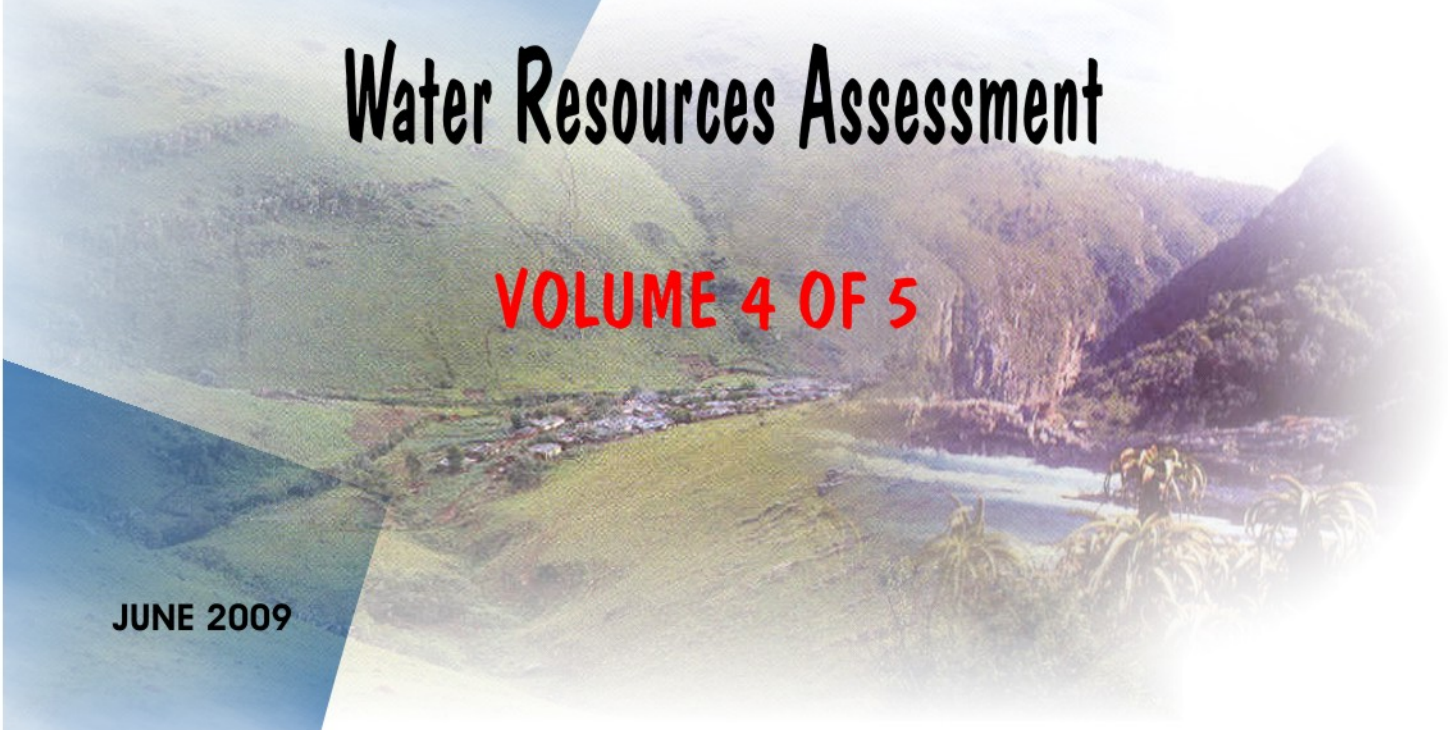
Project No: P WMA 12/000/00/3609

water & forestry

Department:
Water Affairs and Forestry
REPUBLIC OF SOUTH AFRICA

DWAF Water Resource Study in Support of the ASGISA EC Mzimvubu Development Project



Water Resources Assessment

VOLUME 4 OF 5

JUNE 2009

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DWA WATER RESOURCE STUDY IN SUPPORT OF THE ASGISA-EC MZIMVUBU DEVELOPMENT PROJECT

LIST OF STUDY REPORTS

REPORT	DWA report number
Summary Report	P WMA 12/000/00/3609
Existing water supply infrastructure assessment	P WMA 12/000/00/3609 Volume 1 of 5
Agricultural assessment and irrigation water use	P WMA 12/000/00/3609 Volume 2 of 5
Groundwater assessment	P WMA 12/000/00/3609 Volume 3 of 5
Water resources assessment	P WMA 12/000/00/3609 Volume 4 of 5
Assessment of potential for pumped storage and hydropower schemes	**P WMA 12/000/00/3609 Volume 5 of 5**
Rainwater Harvesting	P WMA 12/000/00/3609
An assessment of rain-fed crop production potential in South Africa's neighboring countries	P RSA 000/00/12510

Title	***Water Resources Assessment***
Authors	*JH Schroder*
Project Name	*DWAF Water Resource Study in Support of the AsgiSA-EC Mzimvubu Development Project*
BKS Project No	*J00105*
Status of Report	*Final*
DWAF Report No	*P WMA 12/000/00/3609 - Volume 4 of 5*
First Issue	*31 March 2009*
Final Issue	*12 June 2009*

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DWAF WATER RESOURCE STUDY IN SUPPORT OF THE ASGISA-EC MZIMVUBU DEVELOPMENT PROJECT

WATER RESOURCES ASSESSMENT

EXECUTIVE SUMMARY

Introduction

Harnessing the water resources of the Mzimvubu River, the only major river in the country which is still largely unutilised, can potentially be of great socio-economic benefit if the water is used for viable development projects in the catchment.

This report describes the assessment of the water resources of the Mzimvubu River catchment and gives a first-order perspective on the potential for water resource development in the catchment.

The purpose of the work was to evaluate the hydrology and assess the water resources potential with the latest available information and to a common level of detail, in order to facilitate the quick assessment of the water resource availability to support potential development options that may be considered by AsgiSA-EC. This work also enabled the general identification of potential water resource related development options, which are covered in the report. Possible new dams for water supply and/or transfer, potential hydropower generation as well as sites for pumped storage schemes have been considered at a cursory, project-identification level.

This report forms part of the work of a general nature by the DWAF, to assist the AsgiSA-EC initiatives. The conclusions reached and recommendations made are therefore of an indicative nature and could be subject to further investigation and review.

Surface Water Resources

The main focus of the work conducted has been on the assessment of the surface water resources and the potential for development thereof. Groundwater is covered in a separate report, and is only concisely referred to in this report.

The work included evaluating the hydrology, accounting for existing water resource and land use developments (small dams, irrigation, afforestation), provision for existing water uses and known future requirements, as well as specific provision for Ecological Water Requirements (EWR). The latter provisions were based on provisional "desktop" assessments. More detailed assessments of the EWR will be required in specific areas.

Yield Assessments

Yield analyses were performed for a number of sites that were identified as potentially feasible for the construction of large dams. The yields achievable from different sizes of dams were assessed to provide an indication of the likely water availability to supply

possible larger-scale developments. Provisional assessments were also made of the potential for hydropower generation at the respective dam sites.

Particular provision was made for the accumulation of sediment in all potential dams, as sediment load in the Mzimvubu River is appreciable.

Potential Water Resources Development

First-order cost estimates were done for each of the possible dams that were identified. Unit reference values were determined as an indication of the cost of water from each dam, to facilitate assessment of the likely economic feasibility of potential developments. The unit reference values of water from the potential dams assessed were generally low, but did not include the costs of distributing the water, which are likely to be high in the Mzimvubu catchment.

Cost estimates and unit reference values were also determined for the possible large-scale transfer of water to the western part of the Eastern Cape Province. All the initial evaluations were based on single-purpose developments only, whereas possible multi-purpose schemes could offer greater opportunity.

Similarly, cost estimates and first order assessments were performed with respect to potential conventional hydropower developments (for both base load and peaking power) as well as for possible pumped storage hydropower schemes. These are covered in more detail in a separate report.

Summary

With the latest available hydrology and water resources assessments, a reliable base now exists for the first-order and comparative evaluations of potential development options. However, more detailed assessments will be required if specific development options are to be investigated.

The yields achievable as well as the potential for hydropower generation, as determined during this study, are lower than the comparative values from previous studies. This is attributable to the provision that was made with respect to releases for ecological water requirements, which were not provided for in the past, as well as the reduced average runoff resulting from the updated hydrology.

The provisional findings at this stage are that sufficient economic uses for the water have not yet been identified to motivate the construction of a large dam in the Mzimvubu River catchment, nor the large-scale transfer of water. Similarly, the potential for the development of hydropower schemes appears to be marginal at this stage and under current pricing structures for electricity. Other needs and uses may still be identified, however, which could warrant the consideration of possible multi-purpose developments.

The information contained in this report is therefore not sufficiently conclusive for final decisions to be taken on any of the development options.

DWAF WATER RESOURCE STUDY IN SUPPORT OF THE ASGISA-EC MZIMVUBU DEVELOPMENT PROJECT

WATER RESOURCES ASSESSMENT

TABLE OF CONTENTS

Page

APPENDICES

1 INTRODUCTION

1.1 BACKGROUND

The Mzimvubu River area in the Eastern Cape Province is one of the poorest and least developed parts of South Africa. Development of the area, with the express purpose of accelerating the social and economic upliftment of the people in the region, was therefore identified as one of the priority initiatives of the Eastern Cape Provincial Government. The Mzimvubu Development Project was consequently identified as a Presidential Icon Project and has been accepted as such by the National Government.

Harnessing the water resources of the Mzimvubu River, the only major river in the country which is still largely unutilised, was considered by the Eastern Cape Government as offering one of the best opportunities in the province to achieve such development. In 2007, they therefore established a special-purpose vehicle (SPV) in terms of the Companies Act, the so-called AsgiSA-Eastern Cape (Pty) Ltd (AsgiSA-EC), to initiate planning and to facilitate and drive the development.

The five pillars on which the EC Provincial Government and AsgiSA-EC proposed to build the Mzimvubu Development Project are:

- Afforestation;
- Irrigation;
- Hydropower;
- Water transfer; and
- Tourism.

In 2006 the DWAF Directorate: National Water Resource Planning appointed PSPs to assist in the provision of water-related support to the Eastern Cape Provincial Government (later AsgiSA-EC after its establishment). The main component of the task was supposed to be direct water resource planning inputs to specific development projects, for example an irrigation project, that AsgiSA-EC may identify and want to pursue as a poverty alleviation project. As a secondary component the DWAF undertook to provide some general water resource information which could facilitate the identification of other potentially viable projects by AsgiSA-EC. Work in this regard commenced in December 2006.

1.2 STUDY AREA

This report on the water resources assessment was conducted for the Mzimvubu River catchment.

AsgiSA-EC is focused on upliftment in a larger area, the "Mzimvubu Development Zone", which covers not only the Mzimvubu River catchment, but also neighbouring areas such as the Pondoland area to the north-east and parts of the Mthatha River catchment to the south-west.

Some tasks, such as the irrigation assessment and ecological water requirements, were conducted for the Mzimvubu development zone and included the Pondoland and parts of the Mthatha River catchment

The Mzimvubu River catchment study area and the Mzimvubu Development Zone are presented graphically in **Map A1** of **Appendix A**, and fall under the OR Tambo, Alfred Nzo, Sisonke and Ukhahlamba District Municipalities.

1.3 SUMMARY OF FINDINGS OF PREVIOUS STUDIES

Previous studies, including the ***Vaal Augmentation Planning Study***, were undertaken to investigate the possible transfer of water from the Mzimvubu River catchment to the Orange River and the Fish River to augment water supply in those areas. It was, however, found that transfers from the Lesotho Highlands Water Project Phase 2 and the Tugela-Vaal Water Project were more feasible and should be developed before the Mzimvubu River is used as source for water transfer to other catchments.

The relevant information gathered from previous studies that can be used in this study is reported on under the individual tasks.

1.4 PURPOSE OF THE REPORT

The purpose of this report is to present the generalised water resource availability and development potential assessed by the DWAF to assist the AsgiSA-EC initiatives. The conclusions reached and the recommendations made are therefore of an indicative nature and will be subject to further investigations and review for specific development project proposals.

The main tasks in providing an assessment of the generalised water resource availability and development potential are:

- Updating and refining the broad assessment of the water resources of the Mzimvubu River.
- Broad assessment of the irrigation potential in the Mzimvubu River catchment.
- Documentation of existing forestry developments and assistance with the assessment of further potential, which impact on the catchment hydrology.
- A first level assessment of possible dams.
- Indicative assessment of conventional hydropower potential.
- Identification of sites for possible pumped storage hydropower developments.
- Review of the previously identified potential for possible bulk transfer of water out of the catchment.

2 SURFACE WATER RESOURCES

2.1 HYDROLOGY

2.1.1 General

The hydrology for the Mzimvubu River system was updated as part of the Water Resources 2005 Study (WR2005).

2.1.2 Rainfall

Rainfall in the catchment is significantly higher than the South African average. Rainfall ranges from above 1 000 mm at the coast and against the mountainous Drakensberg, to between 700 and 800 mm in the upper plateau region. The rainfall is presented graphically in **Map A2** of **Appendix A**. The water resource modelling for this study used Mean Annual Precipitation (MAP) figures per quaternary catchment from the WR2005 study, which are presented in **Table 2.1**. Quaternary catchments (runoff units) are presented in **Map A3** in **Appendix A**.

2.1.3 Evaporation

Annual evaporation ranges from 1 150 mm at the coast to 1 400 mm inland. The mean annual evaporation (MAE) isohyets are displayed in **Map A2** of **Appendix A**. The MAE per quaternary catchment for the Mzimvubu River catchment is also included in **Table 2.1**.

2.1.4 Streamflow

The natural (virgin) streamflows for the Mzimvubu River and all its tributaries were updated as part of the hydrology assessment of the WR2005 study. These naturalised streamflows were assumed to be the best available streamflow data to be used for the water balance and yield modelling for the Mzimvubu catchment.

The total average streamflow for the whole Mzimvubu Catchment as given in the WR2005 report is 2 613 million m^3/a. This is a decrease of the total naturalised mean annual runoff (MAR) from the Water Resources 1990 (WR90) study of 219 million m^3/a (from 2 832 million m^3/a). This decrease is likely due to the extended record period of the WR2005 study. The average streamflow per quaternary is presented in **Table 2.2**.

Table 2.1 Average rainfall and evaporation per quaternary catchment

Quaternary catchment	MAP (mm)	Evaporation zone	MAE (mm)
T31A	907	29A	1 350
T31B	833	29A	1 350
T31C	830	29A	1 350
T31D	736	29A	1 350
T31E	756	29A	1 350
T31F	713	29A	1 350
T31G	801	29A	1 300
T31H	808	29A	1 300
T31J	807	29A	1 300
T32A	804	29A	1 300
T32B	814	29A	1 250
T32C	781	29A	1 200
T32D	789	29A	1 250
T32E	844	29A	1 200
T32F	924	29A	1 200
T32G	862	29A	1 200
T32H	892	29A	1 200
T33A	757	29A	1 350
T33B	801	29A	1 400
T33C	768	29A	1 400
T33D	736	29A	1 350
T33E	748	29A	1 350
T33F	829	29A	1 350
T33G	835	29A	1 300
T33H	780	29A	1 250
T33J	730	29A	1 200
T33K	856	29A	1 200
T34A	905	29A	1 400
T34B	860	29A	1 400
T34C	807	29A	1 400
T34D	850	29A	1 350
T34E	901	29A	1 400
T34F	875	29A	1 350
T34G	894	29A	1 350
T34H	863	29A	1 300
T34J	771	29A	1 250
T34K	715	29A	1 200
T35A	912	29B	1 400
T35B	915	29B	1 400
T35C	1 008	29B	1 400
T35D	818	29B	1 350
T35E	918	29B	1 350
T35F	860	29B	1 400
T35G	759	29B	1 400
T35H	845	29B	1 350
T35J	924	29B	1 300
T35K	783	29B	1 300
T35L	764	29B	1 250
T35M	861	29B	1 200
T36A	930	29B	1 200
T36B	1 029	29B	1 150

Table 2.2 Naturalised average annual streamflows per quaternary catchment

Quaternary catchment	WR90	WR2005
	(million m^3/a)	(million m^3/a)
T31A	37.8	32.73
T31B	36.9	31.33
T31C	37.3	31.88
T31D	30.3	24.97
T31E	47.8	39.92
T31F	45.4	37.04
T31G	24.9	20.15
T31H	75.7	64.81
T31J	49.4	52.84
T31	**385.5**	**335.67**
T32A	31.4	30.52
T32B	31.6	30.77
T32C	36.3	35.53
T32D	32.4	32.91
T32E	45.9	47.56
T32F	47.8	48.37
T32G	56.3	57.16
T32H	65.1	66.03
T32	**346.8**	**348.85**
T33A	67.7	97.37
T33B	68.3	94.27
T33C	36.2	51.52
T33D	42.2	61.01
T33E	24.4	20.54
T33F	55.7	51.90
T33G	70.2	60.93
T33H	45.7	46.08
T33J	35	35.60
T33K	22.3	22.35
T33	**467.7**	**541.57**
T34A	50.6	41.13
T34B	45.3	35.90
T34C	44.2	33.92
T34D	64.4	52.17
T34E	55.4	45.20
T34F	48.1	39.50
T34G	68.8	57.72
T34H	109.8	91.25
T34J	26.4	27.27
T34K	24.7	25.90
T34	**537.7**	**449.96**
T35A	109.8	92.36
T35B	92.3	78.09
T35C	88.6	86.77
T35D	65.2	52.86
T35E	120.4	102.86
T35F	72.0	58.16
T35G	85.6	64.04
T35H	104.6	84.58
T35J	48.5	40.26
T35K	111.1	86.05
T35L	28.8	29.01
T35M	42.0	42.25
T35	**968.9**	**817.29**
T36A	68.4	65.19
T36B	57.8	55.15
T36	**126.2**	**120.34**
Total	**2 832.8**	**2 613.68**

2.2 EXISTING WATER RESOURCES INFRASTRUCTURE

2.2.1 Existing dams

Existing dams in the Mzimvubu River catchment are limited in size and predominantly distributed in the old Natal and Eastern Cape regions of the catchment. There are 10 dams which have been identified as dams to be modelled individually, as they are either DWAF dams, or support communities with water supply and not just individuals or single farm dams. The purpose of including the dams individually in the WRYM analysis was to include more detail were available, so that water use in the catchment as a whole is more accurately represented. As such the water balances of these dams included individually should not be taken as a sufficiently accurate assessment of the local water resource to be used for detailed planning for water supply to local towns or villages.

The existing community-based dams in the Mzimvubu River catchment included in the WRYM input data files are listed in **Table 2.3**, and their locations presented in **Map A4** of **Appendix A**.

Table 2.3 Existing community-based dams in the study area

Name	Quaternary catchment	Supply water to	River	Nearest town	Capacity (million m^3)	Surface area (km^2)
Mountain Lake	T31H	Matatiele	Mvenyane	Matatiele	1.65	0.55
Crystal Springs	T32C	Kokstad	Mzintlava	Kokstad	2.14	0.29
Mountain Dam	T33A	Matatiele	Keneka	Matatiele	1.08	0.14
Belfort Dam	T33A	Maluti Scheme	Mafube	None	0.54	0.12
Ntenetyana	T33G	Kwa Bacha Scheme	Ntenetyana	-	1.85	0.27
Ugie Dam	T35F	Ugie Town	Wildebees	Ugie	0.38	0.16
Nquadu Dam	T35K	Sidwadeni Scheme	Nqadu	Tsolo	1.44	0.24
Majola Dam	T36B	Irrigation	Ntshongweni		0.40	0.08
Mount Fletcher Dam	T34C	Former Townships & Mount Fletcher	-	Mount Fletcher	0.50	0.14
Maclear Dams (1)	T35D	Former Townships & Maclear	-	Maclear	0.14	0.06
Forest Dam	T33H	Ntabankulu	-	Ntabankulu	0.20	0.05

So-called farm dams were also included in the WRYM setup to include the effect of irrigation from farm dams, as well as the effect of multiple small dams' regulation in streamflow and loss of water by evaporation from the dam surfaces. The subsequent result is a reduction in water yield from water resource developments downstream of these dams.

In many cases a quaternary catchment had multiple farm dams. These were consolidated into a single water body and included in the WRYM as a dummy dam. Very little information on capacities was available for the farm dams. The total surface area of farm dams per quaternary catchment could be measured using GIS. These surface areas of the farm dams were converted to capacities using a capacity to surface area ratio derived from dams with known capacities in the catchment and adjacent catchments. A ratio of 2.5 between capacity (m^3) and surface area (m^2) was used for the old Natal and Eastern Cape regions of the catchment and a ratio of 3 was used for the old Transkei region of the catchment.

The total number of smaller existing farm or privately owned dams in the catchment is 924 with a combined surface area of 11.7 km^2 and a total storage capacity of approximately 34 million m^3.

The dummy dams per quaternary catchment used to represent farm dams in the Mzimvubu basin are listed in **Table 2.4**.

Table 2.4 Existing minor farm dams in the Mzimvubu River catchment

Quaternary catchment	Number of dams	Capacity (million m^3)	Surface area (km^2)
T31A	5	0.09	0.031
T31B	106	10.00	3.333
T31C	25	0.86	0.285
T31D	41	2.92	0.975
T31E	37	1.04	0.346
T31F	49	3.65	1.218
T31G	19	0.37	0.122
T31J	47	0.98	0.328
T32A	109	3.34	1.113
T32B	39	1.24	0.414
T32C	28	0.72	0.529
T32D	41	1.53	0.509
T33H	11	0.01	0.003
T33J	1	0.01	0.004
T34H	4	0.02	0.008
T34J	16	0.08	0.031
T35B	8	0.28	0.092
T35C	5	0.13	0.043
T35D	58	0.62	0.208
T35E	8	0.29	0.095
T35F	13	0.43	0.144
T35G	139	3.80	1.268
T35H	25	0.62	0.249
T35J	9	0.11	0.044
T35K	68	0.71	0.285
T35L	13	0.14	0.057
Total	**924**	**34.0**	**11.7**

2.2.2 Existing water supply schemes

The results of this task of the study have been presented in a stand-alone report entitled ***Existing Water Supply Infrastructure Assessment***, report no. P WMA 12/000/00/3609, Volume 1 of 5. A concise overview of the work conducted in the report is included below.

The purpose of this task was to identify, describe and map all existing and planned bulk and potable water supply infrastructure in the Mzimvubu Catchment Area by means of a desktop study. However, as a result of future planned projects by the DWAF to evaluate all water supply infrastructures as part of the ***All Towns Reconciliation Strategy Study***, it was concluded that this task would be reduced and only the information collated to the middle of 2008 would be presented to prevent duplication of work. The information that has been collated to date will be of benefit to future study teams who will be carrying out a full infrastructure assessment. The report also presents sources of information, details of information available, and notes the information gaps determined.

A synopsis of the history of water development in the study area, which was substantially part of the former Transkei, has been included as this aspect has a bearing on the present status of water infrastructure.

All sources of information used in establishing the database are discussed. Reliance has been placed on information provided in GIS format from the DWAF and the Water Service Development Plans. No Water Board has as yet been established in the study area.

The amount of information available regarding the existing and planned water infrastructure varies in terms of quantity and quality. All information from the various sources has been noted in the relevant sections with no field verification of the data.

No inter-basin transfers of water were identified except parts of the Libode Region inside the study area which are supplied with water from the adjacent catchment.

The water supply infrastructure for the 210 identified water supply schemes are presented on a District Municipality basis, as the District Municipalities are also functioning as the Water Services Authorities and most information sources are split either by a District Municipality or a Local Municipality.

The raw information that has been gathered from different sources has not been verified. Some key contact persons have been identified, which will assist in the collection of outstanding information, and for the DWAF ***All Towns Reconciliation Strategy Study***.

Whilst the original objective of this task to identify the existing and planned water supply infrastructure in the catchment area has largely not been achieved, there is a fair amount of spatial information available, although the actual details of capacities and sizes were not available. Hence there are substantial gaps in the collected information. All data collected has been presented with the goal of simplifying the tasks of future researches into the details of existing infrastructure.

Existing water supply as well as rail and road infrastructure are presented in **Map A5** in **Appendix A**.

3 GROUNDWATER ASSESSMENT

The groundwater task is currently being undertaken and a stand-alone report will be produced.

4 WATER REQUIREMENTS

The water requirements for 2005 (taken as the current requirements) have been included in this report to give an indication of current water usage in the catchment and also to provide an indication of how much of the water resource is still available for possible further development and use.

4.1 DOMESTIC WATER REQUIREMENTS

Information on domestic water use within the catchment was obtained from the following sources.

- DWAF
- Water Service Development Plans (WSDP)
- National Water Resource Strategy
- Internet

The information on domestic water use within the catchment is limited. As such, the water use data was augmented by calculations using urban and rural population figures and their associated distributions, and water consumption per capita.

Two detailed databases on populations within the relevant municipalities (obtained from the Water Service Development Plans) were used to calculate the water use. Final population figures are summarised in **Table 4.1**. These figures compare well with those of the ***National Water Resources Strategy*** of 1 052 896, and the ***DWAF Population Database*** of 1 184 823.

Table 4.1 Summary of population in the Mzimvubu River catchment

User sector	Population (2005)
Urban	99 011
Rural	1 033 594
TOTAL	**1 132 605**

The population figures for each quaternary catchment were multiplied with the urban and rural unit consumption rates presented in **Table 4.2**. These consumption figures were obtained from the ***National Water Resource Strategy***.

Table 4.2 Basic human unit consumption in the Mzimvubu River abstracted from the National Water Resource Strategy

User sector	Per capita consumption (2005) (ℓ/c/d)
Rural	25
Urban	87

No provision was made for return flows from urban and rural abstractions as there are only a few waste water treatment works within the catchment, and where these exist little or no information is available. The total effect of return flows on the hydrology is also assumed to be negligible. The total urban and rural domestic water requirements per quaternary catchment for the year 2005 are presented in **Table 4.3**.

4.2 INDUSTRIAL WATER REQUIREMENTS

There are no industries within the study area that are not supplied with water through the existing municipal water supply systems.

4.3 MINING WATER REQUIREMENTS

There are no significant mining activities in the Mzimvubu River catchment.

4.4 LIVESTOCK AND WILDLIFE WATER REQUIREMENTS

The annual livestock and wildlife water requirement figure was obtained from the ***National Water Resources Strategy*** and is estimated at 0.9 million m^3. This requirement is very small compared to the total MAR and due to that, together with the poor spatial distribution associated with the data, it was not included in the Water Resources Yield Model (WRYM).

4.5 IRRIGATION WATER REQUIREMENTS

Irrigation water requirements are strongly linked to land tenure systems present in the catchment. On the basis of land tenure, the catchment can be roughly divided into two sectors. Sector one is the old Natal and Eastern Cape regions of the catchment outside of the former Transkei borders. Sector two is the former Transkei region of the catchment.

Sector one is characterised by commercial agricultural and irrigation operations, and freehold land tenure. Sector two, the old Transkei regions of the catchment, is characterised by state owned land mostly administered through the tribal land tenure system, and subsistence agriculture. The spatial extent of the two sectors is presented graphically in **Map A1** in **Appendix A**.

Hawkins Associates (1980) determined agro-ecological units for the catchment by selecting rainfall as the over-riding control and delineating sub-units according to temperature regime and relief.

Table 4.3 Urban and rural domestic water requirements (2005)

Quaternary catchment	Urban		Rural		Total domestic (Urban + rural) (million m^3/a)
	Urban population	Water use (million m^3/a)	Rural population	Water use (million m^3/a)	
T31A	0	0.000	236	0.002	0.002
T31B	0	0.000	1 121	0.010	0.010
T31C	0	0.000	14 879	0.136	0.136
T31D	0	0.000	4 351	0.040	0.040
T31E	0	0.000	14 565	0.133	0.133
T31F	1 925	0.061	5 643	0.052	0.113
T31G	0	0.000	835	0.008	0.008
T31H	0	0.000	32 859	0.300	0.300
T31J	0	0.000	17 273	0.158	0.158
Sub-total T31	**1 925**	**0.061**	**91 762**	**0.838**	**0.899**
T32A	0	0.000	4 598	0.042	0.042
T32B	0	0.000	3 354	0.031	0.031
T32C	21 036	0.668	7 586	0.069	0.738
T32D	0	0.000	2 992	0.027	0.027
T32E	0	0.000	34 829	0.318	0.318
T32F	3 403	0.108	22 761	0.208	0.316
T32G	0	0.000	45 725	0.418	0.418
T32H	3 085	0.098	37 868	0.346	0.444
Sub-total T32	**27 524**	**0.875**	**159 713**	**1.458**	**2.333**
T33A	5 371	0.171	84 566	0.772	0.943
T33B	0	0.000	33 195	0.303	0.303
T33C	0	0.000	16 388	0.150	0.150
T33D	0	0.000	37 306	0.341	0.341
T33E	0	0.000	16 201	0.148	0.148
T33F	0	0.000	23 892	0.218	0.218
T33G	0	0.000	30 271	0.276	0.276
T33H	11 000	0.350	45 188	0.413	0.762
T33J	1 392	0.044	36 900	0.337	0.381
T33K	0	0.000	16 384	0.150	0.150
Sub-total T33	**17 763**	**0.564**	**340 291**	**3.107**	**3.672**
T34A	0	0.000	7 353	0.067	0.067
T34B	0	0.000	12 449	0.114	0.114
T34C	3 350	0.106	13 089	0.120	0.226
T34D	6 973	0.222	14 413	0.132	0.353
T34E	0	0.000	0	0.000	0.000
T34F	0	0.000	5 129	0.047	0.047
T34G	0	0.000	14 013	0.128	0.128
T34H	2 723	0.087	48 957	0.447	0.534
T34J	0	0.000	27 365	0.250	0.250
T34K	1 075	0.034	29 496	0.269	0.303
Sub-total T34	**14 121**	**0.449**	**172 264**	**1.573**	**2.022**
T35A	0	0.000	9 558	0.087	0.087
T35B	0	0.000	0	0.000	0.000
T35C	13 850	0.440	0	0.000	0.440
T35D	0	0.000	8 898	0.081	0.081
T35E	296	0.009	28 764	0.263	0.272
T35F	5 456	0.173	0	0.000	0.173
T35G	0	0.000	5 687	0.052	0.052
T35H	0	0.000	31 365	0.286	0.286
T35J	0	0.000	19 392	0.177	0.177
T35K	15 047	0.478	62 087	0.567	1.045
T35L	2 306	0.073	26 753	0.244	0.318
T35M	0	0.000	20 859	0.190	0.190
Sub-total T35	**36 955**	**1.174**	**213 363**	**1.948**	**3.123**
T36A	0	0.000	32 140	0.293	0.293
T36B	723	0.023	24 061	0.220	0.243
Sub-total T36	**723**	**0.023**	**56 201**	**0.513**	**0.536**
Total	**99 011**	**3.146**	**1 033 594**	**9.438**	**12.584**

For the purposes of this study the original agro-ecological units system was modified to produce seven agro-ecological zones. These zones have been based mainly on the physiographic characteristics and rainfall patterns of the catchment. Irrigation was chosen to be presented by agro-ecological zones, as it is the best description of the regions with similar cropping patterns. This was particularly relevant when assessing the future potential irrigation in the catchment.

A summary of the present irrigation water requirements by sectors and by agro-ecological zone are presented in **Table 4.4**. The spatial distribution of the existing irrigation is indicated graphically in **Map A6** in **Appendix A.** The stand-alone report on agriculture and irrigation also includes discussions on irrigation potential and is entitled ***Agricultural assessment and irrigation water use***.

Table 4.4 Summary of irrigation water requirements in the Mzimvubu River catchment

<table>
<tr><th colspan="6">Irrigation area and water use</th><th rowspan="3">Water use (million m³/a)</th></tr>
<tr><th rowspan="2">Sector</th><th rowspan="2">Zone*</th><th rowspan="2">Production centers</th><th rowspan="2">Tertiary catchment</th><th>Area</th><th>Crops</th></tr>
<tr><th>(ha)</th><th>(% total irrigated area)</th></tr>
<tr><td rowspan="2">1
(Old Natal and Eastern Cape regions)</td><td>2a</td><td>Cedarville/ Kokstad/ Franklin/ Swartberg</td><td>T31 & T32</td><td>6 553</td><td>Pastures (75%)
Maize (20%)
Vegetables (5%)</td><td>35.0</td></tr>
<tr><td>3</td><td>Ugie/ Maclear</td><td>T32 & T35</td><td>3 418</td><td>Pastures (75%)
Potatoes (25%)
Maize (20%)</td><td>17.8</td></tr>
<tr><td rowspan="2">2
(Old Transkei region)</td><td>2a, 3, 4</td><td>Mount Frere/ Matatiele/ Thabankulu/ Qumbu</td><td>T33 & T34</td><td>788</td><td>Vegetables (50%)
Maize (50%)</td><td>2.2</td></tr>
<tr><td>5</td><td>Port St Johns</td><td>T36</td><td>100</td><td>Fruit trees (60%)
Vegetables (40%)</td><td>0.4</td></tr>
<tr><td colspan="4">Total Irrigation</td><td>10 859</td><td></td><td>55.4</td></tr>
</table>

* ***Zones*** refers to agro-ecological zones which are regions in which common cropping patterns and climate occur

4.6 AFFORESTATION WATER REQUIREMENTS

Commercial forestry has been declared a streamflow reduction activity and reduces baseflow in rivers. Existing forestry water use needs to be considered before additional yields from water resources are determined for potential developments, so as not to over utilise water resources and impinge on the ecological water requirements (EWR).

Forestry has been identified as a development and poverty alleviation activity in the region. Water use by potential new forestry therefore needs to be determined so that new forestry developments themselves do not over utilise the available water resources and in particular impinge on the EWR.

Commercial forestry covers approximately 485 km^2 in the Mzimvubu River catchment and uses an average of 43 million m^3/a. This is an average water use of approximately 835 $m^3/ha/a$ by commercial forestry. The majority of the afforestation occurs in the south-west part of the catchment around the towns of Ugie and Maclear.

A summary of the present afforestation per quaternary catchment and the associated water requirements are presented in **Table 4.5** and the spatial distribution is presented graphically in **Map A7** in **Appendix A**.

Present and future potential forestry in the Mzimvubu River catchment are discussed in more detail in the ***Main Report***, DWAF report number P WMA 12/000/00/3609.

4.7 ALIEN VEGETATION WATER REQUIREMENTS

Invasive alien vegetation, particularly in the riparian zones also causes a reduction of baseflow in rivers. The areas of invasive alien vegetation in the Mzimvubu catchment were obtained from the WR2005 study report, and the effects of the alien vegetation on water resources were included in this study's water balance model.

The total area covered by invasive alien vegetation in the catchment is estimated at 226 km^2, and uses approximately 24 million m^3 of water per annum. This is a significant impact on water resources of the catchment, and equal to approximately half of the water use of commercial forestry.

The areas and associated water use of invasive alien vegetation per quaternary catchment are included in **Table 4.6**. Clearing of alien vegetation could provide water for other uses such as forestry in more water stressed areas of the catchment.

4.8 ECOLOGICAL WATER REQUIREMENTS

Ecological Water Requirements refer to the estimated streamflow that needs to be maintained in a river to support ecological ecosystems in the river, as well as basic human needs. The ecological water requirements (EWR) for input into the water balance model have been determined at a desktop level for the Mzimvubu catchment. The ecological water requirements will also be updated at a high level of confidence as part of a separate and ongoing environmental reserve study on the Mzimvubu River. The desktop level EWR determinations for the Mzimvubu River and the tables used to calculate the provisionally recommended reserve levels for further studies are presented in more detail in **Appendix B**.

The EWR takes the current ecological status (category) of the river and the present water uses into account, to determine the flow requirements for a river.

The total EWR requirements for the Mzimvubu River are provisionally estimated at 880 million m^3/a, which is approximately 33% of the total MAR. 530 million m^3/a of this is required as low flows.

Table 4.7 lists the ecological category and associated EWR requirements for each quaternary catchment and potential dam in the Mzimvubu, as required for input into the WRYM.

Table 4.5 Existing afforestation and associated water requirements (2007)

Quaternary catchment	Area (km^2)		Water use	
	(2008)	Total	(million m^3/a)	(m^3/ha/a)
T31A	9.00	10.6	0.68	756
T31B	1.10		0.08	749
T31C	0.00		0.00	0
T31D	0.00		0.00	0
T31E	0.50		0.03	674
T31F	0.00		0.00	0
T31G	0.00		0.00	0
T31H	0.00		0.52	746
T31J	0.00		0.00	0
T32A	0.90	25.0	0.14	657
T32B	0.00		0.00	0
T32C	5.40		0.56	546
T32D	0.00		0.00	0
T32E	0.00		0.00	0
T32F	4.80		0.64	874
T32G	8.00		0.79	663
T32H	5.90		0.53	774
T33A	0.00	10.4	0.00	0
T33B	0.00		0.00	0
T33C	0.00		0.00	0
T33D	0.00		0.00	0
T33E	0.00		0.00	0
T33F	4.90		0.31	730
T33G	1.50		0.13	884
T33H	2.50		0.35	580
T33J	1.50		0.07	671
T33K	0.00		0.00	0
T34A	0.00	76.1	0.00	0
T34B	0.90		0.09	1 027
T34C	0.00		0.00	0
T34D	1.10		0.29	1 058
T34E	5.60		0.34	888
T34F	0.00		0.00	0
T34G	7.30		0.31	859
T34H	58.90		4.38	811
T34J	2.30		0.17	696
T34K	0.00		0.00	0
T35A	33.09	361.0	3.20	968
T35B	24.45		2.40	981
T35C	54.09		6.59	1 219
T35D	17.77		1.53	857
T35E	1.02		0.12	1 166
T35F	86.08		7.41	860
T35G	62.00		4.12	665
T35H	29.20		2.51	860
T35J	19.00		1.97	1 012
T35K	32.20		2.77	858
T35L	2.10		0.03	691
T35M	0.00		0.00	0
T36A	0.90	0.9	0.05	1 077
T36B	0.00		0.00	0
TOTAL	**484**	**484**	**43**	**Average 834**

Table 4.6 Invasive alien vegetation and its associated water use (2005)

Quaternary catchment	Area		Water requirement	
	(km²)	Total	(million m³/a)	(m³/ha/a)
T31A	1.6	65.5	0.20	1 224
T31B	2.0		0.17	853
T31C	5.8		0.64	1 095
T31D	1.1		0.08	707
T31E	13.8		0.88	639
T31F	5.0		0.31	612
T31G	4.5		0.43	964
T31H	28.9		2.38	822
T31J	2.8		0.29	1 042
T32A	7.0	74.4	0.46	663
T32B	12.6		1.26	1 002
T32C	12.1		1.02	845
T32D	10.0		0.94	938
T32E	13.9		1.73	1 242
T32F	2.1		0.27	1 295
T32G	8.4		0.82	972
T32H	8.3		0.81	976
T33A	17.3	33.6	2.51	1 449
T33B	1.0		0.16	1 566
T33C	0.6		0.08	1 404
T33D	22.7		3.00	1 323
T33E	0.0		0.00	0
T33F	2.3		0.20	883
T33G	0.5		0.04	811
T33H	2.9		0.22	753
T33J	3.6		0.23	640
T33K	0.0		0.00	0
T34A	0.0	27.3	0.00	0
T34B	1.0		0.12	1 159
T34C	0.0		0.00	0
T34D	1.3		0.14	1 064
T34E	6.7		0.77	1 149
T34F	9.4		1.56	1 659
T34G	0.6		0.07	1 112
T34H	8.3		0.84	1 014
T34J	0.0		0.00	0
T34K	0.0		0.00	0
T35A	1.8	6.0	0.25	1 389
T35B	0.0		0.00	0
T35C	0.0		0.00	0
T35D	0.0		0.00	0
T35E	0.0		0.00	0
T35F	0.0		0.00	0
T35G	0.0		0.00	0
T35H	0.0		0.00	0
T35J	0.8		0.06	766
T35K	3.4		0.47	1 377
T35L	0.0		0.00	0
T35M	0.0		0.00	0
T36A	0.0	1.5	0.00	0
T36B	1.5		0.31	2 081
Total	**225.6**	**208.3**	**23.72**	**Average 1 051**

Table 4.7 Ecological category and associated preliminary EWR

Quaternary catchment	MAR	Total MAR	Ecological category	EWR low flow requirement	Total EWR requirement	EWR % of MAR	Comments
	(million m³/a)			(million m³/a)			
T31A	32.7	32.7	A	12.4	19.0	58	
T31B	31.3	31.3	B	7.6	12.6	40	
T31C	31.9	95.9	B	23.2	38.5	40	
T31D	25.0	120.9	B	29.3	48.4	40	
T31E	39.9	39.9	B	9.7	16.0	40	
T31F	37.0	197.9	A	75.0	115.3	58	
T31G	20.2	218.0	C	30.8	58.2	27	
T31H	64.8	64.8	B	12.6	22.6	35	
T31J	52.8	240.0	A/B	61.7	106.1	44	D/s of Dam 2
T31	**335.6**		**A/B**	**83.0**	**142.5**	**42**	**Outlet of T31J**
T32A	30.5	30.5	B	5.8	9.6	31	
T32B	30.8	61.3	C	6.7	12.9	21	
T32C	35.5	96.8	B/C	23.2	34.0	35	
T32D	32.9	129.7	C	14.6	27.5	21	D/s of Bokpoort Dam
T32E	47.6	177.3	C	19.8	37.5	21	
T32F	48.4	196.6	C	21.8	41.5	21	D/s of Luzi site
T32F_1		225.7	C	24.7	47.5	21	
T32G	57.2	282.8	C	30.3	59.2	21	D/s of Dam B site
T32H	66.0	348.9	C	36.8	72.7	21	
T32	**348.9**		**C**	**36.8**	**72.7**	21	**Tertiary T32**
T33A	97.4	97.4	C	10.5	20.4	21	
T33B	94.3	94.3	C	9.5	19.4	21	
T33C	51.5	51.5	D	2.4	6.9	13	
T33D	61.0	304.2	D	14.5	41.2	14	D/s of Thabeng site
T33E	20.5	324.7	C	34.1	67.6	21	D/s of Somabadi site
T33F	51.9	376.6	C	39.8	78.5	21	
T33G	60.9	728.3	C	86.7	163.4	22	D/s of Siqingeni site
T33G_1		407.1	C	43.1	84.9	21	D/s of Ntlabeni site
T33H	46.1	777.4	C	92.0	173.7	22	
T33J	35.6	813.0	C	95.9	181.2	22	
T33K	22.4	1 184.2	C	136.0	259.1	22	
T33	**541.6**		**C**				
T34A	30.5	30.5	C	5.7	10.6	35	
T34B	35.9	66.4	C	10.7	19.8	30	
T34C	33.9	100.3	C	15.3	28.6	29	
T34D	52.2	152.5	C	22.5	42.0	28	
T34E	45.2	45.2	C	5.5	11.5	25	
T34F	39.5	55.1	C	7.5	14.0	25	D/s of Pitseng site
T34F_1		237.2	C	34.2	63.9	27	D/s of Hlabakazi site
T34G	57.7	294.9	C	42.3	78.9	27	
T34H	91.2	331.4	C	47.3	88.1	27	D/s of Mpindweni site
T34J	27.3	396.4	B/C	78.3	131.9	33	D/s of Mangwaneni site
T34J_1		413.4	B/C	81.7	137.4	33	D/s of Ku-Mdyobe site
T34K	25.9	439.3	C	62.0	115.8	26	
T34	**439.3**			**62.0**	**115.8**	26	**Outlet of T34K**
T35A	92.4	92.4	C	12.7	23.6	26	
T35B	78.1	78.1	C	10.7	19.9	25	
T35C	86.8	86.8	C	11.9	22.1	25	
T35D	52.9	310.1	C	42.4	79.3	26	
T35E	102.9	407.8	C	55.8	104.0	26	D/s of Ntabelanga site
T35F	58.2	58.2	C	8.4	15.6	27	
T35G	64.0	122.2	B	31.1	49.4	40	
T35H	84.6	202.6	C	29.1	54.4	27	D/s of Nomhala site
T35J	40.3	247.0	C	35.4	66.3	27	
T35K	86.1	694.4	B/C	131.6	222.3	32	D/s of Malepelepe site
T35L	29.0	753.3	C	102.8	192.1	26	D/s of Laleni site
T35M	42.3	800.4	C	109.7	204.4	26	D/s of Gongo site
T35	**817.3**		**C**	**112.1**	**208.7**	26	**Outlet of T35M**
T36A	65.2	2 548.2	B	514.3	861.7	34	D/s of Mbokazi site
T36B	55.2	2 603.4	B	526.7	881.0	34	
T36	**120.4**						
Total	**2 603**			**526.7**	**881.0**	34	**Estuary**

This study differs from previous water resource related studies that focused on potential developments in the Mzimvubu River catchment, due to the inclusion of the EWR in the current water balance model and the yield and hydropower simulations.

4.9 SUMMARY OF STUDY AREA WATER REQUIREMENTS

A summary of the total water requirements of the study area is presented in **Table 4.8**. The total water abstraction which in the case of the Mzimvubu River catchment is almost all consumptive water use, is approximately 5% of the average annual streamflow of 2 613 million m^3/a. The ecological water requirements are provisionally estimated to require approximately 33% of the total streamflow to remain in the rivers.

Table 4.8 Summary of study area water requirements

User group	Volume (year 2005) (million m^3/a)
Urban	3
Rural	9
Industrial	0
Mining	0
Irrigation	55
Afforestation	43
Alien vegetation	24
Consumptive total	**134**
Ecological water requirements	881
Total (including EWR)	**1 015**

5 WATER RESOURCE DEVELOPMENT POTENTIAL

5.1 GENERAL

An insignificant portion of the available surface water resources in the Mzimvubu are currently being utilised. The rainfall and thus runoff in the catchment is seasonal, and to reliably utilise significant proportions of the runoff water, regulation and storage is required. The Mzimvubu River and its tributaries currently have very little regulation in the form of hydraulic structures.

Through the implementation of hydraulic structures the surface water resources of the Mzimvubu River could be utilised to supply water for potential developments. Water could be supplied to meet domestic needs, as well as industry and irrigation. The energy potential in the river flowing to the ocean could be harnessed as hydropower. The water could also be used by neighbouring regions where local resources are over utilised, provided the transfer of water is not too costly. This chapter explores at a low level of detail, the potential of developing the water resources through the implementation of dams which could be used for the above-mentioned purposes.

5.2 POTENTIAL DAMS ASSESSMENT

5.2.1 Potential dam sites

A number of possible dam sites have been identified in previous studies on the Mzimvubu River. Together with a few new sites identified from topographical maps, a total of 19 possible dam sites were included in this study. For the purpose of this report, the reservoirs that would be created by the possible dams will be referred to by the name of the dam site, derived from the name of the local area or village closest to the site.

The potential dam sites that have been considered in this study and included in the water resources yield assessment are listed in **Table 5.1**. The location of these dams is presented in **Map A8** of **Appendix A**.

Table 5.1 Potential dam sites with estimated 50-year sedimentation in the Mzimvubu River catchment

Catchment	River	Dam name	Mean annual runoff	Wall height for 1 x MAR capacity	Sedimentation 50 yrs	Dead storage level from bottom
			(million m^3)	(m)	(million m^3)	(m)
T31	Upper Mzimvubu	Dam 2	240	49	47	18
		Siqingeni	709	80	113	37
T32	Mzintlava	Bokpoort	130	60	24	30
		Luzi	198	63	33	26
		Dam B	282	93	43	36
T33	Kinira	Thabeng	307	53	31	26
		Somabadi	324	59	37	27
		Ntlabeni	396	65	47	28
T34	Tina	Pitseng	55	34	7	10
		Hlabakazi	248	57	28	18
		Mpindweni	337	56	38	23
		Mangwaneni	414	55	48	19
		Ku-Mdyobe	424	80 (*)	50	37
T35	Itsitsa	Nomhala	206	43	25	14
		Ntabelanga	403	53	35	12
		Malepelepe	696	42	68	18
		Laleni	755	62 (*)	75	26
		Gongo	800	100 (*)	81	58
T36	Mzimvubu	Mbokazi	2520	100 (*)	328	65

(*) Wall heights stated for dams of storage capacity less than 1 MAR due to geographical limitations

It must be noted that these are not all the potential dam sites in the Mzimvubu catchment, but have been included to be indicative of the more favourable sites in the catchment. Other potential sites may exist closer to future identified water users, and a more complete assessment will need to be made to determine the optimal dam site choice for each potential development. The best site will depend largely on the volume of the water required by the future potential developments. Smaller water requirements will most likely be better suited to be supplied from small off-channel dams, or dams on smaller tributaries.

Capacity curves for the potential dam sites are required for yield and hydropower assessments. These were generated using 1:50 000 maps and 20 m contours, and are presented in **Appendix C.** The capacity curves include dead storage levels based on sedimentation estimates for the dams. Sedimentation of reservoirs in the Eastern Cape is appreciable, and potential reservoirs in the Mzimvubu River tributaries are likely to also have significant sedimentation and corresponding impacts on storage and yield.

5.2.2 Sedimentation

Calculation of catchment sediment yield at a dam site requires a number of variables such as the hydrological characteristics of the catchment, geology, ground cover, land use and river mechanics to be taken into account. Sufficient information regarding the above-mentioned variables and how they change in time does not exist for the Mzimvubu catchment.

Sediment accumulation is recorded at a number of existing reservoirs throughout South Africa by the DWAF. The analysis of these measurements has made it possible to calculate average sediment yields and generate sediment yield maps for South Africa.

Sediment yields in the Mzimvubu have been estimated according to catchment size and sediment yield potential based on the latest sediment yield maps. In the absence of comprehensive measured data, sediment yield maps form a basis for catchment sediment yield estimation in the Mzimvubu River catchment.

A more detailed description of sedimentation in the Mzimvubu River catchment is included in **Appendix D**. The most likely foreseeable sediment yields at the potential dam sites were estimated at different levels of confidence. The recommended sedimentation volumes of the potential dams are provided in Table 5.1, and based on the 80% confidence level. These sedimentation volumes form the basis for estimation of dead storage levels to be assigned to the corresponding reservoirs.

Actual sedimentation rates of these dams, should any be constructed, could vary significantly from those in Table 5.1.

5.2.3 Yield assessment

The historic firm yields available from the potential dam sites were assessed with the Water Resources Yield Model (WRYM) to provide an indication of the volume of water that can be reliably abstracted from the dams. The historic firm yield is defined as the maximum annual water volume that can be abstracted from a dam without the dam failing once over the total historical hydrological record.

The total hydrological record period for the Mzimvubu River catchment was from 1920 to 2004. For the purpose of this study the annual abstraction was distributed evenly over the 12 months.

The schematic diagram of the WRYM set-up for the Mzimvubu River catchment is shown in **Appendix E**. The data files input into the model are included in **Appendix G (on CD).** The WRYM model analyses a system at constant development levels, i.e. the system infrastructure and the water requirements remain constant throughout the full simulation period. The Mzimvubu catchment was set up and analysed for the 2005 conditions, assumed to be the current day level.

The historic firm yields of the potential large dams in the Mzimvubu River catchment were calculated for each dam on its own, representing a single large dam development scenario. No combinations of potential dams were considered at this stage.

The historic firm yields from the potential dam sites have been calculated for three different gross reservoir capacity sizes, namely 0.5, 1 and 1.5 times the mean annual runoff (MAR) at the dam site. The reservoir capacities stated are before sedimentation and the net capacities will be reduced by the sedimentation assigned as dead storage. Where the topography at some specific possible dam sites can only accommodate the smaller reservoir capacity sizes, the dam wall heights were capped at 100 m for the analyses.

The results of the historic firm yield analyses are summarised in **Table 5.2** and presented graphically in **Figure 5.1**. The historic firm yields are presented <u>after</u> making water releases to satisfy the ecological water requirements (EWRs).

Table 5.2 Historic firm yields from potential dams on the Mzimvubu River catchment

Catchment	River	Dam name	Mean annual runoff (MAR)	Historic firm yield * (million m³/a)		
				Dam capacity		
				0.5 x MAR	1 x MAR	1.5 x MAR
T31	Upper Mzimvubu	Dam 2	240	26	56	73
		Siqingeni	709	184	289	
T32	Mzintlava	Bokpoort	130	24	37	53
		Luzi	198	46	72	93
		Dam B	282	82	125	135
T33	Kinira	Thabeng	307	102	144	174
		Somabadi	324	104	150	183
		Ntlabeni	396	138	187	227
T34	Tina	Pitseng	55	13	20	24
		Hlabakazi	248	62	93	108
		Mpindweni	337	84	125	149
		Mangwaneni	414	91	140	149
		Ku-Mdyobe	424	93	140	
T35	Itsitsa	Nomhala	206	43	76	90
		Ntabelanga	403	115	155	183
		Malepelepe	696	248	277	316
		Laleni	755	205	254	
		Gongo	800	148		
T36	Mzimvubu	Mbokazi	2520	563		

* Historic firm yields are presented <u>after</u> releases for provisional EWRs were made

The reduction in firm yield available as a result of making releases to satisfy the EWRs are summarised in **Table 5.3**. Again, the EWRs have been provisionally calculated at a desktop level and will need to be revised for more specific development options.

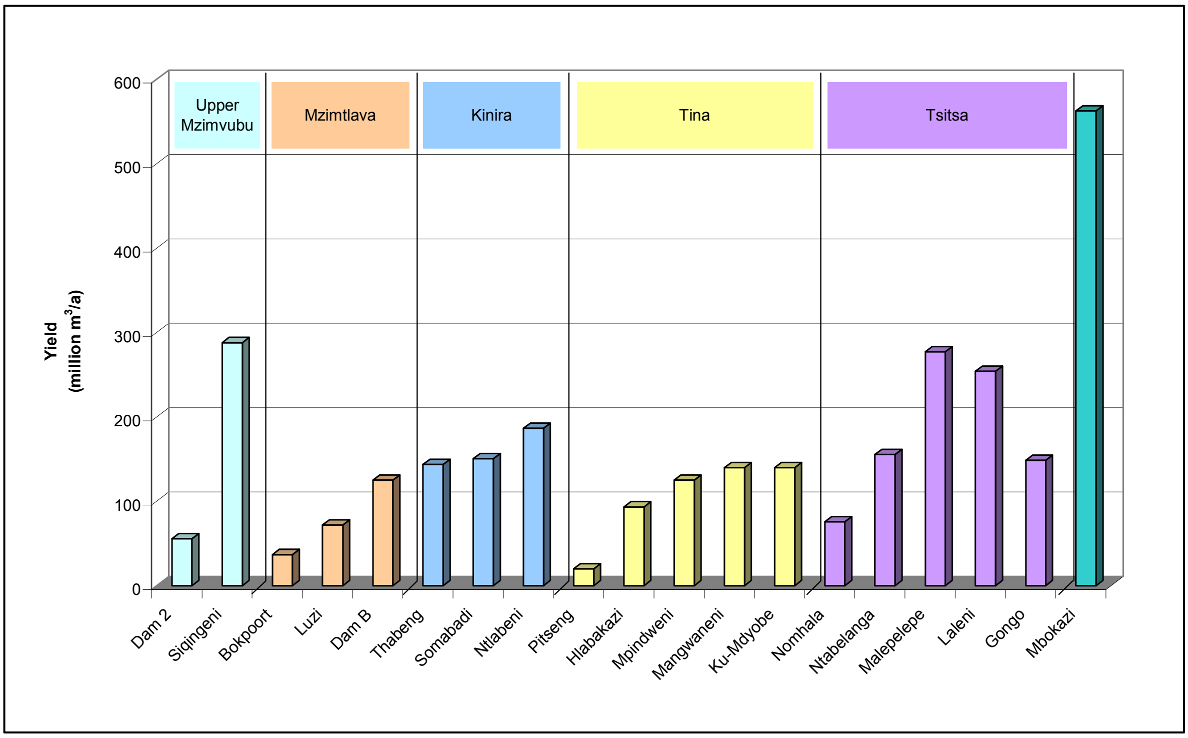

Figure 5.1 Firm yield estimates at potential dam sites in the Mzimvubu River catchment

Table 5.3 Impact of ecological water requirements on historic firm yields

Catch-ment	River	Dam name	Mean annual runoff (million m^3)	Total EWR (million m^3)	EWR as % of MAR	Percentage reduction in yield by EWR – Dam capacity (x MAR) 0.5	1	1.5
T31	Upper Mzimvubu	Dam 2	240	106	44	63	47	40
		Siqingeni	709	154	22	24	25	
T32	Mzintlava	Bokpoort	130	28	22	38	30	23
		Luzi	198	42	21	28	27	23
		Dam B	282	59	21	19	20	20
T33	Kinira	Thabeng	307	41	13	18	19	17
		Somabadi	324	68	21	20	22	19
		Ntlabeni	396	85	21	20	21	19
T34	Tina	Pitseng	55		0	34	32	29
		Hlabakazi	248	60	24	36	31	29
		Mpindweni	337	85	25	41	34	30
		Mangwaneni	414	133	32	45	38	37
		Ku-Mdyobe	424	138	33	45	38	
T35	Itsitsa	Nomhala	206	54	26	32	32	28
		Ntabelanga	403	104	26	28	31	28
		Malepelepe	696	177	25	29	30	28
		Laleni	755	192	25	26	28	
		Gongo	800	204	26	34		
T36	Mzimvubu	Mbokazi	2520	860	34	36		

5.2.4 Cost estimates of water

Capital costs were determined for the potential dams and unit reference values (URVs) of water were calculated. The URVs give an indication of the likely cost of water yielded from dams in the Mzimvubu River catchment, and allows comparison between the different dam sites.

The capital cost estimates were conducted at a desktop level of detail and based on maps with 20 m contours. The geological information available at potential dam sites is not at an equal level of detail and is very limited at many sites. As part of a previous study at a potential dam site which assessed the geology at a detailed level, exploratory drillings were conducted. Only general information gathered using geological maps is available at most dam sites.

To compare all dam sites on an equal basis, earthfill dams were provisionally assumed to be the most suitable in the Mzimvubu River catchment. This correlates with previous desktop studies which also suggested earthfill dams to be used.

Where the topography at particular dam sites limits spillway chute construction, roller compacted concrete (RCC) gravity dams were considered and costed. Further geological investigations will be needed to determine the most feasible dam types for specific sites.

The capital cost estimates of the dams are presented in **Table 5.4** and **Figure 5.2,** and are based on March 2008 prices.

Table 5.4 Cost estimates of potential dam sites in the Mzimvubu River catchment

River	Dam name	Dam cost estimate (R million)		
		Dam capacity		
		0.5 x MAR	1 x MAR	1.5 x MAR
Upper Mzimvubu	Dam 2	640	800	980
	Siqingeni	1 120	1 470	
Mzintlava	Bokpoort	630	910	1 110
	Luzi	660	880	1 100
	Dam B	1 140	1 980	2 310
Kinira	Thabeng	490	710	790
	Somabadi	520	760	850
	Ntlabeni	590	770	1 010
Tina	Pitseng	290	380	450
	Hlabakazi	380	640	870
	Mpindweni	520	640	810
	Mangwaneni	1 100	1 490	1 670
	Ku-Mdyobe	1 220	1 940	
Itsitsa	Nomhala	490	620	720
	Ntabelanga	350	420	470
	Malepelepe	840	1 000	1 120
	Laleni	940	1 170	
	Gongo	2 010		
Lower Mzimvubu	Mbokazi	2 070		

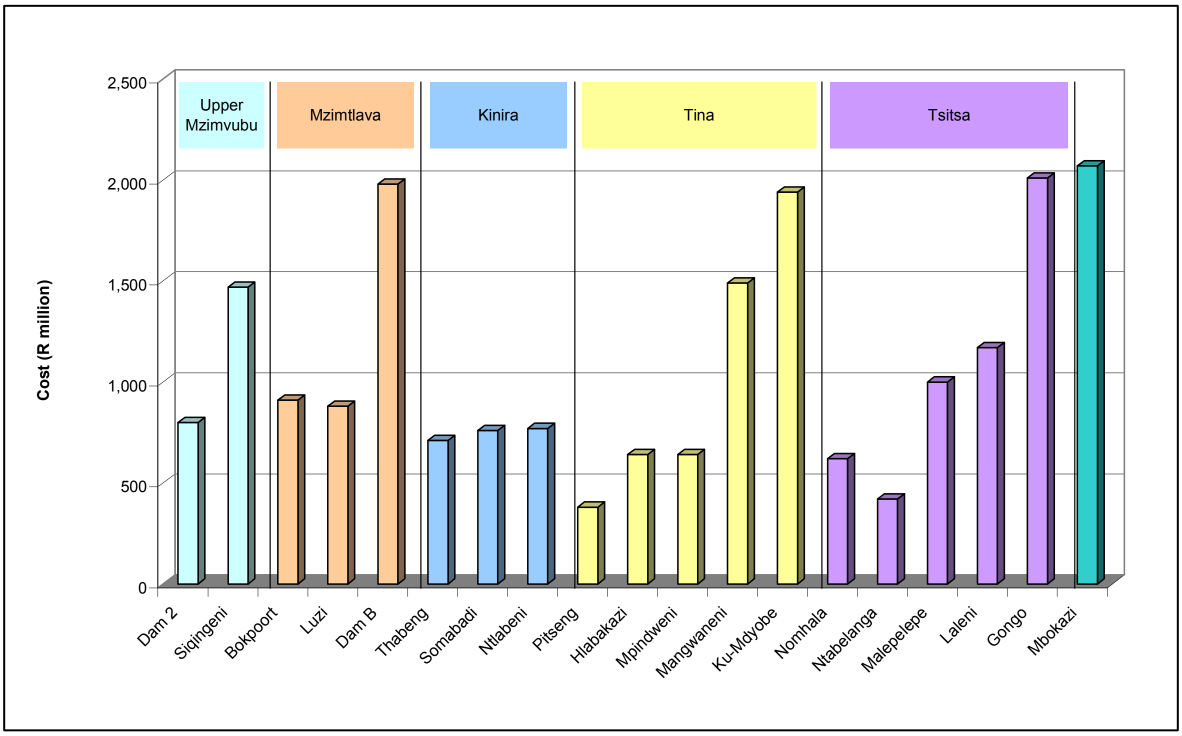

Figure 5.2 Cost estimates of potential large dams in the Mzimvubu River catchment

The costs estimates required assumptions to be made, and these, along with more detail on the cost estimates of dams, are described in **Appendix F**.

Unit reference values (URV) of the water have been calculated from the capital costs of the dams and their corresponding historic firm yields. The URVs provide an indication of the cost of the water. URVs have been calculated for a 45 year period, a discount rate of 8%, and with the construction of dams assumed to start in 2011 and finish in three years. The URVs are presented in **Table 5.5,** and in **Figure 5.3**.

The unit reference values of water at some of the dam sites are relatively low. These URVs, however, do not include the cost of distributing the water to the points of use. Due to the predominantly hilly topography in the catchment, the cost of distribution is likely to be high, particularly for water users remote from dam sites.

The cost of distributing water to potential users must be included if specific developments are identified, as it is likely to affect the feasibility of the development.

Table 5.5 Unit reference values of cost of water at potential dam sites in the Mzimvubu River catchment

Catchment	River	Dam name	Mean annual runoff (MAR)	Unit reference values (R/m³) Dam capacity 0.5 x MAR	1 x MAR	1.5 x MAR
T31	Upper Mzimvubu	Dam 2	240	3.70	2.10	2.00
		Siqingeni	709	0.90	0.80	-
T32	Mzintlava	Bokpoort	130	3.90	3.70	3.20
		Luzi	198	2.20	1.80	1.80
		Dam B	282	2.10	2.40	2.60
T33	Kinira	Thabeng	307	0.70	0.70	0.70
		Somabadi	324	0.80	0.80	0.70
		Ntlabeni	396	0.60	0.60	0.70
T34	Tina	Pitseng	55	3.40	2.90	2.80
		Hlabakazi	248	0.90	1.00	1.20
		Mpindweni	337	0.90	0.80	0.80
		Mangwaneni	414	1.80	1.60	1.70
		Ku-Mdyobe	424	2.00	2.10	-
T35	Itsitsa	Nomhala	206	1.70	1.20	1.20
		Ntabelanga	403	0.50	0.40	0.40
		Malepelepe	696	0.50	0.50	0.50
		Laleni	755	0.70	0.70	-
		Gongo	800	2.00	-	-
T36	Lower Mzimvubu	Mbokazi	2520	0.60	-	-

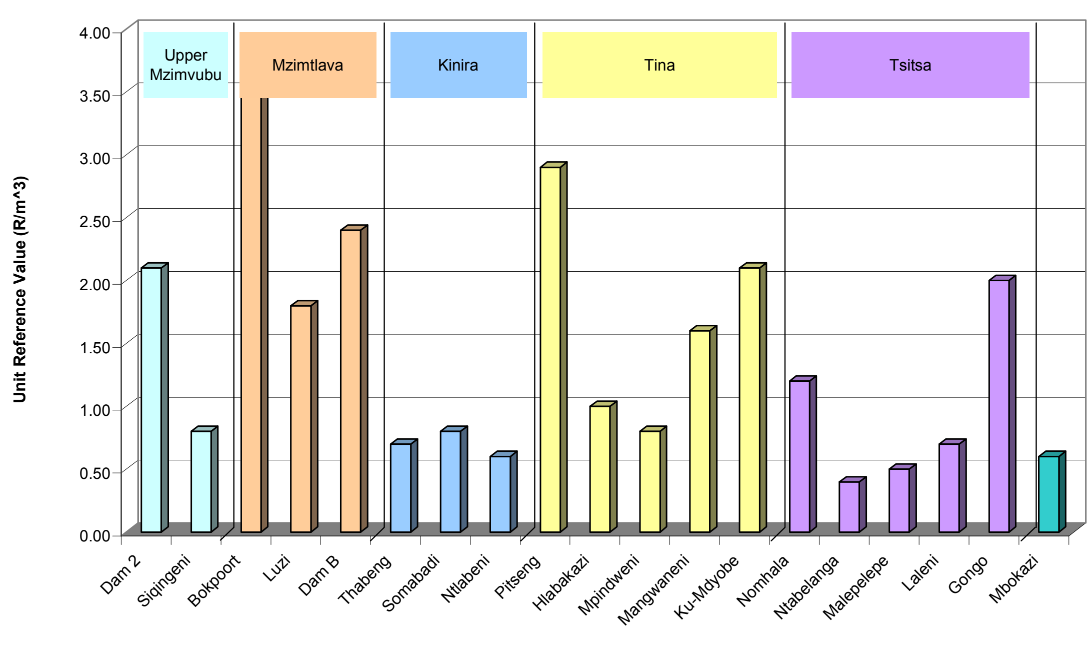

Figure 5.3 Unit reference value of water at potential 1 x MAR dam sites

5.3 WATER TRANSFER ASSESSMENT

5.3.1 General

Water transfers from the Mzimvubu River have been identified as a water resource development option that could utilise the water to supply surrounding regions. Regions that have been previously identified as possibly benefiting from water transfers from the Mzimvubu River are north to the Vaal River, east towards Durban and west towards the western parts of the Eastern Cape.

Water transfers to the Vaal River to augment the growing future demands can be made from catchments closer to the Vaal River such as the Senqu River and the Tugela River. The high cost of getting water from the Mzimvubu River to the Vaal River system makes this a less favourable option.

The catchments to the east of the Mzimvubu River, including the Mzimkhulu River, which are closer to Durban, still have capacity to service the growing water requirements of Durban and the local areas. Transfers to the east of the Mzimvubu River are not necessary in the foreseeable future.

Water requirements west of the Mzimvubu River, such as for East London, can also be met by the local river catchments. Irrigation in the western parts of the Eastern Cape could be expanded if water was made available at a feasible cost.

A previous report on the Mzimvubu River by ECH Sellick identified three possible transfer options towards the western parts of the Eastern Cape. The lowest cost option at that time was the Northern Transfer Option which transferred water over the divide into one of the headwaters of the Orange River, namely the Kraai River.

5.3.2 Mzimvubu River to western parts of the Eastern Cape transfer option

For the purpose of this report an option of transferring the water from a potential dam in the western part of the catchment to the headwaters of the Kraai River was assessed. The transfer layout is shown in **Map A11** in **Appendix A**. This is possibly the most favourable potential single dam development transfer scenario, similar to the previous Northern Transfer option. The chosen dam site at Ntabelanga has the potential to provide some of the cheapest water available in the Mzimvubu River. The dam site is also located high up in the catchment near to the western divide. A 90 km long, 2 m diameter steel pipeline would be required to transfer the water from the dam to the headwaters of the Kraai River. All other transfer options are likely to be more expensive and less viable.

With the construction of a dam at the potential site at Ntabelanga, 180 million m^3/a could be yielded from a reservoir of capacity 1.5 x MAR. Assuming most of the water is made available for transfer and a small portion is reserved for local supply, a total of 150 million m^3/a could be allocated for transfer.

The capital costs of the infrastructure are estimated to be R2 800 million for the pipelines, pump stations and the reservoir at Ntabelanga. The water needs to be pumped over the divide through a static height of 1 500 m. Including friction losses and the assumption of pumping 20 out of 24 hours, the total energy requirements to pump the water would be 130 MW. At an assumed total energy tariff of 30 cents per kWh, the annual energy cost would be approximately R280 million.

Conveyance losses of 1.2 m^3/s of water from the point of discharge in the Kraai River near Rhodes to the Orange River have been provided for. Of the 150 million m^3/s transferred over the divide, a net of 110 million m^3/a could be made available in the Orange River at a unit reference value of about R7/m^3.

The intention of the transfer would be to supply water to irrigators in the western parts of the Eastern Cape through the Orange-Fish Tunnel from Gariep Dam. At around R 7/m^3 this water, however, would most likely be far too expensive for irrigation. The unit cost does not include distribution infrastructure to the farms. Adding on the distribution infrastructure will further increase the cost of the water.

In summary, water transfers from the Mzimvubu River would be too expensive for agriculture in this region. Water transfers from the Mzimvubu River are therefore not foreseeable in the near future.

5.4 CONVENTIONAL HYDROPOWER POTENTIAL ASSESSMENT

5.4.1 Introduction

The modelling of water yield from potential dams in the catchment provided the opportunity to assess the hydropower potential at these dam sites. For simplicity, the potential for a single purpose hydropower development only, were assessed. Possible multipurpose developments could be investigated as more information on other development options becomes available.

The work conducted on the hydropower assessment has been presented in detail in a separate report on hydropower in the Mzimvubu River catchment, ***Assessment of potential for pumped storage and hydropower schemes***, report P WMA 12/000/00/3609, Volume 5 of 5. A summary is presented below.

5.5 HYDROPOWER POTENTIAL

The generation of hydropower was simulated with the WRYM. The firm hydropower available at a 99.5% assurance of supply for each potential dam site is presented in **Figure 5.4**.

The results are average monthly hydropower available and are presented as mega-watt continuous (MW_C), which is analogous to base load-power. This can be converted for load factor. A load factor of say 10% was assumed to be indicative of peaking power.

5.5.1 Estimates of hydropower cost

The costs of the power plants were estimated based on generating capacity and head, and were added to the cost estimates of the dams to determine the total hydropower scheme costs. The total base load and peaking hydropower scheme costs are presented in **Figure 5.5**.

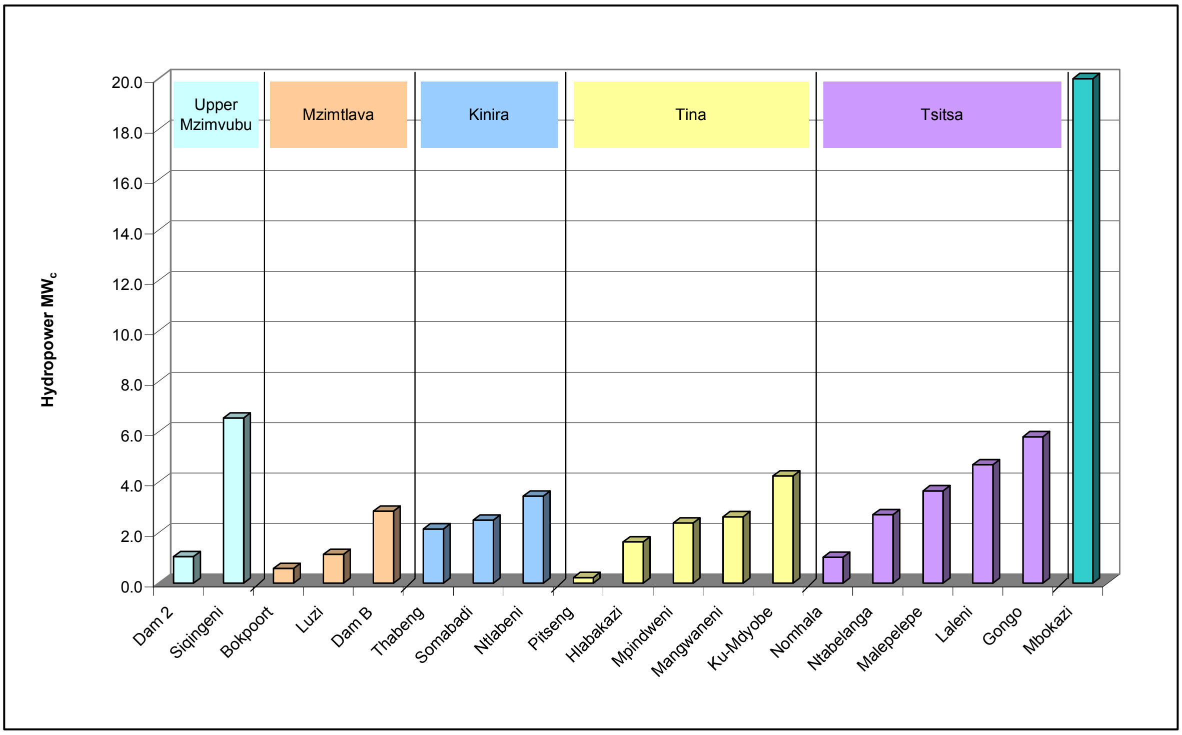

Figure 5.4 Firm hydropower available at potential dam sites

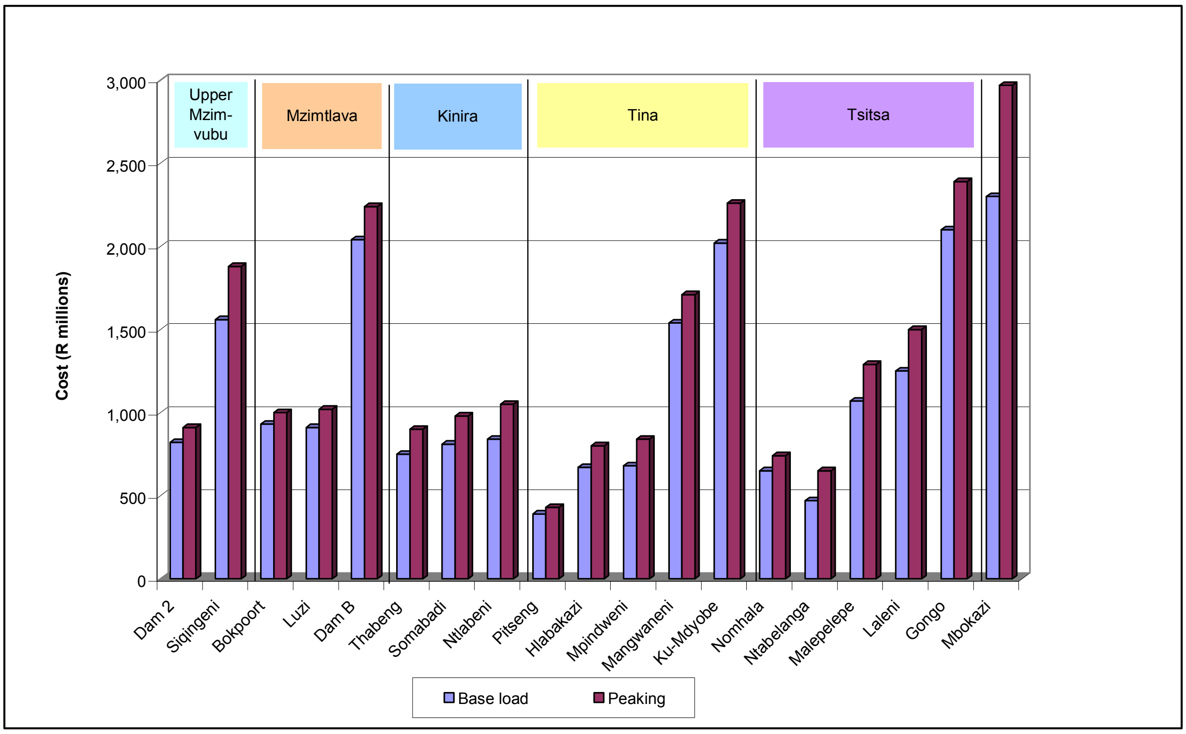

Figure 5.5 Total scheme costs for base-load and peaking hydropower generation at potential dam sites

The total scheme costs were converted to unit costs per installed generating capacity for comparative purposes. To compare the hydropower available at the potential dam sites, a scheme at the Tsitsa Falls, a site previously identified as showing the most potential in the catchment, was assessed. The Tsitsa Falls scheme incorporates a dam upstream of the falls and utilises the additional head at the falls to generate power.

The Tsitsa Falls scheme could produce an estimated 25 MW_C base load power at a unit cost of R100 million per MW_C, or 250 MW at a 10% load factor indicative of peaking power, at R16 million per MW.

A basic financial analysis was conducted to determine whether the capital cost of the Tsitsa Falls scheme could be off-set by the sales of hydropower. The preliminary results based on provisionally assumed prices for electricity of R0.30/kWh and R1/kWh for base-load and peaking power respectively, suggest that the Tsitsa Falls scheme is approximately double the cost that could be financed by the sales of electricity for base load. The scheme can only be financed by the sales of electricity at low discount rates for peaking power. The unit costs of the Tsitsa Falls scheme have been overlaid on the unit costs of hydropower at potential dam sites for base load in **Figure 5.6** and for peaking power in **Figure 5.7** for comparison.

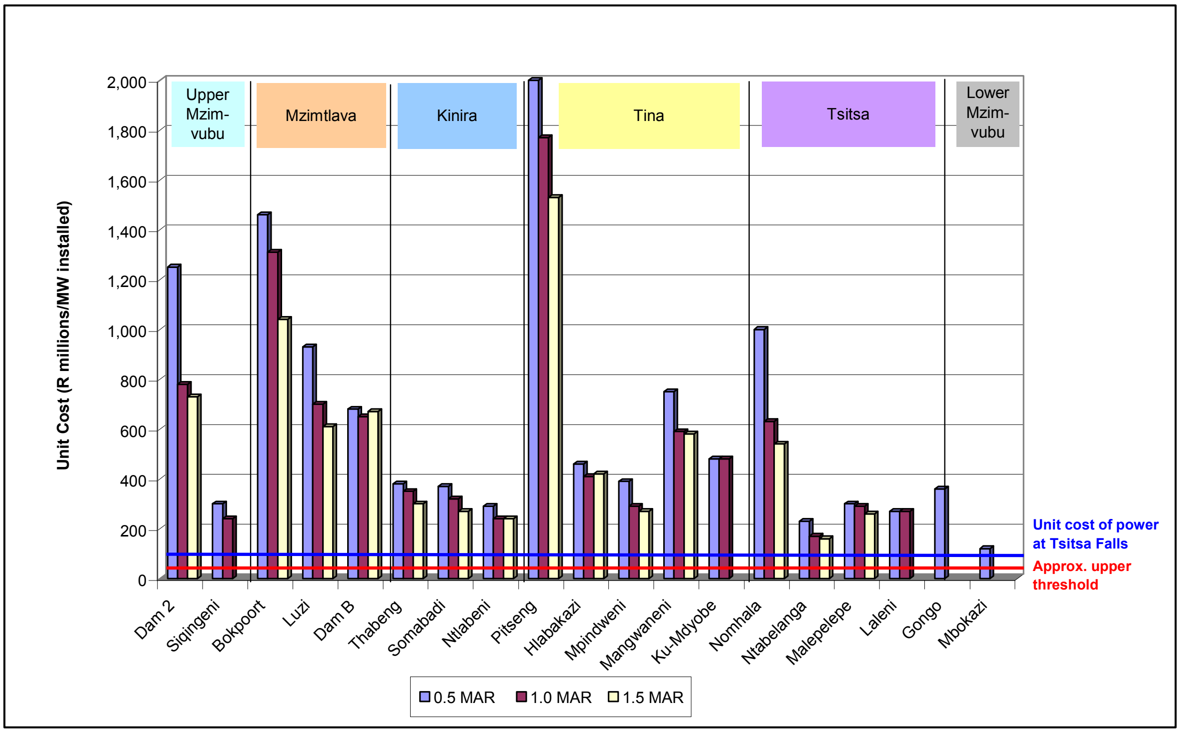

Figure 5.6 Unit costs of base load hydropower at potential dam sites compared with Tsitsa Falls and approximate upper threshold of feasible base-load cost

Figures 5.5 and 5.6 suggest that the sales of base-load hydropower cannot finance any of the hydropower schemes, both at the Tsitsa Falls and the potential dam sites. Only a few potential dams in the catchment had similar unit costs of peaking hydropower to the Tsitsa Falls scheme, and could be marginally feasible.

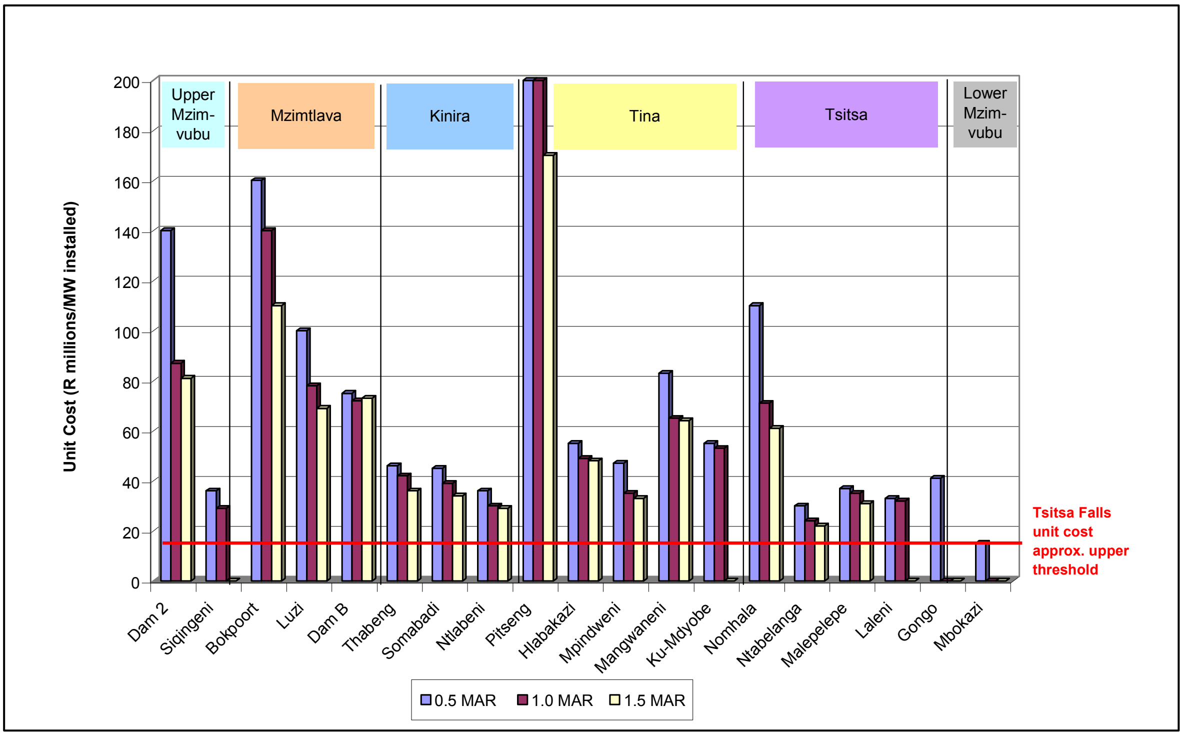

Figure 5.7 Unit costs of peaking hydropower at potential dam sites compared with Tsitsa Falls approximate upper threshold of feasible base-load cost

5.5.2 Conventional hydropower: Summary

Base load power generation is not viable at current electricity tariffs as a single-purpose development. Peaking power is only marginal as a single-purpose development. Power generation at a potential dam site may be considered if part of a multipurpose development, and for local power supply.

Development of peaking power should be focused on Tsitsa Falls and a few potential dam sites. If the purpose of the development is primarily for peaking power generation, Tsitsa Falls and the site near Mbokazi could be considered. If the hydropower generation is to be part of a multipurpose development then a few potential dam sites, such as Ntabelanga and Somabadi, could be considered.

If further investigations are conducted, some additional detail should be included:

- The confidence in the value of power at different load factors should be improved.
- The specific conditions at each site should be accounted for in the cost of the hydropower plants.
- The costs of the transmission lines.
- The effects of releases of water for the generation of hydropower on the ecological functioning of the river and the estuary need to be considered. This is particularly important at the Tsitsa Falls.

5.6 POTENTIAL PUMPED STORAGE SCHEMES

Although both pumped storage and conventional hydropower schemes use water-driven turbines for the generation of power, there is a fundamental difference between the schemes with respect to the primary source of energy used. For conventional hydropower, power is generated from harnessing the energy in the streamflow, which is a source of renewable energy. Pumped storage schemes in contrast use the excess energy generated by other sources to pump water to a higher elevation during off-peak periods, from where the water is released for the generation of power during peak demand periods, much like a huge battery. Once the initial filling (priming) of the reservoirs of a pumped storage scheme has been complete, pumped storage schemes are essentially closed systems, apart from replacing evaporative and seepage losses, and are independent of river flows.

Due to the topography of the catchment and available water resources, pumped storage schemes are potential developments in the Mzimvubu Development Zone.

Pumped storage schemes have been included in the assessment of water resource development due to the possibility that a pumped storage scheme could be linked to a dam with other purposes such as water supply, as a multi-purpose scheme.

A desktop study was conducted to assess the potential pumped storage schemes in the Eastern Cape. This included potential sites in the Mzimvubu River and surrounding catchments that were identified by Eskom, listed in previous studies of the Mzimvubu River, and identified by the study team close to potential dams. A stand-alone report on potential pumped storage schemes in the Eastern Cape entitled "***Assessment of pumped storage and hydropower schemes***" has been compiled.

Using very basic parameters of available head and tunnel length, some of the sites were eliminated before cost estimates were conducted. The pumped storage sites were ranked according to a number of factors and the results were discussed with Eskom.

A summary of the top ten potential pumped storage sites is presented in **Table 5.6**. The location of the potential pumped storage sites are presented in **Map A10** of **Appendix A.**

Table 5.6 Assessment of potential pumped storage schemes in the Eastern Cape

Item/Parameter	Options									
	Somabadi	Mfanta	T10	Dam 2	Siqingeni A	Siqingeni B	Luzi A	Luzi B	Ntsizwa A	Ntsizwa B
1. Physical parameters	3	5.5	1	3	7.5	9.5	5.5	3	9.5	7.5
2. Operational	3	10	2	6	4.5	7	1	9	4.5	8
3. Water supply	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4. Geological	1	4	8.5	8.5	4	4	4	4	8.5	8.5
5. Environmental	4.5	2	9.5	9.5	4.5	2	8	6.5	6.5	2
6. Access	4	1	10	7	7	7	7	7	2.5	2.5
7. Cost	1.5	6	1.5	6	6	6	6	10	6	6
8. Expandability	1	6	6	6	6	6	6	6	6	6
Total	**18**	**34.5**	**38.5**	**46**	**39.5**	**41.5**	**37.5**	**45.5**	**43.5**	**40.5**
Overall ranking	**1**	**2**	**4**	**10**	**5**	**7**	**3**	**9**	**8**	**6**

6 SUMMARISED DISCUSSION ON WATER RESOURCE DEVELOPMENTS

Hydrology

The existing water use in the catchment is generally low, with a few areas showing higher water use, such as Kokstad and Matatiele in the old Natal region and the Ugie-Maclear region of the Eastern Cape. Existing consumptive water use in the catchment is estimated at 134 million m^3/a, which is approximately 5% of the average total annual streamflow of the Mzimvubu River. The ecological water requirements provisionally determined through a desktop study, estimates 880 million m^3/a needs to be maintained in the river for healthy ecological functioning.

Theoretically there may be considerable potential for water resource development in the catchment through the implementation of dams, subject to the feasibility of such developments.

Large dams

Potential development of dam sites to store seasonal runoff could yield considerable quantities of water in the Mzimvubu River catchment.

Potential large dam sites in the catchment were analysed for gross reservoir capacities of 0.5, 1 and 1.5 times the mean annual runoff (MAR). Sedimentation of the reservoirs is expected to be in the order of 10 to 20% of the gross capacity after 50 years. The estimated capital costs of the dams range from approximately R300 million for a smaller dam near the headwaters, to over R2 000 million for larger dams lower in the catchment. The corresponding yields range from 15 to 560 million m^3/a, after releases to satisfy the ecological water requirements (EWRs). Due to EWRs being taken into account in this study, the yields assessed are lower than those determined in previous studies. The unit cost of water yielded at potential dams, excluding distribution costs, ranges between R0.40 and R4 per m^3.

The driving force behind a large scale dam development will be a significant water requirement of a new potential development such as a large irrigation scheme, the transfer of water, or domestic and industrial water supply.

Irrigated agriculture appears to have limited potential in the catchment. The hilly topography, disaggregated areas of flatter land and good soils, and high rainfall do not suit large-scale irrigated agriculture. The limited irrigation potential in the catchment could most likely be supplied directly from the river or by smaller dams located close to the fields to reduce pumping cost. Large potential for rain-fed agriculture development exists in the catchment.

The likelihood of water transfer from the Mzimvubu River catchment is very small. Water users in surrounding catchments can all be supplied from local water resources, or by closer neighbouring catchments. Agricultural could be expanded in the western parts of the Eastern Cape if water could be made available at an affordable cost. A transfer of water from the Mzimvubu River to the Orange River, which could then be conveyed through the Orange-Fish Tunnel to the western parts of the Eastern Cape, was assessed.

At a unit cost of around R 7/m^3 (which includes a dam development and the necessary transfer infrastructure to the Orange River, but excludes the distribution infrastructure to the farms), this transfer of water will most likely be far too expensive for agriculture to pay for. All other transfers of water from the Mzimvubu River are likely to be more expensive and less viable.

Domestic water supply in the catchment is not likely to be met from a single large dam. The population in the catchment is widely spread and not consolidated in large towns. The majority of the population in the catchment is located on top of the hills and this adds further expense to the distribution of surface water from large dams in the valleys. Multiple water sources such as groundwater, smaller dams on tributaries and abstractions from rivers close to the villages are likely to better meet the water needs of smaller villages spread throughout the catchment.

No potential industrial developments that will require large amounts of water have as yet been identified in the catchment. Industry is not currently a potential water user that will drive a large-scale water resource development.

The concept of mitigation through the release of stored water from dams has been considered to allow more forestry to be implemented in water-stressed catchments. The size of dams required to augment low flows and mitigate the effects of forestry are, however, small. Mitigation is also not yet widely practised, and has limitations due to practicality of implementation. Mitigation for forestry implementation is not a likely driving force behind a large dam development in the catchment.

Hydropower

Hydropower potential at the possible dam sites as well as the Tsitsa Falls was assessed. The hydropower availability was in the order of between 0.5 and 25 MW continuous power, or between 5 and 250 MW peaking power at an indicative load factor of 10%, and the assessment included provisional ecological water requirements. However, the effect of hydropower generation on the EWRs should be determined in more detail if any additional studies are conducted, particularly for the Tsitsa Falls option.

Base load hydropower was found to be generally expensive per unit installed capacity. The unit costs for peaking power scenarios ranged between R15 million and R300 million per MW installed. Although peaking power generation showed more promise, a basic financial feasibility analysis suggests that hydropower in the Mzimvubu River catchment is not likely to afford the construction cost of a large dam without the support of other users of the dam as part of a multi-purpose development, given the current prices for electricity.

The Eastern Cape region has favourable topography and water availability for potential pumped storage schemes. A desktop study was conducted to identify and compare such schemes in the region, and to assess if any potential exists to couple a pumped storage scheme with a dam development. The findings of this pumped storage scheme assessment have been discussed with Eskom, who could take it forward for more detailed analyses.

Summary

The DWAF has initiated a study of the Mzimvubu River catchment to assist the Eastern Cape Government with identified developments in the province. In conjunction the DWAF has conducted some preparatory work to provide more general water resource development potential. This preparatory work has provided valuable background into the water resources of the catchment and should assist the special purpose vehicle AsgiSA-EC with the development initiative.

The work included assessing the existing water users in the catchment and determining the potential for water yield at potential dam sites in the catchment. This also provided an opportunity to assess the conventional hydropower potential at potential dam sites in the catchment.

The preparatory work conducted has not been focused on water supply to specific locations, and attention has not been given to the distribution of the water from the potential dam sites. This is likely to be a significant factor in the planning of future projects due to the topography of the catchment and population distribution, and could influence the feasibility of potential developments.

No large-scale water users currently exist, or have yet been identified, that require the implementation of a large dam. If potential developments that require water are identified, the results of the work conducted for this study could provide an indication of the likely quantity and cost of water that could be made available through the construction of a dam.

Potential dam sites that have shown to be more favourable in this study may be considered if suitable development scenarios in the region are identified that can make sustainable use of the water.

7 REFERENCES

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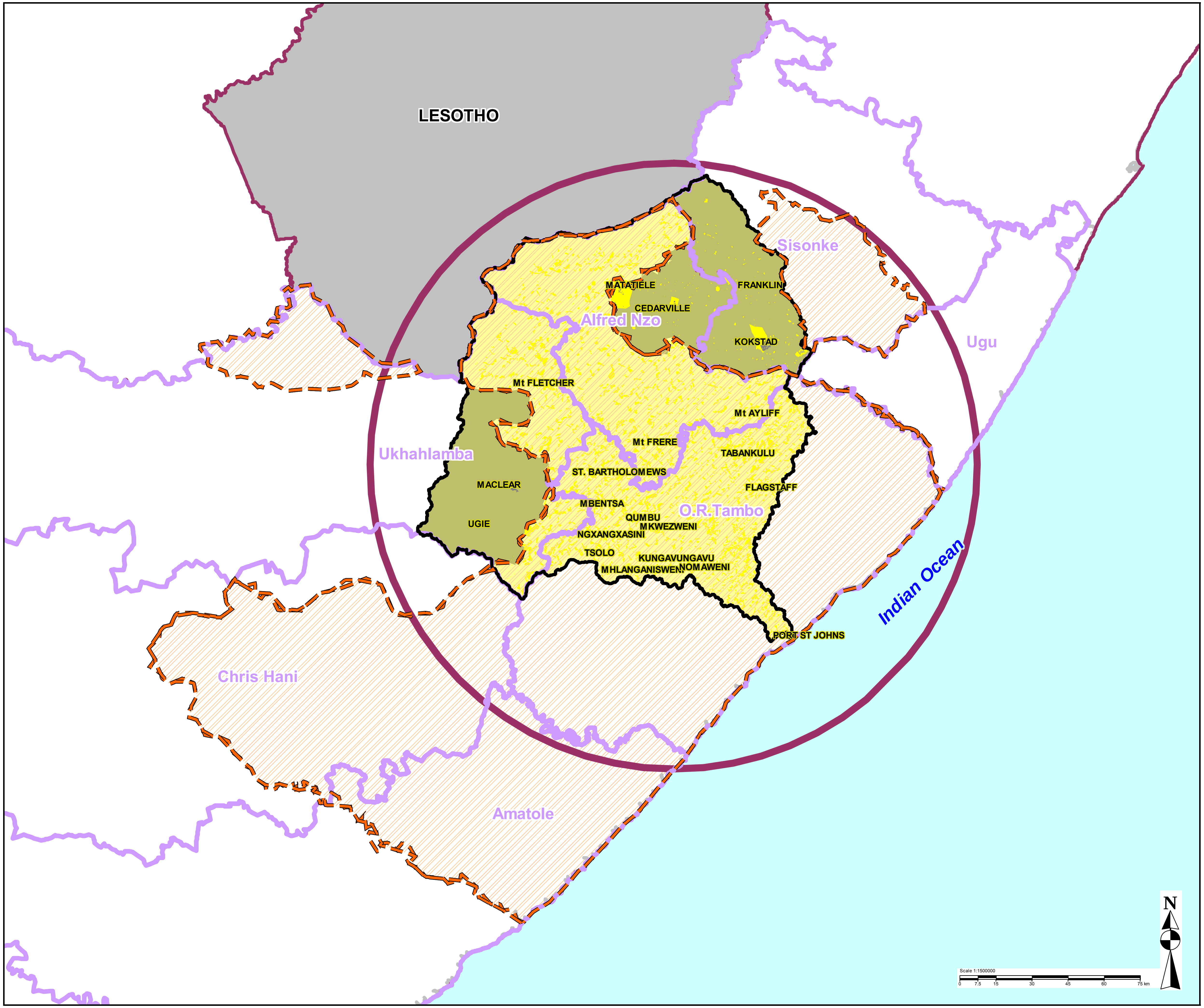
APPENDIX A

Maps

Map A1	Mzimvubu and extended study area
Map A2	Mzimvubu climate
Map A3	Mzimvubu runoff catchments
Map A4	Existing dams in the Mzimvubu River catchment
Map A5	Mzimvubu infrastructure
Map A6	Existing irrigation in the Mzimvubu River catchment
Map A7	Existing forestry in the Mzimvubu River catchment
Map A8	Potential water resource developments in the Mzimvubu River catchment
Map A9	Water transfer options from the Mzimvubu River catchment



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Legend

- Provinces
- Mzimvubu Development Zone
- Mzimvubu Catchment
- Former Transkei portion of Mzimvubu Catchment
- Former Eastern Cape/Natal portions of Mzimvubu Catchment
- District Municipality Boundary
- Old Transkei Border

Communities

- Rural Settlements
- Urban Settlements
- Lesotho

Locality Map

MAP A1

STUDY AREA

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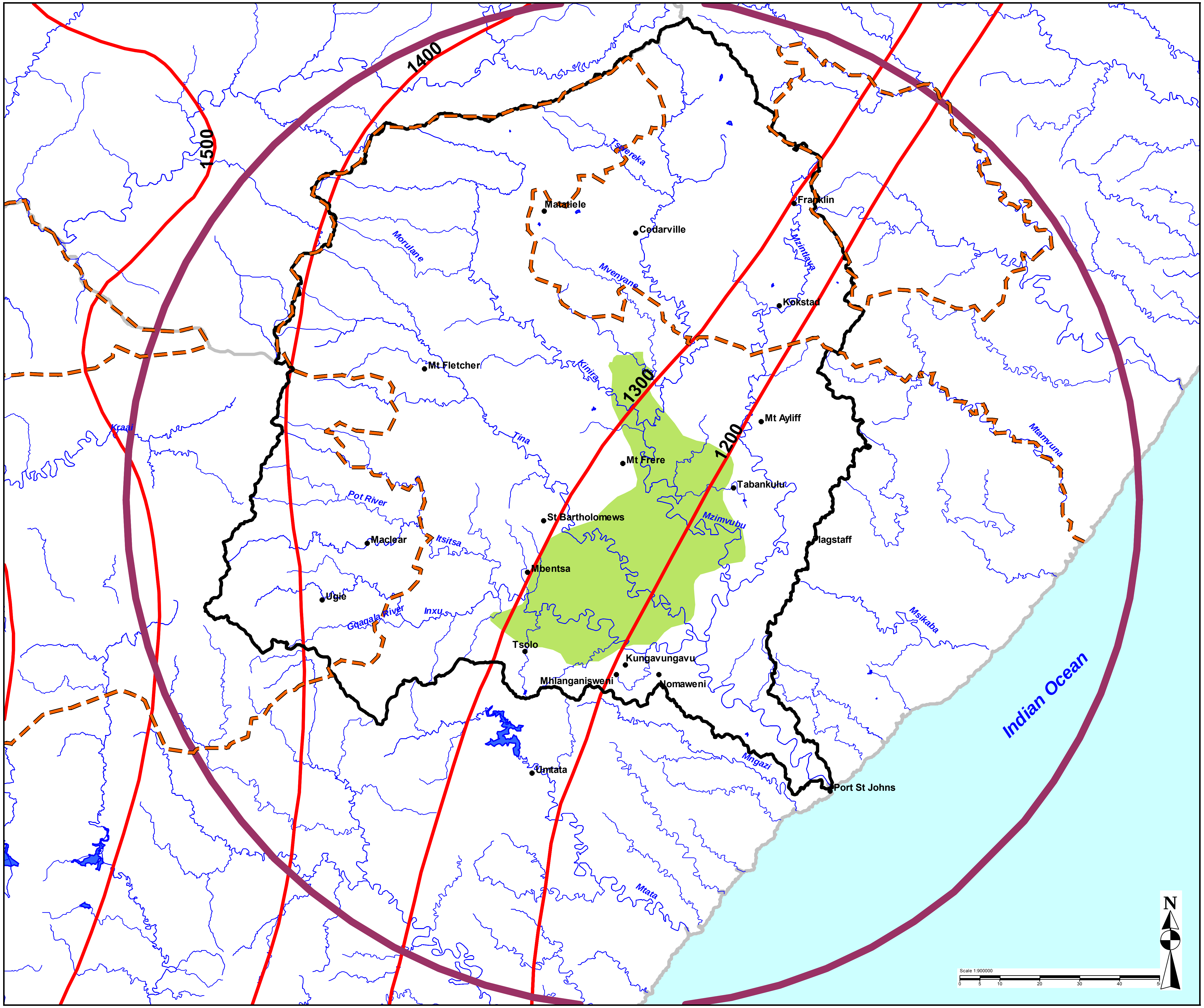
Map Reference: P:/GisProjects/.../Mzimvubu to Keiskamma.map
System: WGS84 Lat/Long



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Legend

- Mzimvubu Development Zone
- Mzimvubu Catchment
- Old Transkei Borders
- Mean Evaporation Isolines
- Main Towns

Locality Map

MAP A2

CLIMATE

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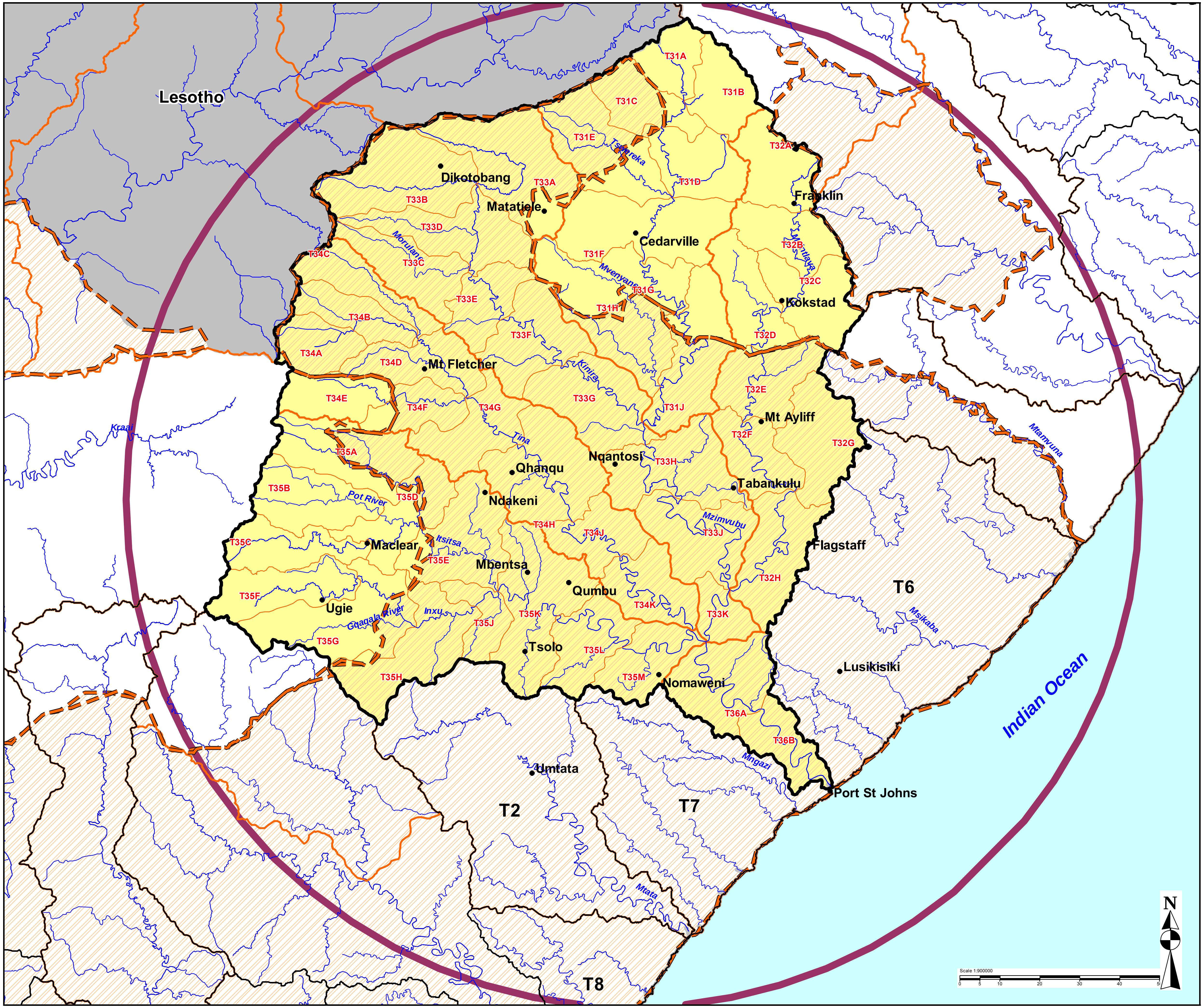
System:	WGS84 Lat/Long



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Legend

- Mzimvubu Development Zone
- Mzimvubu Catchment
- Main Towns
- Lesotho
- Old Transkei Border
- Tertiary Catchments
- Secondary Catchments
- Quaternary Catchments
- Rivers

Locality Map

MAP A3

RUNOFF CATCHMENTS

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System: WGS84 Lat/Long

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Legend

- Mzimvubu Development Zone
- Mzimvubu Catchment
- Former Transkei
- Lesotho
- Rivers
- Existing Dams
- Existing Farm Dams
- Main Towns

Locality Map

MAP A4

EXISTING DAMS

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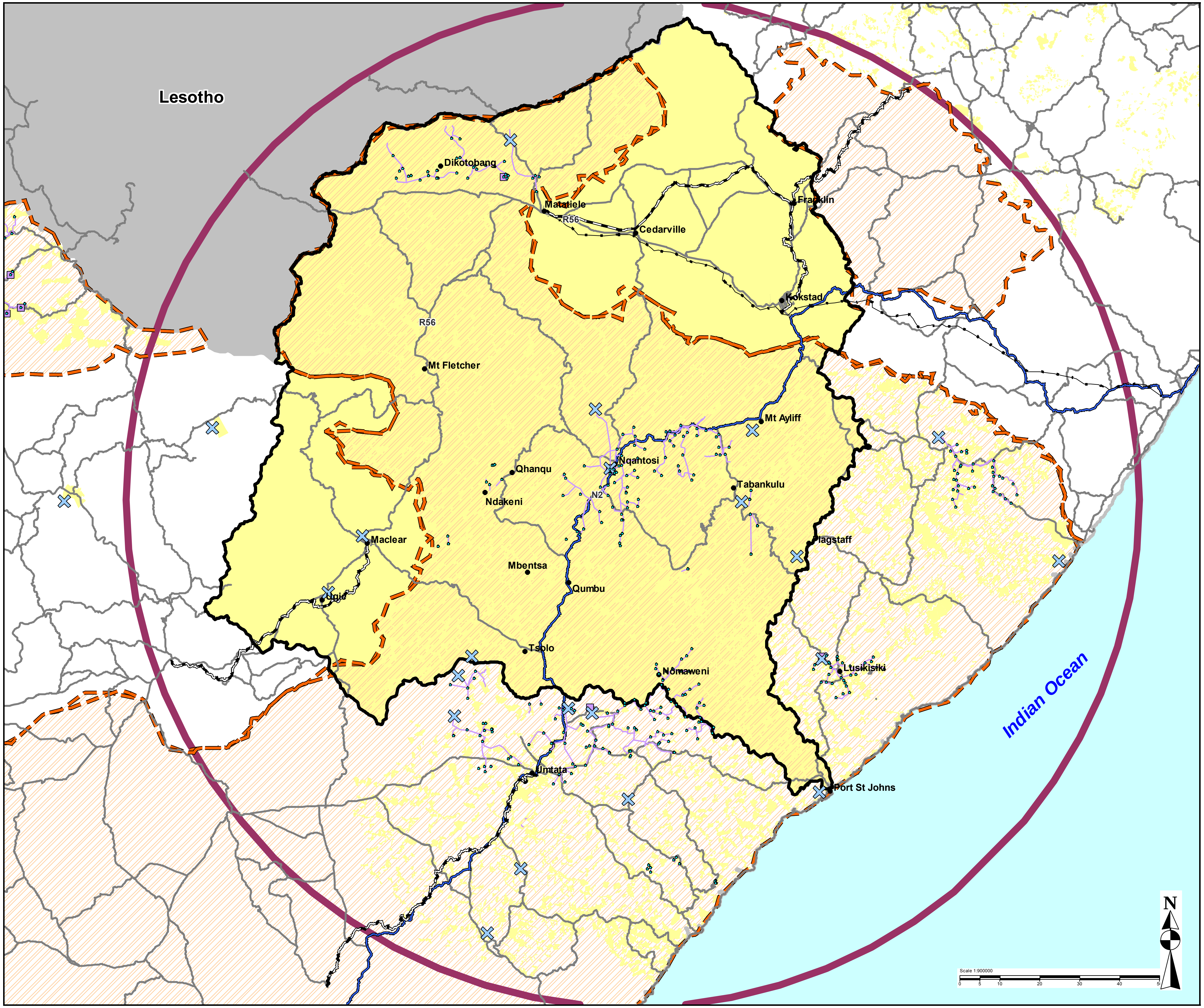
Map Reference:	P:/GisProjects/.../Mzimvubu to Keiskamma.map
System:	WGS84 Lat/Long



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MZIMVUBU CATCHMENT DEVELOPMENT STUDY

Legend

- Lesotho
- Mzimvubu Development Zone
- Mzimvubu Catchment
- Old Transkei Border

Communities
- communities
- final townsettlements
- final ruralfamrsettlement
- Main Towns

Infrastruture
- Roads
- N2
- Railways
- Powerlines
- Existing Pipelines
- Pumpstation
- WTW
- Reservoirs

Locality Map

MAP A5

INFRASTRUCTURE

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Engineering and Management

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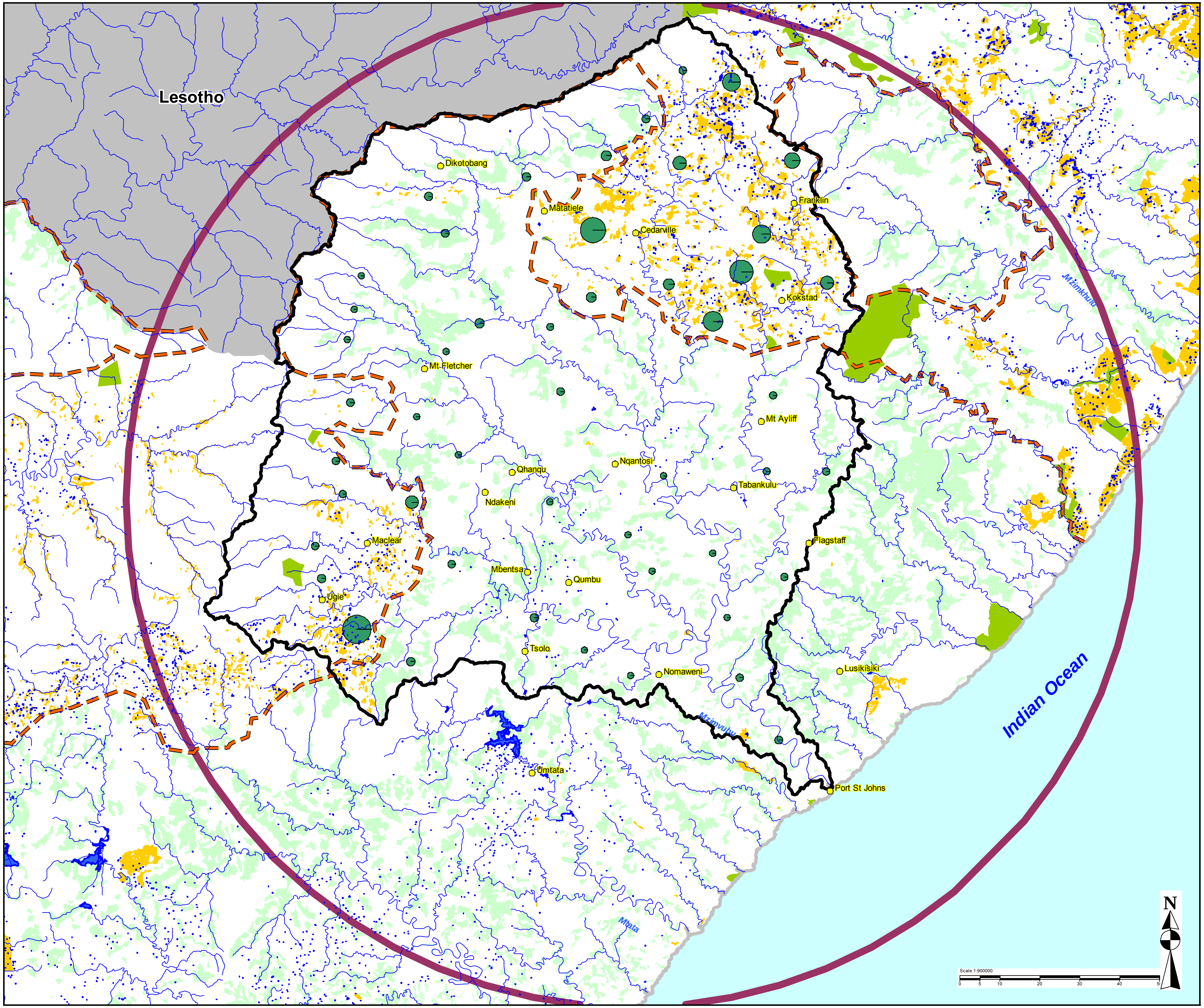
Map Reference:	P:/GisProjects/.../Mzimvubu to Keiskamma.map
System:	WGS84 Lat/Long



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MZIMVUBU CATCHMENT DEVELOPMENT STUDY

Legend

- Lesotho
- Mzimvubu Development Zone
- Mzimvubu Catchment
- Old Transkei Border
- Main Towns

Landuse (ENPAT)

- Irrigated Area
- Conservation
- Cultivated Land
- Subsistance Farming
- Dams
- Rivers

Locality Map

MAP A6

EXISTING IRRIGATION AREAS

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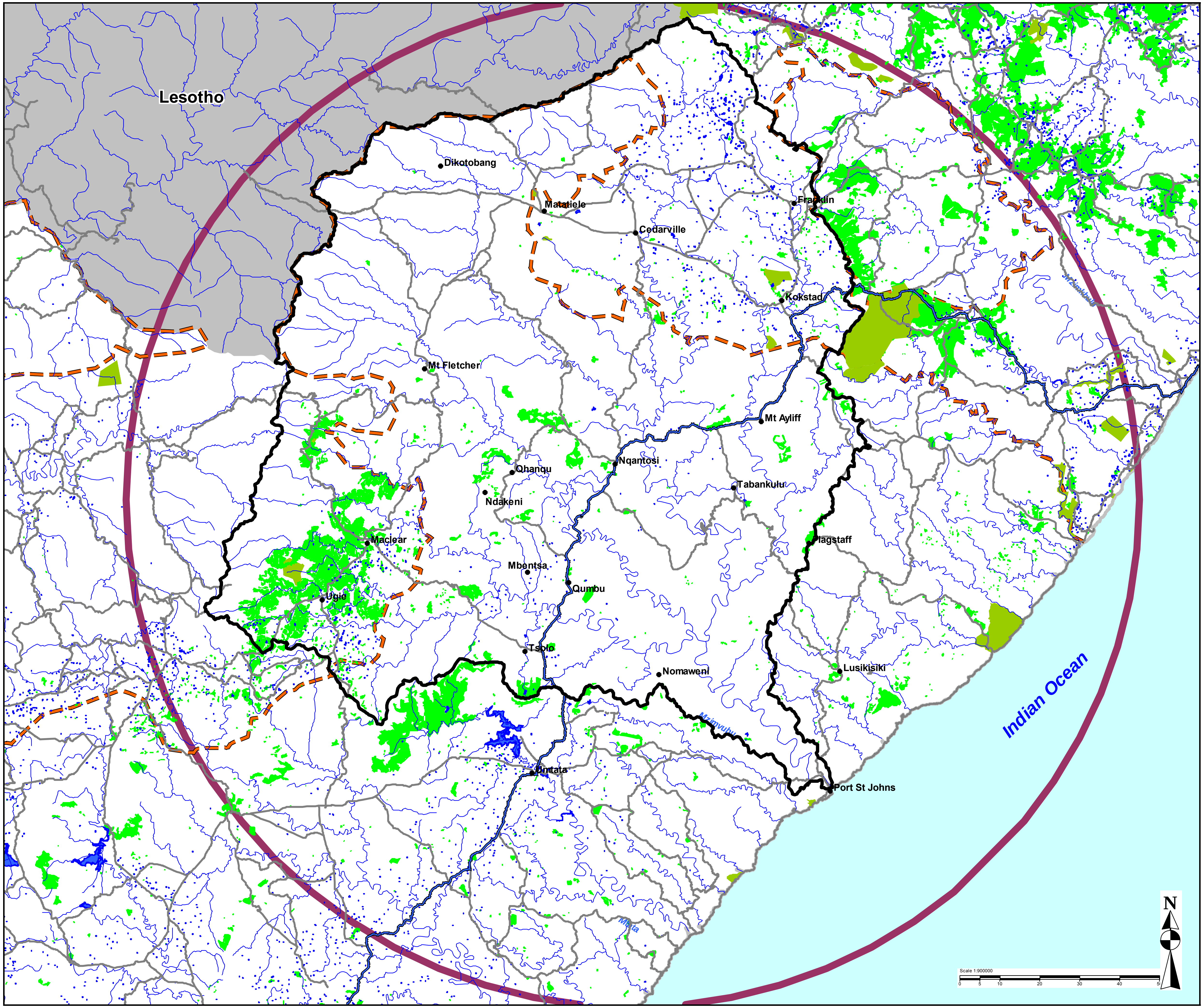
Engineering and Management

in association with FST

Date: March 2009
Map Reference: P:/GisProjects/.../Mzimvubu to Keiskamma.map
System: WGS84 Lat/Long



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Legend

- Lesotho
- Mzimvubu Development Zone
- Mzimvubu Catchment
- Old Transkei Border

Landuse (ENPAT)

- Conservation
- Forestry
- Dams
- Rivers
- Roads
- Roads_N2
- Main Towns

Locality Map

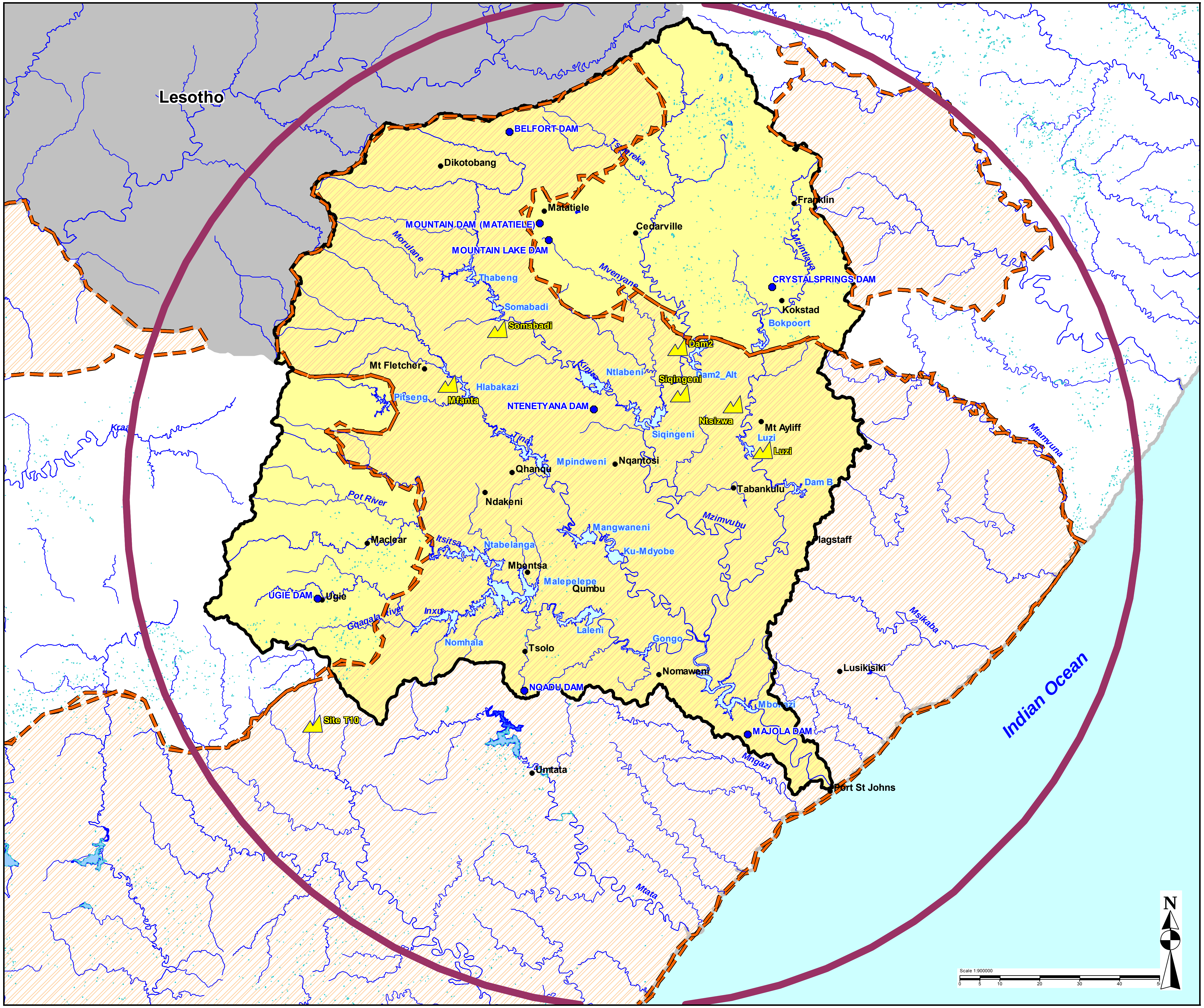
MAP A7

EXISTING FORESTRY AREAS

BKS (Pty Ltd)
Engineering and Management

in association with FST

Date: March 2009
Map Reference: P:/GisProjects/.../Mzimvubu to Keiskamma.map
System: WGS84 Lat/Long



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Legend

- Lesotho
- Mzimvubu Development Zone
- Mzimvubu Catchment
- Former Transkei Border
- Existing Dams
- Main Towns
- Existing Farm Dams
- Potential Dams
- Potential Pumped Storage Sites

Locality Map

MAP A8

POTENTIAL WATER RESOURCE DEVELOPMENT

BKS (Pty Ltd)
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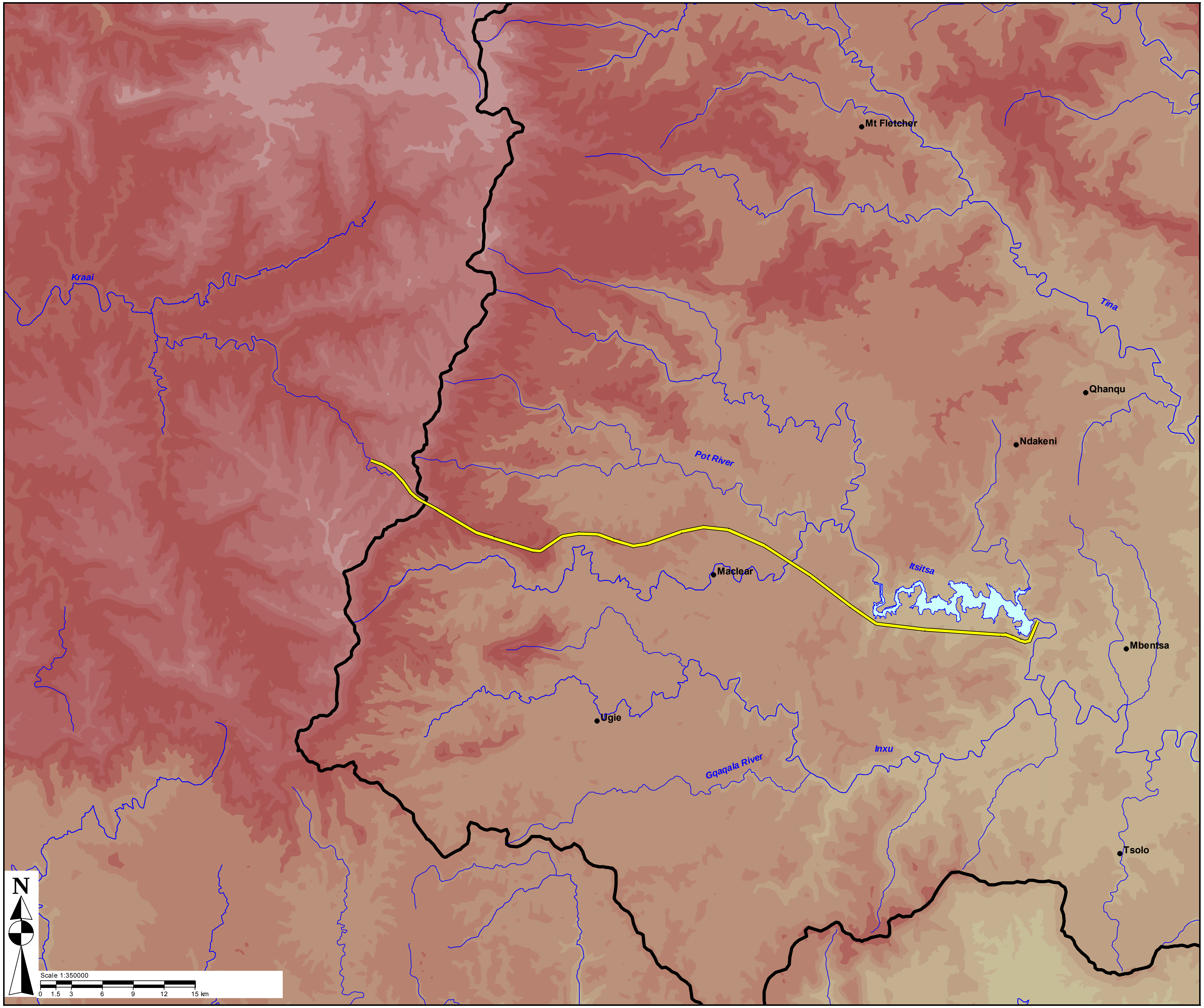
in association with FST

Date: March 2009
Map Reference: P:/GisProjects/.../Mzimvubu to Keiskamma.map
System: WGS84 Lat/Long



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MZIMVUBU CATCHMENT DEVELOPMENT STUDY

Legend

Relief
- 0mm - 200mm
- 200m - 400mm
- 400mm - 600mm
- 600mm - 800mm
- 800mm - 1000mm
- 1000mm - 1200mm
- 1200mm - 1400mm
- 1400mm - 1600mm
- 1600mm 1800mm
- 1800mm - 2000mm
- 2000mm - 2200mm
- 2200mm - 2400mm
- 2400mm - 2600mm
- 2600mm - 2800mm
- Ntabelanga Potential Dam
- Ntabelanga - Kraai Transfer Pipeline
- Main Towns

Locality Map

MAP A9

POTENTIAL WATER TRANSFER SCHEME

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in association with FST

Date: March 2009
Map Reference: P:/GisProjects/.../Mzimvubu to Keiskamma.map
System: WGS84 Lat/Long

APPENDIX B

Ecological water requirements

INTRODUCTION

There are usually negative biophysical impacts associated with catchment development, including the attenuation of small freshets or floods through dam construction or the abstraction of water, reduced base flows due to afforestation as well as water quality changes with irrigation return flows or discharges from waste water treatment works. In addition, the integrity of downstream aquatic habitats and biota can be threatened both during and after these developments.

Potential developments of the water resources of the Mzimvubu catchment need to take these impacts on the aquatic ecosystems and provision of the basic human needs into account.

The Reserve is one of a range of measures aimed at the ecological protection of water resources and the provision of basic human needs. The Reserve is defined in terms of the Ecological Water Requirements (EWR) of the resource and assurance of supply provided at a defined spatial and temporal distribution and the basic human needs. The EWRs need to be determined to protect the template and functioning of ecosystems so as to ensure ecologically sustainable development and utilisation of a water resource.

WATER RESOURCES COMPONENTS

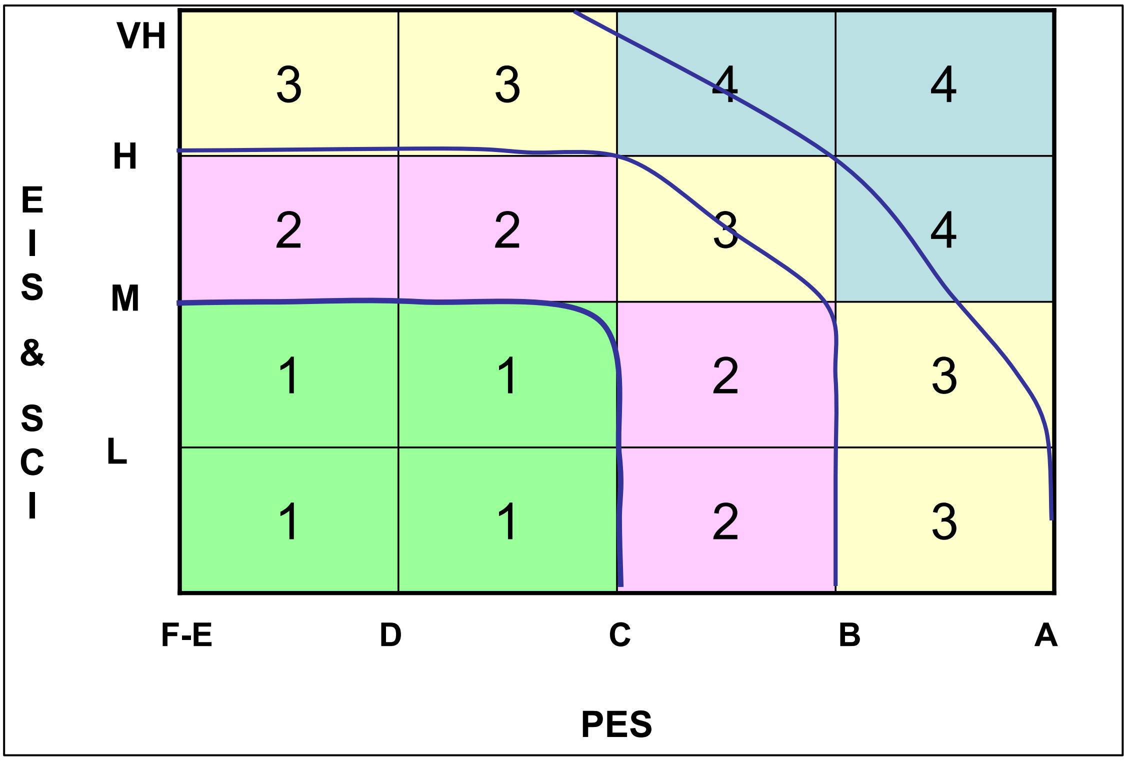
The impact of existing developments, the present state of the water resource, and the ecological sensitivity and importance of the water resources have been considered during this general water resources assignment.

However, the impacts on the wetlands, groundwater, and the Mzimvubu River Estuary should also be investigated if any of the possible water resource developments are considered as a specific option.

APPROACH AND RESULTS

A desktop eco-classification was undertaken per quaternary catchment for the Mzimvubu River and its main tributaries. This included the following:

The Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) were sourced for each quaternary catchment. The results of Kleynhans, 1999 were used for this and adjusted for those quaternary catchments where higher confidence results are available. The PES and EIS were integrated using the matrix in **Figure B.1**. The results are included in **Table B.1** for the Mzimvubu River and **Table B.2** for the Pondoland and Extended Area.



* Ecological Importance and Sensitivity (EIS); Social and cultural Importance (SCI); Present Ecological State (PES)

Figure B.1 Matrix used to determine a combined EIS and PES value which provides an integrated importance value on a scale of 0 to 4

Water use scores were given per quaternary catchment and are based on the current and proposed water use in the catchment. A score of 0 were given in catchments where no or very little developments occur and a score of 4 where large areas of existing irrigation, commercial forestry, or damming of rivers occur. The water use scores are included in **Table B.3**.

All previous Reserve determinations undertaken in the catchment area were identified and are summarised in the **Table B.4**.

Integrated importance and water use scores were used to derive the level of reserve determination that should be undertaken through the use of the matrix presented in **Figure B.2**. These results are provided in **Table B.5**.

Where an existing rapid reserve determination has already been conducted in the study area, the recommended reserve level can be increased if the suggested level is only a desktop. The recommended revere levels for future studies are presented in **Figure B.3** for the Mzimvubu catchment, and some of the surrounding catchments that fall within the Mzimvubu Development Zone.

Table B.1 Combined EIS and PES scores for the quaternary catchments

Quaternary catchment	EIS	PES/EC*	Scores*
T31A	Moderate	A	3
T31B	Moderate	B	2
T31C	Moderate	B	2
T31D	Low	B	2
T31E	Low	B	2
T31F	Low	A	3
T31G	Moderate	C	1
T31H	Low	B	2
T31J	High	A/B	4
T32A	Moderate	B	2
T32A	Moderate	B	2
T32B	Moderate	A/B	3
T32B	Moderate	C	1
T32B	High	C	2
T32C	Moderate	B/C	2
T32D	Low	C	1
T32E	Moderate	C	1
T32F	Moderate	C	1
T32G	Moderate	C	1
T32H	Moderate	C	1
T33A	High	C	2
T33B	High	C	2
T33C	Low	D	1
T33D	Low	D	1
T33D	Moderate	D	1
T33E	High	C	2
T33F	High	C	2
T33G	Moderate	C	1
T33H	Moderate	C	1
T33J	Moderate	C	1
T33K	Moderate	C	1
T34A	High	C	2
T34B	High	C	2
T34C	High	C	2
T34D	High	C	2
T34E	High	C	2
T34F	High	C	2
T34G	High	C	2
T34H	Moderate	C	1
T34J	Moderate	B/C	2
T34K	Moderate	C	1
T35A	High	C	2
T35B	High	C	2
T35C	High	C	2
T35D	High	C	2
T35E	High	C	2
T35F	High	C	2
T35G	Moderate	B	2
T35H	High	C	2
T35J	High	C	2
T35K	Moderate	B/C	2
T35L	Moderate	C	1
T35M	Moderate	C	1
T36A	Moderate	B	2
T36B	Moderate	B	2

* Ecological Importance and Sensitivity (EIS); Present Ecological State (PES); Ecological Category (EC);
* Score is the combined EIS and PES rating or integrated importance derived from the matrix in Figure B.1.

Table B.2 Combined EIS and PES scores for the quaternary catchments of extended area surrounding the Mzimvubu River catchment.

Quaternary catchment	EIS	PES/EC*	Scores*
T40A	Moderate	B	2
T40B	Moderate	C	1
T40C	Moderate	B	2
T40D	Moderate	B	2
T40E	Very High	A/B	4
T40F	Moderate	C	1
T40G	Moderate	C	1
T60A	Very High	B	4
T60B	Very High	B	4
T60C	High	B/C	3
T60D	Very High	B	4
T60E	High	B/C	3
T60F	Very High	B	4
T60G	Very High	B	4
T60H	Very High	B	4
T60J	High	B/C	3
T60K	High	B	3
T70A	High	B	3
T70B	High	B	3
T70C	High	B	3
T70D	High	B	3
T70E	High	B	3
T70F	High	B	3
T70G	High	B	3
T80A	High	C	2
T80A	High	C	2
T80A	High	B	3
T80B	High	B	3
T80C	High	B	3
T80D	High	B	3
T90A	High	B	3
T90B	High	B	3
T90C	High	B	3
T90D	High	B	3
T90E	High	B	3
T90F	High	B	3
T90G	High	B	3

* Ecological Importance and Sensitivity (EIS); Present Ecological State (PES); Ecological Category (EC);

* Score is the combined EIS and PES rating or integrated importance derived from the matrix in Figure B.1.

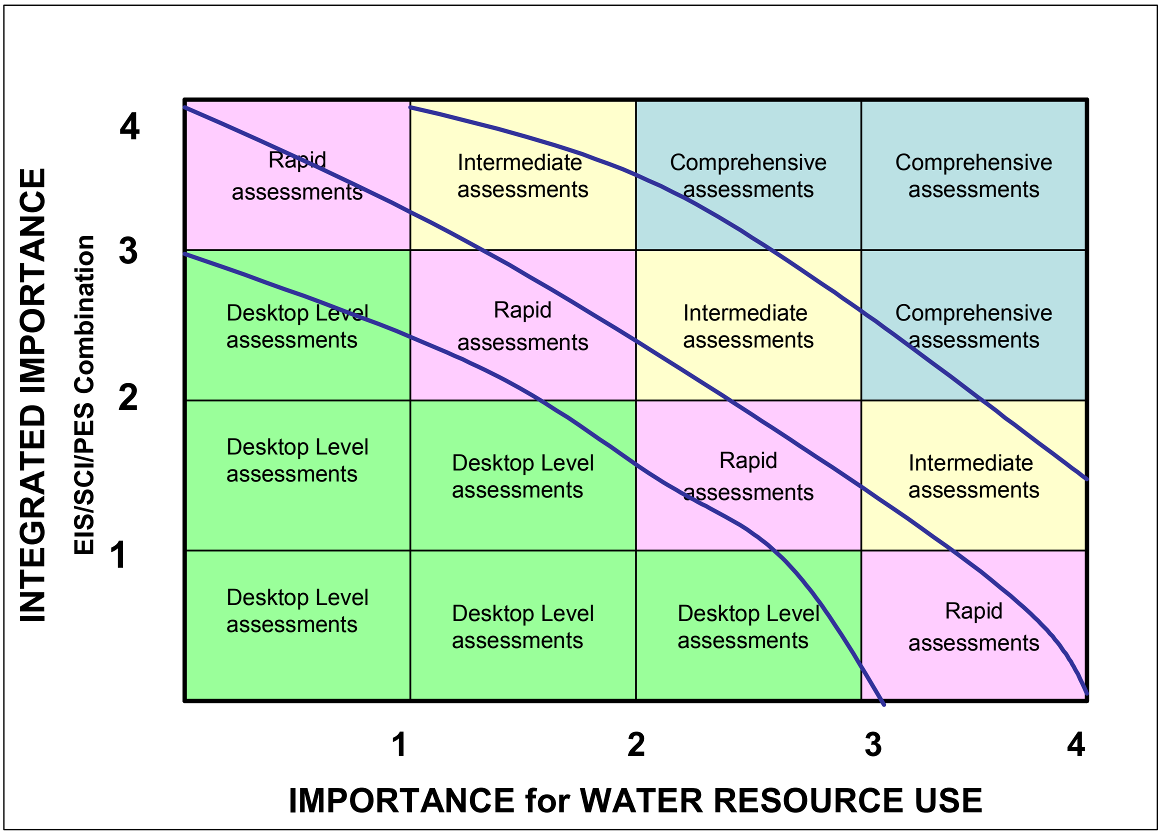


Figure B.2 Matrix indicating the level of EWR assessments required

Table B.3 Water use scores for quaternary catchments in the Mzimvubu River

			Land use														
			Afforestation				Irrigation		Domestic water use				Existing dams		Potential major dams		Total score
Quat	Area	MAR	WR2005	Landsat 2000	% area	Score	Area	Score	Urban	Rural	Total % MAR	Score	Capacity	Score	Dam name	Score	
	km²	***Mm³/a***	***km²***	***km²***			***ha***		***Mm³/a***	***Mm³/a***			***Mm³***				
T31A	222	32.73	9.00	0.33	4.1	***1***	82	***1***	0.000	0.002	0.007	***0***	0.09	***0***		***0***	**1**
T31B	284	31.33	1.10	0.64	0.4	***0***	750	***3***	0.000	0.010	0.033	***0***	10.00	***3***		***0***	**3**
T31C	291	31.88	0.00	0.00	0.0	***0***	107	***2***	0.000	0.136	0.426	***0***	0.86	***0***		***0***	**2**
T31D	353	27.97	0.00	0.12	0.0	***0***	450	***3***	0.000	0.040	0.142	***0***	2.92	***1***		***0***	**3**
T31E	509	39.92	0.50	0.53	0.1	***0***	240	***2***	0.000	0.133	0.333	***0***	1.04	***1***		***0***	**2**
T31F	605	37.04	0.00	0.00	0.0	***0***	1195	***4***	0.061	0.052	0.304	***0***	3.65	***2***		***0***	**4**
T31G	209	20.15	0.00	1.17	0.6	***0***	295	***2***	0.000	0.008	0.038	***0***	0.37	***0***		***0***	**2**
T31H	617	22.9	0.00	6.98	1.1	***1***	225	***2***	0.000	0.300	1.310	***1***	1.65	***1***		***0***	**2**
T31J	507	52.84	0.00	2.52	0.5	***0***	840	***3***	0.000	0.158	0.298	***0***	0.98	***0***	Dam 2	***1***	**3**
T32A	348	30.52	0.90	2.13	0.6	***0***	590	***3***	0.000	0.042	0.138	***0***	3.34	***2***		***0***	**3**
T32B	307	30.77	0.00	5.74	1.9	***1***	750	***3***	0.000	0.031	0.100	***0***	1.24	***1***		***0***	**3**
T32C	373	35.53	5.40	10.29	2.8	***1***	440	***3***	0.668	0.069	2.076	***1***	2.86	***1***		***0***	**3**
T32D	351	32.91	0.00	1.61	0.5	***0***	1080	***4***	0.000	0.027	0.083	***0***	1.53	***1***	Bokpoort	***1***	**4**
T32E	383	47.56	0.00	1.24	0.3	***0***	61	***1***	0.000	0.318	0.669	***0***	0.00	***0***		***0***	**1**
T32F	297	48.37	4.80	7.30	2.5	***1***	49	***1***	0.108	0.208	0.653	***0***	0.00	***0***	Luzi	***1***	**1**
T32G	438	57.16	8.00	11.91	2.7	***1***	70	***1***	0.000	0.418	0.730	***0***	0.00	***0***	Dam B	***1***	**1**
T32H	453	66.03	5.90	6.93	1.5	***1***	73	***1***	0.098	0.346	0.672	***0***	0.00	***0***	Dam B	***1***	**1**
T33A	348	97.37	0.00	2.16	0.6	***0***	143	***2***	0.171	0.503	0.692	***0***	1.62	***1***		***0***	**2**
T33B	602	94.27	0.00	0.26	0.0	***0***	128	***2***	0.000	0.303	0.322	***0***	0.00	***0***		***0***	**2**
T33C	367	51.52	0.00	0.54	0.1	***0***	0	***0***	0.000	0.150	0.290	***0***	0.00	***0***	Thabeng	***1***	**1**
T33D	461	61.01	0.00	0.10	0.0	***0***	100	***1***	0.000	0.341	0.558	***0***	0.00	***0***	Thabeng	***1***	**1**
T33E	267	20.54	0.00	0.00	0.0	***0***	189	***2***	0.000	0.148	0.720	***0***	0.00	***0***	Somabadi	***1***	**2**
T33F	437	51.9	4.90	4.18	0.0	***0***	55	***1***	0.000	0.218	0.420	***0***	0.00	***0***		***0***	**1**
T33G	503	60.93	1.50	1.54	0.3	***0***	91	***1***	0.000	0.276	0.454	***0***	1.85	***1***	Ntlabeni	***1***	**1**
T33H	517	46.08	2.50	6.14	1.2	***1***	6	***0***	0.350	0.413	1.654	***1***	0.21	***0***		***0***	**1**
T33J	457	35.6	1.50	1.02	0.3	***0***	6	***0***	0.044	0.337	1.071	***1***	0.01	***0***		***0***	**1**
T33K	169	22.35	0.00	1.02	0.0	***0***	3	***0***	0.000	0.150	0.669	***0***	0.00	***0***		***0***	**0**
T34A	242	41.13	0.00	0.00	0.0	***0***	6	***0***	0.000	0.067	0.163	***0***	0.00	***0***		***0***	**0**
T34B	246	35.9	0.90	0.00	0.4	***0***	6	***0***	0.000	0.114	0.317	***0***	0.00	***0***		***0***	**0**

			Land use														
			Afforestation				Irrigation		Domestic water use				Existing dams		Potential major dams		Total score
Quat	**Area**	**MAR**	**WR2005**	**Landsat 2000**	**% area**	**Score**	**Area**	**Score**	**Urban**	**Rural**	**Total % MAR**	**Score**	**Capacity**	**Score**	**Dam name**	**Score**	
	km²	***Mm³/a***	***km²***	***km²***			***ha***		***Mm³/a***	***Mm³/a***			***Mm³***				
T34C	282	33.92	0.00	0.00	0.0	***0***	9	***0***	0.106	0.120	0.666	***0***	0.50	***0***		***0***	**0**
T34D	342	52.17	1.10	2.74	0.8	***0***	9	***0***	0.222	0.132	0.677	***0***	0.00	***0***	Hlabakazi	***1***	**1**
T34E	268	45.2	5.60	3.84	2.1	***1***	6	***0***	0.000	0.000	0.000	***0***	0.00	***0***	Pitseng	***1***	**1**
T34F	238	39.5	0.00	0.09	0.0	***0***	6	***0***	0.000	0.047	0.119	***0***	0.00	***0***	Pitseng	***1***	**1**
T34G	358	57.72	7.30	3.64	2.0	***1***	9	***0***	0.000	0.128	0.222	***0***	0.00	***0***	Hlabakazi	***1***	**1**
T34H	591	91.25	58.90	53.99	10.0	***2***	12	***1***	0.087	0.447	0.585	***0***	0.02	***0***	Mpindweni	***1***	**2**
T34J	297	27.27	2.30	2.53	0.8	***0***	3	***0***	0.000	0.250	0.916	***0***	0.08	***0***	Siqingeni	***1***	**1**
T34K	333	25.9	0.00	0.00	0.0	***0***	6	***0***	0.034	0.269	1.172	***1***	0.00	***0***		***0***	**1**
T35A	475	92.36	33.09	23.44	7.0	***2***	79	***1***	0.000	0.087	0.094	***0***	0.00	***0***		***0***	**2**
T35B	396	78.09	24.45	2.70	6.2	***2***	58	***1***	0.000	0.000	0.000	***0***	0.28	***0***		***0***	**2**
T35C	306	86.77	54.09	25.38	17.7	***3***	79	***1***	0.440	0.000	0.507	***0***	0.13	***0***		***0***	**3**
T35D	348	52.86	17.77	17.71	5.1	***2***	58	***1***	0.000	0.081	0.154	***0***	0.76	***0***		***0***	**2**
T35E	492	102.8	1.02	11.10	0.2	***0***	82	***1***	0.009	0.263	0.264	***0***	0.29	***0***	Ntabelanga	***1***	**1**
T35F	359	58.16	86.08	31.05	24.0	***4***	80	***1***	0.173	0.000	0.298	***0***	0.82	***0***		***0***	**4**
T35G	575	64.04	62.00	27.92	10.8	***3***	1090	***4***	0.000	0.052	0.081	***0***	3.80	***2***		***0***	**4**
T35H	520	84.58	29.20	10.33	5.6	***2***	88	***1***	0.000	0.286	0.339	***0***	0.62	***0***	Nomhala	***1***	**2**
T35J	188	40.26	19.00	19.45	10.1	***2***	0	***0***	0.000	0.177	0.440	***0***	0.11	***0***	Malepelepe	***1***	**2**
T35K	625	86.05	32.20	32.26	5.2	***2***	131	***2***	0.478	0.567	1.214	***1***	2.15	***1***	Malepelepe	***1***	**2**
T35L	340	29.01	2.10	0.36	0.6	***0***	3	***0***	0.073	0.244	1.095	***1***	0.14	***0***	Laleni	***1***	**1**
T35M	305	42.25	0.00	0.38	0.0	***0***	3	***0***	0.000	0.190	0.451	***0***	0.00	***0***	Gongo	***1***	**1**
T36A	462	65.19	0.90	0.38	0.2	***0***	550	***3***	0.000	0.293	0.450	***0***	0.41	***0***	Mbokazi	***1***	**3**
T36B	265	55.15	0.00	0.55	0.0	***0***	150	***2***	0.023	0.220	0.440	***0***	0.00	***0***		***0***	**2**
	19528	2574	**484**	**346**		**0.55**	**10541**	**1.08**	**3.15**	**9.17**	**25.53**	**0.11**	**44.32**	**0.29**	**0.00**	**0.35**	

0	< 1%	0	< 10ha	0	< 1%	0	<1 Mn^3	0	no potential dams
1	1-5%	1	10-100	1	1-3%	1	1-3 Mn^3	1	potential dam in quat
2	5-10%	2	100-400	2	3-10%	2	3-9 Mm^3	2	large potential dam in pre-feasibility phase
3	10-20%	3	400-1000	3	10-25%	3	9-20 Mm^3	3	large potential dam in feasibility phase
4	>20%	4	> 1000	4	>25%	4	>20 Mm^3	4	large potential dam in design phase

Table B.4 Existing Reserve studies in the Mzimvubu River catchment

Quaternary catchment	River	Latitude	Longitude	EIS	PES	EC	Comments
T31G	Mzimvubu	S30 29 48	E29 06 10	Moderate	C	C	Rapid 3
T31J	Mzimvubu	S30 33 52	E29 10 37	High	A/B	A/B	Rapid 3
T32A	Mzintlava	S30 11 13	E29 20 46	Moderate	B	B	Rapid 3
T32A	Mzintlava	S30 15 53	E29 28 42	Moderate	B	B	Rapid 3
T32B	Tributary of Mzintlava	S30 23 57	E29 25 37	Moderate	A/B	A/B	Rapid 1
T32B	Mzintlava	S30 23 39	E29 26 53	Moderate	C	C	Rapid 3
T32B	Franklin Vlei (wetland)	S30 25 46	E29 28 21	High	C	C	Rapid
T32C	Mzintlava	S30 34 03	E29 25 15	Moderate	C	B/C	Rapid 3
T32D	Droewig	S30 32 46	E29 23 02	Low	C/D	C	Rapid 3
T32H	Mzintlava	S31 05 55	E29 24 03	Moderate	C	C	Rapid 3
T33C	Marulane	S30 27 59	E28 36 02	Low	D	D	Rapid 3
T33D	Phaballong	S30 23 10	E28 30 34	Low	D	D	Rapid 3
T33D	Kinira	S30 28 51	E28 37 22	Moderate	D	D	Rapid 3
T34J	Tina	S31 04 20	E28 54 44	Moderate	B/C	B/C	Rapid 3
T35G	Inxu	S31 11 51	E28 25 40	Moderate	B/C	B	Rapid 3
T35K	Tsitsa	S31 14 18	E28 50 33	Moderate	C	B/C	Rapid 3

Table B.5 Summary of the EWR estimated per quaternary catchment as from the RDM

Quaternary catchment	MAR	Cumulative MAR	Ecological category	EWR low Flow requireme	Total EWR requireme	EWR% of MAR	Comments
	million m³/a			million m³/a			
T31A	32.7	32.7	A	12.4	19.0	58	
T31B	31.3	31.3	B	7.6	12.6	40	
T31C	31.9	95.9	B	23.2	38.5	40	
T31D	25.0	120.9	B	29.3	48.4	40	
T31E	39.9	39.9	B	9.7	16.0	40	
T31F	37.0	197.9	A	75.0	115.3	58	
T31G	20.2	218.0	C	30.8	58.2	27	
T31H	64.8	64.8	B	12.6	22.6	35	
T31J	52.8	240.0	A/B	61.7	106.1	44	D/s of Dam 2
T31	**335.7**		**A/B**	**83.0**	**142.5**	**42**	**Outlet of T31J**
T32A	30.5	30.5	B	5.8	9.6	31	
T32B	30.8	61.3	C	6.7	12.9	21	
T32C	35.5	96.8	B/C	23.2	34.0	35	
T32D	32.9	129.7	C	14.6	27.5	21	D/s of Bokpoort
T32E	47.6	177.3	C	19.8	37.5	21	
T32F	48.4	196.6	C	21.8	41.5	21	D/s of Luzi site
T32F_1		225.7	C	24.7	47.5	21	
T32G	57.2	282.8	C	30.3	59.2	21	D/s of Dam B site
T32H	66.0	348.9	C	36.8	72.7	21	
T32	**348.9**		**C**	**36.8**	**72.7**	21	**Tertiary T32**
T33A	97.4	97.4	C	10.5	20.4	21	
T33B	94.3	94.3	C	9.5	19.4	21	
T33C	51.5	51.5	D	2.4	6.9	13	
T33D	61.0	304.2	D	14.5	41.2	14	D/s of Thabeng
T33E	20.5	324.7	C	34.1	67.6	21	D/s of Somabadi
T33F	51.9	376.6	C	39.8	78.5	21	
T33G	60.9	728.3	C	86.7	163.4	22	D/s of Siqingeni
T33G_1		407.1	C	43.1	84.9	21	D/s of Ntlabeni
T33H	46.1	777.4	C	92.0	173.7	22	
T33J	35.6	813.0	C	95.9	181.2	22	
T33K	22.4	1 184.2	C	136.0	259.1	22	
T33	**541.6**		**C**				
T34A	30.5	30.5	C	5.7	10.6	35	
T34B	35.9	66.4	C	10.7	19.8	30	
T34C	33.9	100.3	C	15.3	28.6	29	
T34D	52.2	152.5	C	22.5	42.0	28	
T34E	45.2	45.2	C	5.5	11.5	25	
T34F	39.5	55.1	C	7.5	14.0	25	D/s of Pitseng site
T34F_1		237.2	C	34.2	63.9	27	D/s of Hlabakazi
T34G	57.7	294.9	C	42.3	78.9	27	
T34H	91.2	331.4	C	47.3	88.1	27	D/s of Mpindweni
T34J	27.3	396.4	B/C	78.3	131.9	33	D/s of
T34J_1		413.4	B/C	81.7	137.4	33	D/s of Ku-Mdyobe
T34K	25.9	439.3	C	62.0	115.8	26	
T34	**439.3**			**62.0**	**115.8**	26	**Outlet of T34K**
T35A	92.4	92.4	C	12.7	23.6	26	
T35B	78.1	78.1	C	10.7	19.9	25	
T35C	86.8	86.8	C	11.9	22.1	25	
T35D	52.9	310.1	C	42.4	79.3	26	
T35E	102.9	407.8	C	55.8	104.0	26	D/s of Ntabelanga
T35F	58.2	58.2	C	8.4	15.6	27	
T35G	64.0	122.2	B	31.1	49.4	40	
T35H	84.6	202.6	C	29.1	54.4	27	D/s of Nomhala
T35J	40.3	247.0	C	35.4	66.3	27	
T35K	86.1	694.4	B/C	131.6	222.3	32	D/s of Malepelepe
T35L	29.0	753.3	C	102.8	192.1	26	D/s of Laleni site
T35M	42.3	800.4	C	109.7	204.4	26	D/s of Gongo site
T35	**817.3**		**C**	**112.1**	**208.7**	26	**Outlet of T35M**
T36A	65.2	2 506.0	B	514.3	861.7	34	D/s of Mbokazi
T36B	55.2	2 561.1	B	526.7	881.0	34	
T36	**120.4**						
T36	**2 561.1**			**526.7**	**881.0**	34	**Estuary**

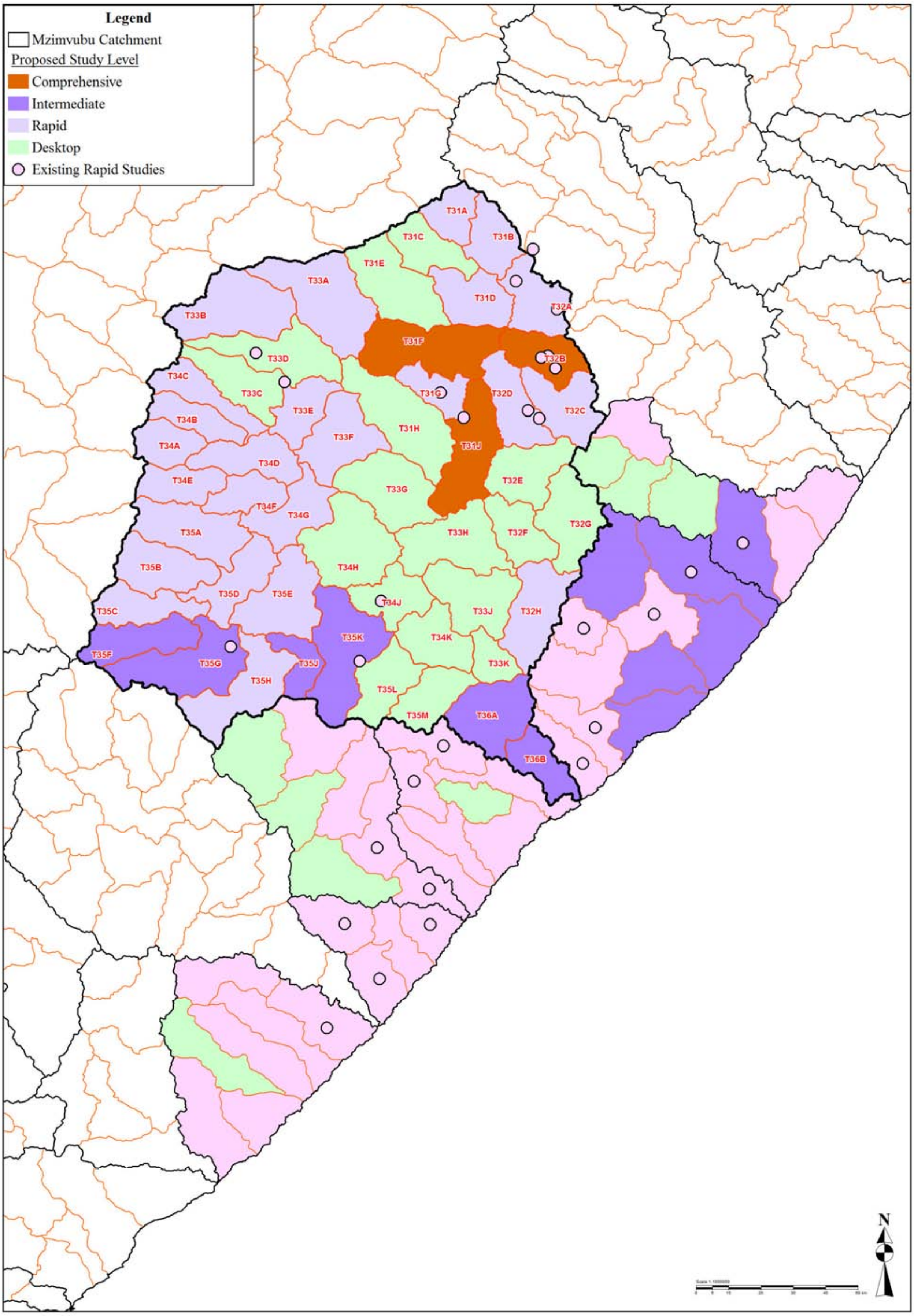


Figure B.3 Recommended reserve levels for the Mzimvubu Development Zone

The available Reserve determination results have been used for extrapolation purposes to other adjacent quaternary catchments and the Desktop Reserve Model (DRM) was run to provide estimates of the EWR per quaternary.

The EWR results are of low confidence as the DRM and results of rapid level III Reserve determinations have been used. The updated WR2005 naturalised flows were used as the base data and adjusted where the flows differed by more than 5% from the WR90 data that was used during the rapid level III studies.

The following provides a summary of the adjustments made to the desktop results due to previous EWR results or due to changes in hydrology. Quaternary catchments not listed indicate that no adjustment was required.

T31:

T31A-G

EWR site in T31G

WR90 MAR = 241.28 x $10^6 m^3$

WR2005 MAR = 203.92 x $10^6 m^3$

Adjustment ratio = 1.18

T31H-J

EWR site in T31J

WR90 MAR = 266.23 x 106m3

WR2005 MAR = 226.47 x 106m3

Adjustment ratio = 1.15

T32:

T32C

Adjustments required for the low flow months, especially August, as a results of the Reserve determination study undertaken in this quaternary catchment. The total EWR = 35.07% of MAR and the maintenance low flow = 23.96% of MAR.

T33:

No adjustments required

T34:

T34A-K

EWR site in T34J

WR90 MAR = 491.06 x $10^6 m^3$

WR2005 MAR = 404.94 x $10^6 m^3$

Adjustment ratio = 1.21

T35:

T35F-J

EWR site in T35G

WR90 MAR = 96.55 x 10^6m^3

WR2005 MAR = 76.73 x 10^6m^3

Adjustment ration = 1.26

T35A-E, K, L, M

EWR site in T35J

WR90 MAR = 892.0 x 10^6m^3

WR2005 MAR = 746.0 x 10^6m^3

Adjustment ration = 1.20

T36:

T36A, B

No EWR site

WR90 MAR = 2 810.0 x 10^6m^3

WR2005 MAR = 2 613.0 x 10^6m^3

Adjustment ration = 1.08

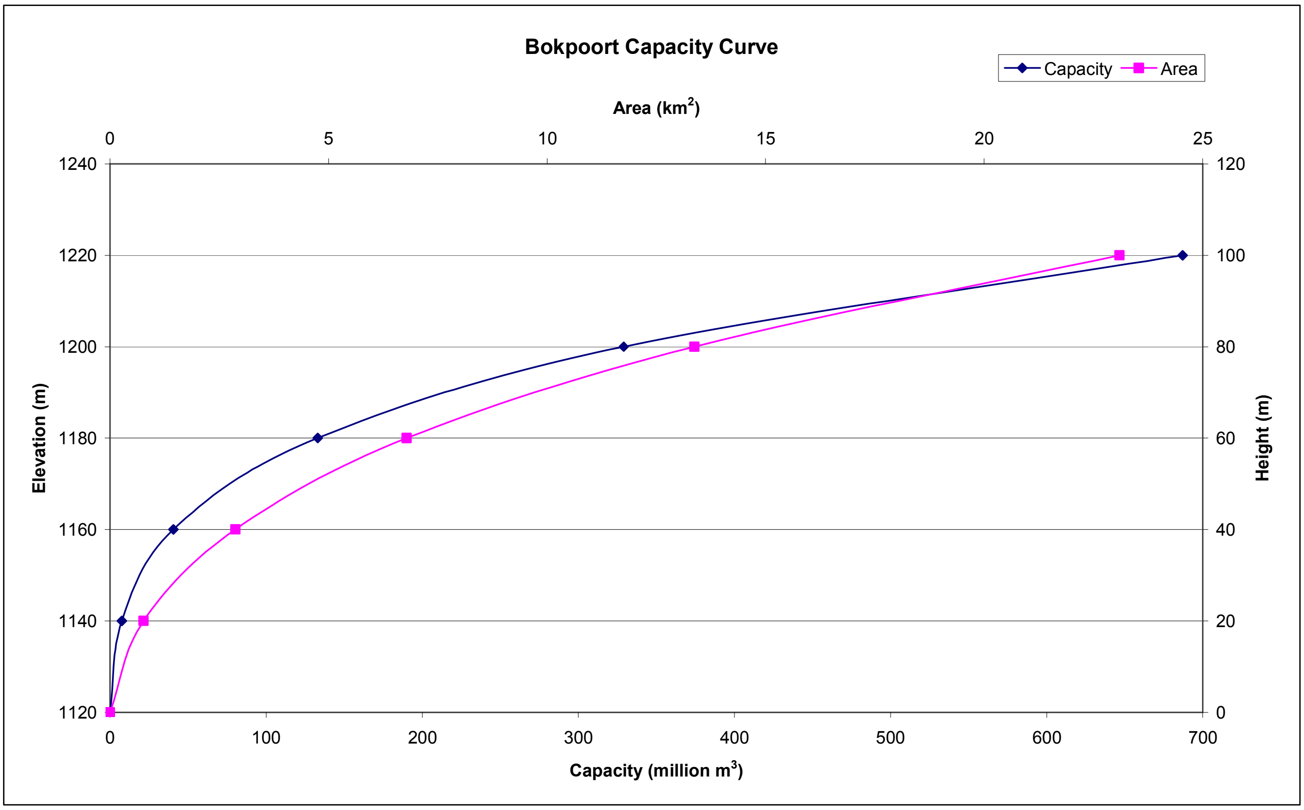
A summary of the EWR estimated per quaternary catchment as from the DRM is provided in **Table B.5**. The EWRs were input into the monthly water balance model and used to ensure that all potential water resources development analyses accommodated the EWRs.

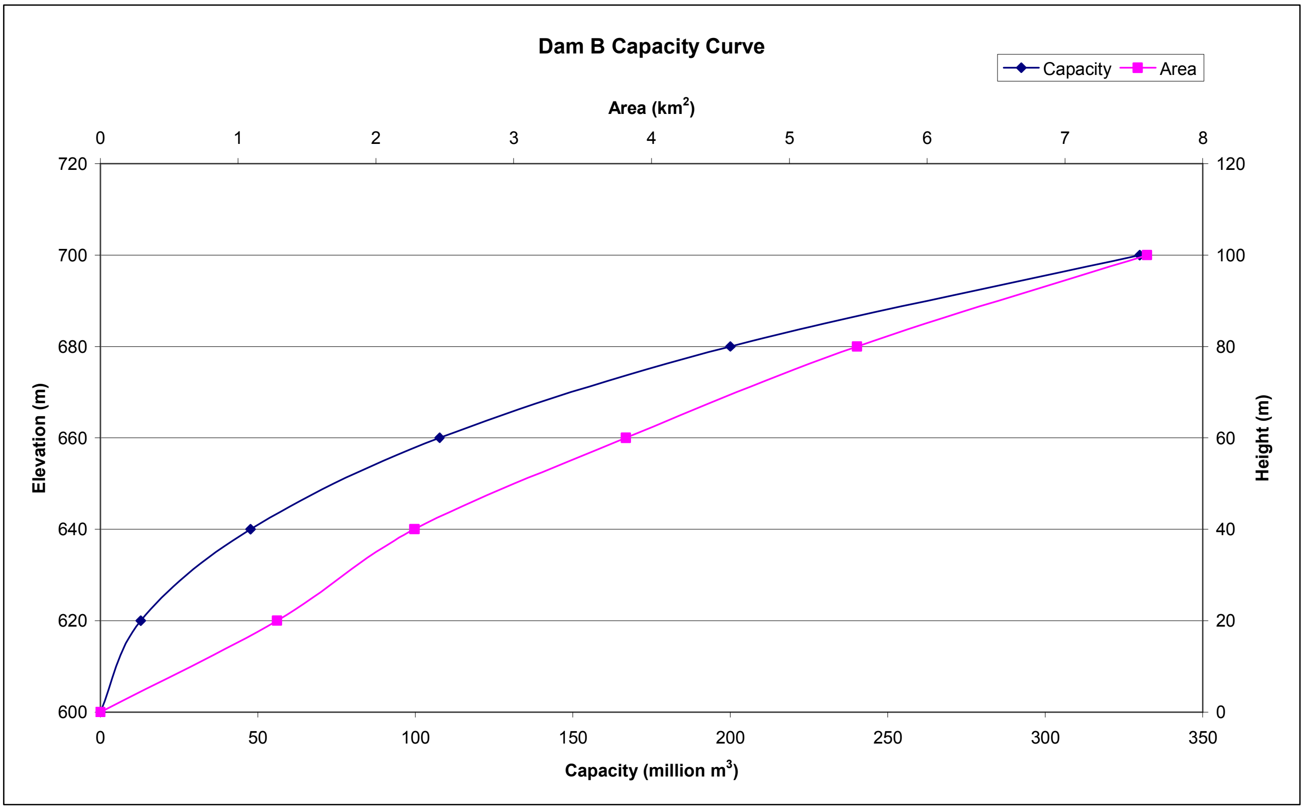
<u>**References**</u>

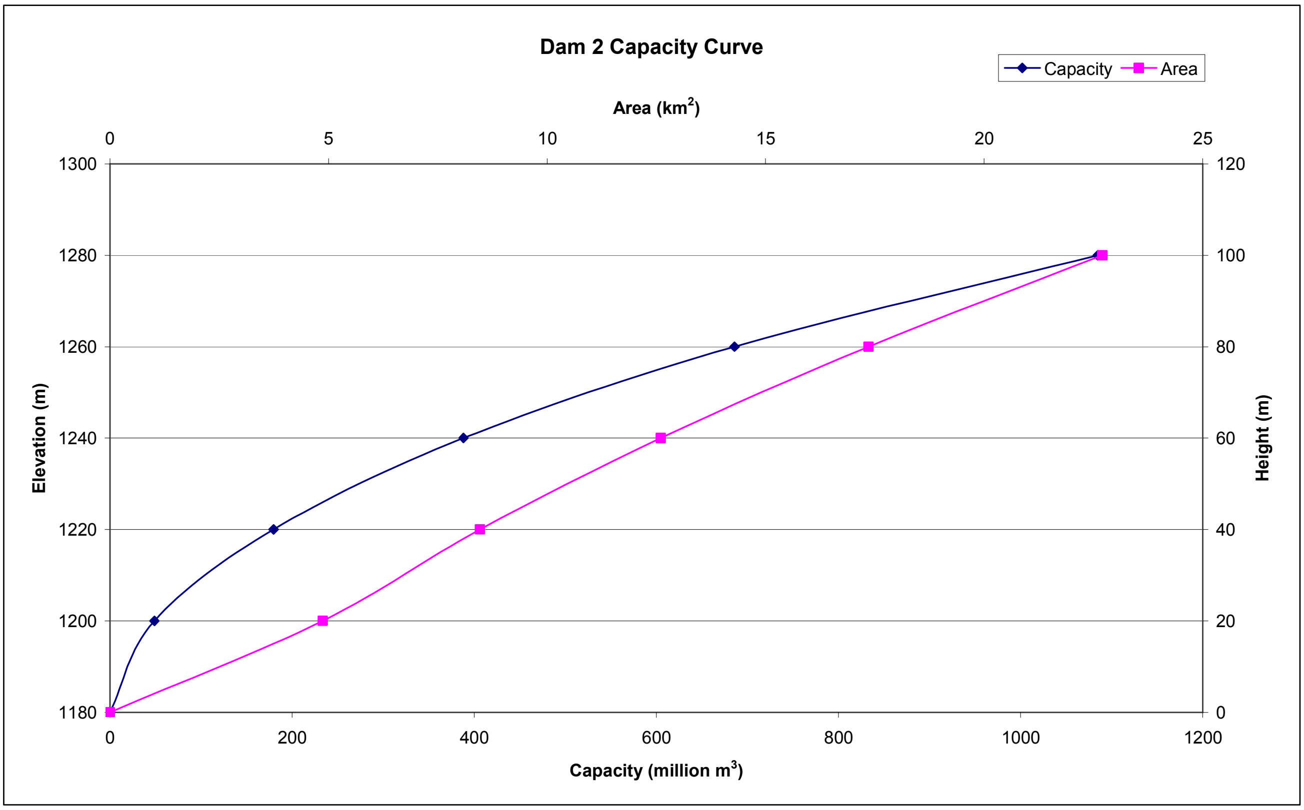
KLEYNHANS, C.J. (1999). **A procedure for the determination of the ecological Reserve for the purpose of the national water balance model for South African rivers**. Internal Report, IWQS, DWAF, Pretoria. pp. 19. (Updated Ecological Importance and Sensitivity, 2002).

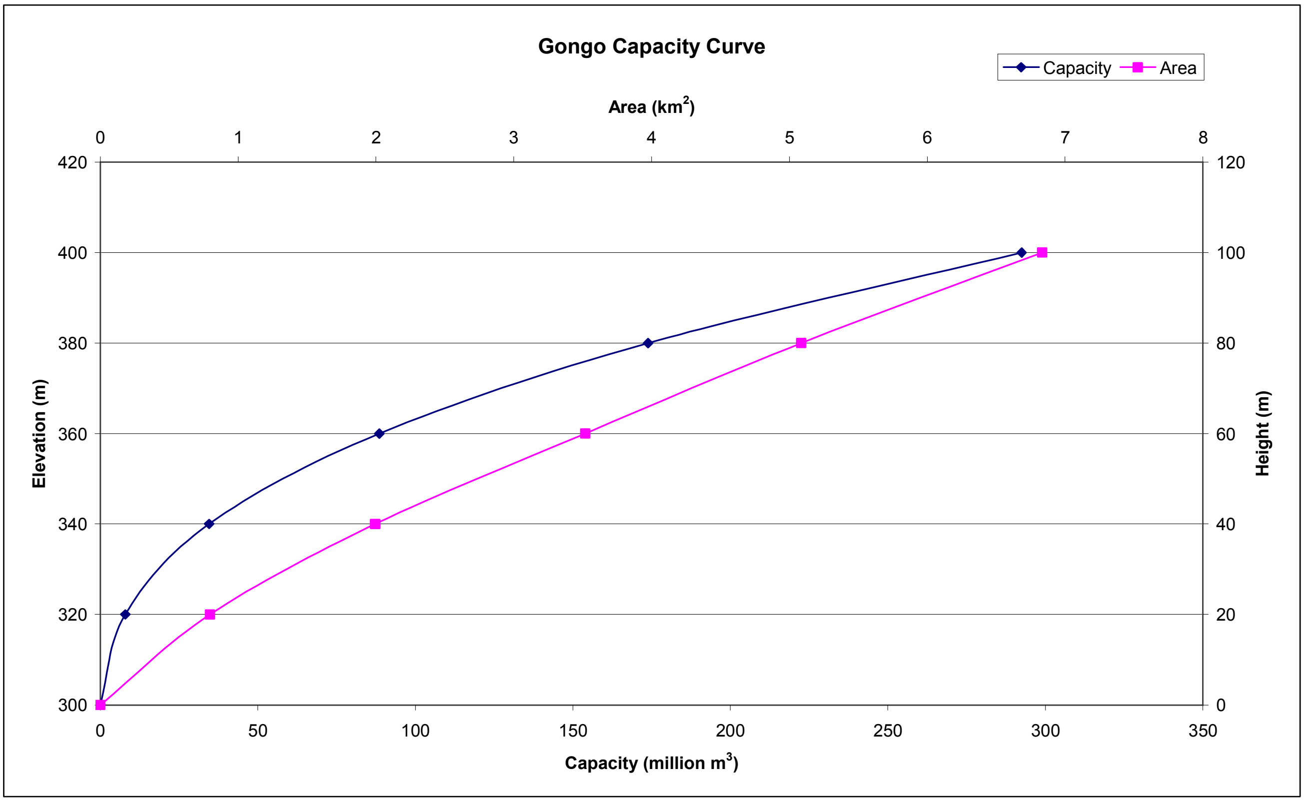
APPENDIX C

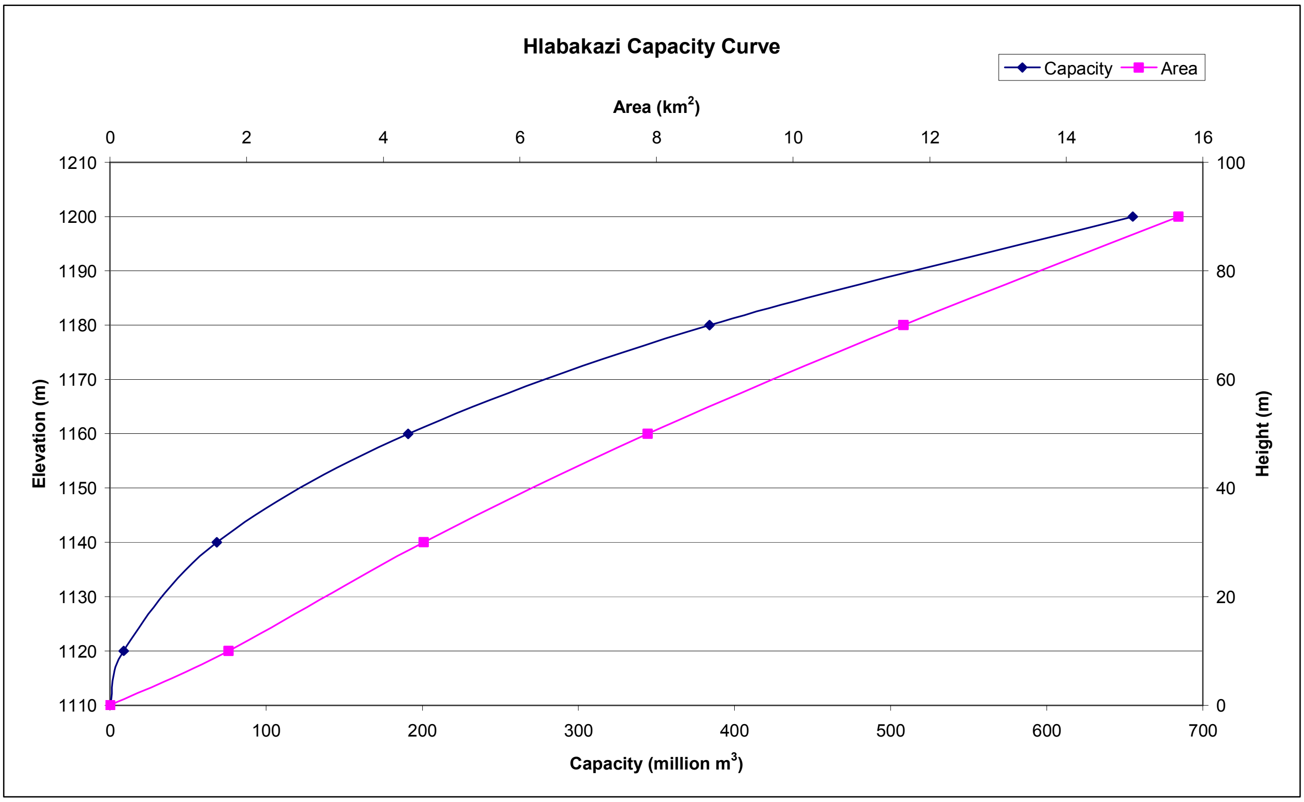
Potential dam capacity curves

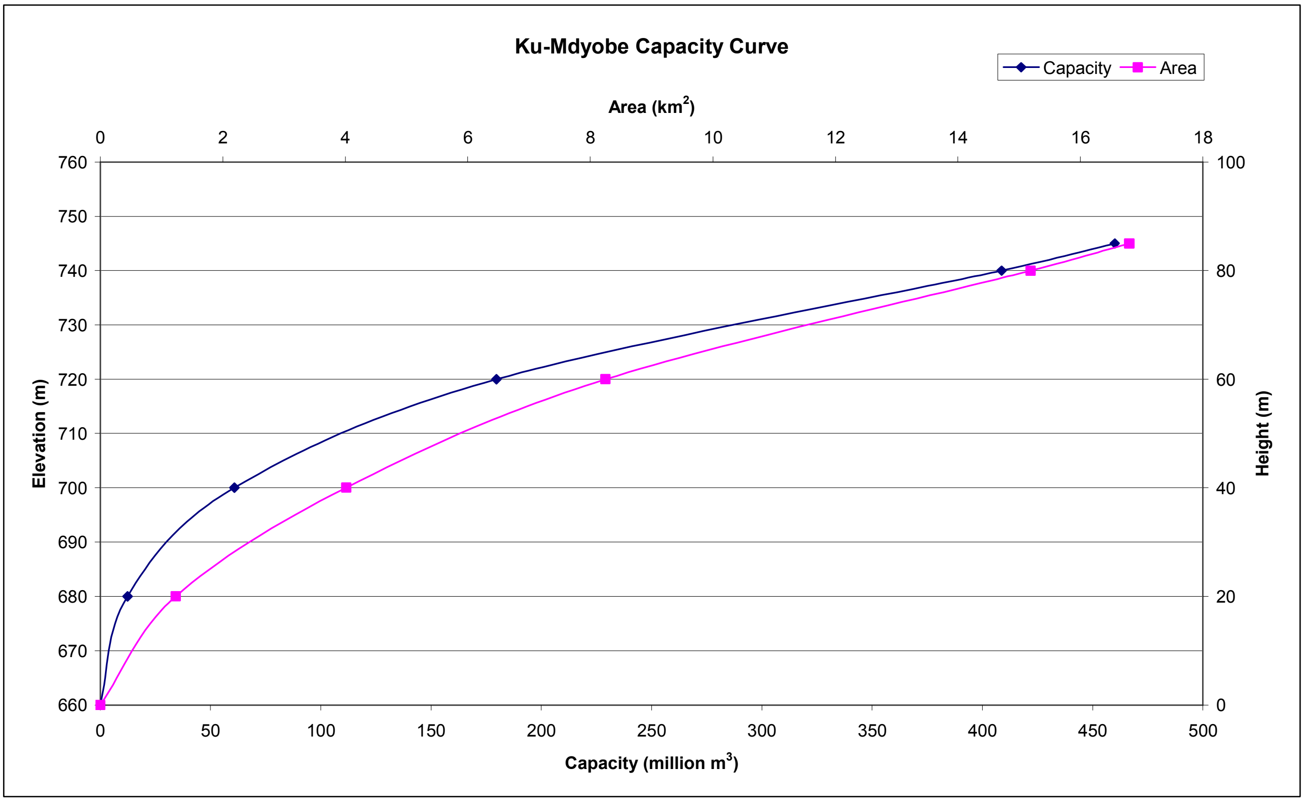

Bokpoort Capacity Curve
Capacity
Area
Area (km²)
0
5
10
15
20
25
1240
1220
1200
1180
1160
1140
1120
120
100
80
60
40
20
0
Elevation (m)
Height (m)
0
100
200
300
400
500
600
700
Capacity (million m³)

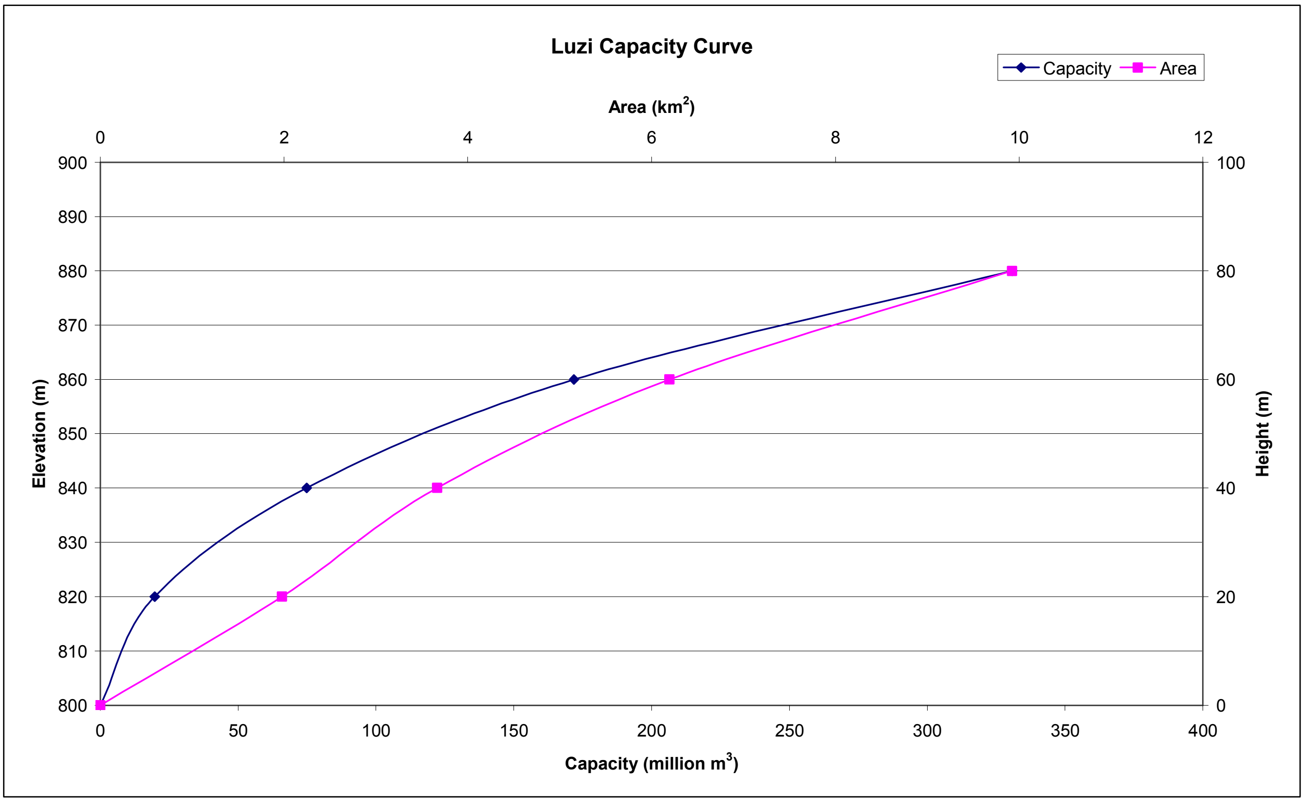

Dam B Capacity Curve
Capacity
Area
Area (km²)
0
1
2
3
4
5
6
7
8
720
700
680
660
640
620
600
120
100
80
60
40
20
0
Elevation (m)
Height (m)
0
50
100
150
200
250
300
350
Capacity (million m³)


Dam 2 Capacity Curve
Capacity
Area
Area (km^2)
0
5
10
15
20
25
1300
1280
1260
1240
1220
1200
1180
Elevation (m)
120
100
80
60
40
20
0
Height (m)
0
200
400
600
800
1000
1200
Capacity (million m^3)

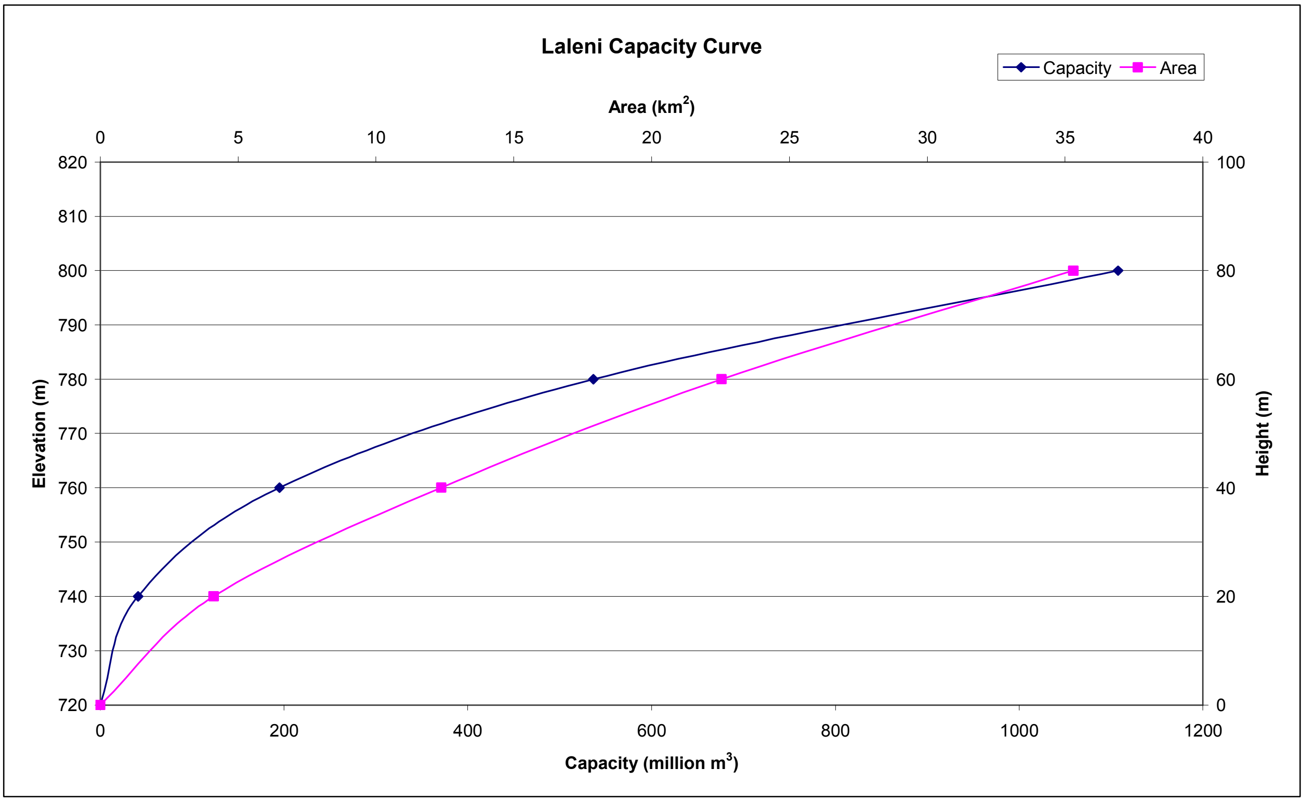

Gongo Capacity Curve
Capacity
Area
Area (km^2)
0
1
2
3
4
5
6
7
8
420
400
380
360
340
320
300
Elevation (m)
120
100
80
60
40
20
0
Height (m)
0
50
100
150
200
250
300
350
Capacity (million m^3)


Hlabakazi Capacity Curve
Capacity
Area
Area (km²)
0
2
4
6
8
10
12
14
16
1210
1200
1190
1180
1170
1160
1150
1140
1130
1120
1110
Elevation (m)
100
80
60
40
20
0
Height (m)
0
100
200
300
400
500
600
700
Capacity (million m³)

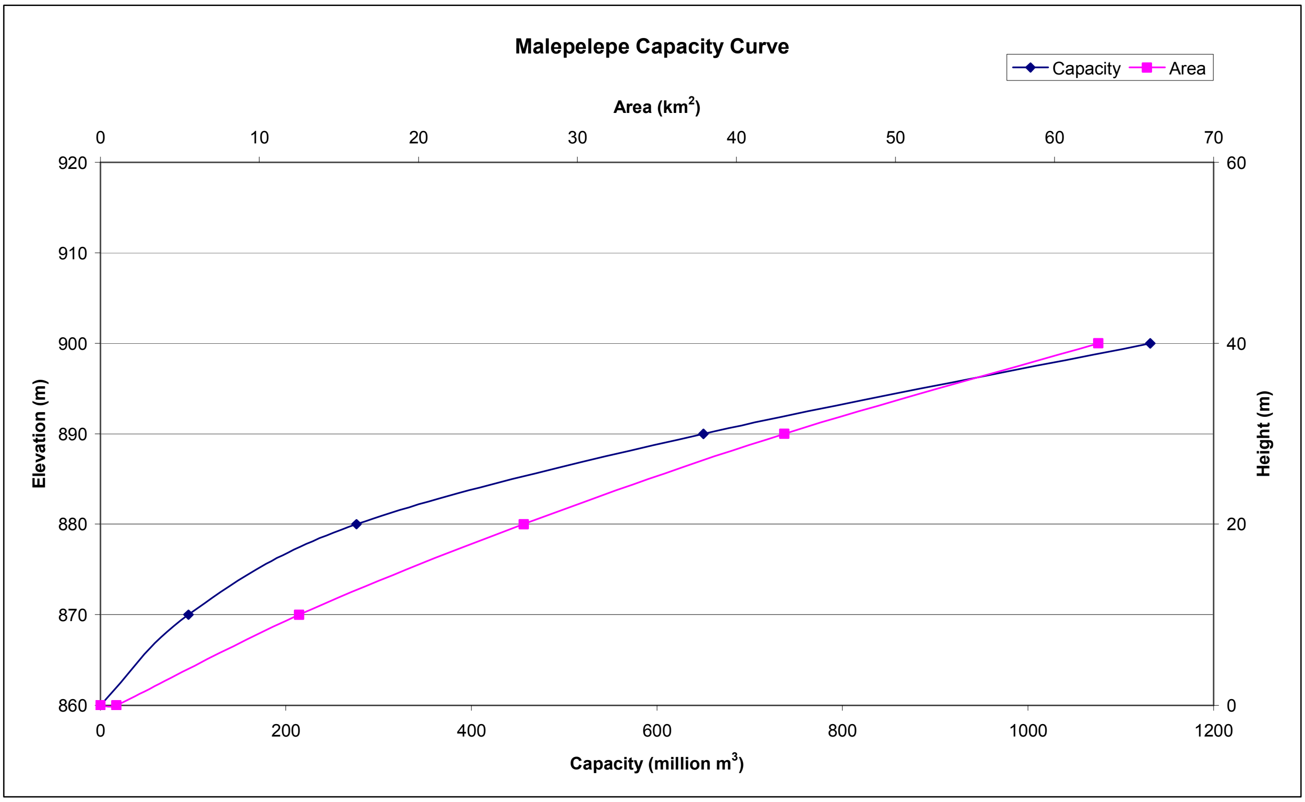

Ku-Mdyobe Capacity Curve
Capacity
Area
Area (km²)
0
2
4
6
8
10
12
14
16
18
760
750
740
730
720
710
700
690
680
670
660
Elevation (m)
100
80
60
40
20
0
Height (m)
0
50
100
150
200
250
300
350
400
450
500
Capacity (million m³)

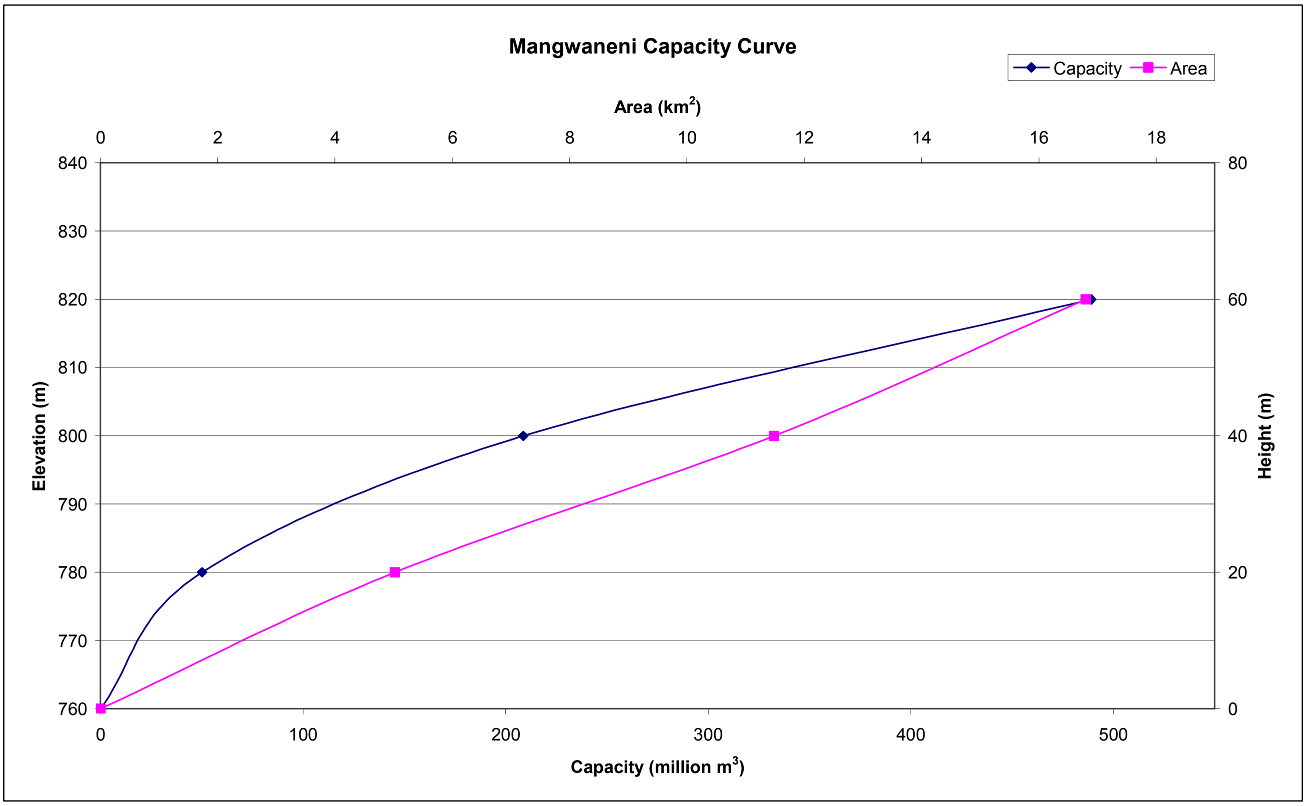


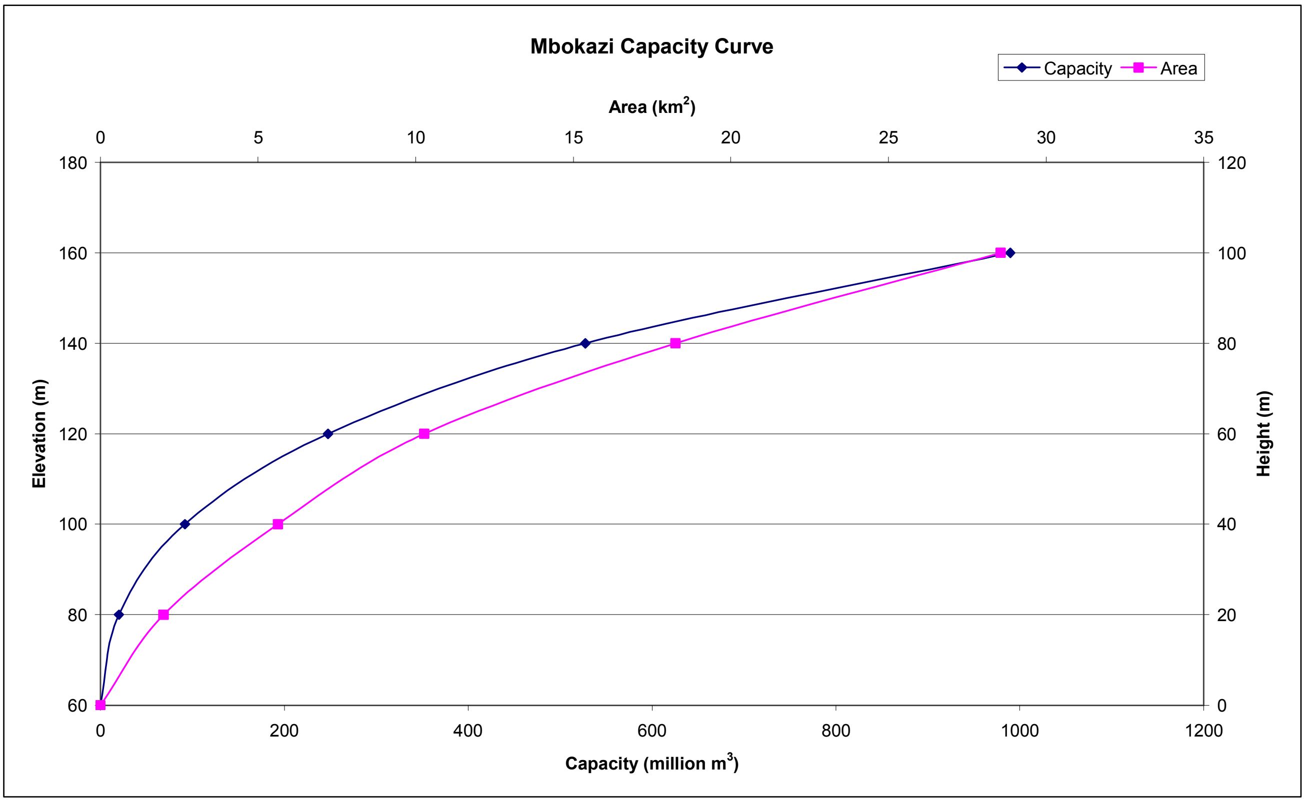
Luzi Capacity Curve
Capacity
Area
Area (km2)
0
2
4
6
8
10
12
900
890
880
870
860
850
840
830
820
810
800
Elevation (m)
100
80
60
40
20
0
Height (m)
0
50
100
150
200
250
300
350
400
Capacity (million m3)

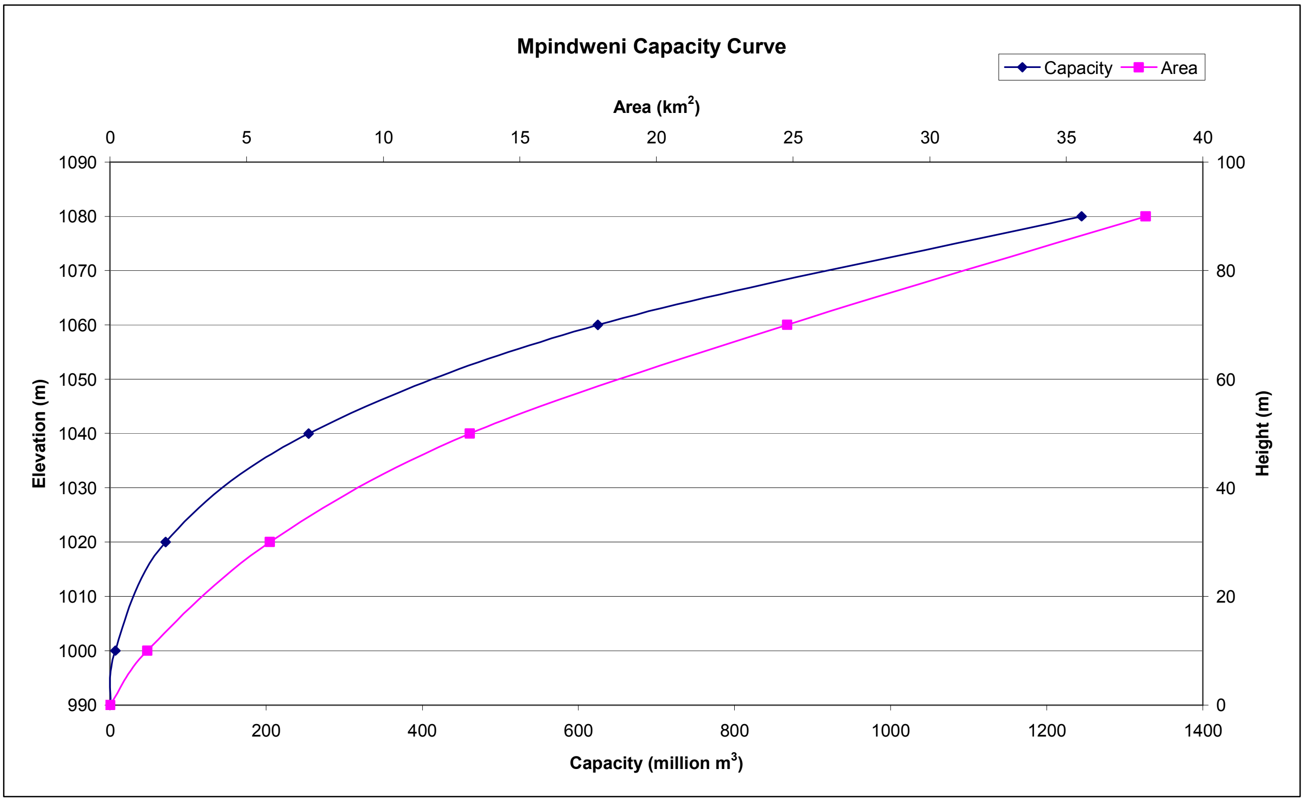


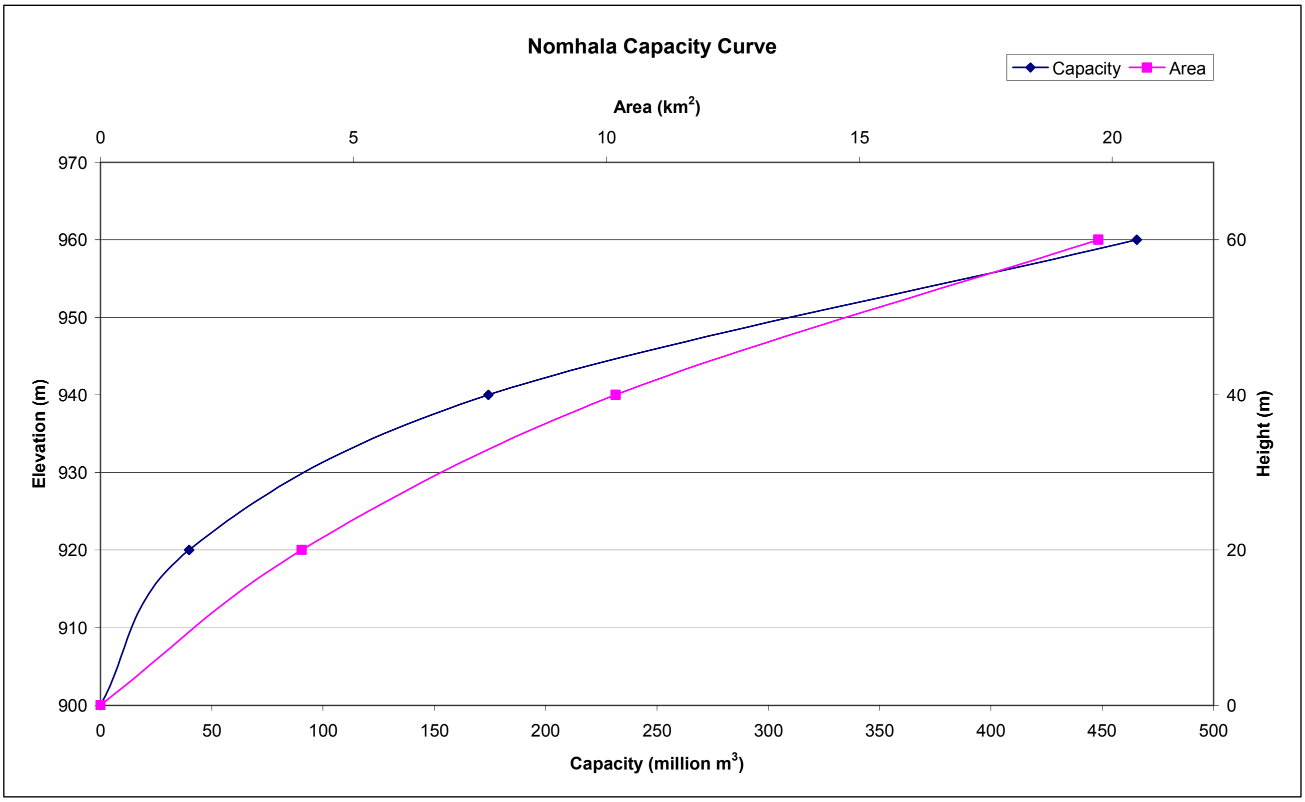
Laleni Capacity Curve
Capacity
Area
Area (km2)
0
5
10
15
20
25
30
35
40
820
810
800
790
780
770
760
750
740
730
720
Elevation (m)
100
80
60
40
20
0
Height (m)
0
200
400
600
800
1000
1200
Capacity (million m3)


Malepelepe Capacity Curve
Capacity
Area
Area (km2)
0 10 20 30 40 50 60 70
920 910 900 890 880 870 860
Elevation (m)
60 40 20 0
Height (m)
0 200 400 600 800 1000 1200
Capacity (million m3)

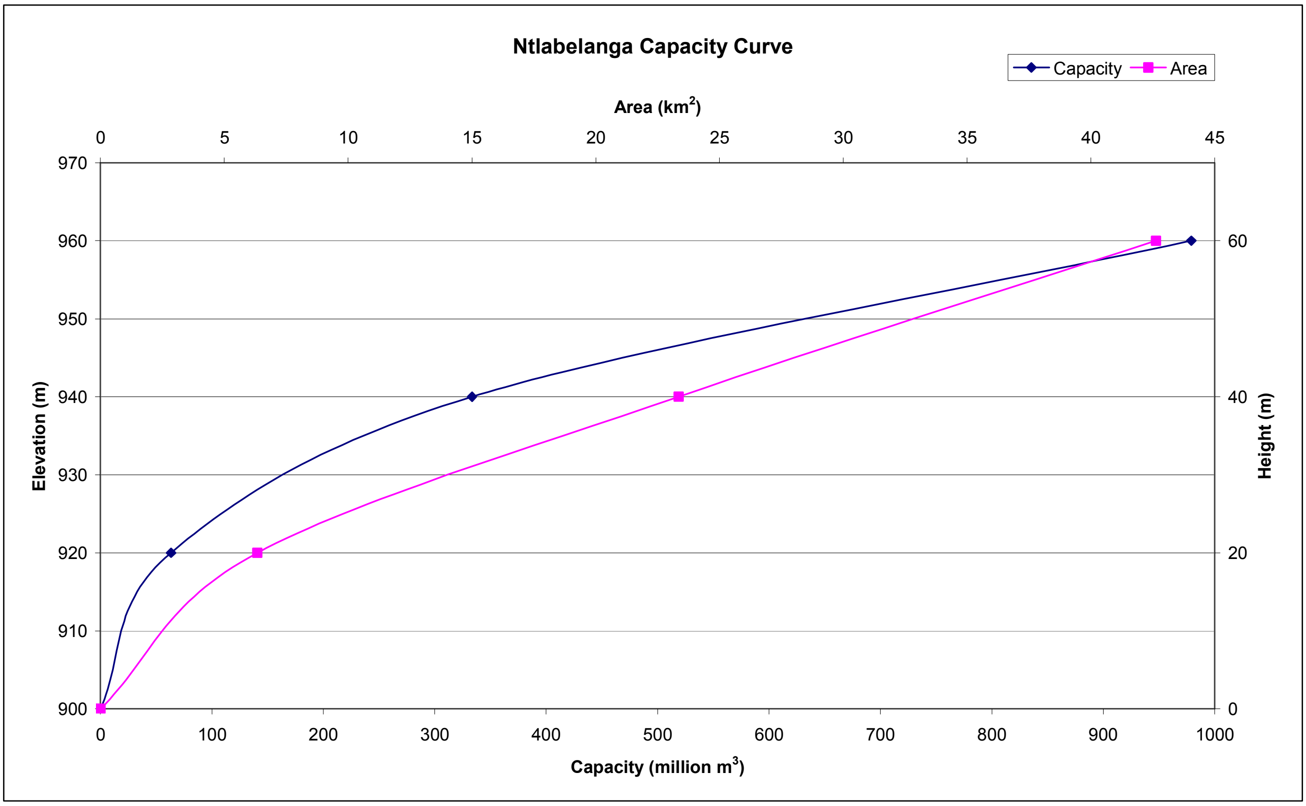

Mangwaneni Capacity Curve
Capacity
Area
Area (km2)
0 2 4 6 8 10 12 14 16 18
840 830 820 810 800 790 780 770 760
Elevation (m)
80 60 40 20 0
Height (m)
0 100 200 300 400 500
Capacity (million m3)


Mbokazi Capacity Curve
Capacity
Area
Area (km2)
0
5
10
15
20
25
30
35
180
160
140
120
100
80
60
Elevation (m)
120
100
80
60
40
20
0
Height (m)
0
200
400
600
800
1000
1200
Capacity (million m3)

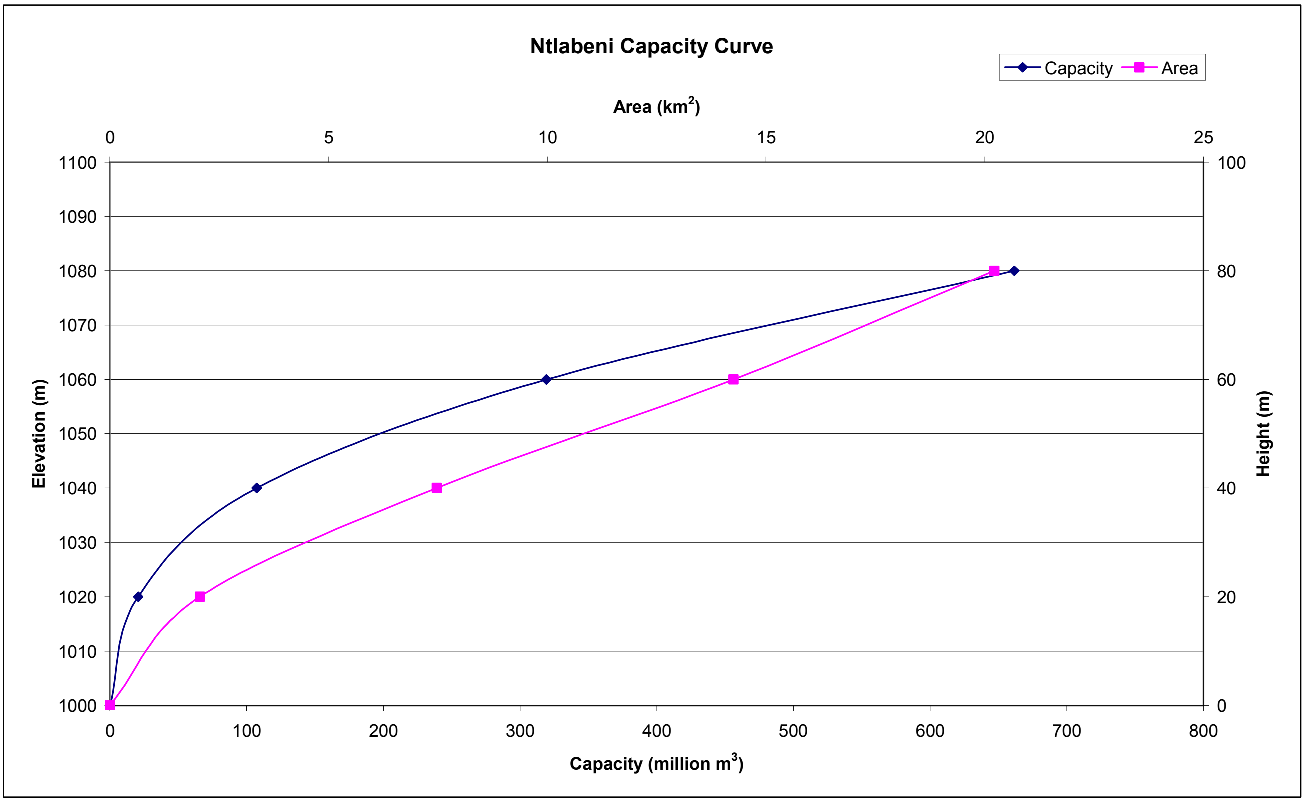

Mpindweni Capacity Curve
Capacity
Area
Area (km2)
0
5
10
15
20
25
30
35
40
1090
1080
1070
1060
1050
1040
1030
1020
1010
1000
990
Elevation (m)
100
80
60
40
20
0
Height (m)
0
200
400
600
800
1000
1200
1400
Capacity (million m3)

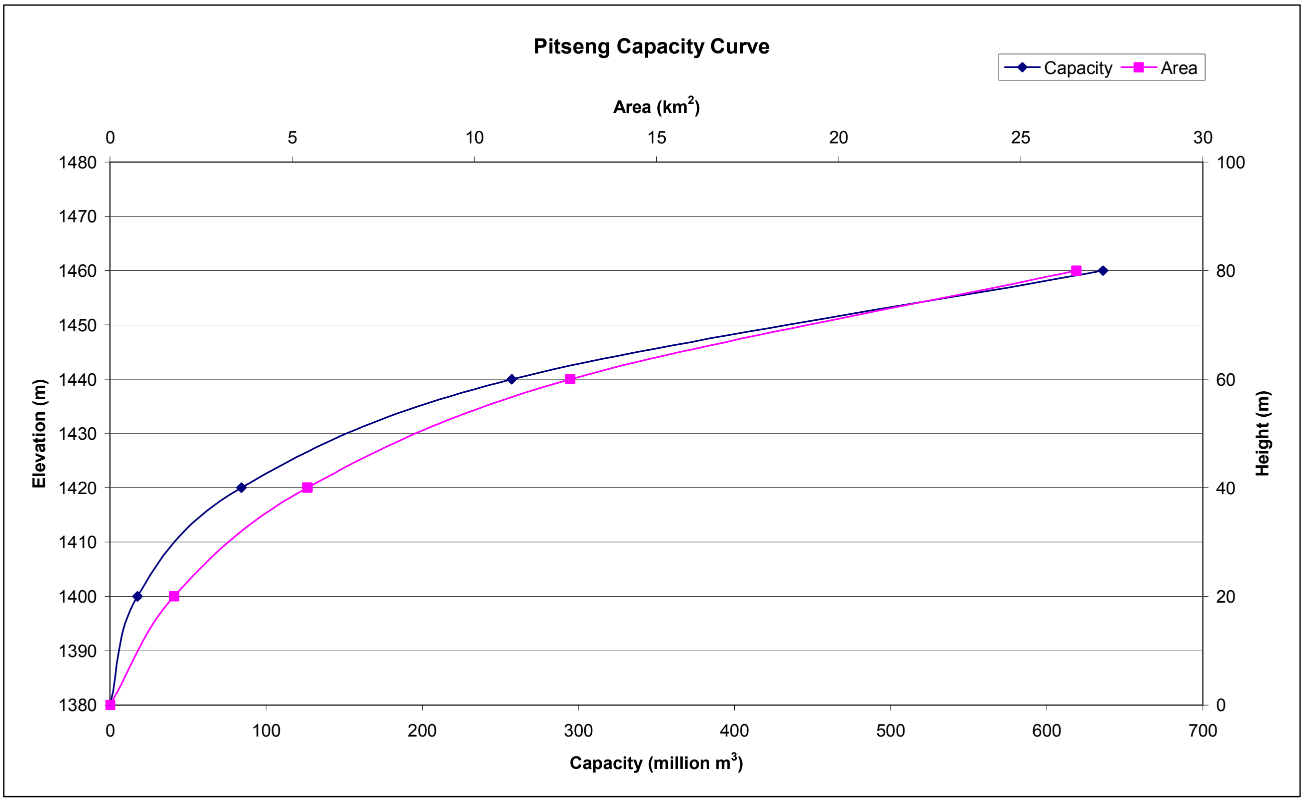


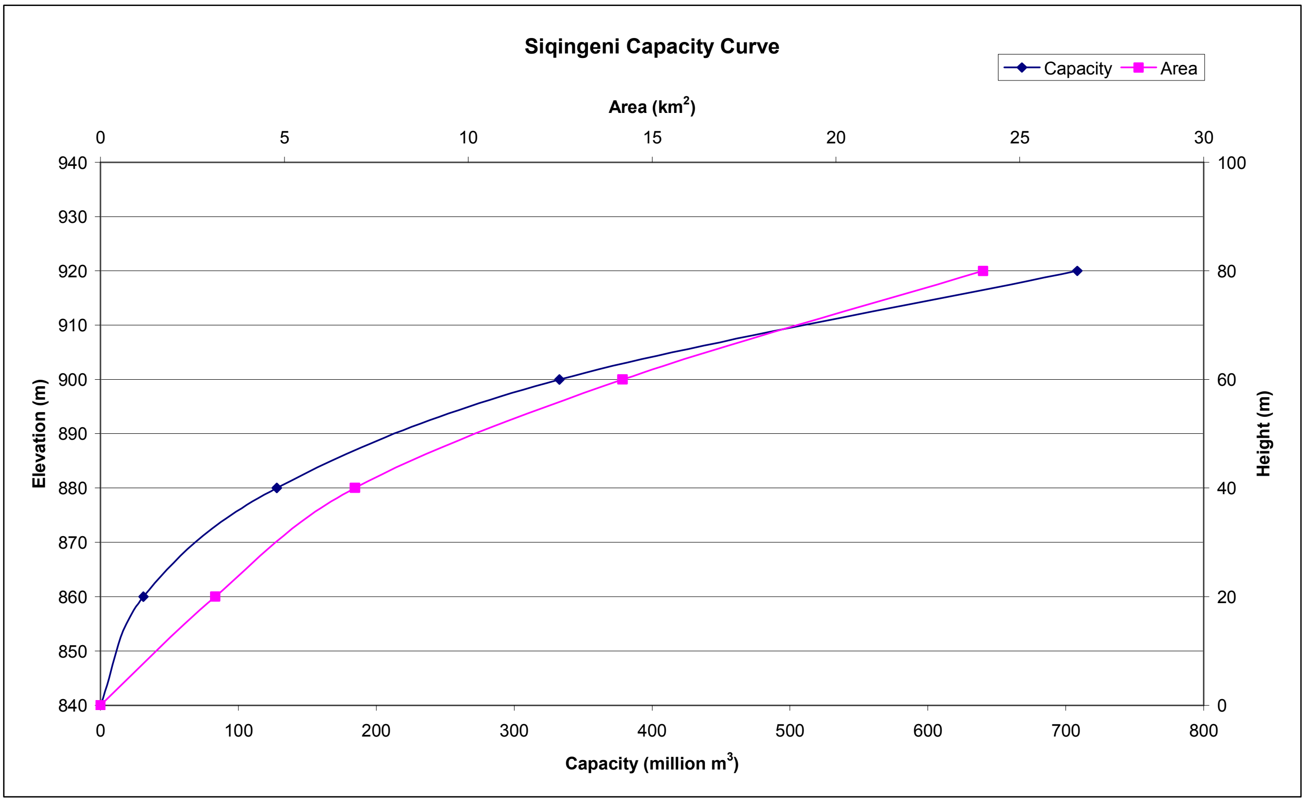
Nomhala Capacity Curve
Capacity
Area
Area (km²)
0
5
10
15
20
970
960
950
940
930
920
910
900
Elevation (m)
60
40
20
0
Height (m)
0
50
100
150
200
250
300
350
400
450
500
Capacity (million m³)

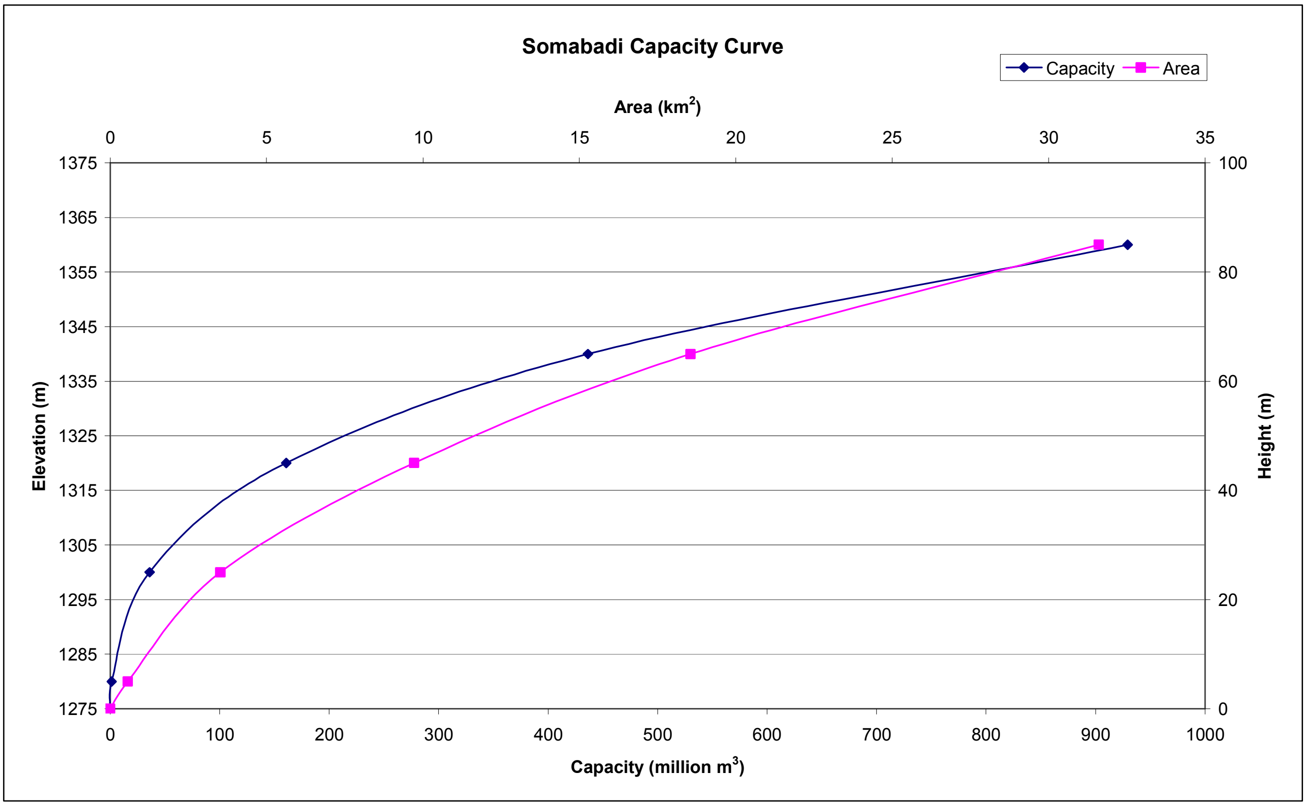


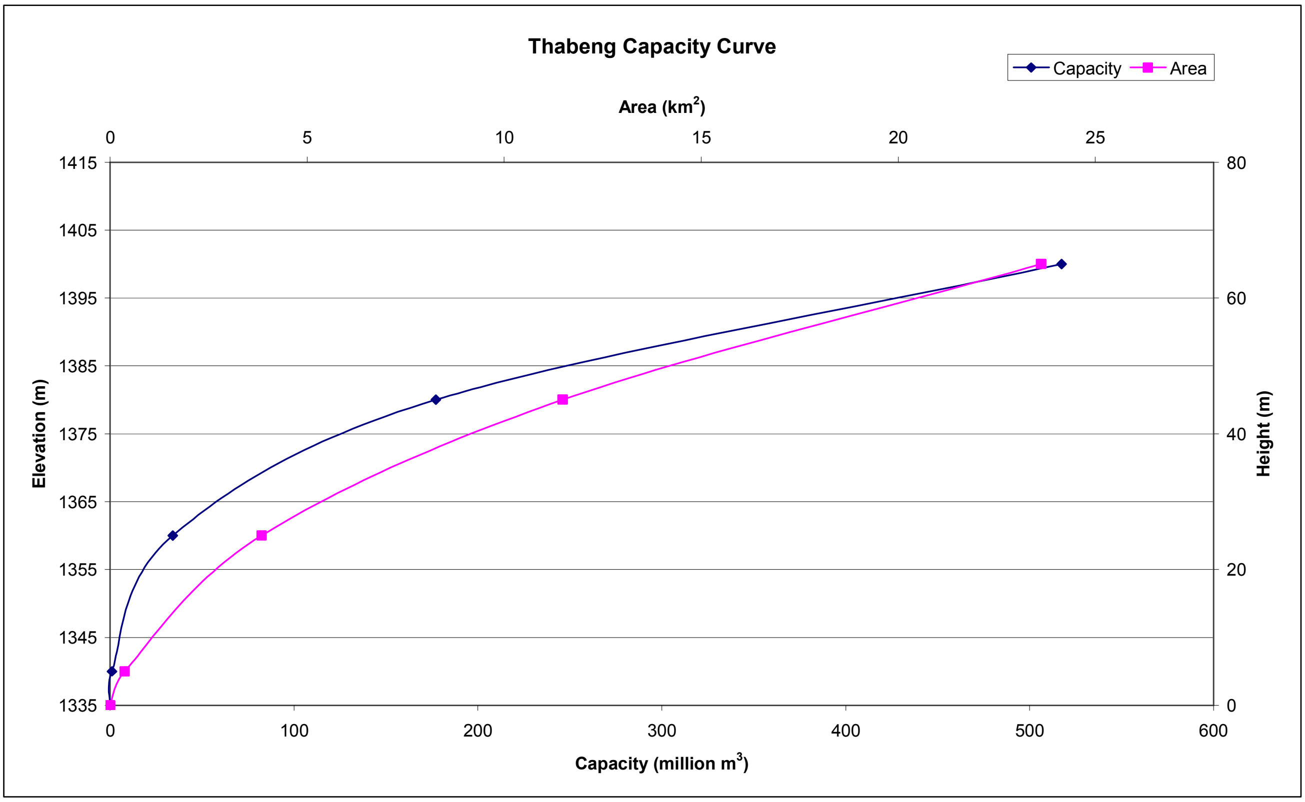
Ntlabelanga Capacity Curve
Capacity
Area
Area (km²)
0
5
10
15
20
25
30
35
40
45
970
960
950
940
930
920
910
900
Elevation (m)
60
40
20
0
Height (m)
0
100
200
300
400
500
600
700
800
900
1000
Capacity (million m³)


Ntlabeni Capacity Curve
Capacity
Area
Area (km²)
0
5
10
15
20
25
1100
1090
1080
1070
1060
1050
1040
1030
1020
1010
1000
Elevation (m)
100
80
60
40
20
0
Height (m)
0
100
200
300
400
500
600
700
800
Capacity (million m³)


Pitseng Capacity Curve
Capacity
Area
Area (km²)
0
5
10
15
20
25
30
1480
1470
1460
1450
1440
1430
1420
1410
1400
1390
1380
Elevation (m)
100
80
60
40
20
0
Height (m)
0
100
200
300
400
500
600
700
Capacity (million m³)


Siqingeni Capacity Curve
Capacity
Area
Area (km^2)
0
5
10
15
20
25
30
940
930
920
910
900
890
880
870
860
850
840
Elevation (m)
100
80
60
40
20
0
Height (m)
0
100
200
300
400
500
600
700
800
Capacity (million m^3)


Somabadi Capacity Curve
Capacity
Area
Area (km^2)
0
5
10
15
20
25
30
35
1375
1365
1355
1345
1335
1325
1315
1305
1295
1285
1275
Elevation (m)
100
80
60
40
20
0
Height (m)
0
100
200
300
400
500
600
700
800
900
1000
Capacity (million m^3)


Thabeng Capacity Curve
Capacity
Area
Area (km²)
0
5
10
15
20
25
1415
1405
1395
1385
1375
1365
1355
1345
1335
Elevation (m)
80
60
40
20
0
Height (m)
0
100
200
300
400
500
600
Capacity (million m³)

APPENDIX D

Sedimentation Report

1 GENERAL

Sediment loads transported by rivers are partly and often largely deposited in reservoirs, causing a loss in storage capacity and adversely affecting reservoir yield. This does not only impact on the active life of a reservoir, but also influences the related infrastructure, e.g. outlet works, as well as the upstream backwater effects and riverine ecological systems. As the Mzimvubu River catchment contains areas with high sediment yield potential, reservoir sedimentation can be a major factor in the development of water resources in the catchment.

This section contains selected information on the verification of sediment yield of the Mzimvubu River catchment and the potential impact thereof on proposed dams within the catchment. This includes information on the estimation of catchment sediment yield for various parts of the river basin and the consequent reductions in storage capacity that can be expected for proposed reservoir. No attention is given to the distribution patterns of deposited sediment.

2 FACTORS IMPACTING OF SEDIMENT YIELD ESTIMATION

The hydraulic and geometrical characteristics of rivers and the closely associated properties of catchment sediment yield and sediment transport are a complex science. The quantity of sediment transported by a given river depends upon the availability of transportable material, i.e. sediment yield potential of the soils within the catchment.

Although transporting capacity determines the quantity of sediment to be transported, either by wind or aeolian transport or run-off, land use determines the potential sediment yield from a catchment. Therefore, one of the practical problems encountered in the analysis of catchment sediment yield is that it not only varies in space but also in time as conditions change. Also, both the water flow and sediment load in a river vary over a wide range with time. In addition, the water/sediment ratio also varies. A river system is therefore in a continuous state of tending towards an equilibrium condition associated with the water and sediment load at that moment, but which can change from day-to-day. Major changes are, however, only expected during and after floods.

In the assessment of catchment sediment yield, the hydrological characteristics of the catchment, geology, ground cover, erosion and sediment characteristics, land use and river mechanics all play important roles. A large number of combinations of these variables occur in the Mzimvubu River catchment area. No data base containing sufficient information regarding the above-mentioned variables in the study area, however, exists.

3 CATCHMENT DESCRIPTION

The Mzimvubu River catchment stretches from the Drakensberg Mountains in Lesotho south-east towards the town of Port St Johns where it drains into the Indian Ocean. The catchment is located in the primary drainage region T and comprises of tertiary drainage regions T31, T32, T33, T34, T35 and T36. The catchment borders on the north-eastern side with the Mzimkhulu River catchment and to the south with the Mbashe and Mthatha river catchments. The catchment includes various towns of which the most important are Ugie, Tsolo, Qumbu, Maclear, Mount Fletcher, Mount Ayliff, Mount Frere, Matatiele, Tabankulu, Kokstad, Flagstaff and Port St Johns.

No major existing dams are located in the Mzimvubu River catchment. Various smaller dams are, however, located within the catchment. These dams are listed in **Table D.1**.

Table D.1 Existing dams within the Mzimvubu River catchment

Dam name	River	Location number	Quaternary catchment	Date of construction	Comment
Hopewell	Krom		T31B	-	Not listed in DWAF Dam list
Poortjie	Riet		T31B	-	Not listed in DWAF Dam list
Bon Accord	Mzimvubu		T31F		Not listed in DWAF Dam list
Crystal Springs	Mzintlava	T300-16	T32C	1967	No dam survey information
Elandskuil	Manzamnyama		T32C	-	Not listed in DWAF Dam list
Mountain	Keneka	T300-04	T33 A	1914	Dam survey in 1970
Belfort	Mafube	T3R001	T33A	2000	No dam survey information
Ntenetyana	Ntenetyana	R3R003	T33G	-	Not listed in DWAF Dam list
Nqadu	Nqadu	T3R004	T35K	-	Not listed in DWAF Dam list
Majola	Kuguduzwe/ Nkonkweni	T306-17	T36B	1999	No dam survey information

A locality plan indicating the positions of the proposed and existing dams in and nearby the Mzimvubu River catchment is presented in **Figure D.1 (Map 1** and **Map 2)**.

Land use in the Mzimvubu River catchment is schematically indicated in **Figure D.2**.

The Mzimvubu River catchment contains significant areas with high sediment yield and transportation potential. Sediment deposition in reservoirs is therefore likely to have major impacts on water development schemes in this region.

The Mthatha Dam on the Mthatha River to the south of the catchment is the closest larger dam. Other existing nearby large dams include the Xilinxa, Indwe (Doring River), Lubisi, Xonxa, Tsojana and Ncora dams to the south-west of the Mzimvubu River catchment. Smaller dams to the south-east of the Mzimvubu River catchment include the Magnu and

Mhlanga dams. Smaller dams to the south-west of the catchment include the Toleni, Gcuwa and Mabeleni dams. Although the Mthatha Dam's catchment area are close to that of the Mzimvubu River catchment, the catchments of the Indwe, Lubisi, Xonxa and Ncora dams are located in much more densely populated areas around Queenstown. The Xilinxa Dam is located in a rural area between Idutywa and Butterworth.

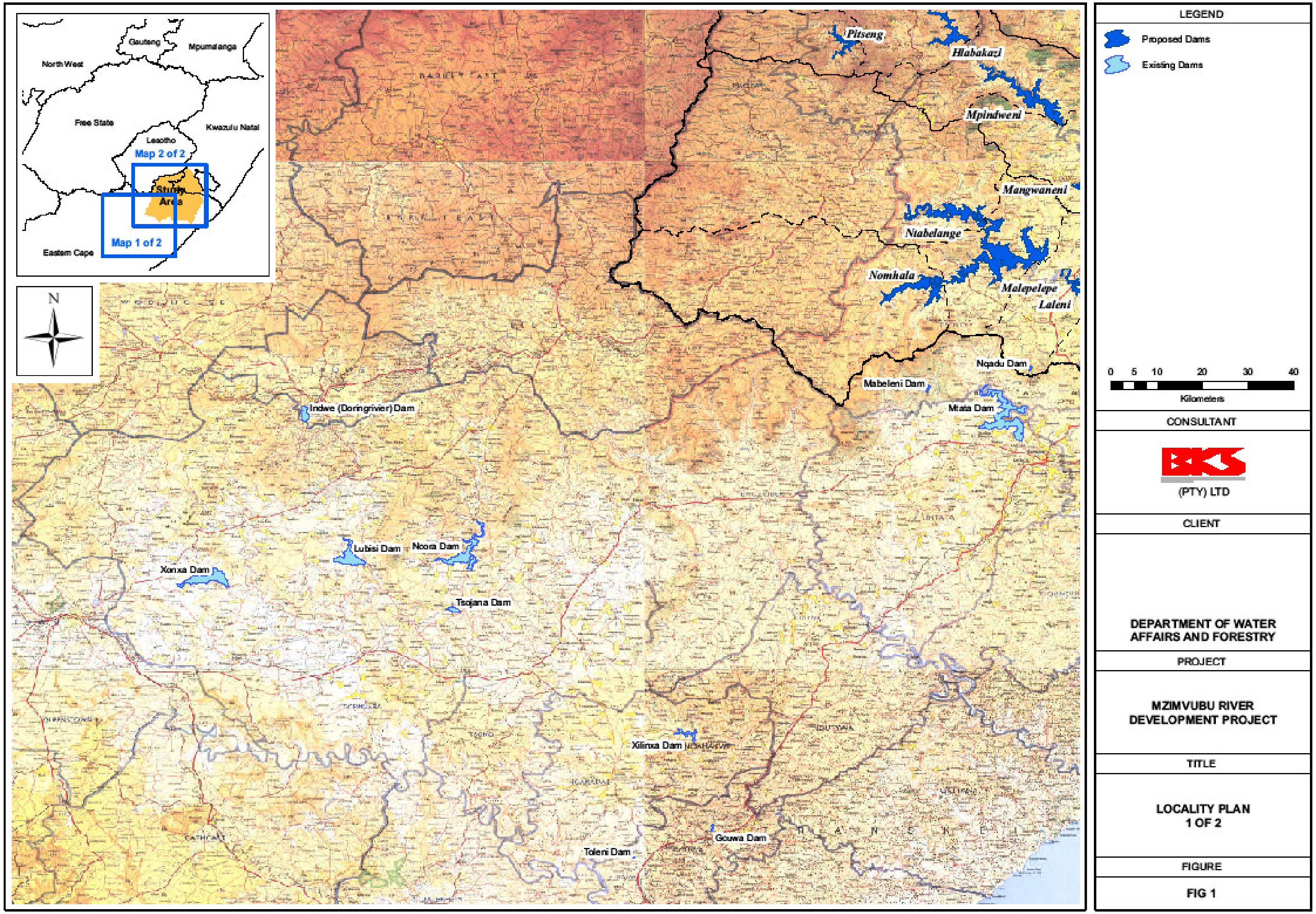


Figure D.1a **Locality of existing dams in and nearby the Mzimvubu River catchment**

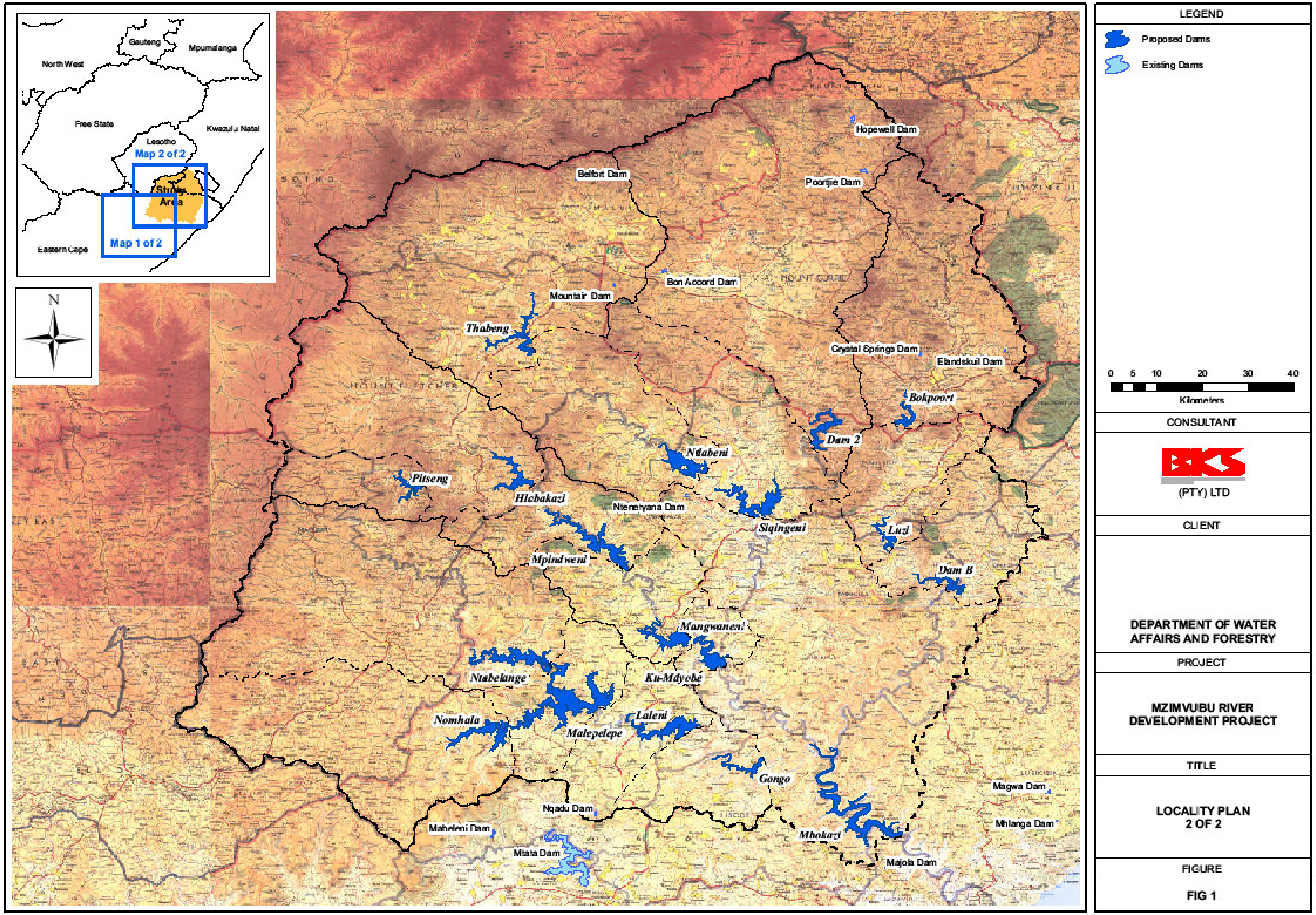


Figure D.1b Locality of existing dams in and nearby the Mzimvubu River Catchment

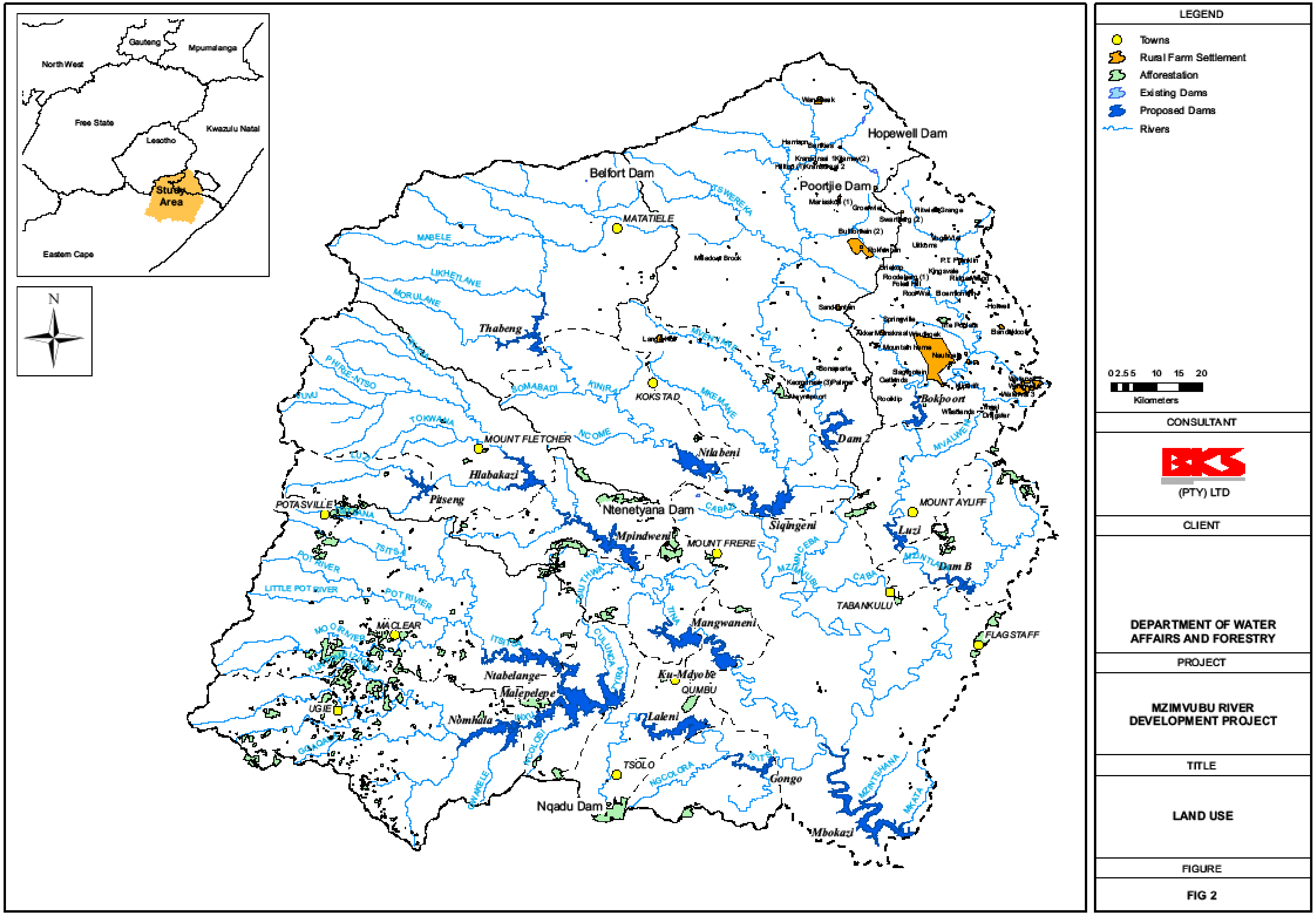


Figure D.2 Land use in the Mzimvubu River catchment

4 CATCHMENT SEDIMENT YIELD POTENTIAL

4.1 SEDIMENT YIELD PATTERNS

Sediment accumulation is recorded at a number of reservoirs, over many years, throughout South Africa by the Department of Water Affairs and Forestry (DWAF). The analysis of these measurements has made it possible to calculate average sediment yields for the catchments related to these reservoirs. In order to make use of this recorded data, especially for the purposes of predicting sedimentation rates, various sediment yield maps were produced in the past.

Using available recorded sedimentation data and additional data on sediment loads in rivers, a new sediment yield map of Southern Africa was prepared. This map is based on dividing Southern Africa into nine sediment yield regions and subsequent calibration in terms of recorded yield values. Sediment yields are calculated according to catchment location and size, as well as sediment yield potential within the catchment. In the absence of comprehensive measured data the new sediment yield map forms a basis for catchment sediment yield estimation.

Sediment yield potential or erodibility is based on a distinction between 20 categories representing eroding and transporting capacity (e.g. soil types, land use, rainfall characteristics, slopes, etc.). The erodibility index of the Mzimvubu River catchment is graphically indicated in **Figure D.3**. These erodibility index categories are combined to establish three classes of sediment yield potential, i.e. ***high, medium*** and ***low***, creating the sediment yield map. The sediment yield classification for the Mzimvubu River catchment and the area south-west of the catchment are graphically indicated in **Figure D.4** and **Figure D.5**, respectively.

4.2 REGIONAL STANDARDISED CATCHMENT SEDIMENT YIELD

The Mzimvubu River catchment falls within Sediment Yield Region 9 with a standard average catchment sediment yield of 185 t/km²/year.

The regional standardised sediment yield pattern for Region 9 was previously obtained from reservoir surveys available for 18 sites, with record lengths that vary in length from 8 to 72 years. The degree of variability from 4 to 881 t/km²/a for catchment sediment yield is high. The region is geologically, however, diverse with readily erodible top-soil removed, especially where steep slopes and high population densities are present. The land use varies and includes urbanised areas, as well as cattle, maize and subsistence farming areas.

5 SEDIMENT YIELDS FOR THE MZIMVUBU RIVER CATCHMENT

As it is not possible to predict sedimentation rates accurately, estimates were made of the most likely foreseeable yields, which were then converted into equivalent storage losses. Estimates were based on:

- available recorded yield data; and
- basic erodibility/sediment yield map.

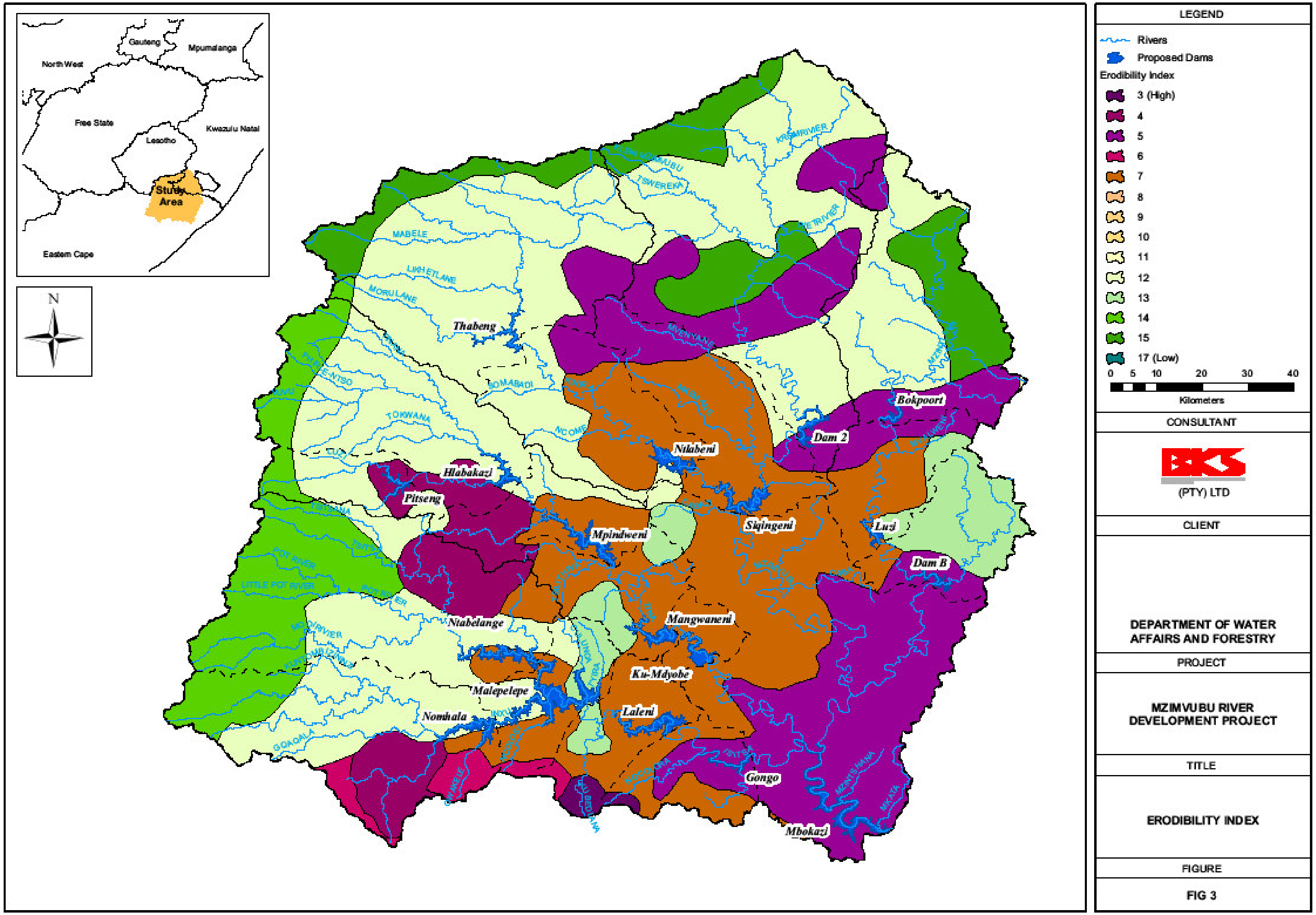


Figure D.3 Erodibility index in the Mzimvubu River catchment

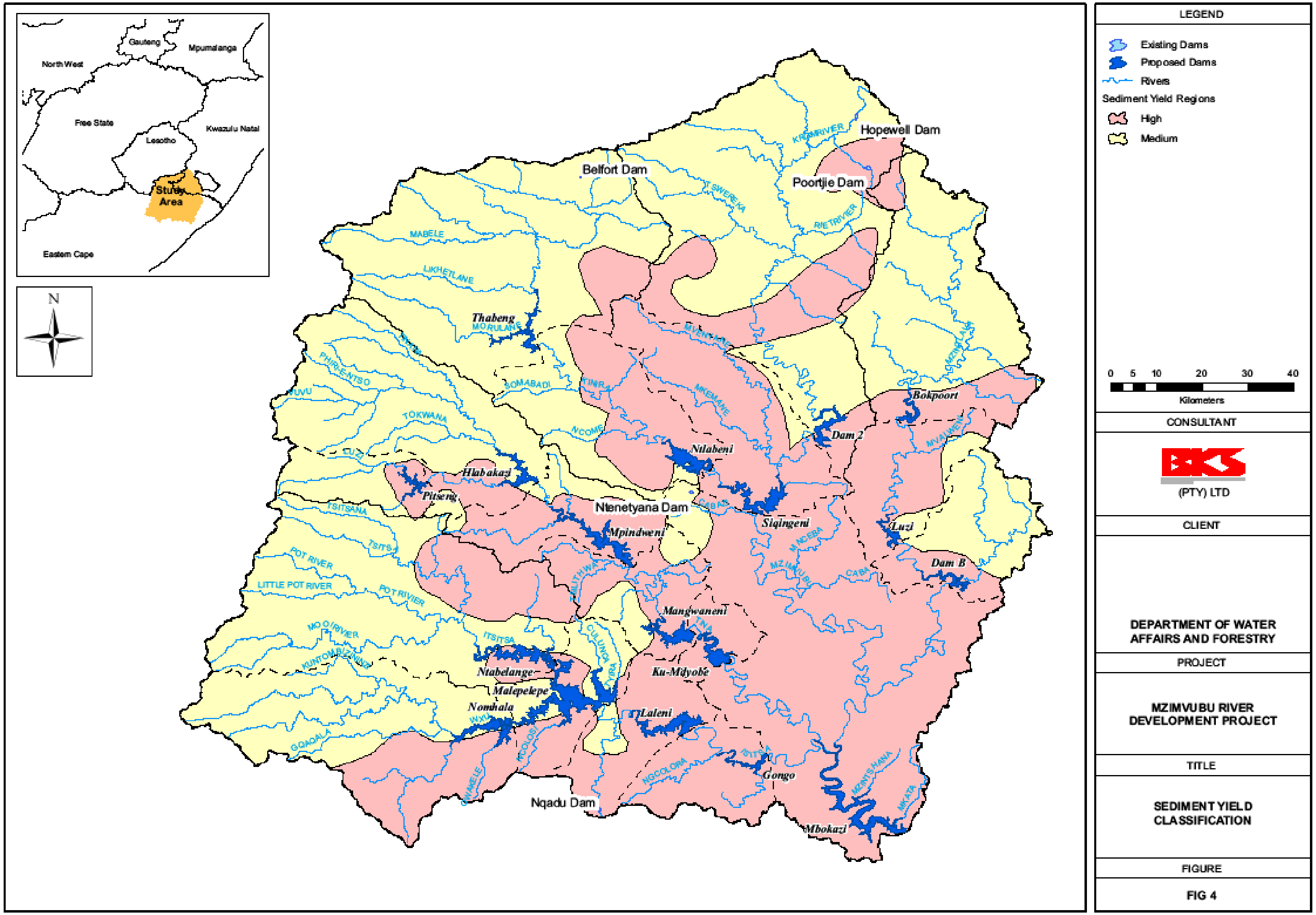


Figure D.4 Sediment yield classification in the Mzimvubu River catchment

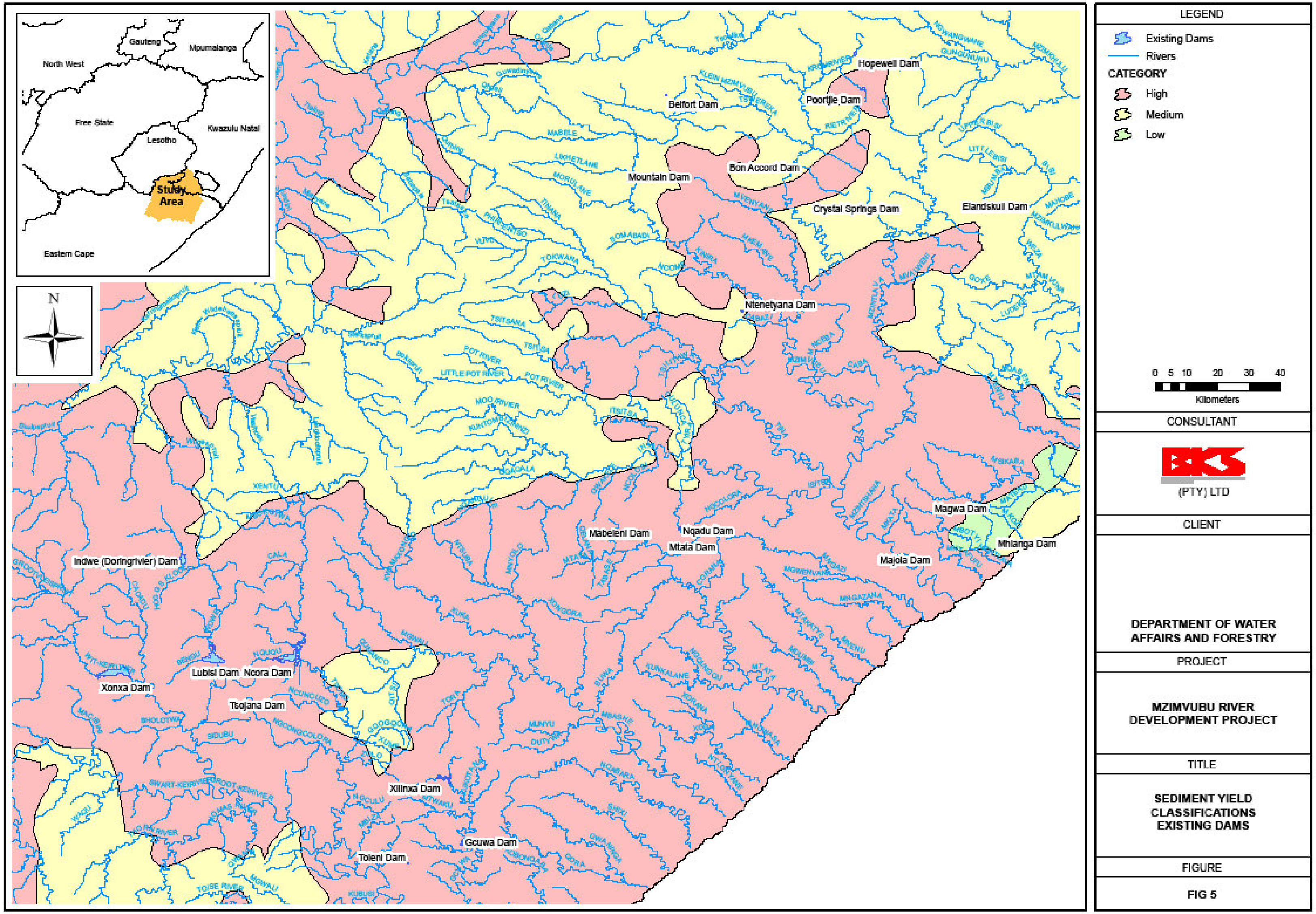


Figure D.5 Sediment yield classification in the Eastern Cape

5.1 RECORDED CATCHMENT SEDIMENT YIELD

Sediment yields of catchments can be estimated from recorded reservoir sedimentation surveys by converting recorded sediment volumes to annual sediment yields per unit area of catchment. An important factor in the conversion of sediment value into mass is the variable density of the sediment deposits. The sediment volume in a reservoir after any given period of time has been found to follow a logarithmic relationship for accumulations in excess of approximately 10 years. It was found that it was possible to express the volume V_T of a sediment deposit after T years as:

$$\frac{V_T}{V_{50}} = \mathbf{0.376\ell n}\frac{T}{3.5}$$

for $\boldsymbol{T} \geq 10$ years and $\boldsymbol{V_{50}}$ the sediment volume after 50 years.

It is thus possible to convert the equivalent 50-year volume into the volume after T years and vice versa. Choice of the 50-year volume as reference is arbitrary, but it is possible to estimate the average density after 50-years more accurately than after say 10 years.

A density value of 1 350 kg/m³ for the 50-year sediment was found to be realistic for South African reservoirs. In order to convert the 50-year sediment mass to an annual mass, the average sediment yield is assumed to remain constant with time. This assumption allows working from a common base (i.e. 50-year old sediment) to estimate the volume of sediment for any other age.

5.1.1 Dams located within the Mzimvubu River catchment

Although located in the Mzimvubu River catchment, no sufficient information is available for the Hopewell, Poortjie, Bon Accord, Chrystal Springs, Elandskuil, Belfort, Nqadu, Majola and Ntenetyana Dams (refer to **Table 1**) to determine representative recorded catchment sediment yield for these reservoirs. Dam resurvey information is, however, available for the Mountain Dam.

5.1.2 Dams located outside the Mzimvubu River catchment

Various existing dams are located nearby the Mzimvubu River catchment. Sufficient dam resurvey information, is available for the Indwe, Xonxa, Ncora, Mthatha and Xilinxa, Mabeleni, Toleni and Gcuwa dams. No resurvey data is available for the Lubisi and Mabeleni Dams. The Tsojana, Magwa and Mhlanga Dams are not listed in the DWAF Dam list 2006.

5.1.3 Recorded reservoir sedimentation

Dam characteristic and sediment accumulation data within these reservoirs were obtained from the DWAF Dam list 2006 and is provided in **Table D.2**. The associated river, reservoir, location number, sediment yield region, recorded period, sediment volume at end of period $\boldsymbol{V_T}$, equivalent 50-year sediment volume $\boldsymbol{V_{50}}$, effective catchment area (ECA) and average catchment sediment yield are listed in Table D.2.

Table D.2 Recorded reservoir and catchment sedimentation rates for selected existing reservoirs

River	Reservoir name	Location number	Sediment yield region	Record period				Original or amended capacity (V_w) (million	Latest capacity at full supply level (million	Volume of sediment deposit (V_t) (million m³)	% Sedimen-tation	Equivalent 50 year sediment volume (V_{50}) (million m³)	Total catchment area (km²)	Effective catchment (ECA) (km²)	Sediment yield (t/km²/a)	Sediment yield (million t/a)
				Date of construc-tion	Assumed date of latest raising	Date of latest survey	Period (years)									
Doring	Indwe (Doring River)	S200-01	9	1969	-	1998	29	23.443	17.933	5.51	23.5	6.93	295	295	634.27	0.187
White	Xonxa	S100-01	9	1974	-	2003	29	157.566	121.1	36.466	23.14	45.87	1 487	1 487	832.88	1.238
Tsomo	Ncora	S500-01	9	1976	-	1999	23	162.307	150.093	12.214	7.5	17.25	1 772	1 772	262.84	0.466
Mthatha	Mthatha	T201-03	9	1977	-	1998	22	258.226	253.674	4.552	1.76	6.59	868	868	204.99	0.178
Xilinxa	Xilinxa	S702-07	9	1973	-	1996	23	17.7	16.029	1.67	9.44	2.36	200	200	318.60	0.064
Keneka	Mountain	T300-04	9	1914	-	1970	56	0.272	0.984	Undetermined	-	-	12	12	-	-
Gcuwa	Gcuwa	S702-08	9	1976	-	1995	19	0.8997	0.8997	0	0	0	0	0	0	0
Toleni	Toleni	S700-02	9	1971	-	1996	25	0.211	0.211	0	0	0	13	13	0	0

The recorded catchment sediment yield values indicated in Table 2 show the typical variability of sediment yield that can be expected in sediment yield Region 9.

The Mountain Dam is the only existing dam with available reservoir resurvey data within the Mzimvubu River catchment. However, the reservoir resurvey data indicates a surveyed capacity more than the original capacity resulting in an undetermined reservoir sedimentation situation.

The reservoir resurvey data for the Gcuwa and Toleni Dams indicated capacities equal to the original dam capacities, resulting in assumed no sedimentation within the reservoirs. It is proposed to not include these results for further analysis and comparison purposes.

5.2 REGIONALISED CATCHMENT SEDIMENT YIELD

5.2.1 Confidence limits

Previous methodologies on sedimentation prediction allowed a great deal of subjectivity in the estimation of catchment sediment yield. Based on the new sediment map approach an attempt is made to provide statistical bands of confidence around the mean.

Although the most likely yield value for an area still has to be estimated with due consideration of the availability of sediment within the catchment as well as other factors which influence sediment yields, it is, however, possible to put some statistical meaning to an estimate and to bring catchment size into consideration.

5.2.2 Proposed dams

Using the regional standardised yield values based on the sediment yield map (refer to **Section 4**), site-specific, weighted-average catchment sediment yield values were calculated for the proposed dams subject to various confidence levels, as indicated in **Table D.3**. The respective erodibility and sediment yield potential maps are provided in **Figure D.3** and **Figure D.4**, respectively.

It will, however, always be necessary to consider existing catchment conditions and compare the values obtained by means of the sediment yield map to recorded values for comparable catchments. Therefore a similar approach was followed to determine catchment sediment yield values based on regional standardised yield values for those dams with recorded sediment accumulation data for comparison purposes.

5.2.3 Existing dams

Although not part of the Mzimvubu River catchment, the nearby Mtata, Xonxa, Ncora, Indwe, Xilinxa Dams, located in adjacent catchment areas, were analysed for comparison purposes. These sediment yield values, as indicated in Table D.3, however, exclude the consideration of sediment retention within the reservoirs.

Table D.3 Regionalised weighted average sediment yield

River	Reservoir name	Sedi-ment yield region	Mean annual runoff (million m³)	Max storage %MAR	Catchment areas (km²)			Regional standardised yield (t/km²/a)								Weighted average sediment yield (t/km²/a)[5]			
					Total effective catchment area[1), 2)] (ECA) (km²)	Area of medium yield potential (km²)	Area of high yield potential (km²)	Confidence level								Confidence level			
								50%		80%		90%		95%		50%	80%	90%	95%
								Factor	Yield	Factor	Yield	Factor	Yield	Factor	Yield				
Proposed dam sites:																			
Itsitsa	Malepelepe	9	696	150	3 934	2 768.3	1 165	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
	Laleni	9	755	60	4 324	2 757.8	1 566	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
	Gongo	9	800	31	4 774	2 767.4	2 006	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
	Ntabelanga	9	403	150	2 017	1 561.5	455	1	185	2.60	481	3.23	598	4.28	791	185	481	597	791
Lower Mzimvubu	Mbokazi	9	2 520	38	19 263	10 637.8	89 492	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
Tina	Mangwaneni	9	414	100	2 764	1 740.8	1 023	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
	Mpindweni	9	337	150	2 176	1 559.8	616	1	185	2.60	481	3.20	592	4.20	777	185	481	592	777
	Hlabakazi	9	248	150	1 618	1 418.0	200	1	185	2.65	482	3.44	636	4.56	843	185	481	619	843
	Pitseng	9	55	150	300	229.5	70	1	185	3.57	660	6.14	1 134	8.00	1 480	185	660	1 139	1 480
	Ku-Mdyobe	9	424	96	2 864	1 689.4	1 174	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
Mzintlava	Bokpoort	9	130	150	1 379	1 084.2	294	1	185	2.64	488	3.65	675	4.80	888	185	487	675	888
	Dam B	9	282	100	2 497	1 578.5	918	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
	Luzi	9	198	150	1 909	1 167.6	741	1	185	2.60	481	3.28	607	4.34	802	185	481	606	802
Kinira	Ntlabeni	9	396	150	2 685	2 383.8	662	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
	Thabeng	9	164	150	1 778	1650	128	1	185	2.60	481	3.35	619	4.44	821	185	481	619	821
Kinira/Upper Mzimvubu	Dam 2	9	240	150	2 680	1 979.8	700	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
	Siqingeni	9	731	100	6 482	4 496.6	2 269	1	185	2.60	481	3.18	588	4.15	767	185	481	588	767
Inxu	Nomhala	9	206	150	1 405	929.5	475	1	185	2.63	486	3.65	674	4.75	878	185	486	674	878
Existing nearby large dams:																			
Doring	Indwe [3)] (Doring River)	9	S20A		295	0.0	295	1	185	3.58	662	6.15	1 137	8.00	1 480	185	662	1 137	1 480
Indwe	Lubisi [3)]	9	S20C		1 105	107.2	897	1	185	2.74	506	4.00	740	5.23	967	185	506	740	967
White Kei	Xonxa [3)]	9	S10E		1 487	0.0	1487	1	185	2.625	483	3.64	673	4.67	863	185	483	673	863
Tsomo	Ncora [3)]	9	S50E		1 772	501.5	1270	1	185	2.60	481	3.35	619	4.45	814	185	481	619	814
Mtata	Mtata [3)]	9	T20B		868	0.0	868	1	185	2.88	532	4.47	826	5.78	1 069	185	532	826	1 069
Xilinxa	Xilinxa [3)]	9	S70C		200	1.1	198	1	185	3.75	693	6.48	1 198	8.46	1 565	185	693	1 198	1 565

1) No incremental areas; areas apply to a single dam situation
2) Total catchment area
3) Outside Mzimvubu River catchment but used for comparison purposes
4) Existing dams in Mzimvubu River catchment
5) Factors F_m & F_H = 1

Table D.4 Comparison between recorded catchment sediment yield and weighted average sediment yield

River	Reservoir	Effective catchment area (km²)	Weighted average sediment yield (t/km²/a)[1] Confidence level (%) 50%	80%	90%	95%	Recorded sediment yield[2] (t/km²/a)	Comparative confidence level (%)	Record period (years)
Doring	Indwe	295	185	662	1 138	1 480	634	79	29
White Kei	Xonxa	1 487	185	484	673	864	833	94	29
Xilinxa	Xilinxa	200	185	694	1 199	1 565	319	59	23
Tsomo	Ncora	1 772	185	481	620	814	263	60	23
Mtata	Mtata	868	185	533	827	1 071	205	53	22
Average		**1 156**	**185**	**571**	**891**	**1 159**	**451**	**74**	**25**
Weighted average		**1 156**	**185**	**512**	**733**	**953**	**462**	**75**	**25**

[1] From Table D.2
[2] From Table D.3

5.3 COMPARISON OF RECORDED AND REGIONALISED SEDIMENT YIELD

Comparison of the recorded catchment yield values indicated in Table D.1 with the regionalised weighted average sediment values based on the sediment yield map is provided in Table D.3. It follows that the respective catchment sediment yields cannot be predicted by a single confidence band.

This comparison reveals the following:

- The recorded catchment sediment yield values for Xonxa Dam on the Wit Kei River relate to 94% confidence level. It could therefore be assumed that the recorded sediment yield value is a true reflection of the respective catchment erodibility and sediment yield potential. The reasonably high catchment sediment yield value and associated higher confidence level for the Xonxa Dam could be attributed to catchment specific conditions, i.e. the catchment relates to a high sediment yield potential.
- The recorded catchment sediment yield value for the Indwe (Doring River) Dam relates to an almost 80% confidence level. It could therefore be assumed that the respective catchment sediment yield could, based on the recorded reservoir sedimentation, be estimated with an 80% confidence. As for Xonxa Dam, the catchment relates to a high sediment yield potential.
- The recorded catchment sediment yield values for Nqadu and Xilinxa Dams relate to 60% and 58.5% confidence level, respectively. The Mtata Dam's recorded sediment yield value relates to a 52.5% confidence level.

Based on the variation in confidence level of between 52.5% and 94%, the respective average and weighted average sediment yield values of the existing dams were also compared. Such a comparison of the recorded average sediment yield with the average regionalised sediment yield indicates a confidence level of 75% with an average recorded sediment yield in the order of 450 t/km²/a (refer to Table D.4).

Given the catchment characteristics of steep slopes, high rainfall in the form of thunder storms, erodibility due to overgrazing and population density, the recorded sediment values relating to a lower confidence level should be used with great care for the purposes of future reservoir sedimentation prediction and are not recommended for reference purposes.

Based on the above comparisons, it is proposed that future sedimentation predictions for the possible reservoirs based on the regionalised sediment yield approach be based on a 80% confidence level with the 95% confidence level as the higher limit.

6 SEDIMENT RETENTION WITHIN RESERVOIRS

Having estimated the average annual sediment yield for a catchment, this sediment yield could be used to predict the volume which can be lost to reservoir storage. This volume loss is a function of the trap efficiency of the reservoir under consideration as well as a function of time.

The percentage of the total incoming sediment retained in a reservoir is referred to as the trap efficiency of a reservoir. It is commonly expressed as a ratio of the quantity of sediment deposited to the total sediment inflow. The sediment retained in the reservoir is a function of the relative size of the reservoir in comparison to the Mean Annual Run-off (MAR) at the reservoir site. A reasonable estimate of reservoir trap efficiency can thus be based on the ratio of storage capacity to MAR.

Various trap efficiency curves have been developed for determining the percentage of incoming sediment which will be trapped within a reservoir. Probably the best known and most often used are those of Brune and Churchill. The Brune curve can be used for large storage or normal ponded reservoirs, whereas the Churchill curve should be used for settling basins, small reservoirs, flood retarding structures, semi-dry reservoirs or reservoirs that are continuously sluiced.

Both the Brune and Churchill curves indicate that reservoirs with capacities in excess of 10% of the MAR will retain at least 70% of incoming sediments. It is therefore only where reservoirs are very small (< 10% MAR) that it becomes possible to pass most of the incoming sediments through the reservoir.

Depending upon the relative size of the reservoir, the percentage of the sediment to be retained is calculated and from this, the expected future sedimentation rate of the reservoir can be determined. These sediment rates can then be converted to expected volumes for different future dates.

Estimates of sediment trapped based on the Full Supply Capacity (FSC)/MAR ratio for major reservoirs in the Mzimvubu River catchment are summarised in **Table D.5**. Based on the median Brune trap efficiency curve for normal ponded reservoirs it follows that a trap efficiency of 97% could be expected for all reservoirs with capacity equal to 0.5 x MAR. For larger reservoirs with capacities equal to 1 x MAR or 1.5 x MAR a median trap efficiency of 98% could be expected. The exception is the proposed Mbokazi Dam with a storage capacity of 0.38 x MAR with a trap efficiency of 92%.

Expected sedimentation rates based on regionalised catchment yield values for confidence levels of 80%, 90% and 95%, respectively, with consideration of sediment retention within reservoirs, are summarised in **Table D.6** for planning purposes. Based on the abovementioned discussion all proposed dam sizes were evaluated for an average trap efficiency of 97.5%. The Mbokazi Dam was, however, evaluated for trap efficiencies of both 92% and 97.5%.

Table D.5 Regionalised weighted average sediment yield of Mzimvubu River catchment

River	Reservoir name	Mean annual runoff (MAR- million m³)	Maximum storage capacity (million m³)	Full supply capacity (x MAR)	Percentage sediment trapped[1] (%)
Proposed dam sites:					
Itsitsa	Malepelepe	696	1 044 (1.5 MAR)	0.5 1.0 1.5	97 98 98
	Laleni	755	453 (0.6 MAR)	0.6 1.0 1.5	98 98 98
	Gongo	800	248 (0.31 MAR)	0.3 1.0 1.5	95 98 98
	Ntabelanga	403	605 (1.5 MAR)	0.5 1.0 1.5	97 98 98
Lower Mzimvubu	Mbokazi	2520	958 (0.38 MAR)	0.4 0.5 1.0	96 97 98
Tina	Mangwaneni	414	414 (1 MAR)	0.5 1.0 1.5	97 98 98
	Mpindweni	337	506 (1.5 MAR)	0.5 1.0 1.5	97 98 98
	Hlabakazi	248	372 (1.5 MAR)	0.5 1.0 1.5	97 98 98
Tina	Pitseng	55	83 (1.5 MAR)	0.5 1.0 1.5	97 98 98
	Ku-Mdyobe	424	407 (0.96 MAR)	0.5 1.0 1.5	97 98 98
Mzintlava	Bokpoort	130	195 (1.5 MAR)	0.5 1.0 1.5	97 98 98
	Dam B	282	282 (1 MAR)	0.5 1.0 1.5	97 98 98
	Luzi	198	297 (1.5 MAR)	0.5 1.0 1.5	97 98 98
Kinira	Ntlabeni	396	594 (1.5 MAR)	0.5 1.0 1.5	97 98 98
	Thabeng	164	246 (1.5 MAR)	0.5 1.0 1.5	97 98 98
Kinira Upper / Mzimvubu	Dam 2	240	360 (1.5 MAR)	0.5 1.0 1.5	97 98 98
	Siqingeni	731	731 (1.0 MAR)	0.5 1.0 1.5	97 98 98
Inxu	Nomhala	206	309 (1.5 MAR)	0.5 1.0 1.5	97 98 98

1) Based on median Brune trap efficiency curve for normal ponded reservoirs

Table D.6 Expected sedimentation rates without considering upstream reservoirs with potential sediment retention

River	Reservoir	Effective catchment area (km²)	Regionalised confidence level (5)	Catchment sediment yield (t/km²/a)	Percentage sediment trapped (%)	Sediment yield (million t/a)	Expected retained sediment (million t/a)	Equivalent 50 year sediment volume V_{50} (million m³)
Itsitsa	Malepelepe	3 934	80	481	97.5	1.892	1.845	68
			90	588	97.5	2.314	2.256	84
			95	768	97.5	3.020	2.945	109
	Laleni	4 324	80	481	97.5	2.080	2.028	75
			90	588	97.5	2.544	2.480	92
			95	768	97.5	3.320	3.237	120
	Gongo (0.31 x MAR)	4 774	80	481	95.0	2.296	2.181	81
			90	588	95.0	2.809	2.669	99
			95	768	95.0	3.665	3.481	129
	Gongo (>0.31 x MAR)	4 774	80	481	97.5	2.296	2.239	83
			90	588	97.5	2.809	2.738	101
			95	768	97.5	3.665	3.374	132
	Ntabelanga	2 017	80	481	97.5	0.970	0.946	35
			90	598	97.5	1.205	1.175	44
			95	792	97.5	1.597	1.557	58
Lower Mzimvubu	Mbokazi (0.38 x MAR)	19 263	80	481	95.5	9.266	8.849	328
			90	588	95.5	11.332	10.822	401
			95	768	95.5	14.789	14.123	523
	Mbokazi (>0.38 x MAR)	19 263	80	481	97.5	9.266	9.034	335
			90	588	97.5	11.332	11.049	409
			95	768	97.5	14.782	14.419	534
Tina	Mangwaneni	2 764	80	481	97.5	1.329	1.296	48
			90	588	97.5	1.626	1.585	59
			95	768	97.5	2.122	2.069	77
	Mpindweni	2 176	80	481	97.5	1.046	1.020	38
			90	592	97.5	1.288	1.256	47
			95	777	97.5	1.691	1.648	61
	Hlabakazi	1 618	80	482	97.5	0.780	0.761	28
			90	620	97.5	1.003	0.978	36
			95	844	97.5	1.365	1.331	49
Tina	Pitseng	300	80	660	97.5	0.198	0.193	7
			90	1 136	97.5	0.342	0.333	12
			95	1 480	97.5	0.444	0.433	16
	Ku-Mdyobe	2 864	80	481	97.5	1.378	1.343	50
			90	588	97.5	1.685	1.643	61
			95	768	97.5	2.199	2.144	79

River	Reservoir	Effective catchment area (km²)	Regionalised confidence level (5)	Catchment sediment yield (t/km²/a)	Percentage sediment trapped (%)	Sediment yield (million t/a)	Expected retained sediment (million t/a)	Equivalent 50 year sediment volume V_{50} (million m³)
Mzintlava	Bokpoort	1 379	80	488	97.5	0.673	0.655	24
			90	675	97.5	0.932	0.909	34
			95	888	97.5	1.225	1.194	45
	Dam B	2 497	80	481	97.5	1.201	1.171	43
			90	588	97.5	1.469	1.432	53
			95	768	97.5	1.917	1.869	69
	Luzi	1 909	80	481	97.5	0.918	0.895	33
			90	607	97.5	1.158	1.129	42
			95	803	97.5	1.533	1.494	55
Kinira	Ntabeni	2 685	80	481	97.5	1.292	1.259	47
			90	588	97.5	1.580	1.540	57
			95	768	97.5	2.061	2.010	74
	Thabeng	1 778	80	481	97.5	0.855	0.834	31
			90	620	97.5	1.102	1.074	40
			95	821	97.5	1.460	1.424	58
Kinira / Upper Mzimvubu	Dam 2	2 680	80	481	97.5	1.289	1.257	47
			90	588	97.5	1.577	1.537	57
			95	768	97.5	2.058	2.006	77
	Siqingeni	6 482	80	481	97.5	3.118	3.040	113
			90	588	97.5	3.813	3.718	138
			95	768	97.5	4.977	4.852	180
Inxu	Nomhala	1 405	80	487	97.5	0.684	0.667	25
			90	674	97.5	0.947	0.924	34
			95	879	97.5	1.235	1.204	45

7 VOLUMES OF SEDIMENT DEPOSITS IN RESERVOIRS

Estimated sediment yield values for the proposed dams in the Mzimvubu River catchment are provided in **Table D.7**.

These are based on the assumed catchment sediment yield values and an average sediment density of 1.35 t/m³ after 50 years and equivalent to 50 year sediment volumes (V_{50}). Sediment volumes for periods 10, 20, 30 and 40 years after construction completion are also indicated in Table D.7. The confidence levels of estimated different sediment deposition volumes are indicated. Lower sediment values relate to a lower confidence in prediction.

In addition, the predicted sedimentation volumes for each confidence level are also compared for various dam sizes as indicated in **Table D.8** (80% confidence), **Table D.9** (90% confidence) and **Table D.10** (95% confidence). It follows from this comparison that the estimated future sedimentation could play a decisive role in recommending future reservoir sizes.

Depending on a specific dam and the associated confidence level, dams with a storage capacity equal to or less than 0.5 MAR are subject to potential serious future sedimentation. In the case of the 80% confidence level of prediction the future sedimentation of some dams could be as high as 25% after 20 years and 38% after 50 years, respectively. In the case of the 90% confidence level of prediction the future sedimentation of some dams could be as high as 34% after 20 years and 50% after 50 years, respectively, with even higher values for the 95% confidence level.

Careful consideration of the above should ensure that too small storage capacities, which could be seriously impacted on in terms of potential future sedimentation, are not proposed.

Table D.7 Future sediment volumes in reservoirs

River	Reservoir	Sediment prediction confidence level	Sediment yield[1)] (million t/a)	Estimated future sediment volume (million m³)					Dead storage level for T50
				Sedimentation period (years)					masl
				10	20	30	40	50	(m)
Itsitsa	Malepelepe	80	1.845	27	45	55	63	68	867.5
		90	2.256	33	55	68	77	84	868.5
		95	2.945	43	71	88	100	109	871.0
	Laleni	80	2.028	30	49	61	69	75	746.0
		90	2.48	36	60	74	84	92	749.0
		95	3.237	47	79	97	110	120	752.0
	Gongo (0.31 MAR)	80	2.181	32	53	65	74	81	358.0
		90	2.669	39	65	80	91	99	363.0
		95	3.481	51	84	104	118	129	370.0
	Gongo (>0.31 MAR)	80	2.239	33	54	67	76	83	
		90	2.738	40	66	82	93	101	
		95	3.574	52	87	107	121	132	
	Ntabelanga	80	0.946	14	23	28	32	35	912.0
		90	1.175	17	29	35	40	44	915.0
		95	1.557	23	38	47	53	58	918.0
Lower Mzimvubu	Mbokazi (0.38 MAR)	80	8.849	129	215	265	300	328	125.0
		90	10.822	158	263	324	367	401	133.0
		95	14.123	207	343	423	479	523	140.0
	Mbokazi (>0.38 MAR)	80	9.034	132	219	270	306	335	
		90	11.49	162	268	331	375	409	
		95	14.419	211	350	432	489	534	
Tina	Mangwaneni	80	1.296	19	31	39	44	48	779.0
		90	1.585	23	38	47	54	59	782.0
		95	2.069	30	50	62	70	77	784.0
	Mpindweni	80	1.02	15	25	31	35	38	1 013.0
		90	1.256	18	30	38	43	47	1 015.0
		95	1.648	24	40	49	56	61	1 018.0
	Hlabakazi	80	0.761	11	18	23	26	28	1 128.0
		90	0.978	14	24	29	33	36	1 131.0
		95	1.331	19	32	40	45	49	1 135.0

River	Reservoir	Sediment prediction confidence level	Sediment yield[1)] (million t/a)	Estimated future sediment volume (million m³)					Dead storage level for T50
				Sedimentation period (years)					masl
				10	20	30	40	50	(m)
Tina	Pitseng	80	0.193	3	5	6	7	7	1 390.0
		90	0.333	5	8	10	11	12	1 395.0
		95	0.433	6	11	13	15	16	1 400.0
	Ku-Mdyobe	80	1.343	20	33	40	46	50	697.0
		90	1.643	24	40	49	56	61	700.0
		95	2.144	31	52	64	73	79	704.0
Mzintlava	Bokpoort	80	0.655	10	16	20	22	24	1 150.0
		90	0.909	13	22	27	31	34	1 156.0
		95	1.194	17	29	36	41	44	1 162.0
	Dam B	80	1.171	17	28	35	40	43	636.0
		90	1.432	21	35	43	49	53	642.0
		95	1.869	27	45	56	63	69	648.0
	Luzi	80	0.895	13	22	27	30	33	826.0
		90	1.129	17	27	34	38	42	830.0
		95	1.494	22	36	45	51	55	834.0
Kinira	Ntlabeni	80	1.259	18	31	38	43	47	1 028.0
		90	1.540	23	37	46	52	57	1 031.0
		95	2.010	29	49	60	68	74	1 034.0
	Thabeng	80	0.834	12	20	25	28	31	1 361.0
		90	1.074	16	26	32	36	40	1 363.0
		95	1.424	23	38	47	53	58	1 365.0
	Somabadi	80	1	15	24	30	34	37	1 302.5
		90	1.25	18	31	38	43	47	1 305
		95	1.7	25	42	52	59	64	1 308
Kinira / Upper Mzimvubu	Dam 2	80	1.257	18	31	38	43	47	877.5
		90	1.537	22	37	46	52	57	881.0
		95	2.006	30	50	62	70	77	886.0
	Siqingeni	80	3.040	44	74	91	103	113	914.0
		90	3.718	54	90	111	126	138	918.0
		95	4.852	71	118	145	165	180	921.0
Inxu	Nomhala	80	0.667	10	16	20	23	25	
		90	0.924	14	22	28	31	34	
		95	1.204	18	29	36	41	45	

Table D.8 Future sedimentation reservoirs with 80% confidence

River	Reservoir	MAR (million m³)	Storage capacity as factor of MAR	Storage capacity (million m³)	Estimated future sediment volume (percentage of storage capacity)				
					Sedimentation period (years)				
					10	20	30	40	50
Itsitsa	Malepelepe	696	0.5	348	7.8	12.9	15.9	18.0	19.6
			1.0	696	3.9	6.4	7.9	9.0	9.8
			1.5	1044	2.6	4.3	5.3	6.0	6.6
	Laleni	755	0.6	453	6.6	10.9	13.4	15.2	16.6
			1.0	755	3.9	6.5	8.0	9.1	10.0
			1.5	1 133	2.6	4.3	5.4	6.1	6.6
	Gongo	800	0.31	248	12.9	21.3	26.3	29.8	32.6
			1.0	800	4.0	6.6	8.2	9.3	10.1
			1.5	1 200	2.7	4.4	5.4	6.2	6.7
	Ntabelanga	403	0.5	202	6.9	11.4	14.1	15.9	17.4
			1.0	403	3.4	5.7	7.0	8.0	8.7
			1.5	605	2.3	3.8	4.7	5.3	5.8
Lower Mzimvubu	Mbokazi	2520	0.38	958	13.5	22.4	27.7	31.4	34.2
			0.5	1260	10.3	17.0	21.0	23.8	26.0
			1.0	2 520	5.1	8.5	10.5	11.9	13.0
Tina	Mangwaneni	414	0.5	207	9.2	15.2	18.7	21.2	23.2
			1.0	414	4.6	7.6	9.4	10.6	11.6
			1.5	621	3.1	5.1	6.3	7.1	7.7
	Mpindweni	337	0.5	169	8.9	14.7	18.1	20.5	22.4
			1.0	337	4.4	7.3	9.1	10.3	11.2
			1.5	506	3.0	4.9	6.0	6.9	7.5
	Hlabakazi	248	0.5	124	9.0	14.9	18.4	20.8	22.7
			1.0	248	4.5	7.5	9.2	10.4	11.4
			1.5	372	3.0	5.0	6.1	6.9	7.6
Tina	Pitseng	55	0.5	28	10.3	17.0	21.0	23.8	26.0
			1.0	55	5.1	8.5	10.5	11.9	13.0
			1.5	83	3.4	5.7	7.0	7.9	8.7
	Ku-Mdyobe	424	0.5	212	9.3	15.4	19.0	21.5	23.5
			0.96	407	4.8	8.0	9.9	11.2	12.2
			1.5	636	3.1	5.1	6.3	7.2	7.8

River	Reservoir	MAR (million m³)	Storage capacity as factor of MAR	Storage capacity (million m³)	Estimated future sediment volume (percentage of storage capacity)				
					Sedimentation period (years)				
					10	20	30	40	50
Mzintlava	Bokpoort	130	0.5	65	14.7	24.4	30.1	34.1	37.2
			1.0	130	7.3	12.2	15.0	17.0	18.6
			1.5	195	4.9	8.1	10.0	11.4	12.4
	Dam B	282	0.5	141	12.2	21.6	26.7	28.2	30.8
			1.0	282	6.1	10.8	13.3	14.1	15.4
			1.5	423	4.1	7.2	8.9	9.4	10.3
	Luzi	198	0.5	99	13.2	21.9	27.1	30.7	33.5
			1.0	198	6.6	11.0	13.5	15.3	16.7
			1.5	297	4.4	7.3	9.0	10.2	11.2
Kinira	Ntlabeni	396	0.5	198	9.3	15.4	19.0	21.6	23.6
			1.0	396	4.7	7.7	9.5	10.8	11.8
			1.5	594	3.1	5.1	6.3	7.2	7.9
	Thabeng	164	0.5	82	14.9	24.7	30.4	34.5	37.7
			1.0	164	7.4	12.3	15.2	17.3	18.8
			1.5	246	5.0	8.2	10.2	11.5	12.6
Kinira / Upper Mzimvubu	Dam 2	240	0.5	120	15.3	25.4	31.4	35.6	38.8
			1.0	240	7.7	12.7	15.7	17.8	19.4
			1.5	360	5.1	8.5	10.5	11.9	12.9
	Siqingeni	731	0.5	366	12.2	20.2	24.9	28.2	30.8
			1.0	731	6.1	10.1	12.4	14.1	15.4
			1.5	1 097	4.1	6.7	8.3	9.4	10.3
Inxu	Nomhala	206	0.5	103	9.5	15.7	19.4	22.0	24.0
			1.0	206	4.7	7.9	9.7	11.0	12.0
			1.5	309	3.2	5.2	6.5	7.3	8.0

1) Refer to expected retained yield as listed in Table 7.

2) V50 determined in Table 7.

Table D.9 Future sedimentation reservoirs with 90% confidence

River	Reservoir	MAR (million m³)	Storage capacity as % MAR	Storage capacity (million m³)	Estimated future sediment volume (Percentage of million m³)				
					Sedimentation period (years)				
					10	20	30	40	50
Itsitsa	Malepelepe	696	0.5	348	9.5	15.7	19.4	22.0	24.0
			1.0	696	4.7	7.9	9.7	11.0	12.0
			1.5	1044	3.2	5.2	6.5	7.3	8.0
	Laleni	755	0.6	453	7.3	13.3	16.4	18.6	20.3
			1.0	755	4.4	8.0	9.8	11.1	12.2
			1.5	1 133	2.9	5.3	6.6	7.4	8.1
	Gongo	800	0.31	248	15.7	26.1	32.2	36.5	39.9
			1.0	800	4.9	8.1	10.0	11.3	12.4
			1.5	1 200	3.3	5.4	6.7	7.6	8.2
	Ntabelanga	403	0.5	202	8.5	14.2	17.5	19.8	21.6
			1.0	403	4.3	7.1	8.7	9.9	10.8
			1.5	605	2.8	4.7	5.8	6.6	7.2
Lower Mzimvubu	Mbokazi (0.38 MAR)	2520	0.38	958	16.5	27.4	33.8	38.3	41.9
			0.5	1260	12.6	20.8	25.7	29.1	31.8
			1.0	2 520	6.3	10.4	12.9	14.6	15.9
Tina	Mangwaneni	414	0.5	207	11.2	18.6	22.9	26.0	28.4
			1.0	414	5.6	9.3	11.5	13.0	14.2
			1.5	621	3.7	6.2	7.6	8.7	9.5
	Mpindweni	337	0.5	169	10.9	18.1	22.3	25.3	27.6
			1.0	337	5.5	9.0	9.1	12.6	13.8
			1.5	506	3.6	6.0	6.0	8.4	9.2
	Hlabakazi	248	0.5	124	11.5	19.1	23.6	26.8	29.2
			1.0	248	5.8	9.6	11.8	13.4	14.6
			1.5	372	3.9	6.4	7.9	8.9	9.7
Tina	Pitseng	55	0.5	28	17.7	29.4	36.2	41.1	44.8
			1	55	8.9	14.7	18.1	11.9	22.4
			1.5	83	5.9	9.8	12.1	7.9	15.0
	Ku-Mdyobe	424	0.5	212	11.3	18.8	23.2	26.3	28.7
			0.96	407	5.9	9.8	12.1	13.7	15.0
			1.5	636	3.8	6.3	7.7	8.8	9.6

River	Reservoir	MAR (million m³)	Storage capacity as % MAR	Storage capacity (million m³)	Estimated future sediment volume (Percentage of million m³)				
					Sedimentation period (years)				
					10	20	30	40	50
Mzintlava	Bokpoort	130	0.5	65	20.5	33.9	41.9	47.5	51.8
			1.0	130	10.2	17.0	20.9	23.7	25.9
			1.5	195	6.8	11.3	14.0	15.8	17.3
	Dam B	282	0.5	141	14.9	24.6	30.4	34.5	37.6
			1.0	282	7.4	12.3	15.2	17.2	18.8
			1.5	423	5.0	8.2	10.1	11.5	12.5
	Luzi	198	0.5	99	16.7	27.7	34.1	38.7	42.2
			1.0	198	8.3	13.8	17.1	19.4	21.1
			1.5	297	5.6	9.2	11.4	12.9	14.1
Kinira	Ntlabeni	396	0.5	198	11.4	18.9	23.3	26.4	28.8
			1.0	396	5.7	9.4	11.6	13.2	14.4
			1.5	594	3.8	6.3	7.8	8.8	9.6
	Thabeng	164	0.5	82	19.2	31.8	39.2	44.4	48.5
			1.0	164	9.6	15.9	19.6	22.2	24.3
			1.5	246	6.4	10.6	13.1	14.8	16.2
Kinira / Upper Mzimvubu	Dam 2	240	0.5	120	18.7	31.1	38.3	43.5	47.4
			1.0	240	9.4	15.5	19.2	21.7	23.7
			1.5	360	6.3	10.4	12.8	14.5	15.8
	Siqingeni	731	0.5	366	14.9	24.7	30.4	34.5	37.7
			1.0	731	7.4	12.3	15.2	17.3	18.8
			1.5	1 097	5.0	8.2	10.2	11.5	12.6
Inxu	Nomhala	206	0.5	103	13.1	21.8	26.8	30.4	33.2
			1.0	206	6.6	10.9	13.4	15.2	16.6
			1.5	309	4.4	7.3	9.0	10.1	11.1

1) Refer to expected retained yield as listed in Table 7.

2) V50 determined in Table 7.

Table D.10 Future sedimentation reservoirs with 95% confidence

River	Reservoir	MAR (million m³)	Storage Capacity as % MAR	Storage Capacity (million m³)	Estimated future sediment volume (% of storage)				
					Sedimentation period (years)				
					10	20	30	40	50
Itsitsa	Malepelepe	696	0.5	348	12.4	20.5	25.3	28.7	31.3
			1.0	696	6.2	10.3	12.7	14.4	15.7
			1.5	1044	4.1	6.8	8.4	9.6	10.5
	Laleni	755	0.6	453	10.5	17.3	21.4	24.2	26.5
			1.0	755	6.3	10.4	12.8	14.6	15.9
			1.5	1 133	4.2	6.9	8.6	9.7	10.6
	Gongo	800	0.31	248	20.5	34.1	42.0	47.6	52.0
			1.0	800	6.4	10.6	13.0	14.8	16.1
			1.5	1 200	4.2	7.0	8.7	9.8	10.7
	Ntabelanga	403	0.5	202	11.3	18.8	23.1	26.2	28.6
			1.0	403	5.7	9.4	11.6	13.1	14.3
			1.5	605	3.8	6.3	7.7	8.7	9.5
Lower Mzimvubu	Mbokazi (0.38 MAR)	2520	0.38	958	21.6	35.8	44.1	50.0	54.6
			0.5	1260	16.4	27.2	33.5	38.0	41.5
			1.0	2 520	8.2	13.6	16.8	19.0	20.8
Tina	Mangwaneni	414	0.5	207	14.6	24.2	29.9	33.9	37.0
			1.0	414	7.3	12.1	15.0	17.0	18.5
			1.5	621	4.9	8.1	10.0	11.3	12.3
	Mpindweni	337	0.5	169	14.3	23.7	29.3	33.2	36.2
			1.0	337	7.2	11.9	14.6	16.6	8.4
			1.5	506	4.8	7.9	9.8	11.1	7.2
	Hlabakazi	248	0.5	124	15.7	26.0	32.1	36.4	39.8
			1.0	248	7.9	13.0	16.1	18.2	19.9
			1.5	372	5.2	8.7	10.7	12.1	13.3
Tina	Pitseng	55	0.5	28	23.0	38.2	47.1	53.4	58.3
			1	55	11.5	19.1	23.6	26.7	29.2
			1.5	83	7.7	12.7	15.7	17.8	19.4
	Ku-Mdyobe	424	0.5	212	14.8	24.5	30.3	34.3	37.5
			0.96	407	7.7	12.8	15.8	17.9	19.5
			1.5	636	4.9	8.2	10.1	11.4	12.5

River	Reservoir	MAR (million m³)	Storage Capacity as % MAR	Storage Capacity (million m³)	Estimated future sediment volume (% of storage)				
					Sedimentation period (years)				
					10	20	30	40	50
Mzintlava	Bokpoort	130	0.5	65	26.9	44.6	55.0	62.3	68.0
			1.0	130	13.4	22.3	27.5	31.2	34.0
			1.5	195	9.0	14.9	18.3	20.8	22.7
	Dam B	282	0.5	141	19.4	32.2	39.7	45.0	49.1
			1.0	282	9.7	16.1	19.8	22.5	24.6
			1.5	423	6.5	10.7	13.2	15.0	16.4
Mzintlava	Luzi	198	0.5	99	22.1	36.6	45.2	51.2	55.9
			1.0	198	11.0	18.3	22.6	25.6	27.9
			1.5	297	7.4	12.2	15.1	17.1	18.6
Kinira	Ntlabeni	396	0.5	198	14.9	24.6	30.4	34.4	37.6
			1.0	396	7.4	12.3	15.2	17.2	18.8
			1.5	594	5.0	8.2	10.1	11.5	12.5
	Thabeng	164	0.5	82	27.8	46.1	56.9	64.5	70.4
			1.0	164	13.9	23.1	28.5	32.3	35.2
			1.5	246	9.3	15.4	19.0	21.5	23.5
Kinira / Upper Mzimvubu	Dam 2	240	0.5	120	25.2	41.8	51.5	58.4	63.8
			1.0	240	12.6	20.9	25.8	29.2	31.9
			1.5	360	8.4	13.9	17.2	19.5	21.3
	Siqingeni	731	0.5	366	19.4	32.2	39.7	45.0	4.9
			1.0	731	9.7	16.1	19.9	22.5	2.5
			1.5	1 097	6.5	10.7	13.2	15.0	1.6
Inxu	Nomhala	206	0.5	103	17.1	28.4	35.0	39.7	43.3
			1.0	206	8.6	14.2	9.7	19.8	21.7
			1.5	309	5.7	9.5	6.5	13.2	14.4

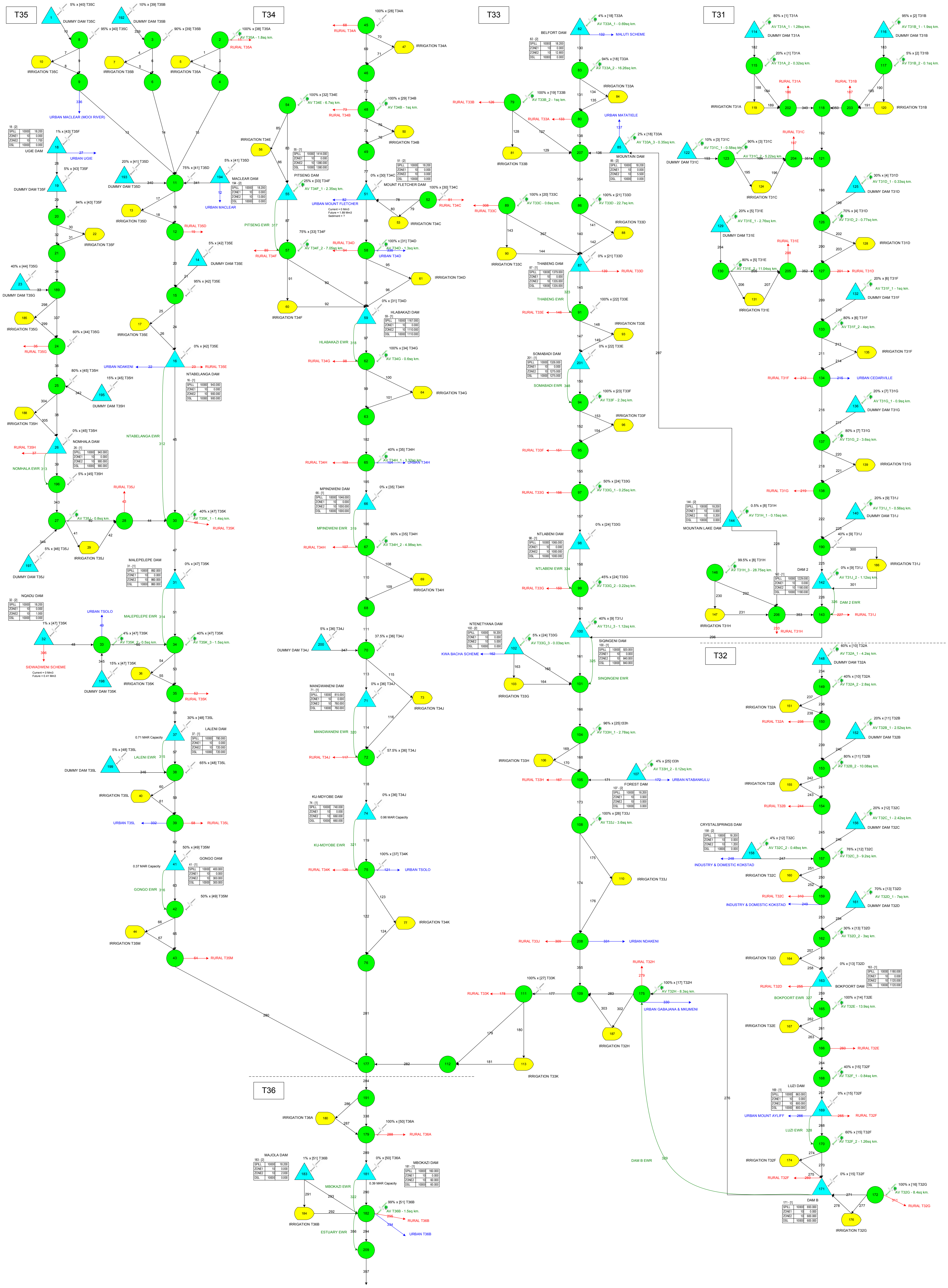
1) Refer to expected retained yield as listed in Table 7

2) V50 determined in Table 7

APPENDIX E

WRYM Schematic

MZIMVUBU DEVELOPMENT PROJECT: WRYM SCHEMATIC DIAGRAM



APPENDIX F

Potential dam cost estimates

ASSUMPTIONS

- A 10 m deep overburden to reach a solid rock surface suitable for foundations
- A 4.5 km average haul distance for the materials
- 3:1 and 2:1 slopes for the upstream and downstream earth embankment slopes respectively
- Average freeboard and spillway height of 7 m to handle design floods
- Side-channel spillways used when dam site topography allowed
- 1 m of concrete used to line spillway chutes (assumed due to relatively poor geology for foundations)
- 4 m high sidewalls for spillway chute of 0.75 m thickness
- Narrowing of spillway chutes at a slope of 1:6
- Dam heights capped at 100 m
- Quantities and basic cost estimates based on 20 m contours and 1:50 000 maps.

GENERAL CATCHMENT GEOLOGY

The general information based on the maps is that many of the centre-lines of the dams appear to be underlain by shale or mudstone in the river sections and lower flanks, while the upper flanks are underlain by dolerite. This configuration does not offer favourable conditions for concrete dams due to problems with sliding and rapid deterioration of the sedimentary rocks, and deep weathering in the dolerite. Concrete aggregate will have to be obtained from dolerite and is likely to be expensive because of a 10 m thick overburden.

Bokpoort Dam (1 MAR) Roller Compacted Concrete

FSL	**1 180**	**m**
NOC	**1 185**	**m**

No	Description	Unit	Rate (R)	Quantity	Amount (R million)
1	Site clearing	ha	14 871	13	0.2
2	River diversion	Sum			0.3
3	Excavation				
	a) Soft excavation	m^3	39	171 605	6.7
	b) Hard excavation	m^3	156	19 067	3.0
4	Foundation preparation	m^2	130	15 367	2.0
5	Curtain grouting (for m length of hole)	m	1 000	10 184	10.2
6	Formwork				
	a) Rough	m^2	338	40 735	13.8
	b) Smooth	m^2	416	4 074	1.7
7	Concrete works				
	a) Rollcrete / mass concrete	m^3	700	457 999	320.6
	b) Skin concrete	m^3	1 560	37 024	57.8
	c) Structural	m^3	1 950	3 702	7.2
	d) Reinforcing (100 kg/m^3)	t	12 167	370	4.5
8	Waterstop	m	325	2 037	0.7
10	Outlet works	Sum			20.0
	Access roads and diversions	sum			10.0
11	Miscellaneous (% of 1-10)	%	20		91.7
	SUB-TOTAL A				**550.3**
12	Preliminary and General (% of sub-total A)	%	50		275.1
	Contingencies	%	10		82.5
	TOTAL CONSTRUCTION COST				**907.9**

Dam B (1 MAR) Roller Compacted Concrete

FSL **693 m**
NOC **698 m**

No	Description	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 871	13	0.2
2	River diversion	Sum			0.3
3	Excavation				
	a) Soft excavation	m^3	39	275 740	10.8
	b) Hard excavation	m^3	156	30 638	4.8
4	Foundation preparation	m^2	130	25 988	3.4
5	Curtain grouting (for m length of hole)	m	1 000	17 566	17.6
6	Formwork				
	a) Rough	m^2	338	70 265	23.7
	b) Smooth	m^2	416	7 027	2.9
7	Concrete works				
	a) Rollcrete / mass concrete	m^3	700	1 125 293	787.7
	b) Skin concrete	m^3	1 560	63 240	98.7
	c) Structural	m^3	1 950	6 324	12.3
	d) Reinforcing (100 kg/m^3)	t	12 167	632	7.7
8	Waterstop	m	325	3 513	1.1
	Access roads	Sum			10.0
10	Outlet works	Sum			20.0
11	Miscellaneous (% of 1-10)	%	20		200.2
	SUB-TOTAL A				**1 201.4**
12	Preliminary and General (% of sub-total A)	%	50		600.7
	Contingencies	%	10		180.2
	TOTAL CONSTRUCTION COST				**1 982.3**

Dam 2 (1 MAR) Earthfill

FSL	**1 229**	**m**
NOC	**1 232**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	268 390	5.6
3	Excavation - clay core trench to spoil	m^3	27.3	59 040	1.6
4	Foundation preparation	m^2	13	129 275	1.7
5	Earthfill - shell (including excavation)	m^3	40.3	3 113 676	125.5
6	Clay core (including excavation)	m^3	46.8	445 636	20.9
7	Overhaul	m^3/km	7.8	2 005 361	15.6
8	Curtain grouting	m	811.2	9 094	7.4
9	Upstream rip rap (excl excavation)	m^3	122.2	85 650	10.5
10	Downstream gravel protection	m^3	80.6	17 344	1.4
11	Filters and drains	m^3	243.1	99 092	24.1
12	Toe drain	m	1 622.4	615	1.0
13	Spillway	Sum			40.0
	Access roads	Sum			10.0
14	Outlet works	Sum			10.0
	SUB-TOTAL A				**275.5**
15	Miscellaneous (% of 1- 14)	%	20		55.1
	SUB-TOTAL B				**330.6**
16	Preliminary and General (% of sub-total B)	%	50		165.3
	TOTAL CONSTRUCTION COST				**495.9**

Component	Amount (R million)
Main wall	495.9
Saddle wall	0.0
Spillway	31.6
Chute	197.4
Sub-Total	**724.9**
Contingencies	72.5
Total	**797.4**

Gongo (0.37 MAR) Roller Compacted Concrete Dam

FSL **400 m**
NOC **405 m**

No	Description	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 871	13	0.2
2	River diversion	Sum			0.3
3	Excavation				
	a) Soft excavation	m^3	39	272 048	10.6
	b) Hard excavation	m^3	156	30 228	4.7
4	Foundation preparation	m^2	130	25 728	3.3
5	Curtain grouting (for m length of hole)	m	1 000	17 413	17.4
6	Formwork				
	a) Rough	m^2	338	69 650	23.5
	b) Smooth	m^2	416	6 965	2.9
7	Concrete works				
	a) Rollcrete / mass concrete	m^3	700	1 139 297	797.5
	b) Skin concrete	m^3	1 560	62 647	97.7
	c) Structural	m^3	1 950	6 265	12.2
	d) Reinforcing (100 kg/m^3)	t	12 167	626	7.6
8	Waterstop	m	325	3 483	1.1
	Access roads	Sum			15.0
10	Outlet works	Sum			20.0
11	Miscellaneous (% of 1-10)	%	20		202.8
	SUB-TOTAL A				**1 217.1**
12	Preliminary and General (% of sub-total A)	%	50		608.5
	Contingencies	%	10		182.6
	TOTAL CONSTRUCTION COST				**2 008.2**

Hlabakazi (1 MAR) Roller Compacted Concrete Dam

FSL	**1 167**	**m**
NOC	**1 172**	**m**

No	Description	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 871	13	0.2
2	River diversion	Sum			0.3
3	Excavation				
	a) Soft excavation	m^3	39	128 290	5.0
	b) Hard excavation	m^3	156	14 254	2.2
4	Foundation preparation	m^2	130	11 244	1.5
5	Curtain grouting (for m length of hole)	m	1 000	7 387	7.4
6	Formwork				
	a) Rough	m^2	338	29 547	10.0
	b) Smooth	m^2	416	2 955	1.2
7	Concrete works				
	a) Rollcrete / mass concrete	m^3	700	297 788	208.5
	b) Skin concrete	m^3	1 560	26 973	42.1
	c) Structural	m^3	1 950	2 697	5.3
	d) Reinforcing (100 kg/m^3)	t	12 167	270	3.3
8	Waterstop	m	325	1 477	0.5
	Access roads	Sum			15.0
10	Outlet works	Sum			20.0
11	Miscellaneous (% of 1-10)	%	20		64.5
	SUB-TOTAL A				**386.8**
12	Preliminary and General (% of sub-total A)	%	50		193.4
	Contingencies	%	10		58.0
	TOTAL CONSTRUCTION COST				**638.2**

Ku-Mdyobe (1 MAR) Earthfill Dam

FSL	**740**	**m**
NOC	**743**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	295 250	6.1
3	Excavation - clay core trench to spoil	m^3	27.3	48 000	1.3
4	Foundation preparation	m^2	13	143 625	1.9
5	Earthfill - shell (including excavation)	m^3	40.3	4 831 449	194.7
6	Clay core (including excavation)	m^3	46.8	597 984	28.0
7	Overhaul	m^3/km	7.8	2 690 927	21.0
8	Curtain grouting	m	811.2	9 715	7.9
9	Upstream rip rap (excl excavation)	m^3	122.2	93 999	11.5
10	Downstream gravel protection	m^3	80.6	19 269	1.6
11	Filters and drains	m^3	243.1	106 970	26.0
12	Toe drain	m	1 622.4	500	0.8
13	Spillway	Sum			
	Access roads	Sum			10.0
14	Outlet works	Sum			20.0
	SUB-TOTAL A				**331.0**
15	Miscellaneous (% of 1- 14)	%	20		66.2
	SUB-TOTAL B				**397.2**
16	Preliminary and General (% of sub-total B)	%	50		198.6
	TOTAL CONSTRUCTION COST				**595.8**

Component	Amount (R million)
Main wall	595.9
Spillway	818.3
Chute	354.0
Sub-Total	**1 768.1**
Contingencies	176.8
Total	**1 944.9**

Laleni (0.71 MAR) Roller Compacted Concrete Dam

FSL	**780**	**m**
NOC	**785**	**m**

No	Description	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 871	13	0.2
2	River diversion	Sum			0.3
3	Excavation				
	a) Soft excavation	m^3	39	194 578	7.6
	b) Hard excavation	m^3	156	21 620	3.4
4	Foundation preparation	m^2	130	17 370	2.3
5	Curtain grouting (for m length of hole)	m	1 000	11 496	11.5
6	Formwork				
	a) Rough	m^2	338	45 985	15.5
	b) Smooth	m^2	416	4 599	1.9
7	Concrete works				
	a) Rollcrete / mass concrete	m^3	700	517 916	362.5
	b) Skin concrete	m^3	1 560	41 822	65.2
	c) Structural	m^3	1 950	4 182	8.2
	d) Reinforcing (100 kg/m^3)	t	12 167	418	5.1
8	Waterstop	m	325	2 299	0.8
	Access roads	Sum			85.0
10	Outlet works	Sum			20.0
11	Miscellaneous (% of 1-10)	%	20		117.9
	SUB-TOTAL A				**707.3**
12	Preliminary and General (% of sub-total A)	%	50		353.7
	Contingencies	%	10		106.1
	TOTAL CONSTRUCTION COST				**1 167.1**

LUZI (1 MAR) Earthfill Dam

FSL	**863**	**m**
NOC	**870**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	294 865	6.1
3	Excavation - clay core trench to spoil	m^3	27.3	49 440	1.3
4	Foundation preparation	m^2	13	143 313	1.9
5	Earthfill - shell (including excavation)	m^3	40.3	4 362 438	175.8
6	Clay core (including excavation)	m^3	46.8	560 121	26.2
7	Overhaul	m^3/km	7.8	2 520 543	20.0
8	Curtain grouting	m	811.2	9 130	7.4
9	Upstream rip rap (excl excavation)	m^3	122.2	93 896	11.5
10	Downstream gravel protection	m^3	80.6	19 227	1.5
11	Filters and drains	m^3	243.1	107 011	26.0
12	Toe drain	m	1 622.4	515	0.8
13	Spillway	Sum			0.0
14	Chute	sum			0.0
	Access roads	Sum			10.0
15	Outlet works	Sum			20.0
	SUB-TOTAL A				**308.6**
15	Miscellaneous (% of 1- 14)	%	20		61.7
	SUB-TOTAL B				**370.3**
16	Preliminary and General (% of sub-total B)	%	50		185.2
	TOTAL CONSTRUCTION COST				**555.5**

Component	Amount (R million)
Main wall	555.5
Saddle wall	0.0
Spillway	27.9
Chute	220.1
Sub-Total	**803.5**
Contingencies	80.3
Total	**883.8**

Malepelepe (1 MAR) Earthfill Dam

FSL	**892**	**m**
NOC	**900**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	19 331.91	20	0.4
2	Excavation - footprint to spoil	m^3	27.04	238 320	6.4
3	Excavation - clay core trench to spoil	m^3	35.49	73 920	2.6
4	Foundation preparation	m^2	16.9	113 000	1.9
5	Earthfill - shell (including excavation)	m^3	52.39	2 017 117	105.7
6	Clay core (including excavation)	m^3	60.84	356 536	21.7
7	Overhaul	m^3/km	10.14	1 604 410	16.3
8	Curtain grouting	m	1 054.56	7 642	8.1
9	Upstream rip rap (excl excavation)	m^3	158.86	76 337	12.1
10	Downstream gravel protection	m^3	104.78	15 161	1.6
11	Filters and drains	m^3	316.03	90 577	28.6
12	Toe drain	m	2 109.12	770	1.6
13	Spillway	Sum			0.0
	Access roads	Sum			80.0
14	Outlet works	Sum			20.0
	SUB-TOTAL A				**307.0**
15	Miscellaneous (% of 1- 14)	%	20		61.4
	SUB-TOTAL B				**368.4**
16	Preliminary and General (% of sub-total B)	%	50		184.2
	TOTAL CONSTRUCTION COST				**552.6**

Component	Amount (R million)
Main wall	552.6
Saddle wall	59.8
Spillway	75.6
Chute	221.4
Sub-Total	**909.4**
Contingencies	90.9
Total	**1 000.3**

Mangwaneni (1 MAR) Earthfill Dam

FSL	**915**	**m**
NOC	**923**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	440 660	9.2
3	Excavation - clay core trench to spoil	m^3	27.3	92 160	2.5
4	Foundation preparation	m^2	13	212 650	2.8
5	Earthfill - Shell (including excavation)	m^3	40.3	5 270 548	212.4
6	Clay core (including excavation)	m^3	46.8	741 225	34.7
7	Overhaul	m^3/km	7.8	3 335 512	26.0
8	Curtain grouting	m	811.2	13 478	10.9
9	Upstream rip rap (excl excavation)	m^3	122.2	140 563	17.2
10	Downstream gravel protection	m^3	80.6	28 530	2.3
11	Filters and drains	m^3	243.1	162 121	39.4
12	Toe drain	m	1 622.4	960	1.6
13	Spillway	Sum			
	Access roads	Sum			140.0
14	Outlet works	Sum			20.0
	SUB-TOTAL A				**519.2**
15	Miscellaneous (% of 1- 14)	%	20		103.8
	SUB-TOTAL B				**623.1**
16	Preliminary and General (% of sub-total B)	%	50		311.5
	TOTAL CONSTRUCTION COST				**934.6**

Component	Amount (R million)
Main wall	934.6
Saddle wall	58.3
Spillway	9.6
Chute	349.5
Sub-Total	**1 352.0**
Contingencies	135.2
Total	**1 487.2**

Mbokazi (0.39 MAR) Roller Compacted Concrete Dam

FSL **160 m**
NOC **165 m**

No	Description	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 871	13	0.2
2	River diversion	Sum			0.3
3	Excavation				
	a) Soft excavation	m^3	39	276 255	10.8
	b) Hard excavation	m^3	156	30 695	4.8
4	Foundation preparation	m^2	130	26 145	3.4
5	Curtain grouting (for m length of hole)	m	1 000	17 700	17.7
6	Formwork				
	a) Rough	m^2	338	70 800	23.9
	b) Smooth	m^2	416	7 080	2.9
7	Concrete works				
	a) Rollcrete / mass concrete	m^3	700	1 165 502	815.9
	b) Skin concrete	m^3	1 560	63 673	99.3
	c) Structural	m^3	1 950	6 367	12.4
	d) Reinforcing (100 kg/m^3)	t	12 167	637	7.7
8	Waterstop	m	325	3540	1.2
	Access roads	Sum			15.0
10	Outlet works	Sum			30.0
11	Miscellaneous (% of 1-10)	%	20		209.1
	SUB-TOTAL A				**1 254.6**
12	Preliminary and General (% of sub-total A)	%	50		627.3
	Contingencies	%	10		188.2
	TOTAL CONSTRUCTION COST				**2 070.1**

Mpindweni (1 MAR) Earthfill Dam

FSL	**1046**	**m**
NOC	**1049**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	155 580	3.2
3	Excavation - clay core trench to spoil	m^3	27.3	41 280	1.1
4	Foundation preparation	m^2	13	74 350	1.0
5	Earthfill - Shell (including excavation)	m^3	40.3	1 589 771	64.1
6	Clay core (including excavation)	m^3	46.8	245 948	11.5
7	Overhaul	m^3/km	7.8	1 106 764	8.6
8	Curtain grouting	m	811.2	5 404	4.4
9	Upstream rip rap (excl excavation)	m^3	122.2	49 743	6.1
10	Downstream gravel protection	m^3	80.6	9 975	0.8
11	Filters and drains	m^3	243.1	58 291	14.2
12	Toe drain	m	1 622.4	430	0.7
13	Spillway	Sum			0.0
	Access roads	Sum			90.0
14	Outlet works	Sum			20.0
	SUB-TOTAL A				**226.0**
15	Miscellaneous (% of 1- 14)	%	20		45.2
	SUB-TOTAL B				**271.2**
16	Preliminary and General (% of sub-total B)	%	50		135.6
	TOTAL CONSTRUCTION COST				**406.8**

Component	Amount (R million)
Main wall	406.8
Saddle wall	0.0
Spillway	21.8
Chute	148.9
Sub-Total	**577.4**
Contingencies	57.7
Total	**635.1**

Nomhala (1 MAR) Earthfill Dam

FSL	**943**	**m**
NOC	**950**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	212 505	4.4
3	Excavation - clay core trench to spoil	m^3	27.3	53 280	1.5
4	Foundation preparation	m^2	13	101 813	1.3
5	Earthfill - shell (including excavation)	m^3	40.3	2 191 590	88.3
6	Clay core (including excavation)	m^3	46.8	334 715	15.7
7	Overhaul	m^3/km	7.8	1 506 219	11.7
8	Curtain grouting	m	811.2	6 681	5.4
9	Upstream rip rap (excl excavation)	m^3	122.2	67 902	8.3
10	Downstream gravel protection	m^3	80.6	13 660	1.1
11	Filters and drains	m^3	243.1	79 245	19.3
12	Toe drain	m	1 622.4	555	0.9
13	Spillway	Sum			0.0
	Access roads	Sum			10.0
14	Outlet works	Sum			15.0
	SUB-TOTAL A				**183.2**
15	Miscellaneous (% of 1- 14)	%	20		36.6
	SUB-TOTAL B				**219.8**
16	Preliminary and General (% of sub-total B)	%	50		110.0
	TOTAL CONSTRUCTION COST				**329.8**

Component	Amount (R million)
Main wall	329.8
Saddle wall	0.0
Spillway	6.6
Chute	229.5
Sub-Total	**565.9**
Contingencies	56.6
Total	**622.5**

Ntabelanga (1 MAR) Earthfill Dam

FSL	**943**	**m**
NOC	**950**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	152 400	3.2
3	Excavation - clay core trench to spoil	m^3	27.3	38 400	1.0
4	Foundation preparation	m^2	13	73 000	0.9
5	Earthfill - shell (including excavation)	m^3	40.3	1 561 647	62.9
6	Clay core (including excavation)	m^3	46.8	239 627	11.2
7	Overhaul	m^3/km	7.8	1 078 322	8.4
8	Curtain grouting	m	811.2	4 779	3.9
9	Upstream rip rap (excl excavation)	m^3	122.2	48 699	6.0
10	Downstream gravel protection	m^3	80.6	9 794	0.8
11	Filters and drains	m^3	243.1	56 854	13.8
12	Toe drain	m	1 622.4	400	0.6
13	Spillway	Sum			0.0
14	Chute	sum			0.0
	Access roads	Sum			20.0
15	Outlet works	Sum			20.0
	SUB-TOTAL A				**153.1**
15	Miscellaneous (% of 1- 14)	%	20		30.6
	SUB-TOTAL B				**183.7**
16	Preliminary and General (% of sub-total B)	%	50		91.9
	TOTAL CONSTRUCTION COST				**275.6**

Component	Amount (R million)
Main wall	275.6
Saddle wall	0.0
Spillway	13.8
Chute	92.1
Sub-Total	**381.5**
Contingencies	38.1
Total	**419.6**

Ntlabeni (1 MAR) Earthfill Dam

FSL	**1065**	**m**
NOC	**1068**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	231 780	4.8
3	Excavation - clay core trench to spoil	m^3	27.3	43 680	1.2
4	Foundation preparation	m^2	13	112 250	1.5
5	Earthfill - shell (including excavation)	m^3	40.3	3 168 717	127.7
6	Clay core (including excavation)	m^3	46.8	419 031	19.6
7	Overhaul	m^3/km	7.8	1 885 640	14.7
8	Curtain grouting	m	811.2	7 711	6.3
9	Upstream rip rap (excl excavation)	m^3	122.2	73 871	9.0
10	Downstream gravel protection	m^3	80.6	15 060	1.2
11	Filters and drains	m^3	243.1	84 696	20.6
12	Toe drain	m	1 622.4	455	0.7
13	Spillway	Sum			0.0
	Access roads	Sum			15.0
14	Outlet Works	Sum			20.0
	SUB-TOTAL A				**242.6**
15	Miscellaneous (% of 1- 14)	%	20		48.5
	SUB-TOTAL B				**291.1**
16	Preliminary and General (% of sub-total B)	%	50		145.6
	TOTAL CONSTRUCTION COST				**436.7**

Component	Amount (R million)
Main wall	436.7
Spillway	74.8
Chute	192.0
Sub-Total	**703.5**
Contingencies	70.3
Total	**773.8**

Pitseng (1 MAR) Roller Compacted Concrete Dam

FSL **1 414 m**
NOC **1 418 m**

No	Description	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 871	13	0.2
2	River diversion	Sum			0.3
3	Excavation				
	a) Soft excavation	m^3	39	69 089	2.7
	b) Hard excavation	m^3	156	7 677	1.2
4	Foundation preparation	m^2	130	5 727	0.7
5	Curtain grouting (for m length of hole)	m	1 000	3 673	3.7
6	Formwork				
	a) Rough	m^2	338	14 690	5.0
	b) Smooth	m^2	416	1 469	0.6
7	Concrete works				
	a) Rollcrete / mass concrete	m^3	800	115 857	92.7
	b) Skin concrete	m^3	1 560	13 573	21.2
	c) Structural	m^3	1 950	1 357	2.6
	d) Reinforcing (100 kg/m^3)	t	12 167	136	1.7
8	Waterstop	m	325	735	0.2
	Access roads	Sum			50.0
10	Outlet works	Sum			10.0
11	Miscellaneous (% of 1-10)	%	20		38.6
	SUB-TOTAL A				**231.3**
12	Preliminary and General (% of sub total A)	%	50		115.7
	Contingencies	%	10		34.7
	TOTAL CONSTRUCTION COST				**381.7**

Siqingeni (1 MAR) Earthfill Dam

FSL	**920**	**m**
NOC	**927**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	446 330	9.3
3	Excavation - clay core trench to spoil	m^3	27.3	62 880	1.7
4	Foundation preparation	m^2	13	217 925	2.8
5	Earthfill - shell (including excavation)	m^3	40.3	7 767 007	313.0
6	Clay core (including excavation)	m^3	46.8	938 302	43.9
7	Overhaul	m^3/km	7.8	4 222 357	32.9
8	Curtain grouting	m	811.2	13 700	11.1
9	Upstream rip rap (excl excavation)	m^3	122.2	141 970	17.3
10	Downstream gravel protection	m^3	80.6	29 238	2.4
11	Filters and drains	m^3	243.1	160 541	39.0
12	Toe drain	m	1 622.4	655	1.1
13	Spillway	Sum			
	Access roads	Sum			10.0
14	Outlet works	Sum			20.0
	SUB-TOTAL A				**504.9**
15	Miscellaneous (% of 1- 14)	%	20		101.0
	SUB-TOTAL B				**605.9**
16	Preliminary and General (% of sub-total B)	%	50		302.9
	TOTAL CONSTRUCTION COST				**908.8**

Component	Amount (R million)
Main wall	908.8
Saddle wall	0.0
Spillway	49.0
Chute	377.6
Sub-Total	**1 335.4**
Contingencies	133.5
Total	**1 468.9**

Somabadi (1 MAR) Earthfill Dam

FSL	**1 334**	**m**
NOC	**1 341**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	19 331.91	20	0.4
2	Excavation - footprint to spoil	m^3	27.04	254970	6.9
3	Excavation - clay core trench to spoil	m^3	35.49	69120	2.5
4	Foundation preparation	m^2	16.9	121725	2.1
5	Earthfill - shell (including excavation)	m^3	52.39	2820667	147.8
6	Clay core (including excavation)	m^3	60.84	426760	26.0
7	Overhaul	m^3/km	10.14	1920419	19.5
8	Curtain grouting	m	1 054.56	8166	8.6
9	Upstream rip rap (excl excavation)	m^3	158.86	81539	13.0
10	Downstream gravel protection	m^3	104.78	16331	1.7
11	Filters and drains	m^3	316.03	95706	30.2
12	Toe drain	m	2 109.12	720	1.5
13	Spillway	Sum			0.0
	Access roads	Sum			45.0
14	Outlet works	Sum			20.0
	SUB-TOTAL A				**325.0**
15	Miscellaneous (% of 1- 14)	%	20		65.0
	SUB-TOTAL B				**390.1**
16	Preliminary and General (% of sub-total B)	%	50		195.0
	TOTAL CONSTRUCTION COST				**585.1**

Component	Amount (R million)
Main wall	585.1
Spillway	13.6
Chute	93.7
Sub-Total	**692.4**
Contingencies	69.2
Total	**761.6**

Thabeng (1 MAR) Earthfill Dam

FSL	**1 388**	**m**
NOC	**1 395**	**m**

No	Item	Unit	Rate	Quantity	Amount (R million)
1	Site clearing	ha	14 870.7	20	0.3
2	Excavation - footprint to spoil	m^3	20.8	135 755	2.8
3	Excavation - clay core trench to spoil	m^3	27.3	29 280	0.8
4	Foundation preparation	m^2	13	65 438	0.9
5	Earthfill - shell (including excavation)	m^3	40.3	1 538 070	62.0
6	Clay core (including excavation)	m^3	46.8	221 816	10.4
7	Overhaul	m^3/km	7.8	998 171	7.8
8	Curtain grouting	m	811.2	4 221	3.4
9	Upstream rip rap (excl excavation)	m^3	122.2	43 315	5.3
10	Downstream gravel protection	m^3	80.6	8 779	0.7
11	Filters and drains	m^3	243.1	50 052	12.2
12	Toe drain	m	1 622.4	305	0.5
13	Spillway	Sum			
14	Access roads	Sum			165.0
15	Outlet works	Sum			20.0
	SUB-TOTAL A				**292.0**
16	Miscellaneous (% of 1- 14)	%	20		58.4
	SUB-TOTAL B				**350.4**
17	Preliminary and General (% of sub-total B)	%	50		175.2
	TOTAL CONSTRUCTION COST				**525.6**

Component	Amount (R million)
Main wall	525.6
Saddle wall	0.0
Spillway	17.9
Chute	98.3
Sub-Total	**641.8**
Contingencies	64.2
Total	**706.0**