	2.86	3.54	3.45	2.15	4.08	16.27	6.92	2.90	2.75	1.85	1.39	1.32	49.48
1969	1.95	3.12	3.37	2.37	1.73	1.22	0.77	0.81	1.24	1.28	1.86	2.86	22.58
1970	21.49	10.52	5.05	3.81	3.14	2.78	2.37	6.34	4.03	2.65	7.42	4.90	74.50
1971	24.22	10.49	3.03	2.92	14.31	6.80	2.08	1.14	0.86	0.84	0.69	0.57	67.95
1972	0.70	3.06	3.30	2.49	2.30	2.50	2.34	1.52	0.78	0.51	0.73	1.53	21.76
1973	2.34	8.56	4.80	2.86	5.18	11.99	5.58	7.48	4.94	2.61	1.44	0.90	58.68
1974	1.04	2.31	6.23	4.23	3.42	3.52	2.62	1.45	0.77	0.53	0.48	1.97	28.57
1975	2.99	2.76	18.44	14.16	17.96	53.20	18.70	3.41	2.63	1.54	0.96	1.36	138.11
1976	21.12	9.35	3.00	2.82	2.85	2.72	1.91	1.06	0.74	0.68	0.71	1.11	48.07
1977	4.25	13.77	13.09	5.65	3.20	3.01	74.05	27.33	2.61	1.45	1.09	1.48	150.98
1978	4.97	10.50	5.65	2.74	2.27	2.72	2.42	1.39	0.73	1.08	1.52	1.50	37.49
1979	1.94	2.35	2.41	1.89	1.47	1.48	1.18	0.85	0.64	0.49	0.42	3.16	18.28
1980	3.70	17.64	9.36	4.29	3.72	2.94	1.72	1.39	1.30	0.90	1.12	1.43	49.51
1981	1.25	1.34	1.48	2.26	2.53	7.07	4.76	2.54	1.54	1.10	0.76	0.68	27.31
1982	1.71	2.08	1.47	1.18	1.14	0.98	0.89	0.80	0.60	0.69	0.84	0.94	13.32
1983	1.47	3.65	3.88	13.25	12.01	6.82	9.21	4.61	1.94	1.89	1.83	1.50	62.06
1984	1.59	2.73	5.79	4.40	36.51	13.90	1.70	0.85	0.56	0.51	0.40	0.33	69.27
1985	10.45	10.40	8.75	4.66	2.76	1.96	1.28	0.76	0.51	0.44	1.43	2.66	46.06
1986	10.63	15.74	6.37	2.92	2.50	2.64	2.39	1.52	0.96	0.67	1.09	43.67	91.10
1987	17.61	12.08	20.46	7.74	23.24	46.61	15.58	3.97	3.74	3.68	3.78	3.20	161.69
1988	2.87	12.42	19.05	6.99	29.72	11.86	3.04	2.61	1.84	1.45	0.98	0.75	93.58
1989	4.28	44.29	16.72	2.77	2.00	10.83	5.50	1.70	0.89	0.57	1.22	1.76	92.53
1990	2.76	3.13	2.60	4.95	4.12	2.80	1.46	0.72	0.53	0.41	0.40	0.82	24.70
1991	12.98	11.38	4.53	2.42	2.08	2.05	1.77	1.12	0.62	0.42	0.41	0.58	40.36
1992	1.07	2.50	4.84	3.52	2.91	2.20	1.42	0.90	0.52	0.36	0.37	1.43	22.04
1993	18.23	9.00	16.75	7.43	10.89	16.96	6.18	1.20	0.63	0.89	1.20	0.91	90.27
1994	0.72	0.81	1.05	1.68	1.56	9.99	6.21	3.25	2.77	2.24	1.27	0.95	32.50
1995	1.55	2.78	48.82	22.48	20.89	8.81	2.24	1.05	0.55	1.07	1.46	1.28	112.98
1996	1.78	21.73	9.86	9.57	7.86	4.51	16.36	7.28	30.86	13.14	3.19	2.43	128.57
month	364.83	689.08	661.78	458.78	543.54	662.32	447.46	264.94	238.47	195.07	128.08	173.83	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.48	0.81	1.05	0.89	1.10	0.98	0.68	0.67	0.51	0.36	0.37	0.33	13.32
max	28.17	54.88	48.82	24.33	36.51	53.20	74.05	36.67	30.86	32.26	13.23	43.67	161.69
median	2.05	3.55	5.01	3.61	3.20	3.52	2.92	1.70	1.24	1.10	1.09	1.32	49.51
mean	4.74	8.95	8.59	5.96	7.06	8.60	5.81	3.44	3.10	2.53	1.66	2.26	62.70
Sum of the monthly means = 62.70													
s.d.	6.22	10.51	9.23	5.46	8.06	10.43	9.32	5.45	5.52	4.72	1.99	5.05	36.45
c.v.	1.31	1.17	1.07	0.92	1.14	1.21	1.60	1.58	1.78	1.86	1.20	2.24	0.58

APPENDIX 2.4
T60D

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.20	2.49	10.45	6.05	3.54	13.03	6.96	2.69	1.41	0.80	0.54	0.74	49.90
1921	1.93	29.74	36.94	12.09	3.43	2.08	0.97	12.65	16.28	6.59	3.12	2.72	128.54
1922	3.42	33.66	13.63	17.00	51.35	36.61	8.92	1.44	0.87	33.10	13.64	2.15	215.79
1923	1.37	1.35	2.09	40.19	32.43	8.31	1.43	0.86	0.75	0.63	0.66	1.11	91.18
1924	2.32	9.23	20.95	7.80	1.81	18.42	8.84	2.74	1.56	0.98	0.68	0.71	76.04
1925	1.65	6.78	4.95	7.76	4.78	32.33	12.54	1.90	2.20	2.23	1.44	1.72	80.28
1926	5.66	8.08	12.06	5.63	2.65	45.48	16.90	1.47	0.80	0.63	0.81	1.10	101.27
1927	2.20	2.42	14.36	31.76	18.19	5.51	2.10	1.21	0.94	0.75	0.99	1.27	81.70
1928	1.84	2.80	2.74	2.30	1.82	9.57	5.16	2.02	13.95	8.59	4.19	14.76	69.74
1929	16.41	12.28	5.55	4.33	3.60	8.43	5.23	2.51	2.44	2.58	2.89	5.04	71.29
1930	4.70	3.99	14.75	33.72	20.74	36.83	13.29	1.76	0.86	47.00	18.62	2.51	198.77
1931	2.59	3.17	2.95	2.38	20.58	9.32	2.22	1.50	1.63	2.04	1.91	4.47	54.76
1932	9.94	49.39	44.53	11.33	1.41	1.97	2.30	1.68	1.09	0.86	0.73	0.62	125.85
1933	0.64	19.87	32.19	23.11	7.70	3.70	3.33	2.45	1.51	1.92	2.07	1.45	99.94
1934	1.44	2.83	24.47	10.37	2.88	3.02	17.83	26.94	29.08	10.02	3.53	3.05	135.46
1935	2.39	2.77	1.89	1.35	30.99	28.70	7.99	6.79	4.81	2.72	1.64	1.38	93.42
1936	3.55	76.84	28.24	7.47	36.54	15.47	3.40	1.65	0.92	0.77	0.75	0.75	176.35
1937	1.26	2.16	3.31	3.73	10.39	5.17	3.06	2.86	2.13	1.98	1.83	1.42	39.30
1938	1.56	2.87	14.28	7.33	21.67	9.47	2.57	2.24	1.93	1.91	2.11	21.27	89.21
1939	14.45	7.18	13.00	6.03	2.56	2.80	2.71	13.62	7.19	2.71	1.61	1.27	75.13
1940	1.58	10.55	15.70	6.20	1.84	1.83	1.95	1.35	0.86	0.77	0.83	1.07	44.53
1941	1.95	2.95	2.84	20.43	9.45	9.14	5.16	2.78	2.01	1.22	1.18	1.65	60.76
1942	3.04	43.31	45.01	13.28	3.31	20.30	23.86	8.43	3.08	2.81	10.34	6.22	182.99
1943	14.94	32.68	26.78	8.29	11.04	6.14	2.69	1.77	1.43	1.44	1.22	9.43	117.85
1944	7.31	3.91	1.98	2.35	3.68	13.40	6.04	1.80	1.29	0.99	0.74	0.84	44.33
1945	15.97	7.36	1.80	1.58	5.23	20.86	9.13	2.54	1.49	1.06	0.81	0.91	68.74
1946	1.64	8.72	5.87	3.98	12.89	20.13	13.29	5.14	17.25	8.51	2.74	2.01	102.17
1947	2.23	61.68	30.01	9.42	18.95	14.94	5.98	2.63	1.33	0.74	0.53	0.48	148.92
1948	5.15	4.86	4.58	4.30	20.88	9.85	4.31	3.08	1.56	0.97	0.86	0.96	61.36
1949	1.97	17.67	8.30	17.56	9.20	5.19	4.23	4.03	3.19	2.44	3.29	3.38	80.45
1950	3.20	2.93	30.84	13.05	3.43	9.01	4.75	1.76	1.18	0.96	1.20	1.96	74.27
1951	13.11	6.29	6.89	9.11	8.15	4.78	6.11	4.08	2.06	1.26	0.83	1.13	63.80
1952	1.56	1.90	2.16	2.22	2.86	3.06	2.70	1.90	1.14	0.76	0.81	1.77	22.84
1953	6.18	20.86	23.43	8.40	3.59	4.02	2.99	2.51	2.76	2.35	1.54	1.81	80.44
1954	43.31	17.60	3.50	22.90	39.08	16.87	4.70	2.49	1.67	1.20	0.78	1.27	155.37
1955	2.51	3.75	2.99	1.33	2.20	31.93	17.72	4.86	2.49	1.85	1.33	1.51	74.47
1956	6.28	33.94	60.59	24.18	8.69	24.04	19.00	6.15	2.21	1.67	1.57	4.25	192.57
1957	15.35	20.93	8.24	13.45	28.24	11.02	12.11	5.75	1.56	0.99	0.81	0.88	119.33
1958	1.37	10.91	9.12	4.32	3.49	3.79	3.76	54.85	20.54	2.80	3.02	2.94	120.91
1959	3.08	4.39	4.43	3.81	3.44	5.58	4.64	3.66	2.52	1.59	1.37	1.90	40.41
1960	2.49	11.50	22.53	16.79	6.00	10.01	41.30	15.48	2.50	1.80	1.43	1.28	133.11
1961	1.53	12.02	7.12	6.55	17.58	19.69	6.91	2.07	1.41	0.89	1.07	1.40	78.24
1962	3.02	25.86	12.28	30.26	12.39	61.49	23.01	2.58	1.59	12.22	6.57	2.22	193.49
1963	4.80	22.82	22.70	31.70	12.72	6.66	13.12	5.97	41.15	16.51	2.69	2.23	183.07
1964	27.41	11.34	2.67	3.04	3.27	2.25	1.31	1.32	24.29	12.82	7.91	5.57	103.20
1965	30.22	28.28	8.90	3.58	3.19	1.87	1.08	22.52	10.12	2.33	1.62	2.03	115.74
1966	2.51	2.98	3.75	10.63	8.30	47.43	25.42	5.59	2.34	3.10	3.06	1.83	116.94
1967	1.57	5.89	4.19	2.70	2.72	2.85	2.66	1.80	0.98	0.68	1.17	2.66	29.87
1968	4.53	9.32	5.89	2.88	12.46	27.33	10.07	5.26	3.94	2.27	1.75	1.74	87.44
1969	2.74	9.16	5.98	3.21	2.54	1.84	1.15	1.20	1.83	1.85	2.69	4.19	38.38
1970	34.83	19.05	11.40	7.17	4.48	3.93	3.47	15.00	7.17	3.25	14.13	7.61	131.49
1971	35.68	14.91	4.07	6.57	24.91	10.53	2.71	1.52	1.15	1.12	0.91	0.76	104.84
1972	0.96	10.69	6.43	3.40	3.43	3.85	3.59	2.28	1.11	0.69	1.01	2.19	39.63
1973	3.43	18.08	8.42	5.88	12.69	20.85	8.25	14.25	7.67	3.17	1.76	1.12	105.57
1974	1.40	6.12	13.99	7.09	10.29	6.32	3.38	1.92	1.01	0.68	0.62	6.24	59.06
1975	4.91	3.60	30.96	25.15	28.55	73.89	25.34	4.52	3.57	2.05	1.25	1.88	205.67
1976	33.98	14.15	4.26	4.07	5.02	4.20	2.74	1.51	1.03	0.93	0.97	1.56	74.42
1977	12.01	23.26	22.09	11.39	4.97	4.12	102.64	37.45	3.28	1.82	1.39	2.02	226.44
1978	12.61	18.68	9.07	3.84	3.22	5.96	3.99	1.86	0.95	1.47	2.13	2.10	65.88
1979	2.79	3.46	3.64	2.93	2.31	2.33	1.83	1.27	0.93	0.68	0.56	10.31	33.04
1980	6.65	27.84	17.69	11.00	8.91	4.54	2.17	1.88	1.78	1.21	1.54	2.01	87.22
1981	1.77	1.95	2.23	6.62	4.59	15.95	8.28	3.26	2.01	1.43	0.98	0.89	49.96
1982	2.46	3.05	2.18	1.83	1.80	1.55	1.37	1.20	0.87	0.98	1.18	1.32	19.79
1983	2.12	11.69	9.91	21.97	20.92	13.85	16.30	6.78	2.35	2.43	2.43	2.03	112.78
1984	2.22	8.73	12.94	10.59	51.74	18.97	2.18	1.11	0.73	0.66	0.50	0.43	110.80
1985	19.93	18.91	16.38	8.13	3.88	2.71	1.83	1.07	0.71	0.58	2.06	3.89	80.08
1986	20.36	25.57	9.16	6.11	4.08	5.03	3.69	2.04	1.28	0.88	1.51	62.97	142.68
1987	25.22	19.61	31.87	11.33	36.77	66.44	21.34	9.70	6.11	4.78	4.93	4.25	242.35
1988	3.96	22.56	30.91	10.35	45.13	17.47	5.92	3.96	2.34	1.88	1.26	0.98	146.72
1989	11.63	62.53	22.64	3.85	2.95	21.96	9.56	2.09	1.11	0.70	1.67	2.48	143.17
1990	8.55	5.47	3.42	13.66	9.70	4.17	1.85	0.94	0.68	0.52	0.51	1.12	50.59
1991	23.50	20.23	6.85	3.31	3.08	3.13	2.70	1.66	0.88	0.56	0.55	0.78	67.23
1992	1.53	8.12	11.90	5.85	5.30	3.42	1.95	1.25	0.70	0.46	0.48	2.05	43.01
1993	30.60	16.67	26.00	10.71	20.36	27.66	9.00	1.42	0.76	1.16	1.61	1.22	147.17
1994	0.97	1.14	1.57	2.64	2.47	21.32	13.47	4.77	3.41	2.86	1.60	1.23	57.45
1995	2.17	7.66	69.13	35.16	32.66	12.72	2.94	1.39	0.72	1.48	2.03	1.79	169.85
1996	2.57	35.53	16.91	17.71	15.70	10.42	24.62	9.98	43.80	18.04	3.95	3.16	202.39
month	621.88	1165.52	1100.42	801.54	929.78	1100.81	696.01	412.41	352.23	276.13	183.04	269.42	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.64	1.14	1.57	1.33	1.41	1.55	0.97	0.86	0.68	0.46	0.48	0.43	19.79
max	43.31	76.84	69.13	40.19	51.74	73.89	102.64	54.85	43.80	47.00	18.62	62.97	242.35
median	3.04	10.55	9.16	7.33	6.00	9.32	4.70	2.49	1.63	1.48	1.44	1.81	89.21
mean	8.08	15.14	14.29	10.41	12.08	14.30	9.04	5.36	4.57	3.59	2.38	3.50	102.72
Sum of the monthly means = 102.72													
s.d.	10.01	15.04	13.60	9.04	12.43	15.09	13.24	8.37	8.23	7.00	3.14	7.57	53.43
c.v.	1.24	0.99	0.95	0.87	1.03	1.06	1.47	1.56	1.80	1.95	1.32	2.16	0.52

APPENDIX 2.5
T60E

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.44	0.85	1.49	1.48	1.30	1.56	1.59	1.06	0.55	0.32	0.22	0.33	11.19
1921	0.71	5.39	6.19	2.56	0.97	0.50	0.27	1.10	2.51	1.91	1.43	1.39	24.93
1922	4.93	14.38	5.32	11.34	16.06	7.83	2.11	0.70	0.42	7.20	3.55	0.93	74.77
1923	0.59	0.64	0.85	4.69	4.06	1.64	0.55	0.31	0.27	0.25	0.29	0.54	14.68
1924	0.91	1.31	1.72	1.52	1.31	5.93	3.15	1.21	0.69	0.49	0.38	0.60	19.22
1925	0.95	1.21	1.24	1.25	1.33	8.27	3.65	0.91	0.93	0.92	0.62	0.66	21.94
1926	1.20	2.61	2.26	1.48	0.97	13.08	5.17	0.64	0.33	0.24	0.23	0.36	28.57
1927	0.79	0.81	0.90	1.24	1.58	1.48	0.90	0.55	0.45	0.36	0.50	0.61	10.17
1928	0.72	1.10	1.21	1.08	0.87	1.15	1.05	0.70	4.48	3.70	2.23	5.17	23.46
1929	9.25	7.32	2.68	1.06	0.69	0.71	0.81	0.66	0.78	0.96	1.11	1.75	27.78
1930	1.82	1.40	1.11	5.67	5.71	9.98	3.98	0.89	0.45	31.31	11.66	1.19	75.17
1931	1.21	1.32	1.15	0.77	3.48	2.35	1.04	0.72	0.75	0.84	0.75	2.71	17.09
1932	2.76	18.42	13.69	3.28	0.74	0.87	0.75	0.50	0.36	0.30	0.26	0.27	42.20
1933	0.32	1.47	5.86	7.77	3.08	1.39	1.16	0.79	0.52	0.87	1.02	0.64	24.89
1934	0.49	0.95	3.41	2.08	0.89	0.90	2.55	6.66	12.41	4.82	1.70	1.41	38.27
1935	1.07	1.09	0.72	0.45	9.30	10.09	3.27	1.53	1.77	1.37	0.82	0.63	32.11
1936	1.29	24.64	9.13	0.93	1.31	2.65	1.73	0.78	0.42	0.40	0.45	0.46	44.19
1937	0.60	0.73	1.16	1.39	1.22	0.79	0.96	1.04	0.86	0.86	0.76	0.52	10.89
1938	0.49	0.93	1.36	1.47	3.19	2.18	1.22	1.02	0.87	0.91	1.08	7.69	22.41
1939	4.48	1.92	1.55	1.09	0.69	0.71	0.66	0.98	1.14	0.83	0.57	0.50	15.12
1940	0.53	1.17	1.48	1.04	0.54	0.39	0.40	0.33	0.28	0.31	0.33	0.37	7.17
1941	0.65	1.09	0.97	6.88	3.17	1.13	0.89	0.79	0.69	0.45	0.46	0.65	17.82
1942	0.99	15.94	11.25	3.07	1.00	1.22	3.66	2.24	1.18	0.93	1.34	1.64	44.46
1943	1.76	6.10	3.49	1.55	1.46	1.33	0.89	0.55	0.44	0.48	0.44	3.16	21.65
1944	2.67	1.64	0.85	0.78	1.16	1.42	1.09	0.69	0.49	0.40	0.33	0.43	11.95
1945	7.66	3.47	0.75	0.53	0.89	2.00	1.83	1.13	0.64	0.47	0.35	0.35	20.07
1946	0.55	1.27	1.56	1.24	1.11	1.74	4.32	2.50	2.43	2.06	1.20	0.83	20.81
1947	0.81	21.13	8.54	1.56	2.01	2.01	1.63	0.99	0.50	0.30	0.22	0.20	39.90
1948	0.93	1.52	1.39	1.06	9.21	4.52	1.82	1.18	0.60	0.37	0.34	0.42	23.36
1949	0.74	4.71	2.66	1.55	1.60	1.42	1.29	1.37	1.12	0.85	1.02	1.02	19.35
1950	1.10	1.01	4.65	2.80	1.32	1.23	1.02	0.62	0.43	0.37	0.43	0.65	15.63
1951	2.04	1.55	1.45	1.84	1.58	1.34	1.35	1.09	0.68	0.44	0.30	0.45	14.11
1952	0.65	0.72	0.70	0.64	0.75	0.80	0.76	0.58	0.38	0.28	0.30	0.72	7.28
1953	1.40	7.40	4.70	1.79	0.98	1.02	0.85	0.73	0.83	0.79	0.57	0.69	21.75
1954	14.43	6.12	1.28	3.00	6.51	3.30	1.46	0.86	0.57	0.42	0.29	0.50	38.74
1955	0.91	1.22	0.90	0.38	0.60	7.10	3.70	1.37	0.94	0.71	0.51	0.62	18.96
1956	1.31	13.64	23.08	7.63	1.70	4.04	5.56	2.49	1.00	0.73	0.63	0.95	62.76
1957	1.58	1.96	1.94	2.60	7.10	3.41	2.91	1.79	0.73	0.47	0.40	0.40	25.29
1958	0.53	1.20	1.59	1.06	0.83	0.90	0.91	14.21	5.84	1.31	1.43	1.40	31.21
1959	1.30	1.31	1.22	1.03	0.81	0.99	1.24	1.29	0.99	0.67	0.60	0.80	12.25
1960	0.93	1.38	3.57	2.44	1.44	1.31	12.11	5.27	1.25	1.02	0.91	0.73	32.36
1961	0.72	1.81	1.88	1.40	1.23	2.15	1.60	0.91	0.57	0.36	0.46	0.61	13.70
1962	1.11	5.40	2.87	5.72	2.82	18.95	7.36	1.10	0.75	4.03	2.49	0.98	53.58
1963	1.10	1.79	1.85	7.22	3.77	1.98	2.73	1.78	14.18	5.99	1.20	0.90	44.49
1964	2.93	1.98	0.94	0.75	0.68	0.43	0.26	0.34	6.77	3.88	2.06	1.87	22.89
1965	12.01	8.32	2.61	1.16	0.87	0.50	0.29	2.42	2.02	1.08	0.71	0.80	32.79
1966	0.87	0.84	0.91	1.25	1.38	10.59	8.07	2.56	0.98	1.28	1.34	0.84	30.91
1967	0.61	1.01	1.05	0.77	0.73	0.71	0.62	0.44	0.28	0.24	0.40	0.94	7.80
1968	1.43	1.78	1.71	1.02	1.21	6.56	3.12	4.17	2.49	1.14	0.80	0.68	26.11
1969	0.90	1.46	1.50	0.91	0.65	0.49	0.35	0.36	0.58	0.66	2.75	2.47	13.08
1970	13.50	6.92	2.06	1.28	1.12	1.02	0.97	5.21	2.82	1.57	3.97	2.59	43.03
1971	11.41	5.12	1.63	1.22	7.40	3.45	0.97	0.58	0.45	0.44	0.42	0.37	33.46
1972	0.37	1.06	1.54	1.26	0.92	0.87	1.19	1.02	0.54	0.33	0.47	0.95	10.52
1973	1.38	5.37	2.79	1.11	1.16	1.44	1.26	5.38	3.20	1.52	0.88	0.58	26.07
1974	0.58	0.96	1.43	1.27	1.00	0.92	0.80	0.59	0.40	0.32	0.33	4.89	13.49
1975	2.85	1.33	3.24	2.10	6.49	30.33	10.95	2.09	1.66	0.98	0.64	0.86	63.52
1976	20.37	7.90	1.04	0.88	1.46	1.62	1.05	0.53	0.39	0.41	0.56	0.90	37.11
1977	1.39	6.97	7.90	3.02	1.11	0.94	43.44	16.14	1.67	1.01	0.73	0.80	85.12
1978	3.34	2.66	1.62	0.99	0.73	1.04	1.03	0.68	0.44	0.76	1.18	1.27	15.74
1979	1.50	1.43	1.12	0.77	0.68	0.68	0.52	0.42	0.36	0.32	0.29	1.14	9.23
1980	1.76	4.96	2.85	1.67	1.40	0.93	0.52	0.72	0.89	0.67	0.80	0.90	18.07
1981	0.72	0.73	0.71	0.79	0.74	7.91	4.01	1.37	0.82	0.59	0.44	0.39	19.22
1982	0.74	0.94	0.63	0.42	0.39	0.33	0.28	0.24	0.21	4.76	2.88	1.31	13.13
1983	1.25	1.72	1.80	1.74	1.64	1.32	1.26	1.12	0.99	1.48	1.55	1.16	17.03
1984	1.05	3.63	2.39	1.34	18.64	7.20	0.88	0.45	0.30	0.28	0.24	0.21	36.61
1985	0.84	4.24	2.51	1.69	1.36	0.94	0.75	0.54	0.35	0.26	0.60	1.35	15.43
1986	4.39	2.88	1.45	1.08	0.72	0.79	0.85	0.61	0.46	0.38	0.50	30.12	44.23
1987	11.63	4.99	2.69	1.12	4.66	22.05	8.15	1.89	1.87	1.84	1.95	1.57	64.41
1988	1.38	5.55	12.82	4.50	8.28	3.96	2.87	1.90	1.06	0.82	0.56	0.48	44.18
1989	2.43	12.02	4.67	1.00	0.72	1.37	1.34	0.73	0.39	0.28	0.58	0.87	26.40
1990	1.18	1.19	0.87	0.94	1.39	1.29	0.73	0.43	0.35	0.29	0.32	0.56	9.54
1991	1.55	5.89	2.83	1.04	0.74	0.53	0.54	0.46	0.32	0.25	0.27	0.46	14.88
1992	0.79	0.98	1.05	0.89	0.66	0.42	0.31	0.27	0.22	0.19	0.22	0.62	6.62
1993	1.33	1.70	4.05	2.09	11.37	5.00	1.06	0.46	0.26	0.33	0.69	0.71	29.05
1994	0.59	0.51	1.09	1.31	0.83	2.58	8.94	3.89	1.67	1.58	0.97	0.69	24.65
1995	0.93	1.12	14.22	5.99	2.00	1.43	0.85	0.58	0.40	0.97	1.32	0.98	30.79
1996	1.20	16.10	6.49	1.51	3.15	2.16	6.69	3.24	21.51	8.82	1.74	1.32	73.93
month	190.62	317.30	243.83	160.29	198.62	261.56	212.87	130.44	125.59	122.80	79.34	113.48	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.32	0.51	0.63	0.38	0.39	0.33	0.26	0.24	0.21	0.19	0.22	0.20	6.62
max	20.37	24.64	23.08	11.34	18.64	30.33	43.44	16.14	21.51	31.31	11.66	30.12	85.12
median	1.11	1.70	1.63	1.28	1.30	1.42	1.19	0.91	0.69	0.71	0.60	0.80	23.36
mean	2.48	4.12	3.17	2.08	2.58	3.40	2.76	1.69	1.63	1.59	1.03	1.47	28.01
Sum of the monthly means = 28.01													
s.d.	3.75	5.05	3.79	2.03	3.38	5.06	5.31	2.57	3.23	3.79	1.45	3.50	17.74
c.v.	1.51	1.23	1.20	0.98	1.31	1.49	1.92	1.51	1.98	2.37	1.40	2.38	0.63

APPENDIX 2.6
T60F

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.07	2.20	4.40	3.98	3.44	4.39	4.19	2.71	1.39	0.80	0.54	0.84	29.95
1921	1.87	17.37	18.95	7.09	2.46	1.30	0.70	5.64	7.49	4.69	3.46	3.48	74.50
1922	15.40	38.71	13.81	31.56	43.51	22.41	5.86	1.69	1.02	20.89	9.68	2.20	206.74
1923	1.44	1.63	2.27	16.24	13.79	4.72	1.33	0.76	0.68	0.61	0.72	1.41	45.60
1924	2.40	3.49	6.77	4.55	3.36	18.88	9.13	2.97	1.72	1.21	0.95	1.54	56.97
1925	2.48	3.21	3.34	3.43	3.66	25.10	10.45	2.22	2.35	2.34	1.56	1.70	61.84
1926	3.17	10.28	7.05	3.73	2.47	36.81	14.18	1.52	0.79	0.57	0.57	0.92	82.06
1927	2.07	2.13	2.44	3.41	4.72	4.02	2.34	1.42	1.16	0.92	1.30	1.57	27.50
1928	1.90	2.95	3.26	2.97	2.39	3.18	2.87	1.90	14.90	11.44	5.72	15.03	68.51
1929	25.29	20.54	7.22	2.70	1.83	1.91	2.19	1.78	2.08	2.54	2.92	7.79	78.79
1930	5.56	3.46	2.88	18.52	17.92	27.77	10.55	2.16	1.09	81.35	30.02	2.86	204.14
1931	3.05	3.42	3.04	2.08	13.13	7.27	2.60	1.83	1.94	2.17	1.95	10.10	52.58
1932	9.40	48.20	37.05	8.87	1.88	2.31	2.00	1.34	0.94	0.77	0.65	0.67	114.08
1933	0.82	7.34	18.10	22.59	8.44	3.56	3.05	2.08	1.34	2.28	2.68	1.66	73.94
1934	1.27	2.53	12.79	6.56	2.24	2.39	10.34	19.16	32.51	12.24	4.15	3.54	109.72
1935	2.71	2.86	1.91	1.22	27.95	28.66	8.68	4.79	4.57	3.28	1.98	1.57	90.18
1936	3.35	65.47	24.02	2.34	7.18	9.91	4.88	1.87	1.03	0.98	1.11	1.18	123.32
1937	1.55	1.94	3.15	3.83	3.36	2.18	2.64	2.83	2.30	2.26	1.98	1.35	29.37
1938	1.28	2.47	3.68	4.04	12.58	6.89	3.07	2.62	2.26	2.35	2.81	22.71	66.76
1939	13.76	5.15	3.92	2.87	1.86	1.93	1.81	2.65	3.05	2.20	1.48	1.29	41.97
1940	1.37	3.13	4.01	2.83	1.49	1.08	1.09	0.88	0.75	0.79	0.84	0.96	19.22
1941	1.70	2.91	2.61	21.85	9.38	2.88	2.33	2.09	1.80	1.17	1.18	1.69	51.59
1942	2.62	43.88	31.48	8.32	2.53	3.28	13.23	6.81	2.87	2.29	3.45	4.25	125.01
1943	4.63	18.88	11.96	4.51	3.79	3.53	2.38	1.46	1.14	1.24	1.12	11.32	65.96
1944	7.71	4.09	2.16	2.10	3.19	3.92	2.98	1.85	1.30	1.05	0.83	1.10	32.28
1945	22.83	9.78	1.84	1.38	2.42	9.34	5.91	2.77	1.58	1.15	0.87	0.89	60.76
1946	1.42	3.74	4.13	3.26	3.02	8.59	13.90	6.68	8.12	5.66	2.86	2.02	63.40
1947	2.05	56.43	22.48	3.88	8.54	6.17	4.13	2.55	1.28	0.75	0.54	0.49	109.29
1948	2.46	4.07	3.74	2.89	27.80	13.14	4.56	2.92	1.47	0.92	0.83	1.07	65.87
1949	1.94	15.60	7.85	4.02	4.30	3.86	3.49	3.70	2.99	2.23	2.67	2.67	55.32
1950	2.91	2.68	15.83	8.36	3.39	3.28	2.73	1.65	1.13	0.95	1.12	1.69	45.72
1951	8.62	4.93	5.61	5.17	4.01	3.54	3.61	2.90	1.78	1.14	0.75	1.15	43.21
1952	1.69	1.91	1.88	1.76	2.07	2.22	2.07	1.56	1.00	0.71	0.78	1.89	19.54
1953	3.74	22.29	15.10	5.13	2.49	2.71	2.28	1.94	2.20	2.07	1.47	1.79	63.21
1954	39.80	16.45	3.21	11.45	19.80	8.96	3.68	2.21	1.44	1.07	0.72	1.29	110.08
1955	2.40	3.26	2.41	1.02	1.65	22.51	10.75	3.40	2.35	1.80	1.29	1.58	54.42
1956	3.45	38.17	61.23	19.82	4.41	14.12	16.93	6.66	2.41	1.79	1.56	2.44	172.99
1957	4.15	6.41	5.37	10.13	21.17	9.21	10.16	5.30	1.71	1.11	0.97	1.00	76.69
1958	1.36	3.21	4.30	2.89	2.28	2.49	2.50	39.66	15.82	3.18	3.59	3.56	84.84
1959	3.37	3.45	3.28	2.81	2.24	2.74	3.42	3.52	2.65	1.75	1.56	2.10	32.89
1960	2.46	3.55	12.26	7.18	3.72	3.48	34.45	14.42	3.05	2.54	2.28	1.86	91.25
1961	1.85	8.09	5.85	3.59	3.29	9.56	5.26	2.21	1.42	0.89	1.14	1.58	44.73
1962	2.93	17.44	8.40	17.86	8.19	50.73	19.43	2.72	1.88	12.95	7.02	2.33	151.88
1963	2.77	7.03	5.35	21.44	11.87	5.27	9.42	5.20	37.50	15.51	2.86	2.21	126.43
1964	10.33	5.84	2.32	1.98	1.84	1.17	0.69	0.91	20.70	10.79	5.07	4.72	66.36
1965	33.20	23.63	7.04	2.94	2.31	1.34	0.77	9.88	6.17	2.56	1.71	2.01	93.56
1966	2.23	2.19	2.44	3.43	3.81	31.23	23.49	6.86	2.35	3.22	3.41	2.12	86.78
1967	1.57	2.68	2.83	2.10	2.00	1.95	1.69	1.18	0.75	0.62	1.04	2.48	20.89
1968	3.81	5.71	4.69	2.62	3.90	19.27	8.55	12.91	6.90	2.71	1.94	1.69	74.70
1969	2.32	3.87	4.02	2.47	1.78	1.35	0.95	0.96	1.55	1.74	10.31	7.19	38.51
1970	36.11	19.84	5.66	3.27	3.01	2.76	2.64	17.04	8.20	3.84	12.39	7.16	121.92
1971	30.84	13.50	4.14	3.23	22.98	10.01	2.41	1.46	1.13	1.12	1.07	0.95	92.84
1972	0.95	2.83	4.18	3.44	2.54	2.39	3.26	2.76	1.43	0.85	1.21	2.52	28.36
1973	3.68	17.38	8.21	2.82	3.10	3.92	3.43	17.41	9.15	3.68	2.16	1.42	76.36
1974	1.46	2.53	3.85	3.48	2.76	2.53	2.19	1.59	1.05	0.83	0.84	15.72	38.83
1975	8.16	3.29	11.66	6.39	19.78	78.95	27.97	7.70	4.82	2.33	1.53	2.16	174.74
1976	54.25	20.75	2.59	2.32	7.17	5.04	2.53	1.30	0.97	1.02	1.44	2.34	101.72
1977	3.69	21.14	23.19	8.24	2.84	2.49	112.53	41.56	4.13	2.51	1.82	2.04	226.18
1978	11.70	7.88	4.03	2.51	1.95	2.83	2.80	1.82	1.15	2.00	3.11	3.34	45.12
1979	3.97	3.82	3.02	2.09	1.87	1.88	1.42	1.13	0.96	0.82	0.75	5.44	27.17
1980	5.03	14.58	7.83	4.32	3.74	2.52	1.39	1.93	2.38	1.75	2.10	2.37	49.94
1981	1.88	1.94	1.91	2.16	2.06	24.44	11.49	3.41	2.05	1.48	1.09	0.97	54.88
1982	1.94	2.48	1.68	1.14	1.06	0.90	0.76	0.65	0.54	14.33	7.85	3.18	36.51
1983	3.15	6.88	5.22	4.84	4.31	3.42	3.35	2.99	2.61	3.91	4.10	3.04	47.82
1984	2.75	12.84	7.18	3.45	50.88	19.33	2.19	1.13	0.75	0.71	0.58	0.51	102.30
1985	2.23	14.56	7.51	6.66	4.07	2.30	1.94	1.39	0.91	0.67	1.55	3.57	47.36
1986	14.69	8.34	3.65	2.86	1.95	2.18	2.32	1.63	1.22	1.00	1.29	78.80	119.93
1987	30.14	15.20	7.59	2.85	15.73	58.52	20.96	6.57	5.03	4.42	4.87	3.99	175.87
1988	3.57	17.56	35.48	11.92	24.21	11.03	10.07	5.57	2.54	2.00	1.39	1.20	126.54
1989	9.35	32.91	12.18	2.54	1.92	7.48	4.59	1.74	0.95	0.68	1.47	2.25	78.06
1990	3.10	3.16	2.34	2.58	3.84	3.55	1.99	1.14	0.91	0.75	0.82	1.47	25.65
1991	7.41	17.67	7.58	2.65	1.95	1.44	1.47	1.24	0.84	0.63	0.68	1.20	44.76
1992	2.09	2.61	2.83	2.45	1.82	1.14	0.83	0.73	0.59	0.49	0.57	1.62	17.77
1993	3.56	4.57	14.43	6.57	31.54	13.49	2.64	1.15	0.64	0.84	1.80	1.85	83.08
1994	1.52	1.35	3.25	3.51	2.17	10.49	25.45	10.18	4.14	3.99	2.44	1.74	70.23
1995	2.41	2.96	39.92	16.41	8.36	4.62	2.11	1.46	1.02	2.53	3.45	2.56	87.81
1996	3.18	44.29	17.51	3.90	11.95	6.69	19.72	8.98	55.77	22.57	4.24	3.31	202.11
month	536.34	907.51	694.35	460.37	590.41	754.85	594.14	367.36	338.55	323.99	208.62	313.27	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.82	1.35	1.68	1.02	1.06	0.90	0.69	0.65	0.54	0.49	0.54	0.49	17.77
max	54.25	65.47	61.23	31.56	50.88	78.95	112.53	41.56	55.77	81.35	30.02	78.80	226.18
median	2.93	5.15	4.69	3.45	3.39	3.92	3.07	2.21	1.72	1.79	1.55	2.01	66.76
mean	6.97	11.79	9.02	5.98	7.67	9.80	7.72	4.77	4.40	4.21	2.71	4.07	79.09
Sum of the monthly means =				79.09									
s.d.	10.24	13.68	10.39	6.03	9.69	13.64	13.99	7.10	8.60	9.95	3.88	9.36	48.08
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.96	2.36	1.43	2.30	0.61

APPENDIX 2.7
T60G

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.94	2.29	13.58	6.77	4.14	12.43	6.37	2.43	1.25	0.70	0.46	0.81	52.17
1921	2.00	25.21	25.70	8.21	2.44	1.38	0.76	14.09	12.62	4.84	2.98	3.31	103.54
1922	21.46	42.53	14.08	38.01	48.79	27.47	6.79	1.40	0.89	26.28	10.92	1.79	240.41
1923	1.27	1.63	2.55	25.90	21.63	5.93	1.12	0.69	0.64	0.57	0.69	1.47	64.09
1924	2.62	7.56	14.64	6.47	4.25	26.03	11.00	2.70	1.59	1.12	0.88	1.59	80.45
1925	2.68	4.59	4.00	7.29	6.31	31.59	12.05	1.94	2.30	2.34	1.52	1.74	78.35
1926	6.29	16.81	13.56	5.01	2.46	43.99	16.18	1.25	0.66	0.47	0.50	0.89	108.07
1927	2.24	2.33	3.57	8.05	12.67	5.86	2.16	1.38	1.15	0.89	1.32	1.63	43.25
1928	2.04	4.43	3.95	3.41	2.87	10.34	4.91	1.69	20.51	15.19	5.74	18.78	93.86
1929	28.61	24.26	7.91	2.69	2.02	2.26	2.60	2.05	2.34	2.80	3.19	15.43	96.16
1930	7.57	3.18	3.01	27.48	25.16	32.49	11.23	1.87	0.95	82.98	29.98	2.37	228.27
1931	2.93	3.58	3.39	2.43	22.74	10.13	2.44	1.83	2.01	2.26	2.01	17.38	73.13
1932	14.82	49.95	41.21	9.89	1.85	2.60	2.28	1.49	1.00	0.77	0.64	0.66	127.16
1933	0.83	15.76	24.89	28.24	9.59	5.38	3.61	2.04	1.32	2.40	2.83	1.70	98.59
1934	1.30	5.06	20.52	8.60	2.19	2.70	19.18	24.36	33.97	11.85	4.30	3.39	137.42
1935	2.55	2.97	2.06	1.41	36.75	35.33	9.52	10.19	5.83	2.78	1.72	1.45	112.56
1936	10.17	66.24	23.19	2.30	16.35	17.30	5.91	1.58	0.89	0.89	1.06	1.16	147.04
1937	1.62	2.12	10.02	6.27	3.48	2.32	5.17	3.59	2.25	2.27	1.99	1.34	42.44
1938	1.32	3.42	8.19	8.53	18.98	8.36	2.94	2.70	2.35	2.46	2.98	29.07	91.30
1939	18.88	5.71	7.50	3.95	1.88	2.19	2.09	4.61	3.66	2.14	1.42	1.26	55.29
1940	1.41	11.18	6.24	2.72	1.59	1.23	1.27	0.99	0.80	0.82	0.85	0.99	30.09
1941	1.85	4.00	3.10	30.53	11.96	2.88	2.50	2.28	1.93	1.19	1.20	1.79	65.21
1942	2.89	50.46	37.88	9.47	2.52	10.47	18.68	7.33	2.49	2.09	8.20	5.31	157.79
1943	9.13	22.78	17.40	5.79	10.30	5.35	2.18	1.41	1.12	1.24	1.11	18.48	96.29
1944	12.17	4.33	1.93	2.33	7.33	8.15	3.74	1.71	1.24	0.99	0.78	1.11	45.81
1945	29.43	11.55	1.64	1.47	5.55	17.52	7.88	2.49	1.45	1.06	0.80	0.85	81.69
1946	1.49	12.24	6.65	3.30	3.44	18.11	20.16	7.22	12.48	6.53	2.34	1.80	95.76
1947	2.00	61.04	28.94	5.25	16.18	12.35	4.86	2.22	1.13	0.64	0.46	0.44	135.51
1948	8.37	5.62	3.68	3.19	36.22	20.44	5.65	2.64	1.34	0.82	0.76	1.05	89.78
1949	2.07	23.55	10.17	11.35	7.32	3.92	3.60	4.48	3.21	2.20	2.75	2.80	77.42
1950	3.14	2.94	24.55	13.58	3.98	5.28	3.33	1.59	1.10	0.91	1.11	1.76	63.27
1951	16.48	7.11	12.36	12.43	5.25	3.49	4.05	3.10	1.81	1.11	0.71	1.18	69.08
1952	1.79	2.10	2.17	2.14	2.58	2.75	2.51	1.81	1.09	0.72	0.78	2.06	22.50
1953	9.45	27.71	20.90	6.40	2.47	3.15	2.53	2.10	2.39	2.20	1.51	1.90	82.71
1954	45.82	18.03	3.09	20.12	26.65	13.32	4.27	1.92	1.31	0.98	0.64	1.31	137.46
1955	2.60	4.76	2.95	1.08	2.01	31.91	13.45	3.16	2.26	1.74	1.23	1.61	68.76
1956	9.89	41.77	63.54	24.46	7.06	19.49	21.63	7.19	2.03	1.58	1.44	2.51	202.59
1957	10.91	12.06	10.55	15.96	26.42	10.14	16.31	6.91	1.35	0.92	0.84	0.93	113.30
1958	1.38	11.09	6.83	2.76	2.44	2.89	2.92	46.44	17.49	2.72	3.42	3.57	103.95
1959	3.53	3.77	3.76	3.36	2.74	5.59	4.49	3.80	2.82	1.79	1.58	2.22	39.45
1960	2.66	12.10	19.30	12.55	4.71	4.90	39.57	15.46	2.67	2.37	2.19	1.83	120.31
1961	1.91	16.32	9.26	3.79	4.41	17.62	7.41	1.93	1.29	0.79	1.10	1.60	67.43
1962	6.69	23.24	9.60	24.98	10.30	55.17	20.55	2.46	1.77	18.95	8.46	1.91	184.08
1963	3.38	13.43	7.97	27.34	18.54	10.29	13.73	5.76	39.70	15.68	2.37	2.00	160.19
1964	16.92	7.62	2.13	2.17	2.16	1.39	0.80	1.03	27.92	12.54	6.76	4.96	86.40
1965	37.01	28.14	7.78	2.96	2.59	1.54	0.87	18.42	8.45	2.09	1.46	1.93	113.24
1966	2.27	2.35	2.80	11.28	6.19	37.42	28.67	7.40	1.97	3.80	3.44	1.96	109.55
1967	1.52	4.66	3.53	2.31	2.38	2.36	2.02	1.35	0.80	0.63	1.08	2.74	25.38
1968	6.59	13.03	6.53	2.56	12.94	26.00	9.38	17.98	8.07	2.23	1.68	1.57	108.56
1969	2.39	11.06	6.05	2.38	1.97	1.57	1.09	1.08	1.74	1.90	17.81	9.87	58.91
1970	38.22	24.01	6.50	3.32	3.42	3.26	3.12	25.17	10.31	3.98	16.23	7.85	145.39
1971	34.21	14.75	4.37	3.42	31.04	12.35	2.25	1.42	1.12	1.11	1.06	0.94	108.04
1972	0.97	10.51	6.53	3.36	2.74	2.77	7.30	3.92	1.29	0.75	1.16	2.67	43.97
1973	5.28	24.13	9.97	2.82	6.71	8.33	4.28	22.72	10.36	3.18	1.89	1.29	100.96
1974	1.44	3.11	10.06	5.28	2.84	2.86	2.52	1.79	1.12	0.84	0.84	22.92	55.62
1975	10.06	3.04	19.42	8.74	26.65	80.81	28.77	12.10	5.61	1.86	1.28	2.11	200.45
1976	58.38	21.71	2.43	2.57	16.85	7.91	2.36	1.25	0.94	1.00	1.47	2.52	119.39
1977	8.36	26.84	28.48	9.29	2.87	2.79	117.03	42.46	3.56	2.17	1.64	2.00	247.49
1978	18.60	13.91	4.95	2.46	2.17	6.90	4.05	1.76	1.11	2.08	3.33	3.61	64.93
1979	8.30	5.03	3.06	2.32	2.24	2.29	1.70	1.29	1.05	0.85	0.75	13.17	42.05
1980	7.10	19.68	10.59	9.19	4.99	2.46	1.43	2.13	2.61	1.84	2.23	2.54	66.79
1981	2.00	2.13	2.20	2.64	2.55	33.49	14.48	3.17	1.85	1.36	1.00	0.93	67.80
1982	2.06	2.74	1.89	1.35	1.32	1.11	0.91	0.75	0.58	21.68	9.72	2.77	46.88
1983	3.08	14.32	7.51	11.95	6.43	3.42	4.17	3.31	2.70	9.67	5.42	2.62	74.60
1984	2.64	19.91	9.24	3.52	57.55	21.21	2.02	1.07	0.71	0.67	0.54	0.48	119.56
1985	5.75	20.63	8.82	14.49	6.40	2.22	2.06	1.48	0.93	0.65	1.65	8.54	73.62
1986	19.78	11.96	4.13	2.89	2.16	2.58	2.74	1.86	1.32	1.03	1.35	81.53	133.33
1987	30.57	20.51	9.10	2.83	24.24	62.44	20.93	12.10	6.33	5.23	5.72	3.85	203.85
1988	3.44	24.34	40.93	12.70	30.53	12.86	16.26	7.18	2.16	1.80	1.26	1.14	154.60
1989	16.66	37.47	12.55	2.55	2.13	16.94	7.31	1.46	0.82	0.58	1.48	2.36	102.31
1990	4.82	3.72	2.48	4.08	11.99	5.71	1.76	1.07	0.88	0.71	0.79	1.53	39.54
1991	15.36	23.24	8.23	2.65	2.17	1.67	1.73	1.42	0.90	0.63	0.68	1.26	59.94
1992	2.30	2.94	3.32	2.97	2.25	1.40	0.99	0.83	0.63	0.49	0.56	1.76	20.44
1993	9.03	8.42	19.97	7.91	37.76	15.29	2.49	1.09	0.59	0.81	1.88	1.95	107.19
1994	1.60	1.44	12.65	6.37	2.11	19.11	30.96	10.57	6.64	4.35	2.01	1.54	99.35
1995	2.44	3.20	47.44	21.26	14.62	6.10	1.93	1.43	0.99	5.78	4.22	2.33	111.74
1996	5.52	48.23	18.26	8.65	18.71	8.09	25.24	10.37	56.64	22.88	3.79	3.02	229.40
month	707.25	1171.59	905.88	642.50	822.19	989.14	709.20	442.71	377.15	357.21	229.94	370.49	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.83	1.44	1.64	1.08	1.32	1.11	0.76	0.69	0.58	0.47	0.46	0.44	20.44
max	58.38	66.24	63.54	38.01	57.55	80.81	117.03	46.44	56.64	82.98	29.98	81.53	247.49
median	3.44	11.55	7.97	5.25	4.99	6.90	4.05	2.13	1.74	1.80	1.48	1.91	95.76
mean	9.19	15.22	11.76	8.34	10.68	12.85	9.21	5.75	4.90	4.64	2.99	4.81	100.33

Sum of the monthly means = 100.33

s.d.	11.50	14.53	11.73	8.19	12.01	15.04	15.01	8.50	9.31	10.56	4.46	10.38	52.39
c.v.	1.25	0.95	1.00	0.98	1.12	1.17	1.63	1.48	1.90	2.28	1.49	2.16	0.52

APPENDIX 2.8
T60H

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.85	2.39	14.11	6.82	9.25	19.64	9.08	3.05	1.65	0.99	0.65	1.05	69.53
1921	2.31	27.56	27.17	8.32	2.53	1.65	1.06	25.15	21.08	6.38	4.99	4.03	132.23
1922	24.05	42.86	13.57	41.72	55.16	35.16	8.84	1.66	1.24	35.73	13.99	1.77	275.75
1923	1.22	1.46	2.33	29.86	27.13	7.34	1.29	0.98	0.99	0.88	1.02	1.96	76.46
1924	3.07	9.25	15.73	6.53	9.38	33.92	14.73	3.59	2.07	1.57	1.24	2.06	103.14
1925	3.10	6.10	4.13	9.98	11.09	39.18	14.27	2.38	5.37	3.77	1.96	2.17	103.50
1926	10.55	17.28	13.75	5.03	2.58	53.91	19.52	1.46	0.91	0.68	0.70	1.16	127.53
1927	3.31	2.44	4.68	10.92	17.49	7.38	2.53	1.90	1.76	1.38	1.96	2.23	57.98
1928	2.39	6.22	4.18	4.32	3.23	18.03	7.52	2.05	31.00	22.22	6.95	23.02	131.13
1929	30.65	23.61	7.28	2.49	2.12	4.76	3.95	2.86	7.02	4.79	7.91	20.12	117.56
1930	8.29	2.68	2.55	30.86	30.80	40.27	13.48	2.26	1.33	95.47	34.08	2.35	264.42
1931	4.93	3.69	2.79	2.14	28.83	15.22	3.55	2.33	2.93	3.36	2.94	25.01	97.72
1932	17.66	49.70	42.00	10.01	1.96	5.97	3.71	2.01	1.52	1.20	0.96	0.91	137.61
1933	0.97	18.61	26.60	31.43	10.62	12.94	6.25	2.50	1.87	10.32	5.34	1.66	129.11
1934	1.24	6.27	21.64	8.70	2.25	10.19	26.71	32.56	41.60	13.66	9.77	5.01	179.60
1935	2.31	2.63	1.70	1.26	43.75	43.99	11.70	18.84	8.87	3.20	2.10	1.76	142.11
1936	14.52	67.61	22.85	2.10	22.22	24.87	7.87	1.88	1.24	1.29	1.52	1.55	169.52
1937	1.88	2.12	11.88	9.19	4.37	2.59	13.95	6.63	2.78	3.08	2.74	1.76	62.97
1938	1.50	5.40	9.30	11.10	24.20	13.13	4.22	4.73	3.58	4.10	4.57	35.75	121.58
1939	21.36	5.38	7.59	3.86	1.93	3.15	2.92	15.22	7.23	2.39	1.72	1.52	74.27
1940	1.54	13.16	6.56	2.50	1.61	1.53	1.81	1.55	1.33	1.33	1.32	1.38	35.62
1941	2.19	5.92	3.37	34.08	13.17	7.97	4.32	2.93	2.80	1.79	1.75	2.40	82.69
1942	5.54	51.50	38.78	9.62	2.63	18.83	27.14	9.42	3.10	2.83	16.97	7.99	194.35
1943	10.52	22.42	17.67	5.84	15.62	7.29	2.66	2.00	1.75	1.93	1.68	26.14	115.52
1944	14.99	3.98	1.48	3.81	11.76	14.86	5.60	2.07	1.75	1.46	1.14	1.47	64.37
1945	35.08	13.01	1.26	1.30	11.24	25.32	10.91	3.18	1.92	1.50	1.14	1.12	106.98
1946	1.71	14.50	7.04	3.13	8.30	25.05	27.60	9.35	21.03	9.35	2.48	2.00	131.54
1947	2.11	63.51	30.37	5.32	21.71	19.58	6.85	2.71	1.58	0.95	0.67	0.58	155.94
1948	13.52	6.86	3.14	2.96	42.75	28.19	10.53	3.80	1.61	1.08	1.02	1.35	116.81
1949	2.37	25.76	10.54	14.28	12.18	8.10	8.21	11.82	5.30	2.47	5.53	3.80	110.36
1950	4.45	2.94	25.19	16.31	4.80	12.75	5.89	1.90	1.54	1.34	1.60	2.34	81.05
1951	21.35	8.30	12.99	15.26	6.16	10.61	10.73	4.69	2.17	1.46	0.95	1.50	96.17
1952	2.05	2.07	1.97	2.06	4.07	3.67	3.35	2.69	1.77	1.18	1.20	5.24	31.32
1953	12.54	27.64	21.25	6.46	2.59	11.18	5.24	2.62	3.44	3.25	2.21	2.53	100.95
1954	51.84	19.52	2.56	23.21	32.31	20.20	6.18	2.33	1.86	1.45	0.94	1.72	164.12
1955	3.03	6.35	3.12	0.87	6.72	39.31	20.22	4.84	2.71	2.30	1.66	2.07	93.20
1956	14.36	42.72	64.75	27.52	11.80	26.72	29.32	9.23	2.48	2.12	1.97	6.61	239.60
1957	13.30	11.42	10.68	18.58	31.84	16.03	23.14	8.79	1.57	1.19	1.12	1.19	138.85
1958	1.56	13.27	7.93	2.71	3.37	4.75	4.33	57.97	21.34	3.15	9.18	5.34	134.90
1959	3.37	3.41	3.26	3.07	2.86	13.80	10.84	8.39	4.11	2.08	1.99	2.75	59.93
1960	2.98	13.64	20.44	15.26	5.57	12.37	48.37	18.17	3.33	3.13	2.98	2.37	148.61
1961	2.18	18.14	10.26	3.80	9.54	25.23	9.47	2.36	1.82	1.17	1.59	2.14	87.70
1962	11.44	23.97	8.99	28.28	11.47	64.59	23.89	3.08	2.56	29.03	11.70	1.90	220.90
1963	6.19	13.60	8.10	30.46	23.59	16.96	20.81	7.66	48.95	18.77	2.53	2.25	199.87
1964	20.54	8.37	1.68	2.00	2.32	1.69	1.13	1.64	40.44	18.80	11.26	6.44	116.31
1965	38.18	27.66	7.16	2.78	2.78	1.85	1.22	29.89	12.36	2.34	1.78	2.34	130.34
1966	2.52	2.27	2.58	14.76	9.81	44.75	36.70	9.47	2.41	12.24	6.15	1.95	145.61
1967	1.48	5.75	3.56	2.10	2.59	2.98	2.86	2.09	1.33	1.03	1.64	9.75	37.16
1968	8.51	11.92	6.07	2.28	18.36	33.98	11.56	27.21	11.23	2.52	2.06	1.91	137.61
1969	2.66	12.57	6.19	2.13	2.10	1.94	1.54	1.71	2.82	3.03	28.26	14.81	79.76
1970	39.60	23.55	5.91	3.77	6.46	4.40	5.73	35.28	13.48	10.13	22.10	8.96	179.37
1971	36.18	14.47	4.40	3.40	37.31	14.63	2.75	2.02	1.75	1.74	1.61	1.31	121.57
1972	1.14	13.13	7.78	3.35	2.89	5.82	15.72	6.46	1.48	0.96	1.56	7.44	67.73
1973	7.36	23.49	9.36	2.63	12.28	15.65	6.24	32.47	15.27	3.92	2.14	1.48	132.29
1974	1.53	4.69	11.08	5.31	3.03	5.10	3.75	2.52	1.74	1.33	1.28	30.64	72.00
1975	12.27	2.56	20.03	8.87	32.81	90.30	36.62	19.85	7.66	2.04	1.54	2.90	237.45
1976	62.82	22.68	1.96	2.42	22.99	11.07	3.00	1.63	1.40	1.51	2.15	4.52	138.15
1977	12.03	27.09	28.98	9.43	3.04	5.69	130.54	51.44	5.25	2.42	1.99	2.43	280.33
1978	23.08	14.39	4.28	2.24	2.33	15.24	6.90	2.13	1.56	7.34	5.42	5.05	89.96
1979	10.19	5.05	2.54	2.07	2.41	2.89	2.39	2.01	1.74	1.40	1.18	21.03	54.90
1980	9.35	19.20	10.88	11.81	5.87	2.84	1.91	9.23	5.20	2.20	4.33	3.40	86.22
1981	2.05	1.97	1.93	3.37	2.88	42.55	22.69	5.03	2.23	1.81	1.35	1.19	89.05
1982	2.19	2.60	1.62	1.22	1.41	1.40	1.32	1.19	0.98	31.97	13.11	2.86	61.87
1983	3.14	15.05	8.12	14.68	10.90	4.70	11.30	5.86	3.38	18.73	8.33	2.68	106.87
1984	2.66	20.90	9.12	3.58	63.41	23.33	2.45	1.51	1.12	1.05	0.82	0.66	130.61
1985	10.90	21.51	8.21	17.27	7.34	2.60	2.81	2.24	1.52	1.07	4.70	14.40	94.57
1986	21.89	11.13	3.46	3.86	2.46	9.31	5.00	2.17	1.84	1.50	1.93	93.12	157.67
1987	33.94	19.02	8.31	2.62	30.52	71.58	24.09	20.73	9.27	11.57	11.19	4.78	247.62
1988	3.90	23.51	41.59	12.86	36.79	19.13	23.22	9.19	2.66	2.42	1.73	1.48	178.48
1989	21.47	38.46	12.02	2.41	2.27	25.61	10.27	1.73	1.14	0.84	2.09	3.10	121.41
1990	9.23	4.68	2.00	6.73	16.92	7.19	2.09	1.52	1.37	1.12	1.19	2.06	56.10
1991	20.37	24.02	7.61	2.47	2.30	2.08	2.46	2.20	1.50	1.05	1.05	1.72	68.83
1992	2.72	2.99	3.69	2.93	2.31	1.67	1.39	1.30	1.05	0.81	0.87	3.25	24.98
1993	12.69	8.47	20.30	7.97	44.21	21.89	3.96	1.22	0.80	1.15	2.76	2.52	127.94
1994	1.77	1.36	14.77	6.96	2.16	27.70	39.89	12.81	14.82	7.02	2.09	1.70	133.05
1995	2.60	3.08	49.38	24.44	19.52	7.54	2.34	2.04	1.56	15.70	7.44	2.36	138.00
1996	8.26	48.77	17.80	11.45	24.08	12.82	32.72	12.70	68.19	29.99	4.84	3.13	274.75
month	845.59	1217.23	921.90	719.50	1047.41	1370.10	963.12	638.08	528.41	515.52	344.37	492.40	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.85	1.36	1.26	0.87	1.41	1.40	1.06	0.98	0.80	0.68	0.65	0.58	24.98
max	62.82	67.61	64.75	41.72	63.41	90.30	130.54	57.97	68.19	95.47	34.08	93.12	280.33
median	5.54	13.01	8.10	5.32	9.25	12.94	6.85	2.86	2.17	2.20	1.99	2.35	121.41
mean	10.98	15.81	11.97	9.34	13.60	17.79	12.51	8.29	6.86	6.70	4.47	6.39	124.72
Sum of the monthly means = 124.72													
s.d.	12.59	14.67	12.14	9.39	13.99	17.25	17.31	11.31	11.85	12.91	6.03	12.37	59.06
c.v.	1.15	0.93	1.01	1.00	1.03	0.97	1.38	1.36	1.73	1.93	1.35	1.93	0.47

APPENDIX 2.9
T60J

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.69	1.47	5.47	3.51	2.70	11.61	5.96	2.39	1.41	0.85	0.56	0.80	37.42
1921	1.60	15.59	15.86	5.37	1.83	1.13	0.73	14.82	13.51	4.80	2.70	2.88	80.82
1922	15.11	29.23	9.65	27.06	38.03	23.56	6.13	1.41	1.02	24.30	9.95	1.55	187.00
1923	0.98	1.04	1.49	16.54	15.94	4.86	1.08	0.78	0.77	0.69	0.78	1.38	46.33
1924	2.07	2.63	7.36	3.97	2.54	22.20	9.60	2.65	1.77	1.31	1.01	1.50	58.61
1925	2.14	2.40	2.32	2.54	4.36	27.08	10.41	1.93	2.46	2.53	1.67	1.67	61.51
1926	3.72	9.17	6.44	2.84	1.85	36.42	13.53	1.25	0.77	0.58	0.57	0.87	78.01
1927	1.77	1.57	1.70	3.15	9.14	4.87	2.03	1.47	1.33	1.06	1.42	1.59	31.10
1928	1.65	2.21	2.28	2.17	1.95	8.72	4.27	1.70	20.70	14.96	5.24	14.96	80.81
1929	20.56	14.80	4.78	1.78	1.39	1.82	2.35	2.08	2.52	3.00	3.73	12.95	71.76
1930	5.98	2.07	1.73	17.38	18.64	27.66	9.76	1.85	1.09	70.79	25.59	2.01	184.55
1931	2.19	2.31	1.97	1.39	16.28	7.71	2.27	1.92	2.23	2.48	2.16	15.27	58.18
1932	10.04	35.16	28.18	6.69	1.41	2.19	2.10	1.55	1.17	0.93	0.75	0.69	90.86
1933	0.70	8.87	15.30	19.68	7.10	5.65	3.54	2.03	1.48	4.44	3.20	1.47	73.46
1934	1.00	1.84	12.09	5.55	1.65	2.70	16.93	23.08	30.77	10.53	5.27	3.30	114.71
1935	1.88	1.87	1.15	0.79	27.42	29.27	8.35	11.82	6.18	2.68	1.73	1.37	94.51
1936	6.68	48.45	16.96	1.52	11.48	14.71	5.38	1.58	1.02	1.02	1.16	1.15	111.11
1937	1.32	1.41	3.12	3.00	2.66	1.98	6.43	3.91	2.31	2.40	2.09	1.34	31.97
1938	1.09	1.84	2.64	4.31	14.76	6.89	2.74	2.77	2.61	2.70	3.11	24.82	70.28
1939	13.32	3.51	2.41	1.89	1.42	1.84	1.94	7.47	4.44	2.08	1.44	1.20	42.96
1940	1.14	4.90	3.36	1.79	1.07	0.99	1.17	1.04	0.92	0.95	0.95	0.98	19.26
1941	1.49	2.20	1.79	20.55	8.34	2.49	2.34	2.36	2.16	1.40	1.33	1.72	48.17
1942	2.31	35.44	25.25	6.30	1.90	9.33	17.21	6.82	2.55	2.23	9.78	5.26	124.38
1943	4.76	13.36	9.36	3.43	7.36	4.17	2.06	1.50	1.30	1.42	1.24	16.00	65.96
1944	7.96	2.47	1.17	1.44	3.93	7.34	3.65	1.71	1.39	1.15	0.90	1.08	34.19
1945	22.25	8.58	0.99	0.86	2.69	15.02	7.08	2.45	1.61	1.24	0.93	0.87	64.57
1946	1.21	5.71	3.65	2.20	2.43	15.13	18.29	6.76	13.90	6.70	2.15	1.61	79.74
1947	1.56	44.08	18.33	2.99	12.03	11.04	4.61	2.19	1.27	0.78	0.56	0.47	99.91
1948	5.76	3.83	2.26	1.93	26.79	17.16	5.24	2.49	1.44	0.95	0.86	1.03	69.74
1949	1.66	14.44	6.39	5.84	4.76	3.32	3.90	7.13	3.90	2.13	2.66	2.55	58.68
1950	2.46	1.95	14.36	7.49	2.66	5.56	3.29	1.59	1.24	1.06	1.21	1.67	44.54
1951	11.72	4.98	5.34	6.75	3.66	3.92	4.80	3.17	1.87	1.24	0.81	1.12	49.38
1952	1.45	1.40	1.26	1.26	1.75	2.17	2.25	1.83	1.25	0.87	0.89	1.89	18.27
1953	5.96	17.57	12.09	3.90	1.86	3.38	2.49	2.09	2.57	2.41	1.66	1.81	57.79
1954	35.30	13.60	1.89	12.06	20.04	12.10	4.11	1.91	1.47	1.14	0.76	1.24	105.62
1955	2.06	2.44	1.61	0.64	1.44	26.27	12.52	3.26	2.27	1.85	1.33	1.53	57.22
1956	6.46	28.84	46.05	16.70	5.03	17.16	19.77	6.68	2.09	1.72	1.54	2.31	154.35
1957	7.07	5.30	4.09	9.98	20.58	8.83	15.03	6.36	1.40	1.03	0.93	0.92	81.52
1958	1.12	4.85	3.54	1.82	1.78	2.36	2.65	41.87	15.81	2.61	4.03	3.30	85.74
1959	2.63	2.41	2.18	1.98	1.80	4.71	4.37	4.29	2.95	1.84	1.64	2.05	32.85
1960	2.11	5.20	10.81	7.31	3.23	5.25	34.24	13.46	2.73	2.51	2.30	1.78	90.93
1961	1.56	8.74	4.87	2.45	2.66	15.91	6.82	1.92	1.44	0.94	1.20	1.54	50.05
1962	4.06	14.11	6.05	16.55	7.15	45.94	17.27	2.43	1.96	18.97	8.14	1.64	144.27
1963	2.04	6.71	4.10	19.15	14.01	9.67	13.21	5.47	35.92	14.11	2.17	1.78	128.34
1964	11.66	5.20	1.29	1.30	1.44	1.06	0.73	1.08	26.54	11.80	7.02	4.44	73.56
1965	26.83	17.70	4.66	1.97	1.81	1.20	0.81	18.38	8.24	2.03	1.48	1.77	86.88
1966	1.80	1.54	1.64	4.81	3.63	31.64	25.47	6.85	2.03	6.50	4.02	1.69	91.62
1967	1.17	1.89	1.89	1.46	1.65	1.88	1.83	1.39	0.93	0.75	1.16	2.84	18.84
1968	3.31	6.08	3.70	1.68	8.79	21.93	8.25	18.13	7.96	2.17	1.69	1.48	85.17
1969	1.88	4.30	3.05	1.56	1.37	1.24	1.01	1.14	1.88	2.07	17.42	8.29	45.21
1970	28.55	14.78	3.64	2.21	2.42	2.60	2.80	24.61	9.97	5.75	15.03	6.68	119.04
1971	24.67	10.13	2.54	2.18	23.18	9.54	2.11	1.50	1.30	1.29	1.19	0.96	80.59
1972	0.82	4.71	3.53	2.27	1.97	2.26	8.02	4.09	1.34	0.86	1.23	2.41	33.51
1973	3.15	15.04	6.41	1.87	3.77	7.60	4.12	22.26	9.97	3.05	1.90	1.24	80.38
1974	1.16	1.83	3.50	2.65	2.15	2.37	2.31	1.84	1.29	1.01	0.96	19.24	40.31
1975	8.17	1.97	10.00	5.05	20.40	66.35	25.47	13.15	5.70	1.81	1.31	1.90	161.28
1976	45.03	16.50	1.48	1.56	11.57	5.92	2.21	1.33	1.10	1.16	1.57	2.34	91.77
1977	5.14	16.89	18.07	6.17	2.16	2.31	97.35	37.82	4.01	2.11	1.65	1.84	195.52
1978	13.41	6.87	2.45	1.62	1.52	6.08	3.64	1.76	1.25	2.15	3.21	3.23	47.19
1979	4.81	3.08	1.87	1.37	1.50	1.80	1.52	1.33	1.19	1.00	0.86	11.57	31.90
1980	5.83	10.82	5.48	4.86	3.34	2.11	1.37	2.65	2.80	1.93	2.26	2.37	45.82
1981	1.64	1.40	1.27	1.59	1.70	27.30	13.50	3.39	1.91	1.49	1.10	0.93	57.22
1982	1.65	1.84	1.09	0.76	0.86	0.87	0.84	0.79	0.68	20.61	9.01	2.34	41.34
1983	2.32	6.56	3.99	6.78	4.29	2.93	5.80	3.76	2.75	11.51	5.70	2.22	58.61
1984	1.99	11.13	5.49	2.34	44.34	16.61	1.90	1.15	0.86	0.80	0.64	0.51	87.76
1985	3.65	12.16	5.43	8.25	4.07	1.93	1.95	1.56	1.09	0.80	1.71	7.82	50.42
1986	13.85	6.10	2.16	1.92	1.48	2.24	2.40	1.79	1.45	1.18	1.44	66.73	102.74
1987	24.70	11.21	5.28	1.87	17.73	51.30	17.62	13.60	6.66	6.97	6.55	3.44	166.93
1988	2.52	13.95	27.52	8.93	23.67	10.55	15.08	6.67	2.22	1.94	1.37	1.13	115.55
1989	12.08	25.45	8.46	1.70	1.48	14.20	6.27	1.46	0.94	0.70	1.52	2.18	76.44
1990	2.66	2.34	1.55	1.89	8.47	4.50	1.66	1.16	1.04	0.86	0.89	1.45	28.47
1991	10.83	14.23	5.05	1.75	1.50	1.33	1.58	1.46	1.04	0.76	0.77	1.21	41.51
1992	1.83	1.95	1.96	1.76	1.47	1.06	0.90	0.87	0.74	0.59	0.64	1.61	15.38
1993	5.59	3.94	11.79	5.07	29.43	12.68	2.36	1.08	0.69	0.92	1.91	1.85	77.31
1994	1.31	0.96	5.46	3.43	1.58	16.32	27.16	9.46	9.19	4.93	1.85	1.39	83.04
1995	1.87	2.09	31.98	13.39	11.13	5.02	1.83	1.52	1.16	8.15	4.68	1.99	84.81
1996	2.51	33.87	12.95	3.71	13.94	6.67	23.11	9.56	49.79	21.22	3.68	2.54	183.55
month	508.98	729.06	540.32	396.23	601.31	835.49	636.88	437.83	374.68	356.25	231.52	322.55	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.69	0.96	0.99	0.64	0.86	0.87	0.73	0.78	0.68	0.58	0.56	0.47	15.38
max	45.03	48.45	46.05	27.06	44.34	66.35	97.35	41.87	49.79	70.79	25.59	66.73	195.52
median	2.51	5.20	3.99	2.65	3.23	5.92	4.11	2.19	1.87	1.85	1.57	1.77	73.46
mean	6.61	9.47	7.02	5.15	7.81	10.85	8.27	5.69	4.87	4.63	3.01	4.19	77.55
Sum of the monthly means = 77.55													
s.d.	8.66	10.35	8.13	5.56	9.24	12.45	12.65	7.88	8.43	9.22	4.04	8.54	42.14
c.v.	1.31	1.09	1.16	1.08	1.18	1.15	1.53	1.39	1.73	1.99	1.34	2.04	0.54

APPENDIX 2.10
T60K

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.56	1.16	3.56	2.55	2.13	8.64	4.58	1.92	1.14	0.69	0.45	0.64	28.02
1921	1.26	11.86	12.01	4.15	1.45	0.89	0.57	11.18	10.41	3.83	2.19	2.30	62.10
1922	11.48	22.82	7.62	20.95	29.81	18.36	4.81	1.15	0.83	18.99	7.85	1.26	145.93
1923	0.79	0.83	1.16	12.29	12.03	3.77	0.88	0.63	0.62	0.55	0.62	1.09	35.26
1924	1.60	2.00	3.71	2.49	2.59	17.24	7.42	2.08	1.41	1.08	0.87	1.24	43.73
1925	1.62	1.70	1.62	1.76	3.77	19.21	7.49	1.61	2.11	2.17	1.41	1.37	45.84
1926	3.95	7.49	3.90	1.87	1.46	25.91	9.76	1.01	0.63	0.47	0.46	0.68	57.59
1927	1.42	1.25	1.26	1.76	3.91	2.90	1.69	1.27	1.15	0.91	1.19	1.29	20.00
1928	1.38	1.96	1.98	1.75	1.54	7.44	3.58	1.37	17.74	13.72	4.72	10.68	67.86
1929	18.08	13.13	3.99	1.29	0.97	1.30	1.73	1.58	2.02	2.48	2.66	11.37	60.60
1930	5.16	1.57	1.26	11.22	12.22	20.57	7.42	1.39	0.83	53.94	19.62	1.66	136.86
1931	1.76	1.73	1.40	1.00	7.21	4.27	1.87	1.63	1.89	2.08	1.84	11.75	38.43
1932	8.18	29.29	21.89	5.06	1.22	2.02	2.01	1.54	1.17	0.91	0.71	0.60	74.60
1933	0.57	5.62	11.64	16.07	5.75	4.96	3.01	1.62	1.18	4.28	2.84	1.19	58.73
1934	0.82	1.61	10.72	4.78	1.28	1.72	14.57	20.29	23.07	7.78	3.88	2.66	93.18
1935	1.70	1.60	0.94	0.68	22.99	24.58	6.97	9.43	4.94	2.20	1.49	1.23	78.75
1936	5.69	39.09	13.72	1.28	10.32	11.83	4.26	1.31	0.86	0.92	1.11	1.06	91.45
1937	1.10	1.17	2.44	2.28	1.88	1.40	5.30	3.25	1.94	2.04	1.76	1.13	25.69
1938	0.90	1.57	2.95	3.05	14.91	7.47	2.36	1.99	1.84	2.06	2.29	18.38	59.77
1939	10.00	2.84	2.03	1.63	1.50	1.86	1.69	4.93	3.17	1.58	1.07	1.02	33.32
1940	1.00	4.56	2.85	1.36	0.81	0.87	1.07	0.91	0.81	0.85	0.84	0.81	16.74
1941	1.16	1.72	1.35	11.09	4.99	2.86	2.30	2.61	2.22	1.32	1.12	1.37	34.11
1942	1.80	32.29	21.42	5.13	1.62	6.31	13.42	5.58	2.15	1.82	9.36	4.76	105.66
1943	3.38	10.09	6.46	2.50	4.17	3.72	2.34	1.48	1.18	1.19	1.00	16.47	53.98
1944	7.84	2.13	1.01	1.14	4.48	6.57	3.02	1.35	1.09	0.90	0.70	0.87	31.10
1945	18.41	7.09	0.80	0.64	1.30	10.22	5.14	1.94	1.31	0.99	0.72	0.67	49.23
1946	0.94	2.11	1.96	1.58	1.74	12.22	13.94	5.11	11.20	5.44	1.78	1.39	59.41
1947	1.34	35.38	15.36	2.54	7.69	9.39	4.33	2.06	1.20	0.72	0.52	0.42	80.95
1948	4.74	3.15	1.78	1.48	16.92	12.57	4.35	2.07	1.20	0.78	0.68	0.81	50.53
1949	1.25	9.49	4.38	2.27	3.15	2.62	2.44	5.40	3.14	1.79	2.18	2.04	40.15
1950	1.96	1.51	8.79	4.53	1.80	1.93	1.84	1.30	0.97	0.80	0.88	1.32	27.63
1951	9.65	4.08	3.67	7.24	3.67	7.28	5.18	2.68	1.71	1.18	0.78	1.04	48.16
1952	1.31	1.20	1.07	1.10	1.42	1.65	1.68	1.38	0.99	0.72	0.71	1.62	14.85
1953	6.75	15.63	7.53	2.32	1.38	2.08	1.85	1.76	2.24	2.14	1.47	1.50	46.65
1954	25.81	10.06	1.50	6.88	14.86	6.92	2.36	1.47	1.17	0.93	0.61	1.02	73.59
1955	1.74	2.07	1.34	0.52	1.08	22.40	10.12	2.58	2.07	1.74	1.25	1.35	48.26
1956	5.09	24.81	35.92	11.57	2.65	13.65	16.11	5.52	1.86	1.56	1.35	1.93	122.02
1957	4.16	3.09	2.42	7.71	15.03	6.11	12.20	5.23	1.15	0.91	0.89	0.89	59.79
1958	1.03	5.11	3.24	1.49	1.31	1.60	1.80	26.37	10.29	2.19	3.67	3.03	61.13
1959	2.47	2.20	1.93	1.70	1.50	2.49	3.91	3.11	2.13	1.43	1.26	1.65	25.78
1960	1.85	3.30	10.02	7.50	3.02	2.29	27.46	11.01	2.13	1.81	1.59	1.26	73.24
1961	1.16	5.86	3.60	2.00	2.09	13.85	5.86	1.55	1.16	0.77	0.92	1.13	39.95
1962	3.75	10.33	4.51	13.45	5.81	38.48	14.45	1.94	1.49	14.57	6.34	1.32	116.44
1963	1.72	4.81	3.06	12.96	10.32	7.22	8.47	3.75	31.16	12.14	1.73	1.38	98.72
1964	8.39	3.88	1.07	1.06	1.21	0.91	0.61	0.86	19.25	9.12	4.43	3.31	54.10
1965	23.62	15.87	4.07	1.59	1.48	1.01	0.67	14.16	6.45	1.66	1.18	1.32	73.08
1966	1.35	1.22	1.33	3.78	2.84	27.73	22.20	5.86	1.70	3.76	2.77	1.38	75.92
1967	0.94	1.57	1.60	1.20	1.29	1.46	1.42	1.08	0.71	0.56	0.92	2.68	15.43
1968	3.31	5.35	2.96	1.20	5.66	16.88	6.64	13.80	6.11	1.66	1.23	1.02	65.82
1969	1.33	2.92	2.32	1.28	1.29	1.22	0.93	0.95	1.48	1.60	15.23	7.11	37.66
1970	25.43	12.46	2.84	1.68	1.89	2.03	2.22	17.74	7.35	3.73	13.72	5.98	97.07
1971	18.67	7.78	1.97	1.59	15.11	6.43	1.52	1.07	0.98	0.98	0.89	0.71	57.70
1972	0.62	1.43	1.96	1.67	1.42	1.61	3.34	2.30	1.10	0.69	0.89	1.56	18.59
1973	2.12	7.47	3.39	1.22	1.70	5.62	3.30	17.08	7.62	2.20	1.34	0.87	53.93
1974	0.78	1.36	2.89	2.20	1.61	1.74	1.69	1.33	0.95	0.75	0.69	10.38	26.37
1975	4.88	1.61	10.71	5.05	14.89	52.75	18.19	9.84	4.64	1.51	1.08	1.44	126.59
1976	34.62	12.80	1.21	1.13	7.78	4.23	1.70	0.99	0.78	0.79	1.09	1.65	68.77
1977	2.36	12.95	14.34	4.88	1.68	1.77	75.53	28.93	3.04	1.67	1.32	1.52	149.99
1978	11.79	5.97	2.06	1.28	1.13	3.81	2.56	1.37	0.97	1.73	2.71	2.65	38.03
1979	2.68	2.07	1.45	1.05	1.13	1.40	1.21	1.03	0.89	0.73	0.62	6.38	20.64
1980	3.65	6.63	3.67	3.58	2.69	1.80	1.10	2.71	2.47	1.54	1.77	1.86	33.47
1981	1.24	1.03	0.97	1.25	1.36	20.42	8.67	2.08	1.43	1.11	0.82	0.65	41.03
1982	1.01	1.13	0.69	0.52	0.63	0.63	0.57	0.52	0.45	12.03	5.75	1.97	25.90
1983	1.90	3.94	2.76	3.37	2.74	2.12	2.28	2.20	1.86	5.37	3.37	1.82	33.73
1984	1.53	2.48	2.23	1.80	35.58	13.29	1.41	0.82	0.61	0.58	0.46	0.37	61.16
1985	2.72	10.47	4.60	3.77	2.30	1.44	1.37	1.07	0.76	0.57	1.36	5.26	35.69
1986	10.63	4.87	1.72	1.55	1.22	1.57	1.79	1.37	1.10	0.88	1.07	54.38	82.15
1987	20.13	9.53	4.46	1.63	19.63	44.19	14.56	10.20	5.10	4.44	5.16	2.89	141.92
1988	2.10	10.65	19.03	6.22	16.44	7.24	10.15	4.75	1.76	1.52	1.08	0.90	81.84
1989	7.95	18.94	6.44	1.22	1.04	9.89	4.54	1.15	0.73	0.54	1.07	1.49	55.00
1990	1.93	1.75	1.14	1.37	2.65	2.24	1.30	0.86	0.74	0.61	0.64	0.98	16.21
1991	5.44	8.97	3.50	1.11	0.89	0.85	1.08	1.04	0.75	0.55	0.56	0.87	25.61
1992	1.29	1.36	1.58	1.42	1.01	0.72	0.66	0.62	0.49	0.38	0.42	2.96	12.91
1993	6.53	3.50	10.03	4.24	24.93	10.21	1.85	0.94	0.59	0.76	1.78	1.81	67.17
1994	1.14	0.65	7.33	3.69	1.16	12.71	24.43	8.45	5.22	3.26	1.48	1.02	70.54
1995	1.25	1.31	23.07	10.64	4.89	2.64	1.51	1.20	0.86	10.93	5.29	1.57	65.16
1996	2.61	25.21	9.61	4.60	6.17	3.33	14.39	6.43	37.02	16.21	2.99	2.12	130.69
month	404.27	561.49	414.77	292.45	439.19	647.53	493.00	334.14	290.93	275.79	186.56	255.53	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.56	0.65	0.69	0.52	0.63	0.63	0.57	0.52	0.45	0.38	0.42	0.37	12.91
max	34.62	39.09	35.92	20.95	35.58	52.75	75.53	28.93	37.02	53.94	19.62	54.38	149.99
median	1.96	3.88	2.95	1.87	2.30	4.23	3.01	1.92	1.43	1.54	1.25	1.38	55.00
mean	5.25	7.29	5.39	3.80	5.70	8.41	6.40	4.34	3.78	3.58	2.42	3.32	59.68
Sum of the monthly means = 59.68													
s.d.	6.93	8.50	6.31	4.03	7.21	10.14	9.91	5.77	6.52	7.03	3.31	6.83	33.68
c.v.	1.32	1.17	1.17	1.06	1.26	1.21	1.55	1.33	1.73	1.96	1.37	2.06	0.56

APPENDIX 3

NATURAL INFLOW RECORDS FOR PROPOSED DAM SITES

APPENDIX 3.1
XURA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.52	1.06	2.14	1.93	1.67	2.13	2.03	1.32	0.67	0.39	0.26	0.41	14.53
1921	0.91	8.42	9.19	3.44	1.19	0.63	0.34	2.74	3.63	2.27	1.68	1.69	36.13
1922	7.47	18.77	6.70	15.30	21.10	10.87	2.84	0.82	0.50	10.13	4.69	1.07	100.26
1923	0.70	0.79	1.10	7.87	6.69	2.29	0.65	0.37	0.33	0.30	0.35	0.68	22.12
1924	1.16	1.69	3.28	2.21	1.63	9.16	4.43	1.44	0.83	0.59	0.46	0.75	27.63
1925	1.20	1.55	1.62	1.66	1.78	12.17	5.07	1.07	1.14	1.14	0.76	0.82	29.98
1926	1.54	4.98	3.42	1.81	1.20	17.85	6.88	0.74	0.38	0.27	0.27	0.44	39.78
1927	1.01	1.03	1.18	1.65	2.29	1.95	1.14	0.69	0.56	0.45	0.63	0.76	13.34
1928	0.92	1.43	1.58	1.44	1.16	1.54	1.39	0.92	7.22	5.55	2.77	7.29	33.21
1929	12.26	9.96	3.50	1.31	0.89	0.93	1.06	0.86	1.01	1.23	1.42	3.78	38.21
1930	2.69	1.68	1.40	8.98	8.69	13.47	5.11	1.05	0.53	39.45	14.56	1.38	98.99
1931	1.48	1.66	1.47	1.01	6.37	3.53	1.26	0.89	0.94	1.05	0.94	4.90	25.50
1932	4.56	23.37	17.97	4.30	0.91	1.12	0.97	0.65	0.46	0.37	0.32	0.33	55.33
1933	0.40	3.56	8.78	10.96	4.09	1.73	1.48	1.01	0.65	1.11	1.30	0.81	35.88
1934	0.62	1.23	6.20	3.18	1.09	1.16	5.01	9.29	15.77	5.94	2.01	1.72	53.22
1935	1.31	1.38	0.92	0.59	13.55	13.90	4.21	2.32	2.22	1.59	0.96	0.76	43.71
1936	1.63	31.75	11.65	1.13	3.48	4.81	2.37	0.91	0.50	0.47	0.54	0.57	59.81
1937	0.75	0.94	1.53	1.86	1.63	1.06	1.28	1.37	1.11	1.10	0.96	0.65	14.24
1938	0.62	1.20	1.79	1.96	6.10	3.34	1.49	1.27	1.10	1.14	1.36	11.01	32.38
1939	6.67	2.50	1.90	1.39	0.90	0.94	0.88	1.28	1.48	1.07	0.72	0.62	20.35
1940	0.67	1.52	1.94	1.37	0.72	0.52	0.53	0.43	0.36	0.38	0.41	0.47	9.32
1941	0.83	1.41	1.26	10.59	4.55	1.40	1.13	1.01	0.87	0.57	0.57	0.82	25.01
1942	1.27	21.28	15.26	4.03	1.23	1.59	6.42	3.30	1.39	1.11	1.67	2.06	60.61
1943	2.24	9.15	5.80	2.19	1.84	1.71	1.15	0.71	0.55	0.60	0.54	5.49	31.97
1944	3.74	1.98	1.05	1.02	1.55	1.90	1.45	0.90	0.63	0.51	0.40	0.54	15.67
1945	11.07	4.74	0.89	0.67	1.17	4.53	2.87	1.34	0.77	0.56	0.42	0.43	29.46
1946	0.69	1.81	2.00	1.58	1.46	4.16	6.74	3.24	3.94	2.74	1.39	0.98	30.73
1947	0.99	27.36	10.90	1.88	4.14	2.99	2.00	1.24	0.62	0.36	0.26	0.24	52.98
1948	1.19	1.97	1.81	1.40	13.48	6.37	2.21	1.42	0.72	0.44	0.40	0.52	31.93
1949	0.94	7.57	3.81	1.95	2.09	1.87	1.69	1.79	1.45	1.08	1.29	1.30	26.83
1950	1.41	1.30	7.68	4.06	1.64	1.59	1.32	0.80	0.55	0.46	0.54	0.82	22.17
1951	4.18	2.39	2.72	2.51	1.94	1.72	1.75	1.41	0.87	0.55	0.37	0.56	20.97
1952	0.82	0.92	0.91	0.86	1.00	1.08	1.00	0.76	0.49	0.34	0.38	0.91	9.47
1953	1.81	10.81	7.32	2.49	1.21	1.31	1.11	0.94	1.07	1.01	0.71	0.87	30.66
1954	19.30	7.98	1.56	5.55	9.60	4.35	1.78	1.07	0.70	0.52	0.35	0.62	53.38
1955	1.16	1.58	1.17	0.49	0.80	10.92	5.21	1.65	1.14	0.87	0.62	0.77	26.38
1956	1.67	18.51	29.69	9.61	2.14	6.85	8.21	3.23	1.17	0.87	0.75	1.18	83.88
1957	2.01	3.11	2.60	4.91	10.27	4.46	4.93	2.57	0.83	0.54	0.47	0.49	37.19
1958	0.66	1.55	2.08	1.40	1.11	1.21	1.21	19.23	7.67	1.54	1.74	1.73	41.13
1959	1.64	1.67	1.59	1.36	1.08	1.33	1.66	1.71	1.28	0.85	0.76	1.02	15.95
1960	1.19	1.72	5.94	3.48	1.80	1.69	16.70	6.99	1.48	1.23	1.11	0.90	44.23
1961	0.90	3.93	2.83	1.74	1.60	4.64	2.55	1.07	0.69	0.43	0.56	0.76	21.70
1962	1.42	8.46	4.07	8.66	3.97	24.60	9.42	1.32	0.91	6.28	3.41	1.13	73.65
1963	1.35	3.41	2.60	10.40	5.76	2.55	4.57	2.52	18.18	7.52	1.39	1.07	61.32
1964	5.01	2.83	1.12	0.96	0.89	0.57	0.33	0.44	10.04	5.23	2.46	2.29	32.17
1965	16.10	11.46	3.42	1.43	1.12	0.65	0.37	4.79	2.99	1.24	0.83	0.97	45.37
1966	1.08	1.06	1.18	1.66	1.85	15.15	11.39	3.32	1.14	1.56	1.65	1.03	42.07
1967	0.76	1.30	1.37	1.02	0.97	0.95	0.82	0.57	0.36	0.30	0.50	1.20	10.12
1968	1.85	2.77	2.27	1.27	1.89	9.34	4.15	6.26	3.35	1.32	0.94	0.82	36.23
1969	1.12	1.88	1.95	1.20	0.86	0.66	0.46	0.46	0.75	0.85	5.00	3.48	18.67
1970	17.51	9.62	2.74	1.58	1.46	1.34	1.28	8.26	3.97	1.86	6.01	3.47	59.10
1971	14.95	6.54	2.01	1.57	11.14	4.85	1.17	0.71	0.55	0.54	0.52	0.46	45.01
1972	0.46	1.37	2.03	1.67	1.23	1.16	1.58	1.34	0.70	0.41	0.59	1.22	13.76
1973	1.78	8.43	3.98	1.37	1.50	1.90	1.66	8.44	4.44	1.78	1.05	0.69	37.02
1974	0.71	1.23	1.87	1.69	1.34	1.23	1.06	0.77	0.51	0.40	0.41	7.62	18.84
1975	3.96	1.60	5.66	3.10	9.59	38.28	13.56	3.74	2.34	1.13	0.74	1.05	84.75
1976	26.31	10.06	1.25	1.12	3.47	2.44	1.23	0.63	0.47	0.49	0.70	1.14	49.31
1977	1.79	10.25	11.25	3.99	1.38	1.21	54.57	20.15	2.00	1.22	0.88	0.99	109.68
1978	5.67	3.82	1.96	1.22	0.94	1.37	1.36	0.88	0.56	0.97	1.51	1.62	21.88
1979	1.93	1.85	1.46	1.01	0.91	0.91	0.69	0.55	0.46	0.40	0.36	2.64	13.17
1980	2.44	7.07	3.80	2.09	1.81	1.22	0.67	0.94	1.15	0.85	1.02	1.15	24.21
1981	0.91	0.94	0.93	1.05	1.00	11.85	5.57	1.65	1.00	0.72	0.53	0.47	26.62
1982	0.94	1.20	0.81	0.55	0.52	0.44	0.37	0.32	0.26	6.95	3.81	1.54	17.71
1983	1.53	3.34	2.53	2.35	2.09	1.66	1.62	1.45	1.26	1.90	1.99	1.48	23.20
1984	1.33	6.22	3.48	1.67	24.67	9.37	1.06	0.55	0.37	0.34	0.28	0.25	49.59
1985	1.08	7.06	3.64	3.23	1.97	1.12	0.94	0.67	0.44	0.32	0.75	1.73	22.95
1986	7.12	4.05	1.77	1.39	0.95	1.06	1.12	0.79	0.59	0.48	0.63	38.21	58.16
1987	14.61	7.37	3.68	1.38	7.63	28.38	10.16	3.19	2.44	2.14	2.36	1.93	85.27
1988	1.73	8.51	17.20	5.78	11.74	5.35	4.88	2.70	1.23	0.97	0.67	0.58	61.34
1989	4.54	15.96	5.91	1.23	0.93	3.63	2.22	0.85	0.46	0.33	0.71	1.09	37.86
1990	1.51	1.53	1.13	1.25	1.86	1.72	0.96	0.55	0.44	0.37	0.40	0.71	12.43
1991	3.59	8.57	3.68	1.29	0.95	0.70	0.71	0.60	0.41	0.30	0.33	0.58	21.71
1992	1.01	1.26	1.37	1.19	0.88	0.55	0.40	0.35	0.28	0.24	0.28	0.79	8.60
1993	1.73	2.22	7.00	3.19	15.30	6.54	1.28	0.56	0.31	0.41	0.87	0.90	40.31
1994	0.74	0.65	1.58	1.70	1.05	5.09	12.34	4.94	2.01	1.94	1.18	0.84	34.06
1995	1.17	1.44	19.36	7.96	4.05	2.24	1.02	0.71	0.49	1.23	1.67	1.24	42.58
1996	1.54	21.47	8.49	1.89	5.80	3.25	9.56	4.36	27.05	10.94	2.05	1.60	98.00
month	260.08	440.01	336.68	223.23	286.30	366.10	288.06	178.15	164.18	157.10	101.15	151.90	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.40	0.65	0.81	0.49	0.52	0.44	0.33	0.32	0.26	0.24	0.26	0.24	8.60
max	26.31	31.75	29.69	15.30	24.67	38.28	54.57	20.15	27.05	39.45	14.56	38.21	109.68
median	1.42	2.50	2.27	1.67	1.64	1.90	1.49	1.07	0.83	0.87	0.75	0.97	32.38
mean	3.38	5.71	4.37	2.90	3.72	4.75	3.74	2.31	2.13	2.04	1.31	1.97	38.35
Sum of the monthly means =				38.35									
s.d.	4.97	6.63	5.04	2.93	4.70	6.61	6.78	3.44	4.17	4.82	1.88	4.54	23.32
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.96	2.36	1.43	2.30	0.61

APPENDIX 3.2
ZALU DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.16	0.34	0.67	0.61	0.53	0.67	0.64	0.42	0.21	0.12	0.08	0.13	4.58
1921	0.29	2.66	2.90	1.08	0.38	0.20	0.11	0.86	1.15	0.72	0.53	0.53	11.41
1922	2.36	5.92	2.11	4.83	6.66	3.43	0.90	0.26	0.16	3.20	1.48	0.34	31.65
1923	0.22	0.25	0.35	2.48	2.11	0.72	0.20	0.12	0.10	0.09	0.11	0.22	6.97
1924	0.37	0.53	1.04	0.70	0.51	2.89	1.40	0.45	0.26	0.19	0.15	0.24	8.73
1925	0.38	0.49	0.51	0.52	0.56	3.84	1.60	0.34	0.36	0.36	0.24	0.26	9.46
1926	0.49	1.57	1.08	0.57	0.38	5.63	2.17	0.23	0.12	0.09	0.09	0.14	12.56
1927	0.32	0.33	0.37	0.52	0.72	0.62	0.36	0.22	0.18	0.14	0.20	0.24	4.22
1928	0.29	0.45	0.50	0.45	0.37	0.49	0.44	0.29	2.28	1.75	0.88	2.30	10.49
1929	3.87	3.14	1.10	0.41	0.28	0.29	0.33	0.27	0.32	0.39	0.45	1.19	12.04
1930	0.85	0.53	0.44	2.83	2.74	4.25	1.61	0.33	0.17	12.45	4.59	0.44	31.23
1931	0.47	0.52	0.47	0.32	2.01	1.11	0.40	0.28	0.30	0.33	0.30	1.55	8.06
1932	1.44	7.38	5.67	1.36	0.29	0.35	0.31	0.20	0.14	0.12	0.10	0.10	17.46
1933	0.12	1.12	2.77	3.46	1.29	0.55	0.47	0.32	0.21	0.35	0.41	0.25	11.32
1934	0.19	0.39	1.96	1.00	0.34	0.37	1.58	2.93	4.97	1.87	0.64	0.54	16.78
1935	0.41	0.44	0.29	0.19	4.28	4.39	1.33	0.73	0.70	0.50	0.30	0.24	13.80
1936	0.51	10.02	3.68	0.36	1.10	1.52	0.75	0.29	0.16	0.15	0.17	0.18	18.89
1937	0.24	0.30	0.48	0.59	0.51	0.33	0.40	0.43	0.35	0.35	0.30	0.21	4.49
1938	0.20	0.38	0.56	0.62	1.93	1.05	0.47	0.40	0.35	0.36	0.43	3.47	10.22
1939	2.11	0.79	0.60	0.44	0.28	0.30	0.28	0.41	0.47	0.34	0.23	0.20	6.45
1940	0.21	0.48	0.61	0.43	0.23	0.17	0.17	0.13	0.11	0.12	0.13	0.15	2.94
1941	0.26	0.45	0.40	3.34	1.43	0.44	0.36	0.32	0.27	0.18	0.18	0.26	7.89
1942	0.40	6.71	4.82	1.27	0.39	0.50	2.02	1.04	0.44	0.35	0.53	0.65	19.12
1943	0.71	2.89	1.83	0.69	0.58	0.54	0.36	0.22	0.17	0.19	0.17	1.73	10.08
1944	1.18	0.63	0.33	0.32	0.49	0.60	0.46	0.28	0.20	0.16	0.13	0.17	4.95
1945	3.49	1.50	0.28	0.21	0.37	1.43	0.90	0.42	0.24	0.18	0.13	0.14	9.29
1946	0.22	0.57	0.63	0.50	0.46	1.31	2.13	1.02	1.24	0.87	0.44	0.31	9.70
1947	0.31	8.63	3.44	0.59	1.31	0.94	0.63	0.39	0.20	0.11	0.08	0.08	16.71
1948	0.38	0.62	0.57	0.44	4.25	2.01	0.70	0.45	0.23	0.14	0.13	0.16	10.08
1949	0.30	2.39	1.20	0.62	0.66	0.59	0.53	0.57	0.46	0.34	0.41	0.41	8.48
1950	0.45	0.41	2.42	1.28	0.52	0.50	0.42	0.25	0.17	0.15	0.17	0.26	7.00
1951	1.32	0.75	0.86	0.79	0.61	0.54	0.55	0.44	0.27	0.17	0.12	0.18	6.60
1952	0.26	0.29	0.29	0.27	0.32	0.34	0.32	0.24	0.15	0.11	0.12	0.29	3.00
1953	0.57	3.41	2.31	0.79	0.38	0.41	0.35	0.30	0.34	0.32	0.23	0.27	9.68
1954	6.09	2.52	0.49	1.75	3.03	1.37	0.56	0.34	0.22	0.16	0.11	0.20	16.84
1955	0.37	0.50	0.37	0.16	0.25	3.45	1.64	0.52	0.36	0.28	0.20	0.24	8.34
1956	0.53	5.84	9.37	3.03	0.68	2.16	2.59	1.02	0.37	0.27	0.24	0.37	26.47
1957	0.64	0.98	0.82	1.55	3.24	1.41	1.55	0.81	0.26	0.17	0.15	0.15	11.73
1958	0.21	0.49	0.66	0.44	0.35	0.38	0.38	6.07	2.42	0.49	0.55	0.54	12.98
1959	0.52	0.53	0.50	0.43	0.34	0.42	0.52	0.54	0.40	0.27	0.24	0.32	5.03
1960	0.38	0.54	1.88	1.10	0.57	0.53	5.27	2.21	0.47	0.39	0.35	0.28	13.97
1961	0.28	1.24	0.89	0.55	0.50	1.46	0.81	0.34	0.22	0.14	0.18	0.24	6.85
1962	0.45	2.67	1.29	2.73	1.25	7.76	2.97	0.42	0.29	1.98	1.07	0.36	23.24
1963	0.42	1.08	0.82	3.28	1.82	0.81	1.44	0.80	5.74	2.37	0.44	0.34	19.36
1964	1.58	0.89	0.35	0.30	0.28	0.18	0.11	0.14	3.17	1.65	0.78	0.72	10.15
1965	5.08	3.62	1.08	0.45	0.35	0.20	0.12	1.51	0.94	0.39	0.26	0.31	14.31
1966	0.34	0.34	0.37	0.52	0.58	4.78	3.59	1.05	0.36	0.49	0.52	0.32	13.26
1967	0.24	0.41	0.43	0.32	0.31	0.30	0.26	0.18	0.11	0.10	0.16	0.38	3.20
1968	0.58	0.87	0.72	0.40	0.60	2.95	1.31	1.98	1.06	0.42	0.30	0.26	11.45
1969	0.35	0.59	0.62	0.38	0.27	0.21	0.14	0.15	0.24	0.27	1.58	1.10	5.90
1970	5.53	3.04	0.87	0.50	0.46	0.42	0.40	2.61	1.25	0.59	1.90	1.10	18.67
1971	4.72	2.07	0.63	0.49	3.52	1.53	0.37	0.22	0.17	0.17	0.16	0.15	14.20
1972	0.15	0.43	0.64	0.53	0.39	0.37	0.50	0.42	0.22	0.13	0.18	0.39	4.35
1973	0.56	2.66	1.26	0.43	0.47	0.60	0.52	2.66	1.40	0.56	0.33	0.22	11.67
1974	0.22	0.39	0.59	0.53	0.42	0.39	0.34	0.24	0.16	0.13	0.13	2.40	5.94
1975	1.25	0.50	1.78	0.98	3.03	12.08	4.28	1.18	0.74	0.36	0.23	0.33	26.74
1976	8.30	3.18	0.40	0.35	1.10	0.77	0.39	0.20	0.15	0.16	0.22	0.36	15.58
1977	0.56	3.24	3.55	1.26	0.43	0.38	17.22	6.36	0.63	0.38	0.28	0.31	34.60
1978	1.79	1.21	0.62	0.38	0.30	0.43	0.43	0.28	0.18	0.31	0.48	0.51	6.92
1979	0.61	0.58	0.46	0.32	0.29	0.29	0.22	0.17	0.15	0.13	0.11	0.83	4.16
1980	0.77	2.23	1.20	0.66	0.57	0.39	0.21	0.30	0.36	0.27	0.32	0.36	7.64
1981	0.29	0.30	0.29	0.33	0.31	3.74	1.76	0.52	0.31	0.23	0.17	0.15	8.40
1982	0.30	0.38	0.26	0.17	0.16	0.14	0.12	0.10	0.08	2.19	1.20	0.49	5.59
1983	0.48	1.05	0.80	0.74	0.66	0.52	0.51	0.46	0.40	0.60	0.63	0.47	7.32
1984	0.42	1.96	1.10	0.53	7.79	2.96	0.34	0.17	0.12	0.11	0.09	0.08	15.67
1985	0.34	2.23	1.15	1.02	0.62	0.35	0.30	0.21	0.14	0.10	0.24	0.55	7.25
1986	2.25	1.28	0.56	0.44	0.30	0.33	0.35	0.25	0.19	0.15	0.20	12.06	18.36
1987	4.61	2.33	1.16	0.44	2.41	8.95	3.21	1.01	0.77	0.68	0.74	0.61	26.92
1988	0.55	2.69	5.43	1.82	3.70	1.69	1.54	0.85	0.39	0.31	0.21	0.18	19.36
1989	1.43	5.04	1.86	0.39	0.29	1.15	0.70	0.27	0.15	0.10	0.23	0.34	11.95
1990	0.47	0.48	0.36	0.39	0.59	0.54	0.30	0.17	0.14	0.12	0.13	0.22	3.91
1991	1.13	2.70	1.16	0.41	0.30	0.22	0.22	0.19	0.13	0.10	0.10	0.18	6.84
1992	0.32	0.40	0.43	0.38	0.28	0.17	0.13	0.11	0.09	0.07	0.09	0.25	2.72
1993	0.54	0.70	2.21	1.01	4.83	2.06	0.40	0.18	0.10	0.13	0.27	0.28	12.71
1994	0.23	0.21	0.50	0.54	0.33	1.61	3.89	1.56	0.63	0.61	0.37	0.27	10.75
1995	0.37	0.45	6.11	2.51	1.28	0.71	0.32	0.22	0.16	0.39	0.53	0.39	13.44
1996	0.49	6.78	2.68	0.60	1.83	1.02	3.02	1.37	8.53	3.45	0.65	0.51	30.93
month	82.09	138.90	106.26	70.42	90.35	115.50	90.90	56.21	51.82	49.63	31.97	47.95	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.12	0.21	0.26	0.16	0.16	0.14	0.11	0.10	0.08	0.07	0.08	0.08	2.72
max	8.30	10.02	9.37	4.83	7.79	12.08	17.22	6.36	8.53	12.45	4.59	12.06	34.60
median	0.45	0.79	0.72	0.53	0.52	0.60	0.47	0.34	0.26	0.27	0.24	0.31	10.22
mean	1.07	1.80	1.38	0.91	1.17	1.50	1.18	0.73	0.67	0.64	0.42	0.62	12.10
Sum of the monthly means = 12.10													
s.d.	1.57	2.09	1.59	0.92	1.48	2.09	2.14	1.09	1.32	1.52	0.59	1.43	7.36
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.95	2.36	1.43	2.30	0.61

APPENDIX 3.3
LUSIKISIKI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.21	0.43	0.86	0.78	0.68	0.86	0.82	0.53	0.27	0.16	0.11	0.16	5.87
1921	0.37	3.41	3.72	1.39	0.48	0.26	0.14	1.11	1.47	0.92	0.68	0.68	14.63
1922	3.02	7.59	2.71	6.19	8.53	4.39	1.15	0.33	0.20	4.10	1.90	0.43	40.54
1923	0.28	0.32	0.44	3.18	2.70	0.93	0.26	0.15	0.13	0.12	0.14	0.28	8.93
1924	0.47	0.69	1.33	0.89	0.66	3.70	1.79	0.58	0.34	0.24	0.19	0.30	11.18
1925	0.49	0.63	0.66	0.67	0.72	4.92	2.05	0.43	0.46	0.46	0.31	0.33	12.13
1926	0.62	2.02	1.38	0.73	0.48	7.22	2.78	0.30	0.15	0.11	0.11	0.18	16.08
1927	0.41	0.42	0.48	0.67	0.93	0.79	0.46	0.28	0.23	0.18	0.26	0.31	5.42
1928	0.37	0.58	0.64	0.58	0.47	0.62	0.56	0.37	2.92	2.24	1.12	2.95	13.42
1929	4.96	4.03	1.42	0.53	0.36	0.37	0.43	0.35	0.41	0.50	0.57	1.53	15.46
1930	1.09	0.68	0.56	3.63	3.51	5.45	2.07	0.42	0.21	15.95	5.89	0.56	40.02
1931	0.60	0.67	0.60	0.41	2.57	1.43	0.51	0.36	0.38	0.42	0.38	1.98	10.31
1932	1.84	9.45	7.27	1.74	0.37	0.45	0.39	0.26	0.19	0.15	0.13	0.13	22.37
1933	0.16	1.44	3.55	4.43	1.66	0.70	0.60	0.41	0.26	0.45	0.53	0.33	14.52
1934	0.25	0.50	2.51	1.29	0.44	0.47	2.03	3.76	6.38	2.40	0.81	0.69	21.53
1935	0.53	0.56	0.37	0.24	5.48	5.62	1.70	0.94	0.90	0.64	0.39	0.31	17.68
1936	0.66	12.84	4.71	0.46	1.41	1.94	0.96	0.37	0.20	0.19	0.22	0.23	24.19
1937	0.30	0.38	0.62	0.75	0.66	0.43	0.52	0.55	0.45	0.44	0.39	0.26	5.75
1938	0.25	0.48	0.72	0.79	2.47	1.35	0.60	0.51	0.44	0.46	0.55	4.45	13.07
1939	2.70	1.01	0.77	0.56	0.36	0.38	0.36	0.52	0.60	0.43	0.29	0.25	8.23
1940	0.27	0.61	0.79	0.56	0.29	0.21	0.21	0.17	0.15	0.16	0.16	0.19	3.77
1941	0.33	0.57	0.51	4.28	1.84	0.56	0.46	0.41	0.35	0.23	0.23	0.33	10.10
1942	0.51	8.61	6.17	1.63	0.50	0.64	2.60	1.34	0.56	0.45	0.68	0.83	24.52
1943	0.91	3.70	2.35	0.88	0.74	0.69	0.47	0.29	0.22	0.24	0.22	2.22	12.93
1944	1.51	0.80	0.42	0.41	0.63	0.77	0.58	0.36	0.26	0.21	0.16	0.22	6.33
1945	4.48	1.92	0.36	0.27	0.47	1.83	1.16	0.54	0.31	0.23	0.17	0.17	11.91
1946	0.28	0.73	0.81	0.64	0.59	1.68	2.73	1.31	1.59	1.11	0.56	0.40	12.43
1947	0.40	11.07	4.41	0.76	1.68	1.21	0.81	0.50	0.25	0.15	0.11	0.10	21.45
1948	0.48	0.80	0.73	0.57	5.45	2.58	0.89	0.57	0.29	0.18	0.16	0.21	12.91
1949	0.38	3.06	1.54	0.79	0.84	0.76	0.69	0.73	0.59	0.44	0.52	0.52	10.86
1950	0.57	0.52	3.10	1.64	0.67	0.64	0.53	0.32	0.22	0.19	0.22	0.33	8.95
1951	1.69	0.97	1.10	1.01	0.79	0.69	0.71	0.57	0.35	0.22	0.15	0.23	8.48
1952	0.33	0.37	0.37	0.35	0.41	0.43	0.41	0.31	0.20	0.14	0.15	0.37	3.84
1953	0.73	4.37	2.96	1.01	0.49	0.53	0.45	0.38	0.43	0.41	0.29	0.35	12.40
1954	7.81	3.23	0.63	2.25	3.88	1.76	0.72	0.43	0.28	0.21	0.14	0.25	21.59
1955	0.47	0.64	0.47	0.20	0.32	4.42	2.11	0.67	0.46	0.35	0.25	0.31	10.67
1956	0.68	7.49	12.01	3.89	0.87	2.77	3.32	1.31	0.47	0.35	0.31	0.48	33.95
1957	0.81	1.26	1.05	1.99	4.15	1.81	1.99	1.04	0.34	0.22	0.19	0.20	15.05
1958	0.27	0.63	0.84	0.57	0.45	0.49	0.49	7.78	3.10	0.62	0.70	0.70	16.64
1959	0.66	0.68	0.64	0.55	0.44	0.54	0.67	0.69	0.52	0.34	0.31	0.41	6.45
1960	0.48	0.70	2.40	1.41	0.73	0.68	6.76	2.83	0.60	0.50	0.45	0.36	17.90
1961	0.36	1.59	1.15	0.70	0.65	1.87	1.03	0.43	0.28	0.17	0.22	0.31	8.76
1962	0.58	3.42	1.65	3.50	1.61	9.95	3.81	0.53	0.37	2.54	1.38	0.46	29.80
1963	0.54	1.38	1.05	4.20	2.33	1.03	1.85	1.02	7.35	3.04	0.56	0.43	24.78
1964	2.03	1.15	0.45	0.39	0.36	0.23	0.14	0.18	4.06	2.12	0.99	0.93	13.03
1965	6.51	4.64	1.38	0.58	0.45	0.26	0.15	1.94	1.21	0.50	0.34	0.39	18.35
1966	0.44	0.43	0.48	0.67	0.75	6.13	4.61	1.34	0.46	0.63	0.67	0.42	17.03
1967	0.31	0.53	0.56	0.41	0.39	0.38	0.33	0.23	0.15	0.12	0.20	0.49	4.10
1968	0.75	1.12	0.92	0.51	0.76	3.78	1.68	2.53	1.35	0.53	0.38	0.33	14.64
1969	0.45	0.76	0.79	0.49	0.35	0.27	0.19	0.19	0.30	0.34	2.02	1.41	7.56
1970	7.08	3.89	1.11	0.64	0.59	0.54	0.52	3.34	1.61	0.75	2.43	1.40	23.90
1971	6.05	2.65	0.81	0.63	4.51	1.96	0.47	0.29	0.22	0.22	0.21	0.19	18.21
1972	0.19	0.56	0.82	0.67	0.50	0.47	0.64	0.54	0.28	0.17	0.24	0.49	5.57
1973	0.72	3.41	1.61	0.55	0.61	0.77	0.67	3.41	1.79	0.72	0.42	0.28	14.96
1974	0.29	0.50	0.76	0.68	0.54	0.50	0.43	0.31	0.21	0.16	0.17	3.08	7.63
1975	1.60	0.65	2.29	1.25	3.88	15.48	5.48	1.51	0.94	0.46	0.30	0.42	34.26
1976	10.64	4.07	0.51	0.45	1.41	0.99	0.50	0.26	0.19	0.20	0.28	0.46	19.96
1977	0.72	4.15	4.55	1.62	0.56	0.49	22.07	8.15	0.81	0.49	0.36	0.40	44.37
1978	2.29	1.55	0.79	0.49	0.38	0.56	0.55	0.36	0.22	0.39	0.61	0.66	8.85
1979	0.78	0.75	0.59	0.41	0.37	0.37	0.28	0.22	0.19	0.16	0.15	1.07	5.34
1980	0.99	2.86	1.54	0.85	0.73	0.49	0.27	0.38	0.47	0.34	0.41	0.47	9.80
1981	0.37	0.38	0.37	0.42	0.40	4.79	2.25	0.67	0.40	0.29	0.21	0.19	10.74
1982	0.38	0.49	0.33	0.22	0.21	0.18	0.15	0.13	0.11	2.81	1.54	0.62	7.17
1983	0.62	1.35	1.02	0.95	0.84	0.67	0.66	0.59	0.51	0.77	0.80	0.60	9.38
1984	0.54	2.52	1.41	0.68	9.98	3.79	0.43	0.22	0.15	0.14	0.11	0.10	20.07
1985	0.44	2.86	1.47	1.31	0.80	0.45	0.38	0.27	0.18	0.13	0.30	0.70	9.29
1986	2.88	1.64	0.72	0.56	0.38	0.43	0.45	0.32	0.24	0.20	0.25	15.45	23.52
1987	5.91	2.98	1.49	0.56	3.08	11.48	4.11	1.29	0.99	0.87	0.95	0.78	34.49
1988	0.70	3.44	6.96	2.34	4.75	2.16	1.98	1.09	0.50	0.39	0.27	0.24	24.82
1989	1.83	6.45	2.39	0.50	0.38	1.47	0.90	0.34	0.19	0.13	0.29	0.44	15.31
1990	0.61	0.62	0.46	0.51	0.75	0.70	0.39	0.22	0.18	0.15	0.16	0.29	5.04
1991	1.45	3.46	1.49	0.52	0.38	0.28	0.29	0.24	0.16	0.12	0.13	0.23	8.75
1992	0.41	0.51	0.55	0.48	0.36	0.22	0.16	0.14	0.12	0.10	0.11	0.32	3.48
1993	0.70	0.90	2.83	1.29	6.19	2.65	0.52	0.22	0.13	0.17	0.35	0.36	16.31
1994	0.30	0.26	0.64	0.69	0.43	2.06	4.99	2.00	0.81	0.78	0.48	0.34	13.78
1995	0.47	0.58	7.83	3.22	1.64	0.91	0.41	0.29	0.20	0.50	0.68	0.50	17.23
1996	0.62	8.69	3.43	0.77	2.34	1.31	3.87	1.76	10.94	4.43	0.83	0.65	39.64
month	105.18	178.05	136.18	90.28	115.81	148.04	116.55	72.03	66.40	63.54	40.90	61.42	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.16	0.26	0.33	0.20	0.21	0.18	0.14	0.13	0.11	0.10	0.11	0.10	3.48
max	10.64	12.84	12.01	6.19	9.98	15.48	22.07	8.15	10.94	15.95	5.89	15.45	44.37
median	0.58	1.01	0.92	0.68	0.67	0.77	0.60	0.43	0.34	0.35	0.30	0.39	13.07
mean	1.37	2.31	1.77	1.17	1.50	1.92	1.51	0.94	0.86	0.83	0.53	0.80	15.51
Sum of the monthly means =				15.51									
s.d.	2.01	2.68	2.04	1.18	1.90	2.68	2.74	1.39	1.69	1.95	0.76	1.84	9.43
c.v.	1.47	1.16	1.15	1.01	1.26	1.39	1.81	1.49	1.96	2.36	1.43	2.30	0.61

APPENDIX 3.4
TUNGWANE DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.28	0.52	0.92	0.94	0.94	2.46	1.69	0.95	0.56	0.34	0.23	0.30	10.13
1921	0.56	3.99	4.18	1.66	0.67	0.40	0.26	3.89	4.16	1.80	1.10	1.10	23.77
1922	4.26	9.67	3.39	8.46	12.85	7.76	2.11	0.59	0.41	8.17	3.52	0.66	61.85
1923	0.39	0.38	0.49	3.91	4.20	1.55	0.45	0.31	0.30	0.27	0.30	0.50	13.05
1924	0.72	0.88	1.08	0.97	0.94	6.74	3.15	1.04	0.69	0.51	0.39	0.55	17.66
1925	0.75	0.81	0.75	0.80	0.97	8.48	3.49	0.78	0.92	0.94	0.63	0.61	19.93
1926	0.95	1.84	1.44	0.92	0.67	11.97	4.59	0.53	0.32	0.24	0.23	0.33	24.03
1927	0.62	0.54	0.55	0.81	1.48	1.27	0.79	0.55	0.50	0.40	0.52	0.57	8.60
1928	0.58	0.74	0.74	0.68	0.61	1.16	0.99	0.69	6.72	4.95	1.97	4.76	24.59
1929	6.74	4.36	1.51	0.65	0.47	0.60	0.77	0.70	0.86	1.04	1.14	3.56	22.40
1930	1.91	0.80	0.61	4.42	5.36	9.32	3.49	0.75	0.44	25.92	9.49	0.84	63.35
1931	0.83	0.82	0.66	0.45	3.92	2.22	0.88	0.71	0.81	0.89	0.78	4.20	17.17
1932	2.50	12.24	9.21	2.18	0.52	0.74	0.71	0.53	0.42	0.34	0.28	0.26	29.93
1933	0.26	1.43	4.03	5.95	2.35	1.13	1.07	0.81	0.58	0.92	1.05	0.62	20.20
1934	0.40	0.64	2.41	1.41	0.61	0.76	4.93	7.82	11.24	4.01	1.33	1.12	36.68
1935	0.78	0.69	0.40	0.26	8.29	9.50	2.94	3.45	2.10	1.10	0.70	0.53	30.74
1936	0.96	17.12	6.23	0.56	2.32	4.04	1.83	0.65	0.42	0.40	0.45	0.43	35.41
1937	0.47	0.48	0.73	0.91	0.88	0.65	0.92	1.08	0.95	0.94	0.80	0.51	9.32
1938	0.40	0.63	0.85	0.96	3.72	2.10	1.04	1.00	0.94	0.97	1.11	7.83	21.55
1939	3.75	1.12	0.88	0.64	0.46	0.59	0.63	1.01	1.19	0.88	0.60	0.47	12.22
1940	0.43	0.79	0.93	0.64	0.36	0.33	0.39	0.35	0.33	0.34	0.35	0.36	5.60
1941	0.52	0.73	0.58	5.54	2.46	0.91	0.82	0.82	0.76	0.51	0.49	0.61	14.75
1942	0.79	11.47	7.77	2.03	0.69	1.67	5.20	2.44	1.03	0.88	2.47	1.66	38.10
1943	1.22	3.81	2.15	1.01	1.22	1.10	0.80	0.56	0.49	0.52	0.46	4.48	17.82
1944	2.50	0.96	0.44	0.47	0.85	1.20	1.02	0.72	0.56	0.46	0.35	0.41	9.94
1945	6.85	2.78	0.39	0.29	0.65	3.92	2.20	0.97	0.63	0.48	0.36	0.33	19.85
1946	0.44	0.86	0.97	0.78	0.80	3.68	5.55	2.41	4.52	2.39	0.91	0.64	23.95
1947	0.58	15.00	5.92	0.98	2.76	2.67	1.51	0.88	0.51	0.32	0.23	0.19	31.55
1948	0.73	1.04	0.85	0.65	8.12	4.89	1.75	1.02	0.59	0.39	0.34	0.39	20.76
1949	0.59	3.48	1.79	1.00	1.16	1.18	1.21	1.50	1.21	0.90	1.03	0.95	16.00
1950	0.88	0.68	3.29	1.93	0.94	1.04	0.95	0.65	0.49	0.42	0.46	0.61	12.34
1951	2.70	1.37	0.85	1.18	1.12	1.11	1.26	1.12	0.76	0.50	0.33	0.42	12.72
1952	0.52	0.48	0.41	0.40	0.54	0.68	0.73	0.61	0.44	0.32	0.33	0.66	6.12
1953	1.11	5.22	3.06	1.12	0.68	0.86	0.80	0.76	0.92	0.87	0.61	0.65	16.66
1954	11.70	4.64	0.71	2.47	5.94	3.36	1.33	0.77	0.58	0.45	0.30	0.46	32.71
1955	0.72	0.82	0.53	0.21	0.45	7.70	3.60	1.19	0.93	0.74	0.53	0.57	17.99
1956	1.03	9.71	16.17	5.29	1.24	5.35	6.45	2.39	0.86	0.69	0.60	0.84	50.62
1957	1.23	1.32	1.20	2.17	6.28	2.86	4.76	2.20	0.61	0.43	0.38	0.36	23.80
1958	0.41	0.81	0.99	0.65	0.59	0.76	0.87	14.21	5.55	1.07	1.25	1.19	28.35
1959	0.99	0.85	0.73	0.63	0.57	0.84	1.18	1.34	1.09	0.75	0.64	0.76	10.37
1960	0.75	0.94	2.37	1.62	1.03	1.09	12.01	4.97	1.10	0.97	0.87	0.67	28.39
1961	0.56	1.42	1.24	0.87	0.88	3.98	1.98	0.78	0.57	0.38	0.46	0.56	13.68
1962	0.88	3.83	1.89	4.50	2.16	16.09	6.16	0.96	0.75	6.07	2.81	0.69	46.79
1963	0.76	1.14	1.12	5.49	3.66	2.41	4.05	1.95	13.01	5.24	0.91	0.70	40.44
1964	2.88	1.51	0.50	0.44	0.47	0.34	0.24	0.37	8.41	3.98	2.01	1.54	22.69
1965	9.05	5.31	1.46	0.71	0.60	0.40	0.27	5.18	2.64	0.86	0.61	0.67	27.76
1966	0.66	0.54	0.54	0.81	1.01	10.26	8.36	2.45	0.84	1.42	1.27	0.71	28.87
1967	0.46	0.66	0.63	0.47	0.52	0.59	0.59	0.47	0.33	0.28	0.42	0.86	6.28
1968	1.13	1.20	1.05	0.61	1.32	6.77	2.91	5.95	2.81	0.91	0.69	0.57	25.92
1969	0.68	0.96	0.91	0.54	0.45	0.40	0.33	0.39	0.64	0.72	5.10	2.72	13.84
1970	9.69	4.22	1.08	0.79	0.80	0.85	0.92	7.54	3.30	1.45	5.00	2.47	38.11
1971	8.22	3.50	0.93	0.73	6.69	2.98	0.82	0.57	0.49	0.48	0.44	0.36	26.21
1972	0.30	0.72	0.98	0.80	0.65	0.73	1.08	1.00	0.59	0.37	0.48	0.87	8.57
1973	1.10	3.78	1.83	0.68	0.84	1.23	1.14	7.47	3.55	1.24	0.77	0.49	24.12
1974	0.44	0.63	0.89	0.81	0.71	0.77	0.76	0.62	0.45	0.37	0.35	5.75	12.55
1975	2.66	0.76	1.85	1.29	6.10	24.10	8.70	4.28	2.12	0.78	0.55	0.71	53.90
1976	15.62	5.82	0.56	0.52	2.19	1.57	0.85	0.51	0.42	0.44	0.57	0.82	29.89
1977	1.10	4.90	5.32	1.99	0.78	0.78	35.37	13.46	1.50	0.89	0.67	0.70	67.46
1978	3.46	2.05	0.92	0.57	0.50	0.88	0.97	0.71	0.50	0.81	1.20	1.18	13.75
1979	1.19	0.97	0.67	0.45	0.48	0.57	0.50	0.45	0.42	0.36	0.32	2.73	9.11
1980	1.73	2.65	1.61	1.07	1.00	0.76	0.48	0.75	0.98	0.74	0.83	0.86	13.46
1981	0.59	0.48	0.42	0.50	0.53	8.30	3.83	1.19	0.82	0.62	0.45	0.36	18.09
1982	0.59	0.63	0.36	0.24	0.27	0.28	0.27	0.27	0.24	6.23	2.99	0.95	13.32
1983	0.86	1.09	1.08	1.11	1.18	1.09	1.18	1.16	1.09	3.31	1.91	0.91	15.97
1984	0.76	2.42	1.51	0.84	14.86	5.70	0.74	0.44	0.33	0.31	0.25	0.20	28.36
1985	0.67	3.11	1.67	1.33	0.98	0.73	0.69	0.55	0.40	0.30	0.61	1.29	12.33
1986	4.00	2.12	0.81	0.64	0.48	0.67	0.80	0.63	0.52	0.43	0.52	24.04	35.66
1987	9.00	2.75	1.52	0.68	4.76	18.15	6.52	4.15	2.29	1.91	1.74	1.23	54.70
1988	0.99	3.63	8.75	3.04	7.42	3.40	4.73	2.30	0.91	0.77	0.54	0.43	36.91
1989	2.92	8.14	2.93	0.61	0.50	3.34	1.77	0.61	0.39	0.29	0.56	0.78	22.84
1990	0.92	0.79	0.51	0.59	1.03	1.08	0.68	0.45	0.40	0.33	0.34	0.52	7.64
1991	2.34	3.80	1.62	0.64	0.51	0.44	0.52	0.49	0.37	0.28	0.29	0.43	11.73
1992	0.63	0.66	0.63	0.55	0.46	0.34	0.30	0.30	0.26	0.22	0.24	0.56	5.15
1993	1.05	1.15	2.63	1.34	9.52	4.11	0.89	0.44	0.28	0.36	0.69	0.67	23.13
1994	0.47	0.34	0.70	0.86	0.58	4.28	9.01	3.45	2.64	1.69	0.79	0.56	25.37
1995	0.69	0.73	9.98	4.16	2.77	1.50	0.71	0.57	0.44	1.67	1.40	0.82	25.44
1996	0.90	11.33	4.44	0.96	3.63	2.07	7.48	3.28	18.38	7.44	1.35	1.02	62.28
month	154.75	217.20	158.70	110.83	171.97	252.58	207.72	145.86	132.57	123.38	80.04	107.69	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.26	0.34	0.36	0.21	0.27	0.28	0.24	0.27	0.24	0.22	0.23	0.19	5.15
max	15.62	17.12	16.17	8.46	14.86	24.10	35.37	14.21	18.38	25.92	9.49	24.04	67.46
median	0.86	1.14	0.99	0.81	0.94	1.23	1.07	0.81	0.69	0.74	0.61	0.67	22.40
mean	2.01	2.82	2.06	1.44	2.23	3.28	2.70	1.89	1.72	1.60	1.04	1.40	24.20
Sum of the monthly means =				24.20									
s.d.	2.89	3.51	2.66	1.57	2.90	4.32	4.51	2.63	2.99	3.27	1.36	2.93	14.56
c.v.	1.44	1.25	1.29	1.09	1.30	1.32	1.67	1.39	1.74	2.04	1.31	2.09	0.60

APPENDIX 3.5
LOWER MZINTLAVA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.21	0.38	0.65	0.67	0.66	1.45	1.13	0.71	0.42	0.26	0.17	0.22	6.93
1921	0.41	2.60	2.76	1.16	0.49	0.29	0.19	2.57	2.89	1.32	0.83	0.81	16.32
1922	2.88	6.87	2.45	6.00	9.21	5.49	1.51	0.44	0.31	5.81	2.54	0.50	44.01
1923	0.29	0.28	0.35	2.48	2.78	1.09	0.34	0.23	0.22	0.20	0.22	0.36	8.84
1924	0.52	0.63	0.77	0.69	0.66	4.65	2.23	0.77	0.51	0.38	0.29	0.40	12.50
1925	0.54	0.58	0.54	0.57	0.68	5.86	2.46	0.58	0.68	0.69	0.46	0.45	14.09
1926	0.69	1.03	0.96	0.67	0.48	8.47	3.28	0.40	0.24	0.18	0.17	0.24	16.81
1927	0.45	0.39	0.39	0.57	0.83	0.88	0.60	0.41	0.37	0.30	0.38	0.42	5.99
1928	0.42	0.53	0.53	0.48	0.43	0.70	0.70	0.53	4.86	3.55	1.45	3.33	17.51
1929	4.77	2.99	1.06	0.47	0.34	0.43	0.55	0.50	0.62	0.75	0.83	2.33	15.64
1930	1.32	0.59	0.44	2.87	3.64	6.66	2.53	0.56	0.33	18.92	6.95	0.63	45.44
1931	0.61	0.59	0.47	0.32	2.50	1.51	0.65	0.52	0.59	0.65	0.57	2.82	11.80
1932	1.73	8.97	6.61	1.56	0.38	0.53	0.51	0.39	0.30	0.25	0.21	0.19	21.63
1933	0.19	0.73	2.65	4.10	1.67	0.83	0.77	0.59	0.42	0.67	0.76	0.45	13.83
1934	0.29	0.46	1.40	0.92	0.45	0.55	3.30	5.56	8.20	2.96	0.99	0.83	25.91
1935	0.57	0.50	0.29	0.18	5.71	6.71	2.13	2.36	1.50	0.83	0.53	0.40	21.71
1936	0.71	12.53	4.56	0.41	1.36	2.70	1.31	0.49	0.31	0.30	0.33	0.32	25.33
1937	0.34	0.35	0.52	0.64	0.62	0.46	0.65	0.77	0.69	0.68	0.58	0.37	6.67
1938	0.29	0.45	0.61	0.68	2.34	1.42	0.77	0.73	0.69	0.71	0.80	5.49	14.98
1939	2.60	0.83	0.66	0.46	0.33	0.42	0.45	0.73	0.89	0.66	0.45	0.35	8.83
1940	0.31	0.57	0.66	0.46	0.26	0.23	0.28	0.25	0.24	0.25	0.25	0.26	4.02
1941	0.37	0.53	0.41	3.68	1.68	0.67	0.60	0.60	0.55	0.37	0.36	0.45	10.27
1942	0.57	8.10	5.40	1.43	0.51	0.92	3.60	1.77	0.77	0.65	1.61	1.17	26.50
1943	0.90	2.51	1.48	0.73	0.78	0.80	0.60	0.42	0.36	0.39	0.34	3.03	12.34
1944	1.76	0.71	0.32	0.33	0.60	0.85	0.73	0.51	0.40	0.33	0.26	0.30	7.10
1945	4.74	1.96	0.29	0.21	0.46	2.51	1.51	0.72	0.47	0.36	0.27	0.24	13.74
1946	0.32	0.62	0.69	0.55	0.57	2.33	3.89	1.77	3.19	1.73	0.68	0.48	16.82
1947	0.43	10.75	4.26	0.71	1.68	1.70	1.07	0.65	0.38	0.24	0.17	0.14	22.18
1948	0.53	0.75	0.61	0.46	5.58	3.31	1.25	0.76	0.44	0.29	0.25	0.29	14.52
1949	0.43	2.23	1.22	0.72	0.83	0.84	0.86	1.01	0.89	0.68	0.77	0.70	11.18
1950	0.64	0.49	2.06	1.30	0.68	0.74	0.68	0.47	0.36	0.30	0.34	0.44	8.50
1951	1.69	0.92	0.62	0.84	0.80	0.79	0.90	0.80	0.55	0.37	0.24	0.31	8.83
1952	0.38	0.35	0.30	0.28	0.38	0.48	0.52	0.44	0.32	0.23	0.24	0.48	4.40
1953	0.80	3.49	1.94	0.76	0.50	0.62	0.58	0.55	0.66	0.63	0.44	0.47	11.44
1954	8.32	3.33	0.52	1.47	4.08	2.26	0.94	0.58	0.43	0.33	0.22	0.33	22.81
1955	0.52	0.59	0.38	0.15	0.32	5.28	2.53	0.88	0.69	0.55	0.39	0.42	12.70
1956	0.74	6.80	11.60	3.83	0.90	3.66	4.54	1.73	0.65	0.52	0.45	0.61	36.03
1957	0.89	0.95	0.85	1.21	4.38	2.07	3.27	1.56	0.46	0.33	0.28	0.27	16.52
1958	0.30	0.58	0.71	0.46	0.42	0.54	0.62	10.16	4.00	0.80	0.93	0.87	20.39
1959	0.72	0.61	0.52	0.45	0.40	0.60	0.84	0.96	0.79	0.54	0.47	0.55	7.45
1960	0.55	0.67	1.37	1.07	0.75	0.79	8.53	3.57	0.82	0.72	0.64	0.49	19.97
1961	0.41	0.73	0.81	0.64	0.63	2.57	1.36	0.58	0.42	0.28	0.34	0.41	9.18
1962	0.63	2.47	1.28	3.00	1.49	11.61	4.47	0.71	0.56	4.25	2.01	0.52	33.00
1963	0.56	0.83	0.80	3.64	2.39	1.56	2.81	1.41	9.47	3.84	0.69	0.52	28.52
1964	1.86	1.04	0.37	0.32	0.33	0.24	0.18	0.26	5.90	2.85	1.34	1.10	15.79
1965	6.46	3.67	1.02	0.52	0.43	0.28	0.20	3.50	1.86	0.65	0.46	0.50	19.55
1966	0.48	0.39	0.38	0.58	0.71	7.18	5.90	1.77	0.63	0.87	0.90	0.54	20.33
1967	0.34	0.48	0.45	0.33	0.37	0.42	0.42	0.34	0.24	0.20	0.30	0.62	4.51
1968	0.82	0.86	0.74	0.43	0.60	4.71	2.10	4.21	2.03	0.69	0.51	0.42	18.12
1969	0.49	0.69	0.65	0.39	0.32	0.29	0.24	0.28	0.46	0.52	3.48	1.93	9.74
1970	6.93	3.01	0.80	0.59	0.58	0.61	0.66	5.24	2.35	0.94	3.56	1.80	27.07
1971	5.85	2.52	0.68	0.52	4.55	2.07	0.60	0.42	0.36	0.35	0.33	0.26	18.51
1972	0.22	0.52	0.70	0.57	0.46	0.52	0.80	0.75	0.44	0.28	0.36	0.64	6.26
1973	0.79	2.45	1.24	0.50	0.60	0.87	0.85	5.33	2.57	0.93	0.57	0.36	17.06
1974	0.32	0.45	0.63	0.57	0.50	0.55	0.54	0.45	0.33	0.27	0.26	3.95	8.82
1975	1.87	0.56	1.04	0.85	4.19	17.55	6.29	3.14	1.59	0.59	0.41	0.53	38.61
1976	11.24	4.21	0.42	0.37	1.25	1.04	0.63	0.37	0.31	0.32	0.42	0.60	21.18
1977	0.79	3.26	3.60	1.40	0.57	0.56	25.76	9.75	1.10	0.67	0.50	0.52	48.48
1978	2.28	1.42	0.67	0.41	0.35	0.63	0.69	0.51	0.36	0.58	0.86	0.85	9.61
1979	0.86	0.69	0.48	0.32	0.34	0.41	0.35	0.32	0.30	0.26	0.23	1.73	6.29
1980	1.19	1.70	1.10	0.78	0.71	0.54	0.35	0.54	0.70	0.53	0.60	0.62	9.36
1981	0.43	0.35	0.30	0.35	0.37	5.73	2.71	0.88	0.60	0.46	0.33	0.27	12.78
1982	0.43	0.45	0.26	0.17	0.19	0.20	0.20	0.19	0.18	4.31	2.12	0.71	9.41
1983	0.64	0.79	0.77	0.79	0.84	0.77	0.84	0.83	0.78	2.17	1.33	0.68	11.23
1984	0.56	1.48	1.01	0.61	10.61	4.10	0.55	0.33	0.24	0.23	0.18	0.15	20.05
1985	0.48	1.94	1.12	0.79	0.69	0.55	0.51	0.41	0.29	0.22	0.44	0.88	8.32
1986	2.84	1.54	0.59	0.46	0.34	0.48	0.57	0.46	0.38	0.32	0.38	17.47	25.83
1987	6.56	1.77	1.04	0.50	3.16	13.13	4.78	2.87	1.64	1.28	1.25	0.93	38.91
1988	0.74	2.41	6.15	2.18	5.17	2.42	3.25	1.63	0.69	0.57	0.40	0.32	25.93
1989	1.87	5.73	2.11	0.45	0.36	2.11	1.20	0.46	0.29	0.22	0.41	0.57	15.78
1990	0.67	0.57	0.36	0.42	0.73	0.76	0.49	0.33	0.29	0.24	0.25	0.38	5.49
1991	1.42	2.53	1.14	0.47	0.36	0.31	0.37	0.36	0.27	0.21	0.21	0.31	7.96
1992	0.46	0.47	0.45	0.39	0.32	0.24	0.21	0.21	0.19	0.16	0.17	0.41	3.68
1993	0.76	0.83	1.56	0.87	6.73	2.94	0.66	0.33	0.21	0.26	0.51	0.49	16.15
1994	0.34	0.24	0.50	0.61	0.41	2.78	6.39	2.52	1.80	1.21	0.60	0.42	17.82
1995	0.50	0.52	6.98	2.95	1.75	1.02	0.53	0.42	0.32	0.99	0.97	0.62	17.57
1996	0.66	8.03	3.17	0.70	2.31	1.41	5.28	2.36	13.44	5.39	1.01	0.78	44.54
month	109.49	151.39	110.25	76.44	117.83	176.25	148.14	104.47	96.05	88.79	57.80	77.02	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.19	0.24	0.26	0.15	0.19	0.20	0.18	0.19	0.18	0.16	0.17	0.14	3.68
max	11.24	12.53	11.60	6.00	10.61	17.55	25.76	10.16	13.44	18.92	6.95	17.47	48.48
median	0.63	0.79	0.71	0.59	0.66	0.87	0.77	0.59	0.51	0.54	0.45	0.49	15.64
mean	1.42	1.97	1.43	0.99	1.53	2.29	1.92	1.36	1.25	1.15	0.75	1.00	17.06
Sum of the monthly means = 17.06													
s.d.	2.06	2.52	1.88	1.08	2.03	3.10	3.26	1.87	2.17	2.37	0.97	2.11	10.43
c.v.	1.45	1.28	1.31	1.08	1.33	1.36	1.69	1.38	1.74	2.06	1.29	2.11	0.61

APPENDIX 4

NATURAL INFLOW RECORDS FOR EXISTING DAMS AND WEIRS

APPENDIX 4.1
LUSINDISWENI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.37	2.43	4.01	4.04	3.35	4.28	4.55	3.02	1.57	0.93	0.64	0.80	30.99
1921	1.84	20.62	29.40	10.90	3.42	1.94	0.91	3.15	11.89	6.95	3.75	3.02	97.79
1922	3.41	25.12	11.22	7.75	45.47	31.25	7.95	1.79	1.04	27.61	12.51	2.67	177.79
1923	1.59	1.41	1.90	29.72	23.94	7.07	1.70	0.95	0.81	0.69	0.71	1.11	71.60
1924	2.16	3.87	12.16	5.83	1.93	8.01	5.89	3.11	1.74	1.11	0.78	0.77	47.36
1925	1.59	3.35	3.78	3.85	3.46	23.43	10.09	2.25	2.32	2.30	1.52	1.72	59.66
1926	3.40	4.70	5.24	4.01	2.71	36.84	14.52	1.81	0.96	0.75	0.89	1.14	76.97
1927	2.08	2.23	3.77	24.08	11.89	4.40	2.41	1.32	1.00	0.82	1.03	1.27	56.30
1928	1.75	2.53	2.39	1.91	1.47	2.88	3.19	2.17	5.89	6.58	4.93	8.77	44.46
1929	10.98	7.38	4.80	3.93	3.25	3.70	3.82	2.60	2.42	2.54	2.80	3.91	52.13
1930	4.28	3.79	4.64	26.17	13.70	31.50	12.66	2.12	1.03	42.97	17.98	3.04	163.88
1931	2.74	3.07	2.68	2.03	8.47	5.75	2.47	1.56	1.63	2.01	1.88	2.99	37.28
1932	4.93	45.43	39.28	10.22	1.56	1.78	2.02	1.52	1.04	0.86	0.75	0.65	110.04
1933	0.66	10.05	24.23	15.52	6.07	3.74	3.11	2.28	1.46	1.84	1.99	1.43	72.38
1934	1.40	2.54	13.35	7.04	2.92	2.72	7.07	20.85	26.73	10.29	4.16	3.34	102.41
1935	2.49	2.64	1.75	1.16	19.76	20.33	6.94	3.81	4.29	3.19	1.90	1.51	69.77
1936	2.96	73.11	27.46	4.14	28.68	13.07	3.57	1.82	1.02	0.86	0.82	0.80	158.31
1937	1.23	1.98	2.84	3.07	3.76	3.16	2.97	2.69	2.04	1.93	1.80	1.41	28.88
1938	1.51	2.57	4.39	4.41	13.08	7.00	2.80	2.24	1.91	1.89	2.07	12.63	56.50
1939	8.79	5.80	6.01	4.12	2.63	2.53	2.38	4.11	4.88	3.41	1.97	1.46	48.09
1940	1.64	3.55	7.36	4.57	1.98	1.68	1.73	1.23	0.83	0.78	0.85	1.06	27.26
1941	1.82	2.64	2.46	8.19	5.78	4.51	3.91	2.98	2.10	1.31	1.24	1.64	38.58
1942	2.82	34.70	37.92	12.19	3.32	9.85	16.78	7.86	3.57	3.06	4.42	4.92	141.41
1943	9.29	27.77	20.79	6.97	4.29	4.24	2.88	1.81	1.45	1.45	1.25	3.14	85.33
1944	5.23	4.19	2.11	2.07	3.11	4.49	3.59	2.13	1.45	1.11	0.84	0.90	31.22
1945	6.86	4.86	2.07	1.50	2.68	10.79	6.59	2.91	1.66	1.19	0.91	0.96	42.98
1946	1.59	3.41	4.23	3.74	4.34	11.68	7.94	4.67	12.64	7.70	3.39	2.30	67.63
1947	2.32	55.96	22.98	5.36	11.95	7.92	5.00	3.09	1.54	0.88	0.64	0.55	118.19
1948	2.43	4.02	4.00	3.77	9.65	6.55	4.42	3.04	1.59	1.03	0.92	0.99	42.41
1949	1.86	7.41	5.32	8.37	6.10	4.58	4.03	3.88	3.08	2.40	3.14	3.20	53.37
1950	2.99	2.69	20.67	10.00	3.42	3.79	3.26	1.93	1.28	1.04	1.24	1.90	54.21
1951	4.20	3.97	3.77	4.55	4.77	4.18	4.20	3.56	2.19	1.37	0.92	1.16	38.84
1952	1.52	1.77	1.89	1.84	2.29	2.47	2.24	1.65	1.05	0.75	0.82	1.67	19.96
1953	3.47	12.53	15.97	7.08	3.55	3.58	2.64	2.24	2.51	2.21	1.52	1.73	59.03
1954	35.75	15.63	3.70	12.64	31.53	13.24	4.34	2.77	1.80	1.30	0.87	1.28	124.85
1955	2.35	3.42	2.73	1.20	1.79	20.43	11.02	4.51	2.97	2.12	1.50	1.58	55.62
1956	3.29	27.03	56.24	19.84	5.07	17.66	12.91	5.36	2.70	1.94	1.73	3.14	156.91
1957	7.84	14.84	7.42	4.78	21.73	10.25	5.16	4.06	2.07	1.26	0.99	0.98	81.38
1958	1.39	3.48	4.92	3.89	3.29	3.31	3.23	47.32	18.77	3.39	3.31	3.05	99.35
1959	3.02	3.69	3.92	3.30	2.85	3.34	3.71	3.36	2.38	1.57	1.38	1.83	34.35
1960	2.33	3.92	14.60	8.85	4.35	4.35	36.63	15.19	2.99	2.07	1.60	1.37	98.25
1961	1.53	3.61	4.76	4.41	8.17	11.78	5.76	2.43	1.58	1.02	1.15	1.42	47.62
1962	2.75	17.34	9.31	23.07	10.38	56.51	21.82	2.93	1.76	4.54	4.73	2.76	157.90
1963	3.33	15.95	15.24	25.10	10.91	4.73	5.61	4.28	38.51	16.34	3.32	2.51	145.83
1964	20.60	9.59	2.89	2.76	2.77	1.89	1.13	1.17	14.86	9.72	6.25	5.60	79.23
1965	25.20	22.94	8.12	3.57	2.86	1.64	0.95	12.47	7.49	2.92	1.94	2.16	92.26
1966	2.49	2.78	3.27	3.99	4.44	41.40	19.16	4.73	2.82	3.31	3.17	1.91	93.47
1967	1.58	3.08	3.25	2.48	2.30	2.36	2.23	1.57	0.92	0.69	1.14	2.45	24.05
1968	3.79	4.66	4.50	2.79	3.52	20.04	9.15	4.08	3.80	2.57	1.93	1.81	62.64
1969	2.62	4.13	4.41	3.07	2.22	1.57	1.00	1.06	1.65	1.72	2.49	3.80	29.74
1970	26.24	12.95	5.80	5.09	4.34	3.71	3.13	4.97	4.56	3.86	7.89	6.19	88.73
1971	31.66	14.03	4.22	3.87	15.38	8.08	2.94	1.59	1.19	1.16	0.96	0.80	85.88
1972	0.96	3.15	4.26	3.39	3.02	3.24	3.04	2.00	1.05	0.70	1.00	2.05	27.86
1973	3.12	7.97	5.50	3.92	4.79	13.94	7.27	7.92	6.25	3.81	2.10	1.29	67.88
1974	1.46	3.08	5.04	4.88	4.73	4.69	3.47	1.93	1.05	0.74	0.68	2.63	34.38
1975	3.97	3.66	21.63	15.99	22.08	72.07	25.73	4.78	3.64	2.15	1.35	1.86	178.91
1976	26.31	12.14	4.16	3.75	3.70	3.51	2.48	1.40	1.00	0.94	0.98	1.50	61.87
1977	3.85	17.20	15.65	7.21	4.36	3.98	100.06	37.21	3.75	2.08	1.55	2.05	198.95
1978	4.28	12.68	7.61	3.78	3.00	3.53	3.15	1.84	0.98	1.46	2.06	2.02	46.39
1979	2.59	3.12	3.15	2.44	1.88	1.89	1.52	1.11	0.86	0.67	0.58	2.93	22.74
1980	4.83	22.29	11.29	5.43	5.18	4.05	2.34	1.87	1.75	1.24	1.52	1.94	63.73
1981	1.70	1.80	1.95	2.90	3.23	5.26	5.26	3.62	2.18	1.55	1.07	0.95	31.47
1982	2.30	2.78	1.94	1.53	1.46	1.26	1.14	1.05	0.81	0.94	1.15	1.28	17.64
1983	1.97	3.92	5.02	14.50	13.23	7.28	11.42	6.30	2.84	2.68	2.56	2.09	73.81
1984	2.17	3.63	5.16	5.27	47.69	18.42	2.42	1.20	0.80	0.73	0.57	0.48	88.54
1985	11.03	11.56	9.47	5.85	3.79	2.61	1.69	1.01	0.70	0.61	1.92	3.55	53.79
1986	11.07	19.00	8.41	4.00	3.30	3.44	3.11	2.01	1.28	0.92	1.48	57.72	115.74
1987	23.65	14.12	25.49	10.16	29.33	62.34	21.32	5.21	5.22	5.19	5.23	4.39	211.65
1988	3.89	13.53	23.45	9.21	38.08	15.51	4.21	3.56	2.52	1.99	1.36	1.05	118.36
1989	3.41	60.52	23.28	3.81	2.65	10.76	6.37	2.46	1.28	0.82	1.69	2.40	119.45
1990	3.69	4.15	3.42	4.23	4.95	3.88	2.00	0.99	0.73	0.58	0.56	1.12	30.30
1991	14.42	12.89	5.84	3.33	2.75	2.66	2.31	1.47	0.84	0.58	0.58	0.80	48.47
1992	1.45	3.29	4.91	4.33	3.93	2.91	1.87	1.20	0.71	0.50	0.53	1.91	27.54
1993	21.97	11.54	20.38	9.42	11.64	20.42	8.08	1.77	0.93	1.26	1.66	1.26	110.33
1994	1.00	1.10	1.39	2.16	1.99	9.31	7.25	4.58	3.83	3.09	1.77	1.32	38.79
1995	2.10	3.68	63.96	27.56	26.22	11.69	3.16	1.47	0.78	1.47	1.99	1.75	145.83
1996	2.39	26.76	12.66	9.73	7.59	5.66	20.10	9.42	41.30	17.94	4.61	3.44	161.60
month	446.54	856.72	811.16	557.58	661.22	816.29	570.88	339.38	312.51	261.95	173.88	228.98	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.66	1.10	1.39	1.16	1.46	1.26	0.91	0.95	0.70	0.50	0.53	0.48	17.64
max	35.75	73.11	63.96	29.72	47.69	72.07	100.06	47.32	41.30	42.97	17.98	57.72	211.65
median	2.75	4.15	5.04	4.41	4.29	4.58	3.71	2.46	1.75	1.55	1.52	1.81	63.73
mean	5.80	11.13	10.53	7.24	8.59	10.60	7.41	4.41	4.06	3.40	2.26	2.97	78.40
Sum of the monthly means = 78.40													
s.d.	7.68	13.75	11.92	6.62	10.13	13.66	12.46	7.03	7.22	6.21	2.60	6.58	47.40
c.v.	1.32	1.24	1.13	0.91	1.18	1.29	1.68	1.59	1.78	1.82	1.15	2.21	0.60

APPENDIX 4.2
KWAHLATHI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.84	3.30	5.49	5.55	4.63	6.54	6.36	4.06	2.11	1.24	0.85	1.08	43.05
1921	2.50	29.21	40.88	14.94	4.64	2.65	1.24	5.36	16.42	9.31	5.01	4.05	136.21
1922	4.62	35.18	15.53	11.70	62.44	43.13	10.92	2.38	1.39	38.23	17.14	3.55	246.21
1923	2.13	1.90	2.59	41.59	33.58	9.76	2.27	1.27	1.10	0.93	0.96	1.51	99.59
1924	2.94	5.30	17.98	8.35	2.60	12.21	8.37	4.16	2.33	1.48	1.05	1.04	67.81
1925	2.16	4.59	5.19	5.31	4.78	33.14	14.06	3.01	3.13	3.11	2.05	2.32	82.85
1926	4.65	6.43	7.90	5.65	3.66	51.10	20.01	2.41	1.29	1.00	1.20	1.54	106.84
1927	2.84	3.04	6.34	33.40	16.69	6.03	3.22	1.77	1.35	1.10	1.39	1.72	78.89
1928	2.38	3.45	3.28	2.64	2.04	3.98	4.40	2.98	9.28	9.23	6.59	12.73	62.98
1929	15.61	10.51	6.55	5.30	4.44	5.09	5.25	3.57	3.31	3.46	3.81	5.34	72.24
1930	5.85	5.19	7.46	36.28	19.43	43.42	17.25	2.83	1.38	58.70	24.43	4.06	226.28
1931	3.69	4.17	3.66	2.79	13.05	8.26	3.32	2.11	2.21	2.72	2.55	4.08	52.61
1932	6.80	62.28	54.07	14.01	2.10	2.44	2.76	2.07	1.42	1.16	1.02	0.88	151.01
1933	0.89	14.91	33.90	22.04	8.44	5.06	4.24	3.11	1.99	2.51	2.71	1.95	101.75
1934	1.90	3.47	19.58	9.99	3.95	3.71	10.98	29.07	36.57	13.92	5.55	4.49	143.18
1935	3.36	3.60	2.39	1.59	28.32	28.71	9.56	5.13	5.82	4.31	2.57	2.04	97.40
1936	4.04	99.87	37.43	5.62	40.21	18.11	4.81	2.46	1.37	1.15	1.10	1.07	217.24
1937	1.67	2.70	3.90	4.23	5.19	4.36	4.10	3.70	2.80	2.62	2.45	1.91	39.63
1938	2.05	3.52	6.83	6.22	18.87	9.82	3.76	3.04	2.59	2.56	2.81	18.26	80.33
1939	12.46	7.82	9.15	5.88	3.55	3.46	3.27	6.62	6.83	4.52	2.62	1.95	68.13
1940	2.21	5.09	10.97	6.44	2.67	2.29	2.37	1.68	1.13	1.05	1.15	1.44	38.49
1941	2.48	3.61	3.38	12.68	8.31	6.12	5.33	4.07	2.86	1.78	1.68	2.23	54.53
1942	3.85	48.21	52.37	16.67	4.50	14.70	23.71	10.74	4.78	4.12	6.40	6.72	196.77
1943	13.33	38.31	29.01	9.64	6.13	5.81	3.89	2.45	1.97	1.97	1.69	4.43	118.63
1944	7.11	5.66	2.86	2.85	4.29	6.79	5.04	2.85	1.95	1.48	1.12	1.21	43.21
1945	10.50	6.92	2.77	2.04	3.69	16.19	9.38	3.90	2.23	1.59	1.22	1.29	61.72
1946	2.16	4.67	5.81	5.15	6.43	16.91	11.31	6.32	17.69	10.53	4.51	3.08	94.57
1947	3.13	76.66	31.92	7.36	17.28	11.68	6.85	4.11	2.05	1.17	0.85	0.74	163.80
1948	3.31	5.50	5.49	5.19	14.68	9.36	5.97	4.12	2.15	1.39	1.24	1.34	59.74
1949	2.53	11.37	7.59	12.54	8.62	6.20	5.50	5.30	4.20	3.26	4.27	4.36	75.74
1950	4.08	3.67	29.42	13.98	4.64	5.19	4.47	2.64	1.74	1.40	1.68	2.59	75.50
1951	6.74	5.62	5.07	6.21	6.55	5.76	5.78	4.89	2.99	1.87	1.25	1.57	54.30
1952	2.07	2.42	2.59	2.54	3.17	3.41	3.08	2.26	1.44	1.02	1.10	2.28	27.38
1953	4.75	18.34	22.79	9.78	4.81	4.90	3.61	3.07	3.43	3.01	2.06	2.36	82.91
1954	49.48	21.46	4.99	18.51	43.76	18.09	5.87	3.75	2.44	1.76	1.17	1.74	173.02
1955	3.21	4.67	3.74	1.64	2.48	29.14	15.44	6.04	3.97	2.84	2.02	2.14	77.33
1956	4.49	37.85	76.99	26.97	6.90	25.20	18.48	7.37	3.59	2.60	2.33	4.27	217.04
1957	11.81	21.04	10.18	7.44	30.01	13.91	7.71	5.65	2.72	1.67	1.31	1.32	114.77
1958	1.88	5.09	6.76	5.29	4.52	4.56	4.45	65.20	25.70	4.52	4.45	4.12	136.54
1959	4.10	5.04	5.37	4.55	3.94	4.61	5.11	4.62	3.26	2.14	1.87	2.49	47.10
1960	3.18	5.68	20.79	13.08	6.11	5.95	50.26	20.71	3.98	2.77	2.14	1.85	136.50
1961	2.08	5.64	6.63	5.97	12.47	17.09	7.96	3.25	2.12	1.37	1.55	1.92	68.05
1962	3.75	24.70	12.97	32.29	14.37	77.31	29.75	3.93	2.36	7.17	6.65	3.67	218.92
1963	4.50	22.69	21.72	34.84	14.93	6.41	8.86	6.14	52.59	22.18	4.42	3.37	202.65
1964	28.88	13.26	3.89	3.77	3.81	2.60	1.55	1.61	21.38	13.49	8.39	7.57	110.20
1965	35.09	31.92	11.12	4.84	3.91	2.25	1.31	18.22	10.50	3.89	2.59	2.91	128.55
1966	3.38	3.79	4.49	5.50	6.13	57.51	27.01	6.53	3.76	4.46	4.28	2.58	129.42
1967	2.14	4.21	4.46	3.41	3.18	3.26	3.07	2.16	1.26	0.93	1.55	3.34	32.97
1968	5.18	6.39	6.19	3.84	5.50	27.97	12.53	5.49	5.15	3.48	2.61	2.46	86.79
1969	3.57	5.65	6.06	4.23	3.06	2.16	1.37	1.46	2.25	2.35	3.39	5.20	40.75
1970	36.71	18.08	8.26	6.94	5.88	5.07	4.29	8.06	6.53	5.15	11.51	8.58	125.06
1971	43.47	19.14	5.70	5.29	22.36	11.40	3.95	2.15	1.61	1.57	1.30	1.08	119.02
1972	1.30	4.64	5.87	4.60	4.14	4.47	4.18	2.75	1.43	0.95	1.36	2.80	38.49
1973	4.26	12.14	7.84	5.32	7.31	19.79	10.00	11.56	8.65	5.08	2.81	1.73	96.49
1974	1.97	4.21	8.08	6.94	6.40	6.41	4.75	2.63	1.42	1.00	0.91	3.59	48.31
1975	5.42	5.00	30.62	22.90	30.83	98.02	34.85	6.44	4.92	2.90	1.82	2.52	246.24
1976	36.61	16.70	5.63	5.13	5.09	4.84	3.41	1.92	1.36	1.27	1.33	2.04	85.33
1977	5.92	23.92	22.03	9.96	5.92	5.44	136.16	50.54	5.02	2.78	2.08	2.77	272.54
1978	6.70	17.80	10.37	5.12	4.11	4.85	4.33	2.52	1.34	1.98	2.80	2.76	64.68
1979	3.54	4.26	4.32	3.37	2.60	2.61	2.09	1.52	1.18	0.91	0.79	4.47	31.66
1980	6.63	30.89	15.86	7.52	6.99	5.48	3.18	2.55	2.39	1.68	2.07	2.63	87.87
1981	2.31	2.45	2.67	4.00	4.46	8.71	7.58	4.85	2.93	2.09	1.44	1.28	44.77
1982	3.14	3.79	2.65	2.11	2.02	1.74	1.58	1.43	1.10	1.28	1.56	1.74	24.14
1983	2.68	5.70	6.92	20.96	19.08	10.60	15.91	8.55	3.78	3.60	3.46	2.82	104.06
1984	2.95	4.96	7.98	7.42	65.49	25.20	3.25	1.61	1.07	0.98	0.76	0.64	122.31
1985	16.12	16.63	13.74	8.13	5.14	3.56	2.32	1.38	0.95	0.82	2.62	4.84	76.25
1986	16.26	26.68	11.52	5.42	4.52	4.73	4.27	2.75	1.75	1.25	2.02	79.02	160.19
1987	32.24	20.01	35.46	13.93	40.66	85.07	28.92	7.14	7.04	6.99	7.07	5.95	290.48
1988	5.29	19.59	32.74	12.62	52.57	21.29	5.69	4.83	3.41	2.70	1.84	1.42	163.99
1989	5.50	82.12	31.43	5.16	3.62	16.05	9.05	3.29	1.72	1.10	2.28	3.26	164.58
1990	5.04	5.67	4.68	6.65	6.95	5.25	2.71	1.34	0.98	0.78	0.76	1.51	42.32
1991	20.75	18.44	8.04	4.51	3.77	3.66	3.17	2.02	1.14	0.78	0.78	1.08	68.14
1992	1.97	4.51	7.27	6.05	5.35	3.99	2.57	1.64	0.97	0.67	0.71	2.61	38.31
1993	30.86	15.92	28.55	13.04	16.95	28.69	11.09	2.35	1.24	1.70	2.25	1.71	154.35
1994	1.35	1.49	1.90	2.98	2.76	14.18	10.28	6.16	5.18	4.19	2.39	1.78	54.64
1995	2.85	5.04	87.76	38.52	36.41	15.99	4.26	1.99	1.05	1.99	2.70	2.38	200.94
1996	3.26	37.35	17.47	14.39	11.42	7.86	28.08	12.97	56.35	24.35	6.17	4.63	224.30
month	624.45	1192.70	1133.85	781.30	926.26	1139.26	789.09	468.58	428.84	357.06	236.39	313.80	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.89	1.49	1.90	1.59	2.02	1.74	1.24	1.27	0.95	0.67	0.71	0.64	24.14
max	49.48	99.87	87.76	41.59	65.49	98.02	136.16	65.20	56.35	58.70	24.43	79.02	290.48
median	3.75	5.68	7.59	6.21	5.88	6.41	5.11	3.29	2.36	2.09	2.06	2.46	87.87
mean	8.11	15.49	14.73	10.15	12.03	14.80	10.25	6.09	5.57	4.64	3.07	4.08	108.98
Sum of the monthly means = 108.98													
s.d.	10.70	18.86	16.41	9.26	14.04	18.73	17.00	9.67	9.91	8.51	3.57	9.04	65.15
c.v.	1.32	1.22	1.11	0.91	1.17	1.27	1.66	1.59	1.78	1.83	1.16	2.22	0.60

APPENDIX 4.3
MBONGWENI WEIR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.49	0.85	1.38	1.38	1.14	1.43	1.55	1.04	0.55	0.33	0.23	0.28	10.65
1921	0.64	6.59	9.80	3.75	1.21	0.68	0.32	1.05	3.55	2.29	1.36	1.08	32.32
1922	1.20	8.37	3.82	2.12	15.56	10.58	2.72	0.65	0.38	9.28	4.30	0.97	59.95
1923	0.57	0.50	0.66	9.70	7.81	2.39	0.61	0.34	0.29	0.25	0.25	0.39	23.76
1924	0.75	1.34	3.52	1.82	0.69	2.13	1.88	1.12	0.62	0.40	0.28	0.28	14.83
1925	0.56	1.16	1.30	1.31	1.18	7.46	3.32	0.81	0.83	0.81	0.54	0.60	19.88
1926	1.18	1.62	1.78	1.36	0.92	12.41	4.96	0.66	0.35	0.27	0.32	0.41	26.24
1927	0.73	0.78	1.25	7.80	3.97	1.55	0.85	0.46	0.35	0.29	0.36	0.45	18.84
1928	0.61	0.87	0.82	0.65	0.50	0.98	1.09	0.75	1.41	2.15	1.78	2.65	14.26
1929	3.48	2.54	1.70	1.36	1.12	1.26	1.30	0.90	0.84	0.88	0.97	1.36	17.71
1930	1.48	1.31	1.56	8.55	4.24	10.69	4.40	0.77	0.37	14.76	6.25	1.10	55.48
1931	0.98	1.08	0.93	0.70	2.19	1.79	0.89	0.55	0.58	0.70	0.66	1.04	12.09
1932	1.70	15.42	13.31	3.51	0.56	0.62	0.70	0.53	0.36	0.30	0.27	0.23	37.51
1933	0.23	2.87	8.07	4.98	2.02	1.32	1.08	0.79	0.51	0.64	0.70	0.50	23.71
1934	0.49	0.88	3.94	2.25	1.03	0.94	1.78	7.01	9.25	3.63	1.50	1.19	33.89
1935	0.88	0.93	0.61	0.40	6.17	6.55	2.36	1.36	1.51	1.12	0.67	0.53	23.09
1936	1.03	25.28	9.54	1.45	9.53	4.44	1.27	0.64	0.36	0.31	0.29	0.28	54.42
1937	0.43	0.69	0.97	1.05	1.27	1.07	1.02	0.92	0.71	0.67	0.63	0.49	9.92
1938	0.53	0.89	1.48	1.50	3.80	2.23	1.00	0.79	0.67	0.66	0.73	3.86	18.14
1939	2.93	2.06	1.96	1.44	0.94	0.88	0.82	1.38	1.68	1.19	0.69	0.52	16.49
1940	0.57	1.22	1.86	1.39	0.71	0.58	0.60	0.43	0.29	0.27	0.30	0.37	8.59
1941	0.63	0.91	0.85	2.08	1.79	1.59	1.36	1.03	0.73	0.46	0.44	0.57	12.44
1942	0.98	11.59	12.82	4.20	1.17	2.77	5.40	2.71	1.29	1.09	1.54	1.72	47.28
1943	2.70	9.35	6.88	2.36	1.49	1.46	1.00	0.63	0.51	0.51	0.44	1.08	28.41
1944	1.81	1.45	0.73	0.71	1.06	1.50	1.22	0.73	0.50	0.39	0.30	0.32	10.72
1945	1.78	1.53	0.75	0.52	0.92	3.01	2.09	1.05	0.60	0.43	0.33	0.34	13.35
1946	0.56	1.18	1.45	1.28	1.46	3.31	2.56	1.66	3.99	2.60	1.23	0.83	22.11
1947	0.82	19.24	7.94	1.87	3.49	2.56	1.76	1.09	0.55	0.31	0.23	0.20	40.06
1948	0.84	1.39	1.37	1.29	2.58	2.07	1.56	1.07	0.56	0.37	0.33	0.35	13.78
1949	0.65	1.94	1.67	2.34	1.96	1.61	1.40	1.34	1.07	0.84	1.09	1.12	17.03
1950	1.04	0.93	6.55	3.30	1.21	1.31	1.12	0.67	0.45	0.36	0.44	0.66	18.04
1951	1.42	1.36	1.30	1.55	1.62	1.42	1.43	1.22	0.76	0.48	0.33	0.41	13.30
1952	0.53	0.62	0.65	0.63	0.78	0.84	0.76	0.57	0.37	0.27	0.29	0.58	6.89
1953	1.20	3.72	5.03	2.39	1.25	1.24	0.91	0.78	0.87	0.77	0.53	0.61	19.30
1954	12.03	5.35	1.32	3.75	10.55	4.58	1.54	0.97	0.63	0.46	0.31	0.45	41.94
1955	0.82	1.18	0.94	0.41	0.61	6.38	3.64	1.61	1.06	0.75	0.54	0.56	18.50
1956	1.15	8.87	19.36	6.93	1.77	5.51	4.03	1.83	0.98	0.70	0.62	1.10	52.85
1957	2.16	4.75	2.55	1.64	6.95	3.41	1.79	1.42	0.73	0.45	0.35	0.35	26.55
1958	0.49	1.19	1.69	1.33	1.12	1.13	1.10	16.06	6.45	1.23	1.18	1.08	34.05
1959	1.06	1.28	1.35	1.13	0.97	1.14	1.26	1.15	0.82	0.55	0.48	0.64	11.83
1960	0.81	1.34	4.39	2.83	1.57	1.55	12.39	5.22	1.08	0.75	0.57	0.49	32.99
1961	0.54	1.23	1.63	1.51	2.07	3.54	1.95	0.88	0.57	0.37	0.41	0.50	15.20
1962	0.96	5.43	3.08	7.52	3.48	19.48	7.57	1.05	0.63	1.33	1.67	1.04	53.24
1963	1.20	5.08	4.82	8.35	3.74	1.66	1.88	1.52	13.35	5.73	1.21	0.90	49.44
1964	6.75	3.24	1.03	0.96	0.95	0.65	0.39	0.40	4.58	3.26	2.24	1.98	26.43
1965	8.38	7.63	2.79	1.26	0.99	0.56	0.33	3.71	2.45	1.07	0.70	0.77	30.64
1966	0.88	0.97	1.13	1.36	1.51	13.83	6.21	1.61	1.02	1.18	1.12	0.68	31.50
1967	0.56	1.07	1.12	0.85	0.78	0.80	0.76	0.54	0.32	0.24	0.40	0.85	8.29
1968	1.31	1.61	1.55	0.96	1.17	6.26	2.99	1.45	1.34	0.91	0.68	0.64	20.87
1969	0.91	1.43	1.52	1.05	0.75	0.53	0.34	0.37	0.57	0.60	0.86	1.32	10.25
1970	8.75	4.43	2.03	1.76	1.49	1.27	1.07	1.56	1.60	1.41	2.40	2.09	29.86
1971	10.83	4.86	1.50	1.34	4.64	2.62	1.05	0.57	0.42	0.41	0.34	0.29	28.87
1972	0.34	1.08	1.46	1.16	1.03	1.10	1.04	0.69	0.36	0.25	0.35	0.72	9.58
1973	1.08	2.12	1.74	1.38	1.62	4.16	2.35	2.36	2.10	1.38	0.76	0.47	21.52
1974	0.52	1.07	1.69	1.66	1.61	1.60	1.19	0.67	0.37	0.26	0.24	0.91	11.79
1975	1.37	1.26	6.88	4.98	7.29	25.15	9.05	1.70	1.29	0.76	0.48	0.65	60.86
1976	8.69	4.12	1.48	1.30	1.27	1.20	0.85	0.48	0.35	0.33	0.35	0.53	20.95
1977	1.31	5.38	4.93	2.43	1.53	1.37	34.86	13.02	1.35	0.75	0.56	0.72	68.21
1978	1.46	3.82	2.49	1.33	1.04	1.21	1.08	0.63	0.34	0.51	0.72	0.71	15.34
1979	0.90	1.08	1.08	0.83	0.64	0.64	0.52	0.38	0.30	0.24	0.21	1.00	7.82
1980	1.67	7.20	3.77	1.90	1.79	1.39	0.80	0.65	0.61	0.43	0.53	0.68	21.42
1981	0.59	0.62	0.67	0.99	1.10	1.52	1.80	1.31	0.79	0.56	0.39	0.34	10.68
1982	0.80	0.96	0.67	0.52	0.50	0.43	0.39	0.36	0.28	0.33	0.40	0.45	6.09
1983	0.68	1.34	1.72	4.30	4.02	2.44	3.53	2.09	1.03	0.96	0.91	0.74	23.76
1984	0.76	1.26	1.74	1.79	16.07	6.27	0.87	0.43	0.28	0.26	0.20	0.17	30.10
1985	3.27	3.57	2.87	1.96	1.33	0.91	0.59	0.35	0.25	0.22	0.67	1.23	17.22
1986	3.26	6.21	2.90	1.41	1.14	1.18	1.07	0.69	0.45	0.32	0.52	19.87	39.02
1987	8.22	4.52	8.59	3.52	9.76	21.58	7.48	1.84	1.84	1.82	1.83	1.53	72.53
1988	1.36	4.11	7.70	3.15	12.88	5.31	1.49	1.25	0.88	0.70	0.48	0.37	39.68
1989	1.15	20.80	8.06	1.34	0.92	3.04	2.03	0.89	0.46	0.30	0.60	0.84	40.43
1990	1.28	1.44	1.18	1.42	1.68	1.33	0.68	0.34	0.25	0.20	0.20	0.39	10.39
1991	4.45	4.04	1.98	1.18	0.95	0.91	0.79	0.51	0.29	0.20	0.21	0.28	15.79
1992	0.51	1.14	1.66	1.48	1.34	0.99	0.64	0.42	0.25	0.18	0.19	0.66	9.46
1993	7.11	3.89	6.64	3.16	3.50	6.66	2.77	0.64	0.34	0.45	0.59	0.45	36.20
1994	0.35	0.38	0.48	0.74	0.68	2.48	2.32	1.63	1.35	1.09	0.63	0.47	12.60
1995	0.73	1.27	21.92	9.09	8.89	4.07	1.13	0.52	0.28	0.52	0.70	0.61	49.73
1996	0.83	8.78	4.27	2.81	2.30	2.01	6.75	3.24	14.32	6.29	1.66	1.23	54.49
month	148.70	284.86	270.62	183.76	217.33	270.52	193.45	116.51	106.72	90.79	61.06	79.12	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.23	0.38	0.48	0.40	0.50	0.43	0.32	0.34	0.25	0.18	0.19	0.17	6.09
max	12.03	25.28	21.92	9.70	16.07	25.15	34.86	16.06	14.32	14.76	6.25	19.87	72.53
median	0.98	1.44	1.70	1.48	1.46	1.59	1.27	0.89	0.62	0.55	0.54	0.64	21.42
mean	1.93	3.70	3.51	2.39	2.82	3.51	2.51	1.51	1.39	1.18	0.79	1.03	26.28
Sum of the monthly means = 26.28													
s.d.	2.55	4.68	4.04	2.15	3.38	4.68	4.32	2.39	2.47	2.12	0.90	2.25	16.18
c.v.	1.32	1.27	1.15	0.90	1.20	1.33	1.72	1.58	1.79	1.80	1.13	2.19	0.62

APPENDIX 4.4
GXALIBOMVU WEIR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.59	3.24	7.03	6.02	5.09	6.99	6.31	3.97	2.04	1.18	0.79	1.24	45.49
1921	2.75	24.86	27.28	10.33	3.64	1.92	1.04	7.92	11.05	7.01	5.14	5.14	108.08
1922	22.13	56.63	20.31	46.06	63.63	32.53	8.53	2.51	1.52	30.28	14.14	3.28	301.55
1923	2.14	2.40	3.33	23.08	19.65	6.86	1.98	1.13	1.01	0.91	1.07	2.08	65.64
1924	3.53	5.43	9.71	6.61	5.02	26.98	13.19	4.40	2.54	1.79	1.41	2.28	82.89
1925	3.65	4.79	4.92	5.29	5.51	36.01	15.11	3.29	3.47	3.46	2.31	2.51	90.32
1926	4.90	14.29	10.44	5.62	3.64	53.55	20.70	2.26	1.17	0.84	0.84	1.35	119.60
1927	3.05	3.13	3.64	5.32	7.35	5.99	3.43	2.09	1.71	1.35	1.92	2.31	41.29
1928	2.79	4.42	4.80	4.33	3.49	5.19	4.33	2.75	21.08	16.41	8.43	21.76	99.78
1929	36.92	29.88	10.56	3.99	2.69	2.81	3.21	2.62	3.05	3.73	4.29	10.82	114.57
1930	8.01	5.12	4.24	26.49	25.73	40.47	15.47	3.20	1.61	119.57	44.18	4.25	298.34
1931	4.51	5.04	4.47	3.05	18.50	10.47	3.85	2.70	2.86	3.19	2.87	14.26	75.77
1932	13.40	70.79	54.17	12.98	2.78	3.40	2.93	1.96	1.39	1.13	0.96	0.99	166.88
1933	1.20	10.12	26.03	32.72	12.32	5.41	4.51	3.04	1.97	3.35	3.94	2.45	107.06
1934	1.87	3.90	17.91	9.36	3.32	3.52	14.49	27.85	47.75	18.05	6.21	5.23	159.46
1935	3.99	4.20	2.80	1.79	40.32	41.69	12.74	7.17	6.83	4.88	2.95	2.32	131.68
1936	5.49	95.63	35.08	3.45	9.85	14.01	7.11	2.78	1.53	1.45	1.65	1.74	179.77
1937	2.28	2.85	5.15	5.75	4.87	3.17	4.03	4.17	3.35	3.31	2.90	1.98	43.81
1938	1.89	3.68	5.72	6.22	17.36	9.77	4.54	3.86	3.33	3.46	4.14	32.81	96.78
1939	19.82	7.54	6.09	4.29	2.70	2.82	2.65	4.01	4.49	3.21	2.17	1.89	61.68
1940	2.02	5.23	6.01	4.10	2.17	1.57	1.60	1.29	1.10	1.17	1.24	1.42	28.92
1941	2.50	4.33	3.83	31.27	13.54	4.25	3.43	3.07	2.64	1.72	1.74	2.49	74.81
1942	3.85	64.02	45.88	12.18	3.74	5.37	18.45	9.67	4.27	3.39	5.47	6.33	182.62
1943	7.15	26.87	16.90	6.54	6.12	5.31	3.45	2.13	1.67	1.82	1.65	16.03	95.64
1944	11.39	6.09	3.17	3.08	4.97	6.02	4.38	2.68	1.90	1.54	1.23	1.62	48.07
1945	32.94	14.21	2.73	2.03	3.77	12.80	8.40	4.11	2.34	1.71	1.30	1.31	87.65
1946	2.10	6.03	6.24	4.77	4.42	11.84	19.90	9.78	11.58	8.26	4.25	3.00	92.17
1947	3.03	82.65	33.43	5.87	11.90	9.21	6.16	3.73	1.88	1.10	0.80	0.73	160.49
1948	4.08	6.06	5.44	4.22	40.02	19.36	6.84	4.32	2.18	1.36	1.23	1.58	96.69
1949	2.86	22.28	11.36	6.52	6.51	5.61	5.08	5.44	4.37	3.26	3.91	3.92	81.12
1950	4.28	3.93	22.53	12.29	5.04	4.95	4.02	2.41	1.65	1.39	1.65	2.48	66.62
1951	12.03	7.07	8.09	8.04	6.02	5.18	5.30	4.25	2.61	1.67	1.11	1.70	63.07
1952	2.48	2.80	2.77	2.59	3.03	3.25	3.04	2.28	1.47	1.05	1.15	2.77	28.68
1953	5.93	32.00	21.54	7.46	3.67	3.99	3.34	2.84	3.23	3.05	2.17	2.64	91.86
1954	58.06	24.07	4.75	16.13	28.53	13.38	5.49	3.24	2.12	1.58	1.06	1.90	160.31
1955	3.53	4.87	3.56	1.49	2.41	32.27	15.58	5.04	3.48	2.66	1.90	2.34	79.13
1956	5.58	55.30	89.61	29.49	6.70	19.78	24.29	9.75	3.58	2.65	2.30	3.60	252.63
1957	6.64	9.38	8.19	14.06	30.47	13.46	14.43	7.66	2.55	1.65	1.44	1.48	111.41
1958	2.01	5.33	6.46	4.18	3.31	3.64	3.65	57.74	23.12	4.72	5.31	5.25	124.72
1959	4.97	5.07	4.82	4.11	3.28	4.19	5.04	5.13	3.87	2.57	2.29	3.08	48.42
1960	3.61	5.94	17.44	10.67	5.55	5.19	49.85	20.97	4.53	3.77	3.37	2.74	133.63
1961	2.73	11.26	8.50	5.31	4.89	13.18	7.48	3.28	2.10	1.32	1.69	2.32	64.06
1962	4.60	24.78	12.07	25.66	11.87	74.29	28.51	4.02	2.78	18.56	10.22	3.47	220.83
1963	4.16	9.94	7.87	30.94	17.18	8.11	13.30	7.46	54.99	22.81	4.26	3.27	184.29
1964	14.67	8.46	3.43	2.92	2.70	1.71	1.01	1.33	29.80	15.71	7.70	7.00	96.44
1965	48.29	34.30	10.30	4.35	3.39	1.96	1.12	13.84	8.90	3.81	2.54	2.97	135.77
1966	3.29	3.23	3.59	5.62	5.71	44.95	33.95	10.04	3.50	4.81	5.03	3.12	126.84
1967	2.31	4.08	4.18	3.06	2.93	2.85	2.48	1.73	1.10	0.92	1.53	3.65	30.82
1968	5.79	8.57	6.94	3.85	6.18	27.99	12.45	18.58	10.06	4.04	2.87	2.50	109.82
1969	3.41	6.25	6.02	3.58	2.59	1.98	1.39	1.40	2.28	2.56	14.54	10.48	56.48
1970	52.80	28.77	8.26	4.82	4.42	4.05	3.87	24.35	11.87	5.75	17.71	10.41	177.08
1971	45.09	19.84	6.13	4.74	32.97	14.49	3.57	2.15	1.67	1.66	1.58	1.40	135.29
1972	1.41	4.77	6.27	4.97	3.69	3.49	5.05	4.11	2.08	1.25	1.77	3.69	42.55
1973	5.50	24.76	11.83	4.17	4.82	6.06	5.05	24.68	13.21	5.46	3.20	2.11	110.85
1974	2.16	3.75	6.12	5.19	4.00	3.69	3.20	2.33	1.54	1.22	1.24	22.52	56.96
1975	11.85	4.88	16.52	9.22	28.49	116.01	41.32	10.80	6.94	3.46	2.28	3.19	254.96
1976	79.48	30.46	3.83	3.41	10.03	7.32	3.77	1.94	1.43	1.51	2.12	3.45	148.75
1977	5.77	30.35	33.47	12.03	4.19	3.66	165.72	61.23	6.09	3.70	2.69	3.01	331.91
1978	16.59	11.70	6.07	3.70	2.86	4.45	4.17	2.65	1.67	2.93	4.57	4.91	66.27
1979	6.16	5.68	4.39	3.04	2.74	2.75	2.09	1.65	1.41	1.21	1.11	7.68	39.91
1980	7.38	21.19	11.56	6.75	5.55	3.66	2.03	2.83	3.49	2.57	3.09	3.49	73.59
1981	2.77	2.85	2.81	3.17	3.01	35.14	16.71	5.05	3.03	2.19	1.61	1.44	79.78
1982	2.85	3.65	2.47	1.67	1.56	1.32	1.12	0.96	0.80	20.90	11.54	4.72	53.56
1983	4.65	9.80	7.65	7.58	6.48	5.02	4.96	4.39	3.82	6.19	6.10	4.42	71.06
1984	4.02	18.12	10.34	5.08	74.32	28.29	3.24	1.67	1.11	1.05	0.86	0.76	148.86
1985	3.55	20.52	10.75	9.56	5.96	3.42	2.87	2.05	1.34	0.99	2.29	5.63	68.93
1986	20.73	12.22	5.44	4.18	2.85	3.19	3.39	2.39	1.79	1.47	1.90	115.72	175.27
1987	44.31	21.90	11.04	4.21	22.41	85.77	30.85	9.47	7.43	6.69	7.29	5.88	257.25
1988	5.24	25.14	51.70	17.48	35.03	16.06	14.30	8.06	3.78	2.97	2.06	1.78	183.60
1989	13.17	48.05	17.89	3.75	2.82	10.26	6.54	2.59	1.41	1.00	2.17	3.31	112.96
1990	4.68	4.66	3.42	3.86	6.22	5.32	2.86	1.65	1.34	1.11	1.21	2.16	38.49
1991	10.24	25.49	11.10	3.92	2.87	2.11	2.16	1.83	1.23	0.93	1.01	1.76	64.65
1992	3.08	3.83	4.15	3.59	2.67	1.67	1.22	1.07	0.86	0.72	0.84	2.38	26.08
1993	5.65	6.97	20.14	9.32	46.06	19.76	3.91	1.69	0.95	1.25	2.64	2.73	121.07
1994	2.24	1.98	5.40	5.35	3.18	14.67	36.97	14.95	6.36	5.94	3.58	2.55	103.17
1995	3.54	4.35	58.09	24.18	11.57	6.56	3.12	2.16	1.50	3.98	5.12	3.74	127.91
1996	4.84	64.40	25.52	6.13	16.66	9.53	28.52	13.09	82.00	33.29	6.29	4.88	295.15
month	785.95	1322.42	1013.69	674.20	857.50	1098.92	866.14	534.68	495.55	476.58	307.13	457.60	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	1.20	1.98	2.47	1.49	1.56	1.32	1.01	0.96	0.80	0.72	0.79	0.73	26.08
max	79.48	95.63	89.61	46.06	74.32	116.01	165.72	61.23	82.00	119.57	44.18	115.72	331.91
median	4.51	7.54	7.03	5.31	5.04	5.99	4.54	3.28	2.55	2.65	2.29	2.97	96.78
mean	10.21	17.17	13.16	8.76	11.14	14.27	11.25	6.94	6.44	6.19	3.99	5.94	115.46
Sum of the monthly means = 115.46													
s.d.	14.91	19.90	15.11	8.71	14.03	19.91	20.53	10.34	12.60	14.60	5.68	13.71	70.13
c.v.	1.46	1.16	1.15	0.99	1.26	1.40	1.83	1.49	1.96	2.36	1.43	2.31	0.61

APPENDIX 4.5
SPES BONA WEIR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.42	2.52	4.16	4.19	3.48	4.51	4.73	3.13	1.63	0.96	0.66	0.83	32.22
1921	1.91	21.49	30.57	11.31	3.55	2.02	0.94	3.37	12.35	7.19	3.88	3.12	101.70
1922	3.53	26.14	11.65	8.15	47.19	32.46	8.25	1.85	1.08	28.69	12.98	2.76	184.73
1923	1.64	1.46	1.97	30.93	24.92	7.35	1.75	0.98	0.84	0.71	0.74	1.15	74.44
1924	2.24	4.02	12.75	6.09	2.00	8.44	6.14	3.21	1.80	1.15	0.81	0.80	49.45
1925	1.64	3.48	3.93	4.00	3.60	24.42	10.49	2.33	2.41	2.38	1.57	1.78	62.03
1926	3.53	4.88	5.51	4.17	2.80	38.29	15.08	1.87	1.00	0.78	0.92	1.18	80.01
1927	2.16	2.31	4.03	25.03	12.38	4.57	2.49	1.36	1.04	0.85	1.07	1.32	58.61
1928	1.81	2.62	2.48	1.99	1.53	2.99	3.32	2.26	6.24	6.85	5.10	9.17	46.36
1929	11.45	7.70	4.98	4.07	3.38	3.84	3.96	2.70	2.51	2.63	2.90	4.06	54.18
1930	4.44	3.93	4.93	27.20	14.28	32.71	13.12	2.19	1.07	44.57	18.63	3.15	170.22
1931	2.84	3.18	2.78	2.11	8.94	6.01	2.56	1.62	1.69	2.08	1.95	3.10	38.86
1932	5.12	47.14	40.79	10.61	1.62	1.85	2.09	1.57	1.08	0.89	0.78	0.67	114.21
1933	0.69	10.54	25.21	16.18	6.31	3.87	3.22	2.37	1.51	1.91	2.07	1.49	75.37
1934	1.45	2.63	13.98	7.34	3.02	2.82	7.47	21.68	27.73	10.66	4.30	3.46	106.54
1935	2.58	2.74	1.81	1.20	20.63	21.18	7.21	3.95	4.45	3.30	1.97	1.56	72.58
1936	3.07	75.83	28.48	4.29	29.86	13.59	3.69	1.88	1.05	0.89	0.85	0.83	164.31
1937	1.27	2.05	2.94	3.19	3.90	3.28	3.09	2.79	2.12	2.00	1.87	1.46	29.96
1938	1.56	2.67	4.64	4.60	13.67	7.29	2.90	2.32	1.98	1.96	2.14	13.21	58.94
1939	9.17	6.00	6.33	4.30	2.72	2.63	2.47	4.37	5.08	3.53	2.04	1.51	50.15
1940	1.70	3.70	7.73	4.76	2.05	1.74	1.79	1.28	0.86	0.80	0.88	1.10	28.39
1941	1.88	2.74	2.55	8.65	6.04	4.68	4.05	3.09	2.18	1.36	1.29	1.70	40.21
1942	2.92	36.07	39.39	12.64	3.44	10.34	17.48	8.15	3.70	3.17	4.62	5.11	147.03
1943	9.70	28.84	21.63	7.24	4.48	4.40	2.99	1.87	1.50	1.51	1.29	3.27	88.72
1944	5.43	4.34	2.18	2.15	3.23	4.72	3.73	2.20	1.50	1.14	0.87	0.93	32.42
1945	7.23	5.07	2.14	1.55	2.78	11.34	6.87	3.01	1.72	1.23	0.94	0.99	44.87
1946	1.65	3.54	4.39	3.88	4.55	12.21	8.28	4.84	13.15	7.99	3.50	2.38	70.36
1947	2.40	58.06	23.89	5.56	12.49	8.31	5.19	3.20	1.59	0.91	0.66	0.57	122.83
1948	2.52	4.17	4.15	3.91	10.16	6.84	4.58	3.15	1.65	1.06	0.95	1.03	44.17
1949	1.93	7.82	5.55	8.80	6.35	4.74	4.18	4.03	3.19	2.49	3.25	3.32	55.65
1950	3.10	2.79	21.56	10.41	3.55	3.93	3.38	2.00	1.32	1.07	1.28	1.97	56.36
1951	4.46	4.13	3.90	4.72	4.95	4.34	4.36	3.70	2.27	1.42	0.96	1.20	40.41
1952	1.58	1.84	1.96	1.92	2.38	2.56	2.32	1.71	1.09	0.78	0.85	1.73	20.72
1953	3.60	13.12	16.66	7.35	3.68	3.71	2.74	2.33	2.60	2.29	1.57	1.80	61.45
1954	37.14	16.22	3.83	13.24	32.77	13.74	4.50	2.87	1.87	1.35	0.90	1.33	129.76
1955	2.44	3.54	2.83	1.24	1.86	21.31	11.47	4.66	3.08	2.19	1.56	1.64	57.82
1956	3.42	28.13	58.35	20.56	5.26	18.42	13.48	5.56	2.79	2.01	1.79	3.26	163.03
1957	8.24	15.47	7.70	5.05	22.57	10.62	5.42	4.22	2.13	1.30	1.02	1.02	84.76
1958	1.44	3.64	5.10	4.03	3.42	3.44	3.36	49.14	19.47	3.51	3.43	3.16	103.14
1959	3.13	3.83	4.07	3.43	2.96	3.47	3.85	3.49	2.47	1.63	1.43	1.90	35.66
1960	2.42	4.09	15.23	9.28	4.53	4.51	38.01	15.75	3.09	2.14	1.65	1.42	102.12
1961	1.59	3.82	4.95	4.57	8.61	12.32	5.98	2.51	1.64	1.05	1.19	1.47	49.70
1962	2.85	18.09	9.69	24.00	10.79	58.63	22.63	3.04	1.82	4.81	4.92	2.85	164.12
1963	3.45	16.63	15.90	26.09	11.32	4.90	5.94	4.47	39.94	16.93	3.43	2.60	151.60
1964	21.44	9.97	2.99	2.86	2.88	1.96	1.17	1.22	15.52	10.11	6.47	5.80	82.39
1965	26.20	23.85	8.43	3.70	2.96	1.70	0.99	13.05	7.79	3.02	2.01	2.24	95.94
1966	2.59	2.89	3.39	4.14	4.61	43.04	19.96	4.91	2.92	3.43	3.28	1.98	97.14
1967	1.64	3.20	3.38	2.58	2.39	2.45	2.32	1.63	0.96	0.71	1.18	2.54	24.98
1968	3.93	4.84	4.68	2.90	3.72	20.84	9.50	4.22	3.94	2.67	2.00	1.88	65.12
1969	2.72	4.28	4.58	3.19	2.30	1.63	1.04	1.10	1.71	1.78	2.58	3.95	30.86
1970	27.30	13.47	6.05	5.28	4.50	3.85	3.25	5.29	4.76	3.99	8.26	6.44	92.44
1971	32.86	14.55	4.37	4.01	16.09	8.42	3.04	1.65	1.23	1.21	1.00	0.83	89.26
1972	0.99	3.30	4.43	3.51	3.13	3.37	3.16	2.08	1.09	0.73	1.04	2.13	28.96
1973	3.23	8.39	5.74	4.06	5.05	14.54	7.55	8.29	6.49	3.94	2.17	1.34	70.79
1974	1.51	3.20	5.35	5.09	4.90	4.87	3.60	2.00	1.09	0.77	0.70	2.72	35.80
1975	4.12	3.79	22.54	16.69	22.97	74.71	26.66	4.94	3.77	2.23	1.40	1.93	185.75
1976	27.36	12.61	4.31	3.89	3.84	3.65	2.57	1.46	1.04	0.97	1.02	1.56	64.28
1977	4.06	17.89	16.30	7.49	4.52	4.13	103.73	38.57	3.88	2.15	1.61	2.12	206.45
1978	4.52	13.20	7.89	3.92	3.12	3.66	3.27	1.91	1.02	1.51	2.13	2.10	48.25
1979	2.69	3.23	3.27	2.54	1.96	1.96	1.58	1.15	0.89	0.70	0.60	3.08	23.65
1980	5.01	23.17	11.76	5.64	5.36	4.20	2.42	1.94	1.82	1.28	1.58	2.01	66.19
1981	1.76	1.86	2.02	3.01	3.35	5.61	5.50	3.74	2.26	1.61	1.11	0.98	32.81
1982	2.39	2.88	2.01	1.59	1.52	1.31	1.19	1.08	0.84	0.98	1.19	1.33	18.31
1983	2.04	4.11	5.22	15.16	13.82	7.61	11.88	6.53	2.93	2.78	2.65	2.16	76.89
1984	2.25	3.77	5.44	5.49	49.50	19.10	2.51	1.24	0.82	0.75	0.59	0.49	91.95
1985	11.55	12.07	9.91	6.08	3.93	2.71	1.76	1.05	0.73	0.63	1.99	3.68	56.09
1986	11.60	19.78	8.73	4.14	3.43	3.57	3.23	2.08	1.33	0.95	1.54	59.89	120.27
1987	24.53	14.72	26.50	10.54	30.48	64.65	22.09	5.40	5.40	5.38	5.42	4.55	219.66
1988	4.03	14.15	24.40	9.56	39.55	16.09	4.36	3.69	2.61	2.06	1.41	1.09	123.00
1989	3.62	62.72	24.11	3.94	2.75	11.30	6.65	2.55	1.33	0.85	1.75	2.49	124.06
1990	3.83	4.30	3.54	4.48	5.15	4.02	2.07	1.03	0.75	0.60	0.58	1.16	31.51
1991	15.07	13.46	6.06	3.45	2.86	2.77	2.39	1.53	0.87	0.60	0.60	0.83	50.49
1992	1.50	3.42	5.15	4.51	4.07	3.02	1.94	1.25	0.74	0.52	0.55	1.98	28.65
1993	22.87	11.98	21.21	9.79	12.18	21.26	8.39	1.83	0.96	1.31	1.72	1.31	114.81
1994	1.03	1.14	1.44	2.24	2.07	9.81	7.56	4.74	3.97	3.20	1.83	1.36	40.39
1995	2.17	3.82	66.38	28.67	27.26	12.13	3.28	1.53	0.81	1.52	2.06	1.82	151.45
1996	2.48	27.83	13.15	10.20	7.98	5.88	20.91	9.78	42.83	18.60	4.77	3.56	167.97
month	464.63	890.86	843.98	580.32	688.20	849.16	593.07	352.53	324.38	271.66	180.25	237.69	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.69	1.14	1.44	1.20	1.52	1.31	0.94	0.98	0.73	0.52	0.55	0.49	18.31
max	37.14	75.83	66.38	30.93	49.50	74.71	103.73	49.14	42.83	44.57	18.63	59.89	219.66
median	2.85	4.30	5.35	4.57	4.48	4.74	3.85	2.55	1.82	1.61	1.57	1.88	66.19
mean	6.03	11.57	10.96	7.54	8.94	11.03	7.70	4.58	4.21	3.53	2.34	3.09	81.52
Sum of the monthly means = 81.52													
s.d.	7.98	14.27	12.38	6.89	10.52	14.17	12.92	7.29	7.50	6.44	2.70	6.83	49.20
c.v.	1.32	1.23	1.13	0.91	1.18	1.29	1.68	1.59	1.78	1.83	1.15	2.21	0.60

APPENDIX 5

NATURAL FLOW RECORDS FOR ESTUARIES

APPENDIX 5.1
MTENTU RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	2.46	4.47	8.58	7.93	6.34	10.83	9.17	5.45	2.85	1.67	1.14	1.44	62.33
1921	3.38	40.80	56.89	20.60	6.33	3.64	1.69	9.54	22.26	12.27	6.72	5.48	189.60
1922	6.29	49.64	21.66	17.28	86.36	59.70	15.02	3.18	1.86	53.86	23.83	4.75	343.43
1923	2.85	2.55	3.52	58.01	46.93	13.48	3.04	1.71	1.47	1.24	1.28	2.02	138.10
1924	3.98	8.11	25.71	11.62	3.51	17.82	11.72	5.62	3.15	2.00	1.41	1.40	96.05
1925	2.91	6.80	7.25	7.91	6.75	46.45	19.51	4.04	4.23	4.20	2.77	3.14	115.96
1926	6.68	9.34	12.41	8.10	4.95	71.10	27.67	3.23	1.72	1.34	1.60	2.07	150.21
1927	3.83	4.14	11.13	46.60	24.00	8.50	4.32	2.38	1.81	1.47	1.86	2.31	112.35
1928	3.21	4.70	4.49	3.62	2.80	6.53	6.32	4.02	13.37	12.74	8.89	18.16	88.85
1929	21.97	15.41	9.14	7.29	6.12	7.76	7.41	4.86	4.50	4.71	5.19	7.46	101.82
1930	8.05	7.11	12.60	50.53	27.32	60.15	23.67	3.79	1.85	81.66	33.74	5.45	315.92
1931	4.99	5.68	5.02	3.84	19.26	11.68	4.49	2.85	3.00	3.68	3.46	5.77	73.72
1932	10.15	85.67	74.72	19.32	2.82	3.31	3.78	2.83	1.92	1.57	1.37	1.18	208.64
1933	1.20	21.15	47.54	31.23	11.72	6.89	5.82	4.27	2.71	3.41	3.68	2.64	142.26
1934	2.57	4.72	28.14	14.05	5.37	5.10	16.37	40.48	50.21	18.94	7.47	6.08	199.50
1935	4.56	4.90	3.26	2.18	39.87	40.21	13.17	7.51	8.03	5.81	3.46	2.75	135.71
1936	5.56	137.33	51.35	8.26	56.36	25.18	6.55	3.33	1.85	1.55	1.48	1.44	300.24
1937	2.24	3.66	5.33	5.85	8.22	6.29	5.59	5.06	3.81	3.57	3.32	2.59	55.53
1938	2.77	4.80	11.49	9.08	26.77	13.68	5.09	4.13	3.52	3.47	3.80	25.76	114.36
1939	17.94	10.97	14.09	8.62	4.92	4.79	4.51	11.25	9.81	5.97	3.48	2.61	98.96
1940	2.97	8.25	15.79	8.86	3.61	3.12	3.23	2.29	1.54	1.42	1.54	1.93	54.55
1941	3.34	4.92	4.63	18.80	11.77	9.17	7.52	5.52	3.89	2.41	2.27	3.01	77.25
1942	5.23	67.08	72.69	22.96	6.14	21.51	33.27	14.70	6.44	5.57	10.00	9.43	275.02
1943	18.70	52.98	40.46	13.32	9.72	8.29	5.25	3.32	2.66	2.66	2.27	7.19	166.82
1944	10.01	7.64	3.86	3.89	5.91	11.17	7.38	3.79	2.60	1.99	1.50	1.62	61.36
1945	15.03	9.59	3.72	2.76	5.42	23.37	13.09	5.26	3.02	2.15	1.64	1.74	86.79
1946	2.91	7.24	8.18	7.06	10.53	24.12	16.40	8.75	24.52	14.38	6.04	4.15	134.28
1947	4.24	105.71	45.16	10.84	24.61	17.49	9.61	5.51	2.76	1.58	1.13	0.99	229.63
1948	4.93	7.61	7.56	7.17	21.71	13.26	8.15	5.65	2.94	1.88	1.67	1.81	84.34
1949	3.42	16.60	10.65	18.40	12.20	8.59	7.57	7.28	5.76	4.46	5.83	5.97	106.73
1950	5.58	5.03	41.50	19.47	6.33	8.00	6.37	3.57	2.35	1.89	2.26	3.50	105.85
1951	11.29	8.17	7.37	9.24	9.54	7.99	8.24	6.78	4.07	2.53	1.68	2.12	79.02
1952	2.80	3.27	3.54	3.49	4.37	4.71	4.25	3.11	1.96	1.38	1.49	3.08	37.45
1953	6.88	26.03	32.07	13.52	6.57	6.76	5.00	4.22	4.70	4.11	2.80	3.20	115.86
1954	68.52	29.53	6.78	26.74	60.95	25.34	8.09	5.08	3.31	2.38	1.58	2.35	240.65
1955	4.35	6.38	5.12	2.25	3.40	41.13	22.10	8.32	5.32	3.82	2.71	2.88	107.78
1956	6.60	52.66	106.09	37.69	10.08	35.48	26.03	10.12	4.82	3.49	3.13	5.97	302.16
1957	17.02	29.46	13.98	12.25	41.65	18.92	12.19	8.12	3.60	2.21	1.74	1.76	162.90
1958	2.52	8.38	9.94	7.25	6.18	6.29	6.15	90.34	35.40	6.06	6.01	5.59	190.11
1959	5.58	6.98	7.41	6.29	5.46	6.67	7.13	6.35	4.47	2.92	2.53	3.38	65.17
1960	4.32	9.21	29.21	19.47	8.91	9.27	69.67	28.39	5.36	3.73	2.89	2.49	192.92
1961	2.80	9.52	9.50	8.47	18.35	24.37	10.99	4.36	2.86	1.84	2.08	2.59	97.73
1962	5.11	34.67	18.06	45.25	19.93	106.76	40.95	5.31	3.19	11.08	9.59	5.05	304.95
1963	6.45	32.13	30.72	48.45	20.64	9.11	14.09	9.02	72.79	30.49	5.92	4.53	284.34
1964	40.18	18.26	5.26	5.17	5.26	3.60	2.13	2.19	29.95	18.68	11.79	10.37	152.84
1965	48.90	44.38	15.27	6.60	5.39	3.10	1.79	25.78	14.51	5.21	3.47	3.93	178.33
1966	4.58	5.17	6.17	8.65	9.05	79.81	37.80	8.98	5.04	6.03	5.81	3.50	180.59
1967	2.90	6.19	6.23	4.67	4.38	4.50	4.24	2.96	1.72	1.26	2.08	4.54	45.67
1968	7.14	9.50	8.69	5.27	9.44	38.82	17.01	7.69	7.05	4.70	3.52	3.32	122.15
1969	4.85	8.55	8.53	5.79	4.22	2.98	1.88	1.98	3.05	3.18	4.60	7.10	56.71
1970	51.34	25.81	12.55	9.89	8.04	6.96	5.92	13.22	9.66	7.04	16.90	12.00	179.33
1971	60.08	26.31	7.76	7.70	32.02	15.94	5.36	2.92	2.18	2.12	1.75	1.45	165.59
1972	1.74	7.77	8.36	6.22	5.69	6.17	5.79	3.79	1.95	1.29	1.84	3.79	54.40
1973	5.80	17.78	11.04	7.60	11.83	27.83	13.63	16.54	11.95	6.84	3.78	2.33	136.95
1974	2.65	6.22	13.26	10.02	9.67	9.04	6.49	3.60	1.93	1.36	1.23	5.47	70.94
1975	7.53	6.79	43.06	32.50	42.97	134.55	47.68	8.76	6.72	3.96	2.47	3.42	340.41
1976	50.73	22.97	7.70	7.06	7.18	6.73	4.70	2.64	1.85	1.72	1.79	2.75	117.82
1977	9.83	32.91	30.69	14.27	8.21	7.47	187.31	69.37	6.79	3.76	2.81	3.74	377.16
1978	11.07	24.69	14.14	7.02	5.65	7.03	6.06	3.44	1.82	2.68	3.80	3.74	91.14
1979	4.81	5.83	5.95	4.66	3.59	3.59	2.88	2.08	1.60	1.23	1.06	7.61	44.89
1980	9.35	42.52	22.80	11.37	10.20	7.57	4.31	3.46	3.24	2.27	2.80	3.57	123.46
1981	3.13	3.33	3.65	6.06	6.29	13.99	11.15	6.71	4.03	2.85	1.96	1.73	64.88
1982	4.26	5.19	3.63	2.89	2.77	2.38	2.15	1.95	1.49	1.72	2.10	2.34	32.87
1983	3.62	9.26	10.28	29.60	27.04	15.88	22.21	11.60	5.07	4.86	4.67	3.81	147.90
1984	4.00	7.62	12.77	11.18	90.29	34.56	4.39	2.18	1.44	1.31	1.02	0.86	171.62
1985	22.71	23.49	19.67	11.42	7.04	4.89	3.18	1.89	1.29	1.11	3.55	6.62	106.86
1986	23.32	37.24	15.80	7.77	6.32	6.72	5.93	3.75	2.38	1.68	2.72	108.67	222.30
1987	44.26	28.17	49.68	19.29	56.61	117.09	39.59	10.62	9.78	9.46	9.62	8.12	402.29
1988	7.23	28.07	45.72	17.36	73.07	29.43	8.06	6.67	4.63	3.66	2.49	1.91	228.30
1989	9.38	112.17	42.66	7.05	5.00	23.37	12.75	4.43	2.31	1.48	3.08	4.43	228.11
1990	7.68	7.95	6.38	11.20	10.42	7.18	3.67	1.82	1.32	1.04	1.01	2.03	61.70
1991	29.07	25.97	11.09	6.15	5.19	5.06	4.37	2.77	1.56	1.06	1.05	1.45	94.79
1992	2.65	6.93	11.41	8.58	7.50	5.52	3.50	2.24	1.31	0.91	0.95	3.53	55.03
1993	42.94	22.43	39.90	18.01	24.41	40.16	15.25	3.15	1.66	2.27	3.02	2.30	215.50
1994	1.81	2.01	2.58	4.08	3.80	20.69	14.88	8.47	7.02	5.68	3.23	2.40	76.65
1995	3.86	7.53	121.07	53.80	50.71	22.00	5.79	2.70	1.43	2.72	3.69	3.24	278.54
1996	4.45	52.01	24.43	20.92	17.01	11.79	39.81	18.02	77.38	33.27	8.32	6.27	313.68
month	876.04	1672.01	1596.49	1105.63	1306.96	1600.38	1099.29	653.06	589.37	489.97	324.23	433.17	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	1.20	2.01	2.58	2.18	2.77	2.38	1.69	1.71	1.29	0.91	0.95	0.86	32.87
max	68.52	137.33	121.07	58.01	90.29	134.55	187.31	90.34	77.38	81.66	33.74	108.67	402.29
median	5.11	9.26	11.41	8.86	8.22	9.27	7.38	4.43	3.19	2.85	2.80	3.32	123.46
mean	11.38	21.71	20.73	14.36	16.97	20.78	14.28	8.48	7.65	6.36	4.21	5.63	152.55

Sum of the monthly means = 152.55

s.d.	14.87	25.90	22.64	12.94	19.49	25.79	23.43	13.40	13.68	11.85	5.00	12.46	90.13
c.v.	1.31	1.19	1.09	0.90	1.15	1.24	1.64	1.58	1.79	1.86	1.19	2.22	0.59

APPENDIX 5.2
LUTUNGULU RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.05	0.10	0.40	0.23	0.14	0.50	0.27	0.10	0.05	0.03	0.02	0.03	1.92
1921	0.07	1.15	1.42	0.47	0.13	0.08	0.04	0.49	0.63	0.25	0.12	0.10	4.95
1922	0.13	1.30	0.53	0.66	1.98	1.41	0.34	0.06	0.03	1.28	0.53	0.08	8.33
1923	0.05	0.05	0.08	1.55	1.25	0.32	0.06	0.03	0.03	0.02	0.03	0.04	3.51
1924	0.09	0.36	0.81	0.30	0.07	0.71	0.34	0.11	0.06	0.04	0.03	0.03	2.95
1925	0.06	0.26	0.19	0.30	0.18	1.25	0.48	0.07	0.08	0.09	0.06	0.07	3.09
1926	0.22	0.31	0.47	0.22	0.10	1.75	0.65	0.06	0.03	0.02	0.03	0.04	3.90
1927	0.08	0.09	0.55	1.22	0.70	0.21	0.08	0.05	0.04	0.03	0.04	0.05	3.14
1928	0.07	0.11	0.11	0.09	0.07	0.37	0.20	0.08	0.54	0.33	0.16	0.57	2.70
1929	0.63	0.47	0.21	0.17	0.14	0.33	0.20	0.10	0.09	0.10	0.11	0.19	2.74
1930	0.18	0.15	0.57	1.30	0.80	1.42	0.51	0.07	0.03	1.81	0.72	0.10	7.66
1931	0.10	0.12	0.11	0.09	0.79	0.36	0.09	0.06	0.06	0.08	0.07	0.17	2.10
1932	0.38	1.90	1.72	0.44	0.05	0.08	0.09	0.06	0.04	0.03	0.03	0.02	4.84
1933	0.02	0.77	1.24	0.89	0.30	0.14	0.13	0.09	0.06	0.07	0.08	0.06	3.85
1934	0.06	0.11	0.94	0.40	0.11	0.12	0.69	1.04	1.12	0.39	0.14	0.12	5.24
1935	0.09	0.11	0.07	0.05	1.19	1.11	0.31	0.26	0.19	0.10	0.06	0.05	3.59
1936	0.14	2.96	1.09	0.29	1.41	0.60	0.13	0.06	0.04	0.03	0.03	0.03	6.81
1937	0.05	0.08	0.13	0.14	0.40	0.20	0.12	0.11	0.08	0.08	0.07	0.05	1.51
1938	0.06	0.11	0.55	0.28	0.84	0.37	0.10	0.09	0.07	0.07	0.08	0.82	3.44
1939	0.56	0.28	0.50	0.23	0.10	0.11	0.10	0.53	0.28	0.10	0.06	0.05	2.90
1940	0.06	0.41	0.61	0.24	0.07	0.07	0.08	0.05	0.03	0.03	0.03	0.04	1.72
1941	0.08	0.11	0.11	0.79	0.36	0.35	0.20	0.11	0.08	0.05	0.05	0.06	2.35
1942	0.12	1.67	1.74	0.51	0.13	0.78	0.92	0.33	0.12	0.11	0.40	0.24	7.07
1943	0.58	1.26	1.03	0.32	0.43	0.24	0.10	0.07	0.06	0.06	0.05	0.36	4.56
1944	0.28	0.15	0.08	0.09	0.14	0.52	0.23	0.07	0.05	0.04	0.03	0.03	1.71
1945	0.62	0.28	0.07	0.06	0.20	0.80	0.35	0.10	0.06	0.04	0.03	0.03	2.64
1946	0.06	0.34	0.23	0.15	0.50	0.78	0.51	0.20	0.67	0.33	0.11	0.08	3.96
1947	0.09	2.38	1.16	0.36	0.73	0.58	0.23	0.10	0.05	0.03	0.02	0.02	5.75
1948	0.20	0.19	0.18	0.17	0.81	0.38	0.17	0.12	0.06	0.04	0.03	0.04	2.39
1949	0.08	0.68	0.32	0.68	0.35	0.20	0.16	0.16	0.12	0.09	0.13	0.13	3.10
1950	0.12	0.11	1.19	0.50	0.13	0.35	0.18	0.07	0.05	0.04	0.05	0.08	2.87
1951	0.51	0.24	0.27	0.35	0.31	0.18	0.24	0.16	0.08	0.05	0.03	0.04	2.46
1952	0.06	0.07	0.08	0.09	0.11	0.12	0.10	0.07	0.04	0.03	0.03	0.07	0.87
1953	0.24	0.80	0.90	0.32	0.14	0.16	0.12	0.10	0.11	0.09	0.06	0.07	3.11
1954	1.67	0.68	0.14	0.88	1.51	0.65	0.18	0.10	0.06	0.05	0.03	0.05	6.00
1955	0.10	0.14	0.12	0.05	0.08	1.23	0.68	0.19	0.10	0.07	0.05	0.06	2.87
1956	0.24	1.31	2.34	0.93	0.33	0.93	0.73	0.24	0.09	0.06	0.06	0.16	7.42
1957	0.59	0.81	0.32	0.52	1.09	0.42	0.47	0.22	0.06	0.04	0.03	0.03	4.60
1958	0.05	0.42	0.35	0.17	0.13	0.15	0.14	2.11	0.79	0.11	0.12	0.11	4.65
1959	0.12	0.17	0.17	0.15	0.13	0.21	0.18	0.14	0.10	0.06	0.05	0.07	1.55
1960	0.10	0.44	0.87	0.65	0.23	0.39	1.59	0.60	0.10	0.07	0.06	0.05	5.15
1961	0.06	0.46	0.27	0.25	0.68	0.76	0.27	0.08	0.05	0.03	0.04	0.05	3.00
1962	0.12	1.00	0.47	1.17	0.48	2.37	0.89	0.10	0.06	0.47	0.25	0.09	7.47
1963	0.19	0.88	0.88	1.22	0.49	0.26	0.51	0.23	1.59	0.64	0.10	0.09	7.08
1964	1.06	0.44	0.10	0.12	0.13	0.09	0.05	0.05	0.94	0.49	0.30	0.21	3.98
1965	1.16	1.09	0.34	0.14	0.12	0.07	0.04	0.87	0.39	0.09	0.06	0.08	4.45
1966	0.10	0.12	0.14	0.41	0.32	1.83	0.98	0.22	0.09	0.12	0.12	0.07	4.52
1967	0.06	0.23	0.16	0.10	0.10	0.11	0.10	0.07	0.04	0.03	0.04	0.10	1.14
1968	0.17	0.36	0.23	0.11	0.48	1.05	0.39	0.20	0.15	0.09	0.07	0.07	3.37
1969	0.11	0.35	0.23	0.12	0.10	0.07	0.04	0.05	0.07	0.07	0.10	0.16	1.47
1970	1.34	0.73	0.44	0.28	0.17	0.15	0.13	0.58	0.28	0.13	0.54	0.29	5.06
1971	1.38	0.57	0.16	0.25	0.96	0.41	0.10	0.06	0.04	0.04	0.04	0.03	4.04
1972	0.04	0.41	0.25	0.13	0.13	0.15	0.14	0.09	0.04	0.03	0.04	0.08	1.53
1973	0.13	0.70	0.32	0.23	0.49	0.80	0.32	0.55	0.30	0.12	0.07	0.04	4.07
1974	0.05	0.24	0.54	0.27	0.40	0.24	0.13	0.07	0.04	0.03	0.02	0.24	2.27
1975	0.19	0.14	1.19	0.97	1.10	2.85	0.98	0.17	0.14	0.08	0.05	0.07	7.93
1976	1.31	0.55	0.16	0.16	0.19	0.16	0.11	0.06	0.04	0.04	0.04	0.06	2.88
1977	0.46	0.90	0.85	0.44	0.19	0.16	3.96	1.44	0.13	0.07	0.05	0.08	8.73
1978	0.49	0.72	0.35	0.15	0.12	0.23	0.15	0.07	0.04	0.06	0.08	0.08	2.54
1979	0.11	0.13	0.14	0.11	0.09	0.09	0.07	0.05	0.04	0.03	0.02	0.40	1.28
1980	0.26	1.07	0.68	0.42	0.34	0.17	0.08	0.07	0.07	0.05	0.06	0.08	3.35
1981	0.07	0.08	0.09	0.26	0.18	0.61	0.32	0.13	0.08	0.06	0.04	0.03	1.95
1982	0.09	0.12	0.08	0.07	0.07	0.06	0.05	0.05	0.03	0.04	0.05	0.05	0.76
1983	0.08	0.45	0.38	0.85	0.81	0.53	0.63	0.26	0.09	0.09	0.09	0.08	4.34
1984	0.09	0.34	0.50	0.41	1.99	0.73	0.08	0.04	0.03	0.03	0.02	0.02	4.28
1985	0.77	0.73	0.63	0.31	0.15	0.10	0.07	0.04	0.03	0.02	0.08	0.15	3.08
1986	0.78	0.99	0.35	0.24	0.16	0.19	0.14	0.08	0.05	0.03	0.06	2.43	5.50
1987	0.97	0.76	1.23	0.44	1.42	2.56	0.82	0.37	0.24	0.18	0.19	0.16	9.34
1988	0.15	0.87	1.19	0.40	1.74	0.67	0.23	0.15	0.09	0.07	0.05	0.04	5.65
1989	0.45	2.41	0.87	0.15	0.11	0.85	0.37	0.08	0.04	0.03	0.06	0.10	5.52
1990	0.33	0.21	0.13	0.53	0.37	0.16	0.07	0.04	0.03	0.02	0.02	0.04	1.95
1991	0.91	0.78	0.26	0.13	0.12	0.12	0.10	0.06	0.03	0.02	0.02	0.03	2.58
1992	0.06	0.31	0.46	0.23	0.20	0.13	0.08	0.05	0.03	0.02	0.02	0.08	1.67
1993	1.18	0.64	1.00	0.41	0.79	1.07	0.35	0.05	0.03	0.04	0.06	0.05	5.67
1994	0.04	0.04	0.06	0.10	0.10	0.82	0.52	0.18	0.13	0.11	0.06	0.05	2.21
1995	0.08	0.30	2.67	1.36	1.26	0.49	0.11	0.05	0.03	0.06	0.08	0.07	6.56
1996	0.10	1.37	0.65	0.68	0.61	0.40	0.95	0.38	1.69	0.70	0.15	0.12	7.80
month	24.00	44.94	42.42	30.92	35.82	42.44	26.82	15.92	13.62	10.67	7.06	10.36	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.02	0.04	0.06	0.05	0.05	0.06	0.04	0.03	0.03	0.02	0.02	0.02	0.76
max	1.67	2.96	2.67	1.55	1.99	2.85	3.96	2.11	1.69	1.81	0.72	2.43	9.34
median	0.12	0.41	0.35	0.28	0.23	0.36	0.18	0.10	0.06	0.06	0.06	0.07	3.44
mean	0.31	0.58	0.55	0.40	0.47	0.55	0.35	0.21	0.18	0.14	0.09	0.13	3.96
Sum of the monthly means =				3.96									
s.d.	0.39	0.58	0.52	0.35	0.48	0.58	0.51	0.32	0.32	0.27	0.12	0.29	2.06
c.v.	1.24	0.99	0.95	0.87	1.03	1.06	1.47	1.56	1.80	1.95	1.32	2.17	0.52

APPENDIX 5.3
MKOZI RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.11	0.32	1.88	0.91	1.24	2.62	1.21	0.41	0.22	0.13	0.09	0.14	9.28
1921	0.31	3.68	3.63	1.11	0.34	0.22	0.14	3.36	2.82	0.85	0.67	0.54	17.67
1922	3.21	5.72	1.81	5.57	7.37	4.70	1.18	0.22	0.17	4.77	1.87	0.24	36.83
1923	0.16	0.20	0.31	3.99	3.62	0.98	0.17	0.13	0.13	0.12	0.14	0.26	10.21
1924	0.41	1.24	2.10	0.87	1.25	4.53	1.97	0.48	0.28	0.21	0.17	0.28	13.79
1925	0.41	0.81	0.55	1.33	1.48	5.23	1.91	0.32	0.72	0.50	0.26	0.29	13.81
1926	1.41	2.31	1.84	0.67	0.34	7.20	2.61	0.19	0.12	0.09	0.09	0.16	17.03
1927	0.44	0.33	0.62	1.46	2.34	0.99	0.34	0.25	0.23	0.18	0.26	0.30	7.74
1928	0.32	0.83	0.56	0.58	0.43	2.41	1.00	0.27	4.14	2.97	0.93	3.07	17.51
1929	4.09	3.15	0.97	0.33	0.28	0.64	0.53	0.38	0.94	0.64	1.06	2.69	15.70
1930	1.11	0.36	0.34	4.12	4.11	5.38	1.80	0.30	0.18	12.75	4.55	0.31	35.31
1931	0.66	0.49	0.37	0.29	3.85	2.03	0.47	0.31	0.39	0.45	0.39	3.34	13.04
1932	2.36	6.64	5.61	1.34	0.26	0.80	0.50	0.27	0.20	0.16	0.13	0.12	18.39
1933	0.13	2.49	3.55	4.20	1.42	1.73	0.83	0.33	0.25	1.38	0.71	0.22	17.24
1934	0.17	0.84	2.89	1.16	0.30	1.36	3.57	4.35	5.56	1.82	1.30	0.67	23.99
1935	0.31	0.35	0.23	0.17	5.84	5.87	1.56	2.52	1.19	0.43	0.28	0.23	18.98
1936	1.94	9.03	3.05	0.28	2.97	3.32	1.05	0.25	0.17	0.17	0.20	0.21	22.64
1937	0.25	0.28	1.59	1.23	0.58	0.35	1.86	0.89	0.37	0.41	0.37	0.24	8.42
1938	0.20	0.72	1.24	1.48	3.23	1.75	0.56	0.63	0.48	0.55	0.61	4.77	16.22
1939	2.85	0.72	1.01	0.52	0.26	0.42	0.39	2.03	0.97	0.32	0.23	0.20	9.92
1940	0.21	1.76	0.88	0.33	0.21	0.20	0.24	0.21	0.18	0.18	0.18	0.18	4.76
1941	0.29	0.79	0.45	4.55	1.76	1.06	0.58	0.39	0.37	0.24	0.23	0.32	11.03
1942	0.74	6.88	5.18	1.28	0.35	2.51	3.62	1.26	0.41	0.38	2.27	1.07	25.95
1943	1.41	2.99	2.36	0.78	2.09	0.97	0.36	0.27	0.23	0.26	0.22	3.49	15.43
1944	2.00	0.53	0.20	0.51	1.57	1.98	0.75	0.28	0.23	0.20	0.15	0.20	8.60
1945	4.68	1.74	0.17	0.17	1.50	3.38	1.46	0.42	0.26	0.20	0.15	0.15	14.28
1946	0.23	1.94	0.94	0.42	1.11	3.35	3.69	1.25	2.81	1.25	0.33	0.27	17.59
1947	0.28	8.48	4.06	0.71	2.90	2.61	0.91	0.36	0.21	0.13	0.09	0.08	20.82
1948	1.81	0.92	0.42	0.40	5.71	3.76	1.41	0.51	0.22	0.14	0.14	0.18	15.62
1949	0.32	3.44	1.41	1.91	1.63	1.08	1.10	1.58	0.71	0.33	0.74	0.51	14.76
1950	0.59	0.39	3.36	2.18	0.64	1.70	0.79	0.25	0.21	0.18	0.21	0.31	10.81
1951	2.85	1.11	1.73	2.04	0.82	1.42	1.43	0.63	0.29	0.20	0.13	0.20	12.85
1952	0.27	0.28	0.26	0.28	0.54	0.49	0.45	0.36	0.24	0.16	0.16	0.70	4.19
1953	1.67	3.69	2.84	0.86	0.35	1.49	0.70	0.35	0.46	0.43	0.30	0.34	13.48
1954	6.92	2.61	0.34	3.10	4.31	2.70	0.83	0.31	0.25	0.19	0.13	0.23	21.92
1955	0.40	0.85	0.42	0.12	0.90	5.25	2.70	0.65	0.36	0.31	0.22	0.28	12.46
1956	1.92	5.70	8.65	3.68	1.58	3.57	3.92	1.23	0.33	0.28	0.26	0.88	32.00
1957	1.78	1.52	1.43	2.48	4.25	2.14	3.09	1.17	0.21	0.16	0.15	0.16	18.54
1958	0.21	1.77	1.06	0.36	0.45	0.63	0.58	7.74	2.85	0.42	1.23	0.71	18.01
1959	0.45	0.46	0.44	0.41	0.38	1.84	1.45	1.12	0.55	0.28	0.27	0.37	8.02
1960	0.40	1.82	2.73	2.04	0.74	1.65	6.46	2.43	0.44	0.42	0.40	0.32	19.85
1961	0.29	2.42	1.37	0.51	1.27	3.37	1.26	0.32	0.24	0.16	0.21	0.29	11.71
1962	1.53	3.20	1.20	3.78	1.53	8.63	3.19	0.41	0.34	3.88	1.56	0.25	29.50
1963	0.83	1.82	1.08	4.07	3.15	2.27	2.78	1.02	6.54	2.51	0.34	0.30	26.71
1964	2.74	1.12	0.22	0.27	0.31	0.23	0.15	0.22	5.40	2.51	1.50	0.86	15.53
1965	5.10	3.69	0.96	0.37	0.37	0.25	0.16	3.99	1.65	0.31	0.24	0.31	17.40
1966	0.34	0.30	0.34	1.97	1.31	5.98	4.90	1.26	0.32	1.63	0.82	0.26	19.43
1967	0.20	0.77	0.47	0.28	0.35	0.40	0.38	0.28	0.18	0.14	0.22	1.30	4.97
1968	1.14	1.59	0.81	0.30	2.45	4.54	1.54	3.63	1.50	0.34	0.27	0.25	18.36
1969	0.36	1.68	0.83	0.28	0.28	0.26	0.21	0.23	0.38	0.40	3.77	1.98	10.66
1970	5.29	3.15	0.79	0.50	0.86	0.59	0.77	4.71	1.80	1.35	2.95	1.20	23.96
1971	4.83	1.93	0.59	0.45	4.98	1.95	0.37	0.27	0.23	0.23	0.21	0.17	16.21
1972	0.15	1.75	1.04	0.45	0.39	0.78	2.10	0.86	0.20	0.13	0.21	0.99	9.05
1973	0.98	3.14	1.25	0.35	1.64	2.09	0.83	4.34	2.04	0.52	0.29	0.20	17.67
1974	0.20	0.63	1.48	0.71	0.40	0.68	0.50	0.34	0.23	0.18	0.17	4.09	9.61
1975	1.64	0.34	2.68	1.19	4.38	12.06	4.89	2.65	1.02	0.27	0.21	0.39	31.72
1976	8.39	3.03	0.26	0.32	3.07	1.48	0.40	0.22	0.19	0.20	0.29	0.60	18.45
1977	1.61	3.62	3.87	1.26	0.41	0.76	17.43	6.87	0.70	0.32	0.27	0.32	37.44
1978	3.08	1.92	0.57	0.30	0.31	2.04	0.92	0.28	0.21	0.98	0.72	0.68	12.01
1979	1.36	0.67	0.34	0.28	0.32	0.39	0.32	0.27	0.23	0.19	0.16	2.81	7.34
1980	1.25	2.56	1.45	1.58	0.78	0.38	0.26	1.23	0.69	0.29	0.58	0.45	11.50
1981	0.27	0.26	0.26	0.45	0.38	5.68	3.03	0.67	0.30	0.24	0.18	0.16	11.88
1982	0.29	0.35	0.22	0.16	0.19	0.19	0.18	0.16	0.13	4.27	1.75	0.38	8.27
1983	0.42	2.01	1.08	1.96	1.46	0.63	1.51	0.78	0.45	2.50	1.11	0.36	14.27
1984	0.35	2.79	1.22	0.48	8.47	3.12	0.33	0.20	0.15	0.14	0.11	0.09	17.45
1985	1.46	2.87	1.10	2.31	0.98	0.35	0.38	0.30	0.20	0.14	0.63	1.92	12.64
1986	2.92	1.49	0.46	0.52	0.33	1.24	0.67	0.29	0.25	0.20	0.26	12.44	21.07
1987	4.53	2.54	1.11	0.35	4.08	9.56	3.22	2.77	1.24	1.54	1.49	0.64	33.07
1988	0.52	3.14	5.55	1.72	4.91	2.55	3.10	1.23	0.35	0.32	0.23	0.20	23.82
1989	2.87	5.14	1.61	0.32	0.30	3.42	1.37	0.23	0.15	0.11	0.28	0.41	16.21
1990	1.23	0.63	0.27	0.90	2.26	0.96	0.28	0.20	0.18	0.15	0.16	0.27	7.49
1991	2.72	3.21	1.02	0.33	0.31	0.28	0.33	0.29	0.20	0.14	0.14	0.23	9.20
1992	0.36	0.40	0.49	0.39	0.31	0.22	0.19	0.17	0.14	0.11	0.12	0.43	3.33
1993	1.69	1.13	2.71	1.06	5.90	2.92	0.53	0.16	0.11	0.15	0.37	0.34	17.07
1994	0.24	0.18	1.97	0.93	0.29	3.70	5.33	1.71	1.98	0.94	0.28	0.23	17.78
1995	0.35	0.41	6.59	3.26	2.61	1.01	0.31	0.27	0.21	2.10	0.99	0.32	18.43
1996	1.10	6.51	2.38	1.53	3.22	1.71	4.37	1.70	9.11	4.00	0.65	0.42	36.70
month	112.91	162.57	123.12	96.11	139.86	182.98	128.66	85.19	70.59	68.83	46.01	65.77	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.11	0.18	0.17	0.12	0.19	0.19	0.14	0.13	0.11	0.09	0.09	0.08	3.33
max	8.39	9.03	8.65	5.57	8.47	12.06	17.43	7.74	9.11	12.75	4.55	12.44	37.44
median	0.74	1.74	1.08	0.71	1.24	1.73	0.91	0.38	0.29	0.29	0.27	0.31	16.21
mean	1.47	2.11	1.60	1.25	1.82	2.38	1.67	1.11	0.92	0.89	0.60	0.85	16.66

Sum of the monthly means = 16.66

s.d.	1.68	1.96	1.62	1.25	1.87	2.30	2.31	1.51	1.58	1.72	0.80	1.65	7.89
c.v.	1.15	0.93	1.01	1.00	1.03	0.97	1.38	1.36	1.73	1.93	1.35	1.93	0.47

APPENDIX 5.4
SIKOMBE RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.08	0.17	0.71	0.41	0.24	0.88	0.47	0.18	0.09	0.05	0.04	0.05	3.37
1921	0.13	2.01	2.49	0.82	0.23	0.14	0.07	0.85	1.10	0.44	0.21	0.18	8.67
1922	0.23	2.27	0.92	1.15	3.46	2.47	0.60	0.10	0.06	2.23	0.92	0.14	14.55
1923	0.09	0.09	0.14	2.71	2.19	0.56	0.10	0.06	0.05	0.04	0.04	0.07	6.14
1924	0.16	0.62	1.41	0.53	0.12	1.24	0.60	0.19	0.11	0.07	0.05	0.05	5.15
1925	0.11	0.46	0.33	0.52	0.32	2.18	0.85	0.13	0.15	0.15	0.10	0.12	5.42
1926	0.38	0.55	0.81	0.38	0.18	3.07	1.14	0.10	0.05	0.04	0.05	0.07	6.82
1927	0.15	0.16	0.97	2.14	1.23	0.37	0.14	0.08	0.06	0.05	0.07	0.09	5.51
1928	0.12	0.19	0.19	0.16	0.12	0.65	0.35	0.14	0.94	0.58	0.28	1.00	4.72
1929	1.11	0.83	0.37	0.29	0.24	0.57	0.35	0.17	0.16	0.17	0.20	0.34	4.80
1930	0.32	0.27	1.00	2.27	1.40	2.49	0.90	0.12	0.06	3.17	1.26	0.17	13.43
1931	0.17	0.21	0.20	0.16	1.39	0.63	0.15	0.10	0.11	0.14	0.13	0.30	3.69
1932	0.67	3.33	3.00	0.76	0.10	0.13	0.15	0.11	0.07	0.06	0.05	0.04	8.47
1933	0.04	1.34	2.17	1.56	0.52	0.25	0.22	0.17	0.10	0.13	0.14	0.10	6.74
1934	0.10	0.19	1.65	0.70	0.19	0.20	1.20	1.82	1.96	0.68	0.24	0.21	9.14
1935	0.16	0.19	0.13	0.09	2.09	1.94	0.54	0.46	0.32	0.18	0.11	0.09	6.30
1936	0.24	5.18	1.91	0.50	2.47	1.04	0.23	0.11	0.06	0.05	0.05	0.05	11.89
1937	0.08	0.15	0.22	0.25	0.70	0.35	0.21	0.19	0.14	0.13	0.12	0.10	2.64
1938	0.11	0.19	0.96	0.49	1.46	0.64	0.17	0.15	0.13	0.13	0.14	1.43	6.00
1939	0.97	0.48	0.88	0.41	0.17	0.19	0.18	0.92	0.48	0.18	0.11	0.09	5.06
1940	0.11	0.71	1.06	0.42	0.12	0.12	0.13	0.09	0.06	0.05	0.06	0.07	3.00
1941	0.13	0.20	0.19	1.38	0.64	0.62	0.35	0.19	0.14	0.08	0.08	0.11	4.11
1942	0.21	2.92	3.04	0.90	0.22	1.37	1.61	0.57	0.21	0.19	0.70	0.42	12.36
1943	1.01	2.21	1.81	0.56	0.74	0.41	0.18	0.12	0.10	0.10	0.08	0.64	7.96
1944	0.49	0.26	0.13	0.16	0.25	0.90	0.41	0.12	0.09	0.07	0.05	0.06	2.99
1945	1.08	0.50	0.12	0.11	0.35	1.41	0.62	0.17	0.10	0.07	0.05	0.06	4.64
1946	0.11	0.59	0.40	0.27	0.87	1.36	0.90	0.35	1.16	0.57	0.18	0.14	6.90
1947	0.15	4.16	2.02	0.64	1.28	1.01	0.40	0.18	0.09	0.05	0.04	0.03	10.05
1948	0.35	0.33	0.31	0.29	1.41	0.66	0.29	0.21	0.11	0.07	0.06	0.06	4.15
1949	0.13	1.19	0.56	1.19	0.62	0.35	0.29	0.27	0.22	0.16	0.22	0.23	5.43
1950	0.22	0.20	2.08	0.88	0.23	0.61	0.32	0.12	0.08	0.06	0.08	0.13	5.01
1951	0.88	0.42	0.46	0.61	0.55	0.32	0.41	0.28	0.14	0.09	0.06	0.08	4.30
1952	0.10	0.13	0.15	0.15	0.19	0.21	0.18	0.13	0.08	0.05	0.05	0.12	1.54
1953	0.42	1.41	1.58	0.57	0.24	0.27	0.20	0.17	0.19	0.16	0.10	0.12	5.43
1954	2.92	1.19	0.24	1.55	2.64	1.14	0.32	0.17	0.11	0.08	0.05	0.09	10.50
1955	0.17	0.25	0.20	0.09	0.15	2.15	1.20	0.33	0.17	0.12	0.09	0.10	5.02
1956	0.42	2.29	4.09	1.63	0.59	1.62	1.28	0.41	0.15	0.11	0.11	0.29	12.99
1957	1.04	1.41	0.56	0.91	1.91	0.74	0.82	0.39	0.11	0.07	0.05	0.06	8.07
1958	0.09	0.74	0.62	0.29	0.24	0.26	0.25	3.70	1.39	0.19	0.20	0.20	8.17
1959	0.21	0.30	0.30	0.26	0.23	0.38	0.31	0.25	0.17	0.11	0.09	0.13	2.74
1960	0.17	0.78	1.52	1.13	0.40	0.68	2.79	1.04	0.17	0.12	0.10	0.09	8.99
1961	0.10	0.81	0.48	0.44	1.19	1.33	0.47	0.14	0.10	0.06	0.07	0.09	5.28
1962	0.20	1.74	0.83	2.04	0.84	4.15	1.55	0.17	0.11	0.82	0.44	0.15	13.04
1963	0.32	1.54	1.53	2.14	0.86	0.45	0.89	0.40	2.78	1.11	0.18	0.15	12.35
1964	1.85	0.76	0.18	0.21	0.22	0.15	0.09	0.09	1.64	0.87	0.53	0.38	6.97
1965	2.04	1.91	0.60	0.24	0.22	0.13	0.07	1.52	0.68	0.16	0.11	0.14	7.82
1966	0.17	0.20	0.25	0.72	0.56	3.20	1.71	0.38	0.16	0.21	0.21	0.12	7.89
1967	0.11	0.40	0.28	0.18	0.18	0.19	0.18	0.12	0.07	0.05	0.08	0.18	2.02
1968	0.31	0.63	0.40	0.19	0.84	1.84	0.68	0.35	0.27	0.15	0.12	0.12	5.90
1969	0.18	0.62	0.40	0.22	0.17	0.12	0.08	0.08	0.12	0.12	0.18	0.28	2.57
1970	2.35	1.29	0.77	0.48	0.30	0.26	0.23	1.01	0.48	0.22	0.95	0.51	8.85
1971	2.41	1.01	0.27	0.44	1.68	0.71	0.18	0.10	0.08	0.08	0.06	0.05	7.07
1972	0.06	0.72	0.43	0.23	0.23	0.26	0.24	0.15	0.07	0.05	0.07	0.15	2.66
1973	0.23	1.22	0.57	0.40	0.86	1.41	0.56	0.96	0.52	0.21	0.12	0.08	7.14
1974	0.09	0.41	0.94	0.48	0.69	0.43	0.23	0.13	0.07	0.05	0.04	0.42	3.98
1975	0.33	0.24	2.09	1.70	1.93	4.99	1.71	0.31	0.24	0.14	0.08	0.13	13.89
1976	2.29	0.95	0.29	0.27	0.34	0.28	0.19	0.10	0.07	0.06	0.07	0.11	5.02
1977	0.81	1.57	1.49	0.77	0.34	0.28	6.93	2.53	0.22	0.12	0.09	0.14	15.29
1978	0.85	1.26	0.61	0.26	0.22	0.40	0.27	0.13	0.06	0.10	0.14	0.14	4.44
1979	0.19	0.23	0.25	0.20	0.16	0.16	0.12	0.09	0.06	0.05	0.04	0.70	2.25
1980	0.45	1.88	1.19	0.74	0.60	0.31	0.15	0.13	0.12	0.08	0.10	0.14	5.89
1981	0.12	0.13	0.15	0.45	0.31	1.08	0.56	0.22	0.14	0.10	0.07	0.06	3.39
1982	0.17	0.21	0.15	0.12	0.12	0.10	0.09	0.08	0.06	0.07	0.08	0.09	1.34
1983	0.14	0.79	0.67	1.48	1.41	0.93	1.10	0.46	0.16	0.16	0.16	0.14	7.60
1984	0.15	0.59	0.87	0.71	3.49	1.28	0.15	0.08	0.05	0.04	0.03	0.03	7.47
1985	1.34	1.28	1.11	0.55	0.26	0.18	0.12	0.07	0.05	0.04	0.14	0.26	5.40
1986	1.37	1.72	0.62	0.41	0.28	0.34	0.25	0.14	0.09	0.06	0.10	4.25	9.63
1987	1.70	1.32	2.15	0.76	2.48	4.48	1.44	0.65	0.41	0.32	0.33	0.29	16.33
1988	0.27	1.52	2.09	0.70	3.04	1.18	0.40	0.27	0.16	0.13	0.09	0.07	9.92
1989	0.78	4.22	1.53	0.26	0.20	1.48	0.64	0.14	0.07	0.05	0.11	0.17	9.65
1990	0.58	0.37	0.23	0.92	0.65	0.28	0.13	0.06	0.05	0.04	0.03	0.08	3.42
1991	1.59	1.37	0.46	0.22	0.21	0.21	0.18	0.11	0.06	0.04	0.04	0.05	4.54
1992	0.10	0.55	0.80	0.39	0.36	0.23	0.13	0.08	0.05	0.03	0.03	0.14	2.89
1993	2.06	1.12	1.75	0.72	1.37	1.87	0.61	0.10	0.05	0.08	0.11	0.08	9.92
1994	0.07	0.08	0.11	0.18	0.17	1.44	0.91	0.32	0.23	0.19	0.11	0.08	3.89
1995	0.15	0.52	4.66	2.37	2.20	0.86	0.20	0.09	0.05	0.10	0.14	0.12	11.46
1996	0.17	2.40	1.14	1.20	1.06	0.70	1.66	0.67	2.95	1.22	0.27	0.21	13.65
month	41.93	78.65	74.24	54.08	62.73	74.27	46.98	27.84	23.79	18.62	12.33	18.22	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.04	0.08	0.11	0.09	0.10	0.10	0.07	0.06	0.05	0.03	0.03	0.03	1.34
max	2.92	5.18	4.66	2.71	3.49	4.99	6.93	3.70	2.95	3.17	1.26	4.25	16.33
median	0.21	0.71	0.62	0.49	0.40	0.63	0.32	0.17	0.11	0.10	0.10	0.12	6.00
mean	0.54	1.02	0.96	0.70	0.81	0.96	0.61	0.36	0.31	0.24	0.16	0.24	6.93
Sum of the monthly means =				6.93									
s.d.	0.68	1.01	0.92	0.61	0.84	1.02	0.89	0.56	0.56	0.47	0.21	0.51	3.60
c.v.	1.24	0.99	0.95	0.87	1.03	1.06	1.47	1.56	1.80	1.95	1.32	2.16	0.52

APPENDIX 5.5
MNYAMENI RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.54	1.12	4.68	2.71	1.59	5.84	3.12	1.20	0.63	0.36	0.24	0.33	22.36
1921	0.87	13.33	16.56	5.42	1.54	0.93	0.44	5.67	7.30	2.95	1.40	1.22	57.63
1922	1.53	15.08	6.11	7.62	23.02	16.41	4.00	0.64	0.39	14.83	6.11	0.96	96.70
1923	0.61	0.60	0.94	18.01	14.54	3.72	0.64	0.38	0.34	0.28	0.29	0.50	40.85
1924	1.04	4.14	9.39	3.50	0.81	8.26	3.96	1.23	0.70	0.44	0.31	0.32	34.10
1925	0.74	3.04	2.22	3.48	2.14	14.49	5.62	0.85	0.99	1.00	0.65	0.77	35.99
1926	2.54	3.62	5.41	2.53	1.19	20.38	7.57	0.66	0.36	0.28	0.36	0.49	45.39
1927	0.99	1.08	6.44	14.24	8.15	2.47	0.94	0.54	0.42	0.34	0.44	0.57	36.62
1928	0.82	1.25	1.23	1.03	0.81	4.29	2.31	0.90	6.25	3.85	1.88	6.62	31.24
1929	7.35	5.50	2.49	1.94	1.61	3.78	2.35	1.12	1.09	1.16	1.30	2.26	31.95
1930	2.11	1.79	6.61	15.11	9.30	16.51	5.96	0.79	0.39	21.07	8.34	1.13	89.11
1931	1.16	1.42	1.32	1.07	9.23	4.18	1.00	0.67	0.73	0.92	0.85	2.00	24.55
1932	4.46	22.14	19.96	5.08	0.63	0.88	1.03	0.75	0.49	0.38	0.33	0.28	56.41
1933	0.29	8.91	14.43	10.36	3.45	1.66	1.49	1.10	0.68	0.86	0.93	0.65	44.81
1934	0.65	1.27	10.97	4.65	1.29	1.35	7.99	12.07	13.03	4.49	1.58	1.37	60.71
1935	1.07	1.24	0.85	0.60	13.89	12.86	3.58	3.04	2.16	1.22	0.73	0.62	41.86
1936	1.59	34.44	12.66	3.35	16.37	6.93	1.53	0.74	0.41	0.35	0.33	0.33	79.03
1937	0.56	0.97	1.48	1.67	4.66	2.32	1.37	1.28	0.96	0.89	0.82	0.63	17.61
1938	0.70	1.28	6.40	3.28	9.71	4.24	1.15	1.00	0.86	0.85	0.94	9.53	39.94
1939	6.48	3.22	5.83	2.70	1.15	1.26	1.22	6.11	3.22	1.22	0.72	0.57	33.70
1940	0.71	4.73	7.04	2.78	0.83	0.82	0.87	0.61	0.39	0.35	0.37	0.48	19.98
1941	0.87	1.32	1.27	9.16	4.24	4.10	2.31	1.25	0.90	0.55	0.53	0.74	27.24
1942	1.36	19.41	20.17	5.95	1.48	9.10	10.69	3.78	1.38	1.26	4.64	2.79	82.01
1943	6.70	14.65	12.00	3.72	4.95	2.75	1.20	0.79	0.64	0.64	0.55	4.23	52.82
1944	3.27	1.75	0.89	1.05	1.65	6.01	2.71	0.81	0.58	0.44	0.33	0.38	19.87
1945	7.16	3.30	0.80	0.71	2.34	9.35	4.09	1.14	0.67	0.48	0.36	0.41	30.81
1946	0.74	3.91	2.63	1.79	5.78	9.02	5.96	2.31	7.73	3.82	1.23	0.90	45.82
1947	1.00	27.65	13.45	4.22	8.49	6.70	2.68	1.18	0.60	0.33	0.24	0.21	66.75
1948	2.31	2.18	2.05	1.93	9.36	4.41	1.93	1.38	0.70	0.43	0.39	0.43	27.50
1949	0.88	7.92	3.72	7.87	4.12	2.33	1.90	1.81	1.43	1.09	1.47	1.51	36.05
1950	1.43	1.31	13.82	5.85	1.54	4.04	2.13	0.79	0.53	0.43	0.54	0.88	33.29
1951	5.88	2.82	3.09	4.08	3.65	2.14	2.74	1.83	0.92	0.57	0.37	0.51	28.60
1952	0.70	0.85	0.97	1.00	1.28	1.37	1.21	0.85	0.51	0.34	0.36	0.79	10.23
1953	2.77	9.35	10.50	3.76	1.61	1.80	1.34	1.13	1.24	1.05	0.69	0.81	36.05
1954	19.41	7.89	1.57	10.26	17.52	7.56	2.11	1.12	0.75	0.54	0.35	0.57	69.65
1955	1.12	1.68	1.34	0.60	0.99	14.31	7.94	2.18	1.11	0.83	0.60	0.68	33.38
1956	2.82	15.21	27.16	10.84	3.89	10.77	8.51	2.76	0.99	0.75	0.70	1.91	86.31
1957	6.88	9.38	3.69	6.03	12.66	4.94	5.43	2.58	0.70	0.44	0.36	0.39	53.48
1958	0.62	4.89	4.09	1.94	1.57	1.70	1.68	24.58	9.21	1.26	1.35	1.32	54.21
1959	1.38	1.97	1.99	1.71	1.54	2.50	2.08	1.64	1.13	0.71	0.61	0.85	18.11
1960	1.12	5.15	10.10	7.52	2.69	4.49	18.51	6.94	1.12	0.81	0.64	0.58	59.67
1961	0.68	5.39	3.19	2.93	7.88	8.82	3.10	0.93	0.63	0.40	0.48	0.63	35.06
1962	1.35	11.59	5.50	13.56	5.55	27.56	10.31	1.16	0.71	5.48	2.95	1.00	86.72
1963	2.15	10.23	10.17	14.21	5.70	2.98	5.88	2.67	18.44	7.40	1.21	1.00	82.04
1964	12.29	5.08	1.20	1.36	1.47	1.01	0.59	0.59	10.89	5.75	3.54	2.50	46.27
1965	13.54	12.68	3.99	1.61	1.43	0.84	0.48	10.09	4.54	1.05	0.73	0.91	51.89
1966	1.13	1.34	1.68	4.77	3.72	21.26	11.39	2.51	1.05	1.39	1.37	0.82	52.43
1967	0.70	2.64	1.88	1.21	1.22	1.28	1.19	0.81	0.44	0.31	0.52	1.19	13.39
1968	2.03	4.18	2.64	1.29	5.59	12.25	4.51	2.36	1.76	1.02	0.79	0.78	39.20
1969	1.23	4.11	2.68	1.44	1.14	0.82	0.52	0.54	0.82	0.83	1.21	1.88	17.22
1970	15.61	8.54	5.11	3.21	2.01	1.76	1.56	6.72	3.21	1.46	6.33	3.41	58.93
1971	15.99	6.68	1.83	2.95	11.16	4.72	1.21	0.68	0.51	0.50	0.41	0.34	46.98
1972	0.43	4.79	2.88	1.53	1.54	1.72	1.61	1.02	0.50	0.31	0.45	0.98	17.76
1973	1.54	8.11	3.77	2.64	5.69	9.34	3.70	6.39	3.44	1.42	0.79	0.50	47.33
1974	0.63	2.74	6.27	3.18	4.61	2.83	1.51	0.86	0.45	0.31	0.28	2.79	26.46
1975	2.20	1.61	13.88	11.27	12.80	33.12	11.36	2.03	1.60	0.92	0.56	0.84	92.19
1976	15.23	6.34	1.91	1.82	2.25	1.88	1.23	0.68	0.46	0.42	0.43	0.70	33.35
1977	5.38	10.42	9.90	5.11	2.23	1.85	46.00	16.79	1.47	0.81	0.62	0.90	101.48
1978	5.65	8.37	4.06	1.72	1.44	2.67	1.79	0.83	0.43	0.66	0.95	0.94	29.51
1979	1.25	1.55	1.63	1.31	1.04	1.04	0.82	0.57	0.41	0.30	0.25	4.62	14.79
1980	2.98	12.48	7.93	4.93	3.99	2.03	0.97	0.84	0.80	0.54	0.69	0.90	39.08
1981	0.79	0.87	1.00	2.97	2.06	7.15	3.71	1.46	0.90	0.64	0.44	0.40	22.39
1982	1.10	1.37	0.98	0.82	0.81	0.69	0.62	0.54	0.39	0.44	0.53	0.59	8.88
1983	0.95	5.24	4.44	9.84	9.38	6.21	7.30	3.04	1.05	1.09	1.09	0.91	50.54
1984	1.00	3.91	5.80	4.75	23.19	8.50	0.98	0.50	0.33	0.30	0.23	0.19	49.68
1985	8.93	8.48	7.34	3.64	1.74	1.21	0.82	0.48	0.32	0.26	0.92	1.74	35.88
1986	9.12	11.46	4.10	2.74	1.83	2.26	1.65	0.91	0.57	0.39	0.68	28.22	63.93
1987	11.30	8.79	14.29	5.08	16.48	29.78	9.56	4.35	2.74	2.14	2.21	1.90	108.62
1988	1.78	10.11	13.85	4.64	20.22	7.83	2.65	1.78	1.05	0.84	0.57	0.44	65.76
1989	5.21	28.03	10.15	1.72	1.32	9.84	4.28	0.94	0.50	0.31	0.75	1.11	64.16
1990	3.83	2.45	1.53	6.12	4.35	1.87	0.83	0.42	0.31	0.23	0.23	0.50	22.67
1991	10.53	9.07	3.07	1.48	1.38	1.40	1.21	0.74	0.39	0.25	0.25	0.35	30.12
1992	0.68	3.64	5.33	2.62	2.38	1.53	0.87	0.56	0.31	0.21	0.22	0.92	19.27
1993	13.71	7.47	11.65	4.80	9.13	12.40	4.04	0.63	0.34	0.52	0.72	0.55	65.96
1994	0.44	0.51	0.70	1.18	1.11	9.55	6.03	2.14	1.53	1.28	0.72	0.55	25.74
1995	0.97	3.43	30.98	15.76	14.64	5.70	1.32	0.62	0.32	0.66	0.91	0.80	76.11
1996	1.15	15.93	7.58	7.94	7.04	4.67	11.04	4.47	19.63	8.08	1.77	1.42	90.72
month	278.71	522.39	493.21	359.27	416.78	493.34	311.93	184.85	157.87	123.78	82.03	120.74	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.29	0.51	0.70	0.60	0.63	0.69	0.44	0.38	0.31	0.21	0.22	0.19	8.88
max	19.41	34.44	30.98	18.01	23.19	33.12	46.00	24.58	19.63	21.07	8.34	28.22	108.62
median	1.36	4.73	4.10	3.28	2.69	4.18	2.11	1.12	0.73	0.66	0.65	0.81	39.94
mean	3.62	6.78	6.41	4.67	5.41	6.41	4.05	2.40	2.05	1.61	1.07	1.57	46.04
Sum of the monthly means =				46.04									
s.d.	4.49	6.74	6.10	4.05	5.57	6.76	5.94	3.75	3.69	3.14	1.41	3.39	23.95
c.v.	1.24	0.99	0.95	0.87	1.03	1.06	1.47	1.56	1.80	1.95	1.32	2.16	0.52

APPENDIX 5.6
MZAMBA RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.25	2.16	3.50	3.49	2.89	3.63	3.92	2.64	1.39	0.83	0.57	0.72	26.99
1921	1.62	16.67	24.78	9.48	3.05	1.71	0.80	2.65	8.98	5.80	3.44	2.73	81.71
1922	3.04	21.17	9.66	5.37	39.36	26.78	6.87	1.65	0.96	23.49	10.89	2.46	151.70
1923	1.45	1.26	1.66	24.55	19.76	6.06	1.55	0.86	0.74	0.62	0.64	0.99	60.14
1924	1.90	3.38	8.90	4.62	1.74	5.39	4.75	2.82	1.57	1.01	0.71	0.70	37.49
1925	1.41	2.93	3.29	3.32	2.98	18.88	8.41	2.06	2.09	2.06	1.37	1.53	50.33
1926	2.99	4.11	4.49	3.45	2.34	31.41	12.55	1.67	0.88	0.69	0.81	1.03	66.42
1927	1.84	1.96	3.17	19.72	10.04	3.92	2.14	1.17	0.89	0.73	0.92	1.13	47.63
1928	1.54	2.21	2.08	1.65	1.27	2.47	2.75	1.89	3.57	5.43	4.49	6.71	36.06
1929	8.81	6.42	4.30	3.45	2.83	3.20	3.30	2.27	2.12	2.23	2.47	3.44	44.84
1930	3.76	3.32	3.94	21.63	10.72	27.05	11.12	1.94	0.95	37.34	15.81	2.79	140.37
1931	2.47	2.72	2.35	1.76	5.53	4.52	2.24	1.40	1.46	1.78	1.67	2.64	30.54
1932	4.31	39.00	33.68	8.89	1.41	1.57	1.76	1.33	0.92	0.76	0.68	0.58	94.89
1933	0.59	7.27	20.42	12.60	5.12	3.34	2.74	2.01	1.29	1.63	1.77	1.28	60.06
1934	1.24	2.22	9.98	5.70	2.61	2.38	4.51	17.72	23.40	9.18	3.80	3.02	85.76
1935	2.23	2.34	1.54	1.01	15.60	16.58	5.98	3.43	3.83	2.85	1.70	1.35	58.44
1936	2.61	63.96	24.14	3.68	24.12	11.24	3.21	1.63	0.91	0.77	0.74	0.72	137.73
1937	1.09	1.74	2.46	2.65	3.23	2.72	2.57	2.34	1.79	1.70	1.59	1.25	25.13
1938	1.33	2.25	3.73	3.79	9.62	5.64	2.53	2.00	1.70	1.68	1.84	9.76	45.87
1939	7.41	5.21	4.97	3.63	2.38	2.23	2.09	3.50	4.25	3.01	1.76	1.30	41.74
1940	1.45	3.08	4.71	3.52	1.79	1.48	1.51	1.08	0.74	0.69	0.76	0.94	21.75
1941	1.60	2.31	2.14	5.27	4.53	4.01	3.44	2.62	1.85	1.17	1.11	1.45	31.50
1942	2.48	29.32	32.44	10.64	2.96	7.02	13.67	6.87	3.26	2.77	3.89	4.35	119.67
1943	6.83	23.66	17.41	5.96	3.78	3.70	2.52	1.59	1.28	1.29	1.11	2.74	71.87
1944	4.58	3.68	1.84	1.79	2.67	3.80	3.09	1.86	1.28	0.98	0.75	0.80	27.12
1945	4.51	3.88	1.89	1.32	2.32	7.61	5.29	2.65	1.51	1.08	0.82	0.86	33.74
1946	1.41	2.98	3.67	3.23	3.69	8.39	6.47	4.21	10.08	6.59	3.12	2.10	55.94
1947	2.08	48.68	20.09	4.74	8.84	6.47	4.46	2.76	1.38	0.80	0.58	0.50	101.38
1948	2.13	3.51	3.47	3.25	6.53	5.23	3.96	2.70	1.42	0.92	0.83	0.89	34.84
1949	1.64	4.90	4.24	5.93	4.97	4.07	3.55	3.40	2.71	2.12	2.77	2.82	43.12
1950	2.63	2.36	16.58	8.35	3.05	3.31	2.84	1.69	1.13	0.92	1.10	1.68	45.64
1951	3.58	3.45	3.29	3.93	4.10	3.60	3.63	3.09	1.92	1.22	0.82	1.03	33.66
1952	1.35	1.56	1.65	1.59	1.97	2.12	1.93	1.43	0.93	0.67	0.73	1.48	17.41
1953	3.04	9.41	12.74	6.05	3.16	3.13	2.30	1.96	2.20	1.95	1.35	1.54	48.83
1954	30.43	13.54	3.33	9.48	26.69	11.59	3.89	2.46	1.61	1.17	0.78	1.14	106.11
1955	2.07	2.99	2.38	1.04	1.54	16.15	9.21	4.07	2.67	1.90	1.35	1.41	46.78
1956	2.90	22.43	48.98	17.52	4.49	13.95	10.19	4.63	2.48	1.77	1.57	2.79	133.70
1957	5.46	12.01	6.44	4.15	17.58	8.62	4.53	3.59	1.85	1.13	0.89	0.88	67.13
1958	1.23	3.01	4.26	3.37	2.84	2.85	2.79	40.63	16.33	3.11	2.99	2.73	86.14
1959	2.68	3.25	3.41	2.86	2.45	2.87	3.20	2.92	2.09	1.39	1.22	1.62	29.96
1960	2.05	3.39	11.10	7.16	3.96	3.92	31.34	13.20	2.74	1.89	1.45	1.24	83.44
1961	1.37	3.10	4.13	3.81	5.25	8.96	4.92	2.22	1.44	0.93	1.03	1.27	38.43
1962	2.42	13.75	7.80	19.03	8.79	49.30	19.16	2.67	1.59	3.37	4.22	2.62	134.72
1963	3.03	12.85	12.20	21.12	9.46	4.21	4.75	3.84	33.78	14.49	3.05	2.28	125.06
1964	17.07	8.20	2.61	2.42	2.40	1.64	0.98	1.02	11.59	8.25	5.67	5.02	66.87
1965	21.19	19.31	7.07	3.18	2.50	1.43	0.83	9.38	6.20	2.70	1.78	1.95	77.52
1966	2.22	2.45	2.85	3.44	3.82	34.99	15.71	4.06	2.59	2.98	2.84	1.72	79.67
1967	1.41	2.70	2.84	2.15	1.98	2.03	1.93	1.37	0.81	0.61	1.01	2.15	20.99
1968	3.32	4.07	3.91	2.42	2.97	15.83	7.58	3.67	3.40	2.30	1.73	1.62	52.82
1969	2.31	3.61	3.83	2.66	1.91	1.35	0.87	0.93	1.44	1.51	2.19	3.34	25.95
1970	22.15	11.20	5.14	4.45	3.77	3.21	2.71	3.95	4.05	3.56	6.06	5.30	75.55
1971	27.41	12.31	3.78	3.39	11.74	6.62	2.65	1.43	1.07	1.04	0.87	0.72	73.03
1972	0.86	2.72	3.70	2.93	2.60	2.79	2.63	1.74	0.92	0.63	0.89	1.81	24.22
1973	2.73	5.37	4.39	3.49	4.11	10.53	5.95	5.97	5.31	3.49	1.92	1.18	54.44
1974	1.31	2.71	4.28	4.20	4.09	4.05	3.00	1.68	0.92	0.66	0.61	2.30	29.81
1975	3.48	3.20	17.40	12.60	18.45	63.62	22.90	4.29	3.25	1.93	1.22	1.66	154.00
1976	21.99	10.42	3.73	3.29	3.20	3.03	2.14	1.23	0.88	0.83	0.87	1.33	52.94
1977	3.31	13.62	12.46	6.16	3.88	3.48	88.19	32.94	3.41	1.89	1.41	1.83	172.58
1978	3.68	9.66	6.31	3.37	2.63	3.05	2.73	1.60	0.87	1.29	1.82	1.79	38.80
1979	2.28	2.73	2.74	2.11	1.62	1.62	1.31	0.97	0.76	0.60	0.52	2.52	19.78
1980	4.22	18.21	9.54	4.80	4.52	3.52	2.04	1.64	1.54	1.10	1.35	1.71	54.19
1981	1.50	1.58	1.70	2.50	2.77	3.84	4.56	3.32	1.99	1.41	0.98	0.86	27.01
1982	2.03	2.44	1.69	1.33	1.26	1.08	0.99	0.91	0.71	0.84	1.02	1.14	15.44
1983	1.73	3.39	4.35	10.87	10.18	6.18	8.93	5.30	2.60	2.43	2.30	1.87	60.13
1984	1.93	3.18	4.40	4.54	40.65	15.87	2.20	1.08	0.72	0.66	0.51	0.43	76.17
1985	8.29	9.03	7.27	4.96	3.37	2.29	1.48	0.89	0.62	0.54	1.69	3.11	43.54
1986	8.24	15.70	7.33	3.56	2.89	2.98	2.70	1.75	1.13	0.82	1.31	50.28	98.69
1987	20.79	11.43	21.74	8.91	24.70	54.59	18.92	4.66	4.64	4.61	4.63	3.88	183.50
1988	3.43	10.40	19.48	7.97	32.59	13.43	3.76	3.15	2.23	1.77	1.22	0.94	100.37
1989	2.92	52.62	20.38	3.39	2.32	7.70	5.13	2.25	1.17	0.75	1.51	2.13	102.27
1990	3.24	3.63	2.97	3.58	4.24	3.35	1.73	0.87	0.64	0.52	0.50	0.99	26.26
1991	11.25	10.22	5.02	2.98	2.41	2.31	2.00	1.29	0.74	0.52	0.52	0.71	39.97
1992	1.28	2.87	4.21	3.73	3.38	2.51	1.62	1.05	0.63	0.45	0.47	1.68	23.88
1993	17.98	9.83	16.80	7.99	8.85	16.85	7.00	1.63	0.85	1.14	1.49	1.13	91.54
1994	0.89	0.97	1.21	1.86	1.71	6.28	5.87	4.13	3.42	2.76	1.59	1.18	31.87
1995	1.85	3.22	55.45	23.00	22.50	10.31	2.85	1.33	0.71	1.31	1.77	1.56	125.86
1996	2.11	22.20	10.79	7.11	5.82	5.08	17.07	8.19	36.22	15.91	4.21	3.11	137.82
month	376.24	720.60	684.60	464.89	549.84	684.52	489.39	294.79	269.99	229.72	154.44	200.24	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.59	0.97	1.21	1.01	1.26	1.08	0.80	0.86	0.62	0.45	0.47	0.43	15.44
max	30.43	63.96	55.45	24.55	40.65	63.62	88.19	40.63	36.22	37.34	15.81	50.28	183.50
median	2.47	3.63	4.30	3.73	3.69	4.01	3.21	2.25	1.57	1.39	1.35	1.62	54.19
mean	4.89	9.36	8.89	6.04	7.14	8.89	6.36	3.83	3.51	2.98	2.01	2.60	66.48
Sum of the monthly means = 66.48													
s.d.	6.45	11.84	10.23	5.44	8.55	11.85	10.92	6.06	6.26	5.38	2.27	5.70	40.93
c.v.	1.32	1.27	1.15	0.90	1.20	1.33	1.72	1.58	1.79	1.80	1.13	2.19	0.62

APPENDIX 5.7
MTAFUFU RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.43	0.89	2.73	1.96	1.64	6.64	3.52	1.48	0.87	0.53	0.35	0.49	21.53
1921	0.97	9.10	9.22	3.19	1.12	0.69	0.44	8.60	8.00	2.94	1.69	1.76	47.72
1922	8.79	17.53	5.85	16.10	22.91	14.11	3.70	0.88	0.63	14.60	6.03	0.97	112.10
1923	0.61	0.63	0.89	9.44	9.24	2.90	0.68	0.48	0.47	0.42	0.48	0.84	27.08
1924	1.22	1.53	2.84	1.91	1.99	13.25	5.70	1.60	1.09	0.83	0.67	0.95	33.58
1925	1.24	1.30	1.24	1.36	2.89	14.76	5.76	1.24	1.62	1.66	1.09	1.05	35.21
1926	3.01	5.75	3.00	1.44	1.12	19.92	7.50	0.78	0.48	0.36	0.35	0.52	44.23
1927	1.08	0.96	0.97	1.35	3.01	2.23	1.30	0.97	0.89	0.70	0.91	0.99	15.36
1928	1.06	1.51	1.52	1.34	1.18	5.72	2.75	1.05	13.63	10.55	3.62	8.16	52.09
1929	13.87	10.09	3.06	0.99	0.75	1.00	1.33	1.21	1.56	1.91	2.04	8.69	46.50
1930	3.95	1.21	0.96	8.62	9.39	15.81	5.70	1.07	0.64	41.46	15.08	1.27	105.16
1931	1.35	1.33	1.08	0.77	5.54	3.28	1.44	1.25	1.45	1.60	1.41	8.99	29.49
1932	6.26	22.51	16.83	3.89	0.94	1.55	1.54	1.19	0.90	0.70	0.55	0.46	57.32
1933	0.44	4.31	8.94	12.35	4.42	3.81	2.32	1.25	0.90	3.29	2.19	0.91	45.13
1934	0.63	1.24	8.23	3.67	0.99	1.32	11.20	15.60	17.73	5.98	2.98	2.04	71.61
1935	1.30	1.23	0.72	0.53	17.67	18.89	5.36	7.25	3.80	1.69	1.14	0.95	60.53
1936	4.34	30.03	10.55	0.99	7.93	9.10	3.27	1.01	0.66	0.71	0.85	0.81	70.25
1937	0.85	0.90	1.87	1.75	1.45	1.07	4.07	2.50	1.49	1.57	1.36	0.87	19.75
1938	0.69	1.20	2.26	2.34	11.46	5.74	1.81	1.53	1.41	1.58	1.76	14.08	45.86
1939	7.66	2.18	1.56	1.26	1.16	1.43	1.30	3.79	2.44	1.21	0.82	0.78	25.59
1940	0.76	3.49	2.18	1.05	0.62	0.67	0.82	0.70	0.62	0.65	0.65	0.62	12.83
1941	0.89	1.32	1.04	8.52	3.84	2.20	1.77	2.01	1.70	1.02	0.86	1.05	26.22
1942	1.38	24.80	16.46	3.94	1.25	4.85	10.31	4.29	1.65	1.40	7.19	3.65	81.17
1943	2.56	7.75	4.97	1.92	3.20	2.86	1.80	1.14	0.90	0.92	0.77	12.62	41.41
1944	6.00	1.63	0.77	0.88	3.45	5.05	2.32	1.04	0.84	0.69	0.54	0.67	23.88
1945	14.12	5.44	0.61	0.49	1.00	7.86	3.95	1.49	1.01	0.76	0.56	0.52	37.81
1946	0.72	1.61	1.50	1.21	1.33	9.39	10.71	3.93	8.61	4.18	1.37	1.06	45.62
1947	1.03	27.17	11.80	1.95	5.91	7.22	3.32	1.58	0.93	0.56	0.40	0.32	62.19
1948	3.62	2.41	1.37	1.13	13.00	9.66	3.34	1.59	0.92	0.60	0.53	0.62	38.79
1949	0.96	7.28	3.36	1.75	2.42	2.01	1.88	4.15	2.41	1.37	1.67	1.56	30.82
1950	1.50	1.16	6.75	3.48	1.38	1.48	1.41	1.00	0.75	0.62	0.68	1.01	21.22
1951	7.38	3.13	2.82	5.57	2.82	5.60	3.98	2.06	1.31	0.90	0.60	0.79	36.96
1952	1.00	0.92	0.82	0.84	1.09	1.27	1.29	1.06	0.76	0.56	0.55	1.24	11.40
1953	5.15	12.00	5.79	1.78	1.06	1.60	1.42	1.35	1.72	1.64	1.13	1.15	35.79
1954	19.80	7.72	1.15	5.29	11.43	5.32	1.82	1.13	0.90	0.72	0.47	0.78	56.53
1955	1.33	1.59	1.03	0.40	0.83	17.21	7.78	1.98	1.59	1.34	0.96	1.03	37.07
1956	3.88	19.06	27.61	8.89	2.04	10.49	12.38	4.24	1.43	1.20	1.04	1.48	93.74
1957	3.17	2.36	1.86	5.93	11.55	4.70	9.38	4.02	0.88	0.70	0.68	0.68	45.91
1958	0.79	3.92	2.49	1.14	1.00	1.23	1.39	20.27	7.91	1.68	2.82	2.32	46.96
1959	1.89	1.69	1.48	1.30	1.15	1.91	3.00	2.39	1.63	1.10	0.97	1.26	19.77
1960	1.42	2.52	7.70	5.77	2.32	1.76	21.10	8.47	1.64	1.39	1.22	0.97	56.28
1961	0.88	4.49	2.76	1.54	1.61	10.64	4.50	1.19	0.89	0.59	0.71	0.87	30.67
1962	2.86	7.93	3.47	10.34	4.46	29.58	11.11	1.49	1.15	11.19	4.87	1.01	89.46
1963	1.32	3.68	2.35	9.96	7.93	5.55	6.51	2.88	23.95	9.33	1.33	1.05	75.84
1964	6.42	2.98	0.82	0.82	0.93	0.70	0.47	0.66	14.80	7.01	3.40	2.54	41.55
1965	18.11	12.19	3.13	1.22	1.14	0.77	0.51	10.88	4.96	1.27	0.91	1.01	56.10
1966	1.03	0.93	1.02	2.90	2.18	21.31	17.06	4.50	1.31	2.89	2.13	1.06	58.32
1967	0.72	1.20	1.23	0.92	0.99	1.13	1.09	0.83	0.55	0.43	0.71	2.02	11.82
1968	2.52	4.11	2.27	0.93	4.35	12.98	5.10	10.60	4.70	1.28	0.94	0.78	50.56
1969	1.02	2.23	1.78	0.99	0.99	0.94	0.71	0.73	1.14	1.23	11.71	5.46	28.93
1970	19.50	9.57	2.18	1.29	1.45	1.56	1.71	13.63	5.65	2.87	10.54	4.59	74.54
1971	14.31	5.97	1.51	1.22	11.61	4.94	1.17	0.82	0.75	0.76	0.68	0.55	44.29
1972	0.48	1.10	1.51	1.28	1.09	1.24	2.57	1.77	0.84	0.53	0.68	1.20	14.29
1973	1.62	5.73	2.60	0.94	1.31	4.32	2.54	13.13	5.85	1.69	1.03	0.67	41.43
1974	0.60	1.04	2.22	1.69	1.24	1.34	1.30	1.02	0.73	0.58	0.53	7.94	20.23
1975	3.73	1.24	8.23	3.88	11.44	40.54	13.98	7.56	3.57	1.16	0.83	1.11	97.27
1976	26.57	9.83	0.93	0.87	5.98	3.25	1.31	0.76	0.60	0.61	0.84	1.26	52.81
1977	1.78	9.94	11.02	3.75	1.29	1.36	58.06	22.23	2.33	1.28	1.02	1.17	115.23
1978	9.03	4.58	1.58	0.98	0.87	2.93	1.97	1.06	0.75	1.33	2.08	2.03	29.19
1979	2.03	1.58	1.11	0.81	0.87	1.07	0.93	0.79	0.68	0.56	0.48	4.87	15.78
1980	2.80	5.09	2.82	2.76	2.07	1.38	0.85	2.08	1.90	1.18	1.36	1.43	25.72
1981	0.95	0.79	0.75	0.96	1.04	15.69	6.66	1.60	1.10	0.85	0.63	0.50	31.52
1982	0.77	0.86	0.53	0.40	0.48	0.49	0.44	0.40	0.35	9.25	4.42	1.51	19.90
1983	1.46	3.01	2.12	2.59	2.11	1.63	1.75	1.69	1.43	4.13	2.59	1.40	25.91
1984	1.17	1.89	1.71	1.38	27.35	10.22	1.08	0.63	0.47	0.45	0.36	0.29	47.00
1985	2.07	8.04	3.54	2.90	1.77	1.11	1.05	0.82	0.58	0.44	1.04	4.00	27.36
1986	8.14	3.74	1.32	1.19	0.94	1.21	1.38	1.06	0.85	0.68	0.83	41.75	63.09
1987	15.45	7.32	3.43	1.25	15.09	33.97	11.19	7.84	3.92	3.41	3.96	2.22	109.05
1988	1.61	8.17	14.62	4.78	12.64	5.57	7.81	3.65	1.35	1.17	0.83	0.69	62.89
1989	6.08	14.55	4.95	0.94	0.80	7.60	3.49	0.88	0.56	0.42	0.82	1.14	42.23
1990	1.48	1.34	0.88	1.05	2.04	1.72	1.00	0.66	0.57	0.47	0.49	0.75	12.45
1991	4.16	6.89	2.69	0.85	0.68	0.65	0.83	0.80	0.58	0.42	0.43	0.67	19.65
1992	0.99	1.05	1.22	1.09	0.78	0.56	0.51	0.47	0.37	0.29	0.32	2.24	9.89
1993	4.99	2.68	7.71	3.26	19.16	7.84	1.42	0.72	0.45	0.58	1.37	1.39	51.57
1994	0.87	0.50	5.62	2.83	0.89	9.77	18.78	6.50	4.01	2.51	1.13	0.78	54.19
1995	0.96	1.01	17.73	8.17	3.76	2.03	1.16	0.92	0.66	8.40	4.06	1.21	50.07
1996	1.98	19.37	7.38	3.53	4.74	2.56	11.06	4.94	28.45	12.46	2.30	1.62	100.39
month	309.56	431.02	318.62	224.74	337.56	497.71	378.92	256.81	223.57	211.99	143.39	195.76	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.43	0.50	0.53	0.40	0.48	0.49	0.44	0.40	0.35	0.29	0.32	0.29	9.89
max	26.57	30.03	27.61	16.10	27.35	40.54	58.06	22.23	28.45	41.46	15.08	41.75	115.23
median	1.50	2.98	2.26	1.44	1.77	3.25	2.32	1.48	1.10	1.18	0.96	1.06	42.23
mean	4.02	5.60	4.14	2.92	4.38	6.46	4.92	3.34	2.90	2.75	1.86	2.54	45.84
Sum of the monthly means =				45.84									
s.d.	5.32	6.53	4.85	3.10	5.54	7.79	7.62	4.43	5.01	5.40	2.55	5.24	25.88
c.v.	1.32	1.17	1.17	1.06	1.26	1.21	1.55	1.33	1.73	1.96	1.37	2.06	0.56

APPENDIX 5.8
MZIMPUNZI RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.06	0.18	1.05	0.51	0.69	1.46	0.68	0.23	0.12	0.07	0.05	0.08	5.18
1921	0.17	2.05	2.02	0.62	0.19	0.12	0.08	1.87	1.57	0.48	0.37	0.30	9.84
1922	1.79	3.19	1.01	3.11	4.11	2.62	0.66	0.12	0.09	2.66	1.04	0.13	20.53
1923	0.09	0.11	0.17	2.23	2.02	0.55	0.10	0.07	0.07	0.07	0.08	0.15	5.71
1924	0.23	0.69	1.17	0.49	0.70	2.53	1.10	0.27	0.15	0.12	0.09	0.15	7.69
1925	0.23	0.45	0.31	0.74	0.83	2.92	1.06	0.18	0.40	0.28	0.15	0.16	7.71
1926	0.79	1.29	1.02	0.37	0.19	4.02	1.46	0.11	0.07	0.05	0.05	0.09	9.51
1927	0.25	0.18	0.35	0.81	1.30	0.55	0.19	0.14	0.13	0.10	0.15	0.17	4.32
1928	0.18	0.46	0.31	0.32	0.24	1.34	0.56	0.15	2.31	1.66	0.52	1.72	9.77
1929	2.28	1.76	0.54	0.19	0.16	0.35	0.29	0.21	0.52	0.36	0.59	1.50	8.75
1930	0.62	0.20	0.19	2.30	2.30	3.00	1.00	0.17	0.10	7.12	2.54	0.18	19.72
1931	0.37	0.28	0.21	0.16	2.15	1.13	0.26	0.17	0.22	0.25	0.22	1.86	7.28
1932	1.32	3.70	3.13	0.75	0.15	0.45	0.28	0.15	0.11	0.09	0.07	0.07	10.27
1933	0.07	1.39	1.98	2.34	0.79	0.96	0.47	0.19	0.14	0.77	0.40	0.12	9.62
1934	0.09	0.47	1.61	0.65	0.17	0.76	1.99	2.43	3.10	1.02	0.73	0.37	13.39
1935	0.17	0.20	0.13	0.09	3.26	3.28	0.87	1.40	0.66	0.24	0.16	0.13	10.59
1936	1.08	5.04	1.70	0.16	1.66	1.85	0.59	0.14	0.09	0.10	0.11	0.12	12.64
1937	0.14	0.16	0.89	0.68	0.33	0.19	1.04	0.49	0.21	0.23	0.20	0.13	4.69
1938	0.11	0.40	0.69	0.83	1.80	0.98	0.31	0.35	0.27	0.31	0.34	2.66	9.05
1939	1.59	0.40	0.57	0.29	0.14	0.24	0.22	1.13	0.54	0.18	0.13	0.11	5.54
1940	0.11	0.98	0.49	0.19	0.12	0.11	0.14	0.12	0.10	0.10	0.10	0.10	2.66
1941	0.16	0.44	0.25	2.54	0.98	0.59	0.32	0.22	0.21	0.13	0.13	0.18	6.15
1942	0.41	3.84	2.89	0.72	0.20	1.40	2.02	0.70	0.23	0.21	1.26	0.60	14.48
1943	0.78	1.67	1.32	0.44	1.16	0.54	0.20	0.15	0.13	0.14	0.13	1.95	8.61
1944	1.12	0.30	0.11	0.28	0.88	1.11	0.42	0.15	0.13	0.11	0.09	0.11	4.81
1945	2.61	0.97	0.09	0.10	0.84	1.89	0.81	0.24	0.14	0.11	0.08	0.08	7.96
1946	0.13	1.08	0.52	0.23	0.62	1.87	2.06	0.70	1.57	0.70	0.19	0.15	9.82
1947	0.16	4.73	2.26	0.40	1.62	1.46	0.51	0.20	0.12	0.07	0.05	0.04	11.62
1948	1.01	0.51	0.23	0.22	3.19	2.10	0.78	0.28	0.12	0.08	0.08	0.10	8.70
1949	0.18	1.92	0.79	1.06	0.91	0.60	0.61	0.88	0.39	0.18	0.41	0.28	8.21
1950	0.33	0.22	1.88	1.22	0.36	0.95	0.44	0.14	0.12	0.10	0.12	0.17	6.05
1951	1.59	0.62	0.97	1.14	0.46	0.79	0.80	0.35	0.16	0.11	0.07	0.11	7.17
1952	0.15	0.15	0.15	0.15	0.30	0.27	0.25	0.20	0.13	0.09	0.09	0.39	2.32
1953	0.93	2.06	1.58	0.48	0.19	0.83	0.39	0.20	0.26	0.24	0.16	0.19	7.51
1954	3.86	1.45	0.19	1.73	2.41	1.51	0.46	0.17	0.14	0.11	0.07	0.13	12.23
1955	0.23	0.47	0.23	0.06	0.50	2.93	1.51	0.36	0.20	0.17	0.12	0.15	6.93
1956	1.07	3.18	4.83	2.05	0.88	1.99	2.19	0.69	0.18	0.16	0.15	0.49	17.86
1957	0.99	0.85	0.80	1.39	2.37	1.19	1.72	0.65	0.12	0.09	0.08	0.09	10.34
1958	0.12	0.99	0.59	0.20	0.25	0.35	0.32	4.32	1.59	0.23	0.68	0.40	10.04
1959	0.25	0.25	0.24	0.23	0.21	1.03	0.81	0.63	0.31	0.16	0.15	0.20	4.47
1960	0.22	1.02	1.52	1.14	0.42	0.92	3.61	1.35	0.25	0.23	0.22	0.18	11.08
1961	0.16	1.35	0.76	0.28	0.71	1.88	0.71	0.18	0.14	0.09	0.12	0.16	6.54
1962	0.85	1.79	0.67	2.11	0.86	4.81	1.78	0.23	0.19	2.16	0.87	0.14	16.46
1963	0.46	1.01	0.60	2.27	1.76	1.26	1.55	0.57	3.65	1.40	0.19	0.17	14.89
1964	1.53	0.62	0.13	0.15	0.17	0.13	0.08	0.12	3.01	1.40	0.84	0.48	8.66
1965	2.85	2.06	0.53	0.21	0.21	0.14	0.09	2.23	0.92	0.17	0.13	0.17	9.71
1966	0.19	0.17	0.19	1.10	0.73	3.34	2.74	0.71	0.18	0.91	0.46	0.15	10.87
1967	0.11	0.43	0.27	0.16	0.19	0.22	0.21	0.16	0.10	0.08	0.12	0.73	2.78
1968	0.63	0.89	0.45	0.17	1.37	2.53	0.86	2.03	0.84	0.19	0.15	0.14	10.25
1969	0.20	0.94	0.46	0.16	0.16	0.14	0.11	0.13	0.21	0.23	2.11	1.10	5.95
1970	2.95	1.76	0.44	0.28	0.48	0.33	0.43	2.63	1.00	0.76	1.65	0.67	13.38
1971	2.70	1.08	0.33	0.25	2.78	1.09	0.20	0.15	0.13	0.13	0.12	0.10	9.06
1972	0.09	0.98	0.58	0.25	0.22	0.43	1.17	0.48	0.11	0.07	0.12	0.55	5.05
1973	0.55	1.75	0.70	0.20	0.92	1.17	0.46	2.42	1.14	0.29	0.16	0.11	9.87
1974	0.11	0.35	0.83	0.40	0.23	0.38	0.28	0.19	0.13	0.10	0.10	2.28	5.38
1975	0.91	0.19	1.49	0.66	2.45	6.73	2.73	1.48	0.57	0.15	0.11	0.22	17.69
1976	4.68	1.69	0.15	0.18	1.71	0.82	0.22	0.12	0.10	0.11	0.16	0.34	10.28
1977	0.90	2.02	2.16	0.70	0.23	0.42	9.73	3.83	0.39	0.18	0.15	0.18	20.89
1978	1.72	1.07	0.32	0.17	0.17	1.14	0.51	0.16	0.12	0.55	0.40	0.38	6.71
1979	0.76	0.38	0.19	0.15	0.18	0.22	0.18	0.15	0.13	0.10	0.09	1.57	4.10
1980	0.70	1.43	0.81	0.88	0.44	0.21	0.14	0.69	0.39	0.16	0.32	0.25	6.42
1981	0.15	0.15	0.14	0.25	0.21	3.17	1.69	0.37	0.17	0.13	0.10	0.09	6.62
1982	0.16	0.19	0.12	0.09	0.11	0.10	0.10	0.09	0.07	2.38	0.98	0.21	4.60
1983	0.23	1.12	0.60	1.09	0.81	0.35	0.84	0.44	0.25	1.40	0.62	0.20	7.95
1984	0.20	1.56	0.68	0.27	4.73	1.74	0.18	0.11	0.08	0.08	0.06	0.05	9.74
1985	0.81	1.60	0.61	1.29	0.55	0.19	0.21	0.17	0.11	0.08	0.35	1.07	7.04
1986	1.63	0.83	0.26	0.29	0.18	0.69	0.37	0.16	0.14	0.11	0.14	6.94	11.74
1987	2.53	1.42	0.62	0.20	2.27	5.34	1.80	1.54	0.69	0.86	0.83	0.36	18.46
1988	0.29	1.75	3.10	0.96	2.74	1.43	1.73	0.68	0.20	0.18	0.13	0.11	13.30
1989	1.60	2.87	0.90	0.18	0.17	1.91	0.77	0.13	0.08	0.06	0.16	0.23	9.06
1990	0.69	0.35	0.15	0.50	1.26	0.54	0.16	0.11	0.10	0.08	0.09	0.15	4.18
1991	1.52	1.79	0.57	0.18	0.17	0.15	0.18	0.16	0.11	0.08	0.08	0.13	5.12
1992	0.20	0.22	0.28	0.22	0.17	0.12	0.10	0.10	0.08	0.06	0.06	0.24	1.85
1993	0.95	0.63	1.51	0.59	3.30	1.63	0.30	0.09	0.06	0.09	0.21	0.19	9.55
1994	0.13	0.10	1.10	0.52	0.16	2.06	2.97	0.95	1.10	0.52	0.16	0.13	9.90
1995	0.19	0.23	3.68	1.82	1.45	0.56	0.17	0.15	0.12	1.17	0.55	0.18	10.27
1996	0.62	3.64	1.33	0.85	1.79	0.96	2.44	0.95	5.08	2.24	0.36	0.23	20.49
month	62.99	90.71	68.69	53.64	78.09	102.06	71.77	47.53	39.36	38.43	25.67	36.69	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.06	0.10	0.09	0.06	0.11	0.10	0.08	0.07	0.06	0.05	0.05	0.04	1.85
max	4.68	5.04	4.83	3.11	4.73	6.73	9.73	4.32	5.08	7.12	2.54	6.94	20.89
median	0.41	0.97	0.60	0.40	0.69	0.96	0.51	0.21	0.16	0.16	0.15	0.18	9.05
mean	0.82	1.18	0.89	0.70	1.01	1.33	0.93	0.62	0.51	0.50	0.33	0.48	9.29
Sum of the monthly means =				9.29									
s.d.	0.94	1.09	0.90	0.70	1.04	1.29	1.29	0.84	0.88	0.96	0.45	0.92	4.40
c.v.	1.15	0.93	1.01	1.00	1.03	0.97	1.38	1.36	1.73	1.93	1.35	1.93	0.47

APPENDIX 5.9
MBOTYI RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.08	0.22	1.27	0.61	0.83	1.77	0.82	0.27	0.15	0.09	0.06	0.09	6.26
1921	0.21	2.48	2.45	0.75	0.23	0.15	0.10	2.27	1.88	0.57	0.45	0.36	11.90
1922	2.17	3.86	1.22	3.76	4.97	3.17	0.80	0.15	0.11	3.21	1.26	0.16	24.84
1923	0.11	0.13	0.21	2.69	2.44	0.66	0.12	0.09	0.09	0.08	0.09	0.18	6.89
1924	0.28	0.83	1.42	0.59	0.84	3.06	1.33	0.32	0.19	0.14	0.11	0.18	9.29
1925	0.28	0.55	0.37	0.90	1.00	3.53	1.29	0.21	0.47	0.33	0.18	0.19	9.30
1926	0.95	1.56	1.24	0.45	0.23	4.85	1.76	0.13	0.08	0.06	0.06	0.10	11.47
1927	0.30	0.22	0.42	0.98	1.57	0.66	0.23	0.17	0.16	0.12	0.18	0.20	5.21
1928	0.22	0.56	0.38	0.39	0.29	1.62	0.68	0.19	2.78	1.99	0.62	2.07	11.79
1929	2.76	2.13	0.66	0.22	0.19	0.43	0.36	0.26	0.62	0.43	0.71	1.81	10.58
1930	0.75	0.24	0.23	2.78	2.77	3.63	1.21	0.20	0.12	8.59	3.07	0.21	23.80
1931	0.44	0.33	0.25	0.19	2.60	1.37	0.32	0.21	0.26	0.30	0.26	2.25	8.78
1932	1.59	4.48	3.78	0.90	0.18	0.54	0.33	0.18	0.14	0.11	0.09	0.08	12.40
1933	0.09	1.67	2.39	2.83	0.96	1.17	0.56	0.22	0.17	0.92	0.48	0.15	11.61
1934	0.11	0.56	1.95	0.78	0.20	0.92	2.41	2.93	3.73	1.22	0.88	0.45	16.14
1935	0.21	0.24	0.15	0.11	3.94	3.96	1.05	1.70	0.80	0.29	0.19	0.16	12.80
1936	1.31	6.09	2.06	0.19	2.00	2.24	0.71	0.17	0.11	0.12	0.14	0.14	15.28
1937	0.17	0.19	1.07	0.83	0.39	0.23	1.26	0.60	0.25	0.28	0.24	0.16	5.67
1938	0.13	0.49	0.84	1.00	2.18	1.18	0.38	0.43	0.32	0.36	0.41	3.22	10.94
1939	1.92	0.48	0.68	0.35	0.17	0.28	0.26	1.37	0.65	0.21	0.15	0.14	6.66
1940	0.14	1.18	0.59	0.22	0.14	0.14	0.16	0.14	0.12	0.12	0.12	0.12	3.19
1941	0.20	0.53	0.30	3.07	1.19	0.72	0.39	0.26	0.25	0.16	0.16	0.22	7.45
1942	0.50	4.64	3.49	0.87	0.24	1.70	2.44	0.85	0.28	0.25	1.52	0.72	17.50
1943	0.95	2.02	1.59	0.53	1.41	0.66	0.24	0.18	0.16	0.17	0.15	2.35	10.41
1944	1.35	0.36	0.13	0.34	1.06	1.34	0.50	0.19	0.16	0.13	0.10	0.13	5.79
1945	3.16	1.17	0.11	0.12	1.01	2.28	0.98	0.29	0.17	0.13	0.10	0.10	9.62
1946	0.15	1.30	0.63	0.28	0.75	2.26	2.49	0.84	1.88	0.84	0.22	0.18	11.82
1947	0.19	5.72	2.73	0.48	1.96	1.76	0.62	0.24	0.14	0.08	0.06	0.05	14.03
1948	1.22	0.62	0.28	0.27	3.85	2.54	0.95	0.34	0.14	0.10	0.09	0.12	10.52
1949	0.21	2.32	0.95	1.29	1.10	0.73	0.74	1.06	0.48	0.22	0.49	0.34	9.93
1950	0.40	0.26	2.27	1.47	0.43	1.15	0.53	0.17	0.14	0.12	0.14	0.21	7.29
1951	1.92	0.75	1.17	1.37	0.55	0.96	0.97	0.42	0.19	0.13	0.09	0.13	8.65
1952	0.18	0.19	0.18	0.19	0.37	0.33	0.30	0.24	0.16	0.11	0.11	0.47	2.83
1953	1.13	2.49	1.91	0.58	0.23	1.01	0.47	0.24	0.31	0.29	0.20	0.23	9.09
1954	4.67	1.76	0.23	2.09	2.91	1.82	0.56	0.21	0.17	0.13	0.08	0.15	14.78
1955	0.27	0.57	0.28	0.08	0.60	3.54	1.82	0.44	0.24	0.21	0.15	0.19	8.39
1956	1.29	3.85	5.83	2.48	1.06	2.41	2.64	0.83	0.22	0.19	0.18	0.59	21.57
1957	1.20	1.03	0.96	1.67	2.87	1.44	2.08	0.79	0.14	0.11	0.10	0.11	12.50
1958	0.14	1.19	0.71	0.24	0.30	0.43	0.39	5.22	1.92	0.28	0.82	0.48	12.12
1959	0.30	0.31	0.29	0.28	0.26	1.24	0.98	0.76	0.37	0.19	0.18	0.25	5.41
1960	0.27	1.23	1.84	1.37	0.50	1.11	4.36	1.64	0.30	0.28	0.27	0.21	13.38
1961	0.20	1.63	0.92	0.34	0.86	2.27	0.85	0.21	0.16	0.10	0.14	0.19	7.87
1962	1.03	2.16	0.81	2.55	1.03	5.82	2.15	0.28	0.23	2.60	1.05	0.17	19.88
1963	0.56	1.22	0.73	2.74	2.13	1.53	1.87	0.69	4.39	1.68	0.23	0.20	17.97
1964	1.85	0.75	0.15	0.18	0.21	0.15	0.10	0.15	3.63	1.68	1.01	0.58	10.44
1965	3.44	2.49	0.64	0.25	0.25	0.17	0.11	2.69	1.11	0.21	0.16	0.21	11.73
1966	0.23	0.20	0.23	1.33	0.88	4.03	3.31	0.85	0.22	1.09	0.55	0.18	13.10
1967	0.13	0.52	0.32	0.19	0.23	0.27	0.26	0.19	0.12	0.09	0.15	0.87	3.34
1968	0.76	1.07	0.55	0.21	1.65	3.06	1.04	2.45	1.01	0.22	0.18	0.17	12.37
1969	0.24	1.13	0.56	0.19	0.19	0.17	0.14	0.15	0.25	0.27	2.54	1.33	7.16
1970	3.57	2.12	0.53	0.34	0.58	0.40	0.52	3.18	1.21	0.90	1.99	0.81	16.15
1971	3.26	1.30	0.40	0.31	3.36	1.32	0.25	0.18	0.16	0.16	0.14	0.12	10.96
1972	0.10	1.18	0.70	0.30	0.26	0.52	1.42	0.58	0.13	0.09	0.14	0.67	6.09
1973	0.66	2.12	0.84	0.24	1.11	1.41	0.56	2.92	1.36	0.35	0.19	0.13	11.89
1974	0.14	0.42	1.00	0.48	0.27	0.46	0.34	0.23	0.16	0.12	0.11	2.76	6.49
1975	1.10	0.23	1.80	0.80	2.96	8.13	3.30	1.79	0.69	0.18	0.14	0.26	21.38
1976	5.66	2.04	0.18	0.22	2.07	1.00	0.27	0.15	0.13	0.14	0.19	0.40	12.45
1977	1.08	2.44	2.61	0.85	0.27	0.51	11.76	4.63	0.47	0.22	0.18	0.22	25.24
1978	2.08	1.30	0.39	0.20	0.21	1.37	0.62	0.19	0.14	0.65	0.49	0.46	8.10
1979	0.92	0.46	0.23	0.19	0.22	0.26	0.21	0.18	0.16	0.13	0.11	1.89	4.96
1980	0.84	1.73	0.98	1.06	0.53	0.26	0.17	0.83	0.47	0.20	0.38	0.30	7.75
1981	0.18	0.18	0.17	0.30	0.26	3.83	2.04	0.45	0.20	0.16	0.12	0.11	8.00
1982	0.21	0.25	0.15	0.11	0.13	0.13	0.12	0.11	0.09	2.87	1.18	0.26	5.61
1983	0.28	1.36	0.73	1.32	0.98	0.42	1.02	0.53	0.30	1.67	0.75	0.24	9.60
1984	0.24	1.88	0.82	0.32	5.71	2.10	0.22	0.14	0.10	0.09	0.07	0.06	11.75
1985	0.98	1.94	0.74	1.56	0.66	0.23	0.25	0.20	0.14	0.10	0.42	1.29	8.51
1986	1.97	1.00	0.31	0.35	0.22	0.84	0.45	0.20	0.16	0.13	0.17	8.38	14.18
1987	3.06	1.71	0.75	0.24	2.75	6.45	2.17	1.87	0.83	1.03	1.00	0.43	22.29
1988	0.35	2.12	3.75	1.16	3.31	1.72	2.09	0.83	0.24	0.22	0.15	0.13	16.07
1989	1.93	3.46	1.08	0.22	0.20	2.31	0.92	0.16	0.10	0.08	0.19	0.28	10.93
1990	0.83	0.42	0.18	0.61	1.52	0.65	0.19	0.14	0.12	0.10	0.11	0.18	5.05
1991	1.83	2.16	0.69	0.22	0.21	0.19	0.22	0.20	0.13	0.09	0.09	0.15	6.18
1992	0.24	0.27	0.33	0.26	0.21	0.15	0.12	0.12	0.09	0.07	0.08	0.29	2.23
1993	1.14	0.76	1.83	0.72	3.98	1.97	0.36	0.11	0.07	0.10	0.24	0.23	11.51
1994	0.16	0.12	1.33	0.63	0.19	2.49	3.59	1.15	1.32	0.63	0.19	0.15	11.95
1995	0.23	0.28	4.45	2.20	1.76	0.68	0.21	0.18	0.14	1.40	0.67	0.21	12.41
1996	0.74	4.39	1.60	1.03	2.17	1.15	2.95	1.14	6.12	2.69	0.44	0.28	24.70
month	76.14	109.61	82.99	64.81	94.30	123.41	86.76	57.47	47.37	46.17	30.90	44.24	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.08	0.12	0.11	0.08	0.13	0.13	0.10	0.09	0.07	0.06	0.06	0.05	2.23
max	5.66	6.09	5.83	3.76	5.71	8.13	11.76	5.22	6.12	8.59	3.07	8.38	25.24
median	0.50	1.17	0.73	0.48	0.83	1.17	0.62	0.26	0.19	0.20	0.18	0.21	10.93
mean	0.99	1.42	1.08	0.84	1.22	1.60	1.13	0.75	0.62	0.60	0.40	0.57	11.22
Sum of the monthly means =				11.22									
s.d.	1.13	1.32	1.09	0.85	1.26	1.55	1.56	1.02	1.06	1.16	0.54	1.11	5.32
c.v.	1.15	0.93	1.01	1.00	1.03	0.97	1.38	1.36	1.73	1.94	1.35	1.94	0.47

APPENDIX 5.10
MYEKANE RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.01	0.04	0.22	0.11	0.14	0.30	0.14	0.05	0.03	0.02	0.01	0.02	1.09
1921	0.04	0.43	0.42	0.13	0.04	0.03	0.02	0.39	0.33	0.10	0.08	0.06	2.07
1922	0.37	0.67	0.21	0.65	0.86	0.55	0.14	0.03	0.02	0.55	0.22	0.03	4.30
1923	0.02	0.02	0.04	0.46	0.42	0.11	0.02	0.02	0.02	0.01	0.02	0.03	1.19
1924	0.05	0.14	0.24	0.10	0.15	0.53	0.23	0.06	0.03	0.02	0.02	0.03	1.60
1925	0.05	0.09	0.06	0.15	0.17	0.61	0.22	0.04	0.08	0.06	0.03	0.03	1.59
1926	0.16	0.27	0.21	0.08	0.04	0.84	0.30	0.02	0.01	0.01	0.01	0.02	1.97
1927	0.05	0.04	0.07	0.17	0.27	0.11	0.04	0.03	0.03	0.02	0.03	0.03	0.89
1928	0.04	0.10	0.06	0.07	0.05	0.28	0.12	0.03	0.48	0.35	0.11	0.36	2.05
1929	0.48	0.37	0.11	0.04	0.03	0.07	0.06	0.04	0.11	0.07	0.12	0.31	1.81
1930	0.13	0.04	0.04	0.48	0.48	0.63	0.21	0.04	0.02	1.48	0.53	0.04	4.12
1931	0.08	0.06	0.04	0.03	0.45	0.24	0.06	0.04	0.05	0.05	0.05	0.39	1.54
1932	0.27	0.77	0.65	0.16	0.03	0.09	0.06	0.03	0.02	0.02	0.01	0.01	2.12
1933	0.02	0.29	0.41	0.49	0.16	0.20	0.10	0.04	0.03	0.16	0.08	0.03	2.01
1934	0.02	0.10	0.34	0.14	0.03	0.16	0.41	0.51	0.65	0.21	0.15	0.08	2.80
1935	0.04	0.04	0.03	0.02	0.68	0.68	0.18	0.29	0.14	0.05	0.03	0.03	2.21
1936	0.23	1.05	0.35	0.03	0.35	0.39	0.12	0.03	0.02	0.02	0.02	0.02	2.63
1937	0.03	0.03	0.18	0.14	0.07	0.04	0.22	0.10	0.04	0.05	0.04	0.03	0.97
1938	0.02	0.08	0.14	0.17	0.38	0.20	0.07	0.07	0.06	0.06	0.07	0.56	1.88
1939	0.33	0.08	0.12	0.06	0.03	0.05	0.05	0.24	0.11	0.04	0.03	0.02	1.16
1940	0.02	0.20	0.10	0.04	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.53
1941	0.03	0.09	0.05	0.53	0.20	0.12	0.07	0.05	0.04	0.03	0.03	0.04	1.28
1942	0.09	0.80	0.60	0.15	0.04	0.29	0.42	0.15	0.05	0.04	0.26	0.12	3.01
1943	0.16	0.35	0.27	0.09	0.24	0.11	0.04	0.03	0.03	0.03	0.03	0.41	1.79
1944	0.23	0.06	0.02	0.06	0.18	0.23	0.09	0.03	0.03	0.02	0.02	0.02	0.99
1945	0.54	0.20	0.02	0.02	0.17	0.39	0.17	0.05	0.03	0.02	0.02	0.02	1.65
1946	0.03	0.23	0.11	0.05	0.13	0.39	0.43	0.15	0.33	0.15	0.04	0.03	2.07
1947	0.03	0.99	0.47	0.08	0.34	0.30	0.11	0.04	0.02	0.01	0.01	0.01	2.41
1948	0.21	0.11	0.05	0.05	0.66	0.44	0.16	0.06	0.03	0.02	0.02	0.02	1.83
1949	0.04	0.40	0.16	0.22	0.19	0.13	0.13	0.18	0.08	0.04	0.09	0.06	1.72
1950	0.07	0.05	0.39	0.25	0.07	0.20	0.09	0.03	0.02	0.02	0.02	0.04	1.25
1951	0.33	0.13	0.20	0.24	0.10	0.16	0.17	0.07	0.03	0.02	0.01	0.02	1.48
1952	0.03	0.03	0.03	0.03	0.06	0.06	0.05	0.04	0.03	0.02	0.02	0.08	0.48
1953	0.19	0.43	0.33	0.10	0.04	0.17	0.08	0.04	0.05	0.05	0.03	0.04	1.55
1954	0.80	0.30	0.04	0.36	0.50	0.31	0.10	0.04	0.03	0.02	0.01	0.03	2.54
1955	0.05	0.10	0.05	0.01	0.10	0.61	0.31	0.08	0.04	0.04	0.03	0.03	1.45
1956	0.22	0.66	1.01	0.43	0.18	0.41	0.46	0.14	0.04	0.03	0.03	0.10	3.71
1957	0.21	0.18	0.17	0.29	0.49	0.25	0.36	0.14	0.02	0.02	0.02	0.02	2.17
1958	0.02	0.21	0.12	0.04	0.05	0.07	0.07	0.90	0.33	0.05	0.14	0.08	2.08
1959	0.05	0.05	0.05	0.05	0.04	0.21	0.17	0.13	0.06	0.03	0.03	0.04	0.91
1960	0.05	0.21	0.32	0.24	0.09	0.19	0.75	0.28	0.05	0.05	0.05	0.04	2.32
1961	0.03	0.28	0.16	0.06	0.15	0.39	0.15	0.04	0.03	0.02	0.02	0.03	1.36
1962	0.18	0.37	0.14	0.44	0.18	1.00	0.37	0.05	0.04	0.45	0.18	0.03	3.43
1963	0.10	0.21	0.13	0.47	0.37	0.26	0.32	0.12	0.76	0.29	0.04	0.03	3.10
1964	0.32	0.13	0.03	0.03	0.04	0.03	0.02	0.03	0.63	0.29	0.17	0.10	1.82
1965	0.59	0.43	0.11	0.04	0.04	0.03	0.02	0.46	0.19	0.04	0.03	0.04	2.02
1966	0.04	0.04	0.04	0.23	0.15	0.69	0.57	0.15	0.04	0.19	0.10	0.03	2.27
1967	0.02	0.09	0.06	0.03	0.04	0.05	0.04	0.03	0.02	0.02	0.03	0.15	0.58
1968	0.13	0.19	0.09	0.04	0.29	0.53	0.18	0.42	0.17	0.04	0.03	0.03	2.14
1969	0.04	0.20	0.10	0.03	0.03	0.03	0.02	0.03	0.04	0.05	0.44	0.23	1.24
1970	0.61	0.37	0.09	0.06	0.10	0.07	0.09	0.55	0.21	0.16	0.34	0.14	2.79
1971	0.56	0.22	0.07	0.05	0.58	0.23	0.04	0.03	0.03	0.03	0.02	0.02	1.88
1972	0.02	0.20	0.12	0.05	0.04	0.09	0.24	0.10	0.02	0.01	0.02	0.12	1.03
1973	0.11	0.36	0.15	0.04	0.19	0.24	0.10	0.50	0.24	0.06	0.03	0.02	2.04
1974	0.02	0.07	0.17	0.08	0.05	0.08	0.06	0.04	0.03	0.02	0.02	0.48	1.12
1975	0.19	0.04	0.31	0.14	0.51	1.40	0.57	0.31	0.12	0.03	0.02	0.04	3.68
1976	0.98	0.35	0.03	0.04	0.36	0.17	0.05	0.03	0.02	0.02	0.03	0.07	2.15
1977	0.19	0.42	0.45	0.15	0.05	0.09	2.03	0.80	0.08	0.04	0.03	0.04	4.37
1978	0.36	0.22	0.07	0.03	0.04	0.24	0.11	0.03	0.02	0.11	0.08	0.08	1.39
1979	0.16	0.08	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.33	0.86
1980	0.15	0.30	0.17	0.18	0.09	0.04	0.03	0.14	0.08	0.03	0.07	0.05	1.33
1981	0.03	0.03	0.03	0.05	0.04	0.66	0.35	0.08	0.03	0.03	0.02	0.02	1.37
1982	0.03	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.50	0.20	0.04	0.96
1983	0.05	0.23	0.13	0.23	0.17	0.07	0.18	0.09	0.05	0.29	0.13	0.04	1.66
1984	0.04	0.32	0.14	0.06	0.98	0.36	0.04	0.02	0.02	0.02	0.01	0.01	2.02
1985	0.17	0.33	0.13	0.27	0.11	0.04	0.04	0.03	0.02	0.02	0.07	0.22	1.45
1986	0.34	0.17	0.05	0.06	0.04	0.14	0.08	0.03	0.03	0.02	0.03	1.45	2.44
1987	0.53	0.30	0.13	0.04	0.47	1.11	0.37	0.32	0.14	0.18	0.17	0.07	3.83
1988	0.06	0.37	0.65	0.20	0.57	0.30	0.36	0.14	0.04	0.04	0.03	0.02	2.78
1989	0.33	0.60	0.19	0.04	0.04	0.40	0.16	0.03	0.02	0.01	0.03	0.05	1.90
1990	0.14	0.07	0.03	0.10	0.26	0.11	0.03	0.02	0.02	0.02	0.02	0.03	0.85
1991	0.32	0.37	0.12	0.04	0.04	0.03	0.04	0.03	0.02	0.02	0.02	0.03	1.08
1992	0.04	0.05	0.06	0.05	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.05	0.40
1993	0.20	0.13	0.32	0.12	0.69	0.34	0.06	0.02	0.01	0.02	0.04	0.04	1.99
1994	0.03	0.02	0.23	0.11	0.03	0.43	0.62	0.20	0.23	0.11	0.03	0.03	2.07
1995	0.04	0.05	0.77	0.38	0.30	0.12	0.04	0.03	0.02	0.24	0.12	0.04	2.15
1996	0.13	0.76	0.28	0.18	0.37	0.20	0.51	0.20	1.06	0.47	0.08	0.05	4.29
month	13.12	18.90	14.32	11.18	16.23	21.23	15.00	9.92	8.19	8.00	5.32	7.65	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.40
max	0.98	1.05	1.01	0.65	0.98	1.40	2.03	0.90	1.06	1.48	0.53	1.45	4.37
median	0.09	0.20	0.13	0.08	0.14	0.20	0.11	0.04	0.03	0.03	0.03	0.04	1.88
mean	0.17	0.25	0.19	0.15	0.21	0.28	0.19	0.13	0.11	0.10	0.07	0.10	1.94
Sum of the monthly means =				1.94									
s.d.	0.20	0.23	0.19	0.15	0.22	0.27	0.27	0.18	0.18	0.20	0.09	0.19	0.92
c.v.	1.15	0.93	1.01	1.01	1.03	0.97	1.38	1.36	1.73	1.93	1.35	1.94	0.48

APPENDIX 5.11
LUPATANA RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.05	0.15	0.88	0.42	0.57	1.22	0.56	0.19	0.10	0.06	0.04	0.07	4.31
1921	0.14	1.71	1.69	0.52	0.16	0.10	0.07	1.56	1.31	0.40	0.31	0.25	8.22
1922	1.49	2.66	0.84	2.59	3.43	2.18	0.55	0.10	0.08	2.22	0.87	0.11	17.12
1923	0.08	0.09	0.14	1.85	1.69	0.46	0.08	0.06	0.06	0.05	0.06	0.12	4.74
1924	0.19	0.57	0.98	0.41	0.58	2.11	0.92	0.22	0.13	0.10	0.08	0.13	6.42
1925	0.19	0.38	0.26	0.62	0.69	2.43	0.89	0.15	0.33	0.23	0.12	0.13	6.42
1926	0.66	1.07	0.85	0.31	0.16	3.35	1.21	0.09	0.06	0.04	0.04	0.07	7.91
1927	0.21	0.15	0.29	0.68	1.09	0.46	0.16	0.12	0.11	0.09	0.12	0.14	3.62
1928	0.15	0.39	0.26	0.27	0.20	1.12	0.47	0.13	1.93	1.38	0.43	1.43	8.16
1929	1.90	1.47	0.45	0.15	0.13	0.30	0.25	0.18	0.44	0.30	0.49	1.25	7.31
1930	0.51	0.17	0.16	1.92	1.91	2.50	0.84	0.14	0.08	5.93	2.12	0.15	16.43
1931	0.31	0.23	0.17	0.13	1.79	0.95	0.22	0.14	0.18	0.21	0.18	1.55	6.06
1932	1.10	3.09	2.61	0.62	0.12	0.37	0.23	0.12	0.09	0.07	0.06	0.06	8.54
1933	0.06	1.16	1.65	1.95	0.66	0.80	0.39	0.16	0.12	0.64	0.33	0.10	8.02
1934	0.08	0.39	1.34	0.54	0.14	0.63	1.66	2.02	2.58	0.85	0.61	0.31	11.15
1935	0.14	0.16	0.11	0.08	2.72	2.73	0.73	1.17	0.55	0.20	0.13	0.11	8.83
1936	0.90	4.20	1.42	0.13	1.38	1.54	0.49	0.12	0.08	0.08	0.09	0.10	10.53
1937	0.12	0.13	0.74	0.57	0.27	0.16	0.87	0.41	0.17	0.19	0.17	0.11	3.91
1938	0.09	0.34	0.58	0.69	1.50	0.82	0.26	0.29	0.22	0.25	0.28	2.22	7.54
1939	1.33	0.33	0.47	0.24	0.12	0.20	0.18	0.95	0.45	0.15	0.11	0.09	4.62
1940	0.10	0.82	0.41	0.15	0.10	0.10	0.11	0.10	0.08	0.08	0.08	0.09	2.22
1941	0.14	0.37	0.21	2.12	0.82	0.49	0.27	0.18	0.17	0.11	0.11	0.15	5.14
1942	0.34	3.20	2.41	0.60	0.16	1.17	1.69	0.59	0.19	0.18	1.05	0.50	12.08
1943	0.65	1.39	1.10	0.36	0.97	0.45	0.17	0.12	0.11	0.12	0.10	1.62	7.16
1944	0.93	0.25	0.09	0.24	0.73	0.92	0.35	0.13	0.11	0.09	0.07	0.09	4.00
1945	2.18	0.81	0.08	0.08	0.70	1.57	0.68	0.20	0.12	0.09	0.07	0.07	6.65
1946	0.11	0.90	0.44	0.19	0.52	1.56	1.71	0.58	1.31	0.58	0.15	0.12	8.17
1947	0.13	3.94	1.89	0.33	1.35	1.22	0.43	0.17	0.10	0.06	0.04	0.04	9.70
1948	0.84	0.43	0.19	0.18	2.66	1.75	0.65	0.24	0.10	0.07	0.06	0.08	7.25
1949	0.15	1.60	0.65	0.89	0.76	0.50	0.51	0.73	0.33	0.15	0.34	0.24	6.85
1950	0.28	0.18	1.56	1.01	0.30	0.79	0.37	0.12	0.10	0.08	0.10	0.15	5.04
1951	1.33	0.52	0.81	0.95	0.38	0.66	0.67	0.29	0.13	0.09	0.06	0.09	5.98
1952	0.13	0.13	0.12	0.13	0.25	0.23	0.21	0.17	0.11	0.07	0.07	0.33	1.95
1953	0.78	1.72	1.32	0.40	0.16	0.69	0.33	0.16	0.21	0.20	0.14	0.16	6.27
1954	3.22	1.21	0.16	1.44	2.01	1.25	0.38	0.14	0.12	0.09	0.06	0.11	10.19
1955	0.19	0.39	0.19	0.05	0.42	2.44	1.26	0.30	0.17	0.14	0.10	0.13	5.78
1956	0.89	2.65	4.02	1.71	0.73	1.66	1.82	0.57	0.15	0.13	0.12	0.41	14.86
1957	0.83	0.71	0.66	1.15	1.98	1.00	1.44	0.55	0.10	0.07	0.07	0.07	8.63
1958	0.10	0.82	0.49	0.17	0.21	0.30	0.27	3.60	1.33	0.20	0.57	0.33	8.39
1959	0.21	0.21	0.20	0.19	0.18	0.86	0.67	0.52	0.26	0.13	0.12	0.17	3.72
1960	0.19	0.85	1.27	0.95	0.35	0.77	3.00	1.13	0.21	0.19	0.18	0.15	9.24
1961	0.14	1.13	0.64	0.24	0.59	1.57	0.59	0.15	0.11	0.07	0.10	0.13	5.46
1962	0.71	1.49	0.56	1.76	0.71	4.01	1.48	0.19	0.16	1.80	0.73	0.12	13.72
1963	0.38	0.84	0.50	1.89	1.47	1.05	1.29	0.48	3.04	1.17	0.16	0.14	12.41
1964	1.28	0.52	0.10	0.12	0.14	0.10	0.07	0.10	2.51	1.17	0.70	0.40	7.21
1965	2.37	1.72	0.44	0.17	0.17	0.11	0.08	1.86	0.77	0.15	0.11	0.15	8.10
1966	0.16	0.14	0.16	0.92	0.61	2.78	2.28	0.59	0.15	0.76	0.38	0.12	9.05
1967	0.09	0.36	0.22	0.13	0.16	0.19	0.18	0.13	0.08	0.06	0.10	0.61	2.31
1968	0.53	0.74	0.38	0.14	1.14	2.11	0.72	1.69	0.70	0.16	0.13	0.12	8.56
1969	0.17	0.78	0.38	0.13	0.13	0.12	0.10	0.11	0.18	0.19	1.76	0.92	4.97
1970	2.46	1.46	0.37	0.23	0.40	0.27	0.36	2.19	0.84	0.63	1.37	0.56	11.14
1971	2.25	0.90	0.27	0.21	2.32	0.91	0.17	0.13	0.11	0.11	0.10	0.08	7.56
1972	0.07	0.82	0.48	0.21	0.18	0.36	0.98	0.40	0.09	0.06	0.10	0.46	4.21
1973	0.46	1.46	0.58	0.16	0.76	0.97	0.39	2.02	0.95	0.24	0.13	0.09	8.21
1974	0.10	0.29	0.69	0.33	0.19	0.32	0.23	0.16	0.11	0.08	0.08	1.90	4.48
1975	0.76	0.16	1.24	0.55	2.04	5.61	2.27	1.23	0.48	0.13	0.10	0.18	14.75
1976	3.90	1.41	0.12	0.15	1.43	0.69	0.19	0.10	0.09	0.09	0.13	0.28	8.58
1977	0.75	1.68	1.80	0.59	0.19	0.35	8.11	3.20	0.33	0.15	0.12	0.15	17.42
1978	1.43	0.89	0.27	0.14	0.14	0.95	0.43	0.13	0.10	0.46	0.34	0.31	5.59
1979	0.63	0.31	0.16	0.13	0.15	0.18	0.15	0.12	0.11	0.09	0.07	1.31	3.41
1980	0.58	1.19	0.68	0.73	0.36	0.18	0.12	0.57	0.32	0.14	0.27	0.21	5.35
1981	0.13	0.12	0.12	0.21	0.18	2.64	1.41	0.31	0.14	0.11	0.08	0.07	5.52
1982	0.14	0.16	0.10	0.08	0.09	0.09	0.08	0.07	0.06	1.99	0.81	0.18	3.85
1983	0.20	0.93	0.50	0.91	0.68	0.29	0.70	0.36	0.21	1.16	0.52	0.17	6.63
1984	0.17	1.30	0.57	0.22	3.94	1.45	0.15	0.09	0.07	0.07	0.05	0.04	8.12
1985	0.68	1.34	0.51	1.07	0.46	0.16	0.17	0.14	0.09	0.07	0.29	0.89	5.87
1986	1.36	0.69	0.21	0.24	0.15	0.58	0.31	0.13	0.11	0.09	0.12	5.78	9.77
1987	2.11	1.18	0.52	0.16	1.90	4.45	1.50	1.29	0.58	0.72	0.69	0.30	15.40
1988	0.24	1.46	2.58	0.80	2.28	1.19	1.44	0.57	0.16	0.15	0.11	0.09	11.07
1989	1.33	2.39	0.75	0.15	0.14	1.59	0.64	0.11	0.07	0.05	0.13	0.19	7.54
1990	0.57	0.29	0.12	0.42	1.05	0.45	0.13	0.09	0.09	0.07	0.07	0.13	3.48
1991	1.27	1.49	0.47	0.15	0.14	0.13	0.15	0.14	0.09	0.07	0.07	0.11	4.28
1992	0.17	0.19	0.23	0.18	0.14	0.10	0.09	0.08	0.07	0.05	0.05	0.20	1.55
1993	0.79	0.53	1.26	0.50	2.75	1.36	0.25	0.08	0.05	0.07	0.17	0.16	7.97
1994	0.11	0.08	0.92	0.43	0.13	1.72	2.48	0.80	0.92	0.44	0.13	0.11	8.27
1995	0.16	0.19	3.07	1.52	1.21	0.47	0.15	0.13	0.10	0.98	0.46	0.15	8.59
1996	0.51	3.03	1.11	0.71	1.50	0.80	2.03	0.79	4.24	1.86	0.30	0.19	17.07
month	52.58	75.60	57.24	44.66	65.07	85.11	59.89	39.64	32.86	32.02	21.33	30.60	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.05	0.08	0.08	0.05	0.09	0.09	0.07	0.06	0.05	0.04	0.04	0.04	1.55
max	3.90	4.20	4.02	2.59	3.94	5.61	8.11	3.60	4.24	5.93	2.12	5.78	17.42
median	0.34	0.81	0.50	0.33	0.57	0.80	0.43	0.18	0.13	0.14	0.12	0.15	7.54
mean	0.68	0.98	0.74	0.58	0.85	1.11	0.78	0.51	0.43	0.42	0.28	0.40	7.75
Sum of the monthly means =				7.75									
s.d.	0.78	0.91	0.75	0.58	0.87	1.07	1.07	0.70	0.74	0.80	0.37	0.77	3.67
c.v.	1.14	0.93	1.01	1.01	1.03	0.97	1.38	1.36	1.73	1.93	1.35	1.93	0.47

APPENDIX 5.12
MKWENI RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.13	0.36	2.10	1.02	1.38	2.93	1.35	0.46	0.25	0.15	0.10	0.16	10.39
1921	0.34	4.11	4.05	1.24	0.38	0.25	0.16	3.75	3.14	0.95	0.74	0.60	19.71
1922	3.59	6.39	2.02	6.22	8.22	5.24	1.32	0.25	0.18	5.33	2.09	0.26	41.11
1923	0.18	0.22	0.35	4.45	4.04	1.09	0.19	0.15	0.15	0.13	0.15	0.29	11.39
1924	0.46	1.38	2.35	0.97	1.40	5.06	2.20	0.54	0.31	0.23	0.19	0.31	15.40
1925	0.46	0.91	0.62	1.49	1.65	5.84	2.13	0.35	0.80	0.56	0.29	0.32	15.42
1926	1.57	2.58	2.05	0.75	0.38	8.04	2.91	0.22	0.14	0.10	0.10	0.17	19.01
1927	0.49	0.36	0.70	1.63	2.61	1.10	0.38	0.28	0.26	0.21	0.29	0.33	8.64
1928	0.36	0.93	0.62	0.64	0.48	2.69	1.12	0.31	4.62	3.31	1.04	3.43	19.55
1929	4.57	3.52	1.09	0.37	0.32	0.71	0.59	0.43	1.05	0.71	1.18	3.00	17.54
1930	1.24	0.40	0.38	4.60	4.59	6.00	2.01	0.34	0.20	14.23	5.08	0.35	39.42
1931	0.73	0.55	0.42	0.32	4.30	2.27	0.53	0.35	0.44	0.50	0.44	3.73	14.58
1932	2.63	7.41	6.26	1.49	0.29	0.89	0.55	0.30	0.23	0.18	0.14	0.14	20.51
1933	0.14	2.77	3.96	4.69	1.58	1.93	0.93	0.37	0.28	1.54	0.80	0.25	19.24
1934	0.19	0.93	3.23	1.30	0.34	1.52	3.98	4.85	6.20	2.04	1.46	0.75	26.79
1935	0.34	0.39	0.25	0.19	6.52	6.56	1.74	2.81	1.32	0.48	0.31	0.26	21.17
1936	2.16	10.08	3.41	0.31	3.31	3.71	1.17	0.28	0.19	0.19	0.23	0.23	25.27
1937	0.28	0.32	1.77	1.37	0.65	0.39	2.08	0.99	0.41	0.46	0.41	0.26	9.39
1938	0.22	0.81	1.39	1.66	3.61	1.96	0.63	0.70	0.53	0.61	0.68	5.33	18.13
1939	3.18	0.80	1.13	0.58	0.29	0.47	0.44	2.27	1.08	0.36	0.26	0.23	11.09
1940	0.23	1.96	0.98	0.37	0.24	0.23	0.27	0.23	0.20	0.20	0.20	0.21	5.32
1941	0.33	0.88	0.50	5.08	1.96	1.19	0.64	0.44	0.42	0.27	0.26	0.36	12.33
1942	0.83	7.68	5.78	1.43	0.39	2.81	4.05	1.40	0.46	0.42	2.53	1.19	28.97
1943	1.57	3.34	2.63	0.87	2.33	1.09	0.40	0.30	0.26	0.29	0.25	3.90	17.23
1944	2.23	0.59	0.22	0.57	1.75	2.21	0.83	0.31	0.26	0.22	0.17	0.22	9.58
1945	5.23	1.94	0.19	0.19	1.68	3.77	1.63	0.47	0.29	0.22	0.17	0.17	15.95
1946	0.26	2.16	1.05	0.47	1.24	3.73	4.11	1.39	3.13	1.39	0.37	0.30	19.60
1947	0.31	9.47	4.53	0.79	3.24	2.92	1.02	0.40	0.24	0.14	0.10	0.09	23.25
1948	2.02	1.02	0.47	0.44	6.37	4.20	1.57	0.57	0.24	0.16	0.15	0.20	17.41
1949	0.35	3.84	1.57	2.13	1.82	1.21	1.22	1.76	0.79	0.37	0.82	0.57	16.45
1950	0.66	0.44	3.76	2.43	0.72	1.90	0.88	0.28	0.23	0.20	0.24	0.35	12.09
1951	3.18	1.24	1.94	2.27	0.92	1.58	1.60	0.70	0.32	0.22	0.14	0.22	14.33
1952	0.31	0.31	0.29	0.31	0.61	0.55	0.50	0.40	0.26	0.18	0.18	0.78	4.68
1953	1.87	4.12	3.17	0.96	0.39	1.67	0.78	0.39	0.51	0.48	0.33	0.38	15.05
1954	7.73	2.91	0.38	3.46	4.82	3.01	0.92	0.35	0.28	0.22	0.14	0.26	24.48
1955	0.45	0.95	0.47	0.13	1.00	5.86	3.01	0.72	0.40	0.34	0.25	0.31	13.89
1956	2.14	6.37	9.65	4.10	1.76	3.98	4.37	1.38	0.37	0.32	0.29	0.99	35.72
1957	1.98	1.70	1.59	2.77	4.75	2.39	3.45	1.31	0.23	0.18	0.17	0.18	20.70
1958	0.23	1.98	1.18	0.40	0.50	0.71	0.65	8.64	3.18	0.47	1.37	0.80	20.11
1959	0.50	0.51	0.49	0.46	0.43	2.06	1.62	1.25	0.61	0.31	0.30	0.41	8.95
1960	0.44	2.03	3.05	2.28	0.83	1.84	7.21	2.71	0.50	0.47	0.44	0.35	22.15
1961	0.32	2.70	1.53	0.57	1.42	3.76	1.41	0.35	0.27	0.18	0.24	0.32	13.07
1962	1.71	3.57	1.34	4.22	1.71	9.63	3.56	0.46	0.38	4.33	1.74	0.28	32.93
1963	0.92	2.03	1.21	4.54	3.52	2.53	3.10	1.14	7.30	2.80	0.38	0.34	29.81
1964	3.06	1.25	0.25	0.30	0.35	0.25	0.17	0.24	6.03	2.80	1.68	0.96	17.34
1965	5.69	4.12	1.07	0.41	0.42	0.28	0.18	4.46	1.84	0.35	0.27	0.35	19.44
1966	0.38	0.34	0.38	2.20	1.46	6.67	5.47	1.41	0.36	1.82	0.92	0.29	21.70
1967	0.22	0.86	0.53	0.31	0.39	0.44	0.43	0.31	0.20	0.15	0.24	1.45	5.53
1968	1.27	1.78	0.90	0.34	2.74	5.07	1.72	4.06	1.67	0.38	0.31	0.28	20.52
1969	0.40	1.87	0.92	0.32	0.31	0.29	0.23	0.25	0.42	0.45	4.21	2.21	11.88
1970	5.90	3.51	0.88	0.56	0.96	0.66	0.85	5.26	2.01	1.51	3.29	1.34	26.73
1971	5.39	2.16	0.66	0.51	5.56	2.18	0.41	0.30	0.26	0.26	0.24	0.19	18.12
1972	0.17	1.96	1.16	0.50	0.43	0.87	2.34	0.96	0.22	0.14	0.23	1.11	10.09
1973	1.10	3.50	1.39	0.39	1.83	2.33	0.93	4.84	2.28	0.58	0.32	0.22	19.71
1974	0.23	0.70	1.65	0.79	0.45	0.76	0.56	0.38	0.26	0.20	0.19	4.57	10.74
1975	1.83	0.38	2.99	1.32	4.89	13.46	5.46	2.96	1.14	0.30	0.23	0.43	35.39
1976	9.36	3.38	0.29	0.36	3.43	1.65	0.45	0.24	0.21	0.23	0.32	0.67	20.59
1977	1.79	4.04	4.32	1.41	0.45	0.85	19.46	7.67	0.78	0.36	0.30	0.36	41.79
1978	3.44	2.15	0.64	0.33	0.35	2.27	1.03	0.32	0.23	1.09	0.81	0.75	13.41
1979	1.52	0.75	0.38	0.31	0.36	0.43	0.36	0.30	0.26	0.21	0.18	3.14	8.20
1980	1.39	2.86	1.62	1.76	0.87	0.42	0.28	1.38	0.78	0.33	0.64	0.51	12.84
1981	0.31	0.29	0.29	0.50	0.43	6.34	3.38	0.75	0.33	0.27	0.20	0.18	13.27
1982	0.33	0.39	0.24	0.18	0.21	0.21	0.20	0.18	0.15	4.77	1.95	0.43	9.24
1983	0.47	2.24	1.21	2.19	1.62	0.70	1.68	0.87	0.50	2.79	1.24	0.40	15.91
1984	0.40	3.12	1.36	0.53	9.45	3.48	0.36	0.23	0.17	0.16	0.12	0.10	19.48
1985	1.62	3.21	1.22	2.58	1.09	0.39	0.42	0.33	0.23	0.16	0.70	2.15	14.10
1986	3.26	1.66	0.52	0.58	0.37	1.39	0.75	0.32	0.27	0.22	0.29	13.88	23.51
1987	5.06	2.84	1.24	0.39	4.55	10.67	3.59	3.09	1.38	1.72	1.67	0.71	36.91
1988	0.58	3.50	6.20	1.92	5.48	2.85	3.46	1.37	0.40	0.36	0.26	0.22	26.60
1989	3.20	5.73	1.79	0.36	0.34	3.82	1.53	0.26	0.17	0.13	0.31	0.46	18.10
1990	1.38	0.70	0.30	1.00	2.52	1.07	0.31	0.23	0.20	0.17	0.18	0.31	8.37
1991	3.04	3.58	1.13	0.37	0.34	0.31	0.37	0.33	0.22	0.16	0.16	0.26	10.27
1992	0.41	0.45	0.55	0.44	0.34	0.25	0.21	0.19	0.16	0.12	0.13	0.48	3.73
1993	1.89	1.26	3.03	1.19	6.59	3.26	0.59	0.18	0.12	0.17	0.41	0.38	19.07
1994	0.26	0.20	2.20	1.04	0.32	4.13	5.95	1.91	2.21	1.05	0.31	0.25	19.83
1995	0.39	0.46	7.36	3.64	2.91	1.12	0.35	0.30	0.23	2.34	1.11	0.35	20.56
1996	1.23	7.27	2.65	1.71	3.59	1.91	4.88	1.89	10.17	4.47	0.72	0.47	40.96
month	126.03	181.47	137.44	107.27	156.14	204.26	143.57	95.12	78.77	76.87	51.35	73.44	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.13	0.20	0.19	0.13	0.21	0.21	0.16	0.15	0.12	0.10	0.10	0.09	3.73
max	9.36	10.08	9.65	6.22	9.45	13.46	19.46	8.64	10.17	14.23	5.08	13.88	41.79
median	0.83	1.94	1.21	0.79	1.38	1.93	1.02	0.43	0.32	0.33	0.30	0.35	18.10
mean	1.64	2.36	1.78	1.39	2.03	2.65	1.86	1.24	1.02	1.00	0.67	0.95	18.59
Sum of the monthly means = 18.59													
s.d.	1.88	2.19	1.81	1.40	2.09	2.57	2.58	1.69	1.77	1.93	0.90	1.84	8.80
c.v.	1.15	0.93	1.01	1.00	1.03	0.97	1.38	1.36	1.73	1.93	1.35	1.93	0.47

APPENDIX 5.13
MSIKABA RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	2.45	5.34	19.48	12.23	8.88	18.39	12.15	6.20	3.19	1.83	1.22	1.98	93.34
1921	4.59	47.97	50.83	17.86	5.87	3.19	1.73	20.83	22.62	11.45	7.87	8.17	202.98
1922	41.80	95.62	33.21	80.90	108.36	57.70	14.76	3.79	2.33	54.37	24.15	4.92	521.91
1923	3.30	3.90	5.67	46.83	39.48	12.29	3.01	1.77	1.60	1.43	1.70	3.42	124.40
1924	5.93	12.36	23.13	12.54	8.92	50.84	23.28	6.88	4.00	2.82	2.22	3.73	156.65
1925	6.10	9.00	8.58	11.97	11.30	64.96	26.16	5.07	5.58	5.60	3.71	4.10	162.13
1926	10.66	29.69	22.87	10.22	5.90	93.87	35.53	3.41	1.77	1.28	1.29	2.17	218.66
1927	5.10	5.27	6.90	12.70	18.96	11.36	5.41	3.36	2.76	2.17	3.13	3.81	80.93
1928	4.66	8.48	8.42	7.46	6.12	14.67	8.83	4.30	39.88	30.34	13.68	38.97	185.81
1929	63.15	52.12	17.81	6.45	4.54	4.87	5.59	4.50	5.20	6.30	7.22	24.97	202.72
1930	14.94	8.04	7.00	51.68	48.79	70.25	25.76	4.91	2.49	195.64	71.66	6.42	507.58
1931	7.19	8.33	7.58	5.28	39.35	19.75	6.08	4.38	4.70	5.26	4.71	30.19	142.80
1932	26.98	116.58	91.95	22.04	4.47	5.78	5.02	3.33	2.31	1.84	1.54	1.60	283.44
1933	1.96	24.57	48.85	58.60	21.11	10.34	7.82	4.91	3.18	5.55	6.53	4.01	197.43
1934	3.06	8.54	36.72	17.25	5.33	5.99	32.07	50.17	78.89	28.91	10.15	8.34	285.42
1935	6.33	6.92	4.69	3.08	74.01	74.08	21.47	16.52	12.18	7.42	4.52	3.65	234.87
1936	14.81	156.35	56.34	5.56	24.84	29.87	12.53	4.23	2.34	2.26	2.62	2.80	314.55
1937	3.76	4.79	14.33	11.50	8.05	5.30	8.77	7.46	5.41	5.39	4.72	3.21	82.69
1938	3.09	6.81	13.23	14.04	34.76	17.43	7.23	6.33	5.49	5.71	6.87	59.47	180.46
1939	37.12	12.78	12.97	7.92	4.43	4.83	4.57	8.24	7.84	5.17	3.47	3.05	112.39
1940	3.31	15.48	11.73	6.59	3.63	2.70	2.76	2.19	1.82	1.92	2.02	2.33	56.48
1941	4.20	7.99	6.67	59.26	24.50	6.89	5.72	5.16	4.41	2.81	2.84	4.13	134.58
1942	6.50	110.28	80.61	20.86	6.05	14.97	35.58	16.39	6.55	5.30	12.99	11.20	327.28
1943	15.52	47.75	32.85	11.86	15.56	10.21	5.45	3.43	2.70	2.96	2.66	32.97	183.92
1944	22.55	10.05	4.94	5.22	11.68	13.49	7.81	4.25	3.03	2.45	1.94	2.64	90.05
1945	59.92	24.79	4.24	3.38	8.86	28.86	15.63	6.40	3.67	2.68	2.03	2.10	162.56
1946	3.46	17.25	12.33	7.80	7.57	28.44	38.38	16.40	23.02	14.24	6.40	4.64	179.93
1947	4.87	138.60	59.96	10.69	26.73	20.53	10.61	5.77	2.91	1.68	1.22	1.13	284.70
1948	11.75	11.22	8.81	7.14	73.22	38.10	12.03	6.74	3.41	2.11	1.92	2.55	179.00
1949	4.76	43.87	20.68	16.93	13.22	9.20	8.38	9.55	7.32	5.28	6.43	6.49	152.11
1950	7.16	6.63	45.04	24.74	8.69	9.80	7.07	3.87	2.66	2.23	2.66	4.10	124.65
1951	27.14	13.59	19.42	19.44	10.84	8.37	9.01	7.09	4.27	2.68	1.76	2.78	126.39
1952	4.13	4.73	4.76	4.54	5.40	5.77	5.34	3.95	2.48	1.71	1.86	4.66	49.33
1953	14.59	57.40	40.70	13.33	5.94	6.88	5.66	4.76	5.43	5.06	3.55	4.38	167.68
1954	100.06	40.60	7.58	34.57	52.96	25.59	9.41	5.00	3.33	2.48	1.65	3.10	286.33
1955	5.91	9.24	6.26	2.48	4.26	61.53	27.91	7.93	5.55	4.26	3.03	3.82	142.18
1956	14.64	93.59	147.85	51.91	13.17	37.65	44.11	16.35	5.44	4.10	3.62	5.90	438.33
1957	16.64	20.43	17.86	28.69	54.69	22.76	29.38	13.99	3.78	2.49	2.21	2.34	215.26
1958	3.28	15.50	12.72	6.71	5.55	6.28	6.33	100.31	39.15	7.21	8.45	8.53	220.02
1959	8.21	8.53	8.26	7.20	5.79	9.32	9.15	8.61	6.45	4.21	3.74	5.12	84.59
1960	6.05	17.03	35.13	22.17	9.87	9.68	86.12	35.15	6.98	5.93	5.38	4.42	243.91
1961	4.48	26.22	16.99	8.78	8.93	29.34	14.28	5.05	3.27	2.04	2.70	3.79	125.87
1962	10.73	46.08	20.87	48.56	21.31	124.86	47.34	6.28	4.41	35.93	17.97	5.22	389.56
1963	7.26	22.25	15.18	56.00	34.17	17.54	25.89	12.75	91.38	37.18	6.43	5.10	331.13
1964	30.18	15.44	5.38	4.91	4.68	2.98	1.75	2.28	55.39	27.20	13.90	11.55	175.64
1965	82.22	60.09	17.43	7.06	5.77	3.37	1.92	30.73	16.65	5.73	3.89	4.73	239.59
1966	5.37	5.38	6.16	15.96	11.38	79.25	60.24	16.82	5.31	8.29	8.18	4.92	227.26
1967	3.70	8.35	7.41	5.18	5.11	5.02	4.34	2.97	1.83	1.49	2.52	6.16	54.08
1968	11.83	20.52	12.92	6.20	18.04	51.82	21.05	35.06	17.46	6.08	4.42	3.93	209.33
1969	5.61	16.39	11.57	5.76	4.40	3.41	2.38	2.39	3.87	4.31	30.87	19.52	110.48
1970	87.83	50.78	14.22	7.86	7.55	7.04	6.73	47.42	21.32	9.40	32.59	17.61	310.35
1971	76.45	33.36	10.14	7.87	61.42	25.81	5.63	3.45	2.70	2.68	2.55	2.26	234.32
1972	2.30	14.40	12.26	8.05	6.20	6.03	11.74	7.70	3.26	1.93	2.84	6.14	82.85
1973	10.35	46.87	20.97	6.76	10.96	13.70	8.97	45.51	22.70	8.37	4.93	3.29	203.38
1974	3.48	6.61	15.34	10.04	6.61	6.31	5.51	3.97	2.57	2.00	2.02	43.52	107.98
1975	21.06	7.66	34.32	17.23	52.92	190.08	67.69	21.90	12.09	5.17	3.45	5.12	438.69
1976	133.00	50.36	6.05	5.76	25.48	14.57	5.93	3.08	2.29	2.42	3.47	5.76	258.17
1977	13.44	54.95	59.57	20.54	6.82	6.22	273.00	100.15	9.36	5.69	4.19	4.84	558.77
1978	33.63	24.46	10.60	5.96	4.85	10.77	7.88	4.26	2.69	4.83	7.62	8.22	125.77
1979	13.76	10.29	7.20	5.17	4.79	4.85	3.64	2.83	2.37	2.00	1.80	19.76	78.46
1980	13.89	39.23	21.27	15.17	10.13	5.92	3.34	4.78	5.88	4.25	5.14	5.82	134.82
1981	4.61	4.80	4.82	5.59	5.35	65.84	29.98	7.95	4.72	3.43	2.52	2.29	141.90
1982	4.74	6.16	4.20	2.91	2.77	2.35	1.95	1.65	1.33	40.77	20.45	7.26	96.54
1983	7.47	22.93	14.53	18.54	12.38	8.16	8.78	7.43	6.29	15.06	11.07	6.82	139.46
1984	6.44	36.37	18.81	8.31	127.08	47.74	5.09	2.65	1.77	1.66	1.36	1.20	258.48
1985	8.82	39.44	18.84	22.84	11.83	5.46	4.75	3.41	2.19	1.58	3.81	13.46	136.43
1986	38.86	23.19	9.23	6.83	4.83	5.55	5.91	4.10	3.00	2.42	3.14	190.46	297.52
1987	72.34	40.71	19.38	6.80	44.63	143.01	50.03	20.56	13.23	11.49	12.53	9.41	444.12
1988	8.40	47.45	89.22	29.12	63.02	27.85	29.21	14.64	5.76	4.61	3.21	2.82	325.31
1989	28.44	82.40	29.40	6.09	4.77	25.79	13.24	3.93	2.16	1.54	3.53	5.47	206.76
1990	9.10	8.07	5.69	7.60	17.21	10.55	4.47	2.64	2.14	1.76	1.93	3.56	74.72
1991	24.32	46.79	18.64	6.34	4.86	3.64	3.74	3.13	2.06	1.50	1.63	2.91	119.56
1992	5.19	6.52	7.19	6.32	4.74	2.96	2.13	1.83	1.44	1.17	1.36	4.00	44.85
1993	13.93	14.69	38.45	16.57	80.67	33.77	6.19	2.69	1.49	1.99	4.37	4.52	219.33
1994	3.70	3.30	17.00	11.20	5.12	32.19	65.36	24.64	12.44	9.92	5.42	3.97	194.26
1995	5.78	7.28	101.57	43.67	24.98	12.15	4.89	3.46	2.41	9.27	8.98	5.88	230.32
1996	9.90	108.61	42.26	14.06	33.81	16.95	51.66	22.59	133.92	54.26	9.77	7.65	505.44
month	1434.24	2396.41	1844.04	1263.23	1611.22	2005.63	1516.24	940.56	841.27	803.95	517.90	797.25	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	1.96	3.30	4.20	2.48	2.77	2.35	1.73	1.65	1.33	1.17	1.22	1.13	44.85
max	133.00	156.35	147.85	80.90	127.08	190.08	273.00	100.31	133.92	195.64	71.66	190.46	558.77
median	8.21	17.03	15.18	10.22	9.87	12.29	8.77	5.07	4.00	4.26	3.62	4.66	183.92
mean	18.63	31.12	23.95	16.41	20.92	26.05	19.69	12.22	10.93	10.44	6.73	10.35	207.43
Sum of the monthly means = 207.43													
s.d.	25.32	33.06	25.69	16.08	24.88	33.54	34.22	18.02	21.08	24.22	9.70	23.11	117.95
c.v.	1.36	1.06	1.07	0.98	1.19	1.29	1.74	1.47	1.93	2.32	1.44	2.23	0.57

APPENDIX 5.14
MPAHLANE RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.05	0.09	0.14	0.14	0.11	0.14	0.15	0.10	0.06	0.03	0.02	0.03	1.06
1921	0.06	0.66	0.99	0.38	0.12	0.07	0.03	0.10	0.36	0.23	0.14	0.11	3.25
1922	0.12	0.84	0.38	0.21	1.56	1.06	0.27	0.07	0.04	0.93	0.43	0.10	6.01
1923	0.06	0.05	0.07	0.97	0.78	0.24	0.06	0.03	0.03	0.02	0.03	0.04	2.38
1924	0.08	0.13	0.36	0.18	0.07	0.21	0.19	0.11	0.06	0.04	0.03	0.03	1.49
1925	0.06	0.12	0.13	0.13	0.12	0.75	0.33	0.08	0.08	0.08	0.05	0.06	1.99
1926	0.12	0.16	0.18	0.14	0.09	1.24	0.50	0.07	0.04	0.03	0.03	0.04	2.64
1927	0.07	0.08	0.13	0.78	0.40	0.15	0.08	0.05	0.04	0.03	0.04	0.04	1.89
1928	0.06	0.09	0.08	0.07	0.05	0.10	0.11	0.07	0.15	0.22	0.18	0.27	1.45
1929	0.35	0.25	0.17	0.14	0.11	0.13	0.13	0.09	0.08	0.09	0.10	0.14	1.78
1930	0.15	0.13	0.16	0.86	0.43	1.07	0.44	0.08	0.04	1.48	0.63	0.11	5.58
1931	0.10	0.11	0.09	0.07	0.22	0.18	0.09	0.06	0.06	0.07	0.07	0.10	1.22
1932	0.17	1.54	1.34	0.35	0.06	0.06	0.07	0.05	0.04	0.03	0.03	0.02	3.76
1933	0.02	0.29	0.81	0.50	0.20	0.13	0.11	0.08	0.05	0.06	0.07	0.05	2.37
1934	0.05	0.09	0.40	0.23	0.10	0.09	0.18	0.70	0.93	0.36	0.15	0.12	3.40
1935	0.09	0.09	0.06	0.04	0.62	0.65	0.24	0.14	0.15	0.11	0.07	0.05	2.31
1936	0.10	2.53	0.96	0.15	0.96	0.44	0.13	0.06	0.04	0.03	0.03	0.03	5.46
1937	0.04	0.07	0.10	0.11	0.13	0.11	0.10	0.09	0.07	0.07	0.06	0.05	1.00
1938	0.05	0.09	0.15	0.15	0.38	0.22	0.10	0.08	0.07	0.07	0.07	0.39	1.82
1939	0.29	0.21	0.20	0.14	0.09	0.09	0.08	0.14	0.17	0.12	0.07	0.05	1.65
1940	0.06	0.12	0.19	0.14	0.07	0.06	0.06	0.04	0.03	0.03	0.03	0.04	0.87
1941	0.06	0.09	0.09	0.21	0.18	0.16	0.14	0.10	0.07	0.05	0.04	0.06	1.25
1942	0.10	1.16	1.29	0.42	0.12	0.28	0.54	0.27	0.13	0.11	0.15	0.17	4.74
1943	0.27	0.94	0.69	0.24	0.15	0.15	0.10	0.06	0.05	0.05	0.04	0.11	2.85
1944	0.18	0.15	0.07	0.07	0.11	0.15	0.12	0.07	0.05	0.04	0.03	0.03	1.07
1945	0.18	0.15	0.07	0.05	0.09	0.30	0.21	0.11	0.06	0.04	0.03	0.03	1.32
1946	0.06	0.12	0.15	0.13	0.15	0.33	0.26	0.17	0.41	0.26	0.12	0.08	2.24
1947	0.08	1.93	0.80	0.19	0.35	0.26	0.18	0.11	0.05	0.03	0.02	0.02	4.02
1948	0.08	0.14	0.14	0.13	0.26	0.21	0.16	0.11	0.06	0.04	0.03	0.04	1.40
1949	0.06	0.20	0.17	0.24	0.20	0.16	0.14	0.13	0.11	0.08	0.11	0.11	1.71
1950	0.10	0.09	0.66	0.33	0.12	0.13	0.11	0.07	0.04	0.04	0.04	0.07	1.80
1951	0.14	0.14	0.13	0.16	0.16	0.14	0.14	0.12	0.08	0.05	0.03	0.04	1.33
1952	0.05	0.06	0.07	0.06	0.08	0.08	0.08	0.06	0.04	0.03	0.03	0.06	0.70
1953	0.12	0.38	0.51	0.24	0.12	0.12	0.09	0.08	0.09	0.08	0.05	0.06	1.94
1954	1.20	0.54	0.13	0.38	1.06	0.46	0.15	0.10	0.06	0.05	0.03	0.05	4.21
1955	0.08	0.12	0.09	0.04	0.06	0.64	0.36	0.16	0.11	0.08	0.05	0.06	1.85
1956	0.11	0.89	1.94	0.69	0.18	0.55	0.40	0.18	0.10	0.07	0.06	0.11	5.28
1957	0.22	0.48	0.26	0.16	0.70	0.34	0.18	0.14	0.07	0.05	0.04	0.03	2.67
1958	0.05	0.12	0.17	0.13	0.11	0.11	0.11	1.61	0.65	0.12	0.12	0.11	3.41
1959	0.11	0.13	0.14	0.11	0.10	0.11	0.13	0.12	0.08	0.06	0.05	0.06	1.20
1960	0.08	0.13	0.45	0.28	0.16	0.15	1.24	0.52	0.11	0.07	0.06	0.05	3.30
1961	0.05	0.12	0.16	0.15	0.21	0.35	0.19	0.09	0.06	0.04	0.04	0.05	1.51
1962	0.10	0.55	0.31	0.75	0.35	1.95	0.76	0.11	0.06	0.13	0.17	0.10	5.34
1963	0.12	0.51	0.49	0.84	0.37	0.17	0.19	0.15	1.34	0.57	0.12	0.09	4.96
1964	0.68	0.32	0.10	0.10	0.10	0.06	0.04	0.04	0.46	0.33	0.22	0.20	2.65
1965	0.84	0.77	0.28	0.13	0.10	0.06	0.03	0.37	0.25	0.11	0.07	0.08	3.09
1966	0.09	0.10	0.11	0.14	0.15	1.38	0.62	0.16	0.10	0.12	0.11	0.07	3.15
1967	0.06	0.11	0.11	0.09	0.08	0.08	0.08	0.05	0.03	0.02	0.04	0.09	0.84
1968	0.13	0.16	0.16	0.10	0.12	0.62	0.30	0.15	0.13	0.09	0.07	0.06	2.09
1969	0.09	0.14	0.15	0.11	0.08	0.05	0.03	0.04	0.06	0.06	0.09	0.13	1.03
1970	0.88	0.44	0.20	0.18	0.15	0.13	0.11	0.16	0.16	0.14	0.24	0.21	3.00
1971	1.08	0.49	0.15	0.13	0.47	0.26	0.10	0.06	0.04	0.04	0.03	0.03	2.88
1972	0.03	0.11	0.15	0.12	0.10	0.11	0.10	0.07	0.04	0.02	0.04	0.07	0.96
1973	0.11	0.22	0.18	0.14	0.16	0.41	0.23	0.24	0.21	0.14	0.08	0.05	2.17
1974	0.05	0.11	0.17	0.17	0.16	0.16	0.12	0.07	0.04	0.03	0.02	0.09	1.19
1975	0.14	0.13	0.69	0.50	0.73	2.51	0.90	0.17	0.13	0.08	0.05	0.07	6.10
1976	0.87	0.41	0.15	0.13	0.13	0.12	0.08	0.05	0.04	0.03	0.03	0.05	2.09
1977	0.13	0.54	0.50	0.25	0.15	0.14	3.49	1.30	0.14	0.08	0.06	0.07	6.85
1978	0.15	0.38	0.25	0.13	0.10	0.12	0.11	0.06	0.03	0.05	0.07	0.07	1.52
1979	0.09	0.11	0.11	0.08	0.06	0.06	0.05	0.04	0.03	0.02	0.02	0.10	0.77
1980	0.17	0.72	0.38	0.19	0.18	0.14	0.08	0.06	0.06	0.04	0.05	0.07	2.14
1981	0.06	0.06	0.07	0.10	0.11	0.15	0.18	0.13	0.08	0.06	0.04	0.03	1.07
1982	0.08	0.10	0.07	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.04	0.05	0.62
1983	0.07	0.13	0.17	0.43	0.41	0.24	0.35	0.21	0.10	0.10	0.09	0.07	2.37
1984	0.08	0.13	0.17	0.18	1.61	0.63	0.09	0.04	0.03	0.03	0.02	0.02	3.03
1985	0.33	0.36	0.29	0.20	0.13	0.09	0.06	0.04	0.02	0.02	0.07	0.12	1.73
1986	0.33	0.62	0.29	0.14	0.11	0.12	0.11	0.07	0.04	0.03	0.05	1.99	3.90
1987	0.82	0.45	0.87	0.35	0.98	2.15	0.75	0.18	0.18	0.18	0.18	0.15	7.24
1988	0.14	0.41	0.78	0.32	1.29	0.53	0.15	0.12	0.09	0.07	0.05	0.04	3.99
1989	0.12	2.08	0.81	0.13	0.09	0.30	0.20	0.09	0.05	0.03	0.06	0.08	4.04
1990	0.13	0.14	0.12	0.14	0.17	0.13	0.07	0.03	0.03	0.02	0.02	0.04	1.04
1991	0.45	0.41	0.20	0.12	0.10	0.09	0.08	0.05	0.03	0.02	0.02	0.03	1.60
1992	0.05	0.11	0.17	0.15	0.13	0.10	0.06	0.04	0.03	0.02	0.02	0.07	0.95
1993	0.71	0.39	0.67	0.32	0.35	0.66	0.28	0.06	0.03	0.05	0.06	0.04	3.62
1994	0.04	0.04	0.05	0.07	0.07	0.25	0.23	0.16	0.14	0.11	0.06	0.05	1.27
1995	0.07	0.13	2.20	0.91	0.89	0.41	0.11	0.05	0.03	0.05	0.07	0.06	4.98
1996	0.08	0.88	0.43	0.28	0.23	0.20	0.68	0.32	1.44	0.63	0.17	0.12	5.46
month	14.90	28.58	27.27	18.46	21.80	26.99	19.34	11.65	10.77	9.12	6.10	7.93	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.02	0.04	0.05	0.04	0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.62
max	1.20	2.53	2.20	0.97	1.61	2.51	3.49	1.61	1.44	1.48	0.63	1.99	7.24
median	0.10	0.14	0.17	0.15	0.15	0.16	0.13	0.09	0.06	0.06	0.05	0.06	2.14
mean	0.19	0.37	0.35	0.24	0.28	0.35	0.25	0.15	0.14	0.12	0.08	0.10	2.64
Sum of the monthly means =				2.64									
s.d.	0.25	0.47	0.41	0.22	0.34	0.47	0.43	0.24	0.25	0.21	0.09	0.23	1.62
c.v.	1.32	1.26	1.15	0.90	1.20	1.33	1.72	1.58	1.78	1.80	1.14	2.19	0.61

APPENDIX 5.15
MPAHLANYANA RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.02	0.04	0.06	0.06	0.05	0.06	0.07	0.05	0.02	0.01	0.01	0.01	0.46
1921	0.03	0.30	0.44	0.17	0.05	0.03	0.01	0.05	0.16	0.10	0.06	0.05	1.45
1922	0.05	0.38	0.17	0.10	0.70	0.48	0.12	0.03	0.02	0.42	0.19	0.04	2.70
1923	0.03	0.02	0.03	0.44	0.35	0.11	0.03	0.02	0.01	0.01	0.01	0.02	1.08
1924	0.03	0.06	0.16	0.08	0.03	0.10	0.08	0.05	0.03	0.02	0.01	0.01	0.66
1925	0.03	0.05	0.06	0.06	0.05	0.34	0.15	0.04	0.04	0.04	0.02	0.03	0.91
1926	0.05	0.07	0.08	0.06	0.04	0.56	0.22	0.03	0.02	0.01	0.01	0.02	1.17
1927	0.03	0.03	0.06	0.35	0.18	0.07	0.04	0.02	0.02	0.01	0.02	0.02	0.85
1928	0.03	0.04	0.04	0.03	0.02	0.04	0.05	0.03	0.06	0.10	0.08	0.12	0.64
1929	0.16	0.11	0.08	0.06	0.05	0.06	0.06	0.04	0.04	0.04	0.04	0.06	0.80
1930	0.07	0.06	0.07	0.38	0.19	0.48	0.20	0.03	0.02	0.66	0.28	0.05	2.49
1931	0.04	0.05	0.04	0.03	0.10	0.08	0.04	0.02	0.03	0.03	0.03	0.05	0.54
1932	0.08	0.69	0.60	0.16	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	1.69
1933	0.01	0.13	0.36	0.22	0.09	0.06	0.05	0.04	0.02	0.03	0.03	0.02	1.06
1934	0.02	0.04	0.18	0.10	0.05	0.04	0.08	0.32	0.42	0.16	0.07	0.05	1.53
1935	0.04	0.04	0.03	0.02	0.28	0.29	0.11	0.06	0.07	0.05	0.03	0.02	1.04
1936	0.05	1.14	0.43	0.07	0.43	0.20	0.06	0.03	0.02	0.01	0.01	0.01	2.46
1937	0.02	0.03	0.04	0.05	0.06	0.05	0.05	0.04	0.03	0.03	0.03	0.02	0.45
1938	0.02	0.04	0.07	0.07	0.17	0.10	0.04	0.04	0.03	0.03	0.03	0.17	0.81
1939	0.13	0.09	0.09	0.06	0.04	0.04	0.04	0.06	0.08	0.05	0.03	0.02	0.73
1940	0.03	0.05	0.08	0.06	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.02	0.38
1941	0.03	0.04	0.04	0.09	0.08	0.07	0.06	0.05	0.03	0.02	0.02	0.03	0.56
1942	0.04	0.52	0.58	0.19	0.05	0.12	0.24	0.12	0.06	0.05	0.07	0.08	2.12
1943	0.12	0.42	0.31	0.11	0.07	0.07	0.04	0.03	0.02	0.02	0.02	0.05	1.28
1944	0.08	0.07	0.03	0.03	0.05	0.07	0.05	0.03	0.02	0.02	0.01	0.01	0.47
1945	0.08	0.07	0.03	0.02	0.04	0.14	0.09	0.05	0.03	0.02	0.01	0.02	0.60
1946	0.03	0.05	0.07	0.06	0.07	0.15	0.12	0.07	0.18	0.12	0.06	0.04	1.02
1947	0.04	0.87	0.36	0.08	0.16	0.12	0.08	0.05	0.02	0.01	0.01	0.01	1.81
1948	0.04	0.06	0.06	0.06	0.12	0.09	0.07	0.05	0.03	0.02	0.01	0.02	0.63
1949	0.03	0.09	0.08	0.11	0.09	0.07	0.06	0.06	0.05	0.04	0.05	0.05	0.78
1950	0.05	0.04	0.29	0.15	0.05	0.06	0.05	0.03	0.02	0.02	0.02	0.03	0.81
1951	0.06	0.06	0.06	0.07	0.07	0.06	0.06	0.06	0.03	0.02	0.01	0.02	0.58
1952	0.02	0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.02	0.01	0.01	0.03	0.32
1953	0.05	0.17	0.23	0.11	0.06	0.06	0.04	0.03	0.04	0.03	0.02	0.03	0.87
1954	0.54	0.24	0.06	0.17	0.47	0.21	0.07	0.04	0.03	0.02	0.01	0.02	1.88
1955	0.04	0.05	0.04	0.02	0.03	0.29	0.16	0.07	0.05	0.03	0.02	0.03	0.83
1956	0.05	0.40	0.87	0.31	0.08	0.25	0.18	0.08	0.04	0.03	0.03	0.05	2.37
1957	0.10	0.21	0.11	0.07	0.31	0.15	0.08	0.06	0.03	0.02	0.02	0.02	1.18
1958	0.02	0.05	0.08	0.06	0.05	0.05	0.05	0.72	0.29	0.06	0.05	0.05	1.53
1959	0.05	0.06	0.06	0.05	0.04	0.05	0.06	0.05	0.04	0.02	0.02	0.03	0.53
1960	0.04	0.06	0.20	0.13	0.07	0.07	0.56	0.23	0.05	0.03	0.03	0.02	1.49
1961	0.02	0.06	0.07	0.07	0.09	0.16	0.09	0.04	0.03	0.02	0.02	0.02	0.69
1962	0.04	0.24	0.14	0.34	0.16	0.88	0.34	0.05	0.03	0.06	0.07	0.05	2.40
1963	0.05	0.23	0.22	0.38	0.17	0.07	0.08	0.07	0.60	0.26	0.05	0.04	2.22
1964	0.30	0.15	0.05	0.04	0.04	0.03	0.02	0.02	0.21	0.15	0.10	0.09	1.20
1965	0.38	0.34	0.13	0.06	0.04	0.03	0.01	0.17	0.11	0.05	0.03	0.03	1.38
1966	0.04	0.04	0.05	0.06	0.07	0.62	0.28	0.07	0.05	0.05	0.05	0.03	1.41
1967	0.03	0.05	0.05	0.04	0.04	0.04	0.03	0.02	0.01	0.01	0.02	0.04	0.38
1968	0.06	0.07	0.07	0.04	0.05	0.28	0.13	0.07	0.06	0.04	0.03	0.03	0.93
1969	0.04	0.06	0.07	0.05	0.03	0.02	0.02	0.02	0.03	0.03	0.04	0.06	0.47
1970	0.39	0.20	0.09	0.08	0.07	0.06	0.05	0.07	0.07	0.06	0.11	0.09	1.34
1971	0.49	0.22	0.07	0.06	0.21	0.12	0.05	0.03	0.02	0.02	0.02	0.01	1.32
1972	0.02	0.05	0.07	0.05	0.05	0.05	0.05	0.03	0.02	0.01	0.02	0.03	0.45
1973	0.05	0.10	0.08	0.06	0.07	0.19	0.11	0.11	0.09	0.06	0.03	0.02	0.97
1974	0.02	0.05	0.08	0.07	0.07	0.07	0.05	0.03	0.02	0.01	0.01	0.04	0.52
1975	0.06	0.06	0.31	0.22	0.33	1.13	0.41	0.08	0.06	0.03	0.02	0.03	2.74
1976	0.39	0.19	0.07	0.06	0.06	0.05	0.04	0.02	0.02	0.01	0.02	0.02	0.95
1977	0.06	0.24	0.22	0.11	0.07	0.06	1.57	0.59	0.06	0.03	0.03	0.03	3.07
1978	0.07	0.17	0.11	0.06	0.05	0.05	0.05	0.03	0.02	0.02	0.03	0.03	0.69
1979	0.04	0.05	0.05	0.04	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.04	0.35
1980	0.08	0.32	0.17	0.09	0.08	0.06	0.04	0.03	0.03	0.02	0.02	0.03	0.97
1981	0.03	0.03	0.03	0.04	0.05	0.07	0.08	0.06	0.04	0.03	0.02	0.02	0.50
1982	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.27
1983	0.03	0.06	0.08	0.19	0.18	0.11	0.16	0.09	0.05	0.04	0.04	0.03	1.06
1984	0.03	0.06	0.08	0.08	0.72	0.28	0.04	0.02	0.01	0.01	0.01	0.01	1.35
1985	0.15	0.16	0.13	0.09	0.06	0.04	0.03	0.02	0.01	0.01	0.03	0.06	0.79
1986	0.15	0.28	0.13	0.06	0.05	0.05	0.05	0.03	0.02	0.01	0.02	0.89	1.74
1987	0.37	0.20	0.39	0.16	0.44	0.97	0.34	0.08	0.08	0.08	0.08	0.07	3.26
1988	0.06	0.18	0.35	0.14	0.58	0.24	0.07	0.06	0.04	0.03	0.02	0.02	1.79
1989	0.05	0.94	0.36	0.06	0.04	0.14	0.09	0.04	0.02	0.01	0.03	0.04	1.82
1990	0.06	0.06	0.05	0.06	0.08	0.06	0.03	0.02	0.01	0.01	0.01	0.02	0.47
1991	0.20	0.18	0.09	0.05	0.04	0.04	0.04	0.02	0.01	0.01	0.01	0.01	0.70
1992	0.02	0.05	0.07	0.07	0.06	0.04	0.03	0.02	0.01	0.01	0.01	0.03	0.42
1993	0.32	0.17	0.30	0.14	0.16	0.30	0.12	0.03	0.02	0.02	0.03	0.02	1.63
1994	0.02	0.02	0.02	0.03	0.03	0.11	0.10	0.07	0.06	0.05	0.03	0.02	0.56
1995	0.03	0.06	0.99	0.41	0.40	0.18	0.05	0.02	0.01	0.02	0.03	0.03	2.23
1996	0.04	0.39	0.19	0.13	0.10	0.09	0.30	0.15	0.64	0.28	0.07	0.06	2.44
month	6.71	12.79	12.22	8.26	9.78	12.18	8.70	5.27	4.84	4.02	2.70	3.57	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.27
max	0.54	1.14	0.99	0.44	0.72	1.13	1.57	0.72	0.64	0.66	0.28	0.89	3.26
median	0.04	0.06	0.08	0.07	0.07	0.07	0.06	0.04	0.03	0.02	0.02	0.03	0.97
mean	0.09	0.17	0.16	0.11	0.13	0.16	0.11	0.07	0.06	0.05	0.04	0.05	1.18
Sum of the monthly means =				1.18									
s.d.	0.11	0.21	0.18	0.10	0.15	0.21	0.19	0.11	0.11	0.10	0.04	0.10	0.73
c.v.	1.31	1.27	1.15	0.90	1.20	1.33	1.72	1.58	1.77	1.83	1.15	2.17	0.62

APPENDIX 5.16
MZINTLAVA RIVER

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.64	1.35	5.02	3.23	2.48	10.66	5.48	2.19	1.29	0.78	0.51	0.74	34.37
1921	1.47	14.32	14.56	4.93	1.68	1.04	0.67	13.61	12.40	4.41	2.48	2.64	74.21
1922	13.87	26.84	8.87	24.85	34.93	21.64	5.63	1.29	0.94	22.32	9.14	1.42	171.74
1923	0.90	0.96	1.37	15.19	14.64	4.47	0.99	0.71	0.71	0.63	0.71	1.27	42.55
1924	1.91	2.42	6.76	3.64	2.33	20.39	8.82	2.44	1.62	1.20	0.93	1.38	53.84
1925	1.97	2.20	2.13	2.33	4.00	24.87	9.56	1.77	2.26	2.32	1.53	1.53	56.47
1926	3.41	8.42	5.91	2.61	1.70	33.45	12.43	1.15	0.71	0.53	0.53	0.80	71.65
1927	1.62	1.44	1.56	2.89	8.39	4.47	1.86	1.35	1.22	0.97	1.31	1.46	28.54
1928	1.51	2.03	2.09	1.99	1.79	8.00	3.92	1.56	19.01	13.74	4.82	13.74	74.20
1929	18.88	13.59	4.39	1.63	1.28	1.68	2.16	1.91	2.31	2.75	3.43	11.90	65.91
1930	5.49	1.90	1.59	15.96	17.12	25.40	8.97	1.70	1.00	65.01	23.50	1.84	169.48
1931	2.01	2.12	1.81	1.28	14.95	7.08	2.09	1.76	2.05	2.28	1.99	14.02	53.44
1932	9.22	32.29	25.88	6.14	1.30	2.01	1.93	1.42	1.07	0.85	0.69	0.63	83.43
1933	0.65	8.14	14.05	18.08	6.52	5.18	3.25	1.86	1.36	4.08	2.94	1.35	67.46
1934	0.92	1.69	11.10	5.10	1.51	2.48	15.55	21.20	28.26	9.67	4.84	3.03	105.35
1935	1.73	1.72	1.06	0.73	25.18	26.88	7.67	10.85	5.68	2.46	1.59	1.26	86.81
1936	6.13	44.50	15.58	1.39	10.55	13.51	4.94	1.45	0.94	0.94	1.07	1.05	102.05
1937	1.21	1.30	2.86	2.76	2.44	1.82	5.90	3.59	2.12	2.21	1.92	1.23	29.36
1938	1.00	1.69	2.42	3.96	13.55	6.33	2.52	2.54	2.39	2.48	2.86	22.79	64.53
1939	12.23	3.22	2.22	1.74	1.30	1.69	1.78	6.86	4.08	1.91	1.33	1.10	39.46
1940	1.04	4.50	3.08	1.65	0.99	0.91	1.08	0.95	0.85	0.87	0.87	0.90	17.69
1941	1.37	2.02	1.64	18.88	7.66	2.29	2.15	2.17	1.98	1.29	1.22	1.58	44.25
1942	2.12	32.55	23.19	5.78	1.74	8.57	15.80	6.27	2.34	2.05	8.98	4.83	114.22
1943	4.37	12.27	8.60	3.15	6.75	3.83	1.89	1.38	1.19	1.30	1.14	14.69	60.56
1944	7.31	2.27	1.07	1.32	3.61	6.74	3.35	1.57	1.28	1.06	0.82	1.00	31.40
1945	20.43	7.88	0.91	0.79	2.47	13.79	6.50	2.25	1.48	1.14	0.85	0.80	59.29
1946	1.11	5.24	3.36	2.02	2.24	13.89	16.80	6.20	12.77	6.16	1.97	1.48	73.24
1947	1.43	40.48	16.84	2.74	11.05	10.14	4.23	2.01	1.17	0.72	0.51	0.43	91.75
1948	5.29	3.52	2.08	1.77	24.61	15.76	4.81	2.29	1.32	0.87	0.79	0.95	64.06
1949	1.52	13.26	5.87	5.36	4.38	3.05	3.58	6.55	3.58	1.96	2.44	2.34	53.89
1950	2.26	1.79	13.18	6.88	2.44	5.10	3.02	1.46	1.14	0.97	1.11	1.54	40.89
1951	10.76	4.57	4.91	6.20	3.36	3.60	4.41	2.91	1.72	1.14	0.74	1.03	45.35
1952	1.33	1.28	1.16	1.15	1.61	1.99	2.06	1.68	1.15	0.80	0.82	1.74	16.77
1953	5.48	16.13	11.10	3.58	1.71	3.10	2.29	1.92	2.36	2.21	1.52	1.66	53.06
1954	32.42	12.49	1.73	11.08	18.40	11.12	3.77	1.75	1.35	1.05	0.70	1.14	97.00
1955	1.89	2.24	1.48	0.58	1.32	24.13	11.50	3.00	2.08	1.70	1.22	1.40	52.54
1956	5.94	26.48	42.29	15.34	4.62	15.76	18.16	6.14	1.92	1.58	1.41	2.12	141.76
1957	6.49	4.87	3.76	9.17	18.90	8.11	13.80	5.84	1.29	0.94	0.85	0.85	74.87
1958	1.03	4.45	3.25	1.67	1.64	2.17	2.44	38.45	14.52	2.40	3.70	3.03	78.75
1959	2.42	2.22	2.00	1.82	1.65	4.33	4.01	3.94	2.71	1.69	1.50	1.88	30.17
1960	1.94	4.78	9.93	6.71	2.97	4.82	31.45	12.36	2.50	2.30	2.11	1.63	83.50
1961	1.43	8.03	4.47	2.25	2.44	14.61	6.26	1.77	1.33	0.87	1.10	1.42	45.98
1962	3.73	12.96	5.56	15.20	6.57	42.19	15.86	2.23	1.80	17.42	7.48	1.51	132.51
1963	1.88	6.16	3.76	17.59	12.86	8.88	12.13	5.02	32.99	12.96	1.99	1.63	117.85
1964	10.71	4.78	1.18	1.20	1.33	0.97	0.67	0.99	24.38	10.83	6.45	4.08	67.57
1965	24.64	16.26	4.28	1.81	1.66	1.10	0.74	16.88	7.57	1.87	1.36	1.62	79.79
1966	1.66	1.42	1.51	4.42	3.33	29.05	23.39	6.29	1.87	5.97	3.69	1.55	84.15
1967	1.07	1.73	1.74	1.34	1.51	1.72	1.68	1.27	0.86	0.69	1.07	2.61	17.29
1968	3.04	5.58	3.40	1.54	8.07	20.14	7.58	16.65	7.31	1.99	1.55	1.36	78.21
1969	1.73	3.95	2.80	1.43	1.26	1.14	0.92	1.04	1.73	1.90	16.00	7.62	41.52
1970	26.22	13.58	3.34	2.03	2.22	2.39	2.57	22.60	9.16	5.28	13.81	6.13	109.33
1971	22.65	9.31	2.33	2.00	21.29	8.76	1.94	1.38	1.19	1.18	1.09	0.89	74.01
1972	0.76	4.33	3.24	2.09	1.81	2.07	7.37	3.76	1.23	0.79	1.13	2.22	30.80
1973	2.90	13.81	5.88	1.72	3.47	6.98	3.78	20.45	9.16	2.80	1.74	1.14	73.83
1974	1.07	1.68	3.21	2.44	1.97	2.18	2.13	1.69	1.19	0.92	0.88	17.67	37.03
1975	7.50	1.81	9.18	4.64	18.73	60.93	23.39	12.07	5.24	1.66	1.20	1.74	148.09
1976	41.35	15.15	1.35	1.43	10.63	5.44	2.03	1.22	1.01	1.07	1.44	2.15	84.27
1977	4.72	15.51	16.60	5.66	1.98	2.12	89.41	34.73	3.68	1.94	1.51	1.69	179.55
1978	12.32	6.31	2.25	1.49	1.39	5.58	3.34	1.62	1.15	1.97	2.95	2.96	43.33
1979	4.42	2.83	1.72	1.26	1.38	1.65	1.40	1.22	1.10	0.92	0.79	10.63	29.32
1980	5.35	9.94	5.03	4.47	3.07	1.94	1.26	2.43	2.57	1.77	2.08	2.18	42.09
1981	1.50	1.29	1.17	1.46	1.56	25.07	12.40	3.11	1.75	1.37	1.01	0.85	52.54
1982	1.51	1.69	1.00	0.70	0.79	0.80	0.77	0.73	0.63	18.93	8.27	2.15	37.97
1983	2.13	6.02	3.66	6.23	3.94	2.69	5.33	3.45	2.52	10.57	5.24	2.04	53.82
1984	1.83	10.22	5.04	2.15	40.72	15.26	1.74	1.06	0.79	0.74	0.59	0.47	80.61
1985	3.35	11.16	4.99	7.58	3.73	1.77	1.79	1.43	1.00	0.73	1.57	7.19	46.29
1986	12.72	5.60	1.99	1.77	1.36	2.06	2.20	1.64	1.33	1.08	1.32	61.29	94.36
1987	22.69	10.30	4.85	1.72	16.28	47.11	16.18	12.49	6.11	6.40	6.02	3.16	153.31
1988	2.32	12.81	25.27	8.20	21.74	9.69	13.85	6.12	2.04	1.78	1.26	1.04	106.12
1989	11.09	23.37	7.77	1.56	1.36	13.04	5.76	1.34	0.87	0.64	1.40	2.01	70.21
1990	2.45	2.15	1.42	1.74	7.78	4.13	1.53	1.06	0.95	0.79	0.82	1.33	26.15
1991	9.95	13.07	4.64	1.61	1.38	1.22	1.45	1.34	0.96	0.70	0.71	1.11	38.14
1992	1.68	1.79	1.80	1.62	1.35	0.98	0.83	0.80	0.68	0.54	0.59	1.48	14.14
1993	5.14	3.62	10.83	4.66	27.03	11.64	2.17	0.99	0.64	0.84	1.75	1.70	71.01
1994	1.20	0.88	5.01	3.15	1.45	14.99	24.95	8.69	8.44	4.53	1.70	1.27	76.26
1995	1.72	1.92	29.37	12.30	10.22	4.61	1.68	1.39	1.07	7.49	4.30	1.82	77.89
1996	2.30	31.11	11.89	3.40	12.80	6.13	21.22	8.78	45.73	19.48	3.38	2.33	168.55
month	467.45	669.56	496.19	363.93	552.22	767.28	584.92	402.03	344.15	327.15	212.63	296.24	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.64	0.88	0.91	0.58	0.79	0.80	0.67	0.71	0.63	0.53	0.51	0.43	14.14
max	41.35	44.50	42.29	24.85	40.72	60.93	89.41	38.45	45.73	65.01	23.50	61.29	179.55
median	2.30	4.78	3.66	2.44	2.97	5.44	3.77	2.01	1.72	1.70	1.44	1.62	67.46
mean	6.07	8.70	6.44	4.73	7.17	9.96	7.60	5.22	4.47	4.25	2.76	3.85	71.22
Sum of the monthly means =				71.22									
s.d.	7.95	9.50	7.47	5.10	8.49	11.43	11.62	7.24	7.74	8.47	3.71	7.84	38.70
c.v.	1.31	1.09	1.16	1.08	1.18	1.15	1.53	1.39	1.73	1.99	1.35	2.04	0.54

APPENDIX 6

PRESENT DAY FLOW RECORDS FOR QUATERNARY CATCHMENTS (2000)

APPENDIX 6.1
T60A (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.30	2.25	3.69	3.68	3.04	3.83	4.16	2.79	1.45	0.85	0.58	0.72	28.34
1921	1.68	17.62	26.46	10.12	3.23	1.78	0.81	2.78	9.42	6.15	3.68	2.90	86.63
1922	3.22	22.56	10.29	5.51	42.24	28.66	7.32	1.73	0.99	25.05	11.63	2.61	161.81
1923	1.51	1.30	1.72	26.10	21.01	6.43	1.62	0.87	0.75	0.63	0.65	1.01	63.60
1924	1.99	3.56	9.28	4.83	1.81	5.46	4.98	3.00	1.66	1.04	0.73	0.70	39.04
1925	1.46	3.08	3.47	3.49	3.14	20.04	8.94	2.17	2.21	2.17	1.43	1.59	53.19
1926	3.16	4.35	4.77	3.64	2.45	33.55	13.40	1.75	0.91	0.70	0.83	1.05	70.56
1927	1.92	2.04	3.33	20.95	10.69	4.16	2.26	1.21	0.92	0.75	0.95	1.16	50.34
1928	1.60	2.31	2.17	1.70	1.30	2.58	2.90	1.98	3.52	5.73	4.81	7.02	37.62
1929	9.30	6.84	4.58	3.64	2.98	3.37	3.49	2.38	2.24	2.36	2.61	3.64	47.43
1930	3.99	3.51	4.17	23.04	11.51	30.17	12.29	2.05	0.98	39.96	16.93	2.97	151.57
1931	2.61	2.87	2.46	1.82	5.58	4.71	2.37	1.46	1.52	1.87	1.76	2.78	31.81
1932	4.58	41.84	36.10	9.48	1.46	1.62	1.83	1.37	0.95	0.78	0.68	0.58	101.27
1933	0.58	7.45	21.73	13.33	5.42	3.53	2.90	2.11	1.35	1.71	1.86	1.32	63.29
1934	1.28	2.32	10.41	5.98	2.75	2.49	4.55	18.88	25.09	9.85	4.06	3.20	90.86
1935	2.35	2.45	1.59	1.01	16.42	17.57	6.35	3.65	4.08	3.03	1.80	1.40	61.70
1936	2.75	68.78	25.93	3.89	25.75	11.99	3.41	1.71	0.94	0.79	0.75	0.72	147.41
1937	1.12	1.80	2.58	2.76	3.40	2.85	2.70	2.46	1.88	1.78	1.67	1.29	26.29
1938	1.38	2.35	3.94	4.00	10.07	5.94	2.68	2.10	1.79	1.77	1.93	10.20	48.15
1939	7.86	5.56	5.30	3.84	2.50	2.33	2.19	3.70	4.52	3.20	1.85	1.35	44.20
1940	1.51	3.24	5.10	3.88	1.94	1.55	1.58	1.11	0.76	0.71	0.77	0.96	23.11
1941	1.66	2.41	2.23	5.30	4.73	4.26	3.65	2.77	1.95	1.22	1.15	1.51	32.84
1942	2.60	31.33	34.75	11.37	3.13	7.27	14.49	7.32	3.48	2.94	4.15	4.64	127.47
1943	7.12	25.31	18.55	6.31	4.01	3.92	2.66	1.66	1.34	1.34	1.15	2.88	76.25
1944	4.87	3.89	1.92	1.85	2.80	4.02	3.26	1.95	1.33	1.01	0.76	0.81	28.47
1945	4.50	4.03	1.97	1.35	2.42	7.86	5.56	2.81	1.59	1.12	0.85	0.88	34.94
1946	1.46	3.14	3.88	3.39	3.90	8.75	6.85	4.49	10.67	7.02	3.33	2.21	59.09
1947	2.19	52.27	21.55	5.04	9.29	6.85	4.76	2.93	1.45	0.82	0.58	0.49	108.22
1948	2.23	3.71	3.67	3.42	6.73	5.49	4.22	2.86	1.49	0.96	0.85	0.91	36.54
1949	1.71	4.93	4.41	6.11	5.23	4.33	3.77	3.61	2.87	2.24	2.93	2.98	45.12
1950	2.78	2.48	17.54	8.84	3.23	3.50	3.00	1.77	1.17	0.95	1.14	1.75	48.15
1951	3.79	3.65	3.47	4.15	4.35	3.81	3.85	3.28	2.03	1.27	0.85	1.06	35.56
1952	1.39	1.61	1.70	1.63	2.04	2.21	2.01	1.49	0.95	0.68	0.74	1.53	17.98
1953	3.20	9.82	13.46	6.42	3.34	3.30	2.42	2.06	2.32	2.05	1.41	1.60	51.40
1954	32.53	14.46	3.53	9.92	28.54	12.41	4.15	2.61	1.69	1.22	0.80	1.18	113.04
1955	2.17	3.14	2.49	1.04	1.58	17.03	9.78	4.34	2.84	2.01	1.42	1.47	49.31
1956	3.06	23.91	52.63	18.81	4.78	14.80	10.76	4.90	2.64	1.87	1.65	2.94	142.75
1957	5.62	12.71	6.85	4.40	18.72	9.18	4.83	3.82	1.95	1.18	0.92	0.90	71.08
1958	1.27	3.16	4.51	3.55	2.98	3.00	2.95	43.58	17.51	3.32	3.19	2.89	91.91
1959	2.83	3.43	3.61	3.00	2.57	3.02	3.38	3.08	2.20	1.45	1.27	1.69	31.53
1960	2.15	3.57	11.67	7.57	4.21	4.15	33.60	14.14	2.91	1.99	1.52	1.28	88.76
1961	1.42	3.26	4.37	4.03	5.36	9.39	5.22	2.34	1.51	0.96	1.07	1.31	40.24
1962	2.55	14.50	8.26	20.28	9.37	53.00	20.59	2.83	1.68	3.58	4.49	2.78	143.91
1963	3.21	13.58	12.89	22.52	10.09	4.47	5.07	4.09	36.24	15.54	3.26	2.41	133.37
1964	18.14	8.72	2.75	2.53	2.51	1.69	1.00	1.04	12.13	8.75	6.08	5.37	70.71
1965	22.99	20.72	7.52	3.36	2.63	1.47	0.84	9.73	6.55	2.87	1.88	2.04	82.60
1966	2.34	2.57	3.00	3.62	4.04	37.49	16.71	4.30	2.75	3.17	3.02	1.80	84.81
1967	1.47	2.83	2.98	2.23	2.06	2.11	2.01	1.42	0.83	0.62	1.04	2.26	21.86
1968	3.51	4.30	4.14	2.53	3.12	16.76	8.04	3.91	3.62	2.44	1.82	1.69	55.88
1969	2.43	3.81	4.06	2.78	1.99	1.39	0.88	0.94	1.50	1.58	2.30	3.53	27.19
1970	23.59	11.94	5.48	4.73	4.00	3.40	2.87	4.20	4.32	3.79	6.30	5.60	80.22
1971	29.40	13.18	4.02	3.58	12.38	7.01	2.81	1.49	1.11	1.08	0.89	0.73	77.68
1972	0.87	2.85	3.91	3.07	2.73	2.93	2.77	1.82	0.95	0.63	0.92	1.89	25.34
1973	2.88	5.46	4.59	3.68	4.36	11.09	6.30	6.21	5.63	3.73	2.04	1.22	57.19
1974	1.35	2.84	4.54	4.44	4.33	4.29	3.18	1.76	0.95	0.67	0.61	2.42	31.38
1975	3.68	3.37	18.45	13.29	19.65	68.48	24.65	4.58	3.47	2.04	1.27	1.73	164.66
1976	23.41	11.10	3.96	3.46	3.38	3.20	2.25	1.27	0.91	0.85	0.90	1.37	56.06
1977	3.49	14.38	13.17	6.53	4.12	3.68	95.02	35.46	3.64	2.00	1.48	1.91	184.88
1978	3.90	10.14	6.68	3.57	2.76	3.22	2.88	1.67	0.89	1.34	1.91	1.87	40.83
1979	2.39	2.86	2.87	2.19	1.67	1.68	1.35	0.99	0.77	0.60	0.52	2.65	20.54
1980	4.48	19.35	10.16	5.10	4.81	3.73	2.14	1.71	1.61	1.14	1.41	1.78	57.42
1981	1.56	1.63	1.76	2.60	2.91	4.05	4.85	3.53	2.10	1.48	1.01	0.87	28.35
1982	2.13	2.56	1.76	1.35	1.28	1.09	1.01	0.92	0.72	0.85	1.05	1.17	15.89
1983	1.80	3.57	4.61	11.41	10.70	6.56	9.45	5.62	2.77	2.57	2.44	1.96	63.46
1984	2.02	3.35	4.66	4.81	43.64	17.01	2.32	1.11	0.73	0.67	0.51	0.42	81.25
1985	8.57	9.46	7.61	5.23	3.57	2.41	1.54	0.91	0.63	0.55	1.77	3.28	45.53
1986	8.59	16.68	7.81	3.76	3.05	3.14	2.84	1.83	1.18	0.84	1.37	53.97	105.06
1987	22.31	12.13	23.22	9.50	26.39	58.70	20.34	4.98	4.96	4.93	4.95	4.13	196.54
1988	3.64	10.94	20.75	8.49	34.93	14.37	4.00	3.34	2.36	1.87	1.27	0.96	106.92
1989	3.08	56.52	21.87	3.58	2.44	7.97	5.40	2.38	1.22	0.77	1.58	2.24	109.05
1990	3.43	3.84	3.13	3.77	4.50	3.55	1.81	0.88	0.65	0.51	0.50	1.01	27.58
1991	11.77	10.74	5.32	3.14	2.53	2.42	2.10	1.33	0.76	0.52	0.52	0.71	41.86
1992	1.32	3.01	4.45	3.94	3.57	2.64	1.69	1.08	0.64	0.44	0.47	1.75	25.00
1993	19.05	10.45	17.91	8.50	9.28	17.91	7.46	1.71	0.88	1.18	1.56	1.17	97.06
1994	0.91	0.98	1.24	1.91	1.77	6.38	6.18	4.40	3.65	2.93	1.67	1.22	33.24
1995	1.94	3.40	59.58	24.53	24.03	11.02	3.03	1.38	0.72	1.36	1.86	1.62	134.47
1996	2.21	23.61	11.49	7.42	6.16	5.42	18.21	8.74	38.92	17.09	4.51	3.30	147.08
month	398.11	765.67	728.43	491.62	583.38	728.89	521.49	312.63	286.26	243.48	162.87	210.91	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.58	0.98	1.24	1.01	1.28	1.09	0.81	0.87	0.63	0.44	0.47	0.42	15.89
max	32.53	68.78	59.58	26.10	43.64	68.48	95.02	43.58	38.92	39.96	16.93	53.97	196.54
median	2.60	3.84	4.58	3.94	3.90	4.26	3.41	2.38	1.66	1.45	1.42	1.69	57.19
mean	5.17	9.94	9.46	6.38	7.58	9.47	6.77	4.06	3.72	3.16	2.12	2.74	70.57

Sum of the monthly means = 70.57

s.d.	6.90	12.72	10.98	5.81	9.16	12.76	11.76	6.51	6.72	5.76	2.43	6.11	44.01
c.v.	1.33	1.28	1.16	0.91	1.21	1.35	1.74	1.60	1.81	1.82	1.15	2.23	0.62

APPENDIX 6.2
ACCUMALTIVE RUNOFF FOR T60B, C AND D (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	3.27	6.34	16.99	12.69	9.05	21.39	14.72	7.51	3.86	2.21	1.44	1.89	101.36
1921	4.79	65.13	87.13	30.34	8.95	5.18	2.32	19.80	35.53	17.58	9.15	7.56	293.46
1922	8.93	77.20	32.69	31.07	128.47	89.69	22.19	4.21	2.44	81.01	34.94	6.36	519.20
1923	3.80	3.48	5.04	90.92	73.45	20.14	4.04	2.26	1.95	1.64	1.69	2.77	211.18
1924	5.71	15.53	42.76	17.83	4.79	32.82	18.82	7.73	4.30	2.69	1.83	1.82	156.63
1925	4.08	12.20	11.12	14.08	10.48	72.91	29.67	5.44	5.90	5.92	3.82	4.40	180.02
1926	11.16	15.82	22.14	12.52	6.92	108.39	41.42	4.28	2.24	1.74	2.13	2.82	231.58
1927	5.47	5.95	22.76	72.55	38.78	12.86	5.87	3.22	2.44	1.97	2.54	3.19	177.60
1928	4.55	6.82	6.54	5.30	4.09	14.24	10.39	5.53	24.73	19.70	12.20	30.17	144.26
1929	35.32	25.35	13.50	10.64	8.88	14.53	11.54	6.76	6.38	6.72	7.44	11.45	158.51
1930	11.74	10.22	24.54	78.10	44.20	90.32	34.44	5.08	2.42	120.28	48.94	7.36	477.64
1931	6.94	8.11	7.25	5.58	36.01	19.18	6.14	3.93	4.20	5.25	4.89	9.29	116.77
1932	18.17	126.19	111.21	28.44	3.77	4.76	5.49	4.06	2.68	2.15	1.83	1.53	310.28
1933	1.55	37.35	73.85	50.05	17.86	9.76	8.38	6.14	3.82	4.87	5.25	3.67	222.55
1934	3.58	6.87	48.10	22.38	7.54	7.41	30.88	62.52	74.03	27.07	10.23	8.43	309.04
1935	6.35	7.00	4.61	3.07	65.19	63.68	19.58	12.94	11.86	7.94	4.67	3.72	210.61
1936	8.31	200.48	74.42	14.19	86.26	37.75	9.18	4.53	2.47	2.07	1.95	1.90	443.51
1937	3.10	5.27	7.85	8.70	16.57	10.37	7.93	7.26	5.43	5.07	4.69	3.59	85.83
1938	3.87	6.98	23.05	14.90	44.41	21.31	7.03	5.81	4.97	4.93	5.40	43.13	185.79
1939	29.67	16.70	24.59	13.38	6.82	6.92	6.57	22.32	15.59	8.09	4.67	3.50	158.82
1940	4.09	16.77	28.51	13.75	4.92	4.45	4.66	3.25	2.11	1.93	2.09	2.65	89.18
1941	4.77	7.17	6.75	35.42	19.35	16.52	11.59	7.65	5.40	3.29	3.10	4.20	125.21
1942	7.56	102.59	109.57	33.68	8.66	38.06	52.75	21.49	8.84	7.76	18.39	14.39	423.74
1943	30.83	79.74	62.32	19.93	18.61	13.17	7.29	4.62	3.70	3.72	3.13	14.80	261.86
1944	15.85	10.68	5.28	5.60	8.73	22.03	12.18	5.12	3.53	2.68	1.97	2.15	95.80
1945	28.01	15.48	4.99	3.84	9.52	40.38	20.43	7.20	4.10	2.90	2.16	2.32	141.33
1946	4.09	14.24	12.81	10.12	20.94	40.52	27.17	12.83	38.60	21.28	8.16	5.64	216.40
1947	5.90	156.36	69.68	18.39	40.02	29.62	14.36	7.52	3.72	2.07	1.43	1.22	350.29
1948	9.00	11.43	11.13	10.50	38.71	21.19	11.53	8.03	4.09	2.56	2.24	2.44	132.85
1949	4.86	30.98	17.28	32.65	19.57	12.69	10.87	10.44	8.25	6.35	8.40	8.59	170.93
1950	8.03	7.27	66.71	30.01	8.95	15.24	10.11	4.86	3.18	2.56	3.11	4.95	164.98
1951	21.91	13.17	12.84	16.54	16.05	11.75	13.10	9.98	5.63	3.45	2.22	2.89	129.53
1952	3.90	4.66	5.11	5.10	6.51	7.05	6.30	4.52	2.76	1.89	2.01	4.38	54.19
1953	11.79	43.04	51.17	20.21	9.31	9.90	7.28	6.13	6.83	5.92	3.92	4.53	180.03
1954	104.02	43.85	9.46	45.39	92.95	39.06	11.78	6.98	4.54	3.25	2.08	3.24	366.60
1955	6.24	9.29	7.38	3.12	5.01	67.26	36.52	12.17	7.23	5.22	3.67	3.96	167.07
1956	11.59	80.44	155.81	57.40	17.03	55.11	41.50	15.02	6.50	4.74	4.28	9.32	458.74
1957	29.49	46.53	20.56	23.12	64.72	27.81	21.99	12.70	4.75	2.91	2.27	2.32	259.17
1958	3.47	17.19	17.25	10.60	8.85	9.23	9.07	135.38	52.19	8.25	8.35	7.86	287.69
1959	7.94	10.41	10.85	9.21	8.08	11.08	10.78	9.21	6.41	4.10	3.52	4.79	96.38
1960	6.19	18.50	47.57	33.08	13.64	17.34	103.53	40.99	7.27	5.10	3.92	3.39	300.52
1961	3.88	19.24	15.16	13.64	32.63	40.42	16.51	5.90	3.88	2.45	2.82	3.58	160.11
1962	7.41	55.81	27.97	69.96	29.93	157.25	59.73	7.28	4.37	21.03	14.86	6.72	462.32
1963	10.23	50.75	49.22	74.35	30.91	14.42	24.72	13.78	106.56	43.97	8.00	6.21	433.12
1964	62.59	27.42	7.25	7.46	7.75	5.27	3.04	3.12	49.83	29.12	18.16	14.80	235.81
1965	73.62	67.51	22.39	9.33	7.81	4.47	2.50	44.18	22.71	7.01	4.67	5.44	271.64
1966	6.48	7.45	9.05	17.19	15.68	118.72	58.57	13.43	6.83	8.46	8.20	4.84	274.90
1967	4.01	10.86	9.47	6.68	6.41	6.67	6.25	4.28	2.39	1.71	2.90	6.57	68.20
1968	10.69	17.00	13.33	7.42	19.50	61.16	25.13	11.86	10.16	6.45	4.83	4.59	192.12
1969	6.93	15.92	13.25	8.22	6.10	4.32	2.65	2.81	4.42	4.58	6.68	10.40	86.28
1970	79.87	41.33	21.73	15.58	11.52	10.02	8.60	25.42	15.43	9.60	28.40	18.11	285.61
1971	89.30	38.41	10.91	12.90	52.34	24.43	7.41	4.01	2.98	2.92	2.36	1.92	249.89
1972	2.35	16.40	13.45	8.81	8.30	9.16	8.56	5.51	2.73	1.74	2.53	5.44	84.98
1973	8.45	32.50	17.76	12.22	22.07	44.83	20.25	28.13	18.14	9.33	5.09	3.08	221.85
1974	3.62	11.09	24.58	15.64	17.94	14.06	9.09	5.02	2.62	1.80	1.60	10.45	117.51
1975	11.40	9.58	68.36	53.01	66.29	195.27	68.38	12.32	9.53	5.53	3.36	4.81	507.84
1976	78.55	34.44	11.00	10.19	11.10	10.01	6.78	3.72	2.56	2.36	2.45	3.88	177.04
1977	19.54	51.90	48.69	23.43	12.10	10.69	271.71	100.07	9.35	5.14	3.82	5.25	561.69
1978	21.28	39.91	21.41	9.96	8.09	11.77	9.17	4.81	2.47	3.77	5.41	5.31	143.36
1979	6.93	8.51	8.74	6.85	5.29	5.33	4.21	2.96	2.22	1.67	1.38	15.94	70.03
1980	14.65	65.28	37.16	20.22	17.33	11.13	5.92	4.85	4.57	3.15	3.92	5.06	193.24
1981	4.41	4.75	5.28	11.30	9.86	26.95	17.80	9.24	5.55	3.91	2.62	2.30	103.97
1982	6.11	7.52	5.22	4.18	4.05	3.48	3.10	2.77	2.07	2.41	2.93	3.27	47.11
1983	5.19	18.72	18.24	47.48	44.08	27.11	35.46	17.03	6.87	6.74	6.53	5.32	238.77
1984	5.65	14.64	23.22	19.69	132.72	50.01	6.01	2.94	1.91	1.74	1.29	1.05	260.87
1985	38.95	38.89	32.96	17.90	10.03	6.94	4.50	2.61	1.73	1.47	5.10	9.66	170.74
1986	39.92	58.13	23.14	12.58	9.47	10.69	8.79	5.27	3.29	2.29	3.83	160.40	337.80
1987	64.86	44.15	75.73	28.41	86.70	171.67	56.99	18.46	14.68	13.28	13.54	11.46	599.93
1988	10.32	46.48	70.98	25.67	110.04	43.65	12.76	9.78	6.42	5.08	3.39	2.56	347.13
1989	18.79	163.52	61.10	10.00	7.22	41.29	20.45	5.99	3.09	1.94	4.32	6.31	344.02
1990	14.55	12.28	8.99	22.24	18.20	10.44	5.01	2.43	1.75	1.35	1.29	2.80	101.33
1991	48.26	42.47	16.52	8.66	7.51	7.46	6.42	3.98	2.15	1.40	1.36	1.93	148.12
1992	3.73	13.44	21.01	13.18	11.66	8.16	4.93	3.11	1.75	1.16	1.21	5.06	88.40
1993	67.98	35.99	61.12	26.62	40.98	62.77	22.49	4.15	2.15	3.11	4.20	3.14	334.70
1994	2.44	2.76	3.66	6.03	5.63	38.08	25.80	12.25	9.69	7.92	4.42	3.25	121.93
1995	5.47	13.66	177.83	82.56	77.42	32.30	8.03	3.69	1.88	3.81	5.23	4.55	416.43
1996	6.38	81.11	38.15	35.30	29.74	20.21	59.92	26.08	113.34	48.02	11.44	8.72	478.41
month	1374.68	2618.60	2487.20	1749.25	2057.02	2493.68	1659.03	980.66	868.94	708.25	464.26	642.76	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	1.55	2.76	3.66	3.07	3.77	3.48	2.32	2.26	1.73	1.16	1.21	1.05	47.11
max	104.02	200.48	177.83	90.92	132.72	195.27	271.71	135.38	113.34	120.28	48.94	160.40	599.93
median	7.56	16.77	21.01	14.90	13.64	17.34	10.87	6.14	4.42	3.91	3.83	4.59	193.24
mean	17.85	34.01	32.30	22.72	26.71	32.39	21.55	12.74	11.28	9.20	6.03	8.35	235.12
Sum of the monthly means = 235.12													
s.d.	23.01	38.17	33.71	20.27	29.59	38.07	34.27	20.18	20.41	17.59	7.53	18.64	133.97
c.v.	1.29	1.12	1.04	0.89	1.11	1.18	1.59	1.58	1.81	1.91	1.25	2.23	0.57

APPENDIX 6.3
ACCUMALATIVE RUNOFF FOR T60E, F AND G (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	2.18	5.01	18.82	11.75	8.45	17.81	11.78	5.95	2.97	1.64	1.00	1.74	89.10
1921	4.28	46.96	49.91	17.38	5.54	2.89	1.46	20.16	21.88	11.14	7.65	7.92	197.17
1922	41.04	94.83	32.78	80.00	107.46	56.93	14.37	3.56	2.11	53.51	23.71	4.69	514.99
1923	3.03	3.58	5.31	45.77	38.56	11.88	2.74	1.53	1.37	1.24	1.47	3.15	119.63
1924	5.61	11.89	22.48	12.08	8.48	49.96	22.82	6.64	3.78	2.63	1.99	3.47	151.83
1925	5.79	8.56	8.19	11.49	10.84	64.07	25.70	4.82	5.34	5.39	3.48	3.84	157.51
1926	10.24	28.84	22.19	9.80	5.56	92.95	35.05	3.18	1.56	1.09	1.08	1.92	213.46
1927	4.79	4.94	6.42	12.18	18.33	10.96	5.13	3.11	2.53	1.97	2.89	3.54	76.79
1928	4.35	8.03	8.02	7.07	5.77	14.22	8.49	4.04	39.29	29.81	13.40	38.38	180.87
1929	62.46	51.40	17.38	6.09	4.20	4.55	5.28	4.23	4.94	6.07	6.95	24.42	197.97
1930	14.62	7.77	6.67	50.75	47.90	69.47	25.37	4.68	2.27	194.29	71.30	6.26	501.35
1931	6.90	8.00	7.22	4.90	38.32	19.22	5.81	4.13	4.46	5.04	4.46	29.30	137.76
1932	26.23	115.86	91.15	21.57	4.13	5.45	4.72	3.07	2.08	1.65	1.32	1.36	278.59
1933	1.68	23.49	47.90	57.73	20.65	9.94	7.50	4.65	2.95	5.32	6.27	3.76	191.84
1934	2.78	8.08	35.75	16.69	5.00	5.67	31.20	49.44	78.28	28.63	9.86	8.07	279.45
1935	6.04	6.60	4.35	2.71	72.84	73.14	21.07	16.02	11.86	7.23	4.30	3.40	229.56
1936	14.38	155.46	55.83	5.20	24.23	29.47	12.26	4.00	2.13	2.07	2.39	2.55	309.97
1937	3.46	4.46	13.82	10.98	7.67	4.99	8.35	7.15	5.17	5.18	4.48	2.96	78.67
1938	2.80	6.36	12.74	13.54	33.87	16.96	6.95	6.07	5.25	5.50	6.62	58.60	175.26
1939	36.38	12.40	12.55	7.52	4.09	4.50	4.27	7.84	7.55	4.96	3.24	2.79	108.09
1940	3.02	15.00	11.31	6.21	3.29	2.39	2.47	1.94	1.59	1.72	1.79	2.07	52.80
1941	3.89	7.53	6.27	58.19	23.94	6.57	5.43	4.90	4.17	2.62	2.60	3.86	129.97
1942	6.18	109.31	79.69	20.38	5.72	14.53	34.76	15.98	6.33	5.11	12.64	10.89	321.52
1943	15.14	46.99	32.17	11.48	15.15	9.88	5.17	3.18	2.47	2.75	2.43	32.02	178.83
1944	21.98	9.74	4.62	4.84	11.21	13.05	7.49	3.99	2.80	2.25	1.72	2.39	86.08
1945	58.87	24.25	3.91	3.01	8.36	27.91	15.16	6.15	3.45	2.49	1.81	1.85	157.22
1946	3.16	16.56	11.85	7.42	7.22	27.73	38.10	16.20	22.43	13.93	6.18	4.40	175.18
1947	4.58	137.67	59.40	10.43	26.33	20.12	10.31	5.52	2.69	1.50	1.01	0.89	280.45
1948	11.30	10.82	8.44	6.76	72.21	37.40	11.69	6.49	3.19	1.92	1.70	2.29	174.21
1949	4.45	42.87	20.12	16.45	12.77	8.86	8.08	9.21	7.06	5.07	6.18	6.22	147.34
1950	6.85	6.30	44.06	24.09	8.33	9.39	6.75	3.62	2.43	2.03	2.43	3.83	120.11
1951	26.17	13.07	18.81	18.89	10.47	8.05	8.63	6.81	4.04	2.49	1.54	2.52	121.49
1952	3.83	4.40	4.40	4.16	5.03	5.44	5.03	3.68	2.25	1.52	1.64	4.38	45.76
1953	14.14	56.49	39.84	12.85	5.60	6.45	5.34	4.50	5.18	4.85	3.32	4.11	162.67
1954	99.09	40.07	7.25	33.65	52.06	25.09	9.11	4.75	3.10	2.29	1.43	2.84	280.73
1955	5.59	8.80	5.88	2.12	3.89	60.44	27.37	7.69	5.32	4.06	2.80	3.56	137.52
1956	14.20	92.69	146.97	51.34	12.73	36.88	43.36	16.00	5.21	3.91	3.39	5.62	432.30
1957	16.21	19.86	17.38	27.87	53.82	22.32	28.71	13.62	3.57	2.31	1.99	2.09	209.75
1958	2.99	15.02	12.24	6.31	5.19	5.95	6.02	99.38	38.71	7.01	8.20	8.26	215.28
1959	7.91	8.20	7.90	6.81	5.44	8.88	8.80	8.33	6.21	4.01	3.51	4.85	80.85
1960	5.74	16.73	35.23	21.87	9.51	9.28	85.30	34.73	6.76	5.73	5.15	4.16	240.19
1961	4.19	25.27	16.38	8.39	8.50	28.51	13.84	4.80	3.05	1.86	2.47	3.53	120.79
1962	10.29	45.17	20.35	47.70	20.82	124.05	46.90	6.03	4.18	35.15	17.56	4.98	383.18
1963	6.87	21.68	14.69	55.12	33.49	17.10	25.23	12.39	90.72	36.84	6.21	4.85	325.19
1964	29.35	14.97	5.05	4.53	4.33	2.67	1.47	2.02	54.31	26.72	13.61	11.28	170.31
1965	81.53	59.34	17.00	6.69	5.43	3.07	1.64	29.69	16.16	5.54	3.67	4.47	234.23
1966	5.07	5.06	5.79	15.44	10.97	78.50	59.48	16.47	5.08	7.99	7.91	4.67	222.43
1967	3.42	7.91	7.02	4.80	4.75	4.69	4.03	2.71	1.60	1.30	2.28	5.87	50.38
1968	11.40	19.92	12.49	5.83	17.38	50.93	20.62	34.35	17.09	5.90	4.19	3.68	203.78
1969	5.30	15.93	11.17	5.39	4.05	3.10	2.10	2.13	3.61	4.08	29.93	18.99	105.78
1970	87.18	50.06	13.79	7.49	7.20	6.72	6.43	46.55	20.90	9.13	31.98	17.25	304.68
1971	75.78	32.88	9.72	7.48	60.50	25.31	5.35	3.21	2.47	2.48	2.32	2.01	229.51
1972	2.01	13.91	11.77	7.64	5.85	5.71	11.33	7.40	3.04	1.74	2.60	5.85	78.85
1973	9.93	45.99	20.46	6.39	10.51	13.26	8.65	44.69	22.29	8.18	4.71	3.04	198.10
1974	3.19	6.16	14.86	9.62	6.25	5.98	5.21	3.71	2.34	1.80	1.79	42.52	103.43
1975	20.54	7.35	33.47	16.70	52.08	189.24	67.23	21.49	11.87	5.02	3.25	4.87	433.11
1976	132.15	49.88	5.72	5.38	24.81	14.15	5.65	2.84	2.06	2.23	3.23	5.47	253.57
1977	13.00	54.06	58.70	20.06	6.48	5.90	272.14	99.68	9.12	5.50	3.96	4.58	553.18
1978	32.76	23.81	10.22	5.59	4.51	10.32	7.54	4.01	2.46	4.61	7.36	7.93	121.12
1979	13.36	9.94	6.85	4.80	4.43	4.52	3.35	2.58	2.13	1.80	1.57	19.10	74.43
1980	13.46	38.44	20.71	14.70	9.76	5.61	3.06	4.51	5.63	4.05	4.89	5.55	130.37
1981	4.31	4.48	4.47	5.19	4.99	64.77	29.39	7.69	4.50	3.24	2.30	2.04	137.37
1982	4.43	5.82	3.86	2.54	2.42	2.03	1.66	1.39	1.10	40.80	20.30	7.01	93.36
1983	7.18	22.56	14.11	17.93	11.96	7.84	8.40	7.14	6.05	14.74	10.79	6.56	135.26
1984	6.14	35.50	18.28	7.94	126.20	47.26	4.82	2.41	1.55	1.47	1.14	0.96	253.67
1985	8.36	38.49	18.32	22.23	11.41	5.15	4.46	3.15	1.96	1.39	3.56	13.05	131.53
1986	38.02	22.66	8.88	6.45	4.49	5.22	5.60	3.84	2.77	2.22	2.90	189.47	292.52
1987	71.81	40.03	18.92	6.44	43.70	142.13	49.63	20.10	12.94	11.22	12.23	9.15	438.30
1988	8.10	46.65	88.36	28.65	62.08	27.34	28.53	14.27	5.54	4.42	2.99	2.57	319.50
1989	27.50	81.54	28.96	5.72	4.43	25.04	12.87	3.73	1.95	1.36	3.29	5.20	201.59
1990	8.68	7.71	5.35	7.10	16.72	10.20	4.19	2.39	1.91	1.57	1.70	3.29	70.81
1991	23.55	46.41	18.34	5.97	4.52	3.33	3.44	2.86	1.83	1.31	1.40	2.65	115.61
1992	4.87	6.18	6.82	5.92	4.38	2.65	1.84	1.58	1.21	0.98	1.14	3.72	41.29
1993	13.47	14.24	37.57	16.05	79.77	33.28	5.92	2.45	1.28	1.80	4.11	4.25	214.19
1994	3.41	2.99	16.27	10.69	4.78	31.20	64.52	24.29	12.13	9.70	5.20	3.72	188.90
1995	5.48	6.95	100.61	43.02	24.31	11.81	4.65	3.23	2.19	8.93	8.69	5.62	225.49
1996	9.50	107.73	41.75	13.59	32.98	16.49	51.02	22.21	133.25	53.88	9.53	7.39	499.32
month	1399.92	2352.56	1804.30	1225.50	1571.40	1966.72	1485.59	914.93	819.00	784.88	498.08	772.36	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	1.68	2.99	3.86	2.12	2.42	2.03	1.46	1.39	1.10	0.98	1.00	0.89	41.29
max	132.15	155.46	146.97	80.00	126.20	189.24	272.14	99.68	133.25	194.29	71.30	189.47	553.18
median	7.91	16.56	14.69	9.80	9.51	11.88	8.35	4.82	3.78	4.06	3.39	4.40	178.83
mean	18.18	30.55	23.43	15.92	20.41	25.54	19.29	11.88	10.64	10.19	6.47	10.03	202.54
Sum of the monthly means = 202.54													
s.d.	25.16	32.89	25.55	15.92	24.68	33.38	34.11	17.89	20.97	24.07	9.64	22.98	117.37
c.v.	1.38	1.08	1.09	1.00	1.21	1.31	1.77	1.51	1.97	2.36	1.49	2.29	0.58

APPENDIX 6.4
T60H (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.81	2.05	14.16	6.82	8.77	19.09	8.64	2.94	1.63	0.97	0.63	1.01	67.52
1921	2.22	26.91	26.53	8.14	2.47	1.60	1.01	24.43	20.57	6.27	4.61	3.88	128.64
1922	23.62	42.30	13.39	41.13	54.53	34.61	8.67	1.62	1.20	35.11	13.77	1.75	271.70
1923	1.17	1.39	2.23	29.17	26.49	7.17	1.25	0.94	0.95	0.84	0.98	1.88	74.46
1924	2.96	8.67	15.09	6.33	8.87	33.35	14.28	3.47	2.05	1.54	1.21	1.99	99.81
1925	3.01	5.56	3.91	9.47	10.50	38.63	14.10	2.34	4.92	3.60	1.93	2.12	100.09
1926	10.00	16.71	13.18	4.84	2.51	53.32	19.30	1.43	0.88	0.66	0.67	1.11	124.61
1927	2.62	2.19	4.07	10.27	16.92	7.22	2.57	1.93	1.75	1.36	1.91	2.17	54.98
1928	2.32	5.65	3.95	3.85	3.03	17.53	7.33	2.01	30.44	21.77	6.84	22.65	127.37
1929	30.15	23.09	7.11	2.42	2.05	4.15	3.72	2.83	6.60	4.64	7.58	19.68	114.02
1930	8.14	2.62	2.47	30.25	30.18	39.71	13.31	2.22	1.31	95.36	34.03	2.33	261.93
1931	4.42	3.49	2.73	2.07	28.16	14.63	3.40	2.28	2.87	3.29	2.89	24.47	94.70
1932	17.12	49.17	41.42	9.84	1.88	5.37	3.49	1.97	1.49	1.16	0.92	0.86	134.69
1933	0.91	17.75	25.88	30.84	10.42	12.45	6.06	2.46	1.83	9.78	5.14	1.63	125.15
1934	1.19	5.58	20.99	8.52	2.19	9.57	26.12	32.08	41.14	13.53	9.39	4.87	175.17
1935	2.26	2.55	1.64	1.19	42.95	43.31	11.53	18.36	8.69	3.17	2.07	1.71	139.43
1936	13.88	66.99	22.67	2.04	21.57	24.26	7.71	1.85	1.21	1.25	1.47	1.50	166.40
1937	1.80	2.03	11.15	8.52	4.10	2.61	13.80	6.56	2.74	3.03	2.69	1.73	60.76
1938	1.44	4.74	8.65	10.51	23.63	12.62	4.06	4.36	3.45	3.78	4.25	35.32	116.81
1939	20.88	5.22	7.05	3.65	1.87	2.56	2.70	14.78	7.06	2.36	1.68	1.48	71.29
1940	1.47	12.42	6.27	2.43	1.55	1.46	1.73	1.49	1.27	1.28	1.27	1.32	33.96
1941	2.10	5.29	3.14	33.48	12.93	7.44	4.12	2.88	2.75	1.76	1.71	2.33	79.93
1942	4.99	50.92	38.22	9.43	2.57	18.27	26.58	9.27	3.06	2.79	16.51	7.82	190.43
1943	10.09	21.89	17.09	5.64	15.28	7.14	2.61	1.96	1.71	1.88	1.63	25.50	112.42
1944	14.44	3.84	1.44	3.09	11.09	14.30	5.43	2.03	1.71	1.42	1.10	1.41	61.30
1945	34.37	12.76	1.21	1.23	10.43	24.65	10.46	3.06	1.89	1.47	1.11	1.08	103.72
1946	1.63	13.76	6.75	3.06	7.79	24.49	27.09	9.20	20.66	9.21	2.46	1.96	128.06
1947	2.04	62.87	29.73	5.13	21.20	19.03	6.68	2.68	1.55	0.92	0.65	0.55	153.03
1948	12.73	6.56	3.07	2.89	42.18	27.62	10.06	3.67	1.59	1.06	0.99	1.29	113.71
1949	2.28	25.11	10.29	13.71	11.58	7.60	7.76	11.55	5.23	2.44	5.12	3.65	106.32
1950	4.02	2.77	24.61	15.67	4.61	12.22	5.69	1.87	1.51	1.30	1.54	2.27	78.08
1951	20.72	8.07	12.32	14.57	5.96	10.15	10.24	4.56	2.14	1.43	0.93	1.44	92.53
1952	1.97	1.99	1.89	1.97	3.42	3.42	3.30	2.65	1.73	1.15	1.16	4.62	29.27
1953	12.00	27.12	20.66	6.26	2.53	10.60	5.02	2.57	3.38	3.20	2.17	2.47	97.98
1954	51.27	19.29	2.50	22.60	31.68	19.67	6.02	2.30	1.82	1.42	0.91	1.66	161.14
1955	2.93	5.81	2.92	0.82	5.89	38.62	19.73	4.71	2.67	2.26	1.63	2.01	90.00
1956	13.79	42.12	64.17	26.92	11.22	26.18	28.81	9.09	2.44	2.08	1.92	6.06	234.80
1957	12.78	10.91	10.12	18.01	31.26	15.50	22.64	8.65	1.54	1.16	1.09	1.14	134.80
1958	1.49	12.51	7.28	2.54	2.79	4.21	3.91	57.51	21.20	3.10	8.80	5.19	130.53
1959	3.31	3.35	3.25	3.12	2.86	13.39	10.37	8.00	4.00	2.05	1.95	2.68	58.33
1960	2.91	13.05	19.83	14.67	5.37	11.87	47.80	17.79	3.23	3.09	2.94	2.33	144.88
1961	2.11	17.53	9.65	3.62	9.05	24.67	9.31	2.32	1.79	1.14	1.54	2.07	84.80
1962	10.79	23.36	8.81	27.75	11.25	64.08	23.69	3.04	2.52	28.52	11.51	1.87	217.19
1963	5.62	12.99	7.55	29.88	23.03	16.44	20.32	7.52	48.49	18.59	2.50	2.20	195.13
1964	19.98	8.16	1.62	1.92	2.23	1.62	1.07	1.56	39.69	18.34	10.92	6.09	113.20
1965	37.71	27.13	6.98	2.71	2.71	1.79	1.16	29.16	12.10	2.31	1.75	2.28	127.79
1966	2.45	2.19	2.49	14.10	9.20	44.20	36.18	9.32	2.37	11.77	5.98	1.92	142.17
1967	1.42	5.10	3.31	2.03	2.50	2.89	2.78	2.04	1.29	1.00	1.58	9.11	35.05
1968	7.97	11.41	5.68	2.25	18.08	33.47	11.39	26.75	11.06	2.49	2.02	1.86	134.43
1969	2.57	11.99	5.96	2.08	2.02	1.86	1.47	1.64	2.73	2.95	27.67	14.33	77.27
1970	39.11	23.01	5.73	3.28	5.91	4.24	6.01	35.02	13.34	9.73	21.66	8.83	175.87
1971	35.73	14.28	4.52	3.40	36.79	14.42	2.70	1.98	1.71	1.69	1.56	1.26	120.04
1972	1.08	12.33	7.12	3.17	2.82	5.33	15.21	6.33	1.46	0.94	1.51	6.86	64.16
1973	6.84	22.99	9.18	2.56	11.69	15.05	6.06	32.02	14.90	3.83	2.11	1.45	128.68
1974	1.47	4.03	10.43	5.12	2.96	4.64	3.57	2.48	1.71	1.30	1.24	29.97	68.92
1975	12.01	2.49	19.45	8.64	32.31	89.72	36.15	19.43	7.53	2.02	1.50	2.36	233.61
1976	62.25	22.51	1.90	2.33	22.36	10.52	2.85	1.60	1.36	1.47	2.09	3.99	135.23
1977	11.49	26.57	28.42	9.23	2.97	5.21	130.29	51.21	5.17	2.40	1.96	2.38	277.30
1978	22.51	13.82	4.11	2.18	2.25	14.81	6.73	2.09	1.53	6.78	5.16	5.24	87.21
1979	9.91	4.90	2.47	2.00	2.32	2.80	2.31	1.95	1.69	1.36	1.14	20.28	53.13
1980	9.07	18.73	10.31	11.21	5.67	2.79	1.86	8.63	4.99	2.17	3.88	3.23	82.54
1981	2.01	1.90	1.85	2.70	2.62	42.00	22.16	4.89	2.20	1.77	1.32	1.15	86.57
1982	2.27	2.66	1.61	1.17	1.34	1.33	1.24	1.14	0.93	31.22	12.84	2.82	60.57
1983	3.07	14.56	7.56	14.07	10.33	4.55	11.43	5.89	3.34	18.36	8.19	2.64	103.99
1984	2.59	20.35	9.01	3.70	63.02	23.14	2.40	1.48	1.08	1.01	0.79	0.62	129.19
1985	10.11	20.86	8.03	16.76	7.13	2.53	2.74	2.19	1.48	1.03	4.10	13.88	90.84
1986	21.42	10.63	3.29	3.29	2.24	8.70	4.77	2.14	1.80	1.46	1.87	92.79	154.40
1987	33.72	19.19	8.33	2.55	29.92	70.96	23.65	20.31	9.14	11.26	10.82	4.67	244.52
1988	3.49	22.97	41.02	12.68	36.16	18.54	22.73	9.04	2.62	2.38	1.69	1.43	174.75
1989	20.81	37.83	11.85	2.32	2.19	24.96	10.02	1.70	1.10	0.82	2.01	3.03	118.64
1990	8.68	4.47	1.94	6.07	16.29	7.01	2.05	1.48	1.33	1.08	1.14	1.98	53.52
1991	19.71	23.41	7.44	2.39	2.23	2.00	2.37	2.14	1.45	1.01	1.01	1.65	66.81
1992	2.62	2.89	3.13	2.71	2.25	1.61	1.32	1.25	1.01	0.77	0.82	2.56	22.94
1993	12.12	7.99	19.76	7.79	43.62	21.32	3.81	1.19	0.77	1.10	2.55	2.52	124.54
1994	1.78	1.33	14.07	6.68	2.10	27.07	39.28	12.65	14.45	6.88	2.07	1.66	130.02
1995	2.51	3.00	48.79	23.81	18.95	7.36	2.29	1.99	1.51	15.06	7.21	2.32	134.80
1996	7.72	48.18	17.62	10.92	23.48	12.31	32.21	12.55	68.04	29.77	4.76	3.08	270.64
month	820.97	1184.81	896.02	696.18	1019.27	1337.53	944.68	626.47	519.54	505.72	334.72	479.30	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.81	1.33	1.21	0.82	1.34	1.33	1.01	0.94	0.77	0.66	0.63	0.55	22.94
max	62.25	66.99	64.17	41.13	63.02	89.72	130.29	57.51	68.04	95.36	34.03	92.79	277.30
median	4.99	12.33	7.55	5.13	8.77	12.45	6.68	2.83	2.14	2.17	1.95	2.32	116.81
mean	10.66	15.39	11.64	9.04	13.24	17.37	12.27	8.14	6.75	6.57	4.35	6.22	121.63
Sum of the monthly means = 121.63													
s.d.	12.45	14.55	12.00	9.22	13.84	17.14	17.22	11.18	11.75	12.83	5.94	12.27	58.65
c.v.	1.17	0.95	1.03	1.02	1.05	0.99	1.40	1.37	1.74	1.95	1.37	1.97	0.48

APPENDIX 6.5
T60J (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.66	1.41	5.07	3.35	2.64	11.46	5.89	2.35	1.38	0.83	0.53	0.76	36.33
1921	1.54	15.19	15.46	5.24	1.77	1.08	0.69	14.36	13.20	4.74	2.66	2.83	78.76
1922	14.83	28.90	9.54	26.71	37.66	23.24	6.03	1.37	0.98	23.96	9.81	1.51	184.54
1923	0.94	0.98	1.42	16.06	15.53	4.74	1.05	0.74	0.73	0.66	0.73	1.32	44.90
1924	2.01	2.55	7.01	3.81	2.57	22.57	9.69	2.61	1.73	1.28	0.97	1.45	58.25
1925	2.08	2.32	2.25	2.47	4.04	26.74	10.30	1.89	2.41	2.49	1.63	1.62	60.24
1926	3.39	8.83	6.12	2.72	1.80	36.04	13.39	1.22	0.74	0.56	0.54	0.82	76.17
1927	1.70	1.51	1.62	2.76	8.76	4.74	1.99	1.43	1.29	1.03	1.37	1.53	29.73
1928	1.59	2.13	2.21	2.10	1.88	8.32	4.13	1.66	20.38	14.72	5.17	14.74	79.03
1929	20.28	14.48	4.66	1.72	1.33	1.75	2.28	2.02	2.46	2.95	3.48	12.69	70.10
1930	5.89	2.01	1.67	17.20	18.34	27.34	9.66	1.81	1.06	70.76	25.56	1.98	183.28
1931	2.14	2.25	1.90	1.33	15.80	7.52	2.24	1.87	2.18	2.44	2.12	14.91	56.70
1932	9.73	34.85	27.85	6.57	1.35	2.11	2.05	1.50	1.12	0.90	0.71	0.65	89.39
1933	0.66	8.39	14.90	19.35	6.98	5.36	3.43	1.99	1.44	4.15	3.08	1.43	71.16
1934	0.96	1.76	11.69	5.38	1.59	2.34	16.61	22.82	30.51	10.45	5.05	3.21	112.37
1935	1.84	1.81	1.10	0.74	26.93	28.87	8.25	11.52	6.06	2.65	1.70	1.33	92.80
1936	6.33	48.10	16.85	1.46	11.06	14.34	5.28	1.54	0.99	0.99	1.12	1.10	109.16
1937	1.26	1.35	2.69	2.82	2.60	1.93	6.09	3.77	2.27	2.37	2.04	1.30	30.49
1938	1.05	1.77	2.56	3.98	14.41	6.77	2.70	2.72	2.56	2.66	3.06	24.54	68.78
1939	13.04	3.41	2.35	1.84	1.36	1.77	1.88	7.10	4.30	2.05	1.41	1.16	41.67
1940	1.09	4.49	3.18	1.74	1.02	0.93	1.12	0.99	0.88	0.91	0.91	0.94	18.20
1941	1.43	2.12	1.72	20.13	8.16	2.42	2.29	2.30	2.11	1.37	1.29	1.67	47.01
1942	2.24	35.07	24.88	6.18	1.84	8.95	16.88	6.73	2.51	2.20	9.49	5.14	122.11
1943	4.52	13.05	9.04	3.31	7.02	4.03	2.02	1.46	1.26	1.38	1.19	15.58	63.86
1944	7.65	2.37	1.12	1.37	3.54	6.99	3.55	1.68	1.35	1.12	0.86	1.04	32.64
1945	21.84	8.42	0.94	0.80	2.23	14.64	6.97	2.41	1.58	1.21	0.89	0.83	62.76
1946	1.16	5.28	3.48	2.14	2.37	14.79	17.99	6.66	13.69	6.62	2.11	1.57	77.86
1947	1.51	43.69	17.97	2.87	11.69	10.70	4.51	2.15	1.24	0.76	0.53	0.44	98.06
1948	5.33	3.65	2.21	1.86	26.40	16.80	5.17	2.54	1.46	0.95	0.83	1.00	68.20
1949	1.60	14.04	6.22	5.50	4.43	3.20	3.69	6.90	3.82	2.11	2.61	2.50	56.62
1950	2.41	1.89	13.94	7.11	2.54	5.26	3.17	1.56	1.20	1.03	1.17	1.62	42.90
1951	11.32	4.81	4.98	6.38	3.54	3.65	4.54	3.09	1.83	1.22	0.78	1.08	47.22
1952	1.40	1.33	1.19	1.19	1.67	2.09	2.18	1.78	1.21	0.84	0.85	1.83	17.56
1953	5.62	17.23	11.76	3.78	1.81	3.03	2.36	2.05	2.52	2.37	1.62	1.76	55.91
1954	34.94	13.44	1.83	11.65	19.66	11.79	4.01	1.87	1.43	1.12	0.72	1.19	103.65
1955	2.00	2.36	1.55	0.59	1.36	25.82	12.20	3.17	2.23	1.83	1.29	1.48	55.88
1956	6.12	28.48	45.72	16.37	4.72	16.86	19.49	6.59	2.05	1.69	1.50	2.25	151.84
1957	6.77	4.99	3.79	9.64	20.24	8.54	14.76	6.27	1.37	1.00	0.89	0.88	79.14
1958	1.07	4.42	3.36	1.77	1.72	2.29	2.59	41.53	15.67	2.58	3.81	3.20	84.01
1959	2.59	2.35	2.11	1.92	1.73	4.33	4.07	4.08	2.88	1.82	1.60	2.00	31.48
1960	2.06	4.85	10.43	6.97	3.11	4.96	33.93	13.36	2.69	2.48	2.26	1.74	88.84
1961	1.51	8.35	4.70	2.39	2.59	15.60	6.70	1.88	1.40	0.92	1.15	1.49	48.68
1962	3.69	13.76	5.93	16.22	7.01	45.62	17.14	2.39	1.91	18.67	8.02	1.61	141.97
1963	1.99	6.39	3.95	18.85	13.66	9.36	12.94	5.38	35.65	14.00	2.13	1.73	126.03
1964	11.31	5.05	1.24	1.24	1.38	1.00	0.69	1.03	26.08	11.53	6.83	4.36	71.74
1965	26.58	17.38	4.54	1.91	1.74	1.14	0.76	17.90	8.06	2.01	1.45	1.72	85.19
1966	1.75	1.48	1.57	4.41	3.46	31.35	25.17	6.75	1.99	6.25	3.91	1.66	89.75
1967	1.13	1.82	1.82	1.39	1.57	1.80	1.77	1.34	0.89	0.73	1.11	2.47	17.84
1968	3.16	5.83	3.58	1.63	8.38	21.56	8.15	17.86	7.85	2.14	1.65	1.43	83.22
1969	1.82	3.95	2.90	1.51	1.31	1.18	0.96	1.08	1.82	2.02	17.05	8.14	43.74
1970	28.31	14.48	3.52	2.15	2.35	2.53	2.74	24.31	9.85	5.54	14.79	6.59	117.16
1971	24.40	10.01	2.48	2.12	22.82	9.39	2.07	1.46	1.26	1.25	1.14	0.92	79.32
1972	0.78	4.26	3.34	2.22	1.91	2.18	7.69	3.97	1.31	0.84	1.18	2.35	32.03
1973	3.09	14.73	6.27	1.81	3.41	7.26	4.02	22.00	9.86	3.02	1.87	1.20	78.54
1974	1.12	1.76	3.13	2.50	2.09	2.30	2.26	1.79	1.25	0.98	0.92	18.84	38.94
1975	8.02	1.91	9.62	4.89	20.08	66.00	25.20	12.91	5.62	1.79	1.27	1.85	159.16
1976	44.67	16.35	1.42	1.49	11.14	5.75	2.17	1.29	1.06	1.13	1.52	2.27	90.26
1977	4.82	16.56	17.75	6.04	2.10	2.24	97.17	37.64	3.94	2.09	1.61	1.79	193.75
1978	13.05	6.55	2.34	1.56	1.45	5.68	3.49	1.72	1.22	2.15	3.29	3.27	45.77
1979	4.77	3.03	1.81	1.31	1.43	1.72	1.47	1.28	1.14	0.97	0.82	11.14	30.89
1980	5.66	10.51	5.34	4.57	3.21	2.06	1.33	2.30	2.67	1.91	2.22	2.33	44.11
1981	1.59	1.34	1.21	1.51	1.63	26.87	13.18	3.30	1.87	1.47	1.07	0.89	55.93
1982	1.59	1.77	1.03	0.70	0.79	0.80	0.79	0.74	0.64	20.91	9.08	2.30	41.14
1983	2.27	6.23	3.84	6.48	4.15	2.88	5.55	3.65	2.71	11.30	5.61	2.18	56.85
1984	1.95	10.76	5.33	2.28	43.98	16.46	1.86	1.12	0.82	0.77	0.60	0.47	86.40
1985	3.23	11.79	5.31	7.92	3.92	1.87	1.90	1.51	1.05	0.77	1.65	7.49	48.41
1986	13.55	5.99	2.11	1.86	1.42	1.85	2.25	1.75	1.41	1.15	1.39	66.35	101.08
1987	24.55	10.93	5.15	1.82	17.57	51.00	17.51	13.38	6.56	6.79	6.35	3.37	164.98
1988	2.48	13.65	27.17	8.81	23.31	10.23	14.81	6.57	2.18	1.91	1.33	1.09	113.54
1989	11.68	25.07	8.35	1.64	1.42	13.75	6.10	1.43	0.91	0.68	1.47	2.13	74.63
1990	2.60	2.27	1.48	1.82	8.08	4.34	1.62	1.12	0.99	0.83	0.85	1.39	27.39
1991	10.42	13.85	4.93	1.69	1.44	1.27	1.52	1.40	1.00	0.74	0.73	1.15	40.14
1992	1.77	1.88	1.89	1.69	1.40	1.00	0.85	0.83	0.69	0.56	0.60	1.54	14.70
1993	5.22	3.78	11.49	4.94	29.08	12.36	2.27	1.05	0.66	0.89	1.85	1.80	75.39
1994	1.26	0.90	5.00	3.24	1.53	15.89	26.81	9.36	8.96	4.85	1.82	1.35	80.97
1995	1.82	2.02	31.59	13.03	10.80	4.90	1.79	1.47	1.12	7.80	4.53	1.95	82.82
1996	2.39	34.30	13.06	3.40	13.60	6.55	22.86	9.45	49.52	21.00	3.61	2.50	182.24
month	496.59	713.02	526.53	383.92	586.41	818.84	626.68	429.87	368.69	351.61	226.41	315.73	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.66	0.90	0.94	0.59	0.79	0.80	0.69	0.74	0.64	0.56	0.53	0.44	14.70
max	44.67	48.10	45.72	26.71	43.98	66.00	97.17	41.53	49.52	70.76	25.56	66.35	193.75
median	2.41	4.99	3.79	2.50	3.11	5.68	4.01	2.15	1.82	1.83	1.52	1.72	71.16
mean	6.45	9.26	6.84	4.99	7.62	10.63	8.14	5.58	4.79	4.57	2.94	4.10	75.90
Sum of the monthly means =				75.90									
s.d.	8.58	10.29	8.05	5.47	9.14	12.38	12.60	7.81	8.36	9.20	4.01	8.46	41.90
c.v.	1.33	1.11	1.18	1.10	1.20	1.16	1.55	1.40	1.75	2.01	1.36	2.06	0.55

APPENDIX 6.6
T60K (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.52	1.09	3.23	2.40	2.06	8.38	4.47	1.88	1.10	0.66	0.42	0.59	26.80
1921	1.19	11.48	11.67	4.03	1.39	0.83	0.53	10.81	10.17	3.76	2.15	2.24	60.25
1922	11.20	22.53	7.51	20.65	29.51	18.10	4.72	1.10	0.79	18.72	7.73	1.22	143.78
1923	0.74	0.76	1.09	11.90	11.69	3.66	0.84	0.58	0.58	0.52	0.58	1.03	33.97
1924	1.52	1.91	3.41	2.35	2.33	16.97	7.32	2.03	1.38	1.04	0.83	1.18	42.27
1925	1.55	1.62	1.55	1.69	3.47	18.92	7.39	1.56	2.06	2.12	1.38	1.31	44.62
1926	3.64	7.19	3.79	1.81	1.39	25.59	9.62	0.97	0.59	0.44	0.42	0.63	56.08
1927	1.34	1.18	1.18	1.68	3.61	2.76	1.64	1.22	1.11	0.87	1.14	1.24	18.97
1928	1.32	1.88	1.90	1.67	1.46	7.11	3.44	1.32	17.48	13.52	4.65	10.44	66.19
1929	17.81	12.86	3.88	1.23	0.91	1.22	1.66	1.52	1.97	2.43	2.60	11.08	59.17
1930	5.04	1.51	1.19	10.86	11.89	20.30	7.32	1.34	0.80	53.89	19.59	1.61	135.34
1931	1.69	1.66	1.33	0.93	6.82	4.10	1.82	1.58	1.85	2.03	1.79	11.41	37.01
1932	7.89	29.03	21.62	4.95	1.15	1.94	1.94	1.49	1.13	0.87	0.67	0.56	73.24
1933	0.52	5.22	11.29	15.79	5.64	4.71	2.90	1.58	1.14	4.03	2.74	1.14	56.70
1934	0.77	1.53	10.53	4.68	1.22	1.65	14.29	20.04	22.87	7.70	3.71	2.57	91.56
1935	1.65	1.53	0.88	0.62	22.59	24.26	6.87	9.19	4.84	2.17	1.45	1.18	77.23
1936	5.37	38.78	13.61	1.22	9.97	11.52	4.16	1.27	0.83	0.88	1.06	1.00	89.67
1937	1.04	1.10	2.09	2.12	1.82	1.33	5.00	3.12	1.90	2.00	1.72	1.08	24.32
1938	0.85	1.49	2.64	2.75	14.64	7.23	2.27	1.94	1.80	2.01	2.24	18.07	57.93
1939	9.73	2.74	1.97	1.57	1.43	1.78	1.63	4.65	3.06	1.55	1.03	0.96	32.10
1940	0.94	4.20	2.69	1.30	0.75	0.80	1.01	0.85	0.76	0.81	0.80	0.75	15.66
1941	1.10	1.63	1.28	10.70	4.83	2.61	2.19	2.42	2.13	1.29	1.08	1.31	32.57
1942	1.73	31.96	21.11	5.01	1.56	6.01	13.15	5.49	2.11	1.78	9.12	4.64	103.67
1943	3.13	9.81	6.19	2.39	3.90	3.46	2.25	1.43	1.14	1.15	0.96	16.11	51.92
1944	7.56	2.03	0.95	1.07	4.15	6.28	2.92	1.31	1.05	0.86	0.66	0.81	29.65
1945	18.04	6.93	0.74	0.58	1.22	9.86	4.99	1.89	1.28	0.96	0.69	0.62	47.80
1946	0.88	1.76	1.80	1.51	1.66	11.92	13.68	5.02	11.02	5.35	1.75	1.33	57.68
1947	1.28	35.03	15.05	2.43	7.41	9.11	4.23	2.01	1.17	0.69	0.48	0.38	79.27
1948	4.37	2.99	1.72	1.41	16.59	12.27	4.25	2.02	1.17	0.75	0.65	0.76	48.95
1949	1.19	9.11	4.22	2.00	2.87	2.51	2.39	5.21	3.06	1.75	2.13	1.98	38.42
1950	1.90	1.44	8.44	4.37	1.73	1.86	1.78	1.25	0.93	0.76	0.84	1.25	26.55
1951	9.28	3.92	3.37	6.93	3.55	7.03	4.95	2.59	1.68	1.14	0.75	0.98	46.17
1952	1.25	1.13	1.00	1.02	1.34	1.57	1.61	1.32	0.95	0.69	0.67	1.55	14.10
1953	6.42	15.33	7.27	2.21	1.32	1.79	1.73	1.71	2.20	2.10	1.43	1.44	44.95
1954	25.47	9.91	1.43	6.55	14.56	6.67	2.27	1.43	1.13	0.90	0.58	0.96	71.86
1955	1.67	1.99	1.27	0.46	1.00	22.02	9.85	2.50	2.03	1.71	1.21	1.29	47.00
1956	4.77	24.51	35.64	11.30	2.40	13.40	15.88	5.43	1.83	1.53	1.31	1.86	119.86
1957	3.88	2.95	2.35	7.45	14.74	6.08	12.49	5.29	1.12	0.88	0.85	0.83	58.91
1958	0.97	4.75	3.08	1.43	1.24	1.53	1.74	26.07	10.17	2.15	3.50	2.93	59.56
1959	2.41	2.13	1.86	1.63	1.43	2.19	3.66	3.02	2.09	1.39	1.22	1.59	24.62
1960	1.79	2.99	9.71	7.22	2.90	2.23	27.21	10.90	2.09	1.77	1.55	1.21	71.57
1961	1.10	5.50	3.44	1.94	2.02	13.58	5.75	1.50	1.13	0.73	0.88	1.07	38.64
1962	3.41	10.03	4.40	13.15	5.67	38.22	14.34	1.89	1.46	14.32	6.23	1.27	114.39
1963	1.66	4.53	2.93	12.70	10.03	6.96	8.24	3.66	30.95	12.04	1.70	1.32	96.72
1964	8.06	3.74	1.01	0.99	1.14	0.84	0.56	0.80	18.89	8.90	4.28	3.23	52.44
1965	23.37	15.59	3.96	1.52	1.41	0.94	0.62	13.78	6.30	1.62	1.14	1.26	71.51
1966	1.29	1.14	1.26	3.44	2.69	27.48	21.94	5.77	1.67	3.56	2.68	1.34	74.26
1967	0.89	1.49	1.53	1.13	1.21	1.39	1.36	1.02	0.67	0.53	0.88	2.32	14.42
1968	3.04	5.11	2.85	1.15	5.32	16.58	6.54	13.58	6.02	1.63	1.19	0.97	63.98
1969	1.27	2.60	2.18	1.22	1.22	1.15	0.87	0.89	1.43	1.54	14.94	6.97	36.28
1970	25.17	12.19	2.73	1.61	1.82	1.96	2.16	17.48	7.25	3.56	13.52	5.89	95.34
1971	18.40	7.65	1.91	1.52	14.79	6.29	1.48	1.02	0.94	0.94	0.85	0.66	56.45
1972	0.57	1.35	1.88	1.59	1.35	1.53	3.06	2.18	1.07	0.66	0.85	1.49	17.58
1973	2.04	7.16	3.25	1.16	1.63	5.32	3.18	16.86	7.52	2.17	1.30	0.83	52.42
1974	0.73	1.28	2.57	2.05	1.54	1.67	1.63	1.28	0.91	0.71	0.65	9.98	25.00
1975	4.71	1.55	10.39	4.90	14.63	52.47	18.09	9.66	4.57	1.48	1.05	1.38	124.88
1976	34.28	12.65	1.15	1.06	7.42	4.08	1.65	0.95	0.74	0.75	1.04	1.58	67.35
1977	2.23	13.18	14.23	4.77	1.61	1.70	75.37	28.77	2.98	1.64	1.29	1.46	149.23
1978	11.62	5.74	1.95	1.22	1.06	3.48	2.42	1.33	0.94	1.68	2.65	2.58	36.67
1979	2.55	2.05	1.43	1.00	1.07	1.32	1.15	0.98	0.85	0.69	0.59	5.99	19.67
1980	3.49	6.36	3.54	3.33	2.57	1.74	1.05	2.42	2.35	1.51	1.73	1.80	31.89
1981	1.19	0.96	0.90	1.17	1.28	20.06	8.52	2.03	1.40	1.07	0.78	0.60	39.96
1982	0.95	1.05	0.63	0.46	0.56	0.57	0.51	0.47	0.41	12.11	5.75	1.92	25.39
1983	1.84	3.66	2.63	3.12	2.62	2.06	2.22	2.15	1.82	5.15	3.28	1.77	32.32
1984	1.48	2.18	2.09	1.73	35.28	13.16	1.36	0.77	0.57	0.54	0.43	0.33	59.92
1985	2.34	10.16	4.50	3.50	2.17	1.38	1.31	1.01	0.72	0.53	1.31	4.93	33.86
1986	10.35	4.76	1.66	1.48	1.16	1.50	1.73	1.32	1.06	0.84	1.03	53.99	80.88
1987	19.96	9.28	4.34	1.56	19.32	43.89	14.45	10.00	5.02	4.29	4.99	2.82	139.92
1988	2.04	10.38	18.73	6.10	16.33	7.17	9.95	4.65	1.72	1.48	1.05	0.85	80.45
1989	7.58	18.62	6.33	1.15	0.98	9.52	4.39	1.10	0.69	0.51	1.03	1.42	53.32
1990	1.86	1.68	1.08	1.29	2.34	2.09	1.25	0.81	0.70	0.57	0.60	0.92	15.19
1991	5.07	8.65	3.39	1.04	0.82	0.78	1.02	0.98	0.71	0.51	0.52	0.81	24.30
1992	1.22	1.29	1.50	1.35	0.94	0.66	0.61	0.56	0.45	0.34	0.38	2.56	11.86
1993	6.22	3.39	9.76	4.12	24.63	10.06	1.80	0.90	0.55	0.72	1.73	1.75	65.63
1994	1.08	0.59	6.93	3.52	1.10	12.35	24.13	8.36	5.04	3.18	1.44	0.97	68.69
1995	1.19	1.24	22.72	10.32	4.63	2.53	1.46	1.15	0.82	10.63	5.16	1.52	63.37
1996	2.32	24.92	9.49	4.32	5.88	3.21	14.17	6.33	36.81	16.04	2.93	2.06	128.48
month	391.98	547.29	402.80	281.55	426.38	633.25	484.40	326.76	285.69	270.79	181.98	247.73	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.52	0.59	0.63	0.46	0.56	0.57	0.51	0.47	0.41	0.34	0.38	0.33	11.86
max	34.28	38.78	35.64	20.65	35.28	52.47	75.37	28.77	36.81	53.89	19.59	53.99	149.23
median	1.90	3.66	2.73	1.81	2.17	4.08	2.90	1.88	1.40	1.51	1.21	1.33	53.32
mean	5.09	7.11	5.23	3.66	5.54	8.22	6.29	4.24	3.71	3.52	2.36	3.22	58.19
Sum of the monthly means =				58.19									
s.d.	6.86	8.44	6.25	3.96	7.13	10.08	9.88	5.71	6.47	7.01	3.28	6.76	33.48
c.v.	1.35	1.19	1.19	1.08	1.29	1.23	1.57	1.35	1.74	1.99	1.39	2.10	0.58

APPENDIX 7

PRESENT DAY FLOW RECORDS FOR QUATERNARY CATCHMENT (2030)

APPENDIX 7.1
T60A (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.21	2.13	3.51	3.51	2.88	3.67	4.01	2.68	1.37	0.80	0.51	0.64	26.92
1921	1.56	16.44	25.74	9.92	3.10	1.68	0.72	2.63	8.53	5.84	3.60	2.81	82.57
1922	3.09	21.63	9.90	4.71	41.36	27.87	7.07	1.66	0.92	24.01	11.23	2.54	155.99
1923	1.43	1.20	1.57	24.82	19.98	6.17	1.54	0.80	0.67	0.58	0.58	0.92	60.26
1924	1.85	3.38	8.28	4.43	1.69	4.41	4.57	2.92	1.58	1.00	0.66	0.63	35.40
1925	1.34	2.91	3.28	3.31	2.97	18.95	8.53	2.10	2.11	2.09	1.35	1.49	50.43
1926	3.00	4.18	4.58	3.49	2.31	32.37	12.96	1.68	0.85	0.65	0.75	0.96	67.78
1927	1.79	1.91	3.14	19.87	10.25	4.06	2.16	1.13	0.84	0.69	0.86	1.07	47.77
1928	1.48	2.16	2.01	1.55	1.15	2.40	2.74	1.86	3.63	5.89	4.86	6.70	36.43
1929	8.75	6.62	4.46	3.50	2.83	3.22	3.35	2.28	2.13	2.27	2.49	3.49	45.39
1930	3.84	3.37	3.99	22.07	11.10	29.51	12.02	1.98	0.92	40.48	17.05	2.90	149.23
1931	2.50	2.74	2.32	1.67	4.41	4.27	2.28	1.37	1.43	1.79	1.65	2.64	29.07
1932	4.40	40.90	35.21	9.21	1.35	1.49	1.70	1.27	0.86	0.72	0.61	0.50	98.22
1933	0.49	6.25	20.70	12.53	5.13	3.42	2.78	2.01	1.27	1.63	1.75	1.23	59.19
1934	1.17	2.17	9.30	5.54	2.62	2.37	4.11	19.38	24.88	9.68	3.98	3.12	88.32
1935	2.25	2.33	1.47	0.88	15.08	16.57	6.11	3.54	3.97	2.95	1.72	1.32	58.19
1936	2.60	67.72	25.50	3.75	24.80	11.61	3.32	1.63	0.87	0.74	0.68	0.64	143.86
1937	1.01	1.66	2.39	2.58	3.20	2.71	2.56	2.34	1.78	1.70	1.57	1.20	24.70
1938	1.26	2.20	3.74	3.82	9.08	5.57	2.58	2.01	1.69	1.69	1.83	9.17	44.64
1939	7.45	5.46	5.15	3.71	2.36	2.20	2.06	3.54	4.37	3.11	1.76	1.27	42.44
1940	1.40	3.07	4.89	3.72	1.81	1.43	1.46	1.02	0.67	0.65	0.69	0.87	21.68
1941	1.53	2.26	2.07	4.14	4.26	4.14	3.53	2.66	1.86	1.16	1.07	1.41	30.09
1942	2.46	30.26	33.81	11.08	3.00	6.35	13.67	7.10	3.40	2.87	4.02	4.51	122.53
1943	6.37	24.55	17.79	6.04	3.85	3.79	2.55	1.57	1.25	1.27	1.06	2.74	72.83
1944	4.69	3.75	1.80	1.69	2.61	3.83	3.12	1.85	1.24	0.95	0.69	0.73	26.95
1945	3.38	3.60	1.87	1.22	2.24	6.79	5.16	2.74	1.52	1.07	0.77	0.80	31.16
1946	1.34	2.97	3.69	3.22	3.72	7.86	6.49	4.41	9.99	6.77	3.26	2.13	55.85
1947	2.08	51.25	21.12	4.90	8.53	6.54	4.66	2.85	1.38	0.77	0.52	0.42	105.02
1948	2.09	3.54	3.49	3.25	5.75	5.11	4.11	2.78	1.42	0.91	0.78	0.82	34.05
1949	1.58	3.86	3.98	5.30	4.87	4.21	3.65	3.49	2.77	2.17	2.81	2.86	41.55
1950	2.65	2.35	16.42	8.39	3.10	3.36	2.88	1.68	1.09	0.89	1.05	1.64	45.50
1951	3.61	3.49	3.29	3.96	4.17	3.67	3.70	3.16	1.94	1.21	0.78	0.97	33.95
1952	1.28	1.48	1.55	1.47	1.87	2.06	1.87	1.38	0.87	0.62	0.66	1.42	16.53
1953	3.03	8.83	12.56	6.14	3.20	3.17	2.31	1.95	2.20	1.96	1.32	1.49	48.16
1954	31.78	14.15	3.41	8.98	27.63	12.13	4.04	2.52	1.61	1.16	0.73	1.08	109.22
1955	2.04	2.98	2.34	0.92	1.42	15.78	9.29	4.25	2.76	1.95	1.34	1.38	46.45
1956	2.90	23.20	51.79	18.51	4.64	14.03	10.03	4.70	2.56	1.81	1.56	2.81	138.54
1957	5.04	13.20	6.99	4.25	17.87	8.84	4.71	3.72	1.88	1.13	0.85	0.82	69.30
1958	1.16	2.99	4.31	3.38	2.82	2.85	2.80	42.53	17.12	3.26	3.09	2.79	89.10
1959	2.71	3.28	3.44	2.84	2.41	2.86	3.23	2.95	2.10	1.39	1.19	1.58	29.98
1960	2.02	3.40	10.68	7.16	4.09	4.02	32.77	13.82	2.84	1.94	1.44	1.20	85.38
1961	1.31	3.10	4.18	3.85	4.46	8.57	4.98	2.27	1.43	0.91	0.99	1.22	37.27
1962	2.40	13.46	7.83	19.48	9.02	52.19	20.26	2.75	1.60	3.46	4.36	2.68	139.49
1963	3.07	12.68	12.03	21.68	9.78	4.35	4.93	3.99	35.43	15.25	3.19	2.32	128.70
1964	17.21	8.35	2.63	2.38	2.36	1.58	0.90	0.94	10.90	8.31	5.99	5.28	66.83
1965	22.29	19.97	7.26	3.22	2.49	1.37	0.75	8.52	6.10	2.83	1.80	1.95	78.55
1966	2.21	2.44	2.82	3.43	3.85	36.52	16.34	4.37	2.78	3.16	2.96	1.73	82.61
1967	1.37	2.69	2.82	2.08	1.90	1.97	1.87	1.31	0.75	0.57	0.95	2.12	20.40
1968	3.34	4.13	3.97	2.39	2.94	15.75	7.66	3.80	3.52	2.38	1.74	1.60	53.22
1969	2.30	3.65	3.88	2.63	1.84	1.27	0.77	0.84	1.38	1.49	2.16	3.37	25.58
1970	22.54	11.53	5.35	4.59	3.86	3.27	2.74	4.04	4.19	3.69	5.55	5.31	76.66
1971	28.76	12.90	3.89	3.43	11.44	6.64	2.72	1.41	1.03	1.02	0.81	0.65	74.70
1972	0.77	2.68	3.71	2.91	2.56	2.78	2.62	1.72	0.87	0.58	0.83	1.77	23.80
1973	2.72	4.47	4.19	3.54	4.19	10.28	5.98	5.55	5.37	3.68	1.97	1.15	53.09
1974	1.25	2.69	4.34	4.26	4.16	4.14	3.06	1.67	0.88	0.62	0.54	2.28	29.89
1975	3.52	3.23	17.39	12.35	18.82	67.67	24.37	4.48	3.38	1.99	1.20	1.63	160.03
1976	22.31	10.68	3.83	3.32	3.22	3.06	2.14	1.18	0.82	0.79	0.81	1.27	53.43
1977	3.31	13.39	12.28	6.24	3.98	3.56	94.09	35.10	3.57	1.95	1.40	1.81	180.68
1978	3.74	9.29	6.31	3.44	2.62	3.07	2.75	1.58	0.82	1.26	1.79	1.76	38.43
1979	2.25	2.71	2.70	2.04	1.53	1.54	1.23	0.89	0.69	0.55	0.45	2.50	19.08
1980	4.30	18.38	9.75	4.96	4.66	3.62	2.04	1.61	1.51	1.08	1.31	1.67	54.89
1981	1.45	1.51	1.60	2.41	2.73	3.87	4.68	3.41	2.01	1.41	0.93	0.79	26.80
1982	1.99	2.41	1.61	1.20	1.13	0.97	0.89	0.82	0.64	0.78	0.96	1.06	14.46
1983	1.66	3.39	4.41	10.46	9.82	6.29	8.86	5.39	2.70	2.50	2.34	1.86	59.68
1984	1.90	3.19	4.47	4.63	42.73	16.66	2.23	1.04	0.66	0.61	0.44	0.35	78.91
1985	7.44	8.61	6.91	4.96	3.45	2.30	1.44	0.83	0.56	0.49	1.65	3.14	41.78
1986	7.63	15.85	7.55	3.62	2.90	2.99	2.71	1.73	1.09	0.78	1.27	52.84	100.96
1987	21.86	11.52	22.40	9.21	25.49	57.81	20.07	4.87	4.86	4.84	4.84	4.03	191.80
1988	3.52	10.09	19.86	8.20	34.07	14.03	3.88	3.24	2.27	1.80	1.19	0.88	103.03
1989	2.92	55.49	21.45	3.44	2.30	6.94	5.00	2.30	1.15	0.73	1.48	2.12	105.32
1990	3.27	3.69	2.97	3.59	4.31	3.41	1.71	0.81	0.58	0.47	0.43	0.92	26.16
1991	10.58	9.87	5.07	3.01	2.39	2.28	1.97	1.24	0.68	0.47	0.45	0.63	38.64
1992	1.20	2.84	4.24	3.76	3.40	2.51	1.58	0.99	0.56	0.39	0.40	1.63	23.50
1993	17.91	10.01	17.21	8.18	8.47	17.07	7.21	1.64	0.82	1.12	1.46	1.08	92.18
1994	0.81	0.88	1.09	1.74	1.61	5.16	5.71	4.32	3.55	2.86	1.60	1.14	30.47
1995	1.82	3.23	58.52	23.62	23.18	10.73	2.94	1.31	0.66	1.32	1.79	1.54	130.66
1996	2.09	22.54	11.05	6.70	5.83	5.30	17.51	8.47	38.23	16.83	4.43	3.21	142.19
month	376.63	733.36	699.10	466.38	555.00	698.86	503.79	302.37	275.18	237.19	155.63	201.00	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.49	0.88	1.09	0.88	1.13	0.97	0.72	0.80	0.56	0.39	0.40	0.35	14.46
max	31.78	67.72	58.52	24.82	42.73	67.67	94.09	42.53	38.23	40.48	17.05	52.84	191.80
median	2.46	3.65	4.34	3.76	3.72	4.14	3.32	2.28	1.58	1.39	1.34	1.58	53.43
mean	4.89	9.52	9.08	6.06	7.21	9.08	6.54	3.93	3.57	3.08	2.02	2.61	67.59
Sum of the monthly means = 67.59													
s.d.	6.67	12.47	10.75	5.58	8.92	12.55	11.63	6.41	6.58	5.74	2.42	5.98	43.20
c.v.	1.36	1.31	1.18	0.92	1.24	1.38	1.78	1.63	1.84	1.86	1.20	2.29	0.64

APPENDIX 7.2
ACCUMALTIVE RUNOFF FOR T60B, C AND D (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	2.96	5.95	16.18	12.12	8.65	20.65	14.26	7.21	3.61	1.99	1.20	1.61	96.39
1921	4.43	63.73	85.91	29.75	8.57	4.82	2.01	18.99	34.51	17.17	8.89	7.27	286.05
1922	8.58	76.07	32.07	29.96	127.32	88.63	21.72	3.94	2.19	79.63	34.30	6.09	510.50
1923	3.49	3.12	4.63	89.42	72.20	19.62	3.74	1.98	1.69	1.42	1.43	2.47	205.21
1924	5.34	14.69	41.54	17.20	4.42	31.48	18.18	7.45	4.05	2.47	1.58	1.54	149.94
1925	3.74	11.36	10.57	13.34	9.99	71.72	29.08	5.16	5.62	5.67	3.55	4.09	173.89
1926	10.41	15.09	21.43	12.01	6.53	107.13	40.82	4.01	2.00	1.52	1.87	2.52	225.34
1927	5.10	5.55	21.87	71.22	37.90	12.42	5.56	2.94	2.18	1.75	2.27	2.89	171.65
1928	4.19	6.40	6.12	4.85	3.69	13.35	9.89	5.23	23.58	19.05	11.91	29.33	137.59
1929	34.42	24.65	13.06	9.93	8.40	13.83	11.10	6.47	6.09	6.46	7.14	10.82	152.37
1930	11.30	9.84	23.83	76.92	43.11	89.29	33.97	4.81	2.18	118.81	48.27	7.08	469.41
1931	6.61	7.72	6.84	5.14	34.61	18.48	5.83	3.64	3.92	4.98	4.60	8.56	110.93
1932	17.48	125.10	110.11	27.88	3.41	4.36	5.13	3.75	2.42	1.92	1.57	1.25	304.38
1933	1.23	35.84	72.57	48.93	17.30	9.38	8.04	5.84	3.56	4.61	4.96	3.38	215.64
1934	3.25	6.46	46.79	21.66	7.16	7.01	29.72	61.54	73.25	26.72	9.97	8.14	301.67
1935	6.03	6.61	4.23	2.64	63.66	62.44	19.11	12.32	11.47	7.70	4.41	3.44	204.06
1936	7.57	199.25	73.81	13.46	85.13	36.95	8.79	4.26	2.22	1.85	1.70	1.61	436.60
1937	2.76	4.86	7.41	8.22	15.79	9.87	7.58	6.94	5.15	4.82	4.41	3.30	81.11
1938	3.53	6.56	22.21	14.32	43.29	20.70	6.71	5.51	4.69	4.67	5.11	41.89	179.19
1939	28.85	16.09	23.90	12.88	6.43	6.52	6.22	21.58	15.16	7.85	4.41	3.21	153.10
1940	3.76	15.91	27.32	13.12	4.55	4.07	4.31	2.95	1.84	1.70	1.82	2.35	83.70
1941	4.41	6.74	6.33	33.98	18.64	15.86	11.17	7.36	5.13	3.06	2.83	3.90	119.41
1942	7.18	101.30	108.39	33.09	8.28	36.89	51.70	21.06	8.57	7.52	17.77	13.98	415.73
1943	29.90	78.72	61.30	19.36	17.88	12.69	6.96	4.33	3.43	3.48	2.86	14.03	254.94
1944	15.17	10.24	4.91	5.15	8.37	22.15	12.01	4.83	3.26	2.45	1.72	1.87	92.13
1945	26.64	14.79	4.63	3.42	8.65	39.11	19.87	6.92	3.85	2.68	1.91	2.04	134.51
1946	3.74	13.38	12.24	9.68	20.22	39.39	26.42	12.48	37.74	20.85	7.91	5.36	209.41
1947	5.56	155.10	68.77	17.64	38.96	28.82	13.96	7.24	3.47	1.85	1.19	0.95	343.51
1948	8.18	10.88	10.47	9.97	37.62	20.59	11.20	7.74	3.83	2.34	1.99	2.15	126.96
1949	4.51	29.63	16.59	31.53	18.73	12.03	10.47	10.13	7.97	6.11	8.10	8.27	164.07
1950	7.68	6.88	65.42	29.29	8.57	14.52	9.67	4.58	2.92	2.33	2.83	4.63	159.32
1951	21.09	12.64	12.10	15.72	15.33	11.29	12.50	9.60	5.37	3.22	1.97	2.60	123.43
1952	3.56	4.27	4.69	4.64	6.08	6.63	5.93	4.21	2.49	1.66	1.75	4.06	49.97
1953	11.01	41.85	50.08	19.64	8.92	9.50	6.95	5.82	6.54	5.67	3.66	4.22	173.86
1954	102.73	43.17	9.09	44.49	91.89	38.29	11.39	6.70	4.28	3.02	1.83	2.94	359.82
1955	5.87	8.93	7.09	2.77	4.61	65.95	35.67	11.82	6.97	4.99	3.41	3.66	161.74
1956	10.83	79.25	154.68	56.56	16.33	54.08	40.55	14.60	6.25	4.51	4.01	8.62	450.27
1957	28.46	45.55	20.04	22.37	63.61	27.25	21.39	12.32	4.50	2.69	2.02	2.04	252.24
1958	3.14	16.29	16.44	10.08	8.44	8.83	8.71	134.25	51.66	8.02	8.07	7.55	281.48
1959	7.60	9.71	10.35	8.77	7.68	10.37	10.32	8.89	6.14	3.87	3.26	4.47	91.43
1960	5.83	17.68	46.36	32.18	13.18	16.64	102.49	40.51	7.02	4.87	3.66	3.10	293.52
1961	3.55	18.36	14.58	12.93	31.49	39.33	16.03	5.62	3.62	2.23	2.55	3.28	153.57
1962	6.99	55.66	27.46	68.87	29.36	156.19	59.19	7.00	4.11	20.37	14.45	6.44	456.09
1963	9.55	49.64	48.13	73.22	30.12	13.75	24.09	13.41	105.62	43.52	7.74	5.92	424.71
1964	61.47	26.81	6.87	7.01	7.33	4.89	2.71	2.81	48.42	28.38	17.70	14.47	228.87
1965	72.78	66.52	21.87	8.90	7.42	4.11	2.18	42.77	22.08	6.79	4.42	5.14	264.98
1966	6.13	7.05	8.62	16.39	14.93	117.59	57.59	13.02	6.57	8.20	7.91	4.56	268.56
1967	3.69	10.05	8.94	6.24	6.00	6.26	5.89	3.98	2.13	1.48	2.63	6.22	63.51
1968	9.97	16.28	12.86	7.00	18.69	59.95	24.59	11.28	9.79	6.22	4.57	4.29	185.49
1969	6.57	15.15	12.73	7.79	5.70	3.94	2.33	2.51	4.11	4.31	6.36	10.03	81.53
1970	78.95	40.57	21.04	14.84	11.05	9.64	8.26	24.76	15.03	9.35	27.51	17.63	278.63
1971	88.44	37.87	10.53	12.18	51.20	23.85	7.10	3.74	2.72	2.69	2.10	1.64	244.06
1972	2.03	15.48	12.86	8.36	7.89	8.75	8.21	5.21	2.47	1.52	2.26	5.11	80.15
1973	8.06	31.29	17.12	11.50	21.32	43.78	19.74	27.24	17.68	9.11	4.84	2.81	214.49
1974	3.29	10.26	23.77	15.11	17.26	13.58	8.76	4.74	2.37	1.58	1.35	9.67	111.74
1975	10.89	9.19	67.18	51.78	65.21	194.19	67.88	12.02	9.26	5.30	3.11	4.50	500.51
1976	77.28	33.78	10.35	9.67	10.45	9.54	6.45	3.44	2.30	2.13	2.18	3.57	171.14
1977	18.70	50.69	47.59	22.60	11.64	10.31	270.66	99.54	9.09	4.92	3.56	4.94	554.24
1978	20.51	38.81	20.62	9.48	7.70	11.06	8.73	4.53	2.21	3.53	5.11	4.99	137.28
1979	6.56	8.09	8.31	6.41	4.89	4.93	3.86	2.67	1.95	1.44	1.12	15.13	65.36
1980	14.12	64.20	36.31	19.46	16.62	10.68	5.61	4.55	4.29	2.92	3.64	4.75	187.15
1981	4.07	4.36	4.87	10.39	9.31	26.21	17.33	8.94	5.29	3.68	2.37	2.02	98.84
1982	5.74	7.11	4.82	3.74	3.64	3.09	2.76	2.47	1.80	2.16	2.65	2.97	42.95
1983	4.82	17.85	17.44	46.31	42.96	26.34	34.58	16.59	6.61	6.49	6.25	5.02	231.26
1984	5.30	13.83	22.43	18.91	131.60	49.44	5.70	2.66	1.66	1.52	1.04	0.78	254.87
1985	37.55	37.74	31.96	17.09	9.58	6.57	4.18	2.33	1.48	1.24	4.79	9.30	163.81
1986	38.79	57.06	22.62	11.86	8.99	10.00	8.36	4.99	3.03	2.06	3.54	159.11	330.41
1987	64.05	43.26	74.68	27.82	85.60	170.53	56.50	17.91	14.32	12.86	13.20	11.17	591.90
1988	9.98	45.44	69.87	25.09	108.94	43.04	12.15	9.40	6.15	4.85	3.13	2.28	340.32
1989	17.96	162.27	60.49	9.57	6.83	40.01	19.84	5.72	2.84	1.72	4.04	5.99	337.28
1990	13.79	11.76	8.59	21.43	17.44	9.99	4.70	2.15	1.49	1.13	1.04	2.50	96.01
1991	46.81	41.30	16.01	8.23	7.12	7.06	6.07	3.69	1.89	1.18	1.11	1.65	142.12
1992	3.38	12.55	20.19	12.65	10.97	7.70	4.60	2.83	1.50	0.95	0.96	4.73	83.01
1993	66.66	35.09	60.14	26.03	40.20	61.77	22.01	3.89	1.90	2.87	3.92	2.85	327.33
1994	2.12	2.39	3.26	5.55	5.21	36.62	24.91	11.90	9.42	7.68	4.16	2.97	116.19
1995	5.12	12.87	176.58	81.38	76.35	31.76	7.72	3.42	1.63	3.56	4.93	4.24	409.56
1996	6.01	79.75	37.22	34.23	28.92	19.52	58.99	25.63	112.46	47.58	11.18	8.43	469.92
month	1329.80	2558.23	2431.28	1695.32	2004.03	2439.57	1621.36	951.27	842.06	685.47	441.54	614.38	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	1.23	2.39	3.26	2.64	3.41	3.09	2.01	1.98	1.48	0.95	0.96	0.78	42.95
max	102.73	199.25	176.58	89.42	131.60	194.19	270.66	134.25	112.46	118.81	48.27	159.11	591.90
median	7.18	16.09	20.19	14.32	13.18	16.64	10.47	5.84	4.11	3.68	3.56	4.29	187.15
mean	17.27	33.22	31.58	22.02	26.03	31.68	21.06	12.35	10.94	8.90	5.73	7.98	228.76

Sum of the monthly means = 228.76

s.d.	22.76	37.96	33.49	20.04	29.35	37.86	34.13	20.03	20.24	17.39	7.44	18.49	133.13
c.v.	1.32	1.14	1.06	0.91	1.13	1.19	1.62	1.62	1.85	1.95	1.30	2.32	0.58

APPENDIX 7.3
ACCUMALATIVE RUNOFF FOR T60E, F AND G (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.23	3.96	17.67	10.51	7.30	16.76	10.83	5.09	2.21	0.97	0.37	0.88	77.78
1921	3.33	45.91	48.76	16.14	4.39	1.84	0.65	19.30	21.12	10.47	6.89	7.06	185.86
1922	40.09	93.78	31.63	78.76	106.31	55.88	13.42	2.70	1.35	52.84	22.95	3.83	503.54
1923	2.08	2.53	4.16	44.53	37.41	10.83	1.79	0.67	0.61	0.57	0.71	2.29	108.18
1924	4.66	10.84	21.33	10.84	7.33	48.91	21.87	5.78	3.02	1.96	1.23	2.61	140.38
1925	4.84	7.51	7.04	10.25	9.69	63.02	24.75	3.96	4.58	4.72	2.72	2.98	146.06
1926	9.29	27.79	21.04	8.56	4.41	91.90	34.10	2.32	0.80	0.42	0.40	1.06	202.09
1927	3.84	3.89	5.27	10.94	17.18	9.91	4.18	2.25	1.77	1.30	2.13	2.68	65.34
1928	3.40	6.98	6.87	5.83	4.62	13.17	7.54	3.18	38.53	29.14	12.64	37.52	169.42
1929	61.51	50.35	16.23	4.85	3.05	3.50	4.33	3.37	4.18	5.40	6.19	23.56	186.52
1930	13.67	6.72	5.52	49.51	46.75	68.42	24.42	3.82	1.51	193.62	70.54	5.40	489.90
1931	5.95	6.95	6.07	3.66	37.17	18.17	4.86	3.27	3.70	4.37	3.70	28.44	126.31
1932	25.28	114.81	90.00	20.33	2.98	4.40	3.77	2.21	1.32	0.98	0.56	0.56	267.20
1933	0.73	22.44	46.75	56.49	19.50	8.89	6.55	3.79	2.19	4.65	5.51	2.90	180.39
1934	1.83	7.03	34.60	15.45	3.85	4.62	30.25	48.58	77.52	27.96	9.10	7.21	268.00
1935	5.09	5.55	3.20	1.47	71.69	72.09	20.12	15.16	11.10	6.56	3.54	2.54	218.11
1936	13.43	154.41	54.68	3.96	23.08	28.42	11.31	3.14	1.37	1.40	1.63	1.69	298.52
1937	2.51	3.41	12.67	9.74	6.52	3.94	7.40	6.29	4.41	4.51	3.72	2.10	67.22
1938	1.85	5.31	11.59	12.30	32.72	15.91	6.00	5.21	4.49	4.83	5.86	57.74	163.81
1939	35.43	11.35	11.40	6.28	2.94	3.45	3.32	6.98	6.79	4.29	2.48	1.93	96.64
1940	2.07	13.95	10.16	4.97	2.14	1.34	1.52	1.08	0.83	1.05	1.03	1.21	41.35
1941	2.94	6.48	5.12	56.95	22.79	5.52	4.48	4.04	3.41	1.95	1.84	3.00	118.52
1942	5.23	108.26	78.54	19.14	4.57	13.48	33.81	15.12	5.57	4.44	11.88	10.03	310.07
1943	14.19	45.94	31.02	10.24	14.00	8.83	4.22	2.32	1.71	2.08	1.67	31.16	167.38
1944	21.03	8.69	3.47	3.60	10.06	12.00	6.54	3.13	2.04	1.58	0.96	1.53	74.63
1945	57.92	23.20	2.76	1.77	7.21	26.86	14.21	5.29	2.69	1.82	1.05	0.99	145.77
1946	2.21	15.51	10.70	6.18	6.07	26.68	37.15	15.34	21.67	13.26	5.42	3.54	163.73
1947	3.63	136.62	58.25	9.19	25.18	19.07	9.36	4.66	1.93	0.83	0.37	0.33	269.42
1948	10.35	9.77	7.29	5.52	71.06	36.35	10.74	5.63	2.43	1.25	0.94	1.43	162.76
1949	3.50	41.82	18.97	15.21	11.62	7.81	7.13	8.35	6.30	4.40	5.42	5.36	135.89
1950	5.90	5.25	42.91	22.85	7.18	8.34	5.80	2.76	1.67	1.36	1.67	2.97	108.66
1951	25.22	12.02	17.66	17.65	9.32	7.00	7.68	5.95	3.28	1.82	0.78	1.66	110.04
1952	2.88	3.35	3.25	2.92	3.88	4.39	4.08	2.82	1.49	0.85	0.88	3.52	34.31
1953	13.19	55.44	38.69	11.61	4.45	5.40	4.39	3.64	4.42	4.18	2.56	3.25	151.22
1954	98.14	39.02	6.10	32.41	50.91	24.04	8.16	3.89	2.34	1.62	0.67	1.98	269.28
1955	4.64	7.75	4.73	0.93	2.74	59.39	26.42	6.83	4.56	3.39	2.04	2.70	126.12
1956	13.25	91.64	145.82	50.10	11.58	35.83	42.41	15.14	4.45	3.24	2.63	4.76	420.85
1957	15.26	18.81	16.23	26.63	52.67	21.27	27.76	12.76	2.81	1.64	1.23	1.23	198.30
1958	2.04	13.97	11.09	5.07	4.04	4.90	5.07	98.52	37.95	6.34	7.44	7.40	203.83
1959	6.96	7.15	6.75	5.57	4.29	7.83	7.85	7.47	5.45	3.34	2.75	3.99	69.40
1960	4.79	15.68	34.08	20.63	8.36	8.23	84.35	33.87	6.00	5.06	4.39	3.30	228.74
1961	3.24	24.22	15.23	7.15	7.35	27.46	12.89	3.94	2.29	1.19	1.71	2.67	109.34
1962	9.34	44.12	19.20	46.46	19.67	123.00	45.95	5.17	3.42	34.48	16.80	4.12	371.73
1963	5.92	20.63	13.54	53.88	32.34	16.05	24.28	11.53	89.96	36.17	5.45	3.99	313.74
1964	28.40	13.92	3.90	3.29	3.18	1.62	0.69	1.16	53.55	26.05	12.85	10.42	159.03
1965	80.58	58.29	15.85	5.45	4.28	2.02	0.76	28.83	15.40	4.87	2.91	3.61	222.85
1966	4.12	4.01	4.64	14.20	9.82	77.45	58.53	15.61	4.32	7.32	7.15	3.81	210.98
1967	2.47	6.86	5.87	3.56	3.60	3.64	3.08	1.85	0.84	0.63	1.52	5.01	38.93
1968	10.45	18.87	11.34	4.59	16.23	49.88	19.67	33.49	16.33	5.23	3.43	2.82	192.33
1969	4.35	14.88	10.02	4.15	2.90	2.05	1.15	1.27	2.85	3.41	29.17	18.13	94.33
1970	86.23	49.01	12.64	6.25	6.05	5.67	5.48	45.69	20.14	8.46	31.22	16.39	293.23
1971	74.83	31.83	8.57	6.24	59.35	24.26	4.40	2.35	1.71	1.81	1.56	1.15	218.06
1972	1.06	12.86	10.62	6.40	4.70	4.66	10.38	6.54	2.28	1.07	1.84	4.99	67.40
1973	8.98	44.94	19.31	5.15	9.36	12.21	7.70	43.83	21.53	7.51	3.95	2.18	186.65
1974	2.24	5.11	13.71	8.38	5.10	4.93	4.26	2.85	1.58	1.13	1.03	41.66	91.98
1975	19.59	6.30	32.32	15.46	50.93	188.19	66.28	20.63	11.11	4.35	2.49	4.01	421.66
1976	131.20	48.83	4.57	4.14	23.66	13.10	4.70	1.98	1.30	1.56	2.47	4.61	242.12
1977	12.05	53.01	57.55	18.82	5.33	4.85	271.19	98.82	8.36	4.83	3.20	3.72	541.73
1978	31.81	22.76	9.07	4.35	3.36	9.27	6.59	3.15	1.70	3.94	6.60	7.07	109.67
1979	12.41	8.89	5.70	3.56	3.28	3.47	2.40	1.72	1.37	1.13	0.81	18.24	62.98
1980	12.51	37.39	19.56	13.46	8.61	4.56	2.11	3.65	4.87	3.38	4.13	4.69	118.92
1981	3.36	3.43	3.32	3.95	3.84	63.72	28.44	6.83	3.74	2.57	1.54	1.18	125.92
1982	3.48	4.77	2.71	1.30	1.27	0.99	0.79	0.64	0.48	40.13	19.54	6.15	82.25
1983	6.23	21.51	12.96	16.69	10.81	6.79	7.45	6.28	5.29	14.07	10.03	5.70	123.81
1984	5.19	34.45	17.13	6.70	125.05	46.21	3.87	1.55	0.79	0.80	0.45	0.37	242.56
1985	7.41	37.44	17.17	20.99	10.26	4.10	3.51	2.29	1.20	0.72	2.80	12.19	120.08
1986	37.07	21.61	7.73	5.21	3.34	4.17	4.65	2.98	2.01	1.55	2.14	188.61	281.07
1987	70.86	38.98	17.77	5.20	42.55	141.08	48.68	19.24	12.18	10.55	11.47	8.29	426.85
1988	7.15	45.60	87.21	27.41	60.93	26.29	27.58	13.41	4.78	3.75	2.23	1.71	308.05
1989	26.55	80.49	27.81	4.48	3.28	23.99	11.92	2.87	1.19	0.69	2.53	4.34	190.14
1990	7.73	6.66	4.20	5.86	15.57	9.15	3.24	1.53	1.15	0.90	0.94	2.43	59.36
1991	22.60	45.36	17.19	4.73	3.37	2.28	2.49	2.00	1.07	0.64	0.64	1.79	104.16
1992	3.92	5.13	5.67	4.68	3.23	1.60	0.89	0.72	0.53	0.41	0.47	2.86	30.11
1993	12.52	13.19	36.42	14.81	78.62	32.23	4.97	1.59	0.52	1.13	3.35	3.39	202.74
1994	2.46	1.94	15.12	9.45	3.63	30.15	63.57	23.43	11.37	9.03	4.44	2.86	177.45
1995	4.53	5.90	99.46	41.78	23.16	10.76	3.70	2.37	1.43	8.26	7.93	4.76	214.04
1996	8.55	106.68	40.60	12.35	31.83	15.44	49.98	21.35	132.49	53.21	8.77	6.53	487.78
month	1326.77	2271.71	1715.75	1130.07	1482.85	1885.88	1412.81	848.82	760.70	733.39	440.05	706.77	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.73	1.94	2.71	0.93	1.27	0.99	0.65	0.64	0.48	0.41	0.37	0.33	30.11
max	131.20	154.41	145.82	78.76	125.05	188.19	271.19	98.82	132.49	193.62	70.54	188.61	541.73
median	6.96	15.51	13.54	8.56	8.36	10.83	7.40	3.96	3.02	3.39	2.63	3.54	167.38
mean	17.23	29.50	22.28	14.68	19.26	24.49	18.35	11.02	9.88	9.52	5.71	9.18	191.11
Sum of the monthly means = 191.11													
s.d.	25.16	32.89	25.55	15.92	24.68	33.38	34.10	17.88	20.97	24.07	9.64	22.97	117.36
c.v.	1.46	1.11	1.15	1.08	1.28	1.36	1.86	1.62	2.12	2.53	1.69	2.50	0.61

APPENDIX 7.4
T60H (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.78	1.93	12.97	6.39	7.83	18.05	7.99	2.93	1.73	1.02	0.64	0.97	63.23
1921	2.12	25.66	25.29	7.81	2.41	1.56	0.97	23.03	19.57	6.10	3.91	3.62	122.05
1922	22.81	41.24	13.09	39.98	53.28	33.55	8.41	1.60	1.18	33.44	13.20	1.73	263.51
1923	1.14	1.32	2.08	27.78	25.23	6.90	1.24	0.91	0.91	0.82	0.92	1.76	71.01
1924	2.82	7.51	13.84	5.99	7.89	32.24	13.43	3.26	2.03	1.53	1.18	1.90	93.62
1925	2.90	4.54	3.53	8.49	9.38	37.57	13.82	2.30	4.05	3.32	1.92	2.05	93.87
1926	8.95	15.64	12.10	4.52	2.44	52.15	18.91	1.41	0.87	0.65	0.64	1.04	119.32
1927	2.34	2.16	3.16	9.09	15.84	6.92	2.54	1.88	1.70	1.33	1.82	2.08	50.86
1928	2.22	4.51	3.53	3.09	2.92	17.27	7.22	1.97	29.33	20.92	6.65	21.95	121.58
1929	29.21	22.11	6.82	2.34	1.97	2.95	3.30	2.79	5.80	4.37	6.96	18.85	107.47
1930	7.91	2.58	2.38	29.03	28.95	38.63	13.02	2.20	1.29	94.37	33.69	2.31	256.36
1931	3.47	3.15	2.65	2.00	26.82	13.50	3.17	2.23	2.79	3.22	2.83	23.42	89.25
1932	16.10	48.16	40.31	9.54	1.78	4.21	3.11	1.94	1.45	1.14	0.89	0.82	129.45
1933	0.86	16.05	24.48	29.70	10.09	11.53	5.74	2.42	1.80	8.75	4.79	1.62	117.83
1934	1.16	4.24	19.72	8.20	2.14	8.35	25.00	31.17	40.25	13.30	8.67	4.62	166.82
1935	2.23	2.47	1.58	1.11	41.31	41.98	11.26	17.43	8.37	3.15	2.05	1.67	134.61
1936	12.65	65.79	22.37	1.96	20.27	23.08	7.44	1.83	1.19	1.22	1.41	1.42	160.63
1937	1.70	1.92	9.71	7.23	3.78	2.57	12.69	6.17	2.70	2.98	2.64	1.69	55.78
1938	1.39	3.45	7.41	9.38	22.52	11.65	3.82	3.66	3.21	3.32	4.63	34.81	109.25
1939	19.97	4.97	6.04	3.29	1.80	2.57	2.77	14.36	6.91	2.36	1.66	1.43	68.13
1940	1.41	10.97	5.75	2.37	1.50	1.38	1.64	1.41	1.21	1.22	1.20	1.24	31.30
1941	1.97	4.05	2.71	32.29	12.51	6.43	3.78	2.81	2.70	1.74	1.65	2.24	74.88
1942	3.94	49.79	37.11	9.10	2.50	17.17	25.51	9.01	3.02	2.76	15.61	7.50	183.02
1943	9.29	20.87	15.97	5.31	14.18	6.76	2.57	1.92	1.65	1.82	1.57	24.21	106.12
1944	13.39	3.61	1.40	2.00	11.19	13.69	5.17	2.00	1.67	1.39	1.07	1.34	57.92
1945	32.96	12.29	1.16	1.13	8.80	23.36	9.64	2.86	1.88	1.46	1.08	1.03	97.65
1946	1.55	12.29	6.23	2.98	6.82	23.41	26.13	8.94	19.95	8.98	2.44	1.91	121.63
1947	1.98	61.60	28.48	4.81	20.21	17.98	6.42	2.65	1.54	0.92	0.64	0.53	147.76
1948	11.19	6.02	2.99	2.80	41.05	26.51	9.21	3.46	1.58	1.06	0.96	1.23	108.06
1949	2.16	23.81	9.82	12.60	10.42	6.65	6.92	10.77	5.03	2.42	4.34	3.38	98.32
1950	3.22	2.49	23.48	14.44	4.29	11.23	5.35	1.84	1.47	1.27	1.48	2.16	72.72
1951	19.49	7.66	11.03	13.25	5.62	9.29	9.32	4.33	2.12	1.43	0.92	1.37	85.83
1952	1.88	1.89	1.78	1.85	2.64	3.30	3.38	2.68	1.74	1.16	1.13	3.45	26.88
1953	11.06	26.18	19.51	5.93	2.45	9.49	4.65	2.50	3.30	3.14	2.13	2.38	92.72
1954	50.13	18.89	2.44	21.40	30.44	18.76	5.79	2.26	1.79	1.39	0.89	1.57	155.75
1955	2.80	4.76	2.56	0.80	4.26	37.28	18.81	4.48	2.64	2.24	1.60	1.93	84.16
1956	12.75	40.99	63.04	25.77	10.13	25.14	27.84	8.83	2.41	2.05	1.87	5.00	225.82
1957	11.80	9.97	9.05	16.90	30.14	14.51	21.70	8.40	1.54	1.15	1.06	1.09	127.31
1958	1.41	11.01	6.03	2.27	2.43	4.25	3.89	57.62	21.23	3.06	8.08	4.94	126.22
1959	3.27	3.28	3.17	3.02	2.78	12.29	9.38	7.28	3.83	2.05	1.91	2.59	54.85
1960	2.82	11.90	18.63	13.52	5.04	10.93	46.72	17.45	3.29	3.15	2.95	2.31	138.71
1961	2.07	16.46	8.53	3.31	8.12	23.61	9.04	2.28	1.75	1.13	1.47	1.98	79.75
1962	9.52	22.19	8.52	26.71	10.87	63.09	23.34	2.99	2.47	27.52	11.17	1.85	210.24
1963	4.52	11.84	6.52	28.77	21.95	15.55	19.43	7.28	47.63	18.30	2.48	2.14	186.41
1964	18.90	7.79	1.57	1.80	2.10	1.54	1.02	1.46	38.14	17.42	10.30	5.76	107.80
1965	37.79	26.43	6.69	2.62	2.61	1.75	1.12	27.70	11.60	2.31	1.71	2.20	124.53
1966	2.37	2.11	2.36	12.79	8.02	43.16	35.18	9.07	2.33	10.87	5.67	1.91	135.84
1967	1.39	3.84	2.86	1.96	2.38	2.78	2.69	1.98	1.26	0.98	1.50	7.85	31.47
1968	6.96	10.45	5.37	2.21	16.71	32.22	11.11	25.85	10.75	2.47	1.98	1.80	127.88
1969	2.47	10.84	5.55	2.02	1.92	1.78	1.41	1.55	2.58	2.84	26.46	13.38	72.80
1970	38.20	21.99	5.42	2.99	5.91	4.24	5.33	34.11	13.10	8.99	20.83	8.61	169.72
1971	34.89	13.97	3.69	3.08	35.78	14.06	2.66	1.94	1.66	1.65	1.50	1.21	116.09
1972	1.03	10.75	6.00	3.10	2.88	4.70	14.34	6.10	1.46	0.94	1.45	5.71	58.46
1973	5.88	22.04	8.89	2.48	10.52	13.90	5.79	31.15	14.18	3.69	2.10	1.42	122.04
1974	1.42	2.76	9.16	4.79	2.87	3.78	3.28	2.45	1.69	1.28	1.20	28.64	63.32
1975	11.56	2.44	18.31	8.21	31.33	88.58	35.26	18.63	7.33	2.01	1.48	2.38	227.52
1976	62.12	22.44	1.84	2.20	21.11	9.46	2.63	1.58	1.32	1.42	1.99	3.14	131.25
1977	11.49	25.90	27.33	8.91	2.90	4.30	129.97	50.69	4.99	2.40	1.92	2.30	273.10
1978	21.41	12.73	3.83	2.11	2.14	13.52	6.30	2.06	1.49	6.10	4.91	4.70	81.30
1979	9.09	4.66	2.40	1.92	2.20	2.68	2.24	1.88	1.62	1.32	1.09	18.78	49.88
1980	8.55	17.82	9.23	10.08	5.33	2.74	1.83	7.46	4.59	2.17	3.03	2.94	75.77
1981	1.99	1.83	1.76	2.34	2.58	41.39	21.29	4.66	2.18	1.75	1.29	1.11	84.17
1982	2.16	2.55	1.54	1.08	1.23	1.23	1.16	1.06	0.87	29.14	12.13	2.78	56.93
1983	3.00	13.62	6.74	14.04	9.60	4.26	10.79	5.66	3.29	17.65	7.95	2.60	99.20
1984	2.53	19.27	8.60	3.20	63.21	23.24	2.37	1.45	1.05	0.98	0.76	0.59	127.25
1985	8.56	19.58	7.73	15.83	6.80	2.46	2.66	2.13	1.44	1.02	2.91	12.89	84.01
1986	20.55	9.71	3.03	2.56	2.12	8.13	4.55	2.10	1.75	1.44	1.80	92.12	149.86
1987	33.51	18.46	8.05	2.49	28.74	69.75	23.06	20.52	9.23	10.70	10.14	4.49	239.14
1988	3.11	23.08	40.25	12.37	34.93	17.43	21.79	8.80	2.58	2.35	1.66	1.38	169.73
1989	19.53	36.61	11.56	2.22	2.10	23.66	9.58	1.67	1.08	0.81	1.91	2.91	113.64
1990	7.60	4.11	1.88	4.78	15.08	6.73	2.02	1.44	1.28	1.05	1.09	1.87	48.93
1991	18.40	22.23	7.15	2.31	2.14	1.92	2.27	2.05	1.40	0.99	0.97	1.55	63.38
1992	2.49	2.77	2.90	2.70	2.25	1.59	1.28	1.19	0.96	0.75	0.78	2.12	21.78
1993	12.05	7.33	18.71	7.49	42.44	20.22	3.57	1.18	0.76	1.07	2.42	2.42	119.66
1994	1.71	1.27	12.44	6.10	2.05	25.82	38.11	12.38	13.75	6.65	2.06	1.62	123.96
1995	2.42	2.89	47.61	22.58	17.87	7.08	2.24	1.93	1.47	14.14	6.89	2.29	129.41
1996	6.70	47.05	17.31	9.89	22.33	11.34	31.24	12.28	67.76	29.38	4.65	3.04	262.97
month	781.14	1125.53	846.73	655.50	971.17	1280.73	911.62	607.70	505.51	488.85	319.33	457.64	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.78	1.27	1.16	0.80	1.23	1.23	0.97	0.91	0.76	0.65	0.64	0.53	21.78
max	62.12	65.79	63.04	39.98	63.21	88.58	129.97	57.62	67.76	94.37	33.69	92.12	273.10
median	3.94	10.84	6.82	4.79	7.83	11.53	6.30	2.79	2.12	2.17	1.91	2.20	109.25
mean	10.14	14.62	11.00	8.51	12.61	16.63	11.84	7.89	6.57	6.35	4.15	5.94	116.25

Sum of the monthly means = 116.25

s.d.	12.24	14.33	11.72	8.87	13.52	16.88	17.05	10.99	11.54	12.56	5.74	12.07	57.81
c.v.	1.21	0.98	1.07	1.04	1.07	1.01	1.44	1.39	1.76	1.98	1.38	2.03	0.50

APPENDIX 7.5
T60J (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.65	1.41	5.07	3.34	2.64	11.46	5.88	2.35	1.38	0.82	0.53	0.76	36.29
1921	1.53	15.19	15.46	5.23	1.77	1.08	0.68	14.36	13.20	4.73	2.66	2.83	78.72
1922	14.82	28.90	9.54	26.70	37.66	23.24	6.02	1.37	0.98	23.95	9.81	1.51	184.50
1923	0.93	0.98	1.42	16.05	15.53	4.74	1.04	0.74	0.73	0.65	0.73	1.32	44.86
1924	2.00	2.55	7.01	3.80	2.57	22.57	9.68	2.61	1.73	1.27	0.97	1.45	58.21
1925	2.07	2.32	2.25	2.46	4.04	26.74	10.29	1.89	2.41	2.48	1.63	1.62	60.20
1926	3.38	8.83	6.12	2.71	1.80	36.04	13.38	1.22	0.74	0.55	0.54	0.82	76.13
1927	1.69	1.51	1.62	2.75	8.76	4.74	1.98	1.43	1.29	1.02	1.37	1.53	29.69
1928	1.58	2.13	2.21	2.09	1.88	8.32	4.12	1.66	20.38	14.71	5.17	14.74	78.99
1929	20.27	14.48	4.66	1.71	1.33	1.75	2.27	2.02	2.46	2.94	3.48	12.69	70.06
1930	5.88	2.01	1.67	17.19	18.34	27.34	9.65	1.81	1.06	70.75	25.56	1.98	183.24
1931	2.13	2.25	1.90	1.32	15.80	7.52	2.23	1.87	2.18	2.43	2.12	14.91	56.66
1932	9.72	34.85	27.85	6.56	1.35	2.11	2.04	1.50	1.12	0.89	0.71	0.65	89.35
1933	0.65	8.39	14.90	19.34	6.98	5.36	3.42	1.99	1.44	4.14	3.08	1.43	71.12
1934	0.95	1.76	11.69	5.37	1.59	2.34	16.60	22.82	30.51	10.44	5.05	3.21	112.33
1935	1.83	1.81	1.10	0.73	26.93	28.87	8.24	11.52	6.06	2.64	1.70	1.33	92.76
1936	6.32	48.10	16.85	1.45	11.06	14.34	5.27	1.54	0.99	0.98	1.12	1.10	109.12
1937	1.25	1.35	2.69	2.81	2.60	1.93	6.08	3.77	2.27	2.36	2.04	1.30	30.45
1938	1.04	1.77	2.56	3.97	14.41	6.77	2.69	2.72	2.56	2.65	3.06	24.54	68.74
1939	13.03	3.41	2.35	1.83	1.36	1.77	1.87	7.10	4.30	2.04	1.41	1.16	41.63
1940	1.08	4.49	3.18	1.73	1.02	0.93	1.11	0.99	0.88	0.90	0.91	0.94	18.16
1941	1.42	2.12	1.72	20.12	8.16	2.42	2.28	2.30	2.11	1.36	1.29	1.67	46.97
1942	2.23	35.07	24.88	6.17	1.84	8.95	16.87	6.73	2.51	2.19	9.49	5.14	122.07
1943	4.51	13.05	9.04	3.30	7.02	4.03	2.01	1.46	1.26	1.37	1.19	15.58	63.82
1944	7.64	2.37	1.12	1.36	3.54	6.99	3.54	1.68	1.35	1.11	0.86	1.04	32.60
1945	21.83	8.42	0.94	0.79	2.23	14.64	6.96	2.41	1.58	1.20	0.89	0.83	62.72
1946	1.15	5.28	3.48	2.13	2.37	14.79	17.98	6.66	13.69	6.61	2.11	1.57	77.82
1947	1.50	43.69	17.97	2.86	11.69	10.70	4.50	2.15	1.24	0.75	0.53	0.44	98.02
1948	5.32	3.65	2.21	1.85	26.40	16.80	5.16	2.54	1.46	0.94	0.83	1.00	68.16
1949	1.59	14.04	6.22	5.49	4.43	3.20	3.68	6.90	3.82	2.10	2.61	2.50	56.58
1950	2.40	1.89	13.94	7.10	2.54	5.26	3.16	1.56	1.20	1.02	1.17	1.62	42.86
1951	11.31	4.81	4.98	6.37	3.54	3.65	4.53	3.09	1.83	1.21	0.78	1.08	47.18
1952	1.39	1.33	1.19	1.18	1.67	2.09	2.17	1.78	1.21	0.83	0.85	1.83	17.52
1953	5.61	17.23	11.76	3.77	1.81	3.03	2.35	2.05	2.52	2.36	1.62	1.76	55.87
1954	34.93	13.44	1.83	11.64	19.66	11.79	4.00	1.87	1.43	1.11	0.72	1.19	103.61
1955	1.99	2.36	1.55	0.58	1.36	25.82	12.19	3.17	2.23	1.82	1.29	1.48	55.84
1956	6.11	28.48	45.72	16.36	4.72	16.86	19.48	6.59	2.05	1.68	1.50	2.25	151.80
1957	6.76	4.99	3.79	9.63	20.24	8.54	14.75	6.27	1.37	0.99	0.89	0.88	79.10
1958	1.06	4.42	3.36	1.76	1.72	2.29	2.58	41.53	15.67	2.57	3.81	3.20	83.97
1959	2.58	2.35	2.11	1.91	1.73	4.33	4.06	4.08	2.88	1.81	1.60	2.00	31.44
1960	2.05	4.85	10.43	6.96	3.11	4.96	33.92	13.36	2.69	2.47	2.26	1.74	88.80
1961	1.50	8.35	4.70	2.38	2.59	15.60	6.69	1.88	1.40	0.91	1.15	1.49	48.64
1962	3.68	13.76	5.93	16.21	7.01	45.62	17.13	2.39	1.91	18.66	8.02	1.61	141.93
1963	1.98	6.39	3.95	18.84	13.66	9.36	12.93	5.38	35.65	13.99	2.13	1.73	125.99
1964	11.30	5.05	1.24	1.23	1.38	1.00	0.68	1.03	26.08	11.52	6.83	4.36	71.70
1965	26.57	17.38	4.54	1.90	1.74	1.14	0.75	17.90	8.06	2.00	1.45	1.72	85.15
1966	1.74	1.48	1.57	4.40	3.46	31.35	25.16	6.75	1.99	6.24	3.91	1.66	89.71
1967	1.12	1.82	1.82	1.38	1.57	1.80	1.76	1.34	0.89	0.72	1.11	2.47	17.80
1968	3.15	5.83	3.58	1.62	8.38	21.56	8.14	17.86	7.85	2.13	1.65	1.43	83.18
1969	1.81	3.95	2.90	1.50	1.31	1.18	0.95	1.08	1.82	2.01	17.05	8.14	43.70
1970	28.30	14.48	3.52	2.14	2.35	2.53	2.73	24.31	9.85	5.53	14.79	6.59	117.12
1971	24.39	10.01	2.48	2.11	22.82	9.39	2.06	1.46	1.26	1.24	1.14	0.92	79.28
1972	0.77	4.26	3.34	2.21	1.91	2.18	7.68	3.97	1.31	0.83	1.18	2.35	31.99
1973	3.08	14.73	6.27	1.80	3.41	7.26	4.01	22.00	9.86	3.01	1.87	1.20	78.50
1974	1.11	1.76	3.13	2.49	2.09	2.30	2.25	1.79	1.25	0.97	0.92	18.84	38.90
1975	8.01	1.91	9.62	4.88	20.08	66.00	25.19	12.91	5.62	1.78	1.27	1.85	159.12
1976	44.66	16.35	1.42	1.48	11.14	5.75	2.16	1.29	1.06	1.12	1.52	2.27	90.22
1977	4.81	16.56	17.75	6.03	2.10	2.24	97.16	37.64	3.94	2.08	1.61	1.79	193.71
1978	13.04	6.55	2.34	1.55	1.45	5.68	3.48	1.72	1.22	2.14	3.29	3.27	45.73
1979	4.76	3.03	1.81	1.30	1.43	1.72	1.46	1.28	1.14	0.96	0.82	11.14	30.85
1980	5.65	10.51	5.34	4.56	3.21	2.06	1.32	2.30	2.67	1.90	2.22	2.33	44.07
1981	1.58	1.34	1.21	1.50	1.63	26.87	13.17	3.30	1.87	1.46	1.07	0.89	55.89
1982	1.58	1.77	1.03	0.69	0.79	0.80	0.78	0.74	0.64	20.90	9.08	2.30	41.10
1983	2.26	6.23	3.84	6.47	4.15	2.88	5.54	3.65	2.71	11.29	5.61	2.18	56.81
1984	1.94	10.76	5.33	2.27	43.98	16.46	1.85	1.12	0.82	0.76	0.60	0.47	86.36
1985	3.22	11.79	5.31	7.91	3.92	1.87	1.89	1.51	1.05	0.76	1.65	7.49	48.37
1986	13.54	5.99	2.11	1.85	1.42	1.85	2.24	1.75	1.41	1.14	1.39	66.35	101.04
1987	24.54	10.93	5.15	1.81	17.57	51.00	17.50	13.38	6.56	6.78	6.35	3.37	164.94
1988	2.47	13.65	27.17	8.80	23.31	10.23	14.80	6.57	2.18	1.90	1.33	1.09	113.50
1989	11.67	25.07	8.35	1.63	1.42	13.75	6.09	1.43	0.91	0.67	1.47	2.13	74.59
1990	2.59	2.27	1.48	1.81	8.08	4.34	1.61	1.12	0.99	0.82	0.85	1.39	27.35
1991	10.41	13.85	4.93	1.68	1.44	1.27	1.51	1.40	1.00	0.73	0.73	1.15	40.10
1992	1.76	1.88	1.89	1.68	1.40	1.00	0.84	0.83	0.69	0.55	0.60	1.54	14.66
1993	5.21	3.78	11.49	4.93	29.08	12.36	2.26	1.05	0.66	0.88	1.85	1.80	75.35
1994	1.25	0.90	5.00	3.23	1.53	15.89	26.80	9.36	8.96	4.84	1.82	1.35	80.93
1995	1.81	2.02	31.59	13.02	10.80	4.90	1.78	1.47	1.12	7.79	4.53	1.95	82.78
1996	2.38	34.30	13.06	3.39	13.60	6.55	22.85	9.45	49.52	20.99	3.61	2.50	182.20
month	495.82	713.02	526.53	383.15	586.41	818.84	625.91	429.87	368.69	350.84	226.41	315.73	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.65	0.90	0.94	0.58	0.79	0.80	0.68	0.74	0.64	0.55	0.53	0.44	14.66
max	44.66	48.10	45.72	26.70	43.98	66.00	97.16	41.53	49.52	70.75	25.56	66.35	193.71
median	2.40	4.99	3.79	2.49	3.11	5.68	4.00	2.15	1.82	1.82	1.52	1.72	71.12
mean	6.44	9.26	6.84	4.98	7.62	10.63	8.13	5.58	4.79	4.56	2.94	4.10	75.86
Sum of the monthly means =				75.86									
s.d.	8.58	10.29	8.05	5.47	9.14	12.38	12.60	7.81	8.36	9.20	4.01	8.46	41.90
c.v.	1.33	1.11	1.18	1.10	1.20	1.16	1.55	1.40	1.75	2.02	1.36	2.06	0.55

APPENDIX 7.6
T60K (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.50	1.08	3.21	2.37	2.04	8.37	4.45	1.87	1.08	0.65	0.40	0.58	26.60
1921	1.17	11.47	11.65	4.00	1.37	0.82	0.51	10.80	10.15	3.75	2.13	2.23	60.05
1922	11.18	22.52	7.49	20.62	29.49	18.09	4.70	1.09	0.77	18.71	7.71	1.21	143.58
1923	0.72	0.75	1.07	11.87	11.67	3.65	0.82	0.57	0.56	0.51	0.56	1.02	33.77
1924	1.50	1.90	3.39	2.32	2.31	16.96	7.30	2.02	1.36	1.03	0.81	1.17	42.07
1925	1.53	1.61	1.53	1.66	3.45	18.91	7.37	1.55	2.04	2.11	1.36	1.30	44.42
1926	3.62	7.18	3.77	1.78	1.37	25.58	9.60	0.96	0.57	0.43	0.40	0.62	55.88
1927	1.32	1.17	1.16	1.65	3.59	2.75	1.62	1.21	1.09	0.86	1.12	1.23	18.77
1928	1.30	1.87	1.88	1.64	1.44	7.10	3.42	1.31	17.46	13.51	4.63	10.43	65.99
1929	17.79	12.85	3.86	1.20	0.89	1.21	1.64	1.51	1.95	2.42	2.58	11.07	58.97
1930	5.02	1.50	1.17	10.83	11.87	20.29	7.30	1.33	0.78	53.88	19.57	1.60	135.14
1931	1.67	1.65	1.31	0.90	6.80	4.09	1.80	1.57	1.83	2.02	1.77	11.40	36.81
1932	7.87	29.02	21.60	4.92	1.13	1.93	1.92	1.48	1.11	0.86	0.65	0.55	73.04
1933	0.50	5.21	11.27	15.76	5.62	4.70	2.88	1.57	1.12	4.02	2.72	1.13	56.50
1934	0.75	1.52	10.51	4.65	1.20	1.64	14.27	20.03	22.85	7.69	3.69	2.56	91.36
1935	1.63	1.52	0.86	0.59	22.57	24.25	6.85	9.18	4.82	2.16	1.43	1.17	77.03
1936	5.35	38.77	13.59	1.19	9.95	11.51	4.14	1.26	0.81	0.87	1.04	0.99	89.47
1937	1.02	1.09	2.07	2.09	1.80	1.32	4.98	3.11	1.88	1.99	1.70	1.07	24.12
1938	0.83	1.48	2.62	2.72	14.62	7.22	2.25	1.93	1.78	2.00	2.22	18.06	57.73
1939	9.71	2.73	1.95	1.54	1.41	1.77	1.61	4.64	3.04	1.54	1.01	0.95	31.90
1940	0.92	4.19	2.67	1.27	0.73	0.79	0.99	0.84	0.74	0.80	0.78	0.74	15.46
1941	1.08	1.62	1.26	10.67	4.81	2.60	2.17	2.41	2.11	1.28	1.06	1.30	32.37
1942	1.71	31.95	21.09	4.98	1.54	6.00	13.13	5.48	2.09	1.77	9.10	4.63	103.47
1943	3.11	9.80	6.17	2.36	3.88	3.45	2.23	1.42	1.12	1.14	0.94	16.10	51.72
1944	7.54	2.02	0.93	1.04	4.13	6.27	2.90	1.30	1.03	0.85	0.64	0.80	29.45
1945	18.02	6.92	0.72	0.55	1.20	9.85	4.97	1.88	1.26	0.95	0.67	0.61	47.60
1946	0.86	1.75	1.78	1.48	1.64	11.91	13.66	5.01	11.00	5.34	1.73	1.32	57.48
1947	1.26	35.02	15.03	2.40	7.39	9.10	4.21	2.00	1.15	0.68	0.46	0.37	79.07
1948	4.35	2.98	1.70	1.38	16.57	12.26	4.23	2.01	1.15	0.74	0.63	0.75	48.75
1949	1.17	9.10	4.20	1.97	2.85	2.50	2.37	5.20	3.04	1.74	2.11	1.97	38.22
1950	1.88	1.43	8.42	4.34	1.71	1.85	1.76	1.24	0.91	0.75	0.82	1.24	26.35
1951	9.26	3.91	3.35	6.90	3.53	7.02	4.93	2.58	1.66	1.13	0.73	0.97	45.97
1952	1.23	1.12	0.98	0.99	1.32	1.56	1.59	1.31	0.93	0.68	0.65	1.54	13.90
1953	6.40	15.32	7.25	2.18	1.30	1.78	1.71	1.70	2.18	2.09	1.41	1.43	44.75
1954	25.45	9.90	1.41	6.52	14.54	6.66	2.25	1.42	1.11	0.89	0.56	0.95	71.66
1955	1.65	1.98	1.25	0.43	0.98	22.01	9.83	2.49	2.01	1.70	1.19	1.28	46.80
1956	4.75	24.50	35.62	11.27	2.38	13.39	15.86	5.42	1.81	1.52	1.29	1.85	119.66
1957	3.86	2.94	2.33	7.42	14.72	6.07	12.47	5.28	1.10	0.87	0.83	0.82	58.71
1958	0.95	4.74	3.06	1.40	1.22	1.52	1.72	26.06	10.15	2.14	3.48	2.92	59.36
1959	2.39	2.12	1.84	1.60	1.41	2.18	3.64	3.01	2.07	1.38	1.20	1.58	24.42
1960	1.77	2.98	9.69	7.19	2.88	2.22	27.19	10.89	2.07	1.76	1.53	1.20	71.37
1961	1.08	5.49	3.42	1.91	2.00	13.57	5.73	1.49	1.11	0.72	0.86	1.06	38.44
1962	3.39	10.02	4.38	13.12	5.65	38.21	14.32	1.88	1.44	14.31	6.21	1.26	114.19
1963	1.64	4.52	2.91	12.67	10.01	6.95	8.22	3.65	30.93	12.03	1.68	1.31	96.52
1964	8.04	3.73	0.99	0.96	1.12	0.83	0.54	0.79	18.87	8.89	4.26	3.22	52.24
1965	23.35	15.58	3.94	1.49	1.39	0.93	0.60	13.77	6.28	1.61	1.12	1.25	71.31
1966	1.27	1.13	1.24	3.41	2.67	27.47	21.92	5.76	1.65	3.55	2.66	1.33	74.06
1967	0.87	1.48	1.51	1.10	1.19	1.38	1.34	1.01	0.65	0.52	0.86	2.31	14.22
1968	3.02	5.10	2.83	1.12	5.30	16.57	6.52	13.57	6.00	1.62	1.17	0.96	63.78
1969	1.25	2.59	2.16	1.19	1.20	1.14	0.85	0.88	1.41	1.53	14.92	6.96	36.08
1970	25.15	12.18	2.71	1.58	1.80	1.95	2.14	17.47	7.23	3.55	13.50	5.88	95.14
1971	18.38	7.64	1.89	1.49	14.77	6.28	1.46	1.01	0.92	0.93	0.83	0.65	56.25
1972	0.55	1.34	1.86	1.56	1.33	1.52	3.04	2.17	1.05	0.65	0.83	1.48	17.38
1973	2.02	7.15	3.23	1.13	1.61	5.31	3.16	16.85	7.50	2.16	1.28	0.82	52.22
1974	0.71	1.27	2.55	2.02	1.52	1.66	1.61	1.27	0.89	0.70	0.63	9.97	24.80
1975	4.69	1.54	10.37	4.87	14.61	52.46	18.07	9.65	4.55	1.47	1.03	1.37	124.68
1976	34.26	12.64	1.13	1.03	7.40	4.07	1.63	0.94	0.72	0.74	1.02	1.57	67.15
1977	2.21	13.17	14.21	4.74	1.59	1.69	75.35	28.76	2.96	1.63	1.27	1.45	149.03
1978	11.60	5.73	1.93	1.19	1.04	3.47	2.40	1.32	0.92	1.67	2.63	2.57	36.47
1979	2.53	2.04	1.41	0.97	1.05	1.31	1.13	0.97	0.83	0.68	0.57	5.98	19.47
1980	3.47	6.35	3.52	3.30	2.55	1.73	1.03	2.41	2.33	1.50	1.71	1.79	31.69
1981	1.17	0.95	0.88	1.14	1.26	20.05	8.50	2.02	1.38	1.06	0.76	0.59	39.76
1982	0.93	1.04	0.61	0.43	0.54	0.56	0.49	0.46	0.39	12.10	5.73	1.91	25.19
1983	1.82	3.65	2.61	3.09	2.60	2.05	2.20	2.14	1.80	5.14	3.26	1.76	32.12
1984	1.46	2.17	2.07	1.70	35.26	13.15	1.34	0.76	0.55	0.53	0.41	0.32	59.72
1985	2.32	10.15	4.48	3.47	2.15	1.37	1.29	1.00	0.70	0.52	1.29	4.92	33.66
1986	10.33	4.75	1.64	1.45	1.14	1.49	1.71	1.31	1.04	0.83	1.01	53.98	80.68
1987	19.94	9.27	4.32	1.53	19.30	43.88	14.43	9.99	5.00	4.28	4.97	2.81	139.72
1988	2.02	10.37	18.71	6.07	16.31	7.16	9.93	4.64	1.70	1.47	1.03	0.84	80.25
1989	7.56	18.61	6.31	1.12	0.96	9.51	4.37	1.09	0.67	0.50	1.01	1.41	53.12
1990	1.84	1.67	1.06	1.26	2.32	2.08	1.23	0.80	0.68	0.56	0.58	0.91	14.99
1991	5.05	8.64	3.37	1.01	0.80	0.77	1.00	0.97	0.69	0.50	0.50	0.80	24.10
1992	1.20	1.28	1.48	1.32	0.92	0.65	0.59	0.55	0.43	0.33	0.36	2.55	11.66
1993	6.20	3.38	9.74	4.09	24.61	10.05	1.78	0.89	0.53	0.71	1.71	1.74	65.43
1994	1.06	0.58	6.91	3.49	1.08	12.34	24.11	8.35	5.02	3.17	1.42	0.96	68.49
1995	1.17	1.23	22.70	10.29	4.61	2.52	1.44	1.14	0.80	10.62	5.14	1.51	63.17
1996	2.30	24.91	9.47	4.29	5.86	3.20	14.15	6.32	36.79	16.03	2.91	2.05	128.28
month	390.44	546.52	401.26	279.24	424.84	632.48	482.86	325.99	284.15	270.02	180.44	246.96	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.50	0.58	0.61	0.43	0.54	0.56	0.49	0.46	0.39	0.33	0.36	0.32	11.66
max	34.26	38.77	35.62	20.62	35.26	52.46	75.35	28.76	36.79	53.88	19.57	53.98	149.03
median	1.88	3.65	2.71	1.78	2.15	4.07	2.88	1.87	1.38	1.50	1.19	1.32	53.12
mean	5.07	7.10	5.21	3.63	5.52	8.21	6.27	4.23	3.69	3.51	2.34	3.21	57.99
Sum of the monthly means =				57.99									
s.d.	6.86	8.44	6.25	3.96	7.13	10.08	9.88	5.71	6.47	7.01	3.28	6.76	33.48
c.v.	1.35	1.19	1.20	1.09	1.29	1.23	1.58	1.35	1.75	2.00	1.40	2.11	0.58

APPENDIX 8

PRESENT DAY FLOW RECORDS FOR PROPOSED DAM SITES (2000)

APPENDIX 8.1
XURA DAM (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.48	1.01	1.90	1.81	1.62	1.93	1.94	1.28	0.64	0.36	0.23	0.37	13.57
1921	0.85	8.15	8.95	3.34	1.15	0.59	0.30	2.46	3.45	2.22	1.64	1.65	34.75
1922	7.27	18.57	6.62	15.08	20.88	10.67	2.76	0.79	0.46	9.88	4.59	1.04	98.61
1923	0.65	0.74	1.04	7.59	6.45	2.21	0.60	0.34	0.30	0.26	0.31	0.64	21.13
1924	1.10	1.63	3.05	2.09	1.58	8.93	4.32	1.41	0.80	0.55	0.43	0.71	26.60
1925	1.15	1.49	1.56	1.59	1.72	11.95	4.97	1.04	1.10	1.10	0.72	0.78	29.17
1926	1.48	4.76	3.22	1.72	1.15	17.61	6.77	0.71	0.35	0.24	0.24	0.41	38.66
1927	0.95	0.98	1.12	1.58	2.07	1.85	1.09	0.66	0.53	0.41	0.59	0.72	12.55
1928	0.87	1.37	1.52	1.37	1.10	1.48	1.34	0.88	6.97	5.38	2.72	7.14	32.14
1929	12.09	9.78	3.42	1.25	0.84	0.87	1.00	0.82	0.96	1.19	1.37	3.56	37.15
1930	2.59	1.63	1.34	8.73	8.46	13.27	5.03	1.01	0.50	39.41	14.53	1.35	97.85
1931	1.43	1.61	1.42	0.95	6.09	3.40	1.22	0.85	0.90	1.01	0.90	4.66	24.44
1932	4.36	23.19	17.77	4.21	0.86	1.06	0.91	0.61	0.42	0.34	0.28	0.29	54.30
1933	0.35	3.27	8.53	10.73	4.00	1.68	1.43	0.97	0.62	1.06	1.26	0.77	34.67
1934	0.57	1.17	5.95	3.06	1.04	1.11	4.77	9.10	15.61	5.87	1.98	1.68	51.91
1935	1.27	1.33	0.88	0.53	13.23	13.65	4.13	2.15	2.14	1.56	0.93	0.72	42.52
1936	1.57	31.52	11.54	1.08	3.23	4.59	2.29	0.88	0.47	0.44	0.50	0.53	58.64
1937	0.70	0.88	1.46	1.78	1.57	1.01	1.22	1.32	1.07	1.06	0.92	0.62	13.61
1938	0.57	1.14	1.72	1.89	5.88	3.24	1.44	1.23	1.06	1.10	1.32	10.77	31.36
1939	6.48	2.43	1.85	1.33	0.85	0.88	0.83	1.23	1.43	1.02	0.68	0.59	19.60
1940	0.62	1.45	1.88	1.31	0.68	0.47	0.48	0.39	0.33	0.35	0.37	0.43	8.76
1941	0.77	1.35	1.21	10.30	4.42	1.34	1.08	0.97	0.83	0.53	0.53	0.78	24.11
1942	1.21	21.02	15.04	3.94	1.18	1.53	6.20	3.21	1.36	1.07	1.63	2.02	59.41
1943	2.19	8.97	5.60	2.10	1.79	1.66	1.11	0.67	0.52	0.56	0.51	5.23	30.91
1944	3.62	1.94	1.00	0.96	1.49	1.84	1.39	0.86	0.59	0.47	0.37	0.50	15.03
1945	10.78	4.62	0.85	0.61	1.11	4.27	2.75	1.31	0.73	0.53	0.39	0.40	28.35
1946	0.64	1.55	1.88	1.52	1.41	3.94	6.53	3.17	3.78	2.67	1.35	0.95	29.39
1947	0.95	27.11	10.81	1.89	4.15	2.95	1.95	1.20	0.59	0.33	0.23	0.21	52.37
1948	1.13	1.91	1.76	1.34	13.21	6.15	2.13	1.38	0.68	0.41	0.37	0.48	30.95
1949	0.89	7.29	3.69	1.89	2.03	1.82	1.64	1.75	1.41	1.04	1.25	1.25	25.95
1950	1.36	1.24	7.42	3.93	1.60	1.54	1.27	0.76	0.51	0.43	0.51	0.77	21.34
1951	3.91	2.27	2.51	2.39	1.89	1.67	1.70	1.37	0.83	0.52	0.33	0.52	19.91
1952	0.77	0.87	0.86	0.79	0.95	1.02	0.95	0.71	0.45	0.31	0.34	0.87	8.89
1953	1.75	10.58	7.11	2.40	1.16	1.26	1.05	0.90	1.03	0.96	0.68	0.83	29.71
1954	19.04	7.86	1.51	5.31	9.37	4.26	1.74	1.04	0.67	0.49	0.32	0.59	52.20
1955	1.11	1.52	1.12	0.44	0.74	10.61	5.08	1.62	1.11	0.84	0.59	0.73	25.51
1956	1.61	18.28	29.47	9.51	2.09	6.65	8.01	3.16	1.13	0.83	0.72	1.14	82.60
1957	1.95	2.92	2.51	4.73	10.05	4.37	4.75	2.49	0.80	0.51	0.44	0.45	35.97
1958	0.61	1.49	2.02	1.34	1.05	1.15	1.15	18.98	7.57	1.50	1.70	1.69	40.25
1959	1.58	1.62	1.53	1.30	1.03	1.27	1.60	1.66	1.24	0.81	0.72	0.97	15.33
1960	1.14	1.73	6.20	3.52	1.75	1.63	16.49	6.90	1.45	1.20	1.07	0.86	43.94
1961	0.85	3.67	2.72	1.68	1.54	4.42	2.45	1.04	0.65	0.40	0.52	0.72	20.66
1962	1.36	8.21	3.96	8.44	3.87	24.39	9.32	1.28	0.88	6.06	3.31	1.10	72.18
1963	1.29	3.21	2.50	10.19	5.55	2.47	4.41	2.45	18.01	7.44	1.36	1.03	59.91
1964	4.79	2.73	1.08	0.90	0.84	0.52	0.29	0.40	9.73	5.10	2.42	2.25	31.05
1965	15.92	11.27	3.34	1.37	1.07	0.60	0.33	4.51	2.88	1.21	0.80	0.93	44.23
1966	1.03	1.01	1.13	1.59	1.79	14.92	11.18	3.26	1.11	1.52	1.61	0.99	41.14
1967	0.71	1.24	1.32	0.95	0.92	0.89	0.77	0.53	0.33	0.27	0.47	1.15	9.55
1968	1.78	2.55	2.17	1.22	1.65	9.12	4.07	6.08	3.26	1.28	0.91	0.78	34.87
1969	1.07	1.81	1.89	1.14	0.81	0.61	0.41	0.43	0.71	0.80	4.74	3.37	17.79
1970	17.35	9.44	2.67	1.52	1.40	1.29	1.22	8.02	3.87	1.83	5.85	3.40	57.86
1971	14.78	6.46	1.96	1.51	10.90	4.74	1.12	0.67	0.51	0.51	0.48	0.42	44.06
1972	0.42	1.31	1.96	1.60	1.18	1.11	1.52	1.30	0.66	0.38	0.55	1.17	13.16
1973	1.72	8.19	3.87	1.31	1.45	1.84	1.61	8.22	4.34	1.75	1.01	0.66	35.97
1974	0.66	1.17	1.80	1.62	1.28	1.17	1.01	0.73	0.47	0.37	0.37	7.35	18.00
1975	3.83	1.55	5.44	2.99	9.38	38.06	13.47	3.60	2.27	1.10	0.71	1.01	83.41
1976	26.06	9.95	1.21	1.06	3.23	2.33	1.18	0.60	0.43	0.46	0.66	1.09	48.26
1977	1.72	10.02	11.02	3.90	1.33	1.16	54.32	20.05	1.97	1.18	0.85	0.95	108.47
1978	5.43	3.63	1.88	1.16	0.89	1.31	1.30	0.84	0.52	0.92	1.46	1.57	20.91
1979	1.87	1.80	1.41	0.95	0.85	0.86	0.64	0.51	0.43	0.36	0.33	2.38	12.39
1980	2.32	6.89	3.71	2.03	1.76	1.17	0.63	0.89	1.11	0.81	0.98	1.11	23.41
1981	0.86	0.89	0.87	0.98	0.94	11.55	5.44	1.62	0.96	0.68	0.49	0.44	25.72
1982	0.88	1.15	0.76	0.49	0.46	0.39	0.32	0.28	0.23	7.14	3.85	1.51	17.46
1983	1.48	3.14	2.43	2.16	2.00	1.61	1.57	1.41	1.22	1.85	1.94	1.43	22.24
1984	1.28	5.99	3.37	1.61	24.45	9.27	1.02	0.51	0.33	0.31	0.25	0.22	48.61
1985	1.02	6.80	3.53	3.03	1.88	1.07	0.89	0.64	0.40	0.29	0.71	1.68	21.94
1986	6.89	3.94	1.72	1.32	0.90	1.00	1.07	0.75	0.55	0.45	0.59	37.94	57.12
1987	14.49	7.20	3.59	1.32	7.38	28.14	10.08	3.03	2.37	2.11	2.32	1.90	83.93
1988	1.68	8.30	16.99	5.69	11.49	5.23	4.71	2.62	1.20	0.94	0.64	0.55	60.04
1989	4.28	15.74	5.83	1.17	0.88	3.36	2.11	0.81	0.43	0.30	0.67	1.05	36.63
1990	1.45	1.47	1.08	1.18	1.80	1.67	0.92	0.52	0.41	0.33	0.36	0.67	11.86
1991	3.32	8.34	3.60	1.23	0.90	0.65	0.66	0.56	0.37	0.27	0.30	0.54	20.74
1992	0.96	1.20	1.31	1.12	0.83	0.50	0.36	0.32	0.25	0.20	0.24	0.74	8.03
1993	1.66	2.15	6.78	3.07	15.08	6.44	1.24	0.52	0.28	0.37	0.83	0.86	39.28
1994	0.69	0.60	1.30	1.57	1.01	4.84	12.12	4.87	1.97	1.90	1.15	0.81	32.83
1995	1.12	1.38	19.11	7.83	3.87	2.15	0.98	0.67	0.46	1.18	1.62	1.20	41.57
1996	1.48	21.24	8.38	1.83	5.59	3.15	9.37	4.27	26.87	10.86	2.02	1.57	96.63
month	252.91	429.88	328.53	215.96	278.07	357.38	281.52	173.05	159.83	153.75	97.93	147.21	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.35	0.60	0.76	0.44	0.46	0.39	0.29	0.28	0.23	0.20	0.23	0.21	8.03
max	26.06	31.52	29.47	15.08	24.45	38.06	54.32	20.05	26.87	39.41	14.53	37.94	108.47
median	1.36	2.43	2.17	1.60	1.60	1.84	1.44	1.04	0.80	0.83	0.71	0.93	31.36
mean	3.28	5.58	4.27	2.80	3.61	4.64	3.66	2.25	2.08	2.00	1.27	1.91	37.35
Sum of the monthly means =				37.35									
s.d.	4.92	6.58	5.00	2.88	4.64	6.56	6.75	3.40	4.13	4.82	1.87	4.50	23.14
c.v.	1.50	1.18	1.17	1.03	1.28	1.41	1.85	1.51	1.99	2.41	1.47	2.35	0.62

APPENDIX 8.2
ZALU DAM (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.15	0.30	0.57	0.58	0.51	0.62	0.64	0.42	0.21	0.11	0.07	0.11	4.29
1921	0.26	2.44	2.71	1.03	0.35	0.17	0.09	0.64	1.00	0.69	0.52	0.51	10.41
1922	2.21	5.76	2.06	4.66	6.48	3.27	0.85	0.25	0.14	3.01	1.41	0.33	30.43
1923	0.21	0.22	0.31	2.26	1.92	0.67	0.19	0.10	0.09	0.08	0.10	0.19	6.34
1924	0.34	0.49	0.85	0.62	0.48	2.71	1.33	0.44	0.25	0.17	0.13	0.22	8.03
1925	0.36	0.45	0.48	0.49	0.52	3.66	1.54	0.33	0.34	0.34	0.22	0.24	8.97
1926	0.46	1.39	0.97	0.55	0.37	5.48	2.11	0.22	0.11	0.08	0.07	0.12	11.93
1927	0.29	0.29	0.34	0.48	0.63	0.59	0.36	0.21	0.17	0.13	0.18	0.22	3.89
1928	0.27	0.41	0.46	0.42	0.33	0.45	0.42	0.27	2.08	1.62	0.84	2.19	9.76
1929	3.74	3.00	1.05	0.39	0.25	0.26	0.31	0.25	0.30	0.36	0.42	1.02	11.35
1930	0.79	0.50	0.41	2.64	2.56	4.09	1.57	0.32	0.15	12.36	4.56	0.43	30.38
1931	0.45	0.49	0.43	0.29	1.78	1.02	0.38	0.26	0.28	0.31	0.28	1.35	7.32
1932	1.30	7.24	5.52	1.30	0.26	0.32	0.28	0.19	0.13	0.10	0.09	0.09	16.82
1933	0.11	0.89	2.57	3.29	1.23	0.52	0.45	0.30	0.19	0.33	0.39	0.24	10.51
1934	0.18	0.35	1.75	0.92	0.32	0.33	1.40	2.78	4.86	1.84	0.62	0.53	15.88
1935	0.40	0.41	0.26	0.16	4.01	4.18	1.28	0.60	0.65	0.49	0.29	0.22	12.95
1936	0.49	9.83	3.60	0.33	0.90	1.34	0.70	0.27	0.15	0.14	0.16	0.16	18.07
1937	0.22	0.26	0.44	0.55	0.48	0.30	0.38	0.41	0.33	0.33	0.28	0.19	4.17
1938	0.18	0.34	0.52	0.58	1.75	0.98	0.45	0.38	0.33	0.34	0.41	3.29	9.55
1939	1.96	0.74	0.57	0.41	0.26	0.26	0.26	0.38	0.44	0.32	0.21	0.18	5.99
1940	0.19	0.44	0.57	0.40	0.20	0.14	0.15	0.12	0.10	0.11	0.11	0.13	2.66
1941	0.24	0.40	0.36	3.11	1.34	0.41	0.34	0.30	0.26	0.16	0.16	0.24	7.32
1942	0.37	6.50	4.66	1.22	0.36	0.47	1.86	0.98	0.43	0.34	0.50	0.63	18.32
1943	0.68	2.74	1.68	0.63	0.55	0.51	0.35	0.21	0.16	0.17	0.16	1.52	9.36
1944	1.10	0.60	0.31	0.29	0.45	0.56	0.43	0.27	0.18	0.15	0.11	0.15	4.60
1945	3.26	1.40	0.26	0.18	0.33	1.22	0.83	0.41	0.23	0.16	0.12	0.12	8.52
1946	0.20	0.48	0.60	0.48	0.44	1.15	1.98	0.98	1.13	0.82	0.43	0.29	8.98
1947	0.30	8.43	3.36	0.59	1.21	0.89	0.62	0.38	0.18	0.10	0.07	0.06	16.19
1948	0.35	0.58	0.54	0.41	4.03	1.87	0.69	0.45	0.22	0.13	0.12	0.15	9.54
1949	0.27	2.17	1.11	0.58	0.62	0.56	0.51	0.54	0.44	0.32	0.39	0.39	7.90
1950	0.42	0.38	2.21	1.19	0.49	0.47	0.40	0.24	0.16	0.13	0.15	0.24	6.48
1951	1.11	0.67	0.70	0.72	0.59	0.51	0.53	0.43	0.26	0.16	0.10	0.16	5.94
1952	0.24	0.26	0.26	0.24	0.28	0.30	0.29	0.22	0.14	0.10	0.10	0.26	2.69
1953	0.54	3.22	2.14	0.73	0.35	0.38	0.33	0.28	0.32	0.30	0.21	0.25	9.05
1954	5.88	2.43	0.47	1.57	2.85	1.31	0.55	0.32	0.21	0.15	0.10	0.18	16.02
1955	0.34	0.46	0.34	0.13	0.22	3.20	1.56	0.51	0.35	0.26	0.18	0.22	7.77
1956	0.50	5.65	9.19	2.97	0.65	2.01	2.44	0.98	0.36	0.26	0.22	0.35	25.58
1957	0.61	0.83	0.75	1.41	3.07	1.35	1.43	0.76	0.25	0.16	0.14	0.14	10.90
1958	0.19	0.45	0.62	0.41	0.32	0.35	0.36	5.87	2.35	0.47	0.53	0.53	12.45
1959	0.50	0.50	0.47	0.40	0.31	0.38	0.50	0.51	0.38	0.25	0.22	0.30	4.72
1960	0.35	0.53	1.85	1.07	0.54	0.50	5.11	2.14	0.45	0.37	0.33	0.27	13.51
1961	0.26	1.04	0.81	0.52	0.47	1.29	0.74	0.32	0.20	0.12	0.16	0.22	6.15
1962	0.42	2.47	1.20	2.57	1.18	7.60	2.91	0.40	0.27	1.81	1.01	0.34	22.18
1963	0.40	0.92	0.75	3.12	1.65	0.75	1.33	0.75	5.60	2.32	0.43	0.32	18.34
1964	1.41	0.82	0.33	0.27	0.25	0.15	0.09	0.12	2.91	1.56	0.76	0.71	9.38
1965	4.95	3.47	1.02	0.42	0.32	0.18	0.10	1.28	0.86	0.38	0.25	0.29	13.52
1966	0.32	0.30	0.34	0.48	0.55	4.59	3.44	1.01	0.35	0.47	0.50	0.31	12.66
1967	0.22	0.37	0.40	0.29	0.27	0.26	0.24	0.16	0.10	0.08	0.14	0.35	2.88
1968	0.55	0.70	0.64	0.38	0.46	3.00	1.33	1.83	1.00	0.40	0.28	0.24	10.81
1969	0.33	0.55	0.58	0.35	0.24	0.18	0.13	0.13	0.21	0.24	1.37	1.02	5.33
1970	5.41	2.90	0.81	0.47	0.43	0.39	0.38	2.42	1.18	0.57	1.78	1.05	17.79
1971	4.60	2.00	0.60	0.47	3.32	1.45	0.35	0.21	0.16	0.16	0.15	0.13	13.60
1972	0.13	0.39	0.60	0.49	0.36	0.33	0.47	0.40	0.20	0.12	0.17	0.36	4.02
1973	0.53	2.47	1.18	0.40	0.44	0.56	0.50	2.49	1.33	0.55	0.32	0.20	10.97
1974	0.21	0.35	0.55	0.50	0.39	0.35	0.31	0.23	0.15	0.11	0.11	2.18	5.44
1975	1.17	0.48	1.61	0.90	2.86	11.90	4.23	1.08	0.70	0.35	0.22	0.31	25.81
1976	8.11	3.09	0.37	0.32	0.90	0.69	0.37	0.19	0.13	0.14	0.20	0.33	14.84
1977	0.53	3.05	3.37	1.20	0.41	0.35	17.03	6.28	0.62	0.37	0.26	0.29	33.76
1978	1.61	1.10	0.60	0.37	0.27	0.40	0.41	0.26	0.16	0.28	0.45	0.49	6.40
1979	0.58	0.55	0.43	0.29	0.25	0.25	0.20	0.15	0.13	0.11	0.10	0.62	3.66
1980	0.69	2.09	1.13	0.63	0.54	0.36	0.20	0.27	0.34	0.25	0.30	0.34	7.14
1981	0.27	0.26	0.26	0.29	0.28	3.49	1.67	0.51	0.30	0.21	0.15	0.13	7.82
1982	0.27	0.34	0.23	0.15	0.13	0.11	0.10	0.08	0.07	2.06	1.15	0.47	5.16
1983	0.46	0.89	0.73	0.65	0.64	0.51	0.50	0.44	0.38	0.57	0.60	0.45	6.82
1984	0.40	1.78	1.02	0.50	7.61	2.88	0.32	0.16	0.10	0.10	0.08	0.07	15.02
1985	0.31	2.02	1.06	0.87	0.56	0.33	0.28	0.20	0.12	0.09	0.22	0.52	6.58
1986	2.07	1.20	0.53	0.41	0.27	0.30	0.33	0.23	0.17	0.14	0.18	11.84	17.67
1987	4.53	2.20	1.10	0.41	2.21	8.77	3.16	0.89	0.72	0.66	0.73	0.59	25.97
1988	0.53	2.52	5.26	1.77	3.51	1.60	1.41	0.80	0.38	0.29	0.20	0.17	18.44
1989	1.23	4.86	1.81	0.36	0.26	0.93	0.63	0.26	0.13	0.09	0.21	0.32	11.09
1990	0.45	0.45	0.33	0.36	0.55	0.51	0.29	0.16	0.13	0.10	0.11	0.20	3.64
1991	0.92	2.52	1.11	0.38	0.27	0.19	0.20	0.17	0.11	0.08	0.09	0.16	6.20
1992	0.29	0.36	0.40	0.34	0.25	0.15	0.11	0.10	0.08	0.06	0.07	0.22	2.43
1993	0.51	0.66	2.03	0.93	4.65	1.99	0.39	0.16	0.09	0.11	0.25	0.26	12.03
1994	0.21	0.18	0.41	0.51	0.32	1.44	3.74	1.51	0.61	0.59	0.36	0.25	10.13
1995	0.35	0.42	5.91	2.43	1.14	0.65	0.31	0.21	0.14	0.36	0.50	0.37	12.79
1996	0.46	6.59	2.60	0.57	1.67	0.95	2.88	1.32	8.40	3.40	0.64	0.49	29.97
month	77.70	131.28	100.43	66.05	84.47	109.59	87.33	53.10	49.29	47.52	30.20	45.02	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.11	0.18	0.23	0.13	0.13	0.11	0.09	0.08	0.07	0.06	0.07	0.06	2.43
max	8.11	9.83	9.19	4.66	7.61	11.90	17.03	6.28	8.40	12.36	4.56	11.84	33.76
median	0.42	0.70	0.64	0.50	0.48	0.56	0.45	0.32	0.25	0.26	0.22	0.29	9.55
mean	1.01	1.70	1.30	0.86	1.10	1.42	1.13	0.69	0.64	0.62	0.39	0.58	11.45
Sum of the monthly means = 11.45													
s.d.	1.52	2.05	1.55	0.88	1.43	2.04	2.11	1.05	1.28	1.50	0.58	1.40	7.20
c.v.	1.51	1.20	1.19	1.03	1.30	1.44	1.86	1.53	2.01	2.44	1.48	2.39	0.63

APPENDIX 8.3
LUSIKISIKI DAM (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.19	0.40	0.75	0.75	0.67	0.81	0.82	0.54	0.27	0.15	0.10	0.15	5.60
1921	0.34	3.19	3.53	1.33	0.46	0.23	0.11	0.88	1.32	0.89	0.66	0.66	13.60
1922	2.86	7.43	2.65	6.02	8.35	4.24	1.09	0.32	0.19	3.90	1.82	0.42	39.29
1923	0.26	0.29	0.41	2.96	2.51	0.87	0.24	0.14	0.12	0.11	0.13	0.26	8.30
1924	0.43	0.64	1.14	0.82	0.63	3.52	1.71	0.57	0.32	0.22	0.17	0.28	10.45
1925	0.45	0.59	0.62	0.64	0.68	4.74	1.98	0.42	0.44	0.44	0.29	0.31	11.60
1926	0.58	1.83	1.26	0.72	0.48	7.08	2.72	0.29	0.14	0.10	0.10	0.16	15.46
1927	0.37	0.38	0.44	0.63	0.82	0.77	0.45	0.27	0.22	0.17	0.24	0.29	5.05
1928	0.34	0.54	0.60	0.55	0.44	0.58	0.53	0.35	2.72	2.11	1.09	2.83	12.68
1929	4.82	3.89	1.36	0.50	0.33	0.34	0.39	0.33	0.38	0.47	0.55	1.36	14.72
1930	1.01	0.65	0.53	3.43	3.33	5.29	2.01	0.41	0.20	15.87	5.85	0.55	39.13
1931	0.57	0.64	0.56	0.38	2.35	1.33	0.49	0.34	0.36	0.40	0.36	1.79	9.57
1932	1.69	9.31	7.11	1.68	0.34	0.42	0.36	0.24	0.17	0.14	0.11	0.12	21.69
1933	0.13	1.20	3.35	4.26	1.59	0.67	0.57	0.39	0.25	0.43	0.50	0.31	13.65
1934	0.22	0.46	2.30	1.20	0.41	0.44	1.83	3.61	6.26	2.36	0.80	0.68	20.57
1935	0.50	0.53	0.35	0.21	5.22	5.42	1.65	0.80	0.84	0.63	0.38	0.29	16.82
1936	0.62	12.65	4.63	0.43	1.21	1.77	0.90	0.36	0.19	0.18	0.20	0.21	23.35
1937	0.27	0.35	0.58	0.71	0.62	0.40	0.48	0.53	0.43	0.42	0.37	0.25	5.41
1938	0.22	0.45	0.68	0.75	2.29	1.28	0.58	0.49	0.43	0.44	0.53	4.26	12.40
1939	2.55	0.96	0.74	0.54	0.34	0.35	0.32	0.49	0.57	0.41	0.27	0.24	7.78
1940	0.24	0.57	0.75	0.52	0.27	0.18	0.19	0.16	0.13	0.14	0.15	0.17	3.47
1941	0.30	0.53	0.48	4.05	1.75	0.53	0.43	0.39	0.33	0.21	0.22	0.31	9.53
1942	0.48	8.39	6.03	1.59	0.47	0.61	2.42	1.27	0.55	0.43	0.65	0.81	23.70
1943	0.87	3.56	2.19	0.83	0.71	0.66	0.44	0.27	0.21	0.23	0.20	2.01	12.18
1944	1.42	0.78	0.40	0.38	0.59	0.73	0.55	0.34	0.24	0.19	0.15	0.20	5.97
1945	4.24	1.82	0.34	0.24	0.44	1.62	1.08	0.53	0.30	0.21	0.16	0.16	11.14
1946	0.25	0.62	0.78	0.63	0.57	1.53	2.57	1.27	1.48	1.06	0.55	0.38	11.69
1947	0.37	10.86	4.33	0.76	1.60	1.16	0.78	0.49	0.24	0.14	0.10	0.08	20.91
1948	0.44	0.76	0.70	0.53	5.23	2.40	0.84	0.56	0.28	0.17	0.15	0.19	12.25
1949	0.35	2.84	1.45	0.76	0.81	0.73	0.65	0.70	0.57	0.42	0.50	0.50	10.28
1950	0.54	0.49	2.89	1.55	0.64	0.61	0.50	0.31	0.21	0.17	0.20	0.31	8.42
1951	1.47	0.88	0.94	0.94	0.76	0.66	0.68	0.55	0.33	0.21	0.14	0.21	7.77
1952	0.30	0.34	0.34	0.31	0.37	0.40	0.37	0.29	0.18	0.13	0.14	0.35	3.52
1953	0.69	4.18	2.79	0.95	0.46	0.50	0.42	0.36	0.41	0.39	0.27	0.33	11.75
1954	7.59	3.14	0.60	2.06	3.70	1.69	0.70	0.42	0.27	0.20	0.13	0.23	20.73
1955	0.44	0.60	0.44	0.17	0.29	4.16	2.01	0.65	0.45	0.34	0.24	0.29	10.08
1956	0.64	7.30	11.83	3.82	0.84	2.62	3.16	1.26	0.46	0.34	0.29	0.46	33.02
1957	0.78	1.10	0.99	1.85	3.98	1.74	1.86	0.99	0.32	0.21	0.18	0.18	14.18
1958	0.24	0.59	0.80	0.53	0.41	0.45	0.46	7.57	3.03	0.61	0.69	0.68	16.06
1959	0.63	0.64	0.61	0.52	0.41	0.50	0.63	0.66	0.50	0.33	0.29	0.39	6.11
1960	0.45	0.69	2.42	1.39	0.70	0.65	6.58	2.76	0.59	0.48	0.43	0.35	17.49
1961	0.33	1.38	1.06	0.68	0.61	1.70	0.96	0.42	0.26	0.16	0.21	0.29	8.06
1962	0.54	3.22	1.57	3.34	1.53	9.78	3.74	0.52	0.35	2.37	1.31	0.45	28.72
1963	0.51	1.22	0.98	4.05	2.16	0.97	1.73	0.98	7.22	2.99	0.55	0.42	23.78
1964	1.85	1.07	0.43	0.36	0.33	0.20	0.11	0.16	3.80	2.02	0.98	0.91	12.22
1965	6.37	4.48	1.33	0.55	0.42	0.24	0.13	1.70	1.13	0.49	0.32	0.38	17.54
1966	0.41	0.40	0.44	0.63	0.71	5.94	4.44	1.30	0.45	0.61	0.65	0.40	16.38
1967	0.28	0.49	0.52	0.38	0.36	0.35	0.30	0.21	0.13	0.11	0.19	0.46	3.78
1968	0.71	0.95	0.85	0.49	0.57	3.65	1.64	2.39	1.30	0.52	0.37	0.32	13.76
1969	0.42	0.72	0.75	0.46	0.32	0.24	0.16	0.17	0.28	0.32	1.81	1.33	6.98
1970	6.96	3.75	1.06	0.61	0.56	0.51	0.48	3.15	1.54	0.74	2.31	1.36	23.03
1971	5.92	2.59	0.78	0.60	4.31	1.88	0.45	0.27	0.21	0.20	0.19	0.17	17.57
1972	0.16	0.52	0.78	0.64	0.47	0.44	0.60	0.52	0.27	0.15	0.22	0.47	5.24
1973	0.68	3.22	1.53	0.53	0.57	0.73	0.64	3.24	1.73	0.71	0.41	0.27	14.26
1974	0.26	0.46	0.72	0.65	0.51	0.46	0.40	0.29	0.19	0.15	0.15	2.86	7.10
1975	1.51	0.62	2.12	1.18	3.71	15.31	5.42	1.41	0.90	0.45	0.29	0.40	33.32
1976	10.44	3.99	0.48	0.42	1.21	0.91	0.47	0.24	0.18	0.19	0.26	0.43	19.22
1977	0.68	3.96	4.37	1.55	0.53	0.46	21.87	8.08	0.80	0.48	0.34	0.38	43.50
1978	2.10	1.43	0.78	0.48	0.36	0.52	0.52	0.34	0.21	0.37	0.58	0.63	8.32
1979	0.74	0.72	0.56	0.38	0.33	0.34	0.25	0.20	0.17	0.15	0.13	0.85	4.82
1980	0.90	2.72	1.47	0.82	0.70	0.47	0.25	0.36	0.44	0.32	0.39	0.44	9.28
1981	0.34	0.35	0.34	0.39	0.37	4.55	2.15	0.65	0.39	0.28	0.20	0.18	10.19
1982	0.35	0.45	0.30	0.19	0.18	0.15	0.12	0.11	0.09	2.72	1.50	0.61	6.77
1983	0.59	1.19	0.95	0.81	0.78	0.64	0.63	0.57	0.49	0.74	0.78	0.58	8.75
1984	0.51	2.33	1.33	0.65	9.80	3.72	0.41	0.21	0.14	0.13	0.10	0.09	19.42
1985	0.40	2.65	1.39	1.15	0.73	0.42	0.35	0.26	0.16	0.12	0.28	0.67	8.58
1986	2.70	1.56	0.69	0.53	0.35	0.39	0.42	0.30	0.22	0.18	0.23	15.23	22.80
1987	5.82	2.85	1.43	0.53	2.89	11.29	4.05	1.17	0.94	0.85	0.94	0.77	33.53
1988	0.67	3.28	6.79	2.28	4.55	2.08	1.84	1.04	0.49	0.38	0.26	0.22	23.88
1989	1.63	6.28	2.33	0.47	0.35	1.25	0.81	0.33	0.17	0.12	0.27	0.42	14.43
1990	0.57	0.58	0.43	0.47	0.71	0.66	0.36	0.21	0.16	0.13	0.15	0.27	4.70
1991	1.23	3.28	1.43	0.49	0.35	0.25	0.26	0.23	0.15	0.11	0.12	0.22	8.12
1992	0.37	0.47	0.52	0.45	0.33	0.20	0.14	0.13	0.10	0.08	0.10	0.29	3.18
1993	0.65	0.85	2.65	1.21	6.01	2.57	0.49	0.21	0.11	0.15	0.33	0.34	15.57
1994	0.27	0.24	0.54	0.67	0.42	1.90	4.83	1.95	0.79	0.77	0.47	0.33	13.18
1995	0.44	0.55	7.63	3.13	1.50	0.84	0.39	0.27	0.19	0.47	0.65	0.48	16.54
1996	0.59	8.49	3.35	0.73	2.18	1.24	3.72	1.71	10.80	4.37	0.82	0.63	38.63
month	100.05	170.37	130.37	85.84	109.84	141.93	112.08	68.87	63.85	61.55	39.21	58.56	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.13	0.24	0.30	0.17	0.18	0.15	0.11	0.11	0.09	0.08	0.10	0.08	3.18
max	10.44	12.65	11.83	6.02	9.80	15.31	21.87	8.08	10.80	15.87	5.85	15.23	43.50
median	0.54	0.95	0.85	0.65	0.63	0.73	0.58	0.42	0.32	0.34	0.29	0.38	12.40
mean	1.30	2.21	1.69	1.11	1.43	1.84	1.46	0.89	0.83	0.80	0.51	0.76	14.84
Sum of the monthly means = 14.84													
s.d.	1.97	2.64	2.00	1.14	1.85	2.63	2.71	1.36	1.65	1.93	0.75	1.80	9.27
c.v.	1.51	1.19	1.18	1.02	1.29	1.43	1.86	1.52	2.00	2.42	1.47	2.37	0.62

APPENDIX 8.4
TUNGWANE DAM (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.27	0.49	0.87	0.90	0.89	2.25	1.61	0.93	0.55	0.33	0.22	0.29	9.60
1921	0.54	3.72	3.94	1.59	0.65	0.37	0.24	3.62	3.98	1.77	1.09	1.08	22.59
1922	4.09	9.47	3.32	8.34	12.66	7.56	2.06	0.58	0.40	7.95	3.44	0.64	60.51
1923	0.38	0.35	0.46	3.62	3.96	1.48	0.43	0.29	0.28	0.25	0.28	0.47	12.25
1924	0.69	0.84	1.04	0.93	0.90	6.52	3.07	1.03	0.67	0.49	0.38	0.53	17.09
1925	0.72	0.77	0.71	0.76	0.92	8.25	3.41	0.76	0.90	0.92	0.61	0.59	19.32
1926	0.92	1.64	1.36	0.90	0.64	11.73	4.51	0.52	0.31	0.23	0.22	0.31	23.29
1927	0.59	0.50	0.51	0.77	1.25	1.18	0.78	0.54	0.48	0.38	0.50	0.55	8.03
1928	0.56	0.70	0.70	0.64	0.57	0.91	0.90	0.68	6.61	4.84	1.94	4.62	23.67
1929	6.58	4.18	1.45	0.62	0.44	0.56	0.74	0.67	0.83	1.01	1.11	3.37	21.56
1930	1.84	0.77	0.57	4.16	5.12	9.13	3.44	0.74	0.43	25.84	9.46	0.83	62.33
1931	0.81	0.78	0.62	0.41	3.62	2.10	0.86	0.69	0.79	0.87	0.76	3.99	16.30
1932	2.38	12.35	9.17	2.13	0.49	0.70	0.68	0.51	0.40	0.32	0.26	0.24	29.63
1933	0.24	1.15	3.78	5.73	2.27	1.10	1.05	0.79	0.56	0.90	1.02	0.60	19.19
1934	0.38	0.60	2.16	1.31	0.58	0.73	4.71	7.64	11.10	3.97	1.31	1.11	35.60
1935	0.76	0.66	0.38	0.23	7.95	9.25	2.89	3.28	2.03	1.09	0.69	0.52	29.73
1936	0.94	17.23	6.25	0.53	2.06	3.82	1.77	0.64	0.40	0.39	0.43	0.41	34.87
1937	0.45	0.45	0.68	0.87	0.84	0.62	0.88	1.05	0.93	0.92	0.78	0.50	8.97
1938	0.38	0.59	0.81	0.92	3.49	2.01	1.02	0.98	0.92	0.95	1.08	7.65	20.80
1939	3.59	1.07	0.85	0.61	0.43	0.55	0.60	0.99	1.21	0.90	0.60	0.47	11.87
1940	0.41	0.75	0.89	0.61	0.33	0.29	0.37	0.33	0.31	0.32	0.33	0.34	5.28
1941	0.49	0.69	0.55	5.24	2.34	0.88	0.80	0.80	0.74	0.49	0.47	0.59	14.08
1942	0.77	11.22	7.54	1.96	0.67	1.45	5.02	2.40	1.02	0.86	2.31	1.60	36.82
1943	1.20	3.64	2.07	0.98	1.02	1.02	0.78	0.55	0.47	0.51	0.44	4.24	16.92
1944	2.41	0.93	0.41	0.43	0.80	1.16	0.99	0.70	0.54	0.44	0.34	0.39	9.54
1945	6.58	2.68	0.37	0.26	0.61	3.65	2.10	0.95	0.62	0.47	0.35	0.31	18.95
1946	0.41	0.82	0.93	0.75	0.76	3.44	5.42	2.39	4.39	2.34	0.89	0.63	23.17
1947	0.57	14.76	5.82	0.95	2.55	2.47	1.46	0.86	0.50	0.31	0.22	0.18	30.65
1948	0.70	1.00	0.82	0.62	7.84	4.67	1.70	1.00	0.58	0.38	0.33	0.37	20.01
1949	0.56	3.22	1.69	0.96	1.13	1.15	1.18	1.36	1.16	0.89	1.01	0.94	15.25
1950	0.86	0.65	3.04	1.82	0.91	1.00	0.93	0.63	0.47	0.40	0.44	0.58	11.73
1951	2.47	1.27	0.81	1.14	1.08	1.08	1.24	1.10	0.74	0.49	0.32	0.40	12.14
1952	0.50	0.45	0.38	0.36	0.50	0.64	0.70	0.59	0.42	0.30	0.31	0.63	5.78
1953	1.08	5.00	2.85	1.05	0.65	0.82	0.78	0.74	0.89	0.84	0.59	0.63	15.92
1954	11.48	4.55	0.68	2.23	5.71	3.18	1.28	0.76	0.57	0.44	0.29	0.44	31.61
1955	0.69	0.78	0.50	0.18	0.41	7.40	3.49	1.18	0.92	0.73	0.51	0.55	17.34
1956	1.00	9.49	15.95	5.21	1.20	5.24	6.31	2.34	0.85	0.68	0.59	0.81	49.67
1957	1.20	1.28	1.16	1.98	6.08	2.79	4.61	2.15	0.60	0.42	0.37	0.34	22.98
1958	0.39	0.76	0.95	0.62	0.55	0.72	0.84	13.97	5.46	1.05	1.23	1.17	27.71
1959	0.97	0.82	0.69	0.60	0.53	0.80	1.15	1.31	1.07	0.73	0.62	0.73	10.02
1960	0.73	0.90	2.16	1.53	1.00	1.06	11.83	4.89	1.09	0.96	0.86	0.65	27.66
1961	0.54	1.19	1.14	0.84	0.84	3.76	1.91	0.76	0.55	0.36	0.44	0.54	12.87
1962	0.84	3.60	1.80	4.29	2.07	15.89	6.09	0.94	0.73	5.87	2.74	0.68	45.54
1963	0.74	1.10	1.08	5.27	3.45	2.24	3.89	1.90	12.85	5.18	0.90	0.68	39.28
1964	2.69	1.43	0.47	0.41	0.43	0.31	0.23	0.34	8.12	3.87	1.91	1.50	21.71
1965	8.90	5.12	1.40	0.68	0.57	0.37	0.26	4.89	2.53	0.85	0.60	0.65	26.82
1966	0.63	0.51	0.50	0.77	0.97	10.03	8.17	2.40	0.83	1.28	1.22	0.70	28.01
1967	0.45	0.62	0.59	0.43	0.48	0.56	0.57	0.44	0.31	0.26	0.40	0.82	5.93
1968	1.10	1.16	1.01	0.58	1.07	6.55	2.86	5.79	2.74	0.90	0.67	0.56	24.99
1969	0.65	0.92	0.87	0.51	0.41	0.37	0.31	0.36	0.61	0.69	4.86	2.63	13.19
1970	9.55	4.11	1.07	0.79	0.78	0.82	0.90	7.34	3.23	1.33	4.87	2.42	37.21
1971	8.07	3.42	0.90	0.70	6.43	2.87	0.80	0.55	0.47	0.46	0.43	0.34	25.44
1972	0.28	0.68	0.93	0.76	0.61	0.69	1.10	1.02	0.59	0.37	0.47	0.85	8.35
1973	1.07	3.58	1.75	0.65	0.80	1.18	1.16	7.46	3.54	1.23	0.75	0.48	23.65
1974	0.42	0.59	0.84	0.77	0.67	0.73	0.73	0.60	0.44	0.35	0.34	5.49	11.97
1975	2.56	0.73	1.63	1.20	5.89	23.89	8.55	4.14	2.08	0.77	0.53	0.69	52.66
1976	15.40	5.73	0.54	0.49	1.93	1.46	0.84	0.49	0.40	0.42	0.55	0.79	29.04
1977	1.07	4.68	5.10	1.91	0.75	0.75	35.24	13.35	1.47	0.88	0.66	0.68	66.54
1978	3.26	1.96	0.89	0.54	0.46	0.84	0.94	0.68	0.48	0.78	1.17	1.15	13.15
1979	1.16	0.93	0.63	0.42	0.44	0.53	0.47	0.43	0.40	0.34	0.30	2.48	8.53
1980	1.63	2.47	1.53	1.04	0.96	0.73	0.47	0.73	0.95	0.71	0.81	0.83	12.86
1981	0.57	0.45	0.39	0.46	0.49	7.99	3.72	1.18	0.80	0.60	0.44	0.35	17.44
1982	0.56	0.59	0.34	0.21	0.24	0.24	0.25	0.25	0.22	6.15	2.95	0.93	12.93
1983	0.84	1.05	1.04	1.07	1.14	1.05	1.15	1.14	1.06	3.15	1.85	0.89	15.43
1984	0.74	2.20	1.42	0.81	14.63	5.61	0.72	0.43	0.32	0.29	0.24	0.18	27.59
1985	0.64	2.87	1.57	1.14	0.90	0.70	0.67	0.53	0.38	0.29	0.58	1.19	11.46
1986	4.09	2.14	0.78	0.61	0.45	0.63	0.78	0.61	0.50	0.42	0.50	23.79	35.30
1987	8.91	2.59	1.45	0.65	4.51	17.92	6.47	4.01	2.23	1.81	1.69	1.24	53.48
1988	0.99	3.49	8.55	2.98	7.17	3.30	4.58	2.24	0.90	0.76	0.53	0.42	35.91
1989	2.69	7.92	2.87	0.58	0.46	3.07	1.68	0.59	0.37	0.28	0.54	0.76	21.81
1990	0.89	0.76	0.48	0.55	0.98	1.04	0.66	0.43	0.38	0.32	0.32	0.50	7.31
1991	2.10	3.58	1.55	0.61	0.47	0.41	0.50	0.47	0.35	0.27	0.27	0.41	10.99
1992	0.60	0.62	0.60	0.52	0.42	0.31	0.28	0.28	0.24	0.20	0.22	0.53	4.82
1993	1.02	1.11	2.42	1.26	9.30	4.02	0.87	0.43	0.27	0.34	0.67	0.64	22.35
1994	0.45	0.31	0.65	0.82	0.55	4.01	8.79	3.40	2.52	1.64	0.78	0.55	24.47
1995	0.67	0.69	9.73	4.06	2.59	1.43	0.70	0.55	0.42	1.46	1.32	0.81	24.43
1996	0.88	11.12	4.35	0.93	3.42	1.98	7.33	3.22	18.23	7.32	1.32	1.01	61.11
month	150.23	209.99	152.75	105.76	164.13	244.01	203.27	142.30	129.70	120.57	77.84	104.45	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.24	0.31	0.34	0.18	0.24	0.24	0.23	0.25	0.22	0.20	0.22	0.18	4.82
max	15.40	17.23	15.95	8.34	14.63	23.89	35.24	13.97	18.23	25.84	9.46	23.79	66.54
median	0.84	1.10	0.95	0.79	0.90	1.18	1.05	0.79	0.67	0.73	0.59	0.64	21.56
mean	1.95	2.73	1.98	1.37	2.13	3.17	2.64	1.85	1.68	1.57	1.01	1.36	23.44
Sum of the monthly means =				23.44									
s.d.	2.84	3.49	2.61	1.52	2.83	4.27	4.47	2.58	2.95	3.25	1.34	2.89	14.37
c.v.	1.46	1.28	1.32	1.11	1.33	1.35	1.69	1.40	1.75	2.08	1.32	2.13	0.61

APPENDIX 8.5
LOWER MZINTLAVA (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.20	0.37	0.64	0.65	0.65	1.44	1.12	0.70	0.41	0.25	0.16	0.21	6.80
1921	0.40	2.59	2.75	1.14	0.48	0.28	0.18	2.56	2.88	1.31	0.82	0.80	16.19
1922	2.87	6.86	2.44	5.98	9.20	5.48	1.50	0.43	0.30	5.80	2.53	0.49	43.88
1923	0.28	0.27	0.34	2.46	2.77	1.08	0.33	0.22	0.21	0.19	0.21	0.35	8.71
1924	0.51	0.62	0.76	0.67	0.65	4.64	2.22	0.76	0.50	0.37	0.28	0.39	12.37
1925	0.53	0.57	0.53	0.55	0.67	5.85	2.45	0.57	0.67	0.68	0.45	0.44	13.96
1926	0.68	1.02	0.95	0.65	0.47	8.46	3.27	0.39	0.23	0.17	0.16	0.23	16.68
1927	0.44	0.38	0.38	0.55	0.82	0.87	0.59	0.40	0.36	0.29	0.37	0.41	5.86
1928	0.41	0.52	0.52	0.46	0.42	0.69	0.69	0.52	4.85	3.54	1.44	3.32	17.38
1929	4.76	2.98	1.05	0.45	0.33	0.42	0.54	0.49	0.61	0.74	0.82	2.32	15.51
1930	1.31	0.58	0.43	2.85	3.63	6.65	2.52	0.55	0.32	18.91	6.94	0.62	45.31
1931	0.60	0.58	0.46	0.30	2.49	1.50	0.64	0.51	0.58	0.64	0.56	2.81	11.67
1932	1.72	8.96	6.60	1.54	0.37	0.52	0.50	0.38	0.29	0.24	0.20	0.18	21.50
1933	0.18	0.72	2.64	4.08	1.66	0.82	0.76	0.58	0.41	0.66	0.75	0.44	13.70
1934	0.28	0.45	1.39	0.90	0.44	0.54	3.29	5.55	8.19	2.95	0.98	0.82	25.78
1935	0.56	0.49	0.28	0.16	5.70	6.70	2.12	2.35	1.49	0.82	0.52	0.39	21.58
1936	0.70	12.52	4.55	0.39	1.35	2.69	1.30	0.48	0.30	0.29	0.32	0.31	25.20
1937	0.33	0.34	0.51	0.62	0.61	0.45	0.64	0.76	0.68	0.67	0.57	0.36	6.54
1938	0.28	0.44	0.60	0.66	2.33	1.41	0.76	0.72	0.68	0.70	0.79	5.48	14.85
1939	2.59	0.82	0.65	0.44	0.32	0.41	0.44	0.72	0.88	0.65	0.44	0.34	8.70
1940	0.30	0.56	0.65	0.44	0.25	0.22	0.27	0.24	0.23	0.24	0.24	0.25	3.89
1941	0.36	0.52	0.40	3.66	1.67	0.66	0.59	0.59	0.54	0.36	0.35	0.44	10.14
1942	0.56	8.09	5.39	1.41	0.50	0.91	3.59	1.76	0.76	0.64	1.60	1.16	26.37
1943	0.89	2.50	1.47	0.71	0.77	0.79	0.59	0.41	0.35	0.38	0.33	3.02	12.21
1944	1.75	0.70	0.31	0.31	0.59	0.84	0.72	0.50	0.39	0.32	0.25	0.29	6.97
1945	4.73	1.95	0.28	0.19	0.45	2.50	1.50	0.71	0.46	0.35	0.26	0.23	13.61
1946	0.31	0.61	0.68	0.53	0.56	2.32	3.88	1.76	3.18	1.72	0.67	0.47	16.69
1947	0.42	10.74	4.25	0.69	1.67	1.69	1.06	0.64	0.37	0.23	0.16	0.13	22.05
1948	0.52	0.74	0.60	0.44	5.57	3.30	1.24	0.75	0.43	0.28	0.24	0.28	14.39
1949	0.42	2.22	1.21	0.70	0.82	0.83	0.85	1.00	0.88	0.67	0.76	0.69	11.05
1950	0.63	0.48	2.05	1.28	0.67	0.73	0.67	0.46	0.35	0.29	0.33	0.43	8.37
1951	1.68	0.91	0.61	0.82	0.79	0.78	0.89	0.79	0.54	0.36	0.23	0.30	8.70
1952	0.37	0.34	0.29	0.26	0.37	0.47	0.51	0.43	0.31	0.22	0.23	0.47	4.27
1953	0.79	3.48	1.93	0.74	0.49	0.61	0.57	0.54	0.65	0.62	0.43	0.46	11.31
1954	8.31	3.32	0.51	1.45	4.07	2.25	0.93	0.57	0.42	0.32	0.21	0.32	22.68
1955	0.51	0.58	0.37	0.13	0.31	5.27	2.52	0.87	0.68	0.54	0.38	0.41	12.57
1956	0.73	6.79	11.59	3.81	0.89	3.65	4.53	1.72	0.64	0.51	0.44	0.60	35.90
1957	0.88	0.94	0.84	1.19	4.37	2.06	3.26	1.55	0.45	0.32	0.27	0.26	16.39
1958	0.29	0.57	0.70	0.44	0.41	0.53	0.61	10.15	3.99	0.79	0.92	0.86	20.26
1959	0.71	0.60	0.51	0.43	0.39	0.59	0.83	0.95	0.78	0.53	0.46	0.54	7.32
1960	0.54	0.66	1.36	1.05	0.74	0.78	8.52	3.56	0.81	0.71	0.63	0.48	19.84
1961	0.40	0.72	0.80	0.62	0.62	2.56	1.35	0.57	0.41	0.27	0.33	0.40	9.05
1962	0.62	2.46	1.27	2.98	1.48	11.60	4.46	0.70	0.55	4.24	2.00	0.51	32.87
1963	0.55	0.82	0.79	3.62	2.38	1.55	2.80	1.40	9.46	3.83	0.68	0.51	28.39
1964	1.85	1.03	0.36	0.30	0.32	0.23	0.17	0.25	5.89	2.84	1.33	1.09	15.66
1965	6.45	3.66	1.01	0.50	0.42	0.27	0.19	3.49	1.85	0.64	0.45	0.49	19.42
1966	0.47	0.38	0.37	0.56	0.70	7.17	5.89	1.76	0.62	0.86	0.89	0.53	20.20
1967	0.33	0.47	0.44	0.31	0.36	0.41	0.41	0.33	0.23	0.19	0.29	0.61	4.38
1968	0.81	0.85	0.73	0.41	0.59	4.70	2.09	4.20	2.02	0.68	0.50	0.41	17.99
1969	0.48	0.68	0.64	0.37	0.31	0.28	0.23	0.27	0.45	0.51	3.47	1.92	9.61
1970	6.92	3.00	0.79	0.57	0.57	0.60	0.65	5.23	2.34	0.93	3.55	1.79	26.94
1971	5.84	2.51	0.67	0.50	4.54	2.06	0.59	0.41	0.35	0.34	0.32	0.25	18.38
1972	0.21	0.51	0.69	0.55	0.45	0.51	0.79	0.74	0.43	0.27	0.35	0.63	6.13
1973	0.78	2.44	1.23	0.48	0.59	0.86	0.84	5.32	2.56	0.92	0.56	0.35	16.93
1974	0.31	0.44	0.62	0.55	0.49	0.54	0.53	0.44	0.32	0.26	0.25	3.94	8.69
1975	1.86	0.55	1.03	0.83	4.18	17.54	6.28	3.13	1.58	0.58	0.40	0.52	38.48
1976	11.23	4.20	0.41	0.35	1.24	1.03	0.62	0.36	0.30	0.31	0.41	0.59	21.05
1977	0.78	3.25	3.59	1.38	0.56	0.55	25.75	9.74	1.09	0.66	0.49	0.51	48.35
1978	2.27	1.41	0.66	0.39	0.34	0.62	0.68	0.50	0.35	0.57	0.85	0.84	9.48
1979	0.85	0.68	0.47	0.30	0.33	0.40	0.34	0.31	0.29	0.25	0.22	1.72	6.16
1980	1.18	1.69	1.09	0.76	0.70	0.53	0.34	0.53	0.69	0.52	0.59	0.61	9.23
1981	0.42	0.34	0.29	0.33	0.36	5.72	2.70	0.87	0.59	0.45	0.32	0.26	12.65
1982	0.42	0.44	0.25	0.15	0.18	0.19	0.19	0.18	0.17	4.30	2.11	0.70	9.28
1983	0.63	0.78	0.76	0.77	0.83	0.76	0.83	0.82	0.77	2.16	1.32	0.67	11.10
1984	0.55	1.47	1.00	0.59	10.60	4.09	0.54	0.32	0.23	0.22	0.17	0.14	19.92
1985	0.47	1.93	1.11	0.77	0.68	0.54	0.50	0.40	0.28	0.21	0.43	0.87	8.19
1986	2.83	1.53	0.58	0.44	0.33	0.47	0.56	0.45	0.37	0.31	0.37	17.46	25.70
1987	6.55	1.76	1.03	0.48	3.15	13.12	4.77	2.86	1.63	1.27	1.24	0.92	38.78
1988	0.73	2.40	6.14	2.16	5.16	2.41	3.24	1.62	0.68	0.56	0.39	0.31	25.80
1989	1.86	5.72	2.10	0.43	0.35	2.10	1.19	0.45	0.28	0.21	0.40	0.56	15.65
1990	0.66	0.56	0.35	0.40	0.72	0.75	0.48	0.32	0.28	0.23	0.24	0.37	5.36
1991	1.41	2.52	1.13	0.45	0.35	0.30	0.36	0.35	0.26	0.20	0.20	0.30	7.83
1992	0.45	0.46	0.44	0.37	0.31	0.23	0.20	0.20	0.18	0.15	0.16	0.40	3.55
1993	0.75	0.82	1.55	0.85	6.72	2.93	0.65	0.32	0.20	0.25	0.50	0.48	16.02
1994	0.33	0.23	0.49	0.59	0.40	2.77	6.38	2.51	1.79	1.20	0.59	0.41	17.69
1995	0.49	0.51	6.97	2.93	1.74	1.01	0.52	0.41	0.31	0.98	0.96	0.61	17.44
1996	0.65	8.02	3.16	0.68	2.30	1.40	5.27	2.35	13.43	5.38	1.00	0.77	44.41
month	108.72	150.62	109.48	74.90	117.06	175.48	147.37	103.70	95.28	88.02	57.03	76.25	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.18	0.23	0.25	0.13	0.18	0.19	0.17	0.18	0.17	0.15	0.16	0.13	3.55
max	11.23	12.52	11.59	5.98	10.60	17.54	25.75	10.15	13.43	18.91	6.94	17.46	48.35
median	0.62	0.78	0.70	0.57	0.65	0.86	0.76	0.58	0.50	0.53	0.44	0.48	15.51
mean	1.41	1.96	1.42	0.97	1.52	2.28	1.91	1.35	1.24	1.14	0.74	0.99	16.93
Sum of the monthly means =				16.93									
s.d.	2.06	2.52	1.88	1.08	2.03	3.10	3.26	1.87	2.17	2.37	0.97	2.11	10.43
c.v.	1.46	1.29	1.32	1.11	1.34	1.36	1.70	1.39	1.75	2.08	1.31	2.13	0.62

APPENDIX 9

PRESENT DAY FLOW RECORDS FOR PROPOSED DAM SITES (2030)

APPENDIX 9.1
XURA DAM (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.49	1.02	1.91	1.82	1.63	1.94	1.95	1.29	0.65	0.37	0.24	0.38	13.69
1921	0.86	8.16	8.96	3.35	1.16	0.60	0.31	2.47	3.46	2.23	1.65	1.66	34.87
1922	7.28	18.58	6.63	15.09	20.89	10.68	2.77	0.80	0.47	9.89	4.60	1.05	98.73
1923	0.66	0.75	1.05	7.60	6.46	2.22	0.61	0.35	0.31	0.27	0.32	0.65	21.25
1924	1.11	1.64	3.06	2.10	1.59	8.94	4.33	1.42	0.81	0.56	0.44	0.72	26.72
1925	1.16	1.50	1.57	1.60	1.73	11.96	4.98	1.05	1.11	1.11	0.73	0.79	29.29
1926	1.49	4.77	3.23	1.73	1.16	17.62	6.78	0.72	0.36	0.25	0.25	0.42	38.78
1927	0.96	0.99	1.13	1.59	2.08	1.86	1.10	0.67	0.54	0.42	0.60	0.73	12.67
1928	0.88	1.38	1.53	1.38	1.11	1.49	1.35	0.89	6.98	5.39	2.73	7.15	32.26
1929	12.10	9.79	3.43	1.26	0.85	0.88	1.01	0.83	0.97	1.20	1.38	3.57	37.27
1930	2.60	1.64	1.35	8.74	8.47	13.28	5.04	1.02	0.51	39.42	14.54	1.36	97.97
1931	1.44	1.62	1.43	0.96	6.10	3.41	1.23	0.86	0.91	1.02	0.91	4.67	24.56
1932	4.37	23.20	17.78	4.22	0.87	1.07	0.92	0.62	0.43	0.35	0.29	0.30	54.42
1933	0.36	3.28	8.54	10.74	4.01	1.69	1.44	0.98	0.63	1.07	1.27	0.78	34.79
1934	0.58	1.18	5.96	3.07	1.05	1.12	4.78	9.11	15.62	5.88	1.99	1.69	52.03
1935	1.28	1.34	0.89	0.54	13.24	13.66	4.14	2.16	2.15	1.57	0.94	0.73	42.64
1936	1.58	31.53	11.55	1.09	3.24	4.60	2.30	0.89	0.48	0.45	0.51	0.54	58.76
1937	0.71	0.89	1.47	1.79	1.58	1.02	1.23	1.33	1.08	1.07	0.93	0.63	13.73
1938	0.58	1.15	1.73	1.90	5.89	3.25	1.45	1.24	1.07	1.11	1.33	10.78	31.48
1939	6.49	2.44	1.86	1.34	0.86	0.89	0.84	1.24	1.44	1.03	0.69	0.60	19.72
1940	0.63	1.46	1.89	1.32	0.69	0.48	0.49	0.40	0.34	0.36	0.38	0.44	8.88
1941	0.78	1.36	1.22	10.31	4.43	1.35	1.09	0.98	0.84	0.54	0.54	0.79	24.23
1942	1.22	21.03	15.05	3.95	1.19	1.54	6.21	3.22	1.37	1.08	1.64	2.03	59.53
1943	2.20	8.98	5.61	2.11	1.80	1.67	1.12	0.68	0.53	0.57	0.52	5.24	31.03
1944	3.63	1.95	1.01	0.97	1.50	1.85	1.40	0.87	0.60	0.48	0.38	0.51	15.15
1945	10.79	4.63	0.86	0.62	1.12	4.28	2.76	1.32	0.74	0.54	0.40	0.41	28.47
1946	0.65	1.56	1.89	1.53	1.42	3.95	6.54	3.18	3.79	2.68	1.36	0.96	29.51
1947	0.96	27.12	10.82	1.90	4.16	2.96	1.96	1.21	0.60	0.34	0.24	0.22	52.49
1948	1.14	1.92	1.77	1.35	13.22	6.16	2.14	1.39	0.69	0.42	0.38	0.49	31.07
1949	0.90	7.30	3.70	1.90	2.04	1.83	1.65	1.76	1.42	1.05	1.26	1.26	26.07
1950	1.37	1.25	7.43	3.94	1.61	1.55	1.28	0.77	0.52	0.44	0.52	0.78	21.46
1951	3.92	2.28	2.52	2.40	1.90	1.68	1.71	1.38	0.84	0.53	0.34	0.53	20.03
1952	0.78	0.88	0.87	0.80	0.96	1.03	0.96	0.72	0.46	0.32	0.35	0.88	9.01
1953	1.76	10.59	7.12	2.41	1.17	1.27	1.06	0.91	1.04	0.97	0.69	0.84	29.83
1954	19.05	7.87	1.52	5.32	9.38	4.27	1.75	1.05	0.68	0.50	0.33	0.60	52.32
1955	1.12	1.53	1.13	0.45	0.75	10.62	5.09	1.63	1.12	0.85	0.60	0.74	25.63
1956	1.62	18.29	29.48	9.52	2.10	6.66	8.02	3.17	1.14	0.84	0.73	1.15	82.72
1957	1.96	2.93	2.52	4.74	10.06	4.38	4.76	2.50	0.81	0.52	0.45	0.46	36.09
1958	0.62	1.50	2.03	1.35	1.06	1.16	1.16	18.99	7.58	1.51	1.71	1.70	40.37
1959	1.59	1.63	1.54	1.31	1.04	1.28	1.61	1.67	1.25	0.82	0.73	0.98	15.45
1960	1.15	1.74	6.21	3.53	1.76	1.64	16.50	6.91	1.46	1.21	1.08	0.87	44.06
1961	0.86	3.68	2.73	1.69	1.55	4.43	2.46	1.05	0.66	0.41	0.53	0.73	20.78
1962	1.37	8.22	3.97	8.45	3.88	24.40	9.33	1.29	0.89	6.07	3.32	1.11	72.30
1963	1.30	3.22	2.51	10.20	5.56	2.48	4.42	2.46	18.02	7.45	1.37	1.04	60.03
1964	4.80	2.74	1.09	0.91	0.85	0.53	0.30	0.41	9.74	5.11	2.43	2.26	31.17
1965	15.93	11.28	3.35	1.38	1.08	0.61	0.34	4.52	2.89	1.22	0.81	0.94	44.35
1966	1.04	1.02	1.14	1.60	1.80	14.93	11.19	3.27	1.12	1.53	1.62	1.00	41.26
1967	0.72	1.25	1.33	0.96	0.93	0.90	0.78	0.54	0.34	0.28	0.48	1.16	9.67
1968	1.79	2.56	2.18	1.23	1.66	9.13	4.08	6.09	3.27	1.29	0.92	0.79	34.99
1969	1.08	1.82	1.90	1.15	0.82	0.62	0.42	0.44	0.72	0.81	4.75	3.38	17.91
1970	17.36	9.45	2.68	1.53	1.41	1.30	1.23	8.03	3.88	1.84	5.86	3.41	57.98
1971	14.79	6.47	1.97	1.52	10.91	4.75	1.13	0.68	0.52	0.52	0.49	0.43	44.18
1972	0.43	1.32	1.97	1.61	1.19	1.12	1.53	1.31	0.67	0.39	0.56	1.18	13.28
1973	1.73	8.20	3.88	1.32	1.46	1.85	1.62	8.23	4.35	1.76	1.02	0.67	36.09
1974	0.67	1.18	1.81	1.63	1.29	1.18	1.02	0.74	0.48	0.38	0.38	7.36	18.12
1975	3.84	1.56	5.45	3.00	9.39	38.07	13.48	3.61	2.28	1.11	0.72	1.02	83.53
1976	26.07	9.96	1.22	1.07	3.24	2.34	1.19	0.61	0.44	0.47	0.67	1.10	48.38
1977	1.73	10.03	11.03	3.91	1.34	1.17	54.33	20.06	1.98	1.19	0.86	0.96	108.59
1978	5.44	3.64	1.89	1.17	0.90	1.32	1.31	0.85	0.53	0.93	1.47	1.58	21.03
1979	1.88	1.81	1.42	0.96	0.86	0.87	0.65	0.52	0.44	0.37	0.34	2.39	12.51
1980	2.33	6.90	3.72	2.04	1.77	1.18	0.64	0.90	1.12	0.82	0.99	1.12	23.53
1981	0.87	0.90	0.88	0.99	0.95	11.56	5.45	1.63	0.97	0.69	0.50	0.45	25.84
1982	0.89	1.16	0.77	0.50	0.47	0.40	0.33	0.29	0.24	7.15	3.86	1.52	17.58
1983	1.49	3.15	2.44	2.17	2.01	1.62	1.58	1.42	1.23	1.86	1.95	1.44	22.36
1984	1.29	6.00	3.38	1.62	24.46	9.28	1.03	0.52	0.34	0.32	0.26	0.23	48.73
1985	1.03	6.81	3.54	3.04	1.89	1.08	0.90	0.65	0.41	0.30	0.72	1.69	22.06
1986	6.90	3.95	1.73	1.33	0.91	1.01	1.08	0.76	0.56	0.46	0.60	37.95	57.24
1987	14.50	7.21	3.60	1.33	7.39	28.15	10.09	3.04	2.38	2.12	2.33	1.91	84.05
1988	1.69	8.31	17.00	5.70	11.50	5.24	4.72	2.63	1.21	0.95	0.65	0.56	60.16
1989	4.29	15.75	5.84	1.18	0.89	3.37	2.12	0.82	0.44	0.31	0.68	1.06	36.75
1990	1.46	1.48	1.09	1.19	1.81	1.68	0.93	0.53	0.42	0.34	0.37	0.68	11.98
1991	3.33	8.35	3.61	1.24	0.91	0.66	0.67	0.57	0.38	0.28	0.31	0.55	20.86
1992	0.97	1.21	1.32	1.13	0.84	0.51	0.37	0.33	0.26	0.21	0.25	0.75	8.15
1993	1.67	2.16	6.79	3.08	15.09	6.45	1.25	0.53	0.29	0.38	0.84	0.87	39.40
1994	0.70	0.61	1.31	1.58	1.02	4.85	12.13	4.88	1.98	1.91	1.16	0.82	32.95
1995	1.13	1.39	19.12	7.84	3.88	2.16	0.99	0.68	0.47	1.19	1.63	1.21	41.69
1996	1.49	21.25	8.39	1.84	5.60	3.16	9.38	4.28	26.88	10.87	2.03	1.58	96.75
month	253.68	430.65	329.30	216.73	278.84	358.15	282.29	173.82	160.60	154.52	98.70	147.98	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.36	0.61	0.77	0.45	0.47	0.40	0.30	0.29	0.24	0.21	0.24	0.22	8.15
max	26.07	31.53	29.48	15.09	24.46	38.07	54.33	20.06	26.88	39.42	14.54	37.95	108.59
median	1.37	2.44	2.18	1.61	1.61	1.85	1.45	1.05	0.81	0.84	0.72	0.94	31.48
mean	3.29	5.59	4.28	2.81	3.62	4.65	3.67	2.26	2.09	2.01	1.28	1.92	37.47
Sum of the monthly means =				37.47									
s.d.	4.92	6.58	5.00	2.88	4.64	6.56	6.75	3.40	4.13	4.82	1.87	4.50	23.14
c.v.	1.49	1.18	1.17	1.02	1.28	1.41	1.84	1.51	1.98	2.40	1.46	2.34	0.62

APPENDIX 9.2
ZALU DAM (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.14	0.30	0.57	0.58	0.51	0.62	0.63	0.42	0.21	0.11	0.07	0.11	4.27
1921	0.25	2.44	2.71	1.03	0.35	0.17	0.08	0.64	1.00	0.69	0.52	0.51	10.39
1922	2.20	5.76	2.06	4.66	6.48	3.27	0.84	0.25	0.14	3.01	1.41	0.33	30.41
1923	0.20	0.22	0.31	2.26	1.92	0.67	0.18	0.10	0.09	0.08	0.10	0.19	6.32
1924	0.33	0.49	0.85	0.62	0.48	2.71	1.32	0.44	0.25	0.17	0.13	0.22	8.01
1925	0.35	0.45	0.48	0.49	0.52	3.66	1.53	0.33	0.34	0.34	0.22	0.24	8.95
1926	0.45	1.39	0.97	0.55	0.37	5.48	2.10	0.22	0.11	0.08	0.07	0.12	11.91
1927	0.28	0.29	0.34	0.48	0.63	0.59	0.35	0.21	0.17	0.13	0.18	0.22	3.87
1928	0.26	0.41	0.46	0.42	0.33	0.45	0.41	0.27	2.08	1.62	0.84	2.19	9.74
1929	3.73	3.00	1.05	0.39	0.25	0.26	0.30	0.25	0.30	0.36	0.42	1.02	11.33
1930	0.78	0.50	0.41	2.64	2.56	4.09	1.56	0.32	0.15	12.36	4.56	0.43	30.36
1931	0.44	0.49	0.43	0.29	1.78	1.02	0.37	0.26	0.28	0.31	0.28	1.35	7.30
1932	1.29	7.24	5.52	1.30	0.26	0.32	0.27	0.19	0.13	0.10	0.09	0.09	16.80
1933	0.10	0.89	2.57	3.29	1.23	0.52	0.44	0.30	0.19	0.33	0.39	0.24	10.49
1934	0.17	0.35	1.75	0.92	0.32	0.33	1.39	2.78	4.86	1.84	0.62	0.53	15.86
1935	0.39	0.41	0.26	0.16	4.01	4.18	1.27	0.60	0.65	0.49	0.29	0.22	12.93
1936	0.48	9.83	3.60	0.33	0.90	1.34	0.69	0.27	0.15	0.14	0.16	0.16	18.05
1937	0.21	0.26	0.44	0.55	0.48	0.30	0.37	0.41	0.33	0.33	0.28	0.19	4.15
1938	0.17	0.34	0.52	0.58	1.75	0.98	0.44	0.38	0.33	0.34	0.41	3.29	9.53
1939	1.95	0.74	0.57	0.41	0.26	0.26	0.25	0.38	0.44	0.32	0.21	0.18	5.97
1940	0.18	0.44	0.57	0.40	0.20	0.14	0.14	0.12	0.10	0.11	0.11	0.13	2.64
1941	0.23	0.40	0.36	3.11	1.34	0.41	0.33	0.30	0.26	0.16	0.16	0.24	7.30
1942	0.36	6.50	4.66	1.22	0.36	0.47	1.85	0.98	0.43	0.34	0.50	0.63	18.30
1943	0.67	2.74	1.68	0.63	0.55	0.51	0.34	0.21	0.16	0.17	0.16	1.52	9.34
1944	1.09	0.60	0.31	0.29	0.45	0.56	0.42	0.27	0.18	0.15	0.11	0.15	4.58
1945	3.25	1.40	0.26	0.18	0.33	1.22	0.82	0.41	0.23	0.16	0.12	0.12	8.50
1946	0.19	0.48	0.60	0.48	0.44	1.15	1.97	0.98	1.13	0.82	0.43	0.29	8.96
1947	0.29	8.43	3.36	0.59	1.21	0.89	0.61	0.38	0.18	0.10	0.07	0.06	16.17
1948	0.34	0.58	0.54	0.41	4.03	1.87	0.68	0.45	0.22	0.13	0.12	0.15	9.52
1949	0.26	2.17	1.11	0.58	0.62	0.56	0.50	0.54	0.44	0.32	0.39	0.39	7.88
1950	0.41	0.38	2.21	1.19	0.49	0.47	0.39	0.24	0.16	0.13	0.15	0.24	6.46
1951	1.10	0.67	0.70	0.72	0.59	0.51	0.52	0.43	0.26	0.16	0.10	0.16	5.92
1952	0.23	0.26	0.26	0.24	0.28	0.30	0.28	0.22	0.14	0.10	0.10	0.26	2.67
1953	0.53	3.22	2.14	0.73	0.35	0.38	0.32	0.28	0.32	0.30	0.21	0.25	9.03
1954	5.87	2.43	0.47	1.57	2.85	1.31	0.54	0.32	0.21	0.15	0.10	0.18	16.00
1955	0.33	0.46	0.34	0.13	0.22	3.20	1.55	0.51	0.35	0.26	0.18	0.22	7.75
1956	0.49	5.65	9.19	2.97	0.65	2.01	2.43	0.98	0.36	0.26	0.22	0.35	25.56
1957	0.60	0.83	0.75	1.41	3.07	1.35	1.42	0.76	0.25	0.16	0.14	0.14	10.88
1958	0.18	0.45	0.62	0.41	0.32	0.35	0.35	5.87	2.35	0.47	0.53	0.53	12.43
1959	0.49	0.50	0.47	0.40	0.31	0.38	0.49	0.51	0.38	0.25	0.22	0.30	4.70
1960	0.34	0.53	1.85	1.07	0.54	0.50	5.10	2.14	0.45	0.37	0.33	0.27	13.49
1961	0.25	1.04	0.81	0.52	0.47	1.29	0.73	0.32	0.20	0.12	0.16	0.22	6.13
1962	0.41	2.47	1.20	2.57	1.18	7.60	2.90	0.40	0.27	1.81	1.01	0.34	22.16
1963	0.39	0.92	0.75	3.12	1.65	0.75	1.32	0.75	5.60	2.32	0.43	0.32	18.32
1964	1.40	0.82	0.33	0.27	0.25	0.15	0.08	0.12	2.91	1.56	0.76	0.71	9.36
1965	4.94	3.47	1.02	0.42	0.32	0.18	0.09	1.28	0.86	0.38	0.25	0.29	13.50
1966	0.31	0.30	0.34	0.48	0.55	4.59	3.43	1.01	0.35	0.47	0.50	0.31	12.64
1967	0.21	0.37	0.40	0.29	0.27	0.26	0.23	0.16	0.10	0.08	0.14	0.35	2.86
1968	0.54	0.70	0.64	0.38	0.46	3.00	1.32	1.83	1.00	0.40	0.28	0.24	10.79
1969	0.32	0.55	0.58	0.35	0.24	0.18	0.12	0.13	0.21	0.24	1.37	1.02	5.31
1970	5.40	2.90	0.81	0.47	0.43	0.39	0.37	2.42	1.18	0.57	1.78	1.05	17.77
1971	4.59	2.00	0.60	0.47	3.32	1.45	0.34	0.21	0.16	0.16	0.15	0.13	13.58
1972	0.12	0.39	0.60	0.49	0.36	0.33	0.46	0.40	0.20	0.12	0.17	0.36	4.00
1973	0.52	2.47	1.18	0.40	0.44	0.56	0.49	2.49	1.33	0.55	0.32	0.20	10.95
1974	0.20	0.35	0.55	0.50	0.39	0.35	0.30	0.23	0.15	0.11	0.11	2.18	5.42
1975	1.16	0.48	1.61	0.90	2.86	11.90	4.22	1.08	0.70	0.35	0.22	0.31	25.79
1976	8.10	3.09	0.37	0.32	0.90	0.69	0.36	0.19	0.13	0.14	0.20	0.33	14.82
1977	0.52	3.05	3.37	1.20	0.41	0.35	17.02	6.28	0.62	0.37	0.26	0.29	33.74
1978	1.60	1.10	0.60	0.37	0.27	0.40	0.40	0.26	0.16	0.28	0.45	0.49	6.38
1979	0.57	0.55	0.43	0.29	0.25	0.25	0.19	0.15	0.13	0.11	0.10	0.62	3.64
1980	0.68	2.09	1.13	0.63	0.54	0.36	0.19	0.27	0.34	0.25	0.30	0.34	7.12
1981	0.26	0.26	0.26	0.29	0.28	3.49	1.66	0.51	0.30	0.21	0.15	0.13	7.80
1982	0.26	0.34	0.23	0.15	0.13	0.11	0.09	0.08	0.07	2.06	1.15	0.47	5.14
1983	0.45	0.89	0.73	0.65	0.64	0.51	0.49	0.44	0.38	0.57	0.60	0.45	6.80
1984	0.39	1.78	1.02	0.50	7.61	2.88	0.31	0.16	0.10	0.10	0.08	0.07	15.00
1985	0.30	2.02	1.06	0.87	0.56	0.33	0.27	0.20	0.12	0.09	0.22	0.52	6.56
1986	2.06	1.20	0.53	0.41	0.27	0.30	0.32	0.23	0.17	0.14	0.18	11.84	17.65
1987	4.52	2.20	1.10	0.41	2.21	8.77	3.15	0.89	0.72	0.66	0.73	0.59	25.95
1988	0.52	2.52	5.26	1.77	3.51	1.60	1.40	0.80	0.38	0.29	0.20	0.17	18.42
1989	1.22	4.86	1.81	0.36	0.26	0.93	0.62	0.26	0.13	0.09	0.21	0.32	11.07
1990	0.44	0.45	0.33	0.36	0.55	0.51	0.28	0.16	0.13	0.10	0.11	0.20	3.62
1991	0.91	2.52	1.11	0.38	0.27	0.19	0.19	0.17	0.11	0.08	0.09	0.16	6.18
1992	0.28	0.36	0.40	0.34	0.25	0.15	0.10	0.10	0.08	0.06	0.07	0.22	2.41
1993	0.50	0.66	2.03	0.93	4.65	1.99	0.38	0.16	0.09	0.11	0.25	0.26	12.01
1994	0.20	0.18	0.41	0.51	0.32	1.44	3.73	1.51	0.61	0.59	0.36	0.25	10.11
1995	0.34	0.42	5.91	2.43	1.14	0.65	0.30	0.21	0.14	0.36	0.50	0.37	12.77
1996	0.45	6.59	2.60	0.57	1.67	0.95	2.87	1.32	8.40	3.40	0.64	0.49	29.95
month	76.93	131.28	100.43	66.05	84.47	109.59	86.56	53.10	49.29	47.52	30.20	45.02	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.10	0.18	0.23	0.13	0.13	0.11	0.08	0.08	0.07	0.06	0.07	0.06	2.41
max	8.10	9.83	9.19	4.66	7.61	11.90	17.02	6.28	8.40	12.36	4.56	11.84	33.74
median	0.41	0.70	0.64	0.50	0.48	0.56	0.44	0.32	0.25	0.26	0.22	0.29	9.53
mean	1.00	1.70	1.30	0.86	1.10	1.42	1.12	0.69	0.64	0.62	0.39	0.58	11.43
Sum of the monthly means = 11.43													
s.d.	1.52	2.05	1.55	0.88	1.43	2.04	2.11	1.05	1.28	1.50	0.58	1.40	7.20
c.v.	1.53	1.20	1.19	1.03	1.30	1.44	1.88	1.53	2.01	2.44	1.48	2.39	0.63

APPENDIX 9.3
LUSIKISIKI DAM (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.19	0.40	0.75	0.75	0.67	0.81	0.82	0.53	0.27	0.15	0.10	0.14	5.58
1921	0.34	3.19	3.53	1.33	0.46	0.23	0.11	0.87	1.32	0.89	0.66	0.65	13.58
1922	2.86	7.43	2.65	6.02	8.35	4.24	1.09	0.31	0.19	3.90	1.82	0.41	39.27
1923	0.26	0.29	0.41	2.96	2.51	0.87	0.24	0.13	0.12	0.11	0.13	0.25	8.28
1924	0.43	0.64	1.14	0.82	0.63	3.52	1.71	0.56	0.32	0.22	0.17	0.27	10.43
1925	0.45	0.59	0.62	0.64	0.68	4.74	1.98	0.41	0.44	0.44	0.29	0.30	11.58
1926	0.58	1.83	1.26	0.72	0.48	7.08	2.72	0.28	0.14	0.10	0.10	0.15	15.44
1927	0.37	0.38	0.44	0.63	0.82	0.77	0.45	0.26	0.22	0.17	0.24	0.28	5.03
1928	0.34	0.54	0.60	0.55	0.44	0.58	0.53	0.34	2.72	2.11	1.09	2.82	12.66
1929	4.82	3.89	1.36	0.50	0.33	0.34	0.39	0.32	0.38	0.47	0.55	1.35	14.70
1930	1.01	0.65	0.53	3.43	3.33	5.29	2.01	0.40	0.20	15.87	5.85	0.54	39.11
1931	0.57	0.64	0.56	0.38	2.35	1.33	0.49	0.33	0.36	0.40	0.36	1.78	9.55
1932	1.69	9.31	7.11	1.68	0.34	0.42	0.36	0.23	0.17	0.14	0.11	0.11	21.67
1933	0.13	1.20	3.35	4.26	1.59	0.67	0.57	0.38	0.25	0.43	0.50	0.30	13.63
1934	0.22	0.46	2.30	1.20	0.41	0.44	1.83	3.60	6.26	2.36	0.80	0.67	20.55
1935	0.50	0.53	0.35	0.21	5.22	5.42	1.65	0.79	0.84	0.63	0.38	0.28	16.80
1936	0.62	12.65	4.63	0.43	1.21	1.77	0.90	0.35	0.19	0.18	0.20	0.20	23.33
1937	0.27	0.35	0.58	0.71	0.62	0.40	0.48	0.52	0.43	0.42	0.37	0.24	5.39
1938	0.22	0.45	0.68	0.75	2.29	1.28	0.58	0.48	0.43	0.44	0.53	4.25	12.38
1939	2.55	0.96	0.74	0.54	0.34	0.35	0.32	0.48	0.57	0.41	0.27	0.23	7.76
1940	0.24	0.57	0.75	0.52	0.27	0.18	0.19	0.15	0.13	0.14	0.15	0.16	3.45
1941	0.30	0.53	0.48	4.05	1.75	0.53	0.43	0.38	0.33	0.21	0.22	0.30	9.51
1942	0.48	8.39	6.03	1.59	0.47	0.61	2.42	1.26	0.55	0.43	0.65	0.80	23.68
1943	0.87	3.56	2.19	0.83	0.71	0.66	0.44	0.26	0.21	0.23	0.20	2.00	12.16
1944	1.42	0.78	0.40	0.38	0.59	0.73	0.55	0.33	0.24	0.19	0.15	0.19	5.95
1945	4.24	1.82	0.34	0.24	0.44	1.62	1.08	0.52	0.30	0.21	0.16	0.15	11.12
1946	0.25	0.62	0.78	0.63	0.57	1.53	2.57	1.26	1.48	1.06	0.55	0.37	11.67
1947	0.37	10.86	4.33	0.76	1.60	1.16	0.78	0.48	0.24	0.14	0.10	0.07	20.89
1948	0.44	0.76	0.70	0.53	5.23	2.40	0.84	0.55	0.28	0.17	0.15	0.18	12.23
1949	0.35	2.84	1.45	0.76	0.81	0.73	0.65	0.69	0.57	0.42	0.50	0.49	10.26
1950	0.54	0.49	2.89	1.55	0.64	0.61	0.50	0.30	0.21	0.17	0.20	0.30	8.40
1951	1.47	0.88	0.94	0.94	0.76	0.66	0.68	0.54	0.33	0.21	0.14	0.20	7.75
1952	0.30	0.34	0.34	0.31	0.37	0.40	0.37	0.28	0.18	0.13	0.14	0.34	3.50
1953	0.69	4.18	2.79	0.95	0.46	0.50	0.42	0.35	0.41	0.39	0.27	0.32	11.73
1954	7.59	3.14	0.60	2.06	3.70	1.69	0.70	0.41	0.27	0.20	0.13	0.22	20.71
1955	0.44	0.60	0.44	0.17	0.29	4.16	2.01	0.64	0.45	0.34	0.24	0.28	10.06
1956	0.64	7.30	11.83	3.82	0.84	2.62	3.16	1.25	0.46	0.34	0.29	0.45	33.00
1957	0.78	1.10	0.99	1.85	3.98	1.74	1.86	0.98	0.32	0.21	0.18	0.17	14.16
1958	0.24	0.59	0.80	0.53	0.41	0.45	0.46	7.56	3.03	0.61	0.69	0.67	16.04
1959	0.63	0.64	0.61	0.52	0.41	0.50	0.63	0.65	0.50	0.33	0.29	0.38	6.09
1960	0.45	0.69	2.42	1.39	0.70	0.65	6.58	2.75	0.59	0.48	0.43	0.34	17.47
1961	0.33	1.38	1.06	0.68	0.61	1.70	0.96	0.41	0.26	0.16	0.21	0.28	8.04
1962	0.54	3.22	1.57	3.34	1.53	9.78	3.74	0.51	0.35	2.37	1.31	0.44	28.70
1963	0.51	1.22	0.98	4.05	2.16	0.97	1.73	0.97	7.22	2.99	0.55	0.41	23.76
1964	1.85	1.07	0.43	0.36	0.33	0.20	0.11	0.15	3.80	2.02	0.98	0.90	12.20
1965	6.37	4.48	1.33	0.55	0.42	0.24	0.13	1.69	1.13	0.49	0.32	0.37	17.52
1966	0.41	0.40	0.44	0.63	0.71	5.94	4.44	1.29	0.45	0.61	0.65	0.39	16.36
1967	0.28	0.49	0.52	0.38	0.36	0.35	0.30	0.20	0.13	0.11	0.19	0.45	3.76
1968	0.71	0.95	0.85	0.49	0.57	3.65	1.64	2.38	1.30	0.52	0.37	0.31	13.74
1969	0.42	0.72	0.75	0.46	0.32	0.24	0.16	0.16	0.28	0.32	1.81	1.32	6.96
1970	6.96	3.75	1.06	0.61	0.56	0.51	0.48	3.14	1.54	0.74	2.31	1.35	23.01
1971	5.92	2.59	0.78	0.60	4.31	1.88	0.45	0.26	0.21	0.20	0.19	0.16	17.55
1972	0.16	0.52	0.78	0.64	0.47	0.44	0.60	0.51	0.27	0.15	0.22	0.46	5.22
1973	0.68	3.22	1.53	0.53	0.57	0.73	0.64	3.23	1.73	0.71	0.41	0.26	14.24
1974	0.26	0.46	0.72	0.65	0.51	0.46	0.40	0.28	0.19	0.15	0.15	2.85	7.08
1975	1.51	0.62	2.12	1.18	3.71	15.31	5.42	1.40	0.90	0.45	0.29	0.39	33.30
1976	10.44	3.99	0.48	0.42	1.21	0.91	0.47	0.23	0.18	0.19	0.26	0.42	19.20
1977	0.68	3.96	4.37	1.55	0.53	0.46	21.87	8.07	0.80	0.48	0.34	0.37	43.48
1978	2.10	1.43	0.78	0.48	0.36	0.52	0.52	0.33	0.21	0.37	0.58	0.62	8.30
1979	0.74	0.72	0.56	0.38	0.33	0.34	0.25	0.19	0.17	0.15	0.13	0.84	4.80
1980	0.90	2.72	1.47	0.82	0.70	0.47	0.25	0.35	0.44	0.32	0.39	0.43	9.26
1981	0.34	0.35	0.34	0.39	0.37	4.55	2.15	0.64	0.39	0.28	0.20	0.17	10.17
1982	0.35	0.45	0.30	0.19	0.18	0.15	0.12	0.10	0.09	2.72	1.50	0.60	6.75
1983	0.59	1.19	0.95	0.81	0.78	0.64	0.63	0.56	0.49	0.74	0.78	0.57	8.73
1984	0.51	2.33	1.33	0.65	9.80	3.72	0.41	0.20	0.14	0.13	0.10	0.08	19.40
1985	0.40	2.65	1.39	1.15	0.73	0.42	0.35	0.25	0.16	0.12	0.28	0.66	8.56
1986	2.70	1.56	0.69	0.53	0.35	0.39	0.42	0.29	0.22	0.18	0.23	15.22	22.78
1987	5.82	2.85	1.43	0.53	2.89	11.29	4.05	1.16	0.94	0.85	0.94	0.76	33.51
1988	0.67	3.28	6.79	2.28	4.55	2.08	1.84	1.03	0.49	0.38	0.26	0.21	23.86
1989	1.63	6.28	2.33	0.47	0.35	1.25	0.81	0.32	0.17	0.12	0.27	0.41	14.41
1990	0.57	0.58	0.43	0.47	0.71	0.66	0.36	0.20	0.16	0.13	0.15	0.26	4.68
1991	1.23	3.28	1.43	0.49	0.35	0.25	0.26	0.22	0.15	0.11	0.12	0.21	8.10
1992	0.37	0.47	0.52	0.45	0.33	0.20	0.14	0.12	0.10	0.08	0.10	0.28	3.16
1993	0.65	0.85	2.65	1.21	6.01	2.57	0.49	0.20	0.11	0.15	0.33	0.33	15.55
1994	0.27	0.24	0.54	0.67	0.42	1.90	4.83	1.94	0.79	0.77	0.47	0.32	13.16
1995	0.44	0.55	7.63	3.13	1.50	0.84	0.39	0.26	0.19	0.47	0.65	0.47	16.52
1996	0.59	8.49	3.35	0.73	2.18	1.24	3.72	1.70	10.80	4.37	0.82	0.62	38.61
month	100.05	170.37	130.37	85.84	109.84	141.93	112.08	68.10	63.85	61.55	39.21	57.79	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.13	0.24	0.30	0.17	0.18	0.15	0.11	0.10	0.09	0.08	0.10	0.07	3.16
max	10.44	12.65	11.83	6.02	9.80	15.31	21.87	8.07	10.80	15.87	5.85	15.22	43.48
median	0.54	0.95	0.85	0.65	0.63	0.73	0.58	0.41	0.32	0.34	0.29	0.37	12.38
mean	1.30	2.21	1.69	1.11	1.43	1.84	1.46	0.88	0.83	0.80	0.51	0.75	14.82
Sum of the monthly means = 14.82													
s.d.	1.97	2.64	2.00	1.14	1.85	2.63	2.71	1.36	1.65	1.93	0.75	1.80	9.27
c.v.	1.51	1.19	1.18	1.02	1.29	1.43	1.86	1.54	2.00	2.42	1.47	2.40	0.63

APPENDIX 9.4
TUNGWANE DAM (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.27	0.50	0.87	0.90	0.89	2.26	1.61	0.93	0.55	0.33	0.22	0.29	9.62
1921	0.54	3.73	3.94	1.59	0.65	0.38	0.24	3.62	3.98	1.77	1.09	1.08	22.61
1922	4.09	9.48	3.32	8.34	12.66	7.57	2.06	0.58	0.40	7.95	3.44	0.64	60.53
1923	0.38	0.36	0.46	3.62	3.96	1.49	0.43	0.29	0.28	0.25	0.28	0.47	12.27
1924	0.69	0.85	1.04	0.93	0.90	6.53	3.07	1.03	0.67	0.49	0.38	0.53	17.11
1925	0.72	0.78	0.71	0.76	0.92	8.26	3.41	0.76	0.90	0.92	0.61	0.59	19.34
1926	0.92	1.65	1.36	0.90	0.64	11.74	4.51	0.52	0.31	0.23	0.22	0.31	23.31
1927	0.59	0.51	0.51	0.77	1.25	1.19	0.78	0.54	0.48	0.38	0.50	0.55	8.05
1928	0.56	0.71	0.70	0.64	0.57	0.92	0.90	0.68	6.61	4.84	1.94	4.62	23.69
1929	6.58	4.19	1.45	0.62	0.44	0.57	0.74	0.67	0.83	1.01	1.11	3.37	21.58
1930	1.84	0.78	0.57	4.16	5.12	9.14	3.44	0.74	0.43	25.84	9.46	0.83	62.35
1931	0.81	0.79	0.62	0.41	3.62	2.11	0.86	0.69	0.79	0.87	0.76	3.99	16.32
1932	2.38	12.36	9.17	2.13	0.49	0.71	0.68	0.51	0.40	0.32	0.26	0.24	29.65
1933	0.24	1.16	3.78	5.73	2.27	1.11	1.05	0.79	0.56	0.90	1.02	0.60	19.21
1934	0.38	0.61	2.16	1.31	0.58	0.74	4.71	7.64	11.10	3.97	1.31	1.11	35.62
1935	0.76	0.67	0.38	0.23	7.95	9.26	2.89	3.28	2.03	1.09	0.69	0.52	29.75
1936	0.94	17.24	6.25	0.53	2.06	3.83	1.77	0.64	0.40	0.39	0.43	0.41	34.89
1937	0.45	0.46	0.68	0.87	0.84	0.63	0.88	1.05	0.93	0.92	0.78	0.50	8.99
1938	0.38	0.60	0.81	0.92	3.49	2.02	1.02	0.98	0.92	0.95	1.08	7.65	20.82
1939	3.59	1.08	0.85	0.61	0.43	0.56	0.60	0.99	1.21	0.90	0.60	0.47	11.89
1940	0.41	0.76	0.89	0.61	0.33	0.30	0.37	0.33	0.31	0.32	0.33	0.34	5.30
1941	0.49	0.70	0.55	5.24	2.34	0.89	0.80	0.80	0.74	0.49	0.47	0.59	14.10
1942	0.77	11.23	7.54	1.96	0.67	1.46	5.02	2.40	1.02	0.86	2.31	1.60	36.84
1943	1.20	3.65	2.07	0.98	1.02	1.03	0.78	0.55	0.47	0.51	0.44	4.24	16.94
1944	2.41	0.94	0.41	0.43	0.80	1.17	0.99	0.70	0.54	0.44	0.34	0.39	9.56
1945	6.58	2.69	0.37	0.26	0.61	3.66	2.10	0.95	0.62	0.47	0.35	0.31	18.97
1946	0.41	0.83	0.93	0.75	0.76	3.45	5.42	2.39	4.39	2.34	0.89	0.63	23.19
1947	0.57	14.77	5.82	0.95	2.55	2.48	1.46	0.86	0.50	0.31	0.22	0.18	30.67
1948	0.70	1.01	0.82	0.62	7.84	4.68	1.70	1.00	0.58	0.38	0.33	0.37	20.03
1949	0.56	3.23	1.69	0.96	1.13	1.16	1.18	1.36	1.16	0.89	1.01	0.94	15.27
1950	0.86	0.66	3.04	1.82	0.91	1.01	0.93	0.63	0.47	0.40	0.44	0.58	11.75
1951	2.47	1.28	0.81	1.14	1.08	1.09	1.24	1.10	0.74	0.49	0.32	0.40	12.16
1952	0.50	0.46	0.38	0.36	0.50	0.65	0.70	0.59	0.42	0.30	0.31	0.63	5.80
1953	1.08	5.01	2.85	1.05	0.65	0.83	0.78	0.74	0.89	0.84	0.59	0.63	15.94
1954	11.48	4.56	0.68	2.23	5.71	3.19	1.28	0.76	0.57	0.44	0.29	0.44	31.63
1955	0.69	0.79	0.50	0.18	0.41	7.41	3.49	1.18	0.92	0.73	0.51	0.55	17.36
1956	1.00	9.50	15.95	5.21	1.20	5.25	6.31	2.34	0.85	0.68	0.59	0.81	49.69
1957	1.20	1.29	1.16	1.98	6.08	2.80	4.61	2.15	0.60	0.42	0.37	0.34	23.00
1958	0.39	0.77	0.95	0.62	0.55	0.73	0.84	13.97	5.46	1.05	1.23	1.17	27.73
1959	0.97	0.83	0.69	0.60	0.53	0.81	1.15	1.31	1.07	0.73	0.62	0.73	10.04
1960	0.73	0.91	2.16	1.53	1.00	1.07	11.83	4.89	1.09	0.96	0.86	0.65	27.68
1961	0.54	1.20	1.14	0.84	0.84	3.77	1.91	0.76	0.55	0.36	0.44	0.54	12.89
1962	0.84	3.61	1.80	4.29	2.07	15.90	6.09	0.94	0.73	5.87	2.74	0.68	45.56
1963	0.74	1.11	1.08	5.27	3.45	2.25	3.89	1.90	12.85	5.18	0.90	0.68	39.30
1964	2.69	1.44	0.47	0.41	0.43	0.32	0.23	0.34	8.12	3.87	1.91	1.50	21.73
1965	8.90	5.13	1.40	0.68	0.57	0.38	0.26	4.89	2.53	0.85	0.60	0.65	26.84
1966	0.63	0.52	0.50	0.77	0.97	10.04	8.17	2.40	0.83	1.28	1.22	0.70	28.03
1967	0.45	0.63	0.59	0.43	0.48	0.57	0.57	0.44	0.31	0.26	0.40	0.82	5.95
1968	1.10	1.17	1.01	0.58	1.07	6.56	2.86	5.79	2.74	0.90	0.67	0.56	25.01
1969	0.65	0.93	0.87	0.51	0.41	0.38	0.31	0.36	0.61	0.69	4.86	2.63	13.21
1970	9.55	4.12	1.07	0.79	0.78	0.83	0.90	7.34	3.23	1.33	4.87	2.42	37.23
1971	8.07	3.43	0.90	0.70	6.43	2.88	0.80	0.55	0.47	0.46	0.43	0.34	25.46
1972	0.28	0.69	0.93	0.76	0.61	0.70	1.10	1.02	0.59	0.37	0.47	0.85	8.37
1973	1.07	3.59	1.75	0.65	0.80	1.19	1.16	7.46	3.54	1.23	0.75	0.48	23.67
1974	0.42	0.60	0.84	0.77	0.67	0.74	0.73	0.60	0.44	0.35	0.34	5.49	11.99
1975	2.56	0.74	1.63	1.20	5.89	23.90	8.55	4.14	2.08	0.77	0.53	0.69	52.68
1976	15.40	5.74	0.54	0.49	1.93	1.47	0.84	0.49	0.40	0.42	0.55	0.79	29.06
1977	1.07	4.69	5.10	1.91	0.75	0.76	35.24	13.35	1.47	0.88	0.66	0.68	66.56
1978	3.26	1.97	0.89	0.54	0.46	0.85	0.94	0.68	0.48	0.78	1.17	1.15	13.17
1979	1.16	0.94	0.63	0.42	0.44	0.54	0.47	0.43	0.40	0.34	0.30	2.48	8.55
1980	1.63	2.48	1.53	1.04	0.96	0.74	0.47	0.73	0.95	0.71	0.81	0.83	12.88
1981	0.57	0.46	0.39	0.46	0.49	8.00	3.72	1.18	0.80	0.60	0.44	0.35	17.46
1982	0.56	0.60	0.34	0.21	0.24	0.25	0.25	0.25	0.22	6.15	2.95	0.93	12.95
1983	0.84	1.06	1.04	1.07	1.14	1.06	1.15	1.14	1.06	3.15	1.85	0.89	15.45
1984	0.74	2.21	1.42	0.81	14.63	5.62	0.72	0.43	0.32	0.29	0.24	0.18	27.61
1985	0.64	2.88	1.57	1.14	0.90	0.71	0.67	0.53	0.38	0.29	0.58	1.19	11.48
1986	4.09	2.15	0.78	0.61	0.45	0.64	0.78	0.61	0.50	0.42	0.50	23.79	35.32
1987	8.91	2.60	1.45	0.65	4.51	17.93	6.47	4.01	2.23	1.81	1.69	1.24	53.50
1988	0.99	3.50	8.55	2.98	7.17	3.31	4.58	2.24	0.90	0.76	0.53	0.42	35.93
1989	2.69	7.93	2.87	0.58	0.46	3.08	1.68	0.59	0.37	0.28	0.54	0.76	21.83
1990	0.89	0.77	0.48	0.55	0.98	1.05	0.66	0.43	0.38	0.32	0.32	0.50	7.33
1991	2.10	3.59	1.55	0.61	0.47	0.42	0.50	0.47	0.35	0.27	0.27	0.41	11.01
1992	0.60	0.63	0.60	0.52	0.42	0.32	0.28	0.28	0.24	0.20	0.22	0.53	4.84
1993	1.02	1.12	2.42	1.26	9.30	4.03	0.87	0.43	0.27	0.34	0.67	0.64	22.37
1994	0.45	0.32	0.65	0.82	0.55	4.02	8.79	3.40	2.52	1.64	0.78	0.55	24.49
1995	0.67	0.70	9.73	4.06	2.59	1.44	0.70	0.55	0.42	1.46	1.32	0.81	24.45
1996	0.88	11.13	4.35	0.93	3.42	1.99	7.33	3.22	18.23	7.32	1.32	1.01	61.13
month	150.23	210.76	152.75	105.76	164.13	244.78	203.27	142.30	129.70	120.57	77.84	104.45	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.24	0.32	0.34	0.18	0.24	0.25	0.23	0.25	0.22	0.20	0.22	0.18	4.84
max	15.40	17.24	15.95	8.34	14.63	23.90	35.24	13.97	18.23	25.84	9.46	23.79	66.56
median	0.84	1.11	0.95	0.79	0.90	1.19	1.05	0.79	0.67	0.73	0.59	0.64	21.58
mean	1.95	2.74	1.98	1.37	2.13	3.18	2.64	1.85	1.68	1.57	1.01	1.36	23.46
Sum of the monthly means =				23.46									
s.d.	2.84	3.49	2.61	1.52	2.83	4.27	4.47	2.58	2.95	3.25	1.34	2.89	14.37
c.v.	1.46	1.27	1.32	1.11	1.33	1.34	1.69	1.40	1.75	2.08	1.32	2.13	0.61

APPENDIX 9.5
LOWER MZINTLAVA (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.20	0.37	0.64	0.66	0.65	1.44	1.12	0.70	0.41	0.25	0.16	0.21	6.81
1921	0.40	2.59	2.75	1.15	0.48	0.28	0.18	2.56	2.88	1.31	0.82	0.80	16.20
1922	2.87	6.86	2.44	5.99	9.20	5.48	1.50	0.43	0.30	5.80	2.53	0.49	43.89
1923	0.28	0.27	0.34	2.47	2.77	1.08	0.33	0.22	0.21	0.19	0.21	0.35	8.72
1924	0.51	0.62	0.76	0.68	0.65	4.64	2.22	0.76	0.50	0.37	0.28	0.39	12.38
1925	0.53	0.57	0.53	0.56	0.67	5.85	2.45	0.57	0.67	0.68	0.45	0.44	13.97
1926	0.68	1.02	0.95	0.66	0.47	8.46	3.27	0.39	0.23	0.17	0.16	0.23	16.69
1927	0.44	0.38	0.38	0.56	0.82	0.87	0.59	0.40	0.36	0.29	0.37	0.41	5.87
1928	0.41	0.52	0.52	0.47	0.42	0.69	0.69	0.52	4.85	3.54	1.44	3.32	17.39
1929	4.76	2.98	1.05	0.46	0.33	0.42	0.54	0.49	0.61	0.74	0.82	2.32	15.52
1930	1.31	0.58	0.43	2.86	3.63	6.65	2.52	0.55	0.32	18.91	6.94	0.62	45.32
1931	0.60	0.58	0.46	0.31	2.49	1.50	0.64	0.51	0.58	0.64	0.56	2.81	11.68
1932	1.72	8.96	6.60	1.55	0.37	0.52	0.50	0.38	0.29	0.24	0.20	0.18	21.51
1933	0.18	0.72	2.64	4.09	1.66	0.82	0.76	0.58	0.41	0.66	0.75	0.44	13.71
1934	0.28	0.45	1.39	0.91	0.44	0.54	3.29	5.55	8.19	2.95	0.98	0.82	25.79
1935	0.56	0.49	0.28	0.17	5.70	6.70	2.12	2.35	1.49	0.82	0.52	0.39	21.59
1936	0.70	12.52	4.55	0.40	1.35	2.69	1.30	0.48	0.30	0.29	0.32	0.31	25.21
1937	0.33	0.34	0.51	0.63	0.61	0.45	0.64	0.76	0.68	0.67	0.57	0.36	6.55
1938	0.28	0.44	0.60	0.67	2.33	1.41	0.76	0.72	0.68	0.70	0.79	5.48	14.86
1939	2.59	0.82	0.65	0.45	0.32	0.41	0.44	0.72	0.88	0.65	0.44	0.34	8.71
1940	0.30	0.56	0.65	0.45	0.25	0.22	0.27	0.24	0.23	0.24	0.24	0.25	3.90
1941	0.36	0.52	0.40	3.67	1.67	0.66	0.59	0.59	0.54	0.36	0.35	0.44	10.15
1942	0.56	8.09	5.39	1.42	0.50	0.91	3.59	1.76	0.76	0.64	1.60	1.16	26.38
1943	0.89	2.50	1.47	0.72	0.77	0.79	0.59	0.41	0.35	0.38	0.33	3.02	12.22
1944	1.75	0.70	0.31	0.32	0.59	0.84	0.72	0.50	0.39	0.32	0.25	0.29	6.98
1945	4.73	1.95	0.28	0.20	0.45	2.50	1.50	0.71	0.46	0.35	0.26	0.23	13.62
1946	0.31	0.61	0.68	0.54	0.56	2.32	3.88	1.76	3.18	1.72	0.67	0.47	16.70
1947	0.42	10.74	4.25	0.70	1.67	1.69	1.06	0.64	0.37	0.23	0.16	0.13	22.06
1948	0.52	0.74	0.60	0.45	5.57	3.30	1.24	0.75	0.43	0.28	0.24	0.28	14.40
1949	0.42	2.22	1.21	0.71	0.82	0.83	0.85	1.00	0.88	0.67	0.76	0.69	11.06
1950	0.63	0.48	2.05	1.29	0.67	0.73	0.67	0.46	0.35	0.29	0.33	0.43	8.38
1951	1.68	0.91	0.61	0.83	0.79	0.78	0.89	0.79	0.54	0.36	0.23	0.30	8.71
1952	0.37	0.34	0.29	0.27	0.37	0.47	0.51	0.43	0.31	0.22	0.23	0.47	4.28
1953	0.79	3.48	1.93	0.75	0.49	0.61	0.57	0.54	0.65	0.62	0.43	0.46	11.32
1954	8.31	3.32	0.51	1.46	4.07	2.25	0.93	0.57	0.42	0.32	0.21	0.32	22.69
1955	0.51	0.58	0.37	0.14	0.31	5.27	2.52	0.87	0.68	0.54	0.38	0.41	12.58
1956	0.73	6.79	11.59	3.82	0.89	3.65	4.53	1.72	0.64	0.51	0.44	0.60	35.91
1957	0.88	0.94	0.84	1.20	4.37	2.06	3.26	1.55	0.45	0.32	0.27	0.26	16.40
1958	0.29	0.57	0.70	0.45	0.41	0.53	0.61	10.15	3.99	0.79	0.92	0.86	20.27
1959	0.71	0.60	0.51	0.44	0.39	0.59	0.83	0.95	0.78	0.53	0.46	0.54	7.33
1960	0.54	0.66	1.36	1.06	0.74	0.78	8.52	3.56	0.81	0.71	0.63	0.48	19.85
1961	0.40	0.72	0.80	0.63	0.62	2.56	1.35	0.57	0.41	0.27	0.33	0.40	9.06
1962	0.62	2.46	1.27	2.99	1.48	11.60	4.46	0.70	0.55	4.24	2.00	0.51	32.88
1963	0.55	0.82	0.79	3.63	2.38	1.55	2.80	1.40	9.46	3.83	0.68	0.51	28.40
1964	1.85	1.03	0.36	0.31	0.32	0.23	0.17	0.25	5.89	2.84	1.33	1.09	15.67
1965	6.45	3.66	1.01	0.51	0.42	0.27	0.19	3.49	1.85	0.64	0.45	0.49	19.43
1966	0.47	0.38	0.37	0.57	0.70	7.17	5.89	1.76	0.62	0.86	0.89	0.53	20.21
1967	0.33	0.47	0.44	0.32	0.36	0.41	0.41	0.33	0.23	0.19	0.29	0.61	4.39
1968	0.81	0.85	0.73	0.42	0.59	4.70	2.09	4.20	2.02	0.68	0.50	0.41	18.00
1969	0.48	0.68	0.64	0.38	0.31	0.28	0.23	0.27	0.45	0.51	3.47	1.92	9.62
1970	6.92	3.00	0.79	0.58	0.57	0.60	0.65	5.23	2.34	0.93	3.55	1.79	26.95
1971	5.84	2.51	0.67	0.51	4.54	2.06	0.59	0.41	0.35	0.34	0.32	0.25	18.39
1972	0.21	0.51	0.69	0.56	0.45	0.51	0.79	0.74	0.43	0.27	0.35	0.63	6.14
1973	0.78	2.44	1.23	0.49	0.59	0.86	0.84	5.32	2.56	0.92	0.56	0.35	16.94
1974	0.31	0.44	0.62	0.56	0.49	0.54	0.53	0.44	0.32	0.26	0.25	3.94	8.70
1975	1.86	0.55	1.03	0.84	4.18	17.54	6.28	3.13	1.58	0.58	0.40	0.52	38.49
1976	11.23	4.20	0.41	0.36	1.24	1.03	0.62	0.36	0.30	0.31	0.41	0.59	21.06
1977	0.78	3.25	3.59	1.39	0.56	0.55	25.75	9.74	1.09	0.66	0.49	0.51	48.36
1978	2.27	1.41	0.66	0.40	0.34	0.62	0.68	0.50	0.35	0.57	0.85	0.84	9.49
1979	0.85	0.68	0.47	0.31	0.33	0.40	0.34	0.31	0.29	0.25	0.22	1.72	6.17
1980	1.18	1.69	1.09	0.77	0.70	0.53	0.34	0.53	0.69	0.52	0.59	0.61	9.24
1981	0.42	0.34	0.29	0.34	0.36	5.72	2.70	0.87	0.59	0.45	0.32	0.26	12.66
1982	0.42	0.44	0.25	0.16	0.18	0.19	0.19	0.18	0.17	4.30	2.11	0.70	9.29
1983	0.63	0.78	0.76	0.78	0.83	0.76	0.83	0.82	0.77	2.16	1.32	0.67	11.11
1984	0.55	1.47	1.00	0.60	10.60	4.09	0.54	0.32	0.23	0.22	0.17	0.14	19.93
1985	0.47	1.93	1.11	0.78	0.68	0.54	0.50	0.40	0.28	0.21	0.43	0.87	8.20
1986	2.83	1.53	0.58	0.45	0.33	0.47	0.56	0.45	0.37	0.31	0.37	17.46	25.71
1987	6.55	1.76	1.03	0.49	3.15	13.12	4.77	2.86	1.63	1.27	1.24	0.92	38.79
1988	0.73	2.40	6.14	2.17	5.16	2.41	3.24	1.62	0.68	0.56	0.39	0.31	25.81
1989	1.86	5.72	2.10	0.44	0.35	2.10	1.19	0.45	0.28	0.21	0.40	0.56	15.66
1990	0.66	0.56	0.35	0.41	0.72	0.75	0.48	0.32	0.28	0.23	0.24	0.37	5.37
1991	1.41	2.52	1.13	0.46	0.35	0.30	0.36	0.35	0.26	0.20	0.20	0.30	7.84
1992	0.45	0.46	0.44	0.38	0.31	0.23	0.20	0.20	0.18	0.15	0.16	0.40	3.56
1993	0.75	0.82	1.55	0.86	6.72	2.93	0.65	0.32	0.20	0.25	0.50	0.48	16.03
1994	0.33	0.23	0.49	0.60	0.40	2.77	6.38	2.51	1.79	1.20	0.59	0.41	17.70
1995	0.49	0.51	6.97	2.94	1.74	1.01	0.52	0.41	0.31	0.98	0.96	0.61	17.45
1996	0.65	8.02	3.16	0.69	2.30	1.40	5.27	2.35	13.43	5.38	1.00	0.77	44.42
month	108.72	150.62	109.48	75.67	117.06	175.48	147.37	103.70	95.28	88.02	57.03	76.25	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.18	0.23	0.25	0.14	0.18	0.19	0.17	0.18	0.17	0.15	0.16	0.13	3.56
max	11.23	12.52	11.59	5.99	10.60	17.54	25.75	10.15	13.43	18.91	6.94	17.46	48.36
median	0.62	0.78	0.70	0.58	0.65	0.86	0.76	0.58	0.50	0.53	0.44	0.48	15.52
mean	1.41	1.96	1.42	0.98	1.52	2.28	1.91	1.35	1.24	1.14	0.74	0.99	16.94
Sum of the monthly means = 16.94													
s.d.	2.06	2.52	1.88	1.08	2.03	3.10	3.26	1.87	2.17	2.37	0.97	2.11	10.43
c.v.	1.46	1.29	1.32	1.09	1.34	1.36	1.70	1.39	1.75	2.08	1.31	2.13	0.62

APPENDIX 10

PRESENT DAY INFLOW RECORDS FOR EXISTING DAMS AND WEIRS

APPENDIX 10.1
LUSINDISWENI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.25	2.24	3.75	3.79	3.14	4.03	4.32	2.87	1.47	0.85	0.56	0.69	28.96
1921	1.65	18.69	27.85	10.47	3.26	1.81	0.79	2.91	10.46	6.45	3.65	2.90	90.89
1922	3.23	23.96	10.74	6.46	44.05	29.96	7.55	1.70	0.96	27.21	12.32	2.57	170.71
1923	1.47	1.27	1.70	27.64	22.28	6.66	1.59	0.85	0.72	0.61	0.62	0.98	66.39
1924	1.95	3.59	10.54	5.22	1.78	6.28	5.23	3.00	1.65	1.03	0.70	0.67	41.64
1925	1.42	3.10	3.53	3.58	3.24	21.69	9.44	2.15	2.19	2.17	1.41	1.57	55.49
1926	3.17	4.44	4.98	3.79	2.52	35.13	13.89	1.72	0.88	0.68	0.79	1.01	73.00
1927	1.88	2.03	3.49	22.68	11.32	4.25	2.28	1.21	0.90	0.73	0.92	1.13	52.82
1928	1.57	2.30	2.17	1.70	1.29	2.61	2.95	2.00	4.23	5.97	4.83	7.74	39.36
1929	9.93	7.04	4.65	3.73	3.06	3.48	3.61	2.45	2.27	2.39	2.63	3.69	48.93
1930	4.06	3.59	4.39	24.75	12.35	30.27	12.26	2.02	0.95	42.59	17.79	2.94	157.96
1931	2.59	2.89	2.48	1.83	6.59	5.05	2.35	1.44	1.51	1.87	1.74	2.78	33.12
1932	4.66	43.94	37.87	9.81	1.43	1.60	1.82	1.36	0.93	0.76	0.65	0.54	105.37
1933	0.54	8.07	22.87	14.32	5.64	3.58	2.94	2.14	1.35	1.71	1.85	1.30	66.31
1934	1.25	2.31	11.56	6.35	2.76	2.53	5.51	19.59	25.80	10.02	4.05	3.21	94.94
1935	2.35	2.47	1.59	0.98	17.59	18.68	6.56	3.65	4.14	3.07	1.80	1.39	64.27
1936	2.75	71.41	26.81	3.94	27.30	12.52	3.44	1.71	0.93	0.78	0.72	0.69	153.00
1937	1.07	1.78	2.58	2.81	3.48	2.95	2.76	2.51	1.90	1.79	1.66	1.28	26.57
1938	1.34	2.35	4.10	4.15	11.53	6.42	2.67	2.10	1.78	1.76	1.92	10.94	51.06
1939	8.14	5.65	5.56	4.01	2.56	2.39	2.22	3.88	4.67	3.27	1.86	1.34	45.55
1940	1.48	3.29	5.88	3.99	1.85	1.52	1.55	1.09	0.73	0.68	0.74	0.93	23.73
1941	1.62	2.41	2.24	6.31	5.06	4.33	3.74	2.83	1.98	1.22	1.13	1.49	34.36
1942	2.60	32.97	36.42	11.75	3.16	8.35	15.43	7.50	3.47	2.95	4.24	4.74	133.58
1943	8.08	26.54	19.57	6.55	4.09	4.04	2.72	1.68	1.33	1.34	1.13	2.91	79.98
1944	4.97	3.99	1.95	1.85	2.85	4.21	3.38	1.98	1.33	1.01	0.74	0.78	29.04
1945	5.03	4.19	1.94	1.32	2.43	9.05	5.94	2.81	1.57	1.11	0.82	0.85	37.06
1946	1.42	3.15	3.96	3.49	4.08	10.26	7.38	4.55	11.54	7.29	3.30	2.19	62.61
1947	2.17	54.31	22.32	5.17	10.77	7.43	4.85	2.98	1.46	0.81	0.56	0.46	113.29
1948	2.21	3.77	3.75	3.52	8.10	5.96	4.27	2.91	1.50	0.95	0.83	0.88	38.65
1949	1.67	5.66	4.65	7.05	5.55	4.41	3.86	3.71	2.94	2.28	2.97	3.02	47.77
1950	2.80	2.51	18.87	9.29	3.26	3.58	3.08	1.80	1.17	0.94	1.12	1.73	50.15
1951	3.92	3.74	3.53	4.28	4.52	3.98	3.99	3.39	2.07	1.28	0.83	1.03	36.56
1952	1.36	1.59	1.69	1.62	2.05	2.24	2.03	1.49	0.94	0.67	0.71	1.50	17.89
1953	3.21	10.91	14.52	6.65	3.37	3.38	2.47	2.08	2.34	2.07	1.40	1.58	53.98
1954	33.96	14.95	3.55	11.13	30.06	12.81	4.20	2.65	1.70	1.22	0.78	1.15	118.16
1955	2.15	3.17	2.52	1.03	1.57	18.39	10.25	4.39	2.87	2.03	1.41	1.45	51.23
1956	3.06	25.45	54.76	19.38	4.89	16.41	11.72	5.03	2.61	1.85	1.62	2.94	149.72
1957	6.47	13.58	7.04	4.57	20.40	9.72	4.98	3.92	1.97	1.18	0.90	0.87	75.60
1958	1.23	3.21	4.63	3.66	3.07	3.10	3.02	45.66	18.17	3.30	3.18	2.90	95.13
1959	2.84	3.48	3.69	3.08	2.64	3.11	3.48	3.17	2.24	1.47	1.26	1.67	32.13
1960	2.14	3.65	13.03	8.13	4.32	4.28	35.67	14.80	2.90	1.98	1.50	1.25	93.65
1961	1.38	3.36	4.49	4.15	6.75	10.44	5.38	2.32	1.49	0.94	1.04	1.29	43.03
1962	2.53	15.64	8.65	21.78	9.86	55.20	21.30	2.82	1.66	3.74	4.60	2.80	150.58
1963	3.23	14.85	13.97	23.73	10.43	4.56	5.34	4.26	37.97	16.10	3.23	2.39	140.06
1964	19.08	9.02	2.74	2.55	2.56	1.72	0.99	1.03	12.85	9.00	6.14	5.47	73.15
1965	24.16	21.75	7.73	3.38	2.67	1.49	0.82	10.49	6.78	2.85	1.85	2.02	85.99
1966	2.32	2.58	3.03	3.72	4.18	39.89	17.91	4.41	2.72	3.18	3.03	1.79	88.76
1967	1.44	2.85	3.03	2.26	2.09	2.15	2.03	1.42	0.82	0.61	1.01	2.24	21.95
1968	3.53	4.40	4.26	2.60	3.26	18.42	8.55	3.92	3.67	2.47	1.82	1.68	58.58
1969	2.42	3.88	4.16	2.86	2.02	1.40	0.86	0.92	1.48	1.57	2.29	3.56	27.42
1970	24.64	12.33	5.63	4.89	4.16	3.53	2.95	4.46	4.48	3.88	7.27	5.91	84.13
1971	30.63	13.60	4.06	3.66	13.90	7.51	2.81	1.49	1.09	1.07	0.86	0.69	81.37
1972	0.82	2.89	3.99	3.15	2.79	3.02	2.83	1.86	0.95	0.62	0.89	1.87	25.68
1973	2.88	6.35	4.88	3.72	4.56	12.64	6.77	6.83	5.83	3.73	2.02	1.20	61.41
1974	1.31	2.85	4.76	4.62	4.50	4.48	3.30	1.81	0.95	0.67	0.59	2.42	32.26
1975	3.73	3.44	19.94	14.47	20.73	70.76	25.31	4.63	3.52	2.07	1.26	1.71	171.57
1976	24.53	11.47	3.99	3.54	3.48	3.31	2.31	1.28	0.89	0.84	0.87	1.34	57.85
1977	3.57	15.60	14.23	6.77	4.19	3.79	98.58	36.65	3.65	2.00	1.46	1.90	192.39
1978	4.03	11.31	7.06	3.61	2.82	3.31	2.96	1.70	0.89	1.33	1.90	1.86	42.78
1979	2.38	2.89	2.91	2.23	1.68	1.69	1.35	0.97	0.75	0.59	0.49	2.70	20.63
1980	4.56	20.72	10.67	5.24	4.98	3.89	2.20	1.73	1.62	1.14	1.39	1.77	59.91
1981	1.54	1.62	1.74	2.63	2.97	4.35	5.06	3.64	2.14	1.49	1.00	0.85	29.03
1982	2.11	2.57	1.75	1.33	1.26	1.08	0.98	0.90	0.69	0.83	1.02	1.13	15.65
1983	1.76	3.64	4.73	12.99	11.82	6.85	10.47	5.93	2.74	2.57	2.43	1.95	67.88
1984	2.00	3.39	4.88	5.01	46.29	17.88	2.30	1.10	0.71	0.65	0.48	0.38	85.07
1985	9.16	10.16	8.34	5.43	3.62	2.45	1.55	0.90	0.61	0.53	1.75	3.31	47.81
1986	9.52	17.65	8.02	3.80	3.12	3.22	2.92	1.86	1.17	0.83	1.35	55.88	109.34
1987	22.95	13.12	24.47	9.81	27.88	60.89	20.89	5.05	5.07	5.05	5.08	4.24	204.50
1988	3.72	12.17	22.02	8.77	36.70	14.96	4.04	3.41	2.39	1.88	1.26	0.94	112.26
1989	3.17	58.86	22.64	3.62	2.48	9.09	5.74	2.36	1.20	0.75	1.55	2.23	113.69
1990	3.45	3.92	3.20	3.96	4.69	3.69	1.86	0.88	0.63	0.50	0.47	0.98	28.23
1991	12.47	11.47	5.47	3.16	2.56	2.47	2.12	1.34	0.74	0.50	0.49	0.68	43.47
1992	1.27	3.03	4.61	4.08	3.69	2.73	1.72	1.08	0.62	0.43	0.44	1.73	25.43
1993	20.10	10.83	19.27	8.94	10.34	19.04	7.69	1.68	0.85	1.16	1.53	1.14	102.57
1994	0.87	0.95	1.20	1.90	1.78	7.33	6.50	4.46	3.70	2.98	1.67	1.20	34.54
1995	1.92	3.44	62.28	26.08	24.96	11.27	3.04	1.38	0.70	1.38	1.88	1.62	139.95
1996	2.21	24.95	11.95	8.57	6.66	5.57	19.79	9.24	40.19	17.52	4.51	3.32	154.48
month	412.05	803.19	764.47	518.84	617.69	768.52	543.41	321.89	294.73	250.79	164.56	213.87	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.54	0.95	1.20	0.98	1.26	1.08	0.79	0.85	0.61	0.43	0.44	0.38	15.65
max	33.96	71.41	62.28	27.64	46.29	70.76	98.58	45.66	40.19	42.59	17.79	55.88	204.50
median	2.59	3.92	4.73	4.08	4.08	4.35	3.48	2.36	1.65	1.47	1.41	1.67	59.91
mean	5.35	10.43	9.93	6.74	8.02	9.98	7.06	4.18	3.83	3.26	2.14	2.78	73.69
Sum of the monthly means = 73.69													
s.d.	7.26	13.32	11.53	6.23	9.70	13.29	12.25	6.80	7.01	6.13	2.57	6.35	46.11
c.v.	1.36	1.28	1.16	0.93	1.21	1.33	1.74	1.63	1.83	1.88	1.20	2.29	0.63

APPENDIX 10.2
KWAHLATHI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.69	3.08	5.20	5.27	4.38	6.26	6.11	3.89	1.99	1.15	0.75	0.95	40.72
1921	2.28	27.25	39.30	14.48	4.44	2.48	1.10	5.10	14.97	8.79	4.88	3.91	128.98
1922	4.41	33.99	15.02	10.38	60.99	41.80	10.50	2.27	1.29	37.82	16.93	3.44	238.84
1923	1.98	1.73	2.36	39.48	31.89	9.33	2.14	1.15	0.98	0.83	0.84	1.35	94.06
1924	2.70	5.00	16.34	7.71	2.42	10.45	7.69	4.03	2.22	1.39	0.95	0.92	61.82
1925	1.95	4.30	4.91	5.01	4.52	31.37	13.40	2.88	2.98	2.96	1.92	2.16	78.36
1926	4.38	6.15	7.62	5.40	3.44	49.36	19.35	2.30	1.18	0.91	1.08	1.39	102.56
1927	2.61	2.82	6.03	31.97	16.09	5.85	3.07	1.63	1.23	0.99	1.26	1.56	75.11
1928	2.17	3.20	3.03	2.39	1.82	3.68	4.14	2.80	7.59	8.61	6.48	11.68	57.59
1929	14.54	10.14	6.37	5.08	4.22	4.84	5.02	3.39	3.14	3.30	3.62	5.11	68.77
1930	5.60	4.95	7.18	34.82	18.06	42.17	16.84	2.71	1.28	58.30	24.22	3.94	220.07
1931	3.51	3.96	3.43	2.56	11.14	7.52	3.18	1.97	2.07	2.56	2.39	3.85	48.14
1932	6.50	60.77	52.63	13.57	1.93	2.22	2.55	1.90	1.28	1.05	0.90	0.75	146.05
1933	0.74	12.90	32.51	20.80	7.98	4.87	4.05	2.95	1.86	2.36	2.55	1.79	95.36
1934	1.72	3.22	17.76	9.27	3.75	3.50	9.39	27.79	35.61	13.63	5.42	4.34	135.40
1935	3.19	3.39	2.19	1.39	26.12	27.04	9.16	4.95	5.64	4.18	2.44	1.90	91.59
1936	3.79	98.14	36.74	5.39	38.80	17.53	4.66	2.33	1.26	1.05	0.99	0.94	211.62
1937	1.48	2.47	3.61	3.94	4.89	4.12	3.86	3.50	2.63	2.47	2.29	1.76	37.02
1938	1.86	3.27	6.51	5.93	17.29	9.21	3.61	2.88	2.44	2.42	2.64	16.55	74.61
1939	11.78	7.65	8.67	5.74	3.45	3.29	3.08	6.36	6.59	4.36	2.49	1.81	65.27
1940	2.02	4.81	9.46	5.84	2.50	2.10	2.17	1.52	1.01	0.94	1.02	1.28	34.67
1941	2.25	3.35	3.12	10.78	7.56	5.91	5.14	3.90	2.72	1.67	1.55	2.06	50.01
1942	3.60	46.45	50.84	16.20	4.30	13.18	22.34	10.36	4.65	3.99	6.20	6.52	188.63
1943	12.09	37.05	27.77	9.18	5.90	5.59	3.71	2.30	1.83	1.83	1.55	4.19	112.99
1944	6.81	5.43	2.67	2.60	4.00	6.49	4.82	2.68	1.81	1.37	1.01	1.07	40.76
1945	8.63	6.21	2.61	1.83	3.41	14.42	8.71	3.77	2.12	1.49	1.11	1.16	55.47
1946	1.96	4.38	5.51	4.87	6.14	15.46	10.73	6.18	16.57	10.10	4.40	2.95	89.25
1947	2.95	74.98	31.22	7.14	16.06	11.16	6.68	3.98	1.95	1.09	0.75	0.62	158.58
1948	3.07	5.22	5.21	4.92	13.10	8.73	5.80	3.98	2.04	1.29	1.13	1.20	55.69
1949	2.31	9.59	6.89	11.19	8.04	6.01	5.31	5.11	4.04	3.13	4.08	4.16	69.86
1950	3.86	3.46	27.59	13.24	4.44	4.95	4.27	2.49	1.61	1.29	1.54	2.40	71.14
1951	6.43	5.36	4.79	5.91	6.28	5.52	5.55	4.70	2.86	1.76	1.14	1.43	51.73
1952	1.88	2.20	2.36	2.29	2.90	3.15	2.86	2.09	1.30	0.92	0.98	2.09	25.02
1953	4.46	16.69	21.31	9.32	4.60	4.67	3.43	2.89	3.24	2.85	1.92	2.18	77.56
1954	47.67	20.75	4.81	16.97	42.27	17.63	5.70	3.61	2.31	1.65	1.06	1.59	166.02
1955	2.98	4.40	3.50	1.45	2.23	27.07	14.65	5.90	3.84	2.72	1.90	1.98	72.62
1956	4.23	36.24	75.48	26.48	6.68	23.93	17.27	7.02	3.48	2.49	2.20	4.05	209.55
1957	10.41	19.75	9.77	7.20	28.65	13.36	7.51	5.49	2.61	1.57	1.20	1.18	108.70
1958	1.69	4.80	6.44	5.02	4.27	4.31	4.22	63.52	25.08	4.41	4.30	3.95	132.01
1959	3.89	4.80	5.11	4.29	3.69	4.35	4.86	4.41	3.10	2.02	1.73	2.31	44.56
1960	2.95	5.38	19.20	12.33	6.05	5.85	49.28	20.30	3.87	2.67	2.02	1.71	131.61
1961	1.89	5.35	6.33	5.68	11.02	15.72	7.56	3.12	2.01	1.27	1.42	1.77	63.14
1962	3.50	22.97	12.28	30.97	13.82	75.97	29.22	3.80	2.25	6.34	6.50	3.69	211.31
1963	4.37	21.56	20.42	33.44	14.43	6.21	8.57	6.10	52.02	21.92	4.31	3.22	196.57
1964	27.34	12.65	3.70	3.53	3.56	2.40	1.39	1.44	19.36	12.75	8.26	7.42	103.80
1965	34.02	30.71	10.70	4.62	3.69	2.07	1.15	16.23	9.76	3.80	2.48	2.75	121.98
1966	3.18	3.56	4.22	5.20	5.85	55.97	25.73	6.18	3.64	4.31	4.12	2.44	124.40
1967	1.97	3.95	4.20	3.17	2.93	3.02	2.85	1.99	1.13	0.83	1.40	3.12	30.56
1968	4.90	6.09	5.91	3.62	5.22	26.32	11.91	5.32	4.99	3.35	2.48	2.30	82.41
1969	3.34	5.37	5.78	3.99	2.83	1.97	1.21	1.29	2.06	2.18	3.18	4.94	38.14
1970	35.09	17.43	8.06	6.72	5.66	4.86	4.09	7.53	6.43	5.15	10.87	8.28	120.17
1971	42.41	18.68	5.51	5.05	20.85	10.80	3.81	2.02	1.49	1.45	1.18	0.95	114.20
1972	1.13	4.35	5.56	4.33	3.88	4.21	3.95	2.58	1.31	0.85	1.23	2.59	35.97
1973	3.99	10.49	7.19	5.09	7.05	18.46	9.47	10.45	8.21	4.98	2.70	1.61	89.69
1974	1.79	3.95	7.77	6.66	6.13	6.17	4.56	2.49	1.31	0.91	0.81	3.36	45.91
1975	5.15	4.75	28.90	21.35	29.46	96.67	34.40	6.27	4.78	2.80	1.71	2.36	238.60
1976	34.80	16.00	5.42	4.89	4.84	4.60	3.22	1.78	1.24	1.15	1.20	1.86	81.00
1977	5.61	22.29	20.58	9.49	5.72	5.23	134.66	49.95	4.90	2.69	1.97	2.60	265.69
1978	6.42	16.40	9.79	4.92	3.89	4.60	4.12	2.36	1.22	1.84	2.62	2.57	60.75
1979	3.30	4.01	4.06	3.12	2.37	2.38	1.90	1.36	1.04	0.81	0.67	4.22	29.24
1980	6.33	29.29	15.20	7.30	6.77	5.29	3.02	2.39	2.23	1.56	1.92	2.45	83.75
1981	2.12	2.24	2.44	3.70	4.18	7.77	7.37	4.86	2.87	2.01	1.35	1.16	42.07
1982	2.91	3.56	2.44	1.88	1.79	1.53	1.39	1.27	0.97	1.15	1.41	1.57	21.87
1983	2.45	5.39	6.60	19.43	17.64	10.15	14.95	8.16	3.67	3.47	3.31	2.66	97.88
1984	2.75	4.69	7.67	7.13	64.06	24.63	3.11	1.49	0.96	0.88	0.65	0.53	118.55
1985	14.22	15.20	12.58	7.68	4.94	3.38	2.15	1.25	0.84	0.72	2.43	4.59	69.98
1986	14.67	25.30	11.10	5.20	4.30	4.48	4.06	2.59	1.62	1.14	1.86	77.16	153.48
1987	31.51	18.98	34.42	13.55	39.19	83.59	28.47	6.97	6.88	6.83	6.90	5.78	283.07
1988	5.08	18.20	31.28	12.15	51.16	20.72	5.50	4.66	3.27	2.57	1.72	1.28	157.59
1989	5.22	80.43	30.76	4.94	3.42	14.34	8.40	3.17	1.61	1.01	2.13	3.07	158.50
1990	4.77	5.41	4.44	6.35	6.67	5.03	2.55	1.21	0.87	0.68	0.65	1.35	39.98
1991	18.77	16.99	7.65	4.30	3.55	3.43	2.97	1.86	1.03	0.69	0.67	0.94	62.85
1992	1.76	4.22	6.94	5.77	5.08	3.77	2.39	1.50	0.85	0.58	0.60	2.40	35.86
1993	28.96	15.19	27.40	12.53	15.62	27.28	10.68	2.24	1.14	1.57	2.09	1.56	146.26
1994	1.19	1.31	1.68	2.69	2.51	12.17	9.51	6.02	5.04	4.06	2.27	1.64	50.09
1995	2.64	4.77	86.06	37.01	35.12	15.54	4.12	1.87	0.95	1.88	2.57	2.23	194.76
1996	3.05	35.52	16.73	13.21	10.47	7.74	27.75	12.77	55.22	23.90	6.05	4.48	216.89
month	587.62	1136.93	1084.84	740.29	880.36	1089.20	760.07	449.52	409.44	344.46	225.52	297.08	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.74	1.31	1.68	1.39	1.79	1.53	1.10	1.15	0.84	0.58	0.60	0.53	21.87
max	47.67	98.14	86.06	39.48	64.06	96.67	134.66	63.52	55.22	58.30	24.22	77.16	283.07
median	3.51	5.41	7.18	5.84	5.66	6.21	4.86	3.17	2.23	2.01	1.92	2.30	83.75
mean	7.63	14.77	14.09	9.61	11.43	14.15	9.87	5.84	5.32	4.47	2.93	3.86	103.97

Sum of the monthly means = 103.97

s.d.	10.27	18.42	16.01	8.87	13.61	18.35	16.79	9.44	9.68	8.43	3.54	8.81	63.85
c.v.	1.35	1.25	1.14	0.92	1.19	1.30	1.70	1.62	1.82	1.88	1.21	2.28	0.61

APPENDIX 10.3
MBONGWENI WEIR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.47	0.82	1.33	1.32	1.10	1.39	1.50	1.01	0.52	0.31	0.20	0.26	10.23
1921	0.60	6.23	9.60	3.69	1.17	0.65	0.29	1.00	3.27	2.20	1.33	1.05	31.08
1922	1.16	8.08	3.70	1.87	15.29	10.34	2.64	0.63	0.35	8.99	4.19	0.95	58.19
1923	0.55	0.47	0.62	9.30	7.50	2.32	0.59	0.32	0.27	0.23	0.23	0.36	22.76
1924	0.71	1.28	3.21	1.70	0.66	1.80	1.75	1.09	0.60	0.38	0.26	0.25	13.69
1925	0.52	1.11	1.25	1.25	1.13	7.13	3.20	0.79	0.79	0.79	0.51	0.57	19.04
1926	1.14	1.57	1.73	1.31	0.89	12.05	4.82	0.64	0.33	0.26	0.29	0.38	25.41
1927	0.69	0.74	1.20	7.46	3.84	1.52	0.82	0.44	0.33	0.27	0.34	0.42	18.07
1928	0.57	0.83	0.78	0.60	0.47	0.92	1.04	0.71	1.36	2.19	1.81	2.59	13.87
1929	3.33	2.47	1.67	1.32	1.08	1.22	1.26	0.86	0.80	0.86	0.94	1.31	17.12
1930	1.44	1.27	1.51	8.24	4.15	10.92	4.45	0.75	0.35	15.06	6.33	1.08	55.55
1931	0.94	1.04	0.89	0.65	1.83	1.65	0.86	0.53	0.55	0.68	0.63	1.00	11.25
1932	1.65	15.13	13.04	3.43	0.53	0.58	0.66	0.49	0.34	0.29	0.24	0.21	36.59
1933	0.21	2.50	7.76	4.73	1.94	1.29	1.05	0.76	0.48	0.62	0.66	0.47	22.47
1934	0.46	0.83	3.61	2.11	1.00	0.90	1.49	6.75	9.06	3.58	1.47	1.16	32.42
1935	0.85	0.89	0.58	0.36	5.76	6.24	2.29	1.32	1.48	1.10	0.65	0.51	22.03
1936	0.99	24.95	9.42	1.41	9.25	4.33	1.24	0.62	0.34	0.29	0.27	0.26	53.37
1937	0.40	0.65	0.93	0.99	1.22	1.03	0.97	0.88	0.67	0.65	0.60	0.46	9.45
1938	0.49	0.85	1.42	1.44	3.51	2.11	0.97	0.76	0.64	0.64	0.69	3.54	17.06
1939	2.80	2.03	1.93	1.39	0.91	0.84	0.79	1.33	1.63	1.17	0.67	0.49	15.98
1940	0.54	1.17	1.84	1.40	0.70	0.56	0.57	0.40	0.27	0.26	0.27	0.34	8.32
1941	0.59	0.87	0.80	1.72	1.66	1.55	1.32	1.00	0.70	0.45	0.41	0.54	11.61
1942	0.93	11.26	12.54	4.11	1.14	2.49	5.15	2.64	1.26	1.07	1.50	1.68	45.77
1943	2.47	9.12	6.65	2.27	1.45	1.42	0.96	0.60	0.48	0.49	0.41	1.04	27.36
1944	1.76	1.41	0.70	0.66	1.01	1.45	1.18	0.70	0.48	0.37	0.27	0.29	10.28
1945	1.44	1.40	0.72	0.48	0.87	2.68	1.97	1.02	0.57	0.41	0.30	0.32	12.18
1946	0.52	1.13	1.40	1.22	1.41	3.04	2.45	1.64	3.77	2.53	1.21	0.80	21.12
1947	0.79	18.93	7.81	1.83	3.27	2.46	1.73	1.06	0.52	0.30	0.21	0.18	39.09
1948	0.80	1.34	1.33	1.23	2.29	1.95	1.53	1.04	0.54	0.35	0.30	0.32	13.02
1949	0.61	1.61	1.55	2.09	1.86	1.58	1.37	1.31	1.04	0.82	1.05	1.08	15.97
1950	1.00	0.90	6.21	3.16	1.17	1.27	1.09	0.64	0.42	0.35	0.41	0.63	17.25
1951	1.36	1.32	1.25	1.49	1.57	1.38	1.39	1.19	0.73	0.47	0.30	0.38	12.83
1952	0.50	0.58	0.61	0.58	0.73	0.79	0.72	0.53	0.34	0.25	0.26	0.55	6.44
1953	1.15	3.41	4.76	2.30	1.21	1.20	0.88	0.74	0.83	0.74	0.50	0.57	18.29
1954	11.69	5.22	1.29	3.45	10.27	4.50	1.51	0.95	0.61	0.45	0.29	0.42	40.65
1955	0.78	1.13	0.90	0.37	0.57	6.00	3.49	1.58	1.03	0.74	0.51	0.53	17.63
1956	1.10	8.56	19.08	6.83	1.74	5.27	3.80	1.76	0.96	0.69	0.59	1.06	51.44
1957	1.90	4.51	2.47	1.59	6.69	3.30	1.76	1.39	0.71	0.43	0.33	0.32	25.40
1958	0.46	1.14	1.63	1.28	1.08	1.08	1.06	15.74	6.33	1.21	1.15	1.05	33.21
1959	1.02	1.24	1.30	1.08	0.93	1.09	1.22	1.11	0.79	0.53	0.46	0.61	11.38
1960	0.77	1.29	4.09	2.70	1.54	1.51	12.13	5.12	1.06	0.73	0.55	0.46	31.95
1961	0.51	1.18	1.58	1.45	1.80	3.29	1.87	0.85	0.54	0.35	0.38	0.47	14.27
1962	0.91	5.11	2.96	7.27	3.38	19.23	7.47	1.03	0.60	1.30	1.62	1.01	51.89
1963	1.16	4.80	4.56	8.08	3.65	1.63	1.84	1.48	13.10	5.64	1.18	0.87	47.99
1964	6.46	3.13	1.00	0.91	0.91	0.61	0.36	0.37	4.20	3.12	2.21	1.95	25.23
1965	8.28	7.44	2.72	1.21	0.95	0.53	0.30	3.33	2.31	1.05	0.68	0.74	29.54
1966	0.84	0.93	1.08	1.30	1.46	13.53	6.05	1.62	1.04	1.18	1.11	0.66	30.80
1967	0.53	1.03	1.08	0.80	0.74	0.76	0.72	0.51	0.29	0.23	0.37	0.81	7.87
1968	1.26	1.56	1.50	0.91	1.12	5.94	2.88	1.42	1.31	0.89	0.66	0.61	20.06
1969	0.87	1.38	1.47	1.00	0.72	0.50	0.31	0.34	0.53	0.57	0.82	1.27	9.78
1970	8.43	4.30	2.00	1.71	1.45	1.23	1.04	1.51	1.56	1.38	2.16	2.00	28.77
1971	10.63	4.78	1.46	1.29	4.36	2.51	1.02	0.54	0.40	0.40	0.32	0.26	27.97
1972	0.31	1.02	1.41	1.10	0.98	1.06	1.00	0.66	0.34	0.23	0.33	0.68	9.12
1973	1.03	1.82	1.62	1.33	1.58	3.91	2.25	2.15	2.01	1.37	0.74	0.44	20.25
1974	0.49	1.02	1.64	1.60	1.57	1.56	1.15	0.64	0.34	0.25	0.22	0.87	11.35
1975	1.33	1.22	6.56	4.69	7.04	24.89	8.97	1.67	1.26	0.75	0.46	0.62	59.46
1976	8.35	3.99	1.44	1.25	1.22	1.16	0.81	0.46	0.32	0.31	0.32	0.49	20.12
1977	1.25	5.08	4.66	2.34	1.50	1.34	34.57	12.90	1.32	0.73	0.53	0.69	66.91
1978	1.41	3.55	2.39	1.29	1.00	1.16	1.04	0.60	0.32	0.49	0.68	0.67	14.60
1979	0.86	1.03	1.04	0.78	0.60	0.60	0.48	0.35	0.27	0.22	0.18	0.95	7.36
1980	1.62	6.90	3.65	1.85	1.75	1.36	0.78	0.61	0.58	0.42	0.50	0.64	20.66
1981	0.56	0.59	0.63	0.93	1.05	1.46	1.75	1.28	0.76	0.54	0.36	0.31	10.22
1982	0.76	0.92	0.63	0.48	0.46	0.39	0.36	0.33	0.25	0.31	0.37	0.42	5.68
1983	0.64	1.29	1.67	4.00	3.76	2.36	3.35	2.02	1.00	0.94	0.88	0.71	22.62
1984	0.73	1.21	1.69	1.74	15.79	6.17	0.84	0.40	0.26	0.25	0.18	0.15	29.41
1985	2.92	3.31	2.66	1.87	1.30	0.87	0.56	0.33	0.22	0.20	0.63	1.18	16.05
1986	2.96	5.95	2.82	1.36	1.11	1.13	1.03	0.66	0.42	0.31	0.49	19.52	37.76
1987	8.08	4.33	8.35	3.43	9.49	21.30	7.39	1.81	1.80	1.80	1.79	1.50	71.07
1988	1.32	3.85	7.43	3.06	12.62	5.20	1.45	1.21	0.85	0.68	0.46	0.34	38.47
1989	1.10	20.48	7.93	1.30	0.88	2.72	1.91	0.86	0.44	0.29	0.56	0.81	39.28
1990	1.23	1.39	1.13	1.36	1.63	1.29	0.65	0.32	0.23	0.19	0.18	0.36	9.96
1991	4.08	3.77	1.91	1.13	0.92	0.87	0.75	0.48	0.27	0.19	0.18	0.25	14.80
1992	0.47	1.08	1.61	1.42	1.29	0.96	0.61	0.39	0.22	0.16	0.16	0.63	9.00
1993	6.75	3.75	6.43	3.06	3.25	6.40	2.69	0.62	0.32	0.43	0.56	0.42	34.68
1994	0.33	0.35	0.44	0.68	0.64	2.11	2.18	1.60	1.32	1.07	0.60	0.44	11.76
1995	0.70	1.23	21.60	8.80	8.64	3.99	1.10	0.50	0.26	0.50	0.66	0.58	48.56
1996	0.79	8.42	4.13	2.58	2.21	1.97	6.53	3.15	14.10	6.21	1.64	1.20	52.93
month	142.10	274.47	261.99	175.77	209.21	261.79	188.02	112.84	102.96	89.15	58.76	76.01	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.21	0.35	0.44	0.36	0.46	0.39	0.29	0.32	0.22	0.16	0.16	0.15	5.68
max	11.69	24.95	21.60	9.30	15.79	24.89	34.57	15.74	14.10	15.06	6.33	19.52	71.07
median	0.93	1.39	1.64	1.42	1.41	1.55	1.24	0.86	0.60	0.53	0.51	0.61	20.25
mean	1.85	3.56	3.40	2.28	2.72	3.40	2.44	1.47	1.34	1.16	0.76	0.99	25.36
Sum of the monthly means =				25.36									
s.d.	2.47	4.60	3.97	2.08	3.30	4.62	4.27	2.35	2.43	2.13	0.90	2.21	15.93
c.v.	1.34	1.29	1.17	0.91	1.21	1.36	1.75	1.60	1.81	1.84	1.17	2.24	0.63

APPENDIX 10.4
GXALIBOMVU WEIR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.38	2.97	6.54	5.64	4.79	6.57	6.02	3.78	1.86	1.04	0.62	1.04	42.25
1921	2.51	24.03	26.52	9.94	3.36	1.67	0.82	7.45	10.46	6.76	4.96	4.94	103.42
1922	21.51	55.99	19.94	45.32	62.91	31.90	8.22	2.32	1.34	29.60	13.79	3.10	295.94
1923	1.92	2.14	3.03	22.21	18.91	6.53	1.76	0.94	0.83	0.76	0.88	1.87	61.78
1924	3.27	5.14	9.23	6.24	4.72	26.26	12.81	4.21	2.36	1.65	1.23	2.07	79.19
1925	3.40	4.52	4.61	4.96	5.21	35.27	14.72	3.10	3.28	3.29	2.12	2.30	86.78
1926	4.64	13.59	9.91	5.29	3.36	52.80	20.31	2.08	0.99	0.70	0.67	1.16	115.50
1927	2.80	2.86	3.33	4.98	6.87	5.67	3.20	1.89	1.52	1.20	1.72	2.11	38.15
1928	2.55	4.14	4.49	4.01	3.20	4.91	4.08	2.54	20.35	15.92	8.20	21.29	95.68
1929	36.37	29.30	10.20	3.69	2.41	2.54	2.96	2.41	2.85	3.55	4.08	10.42	110.78
1930	7.77	4.91	3.97	25.73	25.00	39.84	15.15	3.01	1.44	118.32	43.87	4.14	293.15
1931	4.27	4.78	4.18	2.74	17.64	10.03	3.63	2.50	2.67	3.02	2.67	13.56	71.69
1932	12.80	70.21	53.53	12.59	2.49	3.13	2.69	1.76	1.20	0.98	0.78	0.80	162.96
1933	0.98	9.27	25.26	32.01	11.94	5.15	4.27	2.84	1.79	3.18	3.73	2.25	102.67
1934	1.64	3.63	17.11	8.90	3.04	3.25	13.77	27.26	47.26	17.83	6.02	5.04	154.75
1935	3.76	3.93	2.52	1.48	39.35	40.92	12.42	6.83	6.59	4.72	2.77	2.12	127.41
1936	5.23	94.91	34.65	3.16	9.42	13.78	6.91	2.60	1.35	1.30	1.46	1.54	176.31
1937	2.04	2.58	4.83	5.41	4.56	2.91	3.78	3.95	3.14	3.14	2.70	1.78	40.82
1938	1.66	3.41	5.40	5.88	16.62	9.37	4.31	3.65	3.14	3.29	3.94	32.11	92.78
1939	19.23	7.23	5.81	3.99	2.42	2.55	2.41	3.78	4.27	3.04	1.98	1.69	58.40
1940	1.78	4.94	5.69	3.78	1.89	1.32	1.36	1.09	0.91	1.01	1.05	1.22	26.04
1941	2.26	4.04	3.53	30.37	13.06	3.99	3.19	2.86	2.45	1.57	1.55	2.28	71.15
1942	3.60	63.23	45.14	11.79	3.46	5.10	17.80	9.34	4.09	3.24	5.27	6.11	178.17
1943	6.90	26.25	16.37	6.26	5.86	5.06	3.23	1.94	1.49	1.67	1.46	15.27	91.76
1944	10.98	5.84	2.90	2.77	4.65	5.74	4.14	2.48	1.71	1.38	1.05	1.42	45.06
1945	32.09	13.76	2.46	1.72	3.46	12.03	8.01	3.92	2.16	1.56	1.12	1.12	83.41
1946	1.86	5.53	5.86	4.46	4.12	11.28	19.77	9.65	11.12	8.02	4.08	2.80	88.55
1947	2.80	81.89	33.04	5.71	11.65	8.96	5.93	3.54	1.70	0.95	0.63	0.54	157.34
1948	3.82	5.77	5.13	3.90	39.17	18.82	6.58	4.13	2.01	1.21	1.05	1.39	92.98
1949	2.61	21.46	10.89	6.21	6.21	5.34	4.84	5.22	4.18	3.10	3.71	3.71	77.48
1950	4.03	3.67	21.72	11.81	4.76	4.69	3.78	2.21	1.47	1.24	1.46	2.27	63.11
1951	11.25	6.65	7.64	7.67	5.73	4.91	5.05	4.04	2.43	1.52	0.94	1.50	59.33
1952	2.24	2.54	2.47	2.27	2.73	2.97	2.79	2.08	1.29	0.90	0.96	2.56	25.80
1953	5.66	31.25	20.84	7.08	3.39	3.72	3.10	2.63	3.03	2.88	1.98	2.43	87.99
1954	57.27	23.64	4.47	15.37	27.79	13.02	5.26	3.04	1.94	1.43	0.89	1.69	155.81
1955	3.28	4.59	3.26	1.19	2.11	31.37	15.13	4.85	3.29	2.51	1.72	2.13	75.43
1956	5.32	54.56	88.88	29.09	6.41	19.16	23.68	9.48	3.40	2.50	2.12	3.38	247.98
1957	6.38	8.96	7.85	13.41	29.77	13.11	13.88	7.37	2.37	1.51	1.26	1.29	107.16
1958	1.78	5.04	6.14	3.86	3.01	3.36	3.40	56.98	22.76	4.56	5.12	5.05	121.06
1959	4.73	4.81	4.52	3.80	2.98	3.91	4.77	4.90	3.67	2.41	2.10	2.87	45.47
1960	3.36	5.81	17.70	10.53	5.27	4.93	49.18	20.64	4.35	3.61	3.18	2.54	131.10
1961	2.50	10.50	8.05	5.00	4.59	12.50	7.12	3.09	1.92	1.17	1.51	2.12	60.07
1962	4.34	24.03	11.63	24.96	11.46	73.63	28.15	3.83	2.60	17.94	9.89	3.28	215.74
1963	3.92	9.52	7.53	30.23	16.65	7.82	12.79	7.18	54.46	22.54	4.08	3.07	179.79
1964	14.01	8.08	3.16	2.61	2.40	1.46	0.79	1.13	28.91	15.33	7.51	6.81	92.20
1965	47.73	33.69	9.94	4.04	3.11	1.71	0.90	13.01	8.51	3.67	2.37	2.76	131.44
1966	3.05	2.96	3.29	5.28	5.39	44.34	33.35	9.76	3.32	4.64	4.83	2.92	123.13
1967	2.08	3.81	3.88	2.75	2.63	2.58	2.24	1.53	0.91	0.77	1.34	3.42	27.94
1968	5.52	8.13	6.59	3.55	5.69	27.27	12.10	18.02	9.77	3.89	2.69	2.30	105.52
1969	3.17	5.97	5.72	3.28	2.30	1.72	1.16	1.20	2.07	2.39	13.79	10.10	52.87
1970	52.28	28.19	7.90	4.52	4.12	3.79	3.62	23.63	11.52	5.59	17.23	10.12	172.51
1971	44.56	19.49	5.85	4.43	32.19	14.08	3.34	1.96	1.49	1.50	1.40	1.20	131.49
1972	1.18	4.48	5.95	4.65	3.39	3.22	4.79	3.89	1.90	1.10	1.58	3.47	39.60
1973	5.24	24.02	11.40	3.87	4.52	5.78	4.80	24.01	12.87	5.31	3.02	1.92	106.76
1974	1.93	3.48	5.80	4.87	3.70	3.42	2.96	2.13	1.35	1.07	1.06	21.72	53.49
1975	11.43	4.63	15.82	8.78	27.80	115.32	40.99	10.53	6.79	3.36	2.12	3.00	250.57
1976	78.81	30.07	3.55	3.10	9.53	6.99	3.54	1.74	1.25	1.36	1.93	3.23	145.10
1977	5.51	29.62	32.74	11.63	3.91	3.40	164.97	60.86	5.91	3.55	2.50	2.80	327.40
1978	15.88	11.21	5.76	3.40	2.57	4.17	3.92	2.44	1.49	2.75	4.35	4.68	62.62
1979	5.90	5.40	4.10	2.73	2.44	2.49	1.85	1.45	1.22	1.06	0.92	7.23	36.79
1980	7.05	20.53	11.15	6.44	5.26	3.41	1.80	2.61	3.28	2.40	2.89	3.28	70.10
1981	2.53	2.59	2.51	2.84	2.71	34.25	16.27	4.86	2.85	2.04	1.43	1.25	76.13
1982	2.60	3.37	2.18	1.37	1.27	1.07	0.88	0.76	0.61	21.07	11.47	4.53	51.18
1983	4.42	9.38	7.31	7.13	6.15	4.76	4.71	4.18	3.62	6.01	5.89	4.22	67.78
1984	3.78	17.40	9.91	4.78	73.59	27.90	3.02	1.48	0.94	0.90	0.69	0.57	144.96
1985	3.29	19.75	10.30	9.10	5.63	3.17	2.63	1.85	1.15	0.84	2.09	5.40	65.20
1986	20.04	11.83	5.17	3.87	2.57	2.92	3.14	2.19	1.60	1.31	1.71	114.92	171.27
1987	43.89	21.35	10.66	3.91	21.64	85.06	30.52	9.14	7.20	6.53	7.09	5.68	252.67
1988	5.00	24.47	51.00	17.09	34.26	15.65	13.75	7.77	3.60	2.81	1.88	1.58	178.86
1989	12.42	47.37	17.54	3.45	2.53	9.70	6.27	2.44	1.25	0.87	1.98	3.10	108.92
1990	4.43	4.39	3.13	3.53	5.90	5.04	2.63	1.46	1.15	0.96	1.02	1.95	35.59
1991	9.67	25.28	10.88	3.61	2.59	1.86	1.92	1.62	1.05	0.78	0.83	1.56	61.65
1992	2.82	3.55	3.84	3.27	2.38	1.42	0.99	0.87	0.68	0.57	0.66	2.17	23.22
1993	5.37	6.68	19.41	8.88	45.31	19.35	3.69	1.51	0.78	1.09	2.44	2.52	117.03
1994	2.00	1.73	4.87	4.96	2.90	13.87	36.30	14.68	6.16	5.78	3.40	2.36	99.01
1995	3.30	4.08	57.30	23.71	11.06	6.30	2.93	1.98	1.33	3.80	4.91	3.53	124.23
1996	4.59	63.67	25.09	5.82	15.99	9.16	28.02	12.78	81.46	33.02	6.11	4.68	290.39
month	759.97	1288.47	982.47	644.66	825.83	1068.42	841.96	514.86	477.48	461.84	291.50	438.35	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.98	1.73	2.18	1.19	1.27	1.07	0.79	0.76	0.61	0.57	0.62	0.54	23.22
max	78.81	94.91	88.88	45.32	73.59	115.32	164.97	60.86	81.46	118.32	43.87	114.92	327.40
median	4.27	7.23	6.59	4.96	4.76	5.67	4.31	3.09	2.37	2.50	2.10	2.76	92.98
mean	9.87	16.73	12.76	8.37	10.73	13.88	10.93	6.69	6.20	6.00	3.79	5.69	111.63
Sum of the monthly means = 111.63													
s.d.	14.79	19.76	15.00	8.59	13.87	19.78	20.44	10.25	12.50	14.46	5.64	13.61	69.65
c.v.	1.50	1.18	1.18	1.03	1.29	1.43	1.87	1.53	2.02	2.41	1.49	2.39	0.62

APPENDIX 10.5
SPES BONA WEIR

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	1.30	2.32	3.89	3.93	3.25	4.25	4.51	2.98	1.53	0.88	0.58	0.72	30.14
1921	1.72	19.56	29.01	10.87	3.37	1.87	0.82	3.14	10.92	6.69	3.78	3.00	94.75
1922	3.35	24.97	11.17	6.85	45.77	31.15	7.85	1.76	0.99	28.29	12.79	2.66	177.60
1923	1.53	1.31	1.76	28.84	23.25	6.93	1.65	0.88	0.75	0.63	0.64	1.02	69.19
1924	2.03	3.73	11.13	5.46	1.84	6.70	5.49	3.10	1.71	1.07	0.73	0.70	43.69
1925	1.47	3.21	3.66	3.72	3.36	22.67	9.85	2.22	2.27	2.26	1.47	1.63	57.79
1926	3.30	4.61	5.25	3.95	2.61	36.57	14.45	1.78	0.92	0.70	0.83	1.05	76.02
1927	1.96	2.11	3.74	23.62	11.80	4.41	2.37	1.25	0.94	0.76	0.95	1.18	55.09
1928	1.63	2.39	2.25	1.76	1.33	2.71	3.08	2.09	4.57	6.24	5.00	8.14	41.19
1929	10.41	7.35	4.82	3.86	3.17	3.61	3.75	2.55	2.36	2.49	2.73	3.84	50.94
1930	4.22	3.72	4.67	25.76	12.93	31.48	12.73	2.10	0.99	44.19	18.44	3.05	164.28
1931	2.68	2.99	2.57	1.90	7.04	5.29	2.44	1.50	1.57	1.94	1.81	2.89	34.62
1932	4.85	45.65	39.37	10.19	1.47	1.66	1.90	1.42	0.96	0.79	0.68	0.57	109.51
1933	0.56	8.55	23.84	14.97	5.87	3.70	3.06	2.23	1.40	1.78	1.92	1.36	69.24
1934	1.30	2.40	12.19	6.64	2.85	2.62	5.91	20.43	26.80	10.39	4.19	3.33	99.05
1935	2.44	2.55	1.64	1.02	18.45	19.53	6.82	3.78	4.29	3.19	1.87	1.44	67.02
1936	2.86	74.12	27.81	4.08	28.46	13.02	3.56	1.78	0.96	0.81	0.75	0.71	158.92
1937	1.12	1.84	2.68	2.91	3.62	3.06	2.87	2.61	1.98	1.87	1.73	1.33	27.62
1938	1.40	2.44	4.33	4.32	12.11	6.69	2.77	2.18	1.85	1.83	2.00	11.51	53.43
1939	8.51	5.85	5.87	4.18	2.65	2.47	2.31	4.13	4.87	3.39	1.93	1.39	47.55
1940	1.54	3.44	6.24	4.17	1.91	1.57	1.62	1.14	0.76	0.71	0.77	0.96	24.83
1941	1.69	2.50	2.32	6.76	5.31	4.49	3.88	2.94	2.06	1.27	1.18	1.55	35.95
1942	2.70	34.33	37.88	12.19	3.27	8.84	16.14	7.79	3.59	3.06	4.44	4.92	139.15
1943	8.49	27.61	20.40	6.81	4.27	4.19	2.83	1.74	1.38	1.39	1.17	3.04	83.32
1944	5.16	4.13	2.01	1.92	2.96	4.43	3.53	2.05	1.38	1.05	0.77	0.81	30.20
1945	5.40	4.39	2.00	1.36	2.52	9.59	6.22	2.91	1.63	1.15	0.85	0.88	38.90
1946	1.48	3.27	4.11	3.62	4.28	10.78	7.72	4.72	12.06	7.58	3.42	2.27	65.31
1947	2.25	56.40	23.22	5.36	11.30	7.80	5.04	3.08	1.51	0.84	0.58	0.48	117.86
1948	2.30	3.91	3.89	3.66	8.60	6.23	4.42	3.02	1.56	0.99	0.86	0.91	40.35
1949	1.74	6.05	4.87	7.47	5.80	4.56	4.01	3.85	3.05	2.37	3.08	3.14	49.99
1950	2.91	2.60	19.75	9.69	3.37	3.71	3.20	1.87	1.21	0.98	1.16	1.80	52.25
1951	4.18	3.90	3.65	4.44	4.70	4.13	4.15	3.53	2.15	1.33	0.87	1.08	38.11
1952	1.42	1.64	1.75	1.68	2.13	2.33	2.12	1.55	0.98	0.69	0.74	1.56	18.59
1953	3.34	11.49	15.20	6.91	3.49	3.51	2.57	2.17	2.44	2.15	1.45	1.64	56.36
1954	35.36	15.53	3.67	11.71	31.30	13.29	4.35	2.75	1.76	1.26	0.81	1.20	122.99
1955	2.24	3.29	2.61	1.07	1.63	19.26	10.70	4.54	2.97	2.10	1.46	1.51	53.38
1956	3.19	26.54	56.86	20.09	5.06	17.17	12.29	5.23	2.70	1.92	1.68	3.06	155.79
1957	6.87	14.20	7.31	4.83	21.23	10.09	5.24	4.08	2.04	1.22	0.93	0.90	78.94
1958	1.28	3.37	4.81	3.79	3.19	3.21	3.15	47.48	18.87	3.42	3.30	3.01	98.88
1959	2.95	3.61	3.82	3.19	2.74	3.23	3.62	3.30	2.33	1.53	1.31	1.74	33.37
1960	2.22	3.82	13.65	8.55	4.49	4.43	37.05	15.36	3.00	2.05	1.55	1.30	97.47
1961	1.44	3.55	4.67	4.30	7.18	10.97	5.61	2.40	1.54	0.98	1.08	1.34	45.06
1962	2.63	16.37	9.01	22.71	10.25	57.31	22.11	2.93	1.72	4.00	4.79	2.89	156.72
1963	3.35	15.53	14.62	24.71	10.83	4.72	5.67	4.45	39.40	16.69	3.34	2.47	145.78
1964	19.93	9.38	2.83	2.64	2.65	1.78	1.03	1.07	13.51	9.38	6.36	5.67	76.23
1965	25.17	22.66	8.03	3.50	2.77	1.55	0.86	11.08	7.08	2.95	1.91	2.10	89.66
1966	2.41	2.68	3.15	3.86	4.35	41.51	18.71	4.59	2.82	3.30	3.14	1.86	92.38
1967	1.50	2.96	3.14	2.35	2.17	2.23	2.11	1.48	0.85	0.63	1.05	2.33	22.80
1968	3.67	4.56	4.42	2.70	3.46	19.22	8.90	4.07	3.80	2.56	1.89	1.74	60.99
1969	2.52	4.02	4.32	2.97	2.10	1.45	0.89	0.96	1.54	1.63	2.38	3.70	28.48
1970	25.71	12.84	5.87	5.07	4.30	3.66	3.07	4.77	4.68	4.01	7.64	6.15	87.77
1971	31.83	14.11	4.20	3.79	14.60	7.84	2.92	1.54	1.13	1.11	0.90	0.72	84.69
1972	0.86	3.03	4.14	3.26	2.90	3.13	2.95	1.93	0.99	0.65	0.93	1.95	26.72
1973	3.00	6.76	5.10	3.86	4.81	13.23	7.05	7.20	6.07	3.86	2.09	1.24	64.27
1974	1.37	2.96	5.06	4.82	4.66	4.64	3.43	1.88	0.99	0.69	0.61	2.52	33.63
1975	3.88	3.56	20.84	15.16	21.62	73.38	26.23	4.80	3.65	2.14	1.31	1.78	178.35
1976	25.58	11.93	4.13	3.67	3.61	3.43	2.40	1.33	0.93	0.87	0.90	1.40	60.18
1977	3.78	16.27	14.86	7.04	4.34	3.93	102.25	38.00	3.78	2.07	1.51	1.97	199.80
1978	4.27	11.82	7.33	3.74	2.92	3.43	3.08	1.77	0.92	1.39	1.97	1.93	44.57
1979	2.48	3.00	3.02	2.31	1.75	1.75	1.41	1.01	0.78	0.61	0.51	2.85	21.48
1980	4.75	21.59	11.12	5.44	5.16	4.02	2.28	1.80	1.68	1.18	1.45	1.84	62.31
1981	1.60	1.67	1.81	2.73	3.09	4.69	5.30	3.77	2.22	1.55	1.04	0.88	30.35
1982	2.19	2.67	1.81	1.38	1.31	1.12	1.02	0.94	0.72	0.87	1.06	1.18	16.27
1983	1.84	3.81	4.92	13.64	12.40	7.18	10.93	6.16	2.84	2.66	2.52	2.02	70.92
1984	2.08	3.51	5.16	5.22	48.09	18.56	2.38	1.14	0.73	0.67	0.50	0.40	88.44
1985	9.67	10.67	8.77	5.65	3.75	2.54	1.61	0.94	0.63	0.55	1.82	3.45	50.05
1986	10.04	18.42	8.33	3.94	3.23	3.35	3.04	1.94	1.22	0.87	1.40	58.05	113.83
1987	23.82	13.71	25.48	10.18	29.02	63.19	21.67	5.25	5.26	5.24	5.27	4.40	212.49
1988	3.86	12.78	22.96	9.11	38.16	15.54	4.19	3.53	2.48	1.95	1.31	0.97	116.84
1989	3.38	61.05	23.46	3.75	2.57	9.61	6.01	2.44	1.24	0.78	1.61	2.32	118.22
1990	3.59	4.06	3.32	4.20	4.88	3.82	1.93	0.92	0.66	0.52	0.49	1.02	29.41
1991	13.12	12.03	5.69	3.27	2.66	2.56	2.21	1.39	0.77	0.52	0.51	0.71	45.44
1992	1.33	3.14	4.84	4.24	3.83	2.83	1.79	1.12	0.65	0.44	0.46	1.80	26.47
1993	21.00	11.26	20.09	9.30	10.87	19.87	7.99	1.74	0.88	1.20	1.59	1.18	106.97
1994	0.90	0.98	1.24	1.98	1.84	7.82	6.81	4.62	3.84	3.09	1.74	1.25	36.11
1995	1.99	3.57	64.69	27.19	25.99	11.70	3.15	1.43	0.73	1.43	1.95	1.69	145.51
1996	2.29	26.02	12.43	9.04	7.04	5.78	20.60	9.60	41.72	18.17	4.67	3.44	160.80
month	430.18	836.62	796.53	540.82	643.91	800.57	565.63	335.00	306.51	260.46	170.90	222.49	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.56	0.98	1.24	1.02	1.31	1.12	0.82	0.88	0.63	0.44	0.46	0.40	16.27
max	35.36	74.12	64.69	28.84	48.09	73.38	102.25	47.48	41.72	44.19	18.44	58.05	212.49
median	2.68	4.06	4.92	4.24	4.27	4.56	3.62	2.44	1.71	1.53	1.46	1.74	62.31
mean	5.59	10.87	10.34	7.02	8.36	10.40	7.35	4.35	3.98	3.38	2.22	2.89	76.75
Sum of the monthly means = 76.75													
s.d.	7.56	13.84	11.99	6.50	10.10	13.80	12.71	7.07	7.28	6.37	2.67	6.60	47.91
c.v.	1.35	1.27	1.16	0.93	1.21	1.33	1.73	1.62	1.83	1.88	1.20	2.28	0.62

APPENDIX 11

AFFORESTATION RUNOFF REDUCTION FOR QUATERNARY CATHMENTS (2000)

APPENDIX 11.1
T60A (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.03	0.03	0.02	0.03	0.03	0.01	0.01	0.00	0.00	0.00	0.18
1921	0.02	0.35	0.27	0.06	0.01	0.01	0.00	0.03	0.25	0.08	0.00	0.01	1.09
1922	0.01	0.26	0.09	0.22	0.25	0.23	0.06	0.00	0.00	0.30	0.10	0.00	1.52
1923	0.01	0.00	0.02	0.37	0.29	0.06	0.01	0.01	0.00	0.01	0.01	0.01	0.80
1924	0.02	0.03	0.29	0.09	0.01	0.31	0.10	0.00	0.00	0.01	0.00	0.01	0.87
1925	0.01	0.03	0.02	0.03	0.02	0.31	0.10	0.01	0.01	0.02	0.01	0.01	0.58
1926	0.03	0.03	0.03	0.02	0.02	0.34	0.12	0.00	0.01	0.00	0.01	0.01	0.62
1927	0.02	0.02	0.03	0.30	0.10	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.49
1928	0.02	0.02	0.02	0.02	0.01	0.03	0.03	0.01	0.30	0.10	0.01	0.18	0.75
1929	0.18	0.04	0.01	0.02	0.01	0.03	0.03	0.02	0.01	0.01	0.02	0.02	0.40
1930	0.02	0.02	0.02	0.27	0.01	0.00	0.00	0.00	0.00	0.36	0.12	0.00	0.82
1931	0.01	0.01	0.02	0.01	0.34	0.12	0.00	0.00	0.02	0.02	0.01	0.02	0.58
1932	0.03	0.26	0.24	0.06	0.01	0.01	0.02	0.02	0.00	0.01	0.01	0.00	0.67
1933	0.01	0.35	0.29	0.23	0.06	0.02	0.01	0.01	0.01	0.01	0.01	0.01	1.02
1934	0.01	0.02	0.32	0.11	0.01	0.02	0.28	0.23	0.16	0.04	0.01	0.01	1.22
1935	0.01	0.02	0.01	0.01	0.39	0.29	0.06	0.01	0.02	0.01	0.00	0.01	0.84
1936	0.02	0.30	0.11	0.02	0.27	0.10	0.01	0.00	0.01	0.01	0.01	0.00	0.86
1937	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.24
1938	0.01	0.03	0.04	0.03	0.27	0.10	0.00	0.01	0.01	0.01	0.02	0.30	0.83
1939	0.10	0.01	0.01	0.02	0.01	0.02	0.01	0.03	0.03	0.02	0.01	0.01	0.28
1940	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.07
1941	0.02	0.03	0.03	0.32	0.11	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.59
1942	0.03	0.31	0.26	0.06	0.01	0.26	0.24	0.06	0.00	0.01	0.02	0.02	1.28
1943	0.21	0.21	0.21	0.06	0.01	0.02	0.02	0.01	0.00	0.01	0.01	0.03	0.80
1944	0.03	0.03	0.01	0.02	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.23
1945	0.33	0.11	0.01	0.01	0.02	0.31	0.11	0.01	0.00	0.00	0.00	0.00	0.91
1946	0.02	0.03	0.03	0.03	0.03	0.25	0.09	0.01	0.19	0.06	0.00	0.01	0.75
1947	0.01	0.29	0.11	0.01	0.20	0.08	0.01	0.00	0.00	0.00	0.00	0.00	0.71
1948	0.02	0.03	0.02	0.03	0.27	0.10	0.01	0.01	0.01	0.00	0.00	0.00	0.50
1949	0.01	0.31	0.11	0.23	0.08	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.84
1950	0.02	0.01	0.32	0.12	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.58
1951	0.04	0.02	0.02	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.00	0.01	0.24
1952	0.02	0.01	0.02	0.02	0.03	0.02	0.03	0.01	0.01	0.01	0.01	0.02	0.21
1953	0.03	0.29	0.25	0.06	0.01	0.02	0.02	0.01	0.02	0.01	0.00	0.01	0.73
1954	0.32	0.11	0.01	0.26	0.25	0.06	0.00	0.00	0.01	0.00	0.01	0.01	1.04
1955	0.02	0.03	0.02	0.01	0.03	0.37	0.12	0.01	0.01	0.01	0.00	0.01	0.64
1956	0.02	0.28	0.26	0.06	0.01	0.22	0.21	0.05	0.00	0.00	0.00	0.02	1.13
1957	0.24	0.21	0.05	0.02	0.23	0.08	0.02	0.01	0.01	0.00	0.00	0.00	0.87
1958	0.01	0.03	0.04	0.02	0.03	0.02	0.02	0.30	0.10	0.00	0.01	0.02	0.60
1959	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.22
1960	0.02	0.03	0.27	0.10	0.02	0.02	0.23	0.08	0.01	0.01	0.01	0.01	0.81
1961	0.01	0.03	0.03	0.02	0.25	0.23	0.05	0.01	0.00	0.00	0.01	0.01	0.65
1962	0.02	0.30	0.11	0.23	0.08	0.23	0.08	0.00	0.00	0.02	0.03	0.01	1.11
1963	0.02	0.25	0.24	0.24	0.07	0.02	0.02	0.01	0.24	0.08	0.00	0.00	1.19
1964	0.27	0.09	0.01	0.02	0.03	0.02	0.01	0.02	0.36	0.12	0.01	0.01	0.97
1965	0.00	0.10	0.06	0.01	0.01	0.01	0.01	0.35	0.12	0.01	0.00	0.02	0.70
1966	0.01	0.02	0.02	0.03	0.03	0.27	0.22	0.04	0.01	0.02	0.01	0.00	0.68
1967	0.01	0.03	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0.00	0.01	0.02	0.21
1968	0.03	0.04	0.03	0.01	0.03	0.29	0.10	0.01	0.01	0.01	0.01	0.01	0.58
1969	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.03	0.22
1970	0.30	0.10	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.21	0.08	0.81
1971	0.18	0.06	0.01	0.01	0.26	0.09	0.01	0.01	0.01	0.01	0.01	0.00	0.66
1972	0.01	0.03	0.03	0.03	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.02	0.23
1973	0.02	0.29	0.10	0.02	0.02	0.23	0.08	0.19	0.07	0.01	0.00	0.01	1.04
1974	0.01	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.23
1975	0.03	0.03	0.30	0.26	0.23	0.23	0.06	0.01	0.01	0.01	0.01	0.01	1.19
1976	0.31	0.11	0.01	0.02	0.02	0.02	0.02	0.00	0.00	0.01	0.00	0.02	0.54
1977	0.04	0.28	0.24	0.06	0.01	0.02	0.27	0.09	0.01	0.00	0.00	0.02	1.04
1978	0.03	0.24	0.08	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.47
1979	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.03	0.23
1980	0.03	0.28	0.10	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.54
1981	0.01	0.02	0.02	0.03	0.03	0.04	0.03	0.01	0.01	0.00	0.01	0.01	0.22
1982	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.16
1983	0.02	0.04	0.04	0.27	0.24	0.06	0.16	0.06	0.00	0.01	0.01	0.01	0.92
1984	0.01	0.03	0.04	0.03	0.25	0.09	0.00	0.01	0.01	0.00	0.00	0.00	0.47
1985	0.34	0.25	0.19	0.06	0.02	0.01	0.01	0.00	0.00	0.00	0.02	0.03	0.93
1986	0.27	0.24	0.05	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.01	0.33	0.97
1987	0.11	0.17	0.23	0.07	0.26	0.26	0.06	0.01	0.02	0.01	0.02	0.02	1.24
1988	0.02	0.24	0.25	0.06	0.24	0.09	0.02	0.02	0.01	0.01	0.01	0.00	0.97
1989	0.02	0.30	0.10	0.01	0.01	0.30	0.10	0.00	0.01	0.00	0.01	0.01	0.87
1990	0.03	0.03	0.03	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.22
1991	0.35	0.24	0.05	0.01	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.71
1992	0.01	0.04	0.04	0.03	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.02	0.21
1993	0.34	0.12	0.20	0.07	0.23	0.24	0.06	0.00	0.00	0.01	0.01	0.00	1.28
1994	0.01	0.01	0.01	0.03	0.02	0.35	0.12	0.01	0.01	0.01	0.01	0.01	0.60
1995	0.01	0.02	0.30	0.26	0.23	0.06	0.00	0.00	0.00	0.02	0.01	0.01	0.92
1996	0.02	0.33	0.12	0.20	0.08	0.01	0.19	0.06	0.19	0.07	0.00	0.01	1.28
month	4.96	8.73	7.13	5.71	6.48	7.46	4.03	2.15	2.52	1.75	1.03	1.72	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07
max	0.35	0.35	0.32	0.37	0.39	0.37	0.28	0.35	0.36	0.36	0.21	0.33	1.52
median	0.02	0.03	0.03	0.03	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.71
mean	0.06	0.11	0.09	0.07	0.08	0.10	0.05	0.03	0.03	0.02	0.01	0.02	0.70
Sum of the monthly means =				0.70									
s.d.	0.10	0.12	0.10	0.09	0.11	0.11	0.07	0.06	0.07	0.06	0.03	0.05	0.34
c.v.	1.58	1.03	1.10	1.26	1.26	1.16	1.31	2.17	2.19	2.44	2.15	2.37	0.49

APPENDIX 11.2
T60B (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.03	0.10	0.16	0.14	0.12	0.15	0.14	0.07	0.03	0.02	0.01	0.03	1.00
1921	0.10	1.83	1.45	0.33	0.07	0.05	0.03	0.16	1.36	0.44	0.03	0.04	5.89
1922	0.09	1.07	0.37	1.18	1.32	1.21	0.30	0.01	0.02	0.34	0.13	0.01	6.05
1923	0.03	0.05	0.10	1.97	1.57	0.31	0.02	0.03	0.03	0.02	0.03	0.06	4.22
1924	0.13	0.18	1.52	0.51	0.05	1.64	0.56	0.04	0.02	0.01	0.01	0.03	4.70
1925	0.08	0.16	0.16	0.16	0.13	1.66	0.55	0.03	0.07	0.06	0.04	0.07	3.17
1926	0.15	0.16	0.16	0.11	0.09	1.63	0.54	0.01	0.01	0.02	0.02	0.05	2.95
1927	0.11	0.10	0.18	1.29	0.47	0.06	0.03	0.03	0.03	0.02	0.04	0.06	2.42
1928	0.09	0.13	0.12	0.11	0.09	0.17	0.15	0.09	1.60	0.54	0.03	0.95	4.07
1929	0.95	0.25	0.05	0.08	0.09	0.13	0.12	0.07	0.09	0.08	0.10	0.14	2.15
1930	0.13	0.11	0.15	1.32	1.24	1.13	0.30	0.01	0.01	0.32	0.12	0.02	4.86
1931	0.07	0.09	0.10	0.09	1.78	0.62	0.03	0.04	0.06	0.08	0.07	0.13	3.16
1932	0.18	1.39	1.31	0.30	0.03	0.09	0.11	0.07	0.04	0.04	0.03	0.03	3.62
1933	0.03	1.89	1.26	1.10	0.33	0.07	0.08	0.06	0.04	0.07	0.07	0.06	5.06
1934	0.06	0.14	1.69	0.58	0.06	0.10	1.48	1.18	0.87	0.21	0.04	0.05	6.46
1935	0.06	0.09	0.06	0.07	2.07	1.55	0.29	0.08	0.09	0.06	0.04	0.04	4.50
1936	0.13	1.61	0.56	0.09	1.29	0.46	0.04	0.03	0.02	0.02	0.02	0.03	4.30
1937	0.07	0.11	0.16	0.16	0.17	0.12	0.13	0.10	0.07	0.07	0.07	0.05	1.28
1938	0.07	0.13	0.19	0.16	1.45	0.50	0.05	0.06	0.05	0.07	0.08	1.61	4.42
1939	0.56	0.05	0.35	0.00	0.00	0.05	0.07	0.15	0.14	0.08	0.04	0.05	1.54
1940	0.06	0.16	1.39	0.47	0.04	0.07	0.09	0.06	0.04	0.03	0.04	0.05	2.50
1941	0.10	0.14	0.12	1.77	0.62	0.09	0.08	0.07	0.05	0.03	0.04	0.07	3.18
1942	0.13	1.64	1.40	0.33	0.06	1.40	1.25	0.28	0.04	0.05	0.11	0.10	6.79
1943	1.12	1.14	1.12	0.32	0.11	0.11	0.07	0.05	0.05	0.05	0.04	0.14	4.32
1944	0.18	0.11	0.06	0.11	0.15	0.18	0.12	0.07	0.04	0.04	0.03	0.04	1.13
1945	1.74	0.59	0.03	0.06	0.15	1.65	0.56	0.03	0.02	0.02	0.02	0.04	4.91
1946	0.08	0.17	0.17	0.14	0.16	1.32	0.47	0.04	1.02	0.35	0.02	0.03	3.97
1947	0.06	1.56	0.57	0.08	1.09	0.40	0.06	0.04	0.01	0.00	0.01	0.01	3.89
1948	0.12	0.16	0.14	0.14	1.45	0.51	0.06	0.05	0.03	0.01	0.02	0.04	2.73
1949	0.09	1.66	0.57	1.21	0.44	0.08	0.08	0.09	0.07	0.06	0.10	0.10	4.55
1950	0.10	0.10	1.70	0.60	0.07	0.12	0.09	0.05	0.04	0.03	0.05	0.09	3.04
1951	0.18	0.14	0.15	0.16	0.15	0.11	0.12	0.10	0.05	0.03	0.02	0.05	1.26
1952	0.07	0.09	0.10	0.12	0.14	0.14	0.11	0.08	0.05	0.03	0.04	0.09	1.06
1953	0.17	1.53	1.35	0.32	0.08	0.10	0.07	0.08	0.09	0.08	0.04	0.07	3.98
1954	1.70	0.59	0.05	1.41	1.36	0.35	0.06	0.04	0.04	0.03	0.02	0.05	5.70
1955	0.11	0.15	0.11	0.05	0.12	1.95	0.68	0.04	0.04	0.03	0.03	0.05	3.36
1956	0.14	1.49	1.38	0.35	0.09	1.15	1.10	0.25	0.02	0.03	0.04	0.11	6.15
1957	1.28	1.17	0.29	0.10	1.23	0.44	0.09	0.06	0.02	0.02	0.01	0.03	4.74
1958	0.06	0.17	0.19	0.13	0.13	0.12	0.12	1.58	0.53	0.03	0.06	0.07	3.19
1959	0.09	0.12	0.13	0.11	0.12	0.14	0.14	0.11	0.07	0.04	0.04	0.08	1.19
1960	0.11	0.18	1.47	0.60	0.00	0.00	0.87	0.31	0.02	0.02	0.03	0.04	3.65
1961	0.06	0.17	0.17	0.15	1.32	1.25	0.29	0.03	0.03	0.02	0.04	0.05	3.58
1962	0.14	1.61	0.56	1.18	0.42	1.23	0.43	0.03	0.02	0.74	0.06	0.00	6.42
1963	0.01	1.01	1.17	1.27	0.37	0.08	0.18	0.00	0.47	0.18	0.02	0.05	4.81
1964	1.43	0.48	0.06	0.10	0.11	0.08	0.05	0.07	1.94	0.66	0.04	0.04	5.06
1965	0.95	1.10	0.29	0.08	0.08	0.05	0.04	1.90	0.64	0.01	0.02	0.06	5.22
1966	0.09	0.11	0.13	0.16	0.16	1.42	1.16	0.24	0.03	0.07	0.07	0.04	3.68
1967	0.05	0.14	0.13	0.11	0.12	0.12	0.11	0.07	0.03	0.03	0.06	0.12	1.09
1968	0.17	0.18	0.14	0.08	0.16	1.52	0.51	0.07	0.07	0.05	0.04	0.05	3.04
1969	0.11	0.16	0.14	0.10	0.10	0.07	0.05	0.07	0.10	0.09	0.13	0.16	1.28
1970	1.51	0.53	0.07	0.08	0.09	0.09	0.09	0.44	0.00	0.00	0.55	0.21	3.66
1971	0.94	0.34	0.06	0.10	1.38	0.48	0.04	0.03	0.03	0.03	0.03	0.03	3.49
1972	0.05	0.17	0.18	0.13	0.13	0.14	0.12	0.07	0.03	0.02	0.04	0.10	1.18
1973	0.15	1.52	0.52	0.09	0.13	1.21	0.41	1.01	0.35	0.02	0.01	0.02	5.44
1974	0.05	0.14	0.18	0.14	0.13	0.13	0.08	0.04	0.02	0.02	0.02	0.12	1.07
1975	0.15	0.13	1.59	1.41	1.25	1.23	0.34	0.07	0.05	0.03	0.02	0.07	6.34
1976	1.69	0.59	0.07	0.10	0.11	0.11	0.08	0.04	0.03	0.03	0.04	0.08	2.97
1977	0.19	1.52	1.32	0.33	0.07	0.10	1.39	0.48	0.03	0.01	0.02	0.07	5.53
1978	0.16	1.28	0.45	0.05	0.09	0.13	0.11	0.05	0.03	0.07	0.09	0.08	2.59
1979	0.12	0.14	0.13	0.11	0.09	0.11	0.08	0.06	0.04	0.03	0.02	0.15	1.08
1980	0.18	1.47	0.53	0.08	0.09	0.08	0.05	0.07	0.06	0.04	0.06	0.08	2.79
1981	0.07	0.10	0.11	0.17	0.16	0.81	0.11	0.00	0.00	0.00	0.01	0.02	1.56
1982	0.10	0.11	0.09	0.09	0.10	0.08	0.08	0.07	0.04	0.05	0.06	0.07	0.94
1983	0.12	0.19	0.19	1.40	1.31	0.34	0.86	0.28	0.02	0.05	0.06	0.06	4.88
1984	0.08	0.15	0.18	0.15	1.30	0.44	0.03	0.02	0.02	0.02	0.02	0.01	2.42
1985	1.78	1.31	1.03	0.31	0.06	0.07	0.05	0.04	0.03	0.02	0.10	0.15	4.95
1986	1.46	1.27	0.29	0.08	0.09	0.12	0.10	0.06	0.04	0.03	0.06	1.76	5.36
1987	0.61	0.90	0.92	0.24	1.35	1.36	0.34	0.08	0.07	0.08	0.08	0.07	6.10
1988	0.08	1.27	1.33	0.34	1.27	0.45	0.09	0.07	0.06	0.05	0.04	0.03	5.08
1989	0.15	1.58	0.55	0.08	0.08	1.59	0.55	0.02	0.01	0.01	0.06	0.09	4.77
1990	0.15	0.14	0.11	0.16	0.15	0.10	0.05	0.03	0.02	0.02	0.02	0.06	1.01
1991	1.86	1.33	0.26	0.07	0.09	0.11	0.09	0.06	0.03	0.02	0.02	0.04	3.98
1992	0.09	0.18	0.20	0.15	0.13	0.09	0.07	0.04	0.03	0.01	0.02	0.11	1.12
1993	1.78	0.62	1.02	0.37	1.20	1.28	0.30	0.01	0.01	0.04	0.07	0.05	6.75
1994	0.04	0.06	0.09	0.15	0.12	1.89	0.66	0.05	0.06	0.05	0.03	0.03	3.23
1995	0.08	0.15	1.57	1.36	1.16	0.33	0.03	0.02	0.01	0.03	0.04	0.05	4.83
1996	0.10	1.71	0.61	1.05	0.82	0.00	0.22	0.11	1.05	0.37	0.02	0.05	6.11
month	27.56	46.56	39.03	30.35	35.97	40.82	20.55	11.60	12.49	6.58	3.92	9.09	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.01	0.05	0.03	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.01	0.00	0.94
max	1.86	1.89	1.70	1.97	2.07	1.95	1.48	1.90	1.94	0.74	0.55	1.76	6.79
median	0.11	0.18	0.19	0.15	0.13	0.14	0.11	0.06	0.04	0.03	0.04	0.05	3.68
mean	0.36	0.60	0.51	0.39	0.47	0.53	0.27	0.15	0.16	0.09	0.05	0.12	3.70
Sum of the monthly means =				3.70									
s.d.	0.54	0.61	0.53	0.48	0.56	0.59	0.34	0.32	0.37	0.14	0.06	0.28	1.70
c.v.	1.51	1.02	1.05	1.23	1.21	1.12	1.26	2.13	2.26	1.69	1.27	2.37	0.46

APPENDIX 11.3
T60E (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.01	0.00	0.00	0.01	0.20
1921	0.02	0.36	0.30	0.06	0.01	0.01	0.01	0.04	0.27	0.08	0.01	0.01	1.18
1922	0.24	0.25	0.06	0.29	0.28	0.23	0.06	0.00	0.00	0.31	0.11	0.01	1.84
1923	0.01	0.02	0.02	0.36	0.29	0.06	0.00	0.00	0.00	0.01	0.01	0.01	0.79
1924	0.03	0.04	0.03	0.02	0.03	0.31	0.10	0.01	0.00	0.01	0.00	0.01	0.59
1925	0.03	0.03	0.03	0.03	0.03	0.32	0.11	0.01	0.01	0.01	0.01	0.01	0.63
1926	0.03	0.28	0.10	0.01	0.02	0.32	0.11	0.00	0.00	0.01	0.00	0.01	0.89
1927	0.02	0.03	0.02	0.03	0.04	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.24
1928	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.34	0.20	0.04	0.17	0.96
1929	0.20	0.21	0.06	0.01	0.01	0.02	0.03	0.01	0.02	0.02	0.03	0.04	0.66
1930	0.00	0.00	0.00	0.27	0.27	0.23	0.06	0.01	0.01	1.26	0.18	0.00	2.29
1931	0.01	0.02	0.02	0.02	0.36	0.13	0.00	0.01	0.01	0.02	0.01	0.31	0.92
1932	0.22	0.20	0.23	0.06	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.81
1933	0.01	0.37	0.30	0.25	0.07	0.01	0.02	0.01	0.01	0.02	0.02	0.01	1.10
1934	0.01	0.03	0.32	0.11	0.01	0.02	0.30	0.25	0.19	0.04	0.01	0.01	1.30
1935	0.02	0.02	0.01	0.01	0.42	0.33	0.07	0.01	0.02	0.01	0.01	0.01	0.94
1936	0.03	0.30	0.11	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.50
1937	0.02	0.02	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.25
1938	0.01	0.03	0.04	0.03	0.28	0.10	0.01	0.02	0.01	0.02	0.02	0.32	0.89
1939	0.23	0.05	0.02	0.01	0.01	0.03	0.01	0.03	0.03	0.01	0.01	0.01	0.45
1940	0.02	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.20
1941	0.02	0.04	0.03	0.38	0.13	0.01	0.01	0.01	0.02	0.00	0.01	0.02	0.68
1942	0.02	0.35	0.30	0.06	0.01	0.02	0.27	0.09	0.00	0.01	0.02	0.03	1.18
1943	0.02	0.24	0.11	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.33	0.74
1944	0.12	0.01	0.01	0.02	0.03	0.03	0.02	0.02	0.01	0.00	0.01	0.01	0.29
1945	0.38	0.13	0.00	0.01	0.03	0.33	0.11	0.01	0.01	0.01	0.00	0.00	1.02
1946	0.01	0.04	0.04	0.02	0.02	0.14	0.00	0.00	0.18	0.06	0.00	0.01	0.52
1947	0.01	0.31	0.11	0.01	0.25	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.79
1948	0.03	0.03	0.03	0.02	0.36	0.13	0.02	0.01	0.01	0.00	0.01	0.01	0.66
1949	0.02	0.35	0.12	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.65
1950	0.02	0.02	0.33	0.12	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.60
1951	0.34	0.11	0.02	0.03	0.02	0.02	0.03	0.02	0.01	0.00	0.01	0.01	0.62
1952	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.01	0.01	0.00	0.02	0.23
1953	0.03	0.32	0.27	0.06	0.01	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.83
1954	0.34	0.12	0.01	0.28	0.29	0.07	0.01	0.00	0.01	0.00	0.01	0.01	1.15
1955	0.02	0.03	0.02	0.01	0.03	0.40	0.13	0.01	0.01	0.00	0.00	0.02	0.68
1956	0.04	0.30	0.28	0.07	0.02	0.23	0.24	0.05	0.00	0.00	0.01	0.02	1.26
1957	0.03	0.03	0.02	0.24	0.27	0.07	0.20	0.07	0.01	0.01	0.00	0.00	0.95
1958	0.01	0.03	0.04	0.02	0.02	0.02	0.02	0.36	0.11	0.00	0.01	0.02	0.66
1959	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.24
1960	0.02	0.03	0.28	0.10	0.01	0.02	0.28	0.10	0.00	0.01	0.01	0.01	0.87
1961	0.02	0.32	0.11	0.01	0.02	0.27	0.09	0.01	0.00	0.00	0.01	0.01	0.87
1962	0.03	0.31	0.11	0.25	0.09	0.25	0.09	0.00	0.01	0.29	0.10	0.00	1.53
1963	0.02	0.03	0.02	0.27	0.10	0.01	0.18	0.06	0.21	0.07	0.01	0.01	0.99
1964	0.27	0.09	0.01	0.01	0.02	0.01	0.01	0.01	0.43	0.15	0.01	0.01	1.03
1965	0.21	0.23	0.06	0.02	0.02	0.01	0.01	0.38	0.13	0.01	0.01	0.01	1.10
1966	0.02	0.02	0.02	0.03	0.03	0.18	0.22	0.05	0.01	0.02	0.02	0.01	0.63
1967	0.01	0.02	0.02	0.02	0.03	0.03	0.02	0.01	0.00	0.00	0.01	0.03	0.20
1968	0.04	0.04	0.03	0.02	0.03	0.31	0.11	0.22	0.08	0.01	0.01	0.01	0.91
1969	0.02	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.35	0.12	0.67
1970	0.18	0.20	0.06	0.02	0.02	0.02	0.02	0.32	0.11	0.01	0.19	0.06	1.21
1971	0.20	0.07	0.01	0.01	0.31	0.11	0.01	0.01	0.01	0.01	0.01	0.01	0.77
1972	0.01	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.01	0.00	0.01	0.02	0.24
1973	0.03	0.31	0.10	0.01	0.03	0.03	0.02	0.30	0.10	0.01	0.00	0.01	0.95
1974	0.01	0.02	0.04	0.02	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.37	0.55
1975	0.12	0.01	0.26	0.09	0.25	0.28	0.07	0.00	0.00	0.00	0.00	0.01	1.09
1976	0.26	0.09	0.01	0.02	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.03	0.53
1977	0.03	0.31	0.28	0.07	0.01	0.02	0.33	0.12	0.01	0.00	0.01	0.01	1.20
1978	0.30	0.11	0.01	0.01	0.01	0.03	0.02	0.02	0.01	0.02	0.03	0.03	0.60
1979	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.03	0.21
1980	0.03	0.28	0.10	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.57
1981	0.02	0.02	0.02	0.03	0.02	0.40	0.14	0.00	0.00	0.00	0.01	0.01	0.67
1982	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.00	0.01	0.52	0.18	0.01	0.86
1983	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.02	0.01	0.24
1984	0.02	0.30	0.10	0.01	0.28	0.10	0.00	0.00	0.00	0.00	0.01	0.01	0.83
1985	0.02	0.32	0.11	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.02	0.03	0.58
1986	0.28	0.10	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.00	0.02	0.37	0.88
1987	0.13	0.19	0.07	0.01	0.30	0.28	0.07	0.02	0.02	0.02	0.02	0.01	1.14
1988	0.01	0.26	0.27	0.06	0.30	0.11	0.20	0.07	0.01	0.01	0.00	0.01	1.31
1989	0.32	0.27	0.06	0.02	0.01	0.11	0.00	0.00	0.00	0.00	0.01	0.02	0.82
1990	0.02	0.02	0.02	0.03	0.04	0.03	0.02	0.01	0.01	0.00	0.01	0.02	0.23
1991	0.12	0.00	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.22
1992	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.02	0.19
1993	0.03	0.03	0.29	0.10	0.31	0.11	0.01	0.01	0.00	0.00	0.02	0.01	0.92
1994	0.02	0.01	0.03	0.03	0.02	0.35	0.28	0.06	0.01	0.01	0.00	0.01	0.83
1995	0.02	0.02	0.33	0.11	0.11	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.64
1996	0.02	0.30	0.10	0.02	0.25	0.08	0.23	0.07	0.22	0.08	0.01	0.01	1.39
month	5.63	9.35	6.66	4.71	6.66	7.32	4.84	3.24	2.96	3.62	1.87	2.99	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
max	0.38	0.37	0.33	0.38	0.42	0.40	0.33	0.38	0.43	1.26	0.35	0.37	2.29
median	0.02	0.04	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.79
mean	0.07	0.12	0.09	0.06	0.09	0.10	0.06	0.04	0.04	0.05	0.02	0.04	0.78
Sum of the monthly means =				0.78									
s.d.	0.10	0.12	0.10	0.09	0.12	0.12	0.08	0.08	0.08	0.16	0.05	0.08	0.39
c.v.	1.38	1.02	1.18	1.45	1.36	1.22	1.35	1.95	2.08	3.42	2.18	2.15	0.51

APPENDIX 11.4
T60F (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.19	0.07	0.01	0.16	0.06	0.00	0.00	0.00	0.00	0.01	0.52
1921	0.01	0.24	0.20	0.05	0.00	0.00	0.00	0.25	0.16	0.03	0.00	0.01	0.95
1922	0.16	0.16	0.04	0.17	0.19	0.17	0.05	0.01	0.00	0.22	0.08	0.00	1.25
1923	0.00	0.02	0.02	0.24	0.20	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.53
1924	0.02	0.02	0.19	0.07	0.01	0.19	0.07	0.00	0.01	0.00	0.00	0.01	0.59
1925	0.02	0.02	0.02	0.02	0.02	0.18	0.06	0.01	0.01	0.01	0.00	0.01	0.38
1926	0.02	0.19	0.16	0.04	0.01	0.21	0.07	0.00	0.01	0.01	0.01	0.01	0.74
1927	0.01	0.02	0.02	0.02	0.19	0.06	0.00	0.00	0.00	0.01	0.01	0.01	0.35
1928	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.23	0.14	0.02	0.12	0.66
1929	0.14	0.14	0.04	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.19	0.63
1930	0.07	0.01	0.01	0.21	0.20	0.16	0.05	0.01	0.00	0.00	0.00	0.01	0.73
1931	0.01	0.01	0.01	0.01	0.24	0.08	0.00	0.01	0.01	0.02	0.02	0.21	0.63
1932	0.16	0.14	0.16	0.04	0.01	0.02	0.02	0.01	0.00	0.01	0.00	0.00	0.57
1933	0.01	0.26	0.21	0.17	0.05	0.01	0.01	0.01	0.00	0.01	0.02	0.00	0.76
1934	0.01	0.02	0.22	0.07	0.00	0.01	0.20	0.17	0.13	0.03	0.01	0.01	0.88
1935	0.01	0.02	0.01	0.01	0.28	0.21	0.04	0.15	0.05	0.01	0.00	0.01	0.80
1936	0.02	0.19	0.07	0.01	0.21	0.18	0.04	0.00	0.00	0.01	0.00	0.01	0.74
1937	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.21
1938	0.01	0.02	0.02	0.03	0.18	0.06	0.01	0.01	0.01	0.01	0.01	0.21	0.58
1939	0.15	0.03	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.31
1940	0.01	0.03	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.13
1941	0.01	0.03	0.02	0.25	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.47
1942	0.02	0.22	0.19	0.05	0.00	0.02	0.17	0.06	0.00	0.01	0.02	0.01	0.77
1943	0.02	0.15	0.16	0.04	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.23	0.66
1944	0.09	0.01	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.19
1945	0.26	0.09	0.00	0.01	0.02	0.22	0.07	0.00	0.00	0.00	0.00	0.01	0.68
1946	0.01	0.23	0.08	0.01	0.02	0.19	0.17	0.04	0.13	0.04	0.01	0.00	0.93
1947	0.01	0.21	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.26
1948	0.03	0.02	0.02	0.01	0.24	0.18	0.04	0.01	0.00	0.01	0.00	0.01	0.57
1949	0.01	0.23	0.08	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.44
1950	0.01	0.02	0.22	0.08	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.43
1951	0.23	0.08	0.17	0.07	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.60
1952	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.02	0.15
1953	0.03	0.19	0.18	0.04	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.53
1954	0.22	0.08	0.00	0.19	0.19	0.05	0.01	0.00	0.00	0.00	0.00	0.01	0.75
1955	0.02	0.03	0.01	0.01	0.02	0.26	0.09	0.00	0.00	0.00	0.01	0.00	0.45
1956	0.02	0.19	0.18	0.05	0.01	0.16	0.16	0.03	0.01	0.01	0.01	0.01	0.84
1957	0.02	0.15	0.06	0.13	0.17	0.05	0.14	0.05	0.00	0.00	0.00	0.00	0.77
1958	0.01	0.03	0.03	0.02	0.02	0.02	0.02	0.22	0.08	0.01	0.01	0.01	0.48
1959	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.21
1960	0.02	0.00	0.00	0.00	0.01	0.01	0.18	0.06	0.00	0.00	0.01	0.01	0.30
1961	0.01	0.21	0.08	0.01	0.01	0.18	0.06	0.00	0.01	0.00	0.00	0.01	0.58
1962	0.02	0.21	0.07	0.17	0.06	0.17	0.06	0.01	0.01	0.19	0.06	0.00	1.03
1963	0.01	0.16	0.06	0.16	0.17	0.05	0.12	0.04	0.15	0.06	0.00	0.01	0.99
1964	0.18	0.06	0.01	0.01	0.02	0.01	0.01	0.01	0.28	0.10	0.00	0.00	0.69
1965	0.14	0.15	0.04	0.01	0.01	0.01	0.01	0.26	0.08	0.00	0.00	0.01	0.72
1966	0.01	0.01	0.01	0.02	0.02	0.19	0.17	0.04	0.00	0.02	0.01	0.00	0.50
1967	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.02	0.15
1968	0.03	0.18	0.06	0.00	0.20	0.18	0.04	0.15	0.05	0.00	0.01	0.01	0.91
1969	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.24	0.09	0.46
1970	0.12	0.14	0.04	0.01	0.02	0.01	0.02	0.21	0.07	0.01	0.13	0.04	0.82
1971	0.13	0.05	0.01	0.01	0.21	0.07	0.01	0.01	0.00	0.00	0.00	0.01	0.51
1972	0.00	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.00	0.00	0.01	0.02	0.14
1973	0.02	0.20	0.07	0.01	0.02	0.02	0.01	0.20	0.07	0.01	0.01	0.00	0.64
1974	0.00	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.25	0.36
1975	0.09	0.00	0.17	0.06	0.18	0.19	0.05	0.11	0.04	0.01	0.00	0.01	0.91
1976	0.21	0.07	0.01	0.02	0.21	0.07	0.01	0.00	0.01	0.01	0.01	0.01	0.64
1977	0.03	0.19	0.18	0.05	0.01	0.01	0.21	0.08	0.00	0.01	0.00	0.01	0.78
1978	0.20	0.16	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.52
1979	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.23	0.36
1980	0.09	0.14	0.05	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.37
1981	0.01	0.02	0.01	0.02	0.02	0.27	0.09	0.00	0.00	0.00	0.01	0.00	0.45
1982	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.09
1983	0.01	0.16	0.06	0.14	0.05	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.52
1984	0.01	0.20	0.07	0.01	0.18	0.06	0.00	0.01	0.00	0.01	0.00	0.00	0.55
1985	0.02	0.22	0.08	0.15	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.61
1986	0.19	0.06	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.24	0.60
1987	0.09	0.13	0.05	0.01	0.21	0.20	0.05	0.13	0.04	0.01	0.01	0.01	0.94
1988	0.01	0.17	0.18	0.04	0.21	0.08	0.14	0.05	0.00	0.00	0.00	0.01	0.89
1989	0.22	0.18	0.04	0.01	0.02	0.22	0.08	0.00	0.00	0.01	0.01	0.02	0.81
1990	0.02	0.02	0.01	0.02	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.16
1991	0.23	0.19	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.55
1992	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.16
1993	0.03	0.03	0.18	0.06	0.18	0.07	0.00	0.01	0.00	0.00	0.02	0.01	0.59
1994	0.01	0.01	0.23	0.08	0.00	0.21	0.18	0.04	0.01	0.01	0.00	0.01	0.79
1995	0.01	0.01	0.21	0.07	0.14	0.05	0.01	0.01	0.01	0.02	0.02	0.01	0.57
1996	0.02	0.20	0.07	0.01	0.16	0.05	0.15	0.05	0.14	0.05	0.01	0.01	0.92
month	4.21	7.27	5.38	3.62	5.28	5.64	3.56	2.83	2.08	1.36	1.05	2.42	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
max	0.26	0.26	0.23	0.25	0.28	0.27	0.21	0.26	0.28	0.22	0.24	0.25	1.25
median	0.02	0.06	0.04	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.58
mean	0.05	0.09	0.07	0.05	0.07	0.07	0.05	0.04	0.03	0.02	0.01	0.03	0.58
Sum of the monthly means =				0.58									
s.d.	0.07	0.08	0.07	0.06	0.08	0.08	0.06	0.06	0.05	0.04	0.03	0.06	0.25
c.v.	1.31	0.88	1.03	1.28	1.23	1.10	1.24	1.70	1.96	2.11	2.35	2.02	0.43

APPENDIX 11.5
T60G (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.01	0.01	0.12	0.04	0.09	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.40
1921	0.01	0.13	0.12	0.03	0.01	0.00	0.00	0.16	0.11	0.02	0.01	0.01	0.61
1922	0.09	0.10	0.03	0.11	0.12	0.11	0.02	0.00	0.01	0.14	0.05	0.00	0.78
1923	0.00	0.00	0.01	0.12	0.12	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.31
1924	0.01	0.13	0.12	0.03	0.09	0.10	0.03	0.00	0.00	0.00	0.00	0.01	0.52
1925	0.01	0.11	0.04	0.09	0.10	0.10	0.02	0.00	0.01	0.01	0.00	0.01	0.50
1926	0.12	0.11	0.10	0.03	0.01	0.12	0.04	0.00	0.00	0.00	0.01	0.00	0.54
1927	0.02	0.01	0.14	0.12	0.11	0.03	0.00	0.00	0.01	0.01	0.00	0.01	0.46
1928	0.01	0.12	0.05	0.00	0.01	0.11	0.04	0.00	0.00	0.00	0.02	0.07	0.43
1929	0.09	0.08	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.10	0.36
1930	0.04	0.00	0.01	0.10	0.11	0.10	0.02	0.00	0.00	0.06	0.01	0.00	0.45
1931	0.00	0.01	0.01	0.01	0.12	0.04	0.01	0.00	0.01	0.01	0.01	0.14	0.37
1932	0.11	0.09	0.10	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.38
1933	0.00	0.17	0.13	0.11	0.03	0.09	0.03	0.00	0.00	0.01	0.01	0.00	0.58
1934	0.00	0.13	0.12	0.03	0.00	0.01	0.11	0.10	0.09	0.03	0.07	0.03	0.72
1935	0.00	0.00	0.00	0.00	0.15	0.12	0.02	0.10	0.03	0.00	0.00	0.01	0.43
1936	0.12	0.12	0.03	0.01	0.13	0.12	0.02	0.00	0.00	0.01	0.01	0.01	0.58
1937	0.01	0.01	0.14	0.11	0.03	0.00	0.11	0.04	0.00	0.00	0.01	0.00	0.46
1938	0.01	0.13	0.12	0.10	0.10	0.03	0.00	0.01	0.00	0.01	0.01	0.10	0.62
1939	0.10	0.02	0.08	0.03	0.00	0.01	0.01	0.12	0.04	0.00	0.00	0.00	0.41
1940	0.01	0.14	0.05	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.27
1941	0.01	0.13	0.05	0.10	0.04	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.39
1942	0.02	0.12	0.12	0.03	0.01	0.12	0.11	0.02	0.00	0.01	0.10	0.04	0.70
1943	0.07	0.10	0.10	0.03	0.10	0.04	0.00	0.00	0.01	0.01	0.01	0.15	0.62
1944	0.10	0.02	0.00	0.01	0.12	0.11	0.03	0.00	0.01	0.00	0.00	0.01	0.41
1945	0.15	0.05	0.00	0.01	0.14	0.12	0.02	0.00	0.00	0.00	0.00	0.00	0.49
1946	0.01	0.14	0.06	0.00	0.01	0.10	0.10	0.02	0.08	0.03	0.00	0.01	0.56
1947	0.00	0.13	0.11	0.02	0.11	0.11	0.03	0.00	0.00	0.00	0.00	0.01	0.52
1948	0.15	0.05	0.01	0.00	0.11	0.11	0.02	0.00	0.00	0.00	0.01	0.00	0.46
1949	0.01	0.13	0.05	0.10	0.10	0.03	0.01	0.07	0.02	0.00	0.01	0.01	0.54
1950	0.01	0.01	0.11	0.11	0.03	0.09	0.03	0.00	0.01	0.00	0.01	0.01	0.42
1951	0.14	0.05	0.11	0.11	0.03	0.01	0.08	0.02	0.01	0.01	0.00	0.01	0.58
1952	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.10
1953	0.13	0.11	0.11	0.03	0.00	0.10	0.03	0.01	0.00	0.00	0.01	0.01	0.54
1954	0.13	0.05	0.01	0.11	0.11	0.09	0.02	0.00	0.00	0.00	0.00	0.01	0.53
1955	0.02	0.11	0.04	0.00	0.01	0.13	0.05	0.01	0.00	0.00	0.00	0.00	0.37
1956	0.13	0.11	0.11	0.11	0.10	0.09	0.10	0.02	0.01	0.00	0.01	0.01	0.80
1957	0.11	0.10	0.09	0.11	0.11	0.03	0.08	0.03	0.00	0.01	0.00	0.00	0.67
1958	0.01	0.14	0.11	0.02	0.01	0.01	0.01	0.12	0.04	0.01	0.01	0.00	0.49
1959	0.01	0.01	0.01	0.01	0.01	0.11	0.04	0.01	0.01	0.00	0.00	0.01	0.23
1960	0.01	0.12	0.11	0.10	0.03	0.09	0.10	0.02	0.00	0.01	0.00	0.01	0.60
1961	0.01	0.14	0.11	0.03	0.09	0.10	0.02	0.00	0.01	0.00	0.00	0.01	0.52
1962	0.14	0.11	0.03	0.10	0.03	0.10	0.04	0.00	0.00	0.12	0.05	0.00	0.72
1963	0.10	0.10	0.09	0.10	0.11	0.10	0.09	0.02	0.09	0.04	0.01	0.01	0.86
1964	0.12	0.05	0.01	0.01	0.01	0.01	0.00	0.00	0.16	0.06	0.05	0.02	0.50
1965	0.08	0.10	0.02	0.01	0.00	0.01	0.00	0.16	0.06	0.00	0.00	0.01	0.45
1966	0.01	0.01	0.01	0.12	0.05	0.09	0.10	0.02	0.00	0.10	0.04	0.00	0.55
1967	0.00	0.12	0.05	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.24
1968	0.11	0.10	0.03	0.01	0.13	0.12	0.03	0.10	0.04	0.00	0.00	0.01	0.68
1969	0.01	0.12	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.14	0.10	0.49
1970	0.09	0.08	0.02	0.01	0.01	0.01	0.01	0.11	0.04	0.07	0.08	0.02	0.55
1971	0.08	0.09	0.08	0.03	0.09	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.45
1972	0.01	0.16	0.12	0.03	0.01	0.01	0.11	0.04	0.00	0.00	0.00	0.01	0.50
1973	0.10	0.10	0.03	0.00	0.11	0.10	0.03	0.09	0.04	0.00	0.00	0.00	0.60
1974	0.01	0.12	0.11	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.16	0.47
1975	0.06	0.01	0.10	0.04	0.09	0.11	0.08	0.08	0.02	0.01	0.00	0.01	0.61
1976	0.12	0.04	0.01	0.01	0.12	0.04	0.00	0.00	0.01	0.01	0.01	0.02	0.39
1977	0.12	0.11	0.10	0.03	0.01	0.01	0.05	0.05	0.01	0.00	0.01	0.01	0.51
1978	0.12	0.10	0.03	0.01	0.00	0.12	0.04	0.00	0.01	0.01	0.01	0.01	0.46
1979	0.10	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.15	0.34
1980	0.06	0.08	0.10	0.10	0.03	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.42
1981	0.00	0.01	0.01	0.02	0.01	0.12	0.10	0.03	0.01	0.01	0.01	0.01	0.34
1982	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.10	0.04	0.01	0.22
1983	0.01	0.00	0.03	0.10	0.03	0.00	0.08	0.02	0.01	0.09	0.03	0.01	0.41
1984	0.01	0.10	0.04	0.01	0.09	0.04	0.01	0.00	0.00	0.01	0.00	0.01	0.32
1985	0.15	0.11	0.02	0.10	0.03	0.00	0.01	0.00	0.01	0.00	0.01	0.12	0.56
1986	0.10	0.08	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.14	0.39
1987	0.05	0.07	0.03	0.00	0.11	0.11	0.03	0.08	0.03	0.06	0.07	0.01	0.65
1988	0.00	0.09	0.11	0.03	0.11	0.04	0.08	0.03	0.00	0.01	0.01	0.01	0.52
1989	0.14	0.12	0.03	0.01	0.00	0.14	0.05	0.00	0.01	0.00	0.01	0.01	0.52
1990	0.12	0.04	0.01	0.11	0.12	0.03	0.01	0.00	0.01	0.00	0.01	0.01	0.47
1991	0.15	0.12	0.03	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.36
1992	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.12
1993	0.13	0.11	0.09	0.03	0.11	0.04	0.01	0.00	0.00	0.00	0.01	0.01	0.54
1994	0.01	0.00	0.15	0.05	0.00	0.14	0.11	0.03	0.08	0.03	0.00	0.00	0.60
1995	0.01	0.02	0.12	0.11	0.10	0.03	0.01	0.01	0.00	0.13	0.04	0.00	0.58
1996	0.10	0.11	0.03	0.10	0.10	0.03	0.08	0.03	0.09	0.08	0.01	0.01	0.77
month	4.45	6.09	4.71	3.53	4.30	4.52	2.69	1.90	1.35	1.41	1.12	1.81	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
max	0.15	0.17	0.15	0.12	0.15	0.14	0.11	0.16	0.16	0.14	0.14	0.16	0.86
median	0.02	0.10	0.05	0.03	0.03	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.50
mean	0.06	0.08	0.06	0.05	0.06	0.06	0.03	0.02	0.02	0.02	0.01	0.02	0.49
Sum of the monthly means =				0.49									
s.d.	0.05	0.05	0.05	0.04	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.04	0.15
c.v.	0.94	0.62	0.75	0.95	0.89	0.81	1.00	1.58	1.71	1.80	1.70	1.72	0.30

APPENDIX 11.6
T60H (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.01	0.31	0.00	0.00	0.45	0.52	0.41	0.09	0.00	0.00	0.00	0.02	1.81
1921	0.06	0.62	0.61	0.15	0.03	0.02	0.02	0.70	0.49	0.09	0.36	0.13	3.28
1922	0.40	0.53	0.15	0.56	0.60	0.52	0.14	0.02	0.02	0.60	0.20	0.00	3.74
1923	0.02	0.04	0.07	0.66	0.61	0.14	0.01	0.02	0.02	0.02	0.02	0.06	1.69
1924	0.08	0.55	0.61	0.17	0.48	0.54	0.42	0.10	0.00	0.01	0.01	0.05	3.02
1925	0.06	0.51	0.19	0.48	0.56	0.52	0.14	0.02	0.43	0.15	0.01	0.03	3.10
1926	0.52	0.54	0.54	0.16	0.04	0.56	0.19	0.01	0.01	0.00	0.01	0.03	2.61
1927	0.66	0.22	0.58	0.62	0.54	0.13	0.00	0.00	0.00	0.00	0.03	0.04	2.82
1928	0.04	0.54	0.20	0.44	0.17	0.47	0.16	0.02	0.54	0.43	0.09	0.35	3.45
1929	0.47	0.49	0.14	0.04	0.04	0.58	0.20	0.01	0.40	0.13	0.31	0.42	3.23
1930	0.12	0.03	0.05	0.58	0.59	0.53	0.14	0.02	0.00	0.09	0.03	0.00	2.18
1931	0.48	0.17	0.03	0.04	0.64	0.56	0.12	0.03	0.04	0.05	0.03	0.52	2.71
1932	0.51	0.50	0.55	0.14	0.05	0.57	0.19	0.02	0.01	0.02	0.02	0.03	2.61
1933	0.03	0.83	0.69	0.56	0.17	0.46	0.16	0.02	0.02	0.52	0.18	0.01	3.65
1934	0.02	0.66	0.62	0.15	0.03	0.59	0.56	0.46	0.44	0.11	0.36	0.12	4.12
1935	0.02	0.05	0.03	0.04	0.77	0.65	0.14	0.46	0.16	0.01	0.01	0.03	2.37
1936	0.61	0.59	0.15	0.03	0.62	0.58	0.13	0.01	0.01	0.02	0.03	0.03	2.81
1937	0.05	0.06	0.70	0.64	0.24	0.00	0.12	0.05	0.02	0.03	0.03	0.01	1.95
1938	0.03	0.63	0.62	0.56	0.54	0.48	0.13	0.35	0.11	0.30	0.30	0.41	4.46
1939	0.45	0.13	0.51	0.18	0.03	0.56	0.19	0.42	0.15	0.01	0.02	0.02	2.67
1940	0.04	0.71	0.26	0.04	0.03	0.04	0.05	0.04	0.04	0.03	0.03	0.04	1.35
1941	0.06	0.60	0.20	0.57	0.21	0.50	0.17	0.03	0.03	0.01	0.02	0.05	2.45
1942	0.52	0.55	0.53	0.16	0.03	0.53	0.53	0.13	0.02	0.02	0.44	0.15	3.61
1943	0.40	0.50	0.55	0.17	0.31	0.12	0.02	0.02	0.02	0.03	0.03	0.62	2.79
1944	0.52	0.11	0.01	0.69	0.64	0.53	0.14	0.02	0.02	0.02	0.02	0.04	2.76
1945	0.68	0.22	0.02	0.04	0.78	0.64	0.42	0.10	0.01	0.01	0.01	0.02	2.95
1946	0.05	0.71	0.26	0.04	0.48	0.53	0.48	0.13	0.35	0.12	0.00	0.02	3.17
1947	0.04	0.61	0.61	0.16	0.48	0.52	0.14	0.01	0.01	0.01	0.00	0.01	2.60
1948	0.76	0.27	0.04	0.04	0.54	0.54	0.44	0.11	0.00	0.00	0.01	0.04	2.79
1949	0.06	0.62	0.22	0.54	0.57	0.47	0.42	0.25	0.05	0.01	0.39	0.13	3.73
1950	0.40	0.14	0.55	0.61	0.16	0.50	0.17	0.01	0.01	0.02	0.04	0.05	2.66
1951	0.60	0.20	0.64	0.66	0.17	0.43	0.46	0.11	0.01	0.01	0.00	0.04	3.33
1952	0.05	0.05	0.05	0.06	0.62	0.22	0.02	0.02	0.02	0.01	0.02	0.60	1.74
1953	0.51	0.49	0.56	0.17	0.03	0.55	0.19	0.03	0.04	0.03	0.02	0.04	2.66
1954	0.54	0.20	0.03	0.58	0.60	0.50	0.13	0.01	0.02	0.01	0.01	0.04	2.67
1955	0.07	0.51	0.17	0.02	0.80	0.66	0.46	0.11	0.02	0.02	0.01	0.04	2.89
1956	0.54	0.57	0.55	0.57	0.55	0.51	0.48	0.12	0.02	0.02	0.03	0.53	4.49
1957	0.49	0.48	0.53	0.54	0.55	0.50	0.47	0.12	0.01	0.01	0.01	0.03	3.74
1958	0.04	0.73	0.62	0.14	0.55	0.51	0.39	0.44	0.12	0.03	0.36	0.13	4.06
1959	0.03	0.03	0.00	0.00	0.00	0.38	0.44	0.37	0.09	0.01	0.02	0.05	1.42
1960	0.04	0.56	0.58	0.56	0.17	0.47	0.54	0.36	0.08	0.02	0.02	0.02	3.42
1961	0.04	0.58	0.58	0.15	0.46	0.53	0.13	0.02	0.01	0.01	0.03	0.05	2.59
1962	0.62	0.58	0.15	0.50	0.19	0.48	0.17	0.02	0.02	0.49	0.17	0.01	3.40
1963	0.54	0.58	0.52	0.55	0.53	0.49	0.46	0.12	0.44	0.16	0.01	0.03	4.43
1964	0.53	0.18	0.03	0.05	0.06	0.04	0.03	0.06	0.73	0.44	0.32	0.33	2.80
1965	0.44	0.50	0.15	0.04	0.04	0.03	0.03	0.71	0.24	0.01	0.01	0.04	2.24
1966	0.04	0.05	0.06	0.63	0.58	0.52	0.49	0.13	0.02	0.45	0.15	0.01	3.13
1967	0.03	0.62	0.22	0.04	0.06	0.06	0.05	0.03	0.02	0.01	0.04	0.62	1.80
1968	0.51	0.48	0.36	0.00	0.25	0.48	0.14	0.44	0.15	0.01	0.02	0.03	2.87
1969	0.06	0.55	0.20	0.02	0.05	0.05	0.04	0.05	0.07	0.06	0.57	0.46	2.18
1970	0.46	0.51	0.15	0.46	0.52	0.13	0.00	0.24	0.12	0.38	0.42	0.11	3.50
1971	0.42	0.16	0.00	0.00	0.49	0.18	0.02	0.02	0.02	0.03	0.03	0.03	1.40
1972	0.03	0.77	0.63	0.15	0.04	0.46	0.48	0.11	0.00	0.00	0.03	0.56	3.26
1973	0.49	0.47	0.15	0.04	0.56	0.57	0.15	0.43	0.35	0.07	0.01	0.01	3.30
1974	0.03	0.63	0.62	0.16	0.04	0.43	0.15	0.02	0.01	0.01	0.02	0.65	2.77
1975	0.23	0.04	0.55	0.20	0.47	0.55	0.44	0.40	0.11	0.00	0.02	0.52	3.53
1976	0.54	0.14	0.03	0.06	0.60	0.52	0.12	0.01	0.02	0.02	0.04	0.51	2.61
1977	0.51	0.49	0.53	0.17	0.04	0.45	0.22	0.21	0.06	0.00	0.01	0.03	2.72
1978	0.54	0.54	0.14	0.03	0.05	0.40	0.14	0.02	0.01	0.54	0.24	0.00	2.65
1979	0.25	0.12	0.04	0.04	0.06	0.06	0.05	0.04	0.03	0.02	0.02	0.73	1.46
1980	0.25	0.44	0.54	0.57	0.17	0.02	0.02	0.58	0.19	0.01	0.43	0.15	3.37
1981	0.01	0.04	0.05	0.64	0.23	0.52	0.50	0.12	0.01	0.02	0.01	0.02	2.17
1982	0.00	0.00	0.00	0.02	0.04	0.04	0.05	0.03	0.03	0.73	0.25	0.02	1.21
1983	0.04	0.46	0.53	0.58	0.54	0.12	0.00	0.00	0.02	0.35	0.12	0.02	2.78
1984	0.04	0.52	0.08	0.00	0.36	0.16	0.02	0.01	0.02	0.02	0.01	0.02	1.26
1985	0.76	0.62	0.15	0.48	0.18	0.04	0.04	0.03	0.02	0.02	0.58	0.50	3.42
1986	0.44	0.47	0.14	0.54	0.19	0.58	0.20	0.01	0.02	0.02	0.04	0.31	2.96
1987	0.19	0.00	0.00	0.04	0.57	0.59	0.41	0.40	0.11	0.29	0.35	0.09	3.04
1988	0.38	0.51	0.54	0.15	0.60	0.56	0.46	0.13	0.02	0.02	0.02	0.03	3.42
1989	0.63	0.60	0.14	0.06	0.05	0.62	0.22	0.01	0.02	0.00	0.06	0.05	2.46
1990	0.52	0.18	0.03	0.63	0.60	0.15	0.01	0.02	0.02	0.02	0.03	0.06	2.27
1991	0.63	0.58	0.14	0.05	0.04	0.05	0.06	0.04	0.03	0.02	0.02	0.05	1.71
1992	0.07	0.07	0.53	0.19	0.03	0.03	0.04	0.03	0.02	0.02	0.03	0.67	1.73
1993	0.54	0.45	0.51	0.15	0.56	0.54	0.12	0.01	0.01	0.03	0.19	0.00	3.11
1994	0.00	0.00	0.67	0.25	0.03	0.60	0.58	0.14	0.35	0.12	0.00	0.02	2.76
1995	0.06	0.05	0.56	0.60	0.54	0.15	0.02	0.03	0.03	0.62	0.21	0.02	2.89
1996	0.51	0.56	0.15	0.50	0.57	0.48	0.48	0.13	0.13	0.20	0.06	0.03	3.80
month	22.46	30.40	23.89	21.30	25.86	30.31	16.67	10.17	7.34	8.26	8.11	11.79	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.21
max	0.76	0.83	0.70	0.69	0.80	0.66	0.58	0.71	0.73	0.73	0.58	0.73	4.49
median	0.25	0.49	0.20	0.16	0.36	0.50	0.15	0.04	0.02	0.02	0.03	0.04	2.79
mean	0.29	0.39	0.31	0.28	0.34	0.39	0.22	0.13	0.10	0.11	0.11	0.15	2.81
Sum of the monthly means =				2.81									
s.d.	0.25	0.24	0.24	0.25	0.25	0.21	0.18	0.17	0.15	0.18	0.15	0.21	0.76
c.v.	0.85	0.60	0.79	0.89	0.75	0.53	0.84	1.32	1.59	1.66	1.42	1.39	0.27

APPENDIX 11.7
T60J (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.36	0.12	0.02	0.11	0.04	0.01	0.00	0.00	0.00	0.01	0.69
1921	0.03	0.36	0.36	0.09	0.02	0.01	0.01	0.43	0.28	0.04	0.01	0.02	1.66
1922	0.25	0.29	0.07	0.31	0.33	0.28	0.07	0.01	0.01	0.32	0.11	0.01	2.06
1923	0.01	0.02	0.03	0.44	0.37	0.08	0.00	0.01	0.01	0.01	0.02	0.03	1.03
1924	0.03	0.04	0.31	0.12	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.56
1925	0.03	0.04	0.03	0.03	0.28	0.30	0.08	0.01	0.02	0.02	0.01	0.02	0.87
1926	0.30	0.30	0.28	0.08	0.01	0.34	0.11	0.00	0.00	0.00	0.00	0.02	1.44
1927	0.04	0.02	0.04	0.35	0.34	0.09	0.01	0.01	0.01	0.01	0.02	0.03	0.97
1928	0.03	0.04	0.03	0.03	0.03	0.36	0.11	0.01	0.29	0.22	0.04	0.19	1.38
1929	0.25	0.28	0.08	0.02	0.02	0.03	0.04	0.03	0.03	0.03	0.22	0.23	1.26
1930	0.06	0.02	0.02	0.14	0.26	0.28	0.07	0.01	0.00	0.01	0.00	0.00	0.87
1931	0.02	0.02	0.03	0.02	0.44	0.15	0.00	0.02	0.02	0.02	0.01	0.33	1.08
1932	0.28	0.27	0.29	0.08	0.02	0.04	0.02	0.02	0.02	0.01	0.01	0.01	1.07
1933	0.01	0.44	0.36	0.29	0.08	0.25	0.08	0.01	0.01	0.27	0.09	0.01	1.90
1934	0.01	0.04	0.36	0.13	0.02	0.32	0.29	0.23	0.23	0.06	0.19	0.06	1.94
1935	0.01	0.02	0.01	0.01	0.45	0.36	0.07	0.27	0.09	0.01	0.00	0.01	1.31
1936	0.32	0.31	0.07	0.02	0.38	0.33	0.07	0.01	0.00	0.01	0.01	0.02	1.55
1937	0.03	0.02	0.39	0.14	0.02	0.01	0.31	0.11	0.01	0.01	0.02	0.01	1.08
1938	0.01	0.03	0.04	0.29	0.31	0.08	0.01	0.02	0.02	0.02	0.02	0.25	1.10
1939	0.25	0.06	0.02	0.01	0.02	0.03	0.03	0.34	0.11	0.01	0.00	0.01	0.89
1940	0.02	0.37	0.14	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.66
1941	0.03	0.04	0.03	0.38	0.14	0.03	0.02	0.03	0.02	0.01	0.01	0.02	0.76
1942	0.04	0.33	0.33	0.08	0.02	0.34	0.30	0.06	0.01	0.01	0.26	0.09	1.87
1943	0.21	0.27	0.28	0.08	0.30	0.10	0.01	0.01	0.01	0.02	0.02	0.39	1.70
1944	0.28	0.06	0.01	0.03	0.35	0.31	0.07	0.00	0.01	0.01	0.01	0.01	1.15
1945	0.38	0.12	0.01	0.02	0.42	0.34	0.08	0.01	0.00	0.01	0.01	0.01	1.41
1946	0.02	0.39	0.13	0.02	0.02	0.30	0.27	0.07	0.18	0.06	0.01	0.01	1.48
1947	0.02	0.35	0.32	0.08	0.30	0.30	0.07	0.01	0.00	0.00	0.00	0.00	1.45
1948	0.40	0.14	0.01	0.03	0.35	0.32	0.04	0.00	0.00	0.00	0.00	0.00	1.29
1949	0.03	0.36	0.13	0.30	0.29	0.08	0.18	0.20	0.05	0.00	0.02	0.02	1.66
1950	0.02	0.02	0.38	0.34	0.08	0.26	0.09	0.00	0.01	0.01	0.01	0.02	1.24
1951	0.37	0.13	0.32	0.33	0.08	0.23	0.23	0.05	0.01	0.00	0.00	0.01	1.76
1952	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.02	0.01	0.01	0.01	0.03	0.31
1953	0.31	0.30	0.29	0.08	0.01	0.31	0.10	0.01	0.02	0.02	0.01	0.02	1.48
1954	0.33	0.12	0.02	0.37	0.34	0.27	0.07	0.01	0.01	0.00	0.01	0.02	1.57
1955	0.03	0.04	0.02	0.01	0.04	0.41	0.29	0.06	0.01	0.00	0.01	0.02	0.94
1956	0.31	0.32	0.29	0.29	0.27	0.26	0.25	0.06	0.01	0.01	0.01	0.03	2.11
1957	0.27	0.27	0.26	0.30	0.30	0.25	0.24	0.06	0.00	0.01	0.01	0.01	1.98
1958	0.02	0.39	0.14	0.01	0.02	0.03	0.03	0.31	0.11	0.01	0.19	0.07	1.33
1959	0.01	0.02	0.03	0.02	0.03	0.34	0.27	0.18	0.04	0.00	0.01	0.02	0.97
1960	0.02	0.31	0.34	0.30	0.08	0.25	0.28	0.07	0.01	0.01	0.01	0.01	1.69
1961	0.02	0.35	0.13	0.02	0.03	0.27	0.09	0.01	0.01	0.00	0.02	0.02	0.97
1962	0.34	0.31	0.08	0.29	0.10	0.28	0.10	0.01	0.02	0.28	0.09	0.00	1.90
1963	0.02	0.28	0.11	0.26	0.31	0.27	0.24	0.06	0.24	0.09	0.01	0.02	1.91
1964	0.32	0.11	0.01	0.02	0.02	0.02	0.01	0.02	0.43	0.25	0.16	0.05	1.42
1965	0.22	0.28	0.08	0.02	0.03	0.02	0.02	0.45	0.15	0.00	0.00	0.02	1.29
1966	0.02	0.02	0.03	0.36	0.13	0.25	0.27	0.07	0.01	0.23	0.08	0.00	1.47
1967	0.01	0.03	0.03	0.03	0.04	0.04	0.03	0.02	0.01	0.00	0.02	0.34	0.60
1968	0.12	0.21	0.08	0.01	0.37	0.33	0.07	0.24	0.08	0.01	0.01	0.02	1.55
1969	0.03	0.31	0.11	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.34	0.12	1.07
1970	0.21	0.26	0.08	0.02	0.03	0.03	0.03	0.27	0.09	0.19	0.21	0.06	1.48
1971	0.24	0.08	0.02	0.02	0.32	0.11	0.01	0.01	0.01	0.02	0.02	0.01	0.87
1972	0.01	0.41	0.15	0.01	0.02	0.04	0.30	0.09	0.00	0.00	0.02	0.03	1.08
1973	0.03	0.27	0.10	0.02	0.32	0.30	0.07	0.23	0.08	0.01	0.00	0.01	1.44
1974	0.01	0.03	0.33	0.11	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.37	0.97
1975	0.12	0.02	0.34	0.12	0.28	0.31	0.24	0.21	0.05	0.00	0.01	0.02	1.72
1976	0.33	0.11	0.02	0.03	0.39	0.13	0.01	0.01	0.01	0.01	0.02	0.04	1.11
1977	0.29	0.29	0.28	0.09	0.02	0.03	0.15	0.15	0.04	0.00	0.01	0.02	1.37
1978	0.33	0.28	0.07	0.02	0.03	0.36	0.12	0.01	0.00	0.00	0.00	0.00	1.22
1979	0.01	0.01	0.02	0.02	0.03	0.04	0.02	0.02	0.02	0.01	0.01	0.40	0.61
1980	0.14	0.27	0.10	0.25	0.09	0.01	0.01	0.32	0.10	0.00	0.01	0.01	1.31
1981	0.02	0.02	0.02	0.04	0.03	0.39	0.29	0.06	0.01	0.00	0.00	0.01	0.89
1982	0.03	0.03	0.02	0.02	0.03	0.03	0.02	0.02	0.01	0.00	0.00	0.01	0.22
1983	0.02	0.29	0.11	0.26	0.10	0.01	0.22	0.08	0.01	0.19	0.06	0.01	1.36
1984	0.01	0.33	0.12	0.02	0.32	0.11	0.01	0.00	0.01	0.01	0.01	0.01	0.96
1985	0.39	0.33	0.08	0.29	0.11	0.02	0.02	0.02	0.01	0.01	0.03	0.30	1.61
1986	0.27	0.07	0.01	0.02	0.02	0.35	0.12	0.01	0.01	0.01	0.02	0.35	1.26
1987	0.12	0.24	0.09	0.01	0.12	0.26	0.08	0.19	0.07	0.16	0.17	0.04	1.55
1988	0.01	0.26	0.31	0.08	0.32	0.28	0.24	0.07	0.01	0.01	0.01	0.01	1.61
1989	0.37	0.34	0.07	0.02	0.02	0.41	0.14	0.00	0.00	0.00	0.02	0.02	1.41
1990	0.03	0.03	0.03	0.03	0.35	0.12	0.01	0.01	0.02	0.01	0.01	0.03	0.68
1991	0.38	0.34	0.08	0.02	0.02	0.02	0.03	0.03	0.01	0.00	0.01	0.03	0.97
1992	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.02	0.01	0.01	0.04	0.28
1993	0.34	0.12	0.26	0.09	0.31	0.28	0.06	0.00	0.00	0.01	0.03	0.02	1.52
1994	0.02	0.02	0.42	0.15	0.01	0.39	0.32	0.07	0.20	0.06	0.00	0.01	1.67
1995	0.02	0.03	0.35	0.32	0.29	0.08	0.01	0.02	0.01	0.33	0.12	0.01	1.59
1996	0.09	0.00	0.00	0.27	0.30	0.08	0.22	0.08	0.24	0.20	0.04	0.01	1.53
month	10.08	13.43	10.86	9.23	11.89	13.98	8.01	5.73	3.73	3.46	3.01	4.58	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
max	0.40	0.44	0.42	0.44	0.45	0.41	0.32	0.45	0.43	0.33	0.34	0.40	2.11
median	0.03	0.13	0.08	0.08	0.08	0.23	0.07	0.02	0.01	0.01	0.01	0.02	1.31
mean	0.13	0.17	0.14	0.12	0.15	0.18	0.10	0.07	0.05	0.04	0.04	0.06	1.27
Sum of the monthly means =				1.27									
s.d.	0.14	0.14	0.13	0.13	0.15	0.14	0.10	0.11	0.08	0.08	0.07	0.10	0.42
c.v.	1.06	0.81	0.94	1.06	0.96	0.75	0.98	1.42	1.70	1.87	1.74	1.75	0.33

APPENDIX 11.8
T60K (2000)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.28	0.10	0.02	0.21	0.07	0.00	0.01	0.00	0.00	0.01	0.72
1921	0.03	0.31	0.28	0.07	0.01	0.01	0.00	0.33	0.21	0.04	0.01	0.02	1.32
1922	0.20	0.23	0.06	0.25	0.25	0.21	0.05	0.01	0.01	0.24	0.09	0.00	1.60
1923	0.01	0.01	0.02	0.34	0.29	0.06	0.00	0.01	0.01	0.00	0.01	0.02	0.78
1924	0.03	0.03	0.24	0.08	0.21	0.22	0.06	0.01	0.00	0.01	0.01	0.01	0.91
1925	0.02	0.02	0.02	0.02	0.24	0.23	0.06	0.01	0.02	0.02	0.00	0.02	0.68
1926	0.24	0.24	0.06	0.01	0.02	0.27	0.10	0.00	0.01	0.00	0.01	0.01	0.97
1927	0.03	0.02	0.03	0.03	0.25	0.09	0.01	0.01	0.01	0.01	0.02	0.01	0.52
1928	0.02	0.03	0.02	0.03	0.03	0.28	0.10	0.01	0.23	0.17	0.04	0.14	1.10
1929	0.20	0.22	0.06	0.01	0.01	0.03	0.03	0.02	0.02	0.02	0.03	0.19	0.84
1930	0.06	0.01	0.02	0.31	0.28	0.22	0.06	0.01	0.00	0.02	0.00	0.00	0.99
1931	0.02	0.02	0.02	0.02	0.33	0.12	0.01	0.01	0.01	0.02	0.02	0.25	0.85
1932	0.21	0.21	0.22	0.06	0.02	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.82
1933	0.01	0.33	0.29	0.23	0.06	0.20	0.07	0.00	0.01	0.22	0.07	0.00	1.49
1934	0.01	0.03	0.13	0.05	0.01	0.02	0.24	0.21	0.17	0.05	0.14	0.04	1.10
1935	0.01	0.02	0.01	0.01	0.34	0.27	0.06	0.20	0.07	0.00	0.01	0.01	1.01
1936	0.24	0.24	0.06	0.01	0.30	0.26	0.06	0.00	0.00	0.01	0.02	0.02	1.22
1937	0.02	0.02	0.30	0.11	0.01	0.02	0.26	0.09	0.01	0.01	0.01	0.01	0.87
1938	0.01	0.02	0.25	0.24	0.22	0.19	0.05	0.01	0.01	0.02	0.02	0.21	1.25
1939	0.20	0.04	0.01	0.01	0.02	0.03	0.02	0.24	0.08	0.00	0.01	0.01	0.67
1940	0.01	0.29	0.10	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.53
1941	0.02	0.03	0.02	0.33	0.11	0.20	0.07	0.15	0.06	0.00	0.01	0.01	1.01
1942	0.03	0.26	0.25	0.07	0.01	0.25	0.23	0.05	0.01	0.01	0.21	0.07	1.45
1943	0.16	0.22	0.22	0.06	0.22	0.21	0.05	0.01	0.01	0.01	0.01	0.27	1.45
1944	0.20	0.05	0.01	0.02	0.28	0.24	0.06	0.00	0.01	0.01	0.01	0.02	0.91
1945	0.29	0.10	0.01	0.01	0.03	0.31	0.11	0.01	0.00	0.00	0.00	0.01	0.88
1946	0.01	0.28	0.10	0.02	0.03	0.25	0.22	0.05	0.15	0.06	0.00	0.01	1.18
1947	0.02	0.27	0.25	0.06	0.23	0.23	0.06	0.01	0.00	0.00	0.01	0.00	1.14
1948	0.30	0.10	0.01	0.02	0.28	0.25	0.06	0.01	0.00	0.00	0.00	0.01	1.04
1949	0.02	0.31	0.11	0.22	0.23	0.06	0.01	0.15	0.05	0.01	0.02	0.01	1.20
1950	0.02	0.02	0.29	0.11	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.56
1951	0.29	0.10	0.25	0.26	0.07	0.20	0.19	0.05	0.00	0.01	0.00	0.01	1.43
1952	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.01	0.00	0.01	0.03	0.24
1953	0.24	0.24	0.21	0.06	0.01	0.24	0.08	0.01	0.01	0.01	0.01	0.01	1.13
1954	0.25	0.09	0.02	0.28	0.25	0.20	0.05	0.00	0.01	0.00	0.00	0.02	1.17
1955	0.02	0.03	0.02	0.01	0.03	0.32	0.23	0.04	0.01	0.00	0.01	0.01	0.73
1956	0.24	0.24	0.23	0.22	0.20	0.20	0.19	0.05	0.00	0.00	0.01	0.03	1.61
1957	0.20	0.07	0.02	0.21	0.24	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.76
1958	0.01	0.30	0.11	0.01	0.02	0.02	0.02	0.26	0.09	0.01	0.14	0.05	1.04
1959	0.01	0.01	0.02	0.02	0.01	0.25	0.21	0.05	0.01	0.01	0.01	0.01	0.62
1960	0.02	0.24	0.26	0.23	0.07	0.01	0.21	0.07	0.01	0.01	0.01	0.01	1.15
1961	0.01	0.29	0.10	0.01	0.02	0.22	0.07	0.01	0.00	0.01	0.01	0.02	0.77
1962	0.26	0.24	0.06	0.25	0.09	0.21	0.07	0.01	0.00	0.22	0.08	0.01	1.50
1963	0.02	0.21	0.08	0.21	0.24	0.21	0.19	0.05	0.18	0.07	0.00	0.01	1.47
1964	0.25	0.08	0.01	0.02	0.02	0.02	0.01	0.02	0.33	0.19	0.12	0.03	1.10
1965	0.16	0.22	0.06	0.02	0.02	0.02	0.01	0.34	0.12	0.01	0.01	0.01	1.00
1966	0.01	0.02	0.02	0.28	0.10	0.20	0.22	0.05	0.00	0.17	0.06	0.00	1.13
1967	0.01	0.03	0.02	0.01	0.03	0.02	0.02	0.02	0.01	0.00	0.01	0.27	0.45
1968	0.20	0.19	0.06	0.00	0.29	0.25	0.06	0.18	0.06	0.00	0.01	0.01	1.31
1969	0.02	0.26	0.09	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.26	0.09	0.86
1970	0.17	0.21	0.06	0.02	0.02	0.02	0.02	0.22	0.07	0.14	0.17	0.05	1.17
1971	0.18	0.07	0.01	0.02	0.27	0.09	0.00	0.01	0.01	0.01	0.01	0.01	0.69
1972	0.01	0.03	0.03	0.03	0.02	0.03	0.24	0.08	0.00	0.00	0.01	0.03	0.51
1973	0.03	0.24	0.09	0.01	0.02	0.25	0.08	0.18	0.07	0.00	0.01	0.00	0.98
1974	0.01	0.02	0.26	0.10	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.31	0.80
1975	0.11	0.01	0.26	0.10	0.21	0.23	0.06	0.14	0.04	0.00	0.00	0.02	1.18
1976	0.25	0.09	0.01	0.02	0.31	0.10	0.01	0.00	0.01	0.01	0.02	0.02	0.85
1977	0.05	0.00	0.06	0.06	0.02	0.02	0.12	0.12	0.03	0.00	0.00	0.02	0.50
1978	0.08	0.17	0.06	0.01	0.02	0.28	0.10	0.00	0.00	0.02	0.03	0.02	0.79
1979	0.05	0.00	0.00	0.00	0.01	0.03	0.02	0.01	0.01	0.01	0.00	0.30	0.44
1980	0.11	0.21	0.07	0.20	0.07	0.01	0.01	0.25	0.09	0.00	0.01	0.02	1.05
1981	0.01	0.02	0.02	0.03	0.03	0.31	0.10	0.01	0.00	0.01	0.01	0.01	0.56
1982	0.02	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.01	0.14
1983	0.01	0.21	0.07	0.20	0.07	0.01	0.02	0.01	0.01	0.19	0.06	0.01	0.87
1984	0.01	0.23	0.08	0.02	0.25	0.08	0.01	0.01	0.01	0.01	0.00	0.00	0.71
1985	0.31	0.26	0.05	0.22	0.08	0.01	0.02	0.02	0.01	0.01	0.02	0.24	1.25
1986	0.21	0.06	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.29	0.68
1987	0.11	0.20	0.07	0.02	0.26	0.25	0.07	0.16	0.05	0.12	0.14	0.03	1.48
1988	0.01	0.20	0.24	0.07	0.06	0.02	0.16	0.06	0.01	0.01	0.00	0.01	0.85
1989	0.29	0.26	0.06	0.02	0.01	0.32	0.11	0.01	0.01	0.00	0.01	0.02	1.12
1990	0.03	0.02	0.01	0.03	0.26	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.50
1991	0.30	0.26	0.06	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.77
1992	0.03	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.31	0.50
1993	0.24	0.05	0.22	0.07	0.25	0.10	0.01	0.00	0.01	0.01	0.02	0.02	1.00
1994	0.01	0.01	0.34	0.12	0.01	0.31	0.26	0.05	0.15	0.05	0.01	0.01	1.33
1995	0.02	0.02	0.29	0.27	0.21	0.06	0.01	0.01	0.01	0.27	0.10	0.01	1.28
1996	0.21	0.23	0.07	0.23	0.24	0.07	0.18	0.06	0.18	0.14	0.03	0.01	1.65
month	7.75	10.00	7.95	7.00	8.92	10.42	5.84	4.40	2.93	2.80	2.30	3.87	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
max	0.31	0.33	0.34	0.34	0.34	0.32	0.26	0.34	0.33	0.27	0.26	0.31	1.65
median	0.03	0.09	0.06	0.03	0.06	0.10	0.06	0.01	0.01	0.01	0.01	0.01	0.98
mean	0.10	0.13	0.10	0.09	0.12	0.14	0.08	0.06	0.04	0.04	0.03	0.05	0.96
Sum of the monthly means =				0.96									
s.d.	0.11	0.11	0.10	0.10	0.11	0.11	0.08	0.08	0.06	0.07	0.05	0.09	0.33
c.v.	1.05	0.84	0.98	1.10	0.98	0.80	1.00	1.44	1.66	1.81	1.69	1.72	0.35

APPENDIX 12

AFFORESTATION RUNOFF REDUCTION FOR QUATERNARY CATHMENTS (2030)

APPENDIX 12.1
T60A (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.02	0.07	0.12	0.11	0.09	0.12	0.11	0.06	0.03	0.01	0.01	0.02	0.77
1921	0.07	1.46	0.90	0.17	0.05	0.04	0.02	0.12	1.08	0.35	0.02	0.04	4.32
1922	0.07	1.12	0.39	0.93	1.04	0.95	0.24	0.01	0.01	1.30	0.44	0.01	6.51
1923	0.02	0.03	0.08	1.56	1.23	0.25	0.02	0.02	0.02	0.02	0.02	0.04	3.31
1924	0.09	0.14	1.20	0.40	0.04	1.29	0.44	0.02	0.02	0.01	0.01	0.02	3.68
1925	0.06	0.13	0.12	0.12	0.10	1.33	0.44	0.02	0.05	0.06	0.03	0.05	2.51
1926	0.12	0.13	0.13	0.08	0.07	1.45	0.49	0.01	0.01	0.01	0.03	0.04	2.57
1927	0.08	0.08	0.13	1.29	0.45	0.04	0.03	0.02	0.02	0.02	0.03	0.04	2.23
1928	0.07	0.10	0.09	0.08	0.07	0.14	0.12	0.07	0.13	0.00	0.00	0.44	1.31
1929	0.66	0.19	0.04	0.07	0.07	0.11	0.10	0.06	0.06	0.06	0.08	0.11	1.61
1930	0.10	0.09	0.11	1.15	0.33	0.00	0.00	0.01	0.00	0.00	0.06	0.01	1.86
1931	0.05	0.07	0.07	0.07	1.42	0.49	0.02	0.03	0.05	0.06	0.06	0.10	2.49
1932	0.14	1.13	1.04	0.24	0.03	0.07	0.08	0.06	0.03	0.03	0.02	0.02	2.89
1933	0.03	1.48	1.23	0.94	0.26	0.06	0.06	0.05	0.03	0.05	0.06	0.04	4.29
1934	0.05	0.10	1.34	0.46	0.05	0.07	0.65	0.03	0.31	0.17	0.03	0.03	3.29
1935	0.04	0.07	0.04	0.05	1.64	1.22	0.23	0.06	0.07	0.05	0.02	0.03	3.52
1936	0.10	1.29	0.45	0.07	1.13	0.41	0.03	0.02	0.02	0.02	0.02	0.02	3.58
1937	0.05	0.09	0.12	0.12	0.14	0.10	0.10	0.08	0.06	0.05	0.05	0.04	1.00
1938	0.06	0.11	0.15	0.12	1.17	0.40	0.03	0.04	0.05	0.05	0.06	1.27	3.51
1939	0.44	0.04	0.07	0.06	0.06	0.08	0.07	0.13	0.12	0.07	0.04	0.03	1.21
1940	0.05	0.13	0.05	0.00	0.00	0.04	0.05	0.04	0.03	0.02	0.03	0.04	0.48
1941	0.08	0.11	0.10	1.39	0.49	0.07	0.07	0.06	0.04	0.02	0.03	0.05	2.51
1942	0.10	1.31	1.11	0.26	0.05	1.11	0.99	0.22	0.02	0.04	0.09	0.09	5.39
1943	0.89	0.90	0.88	0.24	0.08	0.08	0.06	0.04	0.03	0.04	0.04	0.11	3.39
1944	0.14	0.10	0.04	0.09	0.13	0.15	0.10	0.05	0.04	0.03	0.02	0.03	0.92
1945	1.38	0.47	0.02	0.05	0.11	1.31	0.44	0.02	0.01	0.01	0.02	0.02	3.86
1946	0.07	0.13	0.13	0.11	0.12	1.07	0.38	0.03	0.81	0.27	0.01	0.03	3.16
1947	0.05	1.24	0.45	0.06	0.87	0.32	0.04	0.02	0.01	0.01	0.00	0.01	3.08
1948	0.09	0.13	0.11	0.11	1.16	0.41	0.05	0.03	0.02	0.01	0.01	0.03	2.16
1949	0.07	1.31	0.45	0.95	0.35	0.06	0.06	0.08	0.05	0.04	0.08	0.08	3.58
1950	0.08	0.07	1.35	0.48	0.05	0.09	0.07	0.04	0.03	0.03	0.04	0.07	2.40
1951	0.15	0.11	0.11	0.13	0.12	0.10	0.10	0.08	0.04	0.03	0.01	0.04	1.02
1952	0.06	0.07	0.08	0.09	0.11	0.10	0.10	0.06	0.03	0.03	0.03	0.07	0.83
1953	0.13	1.21	1.06	0.25	0.06	0.08	0.06	0.06	0.08	0.06	0.03	0.06	3.14
1954	1.00	0.35	0.04	1.11	1.07	0.27	0.04	0.03	0.03	0.02	0.02	0.05	4.03
1955	0.08	0.12	0.08	0.04	0.10	1.55	0.54	0.04	0.03	0.03	0.02	0.04	2.67
1956	0.11	0.92	1.01	0.27	0.06	0.92	0.87	0.19	0.02	0.02	0.03	0.09	4.51
1957	0.75	0.00	0.00	0.08	0.99	0.35	0.07	0.05	0.02	0.01	0.01	0.02	2.35
1958	0.05	0.13	0.15	0.10	0.10	0.10	0.10	1.29	0.43	0.02	0.05	0.06	2.58
1959	0.07	0.10	0.10	0.09	0.09	0.12	0.11	0.09	0.05	0.03	0.03	0.06	0.94
1960	0.08	0.13	1.17	0.42	0.05	0.08	0.99	0.34	0.02	0.02	0.03	0.03	3.36
1961	0.05	0.12	0.13	0.11	1.06	0.98	0.22	0.02	0.02	0.01	0.03	0.04	2.79
1962	0.10	1.27	0.45	0.94	0.34	0.97	0.34	0.02	0.02	0.10	0.10	0.05	4.70
1963	0.09	1.08	1.01	0.99	0.29	0.07	0.09	0.05	0.99	0.33	0.01	0.03	5.03
1964	1.13	0.39	0.04	0.08	0.09	0.06	0.04	0.06	1.53	0.52	0.04	0.04	4.02
1965	0.50	0.78	0.23	0.06	0.06	0.04	0.03	1.50	0.51	0.01	0.02	0.05	3.79
1966	0.07	0.08	0.11	0.13	0.13	1.17	0.52	0.00	0.00	0.00	0.01	0.01	2.23
1967	0.04	0.10	0.10	0.08	0.09	0.10	0.09	0.06	0.03	0.01	0.04	0.10	0.84
1968	0.13	0.14	0.11	0.06	0.12	1.23	0.41	0.06	0.05	0.03	0.03	0.04	2.41
1969	0.08	0.12	0.11	0.08	0.07	0.06	0.05	0.05	0.08	0.07	0.10	0.13	1.00
1970	1.28	0.44	0.05	0.06	0.07	0.07	0.07	0.12	0.09	0.08	0.90	0.31	3.54
1971	0.75	0.27	0.05	0.07	1.11	0.39	0.03	0.03	0.03	0.03	0.03	0.02	2.81
1972	0.04	0.13	0.14	0.10	0.10	0.11	0.10	0.05	0.03	0.02	0.04	0.08	0.94
1973	0.11	1.21	0.41	0.07	0.10	0.97	0.33	0.79	0.27	0.02	0.01	0.02	4.31
1974	0.04	0.11	0.14	0.12	0.11	0.10	0.07	0.04	0.02	0.02	0.02	0.10	0.89
1975	0.12	0.10	1.27	1.11	0.97	0.97	0.27	0.05	0.04	0.02	0.02	0.05	4.99
1976	1.34	0.46	0.05	0.07	0.09	0.09	0.06	0.03	0.03	0.03	0.03	0.06	2.34
1977	0.15	1.20	1.04	0.26	0.06	0.07	1.13	0.39	0.02	0.01	0.02	0.06	4.41
1978	0.12	1.02	0.36	0.05	0.07	0.10	0.08	0.04	0.02	0.05	0.07	0.06	2.04
1979	0.09	0.11	0.11	0.08	0.07	0.09	0.07	0.05	0.03	0.02	0.02	0.12	0.86
1980	0.14	1.18	0.42	0.07	0.08	0.06	0.04	0.05	0.05	0.03	0.05	0.07	2.24
1981	0.05	0.07	0.09	0.13	0.12	0.15	0.13	0.07	0.04	0.03	0.03	0.03	0.94
1982	0.09	0.10	0.07	0.07	0.08	0.07	0.06	0.05	0.03	0.04	0.04	0.06	0.76
1983	0.09	0.15	0.15	1.13	1.03	0.26	0.68	0.23	0.01	0.04	0.05	0.05	3.87
1984	0.06	0.12	0.14	0.12	1.07	0.37	0.02	0.02	0.02	0.02	0.01	0.01	1.98
1985	1.40	1.03	0.80	0.24	0.05	0.05	0.04	0.02	0.01	0.02	0.08	0.11	3.85
1986	1.16	1.00	0.22	0.06	0.07	0.10	0.08	0.05	0.03	0.02	0.05	1.40	4.24
1987	0.49	0.71	0.96	0.27	1.07	1.08	0.26	0.06	0.06	0.06	0.07	0.06	5.15
1988	0.07	1.02	1.05	0.26	1.01	0.36	0.07	0.06	0.04	0.04	0.03	0.02	4.03
1989	0.11	1.26	0.43	0.06	0.06	1.26	0.43	0.02	0.02	0.00	0.05	0.07	3.77
1990	0.12	0.11	0.10	0.12	0.13	0.08	0.04	0.02	0.02	0.01	0.02	0.04	0.81
1991	1.47	1.04	0.21	0.05	0.06	0.09	0.07	0.04	0.02	0.01	0.01	0.03	3.10
1992	0.06	0.14	0.16	0.12	0.11	0.08	0.05	0.04	0.02	0.01	0.01	0.08	0.88
1993	1.41	0.49	0.81	0.30	0.95	1.01	0.24	0.01	0.00	0.03	0.05	0.03	5.33
1994	0.04	0.04	0.07	0.11	0.09	1.50	0.52	0.03	0.05	0.04	0.02	0.03	2.54
1995	0.06	0.12	1.27	1.08	0.99	0.28	0.02	0.01	0.00	0.02	0.02	0.03	3.90
1996	0.07	1.33	0.47	0.83	0.32	0.06	0.82	0.27	0.82	0.29	0.02	0.04	5.34
month	20.92	36.00	29.64	23.95	27.89	31.50	16.14	8.24	9.06	5.27	3.87	7.01	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.48
max	1.47	1.48	1.35	1.56	1.64	1.55	1.13	1.50	1.53	1.30	0.90	1.40	6.51
median	0.09	0.13	0.14	0.12	0.11	0.11	0.08	0.05	0.03	0.03	0.03	0.04	2.81
mean	0.27	0.47	0.38	0.31	0.36	0.41	0.21	0.11	0.12	0.07	0.05	0.09	2.85
Sum of the monthly means =				2.85									
s.d.	0.41	0.49	0.42	0.40	0.44	0.47	0.26	0.24	0.27	0.17	0.11	0.21	1.42
c.v.	1.52	1.05	1.10	1.27	1.23	1.16	1.24	2.23	2.28	2.43	2.20	2.34	0.50

APPENDIX 12.2
T60B (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.04	0.13	0.21	0.19	0.15	0.20	0.18	0.09	0.04	0.03	0.01	0.04	1.31
1921	0.13	2.42	1.91	0.43	0.09	0.07	0.04	0.21	1.80	0.58	0.04	0.06	7.78
1922	0.12	1.52	0.53	1.56	1.73	1.58	0.40	0.02	0.02	1.08	0.38	0.01	8.95
1923	0.04	0.06	0.13	2.60	2.06	0.41	0.02	0.03	0.04	0.03	0.04	0.08	5.54
1924	0.16	0.24	2.00	0.67	0.07	2.16	0.74	0.05	0.03	0.02	0.02	0.03	6.19
1925	0.10	0.21	0.21	0.21	0.17	2.18	0.73	0.03	0.09	0.08	0.05	0.09	4.15
1926	0.20	0.22	0.21	0.14	0.12	2.15	0.71	0.01	0.01	0.02	0.03	0.07	3.89
1927	0.14	0.14	0.24	1.81	0.65	0.07	0.05	0.04	0.04	0.03	0.05	0.08	3.34
1928	0.12	0.18	0.16	0.14	0.12	0.23	0.20	0.12	2.11	0.72	0.03	1.25	5.38
1929	1.25	0.32	0.07	0.11	0.12	0.18	0.16	0.10	0.11	0.11	0.13	0.19	2.85
1930	0.17	0.15	0.20	1.74	1.63	1.49	0.39	0.02	0.01	1.08	0.38	0.03	7.29
1931	0.09	0.12	0.13	0.12	2.35	0.81	0.04	0.05	0.08	0.11	0.10	0.18	4.18
1932	0.23	1.84	1.72	0.39	0.04	0.12	0.14	0.09	0.05	0.05	0.04	0.04	4.75
1933	0.04	2.49	1.75	1.47	0.43	0.09	0.10	0.08	0.05	0.09	0.09	0.07	6.75
1934	0.08	0.18	2.22	0.77	0.08	0.13	1.95	1.55	1.14	0.28	0.05	0.06	8.49
1935	0.07	0.11	0.08	0.09	2.73	2.04	0.39	0.10	0.12	0.08	0.05	0.06	5.92
1936	0.16	2.13	0.74	0.12	1.70	0.61	0.05	0.03	0.02	0.03	0.03	0.04	5.66
1937	0.09	0.15	0.21	0.20	0.23	0.16	0.17	0.13	0.09	0.10	0.09	0.07	1.69
1938	0.09	0.17	0.25	0.21	1.91	0.66	0.06	0.08	0.07	0.09	0.10	2.12	5.81
1939	0.74	0.07	0.38	0.02	0.00	0.08	0.11	0.20	0.19	0.11	0.05	0.06	2.01
1940	0.08	0.22	1.83	0.62	0.05	0.10	0.12	0.08	0.05	0.04	0.05	0.07	3.31
1941	0.13	0.19	0.16	2.33	0.82	0.12	0.10	0.09	0.07	0.04	0.05	0.09	4.19
1942	0.17	2.16	1.85	0.44	0.08	1.85	1.65	0.36	0.05	0.06	0.15	0.14	8.96
1943	1.47	1.50	1.47	0.42	0.14	0.14	0.10	0.07	0.06	0.07	0.06	0.19	5.69
1944	0.23	0.15	0.07	0.14	0.20	0.24	0.16	0.09	0.06	0.05	0.03	0.05	1.47
1945	2.29	0.78	0.04	0.08	0.20	2.18	0.74	0.04	0.03	0.03	0.03	0.05	6.49
1946	0.11	0.22	0.23	0.18	0.21	1.75	0.62	0.06	1.34	0.46	0.02	0.04	5.24
1947	0.08	2.06	0.75	0.11	1.43	0.53	0.07	0.05	0.02	0.01	0.01	0.01	5.13
1948	0.16	0.21	0.19	0.18	1.91	0.68	0.08	0.07	0.03	0.02	0.03	0.05	3.61
1949	0.12	2.19	0.75	1.59	0.58	0.10	0.11	0.12	0.09	0.08	0.13	0.13	5.99
1950	0.13	0.13	2.24	0.79	0.09	0.16	0.12	0.07	0.05	0.04	0.07	0.12	4.01
1951	0.24	0.18	0.19	0.21	0.19	0.15	0.16	0.12	0.07	0.04	0.02	0.06	1.63
1952	0.09	0.12	0.13	0.15	0.19	0.18	0.15	0.10	0.06	0.04	0.05	0.11	1.37
1953	0.23	2.02	1.78	0.42	0.10	0.14	0.09	0.10	0.12	0.10	0.06	0.09	5.25
1954	2.24	0.78	0.07	1.85	1.79	0.45	0.07	0.05	0.05	0.04	0.02	0.07	7.48
1955	0.14	0.20	0.14	0.06	0.16	2.58	0.89	0.05	0.05	0.04	0.04	0.07	4.42
1956	0.18	1.97	1.82	0.46	0.11	1.52	1.45	0.32	0.03	0.04	0.05	0.15	8.10
1957	1.69	1.54	0.37	0.13	1.62	0.58	0.12	0.08	0.03	0.03	0.02	0.04	6.25
1958	0.08	0.23	0.25	0.17	0.16	0.16	0.16	2.09	0.70	0.04	0.08	0.09	4.21
1959	0.12	0.16	0.17	0.15	0.15	0.19	0.18	0.15	0.09	0.06	0.06	0.10	1.58
1960	0.14	0.23	1.94	0.77	0.00	0.01	1.26	0.44	0.03	0.03	0.04	0.05	4.94
1961	0.08	0.22	0.23	0.19	1.74	1.65	0.38	0.04	0.04	0.03	0.05	0.07	4.72
1962	0.18	2.13	0.74	1.55	0.56	1.61	0.56	0.04	0.03	0.78	0.10	0.00	8.28
1963	0.05	1.44	1.57	1.66	0.49	0.11	0.21	0.00	0.86	0.32	0.02	0.06	6.79
1964	1.88	0.64	0.08	0.13	0.15	0.10	0.07	0.09	2.55	0.87	0.06	0.06	6.68
1965	1.24	1.44	0.38	0.10	0.11	0.07	0.06	2.50	0.85	0.01	0.03	0.08	6.87
1966	0.11	0.15	0.18	0.21	0.21	1.88	1.53	0.32	0.03	0.09	0.09	0.06	4.86
1967	0.07	0.18	0.17	0.14	0.15	0.16	0.15	0.10	0.05	0.03	0.07	0.16	1.43
1968	0.22	0.23	0.19	0.11	0.20	2.01	0.68	0.10	0.10	0.06	0.06	0.07	4.03
1969	0.14	0.21	0.19	0.13	0.13	0.10	0.07	0.09	0.13	0.12	0.17	0.21	1.69
1970	1.76	0.62	0.09	0.11	0.12	0.12	0.12	0.48	0.04	0.00	0.91	0.33	4.70
1971	1.23	0.45	0.08	0.13	1.82	0.63	0.05	0.04	0.04	0.05	0.04	0.04	4.60
1972	0.07	0.23	0.24	0.17	0.17	0.18	0.16	0.09	0.04	0.02	0.05	0.13	1.55
1973	0.19	2.01	0.69	0.12	0.17	1.59	0.54	1.33	0.45	0.03	0.01	0.02	7.15
1974	0.07	0.18	0.24	0.19	0.18	0.17	0.11	0.06	0.03	0.02	0.03	0.16	1.44
1975	0.20	0.17	2.09	1.86	1.63	1.61	0.45	0.09	0.07	0.03	0.03	0.09	8.32
1976	2.22	0.77	0.09	0.13	0.15	0.15	0.11	0.05	0.04	0.04	0.06	0.10	3.91
1977	0.25	2.00	1.73	0.43	0.09	0.13	1.84	0.64	0.04	0.02	0.03	0.09	7.29
1978	0.21	1.69	0.60	0.07	0.12	0.17	0.14	0.07	0.03	0.08	0.12	0.11	3.41
1979	0.16	0.18	0.17	0.15	0.12	0.14	0.10	0.08	0.05	0.03	0.03	0.20	1.41
1980	0.24	1.95	0.70	0.11	0.12	0.11	0.07	0.09	0.08	0.05	0.08	0.11	3.71
1981	0.09	0.12	0.14	0.22	0.20	0.87	0.16	0.00	0.00	0.01	0.02	0.03	1.86
1982	0.14	0.15	0.11	0.12	0.13	0.11	0.10	0.09	0.06	0.07	0.08	0.09	1.25
1983	0.15	0.25	0.25	1.85	1.73	0.44	1.13	0.37	0.02	0.06	0.08	0.08	6.41
1984	0.11	0.20	0.23	0.20	1.72	0.59	0.04	0.03	0.03	0.02	0.02	0.02	3.21
1985	2.35	1.72	1.35	0.40	0.08	0.09	0.07	0.05	0.03	0.03	0.13	0.20	6.50
1986	1.93	1.66	0.38	0.11	0.12	0.16	0.14	0.08	0.05	0.04	0.08	2.32	7.07
1987	0.81	1.18	1.30	0.35	1.77	1.79	0.44	0.10	0.10	0.10	0.10	0.09	8.13
1988	0.10	1.67	1.74	0.44	1.68	0.59	0.11	0.09	0.07	0.06	0.05	0.04	6.64
1989	0.20	2.08	0.72	0.10	0.10	2.09	0.72	0.03	0.02	0.02	0.08	0.12	6.28
1990	0.19	0.18	0.15	0.21	0.20	0.14	0.07	0.04	0.03	0.02	0.02	0.08	1.33
1991	2.45	1.75	0.34	0.09	0.12	0.14	0.12	0.07	0.03	0.02	0.02	0.05	5.20
1992	0.11	0.24	0.27	0.19	0.18	0.12	0.09	0.06	0.03	0.01	0.02	0.14	1.46
1993	2.35	0.81	1.34	0.49	1.58	1.69	0.40	0.01	0.01	0.05	0.09	0.06	8.88
1994	0.05	0.08	0.12	0.19	0.15	2.49	0.87	0.06	0.07	0.07	0.03	0.04	4.22
1995	0.11	0.20	2.08	1.79	1.52	0.44	0.04	0.03	0.02	0.06	0.08	0.07	6.44
1996	0.14	2.30	0.81	1.38	0.95	0.03	0.54	0.21	1.37	0.48	0.03	0.06	8.30
month	36.03	61.57	51.57	40.06	47.22	53.70	27.47	15.25	16.68	9.88	5.80	12.04	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.04	0.06	0.04	0.02	0.00	0.01	0.02	0.00	0.00	0.00	0.01	0.00	1.25
max	2.45	2.49	2.24	2.60	2.73	2.58	1.95	2.50	2.55	1.08	0.91	2.32	8.96
median	0.14	0.23	0.25	0.19	0.18	0.19	0.15	0.08	0.05	0.04	0.05	0.07	4.94
mean	0.47	0.80	0.67	0.52	0.61	0.70	0.36	0.20	0.22	0.13	0.08	0.16	4.90
Sum of the monthly means =				4.90									
s.d.	0.71	0.81	0.70	0.64	0.74	0.78	0.45	0.42	0.49	0.23	0.11	0.37	2.28
c.v.	1.51	1.02	1.05	1.23	1.21	1.12	1.25	2.13	2.24	1.81	1.52	2.36	0.47

APPENDIX 12.3
T60D (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.01	0.03	0.41	0.15	0.03	0.36	0.13	0.01	0.01	0.00	0.00	0.01	1.15
1921	0.03	0.49	0.41	0.11	0.02	0.01	0.00	0.50	0.35	0.06	0.01	0.01	2.00
1922	0.03	0.36	0.12	0.36	0.39	0.35	0.09	0.01	0.00	0.43	0.14	0.01	2.29
1923	0.01	0.02	0.04	0.49	0.42	0.10	0.00	0.01	0.01	0.01	0.01	0.03	1.15
1924	0.05	0.46	0.40	0.09	0.02	0.49	0.18	0.01	0.00	0.00	0.00	0.01	1.71
1925	0.04	0.46	0.17	0.32	0.11	0.34	0.11	0.01	0.02	0.02	0.01	0.03	1.64
1926	0.42	0.34	0.32	0.09	0.02	0.42	0.14	0.00	0.00	0.00	0.02	0.02	1.79
1927	0.04	0.04	0.49	0.43	0.36	0.09	0.01	0.01	0.01	0.01	0.02	0.03	1.54
1928	0.04	0.05	0.04	0.04	0.03	0.51	0.17	0.01	0.40	0.26	0.05	0.28	1.88
1929	0.30	0.29	0.08	0.30	0.11	0.33	0.11	0.01	0.02	0.02	0.03	0.33	1.93
1930	0.11	0.01	0.33	0.38	0.36	0.35	0.09	0.01	0.00	0.50	0.18	0.01	2.33
1931	0.03	0.04	0.03	0.03	0.49	0.17	0.01	0.02	0.02	0.03	0.03	0.43	1.33
1932	0.34	0.31	0.34	0.09	0.01	0.04	0.04	0.02	0.01	0.02	0.01	0.01	1.24
1933	0.01	0.58	0.45	0.37	0.11	0.03	0.03	0.02	0.01	0.02	0.03	0.02	1.68
1934	0.02	0.05	0.43	0.15	0.02	0.04	0.40	0.35	0.27	0.07	0.02	0.02	1.84
1935	0.02	0.03	0.02	0.03	0.53	0.42	0.09	0.34	0.11	0.00	0.01	0.01	1.61
1936	0.41	0.38	0.09	0.33	0.38	0.31	0.08	0.00	0.01	0.00	0.01	0.01	2.01
1937	0.03	0.04	0.06	0.05	0.39	0.14	0.02	0.02	0.02	0.02	0.02	0.02	0.83
1938	0.03	0.05	0.44	0.16	0.32	0.12	0.02	0.03	0.02	0.03	0.03	0.47	1.72
1939	0.35	0.27	0.32	0.09	0.02	0.03	0.03	0.42	0.15	0.00	0.00	0.01	1.69
1940	0.02	0.47	0.42	0.09	0.01	0.03	0.03	0.02	0.01	0.01	0.01	0.02	1.14
1941	0.04	0.05	0.05	0.49	0.17	0.31	0.10	0.01	0.01	0.01	0.02	0.03	1.29
1942	0.05	0.44	0.40	0.10	0.02	0.40	0.37	0.08	0.01	0.02	0.34	0.12	2.35
1943	0.28	0.33	0.33	0.10	0.35	0.13	0.02	0.01	0.01	0.02	0.02	0.47	2.07
1944	0.34	0.07	0.01	0.04	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.50
1945	0.54	0.18	0.02	0.03	0.48	0.41	0.09	0.01	0.01	0.01	0.01	0.02	1.81
1946	0.03	0.48	0.17	0.02	0.33	0.38	0.32	0.07	0.30	0.10	0.01	0.01	2.22
1947	0.02	0.43	0.40	0.34	0.37	0.35	0.09	0.01	0.01	0.00	0.00	0.01	2.03
1948	0.49	0.18	0.27	0.10	0.29	0.11	0.02	0.01	0.00	0.01	0.01	0.01	1.50
1949	0.04	0.50	0.18	0.36	0.36	0.31	0.08	0.02	0.01	0.02	0.03	0.03	1.94
1950	0.03	0.03	0.41	0.15	0.02	0.36	0.11	0.00	0.00	0.01	0.02	0.03	1.17
1951	0.47	0.16	0.36	0.38	0.33	0.10	0.27	0.09	0.01	0.00	0.01	0.02	2.20
1952	0.03	0.03	0.04	0.04	0.05	0.05	0.03	0.02	0.02	0.01	0.02	0.03	0.37
1953	0.44	0.37	0.32	0.10	0.03	0.03	0.02	0.02	0.03	0.02	0.01	0.03	1.42
1954	0.47	0.16	0.01	0.08	0.29	0.33	0.09	0.01	0.01	0.01	0.01	0.02	1.49
1955	0.04	0.00	0.00	0.00	0.02	0.36	0.34	0.08	0.01	0.01	0.01	0.02	0.89
1956	0.43	0.39	0.35	0.35	0.34	0.34	0.33	0.08	0.01	0.01	0.02	0.40	3.05
1957	0.33	0.29	0.09	0.34	0.37	0.10	0.29	0.09	0.00	0.00	0.01	0.01	1.92
1958	0.02	0.51	0.40	0.09	0.02	0.03	0.03	0.36	0.12	0.01	0.02	0.02	1.63
1959	0.03	0.33	0.12	0.02	0.03	0.34	0.11	0.02	0.01	0.01	0.01	0.03	1.06
1960	0.03	0.44	0.39	0.36	0.10	0.33	0.36	0.09	0.01	0.01	0.01	0.01	2.14
1961	0.03	0.50	0.18	0.29	0.38	0.36	0.09	0.01	0.01	0.00	0.01	0.03	1.89
1962	0.10	0.00	0.00	0.34	0.11	0.34	0.12	0.01	0.00	0.41	0.13	0.00	1.56
1963	0.35	0.35	0.35	0.36	0.33	0.31	0.31	0.09	0.32	0.11	0.01	0.01	2.90
1964	0.39	0.14	0.02	0.03	0.04	0.02	0.01	0.02	0.55	0.32	0.21	0.06	1.81
1965	0.25	0.31	0.09	0.03	0.02	0.01	0.02	0.55	0.19	0.00	0.00	0.02	1.49
1966	0.03	0.03	0.05	0.37	0.36	0.34	0.32	0.08	0.01	0.03	0.02	0.02	1.66
1967	0.02	0.44	0.15	0.02	0.03	0.04	0.03	0.02	0.01	0.00	0.02	0.05	0.83
1968	0.38	0.34	0.09	0.01	0.42	0.40	0.09	0.30	0.10	0.00	0.01	0.02	2.16
1969	0.04	0.38	0.13	0.02	0.03	0.02	0.01	0.03	0.04	0.03	0.04	0.05	0.82
1970	0.37	0.33	0.32	0.33	0.10	0.03	0.02	0.35	0.12	0.01	0.30	0.10	2.38
1971	0.28	0.11	0.02	0.31	0.37	0.10	0.01	0.01	0.01	0.01	0.01	0.01	1.25
1972	0.02	0.54	0.19	0.02	0.04	0.04	0.03	0.02	0.01	0.01	0.02	0.03	0.97
1973	0.05	0.39	0.14	0.32	0.37	0.34	0.09	0.31	0.11	0.00	0.00	0.01	2.13
1974	0.02	0.45	0.41	0.10	0.29	0.11	0.01	0.01	0.01	0.00	0.01	0.48	1.90
1975	0.16	0.02	0.34	0.40	0.36	0.36	0.10	0.02	0.02	0.00	0.00	0.02	1.80
1976	0.44	0.16	0.28	0.11	0.28	0.10	0.01	0.01	0.01	0.01	0.02	0.03	1.46
1977	0.50	0.39	0.34	0.35	0.10	0.02	0.32	0.11	0.01	0.01	0.01	0.03	2.19
1978	0.43	0.36	0.30	0.09	0.02	0.34	0.12	0.01	0.00	0.02	0.03	0.03	1.75
1979	0.04	0.04	0.04	0.03	0.03	0.04	0.03	0.02	0.02	0.01	0.01	0.51	0.82
1980	0.18	0.28	0.35	0.35	0.34	0.10	0.01	0.02	0.02	0.01	0.03	0.03	1.72
1981	0.03	0.04	0.04	0.47	0.17	0.35	0.12	0.01	0.01	0.01	0.01	0.01	1.27
1982	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.33
1983	0.04	0.48	0.39	0.35	0.36	0.35	0.33	0.08	0.01	0.02	0.03	0.03	2.47
1984	0.03	0.42	0.40	0.35	0.36	0.10	0.01	0.01	0.00	0.00	0.00	0.01	1.69
1985	0.55	0.42	0.34	0.34	0.09	0.02	0.02	0.01	0.01	0.00	0.04	0.05	1.89
1986	0.38	0.35	0.09	0.32	0.12	0.32	0.12	0.01	0.01	0.01	0.03	0.47	2.23
1987	0.33	0.28	0.33	0.09	0.34	0.38	0.10	0.26	0.09	0.18	0.07	0.01	2.46
1988	0.02	0.30	0.35	0.10	0.36	0.13	0.30	0.10	0.01	0.01	0.00	0.01	1.69
1989	0.48	0.41	0.10	0.03	0.03	0.44	0.15	0.00	0.01	0.00	0.02	0.04	1.71
1990	0.42	0.14	0.02	0.37	0.37	0.09	0.00	0.01	0.00	0.00	0.01	0.02	1.45
1991	0.56	0.42	0.09	0.03	0.03	0.03	0.02	0.02	0.01	0.00	0.01	0.01	1.23
1992	0.03	0.50	0.42	0.10	0.30	0.10	0.02	0.01	0.00	0.00	0.00	0.04	1.52
1993	0.47	0.37	0.32	0.10	0.06	0.27	0.08	0.01	0.00	0.02	0.03	0.02	1.75
1994	0.01	0.03	0.03	0.06	0.04	0.52	0.39	0.08	0.01	0.01	0.00	0.02	1.20
1995	0.04	0.41	0.40	0.36	0.36	0.10	0.01	0.00	0.01	0.02	0.02	0.03	1.76
1996	0.04	0.44	0.39	0.36	0.36	0.33	0.31	0.08	0.31	0.11	0.01	0.01	2.75
month	14.04	20.75	17.26	14.98	15.52	16.43	8.61	5.64	4.12	3.21	2.42	5.46	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.33
max	0.56	0.58	0.49	0.49	0.53	0.52	0.40	0.55	0.55	0.50	0.34	0.51	3.05
median	0.04	0.33	0.27	0.11	0.17	0.17	0.09	0.02	0.01	0.01	0.01	0.02	1.71
mean	0.18	0.27	0.22	0.19	0.20	0.21	0.11	0.07	0.05	0.04	0.03	0.07	1.67
Sum of the monthly means =				1.67									
s.d.	0.19	0.18	0.16	0.15	0.16	0.16	0.12	0.12	0.11	0.10	0.06	0.13	0.54
c.v.	1.04	0.66	0.70	0.78	0.82	0.74	1.06	1.70	1.99	2.34	1.90	1.89	0.32

APPENDIX 12.4
T60E (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.03	0.03	0.02	0.03	0.03	0.02	0.01	0.00	0.00	0.01	0.20
1921	0.02	0.36	0.30	0.06	0.01	0.01	0.01	0.04	0.27	0.08	0.01	0.01	1.18
1922	0.24	0.25	0.06	0.29	0.28	0.23	0.06	0.00	0.00	0.31	0.11	0.01	1.84
1923	0.01	0.02	0.02	0.36	0.29	0.06	0.00	0.00	0.00	0.01	0.01	0.01	0.79
1924	0.03	0.04	0.03	0.02	0.03	0.31	0.10	0.01	0.00	0.01	0.00	0.01	0.59
1925	0.03	0.03	0.03	0.03	0.03	0.32	0.11	0.01	0.01	0.01	0.01	0.01	0.63
1926	0.03	0.28	0.10	0.01	0.02	0.32	0.11	0.00	0.00	0.01	0.00	0.01	0.89
1927	0.02	0.03	0.02	0.03	0.04	0.03	0.01	0.01	0.01	0.01	0.01	0.02	0.24
1928	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.01	0.34	0.20	0.04	0.17	0.96
1929	0.20	0.21	0.06	0.01	0.01	0.02	0.03	0.01	0.02	0.02	0.03	0.04	0.66
1930	0.00	0.00	0.00	0.27	0.27	0.23	0.06	0.01	0.01	1.26	0.18	0.00	2.29
1931	0.01	0.02	0.02	0.02	0.36	0.13	0.00	0.01	0.01	0.02	0.01	0.31	0.92
1932	0.22	0.20	0.23	0.06	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.81
1933	0.01	0.37	0.30	0.25	0.07	0.01	0.02	0.01	0.01	0.02	0.02	0.01	1.10
1934	0.01	0.03	0.32	0.11	0.01	0.02	0.30	0.25	0.19	0.04	0.01	0.01	1.30
1935	0.02	0.02	0.01	0.01	0.42	0.33	0.07	0.01	0.02	0.01	0.01	0.01	0.94
1936	0.03	0.30	0.11	0.02	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.50
1937	0.02	0.02	0.03	0.03	0.03	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.25
1938	0.01	0.03	0.04	0.03	0.28	0.10	0.01	0.02	0.01	0.02	0.02	0.32	0.89
1939	0.23	0.05	0.02	0.01	0.01	0.03	0.01	0.03	0.03	0.01	0.01	0.01	0.45
1940	0.02	0.04	0.03	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.20
1941	0.02	0.04	0.03	0.38	0.13	0.01	0.01	0.01	0.02	0.00	0.01	0.02	0.68
1942	0.02	0.35	0.30	0.06	0.01	0.02	0.27	0.09	0.00	0.01	0.02	0.03	1.18
1943	0.02	0.24	0.11	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.01	0.33	0.74
1944	0.12	0.01	0.01	0.02	0.03	0.03	0.02	0.02	0.01	0.00	0.01	0.01	0.29
1945	0.38	0.13	0.00	0.01	0.03	0.33	0.11	0.01	0.01	0.01	0.00	0.00	1.02
1946	0.01	0.04	0.04	0.02	0.02	0.14	0.00	0.00	0.18	0.06	0.00	0.01	0.52
1947	0.01	0.31	0.11	0.01	0.25	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.79
1948	0.03	0.03	0.03	0.02	0.36	0.13	0.02	0.01	0.01	0.00	0.01	0.01	0.66
1949	0.02	0.35	0.12	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.65
1950	0.02	0.02	0.33	0.12	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.60
1951	0.34	0.11	0.02	0.03	0.02	0.02	0.03	0.02	0.01	0.00	0.01	0.01	0.62
1952	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.02	0.01	0.01	0.00	0.02	0.23
1953	0.03	0.32	0.27	0.06	0.01	0.03	0.02	0.02	0.02	0.02	0.01	0.02	0.83
1954	0.34	0.12	0.01	0.28	0.29	0.07	0.01	0.00	0.01	0.00	0.01	0.01	1.15
1955	0.02	0.03	0.02	0.01	0.03	0.40	0.13	0.01	0.01	0.00	0.00	0.02	0.68
1956	0.04	0.30	0.28	0.07	0.02	0.23	0.24	0.05	0.00	0.00	0.01	0.02	1.26
1957	0.03	0.03	0.02	0.24	0.27	0.07	0.20	0.07	0.01	0.01	0.00	0.00	0.95
1958	0.01	0.03	0.04	0.02	0.02	0.02	0.02	0.36	0.11	0.00	0.01	0.02	0.66
1959	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.24
1960	0.02	0.03	0.28	0.10	0.01	0.02	0.28	0.10	0.00	0.01	0.01	0.01	0.87
1961	0.02	0.32	0.11	0.01	0.02	0.27	0.09	0.01	0.00	0.00	0.01	0.01	0.87
1962	0.03	0.31	0.11	0.25	0.09	0.25	0.09	0.00	0.01	0.29	0.10	0.00	1.53
1963	0.02	0.03	0.02	0.27	0.10	0.01	0.18	0.06	0.21	0.07	0.01	0.01	0.99
1964	0.27	0.09	0.01	0.01	0.02	0.01	0.01	0.01	0.43	0.15	0.01	0.01	1.03
1965	0.21	0.23	0.06	0.02	0.02	0.01	0.01	0.38	0.13	0.01	0.01	0.01	1.10
1966	0.02	0.02	0.02	0.03	0.03	0.18	0.22	0.05	0.01	0.02	0.02	0.01	0.63
1967	0.01	0.02	0.02	0.02	0.03	0.03	0.02	0.01	0.00	0.00	0.01	0.03	0.20
1968	0.04	0.04	0.03	0.02	0.03	0.31	0.11	0.22	0.08	0.01	0.01	0.01	0.91
1969	0.02	0.03	0.03	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.35	0.12	0.67
1970	0.18	0.20	0.06	0.02	0.02	0.02	0.02	0.32	0.11	0.01	0.19	0.06	1.21
1971	0.20	0.07	0.01	0.01	0.31	0.11	0.01	0.01	0.01	0.01	0.01	0.01	0.77
1972	0.01	0.03	0.03	0.03	0.02	0.03	0.03	0.02	0.01	0.00	0.01	0.02	0.24
1973	0.03	0.31	0.10	0.01	0.03	0.03	0.02	0.30	0.10	0.01	0.00	0.01	0.95
1974	0.01	0.02	0.04	0.02	0.02	0.02	0.02	0.01	0.01	0.00	0.01	0.37	0.55
1975	0.12	0.01	0.26	0.09	0.25	0.28	0.07	0.00	0.00	0.00	0.00	0.01	1.09
1976	0.26	0.09	0.01	0.02	0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.03	0.53
1977	0.03	0.31	0.28	0.07	0.01	0.02	0.33	0.12	0.01	0.00	0.01	0.01	1.20
1978	0.30	0.11	0.01	0.01	0.01	0.03	0.02	0.02	0.01	0.02	0.03	0.03	0.60
1979	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.03	0.21
1980	0.03	0.28	0.10	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.57
1981	0.02	0.02	0.02	0.03	0.02	0.40	0.14	0.00	0.00	0.00	0.01	0.01	0.67
1982	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.00	0.01	0.52	0.18	0.01	0.86
1983	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.03	0.02	0.01	0.24
1984	0.02	0.30	0.10	0.01	0.28	0.10	0.00	0.00	0.00	0.00	0.01	0.01	0.83
1985	0.02	0.32	0.11	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.02	0.03	0.58
1986	0.28	0.10	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.00	0.02	0.37	0.88
1987	0.13	0.19	0.07	0.01	0.30	0.28	0.07	0.02	0.02	0.02	0.02	0.01	1.14
1988	0.01	0.26	0.27	0.06	0.30	0.11	0.20	0.07	0.01	0.01	0.00	0.01	1.31
1989	0.32	0.27	0.06	0.02	0.01	0.11	0.00	0.00	0.00	0.00	0.01	0.02	0.82
1990	0.02	0.02	0.02	0.03	0.04	0.03	0.02	0.01	0.01	0.00	0.01	0.02	0.23
1991	0.12	0.00	0.00	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.22
1992	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.00	0.00	0.00	0.02	0.19
1993	0.03	0.03	0.29	0.10	0.31	0.11	0.01	0.01	0.00	0.00	0.02	0.01	0.92
1994	0.02	0.01	0.03	0.03	0.02	0.35	0.28	0.06	0.01	0.01	0.00	0.01	0.83
1995	0.02	0.02	0.33	0.11	0.11	0.00	0.00	0.00	0.00	0.02	0.02	0.01	0.64
1996	0.02	0.30	0.10	0.02	0.25	0.08	0.23	0.07	0.22	0.08	0.01	0.01	1.39
month	5.63	9.35	6.66	4.71	6.66	7.32	4.84	3.24	2.96	3.62	1.87	2.99	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
max	0.38	0.37	0.33	0.38	0.42	0.40	0.33	0.38	0.43	1.26	0.35	0.37	2.29
median	0.02	0.04	0.03	0.02	0.02	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.79
mean	0.07	0.12	0.09	0.06	0.09	0.10	0.06	0.04	0.04	0.05	0.02	0.04	0.78
Sum of the monthly means =				0.78									
s.d.	0.10	0.12	0.10	0.09	0.12	0.12	0.08	0.08	0.08	0.16	0.05	0.08	0.39
c.v.	1.38	1.02	1.18	1.45	1.36	1.22	1.35	1.95	2.08	3.42	2.18	2.15	0.51

APPENDIX 12.5
T60F (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.19	0.07	0.01	0.16	0.06	0.00	0.00	0.00	0.00	0.01	0.52
1921	0.01	0.24	0.20	0.05	0.00	0.00	0.00	0.25	0.16	0.03	0.00	0.01	0.95
1922	0.16	0.16	0.04	0.17	0.19	0.17	0.05	0.01	0.00	0.22	0.08	0.00	1.25
1923	0.00	0.02	0.02	0.24	0.20	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.53
1924	0.02	0.02	0.19	0.07	0.01	0.19	0.07	0.00	0.01	0.00	0.00	0.01	0.59
1925	0.02	0.02	0.02	0.02	0.02	0.18	0.06	0.01	0.01	0.01	0.00	0.01	0.38
1926	0.02	0.19	0.16	0.04	0.01	0.21	0.07	0.00	0.01	0.01	0.01	0.01	0.74
1927	0.01	0.02	0.02	0.02	0.19	0.06	0.00	0.00	0.00	0.01	0.01	0.01	0.35
1928	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.23	0.14	0.02	0.12	0.66
1929	0.14	0.14	0.04	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.19	0.63
1930	0.07	0.01	0.01	0.21	0.20	0.16	0.05	0.01	0.00	0.00	0.00	0.01	0.73
1931	0.01	0.01	0.01	0.01	0.24	0.08	0.00	0.01	0.01	0.02	0.02	0.21	0.63
1932	0.16	0.14	0.16	0.04	0.01	0.02	0.02	0.01	0.00	0.01	0.00	0.00	0.57
1933	0.01	0.26	0.21	0.17	0.05	0.01	0.01	0.01	0.00	0.01	0.02	0.00	0.76
1934	0.01	0.02	0.22	0.07	0.00	0.01	0.20	0.17	0.13	0.03	0.01	0.01	0.88
1935	0.01	0.02	0.01	0.01	0.28	0.21	0.04	0.15	0.05	0.01	0.00	0.01	0.80
1936	0.02	0.19	0.07	0.01	0.21	0.18	0.04	0.00	0.00	0.01	0.00	0.01	0.74
1937	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.21
1938	0.01	0.02	0.02	0.03	0.18	0.06	0.01	0.01	0.01	0.01	0.01	0.21	0.58
1939	0.15	0.03	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.31
1940	0.01	0.03	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.13
1941	0.01	0.03	0.02	0.25	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.47
1942	0.02	0.22	0.19	0.05	0.00	0.02	0.17	0.06	0.00	0.01	0.02	0.01	0.77
1943	0.02	0.15	0.16	0.04	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.23	0.66
1944	0.09	0.01	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.19
1945	0.26	0.09	0.00	0.01	0.02	0.22	0.07	0.00	0.00	0.00	0.00	0.01	0.68
1946	0.01	0.23	0.08	0.01	0.02	0.19	0.17	0.04	0.13	0.04	0.01	0.00	0.93
1947	0.01	0.21	0.02	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.26
1948	0.03	0.02	0.02	0.01	0.24	0.18	0.04	0.01	0.00	0.01	0.00	0.01	0.57
1949	0.01	0.23	0.08	0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.44
1950	0.01	0.02	0.22	0.08	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.43
1951	0.23	0.08	0.17	0.07	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.00	0.60
1952	0.02	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.02	0.15
1953	0.03	0.19	0.18	0.04	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.53
1954	0.22	0.08	0.00	0.19	0.19	0.05	0.01	0.00	0.00	0.00	0.00	0.01	0.75
1955	0.02	0.03	0.01	0.01	0.02	0.26	0.09	0.00	0.00	0.00	0.01	0.00	0.45
1956	0.02	0.19	0.18	0.05	0.01	0.16	0.16	0.03	0.01	0.01	0.01	0.01	0.84
1957	0.02	0.15	0.06	0.13	0.17	0.05	0.14	0.05	0.00	0.00	0.00	0.00	0.77
1958	0.01	0.03	0.03	0.02	0.02	0.02	0.02	0.22	0.08	0.01	0.01	0.01	0.48
1959	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.21
1960	0.02	0.00	0.00	0.00	0.01	0.01	0.18	0.06	0.00	0.00	0.01	0.01	0.30
1961	0.01	0.21	0.08	0.01	0.01	0.18	0.06	0.00	0.01	0.00	0.00	0.01	0.58
1962	0.02	0.21	0.07	0.17	0.06	0.17	0.06	0.01	0.01	0.19	0.06	0.00	1.03
1963	0.01	0.16	0.06	0.16	0.17	0.05	0.12	0.04	0.15	0.06	0.00	0.01	0.99
1964	0.18	0.06	0.01	0.01	0.02	0.01	0.01	0.01	0.28	0.10	0.00	0.00	0.69
1965	0.14	0.15	0.04	0.01	0.01	0.01	0.01	0.26	0.08	0.00	0.00	0.01	0.72
1966	0.01	0.01	0.01	0.02	0.02	0.19	0.17	0.04	0.00	0.02	0.01	0.00	0.50
1967	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.02	0.15
1968	0.03	0.18	0.06	0.00	0.20	0.18	0.04	0.15	0.05	0.00	0.01	0.01	0.91
1969	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.24	0.09	0.46
1970	0.12	0.14	0.04	0.01	0.02	0.01	0.02	0.21	0.07	0.01	0.13	0.04	0.82
1971	0.13	0.05	0.01	0.01	0.21	0.07	0.01	0.01	0.00	0.00	0.00	0.01	0.51
1972	0.00	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.00	0.00	0.01	0.02	0.14
1973	0.02	0.20	0.07	0.01	0.02	0.02	0.01	0.20	0.07	0.01	0.01	0.00	0.64
1974	0.00	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.25	0.36
1975	0.09	0.00	0.17	0.06	0.18	0.19	0.05	0.11	0.04	0.01	0.00	0.01	0.91
1976	0.21	0.07	0.01	0.02	0.21	0.07	0.01	0.00	0.01	0.01	0.01	0.01	0.64
1977	0.03	0.19	0.18	0.05	0.01	0.01	0.21	0.08	0.00	0.01	0.00	0.01	0.78
1978	0.20	0.16	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.52
1979	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.23	0.36
1980	0.09	0.14	0.05	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.37
1981	0.01	0.02	0.01	0.02	0.02	0.27	0.09	0.00	0.00	0.00	0.01	0.00	0.45
1982	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.09
1983	0.01	0.16	0.06	0.14	0.05	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.52
1984	0.01	0.20	0.07	0.01	0.18	0.06	0.00	0.01	0.00	0.01	0.00	0.00	0.55
1985	0.02	0.22	0.08	0.15	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.61
1986	0.19	0.06	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.24	0.60
1987	0.09	0.13	0.05	0.01	0.21	0.20	0.05	0.13	0.04	0.01	0.01	0.01	0.94
1988	0.01	0.17	0.18	0.04	0.21	0.08	0.14	0.05	0.00	0.00	0.00	0.01	0.89
1989	0.22	0.18	0.04	0.01	0.02	0.22	0.08	0.00	0.00	0.01	0.01	0.02	0.81
1990	0.02	0.02	0.01	0.02	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.16
1991	0.23	0.19	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.55
1992	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.02	0.16
1993	0.03	0.03	0.18	0.06	0.18	0.07	0.00	0.01	0.00	0.00	0.02	0.01	0.59
1994	0.01	0.01	0.23	0.08	0.00	0.21	0.18	0.04	0.01	0.01	0.00	0.01	0.79
1995	0.01	0.01	0.21	0.07	0.14	0.05	0.01	0.01	0.01	0.02	0.02	0.01	0.57
1996	0.02	0.20	0.07	0.01	0.16	0.05	0.15	0.05	0.14	0.05	0.01	0.01	0.92
month	4.21	7.27	5.38	3.62	5.28	5.64	3.56	2.83	2.08	1.36	1.05	2.42	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
max	0.26	0.26	0.23	0.25	0.28	0.27	0.21	0.26	0.28	0.22	0.24	0.25	1.25
median	0.02	0.06	0.04	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.58
mean	0.05	0.09	0.07	0.05	0.07	0.07	0.05	0.04	0.03	0.02	0.01	0.03	0.58
Sum of the monthly means =				0.58									
s.d.	0.07	0.08	0.07	0.06	0.08	0.08	0.06	0.06	0.05	0.04	0.03	0.06	0.25
c.v.	1.31	0.88	1.03	1.28	1.23	1.10	1.24	1.70	1.96	2.11	2.35	2.02	0.43

APPENDIX 12.6
T60G (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.01	0.01	0.12	0.04	0.09	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.40
1921	0.01	0.13	0.12	0.03	0.01	0.00	0.00	0.16	0.11	0.02	0.01	0.01	0.61
1922	0.09	0.10	0.03	0.11	0.12	0.11	0.02	0.00	0.01	0.14	0.05	0.00	0.78
1923	0.00	0.00	0.01	0.12	0.12	0.03	0.00	0.00	0.00	0.01	0.01	0.01	0.31
1924	0.01	0.13	0.12	0.03	0.09	0.10	0.03	0.00	0.00	0.00	0.00	0.01	0.52
1925	0.01	0.11	0.04	0.09	0.10	0.10	0.02	0.00	0.01	0.01	0.00	0.01	0.50
1926	0.12	0.11	0.10	0.03	0.01	0.12	0.04	0.00	0.00	0.00	0.01	0.00	0.54
1927	0.02	0.01	0.14	0.12	0.11	0.03	0.00	0.00	0.01	0.01	0.00	0.01	0.46
1928	0.01	0.12	0.05	0.00	0.01	0.11	0.04	0.00	0.00	0.00	0.02	0.07	0.43
1929	0.09	0.08	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.10	0.36
1930	0.04	0.00	0.01	0.10	0.11	0.10	0.02	0.00	0.00	0.06	0.01	0.00	0.45
1931	0.00	0.01	0.01	0.01	0.12	0.04	0.01	0.00	0.01	0.01	0.01	0.14	0.37
1932	0.11	0.09	0.10	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.38
1933	0.00	0.17	0.13	0.11	0.03	0.09	0.03	0.00	0.00	0.01	0.01	0.00	0.58
1934	0.00	0.13	0.12	0.03	0.00	0.01	0.11	0.10	0.09	0.03	0.07	0.03	0.72
1935	0.00	0.00	0.00	0.00	0.15	0.12	0.02	0.10	0.03	0.00	0.00	0.01	0.43
1936	0.12	0.12	0.03	0.01	0.13	0.12	0.02	0.00	0.00	0.01	0.01	0.01	0.58
1937	0.01	0.01	0.14	0.11	0.03	0.00	0.11	0.04	0.00	0.00	0.01	0.00	0.46
1938	0.01	0.13	0.12	0.10	0.10	0.03	0.00	0.01	0.00	0.01	0.01	0.10	0.62
1939	0.10	0.02	0.08	0.03	0.00	0.01	0.01	0.12	0.04	0.00	0.00	0.00	0.41
1940	0.01	0.14	0.05	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.27
1941	0.01	0.13	0.05	0.10	0.04	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.39
1942	0.02	0.12	0.12	0.03	0.01	0.12	0.11	0.02	0.00	0.01	0.10	0.04	0.70
1943	0.07	0.10	0.10	0.03	0.10	0.04	0.00	0.00	0.01	0.01	0.01	0.15	0.62
1944	0.10	0.02	0.00	0.01	0.12	0.11	0.03	0.00	0.01	0.00	0.00	0.01	0.41
1945	0.15	0.05	0.00	0.01	0.14	0.12	0.02	0.00	0.00	0.00	0.00	0.00	0.49
1946	0.01	0.14	0.06	0.00	0.01	0.10	0.10	0.02	0.08	0.03	0.00	0.01	0.56
1947	0.00	0.13	0.11	0.02	0.11	0.11	0.03	0.00	0.00	0.00	0.00	0.01	0.52
1948	0.15	0.05	0.01	0.00	0.11	0.11	0.02	0.00	0.00	0.00	0.01	0.00	0.46
1949	0.01	0.13	0.05	0.10	0.10	0.03	0.01	0.07	0.02	0.00	0.01	0.01	0.54
1950	0.01	0.01	0.11	0.11	0.03	0.09	0.03	0.00	0.01	0.00	0.01	0.01	0.42
1951	0.14	0.05	0.11	0.11	0.03	0.01	0.08	0.02	0.01	0.01	0.00	0.01	0.58
1952	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.02	0.10
1953	0.13	0.11	0.11	0.03	0.00	0.10	0.03	0.01	0.00	0.00	0.01	0.01	0.54
1954	0.13	0.05	0.01	0.11	0.11	0.09	0.02	0.00	0.00	0.00	0.00	0.01	0.53
1955	0.02	0.11	0.04	0.00	0.01	0.13	0.05	0.01	0.00	0.00	0.00	0.00	0.37
1956	0.13	0.11	0.11	0.11	0.10	0.09	0.10	0.02	0.01	0.00	0.01	0.01	0.80
1957	0.11	0.10	0.09	0.11	0.11	0.03	0.08	0.03	0.00	0.01	0.00	0.00	0.67
1958	0.01	0.14	0.11	0.02	0.01	0.01	0.01	0.12	0.04	0.01	0.01	0.00	0.49
1959	0.01	0.01	0.01	0.01	0.01	0.11	0.04	0.01	0.01	0.00	0.00	0.01	0.23
1960	0.01	0.12	0.11	0.10	0.03	0.09	0.10	0.02	0.00	0.01	0.00	0.01	0.60
1961	0.01	0.14	0.11	0.03	0.09	0.10	0.02	0.00	0.01	0.00	0.00	0.01	0.52
1962	0.14	0.11	0.03	0.10	0.03	0.10	0.04	0.00	0.00	0.12	0.05	0.00	0.72
1963	0.10	0.10	0.09	0.10	0.11	0.10	0.09	0.02	0.09	0.04	0.01	0.01	0.86
1964	0.12	0.05	0.01	0.01	0.01	0.01	0.00	0.00	0.16	0.06	0.05	0.02	0.50
1965	0.08	0.10	0.02	0.01	0.00	0.01	0.00	0.16	0.06	0.00	0.00	0.01	0.45
1966	0.01	0.01	0.01	0.12	0.05	0.09	0.10	0.02	0.00	0.10	0.04	0.00	0.55
1967	0.00	0.12	0.05	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.24
1968	0.11	0.10	0.03	0.01	0.13	0.12	0.03	0.10	0.04	0.00	0.00	0.01	0.68
1969	0.01	0.12	0.04	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.14	0.10	0.49
1970	0.09	0.08	0.02	0.01	0.01	0.01	0.01	0.11	0.04	0.07	0.08	0.02	0.55
1971	0.08	0.09	0.08	0.03	0.09	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.45
1972	0.01	0.16	0.12	0.03	0.01	0.01	0.11	0.04	0.00	0.00	0.00	0.01	0.50
1973	0.10	0.10	0.03	0.00	0.11	0.10	0.03	0.09	0.04	0.00	0.00	0.00	0.60
1974	0.01	0.12	0.11	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.16	0.47
1975	0.06	0.01	0.10	0.04	0.09	0.11	0.08	0.08	0.02	0.01	0.00	0.01	0.61
1976	0.12	0.04	0.01	0.01	0.12	0.04	0.00	0.00	0.01	0.01	0.01	0.02	0.39
1977	0.12	0.11	0.10	0.03	0.01	0.01	0.05	0.05	0.01	0.00	0.01	0.01	0.51
1978	0.12	0.10	0.03	0.01	0.00	0.12	0.04	0.00	0.01	0.01	0.01	0.01	0.46
1979	0.10	0.03	0.01	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.15	0.34
1980	0.06	0.08	0.10	0.10	0.03	0.01	0.00	0.01	0.01	0.01	0.00	0.01	0.42
1981	0.00	0.01	0.01	0.02	0.01	0.12	0.10	0.03	0.01	0.01	0.01	0.01	0.34
1982	0.01	0.01	0.01	0.00	0.01	0.00	0.01	0.01	0.01	0.10	0.04	0.01	0.22
1983	0.01	0.00	0.03	0.10	0.03	0.00	0.08	0.02	0.01	0.09	0.03	0.01	0.41
1984	0.01	0.10	0.04	0.01	0.09	0.04	0.01	0.00	0.00	0.01	0.00	0.01	0.32
1985	0.15	0.11	0.02	0.10	0.03	0.00	0.01	0.00	0.01	0.00	0.01	0.12	0.56
1986	0.10	0.08	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.14	0.39
1987	0.05	0.07	0.03	0.00	0.11	0.11	0.03	0.08	0.03	0.06	0.07	0.01	0.65
1988	0.00	0.09	0.11	0.03	0.11	0.04	0.08	0.03	0.00	0.01	0.01	0.01	0.52
1989	0.14	0.12	0.03	0.01	0.00	0.14	0.05	0.00	0.01	0.00	0.01	0.01	0.52
1990	0.12	0.04	0.01	0.11	0.12	0.03	0.01	0.00	0.01	0.00	0.01	0.01	0.47
1991	0.15	0.12	0.03	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.36
1992	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.12
1993	0.13	0.11	0.09	0.03	0.11	0.04	0.01	0.00	0.00	0.00	0.01	0.01	0.54
1994	0.01	0.00	0.15	0.05	0.00	0.14	0.11	0.03	0.08	0.03	0.00	0.00	0.60
1995	0.01	0.02	0.12	0.11	0.10	0.03	0.01	0.01	0.00	0.13	0.04	0.00	0.58
1996	0.10	0.11	0.03	0.10	0.10	0.03	0.08	0.03	0.09	0.08	0.01	0.01	0.77
month	4.45	6.09	4.71	3.53	4.30	4.52	2.69	1.90	1.35	1.41	1.12	1.81	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
max	0.15	0.17	0.15	0.12	0.15	0.14	0.11	0.16	0.16	0.14	0.14	0.16	0.86
median	0.02	0.10	0.05	0.03	0.03	0.04	0.02	0.01	0.01	0.01	0.01	0.01	0.50
mean	0.06	0.08	0.06	0.05	0.06	0.06	0.03	0.02	0.02	0.02	0.01	0.02	0.49
Sum of the monthly means =				0.49									
s.d.	0.05	0.05	0.05	0.04	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.04	0.15
c.v.	0.94	0.62	0.75	0.95	0.89	0.81	1.00	1.58	1.71	1.80	1.70	1.72	0.30

APPENDIX 12.7
T60H (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.05	0.44	1.11	0.40	1.39	1.57	1.07	0.10	0.00	0.00	0.00	0.06	6.19
1921	0.17	1.88	1.85	0.48	0.09	0.07	0.07	2.10	1.49	0.27	1.06	0.39	9.92
1922	1.22	1.60	0.45	1.71	1.85	1.59	0.41	0.04	0.04	2.28	0.77	0.02	11.98
1923	0.06	0.12	0.22	2.05	1.87	0.42	0.03	0.05	0.06	0.05	0.08	0.18	5.19
1924	0.23	1.72	1.86	0.51	1.46	1.66	1.28	0.31	0.02	0.03	0.04	0.14	9.26
1925	0.18	1.54	0.57	1.46	1.68	1.59	0.43	0.06	1.30	0.44	0.02	0.10	9.37
1926	1.58	1.62	1.62	0.48	0.11	1.74	0.59	0.03	0.02	0.02	0.04	0.10	7.95
1927	0.95	0.26	1.49	1.80	1.62	0.44	0.00	0.00	0.04	0.04	0.12	0.13	6.89
1928	0.15	1.69	0.62	1.20	0.28	0.74	0.28	0.06	1.65	1.29	0.28	1.05	9.29
1929	1.42	1.48	0.43	0.12	0.12	1.79	0.63	0.05	1.20	0.41	0.93	1.25	9.83
1930	0.36	0.08	0.14	1.80	1.82	1.62	0.44	0.04	0.02	1.09	0.37	0.02	7.80
1931	1.44	0.52	0.11	0.11	1.98	1.70	0.36	0.08	0.12	0.13	0.09	1.57	8.21
1932	1.54	1.52	1.66	0.44	0.15	1.74	0.58	0.05	0.05	0.05	0.05	0.07	7.90
1933	0.09	2.54	2.09	1.70	0.50	1.39	0.49	0.06	0.05	1.56	0.53	0.02	11.02
1934	0.06	2.01	1.89	0.47	0.08	1.82	1.69	1.37	1.33	0.35	1.08	0.37	12.52
1935	0.06	0.14	0.09	0.12	2.41	1.99	0.42	1.39	0.48	0.04	0.03	0.07	7.24
1936	1.85	1.80	0.45	0.11	1.92	1.77	0.41	0.03	0.03	0.06	0.09	0.11	8.63
1937	0.16	0.18	2.14	1.93	0.56	0.00	1.24	0.44	0.06	0.09	0.08	0.05	6.93
1938	0.09	1.93	1.86	1.69	1.65	1.46	0.38	1.05	0.35	0.77	0.00	0.92	12.15
1939	1.37	0.39	1.52	0.54	0.10	0.56	0.13	0.84	0.30	0.02	0.04	0.07	5.88
1940	0.11	2.17	0.78	0.10	0.08	0.13	0.15	0.12	0.10	0.10	0.10	0.12	4.06
1941	0.20	1.85	0.63	1.76	0.63	1.52	0.52	0.10	0.08	0.04	0.08	0.14	7.55
1942	1.58	1.69	1.64	0.49	0.10	1.64	1.61	0.39	0.06	0.06	1.34	0.47	11.07
1943	1.21	1.53	1.67	0.50	1.41	0.51	0.07	0.06	0.08	0.10	0.09	1.91	9.14
1944	1.58	0.35	0.05	1.78	0.54	1.15	0.41	0.05	0.06	0.06	0.05	0.11	6.19
1945	2.10	0.70	0.07	0.14	2.41	1.94	1.25	0.30	0.02	0.03	0.04	0.07	9.07
1946	0.14	2.19	0.78	0.12	1.45	1.62	1.45	0.39	1.06	0.36	0.02	0.07	9.65
1947	0.11	1.89	1.86	0.48	1.47	1.58	0.41	0.04	0.02	0.02	0.01	0.03	7.92
1948	2.31	0.82	0.12	0.13	1.67	1.66	1.30	0.32	0.01	0.01	0.04	0.10	8.49
1949	0.19	1.93	0.69	1.65	1.73	1.43	1.27	1.03	0.25	0.04	1.17	0.40	11.78
1950	1.21	0.43	1.68	1.84	0.48	1.50	0.52	0.04	0.05	0.06	0.10	0.16	8.07
1951	1.84	0.62	1.93	1.98	0.51	1.30	1.39	0.34	0.03	0.02	0.01	0.11	10.08
1952	0.15	0.16	0.16	0.18	1.40	0.35	0.00	0.00	0.01	0.01	0.05	1.77	4.24
1953	1.46	1.44	1.71	0.50	0.11	1.67	0.57	0.10	0.12	0.10	0.06	0.13	7.97
1954	1.69	0.61	0.09	1.78	1.84	1.42	0.37	0.05	0.05	0.05	0.03	0.13	8.11
1955	0.21	1.57	0.53	0.04	2.43	2.01	1.39	0.34	0.05	0.05	0.04	0.12	8.78
1956	1.59	1.71	1.68	1.72	1.64	1.56	1.46	0.38	0.05	0.06	0.08	1.59	13.52
1957	1.48	1.43	1.60	1.65	1.67	1.50	1.42	0.37	0.01	0.03	0.04	0.08	11.28
1958	0.13	2.24	1.87	0.41	0.91	0.48	0.42	0.33	0.09	0.08	1.08	0.38	8.42
1959	0.08	0.11	0.06	0.02	0.05	1.49	1.44	1.09	0.26	0.02	0.06	0.14	4.82
1960	0.14	1.72	1.78	1.71	0.50	1.42	1.63	0.70	0.02	0.00	0.01	0.04	9.67
1961	0.09	1.66	1.70	0.46	1.39	1.60	0.41	0.06	0.05	0.03	0.10	0.14	7.69
1962	1.90	1.76	0.44	1.54	0.57	1.48	0.53	0.07	0.07	1.50	0.51	0.03	10.40
1963	1.65	1.74	1.55	1.66	1.61	1.39	1.36	0.36	1.30	0.46	0.03	0.09	13.20
1964	1.62	0.56	0.08	0.17	0.19	0.13	0.09	0.16	2.28	1.37	0.94	0.66	8.25
1965	0.37	1.21	0.44	0.13	0.14	0.08	0.08	2.17	0.74	0.02	0.05	0.12	5.55
1966	0.13	0.14	0.19	1.94	1.76	1.57	1.50	0.38	0.06	1.36	0.46	0.02	9.51
1967	0.07	1.89	0.67	0.11	0.18	0.18	0.15	0.09	0.05	0.04	0.12	1.88	5.43
1968	1.53	1.45	0.67	0.04	1.62	1.74	0.43	1.34	0.46	0.04	0.06	0.09	9.47
1969	0.17	1.71	0.61	0.08	0.15	0.14	0.11	0.14	0.22	0.18	1.78	1.41	6.70
1970	1.38	1.54	0.46	0.75	0.52	0.14	0.38	1.15	0.36	1.13	1.25	0.33	9.39
1971	1.27	0.48	0.68	0.29	1.50	0.55	0.07	0.06	0.07	0.08	0.09	0.08	5.22
1972	0.09	2.36	1.75	0.22	0.00	1.10	1.36	0.34	0.00	0.01	0.09	1.71	9.03
1973	1.46	1.43	0.44	0.12	1.73	1.73	0.43	1.30	1.07	0.22	0.02	0.04	9.99
1974	0.09	1.91	1.89	0.49	0.13	1.30	0.45	0.05	0.03	0.04	0.06	1.98	8.42
1975	0.69	0.10	1.69	0.63	1.45	1.70	1.34	1.20	0.31	0.02	0.04	0.50	9.67
1976	0.68	0.22	0.09	0.19	1.85	1.59	0.35	0.03	0.06	0.08	0.14	1.36	6.64
1977	0.52	1.17	1.62	0.49	0.11	1.37	0.55	0.73	0.24	0.01	0.05	0.11	6.97
1978	1.65	1.64	0.42	0.10	0.16	1.70	0.58	0.05	0.05	1.23	0.49	0.33	8.40
1979	1.08	0.37	0.11	0.12	0.18	0.19	0.13	0.11	0.10	0.07	0.07	2.23	4.76
1980	0.78	1.36	1.62	1.70	0.51	0.08	0.06	1.75	0.59	0.02	1.28	0.44	10.19
1981	0.04	0.12	0.14	1.00	0.27	1.14	1.38	0.35	0.03	0.05	0.04	0.06	4.62
1982	0.01	0.03	0.05	0.11	0.15	0.15	0.14	0.11	0.09	2.82	0.96	0.06	4.68
1983	0.12	1.41	1.35	0.61	1.27	0.42	0.49	0.18	0.07	1.07	0.36	0.06	7.41
1984	0.11	1.61	0.49	0.35	0.17	0.07	0.06	0.04	0.05	0.06	0.04	0.05	3.10
1985	2.32	1.91	0.45	1.41	0.51	0.12	0.13	0.09	0.06	0.04	1.77	1.49	10.30
1986	1.32	1.40	0.40	1.27	0.31	1.16	0.43	0.05	0.07	0.05	0.11	0.98	7.55
1987	0.41	0.54	0.23	0.10	1.75	1.81	1.01	0.19	0.02	0.86	1.03	0.27	8.22
1988	0.77	0.41	1.31	0.46	1.83	1.68	1.41	0.37	0.06	0.06	0.05	0.08	8.49
1989	1.92	1.83	0.43	0.16	0.14	1.93	0.67	0.04	0.04	0.02	0.16	0.17	7.51
1990	1.61	0.55	0.09	1.92	1.81	0.44	0.05	0.06	0.07	0.06	0.08	0.17	6.91
1991	1.95	1.77	0.43	0.13	0.13	0.14	0.17	0.13	0.08	0.05	0.06	0.15	5.19
1992	0.21	0.20	0.76	0.20	0.03	0.06	0.09	0.09	0.07	0.05	0.07	1.11	2.94
1993	0.62	1.12	1.56	0.45	1.74	1.65	0.37	0.02	0.02	0.07	0.32	0.08	8.02
1994	0.04	0.07	2.30	0.83	0.08	1.86	1.76	0.41	1.05	0.36	0.01	0.06	8.83
1995	0.16	0.17	1.74	1.83	1.62	0.44	0.08	0.09	0.07	1.55	0.53	0.05	8.33
1996	1.54	1.70	0.46	1.53	1.72	1.46	1.46	0.40	0.41	0.60	0.17	0.07	11.52
month	62.91	90.16	72.86	61.69	73.95	87.83	50.04	28.85	21.46	25.97	23.59	33.22	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.01	0.03	0.05	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	2.94
max	2.32	2.54	2.30	2.05	2.43	2.01	1.76	2.17	2.28	2.82	1.78	2.23	13.52
median	0.62	1.44	0.67	0.49	0.63	1.46	0.43	0.12	0.07	0.06	0.08	0.13	8.25
mean	0.82	1.17	0.95	0.80	0.96	1.14	0.65	0.37	0.28	0.34	0.31	0.43	8.21
Sum of the monthly means =				8.21									
s.d.	0.73	0.73	0.71	0.70	0.77	0.66	0.54	0.50	0.47	0.57	0.45	0.60	2.29
c.v.	0.89	0.62	0.75	0.88	0.80	0.58	0.83	1.34	1.67	1.70	1.46	1.38	0.28

APPENDIX 12.8
T60J (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.36	0.12	0.02	0.11	0.04	0.01	0.00	0.00	0.00	0.01	0.69
1921	0.03	0.36	0.36	0.09	0.02	0.01	0.01	0.43	0.28	0.04	0.01	0.02	1.66
1922	0.25	0.29	0.07	0.31	0.33	0.28	0.07	0.01	0.01	0.32	0.11	0.01	2.06
1923	0.01	0.02	0.03	0.44	0.37	0.08	0.00	0.01	0.01	0.01	0.02	0.03	1.03
1924	0.03	0.04	0.31	0.12	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.56
1925	0.03	0.04	0.03	0.03	0.28	0.30	0.08	0.01	0.02	0.02	0.01	0.02	0.87
1926	0.30	0.30	0.28	0.08	0.01	0.34	0.11	0.00	0.00	0.00	0.00	0.02	1.44
1927	0.04	0.02	0.04	0.35	0.34	0.09	0.01	0.01	0.01	0.01	0.02	0.03	0.97
1928	0.03	0.04	0.03	0.03	0.03	0.36	0.11	0.01	0.29	0.22	0.04	0.19	1.38
1929	0.25	0.28	0.08	0.02	0.02	0.03	0.04	0.03	0.03	0.03	0.22	0.23	1.26
1930	0.06	0.02	0.02	0.14	0.26	0.28	0.07	0.01	0.00	0.01	0.00	0.00	0.87
1931	0.02	0.02	0.03	0.02	0.44	0.15	0.00	0.02	0.02	0.02	0.01	0.33	1.08
1932	0.28	0.27	0.29	0.08	0.02	0.04	0.02	0.02	0.02	0.01	0.01	0.01	1.07
1933	0.01	0.44	0.36	0.29	0.08	0.25	0.08	0.01	0.01	0.27	0.09	0.01	1.90
1934	0.01	0.04	0.36	0.13	0.02	0.32	0.29	0.23	0.23	0.06	0.19	0.06	1.94
1935	0.01	0.02	0.01	0.01	0.45	0.36	0.07	0.27	0.09	0.01	0.00	0.01	1.31
1936	0.32	0.31	0.07	0.02	0.38	0.33	0.07	0.01	0.00	0.01	0.01	0.02	1.55
1937	0.03	0.02	0.39	0.14	0.02	0.01	0.31	0.11	0.01	0.01	0.02	0.01	1.08
1938	0.01	0.03	0.04	0.29	0.31	0.08	0.01	0.02	0.02	0.02	0.02	0.25	1.10
1939	0.25	0.06	0.02	0.01	0.02	0.03	0.03	0.34	0.11	0.01	0.00	0.01	0.89
1940	0.02	0.37	0.14	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.66
1941	0.03	0.04	0.03	0.38	0.14	0.03	0.02	0.03	0.02	0.01	0.01	0.02	0.76
1942	0.04	0.33	0.33	0.08	0.02	0.34	0.30	0.06	0.01	0.01	0.26	0.09	1.87
1943	0.21	0.27	0.28	0.08	0.30	0.10	0.01	0.01	0.01	0.02	0.02	0.39	1.70
1944	0.28	0.06	0.01	0.03	0.35	0.31	0.07	0.00	0.01	0.01	0.01	0.01	1.15
1945	0.38	0.12	0.01	0.02	0.42	0.34	0.08	0.01	0.00	0.01	0.01	0.01	1.41
1946	0.02	0.39	0.13	0.02	0.02	0.30	0.27	0.07	0.18	0.06	0.01	0.01	1.48
1947	0.02	0.35	0.32	0.08	0.30	0.30	0.07	0.01	0.00	0.00	0.00	0.00	1.45
1948	0.40	0.14	0.01	0.03	0.35	0.32	0.04	0.00	0.00	0.00	0.00	0.00	1.29
1949	0.03	0.36	0.13	0.30	0.29	0.08	0.18	0.20	0.05	0.00	0.02	0.02	1.66
1950	0.02	0.02	0.38	0.34	0.08	0.26	0.09	0.00	0.01	0.01	0.01	0.02	1.24
1951	0.37	0.13	0.32	0.33	0.08	0.23	0.23	0.05	0.01	0.00	0.00	0.01	1.76
1952	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.02	0.01	0.01	0.01	0.03	0.31
1953	0.31	0.30	0.29	0.08	0.01	0.31	0.10	0.01	0.02	0.02	0.01	0.02	1.48
1954	0.33	0.12	0.02	0.37	0.34	0.27	0.07	0.01	0.01	0.00	0.01	0.02	1.57
1955	0.03	0.04	0.02	0.01	0.04	0.41	0.29	0.06	0.01	0.00	0.01	0.02	0.94
1956	0.31	0.32	0.29	0.29	0.27	0.26	0.25	0.06	0.01	0.01	0.01	0.03	2.11
1957	0.27	0.27	0.26	0.30	0.30	0.25	0.24	0.06	0.00	0.01	0.01	0.01	1.98
1958	0.02	0.39	0.14	0.01	0.02	0.03	0.03	0.31	0.11	0.01	0.19	0.07	1.33
1959	0.01	0.02	0.03	0.02	0.03	0.34	0.27	0.18	0.04	0.00	0.01	0.02	0.97
1960	0.02	0.31	0.34	0.30	0.08	0.25	0.28	0.07	0.01	0.01	0.01	0.01	1.69
1961	0.02	0.35	0.13	0.02	0.03	0.27	0.09	0.01	0.01	0.00	0.02	0.02	0.97
1962	0.34	0.31	0.08	0.29	0.10	0.28	0.10	0.01	0.02	0.28	0.09	0.00	1.90
1963	0.02	0.28	0.11	0.26	0.31	0.27	0.24	0.06	0.24	0.09	0.01	0.02	1.91
1964	0.32	0.11	0.01	0.02	0.02	0.02	0.01	0.02	0.43	0.25	0.16	0.05	1.42
1965	0.22	0.28	0.08	0.02	0.03	0.02	0.02	0.45	0.15	0.00	0.00	0.02	1.29
1966	0.02	0.02	0.03	0.36	0.13	0.25	0.27	0.07	0.01	0.23	0.08	0.00	1.47
1967	0.01	0.03	0.03	0.03	0.04	0.04	0.03	0.02	0.01	0.00	0.02	0.34	0.60
1968	0.12	0.21	0.08	0.01	0.37	0.33	0.07	0.24	0.08	0.01	0.01	0.02	1.55
1969	0.03	0.31	0.11	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.34	0.12	1.07
1970	0.21	0.26	0.08	0.02	0.03	0.03	0.03	0.27	0.09	0.19	0.21	0.06	1.48
1971	0.24	0.08	0.02	0.02	0.32	0.11	0.01	0.01	0.01	0.02	0.02	0.01	0.87
1972	0.01	0.41	0.15	0.01	0.02	0.04	0.30	0.09	0.00	0.00	0.02	0.03	1.08
1973	0.03	0.27	0.10	0.02	0.32	0.30	0.07	0.23	0.08	0.01	0.00	0.01	1.44
1974	0.01	0.03	0.33	0.11	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.37	0.97
1975	0.12	0.02	0.34	0.12	0.28	0.31	0.24	0.21	0.05	0.00	0.01	0.02	1.72
1976	0.33	0.11	0.02	0.03	0.39	0.13	0.01	0.01	0.01	0.01	0.02	0.04	1.11
1977	0.29	0.29	0.28	0.09	0.02	0.03	0.15	0.15	0.04	0.00	0.01	0.02	1.37
1978	0.33	0.28	0.07	0.02	0.03	0.36	0.12	0.01	0.00	0.00	0.00	0.00	1.22
1979	0.01	0.01	0.02	0.02	0.03	0.04	0.02	0.02	0.02	0.01	0.01	0.40	0.61
1980	0.14	0.27	0.10	0.25	0.09	0.01	0.01	0.32	0.10	0.00	0.01	0.01	1.31
1981	0.02	0.02	0.02	0.04	0.03	0.39	0.29	0.06	0.01	0.00	0.00	0.01	0.89
1982	0.03	0.03	0.02	0.02	0.03	0.03	0.02	0.02	0.01	0.00	0.00	0.01	0.22
1983	0.02	0.29	0.11	0.26	0.10	0.01	0.22	0.08	0.01	0.19	0.06	0.01	1.36
1984	0.01	0.33	0.12	0.02	0.32	0.11	0.01	0.00	0.01	0.01	0.01	0.01	0.96
1985	0.39	0.33	0.08	0.29	0.11	0.02	0.02	0.02	0.01	0.01	0.03	0.30	1.61
1986	0.27	0.07	0.01	0.02	0.02	0.35	0.12	0.01	0.01	0.01	0.02	0.35	1.26
1987	0.12	0.24	0.09	0.01	0.12	0.26	0.08	0.19	0.07	0.16	0.17	0.04	1.55
1988	0.01	0.26	0.31	0.08	0.32	0.28	0.24	0.07	0.01	0.01	0.01	0.01	1.61
1989	0.37	0.34	0.07	0.02	0.02	0.41	0.14	0.00	0.00	0.00	0.02	0.02	1.41
1990	0.03	0.03	0.03	0.03	0.35	0.12	0.01	0.01	0.02	0.01	0.01	0.03	0.68
1991	0.38	0.34	0.08	0.02	0.02	0.02	0.03	0.03	0.01	0.00	0.01	0.03	0.97
1992	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.01	0.02	0.01	0.01	0.04	0.28
1993	0.34	0.12	0.26	0.09	0.31	0.28	0.06	0.00	0.00	0.01	0.03	0.02	1.52
1994	0.02	0.02	0.42	0.15	0.01	0.39	0.32	0.07	0.20	0.06	0.00	0.01	1.67
1995	0.02	0.03	0.35	0.32	0.29	0.08	0.01	0.02	0.01	0.33	0.12	0.01	1.59
1996	0.09	0.00	0.00	0.27	0.30	0.08	0.22	0.08	0.24	0.20	0.04	0.01	1.53
month	10.08	13.43	10.86	9.23	11.89	13.98	8.01	5.73	3.73	3.46	3.01	4.58	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
max	0.40	0.44	0.42	0.44	0.45	0.41	0.32	0.45	0.43	0.33	0.34	0.40	2.11
median	0.03	0.13	0.08	0.08	0.08	0.23	0.07	0.02	0.01	0.01	0.01	0.02	1.31
mean	0.13	0.17	0.14	0.12	0.15	0.18	0.10	0.07	0.05	0.04	0.04	0.06	1.27
Sum of the monthly means =				1.27									
s.d.	0.14	0.14	0.13	0.13	0.15	0.14	0.10	0.11	0.08	0.08	0.07	0.10	0.42
c.v.	1.06	0.81	0.94	1.06	0.96	0.75	0.98	1.42	1.70	1.87	1.74	1.75	0.33

APPENDIX 12.9
T60K (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.28	0.10	0.02	0.21	0.07	0.00	0.01	0.00	0.00	0.01	0.72
1921	0.03	0.31	0.28	0.07	0.01	0.01	0.00	0.33	0.21	0.04	0.01	0.02	1.32
1922	0.20	0.23	0.06	0.25	0.25	0.21	0.05	0.01	0.01	0.24	0.09	0.00	1.60
1923	0.01	0.01	0.02	0.34	0.29	0.06	0.00	0.01	0.01	0.00	0.01	0.02	0.78
1924	0.03	0.03	0.24	0.08	0.21	0.22	0.06	0.01	0.00	0.01	0.01	0.01	0.91
1925	0.02	0.02	0.02	0.02	0.24	0.23	0.06	0.01	0.02	0.02	0.00	0.02	0.68
1926	0.24	0.24	0.06	0.01	0.02	0.27	0.10	0.00	0.01	0.00	0.01	0.01	0.97
1927	0.03	0.02	0.03	0.03	0.25	0.09	0.01	0.01	0.01	0.01	0.02	0.01	0.52
1928	0.02	0.03	0.02	0.03	0.03	0.28	0.10	0.01	0.23	0.17	0.04	0.14	1.10
1929	0.20	0.22	0.06	0.01	0.01	0.03	0.03	0.02	0.02	0.02	0.03	0.19	0.84
1930	0.06	0.01	0.02	0.31	0.28	0.22	0.06	0.01	0.00	0.02	0.00	0.00	0.99
1931	0.02	0.02	0.02	0.02	0.33	0.12	0.01	0.01	0.01	0.02	0.02	0.25	0.85
1932	0.21	0.21	0.22	0.06	0.02	0.03	0.03	0.01	0.01	0.01	0.01	0.00	0.82
1933	0.01	0.33	0.29	0.23	0.06	0.20	0.07	0.00	0.01	0.22	0.07	0.00	1.49
1934	0.01	0.03	0.13	0.05	0.01	0.02	0.24	0.21	0.17	0.05	0.14	0.04	1.10
1935	0.01	0.02	0.01	0.01	0.34	0.27	0.06	0.20	0.07	0.00	0.01	0.01	1.01
1936	0.24	0.24	0.06	0.01	0.30	0.26	0.06	0.00	0.00	0.01	0.02	0.02	1.22
1937	0.02	0.02	0.30	0.11	0.01	0.02	0.26	0.09	0.01	0.01	0.01	0.01	0.87
1938	0.01	0.02	0.25	0.24	0.22	0.19	0.05	0.01	0.01	0.02	0.02	0.21	1.25
1939	0.20	0.04	0.01	0.01	0.02	0.03	0.02	0.24	0.08	0.00	0.01	0.01	0.67
1940	0.01	0.29	0.10	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.53
1941	0.02	0.03	0.02	0.33	0.11	0.20	0.07	0.15	0.06	0.00	0.01	0.01	1.01
1942	0.03	0.26	0.25	0.07	0.01	0.25	0.23	0.05	0.01	0.01	0.21	0.07	1.45
1943	0.16	0.22	0.22	0.06	0.22	0.21	0.05	0.01	0.01	0.01	0.01	0.27	1.45
1944	0.20	0.05	0.01	0.02	0.28	0.24	0.06	0.00	0.01	0.01	0.01	0.02	0.91
1945	0.29	0.10	0.01	0.01	0.03	0.31	0.11	0.01	0.00	0.00	0.00	0.01	0.88
1946	0.01	0.28	0.10	0.02	0.03	0.25	0.22	0.05	0.15	0.06	0.00	0.01	1.18
1947	0.02	0.27	0.25	0.06	0.23	0.23	0.06	0.01	0.00	0.00	0.01	0.00	1.14
1948	0.30	0.10	0.01	0.02	0.28	0.25	0.06	0.01	0.00	0.00	0.00	0.01	1.04
1949	0.02	0.31	0.11	0.22	0.23	0.06	0.01	0.15	0.05	0.01	0.02	0.01	1.20
1950	0.02	0.02	0.29	0.11	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.56
1951	0.29	0.10	0.25	0.26	0.07	0.20	0.19	0.05	0.00	0.01	0.00	0.01	1.43
1952	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.02	0.01	0.00	0.01	0.03	0.24
1953	0.24	0.24	0.21	0.06	0.01	0.24	0.08	0.01	0.01	0.01	0.01	0.01	1.13
1954	0.25	0.09	0.02	0.28	0.25	0.20	0.05	0.00	0.01	0.00	0.00	0.02	1.17
1955	0.02	0.03	0.02	0.01	0.03	0.32	0.23	0.04	0.01	0.00	0.01	0.01	0.73
1956	0.24	0.24	0.23	0.22	0.20	0.20	0.19	0.05	0.00	0.00	0.01	0.03	1.61
1957	0.20	0.07	0.02	0.21	0.24	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.76
1958	0.01	0.30	0.11	0.01	0.02	0.02	0.02	0.26	0.09	0.01	0.14	0.05	1.04
1959	0.01	0.01	0.02	0.02	0.01	0.25	0.21	0.05	0.01	0.01	0.01	0.01	0.62
1960	0.02	0.24	0.26	0.23	0.07	0.01	0.21	0.07	0.01	0.01	0.01	0.01	1.15
1961	0.01	0.29	0.10	0.01	0.02	0.22	0.07	0.01	0.00	0.01	0.01	0.02	0.77
1962	0.26	0.24	0.06	0.25	0.09	0.21	0.07	0.01	0.00	0.22	0.08	0.01	1.50
1963	0.02	0.21	0.08	0.21	0.24	0.21	0.19	0.05	0.18	0.07	0.00	0.01	1.47
1964	0.25	0.08	0.01	0.02	0.02	0.02	0.01	0.02	0.33	0.19	0.12	0.03	1.10
1965	0.16	0.22	0.06	0.02	0.02	0.02	0.01	0.34	0.12	0.01	0.01	0.01	1.00
1966	0.01	0.02	0.02	0.28	0.10	0.20	0.22	0.05	0.00	0.17	0.06	0.00	1.13
1967	0.01	0.03	0.02	0.01	0.03	0.02	0.02	0.02	0.01	0.00	0.01	0.27	0.45
1968	0.20	0.19	0.06	0.00	0.29	0.25	0.06	0.18	0.06	0.00	0.01	0.01	1.31
1969	0.02	0.26	0.09	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.26	0.09	0.86
1970	0.17	0.21	0.06	0.02	0.02	0.02	0.02	0.22	0.07	0.14	0.17	0.05	1.17
1971	0.18	0.07	0.01	0.02	0.27	0.09	0.00	0.01	0.01	0.01	0.01	0.01	0.69
1972	0.01	0.03	0.03	0.03	0.02	0.03	0.24	0.08	0.00	0.00	0.01	0.03	0.51
1973	0.03	0.24	0.09	0.01	0.02	0.25	0.08	0.18	0.07	0.00	0.01	0.00	0.98
1974	0.01	0.02	0.26	0.10	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.31	0.80
1975	0.11	0.01	0.26	0.10	0.21	0.23	0.06	0.14	0.04	0.00	0.00	0.02	1.18
1976	0.25	0.09	0.01	0.02	0.31	0.10	0.01	0.00	0.01	0.01	0.02	0.02	0.85
1977	0.05	0.00	0.06	0.06	0.02	0.02	0.12	0.12	0.03	0.00	0.00	0.02	0.50
1978	0.08	0.17	0.06	0.01	0.02	0.28	0.10	0.00	0.00	0.02	0.03	0.02	0.79
1979	0.05	0.00	0.00	0.00	0.01	0.03	0.02	0.01	0.01	0.01	0.00	0.30	0.44
1980	0.11	0.21	0.07	0.20	0.07	0.01	0.01	0.25	0.09	0.00	0.01	0.02	1.05
1981	0.01	0.02	0.02	0.03	0.03	0.31	0.10	0.01	0.00	0.01	0.01	0.01	0.56
1982	0.02	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.01	0.14
1983	0.01	0.21	0.07	0.20	0.07	0.01	0.02	0.01	0.01	0.19	0.06	0.01	0.87
1984	0.01	0.23	0.08	0.02	0.25	0.08	0.01	0.01	0.01	0.01	0.00	0.00	0.71
1985	0.31	0.26	0.05	0.22	0.08	0.01	0.02	0.02	0.01	0.01	0.02	0.24	1.25
1986	0.21	0.06	0.01	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.29	0.68
1987	0.11	0.20	0.07	0.02	0.26	0.25	0.07	0.16	0.05	0.12	0.14	0.03	1.48
1988	0.01	0.20	0.24	0.07	0.06	0.02	0.16	0.06	0.01	0.01	0.00	0.01	0.85
1989	0.29	0.26	0.06	0.02	0.01	0.32	0.11	0.01	0.01	0.00	0.01	0.02	1.12
1990	0.03	0.02	0.01	0.03	0.26	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0.50
1991	0.30	0.26	0.06	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.77
1992	0.03	0.02	0.03	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.31	0.50
1993	0.24	0.05	0.22	0.07	0.25	0.10	0.01	0.00	0.01	0.01	0.02	0.02	1.00
1994	0.01	0.01	0.34	0.12	0.01	0.31	0.26	0.05	0.15	0.05	0.01	0.01	1.33
1995	0.02	0.02	0.29	0.27	0.21	0.06	0.01	0.01	0.01	0.27	0.10	0.01	1.28
1996	0.21	0.23	0.07	0.23	0.24	0.07	0.18	0.06	0.18	0.14	0.03	0.01	1.65
month	7.75	10.00	7.95	7.00	8.92	10.42	5.84	4.40	2.93	2.80	2.30	3.87	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14
max	0.31	0.33	0.34	0.34	0.34	0.32	0.26	0.34	0.33	0.27	0.26	0.31	1.65
median	0.03	0.09	0.06	0.03	0.06	0.10	0.06	0.01	0.01	0.01	0.01	0.01	0.98
mean	0.10	0.13	0.10	0.09	0.12	0.14	0.08	0.06	0.04	0.04	0.03	0.05	0.96
Sum of the monthly means =				0.96									
s.d.	0.11	0.11	0.10	0.10	0.11	0.11	0.08	0.08	0.06	0.07	0.05	0.09	0.33
c.v.	1.05	0.84	0.98	1.10	0.98	0.80	1.00	1.44	1.66	1.81	1.69	1.72	0.35

APPENDIX 13

AFFORESTATION RUNOFF REDUCTION FOR PROPOSED DAM SITES (2000)

APPENDIX 13.1
LUSIKISIKI DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.01	0.09	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.14
1921	0.01	0.20	0.17	0.04	0.00	0.01	0.01	0.22	0.14	0.02	0.01	0.01	0.84
1922	0.14	0.14	0.04	0.15	0.16	0.13	0.04	0.00	0.00	0.19	0.07	0.00	1.06
1923	0.00	0.01	0.01	0.20	0.17	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.44
1924	0.02	0.03	0.17	0.05	0.01	0.16	0.06	0.00	0.01	0.01	0.01	0.01	0.54
1925	0.02	0.02	0.02	0.01	0.02	0.16	0.05	0.00	0.01	0.01	0.01	0.01	0.34
1926	0.02	0.17	0.10	0.00	0.00	0.12	0.04	0.00	0.00	0.00	0.00	0.01	0.46
1927	0.02	0.02	0.02	0.02	0.09	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.19
1928	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.19	0.12	0.02	0.11	0.55
1929	0.12	0.12	0.04	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.16	0.55
1930	0.06	0.01	0.01	0.18	0.16	0.14	0.04	0.00	0.00	0.07	0.03	0.00	0.70
1931	0.01	0.01	0.02	0.01	0.20	0.08	0.00	0.01	0.01	0.01	0.01	0.18	0.55
1932	0.13	0.12	0.14	0.04	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.49
1933	0.01	0.22	0.18	0.15	0.05	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.68
1934	0.01	0.02	0.19	0.07	0.01	0.01	0.18	0.14	0.11	0.03	0.00	0.00	0.77
1935	0.01	0.01	0.00	0.01	0.24	0.18	0.03	0.13	0.05	0.00	0.00	0.01	0.67
1936	0.02	0.17	0.06	0.01	0.18	0.15	0.04	0.00	0.00	0.00	0.01	0.01	0.65
1937	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.15
1938	0.01	0.01	0.02	0.02	0.16	0.05	0.00	0.01	0.00	0.01	0.01	0.18	0.48
1939	0.13	0.03	0.01	0.00	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.26
1940	0.01	0.02	0.02	0.02	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.11
1941	0.01	0.02	0.01	0.21	0.07	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.38
1942	0.01	0.20	0.12	0.02	0.01	0.01	0.16	0.06	0.00	0.01	0.02	0.01	0.63
1943	0.02	0.12	0.14	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.20	0.56
1944	0.07	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.17
1945	0.22	0.08	0.00	0.01	0.01	0.19	0.06	0.00	0.00	0.01	0.00	0.00	0.58
1946	0.01	0.09	0.01	0.00	0.00	0.13	0.14	0.03	0.10	0.04	0.00	0.01	0.56
1947	0.01	0.19	0.06	0.00	0.06	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.37
1948	0.02	0.02	0.01	0.02	0.20	0.16	0.03	0.00	0.00	0.00	0.00	0.01	0.47
1949	0.01	0.20	0.07	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.39
1950	0.01	0.01	0.19	0.07	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.34
1951	0.20	0.07	0.14	0.05	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.52
1952	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.01	0.13
1953	0.02	0.17	0.15	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.46
1954	0.20	0.07	0.01	0.17	0.16	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.67
1955	0.01	0.02	0.01	0.01	0.01	0.24	0.08	0.01	0.00	0.00	0.00	0.01	0.40
1956	0.02	0.17	0.16	0.05	0.01	0.13	0.14	0.04	0.00	0.00	0.01	0.01	0.74
1957	0.01	0.14	0.04	0.12	0.15	0.05	0.11	0.04	0.01	0.00	0.00	0.01	0.68
1958	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.20	0.06	0.00	0.00	0.01	0.39
1959	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.01	0.01	0.15
1960	0.01	0.00	0.00	0.00	0.01	0.01	0.16	0.06	0.00	0.01	0.01	0.00	0.27
1961	0.01	0.19	0.07	0.00	0.02	0.15	0.05	0.00	0.01	0.00	0.00	0.01	0.51
1962	0.02	0.18	0.06	0.14	0.06	0.15	0.05	0.00	0.01	0.16	0.06	0.00	0.89
1963	0.01	0.14	0.05	0.13	0.15	0.04	0.10	0.03	0.12	0.04	0.00	0.00	0.81
1964	0.16	0.06	0.00	0.01	0.01	0.01	0.01	0.01	0.25	0.09	0.00	0.01	0.62
1965	0.12	0.14	0.03	0.01	0.01	0.00	0.00	0.23	0.07	0.00	0.01	0.00	0.62
1966	0.01	0.01	0.02	0.02	0.02	0.17	0.15	0.03	0.00	0.01	0.01	0.01	0.46
1967	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.13
1968	0.02	0.15	0.05	0.00	0.17	0.11	0.02	0.13	0.04	0.00	0.00	0.00	0.69
1969	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.20	0.07	0.39
1970	0.10	0.12	0.03	0.01	0.01	0.01	0.02	0.18	0.06	0.00	0.11	0.03	0.68
1971	0.11	0.04	0.01	0.01	0.18	0.06	0.00	0.01	0.00	0.01	0.01	0.01	0.45
1972	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.14
1973	0.02	0.17	0.06	0.00	0.02	0.02	0.01	0.16	0.05	0.00	0.00	0.00	0.51
1974	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.21	0.34
1975	0.07	0.01	0.15	0.05	0.15	0.15	0.04	0.09	0.03	0.00	0.00	0.01	0.75
1976	0.18	0.06	0.01	0.01	0.18	0.06	0.01	0.01	0.00	0.00	0.01	0.02	0.55
1977	0.02	0.17	0.16	0.05	0.01	0.01	0.18	0.06	0.00	0.00	0.01	0.01	0.68
1978	0.17	0.10	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.01	0.02	0.02	0.36
1979	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.21	0.33
1980	0.07	0.12	0.05	0.01	0.01	0.00	0.00	0.01	0.02	0.01	0.01	0.02	0.33
1981	0.01	0.01	0.01	0.01	0.01	0.22	0.08	0.01	0.00	0.00	0.00	0.00	0.36
1982	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08	0.03	0.00	0.21
1983	0.01	0.14	0.05	0.12	0.04	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.44
1984	0.01	0.17	0.06	0.01	0.16	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.46
1985	0.02	0.19	0.06	0.14	0.05	0.01	0.01	0.00	0.01	0.00	0.01	0.02	0.52
1986	0.16	0.06	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.21	0.53
1987	0.07	0.11	0.04	0.01	0.17	0.17	0.04	0.11	0.04	0.01	0.00	0.00	0.77
1988	0.01	0.14	0.15	0.04	0.18	0.06	0.12	0.04	0.00	0.00	0.00	0.01	0.75
1989	0.18	0.15	0.04	0.01	0.01	0.20	0.07	0.00	0.01	0.00	0.01	0.01	0.69
1990	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.00	0.01	0.01	0.00	0.01	0.15
1991	0.20	0.16	0.04	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.44
1992	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.11
1993	0.03	0.03	0.16	0.06	0.16	0.06	0.01	0.00	0.01	0.01	0.01	0.01	0.55
1994	0.01	0.00	0.08	0.00	0.00	0.14	0.14	0.04	0.01	0.00	0.00	0.00	0.42
1995	0.01	0.01	0.18	0.07	0.12	0.05	0.00	0.01	0.00	0.02	0.02	0.01	0.50
1996	0.01	0.18	0.06	0.02	0.14	0.05	0.13	0.04	0.13	0.05	0.00	0.01	0.82
month	3.59	6.15	4.32	2.95	4.47	4.57	2.96	2.41	1.79	1.22	0.92	2.09	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
max	0.22	0.22	0.19	0.21	0.24	0.24	0.18	0.23	0.25	0.19	0.20	0.21	1.06
median	0.02	0.06	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.49
mean	0.05	0.08	0.06	0.04	0.06	0.06	0.04	0.03	0.02	0.02	0.01	0.03	0.49
Sum of the monthly means =				0.49									
s.d.	0.06	0.07	0.06	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.06	0.21
c.v.	1.31	0.89	1.04	1.37	1.22	1.11	1.29	1.73	1.94	2.14	2.28	2.03	0.43

APPENDIX 13.2
ZALU DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.08	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.15
1921	0.02	0.20	0.17	0.03	0.01	0.01	0.01	0.21	0.14	0.02	0.00	0.01	0.83
1922	0.14	0.14	0.03	0.15	0.16	0.14	0.04	0.00	0.01	0.18	0.06	0.00	1.05
1923	0.00	0.01	0.02	0.20	0.17	0.03	0.00	0.01	0.00	0.00	0.00	0.02	0.46
1924	0.02	0.02	0.17	0.06	0.01	0.16	0.06	0.00	0.00	0.01	0.01	0.01	0.53
1925	0.01	0.02	0.01	0.01	0.02	0.16	0.05	0.00	0.01	0.01	0.01	0.01	0.32
1926	0.02	0.16	0.09	0.00	0.00	0.13	0.05	0.00	0.00	0.00	0.01	0.01	0.47
1927	0.02	0.02	0.01	0.02	0.07	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.17
1928	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.19	0.12	0.03	0.10	0.56
1929	0.12	0.12	0.03	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.16	0.52
1930	0.05	0.01	0.01	0.17	0.16	0.14	0.03	0.00	0.01	0.08	0.02	0.00	0.68
1931	0.01	0.01	0.02	0.01	0.21	0.07	0.01	0.01	0.01	0.01	0.01	0.19	0.57
1932	0.13	0.12	0.13	0.04	0.01	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.47
1933	0.00	0.21	0.18	0.15	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.64
1934	0.00	0.02	0.19	0.06	0.00	0.02	0.17	0.14	0.10	0.02	0.01	0.00	0.73
1935	0.00	0.01	0.01	0.01	0.25	0.19	0.04	0.12	0.04	0.00	0.00	0.01	0.68
1936	0.01	0.17	0.06	0.01	0.18	0.16	0.04	0.01	0.00	0.00	0.00	0.01	0.65
1937	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.15
1938	0.01	0.02	0.02	0.02	0.16	0.05	0.01	0.01	0.01	0.01	0.01	0.17	0.50
1939	0.14	0.03	0.01	0.01	0.00	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.29
1940	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.11
1941	0.01	0.03	0.02	0.21	0.07	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.40
1942	0.02	0.19	0.14	0.03	0.01	0.01	0.15	0.05	0.00	0.00	0.02	0.01	0.63
1943	0.02	0.13	0.13	0.04	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.20	0.55
1944	0.07	0.01	0.00	0.01	0.02	0.02	0.02	0.00	0.01	0.00	0.01	0.01	0.18
1945	0.22	0.08	0.00	0.01	0.02	0.19	0.06	0.00	0.00	0.01	0.00	0.01	0.60
1946	0.01	0.07	0.01	0.00	0.00	0.14	0.14	0.03	0.10	0.04	0.00	0.01	0.55
1947	0.00	0.18	0.06	0.00	0.08	0.03	0.00	0.00	0.01	0.00	0.00	0.01	0.37
1948	0.02	0.02	0.01	0.01	0.20	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.38
1949	0.02	0.20	0.07	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.41
1950	0.02	0.01	0.19	0.07	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.35
1951	0.20	0.06	0.14	0.05	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.49
1952	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.01	0.02	0.14
1953	0.02	0.17	0.15	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.46
1954	0.20	0.07	0.00	0.16	0.16	0.04	0.00	0.01	0.00	0.00	0.00	0.01	0.65
1955	0.02	0.02	0.01	0.01	0.01	0.23	0.07	0.00	0.00	0.01	0.01	0.01	0.40
1956	0.02	0.17	0.16	0.04	0.01	0.13	0.14	0.03	0.00	0.00	0.01	0.01	0.72
1957	0.02	0.13	0.05	0.12	0.15	0.04	0.11	0.04	0.00	0.00	0.00	0.00	0.66
1958	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.19	0.06	0.01	0.01	0.00	0.36
1959	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.14
1960	0.02	0.00	0.01	0.01	0.01	0.01	0.15	0.06	0.01	0.01	0.01	0.00	0.30
1961	0.01	0.18	0.06	0.01	0.01	0.15	0.06	0.01	0.01	0.01	0.01	0.01	0.53
1962	0.02	0.18	0.07	0.14	0.05	0.14	0.05	0.01	0.01	0.16	0.05	0.01	0.89
1963	0.01	0.14	0.05	0.14	0.15	0.04	0.10	0.04	0.13	0.04	0.00	0.01	0.85
1964	0.16	0.05	0.00	0.01	0.01	0.01	0.01	0.01	0.25	0.08	0.01	0.00	0.60
1965	0.12	0.13	0.04	0.01	0.01	0.00	0.01	0.22	0.07	0.00	0.00	0.01	0.62
1966	0.01	0.02	0.01	0.02	0.01	0.17	0.14	0.03	0.00	0.01	0.01	0.00	0.43
1967	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.02	0.15
1968	0.02	0.15	0.06	0.00	0.12	0.00	0.00	0.14	0.05	0.01	0.01	0.01	0.57
1969	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.02	0.02	0.20	0.07	0.40
1970	0.11	0.12	0.04	0.01	0.01	0.01	0.01	0.18	0.06	0.01	0.11	0.04	0.71
1971	0.11	0.05	0.01	0.00	0.18	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.43
1972	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.02	0.16
1973	0.02	0.17	0.06	0.01	0.01	0.02	0.01	0.16	0.06	0.00	0.00	0.01	0.53
1974	0.00	0.02	0.02	0.01	0.01	0.02	0.02	0.00	0.00	0.01	0.01	0.21	0.33
1975	0.07	0.00	0.15	0.06	0.15	0.16	0.04	0.09	0.03	0.00	0.00	0.01	0.76
1976	0.18	0.07	0.01	0.01	0.18	0.06	0.01	0.00	0.01	0.01	0.01	0.02	0.57
1977	0.02	0.17	0.16	0.04	0.00	0.01	0.18	0.07	0.00	0.00	0.01	0.01	0.67
1978	0.17	0.09	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.36
1979	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.20	0.33
1980	0.07	0.12	0.05	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.33
1981	0.01	0.02	0.01	0.02	0.01	0.23	0.08	0.00	0.00	0.01	0.01	0.01	0.41
1982	0.02	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.12	0.04	0.01	0.26
1983	0.01	0.14	0.05	0.07	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.01	0.34
1984	0.01	0.16	0.06	0.01	0.16	0.06	0.01	0.00	0.01	0.00	0.00	0.00	0.48
1985	0.02	0.19	0.07	0.13	0.04	0.00	0.01	0.00	0.01	0.00	0.01	0.02	0.50
1986	0.17	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.21	0.52
1987	0.07	0.11	0.04	0.01	0.18	0.16	0.04	0.11	0.04	0.01	0.00	0.01	0.78
1988	0.01	0.15	0.15	0.03	0.17	0.07	0.12	0.04	0.00	0.01	0.00	0.00	0.75
1989	0.19	0.16	0.03	0.01	0.01	0.20	0.06	0.00	0.01	0.00	0.01	0.01	0.69
1990	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.10
1991	0.20	0.16	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.47
1992	0.02	0.02	0.01	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.12
1993	0.02	0.02	0.16	0.06	0.16	0.05	0.00	0.01	0.00	0.01	0.01	0.01	0.51
1994	0.01	0.01	0.07	0.01	0.00	0.15	0.14	0.04	0.01	0.01	0.00	0.01	0.46
1995	0.01	0.01	0.18	0.06	0.12	0.04	0.00	0.00	0.01	0.02	0.02	0.01	0.48
1996	0.02	0.17	0.06	0.01	0.14	0.05	0.13	0.04	0.12	0.04	0.00	0.01	0.79
month	3.62	6.09	4.29	2.86	4.36	4.45	2.85	2.36	1.77	1.34	1.00	2.16	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
max	0.22	0.21	0.19	0.21	0.25	0.23	0.18	0.22	0.25	0.18	0.20	0.21	1.05
median	0.02	0.05	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.48
mean	0.05	0.08	0.06	0.04	0.06	0.06	0.04	0.03	0.02	0.02	0.01	0.03	0.48
Sum of the monthly means =				0.48									
s.d.	0.06	0.07	0.06	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.05	0.21
c.v.	1.32	0.88	1.04	1.37	1.26	1.15	1.31	1.73	1.96	1.95	2.05	1.93	0.43

APPENDIX 13.3
XURA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.01	0.20	0.07	0.01	0.16	0.05	0.01	0.00	0.00	0.00	0.01	0.52
1921	0.02	0.23	0.20	0.05	0.00	0.00	0.00	0.25	0.15	0.02	0.01	0.01	0.94
1922	0.16	0.16	0.04	0.17	0.18	0.16	0.04	0.00	0.01	0.22	0.07	0.00	1.21
1923	0.01	0.01	0.02	0.23	0.20	0.04	0.01	0.00	0.00	0.01	0.01	0.01	0.55
1924	0.02	0.02	0.19	0.07	0.01	0.19	0.07	0.00	0.00	0.01	0.00	0.01	0.59
1925	0.01	0.02	0.02	0.02	0.02	0.18	0.06	0.00	0.01	0.01	0.01	0.01	0.37
1926	0.02	0.18	0.16	0.04	0.01	0.20	0.07	0.00	0.00	0.00	0.00	0.00	0.68
1927	0.02	0.01	0.02	0.02	0.18	0.06	0.01	0.00	0.00	0.01	0.01	0.01	0.35
1928	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.22	0.14	0.02	0.12	0.63
1929	0.13	0.14	0.04	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.19	0.62
1930	0.06	0.01	0.02	0.20	0.19	0.16	0.04	0.01	0.00	0.01	0.00	0.00	0.70
1931	0.01	0.01	0.01	0.01	0.24	0.09	0.00	0.01	0.01	0.01	0.01	0.21	0.62
1932	0.16	0.14	0.16	0.04	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.59
1933	0.01	0.25	0.21	0.18	0.05	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.77
1934	0.01	0.02	0.21	0.07	0.01	0.01	0.20	0.16	0.13	0.04	0.00	0.01	0.87
1935	0.00	0.01	0.00	0.01	0.28	0.21	0.04	0.14	0.05	0.00	0.00	0.01	0.75
1936	0.02	0.19	0.07	0.00	0.21	0.18	0.04	0.00	0.00	0.00	0.01	0.01	0.73
1937	0.01	0.02	0.03	0.03	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.19
1938	0.01	0.02	0.03	0.02	0.18	0.06	0.01	0.01	0.01	0.01	0.01	0.21	0.58
1939	0.15	0.03	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.00	0.31
1940	0.01	0.03	0.02	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.12
1941	0.02	0.02	0.01	0.24	0.09	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.46
1942	0.02	0.22	0.18	0.04	0.01	0.02	0.18	0.06	0.00	0.01	0.01	0.01	0.76
1943	0.01	0.14	0.16	0.04	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.23	0.62
1944	0.08	0.00	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.20
1945	0.25	0.08	0.00	0.01	0.02	0.22	0.08	0.00	0.01	0.00	0.00	0.00	0.67
1946	0.01	0.22	0.08	0.01	0.01	0.18	0.17	0.04	0.13	0.04	0.01	0.00	0.90
1947	0.00	0.21	0.05	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.28
1948	0.02	0.02	0.01	0.01	0.23	0.18	0.04	0.01	0.01	0.00	0.00	0.01	0.54
1949	0.01	0.24	0.08	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.44
1950	0.01	0.02	0.22	0.08	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.39
1951	0.23	0.08	0.17	0.07	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.62
1952	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.00	0.01	0.01	0.14
1953	0.02	0.19	0.17	0.04	0.01	0.01	0.02	0.01	0.01	0.02	0.00	0.01	0.51
1954	0.22	0.08	0.01	0.19	0.19	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.74
1955	0.01	0.02	0.01	0.00	0.02	0.27	0.09	0.00	0.00	0.00	0.00	0.01	0.43
1956	0.02	0.19	0.18	0.05	0.01	0.16	0.16	0.04	0.01	0.01	0.00	0.01	0.84
1957	0.02	0.15	0.05	0.13	0.18	0.05	0.14	0.05	0.00	0.00	0.00	0.01	0.78
1958	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.22	0.07	0.01	0.01	0.01	0.44
1959	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.18
1960	0.01	0.00	0.00	0.00	0.01	0.02	0.17	0.06	0.00	0.00	0.01	0.01	0.29
1961	0.01	0.22	0.07	0.01	0.02	0.18	0.06	0.00	0.01	0.00	0.01	0.01	0.60
1962	0.02	0.21	0.07	0.17	0.06	0.17	0.06	0.01	0.00	0.19	0.07	0.00	1.03
1963	0.02	0.16	0.06	0.16	0.17	0.04	0.12	0.04	0.14	0.05	0.00	0.01	0.97
1964	0.18	0.06	0.00	0.01	0.01	0.01	0.00	0.01	0.28	0.10	0.01	0.01	0.68
1965	0.14	0.15	0.04	0.01	0.01	0.01	0.00	0.25	0.08	0.00	0.00	0.01	0.70
1966	0.01	0.01	0.01	0.02	0.02	0.19	0.17	0.03	0.00	0.01	0.01	0.01	0.49
1967	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.02	0.13
1968	0.03	0.18	0.06	0.00	0.20	0.18	0.04	0.15	0.06	0.01	0.00	0.01	0.92
1969	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.23	0.08	0.44
1970	0.12	0.14	0.03	0.01	0.02	0.01	0.02	0.21	0.07	0.00	0.13	0.04	0.80
1971	0.13	0.04	0.01	0.01	0.20	0.07	0.01	0.01	0.01	0.00	0.01	0.01	0.51
1972	0.00	0.02	0.03	0.02	0.01	0.01	0.02	0.01	0.01	0.00	0.01	0.02	0.16
1973	0.02	0.20	0.07	0.01	0.01	0.02	0.01	0.19	0.07	0.00	0.01	0.00	0.61
1974	0.01	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.24	0.40
1975	0.09	0.01	0.18	0.06	0.17	0.18	0.05	0.11	0.04	0.00	0.00	0.01	0.90
1976	0.21	0.07	0.00	0.01	0.20	0.07	0.01	0.00	0.01	0.00	0.01	0.02	0.61
1977	0.03	0.19	0.19	0.04	0.01	0.01	0.21	0.07	0.00	0.01	0.00	0.01	0.77
1978	0.20	0.15	0.04	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.53
1979	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.23	0.34
1980	0.08	0.14	0.05	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.36
1981	0.01	0.01	0.02	0.02	0.02	0.26	0.09	0.00	0.01	0.01	0.01	0.00	0.46
1982	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.10
1983	0.01	0.16	0.06	0.14	0.05	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.52
1984	0.01	0.19	0.07	0.01	0.18	0.06	0.00	0.01	0.01	0.00	0.00	0.00	0.54
1985	0.02	0.22	0.07	0.15	0.05	0.01	0.01	0.00	0.01	0.00	0.01	0.02	0.57
1986	0.19	0.07	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.24	0.60
1987	0.08	0.13	0.05	0.01	0.21	0.20	0.04	0.13	0.04	0.00	0.01	0.00	0.90
1988	0.01	0.17	0.17	0.04	0.21	0.08	0.13	0.05	0.00	0.00	0.00	0.00	0.86
1989	0.22	0.18	0.04	0.01	0.01	0.23	0.07	0.01	0.00	0.00	0.01	0.01	0.79
1990	0.02	0.02	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.13
1991	0.23	0.19	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.53
1992	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.13
1993	0.03	0.03	0.18	0.07	0.18	0.06	0.00	0.01	0.00	0.01	0.01	0.01	0.59
1994	0.01	0.01	0.24	0.08	0.00	0.21	0.18	0.04	0.01	0.01	0.00	0.00	0.79
1995	0.01	0.02	0.21	0.08	0.14	0.05	0.00	0.01	0.00	0.02	0.02	0.01	0.57
1996	0.02	0.19	0.07	0.01	0.17	0.06	0.15	0.06	0.15	0.05	0.00	0.00	0.93
month	4.09	7.10	5.37	3.57	5.20	5.64	3.46	2.79	2.04	1.26	0.98	2.38	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
max	0.25	0.25	0.24	0.24	0.28	0.27	0.21	0.25	0.28	0.22	0.23	0.24	1.21
median	0.02	0.06	0.04	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.59
mean	0.05	0.09	0.07	0.05	0.07	0.07	0.04	0.04	0.03	0.02	0.01	0.03	0.57
Sum of the monthly means =				0.57									
s.d.	0.07	0.08	0.07	0.06	0.08	0.08	0.06	0.06	0.05	0.04	0.03	0.06	0.25
c.v.	1.34	0.90	1.04	1.28	1.24	1.09	1.28	1.68	1.96	2.30	2.43	2.04	0.43

APPENDIX 13.4
TUNGWANA DAM

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.01	0.03	0.02	0.03	0.19	0.07	0.01	0.00	0.00	0.00	0.00	0.36
1921	0.01	0.25	0.22	0.05	0.00	0.01	0.01	0.26	0.17	0.02	0.00	0.01	1.01
1922	0.16	0.18	0.05	0.10	0.17	0.18	0.04	0.00	0.00	0.21	0.07	0.01	1.17
1923	0.00	0.01	0.01	0.27	0.22	0.05	0.01	0.01	0.01	0.01	0.01	0.02	0.63
1924	0.02	0.02	0.02	0.02	0.02	0.20	0.07	0.00	0.01	0.01	0.00	0.01	0.40
1925	0.02	0.02	0.02	0.02	0.03	0.21	0.07	0.01	0.01	0.01	0.01	0.01	0.44
1926	0.02	0.18	0.06	0.00	0.01	0.22	0.07	0.00	0.00	0.00	0.00	0.01	0.57
1927	0.02	0.02	0.02	0.02	0.21	0.07	0.00	0.00	0.01	0.01	0.01	0.01	0.40
1928	0.01	0.02	0.02	0.02	0.02	0.23	0.08	0.00	0.10	0.10	0.02	0.13	0.75
1929	0.15	0.16	0.04	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.18	0.67
1930	0.06	0.01	0.02	0.24	0.22	0.17	0.04	0.00	0.00	0.07	0.02	0.00	0.85
1931	0.01	0.02	0.02	0.02	0.28	0.10	0.01	0.01	0.01	0.01	0.01	0.20	0.70
1932	0.11	0.00	0.02	0.03	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.26
1933	0.01	0.26	0.23	0.20	0.06	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.84
1934	0.01	0.02	0.23	0.08	0.01	0.01	0.21	0.17	0.13	0.03	0.01	0.00	0.91
1935	0.01	0.01	0.00	0.01	0.32	0.23	0.04	0.16	0.06	0.00	0.00	0.00	0.84
1936	0.01	0.00	0.00	0.01	0.24	0.20	0.05	0.00	0.01	0.00	0.01	0.01	0.54
1937	0.01	0.01	0.03	0.02	0.02	0.01	0.03	0.02	0.01	0.01	0.01	0.00	0.18
1938	0.01	0.02	0.02	0.02	0.21	0.07	0.01	0.01	0.01	0.01	0.02	0.17	0.58
1939	0.15	0.03	0.01	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.26
1940	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.15
1941	0.02	0.02	0.01	0.28	0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.50
1942	0.01	0.23	0.21	0.05	0.00	0.20	0.17	0.03	0.00	0.01	0.15	0.05	1.11
1943	0.01	0.15	0.06	0.01	0.18	0.06	0.01	0.00	0.01	0.00	0.01	0.23	0.73
1944	0.08	0.01	0.01	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.23
1945	0.26	0.08	0.00	0.01	0.02	0.25	0.09	0.01	0.00	0.00	0.00	0.01	0.73
1946	0.02	0.02	0.02	0.01	0.02	0.22	0.12	0.01	0.12	0.04	0.01	0.00	0.61
1947	0.00	0.22	0.08	0.01	0.19	0.18	0.04	0.01	0.00	0.00	0.00	0.00	0.73
1948	0.02	0.02	0.01	0.01	0.26	0.20	0.04	0.01	0.00	0.00	0.00	0.01	0.58
1949	0.02	0.24	0.08	0.02	0.01	0.01	0.02	0.13	0.04	0.00	0.01	0.00	0.58
1950	0.01	0.01	0.23	0.09	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.44
1951	0.22	0.08	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.41
1952	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.17
1953	0.02	0.20	0.19	0.05	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.57
1954	0.21	0.07	0.01	0.22	0.21	0.16	0.04	0.00	0.00	0.00	0.00	0.01	0.93
1955	0.02	0.02	0.01	0.01	0.02	0.28	0.10	0.00	0.00	0.00	0.01	0.01	0.48
1956	0.02	0.20	0.20	0.06	0.02	0.09	0.13	0.04	0.00	0.00	0.00	0.02	0.78
1957	0.02	0.02	0.02	0.17	0.18	0.05	0.14	0.04	0.00	0.00	0.00	0.01	0.65
1958	0.01	0.03	0.02	0.01	0.02	0.02	0.02	0.23	0.08	0.01	0.01	0.01	0.47
1959	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.18
1960	0.01	0.02	0.19	0.07	0.01	0.01	0.17	0.07	0.00	0.00	0.00	0.01	0.56
1961	0.01	0.21	0.08	0.01	0.02	0.20	0.06	0.01	0.01	0.01	0.01	0.01	0.64
1962	0.03	0.21	0.07	0.19	0.07	0.18	0.06	0.01	0.01	0.19	0.06	0.00	1.08
1963	0.01	0.02	0.02	0.20	0.19	0.15	0.15	0.04	0.15	0.05	0.00	0.01	0.99
1964	0.18	0.06	0.01	0.01	0.02	0.01	0.00	0.02	0.28	0.10	0.09	0.03	0.81
1965	0.14	0.17	0.04	0.01	0.01	0.01	0.00	0.28	0.10	0.00	0.00	0.01	0.77
1966	0.02	0.01	0.02	0.02	0.02	0.21	0.18	0.04	0.00	0.13	0.04	0.00	0.69
1967	0.00	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.03	0.18
1968	0.02	0.02	0.02	0.01	0.23	0.20	0.04	0.15	0.06	0.00	0.01	0.00	0.76
1969	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.23	0.08	0.48
1970	0.13	0.09	0.00	0.00	0.00	0.01	0.01	0.19	0.06	0.11	0.12	0.04	0.76
1971	0.14	0.06	0.01	0.01	0.24	0.09	0.01	0.01	0.01	0.01	0.00	0.01	0.60
1972	0.01	0.02	0.03	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.13
1973	0.02	0.18	0.06	0.01	0.02	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.33
1974	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.00	0.01	0.00	0.25	0.41
1975	0.09	0.01	0.20	0.07	0.19	0.19	0.14	0.13	0.03	0.00	0.01	0.01	1.07
1976	0.21	0.07	0.00	0.01	0.24	0.09	0.00	0.01	0.01	0.01	0.01	0.02	0.68
1977	0.02	0.20	0.20	0.06	0.01	0.01	0.12	0.10	0.02	0.00	0.00	0.01	0.75
1978	0.19	0.07	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.43
1979	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.24	0.41
1980	0.09	0.16	0.06	0.01	0.02	0.01	0.00	0.01	0.02	0.02	0.01	0.02	0.43
1981	0.01	0.01	0.01	0.02	0.02	0.29	0.10	0.00	0.01	0.01	0.00	0.00	0.48
1982	0.02	0.02	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.07	0.03	0.01	0.22
1983	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.15	0.05	0.01	0.37
1984	0.01	0.20	0.07	0.01	0.21	0.07	0.01	0.00	0.00	0.01	0.00	0.01	0.60
1985	0.02	0.22	0.08	0.17	0.06	0.01	0.01	0.01	0.01	0.00	0.02	0.09	0.70
1986	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.24	0.33
1987	0.08	0.14	0.05	0.01	0.23	0.21	0.04	0.13	0.05	0.09	0.04	0.00	1.07
1988	0.00	0.12	0.18	0.04	0.23	0.08	0.14	0.05	0.00	0.00	0.00	0.00	0.84
1989	0.22	0.20	0.04	0.01	0.02	0.25	0.08	0.01	0.01	0.00	0.01	0.01	0.86
1990	0.02	0.01	0.01	0.02	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.16
1991	0.23	0.20	0.05	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.57
1992	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.16
1993	0.02	0.02	0.19	0.06	0.20	0.07	0.01	0.00	0.00	0.01	0.01	0.02	0.61
1994	0.01	0.01	0.03	0.02	0.01	0.25	0.21	0.04	0.11	0.04	0.00	0.00	0.73
1995	0.01	0.02	0.23	0.08	0.16	0.05	0.00	0.01	0.01	0.20	0.07	0.00	0.84
1996	0.01	0.19	0.07	0.01	0.19	0.07	0.14	0.05	0.14	0.11	0.02	0.00	1.00
month	3.86	5.97	4.46	3.55	6.30	7.03	3.74	2.82	2.14	2.08	1.44	2.50	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.13
max	0.26	0.26	0.23	0.28	0.32	0.29	0.21	0.28	0.28	0.21	0.23	0.25	1.17
median	0.02	0.02	0.02	0.02	0.02	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.60
mean	0.05	0.08	0.06	0.05	0.08	0.09	0.05	0.04	0.03	0.03	0.02	0.03	0.60

Sum of the monthly means = 0.60

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
s.d.	0.07	0.08	0.07	0.07	0.09	0.09	0.06	0.06	0.05	0.05	0.04	0.06	0.26
c.v.	1.38	1.08	1.23	1.45	1.16	0.99	1.14	1.70	1.76	1.79	1.91	1.92	0.44

APPENDIX 14

AFFORESTATION RUNOFF REDUCTION FOR PROPOSED DAM (2030)

APPENDIX 14.1
XURA DAM (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.01	0.20	0.07	0.01	0.16	0.05	0.01	0.00	0.00	0.00	0.01	0.52
1921	0.02	0.23	0.20	0.05	0.00	0.00	0.00	0.25	0.15	0.02	0.01	0.01	0.94
1922	0.16	0.16	0.04	0.17	0.18	0.16	0.04	0.00	0.01	0.22	0.07	0.00	1.21
1923	0.01	0.01	0.02	0.23	0.20	0.04	0.01	0.00	0.00	0.01	0.01	0.01	0.55
1924	0.02	0.02	0.19	0.07	0.01	0.19	0.07	0.00	0.00	0.01	0.00	0.01	0.59
1925	0.01	0.02	0.02	0.02	0.02	0.18	0.06	0.00	0.01	0.01	0.01	0.01	0.37
1926	0.02	0.18	0.16	0.04	0.01	0.20	0.07	0.00	0.00	0.00	0.00	0.00	0.68
1927	0.02	0.01	0.02	0.02	0.18	0.06	0.01	0.00	0.00	0.01	0.01	0.01	0.35
1928	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.22	0.14	0.02	0.12	0.63
1929	0.13	0.14	0.04	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.02	0.19	0.62
1930	0.06	0.01	0.02	0.20	0.19	0.16	0.04	0.01	0.00	0.01	0.00	0.00	0.70
1931	0.01	0.01	0.01	0.01	0.24	0.09	0.00	0.01	0.01	0.01	0.01	0.21	0.62
1932	0.16	0.14	0.16	0.04	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.59
1933	0.01	0.25	0.21	0.18	0.05	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.77
1934	0.01	0.02	0.21	0.07	0.01	0.01	0.20	0.16	0.13	0.04	0.00	0.01	0.87
1935	0.00	0.01	0.00	0.01	0.28	0.21	0.04	0.14	0.05	0.00	0.00	0.01	0.75
1936	0.02	0.19	0.07	0.00	0.21	0.18	0.04	0.00	0.00	0.00	0.01	0.01	0.73
1937	0.01	0.02	0.03	0.03	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.19
1938	0.01	0.02	0.03	0.02	0.18	0.06	0.01	0.01	0.01	0.01	0.01	0.21	0.58
1939	0.15	0.03	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.01	0.00	0.31
1940	0.01	0.03	0.02	0.01	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.12
1941	0.02	0.02	0.01	0.24	0.09	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.46
1942	0.02	0.22	0.18	0.04	0.01	0.02	0.18	0.06	0.00	0.01	0.01	0.01	0.76
1943	0.01	0.14	0.16	0.04	0.01	0.01	0.00	0.01	0.00	0.01	0.00	0.23	0.62
1944	0.08	0.00	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.20
1945	0.25	0.08	0.00	0.01	0.02	0.22	0.08	0.00	0.01	0.00	0.00	0.00	0.67
1946	0.01	0.22	0.08	0.01	0.01	0.18	0.17	0.04	0.13	0.04	0.01	0.00	0.90
1947	0.00	0.21	0.05	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.28
1948	0.02	0.02	0.01	0.01	0.23	0.18	0.04	0.01	0.01	0.00	0.00	0.01	0.54
1949	0.01	0.24	0.08	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.44
1950	0.01	0.02	0.22	0.08	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.39
1951	0.23	0.08	0.17	0.07	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.62
1952	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.00	0.01	0.01	0.14
1953	0.02	0.19	0.17	0.04	0.01	0.01	0.02	0.01	0.01	0.02	0.00	0.01	0.51
1954	0.22	0.08	0.01	0.19	0.19	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.74
1955	0.01	0.02	0.01	0.00	0.02	0.27	0.09	0.00	0.00	0.00	0.00	0.01	0.43
1956	0.02	0.19	0.18	0.05	0.01	0.16	0.16	0.04	0.01	0.01	0.00	0.01	0.84
1957	0.02	0.15	0.05	0.13	0.18	0.05	0.14	0.05	0.00	0.00	0.00	0.01	0.78
1958	0.01	0.02	0.02	0.01	0.02	0.02	0.02	0.22	0.07	0.01	0.01	0.01	0.44
1959	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.18
1960	0.01	0.00	0.00	0.00	0.01	0.02	0.17	0.06	0.00	0.00	0.01	0.01	0.29
1961	0.01	0.22	0.07	0.01	0.02	0.18	0.06	0.00	0.01	0.00	0.01	0.01	0.60
1962	0.02	0.21	0.07	0.17	0.06	0.17	0.06	0.01	0.00	0.19	0.07	0.00	1.03
1963	0.02	0.16	0.06	0.16	0.17	0.04	0.12	0.04	0.14	0.05	0.00	0.01	0.97
1964	0.18	0.06	0.00	0.01	0.01	0.01	0.00	0.01	0.28	0.10	0.01	0.01	0.68
1965	0.14	0.15	0.04	0.01	0.01	0.01	0.00	0.25	0.08	0.00	0.00	0.01	0.70
1966	0.01	0.01	0.01	0.02	0.02	0.19	0.17	0.03	0.00	0.01	0.01	0.01	0.49
1967	0.01	0.02	0.01	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.00	0.02	0.13
1968	0.03	0.18	0.06	0.00	0.20	0.18	0.04	0.15	0.06	0.01	0.00	0.01	0.92
1969	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.23	0.08	0.44
1970	0.12	0.14	0.03	0.01	0.02	0.01	0.02	0.21	0.07	0.00	0.13	0.04	0.80
1971	0.13	0.04	0.01	0.01	0.20	0.07	0.01	0.01	0.01	0.00	0.01	0.01	0.51
1972	0.00	0.02	0.03	0.02	0.01	0.01	0.02	0.01	0.01	0.00	0.01	0.02	0.16
1973	0.02	0.20	0.07	0.01	0.01	0.02	0.01	0.19	0.07	0.00	0.01	0.00	0.61
1974	0.01	0.02	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.24	0.40
1975	0.09	0.01	0.18	0.06	0.17	0.18	0.05	0.11	0.04	0.00	0.00	0.01	0.90
1976	0.21	0.07	0.00	0.01	0.20	0.07	0.01	0.00	0.01	0.00	0.01	0.02	0.61
1977	0.03	0.19	0.19	0.04	0.01	0.01	0.21	0.07	0.00	0.01	0.00	0.01	0.77
1978	0.20	0.15	0.04	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.02	0.02	0.53
1979	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.00	0.23	0.34
1980	0.08	0.14	0.05	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.36
1981	0.01	0.01	0.02	0.02	0.02	0.26	0.09	0.00	0.01	0.01	0.01	0.00	0.46
1982	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.10
1983	0.01	0.16	0.06	0.14	0.05	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.52
1984	0.01	0.19	0.07	0.01	0.18	0.06	0.00	0.01	0.01	0.00	0.00	0.00	0.54
1985	0.02	0.22	0.07	0.15	0.05	0.01	0.01	0.00	0.01	0.00	0.01	0.02	0.57
1986	0.19	0.07	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.24	0.60
1987	0.08	0.13	0.05	0.01	0.21	0.20	0.04	0.13	0.04	0.00	0.01	0.00	0.90
1988	0.01	0.17	0.17	0.04	0.21	0.08	0.13	0.05	0.00	0.00	0.00	0.00	0.86
1989	0.22	0.18	0.04	0.01	0.01	0.23	0.07	0.01	0.00	0.00	0.01	0.01	0.79
1990	0.02	0.02	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.13
1991	0.23	0.19	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.53
1992	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.02	0.13
1993	0.03	0.03	0.18	0.07	0.18	0.06	0.00	0.01	0.00	0.01	0.01	0.01	0.59
1994	0.01	0.01	0.24	0.08	0.00	0.21	0.18	0.04	0.01	0.01	0.00	0.00	0.79
1995	0.01	0.02	0.21	0.08	0.14	0.05	0.00	0.01	0.00	0.02	0.02	0.01	0.57
1996	0.02	0.19	0.07	0.01	0.17	0.06	0.15	0.06	0.15	0.05	0.00	0.00	0.93
month	4.09	7.10	5.37	3.57	5.20	5.64	3.46	2.79	2.04	1.26	0.98	2.38	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
max	0.25	0.25	0.24	0.24	0.28	0.27	0.21	0.25	0.28	0.22	0.23	0.24	1.21
median	0.02	0.06	0.04	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.59
mean	0.05	0.09	0.07	0.05	0.07	0.07	0.04	0.04	0.03	0.02	0.01	0.03	0.57

Sum of the monthly means = 0.57

s.d.	0.07	0.08	0.07	0.06	0.08	0.08	0.06	0.06	0.05	0.04	0.03	0.06	0.25
c.v.	1.34	0.90	1.04	1.28	1.24	1.09	1.28	1.68	1.96	2.30	2.43	2.04	0.43

APPENDIX 14.2
LUSIKISIKI DAM (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.01	0.09	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.14
1921	0.01	0.20	0.17	0.04	0.00	0.01	0.01	0.22	0.14	0.02	0.01	0.01	0.84
1922	0.14	0.14	0.04	0.15	0.16	0.13	0.04	0.00	0.00	0.19	0.07	0.00	1.06
1923	0.00	0.01	0.01	0.20	0.17	0.04	0.00	0.00	0.00	0.00	0.00	0.01	0.44
1924	0.02	0.03	0.17	0.05	0.01	0.16	0.06	0.00	0.01	0.01	0.01	0.01	0.54
1925	0.02	0.02	0.02	0.01	0.02	0.16	0.05	0.00	0.01	0.01	0.01	0.01	0.34
1926	0.02	0.17	0.10	0.00	0.00	0.12	0.04	0.00	0.00	0.00	0.00	0.01	0.46
1927	0.02	0.02	0.02	0.02	0.09	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.19
1928	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.19	0.12	0.02	0.11	0.55
1929	0.12	0.12	0.04	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.01	0.16	0.55
1930	0.06	0.01	0.01	0.18	0.16	0.14	0.04	0.00	0.00	0.07	0.03	0.00	0.70
1931	0.01	0.01	0.02	0.01	0.20	0.08	0.00	0.01	0.01	0.01	0.01	0.18	0.55
1932	0.13	0.12	0.14	0.04	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.00	0.49
1933	0.01	0.22	0.18	0.15	0.05	0.01	0.01	0.01	0.00	0.01	0.02	0.01	0.68
1934	0.01	0.02	0.19	0.07	0.01	0.01	0.18	0.14	0.11	0.03	0.00	0.00	0.77
1935	0.01	0.01	0.00	0.01	0.24	0.18	0.03	0.13	0.05	0.00	0.00	0.01	0.67
1936	0.02	0.17	0.06	0.01	0.18	0.15	0.04	0.00	0.00	0.00	0.01	0.01	0.65
1937	0.01	0.01	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.15
1938	0.01	0.01	0.02	0.02	0.16	0.05	0.00	0.01	0.00	0.01	0.01	0.18	0.48
1939	0.13	0.03	0.01	0.00	0.00	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.26
1940	0.01	0.02	0.02	0.02	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.11
1941	0.01	0.02	0.01	0.21	0.07	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.38
1942	0.01	0.20	0.12	0.02	0.01	0.01	0.16	0.06	0.00	0.01	0.02	0.01	0.63
1943	0.02	0.12	0.14	0.03	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.20	0.56
1944	0.07	0.00	0.00	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.17
1945	0.22	0.08	0.00	0.01	0.01	0.19	0.06	0.00	0.00	0.01	0.00	0.00	0.58
1946	0.01	0.09	0.01	0.00	0.00	0.13	0.14	0.03	0.10	0.04	0.00	0.01	0.56
1947	0.01	0.19	0.06	0.00	0.06	0.03	0.01	0.00	0.00	0.00	0.00	0.01	0.37
1948	0.02	0.02	0.01	0.02	0.20	0.16	0.03	0.00	0.00	0.00	0.00	0.01	0.47
1949	0.01	0.20	0.07	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.39
1950	0.01	0.01	0.19	0.07	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.34
1951	0.20	0.07	0.14	0.05	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.52
1952	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01	0.01	0.00	0.00	0.01	0.13
1953	0.02	0.17	0.15	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.46
1954	0.20	0.07	0.01	0.17	0.16	0.05	0.00	0.00	0.00	0.00	0.00	0.01	0.67
1955	0.01	0.02	0.01	0.01	0.01	0.24	0.08	0.01	0.00	0.00	0.00	0.01	0.40
1956	0.02	0.17	0.16	0.05	0.01	0.13	0.14	0.04	0.00	0.00	0.01	0.01	0.74
1957	0.01	0.14	0.04	0.12	0.15	0.05	0.11	0.04	0.01	0.00	0.00	0.01	0.68
1958	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.20	0.06	0.00	0.00	0.01	0.39
1959	0.01	0.02	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.01	0.01	0.15
1960	0.01	0.00	0.00	0.00	0.01	0.01	0.16	0.06	0.00	0.01	0.01	0.00	0.27
1961	0.01	0.19	0.07	0.00	0.02	0.15	0.05	0.00	0.01	0.00	0.00	0.01	0.51
1962	0.02	0.18	0.06	0.14	0.06	0.15	0.05	0.00	0.01	0.16	0.06	0.00	0.89
1963	0.01	0.14	0.05	0.13	0.15	0.04	0.10	0.03	0.12	0.04	0.00	0.00	0.81
1964	0.16	0.06	0.00	0.01	0.01	0.01	0.01	0.01	0.25	0.09	0.00	0.01	0.62
1965	0.12	0.14	0.03	0.01	0.01	0.00	0.00	0.23	0.07	0.00	0.01	0.00	0.62
1966	0.01	0.01	0.02	0.02	0.02	0.17	0.15	0.03	0.00	0.01	0.01	0.01	0.46
1967	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.13
1968	0.02	0.15	0.05	0.00	0.17	0.11	0.02	0.13	0.04	0.00	0.00	0.00	0.69
1969	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.20	0.07	0.39
1970	0.10	0.12	0.03	0.01	0.01	0.01	0.02	0.18	0.06	0.00	0.11	0.03	0.68
1971	0.11	0.04	0.01	0.01	0.18	0.06	0.00	0.01	0.00	0.01	0.01	0.01	0.45
1972	0.01	0.02	0.02	0.01	0.01	0.01	0.02	0.01	0.00	0.01	0.01	0.01	0.14
1973	0.02	0.17	0.06	0.00	0.02	0.02	0.01	0.16	0.05	0.00	0.00	0.00	0.51
1974	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.21	0.34
1975	0.07	0.01	0.15	0.05	0.15	0.15	0.04	0.09	0.03	0.00	0.00	0.01	0.75
1976	0.18	0.06	0.01	0.01	0.18	0.06	0.01	0.01	0.00	0.00	0.01	0.02	0.55
1977	0.02	0.17	0.16	0.05	0.01	0.01	0.18	0.06	0.00	0.00	0.01	0.01	0.68
1978	0.17	0.10	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.01	0.02	0.02	0.36
1979	0.02	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.21	0.33
1980	0.07	0.12	0.05	0.01	0.01	0.00	0.00	0.01	0.02	0.01	0.01	0.02	0.33
1981	0.01	0.01	0.01	0.01	0.01	0.22	0.08	0.01	0.00	0.00	0.00	0.00	0.36
1982	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.08	0.03	0.00	0.21
1983	0.01	0.14	0.05	0.12	0.04	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.44
1984	0.01	0.17	0.06	0.01	0.16	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.46
1985	0.02	0.19	0.06	0.14	0.05	0.01	0.01	0.00	0.01	0.00	0.01	0.02	0.52
1986	0.16	0.06	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.21	0.53
1987	0.07	0.11	0.04	0.01	0.17	0.17	0.04	0.11	0.04	0.01	0.00	0.00	0.77
1988	0.01	0.14	0.15	0.04	0.18	0.06	0.12	0.04	0.00	0.00	0.00	0.01	0.75
1989	0.18	0.15	0.04	0.01	0.01	0.20	0.07	0.00	0.01	0.00	0.01	0.01	0.69
1990	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.00	0.01	0.01	0.00	0.01	0.15
1991	0.20	0.16	0.04	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.44
1992	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.00	0.02	0.11
1993	0.03	0.03	0.16	0.06	0.16	0.06	0.01	0.00	0.01	0.01	0.01	0.01	0.55
1994	0.01	0.00	0.08	0.00	0.00	0.14	0.14	0.04	0.01	0.00	0.00	0.00	0.42
1995	0.01	0.01	0.18	0.07	0.12	0.05	0.00	0.01	0.00	0.02	0.02	0.01	0.50
1996	0.01	0.18	0.06	0.02	0.14	0.05	0.13	0.04	0.13	0.05	0.00	0.01	0.82
month	3.59	6.15	4.32	2.95	4.47	4.57	2.96	2.41	1.79	1.22	0.92	2.09	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11
max	0.22	0.22	0.19	0.21	0.24	0.24	0.18	0.23	0.25	0.19	0.20	0.21	1.06
median	0.02	0.06	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.49
mean	0.05	0.08	0.06	0.04	0.06	0.06	0.04	0.03	0.02	0.02	0.01	0.03	0.49
Sum of the monthly means =				0.49									
s.d.	0.06	0.07	0.06	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.06	0.21
c.v.	1.31	0.89	1.04	1.37	1.22	1.11	1.29	1.73	1.94	2.14	2.28	2.03	0.43

APPENDIX 14.3
ZALU DAM (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.02	0.08	0.01	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.01	0.15
1921	0.02	0.20	0.17	0.03	0.01	0.01	0.01	0.21	0.14	0.02	0.00	0.01	0.83
1922	0.14	0.14	0.03	0.15	0.16	0.14	0.04	0.00	0.01	0.18	0.06	0.00	1.05
1923	0.00	0.01	0.02	0.20	0.17	0.03	0.00	0.01	0.00	0.00	0.00	0.02	0.46
1924	0.02	0.02	0.17	0.06	0.01	0.16	0.06	0.00	0.00	0.01	0.01	0.01	0.53
1925	0.01	0.02	0.01	0.01	0.02	0.16	0.05	0.00	0.01	0.01	0.01	0.01	0.32
1926	0.02	0.16	0.09	0.00	0.00	0.13	0.05	0.00	0.00	0.00	0.01	0.01	0.47
1927	0.02	0.02	0.01	0.02	0.07	0.01	0.00	0.00	0.00	0.00	0.01	0.01	0.17
1928	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.19	0.12	0.03	0.10	0.56
1929	0.12	0.12	0.03	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.16	0.52
1930	0.05	0.01	0.01	0.17	0.16	0.14	0.03	0.00	0.01	0.08	0.02	0.00	0.68
1931	0.01	0.01	0.02	0.01	0.21	0.07	0.01	0.01	0.01	0.01	0.01	0.19	0.57
1932	0.13	0.12	0.13	0.04	0.01	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.47
1933	0.00	0.21	0.18	0.15	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.64
1934	0.00	0.02	0.19	0.06	0.00	0.02	0.17	0.14	0.10	0.02	0.01	0.00	0.73
1935	0.00	0.01	0.01	0.01	0.25	0.19	0.04	0.12	0.04	0.00	0.00	0.01	0.68
1936	0.01	0.17	0.06	0.01	0.18	0.16	0.04	0.01	0.00	0.00	0.00	0.01	0.65
1937	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.15
1938	0.01	0.02	0.02	0.02	0.16	0.05	0.01	0.01	0.01	0.01	0.01	0.17	0.50
1939	0.14	0.03	0.01	0.01	0.00	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.29
1940	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.11
1941	0.01	0.03	0.02	0.21	0.07	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.40
1942	0.02	0.19	0.14	0.03	0.01	0.01	0.15	0.05	0.00	0.00	0.02	0.01	0.63
1943	0.02	0.13	0.13	0.04	0.01	0.01	0.00	0.00	0.00	0.01	0.00	0.20	0.55
1944	0.07	0.01	0.00	0.01	0.02	0.02	0.02	0.00	0.01	0.00	0.01	0.01	0.18
1945	0.22	0.08	0.00	0.01	0.02	0.19	0.06	0.00	0.00	0.01	0.00	0.01	0.60
1946	0.01	0.07	0.01	0.00	0.00	0.14	0.14	0.03	0.10	0.04	0.00	0.01	0.55
1947	0.00	0.18	0.06	0.00	0.08	0.03	0.00	0.00	0.01	0.00	0.00	0.01	0.37
1948	0.02	0.02	0.01	0.01	0.20	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.38
1949	0.02	0.20	0.07	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.41
1950	0.02	0.01	0.19	0.07	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.35
1951	0.20	0.06	0.14	0.05	0.00	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.49
1952	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.00	0.00	0.01	0.02	0.14
1953	0.02	0.17	0.15	0.04	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.46
1954	0.20	0.07	0.00	0.16	0.16	0.04	0.00	0.01	0.00	0.00	0.00	0.01	0.65
1955	0.02	0.02	0.01	0.01	0.01	0.23	0.07	0.00	0.00	0.01	0.01	0.01	0.40
1956	0.02	0.17	0.16	0.04	0.01	0.13	0.14	0.03	0.00	0.00	0.01	0.01	0.72
1957	0.02	0.13	0.05	0.12	0.15	0.04	0.11	0.04	0.00	0.00	0.00	0.00	0.66
1958	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.19	0.06	0.01	0.01	0.00	0.36
1959	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.14
1960	0.02	0.00	0.01	0.01	0.01	0.01	0.15	0.06	0.01	0.01	0.01	0.00	0.30
1961	0.01	0.18	0.06	0.01	0.01	0.15	0.06	0.01	0.01	0.01	0.01	0.01	0.53
1962	0.02	0.18	0.07	0.14	0.05	0.14	0.05	0.01	0.01	0.16	0.05	0.01	0.89
1963	0.01	0.14	0.05	0.14	0.15	0.04	0.10	0.04	0.13	0.04	0.00	0.01	0.85
1964	0.16	0.05	0.00	0.01	0.01	0.01	0.01	0.01	0.25	0.08	0.01	0.00	0.60
1965	0.12	0.13	0.04	0.01	0.01	0.00	0.01	0.22	0.07	0.00	0.00	0.01	0.62
1966	0.01	0.02	0.01	0.02	0.01	0.17	0.14	0.03	0.00	0.01	0.01	0.00	0.43
1967	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.01	0.01	0.02	0.15
1968	0.02	0.15	0.06	0.00	0.12	0.00	0.00	0.14	0.05	0.01	0.01	0.01	0.57
1969	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.02	0.02	0.20	0.07	0.40
1970	0.11	0.12	0.04	0.01	0.01	0.01	0.01	0.18	0.06	0.01	0.11	0.04	0.71
1971	0.11	0.05	0.01	0.00	0.18	0.06	0.01	0.00	0.00	0.00	0.00	0.01	0.43
1972	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.02	0.16
1973	0.02	0.17	0.06	0.01	0.01	0.02	0.01	0.16	0.06	0.00	0.00	0.01	0.53
1974	0.00	0.02	0.02	0.01	0.01	0.02	0.02	0.00	0.00	0.01	0.01	0.21	0.33
1975	0.07	0.00	0.15	0.06	0.15	0.16	0.04	0.09	0.03	0.00	0.00	0.01	0.76
1976	0.18	0.07	0.01	0.01	0.18	0.06	0.01	0.00	0.01	0.01	0.01	0.02	0.57
1977	0.02	0.17	0.16	0.04	0.00	0.01	0.18	0.07	0.00	0.00	0.01	0.01	0.67
1978	0.17	0.09	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.36
1979	0.02	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.20	0.33
1980	0.07	0.12	0.05	0.01	0.01	0.01	0.00	0.02	0.01	0.01	0.01	0.01	0.33
1981	0.01	0.02	0.01	0.02	0.01	0.23	0.08	0.00	0.00	0.01	0.01	0.01	0.41
1982	0.02	0.02	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.12	0.04	0.01	0.26
1983	0.01	0.14	0.05	0.07	0.00	0.00	0.00	0.01	0.01	0.02	0.02	0.01	0.34
1984	0.01	0.16	0.06	0.01	0.16	0.06	0.01	0.00	0.01	0.00	0.00	0.00	0.48
1985	0.02	0.19	0.07	0.13	0.04	0.00	0.01	0.00	0.01	0.00	0.01	0.02	0.50
1986	0.17	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.21	0.52
1987	0.07	0.11	0.04	0.01	0.18	0.16	0.04	0.11	0.04	0.01	0.00	0.01	0.78
1988	0.01	0.15	0.15	0.03	0.17	0.07	0.12	0.04	0.00	0.01	0.00	0.00	0.75
1989	0.19	0.16	0.03	0.01	0.01	0.20	0.06	0.00	0.01	0.00	0.01	0.01	0.69
1990	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.10
1991	0.20	0.16	0.03	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.47
1992	0.02	0.02	0.01	0.02	0.01	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.12
1993	0.02	0.02	0.16	0.06	0.16	0.05	0.00	0.01	0.00	0.01	0.01	0.01	0.51
1994	0.01	0.01	0.07	0.01	0.00	0.15	0.14	0.04	0.01	0.01	0.00	0.01	0.46
1995	0.01	0.01	0.18	0.06	0.12	0.04	0.00	0.00	0.01	0.02	0.02	0.01	0.48
1996	0.02	0.17	0.06	0.01	0.14	0.05	0.13	0.04	0.12	0.04	0.00	0.01	0.79
month	3.62	6.09	4.29	2.86	4.36	4.45	2.85	2.36	1.77	1.34	1.00	2.16	

Statistics Period = 77 years

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10
max	0.22	0.21	0.19	0.21	0.25	0.23	0.18	0.22	0.25	0.18	0.20	0.21	1.05
median	0.02	0.05	0.03	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.48
mean	0.05	0.08	0.06	0.04	0.06	0.06	0.04	0.03	0.02	0.02	0.01	0.03	0.48
Sum of the monthly means =				0.48									
s.d.	0.06	0.07	0.06	0.05	0.07	0.07	0.05	0.05	0.05	0.03	0.03	0.05	0.21
c.v.	1.32	0.88	1.04	1.37	1.26	1.15	1.31	1.73	1.96	1.95	2.05	1.93	0.43

APPENDIX 14.4
TUNGWANA DAM (2030)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
1920	0.00	0.01	0.03	0.02	0.03	0.19	0.07	0.01	0.00	0.00	0.00	0.00	0.36
1921	0.01	0.25	0.22	0.05	0.00	0.01	0.01	0.26	0.17	0.02	0.00	0.01	1.01
1922	0.16	0.18	0.05	0.10	0.17	0.18	0.04	0.00	0.00	0.21	0.07	0.01	1.17
1923	0.00	0.01	0.01	0.27	0.22	0.05	0.01	0.01	0.01	0.01	0.01	0.02	0.63
1924	0.02	0.02	0.02	0.02	0.02	0.20	0.07	0.00	0.01	0.01	0.00	0.01	0.40
1925	0.02	0.02	0.02	0.02	0.03	0.21	0.07	0.01	0.01	0.01	0.01	0.01	0.44
1926	0.02	0.18	0.06	0.00	0.01	0.22	0.07	0.00	0.00	0.00	0.00	0.01	0.57
1927	0.02	0.02	0.02	0.02	0.21	0.07	0.00	0.00	0.01	0.01	0.01	0.01	0.40
1928	0.01	0.02	0.02	0.02	0.02	0.23	0.08	0.00	0.10	0.10	0.02	0.13	0.75
1929	0.15	0.16	0.04	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.18	0.67
1930	0.06	0.01	0.02	0.24	0.22	0.17	0.04	0.00	0.00	0.07	0.02	0.00	0.85
1931	0.01	0.02	0.02	0.02	0.28	0.10	0.01	0.01	0.01	0.01	0.01	0.20	0.70
1932	0.11	0.00	0.02	0.03	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.26
1933	0.01	0.26	0.23	0.20	0.06	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.84
1934	0.01	0.02	0.23	0.08	0.01	0.01	0.21	0.17	0.13	0.03	0.01	0.00	0.91
1935	0.01	0.01	0.00	0.01	0.32	0.23	0.04	0.16	0.06	0.00	0.00	0.00	0.84
1936	0.01	0.00	0.00	0.01	0.24	0.20	0.05	0.00	0.01	0.00	0.01	0.01	0.54
1937	0.01	0.01	0.03	0.02	0.02	0.01	0.03	0.02	0.01	0.01	0.01	0.00	0.18
1938	0.01	0.02	0.02	0.02	0.21	0.07	0.01	0.01	0.01	0.01	0.02	0.17	0.58
1939	0.15	0.03	0.01	0.01	0.01	0.02	0.02	0.01	0.00	0.00	0.00	0.00	0.26
1940	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.15
1941	0.02	0.02	0.01	0.28	0.10	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.50
1942	0.01	0.23	0.21	0.05	0.00	0.20	0.17	0.03	0.00	0.01	0.15	0.05	1.11
1943	0.01	0.15	0.06	0.01	0.18	0.06	0.01	0.00	0.01	0.00	0.01	0.23	0.73
1944	0.08	0.01	0.01	0.02	0.03	0.02	0.02	0.01	0.01	0.01	0.00	0.01	0.23
1945	0.26	0.08	0.00	0.01	0.02	0.25	0.09	0.01	0.00	0.00	0.00	0.01	0.73
1946	0.02	0.02	0.02	0.01	0.02	0.22	0.12	0.01	0.12	0.04	0.01	0.00	0.61
1947	0.00	0.22	0.08	0.01	0.19	0.18	0.04	0.01	0.00	0.00	0.00	0.00	0.73
1948	0.02	0.02	0.01	0.01	0.26	0.20	0.04	0.01	0.00	0.00	0.00	0.01	0.58
1949	0.02	0.24	0.08	0.02	0.01	0.01	0.02	0.13	0.04	0.00	0.01	0.00	0.58
1950	0.01	0.01	0.23	0.09	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.44
1951	0.22	0.08	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.41
1952	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.17
1953	0.02	0.20	0.19	0.05	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.01	0.57
1954	0.21	0.07	0.01	0.22	0.21	0.16	0.04	0.00	0.00	0.00	0.00	0.01	0.93
1955	0.02	0.02	0.01	0.01	0.02	0.28	0.10	0.00	0.00	0.00	0.01	0.01	0.48
1956	0.02	0.20	0.20	0.06	0.02	0.09	0.13	0.04	0.00	0.00	0.00	0.02	0.78
1957	0.02	0.02	0.02	0.17	0.18	0.05	0.14	0.04	0.00	0.00	0.00	0.01	0.65
1958	0.01	0.03	0.02	0.01	0.02	0.02	0.02	0.23	0.08	0.01	0.01	0.01	0.47
1959	0.01	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.02	0.18
1960	0.01	0.02	0.19	0.07	0.01	0.01	0.17	0.07	0.00	0.00	0.00	0.01	0.56
1961	0.01	0.21	0.08	0.01	0.02	0.20	0.06	0.01	0.01	0.01	0.01	0.01	0.64
1962	0.03	0.21	0.07	0.19	0.07	0.18	0.06	0.01	0.01	0.19	0.06	0.00	1.08
1963	0.01	0.02	0.02	0.20	0.19	0.15	0.15	0.04	0.15	0.05	0.00	0.01	0.99
1964	0.18	0.06	0.01	0.01	0.02	0.01	0.00	0.02	0.28	0.10	0.09	0.03	0.81
1965	0.14	0.17	0.04	0.01	0.01	0.01	0.00	0.28	0.10	0.00	0.00	0.01	0.77
1966	0.02	0.01	0.02	0.02	0.02	0.21	0.18	0.04	0.00	0.13	0.04	0.00	0.69
1967	0.00	0.02	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.03	0.18
1968	0.02	0.02	0.02	0.01	0.23	0.20	0.04	0.15	0.06	0.00	0.01	0.00	0.76
1969	0.02	0.02	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.23	0.08	0.48
1970	0.13	0.09	0.00	0.00	0.00	0.01	0.01	0.19	0.06	0.11	0.12	0.04	0.76
1971	0.14	0.06	0.01	0.01	0.24	0.09	0.01	0.01	0.01	0.01	0.00	0.01	0.60
1972	0.01	0.02	0.03	0.02	0.02	0.02	0.00	0.00	0.00	0.00	0.00	0.01	0.13
1973	0.02	0.18	0.06	0.01	0.02	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.33
1974	0.01	0.02	0.03	0.02	0.02	0.02	0.02	0.01	0.00	0.01	0.00	0.25	0.41
1975	0.09	0.01	0.20	0.07	0.19	0.19	0.14	0.13	0.03	0.00	0.01	0.01	1.07
1976	0.21	0.07	0.00	0.01	0.24	0.09	0.00	0.01	0.01	0.01	0.01	0.02	0.68
1977	0.02	0.20	0.20	0.06	0.01	0.01	0.12	0.10	0.02	0.00	0.00	0.01	0.75
1978	0.19	0.07	0.01	0.01	0.02	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.43
1979	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.24	0.41
1980	0.09	0.16	0.06	0.01	0.02	0.01	0.00	0.01	0.02	0.02	0.01	0.02	0.43
1981	0.01	0.01	0.01	0.02	0.02	0.29	0.10	0.00	0.01	0.01	0.00	0.00	0.48
1982	0.02	0.02	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.07	0.03	0.01	0.22
1983	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.15	0.05	0.01	0.37
1984	0.01	0.20	0.07	0.01	0.21	0.07	0.01	0.00	0.00	0.01	0.00	0.01	0.60
1985	0.02	0.22	0.08	0.17	0.06	0.01	0.01	0.01	0.01	0.00	0.02	0.09	0.70
1986	0.00	0.00	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.01	0.24	0.33
1987	0.08	0.14	0.05	0.01	0.23	0.21	0.04	0.13	0.05	0.09	0.04	0.00	1.07
1988	0.00	0.12	0.18	0.04	0.23	0.08	0.14	0.05	0.00	0.00	0.00	0.00	0.84
1989	0.22	0.20	0.04	0.01	0.02	0.25	0.08	0.01	0.01	0.00	0.01	0.01	0.86
1990	0.02	0.01	0.01	0.02	0.03	0.02	0.01	0.01	0.01	0.00	0.01	0.01	0.16
1991	0.23	0.20	0.05	0.01	0.02	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.57
1992	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.16
1993	0.02	0.02	0.19	0.06	0.20	0.07	0.01	0.00	0.00	0.01	0.01	0.02	0.61
1994	0.01	0.01	0.03	0.02	0.01	0.25	0.21	0.04	0.11	0.04	0.00	0.00	0.73
1995	0.01	0.02	0.23	0.08	0.16	0.05	0.00	0.01	0.01	0.20	0.07	0.00	0.84
1996	0.01	0.19	0.07	0.01	0.19	0.07	0.14	0.05	0.14	0.11	0.02	0.00	1.00
month	3.86	5.97	4.46	3.55	6.30	7.03	3.74	2.82	2.14	2.08	1.44	2.50	

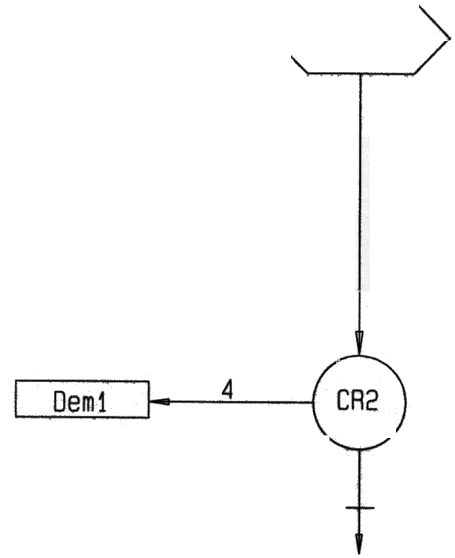
Statistics Period = 77 years

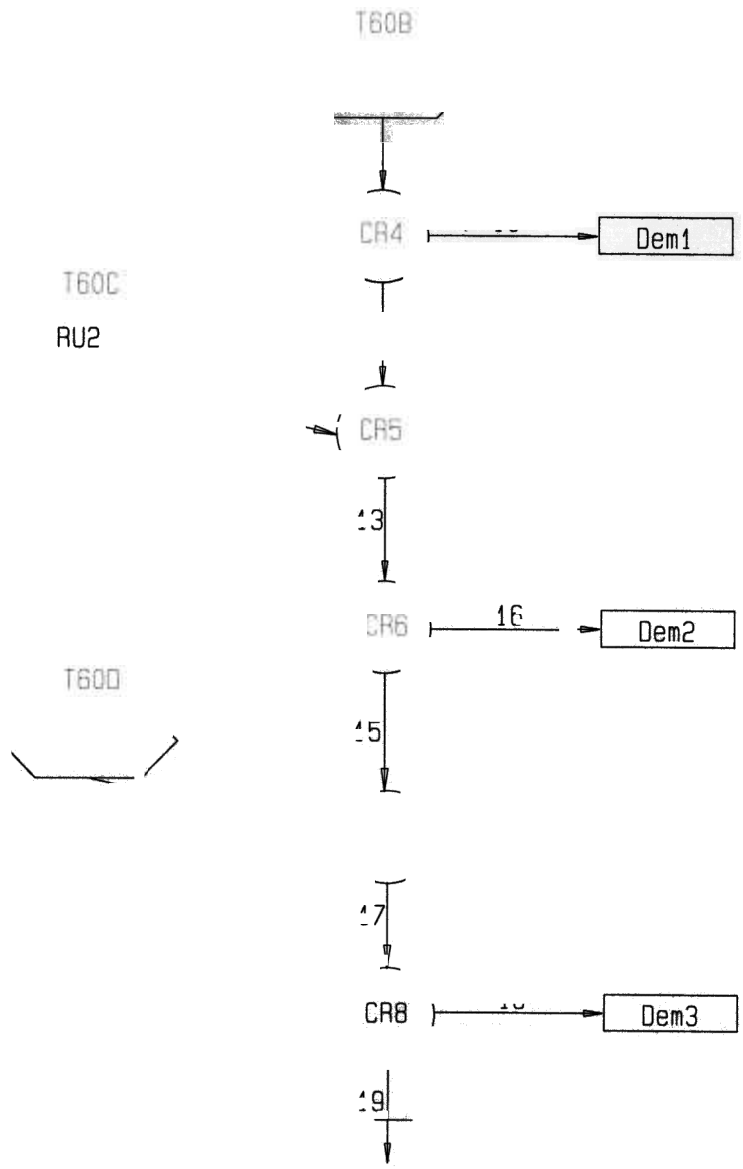
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANN
years	77	77	77	77	77	77	77	77	77	77	77	77	77
min	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.13
max	0.26	0.26	0.23	0.28	0.32	0.29	0.21	0.28	0.28	0.21	0.23	0.25	1.17
median	0.02	0.02	0.02	0.02	0.02	0.05	0.02	0.01	0.01	0.01	0.01	0.01	0.60
mean	0.05	0.08	0.06	0.05	0.08	0.09	0.05	0.04	0.03	0.03	0.02	0.03	0.60
Sum of the monthly means =				0.60									
s.d.	0.07	0.08	0.07	0.07	0.09	0.09	0.06	0.06	0.05	0.05	0.04	0.06	0.26
c.v.	1.38	1.08	1.23	1.45	1.16	0.99	1.14	1.70	1.76	1.79	1.91	1.92	0.44

APPENDIX 15.1

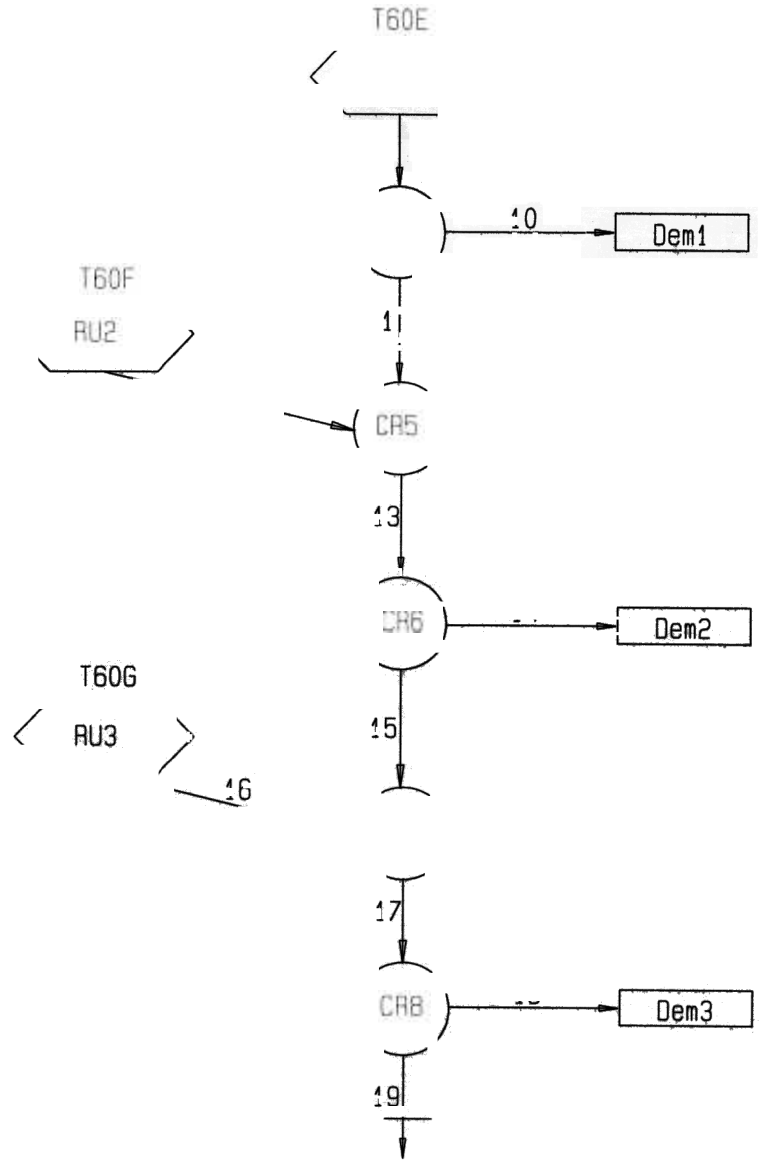
WRSM90 MODEL DIAGRAMS FOR QUATERNARY CATCHMENTS

T60A QUATERNARY CATCHMENT

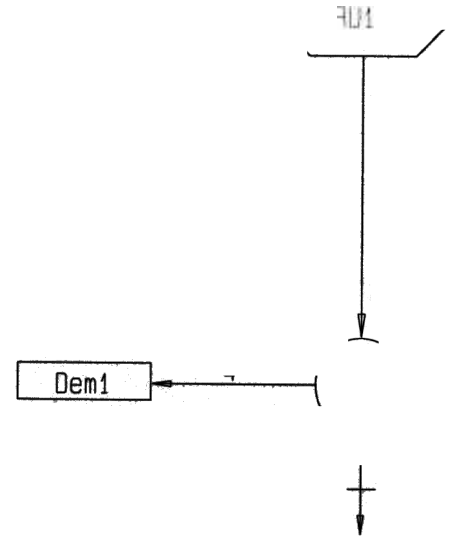



T60B
CR4
Dem1
T60C
RU2
CR5
13
CR6
16
Dem2
T60D
15
17
CR8
Dem3
19

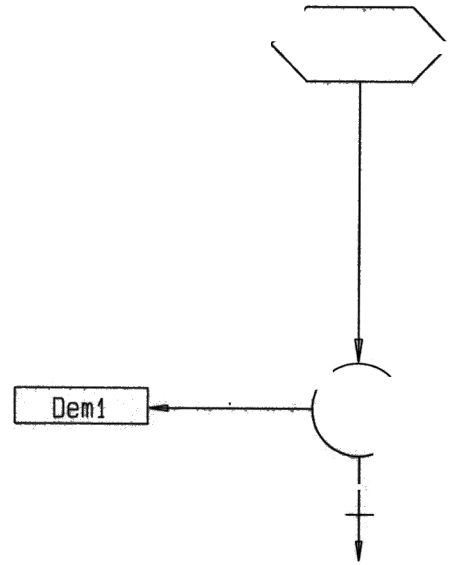
T60E; T60F; T60G



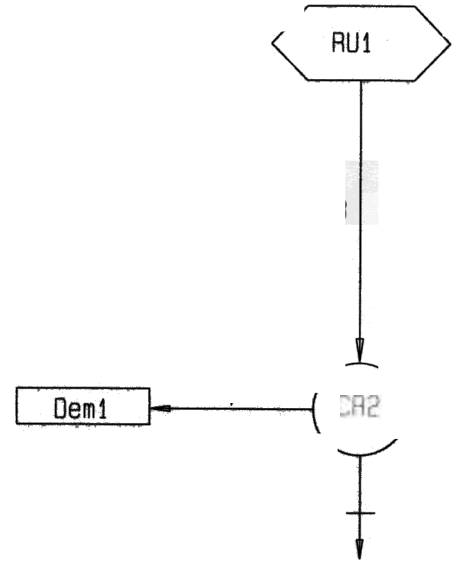
T60H QUATERNARY CATCHMENT



T60J QUATERNARY CATCHMENT



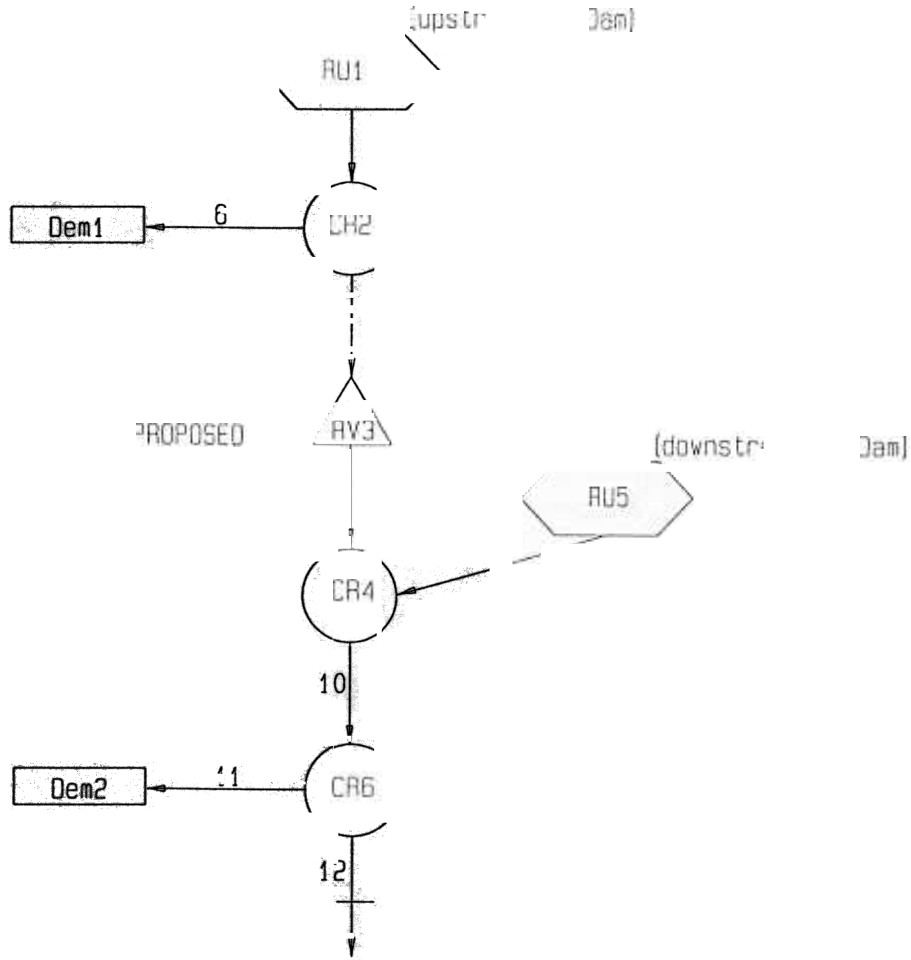
T60K QUATERNARY CATCHMENT



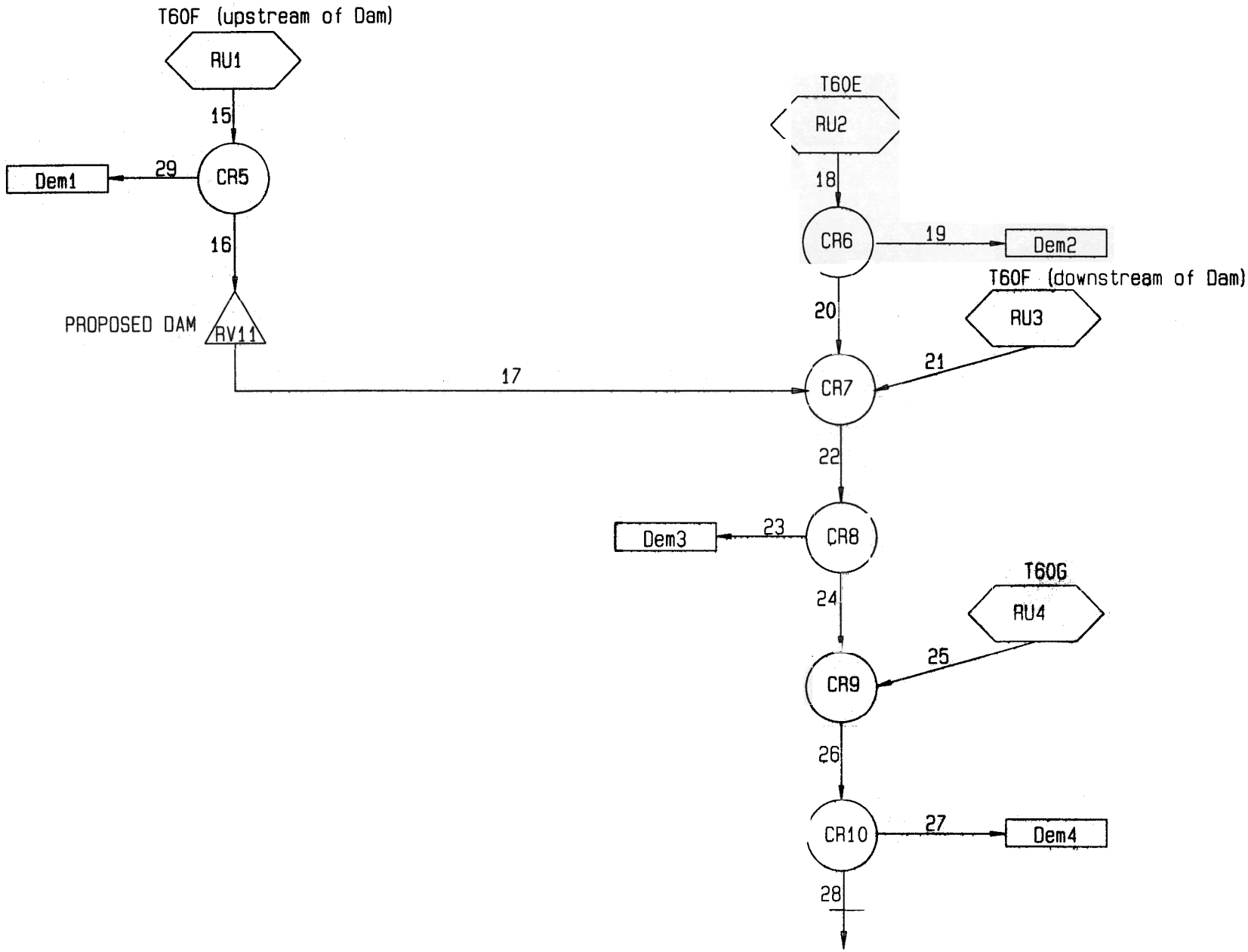
APPENDIX 15.2

WRSM90 MODEL DIAGRAMS FOR WEIRS AND PROPOSED DAMS

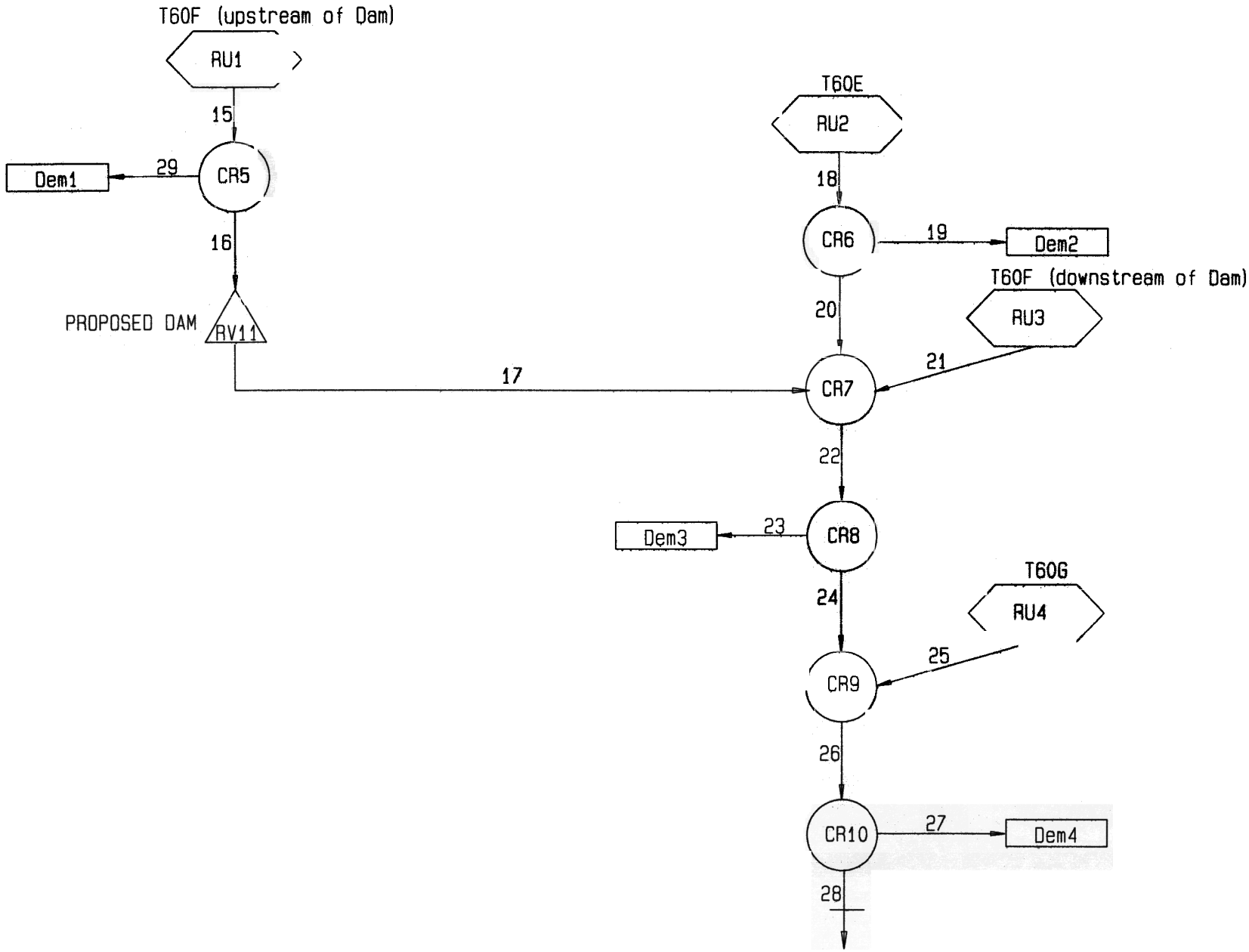
TUNGWANA DAM



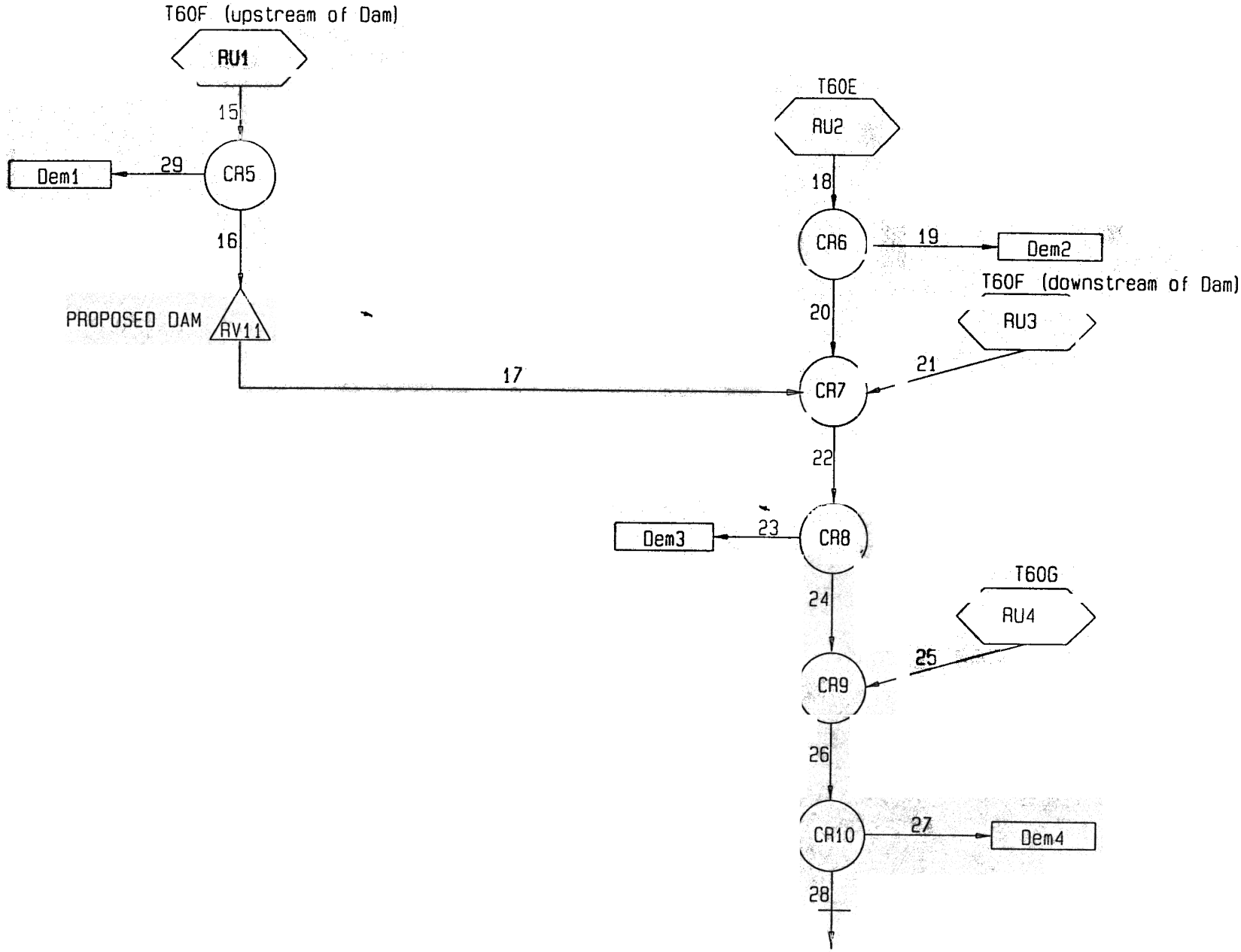
XURA DAM


T60F (upstream of Dam)
RU1
15
Dem1
29
CR5
16
PROPOSED DAM
RV11
17
T60E
RU2
18
CR6
19
Dem2
T60F (downstream of Dam)
RU3
20
21
CR7
22
Dem3
23
CR8
T606
RU4
24
25
CR9
26
CR10
27
Dem4
28

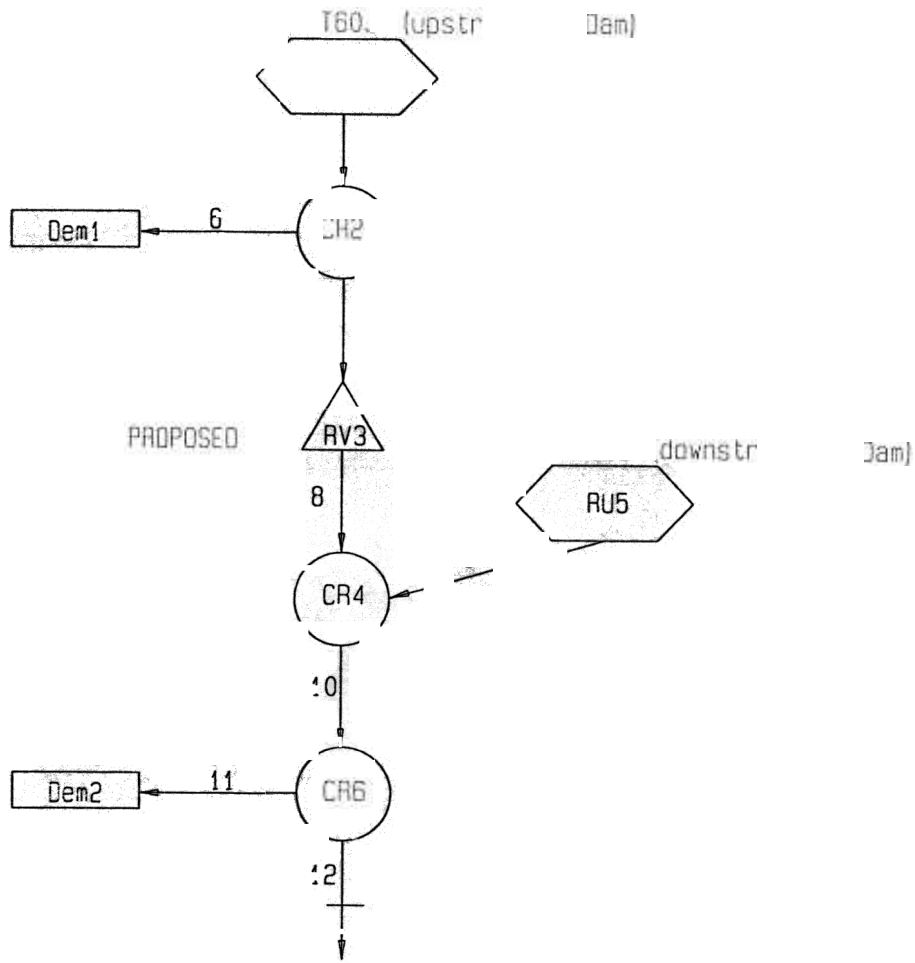
LUSIKISIKI DAM



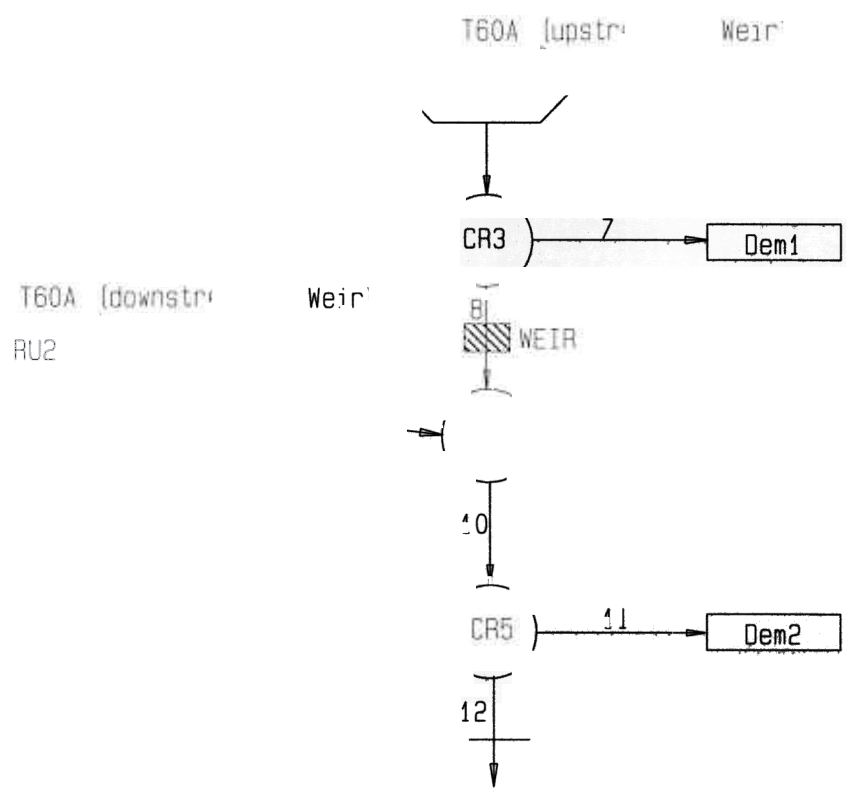
ZALU DAM


T60F (upstream of Dam)
RU1
15
Dem1
29
CR5
16
PROPOSED DAM
RV11
17
T60E
RU2
18
CR6
19
Dem2
T60F (downstream of Dam)
RU3
20
21
CR7
22
Dem3
23
CR8
T60G
RU4
24
25
CR9
26
CR10
27
Dem4
28

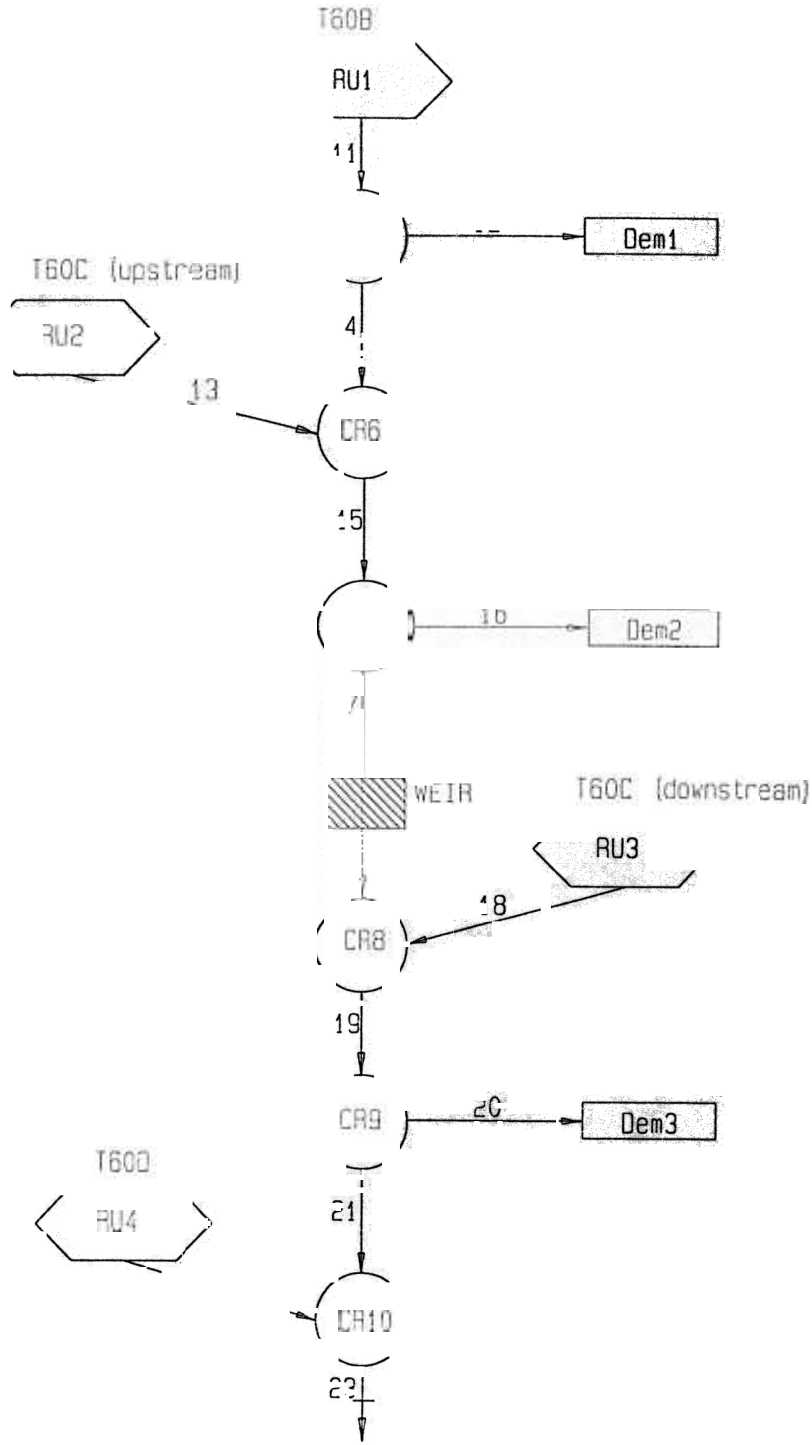
LOWER MZINTLAVA DAM



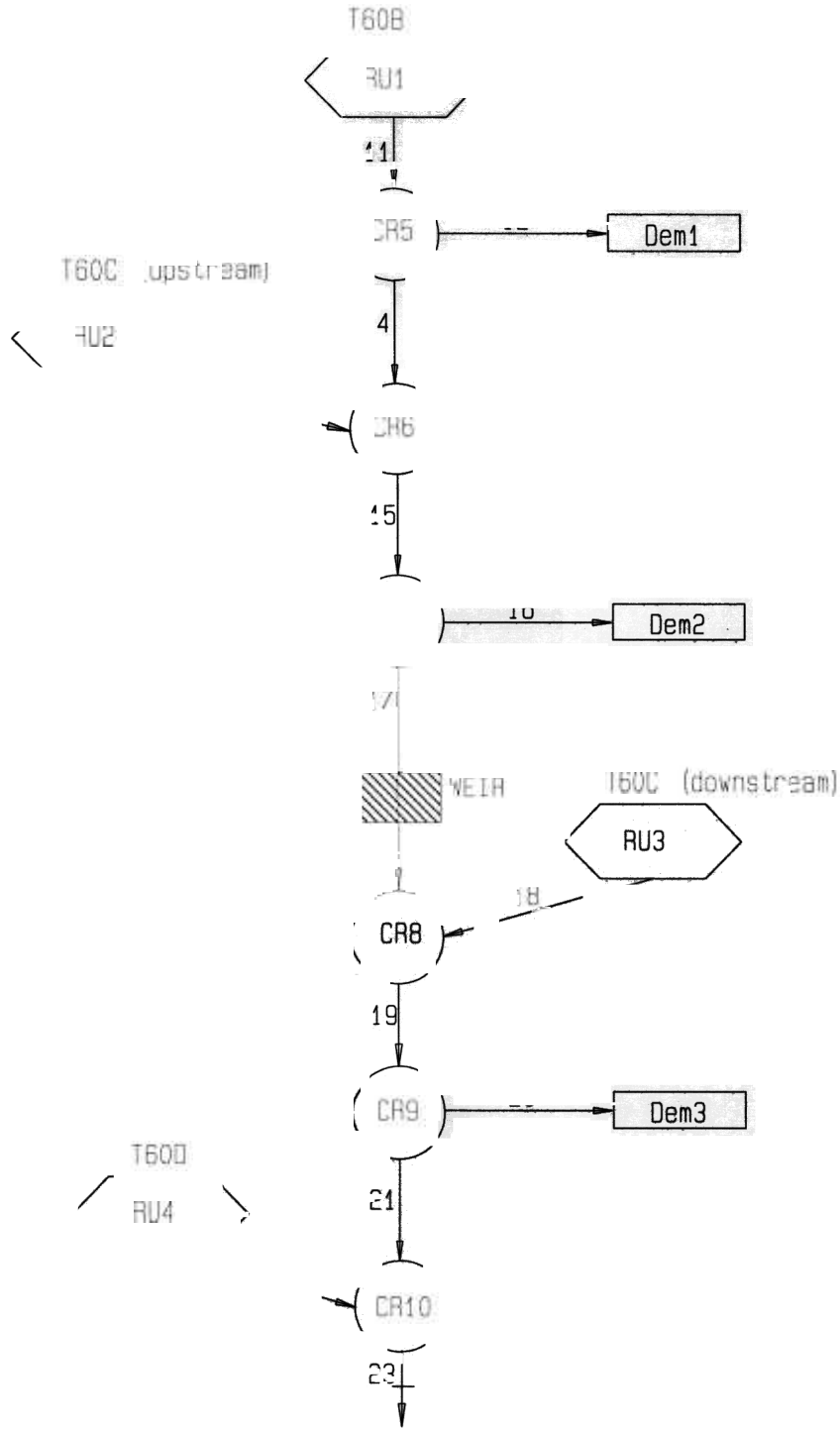
MBONGWENI WEIR



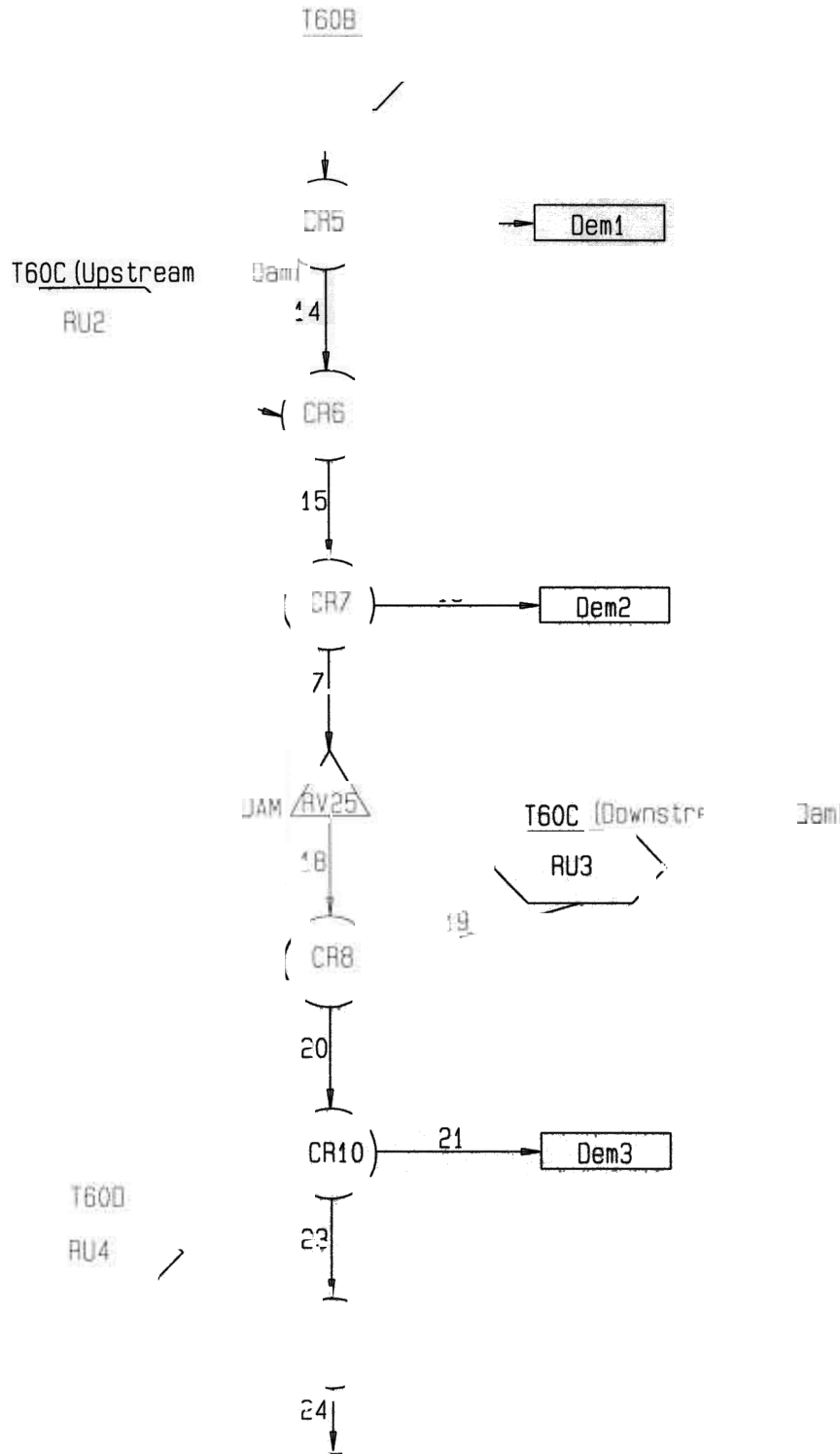
SPES BONA WEIR



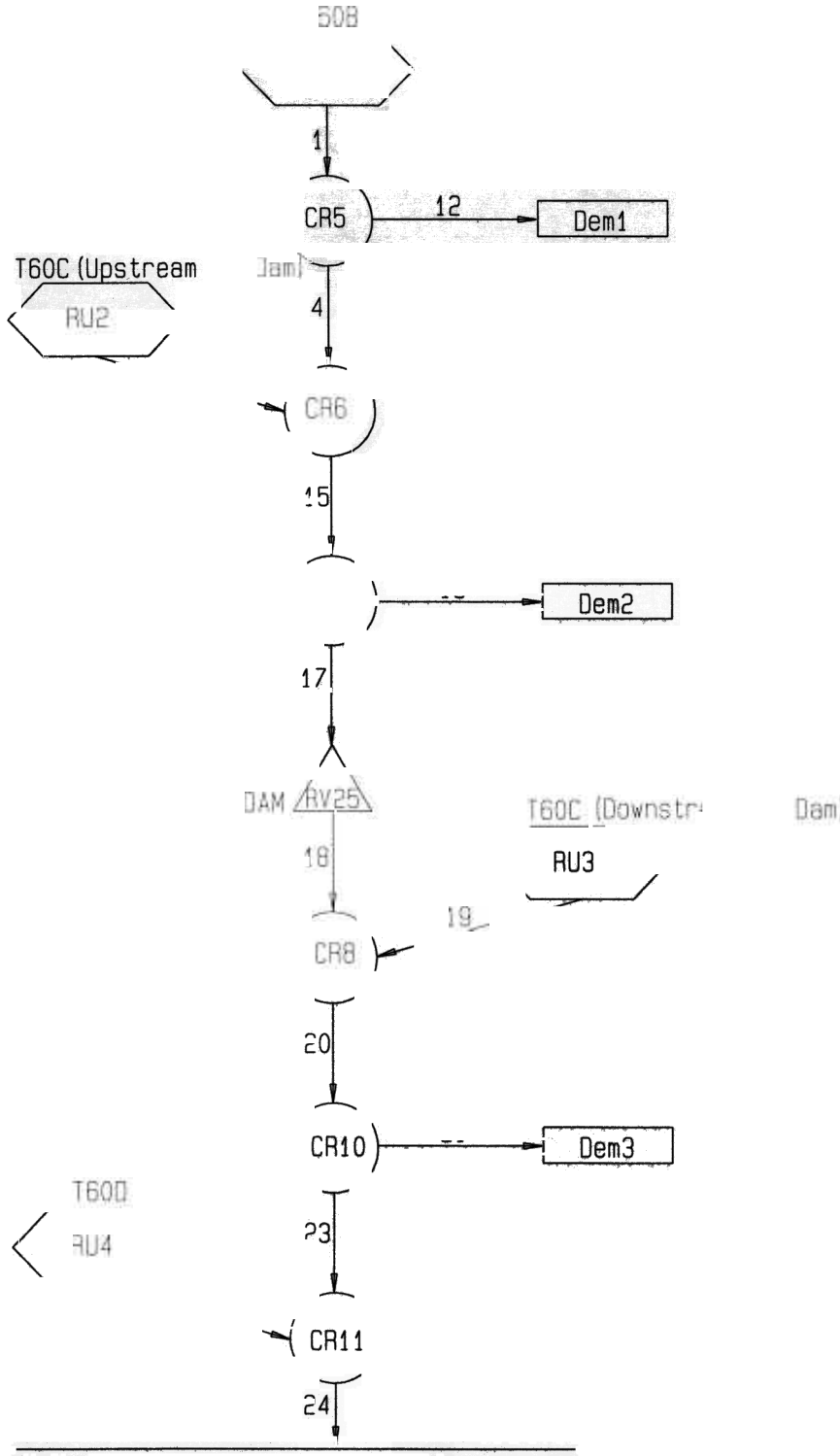
GXALIBOMVU WEIR



LUSINDISWENI DAM



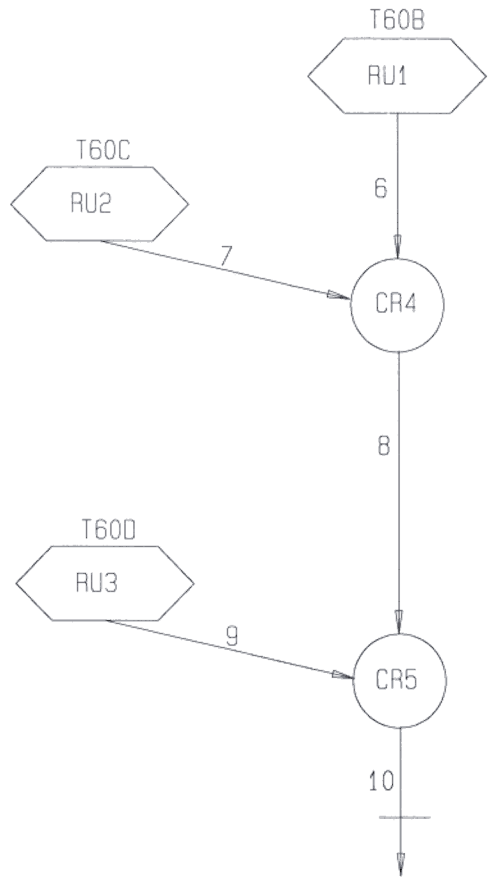
KWAHLATHI DAM



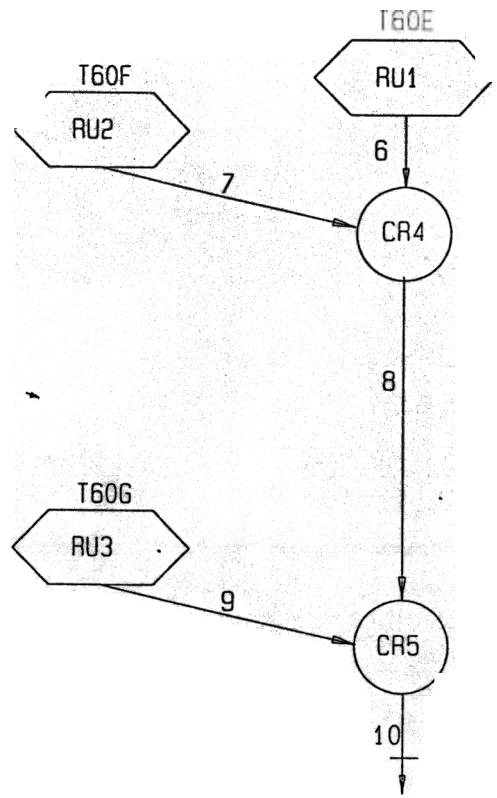
APPENDIX 15.3

WRSM90 MODEL DIAGRAMS FOR ESTUARINE RIVERS

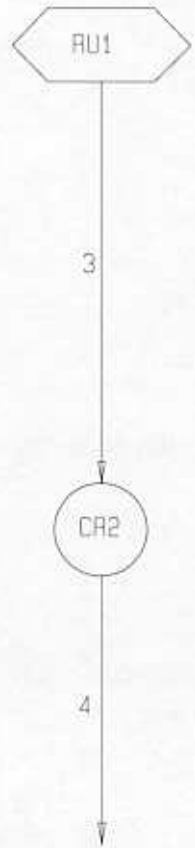
MTENTU RIVER



MSIKABA RIVER



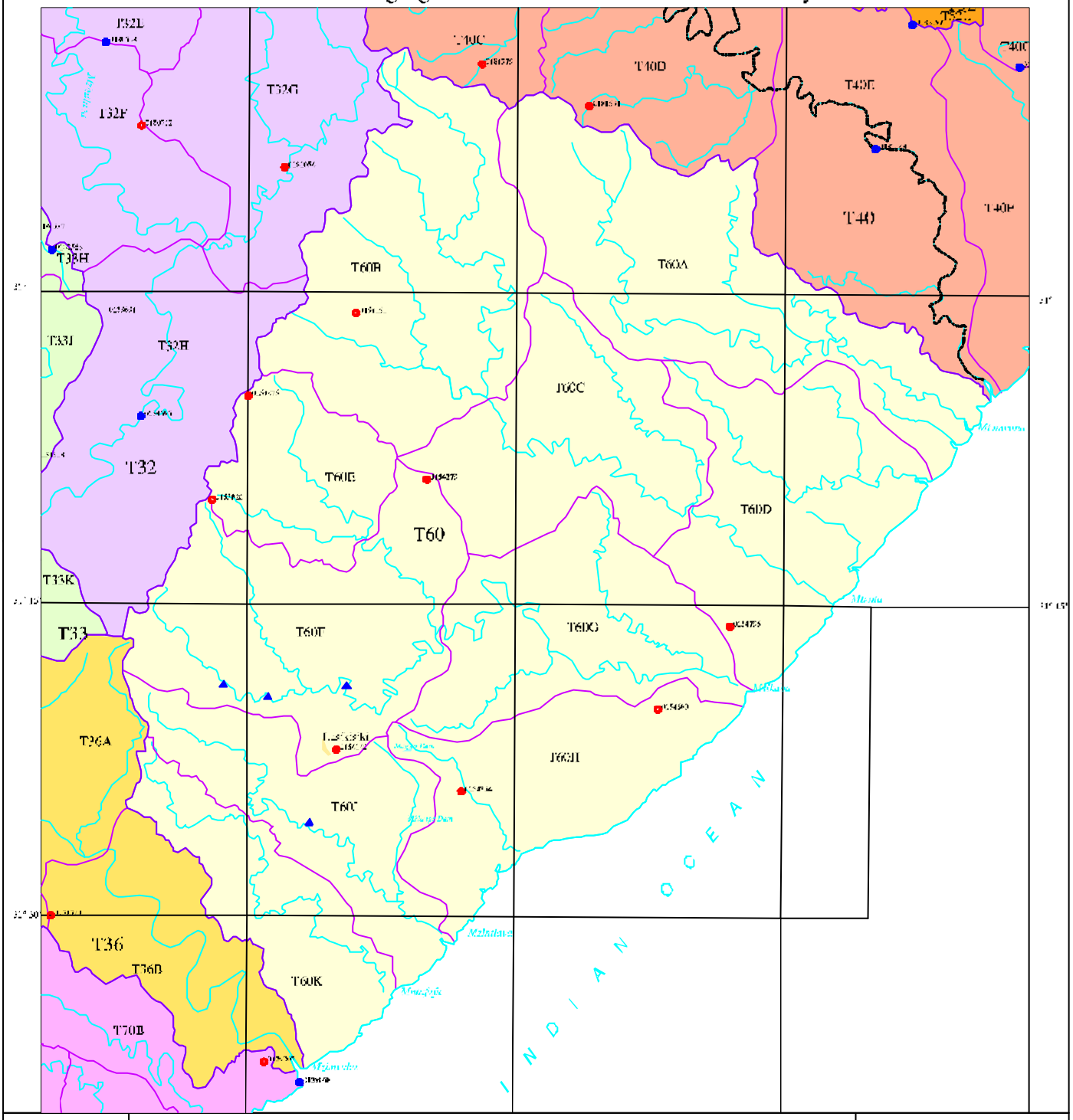
FOURTEEN RIVERS



APPENDIX 16

Figure 1.
MAP SHOWING THE DISTRIBUTION OF RAINFALL STATIONS

Rainfall Gauging Stations for Eastern Pondoland Study



1 : 350 000

Reference

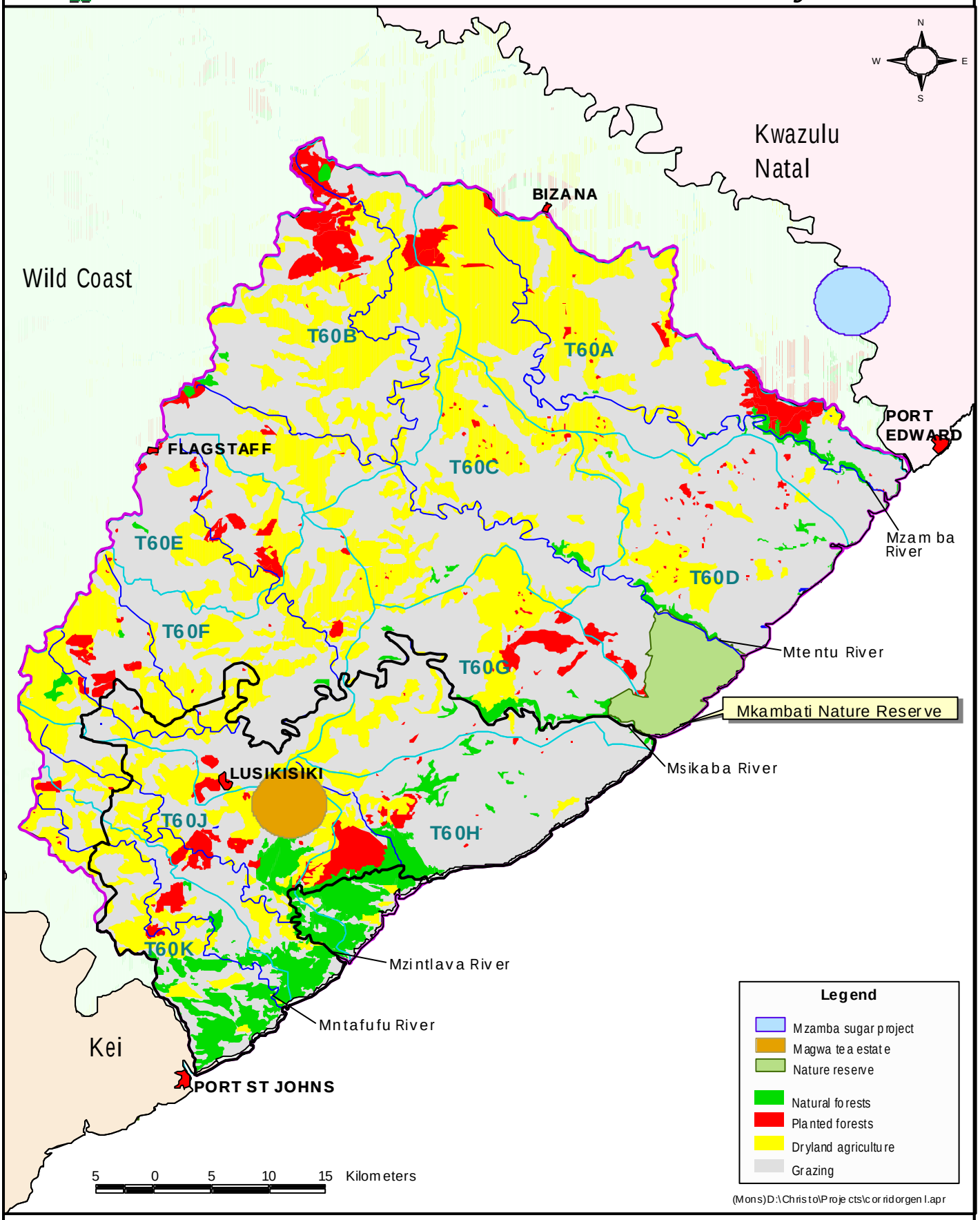
- T60 — Tertiary drainage region boundary and number
- T60A — Quartenary drainage region boundary and number
- Provincial boundary
- Perennial river / coastline
- Perennial river
- Non - perennial river
- Rainfall gauging station in the study area
- Station used to create catchment rainfall
- Station outside study area
- Proposed dam site

Compiler	M.S. Dagane
Source	D.W.A.F
Projection	Lambert
Spheroid	Clarke 1880
Date	16 May 01
Pathname	/gm/tasks/gm72199/work/drgnq.aml

APPENDIX 16

Figure 2.
MAP SHOWING THE PRESENT AFFORESTED AREAS

Eastern Pondoland Basin Study



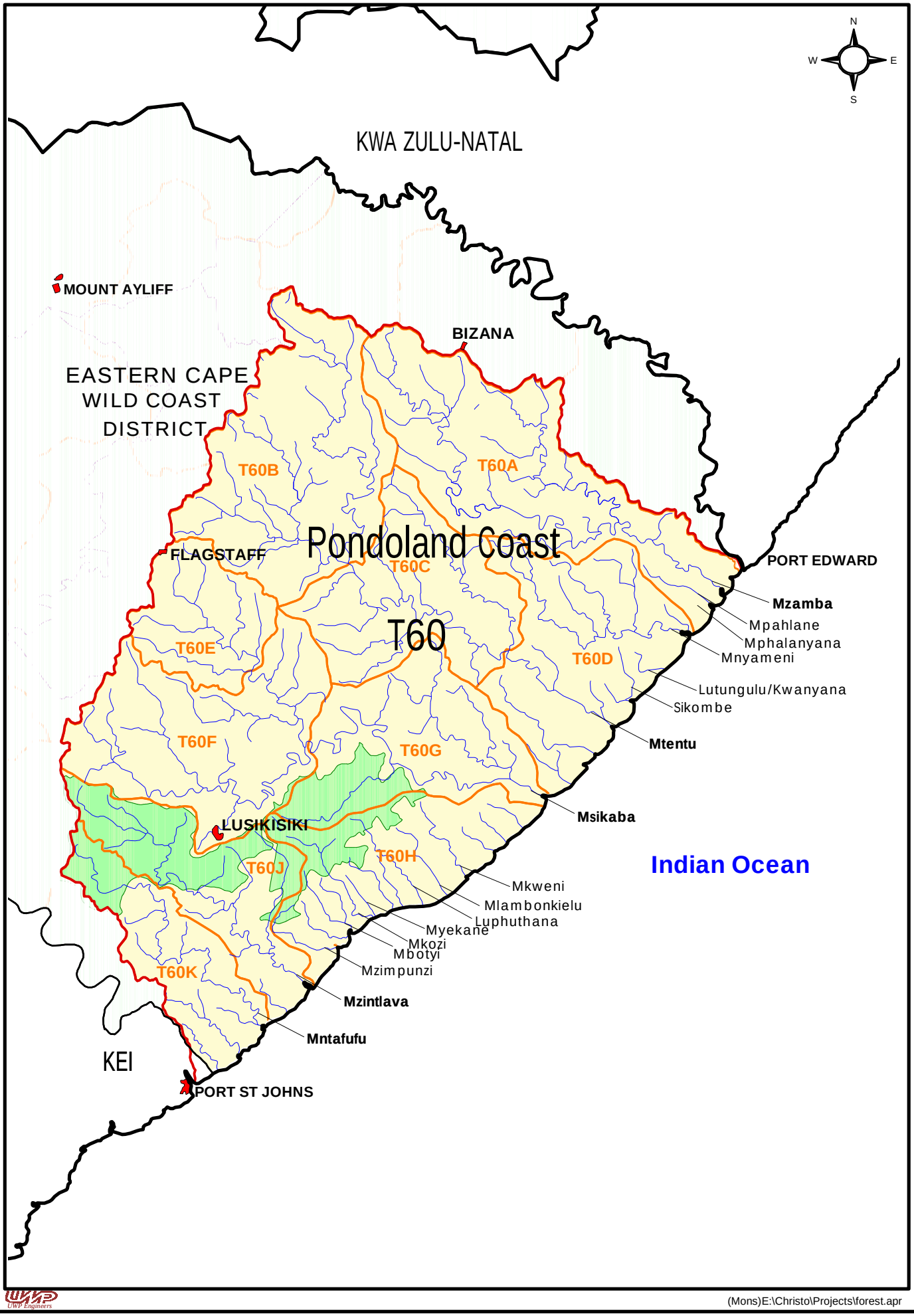
Land Use

UWP Engineers

APPENDIX 16

Figure 3.
MAP SHOWING PROJECTED AFFORESTED AREAS

Eastern Pondoland Basin Study : Projected Afforested Areas

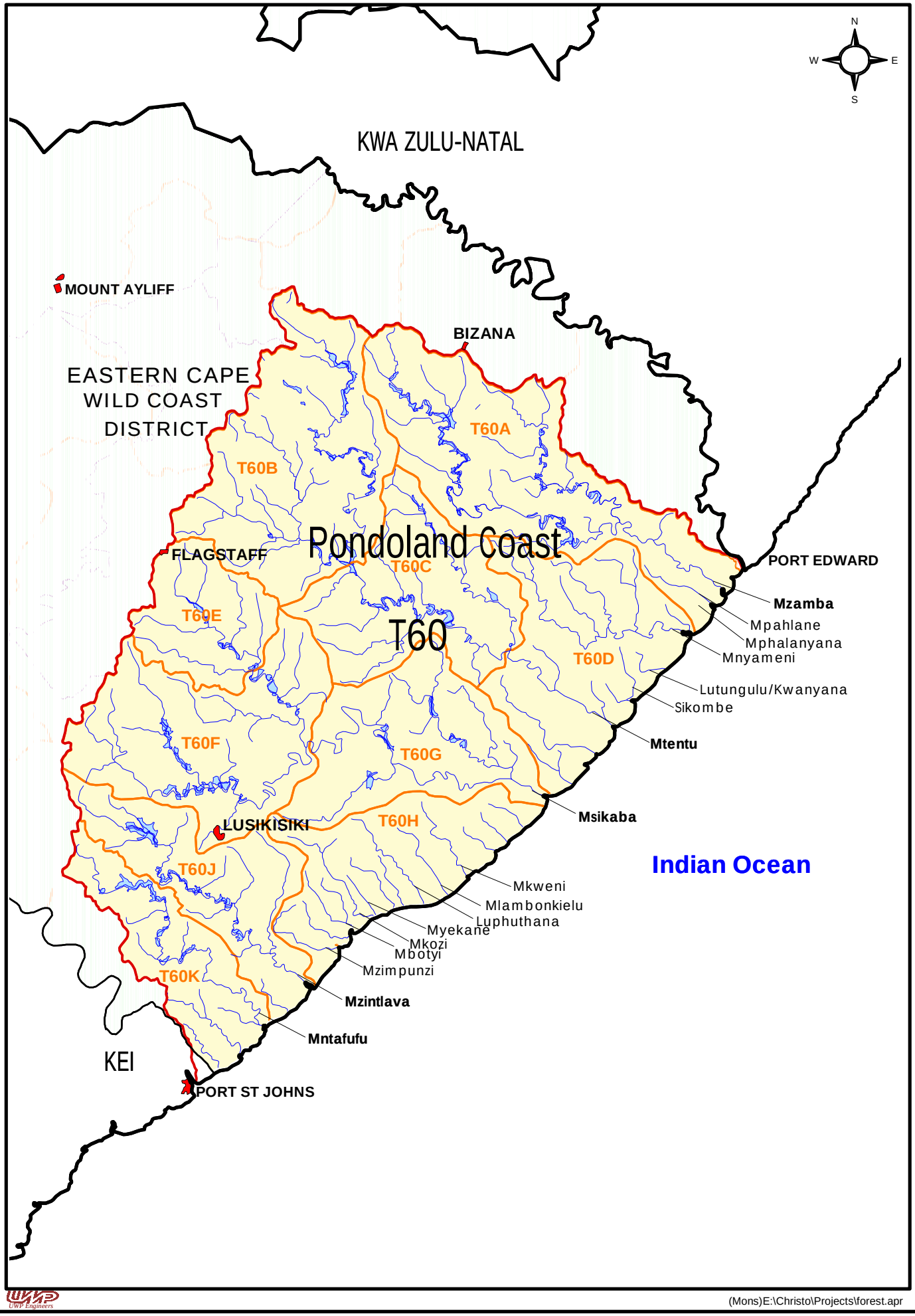


(Mons)E:\Christo\Projects\forest.apr

APPENDIX 16

Figure 4.
MAP SHOWING THE POTENTIAL IRRIGATION AREAS

Eastern Pondoland Basin Study : Potential Irrigation Areas

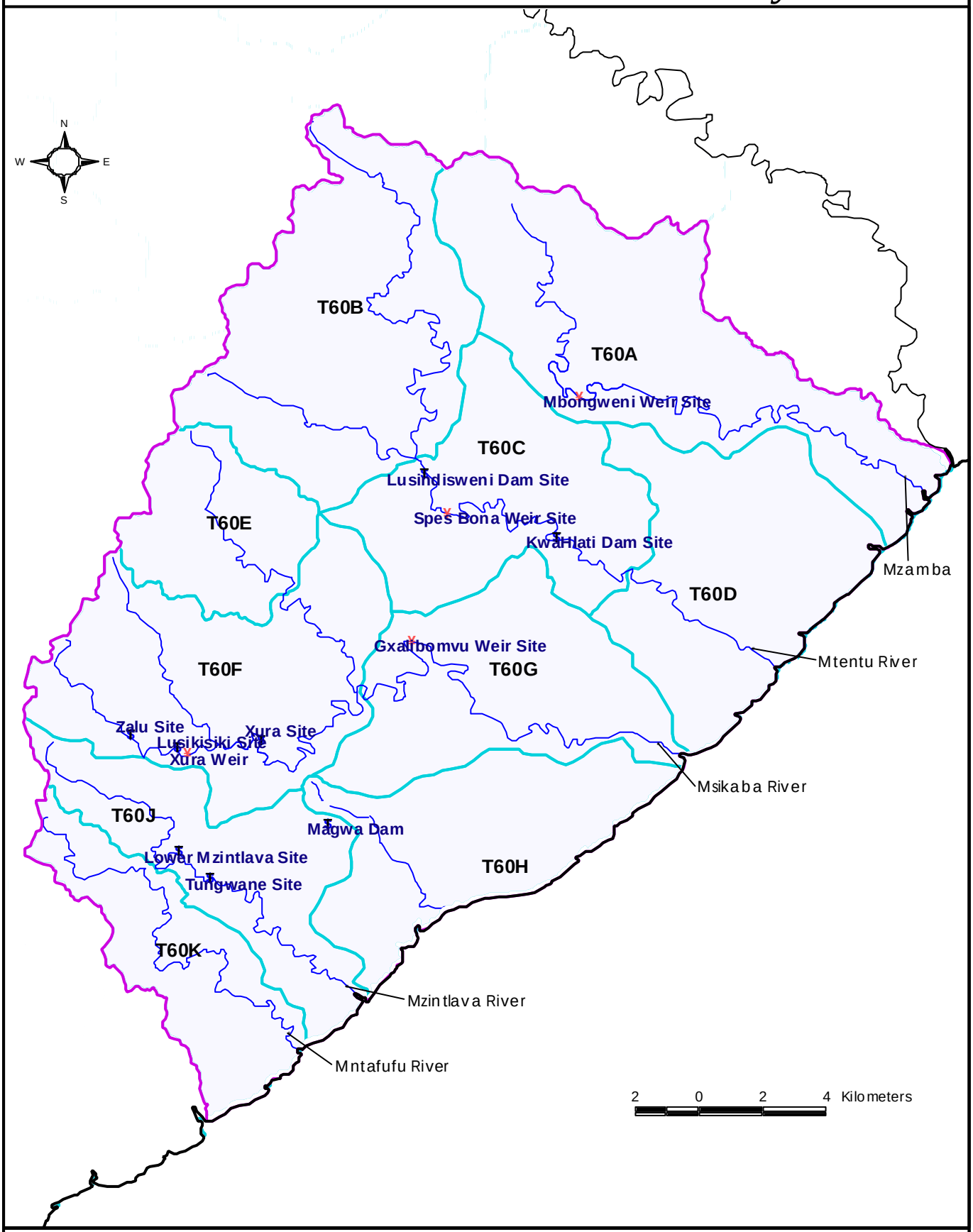


(Mons)E:\Christo\Projects\forest.apr

APPENDIX 16

Figure 5.
MAP SHOWING THE POSITION OF ALL THE PROPOSED DAMS

Eastern Pondoland Basin Study



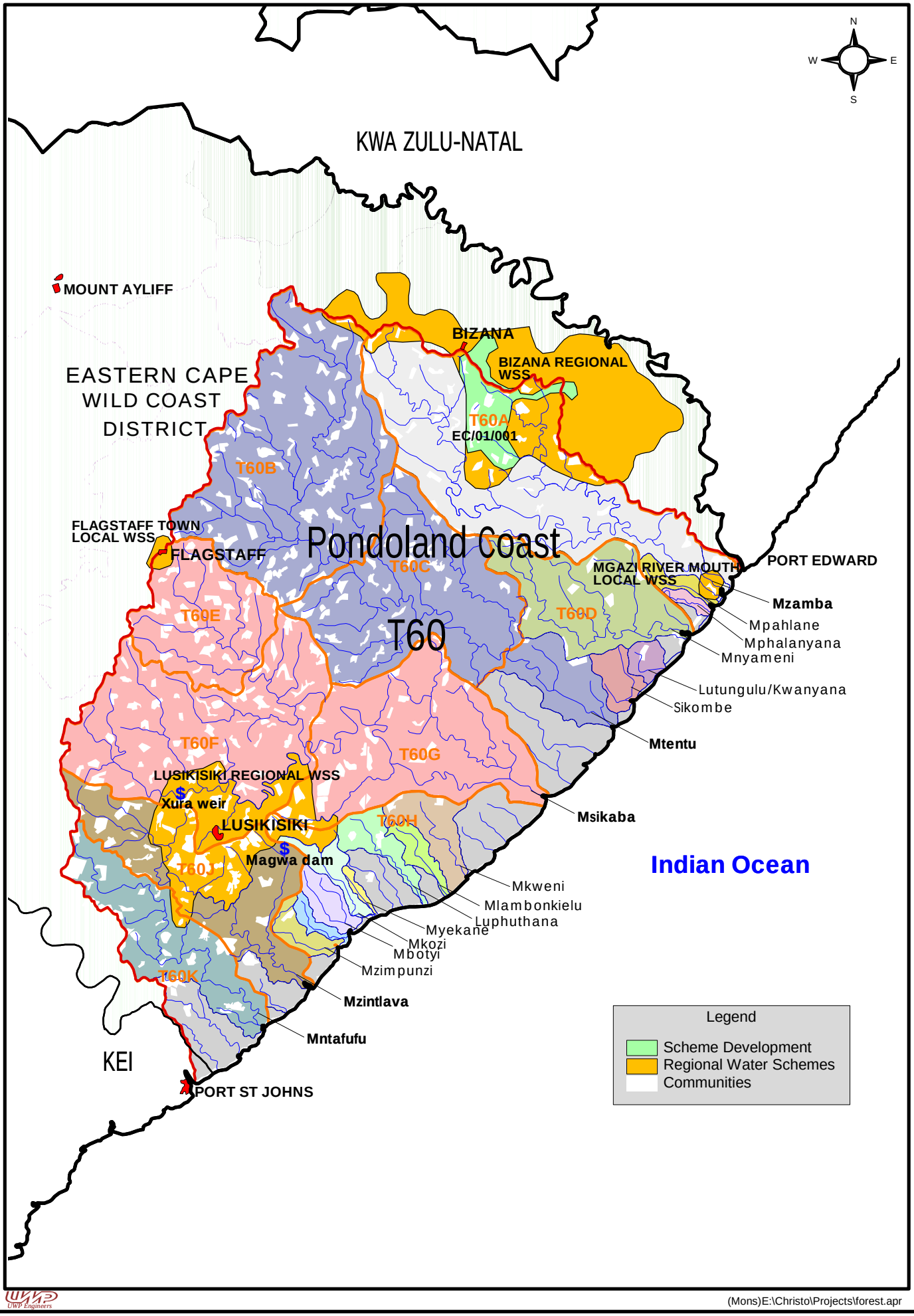
Dam and Weir Sites

(Mons)E:\Christo\Projects\catchanalysis.apr

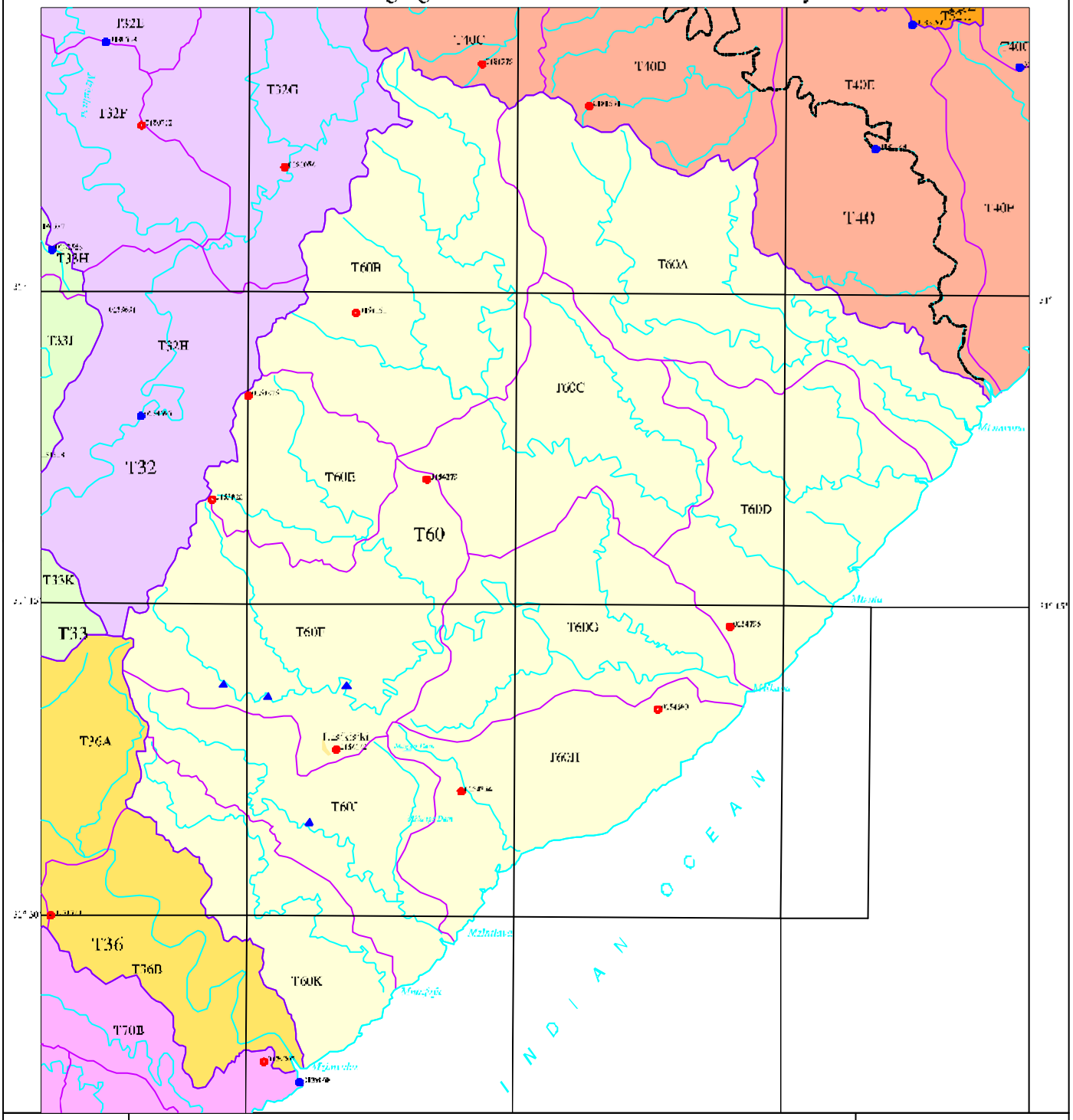
APPENDIX 16

Figure 6.
MAP SHOWING THE ESTUARY RIVERS

Eastern Pondoland Basin Study



Rainfall Gauging Stations for Eastern Pondoland Study



1 : 350 000

Reference

- T60 — Tertiary drainage region boundary and number
- T60A — Quartenary drainage region boundary and number
- Provincial boundary
- Perennial river / coastline
- Perennial river
- Non - perennial river
- Rainfall gauging station in the study area
- Station used to create catchment rainfall
- Station outside study area
- Proposed dam site

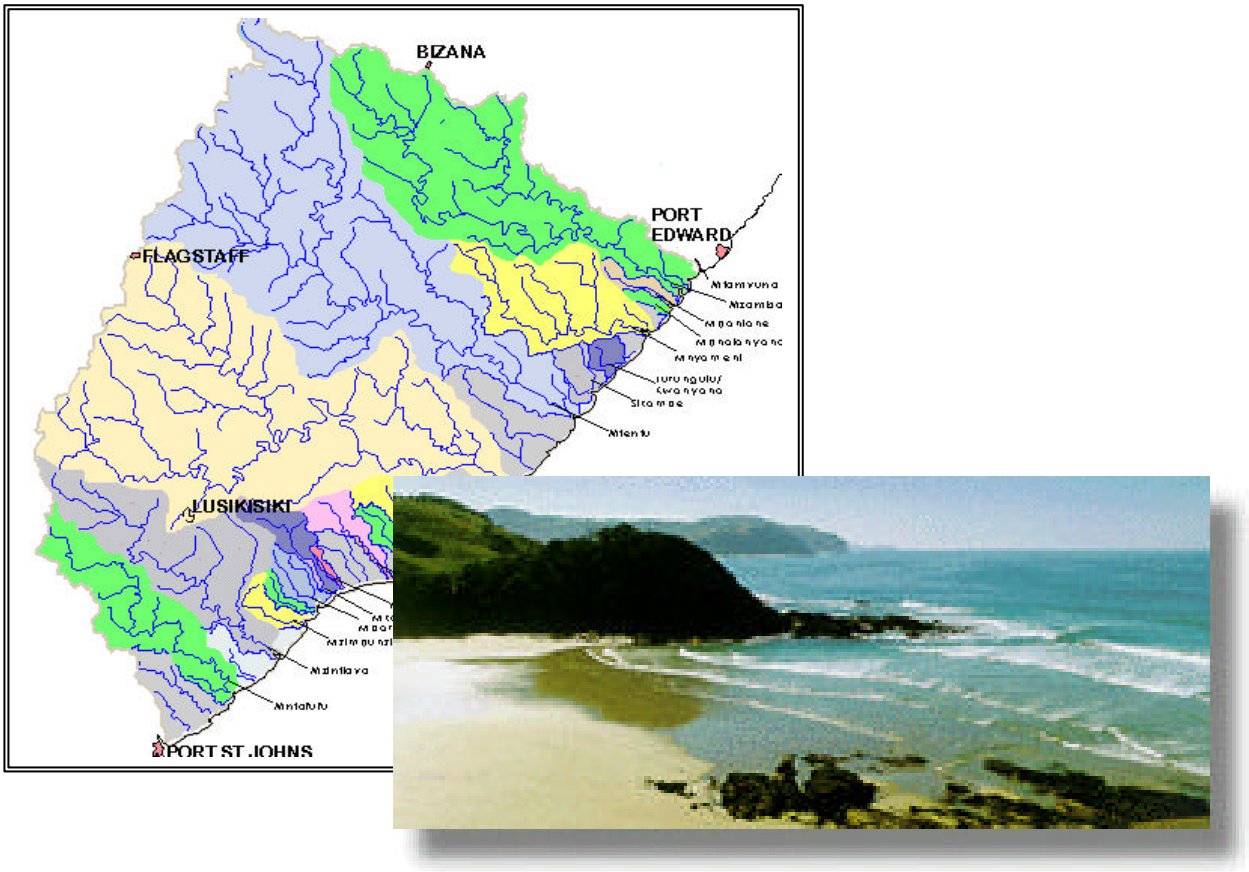
Compiler	M.S. Dagane
Source	D.W.A.F
Projection	Lambert
Spheroid	Clarke 1880
Date	16 May 01
Pathname	/gm/tasks/gm72199/work/drgnq.aml

PB T600/00/1001

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



FLOOD FREQUENCY ANALYSIS

Xura River

Final

June 2001

Prepared By:

Department of Water Affairs and Forestry

DIRECTORATE HYDROLOGY - FLOOD STUDIES
DEPARTMENT OF WATER AFFAIRS AND FORESTRY
PRIVATE BAG X313
PRETORIA 0001
REPUBLIC OF SOUTH AFRICA

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Flood Frequency Analysis: Xura River
AUTHOR	**:**	V Petras
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-1001
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EXECUTIVE SUMMARY

The proposed Zalu, Lusikisiki and Xura dam sites are situated on the Xura river about 50 km north west of the town Port St. Johns, in the Eastern Cape province. Two separate reports, addressing flood frequencies, have been prepared. This particular report deals with the proposed dam sites at Zalu, Lusikisiki and Xura on the Xura River.

The catchment area of the Zalu proposed dam site is 71 km^2, with mean catchment steepness of 14 % and t_c was calculated to be 3.5 hours. The catchment area of Lusikisiki proposed dam site is 91 km^2, with mean catchment steepness of 13.9 % and t_c was calculated to be 5.0 hours. The catchment area of the Xura dam site is 225 km^2, with mean catchment steepness of 13.2 % and t_c was calculated to be 7.0 hours. The position of the catchment is shown in Figure 1, and the layout of the catchment is shown in Appendix A.

Empirical and Deterministic methods were used to determine the flood peaks. The recommended flood peaks are given in the following tables.

Zalu proposed dam site recommended flood peaks (m^3/s)

STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
	50	20	10	5	2	1	0.5	RMF
1.8	50	110	160	220	305	380	455	990
3.5	55	125	180	240	337	420	505	1090
7.0	45	95	140	190	265	330	395	855

Lusikisiki proposed dam site recommended flood peaks (m^3/s)

STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
	50	20	10	5	2	1	0.5	RMF
2.5	55	130	195	270	375	475	580	1170
5.0	60	140	210	285	405	510	622	1250
10.0	45	105	160	220	310	390	480	960

Xura proposed dam site recommended flood peaks (m^3/s)

STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
	50	20	10	5	2	1	0.5	RMF
3.5	100	225	340	465	650	810	1000	2370
7.0	105	240	360	495	695	850	1060	2520
14.0	85	190	280	390	545	670	835	1980

Eastern Pondoland Basin Study

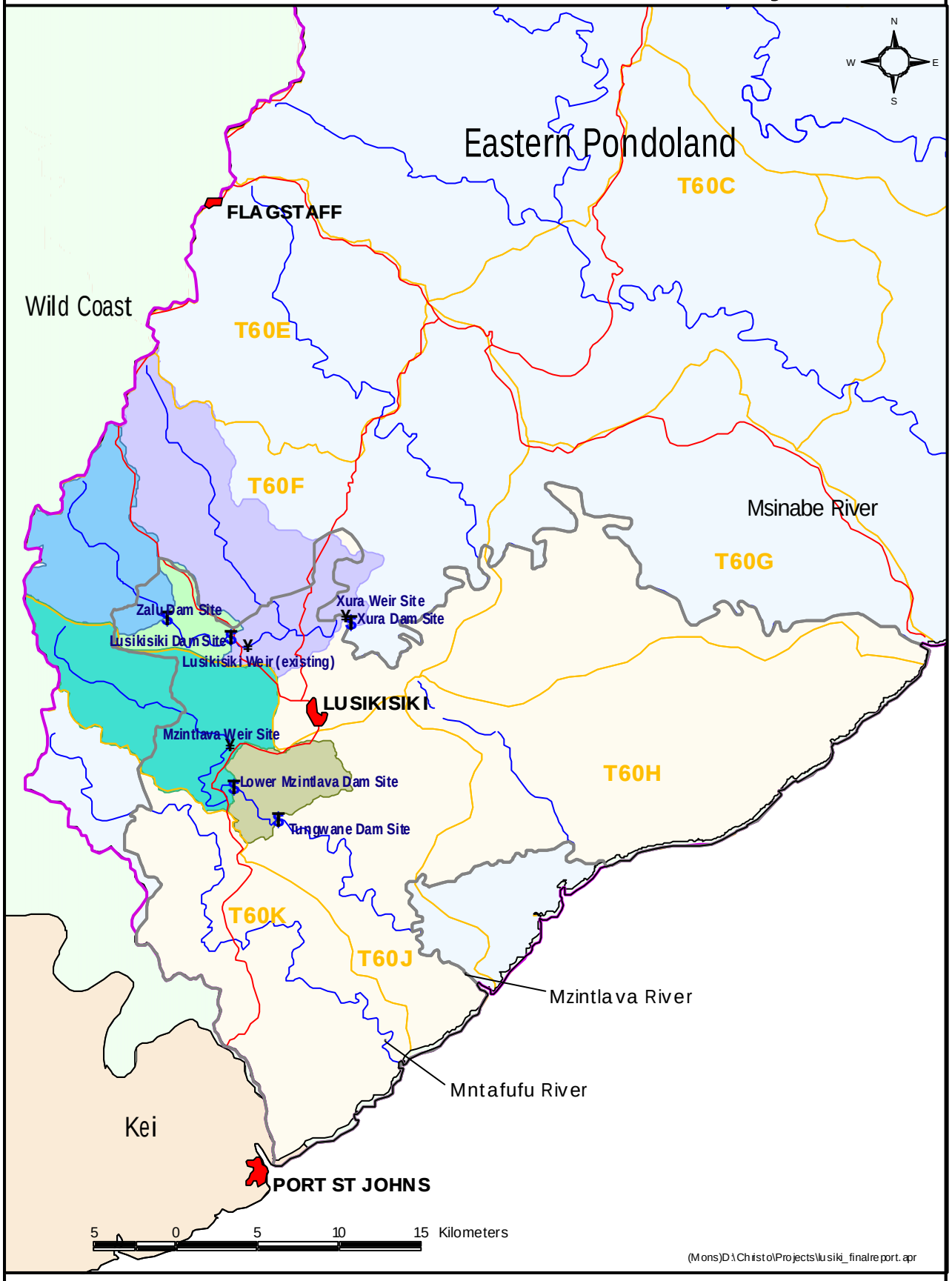
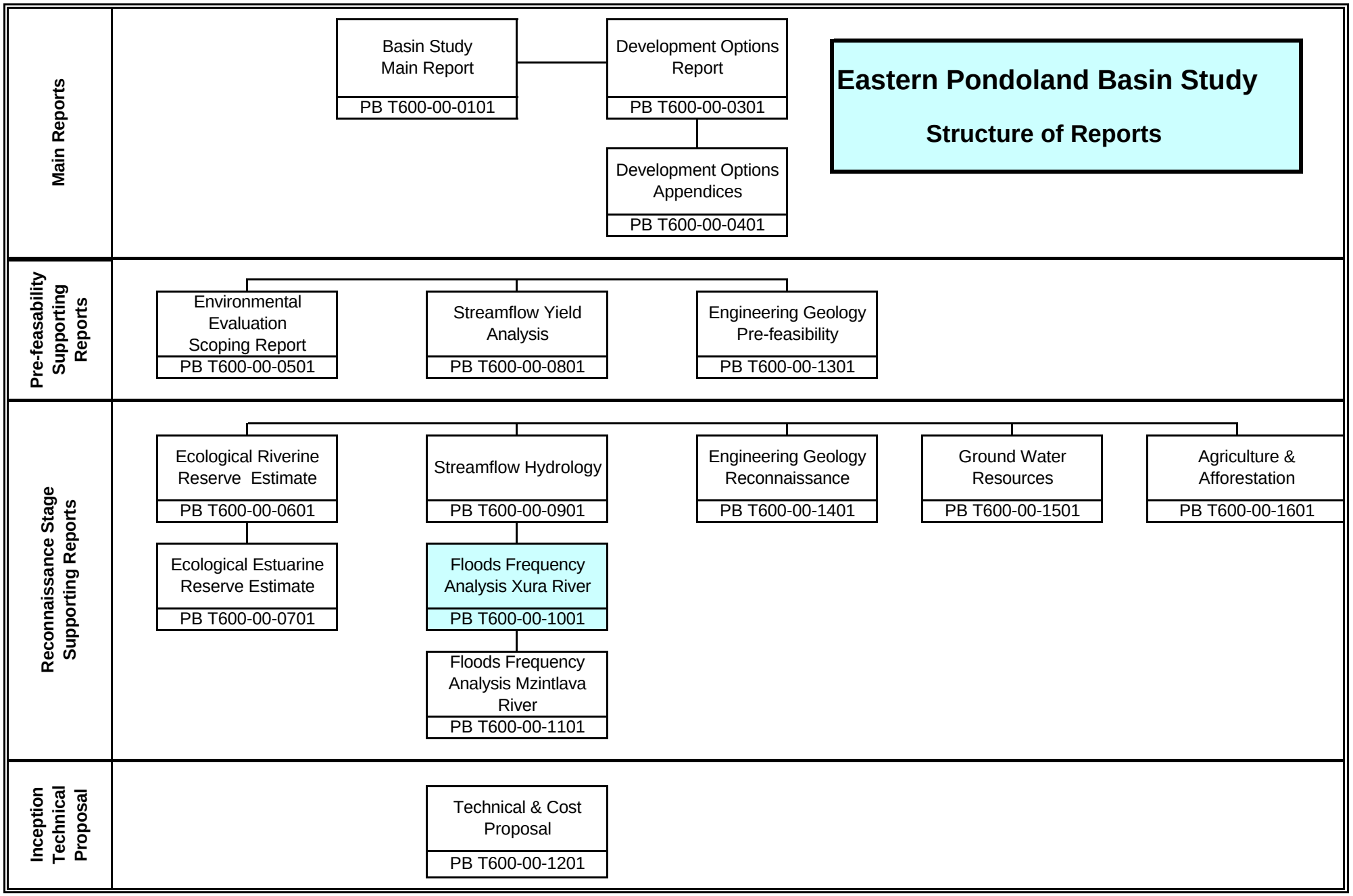


Fig 1 : Proposed Dam and Weir Sites

UWP Engineers

Eastern Pondoland Basin Study

Structure of Reports



INDEX

Executive Summary

List of Tables and Figures ii

List of Abbreviations iv

1. Introduction
1.1 Zalu, Lusikisiki & Xura proposed dam sites and its catchment 1
1.2 Soil and vegetation description 1

2. Previous calculations and historical floods
2.1 Previous calculations 2
2.2 Historical floods 2

3. Calculation methods
3.1 Empirical methods 3
3.2 Deterministic methods 3

4. Results 4

5. Evaluation of estimates 7

6. Recommendations
6.1 Recommended flood peaks 8
6.2 Recommended flood volumes 9
6.3 Safety evaluation flood 9

References 10

Appendices

A Catchment characteristics
B Empirical methods
C Rainfall and Deterministic methods
D Flood Hydrographs

LIST OF TABLES AND FIGURES

Table 1.1	Catchment parameters	1
Table 1.2	Permeability of the soil	2
Table 1.3	Vegetation cover	2
Table 4.1	Summary of the flood peak results at *Zalu* dam site (m^3/s)	4
Table 4.1	Summary of the flood peak results at *Lusikisiki* dam site (m^3/s)	5
Table 4.2	Summary of the flood peak results at *Xura* dam site (m^3/s)	6
Table 5.1	Representative flood peaks for *Zalu* proposed dam site (m^3/s)	7
Table 5.2	Representative flood peaks for *Lusikisiki* proposed dam site (m^3/s)	7
Table 5.3	Representative flood peaks for *Xura* proposed dam site (m^3/s)	7
Table 6.1	Recommended flood peaks for *Zalu* proposed dam site (m^3/s)	8
Table 6.2	Recommended flood peaks for *Lusikisiki* proposed dam site (m^3/s)	8
Table 6.3	Recommended flood peaks for *Xura* proposed dam site (m^3/s)	8
Table 6.4	Flood volumes for *Zalu* proposed dam site ($10^6 m^3$)	9
Table 6.5	Flood volumes for *Lusikisiki* proposed dam site ($10^6 m^3$)	9
Table 6.6	Flood volumes for *Xura* dam proposed site ($10^6 m^3$)	9
Table A.1	Catchment characteristics and information for *Zalu*	
Table A.2	Calculation of river channel and catchment slope for *Zalu*	
Table A.3	Catchment characteristics and information for *Lusikisiki*	
Table A.4	Calculation of river channel and catchment slope for *Lusikisiki*	
Table A.5	Catchment characteristics and information for *Xura*	
Table A.6	Calculation of river channel and catchment slope for *Xura*	
Table B.1	Empirical methods: Flood peak calculations for *Zalu site*	
Table B.2	Empirical methods: Flood peak calculations for *Lusikisiki site*	
Table B.3	Empirical methods: Flood peak calculations for *Xura site*	
Table C.1	Rainfall stations	
Table C.2	*Zalu* estimated areal storm catchment rainfall (mm)	
Table C.3	*Lusikisiki* estimated areal storm catchment rainfall (mm)	
Table C.4	*Xura* estimated areal storm catchment rainfall (mm)	
Table C.5	Deterministic methods, DRH, SUH and Rational for *Zalu site*	
Table C.6	Deterministic methods, DRH, SUH and Rational for *Lusikisiki site*	
Table C.7	Deterministic methods: DRH, SUH and Rational for *Xura site*	

Table D.1 Co-ordinates of the 1-% Exceedance Probability Hydrographs at Zalu proposed dam site
Table D.2 Co-ordinates of the 1-% Exceedance Probability Hydrographs at Lusikisiki proposed dam site
Table D.3 Co-ordinates of the 1-% Exceedance Probability Hydrographs at Xura proposed dam site

Figure A.1 Catchment area of *Zalu, Lusikisiki* and *Xura* proposed dam sites

Figure D.1 1% Exceedance probability flood hydrograph at *Zalu* dam site
Figure D.2 1% Exceedance probability flood hydrograph at *Lusikisiki* dam site
Figure D.3 1% Exceedance probability flood hydrograph at *Xura* dam site

LIST OF ABBREVIATIONS

A	-	Total catchment area (km^2)
A_e	-	Effective catchment area (km^2)
C_s	-	Value dependent on catchment steepness (Rational method)
C_p	-	Value dependent on soil permeability (Rational method)
C_v	-	Value dependent on vegetal cover (Rational method)
DRH	-	Direct runoff hydrograph method (Bauer and Midgley, 1974)
f_{TR137}	-	Factors to calculate Q_{50}, Q_{100} and Q_{200} from RMF
K	-	RMF region
K_e	-	Francou-Rodier value
K_{SEF}	-	Francou-Rodier value used to determine safety evaluation flood
K_c	-	Semi permeable soil
L	-	Length of longest watercourse (km)
L_c	-	Distance from catchment outlet to perpendicular dropped from centre of gravity of the catchment to point on main watercourse (km)
MAP	-	Mean annual precipitation (mm)
MIPI	-	Empirical method devised by Pitman and Midgley, 1971.
Q_T	-	Flood peak for return period T year (m^3/s)
RMF	-	Regional maximum flood (m^3/s) for $t_{crit.}$ (Kovács, 1988)
S	-	Average slope of longest watercourse (m/m)
SEF	-	Safety evaluation flood (m^3/s)
T	-	Return period in years
t_c	-	Time of concentration (h)
S_A	-	Mean catchment steepness (%)

1. INTRODUCTION

1.1 Zalu, Lusikisiki and Xura proposed dam sites and its catchment

The proposed Zalu, Lusikisiki and Xura dam sites are situated on the Xura river about 50 km north west of the town Port St. Johns, in the Eastern Cape province.
The catchment area of the Zalu proposed dam site is 71 km^2, with mean catchment steepness of 14 % and t_c was calculated to be 3.5 hours. The catchment area of Lusikisiki proposed dam site is 91 km^2, with mean catchment steepness of 13.9 % and t_c was calculated to be 5.0 hours. The catchment area of the Xura dam site is 225 km^2, with mean catchment steepness of 13.2 % and t_c was calculated to be 7.0 hours.

Empirical and Deterministic methods were used to determine the flood peaks.
The most important catchment characteristics are tabulated in Table 1.1.

TABLE 1.1 Catchment parameters

Site **River**	Zalu Xura	Lusikisiki Xura	Xura Xura
Catchment area	71.0 km^2	91.0 km^2	225.0 km^2
Longest watercourse	17.0 km	27.5 km	40.0 km
Average catchment steepness	14.0 %	13.9 %	13.2 %
Time of concentration	3.5 hrs	5.0 hrs	7.0 hrs
Mean annual precipitation	920 mm	950 mm	945 mm

1.2 Soil and vegetation description

Acocks (1988) describes veld in these catchments as:

i. Ngongoni Veld
This veld type, together with *Eastern Province Thornveld and Zululand Thornveld*, occupied a narrow and irregular belt of rolling country just above a *Coastal Forest* belt. It lies on the slopes of the escarpment the lowest of the series of plateaux of which South Africa is made up. The sour grassveld, which almost replaced the forest, has become dominant by the *Ngongoni*.

ii. Valley Bushveld
Northern variation of the *Valley Bushveld* is extending as far south as the Great Kei Valley. The variation is transitional to the *Lowveld*, and includes grass, fewer succulents and more species of definitely tropical nature. Fully developed *Valley Bushveld* is scrub forest dominated by tree *Euphobias*, especially in the northern variation.

iii. Highland and Dohne Sourveld

Dohne Sourveld is generally very similar to the *Highland Sourveld*, but lies at lower altitudes, 600-1350 m above sea level. Relics of forest are more numerous, larger and better preserved.
The forest is richer in species than the forest of *Highland Sourveld*. The *Dohne Sourveld*, which replaces this forest, is also dense, sour grassveld. This veld type shows a good deal of variation.

The percentage weighting of the different soil and vegetation types, for the whole catchment area, are listed in Tables 1.2 and 1.3.

TABLE 1.2 Permeability of the soil

Soil type	**Zalu % A**	**Lusikisiki % A**	**Xura %A**
Semi-permeable	10	10	30
Impermeable	90	90	70

TABLE 1.3 Vegetation cover

Vegetation type	**Zalu % A**	**Lusikisiki % A**	**Xura %A**
Forest, Dense bush &woods	30	30	40
Thin bush	40	40	40
Grassland	7	7	13
Bare surface	3	3	7

The catchment area boundaries and reference co-ordinates for all three sites are shown in Figure A.1, Appendix A.
A summary of catchment characteristics is given in Tables A1, A3 and A5 in Appendix A.

2. PREVIOUS CALCULATIONS AND HISTORICAL FLOODS

2.1 Previous calculations

None found

2.2 Historical floods

None found

3. CALCULATION METHODS

No flow data or dam level data is available. There is no gauging station in the catchment with sufficient length of record. Therefore, only Empirical and Deterministic methods were used to estimate the flood peaks.

3.1 Empirical methods

The empirical methods MIPI (Midgley and Pitman 1971), HRU 1/71, CAPA, Roberts and TR 137 were used to calculate the flood peaks. In the TR 137 method, K_e = 5.2 was used to calculate the RMF for Zalu and Lusikisiki sites, and K_e = 5.4 for Xura site. The adjustment factors (f_{TR137}) were used to estimate the 50 years, 100 years and 200 years flood peaks.
The Empflo 98 computer program (Van der Spuy, 1998) was used to calculate flood peaks by MIPI, HRU 1/71, Roberts, CAPA and TR137 methods. (Appendix B)

3.2 Deterministic methods

The deterministic methods include the Rational, DRH (Bauer and Midgley, 1974) and SUH (synthetic unit hydrograph method HRU 1/72).
Two rainfall stations with sufficient length of record were found outside of the catchment, (one is indicated on Fig.A.1, Appendix A.). The daily point rainfalls were obtained from the **H**ydrological **I**nformation **S**ystem (HIS) rainfall database. The Thiessen Polygon method was used to determine the weighted contribution of each station, to the average catchment rainfall.
The RainCalc3 computer program, (C. Linström, 1998) was used to calculate areal storm rainfall for duration ½t_c, t_c and 2t_c, and for 2 - 200 years return periods. (Appendix C)

The Detflo 99 computer program, (P. Rademeyer, 1999) was used to calculate flood peaks by Rational, DRH and SUH methods.

4. RESULTS

The estimation of the applicable methods for all three sites is shown in Tables 4.1, 4.2 and 4.3. The flood peaks derived by the empirical methods are assumed to refer to the storm duration t_c.

TABLE 4.1 Summary of the flood peak results at *Zalu* dam site (m^3/s)

METHOD	STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
		50	20	10	5	2	1	0.5	RMF
DETERMINISTIC									
	1.8	45	99	145	196	272	342	411	
RATIONAL	**3.5**	55	123	178	242	337	418	503	
	7.0	31	70	101	138	190	238	287	
	1.8	51	89	118	150	198	242	283	
DRH	**3.5**	56	97	127	163	216	258	303	
	7.0	44	78	103	132	171	208	244	
	1.8	46	80	107	136	179	219	256	
SUH	**3.5**	43	75	98	126	166	199	234	
	7.0	31	55	73	94	122	147	173	
EMPIRICAL									
MIPI	**3.5**	27	63	96	136	197	249	307	
HRU 1/71	**3.5**	29	72	105	141	198	249	309	
ROBERTS	**3.5**	33	73	108	145	192	225	256	
CAPA	**3.5**	45	71	97	133				
TR 137	**3.5**					440	561	697	1088

TABLE 4.2 Summary of the flood peak results at *Lusikisiki* dam site (m^3/s)

METHOD	STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
		50	**20**	**10**	**5**	**2**	**1**	**0.5**	**RMF**
DETERMINISTIC									
	2.5	52	121	180	248	349	443	537	
RATIONAL	**5.0**	60	140	208	286	404	509	622	
	10.0	32	75	112	154	218	274	335	
	2.5	65	121	166	218	292	362	429	
DRH	**5.0**	63	118	162	210	284	346	414	
	10.0	44	83	115	149	202	246	293	
	2.5	72	133	184	241	323	400	475	
SUH	**5.0**	56	105	144	188	254	309	369	
	10.0	35	66	92	119	162	196	234	
EMPIRICAL									
MIPI	**5.0**	31	71	109	154	222	282	347	
HRU 1/71	**5.0**	29	73	106	143	201	253	314	
ROBERTS	**5.0**	37	83	123	164	217	255	290	
CAPA	**5.0**	49	76	105	143				
TR 137	**5.0**					512	650	790	1250

TABLE 4.3 Summary of the flood peak results at *Xura* dam site (m^3/s)

METHOD	STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
		50	**20**	**10**	**5**	**2**	**1**	**0.5**	**RMF**
DETERMINISTIC									
	3.5	93	213	316	433	609	766	933	
RATIONAL	**7.0**	107	241	360	497	696	851	1064	
	14.0	60	137	204	279	391	494	602	
	3.5	121	222	304	394	529	646	769	
DRH	**7.0**	114	204	283	371	494	576	713	
	14.0	86	160	221	285	379	462	547	
	3.5	128	236	321	417	560	684	814	
SUH	**7.0**	100	179	248	325	433	505	624	
	14.0	67	124	171	221	294	359	425	
EMPIRICAL									
MIPI	**7.0**	48	112	172	242	350	443	546	
HRU 1/71	**7.0**	50	126	184	248	347	437	543	
ROBERTS	**7.0**	59	130	193	258	342	401	457	
CAPA	**7.0**	89	138	189	258				
TR 137	**7.0**					1000	1280	1560	2524

5. EVALUATION OF ESTIMATES

After visual evaluation of the estimates in Tables 4.1, 4.2, 4.3, and a discussion with the officials of Flood Studies Subdirectorate the following were accepted for the flood peak calculations:
Results comparison was made with some of the Tasks in the region, with similar rainfall patterns and catchment parameters. A good experience with the results of Statistical methods in the region an good relation with the Rational method, mostly for small catchments, it was decided to use Rational method for representative flood peaks for all return periods.
No Statistical analysis could be performed because no data is available.
The representative flood peaks for all three sites and all return periods were determined as follows and are summarised in Tables 5.1, 5.2 and.5.3.

Q_T = Rational method
T = 50 % - 0.5% prob. of exceedance

TABLE 5.1 Representative flood peaks for *Zalu* proposed dam site (m^3/s)

PROBABILITY OF EXCEEDANCE (%)	**50**	**20**	**10**	**5**	**2**	**1**	**0.5**
Q_T (m^3/s)	55	123	178	242	337	418	503

TABLE 5.2 Representative flood peaks for *Lusikisiki* proposed dam site (m^3/s)

PROBABILITY OF EXCEEDANCE (%)	**50**	**20**	**10**	**5**	**2**	**1**	**0.5**
Q_T (m^3/s)	60	140	208	286	404	509	622

TABLE 5.3 Representative flood peaks for *Xura* proposed dam site (m^3/s)

PROBABILITY OF EXCEEDANCE (%)	**50**	**20**	**10**	**5**	**2**	**1**	**0.5**
Q_T (m^3/s)	107	241	360	497	696	851	1064

The Rational method was used for calculations of var and var*.
The values of var and var* were applied to the representative flood peaks for each return period and from these the recommended values in Tables 6.1, 6.2 and 6.3 were derived.

6. RECOMMENDATIONS

6.1 Recommended flood peaks

The recommended flood peaks for all three sites are given in Table 6.1, 6.2 and 6.3.

TABLE 6.1 Recommended flood peaks for *Zalu* proposed dam site (m^3/s)

STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
	50	**20**	**10**	**5**	**2**	**1**	**0.5**	**RMF**
1.8	50	110	160	220	305	380	455	990
3.5	55	125	180	240	335	420	505	1090
7.0	45	100	140	190	265	330	395	855

TABLE 6.2 Recommended flood peaks for *Lusikisiki* proposed dam site (m^3/s)

STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
	50	**20**	**10**	**5**	**2**	**1**	**0.5**	**RMF**
2.5	55	130	195	265	375	475	580	1170
5.0	60	140	210	285	405	510	620	1250
10.0	45	105	160	220	310	390	480	960

TABLE 6.3 Recommended flood peaks for *Xura* proposed dam site (m^3/s)

STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
	50	**20**	**10**	**5**	**2**	**1**	**0.5**	**RMF**
3.5	100	227	340	465	650	810	1000	2370
7.0	105	240	360	495	695	850	1060	2520
14.0	85	190	280	390	545	670	835	1980

6.2 Flood volumes

The flood volumes for all three sites are given in Tables 6.4, 6.5 and 6.6. They were estimated using the recommended flood peaks (Tables 6.1, 6.2 and 6.3) and hydrographs determined from the DRH method. The 1.0- % exceedance probability hydrograph and its co-ordinates are given in Appendix D.

TABLE 6.4 Flood volumes for *Zalu* proposed dam site ($10^6 m^3$)

STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
	50	20	10	5	2	1	0.5	RMF
1.8	0.48	1.08	1.57	2.14	2.97	3.71	4.46	9.64
3.5	0.68	1.51	2.19	2.98	4.15	5.14	6.19	13.4
7.0	0.80	1.78	2.58	3.51	4.87	6.06	7.29	15.8

TABLE 6.5 Flood volumes for *Lusikisiki* proposed dam site ($10^6 m^3$)

STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
	50	20	10	5	2	1	0.5	RMF
2.5	0.78	1.82	2.71	3.73	5.26	6.65	8.10	16.3
5.0	1.07	2.49	3.69	5.08	7.18	9.04	11.0	22.2
10.0	1.27	2.96	4.41	6.06	8.57	10.8	13.2	26.5

TABLE 6.6 Flood volumes for *Xura* proposed dam site ($10^6 m^3$)

STORM DURATION (HOURS)	PROBABILITY OF EXCEEDANCE (%)							
	50	20	10	5	2	1	0.5	RMF
3.5	1.96	4.46	6.64	9.13	12.8	15.9	19.6	46.5
7.0	2.71	6.10	9.11	12.6	17.6	21.5	26.9	63.9
14.0	3.22	7.31	10.9	15.0	21.0	26.0	32.2	76.4

6.3 Safety evaluation flood (SEF)

It is recommended that the RMF be used as the PMF and SEF.

REFERENCES AND BIBLIOGRAPHY

Acocks, J.P.H. (1988)
Veld types of South Africa.
Memoirs of the Botanical Survey of South Africa No. 57.
Botanical Research Institute, Department of Agriculture and Water Supply, Pretoria.

Alexander, W.J.R. (1990)
Flood Hydrology for Southern Africa.
SANCOLD, Pretoria.

Bauer, S.W. and Midgley, D.C. (1974)
A simple procedure for synthesising direct runoff hydrographs.
HRU Report No. 1/74, Department of Civil Engineering, University of the Witwatersrand, Johannesburg.

Hydrological Research Unit (1972)
Design flood determination in South Africa.
HRU Report No. 1/72, Department of Civil Engineering, University of the Witwatersrand, Johannesburg.

Kovács, Z.P. (1988)
Regional maximum flood peaks in Southern Africa.
Technical report TR 137. Sub-directorate Flood Studies, Department of Water Affairs, Pretoria.

Kovács, Z.P. (1994)
Flood frequency manual - Part I: Basic information.

Kovács, Z.P. and Zürich, H. (1994)
Flood frequency manual - Part II: Methods of analysis.

Petras, V. and Du Plessis, P.H. (1987)
Catalogue of Hydrological Catchment Parameters.

Pitman, W.V. and Migley, D.C. (1971)
Amendments to Design Flood Manual HRU 4/69.
HRU report No. 1/71, Department of Civil Engineering, University of the Witwatersrand, Johannesburg.

Van Bladeren, D. (1995)
Historical flood documentation in South Africa.
TR 152, Department of Water Affairs and Forestry, Pretoria.

Flood studies Software
Developed for use within Flood Studies due to links to HIS database held at DWAF.
Linström, C. (1998)
RainCalc3 PC program for calculating areal rainfall and mean annual precipitation,
Department of Water Affairs and Forestry, Pretoria.
Rademeyer, P (1999)
Detflo 99 PC program, Department of Water Affairs and Forestry, Pretoria.
Van der Spuy, D. (1998)
Empflo 98 and Statflo 98 PC programs, Department of Water Affairs and Forestry, Pretoria.

APPENDIX A

CATCHMENT CHARACTERISTICS

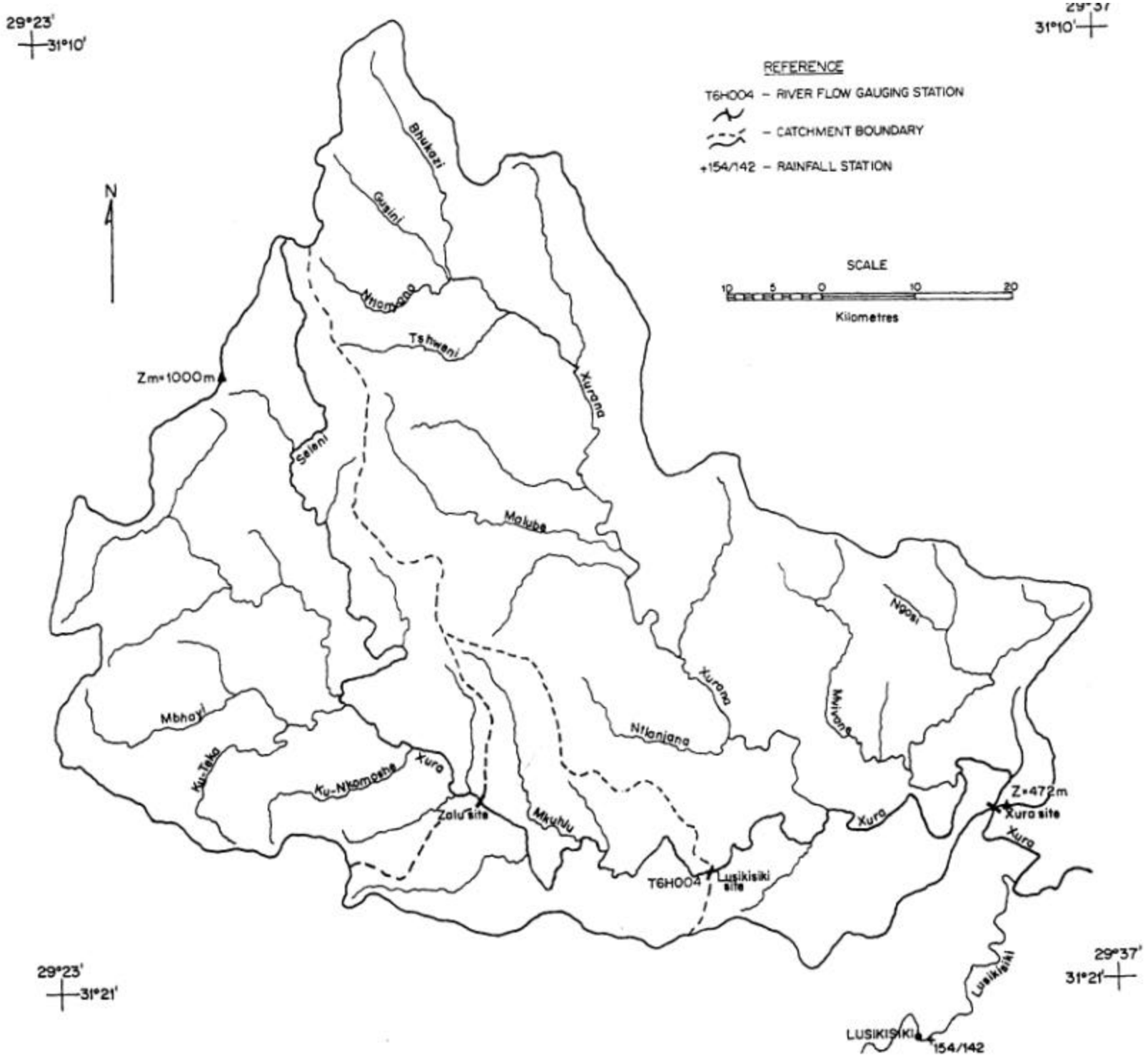


FIGURE A1 CATCHMENT AREA OF ZALU, LUSIKISIKI AND XURA SITES

Table A.1: Catchment Characteristics and information

IDENTIFICATION OF SITE

Place:	Zalu site	Drainage Region:	1860	Latitude:	31º18' 50"
Watercourse:	Xura	Station no.:		Longitude:	29º28'40"

CATCHMENT CHARACTERISTICS

Catchment Area and Slope:

Total:	**A**	=	71	km²	Part of A_e considered as dolomitic: **A_d** =	0	km²
Ineffective:	**A_i**	=	0	km²	Reduction factor **k** =	0.38	
Effective:	**A_e**	=	71	km²	Flood peak reduction coefficient **f_d** =	1.00	
Mean steepness of **A_e**	**S_A**	=	13.98	%	Mean steepness of **A_e** as used in CAPA	18.29	%

Rainfall-Runoff properties:

Veld type zones (HRU 1/72 fig.F1)	8	
Relative Weight (%)	100%	

Catchment coverage as required for Raional method

Rural	Urban	Lakes
100%	0%	0%

Soil Permeability:	**%A**	**Vegetation:**	**%A**	**Rainfall:** (HRU 1/72 fig.C3) *	
Very Permeable (A)		Forest, Dense bush & wood	50%	Mean Annual Rainfall (mm)	920
Permeable (B)		Thin Bush, Cultivated land	40%	Extreme point rainfall region *	3
Semi-Permeable (C)	10%	Grassland	7%	Coastal (**C**) or Inland (**I**)	I
Impermeable (D)	90%	Bare surface	3%	Winter (**W**) or Summer (**S**)	S

Watercourse properties:

Longest Watercourse:				
Natural channel	**L_1**	=	17	km
Overland flow	**L_2**	=		km
Total length	**L**	=	17	km
Distance from site to centre of catchment	**L_c**	=	9	km

Mean Slope:				
Mean slope of L_1	**S_1**	=	0.013560	
Mean slope of L_2	**S_2**	=	0.000000	
Mean slope of L	**S_L**	=	0.013560	

Time of concentration:

TYPE OF FLOW	TIME OF CONCENTRATION (hours)		
Natural channel	$t_{c1} = \tau\,[0.87 * L_1^2 / (1000 * S_1)]^{0.385}$	3.31	**3.5**
Overland	$t_{c2} = 0{,}6 * [\,r * L_2 / (S_2)^{0.5}\,]^{0.467}$	0.00	
Artificial channel	$t_{c1a} = 0.278 * \Sigma\,(l_i / v_i)$		

where

A_e	=	71	to calculate τ
τ	=	1.1	correction to factor according to size of A
r	=	0.20	roughness factor
l_i	=		length of a uniform reach
v_i	=		velocity in a uniform reach

Typical values of r	Pavement	0,02	Bare soil	0,1	Poor grass	0,3	Average grass & Cultivated land	0,4	Dense grass	0,8

ADDITIONAL INFORMATION FOR EMPIRICAL METHODS

RMF region TR137	5.2	Francou-Rodier **K_e**	5.2	**Roberts** "K" (Transvaal)	1

MIPI Flood regions HRU 1/72 fig.B.1	4		
Relative proportion (%)	100%		

Calculation of River Channel, Overland and Catchment Slope

Table A.2

Channel (river) flow

RL (m)	K.A. (km)	Δ RL	Δ K.A.	RL (m)	K.A. (km)	Δ RL	Δ K.A.
929.6							
914.4	0.7	15.2	0.7				
883.9	1.6	30.5	0.9				
853.4	2.1	30.5	0.5				
823.0	3.7	30.4	1.6				
792.5	5.0	30.5	1.3				
762.0	6.8	30.5	1.8				
731.5	8.7	30.5	1.9				
701.0	10.4	30.5	1.7				
670.6	12.4	30.4	2.0				
640.1	17.0	30.5	4.6				
S		289.5	17	S			

Overland flow

RL (m)	K.A. (m)	Δ RL	Δ K.A.
S			

Catchment Flow (grid method)

Δ H (m) = 15.24 Scale: 50000

l_i (as measured on map in mm)

2.0	1.0								
1.0	1.0								
2.0	1.0								
3.0	2.0								
1.0	2.0								
1.0	3.0								
4.0	5.0								
1.0	1.0								
5.0	3.0								
1.0	2.0								
1.0	2.0								
2.0	2.0								
2.0	4.0								
2.0	2.0								
1.0	1.0								
2.0	5.0								
2.0	2.0								
1.0	3.0								
1.0									
2.0									
4.0									
2.0									
2.0									
3.0									
2.0									
2.0									
3.0									
1.0									
2.0									
3.0									
3.0									
4.0									
2.0									
1.0									
1.0									
1.0									
3.0									
1.0									
9.0									
4.0									
2.0									
2.0									
2.0									
3.0									
2.0									
1.0									
1.0									
1.0									
2.0									
1.0									
1.0									
1.0									
3.0									
2.0									
2.0									
2.0									
3.0									
2.0									
3.0									
2.0									
S		8500.0		n		78			

S_1 (river channel)

Taylor	Area	10 @ 85	H/L
0.01356	0.01260	0.01434	0.01703

S_2 (overland)

Taylor	Area	10 @ 85	H/L

S_3 (catchment mean)

Taylor/Schwarz	Alexander	Kovacs
0.11174	0.13985	0.18286

Table A.3: Catchment Characteristics and information

IDENTIFICATION OF SITE

Place:	Lusikisiki site	Drainage Region:	1860	Latitude:	31º19' 25"
Watercourse:	Xura	Station no.:	T6H004	Longitude:	29º31'10"

CATCHMENT CHARACTERISTICS

Catchment Area and Slope:

Total:	**A**	=	91	km^2	Part of A_e considered as dolomitic:	A_d	=	0 km^2
Ineffective:	A_i	=	0	km^2	Reduction factor	**k**	=	0.38
Effective:	A_e	=	91	km^2	Flood peak reduction coefficient	f_d	=	1.00
Mean steepness of A_e	S_A	=	13.91	%	Mean steepness of A_e as used in CAPA			18.52 %

Rainfall-Runoff properties:

Veld type zones (HRU 1/72 fig.F1)	8	
Relative Weight (%)	100%	

Catchment coverage as required for Raional method

Rural	Urban	Lakes
100%	0%	0%

Soil Permeability:	**%A**	**Vegetation:**	**%A**	**Rainfall:** (HRU 1/72 fig.C3) *	
Very Permeable (A)		Forest, Dense bush & wood	50%	Mean Annual Rainfall (mm)	950
Permeable (B)		Thin Bush, Cultivated land	40%	Extreme point rainfall region *	3
Semi-Permeable (C)	10%	Grassland	7%	Coastal (**C**) or Inland (**I**)	I
Impermeable (D)	90%	Bare surface	3%	Winter (**W**) or Summer (**S**)	S

Watercourse properties:

Longest Watercourse:				
Natural channel	L_1	=	28	km
Overland flow	L_2	=		km
Total length	**L**	=	28	km
Distance from site to centre of catchment	L_c	=	15	km

Mean Slope:			
Mean slope of L_1	S_1	=	0.011494
Mean slope of L_2	S_2	=	0.000000
Mean slope of L	S_L	=	0.011494

Time of concentration:

TYPE OF FLOW	TIME OF CONCENTRATION (hours)		
Natural channel	$t_{c1} = \tau\,[0.87 * L_1^2 / (1000 * S_1)]^{0.385}$	4.85	**5.0**
Overland	$t_{c2} = 0{,}6 * [\, r * L_2 / (S_2)^{0.5}\,]^{0{,}467}$	0.00	
Artificial channel	$t_{c1a} = 0.278 * \Sigma\,(\ell_i / v_i)$		

where

A_e	=	91	to calculate τ
τ	=	1.0	correction to factor according to size of A
r	=	0.20	roughness factor
ℓ_i	=		length of a uniform reach
v_i	=		velocity in a uniform reach

Typical values of r	Pavement	0,02	Bare soil	0,1	Poor grass	0,3	Average grass & Cultivated land	0,4	Dense grass	0,8

ADDITIONAL INFORMATION FOR EMPIRICAL METHODS

RMF region TR137	5.2	Francou-Rodier K_e	5.2	

Roberts "K" (Transvaal)	1

MIPI Flood regions HRU 1/72 fig.B.1	4		
Relative proportion (%)	100%		

Calculation of River Channel, Overland and Catchment Slo

Channel (river) flow								Catc		
RL (m)	K.A. (km)	DRL	DK.A.		RL (m)	K.A. (km)	DRL	DK.A.	DH (m) =		
											ℓ_i
929.6											
914.4	0.7	15.2	0.7						2.0	1.0	
883.9	1.6	30.5	0.9						1.0	1.0	
853.4	2.1	30.5	0.5						2.0	1.0	
823.0	3.7	30.4	1.6						3.0	2.0	
792.5	5.0	30.5	1.3						1.0	2.0	
762.0	6.8	30.5	1.8						1.0	3.0	
731.5	8.7	30.5	1.9						4.0	5.0	
701.0	10.4	30.5	1.7						1.0	1.0	
670.6	12.4	30.4	2.0						5.0	3.0	
640.1	15.4	30.5	3.0						1.0	2.0	
609.6	17.3	30.5	1.9						1.0	2.0	
594.4	19.3	15.2	2.0						2.0	2.0	
579.1	20.9	15.3	1.6						2.0	4.0	
563.9	22.7	15.2	1.8						2.0	2.0	
548.6	26.0	15.3	3.3						1.0	1.0	
533.4	27.5	15.2	1.5						2.0	7.0	
									2.0	1.0	
									1.0	3.0	
									1.0	6.0	
									2.0	2.0	
									4.0	1.0	
									2.0	2.0	
									2.0	1.0	
									3.0	1.0	
									2.0	3.0	
									2.0	1.0	
									3.0	2.0	
									1.0	2.0	
									2.0	3.0	
									3.0		
									3.0		
									4.0		
									2.0		
									1.0		
									1.0		
									1.0		
									3.0		
									1.0		
									9.0		
									4.0		
									2.0		

Calculation of River Channel, Overland and Catchment Slope

Table A.4

Channel (river) flow

RL (m)	K.A. (km)	D RL	D K.A.	RL (m)	K.A. (km)	D RL	D K.A.
929.6							
914.4	0.7	15.2	0.7				
883.9	1.6	30.5	0.9				
853.4	2.1	30.5	0.5				
823.0	3.7	30.4	1.6				
792.5	5.0	30.5	1.3				
762.0	6.8	30.5	1.8				
731.5	8.7	30.5	1.9				
701.0	10.4	30.5	1.7				
670.6	12.4	30.4	2.0				
640.1	15.4	30.5	3.0				
609.6	17.3	30.5	1.9				
594.4	19.3	15.2	2.0				
579.1	20.9	15.3	1.6				
563.9	22.7	15.2	1.8				
548.6	26.0	15.3	3.3				
533.4	27.5	15.2	1.5				
S		**396.2**	**27.5**	S			

Overland flow

RL (m)	K.A. (m)	D RL	D K.A.
S			

Catchment Flow (grid method)

D H (m) = **15.24** Scale: **50000**

l_i (as measured on map in mm)

2.0	1.0								
1.0	1.0								
2.0	1.0								
3.0	2.0								
1.0	2.0								
1.0	3.0								
4.0	5.0								
1.0	1.0								
5.0	3.0								
1.0	2.0								
1.0	2.0								
2.0	2.0								
2.0	4.0								
2.0	2.0								
1.0	1.0								
2.0	7.0								
2.0	1.0								
1.0	3.0								
1.0	6.0								
2.0	2.0								
4.0	1.0								
2.0	2.0								
2.0	1.0								
3.0	1.0								
2.0	3.0								
2.0	1.0								
3.0	2.0								
1.0	2.0								
2.0	3.0								
3.0									
3.0									
4.0									
2.0									
1.0									
1.0									
1.0									
3.0									
1.0									
9.0									
4.0									
2.0									
2.0									
2.0									
3.0									
2.0									
1.0									
1.0									
1.0									
2.0									
1.0									
1.0									
1.0									
3.0									
2.0									
2.0									
2.0									
3.0									
2.0									
3.0									
2.0									

S **9750.0** n **89**

S_1 (river channel)

Taylor	Area	10 @ 85	H/L
0.0115	0.0106	0.0126	0.0144

S_2 (overland)

Taylor	Area	10 @ 85	H/L

S_3 (catchment mean)

Taylor/Schwarz	Alexander	Kovacs
0.1086	0.1391	0.1852

Table A.5: Catchment Characteristics and information

IDENTIFICATION OF SITE

Place:	Xura site	Drainage Region:	1860	Latitude:	31º18'55"
Watercourse:	Xura	Station no.:		Longitude:	29º35'35"

CATCHMENT CHARACTERISTICS

Catchment Area and Slope:

Total:	**A**	=	225	km^2	Part of A_e considered as dolomitic:	A_d =	0 km^2
Ineffective:	A_i	=	0	km^2	Reduction factor	**k** =	0.36
Effective:	A_e	=	225	km^2	Flood peak reduction coefficient	f_d =	1.00
Mean steepness of A_e	S_A	=	13.22	%	Mean steepness of A_e as used in CAPA		18.76 %

Rainfall-Runoff properties:

Veld type zones (HRU 1/72 fig.F1)	8	
Relative Weight (%)	100%	

Catchment coverage as required for Raional method

Rural	Urban	Lakes
100%	0%	0%

Soil Permeability:	**%A**	**Vegetation:**	**%A**	**Rainfall:** (HRU 1/72 fig.C3) *	
Very Permeable (A)		Forest, Dense bush & wood	40%	Mean Annual Rainfall (mm)	945
Permeable (B)		Thin Bush, Cultivated land	40%	Extreme point rainfall region *	3
Semi-Permeable (C)	30%	Grassland	13%	Coastal (**C**) or Inland (**I**)	I
Impermeable (D)	70%	Bare surface	7%	Winter (**W**) or Summer (**S**)	S

Watercourse properties:

Longest Watercourse:					Mean Slope:		
Natural channel	L_1	=	40	km	Mean slope of L_1	S_1 =	0.008534
Overland flow	L_2	=		km	Mean slope of L_2	S_2 =	0.000000
Total length	**L**	=	40	km	Mean slope of L	S_L =	0.008534
Distance from site to centre of catchment	L_c	=	21	km			

Time of concentration:

TYPE OF FLOW	TIME OF CONCENTRATION (hours)		
Natural channel	$t_{c1} = \tau\,[0.87 * L_1^2 / (1000 * S_1)]^{0.385}$	7.11	**7.0**
Overland	$t_{c2} = 0{,}6 * [\,r * L_2 / (S_2)^{0.5}\,]^{0.467}$	0.00	
Artificial channel	$t_{c1a} = 0.278 * \Sigma\,(l_i / v_i)$		

where

A_e =	225	to calculate τ
τ =	1.0	correction to factor according to size of A
r =	0.20	roughness factor
l_i =		length of a uniform reach
v_i =		velocity in a uniform reach

Typical values of r	Pavement	0,02	Bare soil	0,1	Poor grass	0,3	Average grass & Cultivated land	0,4	Dense grass	0,8

ADDITIONAL INFORMATION FOR EMPIRICAL METHODS

RMF region TR137	5.4	Francou-Rodier K_e	5.4	**Roberts** "K" (Transvaal)	1

MIPI Flood regions HRU 1/72 fig.B.1	4		
Relative proportion (%)	100%		

Calculation of River Channel, Overland and Catchment Slope

Table A.6

Channel (river) flow

RL (m)	K.A. (km)	D RL	D K.A.	RL (m)	K.A. (km)	D RL	D K.A.
929.6							
914.4	0.7	15.2	0.7				
883.9	1.6	30.5	0.9				
853.4	2.1	30.5	0.5				
823.0	3.7	30.4	1.6				
792.5	5.0	30.5	1.3				
762.0	6.8	30.5	1.8				
731.5	8.7	30.5	1.9				
701.0	10.4	30.5	1.7				
670.6	12.4	30.4	2.0				
640.1	15.4	30.5	3.0				
609.6	17.3	30.5	1.9				
594.4	19.3	15.2	2.0				
579.1	20.9	15.3	1.6				
563.9	22.7	15.2	1.8				
548.6	26.0	15.3	3.3				
533.4	27.5	15.2	1.5				
518.2	28.6	15.2	1.1				
502.9	30.6	15.3	2.0				
487.7	32.8	15.2	2.2				
472.4	37.9	15.3	5.1				
457.2	40.0	15.2	2.1				
S		472.4	40	S			

Overland flow

RL (m)	K.A. (m)	D RL	D K.A.
S			

Catchment Flow (grid method)

D H (m) = 15.24 Scale: 50000

f_i (as measured on map in mm)

2.0	1.0	1.0	1.0						
1.0	1.0	2.0	1.0						
2.0	3.0	1.0	2.0						
3.0	2.0	1.0	1.0						
1.0	1.0	1.0	1.0						
1.0	1.0	1.0	2.0						
4.0	1.0	1.0	2.0						
1.0	2.0	1.0	3.0						
5.0	2.0	3.0	2.0						
1.0	1.0	2.0	2.0						
1.0	2.0	2.0	5.0						
2.0	1.0	7.0	3.0						
2.0	3.0	1.0	6.0						
2.0	1.0	4.0	2.0						
1.0	1.0	3.0	3.0						
2.0	3.0	2.0	13.0						
2.0	1.0	5.0	4.0						
1.0	2.0	5.0	3.0						
1.0	2.0	1.0	2.0						
2.0	3.0	1.0	2.0						
4.0	5.0	2.0	3.0						
2.0	1.0	2.0	1.0						
2.0	3.0	2.0	2.0						
3.0	2.0	3.0	3.0						
2.0	2.0	1.0	3.0						
2.0	1.0	1.0	2.0						
3.0	1.0	1.0	1.0						
1.0	2.0	2.0	1.0						
2.0	2.0	1.0	5.0						
3.0	3.0	2.0	7.0						
3.0	1.0	1.0							
4.0	2.0	1.0							
2.0	1.0	1.0							
1.0	1.0	4.0							
1.0	2.0	2.0							
1.0	1.0	1.0							
3.0	4.0	1.0							
1.0	2.0	1.0							
9.0	1.0	3.0							
4.0	7.0	1.0							
2.0	1.0	1.0							
2.0	3.0	2.0							
2.0	3.0	4.0							
3.0	3.0	6.0							
2.0	2.0	5.0							
1.0	5.0	4.0							
1.0	2.0	1.0							
1.0	1.0	4.0							
2.0	1.0	1.0							
1.0	1.0	1.0							
1.0	1.0	4.0							
1.0	3.0	3.0							
3.0	6.0	2.0							
2.0	3.0	3.0							
2.0	1.0	2.0							
2.0	2.0	3.0							
3.0	3.0	2.0							
2.0	9.0	1.0							
1.0	2.0	7.0							
1.0	3.0	4.0							
S		24200.0		n		210			

S_1 (river channel)

Taylor	Area	10 @ 85	H/L
0.0085	0.0081	0.0102	0.0118

S_2 (overland)

Taylor	Area	10 @ 85	H/L

S_3 (catchment mean)

Taylor/Schwarz	Alexander	Kovacs
0.0966	0.1322	0.1876

APPENDIX B

EMPIRICAL METHODS

EMPIRICAL METHODS

The empirical methods MIPI (Midgley and Pitman 1971), HRU 1/71, CAPA, Roberts and TR 137 were used to calculate the flood peaks.
The Empflo 98 computer program (Van der Spuy, 1998) was used to calculate flood peaks by MIPI, HRU1/71, Roberts, CAPA and TR137 methods.
For the Roberts method a "K" value of 1.0 was used. TR137 was used to determine the RMF. The catchments of Zalu and Lusikisiki lie in RMF region 5.2, and the catchment of Xura lies in RMF region 5.4. Francou Rodier K_e value of 5.2 and 5.4 were used respectively.
`

Tables B.1, B.2 and B.3 are an extract from the Empflo98 computer program, used to calculate flood peaks by MIPI, HRU1/71, CAPA, Roberts method and TR137.

Table B.1: *Zalu site*

Method	Probability of exceedance (%)									RMF
	50	20	10	5	2	1	0.5	0.2	0.1	
	FLOOD PEAKS in m^3/s									
MIPI	27	63	96	136	197	249	307	392	463	
HRU1/71	29	72	105	141	198	249	309	405	493	
Roberts	33	73	108	145	192	225	256	294	320	
CAPA	45	71	97	133	197	265	354	519	691	
TR137					440	561	697			1088

Table B.2: *Lusikisiki site*

Method	Probability of exceedance (%)									RMF
	50	20	10	5	2	1	0.5	0.2	0.1	
	FLOOD PEAKS in m^3/s									
MIPI	31	71	109	154	222	282	347	444	524	
HRU1/71	29	73	106	143	201	253	314	412	501	
Roberts	37	83	123	164	217	255	290	333	363	
CAPA	49	76	105	143	212	284	380	555	739	
TR137					512	650	790			1250

Table B.3: *Xura site*

Method	Probability of exceedance (%)									RMF
	50	20	10	5	2	1	0.5	0.2	0.1	
	FLOOD PEAKS in m^3/s									
MIPI	48	112	172	242	350	443	546	698	824	
HRU 1/71	50	126	184	248	347	437	543	711	866	
Roberts	59	130	193	258	342	401	457	524	570	
CAPA	89	138	189	258	384	514	688	1006	1339	
TR137					1000	1280	1560			2524

Appendix A. contains more information on the catchment parameters, which were used in **Empflo98** program.

APPENDIX C

RAINFALL AND DETERMINISTIC METHODS

RAINFALL STATIONS AND AREAL STORM RAINFALL

The following rainfall stations were selected on reliability of the data, location and record length. The position of Lusikisiki rainfall station is plotted on the catchment map.
The Flagstaff rainfall station is out of a sketch. See Figure A.1, Appendix A.
The daily point rainfalls were obtained from the **H**ydrological **I**nformation **S**ystem (HIS) rainfall database. The Thiessen Polygon method was used to determine the weighted contribution of each station, to the average catchment rainfall.

Table C.1 Rainfall stations

Station no.	**Name**	**Zalu representative catch. size (km^2)**	**Lusikisiki representative catch. size (km^2)**	**Xura representative catch. size (km^2)**	**Record length (years)**
153875	Flagstaff	19.5	16.9	51.6	76
154142	Lusikisiki	55.5	79.1	194.4	68

Table C.2 *Zalu* estimated areal storm catchment rainfall (mm)

Storm duration	**Probability of exceedance %**						
	50	**20**	**10**	**5**	**2**	**1**	**0.5**
$0.5t_c$	54	77	92	107	127	144	159
$1.0t_c$	64	91	108	126	150	168	186
$2.0t_c$	70	100	119	139	164	185	205

Table C.3 *Lusikisiki* estimated areal storm catchment rainfall (mm)

Storm duration	**Probability of exceedance %**						
	50	**20**	**10**	**5**	**2**	**1**	**0.5**
$0.5t_c$	67	99	121	143	172	197	220
$1.0t_c$	74	110	134	158	191	217	244
$2.0t_c$	77	114	140	165	200	227	255

Table C.4 *Xura* estimated areal storm catchment rainfall (mm)

Storm duration	**Probability of exceedance %**						
	50	**20**	**10**	**5**	**2**	**1**	**0.5**
$0.5t_c$	70	103	125	147	177	201	225
$1.0t_c$	77	111	136	161	193	219	245
$2.0t_c$	83	122	149	175	210	239	268

The *RainCalc3* program (Linström, 1998) was used to calculate point storm rainfall, areal storm rainfall as well as the **M**ean **A**nnual **P**recipitation (MAP). MAP for Zalu site is 920 mm, for Lusikisiki site 950 mm and for Xura site 945 mm.

DETERMINISTIC METHODS

The deterministic methods include the Rational, DRH (Bauer and Midgley, 1974) and SUH methods were used to estimate flood peaks for Zalu, Lusikisiki and Xura proposed dam sites.
Storm duration $0.5t_c$, t_c, and $2t_c$ were used to calculate flood peaks for different probabilities of exceedance.
Tables C.5, C.6 and C.7 are extracts from the Detflo 99 computer program, (P. Rademeyer, 1999) used to calculate flood peaks by Rational, DRH and SUH methods.

Table C.5 *Zalu site*

DRH Flood Peaks

EP	50	20	10	5	2	1	0.5
½Tc	51	89	118	150	198	242	283
Tc	56	97	127	163	216	258	303
2Tc	44	78	103	132	171	208	244

SUH Flood Peaks

EP	50	20	10	5	2	1	0.5
½Tc	63	109	144	184	242	296	347
Tc	51	89	117	150	199	238	280
2Tc	35	61	81	104	136	164	193

Rational Flood Peaks

EP	50	20	10	5	2	1	0.5
½Tc	45	99	145	196	272	342	411
Tc	55	123	178	242	337	418	503
2Tc	31	70	101	138	190	238	287

Table C.6 *Lusikisiki site*

DRH Flood Peaks

EP	50	20	10	5	2	1	0.5
½Tc	65	121	166	218	292	362	429
Tc	63	118	162	210	284	346	414
2Tc	44	83	115	149	202	246	293

SUH Flood Peaks

EP	50	20	10	5	2	1	0.5
½Tc	72	133	184	241	323	400	475
Tc	56	105	144	188	254	309	369
2Tc	35	66	92	119	162	196	234

Rational Flood Peaks

EP	50	20	10	5	2	1	0.5
½Tc	52	121	180	248	349	443	537
Tc	60	140	208	286	404	509	622
2Tc	32	75	112	154	218	274	335

Table C.7 *Xura site*

DRH Flood Peaks

EP	50	20	10	5	2	1	0.5
½Tc	121	222	304	394	529	646	769
Tc	114	204	283	371	494	576	713
2Tc	86	160	221	285	379	462	547

SUH Flood Peaks

EP	50	20	10	5	2	1	0.5
½Tc	128	236	321	417	560	684	814
Tc	100	179	248	325	433	505	624
2Tc	67	124	171	221	294	359	425

Rational Flood Peaks

EP	50	20	10	5	2	1	0.5
½Tc	93	213	316	433	609	766	933
Tc	107	241	360	497	696	851	1064
2Tc	60	137	204	279	391	494	602

Appendix A. contains more informations on the catchment parameters, which were used in **Detflo99** program.

APPENDIX D

FLOOD HYDROGRAPHS

HYDROGRAPHS

1-% Exceedance probability flood hydrographs were estimated by using the DRH method and they are shown below in Figures D.1, D.2, and D.3. The co-ordinates are given in Tables D.1, D.2, and D.3.

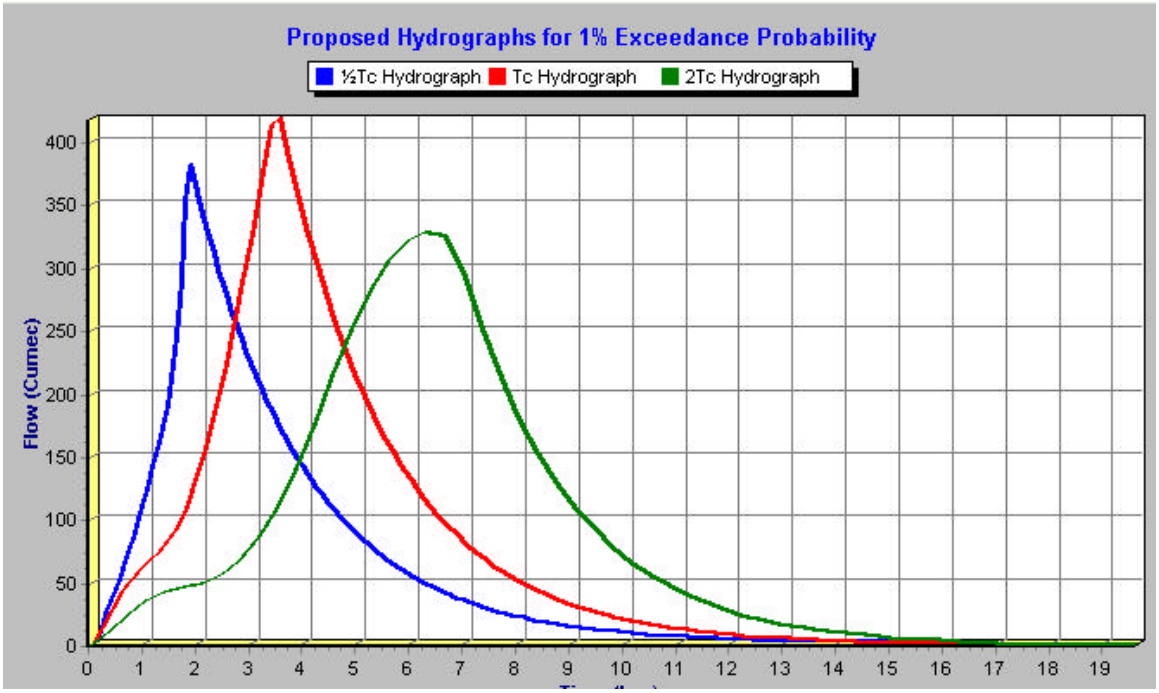


Figure D.1 1-% Exceedance probability flood hydrographs at *Zalu* dam site

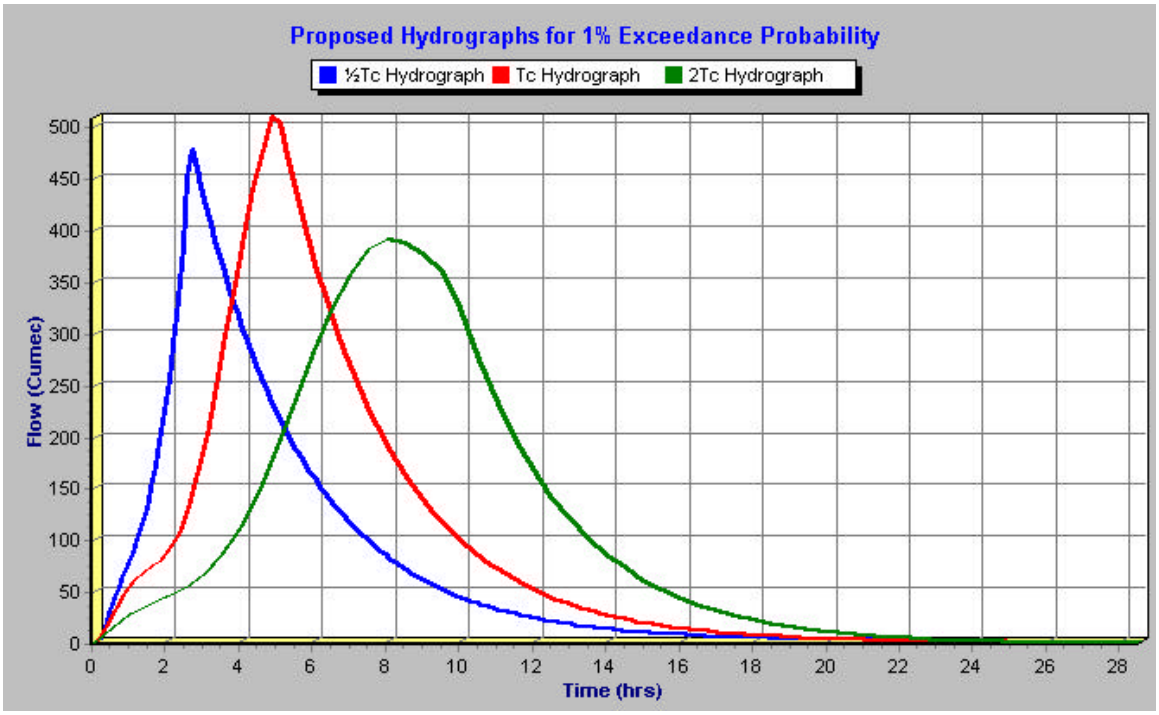


Figure D.2 1-% Exceedance probability flood hydrographs at *Lusikisiki* dam site

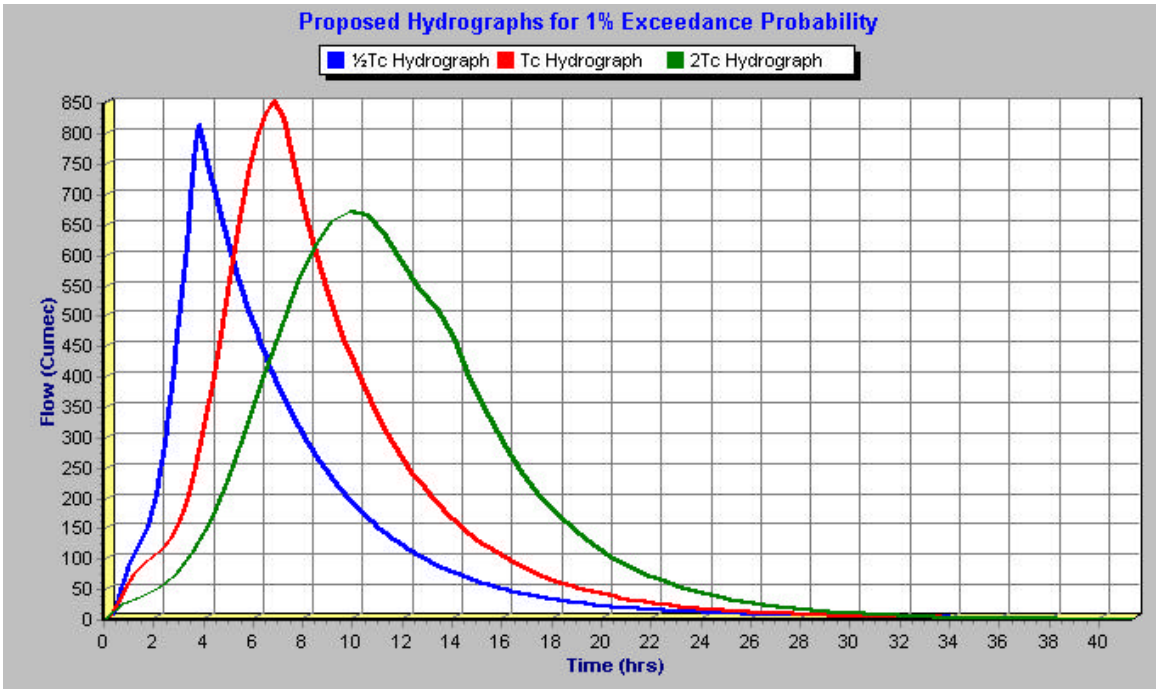


Figure D.3 1-% Exceedance probability flood hydrographs at *Xura* dam site

Table D.1 Coordinates of the 1% Exceedance Probability Hydrographs at Zalu proposed dam site

Coordinates:
Time = Hours
Flow = Cubic meters per second

0.5 tc		tc		2.0 tc	
Time	Flow	Time	Flow	Time	Flow
0.00	0.00	0.00	0.00	0.00	0.00
0.09	12.00	0.17	12.45	0.35	11.42
0.17	22.80	0.35	27.20	0.70	25.47
0.26	32.85	0.52	40.59	1.05	36.49
0.35	42.67	0.70	51.28	1.40	43.21
0.44	52.70	0.88	59.44	1.75	46.95
0.52	63.28	1.05	66.19	2.10	50.34
0.61	74.61	1.23	73.09	2.45	56.24
0.70	86.69	1.40	81.71	2.80	67.15
0.79	99.43	1.57	93.44	3.15	84.65
0.88	112.64	1.75	109.25	3.50	109.24
0.96	126.16	1.92	129.62	3.85	140.24
1.05	139.98	2.10	154.53	4.20	175.89
1.14	154.36	2.27	183.54	4.55	213.56
1.23	170.01	2.45	215.91	4.90	250.08
1.31	188.31	2.63	250.81	5.25	282.18
1.40	211.47	2.80	287.59	5.60	306.93
1.49	242.85	2.97	326.06	5.95	322.35
1.57	287.17	3.15	366.91	6.30	327.99
1.66	350.81	3.33	412.04	6.65	325.63
1.75	380.09	3.50	418.00	7.00	297.46
1.84	364.58	3.67	384.58	7.35	251.79
1.92	349.70	3.85	353.83	7.70	213.14
2.01	335.43	4.03	325.54	8.05	180.42
2.10	321.74	4.20	299.51	8.40	152.72
2.19	308.61	4.38	275.56	8.75	129.27
2.27	296.02	4.55	253.53	9.10	109.43
2.36	283.94	4.72	233.26	9.45	92.63
2.45	272.35	4.90	214.61	9.80	78.41
2.54	261.24	5.07	197.45	10.15	66.37
2.63	250.57	5.25	181.66	10.50	56.18
2.71	240.35	5.42	167.14	10.85	47.56
2.80	230.54	5.60	153.77	11.20	40.26
2.89	221.13	5.78	141.48	11.55	34.08
2.97	212.11	5.95	130.17	11.90	28.85
3.06	203.45	6.13	119.76	12.25	24.42
3.15	195.15	6.30	110.18	12.60	20.67
3.24	187.18	6.47	101.37	12.95	17.50
3.33	179.54	6.65	93.27	13.30	14.81
3.41	172.22	6.82	85.81	13.65	12.54
3.50	165.19	7.00	78.95	14.00	10.61
3.59	158.45	7.17	72.64	14.35	8.98
3.67	151.98	7.35	66.83	14.70	7.60
3.76	145.78	7.53	61.49	15.05	6.44
3.85	139.83	7.70	56.57	15.40	5.45
3.94	134.12	7.88	52.05	15.75	4.61
4.03	128.65	8.05	47.89	16.10	3.90
4.11	123.40	8.22	44.06	16.45	3.30
4.20	118.36	8.40	40.53	16.80	2.80
4.29	113.53	8.57	37.29	17.15	2.37
4.38	108.90	8.75	34.31	17.50	2.00
4.46	104.45	8.93	31.57	17.85	1.70
4.55	100.19	9.10	29.04	18.20	1.44
4.64	96.10	9.27	26.72	18.55	1.22
4.72	92.18	9.45	24.59	18.90	1.03
4.81	88.42	9.63	22.62	19.25	0.87
4.90	84.81	9.80	20.81	19.60	0.74

4.99	81.35	9.97	19.15	0.00	0.00
5.07	78.03	10.15	17.62	0.00	0.00
5.16	74.85	10.32	16.21	0.00	0.00
5.25	71.79	10.50	14.91	0.00	0.00
5.34	68.86	10.68	13.72	0.00	0.00
5.42	66.05	10.85	12.62	0.00	0.00
5.51	63.36	11.02	11.61	0.00	0.00
5.60	60.77	11.20	10.68	0.00	0.00
5.69	58.29	11.38	9.83	0.00	0.00
5.78	55.91	11.55	9.04	0.00	0.00
5.86	53.63	11.72	8.32	0.00	0.00
5.95	51.44	11.90	7.66	0.00	0.00
6.04	49.34	12.07	7.04	0.00	0.00
6.13	47.33	12.25	6.48	0.00	0.00
6.21	45.40	12.43	5.96	0.00	0.00
6.30	43.54	12.60	5.49	0.00	0.00
6.39	41.77	12.77	5.05	0.00	0.00
6.47	40.06	12.95	4.64	0.00	0.00
6.56	38.43	13.13	4.27	0.00	0.00
6.65	36.86	13.30	3.93	0.00	0.00
6.74	35.35	13.47	3.62	0.00	0.00
6.82	33.91	13.65	3.33	0.00	0.00
6.91	32.53	13.82	3.06	0.00	0.00
7.00	31.20	14.00	2.82	0.00	0.00
7.09	29.93	14.18	2.59	0.00	0.00
7.17	28.71	14.35	2.38	0.00	0.00
7.26	27.53	14.52	2.19	0.00	0.00
7.35	26.41	14.70	2.02	0.00	0.00
7.44	25.33	14.88	1.86	0.00	0.00
7.53	24.30	15.05	1.71	0.00	0.00
7.61	23.31	15.22	1.57	0.00	0.00
7.70	22.36	15.40	1.45	0.00	0.00
7.79	21.44	15.57	1.33	0.00	0.00
7.88	20.57	15.75	1.22	0.00	0.00
7.96	19.73	15.93	1.13	0.00	0.00
8.05	18.92	16.10	1.04	0.00	0.00
8.14	18.15	16.27	0.95	0.00	0.00
8.22	17.41	16.45	0.88	0.00	0.00
8.31	16.70	16.63	0.81	0.00	0.00
8.40	16.02	0.00	0.00	0.00	0.00
8.49	15.36	0.00	0.00	0.00	0.00
8.57	14.74	0.00	0.00	0.00	0.00
8.66	14.14	0.00	0.00	0.00	0.00
8.75	13.56	0.00	0.00	0.00	0.00
8.84	13.01	0.00	0.00	0.00	0.00
8.93	12.48	0.00	0.00	0.00	0.00
9.01	11.97	0.00	0.00	0.00	0.00
9.10	11.48	0.00	0.00	0.00	0.00
9.19	11.01	0.00	0.00	0.00	0.00
9.27	10.56	0.00	0.00	0.00	0.00
9.36	10.13	0.00	0.00	0.00	0.00
9.45	9.72	0.00	0.00	0.00	0.00
9.54	9.32	0.00	0.00	0.00	0.00
9.63	8.94	0.00	0.00	0.00	0.00
9.71	8.57	0.00	0.00	0.00	0.00
9.80	8.22	0.00	0.00	0.00	0.00
9.89	7.89	0.00	0.00	0.00	0.00
9.97	7.57	0.00	0.00	0.00	0.00
10.06	7.26	0.00	0.00	0.00	0.00
10.15	6.96	0.00	0.00	0.00	0.00
10.24	6.68	0.00	0.00	0.00	0.00
10.32	6.41	0.00	0.00	0.00	0.00
10.41	6.14	0.00	0.00	0.00	0.00
10.50	5.89	0.00	0.00	0.00	0.00
10.59	5.65	0.00	0.00	0.00	0.00
10.68	5.42	0.00	0.00	0.00	0.00

10.76	5.20	0.00	0.00	0.00	0.00
10.85	4.99	0.00	0.00	0.00	0.00
10.94	4.78	0.00	0.00	0.00	0.00
11.02	4.59	0.00	0.00	0.00	0.00
11.11	4.40	0.00	0.00	0.00	0.00
11.20	4.22	0.00	0.00	0.00	0.00
11.29	4.05	0.00	0.00	0.00	0.00
11.38	3.88	0.00	0.00	0.00	0.00
11.46	3.73	0.00	0.00	0.00	0.00
11.55	3.57	0.00	0.00	0.00	0.00
11.64	3.43	0.00	0.00	0.00	0.00
11.72	3.29	0.00	0.00	0.00	0.00
11.81	3.15	0.00	0.00	0.00	0.00
11.90	3.03	0.00	0.00	0.00	0.00
11.99	2.90	0.00	0.00	0.00	0.00
12.07	2.78	0.00	0.00	0.00	0.00
12.16	2.67	0.00	0.00	0.00	0.00
12.25	2.56	0.00	0.00	0.00	0.00
12.34	2.46	0.00	0.00	0.00	0.00
12.43	2.36	0.00	0.00	0.00	0.00
12.51	2.26	0.00	0.00	0.00	0.00
12.60	2.17	0.00	0.00	0.00	0.00
12.69	2.08	0.00	0.00	0.00	0.00
12.77	1.99	0.00	0.00	0.00	0.00
12.86	1.91	0.00	0.00	0.00	0.00
12.95	1.84	0.00	0.00	0.00	0.00
13.04	1.76	0.00	0.00	0.00	0.00
13.13	1.69	0.00	0.00	0.00	0.00
13.21	1.62	0.00	0.00	0.00	0.00
13.30	1.55	0.00	0.00	0.00	0.00
13.39	1.49	0.00	0.00	0.00	0.00
13.47	1.43	0.00	0.00	0.00	0.00
13.56	1.37	0.00	0.00	0.00	0.00
13.65	1.31	0.00	0.00	0.00	0.00
13.74	1.26	0.00	0.00	0.00	0.00
13.82	1.21	0.00	0.00	0.00	0.00
13.91	1.16	0.00	0.00	0.00	0.00
14.00	1.11	0.00	0.00	0.00	0.00
14.09	1.07	0.00	0.00	0.00	0.00
14.18	1.02	0.00	0.00	0.00	0.00
14.26	0.98	0.00	0.00	0.00	0.00
14.35	0.94	0.00	0.00	0.00	0.00
14.44	0.90	0.00	0.00	0.00	0.00
14.52	0.87	0.00	0.00	0.00	0.00
14.61	0.83	0.00	0.00	0.00	0.00
14.70	0.80	0.00	0.00	0.00	0.00
14.79	0.76	0.00	0.00	0.00	0.00

Table D.2 Coordinates of the 1% Exceedance Probability Hydrographs at Lusikisiki proposed dam site

Coordinates:
Time = Hours
Flow = Cubic meters per second

0.5 tc		tc		2.0 tc	
Time	Flow	Time	Flow	Time	Flow
0.00	0.00	0.00	0.00	0.00	0.00
0.13	13.24	0.25	13.28	0.50	14.58
0.25	27.15	0.50	31.08	1.00	27.67
0.38	40.27	0.75	47.02	1.50	37.49
0.50	52.21	1.00	58.75	2.00	45.38
0.63	63.21	1.25	66.63	2.50	54.16
0.75	73.91	1.50	72.64	3.00	66.92
0.88	85.06	1.75	79.49	3.50	86.16
1.00	97.44	2.00	89.97	4.00	113.32
1.13	111.65	2.25	106.38	4.50	148.43
1.25	128.13	2.50	130.25	5.00	190.13
1.38	147.13	2.75	162.11	5.50	235.80
1.50	168.79	3.00	201.44	6.00	281.84
1.63	193.20	3.25	246.77	6.50	324.13
1.75	220.61	3.50	295.82	7.00	358.58
1.88	251.58	3.75	345.86	7.50	381.78
2.00	287.23	4.00	394.06	8.00	391.73
2.13	329.57	4.25	437.99	8.50	388.62
2.25	381.75	4.50	476.24	9.00	375.74
2.38	448.51	4.75	509.00	9.50	360.34
2.50	475.94	5.00	502.72	10.00	325.46
2.63	456.52	5.25	462.53	10.50	275.50
2.75	437.89	5.50	425.54	11.00	233.20
2.88	420.02	5.75	391.52	11.50	197.40
3.00	402.87	6.00	360.22	12.00	167.10
3.13	386.43	6.25	331.41	12.50	141.45
3.25	370.66	6.50	304.92	13.00	119.73
3.38	355.54	6.75	280.54	13.50	101.35
3.50	341.03	7.00	258.11	14.00	85.79
3.63	327.11	7.25	237.47	14.50	72.62
3.75	313.76	7.50	218.48	15.00	61.47
3.88	300.95	7.75	201.01	15.50	52.03
4.00	288.67	8.00	184.94	16.00	44.05
4.13	276.89	8.25	170.15	16.50	37.28
4.25	265.59	8.50	156.55	17.00	31.56
4.38	254.75	8.75	144.03	17.50	26.72
4.50	244.36	9.00	132.52	18.00	22.61
4.63	234.38	9.25	121.92	18.50	19.14
4.75	224.82	9.50	112.17	19.00	16.20
4.88	215.64	9.75	103.20	19.50	13.72
5.00	206.84	10.00	94.95	20.00	11.61
5.13	198.40	10.25	87.36	20.50	9.83
5.25	190.30	10.50	80.37	21.00	8.32
5.38	182.54	10.75	73.95	21.50	7.04
5.50	175.09	11.00	68.04	22.00	5.96
5.63	167.94	11.25	62.60	22.50	5.05
5.75	161.09	11.50	57.59	23.00	4.27
5.88	154.52	11.75	52.99	23.50	3.62
6.00	148.21	12.00	48.75	24.00	3.06
6.13	142.16	12.25	44.85	24.50	2.59
6.25	136.36	12.50	41.27	25.00	2.19
6.38	130.79	12.75	37.97	25.50	1.86
6.50	125.46	13.00	34.93	26.00	1.57
6.63	120.34	13.25	32.14	26.50	1.33
6.75	115.43	13.50	29.57	27.00	1.13
6.88	110.71	13.75	27.20	27.50	0.95
7.00	106.20	14.00	25.03	28.00	0.81

7.13	101.86	14.25	23.03	28.50	0.68
7.25	97.71	14.50	21.19	0.00	0.00
7.38	93.72	14.75	19.49	0.00	0.00
7.50	89.89	15.00	17.93	0.00	0.00
7.63	86.22	15.25	16.50	0.00	0.00
7.75	82.71	15.50	15.18	0.00	0.00
7.88	79.33	15.75	13.97	0.00	0.00
8.00	76.09	16.00	12.85	0.00	0.00
8.13	72.99	16.25	11.82	0.00	0.00
8.25	70.01	16.50	10.88	0.00	0.00
8.38	67.15	16.75	10.01	0.00	0.00
8.50	64.41	17.00	9.21	0.00	0.00
8.63	61.78	17.25	8.47	0.00	0.00
8.75	59.26	17.50	7.79	0.00	0.00
8.88	56.84	17.75	7.17	0.00	0.00
9.00	54.52	18.00	6.60	0.00	0.00
9.13	52.30	18.25	6.07	0.00	0.00
9.25	50.16	18.50	5.58	0.00	0.00
9.38	48.12	18.75	5.14	0.00	0.00
9.50	46.15	19.00	4.73	0.00	0.00
9.63	44.27	19.25	4.35	0.00	0.00
9.75	42.46	19.50	4.00	0.00	0.00
9.88	40.73	19.75	3.68	0.00	0.00
10.00	39.07	20.00	3.39	0.00	0.00
10.13	37.47	20.25	3.12	0.00	0.00
10.25	35.94	20.50	2.87	0.00	0.00
10.38	34.48	20.75	2.64	0.00	0.00
10.50	33.07	21.00	2.43	0.00	0.00
10.63	31.72	21.25	2.23	0.00	0.00
10.75	30.43	21.50	2.05	0.00	0.00
10.88	29.18	21.75	1.89	0.00	0.00
11.00	27.99	22.00	1.74	0.00	0.00
11.13	26.85	22.25	1.60	0.00	0.00
11.25	25.75	22.50	1.47	0.00	0.00
11.38	24.70	22.75	1.35	0.00	0.00
11.50	23.70	23.00	1.25	0.00	0.00
11.63	22.73	23.25	1.15	0.00	0.00
11.75	21.80	23.50	1.05	0.00	0.00
11.88	20.91	23.75	0.97	0.00	0.00
12.00	20.06	24.00	0.89	0.00	0.00
12.13	19.24	24.25	0.82	0.00	0.00
12.25	18.45	24.50	0.76	0.00	0.00
12.38	17.70	24.75	0.70	0.00	0.00
12.50	16.98	0.00	0.00	0.00	0.00
12.63	16.29	0.00	0.00	0.00	0.00
12.75	15.62	0.00	0.00	0.00	0.00
12.88	14.98	0.00	0.00	0.00	0.00
13.00	14.37	0.00	0.00	0.00	0.00
13.13	13.79	0.00	0.00	0.00	0.00
13.25	13.22	0.00	0.00	0.00	0.00
13.38	12.68	0.00	0.00	0.00	0.00
13.50	12.17	0.00	0.00	0.00	0.00
13.63	11.67	0.00	0.00	0.00	0.00
13.75	11.19	0.00	0.00	0.00	0.00
13.88	10.74	0.00	0.00	0.00	0.00
14.00	10.30	0.00	0.00	0.00	0.00
14.13	9.88	0.00	0.00	0.00	0.00
14.25	9.47	0.00	0.00	0.00	0.00
14.38	9.09	0.00	0.00	0.00	0.00
14.50	8.72	0.00	0.00	0.00	0.00
14.63	8.36	0.00	0.00	0.00	0.00
14.75	8.02	0.00	0.00	0.00	0.00
14.88	7.69	0.00	0.00	0.00	0.00
15.00	7.38	0.00	0.00	0.00	0.00
15.13	7.08	0.00	0.00	0.00	0.00
15.25	6.79	0.00	0.00	0.00	0.00

15.38	6.51	0.00	0.00	0.00	0.00
15.50	6.25	0.00	0.00	0.00	0.00
15.63	5.99	0.00	0.00	0.00	0.00
15.75	5.75	0.00	0.00	0.00	0.00
15.88	5.51	0.00	0.00	0.00	0.00
16.00	5.29	0.00	0.00	0.00	0.00
16.13	5.07	0.00	0.00	0.00	0.00
16.25	4.86	0.00	0.00	0.00	0.00
16.38	4.67	0.00	0.00	0.00	0.00
16.50	4.48	0.00	0.00	0.00	0.00
16.63	4.29	0.00	0.00	0.00	0.00
16.75	4.12	0.00	0.00	0.00	0.00
16.88	3.95	0.00	0.00	0.00	0.00
17.00	3.79	0.00	0.00	0.00	0.00
17.13	3.63	0.00	0.00	0.00	0.00
17.25	3.49	0.00	0.00	0.00	0.00
17.38	3.34	0.00	0.00	0.00	0.00
17.50	3.21	0.00	0.00	0.00	0.00
17.63	3.08	0.00	0.00	0.00	0.00
17.75	2.95	0.00	0.00	0.00	0.00
17.88	2.83	0.00	0.00	0.00	0.00
18.00	2.71	0.00	0.00	0.00	0.00
18.13	2.60	0.00	0.00	0.00	0.00
18.25	2.50	0.00	0.00	0.00	0.00
18.38	2.40	0.00	0.00	0.00	0.00
18.50	2.30	0.00	0.00	0.00	0.00
18.63	2.20	0.00	0.00	0.00	0.00
18.75	2.11	0.00	0.00	0.00	0.00
18.88	2.03	0.00	0.00	0.00	0.00
19.00	1.95	0.00	0.00	0.00	0.00
19.13	1.87	0.00	0.00	0.00	0.00
19.25	1.79	0.00	0.00	0.00	0.00
19.38	1.72	0.00	0.00	0.00	0.00
19.50	1.65	0.00	0.00	0.00	0.00
19.63	1.58	0.00	0.00	0.00	0.00
19.75	1.51	0.00	0.00	0.00	0.00
19.88	1.45	0.00	0.00	0.00	0.00
20.00	1.39	0.00	0.00	0.00	0.00
20.13	1.34	0.00	0.00	0.00	0.00
20.25	1.28	0.00	0.00	0.00	0.00
20.38	1.23	0.00	0.00	0.00	0.00
20.50	1.18	0.00	0.00	0.00	0.00
20.63	1.13	0.00	0.00	0.00	0.00
20.75	1.09	0.00	0.00	0.00	0.00
20.88	1.04	0.00	0.00	0.00	0.00
21.00	1.00	0.00	0.00	0.00	0.00
21.12	0.96	0.00	0.00	0.00	0.00
21.25	0.92	0.00	0.00	0.00	0.00
21.38	0.88	0.00	0.00	0.00	0.00
21.50	0.85	0.00	0.00	0.00	0.00
21.63	0.81	0.00	0.00	0.00	0.00
21.75	0.78	0.00	0.00	0.00	0.00
21.88	0.75	0.00	0.00	0.00	0.00
22.00	0.72	0.00	0.00	0.00	0.00
22.13	0.69	0.00	0.00	0.00	0.00
22.25	0.66	0.00	0.00	0.00	0.00
22.37	0.63	0.00	0.00	0.00	0.00

Table D.3 Coordinates of the 1% Exceedance Probability Hydrographs at Xura proposed dam site

Coordinates:
Time = Hours
Flow = Cubic meters per second

0.5 tc		tc		2.0 tc	
Time	Flow	Time	Flow	Time	Flow
0.00	0.00	0.00	0.00	0.00	0.00
0.17	19.59	0.35	21.04	0.70	25.20
0.35	43.59	0.70	48.59	1.40	37.33
0.52	66.35	1.05	72.37	2.10	49.78
0.70	85.60	1.40	89.42	2.80	71.68
0.88	101.44	1.75	101.49	3.50	108.23
1.05	115.43	2.10	112.96	4.20	161.10
1.23	129.91	2.45	129.11	4.90	228.96
1.40	147.39	2.80	154.85	5.60	308.08
1.57	170.13	3.15	193.82	6.30	392.92
1.75	199.83	3.50	247.76	7.00	476.84
1.92	237.50	3.85	316.23	7.70	552.77
2.10	283.36	4.20	396.65	8.40	614.04
2.27	336.94	4.55	484.55	9.10	655.06
2.45	397.28	4.90	574.05	9.80	672.21
2.63	463.24	5.25	658.62	10.50	664.61
2.80	533.86	5.60	732.00	11.20	634.97
2.97	608.91	5.95	789.30	11.90	590.47
3.15	689.46	6.30	828.33	12.60	543.57
3.33	778.62	6.65	851.00	13.30	512.96
3.50	808.57	7.00	823.92	14.00	464.65
3.67	775.57	7.35	758.04	14.70	393.32
3.85	743.92	7.70	697.43	15.40	332.94
4.03	713.56	8.05	641.67	16.10	281.83
4.20	684.44	8.40	590.36	16.80	238.56
4.38	656.51	8.75	543.16	17.50	201.94
4.55	629.72	9.10	499.73	18.20	170.94
4.72	604.02	9.45	459.77	18.90	144.69
4.90	579.37	9.80	423.01	19.60	122.48
5.07	555.72	10.15	389.19	20.30	103.68
5.25	533.04	10.50	358.07	21.00	87.76
5.42	511.29	10.85	329.44	21.70	74.29
5.60	490.42	11.20	303.10	22.40	62.88
5.78	470.41	11.55	278.87	23.10	53.23
5.95	451.21	11.90	256.57	23.80	45.06
6.13	432.80	12.25	236.06	24.50	38.14
6.30	415.13	12.60	217.18	25.20	32.29
6.47	398.19	12.95	199.82	25.90	27.33
6.65	381.94	13.30	183.84	26.60	23.13
6.82	366.36	13.65	169.14	27.30	19.58
7.00	351.40	14.00	155.62	28.00	16.58
7.17	337.06	14.35	143.18	28.70	14.03
7.35	323.31	14.70	131.73	29.40	11.88
7.53	310.11	15.05	121.20	30.10	10.05
7.70	297.46	15.40	111.51	30.80	8.51
7.88	285.32	15.75	102.59	31.50	7.20
8.05	273.67	16.10	94.39	32.20	6.10
8.22	262.51	16.45	86.84	32.90	5.16
8.40	251.79	16.80	79.90	33.60	4.37
8.57	241.52	17.15	73.51	34.30	3.70
8.75	231.66	17.50	67.63	35.00	3.13
8.93	222.21	17.85	62.22	35.70	2.65
9.10	213.14	18.20	57.25	36.40	2.24
9.27	204.44	18.55	52.67	37.10	1.90
9.45	196.10	18.90	48.46	37.80	1.61
9.63	188.09	19.25	44.59	38.50	1.36
9.80	180.42	19.60	41.02	39.20	1.15

9.97	173.05	19.95	37.74	39.90	0.97
10.15	165.99	20.30	34.72	40.60	0.83
10.32	159.22	20.65	31.95	41.30	0.70
10.50	152.72	21.00	29.39	0.00	0.00
10.68	146.49	21.35	27.04	0.00	0.00
10.85	140.51	21.70	24.88	0.00	0.00
11.02	134.77	22.05	22.89	0.00	0.00
11.20	129.27	22.40	21.06	0.00	0.00
11.38	124.00	22.75	19.38	0.00	0.00
11.55	118.94	23.10	17.83	0.00	0.00
11.72	114.08	23.45	16.40	0.00	0.00
11.90	109.43	23.80	15.09	0.00	0.00
12.07	104.96	24.15	13.88	0.00	0.00
12.25	100.68	24.50	12.77	0.00	0.00
12.43	96.57	24.85	11.75	0.00	0.00
12.60	92.63	25.20	10.81	0.00	0.00
12.77	88.85	25.55	9.95	0.00	0.00
12.95	85.22	25.90	9.15	0.00	0.00
13.13	81.74	26.25	8.42	0.00	0.00
13.30	78.41	26.60	7.75	0.00	0.00
13.47	75.21	26.95	7.13	0.00	0.00
13.65	72.14	27.30	6.56	0.00	0.00
13.82	69.20	27.65	6.03	0.00	0.00
14.00	66.37	28.00	5.55	0.00	0.00
14.18	63.66	28.35	5.11	0.00	0.00
14.35	61.06	28.70	4.70	0.00	0.00
14.52	58.57	29.05	4.32	0.00	0.00
14.70	56.18	29.40	3.98	0.00	0.00
14.88	53.89	29.75	3.66	0.00	0.00
15.05	51.69	30.10	3.37	0.00	0.00
15.22	49.58	30.45	3.10	0.00	0.00
15.40	47.56	30.80	2.85	0.00	0.00
15.57	45.62	31.15	2.62	0.00	0.00
15.75	43.75	31.50	2.41	0.00	0.00
15.93	41.97	31.85	2.22	0.00	0.00
16.10	40.26	32.20	2.04	0.00	0.00
16.27	38.61	32.55	1.88	0.00	0.00
16.45	37.04	32.90	1.73	0.00	0.00
16.63	35.53	33.25	1.59	0.00	0.00
16.80	34.08	33.60	1.46	0.00	0.00
16.98	32.69	33.95	1.35	0.00	0.00
17.15	31.35	34.30	1.24	0.00	0.00
17.32	30.07	34.65	1.14	0.00	0.00
17.50	28.85	35.00	1.05	0.00	0.00
17.67	27.67	35.35	0.96	0.00	0.00
17.85	26.54	35.70	0.89	0.00	0.00
18.02	25.46	36.05	0.82	0.00	0.00
18.20	24.42	36.40	0.75	0.00	0.00
18.38	23.42	36.75	0.69	0.00	0.00
18.55	22.46	0.00	0.00	0.00	0.00
18.73	21.55	0.00	0.00	0.00	0.00
18.90	20.67	0.00	0.00	0.00	0.00
19.07	19.82	0.00	0.00	0.00	0.00
19.25	19.02	0.00	0.00	0.00	0.00
19.42	18.24	0.00	0.00	0.00	0.00
19.60	17.50	0.00	0.00	0.00	0.00
19.77	16.78	0.00	0.00	0.00	0.00
19.95	16.10	0.00	0.00	0.00	0.00
20.13	15.44	0.00	0.00	0.00	0.00
20.30	14.81	0.00	0.00	0.00	0.00
20.48	14.21	0.00	0.00	0.00	0.00
20.65	13.63	0.00	0.00	0.00	0.00
20.82	13.07	0.00	0.00	0.00	0.00
21.00	12.54	0.00	0.00	0.00	0.00
21.17	12.02	0.00	0.00	0.00	0.00
21.35	11.53	0.00	0.00	0.00	0.00

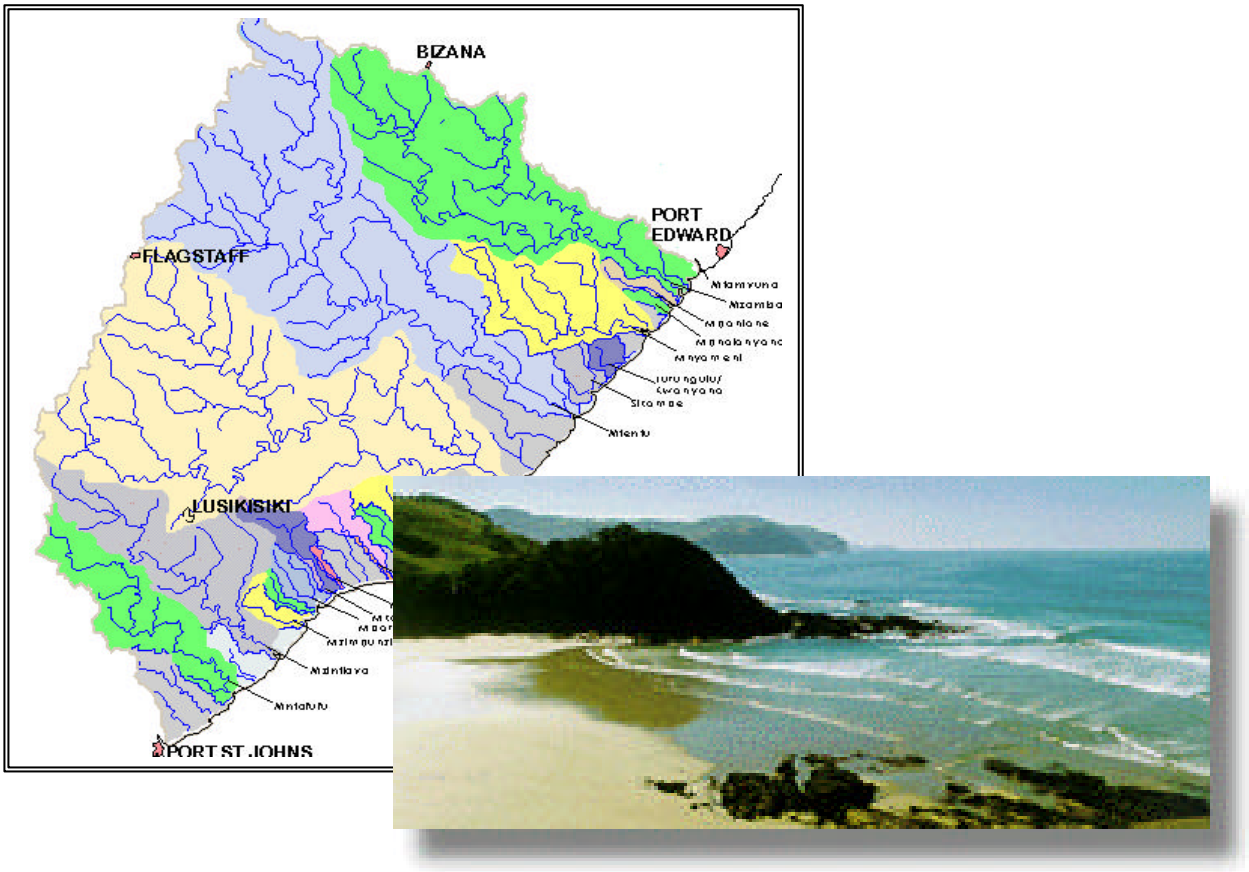
21.52	11.06	0.00	0.00	0.00	0.00
21.70	10.61	0.00	0.00	0.00	0.00
21.88	10.18	0.00	0.00	0.00	0.00
22.05	9.76	0.00	0.00	0.00	0.00
22.23	9.36	0.00	0.00	0.00	0.00
22.40	8.98	0.00	0.00	0.00	0.00
22.57	8.62	0.00	0.00	0.00	0.00
22.75	8.26	0.00	0.00	0.00	0.00
22.92	7.93	0.00	0.00	0.00	0.00
23.10	7.60	0.00	0.00	0.00	0.00
23.27	7.29	0.00	0.00	0.00	0.00
23.45	7.00	0.00	0.00	0.00	0.00
23.62	6.71	0.00	0.00	0.00	0.00
23.80	6.44	0.00	0.00	0.00	0.00
23.98	6.17	0.00	0.00	0.00	0.00
24.15	5.92	0.00	0.00	0.00	0.00
24.32	5.68	0.00	0.00	0.00	0.00
24.50	5.45	0.00	0.00	0.00	0.00
24.67	5.23	0.00	0.00	0.00	0.00
24.85	5.01	0.00	0.00	0.00	0.00
25.02	4.81	0.00	0.00	0.00	0.00
25.20	4.61	0.00	0.00	0.00	0.00
25.38	4.42	0.00	0.00	0.00	0.00
25.55	4.24	0.00	0.00	0.00	0.00
25.73	4.07	0.00	0.00	0.00	0.00
25.90	3.90	0.00	0.00	0.00	0.00
26.07	3.74	0.00	0.00	0.00	0.00
26.25	3.59	0.00	0.00	0.00	0.00
26.42	3.45	0.00	0.00	0.00	0.00
26.60	3.30	0.00	0.00	0.00	0.00
26.77	3.17	0.00	0.00	0.00	0.00
26.95	3.04	0.00	0.00	0.00	0.00
27.13	2.92	0.00	0.00	0.00	0.00
27.30	2.80	0.00	0.00	0.00	0.00
27.48	2.68	0.00	0.00	0.00	0.00
27.65	2.57	0.00	0.00	0.00	0.00
27.82	2.47	0.00	0.00	0.00	0.00
28.00	2.37	0.00	0.00	0.00	0.00
28.17	2.27	0.00	0.00	0.00	0.00
28.35	2.18	0.00	0.00	0.00	0.00
28.52	2.09	0.00	0.00	0.00	0.00
28.70	2.00	0.00	0.00	0.00	0.00
28.88	1.92	0.00	0.00	0.00	0.00
29.05	1.84	0.00	0.00	0.00	0.00
29.23	1.77	0.00	0.00	0.00	0.00
29.40	1.70	0.00	0.00	0.00	0.00
29.57	1.63	0.00	0.00	0.00	0.00
29.75	1.56	0.00	0.00	0.00	0.00
29.92	1.50	0.00	0.00	0.00	0.00
30.10	1.44	0.00	0.00	0.00	0.00
30.27	1.38	0.00	0.00	0.00	0.00
30.45	1.32	0.00	0.00	0.00	0.00
30.63	1.27	0.00	0.00	0.00	0.00
30.80	1.22	0.00	0.00	0.00	0.00
30.98	1.17	0.00	0.00	0.00	0.00
31.15	1.12	0.00	0.00	0.00	0.00
31.32	1.07	0.00	0.00	0.00	0.00
31.50	1.03	0.00	0.00	0.00	0.00
31.67	0.99	0.00	0.00	0.00	0.00
31.85	0.95	0.00	0.00	0.00	0.00
32.02	0.91	0.00	0.00	0.00	0.00
32.20	0.87	0.00	0.00	0.00	0.00
32.38	0.84	0.00	0.00	0.00	0.00
32.55	0.80	0.00	0.00	0.00	0.00
32.72	0.77	0.00	0.00	0.00	0.00
32.90	0.74	0.00	0.00	0.00	0.00

PB T600/00/1101

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



FLOOD FREQUENCY ANALYSIS

Mzintlava River

Final

June 2001

Prepared By:

Department of Water Affairs and Forestry

DIRECTORATE HYDROLOGY - FLOOD STUDIES
DEPARTMENT OF WATER AFFAIRS AND FORESTRY
PRIVATE BAG X313
PRETORIA 0001
REPUBLIC OF SOUTH AFRICA

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Flood Frequency Analysis: Mzintlava River
AUTHOR	**:**	V Petras
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-1101
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EXECUTIVE SUMMARY

UWP Engineers is doing a study on the Eastern Pondoland Coast Basin and approached the Department of Water Affairs and Forestry (DWAF) to do detailed analyses (Flood Frequency Analyses) on proposed dam sites in the basin.

Two separate reports, addressing flood frequencies, have been prepared. This particular report deals with the proposed dam sites at Tungwane and Lower Mzintlava in the **Mzintlava River**. Report number T600-R000-9908-A deals with the proposed dam sites at Zalu, Lusikisiki and Xura in the Xura River.

The catchment lies on the Eastern Pondoland coast and is drained by the Mzintlava River, which has several tributaries flowing into it. The longest stream consists of the Mbotyi, Nyosana and Mzintlava rivers. The nearest town is Lusikisiki, in Transkei, which lies north of Port St Johns. The position of the catchment is shown in Figure 1, and the layout of the catchment is shown in Appendix A.

Table 1: Basic catchment characteristics

Catchment	A (km^2)	L (km)	t_c (hours)	S_L (m/m)	S_A (m/m)	MAP (mm)
Tungwane	129	32	6	0.010299	0.1570	1100
Mzintlava Lower	98	27	5	0.010227	0.1548	1100

Table 2 and Table 3 show the proposed flood peaks calculated for the Tungwane and Mzintlava Lower sites respectively.

Table 2: Proposed flood peaks for the Tungwane site

Storm duration	Exceedance probability (%)							
	50	20	10	5	2	1	0.5	RMF
	Flood peaks (m^3/s)							
3 hrs	70	168	257	356	506	645	791	1829
6 hrs	**75**	**180**	**275**	**380**	**540**	**690**	**845**	**1955**
12 hrs	58	140	215	297	422	539	660	1527

Table 3: Proposed flood peaks for the Mzintlava Lower site

Storm duration	Exceedance probability (%)							
	50	20	10	5	2	1	0.5	RMF
	Flood peaks (m^3/s)							
2.5 hrs	61	145	224	309	441	561	688	1604
5 hrs	**65**	**155**	**240**	**330**	**470**	**600**	**735**	**1715**
10 hrs	51	121	187	258	367	469	574	1340

Eastern Pondoland Basin Study

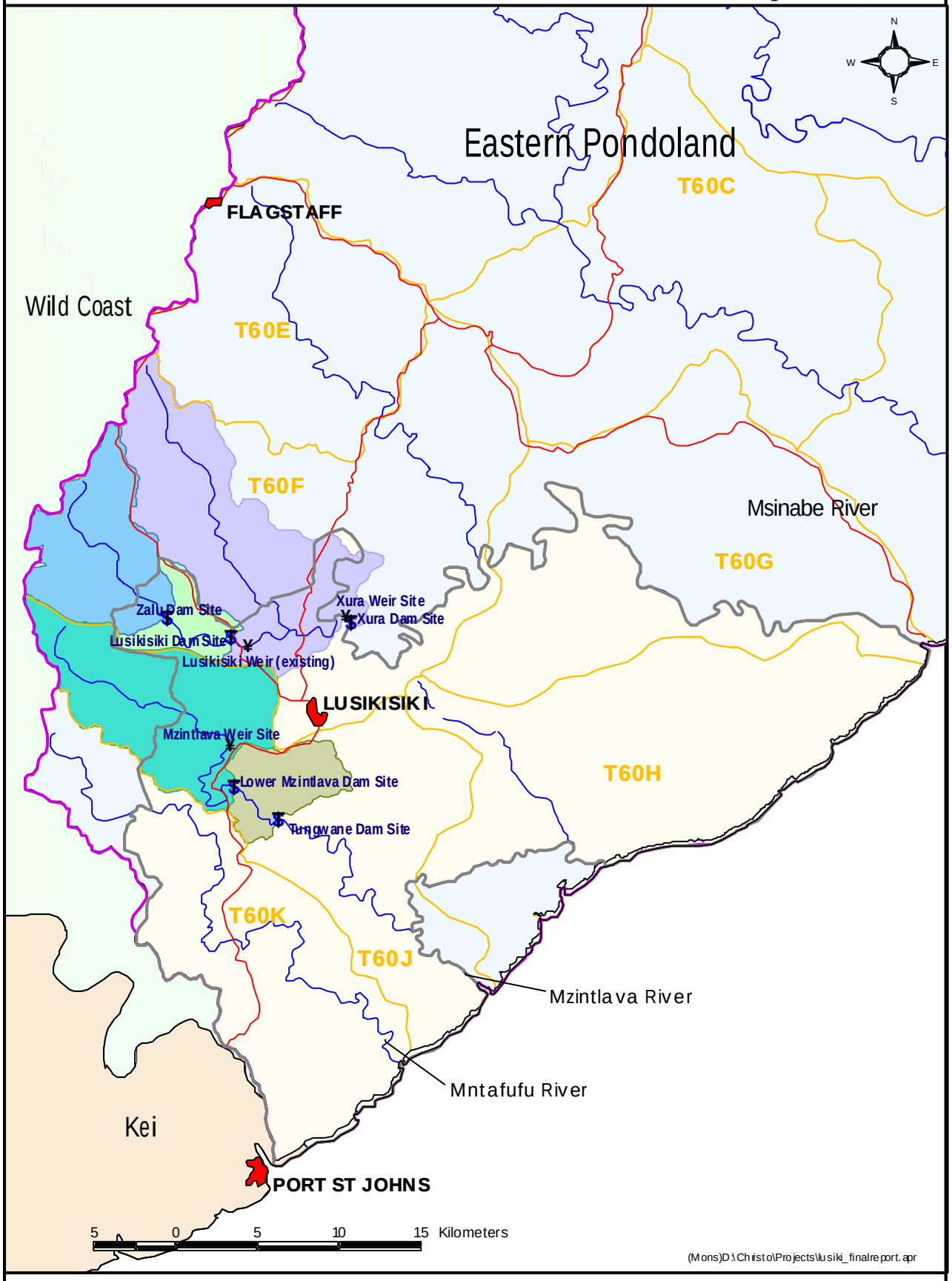


Fig 1 : Proposed Dam and Weir Sites

UWP Engineers

INDEX

1. INTRODUCTION 4

2. THE CATCHMENT 4

3. INFORMATION TO DATE 4

3.1 PREVIOUS ANALYSIS 4

3.2 HISTORICAL FLOODS 5

4. FLOOD FREQUENCY ANALYSIS 5

4.1 INTRODUCTION 5

4.2 CATCHMENT RAINFALL 5

4.3 STATISTICAL METHODS 5

4.4 DETERMINISTIC METHODS 6

4.5 EMPIRICAL METHODS 6

5. EVALUATION OF THE RESULTS 6

5.1 TUNGWANE SITE 6

6. PROPOSED FLOOD PEAKS AND VOLUMES 7

6.1 TUNGWANE SITE 7

6.2 MZINTLAVA LOWER SITE 8

7. MAXIMUM FLOOD 8

LIST OF TABLES

Table 2-1: Basic catchment characteristics 4

Table 2-2: Vegetation and soils 4

Table 4-1: Mean catchment rainfall – Tungwane site 5

Table 4-2: Estimated flood peaks for the Tungwane site – deterministic methods 6

Table 4-3: Estimated flood peaks for the Tungwane site – empirical methods 6

Table 6-1: Proposed flood peaks for the Tungwane site 7

Table 6-2: Proposed flood volumes for the Tungwane site 7

Table 6-3: Proposed flood peaks for the Mzintlava Lower site 8

Table 6-4: Proposed flood volumes for the Mzintlava Lower site 8

LIST OF SYMBOLS AND ABBREVIATIONS

A	-	Catchment area (km^2)
A_e	-	Effective catchment area (km^2)
CAPA	-	**Ca**tchment **Pa**rameter Method (McPherson, 1983)
D	-	Storm duration
DRH	-	**D**irect **R**unoff **H**ydrograph Method (Bauer and Midgley, 1974)
DT	-	**D**ischarge **T**able
EP	-	**E**xceedance **P**robability
GEV	-	**G**eneral **E**xtreme **V**alue distribution
K	-	Francou-Rodier coefficient
L	-	Longest stream
LN	-	**L**og **N**ormal distribution
LP3	-	**L**og **P**earson Type **3** distribution
MAP	-	**M**ean **A**nnual **P**recipitation (mm)
MAR	-	**M**ean **A**nnual **R**unoff ($10^6 m^3$)
MIPI	-	**Mi**dgley and **Pi**tman (1972) method
MIPI 1/71	-	**Mi**dgley and **Pi**tman (1971) method
PMF	-	**P**robable **M**aximum **F**lood
Q	-	Flow (m^3/s)
RMF	-	**R**egional **M**aximum **F**lood (calculated by using TR137)
S_L	-	Mean river slope along L (m/m)
S_A	-	Mean catchment slope (m/m)
SEF	-	**S**afety **E**valuation **F**lood
SUH	-	**S**ynthetic **U**nit **H**ydrograph method
t_c	-	Time of concentration (hour)
TR137	-	Department of Water Affairs Technical Report (Kovacs, 1988)
WAK	-	**Wak**eby distribution

1. INTRODUCTION

UWP Engineers is doing a study on the Eastern Pondoland Coast Basin and approached the Department of Water Affairs and Forestry (DWAF) to do detailed analyses (Flood Frequency Analyses) on proposed dam sites in the basin.
Two separate reports, addressing flood frequencies, have been prepared. This particular report deals with the proposed dam sites at Tungwane and Mzintlava Lower in the **Mzintlava river**. Report number T600-R000-9908-A deals with the proposed dam sites at Zalu, Lusikisiki and Xura in the Xura river.

2. THE CATCHMENT

The catchment lies on the Eastern Pondoland coast and is drained by the Mzintlava river, which has several tributaries flowing into it. The longest stream consists of the Mbotyi-, Nyosana- and Mzintlava rivers. The nearest town is Lusikisiki, in Transkei, which lies north of Port St Johns.

Table 2-1: Basic catchment characteristics

Catchment	A (km^2)	L (km)	t_c (hours)	S_L (m/m)	S_A (m/m)	MAP (mm)
Tungwane	129	32	6	0.010299	0.1570	1100
Mzintlava Lower	98	27	5	0.010227	0.1548	1100

The vegetation (simplified Acocks veld types) and soil characteristics in the catchment, is shown in **Table 2-2** (WRC Report, First Edition 1994).

Table 2-2: Vegetation and soils

Tungwane site				Mzintlava Lower site		
Vegetation		**% A**		**Vegetation**		**% A**
Coastal Tropical Forest		100		Coastal Tropical Forest		100
Soil		**% A**		**Soil**		**% A**
Texture	**Permeability**			**Texture**	**Permeability**	
Sandy Loam	Semi Permeable	100		Sandy Loam	Semi Permeable	100

Appendix A contains more information on the catchment characteristics.

3. INFORMATION TO DATE

3.1 PREVIOUS ANALYSIS

No previous flood frequency analysis was done in this area.

3.2 HISTORICAL FLOODS

There are no historical floods on record in the catchment area of the Tungwane site.

4. FLOOD FREQUENCY ANALYSIS

4.1 INTRODUCTION

A detailed analysis was done on the Tungwane site and from these results proposed flood peaks and volumes were estimated for the Mzintlava Lower site (see section 6, page 6, for details).

4.2 CATCHMENT RAINFALL

The rainfall data of the rainfall station at Lusikisiki was used in the estimation of the mean catchment rainfall, for the different storm durations, for the Tungwane site. This is the only rainfall station that could be found in the vicinity of the catchment that was suitable for use in a rainfall analysis for this particular catchment.
The ***RainCalc3*** program (Linström, 1999) was used for the statistical analysis which was done on the rainfall data, to estimate the mean catchment rainfall for the different storm durations.
Note that when estimating the mean catchment rainfall, it is assumed that in extreme events the storm duration is similar to the time of concentration (t_c).

Table 4-1: Mean catchment rainfall – Tungwane site

Storm duration	Exceedance probability (%)						
	50	20	10	5	2	1	0.5
	Rainfall (mm)						
3 hrs	76	116	144	172	211	241	272
6 hrs	**84**	**128**	**159**	**189**	**231**	**265**	**299**
12 hrs	91	139	173	207	252	289	326

Appendix B contains more information on the estimation of the catchment rainfall.

4.3 STATISTICAL METHODS

Flood Studies considered using the data of the gauging station T6H001 (Ntafufu river at Ntafufu Loc. 35), which lies in an adjacent catchment, in a statistical analysis. This would give an indication of what flow to expect at the Tungwane site, since the catchment characteristics of the two sites are fairly homogeneous. However, it was found that the data record for the station is not good. There are only 62% primary data available. After evaluating the flow data, of the hydrological years without gaps, it was found that the flow exceeded the current DT limit, which is 25 m^3/s, almost every hydrological year. Thus, a sufficient annual maximum flow record could not be generated to do a statistical analysis on.

4.4 DETERMINISTIC METHODS

The ***DetFlo99*** program (Rademeyer, 1999) was used to estimate the flood peaks for the Rational, SUH and DRH methods.
For the purpose of comparing the results of the deterministic and empirical methods, only the estimated flood peaks at t_c (6 hours) are shown in **Table 4-2**. The complete set of results can be found in Appendix C, **Table C-1**.

Table 4-2: Estimated flood peaks for the Tungwane site – deterministic methods

Method	Exceedance probability (%)						
	50	20	10	5	2	1	0.5
	Flood peaks (m^3/s)						
DRH	90	176	249	327	446	548	651
SUH	82	160	227	298	406	499	592
Rational	76	181	274	379	542	689	845

Appendix C contains more information on the deterministic methods.

4.5 EMPIRICAL METHODS

The ***EmpFlo99*** program (Van der Spuy, 1999) was used to estimate the flood peaks for the MIPI, MIPI 1/71 and CAPA methods and the estimation of the RMF by means of TR137.

Table 4-3: Estimated flood peaks for the Tungwane site – empirical methods

Method	Exceedance probability (%)							
	50	20	10	5	2	1	0.5	RMF
	Flood peaks (m^3/s)							
MIPI	37	85	130	183	265	335	414	
MIPI 1/71	43	107	157	211	296	372	462	
CAPA	66	100	136	183	269	359	478	
TR137					756	978	1199	1954

Appendix D contains more information on the empirical methods.

5. EVALUATION OF THE RESULTS

5.1 TUNGWANE SITE

5.1.1 Deterministic methods

The results of the DRH and SUH methods compare well with the results obtained from the Rational method in the higher exceedance probabilities (50% to 10%). However, in the lower

exceedance probabilities (5% to 0.5%), the results of the DRH and SUH methods is much lower than the results of the Rational method.

5.1.2 Empirical methods

The results of the empirical methods are a good deal lower than the results obtained from the deterministic methods. This can be ascribed to the high storm rainfall, which form part of the input for the deterministic methods and not for the empirical methods, experienced in this region.
Although the results of the MIPI and MIPI 1/71 methods compares well with each other, the results of these two methods are much lower than the results of the Rational method.
When the results are plotted, one can see that the tendency of the CAPA method is the same as data with a positive skewness.
TR137's results are unusually high and were not considered in the estimation of the proposed flood peaks.

6. PROPOSED FLOOD PEAKS AND VOLUMES

6.1 TUNGWANE SITE

Experience has shown that in the coastal areas of Transkei and KwaZulu Natal, the results obtained from a deterministic analysis (and in most cases the results obtained form the Rational method) usually compares well with results obtained from a statistical analysis. However, no results from a statistical analysis were available.

Flood Studies suggest the use of the results of the Rational method in the estimation of the proposed flood peaks.

Table 6-1: Proposed flood peaks for the Tungwane site

Storm duration	Exceedance probability (%)							
	50	20	10	5	2	1	0.5	RMF
	Flood peaks (m^3/s)							
3 hrs	70	168	257	356	506	645	791	1829
6 hrs	**75**	**180**	**275**	**380**	**540**	**690**	**845**	**1955**
12 hrs	58	140	215	297	422	539	660	1527

The proposed flood volumes for the Tungwane site were estimated by using the DRH method.

Table 6-2: Proposed flood volumes for the Tungwane site

Storm duration	Exceedance probability (%)							
	50	20	10	5	2	1	0.5	RMF
	Flood volumes (10^6 m^3)							
3 hrs	1.175	2.823	4.312	5.971	8.500	10.839	13.276	30.715
6 hrs	**1.609**	**3.861**	**5.898**	**8.151**	**11.582**	**14.800**	**18.124**	**41.932**
12 hrs	1.952	4.688	7.168	9.928	14.088	18.000	22.041	50.994

6.2 MZINTLAVA LOWER SITE

Flood Studies suggest the use of the following area factor in the estimation of the proposed flood peaks for the Mzintlava Lower site:

$$Q_{\text{Mzintlava Lower}} = Q_{\text{Tungwane}} \times \left[\frac{\sqrt{A_{Mz\,int lava_Lower}}}{\sqrt{A_{Tungwane}}} \right]$$

This could be done because of various reasons:

1. The relative small difference in catchment areas.
2. The two catchment areas are fairly homogeneous (considering both catchment characteristics and rainfall) – the one catchment is contained in the other.
3. The same rainfall station, which was used in the rainfall analysis for Tungwane, would be applicable for Mzintlava Lower.

Table 6-3: Proposed flood peaks for the Mzintlava Lower site

Storm duration	Exceedance probability (%)							
	50	20	10	5	2	1	0.5	RMF
	Flood peaks (m^3/s)							
2.5 hrs	61	145	224	309	441	561	688	1604
5 hrs	**65**	**155**	**240**	**330**	**470**	**600**	**735**	**1715**
10 hrs	51	121	187	258	367	469	574	1340

The proposed flood volumes for the Mzintlava Lower site were estimated by using the DRH method.

Table 6-4: Proposed flood volumes for the Mzintlava Lower site

Storm duration	Exceedance probability (%)							
	50	20	10	5	2	1	0.5	RMF
	Flood volumes (10^6 m^3)							
2.5 hrs	0.847	2.022	3.129	4.313	6.153	7.839	9.604	22.409
5 hrs	**1.155**	**2.753**	**4.263**	**5.862**	**8.349**	**10.658**	**13.056**	**30.465**
10 hrs	1.397	3.333	5.165	7.119	10.124	12.923	15.830	36.936

Appendix E contains the proposed hydrographs and hydrograph coordinates for both sites.

7. MAXIMUM FLOOD

For both the Tungwane and Mzintlava Lower sites, Flood Studies suggest the use of the RMF as the maximum flood for this catchment area.
Flood Studies encourages the use of the RMF as the so-called PMF. The RMF can thus also be used as the SEF.

BIBLIOGRAPHY

Acocks, JHP (1988)
Veld types of South Africa.
Memoirs of the Botanical Survey of South Africa. Botanical Research Institute, Department of Agriculture and Water Supply, South Africa.

Alexander, WRJ (1990)
Flood Hydrology for Southern Africa.
SANCOLD, Pretoria.

Bauer, SW and Midgley, DC (1974)
A simple procedure for synthesizing direct runoff hydrographs.
HRU Report No. 1/74, Department of Civil Engineering, University of the Witwatersrand, Johannesburg.

Hydrological Research Unit (1972)
Design flood determination in South Africa.
HRU Report 1/72, Department of Civil Engineering, University of the Witwatersrand, Johannesburg.

Kovacs, ZP and Zurich, HMG (1995)
Flood frequency manual – Part II: Methods of analysis.
Technical Note No. 7, Sub-Directorate Flood Studies, Department of Water Affairs, Pretoria.

Midgley DC, Pitman WV and Middleton BJ, (1994)
Surface water resources of South Africa – Volume I: First Edition 1994.
Report No. 298/5.1/94 and 298/5.2/94, Water Research Commission, South Africa.

FLOOD STUDIES SOFTWARE

Software uniquely developed for use within Flood Studies because it uses data from mainframe databases as well as data from custom databases as input.

Linstrom, C (1999)
Software: *RainCalc3*, DWAF, Pretoria.

Rademeyer, P (1999)
Software: *DetFlo99*, DWAF, Pretoria.

Van der Spuy, D (1999)
Software: *EmpFlo99*, DWAF, Pretoria.

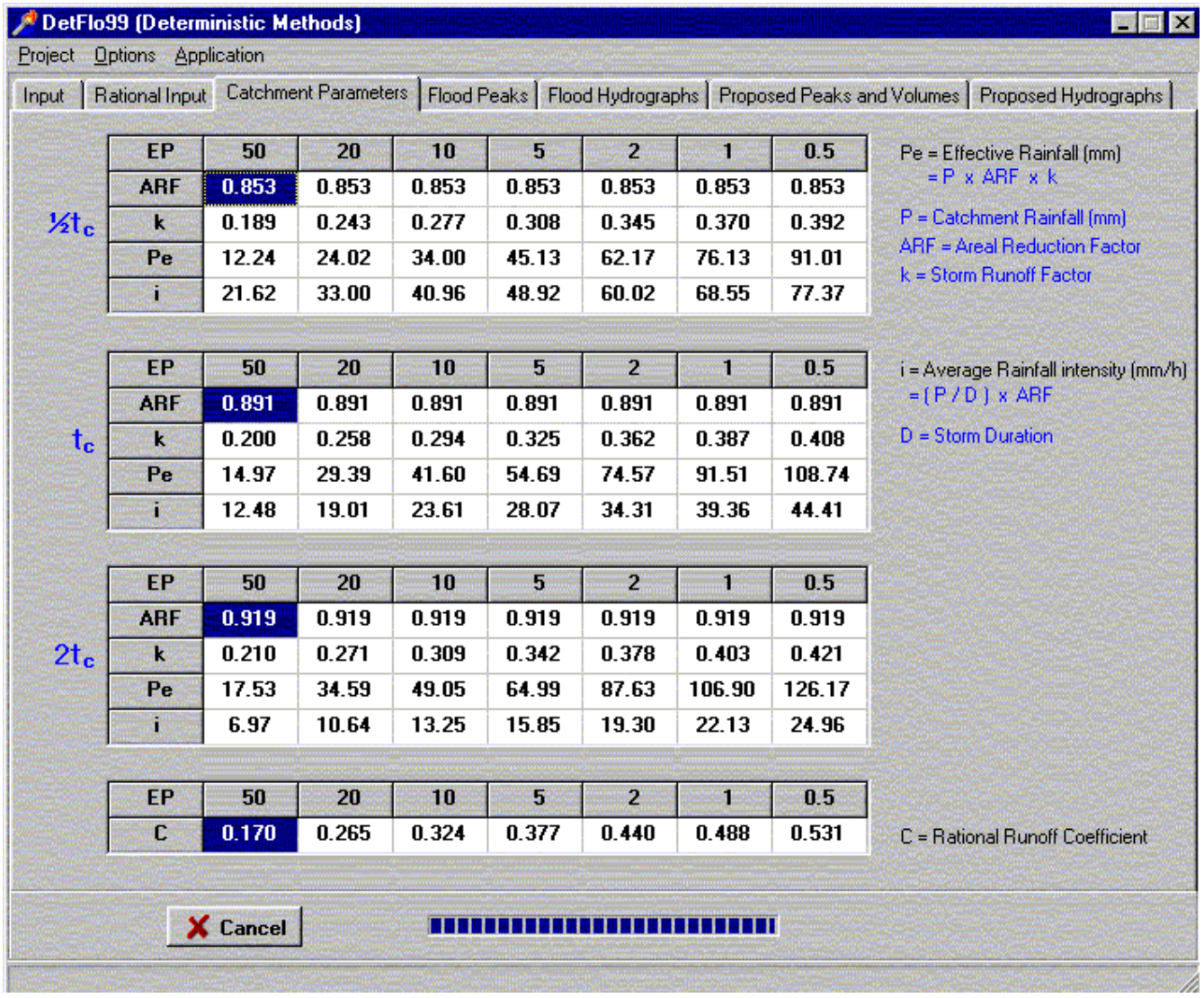
APPENDIX C

Deterministic Methods

C.1. Parameters calculated by DetFlo99

The ***DetFlo99*** program (Rademeyer, 1999) was used to estimate the flood peaks for the deterministic methods. The following extracts from ***DetFlo99*** shows some important deterministic parameters that were calculated for the Tungwane site.

Insert 1 (DetFlo99): Calculated catchment parameters for the Tungwane site



*Appendix A contains more information on the catchment parameters, which were used in **DetFlo99** to obtain these deterministic parameters.*

The following table shows the estimated flood peaks at the Tungwane site, for the different storm durations (based on a t_c of 6 hours), which were calculated by ***DetFlo99***.

Table C-1: Estimated flood peaks for the Tungwane site – deterministic methods

Method	Storm duration	Exceedance probability (%)						
		50	20	10	5	2	1	0.5
		Flood peaks (m^3/s)						
DRH	3 hrs	93	183	259	344	474	580	693
	6 hrs	**90**	**176**	**249**	**327**	**446**	**548**	**651**
	12 hrs	67	132	188	249	335	409	483
SUH	3 hrs	102	201	285	378	521	637	762
	6 hrs	**82**	**160**	**227**	**298**	**406**	**499**	**592**
	12 hrs	54	107	151	200	270	330	389
Rational	3 hrs	66	157	238	330	474	600	736
	6 hrs	**76**	**181**	**274**	**379**	**542**	**689**	**845**
	12 hrs	42	101	154	214	305	387	475

The deterministic methods are used to estimate the proposed flood peaks for the different storm durations. The variation (var) of flood peaks with storm duration were taken into account in the following way:

- The variation (var) value was calculated for each storm duration and exceedance probability by using the results of the Rational method.
- Correct var to obtain var* = (var + 1) / 2. This is necessary to take into account the fact that the representative storm durations for the flood peaks derived by the Empirical methods are unknown.
- Multiply the proposed flood peaks for each exceedance probability by the representative values of var*.

See Kovacs, ZP and Zurich, HMG (1995) for more information.

APPENDIX B

Rainfall

B.1. Catchment rainfall

The rainfall data of the rainfall station at Lusikisiki was used in the estimation of the mean catchment rainfall, for the different storm durations, for the Tungwane site. This is the only rainfall station that could be found in the vicinity of the catchment that was suitable for use in a rainfall analysis for this particular catchment.

Table B-1: Rainfall station used

Station number	Place	Data
154 142	Lusikisiki	1909 - 1995

The ***RainCalc3*** program (Linström, 1999) was used for the statistical analysis which was done on the rainfall data, to estimate the mean catchment rainfall for the different storm durations. The data was extracted from the RFDB2 database (mainframe).

Note that when estimating the mean catchment rainfall, it is assumed that in extreme events the storm duration is similar to the time of concentration (t_c).

Table B-2: Mean catchment rainfall – Tungwane

Storm duration	Exceedance probability (%)						
	50	20	10	5	2	1	0.5
	Rainfall (mm)						
3 hrs	76	116	144	172	211	241	272
6 hrs	**84**	**128**	**159**	**189**	**231**	**265**	**299**
12 hrs	91	139	173	207	252	289	326

APPENDIX A

THE CATCHMENT

A.1. The catchment of Tungwane and Mzintlava Lower sites

The catchment lies on the Eastern Pondoland coast and is drained by the Mzintlava River, which has several tributaries flowing into it. The longest stream consists of the Mbotyi-, Nyosana- and Mzintlava Rivers. The nearest town is Lusikisiki, in Transkei, which lies north of Port St Johns.
Further information regarding the catchment can be found in **Table A-1** and **Table A-2**.

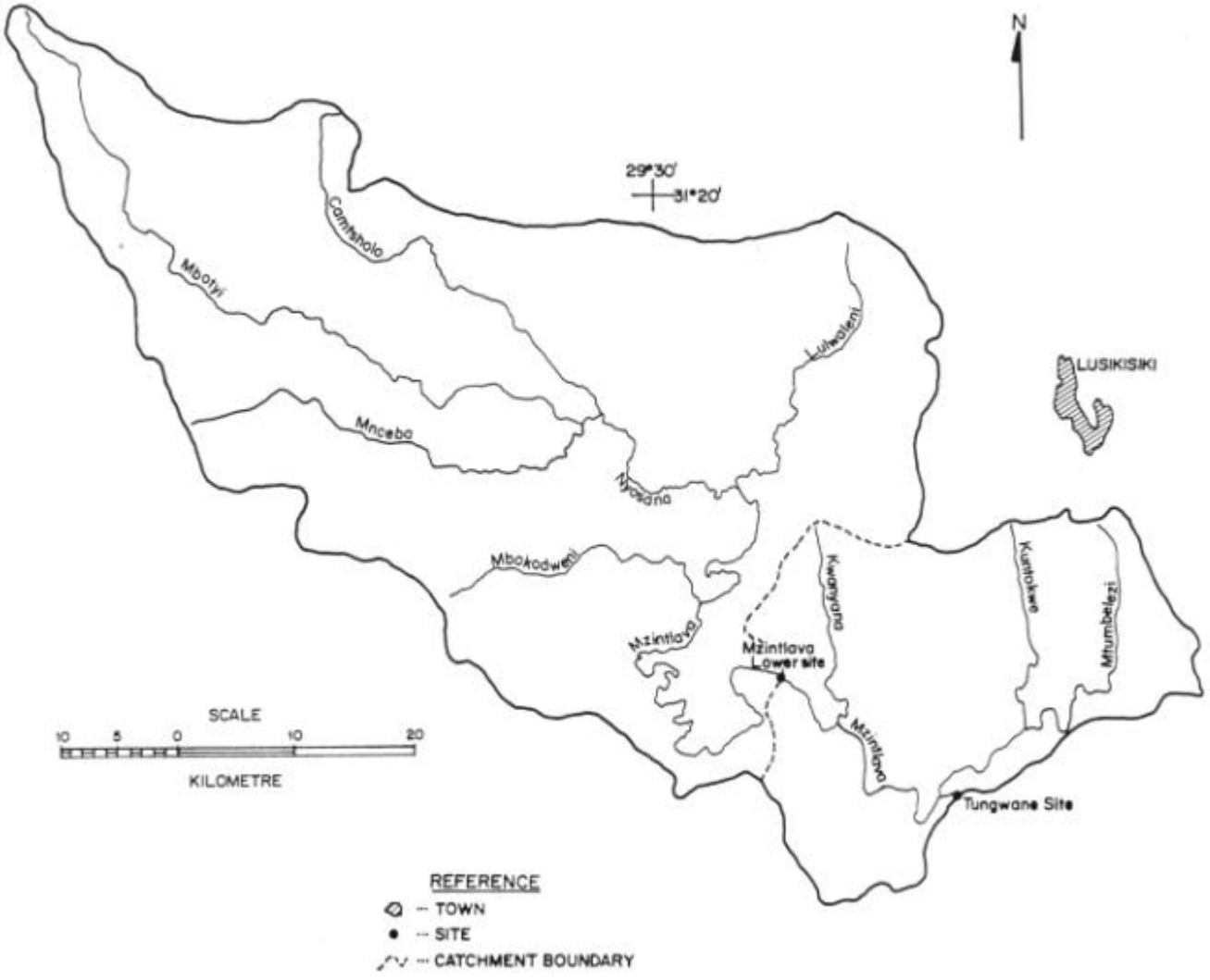


Figure 1: Tungwane and Mzintlava Lower catchment areas

Table A-1: Catchment characteristics and information of the Tungwane site

IDENTIFICATION OF SITE

Place:	Tungwane	Drainage Region:	T600	Latitude:	31º 25' 30"
Watercourse:	Mzintlava River	Station no.:		Longitude:	29º 33' 30"

CATCHMENT CHARACTERISTICS

Catchment Area and Slope:

Total:	**A**	=	129	km^2	Part of A_e considered as dolomitic:	A_d =	0 km^2
Ineffective:	A_i	=	0	km^2	Reduction factor	**k** =	0.41
Effective:	A_e	=	129	km^2	Flood peak reduction coefficient	f_d =	1.00
Mean steepness of A_e	S_A	=	15.70	%	Mean steepness of A_e as used in CAPA		17.56 %

Rainfall-Runoff properties:

Veld type zones (HRU 1/72 fig.F1)	8	
Relative Weight (%)	100%	

Catchment coverage as required for Rational method

Rural	Urban	Lakes
100%	0%	0%

Soil Permeability:	**%A**	**Vegetation:**	**%A**	**Rainfall:** (HRU 1/72 fig.C3) *	
Very Permeable (A)		Forest, Dense bush & wood	40%	Mean Annual Rainfall (mm)	1100
Permeable (B)		Thin Bush, Cultivated land	40%	Extreme point rainfall region *	3
Semi-Permeable (C)	100%	Grassland	15%	Coastal (**C**) or Inland (**I**)	I
Impermeable (D)		Bare surface	5%	Winter (**W**) or Summer (**S**)	S

Watercourse properties:

Longest Watercourse:					Mean Slope:		
Natural channel	L_1	=	32	km	Mean slope of L_1	S_1 =	0.010299
Overland flow	L_2	=	0.0	km	Mean slope of L_2	S_2 =	0.000000
Total length	**L**	=	32	km	Mean slope of L	S_L =	0.010299
Distance from site to centre of catchment	L_c	=	15	km			

Time of concentration:

TYPE OF FLOW	TIME OF CONCENTRATION (hours)		
Natural channel	$t_{c1} = \tau\,[0.87 * L_1^2 / (1000 * S_1)]^{0.385}$	5.52	**6.0**
Overland	$t_{c2} = 0{,}6 * [\,r * L_2 / (S_2)^{0.5}\,]^{0,467}$	0.00	
Artificial channel	$t_{c1a} = 0.278 * \Sigma(l_i / v_i)$		

where

A_e	=	129	to calculate τ
τ	=	1.0	correction to factor according to size of A
r	=	0.20	roughness factor
l_i	=		length of a uniform reach
v_i	=		velocity in a uniform reach

Typical values of r										
Pavement	0,02	Bare soil	0,1	Poor grass	0,3	Average grass & Cultivated land	0,4	Dense grass	0,8

ADDITIONAL INFORMATION FOR EMPIRICAL METHODS

RMF region TR137	5.4	Francou-Rodier K_e	5.4	**Roberts** "K" (Transvaal)	1

MIPI Flood regions HRU 1/72 fig.B.1	4		
Relative proportion (%)	100%		

Table A-2: Catchment characteristics and information of the Mzintlava Lower site

IDENTIFICATION OF SITE

Place:	Mzintlava Lower	Drainage Region:	T600	Latitude:	31º 24' 25"
Watercourse:	Mzintlava River	Station no.:		Longitude:	29º 31' 22"

CATCHMENT CHARACTERISTICS

Catchment Area and Slope:

Total:	**A**	=	98	km^2	Part of A_e considered as dolomitic:	A_d =	0 km^2
Ineffective:	A_i	=	0	km^2	Reduction factor	**k** =	0.41
Effective:	A_e	=	98	km^2	Flood peak reduction coefficient	f_d =	1.00
Mean steepness of A_e	S_A	=	15.48	%	Mean steepness of A_e as used in CAPA		17.24 %

Rainfall-Runoff properties:

Veld type zones (HRU 1/72 fig.F1)	8	
Relative Weight (%)	100%	

Catchment coverage as required for Rational method

Rural	Urban	Lakes
100%	0%	0%

Soil Permeability:	**%A**	**Vegetation:**	**%A**	**Rainfall:** (HRU 1/72 fig.C3) *	
Very Permeable (A)		Forest, Dense bush & wood	40%	Mean Annual Rainfall (mm)	1100
Permeable (B)		Thin Bush, Cultivated land	40%	Extreme point rainfall region *	3
Semi-Permeable (C)	100%	Grassland	15%	Coastal (**C**) or Inland (**I**)	I
Impermeable (D)		Bare surface	5%	Winter (**W**) or Summer (**S**)	S

Watercourse properties:

Longest Watercourse:					Mean Slope:		
Natural channel	L_1	=	27	km	Mean slope of L_1	S_1 =	0.010227
Overland flow	L_2	=	0.0	km	Mean slope of L_2	S_2 =	0.000000
Total length	**L**	=	27	km	Mean slope of L	S_L =	0.010227
Distance from site to centre of catchment	L_c	=	13	km			

Time of concentration:

TYPE OF FLOW	TIME OF CONCENTRATION (hours)			where		
Natural channel	$t_{c1} = \tau\,[0.87 * L_1^2 / (1000 * S_1)]^{0.385}$	4.90	**5.0**	A_e =	98	to calculate τ
Overland	$t_{c2} = 0{,}6 * [\,r * L_2 / (S_2)^{0.5}\,]^{0.467}$	0.00		τ =	1.0	correction to factor according to size of A
Artificial channel	$t_{c1a} = 0.278 * \Sigma(\,l_i / v_i\,)$			r =	0.20	roughness factor
				l_i =		length of a uniform reach
				v^i =		velocity in a uniform reach

Typical values of r	Pavement	0,02	Bare soil	0,1	Poor grass	0,3	Average grass & Cultivated land	0,4	Dense grass	0,8

ADDITIONAL INFORMATION FOR EMPIRICAL METHODS

RMF region	TR137	5.4	Francou-Rodier K_e	5.4	**Roberts** "K" (Transvaal)	1

MIPI Flood regions	HRU 1/72 fig.B.1	4		
Relative proportion (%)		100%		

Table A.3: Catchment Characteristics and information

IDENTIFICATION OF SITE

Place:	Lusikisiki site	Drainage Region:	1860	Latitude:	31º19' 25"
Watercourse:	Xura	Station no.:	T6H004	Longitude:	29º31'10"

CATCHMENT CHARACTERISTICS

Catchment Area and Slope:

Total:	**A**	=	91	km^2	Part of A_e considered as dolomitic:	A_d =	0 km^2
Ineffective:	A_i	=	0	km^2	Reduction factor	**k** =	0.38
Effective:	A_e	=	91	km^2	Flood peak reduction coefficient	f_d =	1.00
Mean steepness of A_e	S_A	=	13.91	%	Mean steepness of A_e as used in CAPA		18.52 %

Rainfall-Runoff properties:

Veld type zones (HRU 1/72 fig.F1)	8	
Relative Weight (%)	100%	

Catchment coverage as required for Raional method

Rural	Urban	Lakes
100%	0%	0%

Soil Permeability:	**%A**	**Vegetation:**	**%A**	**Rainfall:** (HRU 1/72 fig.C3) *	
Very Permeable (A)		Forest, Dense bush & wood	50%	Mean Annual Rainfall (mm)	950
Permeable (B)		Thin Bush, Cultivated land	40%	Extreme point rainfall region *	3
Semi-Permeable (C)	10%	Grassland	7%	Coastal (**C**) or Inland (**I**)	I
Impermeable (D)	90%	Bare surface	3%	Winter (**W**) or Summer (**S**)	S

Watercourse properties:

Longest Watercourse:				Mean Slope:	
Natural channel	L_1 =	28	km	Mean slope of L_1	S_1 = 0.011494
Overland flow	L_2 =		km	Mean slope of L_2	S_2 = 0.000000
Total length	L =	28	km	Mean slope of L	S_L = 0.011494
Distance from site to centre of catchment	L_c =	15	km		

Time of concentration:

TYPE OF FLOW	TIME OF CONCENTRATION (hours)		
Natural channel	$t_{c1} = \tau\,[0.87 * L_1^2 / (1000 * S_1)]^{0.385}$	4.85	**5.0**
Overland	$t_{c2} = 0{,}6 * [r * L_2 / (S_2)^{0.5}]^{0,467}$	0.00	
Artificial channel	$t_{c1a} = 0.278 * \Sigma (l_i / v_i)$		

where

A_e	= 91	to calculate	τ
τ	= 1.0	correction to factor according to size of A	
r	= 0.20	roughness factor	
l_i	=	length of a uniform reach	
v_i	=	velocity in a uniform reach	

Typical values of r	Pavement	0,02	Bare soil	0,1	Poor grass	0,3	Average grass & Cultivated land	0,4	Dense grass	0,8

ADDITIONAL INFORMATION FOR EMPIRICAL METHODS

RMF region TR137	5.2	Francou-Rodier K_e	5.2	**Roberts** "K" (Transvaal)	1

MIPI Flood regions HRU 1/72 fig.B.1	4		
Relative proportion (%)	100%		

APPENDIX D

Empirical Methods

D.1. Empirical methods

The ***EmpFlo99*** program (Van der Spuy, 1999) was used to estimate the flood peaks for the MIPI, MIPI 1/71 and CAPA methods and the estimation of the RMF.
TR137 was used to determine the RMF. For the Tungwane and Mzintlava Lower sites, the biggest part of their catchment areas lies in RMF region 5.4. The sites also lie in RMF region 5.4. A Francou-Rodier K_e value of 5.4 was also used.
Although the Roberts method is not applicable for this catchment area, it is shown here for interest sake. A Roberts "K" value of 1 was used.

Insert 2 (EmpFlo99): Estimated flood peaks for the Tungwane site

Method	Probability of exceedance (%)									RMF
	50	20	10	5	2	1	0.5	0.2	0.1	
	FLOOD PEAKS in m^3/s									
MIPI	37	85	130	183	265	335	414	528	624	
MIPI 1/71	43	107	157	211	296	372	462	606	738	
Roberts	45	99	146	195	259	304	346	397	432	
CAPA	66	100	136	183	269	359	478	695	922	
TR137					756	978	1199			1954

Appendix A contains more information on the catchment parameters, which were used in ***EmpFlo99****.*

APPENDIX E

Hydrographs

E.1. 1% Exceedance Probability hydrographs

The 1% Exceedance Probability hydrographs, for Tungwane and Mzintlava Lower, were estimated by using the DRH method. The coordinates are given in **Table E.1** and **Table E.2** respectively. The graphical representation follows each table.

Table E.1: 1% EP hydrographs for the Tungwane site

3 hrs		6 hrs		12 hrs	
Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)
0.00	0.00	0.00	0.00	0.00	0.00
0.15	16.68	0.30	17.22	0.60	20.64
0.30	35.74	0.60	40.59	1.20	34.33
0.45	53.81	0.90	61.16	1.80	45.30
0.60	69.61	1.20	75.91	2.40	58.45
0.75	83.31	1.50	85.71	3.00	78.19
0.90	95.97	1.80	93.74	3.60	107.68
1.05	109.06	2.10	104.08	4.20	148.38
1.20	124.14	2.40	120.77	4.80	199.87
1.35	142.58	2.70	147.00	5.40	259.89
1.50	165.42	3.00	184.66	6.00	324.63
1.65	193.27	3.30	234.03	6.60	389.12
1.80	226.35	3.60	293.78	7.20	447.78
1.95	264.55	3.90	361.05	7.80	495.12
2.10	307.64	4.20	431.83	8.40	526.50
2.25	355.48	4.50	501.42	9.00	**538.99**
2.40	408.37	4.80	565.09	9.60	532.33
2.55	467.42	5.10	618.85	10.20	509.89
2.70	535.02	5.40	660.37	10.80	479.72
2.85	615.33	5.70	**690.00**	11.40	455.68
3.00	**645.45**	6.00	673.50	12.00	412.10
3.15	619.11	6.30	619.65	12.60	348.83
3.30	593.84	6.60	570.11	13.20	295.28
3.45	569.60	6.90	524.53	13.80	249.95
3.60	546.36	7.20	482.59	14.40	211.58
3.75	524.06	7.50	444.00	15.00	179.10
3.90	502.67	7.80	408.50	15.60	151.60
4.05	482.16	8.10	375.84	16.20	128.33
4.20	462.48	8.40	345.79	16.80	108.63
4.35	443.61	8.70	318.14	17.40	91.95
4.50	425.50	9.00	292.70	18.00	77.83
4.65	408.14	9.30	269.30	18.60	65.89
4.80	391.48	9.60	247.77	19.20	55.77
4.95	375.51	9.90	227.96	19.80	47.21
5.10	360.18	10.20	209.73	20.40	39.96
5.25	345.48	10.50	192.96	21.00	33.83
5.40	331.38	10.80	177.53	21.60	28.63
5.55	317.86	11.10	163.34	22.20	24.24
5.70	304.89	11.40	150.28	22.80	20.52

3 hrs		6 hrs		12 hrs	
Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)
5.85	292.44	11.70	138.26	23.40	17.37
6.00	280.51	12.00	127.21	24.00	14.70
6.15	269.06	12.30	117.04	24.60	12.44
6.30	258.08	12.60	107.68	25.20	10.53
6.45	247.55	12.90	99.07	25.80	8.92
6.60	237.45	13.20	91.15	26.40	7.55
6.75	227.76	13.50	83.86	27.00	6.39
6.90	218.46	13.80	77.16	27.60	5.41
7.05	209.55	14.10	70.99	28.20	4.58
7.20	200.99	14.40	65.31	28.80	3.88
7.35	192.79	14.70	60.09	29.40	3.28
7.50	184.92	15.00	55.28	30.00	2.78
7.65	177.38	15.30	50.86	30.60	2.35
7.80	170.14	15.60	46.80	31.20	1.99
7.95	163.19	15.90	43.06	31.80	1.68
8.10	156.53	16.20	39.61	32.40	1.43
8.25	150.15	16.50	36.45	33.00	1.21
8.40	144.02	16.80	33.53	33.60	1.02
8.55	138.14	17.10	30.85	34.20	0.86
8.70	132.50	17.40	28.38	34.80	0.73
8.85	127.10	17.70	26.11	35.40	0.62
9.00	121.91	18.00	24.03		
9.15	116.93	18.30	22.11		
9.30	112.16	18.60	20.34		
9.45	107.58	18.90	18.71		
9.60	103.19	19.20	17.22		
9.75	98.98	19.50	15.84		
9.90	94.94	19.80	14.57		
10.05	91.07	20.10	13.41		
10.20	87.35	20.40	12.34		
10.35	83.79	20.70	11.35		
10.50	80.37	21.00	10.44		
10.65	77.09	21.30	9.61		
10.80	73.94	21.60	8.84		
10.95	70.92	21.90	8.13		
11.10	68.03	22.20	7.48		
11.25	65.25	22.50	6.88		
11.40	62.59	22.80	6.33		
11.55	60.04	23.10	5.83		

3 hrs		6 hrs		12 hrs	
Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)
11.70	57.59	23.40	5.36		
11.85	55.24	23.70	4.93		
12.00	52.98	24.00	4.54		
12.15	50.82	24.30	4.18		
12.30	48.75	24.60	3.84		
12.45	46.76	24.90	3.53		
12.60	44.85	25.20	3.25		
12.75	43.02	25.50	2.99		
12.90	41.26	25.80	2.75		
13.05	39.58	26.10	2.53		
13.20	37.96	26.40	2.33		
13.35	36.41	26.70	2.14		
13.50	34.93	27.00	1.97		
13.65	33.50	27.30	1.81		
13.80	32.13	27.60	1.67		
13.95	30.82	27.90	1.54		
14.10	29.57	28.20	1.41		
14.25	28.36	28.50	1.30		
14.40	27.20	28.80	1.20		
14.55	26.09	29.10	1.10		
14.70	25.03	29.40	1.01		
14.85	24.01	29.70	0.93		
15.00	23.03	30.00	0.86		
15.15	22.09	30.30	0.79		
15.30	21.18	30.60	0.73		
15.45	20.32	30.90	0.67		
15.60	19.49	31.20	0.61		
15.75	18.70				
15.90	17.93				
16.05	17.20				
16.20	16.50				
16.35	15.83				
16.50	15.18				
16.65	14.56				
16.80	13.97				
16.95	13.40				
17.10	12.85				
17.25	12.32				
17.40	11.82				
17.55	11.34				
17.70	10.88				
17.85	10.43				
18.00	10.01				
18.15	9.60				
18.30	9.21				
18.45	8.83				
18.60	8.47				
18.75	8.12				
18.90	7.79				
19.05	7.48				
19.20	7.17				
19.35	6.88				
19.50	6.60				
19.65	6.33				

3 hrs		6 hrs		12 hrs	
Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)
19.80	6.07				
19.95	5.82				
20.10	5.58				
20.25	5.36				
20.40	5.14				
20.55	4.93				
20.70	4.73				
20.85	4.53				
21.00	4.35				
21.15	4.17				
21.30	4.00				
21.45	3.84				
21.60	3.68				
21.75	3.53				
21.90	3.39				
22.05	3.25				
22.20	3.12				
22.35	2.99				
22.50	2.87				
22.65	2.75				
22.80	2.64				
22.95	2.53				
23.10	2.43				
23.25	2.33				
23.40	2.23				
23.55	2.14				
23.70	2.05				
23.85	1.97				
24.00	1.89				
24.15	1.81				
24.30	1.74				
24.45	1.67				
24.60	1.60				
24.75	1.53				
24.90	1.47				
25.05	1.41				
25.20	1.35				
25.35	1.30				
25.50	1.25				
25.65	1.20				
25.80	1.15				
25.95	1.10				
26.10	1.05				
26.25	1.01				

Table E.2: 1% EP hydrographs for the Mzintlava Lower site

2.5 hrs		5 hrs		10 hrs	
Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)
0.00	0.00	0.00	0.00	0.00	0.00
0.13	15.61	0.25	15.66	0.50	17.45
0.25	32.01	0.50	36.64	1.00	33.11
0.38	47.49	0.75	55.43	1.50	44.86
0.50	61.57	1.00	69.25	2.00	54.30
0.63	74.54	1.25	78.54	2.50	64.81
0.75	87.15	1.50	85.62	3.00	80.07
0.88	100.31	1.75	93.70	3.50	103.11
1.00	114.90	2.00	106.05	4.00	135.60
1.13	131.65	2.25	125.39	4.50	177.61
1.25	151.09	2.50	153.53	5.00	227.52
1.38	173.50	2.75	191.09	5.50	282.17
1.50	199.03	3.00	237.46	6.00	337.26
1.63	227.83	3.25	290.89	6.50	387.86
1.75	260.15	3.50	348.71	7.00	429.09
1.88	296.66	3.75	407.69	7.50	456.85
2.00	338.70	4.00	464.51	8.00	**468.75**
2.13	388.62	4.25	516.30	8.50	465.04
2.25	450.16	4.50	561.38	9.00	449.63
2.38	528.87	4.75	**600.00**	9.50	431.19
2.50	**561.23**	5.00	592.60	10.00	389.46
2.63	538.32	5.25	545.22	10.50	329.67
2.75	516.35	5.50	501.62	11.00	279.06
2.88	495.28	5.75	461.52	11.50	236.22
3.00	475.07	6.00	424.62	12.00	199.95
3.13	455.68	6.25	390.67	12.50	169.26
3.25	437.08	6.50	359.43	13.00	143.27
3.38	419.24	6.75	330.69	13.50	121.28
3.50	402.14	7.00	304.25	14.00	102.66
3.63	385.72	7.25	279.92	14.50	86.90
3.75	369.98	7.50	257.54	15.00	73.56
3.88	354.88	7.75	236.95	15.50	62.27
4.00	340.40	8.00	218.01	16.00	52.71
4.13	326.51	8.25	200.57	16.50	44.62
4.25	313.18	8.50	184.54	17.00	37.77
4.38	300.40	8.75	169.78	17.50	31.97
4.50	288.14	9.00	156.21	18.00	27.06
4.63	276.38	9.25	143.72	18.50	22.91
4.75	265.10	9.50	132.23	19.00	19.39
4.88	254.28	9.75	121.65	19.50	16.41
5.00	243.91	10.00	111.93	20.00	13.89
5.13	233.95	10.25	102.98	20.50	11.76
5.25	224.41	10.50	94.74	21.00	9.96
5.38	215.25	10.75	87.17	21.50	8.43
5.50	206.46	11.00	80.20	22.00	7.13
5.63	198.04	11.25	73.79	22.50	6.04
5.75	189.96	11.50	67.89	23.00	5.11
5.88	182.20	11.75	62.46	23.50	4.33

2.5 hrs		5 hrs		10 hrs	
Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)
6.00	174.77	12.00	57.47	24.00	3.66
6.13	167.63	12.25	52.87	24.50	3.10
6.25	160.79	12.50	48.64	25.00	2.62
6.38	154.23	12.75	44.75	25.50	2.22
6.50	147.94	13.00	41.18	26.00	1.88
6.63	141.90	13.25	37.88	26.50	1.59
6.75	136.11	13.50	34.85	27.00	1.35
6.88	130.55	13.75	32.07	27.50	1.14
7.00	125.23	14.00	29.50	28.00	0.97
7.13	120.12	14.25	27.14	28.50	0.82
7.25	115.21	14.50	24.97	29.00	0.69
7.38	110.51	14.75	22.98	29.50	0.59
7.50	106.00	15.00	21.14		
7.63	101.68	15.25	19.45		
7.75	97.53	15.50	17.89		
7.88	93.55	15.75	16.46		
8.00	89.73	16.00	15.15		
8.13	86.07	16.25	13.94		
8.25	82.55	16.50	12.82		
8.38	79.19	16.75	11.80		
8.50	75.95	17.00	10.85		
8.63	72.85	17.25	9.99		
8.75	69.88	17.50	9.19		
8.88	67.03	17.75	8.45		
9.00	64.29	18.00	7.78		
9.13	61.67	18.25	7.16		
9.25	59.15	18.50	6.58		
9.38	56.74	18.75	6.06		
9.50	54.42	19.00	5.57		
9.63	52.20	19.25	5.13		
9.75	50.07	19.50	4.72		
9.88	48.03	19.75	4.34		
10.00	46.07	20.00	3.99		
10.13	44.19	20.25	3.67		
10.25	42.38	20.50	3.38		
10.38	40.66	20.75	3.11		
10.50	39.00	21.00	2.86		
10.63	37.40	21.25	2.63		
10.75	35.88	21.50	2.42		
10.88	34.41	21.75	2.23		
11.00	33.01	22.00	2.05		
11.13	31.66	22.25	1.89		
11.25	30.37	22.50	1.74		
11.38	29.13	22.75	1.60		
11.50	27.94	23.00	1.47		
11.63	26.80	23.25	1.35		
11.75	25.71	23.50	1.24		
11.88	24.66	23.75	1.14		

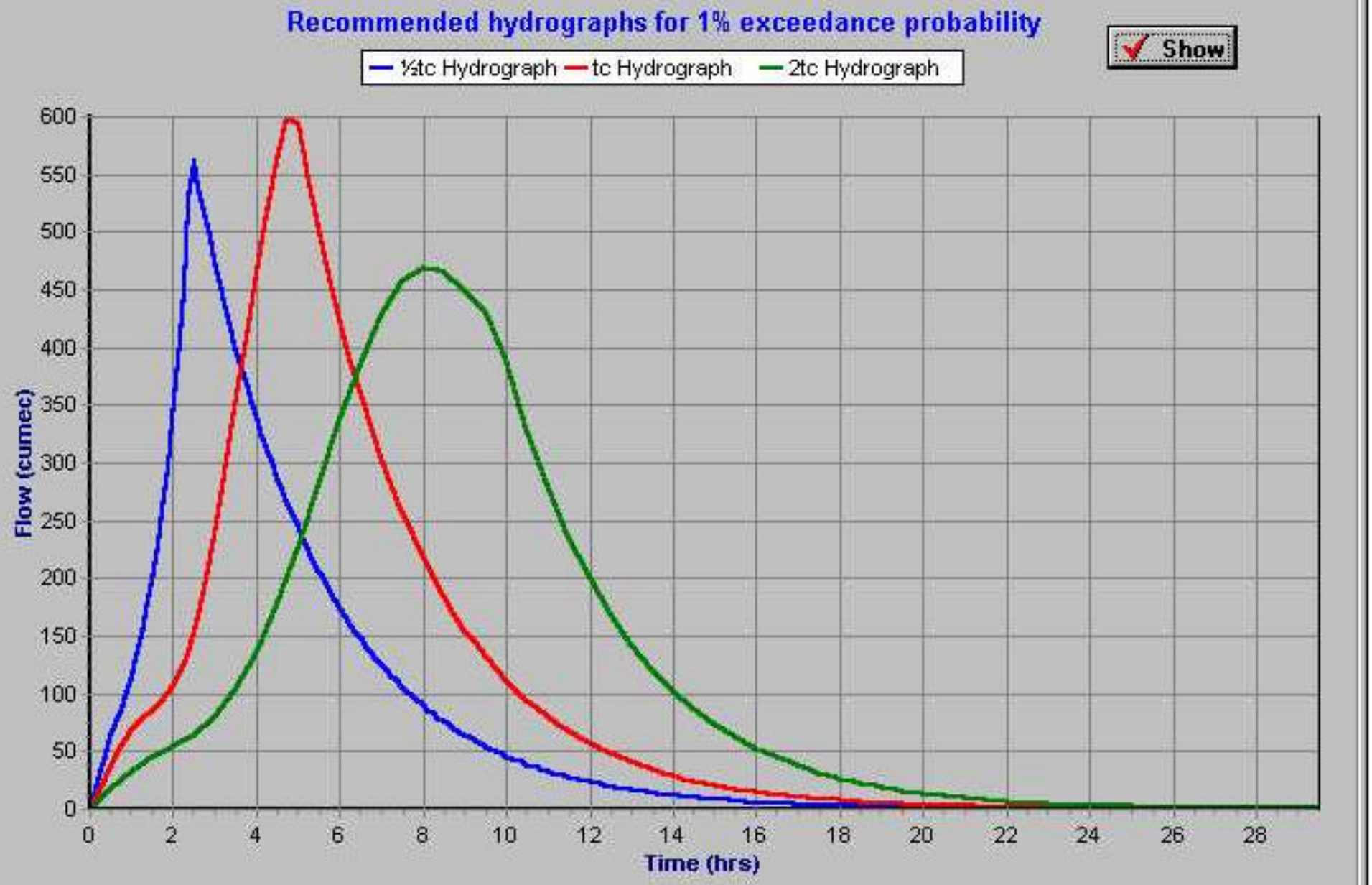
2.5 hrs		5 hrs		10 hrs	
Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)
12.00	23.65	24.00	1.05		
12.13	22.69	24.25	0.97		
12.25	21.76	24.50	0.89		
12.38	20.87	24.75	0.82		
12.50	20.02	25.00	0.75		
12.63	19.20	25.25	0.69		
12.75	18.42	25.50	0.64		
12.88	17.67	25.75	0.59		
13.00	16.95				
13.13	16.26				
13.25	15.59				
13.38	14.96				
13.50	14.35				
13.63	13.76				
13.75	13.20				
13.88	12.66				
14.00	12.14				
14.13	11.65				
14.25	11.17				
14.38	10.72				
14.50	10.28				
14.63	9.86				
14.75	9.46				
14.88	9.07				
15.00	8.70				
15.13	8.35				
15.25	8.01				
15.38	7.68				
15.50	7.37				
15.63	7.06				
15.75	6.78				
15.88	6.50				
16.00	6.23				
16.13	5.98				
16.25	5.74				
16.38	5.50				
16.50	5.28				
16.63	5.06				
16.75	4.86				
16.88	4.66				
17.00	4.47				
17.13	4.29				
17.25	4.11				
17.38	3.94				
17.50	3.78				
17.63	3.63				
17.75	3.48				
17.88	3.34				
18.00	3.20				
18.13	3.07				
18.25	2.95				

2.5 hrs		5 hrs		10 hrs	
Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)	Time (hrs)	Flow (m^3/s)
18.38	2.82				
18.50	2.71				
18.63	2.60				
18.75	2.49				
18.88	2.39				
19.00	2.29				
19.13	2.20				
19.25	2.11				
19.38	2.02				
19.50	1.94				
19.63	1.86				
19.75	1.79				
19.88	1.71				
20.00	1.64				
20.13	1.58				
20.25	1.51				
20.38	1.45				
20.50	1.39				
20.63	1.33				
20.75	1.28				
20.88	1.23				
21.00	1.18				
21.13	1.13				
21.25	1.08				
21.38	1.04				
21.50	1.00				

DetFlo (Deterministic Methods)

File Print Excel Help

Estimated flood peaks | Estimated flood hydrographs | Recommended flood frequencies | Recommended flood hydrographs

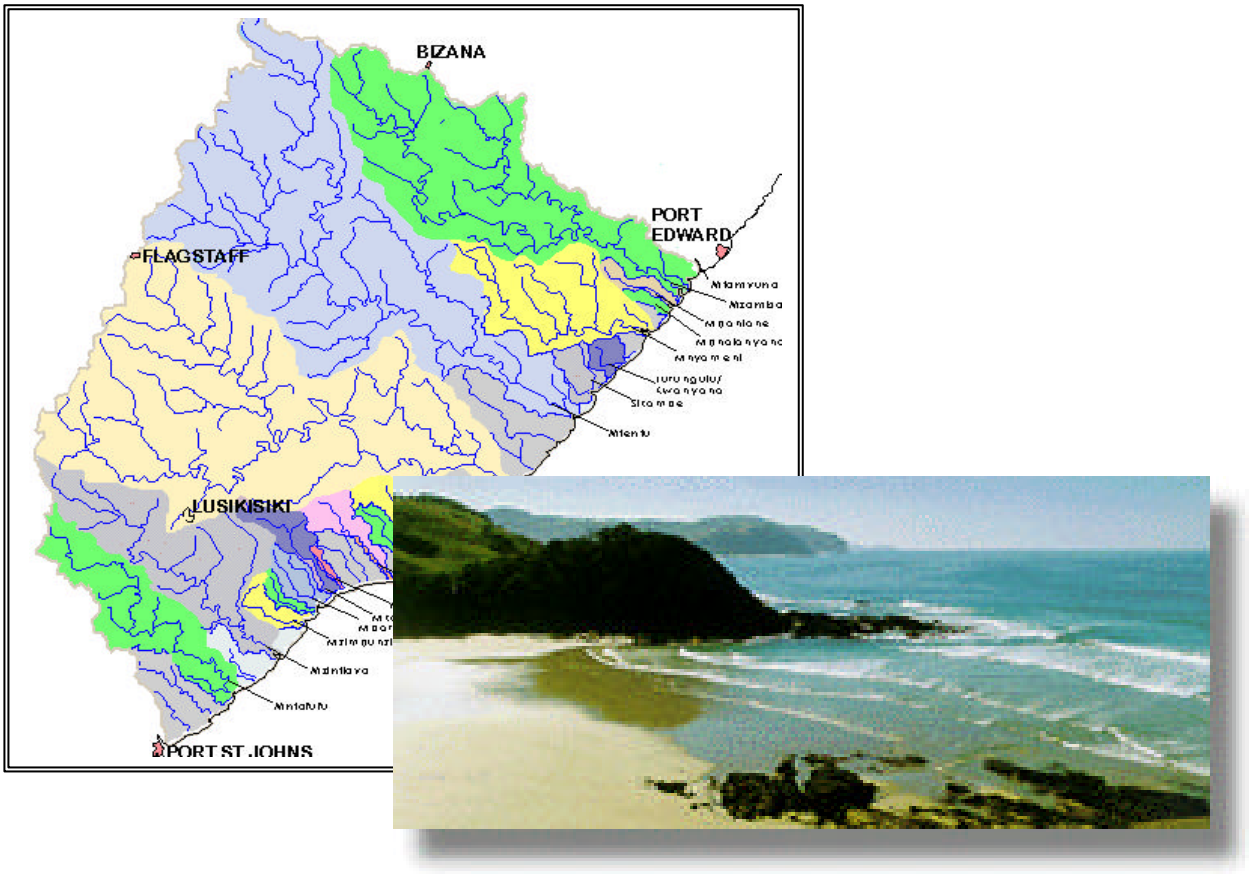


PB T600/00/1301

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



ENGINEERING GEOLOGICAL PRE-FEASABILITY REPORT

Final

June 2001

Prepared By:

Council for Geoscience
Geological Survey
Private Bag X112, Pretoria, 0001

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Engineering Geological Pre-feasibility Report
AUTHOR	**:**	G Davis
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-1301
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EXECUTIVE SUMMARY

This report presents the findings of brief pre-feasibility level engineering geological investigations conducted at the proposed Lusikisiki dam site in order to facilitate comparison with the alternative Zalu dam site, which had previously been investigated in some detail.

The proposed dam site is located on the Xura River near to the town of Lusikisiki in the Eastern Cape Province. An approximate dam height of 23 m is envisaged. These limited investigations comprised the drilling of only four boreholes at the proposed centre-line and three boreholes at a possible quarry site.

The proposed dam site is markedly asymmetrical. The steeper slopes of the left flank are underlain by dolerite. The thickness of the colluvial soil cover is expected to vary between 3 m and 5 m, while the upper portion of the dolerite sill is also intensely weathered. Scattered outcrop of unweathered dolerite is evident within the river section. The dolerite sill is between 12 m and 18 m in thickness and is underlain by unweathered siltstone. The gently sloping right flank is underlain by the completely weathered dolerite sill, which becomes progressively thinner in an up-slope direction. At depth the dolerite is underlain by siltstone of the Ecca Group, Karoo Supergroup.

Good founding conditions at shallow depth within the river section, extending towards the left flank, are considered suitable for the founding of a concrete structure. Poor founding conditions on the right flank would, however, favour an embankment. Excavation depths within the river section are expected to be negligible, and likely to increase to a depth of 10 m at crest level on the left flank. For the embankment cut-off, depths between 3 m and 5 m may be assumed.

The investigated quarry site proved to be unsuitable because of excessive overburden thickness, but an abandoned dolerite quarry located only 7 km from the proposed dam site has been identified as a promising alternative. Embankment fill materials are likely to be located within reasonable distance of the dam site.

The report presents a summary of the geological factors to be considered in the comparison between this Luskisiki dam site and the alternative Zalu site. Recommendations are included for more-detailed follow-up investigations.

CONTENTS

1.	INTRODUCTION	1
2.	REGIONAL GEOLOGY	1
3.	SEISMIC HAZARD ASSESSMENT	2
4.	SITE DESCRIPTION	2
5.	DRILLING RESULTS	2
5.1	Left flank	2
5.2	River section	4
5.3	Right flank	5
6.	ENGINEERING GEOLOGICAL CONSIDERATIONS	6
6.1	Founding conditions and structure layout	6
6.2	Excavation depths	7
6.3	Foundation permeability	7
6.4	Slope stability	8
7.	CONSTRUCTION MATERIALS	8
7.1	Concrete aggregates	8
7.1.1	Drilling results	
7.1.2	Discussion	
7.2	Embankment fill materials	10
8.	COMPARISON BETWEEN ZALU AND LUSIKISIKI DAM SITES	10
9.	CONCLUSIONS AND RECOMMENDATIONS	13
10.	REFERENCES	15
11.	DATA APPENDIX	16

TABLES:

Table 1: Summarized joint data (dolerite sill)

Table 2: Summarized comparison between Lusikisiki and Zalu dam sites

PLATES:

Plate 1: A general view of the proposed Lusikisiki dam site, looking in a downstream direction.

Plate 2: The left flank at the proposed Lusikisiki dam site.

Plate 3: Scattered outcrop of dolerite bedrock is evident within the river section.

Plate 4: The gently sloping right flank at the proposed Lusikisiki dam site.

Plate 5: A view of the abandoned quarry located approximately 7 km north-west of the proposed Lusikisiki dam site.

APPENDICES:

Appendix: Water pressure test data

Appendix: Borehole co-ordinates

Appendix: Borehole logs and core photographs

FIGURES:

Figure 1: Locality plan

Figure 2: Site plan with borehole positions

Figure 3: Geological section

1. INTRODUCTION

A pre-feasibility level engineering geological investigation has been conducted at the proposed Lusikisiki dam site at the request of the Directorate of Water Resources Planning of the Department of Water Affairs and Forestry, dated 13 April 2000.

The Lusikisiki dam site was one of the favoured sites identified during the earlier reconnaissance phase of the Eastern Pondoland Basin Study, by consultants UWP Engineers. Brief reconnaissance-level engineering geological investigations were conducted at the time (Davis, 1999). The other favoured site was the Zalu dam site. Because the Zalu had previously been investigated in some detail (Hill Kaplan Scott, 1979), it was necessary to conduct more detailed investigations at the Lusikisiki site, in order to facilitate meaningful comparison between these two alternatives, and selection of the better development option.

The Lusikisiki dam site is located on the Xura River, roughly 7 km as the crow flies, north-west of the town of Lusikisiki in the Eastern Cape Province (Figure 1).

Initially, a maximum dam height of 40 m was envisaged. With the subsequent optimisation of the dam size, a height of approximately 23 m now appears more favourable (ie approximate crest level 557 m).

These pre-feasibility level investigations comprised the drilling of a limited number of boreholes along the proposed centre-line. In addition to the four boreholes (total length 109,23 m) drilled along the centre-line, three boreholes (total length 82,05 m) were drilled at a possible coarse aggregate quarry site. The boreholes were drilled by DWAF Drilling Branch in the period between June and August 2000.

The findings of the more-detailed investigations as presented in this pre-feasibility report supercede the earlier reconnaissance-level engineering geological report. For the sake of completeness, some comments on the general geological setting are repeated here.

2. REGIONAL GEOLOGY

The Lusikisiki area is underlain by sedimentary rocks belonging to the lower portion of the Karoo Supergroup. A NE-trending line passing through Lusikisiki may be considered to divide the area geologically; inland of this line the geology comprises mudrocks of the Ecca Group while the older tillite of the Dwyka Group occurs to the east of this.

The entire sedimentary sequence of the Karoo Supergroup has been intruded by younger dolerite sills and dykes. Dykes are generally between 3 m and 10 m in width and several kilometres in length (Karpeta & Johnson, 1978). A preferred north-westerly orientation is recognized. Sill thickness varies from less than 1 m to more than 100 m. The sills are generally discordant, ie cut across the bedding. These intrusive dolerites may comprise up to 40 per cent of the geological sequence within the Ecca Group strata, but significantly less within the Dwyka tillite.

The geological structure in this area is mainly characterized by gently dipping strata. Dips vary between 1° and 3° to the north-west, although localized steep dips may be associated with dolerite intrusions. No major regional scale faulting is recognized within the area of interest.

There are no economically important mineral deposits within the area of interest.

3. SEISMIC HAZARD ASSESSMENT

According to seismic hazard maps prepared by the then-Geological Survey (Section 10: Data Appendix), a seismic intensity of VI (modified Mercalli scale) has a 10 % probability of being exceeded at least once in a period of 50 years. This equates to a 10 % probability of peak horizontal ground accelerations between 50 cm/s^{-2} and 100 cm/s^{-2} being exceeded at least one in the same 50 year period.

4. SITE DESCRIPTION

The selected centre-line position is located at a narrowing of the Xura River valley, immediately downstream of a sharp bend in the river (Figure 2).

The relatively straight section of the river upstream of the site may represent a fault zone (see Section 7.1.1).

The site is markedly asymmetrical. The left flank is relatively steep, with gradient varying between 1:1,5 and 1:2,5 although the upper slopes are significantly flatter (estimated at 1:20). The right flank is gently sloping although the 2 m to 3 m high river bank is steep. This slope is convex, with gradient flattening from 1:5 to 1:13 at higher levels.

The width of the river section is approximately 30 m.

5. DRILLING RESULTS

Only four exploratory boreholes were drilled along the proposed centre-line. Borehole positions are indicated on Figure 2. One borehole (BH 1001) was drilled on the left flank, one within the river section angled from the left bank towards the right (BH 1002), another on the mid-right flank (BH 1003) and the fourth on the upper right flank (BH 1004).

5.1 Left flank

The uppermost, flatter slopes of the left flank are presumably underlain at depth by weathered siltstone, covered by silty / sandy colluvial soils. As no boreholes were drilled on these upper slope

areas, the thickness of the unconsolidated overburden as well as the condition of the underlying bedrock remain uncertain. Similarly, the level of the contact between this siltstone and the underlying dolerite sill is not known. As the geological conditions on these upper slopes lie above the proposed crest level, however, they have little bearing on the founding conditions.

The steeper slopes (ie between RL 534 at river bed level and at least RL 575) are covered with colluvial soils comprising silty to fine sands, with weathered siltstone rock fragments indicating an origin of talus or reworked transported soils. Occasional clayey material is presumably derived from fragments of siltstone which have completely weathered.

The thickness of this colluvial soil horizon is likely to decrease in a downslope direction, with scattered outcrop near the foot of the slope indicating the soil cover is least well developed in these parts. The soil thickness is expected to vary in thickness up to 3 m or 5 m. With only a single borehole drilled on this flank, however, the variation in soil thickness cannot be confirmed.

Lithologically, the entire left flank is underlain by dolerite. The base of the sill was not intersected in BH 1001, but from extrapolation may be assumed to extend to significant depths. Sill thickness on the lower flank is assumed to be in the order of 20 m. Because of the attitude of the sill which dips into the flank, sill thickness increases rapidly in an up-slope direction (Figure 3).

The upper part of the dolerite sill has undergone significant weathering. The uppermost 4 m of the dolerite is highly to completely weathered, becoming moderately to highly weathered over a further 2 m wide zone. At a depth of 9,2 m (RL 549,79 m) the dolerite becomes unweathered to slightly weathered. The depth of weathering is expected to mirror the topography, with the thickness of the various weathered zones increasing in an up-slope direction (Figure 3).

The upper horizon of highly to completely weathered rock was essentially recovered as silty- to fine sand and dolerite gravel (diameter up to 10 mm). Occasional dolerite core-stones also occur. It is unlikely that these drilling results are completely representative of *in situ* conditions. The drilling action essentially reduces the soft rock to very soft rock dolerite to sand-size fragments, leaving the medium hard rock fragments as gravel-size pieces.

Similarly, the gravel-size fragments recovered in the borehole suggest the highly to completely weathered dolerite is very highly fractured. Exposures of this material in nearby road cuttings would contradict this view, however, with the *in situ* weathered rock appearing more massive.

Joints within the moderately to highly weathered zone are very closely spaced (less than 50 mm up to 120 mm) producing a very highly fractured rock mass. A marked improvement in the jointing is evident within the slightly weathered to unweathered rock mass, with a medium to wide joint spacing generally varying between 150 mm and 750 mm (highly to slightly fractured).

At least three or four joint sets are recognized, including sub-horizontal and sub-vertical joints as well as a steeply dipping set (approximately 60°) and a moderately steep set (dipping at 30°). Because BH 1001 was drilled vertically, it is most likely that more than one set of sub-vertical joints occurs (see Section 5.2). The

joint surfaces are typically stained, particularly within the more weathered horizons. Within the slightly weathered to unweathered dolerite, joints of the sub-vertical set contain calcite fill material with thickness up to 1 mm or 2 mm. Typically, the joint surfaces are rough to smooth.

5.2 River section

Alluvial deposits at the favoured centre-line are of negligible thickness and mainly comprise patchy silt deposits. Greater accumulations of alluvium are evident both downstream of this centre-line as well as within the proposed dam basin.

The river section is characterized by scattered outcrop of essentially unweathered dolerite (Plate 3). The base of the dolerite sill is approximately 12 m to 18 m beneath river level (approximate RL 522,5 - RL 517,5). Intersection of the lower sill contact in BH's 1002 and 1003 indicates the dolerite sill is not horizontal, but rather exhibits a shallow apparent dip of 8° towards the left flank (Figure 3). It is also quite feasible that this lower sill boundary is irregular, rather than planar. The sill is underlain by unweathered siltstone.

Limited outcrop of massive siltstone on the right bank of the river suggests the relationship between the sedimentary strata and the intrusive dolerite is almost certainly more complex. This is supported by borehole evidence that the lower sill contact is, at least partly, faulted. The borehole core revealed some evidence of a narrow faulted contact, in the form of brecciated siltstone which had been largely recemented with calcite and appeared largely intact. This siltstone body might, however, simply represent an inclusion or xenolith.

Joint Set	Attitude	Characteristics
J1	Sub-vertical joints, striking sub-parallel (but slightly oblique to) the river	Joint spacing varies between 50 mm and 300 mm (ie close); joint continuity 20+ m; joints typically tight with no fill material; slightly rough surfaces.
J2	Sub-vertical joints, striking sub-perpendicular to the river	Joint spacing varies from 500 mm (occasionally 150 mm), ie medium to wide; continuity between 1 m and 3 m, up to 7 m; tight with no fill; rough and non-planar (irregular)
J3	Sub-horizontal joints	Spacing varies between 250 mm and 600 mm (ie medium); limited continuity between 1 m and 2 m; joints surfaces smooth but irregular.
J4	Irregular, sub-vertical joints, striking oblique to the river	

Table 1: Summarized joint data (dolerite sill)

With the exception of the uppermost 0,65 m of the dolerite sill which is slightly weathered, the sill for the most part is unweathered. The dolerite comprises light grey, medium to fine-grained rock ,becoming very fine-grained near the basal contact. The joints in general are closely to medium spaced, varying between 200 mm and 400 mm. At least four joint sets are recognized, including three more prominent sets as well as irregular joints. Joint data collected from surface exposures are summarized in Table 1.

The siltstone / carbonaceous siltstone underlying the dolerite sill comprises unweathered, dark grey to black, hard rock. The joint spacing generally varies between 100 mm and 250 mm, ie closely spaced. Numerous zones of very closely spaced joints are recognized (see Appendix for detailed borehole logs). This fracturing may, at least partly, be ascribed to drilling breaks via the sub-horizontal planes of weakness and the borehole core is therefore not completely representative of actual *in situ* conditions.

At least three joint sets are recognized within this siltstone / carbonaceous siltstone horizon. In addition to the sub-horizontal fractures which are drilling induced but which nevertheless represent sub-horizontal planes of weakness, sub-vertical joints are expected as well as steeply-dipping joints. These sub-horizontal weakness planes represent the bedding, but are not prominent discontinuities. Without the benefit of orientated borehole cores there remains some uncertainty as to actual rock mass jointing.

5.3 Right flank

The gently sloping right flank is covered by a poorly developed clayey to silty topsoil with a thickness of 0,6 m. The underlying soil horizon comprises clay or clayey silt and varies from less than one metre and possibly up to 6 m in thickness. These colluvial clayey soils are presumably derived from reworked dolerite soils.

The transported soils overlie completely weathered dolerite with thickness between 5,5 m and 6 m. Note that the silty or sandy material recovered from the boreholes is not considered representative of actual *in situ* conditions. As mentioned above (Section 5.1), the drilling action most likely reduced the friable but intact rock mass to silt, sand and gravel sized fragments.

Although this weathered dolerite sill underlies the right flank, the dip of the sill implies the thickness of the highly to completely weathered dolerite becomes progressively less in an up-slope direction, in effect ‘pinching out’, naturally assuming the dolerite-siltstone contact may be extrapolated as such.

Some improvement in the degree of weathering of the dolerite sill is noted at depth, with highly to completely weathered dolerite being recovered as gravel-sized fragments (diameter less than 50 mm). Again, this gravel should be considered a disturbed sample which is not entirely representative of *in situ* conditions. The size of the gravel would however indicate the joints within this weathered rock mass are very closely spaced. At least some fracturing is drilling induced. The drilling results indicate alternating horizons of variably-weathered rock.

The lower flank, at least, is underlain at depth by more intact, less weathered dolerite rock mass. Borehole 1003 intersected slightly to moderately weathered dolerite at a depth of 19 m (RL 535, ie approximately at river level). It is likely that this less weathered dolerite extends for some distance beneath the flank, but

probably not the entire flank. This 5,5 m thick horizon (BH 1003) comprises fine-grained, very hard rock dolerite. Joint spacing varies between close and medium (approximately 200 mm), becoming very closely spaced from depth 17,6 m (spacing from <50 mm up to 100 mm). At least three joint sets are recognized, including sub-horizontal, sub-vertical and moderately steep (30°) joints. All joint surfaces are stained, while the sub-vertical joints also contain weathered dolerite fill material with thickness between 2 mm and 3 mm.

The intrusive dolerite sill is underlain, at a depth of 19 m (RL 529,46), by unweathered siltstone. The rock mass is closely fractured at this contact zone and the contact itself is not well-defined. Apart from the close fracturing, this is due to similarity in appearance between the siltstone and the very fine grained dolerite. The nature of the contact zone underlying the upper flank areas is uncertain.

The siltstone comprises dark grey, hard rock. The rock mass is generally closely jointed, but very closely jointed / very highly fractured in the vicinity of the contact with the overlying dolerite sill, to depth 21,7 m (BH 1003). At least four joint sets are recognized. The joint surfaces are generally stained to approximate depth 22 m (BH 1003). This, together with the fractured nature of the rock mass in proximity to the contact, would suggest a zone of greater permeability. The broken nature of the rock mass , however, prevented water pressures tests being conducted and this could not be confirmed.

6. ENGINEERING GEOLOGICAL CONSIDERATIONS

6.1 Founding conditions and structure layout

The geology of the asymmetric site is characterized by outcrop of high strength, resistant bedrock within the river section while the flanks in general, and the right flank in particular, are deeply weathered.

A central concrete spillway might be assumed the most obvious option for a spillway. Excavation depths would be minimal within this river section (Section 6.2) while an apron might not even be required for erosion protection. One constraint on such a central spillway might be the spillway width required. The width of the river section is only 30 - 35 m. While a wider spillway can undoubtably be accommodated, this would require some optimization in order to minimize the excavation depths. In comparing the depths to suitable bedrock on the respective flanks (Figure 3), it would appear that extending such a spillway in the direction of the left flank would be more advantageous than towards the right. The smaller the favoured structure, the more likely that such a mass concrete structure will be extended to include the entire left flank, even if only because of construction practicalities.

The deep weathering of the right flank suggests that an earth embankment is a better option. The larger the envisaged structure, the more likely that an embankment would also be favoured for the upper left flank.
While construction of an embankment dam might be considered, there are no other obvious spillway solutions.

6.2 Excavation depths

Within the river section, excavation depths are expected to be minimal. Unconsolidated overburden is limited to patchy alluvial deposits. Although the bedrock exposed on surface comprises good quality, sound, intact dolerite, the surface is highly irregular due jointing and preferential weathering (Plate 3). Foundation preparation will therefore require limited blasting in order to prevent stress concentrations associated with rock pinnacles. Excavation depths up to 1 m or 2 m may be assumed.

Excavation depths for the central spillway on the respective flanks will naturally depend on how far the concrete structure extends. On the left flank a vertical depth of 9,5 m may be assumed in the vicinity of BH 1001. The further the structure is required to extend in the direction of the flank, the greater the required excavation depth, assuming the depth of weathering increases in an up-slope direction (Figure 3). On the lower right flank, the highly to completely weathered dolerite is not suitable for the founding of a concrete structure. Deep excavation (13,5 m in the vicinity of BH 1003) is required to ensure founding on slightly to moderately weathered dolerite. With the limited drilling undertaken it is not known to what extent this weathering horizon mirrors the topography. Excavation depths for a concrete structure are expected to increase significantly away from the river (Figure 3).

For an embankment on the mid- to upper left flank excavation depths in the order of 3,5 m may be assumed for the cut-off. Similar depths may be assumed at this stage for the right flank. Because of core losses, there is, however, some uncertainty as to the *in situ* founding conditions. *More detailed investigations would be required to verify cut-off depths.*

Stripping the embankment shell zones of the organic-rich topsoil to a nominal depth of 1 m may be assumed at this stage.

6.3 Foundation permeability

Water pressure tests were only possible in two of the four boreholes drilled along the proposed centre-line, namely BH's 1001 and 1002 drilled on the left flank and within the river section, respectively. The continual collapse of the broken rock mass in BH 1003 did not allow a proper sealing of the packer to be achieved, while BH 1004 was cased for the entire depth.

Water pressure tests conducted in the unweathered to slightly weathered dolerite of the left flank revealed an impervious rock mass. None of the test stages recorded any water acceptance. However, the drillers logs do record a total water loss at a depth of 11,3 m. Inspection of the borehole cores (see Appendix) reveals this water loss to be associated with prominent stained joints.

The angled borehole drilled within the river section (BH 1002) was also water pressure tested. For the most part the tests indicated relatively impervious founding conditions, with acceptances varying between one and five lugeons. The test section straddling the dolerite - siltstone contact yielded a higher value (13 lugeons) indicating more pervious conditions. Results from the uppermost test section are meaningless as water was observed to be leaking past the packer.

Although water pressure tests were not possible in BH 1003, the contact zone between the dolerite sill and underlying siltstone is highly fractured. In addition, the joint surfaces are stained and it is to be assumed that this contact is potentially pervious.

6.4 Slope stability

The stability of the natural slopes defining the dam basin has not been considered in any detail as yet. Some general comments and observations can, however, be made.

The natural slopes which define the proposed dam basin are generally gently sloping and are not considered to be at risk from catastrophic failure. The basin geology, predominantly comprising sub-horizontally bedded sedimentary strata and relatively shallow soils, is also not conducive to major slope failure. Steeper slopes occur within the basin but some distance from the proposed dam site. Indications are that these slopes are underlain by clayey soils derived from deeply weathered dolerite. It is possible that soil slope failures will occur with wetting up of these steeper slopes, but their limited extent as well as the distance from the proposed centre-line mitigates against any major risk to the structure. Steeper slopes occuring in the immediate vicinity of the proposed centre-line (Plate 2) are due to the dolerite intrusion. If any instability occurs this will be limited to occasional boulders and rock blocks becoming dislodged.

7. CONSTRUCTION MATERIALS

7.1 Concrete aggregates

The previous reconnaissance-level investigations (Davis, 1999) identified the intrusive dolerite sill on the left flank as the most obvious potential source of coarse aggregate and rip-rap.

Three boreholes (BH's 3001 - 3) were subsequently drilled for this pre-feasibility investigation in order to assess actual quarrying conditions. Borehole positions are indicated in Figure 2.

No further investigation of potential sand (fine aggregate) sources have been conducted. Comments made previously (Davis, 1999) are therefore still valid. Briefly, the sands produced from the Karoo sedimentary strata are generally undesirable because of their fineness as well as the resulting excessive concrete shrinkage. At this stage it may be assumed that sand will have to be sourced from crusher run.

7.1.1 Drilling results

A summary of the geological conditions at this possible quarry site is presented below. Detailed borehole logs as well as core photographs are presented in the Appendix.

The area is covered by a shallow layer of silty topsoil (thickness varying between 0,15 m and 0,25 m). In places the topsoil directly overlies highly to completely weathered siltstone, while in other areas the soil horizon is more well developed, extending to depths up to 7,5 m. Siltstone bedrock extends to depths

varying from 19,25 m (BH 3001) to more than 29,89 m (BH 3002), and is underlain by the intrusive dolerite sill. The thickness of the upper weathered zone of the siltstone rock mass varies between 2,5 m and 5,5 m. For the most part, however, the siltstone is unweathered to slightly weathered. The dolerite is unweathered.

Intersection of the *upper* dolerite - siltstone contact, and the depth at which this sill contact was intersected, compared to the centre-line drilling results where the *lower* sill contact was intersected, suggests the presence of a fault, possibly aligned with the prominent straight length of river upstream of the dam site (Figure 2).

7.1.2 Discussion

The exploratory boreholes have revealed excessive overburden thickness. Although the unconsolidated overburden is not well-developed, and neither is the weathering of the underlying rock mass, siltstone is not considered suitable for manufacture of aggregate. In addition to relatively low crushing strengths, influenced in part by preferential parting via sub-horizontal bedding planes, this siltstone is likely to be non-durable and exhibit slaking characteristics. In contrast, dolerite typically comprises high strength, durable rock. For these reasons, intrusive dolerites usually represent the only suitable source rock for the production of concrete aggregates, in areas underlain by such sedimentary strata.

In the proposed quarry area the dolerite sill occurs at depths varying from 19,25 m to more than 29,89 m. Removal of overburden to depths of this magnitude is not considered viable. **Development of this potential quarry site is consequently not considered a realistic option.**

Subsequent efforts to locate further promising quarry sites within the proposed dam basin proved fruitless.

Scattered dolerite outcrop occurs within the Xura River roughly 3 km due west of the proposed Lusikisiki dam site (Figure 1). Because of the limited area of scattered outcrop, as well as the position within the river bed, this site was not deemed worth investigating further.

Other steeper slopes flanking the Xura River within the basin, located roughly 2 km west north-west of the proposed dam site (Figure 1) were inspected, but proved to be underlain by weathered siltstone.

An existing, abandoned quarry is located on the high-lying area located approximately 7 km north-west of the Lusikisiki dam site (Figure 1). The geological succession essentially comprises an upper horizon of residual soil or weathered dolerite with thickness of approximately 5 m, underlain by dolerite which is unweathered or slightly weathered. The thickness of this horizon is estimated at 50+ m (Plate 5). Because the joint spacing is variable, the block size is variable too. The joint spacing varies between close and wide. The block size varies up to $1m^3$ to $2\ m^3$. No indications of rapid weathering dolerite were recognized. Although there was standing water on the quarry floor, it is most likely that this represents a perched water table associated with the dolerite-siltstone contact, rather than the water table. **This abandoned quarry currently represents the site most suitable for development.** Ordinarily, environmental concerns would not favour the development of such a potentially highly visible site. In this case, however, re-

opening of the abandoned quarry would allow further development to continue in a more environmentally-conscious manner and, more importantly, enable eventual closure in a more acceptable manner.

This quarry is located close to the Lusikisiki - Flagstaff road. While a disadvantage in terms of blasting operations, the advantage is that of good vehicular access between the quarry and the dam site.

If this Lusikisiki dam site is favoured over the Zalu site then the dolerite sill at the Zalu site might be considered an alternative source of coarse aggregate / rip-rap.

Another alternative source of coarse aggregate is an existing commercial quarry located to the east of Lusikisiki. Although not visited by the author, the quarry is located at least 15 km from the proposed dam site, and in addition would require heavily-laden trucks to pass through the town of Lusikisiki.

7.2 Embankment fill materials

No further investigations of potential sources of embankment fill materials were conducted during these pre-feasibility level investigations.

Indications are that vast areas within the dam basin represent potential sources of embankment fill materials, including both impervious core materials as well as semi-pervious transition materials.

8. COMPARISON BETWEEN ZALU AND LUSIKISIKI DAM SITES

As the purpose of these engineering geological investigations was to facilitate meaningful comparison between the respective Lusikisiki and previously-investigated Zalu dam sites, the main geological considerations are discussed below. These factors are summarized in Table 2.

Both sites are asymmetric, although this is more pronounced for the Lusikisiki site. More importantly, the river section is significantly wider for the Zalu site (approximately 80 m) in comparison with the Lusikisiki site (only 30 m to 35 m in width). This has implication for optimisation of the structure layout and therefore excavation depths.

Geologically, both sites are broadly similar in that the sedimentary strata at both sites have been intruded

	Lusikisiki site	**Zalu site**
Topography	Markedly asymmetrical. Left flank moderately steep (1:1,5 to 1:2,5), becoming flatter above approximate RL 565. Right flank convex, with lower slope gradient of 1:5 becoming 1:13 at higher levels. River section approximately 30 m wide.	Asymmetrical. Gently sloping left flank (1:7), steeper right flank (1:2,5). River section approximately 80 m wide.
Geology	Steeper slopes of left flank underlain by dolerite, covered by colluvial soils with thickness 3 - 5 m. Upper part of dolerite sill is weathered. River section underlain by unweathered dolerite sill with thickness 12 - 18 m, underlain by unweathered siltstone. Soil cover on right flank possibly up to 6 m in thickness, underlain by completely weathered dolerite sill.	Upper left flank underlain by weathered siltstone, mid- to lower slopes underlain by dolerite sill. Soil cover 2 - 5 m. Alluvium in river section 5 m thick, overlying unweathered dolerite sill with minimum thickness 35 m. Right flank underlain by unweathered dolerite. Soil cover up to 5 m thick.
Founding conditions & structure type	Composite structure, comprising central concrete spillway extending onto left flank and embankment on deeply weathered right flank, appears most suitable.	Founding conditions suitable for concrete gravity dam, or composite structure with embankment left flank and concrete river section and right flank.
Permeability / grouting requirements	Unweathered to slightly weathered dolerite and underlying siltstone expected to be relatively impervious. Necessary for grouting to intersect dolerite-siltstone contact. Low grout takes expected.	Water pressure and grout tests indicate dolerite relatively impervious. Low grout takes generally expected, with higher takes associated with a fault zone.
Excavation depths	Minimal excavation for concrete structure in river section (1 - 2 m), increasing rapidly in up-slope direction on left flank (up to 10 m at presumed crest level). Deep excavation for concrete structure on lower right flank (13 - 14 m). For embankment cut-off assume depths 3 - 5m.	For concrete structure, depths between 5 m on mid- to lower left flank, 3 - 4 m in river section, 1 - 4,5 m on right flank. Much deeper on upper flanks underlain by siltstone. Cut-off depth for embankment 2 - 5 m.
Construction materials	Abandoned dolerite quarry represents most suitable source of coarse aggregate, rip-rap and crusher sand. Located 7 km from dam site. Embankment fill materials likely to be located within reasonable distance of dam site, but sources not yet confirmed.	Abandoned dolerite quarry represents most suitable source of coarse aggregate, rip-rap and crusher sand. Located 4 km due north of dam site. Previous investigations considered clayey dolerite soils for impervious core, soils from siltstone / alluvium for transition zones.

Table 2: Summarized comparison between Lusikisiki and Zalu dam sites

by a dolerite sill. Some major differences may, however, be recognized. The geological conditions at the Zalu site are relatively uniform, both flanks being underlain by essentially unweathered dolerite. In contrast, the absence of an overlying protective siltstone horizon on the right flank of the Lusikisiki site has resulted in the complete weathering of the dolerite sill on this flank. While the upper flank areas at the Zalu site are underlain by weathered siltstone this only constitutes a minor part of the foundations. The dolerite sill at the Zalu site is substantially thicker than at the Lusikisiki site, with a *minimum* thickness of 35 m in the river section compared to a thickness between 12 m and 18 m at the Lusikisiki site.

These apparent differences in geological conditions at the respective dam sites, and the assessment in terms of suitability as founding materials, naturally have a bearing on the dam structures which might be considered. Founding conditions at the Zalu site are generally more favourable than at the Lusikisiki site, implying greater flexibility in terms of **structure type and configuration**. Although previous investigations only considered an embankment dam, the founding conditions at the Zalu site are also considered suitable for a concrete structure. In contrast, the poor founding conditions on the right flank of the proposed Lusikisiki dam site dictate that an embankment is more suitable than a concrete structure. As the prevailing founding conditions would de suitable for founding a concrete wall in the river section, extending onto the left flank, the favoured solution would comprise a composite dam. While an embankment dam might also be considered at the Zalu site, with spillway options including a side-channel or morning glory and conduit combination, possible embankment spillway configurations at the Lusikisiki site are not as apparent.

The better founding conditions at the Zalu dam site are also reflected in the expected **excavation depths**. Within the river section, shallower excavation depths are expected at the Lusikisiki site (up to 1 m to 2 m), compared with expected depths between 3 m and 4 m at the Zalu site but which only comprises the removal of alluvium. Significantly shallower excavations may be assumed on the respective flanks of the Zalu site, compared to the Lusikisiki site. For the most part, excavation depths up to 5 m may be assumed. At higher levels on the left flank, however, a concrete structure would require deeper excavation to ensure founding on unweathered dolerite. Areas underlain by weathered siltstone on the upper flanks would also require relatively deep excavation. For a concrete structure at the Lusikisiki site, on the other hand, excavation depths up to 9,5 m, increasing further in an up-slope direction, are expected on the left flank, while even deeper excavation will be necessary on the right flank. The excessive excavation depths on the right flank favour an embankment dam for which cut-off depths of 3,5 m may be assumed at this stage. Embankment cut-off depths varying between 2 m and 5 m may be assumed at the Zalu site.

In terms of **construction material availability**, although no hard rock quarry site for coarse aggregate / rip-rap has yet been proven for the respective dam sites, conditions are more favourable for the Zalu site. The abandoned dolerite quarry currently recognized as the most likely source is closer to the Zalu site than the Lusikisiki dam site (4 km, as opposed to 7 km). Furthermore, if an embankment dam is favoured at the Zalu site, together with a side-channel spillway, then these spillway excavations might produce suitable material. Sources of embankment construction materials have been identified at the Zalu dam site. While no investigations have been conducted in this regard at the Lusikisiki site, no major problems are envisaged.

9. CONCLUSIONS AND RECOMMENDATIONS

1. Brief pre-feasibility level engineering geological investigations were conducted at the proposed Lusikisiki dam site in order to facilitate meaningful comparison with the alternative Zalu dam site, which had been investigated previously in some detail.

2. These limited investigations comprised the drilling of four boreholes (total length 109,23 m) along the proposed centre-line, as well as three boreholes (total length 82,05 m) at a possible quarry site. No laboratory or other testing was conducted. Furthermore, investigations of potential embankment construction materials were not considered necessary at this stage.

3. The regional geology comprises sedimentary strata of the Ecca Group, Karoo Supergroup which have been intruded by younger dolerite dykes and sills. The geological structure is mainly characterized by sub-horizontal to shallow-dipping strata. No major regional faulting is recognized, although a lesser fault may possibly be traced between 180 m and 200 m upstream of the proposed centre-line. There are no economically important mineral deposits.

   In terms of seismic hazard, a seismic intensity of VI (modified Mercalli scale) has a 10 % probability of being exceeded at least once in a period of 50 years. This equates to peak horizontal ground accelerations between 50 cm/s^{-2} and 100 cm/s^{-2} being exceeded at least once in the same 50 year period.

4. The proposed dam site is markedly asymmetrical. The left flank is relatively steep while the right flank is gently sloping. The river section is only 30 m to 35 m in width.

5. The steeper slopes of the ***left flank*** are underlain by dolerite. The thickness of the colluvial soil cover is expected to vary between 3 m and 5 m. The uppermost portion of the dolerite is intensely weathered, varying from highly or completely weathered rock to moderately weathered rock. At a depth of 9,2 m (BH 1001) the dolerite becomes unweathered to slightly weathered. Joints within the unweathered to slightly weathered rock mass are medium to widely spaced (150 mm to 750 mm). A closer joint spacing is apparent in the more weathered horizons. At least three or four joint sets are recognized.

   Scattered outcrop of unweathered dolerite occurs within the ***river section***. Unconsolidated alluvial deposits are negligible. The dolerite sill dips gently (8°) towards the left bank, with thickness varying between 12 m and 18 m beneath river level. The joints are closely to medium spaced (200 mm to 400 mm) and at least four sets are recognized. The dolerite sill is underlain by unweathered siltstone.

   Soil cover on the ***right flank*** varies in thickness between 1 m and possibly 6 m. The dolerite sill extends beneath this flank but, because of the attitude, becomes progressively thinner in an up-slope direction. The sill is deeply weathered, with borehole recovery often limited to sandy or silty material. The dolerite is underlain by siltstone which, at depths beneath river level, is unweathered.

6. Founding conditions within the river section, and extending beneath the left flank, might be considered suitable for the founding of a concrete structure. Conditions on the right flank are significantly poorer and, without excessively deep excavations, only suitable for the founding of an embankment. It follows that a composite structure, comprising a concrete spillway and left flank non-overspill section with an embankment on the right flank, would be most suited to these founding conditions.

7. Excavation depths with the river section will be minimal, say 1 m to 2 m essentially to smooth an irregular surface. Excavation depths for a concrete structure on the left flank will increase significantly in an up-slope direction, to a maximum vertical depth of approximately 10 m at presumed crest level (RL 557 m). On the lower right flank even deeper excavations are envisaged for a concrete structure (13 m to 14 m). These depths are likely to further increase in an up-slope direction. For an embankment cut-off, excavation depths between 3 m and 5 m may be assumed.

8. Limited water pressure tests indicated relatively impervious founding conditions. Higher water acceptances were, however, associated with the dolerite-siltstone contact. In places this contact is closely fractured with joints exhibiting stained surfaces. The dolerite sill contact should therefore be considered a potentially pervious zone to be targeted during foundation grouting.

9. The natural slopes defining the dam basin are mainly gently sloping and therefore not considered to be at risk from catastrophic failure.

10. Limited exploratory drilling was conducted at a possible coarse aggregate / rip-rap quarry located near to the proposed dam site. Drilling results revealed the dolerite sill to occur at excessive depths varying between 19 m and more than 29 m. The overlying siltstone bedrock is not considered suitable for use as either coarse aggregate or rip-rap. **Development of this quarry site is therefore not considered feasible.**

    An existing but abandoned dolerite quarry, located roughly 7 km from the proposed dam site, is currently recognized as the most suitable quarry site. Overburden is shallow (5 m) with the underlying dolerite sill thickness estimated at more than 50 m.

11. Indications are that embankment fill materials, including impervious core materials as well as semi-pervious transition materials, will be readily available within a reasonable distance of the proposed dam site.

12. These brief pre-feasibility level engineering geological investigations were essentially aimed at facilitating meaningful comparison between the alternative Lusikisiki and Zalu dam sites. If this Lusikisiki site is favoured, more-detailed site investigations would be required. Feasibility-level studies should include the following;

    · Additional exploratory drilling at the favoured centre-line both to confirm the initial findings as well as investigating actual founding conditions for the envisaged structure

layout. Rather than being drilled along a line, these boreholes should be staggered along the proposed centre-line.

- The presumed fault upstream of the proposed centre-line should be investigated in more detail in order to determine whether or not this discontinuity represents a seepage path with the potential of affecting basin watertightness. Geophysical techniques could be employed as well as exploratory drilling.

- More-detailed investigation of construction materials. Depending on the envisaged structure, this would include hard rock for coarse aggregate / rip-rap as well as embankment construction materials including impervious core materials and semi-pervious transition materials. It would be necessary to prove both the availability of sufficient volumes as well as material of suitable quality.

- A laboratory testing programme, mainly focussing on the suitability of the various construction materials.

- An assessment of the seismic hazard.

If the Zalu site is favoured it is recommended that further investigation of construction materials be conducted, in order to prove the availability of sufficient volumes of suitable material. This would include the potential hard rock quarry site as well as the previously-investigated borrow areas. Laboratory testing of the construction materials would also be required.

10. REFERENCES

Davis, GN. 1999. Eastern Pondoland Basin Study: Zalu, Lusikisiki, Xura, Lower Mzintlava and Tungwane Dam Sites. First Engineering Geological Reconnaissance Report. *Council for Geoscience report 1999-0133*. Unpublished.

Hill Kaplan Scott. 1979. Lusikisiki Water Supply. Zalu Dam Site. Detailed Geological and Materials Investigation. *Unpublished report to Transkei Government*.

Karpeta, WP & Johnson, MR. 1978. The Geology of the Umtata Sheet. Explanation, Sheet 3128. *Geol. Surv. S. Afr.*

11. DATA APPENDIX

Topo–cadastral maps - 1:50 000 (Surveyor General)
3129 AD Sihlito sheet
3129 BC Lusikisiki sheet

Geological maps - published (Council for Geoscience)
1:250 000 3128 Umtata Sheet

Geological maps - unpublished 1:50 000 (Council for Geoscience)
3129 AD Sihlito sheet
3129 BC Lusikisiki sheet

Seismic hazard maps for southern Africa (Council for Geoscience)

Aerial photography (DWAF)
DWAF Job W555, scale 1:8000, flown May / June 2000.
Strip 1, photographs 3 - 7
Strip 2, photographs 376 - 380

APPENDIX 1

PHOTOGRAPHS



Plate 1: A general view of the proposed Lusikisiki dam site, looking in a downstream direction. The marked asymmetry of the centre- line is apparent, with the left flank significantly steeper than the right.



Plate 2: The left flank at the proposed Lusikisiki dam site. River flow is from left to right. The position of BH 1001 is indicated, while bakkie (circle) provided a sense of scale. The steeper slopes are ascribed to the intrusion of a dolerite sill. Exploratory drilling for a quarry upstream of the proposed centre-line revealed the dolerite to occur at significant depths, and therefore the unsuitability of this indicated quarry site.



Plate 3: Scattered outcrop of dolerite bedrock is evident within the river section, with patchy, poorly developed unconsolidated alluvial deposits. The sub-vertical joints which strike roughly parallel to the river are the most prominent discontinuities. The joints are closely spaced but are typically tight. Even for a concrete structure only minimal excavation will be required within the river section, and will mainly be limited to the removal of rock pinnacles.



Plate 4: The gently sloping right flank at the proposed Lusikisiki dam site. Borehole positions are indicated; BH 1003 is located at the tent while the drilling machine stands at BH 1004. The natural slopes which define the proposed basin are mainly very gently sloping and concerns regarding stability are therefore not an issue.

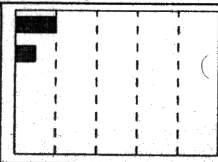
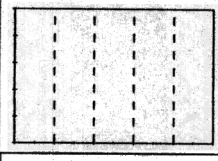
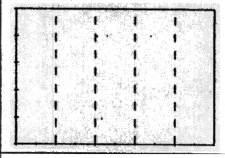
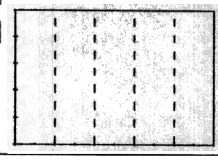


Plate 5: A view of the abandoned quarry located approximately 7km north-west of the proposed Lusikisiki dam site. The thickness of usable dolerite is estimated at more than 50 m, while overburden thickness is minimal. At this stage, this abandoned quarry represents the most promising source of coarse aggregate and rip-rap.

APPENDIX 2

WATER PRESSURE TEST DATA

BH 1001 LUSIKISIKI DAM SITE

Test No	Depth (m)	Test section (m)	Duration (min)	Pressure (kPa)	Water loss (l)	Lugeon	Lugeon pattern	Remarks & lugeon value
i	11,95 - 14,95	3	10	130	7	2		
ii		3	10	230	4			0
iii		3	10	330	0	0		
iv		3	10	230	0	0		no flow
v		3	10	130	0	0		
	14,88 - 17,88			160				
				280				0
				395				
				280				no flow
				160				
	17,88 - 20,88			180				
ii				320				0
iii				450				
iv				320				no flow
v				180				
	20,76 - 23,76			215				
ii				370				0
iii				530				
iv				370				no flow
v				215				

BH 1002 LUSIKISIKI DAM SITE

Test No	Depth (m)	Test section (m)	Duration (min)	Pressure (kPa)	Water loss (l)	Lugeon	Lugeon pattern	Remarks & lugeon value
i	5,87 - 8,64	2.77	10	75	?			
ii		2.77	10	135	?			?
iii		2.77	10	190	?			
iv		2.77	10	135	?			water leak
v		2.77	10	75	?			past packer
i	8,64 - 11,54	2.9	10	105	15	5		
ii		2.9	10	180	25	5		
iii		2.9	10	260	40	5		
iv		2.9	10	180	17	3		laminar flow /
v		2.9	10	105	24	8		wash out
	11,54 - 14,54							
ii								
iv								laminar flow
v								
	14,54 - 17,54							
ii								
iii								
iv								turbulent ?
v								
	17,54 - 20,34							
ii								13
iii								
iv								turbulent
v								flow
	20,34 - 23,20							
ii								
iii								
iv								laminar flow
v								
	23,20 - 26,16							
iii								
iv								laminar flow
v								
	26,16 - 29,12							
ii								
iii								
iv								laminar flow
v								
	29,12 - 32,08							
ii								2
iii								
iv								laminar flow
v								
	32,08 - 35,04							
ii								
iv								laminar flow
v								
	35,04 - 38,00							
ii								2
iii								
iv								laminar flow
v								
	38,00 - 40,95							
ii								
iii								
iv								laminar flow
v								
	40,95 - 43,91							
ii								1
iii								
iv								laminar flow
v								
	43,91 - 45,97							
								2
								laminar flow

APPENDIX 3

BOREHOLE CO-ORDINATES

COORDINATE LIST

PROPOSED LUSIKISIKI DAM SITE- BOREHOLES

CO-ORDINATE SYSTEM LO.29° HEIGHTS BASED ON T15(Degree Square 3129)					
Borehole Name	Co-ordinates		Heights above mean sea level		
	Y	X	Top Pipe	Concrete	Soil
BH1001	-49492.05	3466517.84	559.22	559.08	558.99
BH1002	-49440.78	3466541.89	534.59	534.38	
BH1003					
BH1004					
BH3001					
BH3002					
BH3003					

APPENDIX 4

BOREHOLE LOGS

HOLE No: BH 1003
Sheet 1 of 2

JOB NUMBER: 000

ROCK TYPE
MA - massive
MB - massive
FG - fg/med
CL - clay rich
SH - schistose
CV - convoluted
CA - laminated

DRAW SIZE
RG-fine grained
MG-medium grained
CG-coarse grain

JOINT SPACING
VC - very close spacing < 63mm
C - close spacing 63mm - 200mm
M - medium spacing 200mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing > 3m

WEATHERING
100% - strong Completely weathered
75% - strong Highly weathered
50% - strong Moderately weathered
25% - strong Slightly weathered
W - strong Unweathered
Note: e.g. = slight discolouration

JOINT FILLING
CL - clay
SI - silt/sand
CC - washboard rock
NR - not recovered
O - other

JOINT ROUGHNESS
SL - slickensided
S - smooth
R - rough
VR - very rough
I - light
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI DAM SITE

HOLE No: BH 1003
Sheet 2 of 2

JOB NUMBER: 000

REDUCED LEVEL	CORE RUN DEPTH m	% WATER RECOVERED	% CORE RECOVERED	% RQD	JOINT FREQ	WATER ACCESS TANCE (open/ closed)	ROCK TYPE AND COLOUR	FABRIC WIDTH (mm)	FABRIC SPACING mm	JOINT WIDTH (mm)	JOINT SPACING mm	JOINT ROUGHNESS	JOINT FILL (mm)	WEATHERING	DEPTH Scale 1:100
548	0,6	100	0	0	-	-	-	-	-	-	-	-			
547	1,2	100	0	0	-	-	-	-	-	-	-	-			
547	1,8	97	0	0											
546	3,3	73	0	0											
545															
544	6,26	80	0	0	?	?	?	?	?	?					
543															
542															
541	9,26	80	0	0											
540					20+		MA FG-MG	-	-	0-10 60-70 90	R C? ?	S; R R/S	S; S;		
539															
538	12,24	82	20	0	-		? MG	?	?	? 80-90 40	? ? ?	? R R	? S; S;		
537															
536					20+	NO TEST									
535	15,27	100	83	30	20+										
534					14										
533					6		MA FG	-	-	0-10 80-90	C ?	R/S R/S	S; S;,W		
532	18,11	100	93	62	4										
531					20+										
530					20+										
529	21,06	100	100	22	20+										
528					20+										
527					14								OCC.		

Scale 1:100

0.00	Dark brown, CLAYEY TOPSOIL with ROOTS.	
0.60	Reddish brown CLAY.	REMARKS: Colluvial soil possibly reworked residual dolerite soil.
1.40	Completely / highly weathered dolerite.	REMARKS: Sample recovered as brown, silty to medium sand with minor clay due to fabric of friable rock mass being destroyed by drilling action. Recovered sample therefore not representative of in situ conditions.
7.35	Highly to completely weathered, very closely jointed, medium hard rock to soft rock, grey to brown, medium to fine grained DOLERITE.	REMARKS: Sample mainly recovered as coarse gravel (diameter 10 - 30 mm). In situ rock mass expected to be less broken - recovered sample therefore not truly representative of in situ conditions (broken appearance at least partly ascribed to drilling process).
10.00	AS ABOVE, ie highly to completely weathered DOLERITE.	REMARKS: Recovered as SILTY TO FINE SAND (ie. in situ rock fabric destroyed by drilling action).
11.60	Highly to completely weathered, very closely to closely jointed (spacing typically <20 mm up to 100 mm), medium hard rock to soft rock, grey, medium to fine grained DOLERITE (AS ABOVE).	REMARKS: The more disturbed areas are, at least partly, ascribed to drilling action.
17.45	Slightly to moderately weathered, closely to medium jointed (spacing generally 200 mm), becoming very closely jointed from 17,6 m (spacing <50 - 100 mm), light grey, very hard rock, fine grained DOLERITE.	REMARKS: Very fine grained near lower contact. Lower contact very broken, not readily defined(extremely fine grained dolerite being similar in the indurated structure). Joints stained, sub-vertical set contains fill with thickness 2 - 3 mm.
19.50		

HOLE No. BH 1003
Sheet 2 of 2

JOB NUMBER: 000

CORE SAMPLE
MA - massive
BE - bedded
FO - faulted
CL - calcined
SH - schistose
GN - gneissose
AA - amygdoloid

GRAIN SIZE
FG-fine grained
MG-medium grain
CG-coarse grain

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 200mm
M - medium spacing 200mm - 1000mm
A - wide spacing 1 - 2m
VW - very wide spacing > 2m

WEATHERING
100% strong Completely weathered
75% strong Highly weathered
50% strong Moderately weathered
25% strong Slightly weathered
0% strong Unweathered
Hatching = soft / unconsolidated

JOINT FILLING
CY - clay
Sr - stained
W - weathered rock
MF - cal mineral
O - other

JOINT ROUGHNESS
SL - Slickensided
S - smooth
R - rough
VR - very rough
P - plain
W - wavy

| HOLE No. BH 1003 Sheet 2 of 2 | | |

HOLE No. BH 1004
Sheet 1 of 1

JOB NUMBER: 000

ROCK FABRIC
MA - massive
BE - bedded
LA - laminated
CL - cleaved
SH - schistose
GN - gneissose
FA - foliated

GRAIN SIZE
FG - fine grained
MG - medium grain
CG - coarse grain

JOINT SPACING
VC - very close spacing < 50mm
C - close spacing 50mm - 250mm
M - medium spacing 250mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing > 3m

WEATHERING
FRSH - fresh
SW - slightly weathered
MW - moderately weathered
HW - highly weathered
CW - completely weathered
RS - residual soil
Reliability: 1 = low / uncontrolled

JOINT FILLING
CL - clay
SI - silt/mud
W - weathered rock
NF - not recorded
Q - quartz

JOINT ROUGHNESS
SM - slickensided
S - smooth
R - rough
VR - very rough
P - polished
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI DAM SITE

HOLE No. BH 1004
Sheet 1 of 1

JOB NUMBER: 000

RECOVERED LEVEL	CORE RUN DEPTH (m)	% MATERIAL RECOVERED	% CORE RECOVERED	% RQD	WEATHERING ACCEPTANCE (open)	MAIN FABRIC AND INFILLING	FABRIC SPACING (mm)	FABRIC INCLINATION (deg)	JOINT SPACING (mm)	JOINT INCLINATION (deg)	JOINT ROUGHNESS	JOINT FILLING	WEATHERING GRADE	DEPTH Scale 1:100
556	0,60	75	0	0	-	-	-	-	-	-	-			
555	1,20	67	0	0										
554	1,72	96	0	0										
553	3,22	93	0	0										
552					-	-	-	-	-	-	-			
551	6,22	?	0	0										
550					NO TEST	-	-	-	-	-	-	-		
549														
548	9,22	59	0	0										
547					-	-	-	-	-	-	-			
546														
545	12,20	82	0	0										
					MA	-	-	1	1	1	1			

0.00	Brown to dark brown, SILTY TOPSOIL with ROOTS.	
0.60	Reddish brown, CLAYEY SILT.	REMARKS: Colluvial soil possibly comprising reworked residual soils derived from dolerite. Actual horizon thickness uncertain (poor core loss 3,22 - 6.0 m).
6.00	Ochre to reddish- / pinkish - brown, CLAY.	REMARKS: Possible reworked residual or residual dolerite soils. Horizon thickness possibly thicker (upper boundary uncertain, poor core loss).
6.99	Ochre CLAYEY to GRAVELLY - / SANDY SILT.	REMARKS: Horizon presumably comprises completely weathered, soft rock (friable) dolerite (ie samples not entirely representative of in situ conditions - due to drilling action).
11.05	Highly to moderately weathered, very closely jointed / completely fractured (joint spacing <50 mm), grey to brown, medium hard to soft rock DOLERITE.	REMARKS: Sample recovered as gravel - not likely entirely representative of in situ conditions (more disturbed / broken as result of drilling action). Note hole was collapsing and not all material was recovered.
12.20	END OF HOLE.	

NOTES

1) Borehole stopped at depth 12,20 m.

2) Water pressure tests not possible.

3) Foundation considerations: No suitable founding level for concrete dam at depths shallower than 12,2 m. Assume embankment cut-off a minimum 3 m into (note uncertainty because of core loss).

CONTRACTOR: DWAF
MACHINE: SECO 12
LOGGED BY: W Hlongwane
PROFILED BY: GD
TYPE SET BY: MP
SETUP FILE: GEOSURVE.SET

INCLINATION: 90DEG
DRAW: ROTARY DIAMOND, NX
DATE: 23/8/2000
DATE: 22/08/2000
DATE: 12/10/00 10:38
TEST: ordinary (USA) 2.737

ELEVATION: 556.26
X-COORD: = 3 499 647.28
Y-COORD: - 49 306.96

HOLE No. BH 1004

WATSOFT 3022 - 18/10/00

HOLE No. BH 3001
Sheet 1 of 2

JOB NUMBER: 000

ROCK FABRIC
MA - massive
BE - bedded
FO - foliated
CA - cavernous
SH - sheared
GN - gneissose
LA - laminated

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 200mm
M - medium spacing 200mm - 600mm
W - wide spacing 600mm - 2000mm
VW - very wide spacing > 2m

WEATHERING
100% shading Completely weathered
75% shading Highly weathered
50% shading Moderately weathered
25% shading Slightly weathered
0% shading Unweathered
Hatching = soil / decomposed rock

JOINT ACTING
CL - clay
SI - stained
VR - weathered rock
NO - not recorded
O - open

JOINT ROUGHNESS
SL - slickensided
S - smooth
R - rough
VR - very rough
F - flat
W - wavy

GRAIN SIZE
FG fine grained
MG medium grained
CG coarse grained

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No. BH 3001
Sheet 1 of 2

JOB NUMBER: 000

RUN	% RECOVERY	% CORE RECOVERY	% RQD	JOINT SPACING	WATER STRIKE RANGE (cm)	ROCK STRENGTH AND GRAIN SIZE	FABRIC WEIGHT (deg)	FABRIC SPACING (cm)	JOINT WEIGHT (deg)	JOINT SYSTEM	JOINT ROUGHNESS	JOINT FILL (mm)	WEATHERING	DEPTH Scale 1:100
0,73	96	3	0	-										
1,44	77	30	0			MA-BE FG	0	2-9	0-10 90	VC ?	S-R S	SI,W SI		
2,96	95	95	7	20+										
5,96	100	100	39	17										
				18										
				8		MA-BE FG	0 -	2-9 -	0-10 90	VC-C ?	S-R VR	SOIL, SI SI		
8,92	99	99	86	5										
				12										
				8										
				15										
11,92	99	99	46	13										
				14										
				6										
14,91	99	99	80	2	NO TEST	MA-BE	0	5	0-10 90	VC-M ?	S/R S/R	- CI film		
				11										
				15										
17,80	99	99	68	5										
				5										
				11										
20,87	100	100	83	4										
				3										
				5										

Scale 1:100

0.00 Grey, SILTY TOPSOIL with ROOTS.

0.70 Highly to completely weathered, very closely jointed, pinkish to reddish brown, soft rock to hard rock SILTSTONE.

REMARKS: Mean block size (i.e. joint spacing) < 50 mm.

2.94 Slightly to moderately weathered, very closely to closely jointed (joint spacing <50 mm to 300 mm), dark grey to brown hard rock SILTSTONE with minor interbedded sandstone laminations (width up to 50 mm).

8.40 Unweathered to slightly weathered, very closely to medium jointed (spacing <50 mm up to 450 mm, occasionally 1 m), dark grey, hard rock SILTSTONE.

15.25

HOLE No: BH 3001
Sheet 2 of 2

JOB NUMBER: 000

ROCK FABRIC
MA -massive
BE -bedded
FO -foliated
CL -cleaved
SH -schistose
GN -gneissose
CA -laminated

GRAIN SIZE
FG-fine grained
MG-medium grain
CG-coarse grain

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 300mm
M - medium spacing 300mm - 1000mm
W - wide spacing 1 - 3m
VW -very wide spacing > 3m

WEATHERING
100% showing Chemically weathered
75% showing Highly weathered
50% showing Moderately weathered
25% showing Slightly weathered
0% showing Unweathered
Residual = soil / uncon.sediment

JOINT FILLING
CL - clay
SI - silt/sand
W - weathered rock
NO - not recovered
O - other

JOINT ROUGHNESS
SM - smooth
P - planar
R - rough
UN - undulating
S - slick
V - veiny

DEPTH	RUN	% RECOV	% FRAG	% SOIL	JOINT FREQ	JOINT ROUGH	ROCK FABRIC AND GRAIN SIZE	FABRIC ANGLE	JOINT ANGLE	JOINT WIDTH	JOINT SHAPE	JOINT ROUGH	JOINT FILL	WEATH GRADE
	(m)													
541	23,79	100	100	97	5		MA	-	-	0-10	C-W	S	-	
540					1									
539					1									
538	26,78	100	100	97	0									
537					1									
	27,01	100	100	100										

Unweathered, closely to widely jointed (spacing 70 mm to > 1 m), light grey, medium to fine grained, extremely hard rock DOLERITE.

REMARKS: Sub-horizontal dolerite-siltstone contact open.

No dark disseminated minerals identified.

END OF HOLE.

NOTES

1) Quarrying considerations: Dolerite assumed suitable for manufacture of aggregate, but overburden depth excessive (>19 m). Siltstone considered unsuitable.

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No: BH 3001
Sheet 2 of 2

JOB NUMBER: 000

DRILLED LEVEL

DEPTH Scale 1:100

CONTRACTOR : DWAF
MACHINE : SECO 12
LOGGED BY : HD Leingoana
PLOTTED BY : GD

TYPE SET BY : JP
SETUP FILE : GEOSERVE.STP

DRILLING FOR : 90DEG
DRAM : ROTARY DIAMOND, NX
DATE : 26/07 - 03/08/2000
DATE : 21/08/2000

DATE : 17/10/00 12:28
TEXT : B:\metric\BH3001.TXT

ELEVATION : 563.60
X COORD : + 3 465 428.68
Y COORD : - 49 180.02

HOLE No: BH 3001

HOLE No: BH 2002
Sheet 1 of 2

JOB NUMBER: 000

ROCK FABRIC
MA - massive
BE - bedded
FO - foliated
CL - sheared
SH - schistose
GN - gneissose
FA - weathered

GRAIN SIZE
FG-fine grained
MG-medium grain
CG-coarse grain

JOINT SPACING
VC - very close (spacing < 63mm)
C - close spacing 63mm - 200mm
M - medium spacing 200mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing > 3m

WEATHERING
100% showing Completely weathered
75% - exciting Highly weathered
50% - exciting Moderately weathered
25% - exciting Slightly weathered
0% - exciting Unweathered
(enriched = low / mineralisated)

JOINT FILLING
CL - clay
SI - silt filled
VR - veins/hard rock
NR - not recovered
O - other

JOINT ROUGHNESS
SM - slickensided
S - smooth
R - rough
VR - very rough
P - flat
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No: BH 2002
Sheet 1 of 2

JOB NUMBER: 000

RUN DEPTH	% RECOVERED	% CORE RECOVERED	% RQD	JOINT FREQ.	ROCK FABRIC AND GRAIN SIZE	FABRIC WIDTH mm	FABRIC SPACING mm	JOINT WIDTH mm	JOINT SPACING mm	JOINT ROUGHNESS	JOINT FILL mm	JOINT FORM	DEPTH Scale 1:100
0.80	81	0	0										
1.60	88	0	0										
2.23	87	0	0										
2.83	70	0	0										
3.40	93	0	0										
6.38	20	1	0										
9.24	55	55	22	10+	MA BE FG FG	0	2-?	0-10 90 20	VC-C ? W	S/R R S	SI SI occ calcite		
12.10	98	99	43	16 10 9									
15.26	99	99	66	20+ 16 17									
18.00	98	94	55	6 9 6									
19.71	100	100	81	4 8 5									
21.28	95	99	99	4 1									

Scale 1:100

0.00	Grey SILTY TOPSOIL with ROOTS	
0.15	Reddish brown NODULAR FERRICRETE.	REMARKS: Pedogenic origin indicating fluctuating water table.
1.10	Grey to brown SILT.	REMARKS: Transported soil (hillwash), derived from completely weathered siltstone.
3.27	Reddish to grey, weathered, rounded SILTSTONE GRAVEL in clay matrix.	REMARKS: Transported material - possible indicating a paleo- channel Note core loss.
7.50	Moderately to highly weathered, very closely to closely jointed (joint spacing < 50 mm - 150 mm), dark grey to brown, hard rock to medium hard rock SILTSTONE.	
16.50	Unweathered to slightly weathered, jointing closely to medium, occasionally very closely to widely, dark grey, hard rock SILTSTONE. (rock size generally 250 mm - 40 mm, occasionally < 50 mm).	

HOLE No. BH 3002
Sheet 2 of 2

JOB NUMBER: 000

ROCK LABLING
MA - massive
BE - bedded
FO - foliated
LI - layered
SH - schistose
GN - gneissose
EA - structured

DRAW SIZE
FG fine grained
MG medium grain
CG coarse grain

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 200mm
M - medium spacing 200mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing > 3m

WEATHERING
FR 0% shading Completely weathered
25% shading Highly weathered
50% shading Moderately weathered
75% shading Slightly weathered
no shading Unweathered
Banding = soil / unconsolidated

JOINT INFILL
CL - clay
SI - silt/sand
W - weathered rock
GR - rock fragments
O - other

JOINT ROUGHNESS
SL - slickensided
S - smooth
R - rough
VR - very rough
I - ripple
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No. BH 3002
Sheet 2 of 2

JOB NUMBER: 000

REDUCED LEVEL	DEPTH	SAMPLE No.	% SOIL/ RUBBLE/ CORE LOSS	% GRAVEL/ ALTER/ WEAK	% CORE RECOV./ INTACT	% RQD	JOINT FREQ. /m	ROCK FABRIC AND GRAIN SIZE	FABRIC ANGLE deg	FABRIC SHAPE ANG. deg	JOINT ANGLE deg	JOINT SHAPE ANG. deg	JOINT ROUGH-NESS	JOINT FILL	WEATH-ERING
548			24.20	99	89	91	6								
547							3								
546			27.10	100	100	94	3								
545							4								
544							3								
543			29.89	99	99	99	2								
542							2								
							3								

22
23
24
25
26
27
28
29
29.89

END OF HOLE

NOTES

1) Quarrying considerations: No dolerite intersected (shallower than 29,89 m). Siltstone unsuitable for crushing.

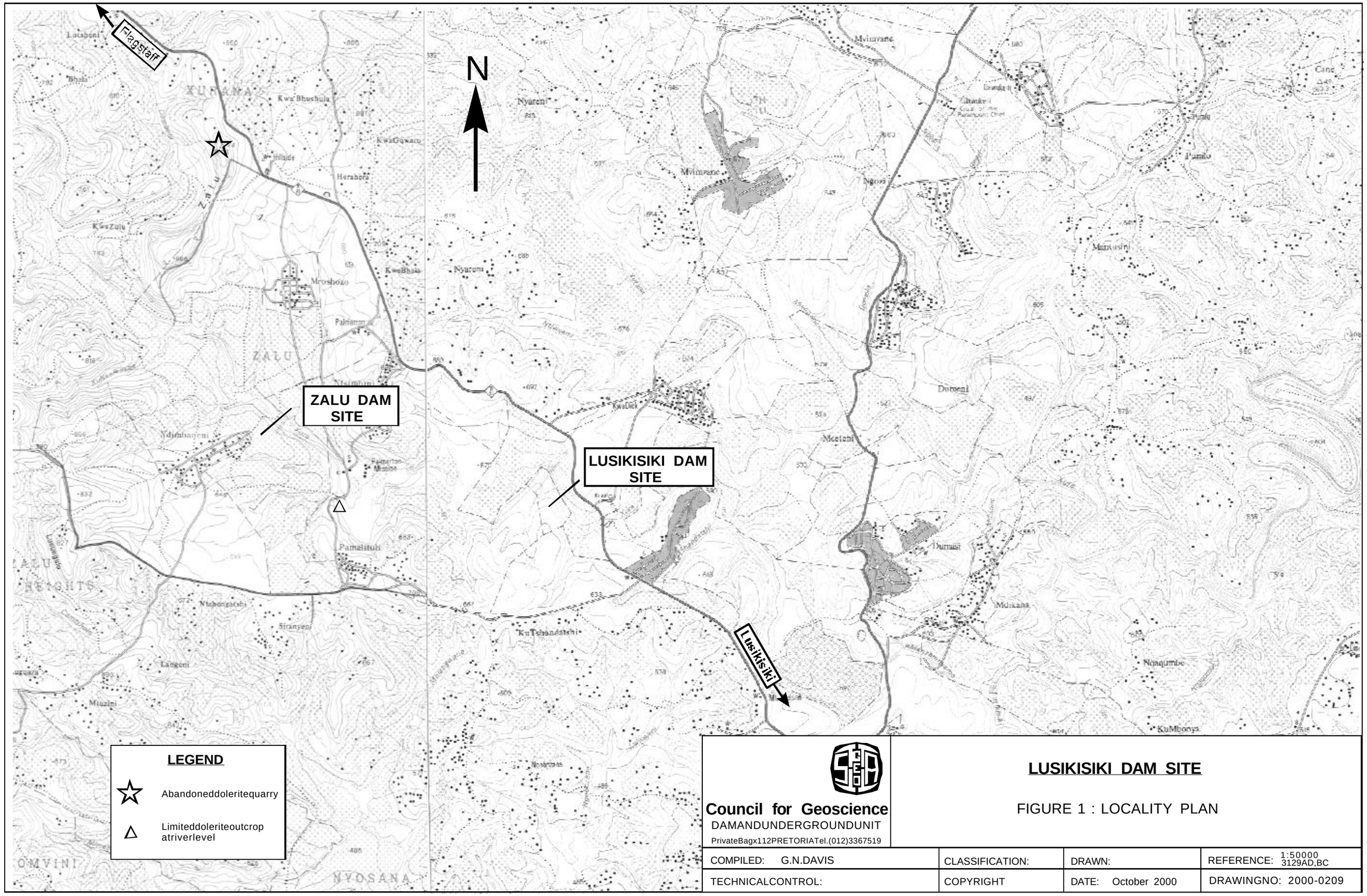
CONTRACTOR : DWAF
MACHINE : SECO T2
DRILLED BY : HD Leligoana
LOGGED BY : GD
LOGGING METHOD : CORE

INCLINATION : 90DEG
DIAM. : ROTARY DIAMOND, NX
DATE : 19 - 2 - 07/2000
DATE : 21/08/2000
DATE : (LOGGED ON)
FILE : G:\geotech\BH3002.TXT

ELEVATION : 571.33
X-COORD : - 3 466 314.83
Y-COORD : - 49 143.71

HOLE No. BH 3002

REVISED 2002 JBW No.



Council for Geoscience
DAMANDUNDERGROUNDUNIT
PrivateBagx112PRETORIATel.(012)3367519

LUSIKISIKI DAM SITE

FIGURE 1 : LOCALITY PLAN

COMPILED: G.N.DAVIS	CLASSIFICATION:	DRAWN:	REFERENCE: 1:50000 3129AD,BC
TECHNICALCONTROL:	COPYRIGHT	DATE: October 2000	DRAWINGNO: 2000-0209

HOLE No. BH 3003
Sheet 1 of 2

JOB NUMBER: 000

ROCK FABRIC
MA -massive
BE -bedded
FO -foliated
CL -jointed
SH -shattered
CM -cemented
CA -laminated

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 200mm
M - medium spacing 200mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing >3m

WEATHERING
100% slightly Completely weathered
75% slightly Highly weathered
50% slightly Moderately weathered
25% slightly Slightly weathered
Nil slightly Unweathered
Residual - soil/consolidated

OPAM SIZE
FG-fine grained
MG-medium grain
CG-coarse grain

JOINT FILLING
CL - clay
SI - silt/sand
M - mechanical rock
(sp) - not recovered
C - calcite

JOINT ROUGHNESS
SL - slickensided
S - smooth
R - rough
VR - very rough
I - Infill
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No. BH 3003
Sheet 1 of 2

JOB NUMBER: 000

RECOVERY RUN DEPTH (m)	% MATERIAL RECOVERED	% CORE RECOVERED	% RQD	JOINT FRAC. FREQ.	WATER ACCEPTANCE (l/min)	ROCK FABRIC AND GRAIN SIZE	WEATHERING (Main)	WEATHERING (Sec.)	JOINT SPACING (mm)	JOINT ROUGHNESS	JOINT FILLING	JOINT INCL. (mm)	WEATHERING	DEPTH Scale 1:100
0,7	100	0	0	-	-	-	-	-	-	-	-	-		
1,67	89	23	0	-	-	-	-	-	-	-	-	-		
2,88	83	83	60	13	-	MA-BE FG	0-10	2-	0-10 80-90	VC-C VC-?	R/S S	occ St St		
4,29	100	100	16	15										
				16										
5,85	100	100	30	14										
				7										
8,95	100	100	76	9										
				5										
				9										
11,78	100	100	67	9										
				6										
				5	NO TEST	MA-BE FG	0-10	2-2	0-10 20-30 80-90	VC-M VC W ?	S/R S/R R/S	occ. St St St		
14,74	100	100	73	10										
				7										
				5										
17,48	99	93	87	4										
				3										
				0										
20,48	98	98	56	16										
				3										
				3										

Scale 1:100

0.00 – 0.25	Grey, SILTY TOPSOIL with ROOTS.	
0.25 – 1.20	Pinkish brown NODULAR FERRICRETE.	REMARKS Pedogenic origin indicating fluctuating water table
1.20 – 4.30	Moderately to highly weathered, closely jointed, occasionally very closely (joint spacing generally 100 - 200 mm), grey to brown, hard to medium hard / soft rock SILTSTONE.	REMARKS. Note core loss.
4.30 – 19.25	Unweathered to slightly weathered, closely to medium jointed occasionally very closely, (joint spacing typically between 150 - 300 mm), dark grey, hard rock SILTSTONE. (Occasionally stained throughout).	REMARKS: Very broken zone above contact 18,85 - 15,4 m at least partly ascribed to drillers breaks.
19.25 –		

HOLE No: BH 3003
Sheet 2 of 2

JOB NUMBER: 000

ROCK FABRIC
MA: massive
BE: bedded
FO: foliated
CL: sheared
SH: schistose
GL: gneissose
LA: laminated

GRAIN SIZE
FG: fine grained
MG: medium grained
CG: coarse grained

JOINT SPACING
VC: very close spacing < 50mm
C: close spacing 50mm - 300mm
M: medium spacing 300mm - 1000mm
W: wide spacing 1 - 3m
VW: very wide spacing > 3m

WEATHERING
FRESH: showing Completely unaltered
SLIGHT: showing Slightly weathered
MOD: showing Moderately weathered
HIGH: showing Highly weathered
COMP: showing Completely weathered
RESIDUAL: showing Converted to soil / unconsolidated

JOINT ROUGHNESS
SL: slickensided
S: smooth
R: rough
VR: very rough
I: light
V: wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No: BH 3003
Sheet 2 of 2

JOB NUMBER: 000

550	23,40	100	100	100	3		MA	-	-	0-10 60-70	M W?	R/S S	calcite up to 5 mm	
549					2									
548	25,13	100	100	96	4									

22														
23														
24														
25														
25,15														

Unweathered, medium jointed (joint spacing generally 300 - 791 mm), grey, extremely hard rock, medium to fine grained DOLERITE.

REMARKS: Contact sub-horizontal, open.

END OF HOLE.

NOTES

1) Quarry considerations: Siltstone unsuitable for crushing.

2) Dolerite very deep (25.1 m), ie overburden depths excessive.

RECEIVED LEVEL	DRILL RUN DEPTH (m)	% MATERIAL RECOVERED	% CORE RECOVERED	% RQD	JOINT FRAC. FREQ.	WATER ACCEPTANCE (Open)	ROCK FABRIC ANG. GRAIN SIZE	FABRIC SPACING (mm)	JOINT INCLIN. (deg)	JOINT SPACING (m)	JOINT ROUGHNESS	JOINT FILL (mm)	WEATHERING	DEPTH (from T-150)

CONTRACTOR: DWAF
MACHINE: SECO 12
DRILLED BY: HD Lelingoana
PROFILED BY: GD
TYPE SET BY: AP
DISPLAY FILE: GEOSERVE.SET

WELL HEAD: 90DEG
DIAM: ROTARY DIAMOND, NX
DATE: ID - 11/07/2000
DATE: 31/08/2000
DATE: VISUAL 02/06
TEXT: BH3003SRC.TXT

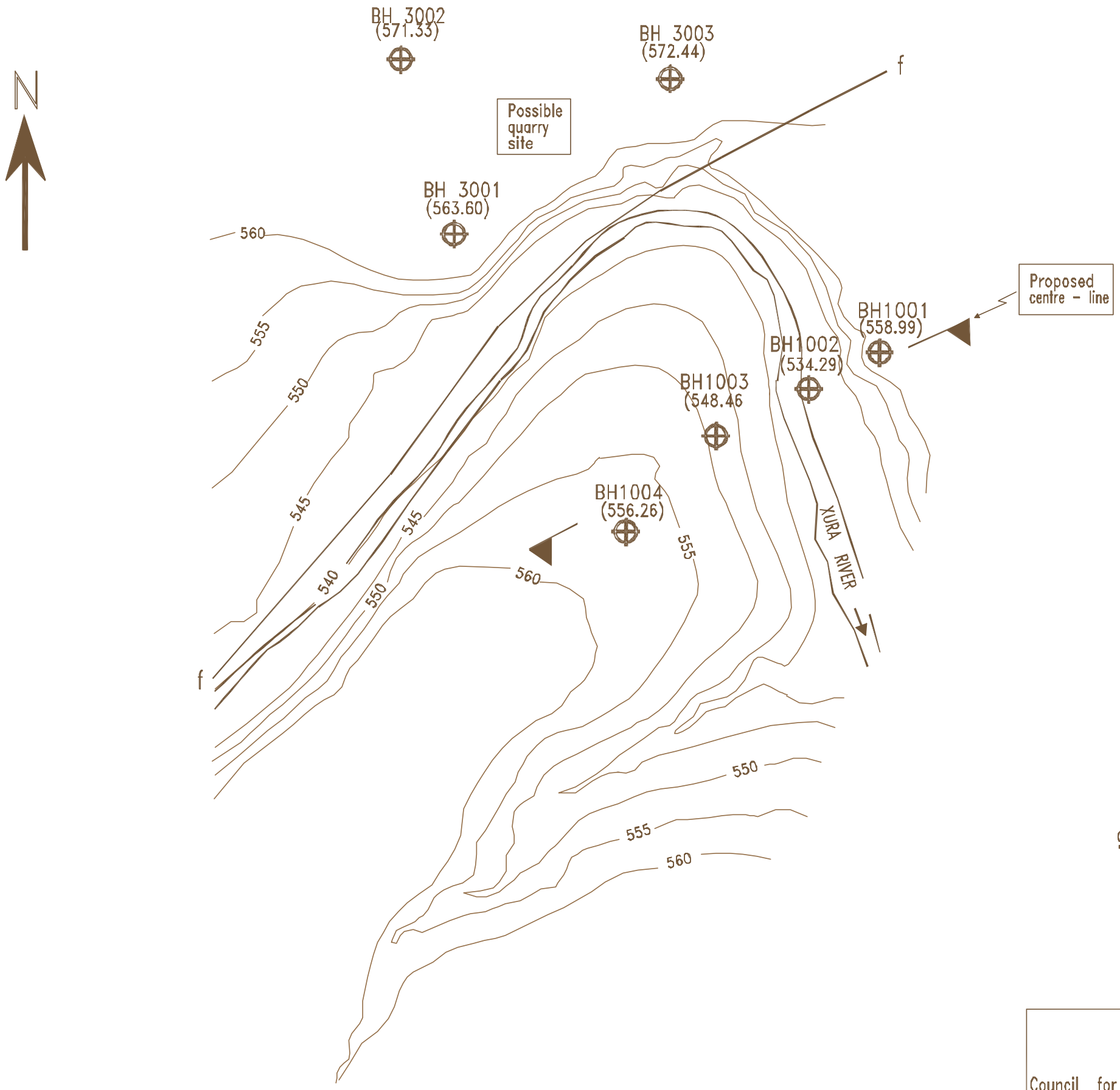
ELEVATION: 572.44
X-COORD: + 3 466 314.83
Y-COORD: - 49 339.56

HOLE No: BH 3003

COORDINATE LIST

PROPOSED LUSIKISIKI DAM SITE- BOREHOLES

CO-ORDINATE SYSTEM LO.29° HEIGHTS BASED ON T15(Degree Square 3129)					
Borehole Name	Co-ordinates		Heights above mean sea level		
	Y	X	Top Pipe	Concrete	Soil
BH1001	-49492.05	3466517.84	559.22	559.08	558.99
BH1002	-49440.78	3466541.89	534.59	534.38	534.29
BH1003	-49370.52	3466577.03	548.64	548.57	548.46
BH1004	-49306.96	3466647.28	556.39	556.33	556.26
BH3001	-49180.02	3466428.68	563.78	563.60	563.60
BH3002	-49143.71	3466303.73	571.59	571.37	571.33
BH3003	-49339.56	3466314.83	572.68	572.55	572.44



LEGEND

BH1002
(534.29)

Borehole position
with collar elevation (RL)

f Possible fault

0 50 100 150 200 250 m

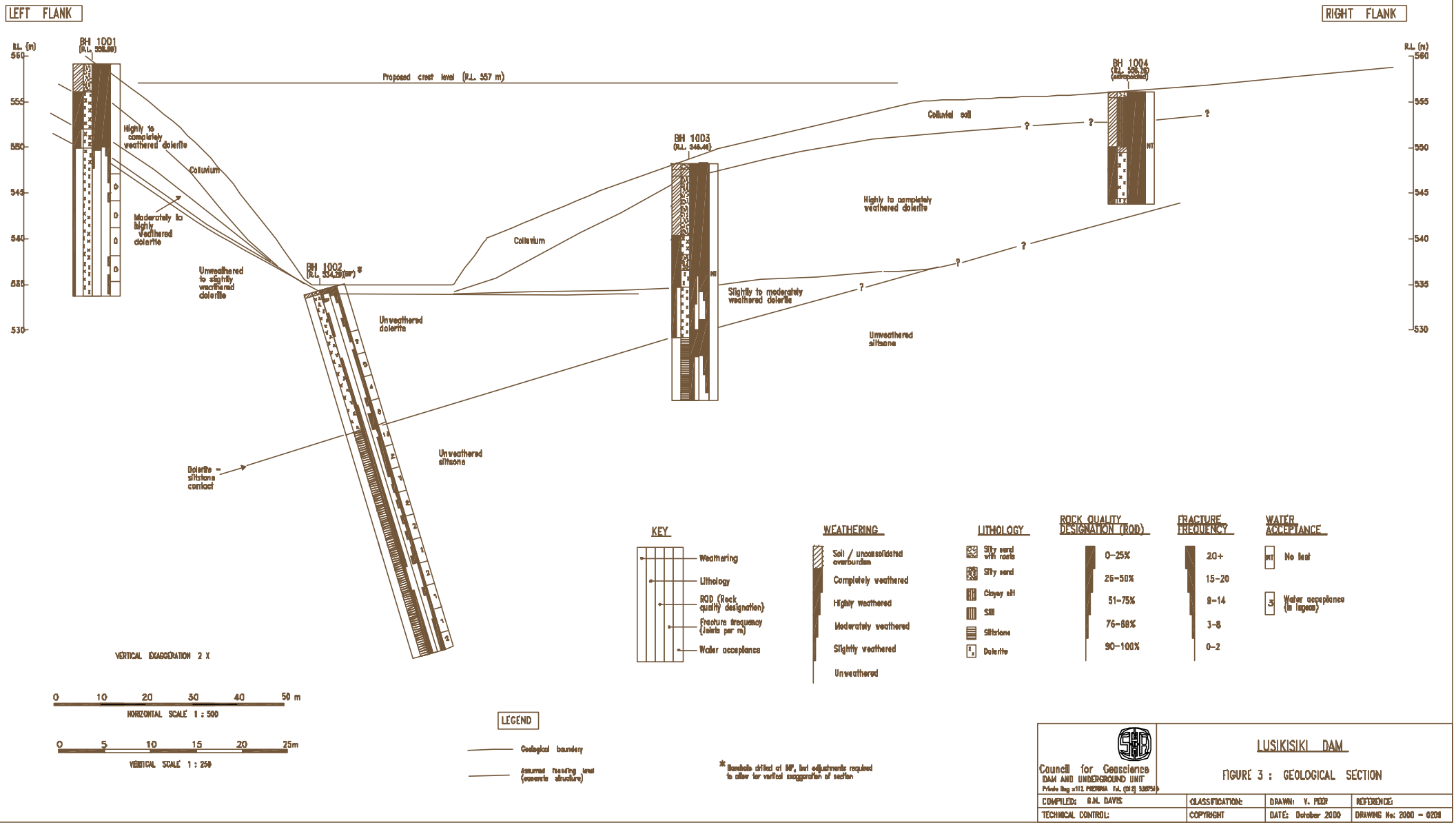
SCALE 1 : 2 500

Council for Geoscience
DAM AND UNDERGROUND UNIT
Private Bag x112 PRETORIA Tel. (012) 3367519

LUSIKISIKI DAM SITE

FIGURE 2 : SITE PLAN WITH BOREHOLE POSITIONS

COMPILED: G.N. DAVIS	CLASSIFICATION:	DRAWN: V. PEER	REFERENCE: DWAF
TECHNICAL CONTROL:	COPYRIGHT	DATE: October 2000	DRAWING NO : 2000 – 0209

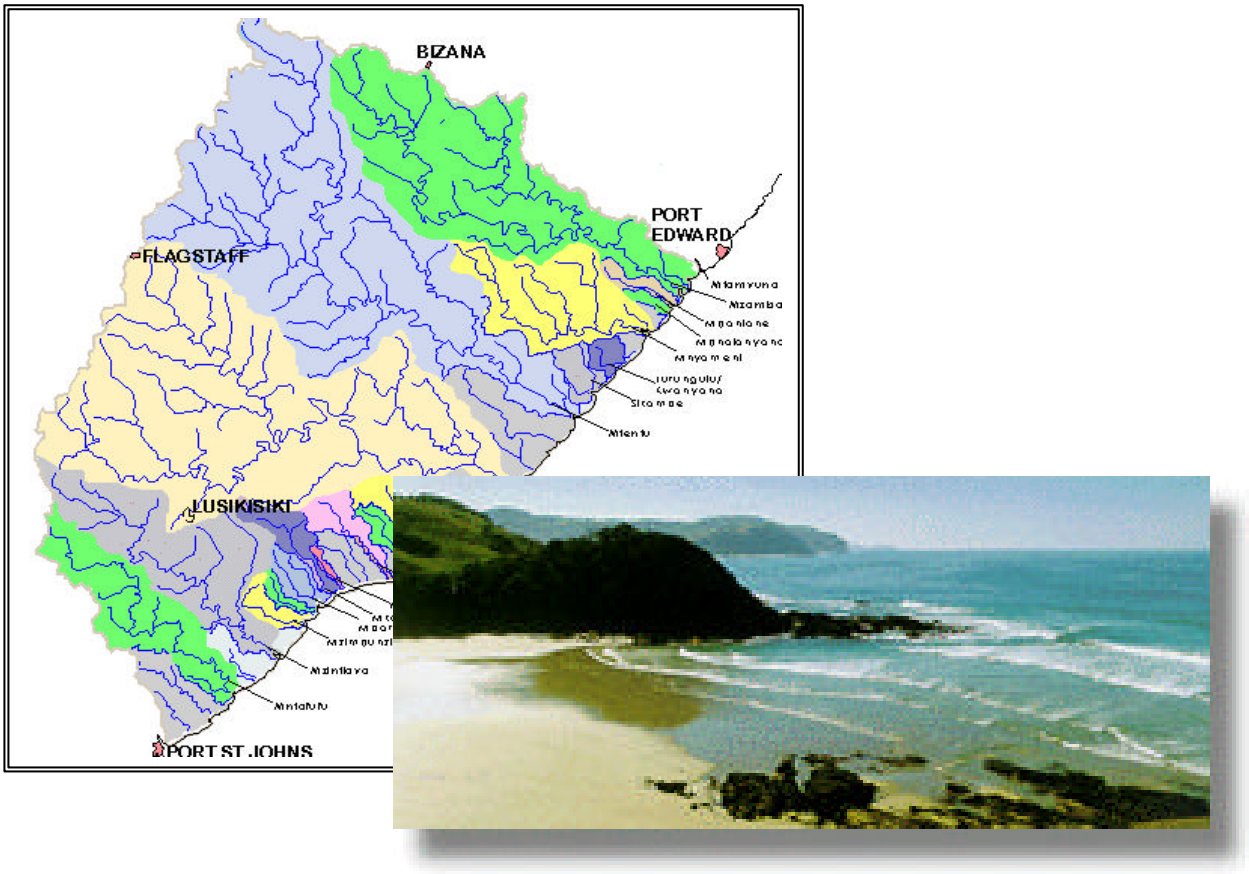

LEFT FLANK
RIGHT FLANK
R.L. (m)
560
555
550
545
540
535
530
BH 1001
(R.L. 558.89)
BH 1002
(R.L. 554.29(par))
BH 1003
(R.L. 548.46)
BH 1004
(R.L. 555.25)
(extrapolated)
Proposed crest level (R.L. 557 m)
Highly to completely weathered dolerite
Colluvium
Moderately to highly weathered dolerite
Unweathered to slightly weathered dolerite
Unweathered dolerite
Unweathered siltstone
Dolerite - siltstone contact
Colluvium
Slightly to moderately weathered dolerite
Highly to completely weathered dolerite
Colluvial soil
Unweathered siltstone
VERTICAL EXAGGERATION 2 X
0 10 20 30 40 50 m
HORIZONTAL SCALE 1 : 500
0 5 10 15 20 25m
VERTICAL SCALE 1 : 250
KEY
Weathering
Lithology
RQD (Rock quality designation)
Fracture frequency (Joints per m)
Water acceptance
WEATHERING
Soil / unconsolidated overburden
Completely weathered
Highly weathered
Moderately weathered
Slightly weathered
Unweathered
LITHOLOGY
Silty sand with roots
Silty sand
Clayey silt
Silt
Siltstone
Dolerite
ROCK QUALITY DESIGNATION (RQD)
0-25%
26-50%
51-75%
76-88%
90-100%
FRACTURE FREQUENCY
20+
15-20
9-14
3-8
0-2
WATER ACCEPTANCE
NT
No test
Water acceptance (in lugeon)
LEGEND
Geological boundary
Assumed bedding trend (concerns structure)
* Borehole drilled at 90°, but adjustments required to allow for vertical exaggeration of section
Council for Geoscience
DAM AND UNDERGROUND UNIT
LUSIKISIKI DAM
FIGURE 3 : GEOLOGICAL SECTION
COMPILED: G.N. DAVIS
CLASSIFICATION:
DRAWN: V. PEER
REFERENCE:
TECHNICAL CONTROL:
COPYRIGHT
DATE: October 2000
DRAWING No: 2000 - 0208

PB T600/00/1301

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



ENGINEERING GEOLOGICAL PRE-FEASABILITY REPORT

Final

June 2001

Prepared By:

Council for Geoscience
Geological Survey
Private Bag X112, Pretoria, 0001

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Engineering Geological Pre-feasibility Report
AUTHOR	**:**	G Davis
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-1301
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EXECUTIVE SUMMARY

This report presents the findings of brief pre-feasibility level engineering geological investigations conducted at the proposed Lusikisiki dam site in order to facilitate comparison with the alternative Zalu dam site, which had previously been investigated in some detail.

The proposed dam site is located on the Xura River near to the town of Lusikisiki in the Eastern Cape Province. An approximate dam height of 23 m is envisaged. These limited investigations comprised the drilling of only four boreholes at the proposed centre-line and three boreholes at a possible quarry site.

The proposed dam site is markedly asymmetrical. The steeper slopes of the left flank are underlain by dolerite. The thickness of the colluvial soil cover is expected to vary between 3 m and 5 m, while the upper portion of the dolerite sill is also intensely weathered. Scattered outcrop of unweathered dolerite is evident within the river section. The dolerite sill is between 12 m and 18 m in thickness and is underlain by unweathered siltstone. The gently sloping right flank is underlain by the completely weathered dolerite sill, which becomes progressively thinner in an up-slope direction. At depth the dolerite is underlain by siltstone of the Ecca Group, Karoo Supergroup.

Good founding conditions at shallow depth within the river section, extending towards the left flank, are considered suitable for the founding of a concrete structure. Poor founding conditions on the right flank would, however, favour an embankment. Excavation depths within the river section are expected to be negligible, and likely to increase to a depth of 10 m at crest level on the left flank. For the embankment cut-off, depths between 3 m and 5 m may be assumed.

The investigated quarry site proved to be unsuitable because of excessive overburden thickness, but an abandoned dolerite quarry located only 7 km from the proposed dam site has been identified as a promising alternative. Embankment fill materials are likely to be located within reasonable distance of the dam site.

The report presents a summary of the geological factors to be considered in the comparison between this Luskisiki dam site and the alternative Zalu site. Recommendations are included for more-detailed follow-up investigations.

CONTENTS

1.	INTRODUCTION	1
2.	REGIONAL GEOLOGY	1
3.	SEISMIC HAZARD ASSESSMENT	2
4.	SITE DESCRIPTION	2
5.	DRILLING RESULTS	2
5.1	Left flank	2
5.2	River section	4
5.3	Right flank	5
6.	ENGINEERING GEOLOGICAL CONSIDERATIONS	6
6.1	Founding conditions and structure layout	6
6.2	Excavation depths	7
6.3	Foundation permeability	7
6.4	Slope stability	8
7.	CONSTRUCTION MATERIALS	8
7.1	Concrete aggregates	8
7.1.1	Drilling results	
7.1.2	Discussion	
7.2	Embankment fill materials	10
8.	COMPARISON BETWEEN ZALU AND LUSIKISIKI DAM SITES	10
9.	CONCLUSIONS AND RECOMMENDATIONS	13
10.	REFERENCES	15
11.	DATA APPENDIX	16

TABLES:

Table 1: Summarized joint data (dolerite sill)

Table 2: Summarized comparison between Lusikisiki and Zalu dam sites

PLATES:

Plate 1: A general view of the proposed Lusikisiki dam site, looking in a downstream direction.

Plate 2: The left flank at the proposed Lusikisiki dam site.

Plate 3: Scattered outcrop of dolerite bedrock is evident within the river section.

Plate 4: The gently sloping right flank at the proposed Lusikisiki dam site.

Plate 5: A view of the abandoned quarry located approximately 7 km north-west of the proposed Lusikisiki dam site.

APPENDICES:

Appendix: Water pressure test data

Appendix: Borehole co-ordinates

Appendix: Borehole logs and core photographs

FIGURES:

Figure 1: Locality plan

Figure 2: Site plan with borehole positions

Figure 3: Geological section

1. INTRODUCTION

A pre-feasibility level engineering geological investigation has been conducted at the proposed Lusikisiki dam site at the request of the Directorate of Water Resources Planning of the Department of Water Affairs and Forestry, dated 13 April 2000.

The Lusikisiki dam site was one of the favoured sites identified during the earlier reconnaissance phase of the Eastern Pondoland Basin Study, by consultants UWP Engineers. Brief reconnaissance-level engineering geological investigations were conducted at the time (Davis, 1999). The other favoured site was the Zalu dam site. Because the Zalu had previously been investigated in some detail (Hill Kaplan Scott, 1979), it was necessary to conduct more detailed investigations at the Lusikisiki site, in order to facilitate meaningful comparison between these two alternatives, and selection of the better development option.

The Lusikisiki dam site is located on the Xura River, roughly 7 km as the crow flies, north-west of the town of Lusikisiki in the Eastern Cape Province (Figure 1).

Initially, a maximum dam height of 40 m was envisaged. With the subsequent optimisation of the dam size, a height of approximately 23 m now appears more favourable (ie approximate crest level 557 m).

These pre-feasibility level investigations comprised the drilling of a limited number of boreholes along the proposed centre-line. In addition to the four boreholes (total length 109,23 m) drilled along the centre-line, three boreholes (total length 82,05 m) were drilled at a possible coarse aggregate quarry site. The boreholes were drilled by DWAF Drilling Branch in the period between June and August 2000.

The findings of the more-detailed investigations as presented in this pre-feasibility report supercede the earlier reconnaissance-level engineering geological report. For the sake of completeness, some comments on the general geological setting are repeated here.

2. REGIONAL GEOLOGY

The Lusikisiki area is underlain by sedimentary rocks belonging to the lower portion of the Karoo Supergroup. A NE-trending line passing through Lusikisiki may be considered to divide the area geologically; inland of this line the geology comprises mudrocks of the Ecca Group while the older tillite of the Dwyka Group occurs to the east of this.

The entire sedimentary sequence of the Karoo Supergroup has been intruded by younger dolerite sills and dykes. Dykes are generally between 3 m and 10 m in width and several kilometres in length (Karpeta & Johnson, 1978). A preferred north-westerly orientation is recognized. Sill thickness varies from less than 1 m to more than 100 m. The sills are generally discordant, ie cut across the bedding. These intrusive dolerites may comprise up to 40 per cent of the geological sequence within the Ecca Group strata, but significantly less within the Dwyka tillite.

The geological structure in this area is mainly characterized by gently dipping strata. Dips vary between 1° and 3° to the north-west, although localized steep dips may be associated with dolerite intrusions. No major regional scale faulting is recognized within the area of interest.

There are no economically important mineral deposits within the area of interest.

3. SEISMIC HAZARD ASSESSMENT

According to seismic hazard maps prepared by the then-Geological Survey (Section 10: Data Appendix), a seismic intensity of VI (modified Mercalli scale) has a 10 % probability of being exceeded at least once in a period of 50 years. This equates to a 10 % probability of peak horizontal ground accelerations between 50 cm/s^{-2} and 100 cm/s^{-2} being exceeded at least one in the same 50 year period.

4. SITE DESCRIPTION

The selected centre-line position is located at a narrowing of the Xura River valley, immediately downstream of a sharp bend in the river (Figure 2).

The relatively straight section of the river upstream of the site may represent a fault zone (see Section 7.1.1).

The site is markedly asymmetrical. The left flank is relatively steep, with gradient varying between 1:1,5 and 1:2,5 although the upper slopes are significantly flatter (estimated at 1:20). The right flank is gently sloping although the 2 m to 3 m high river bank is steep. This slope is convex, with gradient flattening from 1:5 to 1:13 at higher levels.

The width of the river section is approximately 30 m.

5. DRILLING RESULTS

Only four exploratory boreholes were drilled along the proposed centre-line. Borehole positions are indicated on Figure 2. One borehole (BH 1001) was drilled on the left flank, one within the river section angled from the left bank towards the right (BH 1002), another on the mid-right flank (BH 1003) and the fourth on the upper right flank (BH 1004).

5.1 Left flank

The uppermost, flatter slopes of the left flank are presumably underlain at depth by weathered siltstone, covered by silty / sandy colluvial soils. As no boreholes were drilled on these upper slope

areas, the thickness of the unconsolidated overburden as well as the condition of the underlying bedrock remain uncertain. Similarly, the level of the contact between this siltstone and the underlying dolerite sill is not known. As the geological conditions on these upper slopes lie above the proposed crest level, however, they have little bearing on the founding conditions.

The steeper slopes (ie between RL 534 at river bed level and at least RL 575) are covered with colluvial soils comprising silty to fine sands, with weathered siltstone rock fragments indicating an origin of talus or reworked transported soils. Occasional clayey material is presumably derived from fragments of siltstone which have completely weathered.

The thickness of this colluvial soil horizon is likely to decrease in a downslope direction, with scattered outcrop near the foot of the slope indicating the soil cover is least well developed in these parts. The soil thickness is expected to vary in thickness up to 3 m or 5 m. With only a single borehole drilled on this flank, however, the variation in soil thickness cannot be confirmed.

Lithologically, the entire left flank is underlain by dolerite. The base of the sill was not intersected in BH 1001, but from extrapolation may be assumed to extend to significant depths. Sill thickness on the lower flank is assumed to be in the order of 20 m. Because of the attitude of the sill which dips into the flank, sill thickness increases rapidly in an up-slope direction (Figure 3).

The upper part of the dolerite sill has undergone significant weathering. The uppermost 4 m of the dolerite is highly to completely weathered, becoming moderately to highly weathered over a further 2 m wide zone. At a depth of 9,2 m (RL 549,79 m) the dolerite becomes unweathered to slightly weathered. The depth of weathering is expected to mirror the topography, with the thickness of the various weathered zones increasing in an up-slope direction (Figure 3).

The upper horizon of highly to completely weathered rock was essentially recovered as silty- to fine sand and dolerite gravel (diameter up to 10 mm). Occasional dolerite core-stones also occur. It is unlikely that these drilling results are completely representative of *in situ* conditions. The drilling action essentially reduces the soft rock to very soft rock dolerite to sand-size fragments, leaving the medium hard rock fragments as gravel-size pieces.

Similarly, the gravel-size fragments recovered in the borehole suggest the highly to completely weathered dolerite is very highly fractured. Exposures of this material in nearby road cuttings would contradict this view, however, with the *in situ* weathered rock appearing more massive.

Joints within the moderately to highly weathered zone are very closely spaced (less than 50 mm up to 120 mm) producing a very highly fractured rock mass. A marked improvement in the jointing is evident within the slightly weathered to unweathered rock mass, with a medium to wide joint spacing generally varying between 150 mm and 750 mm (highly to slightly fractured).

At least three or four joint sets are recognized, including sub-horizontal and sub-vertical joints as well as a steeply dipping set (approximately 60°) and a moderately steep set (dipping at 30°). Because BH 1001 was drilled vertically, it is most likely that more than one set of sub-vertical joints occurs (see Section 5.2). The

joint surfaces are typically stained, particularly within the more weathered horizons. Within the slightly weathered to unweathered dolerite, joints of the sub-vertical set contain calcite fill material with thickness up to 1 mm or 2 mm. Typically, the joint surfaces are rough to smooth.

5.2 River section

Alluvial deposits at the favoured centre-line are of negligible thickness and mainly comprise patchy silt deposits. Greater accumulations of alluvium are evident both downstream of this centre-line as well as within the proposed dam basin.

The river section is characterized by scattered outcrop of essentially unweathered dolerite (Plate 3). The base of the dolerite sill is approximately 12 m to 18 m beneath river level (approximate RL 522,5 - RL 517,5). Intersection of the lower sill contact in BH's 1002 and 1003 indicates the dolerite sill is not horizontal, but rather exhibits a shallow apparent dip of 8° towards the left flank (Figure 3). It is also quite feasible that this lower sill boundary is irregular, rather than planar. The sill is underlain by unweathered siltstone.

Limited outcrop of massive siltstone on the right bank of the river suggests the relationship between the sedimentary strata and the intrusive dolerite is almost certainly more complex. This is supported by borehole evidence that the lower sill contact is, at least partly, faulted. The borehole core revealed some evidence of a narrow faulted contact, in the form of brecciated siltstone which had been largely recemented with calcite and appeared largely intact. This siltstone body might, however, simply represent an inclusion or xenolith.

Joint Set	Attitude	Characteristics
J1	Sub-vertical joints, striking sub-parallel (but slightly oblique to) the river	Joint spacing varies between 50 mm and 300 mm (ie close); joint continuity 20+ m; joints typically tight with no fill material; slightly rough surfaces.
J2	Sub-vertical joints, striking sub-perpendicular to the river	Joint spacing varies from 500 mm (occasionally 150 mm), ie medium to wide; continuity between 1 m and 3 m, up to 7 m; tight with no fill; rough and non-planar (irregular)
J3	Sub-horizontal joints	Spacing varies between 250 mm and 600 mm (ie medium); limited continuity between 1 m and 2 m; joints surfaces smooth but irregular.
J4	Irregular, sub-vertical joints, striking oblique to the river	

Table 1: Summarized joint data (dolerite sill)

With the exception of the uppermost 0,65 m of the dolerite sill which is slightly weathered, the sill for the most part is unweathered. The dolerite comprises light grey, medium to fine-grained rock ,becoming very fine-grained near the basal contact. The joints in general are closely to medium spaced, varying between 200 mm and 400 mm. At least four joint sets are recognized, including three more prominent sets as well as irregular joints. Joint data collected from surface exposures are summarized in Table 1.

The siltstone / carbonaceous siltstone underlying the dolerite sill comprises unweathered, dark grey to black, hard rock. The joint spacing generally varies between 100 mm and 250 mm, ie closely spaced. Numerous zones of very closely spaced joints are recognized (see Appendix for detailed borehole logs). This fracturing may, at least partly, be ascribed to drilling breaks via the sub-horizontal planes of weakness and the borehole core is therefore not completely representative of actual *in situ* conditions.

At least three joint sets are recognized within this siltstone / carbonaceous siltstone horizon. In addition to the sub-horizontal fractures which are drilling induced but which nevertheless represent sub-horizontal planes of weakness, sub-vertical joints are expected as well as steeply-dipping joints. These sub-horizontal weakness planes represent the bedding, but are not prominent discontinuities. Without the benefit of orientated borehole cores there remains some uncertainty as to actual rock mass jointing.

5.3 Right flank

The gently sloping right flank is covered by a poorly developed clayey to silty topsoil with a thickness of 0,6 m. The underlying soil horizon comprises clay or clayey silt and varies from less than one metre and possibly up to 6 m in thickness. These colluvial clayey soils are presumably derived from reworked dolerite soils.

The transported soils overlie completely weathered dolerite with thickness between 5,5 m and 6 m. Note that the silty or sandy material recovered from the boreholes is not considered representative of actual *in situ* conditions. As mentioned above (Section 5.1), the drilling action most likely reduced the friable but intact rock mass to silt, sand and gravel sized fragments.

Although this weathered dolerite sill underlies the right flank, the dip of the sill implies the thickness of the highly to completely weathered dolerite becomes progressively less in an up-slope direction, in effect ‘pinching out’, naturally assuming the dolerite-siltstone contact may be extrapolated as such.

Some improvement in the degree of weathering of the dolerite sill is noted at depth, with highly to completely weathered dolerite being recovered as gravel-sized fragments (diameter less than 50 mm). Again, this gravel should be considered a disturbed sample which is not entirely representative of *in situ* conditions. The size of the gravel would however indicate the joints within this weathered rock mass are very closely spaced. At least some fracturing is drilling induced. The drilling results indicate alternating horizons of variably-weathered rock.

The lower flank, at least, is underlain at depth by more intact, less weathered dolerite rock mass. Borehole 1003 intersected slightly to moderately weathered dolerite at a depth of 19 m (RL 535, ie approximately at river level). It is likely that this less weathered dolerite extends for some distance beneath the flank, but

probably not the entire flank. This 5,5 m thick horizon (BH 1003) comprises fine-grained, very hard rock dolerite. Joint spacing varies between close and medium (approximately 200 mm), becoming very closely spaced from depth 17,6 m (spacing from <50 mm up to 100 mm). At least three joint sets are recognized, including sub-horizontal, sub-vertical and moderately steep (30°) joints. All joint surfaces are stained, while the sub-vertical joints also contain weathered dolerite fill material with thickness between 2 mm and 3 mm.

The intrusive dolerite sill is underlain, at a depth of 19 m (RL 529,46), by unweathered siltstone. The rock mass is closely fractured at this contact zone and the contact itself is not well-defined. Apart from the close fracturing, this is due to similarity in appearance between the siltstone and the very fine grained dolerite. The nature of the contact zone underlying the upper flank areas is uncertain.

The siltstone comprises dark grey, hard rock. The rock mass is generally closely jointed, but very closely jointed / very highly fractured in the vicinity of the contact with the overlying dolerite sill, to depth 21,7 m (BH 1003). At least four joint sets are recognized. The joint surfaces are generally stained to approximate depth 22 m (BH 1003). This, together with the fractured nature of the rock mass in proximity to the contact, would suggest a zone of greater permeability. The broken nature of the rock mass , however, prevented water pressures tests being conducted and this could not be confirmed.

6. ENGINEERING GEOLOGICAL CONSIDERATIONS

6.1 Founding conditions and structure layout

The geology of the asymmetric site is characterized by outcrop of high strength, resistant bedrock within the river section while the flanks in general, and the right flank in particular, are deeply weathered.

A central concrete spillway might be assumed the most obvious option for a spillway. Excavation depths would be minimal within this river section (Section 6.2) while an apron might not even be required for erosion protection. One constraint on such a central spillway might be the spillway width required. The width of the river section is only 30 - 35 m. While a wider spillway can undoubtably be accommodated, this would require some optimization in order to minimize the excavation depths. In comparing the depths to suitable bedrock on the respective flanks (Figure 3), it would appear that extending such a spillway in the direction of the left flank would be more advantageous than towards the right. The smaller the favoured structure, the more likely that such a mass concrete structure will be extended to include the entire left flank, even if only because of construction practicalities.

The deep weathering of the right flank suggests that an earth embankment is a better option. The larger the envisaged structure, the more likely that an embankment would also be favoured for the upper left flank.
While construction of an embankment dam might be considered, there are no other obvious spillway solutions.

6.2 Excavation depths

Within the river section, excavation depths are expected to be minimal. Unconsolidated overburden is limited to patchy alluvial deposits. Although the bedrock exposed on surface comprises good quality, sound, intact dolerite, the surface is highly irregular due jointing and preferential weathering (Plate 3). Foundation preparation will therefore require limited blasting in order to prevent stress concentrations associated with rock pinnacles. Excavation depths up to 1 m or 2 m may be assumed.

Excavation depths for the central spillway on the respective flanks will naturally depend on how far the concrete structure extends. On the left flank a vertical depth of 9,5 m may be assumed in the vicinity of BH 1001. The further the structure is required to extend in the direction of the flank, the greater the required excavation depth, assuming the depth of weathering increases in an up-slope direction (Figure 3). On the lower right flank, the highly to completely weathered dolerite is not suitable for the founding of a concrete structure. Deep excavation (13,5 m in the vicinity of BH 1003) is required to ensure founding on slightly to moderately weathered dolerite. With the limited drilling undertaken it is not known to what extent this weathering horizon mirrors the topography. Excavation depths for a concrete structure are expected to increase significantly away from the river (Figure 3).

For an embankment on the mid- to upper left flank excavation depths in the order of 3,5 m may be assumed for the cut-off. Similar depths may be assumed at this stage for the right flank. Because of core losses, there is, however, some uncertainty as to the *in situ* founding conditions. *More detailed investigations would be required to verify cut-off depths.*

Stripping the embankment shell zones of the organic-rich topsoil to a nominal depth of 1 m may be assumed at this stage.

6.3 Foundation permeability

Water pressure tests were only possible in two of the four boreholes drilled along the proposed centre-line, namely BH's 1001 and 1002 drilled on the left flank and within the river section, respectively. The continual collapse of the broken rock mass in BH 1003 did not allow a proper sealing of the packer to be achieved, while BH 1004 was cased for the entire depth.

Water pressure tests conducted in the unweathered to slightly weathered dolerite of the left flank revealed an impervious rock mass. None of the test stages recorded any water acceptance. However, the drillers logs do record a total water loss at a depth of 11,3 m. Inspection of the borehole cores (see Appendix) reveals this water loss to be associated with prominent stained joints.

The angled borehole drilled within the river section (BH 1002) was also water pressure tested. For the most part the tests indicated relatively impervious founding conditions, with acceptances varying between one and five lugeons. The test section straddling the dolerite - siltstone contact yielded a higher value (13 lugeons) indicating more pervious conditions. Results from the uppermost test section are meaningless as water was observed to be leaking past the packer.

Although water pressure tests were not possible in BH 1003, the contact zone between the dolerite sill and underlying siltstone is highly fractured. In addition, the joint surfaces are stained and it is to be assumed that this contact is potentially pervious.

6.4 Slope stability

The stability of the natural slopes defining the dam basin has not been considered in any detail as yet. Some general comments and observations can, however, be made.

The natural slopes which define the proposed dam basin are generally gently sloping and are not considered to be at risk from catastrophic failure. The basin geology, predominantly comprising sub-horizontally bedded sedimentary strata and relatively shallow soils, is also not conducive to major slope failure. Steeper slopes occur within the basin but some distance from the proposed dam site. Indications are that these slopes are underlain by clayey soils derived from deeply weathered dolerite. It is possible that soil slope failures will occur with wetting up of these steeper slopes, but their limited extent as well as the distance from the proposed centre-line mitigates against any major risk to the structure. Steeper slopes occuring in the immediate vicinity of the proposed centre-line (Plate 2) are due to the dolerite intrusion. If any instability occurs this will be limited to occasional boulders and rock blocks becoming dislodged.

7. CONSTRUCTION MATERIALS

7.1 Concrete aggregates

The previous reconnaissance-level investigations (Davis, 1999) identified the intrusive dolerite sill on the left flank as the most obvious potential source of coarse aggregate and rip-rap.

Three boreholes (BH's 3001 - 3) were subsequently drilled for this pre-feasibility investigation in order to assess actual quarrying conditions. Borehole positions are indicated in Figure 2.

No further investigation of potential sand (fine aggregate) sources have been conducted. Comments made previously (Davis, 1999) are therefore still valid. Briefly, the sands produced from the Karoo sedimentary strata are generally undesirable because of their fineness as well as the resulting excessive concrete shrinkage. At this stage it may be assumed that sand will have to be sourced from crusher run.

7.1.1 Drilling results

A summary of the geological conditions at this possible quarry site is presented below. Detailed borehole logs as well as core photographs are presented in the Appendix.

The area is covered by a shallow layer of silty topsoil (thickness varying between 0,15 m and 0,25 m). In places the topsoil directly overlies highly to completely weathered siltstone, while in other areas the soil horizon is more well developed, extending to depths up to 7,5 m. Siltstone bedrock extends to depths

varying from 19,25 m (BH 3001) to more than 29,89 m (BH 3002), and is underlain by the intrusive dolerite sill. The thickness of the upper weathered zone of the siltstone rock mass varies between 2,5 m and 5,5 m. For the most part, however, the siltstone is unweathered to slightly weathered. The dolerite is unweathered.

Intersection of the *upper* dolerite - siltstone contact, and the depth at which this sill contact was intersected, compared to the centre-line drilling results where the *lower* sill contact was intersected, suggests the presence of a fault, possibly aligned with the prominent straight length of river upstream of the dam site (Figure 2).

7.1.2 Discussion

The exploratory boreholes have revealed excessive overburden thickness. Although the unconsolidated overburden is not well-developed, and neither is the weathering of the underlying rock mass, siltstone is not considered suitable for manufacture of aggregate. In addition to relatively low crushing strengths, influenced in part by preferential parting via sub-horizontal bedding planes, this siltstone is likely to be non-durable and exhibit slaking characteristics. In contrast, dolerite typically comprises high strength, durable rock. For these reasons, intrusive dolerites usually represent the only suitable source rock for the production of concrete aggregates, in areas underlain by such sedimentary strata.

In the proposed quarry area the dolerite sill occurs at depths varying from 19,25 m to more than 29,89 m. Removal of overburden to depths of this magnitude is not considered viable. **Development of this potential quarry site is consequently not considered a realistic option.**

Subsequent efforts to locate further promising quarry sites within the proposed dam basin proved fruitless.

Scattered dolerite outcrop occurs within the Xura River roughly 3 km due west of the proposed Lusikisiki dam site (Figure 1). Because of the limited area of scattered outcrop, as well as the position within the river bed, this site was not deemed worth investigating further.

Other steeper slopes flanking the Xura River within the basin, located roughly 2 km west north-west of the proposed dam site (Figure 1) were inspected, but proved to be underlain by weathered siltstone.

An existing, abandoned quarry is located on the high-lying area located approximately 7 km north-west of the Lusikisiki dam site (Figure 1). The geological succession essentially comprises an upper horizon of residual soil or weathered dolerite with thickness of approximately 5 m, underlain by dolerite which is unweathered or slightly weathered. The thickness of this horizon is estimated at 50+ m (Plate 5). Because the joint spacing is variable, the block size is variable too. The joint spacing varies between close and wide. The block size varies up to $1m^3$ to $2\ m^3$. No indications of rapid weathering dolerite were recognized. Although there was standing water on the quarry floor, it is most likely that this represents a perched water table associated with the dolerite-siltstone contact, rather than the water table. **This abandoned quarry currently represents the site most suitable for development.** Ordinarily, environmental concerns would not favour the development of such a potentially highly visible site. In this case, however, re-

opening of the abandoned quarry would allow further development to continue in a more environmentally-conscious manner and, more importantly, enable eventual closure in a more acceptable manner.

This quarry is located close to the Lusikisiki - Flagstaff road. While a disadvantage in terms of blasting operations, the advantage is that of good vehicular access between the quarry and the dam site.

If this Lusikisiki dam site is favoured over the Zalu site then the dolerite sill at the Zalu site might be considered an alternative source of coarse aggregate / rip-rap.

Another alternative source of coarse aggregate is an existing commercial quarry located to the east of Lusikisiki. Although not visited by the author, the quarry is located at least 15 km from the proposed dam site, and in addition would require heavily-laden trucks to pass through the town of Lusikisiki.

7.2 Embankment fill materials

No further investigations of potential sources of embankment fill materials were conducted during these pre-feasibility level investigations.

Indications are that vast areas within the dam basin represent potential sources of embankment fill materials, including both impervious core materials as well as semi-pervious transition materials.

8. COMPARISON BETWEEN ZALU AND LUSIKISIKI DAM SITES

As the purpose of these engineering geological investigations was to facilitate meaningful comparison between the respective Lusikisiki and previously-investigated Zalu dam sites, the main geological considerations are discussed below. These factors are summarized in Table 2.

Both sites are asymmetric, although this is more pronounced for the Lusikisiki site. More importantly, the river section is significantly wider for the Zalu site (approximately 80 m) in comparison with the Lusikisiki site (only 30 m to 35 m in width). This has implication for optimisation of the structure layout and therefore excavation depths.

Geologically, both sites are broadly similar in that the sedimentary strata at both sites have been intruded

	Lusikisiki site	**Zalu site**
Topography	Markedly asymmetrical. Left flank moderately steep (1:1,5 to 1:2,5), becoming flatter above approximate RL 565. Right flank convex, with lower slope gradient of 1:5 becoming 1:13 at higher levels. River section approximately 30 m wide.	Asymmetrical. Gently sloping left flank (1:7), steeper right flank (1:2,5). River section approximately 80 m wide.
Geology	Steeper slopes of left flank underlain by dolerite, covered by colluvial soils with thickness 3 - 5 m. Upper part of dolerite sill is weathered. River section underlain by unweathered dolerite sill with thickness 12 - 18 m, underlain by unweathered siltstone. Soil cover on right flank possibly up to 6 m in thickness, underlain by completely weathered dolerite sill.	Upper left flank underlain by weathered siltstone, mid- to lower slopes underlain by dolerite sill. Soil cover 2 - 5 m. Alluvium in river section 5 m thick, overlying unweathered dolerite sill with minimum thickness 35 m. Right flank underlain by unweathered dolerite. Soil cover up to 5 m thick.
Founding conditions & structure type	Composite structure, comprising central concrete spillway extending onto left flank and embankment on deeply weathered right flank, appears most suitable.	Founding conditions suitable for concrete gravity dam, or composite structure with embankment left flank and concrete river section and right flank.
Permeability / grouting requirements	Unweathered to slightly weathered dolerite and underlying siltstone expected to be relatively impervious. Necessary for grouting to intersect dolerite-siltstone contact. Low grout takes expected.	Water pressure and grout tests indicate dolerite relatively impervious. Low grout takes generally expected, with higher takes associated with a fault zone.
Excavation depths	Minimal excavation for concrete structure in river section (1 - 2 m), increasing rapidly in up-slope direction on left flank (up to 10 m at presumed crest level). Deep excavation for concrete structure on lower right flank (13 - 14 m). For embankment cut-off assume depths 3 - 5m.	For concrete structure, depths between 5 m on mid- to lower left flank, 3 - 4 m in river section, 1 - 4,5 m on right flank. Much deeper on upper flanks underlain by siltstone. Cut-off depth for embankment 2 - 5 m.
Construction materials	Abandoned dolerite quarry represents most suitable source of coarse aggregate, rip-rap and crusher sand. Located 7 km from dam site. Embankment fill materials likely to be located within reasonable distance of dam site, but sources not yet confirmed.	Abandoned dolerite quarry represents most suitable source of coarse aggregate, rip-rap and crusher sand. Located 4 km due north of dam site. Previous investigations considered clayey dolerite soils for impervious core, soils from siltstone / alluvium for transition zones.

Table 2: Summarized comparison between Lusikisiki and Zalu dam sites

by a dolerite sill. Some major differences may, however, be recognized. The geological conditions at the Zalu site are relatively uniform, both flanks being underlain by essentially unweathered dolerite. In contrast, the absence of an overlying protective siltstone horizon on the right flank of the Lusikisiki site has resulted in the complete weathering of the dolerite sill on this flank. While the upper flank areas at the Zalu site are underlain by weathered siltstone this only constitutes a minor part of the foundations. The dolerite sill at the Zalu site is substantially thicker than at the Lusikisiki site, with a *minimum* thickness of 35 m in the river section compared to a thickness between 12 m and 18 m at the Lusikisiki site.

These apparent differences in geological conditions at the respective dam sites, and the assessment in terms of suitability as founding materials, naturally have a bearing on the dam structures which might be considered. Founding conditions at the Zalu site are generally more favourable than at the Lusikisiki site, implying greater flexibility in terms of **structure type and configuration**. Although previous investigations only considered an embankment dam, the founding conditions at the Zalu site are also considered suitable for a concrete structure. In contrast, the poor founding conditions on the right flank of the proposed Lusikisiki dam site dictate that an embankment is more suitable than a concrete structure. As the prevailing founding conditions would de suitable for founding a concrete wall in the river section, extending onto the left flank, the favoured solution would comprise a composite dam. While an embankment dam might also be considered at the Zalu site, with spillway options including a side-channel or morning glory and conduit combination, possible embankment spillway configurations at the Lusikisiki site are not as apparent.

The better founding conditions at the Zalu dam site are also reflected in the expected **excavation depths**. Within the river section, shallower excavation depths are expected at the Lusikisiki site (up to 1 m to 2 m), compared with expected depths between 3 m and 4 m at the Zalu site but which only comprises the removal of alluvium. Significantly shallower excavations may be assumed on the respective flanks of the Zalu site, compared to the Lusikisiki site. For the most part, excavation depths up to 5 m may be assumed. At higher levels on the left flank, however, a concrete structure would require deeper excavation to ensure founding on unweathered dolerite. Areas underlain by weathered siltstone on the upper flanks would also require relatively deep excavation. For a concrete structure at the Lusikisiki site, on the other hand, excavation depths up to 9,5 m, increasing further in an up-slope direction, are expected on the left flank, while even deeper excavation will be necessary on the right flank. The excessive excavation depths on the right flank favour an embankment dam for which cut-off depths of 3,5 m may be assumed at this stage. Embankment cut-off depths varying between 2 m and 5 m may be assumed at the Zalu site.

In terms of **construction material availability**, although no hard rock quarry site for coarse aggregate / rip-rap has yet been proven for the respective dam sites, conditions are more favourable for the Zalu site. The abandoned dolerite quarry currently recognized as the most likely source is closer to the Zalu site than the Lusikisiki dam site (4 km, as opposed to 7 km). Furthermore, if an embankment dam is favoured at the Zalu site, together with a side-channel spillway, then these spillway excavations might produce suitable material. Sources of embankment construction materials have been identified at the Zalu dam site. While no investigations have been conducted in this regard at the Lusikisiki site, no major problems are envisaged.

9. CONCLUSIONS AND RECOMMENDATIONS

1. Brief pre-feasibility level engineering geological investigations were conducted at the proposed Lusikisiki dam site in order to facilitate meaningful comparison with the alternative Zalu dam site, which had been investigated previously in some detail.

2. These limited investigations comprised the drilling of four boreholes (total length 109,23 m) along the proposed centre-line, as well as three boreholes (total length 82,05 m) at a possible quarry site. No laboratory or other testing was conducted. Furthermore, investigations of potential embankment construction materials were not considered necessary at this stage.

3. The regional geology comprises sedimentary strata of the Ecca Group, Karoo Supergroup which have been intruded by younger dolerite dykes and sills. The geological structure is mainly characterized by sub-horizontal to shallow-dipping strata. No major regional faulting is recognized, although a lesser fault may possibly be traced between 180 m and 200 m upstream of the proposed centre-line. There are no economically important mineral deposits.

   In terms of seismic hazard, a seismic intensity of VI (modified Mercalli scale) has a 10 % probability of being exceeded at least once in a period of 50 years. This equates to peak horizontal ground accelerations between 50 cm/s^{-2} and 100 cm/s^{-2} being exceeded at least once in the same 50 year period.

4. The proposed dam site is markedly asymmetrical. The left flank is relatively steep while the right flank is gently sloping. The river section is only 30 m to 35 m in width.

5. The steeper slopes of the ***left flank*** are underlain by dolerite. The thickness of the colluvial soil cover is expected to vary between 3 m and 5 m. The uppermost portion of the dolerite is intensely weathered, varying from highly or completely weathered rock to moderately weathered rock. At a depth of 9,2 m (BH 1001) the dolerite becomes unweathered to slightly weathered. Joints within the unweathered to slightly weathered rock mass are medium to widely spaced (150 mm to 750 mm). A closer joint spacing is apparent in the more weathered horizons. At least three or four joint sets are recognized.

   Scattered outcrop of unweathered dolerite occurs within the ***river section***. Unconsolidated alluvial deposits are negligible. The dolerite sill dips gently (8°) towards the left bank, with thickness varying between 12 m and 18 m beneath river level. The joints are closely to medium spaced (200 mm to 400 mm) and at least four sets are recognized. The dolerite sill is underlain by unweathered siltstone.

   Soil cover on the ***right flank*** varies in thickness between 1 m and possibly 6 m. The dolerite sill extends beneath this flank but, because of the attitude, becomes progressively thinner in an up-slope direction. The sill is deeply weathered, with borehole recovery often limited to sandy or silty material. The dolerite is underlain by siltstone which, at depths beneath river level, is unweathered.

6. Founding conditions within the river section, and extending beneath the left flank, might be considered suitable for the founding of a concrete structure. Conditions on the right flank are significantly poorer and, without excessively deep excavations, only suitable for the founding of an embankment. It follows that a composite structure, comprising a concrete spillway and left flank non-overspill section with an embankment on the right flank, would be most suited to these founding conditions.

7. Excavation depths with the river section will be minimal, say 1 m to 2 m essentially to smooth an irregular surface. Excavation depths for a concrete structure on the left flank will increase significantly in an up-slope direction, to a maximum vertical depth of approximately 10 m at presumed crest level (RL 557 m). On the lower right flank even deeper excavations are envisaged for a concrete structure (13 m to 14 m). These depths are likely to further increase in an up-slope direction. For an embankment cut-off, excavation depths between 3 m and 5 m may be assumed.

8. Limited water pressure tests indicated relatively impervious founding conditions. Higher water acceptances were, however, associated with the dolerite-siltstone contact. In places this contact is closely fractured with joints exhibiting stained surfaces. The dolerite sill contact should therefore be considered a potentially pervious zone to be targeted during foundation grouting.

9. The natural slopes defining the dam basin are mainly gently sloping and therefore not considered to be at risk from catastrophic failure.

10. Limited exploratory drilling was conducted at a possible coarse aggregate / rip-rap quarry located near to the proposed dam site. Drilling results revealed the dolerite sill to occur at excessive depths varying between 19 m and more than 29 m. The overlying siltstone bedrock is not considered suitable for use as either coarse aggregate or rip-rap. **Development of this quarry site is therefore not considered feasible.**

    An existing but abandoned dolerite quarry, located roughly 7 km from the proposed dam site, is currently recognized as the most suitable quarry site. Overburden is shallow (5 m) with the underlying dolerite sill thickness estimated at more than 50 m.

11. Indications are that embankment fill materials, including impervious core materials as well as semi-pervious transition materials, will be readily available within a reasonable distance of the proposed dam site.

12. These brief pre-feasibility level engineering geological investigations were essentially aimed at facilitating meaningful comparison between the alternative Lusikisiki and Zalu dam sites. If this Lusikisiki site is favoured, more-detailed site investigations would be required. Feasibility-level studies should include the following;

    · Additional exploratory drilling at the favoured centre-line both to confirm the initial findings as well as investigating actual founding conditions for the envisaged structure

layout. Rather than being drilled along a line, these boreholes should be staggered along the proposed centre-line.

- The presumed fault upstream of the proposed centre-line should be investigated in more detail in order to determine whether or not this discontinuity represents a seepage path with the potential of affecting basin watertightness. Geophysical techniques could be employed as well as exploratory drilling.

- More-detailed investigation of construction materials. Depending on the envisaged structure, this would include hard rock for coarse aggregate / rip-rap as well as embankment construction materials including impervious core materials and semi-pervious transition materials. It would be necessary to prove both the availability of sufficient volumes as well as material of suitable quality.

- A laboratory testing programme, mainly focussing on the suitability of the various construction materials.

- An assessment of the seismic hazard.

If the Zalu site is favoured it is recommended that further investigation of construction materials be conducted, in order to prove the availability of sufficient volumes of suitable material. This would include the potential hard rock quarry site as well as the previously-investigated borrow areas. Laboratory testing of the construction materials would also be required.

10. REFERENCES

Davis, GN. 1999. Eastern Pondoland Basin Study: Zalu, Lusikisiki, Xura, Lower Mzintlava and Tungwane Dam Sites. First Engineering Geological Reconnaissance Report. *Council for Geoscience report 1999-0133*. Unpublished.

Hill Kaplan Scott. 1979. Lusikisiki Water Supply. Zalu Dam Site. Detailed Geological and Materials Investigation. *Unpublished report to Transkei Government*.

Karpeta, WP & Johnson, MR. 1978. The Geology of the Umtata Sheet. Explanation, Sheet 3128. *Geol. Surv. S. Afr.*

11. DATA APPENDIX

Topo–cadastral maps - 1:50 000 (Surveyor General)
3129 AD Sihlito sheet
3129 BC Lusikisiki sheet

Geological maps - published (Council for Geoscience)
1:250 000 3128 Umtata Sheet

Geological maps - unpublished 1:50 000 (Council for Geoscience)
3129 AD Sihlito sheet
3129 BC Lusikisiki sheet

Seismic hazard maps for southern Africa (Council for Geoscience)

Aerial photography (DWAF)
DWAF Job W555, scale 1:8000, flown May / June 2000.
Strip 1, photographs 3 - 7
Strip 2, photographs 376 - 380

APPENDIX 1

PHOTOGRAPHS



Plate 1: A general view of the proposed Lusikisiki dam site, looking in a downstream direction. The marked asymmetry of the centre- line is apparent, with the left flank significantly steeper than the right.



Plate 2: The left flank at the proposed Lusikisiki dam site. River flow is from left to right. The position of BH 1001 is indicated, while bakkie (circle) provided a sense of scale. The steeper slopes are ascribed to the intrusion of a dolerite sill. Exploratory drilling for a quarry upstream of the proposed centre-line revealed the dolerite to occur at significant depths, and therefore the unsuitability of this indicated quarry site.



Plate 3: Scattered outcrop of dolerite bedrock is evident within the river section, with patchy, poorly developed unconsolidated alluvial deposits. The sub-vertical joints which strike roughly parallel to the river are the most prominent discontinuities. The joints are closely spaced but are typically tight. Even for a concrete structure only minimal excavation will be required within the river section, and will mainly be limited to the removal of rock pinnacles.



Plate 4: The gently sloping right flank at the proposed Lusikisiki dam site. Borehole positions are indicated; BH 1003 is located at the tent while the drilling machine stands at BH 1004. The natural slopes which define the proposed basin are mainly very gently sloping and concerns regarding stability are therefore not an issue.

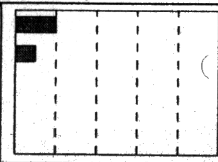
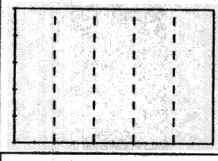
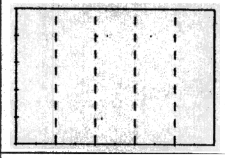
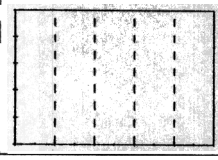


Plate 5: A view of the abandoned quarry located approximately 7km north-west of the proposed Lusikisiki dam site. The thickness of usable dolerite is estimated at more than 50 m, while overburden thickness is minimal. At this stage, this abandoned quarry represents the most promising source of coarse aggregate and rip-rap.

APPENDIX 2

WATER PRESSURE TEST DATA

BH 1001 LUSIKISIKI DAM SITE

Test No	Depth (m)	Test section (m)	Duration (min)	Pressure (kPa)	Water loss (l)	Lugeon	Lugeon pattern	Remarks & lugeon value
i	11,95 - 14,95	3	10	130	7	2		
ii		3	10	230	4			0
iii		3	10	330	0	0		
iv		3	10	230	0	0		no flow
v		3	10	130	0	0		
	14,88 - 17,88			160				
				280				0
				395				
				280				no flow
				160				
	17,88 - 20,88			180				
ii				320				0
iii				450				
iv				320				no flow
v				180				
	20,76 - 23,76			215				
ii				370				0
iii				530				
iv				370				no flow
v				215				

BH 1002 LUSIKISIKI DAM SITE

Test No	Depth (m)	Test section (m)	Duration (min)	Pressure (kPa)	Water loss (l)	Lugeon	Lugeon pattern	Remarks & lugeon value
i	5,87 - 8,64	2.77	10	75	?			
ii		2.77	10	135	?			?
iii		2.77	10	190	?			
iv		2.77	10	135	?			water leak
v		2.77	10	75	?			past packer
i	8,64 - 11,54	2.9	10	105	15	5		
ii		2.9	10	180	25	5		
iii		2.9	10	260	40	5		
iv		2.9	10	180	17	3		laminar flow /
v		2.9	10	105	24	8		wash out
	11,54 - 14,54							
ii								
iv								laminar flow
v								
	14,54 - 17,54							
ii								
iii								
iv								turbulent ?
v								
	17,54 - 20,34							
ii								13
iii								
iv								turbulent
v								flow
	20,34 - 23,20							
ii								
iii								
iv								laminar flow
v								
	23,20 - 26,16							
iii								
iv								laminar flow
v								
	26,16 - 29,12							
ii								
iii								
iv								laminar flow
v								
	29,12 - 32,08							
ii								2
iii								
iv								laminar flow
v								
	32,08 - 35,04							
ii								
iv								laminar flow
v								
	35,04 - 38,00							
ii								2
iii								
iv								laminar flow
v								
	38,00 - 40,95							
ii								
iii								
iv								laminar flow
v								
	40,95 - 43,91							
ii								1
iii								
iv								laminar flow
v								
	43,91 - 45,97							
								2
								laminar flow

APPENDIX 3

BOREHOLE CO-ORDINATES

COORDINATE LIST

PROPOSED LUSIKISIKI DAM SITE- BOREHOLES

CO-ORDINATE SYSTEM LO.29° HEIGHTS BASED ON T15(Degree Square 3129)					
Borehole Name	Co-ordinates		Heights above mean sea level		
	Y	X	Top Pipe	Concrete	Soil
BH1001	-49492.05	3466517.84	559.22	559.08	558.99
BH1002	-49440.78	3466541.89	534.59	534.38	
BH1003					
BH1004					
BH3001					
BH3002					
BH3003					

APPENDIX 4

BOREHOLE LOGS

HOLE No: BH 1003
Sheet 1 of 2

JOB NUMBER: 000

ROCK TYPE
MA - massive
MB - massive
FG - fg/med
CL - clay rich
SH - schistose
CV - convoluted
CA - laminated

DRAW SIZE
RG-fine grained
MG-medium grained
CG-coarse grain

JOINT SPACING
VC - very close spacing < 63mm
C - close spacing 63mm - 200mm
M - medium spacing 200mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing > 3m

WEATHERING
100% - strong Completely weathered
75% - strong Highly weathered
50% - strong Moderately weathered
25% - strong Slightly weathered
W - strong Unweathered
Note: e.g. = slight discolouration

JOINT FILLING
CL - clay
SI - silt/sand
CC - washboard rock
NR - not recovered
O - other

JOINT ROUGHNESS
SL - slickensided
S - smooth
R - rough
VR - very rough
I - light
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI DAM SITE

HOLE No: BH 1003
Sheet 2 of 2

JOB NUMBER: 000

REDUCED LEVEL	CORE RUN DEPTH m	% WATER RECOVERED	% CORE RECOVERED	% RQD	JOINT FREQ	WATER ACCESS TANCE (open/ closed)	ROCK TYPE AND COLOUR	FABRIC WIDTH (mm)	FABRIC SPACING mm	JOINT WIDTH (mm)	JOINT SPACING mm	JOINT ROUGHNESS	JOINT FILL (mm)	WEATHERING	DEPTH Scale 1:100
548	0,6	100	0	0	-	-	-	-	-	-	-	-			
547	1,2	100	0	0	-	-	-	-	-	-	-	-			
547	1,8	97	0	0											
546	3,3	73	0	0											
545															
544	6,26	80	0	0	?	?	?	?	?	?					
543															
542															
541	9,26	80	0	0											
540					20+		MA FG-MG	-	-	0-10 60-70 90	R C? ?	S; R R/S	S; S;		
539															
538	12,24	82	20	0	-		? MG	?	?	? 80-90 40	? ? ?	? R R	? S; S;		
537															
536					20+	NO TEST									
535	15,27	100	83	30	20+										
534					14										
533					6		MA FG	-	-	0-10 80-90	C ?	R/S R/S	S; S;,W		
532	18,11	100	93	62	4										
531					20+										
530					20+										
529	21,06	100	100	22	20+										
528					20+										
527					14								OCC.		

Scale 1:100

0.00	Dark brown, CLAYEY TOPSOIL with ROOTS.	
0.60	Reddish brown CLAY.	REMARKS: Colluvial soil possibly reworked residual dolerite soil.
1.40	Completely / highly weathered dolerite.	REMARKS: Sample recovered as brown, silty to medium sand with minor clay due to fabric of friable rock mass being destroyed by drilling action. Recovered sample therefore not representative of in situ conditions.
7.35	Highly to completely weathered, very closely jointed, medium hard rock to soft rock, grey to brown, medium to fine grained DOLERITE.	REMARKS: Sample mainly recovered as coarse gravel (diameter 10 - 30 mm). In situ rock mass expected to be less broken - recovered sample therefore not truly representative of in situ conditions (broken appearance at least partly ascribed to drilling process).
10.00	AS ABOVE, ie highly to completely weathered DOLERITE.	REMARKS: Recovered as SILTY TO FINE SAND (ie. in situ rock fabric destroyed by drilling action).
11.60	Highly to completely weathered, very closely to closely jointed (spacing typically <20 mm up to 100 mm), medium hard rock to soft rock, grey, medium to fine grained DOLERITE (AS ABOVE).	REMARKS: The more disturbed areas are, at least partly, ascribed to drilling action.
17.45	Slightly to moderately weathered, closely to medium jointed (spacing generally 200 mm), becoming very closely jointed from 17,6 m (spacing <50 - 100 mm), light grey, very hard rock, fine grained DOLERITE.	REMARKS: Very fine grained near lower contact. Lower contact very broken, not readily defined(extremely fine grained dolerite being similar in the indurated structure). Joints stained, sub-vertical set contains fill with thickness 2 - 3 mm.
19.50		

HOLE No. BH 1003
Sheet 2 of 2

JOB NUMBER: 000

CORE SAMPLE
MA - massive
BE - bedded
FO - faulted
CL - calcined
SH - schistose
GN - gneissose
AA - amygdoloid

GRAIN SIZE
FG-fine grained
MG-medium grain
CG-coarse grain

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 200mm
M - medium spacing 200mm - 1000mm
A - wide spacing 1 - 2m
VW - very wide spacing > 2m

WEATHERING
100% strong Completely weathered
75% strong Highly weathered
50% strong Moderately weathered
25% strong Slightly weathered
0% strong Unweathered
Hatching = soft / unconsolidated

JOINT FILLING
CY - clay
Sr - stained
W - weathered rock
MF - cal mineral
O - other

JOINT ROUGHNESS
SL - Slickensided
S - smooth
R - rough
VR - very rough
P - plain
W - wavy

| HOLE No. BH 1003 Sheet 2 of 2 | | |

HOLE No. BH 1004
Sheet 1 of 1

JOB NUMBER: 000

ROCK FABRIC
MA - massive
BE - bedded
LA - laminated
CL - cleaved
SH - schistose
GN - gneissose
FA - foliated

GRAIN SIZE
FG - fine grained
MG - medium grain
CG - coarse grain

JOINT SPACING
VC - very close spacing < 50mm
C - close spacing 50mm - 250mm
M - medium spacing 250mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing > 3m

WEATHERING
FRSH - fresh
SW - slightly weathered
MW - moderately weathered
HW - highly weathered
CW - completely weathered
RS - residual soil
Reliability: 1 = low / uncontrolled

JOINT FILLING
CL - clay
SI - silt/mud
W - weathered rock
NF - not recorded
Q - quartz

JOINT ROUGHNESS
SM - slickensided
S - smooth
R - rough
VR - very rough
P - polished
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI DAM SITE

HOLE No. BH 1004
Sheet 1 of 1

JOB NUMBER: 000

RECOVERED LEVEL	CORE RUN DEPTH (m)	% MATERIAL RECOVERED	% CORE RECOVERED	% RQD	WEATHERING ACCEPTANCE (open)	MAIN FABRIC AND INFILLING	FABRIC SPACING (mm)	FABRIC INCLINATION (deg)	JOINT SPACING (mm)	JOINT INCLINATION (deg)	JOINT ROUGHNESS	JOINT FILLING	WEATHERING GRADE	DEPTH Scale 1:100
556	0,60	75	0	0	-	-	-	-	-	-	-			
555	1,20	67	0	0										
554	1,72	96	0	0										
553	3,22	93	0	0										
552					-	-	-	-	-	-	-			
551	6,22	?	0	0										
550					NO TEST	-	-	-	-	-	-	-		
549														
548	9,22	59	0	0										
547					-	-	-	-	-	-	-			
546														
545	12,20	82	0	0										
					MA	-	-	1	1	1	1			

0.00	Brown to dark brown, SILTY TOPSOIL with ROOTS.	
0.60	Reddish brown, CLAYEY SILT.	REMARKS: Colluvial soil possibly comprising reworked residual soils derived from dolerite. Actual horizon thickness uncertain (poor core loss 3,22 - 6.0 m).
6.00	Ochre to reddish- / pinkish - brown, CLAY.	REMARKS: Possible reworked residual or residual dolerite soils. Horizon thickness possibly thicker (upper boundary uncertain, poor core loss).
6.99	Ochre CLAYEY to GRAVELLY - / SANDY SILT.	REMARKS: Horizon presumably comprises completely weathered, soft rock (friable) dolerite (ie samples not entirely representative of in situ conditions - due to drilling action).
11.05	Highly to moderately weathered, very closely jointed / completely fractured (joint spacing <50 mm), grey to brown, medium hard to soft rock DOLERITE.	REMARKS: Sample recovered as gravel - not likely entirely representative of in situ conditions (more disturbed / broken as result of drilling action). Note hole was collapsing and not all material was recovered.
12.20	END OF HOLE.	

NOTES

1) Borehole stopped at depth 12,20 m.

2) Water pressure tests not possible.

3) Foundation considerations: No suitable founding level for concrete dam at depths shallower than 12,2 m. Assume embankment cut-off a minimum 3 m into (note uncertainty because of core loss).

CONTRACTOR: DWAF
MACHINE: SECO 12
LOGGED BY: W Hlongwane
PROFILED BY: GD
TYPE SET BY: MP
SETUP FILE: GEOSURVE.SET

INCLINATION: 90DEG
DRAW: ROTARY DIAMOND, NX
DATE: 23/8/2000
DATE: 22/08/2000
DATE: 12/10/00 10:38
TEST: ordinary (USA) 2.737

ELEVATION: 556.26
X-COORD: = 3 499 647.28
Y-COORD: - 49 306.96

HOLE No. BH 1004

WATSOFT 3022 - 18/10/00

HOLE No. BH 3001
Sheet 1 of 2

JOB NUMBER: 000

ROCK FABRIC
MA - massive
BE - bedded
FO - foliated
CA - cavernous
SH - sheared
GN - gneissose
LA - laminated

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 200mm
M - medium spacing 200mm - 600mm
W - wide spacing 600mm - 2000mm
VW - very wide spacing > 2m

WEATHERING
100% shading Completely weathered
75% shading Highly weathered
50% shading Moderately weathered
25% shading Slightly weathered
0% shading Unweathered
Hatching = soil / decomposed rock

JOINT ACTING
CL - clay
SI - stained
VR - weathered rock
NO - not recorded
O - open

JOINT ROUGHNESS
SL - slickensided
S - smooth
R - rough
VR - very rough
F - flat
W - wavy

GRAIN SIZE
FG fine grained
MG medium grained
CG coarse grained

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No. BH 3001
Sheet 1 of 2

JOB NUMBER: 000

RUN	% RECOVERY	% CORE RECOVERY	% RQD	JOINT SPACING	WATER STRIKE RANGE (cm)	ROCK STRENGTH AND GRAIN SIZE	FABRIC WEIGHT (deg)	FABRIC SPACING (cm)	JOINT WEIGHT (deg)	JOINT SYSTEM	JOINT ROUGHNESS	JOINT FILL (mm)	WEATHERING	DEPTH Scale 1:100
0,73	96	3	0	-										
1,44	77	30	0			MA-BE FG	0	2-9	0-10 90	VC ?	S-R S	SI,W SI		
2,96	95	95	7	20+										
5,96	100	100	39	17										
				18										
				8		MA-BE FG	0 -	2-9 -	0-10 90	VC-C ?	S-R VR	SOIL, SI SI		
8,92	99	99	86	5										
				12										
				8										
				15										
11,92	99	99	46	13										
				14										
				6										
14,91	99	99	80	2	NO TEST	MA-BE	0	5	0-10 90	VC-M ?	S/R S/R	- CI film		
				11										
				15										
17,80	99	99	68	5										
				5										
				11										
20,87	100	100	83	4										
				3										
				5										

Scale 1:100

0.00 Grey, SILTY TOPSOIL with ROOTS.

0.70 Highly to completely weathered, very closely jointed, pinkish to reddish brown, soft rock to hard rock SILTSTONE.

REMARKS: Mean block size (i.e. joint spacing) < 50 mm.

2.94 Slightly to moderately weathered, very closely to closely jointed (joint spacing <50 mm to 300 mm), dark grey to brown hard rock SILTSTONE with minor interbedded sandstone laminations (width up to 50 mm).

8.40 Unweathered to slightly weathered, very closely to medium jointed (spacing <50 mm up to 450 mm, occasionally 1 m), dark grey, hard rock SILTSTONE.

15.25

HOLE No: BH 3001
Sheet 2 of 2

JOB NUMBER: 000

ROCK FABRIC
MA -massive
BE -bedded
FO -foliated
CL -cleaved
SH -schistose
GN -gneissose
CA -laminated

GRAIN SIZE
FG-fine grained
MG-medium grain
CG-coarse grain

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 300mm
M - medium spacing 300mm - 1000mm
W - wide spacing 1 - 3m
VW -very wide spacing > 3m

WEATHERING
100% showing Chemically weathered
75% showing Highly weathered
50% showing Moderately weathered
25% showing Slightly weathered
0% showing Unweathered
Residual = soil / uncon.sediment

JOINT FILLING
CL - clay
SI - silt/sand
W - weathered rock
NO - not recovered
O - other

JOINT ROUGHNESS
SM - smooth
P - planar
R - rough
UN - undulating
S - slick
V - veiny

DEPTH	RUN	% RECOV	% FRAG	% SOIL	JOINT FREQ	JOINT ROUGH	ROCK FABRIC AND GRAIN SIZE	FABRIC ANGLE	JOINT ANGLE	JOINT WIDTH	JOINT SHAPE	JOINT ROUGH	JOINT FILL	WEATH GRADE
	(m)													
541	23,79	100	100	97	5		MA	-	-	0-10	C-W	S	-	
540					1									
539					1									
538	26,78	100	100	97	0									
537					1									
	27,01	100	100	100										

Unweathered, closely to widely jointed (spacing 70 mm to > 1 m), light grey, medium to fine grained, extremely hard rock DOLERITE.

REMARKS: Sub-horizontal dolerite-siltstone contact open.

No dark disseminated minerals identified.

END OF HOLE.

NOTES

1) Quarrying considerations: Dolerite assumed suitable for manufacture of aggregate, but overburden depth excessive (>19 m). Siltstone considered unsuitable.

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No: BH 3001
Sheet 2 of 2

JOB NUMBER: 000

DRILLED LEVEL

DEPTH Scale 1:100

CONTRACTOR : DWAF
MACHINE : SECO 12
LOGGED BY : HD Leingoana
PLOTTED BY : GD

TYPE SET BY : JP
SETUP FILE : GEOSERVE.STP

DRILLING FOR : 90DEG
DRAM : ROTARY DIAMOND, NX
DATE : 26/07 - 03/08/2000
DATE : 21/08/2000

DATE : 17/10/00 12:28
TEXT : B:\metric\BH3001.TXT

ELEVATION : 563.60
X COORD : + 3 465 428.68
Y COORD : - 49 180.02

HOLE No: BH 3001

HOLE No: BH 2002
Sheet 1 of 2

JOB NUMBER: 000

ROCK FABRIC
MA - massive
BE - bedded
FO - foliated
CL - sheared
SH - schistose
GN - gneissose
FA - weathered

GRAIN SIZE
FG-fine grained
MG-medium grain
CG-coarse grain

JOINT SPACING
VC - very close (spacing < 63mm)
C - close spacing 63mm - 200mm
M - medium spacing 200mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing > 3m

WEATHERING
100% showing Completely weathered
75% - exciting Highly weathered
50% - exciting Moderately weathered
25% - exciting Slightly weathered
0% - exciting Unweathered
(enriched = low / mineralisated)

JOINT FILLING
CL - clay
SI - silt filled
VR - veins/hard rock
NR - not recovered
O - other

JOINT ROUGHNESS
SM - slickensided
S - smooth
R - rough
VR - very rough
P - flat
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No: BH 2002
Sheet 1 of 2

JOB NUMBER: 000

RUN DEPTH	% RECOVERED	% CORE RECOVERED	% RQD	JOINT FREQ.	ROCK FABRIC AND GRAIN SIZE	FABRIC WIDTH mm	FABRIC SPACING mm	JOINT WIDTH mm	JOINT SPACING mm	JOINT ROUGHNESS	JOINT FILL mm	JOINT FORM	DEPTH Scale 1:100
0.80	81	0	0										
1.60	88	0	0										
2.23	87	0	0										
2.83	70	0	0										
3.40	93	0	0										
6.38	20	1	0										
9.24	55	55	22	10+	MA BE FG FG	0	2-?	0-10 90 20	VC-C ? W	S/R R S	SI SI occ calcite		
12.10	98	99	43	16 10 9									
15.26	99	99	66	20+ 16 17									
18.00	98	94	55	6 9 6									
19.71	100	100	81	4 8 5									
21.28	95	99	99	4 1									

Scale 1:100

0.00	Grey SILTY TOPSOIL with ROOTS	
0.15	Reddish brown NODULAR FERRICRETE.	REMARKS: Pedogenic origin indicating fluctuating water table.
1.10	Grey to brown SILT.	REMARKS: Transported soil (hillwash), derived from completely weathered siltstone.
3.27	Reddish to grey, weathered, rounded SILTSTONE GRAVEL in clay matrix.	REMARKS: Transported material - possible indicating a paleo- channel Note core loss.
7.50	Moderately to highly weathered, very closely to closely jointed (joint spacing < 50 mm - 150 mm), dark grey to brown, hard rock to medium hard rock SILTSTONE.	
16.50	Unweathered to slightly weathered, jointing closely to medium, occasionally very closely to widely, dark grey, hard rock SILTSTONE. (rock size generally 250 mm - 40 mm, occasionally < 50 mm).	

HOLE No. BH 3002
Sheet 2 of 2

JOB NUMBER: 000

ROCK LABLING
MA - massive
BE - bedded
FO - foliated
LI - layered
SH - schistose
GN - gneissose
EA - structured

DRAW SIZE
FG fine grained
MG medium grain
CG coarse grain

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 200mm
M - medium spacing 200mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing > 3m

WEATHERING
FR 0% shading Completely weathered
25% shading Highly weathered
50% shading Moderately weathered
75% shading Slightly weathered
no shading Unweathered
Banding = soil / unconsolidated

JOINT INFILL
CL - clay
SI - silt/sand
W - weathered rock
GR - rock fragments
O - other

JOINT ROUGHNESS
SL - slickensided
S - smooth
R - rough
VR - very rough
I - ripple
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No. BH 3002
Sheet 2 of 2

JOB NUMBER: 000

REDUCED LEVEL	DEPTH	SAMPLE No.	% SOIL/ RUBBLE/ CORE LOSS	% GRAVEL/ ALTER/ WEAK	% CORE RECOV./ INTACT	% RQD	JOINT FREQ. /m	ROCK FABRIC AND GRAIN SIZE	FABRIC ANGLE deg	FABRIC SHAPE ANG. deg	JOINT ANGLE deg	JOINT SHAPE ANG. deg	JOINT ROUGH-NESS	JOINT FILL	WEATH-ERING
548			24.20	99	89	91	6								
547							3								
546			27.10	100	100	94	3								
545							4								
544							3								
543			29.89	99	99	99	2								
542							2								
							3								

22
23
24
25
26
27
28
29
29.89

END OF HOLE

NOTES

1) Quarrying considerations: No dolerite intersected (shallower than 29,89 m). Siltstone unsuitable for crushing.

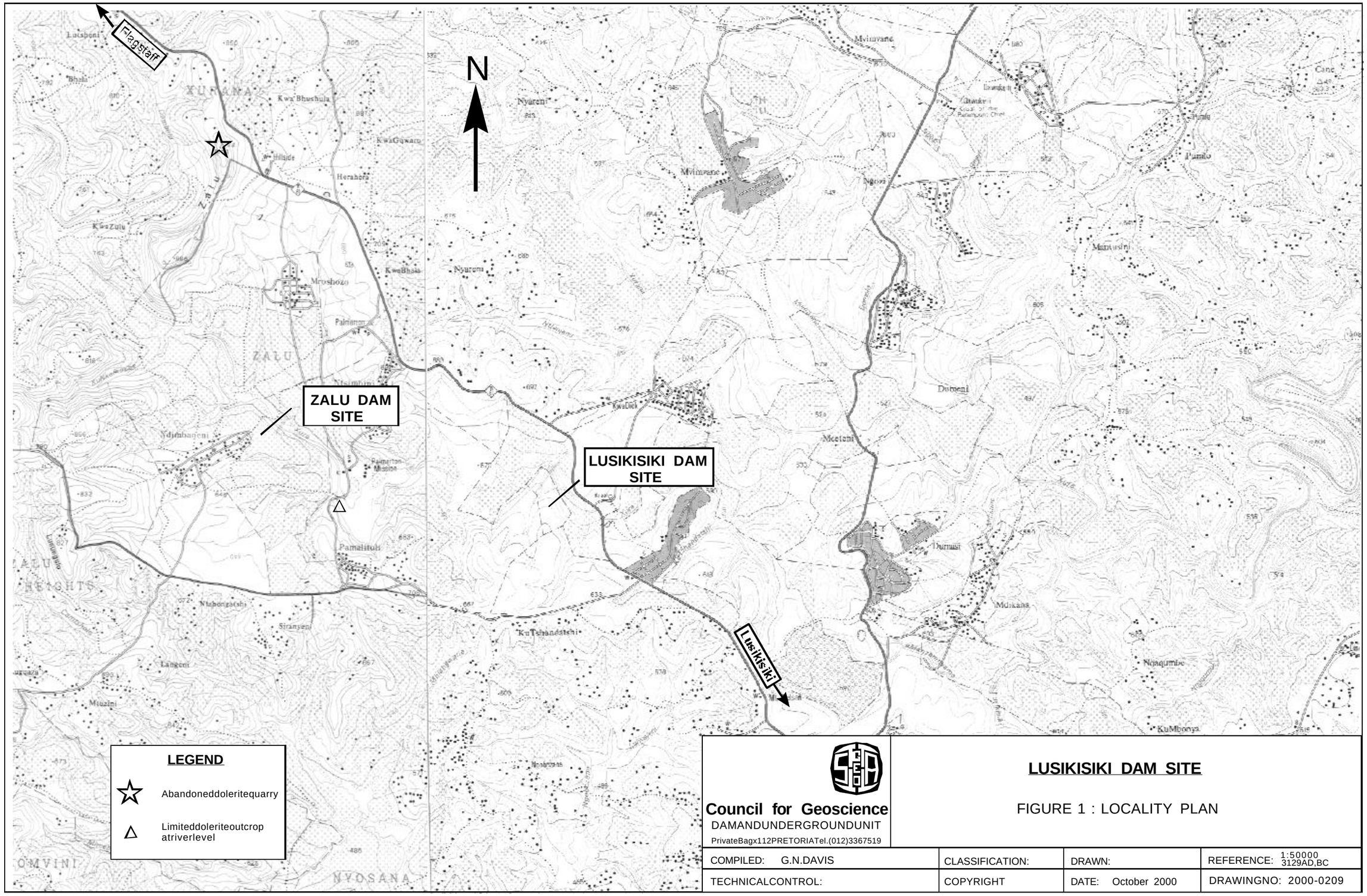
CONTRACTOR : DWAF
MACHINE : SECO T2
DRILLED BY : HD Leligoana
LOGGED BY : GD
LOGGING METHOD : CORE

INCLINATION : 90DEG
DIAM. : ROTARY DIAMOND, NX
DATE : 19 - 2 - 07/2000
DATE : 21/08/2000
DATE : (LOGGED ON)
FILE : G:\geotech\BH3002.TXT

ELEVATION : 571.33
X-COORD : - 3 466 314.83
Y-COORD : - 49 143.71

HOLE No. BH 3002

REVISED 2002 JBW No.



Council for Geoscience
DAMANDUNDERGROUNDUNIT
PrivateBagx112PRETORIATel.(012)3367519

LUSIKISIKI DAM SITE

FIGURE 1 : LOCALITY PLAN

COMPILED: G.N.DAVIS	CLASSIFICATION:	DRAWN:	REFERENCE: 1:50000 3129AD,BC
TECHNICALCONTROL:	COPYRIGHT	DATE: October 2000	DRAWINGNO: 2000-0209

HOLE No. BH 3003
Sheet 1 of 2

JOB NUMBER: 000

ROCK FABRIC
MA -massive
BE -bedded
FO -foliated
CL -jointed
SH -shattered
CM -cemented
CA -laminated

JOINT SPACING
VC - very close spacing < 60mm
C - close spacing 60mm - 200mm
M - medium spacing 200mm - 1000mm
W - wide spacing 1 - 3m
VW - very wide spacing >3m

WEATHERING
100% slightly Completely weathered
75% slightly Highly weathered
50% slightly Moderately weathered
25% slightly Slightly weathered
Nil slightly Unweathered
Residual - soil/consolidated

OPAM SIZE
FG-fine grained
MG-medium grain
CG-coarse grain

JOINT FILLING
CL - clay
SI - silt/sand
M - mechanical rock
(sp) - not recovered
C - calcite

JOINT ROUGHNESS
SL - slickensided
S - smooth
R - rough
VR - very rough
I - Infill
W - wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No. BH 3003
Sheet 1 of 2

JOB NUMBER: 000

RECOVERY RUN DEPTH (m)	% MATERIAL RECOVERED	% CORE RECOVERED	% RQD	JOINT FRAC. FREQ.	WATER ACCEPTANCE (l/min)	ROCK FABRIC AND GRAIN SIZE	WEATHERING (Main)	WEATHERING (Sec.)	JOINT SPACING (mm)	JOINT ROUGHNESS	JOINT FILLING	JOINT INCL. (mm)	WEATHERING	DEPTH Scale 1:100
0,7	100	0	0	-	-	-	-	-	-	-	-	-		
1,67	89	23	0	-	-	-	-	-	-	-	-	-		
2,88	83	83	60	13	-	MA-BE FG	0-10	2-	0-10 80-90	VC-C VC-?	R/S S	occ St St		
4,29	100	100	16	15										
				16										
5,85	100	100	30	14										
				7										
8,95	100	100	76	9										
				5										
				9										
11,78	100	100	67	9										
				6										
				5	NO TEST	MA-BE FG	0-10	2-2	0-10 20-30 80-90	VC-M VC W ?	S/R S/R R/S	occ. St St St		
14,74	100	100	73	10										
				7										
				5										
17,48	99	93	87	4										
				3										
				0										
20,48	98	98	56	16										
				3										
				3										

Scale 1:100

0.00 – 0.25	Grey, SILTY TOPSOIL with ROOTS.	
0.25 – 1.20	Pinkish brown NODULAR FERRICRETE.	REMARKS Pedogenic origin indicating fluctuating water table
1.20 – 4.30	Moderately to highly weathered, closely jointed, occasionally very closely (joint spacing generally 100 - 200 mm), grey to brown, hard to medium hard / soft rock SILTSTONE.	REMARKS. Note core loss.
4.30 – 19.25	Unweathered to slightly weathered, closely to medium jointed occasionally very closely, (joint spacing typically between 150 - 300 mm), dark grey, hard rock SILTSTONE. (Occasionally stained throughout).	REMARKS: Very broken zone above contact 18,85 - 15,4 m at least partly ascribed to drillers breaks.
19.25 –		

HOLE No: BH 3003
Sheet 2 of 2

JOB NUMBER: 000

ROCK FABRIC
MA: massive
BE: bedded
FO: foliated
CL: sheared
SH: schistose
GL: gneissose
LA: laminated

GRAIN SIZE
FG: fine grained
MG: medium grained
CG: coarse grained

JOINT SPACING
VC: very close spacing < 50mm
C: close spacing 50mm - 300mm
M: medium spacing 300mm - 1000mm
W: wide spacing 1 - 3m
VW: very wide spacing > 3m

WEATHERING
FRESH: showing Completely unaltered
SLIGHT: showing Slightly weathered
MOD: showing Moderately weathered
HIGH: showing Highly weathered
COMP: showing Completely weathered
RESIDUAL: showing Converted to soil / unconsolidated

JOINT ROUGHNESS
SL: slickensided
S: smooth
R: rough
VR: very rough
I: light
V: wavy

COUNCIL FOR GEOSCIENCE
Private Bag X112
Pretoria 0001
SOUTH AFRICA

DEPARTMENT OF WATER AFFAIRS & FORESTRY

LUSIKISIKI QUARRY SITE

HOLE No: BH 3003
Sheet 2 of 2

JOB NUMBER: 000

550	23,40	100	100	100	3		MA	-	-	0-10 60-70	M W?	R/S S	calcite up to 5 mm	
549					2									
548	25,13	100	100	96	4									

22														
23														
24														
25														
25,15														

Unweathered, medium jointed (joint spacing generally 300 - 791 mm), grey, extremely hard rock, medium to fine grained DOLERITE.

REMARKS: Contact sub-horizontal, open.

END OF HOLE.

NOTES

1) Quarry considerations: Siltstone unsuitable for crushing.

2) Dolerite very deep (25.1 m), ie overburden depths excessive.

RECEIVED LEVEL	DRILL RUN DEPTH (m)	% MATERIAL RECOVERED	% CORE RECOVERED	% RQD	JOINT FRAC. FREQ.	WATER ACCEPTANCE (Open)	ROCK FABRIC ANG. GRAIN SIZE	FABRIC SPACING (mm)	JOINT INCLIN. (deg)	JOINT SPACING (m)	JOINT ROUGHNESS	JOINT FILL (mm)	WEATHERING	DEPTH (from T-150)

CONTRACTOR: DWAF
MACHINE: SECO 12
DRILLED BY: HD Lelingoana
PROFILED BY: GD
TYPE SET BY: AP
DISPLAY FILE: GEOSERVE.SET

WELL HEAD: 90DEG
DIAM: ROTARY DIAMOND, NX
DATE: ID - 11/07/2000
DATE: 31/08/2000
DATE: VISUAL 02/06
TEXT: BH3003SRC.TXT

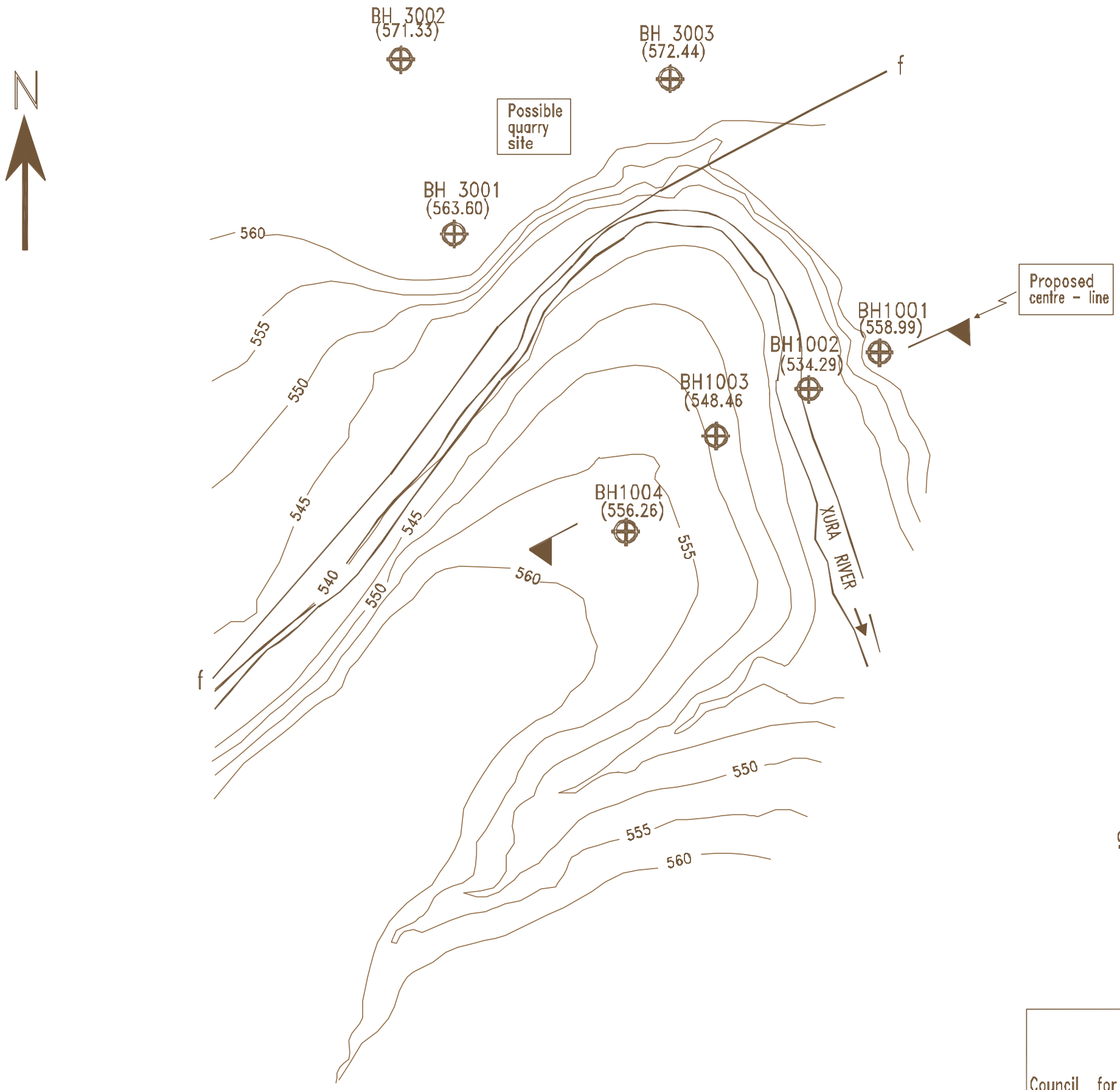
ELEVATION: 572.44
X-COORD: + 3 466 314.83
Y-COORD: - 49 339.56

HOLE No: BH 3003

COORDINATE LIST

PROPOSED LUSIKISIKI DAM SITE- BOREHOLES

CO-ORDINATE SYSTEM LO.29° HEIGHTS BASED ON T15(Degree Square 3129)					
Borehole Name	Co-ordinates		Heights above mean sea level		
	Y	X	Top Pipe	Concrete	Soil
BH1001	-49492.05	3466517.84	559.22	559.08	558.99
BH1002	-49440.78	3466541.89	534.59	534.38	534.29
BH1003	-49370.52	3466577.03	548.64	548.57	548.46
BH1004	-49306.96	3466647.28	556.39	556.33	556.26
BH3001	-49180.02	3466428.68	563.78	563.60	563.60
BH3002	-49143.71	3466303.73	571.59	571.37	571.33
BH3003	-49339.56	3466314.83	572.68	572.55	572.44



LEGEND

BH1002
(534.29)

Borehole position
with collar elevation (RL)

f Possible fault

0 50 100 150 200 250 m

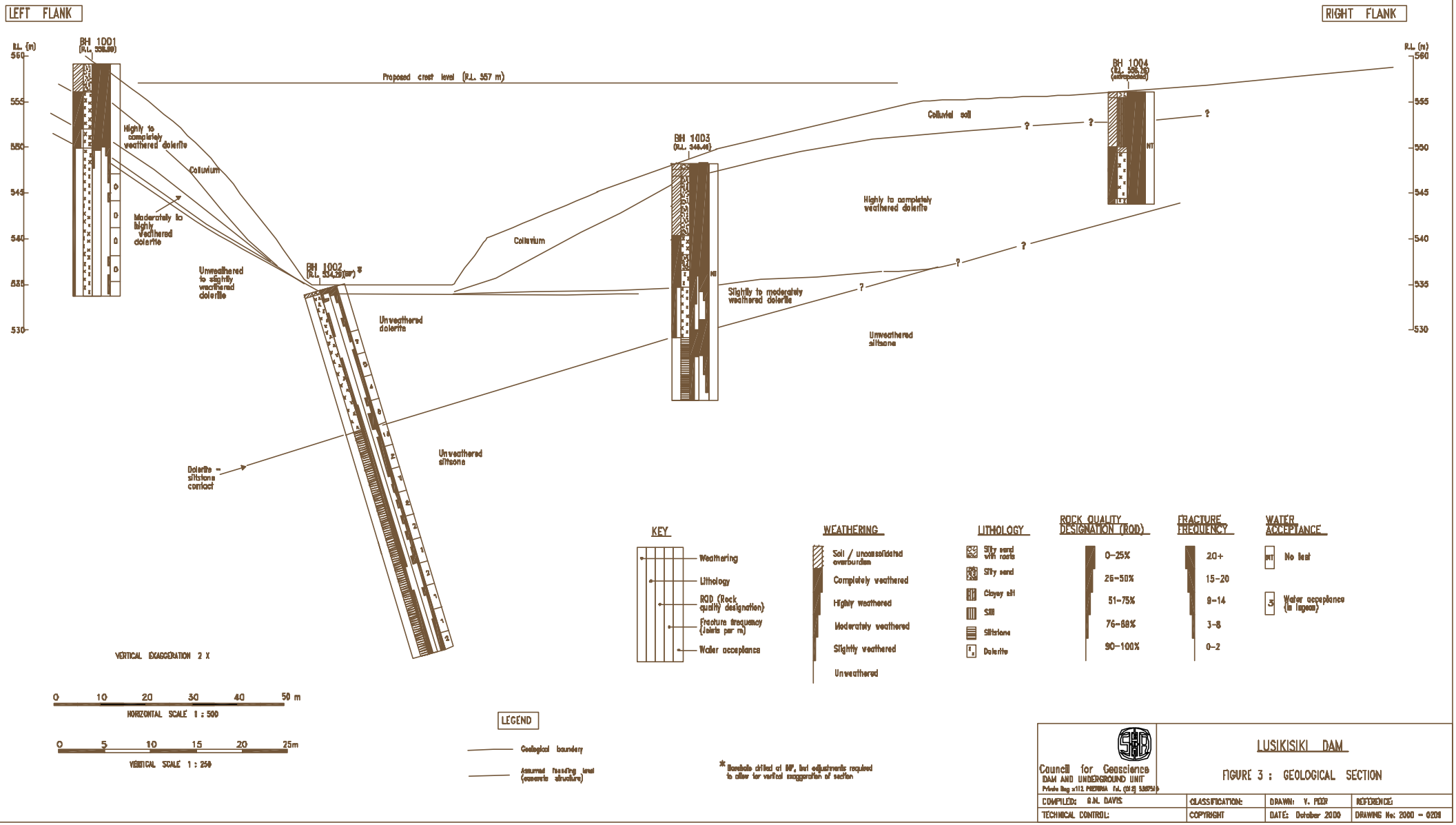
SCALE 1 : 2 500

Council for Geoscience
DAM AND UNDERGROUND UNIT
Private Bag x112 PRETORIA Tel. (012) 3367519

LUSIKISIKI DAM SITE

FIGURE 2 : SITE PLAN WITH BOREHOLE POSITIONS

COMPILED: G.N. DAVIS	CLASSIFICATION:	DRAWN: V. PEER	REFERENCE: DWAF
TECHNICAL CONTROL:	COPYRIGHT	DATE: October 2000	DRAWING NO : 2000 – 0209

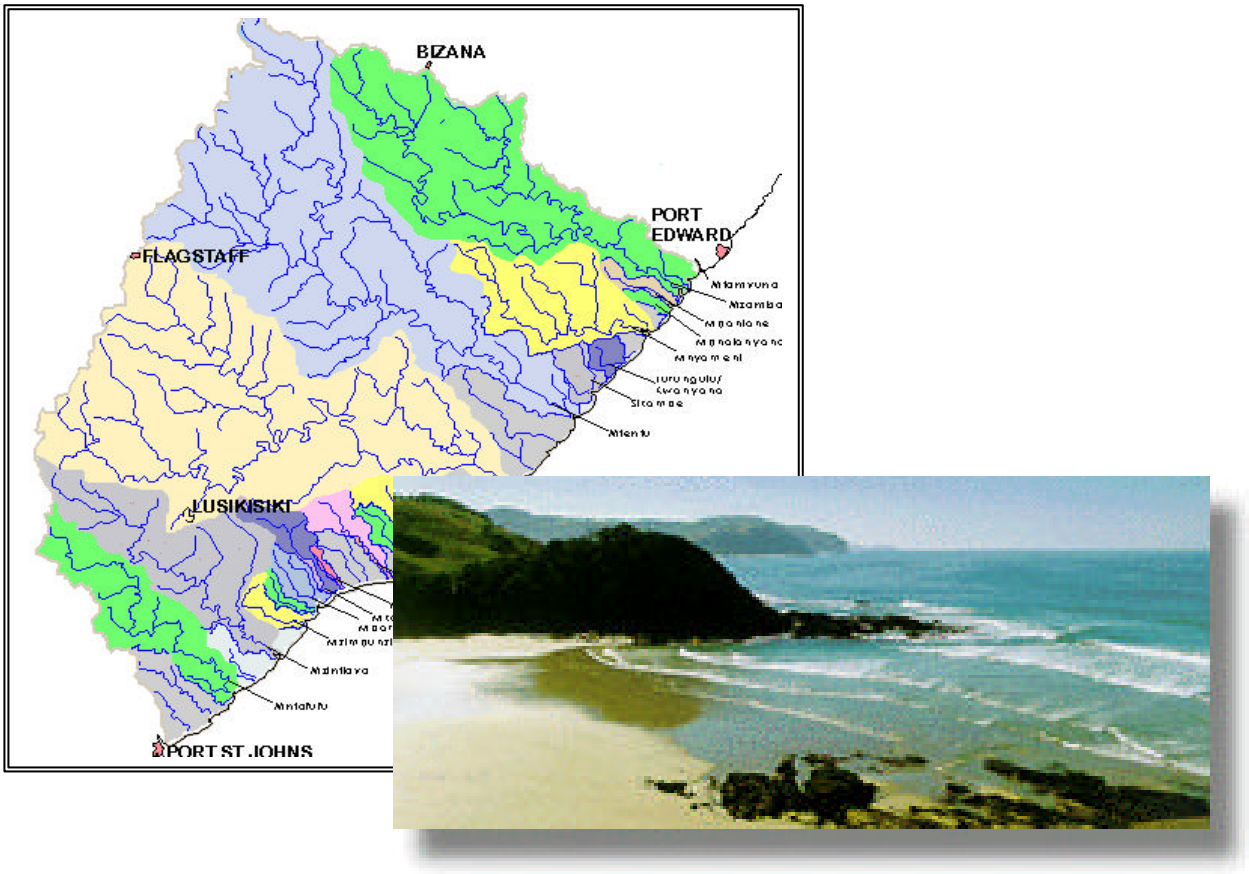

LEFT FLANK
RIGHT FLANK
R.L. (m)
560
555
550
545
540
535
530
BH 1001
(R.L. 558.89)
BH 1002
(R.L. 554.29(par))
BH 1003
(R.L. 548.46)
BH 1004
(R.L. 555.25)
(extrapolated)
Proposed crest level (R.L. 557 m)
Highly to completely weathered dolerite
Colluvium
Moderately to highly weathered dolerite
Unweathered to slightly weathered dolerite
Unweathered dolerite
Unweathered siltstone
Dolerite - siltstone contact
Colluvium
Slightly to moderately weathered dolerite
Highly to completely weathered dolerite
Colluvial soil
Unweathered siltstone
VERTICAL EXAGGERATION 2 X
0 10 20 30 40 50 m
HORIZONTAL SCALE 1 : 500
0 5 10 15 20 25m
VERTICAL SCALE 1 : 250
KEY
Weathering
Lithology
RQD (Rock quality designation)
Fracture frequency (Joints per m)
Water acceptance
WEATHERING
Soil / unconsolidated overburden
Completely weathered
Highly weathered
Moderately weathered
Slightly weathered
Unweathered
LITHOLOGY
Silty sand with roots
Silty sand
Clayey silt
Silt
Siltstone
Dolerite
ROCK QUALITY DESIGNATION (RQD)
0-25%
26-50%
51-75%
76-88%
90-100%
FRACTURE FREQUENCY
20+
15-20
9-14
3-8
0-2
WATER ACCEPTANCE
NT
No test
Water acceptance (in lugeon)
LEGEND
Geological boundary
Assumed bedding trend (concerns structure)
* Borehole drilled at 90°, but adjustments required to allow for vertical exaggeration of section
Council for Geoscience
DAM AND UNDERGROUND UNIT
LUSIKISIKI DAM
FIGURE 3 : GEOLOGICAL SECTION
COMPILED: G.N. DAVIS
CLASSIFICATION:
DRAWN: V. PEER
REFERENCE:
TECHNICAL CONTROL:
COPYRIGHT
DATE: October 2000
DRAWING No: 2000 - 0208

PB T600/00/1401

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



ENGINEERING GEOLOGICAL RECONNAISSANCE REPORT

Final

June 2001

Prepared By:

Council for Geoscience
Geological Survey
Private Bag X112, Pretoria, 0001

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Engineering Geological Reconnaissance Report
AUTHOR	**:**	G Davis
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-1401
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EXECUTIVE SUMMARY

This report presents the findings of *brief* reconnaissance - level engineering geological investigations conducted at the proposed Zalu, Lusikisiki, Xura, Lower Mzintlava and Tungwane dam sites in eastern Pondoland.

The area of interest is underlain by sedimentary strata, comprising Ecca Group mudrocks and Dwyka tillite, which have been intruded by younger dolerite dykes and sills.

Only the Zalu site has previously been investigated in some detail. Actual founding conditions at the alternative sites are therefore not known with complete certainty.

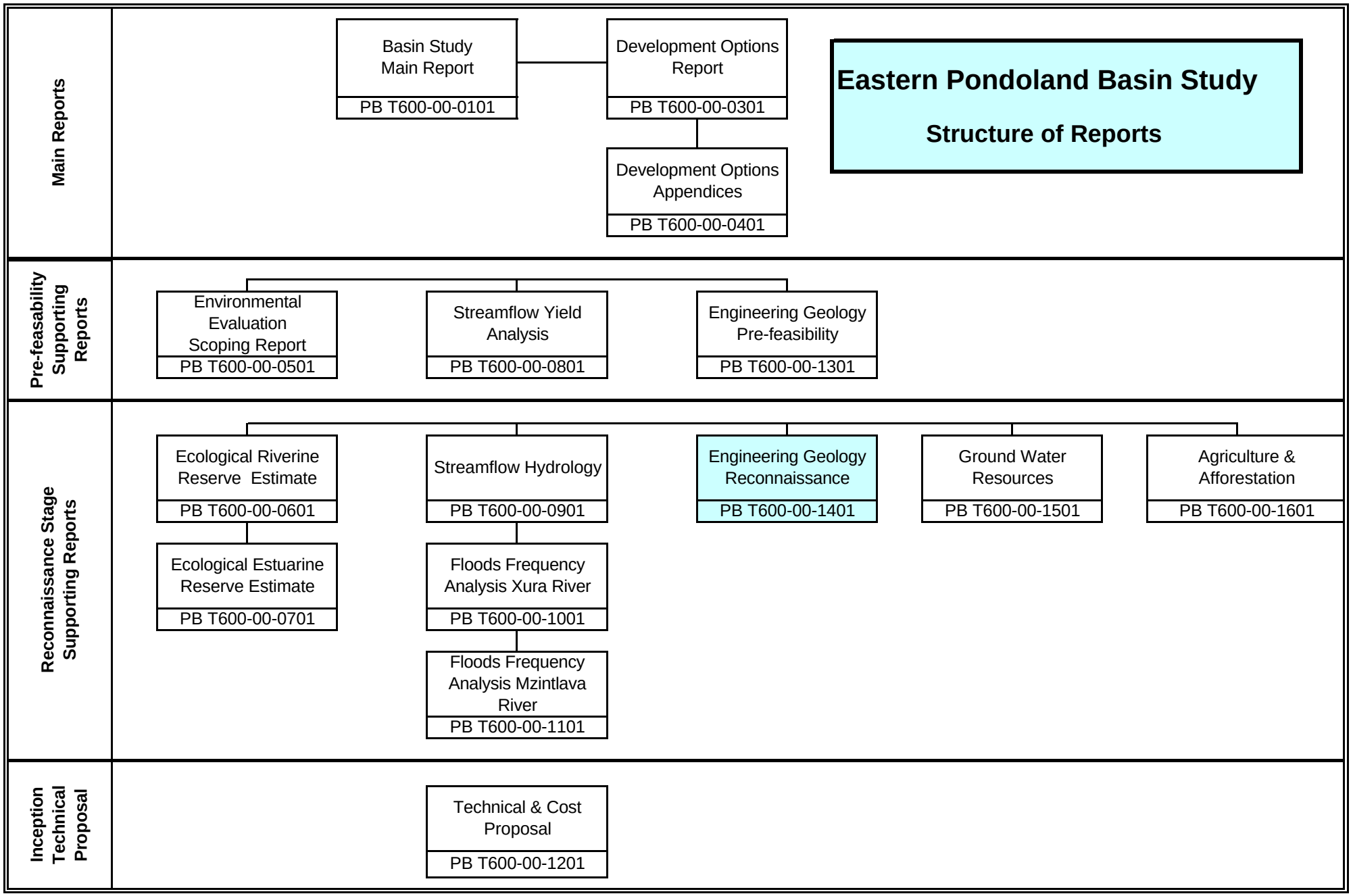
The Zalu site is mainly underlain by good quality dolerite. The upper flanks are however underlain by weathered siltstone. Similarly, a dolerite sill has intruded the siltstone at the Lusikisiki site but appears restricted to the river section and lower left flank. The Xura, Lower Mzintlava and Tungwane sites are all underlain by tillite. While unweathered bedrock is recognized within the river sections, to varying degrees, the flanks are presumably deeply weathered.

For each site the report considers the envisaged founding conditions, and dam type best suited to these. Likely excavation depths are also discussed; as are possible sources of construction materials.

An outline the more detailed site investigations which should follow, is presented.

Eastern Pondoland Basin Study

Structure of Reports



CONTENTS:

1. INTRODUCTION 1

2. GENERAL GEOLOGY 1

3. ZALU DAM SITE 2

3.1 Site geology
3.2 Engineering geological considerations
3.3 Construction materials

4. LUSIKISIKI DAM SITE 5

4.1 Site geology
4.2 Engineering geological considerations
4.3 Construction materials

5. XURA DAM SITE 7

5.1 Site geology
5.2 Engineering geological considerations
5.3 Construction materials

6. LOWER MZINTLAVA DAM SITE 9

6.1 Site geology
6.2 Engineering geological considerations
6.3 Construction materials

7. TUNGWANE DAM SITE 11

7.1 Site geology
7.2 Engineering geological considerations
7.3 Construction materials

8. CONCLUSIONS AND RECOMMENDATIONS 13

9. REFERENCES 17

10. DATA APPENDIX 17

TABLES:
Table 1: Likely dam sizes
Table 2: Summarized dam site characteristics

PLATES:
Plate 1: Zalu dam site
Plate 2: Lusikisiki dam site
Plate 3: Xura dam site
Plate 4: Lower Mzintlava dam site
Plate 5: Tungwane dam site

FIGURES:

Figure 1: Locality plan (Zalu, Lusikisiki & Xura sites)
Figure 2: Locality plan (Lower Mzintlava & Tungwane sites)
Figure 3: Zalu dam - site plan
Figure 4: Zalu dam - sketch geological section
Figure 5: Lusikisiki dam - site plan
Figure 6: Lusikisiki dam - sketch geological section
Figure 7: Xura dam - site plan
Figure 8: Xura dam - sketch geological section
Figure 9: Lower Mzintlava dam - site plan
Figure 10: Lower Mzintlava dam - sketch geological section
Figure 11: Tungwane dam - site plan
Figure 12: Tungwane dam - sketch geological section

	ZALU SITE	LUSIKISIKI SITE	XURA SITE	LOWER MZINTLAVA SITE	TUNGWANE SITE
Topography	Asymmetrical. Gently sloping left flank (1:7), steeper right flank (1:2,5). River section approximately 80 m wide.	Markedly asymmetrical. Left flank moderately steep (1:3), right flank generally very gently sloping (1:33). River section approximately 20 m wide	Roughly symmetrical. Left flank slightly steeper (1:2,5) than right (1:3). River section 30 - 35 m wide.	Asymmetrical. Left flank initially steep then flattens (1:1,5 bec. 1:2,5), right flank more gently sloping. River section 15 - 20 m wide.	Markedly asymmetrical. Left flank initially steep then flattens (1:1 bec 1:6), right flank gently sloping (1:18 steepening to 1:8). River section approximately 80 m wide.
Geology	Upper left flank underlain by weathered siltstone, mid- to lower slopes underlain by dolerite sill. Soil cover 2 - 5 m. Alluvium in river section 5 m thick, overlying unweathered dolerite sill with minimum thickness 35 m. Right flank underlain by unweathered dolerite. Soil cover up to 5 m thick.	Steeper left flank underlain by dolerite sill, flatter upper slopes underlain by weathered siltstone. Extensive dolerite outcrop in river section. Right flank underlain by siltstone, presumably deeply weathered. Soil cover assumed 5 m thickness.	Shallow soils on left flank grade into underlying deeply weathered tillite. Outcrop of unweathered tillite exposed in river section. Negligible alluvium. Colluvial soils on right flank possibly 2 - 5 m, underlain by deeply weathered tillite.	Tillite underlying left flank expect deeply weathered, but slightly weathered outcrop at base of slope. Colluvial soil cover assume 2 - 5 m. Scattered tillite outcrop in river section, patchy alluvium (up to 2 - 3 m assumed) On right flank assume colluvial soils (2 - 5 m) underlain by deeply weathered tillite.	Left flank expect deeply weathered tillite, but slightly weathered bedrock exposed at foot of slope. Soil cover assume 2 - 5 m thick. River section covered with alluvial boulders (2 - 5 m thick), presumably underlain by unweathered tillite. Assume tillite underlying right flank to be deeply weathered. Soil cover up to 5 - 8 m likely, thinning to 2 - 3 m.
Dam type	Max height envisaged 35 m. Crest length 320 m. Suitable founding for concrete gravity dam, or composite structure with embankment left flank and concrete river section and right flank.	Max height envisaged 40 m. Crest length 740 m. Embankment dam favoured, or composite structure with central concrete spillway and embankment flanks.	Max height envisaged 30 m. Crest length 200 m. Deep weathering on flanks favours embankment dam, or composite structure with central concrete spillway	Max height envisaged 39 m. Crest length 375 m. Deep weathering on flanks favours embankment dam. Central concrete section possible but width of river section limited.	Max height envisaged 50 m. Crest length 595 m. Deep weathering favours embankment dam, but central concrete spillway section also possible.
Likely excavation depths	For concrete structure, depths between 5 m on mid- to lower left flank, 3 - 4 m in river section, 1 - 4,5 m on right flank. Much deeper on upper flanks underlain by siltstone. Cut-off depth for embankment 2 - 5 m.	Concrete structure; depths between 0 - 2 m in river section, 2 - 5 m on lower left flank. Much deeper on right flank, upper left flank. Embankment cut-off; 2 - 3 m on left flank, 3 - 5 m on right flank.	Concrete structure; depths of 1 - 2 m in river section. Embankment cut-off; assume 2 - 3 m on left flank, 3 - 5 m on right. Negligible excavation within river section.	Embankment cut-off depths; assume 2 - 3 m on respective flanks, 2- 3 m in river section.	Embankment cut-off depths to vary between 2 - 3 m, possibly up to 5 - 8 m on lower right flank. Central concrete section; 2 - 5 m in river section, possibly up to 5 - 8 m on lower flanks.

Construction material availability	Possible dolerite body for coarse aggregate, rip-rap, crusher sand. Previous investigations considered clayey dolerite soils for impervious core, soils from siltstone / alluvium for transition zones.	Dolerite sill on left flank possible source of coarse aggregate, rip-rap, crusher sand. Other dolerites further afield. Embankment materials likely within basin.	Tillite cliffs upstream of centre-line are possible source of coarse aggregate / rip-rap / crusher sand, but deeply weathered. Embankment fill materials likely within basin.	Either tillite or dolerite possible source of coarse aggregate / rip-rap / crusher sand, but potential site not yet identified. Disused quarry close to site. Embankment fill materials expected within basin.	Potential sites for tillite quarry evident (coarse aggregate / rip-rap / crusher sand). Disused dolerite quarry. Embankment material sources expected within basin.

Table 2: Summarized dam site characteristics

1. INTRODUCTION

This report presents the findings of *brief* reconnaissance-level engineering geological investigations of possible dam sites identified in the vicinity of Lusikisiki in eastern Pondoland, conducted at the request of the Project Planning Directorate of the Department of Water Affairs and Forestry.

The broad aim of the Eastern Pondoland Basin Study is to investigate increasing the water supply to the general area of Lusikisiki. Five dam sites were subsequently identified by consultants UWP Engineers for further consideration. From these alternatives a favoured option or options will be selected for more detailed study. Note, an additional dam site (Upper Mzintlava) was also initially identified, but was discarded after a cursory examination. This site is therefore not discussed further.

The Zalu, Lusikisiki and Xura dam sites are all located on the Xura River (Figure 1), while the Lower Mzintlava and Tungwane dam sites are located on the Mzintlava River (Figure 2). Envisaged dam sizes are summarized below (Table 1).

SITE NAME	Maximum height envisaged	Crest length
Zalu	35 m	320 m
Lusikisiki	40 m	740 m
Xura	30 m	200 m
Mzintlava Lower	39 m	375 m
Tungwane	50 m	595 m

Table 1: Envisaged dam sizes

Of these dam sites, only the Zalu site had been investigated previously (Hill Kaplan Scott & Partners, 1979).

The sites were visited on 28 - 29 June 1999 by the author in the company of Messrs Behrmann, Druyts, Geldenhuys, Kroon, Stoffberg and Van der Walt, all of the Department of Water Affairs and Forestry, and Doudenski of UWP Engineers.

2. GENERAL GEOLOGY

The area of interest is underlain by sedimentary rocks belonging to the lower part of the Karoo Supergroup. A NE-trending line passing through Lusikisiki may be considered to divide the area

geologically; inland of this line mudrocks of the Ecca Group are found, while older tillite of the Dwyka Group occurs to the east of this. Further towards the coast the area is underlain sandstones of the Natal Group.

The entire sedimentary sequence of the Karoo Supergroup has been intruded by younger dolerite dykes and sills. Dykes are generally 3 - 10 m wide and several kilometres long (Karpeta & Johnson, 1979). A preferred NW orientation is recognized. Sill thickness varies from less than 1 m to more than 100 m. These sills are generally discordant, i.e. cutting across bedding. The intrusive dolerites may comprise up to 40 per cent of the sequence within the Ecca Group strata, but is considerably less within the tillite.

The geological structure in this inland area consists mainly of gently dipping strata. Dips vary between 1° - 3° to the north-west, although localized steep dips may be associated with the dolerite intrusions. No major regional scale faults are recognized within the area of interest.

There are no economically important mineral deposits within the area of interest.

3. ZALU DAM SITE

The Zalu dam site is located approximately 11 km, as the crow flies, north-west of Lusikisiki.

As mentioned above, this site was previously investigated in some detail; a total of 28 boreholes were drilled as well as a detailed soil survey of potential borrow areas including laboratory testing. What follows is therefore largely a summary of these earlier findings (Hill Kaplan Scott & Partners, 1979).

3.1 Site geology

The proposed site is asymmetrical; the left flank is relatively gently sloping (1:7), while the right flank is steeper (1:2,5). Above the envisaged dam crest level both slopes become flatter. The river section is approximately 80 m wide (Plate 1). River bed level is at R.L. 585; a maximum dam height of 35 m is envisaged here, suggesting a dam crest at R.L. 620.

The upper left flank is underlain by weathered, medium hard to soft rock siltstone (shale [1]). The soil cover here is approximately 2 m thick. The mid to lower flank is underlain by the dolerite sill. Colluvial soils derived from both dolerite and siltstone attain a thickness up to 5 m. The dolerite is essentially unweathered, although an upper weathered zone may be developed (thickness up

---

[1] The term ‘shale’ is not favoured in an engineering geological context. Shale typically describes fissile mudrocks, but fissility might be considered a weathering phenomenon which is not readily apparent in unweathered rock. Preferred is the term siltstone or mudstone, depending on the grain size, with further reference to the rock fabric (presence or absence of laminations)

to 2 - 5 m). The dolerite sill is essentially horizontal, dipping northwards at 2°, while the siltstone dips in a north-westerly direction at 7°.

The river section is covered with alluvium comprising sandy to clayey silt to a depth of 2 m, overlying a pebble or boulder horizon with a clayey silt matrix to a depth of 5 m. The underlying dolerite is generally unweathered. The lower sill contact was not intersected, implying a *minimum* sill thickness of 35 m underlying the river section.

The right flank is mainly underlain by unweathered dolerite. Only the extreme upper flank areas (above approximate R.L. 614) are underlain by weathered siltstone. Extensive dolerite outcrop is visible along the lower flank. The thickness of colluvial soil cover varies between 1and 5 m.

At least two prominent joint sets are recognized, both vertical; one set striking roughly parallel to the proposed centre-line while the other intersects this centre-line at an oblique angle. A minor fault was intersected on the upper left flank.

3.2 Engineering geological considerations

In terms of dam layout, previous investigations appear to have only considered an earth embankment. Considering the substantial thickness of the generally unweathered dolerite sill, the founding conditions might also be considered suitable for the founding of a concrete gravity structure. Alternatively, if the slightly deeper excavation required for a concrete structure is considered excessive on the upper left flank, a composite wall might be considered with an embankment left flank and concrete river section and right flank.

Spillway options for an embankment dam would include a side channel spillway excavated within the unweathered dolerite of the right flank, while a morning glory - type spillway with a conduit might be considered as an alternative. For river diversion during construction of an embankment a tunnel might be considered through the lower right flank, or a culvert / conduit. Obviously, a central spillway would be best suited for a concrete gravity structure.

Excavation depths for a concrete structure might be expected to vary between 5 m on the left flank underlain by dolerite, 3 - 4 m within the river section and 1 - 4,5 m on that portion of the right flank underlain by dolerite. On the upper left flank, underlain by soft to medium hard rock siltstone, excavation depths of 15 m will be necessary to ensure founding on the underlying dolerite. These upper flank areas may however be considered non-critical in terms of foundation loading, and the normally stringent foundation requirements for a concrete structure might be relaxed in these areas.

For an embankment dam, the cut-off within the river section should also extend to depths between 3 - 4 m, i.e. below the alluvial boulder horizon. On the left flank cut-off depths between 2 - 5 m may be assumed, while on the right flank depths between 1 - 4,5 m are expected. At this stage there is no reason to extend the cut-off to any great depth within the weathered siltstone horizon comprising soft to medium hard rock.

Results from limited water pressure tests conducted give an indication of foundation permeability. Tests were only possible within the dolerite, and generally indicated impervious founding conditions, although a high water loss was associated with the fault.

Slopes in the immediate vicinity of the proposed centre-line, as well as defining most of the basin, are generally gently sloping and do not attain any great heights. Some slopes to the north of the site are however fairly high. Nevertheless, slope instability problems are not expected.

3.3 Construction materials

No sources of coarse aggregate / rip-rap were investigated by drilling. A dolerite sill forming a hill- capping roughly 3,5 km north of the dam site was however identified as a potential quarry site. The report also mentions an existing quarry site located roughly 12 km from Lusikisiki, although doubts were expressed concerning available volumes and quality. Chances of locating a suitable quarry within the confines of the proposed dam basin appear rather remote. Should an embankment dam be favoured, excavations for a side-channel spillway within unweathered dolerite on the lower right flank might represent a potential source of rip-rap. A diversion tunnel through the right flank might similarly be considered a potential source of suitable material.

No suitable sand reserves were identified in the vicinity of the dam site. At the time of the investigation (1979), sand used in Lusikisiki was obtained from various sources located between 23 - 45 km away. Sands derived from the Karoo sedimentary strata are known to produce concrete with dimension problems. At this stage it may be assumed that fine aggregate will be obtained from crusher run.

Detailed investigations were conducted into potential sources of semi-pervious as well as impervious core material. Briefly; the red silty clays of dolerite origin between depths 0,5 - 3,0 m were considered most suitable for use as impervious core, while the finer grained material derived from siltstone and alluvium, respectively, was considered suitable shoulder material (Hill Kaplan Scott, 1979).

Actual laboratory test data would however appear to contradict this. The residual dolerite soils have very high clay contents (generally more than 45 %, and as high as 78 %), suggesting problems with workability. In addition, values obtained for the Atterberg Limits are mainly above normal specifications. The liquid limit typically varies between 60 - 70 %, and the linear shrinkage is generally greater than 15 %. All values obtained for the plastic limit vary between 30 - 40 %. In addition dry densities were low (1245 - 1398 $kg.m^{-3}$) while optimum moisture contents were high (33 - 39 %). Residual dolerite soils at depths below 3 m yielded slightly improved material properties, but generally remain unsuitable. Limited testing indicated only certain horizons were potentially dispersive.

The grading of the alluvial clayey silts indicates possibly better suitability for use as impervious core material, rather than as semi-pervious material; clay content is in the region of 30 %, although some horizons exhibit clay contents approaching 50 %. In addition the Atterberg

Constants are within acceptable limits, with liquid limits generally between 30 - 39 %, plastic limits between 11 - 18 % and linear shrinkages between 5 - 12 %. Importantly, indications are that these alluvial materials are potentially dispersive. The thickness of usable horizons is however limited to material above the boulder bed (upper 1,5 m).

Only limited testing was conducted on materials derived from weathered siltstone (shale). As stated, these materials are probably better suited for use in the transition zones. With a single exception, clay contents are not particularly high and the material predominantly comprises silt. However, liquid limits are too high (24 - 63 %), as are the plastic limits (17 - 33 %) while linear shrinkages up to 15 % were recorded. Indications are that these materials are potentially dispersive.

4. LUSIKISIKI DAM SITE

The Lusikisiki dam site is located roughly 7 km, as the crow flies, north-west of Lusikisiki. The proposed site is almost adjacent to the Lusikisiki - Flagstaff road (Figure 1). Immediately upstream of the proposed centre-line the river flows in a north-easterly direction, turning sharply in a SSE direction. River flow is presumably structurally controlled. The proposed site is located along this SSE length of river.

The proposed centre-line is markedly asymmetrical; the left flank is moderately steep (approximately 1:3),although the upper slopes are flatter (1:20). Note that upstream of the proposed centre-line the left flank is almost vertical adjacent to the river. The right flank is generally very gently sloping (1:33), although the river bank is relatively steep. The river section is approximately 20 m wide.

4.1 Site geology

The steep slopes of the left flank are due to the intrusion of a dolerite sill. Outcrop of unweathered to slightly weathered dolerite bedrock is evident on the near-vertical lower flanks of the south- easterly facing slopes upstream of the proposed centre-line. Here a minimum sill thickness of 5 to 8 m may be assumed. No outcrop is however visible in the dense bush on the left flank along this SSE length of river. The extent of the dolerite sill is loosely defined by the steepening / flattening of the slopes (Plate 2). From the gradual flattening of the left flank in a downstream direction, it may be assumed that the dolerite sill is not continuous in a downstream direction.

The upper, flatter slopes on this left flank are presumably underlain by siltstone. Silty / fine sandy soils cover the slope. The underlying siltstone bedrock is expected to be deeply weathered.

In the vicinity of the proposed centre-line, extensive outcrop of dolerite bedrock occurs across the entire width of the river section. This outcrop is not continuous in a downstream direction,

and considering also the flattening of the left flank must be assumed to represent the end of the dolerite sill. Alluvial deposits are negligible, although occasional loose rock blocks may occur.

In the river section the joints within the dolerite are predominantly sub-vertical, although a sub-horizontal set is also evident upstream of the centre-line, producing a blocky rock mass. The joints are closely to medium spaced.

The right flank is underlain by siltstone. A thickness in the order of 5 m may be assumed for the silty / fine sand colluvial soil cover. The underlying siltstone bedrock is expected to be deeply weathered.

Adjacent to the river, exposures of siltstone approximately at river level are considered to correspond to the upper contact of the dolerite sill. It is not known to what extent the sill continues beneath the right flank.

4.2 Engineering geological considerations

In the case of the Lusikisiki dam site, the selection of favoured centre-line position will be largely influenced by the extent of the dolerite sill. If located too far downstream the left flank becomes flatter and founding conditions within the river section and underlying the left flank more uncertain.

While acknowledging that actual founding conditions have not as yet been confirmed, the most suitable dam type is probably either an embankment or a composite structure comprising a central concrete spillway section and embankment flanks. A composite structure might also be considered where the concrete section encompasses both the river section as well as the steep left flank, although there is a chance that founding conditions on the upper flank in particular would not be entirely suited to a concrete structure. Expected deep weathering of the siltstone on the gently sloping right flank and the resultant deep excavations would suggest a concrete wall on this flank would not be economically feasible.

Selection of a central concrete spillway section would make best advantage of the good founding conditions within the river section. Further advantages would be gained from not requiring diversion works during construction of the embankment, while the resistant dolerite in the river section would not require concrete lining. While an embankment dam with a side-channel spillway might be considered, the resultant spillway chute is likely to require lining.

Excavation depths for a concrete structure within the river section may be expected to vary between 0 - 2 m, mainly ensuring a relatively even surface for concrete placement. Extension of the concrete structure in the direction of the left flank in order to gain spillway length is likely to require founding at depths between 2 - 5 m, primarily involving the removal of loose rock blocks. As mentioned above, the deeply weathered siltstone underlying the upper left flank as well as the right flank, imply excessively deep excavations for a concrete structure (estimated between 8 to 10 m and from 5 m to more than 15 m, respectively). In contrast, excavation depths for an

embankment cut-off are expected to vary between 2 and 3 m on the upper left flank, and between 3 and 5 m on the gently sloping right flank.

The dam basin (Plate 2) is generally defined by very gentle slopes presumably underlain by siltstone. Catastrophic slope failure is therefore not an issue of major concern, while basin watertightness may also be assumed with reasonable certainty.

In general, the founding rock masses may be expected to be relatively impervious. Greater foundation permeability may however occur via the dolerite - siltstone contacts, or very closely jointed zones.

4.3 Construction materials

No detailed investigations into possible construction material sources have been conducted as yet. Some general comments can, however, be made.

The most obvious source of coarse aggregate / rip-rap is the dolerite sill on the left flank; providing the selected centre-line is sufficiently far removed, and overburden depths are not excessive. While other dolerite sills can be expected to occur within a reasonable distance, these may not be within the dam basin.

The supply of suitable sand is an ubiquitous problem. The parent rocks in the area (Karoo mudrocks) typically produce very fine-grained sediments. Furthermore, concrete made with Karoo sand or sandstone displays excessive shrinkage properties. At this stage it may be assumed that sand will mainly have to be sourced from crusher run.

There appear to be vast areas within the proposed dam basin which might be considered potential sources of embankment fill materials, both for impervious core material as well as transition material. It is expected that these areas are underlain by weathered siltstone or alluvial / colluvial soils, and the materials comprise silty- / fine sandy soils with clay.

5. XURA DAM SITE

The proposed Xura dam site is located approximately 6 km, as the crow flies, NNE of Lusikisiki (Figure 1).

The site is roughly symmetrical. The left flank is only slightly steeper than the right (approximately 1:2,5 as opposed to 1:3). Note that the right flank is convex, flattening to approximately 1:7,5. The river section is 30 - 35 m wide (Plate 3).

5.1 Site geology

The site is underlain by tillite of the Dwyka Group. Deposited by ice sheets, the rock typically comprises an unsorted, non-orientated accumulation of rock and mineral fragments in a fine-grained matrix of rock flour.

The moderately steep left flank is covered by clayey colluvial soil. This unconsolidated overburden is not expected to attain any great thickness (1 - 2 m maximum), grading into the underlying weathered tillite. A significant depth of weathering is expected, with unweathered / slightly weathered tillite bedrock not likely at depths shallower than 10 m.

Scattered outcrop of unweathered tillite is exposed within the river section. Unconsolidated overburden of alluvial origin, including occasional boulder accumulations, is therefore negligible. As might be expected, the tillite rock mass appears massive. Sub-vertical joint sets are recognized, striking roughly parallel to the river as well as perpendicular and oblique to the river. In general however, jointing is irregular producing an interlocking rock mass. Cliffs of tillite exposed roughly 500 m upstream of the proposed centre-line illustrate the regular medium to widely spaced sub-vertical joints which strike roughly parallel to the river.

The right flank is covered by colluvial soils with thickness possibly up to 2 - 3 m. The underlying tillite bedrock is expected to be deeply weathered, with unweathered / slightly weathered rock not likely to be intersected at depths shallower than 10 - 15+ m. On the lower slope, just above river level, highly weathered tillite bedrock is exposed. It may be that the unweathered bedrock does not rise much above river level.

5.2 Engineering geological considerations

In terms of dam type, the expected deep weathering of the flanks implies very deep foundation excavations for a concrete structure, therefore favouring an embankment. The good founding conditions within the river section may however be utilized either for a central concrete spillway or conduit. Further spillway options for an embankment dam might include a side-channel spillway on one of the flanks. In this case, however, allowance must be made for full concrete lining of the spillway chute to prevent excessive erosion of the deeply weathered tillite. Lining would not be required within the river section, should this be used as the spillway section / outlet. A saddle on the right flank downstream of the proposed centre-line might be considered for a spillway, but deep weathering and unfavourable founding conditions are expected.

Some difficulties in river diversion during construction of an embankment are likely, unless the central concrete spillway or conduit are opted for, as the topography of the flanks and the expected deep weathering do not favour excavation of a diversion tunnel

Excavation depths for an embankment cut-off may be assumed at depths between 2 - 3 m on the left flank, and 3 - 5 m on the right. Within the river section negligible excavation will be necessary for an embankment, while excavation depths for a concrete structure might be expected to vary up to 1 - 2 m, mainly involving the removal of any major irregularities.

Roughly 1000 m upstream of the proposed centre-line (Figure 7) there is evidence of past slope instability. The possibility of this slide debris becoming reactivated following wetting up within the dam basin must be considered. Another catastrophic failure of similar-magnitude into a full reservoir may result in major overtopping of the dam. Reactivation of the old slide debris is however more likely to produce smaller localized slips.

5.3 Construction materials

While the most obvious source of coarse aggregate / rip-rap / rock-fill would be an unweathered dolerite body, dolerite intrusions are not common within the Dwyka tillite. In the absence of dolerite in the immediate vicinity of the site, unweathered / slightly weathered tillite may be used. Cliffs of tillite located roughly 500 m upstream of the proposed centre-line represent a potential material source. The depth of weathering is however quite significant (estimate 10+ m) implying excessive overburden thickness. These weathering depths might be considered typical. A further consideration, depending on the properties of this material, would be utilization of this weathered rock in construction; either as rockfill or less durable transition material in the case of an earthfill embankment.

Location of natural sand deposits of acceptable quality is likely to present a problem. While crusher run represents the logical alternative, problems with excessive mortar shrinkage have been reported on the odd occasion.

The identification of suitable embankment fill materials should not present major difficulties. Deposits of fine-grained soils located within the basin, whether comprising alluvium or derived from the weathering of tillite, are likely candidates for impervious core materials, or possibly even semi-pervious transition materials. The unconsolidated deposit of previous landslide material may also be suitable for use as transition material.

6. LOWER MZINTLAVA DAM SITE

The proposed Lower Mzintlava dam site is located roughly 7 km, as the crow flies, south west of Lusikisiki.

The site is asymmetrical (Plate 4). The left flank initially rises very steeply above the river (1:1,5) before becoming flatter (approximately 1:2,5), while the right flank is more gently sloping (1;5). The river section is only about 15 - 20 m wide.

6.1 Site geology

The left flank is underlain by tillite. Although unweathered / slightly weathered tillite bedrock is exposed at the foot of the slope, the tillite is mainly expected to be highly or completely weathered. Colluvial soils covering the flatter upper slopes are likely to be up to 2 - 5 m thick.

Scattered outcrop of unweathered / slightly weathered tillite bedrock is exposed within the narrow river section. Alluvial clay / silt deposits are therefore discontinuous and unlikely to attain any great thickness. A maximum thickness between 2 - 3 m may be assumed. The underlying tillite bedrock is likely to be unweathered or slightly weathered.

The moderately steep right flank is covered by fine-grained colluvial soils. Thickness is estimated to vary between 2 - 5 m. The underlying tillite bedrock is probably deeply weathered.

6.2 Engineering geological considerations

In terms of dam type, the expected deep weathering would suggest an embankment dam might be favoured at this site. A composite dam, comprising a central concrete section and embankment flanks, may also be considered. Deep founding levels should be expected where the concrete section extends onto the respective moderately steep flanks, because of the expected deep weathering of these flanks.

While such a central concrete spillway section would, in some ways, represent a spillway option, the relative narrowness of the river section should be borne in mind. Depending on the length of spillway required, significant foundation excavations may be required. Other spillway options which might be considered here include a trough spillway, or a morning glory / conduit combination. A side-channel spillway chute on the right flank represents yet another option, but the deeply weathered tillite would require full lining as erosion protection. For river diversion during construction of the embankment, a conduit within the river section is the most obvious solution. A tunnel through the steeper left flank is also an option, the difficulty of which largely depends on the degree to which the tillite rock mass is weathered.

For an embankment dam, the cut-off excavation depths might be expected to vary between 2 - 5 m on the respective flanks, largely requiring removal of the unconsolidated colluvial soils. Within the river section, cut-off excavations might be expected to be up to 2 - 3 m deep. For a concrete structure, minimum excavation depths up to 2 - 3 m might similarly be expected, assuming the patchy alluvial deposits are underlain directly by unweathered intact tillite bedrock. Depending on the spillway length required and the depth of weathering, excavation depths on the lower flanks might be 10 - 15 m, or greater.

The slopes defining the dam basin are quite steep and also attain a significant height above the proposed dam height. Although there is no evidence of recent slope instability, wetting of the slopes during reservoir filling may result in slope failures.

6.3 Construction materials

Potential sources of coarse aggregate / rip-rap were not specifically identified in the immediate vicinity of the proposed dam site, although no major problems are foreseen in this regard. Either unweathered / slightly weathered tillite or an intrusive dolerite body represent potentially suitable sources. Note that a disused quarry is located roughly 2 km from the proposed dam site (Figure 1). This dolerite quarry may have been developed for the realignment of the Lusikisiki - Port St Johns road. The quality of the material is not known, nor are the available reserves.

Identification of suitable sand deposits is likely to present a problem. Natural or manufactures sands derived from Karoo sedimentary strata are known to produce mortar shrinkage, as is manufactured sand from tillite. At this stage the most obvious source of sand is crusher run from dolerite.

It is expected that reserves of suitable embankment materials occur within the proposed dam basin, or in the vicinity of the proposed dam site. The fine-grained soils derived from the weathering of the tillite or Karoo sediments are likely sources of impervious core or even transition materials.

7. TUNGWANE DAM SITE

The proposed Tungwane dam site is located roughly 7 km SSW of Lusikisiki on the Mzintlava River (Figure 2).

The site is markedly asymmetrical. The left flank initially rises steeply above river level (1:1), then flattens to 1:6 roughly 20 m above river level. The concave right flank is gently sloping, initially rising at 1:18 then steepening to about 1:8. The slopes above the maximum crest level envisaged are even steeper. The river section is approximately 40 m wide (Plate 5).

7.1 Site geology

Outcrop of slightly weathered tillite bedrock is exposed along the base of the very steep left flank, although the flank itself is expected to be deeply weathered. The flatter upper slopes are presumably covered with silty / clayey colluvial soils, possibly between 2 - 5 m thick.

At the proposed centre-line the river section is largely covered with alluvial boulders varying in size between 0,05 - 0,5 m, with the exception of limited outcrop extending from the steep left flank into the river. Note that numerous areas of outcrop are exposed upstream of the proposed site, at intervals all along the river. It is consequently assumed that this boulder deposit does not attain a thickness greater than 2 - 5 m and is underlain by massive, unweathered to slightly weathered tillite bedrock.

The long right flank is underlain at depth by tillite. The flatter, lower slopes are located on the inner bend of the Mzintlava River and the unconsolidated deposits are likely to be of mixed

alluvial and colluvial origin. The presumably silty or clayey soils might be up to 5 - 8 m thick. An extensive boulder horizon, similar to that deposited in the river section, may be present. Tillite bedrock underlies these deposits, but may not rise much above present river level. The slightly steeper mid- to upper slopes appear covered by fine-grained colluvial soils. A thickness up to 2 - 3 m is estimated. The underlying tillite is likely to be deeply weathered.

7.2 Engineering geological considerations

In terms of dam layout, the expected deep weathering would appear to favour construction of an embankment dam rather than a concrete structure. A composite dam might also be considered however, incorporating a concrete spillway section and embankment flanks. Depending on the spillway length required and actual founding conditions on the respective flanks, this spillway might be extended beyond the river section. Other spillway options may also be considered for an embankment dam, including a conduit founded on the tillite bedrock within the river section. A side-channel spillway on the right flank represents an further option, but would in all likelihood require extensive lining to prevent erosion of the weathered bedrock. For river diversion during embankment construction, either a tunnel through the steep left flank, or a conduit may be considered.

In general, excavation depths for an embankment cut-off may be expected to vary between 2 - 3 m, although deeper excavations may be necessary on the lower right flank where the unconsolidated alluvial / colluvial deposits may be up to 5 - 8 m thick, including a boulder horizon. Similar excavation depths may be expected for a concrete structure in the river section / lower flanks, as the unconsolidated deposits in these areas are expected to be underlain by good quality tillite bedrock.

Although the basin slopes are reasonably steep in places and rise high above river level, there is no evidence of any previous stability problem. Localized failures may, however, occur with wetting up of the slopes associated with reservoir filling.

7.3 Construction materials

A disused quarry in a dolerite body is located near a hilltop roughly 3 km from the site (Figure 2), although the road distance will be greater. It is likely this quarry was used to supply aggregate for the realigned Lusikisiki - Port St Johns road and bridge across the Mzintlava River. Rock quality and available volumes are not known at this stage. Other potential sources of coarse aggregate / rip-rap include several areas where unweathered / slightly weathered tillite outcrop occurs adjacent to the Mzintlava River. These areas will certainly fall within the proposed dam basin and are also much closer to the proposed site than the disused dolerite quarry.

As always, identification of suitable concrete / filter sand is likely to be a problem. Crusher run is the most obvious solution, although excessive mortar shrinkage has been recorded on rare occasions.

It is likely that sources of embankment materials occur within the basin. Deposits of fine-grained alluvial / colluvial soils occurring adjacent to the river represent potential sources of impervious or even semi-pervious material.

8. CONCLUSIONS AND RECOMMENDATIONS

1. Brief reconnaissance-level engineering geological investigations have been conducted at the proposed Zalu, Lusikisiki, Xura, Lower Mzintlava and Tungwane dam sites in the vicinity of Lusikisiki in eastern Pondoland. Only the Zalu site had been investigated previously, in some detail.

2. The area of interest is underlain by sedimentary strata from the lower Karoo Supergroup, comprising mudrocks of the Ecca Group and the underlying tillite of the Dwyka Group. This sedimentary sequence has been intruded by younger dolerite dykes and sills, which comprises up to 40 % of the sequence within the Ecca mudrocks but significantly less within the tillites.

   The strata are essentially sub-horizontal. No major regional-scale faults are recognized in the area. No economically important mineral deposits occur.

3. Of these proposed sites, only the Zalu site has been investigated previously, in some detail. Only at the Zalu site are founding conditions therefore known with certainty. The engineering geological / geotechnical appraisal of each of the respective sites is summarized below (see Table 2).

4. The proposed **Zalu** site is underlain by a dolerite sill. Within the river section the dolerite is at least 35 m thick. The mid- to lower left flank and most of the right flank are all underlain by this dolerite sill. The upper left flank is underlain by weathered siltstone. Soil cover generally varies up to 5 m in thickness, although extensive dolerite outcrop occurs on the lower right flank.

   Previous investigations only considered an earth embankment. Founding conditions are however also considered suitable for a concrete structure. Alternatively, the poorer founding conditions on the upper left flank might favour an embankment, with a concrete structure for the rest.

   For a concrete structure, excavation depths are likely to vary between 5 m on the left flank underlain by dolerite, 3 - 4 m in the river section and 1 - 4,5 m on the right flank where underlain by dolerite. Deeper excavation will be necessary on the upper flank areas underlain by weathered siltstone (up to 15 m). Embankment cut-off depths are expected to vary between 2 - 5 m on the left flank, 3 - 4 m in the river section and 1 - 4,5 m on the right flank.

A source of coarse aggregate / rip-rap / crusher sand has not yet been investigated. No suitable sand reserves were identified - a problem common to all sites. In all likelihood, crusher sand will have to be used. Previous investigations identified the red clayey dolerite soils as a source of impervious core material, and fine-grained soils from siltstone and alluvium as semi-pervious transition material. Note however that actual test data are not totally in agreement.

5. The steepness of the left flank at the **Lusikisiki** site is due to the intrusion of a dolerite sill. The flatter upper slopes are presumably underlain by weathered siltstone. Extensive dolerite outcrop occurs within the river section, although sill thickness is unknown. The gently sloping right flank is probably underlain by deeply weathered siltstone.

   Expected founding conditions would favour an embankment dam, or alternatively a composite dam incorporating a central concrete spillway section and embankment flanks.

   Excavation depths between 0 - 2 m are expected for a concrete structure within the river section. Deeper excavation can be expected should this concrete section extend to the lower flanks. Embankment cut-off depths are likely to vary between 2 - 3 m on the left flank and 3 - 5 m on the gently sloping right flank.

   The dolerite sill on the left flank represents the closest possible source of coarse aggregate / rip-rap / crusher sand. Other suitable dolerite bodies are also expected, although probably not within the basin. Embankment fill materials are expected to occur within the dam basin.

6. The proposed **Xura** dam site is underlain by tillite. The flanks are expected to be deeply weathered, with soil cover varying between 1 - 2 m on the moderately steep left flank and possibly 2 - 3 m on the slightly flatter right flank. Scattered outcrop of unweathered tillite bedrock occurs within the river section. Alluvial cover is negligible. There is some evidence of past slope instability within the basin.

   The expected deep weathering of the flanks would favour construction of an embankment dam. Because of good founding conditions within the river section, a central concrete spillway section may, however, also be considered.

   Excavation depths for an embankment cut-off may be assumed to vary between 2 - 3 m on the left flank, and 3 - 5 m on the right. Cut-off excavations within the river section will be negligible, but for a concrete structure may be expected to vary up to 1 - 2 m.

   Dolerite intrusions occur less frequently within the tillite. A potential tillite quarry for coarse aggregate / rip-rap / crusher sand occurs roughly 500 m upstream of the centre-line, but appears deeply weathered. Embankment fill materials are likely to be located within the dam basin.

7. The **Lower Mzintlava** dam site is underlain by tillite. Scattered outcrop of slightly weathered bedrock occurs within the river section and at the foot of the left flank slope. For the rest, the flanks are expected to be deeply weathered. Colluvial soils on the respective flanks are expected to vary between 2 - 5 m in thickness, with alluvium in the river section up to 2 - 3 m thick.

   The deep weathering of the flanks would tend to favour an embankment dam. Cut-off depths might be expected to vary between 2 - 5 m on the flanks and up to 2 - 3 m within the river section. A central concrete spillway section might also be considered, but the river section width is very limited and deep excavations must be expected on the deeply weathered lower flanks (10 - 15 m, or greater).

   Although no potential source of coarse aggregate / rip-rap / crusher sand was identified, major problems are not expected in this regard. A disused dolerite quarry is located roughly 2 km from the site. Embankment fill materials may be expected to occur within the basin.

8. The **Tungwane** site is underlain by tillite. Scattered outcrop is exposed at the foot of the steep left flank. In general, the tillite bedrock underlying the flanks is expected to be deeply weathered. Alluvial boulders cover the river section (horizon thickness 2 - 5 m) but the underlying bedrock is expected to be unweathered.

   The deep weathering of the flanks might be considered to favour an earth embankment. Good founding conditions are however likely at shallow depths within the river section, extending to the lower right flank. A central concrete section may therefore also be considered. Excavations for an embankment cut-off may be assumed to vary between 2 - 3 m, possibly deeper on the lower right flank.

   Several areas of extensive tillite outcrop were identified adjacent to the river which represent potential quarry sites. A disused dolerite quarry is located roughly 3 km from the site. Suitable embankment fill materials probably occur within the basin.

9. With the exception of the Zalu site which was investigated previously in some detail, actual founding conditions at these proposed dam sites are not known with complete certainty. **Should any of the sites other than Zalu be favoured, it would be essential for more detailed site investigations to be conducted in order to confirm early assumptions.**

   As a first step, these investigations would comprise the following;

   - Engineering geological mapping of the proposed dam site and immediate surrounds. This would facilitate centre-line selection and identification of construction material sources. A more-detailed site survey (i.e. larger scale than the currently available 1:10 000 orthophotos) is also recommended.

- Limited exploratory drilling of the proposed centre-line. This would allow confirmation of the actual founding conditions, including overburden type and thickness and condition of underlying bedrock. Initially, limited drilling would suffice. Five or six boreholes should be sufficient; two on each flank and one or two within the river section.

- Identification of potential construction material sources, for coarse aggregate / rip-rap as well as embankment fill materials. Initial exploration of the borrow areas need not be too detailed; excavation of a limited number of test pits will suffice. Similarly, limited exploratory drilling of possible quarry sites will be necessary.

- Laboratory testing of construction materials in order to determine the suitability of these materials.

- An assessment of the seismic hazard.

If the Zalu site is favoured, it is recommended that further consideration be given to construction materials. Depending on the dam type selected, a quarry site would still need to be identified. Such a site/s would require further investigation, including exploratory drilling and laboratory testing. In view of earlier ambiguous results, it is further recommended that additional investigations of the proposed borrow areas be conducted.

9. REFERENCES

Hill Kaplan Scott & Partners. (1979). Lusikisiki Water Supply. Zalu dam site. Detailed geological and materials investigation. Volumes I & II. *Unpublished report to Transkei Government*.

Karpeta, W.P. and Johnson, M.R. (1979). The geology of the Umtata area. Explanation Sheet 3128. *Geol. Surv. S. Afr.*

10. DATA APPENDIX

Topo-cadastral maps (1:50 000)
3129 AD Sihlito Sheet
3129 BC Lusikisiki Sheet

Geological maps (published) - Council for Geoscience
3128 Umtata Sheet

Geological maps (unpublished) - Council for Geoscience
3129 AD Sihlito Sheet
3129 BC Lusikisiki Sheet

Orthophotos (1:10 000)
3129 BC 6, 7, 16, 17



Plate 1: The proposed Zalu dam site viewed from the left flank. River flow is from right to left. Extensive outcrop of dolerite bedrock is evident on the lower right flank.



Plate 2: The Lusikisiki dam site, viewed from the left flank a short distance downstream of the proposed centre-line. Immediately apparent is the marked asymmetry of the site. The steeper left flank slopes are ascribed to intrusion of a dolerite sill, while gently sloping right flank is presumably underlain by weathered siltstone. Basin slopes are typically gently sloping and there's no risk of major slope instability.



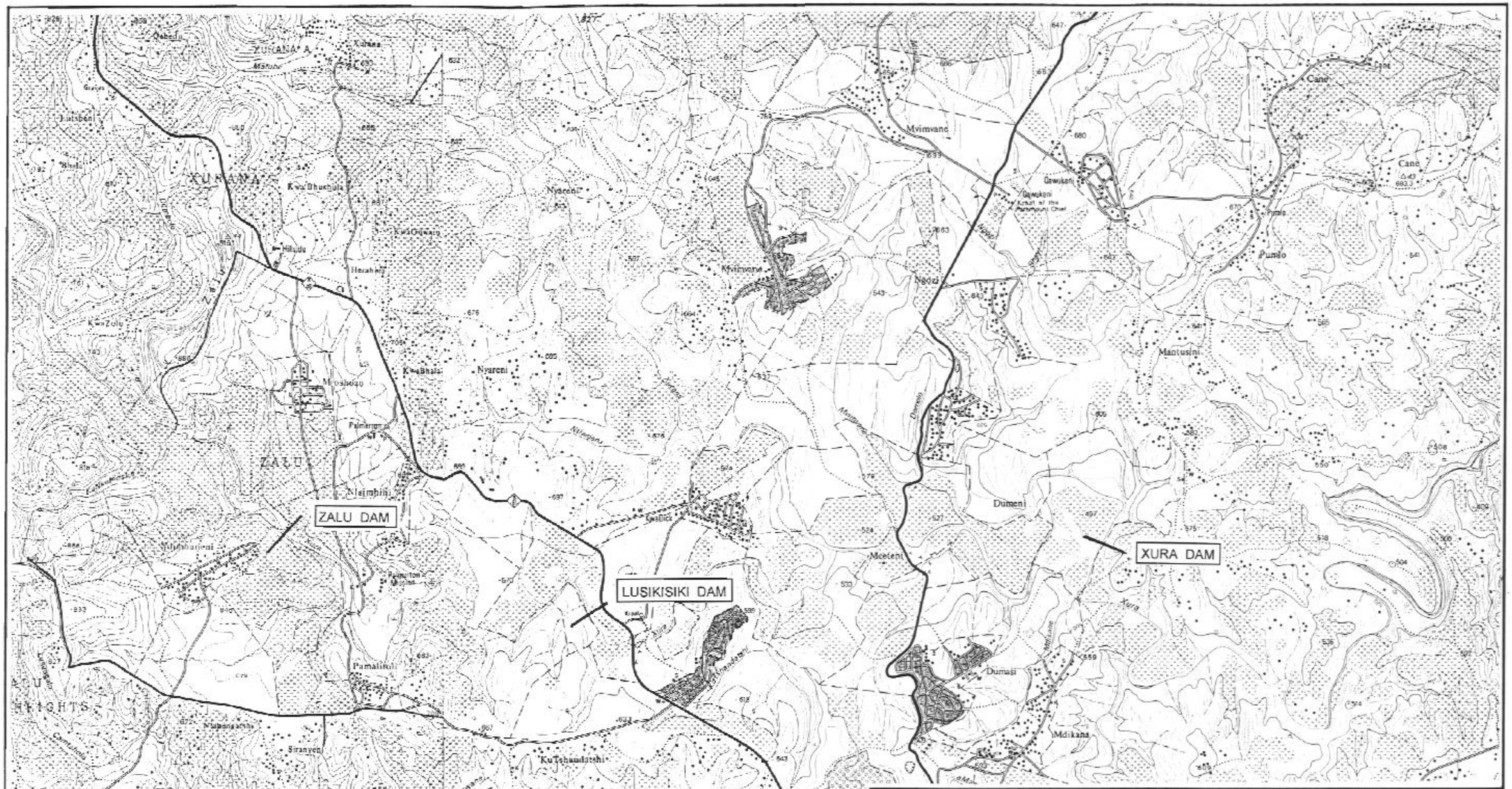
Plate 3: The Xura dam site, viewed from roughly 400 m upstream of the proposed site. The site is more-or-less symmetrical, although the left flank is evidently slightly steeper. Outcrop of slightly weathered tillite bedrock is exposed on the extreme left flank of the photograph. The continuation of this rock outcrop represents a possible quarry site, but the depth of weathering is obviously significant.



Plate 4: The Lower Mzintlava dam site, viewed from the right flank. The left flank is evidently steeper than the right. Limited outcrop of slightly weathered tillite bedrock can just be discerned on the lower slopes of the left flank (partly hidden in shadow). Both flanks are however expected to be relatively deeply weathered.



Plate 5: The proposed Tungwane dam site, viewed from an upstream position. The site asymmetry is immediately apparent; comprising a steep left flank and long, gently sloping right flank. The cliffs adjacent to the river, located roughly 600m upstream of the centre-line, indicate a possible quarry site. Other potential quarry sites are recognised further upstream.



COUNCIL FOR GEOSCIENCE
Private Bag X112
PRETORIA
0001

ENGINEERING, ENVIRONMENTAL AND MARINE GEOSCIENCE DIVISION

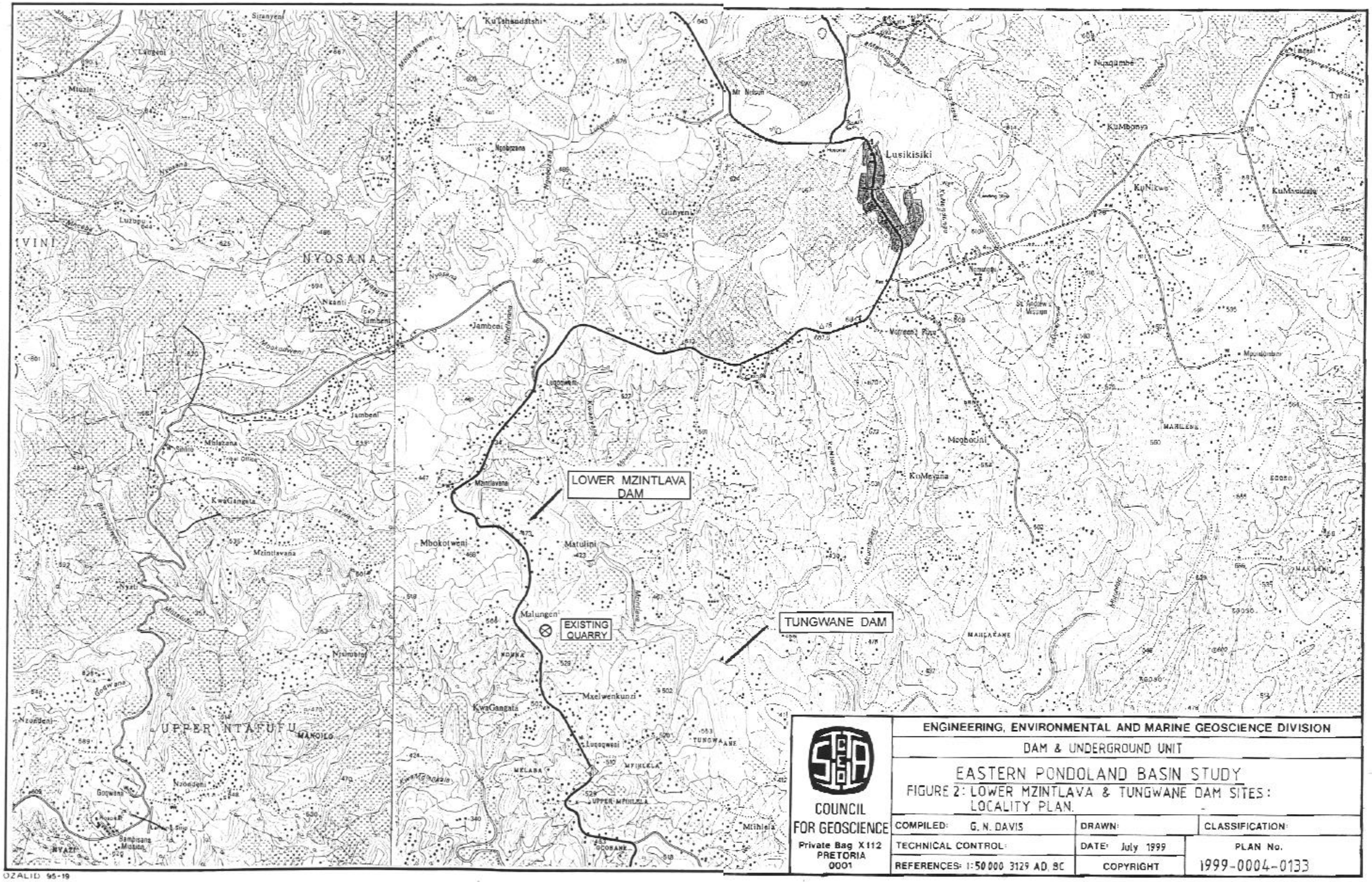
DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY

FIGURE 1: ZALU, LUSIKISIKI & XURA DAM SITES: LOCALITY PLAN.

COMPILED: G. N. DAVIS	DRAWN:	CLASSIFICATION:
TECHNICAL CONTROL:	DATE: July 1999	PLAN No.
REFERENCES: 1:50 000 3129 AD, BC	COPYRIGHT	1999-0003-0133

OZALID 95-19



COUNCIL FOR GEOSCIENCE
Private Bag X112
PRETORIA
0001

ENGINEERING, ENVIRONMENTAL AND MARINE GEOSCIENCE DIVISION

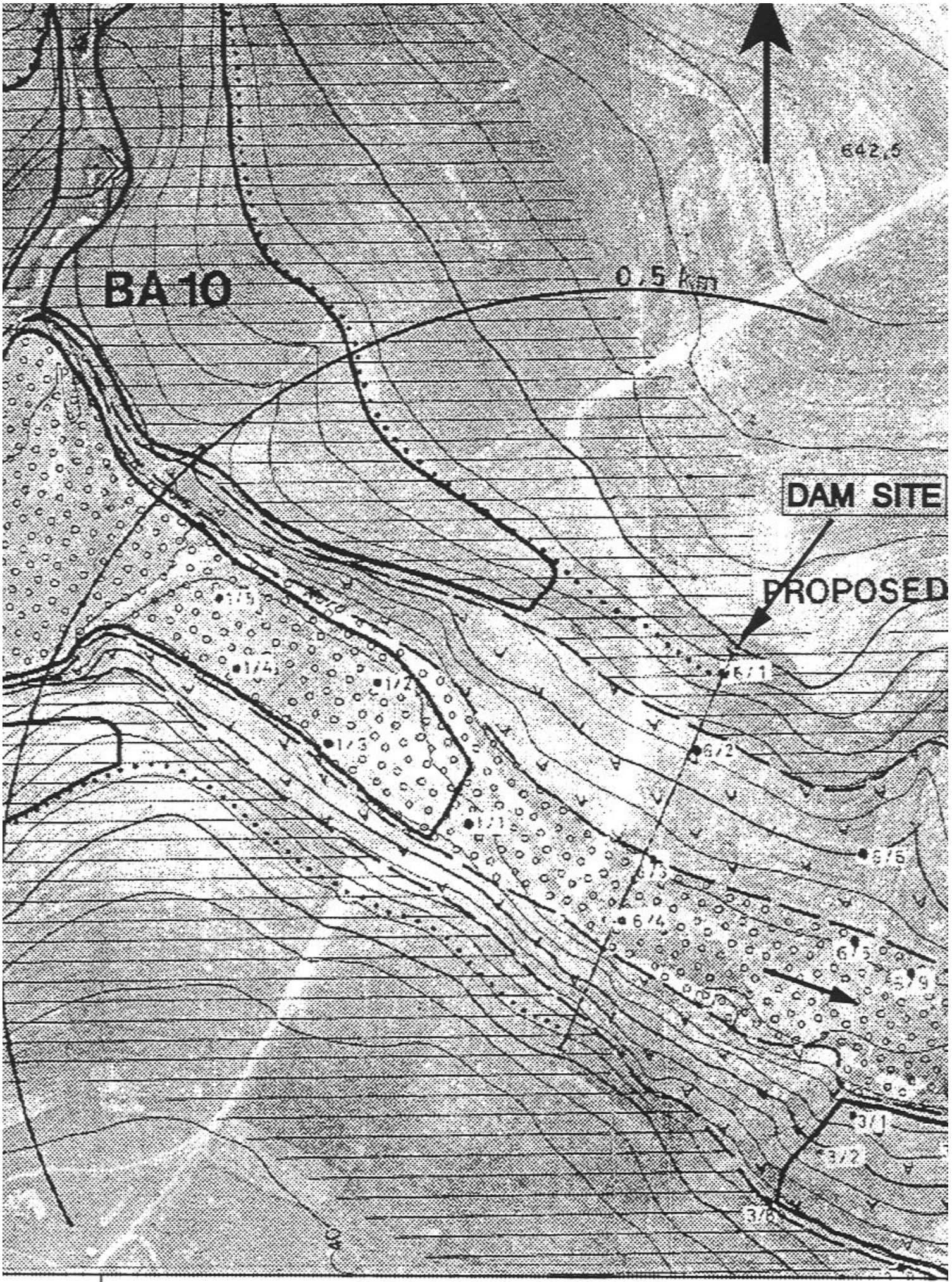
DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY

FIGURE 2: LOWER MZINTLAVA & TUNGWANE DAM SITES: LOCALITY PLAN.

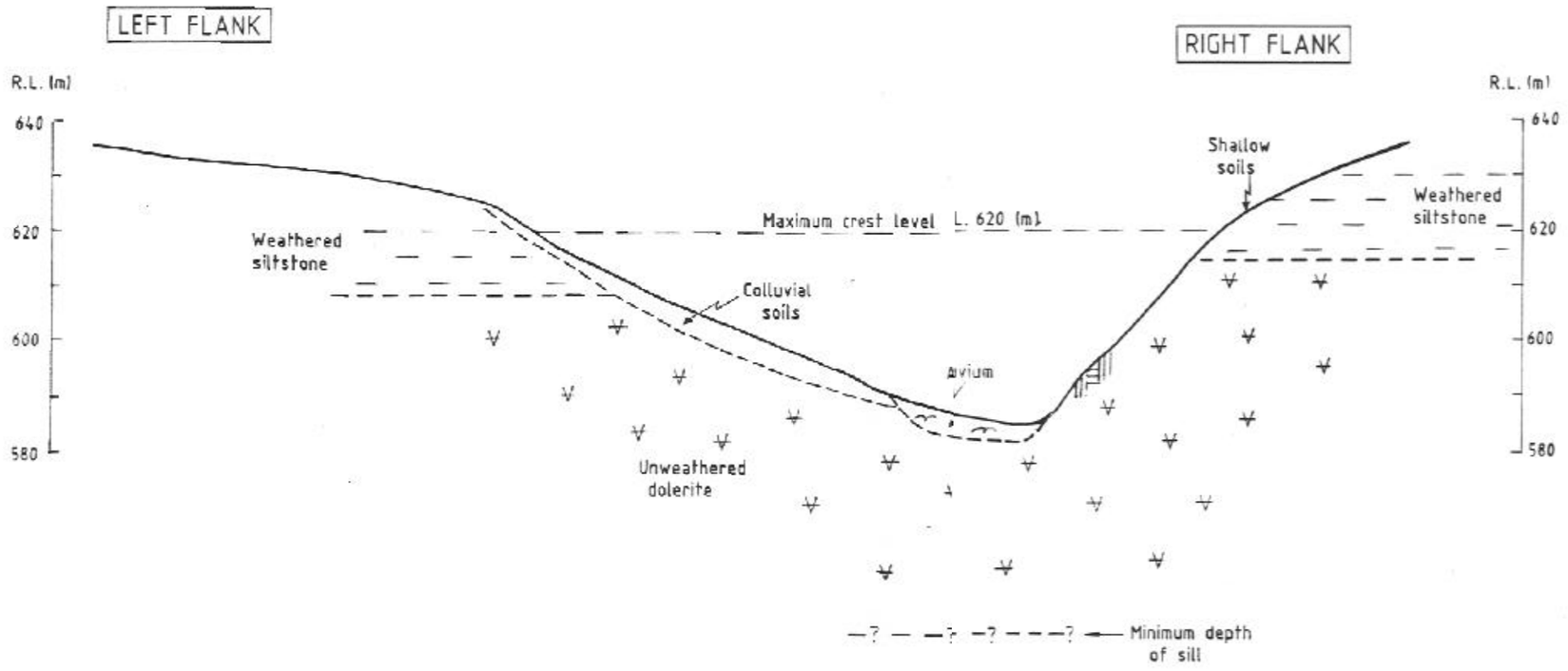
COMPILED: G. N. DAVIS	DRAWN:	CLASSIFICATION:
TECHNICAL CONTROL:	DATE: July 1999	PLAN No.
REFERENCES: 1:50 000 3129 AD, BC	COPYRIGHT	1999-0004-0133

OZALID 95-19



DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY



HORIZONTAL SCALE
1 : 2500

VERTICAL SCALE
1 : 1000

0 100 200 m

0 10 20 30 40 50 60 70 80m

Contours from 1 : 10 000 orthophoto

COUNCIL FOR GEOSCIENCE
Private Bag X112
PRETORIA
0001

ENGINEERING, ENVIRONMENTAL AND MARINE GEOSCIENCE DIVISION

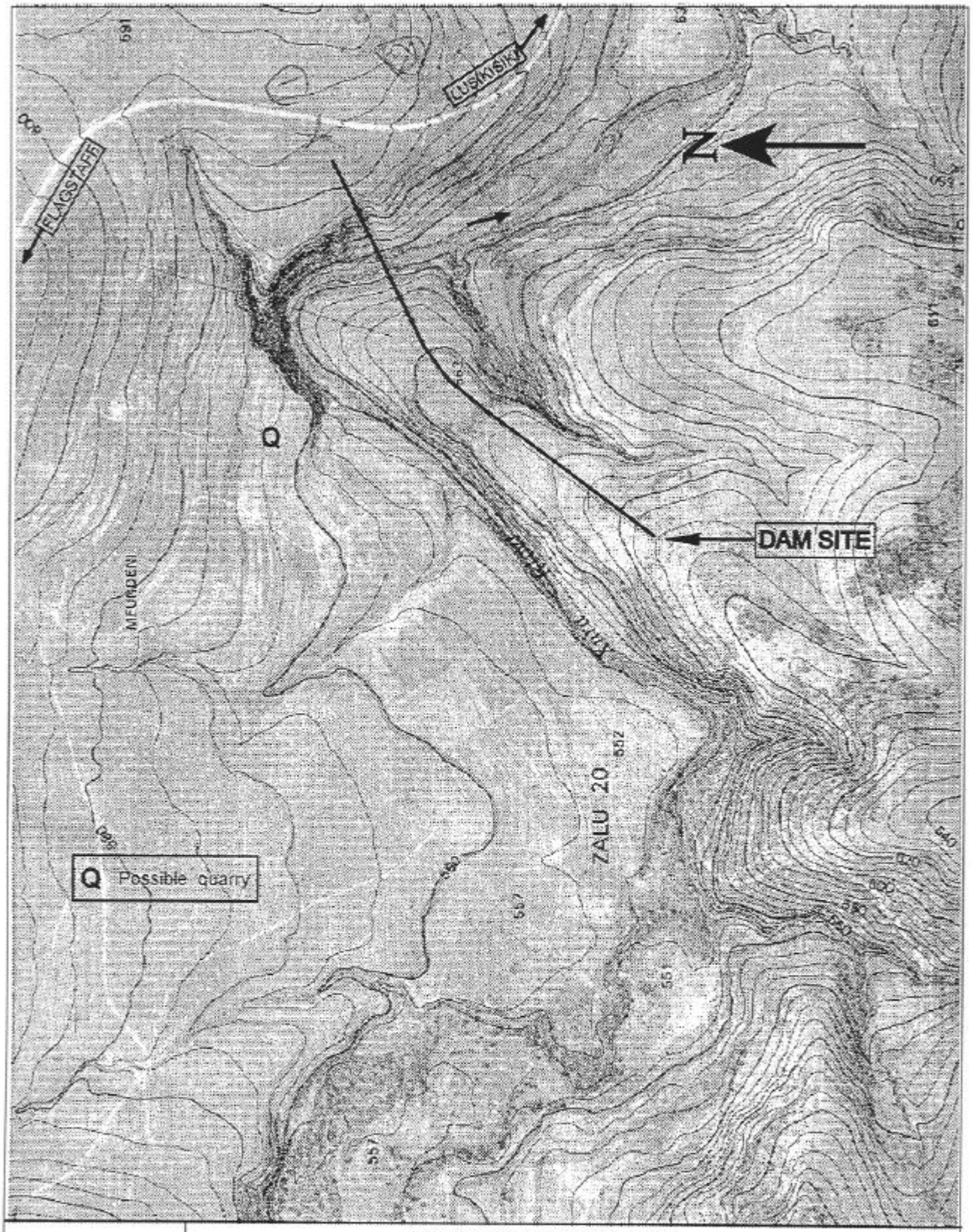
DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY

FIGURE 4 : ZALU DAM SITE : GEOLOGICAL SECTION.

COMPILED: G. N. DAVIS	DRAWN: V. PEER	CLASSIFICATION:
TECHNICAL CONTROL:	DATE: July 1999	PLAN No. 1999-0005-0133
REFERENCES: After HKS, 1979	COPYRIGHT	

02ALID 95-19



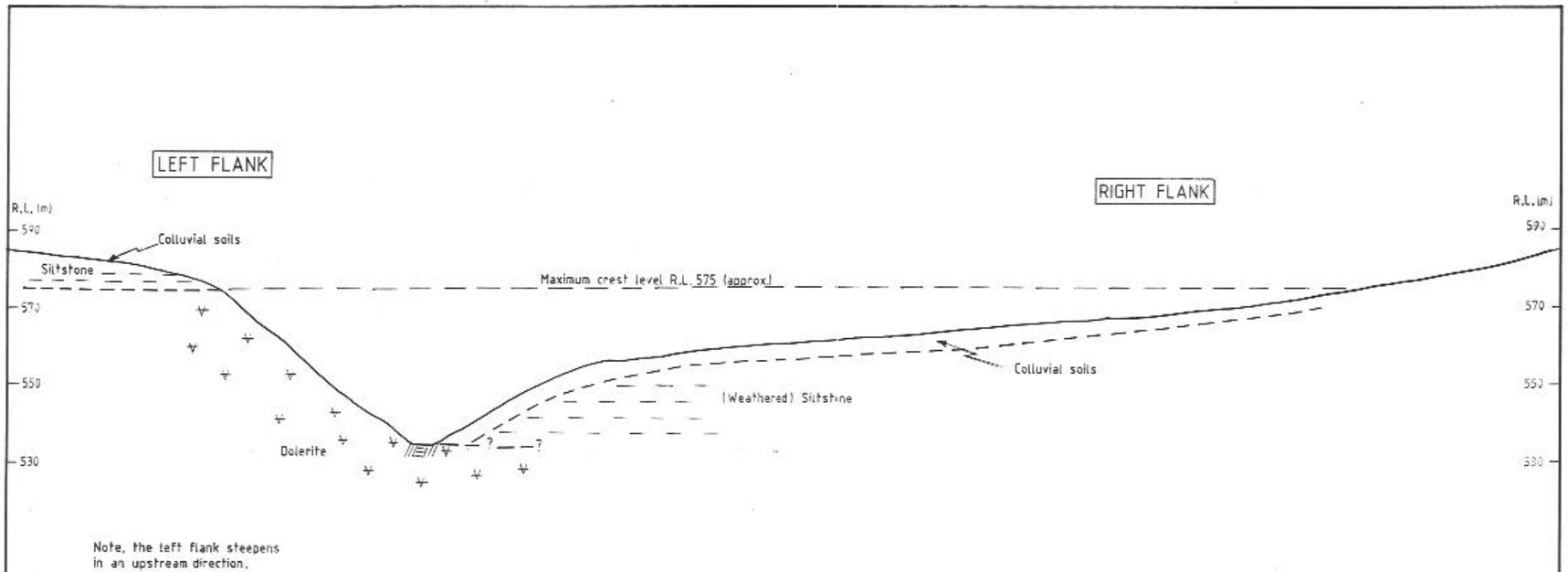
DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY

FIGURE 5 : LUSIKISIKI DAM SITE SITE PLAN (1 : 10 000).

COUNCIL FOR GEOSCIENCE
Private Bag X 112
PRETORIA
0001

Compiled: G.N.Davis	Drawn: V.Peer	Classification: R
Technical control:	Date: .July 1999	Drawing File name
References: 3129 BC 6	COPYRIGHT	Plan No:



COUNCIL FOR GEOSCIENCE
Private Bag X112
PRETORIA
0001

ENGINEERING, ENVIRONMENTAL AND MARINE GEOSCIENCE DIVISION

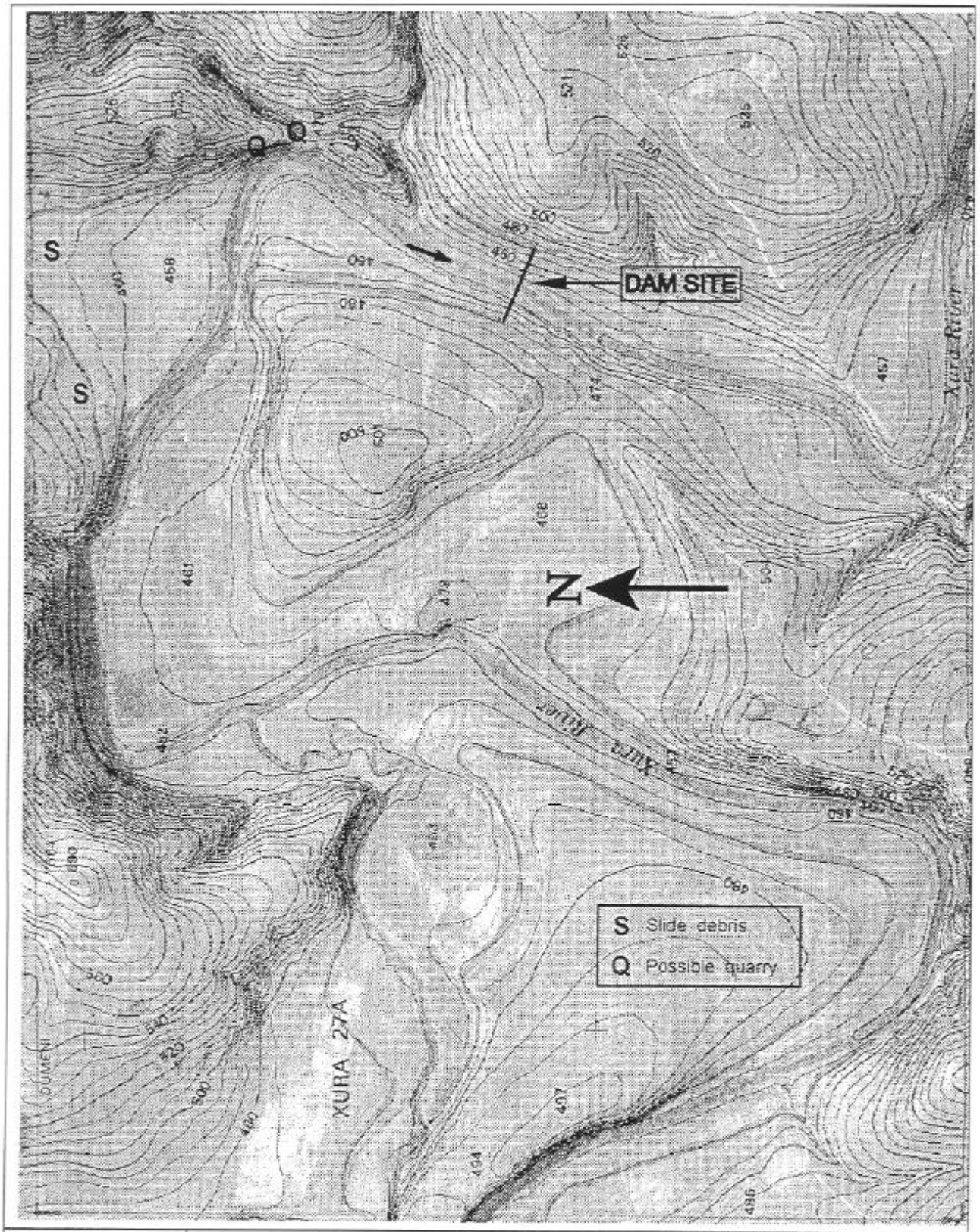
DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY

FIGURE 6: LUSIKISIKI DAM SITE: SKETCH GEOLOGICAL SECTION.

COMPILED: G.N. DAVIS	DRAWN: V. PEER	CLASSIFICATION:
TECHNICAL CONTROL:	DATE: July 1999	PLAN No. 1999-0006-0133
REFERENCES	COPYRIGHT	

QZALID 95-19



DAM & UNDERGROUND UNIT

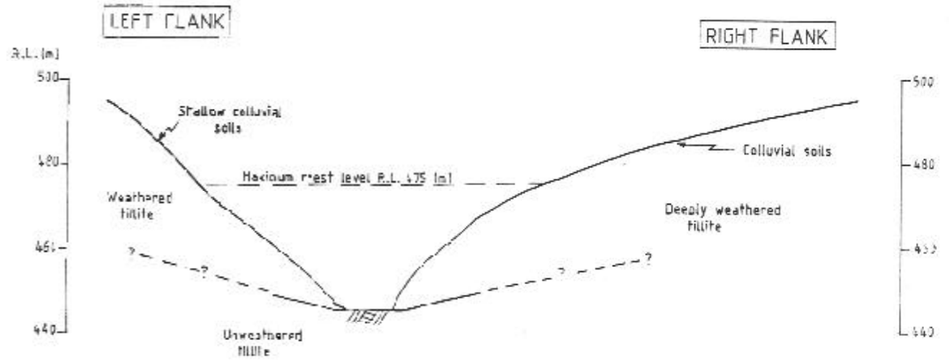
COUNCIL FOR GEOSCIENCE

Private Bag X 112
PRETORIA
0001

EASTERN PONDOLAND BASIN STUDY

FIGURE 7 : XURA DAM SITE SITE PLAN (1 : 10 000).

Compiled: G. N . DAVIS	Drawn: V. PEER	Classification: R
Technical control:	Date: July 1999	Drawing File name
References: 3129 BC 7	COPYRIGHT	Plan No:



0 100 200 m HORIZONTAL SCALE 1 : 2500

0 10 20 30 40 50 60 70 80 m VERTICAL SCALE 1 : 1000

SCALED 95-12

COUNCIL FOR GEOSCIENCE
Private Bag X112
PRETORIA
0001

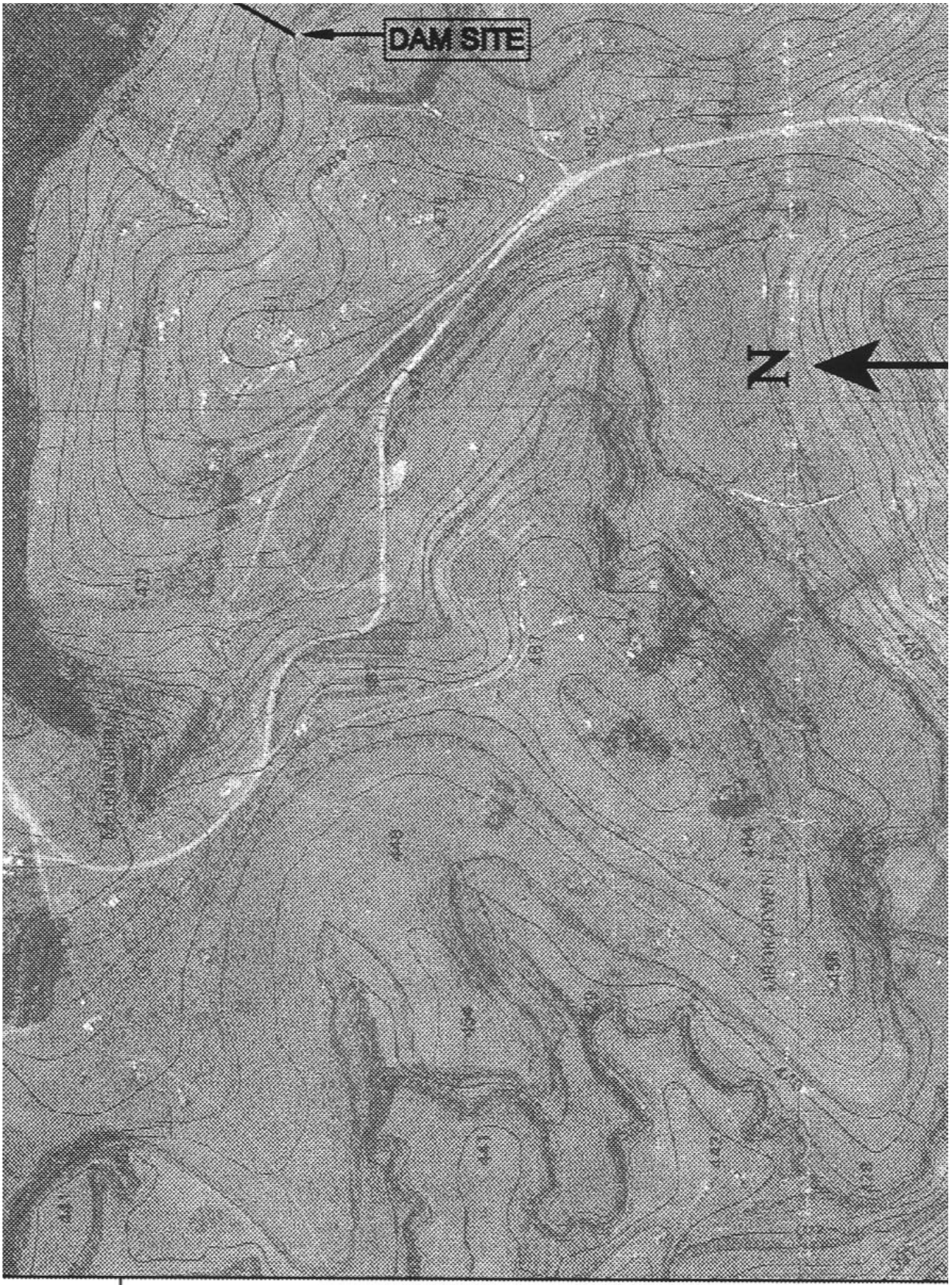
ENGINEERING, ENVIRONMENTAL AND MARINE GEOSCIENCE DIVISION

DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY

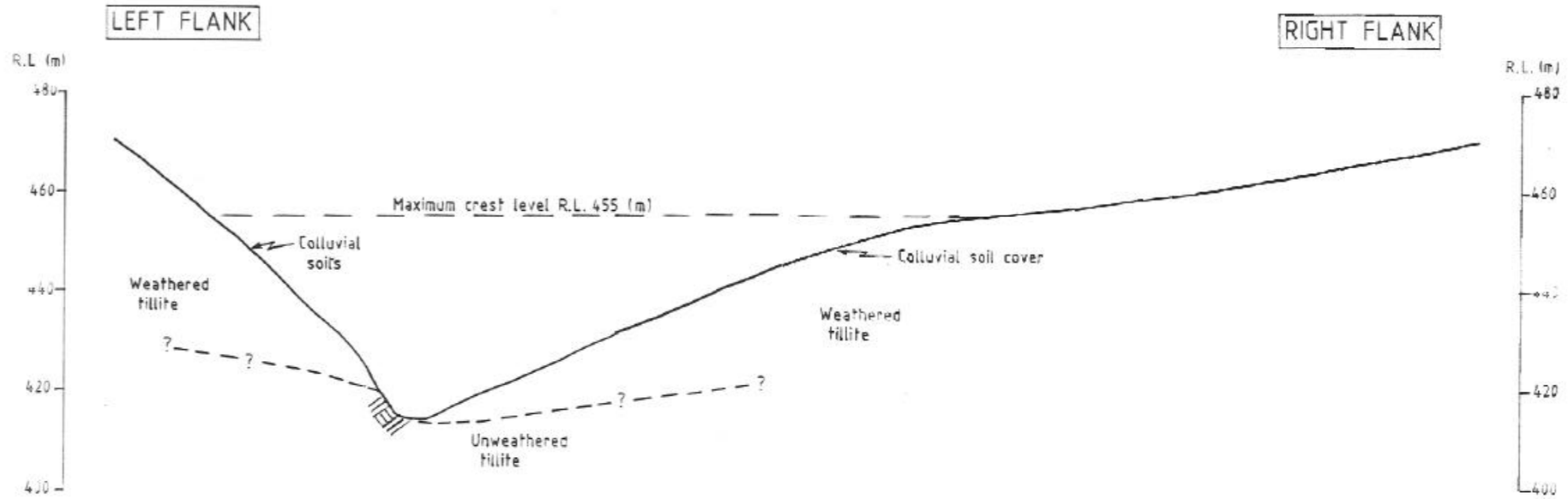
FIGURA 8: XURA DAM SITE: SKETCH GEOLOGICAL SECTION

COMPILED: G. N. DAVIS	DRAWN: V. PEER	CLASSIFICATION:	
TECHNICAL CONTROL:	DATE: July 1999	PLAN No.	
REFERENCES:	COPYRIGHT	1999-0007-0133	



DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY



0 100 200 m HORIZONTAL SCALE 1:2500

0 10 20 30 40 50 60 70 80 m VERTICAL SCALE 1:1000

COUNCIL FOR GEOSCIENCE
Private Bag X112
PRETORIA
0001

ENGINEERING, ENVIRONMENTAL AND MARINE GEOSCIENCE DIVISION

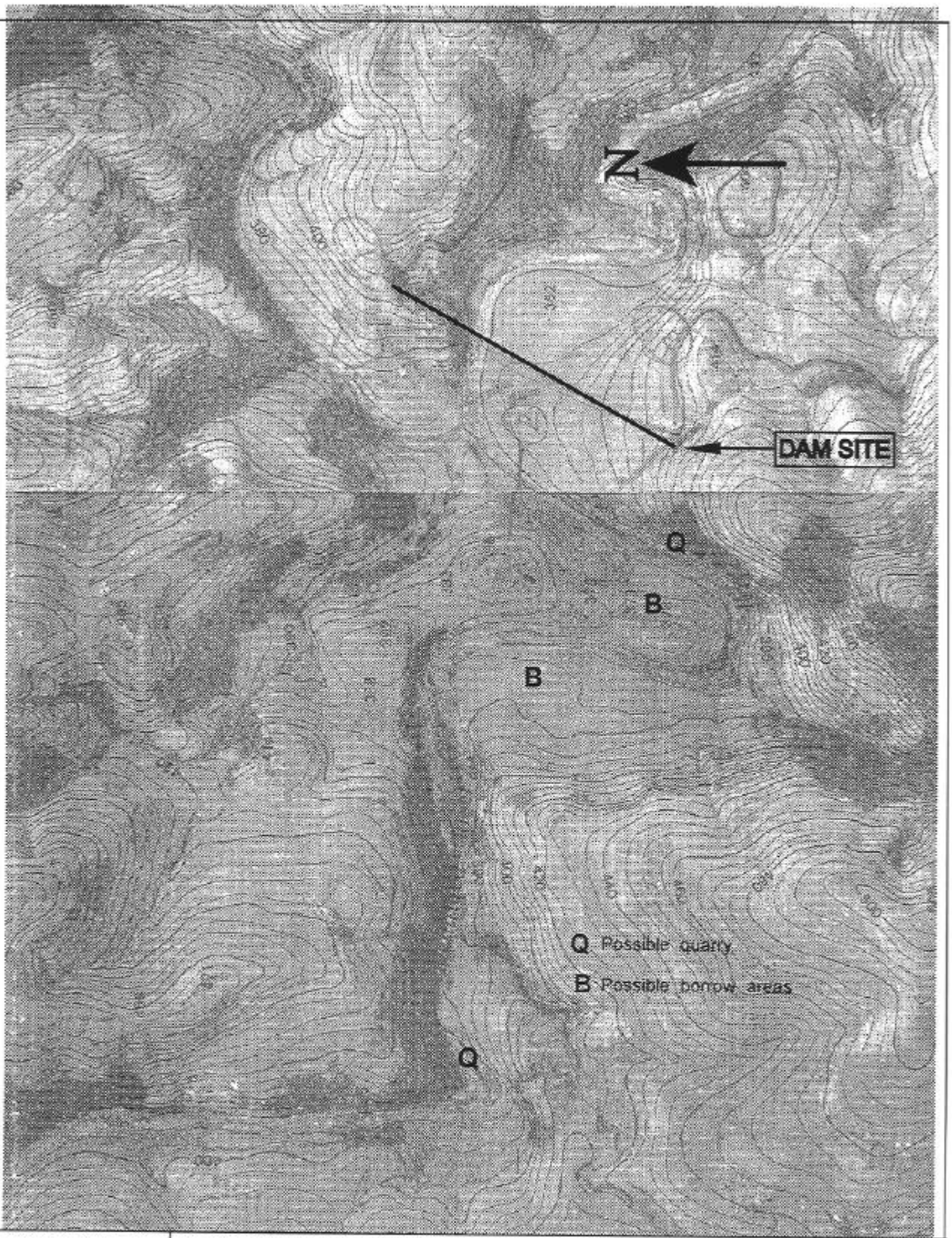
DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY

FIGURE 10: LOWER MZINTLAVA DAM SITE : SKETCH GEOLOGICAL SECTION.

COMPILED: G. N. DAVIS	DRAWN: V. PEER	CLASSIFICATION:
TECHNICAL CONTROL:	DATE: July 1999	PLAN No. 1999-0008-0133
REFERENCES:	COPYRIGHT	

OZALID 95-19



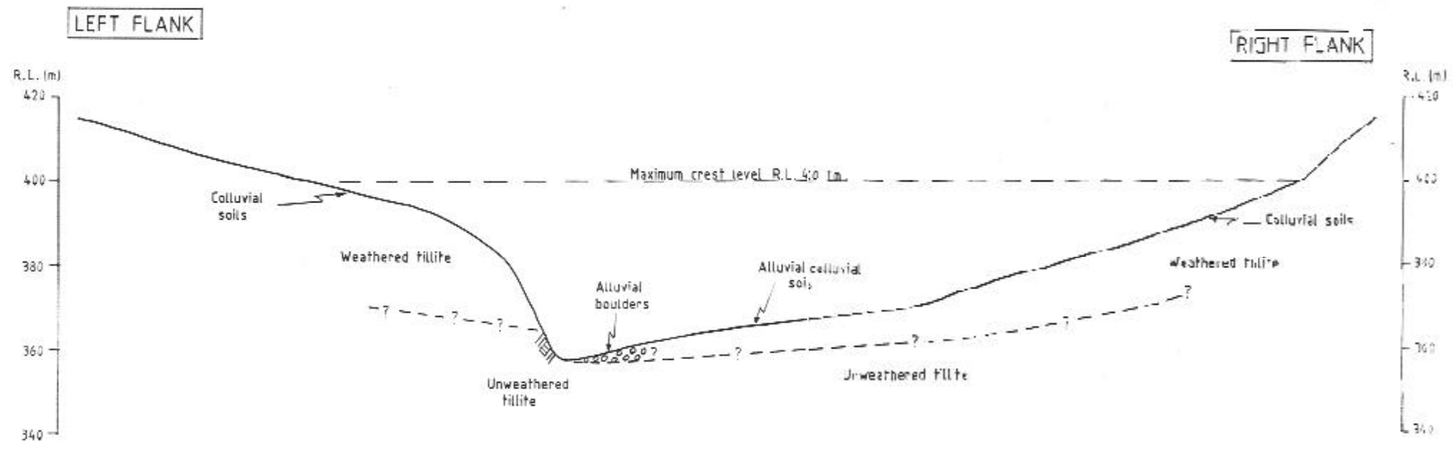
DAM & UNDERGROUND UNIT

COUNCIL FOR GEOSCIENCE
Private Bag X 112
PRETORIA
0001

EASTERN PONDOLAND BASIN STUDY

FIGURE 11 : TUNGWANE DAM SITE SITE PLAN (1 : 10 000).

Compiled: G.N. Davis	Drawn: V.Peer	Classification: R
Technical control:	Date: July 1999	Drawing File name
References: 3129 BC 16 & 17	COPYRIGHT	Plan No:



0 100 200 m HORIZONTAL SCALE 1 : 2500

0 10 20 30 40 50 60 70 80 m VERTICAL SCALE 1 : 1000

Contours from 1 : 10000 orthophoto

COUNCIL FOR GEOSCIENCE
Private Bag X112
PRETORIA
0001

ENGINEERING, ENVIRONMENTAL AND MARINE GEOSCIENCE DIVISION

DAM & UNDERGROUND UNIT

EASTERN PONDOLAND BASIN STUDY

FIGURE 12: TUNGWANE DAM SITE: SKETCH GEOLOGICAL SECTION.

COMPILED: G. N. DAVIS	DRAWN: V. PETR	CLASSIFICATION
TECHNICAL CONTROL:	DATE: July 1999	PLAN No. 1999-0009 0133
REFERENCES:	COPYRIGHT	

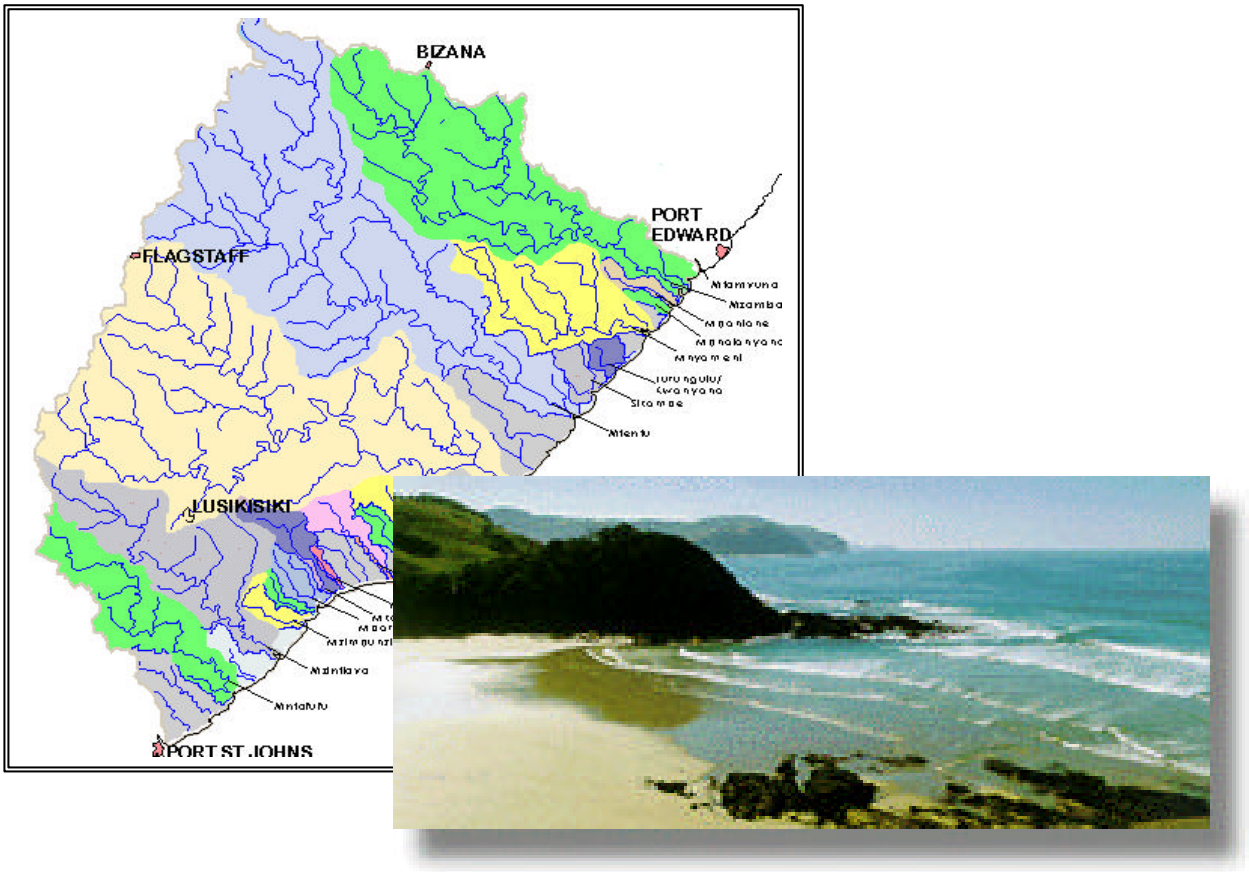
OZALID 95-19

PB T600/00/1501

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



GROUND WATER RESOURCES

T60 Drainage Region

Final

June 2001

Prepared By:

Toens & Partners
PO Box 18959
Wynberg, 2800

TOENS & PARTNERS cc
GEOLOGICAL, GEOHYDROLOGICAL & ENVIRONMENTAL CONSULTANTS

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Ground Water Resources
AUTHOR	**:**	A Woodford
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-1501
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EXECUTIVE SUMMARY

The introduction of the RDP water supply programme has resulted in the identification of the need in many instances for substantial augmentation of domestic water supply schemes serving large rural populations in the Eastern Cape Region. Water resources with adequate yield assurances are required for upgrading of the water supplies in the T60 tertiary drainage region.

The general level of knowledge regarding the water resources of the T60 drainage basin is limited. The scope of the T60 Basin Study is to provide a broad evaluation of the current state and potential for the development of the water resources, as wells as the existing and future potential water requirements of all user sectors. Toens and Partners were appointed by the Department of Water Affairs and Forestry to conduct the groundwater component of this study area.

Groundwater in the T60 drainage region occurs mainly in shallow, weathered-fractured rock aquifers, where the average depth to the waterlevel is 15 metres below surface. A number of semi- to unconsolidated, sandy primary aquifers of limited extent are likely to occur along the major river courses, especially towards the river-mouths and in estuaries.

The groundwater resources of the T60 drainage region are only being utilised at a fraction of their true potential. The present groundwater consumption in the study area is estimated at 3.0×10^6 m^3 per annum.

The groundwater resources of the T60 catchment, as indicated by rainwater recharge, are high - in the order of 280×10^6 m^3 per annum. However, much of this groundwater is 'lost' as base-flow to the many perennial rivers draining the T60 catchment, particularly during the dry season. Presently, the low permeability of the shallow aquifers and inaccessibility of the terrain limit the development potential of the groundwater resources to 12.5 - 23.5×10^6 m^3 per annum. In general the groundwater quality is good and it is suitable for domestic water supply purposes.

With the drilling of deeper and higher yielding production boreholes, it will be possible to abstract between 50.0 - 90.0×10^6 m^3/year of groundwater on a sustainable basis. The costs of exploring and developing such groundwater-supplies will be considerably higher than the existing 'ad-hoc', low-yielding groundwater supply 'schemes'. The sustainability of such groundwater supply schemes will depend upon establishing appropriate groundwater monitoring and management systems, which are to a large extent self-funding.

The development of the groundwater resources of the region should receive attention as it represents a ubiquitous, sustainable, relatively inexpensive and good quality source of water. In this regard, the following Quaternary catchments should be prioritised in their order of listing: T60D, T60H, T60E, T60F and T60B.

The cost of establishing and maintaining a groundwater supply scheme may, in certain parts of the T60 region, prove to be a factor limiting its development. The present groundwater development costs are relatively high in terms of the poor drilling success rates and low sustainable yields of the boreholes. The 'sustainability' of these water supplies are severely restricted by a lack of maintenance of the boreholes, pump equipment and reticulation networks. Furthermore, no groundwater monitoring or management programmes are put in place to ensure the long-term sustainability of the supply, which is crucial given the 'invisible' nature of the resource. The present ad-hoc nature of the existing groundwater supply 'schemes' makes it difficult to implement any feasible cost recovery systems, so urgently required to ensure a long-term self-sustaining water supply scheme. Cost reductions can be achieved through better integration of the groundwater development strategies within the overall strategic planning of the region's water resources.

The average groundwater development costs for establishing high- and low- yielding production boreholes within each Quaternary catchment are summarised below:

- It is more cost effective to develop low-yielding (< 0.5 l/s) rather than high-yielding (≥ 2.5 l/s) production boreholes in all catchments (**Figure 35**).

- Individual, low-yielding production boreholes can be most cost effectively developed in catchments T60H and T60D.

- Wellfields of high-yielding production boreholes can be most cost effectively developed in catchments T60B, T60E and T60F.

- Catchments T60D and T60H should receive the highest priority for groundwater development, due to their high groundwater potential and reasonable development costs.

- Catchment T60C has the lowest groundwater development potential due mainly to the rugged terrain and predominance of Dwyka rocks.

The groundwater resources of the T60 basin should be developed within existing or as an integral part of future surface-water supply schemes, where they can be utilised to:

- Augment supplies during droughts / floods (emergency-standby role),
- To span periods of peak water demand (intermittent usage), or
- To gradually increase the capacity of the scheme (continuous usage).

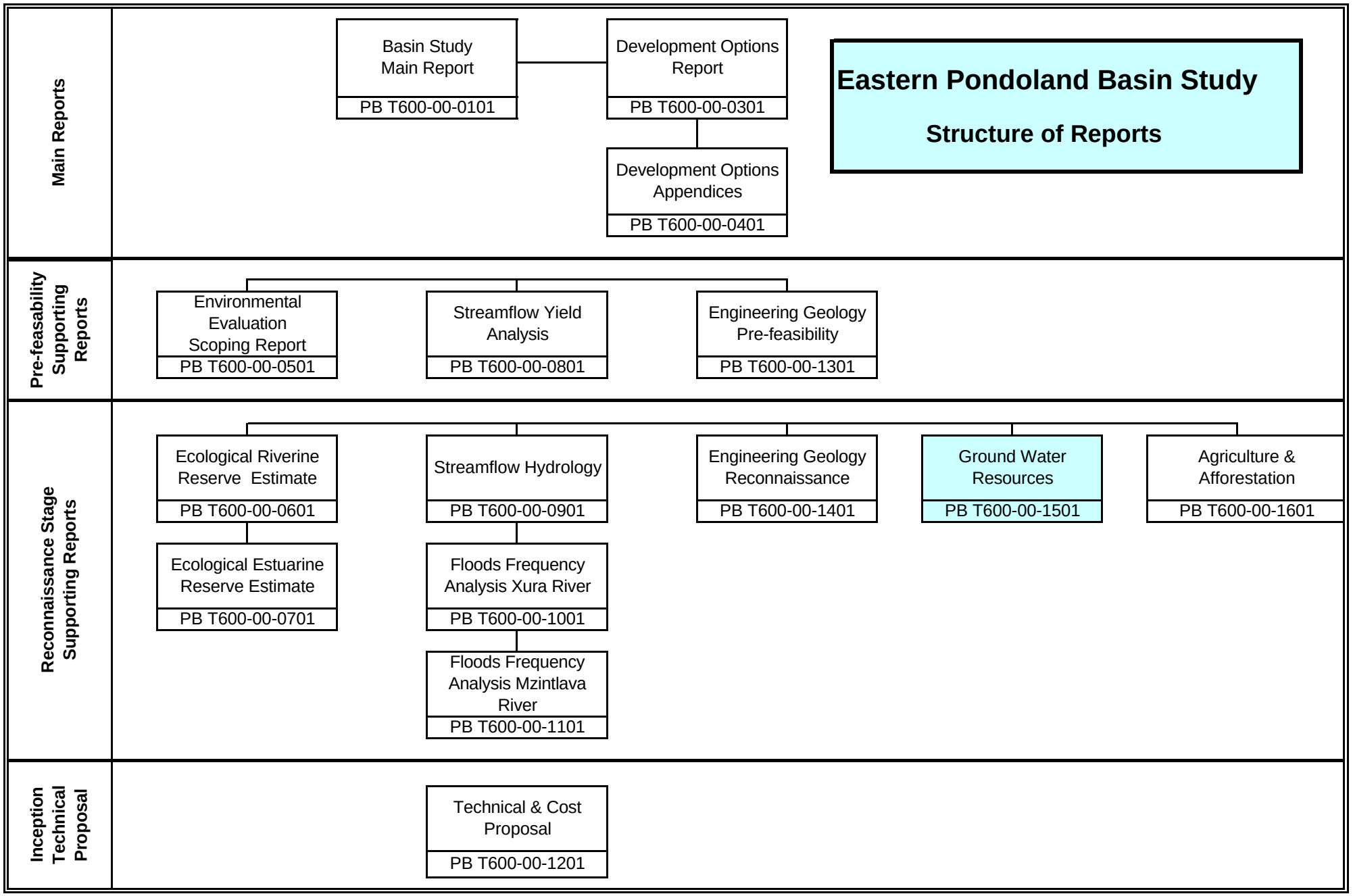

Main Reports
Basin Study Main Report
PB T600-00-0101
Development Options Report
PB T600-00-0301
Development Options Appendices
PB T600-00-0401
Eastern Pondoland Basin Study
Structure of Reports
Pre-feasability Supporting Reports
Environmental Evaluation Scoping Report
PB T600-00-0501
Streamflow Yield Analysis
PB T600-00-0801
Engineering Geology Pre-feasibility
PB T600-00-1301
Reconnaissance Stage Supporting Reports
Ecological Riverine Reserve Estimate
PB T600-00-0601
Ecological Estuarine Reserve Estimate
PB T600-00-0701
Streamflow Hydrology
PB T600-00-0901
Floods Frequency Analysis Xura River
PB T600-00-1001
Floods Frequency Analysis Mzintlava River
PB T600-00-1101
Engineering Geology Reconnaissance
PB T600-00-1401
Ground Water Resources
PB T600-00-1501
Agriculture & Afforestation
PB T600-00-1601
Inception Technical Proposal
Technical & Cost Proposal
PB T600-00-1201

TABLE OF CONTENTS

		PAGE
ABSTRACT		
1.0	INTRODUCTION	1
2.0	TERMS OF REFERENCE (ToR)	1
3.0	DEFINITION OF THE STUDY AREA	1
4.0	PHYSICAL CHARACTERISTICS	2
4.1	Physiography	2
4.1.1	Coastal Plateau	2
4.1.2	Inland Plateau	3
4.2	Mean Annual Precipitation	6
4.3	Geomorphology	7
5.0	GEOLOGY	9
5.1	Pre-Karoo Rocks	9
5.1.1	Sikombe Granite	9
5.1.2	Margate Complex	10
5.1.3	Msikaba Formation	11
5.2	Karoo Supergroup	11
5.2.1	Dwyka Group	11
5.2.2	Ecca Group	12
5.2.3	Beaufort Group (Adelaide Subgroup)	12
5.3	Post-Karoo Deposits	13
5.3.1	Mbotyi and Mzamba Formation	13
5.3.2	Quaternary Sediments	13
5.4	Karoo Dolerite Intrusives	14
5.5	Structure and Tectonics	15
5.5.1	Faults	16
5.5.2	Paleo-Stress Regime	16
5.5.3	Neotectonic Stresses and Seismic Provinces	17
5.5.4	Hydrogeological Significance	20
5.6	Satellite lineament Mapping	21
6.0	PREVIOUS GEOHYDROLOGICAL INVESTIGATIONS	25

TABLE OF CONTENTS **PAGE**

7.0 RECONNAISSANCE HYDROCENSUS 27

7.1 Springs and Seeps 28
7.2 Groundwater Quality 28

8.0 GROUNDWATER CHARACTERISTICS 30

8.1 Groundwater Occurrence 30

8.1.1 Lithology 31

8.1.1.1 Pre-Cambrian Basement Granite 33
8.1.1.2 Msikaba Formation 33
8.1.1.3 Dwyka Group 33
8.1.1.4 Ecca Group 34
8.1.1.5 Beaufort Group 35
8.1.1.6 Cretaceous and Quaternary Deposits 35

8.1.2 Karoo Dolerite Intrusions 36
8.1.3 Geological Lineaments 37
8.1.4 Drainage System 39
8.1.5 Contact between Lithostratigraphic Units 40

8.2 Groundwater Exploration Drilling Targets 40
8.3 Borehole Yield Statistics per Hydrotectonic Domain 42
8.4 Borehole Yield Statistics per Quaternary Catchment 45
8.5 Groundwater level and Yield Variations with Borehole Depth 46
8.6 Springs and Seeps 49
8.7 Groundwater Quality 52

8.7.1 Regional Water Quality Trends 53
8.7.2 Possible Sources of Groundwater Pollution 54

9.0 GROUNDWATER EXPLORATION POTENTIAL OF THE LUSIKISIKI DISTRICT 56

9.1 Existing Water Resources 56
9.2 Exploration Drilling Targets 58

10.0 EXISTING GROUNDWATER USAGE AND CONSUMPTION 61

TABLE OF CONTENTS **PAGE**

11.0 GROUNDWATER RESOURCE POTENTIAL OF THE T60 TERTIARY DRAINAGE REGION **64**

11.1 Aquifer Recharge **65**
11.2 Groundwater Exploitation Potential **68**
11.3 Groundwater Development Potential **69**
11.4 Costs of Groundwater Development **73**

12.0 CONCLUSION AND RECOMMENDATIONS **80**

REFERENCES

LIST OF FIGURES

		PAGE
1	Location of the T60 Tertiary Drainage Region in South Africa	2
2	Digital Elevation Model (30x30m) of the T60 Catchment	3
3	Drainage Density of the T60 Catchment	4
4	Vegetation Types of the T60 Catchment, after (a) Acock's (1988) and (b) Low & Robelo (1996)	5
5	Mean Annual Precipitation of the T60 Catchment	6
6	Coefficient of Variation of Annual Rainfall for the T60 Catchment	7
7	Principle Erosional Landsurfaces of the T60 Catchment	8
8	Geology of the T60 Catchment	10
9	Principle Palaeo-Stress Regimes in the study area over the period 190 to 135 Ma	18
10	Seismic Stress Provinces of Southern Africa	19
11	Landsat 5 Thematic Mapper satellite image of the T60 catchment	22
12	Distribution of Geological and Satellite lineaments in the T60 catchment	23
13	Distribution of palaeo-'extensional' lineaments in the T60 catchment	24
14	Distribution of neo-'extensional' lineaments in the T60 catchment	24
15	Location of Boreholes and Springs inventoried during the Hydrocensus	29
16	Distribution of Boreholes and Springs	31
17	Proximity of Boreholes to buffered, ENE-trending Lineaments	37
18	Borehole Distribution within the Hydrotectonic Domains of the T60 Catchment	43
19	Borehole Yield versus number of water-strikes	47
20	Probability of striking groundwater with drilling depth below the surface and below the regional waterlevel	48
21	Mean Borehole Yields obtained at Water-Strikes in relation to Depth below the Surface	49
22	Schematic Conceptual Diagram indicating the occurrence and hydrological significance of springs and seeps in the study area	50
23	Distribution of Boreholes and Springs with chemistry Information	53
24	Regional Setting of the Lusikisiki Rural Water Supply Scheme	57
25	Exploration Drill Targets in the vicinity of the LRWSS	59
26	GIS spatial-model used to estimate Groundwater Consumption per Quaternary catchment	63
27	Mean Annual Volumes of Recharge using a 5% recharge rate	66
28	Mean Annual Volumes of Recharge using a variable recharge rate	66

LIST OF FIGURES **PAGE**

29	Upper Limit of Mean Annual Volumes of Recharge (variable rate)	67
30	Lower Limit of Mean Annual Volumes of Recharge (variable rate)	67
31	Distribution of 'Structural' Drill Targets in the T60 Catchment	70
32	Groundwater Development Potential of the T60 drainage region	72
33	Groundwater development costs to establish a borehole yielding £ 0.5 l/s	77
34	Groundwater development costs to establish a borehole yielding ³ 2.5 l/s	77
35	Comparison of the costs of developing the groundwater resources using 2.5 l/s and 0.5 l/s production boreholes	79

LIST OF TABLES

		PAGE
1	Lithostratigraphy of the T60 Catchment	9
2	Summary of Boreholes and Springs Inventoried	29
3	Borehole Yield Statistics per major Lithostratigraphic Unit in the T60 Drainage Region	32
4	Literature Review of Borehole Yield Statistics per Litho-Stratigraphic Unit	32
5	Influence of Dolerite Intrusions on Borehole Yields of the T60 catchment	36
6	Influence of Dolerite Dykes and Satellite Lineaments on borehole yields of the T60 catchment	38
7	Influence of Drainage Features on Borehole Yield	39
8	Yield Statistics of Boreholes drilled into a Lithostratigraphic contact	40
9	Groundwater Drilling-Targets within each Lithostratigraphic Unit	41
10	Summary of Geological Classification Criteria per Hydrotectonic Domain	44
11	Borehole Yield Statistics per Hydrotectonic Domain	44
12	Borehole Yield Statistics per Quaternary Catchment	45
13	Weighted Median Borehole Yield per Quaternary Catchment	46
14	Statistics of Waterlevels, Depth of Water Interceptions and Borehole Depths in the T60 Catchment	47
15	Chemistry of 'Fresh' Springs sampled during the Hydrocensus	51
16	Chemistry of the hyper-saline Insunka Spring	52
17	Estimated Annual Volumes of Groundwater consumed per Quaternary Catchment	64
18	Hydrological Characteristics of the T60 Quaternary Catchments	64
19	Groundwater Recharge and Exploitation Potential of the T60 Catchments	68
20	Groundwater Development Potential of the T60 Catchments	70
21	Average Groundwater Development Potential between Quaternary Catchments	71
22	Borehole Development Potential according to Yield	73
23	Comparison of groundwater development potential and costs between Quaternary Catchments for establishing (i) low-yielding and (ii) high-yielding production boreholes	79

1.0 INTRODUCTION

The introduction of the RDP water supply programme has resulted in the identification of the need in many instances for substantial augmentation of domestic water supply schemes serving large rural populations in the Eastern Cape Region. Water resources with adequate yield assurances are required for upgrading of the water supplies in the T60 tertiary drainage region.

The general level of knowledge regarding the water resources of the T60 catchment is limited. The aim of this study is to provide planners with an information base from which strategies for the sustainable and efficient utilisation of the water resources can be formulated, as well as for establishing water management areas and a catchment development strategy plan, as stipulated by the new Water Act.

The scope of this study is to provide a broad evaluation of the current status and potential for development of the water resources of the T60 catchment, as well as the existing and future water requirements of all user sectors.

Toens and Partners were appointed by the Department of Water Affairs and Forestry to conduct the groundwater component of the 'Eastern Pondoland' or T60 Drainage Basin Study, under the supervision of the Lead Consultants, Uhlmann, Witthaus and Prins (UWP) Consulting Engineers.

2.0 TERMS OF REFERENCE (TOR)

Toens and Partners were instructed by UWP to commence the groundwater study on the 8th March 1999 (Telefax No. 19278BS 1/9-UF-98), in accordance with our project proposal dated the 25th January 1999 (**Appendix 1**).

The purchase of the Landsat imagery and remote sensing for the groundwater study was approved on the 10/04/1999. Toens and Partners were also requested to conduct a satellite remote sensing study aimed at mapping the extent of soil erosion in the study area.

3.0 DEFINITION OF THE STUDY AREA

The study area encompasses the T60 Tertiary Drainage Region (**Figure 1**), which is located in the most north-eastern, coastal portion of the Wild Coast District of the Eastern Cape Province (formerly part of the Transkei). This area is also known as the Pondoland coast.

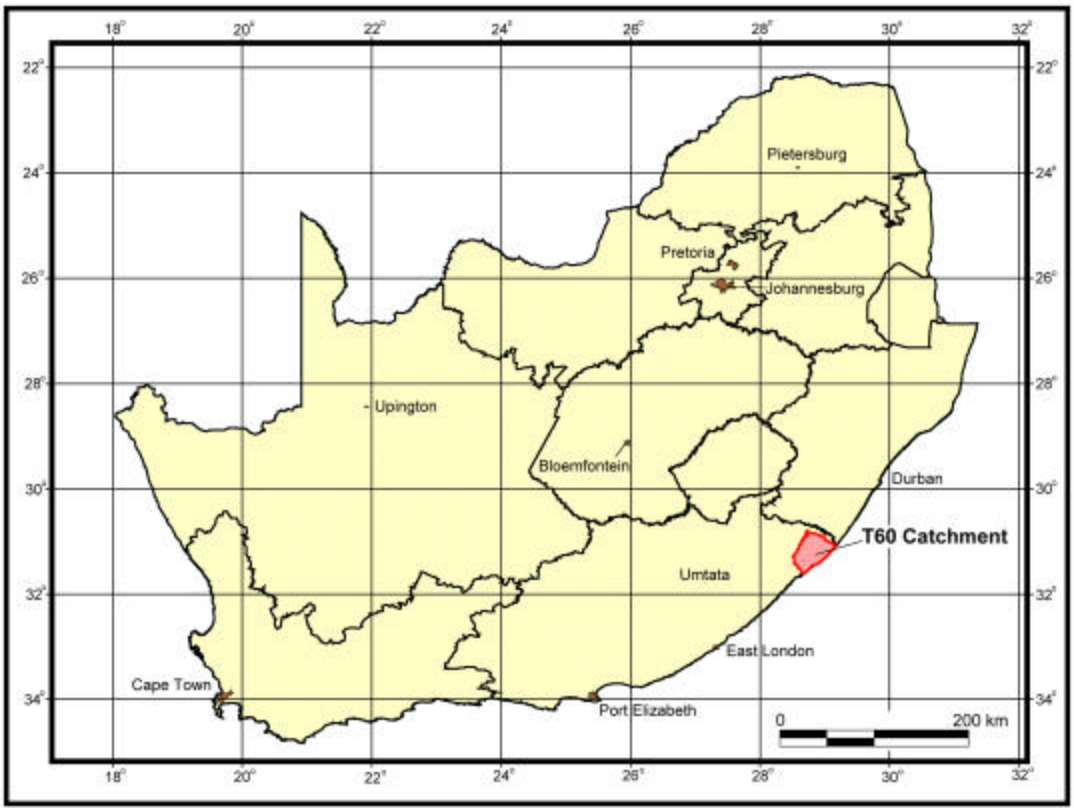


Figure 1: Location of the T60 Tertiary Drainage Region in South Africa

4.0 PHYSICAL CHARACTERISTICS

4.1 PHYSIOGRAPHY

The physiography of the T60 catchment is variable and is strongly controlled by the underlying geological formations with different resistance to weathering and erosion. The ground elevation rises in a series of 'steps' from the coastline to a maximum of 1245 m.amsl in the north-western portion of the study area (**Figure 2**). The digital elevation model (DEM) shows two major physiographic regions, namely:

4.1.1 Coastal Plateau

The coastal belt is generally 10-20km wide and comprises a relatively flat, gentle seaward-sloping peneplain, lying between 0 and 400 m.amsl. The drainage channels are often linear and tend to follow the dominant fracture systems, especially the NW trend (i.e. **Figure 2** – the Mtentu River). This region is underlain by sandstone of the Msikaba Formation. Where rivers cut across the Msikaba sandstones, major steep sided gorges have been formed. The shape of the coastline is controlled by geological structures. The coastal zone between the Mkozi River and Port St. Johns is low-lying, commonly less 200 m.amsl, and

consists of more rugged terrain. This area is underlain by faulted Ecca shale and Dwyka diamictite.

4.1.2 Inland Plateau

The inland plateau is characterised by an uneven, seaward-sloping surface, lying between 400 -11 000 m.amsl, which has been extensively incised by the major drainage systems. The western and north-western sections of the study area are dominated by several mountain ranges, which are invariably capped by massive dolerite sills. The area is underlain by Dwyka diamictite and Ecca shale.

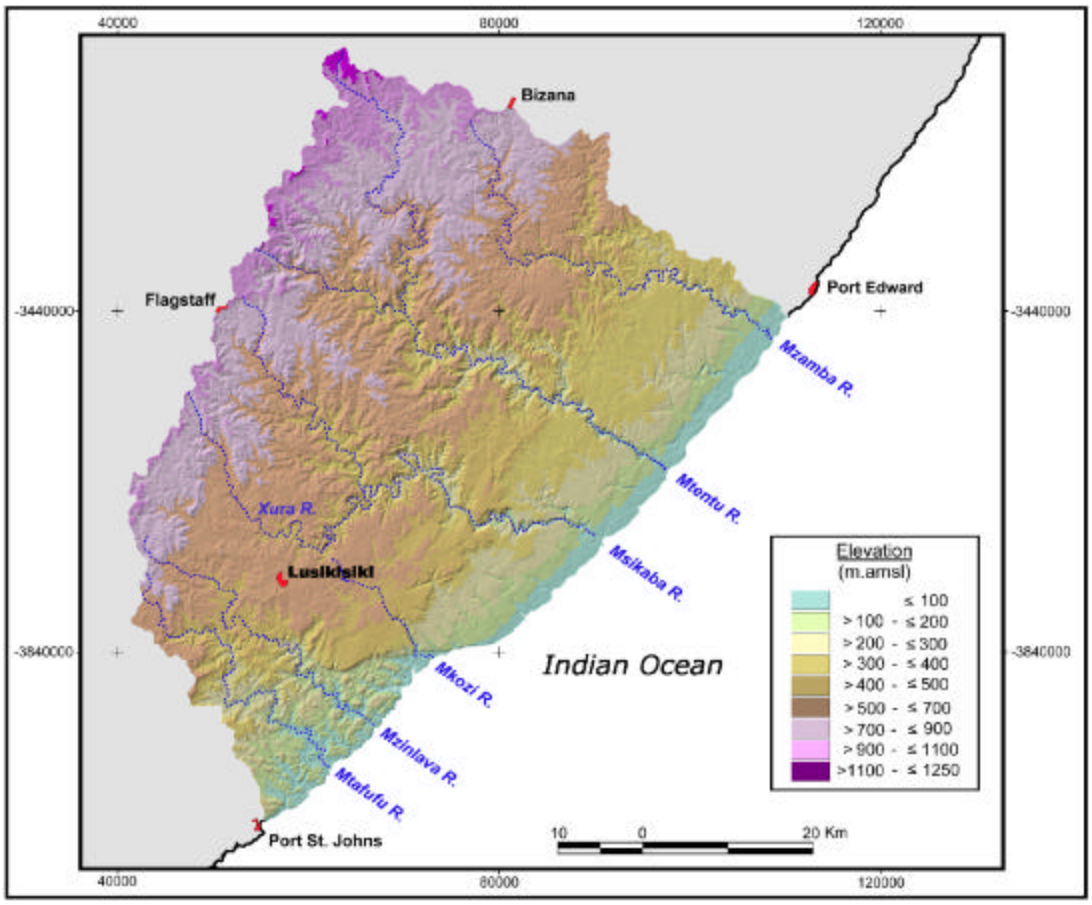


Figure 2: Digital Elevation Model (30x30m) of the T60 Catchment

The major rivers in the study area are the Mtentu, Msikaba, Mzintlava, Mtafufu and Mzamba, which flow in a south-easterly direction from the more elevated areas into the Indian Ocean (**Figure 2**). A large portion of the drainage system is clearly controlled by geological lineaments (i.e. dolerite dykes, faults).

The drainage density is highest in the Dwyka Formation, probably due to its low resistance to weathering and low permeability (**Figure 3**). The numerous steeply incised gorges and tributaries in these areas restrict its accessibility to humans. The drainage density is the lowest along the coastal plateau, which is underlain by the more resistant Msikaba sandstones. A zone of anomalous high drainage density, which occurs in the area between Port St. Johns and the Mzintlava River, has probably been enhanced by the intense structural deformation of this area.

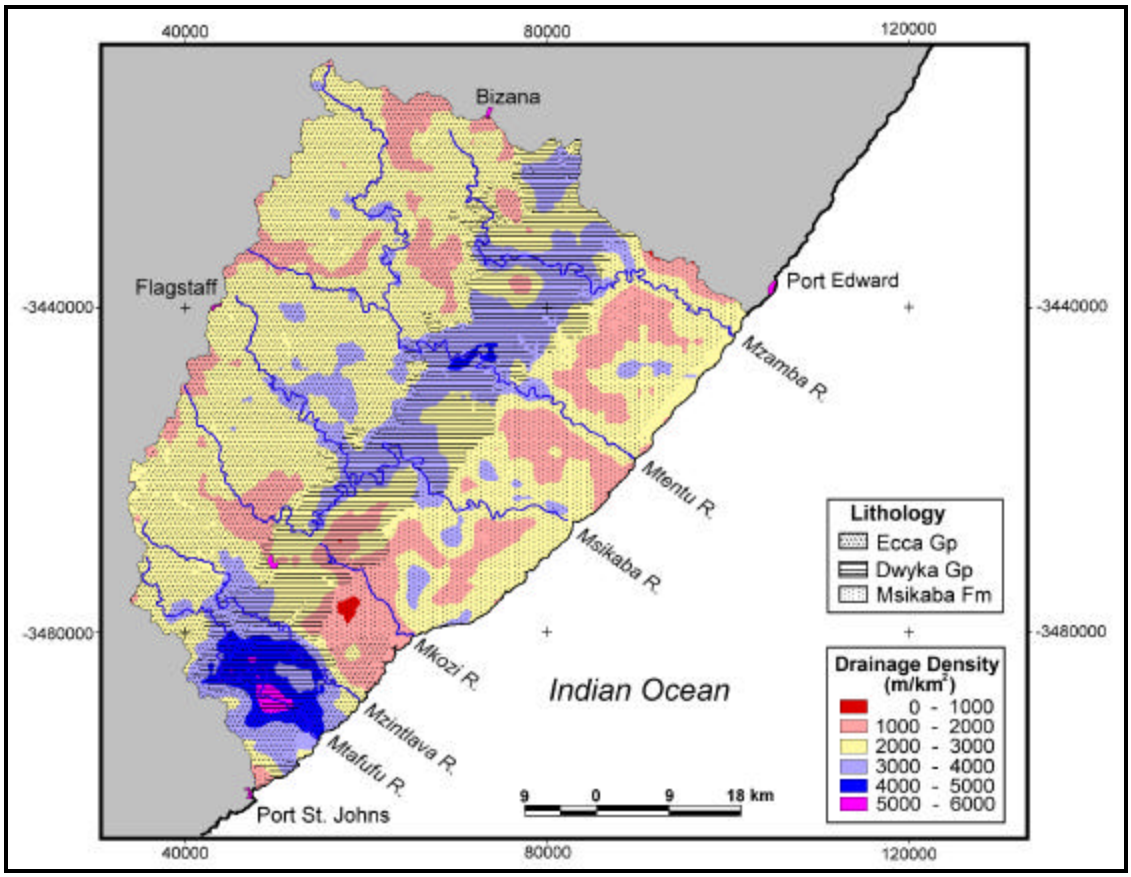


Figure 3: Drainage Density of the T60 Catchment

The distribution of the major vegetation types in the T60 catchment are depicted in **Figures 4(a)** and **4(b)**, after Acocks (1988) and Low-Rebello (1996). Both classifications indicate that the Interior Plateau is dominated by grasslands (*Acock's Sourveld*), and bushveld along the major river valleys. Isolated patches of indigenous forests (**Figure 4(b)** - *Afromontane Forest*) occur along the slopes of mountains and steep-sided river valleys. The vegetation along the Coastal Plateau is more varied and consists of forest, bushveld and grasslands.

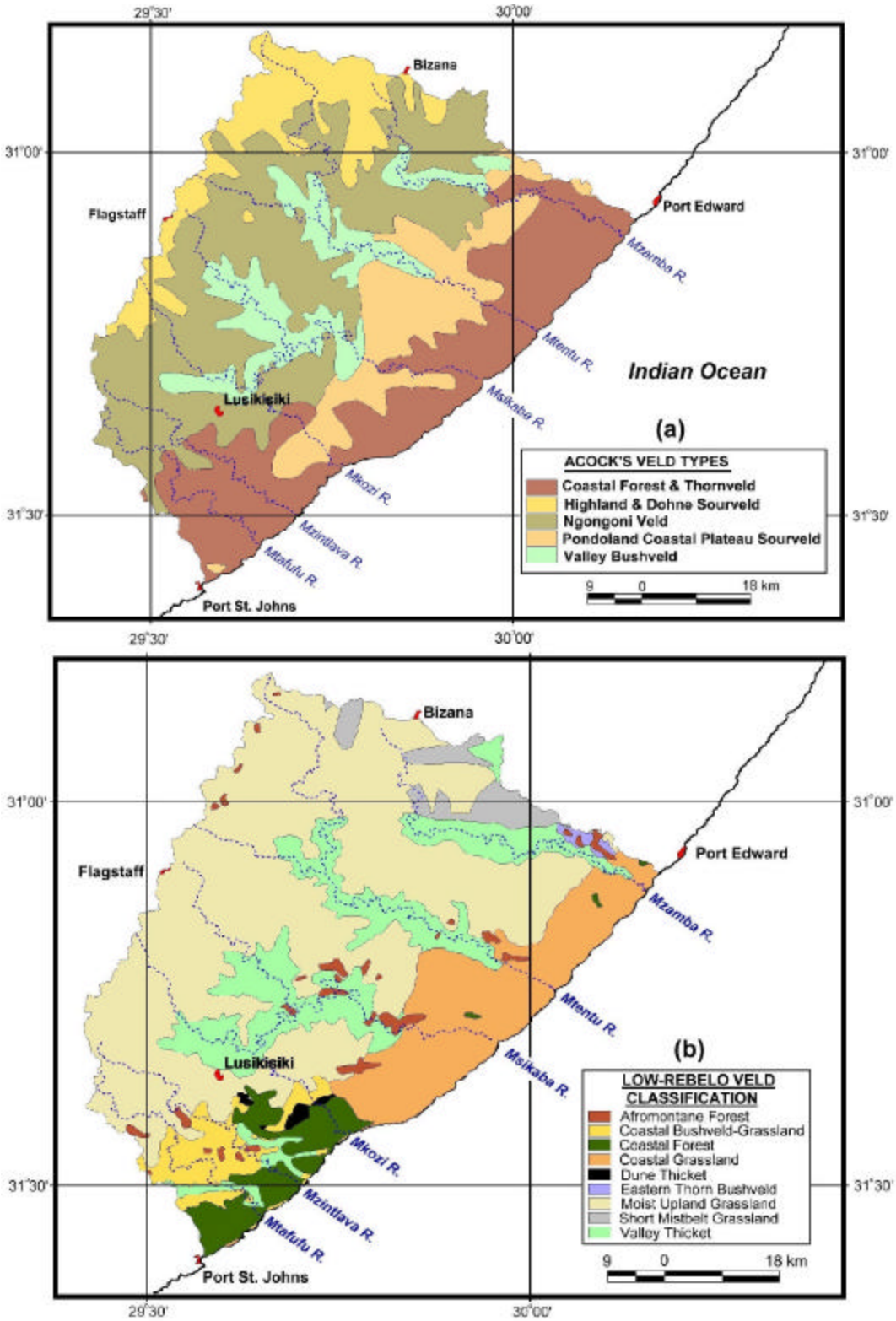


Figure 4: Vegetation Types of the T60 Catchment, after (a) Acocks (1988) and (b) Low & Robello (1996)

4.2 MEAN ANNUAL PRECIPITATION

A map showing the Mean Annual Precipitation (MAP) was interpolated from the CCWR's 1'x1' grid data (**Figure 5**). In general, the MAP decreases inland from the coast and from the south-west to the north-east of the study area. The Coastal Plateau receives between 1000 and 1400 mm of rainfall per annum, while the Inland Plateau receives an average of 800 to 1000 mm/year. Isolated areas in the Inland Plateau receive a MAP in excess of 1000mm due to orographic effects. Areas in the Bizana district receive less than 800mm of rain per annum.

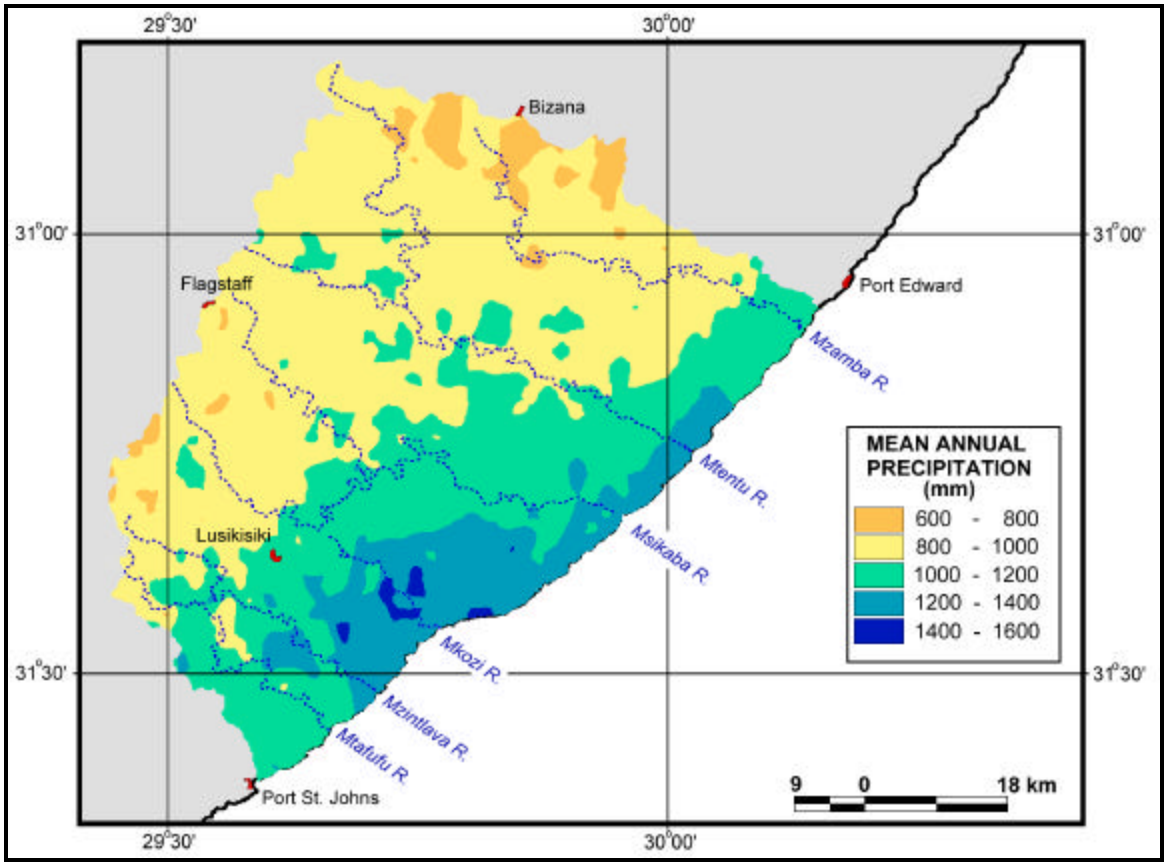


Figure 5: Mean Annual Precipitation of the T60 Catchment

The percentage coefficient of variation (CV) of year-to-year rainfall in the T60 catchment is illustrated in **Figure 6**. The CV of annual precipitation is an index of climatic risk, indicating the likelihood of fluctuations in reservoir storage, aquifer recharge etc. The higher the MAP the lower its inter-annual variability – in other words the lower the rainfall the more variable will be the groundwater recharge. The CV is less than 19% along the coastal plateau and increases inland to a maximum of 25% in the east and northeast of the study area.

The majority of the rain falls during the mid summer months of January to February. The mean potential evaporation (A-pan equivalent) varies between 1400–1800 mm (Schulze et al, 1997).

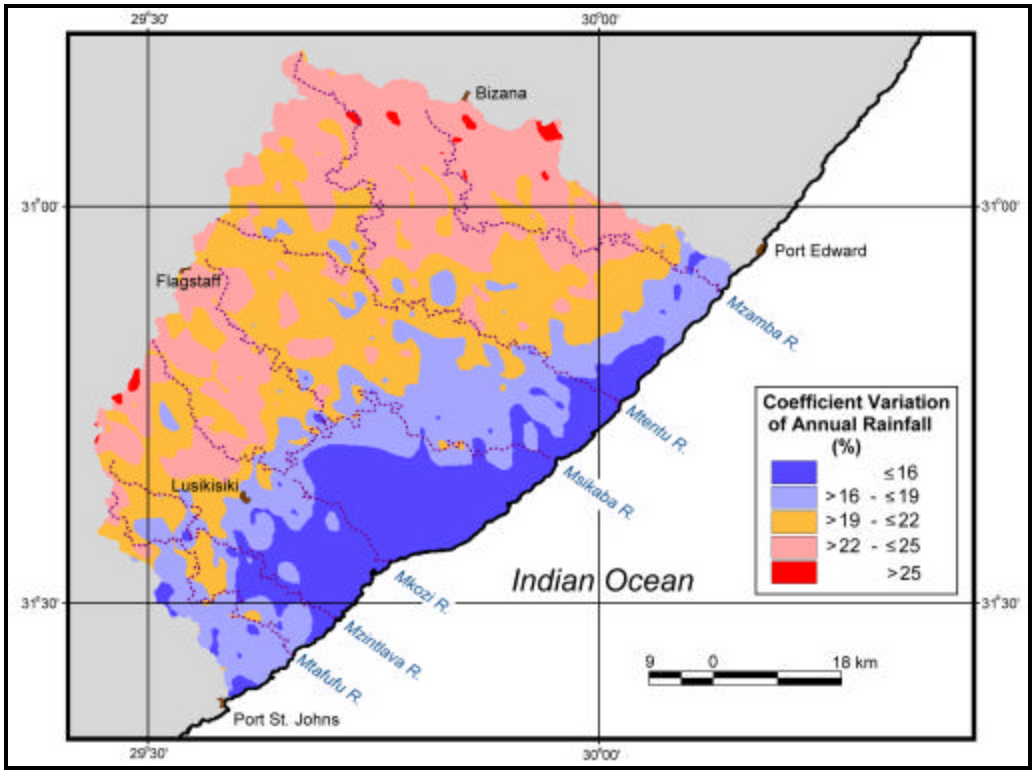


Figure 6: Coefficient of Variation of Annual Rainfall for the T60 Catchment

4.3 GEOMORPHOLOGY

A single cycle of erosion, interrupted by minor tectonic interludes, prevailed from the Late Jurassic times of continental rifting and up until the early Miocene (~22.5 Ma). By the end of this period, a gentle erosional surface or pediplain, the so-called African Surface, extended across most of southern Africa at elevations of 500 to 600m. The long duration of this event resulted in deep weathering and kaolinisation of the underlying bedrock.

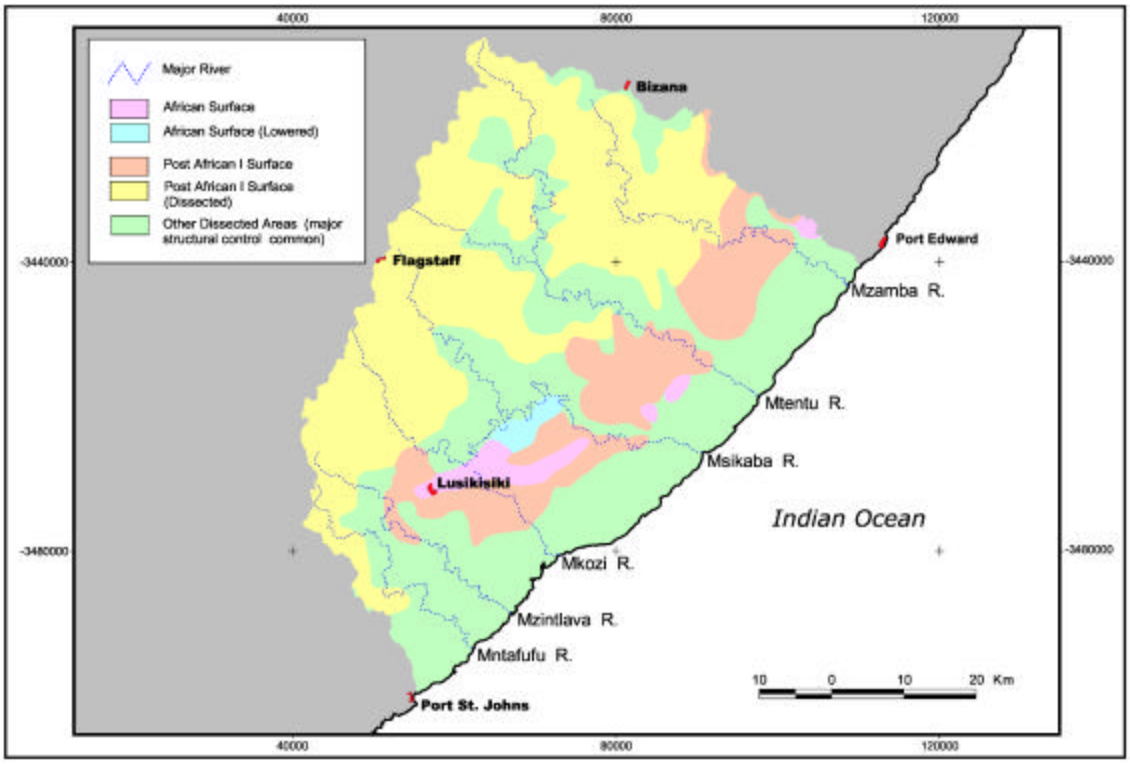


Figure 7: Principle Erosional Landsurfaces of the T60 Catchment (after Partridge & Maud, 1987)

Modest renewed uplift of 150-300m in the Miocene (~ 18Ma) tilted the continent slightly to the west and initiated a new erosional cycle – the Post African I surface. The cycle was terminated near the end of the Pliocene and its relatively short duration (15-16 Ma) resulted in imperfect planation in most areas to levels of no more than 100-300m below the African Surface. The relatively short duration of the Post African I cycle is reflected in the absence of advanced weathering and kaolinisation of the underlying rocks. The lowermost 3-5km of most of the major river courses along the south-eastern margin of the subcontinent are linear, in contrast to the meandering and incised rivers of the hinterland. These linear sections are extensions of the rivers across former areas of continental shelf, which were exposed as a result of the Miocene uplift.

A second uplift of major proportions at the end of the Pliocene (~2.5Ma), raised the eastern interior of the sub-continent by as much as 600-900m. Major monoclinal warping along the Ciskei-Swaziland Axis resulted in the development of the south-eastern hinterland. The Post African II surface is manifested chiefly in the deep incision of the coastal hinterland and downcutting along major rivers of the interior. Earlier surfaces were severely deformed and dissected, especially in the south-east of the country. The planation was limited to only a few areas along to the coast. The preservation of discrete erosion surfaces with separating escarpments indicates the dominance of backwearing over downwearing in the evolution of the sub-continent (Partridge and Maud, 1987).

A few isolated remnants of the African Surface occur mainly in the vicinity of Lusikisiki and the area extending towards the Msikaba River (**Figure 7**). A large portion of the Coastal and Inland Plateau comprise remnants of the Post African I erosional surface, the north-westerly section having been heavily dissected by the later Post African II erosional cycle.

5.0 GEOLOGY

The lithostratigraphy of the T60 Tertiary drainage region is summarised in **Table 1** and illustrated in **Figure 8**.

Table1: Lithostratigraphy of T60 Catchment

Group / Formation	Major Rock Type	Age
-	Unconsolidated alluvial, aeolian, estuarine and colluvial deposits. Minor travertine.	Quaternary
Mzamba Formation	Clay beds and fossiliferous shelly limestone.	Cretaceous
Mbotyi Formation	Greenish-grey conglomerates and subordinate coarse sandstone.	Cretaceous
Karoo Intrusives	Dolerite.	Jurassic
Beaufort Group	Green-grey to blue-grey, mudstone and sandstone.	Triassic
Ecca Group	Shale and minor sandstone.	Permian
Dwyka Group	Diamictite, minor shale.	Carboniferous
Msikaba Formation	Light, grey, quartzitic sandstone.	Devonian
Sikombe Granite – Margate Complex	Gneiss and granite.	Precambrian

The geology of the study area was captured and compiled in a GIS from the Council for Geoscience's published 1/250 000 scale geological mapsheets of Umtata (3128), Kokstad (3028) and Port Shepstone (3030).

5.1 PRE-KAROO ROCKS

5.1.1 Sikombe Granite

The rock is a strongly foliated, coarse-grained, grey-biotite granite that is exposed as a small outcrop along the coastline between the Mtentu and Mzamba Rivers (**Figure 8**). These rocks are of Precambrian age, i.e. ~1000 Ma (Thomas, 1988).

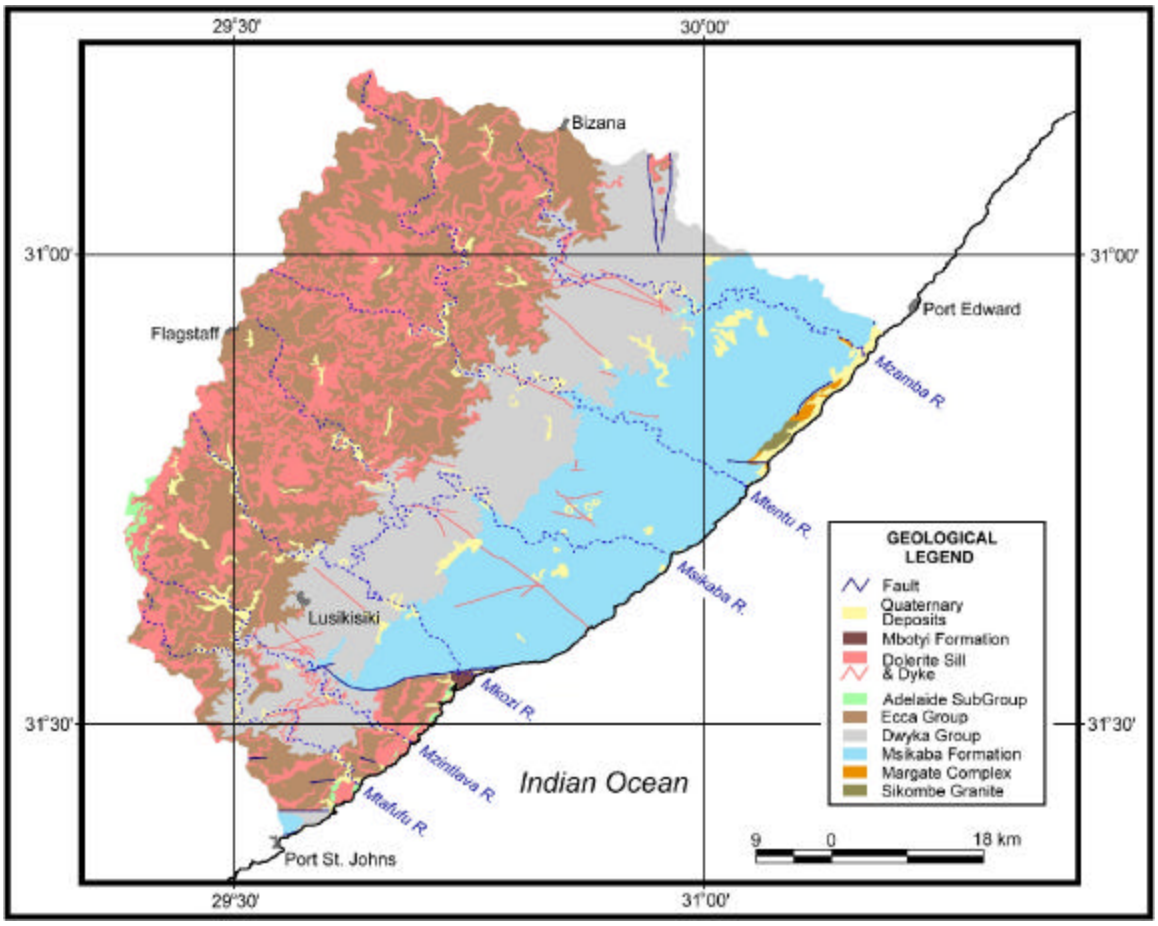


Figure 8: Geology of the T60 Catchment

5.1.2 Margate Complex

The heterogeneous rocks of the complex comprise three main lithological units, which have not as yet been afforded formal lithostratigraphic classification (Thomas, 1988). The most abundant unit and one which outcrops along the coastline between the Mzamba and Mtentu Rivers, is the so-called '*gneissose garnet-leucogranite*'. The rocks are medium-grained, pink and pale-grey gneissose leucogranites in which garnet occur as individual grains and polycrystalline clots (Thomas, 1988). These rocks are of Precambrian age, i.e. ~1000 Ma.

5.1.3 Msikaba Formation

The Msikaba Formation outcrops along most of the coastline to the north of the Mkozi River (**Figure 8**), and covers approximately a third of the study area. The Msikaba Formation underlies the Dwyka Group, but has been juxtaposed against the Ecca by faulting in the vicinity of Port St. Johns and the Mkozi River. The Formation is of Upper Devonian age making it the lateral equivalent of the Witteberg or Bokkeveld Group.

The Formation is mainly comprised of pale-grey, marine, quartz-arenites that contain Devonian fossils, thereby separating it from the Natal Group Sandstone which are unfossiliferous, fluviatile red-beds. Hobday and Mathew (1974) report a quartz content of between 70 to 96% and describe three major lithogenetic units, namely:

1. Sheet-Sandstone Units: laterally persistent (i.e. 4km) units ranging from 0.3 to 1.5m in thickness. The paleo-environmental setting appears to have been shallow marine.
2. Lenticular Sandstone Units: Major sandstone units with a thickness to length ratio of 1 to 50. The external form of the lenticular sandstone units reflects a complex interplay of erosional and depositional processes in a shallow marine environment.
3. Channel Sandstone Units: These are linear features with an erosive base and relatively horizontal upper surfaces. The features probably represent down-filled channels of estuarine origin.

Deposition of this formation probably took place in an elongate down-warped trough, trending roughly parallel to the present-day coastline. The thickness of this formation is estimated to be in the order of 1000m. As a result of post-Gondwana rifting and subsequent erosion the original extent of the trough is unknown (Hobday and Mathew, 1974). The rocks dip between 1º and 10º towards the south-east along the coastline and towards to west in the interior.

5.2 KAROO SUPERGROUP

The T60 catchment contains Karoo rocks of the Dwyka, Ecca and Beaufort Groups, which have been intruded by the Jurassic dolerite intrusives.

5.2.1 Dwyka Group

The Dwyka rocks occur as a ±10km wide strip extending parallel to the coastline and covering approximately a third of the T60 catchment (**Figure 8**). An up-faulted block of Dwyka sediments also occurs to the north of Port St. Johns.

The Dwyka sediments are of fluvio-glacial and glacio-lucustrine origin. The rocks are of Carboniferous to early Permian age and unconformably overly the basement rocks (i.e. Msikaba Formation and Precambrian granite-gneisses).

The unit consists mainly of 'tillite' or diamictite, and is generally massive with little jointing, but is stratified in places. The Dwyka diamictite consists of angular to rounded clasts of basement rocks embedded in a bluish-grey matrix of angular sand grains and clay, with thin lenses of finely laminated bluish-grey to yellowish-grey shale (Karpeta and Johnson, 1979). In the study area, the thickness of the Dwyka rocks is estimated to vary between 200m and 500m, and dips at a low angle towards the north-west (Karpeta and Johnson, 1979; de Dekker, 1981). The Group pinches out against the light grey, quartzitic sandstone of the Msikaba Formation to the east.

Dolerite sills have generally been intruded along the Dwyka-Ecca contact, while a few scattered, north-easterly trending dykes have penetrated the unit. The Dwyka Group is intruded by a number of thin dolerite sills in the area between the Mzintlava and Mtafufu Rivers.

5.2.2 Ecca Group

Ecca sediments cover the entire western and southern portion of the T60 catchment and conformably overly the Dwyka Group (**Figure 8**). Within the study area, the Ecca Group consists almost entirely of undifferentiated shales, referred to as the Ecca Formation (SACS, 1980), while to the north of the study area the Group has been differentiated into the Pietermaritzburg, Vryheid and the Volksrust Formations (de Dekker, 1981). Several outliers of Ecca shale occur in down-faulted blocks to the south-east of Bizana. The shale here only forms a thin cap overlying the Dwyka rocks.

The Ecca sediments have been heavily intruded by dolerite sills, with increasing intensity towards the north-east of the study area and constitute approximately 50% of the total rock outcrop. In the interior, the shales dip gently (< 5º) towards the west and north-west, while in the southern coastal zone the strata dip towards the south and south-east. Locally dips may vary considerably mainly as a result of the dolerite intrusions or faulting.

5.2.3 Beaufort Group (Adelaide Subgroup)

The Adelaide Subgroup of the Beaufort rocks outcrop over an area of less than 2% of the T60 catchment, mainly along the (i) coast between Port St. Johns and the Mkozi River, and (ii) a small strip along the south-western boundary of the study area, in the Mfinizo district (**Figure 8**).

In the study area, the sediments consists of undifferentiated, greenish grey to greyish red mudstone alternating with subordinate fine to medium grained, buff coloured, litho-felspathic sandstones, which rest conformably on the underlying Ecca rocks (Karpeta and Johnson, 1979). The sediment pile is approximately 1000 to 1500m thick.

5.3 POST- KAROO DEPOSITS

5.3.1 Mbotyi and Mzamba Formation

At the Mkozi River mouth, 300m of greenish-grey conglomerates and subordinate coarse sandstones of the Mbotyi Formation, are downfaulted against the Msikaba sandstones along the so-called 'Egosa Fault' (**Figure 8**). These rocks rest unconformably on an eroded basement of Beaufort sediments. The unit is of Cretaceous age and represents an erosional remnant of what was a more extensive deposit (Karpeta and Johnson, 1979).

The conglomerates are composed mainly of sub-angular dolerite boulders and subordinate clasts of shale and sandstone, set in a poorly sorted, greenish-grey sandy matrix. The sediments probably represent an alluvial-fan deposit, which developed at the foot of a rising escarpment to the north of the Egosa Fault (Karpeta and Johnson, 1979).

The Mzamba Formation outcrops sporadically along the coast between the Mtentu and Mzamba Rivers. The outcrops generally consist of 10 to 12m of calcereous and clay beds, alternating with fossiliferous and hard shelly limestone. A basal conglomerate layer is present at many localities. The sediments form extensive wave-cut platforms and do not outcrop inland, except where they can be traced for short distances inland adjacent to some lagoons (Thomas, 1988).

Karpeta and Johnson (1979), state that the Mbotyi Formation is older than the Mzamba Formation, based upon the lack of Msikaba sandstone clasts in the Mbotyi deposits.

5.3.2 Quaternary Sediments

Estuarine, beach and aeolian sands, as well as alluvial and colluvial deposits constitute the bulk of the Quaternary deposits in the T60 catchment (**Figure 8**).

The coastline is largely rocky, but between the outcrops, small bays containing white to beige, medium- to coarse-grained sand deposits are common. A sand spit is often developed at the mouth of the major rivers, and thicknesses of up to 5m have been recorded (Thomas, 1988).

Alluvium is found along the course of the major rivers and some of their tributaries, especially in the vicinity of meanders, intersections and river mouths. The alluvium is typically an aggregate of clay, sand and gritty material. Occasionally a thin boulder-bed is present at the base.

The estuarine deposits of Kwazulu-Natal commonly consist of (i) mud, silty clay and fine sand (i.e. low energy) and (ii) uniform, medium to coarse sand with

frequent lenses of fine sand and black silt (i.e. high energy) fluvial deposits, such as at the Mtamvuna River mouth (Groundwater Development Services, 1995b). The depth of these sediments varies from less than 10m to in excess of 80m in the Mtamvuna estuary (Begg, 1978).

At Port St. Johns, near Insinuka and Lutengele, two deposits of travertine occur. Sulphur-bearing springs associated with faulting are present at both sites, where deposition is still taking place. The Lutengele deposit is the most extensive, being 20-25m thick and covering an area of 0.1 km^2 (Karpeta and Johnson, 1979).

5.4 KAROO DOLERITE INTRUSIVES

In the T60 catchment the Jurassic-aged (~180 Ma) dolerite intrusives are almost exclusively intruded into the Ecca and Beaufort sediments (**Figure 8**), although a number of dolerite dykes do transgress the Dwyka and Msikaba units. Also the Dwyka diamictite to the south of Lusikisiki have been intruded by a number of thin sills.

The proportion of dolerite to host-rock varies in the Karoo Supergroup, reaching a maximum of 40% in the Ecca and decreasing upwards in the sequence (de Decker, 1981). It appears that the competent basement rocks and relatively massive Dwyka diamictite only allowed the rising dolerite magma to fill vertical joints and fissures as dykes. In contrasts, the well-developed horizontal bedding of the Ecca shales and decreasing overburden pressure allowed the magma to spread laterally to from sills in this lithological unit (Thomas, 1988).

The dolerite sills in the Ecca Group are mostly concordant with the host rock, although discordant and undulating inclined-sheets also occur. No dolerite ring-complexes, as described by Chevallier and Woodford (1999), are apparent within the study area. Sills commonly vary in thickness between 5 and 50m, although de Dekker (1981) reports thicknesses in excess of 500m in the Ingeli-Tabankulu-Insizwa Mountain ranges to the north-west of the study area.

Dolerite dykes are apparently uncommon in the T60 catchment, according to the published 1/250,000 geological maps (**Figure 8**). They are rare along the coastal region. According to Du Toit (1929), the dykes represent the last phase of the Karoo igneous activity, based on the observation that they commonly transgress the sills and extrusive basalts. Du Toit and Maud (1961) state that the WNW trending dykes acted as feeder-fissures from which the basaltic lava flows erupted. It is possible that some of the regional dykes may have propagated laterally from a 'Triple-Junction' located in the Indian Ocean, especially the NW to WNW trending structures (Woodford and Chevallier, 1999).

The width of the dolerite dykes varies between 2 and 10m (de Dekker, 1981; Karpeta and Johnson, 1979). The majority of the mapped dykes are NW to WNW trending, while a number of NE to ENE dykes occur in the area to the south of Lusikisiki. The NW-WNW dykes are laterally persistent (i.e. 10-20km

long) and one such dyke transgresses the Msikaba Formation and passes out to sea at Mkweni. Many of the major river courses are controlled by dykes and other geological lineaments, i.e. the linear course of the Mtentu River across the Coastal Plateau may represent the undetected extension of the NW trending dyke mapped further inland. The attitude of the dykes are variable, although dips in excess of 85º are common.

Topographically the dykes may weather positively or negatively, and in the former case stand out as prominent linear ridges. They are often difficult to detect in the flat-lying areas.

The width of the contact metamorphic aureole adjacent to the dolerite intrusive is proportional to the thickness of the body. Mudstone are affected to a much greater degree than are sandstone, being altered to a light-grey to black, flinty rock or 'lydianite' (de Decker, 1981; Karpeta and Johnson, 1979). Vesicles are often developed within the mudstone, probably due to hydrothermal action at the intrusive contact.

Petrographically the dolerite dykes and sills do not differ greatly and their bulk chemical compositions are similar. They do, however, differ mainly in grain size and texture. The thinner dykes are fine-grained with an ophitic texture, while the sills are commonly medium- to coarse-grained and have a porphyritic texture. The rock type varies from olivene dolerite through tholeiite to granophyre (de Dekker, 1981).

5.5 STRUCTURE AND TECTONICS

The study area can be subdivided into two structurally distinct regions, namely:

(i) Inland Plateau – gently WNW dipping (< 5º) Karoo sediments, where faults are uncommon.
(ii) Coastal Plateau – ESE dipping rock strata, which have been disturbed by numerous faults, generally striking E-W at the coast.

The northern and possibly the central portion of the study area was subjected to gentle post-Karoo tilting, which presumably represents the southerly extension of the so-called '*Natal Monocline*' of King (1951). Maud (1961), however, proposed a '*rifted margin, tilted-fault block*' mechanism to explain this phenomenon. According to this theory, the blocks of sediments along the coast have been down-faulted and rotated by marginal rift-faults associated with the break up of Gondwanaland. As a result, various aged rock-units along the coast are juxtaposed alongside each other at sea-level.

5.5.1 Faults

A number of faults have been mapped in the T60 catchment (**Figure 8**), the more prominent being:

(i) the N-S Ntlakwe - Bongwan Fault System to the east of Bizana,
(ii) the E-W Egosa Fault which extends from the Mkozi River mouth to just south of Lusikisiki, and
(iii) the E-W Gates Fault at Port St. Johns.

Faulting is apparently confined to a narrow belt along the coast, except for the Egosa fault that extends some 20km inland.

The 100km long Ntlakwe-Bongwan Fault System has been described by Du Toit (1946) and Gevers (1941). A 3km wide block of dolerite and Ecca shale has been down-faulted between abutments of Dwyka rocks. The Ecca shale have been down-thrown by about 550m to the east of Bizana (Karpeta and Johnson, 1979). The western plane of the fault system is marked by active springs emitting CO^2 gas, travertine deposits and silicified, brecciated Dwyka sediments. The fault system extends to the north of the study area into the Mzimkulu River valley. Gevers (1941) states that the fault system is related to the regional monoclinal flexuring that occurred along the Kwazulu-Natal coastline.

In general, the southern portions of the faults are down-thrown and movements of up to 3000m have been recorded (Karpeta and Johnson, 1979). A horst of upfaulted Msikaba Formation is exposed at the 'Gates' near Port St. Johns.

Karpeta and Johnson (1979) deduced that the faulting commenced during the early Cretaceous and terminated towards the end of this period, based upon the presence of Cretaceous sediments in the area.

These features may be related to Maud's (1961) horst-n-graben structures, induced within a tensional stress regime acting at approximately at right angles to the present coastline (i.e. south-easterly).

5.5.2 Paleo-Stress Regime

Von Veh (1994) describes the various stress regimes that prevailed during three major tectonic events in the southern and south-eastern areas of Kwazulu-Natal, namely:

<u>Phase 1 – Jurassic Dolerite Magmatism (180 Ma)</u>

The intrusion of dolerite magma into the Karoo Basin in the form of sills and dykes. Von Veh states that the dominance of the WNW trending dykes related to this event would tend to indicate that the region was subjected to a stress field in which σ_3 had a SSW azimuth. The association of these dyke swarms with the

NNW and ENE trending sets of brittle discontinuities to the south of the Kaapvaal Craton indicates that the latter sets represent a conjugate system of shear fractures (**Figure 9 - Phase 1**). The orientation of σ_1 would thus bisect these WNW shear fractures, while σ_2 was sub-vertical.

Phase 2 – Early Gondwanaland Breakup (160-180 Ma)

The event involved the separation of Africa, Antarctica and Madagascar. According to von Veh, this event is manifested in the region by N-S striking structures, in particular the N-S striking dyke swarms and normal faults associated with the Lebombo Monocline. The stress regime is depicted in **Figure 9 - Phase 2**.

Phase 3 – Late Gondwanaland Breakup (160-135 Ma)

The later separation of South America from Africa and the Falklands Plateau, which sheared-off form the east coast in a right-lateral motion. This event caused the reactivation of many pre-existing fractures. In the study area, it is likely that the ENE-trending fractures were reactivated. The ENE-trending dolerite dykes can also be correlated with this event. The coast-parallel shearing resulted in the N-S fractures being reactivated by right-lateral strike–slip or reverse movement (Von Vey, 1994). The orientations of the principal stress components are indicated in **Figure 9 - Phase3**.

5.5.3 Neotectonic Stresses and Seismic Provinces

The contemporary crustal stress regime has been estimated from scanty, but complementary information derived from the analysis of seismic data and direct in-situ stress measurements (Hartnady, 1998).

The study area lies within the broad, E-W trending *Senqu seismic belt* (Du Plessis et al, 1997). Hartnady (1998) describes two distinct stress provinces in Southern Africa (**Figure 10**), namely:

1. Cape Stress Province - a region to the south of the Senqu belt which is characterised by a strike-slip regime**,** with an E-W trending horizontal maximal compressive stress axis (S_{Hmax}).

2. Transgariep Stress Province - a region to the north of the Senqu belt which is characterised by a normal-faulting regime, with a NNW–SSE trending horizontal maximal compressive stress axis (S_{Hmax}) (Zoback, 1992).

Hartnady concludes that the Senqu belt is a geodynamically significant boundary or transition zone between two major neotectonic domains within the Southern African crust. The T60 drainage region lies within this seismically active transition zone, which implies that specific fracture systems are presently being

reactivated and new fractures generated – which should greatly enhance the groundwater potential of the area. The active stress regime within this transition zone is likely to display temporal variations, which will depend upon the local state of strain buildup during a particular earthquake cycle.

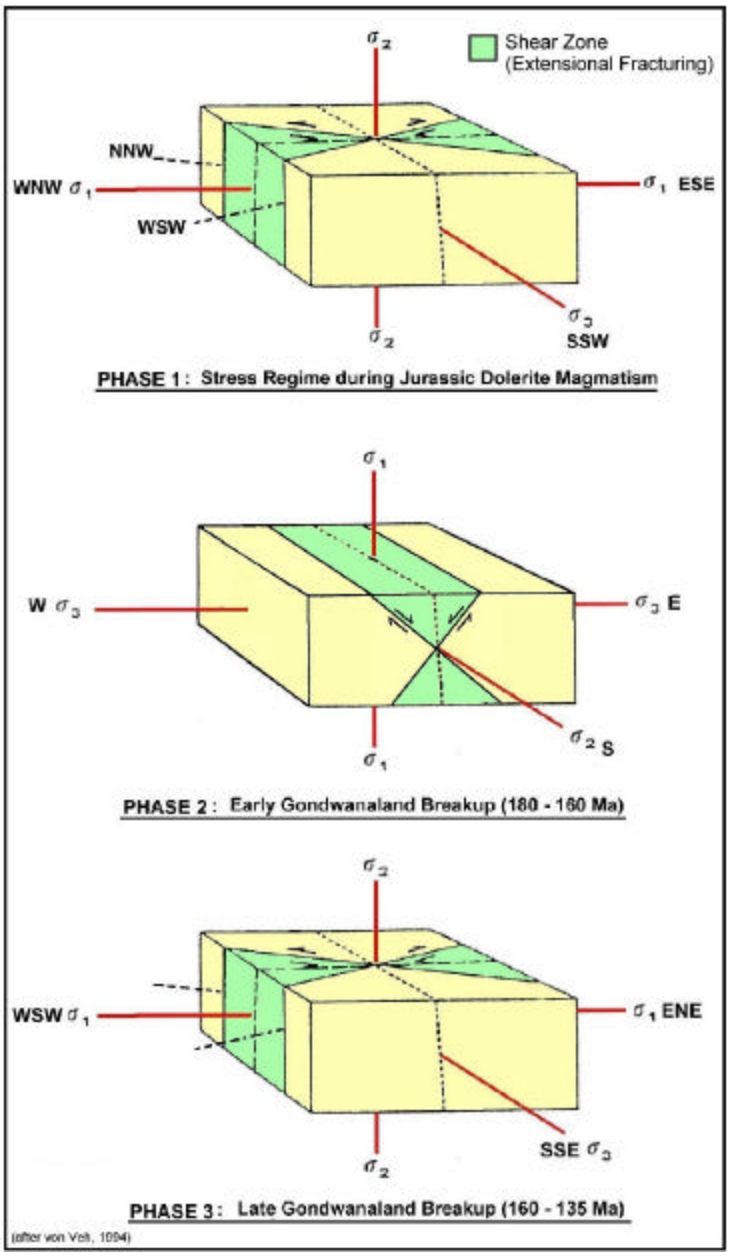


Figure 9: Principle Paleo-Stress Regimes in the Study Area over the period 190 to 135 Ma (after von Veh, 1994)



Figure 10: Seismic Stress Provinces of Southern Africa

Halbich and Chevallier (1998) describe a N-S orientated, maximum horizontal stress (S_{Hmax}) over Lesotho (Transgariep Stress Province), which results in E-W extension. This stress regime has also been collaborated by theoretical analysis of global stress fields over the continents, which is based upon present continental plate movements and variations in the thickness of the lithosphere across these areas. They conclude that all similarly orientated lineaments may be reactivated within this stress regime, depending on the frictional strength across the structure and the existing cumulative stress differential.

Andreoli et al (1996) determined a NW-SE trending maximum horizontal compressive stress (S_{hmax}), extending from southern Angola to the Transkei coast (Cape Stress Province), based upon their neotectonic studies of Southern Africa. According to this stress regime, fractures trending in a NW-SE direction are likely to be under tension or "open" and those orthogonal to this (i.e. NE-SW) are likely to be under compression or "closed".

Gay (1975) compared the vertical and horizontal stresses in Southern Africa and concluded that the horizontal stresses tended to be greater than the vertical stresses at shallow depths, while at greater depths the vertical stresses tend to be more than double those acting horizontally. The implication is that the horizontal bedding-plane joints are only likely to be open at shallow depths.

The above discussion deals with the regional tectonics of the area. More localised stress systems may also develop in the near surface due to isostatic rebound and thermal cooling following erosional unloading or due to differential overburden loading in areas of sharply contrasting relief. It is thus possible that

the NE trending geological structures are 'open' in the near-surface due to such terrain or topographical effects.

5.5.4 Hydrogeological Significance

No direct relationship has thus far been made between the seismo-tectonic provinces and groundwater occurrence. In theory, however, the extensional structures (faults, joints, dykes, veins) within the study area may offer a higher potential for developing high-yielding boreholes, i.e. all linear discontinuities orientated at acute-angles to the maximum horizontal compressive stress direction (S_{hmax}) during the deformational history of the area (after von Veh, 1994), namely:

(i)	NW-SE to E-W and NE	- Recent (Cape Stress Province)
(ii)	ENE	- 160 to 135 Ma
(iii)	N-S	- 180 to 160 Ma
(iv)	WNW	- 180 Ma

It is important to note that stress orientations (ii) – (iv) are based purely upon the analysis of remotely sensed information, rather than field observations. Furthermore, the underlying assumption that *higher yielding boreholes are more likely to be drilled on fractures of extensional origin* must be treated with due caution, according to von Veh (1994), as:

- The degree of tectonism and the accompanying development of open voids in a fault zone are not necessarily the greatest during extensional faulting. The extent to which voids are developed depends upon the geometry of the fault, the degree of roughness and planarity of the fault surface and fluid pressures during faulting.
- Open spaces within older faults may have been re-cemented by the precipitation of quartz, calcite, zeolite and other vein material. The potential for open fractures may thus be greater in younger faults, irrespective of their type or orientation.

Gevers (1941) concluded that the H_2S springs associated with faulting at Port St. Johns and the CO_2 springs associated with the N-S Ntlakwe-Bongwan fault system were originally strongly artesian. At present many of the springs are sub-artesian or only weakly artesian, due to 'sealing' of the open fractures in the near surface by the precipitation of secondary minerals (mainly calcium carbonate and quartz, as well limonite, pyrite and minor fluorite).

von Veh (1994) concludes that not all extensional structures will be presently "open" to groundwater movement, because:

- in some areas they may have been subjected to a number of major and minor tectonic events with differing principal stress regimes,

- an extensional structure may be reactivated during subsequent events, so that its history may be dominated by later compressional or strike-slip stress regimes, and
- the orientation of these structures may be influenced by pre-existing zones of weakness or heterogeneities in the basement, that run oblique to the extension direction. These structures may then exhibit strike-slip motion.

5.6 SATELLITE LINEAMENT MAPPING

The objectives of the satellite lineament mapping programme are as follows:

1. To describe the broad structural and tectonic trends within the study area in relation to the regional structural trends in the Eastern Karoo Basin. The possible geohydrological significance of certain dominant trends will also be discussed.

2. The lineament density and patterns, along with other relevant geohydrological information, will be used to assess the groundwater development potential within the various Quaternary catchments (i.e. the likelihood of obtaining a specific borehole yield).

3. This information will also be useful in providing a first order assessment of the availability of groundwater exploration drilling-targets within the study area, more specifically in the Lusikisiki district.

The portion of the 7-band Landsat Thematic Mapper (TM) imagery, WRS No. 168-82, covering the T60 drainage region was purchased from the Satellite Applications Centre of the CSIR and geo-referenced using the 1/50 000 topocadastral mapsheets, to a level of spatial accuracy acceptable for this study.

Erdas Imagine V8.3.1 image-processing software was then used to produce various derivative images aimed at enhancing the visibility of geological lineaments. The lineaments were mapped on-screen from the various false-colour composites and grey-scale derivative images (**Figure 11**). The satellite lineament data was then overlain on the 1/50 000 scale digital topocadastral maps and any obvious “anthropogenic” lineaments removed. The distribution of the satellite lineaments are shown in **Figure 12**, as well as dolerite dykes and faults obtained from the Council for Geoscience’s 1/250 000 scale geological maps.

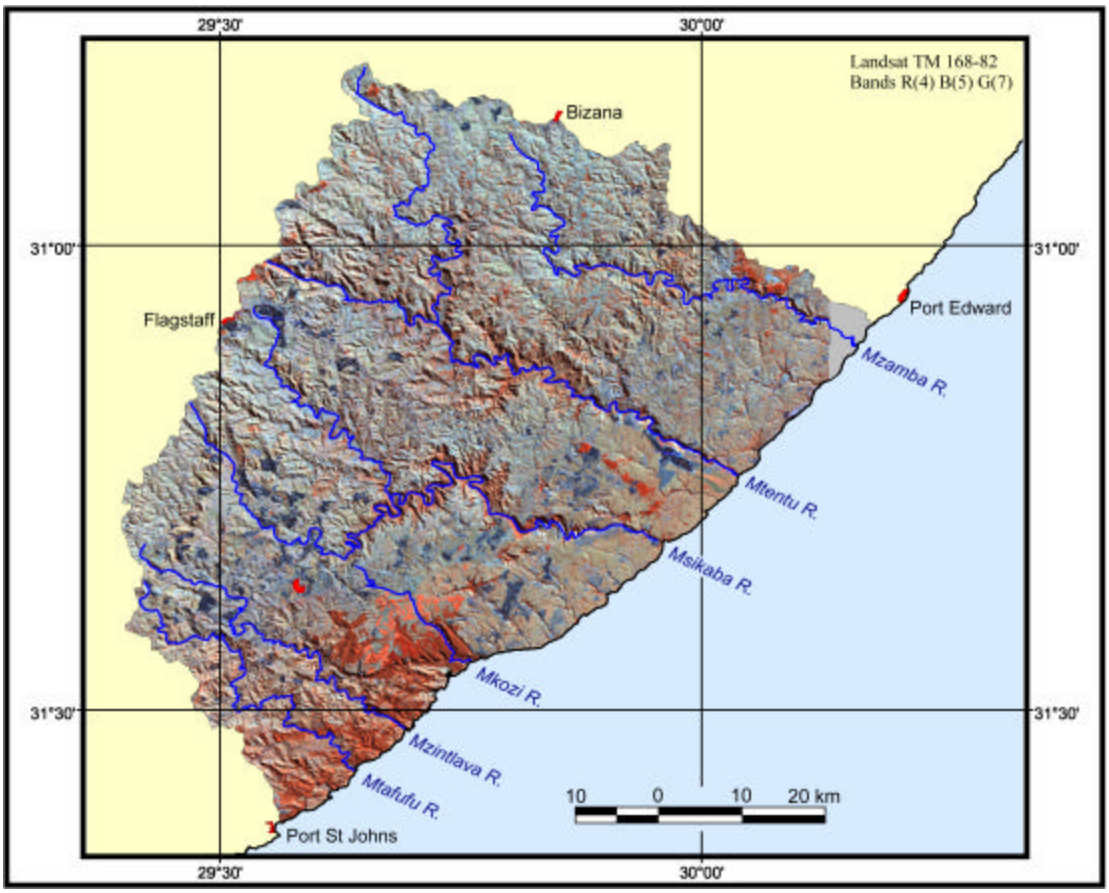


Figure 11: Landsat 5 Thematic Mapper satellite image of the T60 Catchment

The distribution of satellite lineaments in the T60 drainage region show the following (**Figure 12**):

- Clearly a large proportion of the satellite lineaments represent the unmapped extension of known dolerite dykes and faults. Many of the satellite lineaments with trends similar to the main dyke orientations probably represent unmapped dolerite dykes (i.e. the regional NW dyke - lineament system that enters the Indian Ocean at the Mtentu River mouth).

- Lineament patterns within the study area vary from areas of complexity or 'knots' (extensive features, high density and numerous orientations), to more sparse areas (short features, low density and fewer orientations). For example, the zone between the Mzamba and Mtentu Rivers is structurally more complex than the adjoining coastal zone between the Mtentu and Msikaba Rivers.

- Geological lineaments strongly control many of the river courses, i.e. almost the entire length of the Mtentu River is controlled by a extensive NW striking dolerite dyke.

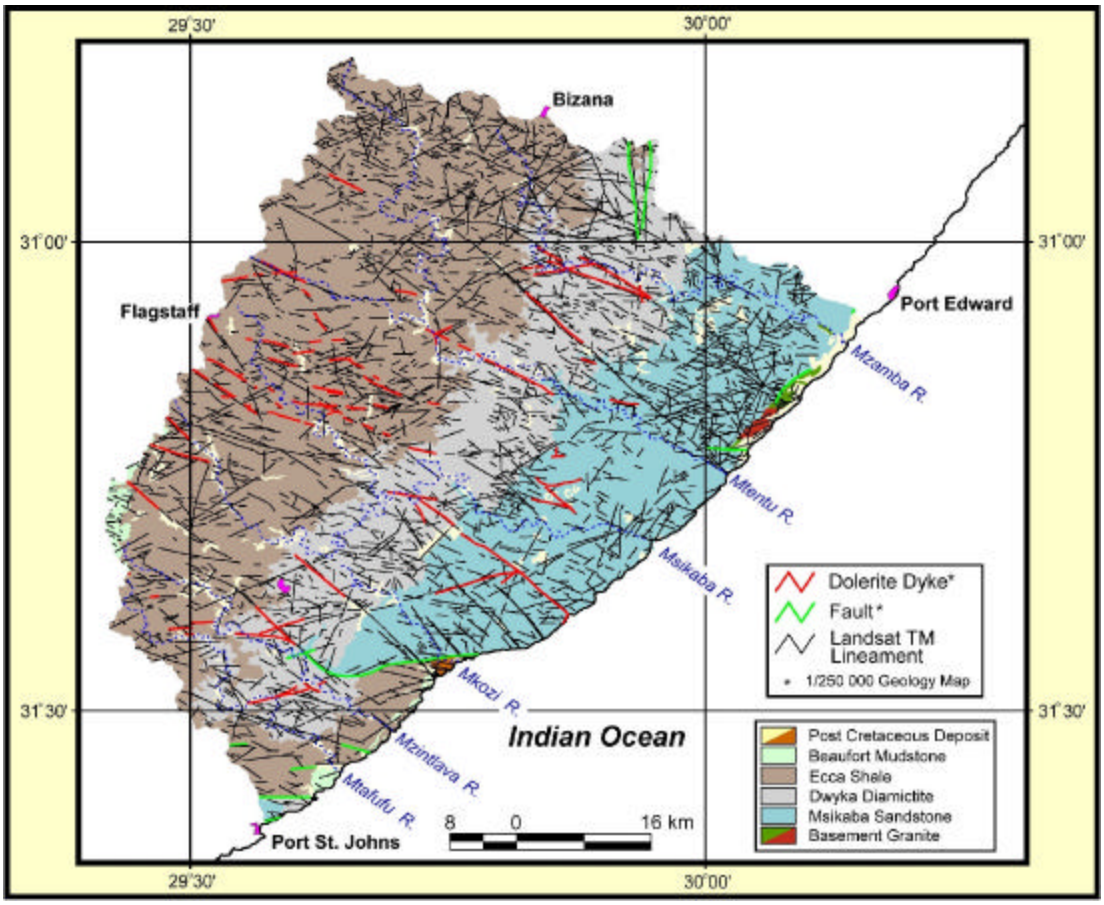


Figure 12: Distribution of Geological and Satellite Lineaments in the T60 Catchment

- The short satellite lineaments of variable orientation that do not correlate with the mapped dykes and faults in the area, probably represent a tectonic fabric related to master-joints or fractures across which there has been little fault displacement (Woodford & Chevallier, 1999; von Vey, 1994).

- The distributions of paleo- and neo-'extensional' lineaments (**Chapter 5.5.4**) are indicated in **Figures 13** and **14**, respectively.

It should be noted that the satellite lineament coverage produced for this study depicts the regional structural trends in the T60 catchment and is used to select exploration drill-sites in the Lusikisiki district. The siting of boreholes in the field should only be carried out after further lineament mapping from the panchromatic 1:50 000 aerial photographs. Experience in many such siting exercises has indicated that the air-photograph lineaments tend to complement rather that duplicate the satellite lineament information (Woodford & Chevallier, 1999), often highlighting zones of more intense fracturing along the major satellite lineaments.

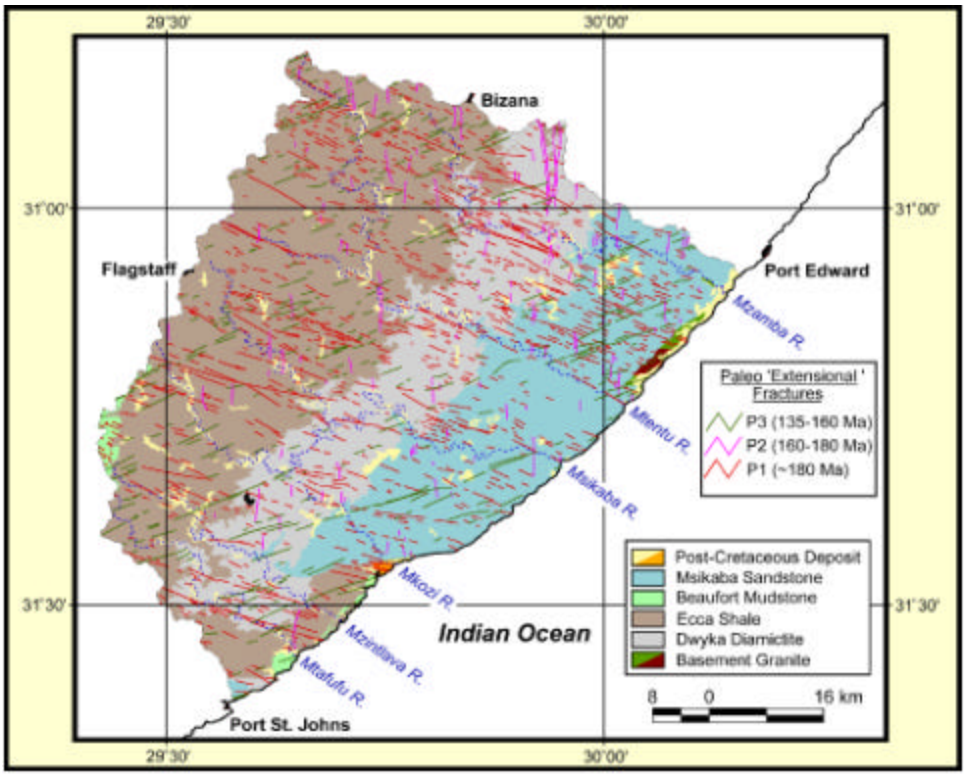


Figure 13: Distribution of palaeo-'extensional' lineaments in the T60 Catchment

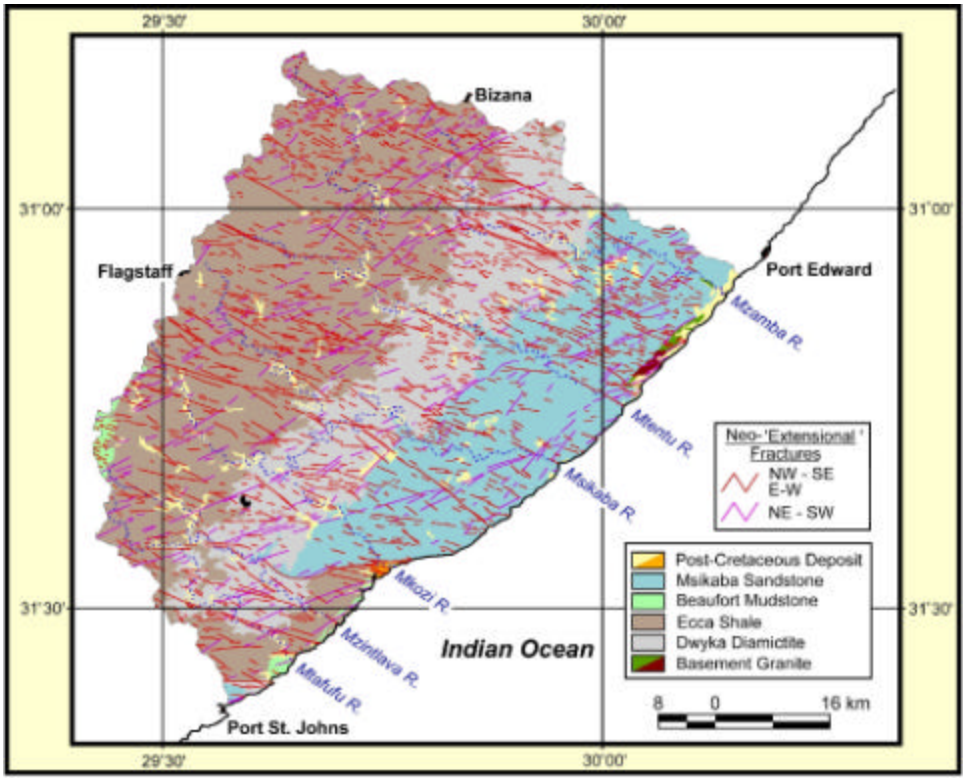


Figure 14: Distribution of neo-'extensional' lineaments in the T60 Catchment

6.0 PREVIOUS GEOHYDOGEOLOGICAL INVESTIGATIONS

A number of geohydrological investigations have been conducted that fall within or cover a portion of the T60 drainage region. Consultants carried out most of the work on behalf of the Government. This section outlines the nature and scope of these studies, while the pertinent geohydrological information is referenced within the relevant chapters of this report. Groundwater investigations in adjoining, hydrogeologically similar areas are also included.

The following important geohydrological reports were reviewed during this study:

- **Northern Zone – Village Water Supply Study** (SRK, 1991)

  Steffen, Robertson & Kirsten carried out a study of the groundwater resources of the so-called 'Northern Zone' for the former Department of Agriculture and Forestry (DAF) of the then Transkei. Their study area covered most of the T60 catchment, extending from Port Edward in the north to the Mtafufu River in the south (i.e. the districts of Bizana, Lusikisiki, Flagstaff, Tabankulu, Mount Ayliff, Qumbu, Mount Frere, Mount Fletcher and Matatiele). The investigation served as a pilot project to assess the feasibility of establishing small-scale water supply schemes to service villages and to assess the willingness of the communities to accept the responsibility for maintaining their schemes. Villages with severe water supply shortfalls were targeted. The project commenced in August 1989. During this study some 77 exploration boreholes were drilled. They concluded that handpump-based groundwater supply schemes presented a practical and cost effective (i.e. R10,650/scheme at 1990 prices, excluding consultant fees) method of supplying water to small rural communities. They found that many communities were in favour of taking responsibility for the operation and maintenance of their water-supply scheme, with some form of 'assistance' from Government.

- **Natal Sandstones – Hydrogeological Investigation** (SRK, 1993)

  Steffen, Robertson & Kirsten conducted an investigation on behalf of the former Department of Agriculture and Forestry to determine the groundwater potential of the sandstone of the Msikaba Formation. The project formed part of the 'Transkei National Ground Water Plan' and commenced in 1986. The investigation was completed in 1993, after a number of lengthy delays. SRK's exploration drilling in the Msikaba sandstone led them to conclude that the groundwater potential of this unit is low.

- **DWAF's Hydrogeological Characterisation and Mapping Programme for the Kwazulu-Natal Province:**

  The Directorate: Geohydrology (DWAF) subdivided the Kwazulu-Natal Province into 11 hydrogeological 'mapping-units', as part of their national

groundwater characterisation and mapping programme. During 1994 to 1995, groundwater consultants were appointed to evaluate the groundwater resources within each of the mapping-units. This information is presently being used to compile the following 1:500,000 scale hydrogeological maps: Durban (2928) and Vryheid (2730), as well as portions of Nelspruit (2928) and Kroonstad (2726).

Three of the mapping-units, namely units 4, 6 and 10, share a common boundary with the northern edge of the T60 drainage region and are thus directly relevant to this study.

Mapping-Unit 4 (Davies, Lynn & Partners, 1995)

The study area is located on the South Coast of Kwazulu-Natal between Durban and Port Edward and extends inland as far as Harding-Ixopo. They found that the rocks of the Msikaba Formation are most favourable for groundwater development, whilst the Dwyka Group and Precambrian basement rocks exhibit exceptionally poor hydrological properties. They state that the potential for groundwater development in Unit 4 is largely determined by the rate of recharge.

Mapping-Unit 10 (Groundwater Development Services, 1995a).

The investigation encompassed the area between the towns of Harding, Kokstad, Matatiele, Donnybrook and Underberg, and shares a common boundary with Unit 4 to the west. The hydrogeological assessment of the Ecca and Beaufort Group rocks, as well as the Karoo dolerite intrusives are of relevance to this study. The highest percentage of boreholes yielding more than 3 l/s were located in the Vryheid sandstones of the Ecca Group, while the dolerite intrusions yielded the highest success rate in the yield range of less than 1 l/s. GDS concluded that the groundwater resources of the area are capable of meeting the entire rural community's water needs.

Mapping-Unit 6 (Groundwater Development Services, 1995b)

The investigation covered a 4-5km wide strip of the coast extending from the Mtunzini River in the north to the Mtamvuna River in the south, near Port Edward. Particular attention was paid to the alluvial and estuarine sediments, as well as the beach and aeolian deposits – which cover almost 30% of the unit. It was found that the coastal quaternary aquifers, if properly developed, generally yield in excess of 10 l/s. GDS found that these primary, 'strip' aquifers are not currently being exploited.

- **1:500,000-scale Queenstown Hydrogeological Map** (Smart, 1998)

  The methodology and results of the Queenstown (3126) mapping programme are of direct relevance to this study. This regional geohydrological study covers almost the entire T60 drainage region, except for the Bizana area to the north of latitude 31°S.

7.0 RECONNAISSANCE HYDROCENSUS

Mr. B. Malghas of Kei Water Solutions in Umtata conducted a 6-day reconnaissance hydrocensus of specific areas of hydrogeological data deficiency, which were identified during the literature review and evaluation of the groundwater GIS database. The original objectives of the hydrocensus were to:

- Locate and collect geohydrological and construction information from borehole and springs; e.g. depth, collar height, position, usage, geology, position of borehole in relation to prominent geological structures.
- Obtain water quality and chemistry data from boreholes and springs within different lithological formations and climatic zones.
- Assess the usage and protection-status of springs/seeps.
- Evaluate the degree of groundwater usage and perceptions towards groundwater in the area.
- Verify, where possible, documented borehole information with field observations.

The inaccessibility of the terrain, the scarcity and poor operational status of boreholes in these areas yielded very limited useful results. Water samples for quality testing could not be collected from inoperative boreholes. The local inhabitants could not supply any geohydrological or construction details on their boreholes. The boreholes and springs inventoried during the study are summarized in **Table 2**, while their positions are indicated in **Figure 15**. The numerous seeps along the many deeply incised river valleys have not been indicated.

The following general observations were made during the hydrocensus:

- Most of the public boreholes are not in operation, due either to broken equipment and/or having “dried-up” or collapsed. Operational boreholes are used mainly for domestic water supply purposes.
- The waterlevel dipmeter could not be used because the equipped boreholes (i.e. handpumps and windpumps) are sealed and any open boreholes are either fitted with welded-caps or are filled with stones.
- Some areas visited did not have any boreholes because the area is extremely rugged and inaccessible to drilling-rigs, i.e. the areas to the south of Lusikisiki where people rely solely on springs and river water.
- Springs are widely used for potable drinking-water.

- The groundwater quality as indicated by the Electrical Conductivity (EC) values are relatively low (<100 mS/m), falling within the acceptable limits stipulated by DWAF.
- The majority of the people in the area do not have access to drinking water within 200m of their dwellings (as stipulated by the RDP regulations).

7.1 SPRINGS AND SEEPS

Springs are commonly located at the contact between dolerite intrusions and the host rocks, especially in the Magusheni area. In the coarse-grained quartzitic sandstone of the Msikaba Formation, water seeps from fault zones, bedding-plane joints and other zones of hydraulic discontinuity. The sustainable flow of these springs is proportional to the geographic extent of the effective catchment area, permeability of the aquifer and rates of recharge. Most of the springs in the areas visited are inaccessible since they are situated on steep hillsides and at the base of river gorges.

- Springs are common and are used for drinking water purposes. The communities of Sikombe, Kwanyana and Mtolane depend largely upon springs and resort to water from the Bizane and Mnyameni Rivers during the dry seasons only.
- Many of the 'springs' are seasonal with the exception of a few (i.e. SP1 close to Mnyameni River mouth – **Figure 15**) and people have to rely on perennial rivers like Bizane, Msikaba and Mtentu for their dry-season water supplies.
- Springs can be developed to serve small communities where both surface water reticulation and borehole drilling are not economically viable, especially in the rugged and inaccessible terrain.
- The springs are not developed to enhance their yield or protected to avoid contamination of the resource.

7.2 GROUNDWATER WATER QUALITY

- The electrical conductivity (EC) of the spring water in the areas inventoried varies between 4–20 mS/m, irrespective of lithology, which is indicative of the regular recharge and short residence time of water beneath the surface. This water is for all intents and purposes an 'attenuated' rainwater. Spring water emanating nearer to the coast has a higher EC, in the range of 30–37 mS/m. This is probably due to the influence of wind-borne salts and the NaCl content of the rainwater, which decreases with distance inland.
- The water quality deteriorates during the dry season due to lower recharge and animal fecal contamination.

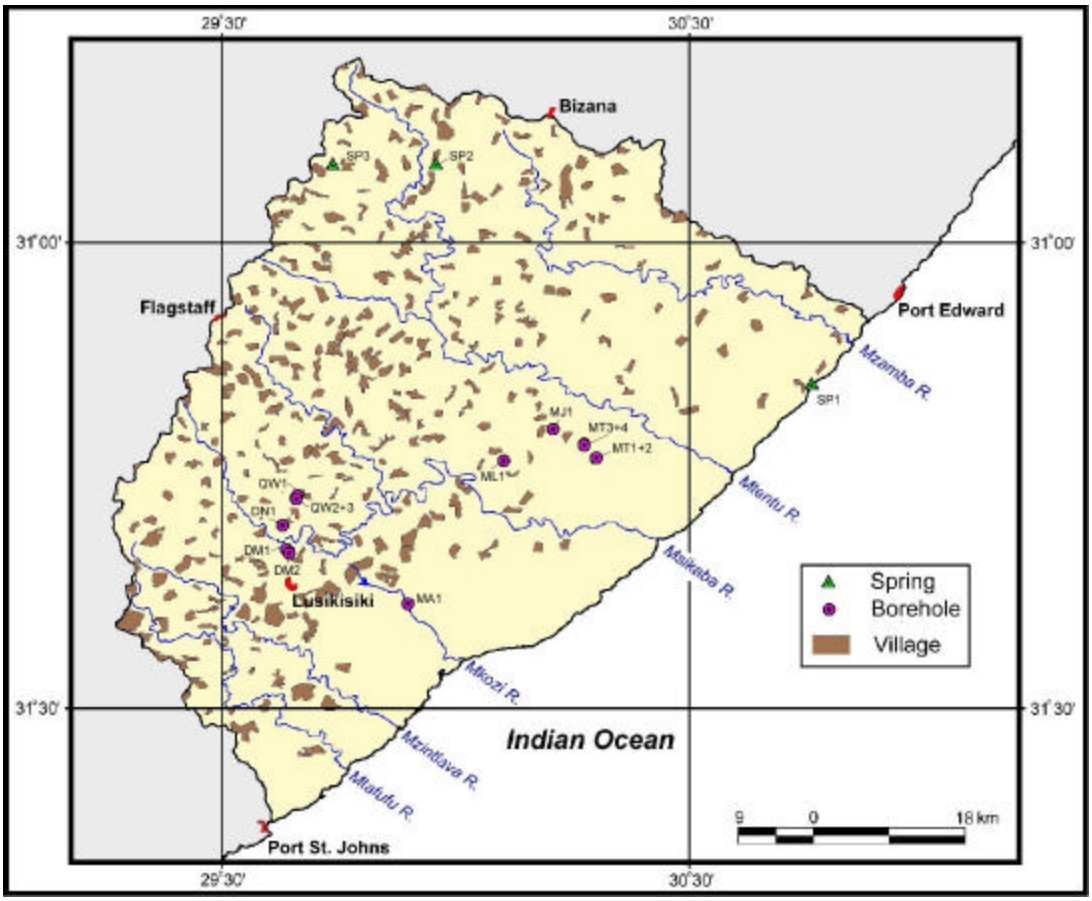


Figure 15: Location of Boreholes and Springs inventoried during the Hydrocensus

TABLE 2: Summary of Boreholes and Springs Inventoried

Map Ref No.	Village	Bore Number	Borehole Status	Depth (m)	EC (mS/m)	Equipment	Water Usage
3129BC	Lusikisiki-Dumisa, Gunyeni and Qawukeni - Great Places.	DM1	WP broken	no access	-	Windpump	Domestic
		DM2	WP broken	no access	-	Windpump	-
		DN1	WP broken	no access	-	Windpump	-
		QW2		no access	-		-
		QW1	WP broken	100	-	Windpump	Domestic
		QW3		no access	-	-	-
		MA1	WP broken	no access	-	Windpump	Domestic
3129BB	Kanyayo	MJ1	sealed	no access	-	-	-
		MT4	Dry	no access	-	-	-
		MT3	-	no access	19	handpump	Domestic
		MT2	-	no access	-	handpump	Domestic
		MT1	-	no access	16	handpump	Domestic
		ML1	-	no access	15	handpump	Domestic
3029DC	Magusheni, KuGwabeni	Sp3	-	-	-	-	Domestic
		Sp2	-	-	-	-	Domestic
3130AA & AB	Xolobeni, Sikombe, Kwanyana & Mtolane	Sp1	-	-	-	-	Domestic

8.0 GROUNDWATER CHARACTERISTICS

This Chapter describes the local and regional factors controlling the nature and occurrence of groundwater within the study area. The general chemical character of the groundwater in the T60 catchment will also be discussed. Relevant information from groundwater investigations carried out in similar geohydrological environments, outside of the T60 drainage region has also been included.

8.1 GROUNDWATER OCCURRENCE

This section examines the nature and occurrence of groundwater in the broader context of the T60 Tertiary catchment, using the following site-specific (local) information:

- Borehole Depth.
- Borehole yield (mainly 'drillstem-blow' estimates).
- Depth of major water interceptions.
- Depth to watertable or piezometric surface.

During the course of this study an Arc/Info GIS database of 159 boreholes was compiled using information gathered from the National Groundwater Database of the Department of Water Affairs & Forestry, reports and a reconnaissance hydrocensus (**Chapter 7.0**) conducted as part of this study (**Figure 16**). Note that due to the severe lack of borehole information within the T60 drainage region, a number of boreholes, located in similar geohydrological environments outside of the study area boundaries were also included in the analysis.

Smart (1998) found the following general trends when analysing borehole yield information from the area between latitude 31° – 33° and longitude 26° – 30° 30' (i.e. 1:500,000 scale Queenstown Sheet 3126):

- Yields associated with dolerite intrusions are higher than those associated with sedimentary rocks only.
- Yield characteristics of dolerite dykes and sills are broadly similar.
- Yields associated with dolerite intrusions are highly variable at both the regional- and local- scale.
- Regions with higher than average yields in the sedimentary rocks will also have correspondingly higher than average yields in the dolerite intrusions.

Smart concluded that regional-scale fracturing affects all the rock types similarly within a particular tectonic domain (i.e. both the dolerite intrusions themselves, as well as the sedimentary rocks remote from these intrusions). On the local-scale, however, fractures associated with dolerite intrusions are more permeable.

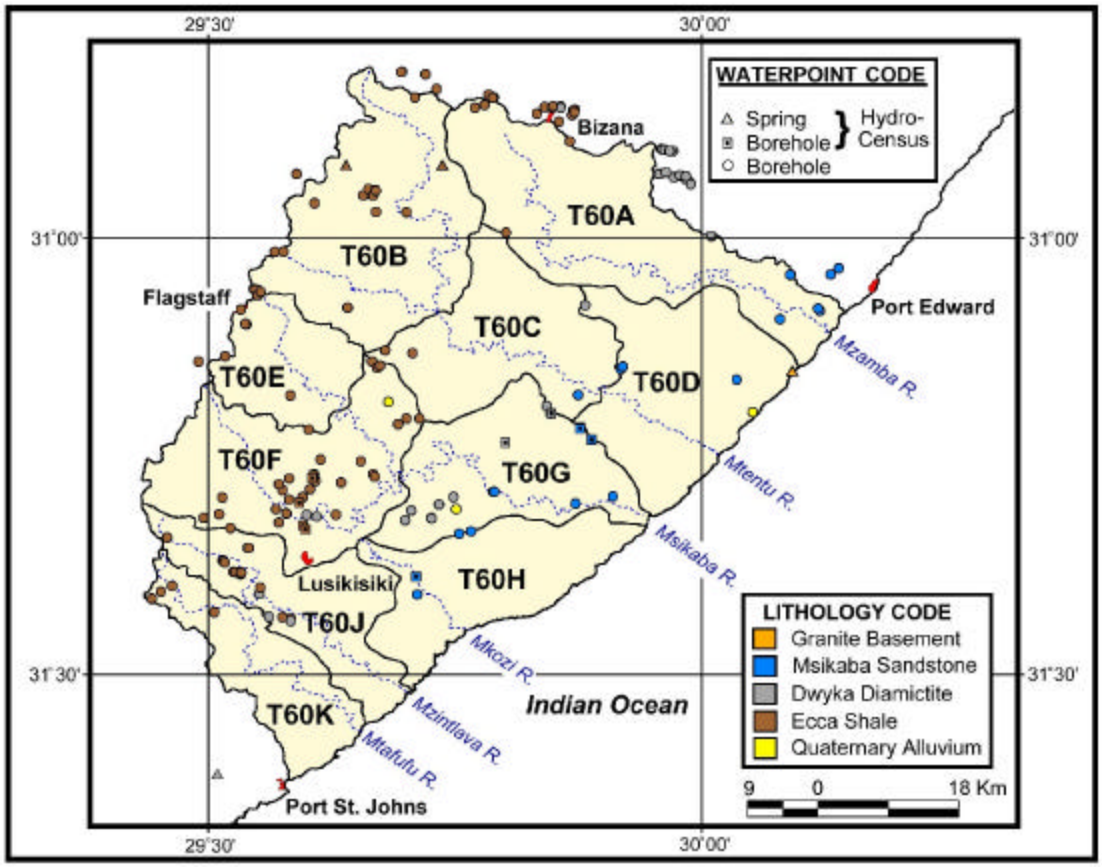


Figure 16: Distribution of Boreholes and Springs

8.1.1 Lithology

The physical and chemical character (permeability, grain size, mineralogy etc.) of the aquifer material both directly and indirectly controls the local and regional occurrence of groundwater. **Table 3** shows the influence of lithology on regional variations in the borehole yields of the study area. A review of similar analyses conduced elsewhere in the Eastern Cape and Kwazulu-Natal are summarised in **Table 4**.

The borehole yield statistics per lithostratigraphic unit will be discussed in detail below and are utilised in **Chapter 9.0** to assess the groundwater development potential of the study area.

Table 3: Borehole Yield Statistics per major Lithostratigraphic Unit in the T60 Drainage Region

Lithological Unit	No. Bores	No. Bores No Data	No. Dry Bores (%)	Max. Yield 'Wet' Bores (R/s)	Median Yield 'Wet' Bores (R/s)	Mean Yield 'Wet' Bores (R/s)	Standard Deviation
Msikaba Sandstone	21	4	4 (24)	6.9	0.14	0.76	1.86
Ecca Shale	102[B]	16	25 (29)	10.0	1.20	1.78	2.15
	17[A]	-	-	10.0	1.14	1.86	2.50
Dwyka Diamictite	36	4	12 (38)	6.8	0.59	1.85	2.01
TOTAL	**159**	**24**	**41 (30)**				
Note: [A] – Boreholes in Ecca Shale more than 500m from a dolerite dyke or sill (subset of B). [B] – All boreholes drilled into Ecca Shale, including dolerite intrusions.							

Table 4: Literature Review of Borehole Yield Statistics per Lithostratigraphic Unit

LITHOLOGICAL UNIT	NO. BORES	YIELD RANGE (R/s)	MEDIAN YIELD (R/s)	MEAN YIELD (R/s)	STD DEV.	% DRY BOREHOLES (dry / total bores)
Pre-Cambrian Basement Gneiss and Granite	-	0.10 – 4.7[A]	0.10[A]			-
	72[B]	-	0.21[B]	0.59[B]	-	22.2 (16/72)[B]
Msikaba Formation (Natal Group)	-	0.20 – 1.0[A]	0.50[A]		-	-
	363[B]	-	0.38[B]	1.18[B]	-	12.4 (45/363)[B]
	28[D]	-	0.50[D]	0.47[D]	0.04[D]	-
Dwyka Group		0.02 – 3.2[A]	0.05[A]		-	-
	293	-	0.15[B]	0.76[B]	-	29.0 (85/293)[B]
	55[D]	-	0.30[D]	0.02[D]	0.53[D]	-
Ecca Group	-	0.01 – 23.2[A]	0.55[A]			
	236[B]	-	0.68[B]	1.90[B]	-	11.8 (28/236)[B]
	-	0.01 – 34.0[C]	0.55[C]			
	80[D]	-	1.17[D]	0.66[D]	0.35[D]	-
Beaufort Group	-	0.01 – 34.0[C]	1.00[C]			-
	52[D]	-	0.62[D]	0.62[D]	0.38[D]	-
Karoo Dolerite Intrusions	-	0.02 – 23.2[A]	0.15[A]		-	
	236[B]	-	0.68[B]	1.90[B]	-	11.8 (28 /236)[B]
	-	0.05 – 15.3[C]	1.11[C]			
Cretaceous Semi-Consolidated Deposits	-					
Quaternary Unconsolidated Deposits	-	0.10 – 33.0[A]	6.0[A]			
Source: [A] – Groundwater Development Services (1995b). [B] – Davies, Lynn & Partners (1995)). [C] – Groundwater Development Services (1995a). [D] – Smart (1998) [Yield Domain 11 = Msikaba, 10 = Dwyka, 9 =Ecca & 8 = Beaufort]						

8.1.1.1 Pre-Cambrian Basement Granite

Only a thin strip of granitic basement outcrops along the coast between the Mtentu and Msikaba River (**Figure 8**). Groundwater Development Services (1995b) state that the water-bearing properties of these rocks are controlled by a complex history of physical and chemical geological processes of intrusion, deep-seated tectonic activity related to fracturing and folding, as well as subsequent near-surface processes of physical and chemical weathering. In Kwazulu-Natal, where these rocks are common, the majority of the boreholes strike groundwater in fracture or fault zones and 'basins' of deep weathering.

Davies, Lynn and Partners (1995) report borehole yields ranging from 0.1 to 4.7 l/s, with a median yield of only 0.1 l/s.

8.1.1.2 Msikaba Formation

Groundwater occurrence is associated with abundant master-joints, faults and bedding-planes, as well as the occasional dolerite dyke. The majority of the high-yielding boreholes in this Formation are associated with the extensive NW-trending dolerite dykes (SRK, 1993). The characteristic block-jointing of these sandstones are expected to enhance the potential for recharge from rainfall.

Steffen, Robertson & Kirsten (1993) state that the contact between the Dwyka Group and Msikaba Formation may prove to be a promising groundwater exploration target. In the past, efforts were made to intercept this contact by drilling deep boreholes through the Dwyka rocks, but they failed to quantify the water-yielding capability of this contact (SRK, 1993).

In the T60 catchment, the median yield of 13 boreholes in the Msikaba Formation is 0.14 l/s, while other studies indicate a more acceptable yield of 0.5 l/s. The mean borehole yield is in the order of 0.8 l/s.

Smart (1998) noted that the Msikaba Formation shows an unusually low incidence of dry boreholes of less than 15%.

8.1.1.3 Dwyka Group

In general, the Dwyka rocks are massive and have a low permeability. They tend to form aquitards rather than aquifers. However, in certain areas, where the diamictite is well fractured, moderate to high borehole yields have been reported (SRK, 1993).

The median and mean yield of boreholes tapping the Dwyka rocks of the T60 catchment is 0.59 and 1.85 l/s, respectively - which is substantially

higher than that obtained in the adjoining areas. Of importance is the high incidence of dry boreholes (38%).

Smart (1988) ascribes the generally lower borehole yields in the Dwyka to:

- the scarcity of dolerite intrusions in this unit,
- the massive nature of the rocks which results in a lack of bedding-plane joints more typical of other interbedded sedimentary units, and
- a permeability controlled by discrete tectonic fracturing.

The water in these aquifers tends to be more saline than that in the Ecca and Msikaba rocks, possibly due to the slower rates of groundwater movement resulting from its low permeability and the dissolution of salts of marine origin entrapped in the sediments during deposition. In general, the Dwyka rocks are not suited for the large-scale exploitation of groundwater.

8.1.1.4 Ecca Group

In the study area the water-yielding capacity of the Ecca shales are enhanced by the dense network of dolerite intrusions.

The subordinate, thin sandstone intercalations are thought to form permeable horizons within the tectonically deformed Ecca shales, as a result of:

- enhanced fracturing in the more brittle sandstone layers, and
- the development of 'open' bedding-plane joints along the shale-sandstone contact due to the large contrasts in rock competency.

The median and mean yield (**Table 3**) of 102 boreholes in the Ecca shale is 1.20 and 1.70 l/s, respectively. This statistic includes a considerable number of boreholes sited on dolerite sills and dykes. Exclusion of these boreholes, results in a lower median yield of 1.14 l/s and a higher mean yield of 1.86 l/s. The variable yield statistics of the Ecca in **Table 4** are probably related to varying degrees of tectonic deformation and density of dolerite intrusion.

Smart (1998) postulates that the relatively high borehole yields of the Ecca rocks are related to a higher frequency of bedding related fractures, when compared to the other sedimentary units where the more thick and massive mudrock predominate.

8.1.1.5 Beaufort Group

Outcrop of Beaufort rocks are limited to isolated occurrences along the coast between Port St. Johns and the Mkozi River, as well as along the south-eastern border of the study area (**Figure 8**). The occurrence of groundwater in the Beaufort mudstone and subordinate sandstone is similar to that of the Ecca Group, except that they are not as heavily intruded by dolerite magma.

The primary permeability and storativity of the Beaufort sediments are very low. The groundwater potential of the Beaufort rocks has been greatly enhanced by the development of secondary permeability and porosity due to tectonic fracturing and the associated intrusion of dolerite dykes and sills.

No boreholes penetrating this formation could be located in the T60 drainage region. Geohydrological studies conducted elsewhere in the region indicate that a median and mean borehole yield in the order of 0.62 l/s is likely (**Table 4**).

8.1.1.6 Cretaceous and Quaternary Deposits

Rapid incision and erosion by the major rivers in the study area, i.e. the Msikaba River, has resulted in isolated accumulations of unconsolidated, sandy and occasionally gravel-rich alluvial deposits along parts of their course. Saturated alluvium of between 5 to 7m in thickness is reported in Mapping Unit 8 of Kwazulu-Natal, where local thickening of these deposits are associated with zones of bedrock weakness.

Saturated alluvial deposits with appreciable volumes of exploitable groundwater are unlikely to occur within the Interior Plateau of the study area, as many of the major rivers have eroded below the base of these deposits due to more recent uplift. Furthermore, the weathering of Ecca and Dwyka rocks produces predominantly clay-rich deposits. Only localised 'pockets' of saturated deposits are therefore likely. Significant deposits of saturated alluvial and estuarine deposits are likely towards the mouths of the major rivers.

High-yielding boreholes are common in well-developed coarser basal-channel deposits. Appreciable amounts of groundwater are also intercepted along the weathered and fractured bedrock contact, below such deposits. The Mzintlava community obtains their water from saturated alluvial sediments in the vicinity of the village. Steffen, Robertson and Kirsten successfully established production boreholes in a thin strip of saturated alluvium in the Flagstaff area (SRK, 1993).

Primary aquifers in the coastal deposits are only likely to be of local importance due to their limited extent (Groundwater Development Services, 1995b).

8.1.2 Karoo Dolerite Intrusions

Dolerite sills preferentially intruded the weaker argillaceous layers of the Ecca Group, while only a number of regional dykes intruded the more competent Dwyka Group and Msikaba Formation (**Figure 8**).

Groundwater is often intercepted along the contact between the dolerite intrusion and its host rock, as well as within the dolerite itself. Fracture permeability is drastically reduced when secondary minerals (e.g. calcite, zeolite) and clay-fillings are present. The dolerite dykes and sills are often jointed and fractured. The upper portions of dolerite sills may be highly decomposed to a granular, friable material. Sills that are weathered to depths of up to 35 metres below surface are reported in the Kwazulu-Natal Mapping Unit 8, which if saturated form exploitable localised aquifers. Groundwater Development Services (1995b) found that the low-yielding contact between the decomposed and fresh dolerite is often tapped for community water supply.

The relationship between the yield of a borehole and its proximity to a dolerite dyke or sill was assessed, assuming a 'zone of influence' extending up to 500m away from the intrusion contact (**Table 5**). A distance of 500m is not realistic for dolerite dykes, but this figure also allows for mapping inaccuracies related to the 1/250 000 scale geological data.

Table 5: Influence of Dolerite Intrusions on Borehole Yields of the T60 Catchment

Distance (m) from Dolerite Sill or Dyke	Number Bores	Median Yield (l/s)	Mean Yield (l/s)	Standard Deviation
≤ 500m	46	1.20	1.76	1.83
> 500m	47	0.58	1.55	2.24
TOTAL	93			

Note: Only 'wet' borehole information utilised (i.e. yield > 0 l/s).

The median yield of boreholes drilled within 500m of a dolerite intrusion is double that of boreholes sited further away from these features, while the mean borehole yields are similar. The abundance of dolerite intrusions in the Ecca shale may also explain the relatively higher borehole yields encountered in this formation.

Smart (1988) found that boreholes drilled into fractured Karoo rocks, not influenced by dolerite intrusions, tend to yield less than 1 l/s, while yields of between 3 to 5 l/s are exceptional. Approximately 20% of all boreholes targeting dolerite intrusions yielded more than 5 l/s.

In Kwazulu-Natal, statistical analysis of exploration drilling in Mapping Unit 8 showed that boreholes tapping dolerite intrusions, including the contact host-rock, have a median yield of 0.4 l/s.

8.1.3 Geological Lineaments

The influence of geological structures, namely dykes and faults, and satellite lineaments on borehole yields within the study area were assessed (**Table 6**). The lineaments were 'buffered' by 500m or in other words a 'zone influence' was created which extended up to 500m away from either side of the structure. Various lineament orientations, according to the regional stress analysis in **Chapter 5.5.4,** were investigated. **Figure 17** is an example of the 500m buffered, ENE trending lineaments and boreholes classed according to whether they are located withIN or OUTside of the buffer zone.

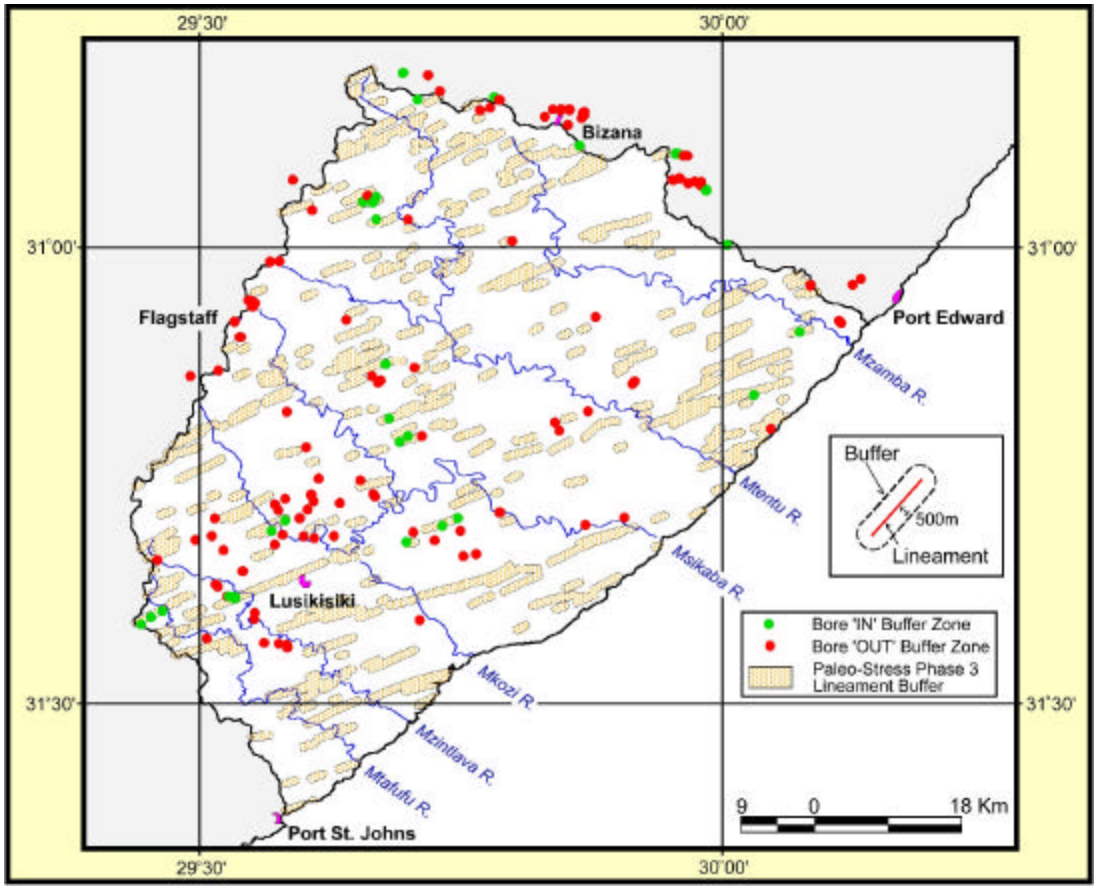


Figure 17: Proximity of Boreholes to the buffered, ENE-trending lineaments

The result of the analyses (**Table 6**) tends to show the following:

- In general, the higher yielding boreholes appear to be located more than 500m from the mapped dolerite dykes and satellite lineaments. This is contrary expectations and the results of many other investigations of this nature (Woodford and Chevallier, 1999; Gustafsson, 1993; Bobba et al, 1992, Waters et al, 1990; Rauch et al, 1984; Schowengerdt, et al, 1979; Lattman and Parizek, 1964). If this assertion is accepted, then another more dominant factor may be controlling borehole yields in the T60 drainage region – especially in the Ecca shales where most of the boreholes occur. In order to verify these results it would be necessary to include a more detailed analysis using aerial-photograph lineament mapping and GPS co-ordinated borehole positions. The relatively shallow depths of drilling (average 62m) may also 'hide' the true potential of many of these extensive regional structures.
- Notwithstanding the above statement, the ENE-trending paleo-stress phase 3 and the NE-trending lineaments would appear to be the most favourable drilling targets for higher yielding boreholes.

Table 6: Influence of Dolerite Dykes and Satellite Lineaments on Borehole Yields of the T60 Catchment

Lineament Description	Number Bores	Median Yield (l/s)	Mean Yield (l/s)	Standard Deviation
Paleo-Stress Ph-1	42	0.50	1.12	1.42
Paleo-Stress Ph-2	7	0.72	1.59	1.94
Paleo-Stress Ph-3	18	1.01	1.53	1.64
Neotectonic R1	47	0.49	1.22	1.60
Neotectonic L1	20	1.09	1.67	1.74
Intersect Ph1-L1	7	1.17	1.48	1.77
Intersect Ph2-L1	4	-	3.72	2.24
Intersect Ph3-L1	14	0.90	1.54	1.82
Intersect Ph1-R1	40	0.49	1.13	1.45
Intersect Ph2-R1	3	-	1.14	-
Intersect Ph3-R1	5	-	1.15	1.04
Intersect Ph1-Ph2	4	-	1.04	0.98
Intersect Ph1-Ph3	5	-	1.15	1.04
Intersect Ph2-Ph3	3	-	4.57	1.79
All Lineaments	66	0.71	1.31	1.58
'Off'-Lineaments & 'On' Sills	26	1.75	2.65	2.71
'Off'-Lineaments & 'Off' Sills	10	1.30	2.38	3.22
Lineament in Dwyka Group	15	0.49	1.98	2.29
Lineament in Ecca Group	41	0.96	1.15	1.01
Lineament in Msikaba Fm.	10	0.28	0.95	2.10
Dwyka Group (>500m linear)	5	-	1.43	1.79
Ecca Group (>500m linear)	20	1.85	3.08	2.84
Msikaba Fm (>500m linear)	1	-	0.14	-
Dolerite Dykes	7	0.75	0.98	0.97
Faults	0	-	-	-
TOTAL	93			

Note: Only 'wet' borehole information utilised (i.e. yield > 0 P/s) situated within 500m of the structure (ON), else (OFF).

- The extensive, well-developed, WNW-trending paleo-stress phase 1 lineaments may have been recently reactivated within a NW-SE to E-W orientated extensional stress regime and should also represent good exploration targets, even though **Table 6** points to the contrary, especially considering that the study area lies within the seismically active Senqu belt.
- The intersection of the N-S trending, paleo-stress phase lineaments and NE-SW trending lineaments may also offer better borehole yield prospects in the northern portion of the study area.

No Information on boreholes targeting the major faults in the study area could be obtained. Smart (1998) states that, although information is scarce, faults are generally poor groundwater exploration targets. He describes a 116m deep borehole drilled into an E-W trending fault along the coast, with a 3000m throw, which only yielded seepage water. The borehole became weakly artesian a few hours after completion of the borehole. The rock material was very soft and highly friable, which Smart speculates results in many faults having a low permeability.

The regional nature of the lineament mapping and scarcity of reliable borehole information must be taken into consideration when viewing the results of the above borehole productivity analysis.

8.1.4 Drainage System

Woodford and Chevallier (1999) found that borehole yields in fractured-rocks of the Western Karoo are generally higher in the vicinity of a river-course. Borehole yields in the study area show a similar correlation (**Table 7**).

Table 7: Influence of Drainage Features on Borehole Yield

Distance (m) from 1/50 000 river feature	Borehole Yield (l/s) Statistics			
	Number	Median	Mean	Standard Deviation
≤ 50	30	1.75	2.28	2.41
> 50 - ≤ 100	14	0.74	1.80	1.80
> 100 - ≤ 150	15	0.70	1.34	1.25
> 150	34	0.72	1.34	2.00
TOTAL	93			

The median yield of 'wet' boreholes drilled within 50m of a river channel is more than double that of boreholes drilled further away. The mean borehole yield also decreases significantly with distance from the drainage feature. There are a number of possible reasons for this important phenomenon, namely:

- Groundwater flows towards the river and often discharges into it. The groundwater-level is therefore at its shallowest beneath the river channel, which is where the depth of weathering and fracturing is commonly the

greatest. This local 'thickening' of the shallow, phreatic aquifer beneath major drainage channels often equates to zone of enhanced transmissivity (i.e. permeability x saturated thickness).
- Many river courses are controlled by geological structures (**Chapter 5.6**), where faults, fracture zones and dykes are more easily eroded.
- Enhancement of near-surface fractures in steep-sided river valleys due to differential overburden stresses created by terrain effects.

8.1.5 Contact between Lithostratigraphic Units

Yield analysis of boreholes drilled within 500m of the contact between the Msikaba-Dwyka and Dwyka-Ecca rocks would, tentatively, indicate that they represent favourable groundwater drilling targets. Toens and Partners (1997) tested the Dwyka-Ecca contact in an area to the south of Peddie and obtained borehole yields in the excess of 5 l/s.

Table 8: Yield Statistics of Boreholes drilled into a Litho-stratigraphic contact.

Lithostratigraphic Contact	Borehole Yield (l/s) Statistics			
	Number	Median	Mean	Standard Deviation
Dwyka-Ecca Group	8	1.95	3.05	2.85
Dwyka-Msikaba Fm	5	0.75	2.60	2.74
(boreholes within 500m of mapped lithological contact)				

SRK (1993) tested the water-yielding potential of the Dwyka-Misikaba lithostratigraphic contact at two localities, and obtained borehole yields of 5.6 and 6.8 l/s in this zone. SRK concluded that their test drilling of the Dwyka-Msikaba contact was not able to fully quantify its true potential due to their inability to drill deep boreholes to penetrate the Msikaba sandstones beneath the Dwyka rocks.

8.2 GROUNDWATER EXPLORATION DRILLING TARGETS

The groundwater drilling targets commonly associated with higher yielding boreholes within each of the lithostratigraphic units are summarised in **Table 9**.

Sophisticated exploration techniques are not commonly used in many groundwater community water supply investigations due to budgetary constraints, which contributes to the all too often poor drilling results obtained.

The scarce but valuable geohydrological information being gathered during these ad-hoc investigations needs to be collated and scientifically interpreted to provide a clearer indication of favourable drilling targets in the eastern Karoo Basin. This

research will lead to a better conceptualisation of groundwater occurrence and thereby improve the exploration drilling success rates and average borehole yields. Specific research aimed at assessing the water-bearing capacity of the Dwyka–Ecca and Msikaba-Dwyka contacts, drilling of deeper boreholes to intercept regional fracture systems or the Msikaba sandstones underlying the Dwyka diamictite, and the assessment of new geophysical and remote-sensing techniques are required.

Table 9: Groundwater Drilling-Targets within each Lithostratigraphic Unit.

LITHOLOGICAL UNIT	AQUIFER DESCRIPTION	DRILLING TARGETS
Pre-Cambrian Basement Gneiss and Granite	Secondary, fractured and intergranular.	Faults, Fracture-zones, Weathered 'basins'.
Msikaba Formation (Natal Group)	Secondary, fractured.	Faults, Dolerite dykes, Fracture-zones, Msikaba-Dwyka contact.
Dwyka Group	Secondary, fractured.	Fracture-zones, Dolerite dykes, Dwyka-Ecca contact.
Ecca Group	Secondary, fractured.	Dolerite dykes-sills, Lithological contacts, Fracture-zones, Faults Dwyka-Ecca Contact.
Beaufort Group	Secondary, fractured.	Dolerite dykes-sills, Lithological contacts, Fracture-zones, Faults.
Karoo Dolerite Intrusions	Secondary, fractured, minor intergranular.	Weathered/jointed zones, Fissured dolerite, Fractured/brecciated contacts.
Cretaceous Semi-Consolidated and Quaternary Unconsolidated Deposits	Primary, intergranular.	Medium to coarse grained sand and gravel-rich zones. Composite alluvial – weathered bedrock aquifer.

Unfortunately, the Karoo rocks of the Eastern Cape have acquired the stigma of being 'low-yielding'. Borehole yields in the Central and Western Karoo Basin are thought to be 'somewhat higher-yielding', but the analysis of private drilling results (i.e. boreholes sited mainly by dowsers, drilled to shallow depths within a limited drilling budget) conducted by farmers in these areas do not vindicate this statement. Woodford and Chevallier (1999) examined the yields of some 2500 private boreholes drilled into the Beaufort rocks within an 11,600 km^2 area between Loxton and Victoria West. A mean and median borehole yield of 2.4 l/s (standard deviation of 4.3) and 1.3 l/s, respectively, was obtained. This is similar to the results presented for the Beaufort rocks in **Table 4** Woodford and Chevallier scientifically sited 39 boreholes on regional lineaments in the same area, with a mean and median yield of 6.3 l/s (standard deviation of 8.8) and 2.3 l/s. Note that these statistics also include observation boreholes that are not necessarily sited with the aim of maximising yield.

In the Western Karoo Basin, the groundwater abstraction schemes supplying the larger towns, such as Beaufort West, De Aar, Middelburg and Graaff-Reinet, are only 'successful' because of the thousands of scientifically sited exploration boreholes drilled at significant cost by the Department of Water Affairs and

Forestry. During these geohydrological investigations it was accepted that a certain number of exploration boreholes had to drilled in order to obtain a single high-yielding production borehole (i.e. > 3 l/s), required for the establishment of large-scale abstraction wellfields. The results of the exploration and drilling techniques employed were continually evaluated and refined, which in turn led to improved borehole success rates. No such effort has been launched in the Eastern Cape, except for the Queenstown area.

The present approach to rural community groundwater supply needs to re-assessed, if the groundwater resources of the Eastern Karoo Basin are to be utilised to their full potential. For instance, where individual boreholes are drilled in geohydrologically unfavourable sites (i.e. on summit hills) for ease of access by foot and equipped with either handpumps or windpumps. Groundwater supply projects are often planned, financed and executed with the forgone conclusion that the borehole yields will be low. High-yielding groundwater abstraction schemes should be investigated where feasible, either as a sole-source supply or as part of a surface-water reticulation scheme. The cost-benefits of developing such groundwater schemes needs, as was conducted in the Western Karoo, to carefully assessed in relation to water-demand and alternative sources of water.

8.3 BOREHOLE YIELD STATISTICS PER HYDROTECTONIC DOMAIN

The T60 drainage region was subdivided into 12 hydrotectonic domains (**Figure 18**) based upon the nature and occurrence of the following:

- Lithology
- Dolerite Sills
- Geometry and density of geological lineaments.
- Climate (MAP) and physiography (i.e. river density, geomorphology).

The main characteristics of each hydrotectonic domain are summarised in **Table 10**, while the results of the borehole yield analysis within each domain are contained in **Table 11**.

No borehole information is available for domains 5 and 12. Domains 1, 6 and 9 show relatively higher borehole yields, again showing the dominant influence of the Ecca shale and associated dolerite intrusions. However, boreholes in Domain 3, also containing Ecca shale, are relatively low yielding. A reason for these lower than expected yields in domain 3 may be due to the low lineament density, particularly in the vicinity of the boreholes, and the rugged, deeply incised nature of the area. Boreholes in Domain 4 are low yielding, which may not be a true reflection of the yield potential of this well fractured, sandstone-rich zone.

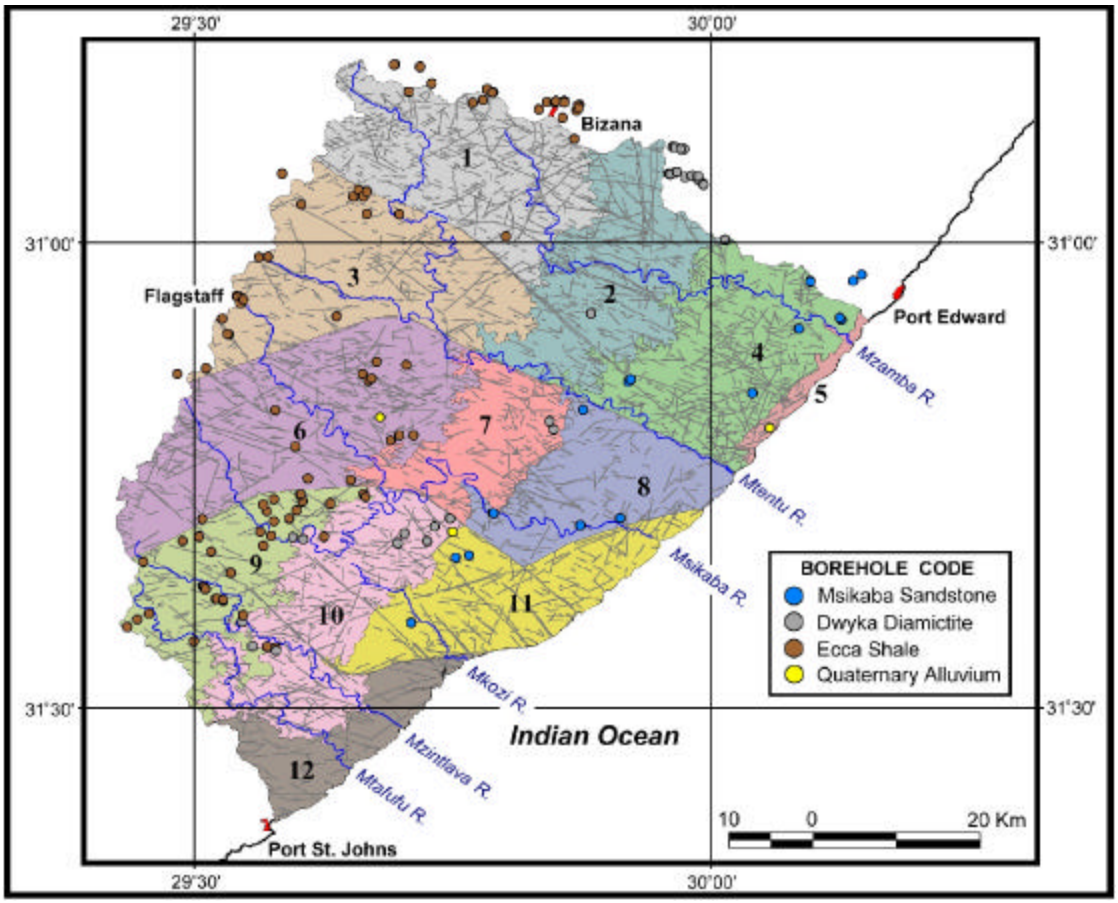


Figure 18: Borehole Distribution within the Hydrotectonic Domains of the T60 Catchment

Table 10: Summary of Geological Classification Criteria per Hydrotectonic Domain

HYDRO-TECTONIC DOMAIN	CLASSIFICATION CRITERIA		
	Predominant Lithology	Sills	Lineaments
1	Ecca	abundant	High density, complex 'knots'; NW, NE, EW and NS lineaments.
2	Dwyka	none	Mostly high density, complex 'knots', regional NW-NNW and N-S lineaments, including the Ntlakwe-Bongwan Fault system.
3	Ecca	abundant	Low density; E-W, NE and regional NW lineaments.
4	Msikaba	none	Mostly high density; complex 'knots';, NE, WNW, regional NW and NS Lineaments. Major regional lineament, controlling Mtentu River course forms southern boundary.
5	Basement – Unconsolidated Deposits	none	Overburden restricts mapping, anticipated to be similar to Domain 4, with E-W to NE faulting.
6	Ecca	abundant	High density; dominant NE, WNW –NW lineaments.
7	Dwyka	none	Moderate to low density; short lineaments of NW to WNW orientation.
8	Msikaba	none	Low density, short lineaments of WNW to NW, and minor of NE orientation.
9	Ecca	abundant	Low density, NE and WNW-NW trending lineaments.
10	Dwyka	Minor	Moderate density, complex 'knots'; regional NE and NW, with minor E-W trends.
11	Msikaba	none	Dense, NW and ESE lineaments. Egosa Fault forms southern boundary.
12	Ecca	abundant	Moderate density; regional WNW to NW, ENE to E-W (faults) trending lineaments. Egosa Fault forms the northern boundary.

Table 11: Borehole Yield Statistics per Hydrotectonic Domain

Hydotectonic Domain	Statistics					
	Number	Min	Max	Median	Mean	Std. Deviation
1	14	0.22	10.00	1.41	3.03	3.52
2	11	0.10	5.60	0.49	1.59	2.11
3	11	0.05	1.80	0.55	0.77	0.69
4	6	0.10	0.72	0.12	0.22	0.25
5	0	-	-	-	-	-
6	11	0.32	3.00	1.20	1.66	0.95
7	2	2.80	6.80	-	-	-
8	4	0.25	6.90	-	2.05	3.24
9	23	0.19	5.00	1.25	1.46	1.06
10	9	0.04	4.43	0.96	1.73	1.74
11	3	0.03	0.30	-	0.12	0.15
12	0	-	-	-	-	-

8.4 BOREHOLE YIELD STATISTICS PER QUATERNARY CATCHMENT

The borehole yield statistics per quaternary catchment are presented in **Table 12**, which may not be the most appropriate geohydrological unit for classification, but is required to ensure compatibility and integration of the groundwater study with the other water resource components of the T60 Basin Study.

Table 12: Borehole Yield statistics per Quaternary Catchment

Quaternary Catchment	Total No. Bores	No. Dry Bores (%)	Yield (l/s) Statistics			
			Median	Mean (Std Dev)	Max	Min
T60A	38	14 (37)	0.67	2.34 (3.12)	10.0	0.10
T60B	16	5 (31)	0.38	0.95 (0.86)	2.00	0.05
T60C	3	2 (75)	-	-	9.90	9.90
T60D	5	1 (20)	0.14	0.17 (0.09)	0.30	0.10
T60E	7	2 (29)	1.14	1.69 (1.22)	3.00	0.55
T60F	30	7 (23)	1.26	1.67 (1.04)	5.00	0.16
T60G	13	4 (31)	0.50	2.01 (2.84)	6.90	0.04
T60H	2	0 (0)	-	0.04 (-)	0.04	0.03
T60J	18	6 (33)	0.88	1.51 (1.45)	4.43	0.20
T60K	4	2 (50)	0.90	0.90 (-)	1.00	0.80

In order to obtain a more hydrogeologically representative median borehole yield for each quaternary catchment (**Table 13**), a weighted-average median yield was calculated according to the percentage outcrop area of the three major lithological units, the Msikaba Formation, Dwyka and Ecca Group. The influence of the numerous dolerite intrusives in the Ecca shales are integrated into the yield statistics of this lithological unit (see **Table 3**). This yield information will be used to assess the groundwater development potential per quaternary catchment (**Chapter 11.3**).

Table 13: Weighted Median Borehole Yield per Quaternary Catchment

Quaternary Catchment	Lithology Weighted Median Bore Yield (R/s)	% Area		
		Msikaba Formation	Dwyka Group	Ecca Group
T60A	0.80 (0.67)	23	40	37
T60B	1.20 (1.17)	0	0	100
T60C	0.87 (0.74)	10	42	48
T60D	0.51 (0.48)	90	10	0
T60E	1.20 (1.17)	0	0	100
T60F	1.07 (0.99)	0	21	79
T60G	0.55 (0.39)	46	54	0
T60H	0.57 (0.55)	85	6	9
T60J	0.86 (0.71)	7	48	45
T60K	1.15 (1.11)	3	5	92

Note: (0.67) – Median Borehole Yield from **Table 4**, after Smart (1988).

8.5 GROUNDWATER LEVEL AND YIELD VARIATIONS WITH BOREHOLE DEPTH

The average depth of boreholes drilled in the study area is 62.4 metres **(Table 14**), while the average groundwater-level is 15.4 m below ground surface.

The majority of the boreholes intercepted a single 'measurable' water-strike, whilst the higher yielding boreholes commonly show multiple water interceptions with drilling depth (**Figure 19**).

The median and average depth of the first, measurable water-strike is 27 and 31 metres below ground-level, respectively - or more importantly, 11 and 19 metres below the groundwater-level, respectively. The second and third water strikes normally occurs at each 10m incremental depth of drilling below this datum.

Table 14: Statistics of Waterlevels, Depth of Water Interceptions and Borehole Depths in the T60 Catchment

Parameter	Statistics					
	Number	Min	Max	Median	Mean	Std. Deviation
Drill Depth (m)	93	15.85	150.0	-	62.4	28.45
Waterlevel (mbgl)	63	0.100	65.00	-	15.4	12.71
1st Water Strike						
(mbgl)	35	6.0	114.0	27.0	30.7	22.59
(mbwl)	32	1.0	102.0	10.6	18.6	20.57
2st Water Strike						
(mbgl)	17	6.0	89.0	34.0	40.7	21.74
(mbwl)	17	4.1	84.0	23.1	28.0	20.51
3st Water Strike						
(mbgl)	8	23.0	70.0	45.5	46.3	16.40
(mbwl)	8	8.9	67.0	33.5	36.5	18.40
4st Water Strike						
(mbgl)	6	24.0	74.0	49.5	51.2	18.81
(mbwl)	6	9.9	74.0	46.5	47.0	23.90

NOTE: mbgl – metres below ground-level.
Mbwl – metres below static groundwater-level.

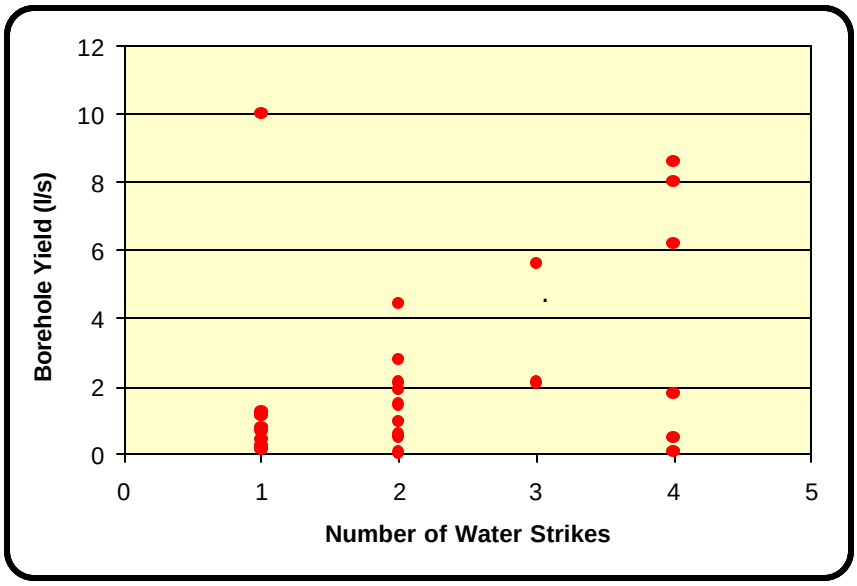


Figure 19: Borehole Yield versus number of Water-strikes

The probability of striking water bearing fractures with drilling depth below the ground surface and regional waterlevel are indicated in **Figure 20**.

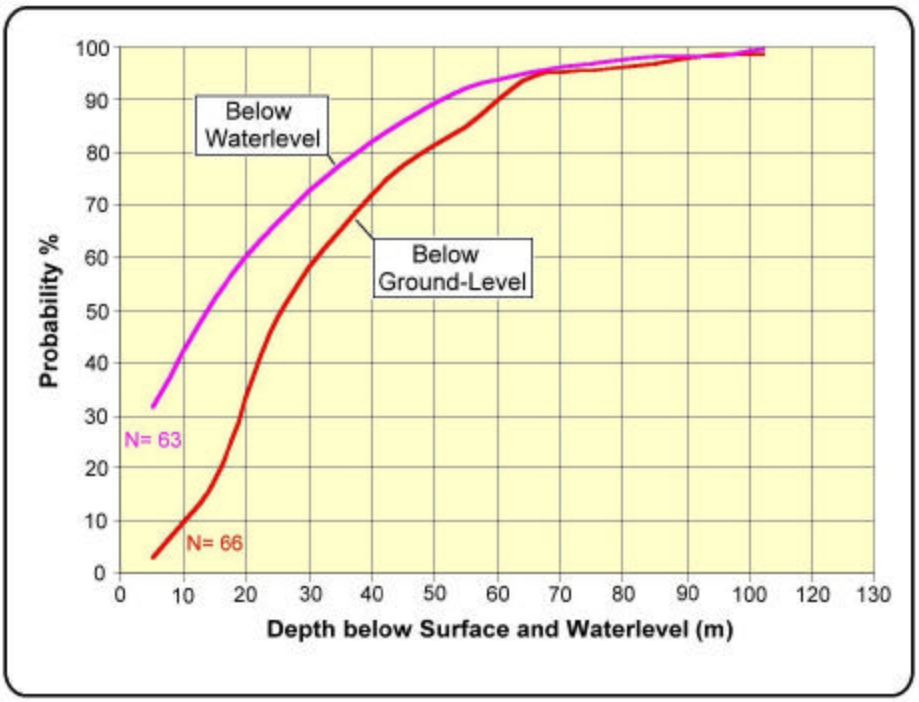


Figure 20: Probability of striking groundwater with drilling depth below the surface and below the regional waterlevel

The general trend is a decrease in the likelihood of intercepting water-bearing fractures with depth below the surface or regional waterlevel. The probability graph flattens rapidly after about 55m and 65m below the regional waterlevel and ground surface, respectively – indicating a sharp decline in the number of water bearing fractures below these depths. **Figure 20** shows that 50% of the water-strikes occur within the first 15m of drilling below the regional waterlevel. These graphs only reflect the general drilling conditions related to the near-surface zone, where the influence of weathering and horizontal fracture enhancement by erosional unloading are dominant. It is likely that boreholes correctly sited on regional fracture systems of tectonic origin will show less frequent, higher yielding water-strikes, which are independent of drilling depth.

The relationship between the yield of individual water-interceptions and drilling depth could not be assessed due to a lack of reliable water-strike yield information in the study area. Smart (1998) produced a graph of mean yield of water strikes in relation to depth below surface (**Figure 21**), which shows no significant variation in individual water-strike yields with depth.

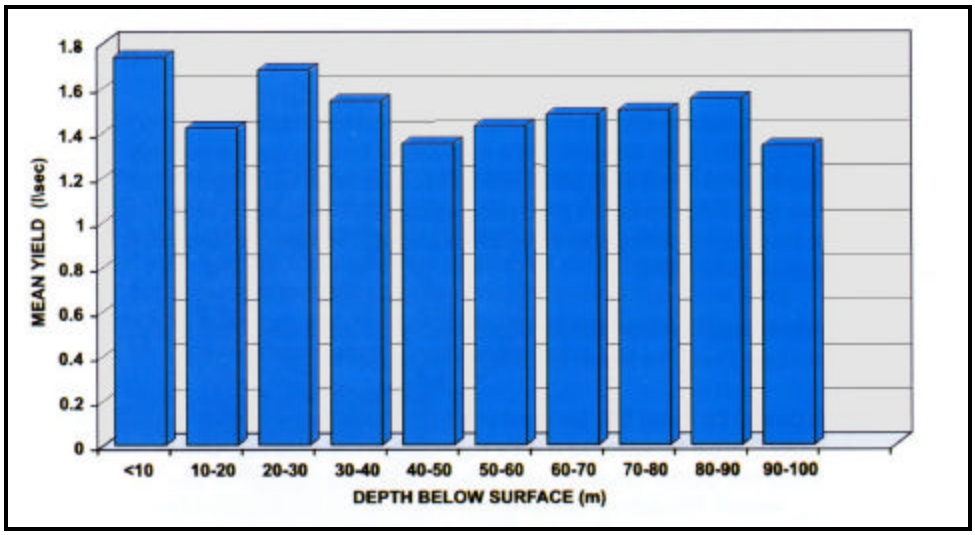


Figure 21: Mean Borehole Yields obtained at Water-Strikes in relation to Depth below the Surface (Smart, 1998).

8.6 SPRINGS AND SEEPS

The concept of springs and seeps needs to be understood by water planners, as the two sources have different potential for development as a water supply, namely:

Seeps represent the attenuated discharge of infiltrated rainwater from the vadose zone or from a locally "perched"-aquifer, before it actually reaches the main groundwater body (**Figure 22**). They tend to show marked seasonal fluctuations in yield (i.e. are directly correlated to local rainfall variability), and their water chemistry is similar to that of rainwater (i.e. electrical conductivity or EC < 20 mS/m) – see **Table 15** and **Figure 23**.

The springs in the area tend to emanate in the lower-lying areas, especially in the deeply incised valleys, along bedding-planes, intrusive contacts and other structural features – where the groundwater phreatic- or piezometric-level intersects the surface (**Figure 22**). The chemistry of the spring-water therefore reflects that of the local shallow aquifer (EC 20-70 mS/m) or in more rare cases a deeper-seated aquifer (>500 mS/m). The yield of a spring is more regular than that of a seep, i.e. seasonal fluctuations in flow are not as marked, because the spring is linked to a relatively large groundwater storage reservoir. Springs are therefore more favourable for development as community water supplies.

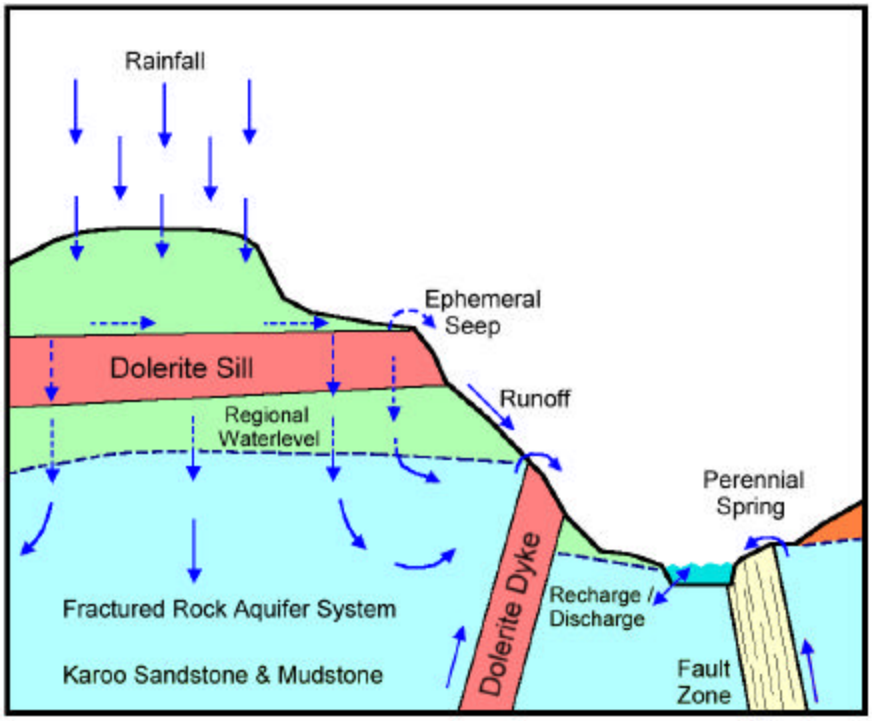


Figure 22: Schematic Conceptual Diagram indicating the occurrence and hydrological significance of springs and seeps in the study area.

It is the author's opinion that the electrical conductivity, as well as other macro-chemical and isotopic constituents, of this water may be used to obtain a first-order approximation of the sustainability of the resource (i.e. spring versus seep). The nature and degree of correlation between the rate of flow (l/s) and local rainfall (mm) will provide a more reliable definition between the two types, as well as quantitative estimates of the long-term sustainable yield of the supply. Such applied research would greatly enhance our understanding and selection of 'true' springs suitable for community water supply - especially in this area where they form an important freshwater resource for cost-effective, small-scale development, but have the stigma of being 'unreliable'

Smart (1998) states that springs are important sources of water in areas of high rainfall and found that they commonly develop along:

- Dykes intersecting drainage features.
- Contact of dolerite sills and sheets.
- Basal contacts of fractured sandstones with an underlying less permeable mudrock horizon.
- Weathered basins, usually dolerite sills.

The yield and sustainability of a spring depends upon the interplay between the rate of aquifer recharge, aquifer storage capacity, piezometric pressure at the spring and permeability of the formation or fracture.

Table 15: Chemistry of 'Fresh' Springs sampled during the Hydrocensus

	Spring Number		
	TPS-1	TPS-2	TPS-3
Latitude	31.91601	31.15164	30.91555
Longitude	29.61855	30.13133	29.72909
Date Sampled	26/5/99	27/5/99	28/5/99
Conductivity (mS/m)	6	18	18
Total Dissolved Solids (mg/l)	38	115	115
pH (Laboratory)	6.1	6.0	7.1
Sodium (mg/l)	5.1	28.0	13.0
Calcium (mg/l)	2.7	1.7	11.0
Magnesium (mg/l)	2.1	3.3	7.2
Sulphate (mg/l)	0.2	9.8	2.1
Chloride (mg/l)	5.0	34.0	13.0
Alkalinity (mg/l)	17.0	17.0	52.0
Nitrate + Nitrite as N (mg/l)	0.6	1.3	3.4
Fluoride (mg/l)	< 0.1	< 0.1	<0.1
Hardness as $CaCO_3$ (mg/l)	15.0	18.0	57.0

Gevers (1941) describes the occurrences of highly mineralised springs (1400 mS/m) in the vicinity of Port St. Johns and along the banks of the Umtamvuna River to the east of Bizana. Cones of travertine of varying proportions have built-up around their orifices. Gevers concluded that the springs represent highly concentrated Dwyka groundwater that originates from shallow depths. He based this assertion on the normal temperature of the Umtamvuna spring water of 20.1 – 21.0 °C (air-temperature of 22°C). The Port St. Johns springs are rich in H_2S, while those along the Umtamvuna River contain CO_2 and no H_2S. The Umtamvuna springs rise along the Ntlakwe-Bongwan Fault system. Further to the north, at the Bongwan Railway Siding, the CO_2 exhalations represent the only commercially exploited natural sources of CO_2 gas in South Africa. Gevers postulated that the gases were not of volcanic origin, but that they resulted from the reaction of acidic (H_2S) groundwater with crystalline limestone at depth. The source of this limestone is uncertain, although Gevers points to carbonate-rich xenoliths in the underlying granite basement, some distance to the east (Marble Delta). Gevers claims that the sulphuric acid in the groundwater could be generated by the oxidation of pyrite within the overlying Ecca shales.

Table 16: Chemistry of the hyper-saline Insunka Spring

Parameter	Insunka Spring, Port St. Johns
Latitude	31.60917
Longitude	29.48306
Date Sample	17/11/94
pH (Lab)	7.6
EC (mS/m)	4 500
TDS (mg/l)	28 800
Sodium (mg/l)	11 700
Calcium (mg/l)	108
Magnesium (mg/l)	117
Potassium (mg/l)	384
Chloride (mg/l)	9 990
Sulphate (mg/l)	7 402
Alkalinity $CACO_3$ (mg/l)	5 794
Ammonia as N (mg/l)	2.35
Nitrate as N (mg/l)	1.69
Phosphate (mg/l)	<0.1
Iron as Fe (mg/l)	<0.05
Manganese as Mn (mg/l)	<0.05
Fluoride as F (mg/l)	1.32
(Source DWAF)	

8.7 GROUNDWATER QUALITY

The chemistry of natural groundwater is commonly controlled by the soluble products of rock weathering, as well as recharge and rates of flow in the aquifer. It is often significantly altered by pollution.

The severe lack of groundwater chemistry data makes it impossible to even analyse the distribution of salinity in the study area. The following hydrochemical information was located and used for this study (**Figure 23**):

- 18 boreholes with full macro-chemistry, 9 of which actually fall within the T60 drainage region (source DWAF National Groundwater Chemistry Database),
- 4 springs with full macro-chemistry, 3 of which were analysed during this study (**Tables 15** and **16**).
- 13 boreholes with electrical conductivity information, 3 of which were collected during this study (**Table 2**).

Groundwater Development Services (1995a) collected groundwater samples from 128 boreholes and springs in the Ecca and Beaufort Group rocks in Mapping Unit 10, to the north of the T60 catchment. The electrical conductivity (EC) of the groundwater varied between 60 and 300 mS/m, with only one sample exceeding 300 mS/m (TDS > 2000 mg/l). They found elevated fluoride (> 1.5 mg/l) concentrations in groundwater from the Ecca shale (4 samples).

8.7.1 Regional Water Quality Trends

Smart (1998) states that the electrical conductivity (EC) of the groundwater in the area between latitude 31° - 33°S and longitude 26° - 30.5°E, rarely exceeds 300 mS/m, which is the maximum acceptable limit for human consumption (DWAF, 1993). Smart's regional salinity map indicates that the EC of groundwater in the T60 drainage region is generally below 70 mS/m, although localised values in excess of 1000 mS/m occur in the vicinity of Port St. Johns (**Table 16**). This water is emanating along regional faults as springs and probably represents the leakage from a deeper, artesian aquifer system. The scant EC information tends to confirm this assessment (**Figure 23**), although groundwater with EC's of 150-160 mS/m occur to the west of Lusikisiki. These elevated salinity values are 'anomalous' and may be associated with water emanating from the saturated alluvial deposits in the area.

Smart (1998) states that local quality variations do occur, with the result that the general trends depicted on his generalised EC map may differ significantly from that found at a particular locality in the field.

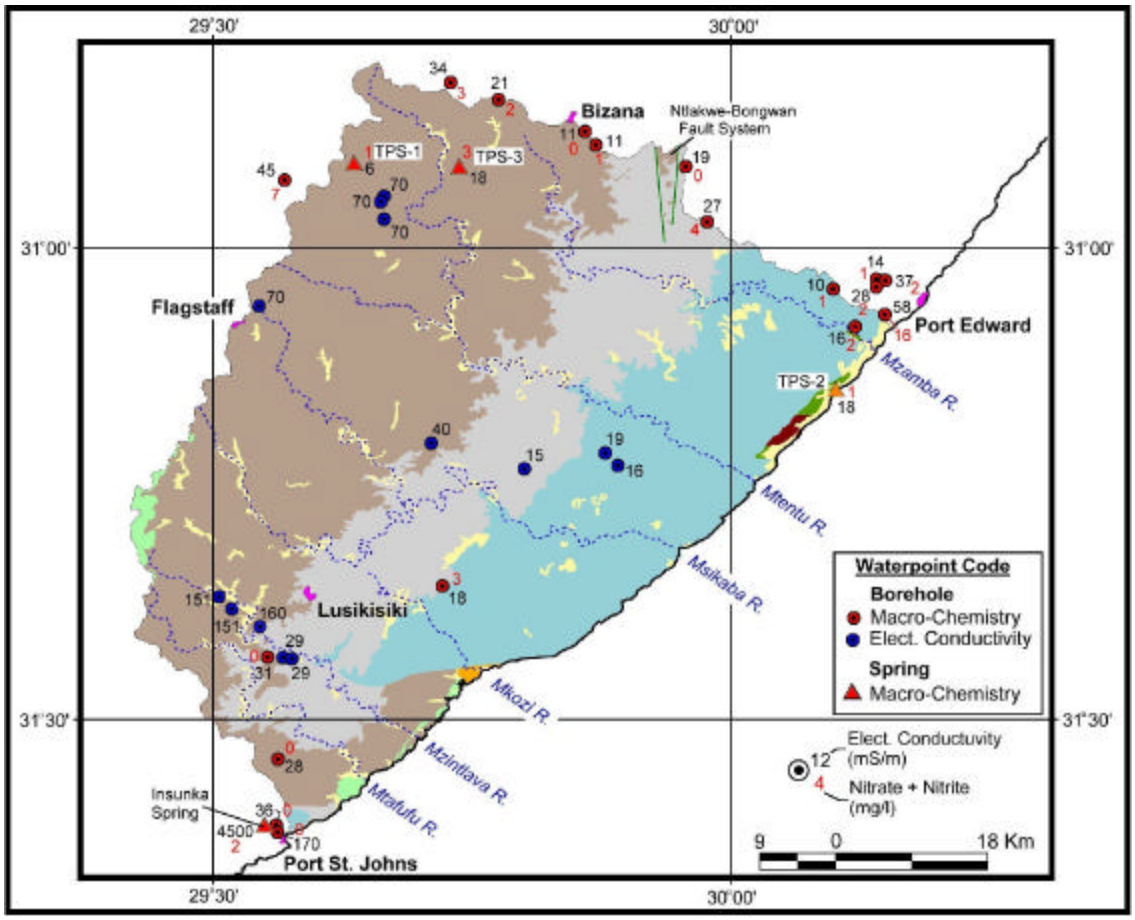


Figure 23: Distribution of Boreholes and Springs with water chemistry information

The characteristic trend of groundwater quality in the Karoo rocks, i.e. increasing salinity with increasing aridity, is apparent in **Figure 23**. The groundwater EC increases from between 10-20 mS/m along the Coastal Plateau to between 40-160 mS/m in the interior. Higher EC's along the coastline are probably due to the influx of wind-borne salts from the sea or the mixing with a deeper, more saline groundwater rising along the numerous coastal faults.

The groundwater in the Dwyka Group is commonly more saline than that in the Ecca (Toens and Partners, 1997). The few groundwater salinity measurements available in the Dwyka rocks of the study area do not show this relationship.

The groundwater quality of the study area is generally potable and within DWAF's recommended drinking-water health standards (DWAF, 1993). The macro-chemical analyses of the groundwater, although limited in number, do not indicate any constituents that are in excess of the maximum recommended limits for domestic consumption. However, elevated nitrate levels (**Figure 23**), are a cause for concern and are probably related to point source pollution of the groundwater resource. Regardless of the above, it is imperative that no groundwater resource be developed prior to thorough chemical and bacteriological analysis of the water.

8.7.2 Possible Sources of Groundwater Pollution

The natural quality of groundwater may be altered by anthropogenic contamination in many ways, including some of the most basic human activities.

Human and animal faecal contamination is the most common sources of pollution in these rural areas, the main pollutants being pathogens (indicators total Coliform, Faecal Colliform and Faecal Streptococci) and nitrate. Faecal contamination of shallow aquifers and springs is likely to be a problem, particularly in areas where the density of on-site sanitation facilities is high.

Groundwater Development Services (1995a) report E.Coli counts of up to 2500 per litre of groundwater in an unprotected production borehole, south of Donny Brook in the Mount Curry district, to the north-west of the study area.

Cattle dips, uncontrolled rural waste-dumps and poorly managed municipal landfill sites are all to a varying degree potential sources of potential pollution

Human and stock activities in the proximity of boreholes and springs are the most common source of localised or "point-source" groundwater pollution, especially where the borehole is improperly constructed. The need to insert adequate lengths of casing and to grout the annulus between the casing and the formation is important, but often overlooked. The construction of a sanitary apron, allowing for proper drainage away from the immediate surroundings of the pump installation, and fencing to keep animals away from the water source, especially springs, is rarely practised.

Unsealed, abandoned boreholes, commonly as a result of unsuccessful drilling or failure of the pump equipment, may constitute a health hazard, as they frequently become convenient receptacles for the disposal of wastes. Borehole and dug-wells represent a direct and rapid path whereby pollutants can enter the aquifer.

A detailed description and evaluation of the potential pollution hazards in the T60 basin is beyond the scope of this study.

9.0 GROUNDWATER EXPLORATION POTENTIAL OF THE LUSIKISIKI DISTRICT

The Lusikisiki District embraces most of the southern part of the T60 catchment (**Figure 24**). The area is situated on a plateau between 400 and 700 m.amsl, which has been incised by the Msikaba, Mzintlava, Xura, Mkozi and Mtafufu rivers. These rivers form steep gorges to the south, south-east and north of the area resulting in extremely rugged terrain, where vehicle accessibility is confined to the hill-tops.

9.1 EXISTING WATER RESOURCES

The Lusikisiki Regional Water Supply Scheme (LRWSS) was commissioned in July 1989 and currently supplies the town of Lusikisiki (1996 population ± 4450), certain bulk consumers (i.e. Government institutions) and 21 rural villages (1996 population ± 40350) surrounding Lusikisiki with potable water (**Figure 24**). The 21 rural communities do not have village reticulation but are serviced by a bank of standpipes located near the village reservoirs. It is also envisaged that a further 25 rural villages will be added to the scheme at a later stage (UWP, 1999).

Raw water is abstracted from a weir on the Xura River to the north-west of Lusikisiki and is then pumped up some 650m to a water treatment works situated near the Kutshandashi village. The treated water is then pumped from the treatment works to a bulk storage reservoir (Res-A), where after it is gravity fed to a further bulk reservoir (Res-B), as well as reservoirs in the 21 villages (**Figure 24**). The scheme has a supply capacity of 2 760 m^3/day or 32 l/s. Recently water supply shortfalls have occurred and UWP have recommended augmenting the scheme from groundwater resources, as part of a medium-term 'emergency' measure.

The communities outside of the LRWSS depend mainly upon water obtained from perennial rivers, springs and boreholes. The boreholes are equipped with either windpumps or handpumps, and are often inoperative or completely vandalised. The water is collected at source and carried 'on-foot' many hundreds of metres to the dwellings.

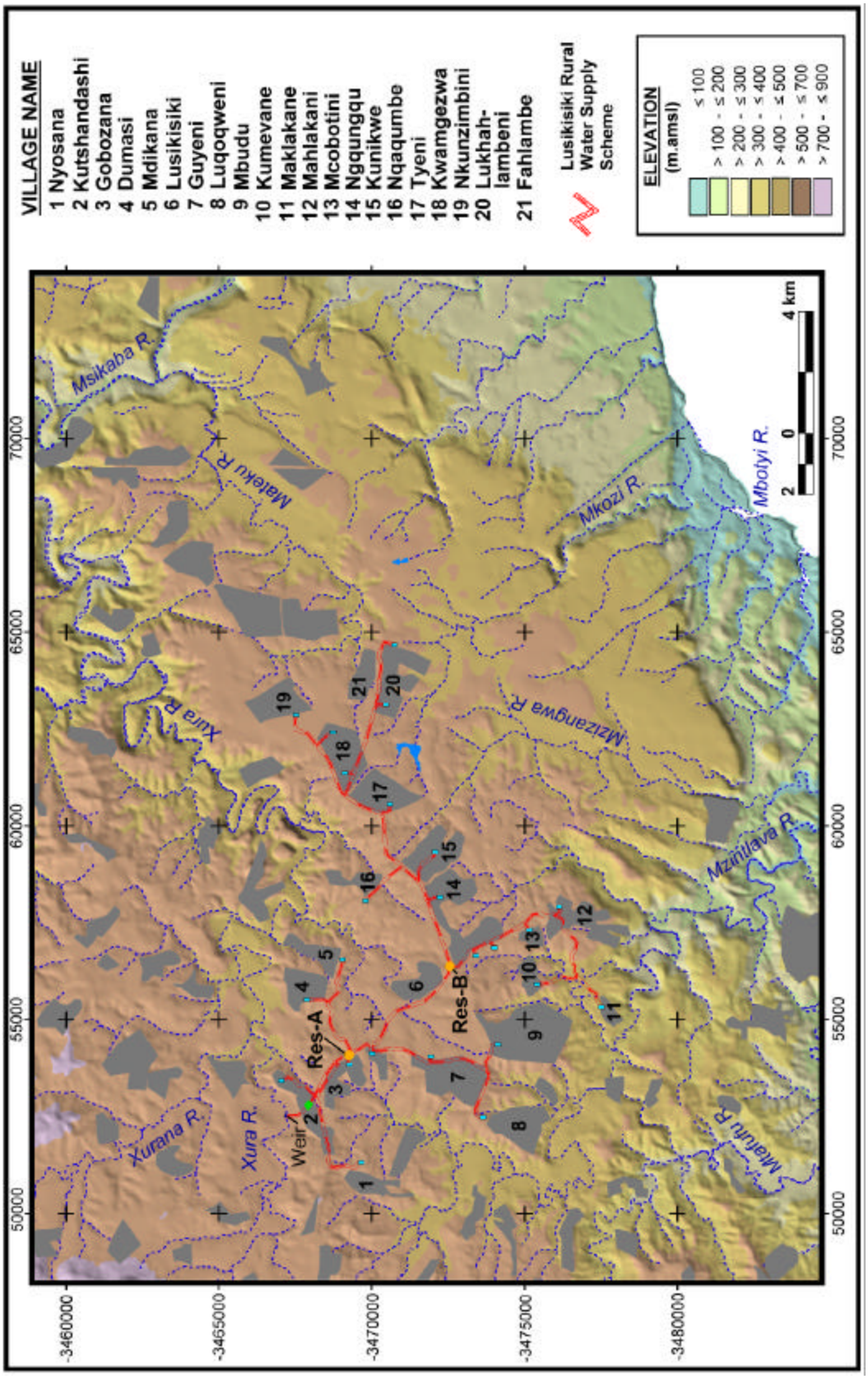


Figure 24: Regional Setting of the Lusikisiki Rural Water supply Scheme

9.2 EXPLORATION DRILLING TARGETS

The area is underlain by shales of the Ecca Group, diamictite of the Dwyka Group, and quartzitic sandstones of the Msikaba Formation in the south (**Figure 25**). Jurassic dolerite sills have been intruded into the Ecca shales to the north of Lusikisiki. Only a few dolerite dykes have been mapped within the area of interest (1/250,000 scale geological map). However, the recently completed satellite lineament study of the T60 catchment, indicates a greater degree of tectonic fracturing, and thus the likelihood of a large number of unmapped dolerite dykes, faults and fissure zones. In general, higher yielding boreholes are associated with these zones of enhanced fracturing.

Relatively high-yielding boreholes of up to 5 l/s were drilled in the Lusikisiki district (SRK, 1991). In the vicinity of the Nyosana Village, moderate borehole yields (2 l/s) were obtained along the contact of dolerite sills intruded into the Ecca shales. It is not known whether these boreholes are in production.

The potential for developing high-yielding boreholes (> 2 l/s) in the Lusikisiki District are moderate to high, when compared to the remainder of the T60 catchment, for the following reasons:

- Higher borehole yields in the Ecca shale and associated dolerite sills (**Chapter 8.1.1** and **8.1.2**).
- Higher borehole yields along the Dwyka-Ecca and Dwyka-Msikaba lithostratigraphic contact (**Chapter 8.1.5**).
- Anticipated higher borehole yields associated with regional dykes, faults and lineaments – despite the findings reported in **Chapter 8.1.3.**
- Lower yields in the Dwyka rocks (**Chapter 8.1.1**) and the groundwater may show elevated salinity levels.

A total of 61 exploration drill-sites were selected within "close" proximity (< 3 km) to the existing water supply infra-structure of the LRWSS (**Figure 25**), using the following information:

- 1/250,000 scale, digital, geological map; geo-referenced using the 1/50 000 topocadastral maps (lithology, dolerite dykes/sills, faults and satellite/ aeromagnetic lineaments).
- Landsat TM lineaments mapped during this study.
- Slope maps (drill-rig accessibility) derived from a 30x30m digital elevation model of the area.
- Topocadstral information (rivers etc.) obtained from the 1/50 000 scale mapsheets.

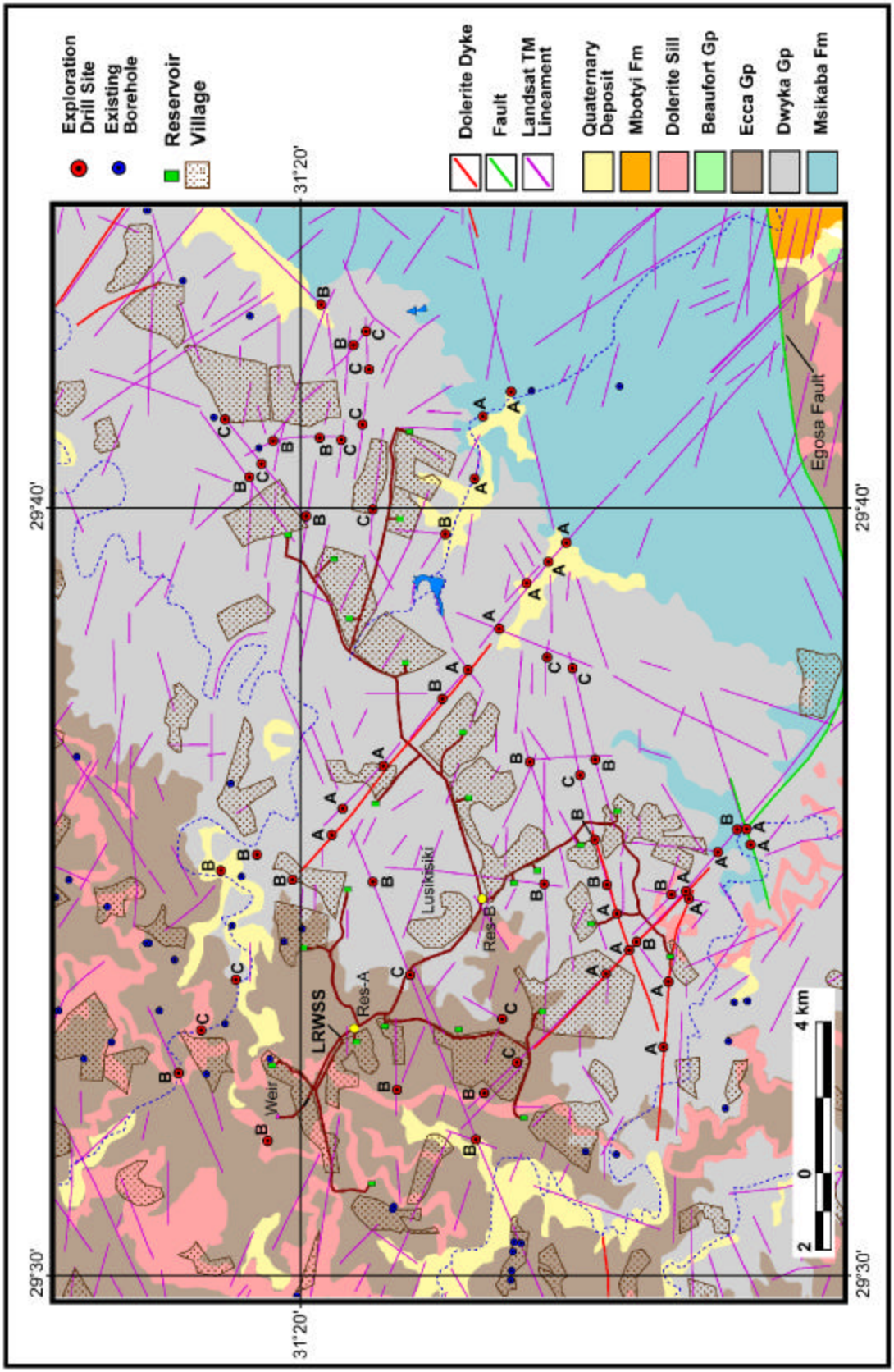


Figure 25: Exploration Drill Targets in the vicinity of the LRWSS

The exploration drill-sites are subdivided into three categories according to their anticipated water-yielding potential, namely:

- Category **A** – Good (21 sites)
- Category **B** – Moderate (25 sites)
- Category **C** – Reasonable (15 sites)

Figure 25 indicates that the area to the south and south-east of Lusikisiki has the highest groundwater development potential. In some cases, more than one exploration site has been indicated along a regional geological structure, which will result in the "clustering" of boreholes. This situation is ideal for the development of production "wellfields" (i.e. a number of closely-spaced boreholes). There are a number of operational and aquifer management advantages associated with such a production scheme.

The satellite lineament map must, prior to any fieldwork, be refined by detailed analysis of the relevant 1/50,000 scale, panchromatic aerial-photographs. Experience in many such siting exercises has indicated that the air-photograph lineaments tend to complement rather that duplicate the satellite lineament information (Woodford & Chevallier, 1999), often highlighting zones of more intense fracturing along the major satellite lineaments. The final important task of siting the boreholes must involve field mapping and appropriate geophysical work to determine the existence, nature and suitability of the drill-target determined in the office. The poor drilling success rates often reported in these areas, when using satellite lineaments, is often due to the 'short-circuiting' of the above process.

The groundwater chemistry of the T60 catchment is poorly understood, due to a lack of hydrochemical information. In general, the quality of the groundwater in the Ecca shales is potable, whilst that in the Dwyka diamictite is often saline. These conditions are not anticipated in the Lusikisiki area, although this should be confirmed during the fieldwork.

The exploitation potential of the groundwater resources of the Lusikisiki area are not restricted by the volumes of water stored in or the volumes of water recharging the aquifer systems, but rather the inability to drill boreholes of sufficient yield capacity to abstract the water. This situation can be vastly improved via the application of appropriate exploration and borehole development techniques.

The drilling success rates can be dramatically improved by utilising "hydraulic-fracturing" techniques as part of the drilling programme, if the boreholes are correctly sited and constructed. Hydraulic-fracturing should be conducted on boreholes with (i) yields too low for economical pumping (≤0.1 l/s) and (ii) to increase the yield of boreholes located near specific fracture-systems. DWAF's results show that yield improvements of up to 300% can be expected in marginal-yielding boreholes, if sited on specific fracture systems. This technique will undoubtedly improve the overall drilling success rate and is particularly useful in

areas such as Lusikisiki, where many of the exploration targets are narrow linear features "hidden" from sight by overburden and where budget constraints restrict the drilling of only one exploration borehole per drill-site. Should drilling reveal that a borehole is not optimally sited on the geological structure, then the borehole can be artificially "connected" to the fracture-zone via hydraulic-fracturing, up to a distance of 50m.

10.0 EXISTING GROUNDWATER USAGE AND CONSUMPTION

Groundwater is used for domestic and livestock watering purposes. The main groundwater source in the study area are the perennial springs and ephemeral seeps (i.e. only flowing during the wet season) (**Chapter 8.6**). The springs tend to emanate in the lower-lying areas, especially in the deeply incised valleys, along bedding-planes, intrusive contacts and other structural features – where the groundwater-level intersects the surface. The majority of the springs used for domestic supply have not been protected (i.e. fenced-off, cement-lined) or developed (i.e. deepened to increase yields), and pose a health hazard, especially during the dry season when both the inhabitants and their stock place pressure on these water resources.

Relatively few boreholes have been drilled in the study area, the majority of those included in the borehole GIS were drilled by or on behalf of the former 'Transkei' Government Department of Water Affairs (T-boreholes). Many of these boreholes are not in use or the pump-equipment, mainly windpumps and hand-pumps, are out of order. A number of the T-boreholes have not been equipped for production purposes due to their low yields.

The existing annual groundwater abstraction is estimated per quaternary catchment using the following information:

- existing geohydrological reports,
- the borehole GIS database,
- a limited reconnaissance hydrocensus within specified hydrogeological domains in the study area,
- population census (1996) per village, and
- digital topocadastral information (i.e. perennial rivers, location of villages) captured at a scale of 1/50 000.

The information was spatially processed in the GIS to estimate the annual groundwater consumption per Quaternary catchment using the following methodology:

1. The total number of inhabitants per Quaternary catchment was calculated using the individual village population information (**Village Population**).

2. An additional 10% of the Village Population was added to each Quaternary catchment in order to take into account the number of people residing outside of the main villages (**Rural Population**).

3. The degree unto which groundwater is being utilised within a particular area was assessed by considering the availability (i.e. distance from user) of alternative sources of water, as follows (**Figure 26**):

   - It was assumed that village and rural inhabitants within 500m of perennial rivers obtained at least 80% of their water needs from this source (i.e groundwater 20%).
   - Due to the high density of perennial rivers and the scarcity of mapped dams and earth-lined impoundments, outside of the surface-water supply schemes, the latter were excluded from the analysis.
   - Village and rural inhabitants within a reticulated Surface-Water Supply Scheme and within 500m of a perennial river were assumed to obtain 5% and 10% of their water requirements from groundwater, respectively. The higher percentage usage of groundwater by rural inhabitants being due to the limited effectiveness of the reticulation network in these areas. The assumption being that the reticulated water is used mainly for drinking purposes and that the rivers are used for washing etc.
   - Village and rural inhabitants within a reticulated Surface-Water Supply Scheme and further than 500m from a perennial river are estimated to obtain 10% and 20% of there water requirements from groundwater, respectively. The assumption being that the purified water is used mainly for drinking purposes and that additional water is obtained from a nearby groundwater source.
   - Both village and rural inhabitants situated outside of Surface-Water Supply-Schemes and further than 500m fom a perennial river, obtain about 80% of their water needs from a groundwater source.

   This model assumes that the choice of water supply utilised is based purely upon the distance between the user and the available water resources. During the hydrocensus (**Chapter 7.0**), many of the inhabitants expressed the opinion that the river-water may be polluted by upstream users and that they preferred to use the spring-water for drinking purposes. The river-water being used more for the washing of clothes, stock-watering etc. Many of the springs are located along the banks of the perennial rivers and thus groundwater usage in the areas within 500m of perennial rivers will be underestimated, particularly if there is a perception of varying water quality between the two sources. The large groundwater base-flow component of the MAR points to the likelihood that a significant percentage of the groundwater recharged from rainfall enters these river systems via seeps and springs.

4. The average per capita water consumption is assumed to vary between 15 and 25 l/day.

5. It is assumed that livestock obtain approximately 30% of their water needs from a groundwater resource. There is no large-scale groundwater abstraction for irrigation or forestry.

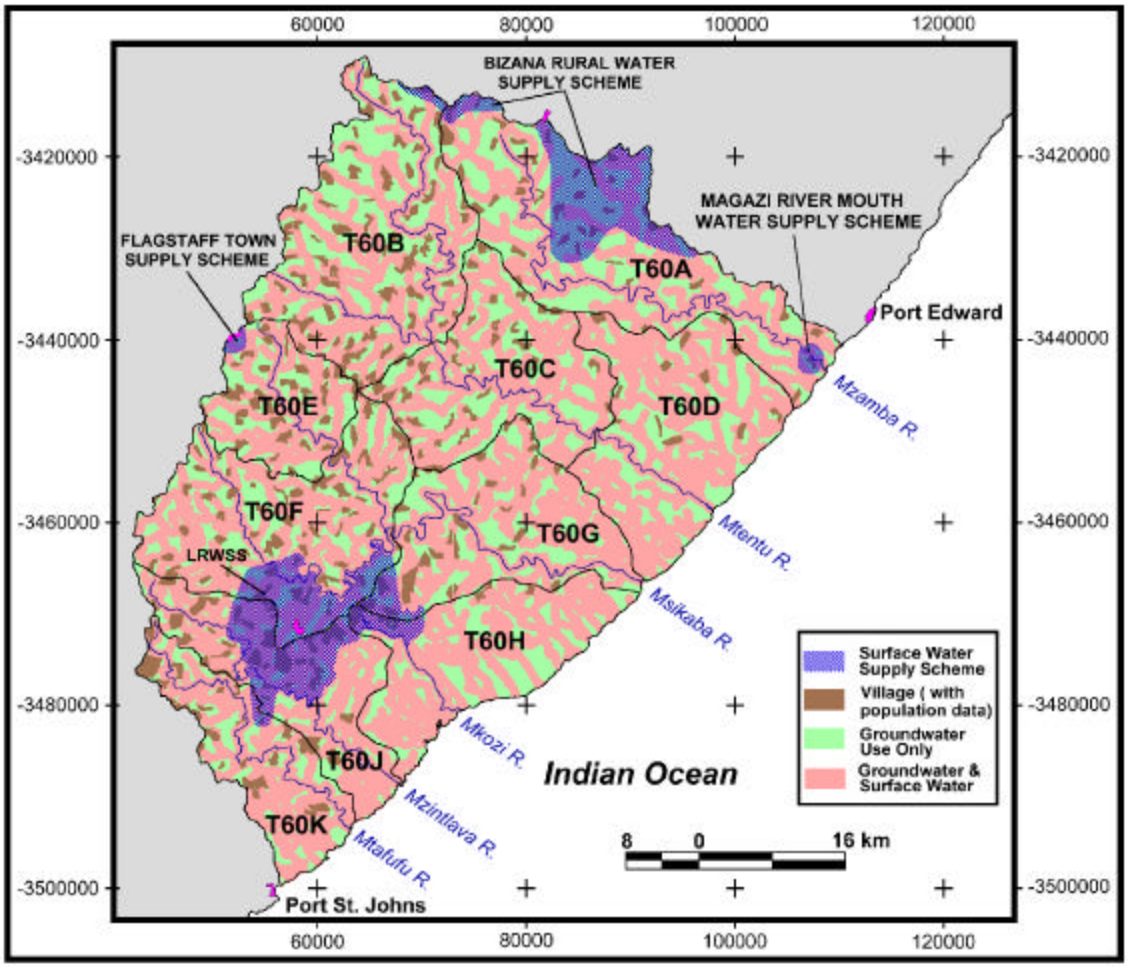


Figure 26: GIS spatial-model used to estimate Groundwater Consumption per Quaternary catchment

The estimated annual volumes of groundwater consumed per Quaternary Catchment are presented in **Table 17**. The total groundwater consumption for the T60 drainage region is estimated at between 2 - 3 x 10^6 m^3 per annum, and rises to 6x10^6 m^3 per annum if a daily per capita consumption of 60 litres is assumed. The groundwater consumption is the highest in the interior (T60B, T60F, T60A and T60C) where the majority of the population resides. The lower population density along the coast results in lower groundwater usage in these catchments.

Table 17: Estimated Annual Volumes of Groundwater Consumed per Quaternary Catchment

Quaternary Catchment	Population (Rural + Village)	Domestic Use (m^3/yr)[1]	Domestic Use (m^3/yr)[2]	Livestock Use (m^3/yr)[3]	TOTAL GROUNDWATER USAGE (m^3/yr)
T60A	71,175	125,644	209,407	126,000	251,644[1] - 335,407[2]
T60B	122,680	350,479	584,131	125,100	475,579[1] - 709,231[2]
T60C	47,970	141,377	235,628	86,100	227,477[1] - 321,728[2]
T60D	20,542	52,876	88,127	96,900	149,776[1] - 185,027[2]
T60E	41,271	114,528	190,880	46,800	161,328[1] - 237,680[2]
T60F	85,288	205,011	341,685	109,800	314,811[1] - 451,485[2]
T60G	51,539	128,627	214,378	85,200	213,827[1] - 299,578[2]
T60H	10,826	10,040	16,733	77,700	87,740[1] - 94,433[2]
T60J	49,353	62,926	104,877	69,900	132,826[1] - 174,777[2]
T60K	46,389	107,335	178,892	57,900	165,235[1] - 236,792[2]
TOTAL	**547,033**	**1,298,843**	**2,164,738**	**881,400**	**2,180,243[1] - 3,046,138[2]**

Note:
1 – assuming a per capita consumption of 15 *l*/day.
2 – assuming a per capita consumption of 25 *l*/day.
3 – assuming 30% of total livestock consumption.

11.0 GROUNDWATER RESOURCE POTENTIAL OF THE T60 TERTIARY DRAINAGE REGION

This chapter deals with the regional groundwater resources of the T60 Tertiary catchment in terms of the potential volumes of water available (Exploitation Potential) and the potential to abstract this water via boreholes (Development Potential). The groundwater resource assessment is presented per Quaternary catchment to facilitate the comparison and integration of this information with that of the surface water resources. The hydrological information for each Quaternary catchment is summarised in **Table 18**.

Table 18 : Hydrological Characteristics of T60 Quaternary Catchments

Quaternary Catchment	1 Area Km^2	2 Mean Annual Precipitation (mm)[A]	3 Mean Annual Volume Ppt ($x10^6 m^3$/year)	4 Mean Annual Runoff ($x10^6 m^3$/year)[A]	5 Mean Annual Baseflow ($x10^6 m^3$/year)[B]
T60A	548.462	873	478.8	72.08	35.107
T60B	530.063	896	474.9	75.68	36.357
T60C	364.611	952	347.1	62.86	29.216
T60D	416.025	1072	446.0	102.93	43.920
T60E	198.885	885	176.0	28.09	13.852
T60F	465.743	940	437.8	79.28	37.776
T60G	361.548	1116	403.5	100.51	43.180
T60H	323.452	1277	413.1	124.66	52.121
T60J	294.739	1101	324.5	77.5	34.812
T60K	243.210	1075	261.5	59.6	27.086

Note: Source of Information [A] – UWP Consulting Engineers (1999)
[B] – Water Systems Management (1999).

11.1 AQUIFER RECHARGE

Aquifer recharge refers to the amount of rainwater that infiltrates into the vadose zone and then actually enters into the main underlying aquifer system. The average groundwater-level in the study area is in the order of 15 m.bgl and therefore the calculated volumes of recharged rainwater already accounts for evapotranspiration losses.

The annual volumes of rainwater recharge within each Quaternary catchment was estimated using the 1'x1' raster data of mean annual rainfall or MAP (**Chapter 4.2**). The following methods were applied in a GIS to simulate the mean annual volumes of recharge:

(a) A fixed recharge rate (R_e) of 5% of MAP (**Figure 27**).

(b) A variable recharge rate (**Figure 28**), where R_e increases with increasing MAP: R_e(%) = [MAP (mm) / 10 000].

(c) Recharge volumes estimated in (b) above, are re-calculated to provide an upper (**Figure 29**) and lower limit (**Figure 30**), according to the variation in the annual rainfall (**Figure 6**).

The results a simulations (a), (b) and (c) are presented in **Table 19**, columns 9, 10, 11 and 12, respectively.

The river base-flow per Quaternary catchment (**Table 18**) makes up some 45-50% of the mean annual runoff (MAR), which is considered to be abnormally high. Estimates of mean annual recharge using a rate of 5% is commonly used in the drier Central and Western Karoo Basin and is considered to be a conservative estimate for the T60 drainage region. Groundwater Development Services (1995b) obtained a similar recharge rate of 4.9% (49 mm/yr) for an area where the MAP is 1000 mm, using river base-flow data. The mean annual base-flow per Quaternary catchment exceeds these volumes of recharge (**Table 19**, Col. 9), by between 30 and 150% - which is physically impossible and further points to a flaw in the river base-flow data.

The mean annual recharge estimates using a variable recharge rate (**Table 19**, Col. 10) are considered to represent a maximum figure for the study area. The 'true' mean annual recharge probably lies between these two extremes (i.e. Cols. 9 and 10 in **Table 19**), and is probably in the order of the lower estimate of recharge (Column 12, **Table 19**)

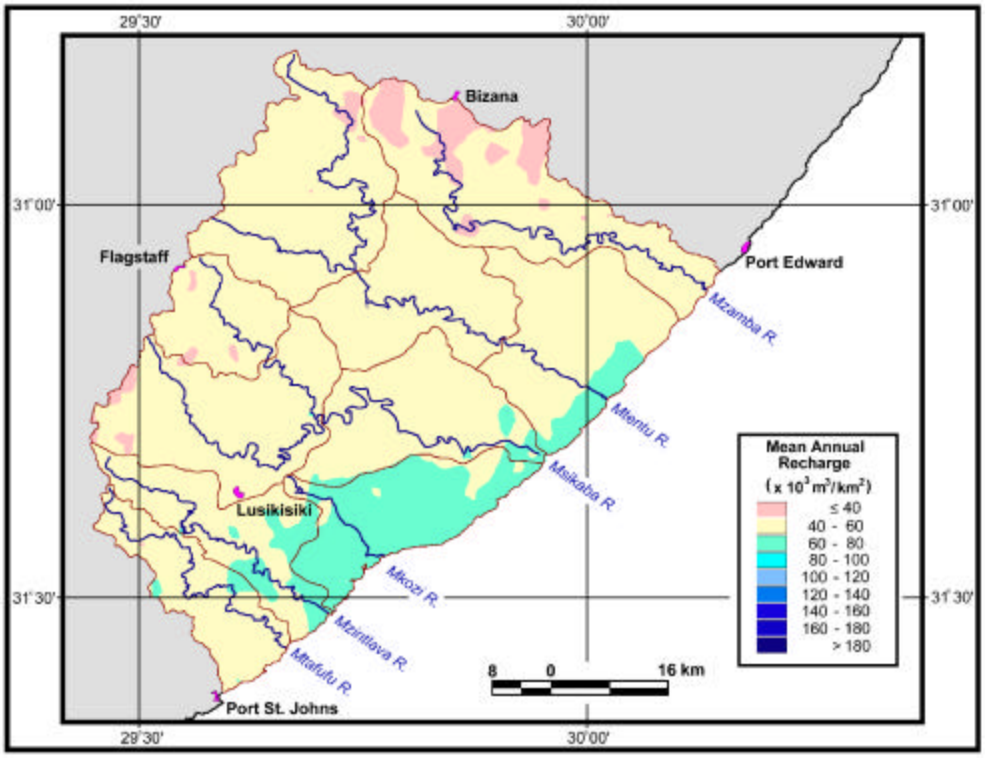


Figure 27: **Mean Annual Volumes of Recharge using a 5% recharge rate.**

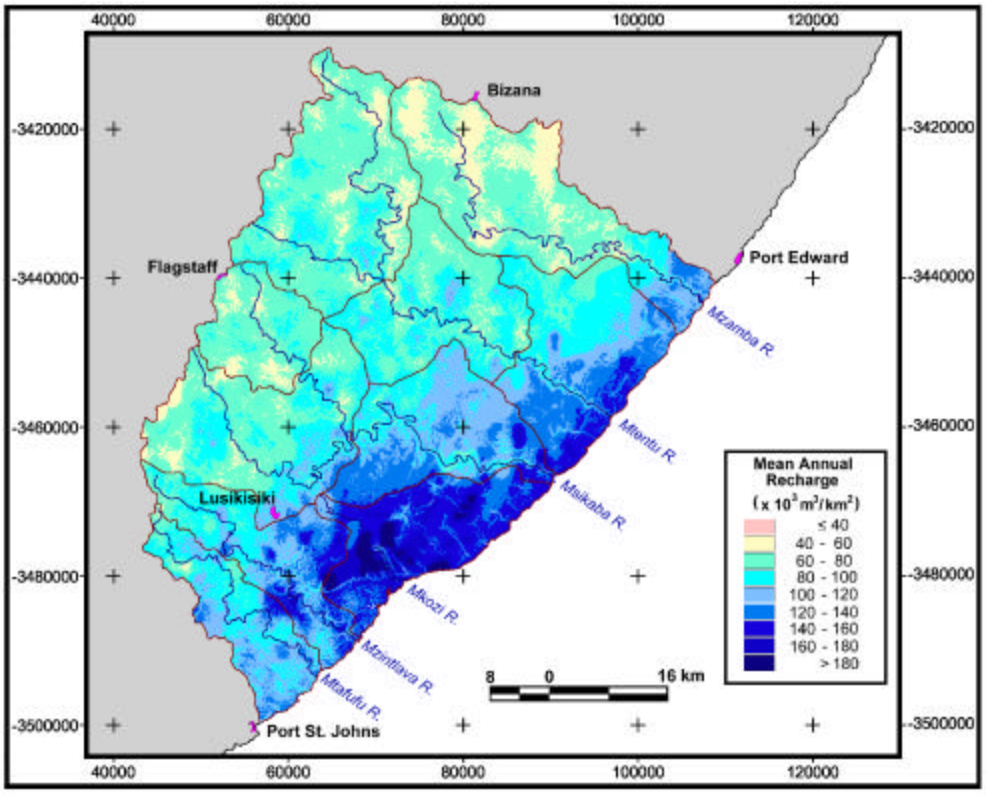


Figure 28: **Mean Annual Volumes of Recharge using a variable recharge rate**

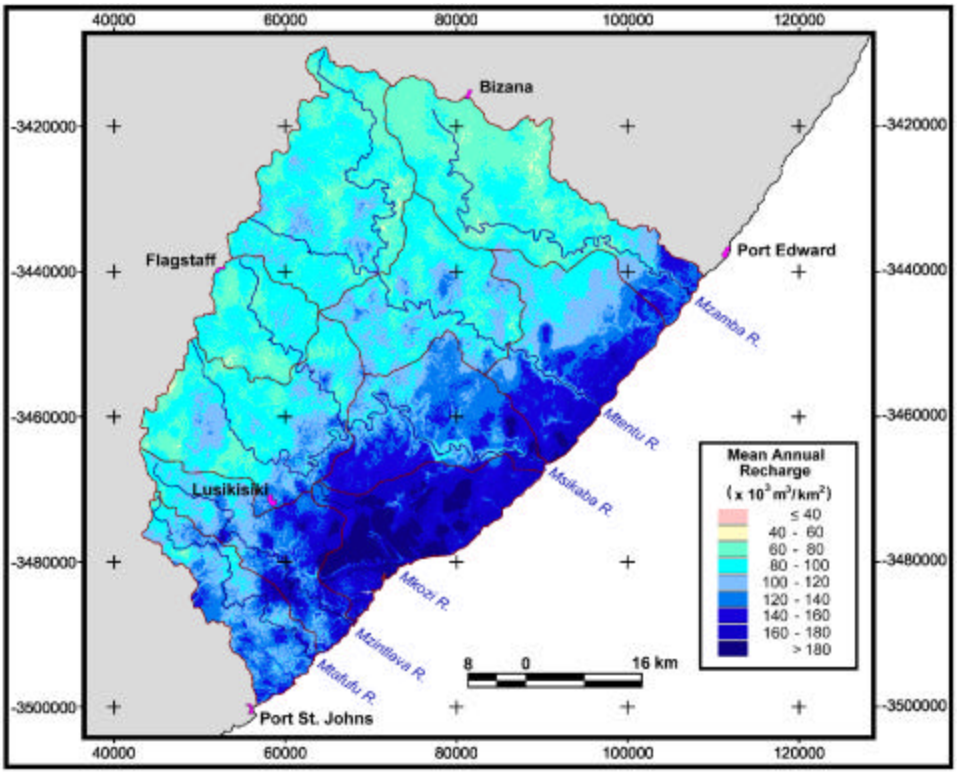


Figure 29: Upper Limit of Mean Annual Volumes of Recharge (variable rate)

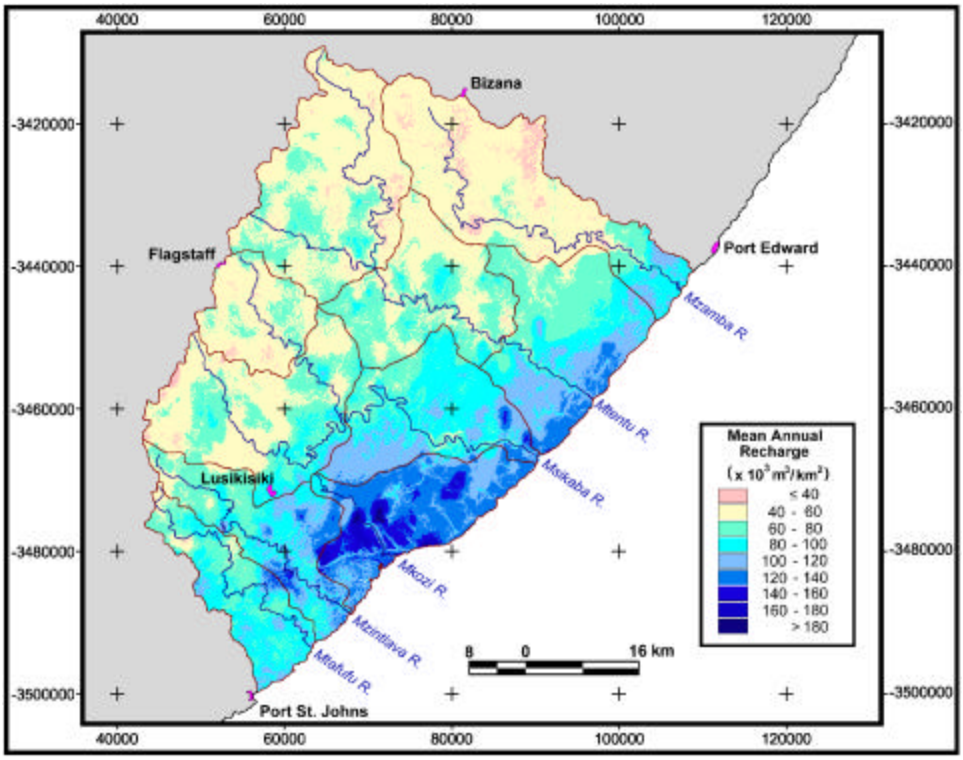


Figure 30: Lower Limit of Mean Annual Volumes of Recharge (variable rate)

Table 19 : Groundwater Recharge and Exploitation Potential of the T60 Quaternary Catchments

Quaternary Catchment	6 Harvest Potential ($x10^6$ m^3/year)	7 Exploitation Potential ($x10^6$ m^3/year)	8 Existing Groundwater Consumption ($x10^6$ m^3/year)	9 Annual Recharge 5% ($x10^6$ m^3/year)	10 Annual Recharge Variable ($x10^6$ m^3/year)	11 Upper Annual Recharge Variable ($x10^6$ m^3/year)	12 Lower Annual Recharge Variable ($x10^6$ m^3/year)
T60A	18.868	13.208	0.335	23.742	37.869	46.003	29.395
T60B	7.209	3.604	0.709	23.547	37.051	45.129	28.871
T60C	8.874	4.437	0.321	17.268	28.501	34.348	22.616
T60D	36.035	18.017	0.185	22.114	44.934	52.239	36.461
T60E	2.705	1.352	0.237	8.744	13.664	16.692	10.614
T60F	6.334	3.167	0.451	21.692	36.625	44.186	29.005
T60G	18.562	5.569	0.299	19.992	40.343	47.216	33.439
T60H	25.433	12.717	0.094	20.479	48.741	55.467	40.890
T60J	6.025	3.012	0.175	16.157	32.299	37.839	26.706
T60K	3.827	1.914	0.237	12.930	23.916	28.186	19.618
TOTAL	**133.872**	**66.997**	**3.043**	**187.152**	**343.943**	**407.305**	**277.615**

Note:
6 Source: after Seymour and Seward (1996)
7 Source: CCWS-DWAF project in progress by Water Systems Management (1999). The Groundwater Exploitation Potential estimates represent a refinement of the Harvest Potential, where the Harvest Potential assessments are re-adjusted using the "average" borehole yield per catchment.
8 (estimation - see **Chapter 10.0**).
9 Annual volumes of groundwater recharge assuming a 5% rate of recharge, based upon Schulze et al (1997) 1x1' grid of Mean Annual Precipitation (mm).
10 Annual volumes of groundwater recharge assuming a variable rate of recharge, based upon Schulze et al (1997) 1x1' grid of Mean Annual Precipitation (mm). Recharge Rate = MAP(mm)/10 000.
11 Upper recharge estimate using a variable recharge rate, where the Schulze et al (1997) 1x1' grid of Coefficient of Variation (%) of Annual Precipitation.
12 Lower recharge estimate using a variable recharge rate, where the Schulze et al (1997) 1x1' grid of Coefficient of Variation (%) of Annual Precipitation.

11.2 GROUNDWATER EXPLOITATION POTENTIAL

The exploitation potential is defined for the purposes of this study as the volumes of groundwater per Quaternary catchment that are potentially available for abstraction on a long-term sustainable basis (i.e. without 'aquifer-mining' taking place). The maximum sustainable yield of an aquifer is therefore equal to the average volumes of recharge to the system.

Seymour and Seward (1996) produced a national map indicating what they termed the groundwater 'Harvest Potential'. The harvest potential is defined as 'the maximum volume of water that is available for abstraction on a sustainable basis, without exhausting the resources'. These estimates are based upon the volumes of groundwater held in storage and the volumes of rainfall recharge. The annual groundwater harvest potential per Quaternary catchment is presented in **Table 19**, col. 6.

Water Systems Management (1999) refined the annual groundwater harvest potential estimates, using the 'average' borehole yield for each Quaternary catchment – which they refer to as the exploitation potential (**Table 19**, col. 7).

This recognises the fact that, in many portions of the country, the low aquifer permeability is the main factor limiting the volumes of groundwater that can be abstracted. This is certainly the case in the T60 drainage region, where a lack of drilling targets, low exploration budgets and limited terrain accessibility further restrict the exploitable potential of the groundwater resources. In this document, the term 'groundwater development potential' is used to take into consideration these restrictions on the utilisation of the resource.

11.3 GROUNDWATER DEVELOPMENT POTENTIAL

The groundwater development potential per Quaternary catchment is estimated as follows:

- Calculation of the annual volumes of groundwater that could theoretically be abstracted from a regular 1 x 1 km grid of production borehole pumping at the lithology-weighted median catchment borehole yield (**Chapter 8.4**) for 12 hours per day (**Table 20**, Col. 13). A median borehole yield of 0.5 l/s was used for the Msikaba Formation, instead of the 0.14 l/s obtained for the T60 catchment.
- A similar calculation was performed using the lithology-weighted mean catchment borehole yield (**Table 20**, col. 14).
- In order to assess the relative availability of drilling-targets within each Quaternary catchment, the 'structural-density' was estimated as a percent of the total catchment area using:

  (a) the outcrop of dolerite sills, and
  (b) geological lineaments, buffered by 50m (i.e. allowing a zone of influence).

- The terrain accessibility was estimated as a percentage of the total Quaternary catchment area, using a slope (°) raster-dataset created from a 30x30m DEM of the T60 catchment. It was assumed that areas with slopes in excess of 12.5° are inaccessible to drilling-rigs (**Table 20**, col. 16).
- The drilling target density and terrain accessibility raster-datasets were then spatially integrated to define the density of accessible 'structural' drilling targets (**Figure 31**), as a percentage of the Quaternary catchment area (**Table 20**, col. 17).
- The initial estimates of 'mean' and 'median' annual volumes of abstractable groundwater were adjusted according to the relative density of accessible drilling targets within each Quaternary catchment (**Table 20**, cols. 18 and 19)

Terrain accessibility is an important factor limiting the development of groundwater in the study area, which is poorly served by tarred-roads. Access to villages from the tarred-roads is by a network of rural roads, which are generally in a poor condition. The villages are commonly situated on the crests of hills and ridges, below which the land slopes steeply to the river valley. Many communities are only accessible by 'paths' and cannot be reached by two-wheel drive vehicles.

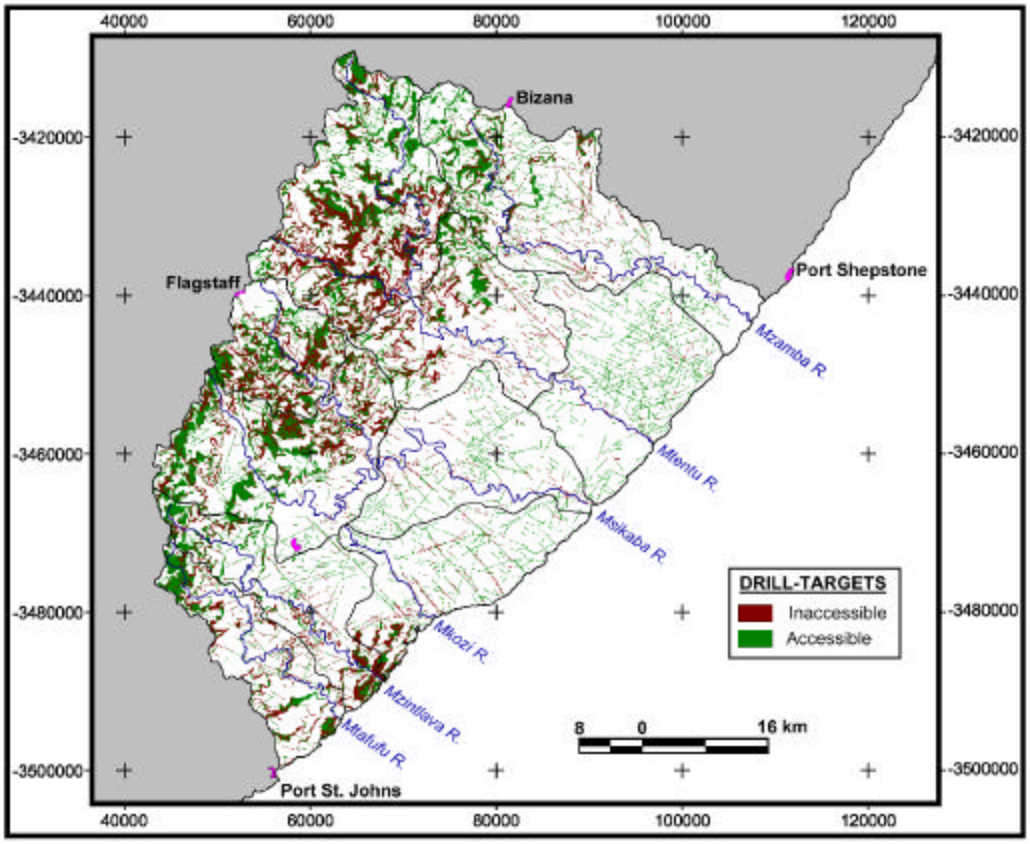


Figure 31: Distribution of 'Structural' Drill Targets in the T60 Catchment.

Table 20: Groundwater Development Potential of the T60 Quaternary Catchments

Quaternary Catchment	13 "Median" Annual Abstraction ($x10^6$ m^3/year)	14 "Mean" Annual Abstraction ($x10^6$ m^3/year)	15 Structural Density (%)	16 Terrain Accessibility (%)	17 Density of Accessible Drill Targets (%)	18 Adjusted "Median" Annual Abstraction ($x10^6$ m^3/year)	19 Adjusted "Mean" Annual Abstraction ($x10^6$ m^3/year)
T60A	6.844 (546)	13.546	16.9	69.9	23.7	1.623	3.213
T60B	9.991 (528)	14.819	41.2	56.7	41.7	4.163	6.175
T60C	5.015 (364)	9.800	19.0	50.1	19.4	0.971	1.897
T60D	3.323 (414)	5.673	9.1	88.0	16.1	0.536	0.914
T60E	1.589 (198)	5.557	44.6	55.6	46.1	0.733	2.564
T60F	7.826 (463)	13.102	31.1	64.6	24.4	1.912	3.202
T60G	3.106 (359)	7.634	7.1	70.7	10.4	0.324	0.796
T60H	2.886 (322)	4.657	11.2	82.4	14.1	0.406	0.655
T60J	3.965 (293)	8.049	22.5	67.9	27.8	1.103	2.238
T60K	4.383 (242)	6.689	23.8	51.8	26.9	1.180	1.801
TOTAL	**48.926 (3729)**	**89.526**		**66.5**		**12.510**	**23.456**

Note: ( ) – Number of production boreholes required (Column 13).

Note the higher density of geological structures (potential drill targets) along the western portion of the study area and extending towards the coast between the Mkozi River and Port St. Johns (**Figure 31**). Large portions of these areas are underlain by Ecca Shales, which will further enhance its development potential. However, a large proportion of these targets, especially in the T60E and T60B catchments, are inaccessible to drilling rigs. The Coastal Plateau is characterised by a lower density of structural drill targets, which are mostly accessible for exploration drilling.

The unadjusted 'mean' annual volume of abstractable groundwater (89.5×10^6 m^3) for T60 drainage region is higher than Water Systems Management's (1999) equivalent exploitation potential (**Table 19**, col. 7). The 'accessibility' adjusted estimates of the total volumes of groundwater that can be feasibly abstracted from the T60 catchment are extremely low and reflect the present 'ad-hoc' approach to groundwater exploration in the Eastern Karoo Basin (**Chapter 8.2**) – ranging between $12.5 - 23.5 \times 10^6$ m^3/annum. Approximately 3.0×10^6 m^3/annum of this groundwater is presently being utilised (**Chapter 10.0**). It is the author's opinion that, with an improved understanding of the occurrence of groundwater in the region and with the appropriate scientific exploration techniques, a far greater volume of groundwater could be abstracted on a sustainable basis from the study area via high-yielding boreholes. This is conservatively estimated at 62.0×10^6 m^3 per annum or a third of the lowest estimate of rainfall recharge. The groundwater quality is moderate to good (**Chapter 8.7**) and is not expected to place any restrictions on the development potential of the study area.

The spatial variability of the groundwater development potential in the T60 catchment is depicted in **Figure 32**, according to the following qualitative ranking system: inaccessible; low-, moderate-, high- and very high- development potential. The average groundwater development potential for each Quaternary catchment is presented in **Table 21**, scaled from low potential (≤ 1) to very high potential (> 3).

Table 21: Average Groundwater Development Potential between Quaternary Catchments

Quaternary Catchment	Average Groundwater Development Potential
T60A	1.64 (1.95)
T60B	1.74 (1.99)
T60C	1.14 (1.75)
T60D	2.15 (2.28)
T60E	1.79 (1.94)
T60F	1.74 (1.99)
T60G	1.34 (1.75)
T60H	1.98 (2.07)
T60J	1.48 (1.75)
T60K	1.32 (1.67)

Note: ( ) Bracketed Values, excludes areas of inaccessible terrain.
Ranking: ≤ 1 : Low 1 – 2 : Moderate 2 – 3 : High > 3 : Very High Potential

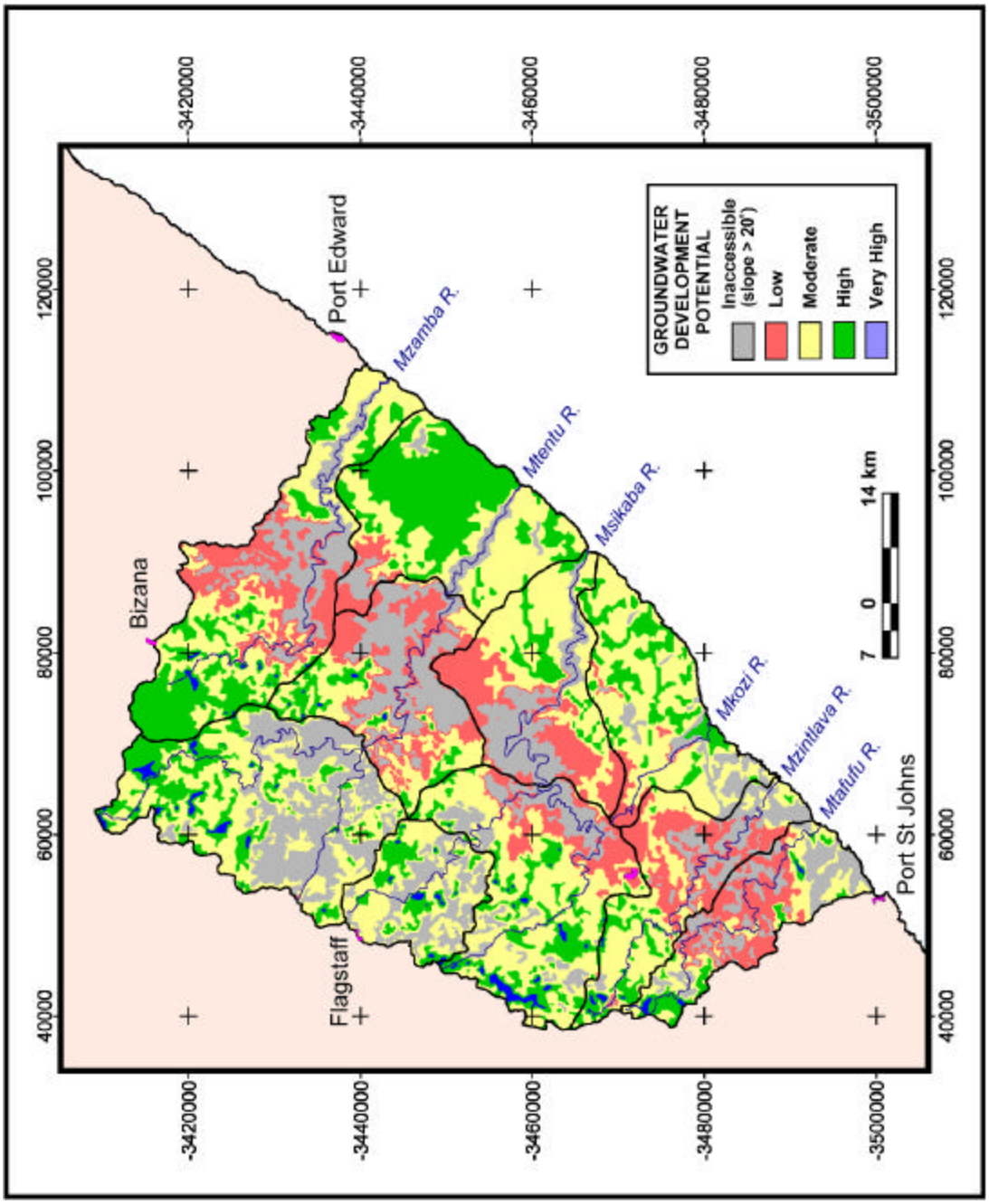


Figure 32: Groundwater Development Potential of the T60 drainage region

The majority of the Quaternary catchments are generally classed as being of 'moderate' groundwater development potential, except of catchment T60D which has a 'high' development potential. Catchment T60H also has a 'high' groundwater development potential, if terrain accessibility is ignored (**Table 21**).

The water-yielding capacity of boreholes have been categorised by DWAF, as part of its regional groundwater mapping programme, in terms of their development potential (**Table 22**)

Table 22: Borehole Development Potential according to Yield

Borehole Yield Range (l/s)	Description	Development Potential
> 3.0	High Yield	Suitable for supply of medium to large-scale water schemes supporting small towns and/or small to medium scale irrigation schemes.
> 0.5 - ≤ 3.0	Moderate Yield	Suitable for reticulation schemes for villages, clinics and schools.
> 0.1 - ≤ 0.5	Low Yield	Primary water supply abstracted using handpumps or windpumps for non-reticulated community and domestic / stock watering purposes.
≤ 0.1	Very Low	Suitable for marginal supply for domestic and domestic stock-watering only.

According to this classification, the majority of the boreholes in the T60 catchment can be described as 'low to moderate yielding', suitable only for non-reticulated and small-scale reticulated village supply.

11.4 COSTS OF GROUNDWATER DEVELOPMENT

The total cost of developing a groundwater resource is difficult to assess and will depend upon many factors, i.e. the required exploration technique(s), drilling-methods, drilling depth, borehole construction, borehole yields, water quality treatment, pump equipment, reticulation pipelines etc.

The cost of establishing and maintaining a groundwater supply scheme may, in certain parts of the T60 region, prove to be a factor limiting its development. The present groundwater development costs are relatively high in terms of the poor drilling success rates and low sustainable yields of the boreholes. The 'sustainability' of these water supplies are severely restricted by a lack of maintenance of the boreholes, pump equipment and reticulation networks. Furthermore, no groundwater monitoring or management programmes are put in place to ensure the long-term sustainability of the supply, which is crucial given the 'invisible' nature of the resource. The present ad-hoc nature of the existing groundwater supply 'schemes' makes it difficult to implement any feasible cost recovery systems, so urgently required to ensure a long-term self-sustaining water supply scheme. Cost reductions can be achieved through better integration of the groundwater development strategies within the overall strategic planning of the region's water resources.

A simple GIS raster-model was created to estimate the relative costs (R/m^3) of developing and abstracting groundwater within the study area, for the following exploitation scenarios:

(i) individual boreholes (≤ 0.5 l/s) to be equipped with windpumps or handpumps (*local supply scenario*), and
(ii) engine-driven borehole wellfields, with borehole yields in excess of 2.5 l/s (*regional supply scenario*).

The following raster-based (100x100m cell-size), GIS approach was applied to obtain groundwater development cost estimates for the T60 drainage region:

1. The percentage of 'dry' boreholes were estimated for each of the major lithological units (**Chapter 8.1.1**):
   - Msikaba Formation ± 15% (i.e. 1 in 6.6 boreholes are dry).
   - Dwyka Group ± 33%
   - Ecca Group ± 25%

2. The percentage of 'wet' boreholes yielding 2.5 l/s and more were estimated for the major lithological units (**Chapter 8.1.1**):
   - Msikaba Formation ± 10% (i.e. 1 in 10 boreholes yield ≥ 2.5 l/s)
   - Dwyka Group ± 25%
   - Ecca Group ± 20%

3. The number of exploration boreholes required per lithological unit to establish a single production borehole yielding ≥2.5 l/s was estimated using items 1 and 2 above:
   - Msikaba Formation ± 12 exploration boreholes
   - Dwyka Group ± 6 exploration boreholes
   - Ecca Group ± 4 exploration boreholes

4. The number of exploration boreholes required per lithological unit to establish a single production borehole yielding between 0.1 and 0.5 l/s were estimated:
   - Msikaba Formation ± 1.5 exploration boreholes.
   - Dwyka + Ecca Group ± 2 exploration boreholes.

5. The number of exploration boreholes required to establish a given production yield within each of the lithological units were adjusted to take into account areas of higher groundwater development potential (**Figure 32**). If a cell coincided with a zone of 'high' or 'very high' groundwater development potential then the number of exploration boreholes required was lowered by 1 or 2 boreholes, respectively. Likewise, the number of exploration boreholes required was increased by 1 if a cell coincided with a zone of 'low' potential.

6. An optimum drilling depth below the groundwater-level of 50m was estimated from **Figure 20**.

7. The regional groundwater-levels' in the study area were approximated by fitting a curved surface through all the cells in a 30x30m DEM that coincide with the course of a perennial river. The assumption being that the regional groundwater-level intersects the ground surface along the course of the perennial rivers, which accounts for the numerous springs along these rivers and the large base-flow component of the MAR.

8. The required borehole drilling depths were estimated by integrating the optimum drilling depth (item 6) with the 'regional groundwater-level' raster dataset (item 7).

9. The inaccessible portions, i.e. terrain with slopes in excess of 20°, of the study area were excluded from the analysis.

10. The costs of drilling an exploration borehole (diameter 165mm) to the required depth (Item 8) was estimated, assuming the following:
    - All boreholes are equipped with 18m of steel casing, costing R120/m.
    - Drilling costs of R110 per metre at depths of up to 80 m.bgl, increasing to R140/m over the depth range of 80 to 150m.bgl and R180/m for depths in excess of 150m.bgl.

11. The exploration costs (remote-sensing, field mapping, geophysical surveys etc.) were assumed to be in the order of R4 500 per exploration borehole.

12. The yield assessment costs (pump-testing and evaluation) were estimated at:
    - 0.5l/s Production borehole – R17 000 per production borehole.
    - 2.5l/s Production borehole – R24 000 per production borehole.

13. The total cost of establishing a production borehole of the required yield was estimated by integrating:

    [No. Expl. Boreholes (Item 4 & 5) x Drill Costs (Item 10)] + Exploration Costs (Item 11) + Yield Assessment Costs (Item 12)

14. The following pumping equipment and costs thereof were assumed:
    - 0.5 l/s Production Borehole: Windpump.
      * R20 000 - pumping head less than or equal to 120m.
      * R30 000 – pumping head greater 120m.
    - 2.5 l/s Production Borehole: Mono-pump and diesel engine.
      * R25 000 - pumping head less than or equal to 120m.
      * R37 000 – pumping head greater 120m.

15. The total 'capital' costs per production borehole were estimated by summing Items 13 + 14.

16. The annual maintenance costs were estimated as follows:
    [(Item 13) / 20 yrs] + [(Item 14) / 5 yrs]

17. The following 'operating' costs per production borehole were assumed:
    - Windpump – R0.10 per m^3 of groundwater abstracted.
    - Diesel Mono Pump – R2.00 per m^3 of groundwater abstracted.

    The operating cost of a diesel-engine pump was obtained from the average fuel and operator salary costs of 9 rural groundwater supply schemes in the Northern Cape Province (range R1.00 - 3.50/m^3). Similarly, an average cost of R0.68/m^3 was obtained from 4 village supply schemes, which use electrically driven pumps.

18. An average 'scheme life' of 20 years was assumed, with high-yielding and low-yielding production boreholes operating at 60% and 70%, respectively, of their maximum capacity on a continual basis (i.e. a 2.5 l/s production borehole pumping continuously at 1.5 l/s for 20 years).

19. The cost of developing groundwater (R/m^3) per exploitation scenario for the study area was estimated by integrating Items 15, 16, 17 and 18 (**Figures 33** and **34**).

This provides a first order estimate of the average 'costs' of developing the groundwater resources of the T60 catchment for regional water resources planning purposes. Note that reticulation costs have not been included. In general, it can be concluded that:

- The average cost of developing a cubic metre of groundwater is R2.18 (range R2.08 - 2.56) and R0.45 (range R0.35 – 0.84) for high- and low- yielding production borehole abstraction scenarios, respectively. In general, the cost of developing a high-yielding borehole is some 5 times greater than that of a low-yielding borehole.

- The cost of developing a low-yielding production borehole in the Msikaba Formation is uniformly low (R0.30-0.40/m^3) – **Figures 33** and **8**. In contrast, it is the most costly (R2.30-2.50/ m^3) lithological unit in which to develop high-yielding production boreholes (**Figure 34**).

- It is most costly to develop low-yielding production boreholes in the Dwyka rocks and heavily dissected areas underlain by Ecca shales (**Figure 33** and **8**). The Ecca and a large portion of the Dwyka rocks are more favourable for the development of high-yielding production boreholes (**Figure 34**).

- **Figure 35** indicates that it is 5 to 6 times more costly (red zone) to develop high-yielding production boreholes in the Msikaba sandstones than it is to develop low-yielding production boreholes.

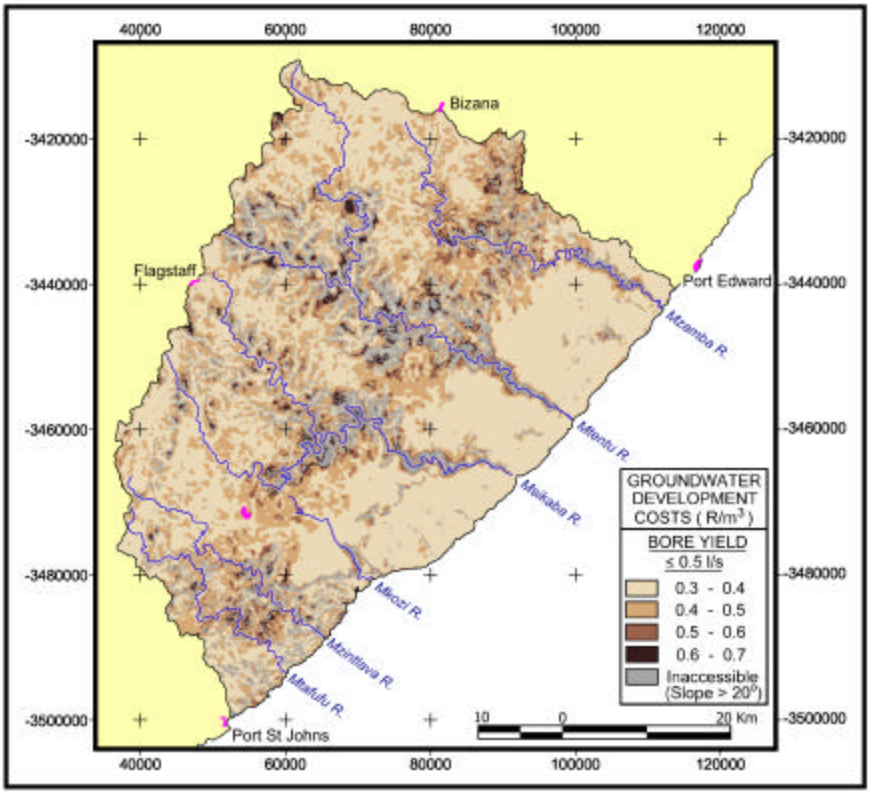


Figure 33: Groundwater development costs to establish a borehole yielding £ 0.5 l/s.

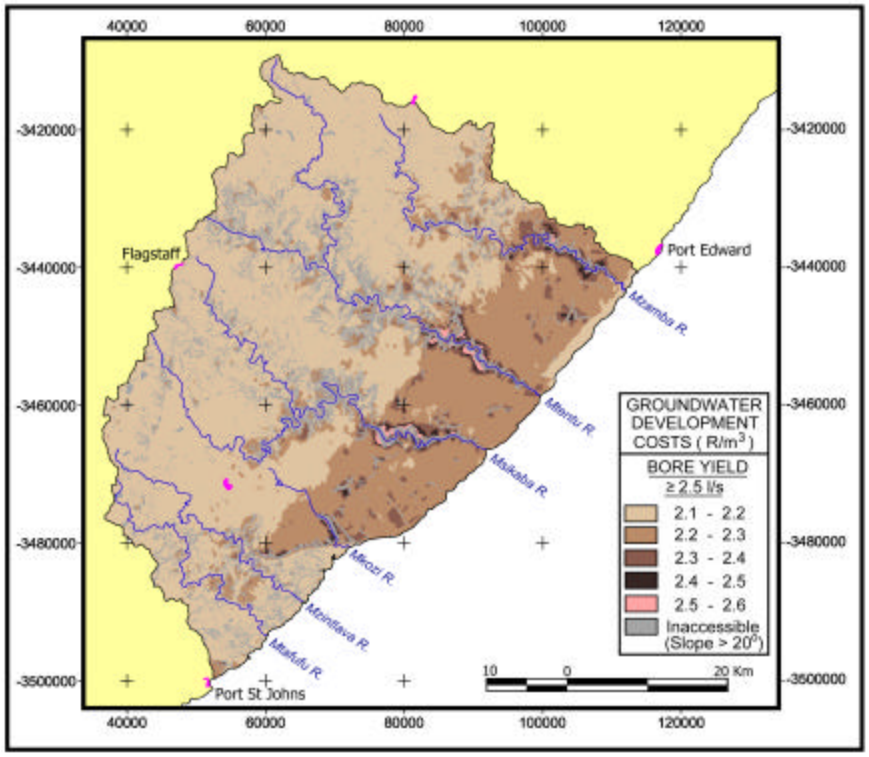


Figure 34: Groundwater development costs to establish a borehole yielding ³ 2.5 l/s.

The average groundwater development costs for establishing high- and low-yielding production boreholes within each Quaternary catchment are summarised in **Table 23**, where it is evident that:

- It is more cost effective to develop low-yielding (< 0.5 l/s) rather than high-yielding (≥ 2.5 l/s) production boreholes in all catchments (**Figure 35**).

- The average cost of developing high- and low-yielding production boreholes does not vary significantly between the Quaternary catchments (i.e. R0.08).

- Individual, low-yielding production boreholes can be most cost effectively developed in catchments T60H and T60D.

- Wellfields of high-yielding production boreholes can be most cost effectively developed in catchments T60B, T60E and T60F.

- Catchments T60D and T60H should receive the highest priority for groundwater development, due to their high groundwater potential and reasonable development costs.

- Catchment T60C has the lowest groundwater development potential due mainly to the rugged terrain and predominance of Dwyka rocks.

Note that, although the above cost estimates indicate that it is some 5 times more costly to develop high-yielding production boreholes, there would be significant long-term 'savings', not accounted for in these estimates, related to the design (reticulation), operation, maintenance, monitoring and management of such abstraction schemes or wellfields.

The groundwater resources of the T60 basin should be developed within existing or as an integral part of future surface-water supply schemes, where they can be utilised to:

- augment supplies during droughts / floods (emergency-standby role),
- to span periods of peak water demand (intermittent usage), or
- to gradually increase the capacity of the scheme (continuous usage).

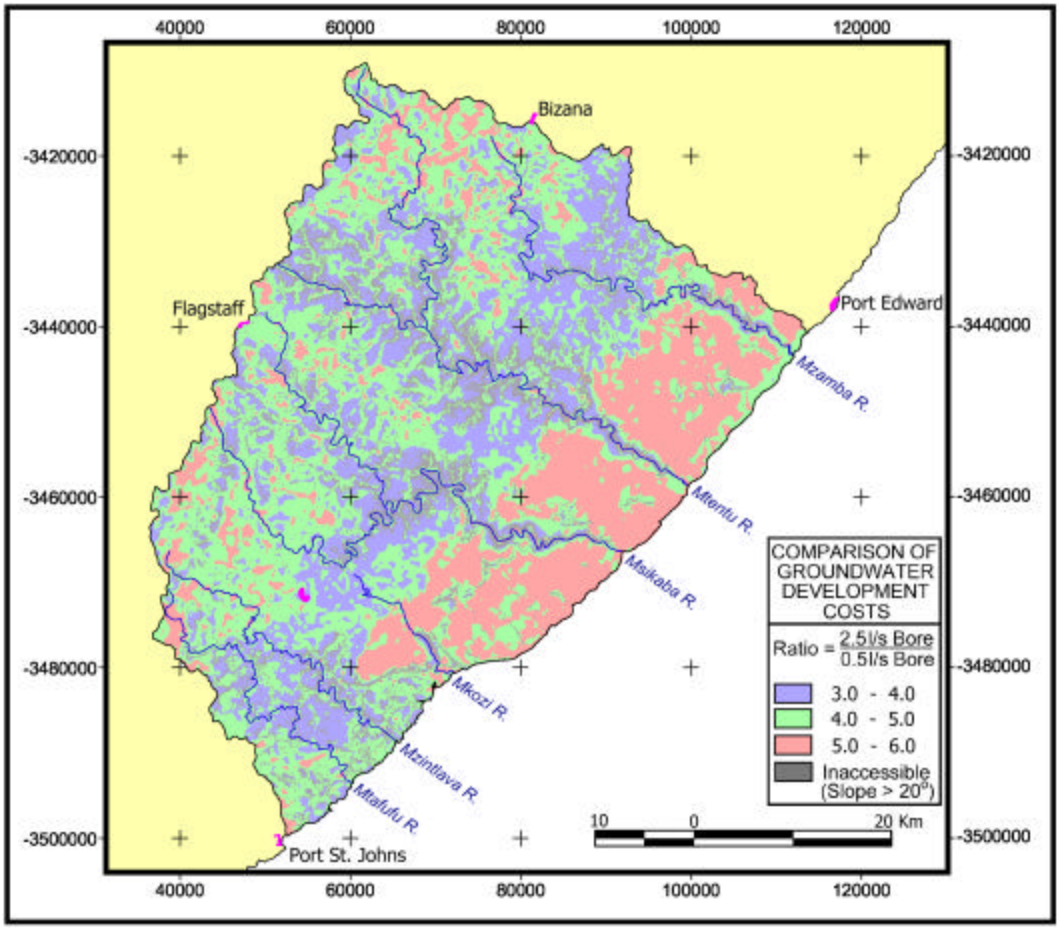


Figure 35: Comparison of the costs of developing the groundwater resources using 2.5 l/s and 0.5 l/s production boreholes (i.e. ratio of Figures 34/33).

Table 23: Comparison of groundwater development potential and costs between Quaternary Catchments for establishing (i) low-yielding and (ii) high-yielding production boreholes

Quaternary Catchment	Groundwater Development Potential[A]	Single Borehole [Q ≤ 0.5 l/s] (R/m^3)	Wellfield [Q ≥ 2.5 l/s] (R/m^3)
T60A	1.64	0.46	2.18
T60B	1.74	0.45	2.13
T60C	1.14	0.48	2.17
T60D	2.15	0.40	2.24
T60E	1.79	0.45	2.13
T60F	1.74	0.45	2.14
T60G	1.34	0.46	2.22
T60H	1.98	0.41	2.23
T60J	1.48	0.45	2.15
T60K	1.32	0.46	2.15

Notes:
[A] – Average Groundwater Development Potential from **Table 21**.

12.0 CONCLUSION AND RECOMMENDATIONS

Groundwater in the T60 drainage region occurs mainly in shallow, weathered-fractured rock aquifers, where the average depth to the waterlevel is 15 metres below the ground surface. Borehole yields are generally higher in the Ecca shales and associated Karoo dolerite sills, while boreholes in the Dwyka rocks are low-yielding. Limited drilling evidence tends to indicate that, contrary to expectations, borehole yields in the Msikaba sandstone are low. There are indications of a deeper-seated, artesian aquifer system containing saline water. A number of semi- to unconsolidated, sandy primary aquifers of limited extent are likely to occur along the major river courses, especially towards the river-mouths and in estuaries. High borehole yields are anticipated at favourable locations.

The groundwater resources of the T60 drainage region are only being utilised at a fraction of their true potential, both actively via boreholes and passively from perennial springs or ephemeral seeps. The present groundwater consumption in the study area is estimated at 3.0×10^6 m^3 per annum.

In general, the groundwater quality is good and is suitable for domestic water supply purposes, although local variability is anticipated. Local point source pollution of the groundwater is likely in densely populated areas, due to anthropogenic activities, resulting in elevated nitrate levels and faecal bacterial counts.

The groundwater resources of the study area, as indicated by rainwater recharge, are high - in the order of 280×10^6 m^3 per annum. However, much of this groundwater is 'lost' as base-flow to the many perennial rivers draining the T60 catchment, particularly during the dry season.

Presently, the low permeability of the shallow aquifers and the inaccessibility of the terrain limit the groundwater development potential of the T60 basin to between 12.5 - 23.5×10^6 m^3 per annum. With the drilling of deeper and higher yielding production boreholes, it will be possible to abstract between 50.0 - 90.0×10^6 m^3/year on a sustainable basis. The costs of exploring and developing such groundwater-supply schemes will be considerably higher (x5) than the existing 'ad-hoc', low-yielding groundwater supply 'schemes'. This will require Water Planners to re-assess groundwater's role within the overall strategy to develop the water resources of the region. The sustainability of these schemes will depend upon establishing appropriate groundwater monitoring and management programmes, which are to a large extent funded by revenue generated by the scheme itself. Lack of maintenance is the main cause of many water-supply schemes failing to deliver, rather than the groundwater 'drying-up'.

The following recommendations are made to improve the development and sustainable utilisation of the groundwater resources of the T60 drainage region:

- The development of the groundwater resources of the region should receive a high priority when compared to alternative sources, as it represents a ubiquitous, sustainable, relatively inexpensive and good quality source of water. In this regard, the following Quaternary catchments should be prioritised in their order of listing: T60D, T60H, T60E, T60F and T60B.

- Identification of high-yielding perennial springs and determining ways to incorporate them into the more 'formal' water-supply schemes (which includes protection from direct and indirect contamination).

- The many low-yielding springs and ephemeral seeps which emanate along the slopes of incised river gorges and along the rivers-banks – should be 'tapped' collectively using suitably located weirs along minor drainage tributaries.

- Springs are often not considered suitable for development as a water supply, because of their yield variability. In this regard, both direct and indirect methods of discerning between perennial springs and ephemeral seeps needs to be investigated.

- Research into the nature and mode of groundwater occurrence in the eastern Karoo Basin is required and should be formulated within the region's broader water resources planning.

- The general quality and detailed chemistry of the groundwaters in the T60 region are unknown – this issue should be addressed as part of a regional development plan.

- Prior to any groundwater exploration programme it important that a proper inventory of abandoned boreholes be carried out to assess the possibility of rehabilitating 'dry', but previously successful boreholes.

- The practical application and cost effectiveness of new remote-sensing and geophysical techniques should be assessed to improve borehole drilling success rates.

- Drilling success rates can be greatly improved by making use of 'hydraulic-fracturing' techniques on marginal yielding or "dry" boreholes. These methods have been shown to increase the yield of marginal boreholes by up to 300%. Low-yielding boreholes (<0.1 l/s) can thus be brought in production rather than abandoned.

- Stricter enforcement of existing guidelines and technical specifications for sanitary borehole construction and spring protection should be applied.

- Deeper exploration drilling, involving borehole depths of 250-300m, along selected regional geological structures should be considered with the aim of developing wellfields of high-yielding production boreholes as part of existing and future water supply schemes. In this regard, the groundwater potential of the Msikaba sandstone needs to be re-assessed – it is the authors opinion that this formation has a significantly higher potential than presently indicated.

- Implementation of appropriate maintenance, monitoring and management programmes for all groundwater supply schemes, which are initially operated by suitably qualified personal for a limited period of time (i.e. two years). Such a project team should consist of a hydrogeologist, civil engineer, technicians and locally based operators and foremen. The advantages of this approach are:

  1. Cost effective, sustainable and safe supplies of water for domestic use in these previously disadvantaged and remote areas.

  2. Expensive infrastructure installed by the Government will be properly managed and maintained.

  3. Scarce groundwater resources will be properly monitored and managed to ensure there long term sustainable utilisation.

  4. Previously disadvantaged communities will be empowered by:

     (a) the employment and training of community members as scheme operators and foremen,
     (b) the attendance of bi-annual management meetings by the Local Councils and their CEO's,
     (c) the holding of awareness and training workshops in the communities, and
     (d) District Councils and other Interested and Affected Parties can, at the same time, be informed and made aware of the need for the proper management and sustainable utilisation of scarce groundwater resources and expensive infrastructure.

  A successful working example of such a project is the Department of Housing and Local Government of the Northern Cape Province's management and monitoring programme of water supply schemes and groundwater resources in the rural areas of Namaqualand and Mier.

- A regional groundwater monitoring-programme should also be instituted to assess the *ambien*t waterlevel and water quality trends, away from the major groundwater supply-schemes. This data, along with that gathered at the local groundwater supply schemes, will provide more quantitative information on the aquifer dynamics (groundwater flow, recharge) and ultimately the sustainable yield of these resources.

REFERENCES

Acocks, J.P.H., (1988): ***Veld Types of South Africa***, 3ed, Botanical Survey, Memoir 57.

Andreoli, M.A.G., Doucoure, M., Van Bever Donker, J., Brandt, D. and Andersen, N.J.B., (1996): ***Neotectonics of Southern Africa - a review***, Africa Geoscience Review, Vol 3, No. 1, pp 1-16.

Begg, G., (1978): ***The estuaries of Natal***, Natal Town and Regional Planning Report No.41.

Bobba, A.G., Bukata, R.P. and Jerome, J.H., (1992): ***Digitally processed satellite data as a tool in detecting potential groundwater flow systems***, Jnl. Hydrology, Vol. 131, pp. 25-62.

Chevallier, L. and Woodford, A.C., (1999): ***Morpho-tectonics and mechanism of emplacement of dolerite rings and sills of the Western Karoo***, S. Afr. J. Geol., V102(1), pp 43-54.

Davies, Lynn & Partners, (1995): ***Characterisation and Mapping of the Groundwater Resources, Kwazulu-Natal Province, Mapping Unit 4***, on behalf of the Department of Water Affairs & Forestry, April 1995, Technical Report N4314, Durban.

de Decker, R.H., (1981***): Explanation to the 1/250 000 scale Kokstad geological mapsheet (3028)***, SA Geological Survey, Department of Mines, Pretoria, 22p.

DWAF, (1993): ***South African Water Quality Guidelines – Volume 1, Domestic Use***, Department of Water Affairs and Forestry, Pretoria.

Du Plessis, A., Hartnady, C.J.H., and Partridge, T.C., (1997*): **Causes of Southern African seismicity*** (abstract)., 29th Int. Union of Seismology and Physics of the Earth's Interior (IASPEI) General Assembly, August, Thessalonika, Greece, pp 18-28, Abstracts Volume.

Du Toit, A.L., (1929): ***The geology of parts of Pondoland, East Griqualand and Natal: explanation of Cape Sheet 35 (Matatiele)***, Geological Survey of South Africa, Pretoria, p.31.

Du Toit, A.L., (1946): ***The geology of the major portion of East Griqualand: explanation Sheet 119 (Port Shepstone)***, Geological Survey of South Africa, Pretoria, p.31.

Gay, N.C., (1975): ***In situ stress measurements in Southern Africa***, Tectonophysics, Vol 29, pp 447-459.

Groundwater Development Services, (1995a): ***Hydrogeological Characterisation and mapping of the Kwazulu-Natal Province – Mapping Unit 10 Draft Final Report***., Directorate: Geohydrology, Department of Water Affairs & Forestry, Pretoria.

Groundwater Development Services, (1995b): ***Hydrogeological Characterisation and mapping of the Kwazulu-Natal Province – Mapping Unit 6 Final Report***., Directorate: Geohydrology, Department of Water Affairs & Forestry, Pretoria.

Gustafsson,P., (1993): ***SPOT satellite data for exploration of fractured aquifers in a semi-arid area of south-eastern Botswana***, Memoires of the XXIVth Congress of the IAH, Oslo, pp. 562-576.

Hälbich, I. And Chevallier, L., (1998): ***Origin and Significance of Lineaments***, Section 3 of the Final Report – A Review of the Seismo-tectonic Model for Lesotho, in preparation for Lesotho Highlands Development Authority.

Hartnady, C.J.H., (1998): ***Zones and Rates of Seismicity within Southern Africa***, Section 2 of the Final Report – A Review of the Seismo-tectonic Model for Lesotho, in preparation for Lesotho Highlands Development Authority.

Hobday, D.K. & Mathew, D., (1974***): Depositional environment of the Cape Supergroup in the Transkei***, Trans. Geol. Soc. S. Afri., V77, pp 223-227.

Karpeta, W.P. and Johnson, M.R., (1979): ***Explanation to the 1/250 000 scale Umtata geological mapsheet (3128)***, SA Geological Survey, Department of Mines, Pretoria.

King, L.C., (1951): ***South African Scenary***, Oliver and Boyd, Edingburgh.

Lattman, L.H. and Parizek, R.R., (1964): ***Relationship between fracture traces and the occurrence of ground water in carbonate rocks***, Jnl. Hydrology, Vol. 2, pp. 73-91.

Low, A.B. & Rebelo, A.G. (eds); (1996***): Vegetation of South Africa, Lesotho and Swaziland***, Department of Environmental Affairs and Tourism, Pretoria.

Maud, R.R., (1961): ***A preliminary review of the structure of coastal Natal***, Trans. Geol. Soc. S. Afr., V64, pp. 247-256.

Rauch, H.W., Bradley, E. and Craig, D., (1984): ***Study of lineament effects water well yield in an eight county area of Western Virginia***, In: Abstracts with Programs, Geol. Soc. Amer. 33rd Annual Meeting, Vol. 16, No.3, p.188.

Schowengerdt, R., Bacock, E.M., Ethridge, L. and Glass, C.E., (1979): ***Correlations of geologic structure inferred from computer enhanced Landsat imagery with underground water supplies in Arizona***, Satellite Hydrology AWRA, pp. 387-397.

SAC, (1980): ***Stratigraphy of South Africa – Handbook 8***, South African Committee for Stratigraphy, Government Printers, Pretoria.

Schultze, R.E., Maharaj, M., Lynch, S.D., Howe, B.J. & Melvil-Thomson, B., (1997): **South African Atlas of Agrohydrology and – Climatology**, Water Research Commission Project Report No. TT82/96, Pretoria.

Seymour, A and Seward, P., (1996***): Groundwater Harvest Potential Map of the Republic of South Africa***, Department Water Affairs & Forestry, Pretoria.

Smart, M.C., (1998): ***An explanation of the 1:500 000 General Hydrogeological Map Queenstown 3126***, ISBN 0-621-28795-4, Directorate: Geohydrology, Department of Water Affairs & Forestry, Pretoria.

SRK, (1991): ***Northern Zone – Village Water Supply Study: Groundwater Water Programme 1990***, Steffen, Robertson & Kirsten, Technical Report No. 174392/3, Volume 1 to 7.

SRK, (1993): ***Hydrogeological Investigation Phase 3: Natal Group Sandstones***, Steffen, Robertson & Kirsten, Technical Report No. 149105/5.

Thomas, R.J., (1988): ***The Geology of the Port Shepstone Area***, Explanation brochure to the 3030 (1/250 000), Geological Survey, Department of Mineral and Energy Affairs, Pretoria.

Toens and Partners, (1997): ***Peddie South Groundwater Supply Investigation – Final Report***, Toens and Partners Technical Report No. TP970131b, Wynberg.

UWP (1999): ***Lusikisiki Regional Water Scheme – Status Report***, Uhlmann, Witthaus and Prins Consulting Engineers, Draft Report 2, East London.

von Vey, M.W., (1994): ***A structural geological analysis of lineaments and faults and dyke traces in the Kwazulu/Natal Province***, University of Natal, prepared for Directorate: Geohydrology, Department of Water Affairs & Forestry, Pretoria.

Water, P., Greenbaum, D., Smart, P.L. and Osmaston, H., (1990)***: Applications of Remote Sensing to Groundwater Hydrology***, Remote Sensing Reviews, Vol. 4, No. 2, pp.223-264.

Water Systems Management (1999): ***Groundwater Exploitation Potential per Quaternary catchment, South Africa***, funded by CCWS, DWAF – provisional data provided by Mr. C. Haupt.

Woodford, A.C. and Chevallier, L., (1999): ***Regional Characterisation and mapping of Karoo fractured aquifer systems – an integrated approach using a geographical information system and digital image processing***, Water Research Commission project K5/653 in preparation.

Zoback, M.L., (1992): ***First- and second-order patterns of stress in the lithosphere: The World Stress Map Project***., J. Geophys. Res., Vol. 97, pp. 11702-11728.

APPENDIX 1

TERMS OF REFERENCE

LUSIKISIKI BASIN STUDY

TERMS OF REFERENCE

1. Background

Lusikisiki magisterial district is located in the most north-eastern, coastal part of the Wild Coast District of the Eastern Cape Province (formerly part of Transkei). This area is also known as the Pondoland coast and includes all river catchments between the Mntafufu and Mzamba Rivers (tertiary drainage region T600).

The introduction of the RDP water supply programme has resulted in the identification of the need in many instances for substantial augmentation of the domestic water supply schemes serving the large rural population in the region. In particular, water resources with adequate yield assurance are required for the upgrading of the water supply to the Lusikisiki magisterial district (213 000 people). The Wild Coast Spatial Development Programme has identified forestry and tourism as the drivers for economic development in the area. Agricultural developments for the production of sugar cane and tea may be viable. Furthermore, the riverine systems and the estuaries of the rivers in the area are in pristine condition. The Mkambati Nature Reserve (Msikaba River estuary) and the entire Pondoland coast are extremely environmentally sensitive. These are national assets and attractions for tourists.

The surface water resources in the area are largely under-utilised. Groundwater may have a potential for cost efficient water supply in certain areas of the district. Conjunctive use of run-of river and ground water may be economically viable in other areas. The economic viability of hydropower generation in the case of construction of dams in the area has not been investigated.

In general, the knowledge level about the water resources in the Pondoland area as well as many other Transkei catchments is very limited. In order to provide a planning tool for the sustainable development and efficient utilisation of the water resources in the area, it is recommended that a basin study be conducted. Such a study will further the aim of bringing the level of available information for the Transkei region in line with the rest of the catchments in South Africa. This study will also contribute valuable information for the establishment of a water management area and a catchment strategy as stipulated by the new Water Act.

The results of the study will be useful for other Government Departments and interested parties for the planning of various development initiatives.

2. Purpose of the Study

The study area is defined as the coastal river catchments between the Mntafufu and Mzamba Rivers (see attached locality map).

The study will provide a broad evaluation of the current state and the potential for development of the water resources in the area, as well as the present and potential water requirements for all user sectors. The Msikaba River catchment within which Lusikisiki lies will be given more detailed attention. Particular attention will be given to establishing the environmental water requirements for the Mkambati Nature Reserve which lies on the estuary of the Msikaba River.

A more specific output of the basin study will be a clear indication at a pre-feasibility level of detail, of a preferred source for augmentation of the domestic supply for the town of Lusikisiki and the surrounding rural areas as well as a recommendation for an implementation programme.

3. Proposed Scope of Work

The following activities are recommended to be undertaken during the course of this study (levels of detail – pre-feasibility for Msikaba River catchment and reconnaissance for the rest of the area) :

3.1 Background Information

- Assemble, collate and present in a suitable form existing information on the study area: climate, topography, demographics and socio-economic development, current and planned land use, institutional and legal aspects, natural resources, etc.
- Assessment of the accuracy and completeness of the existing information. Identification of gaps and further information required.
- Limited verification and patching of information, where necessary.

3.2 Domestic water supply situation

- Population and livestock distribution, present levels of service where this is known, existing projects and projects in process of implementation.
- Population growth and proposed future levels of service.
- Area planning and possible grouping of schemes.

3.3 Existing infrastructure

Existing road, rail and electricity infrastructure will be described. A description of the existing major water supply infrastructure, its operational condition and upgradability will be provided.

3.4 Agricultural developments and afforestation

- In general, this is to be limited to a broad overview of possible developments with reference to the effect of these developments on the runoff and water requirements. For the Msikaba catchment a more detailed assessment is required.
- Determine the extent of existing developments. Document all available information on development potential and identify information gaps. Study and review all development programmes proposed for the area (Wild Coast Spatial Development Initiative, for instance). Assess the feasibility of future developments taking into account available water resources, economic development potential and financial constraints. The assessment should include the effects of dryland farming, irrigation and commercial livestock farming as well as the effects of afforestation (planted forests) and invasive forests.

3.5 Water requirements

- Present and future water use by the various user sectors is to be assessed. Historical water use information should be presented where available and of use for future projections.
- Urban and industrial.
- Rural, domestic and livestock.
- Agricultural developments and afforestation.
- Hydropower generation (desktop evaluation of potential, feasibility and flows, only for proposed dams).
- Environmental and social requirements (the Reserve). IFR's are to be expressed as a percentage of natural annual flows.

3.6 Runoff hydrology, surface water resources and yield analysis

- In general the water resources assessments will be done primarily on the basis of WR90.
- In the case of the Msikaba River, the existing flow data collected by the former DAF of Transkei and by the DWAF prior to Transkei independence in 1968 will be reviewed, and if feasible will be used to determine more accurate Pitman Model parameters than obtainable from WR90. If flow records within the catchment are unsatisfactory then it may be necessary to calibrate a Pitman model for the catchment by making use of flow records for adjacent catchments and cross correlation.

Historical firm yield analysis will be applied for the calculation of the yields of proposed dams. Long term stochastic yield may be considered as an option.

- Floods for proposed dams and river abstractions will be estimated on the basis of TR137 for Msikaba River only.

3.7 Groundwater resources

- Studies for assessments of availability and assurance of groundwater resources will be undertaken on the basis of readily available information (borehole database) and previous experience in the area.
- A more detailed investigation may be required for the Lusikisiki water supply area only. The occurrence of aquifers, fractured rock and faults may have to be identified.

3.8 Reconciliation of supply and demand

- An assessment of the water balance in each catchment at 10 year intervals for the period until 2030 is to be undertaken and presented in a suitable form.

3.9 Water quality, sedimentation and return flows

- The river catchments of the study area are not presently included in any of the water quality monitoring systems and databases (HIS and POLMAN).
- Unless a monitoring programme is established by DWAF as a matter of priority then the consultant will be required to arrange that water samples from specific sites be tested during the course of the study and that the results be documented.
- Available sedimentation mapping and any other information on sedimentation such as the extent of erosion in the various catchments will be documented. This information will be used to predict the rate of sediment accumulation in new dams.
- The effect of return flows in the area is limited. Available information will be documented.

3.10 Development options for water supply to the Lusikisiki area

The various development options for the supply of water to Lusikisiki and surrounding villages are to be identified and described. This will involve:

- Review of previously identified schemes.
- Review, grouping and area planning.
- Shortlisting of options utilising all applicable criteria (technical feasibility, social and environmental acceptability, institutional and

operational viability, phased implementation, labour intensive construction, cost etc.)

3.11 Selection of preferred development option

- Conceptual design and sizing of competitive options, based on approved sizing criteria.
- Topographic surveys where required.
- Costing on the basis of cost models and cost functions agreed upon with the client. Recurrent annual costs will be calculated for each option.
- Economic evaluation will be done on the basis of discounted present cost and the unit reference value (URV) of water supplied by each option. The URV will be calculated for a period of time and discount rate as agreed with the client.
- A sensitivity analysis for various discount rates will be performed.

3.12 Environmental aspects

The purpose of this investigation will be to identify problematic areas and to provide a broad idea of the instream flow requirements for the rivers and the estuaries, to establish the river flows necessary to satisfy basic human needs and to provide a broad estimate of the Reserve. In the case of the Msikaba River a more detailed assessment of these water requirements is required. Results will be based on a desk study, existing information and limited site visits. No workshops are envisaged for this stage.

- Broad classification of rivers (possibly a group classification if rivers are similar).
- Broad estimate of the IFR for each river and estuary (based on D. Hughes planning estimate method) expressed as a percentage of the natural annual runoff.
- Assessment will be based on the Integrated Environmental Management (IEM) procedures as prescribed by the Environmental Conservation Act (1989) and more specifically the Regulations gazetted on 5 September 1998.
- More detailed assessment of the IFR and the Reserve for the Msikaba River (including its estuary) and the Mkambati Nature Reserve and of the impacts related to possible water resources developments for the Lusikisiki area will be undertaken. This could include assessment of the Preliminary Reserve as defined in the new Water Act and a scoping exercise to provide a broad assessment of the impacts of the more favourable dams identified.

3.13 Social aspects

For the schemes identified in the study the following will be established:

- Estimate number of people directly or indirectly affected by the developments.
- Estimate potential health and safety hazards.
- Estimate extent and value of physical assets that will be lost as a result of the development.
- Investigate and estimate the cost of mitigation measures.

3.14 Public involvement and community liaison

Public involvement and community liaison will be performed from the commencement of the study through the formation of a Stakeholders Liaison Committee. All affected communities and interested parties will be informed of the proposed developments and their inputs invited.

APPENDIX 2

PROJECT METADATA REPORT

(Supplied on Separate CD)

METADATA – TITLE OF DATASET:	LITHOLOGY.SHP

ORIGINATOR

Captured By:	P. Dzanga
Organisation:	TOENS & PARTNERS
Contact Person:	AC Woodford
Phone Number:	021- 7625815
E-mail Address:	awoody@iafrica.com

DESCRIPTION OF DATA

Abstract:	Geology of the T60 Tertiary Drainage Region
Purpose:	Groundwater Component : T60 Drainage Basin Study
Supplemental Info:	Client: Department Water Affairs & Forestry
Related Data files:	None.

TIME AND STATUS

Date Captured:	May – June 1999	**Version:**	1.0
Date Last Updated:	May – June 1999	**Progress:**	Complete
Update Frequency:	None.	**Source Date:**	-

PROJECTION INFORMATION

Projection:	Geographic	**Fuzzy Tolerance:**	-
Spheriod:	Clarke 1880	**Minimum X:**	-
Standard Parallel 1:	-	**Minimum Y:**	-
Standard Parallel 2:	-	**Maximum X**	-
Central Meridian:	29	**Maximum Y:**	-

KEYWORDS

Theme Keywords:	Geology Lithology
Theme Reference:	-
Place Keywords:	T60 Drainage Basin
Place Reference:	-

SPATIAL DOMAIN

Data Media:	CD	**Coverage Scale**:	1/250 000
Physical Path:	./T60/GEOLOGY/	**Quality of Data:**	Good
Feature:		**Capture Method:**	Digitise Onscreen.
Format:	Arcview 3.1	**Source Material:**	-
Format Delivered to DWAF:	Arcview 3.1	**Coverage Types:**	Polygon Shape File
Data Source: (comment)	Scanned, georeferenced raster images of portions of 1/250 000 geology maps: Umtata (3128), Kokstad (3028) and Port Shepstone (3030)		

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
1.	Lithology_	Numeric	Unused.
2.	Lithology_	Numeric	Unused.
3.	Lith_	String	Lithology Code: Kmb= Mbotyi Fm; Nml= Sikombe Granite; Ns= Margate Granite; O-Sn= Msikaba Fm; Pa= Adelaide Group; Pd= Dwyka Group; Pe= Ecca Group; Q= Quaternary.
4.	Lith_Code	Numeric	Lithology Code: 8= O-Sn; 2= Pd; 3= Pe; 4= Q; 7= Pa; 1= Kmb; 5= Nml; 6= Ns
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			

Note: The edges of the maps did not match up well and interpolation was necessary – data accuracy relevant to scale of study.

METADATA – TITLE OF DATASET:	DOLSILL.SHP

ORIGINATOR

Captured By:	P. Dzanga
Organisation:	TOENS & PARTNERS
Contact Person:	AC Woodford
Phone Number:	021- 7625815
E-mail Address:	awoody@iafrica.com

DESCRIPTION OF DATA

Abstract:	Karoo Dolerite Sills of the T60 Tertiary Drainage Region
Purpose:	Groundwater Component : T60 Drainage Basin Study
Supplemental Info:	Client: Department Water Affairs & Forestry
Related Data files:	None.

TIME AND STATUS

Date Captured:	May – June 1999	**Version:**	1.0
Date Last Updated:	May – June 1999	**Progress:**	Complete
Update Frequency:	None.	**Source Date:**	-

PROJECTION INFORMATION

Projection:	Geographic	**Fuzzy Tolerance:**	-
Spheriod:	Clarke 1880	**Minimum X:**	-
Standard Parallel 1:	-	**Minimum Y:**	-
Standard Parallel 2:	-	**Maximum X**	-
Central Meridian:	29	**Maximum Y:**	-

KEYWORDS

Theme Keywords:	Dolerite Sills Geology Intrusion
Theme Reference:	-
Place Keywords:	T60 Drainage Basin
Place Reference:	-

SPATIAL DOMAIN

Data Media:	CD	**Coverage Scale**:	1/250 000
Physical Path:	./T60/GEOLOGY/	**Quality of Data:**	Good
Feature:		**Capture Method:**	Digitise Onscreen.
Format:	Arcview 3.1	**Source Material:**	-
Format Delivered to DWAF:	Arcview 3.1	**Coverage Types:**	Polygon Shape File
Data Source: (comment)	Scanned, georeferenced raster images of portions of 1/250 000 geology maps: Umtata (3128), Kokstad (3028) and Port Shepstone (3030)		

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
1.	Area	Numeric	Unused.
2.	Perimeter	Numeric	Unused.
3.	Dolsill#	Numeric	Unused.
4.	Dolsill-Id	Numeric	Unused.
5.	Dol_In	Numeric	Code: 10 = Dolerite Sill 0 = no sill – 'island'
6.	Dolsill	Numeric	Unused.
7.			
8.			
9.			
10.			
11.			
12.			

Note: The edges of the maps did not match up well and interpolation was necessary – data accuracy relevant to scale of study.

METADATA – TITLE OF DATASET:	LINSAT_ALL.SHP

ORIGINATOR

Captured By:	AC Woodford
Organisation:	TOENS & PARTNERS
Contact Person:	AC Woodford
Phone Number:	021- 7625815
E-mail Address:	awoody@iafrica.com

DESCRIPTION OF DATA

Abstract:	Landsat TM Lineaments + Dolerite Dykes and Faults
Purpose:	Groundwater Component : T60 Drainage Basin Study
Supplemental Info:	Client: Department Water Affairs & Forestry
Related Data files:	None.

TIME AND STATUS

Date Captured:	June– August 1999	**Version:**	1.0
Date Last Updated:	June – August 1999	**Progress:**	Complete
Update Frequency:	None.	**Source Date:**	-

PROJECTION INFORMATION

Projection:	Geographic	**Fuzzy Tolerance:**	-
Spheriod:	Clarke 1880	**Minimum X:**	-
Standard Parallel 1:	-	**Minimum Y:**	-
Standard Parallel 2:	-	**Maximum X**	-
Central Meridian:	29	**Maximum Y:**	-

KEYWORDS

Theme Keywords:	Satellite Lineament
Theme Reference:	-
Place Keywords:	T60 Drainage Basin
Place Reference:	-

SPATIAL DOMAIN

Data Media:	CD	**Coverage Scale**:	1/250 000 - Dykes
Physical Path:	./T60/LINEAMENT/	**Quality of Data:**	Good
Feature:	-	**Capture Method:**	Digitise Onscreen.
Format:	Arcview 3.1	**Source Material:**	Landsat TM Imagery
Format Delivered to DWAF:	Arcview 3.1	**Coverage Types:**	Polyline Shape File
Data Source: (comment)	Landsat TM Image WRS 168-82, Dykes-Faults from 1/250 000 geology maps: Umtata (3128), Kokstad (3028) and Port Shepstone (3030)		

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
1.	Lentgh_	Numeric	Unused.
2.	Linsat1_	Numeric	Unused.
3.	Linsat1_Id	Numeric	Unused
4.	Satlin_	Numeric	Unused
5.	Satlin_Id	Numeric	Unused
6.	SatType	Numeric	Lineament Code 1= Satellite Landsat TM lineament mapped this study, 2= Dolerite Dyke from Geology Map, 3= Fault from Geology Map, 4= Satellite-Aeromagnetic Lineament from Geology Map.
7.	Description	String	Description of above codes, i.e. CGSFault = 3
8.			
9.			
10.			
11.			
12.			

Note:

METADATA – TITLE OF DATASET:	BHS_ALL.SHP

ORIGINATOR

Captured By:	P. Dzanga
Organisation:	TOENS & PARTNERS
Contact Person:	AC Woodford
Phone Number:	021- 7625815
E-mail Address:	awoody@iafrica.com

DESCRIPTION OF DATA

Abstract:	Borehole Database – obtained from reports, DWAF National Groundwater Database during Literature Review.
Purpose:	Groundwater Component : T60 Drainage Basin Study
Supplemental Info:	Client: Department Water Affairs & Forestry
Related Data files:	None.

TIME AND STATUS

Date Captured:	May– June1999	**Version:**	1.0
Date Last Updated:	May – June1999	**Progress:**	Complete
Update Frequency:	None.	**Source Date:**	-

PROJECTION INFORMATION

Projection:	Geographic	**Fuzzy Tolerance:**	-
Spheriod:	Clarke 1880	**Minimum X:**	-
Standard Parallel 1:	-	**Minimum Y:**	-
Standard Parallel 2:	-	**Maximum X**	-
Central Meridian:	29	**Maximum Y:**	-

KEYWORDS

Theme Keywords:	Borehole
Theme Reference:	-
Place Keywords:	T60 Drainage Basin
Place Reference:	-

SPATIAL DOMAIN

Data Media:	CD	**Coverage Scale**:	variable
Physical Path:	./T60/BOREHOLE/	**Quality of Data:**	Reasonable
Feature:	-	**Capture Method:**	Digitise Onscreen.
Format:	Arcview 3.1	**Source Material:**	NGDbase, Reports
Format Delivered to DWAF:	Arcview 3.1	**Coverage Types:**	Point Shape File
Data Source: (comment)	Department Water Affairs National Groundwater Database (NGDB), Groundwater Investigation Reports. Accuracy of NGDB data variable, Reports captured off 1/50 000 topocadastral sheets.		

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
1.	Idcode	String	Borehole Number, NGDB IDCode atc.
2.	Longitude	Numeric	Original Longitude Info – Unused.
3.	Latitude	Numeric	Original Latitude Info – Unused
4.	Depth	Numeric	Depth (m), -999 No Data.
5.	Yield	Numeric	Borehole Yield (l/s) either tested or estimated.
6.	WLevel	Numeric	Waterlevel (m. bgl)
7.	Id	String	General Data Source – sma= DWAF 1/500 000 Queenstown Map Database, stat4= NGDB, repor = Report.
8.	TDS	Numeric	Total Dissolved Solids (mg/l)
9.	W_S1	Numeric	Depth of 1st Water Strike (m.bgl).
10.	W_S2	Numeric	Depth of 2nd Water Strike (m.bgl).
11.	W_S3	Numeric	Depth of 3rd Water Strike (m.bgl).
12.	W_S4	Numeric	Depth of 4th Water Strike (m.bgl).
13.	Aqf_Main	String	Description of aquifer type – drill target: Fr= fracture; Dwyka= Dwyka Group, Sill = dolerite sill, L.C. = Lower contact, U.C.= Upper Contact, W= weathered.

Note:

METADATA – TITLE OF DATASET:	BHS_ALL.SHP

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
14.	W_Use	String	Water Use: domestic ?=unknown.
15.	Status	String	P= production, sealed = abandoned, none= not in use, ?= unknown.
16.	Test_Q	Numeric	Tested Yield (l/s)
17.	Est_Q	Numeric	Estimated Yield (l/s)
18.	Source	String	Source of data, i.e. report number."Qu"
19.	Lithology	String	Lithology drilled into. Pe= Ecca Group, Pd= Dwyka Group, Qu= Quaternary Deposit, MF= Msikaba Formation.
20.	Dyke_Dist	Numeric	Distance from dyke, -1 > 500m, other numeric = distance in metres.
21.	Sill	Numeric	Code = 1 located on dolerite sill, -1 located off sill.
22.	Sillcont	Numeric	Distance from sill, -1 > 500m, other numeric = distance in metres.
23.	Fault250	Numeric	Distance from fault, -1 > 500m, other numeric = distance in metres.
24.	Linsat250	Numeric	Distance from Linsat, -1 > 500m, other numeric = distance in metres.
25.	River_50	Numeric	Distance from 1/50 000 topomap river, -1 > 500m, other numeric = distance in metres.
26.	Dwy-Mkb	Numeric	Distance from Dwyka-Msikaba Contact, -1 > 500m, other numeric = distance in metres.
27.	Dwy_Ecc	Numeric	Distance from Dwyka-Ecca Contact, -1 > 500m, other numeric = distance in metres.
28.	Dwy-Qua	Numeric	Distance from Dwyka-Quaternary Contact, -1 > 500m, other numeric = distance in metres.
29.	Date	Numeric	Date Drilled.
30.	Catch_num	String	Quaternary Catchment Number.
31.	Catch_comm	String	Indicate boreholes out of T60 basin, shows closest Quaternary T60 catchment.
32.	Hdomain	Numeric	Show which hydrotectonic domain borehole lies in.
33.	Dol_sill	Numeric	Re-check of distance from a dolerite sill (m).
34.	NeoNW	Numeric	Distance from NW trending lineament, -1 > 500m, other numeric = distance in metres. –999 = unknown.
35.	NeoNE	Numeric	Distance from NW trending lineament, -1 > 500m, other numeric = distance in metres. –999 = unknown.
36.	VVPhas1	Numeric	Distance from Paleo-Phase 1 Lineament, -1 > 500m, other numeric = distance in metres. –999 = unknown.
37.	VVPhas2	Numeric	Distance from Paleo-Phase 2 Lineament, -1 > 500m, other numeric = distance in metres. –999 = unknown.
38.	VVPhas3	Numeric	Distance from Paleo-Phase 3 Lineament, -1 > 500m, other numeric = distance in metres. –999 = unknown.
39.	Sat_depth	Numeric	Saturated Depth, i.e. Depth-Waterlevel (m).

Note:

METADATA – TITLE OF DATASET:	LUS_CHEM.SHP

ORIGINATOR

Captured By:	W Stadler
Organisation:	TOENS & PARTNERS
Contact Person:	AC Woodford
Phone Number:	021- 7625815
E-mail Address:	awoody@iafrica.com

DESCRIPTION OF DATA

Abstract:	Groundwater Chemistry from DWAF Groundwater Chemistry Database
Purpose:	Groundwater Component : T60 Drainage Basin Study
Supplemental Info:	Client: Department Water Affairs & Forestry
Related Data files:	None.

TIME AND STATUS

Date Captured:	June 1999	**Version:**	1.0
Date Last Updated:	June 1999	**Progress:**	Complete
Update Frequency:	None.	**Source Date:**	-

PROJECTION INFORMATION

Projection:	Geographic	**Fuzzy Tolerance:**	-
Spheriod:	Clarke 1880	**Minimum X:**	-
Standard Parallel 1:	-	**Minimum Y:**	-
Standard Parallel 2:	-	**Maximum X**	-
Central Meridian:	29	**Maximum Y:**	-

KEYWORDS

Theme Keywords:	Borehole Chemistry
Theme Reference:	-
Place Keywords:	T60 Drainage Basin Lusikisiki
Place Reference:	-

SPATIAL DOMAIN

Data Media:	CD	**Coverage Scale**:	variable
Physical Path:	./T60/BOREHOLE/	**Quality of Data:**	Reasonable.
Feature:	-	**Capture Method:**	Import ASCII File
Format:	Arcview 3.1	**Source Material:**	-
Format Delivered to DWAF:	Arcview 3.1	**Coverage Types:**	Point Shape File
Data Source: (comment)	DWAF Chemistry Groundwater Data Base		

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
1.	H_No_	String	Laboratory Sample Number
2.	G_No	String	Government G-borehole number DWAF.
3.	S_Id	String	Other Sample Identifier
4.	Latitude_	Numeric	Latitude
5.	Longitude_	Numeric	Longitude
6.	Drn_Rg	String	Tertiary Drainage Number.
7.	Farm_no	String	Farm Number.
8.	Place_Name	String	Local Farm Name.
9.	Type	String	Type of Analyses.
10.	Bott_No_	String	Sample Bottle Number.
11.	Elect_Cond	Numeric	Electrical Conductivity (mS/m)
12.	Tot_dis_sa	Numeric	Total Dissolved Solids (mg/l)
13.	Ph___	Numeric	pH
14.	Na_dissolv	Numeric	Sodium (mg/l)
15.	Mg_dissolv	Numeric	Magnesium (mg/l)
16.	Ca_dissolv	Numeric	Calcium (mg/l)
17.	F_dissolve	Numeric	Fluoride (mg/l)

Note:

METADATA – TITLE OF DATASET:	LUS_CHEM.SHP

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
18.	Cl_dissolv	Numeric	Chloride (mg/l).
19.	No3_No2_n	Numeric	Nitrate and Nitrite as N (mg/l)
20.	So4_dissol	Numeric	Sulphate (mg/l)
21.	Po4_p_orth	Numeric	Ortho-phosphate as P (mg/l)
22.	Tal_as_CaC	Numeric	Total Alkalinity as Ca CO_3 (mg/l)
23.	Si_dissolv	Numeric	Silica (mg/l)
24.	K-dissolve	Numeric	Potassium (mg/l)
25.	Nh4_N_	Numeric	Ammonia (mg/l)

Note:

METADATA – TITLE OF DATASET:	HYDRO_BH.SHP

ORIGINATOR

Captured By:	P Dzanga
Organisation:	TOENS & PARTNERS
Contact Person:	AC Woodford
Phone Number:	021- 7625815
E-mail Address:	awoody@iafrica.com

DESCRIPTION OF DATA

Abstract:	Borehole Inventoried during Hydrocensus
Purpose:	Groundwater Component : T60 Drainage Basin Study
Supplemental Info:	Client: Department Water Affairs & Forestry
Related Data files:	None.

TIME AND STATUS

Date Captured:	August 1999	**Version:**	1.0
Date Last Updated:	August 1999	**Progress:**	Complete
Update Frequency:	None.	**Source Date:**	-

PROJECTION INFORMATION

Projection:	Geographic	**Fuzzy Tolerance:**	-
Spheriod:	Clarke 1880	**Minimum X:**	-
Standard Parallel 1:	-	**Minimum Y:**	-
Standard Parallel 2:	-	**Maximum X**	-
Central Meridian:	29	**Maximum Y:**	-

KEYWORDS

Theme Keywords:	Borehole Hydrocensus
Theme Reference:	-
Place Keywords:	T60 Drainage Basin Lusikisiki
Place Reference:	-

SPATIAL DOMAIN

Data Media:	CD	**Coverage Scale**:	variable
Physical Path:	./T60/BOREHOLE/	**Quality of Data:**	Good
Feature:	-	**Capture Method:**	GPS
Format:	Arcview 3.1	**Source Material:**	-
Format Delivered to DWAF:	Arcview 3.1	**Coverage Types:**	Point Shape File
Data Source: (comment)	Boreholes inventoried during Hydrocensus by B. Malghas, Kei Water Solutions		

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
1.	Long	Numeric	Longitude GPS
2.	Lat	Numeric	Latitude GPS
3.	ID	String	Description of area + borehole field ID
4.	EC	Numeric	Groundwater Electrical Conductivity (mS/m)
5.	Status	String	Status of Borehole.
6.	Equip	String	Description of borehole equipment.
8.	Lithology	String	PE – Ecca, MF = Msikaba Formation, PD = Dwyka.
9.	Bh_ID	String	Borehole Number.
10.			
11.			
12.			
13.			
14.			

Note:

METADATA – TITLE OF DATASET:	HYDRO_SP.SHP

ORIGINATOR

Captured By:	P Dzanga
Organisation:	TOENS & PARTNERS
Contact Person:	AC Woodford
Phone Number:	021- 7625815
E-mail Address:	awoody@iafrica.com

DESCRIPTION OF DATA

Abstract:	Springs Inventoried during Hydrocensus
Purpose:	Groundwater Component : T60 Drainage Basin Study
Supplemental Info:	Client: Department Water Affairs & Forestry
Related Data files:	None.

TIME AND STATUS

Date Captured:	August 1999	**Version:**	1.0
Date Last Updated:	August 1999	**Progress:**	Complete
Update Frequency:	None.	**Source Date:**	-

PROJECTION INFORMATION

Projection:	Geographic	**Fuzzy Tolerance:**	-
Spheriod:	Clarke 1880	**Minimum X:**	-
Standard Parallel 1:	-	**Minimum Y:**	-
Standard Parallel 2:	-	**Maximum X**	-
Central Meridian:	29	**Maximum Y:**	-

KEYWORDS

Theme Keywords:	Spring Hydrocensus
Theme Reference:	-
Place Keywords:	T60 Drainage Basin Lusikisiki
Place Reference:	-

SPATIAL DOMAIN

Data Media:	CD	**Coverage Scale**:	variable
Physical Path:	./T60/BOREHOLE/	**Quality of Data:**	Good
Feature:	-	**Capture Method:**	GPS
Format:	Arcview 3.1	**Source Material:**	-
Format Delivered to DWAF:	Arcview 3.1	**Coverage Types:**	Point Shape File
Data Source: (comment)	Springs inventoried during Hydrocensus by B. Malghas, Kei Water Solutions. All sampled for macro-chemistry.		

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
1.	ID	Numeric	Spring Identifier number
2.	Long	Numeric	Longitude GPS
3.	Lat	Numeric	Latitude GPS
4.	Lithology	String	Lithology Code
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			

Note:

METADATA – TITLE OF DATASET:	DRILLTARGETS.SHP

ORIGINATOR

Captured By:	AC Woodford
Organisation:	TOENS & PARTNERS
Contact Person:	AC Woodford
Phone Number:	021- 7625815
E-mail Address:	awoody@iafrica.com

DESCRIPTION OF DATA

Abstract:	Exploration Drill Targets Sited Lusikisiki
Purpose:	Groundwater Component : T60 Drainage Basin Study
Supplemental Info:	Client: Department Water Affairs & Forestry
Related Data files:	None.

TIME AND STATUS

Date Captured:	August 1999	**Version:**	1.0
Date Last Updated:	August 1999	**Progress:**	Complete
Update Frequency:	None.	**Source Date:**	-

PROJECTION INFORMATION

Projection:	Geographic	**Fuzzy Tolerance:**	-
Spheriod:	Clarke 1880	**Minimum X:**	-
Standard Parallel 1:	-	**Minimum Y:**	-
Standard Parallel 2:	-	**Maximum X**	-
Central Meridian:	29	**Maximum Y:**	-

KEYWORDS

Theme Keywords:	Borehole Drill Target Exploration
Theme Reference:	-
Place Keywords:	T60 Drainage Basin Lusikisiki
Place Reference:	-

SPATIAL DOMAIN

Data Media:	CD	**Coverage Scale**:	variable
Physical Path:	./T60/DRILLTARGET/	**Quality of Data:**	Good
Feature:	-	**Capture Method:**	Digitise Onscreen.
Format:	Arcview 3.1	**Source Material:**	-
Format Delivered to DWAF:	Arcview 3.1	**Coverage Types:**	Point Shape File
Data Source: (comment)	Drill Targets sited in the Lusikisiki district, using geology, drainage, accessibility, geological and satellite lineaments.		

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
1.	ID	Numeric	Unused.
2.	Rating	String	A= High, B= Moderate C= Reasonable Yield Potential.
3.	Target	String	Description of Drilling Target.
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			

Note:

METADATA – TITLE OF DATASET:	STUDYAREA.SHP

ORIGINATOR

Captured By:	W Stadler
Organisation:	TOENS & PARTNERS
Contact Person:	AC Woodford
Phone Number:	021- 7625815
E-mail Address:	awoody@iafrica.com

DESCRIPTION OF DATA

Abstract:	Outline of T60 Tertiary Boundary or Study Area
Purpose:	Groundwater Component : T60 Drainage Basin Study
Supplemental Info:	Client: Department Water Affairs & Forestry
Related Data files:	None.

TIME AND STATUS

Date Captured:	May 1999	**Version:**	1.0
Date Last Updated:	May 1999	**Progress:**	Complete
Update Frequency:	None.	**Source Date:**	-

PROJECTION INFORMATION

Projection:	Geographic	**Fuzzy Tolerance:**	-
Spheriod:	Clarke 1880	**Minimum X:**	-
Standard Parallel 1:	-	**Minimum Y:**	-
Standard Parallel 2:	-	**Maximum X**	-
Central Meridian:	29	**Maximum Y:**	-

KEYWORDS

Theme Keywords:	T60 Tertiary Drainage Catchment
Theme Reference:	-
Place Keywords:	T60 Drainage Basin Lusikisiki
Place Reference:	-

SPATIAL DOMAIN

Data Media:	CD	**Coverage Scale**:	variable
Physical Path:	./T60/STUDYAREA/	**Quality of Data:**	Good
Feature:	-	**Capture Method:**	Onscreen
Format:	Arcview 3.1	**Source Material:**	-
Format Delivered to DWAF:	Arcview 3.1	**Coverage Types:**	Polygon Shape File
Data Source: (comment)	WR90 – DWAF		

COVERAGE ATTRIBUTES (ADDED)

#	Field Title	Format	Description
1.	Shape	Numeric	Unused.
2.	ID	Numeric	Unused.
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			
11.			
12.			
13.			
14.			

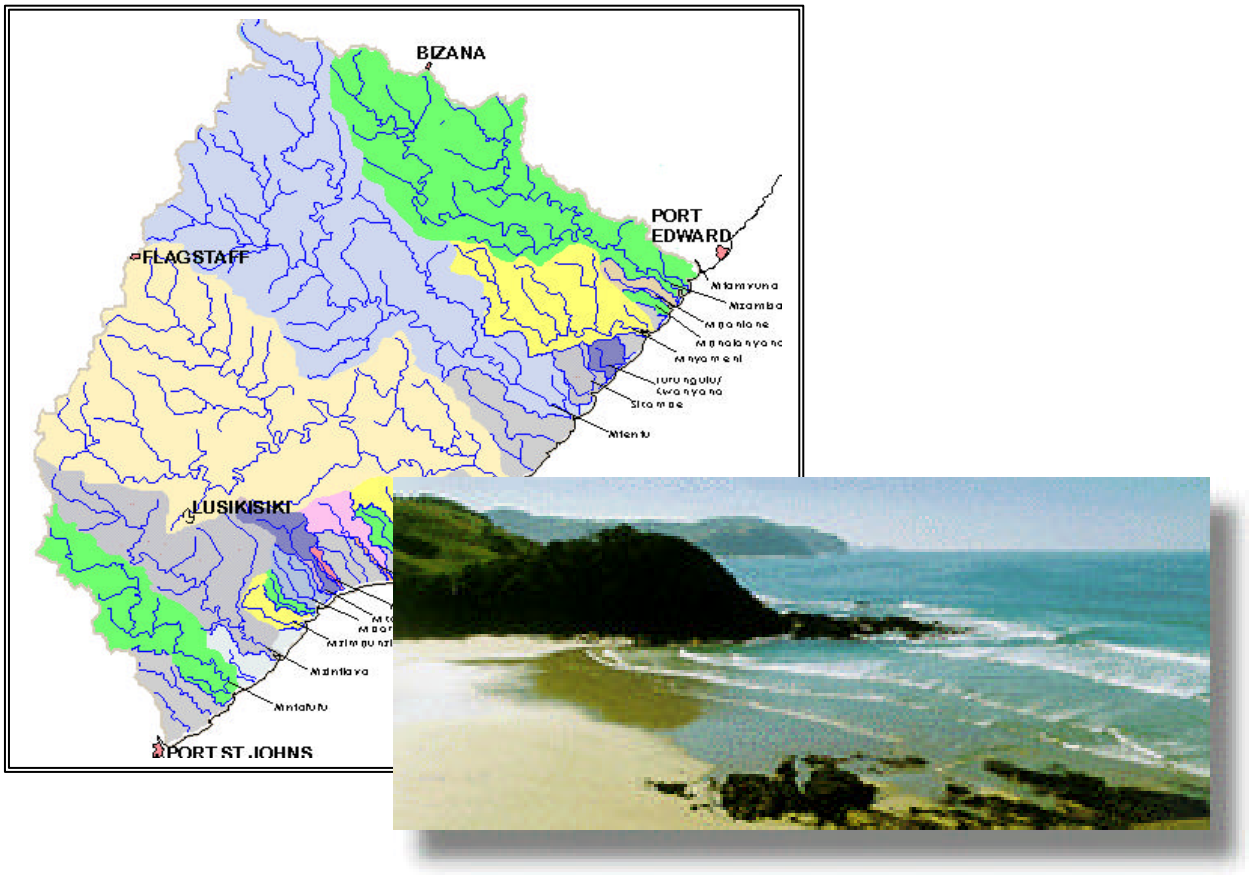
Note:

PB T600/00/1601

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate Of Water Resources Planning

EASTERN PONDOLAND BASIN STUDY



AGRICULTURE AND AFFORESTATION

Final

June 2001

Prepared By:

A J Roets & Associates CC

Engineering Services

Lead Consultant:

UWP Engineers
Private Bag X66
BRYANSTON 2021

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF WATER RESOURCES PLANNING

PROJECT NAME	**:**	EASTERN PONDOLAND BASIN STUDY
TITLE	**:**	Agriculture & Afforestation
AUTHOR	**:**	A Roets
REPORT STATUS	**:**	Final
DWAF REPORT NO.	**:**	PB T600-00-1601
DATE	**:**	June 2001

Submitted on behalf of UWP Engineers by:

.....

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate of Water Resources Planning

Approved for Department of Water Affairs and Forestry by:

.....

FA STOFFBERG
Chief Engineer: Water Resources Planning

.....

JA VAN ROOYEN
Director: Water Resources Planning

EASTERN PONDOLAND BASIN STUDY

AGRICULTURE AND AFFORESTATION

EXECUTIVE SUMMARY

1. BACKGROUND

Due to the limited knowledge available for the water resources in the Eastern Pondoland, in 1999 the Directorate of Water Resources Studies commissioned the Eastern Pondoland Basin Study (EPBS). The scope of the study is to provide a broad evaluation of the state of the water resources in the study area as well as to identify a suitable water source for the augmentation of the Lusikisiki Regional Water Scheme.

This report is one of the supporting reports issued as part of the Eastern Pondoland Basin Study's set of reports. The objective of the Agriculture and Afforestation component of the study was to provide the necessary information with regards to the following user groups:

- **Irrigation:** present, and projected irrigation areas and potentially irrigable land, with the associated water requirements.
- **Afforestation:** present, projected and potential afforestation areas and the associated reduction in runoff.
- **Farm dams:** location and sizes of existing farm dams.

The study was undertaken at a desktop level of detail, based on existing topographical and soil maps, previous studies and interviews with relevant role players – Department of Water Affairs, Department of Agriculture, various local authorities, etc.

2. FINDINGS

Irrigation

The high rainfall in the region facilitates dry land crop production, and there is no significant irrigated agriculture at present. Only about 14 ha of land are currently being irrigated. This excludes area of the Magwa Tea Estate, which is regarded as dry-land agricultural land. The existing irrigation water use is negligible.

The study shows that about 48% of the soils in the study area are arable. Taking into consideration the natural factors restricting the development of irrigation: steepness of slopes, availability of suitable water source, elevation, etc. it was estimated that the extent of available irrigable land is about 8 500 ha.

In general, irrigation does not appear to be particularly attractive in the study area. The high mean annual precipitation (above 900 mm) allows high yielding dry-land agriculture and this would probably not justify the high capital costs of irrigation development. The area is deeply incised by the main rivers, and the irrigable land is normally located in the alluvial flood plains within the river valleys. These valleys are usually not accessible by roads of satisfactory standards, which limits access to potential markets. The development

of irrigation on the plateau is severely restricted by the high pumping heads (100 to 500 m) and the associated high costs of the water supply infrastructure.

Taking into consideration the aforementioned limitations it was estimated that a maximum of about 460 ha of irrigation could be developed by 2030. Most of the planned irrigation development in the region will probably be small, community based projects. These projects generally vary in size from 1 ha to 25 ha, with the majority below 10 ha.

The irrigation water requirements were estimated taking into consideration suitable cropping patterns and the associated crop factors, irrigation efficiency, etc. The total present and projected water requirements were estimated at 0,02 million m^3/a and 0,8 million m^3/a respectively.

Afforestation

Large portions of the former Transkei are ideally suited for afforestation and much has already been done to develop this industry, which appears to be one of the fastest growing sectors of the economy in the region. Based on the available information (CSIR, 1998 Wild Coast SDI Forestry Task Team Investigation) approximately 8 500 ha of afforestation has already been established within the Eastern Pondoland Region, which includes eucalyptus, pine, wattle and indigenous plantations.

It was estimated that the total potential area suitable for afforestation development in the study area is about 35 000 ha. The extent of the actual development could however be limited by the associated reduction of runoff, requirements for access infrastructure, etc. It was estimated that the total afforestation area would increase to about 15 500 ha by the year 2030.

The existing and projected afforestation water requirements (reduction of runoff) were estimated at 11 million m^3/a and 22 million m^3/a respectively.

Dams

The Magwa Dam (wall height of 25 m) on the Mkozi River is the only registered dam in the area, but has a very small catchment area of approximately 5.5 km^2.

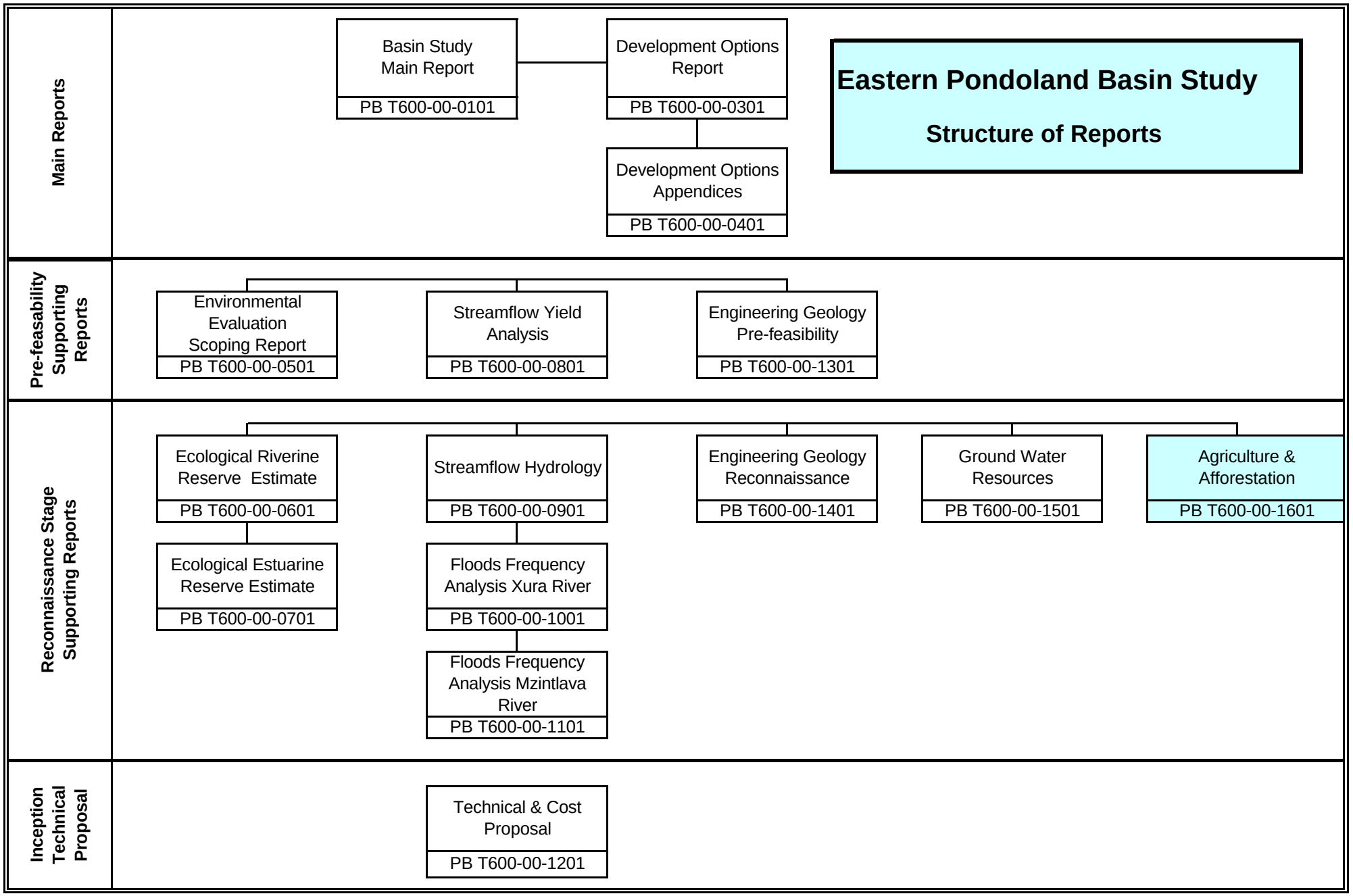
Three other small dams (wall height less than 5 m) were identified.

Table of Contents

1.	Terms of reference	1
2.	Background information	5
3.	Irrigation	11
4.	Forestry	33
5.	Farm dams	50

Eastern Pondoland Basin Study

Structure of Reports



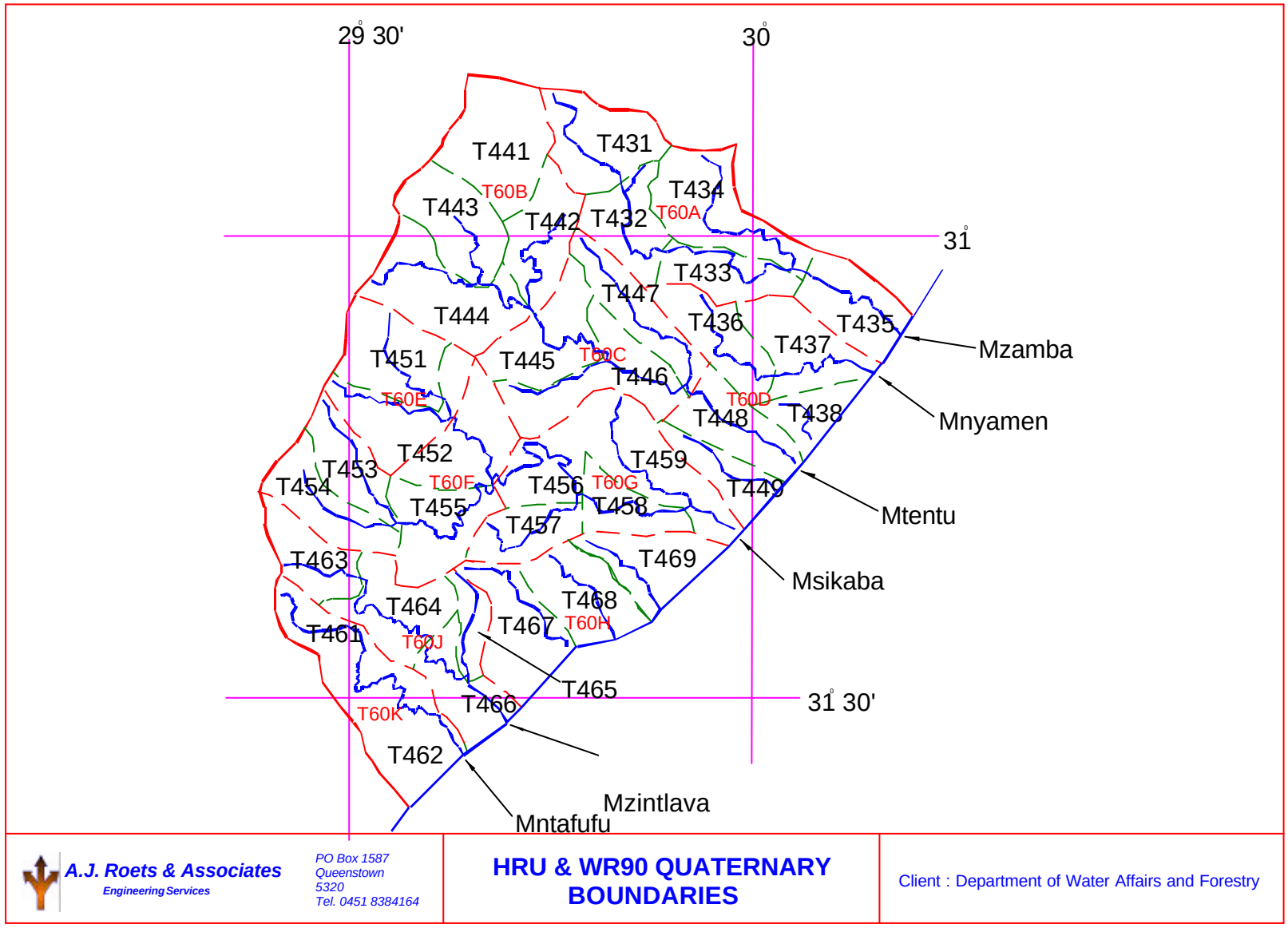
1. Terms of Reference and Introduction:

The main objective of the study is to assess the potential for development of irrigation and forestry within the study area. The effect of this development on the water resources in the area is of special significance with regards to the effect of these developments on the run-off and water requirements. The agricultural component is considered to be supplementary and will be studied at a low level of detail.

The influence of existing farm dams if any will also be taken into account.

According to the scope of services this study was undertaken as a desktop study, on the basis of available information, maps and previous reports by other consultants. No site investigations and verification of the available information was undertaken.

Map 1.1 HRU and WR90 Quaternary catchment boundaries



A.J. Roets & Associates
Engineering Services
PO Box 1587
Queenstown
5320
Tel. 0451 8384164

HRU & WR90 QUATERNARY BOUNDARIES

Client : Department of Water Affairs and Forestry

2 Background Information

2.1 Topography

According to Woods & Van Schoor (1976) *a slope analysis of Transkei reveals that at least 60% of the total area has a slope greater than 15% while only 10% of the area has a slope of less than 5%*.

The relief of Transkei shows great variance and the most outstanding characteristic is the sharp fall from the inland boundary to the coast. This observation is of particular significance in the study area where the altitude increases from 0 m at sea level to 600m at Lusikisiki over a distance of 19 Km. The study area can be described as having deep river valleys and a broken landscape.

The main aspect of the study area is south– eastern, with an overall impression of great unevenness.

2.2 Climate

The climate of the study area can be described as mild inland, to sub-tropical on the coast especially in the northern areas.

The rainfall varies between 750mm-1200mm, with the higher falls concentrated in the coastal areas. The inland areas receive 80% and more of their average annual rainfall between the months of October to March, while the coastal strip shows a slightly better distribution in that a greater proportion falls during the remainder of the year. (Woods & Van Schoor-1976)

Rain fronts lasting a number of days are characteristic of the coastal area, while thundershowers are frequent on warm summer days inland. The area has approximately 30% rainy days per annum.

The coastal strip has a mild climate and is completely frost free, while the limiting effect of frost increases in proportion to the increase in altitude and distance from the sea.

2.3 Water Resources

Transkei is richly blessed with water due to its high rainfall. In general as the rainfall increases the run-off increases more steeply as is shown in the generalised relationship below: (Woods and van Schoor-1976)

Table 2.1 Relationship between rainfall and run-off: (Woods & van Schoor – 1976)

RAINFALL (mm)	RUNOFF (mm)	% OF RAINFALL
600	37	6.2
800	113	14.1
1000	210	21.0
1200	357	29.2

For South Africa as a whole the run-off amounts to only 44mm from an average of 464 mm, which is about 9.5%. Transkei with an average rainfall of just over 800mm the run-off amounts to 150mm, or about 19% of the rainfall.

Run-off will be affected by land use and the effective life span of any storage dams will be influenced by soil erosion.

Previous studies have shown that the quantity of water that could with adequate storage, be made available in Transkei is far in excess of the present demands that might arise in the foreseeable future.

This is especially true for the study area. To illustrate this the following table gives an indication of the run-off that can be expected from the rivers on the Pondoland coast between the Mzimvubu and Mtamvuna rivers but excluding the afore mentioned rivers.

Table 2.2 Run-off from pondoland coastal rivers: Between Mzimvubu & Mtamvuna rivers (Hydrological survey of Transkei-1974)

NAME	AVERAGE ANNUAL RAINFALL (mm)	CATCHMENT AREA (km^2)	AVERAGE ANNUAL RUN-OFF ($10^6 m^3$)	UNIT RUN-OFF (1000 m^3/km^2)
Mzamba	1021	505.2	72.5	144
Mnyameni	1170	179.5	40.2	223
Mtentu	981	964.6	120.7	125
Msikaba	980	1010.7	130.7	129
Mzintlava	1185	279.9	64.9	232
Mtafufu	1231	177.5	47.9	270
Other small rivers	1330	607.2	209.5	345
AVERAGE/TOTAL	**1079**	**3724.6**	**686.4**	**184**

Although certain assumptions can be made from the above table one must not be misled by the fact that many of these rivers have small catchments in a steep topography that will affect their overall yield – especially on a monthly basis.

According to a report by Loxton, Venn and Associates for the Wild Coast SDI (September 1997), *the largest source of water in the area is the Mzimvubu, which is one of South Africa's major rivers, and the last major undeveloped river in the country. Communication with DWAF regarding the potential large-scale usage of waters of the Mzimvubu cautions such planning, as this river constitutes an important possibility for the exporting of water to other regions. In combination with hydropower generation, it is considered that the Mzimvubu will eventually be diverted (at least the upper tributaries) into the headwaters of other river systems, and ultimately to Gauteng.*

DWAF have expressed reluctance to endorse planning in regard to major irrigation development. This is especially so in light of the present under utilisation of other schemes such as Ncora, Xonxa and Qamata.

2.4 Soils

Unfortunately no general soil map exists for the study area, or for any other part of Transkei.

All previous reports on agricultural potential within the study area are rather vague when it comes to soil potential, and are largely based on reconnaissance visits. The "Transkei Agricultural Development Study" quotes from Wood and van Schoor (1976) *'the lack of proper profile description and analytical data makes it impossible to give anything but a very cursory description of the soils identified in Transkei".*

The soils in the study area can be broken up into 3 major groups. (Woods & Van Schoor – 1976, map titled Generalised soil map-Transkei.) The table below gives a brief description of each group with an approximate percentage of the area covered by each:

Table 2.3 Main soil groups within the study area: (Woods & van Schoor – 1976)

Locality	Description	Approx. percentage of area
A	Red and Yellow/Brown apedal soils with an orthic epipedon (Hutton, Clovelly, Griffin)	40
B	Soils with a Humic Epipedon (Magwa,Inanda,Kranskop,Nomanci)	8
E	Weakly developed soils on rock (Glenrosa, Mispah, Swartland)	52

Information on soils in the study area is very limited; therefore the map and table above can only be used on a very broad planning basis.

From the table above it can be assumed that approximately 48% of the soils in the study area are arable. Assuming that the slope analysis of Woods & van Schoor (see page 5) is correct and applicable for the study area, 10% of the region has a slope of less than 5% and is suitable for irrigation. Therefore only 4.8% of the total area can possibly be irrigated. Excluding all areas that are not in close proximity to the water source will further reduce this figure by an estimated 50%, which gives an approximate area of 9000 Ha.

This figure equates favourably with the one mentioned by "Hidrologiese opname van Transkei - O'Connel, Manthé – 1974". According to this report the approximate area available for irrigation with a slope <8% and fed by the northern coastal rivers is 7970 Ha.

The report by Loxton, Venn and Associates (1997) titled "Irrigation Potential" in the Wild Coast SDI describes the soils according to their parent material in the following categories in their study area (which includes Pondoland) as follows:

- *Soils on Beaufort sediments*
- *Soils on Ecca sediments*
- *Dwyka tillite*
- *Table mountain sandstone*
- *Dolerite*
- *Coastal sands*

Any of the soils formed on the above parent material could be suitable for irrigation provided certain basic criteria are met i.e.:

- Effective depth
- Slope
- Drainage
- Proximity to water source

A detailed soil and slope study would have to be undertaken before any future projects are recommended in specific areas.

2.5 Existing agricultural projects

The following existing projects have been identified within the study area:

2.5.1 Magwa tea estate

Is approximately 4300 ha in size, excluding Mazizi and Majola sections for which no size could be obtained. The entire area is under dryland, concentrating on tea production. There are plans underway for the establishment under irrigation of 12

ha of cabbages, 100 ha of granadillas and 40 ha of bananas on the estate. The water source for the irrigation is one of the small local rivers. A small hydroelectric power station is also envisaged as part of the future development.

2.5.2 Pondoland sugar project

The area planted to sugar cane under dry land at present seems to fall in between the Mzamba and Mtamvuna rivers. The project initially involved 250 small-scale growers of 11 ha each. The current status of the project is not known but according to a report by ”MBB” dated September 1997 there is room for expansion, but reservations were expressed about the impact of future sugar cane plantations on the hydrology of the area. The availability of finance for infrastructure and the building of the toll road will also determine to a large extent if any future expansion will take place. According to the locality plan in the above mentioned report the area of sugar cane that falls within the study area is about 25% of the current area. An area of 690 ha of sugar cane can be allocated toT434. This area may be considered with the forestry demand.

2.5.3 Mkongwane project

Situated in the Flagstaff district consists of 5 ha of cabbages and potatoes under irrigation (T452).

2.5.4 Zimanga project

Situated in the Lusikisiki district consists of 1.5 ha nursery and fruit under irrigation (T453).

2.5.5 Public Works Project

The exact locality of the project could not be ascertained except that it is located just north of Port St.Johns. It is a community vegetable garden of 7.5ha (T462).

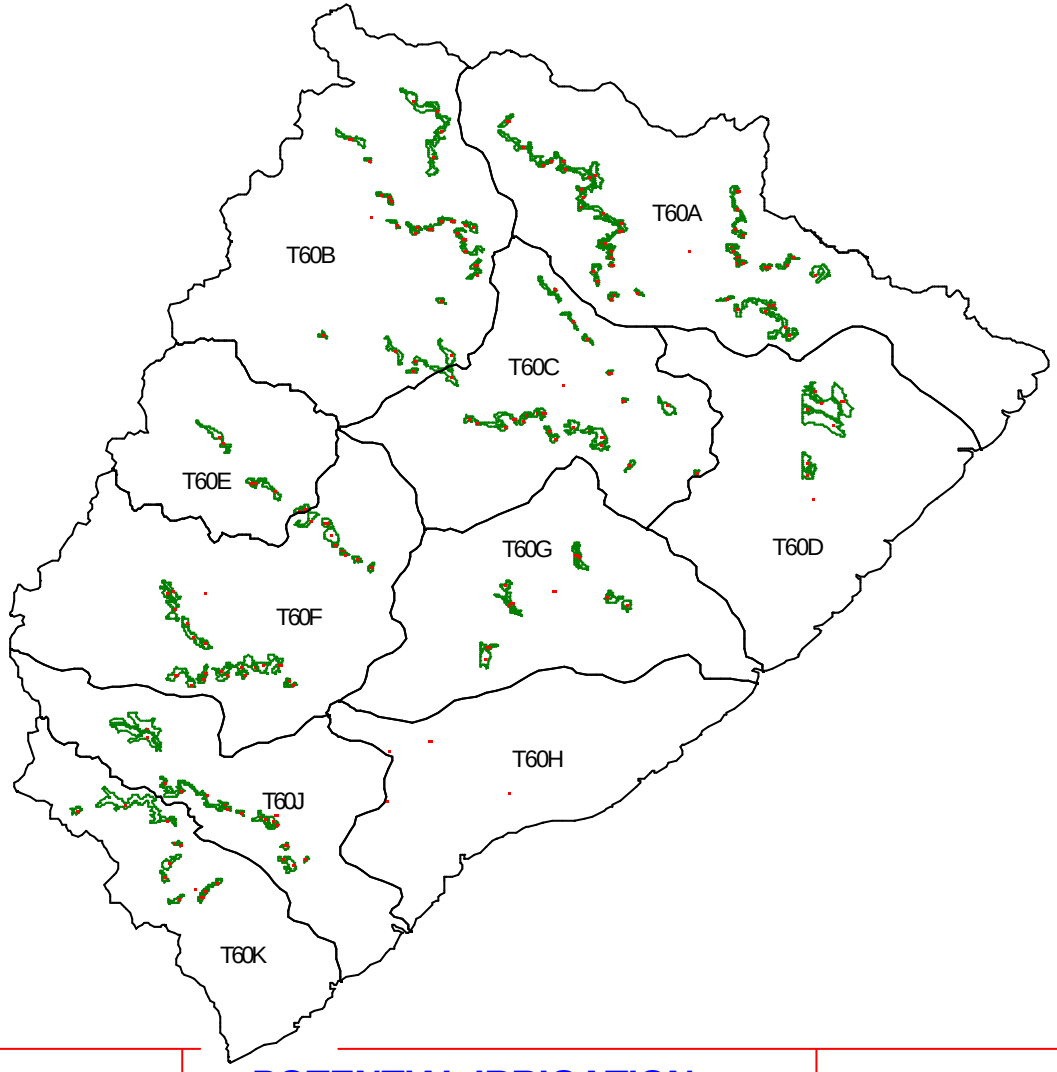
3 Irrigation

To arrive at the sizes for potential irrigation areas shown in the table below the following criteria were used:

- Only ground on the banks of rivers and with a slope of <5% was considered
- Land considered was restricted to a maximum elevation of 40 m above the river
- All ground where the river could possibly be influenced by the tidal zone was ignored
- Ground in the upper 20% of catchment areas of the rivers was not considered as the yield of the rivers might not be sufficient to sustain irrigation and the topography might not be suited for dam sites.

Using 1:50000 topographical maps (1983) the potential areas for irrigation were identified using the above mentioned criteria and measured by means of a planimeter. All the quaternary catchment area boundaries were transferred and marked on the 1:50000 maps to facilitate the recording of information per quaternary catchment

Map 3.1 Potential irrigation areas according to the criteria listed in paragraph above



A.J. Roets & Associates
Engineering Services
PO Box 1587
Queenstown
5320
Tel. 0451 8384164

POTENTIAL IRRIGATION AREAS

Client : Department of Water Affairs and Forestry

Table 3.1 Existing and potential irrigation areas per quaternary

QUATERNARY (HRU No.)	QUATERNARY WR90	EXISTING IRRIGATION (ha)	POTENTIAL IRRIGATION (ha)
T431	T60A	0	475
T432	T60A	0	263
T433	T60A	0	383
T434	T60A	0	290
T435	T60A	0	0
T436	T60D	0	130
T437	T60D	0	950
T438	T60D	0	0
T441	T60B	0	510
T442	T60B	0	395
T443	T60B	0	0
T444	T60B	0	225
T445	T60C	0	198
T446	T60C	0	305
T447	T60C	0	195
T448	T60D	0	0
T449	T60D	0	0
T451	T60E	0	218
T452	T60E/ T60F	5	280
T453	T60F	1.5	545
T454	T60F	0	300
T455	T60F	0	900
T456	T60G	0	123
T457	T60G	0	123
T458	T60G	0	0
T459	T60G	0	198
T461	T60K	0	420
T462	T60K	7.5	185
T463	T60J	0	458
T464	T60J	0	448
T465	T60J	0	0
T466	T60J	0	0
T467	T60H	0	0
T468	T60H	0	0
T469	T60H	0	0
TOTAL		**14**	**8517**

The total of 8517 ha of potential irrigation ground equates favourably with the two totals mentioned in the section dealing with soils i.e. 9000 ha and 7970 ha respectively.

3.1 Future irrigation development

The development programmes for the study area do mention the possibility of agricultural development but future irrigation development will be limited due to the following constraints.

3.1.1 Infrastructure

(a) Roads

Large sections of the study area have a poor road infrastructure. The irrigable ground is often in the alluvial flood plains and no roads exist at all in these areas. If roads have to be constructed it would influence the economic viability of the irrigation area.

(b) Electricity

The availability of a cheap power source like electricity within close proximity of the proposed irrigation areas will have a marked impact on their economic viability.

3.1.2 Markets

The necessary research must be undertaken to establish whether the price of the product produced is competitive.

3.1.3 Training and extension

Irrigation farming is a highly specialised and intensive. The incumbent must have a thorough knowledge of various subjects to enable him to make informed decisions with regards to his enterprise. It is doubtful whether the necessary human resources with sufficient training are available in the study area. Therefore a co-operative type system will probably have to be introduced and the bulk of the necessary training and extension services will have to be provided by the State.

Private institutions, which currently have their own extension and advisory services can also play an important role in training.

3.1.4 Finance

The necessary finance to establish the irrigation will have to be provided. Government will obviously have a substantial input. National and provincial planners will determine the allocation method and amount.

3.1.5 Land tenure

The various types of land tenure found in the Wild Coast region are summarised as follows: (Wild Coast SDI – Loxton, Venn and Associates – 1997)

- ***Freehold*** *- currently this is found mainly in urban areas*
- *Leasehold - these include formal leases, unregistered leases and government agreements*
- ***Quitrent*** *- this is similar to leasehold but where the land is occupied in perpetuity and a nominal rent is paid to government*
- ***Traditional*** *- where the right to use land is allocated by the Tribal Authority. Most of the land in the region falls under this category.*
- ***Trust*** *– this relates to government held land.*
- ***Agricultural Schemes****- State run agricultural development schemes.*

In a survey conducted by LAPC (1995) most people interviewed in the former Transkei were living on land administered under traditional (communal) tenure and did not express a desire for individual ownership of land. People felt fairly secure in their tenure but were concerned about land availability for future generations. It was stated that the main advantage of the current system of land allocation (by means of an application to the tribal authority) is that it is relatively easy and cheap access to land.

Experience has shown that individuals within a community are sometimes not prepared to allow land that has been allocated to them, and is presently cultivated under dry land conditions under the communal system to be re-planned for irrigation.

It can be assumed that the majority of land that has been identified as possible irrigation land in this study will already have been allocated to an individual on the afore mentioned basis.

This problem could become a major constraint that will influence irrigation development and will have to be addressed by the relevant authorities i.e. Department of Land Affairs, the local Headmen and the TRC's.

Woods and van Schoor –1976, state the following:

The traditional system of land tenure is one of the causes of the low level of production that prevails. Efforts in the past to increase production within the framework of this system have not been very successful. Many reasons are given for this e.g. men not being farmers by tradition, the migratory labour system, the custom of sharing, inadequate training facilities, shortage of extension personnel, etc.

These factors are not confined to the traditional land tenure, but all previous reports undertaken in Transkei dealing with the future development of agriculture indicate that the present system of land tenure is probably the major reason for the under utilisation of Transkei's agricultural potential.

3.2 Water Demand

3.2.1 Projected irrigation development

Due to the constraints mentioned in paragraph 4 we feel that the development of the irrigation potential will be limited. The climate and high rainfall of this region also favours dry land cultivation thus limiting the demand for irrigation.

The Department of Water Affairs and Forestry is currently running a programme for the upgrading of existing irrigation schemes in the former Transkei. The responsibility for the development and implementation of new irrigation schemes currently lies with the Department of Agriculture. Discussions with both these departments indicate that the

development of additional large irrigation schemes is unlikely. Mr. J Beumer the Chief Engineer of the Department of Water Affairs and Forestry's Eastern Cape Water Resources Management Directorate stated the following:

- *"The Department of Water Affairs and Forestry has no objection to the development of irrigation in the area. This is a pristine area and environmental requirements must be taken into account. Environmental and primary water requirements should receive priority over other water requirements."*

Most of the irrigation development in this area will be in the form of small community based projects as promoted by the current Community Based Public Works Programme. This programme is set to increase in the coming year. These projects vary in size from 1ha to 25ha with the majority below 10ha. The primary aim is poverty alleviation and job creation. Mr K Joubert, Director of Engineering Services of the Eastern Cape's Department of Agriculture and Land Affairs stated the following:

- "*No big irrigation schemes are planned for the area. The only irrigation development might be community gardens",* similar to those mentioned under the Public Works programme.

We made a projection of the possible development of irrigation taking into account factors such as proximity to markets and access to the areas. The projected development have been calculated by applying factors that varies between 2% and 10%, on the potential irrigation area over the next 30 years. These factors were not derived in a scientific manner but it is a "gut feel" based on discussions with governmental departments and the literature quoted in this paragraph.

The following table shows the potential irrigation area, the area of the current known irrigation schemes as well as a projection of the possible areas under irrigation over the next 30 years.

Table 3.2 Projected irrigation development per quaternary catchment up to the year 2030

QUAT NO.	WR 90 NO.	IRRIGATION POTENTIAL (ha)	EXISTING IRRIGATION (ha)	TOTAL PROJECTED IRRIGATION (ha)		
				2010	2020	2030
T431	T60A	475	0	24	36	41
T432	T60A	263	0	7	10	13
T433	T60A	383	0	5	10	4
T434	T60A	290	0	15	18	22
T435	T60A	0	0	0	0	0
T436	T60D	130	0	1	2	4
T437	T60D	950	0	5	12	24
T438	T60D	0	0	0	0	0
T441	T60B	510	0	13	19	26
T442	T60B	395	0	5	10	13
T443	T60B	0	0	0	0	0
T444	T60B	225	0	11	17	20
T445	T60C	198	0	1	4	6
T446	T60C	305	0	2	5	7
T447	T60C	195	0	1	3	5
T448	T60D	0	0	0	0	0
T449	T60D	0	0	0	0	0
T451	T60E	218	0	11	17	19
T452	T60E/F	280	5	13	17	20
T453	T60F	545	1.5	16	24	28
T454	T60F	300	0	15	23	30
T455	T60F	900	0	45	68	90
T456	T60G	123	0	3	5	6
T457	T60G	123	0	3	5	6
T458	T60G	0	0	0	0	0
T459	T60G	198	0	1	3	5
T461	T60K	420	0	11	16	21
T462	T60K	185	7.5	12	14	16
T463	T60J	458	0	6	12	17
T464	T60J	448	0	11	17	22
T465	T60J	0	0	0	0	0
T466	T60J	0	0	0	0	0
T467	T60H	0	0	0	0	0
T468	T60H	0	0	0	0	0
T469	T60H	0	0	0	0	0

3.2.2 Crop factors

Crop factors are a function of the plant physiology and thus quaternary catchments will not influence these factors. The water demand is a function of the evaporation therefore tables are provided giving crop factors as well as the mean evaporation per quaternary catchment area. If the crop factor is applied to the Class-A pan evaporation the water demand can be calculated.

Table 3.3 Crop factors of crops that can be grown in the study area:

MONTH	MAIZE (1 OCT)	MAIZE (15 DEC)	MMMARMARCH)	BRASSICAS (15 DEC)	BRASSICAS (1 SEPT)	BEANS (15 JAN)	BEANS (1 SEPT)	SUGAR CANE	BANANA	MACADAMIA	MANGO	AVERAGE
OCT	0.60				0.65		0.55	0.81	0.75	0.65	0.65	0.66
NOV	0.90				0.70		0.70	0.81	0.75	0.65	0.65	0.74
DEC	1.05	0.68		0.50				0.81	0.75	0.65	0.65	0.73
JAN	1.00	0.98		0.65		0.35		0.79	0.75	0.65	0.65	0.73
FEB	0.50	0.95		0.70		0.55		0.80	0.75	0.65	0.65	0.69
MAR		0.70	0.45			0.70		0.88	0.75	0.65	0.65	0.68
APR			0.55					0.95	0.75	0.65	0.65	0.71
MAY			0.65					0.98	0.75	0.65	0.65	0.74
JUN			0.70					0.94	0.75	0.65	0.65	0.74
JUL								0.89	0.75	0.65	0.65	0.74
AUG								0.85	0.75	0.65	0.65	0.73
SEPT					0.50		0.35	0.82	0.75	0.65	0.65	0.62

3.2.3 Average monthly evaporation figures

The following table gives the average Symon's Pan evaporation for the study area. (Surface Water Resources of South Africa, Volume 5 – Water Research Commission; 1981) The Class-A pan evaporation can be calculated by applying the conversion factors as given in the report by O'Connel and Manthe (Hidrologiese opname van Transkei, 1974).

Table 3.4 Average monthly evaporation figures

Month	Symon's Pan evaporation (mm)	Open water conversion factor	Class A pan conversion factor	Open water evaporation (mm)	Class-A pan evaporation (mm)
Jan	135	0.90	1.28	122	173
Feb	120	0.90	1.32	108	158
Mar	115	0.85	1.31	98	151
Apr	85	0.80	1.35	68	115
May	70	0.85	1.40	60	98
Jun	65	0.90	1.44	59	94
Jul	62	0.90	1.55	56	96
Aug	85	0.90	1.46	76	124
Sep	95	0.96	1.44	91	137
Oct	98	0.85	1.39	83	136
Nov	115	0.85	1.39	98	160
Dec	130	0.90	1.31	117	170
Total/Ave	**1175**	**0.88**	**1.39**	**1036**	**1612**

Gross evaporation within Transkei varies from 1100 mm at the coast to 1800mm at foothills of the Drakensberg (Woods and van Schoor-1976). Utilising the average monthly evaporation figures and a varying gross evaporation (1100 to 1800 mm/a) for the study area, the monthly Class "A" evaporation values were determined per quaternary catchment. The results are shown in Table 3.5. These values were checked against the WR90 (Surface Water Resources of South Africa, 1990, WRC report 298/5.1/94). The lower values are consistent with the WR90, while the higher values are more conservative than the WR90.

Table 3.5 Monthly Class "A" evaporation figure per quaternary catchment.

QUART NO.	WR 90 NO.	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
T431	T60A	149	176	187	190	174	166	126	108	103	106	136	151
T432	T60A	149	176	187	190	174	166	126	108	103	106	136	151
T433	T60A	136	160	170	173	158	151	115	98	94	96	124	137
T434	T60A	149	176	187	190	174	166	126	108	103	106	136	151
T435	T60A	136	160	170	173	158	151	115	98	94	96	124	137
T436	T60D	136	160	170	173	158	151	115	98	94	96	124	137
T437	T60D	136	160	170	173	158	151	115	98	94	96	124	137
T438	T60D	136	160	170	173	158	151	115	98	94	96	124	137
T441	T60B	163	192	204	208	189	181	138	118	113	115	149	164
T442	T60B	149	176	187	190	174	166	126	108	103	106	136	151
T443	T60B	163	192	204	208	189	181	138	118	113	115	149	164
T444	T60B	149	176	187	190	174	166	126	108	103	106	136	151
T445	T60C	149	176	187	190	174	166	126	108	103	106	136	151
T446	T60C	136	160	170	173	158	151	115	98	94	96	124	137
T447	T60C	149	176	187	190	174	166	126	108	103	106	136	151
T448	T60D	136	160	170	173	158	151	115	98	94	96	124	137
T449	T60D	136	160	170	173	158	151	115	98	94	96	124	137
T451	T60E	149	176	187	190	174	166	126	108	103	106	136	151
T452	T60E/F	149	176	187	190	174	166	126	108	103	106	136	151
T453	T60F	149	176	187	190	174	166	126	108	103	106	136	151
T454	T60F	149	176	187	190	174	166	126	108	103	106	136	151
T455	T60F	149	176	187	190	174	166	126	108	103	106	136	151
T456	T60G	136	160	170	173	158	151	115	98	94	96	124	137
T457	T60G	136	160	170	173	158	151	115	98	94	96	124	137
T458	T60G	136	160	170	173	158	151	115	98	94	96	124	137
T459	T60G	136	160	170	173	158	151	115	98	94	96	124	137
T461	T60K	149	176	187	190	174	166	126	108	103	106	136	151
T462	T60K	136	160	170	173	158	151	115	98	94	96	124	137
T463	T60J	149	176	187	190	174	166	126	108	103	106	136	151
T464	T60J	136	160	170	173	158	151	115	98	94	96	124	137
T465	T60J	136	160	170	173	158	151	115	98	94	96	124	137
T466	T60J	136	160	170	173	158	151	115	98	94	96	124	137
T467	T60H	136	160	170	173	158	151	115	98	94	96	124	137
T468	T60H	136	160	170	173	158	151	115	98	94	96	124	137
T469	T60H	136	160	170	173	158	151	115	98	94	96	124	137

3.2.4 Cropping patterns

The cropping patterns for irrigated land in the study area will probably be as follows:

Table 3.3.5 Cropping patterns for irrigated land

CROP / USE	PERCENTAGE OF IRRIGATED AREA
Maize	50
Brassicas	10
Beans	5
Bananas	5
Fallow	30

NB: Macadamias, mangos, and avocados have been excluded, as irrigation is not necessary at the coast.

Table 3.6 Monthly cropping patterns per quaternary catchment

QUART NO.	WR 90 NO.	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
T431	T60A	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T432	T60A	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T433	T60A	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T434	T60A	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T435	T60A	NO IRRIGATION											
T436	T60D	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T437	T60D	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T438	T60D	NO IRRIGATION											
T441	T60B	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T442	T60B	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T443	T60B	NO IRRIGATION											
T444	T60B	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T445	T60C	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T446	T60C	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T447	T60C	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T448	T60D	NO IRRIGATION											
T449	T60D	NO IRRIGATION											
T451	T60E	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T452	T60E/F	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T453	T60F	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T454	T60F	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T455	T60F	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T456	T60G	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T457	T60G	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T458	T60G	NO IRRIGATION											
T459	T60G	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T461	T60K	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T462	T60K	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T463	T60J	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T464	T60J	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T465	T60J	0.55	0.55	0.55	0.70	0.70	0.70	0.15	0.15	0.15	0.05	0.05	0.05
T466	T60J	NO IRRIGATION											
T467	T60H	NO IRRIGATION											
T468	T60H	NO IRRIGATION											
T469	T60H	NO IRRIGATION											

3.2.5 Water sources

For the purposes of this study it has been assumed that all water to be used for irrigation will be drawn from perennial rivers. For bigger irrigation schemes storage dams will be required but for the small irrigation system water can be extracted directly from these rivers.

3.2.6 Estimated effective rainfall and run-off factors

The table below has been derived by using quaternary sub-catchment information from Surface Water Resources of South Africa – Volume V – Part 2. (Appendices) From the MAP, gross area and virgin MAR the effective rainfall and run-off factors were calculated.

Table 3.7 Estimated effective rainfall factor and run-off factor per quaternary

QUART NO.	WR 90 NO.	MAP (mm)	GROSS AREA (Km²)	VIRGIN MAR 10^6M^3	EFFECTIVE RAINFALL FACTOR	RUN-OFF FACTOR
T431	T60A	928	100	17	0.817	0.183
T432	T60A	976	95	20	0.784	0.216
T433	T60A	1102	105	32	0.724	0.276
T434	T60A	1033	130	33	0.754	0.246
T435	T60A	1200	80	34	0.646	0.354
T436	T60D	1125	155	52	0.702	0.298
T437	T60D	1189	80	34	0.643	0.357
T438	T60D	1200	45	18	0.667	0.333
T441	T60B	934	105	15	0.847	0.153
T442	T60B	950	90	15	0.825	0.175
T443	T60B	951	85	14	0.827	0.173
T444	T60B	935	160	24	0.840	0.160
T445	T60C	957	140	22	0.836	0.164
T446	T60C	1035	180	39	0.791	0.209
T447	T60C	1050	120	27	0.786	0.214
T448	T60D	1185	100	34	0.713	0.287
T449	T60D	1220	70	28	0.672	0.328
T451	T60E	883	85	11	0.853	0.147
T452	T60E/ F	915	225	34	0.835	0.165
T453	T60F	867	50	6	0.862	0.138
T454	T60F	939	60	9	0.840	0.160
T455	T60F	1012	130	28	0.787	0.213
T456	T60G	1009	100	21	0.792	0.208
T457	T60G	1104	90	26	0.738	0.262
T458	T60G	1210	80	32	0.669	0.331
T459	T60G	1160	195	69	0.695	0.305
T461	T60K	1127	45	12	0.763	0.237
T462	T60K	1314	110	46	0.682	0.318
T463	T60J	979	55	7	0.870	0.130
T464	T60J	1247	100	37	0.703	0.297
T465	T60J	1354	55	23	0.691	0.309
T466	T60J	1347	85	38	0.668	0.332
T467	T60H	1336	150	67	0.666	0.334
T468	T60H	1300	155	63	0.648	0.352
T469	T60H	1275	140	53	0.703	0.297

3.2.7 Irrigation Efficiency

Irrigation efficiency is dependent on the following factors:

- Type of irrigation e.g. sprinkler, flood
- Design parameters e.g. infiltration rate, irrigation cycle length
- Level of management
- Climatic factors e.g. wind, temperature

Table 3.8 provides estimates of water losses and irrigation system efficiencies for sprinkle and flood irrigation on three different generalised soil types.

Table 3.8 Proposed general irrigation efficiency: (O'Connel, Manthé - 1974.)

FLOOD IRRIGATION

TYPE OF LOSSES	GENERAL SOIL TYPES		
	SAND	LOAM	CLAY
SURFACE RUN-OFF LOSSES	10%	15%	30%
DEEP PERCULATING LOSSES	35%	20%	10%
WATER APPLICATION EFFICIENCY	55%	65%	60%
DISTRIBUTION LOSSES	10%	10%	10%
BULK WATER SUPPLY EFFICIECY	45%	55%	50%

SPRINKLER IRRIGATION

TYPE OF LOSSES	GENERAL SOIL TYPES		
	SAND	LOAM	CLAY
SURFACE RUN-OFF LOSSES	1%	2%	6%
DEEP PERCULATING LOSSES	25%	15%	6%
EVAPORATION LOSSES	8%	8%	8%
WATER APPLICATION EFFICIENCY	66%	75%	80%
DISTRIBUTION LOSSES	5%	5%	5%
BULK WATER SUPPLY EFFICIECY	61%	70%	75%

Due to the unknown variables listed above it is not possible to supply the irrigation efficiency per quaternary catchment area. Therefore it is recommended that an average irrigation efficiency percentage be used for the purposes of this study i.e. 64% (Hidrologiese opname van Transkei - O'Connel, Manthé - 1974.)

3.2.8 Estimated irrigation return flows per quaternary

For the purposes of this study it is felt that the irrigation return flows will not contribute significantly to the water yield of a catchment for the following reasons:

- Percentage of return flow will be very small
- Percentage of irrigated land per quaternary catchment is very small

Therefore it is recommended that irrigation return flows per quaternary be ignored.

3.2.9 Projected annual water demand

The projected annual irrigation demand was calculated taking into account the potential irrigation areas, cropping patterns, evaporation, crop factors, effective rainfall and irrigation efficiency.

Table 3.9 Average annual irrigation demands per quaternary catchment

QUART NO.	WR 90 NO.	POTENTIAL DEMAND (m^3)	CURRENT DEMAND	TOTAL DEMAND IN 2010 (m^3)	TOTAL DEMAND IN 2020 (m^3)	TOTAL DEMAND IN 2030 (m^3)
T431	T60A	994079	0	49704	74294	86328
T432	T60A	536948	0	13271	19906	26541
T433	T60A	472617	0	6170	12340	4936
T434	T60A	563065	0	28153	34949	41744
T435	T60A	0	0	0	0	0
T436	T60D	165693	0	956	2868	4780
T437	T60D	1341096	0	6705	16940	33880
T438	T60D	0	0	0	0	0
T441	T60B	1207308	0	30183	45570	60957
T442	T60B	682320	0	8637	17274	22456
T443	T60B	0	0	0	0	0
T444	T60B	386392	0	19320	29194	33917
T445	T60C	322279	0	1628	5697	9766
T446	T60C	282231	0	1388	4858	6246
T447	T60C	287281	0	1473	3683	7366
T448	T60D	0	0	0	0	0
T449	T60D	0	0	0	0	0
T451	T60E	451325	0	22773	34160	39853
T452	T60E/F	557312	9952	26373	33339	40306
T453	T60F	1151822	3170	33287	50722	58648
T454	T60F	542355	0	27118	40677	54236
T455	T60F	1576028	0	78801	118202	157603
T456	T60G	141003	0	3439	5159	6878
T457	T60G	130479	0	3182	4774	6365
T458	T60G	0	0	0	0	0
T459	T60G	218708	0	1105	2761	5523
T461	T60K	633078	0	15827	23740	31654
T462	T60K	143349	5811	9105	10848	12591
T463	T60J	712178	0	8941	17882	26046
T464	T60J	390152	0	9797	14587	19377
T465	T60J	0	0	0	0	0
T466	T60J	0	0	0	0	0
T467	T60H	0	0	0	0	0
T468	T60H	0	0	0	0	0
T469	T60H	0	0	0	0	0
TOTAL		13889098	18933	409346	626444	800027

Table 3.10 Summary of irrigation data

QUART NO.	WR 90 NO.	IRRIGATION POTENTIAL (ha)	EXISTING IRRIGATION (ha)	PROJECTED IRRIGATION (ha)			POTENTIAL DEMAND (m^3/a)	CURRENT DEMAND (m^3/a)	TOTAL DEMAND IN 2010 (m^3/a)	TOTAL DEMAND IN 2020 (m^3/a)	TOTAL DEMAND IN 2030 (m^3/a)
				2010	2020	2030					
T431	T60A	475	0	24	36	41	994079	0	49704	74294	86328
T432	T60A	263	0	7	10	13	536948	0	13271	19906	26541
T433	T60A	383	0	5	10	4	472617	0	6170	12340	4936
T434	T60A	290	0	15	18	22	563065	0	28153	34949	41744
T435	T60A	0	0	0	0	0	0	0	0	0	0
T436	T60D	130	0	1	2	4	165693	0	956	2868	4780
T437	T60D	950	0	5	12	24	1341096	0	6705	16940	33880
T438	T60D	0	0	0	0	0	0	0	0	0	0
T441	T60B	510	0	13	19	26	1207308	0	30183	45570	60957
T442	T60B	395	0	5	10	13	682320	0	8637	17274	22456
T443	T60B	0	0	0	0	0	0	0	0	0	0
T444	T60B	225	0	11	17	20	386392	0	19320	29194	33917
T445	T60C	198	0	1	4	6	322279	0	1628	5697	9766
T446	T60C	305	0	2	5	7	282231	0	1388	4858	6246
T447	T60C	195	0	1	3	5	287281	0	1473	3683	7366
T448	T60D	0	0	0	0	0	0	0	0	0	0
T449	T60D	0	0	0	0	0	0	0	0	0	0
T451	T60E	218	0	11	17	19	451325	0	22773	34160	39853
T452	T60E/F	280	5	13	17	20	557312	9952	26373	33339	40306
T453	T60F	545	1.5	16	24	28	1151822	3170	33287	50722	58648
T454	T60F	300	0	15	23	30	542355	0	27118	40677	54236
T455	T60F	900	0	45	68	90	1576028	0	78801	118202	157603
T456	T60G	123	0	3	5	6	141003	0	3439	5159	6878
T457	T60G	123	0	3	5	6	130479	0	3182	4774	6365
T458	T60G	0	0	0	0	0	0	0	0	0	0
T459	T60G	198	0	1	3	5	218708	0	1105	2761	5523
T461	T60K	420	0	11	16	21	633078	0	15827	23740	31654
T462	T60K	185	7.5	12	14	16	143349	5811	9105	10848	12591
T463	T60J	458	0	6	12	17	712178	0	8941	17882	26046
T464	T60J	448	0	11	17	22	390152	0	9797	14587	19377
T465	T60J	0	0	0	0	0	0	0	0	0	0
T466	T60J	0	0	0	0	0	0	0	0	0	0
T467	T60H	0	0	0	0	0	0	0	0	0	0
T468	T60H	0	0	0	0	0	0	0	0	0	0
T469	T60H	0	0	0	0	0	0	0	0	0	0
TOTAL		**8517**	**14**	**237**	**367**	**465**	**13889098**	**18933**	**407336**	**624424**	**797997**

3.3 Lusikisiki area

A detailed study of the Lusikisiki area was carried out by HKS in 1979 with the intention of building a dam in the upper reaches of the Xura River. The study seems to indicate that the water from the proposed Zalu Dam would be used for irrigation and domestic purposes in the surrounding district. Approximately 1200 ha have been identified as potential irrigation land. According to the criteria used in our desktop investigation this scheme could be viable. Further field investigations would have to be undertaken before any further comment can be passed.

3.4 Conclusions and recommendations

History has shown that irrigation schemes in Transkei can work if the necessary training, support services and finance is available. However when the back up has been withdrawn the schemes have collapsed. E.g. Qamata and Ncora. It is important to remember however that the reasons for the collapse of the schemes is far deeper rooted than just the lack of the support infrastructure mentioned previously. The system of land tenure has not changed since the Woods and van Schoor report in 1976 and until this problem is addressed by the relevant authorities i.e. Department of Land Affairs, the local Headmen and the TRC's, it will continue to influence agricultural development negatively.

The study area lies within a high rainfall area and therefore the question as to whether irrigation is a priority must be asked. Taking into consideration all the problems attached to running a successful irrigation set-up it is the opinion of the consultant that irrigation is a low priority and will only play a very limited role in the overall development of the agricultural potential of the study area.

In support of the above paragraph the recommendations of Woods and van Schoor –1976 with regards to irrigation systems in Trankei states the following:

- *The efficient utilisation of the existing schemes should receive top priority. Plot holders who do not produce efficiently should be removed from their plots, which should be allocated to farmers who can manage them productively even if it means one farmer having more land than others.*

- *Existing schemes should be replanned so that only land, which has the potential for high-sustained production, is utilised.*

- *Any proposed new schemes should be thoroughly investigated by impartial experts with regards to soils, climate and production potential, and unless they can be economically justified and productively used they should not be developed.*

It has become apparent during the desktop study of the area concerned that many of the previous studies undertaken have placed too much emphasis on irrigation farming. This has forced the choice of crops towards the high-risk end of the scale to make the irrigation economically viable.

It is recommended that the emphasis for improving the agricultural output of the study area should be placed on dry land farming, and not on irrigation even though the study area is known to be rich in water resources.

The opinion of Woods and van Schoor 1976 with regard to irrigation in Transkei is still valid today and the following extract from their report sums up the current situation:

The whole of the eastern part of Transkei, mainly the drainage area of the Umzimvubu River, is not attractive for irrigation. In the first place the rainfall is so high that very high yields, especially of summer crops, can be obtained without the need to apply irrigation water. In the second place the topography is by no means favourable for irrigation. The land suitable for irrigation is very often situated well above the river valleys so that gravitation furrows will be

either impossible or very costly. If pumping has to be resorted to the costs will, except in very favourable situations, be prohibitive.

That costs will be high is borne out by the case of the recently completed Ncora Scheme, on the Tsomo River, comprising a storage dam and canal distribution system to irrigate 6000 ha of land at a capital cost of R25 million.(Late 1960's)

Limited irrigation could nevertheless be carried out in some of the more favourable situations. The total extent of land which, could in this manner be brought under irrigation would however be limited to the total quantity of water that could be made available. Even from an optimistic assessment of the total extent of land that could be brought under irrigation it is clear that only a fraction of the run-off would be needed to satisfy requirements. ***In other words the limiting factor in irrigation development of Transkei will not be water****.*

4 Forestry

4.1 Introduction

Woods & van Schoor – 1976 have the following to say about forestry in Transkei as a whole:

Large areas of Transkei are ideally suited to afforestation and much has already been done to develop this industry, with the result that today it is one of the fastest growing sectors in the economy.

Choice of location is limited to those areas that receive an annual rainfall in excess of 800mm. Within these boundaries the choice becomes one of soil and slope.

Deep soils on fairly level areas are preferred as these offer the highest yields and the least cost of extraction when mature.

The study area has a rainfall ranging between 750-1200 mm, which makes it an ideal area for forestry, as the major portion has an average rainfall in excess of the 800-mm average required. According to a report "Transkei Forestry Strategic Development Plan – Crickmay, Venter & Associates (PTY) Ltd – July 1993" the entire study area is suitable for forestry from a rainfall point of view. The only restriction for forestry development would be the gradient, population density and in certain areas the soils.

The indigenous forests in the study area occur mainly on the cool southern and eastern slopes. They may be classified as either High forests that occur in scattered small to large patches both inland and near the coast, and Scrub and Coastal forest

Although heavily exploited in the past, these areas now enjoy some protection, as they are an invaluable asset for recreation purposes. (Woods & van Schoor-1976)

4.2 Types of forestry

There are various types of forestry which are carried out and they briefly described hereunder according to Crickmay, Venter & Associates – July 1993

- ***Woodlot Forestry:*** *The cultivation of communal patches of trees for domestic consumption by the community.*

- ***Agro Forestry:*** *The integrated use of trees within an agricultural activity. The purpose for which the trees are grown is flexible and can be for domestic consumption or for to the commercial sector.*

- ***Social Forestry****: Is a term used to cover all aspects of tree growing where the main objective is to supply the community with timber, fodder for livestock, soil conservation or work opportunities. Social Forestry includes woodlots, agro forestry, or any other timber growing activity whose objective is primarily social rather than commercial.*

- ***Commercial forestry:*** *Where the main objective is to grow timber for a specific market with a profit motive.*

- ***Small Sawmills/Bushmills:*** *Are one and the same thing but the preferred term is the former for it describes better the improved small sawmill of the future. Such a mill usually has a log intake of up to 4000 m^3 p.a. and does not have kiln-drying facilities.*

4.3 Effects of afforestation on run-off

It is an accepted fact that commercial plantations that replace natural grasslands will diminish run-off. In the study area no significant use is made of the run-off at this stage so the affect of plantations is only of academic importance.

To calculate the extent of the reduction of the run-off is difficult as it depends on many factors such as:

- Rainfall at locality
- Present natural run-off
- Age of trees
- Density of trees
- Type of trees

Woods and van Schoor (1976) stated that the runoff can be reduced by 60% in an area covered by trees. This is a general approximation serving as an initial benchmark. Table 4.1 gives an indication of the actual reduction in runoff due to afforestation in a given area.

Table 4.1 Predicted losses in run-off due to afforestation (Woods & van Schoor)

% AREA UNDER TREES	% REDUCTION IN RUN-OFF
25	15
20	9
10	6
3	3

For the purposes of this study the estimation of the reduction in the MAR was calculated according to the Van Der Zel's (1978) curve for a 15-year rotation. The reduction of runoff due to the afforestation has been calculated for 10 yearly intervals. The preliminary results are shown in Tables 4.4 to4.7.

$$F=0.089V^{1.31}$$

where F = 100% afforested MAR (mm)

V = Virgin MAR (mm)

More accurate estimates of the reduction of runoff have been obtained for the purposes of the hydrological system modelling, using the Afforestek program, based on the revised runoff reduction curves (CSIR, 1997). The results are shown in the **Hydrology Report**

4.4 Development constraints

The major development constraints with regards to forestry are similar to those listed under irrigation i.e. infrastructure, finance, land tenure, training and extension. All of these problems will have to be addressed before any development can take place.

4.5 Existing forestry

As far as can be ascertained (1:50000 topographical maps-1983) the only existing plantation of any note is situated at Ntsubane (T467) in the Lusikisiki district. This plantation is approximately 1 500 ha in size and consists of 1153 ha Pinus species, 62 ha Eucalyptus species, 11 ha other species, with 268 ha unplanted. (Crickmay, Venter & Associates – July 1993). For the calculation of water demands this area has been added to the following data indicating existing forestry (Harbert and Howard. 1997, Wild Coast Forestry Task Team by Fractal Forest Africa, CSIR).

Table 4.2 **Area of potential forestry, existing afforestation and types of trees per quaternary** (CSIR, 1997)

Quaternary (HRU No)	Quaternary (WR90 No.)	POTENTIAL FORESTRY (ha)	AREA EXISTING AFFORESTATION (ha)			
			PINE	GUM	OTHER	INDG.
T431-T435	T60A	5 500	322	304	21	583
T436-T438	T60D	2 100	0	0	0	0
T441-T444	T60B	5 300	3 405	0	0	1 010
T445-T447	T60C	3 600	0	0	0	0
T448-T449	T60D	2 000	0	0	0	0
T451-T452	T60E	2 000	662	36	0	423
T452-T455	T60F	6 700	471	1	0	692
T456-T459	T60G	5 000	0	295	0	941
T461-T462	T60K	2 500	617	15	0	150
T463-T466	T60J	3 200	649	168	0	241
T467-T469	T60H	6 500	0	0	0	0
TOTAL		**44 400**	**6 126**	**819**	**21**	**4 040**

*WOODLOTS HAVE BEEN EXCLUDED FROM THIS TABLE

The areas with potential for forestry developments per quaternary catchment are in accordance with the report by van Zyl, D and Webster, D, 1996. Wild Coast SDI, Industrial Forestry Report.

As an alternative source of information all the existing plantations and indigenous forest areas shown on the 1:50000 topographical maps (latest, 1983) have been identified and the areas measured with a planimeter. Certain quaternary catchments have a proliferation of small woodlots especially numbers 431,432,434.and 442 (T60A and T60B). Most of the woodlots are very small (<2 ha) and a large percentage seem to serve as shelter belts as well. The areas of these woodlots have been excluded from the total area under plantations. Table 4.3 lists the findings per quaternary catchment.

This table can be compared with the data from CSIR to try and make a more accurate assessment of the current situation. It was not possible to establish the type of trees planted.

Table 4.3 Existing plantations and indigenous forests as measured on the 1:50000 topographical maps (1983)

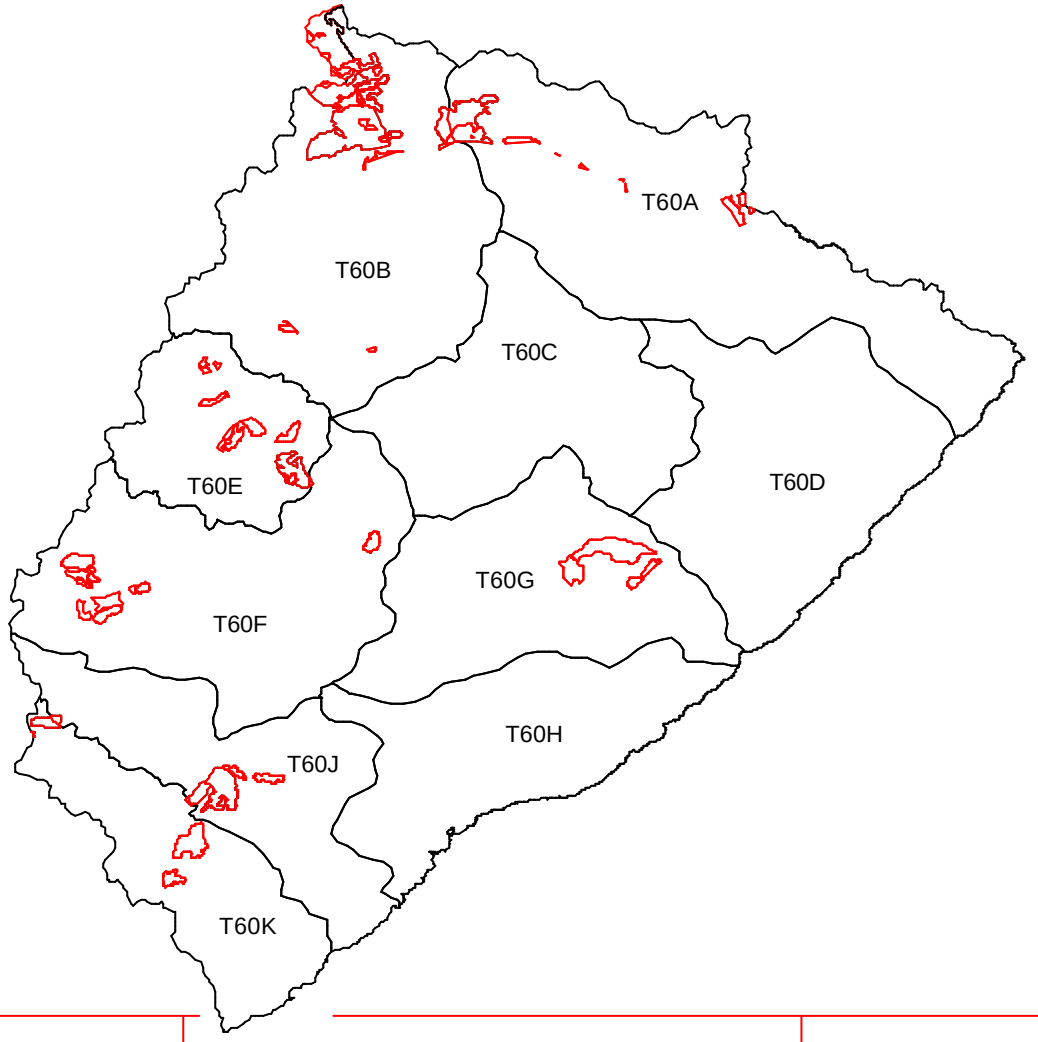
QUARTER.NO.	WR 90 N0.	INDIGENOUS (HA)	PLANTATIONS (HA)
T431	T60A	0	0
T432	T60A	13	0
T433	T60A	15	0
T434	T60A	83	0
T435	T60A	410	0
T436	T60D	25	78
T437	T60D	180	0
T438	T60D	0	0
T441	T60B	45	53
T442	T60B	0	0
T443	T60B	0	30
T444	T60B	138	130
T445	T60C	0	18
T446	T60C	195	0
T447	T60C	0	73
T448	T60D	203	0
T449	T60D	0	353
T451	T60E	0	53
T452	T60E/ F	0	35
T453	T60F	0	0
T454	T60F	0	0
T455	T60F	0	565
T456	T60G	0	0
T457	T60G	0	0
T458	T60G	168	40
T459	T60G	0	5
T461	T60K	0	13
T462	T60K	4583	0
T463	T60J	0	0
T464	T60J	238	0
T465	T60J	1055	0
T466	T60J	1850	0
T467	T60H	3530	1508
T468	T60H	423	0
T469	T60H	78	28
TOTAL		**13232**	**2982**

WOODLOTS HAVE BEEN EXCLUDED FROM THIS TABLE

The comparison between the figures obtained from the CSIR and those obtained from the 1:50000 topographical maps show a substantial increase in plantations from 2982 ha to 6966 ha. As the CSIR study was done in 1997 by means of recent satellite images, it is felt that it is the more reliable data set and should be used, with the addition of the Ntsubane area, in the calculation of water demands.

The area of indigenous forests show a variation from 4040 ha in the CSIR study to 13 232 ha on the topographical maps. When overlaying the two sets of data it is apparent that the coastal forest belt is not included in the CSIR data and the larger area should therefore be a better indication of the magnitude of natural forests. Although the indigenous forests are not used in the calculation of runoff reduction, the area is given for information.

Map 4.1 Existing plantations per quaternary catchment.

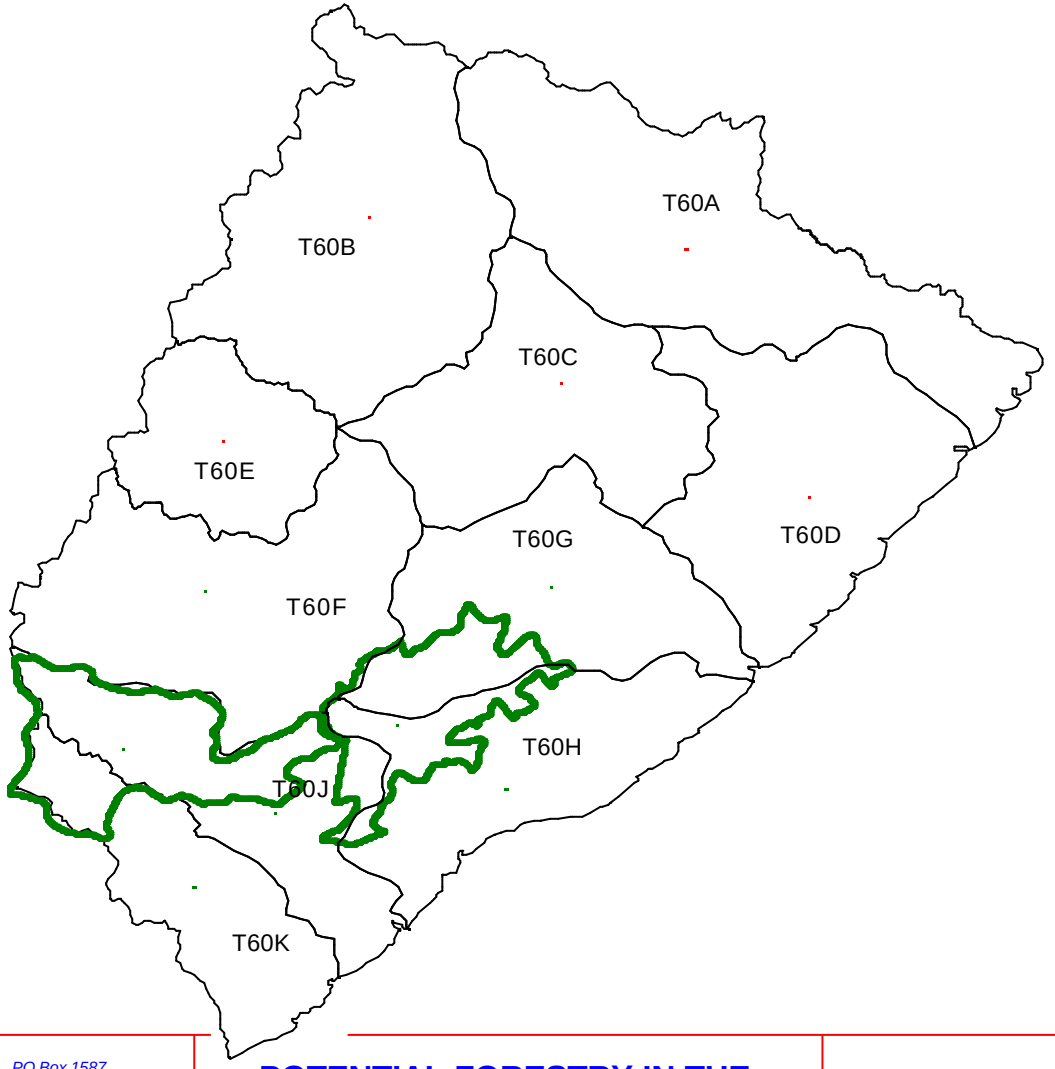


A.J. Roets & Associates
Engineering Services
PO Box 1587
Queenstown
5320
Tel. 0451 8384164

EXISTING PLANTATIONS

Client : Department of Water Affairs and Forestry

Map 4.2 Potential forestry areas in the Lusikisiki area.

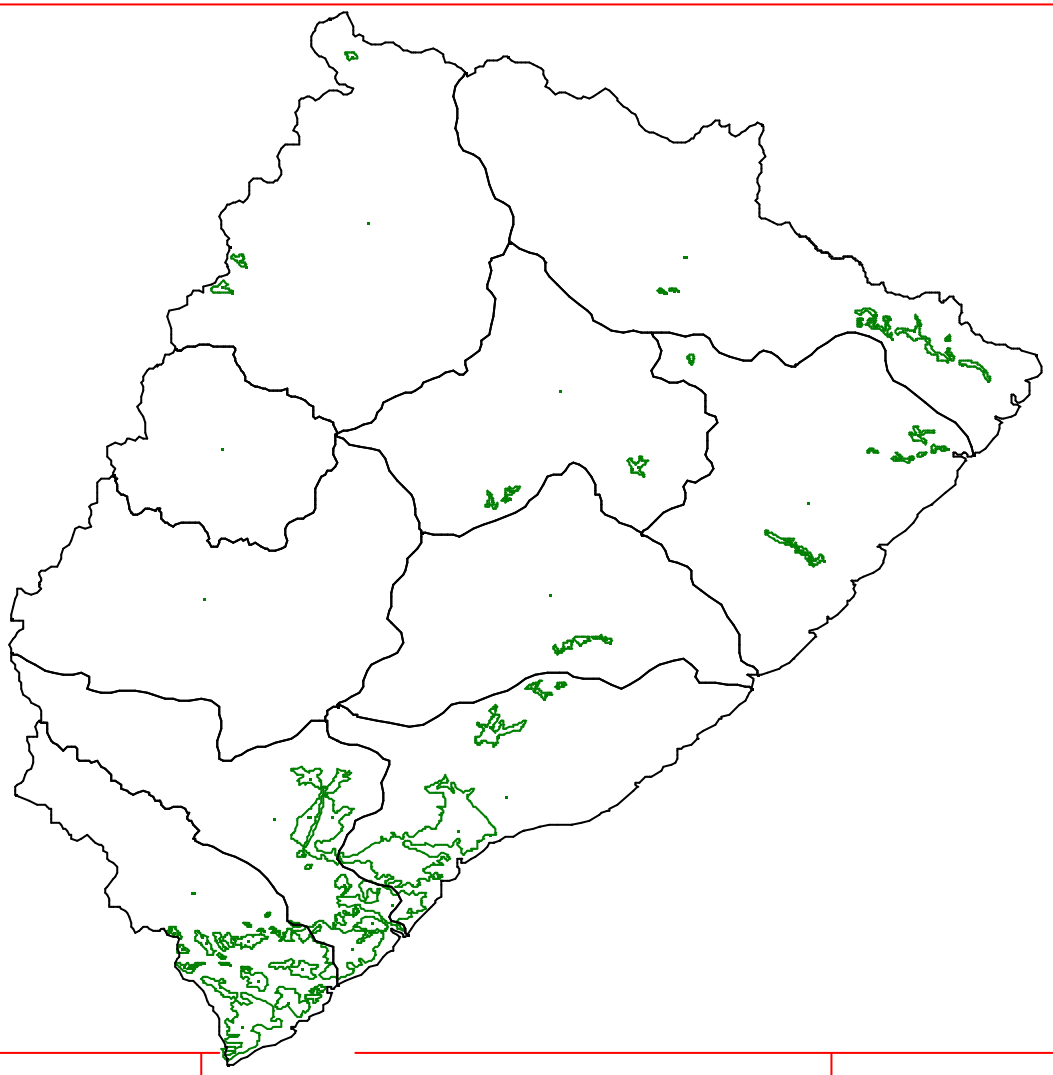


A.J. Roets & Associates
Engineering Services
PO Box 1587
Queenstown
5320
Tel. 0451 8384164

POTENTIAL FORESTRY IN THE LUSIKISIKI EAST AND WEST AREAS

Client : Department of Water Affairs and Forestry

Map 4.3 Indigenous and Coastal forests.



A.J. Roets & Associates
Engineering Services

PO Box 1587
Queenstown
5320
Tel. 0451 8384164

INDIGENOUS AND COASTAL FORESTS

Client : Department of Water Affairs and Forestry

4.6 Woodlots

The “Strategic Forestry plan for Transkei” (Crickmay, Venter & Associates – 1993) states the following about woodlots.

The average production of a woodlot has been calculated at 7.3m³/ha/annum and the average consumption is estimated at 0.6m³ per person per annum. This means that 1 ha of woodlot is required for every 12 people. Shone (1985) used these parameters to calculate that Transkei requires at least a further 60000 ha of woodlots.

During 1985, the DBSA approved the loan and technical support for a project to plant 1800 ha of trees over 3 years for the supply of firewood and poles to the rural people. This is known as the LEAF (Local Energy and Forestry) project. However this project has not met with any success as by July 1987 only 40 ha had been planted. The main finding is that plantations created were financially unsustainable and not particularly successful in supplying fuel wood to villagers.

Clearly a new approach is needed.

As stated previously, certain quaternary catchments within the study area have a substantial number of small woodlots. It will be difficult to assess their current status without field visits. However their importance has probably declined, as other sources of power have become available such as gas and electricity. They do however remain an important source of fuel, as well as building and fencing material for the rural communities.

According to Mr R Mack of SAPPI the existing woodlots are to be upgraded to supply timber on a small scale commercial basis to sawmills.

Their influence on the run-off of the study area is minimal because of the relatively small area they cover i.e. approximately 500 ha in the Bizana and Lusikisiki area. (Shone – 1985)

4.7 Conclusions and recommendations

All indications are that there is a high potential for the development of forestry within the study area. Suitable land with slopes of between 12%-20% can be considered for the development of commercial forestry plantations. This will hopefully also curb the cultivation of excessively steep slopes for agricultural purposes as is happening at present and prevent any conflicts of interest between agriculture and forestry. Further more the influence of commercial plantations on the run-off will have to be monitored carefully and the necessary control measures applied when necessary.

The promotion of woodlots as a source of fuel should be encouraged provided that the types of trees planted are not invasive. This will also relieve the pressure on the indigenous forests in the area that should be protected at all costs.

Considerable development has already taken place. As seen from Table 4.3 about 8460 ha of forestry developments have already been established in the area. Applications for further establishment of 627 ha of commercial plantations in T60A & T60B have already been received, and another 1500 ha expected in these two catchments in the next two years (E Bosman - DWAF).

Additional 1 000 ha of Eucalyptus are planned to be established in the Lambasi area within the next 3 to 4 years and a further 2 000 ha over the next 30 years (T60H). A small grower scheme is also planned between the Mtentu & Mzamba rivers, which will eventually involve 2 000 ha over a 7 year period (T60A & T60D (R Mack – SAPPI).

Apart from the planned development mentioned above, which is included in the projected afforestation no major additional forestry development is foreseen. The projected developments are shown in Table 4.3

Table 4.3 Projected forestry development per quaternary catchment to the year 2030

WR 90 N0.	POTENTIAL FORESTRY (HA)CSIR 1990	EXISTING FORESTRY (HA) CSIR 1990	TOTAL PROJECTED AFFORESTATION (HA)		
			2010	2020	2030
T60A		647	2710	2710	2710
T60B		3405	4468	4468	4468
T60C		0	0	0	0
T60D		0	1000	1000	1000
T60E		698	698	698	698
T60F	394	472	472	472	472
T60G	7271	295	295	295	295
T60H	6488	*1495	2495	3495	4495
T60J	15988	817	817	817	817
T60K	4495	632	632	632	632
TOTAL	**34636**	**8461**	**13587**	**14587**	**15587**

***Nsubane plantation not part of the CSIR data but it is included for the calculation of water demand.**

Table 4.4 Current forestry water demand

Catchment	River		Areas per type of tree				Total	MAR Reduction	Total annual		Monthly distribution of demands (m3/m)									Test
		Eucalyptus	Pine	Wattle	Unknown	Indigenous	Plantations	mm	demand (m3/a)	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total
		ha	ha	ha	ha	ha	ha															
T60A																						
T60A-1		0	0	0	0	0	0	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60A-2	Mphahlanyana	0	0	0	0	0	0	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60A-3	Mphahlane	0	0	0	0	0	0	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60A-4	Mzamba	304.6	322.2	21.9	0	584	648.7	155	1005485	66362.01	67367.5	85466.2	92504.6	77422.3	94515.6	86471.7	88482.7	86471.7	75411.4	96526.6	88482.7	1005485
T60A-5		0	0	0	0	0	0	155	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total T60A		304.6	322.2	21.9	0	584	648.7	155	1005485	66362.01	67367.5	85466.2	92504.6	77422.3	94515.6	86471.7	88482.7	86471.7	75411.4	96526.6	88482.7	1005485
T60B	Mtentu	0	3405.6	0	0	1010.4	3405.6	102	3473712	229265	232739	295266	319582	267476	326529	298739	305687	298739	260528	333476	305687	3473712
T60C	Mtentu	0	0	0	0	0	0	125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60D																						
T60D-1		0	0	0	0	0	0	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60D-2	Mtentu	0	0	0	0	0	0	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60D-3	Sikombe	0	0	0	0	0	0	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60D-4	Lutungulu	0	0	0	0	0	0	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60D-5		0	0	0	0	0	0	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60D-6	Mnyameni	0	0	0	0	0	0	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total T60D		0	0	0	0	0	0	317	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60E	Msikaba	37	662.8	0	0	423.3	699.8	95	664810	43877.46	44542.3	56508.9	61162.5	51190.4	62492.1	57173.7	58503.3	57173.7	49860.8	63821.8	58503.3	664810
T60F	Msikaba	1.4	471.6	0	0	692.3	473	110	520300	34339.8	34860.1	44225.5	47867.6	40063.1	48908.2	44745.8	45786.4	44745.8	39022.5	49948.8	45786.4	520300
T60G	Msikaba	295.7	0	0	0	941.4	295.7	176	520432	34348.51	34868.9	44236.7	47879.7	40073.3	48920.6	44757.2	45798	44757.2	39032.4	49961.5	45798	520432
T60H																						
T60H-1		0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60H-2	Mzinpunzi	0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60H-3		0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60H-4	Mbotyi	0	0	0	240.1	0	240.1	210	504210	33277.86	33782.1	42857.9	46387.3	38824.2	47395.7	43362.1	44370.5	43362.1	37815.8	48404.2	44370.5	504210
T60H-5	Mkozi	0	0	0	1168.1	0	1168.1	210	2453010	161898.7	164352	208506	225677	188882	230583	210959	215865	210959	183976	235489	215865	2453010
T60H-6	Myekane	0	0	0	58.3	0	58.3	210	122430	8080.38	8202.81	10406.6	11263.6	9427.11	11508.4	10529	10773.8	10529	9182.25	11753.3	10773.8	122430
T60H-7		0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60H-8	Luphuthana	0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60H-9		0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60H-10	Mlambonkelu	0	0	0	0	0	0	210	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60H-11	Mkweni	0	0	0	20.8	0	20.8	210	43680	2882.88	2926.56	3712.8	4018.56	3363.36	4105.92	3756.48	3843.84	3756.48	3276	4193.28	3843.84	43680
T60H-12		0	0	0	4.8	0	4.8	210	10080	665.28	675.36	856.8	927.36	776.16	947.52	866.88	887.04	866.88	756	967.68	887.04	10080
Total T60H		0	0	0	1492.1	0	1492.1	210	3133410	206805.1	209938	266340	288274	241273	294541	269473	275740	269473	235006	300807	275740	3133410
T60J																						
T60J-1		0	0	0	0	0	0	190	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60J-2		0	0	0	0	0	0	190	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60J-3	Mzintlava	168.9	649.3	0	0	241.7	818.2	190	1554580	102602.3	104157	132139	143021	119703	146131	133694	136803	133694	116594	149240	136803	1554580
Total T60J		168.9	649.3	0	0	241.7	818.2	190	1554580	102602.3	104157	132139	143021	119703	146131	133694	136803	133694	116594	149240	136803	1554580
T60K																						
T60K-1		0	0	0	0	0	0	197	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60K-2	Mntafufu	15.2	618.9	0	0	150.2	634.1	197	1249177	82445.68	83694.9	106180	114924	96186.6	117423	107429	109928	107429	93688.3	119921	109928	1249177
Total T60K		15.2	618.9	0	0	150.2	634.1	197	1249177	82445.68	83694.9	106180	114924	96186.6	117423	107429	109928	107429	93688.3	119921	109928	1249177
Total T60		822.8	6130.4	21.9	1492.1	4043.3	8467.2		12121906	800046	812168	1030362	1115215	933387	1139459	1042484	1066728	1042484	909143	1163703	1066728	12121906

Table 4.5 Projected forestry demand in the year 2010

Catchment	Areas per type of tree				Total Plantation ha	MAR Reduction mm	Total annual demand (m3/a)	Monthly distribution of demands (m3/m)												Test Total
	Eucalyptus ha	Pine ha	Wattle ha	Unknown Ha				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
T60A	304.6	322.2	21.9	2061.3	2710	155	4200500	277233	281433.5	357043	386446	323439	394847	361243	369644	361243	315038	403248	369644	4200500
T60B	0	3405.6	0	1062.4	4468	102	4557360	300785.76	305343.12	387376	419277	350917	428392	391933	401048	391933	341802	437507	401048	4557360
T60C	0	0	0	0	0	125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60D	0	0	0	1000	1000	317	3170000	209220	212390	269450	291640	244090	297980	272620	278960	272620	237750	304320	278960	3170000
T60E	37	662.8	0	0	699.8	95	664810	43877.46	44542.27	56508.9	61162.5	51190.4	62492.1	57173.7	58503.3	57173.7	49860.8	63821.8	58503.3	664810
T60F	1.4	471.6	0	0	473	110	520300	34339.8	34860.1	44225.5	47867.6	40063.1	48908.2	44745.8	45786.4	44745.8	39022.5	49948.8	45786.4	520300
T60G	295.7	0	0	0	295.7	176	520432	34348.512	34868.944	44236.7	47879.7	40073.3	48920.6	44757.2	45798	44757.2	39032.4	49961.5	45798	520432
T60H	0	0	0	2488.2	2488.2	210	5225220	344864.52	350089.74	444144	480720	402342	491171	449369	459819	449369	391892	501621	459819	5225220
T60J	168.9	649.3	0	0	818.2	190	1554580	102602.28	104156.86	132139	143021	119703	146131	133694	136803	133694	116594	149240	136803	1554580
T60K	15.2	618.9	0	0	634.1	197	1249177	82445.682	83694.859	106180	114924	96186.6	117423	107429	109928	107429	93688.3	119921	109928	1249177
Total T60					13587		21662379	1429717.014	1451379.393	1841302	1992939	1668003	2036264	1862965	1906289	1862965	1624678	2079588	1906289	21662379

Table 4.6 Projected forestry demand in the year 2020

Catchment	Areas per type of tree				Total Plantation ha	MAR Reduction mm	Total annual demand (m3/a)	Monthly distribution of demands (m3/m)												Test Total
	Eucalyptus ha	Pine ha	Wattle ha	Unknown Ha				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
T60A	304.6	322.2	21.9	2061.3	2710	155	4200500	277233	281433.5	357043	386446	323439	394847	361243	369644	361243	315038	403248	369644	4200500
T60B	0	3405.6	0	1062.4	4468	102	4557360	300785.76	305343.12	387376	419277	350917	428392	391933	401048	391933	341802	437507	401048	4557360
T60C	0	0	0	0	0	125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60D	0	0	0	1000	1000	317	3170000	209220	212390	269450	291640	244090	297980	272620	278960	272620	237750	304320	278960	3170000
T60E	37	662.8	0	0	699.8	95	664810	43877.46	44542.27	56508.9	61162.5	51190.4	62492.1	57173.7	58503.3	57173.7	49860.8	63821.8	58503.3	664810
T60F	1.4	471.6	0	0	473	110	520300	34339.8	34860.1	44225.5	47867.6	40063.1	48908.2	44745.8	45786.4	44745.8	39022.5	49948.8	45786.4	520300
T60G	295.7	0	0	0	295.7	176	520432	34348.512	34868.944	44236.7	47879.7	40073.3	48920.6	44757.2	45798	44757.2	39032.4	49961.5	45798	520432
T60H	0	0	0	3488.2	3488.2	210	7325220	483464.52	490789.74	622644	673920	564042	688571	629969	644619	629969	549392	703221	644619	7325220
T60J	168.9	649.3	0	0	818.2	190	1554580	102602.28	104156.86	132139	143021	119703	146131	133694	136803	133694	116594	149240	136803	1554580
T60K	15.2	618.9	0	0	634.1	197	1249177	82445.682	83694.859	106180	114924	96186.6	117423	107429	109928	107429	93688.3	119921	109928	1249177
Total T60					14587		23762379	1568317.014	1592079.393	2019802	2186139	1829703	2233664	2043565	2091089	2043565	1782178	2281188	2091089	23762379

Table 4.7 Projected forestry demand in the year 2030

Catchment	Areas per type of tree				Total Planta tion ha	MAR Reduction mm	Total annual demand (m3/a)	Monthly distribution of demands (m3/m)												Test Total
	Eucalyptus ha	Pine ha	Wattle ha	Unknown Ha				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	
T60A	304.6	322.2	21.9	2061.3	2710	155	4200500	277233	281433.5	357043	386446	323439	394847	361243	369644	361243	315038	403248	369644	4200500
T60B	0	3405.6	0	1062.4	4468	102	4557360	300785.76	305343.12	387376	419277	350917	428392	391933	401048	391933	341802	437507	401048	4557360
T60C	0	0	0	0	0	125	0	0	0	0	0	0	0	0	0	0	0	0	0	0
T60D	0	0	0	1000	1000	317	3170000	209220	212390	269450	291640	244090	297980	272620	278960	272620	237750	304320	278960	3170000
T60E	37	662.8	0	0	699.8	95	664810	43877.46	44542.27	56508.9	61162.5	51190.4	62492.1	57173.7	58503.3	57173.7	49860.8	63821.8	58503.3	664810
T60F	1.4	471.6	0	0	473	110	520300	34339.8	34860.1	44225.5	47867.6	40063.1	48908.2	44745.8	45786.4	44745.8	39022.5	49948.8	45786.4	520300
T60G	295.7	0	0	0	295.7	176	520432	34348.512	34868.944	44236.7	47879.7	40073.3	48920.6	44757.2	45798	44757.2	39032.4	49961.5	45798	520432
T60H	0	0	0	4488.2	4488.2	210	9425220	622064.52	631489.74	801144	867120	725742	885971	810569	829419	810569	706892	904821	829419	9425220
T60J	168.9	649.3	0	0	818.2	190	1554580	102602.28	104156.86	132139	143021	119703	146131	133694	136803	133694	116594	149240	136803	1554580
T60K	15.2	618.9	0	0	634.1	197	1249177	82445.682	83694.859	106180	114924	96186.6	117423	107429	109928	107429	93688.3	119921	109928	1249177
Total T60					15587		25862379	1706917.014	1732779.393	2198302	2379339	1991403	2431064	2224165	2275889	2224165	1939678	2482788	2275889	25862379

5 Farm Dams

5.1 Definition of a farm dam

A farm dam can be defined as any dam that provides water for livestock, irrigation and in many cases domestic use. (Drinking, washing etc.) In the latter case the water usually has to be boiled before consumption because pollution is often a problem especially if situated near residential areas.

The dams can vary in capacity from small stock dams of 1000m³ to substantial irrigation dams of 50000m³ and more. The walls are usually earth fill with side spillways. Maintenance of the wall and spillway is very important and the lack thereof is the main reason for the failure of these dams in the rural areas.

5.2 Existing farm dams

Only four existing dams were identified on the 1:50000 topographical maps (1983) within the study area All four are within close proximity to Magwa Tea and it is assumed that they were constructed to supply water to the estate.

The table hereunder gives details of the existing farm dams

Table 5.3 Existing farm dam details

QUAT NO	WR 90 NO.	VOLUME (M^3)	SURFACE AREA (HA)	APPROXIMATE		
				DEPTH AT WALL (M)	THROW BACK (M)	WALL LENGTH (M)
T465	T60J	10100	0.375	5	150	50
T467	T60H	1856100	32.500	20	900	350
T468	T60H	50400	1.875	5	250	150
T468	T60H	84100	3.125	5	250	250

5.3 Proposed farm dams

The study area has the potential for the construction of farm dams in all the quaternary catchment areas. However it is impossible to identify the actual sites on 1:50000 topographical maps without the necessary field visits.

Furthermore it is felt that the necessity to construct farm dams is of a very low priority because of the high rainfall and abundance of natural water sources such as rivers, streams and fountains. This low priority is probably the reason why so few farm dams have been constructed in the study area in the past.

5.5 Recommendations and conclusions

As far as can be ascertained there are no plans for the development of any significant farm dams in the foreseeable future, unless there are drastic changes to the land tenure system which will encourage commercial farming on a large scale. Which in turn could encourage the construction of farm dams.

For the purposes of this study it is recommended that the influence farm dams will have on the run-off `over the next 30 years be ignored as it will be minimal.

6. References

- The Agricultural Potential of Trankei – P C Woods and A M van Schoor – 1976

- Wild Coast Spatial Development Initiative-Irrigation Potential-Loxton,Venn and Associates-September, 1997

- Wild Coast Spatial Development Initiative – Small Scale Fruit and Vegetable Opportunities – Loxton,Venn and Associates – September, 1997

- Transkei Regering – Hydrologiese Opname Van Die Transkei – O'Connel, Manthé & Vennotte – Maart 1974

- Surface Water Resources of South Africa – Volume V - Part 2 Hydrological Research Unit – 1981

- Estimated Irrigation Requirements Of Crops In South Africa – Part I – G C Green – 1985

- Wild Coast Spatial Development Initiative – Assessment of Magwa Tea Estate and Pondoland Sugar Project – MBB – Report (Project no: Z2044) September-1997

- Transkei Forestry Strategic Development Plan – Crickmay, Venter & Associates (Pty) Ltd. – July 1993.

- Wild Coast Spatial Development Initiative; Industrial Forestry Report, 1996. van Zyl, D and Wabster, D

- Strategic report on site conditions for afforestation in the Mount Ayliff and Bizana Districts of the Eastern Cape. Prepared for the Wild Coast SDI

Forestry Task Team by Fractal Forest Africa. Herber, M and Howard, M. 1997

- Strategic report on site conditions for afforestation in the Lusikisiki District of the Eastern Cape. Prepared for the Wild Coast SDI Forestry Task Team by Fractal Forest Africa. Herber, M and Howard, M. 1997

- Personal communication – K Joubert – Director Engineering Services – Department Agriculture and Land Affairs – Eastern Province

- Personal communication – J Beumer – Chief Engineer – Department Water Affairs and Forestry

- Personal communication – E Bosman - Department Water Affairs and Forestry

- Personal communication – A Chapman – CSIR – Stellenbosch
- Personal communication – H V Doudenski – UWP Engineers – Bryanston Gauteng
- Personal communication – R. Mack – SAPPI.
- Personal communication – J. Greathead – Magwa Tea Estates