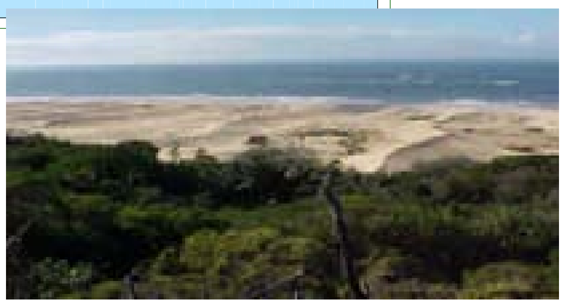
P WMA 15/000/00/0406

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate: National Water Resource Planning

ALBANY COAST SITUATION ASSESSMENT STUDY



Main Report: Volume 1

Final

December 2004

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DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

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Submitted on behalf of UWP Consulting (Pty) Ltd by:

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DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate: National Water Resource Planning

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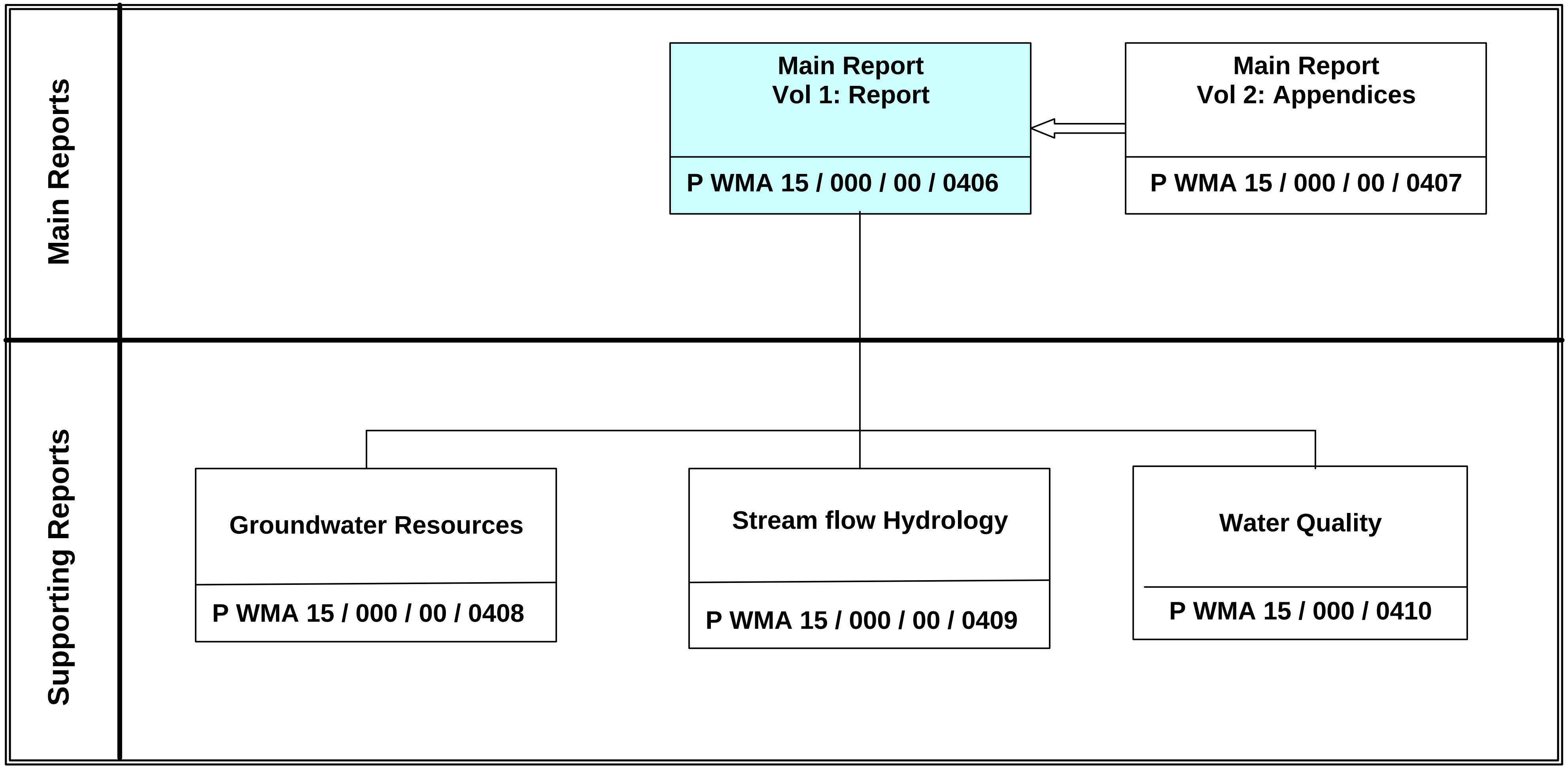
ALBANY COAST SITUATION ASSESSMENT STUDY

Structure of Reports



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Albany Coast Water Board

Cacadu District Municipality

DMM Consultants

DWAF: Eastern Cape Region

DWAF: Hydrology

DWAF: National Water Resource Planning

DWAF: Water Resource Planning Systems

DWAF: Water Quality Management

Ndlambe Local Municipality

P & S Consulting Engineers

WSM Leshika Civil Engineers, Hydrologists & Project Managers

ALBANY COAST SITUATION ASSESSMENT STUDY

MAIN REPORT

EXECUTIVE SUMMARY

1. INTRODUCTION

In October 2003, at the request of the Easter Cape Regional Office, the Directorate: Water Resource Planning of the Department of Water Affairs and Forestry (DWAF) commissioned the Albany Coast Situation Assessment Study.

The study was triggered by the fact that a number of towns situated within the coastal belt of drainage region P (Port Alfred, Bathurst, Kleinemonde, Kenton on Sea, Boesmansriviermond, Boknes, Cannon Rocks and Alexandria) experience serious periodic water supply problems, mainly because of inadequate sources, poor water quality and insufficient capacity of their bulk supply infrastructure. The aim of the study was to investigate the water resources situation in the entire region and in particular the water supply problems of the afore-mentioned towns, as well as to consider possible solutions that may present themselves for ready implementation. The study therefore comprised two main components, both undertaken at reconnaissance level of detail - water resources situation assessment study for drainage region P and a development options study for the augmentation of the water supply to the affected towns.

The set of study reports includes this Main Report, as well as the following supporting reports: Main Report Volume 2: Appendices, Stream Flow Hydrology, Water Quality and Groundwater Resources.

2. BASE INFORMATION

The study area (about 5 300 km^2), known as the Albany Coast, covers drainage region P, which is located along the coast, midway between Port Elizabeth and East London and extends about 70 km inland. The area falls under the jurisdiction of the Cacadu District Municipality and includes a number of formal urban towns, the biggest being Grahamstown and Port Alfred.

The topography around the coast is mainly flat, while it becomes steep and mountainous towards Grahamstown to the north. The area is drained by three main rivers – the Kowie, the Kariega and the Lower Bushmans, which are perennial and flow in the south-easterly direction from the mountainous inland towards the Indian Ocean. The area is divided into 4 tertiary and 16 quaternary catchments **(Figure 3.2)**.

The runoff in the study area is regulated by about 50 small and medium sized dams used predominantly for water supply to the local population and for irrigation. The main dams are the New Year's Dam, the Settlers Dam and the Sarel Hayward Dam. The mean annual precipitation (MAP) for the quaternary catchments within the study area varies between 386 mm and 715 mm. The mean annual evaporation (S-pan equivalent) varies between 1450 and 1650 mm.

According to the latest Census 2001 results, the present (base year 2001) population size in the study area is about 139 000 people, of which 119 000 live in urban areas and about 20 000 in rural areas. It is projected that by year 2025 the total population will grow to about 170 000, resulting in an average growth rate of about 0.8% per annum. The relatively high growth is associated with the increase of the urban population mainly in the costal towns and in Grahamstown.

The predominant type of land-use within drainage region P is for grazing (4 400 km²). The area covered by nature reserves (including the indigenous forests) is 278 km². About 380 km² of land is used for dry land agriculture, while only about 7 km² of land is irrigated. Afforestation covers about 6 km² and urban areas are about 25 km². A significant portion of the land is infested by invasive alien plants – 230 km² (4% of total). The most severe infestation occurs along the coastal strip at Boesmansriviermond and Kenton on Sea.

The number of equivalent large stock units in the study area is estimated at about 90 000.

3. WATER REQUIREMENTS

The water requirements for study area were estimated per quaternary catchment for each of the following user sectors: urban domestic and industrial, rural domestic, stock watering, irrigation, afforestation, invasive alien plants and ecological. The current and projected use of groundwater sources, the inter-basin transfers, as well as the return flows from the urban areas were also taken into consideration. This was done in order to estimate the consumptive water requirements imposed on the surface water resources. The results of the estimates for the water requirements per user sector in the study area are shown in **Table E3** on the following page.

The urban water requirements were estimated on the basis of the methodology developed for the National Demographic Study (NDS) (Schlemmer *et al*, 2001) taking into account the direct and indirect water use. The population in each urban centre was divided into the seven categories of water use on the basis of the relevant data from Census 2001, as well as based on site information obtained during the course of this study. The unit water use per category as recommended by the NDS was applied in order to determine the direct water requirements. In addition, an allowance has been made for bulk conveyance and distribution losses.

The reduction of runoff owing to infestation with invasive alien plants has been modelled using the SHELL model. The estimates for the ecological Reserve were produced on the basis of the desktop methodology applying the Hughes model. The ecological management classes, used as an input to the model, have been assessed by a team of environmental specialists during a workshop in August 1999. The ecological Reserve requirements in the study area vary between 11% and 18% of the mean annual runoff, but these are not included in the table everleaf as they are specific for each development site.

The groundwater usage has been estimated and projected in broad terms. The existing records of current usage from groundwater have been taken into account, while the projected future groundwater usage was based on a regional scale desktop study, which assessed the potential for development of the groundwater resources in the area. Owing to the lack of accurate data, it has been assumed that 40% of the total urban water usage in towns with water-borne sewer systems will return to the surface water system.

The inter-basin transfer scheme from the Lower Fish River Government Water Scheme to Grahamstown has an installed capacity 3.65 million m³/a. The actual volume transferred in 2001 was 2.3 million m³, but it has been assumed that the full capacity of the system will be reached by about 2016.

Table E3: Consumptive Water Requirements per User Sector

User Sector	Water Requirements ($10^6 m^3/a$)			
	2001	**2005**	**2015**	**2025**
Urban domestic and industrial	7.88	9.95	12.35	13.89
Rural domestic	0.40	0.42	0.42	0.39
Stock watering	1.67	1.67	1.67	1.67
Irrigation	12.78	12.78	12.78	12.78
Afforestation	0.16	0.16	0.16	0.16
Invasive alien plants	16.81	16.81	16.81	16.81
Total consumptive requirements	**39.70**	**41.79**	**44.19**	**45.69**
Return Flows	-2.35	-2.69	-3.08	-3.20
Inter-basin transfer	-2.31	-2.80	-3.45	-3.65
Groundwater supply	-1.97	-2.60	-2.73	-3.11
Total inflows	-6.63	-8.09	-9.26	-9.96
Total use from surface water	**33.07**	**33.70**	**34.93**	**35.73**

4. WATER RESOURCES

The stream flow analysis of the surface water resources for drainage region P has been undertaken per quaternary catchment on the basis of WR90. The total natural MAR for the study area is estimated at 173 million m³/a and the present day MAR at 132 million m³/a.

The Water Resources Yield Model (WRYM) was used to determine the yield at the outlets of the quaternary catchments and at three dam sites. The model was configured for two scenarios - with and without provision for the release of the Ecological Reserve Requirements (ERR). All quaternary catchments in the study area are generally in balance (no surplus yield available), except for P40C which has a surplus yield of 4.0 million m³/a.

The surface water quality in the middle and lower reaches of region is generally poor owing to the geology of the catchment, which is of a marine origin. Both the Bushmans and the Kariega Rivers are classified as "completely unacceptable" in terms of water quality according to the Mineralogical Classification of DWAF. The maximum total dissolved salts (TDS) in these rivers are often greater than 3 400 parts per million (ppm). The water quality of the Kowie River is classified as "poor" with maximum levels of TDS in the region of 1 800 to 3 400 ppm.

The groundwater resources of drainage region P are currently not being utilised to their full potential, with present groundwater use in the order of 2.0 million m^3/a. Although many of the towns within the study area already rely on groundwater as the primary water source, more groundwater sources can be harvested in a sustainable manner to augment the water supply to certain areas. In general, the groundwater harvest potential for the area is positive (41 million m^3/a), but the actual utilisable resources are subject to economic, water quality and environmental constrains. It is estimated that additional groundwater sources with acceptable water quality (Class 0 and I) with a yield of about 2.6 million m^3/a can be utilised in a sustainable manner.

A number of sites within the fractured Witpoort aquifer are considered to have relatively high groundwater potential. Exploration drilling undertaken during the course of the study has confirmed the potential for the development of these sites. Drilling depths vary between 100 m to 180 m with success rates of between 30% and 60% and an average yield of about 4 l/s.

Another source with high potential yields is the Intergranular Coastal Aquifers. Boreholes drilled in those areas are expected to yield in the order of 3 to 5 l/s of Class I and Class II water. Some of the sources from the dune aquifer system, like Kwaaihoek and Sunshine Coast well fields, fall within the jurisdiction of the Sanparks and approval from the Department of Environmental Affairs and Tourism (DEAT) is required before any implementation processes for the development of these sources can commence.

This marine-originated geology causes salinization or mineralisation of groundwater, which results in poor quality water. Generally the quality of groundwater varies between a Class I and II. Over-pumping of coastal aquifers results in saline intrusions that cause the water quality to deteriorate. This is currently the phenomenon during peak seasons when water demands are higher than during normal periods.

5. DEVELOPMENT OPTIONS

This part of the report deals with the identification, sizing, costing and evaluation of the development options required to augment the sources of water supply in certain towns within the study area, which experience serious water supply problems.

5.1 POPULATION NUMBERS IN THE AFFECTED TOWNS

The present and projected population numbers in the affected towns were estimated in accordance with the methodology described in detail in **Section 3.1** in this report. The results are shown in the **Table E5.1**. As seen from the table the projected population growth rates vary substantially – from 0.5% per annum in the case of Alexandria to 5% per annum in the case of Boknes and Cannon Rocks. The estimated additional seasonal population is also shown.

Table E5.1: Projected population numbers for selected urban centres

Quat.	Town	Population numbers				
		2001	2005	2015	2025	Seasonal
P10G	Kenton on Sea/ Bushmans	9 480	12 745	13 734	14 539	15 000
P20A	Alexandria	7 715	8 371	9 178	8 720	-
	Boknes / Cannon Rocks	931	1 422	2 573	2 949	2 500
P40C	Port Alfred	20 965	27 526	35 376	40 542	15 000
	Bathurst	5 549	6 497	6 445	6 227	-
P40D	Kleinemonde	1 450	1 833	2 156	2 471	2 000

5.2 PROJECTED WATER REQUIREMENTS FOR THE AFFECTED TOWNS

The projected water requirements were estimated in accordance with the methodology developed for the NDS. The methodology is described in detail in **Section 4.1** of the main body of the report. The results are shown in **Table E5.2**. The table also shows the yield of the existing water sources of supply in each town, as well as the deficit or surplus in water availability in relation to the water requirements in 2005.

Table E5.2: Projected water requirements, capacity of existing source and deficit

Town	Total gross water requirements				Yield of source	Growth in use	Deficit (-) Surplus (+)
	10^6 m^3/a				10^6 m^3/a	%	%
	2001	2005	2015	2025	2005	2005 to 2025	in 2005
Kenton on Sea/ Bushmans	0.66	0.91	1.21	1.49	0.52	64%	-75%
Alexandria	0.52	0.62	0.79	0.76	0.65	23%	+5%
Cannon/Boknes	0.18	0.25	0.46	0.53	0.24	109%	-5%
Port Alfred	1.27	2.16	3.04	3.90	1.73	81%	-25%
Bathurst	0.26	0.34	0.39	0.41	0.30	23%	-12%
Kleinemonde	0.05	0.08	0.12	0.16	0.15	88%	+44%

For the period 2005 to 2025 the water requirements are expected to grow from as little as 23% in Alexandria and Bathurst, to 88% in Port Alfred, and 109% in Cannon Rocks and Boknes.

The deficit in the capacity of the existing water source, compared to the water requirements in 2005 is the greatest for Kenton on Sea/Boesmansriviermond (-75%) followed by Port Alfred (-25%). This indicates that the water supply situation in these towns is the most critical.

5.3 OUTLINE OF PLANNING CONSIDERATIONS

5.3.1 Reasons for water supply problems

Most of the affected towns currently experience severe water supply problems, which are related to one or more of the following reasons:

- **Poor water quality**. All towns except Alexandria are supplied with water with salinity levels exceeding those recommended for long-term use (TDS should be lower than 1 000 mg/l). During normal periods the TDS for the water supplied to these towns exceeds 1 400 mg/l, but during certain periods could reach levels as high as 3 000 mg/l. This is associated with the specific geological conditions in the lower part of the drainage region, where these towns are located.

- **Inadequate capacity of the existing water sources**. The water resources with acceptable water quality in the drainage region are very scarce. As seen from **Table E 5.2** the water sources for some of the affected towns have inadequate capacity to meet the present water requirements and urgent augmentation is required. The existing water sources are insufficient to meet the 2025 requirements for all towns.

- **Inadequate capacity of the bulk supply infrastructure**. Some of the affected towns located in the coastal area are holiday destinations. The summer peak factors (SPF) in these towns vary in the range of 1.5 to 1.8 of the annual average daily demands (AADD), while the extreme peaks can reach as high as 3 times the AADD. In some cases the bulk supply infrastructure (water treatment plants, storage reservoirs, bulk supply conveyance system) have inadequate capacity to provide for the peak requirements.

5.3.2 Possible sources of supply

Owing to the high seasonal variability of flows, the available run-of-river yields are insufficient to supply the demands in the study area at the required assurance level of 98%. Therefore, run-of-river schemes are considered not feasible and do not form part of the proposed development options.

The surface water quality is poor in the middle to lower reaches (a belt within about 40 to 50 km from the coast line) of the study area. Conveying water from surface sources located beyond the problematic areas is expected to be costly.

Areas with high potential for groundwater development were identified during the course of this study. Exploration drilling was also done. In general, the yields per borehole are expected to be low (not exceeding 4 l/s), and the water quality in the lower reaches of the study area is expected to be poor (possibly Class II and higher). However, potential sites with superior water quality have been identified mostly in the coastal aquifer.

The expected yield of acceptable quality groundwater appears to be sufficient to supply the towns of Alexandria, Cannon Rocks/Boknes and partially Kenton on Sea. However, some of the identified sources are located within the environmentally sensitive coastal dunes. Any exploration of these resources will be subject to acceptable environmental impact management measures.

Desalination of seawater through the process of reverse osmosis is currently used as one of the sources of supply to Kenton on Sea and Boesmansriviermond. Subject to the acceptability of the high operation and maintenance costs, this technology is suitable for the study area as it produces water of a superior quality.

5.3.3 Water usage and conservation

No sufficient data was available to assess the current losses in the distribution networks of the affected towns. The water requirement projections were based on the assumption that the best water conservation and demand management practices will be maintained.

At present, the water is generally being used wisely. Owing to the poor water quality supplied to the affected towns, most of the households have rainwater harvesting facilities. The upmarket houses and some of the public buildings are equipped with dual internal plumbing systems, which distribute the harvested rainwater for domestic use. In these cases the municipal supply is used predominantly for gardening. The usage of bottled water for cooking and drinking purposes is a common practice for those who can afford it. The effect of the utilisation of rainwater has not been considered as this source of supply generally has low assurance.

5.4 IDENTIFICATION OF DEVELOPMENT OPTIONS

An investigation of the water supply infrastructure for each of the affected towns has been carried out during the study. A detailed description of the existing infrastructure and its capacity is available in **Section 5** of the main body of the report.

Based on the specific circumstances in and around each town (water supply situation, capacity of infrastructure, available water sources, water quality, etc.) various development options for the augmentation of the water sources and the bulk water supply infrastructure have been identified and evaluated. Options range from individual groundwater supply schemes, regional surface water schemes supplying a number of towns in the area, to conjunctive use schemes and sea or brackish water desalination schemes. Details are available in **Section 8.4** of the main body of the report. The layouts of the proposed development options are illustrated in **Figure 13.1** and **Diagrams S1 to S7**. Diagrams showing the possible timing of implementation of the various components of each scheme are shown in **Figure 13.2**. The milestone parameters for the infrastructure components for each option are summarised in **Table 8.4** (page 74) of the main body of the report.

The economic evaluation was done on the basis of the unit reference value (URV) of water supplied, calculated on the basis of the models developed for the VAPS study. The economic parameters for the development options are summarised in the **Table E5.4**.

Table E5.4: Economic parameters for the development options

Option No.	Development Option	Tot Capital Cost (R mil)	Tot Annual O&M (R mil)	Residual Value (R mil)	Max Energy (R mil)	URV of Water, 6 % discount (R/m³)
1	Alexandria – GW	R 10.609	R 0.151	R 3.674	R 0.056	R 15.22
2	Cannon Rocks – GW	R 5.619	R 0.104	R 1.746	R 0.043	R 5.02
3	Kenton on Sea – GW	R 28.114	R 0.425	R 10.008	R 0.483	R 10.08
4a	Kenton on Sea – RO1	R 34.646	R 0.771	R 14.750	R 0.937	R 13.56
4b	Kenton on Sea – RO2	R 28.767	R 0.606	R 9.709	R 0.739	R 11.33
5	Kenton on Sea – SW	R 41.335	R 0.499	R 14.681	R 0.716	R 10.21
6	Port Alfred – GM 1	R 130.907	R 1.538	R 48.291	R 1.539	R 10.68
7	Port Alfred – GM 2	R 98.241	R 1.196	R 36.947	R 1.212	R 9.97
8a	Port Alfred – SH	R 55.184	R 0.622	R 24.331	R 0.496	R 5.70
8b	Port Alfred – SH & RO	R 73.535	R 1.148	R 31.617	R 1.290	R 8.27
9	Port Alfred – SD	R 100.456	R 1.292	R 38.524	R 1.282	R 10.91
10	Port Alfred – RO	R 84.108	R 2.030	R 31.744	R 2.447	R 10.85

It should be noted that the figures regarding the URV in the above table are very rough and are provided only for comparison purposes. Owing to the reconnaissance nature of this study, the phased implementation of the components associated with the development options has not been taken into account when running the economics models. This may have resulted in certain inaccuracy of the calculated URV's.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 DEVELOPMENT OPTIONS

6.1.1 Introduction

The water supply situation in most of the affected towns is not ideal and steps for the augmentation of the water sources need to be taken. However, the situation in Kenton on Sea/Boesmansriviermond, Cannon Rocks/Boknes and Port Alfred is critical and emergency measures for augmentation of the water sources for these towns are urgently required.

Where possible, this study has identified solutions to the water supply problems that present themselves for immediate implementation. In other cases, more detailed investigations have been recommended to be undertaken before final decisions on the best solutions can be made. A summary of the cost estimates for the proposed augmentation schemes is given in **Section 8.6** and more detail is available in **Appendix 10**. A detailed description of the components of the proposed schemes is given in **Section 8.4** and a summary in **Table 8.4.**

The specific recommendations for each town are offered in the next paragraphs. The responsibility for further actions is indicated in brackets and in bold print after each recommended action. Where the Ndlambe Local Municipality (NLM) has been identified as the responsible institution, they will most likely have to rely on Municipal Infrastructure Grant (MIG) funding. The NLM should draw up an implementation strategy, based on the recommendations in this report. Provision of direct financial assistance from DWAF for implementation of infrastructure is unlikely. However, when the implementation strategy is completed, NLM can approach DWAF for further advice and assistance. Where possible, it terms of current legislation, DWAF will do its best to assist.

When estimating the water requirements it has been assumed that the best water demand management measures would be implemented. In all towns, projects are recommended to assess the levels of existing losses in the bulk supply and reticulation systems, to propose measures for the reduction of those losses and to undertake the necessary remedial work. This will ensure that the limited resources are utilized in the most efficient manner. **(NLM, but DWAF can provide assistance in terms of advice).**

The NLM should not allow substantial housing developments in the most affected towns before solutions to the severe water supply problems are identified and implemented.

6.1.2 Alexandria

- The existing water source (Fishkraal coastal aquifer) has sufficient yield to meet the projected water requirements until 2007. Thereafter the source needs to be augmented.
- The water quality of the source is of acceptable standard.
- The additional water source from the Fishkraal coastal aquifer, identified during the course of this study, has sufficient capacity to meet the water requirements until 2025 and beyond. The development of this source can commence as soon as a record of decision from the Department of Environmental Affairs and Tourism (DEAT) is received. (**NLM, funding from MIG, but DWAF can assist with advice).**
- The NLM should follow up with the DEAT with regards to the outcome of the application for approval of the further exploration of the Fishkraal costal aquifer submitted earlier.
- If the Fishkraal coastal aquifer development is acceptable from an environmental point of view, the source should be developed and the phasing of the upgrading of the bulk supply system should be optimized. The total capital cost for this development is estimated at R10.6 million at April 2004 price levels (**NLM, but DWAF can assist with advice).**
- The existing bulk supply system is undersized and needs to be upgraded urgently. However, a decision on the likely additional water source needs to be made before the upgrading of this system. (**NLM, funding from the MIG as budgeted for in the Water Services Development Plan (WSDP)).**
- If the Fishkraal coastal aquifer development is not acceptable, the existing bulk supply system should be upgraded to the capacity of the source. This will ensure adequate water supply until 2007. Further groundwater investigations should be undertaken at the same time in order to identify alternative groundwater sources. Investigations

should include studies and exploration drilling. (**NLM to appoint a specialised consultant, but DWAF can assist with advice).**

- It should be noted that at a capital cost exceeding R10 million the proposed scheme based on the Fishkraal coastal aquifer is already relatively expensive. Owing to the shortage of water sources with acceptable water quality standards in the area, the alternatives to that scheme, which include the utilization of inland surface water, or groundwater, are expected to be prohibitively expensive.

6.1.3 Cannon Rocks/Boknes

- Although the existing Cannon Rocks water source (boreholes) is theoretically adequate to meet the projected water requirements of Cannon Rocks and Boknes until 2005, the water is of poor quality and the pattern of demand makes supply during the peak holiday season very expensive and unreliable. The water source needs to be augmented urgently.
- Additional storage capacity will be required within the bulk supply system to meet the growing peak requirements **(NLM).**
- The coastal aquifer at the Apies River has sufficient supplementary yield of acceptable quality to meet the projected future requirements at least until 2025. Subject to the approval of the EIA report, this source should be developed at an estimated cost of R5,6 million. (**NLM, but DWAF can be approached for advice).**
- The NLM should follow up with the DEAT with regards to the application for the development of the Apies River coastal aquifer submitted earlier.
- If the Apies River development is not acceptable, further investigations should be undertaken in order to identify alternative groundwater sources. Investigations should include studies and exploration drilling (**NLM to appoint a specialised consultant, but DWAF can be approached for advice)**.
- As it is unlikely that groundwater with acceptable quality standards will be identified in this coastal area, the use of brackish groundwater in combination with reverse osmosis desalination facilities could be considered as an alternative to the proposed Apies River coastal aquifer development. (**NLM to appoint a specialised consultant, but DWAF can be approached for advice).**

6.1.4 Kenton on Sea and Boesmansriviermond

- The existing water sources (Diaz Cross aquifer and a sea water desalination plant) are unable to meet the present water requirements even during low consumption periods. The system is severely stressed during peak periods. Water restrictions and even water outages are common. Urgent measures for the augmentation of the water source need to be taken.
- The water of the coastal aquifer sources (Diaz Cross and Kwaaihoek) is saline, but when mixed with desalinated water, the product is of an acceptable quality.
- The coastal aquifer at Kwaaihoek with a yield of 0.11 million m^3/a can be developed reasonably quickly as the existing bulk supply system from Diaz Cross has sufficient capacity to convey the additional flows. The development of this source at an

estimated cost of R800 000 will bring some relief to the water supply situation, but the total yield of all sources will still be insufficient to meet the present water requirements.

- The Albany Coast Water Board (ACWB) on behalf of NLM should immediately appoint a consultant to prepare and submit an EIA and scoping report for the development of this source for approval by DEAT.
- If approval is granted, the source should be developed urgently as a fast track project (**ACWB and NLM, but DWAF will support with advice).**
- Concurrently with the above, the ACWB should follow up with the DEAT on the application submitted earlier regarding the proposed upgrading of the RO plant.
- If the upgrading is approved, the proposed upgrading of the RO plant should be implemented urgently as a fast track project at an estimated cost of R6.0 million. This will increase the combined capacity of the water sources by 0.3 million m^3/a. The combined available yield will then be sufficient until 2006. (**ACWB and NLM, funding from the MIG as budgeted for in the WSDP).**
- The ACWB should immediately appoint a consultant to prepare and submit an EIA and scoping report for the development of the proposed Merville and Bushfontein groundwater sources and the associated bulk supply conveyance systems**.**
- Concurrently, a geohydrological consultant should be appointed to evaluate the potential for development of the rest of the Witpoort formation to the south east of Merville. The study should include exploration drilling and testing. **(ACWB and NLM, but DWAF can be approached for advice).**
- Once the extent of the possible future development of the overall Witpoort formation is established and DEAT approval is received, the Merville groundwater source (yield 0.29 million m^3/a) should be developed and the bulk conveyance system between Merville and Kenton on Sea should be optimised and constructed as a fast track project. The capital cost of this development is estimated at R12 million. If this source is developed the total combined yield of all sources will be sufficient until about 2010. (**ACWB and NLM, funding from the MIG).**
- The development of the Bushfontein groundwater source (yield 0.29 million m^3/a) and/or other groundwater sources, which may be identified within the Witpoort aquifer, together with the associated conveyance system should follow when required for further augmentation of the source. The incremental cost for the development of the Bushfontein source is estimated at R9 million. If this source is developed the total combined yield of all sources will be sufficient until about 2015. (**ACWB and NLM, possible funding from the MIG, DWAF can assist with advice).**
- At that later stage, the water supply situation will have to be reviewed through additional studies, which need to identify the best further development options to follow. **(NLM, but DWAF can be approached to provide assistance in terms of management and funding for the study)**. At least the following options should be considered:
    - Construction of an additional RO plant sourced by sea water, or brackish water, including a possibility to recharge the coastal aquifer with effluent (subject to confirmation of the availability of a brackish water source with the

required capacity, acceptable environmental impact, and if the water quality problems associated with the creation of a closed loop can be resolved).

- Development of a regional surface water scheme, which would include the supply to Port Alfred. Such a regional scheme is discussed in the following section.

6.1.5 Port Alfred and Regional Schemes

- At present the existing water sources (Sarel Hayward Dam and boreholes) are sufficient. However, substantial proposed new housing developments will most likely necessitate the urgent upgrading of the source before 2006.
- The water quality of the existing sources is below the acceptable standard.
- The internal reticulation system and balancing storage reservoirs do not have sufficient capacity to meet the peak seasonal requirements and urgent upgrading is required **(NLM, MIG funding).**
- Additional groundwater sources with anticipated acceptable water quality and a total yield of 0.64 million m^3/a have been identified to the west of the town in the areas of Glendower and Sunshine Coast. With the development of these sources the water requirements will be met until about 2007, which will provide much needed relief to the present water supply situation and will allow time for further investigations to identify the best augmentation option to follow.
- The NLM should immediately appoint a consultant to prepare and submit an EIA and scoping report for the development of this source for approval by DEAT.
- If approval is granted, the source and the associated conveyance system should be developed urgently as a fast track project at an estimated cost of R 8,0 million **(NLM, but DWAF can assist with advice).**
- A more detailed study should urgently be commissioned in order to assess the feasibility of a possible regional scheme (inter-basin transfer, or joint inter-municipal water supply scheme) to supply Port Alfred and to other towns in the area. Such scheme should be implemented before 2008 at an estimated cost varying between R47 million and R92 million depending on the option selected. **The study can possibly be funded and managed by the DWAF, but the NLM should formally request the Regional Office of the Department for assistance).**

The study should include the following components and activities:

Engineering aspects:

- Overall study management and co-ordination of the multidisciplinary team
- Review of water requirements and water resources
- Review and identification of competitive options. Consider supply from: groundwater, raising of the Sarel Hayward Dam, Glen Melville Dam, Settlers Dam, desalination of sea or brackish water, etc.
- Site investigations and surveys: geotechnical, land surveys, etc as required

- Engineering sizing and costing based on preliminary designs and site specific information
- Economic models and evaluation
- Implementation strategy, including programmes and funding sources

Hydrogeological aspects:

- Undertake further hydro-census and field investigations into the potential for development of groundwater sources for the supply of Port Alfred, Bathurst, Kleinemonde and Kenton on Sea.
- Undertake exploration drilling and testing in order to determine the parameters of each identified source

Ecological aspects:

- Undertake site surveys and acquire necessary field information
- Determine the Ecological Reserve at specific surface water development sites
- Produce EIA and scoping reports for approval by the DEAT for the selected development options
- Public participation and shareholder involvement

It is anticipated that such study can be completed in 18 months at an estimated cost of about R3,0 million.

- A decision on the implementation of further augmentation options should be taken on completion of the afore-mentioned study. **A number of institutions should be party to such a decision, e.g. DWAF, Cacadu DM, NLM, Makana DM, DEAT, etc.**

6.1.6 Bathurst

- The existing water source (Golden Ridge Dam) has sufficient yield to meet the present water requirements until about 2006. However, if the old town is provided with water services, the water source will have to be upgraded. Also an Ecological Reserve determination should be carried out to verify the yield of the Golden Ridge Dam. This should be included in the scope of services for the study referred to in the previous section.
- The water quality of the existing sources is below the acceptable standard.
- The capacity of the existing water treatment works is insufficient and needs to be upgraded urgently as a fast track project **(NLM, MIG funding).**
- The augmentation of the existing water source can be done through one of two options:
    - Supply from a possible regional scheme, which is developed to supply Port Alfred, if the bulk supply system runs near Bathurst. Clarity on this longer term option will be available on completion of the study referred to in the previous section.
    - If augmentation is urgent, local groundwater sources should be sited and developed **(NLM, but DWAF can assist with advice)**.

6.1.7 Kleinemonde / Seafield

- The existing water sources (Mount Wellington Dam and boreholes) have sufficient capacity to meet the present water requirements during normal periods, but not during peak season. Normal requirements can be supplied until about 2015.
- The water quality of the existing sources is below the acceptable standard.
- The capacity of the existing water treatment works is insufficient and needs to be upgraded urgently as a fast track project **(NLM, MIG funding).**
- The capacity of the existing storage reservoirs should be increased in order to provide for peak requirements **(NLM, MIG funding).**
- The NLM should appoint a consultant to verify the yield of the Mount Wellington Dam **(NLM, DWAF can be approached for technical assistance).**
- The augmentation of the available water source could be done through the development of additional groundwater sources. The NLM should appoint a specialised consultant to identify potential drilling sites. **(NLM, but DWAF can assist with advice).**

6.2 IMPLEMENTATION STRATEGY

- NLM is the institution responsible for the implementation of the actions recommended in this report.
- NLM should draw up an implementation strategy for the actions recommended in this report, taking into account the water supply situation in each town, the availability of funds and resources within the municipality and the timing for implementation.
- NLM can appoint a consultant, familiar with the water infrastructure and the water resources in the area, to assists with the compilation of such strategy.
- In the implementation strategy, NLM should make provision for water demand and water loss management project in the affected towns.
- On the basis of the implementation strategy, NLM should seek assistance and support (financial, advisory, etc.) form the Cacadu District Municipality and other institutions and authorities. DWAF should also be approached to discuss the details of the advisory assistance that can be provided.
- NLM should not allow new substantial developments before solutions to the severe water supply problems can be found and implemented.

DEPARTMENT OF WATER AFFAIRS & FORESTRY

DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

ALBANY COAST SITUATION ASSESSMENT STUDY

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LIST OF ACRONYMS

10^6 m^3/a	million cubic metre per year
AADD	average annual daily demand
AEMC	attainable ecological management class
BH	borehole
BPT	break pressure tank
CLRM	clean water raising main
CSIR	Council for Scientific and Industrial Research
CWGM	clean water gravity main
CWPS	clean water pump station
DEAT	Department of Environmental Affairs and Tourism
DEMC	default ecological management class
DESC	default ecological sensitivity class
DM	District Municipality
DSL	dead storage level
DWAF	Department of Water Affairs and Forestry
EIA	Environmental impact assessment
EISC	ecological importance sensitivity class
ELSU	equivalent large stock units
ERR	ecological reserve requirements
GAADD	gross average annual daily demand
GW	groundwater
hr	hour
IAP	invasive alien plants
m^3/d	cubic metre per day
m^3/h	cubic metre per hour
km	kilometre
l/c/d	litre per capita per day
l/day	litre per day
LFw	water treatment loss
LFr	conveyance loss
LM	Local municipality
l/s	litre per second
MAE	mean annual evaporation
mamsl	metres above mean sea level

MAP	mean annual precipitation
MAR	mean annual runoff
mg/l	milligram per litre
MIG	Municipal Infrastructure Grant
m^3/a	cubic metre per year
m^3/d	cubic metre per day
m^3/h	cubic metre per hour
ND	nominal diameter
NDS	National Demographic Study / Schlemmer *et al*, 2001
NGL	natural ground level
No	number
PE	polyethylene
PESC	present ecological status class
ppm	parts per million
Res	reservoir
RO	reverse osmosis
RWGM	raw water gravity main
RWPS	raw water pump station
RWRM	raw water raising main
SDDpl	summer daily demand (for bulk pipelines and pump
SDDpu	summer daily demand (for boreholes and BH pump
SDDww	summer daily demand (for water treatment works)
SPF	summer peak factor
TDS	total dissolved salts
WR90	Surface Water Resources of South Africa, Water Research Commission, 1990
WRYM	Water Resources Yield Model
WTW	water treatment works

1. INTRODUCTION

In October 2003 the Directorate: National Water Resource Planning of the Department of Water Affairs and Forestry (DWAF) commissioned a study titled: "Albany Coast Situation Assessment". UWP Consulting was appointed as the lead consultant, in association with DMM Development Consultants (DMM) and Water System Management (WSM).

The study area, known as the Albany Coast, covers about 5 300 km^2 of land and is situated within the drainage region P. It is located between the catchments of the Great Fish River, the Sundays River and the Indian Ocean, in the south-western part of the Eastern Cape. The study area falls under the jurisdiction of the Cacadu District Municipality and includes portions of four Local Municipalities – Ndlambe, Sunday's River Valley, Blue Crane and Makana (see **Figure 1.1**)

A number of coastal and inland towns situated within the coastal belt of the study area experience serious periodic water supply problems, mainly because of inadequate sources, poor water quality and insufficient capacity of their bulk supply infrastructure. These towns are Port Alfred, Bathurst, Kleinemonde, Kenton on Sea, Boesmansriviermond, Boknes, Cannon Rocks and Alexandria, all situated within the Ndlambe Local Municipality.

The purpose of the study is to investigate at a reconnaissance level the water supply problems of the area, with a specific reference to the afore-mentioned towns, through a broad review of existing information, and to consider possible solutions that may present themselves for ready implementation.

Although the primary focus of the study would be to resolve the water supply problems for the specified towns (urban sector), when investigating the availability of water resources, due consideration has been given to meeting the legitimate water requirements of all other users in the catchment, including rural domestic, agricultural, afforestation, ecological Reserve, etc. For this reason, a water balance for the entire catchment has been compiled.

The study therefore comprises two main components, both undertaken at reconnaissance level of detail:

- Water resources situation assessment for the entire drainage region P
- Development options study for the augmentation of the water supply to the coastal towns

The Terms of Reference for the study is attached in **Appendix 2**. The set of study reports include this main report, as well as three supporting reports namely the Surface Water Resources, Groundwater Resources and Water Quality supporting reports.

This report is structured in the following manner.

An overview of the physical characteristics of the study area is covered in **Section 2** of the report. This includes location boundaries, topography, rivers, drainage regions, climate, geology and soils, natural vegetation cover, ecological sensitivity, and cultural or historical heritage sites.

Section 3 covers the demography and development status and includes current and future land-use, industrial, general and water related development.

Section 4 provides an estimate of the present and future water requirements for all user sectors in the study area, projected until the year 2025.

The water supply situation at each of the affected towns is described in **Section 5**.

Section 6 provides an overview of the existing major water related infrastructure.

An overview of the available water resources (surface and groundwater) is offered in **Section 7**.

A number of development options are presented in **Section 8** including the factors that could affect the feasibility thereof.

Section 9 includes the conclusions and recommendations of this study.

2. BASE INFORMATION

2.1 OVERVIEW OF THE STUDY AREA

The Albany Coast (study area) is located along the coast of the Eastern Cape Province, midway between Port Elizabeth and East London, extends about 70 km inland and covers an area of about 5 300 km^2. From a hydrological perspective the area covers primary drainage region P, which is sub-divided into 4 tertiary and 16 quaternary catchments. Refer to **Figure 1.1** for the locality and overview of the study area.

The area falls under the jurisdiction of the Cacadu District Municipality and includes portions of four Local Municipalities – Blue Crane in the north-west, Makana in the north, Sunday's River Valley in the south-west and Ndlambe in the south-east.

The study area includes a number of formal urban towns, but has no metropolitan centres. The biggest towns are Grahamstown and Port Alfred. Most of the rural population is scattered and consists of farm labour living on private farmland. The following smaller towns are included in the area: Riebeeck East, Bathurst, Kenton on Sea, Boesmansriviermond, Alexandria, Alicedale, Paterson, Boknes, Cannon Rocks and Kleinemonde. Port Elizabeth, part of the Nelson Mandela Metropolitan Municipality, is the nearest metropolitan area and is situated approximately 100 km south-west of Grahamstown.

The study area includes 120 km of coastline with six of the urban towns situated along the coast. The region can be accessed from King William's Town on the N2 south, or from Port Elizabeth on the N2 north. Alternative smaller routes are the R67 south from Fort Beaufort and the R72 west from East London.

2.2 TOPOGRAPHY RIVERS AND DRAINAGE REGIONS

The ground elevation within the study area rises from the coastline to a maximum of 935 m above mean sea level (amsl) in the north-western corner near Riebeeck East (**Figure 2.1**). The topography around the coast is mainly flat, while it becomes steep and mountainous towards Grahamstown, Alicedale and Riebeeck East. North of Alicedale, around Riebeeck East, lays the Swartwaters Mountain with elevations between 700 m and 1000 m amsl. The area is deeply incised by the river valleys.

The study area is situated between the catchments of the Great Fish River, the Sundays River, and the Indian Ocean. The area is drained by three main rivers – the Kowie (P40), the Kariega (P30) and the Lower Bushmans (P10) **(Figure 3.1)**. All three rivers are perennial and flow in the south-easterly direction from the mountainous inland towards the Indian Ocean. A number of smaller coastal rivers are located in quaternary catchments P20A, P20B and P40D. The area is divided into 4 tertiary and 16 quaternary catchments **(Figure 3.2)**.

Water quality of these rivers is generally poor owing to the geology of the catchments. Highly saline base flow causes high levels of total dissolved salts (TDS) with both the Bushmans and Kariega Rivers classified as "Completely Unacceptable Water Quality" according to the Mineralogical Classification by the DWAF. The TDS of the Bushmans and Kariega Rivers is greater than 3 400 parts per million (ppm), while the water quality of the Kowie River is classified as "Poor" with TDS in the region of 1 801 – 3 400 ppm.

Figure 3.1 illustrates the river catchments within the study area. **Table 2.2.1** offers a summary of the characteristics of the main rivers.

Table 2.2.1: Characteristics of the main rivers within the study area

River	**Quaternary Catchment**	**Catchment Area (km^2)**	**Virgin MAR ($10^6 m^3/a$)**
Bushmans River	P10A to G	2 757	57.94
Kariega River	P30A to C	647	20.25
Kowie River	P40A to C	918	35.93
Coastal Rivers	P20A & B, P40D	1 000	58.93
TOTAL		**5 322**	**173.05**

The runoff is regulated by a number of small and medium sized dams used predominantly for water supply to the local population and for irrigation. The following main dams are located in the study area.

Dam	**Quaternary Catchments**	**Wall Height (m)**	**Max Capacity (x 10^3 m^3)**	**Use**
New Year's	P10B	22	4 700	Domestic Supply
Howiesonspoort	P30B	24	883	Domestic Supply & Irrigation
Settlers	P30B	21	5 620	Domestic Supply & Irrigation
Golden Ridge	P40B	13	400	Domestic Supply
Sarel Hayward	P40C	40	2 522	Domestic Supply
Mansfield	P40C	14	165	Domestic Supply
Mount Wellington	P40D	10	250	Farm dam

In addition, 48 registered dams have been built in the area. More information about these dams is provided in **Section 6** and in **Appendix 5**. The position of these dams is shown on **Figure 3.2**.

2.3 CLIMATE, RAINFALL AND EVAPORATION

The climate along the coast is warm to hot throughout the year, with humidity levels rising from December to March. The inland climate is more temperate with warm summers and cool winters. Frost occurs in the inland areas in winter, typically over the period from mid-May to late August. Maximum temperatures are experienced in January and minimum temperatures usually occur in July. Coastal winds are common throughout the year with sea temperatures moderate.

The annual precipitation for the entire region is moderate, while higher annual rainfall values are associated with the coastline. Peak rainfall months are December and January. Annual rainfall values decrease gradually toward the interior. The study area falls within three rainfall zones, P1A, P1B and P4A, as defined by WR90. The mean annual precipitation (MAP) for the quaternary catchments within the study area varies between 386 mm and 715 mm as illustrated in **Figure 4.1** and **Table 2.3.1**. The greatest portion of the study area has a MAP of 400 mm to 500 mm, while the lowest MAP occurs towards the north-west interior – 300 mm to 400 mm. The relative humidity is higher in summer than in winter, generally highest in February and lowest in July. During summer periods the daily mean relative humidity is in the order of 80% and during the winter months the daily mean relative humidity is in the order of 70%.

The mean annual evaporation (MAE) for the region (S-pan equivalent) varies between 1450 and 1650 mm. The entire drainage region falls under evaporation zone 26A. **Figure 4.2** illustrates the mean annual evaporation for the study area and **Table 2.3.1** offers a summary of the mean annual evaporation per quaternary catchment.

Table 2.3.1: Mean Annual Precipitation and Evaporation (S-pan)

Quaternary catchment	Area (km^2)	Rainfall Zone	MAP (mm)	MAE (mm)
P10A	126	P1A	600	1 550
P10B	508		531	1 550
P10C	281		386	1 650
P10D	564		432	1 600
P10E	466	P1B	493	1 550
P10F	469		557	1 550
P10G	343		550	1 500
P20A	422		715	1 500
P20B	332		635	1 550
P30A	176	P4A	623	1 550
P30B	403		559	1 500
P30C	68		536	1 500
P40A	312		635	1 500
P40B	264		570	1 500
P40C	342		616	1 450
P40D	246		666	1 450

2.4 GEOLOGY AND SOILS

Figure 5.1 illustrates the geological zones for the study area, i.e. three different types. Compact, dominantly argillaceous strata (Cape Supergroup) covers the greatest portion of the northern, central, eastern and southern parts of the drainage region P. Part of the P10C quaternary catchment consists of mainly compact tillite, shale and sandstone from the Dwyka formation and Ecca Group. The coastal stretch west of Port Alfred and the south-western portion up to Paterson are underlain predominantly by compact sedimentary strata.

The study area consists of mainly one type of soil, viz. clay loam (illustrated in **Figure 6.1**). This clay loam varies in relief and forms two different categories: flat and undulating. The northern portion consists of moderate to deep clay loam with a flat relief and stretches as far south as Paterson. The area further south of Paterson consists of moderate to deep clay loam with an undulating relief type of soil.

2.5 NATURAL VEGETATION COVER

The major types of vegetation in the study area are Coastal Tropical Forest, False Karoo, False Schlerophyllous Bush, and Karoo and Karroid Types as shown on **Figure 7.1**.

Coastal Tropical Forest

Coastal Tropical Forest type of vegetation is widely spread throughout the study area and crops up as far north as Paterson. This veld type is typically confined to the coastal area or immediate vicinity, and includes areas of forest, thornveld and bushveld. There is considerable turnover in species composition between forest patches and therefore different forest patches typically comprise different species compositions. Rainfall is typically higher than that for Temperate and Transitional Forest and Scrub. Coastal Tropical Forest occurs at any altitude from sea level to 450 m amsl. This veld type exhibits a long history of anthropogenic effects, especially grazing by livestock.

False Karoo Types

This is a less dominant veld type within this study area, occurring towards the northern and north-western parts, excluding the area surrounding Riebeeck East. Similar to Karoo and Karroid veld type, the False Karoo veld type is typified by low vegetation, but in contrast contains more grassy elements. The areas occupied by this veld type are typically very arid and in parts may receive less than 100 mm of rainfall per annum. This veld type generally occurs below 1200 m amsl.

False Sclerophyllous Bush Types

This veld type occurs in certain areas towards the central and northern parts of the study area. It forms a band about 5 km wide and stretches from Alicedale towards the east of Grahamstown, as well as the area surrounding Riebeeck East. False Schlerophyllous Bush is typically indistinguishable from true Fynbos. It is usually dominated by Asterocous elements (daisies). As for Sclerophyllous Bush, the areas occupied by the False Sclerophyllous Bush veld type are typically fairly mosaic, receiving in excess of 500 mm of rainfall per annum.

Karoo and Karroid Types

This veld type occurs in patches widely spread over the entire study area, except along the coast and the far northern areas. The flora is characteristically low, typically less than 1 m in height, and includes scrubs, bushes, dwarf trees and a few grasses. Rainfall within this vegetation type typically ranges between 150 mm and 500 mm per annum, but reaches a maximum of up to 900 mm per annum in some of the river valleys. Karoo and Karroid Types occur at any altitude from sea level to 1700 m amsl.

2.6 ECOLOGICAL SENSITIVITY, RIVER CLASSIFICATION & NATURE RESERVES

Ecological Sensitivity

The conservation of living resources is essential for sustaining development by maintaining the essential ecological process and life support systems, preserving genetic diversity and ensuring that utilisation of species and ecosystems is sustainable. However, for conservation to succeed it should be underpinned by two basis principles, namely the need to plan resource management (including exploration) on the basis of an accurate inventory and the need to implement proactive protective measures to ensure that resources do not become exhausted. Accordingly, a vital component of ensuring sustainable conservation practices is the identification of conservation worthy habitats or sensitive ecosystems.

In terms of section 2(1) of the Environment Conservation Act (No. 73 of 1989), South Africa’s schedule of protected areas was published in the Government Gazette 15726 in May 1994 (Notice 449 of 1994). This classification identifies the following sensitive or protected areas: Scientific and Wilderness Areas, National Parks and Equivalent Reserves, National Monuments and areas of Cultural Significance, Habitat and Wildlife Management Areas and Protected Land/Seascapes, based on their location and the functions they fulfil.

South Africa has also recognised the importance of its wetlands as sensitive ecosystems that require conservation, and accordingly has become a signatory to the international Conservation on Wetlands of International Importance especially as Waterfowl Habitat or RAMSAR Convention. In terms of this convention signatories undertake to include wetland conservation considerations in their national land-use planning, and as far as possible to ensure the wise use of wetlands within their territory.

It would be prudent to give some consideration to the definition of aquatic ecosystems, especially with respect to the National Water Act (No. 36 of 1998). In general terms, an ecosystem may be defined as a community of organisms and their physical environment interacting as an ecological unit. Hence, aquatic ecosystems encompass the aquatic community and water resources necessary to sustain its ecological integrity. Within the National Water Act, the water resource requirements of aquatic ecosystems are recognised and protected by the introduction of the concept of an ecological reserve viz. the water required to protect the aquatic ecosystem of the water resources. The Reserve refers to both the quantity and quality of the resource. Accordingly, development must take cognisance not only of the sensitivity of the receiving ecosystem but also of the resource requirements or ecological reserve of the aquatic communities it supports.

2.6.1 River Classifications

The water resources of South Africa are protected in terms of the National Water Act (No. 36 of 1998). The protection of the river system can be achieved by maintaining riverine flows, which are not lower than the Ecological Reserve.

In order to determine the Ecological Reserve, the river reaches have to be classified in terms of their future attainable ecological management class (AEMC). The classification of the river reaches has been done at the bottom of each quaternary catchment in the study area as part of the Water Resources Situation Assessment of the Fish to Tsitsikamma Water Management Area carried out by Ninham Shand in 2002.

The classification has been undertaken on the basis of the methodology described by Kleynhans in 1999 in a report titled “Procedure for the determination of the ecological reserve for the purpose of the National Water Balance Model for South African Rivers, DWAF”.

During a number of workshops in 2000 the main stems of the rivers within the quaternary catchments have been classified in the following management classes:

- **Ecological Importance and Sensitivity Class (EISC):** The ecological importance of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and broader scales. Ecological sensitivity (or fragility) refers to the system’s ability to resist disturbance and its resilience or capacity to recover from a disturbance that has occurred. This class can range as follows: very high, high, moderate or low margined.

- **Present Ecological Status Class (PESC):** This classification indicates the degree to which present conditions of an area have been modified from natural (undeveloped) conditions. Factors that are considered in the classification include the extent of flow modification, inundation, water quality, stream-bed condition, riparian condition and proportion of exotic biota. Values range from Class A (largely natural) to Class F (critically modified).

- **Default Ecological Management Class (DEMC):** A class indicating the ecological importance and sensitivity of an area, as it is likely to have been under natural (undeveloped) conditions, and the risk of disturbance that should be tolerated. Values range from class A (highly sensitive, no risk allowed) to Class D (resilient systems, large risk allowed).

- **Attainable Ecological Management Class (AEMC):** A class indicating the potential to improve the ecological conditions and can be determined by comparing the difference between the present ecological status class and the default ecological status. Values range from class A (unmodified natural) to Class F (critically modified).

- **Default Ecological Sensitivity Class (DESC):** The DEMC relates to a default ecological status class that is assigned to a resource (i.e. river or river reach) depending on the level of ecological importance and sensitivity.

On the basis of similarity of environmental characteristics the quaternary catchments in drainage region P were sub divided into 3 groups.

Group 1	P10A, P10B, P10C, P10D, P30A, P40A
Group 2	P10E, P10F, P10G, P20A, P20B
Group 3	P30B, P40B, P40C, P40D

The ecological management classes determined during the workshops were as shown in the table below.

Table 2.6.1.1: Ecological Management Classification

Quaternary	EISC	DEMC	PESC	AEMC
Group 1	High	Class B	Class C	Class C
Group 2	Moderate	Class C	Class D	Class D
Group 3	High	Class B	Class C	Class C

The water resources situation assessment has been performed at the quaternary catchments scale of resolution. However, the delineation of these quaternary catchments was not based on ecological principles. In order to provide some ecological basis for the estimates of water requirements to maintain a particular class of river it was decided to base estimates of water requirements on an index of the ecological importance and sensitivity class (EISC) of the rivers in the quaternary catchments of concern. The ecological importance and sensitivity class of the rivers was used to derive the default ecological management class (DEMC), which relates to a default ecological status class (DESC). The default ecological status class and the present ecological status class (PESC) have been used to arrive at a suggested future ecological management class (AEMC) to be considered for the water resources. The default ecological status class would normally be assigned to a water resource on the basis of ecological sensitivity and importance. This methodology is based on the assumption that the ecological importance and sensitivity of a river would generally be closely associated with its default ecological management class and that its current ecological status and potential to recover from past ecological damage will determine the possibility of restoring it to a particular ecological management class.

2.6.2 Sensitivity of Aquatic Ecosystems

Sensitive Aquatic ecosystems refer to those ecosystems that are sensitive with respect to possible changes in water quantity and quality. The river reaches in the P10A-D, P30A, P30B and P40A-D quaternary catchments have a default ecological management class (DEMC) of Class A or B and occur in the conservation areas. Any future human manipulation of these reaches would require very strong motivation. The remaining river reaches in the study area have become modified to various degrees and are classified with an ecological importance and sensitivity class (EISC) of “moderate” to “low”. The present ecological status classes (PESC) are derived from the EISCs and DEMCs and are used to determine the ecological flow requirements of the river reaches.

2.6.3 Other Protected Areas

The study area contains protected areas that may be impacted directly or indirectly upon by development activities associated with water resources. These protected areas include National Heritage Sites, Scientific and Wilderness Areas, National Parks and Equivalent Reserves, National Monuments and Areas of Cultural Significance, Habitat and Wildlife Management Areas and Protected Land/Seascapes. All water resource development and utilisation should take cognisance of these sites and it is the developer's responsibility to identify the exact proximity of activities to any of these sites, and to ensure that activities do not threaten the integrity of these sites. This consideration is particularly pertinent where water resource development activities impact on the supply of water resources to these areas and hence their long-term ecological sustainability.

Table 2.6.3.1 shows the protected areas within the drainage region P.

Table 2.6.3.1: Protected Natural Areas and National Heritage Sites

Quaternary	Area Name	Category
P10E	Tootabi	National Parks and Equivalent Reserves
P20A	Woody Cape Nature Reserve	Habitat and Wildlife Management Area
P20B	Woody Cape West Nature Reserve	Habitat and Wildlife Management Area
P30A	Thomas Baines Nature Reserve	Habitat and Wildlife Management Area
P40A	Beggar's Bush	National Parks and Equivalent Reserves
P40B	Waters Meeting II Nature Reserve	Habitat and Wildlife Management Area
P40C	Barville Park	South African Natural Heritage Site
P40C	Elmhurst	South African Natural Heritage Site
P40C	Glendower	South African Natural Heritage Site
P40C	Kasouga Farm	South African Natural Heritage Site
P40C	Sunshine Coast Nature Reserve -West	Habitat and Wildlife Management Area
P40C	Waters Meeting I Nature Reserve	Habitat and Wildlife Management Area
P40D	Sunshine Coast Nature Reserve -East	Habitat and Wildlife Management Area

Figure 9.1 illustrates the location and boundary of each of the abovementioned areas.

2.7 CULTURAL AND HISTORICAL HERITAGE SITES

Development of water supplies and services can have a negative impact on the archaeological and cultural heritage by way of development of dams, pipelines, canals, water services infrastructure and enterprises following on the provisions of water.

The National Monuments Act (No. 28 of 1969) provides for the protection and conservation of cultural resources including all archaeological sites. In addition, the Environment Conservation Act (No. 73 of 1989) provides for the integration of cultural resources into environmental management processes.

Any given development may have an impact on archaeological or cultural heritage sites. It is essential therefore that the potential impact of any water supply and services related development should be assessed at the earliest possible phase of project planning.

Permission for the development to proceed is granted by the National Monuments Council once it is satisfied that steps have been taken to safeguard archaeological or cultural heritage sites, or that they have been adequately recorded and/or sampled.

The purpose of this section is to highlight the need to take cognisance of any cultural or historical sites that may be present within the study area and accordingly could influence the further development and utilisation of water resources within this area. Cultural and historical sites can be broadly defined as natural or manmade areas that are associated with human activity and history, and which carry social, cultural, religious, spiritual or historic significance. Furthermore, sites of palaeontological significance contain fossilised human or animal remains. The National Heritage Resources Act (No. 25 of 1999) provides automatic protection for palaeontological, archaeological and historical sites and materials older than 60 years, and a permit is required before any alterations can be made to such artefacts.

No general listing of the sites of palaeontological, archaeological and historical significance within the study area is available.

3. DEVELOPMENT STATUS

3.1 DEMOGRAPHY

3.1.1 Base year population numbers

The results from the most recent Census 2001 were published in January 2004. These results compare favourably with other available population data from the following studies: National Demographic Study (Schlemmer *et al*, 2001), Water Services Development Plans, Water Resources Situation Assessment: Fish to Tsitsikamma WMA (Ninham Shand, 2002). After consideration of the other available data sets, it was decided that the data from Census 2001, where available, should be used as an estimate of the base year population numbers for this study.

The present (base year 2001) population size within the study area is estimated at about 139 000 people. About 119 000 live in urban areas, and about 20 000 in rural areas. The distribution of the base year population per quaternary catchment is shown in **Table 3.1.1A**. More detailed information is available in **Appendix 3**.

Table 3.1.1A: Population size per quaternary catchment in 2001

Quaternary	Town	Population in 2001		
		Urban	Rural	Total
P10A		0	363	363
P10B	Riebeeck East	689	1 452	2 141
P10C		0	310	310
P10D	Alicedale *	5 950	977	6 927
P10E	Paterson	4 404	1 328	5 732
P10F		0	1 344	1 344
P10G	Kenton on Sea, Bushmans, Marselle	9 480	2 488	11 968
P20A	Alexandria, Cannon Rocks, Boknes	8 646	3 242	11 888
P20B		0	894	894
P30A		0	484	484
P30B		0	1 575	1 575
P30C		0	328	328
P40A	Grahamstown	61 759	997	62 756
P40B		0	1 228	1 228
P40C	Port Alfred, Bathurst	26 514	1 511	28 025
P40D	Kleinemonde *	1 450	1 117	2 567
TOTAL FOR STUDY AREA		**118 892**	**19 638**	**138 530**

* Census 2001 does not provide an estimate for the population in the town of Alicedale. The estimate for the population in the town of Kleinemonde is unrealistically low. The data from the national demographic study was therefore used to patch the Census data in these instances.

The rural population, consisting mainly of farm labourers was estimated *pro rata* to the enumerator area falling within the relevant quaternary catchment boundaries.

The estimated population numbers per urban centre are shown in the table below.

Table 3.1.1B: Population numbers in urban centres in 2001

Quaternary	Town	Urban Population
P10B	Riebeeck East	689
P10D	Alicedale	5 950
P10E	Paterson	4 404
P10G	Kenton on Sea/Ekuphuleni	4 781
	Marselle/Boesmansriviermond	4 699
P20A	Alexandria	7 715
	Boknes	466
	Cannon Rocks	465
P40A	Grahamstown	61 759
P40C	Port Alfred	20 965
	Bathurst	5 549
P40D	Kleinemonde	1 450
TOTAL URBAN POPULATION		**118 892**

3.1.2 Population growth rates

A national demographic study (Schlemmer *et al*, 2001) to develop water-use projections to the year 2025 was commissioned by the Department of Water Affairs and Forestry in order to support the development of the National Water Resources Strategy. This study included the development of a baseline 1995 population estimate, which was reconciled with the data from Census 1996. The study also included the development of population growth projections until year 2025, which where specific for each enumerator area.

Owing to the absence of more accurate information, the recommended population growth rates by the national demographic study were used in this study. In general, it is expected that until year 2025 the urban population in the coastal belt of the study area will grow at rates varying between 2.3% and 1.3% per annum. The population in the interior urban centres is expected to grow initially at rates around 0.5% per annum, but later during the period, to decline at rates of around –0.5% per annum. Rural population is expected to initially grow marginally at rates of about 0.3% per annum, but to decline at rates exceeding –0.8% per annum towards the end of the projection period. The projected population growth rates used for the purposes of this study are shown in **Appendix 3.3**.

As shown in the table below, certain significant housing developments are being planned and implemented in the coastal towns. It was considered that the additional population associated with these developments is not provided for in the standardised population growth rates. Therefore, provision for additional population numbers for the relevant towns has been made.

Overall, it is expected that the total population in the study area will grow from about 139 000 in 2001 to about 170 000 in 2025, resulting in an average growth rate of about 0.8% per annum.

Table 3.1.2: Planned housing developments

Town	Planned housing development, No of units		
	2001	2005	2015
Kenton on Sea/Ekuphuleni	100	400	
Marselle/Bushmans River		100	500
Alexandria		150	350
Boknes/Cannon Rocks	170	130	400
Port Alfred		3 000	2 000
Bathurst		400	

3.1.3 Projected population numbers

The projected population numbers per quaternary catchment of the study area are shown in the table below. More detail is available in **Appendix 3.3**.

Table 3.1.3: Projected population numbers per quaternary

Quaternary Sub-catchment	Projected population numbers			
	2001	**2005**	**2015**	**2025**
P10A	363	368	358	321
P10B	2 141	2 177	2 118	1 935
P10C	310	313	284	251
P10D	6 927	7 062	6 893	6 498
P10E	5 732	5 840	5 665	5 345
P10F	1 344	1 364	1 324	1 187
P10G	11 968	15 270	16 127	16 737
P20A	11 888	13 084	14 870	14 533
P20B	894	907	860	790
P30A	484	491	477	428
P30B	1 575	1 599	1 515	1 391
P30C	328	333	315	290
P40A	62 756	65 382	67 370	67 471
P40B	1 228	1 246	1 181	1 085
P40C	28 025	35 556	43 275	48 104
P40D	2 567	2 967	3 230	3 458
Urban	**118 592**	**134 029**	**146 855**	**152 499**
Rural	**19 638**	**19 930**	**19 006**	**17 324**
TOTAL	**138 530**	**153 959**	**165 861**	**169 882**

In 2001 a total number of about 139 000 people lived in the study area. About 119 000 (86%) resided in urban centres, while the remaining about 20 000 (14%) people lived in rural areas.

In 2025 the total population in the study area is expected to grow to about 170 000 people, which constitutes and average annual growth of about 0.8% per annum. The relatively high growth is associated with the increase of the urban population mainly in the costal towns and in Grahamstown. In 2025 the urban population is expected to be in the order of 152 000 people (90%) and the rural about 17 000 people (10%).

3.2 SOCIO-ECONOMIC DEVELOPMENT STATUS

3.2.1 Population Density

The highest population density occurs in the Makana Local Municipality, 34 people per km², with Grahamstown, Riebeeck East and Alicedale as the major urban areas within the Municipality. Ndlambe Local Municipality has the second highest population density with 32 people per km², the major urban areas are Port Alfred, Alexandria, Bathurst and Kenton on Sea. Blue Crane Municipality has the lowest population density with 0.6 persons per km². There are no urban areas within this district.

3.2.2 Age Distribution

57% of the total population falls between the age of 19 and 65 years, while 36% are younger than 19 years. The remaining 7% of the population are above the age of 65 years.

3.2.3 Education

61% of the total population are educated at a level of school certification of Grade 1 to 12, while 21% have no education at all. 3% have a certificate or diploma obtained from a grade-12 certification, while 2% are qualified with a degree. The remaining 13% do not apply; they are people not being able to be educated for some or other reason.

3.2.4 Income

More than half the population of the workforce (58%) have no form of financial income, while 39.4% earn a monthly income of less than R6 400. This is an indication of the poor socio-economic status of the permanent residents in the study area. This does not include the holidaymakers that only visit during peak seasons. Only 2.2% currently earn between R6 400 and R25 600 per month.

3.2.5 Employment Status

Only 34% of the population is permanently employed, this excludes the scholars/students that form 18% and pensioners that form 7%. Therefore the total percentage of the population that contributes to the GGP is only 34%, while the remaining 66% are scholars, pensioners or unemployed people.

3.2.6 Employment Sector

The total labour force contributing to the GGP can be divided into the following sectors:

- Agricultural: 13.8%
- Mining: 0.25%
- Manufacturing: 5.2%
- Municipal Services: 0.43%
- Construction: 6.84%
- Trade: 12.8%
- Transport: 2.1%
- Finance: 5.3%
- Government: 26.3%
- Other: 26.98

3.3 LAND-USE

3.3.1 Introduction

The land-use data shown in this section has been obtained from the Fish to Tsitsikamma Water Management Area Situation Assessment Study (DWAF, 2002). The information has been derived from the CSIR, 1999 land-use coverage, obtained by analysing satellite images. The table below summarises the land-use information per type of use and per quaternary catchment as at 1995.

Table 3.3.1: Summary land-use data (1995) (km²)

Quaternary Catchment	Total Area	Area Under Invasive Alien Plants	Area Under Afforestation	Nature Reserves & Natural Forests	Irrigation [1] (maximum)	Urban [3] Areas	Other [2]
P10A	126	5.27	2.14	0.00	0.44	0.00	118.37
P10B	508	4.51	0.00	0.00	1.65	0.72	501.94
P10C	281	0.00	0.00	0.00	0.94	0.00	280.53
P10D	564	0.26	0.00	0.00	1.87	0.30	562.50
P10E	466	0.78	0.00	3.29	1.53	0.44	460.72
P10F	469	11.20	0.00	0.00	1.53	0.00	457.03
P10G	343	0.41	0.00	0.00	1.09	0.35	341.69
P20A	422	51.10	0.00	156.45	0.00	1.44	213.01
P20B	332	57.19	0.00	45.20	0.00	0.00	229.61
P30A	176	22.12	3.40	9.46	1.05	0.00	140.49
P30B	403	5.49	0.00	0.00	2.37	0.00	396.32
P30C	68	0.38	0.00	0.00	0.40	0.08	67.34
P40A	312	40.11	0.75	0.00	0.12	11.86	259.22
P40B	264	5.62	0.00	0.00	0.06	0.26	258.09
P40C	342	10.98	0.00	63.80	0.12	7.71	259.45
P40D	246	13.51	0.00	0.00	0.06	1.30	231.16
TOTAL	**5 322**	**228.93**	**6.29**	**278.20**	**13.23**	**24.46**	**4 777.47**

Notes:

(1) The average area of land being irrigated during years with average rainfall is 6.65 km², while the maximum can be 13.2 km² when sufficient water is available.

(2) "Other" includes: rough grazing, dry land agriculture and water bodies. We were unable to obtain data to differentiate between these per quaternary catchment. However, for the entire drainage region P the area used for dry land agriculture is estimated to be 384 km², and the total area occupied by water bodies – about 8 km². The total area used for rough grazing is therefore estimated at 4 385 km².

(3) Urban areas derived from 1:50 000 maps, excluding small holdings and rural villages.

The predominant type of land-use within drainage region P in 1995 has been for rough grazing, about 4 400 km² (82%).

About 384 km² (7%) has been used for dry land agriculture. The area covered by nature reserves (including the indigenous forests) is 278 km² (5%). A significant portion of the land in drainage region P is infested by invasive alien plants – 229 km² (4.3%).

Figure 9.1 indicates the different coverage of land-use i.e. dry land agriculture, grassland, indigenous forests, afforestation, natural veld, nature reserves, water bodies and built-up areas.

3.3.2 Irrigated Areas

The maximum area covered under irrigation within the drainage region P is about 13.2 km² and is subdivided per quaternary catchment in **Table 3.3.1.** Land is irrigated from farm dams and run-of-river flow when sufficient water is available. The areas irrigated vary from year to year, depending on availability of water, with the average being about 6.6 km², distributed as shown in **Table 3.3.1**.

3.3.3 Dry land Agriculture

The area used for dry land agriculture is estimated at 384 km² or about 7% of the total catchment. Pineapples are grown on a large scale without irrigation along the coast (P20A, P20B, P30C, P40C and P40D). Chicory is also grown as a dry land crop along the coast, mainly in the P20A and P20B quaternary catchments as follows.

3.3.4 Afforestation

The main tree species grown is pine. The total area covered by commercial timber plantations is estimated at 6.29 km², extending over three quaternary catchments as follows:

- P10A with 2.14 km²
- P30A with 3.40 km²
- P40A with 0.75 km²

3.3.5 Invasive Alien Plants

The widespread infestation by invasive alien plants (IAP) and all its related problems are increasingly acknowledged throughout South Africa. This infestation, if not controlled, can result in the loss of much, or possibly even all, of the available water in certain catchment areas. The acacias, pines, eucalyptus, prosopis species and melia azedarachs are among the top ten IAP, which account for about 40% of the water use.

The estimated total area under IAP in the study area is about 229 km². This value is for condensed areas, which are equivalent areas that IAP would occupy if it were condensed to provide a completely closed canopy cover. The most severe infestation occurs along the coastal strip at Boesmansriviermond and Kenton on Sea.

3.3.6 Livestock

Equivalent Large Stock Units (ELSU) are used to measure the water requirements of livestock. Each ELSU is assumed to represent a water requirement of 45 l/day. For example, one ELSU is equivalent to 0.85 head of cattle, or 1 horse or donkey, or 6.5 sheep or goats, or 4 pigs. **Table 3.3.6A** shows the distribution of livestock located in the study area and the total number of ELSU. **Table 3.3.6B** specifies the conversion of mature livestock and game population to ELSU.

The numbers for livestock are approximate because the information was obtained from the 1994 livestock census that gives information in terms of magisterial districts and not hydrological catchments. These numbers have been converted to hydrological catchments by assuming the distribution of livestock to be proportional to land area. No information on numbers of game or ostriches could be obtained.

Table 3.3.6A: Livestock (No of heads)

Drainage Region	Cattle	Horses and Donkeys	Sheep	Goats	Pigs	ELSU
P	72 441	591	14 713	8 750	720	89 757

Table 3.3.6B: Livestock (No of heads)

Quaternary Catchments	ELSU	Quaternary Catchments	ELSU	Quaternary Catchments	ELSU
P10A	849	P10G	8 851	P40A	3 211
P10B	3 436	P20A	12 476	P40B	6 994
P10C	822	P20B	9 812	P40C	9 469
P10D	2 535	P30A	1 188	P40D	6 797
P10E	9 982	P30B	4 082		
P10F	7 392	P30C	1 861	**TOTAL**	**89 757**

Table 3.3.6C: Conversion of Mature Livestock and Game Populations to ELSU

Species	Number per ELSU
Cattle	0.85
Sheep	6.5
Goats	5.8
Horses	1
Donkeys / Mules	1.1
Pigs	4
Game:	
Black Wildebeest	3.3
Blesbuck	5.1
Blou Wildebeest	2.4
Buffalo	1
Eland	1
Elephant	0.3
Gemsbok	2.2
Giraffe	0.7

Species	Number per ELSU
Hippopotamus	0.4
Impala	7
Kudu	2.2
Nyala	3.3
Ostrich	2.7
Red Hartbeest	2.8
Roan Antelope	2
Sable Antelope	2
Southern Reedbuck	7.7
Springbok	10.3
Tsessebe	2.8
Warthog	5
Waerbuck	2.4
Rhinoceros	0.4
Zebra	1.6

3.3.7 Urban Areas

Table 3.3.1 illustrates the urban areas for each quaternary catchment. Data on urban areas was obtained from 1:50 000 maps and exclude the smallholdings and rural villages.

3.3.8 Nature Reserves and Indigenous Forests

Information on nature reserves and indigenous forests was obtained from both the WR90 dataset, and the CSIR Land-use Coverage, 1999. **Table 3.3.1** summarises the area occupied by nature reserves and natural forest per quaternary catchment. The indigenous forests in drainage region P fall within nature reserves and are therefore not shown separately.

4. WATER REQUIREMENTS

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

- Urban and rural
- Stock watering
- Irrigation
- Afforestation
- Invasive alien plants
- Ecological

The current and projected use of groundwater resources, the inter-basin transfers, as well as the return flows from the urban areas were also taken into consideration. This was done in order to estimate the consumptive water requirements imposed on the surface water resources generated from drainage region P.

4.1 URBAN AND RURAL WATER REQUIREMENTS

4.1.1 Introduction

The distribution of urban and rural domestic water requirements is shown in **Tables 4.1.2A** and **4.1.3B**. The requirements shown include distribution and conveyance losses.

The total combined domestic requirement at 2001 levels of development was estimated to be 8.28 million m^3/a, of which approximately 7.88 million m^3/a was required by towns and only about 0.4 million m^3/a by consumers in the rural areas. Until year 2025 the urban requirements are expected to grow substantially to about 13.89 million m^3/a, while the rural requirements are expected to remain constant.

4.1.2 Urban requirements

The methodology and the results of the estimates for the size of the urban and rural population within the study area are shown in **Section 3.1**. The urban water requirements were estimated on the basis of the methodology developed for the National Demographic Study (NDS) (Schlemmer *et al*, 2001), which is outlined below.

4.1.2.1 Methodology developed for the National Demographic Study

This methodology provides a framework for the estimation of the present and projected water requirements per urban centre. The urban water requirements in each centre are divided into two main components - direct usage by the population, and indirect usage by commerce, industries, institutions and municipalities related to the direct use.

- **Direct water use**

  In order to estimate the direct water use, the urban population in each urban centre has been sub-divided into seven categories depending on the following criteria: economic strata, type of housing, and levels of water and sanitation service provided. Each category was then associated with a default unit water use per person. The default water use varies between 320 l/person/day for full water and sewer service on large properties to 6 l/person/day for settlements, where no formal water supply exists. These categories and the associated default unit water use are shown in **Appendix 4.1**.

- **Indirect water use**

  Indirect water use was estimated in terms of four categories, viz. commercial, industrial, institutional and municipal. The urban centres were classified according to shared characteristics related to indirect water use. This classification is shown in **Appendix 4.2.** A standard table relating the components of indirect water use to the total direct water use of an urban centre was developed, and is shown in **Appendix 4.3**.

4.1.2.2 Estimates of urban requirements in drainage region P

Using the methodology developed for the NDS, the water requirements for the urban centres within the study area were estimated as described below. Where accurate or updated information could be obtained, certain amendments were introduced to the default values and assumptions used by the NDS.

The population numbers in 2001 were obtained from the most recent Census 2001, the results of which became available in January 2004. These population figures were projected until 2025 as described in Section 3.1.

The population in each urban centre was divided into the seven categories of water use. This was done on the basis of the relevant data from Census 2001, as well as based on site information obtained during the course of this study. The relevant Census 2001 data relating to water supply service levels and type of housing is shown in **Appendix 3.4**. The unit water use per category as recommended by the NDS was applied in order to determine the direct water requirements.

The indirect water usage was estimated as a percentage of the direct usage as per the methodology of the NDS. For the purposes of this estimate it was assumed that adequate provision for the seasonal population is made through the estimated indirect water usage default values.

The distribution of urban water requirements determined on this basis is shown in **Tables 4.1.2A and 4.1.2B**, where bulk conveyance losses and distribution losses have been added to the estimated direct and indirect water requirements to derive the total water requirements. Owing to the lack of more accurate information, an allowance of 25% (of total use) has been made for bulk conveyance and distribution losses. More detail is available in **Appendix 4.5 and 4.6**.

Table 4.1.2A: Total urban water requirements per quaternary catchment

Quaternary Catchment	Total urban water requirements, x 10^6 m^3/ annum			
	2001	2005	2015	2025
P10A	0.00	0.00	0.00	0.00
P10B	0.04	0.04	0.04	0.05
P10C	0.00	0.00	0.00	0.00
P10D	0.21	0.34	0.42	0.42
P10E	0.19	0.22	0.21	0.20
P10F	0.00	0.00	0.00	0.00
P10G	0.66	0.91	1.21	1.49
P20A	0.69	0.87	1.25	1.28
P20B	0.00	0.00	0.00	0.00
P30A	0.00	0.00	0.00	0.00
P30B	0.00	0.00	0.00	0.00
P30C	0.00	0.00	0.00	0.00
P40A	4.51	5.00	5.65	5.97
P40B	0.00	0.00	0.00	0.00
P40C	1.53	2.49	3.43	4.31
P40D	0.05	0.08	0.12	0.16
TOTAL	**7.88**	**9.95**	**12.35**	**13.89**

Table 4.1.2B: Total water requirements per urban centre

Quaternary	Town	Total water requirements, 106 m3/ annum			
		2001	2005	2015	2025
P10B	Riebeeck East	0.04	0.04	0.04	0.05
P10D	Alicedale	0.21	0.34	0.42	0.42
P10E	Paterson	0.19	0.22	0.21	0.20
P10G	Kenton on Sea/ Bushmans/Marselle	0.66	0.91	1.21	1.49
P20A	Alexandria	0.52	0.62	0.79	0.76
	Boknes	0.09	0.13	0.23	0.26
	Cannon Rocks	0.09	0.12	0.23	0.26
P40A	Grahamstown	4.51	5.00	5.65	5.97
P40C	Port Alfred	1.27	2.16	3.04	3.90
	Bathurst	0.26	0.34	0.39	0.41
P40D	Kleinemonde	0.05	0.08	0.12	0.16
TOTAL STUDY AREA		**7.88**	**9.95**	**12.34**	**13.89**

4.1.3 Rural domestic water requirements

Rural water users include the population of farms, small rural settlements not classified as towns, and coastal resorts that are not classified as towns. No detailed and accurate information on rural water use is available for the study area. Based on the Census 2001 results, it can be concluded that the rural population in the study area constitutes only about 14% of the total. Therefore, the rural water use is relatively low when compared to the urban water use.

The present and projected rural population numbers were determined as described in **Section 3**.

The per capita water requirements assumed for the Fish to Tsitsikamma WRSA study were used. As per that study, rural users were considered to fall into three economic categories, with associated unit water requirements. These categories are “Rural”, being people living far from towns and not part of the communities of large commercial farms, “Developing Urban” being people of the lower income group living close to towns and typically on smallholdings, and “Commercial Farming” being the owners of large commercial farms and their workers.

The assumed unit water requirements are shown in **Table 4.1.3A**. Total losses were assumed to be 20% of total water requirements, including losses.

Table 4.1.3A: Per capita water requirements in rural areas in 2001:

USER CATEGORY	UNIT WATER REQUIREMENTS			
	Direct Use (l/c/d)	Distribution loses		Total (l/c/d)
		(l/c/d)	(%)	
Rural	30	7,5	20	37,5
Developing urban	100	25	20	125
Commercial farming	150	38	20	188

The total rural domestic water requirements were calculated from the estimated number of people in each user category in each quaternary catchment. The results are summarised in **Table 4.1.3B**. Details are given in **Appendix 4.7**.

Table 4.1.3B: Estimated rural domestic water requirements

Quaternary Catchment	Projected Water Usage ($10^6 m^3/a$)			
	2001	2005	2015	2025
P10A	0.02	0.02	0.02	0.02
P10B	0.02	0.03	0.03	0.02
P10C	0.01	0.02	0.01	0.01
P10D	0.02	0.02	0.02	0.02
P10E	0.02	0.02	0.02	0.02
P10F	0.06	0.06	0.06	0.06
P10G	0.04	0.04	0.04	0.04
P20A	0.05	0.05	0.05	0.05
P20B	0.04	0.04	0.04	0.04
P30A	0.02	0.02	0.02	0.02
P30B	0.01	0.01	0.01	0.01
P30C	0.01	0.02	0.02	0.01
P40A	0.01	0.01	0.02	0.01
P40B	0.02	0.02	0.02	0.02
P40C	0.02	0.03	0.03	0.02
P40D	0.02	0.02	0.02	0.02
TOTAL	**0.40**	**0.42**	**0.42**	**0.39**

4.1.4 Livestock watering

Drinking water for livestock is also considered to be part of the rural water requirements and was calculated as 45 l/d per Equivalent Large Stock Unit (ELSU). The total livestock population in the study area is about 100 000 units, of which about 72 000 are cattle, 15 000 sheep, and 9 000 goats. The balance is split between horses, donkeys and pigs. The total number of ELSU in the study area is about 90 000.

The number of ELSU per quaternary catchment has been estimated in previous studies on the basis of the information from the 1994 livestock census.

The estimated water requirements for livestock watering are shown in the table below. It has been assumed that the grazing capacity of the area has been reached and that the livestock population and water requirements would not change significantly during the projection period.

Table 4.1.4: Livestock Numbers and Water Requirements

Quaternary Catchment	No of ELSU	Water requirements ($10^6 m^3/a$)
P10A	849	0.032
P10B	3 436	0.126
P10C	822	0.032
P10D	2 535	0.095
P10E	9 982	0.158
P10F	7 392	0.126
P10G	8 851	0.126
P20A	12 476	0.189
P20B	9 812	0.152
P30A	1 188	0.032
P30B	4 082	0.095
P30C	1 861	0.032
P40A	3 211	0.063
P40B	6 994	0.126
P40C	9 469	0.158
P40D	6 797	0.126
TOTAL	**89 757**	**1.666**

4.2 IRRIGATION WATER REQUIREMENTS

No comprehensive and accurate information about the extent of the irrigated land and the associated water use is available for the study area. The distribution of the irrigable land within the study area was done as described in **Section 3**.

The water requirements were estimated as per the approach used during the WRSA study. The irrigated crops in the area include mostly vegetables and pasture. The water requirements were calculated by applying a typical value for the field edge water requirement (12 000 m^3/ha/a) throughout the entire study area. In addition conveyance losses of 15% of the gross water requirements were provided.

The estimated irrigation water requirements per quaternary catchment are shown in the following table. It is assumed that the irrigated land and the irrigation requirements will not change during the projection period.

Table 4.2: Irrigation water requirements

Quaternary	Maximum area	Net requirement	Conveyance losses	Gross requirements
	ha	$x10^6 m^3/a$		
P10A	44	0.372	0.051	0.423
P10B	165	1.404	0.191	1.595
P10C	94	0.795	0.108	0.903
P10D	187	1.590	0.217	1.806
P10E	153	1.302	0.178	1.480
P10F	153	1.302	0.178	1.480
P10G	109	0.930	0.127	1.057
P20A	0	0.000	0.000	0.000
P20B	0	0.000	0.000	0.000
P30A	105	0.896	0.122	1.018
P30B	237	2.012	0.274	2.287
P30C	40	0.338	0.046	0.384
P40A	12	0.101	0.014	0.115
P40B	6	0.051	0.007	0.058
P40C	12	0.101	0.014	0.115
P40D	6	0.051	0.007	0.058
TOTAL	**1 323**	**11.246**	**1.533**	**12.779**

4.3 AFFORESTATION

Based on the available information the total area of the land presently used for afforestation is about 6.3 km^2. The prevailing species is pine. The potential for development of commercial forestry plantations is not high in the study area. This is owing to the relatively low mean annual precipitation, which is generally below 700 mm.

The reduction of runoff (water requirements) due to afforestation was modelled using the Affdem programme. The distribution of afforestation areas and the water requirements are shown in **Table 4.4** together with the reduction of runoff due to invasive alien plants.

4.4 INVASIVE ALIEN PLANTS

The study area is severely infested with IAP. About 230 km^2, or 4% of the land in drainage region P is overgrown by IAP. The most severe infestation occurs in the coastal area to the west of Kenton on Sea. This results in a notable reduction of the runoff.

The reduction of runoff has been modelled using the SHELL model and the results per quaternary catchment are shown in **Table 4.4.**

Table 4.4: Reduction of runoff due to afforestation and IAP

Quaternary Sub-catchment	Area afforestation (km^{2})	Reduction runoff ($x10^6 m^3/a$)	Area IAP (km^{2})	Reduction ($x10^6 m^3/a$)
P10A	2.14	0.05	5.27	0.38
P10B			4.51	0.30
P10C			0	0
P10D			0.26	0.04
P10E			0.78	0.06
P10F			11.2	0.51
P10G			0.41	0.04
P20A			51.1	4.60
P20B			57.19	3.64
P30A	3.40	0.09	22.12	1.64
P30B			5.49	0.29
P30C			0.38	0.01
P40A	0.75	0.02	40.11	3.22
P40B			5.62	0.32
P40C			10.98	0.69
P40D			13.51	1.07
TOTAL	**6.29**	**0.16**	**228.93**	**16.81**

4.5 ECOLOGICAL RESERVE REQUIREMENTS

The riverine component of the Ecological Reserve Requirements (ERR) (also known as Instream Flow Requirements) was determined for each quaternary catchment in the study area.

The estimates for the ER were produced on the basis of the desktop methodology applying the Hughes DSS model (decision support system) of Rhodes University's IWR. The ecological management classes, used as an input to the model, were assessed by a team of environmental specialists during a workshop in August 1999. The results of the application of the Kleynhans method for the determination of the "attainable" ecological management class (AEMC) are summarised in **Table 2.6.1.1**. The estimated incremental ERR per quaternary catchment are shown in **Table 4.5**. More detailed information including the monthly rule curves are attached in the Surface Water Resources Supporting Report.

Table 4.5: Estimated ERR per Quaternary (incremental)

Quaternary	River	AEMC	Naturalised MAR ($10^6m^3/a$)	ERR	
				% of MAR	10^6m3/a
P10A	Boesmansriviermond	C	4.54	18	0.80
P10B	Boesmansriviermond	C	12.19	18	2.2
P10C	Boesmansriviermond	C	2.39	18	0.43
P10D	Boesmansriviermond	C	6.77	18	1.26
P10E	Boesmansriviermond	D	8.85	11	0.96
P10F	Boesmansriviermond	D	13.6	11.2	1.54
P10G	Boesmansriviermond	D	9.6	11.00	1.08
P20A	Boknes	D	30.38	11.30	3.42
P20B	Boknes	D	15.27	11.20	1.72
P30A	Kariega	C	6.86	18.00	1.25
P30B	Kariega	C	11.69	17.30	2.02
P30C	Kariega	C	1.70	17.30	0.29
P40A	Kowie	C	13.73	18.00	2.45
P40B	Kowie	C	8.18	17.30	1.42
P40C	Kowie	C	14.02	18.00	2.55
P40D	Kowie	C	13.28	17.50	2.34
TOTAL			**173.05**		**25.74**

4.6 ALTERNATIVE SOURCES (INFLOWS)

4.6.1 Groundwater Usage

The groundwater consumption has been estimated and projected in broad terms for each quaternary catchment. The existing records of current usage from groundwater have been taken into account. The projected future groundwater usage was based on a regional scale desktop study, which assessed the potential for development of the groundwater resources in the area.

Table 4.6.1: Estimated usage of groundwater

Quaternary Sub-catchment	Projected Water Usage ($10^6 m^3/a$)			
	2001	2005	2015	2025
P10A	0.02	0.02	0.02	0.02
P10B	0.06	0.07	0.07	0.07
P10C	0.01	0.02	0.01	0.01
P10D	0.02	0.02	0.02	0.02
P10E	0.13	0.22	0.32	0.42
P10F	0.06	0.06	0.06	0.06
P10G	0.04	0.04	0.04	0.04
P20A	1.05	1.55	1.55	1.85
P20B	0.04	0.04	0.04	0.04
P30A	0.02	0.02	0.02	0.02
P30B	0.01	0.01	0.01	0.01
P30C	0.01	0.02	0.02	0.01
P40A	0.01	0.01	0.02	0.01
P40B	0.02	0.02	0.02	0.02
P40C	0.42	0.43	0.43	0.42
P40D	0.05	0.06	0.08	0.10
TOTAL	**1.97**	**2.60**	**2.73**	**3.11**

4.6.2 Return flows

The existing water treatment plants in the study area are listed in **Table 4.6.2A**.

Table 4.6.2A: Sources of urban return flows and sewage treatment works

Water User (Town or suburb)	Catchment	Capacity	Treatment Facility
Alexandria, Wentzel Park, KwaNonqubela	P20A	Unknown	Oxidation ponds
Cannon Rocks, Boknes	P20A	Unknown	Septic tanks with soakaways
Kenton on Sea, Boesmansriviermond, Klipfontein, Marselle, Ekuphumleni	P10G	Unknown	Septic tanks with soakaways, Activated sludge wastewater TW
Port Alfred, Nemato, Mimosa Farm	P40C	1.000 m^3/d	Oxidation ponds
Kleinemonde, Seafield	P40D	Unknown	Septic tanks with soakaways
Bathurst, Nolukhanyo, Freestone	P40C	Unknown	Septic tanks with soakaways

No accurate records are available for the actual return flows of treated sewage effluent from the treatment works. For the purposes of this study it has been assumed that about 40% of the total urban water usage in towns with water-borne sewer systems will return to the surface water system. It is not anticipated that water-borne sanitation will be installed in the rural areas. The projected irrigation requirements are relatively small and the potential return flows have been ignored.

Return flows of treated sewage effluent are estimated to have totalled approximately 3.2 million m^3/a in 2001. Of this, about 0.85 million m^3/a has been generated by the coastal towns and discharged directly into or close to the sea. This portion of the return flows is not included in the table below, as it does not contribute to the surface runoff.

Table 4.6.2B: Estimated return flows from treated sewage

Quaternary Sub-catchment	Return flows ($10^6 m^3/a$)*			
	2001	**2005**	**2015**	**2025**
P10A	0.00	0.00	0.00	0.00
P10B	0.01	0.02	0.02	0.02
P10C	0.00	0.00	0.00	0.00
P10D	0.09	0.14	0.17	0.17
P10E	0.08	0.09	0.09	0.08
P10F	0.00	0.00	0.00	0.00
P10G	0.00	0.00	0.00	0.00
P20A	0.21	0.25	0.32	0.31
P20B	0.00	0.00	0.00	0.00
P30A	0.00	0.00	0.00	0.00
P30B	0.00	0.00	0.00	0.00
P30C	0.00	0.00	0.00	0.00
P40A	1.85	2.05	2.32	2.45
P40B	0.00	0.00	0.00	0.00
P40C	0.11	0.14	0.16	0.17
P40D	0.00	0.00	0.00	0.00
TOTAL	**2.35**	**2.69**	**3.08**	**3.20**

* Return flows exclude the treated effluent from the coastal towns

4.6.3 Inter-basin transfers

The Lower Fish River Government Water Scheme transfers water from drainage region Q to P in order to augment the supply to Grahamstown. The scheme consists of a tunnel that diverts water from the Hermanuskraal Weir into the Glen Melville Dam, water treatment works and a bulk conveyance system. The actual volume transferred in 2001 was 2.31×10^6 m³. It is assumed that the full capacity of the system of 3.65×10^6 m³ will be reached in 2015.

4.7 SUMMARY OF CONSUMPTIVE WATER REQUIREMENTS

The results of the estimates for the consumptive water requirements (urban domestic and industrial, rural domestic, irrigation, stock watering and afforestation) as shown in the previous tables included in this Section are summarised in **Tables 4.7A** and **B** per quaternary catchment and per user sector respectively. For the purposes of modelling of the surface water hydrology, the contributing factors – return flows, inter-basin transfers and groundwater usage have been subtracted. The Ecological Reserve requirements are not included as these are specific for each development site. The naturalised incremental MAR per quaternary catchment is provided for reference.

As seen from **Table 4.7B** the total consumptive water requirements for the study area are estimated to be about 40 million m^3 for the year 2001 and 46 million m^3 for the year 2025. Taking into consideration the estimated contributions from return flows and the supply from groundwater, the total requirements from the surface water resources would be 33 x 10^6 m^3 for the year 2001 and 36 x 10^6 m^3 for the year 2025.

Table 4.7A: Surface Water Requirements per Quaternary

Quaternary Sub-catchment	Projected Water Requirements ($10^6 m^3/a$)				Naturalised MAR
	2001	2005	2015	2025	
P10A	0.88	0.88	0.88	0.88	4.54
P10B	2.01	2.00	2.00	2.00	12.19
P10C	0.93	0.93	0.93	0.93	2.39
P10D	2.07	2.14	2.19	2.19	6.77
P10E	1.70	1.63	1.52	1.42	8.85
P10F	2.12	2.12	2.12	2.12	13.60
P10G	1.88	2.13	2.43	2.72	9.60
P20A	4.27	3.90	4.22	3.96	30.38
P20B	3.79	3.79	3.79	3.79	15.27
P30A	2.78	2.78	2.78	2.78	6.86
P30B	2.67	2.67	2.67	2.67	11.69
P30C	0.43	0.43	0.43	0.43	1.70
P40A	3.77	3.57	3.30	3.29	13.73
P40B	0.50	0.50	0.50	0.50	8.18
P40C	1.99	2.92	3.84	4.71	14.02
P40D	1.28	1.30	1.31	1.33	13.28
TOTAL	**33.07**	**33.70**	**34.93**	**35.73**	**173.05**

Table 4.7B: Consumptive Water Requirements per User Sector

User Sector	Water Requirements ($10^6 m^3/a$)				Distribution, %	
	2001	2005	2015	2025	2015	2025
Urban domestic and industrial	7.88	9.95	12.35	13.89	22.4	33.6
Rural domestic	0.40	0.42	0.42	0.39	1.1	0.9
Stock watering	1.67	1.67	1.67	1.67	4.2	3.6
Irrigation	12.78	12.78	12.78	12.78	22.0	18.9
Afforestation	0.16	0.16	0.16	0.16	0.5	0.4
Invasive alien plants	16.81	16.81	16.81	16.81	49.7	42.6
Total consumptive requirements	**39.70**	**41.79**	**44.19**	**45.69**	**100.0**	**100.0**
Return Flows	-2.35	-2.69	-3.08	-3.20	-5.9	-7.0
Interbasin transfer	-2.31	-2.80	-3.45	-3.65	-5.8	-8.0
Groundwater supply	-1.97	-2.60	-2.73	-3.11	-5.0	-6.8
Total inflows	-6.63	-8.09	-9.26	-9.96	-16.7	-21.8
Total use from surface water	**33.07**	**33.70**	**34.93**	**35.73**	**83.3**	**78.2**

5. WATER SUPPLY SITUATION AT AFFECTED TOWNS

5.1 ALEXANDRIA

The supply area includes the town of Alexandria and the former townships of Wentzel Park and KwaNonqubela with a total population of about 7 800 people.

5.1.1 Levels of Service

Most of the population is serviced to house/yard connection level (in KwaNonqubela there are 643 households and 20 smallholdings that require access to formal water supply).

The townships of Wentzel Park and KwaNonqubela have 80% and 40% water-borne sewer services respectively, while Alexandria is fully serviced with a wastewater system that drains into an oxidation pond. This level of service needs to be provided at 643 households in KwaNonqubela and 80 erven in Phokoza Valley.

5.1.2 Description of Existing Water Supply Infrastructure

Figure S1 is a schematic layout of the existing water supply scheme in Alexandria.

Water is supplied from two major sources:

- Coastal springs near Cape Padrone (7 l/s over 12 hr)
- 2 well points near Fishkraal (12 l/s over 12 hr)

The total maximum source capacity is 0.836×10^6 m^3/a and 0.674×10^6 m^3/a during normal times and during drought periods respectively. The scheme is being operated by Ndlambe Municipality, through a water services contract with P & S Consulting Engineers. The existing conveyance system has a capacity of 19 l/s (1 642 m^3/d) but plans are underway to upgrade this to 24 l/s.

Raw water is being pumped from these sources to a transfer reservoir (240 m^3) located 10 km south of Alexandria and from there it is pumped (1 642 m^3/day) to bulk storage reservoirs (3 400 m^3) west of Alexandria. A separate pumping main supplies water to agricultural and afforestation consumers from the 240 m^3 transfer reservoir.

Water is supplied from the bulk storage reservoirs to all consumers via gravity reticulation networks. The total monthly production flows from the bulk storage reservoirs vary from 32 000 m^3 to 45 500 m^3 per month, with December and January being the peak months.

Information from the WSDP is available in **Appendix 5**.

5.1.3 Overview of Current Problems

The pumping main between the balancing reservoir and the bulk storage reservoir has insufficient capacity (1 642 m^3/day) and does not meet the peak demands.

5.2 CANNON ROCKS AND BOKNES

The existing scheme supplies the coastal resorts of Cannon Rocks and Boknes with a total permanent population of 931.

5.2.1 Levels of Service

Both towns are fully serviced with potable water at a yard connection level.

Sanitation is arranged through septic tanks.

5.2.2 Description of Existing Water Supply Infrastructure

Three boreholes (15 l/s at 12 h/day) located to the west of Cannon Rocks supply water (650 m^3/day) to two storage reservoirs – one at Cannon Rocks (470 m^3) and one at Boknes (530 m^3) through the reticulation system. These two reservoirs supply both towns, which have a joined reticulation system.

The present GAADD is about 500 m^3/d, while the peak requirements are about 1300 m^3/d. The boreholes are utilised for 24 h/day during peaks, which leads to over-pumping and deteriorated water quality.

Information from the WSDP is available in **Appendix 5**.

5.2.3 Overview of Current Problems

Water quality of the boreholes is poor because water is abstracted beyond the permissible rate that causes seawater intrusion.

The existing sources are sufficient to supply the area during normal periods, but insufficient during seasonal peaks. In addition about 200 new erven are being planned and will require some additional supply to that area.

5.3 BOESMANSRIVIERMOND AND KENTON ON SEA

The supply area includes the towns of Kenton on Sea and Boesmansriviermond and the former townships of Klipfontein, Marselle and Ekuphumeleni with a total population of about 9 500 people.

5.3.1 Levels of Service

Water is supplied to the entire population by means of house/yard connections.

The townships of Marselle, Klipfontein and Ekuphumeleni have water-borne sanitation services, while Boesmansriviermond and Kenton on Sea are serviced by septic tanks.

5.3.2 Description of Existing Water Supply Infrastructure

Figure S3 is a schematic layout of the existing water supply scheme for these towns. Currently raw water is obtained from the following sources:

- Six well points near Diaz Cross (average depth is 10 m) (822 m^3/d)
- Five "freshwater" boreholes near the Albany Coast Water Board (ACWB) offices (through a reverse osmosis (RO) plant)
- Eight seawater boreholes located near the mouth of the Bushmans River

  The total capacity of the last two sources is 1 600 m^3/d

Fresh water is being pumped from the well points at Diaz Cross (822 m^3/d) to a balancing reservoir (100 m^3) from where it is pumped directly to the bulk supply reservoirs (4 000 m^3) located at a high point above the town of Kenton on Sea. These wells supply about 60% of the total bulk water to the system, while the remaining 40% is being supplied from high salinity boreholes located near the coast at Boesmansriviermond.

Saline water from these boreholes with a capacity of 1 320 m^3/d is being pumped into plastic tanks (95 m^3). From there it is pumped through a RO desalination plant before being discharged into local storage (100 m^3). The RO plant consists of three separate modules with 20 m^3/h, 20 m^3/h and 10 m^3/h capacity respectively. Owing to the insufficient capacity of the power supply only two modules can operate simultaneously to a maximum capacity of 40 m^3/h. Owing to the limited capacity of the sea water and fresh water boreholes the maximum production capacity of the RO plant is limited to 25 m^3/h. The treated water is then pumped (600 m^3/d) to the bulk storage reservoirs. Desalination of this water is very expensive at R5/m^3 and the process is also not efficient (38%). Brine from the desalination plant is returned to the sea via the Bushmans River, which may have some negative environmental impact. A scoping report is currently being compiled and will outline the influence on the environment.

The total maximum daily production flow from all three sources is 1 422 m^3/d and the scheme is being operated by the Albany Coast Water Board.

The water is distributed from the bulk supply reservoirs via gravity reticulation, including the supply to a separate storage reservoir (100 m^3) at Boesmansriviermond. A separate pumping main (15 m^3/h) and 500 m^3 reservoir supply some farmers about 7 km to the north.

Daily usage varies between 1 200 m^3/day during normal periods to 1 800 m^3/day during peak season. Extreme daily peaks can reach 2 300 m^3/d during the December holidays.

5.3.3 Overview of Current Problems

The well points at Diaz Cross are being pumped beyond their permitted abstraction rate to comply with the peak demands that arise during holiday seasons. The total maximum capacity of all current sources is 1 780 m^3 per day that is not sufficient for the peak requirements. Most households currently augment their water supply by harvesting rainwater. Owing to the restricted availability of the water source at Diaz Cross as well as the power supply to the RO plant, the actual production capacity at present is about 1 400 m^3/d.

The water quality of the wells at Diaz Cross is poor. The current TDS of this water is about 1 400 mg/l, which is classified as class II, but when overexploited salinity levels can exceed 2 500 mg/l.

The bulk storage reservoirs have inadequate storage capacity during peak season and additional storage is required.

Owing to the system's inadequate water sources and low storage capacity, it cannot afford any downtime. Eskom's power supply is very unreliable and this results in insufficient supply to the bulk storage reservoir and puts constant stress on the water balance.

The situation in the towns is critical and needs immediate attention.

Information from the WSDP is available in **Appendix 5**.

5.4 PORT ALFRED

The supply area includes the town of Port Alfred, the former townships of Nemato and Mimosa Farm and the proposed township of Thornhill with a total current population of about 21 000 people. An additional 5 000 stands are proposed to be serviced in the Thornhill township within the next two years.

5.4.1 Levels of Service

Every stand in Port Alfred is supplied with water at erf connection level of service. 60% of the stands in Nemato are supplied with yard connections, while 20% are serviced with communal standpipes.

Port Alfred is 40% serviced with water-borne sanitation and 60% serviced with conservancy tanks. 50% of the township of Nemato has digestive systems with French drains, while the remaining 50% has VIP's.

5.4.2 Description of Existing Water Supply Infrastructure

Figure S4 is a schematic layout of the existing water supply scheme for this area.

Raw water is abstracted from a weir on the Kowie River and pumped (max 12 960 m^3/d) from pump station No.1 to an off-channel storage dam - Sarel Haywood Dam (2.5 x 10^6 m^3 storage and 1.55 x 10^6 m^3/a yield). From here water is conveyed via a 10.3 km long pipeline and two pump stations with a capacity of 4 320 m^3/d to a balancing dam (capacity 16 000 m^3) near the hospital.

Water is gravity fed from the balancing dam to the water treatment works (capacity 5 000 m^3/d), situated to the north of the town, via a 3 km long pipeline. Potable water from the treatment works discharges into a bulk storage reservoir and is then pumped (5 000 m^3/d) to four distribution reservoirs.

From the distribution reservoirs the water is distributed by gravity to the users.

Two well fields in the coastal sand dunes, located near the town of Port Alfred, are used during peak periods to augment the water supply to the town (max capacity 356 m^3/d). It is also possible to augment the water supply by gravity feeding raw water from Mansfield Dam (yield 45 Ml/a) to the water treatment works in the town. This system is however out of order. The pipeline is about 6,5 km long, 150 mm ND and has a maximum capacity of 15 l/s. The daily water use in Port Alfred is as follows:

- Average: 2.0 to 2.5 Ml/d
- Summer peak: 4.0 to 5.0 Ml/d
- Extreme peak: 6.0 to 7.5 Ml/d

The total yield of the existing water sources is as follows:

• Sarel Hayward Dam	1.55×10^6 m³/a
• Boreholes	0.13×10^6 m³/a
• Mansfield Dam	0.05×10^6 m³/a
Total yield	1.73×10^6 m³/a

Information from the WSDP is available in **Appendix 5**.

5.4.3 Overview of Current Problems

The quality of raw water is poor due to the marine origin of the soils underlying the dam basin. In order to meet the peak seasonal demands, the capacity of the bulk supply system needs to increase.

Additional bulk water supply infrastructure is required to meet the demands for the proposed developments in Thornhill (5 000 additional stands).

About 1 800 households in Nemato need access to yard connections.

5.5 BATHURST

Included in this particular supply area are the town Bathurst and the former townships of Nolukhanyo and Freestone with a total population of about 5 600 people.

5.5.1 Levels of Service

The population in Nolukhanyo and Freestone is serviced with potable water at yard connection level of service, while Bathurst relies on private water supplies like boreholes and harvesting rainwater.

Sanitation services are provided in Bathurst through both septic and conservancy tanks, while Nolukhanyo and Freestone are serviced with septic tanks and soakaways.

5.5.2 Description of Existing Water Supply Infrastructure

Figure S5 is a schematic layout of the existing water supply scheme for this area.

Existing water sources are the Golden Ridge Dam (0.25×10^6 m³/a with no provision for the ERR), private boreholes and the Mansfield Dam (0.05×10^6 m³/a).

Raw water is pumped from the Golden Ridge Dam (1 382 m^3/d) to a package treatment works in Bathurst (capacity 432 m^3/d). A second pump station transfers potable water (432 m^3/d) to the Toposcope reservoir (1 000 m^3). From the reservoir water is distributed by gravity to all households.

Ndlambe Municipality is operating this scheme.

The maximum capacity of the Water Treatment Works is 0.16 x 10^6 m^3/a. The capacity of the existing private boreholes is unknown.

Information from the WSDP is available in **Appendix 5**.

5.5.3 Overview of Current Problems

The water treatment works are currently operating at capacity, while the bulk storage is also not sufficient.

The Golden Ridge Dam needs to be investigated in terms of the ERR requirements. The current yield is about 0.25 x 10^6 m^3/a without ERR releases.

5.6 KLEINEMONDE AND SEAFIELD

The supply area includes East Kleinemonde and Seafield with a total population of 1 450.

5.6.1 Levels of Service

Both towns are fully serviced with potable water to house-connection level.

Sanitation services include septic tanks with soakaways at every stand.

The present GAADD is in the order of 230 m^3/d, but grows to about 500 m^3/d during peak season. The existing maximum capacity of the source of about 408 m^3/d is insufficient to meet the peak requirements. Furthermore during certain periods when the water quality in the Wellington Dam is poor, the total capacity of the system is limited to the capacity of the Water Treatment Works (90 m^3/d).

5.6.2 Description of Existing Water Supply Infrastructure

Figure S6 is a schematic layout of the existing water supply scheme for these towns.

The area is supplied with water from the Wellington Dam located 8 km north west of the town. Two coastal boreholes, located in the Seafield area, are utilised during peak seasons to augment the water supply.

Raw water is pumped from the Wellington Dam (360 m^3/d) to a balancing reservoir (40 m^3) situated 2 km south-east of the dam. From this reservoir the water is gravity fed to the treatment works (capacity 90 m^3/d) situated on the East Kleinemonde peninsula, where it is treated and pumped to a bulk storage reservoir (800 m^3) near Seafield. Connected to this pumping main are the two reticulation networks of the Peninsula and South Island that are directly supplied from this pumping main.

The Seafield reservoir supplies a portion of Seafield and a lower laying storage reservoir (60 m^3), which in turn gravity feeds a supply zone within Seafield.

A borehole near Seafield can supply 48 m^3/d, while one near the river mouth currently supplies 32 dwellings but it is highly susceptible to saline infiltration if the system is used at its peak demand. Water is pumped from the borehole situated east of Seafield to the Seafield reservoir, while water from the East Kleinemonde borehole is pumped to the lower-zone reservoir.

The total maximum daily production flow from the Wellington Dam and the borehole near Seafield is 408 m^3. During times when the salinity levels in the dam are very high, the purification capacity is only 90 m^3/d, which results in a maximum daily production flow of 138 m^3.

Ndlambe Municipality is operating these schemes.

More detailed information is available in **Appendix 5**.

5.6.3 Overview of Current Problems

The bulk supply and the reticulation systems are interconnected and lead to a high possibility for water losses.

Wellington Dam is situated in the centre of pine fields and this causes soil and pesticides to wash into the dam during heavy rains. This causes the TDS of the water to rise up to 2 500 parts per million, which is too high for domestic use.

The borehole at the river mouth is highly subjected to contamination owing to seepage from household septic tanks.

The maximum available water source is insufficient to meet peak requirements.

5.7 WATER CONSERVATION AND DEMAND MANAGEMENT

No detailed Water Demand Management (WDM) studies have been undertaken for any of the towns. The water losses in the reticulation networks are therefore unknown. However, owing to the severe limitations of the existing sources and the poor water quality, water is utilised very effectively at household level. Almost all households are fitted with rainfall harvesting facilities and people are forced to utilise this water owing to the lack of alternative sources.

Appendix 8 includes more information on the potential for water conservation and demand management.

6. WATER RELATED INFRASTRUCTURE

6.1 ORANGE - FISH TRANSFER SCHEME

The Orange-Fish Transfer Scheme was developed to utilise surplus water from the Orange River mainly for the purpose of irrigation, supply to urban areas and to generate hydro-electric power. Water is diverted from the Orange River to the Great Fish and Sundays River via a 82.9 km long, 5.4 m diameter tunnel that discharges into the Teebus Spruit. Water flows from the tunnel outlet to the Grassridge Dam on the Great Brak River, a tributary of the Great Fish River. The tunnel has a capacity of 1 700 x 10^6 m^3/a while the mean annual requirement was 560 x 10^6 m^3/a in the year 2002.

Water is released from the Grassridge Dam down the Great Fish River to Elandsdrift Weir. Here it is diverted into a 108 km long aqueduct, of which the Cookhouse Tunnel is the main feature that discharges water into the Little Fish River. Water not diverted into the aqueduct is released from the Elandsdrift Weir into the Great Fish River that supplies the Lower Fish River Government Water Scheme.

6.2 LOWER FISH RIVER GOVERNMENT WATER SCHEME

The Hermanuskraal Weir is used to divert water into the Fish–Ecca Tunnel, with a capacity of 500 x 10^6 m^3/a, which discharges into the Glen Melville Dam on the Ecca River. This dam is a balancing reservoir for raw water supplied to Grahamstown and the Lower Fish River Irrigation Scheme. A municipal pumping scheme conveys water from the WTW at the Glen Melville Dam to Grahamstown via a 350 mm diameter raising main.

The yield from Glen Melville Dam that has been allocated for transfer to Grahamstown is 7.3 x 10^6 m^3/a. At present, the existing bulk supply system supplying Grahamstown (pump station, water treatment works, pipeline) has a capacity of 3.65 x 10^6 m^3/a. If required the allocation for domestic use from the Glen Melville dam can be increased substantially.

6.3 DAMS IN DRAINAGE REGION P

Table 6.3A: Main dams

Dam	Quaternary Catchment	Wall Height (m)	Surface Area (ha)	Capacity (1 000 m^3)	Use
New Year's	P10B	22	96	4 700	Domestic Supply
Howiesonspoort	P30B	24	16	883	Domestic Supply & Irrigation
Settlers	P30B	21	101	5 620	Domestic Supply
Golden Ridge	P40B	13	13	400	Domestic Supply
Sarel Hayward	P40C	40	25	2 522	Domestic Supply
Mansfield	P40C	14	4	165	Domestic Supply
Mount Wellington	P40D	10	2	250	Domestic Supply & Irrigation

Table 6.3B: Registered farm dams

Dam	Quaternary Catchment	Wall Height (m)	Surface Area (ha)	Capacity (1 000 m³)
Jameson	P10A	13	15	575
Milner	P10A	24	7.7	255
Concorde	P10A	?	1	80
Grey	P40A	21	1	68
Kareeleegte	P10C	6	7	64
Blackburn	P10D	10	0	150
Teafontein	P10B	8	3	204
Table Hill Big	P10A	12	8	364
Oakwell	P10B	10	2	82
Mosslands	P30A	15	18	571
Brakkloof River	P10A	7	4	75
Strowan	P10A	9	6	139
Hilton	P10B	6	3	60
Shenfield Camp	P10B	10	2	60
Mountain View	P10F	11	1	250
Springvale	P10B	9	6	163
Proctorsfontein Dipping Tank	P30B	9	3	126
Proctorsfontein House	P30B	11	4	299
Lake Gum	P30B	9	7	251
Birmingham New	P30A	13	10	414
Dogplum	P30B	15	32	101
Yellow Wood	P30B	12	5	130
New Year Park	P30B	8	0	79
Arnhem	P10A	17	2	80
Rochester	P30B	8	0	202
Lindale	P30B	10	17	260
All’s Well	P30B	8	18	492
Assegaai	P30B	9	8	224
Doringkloof	P30B	11	7	198
Le Grange	P30B	8	0	130
Langley Park	P30A	7	5	90
Yarrow	P30B	11	8	462

Table 6.3B: Registered farm dams (Continued)

Dam	Quaternary Catchment	Wall Height (m)	Surface Area (ha)	Capacity (1 000 m³)
Endwell Farm	P30B	9	1	60
Fairfield	P30B	8.5	6	79
Hopeleigh	P30B	6	34	136
Homeleigh	P30B	9	2	82
Avondale	P30B	7	7	272
Weltevrede	P30B	8	10	205
Rosslyn	P40B	14	4	150
Kenkele	P40A	13	4	160
Pinedale	P40A	16	7	300
Willow Park	P40A	11	4	150
Gleniffer Dam 1	P40C	8	3	50
The Home	P40B	10	4	110
Gleniffer Dam 2	P40C	12	6	200
Lanpeter	P40B	10	5	120
Rockwoodvale	P40A	6	3	135
Rhema	P40A	13	2	150
Fairview	P40B	7.9	4	218
The Grove	P40D	11	2	70
Old Mill	P30B	8	4	76

More details regarding the registered dams in the study area are attached in **Appendix 5.2**.

6.4 OVERVIEW OF WATER SUPPLY AND SANITATION SITUATION IN THE STUDY AREA

The total population within the study area during 2001 was about 139 000 of which about 119 000 reside in urban areas. The rural population consists mainly of commercial farmers and farm labourers. The rural population is supplied from private water sources, mainly boreholes and small farm dams.

The urban population is supplied through ten different schemes (see **Figure 10.1**). The schemes supplying the coastal towns are described in detail in **Section 5**, while the schemes supplying the remaining urban towns are described in the following sections.

Service levels are generally above RDP standards. The total capacity of the water supply schemes is about 10.5 $\times 10^6$ m³/a and this relates to an average daily supply per person of 240 l.

Sanitation services are provided at all coastal towns through septic and conservancy tanks. The surrounding former townships have either water-borne sanitation or septic tanks, while about 800 households currently have no sanitation service. The townships around Port Alfred are provided with VIP's and digestive French drains.

The level of sanitation services in and around the remaining urban towns is generally lower than that for the coastal towns. About 4 000 households in Grahamstown are serviced with the bucket system, while about 800 households have no service. Alicedale currently have a high level of service with Riebeeck East and Paterson very low.

6.4.1 Grahamstown

Grahamstown is currently supplied from two different sources. The Glen Melville Dam supplies Grahamstown East via the James Kleynhans Water Treatment Works (WTW), while the Howieson's Poort, Settler's, Jameson and Milner dams supply Grahamstown West via the Waainek Water Treatment works.

Bulk water is supplied from the Orange-Fish Government Water Scheme to the off-channel Glen Melville Dam, approximately 15 km north-east of Grahamstown. From the 10 000 m³/day water treatment works and pump station at the dam, water is pumped via a 350 mm diameter pipeline to the following reservoirs: the high level reservoir at Bothas's Hill (7 000 m³), the Mayfield reservoir (3 000 m³) and the Tantyai reservoir (2 500 m³). From these reservoirs water is distributed by gravity reticulation networks to households in the east.

Raw water is pumped from Settlers Dam to Howieson's Poort Dam via two 250 mm diameter pipelines approximately 3.45 km long. Raw water is pumped (9 000 m³/d) from the Howieson's Poort Dam to the Waainek WTW (capacity 9 000 m³/d) via a 300 mm diameter pipeline. From the storage reservoir (16 000 m³) at the WTW, purified water gravitates through a 375 mm diameter pipeline to the adjacent Waainek reservoir (2 250 m³), the two Town Filter reservoirs (7 500 m³) and a low level reservoir (3 000 m³). From these reservoirs water is distributed through gravity reticulation networks to households in the west.

Water from the small Jameson an Milner dams gravitates to the old "Town Filters" from where it is pumped to the Waainek WTW through a 200 mm diameter pumping main 2.1 km long.

The Settlers/Howieson's Poort Dam system is currently used to maximum capacity. All future water requirements will have to be supplied from the Glen Melville Dam.

6.4.2 Alicedale

Raw water gravitates from the New Years Dam to the WTW (capacity 2 000 m³/d) at Alicedale via a 300 mm and 200 mm pipeline. From the WTW water gravitates to three concrete reservoirs with a total capacity of 573 m³. Water is supplied from these reservoirs to three different areas.

Water gravitates from the reservoirs via a 150 mm diameter cast iron pipe to supply the reticulation network in Alicedale.

A second gravity main, 250 mm diameter, feeds water to a pump station on the bank of the Bushmans River. Water is pumped from the pump station by means of a duplicate pumping system via a 150 mm and 75 mm diameter rising main to two reservoirs (total capacity 1 107 m^3) south of KwaNonzwakazi. From these reservoirs water is distributed through gravity reticulation networks to households in KwaNonzwakazi and Transriviere.

Shamwari Game Park south of Alicedale collects water by means of a tanker.

The raw water demand is very high with daily demand metered at an average of 1 050 m^3/d, which indicated that there must either be excessive system losses or high usage patterns. Alicedale has no high-pressure zones and low pressure in parts of the towns has been a problem in the past.

6.4.3 Riebeeck East

Water is pumped from two boreholes (86 m^3/day) with good water quality. Both these boreholes draw from the same aquifer and a number of privately owned boreholes in town, used mainly for small-scale farming, draw from the same aquifer. These boreholes supply two bulk reservoirs (combined capacity 180 m^3) from where it is pumped to a 43 m^3 elevated reservoir from which the entire town is supplied. Kwanomzamo and the remainder of the town is supplied separately and measured through two different bulk meters.

6.4.4 Paterson

A total number of 1 467 households in Paterson, Kwazenzele, Mandela, Zinyoka and Moreson are supplied from three boreholes (total yield 330 m^3/day), discharging into two reservoirs (combined capacity 750 m^3). Under normal conditions water gravitates from these two reservoirs directly into the distribution network, but when the pressure is insufficient water is pumped from a third town reservoir (500 m^3) into a 46 m^3 header tank.

Water shortages are experienced in the area at times and the possibility of augmenting the water supply by taking Orange River Water from the canal at Kommandokraal must be investigated.

Table 6.4: Existing water supply schemes as at 2001

Scheme Name (town)	Raw-water Source	Town/Township Supplied	Population Supplied	Present Water Use 10^6 m³/a	Max Source Capacity		
					l/c/d	10^6 m³/a	Limiting Factor
Alexandria	Coastal Springs 7 l/s 2 well points 12 l/s extra BH 1,5 l/s	Alexandria Wentzel Park KwaNonqubela	7 715	0.51	213	0.65	Pumping main
Cannon Rocks & Boknes	3 boreholes	Cannon Rocks Boknes	931	0.18	706	0.24	Boreholes, water quality
Boesmansriviermond Kenton on Sea	6 well points 5 freshwater boreholes 8 seawater boreholes	Boesmansriviermond Kenton on Sea Klipfontein, Marselle Ekuphumeleni	9 480	0.44		0.52	Diaz Cross RO Plant Reservoir Capacity Power supply
Port Alfred	Sarel Hayward Dam Wells in coastal dunes Mansfield Dam	Port Alfred Nemato Mimosa Farm	20 965	1.0	130	1.73	Pumping mains
Bathurst	Private boreholes Harvesting rainwater Golden Ridge Dam	Bathurst, Nolukhanyo Freestone	5 549	0.158		0.30	Treatment Works
Kleinemonde and Seafield	Wellington Dam 2 boreholes	Kleinemonde Seafield	1 450	0.09	156	0.15	Purification Plant Boreholes
James Kleynhans	Glen Melville Dam	Grahamstown East	61 759	1.10	162	3.65	WTW
Waainek	Howieson's Poort Dam Settlers Dam	Grahamstown West		2.40		2.20	WTW
Alicedale	New Years Dam	Alicedale KwaNonzwakazi Transriviere	5 950	0.38*	176	0.73	WTW
Riebeeck East	2 boreholes	Riebeeck East Kwanomzamo	689	0.031*	125	0.031	Boreholes
Paterson	3 boreholes (currently only one is operational)	Paterson, Kwazenzele, Mandela, Zinyoka, Moreson	4404	0.11*	75	0.12	Boreholes

* From WSDP

7. WATER RESOURCES

7.1 SURFACE WATER RESOURCES

7.1.1 Stream flow hydrology for drainage region P

The stream flow analysis for drainage region P has been undertaken on a quaternary catchment basis for the purposes of this study. The results of these analyses are described in detail in the supporting report **Surface Water Resources**. This section outlines the findings related to possible development of the surface water sources for the augmentation of the water supply to the affected coastal towns.

The Water Research Commission publication "Surface Water Resources of South Africa, 1990" (WR90) subdivides the study area into three rainfall zones (**Figure 4.1**) and a number of functional rainfall gauging stations have been identified in each zone within region P. The hydrological analyses for the area have been based on the Water Resources Yield Model (WRYM) parameters. The yield at the outlet of each quaternary catchment as well as for 3 dam sites has been determined.

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

Table 7.1.1A: Surface Water Runoff per Quaternary Catchment

Quaternary Catchment	Catchment Area	MAP	Incremental MAR		
			Natural MAR	Natural MAR	Present day MAR
	(km^2)	(mm)	(mm/a)	($10^6m^3/a$)	($10^6m^3/a$)
P10A	126	600	36	4.54	3.66
P10B	508	531	24	12.19	9.92
P10C	281	386	8.5	2.39	1.46
P10D	564	432	12	6.77	4.83
P10E	466	493	19	8.85	7.15
P10F	469	557	29	13.6	11.48
P10G	343	550	28	9.6	8.38
P20A	422	715	72	30.38	25.59
P20B	332	635	46	15.27	11.48
P30A	176	623	39	6.86	4.08
P30B	403	559	29	11.69	4.54
P30C	68	536	25	1.7	1.27
P40A	312	635	44	13.73	10.31

Table 7.1.1A: Continue

P40B	264	570	31	8.18	7.68
P40C	342	616	41	14.02	11.51
P40D	246	666	54	13.28	11.96
TOTAL	**5322**		**537.5**	**173.05**	**132.03**

The distribution of the MAR throughout the study area is shown in **Figure 11.1**.

Table 7.1.1B: Surface Water Runoff for Main Rivers within the Study Area

River	Quaternary catchment	Catchment Area (km^2)	Virgin MAR ($10^6 m^3/a$)
Bushmans River	P10A to G	2757	57.94
Kariega River	P30A to C	647	20.25
Kowie River	P40A to C	918	35.93
Coastal Rivers	P20A & B, P40 D	1000	58.93

7.1.2 Yield Analysis

The WRYM was used to determine the yield at the outlet of the quaternary catchments and at three dam sites. The model was configured for two scenarios: with and without the Ecological Reserve (ERR) and the results are summarised in the table below. The total yield for the drainage region P is 4.63 x 10^6 m^3/a and 7.01 x 10^6 m^3/a respectively with and without taking the ecological reserve (ERR) into account.

The distribution of the cumulative yield per quaternary catchment is shown in **Figure 11.2**.

Table 7.1.2A: Cumulative Yield Results per Quaternary Catchment

Quaternary Catchment	Yield with Ecological Reserve Requirements ($10^6 m^3/a$)	Yield without Ecological Reserve Requirements ($10^6 m^3/a$)
P10A	0.00	0.00
P10B	0.19	1.00
P10C	0.00	0.00
P10D	0.00	0.00
P10E	0.54	2.49
P10F	0.54	2.62
P10G	0.57	2.74
P20A	0.00	0.10
P20B	0.00	0.00
P30A	0.00	0.00
P30B	0.00	0.00
P30C	0.00	0.00
P40A	0.00	0.00
P40B	0.00	2.76
P40C	4.05	4.14
P40D	0.00	0.03
TOTAL	**4.63**	**7.01**

The historic firm yield was determined for the following two existing dam sites: Sarel Hayward Dam and Golden Ridge Dam, as well as for a proposed dam site called Bushfontein Dam.

Golden Ridge Dam can yield 0.002 and 0.23 x 10^6 m³/a with and without provision for the ecological reserve requirements respectively. The following tables summarise the yield results for the two other dam sites.

Table 7.1.2B: Sarel Hayward Dam Yield - (10^6 m³/a)

Pump Rate	FSL 38.9 mamsl Vol = 2.52 x $10^6 m^3$	FSL 42.3 mamsl Vol = 3.41 x $10^6 m^3$	FSL 48.0 mamsl Vol = 5.12 x $10^6 m^3$	FSL 55.0 mamsl Vol = 8.46 x $10^6 m^3$
150	1.55	1.73	2.08	2.44
200	1.89	2.11	2.49	3.07
250	1.89	2.39	2.76	3.35
300	1.89	2.56	2.95	3.59

- Existing NGL at wall = 10.0 mamsl
- Existing Dead Storage Level (DSL) = 25 mamsl
- Existing Full Supply Level (FSL) = 38.9 mamsl

Bushfontein Dam Yield - (10^6 m³/a)

DSL (mamsl)	FSL (mamsl)	Capacity ($\times 10^6 m^3$)	Yield Without ERR	Yield With ERR
290.2	298	1.919	6.11	4.51
286.3	288	0.049	4.35	2.32

The current net available yield of Sarel Hayward Dam is 1.55×10^6 m³/a, after allowing for some flushing of the dam in order to control the water quality. The objective is to get a future yield of about 3×10^6 m³/a by raising the existing dam wall and by upgrading the capacity of the abstraction pump station. From the yield results it is evident that the wall should be raised by 12 m to a Full Supply Level (FSL) of 50.9 mamsl and water should be supplied at a pumping rate of 250 l/s in order to achieve a yield of 3×10^6 m³/a.

According to the height-area-capacity curves, the proposed Bushfontein Dam will have a storage capacity of 0.049×10^6 m³ and 1.919×10^6 m³ in order to produce yields of 2.32×10^6 m³/a and 4.51×10^6 m³/a respectively.

7.1.3 Water Quality

Figure 5.1 illustrates the geological zones for the study area. From this figure it is evident that the Cape Supergroup covers the greatest portion of the northern, central, eastern and southern parts of drainage region P. The Cape Supergroup consists of the Bucketed and Wittenberg Groups that are both of marine origin. Rainfall on these terrains result in flushing of salts released by weathering and the leaching of salts by water percolating through the soils and weathered zone. Water leaching over the Bucketed Group shale’s result in 0.3 g salt/kg rock and water draining through soils developed over the Bucketed Group yield 0.8 – 4 g salt/kg soil. As a result, 25 – 50 tons of salt are expected to be leached per mm of rain, resulting in surface runoff having a TDS of over 2 200 mg/l, given rainfalls of 600 mm/a. Peak TDS is encountered during the first flush of runoff, with a lowering TDS generally appearing several days after peak flows. **Table 7.1.3** indicates the expected average TDS and upper level TDS after rainfall events in the main rivers for each tertiary catchment.

Table 7.1.3 TDS of Main Rivers

Tertiary Catchment	Quaternary Catchment	River	Mean TDS (mg/l)	Upper Level TDS (mg/l)
P10	P10A	New Years River	140	500
	P10B	New Years River	500	3 500
	P10E	Bushmans River	2 200	4 000
P30	P30A	Kariega River	250	1 400
	P30B	Kariega River	2 500	5 500
P40	P40A	Kowie River	825	1 300
	P40C	Kowie River	1 700	

The predicted runoff quality for each of the main rivers in the study area can be summarised as follows:

Bushman's River - P10

In the Bushmans River, good water quality (Class I) can be expected down stream to include Quaternaries P10A-D, which are the New Years and upper Bushmans rivers to Alicedale. South of Alicedale, water quality deteriorates rapidly due to significant salt loads originating from the Manage and Weltered Formations. Runoff continues to become progressively more saline downstream.

Kariega River – P30

In the Kariega catchment acceptable water quality is only present in the head waters of the Kariega, P10A and the headwaters of the Assegai, P30B, which is partially underlain by Westport quartzites. Below the Settlers Dam in catchment P30B water quality deteriorates rapidly due to salt loads from the Weltered shales and irrigation return flows.

Kowie River - P40

In the Kowie River, water quality is acceptable in the headwaters, which are underlain by Dwyka, Lake Mentz and Witpoort rocks (P40A). Water quality deteriorates once the river flows over Weltevrede rocks north of Bloukrans pass. Salinisation is also expected due to irrigation in the Belmont valley of the Bloukrans, south east of Grahamstown.

Boknes and Diepkloof rivers – P20

In the Boknes catchment, good quality water can only be expected from springs emanating from the Alexandria Formation at the base of the Nanaga Formation at its contact with the Bokkeveld. The Boknes River itself flows over Bokkeveld rocks and water quality deteriorates rapidly down channel.

The Diepkloof is an intermittent river with internal drainage into the back dune regions. Water quality of springs draining the Nanaga is generally poor.

7.2 GROUNDWATER

Details regarding the results of the groundwater resources investigations undertaken for this study are offered in the supporting report **Albany Coast Groundwater Potential**. The following paragraphs provide an overview and a brief summary of the results with specific reference to the development potential of the groundwater resources within the study area.

Regional perspective

Groundwater resources of drainage region P are currently not being utilised to their full potential. The present groundwater use in the study area is estimated to be in the order of 2.4×10^3 m³/a. In general, the groundwater harvest potential for the area is positive, subject to the water quality and environmental approval. Although many of the towns within the study are already rely on groundwater as the primary water source, more groundwater sources can be harvested in a sustainable manner to augment the water supply to certain areas. The minimum groundwater harvest potential along the coastal zone (where the biggest shortages occur), varies between 25×10^3 m³/a/km² and 50×10^3 m³/a/km², depending on the underlying geology. Groundwater harvest potential further inland varies between 7.5 x 10^3 m³/a/km² and 15 x 10^3 m³/a/km², again depending on the underlying geology. **Table 7.2A** summarises the harvest potential for every aquifer within the Ndlambe Municipal boundary.

Table 7.2A: Minimum Harvest Potential per Aquifer

Aquifer	**Area** (km^2)	**Harvest Potential** ($m^3/a/km^2$)	**Potential Supply /day** ($10^3m^3/d$)	**Potential Supply** ($10^6m^3/a$)
Unconsolidated (Schelmhoek Fm)	39.17	100 000	10 700	3.92
Semi-Consolidated (Nanaga Alexandria Fms)	340.27	25 000	23 300	8.51
Arenaceous Fractured Rock (Witpoort Fm)	501.55	15 000	20 600	7.52
Argillceous Fractured Rock (Bokkeveld, Lake Mentz, Weltevrede, Ecca, Dwyka Fms)	1 125.72	10 000	30 800	11.26
TOTAL	**2 006.71**		**85 500**	**31.21**

The actual exploitation potential of an aquifer is lower than the harvest potential and an exploitation factor is applied to the harvest potential to determine the quantity that can practically be abstracted. From the total harvest potential quantity for the Ndlambe Municipal area, only **7.49 x 10^6 m³/a** can be utilised in a sustainable manner without overexploiting the sources. **Table 7.2B** includes the total utilisable groundwater resources for the different aquifers.

Table 7.2B: Utilisable Groundwater Resources by Aquifer

Aquifer	**Area** (km^2)	**Exploitation Factor**	**Exploitation Potential** ($10^6m^3/a$)	**Utilisable Resources*1** ($10^6m^3/a$) Exp. Fact Cl I	**Utilisable Resources*2** ($10^6m^3/a$) Exp. Fact Cl II
Witpoort Fm (Western Belt)	190.47	0.50	2.86	0.46	0.97
Witpoort Fm (Central Belt)	59.22	0.50	0.89	0.14	0.30
Witpoort Fm (Eastern Belt)	251.77	0.50	3.78	0.60	1.28
Weltevrede Fm	660.97	0.30	2.54	0.28	0.63
Bokkeveld Gp	222.70	0.20	0.57	0.00	0.00
Lake Mentz Fm	220.33	0.30	0.85	0.08	0.12
Nanaga & Alexandria Fms	340.27	0.30	2.35	0.26	1.00
Karoo SuperGp	21.72	0.30	0.08	0.01	0.02
Schelmhoek Fm	39.17	0.65	5.70	0.79	3.16
TOTAL	**2 006.62**		**19.62**	**2.62**	**7.48**

*1: The total utilisable groundwater of quality equal to Class 0 or I

*2: The total utilisable groundwater of quality equal to Class II

Table 7.2C provides a summary of the maximum utilisable groundwater within each quaternary catchment of the Ndlambe Municipal area. This area covers all the coastal towns where the major water supply problems are experienced.

Table 7.2C: Utilisable Groundwater per Quaternary Catchment

Quaternary Catchment	Area (km^2)	Average Yield per Borehole	Harvest Potential ($10^6 m^3/a$)	Exploitation Potential ($10^6 m^3/a$)	Max Utilisable Groundwater ($10^6 m^3/a$)
P10G	256	1.40	3.87	1.93	0.00
P20A	270	1.17	9.51	4.75	1.87
P30B	195	0.88	2.48	1.24	0.15
P30C	68	1.02	1.99	0.99	0.50
P40A	51	0.59	0.65	0.26	0.08
P40B	257	0.90	3.26	1.63	1.14
P40C	342	0.69	13.11	5.24	2.04
P40D	246	1.76	3.14	1.89	0.63
Q93D	321	1.09	3.80	1.9	0.89
TOTAL	**2 006**		**41.81**	**19.83**	**7.30**

A few areas from the fractured Witpoort Aquifer are considered to have relatively high groundwater potential and have been identified throughout the study area; these are listed below:

- **Bushfontein Farm:** Situated about 22 km north-west of the town Kenton on Sea, potential yield of 800 m³/d
- **Merville Farm:** Situated about 18 km north of the town Kenton on Sea, potential yield of 800 m³/d
- **Barville Park / Glendower Farm:** Situated about 6 km west of the town Port Alfred, potential yield of 1 000 m³/d
- **Fords Party:** Situated about 10 km east of the town Bathurst, potential yield of 1 000 m³/d
- **Palmietheuval Farm:** Situated about 4 km north-east of the town Kleinemonde, potential yield of 800 m³/d
- **The Grove Farm:** Situated about 10 km north-east of the town Bathurst, potential yield of 800 m³/d

Another source with high potential yields is the Intergranular Coastal Aquifers. Boreholes drilled in those areas are expected to yield in the order of 3 to 5 l/s of Class I and Class II water. **Table 7.2B** provides a summary of these sources and its potential yields.

Table 7.2B: Potential of Dune Aquifer Systems

Well Field / Aquifer	Area (km²)		Storage Capacity	Available to Develop	
	Dunes	Back Dunes	($10^6 m^3$)	(m^3/d)	($10^6 m^3$/a)
Cape Padrone - Fishkraals	11.00	13.00	12.00	2 274	0.83
Apies River	9.70	15.30	6.25	2 082	0.76
Diaz Cross	1.08	7.00	4.00	603	0.22
Kwaaihoek	0.52	4.50	2.50	329	0.12
Sunshine Coast Nature Reserve	1.30	10.20	3.00	767	0.28
Bushman's River Mouth	0.42	1.20	0.81	192	0.07
Port Alfred East	0.80	1.76	1.28	329	0.12
Rufanes River	0.80	1.65	0.61	575	0.21
Riet River	0.80	1.30	0.52	300	0.11
Claytons Rock	0.80	0.95	0.43	300	0.11
Fish River Lighthouse	0.80	1.15	0.49	300	0.11
TOTAL	**28**	**58**	**31.89**	**8 055**	**2.84**

Some of the sources from the dune aquifer system, like Kwaaihoek and Sunshine Coast well fields, fall within the jurisdiction of the Sanparks and permission from the Department of Environmental Affairs and Tourism (DEAT) is required before any implementation processes for the development of these sources can commence.

In general, supplementing the supplies with groundwater can eliminate some of the current and projected shortages at the coastal towns. Drilling depths will vary between 100 m to 180 m with success rates of between 30% and 60%. Groundwater resources are available to augment the supplies to the coastal towns and are less expensive to develop than surface water for instance. Supply from groundwater sources can be a relatively quick and inexpensive solution to some of the current problems, but it is not enough to meet the total demand up to the year 2025. Conjunctive use of groundwater sources and alternative sources such as surface water or desalinated water is inevitable and has been investigated and results are discussed in more detail in **Section 8** of the report.

Groundwater Quality

Marine lithologies, shale-dominant and limestones, account for 72% of the surface area by outcrop, whereas chemically inert quartzites make up the remaining 28%. This marine-originated geology causes salinization or mineralisation of groundwater, which results in poor quality water. Generally the quality of groundwater varies between a Class I and II. Over-pumping of coastal aquifers result in saline intrusions that cause the water quality to deteriorate. This is currently the phenomenon during peak seasons when water demands are higher than during normal periods. **Table 7.2C** gives an indication of the mean TDS of the groundwater for each quaternary catchment.

Table 7.2C: TDS of Groundwater for each Quaternary Catchment

Quaternary	P10A	P10B	P10C	P10D	P10E	P10F	P10G	P20A
Mean TDS (mg/l)	353	1 342	1 088	896	2 957	2 828	2 642	2 334
Quaternary	**P20B**	**P30A**	**P30B**	**P30C**	**P40A**	**P40B**	**P40C**	**P40D**
Mean TDS (mg/l)	2 537	600	2 197	1 151	2 481	2 508	2 364	2 151

Economic Considerations

The costs of exploring and developing groundwater sources will be considerably lower than to transfer surface water due to the long distances and high pumping heads of the possible surface water schemes. The cost of establishing and maintaining a groundwater supply scheme may, in certain coastal area, prove to be a factor encouraging its development.

As a first order estimate, the average yield of the coastal dune aquifer well points in the study area is expected to be in the order of 2.0 to 3.0 l/s per borehole, while the fractured aquifers have an average yield of 4 l/s per borehole. It is recommended that environmental impact assessments be initiated if groundwater is considered to be an acceptable solution for the current problems at the coastal towns.

8. DEVELOPMENT OPTIONS

This part of the report deals with the identification, sizing, costing and evaluation of the development options required to augment the sources of water supply in certain towns within the study area, which were specified in the Terms of Reference.

8.1 POPULATION NUMBERS IN THE AFFECTED TOWNS

The present and projected population numbers in the affected towns were estimated in accordance with the methodology described in detail in **Section 3.1.** The results are shown in the table below.

Table 8.1: Projected population numbers per urban centre

Quat.	Town	Population numbers				
		2001	2005	2015	2025	Seasonal
P10G	Kenton on Sea/ Bushmans	9 480	12 745	13 734	14 539	15 000
P20A	Alexandria	7 715	8 371	9 178	8 720	-
	Boknes / Cannon Rocks	931	1 422	2 573	2 949	2 500
P40C	Port Alfred	20 965	27 526	35 376	40 542	15 000
	Bathurst	5 549	6 497	6 445	6 227	-
P40D	Kleinemonde	1 450	1 833	2 156	2 471	2 000

As seen from the above table the projected population growth rates vary substantially – from 0.5% per annum in the case of Alexandria to 5% per annum in the case of Boknes and Cannon Rocks. The estimated additional seasonal population is also shown.

8.2 PROJECTED WATER REQUIREMENTS FOR THE AFFECTED TOWNS

The projected water requirements have been estimated on the basis of the methodology described in detail in **Section 4.1.**

Table 8.2: Projected water requirements, capacity of existing source and deficit

Town	Total gross water requirements				Exist. source	Growth	Deficit
	10^6 m^3/a				10^6 m^3/a	%	%
	2001	2005	2015	2025	2005	2005 to 2025	in 2005
Kenton on Sea/ Bushmans	0.66	0.91	1.21	1.49	0.52	64%	-75%
Alexandria	0.52	0.62	0.79	0.76	0.65	23%	5%
Cannon/Boknes	0.18	0.25	0.46	0.53	0.24	109%	-5%
Port Alfred	1.27	2.16	3.04	3.90	1.73	81%	-25%
Bathurst	0.26	0.34	0.39	0.41	0.30	23%	-12%
Kleinemonde	0.05	0.08	0.12	0.16	0.15	88%	44%

For the period 2005 to 2025 the water requirements are expected to grow from as little as 23% in Alexandria and Bathurst, to 88% in Port Alfred, and 109% in Cannon Rocks and Boknes. The growth in the water requirements is illustrated in **Figure 13.2**.

The deficit in the capacity of the existing water source, compared to the water requirements in 2005 is the greatest for Kenton on Sea/Boesmansriviermond (-75%) followed by Port Alfred (-25%). This indicates that the water supply situation in these towns is the most critical.

8.3 OUTLINE OF PLANNING CONSIDERATIONS

8.3.1 Reasons for water supply problems

Most of the affected towns currently experience severe water supply problems, which are related to one or more of the following reasons:

- **Poor water quality**. All towns except Alexandria are supplied with water with salinity levels exceeding the ones recommended for long-term use (TDS less than 1 000 mg/l). During normal periods the TDS for the water supplied to these towns exceeds 1 400 mg/l, but during certain periods could reach levels as high as 3 000 mg/l. This is associated with the specific geological conditions in the lower part of the drainage region, where these towns are located.
- **Inadequate capacity of the existing water sources**. The water resources with acceptable water quality in the drainage region are very scarce. As seen from **Table 8.2** the water sources for some of the affected towns have inadequate capacity to meet the present water requirements and an urgent augmentation is required. None of the sources are adequate to meet the 2025 requirements.
- **Inadequate capacity of the bulk supply infrastructure**. Some of the affected towns located in the coastal area are holiday destinations. The summer peak factors (SPF) in these towns vary in the range of 1.5 to 1.8 of the annual average daily demands (AADD), while the extreme peaks can reach as high as 3 times the AADD. In some cases the bulk supply infrastructure (water treatment plants, storage reservoirs, bulk supply conveyance system) have inadequate capacity to provide for the peak requirements.

8.3.2 Possible sources of supply

Owing to the high ecological reserve requirements (see **Table 4.5B**), the available run-of-river yields are insufficient to supply the demands of the study area at the required assurance level of 98%. Therefore, run-of-river schemes are considered not feasible and do not form part of the proposed development options. More detailed information is available in the supporting report on surface water quality.

The surface water quality is poor in the middle to lower reaches (a belt within about 40 to 50 km from the coast line) of the study area, with expected TDS levels varying between 1 000 to 2 500 mg/l. Any surface water sources located within these reaches are expected to yield water of poor quality. Conveying water from surface sources located beyond the problematic areas is expected to be costly. More detailed information is available in the supporting report on stream flow hydrology.

At present, groundwater sources are considered to be under-utilised with only some coastal aquifers currently developed. Areas with high potential for groundwater development were identified during the course of this study. Exploration drilling was also done. The results of the groundwater investigations are summarised in **Section 7.2**, and detailed in the supporting report **“Groundwater Resources”**. In general, the yields per borehole are expected to be low (not exceeding 4 l/s), and the water quality in the lower reaches of the study area is expected to be poor (possibly Class II and higher). However, potential sites with superior water quality have been identified mostly in the coastal aquifer.

The expected yield of acceptable quality groundwater appears to be sufficient to supply the towns of Alexandria, Cannon Rocks/Boknes and partially Kenton on Sea. However, some of the identified sources are located within the environmentally sensitive coastal dunes. Any exploration of these resources will be subject to acceptable environmental impact management measures.

Desalination of seawater through the process of reverse osmosis is currently used as one of the sources of supply to Kenton on Sea and Boesmansriviermond. Subject to the acceptability of the high operation and maintenance costs, this technology is suitable for the study area as it produces water of a superior quality.

8.3.3 Water usage and conservation

No sufficient data was available to assess the current losses in the distribution networks of the affected towns. The water requirement projections were based on the assumption that best water conservation and demand management practices will be maintained.

At present, the water is generally being used wisely. Owing to the poor water quality supplied to most of the affected towns, most of the households have rainwater harvesting facilities. Most of the upmarket houses and some of the public developments are also equipped with a dual internal plumbing system, which distributes only the harvested rainwater for domestic use. In these cases the municipal supply is used predominantly for gardening. The usage of bottled water for cooking and drinking purposes is a common practice for those who can afford it. The effect of the utilisation of rainwater has not been considered as this source of supply generally has low assurance.

The water requirements have been estimated assuming that normal levels of water consumption will occur. The reducing effect on the projected consumption caused by the present supply of water with sub-standard quality has not been taken into account because the water supplied in future can be of a better standard.

8.4 IDENTIFICATION OF DEVELOPMENT OPTIONS

This section describes the criteria for identification of development options to meet the water requirements until 2025 for each of the affected towns. A detailed description of the existing infrastructure and its capacity is available in **Section 5**. The layouts of the proposed development options are illustrated in **Figures 13.1 and schematic diagrams S1 to S6**. The milestone parameters for all options described in the sub-sections below are summarised in a tabular form in **Table 8.4** at the end of this section.

8.4.1 Alexandria

Background

The overall water supply situation at Alexandria is considered not to be critical yet. Alexandria had a total water usage of 0.52 x 10^6 m³/a in 2001 and the projected requirement for the year 2025 is 0.76 x 10^6 m³/a. The growth of the projected water requirements is moderate when compared to some of the coastal towns. The summer peak factor is low at 1.2.

Currently the town is supplied with groundwater abstracted from coastal springs near Cape Padrone and two well points near Fishkraal, both located some 20 km to the south of the town. The existing water source yields water of good quality and has a capacity of 0.65 x 10^6 m³/a, which will meet the projected requirements until 2007. The existing bulk conveyance system has a capacity of 0.60 x 10^6 m³/a, which is inadequate to meet the peak requirements. Projects to upgrade the capacity of this system to match the capacity of the existing source have been identified and are included in the water services development plan.

Development options

In order to meet the projected water requirements until 2025, additional water sources with a capacity of 0.11 x 10^6 m³/a would be required.

The supply from surface water does not appear to be economically and technically feasible. The water quality of potential surface sources located within an economical distance would be inadequate for human consumption. An option to supply the town from the existing New Years Dam, which has acceptable water quality, has been investigated at a conceptual level. Owing to exceptionally high costs this option was abandoned. Similarly, the option to supply the town from a regional scheme via Port Alfred and Kenton on Sea was found not to be feasible.

Owing to the relatively low additional source capacity required, it appears that the supply from groundwater would be appropriate. Apart from the dune aquifer source, part of which is currently used to supply the town, no other suitable groundwater development sites are available. The nearest other potential groundwater source is located on the farm Bushfontein, some 15 km away from the town. That source has however been utilised for the development options to supply Kenton on Sea.

An additional source with a capacity of 0.40 x 10^6 m³/a has been identified. This source is located in the dune aquifer adjacent to the existing well fields at Fishkraal and has been used for the development option to supply Alexandria (**Option 1A: GW**) described below. The layout of the proposed scheme is shown in **Figure S1**.

The proposed development entails:

- Develop and equip 6 boreholes at the Fishkraal dune source - total yield 11 l/s (for 12 hours pumping per day)
- Construct a new conveyance system from the water source to the town, including 19 km of pipeline (12.5 l/s), 2 pump stations (12,5 l/s), 2 break pressure tanks (50 m³ each) and an additional bulk reservoir of 800 m³.

It should be noted that the proposed water source is located within an environmentally sensitive National Park, which falls under the jurisdiction of the Sanparks. The implementation of this development option will be subject to acceptable environmental considerations. An environmental impact assessment (EIA) report has been submitted for consideration by the relevant authorities. The outcome is being awaited.

Should developments in the coastal dunes not be allowed, further investigations to identify alternative groundwater sources are recommended.

If no suitable groundwater resources can be identified, the last resort would be to include Alexandria into a regional scheme via Kenton on Sea at a very high capital cost.

8.4.2 Cannon Rocks and Boknes

Background

The overall water supply situation at Cannon Rocks and Boknes is not ideal. The total water usage in 2001 is estimated at 0.18 x 10^6 m³/a and the projected requirement for the year 2025 at 0.53 x 10^6 m³/a. The towns are holiday resorts with summer peak factors exceeding 1.5. Substantial housing developments in the towns are already evident.

Currently the town is supplied with groundwater abstracted from 3 boreholes located within the boundaries of Cannon Rocks, with a total capacity of 0.24 x 10^6 m³/a. The water quality of the source is poor. Although the source has sufficient capacity to meet the present average daily requirements, the capacity is inadequate during peak periods. At present the boreholes supply 2 reservoirs with a total capacity of 1 000 m³ through the joint reticulation system of the towns.

Development options

In order to meet the projected water requirements until 2025, an additional water source with a capacity of 0.29 x 10^6 m³/a will be required. The supply from surface water does not appear to be economically and technically feasible. The water quality of potential surface water sources located within an economical distance would be inadequate for human consumption.

Owing to the relatively low additional source capacity required, it appears that the supply from groundwater would be appropriate. A potential groundwater source with adequate water quality and capacity has been identified in the dune aquifer at Apies River, some 2 km to the west of Cannon Rocks. In addition, a private borehole yielding about 0.06 x 10^6 m³/a is available close to Cannon Rocks, which, subject to negotiations with the property owner, can be used in the interim to bridge the high peak requirements.

The development option to supply the towns of Cannon Rocks and Boknes (**Option 2CR: GW**) is described below. This option is based on the groundwater source at Apies River.

- Develop and equip 12 boreholes at the Apies River dune source - total yield 34 l/s at 12 hours pumping per day (0.56 x 10^6 m³/a).
- Construct a new conveyance system from the water source to Cannon Rocks, including 2.5 km of pipeline (34 l/s), pump station (34 l/s), 2 bulk reservoirs with a total capacity of 1 800 m³.

The layout of the proposed scheme is shown in **Figure S2**. It should be noted that the proposed water source is located within an environmentally sensitive National Park, which falls under the jurisdiction of the Sanparks. The implementation of this development option will be subject to acceptable environmental considerations. An environmental impact assessment (EIA) report has been submitted for consideration by the relevant authorities and the outcome is being awaited.

Should developments in the coastal dunes not be allowed, further investigations to identify alternative groundwater sources are recommended.

As it is unlikely that groundwater with acceptable quality standards can be identified in the area, the development of brackish groundwater sources in combination with reverse osmosis desalination facilities could provide an alternative, but at higher capital and running costs.

8.4.3 Kenton on Sea and Boesmansriviermond

Background

The overall water supply situation at Kenton on Sea and Boesmansriviermond is critical. The total water usage in 2001 has been 0.44 x 10^6 m^3/a, but the projected requirements for the years 2005 and 2025 are estimated at 0.91 x 10^6 m^3/a and 1.49 x 10^6 m^3/a respectively. This is owing to expected growth within the existing towns, as well as owing to considerable proposed new housing developments of about 1 100 houses. The towns are holiday resorts with summer peak factors exceeding 1.5. At present the total production flows from all water sources are 0.52 x 10^6 m^3/a, which is insufficient to meet the present requirements even during low demand periods. The water supply system is completely inadequate to supply the peak holiday requirements. Water restrictions and outages are often evident, despite the facts that water is being used wisely and that rain water harvesting facilities are available at each stand. Urgent measures to upgrade the capacity of the water sources are required.

Currently the towns are supplied with water from 6 well points at Diaz Cross, which is mixed with desalinated water from a Reverse Osmosis (RO) plant that is fed from both seawater and brackish water boreholes.

The Diaz Cross well field has a total capacity 0.30 x 10^6 m^3/a. The water quality is typically class II with TDS values around 1 400 mg/l. However, owing to continuous supply deficit this capacity is often exceeded, leading to over-exploration of the resource and the intrusion of sea water. The water is pumped from the source to the bulk reservoirs in town, where it is being mixed with the desalinated water from the RO plant.

The RO plant has a total installed membrane capacity of 50 m^3/hr (0.44 x 10^6 m^3/a). It is supplied from 6 brackish water and 5 sea water boreholes with a total yield of 1 600 m^3/day (0.60 x 10^6 m^3/a). The RO plant has an average output efficiency of 38% (water in/water out). Owing to problems with various components of the RO plant system the total present production flows are limited to 25 m^3/hr (0.22 x 10^6 m^3/a). The following interventions for the upgrading of the capacity of the RO plant have been identified and included in the WSDP:

- Upgrading of the power supply to the RO plan
- Upgrading of the brine disposal infrastructure
- Construction of a direct sea water intake
- Installation of an additional module to the RO plant with a capacity of 10 m^3/h.

The implementation of the proposed interventions is subject to the acceptance of an environmental management plan, which has already been submitted. The outcome is still pending. If implemented these interventions will lead to the increase of the production capacity of the RO plant to 60 m^3/hr (0.53 x 10^6 m^3/a). The total capacity of the available water sources will then be 0.83 x 10^6 m^3/a, which is equal to the estimated requirements in 2004.

Future water sources

In order to meet the projected water requirements until 2025, after the upgrading of the RO plant, additional water sources with a capacity of 0.63 x 10^6 m^3/a would be required.

The supply from surface water as a local scheme does not appear to be economically and technically feasible. The water quality of potential surface sources located within an economical distance from the town would be inadequate for human consumption. Even if the water quality issue is ignored, the available assured run-of-river flows in the Bushmans and Kariega Rivers are insufficient to meet the future requirements. An option to develop a dam at the Bushfontein site was investigated at conceptual level, but was found to be unacceptable owing to prohibitively high costs and water quality problems.

It is considered that the only feasible option based on surface water would be to supply the town as part of a larger regional scheme. In order to achieve economic viability, such a scheme has to include the supply to Port Alfred. This option has been investigated and is described below.

However, owing to the fact that the augmentation of the water source is very urgent, and that the development of a major regional scheme is expected to take considerable time, options to develop groundwater resources have been investigated. The immediate implementation of available groundwater resources can provide a relief to the critical situation and can postpone the time for the development of a regional scheme.

The following groundwater development sources have been identified during this study:

- Dune aquifer at Kwaaihoek with an estimated capacity of 0.11 x 10^6 m^3/a near Boesmansriviermond.
- Bushfontein field within the Witpoort FM with and estimated capacity of 0.29 x 10^6 m^3/a, about 22 km north west of the town.
- Merville field within the Witpoort FM with an estimated capacity of 0.29 x 10^6 m^3/a, about 17 km north of the town.

Based on the desktop analysis of the hydrogeological conditions it appears likely that additional economically feasible groundwater resources could be available within the Witpoort belt, to the south east of Merville. The exact position of such developments has not been identified with certainty during this study, therefore no specific conveyance infrastructure has been sized and costed.

Development options

All options described below include the following common components:

- Upgrading of the capacity of the RO plant as described above to 60 m^3/hr (0.53 x 10^6 m^3/a) at a cost of R5.33 million including VAT.

- Development of the Kwaaihoek groundwater source with a capacity of 0.11 x 10^6 m³/a at a cost of R0.82 million including VAT.
- The existing groundwater source at Diaz Cross with a capacity of 0.30 x 10^6 m³/a and its conveyance system are utilised.

Both developments are however subject to acceptable environmental management plans and approval by the environmental authorities. An application for approval of the upgrading for the RO plant has been submitted, but the outcome is still pending. Owing to objections from one single property owner the approval has been delayed.

The following options for the supply of Kenton on Sea have been identified and evaluated.

Option 3: KOS: GW: This option is based on the existing resources and on the development of new groundwater resources. It includes the utilisation of the existing Diaz Cross well field, the upgrading of the RO plant, the development of the Kwaaihoek well field and the development of both Merville and Bushfontein groundwater resources. The associated infrastructure includes the following components and its layout is shown in **Figure S 3.1 and S 3.2**:

- Develop and equip 4 boreholes at the Kwaaihoek well field with a total yield of 6.9 l/s (12 hr).
- Install a pipeline (6.9 l/s, length 1000 m) discharging into the existing 100 m³ balancing reservoir currently supplied from the Diaz Cross boreholes. The existing pumping station and rising main conveying the flows from the balancing reservoir have sufficient capacity to utilise the additional flows and do not need to be upgraded.
- Upgrade the capacity of the existing RO desalination plant to 60 m³/hr (0.29 x 10^6 m³/a).
- Develop and equip 3 boreholes at the Bushfontein well field with a total yield of 18.5 l/s (12 hr), or 0.29 x 10^6 m³/a.
- Develop and equip 5 boreholes at the Merville Farm well field with a total yield of 18.5 l/s (12 hr), or 0.29 x 10^6 m³/a.
- Build a new conveyance system from the Merville and Bushfontein sources to the new town reservoirs. This system includes about 26 km of pipeline with 2 balancing reservoirs and 3 break pressure tanks (BPT), 4 pump stations, each with a balancing reservoir.
- Construct 2 new reservoirs with a capacity of 1 500 m³ each.
- Construct an earth fill balancing reservoir with a capacity of 13 000 m³, to provide sufficient storage capacity to meet the exceptionally high seasonal peak requirements.

Option 4a: KOS: RO1: This option is based on the existing resources and on the development of a new reverse osmosis plant designed to desalinate sea water. It includes the utilisation of the existing Diaz Cross well field, the upgrading of the existing RO plant to 60 m^3/hr, and the construction of an additional sea water RO plant with a capacity of 100 m^3/hr. The associated infrastructure includes the following:

- Develop and equip 4 boreholes at the Kwaaihoek well field with a total yield of 6.9 l/s (12 hr).
- Install a pipeline (6.9 l/s, length 1000 m) discharging into the existing 100 m^3 balancing reservoir currently supplied from the Diaz Cross boreholes. The existing pumping station and rising main conveying the flows from the balancing reservoir has sufficient capacity to utilise the additional flows and do not need to be upgraded.
- Upgrade the capacity of the existing RO desalination plant to 60 m^3/hr (0.29 x 10^6 m^3/a).
- Install 8 sea water desalination RO plant units with a total production capacity of 2 400 m^3/d (0.90 x 10^6 m^3/a).
- Construct a sea water intake and filtration infrastructure with a capacity of 6 000 m^3/d (2.2 x 10^6 m^3/a).
- Construct a brine disposal facility with a capacity of 3 600 m^3/d (1.3 x 10^6 m^3/a).
- Install power supply infrastructure.
- Install a conveyance system from the RO plant to the town reservoirs consisting of a pump station, balancing reservoir (100 m^3) and a rising main (3.5 km).
- Construct 2 new reservoirs with a capacity of 1 500 m^3 each.
- Construct an earth fill balancing reservoir to provide sufficient storage capacity, to meet the exceptionally high seasonal peak requirements, with a capacity of 13 000 m^3.

Option 4b: KOS: RO2: This option is based on the existing resources and on the development of a new reverse osmosis plant designed to desalinate brackish water. It includes the utilisation of the existing Diaz Cross well field, the upgrading of the existing RO plant to 60 m^3/hr, and the construction of an additional brackish water RO plant with a capacity of 100 m^3/hr. The associated infrastructure includes the following:

- Develop and equip 4 boreholes at the Kwaaihoek well field with a total yield of 6.9 l/s (12 hr).
- Install a pipeline (6.9 l/s, length 1000 m) discharging into the existing 100 m^3 balancing reservoir currently supplied from the Diaz Cross boreholes. The existing pumping station and rising main conveying the flows from the balancing reservoir have sufficient capacity to utilise the additional flows and do not need to be upgraded.
- Upgrade the capacity of the existing sea water RO desalination plant to 60 m^3/h (0.53 x 10^6 m^3/a).

- Install 8 brackish water desalination RO plant units with a total production capacity of 2 400 m³/d (0.90 x 10^6 m³/a).
- Develop brackish water well fields and a conveyance system to the RO plant with a capacity of 3 800 m³/d (1.4 x 10^6 m³/a). It has been assumed that a groundwater source with the required capacity would be available and that its development would be environmentally acceptable.
- Construct a brine disposal facility with a capacity of 1 400 m³/d (0.50 x 10^6 m³/a).
- Install power supply infrastructure.
- Install a conveyance system from the RO plant to the town reservoirs consisting of a pump station, balancing reservoir (100 m³) and a rising main (3,5 km).
- Construct 2 new reservoirs with a capacity of 1 500 m³ each.
- Construct an earth fill balancing reservoir with a capacity of 13 000 m³.

Option 5: KOS: SW: This option is based on the existing resources and on the development of a new conveyance system to supply water from a regional scheme via Port Alfred. It includes the utilisation of the existing Diaz Cross well field, the upgrading of the existing RO plant to 60 m^3/hr, the development of the Kwaaihoek well field and the construction of the necessary infrastructure required for the supply of Kenton on Sea as part of a larger regional scheme. Glen Melville Dam is to be used as a water source for the regional scheme. Possible layouts are shown in **Figure 13.1**. This option has been developed in order to test the feasibility of a possible future regional scheme, when compared to the local schemes described above. More details about this option are available in **Section 8.4.4**. The infrastructure includes:

- Develop and equip 4 boreholes at the Kwaaihoek well field with a total yield of 6.9 l/s (12 hr).
- Install a pipeline (6.9 l/s, length 1000 m) discharging into the existing 100 m³ balancing reservoir currently supplied from the Diaz Cross boreholes. The existing pumping station and rising main conveying the flows from the balancing reservoir have sufficient capacity to utilise the additional flows and do not need to be upgraded.
- Upgrade the capacity of the existing sea water RO desalination plant to 60 m³/h.
- Install a new conveyance system to supply water from Port Alfred to Kenton on Sea (2 400 m³/d, 23 km).
- In order to determine the incremental cost associated with the supply to Kenton on Sea of the jointly utilised infrastructure (water treatment and conveyance from Glen Melville to Port Alfred) the regional scheme supplying Port Alfred has been sized and costed for two options – with and without provision for the supply of Kenton on Sea. See Options 6 and 7 in the following section.

An option to supply the regional scheme from the existing New Years Dam has been investigated at a conceptual level. It was found that this option is not competitive and was not investigated any further.

Option: Recharge the coastal aquifer with treated effluent: Late during the course of the study the idea to consider the utilization of treated effluent from the existing water treatment plants to recharge the coastal aquifer was suggested by the DWAF. Although this is an interesting idea, which can contribute to the solution of the problems, we did not have sufficient time to investigate it in detail. However the following comments are offered:

- At present the effluent is discharged in wetlands from where it is disposed of by means of evaporation and infiltration.
- It is technically possible to divert the discharge into the natural stream, which terminates at the back of the dunes currently used as a source of brackish water for the RO plant. There is a direct geohydrological link between the stream and the coastal aquifer. Therefore the aquifer can be recharged and can increase the exploration capacity, which can be utilised in conjunction with Option 4b.
- Owing to the environmental sensitivity of the area, the implementation of the above is subject to an EIA and approval. One matter of concern is that this method is likely to substantially increase the salinity levels of the aquifer, beyond acceptability. Previous studies indicated that salinity could be increased by about 300 mg/l per cycle. In the case of the coastal aquifers, which are already saline, any additional increase of TDS may have an irreversible environmental impact.
- Only the newly-developed suburbs to the north of the main road are provided with water-borne sanitation and the effluent is treated at two purification works at Ekuphumeleni and at Marselle. The main towns of Boesmansriviermond and Kenton on Sea are not serviced. The volumes of discharged effluent are not being measured, but rough estimates show that these are not significant - in the order of 0.15×10^6 m³/a, which is only about 16% of the water requirements in 2005.

More detailed investigations, including an EIA are required before further consideration to this option can be given.

Option: Dual water supply system: An option to implement a dual water supply and distribution system (two separate systems: one with good quality water for potable use, and another with inferior quality for other household use) in Kenton on Sea was investigated superficially at a conceptual level. It was found that this option would be costly and was not considered any further. The following comments are offered:

- The implementation of such a system is likely to reduce the requirements from the RO plant, but not the overall requirements. This is expected to somewhat reduce the running costs for the bulk supply system. The development of additional sources would however still be required. The effect on the overall capital requirements to meet future demands is not expected to be significant.
- The cost to construct a new duplicate system was estimated at about R30 million including construction costs, professional fees and VAT. This however excludes the internal plumbing work within each property, which could cost an additional R5 million.
- The above costs exclude the costs for the development of the additional water resources required to meet the future demands

8.4.4 Port Alfred

Background

At present the overall water supply situation at Port Alfred is not critical as far as the water source is concerned. However, the town reservoirs and the internal reticulation system do not have sufficient capacity to meet the peak seasonal water requirements. The water quality of the source is poor, with salinity levels often exceeding 1 700 mg/l. The total water usage in 2001 was 1.27 x 10^6 m³/a, but the projected requirements for the years 2004 and 2025 are estimated at 1.6 x 10^6 m³/a and 3.90 x 10^6 m³/a respectively. The substantial growth in water requirements from 2005 onwards can be attributed to a great extent to the significant low-cost housing development planned to be implemented shortly (5 000 new houses and 1 800 stands to be upgraded to house connections). This would render the existing source insufficient and would require urgent augmentation. The town is a holiday resort with summer peak factors exceeding 1.8.

At present the assured yield of all water sources supplying the town is about 1.73 x 10^6 m³/a. The existing water sources and bulk supply systems are described below:

Sarel Hayward Dam: This is an off-channel storage dam constructed in 1988 with a gross storage capacity 2.5 x 10^6 m³ and assured yield of 1.55 x 10^6 m³/a. The dam is situated about 13 km north west of Port Alfred. It has an earth fill embankment wall with a height of 40 m, which regulates the small catchment of a tributary to the Kowie River. The dam is being supplied with water from run-of-river flows collected at the weir constructed across the Kowie River. The water is pumped from the weir to the dam by a pump station through a rising main (700 m long, 350 mm ND, steel), both with a maximum capacity of 150 l/s. Provision for the release of the Ecological Reserve has been made. From the dam, the water is conveyed to an earth-fill balancing reservoir (16 000 m^3) near the hospital by a conveyance system consisting of 2 pump stations and a pipeline (11 km long, 300/250 mm ND) with a capacity of 50 l/s. From there water gravitates to the water treatment works (5 000 m^3/day) in town, about 2 km further to the south east. From the treatment works the water is pumped to 4 distribution reservoirs.

Mansfield Dam: This dam has a gross storage capacity of 0.17 x 10^6 m³ and assured yield of 0.05 x 10^6 m³/a. The dam is situated about 10 km north of Port Alfred. It is an earth fill embankment dam with a wall height of 14 m. The water from the dam can gravitate into the balancing reservoir in Port Alfred through a 6.5 km, 150 mm ND pipeline with a capacity of 15 l/s. The pipeline is currently out of order.

Dune well fields: two well fields located to the east of Port Alfred, with a combined yield of 0.13 x 10^6 m³/a have been developed to exploit the coastal aquifer. Water from the wells is being pumped directly into the East Bank distribution reservoir during times of peak requirements.

Future water sources

In order to meet the projected water requirements until 2025 the development of additional water sources with a capacity of 2.17 x 10^6 m³/a would be required. This is a significant increase of 125% compared to the existing capacity.

The groundwater resources in the area have been investigated during this study and two potential drilling sites with an estimated combined yield of 0.63 x 10^6 m³/a were identified. The sites (the Glendower field and the Sunshine Coast dune field) are located some 7 km to the west of the West Bank reservoir of Port Alfred.

Further potential groundwater development sites could possibly be located within the Witpoort belt to the east of the town, but the exact position of such developments could not be identified with any degree of certainty. Therefore, only the afore-mentioned well fields have been used as possible development options.

In general, taking into consideration the substantial additional capacity of the water source required to meet future demands, it is unlikely that the long term requirements from the source can be met by groundwater alone. The exceptionally high seasonal peak factors applicable to this system further support that statement. We are of the opinion that a surface water storage scheme would eventually be required to meet the long-term requirements. However, the development of the available groundwater resources would provide the much needed relief to the present water supply situation and will postpone the timing for the implementation of a regional surface water storage scheme.

The water quality of potential surface sources located within an economical distance from the town is inadequate. Even after regular flushing of the Sarel Hayward Dam, the water quality of this source is poor (class II). Water with superior quality can be sourced from other dams located further inland.

The combined available assured run-of-river flows in the entire drainage region P are insufficient to meet the augmentation requirements for the town. Therefore a storage scheme would be required. The following surface water sources have been considered:

Glen Melville Dam: This is an off-channel storage dam located on the Ecca River (Fish River catchment) some 68 km north of Port Alfred. The water in the dam is supplied from the Orange River via the Hermanuskraal weir and the Fish-Ecca tunnel, which has a capacity of 500 x 10^6 m³/a. The dam has an assured yield of 7.3 x 10^6 m³/a, but this yield can be increased by increasing the transfers from Orange River. It is currently being used as a balancing reservoir for the supply to Grahamstown. The existing bulk supply system from the dam to Grahamstown, consisting of water treatment works, a pump station and a rising main, has a capacity of 3.65 x 10^6 m³/a. The present quantity of water supplied to Grahamstown is in the order of 2.4 x 10^6 m³/a. Therefore, sufficient yield in the dam is available for transfers to Port Alfred. Spare capacity in the bulk supply system is also presently available, but later this system can be upgraded. Furthermore, the water supplied from this dam is of a good quality, with salinity levels about 600 mg/l.

Settlers Dam: This dam is located on the Kariega River, some 45 km north west of Port Alfred. The dam has a wall height of 21 m, gross capacity of 5.6 x 10^6 m³ and assured yield of 3.1 x 10^6 m³/a, of which 2.2 x 10^6 m³/a is used for the supply of Grahamstown. The quality of water supplied from this dam is good. Due to its more favourable position, this dam can be used as a source of supply for Port Alfred, but in this case the supply from Glen Melville Dam to Grahamstown has to be increased.

Sarel Hayward Dam: The yield of this dam can be increased by rising of the dam wall and by upgrading the capacity of the weir pump station and the conveyance system. The water quality supplied will however not improve (currently in the order of 1 700 mg/l).

New Years Dam: This dam has sufficient surplus capacity and its water quality is of a good standard. An investigation at conceptual level has been done to use this dam as a source for augmentation of the supply to Port Alfred. However, due its location about 120 km away from Port Alfred, this option was found to be less attractive and was abandoned.

Development options

All options described below include the utilisation of the existing water resources together with the development of the groundwater resources at Glendower and the Sunshine Coast. These developments will meet the requirements until about 2010, which will provide sufficient time for further investigations and implementation of additional schemes.

- Development of the Glendower/Barville groundwater source with a capacity of 0.36×10^6 m³/a. Equip 5 boreholes with a total yield of 23 l/s (12 hr).
- Development of the Sunshine coast groundwater source with a capacity of 0.27×10^6 m³/a. Equip 9 boreholes with a total yield of 18 l/s (12 hr).
- Develop a conveyance system to deliver the water from the source to the West Bank reservoir in town. This system consists of 4 km rising mains, 5 km gravity mains and a 500 m³ balancing reservoir.

Both developments are however subject to acceptable environmental management plans and approval by the environmental authorities.

The following development options have been sized to supply the balance of the requirements for Port Alfred in 2025, which is 1.55×10^6 m³/a.

Option 6: PA: GM1: PA, BT and KoS: This option is based on the existing resources, the development of the proposed two groundwater resources, together with the construction of the necessary infrastructure from Glen Melville Dam. This option has been sized to supply a regional scheme, which includes the towns of Port Alfred, Bathurst and Kenton on Sea. It includes the utilisation of the existing water sources at each town and provides for the supply of the deficit in available resources (2.25×10^6 m³/a) to meet the water requirements in year 2025. The associated infrastructure includes the following components and its layout is shown in **Figure 13.1.**

- Develop groundwater resources in Barville / Glendower and the Sunshine Coast and the associated conveyance system to Port Alfred, as specified above. Develop and equip 9 boreholes at the well field - total yield 18 l/s (12 hr).
- Construct a new conveyance system from the existing Glen Melville Dam via Grahamstown and Bathurst to Port Alfred and further to Kenton on Sea. This system includes:
  - the upgrading of the dam intake works
  - the upgrading of the capacity of the water treatment works and the pump station at the dam (144 l/s). Despite the fact that the existing infrastructure currently has sufficient capacity to convey the required additional flows, a provision for the upgrading has been made as the required transfers for Grahamstown are expected to increase with time.
  - a new rising main (8.5 km, 400 mm ND, steel) from the dam to the reservoir site in Grahamstown
  - new balancing reservoir in Grahamstown with a capacity of 2 500m³
  - new gravity main from Grahamstown to Port Alfred via Bathurst, 59 km, 400 mm and 300 mm ND
  - 4 break pressure tanks, 250 m³ each
  - New gravity main from Port Alfred to Kenton on Sea, 23 km, 200 mm ND
  - New reservoirs at Bathurst (1 200 m³) and at Port Alfred (15 000 m³).

Option 7: PA: GM2: PA and BT: This option is identical to Option 6, but excludes the supply to Kenton on Sea. It is sized to supply only the additional requirements based on the existing resources, the development of the proposed two groundwater resources, together with the construction of the necessary infrastructure from Glen Melville Dam. This option has been sized to supply a regional scheme, which includes the towns of Port Alfred and Bathurst. It includes the utilisation of the existing water sources at each town and provides for the supply of the deficit in available resources (1.69 x 10^6 m³/a) to meet the water requirements in year 2025. The associated infrastructure includes the following components and its layout is shown in **Figure 13.1.**

- Develop groundwater resources in Barville / Glendower and the Sunshine Coast and the associated conveyance system to Port Alfred, as specified above. Develop and equip 9 boreholes at the well field - total yield 18 l/s (12 hr).
- Construct a new conveyance system from the existing Glen Melville Dam via Grahamstown and Bathurst to Port Alfred. This system includes:
    - the upgrading of the dam intake works
    - the upgrading of the capacity of the water treatment works and the pump station at the dam (113 l/s).
    - a new rising main (8.5 km, 450 mm ND, steel) from the dam to the reservoir site in Grahamstown
    - new balancing reservoir in Grahamstown with a capacity of 2 000m³
    - new gravity main from Grahamstown to Port Alfred via Bathurst, 59 km, 300 mm ND
    - 4 break pressure tanks, 150 m³ each
    - New reservoirs at Bathurst (1 200 m³) and at Port Alfred (15 000 m³).

Option 8a: PA: SH: This option is based on the existing resources, the development of the proposed two groundwater resources, together with the raising of Sarel Hayward Dam and the upgrading of the pumping and conveyance system. This option has been sized to supply the deficit in available resources (1.55 x 10^6 m³/a) only for Port Alfred. The associated infrastructure includes the following and its layout is shown in **Figure S4.**

- Develop groundwater resources in Barville / Glendower and the Sunshine Coast and the associated conveyance system to Port Alfred, as specified above. Develop and equip 9 boreholes at the well field - total yield 18 l/s (12 hr).
- Raise the Sarel Hayward Dam wall by 12 m and increase the capacity of the weir pump station and rising main to 250 l/s.
- Develop a new conveyance system from the Sarel Hayward Dam to the water treatment works in Port Alfred consisting of about 13 km of pipeline (93 l/s, 300 mm ND), 2 balancing reservoirs (200 m³ each), 3 delivery pump stations, additional storage capacity of 15 000 m³ in the town, and upgrading of the water treatment works with an additional capacity of 5 000 m³/d.

Option 8b: PA: SH &RO: This option is identical to Option 8a, but includes a RO plant with a capacity to desalinate 50% of the water supplied from Sarel Hayward Dam. When mixed with the rest of the raw water the salinity levels are expected to drop from the current 1 700 mg/l to 850 mg/l. The quality of water supplied by Sarel Hayward Dam is inferior to that supplied from the other surface sources considered for Port Alfred. This option has been investigated in order to bring the various competitive options to the same basis in terms of water quality supplied, so that the options could be compared more realistically. In addition to the infrastructure described above, this option includes the following:

- A RO plant located close to the water treatment works with a capacity of 4 000 m³/d (1.50 x 10^6 m³/a) including the necessary supporting infrastructure.
- A clear water pump station and a 1.3 km rising main to convey the desalinated water to the bulk supply reservoir in town.
- A balancing reservoir with a capacity of 300 m³.

Option 9: PA: SD: This option is similar to Option 6, but instead of supplying the water from Glen Melville Dam, it supplies it from the Settlers Dam. This option is based on the existing resources, the development of the proposed two new groundwater resources, together with the construction of the necessary infrastructure to deliver water from the Settlers Dam to Port Alfred. It also includes the upgrading of the bulk supply infrastructure from the Glen Melville Dam to Grahamstown and a new link pipeline from Botha's Hill Reservoir (currently supplied by the Glen Melville Dam) to the town reservoirs in the south (currently supplied from the Settlers Dam). This infrastructure is provided in order to compensate Grahamstown for the lost yield from Settlers Dam. This option is sized to supply only Port Alfred with a total yield of 1.55 x 10^6 m³/a. The associated infrastructure includes the following components and its layout is shown in **Figure 13.1.**

- Develop groundwater resources in Barville / Glendower and Sunshine Coast and the associated conveyance system to Port Alfred, as specified above. Develop and equip 9 boreholes at the well field - total yield 18 l/s (12 hr).
- Develop a new conveyance system from the Settlers Dam to Port Alfred consisting of about 45 km of pipelines (capacity of 93 l/s, 300 mm ND) with 4 break pressure tanks (200 m³ each) and a raw water pump station.
- Construction of additional storage reservoirs with a capacity of 15 000 m³ and upgrading of the existing water treatment works at Port Alfred with an additional capacity of 5 000 m³/d.
- Upgrading of the existing water treatment works and clear water pump station at Glen Melville Dam with an additional capacity of 5 000 m³/d.
- Construction of a new rising main from Glen Melville Dam to Botha's Hill reservoir (8.5 km, 350 mm ND) and a by-pass gravity main linking Botha's Hill reservoir with the town reservoirs to the south of Grahamstown (105 km, 300 mm ND).

Option 10: PA: RO: This option is based on the existing resources, the development of the proposed two new groundwater resources, together with the construction of a new RO plant to desalinate sea water and the associated infrastructure. The system consists of the following components:

- Develop groundwater resources in Barville / Glendower and the Sunshine Coast and the associated conveyance system to Port Alfred. Develop and equip 9 boreholes at the well field - total yield 18 l/s (12 hr).
- Install 26 sea water desalination RO plant units with a total production capacity of 7 800 m³/d (2.8 x 10^6 m³/a).
- Construct sea water intake works (or sea water boreholes) including a conveyance system with a capacity of 19 200 m³/d (7.0 x 10^6 m³/a).
- Construct a brine disposal facility with a capacity of 11 400 m³/d (4.20 x 10^6 m³/a).
- Install power supply infrastructure.
- Install a conveyance system from the RO plant to the town reservoirs consisting of a pump station, balancing reservoir (200 m³) and a rising main (2,6 km).
- Construct additional storage reservoirs with a capacity of 15 000 m³ in Port Alfred.

8.4.5 Bathurst

Background

The overall water supply situation in Bathurst is considered to be less critical than that for the coastal towns. The total water usage in Bathurst was estimated at 0.26 x 10^6 m³/a for 2001 and the projected requirement for the year 2025 is 0.41 x 10^6 m³/a, a moderate growth in water use. The summer peak factor is low at 1.2.

Currently, the town is supplied from private boreholes, household rainwater harvesting facilities and mostly from the Golden Ridge Dam (yield 0.25 x 106 m³/a, but without provision for the release of the Ecological Reserve), located about 8 km north of the town. The water is conveyed (capacity 0.5 x 106 m³/a) from the dam via the WTW (0.16 x 106 m³/a) into a bulk supply reservoir (1 000 m³). From there, the water is reticulated into the townships of Nolukhanyo and Freestone. The main town is not provided with water services and relies on private resources. The actual usage from the public water sources (Golden Ridge Dam) is estimated at 0.12 x 106 m³/a. The balance of the water requirements is assumed to be supplied from private sources in the old town.

The existing Mansfield Dam, with an estimated yield of 0.05 x 10^6 m³/a can also be used for the supply of the town, but the conveyance system (0.16 x 10^6 m³/a) is currently out of order.

The total yield from the available water sources is therefore 0.30 x 10^6 m³/a (excluding the private sources), which will be sufficient to meet the present requirements until 2006. The water quality in not good and salinity levels exceed 1500 mg/l. If water services are provided to the old town, the water source has to be augmented. The conveyance system from the Golden Ridge Dam has sufficient capacity (16 l/s, 200 mm ND) to meet the peak requirements. The capacity of the water treatment plant is currently the limiting component.

Development options

In order to meet the projected water requirements until 2025, an additional water source with a capacity of 0.11 x 10^6 m³/a would be required, if the old town is provided with water services. However, an assessment of the Ecological Reserve for the stream on which

Golden Ridge Dam is build needs to be undertaken in order to determine the maximum allowable abstraction from this dam.

The supply from surface water from a local scheme does not appear to be economically and technically feasible. The water quality of potential surface sources located within an economical distance would be inadequate for human consumption.

If a regional scheme supplying Port Alfred from the Glen Melville Dam is developed, the long-term requirements for Bathurst will be supplied. This is covered in Option 6, described in Section 8.4.4.

Owing to the relatively low additional source capacity required, it appears that the supply from groundwater would be feasible. Considering that the implementation of a regional scheme may take some time, it is recommended that a hydrogeological study be undertaken in order to identify potential groundwater development targets. If the augmentation of the water source becomes urgent, the groundwater sources could be developed.

The upgrading of the capacity of the water treatment works would result in an immediate improvement of the water supply situation.

8.4.6 Kleinemonde / Seafield

The overall water supply situation in Kleinemonde is considered to be less critical than that for most of the other coastal towns. The total water usage in Kleinemonde was estimated at 0.05×10^6 m³/a for 2001 and the projected requirement for the year 2025 is 0.16×10^6 m³/a. The summer peak factor is about 1.8. The water quality in not good and salinity levels often exceed 2 000 mg/l.

Currently, the town is supplied from 2 boreholes and from Mount Wellington Dam located about 8 km north west of the town. The total yield of the water sources is about 0.15×10^6 m³/a. The system has sufficient capacity to meet the water requirements during normal periods, but is inadequate to supply the peak seasonal requirements. In order to improve the performance of the system the water treatment works and the storage capacity should be upgraded.

Development options

The supply from surface water from a local scheme does not appear to be economically and technically feasible. The water quality of potential surface sources located within economical distance would be inadequate for human consumption.

Owing to the relatively low additional source capacity required, it appears that the supply from groundwater could be feasible. During the course of this reconnaissance study we have been unable to identify suitable groundwater targets with acceptable quality in the vicinity of the town.

Further hydrogeological investigation on a local scale would be required in order to identify suitable groundwater sources.

Table 8.4 provides a summary of the relevant development options and a brief description of the conveyance system.

The possible timing of implementation of the various components of the development options is shown in **Figure 13.2.**

Table 8.4: Summary of the development options

Option No	Option Name	Towns Supplied	Water Source	Primary Conveyance System
1	Alexandria – GW (1 A : GW)	Alexandria	- Fishkraal GW	- Develop GW with 6 BH's (11 l/s, 12 hr) & 2 PS's (12,5 l/s) - CWRM of 10.5 km (12,5 l/s) - 50 m³ Bal Res, 150 m³ BPT - CWGM of 8.5 km (12,5 l/s) - 800 m³ reservoir
2	Cannon Rocks – GW (2 CR : GW)	Cannon Rocks and Boknes	- Apies River mouth GW	- Develop GW with 12 BH's (34 l/s) - 1 PS (34 l/s) - CWRM of 2.5 km (34 l/s) - 2 town reservoirs (1 800 m³)
3	Kenton on Sea – GW (3 KOS : GW)	Kenton on Sea Boesmansriviermond	- Upgrade RO - Kwaaihoek GW - Merville GW - Bushfontein GW	- Upgrade existing RO plant to 60 m³/hr - Develop Kwaaihoek GW with 4 BH's (6.9 l/s) - CWRM1 of 1 km to existing PS (6.9 l/s) - Develop Merville GW with 5 BH's (18.5 l/s) - 1 CWPS & 3 km CWRM with a 100 m³ Bal Res - Develop Bushfontein GW with 3 BH's (18.5 l/s) - 3 CWPS & 9 km CWRM with a 300 m³ Bal Res - CWGM of 13.5 km & 3 BPT's - New PE lined Bal Dam of 13 000 m³ & new Res's of 3 000 m³
4a	Kenton on Sea – RO1 (4a KOS : RO1)	Kenton on Sea Boesmansriviermond	- Upgrade existing RO - Kwaaihoek - New RO (seawater)	- Upgrade existing RO plant to 60 m³/hr - Develop Kwaaihoek GW with 4 BH's (6.9 l/s) - CWRM1 of 1 km to existing PS (6.9 l/s) - New RO (seawater) plant – 2 400 m³/d - 1 CWPS with a 100 m³ Bal Res & CWRM of 3.5 km - New PE lined Bal Dam of 13 000 m³ & new Res's of 3 000 m³
4b	Kenton on Sea – RO2 (4b KOS : RO2)	Kenton on Sea Boesmansriviermond	- Upgrade existing RO - Kwaaihoek - New RO (brackish water)	- Upgrade existing RO plant to 60 m³/hr - Develop Kwaaihoek GW with 4 BH's (6.9 l/s) - CWRM1 of 1 km to existing PS - Develop brackish water source (3 800 m^3/d) & RWRM of 3.3 km - New RO (brackish) plant – 2 400 m³/d - 1 CWPS with a 200 m³ Bal Res & CWRM of 2.5 km - New PE lined Bal Dam of 13 000 m³ & new Res's of 3 000 m³

5	Kenton on Sea – SW (5 KOS : SW)	Kenton on Sea Boesmansriviermond	- SW from Glen Melville Dam	- Upgrade existing RO plant to 60 m³/hr - Develop Kwaaihoek GW with 4 BH's (6.9 l/s) - CWRM1 of 1 km to existing PS - Surface water (2 400 m³/d) from Glen Melville Dam via PA - New PE lined Bal Dam of 13 000 m³ & new Res's of 3 000 m³
6	Port Alfred – GM 1 (6 PA : GM1: PA, BT, KoS)	Port Alfred Bathurst Kenton on Sea	- Barville / Glendower - Sunshine Coast - SW from Glen Melville Dam	- Develop Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Develop Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Glen Melville Dam (144 l/s) & 1 CWPS - CWRM of 8.5 km & a 2 500 m³ Bal Res - CWGM of 83 km with 4 x 250 m³ BPT's - Bathurst Res 1 200 m³ & PA Res 15 000 m³
7	Port Alfred – GM2 (7 PA : GM 2: PA, BT)	Port Alfred Bathurst	- Barville / Glendower - Sunshine Coast - SW from Glen Melville Dam	- Develop Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Develop Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Glen Melville Dam (112 l/s) & 1 CWPS - CWRM of 8.5 km & a 2 000 m³ Bal Res - CWGM of 59 km with 4 x 150 m³ BPT's - Bathurst Res 1 200 m³ & PA Res 15 000 m³
8a	Port Alfred – SH (8a PA : SH)	Port Alfred	- Barville / Glendower - Sunshine Coast - SW from Sarel Hayward Dam	- Develop Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Develop Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to the 500 m³ Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Port Alfred (106 l/s) - 1 RWPS (250 l/s) at river abstraction - 2 RWPS's (106 l/s) with Bal Res's - RWRM of 7.7 km (93 l/s) & a 200 m³ Bal Res - RWGM of 2.6 km (93 l/s) with a 200 m³ Bal Res - RWGM of 3 km (93 l/s) to WTW - Port Alfred Res 15 000 m³ - Raise Sarel Hayward Dam wall by 12 m, from FSL 38.9 to 50.9

8b	Port Alfred – SH & RO (8b PA : SH & RO)	Port Alfred	- Barville / Glendower - Sunshine Coast - SW from Sarel Hayward Dam - Treat 4 000m³/d by RO	- Develop Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Develop Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to the 500 m³ Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Port Alfred (106 l/s) - 1 RWPS (250 l/s) at river abstraction - 2 RWPS's (106 l/s) with Bal Res's - RWRM of 7.7 km (93 l/s) & 1 200 m³ Bal Res - RWGM of 2.6 km (93 l/s) with 1 200 m³ Bal Res - RWGM of 3 km (93 l/s) to WTW - Port Alfred Res 15 000 m³ - Raise Sarel Hayward Dam wall by 12 m, from FSL 38.9 to 50.9 - Treat 4 000 m³/d of SW through 14 RO units - 1 CWPS (56 l/s) with a 300 m³ Bal Res at RO plant - RWGM of 0.5 km (76 l/s) from WTW to RO plant - CWRM of 1.3 km (56 l/s) from RO to town Res
9	Port Alfred – SD (9 PA : SD)	Port Alfred	- Barville / Glendower - Sunshine Coast - SW from Settlers Dam	- Develop Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Develop Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to the 500 m³ Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Port Alfred (106 l/s) - 1 RWPS (106 l/s) at Settlers Dam - RWRM of 2 km (93 l/s) & 1 200 m³ Bal Res - RWGM of 42.5 km with 4 x 200 m³ BPT's - WTW at Glen Melville Dam (106 l/s) - 1 CWPS (96 l/s) with Bal Res from WTW to Botha's Hill Res - CWRM of 8.5 km (93 l/s) from GM WTW to Botha's Hill Res - CWGM of 10.5 km (93 l/s) from Botha's Hill Res to GTown Res - Port Alfred Res 15 000 m³

10	Port Alfred – RO (10 PA : RO)	Port Alfred	- Barville / Glendower - Sunshine Coast - RO plant (seawater)	- Develop Barville/Glendower GW with 5 BH’s (23 l/s) - CWRM of 2 km (30 l/s) to 1 x 500 m³ Bal Res - Develop Sunshine Coast GW with 9 BH’s (18 l/s) - CWRM of 2 km (24 l/s) to the 500 m³ Bal Res - CWGM of 5 km to PA (54 l/s) - Develop GW source at coast with 15 BH’s (155 l/s) - 1 RWPS (155 l/s) with a 250 m³ Bal Res - RWRM of 2.1 km (155 l/s) & 1 250 m³ Bal Res - New RO (seawater) plant – 7 650 m³/d - 1 CWPS (110 l/s) with a 200 m³ Bal Res - CWRM of 0.5 km (110 l/s) to the town Res - Port Alfred Res 15 000 m³

8.5 SIZING AND COSTING OF DEVELOPMENT OPTIONS

This section describes the methodology applied for the sizing and costing of the development options and should be read in conjunction with **Section 8.4**, which describes the infrastructure components for each development option. The layouts for the development options are shown in **Figure 13.1 and diagrams S1 to S7.** The longitudinal sections for the main conveyance systems are shown in **diagrams L1 to L7.**

All major components of the identified development options have been sized at a reconnaissance level of detail, in accordance with the criteria specified in the following paragraph. The sizing for all system components has been for the projected water requirements in 2025, taking into consideration the available capacities of the existing water sources and the bulk infrastructure. No optimisation of the system components has been done at this stage.

8.5.1 General Sizing Criteria: Design Capacities and Flows

The sizing flows for the main infrastructure components are shown per development option in **Table 8.4** and **Appendix 9**. The criteria used are summarised in the table below.

Table 8.5.1: Design capacities and flow rates for sizing of infrastructure components

System component	Demand definition	Sizing criteria
Sizing criteria		
Regulated water source	Gross Average Annual Daily Demand (GAADD)	AADD * (1+LFr + LFw)
Water treatment works & raw water pump stations	Summer Daily Demand (SDDww)	SPF * GAADD * 24/Op time
Clear water bulk pipelines, clear water pump stations	Summer Daily Demand (SDDpl)	SPF * GAADD * (1-LFw) * 24/operation time
System reservoir storage		AADD * Hours
Boreholes & borehole pump stations	Summer Daily Demand (SDDpu)	SPF * GAADD * (1-Lfw) 24/bh operation time
Selected values		
Parameter	**Parameter**	**Selected values**
Conveyance loss	LFr	10 %
Water treatment loss	LFw	10 %
Summer Peak Factor	SPF	Varies (1.2 to 1.8)
Operating period: WTW, pipelines	Hours per day	20
Reservoir capacity: Single Source	Hours	48
Operating period boreholes	Hours per day	12

8.5.2 Dams: Sarel Hayward Dam

The development options do not include the construction of new dams and weirs. The required additional storage at Sarel Hayward Dam was determined by using the Water Resources Yield Model (WRYM) as described in detail in the supporting report **Stream flow Hydrology**. A number of possible scenarios were modelled, which included variations in the sizes of the two components of the system – pump station and dam capacity. The low flow duration curves and the required Ecological Reserve releases in the Kowie River were taken into account. Provision for flushing (1.4 x 10^6 m^3/a) of the dam in order to manage the water quality has been made. The area-capacity curve for the dam was used to determine the required raising height (12 m).

The dam raising was sized in accordance with the guidelines developed for the VAPS study. The cost models developed for the study were used, but the unit rates were escalated to the April 2004 price levels.

8.5.3 Groundwater Development

The sizing parameters for each identified groundwater development were determined site specifically as detailed in Table 13 of the supporting report **Groundwater Resources**. These parameters include: anticipated yield for the entire well field and per borehole, drilling depth, dynamic water level and success rates. It has been assumed that the boreholes will discharge into a collective storage reservoir or pump sump positioned at a command location, from where the water is transferred to the town reservoirs via rising or gravity mains. The sizing of the supporting infrastructure required for the development of the source was done accordingly. The following supporting infrastructure was sized and the relevant costs were estimated for each groundwater development:

- Source development: Siting, EIA scoping and licensing, drilling and testing
- Provision of power supply to each borehole
- Equipping of boreholes: positive displacement pumps driven by electrical motors, housed in a pump houses, including necessary controls and wiring.
- Rising mains from boreholes to balancing reservoirs
- Conveyance system from the balancing reservoir to the main system reservoir.

8.5.4 Conveyance Systems

The layouts of the conveyance system associated with each development option are shown in **Figure S1** to **S7.** The system components are described in detail in **Section 8.4** and summarised in **Table 8.4**. Each option includes some or all of the following components:

- Raw water pump stations (RWPS)
- Raw water rising mains (RWRM) of raw water gravity main (RWGM)
- Water treatment works (WTW)
- Clear water pump station (CWPS)
- Clear water rising main (CWRM) or clear water gravity main (CWGM)
- Storage reservoir (RES)
- Break pressure tank (BPT), or balancing reservoir (BAL RES)

All components have been sized in accordance with the applicable design flow criteria shown in **Table 8.5.1**. The conceptual longitudinal profiles for selected pipeline routes are shown in **Figures L1 to L7**.

The gravity mains have been sized on the basis of available head, while the pumping mains have been sized on the basis of optimal velocities (in the order of 1.5 m/s). A provision for 50% standby capacity at all pump stations has been made.

The position of the new proposed storage reservoirs has been selected to be in the close vicinity of the existing reservoirs, allowing the feeding of the secondary distribution system by gravity. The reservoirs have been sized for 48 hours of storage capacity.

Some of the development options considered in this study may already include some of the components listed above as part of its existing infrastructure, while others will be newly developed schemes. Where applicable, provision for the upgrading of the existing infrastructure and/or for the development of new infrastructure has been made.

The secondary and tertiary distribution systems, that transfer the water from the town reservoirs to the consumers, have not been investigated and do not form part of this study.

The costing of all components has been done by using cost models, based on all-in-one costs based on the salient parameter of each component: length of pipe with specific size and type, volume of treated water (WTW), volume of storage capacity (reservoirs), etc. The cost for the major mechanical equipment (RO plant, pumps, etc) has been determined on the basis of current actual prices. The cost models are attached in **Appendix 10.1**.

8.6 SUMMARY OF CAPITAL COSTS

A summary of the estimated capital costs per development option is provided in the **Table 8.6.1**. A breakdown per component is shown in **Table 8.6.2**. More detail is available in **Appendix 10**. The capital costs have been estimated at April 2004 price levels and include provisions for preliminary and general items (P&G), contingencies, professional fees and VAT. The economic evaluation taking into account the operation and maintenance, running costs and residual values for all options, is discussed in **Section 8.7**.

Table 8.6.1: Summary Capital Cost Per Development Option

Opt No.	Development Option	Capital costs, R million		
		Water Source	Conveyance	Total
1	Alexandria – 1 A: GW	R 0.255	R 10.354	R 10.609
2	Cannon Rocks – 2 CR: GW	R 0.729	R 4.890	R 5.619
3	Kenton on Sea –3 KoS: GW	R 4.037	R 24.077	R 28.114
4a	Kenton on Sea –4a KoS: RO1	R 19.601	R 15.045	R 34.646
4b	Kenton on Sea – 4b KoS: RO2	R 12.841	R 15.926	R 28.767
5	Kenton on Sea – 5 KoS: SW	R 2.961	R 38.374	R 41.335
6	Port Alfred – 6 PA: GM – PA, BT, KoS	R 2.386	R 128.521	R 130.907
7	Port Alfred – 7 PA: GM – PA, BT	R 2.386	R 95.855	R 98.241
8a	Port Alfred – 8a PA: SH	R 17.159	R 38.025	R 55.184
8b	Port Alfred – 8b PA: SH & RO	R 33.539	R 39.996	R 73.535
9	Port Alfred – 9 PA: SD	R 2.386	R 98.07	R 100.456
10	Port Alfred – 10 PA: RO	R 60.821	R 23.287	R 84.108

8.7 EVALUATION OF DEVELOPMENT OPTIONS

8.7.1 Economic Analysis Model

The most efficient scheme is not necessarily the one associated with the lowest capital costs. Running expenses, which influence the total project cost over the design life of the scheme, such as operation, maintenance and energy costs have to be taken into account. Furthermore the volume and quality of water supplied also has to be weighted in the comparative evaluation of alternatives.

Two economic indicators of performance of the scheme have been employed in accordance with the VAPS guidelines and economic evaluation models:

- Net present cost (NPC)
- Net present value of water (NPV)

The economics model calculates the NPC at various discount rates, based on the capital costs, and the operational and maintenance costs. No phasing in the implementation of the infrastructure has been considered at this stage. The NPV of water has been calculated by applying the same discount rates on the projected annual water supplies. The economic evaluation has been undertaken on the basis of the unit reference value of water (URV = NPC/NPV) estimated for each option. The economic analysis was performed for a 20-year horizon using the following parameters pertaining to the calculation of the operation, maintenance, energy and chemical costs:

- A discount rate of 6% was used, but sensitivity to variation of the rate was tested for 4% and 8%.
- The residual values at the end of evaluation period were established for each scheme component, on the basis of the following assumed design life:
    - 45 years for civil works
    - 30 years for M&E items and pipelines
    - 20 years for boreholes
    - 10 years for borehole pumps and diesel engines.
- The annual operation and maintenance (O&M) costs were estimated as a percentage of the total capital costs. The following percentages were applied for the various types of schemes and components.

Table 8.7.1A: O&M costs as a percentage of the capital costs per type of works

Type of works	Surface Scheme	Boreholes
Civil works	0.5%	1%
Mechanical and Electrical works	4%	10%
Pipelines	1%	2%
Boreholes		3%

Table 8.7.1B: O&M costs as a percentage of the capital costs per component

Development Component	RO Plant	SW Source	GW Source	BH Equip	Pump Station	WTW	RES	Pipe-line
% of capital cost	3.00%	0.85%	1.00%	5.50%	2.78%	1.73%	0.50%	1%

- An estimate of the annual energy costs has been done, and the following rates determined:
    - Energy charge 22.22 c / kWh
    - Demand charge R5.43 / kVA per month
    - Costs of chemicals 63 c / m³

8.7.2 Results of Economic Analysis

The calculated residual values, O&M costs, and energy costs for each option are provided in **Appendix 10.2**. The economic models, including the calculated NPC and URV are provided in **Appendix 10.4**. The following table summarises the results of the economic analysis for all development options.

Table 8.7.2: Results of the Economic Analysis

Option No.	Development Option	Tot Capital Cost (R mil)	Tot Annual O&M (R mil)	Residual Value (R mil)	Max Energy (R mil)	URV of Water, 6 % discount (R/m³)
1	Alexandria – GW	R 10.609	R 0.151	R 3.674	R 0.056	R 15.22
2	Cannon Rocks – GW	R 5.619	R 0.104	R 1.746	R 0.043	R 5.02
3	Kenton on Sea – GW	R 28.114	R 0.425	R 10.008	R 0.483	R 10.08
4a	Kenton on Sea – RO1	R 34.646	R 0.771	R 14.750	R 0.937	R 13.56
4b	Kenton on Sea – RO2	R 28.767	R 0.606	R 9.709	R 0.739	R 11.33
5	Kenton on Sea – SW	R 41.335	R 0.499	R 14.681	R 0.716	R 10.21
6	Port Alfred – GM 1	R 130.907	R 1.538	R 48.291	R 1.539	R 10.68
7	Port Alfred – GM 2	R 98.241	R 1.196	R 36.947	R 1.212	R 9.97
8a	Port Alfred – SH	R 55.184	R 0.622	R 24.331	R 0.496	R 5.70
8b	Port Alfred – SH & RO	R 73.535	R 1.148	R 31.617	R 1.290	R 8.27
9	Port Alfred – SD	R 100.456	R 1.292	R 38.524	R 1.282	R 10.91
10	Port Alfred – RO	R 84.108	R 2.030	R 31.744	R 2.447	R 10.85

It should be noted that the figures regarding the URV in the above table are very rough and are provided only for comparison purposes. Owing to the reconnaissance nature of this study, the phased implementation of the components associated with the development options has not been taken into account in the determination of the URV's. This may have resulted in certain inaccuracy.

8.7.3 Evaluation of Development Options

The evaluation of the development options has been undertaken on the basis of technical viability, economic feasibility, and ecological acceptability, taking into consideration other factors that may influence the developments such as operation and maintenance costs, ecological sensitivity, etc.

Alexandria

Option 1: A: GW: The proposed scheme to augment the water supply to Alexandria by developing additional groundwater resources from the Fishkraal coastal aquifer was the only feasible option identified during this study. The proposed scheme will meet the water requirements in Alexandria until 2025 and the water supplied will be of good quality. The estimated costs associated with this option are: capital costs of R10,61 million, annual running costs R0,15 million and URV R15,22/m^3. The high URV for the scheme is associated with the relatively long and expensive conveyance system.

Despite the high URV, this is the only feasible scheme identified on the basis of the information available at present. The costs to supply water from a possible regional scheme based on sources from either the New Years Dam or the Glen Melville Dam, which can provide water of similar quality, would be higher. No alternative groundwater sources could be identified during the course of this study.

The development of the Fishkraal coastal aquifer located with the Sanparks Nature Reserve is ecologically sensitive and needs to be approved by the Department of Environmental Affairs and Tourism. An EIA report has been prepared and submitted for consideration, but the record of decision is still pending. Should the ecological impacts be unacceptable, the following alternatives should be considered:

- Further groundwater resources investigations to identify alternative resources. If necessary and if water quality is an issue, groundwater developments can be combined with desalination facilities for brackish water
- If no suitable groundwater resources can be identified, the last resort would be to include Alexandria into a regional scheme via Kenton on Sea at a very high capital cost.

Cannon Rocks and Boknes

Option 2: CR: GW: This was the only feasible option identified during this study to augment the water supply to Cannon Rocks and Boknes by developing additional groundwater resources from the Apies River coastal aquifer. The proposed scheme will meet the water requirements until 2025 and the water supplied will be of good quality. The estimated costs associated with this option are: capital costs of R5,62 million, annual running costs R0,10 million and URV R5,02/m^3.

The development of the coastal aquifer located within the Sanparks Nature Reserve is ecologically sensitive. An EIA report has been prepared and submitted for consideration, but the record of decision is still pending. If the ecological impacts are unacceptable, further groundwater investigations should be carried out to identify alternative sources. If necessary and if water quality remains an issue, further groundwater developments can be combined with desalination facilities for brackish water.

Kenton on Sea and Boesmansriviermond

A number of options for the augmentation of the water supply to these towns have been considered. All options include the continued utilisation of the existing Diaz Cross well field (0,3 x 10^6 m³/a), the upgrading of the existing RO plant to a total capacity of 0.53 x 10^6 m³/a and the development of the proposed Kwaaihoek well field with a capacity of 0.11 x 10^6 m³/a. The evaluation of the competitive options follows.

Option 3: KOS: GW: The proposed scheme provides for the augmentation of the water supply by developing additional groundwater resources at Merville and Bushfontein. This scheme can meet the water requirements until 2015 and the water supplied will be of marginal quality (Class II). The estimated costs associated with this option are: capital costs of R28,11 million, annual running costs R0,42 million and URV R10,08/m^3.

This scheme provides the lowest URV of water compared to all options considered for Kenton on Sea, and also requires the lowest capital. The additional advantages of this option are that it is a stand-alone scheme, which is independent from regional developments, implementation can start immediately and can be phased. However, the water quality supplied would be of an inferior standard compared to that for the other options. The capacities of the available groundwater resources in the area are limited (even when considering that some additional resources can be developed in the Witpoort). Therefore, the development of either another local scheme based on RO desalination, or a regional surface water scheme could eventually be required to meet the water demands for 2025. The implementation of this option would however result in an immediate relief of the water supply situation and would postpone the timing for the development of a regional scheme.

The implementation of this option is recommended, subject to the approval of an EIA scoping report.

Option 4a: KOS: RO1: The proposed scheme provides for the augmentation of the water supply by the construction of an additional RO desalination plant based on treatment of sea water. This scheme can meet the water requirements until 2015 and the water supplied will be of good quality (Class I). The estimated costs associated with this option are: capital costs of R34,65 million, annual running costs R0,77 million and URV R13,56/m^3.

This scheme provides the highest URV of water compared to all options considered for Kenton on Sea. The URV for this option is about 35% higher than option 3. The implementation of this option is therefore not recommended.

Option 4b: KOS: RO2: The proposed scheme provides for the augmentation of the water supply by the construction of an additional RO desalination plant based on treatment of brackish water. It has been assumed that a groundwater source with the required capacity would be available and that its development would be environmentally acceptable. This scheme can meet the water requirements until 2015 and the water supplied will be of good quality (Class I). The estimated costs associated with this option are: capital costs of R28,77 million, annual running costs R0,61 million and URV R11,33/m^3.

The URV for this scheme is about 11% higher than for Option 3, which is in the range of inaccuracy of the models used during this reconnaissance stage. This option is feasible, supplies water of good quality and can be implemented either as a stand-alone scheme, or in conjunction with Option 3 (to meet the requirements beyond 2015), but subject to environmental acceptability and the availability of a suitable source of groundwater.

Option 5: KOS: SW: The proposed scheme provides for the augmentation of the water supply from a regional surface water scheme, which uses the Glen Melville Dam as a source. This scheme can meet the long-term water requirements and the water supplied will be of good quality (Class I). The estimated costs associated with this option are: capital costs of R41,33 million, annual running costs R0,51 million and URV R10,21/m^3.

The URV for this scheme is about the same as for Option 3, but the capital required is substantially higher. The advantages of this option are that it can provide a once-off long-term solution (capacity of source is unlimited) and the water quality is of a superior standard. However, the development of this scheme requires substantial capital investment and further more detailed studies to identify the best regional scheme, before implementation can commence. Furthermore, this scheme would only be feasible if developed as part of a regional scheme that includes Port Alfred. It is therefore recommended that this scheme can be considered for future augmentation, but immediate steps to improve the situation should be taken by developing Option 3 first.

The identification of the best regional scheme is discussed in more detail in the next paragraphs.

Port Alfred and Regional Schemes

A number of options for the augmentation of the water supply to Port Alfred have been considered. All options include the continued utilisation of the supply from the existing Sarel Hayward Dam (1.55 x 10^6 m^3/a) and the coastal aquifers to the east of the town (0.11 x 10^6 m^3/a). In addition all options include the implementation of the proposed groundwater developments of the Glendower and Sunshine Coast aquifers to the west of the town with a total yield of 0.63 x 10^6 m^3/a. The following has been established during the course of this study:

- The development of the groundwater resources in the Glendower and Sunshine Coast aquifers can be implemented immediately, subject to environmental acceptability, which needs to be confirmed.
- That development would provide the much needed relief to the present water supply situation and will allow time for further investigations to identify the additional development options
- Despite the fact that additional potential groundwater development sites could possibly be identified within the Witpoort belt to the east of the town, taking into consideration the substantial growth in the water requirements, it can be concluded that it is unlikely that the capacities of those resources would be sufficient to meet the long term requirements of the town (or the region).
- Therefore, it is likely that a regional surface water storage scheme would eventually be required to meet the long-term requirements.

- Owing to the fact that the URV for most options investigated are in a narrow range of ± 20% of average (within the error margin for reconnaissance level) it has not been possible during this reconnaissance study to isolate the best development scheme. Further more detailed studies would be required.

Option 6: PA: GM: PA, BT & KoS: The proposed scheme provides for the augmentation of the water supply for the towns of Port Alfred, Bathurst and Kenton on Sea as a regional scheme, based on water supplied from the existing Glen Melville Dam. This scheme can meet the water requirements in the region until 2025 and the water supplied will be of good quality (Class I). The estimated costs associated with this option are: capital costs of R130,91 million, annual running costs R1,54 million and URV R10,68/m^3.

The advantages of this option are that it has practically unlimited capacity and the water quality is good. However, although the URV for this scheme is in line with the others, its capital requirements are the highest.

Option 7: PA: GM: PA & BT: This scheme is identical to Option 6, but provides for the augmentation of the water supply only for the towns of Port Alfred and Bathurst. The estimated costs associated with this option are: capital costs of 98,24 million, annual running costs R1,20 million and URV R9,97/m^3.

The scheme can be compared directly with Option 8b (supply from the Sarel Hayward Dam combined with desalination) and Option 9 (supply from the Settlers Dam). The URVs are very similar and a selection could not be made on the basis of the reconnaissance level of investigation.

Option 8a: PA: SH: This option provides for the augmentation of the water supply to Port Alfred based on increasing the yield from the Sarel Hayward Dam achieved by rising of the dam wall and upgrading of the associated infrastructure. The water quality will not improve from current levels (Class II). This option offers the best economic parameters of all options considered: capital costs of R55,18 million, annual running costs R0,62 million and URV R5,70/m^3. However, the quality of water supplied would not be of the same standard as for the other options. It should also be noted that the Sarel Hayward Dam is located in a very environmentally sensitive area and the raising of the wall will be subject to an acceptable EIA.

Option 8b: PA: SH & RO: This option is identical to Option 8a, but in addition it also includes a RO desalination infrastructure with a capacity to desalinate 50% of the water supplied from the Sarel Hayward Dam. This option has been investigated in order to bring the quality of the water supplied from the Sarel Hayward Dam to a level similar to the one supplied from the other options. This would allow for more realistic comparison of the options.

The estimated costs associated with this option are: capital costs of R73,54 million, annual running costs R1,15 million and URV R8.27/m^3. The URV of water supply is lower than that for the other options supplying good quality water, but a final decision cannot be made at this early stage. The development of this option is subject to an acceptable environmental impact associated with the raising of the Sarel Hayward Dam and the construction of a RO plant near the town.

Option 9: PA: SD: The proposed scheme provides for the augmentation of the water supply to Port Alfred, based on water supplied from the existing Settlers Dam. This option is similar to Option 7, and in fact relies on the surplus yield available at the Glen Melville Dam, but through a different conveyance system. The water supplied will be of good quality (Class I). The estimated costs associated with this option are: capital costs of R100,45 million, annual running costs R1,30 million and URV R10,91/m^3. The economic parameters are similar to the ones for Option 7.

Option 10: PA: RO: The proposed scheme provides for the augmentation of the water supply to Port Alfred, based on water supplied through a newly proposed RO desalination plant. The water supplied will be of good quality (Class I). The estimated costs associated with this option are: capital costs of R84,11 million, annual running costs R2.03 million and URV R10,85/m^3. The economic parameters are similar to the ones for Options 6, 7 and 9.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 DEVELOPMENT OPTIONS/SCHEMES

9.1.1 Introduction

The water supply situation in most of the affected towns is not ideal and steps for the augmentation of the water sources need to be taken. However, the situation in Kenton on Sea/Boesmansriviermond, Cannon Rocks/Boknes and Port Alfred is critical and emergency measures for augmentation of the water sources for these towns are urgently required.

Where possible, this study has identified solutions to the water supply problems that present themselves for immediate implementation. In other cases, more detailed investigations have been recommended to be undertaken before final decisions on the best solutions can be made. A summary of the cost estimates for the proposed augmentation schemes is given in **Section 8.6** and more detail is available in **Appendix 10**. A detailed description of the components of the proposed schemes is given in **Section 8.4** and a summary in **Table 8.4.**

The specific recommendations for each town are offered in the next paragraphs. The responsibility for further actions is indicated in brackets and in bold print after each recommended action. Where the Ndlambe Local Municipality (NLM) has been identified as the responsible institution, they will most likely have to rely on Municipal Infrastructure Grant (MIG) funding. The NLM should draw up an implementation strategy, based on the recommendations in this report. Provision of direct financial assistance from DWAF for implementation of infrastructure is unlikely. However, when the implementation strategy is completed, NLM can approach DWAF for further advice and assistance. Where possible, it terms of current legislation, DWAF will do its best to assist.

When estimating the water requirements it has been assumed that the best water demand management measures would be implemented. In all towns, projects are recommended to assess the levels of existing losses in the bulk supply and reticulation systems, to propose measures for the reduction of those losses and to undertake the necessary remedial work. This will ensure that the limited resources are utilized in the most efficient manner. **(NLM, but DWAF can provide assistance in terms of advice).**

The NLM should not allow substantial housing developments in the most affected towns before solutions to the severe water supply problems are identified and implemented.

9.1.2 Alexandria

- The existing water source (Fishkraal coastal aquifer) has sufficient yield to meet the projected water requirements until 2007. Thereafter the source needs to be augmented.
- The water quality of the source is of acceptable standard.

- The additional water source from the Fishkraal coastal aquifer, identified during the course of this study, has sufficient capacity to meet the water requirements until 2025 and beyond. The development of this source can commence as soon as a record of decision from the Department of Environmental Affairs and Tourism (DEAT) is received. (**NLM, funding from MIG, but DWAF can assist with advice).**

- The NLM should follow up with the DEAT with regards to the outcome of the application for approval of the further exploration of the Fishkraal costal aquifer submitted earlier.

- If the Fishkraal coastal aquifer development is acceptable from an environmental point of view, the source should be developed and the phasing of the upgrading of the bulk supply system should be optimized. The total capital cost for this development is estimated at R10.6 million at April 2004 price levels (**NLM, but DWAF can assist with advice).**

- The existing bulk supply system is undersized and needs to be upgraded urgently. However, a decision on the likely additional water source needs to be made before the upgrading of this system. (**NLM, funding from the MIG as budgeted for in the Water Services Development Plan (WSDP)).**

- If the Fishkraal coastal aquifer development is not acceptable, the existing bulk supply system should be upgraded to the capacity of the source. This will ensure adequate water supply until 2007. Further groundwater investigations should be undertaken at the same time in order to identify alternative groundwater sources. Investigations should include studies and exploration drilling. (**NLM to appoint a specialised consultant, but DWAF can assist with advice).**

- It should be noted that at a capital cost exceeding R10 million the proposed scheme based on the Fishkraal coastal aquifer is already relatively expensive. Owing to the shortage of water sources with acceptable water quality standards in the area, the alternatives to that scheme, which include the utilization of inland surface water, or groundwater, are expected to be prohibitively expensive.

9.1.3 Cannon Rocks/Boknes

- Although the existing Cannon Rocks water source (boreholes) is theoretically adequate to meet the projected water requirements of Cannon Rocks and Boknes until 2005, the water is of poor quality and the pattern of demand makes supply during the peak holiday season very expensive and unreliable. The water source needs to be augmented urgently.

- Additional storage capacity will be required within the bulk supply system to meet the growing peak requirements **(NLM).**

- The coastal aquifer at the Apies River has sufficient supplementary yield of acceptable quality to meet the projected future requirements at least until 2025. Subject to the approval of the EIA report, this source should be developed at an estimated cost of R5,6 million. (**NLM, but DWAF can be approached for advice).**

- The NLM should follow up with the DEAT with regards to the application for the development of the Apies River coastal aquifer submitted earlier.

- If the Apies River development is not acceptable, further investigations should be undertaken in order to identify alternative groundwater sources. Investigations should include studies and exploration drilling (**NLM to appoint a specialised consultant, but DWAF can be approached for advice)**.
- As it is unlikely that groundwater with acceptable quality standards will be identified in this coastal area, the use of brackish groundwater in combination with reverse osmosis desalination facilities could be considered as an alternative to the proposed Apies River coastal aquifer development. (**NLM to appoint a specialised consultant, but DWAF can be approached for advice).**

9.1.4 Kenton on Sea and Boesmansriviermond

- The existing water sources (Diaz Cross aquifer and a sea water desalination plant) are unable to meet the present water requirements even during low consumption periods. The system is severely stressed during peak periods. Water restrictions and even water outages are common. Urgent measures for the augmentation of the water source need to be taken.
- The water of the coastal aquifer sources (Diaz Cross and Kwaaihoek) is saline, but when mixed with desalinated water, the product is of an acceptable quality.
- The coastal aquifer at Kwaaihoek with a yield of 0.11 million m³/a can be developed reasonably quickly as the existing bulk supply system from Diaz Cross has sufficient capacity to convey the additional flows. The development of this source at an estimated cost of R800 000 will bring some relief to the water supply situation, but the total yield of all sources will still be insufficient to meet the present water requirements.
- The Albany Coast Water Board (ACWB) on behalf of NLM should immediately appoint a consultant to prepare and submit an EIA and scoping report for the development of this source for approval by DEAT.
- If approval is granted, the source should be developed urgently as a fast track project (**ACWB and NLM, but DWAF will support with advice).**
- Concurrently with the above, the ACWB should follow up with the DEAT on the application submitted earlier regarding the proposed upgrading of the RO plant.
- If the upgrading is approved, the proposed upgrading of the RO plant should be implemented urgently as a fast track project at an estimated cost of R6.0 million. This will increase the combined capacity of the water sources by 0.3 million m³/a. The combined available yield will then be sufficient until 2006. (**ACWB and NLM, funding from the MIG as budgeted for in the WSDP).**
- The ACWB should immediately appoint a consultant to prepare and submit an EIA and scoping report for the development of the proposed Merville and Bushfontein groundwater sources and the associated bulk supply conveyance systems**.**
- Concurrently, a geohydrological consultant should be appointed to evaluate the potential for development of the rest of the Witpoort formation to the south east of Merville. The study should include exploration drilling and testing. **(ACWB and NLM, but DWAF can be approached for advice).**

- Once the extent of the possible future development of the overall Witpoort formation is established and DEAT approval is received, the Merville groundwater source (yield 0.29 million m³/a) should be developed and the bulk conveyance system between Merville and Kenton on Sea should be optimised and constructed as a fast track project. The capital cost of this development is estimated at R12 million. If this source is developed the total combined yield of all sources will be sufficient until about 2010. (**ACWB and NLM, funding from the MIG).**

- The development of the Bushfontein groundwater source (yield 0.29 million m³/a) and/or other groundwater sources, which may be identified within the Witpoort aquifer, together with the associated conveyance system should follow when required for further augmentation of the source. The incremental cost for the development of the Bushfontein source is estimated at R9 million. If this source is developed the total combined yield of all sources will be sufficient until about 2015. (**ACWB and NLM, possible funding from the MIG, DWAF can assist with advice).**

- At that later stage, the water supply situation will have to be reviewed through additional studies, which need to identify the best further development options to follow. **(NLM, but DWAF can be approached to provide assistance in terms of management and funding for the study)**. At least the following options should be considered:

    - Construction of an additional RO plant sourced by sea water, or brackish water, including a possibility to recharge the coastal aquifer with effluent (subject to confirmation of the availability of a brackish water source with the required capacity, acceptable environmental impact, and if the water quality problems associated with the creation of a closed loop can be resolved).

    - Development of a regional surface water scheme, which would include the supply to Port Alfred. Such a regional scheme is discussed in the following section.

9.1.5 Port Alfred and Regional Schemes

- At present the existing water sources (Sarel Hayward Dam and boreholes) are sufficient. However, substantial proposed new housing developments will most likely necessitate the urgent upgrading of the source before 2006.

- The water quality of the existing sources is below the acceptable standard.

- The internal reticulation system and balancing storage reservoirs do not have sufficient capacity to meet the peak seasonal requirements and urgent upgrading is required **(NLM, MIG funding).**

- Additional groundwater sources with anticipated acceptable water quality and a total yield of 0.64 million m³/a have been identified to the west of the town in the areas of Glendower and Sunshine Coast. With the development of these sources the water requirements will be met until about 2007, which will provide much needed relief to the present water supply situation and will allow time for further investigations to identify the best augmentation option to follow.

- The NLM should immediately appoint a consultant to prepare and submit an EIA and scoping report for the development of this source for approval by DEAT.

- If approval is granted, the source and the associated conveyance system should be developed urgently as a fast track project at an estimated cost of R 8,0 million **(NLM, but DWAF can assist with advice).**
- A more detailed study should urgently be commissioned in order to assess the feasibility of a possible regional scheme (inter-basin transfer, or joint inter-municipal water supply scheme) to supply Port Alfred and to other towns in the area. Such scheme should be implemented before 2008 at an estimated cost varying between R47 million and R92 million depending on the option selected. **The study can possibly be funded and managed by the DWAF, but the NLM should formally request the Regional Office of the Department for assistance).**

The study should include the following components and activities:

Engineering aspects:

- o Overall study management and co-ordination of the multidisciplinary team
- o Review of water requirements and water resources
- o Review and identification of competitive options. Consider supply from: groundwater, raising of the Sarel Hayward Dam, Glen Melville Dam, Settlers Dam, desalination of sea or brackish water, etc.
- o Site investigations and surveys: geotechnical, land surveys, etc as required
- o Engineering sizing and costing based on preliminary designs and site specific information
- o Economic models and evaluation
- o Implementation strategy, including programmes and funding sources

Hydrogeological aspects:

- o Undertake further hydro-census and field investigations into the potential for development of groundwater sources for the supply of Port Alfred, Bathurst, Kleinemonde and Kenton on Sea.
- o Undertake exploration drilling and testing in order to determine the parameters of each identified source

Ecological aspects:

- o Undertake site surveys and acquire necessary field information
- o Determine the Ecological Reserve at specific surface water development sites
- o Produce EIA and scoping reports for approval by the DEAT for the selected development options
- o Public participation and shareholder involvement

It is anticipated that such study can be completed in 18 months at an estimated cost of about R3,0 million.

- A decision on the implementation of further augmentation options should be taken on completion of the afore-mentioned study. **A number of institutions should be party to such a decision, e.g. DWAF, Cacadu DM, NLM, Makana DM, DEAT, etc.**

9.1.6 Bathurst

- The existing water source (Golden Ridge Dam) has sufficient yield to meet the present water requirements until about 2006. However, if the old town is provided with water services, the water source will have to be upgraded. Also an Ecological Reserve determination should be carried out to verify the yield of the Golden Ridge Dam. This should be included in the scope of services for the study referred to in the previous section.
- The water quality of the existing sources is below the acceptable standard.
- The capacity of the existing water treatment works is insufficient and needs to be upgraded urgently as a fast track project **(NLM, MIG funding).**
- The augmentation of the existing water source can be done through one of two options:
    - Supply from a possible regional scheme, which is developed to supply Port Alfred, if the bulk supply system runs near Bathurst. Clarity on this longer term option will be available on completion of the study referred to in the previous section.
    - If augmentation is urgent, local groundwater sources should be sited and developed **(NLM, but DWAF can assist with advice)**.

9.1.7 Kleinemonde / Seafield

- The existing water sources (Mount Wellington Dam and boreholes) have sufficient capacity to meet the present water requirements during normal periods, but not during peak season. Normal requirements can be supplied until about 2015.
- The water quality of the existing sources is below the acceptable standard.
- The capacity of the existing water treatment works is insufficient and needs to be upgraded urgently as a fast track project **(NLM, MIG funding).**
- The capacity of the existing storage reservoirs should be increased in order to provide for peak requirements **(NLM, MIG funding).**
- The NLM should appoint a consultant to verify the yield of the Mount Wellington Dam **(NLM, DWAF can be approached for technical assistance).**
- The augmentation of the available water source could be done through the development of additional groundwater sources. The NLM should appoint a specialised consultant to identify potential drilling sites. **(NLM, but DWAF can assist with advice).**

9.2 IMPLEMENTATION STRATEGY

- NLM is the institution responsible for the implementation of the actions recommended in this report.
- NLM should draw up an implementation strategy for the actions recommended in this report, taking into account the water supply situation in each town, the availability of funds and resources within the municipality and the timing for implementation.
- NLM can appoint a consultant, familiar with the water infrastructure and the water resources in the area, to assists with the compilation of such strategy.
- In the implementation strategy, NLM should make provision for water demand and water loss management project in the affected towns.
- On the basis of the implementation strategy, NLM should seek assistance and support (financial, advisory, etc.) form the Cacadu District Municipality and other institutions and authorities. DWAF should also be approached to discuss the details of the advisory assistance that can be provided.
- NLM should not allow new substantial developments before solutions to the severe water supply problems can be found and implemented.

APPENDIX 1

REFERENCE LIST

REFERENCE LIST

Reference No	Details
1	Ninham Shand Inc, 2002. Report No. P 15000/00/0101. *Fish to Tsitsikamma Water Management Area*, Water Resource Situation Assessment, Vol 1 – Main Report
2	Ninham Shand Inc, 2002. Report No. P 15000/00/0101. *Fish to Tsitsikamma Water Management Area*, Water Resource Situation Assessment, Vol 2 – Appendices
3	Markdata (Pty) Ltd, 2001. Report No. P RSA /00/2200. *The Distribution of South Africa's Population, Economy and Water Usage Into the Long Term Future*
4	BKS, 2003.Report No. P WMA 15/000/00/0203. *Fish to Tsitsikamma Water Management Area*, Overview of Water Resources Availability and Utilisation
5	Department of Water Affairs, 1988. Report No. OKS/1/88. *Report on Preliminary Investigations Into Various Means of Supplying Supplementary Water to the Albany Coast Water Board* (This report was never finalized and was only issued in a Draft format).
6	Van Wyk & Louw Inc, 1991. Report No. P400/xx/0191. *Investigation Into the Possible Contribution of the Proposed Bushmans River Water Transfer Scheme to Towns in the Lower Bushmans River Valley*
7	Water Services Development Plan, 2003.Report No: 24526 Ndlambe Municipality
8	Kwezi V3 Engineers, 2003. Report No: 161780Q0. Water Services Development Plan, Makana Munic ipality (Draft)
9	Kwezi V3 Engineers, 2003. Report No: 161800Q0. Water Services Development Plan, Sundays River Valley Municipality (Draft)
10	Ninham Shand Inc, 2003. Report No: 400014.Water Service Development Plan, Blue Crane Route Municipality (Draft)
11	Ninham Shand Inc, 1998. Report No. P 1834A/5644. *Operation and Maintenance Manual for Safety of Sarel Hayward Dam*
12	Ninham Shand Inc, 1991. Report No. P 1834/5644. *Report on the Safety Inspection of the Sarel Hayward Dam*
13	Ninham Shand Inc, 1987. Report No. 1124/3777. *Bathurst Stream Dam : Expected Salinities and Salinities Management Options*
14	Ninham Shand Inc, 1984. Report No. P 915/3777. Design Report : Construction of a dam on the Bathurst Stream and Ancillary Pumpstations and Pipelines
15	Ninham Shand Inc, 1985. Report No. P 954/3777. Supplementary Design Report : *Construction of a dam on the Bathurst Stream and Ancillary Pumpstations and Pipelines*

16	Ninham Shand Inc, 1982. Report No. P 749/3777. *Report on Proposals for Augmenting the Water Supply, Port Alfred Municipality*
17	Stewart Sviridov & Oliver, 1973. *Report on Extensions to the Water Scheme for the Municipality of Port Alfred*
18	Stewart Sviridov & Oliver, 1975. *Supplementary Report on Extensions to the Water Scheme for the Municipality of Port Alfred*
19	WSM (Pty) Ltd, 2004. *Albany Coast Situation Assessment, Water Quality of Drainage Region P*

APPENDIX 2

TERMS OF REFERENCE

APPENDIX 2

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

NATIONAL WATER RESOURCES PLANNING

ALBANY COAST SITUATION ASSESSMENT

TERMS OF REFERENCE

ALBANY COAST SITUATION ASSESSMENT

TERMS OF REFERENCE

1. Background

A number of coastal and inland towns in the Albany Coast district experience serious periodic water supply problems, predominantly because of inadequate sources, but also often as a result of poor water quality. The Albany Coast Water Board handles the requirements of part of the area, but has a very small institutional base and cannot operate effectively. An investigation is required to establish the actual nature and extent of water balance problems in the area and to identify possible solutions.

For the purpose of this study the Albany Coast area is defined as the area bounded by, but not including the catchments of, the Great Fish and Sundays Rivers. This includes the whole of primary drainage area P with a total surface area of 5 064 Km^2. The towns involved include Port Alfred, Bathurst, Kleinemonde, Kenton on Sea, Bushmans River Mouth, Boknes, Cannon Rocks and Alexandria. The catchments involved comprise those of Kowie, Kariega and Lower Bushmans rivers and the coastal strip to the west of the Bushmans River Mouth.

In general, the knowledge level about the water resources in the Albany Coast area is limited. The following background information on the towns involved was taken from the recently completed Water Resources Situation Assessment Report for the Fish to Tsitsikamma Water Management Area:

1) Grahamstown:
It is supplied with water diverted from the Little Fish River at Hermanuskraal weir and conveyed by means of a tunnel to Glen Melville Dam on the Ecca River. Glen Melville Dam is a balancing dam for raw water supplied to Grahamstown and to the Lower Fish River Irrigation Scheme. It has negligible yield from the Ecca River. The water is treated at a plant near the dam and pumped to Grahamstown. Use in 1995 was about 0,8 million m^3. Raw water availability will be adequate for the foreseeable future.

Water also obtained from four local dams, namely Settlers, Howiesonspoort, Jameson and Milner Dams. The combined 1:50 year yield of these dams is 2,2 million m^3/a. The water is pumped to an 11 Ml/d treatment works on a hill above Grahamstown and distributed from there.

2) Port Alfred
Obtains water from the Mansfield Dam (0,2 million m^3 live storage) and the Sarel Hayward Dam (2,5 million m^3 live storage). The latter is an off-channel dam into which water is pumped from a small weir on the Kowie River. Water stored in the dam becomes saline during dry periods because of the marine origins of the shales underlying the dam basin. Regular flushing of the stored water and replacement with fresh water from the Kowie River during periods of high flow is required to counteract this. The combined yield of the two dams is estimated to be 1,6 million m^3/a (Ninham Shand, 1987). Water is pumped from these dams to a water treatment works with a capacity of 6 Ml/d. The scheme is owned and operated by the Port Afred Municipality.

Water is also abstracted from coastal sand dunes near the town. The yield of this scheme is 0,13 million m^3/a.

Water from Mansfield Dam is supplied by Port Alfred to Nolukhango in the neighbouring town of Bathurst. Nolukhango previously relied on borehole water which was inadequate in quantity and found to have higher than desirable nitrate concentrations. It is not know if the borehole supply has been abandoned or if it is still used but mixed with the Mansfield Dam water. The other areas of Bathurst rely on private supplies from rainwater tanks or boreholes.

3) Bushman's River Mouth and Kenton-on-Sea:
Supplied by the Albany Coast Water Board from Boreholes and wellpoints in the dunes at Bushman's River mouth and at Diaz Cross. The yield of this scheme is estimated to be 1,1 million m^3/a. Because the raw water sources could not meet peak holiday season demand, the supply has been augmented by a reverse osmosis seawater desalination plant. The plant was commissioned in December 1997. It has a capacity of 0,4 Ml/d, or 0,12 million m^3/a, and draws water from boreholes in the saline groundwater zone near the Bushman's River mouth. The supply should be adequate to about 2005.

2. Purpose of the Study

The purpose of the study is to investigate the water supply problems of the area, through a broad review of existing information and to consider possible solutions that may present themselves for ready implementation. If necessary the study will also produce a situation overview from which the Department can draw up a framework for a more comprehensive investigation which may include consideration of sources outside of the focus area.

3. Proposed Scope of Work

The study involves more than just a pure desktop exercise. It will be necessary to contact knowledgeable individuals in the Department and Local Authorities to come to a full understanding of the water situation in the coastal towns and other user sectors. This will include reviewing, where available, the Water Service Development Plans and Integrated Development Plans. Although the primary focus of the work is on unpacking the urban supply sector, the other water use sectors should not be neglected especially where they impact on the available yield of the urban sector. The work will include the following tasks at reconnaissance level:

3.1 Background Information

- Collate and present existing information: present sources of water supply, present and projected water requirements by sector, demographics and expected socio-economic development, current and planned land use, institutional and legal aspects and potential water resources.
- Assessment of the accuracy and completeness of the existing information. Identification of gaps and further information required through collaboration with local authorities.
- Limited verification and patching of information, where necessary.

3.2 Domestic water supply situation

- Population and livestock distribution, present levels of service where this is known, existing projects and projects in process of implementation.

- Population growth and proposed future levels of service. Water requirements for urban use to be given in the seven categories of usage as undertaken for the Situation Assessment studies, an extract of this information as undertaken for this study is included as Appendix A.
- Area planning and possible grouping of schemes.

3.3 Existing infrastructure

Descriptions of existing bulk water supply infrastructure, its operational condition and upgradability to be provided.

3.4 Agricultural developments and afforestation

- In general, this is to be limited to a broad overview of possible developments with reference to the effect of these developments on the runoff and water requirements.
- Verify the extent of existing developments and identify information gaps. The Department's Dam database records a total number of 46 minor dams used for irrigation having total stored capacity of 12,8 million m^3/a. Take note of all development programmes proposed for the area. Assess the feasibility of future developments taking into account available water resources, economic development potential and financial constraints. The assessment should include the effects of dryland farming, irrigation and commercial livestock farming as well as the effects of afforestation (planted forests) and invasive aliens.

3.5 Water requirements

- Present and future water use by the various user sectors is to be assessed. Historical water use information should be presented where available, however, for future projections the national study (Schlemmer *et al*, 2001) to develop water use projections to the year 2025 as undertaken for the Department of Water Affairs and Forestry by a team of specialist should be used.
- Urban and industrial. The work by Schlemmer, Appendix A, to serve as a starting point. However, to improve on this base information the local authorities need to be approached to determine the level of information provided or not provided in their respective Water Service Development Plans. On the question of where the next source of water supply for each town should be, consultation with the Eastern Cape Regional Office is essential.
- Rural, domestic and livestock.
- Agricultural developments and afforestation. Requirements for irrigation (1995) at a 1:50 year assurance was estimated at 7,6 million m^3/a. Afforestation was low and hence zero reduction on the 1:50 year assurance of yield.
- For environmental and social requirements (the Reserve) use the desktop estimates that were determined for the Water Situation Assessment Model.

3.6 Water Demand Management

When determining water usage from towns an assessment of the role that water demand management can play on present and future water requirements needs to be made. A similar assessment with respect to irrigation use needs to be made in terms of best practises and whether there is scope for more efficient water use. The institutional capacity of the authority to implement water demand management needs to be addressed.

3.7 Environmental aspects

The study needs to take cognisance of the Reserve, however, it only needs to apply the Rapid methodology that was used to determine the preliminary Reserve estimates for the NWRS.

3.8 Social aspects

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

- Estimate number of people directly or indirectly affected by the developments.
- Estimate potential health and safety hazards.

3.9 Runoff hydrology, surface water resources and yield analysis

According to the Situation Assessment Report for the Albany Coast area the combined yields of Nuwejaars, Howieson Poort, Settlers, Jamieson and Sarel Haywood Dams is 6,8 million m^3/a. An estimate yield from farm dams and run-of-river abstractions of 8,0 million m^3/a, the estimated impact on yield of alien vegetation of 2,3 million m^3/a giving a total 1:50 year surface water utilised yield in 1995 of 17.1 million m^3/a. Sustainable groundwater exploitation potential not contributing to surface water base flow was estimated at 1,6 million m^3/a resulting in a total water resource 1:50 year utilised yield in 1995 of 18,7 million m^3/a and a total water resources yield potential of 54,6 million m^3/a.

What is required is the yield balance per quaternary (16 off) for P10, P20, P30 and P40 taking cognisance of water usage, stream flow reduction activities, local water sources (i.e. farm dams and groundwater) and return flows as they occur spatially in the quaternary. As this is an unregulated catchment it should not be necessary to set up the Water Resources Yield Model. A rapid assessment using monthly hydrological data to allow assessment of cascading water balances for quaternaries should suffice.

- In general the water resources assessments to be done primarily on the basis of WR90.
- The latest hydrological information on this catchment is being reviewed by the Department's Sub-Directorate Water Resources Studies. If more recent hydrological data is available and will impact on the yield then these should be obtained from the Department and used.

3.10 Groundwater resources

- A renewed look into the potential role that groundwater can play needs to be undertaken in this study. The Department will make members of their staff available where necessary and intend to actively participate in this component of the study. The successful PSP needs to co-ordinate, supplement and guide, where necessary, efforts that the Department will be undertaking to improve the knowledge base of the groundwater potential of the area. A departmental team being led by a water resources planner in Water Resources Planning Systems (WRPS) will provide input into this study. During the briefing session the Department will give greater clarity of their planned involvement. Notwithstanding the Department's intended role in this study the PSP is responsible for reporting on the findings and mapping a way forward. However, in order to utilise local knowledge it is necessary that a provisional amount of R50 000 be provided for a nominated groundwater specialist.

- NWRP is undertaking an Internal Strategy Perspective which includes the Albany Coast and the regional review of the geohydrology of this area will be brought forward to provide a framework for the collation process being undertaken at a localised level.
- It is essential that the successful PSP integrates the findings of the groundwater investigation, being conducted departmentally with his own work.

3.11 Water quality, sedimentation and return flows

- A statement about water quality at source supplying each of the towns listed in the background above is needed.
- As this study is not focused on evaluating yield potential of future developments it is not necessary to do any in depth investigation into sedimentation.
- The effect of return flows in the area is believed to be limited. Available information to be properly accounted for in the water balance.

3.12 Development options for water supply to the coastal towns of the Albany Coast area

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

- Review of previously identified schemes.
- Review, grouping and area planning.
- Shortlisting of options utilising all applicable criteria. This can be undertaken on a cursory review based on experience and judgement which can be revisited if a more detailed study is called for.

3.11 Selection of preferred development option

- If no obvious solution presents itself, then the process to follow to assist in arriving at a development option needs to be set out in a framework report which details further investigations to be undertaken.

3.13 Reconciliation of supply and demand

- Under present day condition (2003) an assessment per quaternary on the water balance needs to be done. The balance also needs to take cognisance of seasonal variation of supply and demand. This assessment needs to be confirmed against the experience of knowledgeable individuals. Projections up to 2025 will suffice.

3.14 Study outcomes

At each study management meeting, these to be held monthly, the way forward will be discussed with progress reports tabled at two monthly intervals. At some point in the study a decision, in collaboration with the Client, needs to be taken either on refinement of preferred identified options or drawing up a plan of action for further option identification and analysis.

The level of investigation needs to be pitched at arriving at an assessment of the problems of supply of water to the coastal towns. This problem statement is considered the most important outcome of the study. Following on this is the report following the actions needed to implement the decision taken in the above paragraph.

3.15 Public involvement and community liaison

Need to plan for two meetings. The first to inform stakeholders about the study and at the close of the study a second report back meeting on findings and recommendations. The EC Regional Office will assist to set up these meetings.

4. Studies undertaken

Appended is a list of departmental reports, which is provided to give an indication of the documents that will have to be considered in the study:

- P15000/00/0101 Water Resources Situation Assessment for Fish to Tsitsikama Water Management Area – Ninham Shand
- P RSA/00/2200 The distribution of South Africa's population, economy and water usage into the long term future. – February 2001 by Lawrence Schlemmer, MarkData and Eric Hall & Associates.
- P000/00/0177 Boesmansrivier-Besproeiingskema : Uitvoerbaarheidstudie – Interdepartementele komitee
- P000/Gh/0084 Coastal sand aquifers between Boesmansriviermond and Boknes (Gh 3441)
- P000/xx/0188 Potensiële impak v watervoorsieningskema vir Boesmansrivier – Univ.PE
- P000/xx/0288 Boesmansrivier : Uitvoerbaarheidsverslag – Eenheid vir Besproeiingsbeplanning
- P000/00/0188 Albany Coast Water Board : Supplementary water
- P000/xx/0190 Boesmansrivier Besproeiingsprojek : Kosteberaming – De Wet Shand
- P100/xx/0172 Boesmansriviermond :Water reticulation scheme – NS
- P100/xx/0173 Cannon Rocks-Kenton-on-Sea RWS : Technical report – Bowler, Van Heerden
- P100/04/0177 Uitvoerbaarheidstudie v besproeiing in Boesmansriviervallei
- P100/01/0181 Nuwejaarsdam : Kapasiteitsbepaling
- P100/13/2023 Geologiese verkenning : Boesmans-PE kanaal – Geol. Opname
- P300/00/0179 Bushmans River Mouth geohidrological survey
- P400/xx/0171 Municipality Port Alfred : Water supply – Ninham Shand
- P400/xx/0271 Grahamstown : raw water augmentation – SSO
- P400/xx/0173 Port Alfred : Water scheme extensions – SSO

- P400/xx/0175 Port Alfred : Water scheme extensions (Supplementary report) – SSO
- P400/00/0178 Waterverbruik v. Munis. Grahamstad
- P400/Gh/0079 Groundwater sampling & reconnaissance survey at Grahamstown (Gh 3119)
- P400/xx/0181 Future water requirements of Grahamstown and additional sources – SSO
- P400/xx/0183 Seawater desalination for Port Alfred – UHDE
- P400/xx/0191 Water tussen Alexandra en Visrivier deur Boesmansrivierprojek – Van Wyk & Louw
- P400/xx/0291 Bushmans River Transfer Scheme water for towns in Lower Bushmans River Valley – Van Wyk & Louw

5. Evaluation System

The attached document entitled "EXTRACT FROM ITEM 8 OF THE POLICY FOR THE APPOINTMENT OF PROFESSIONAL SERVICE PROVIDERS" sets out the evaluation system that will apply. The proposal submitted to be evaluated by a panel of departmental officials who will use the Evaluation System to assist them in comparing competitive proposals.

A team being led by a knowledgeable water resources planner with a proven track record of managing a multi-disciplinary team of experts and who has delivered studies of high quality on time and within budget would receive maximum benefit in the scoring system.

Curricula vitae of all persons proposed on the study team is required with their accompanying charge out rates.

6. Study Duration and briefing session

Technical work should not take more than seven months. A further three months may be taken up by the process of study closure. It is envisaged that the study will commence in August 2003 and be closed in May 2004. Within three months of the study commencing a draft preliminary report on findings need to be presented setting out the courses open to be further investigated. This to firm up on the problem assessment and likely solutions. A similar report is required after six months either towards providing an implementation plan for developing water resources or used to develop a proper situation assessment overview setting out the need for a more comprehensive study. Three months will then be allowed for review, printing and closing the study.

An important consideration in the evaluation of the study proposal is the availability of key personnel to undertake this work during the study period as set out above.

7. Study Budget

There is a limited study budget and this study falls into Project Category # 2: contract value between R150 000 and R3 million. The PSP should familiarise himself with the tasks as set out in this TOR. Any uncertainty needs to be raised at the briefing session provisionally set for 19 June 2003. Confirmation of the date and time of the meeting will be included in the notification notice calling for proposals.

8. Tax clearance certificate

No contract may be awarded to a person who has failed to submit an original Tax Clearance Certificate from the South African Revenue Service ("SARS") certifying that the taxes of that person to be in order or that suitable arrangements have been made with SARS.

9. Costing Considerations

All costs reflected in the study proposal to included VAT.

9.1 Provision for five hard copies of the report and ten CDs containing the report in pdf format to be made.

9.2 A retention amount of R70 000 needs to be provided for in the cash flow of the study. The first release of retention monies of R35 000 to be paid on receipt of the final draft reports and approved as such by the Client, R20 000 when the reports are printed and delivered to the Client and the balance when the study is closed. The Services shall be deemed completed and finally accepted by the Client and the final report shall be deemed approved by the Client as satisfactory ninety calendar days after receipt of the draft final report by the Client unless the Client, within such ninety day period, gives written notice to the PSP specifying in detail deficiencies in the Service, and upon completion of such corrections, the foregoing shall be repeated. On completion of the Service all outstanding retention monies to be released.

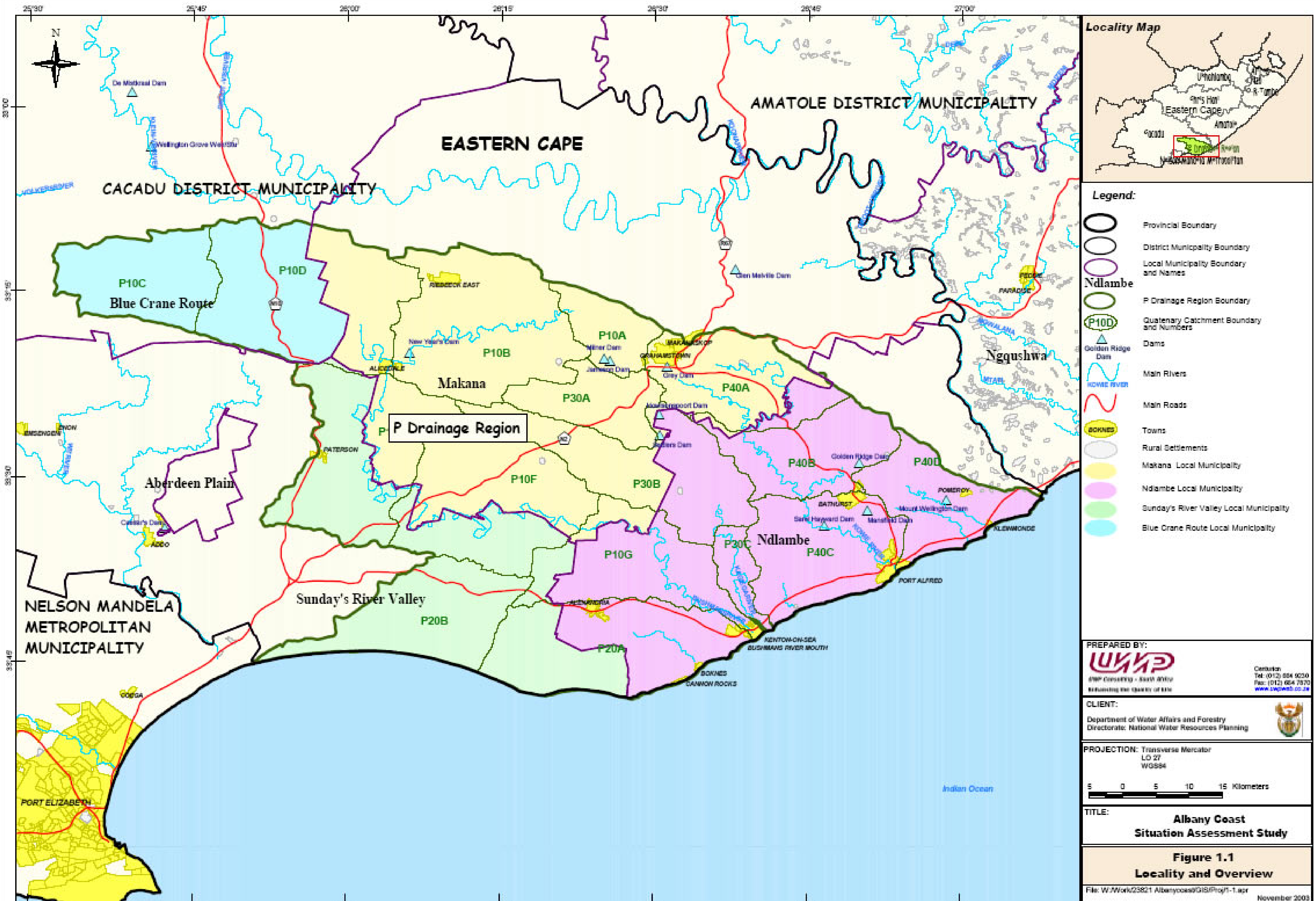
9.3 Provisional Sum of R50 000 to be allowed for to undertake work by a nominated groundwater specialist.

9.4 Provision for escalation to be reflected as a separate task in the cost estimates and limited to 2% of the estimate for professional fees.

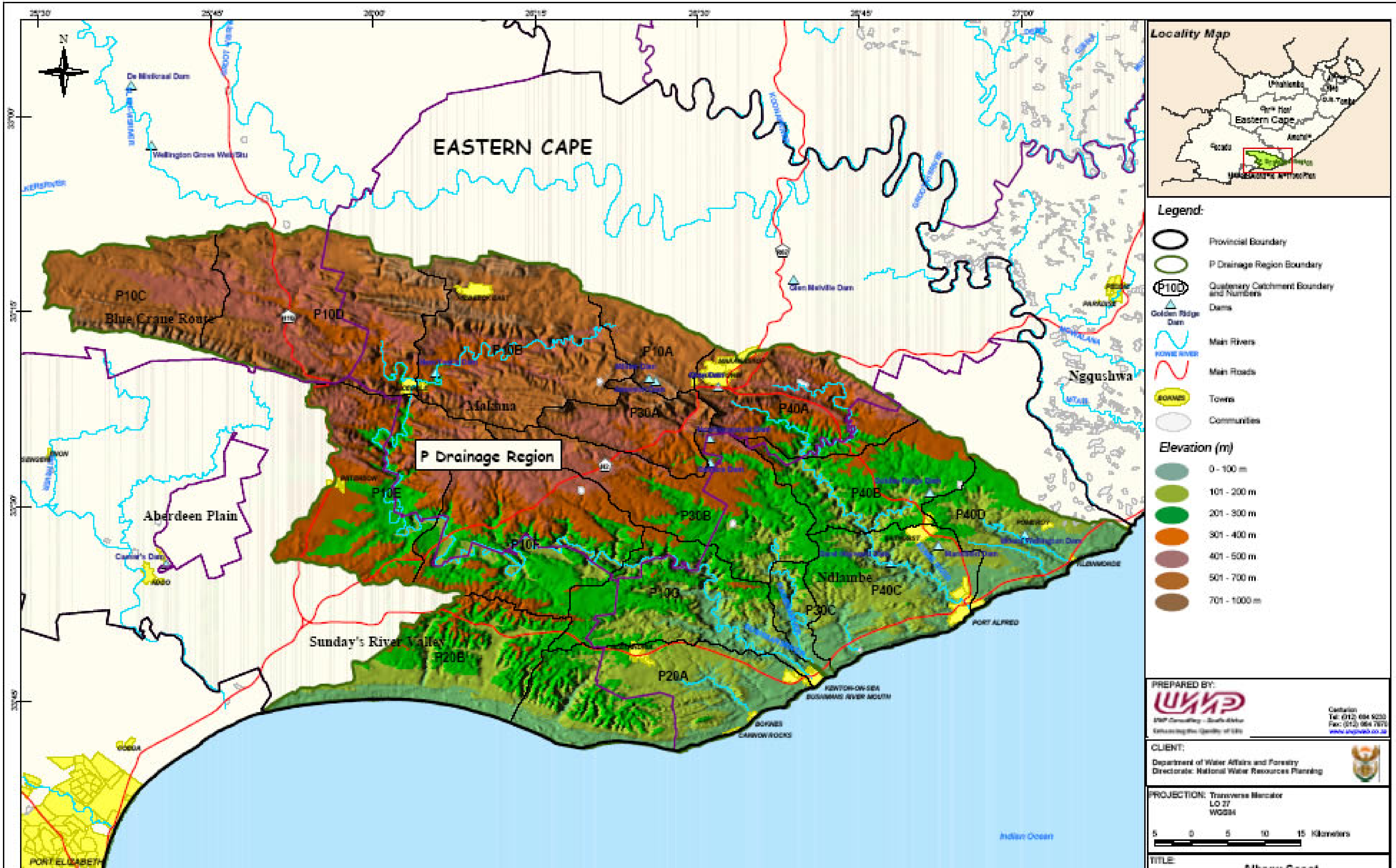
9.5 No provision for escalation need be made.

9.6 As this is a fast track assignment the need has been identified that monthly study management meetings are required. Formal meetings to be held every alternate month. In total the study should plan for ten study management meetings (four of them to be formal) and two stakeholder meetings. All the formal study management meetings to be held in the Eastern Cape. The Department is flexible with respect to the informal meetings and these can be held at the offices of the PSP to save on study team's time (reduced number of people attending) and travel cost. For informal meetings only notes of a meeting are required instead of a full set of minutes and progress report that are required at the formal meetings.

9.7 It is a requirement that expenditure of HDI involvement should exceed 25%.

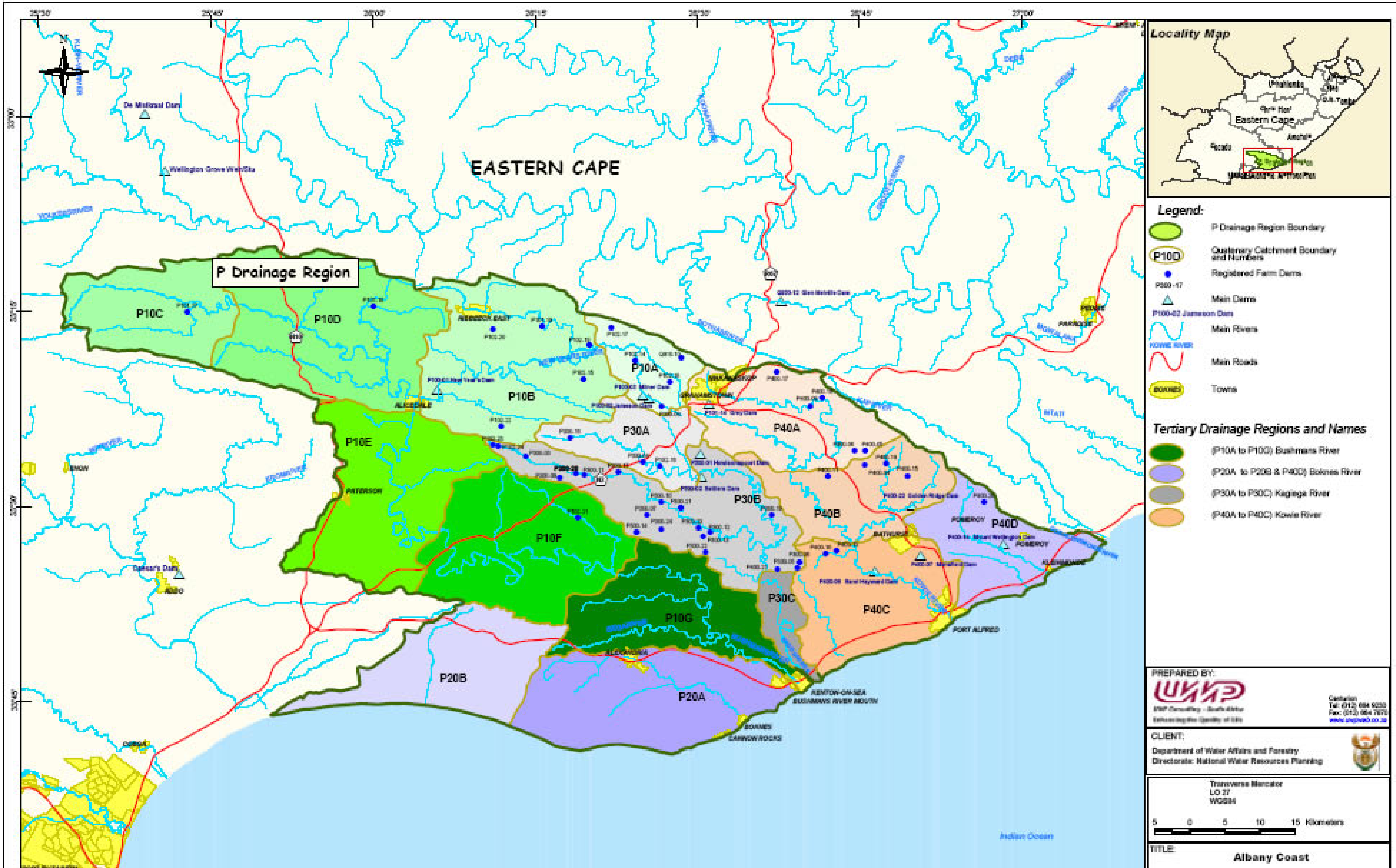


EASTERN CAPE
AMATOLE DISTRICT MUNICIPALITY
CACADU DISTRICT MUNICIPALITY
NELSON MANDELA METROPOLITAN MUNICIPALITY
Blue Crane Route
Makana
Ndlambe
Ngqushwa
Aberdeen Plain
Sunday's River Valley
P Drainage Region
P10A
P10B
P10C
P10D
P10F
P10G
P20A
P20B
P30A
P30B
P30C
P40A
P40B
P40C
P40D
De Mistkraal Dam
Wellington Grove Weir
New Year's Dam
Milner Dam
Jameson Dam
Grey Dam
Glen Melville Dam
Golden Ridge Dam
Settlers Dam
Mount Wellington Dam
Mansfield Dam
RIEBEECK EAST
ALICEDALE
PATERSON
GRAHAMSTOWN
MAKANASKOP
BATHURST
POMEROY
PEDDIE
PARADISE
KLEINMONDE
PORT ALFRED
ALEXANDRIA
KENTON-ON-SEA
BUSHMANS RIVER MOUTH
BOKNES
CANNON ROCKS
ADDO
COEGA
PORT ELIZABETH
Indian Ocean
N
Locality Map
Eastern Cape
Legend:
Provincial Boundary
District Municipality Boundary
Local Municipality Boundary and Names
P Drainage Region Boundary
Quaternary Catchment Boundary and Numbers
Dams
Main Rivers
Main Roads
Towns
Rural Settlements
Makana Local Municipality
Ndlambe Local Municipality
Sunday's River Valley Local Municipality
Blue Crane Route Local Municipality
PREPARED BY:
CLIENT:
Department of Water Affairs and Forestry
Directorate: National Water Resources Planning
PROJECTION: Transverse Mercator
LO 27
WGS84
Kilometers
TITLE:
Albany Coast
Situation Assessment Study
Figure 1.1
Locality and Overview
November 2003



EASTERN CAPE
P Drainage Region
P10A
P10B
P10C
P10D
P10E
P10F
P10G
P20A
P20B
P30A
P30B
P30C
P40A
P40B
P40C
P40D
Blue Crane Route
Makana
Ndlambe
Ngqushwa
Aberdeen Plain
Sunday's River Valley
De Mistkraal Dam
Wellington Grove Weir/Stu
Glen Melville Dam
PORT ALFRED
KENTON-ON-SEA
BUSHMANS RIVER MOUTH
BOKNES
CANNON ROCKS
PORT ELIZABETH
Indian Ocean
Locality Map
Eastern Cape
Legend:
Provincial Boundary
P Drainage Region Boundary
Quaternary Catchment Boundary and Numbers
Dams
Main Rivers
Main Roads
Towns
Communities
Elevation (m)
0 - 100 m
101 - 200 m
201 - 300 m
301 - 400 m
401 - 500 m
501 - 700 m
701 - 1000 m
PREPARED BY:
CLIENT:
Department of Water Affairs and Forestry
Directorate: National Water Resources Planning
PROJECTION: Transverse Mercator
LO 27
WGS84
5 0 5 10 15 Kilometers
TITLE:


EASTERN CAPE
P Drainage Region
Blue Crane Route
Makana
Ndlambe
Ngqushwa
Aberdeen Plain
Sunday's River Valley
P10A
P10B
P10C
P10D
P10E
P10F
P10G
P20A
P20B
P30A
P30B
P30C
P40A
P40B
P40C
P40D
PORT ELIZABETH
PORT ALFRED
Indian Ocean
Locality Map
Eastern Cape
Legend:
Provincial Boundary
P Drainage Region Boundary
Local Municipality Boundary and Names
Quaternary Catchment Boundary and Numbers
Dams
All Rivers
Main Roads
Towns
Tertiary Drainage Regions and Names
P10 Bushman River
P20/P40D Coastal River
P30 Kagiega River
P40 Kowie River
PREPARED BY:
CLIENT:
Department of Water Affairs and Forestry
Directorate: National Water Resources Planning
Transverse Mercator
LO 27
WGS84
5 0 5 10 15 Kilometers
TITLE:
Albany Coast



Locality Map
Eastern Cape
Legend:
P Drainage Region Boundary
Quaternary Catchment Boundary and Numbers
Registered Farm Dams
Main Dams
Main Rivers
Main Roads
Towns
Tertiary Drainage Regions and Names
(P10A to P10G) Bushmans River
(P20A to P20B & P40D) Boknes River
(P30A to P30C) Kariega River
(P40A to P40C) Kowie River
PREPARED BY:
CLIENT:
Department of Water Affairs and Forestry
Directorate: National Water Resources Planning
Transverse Mercator
LO 27
WGS84
5 0 5 10 15 Kilometers
TITLE:
Albany Coast
EASTERN CAPE
P Drainage Region
P10C
P10D
P10A
P10B
P10E
P10F
P10G
P20A
P20B
P30A
P30B
P30C
P40A
P40B
P40C
P40D
PORT ALFRED
KENTON-ON-SEA
BUSHMANS RIVER MOUTH
Indian Ocean

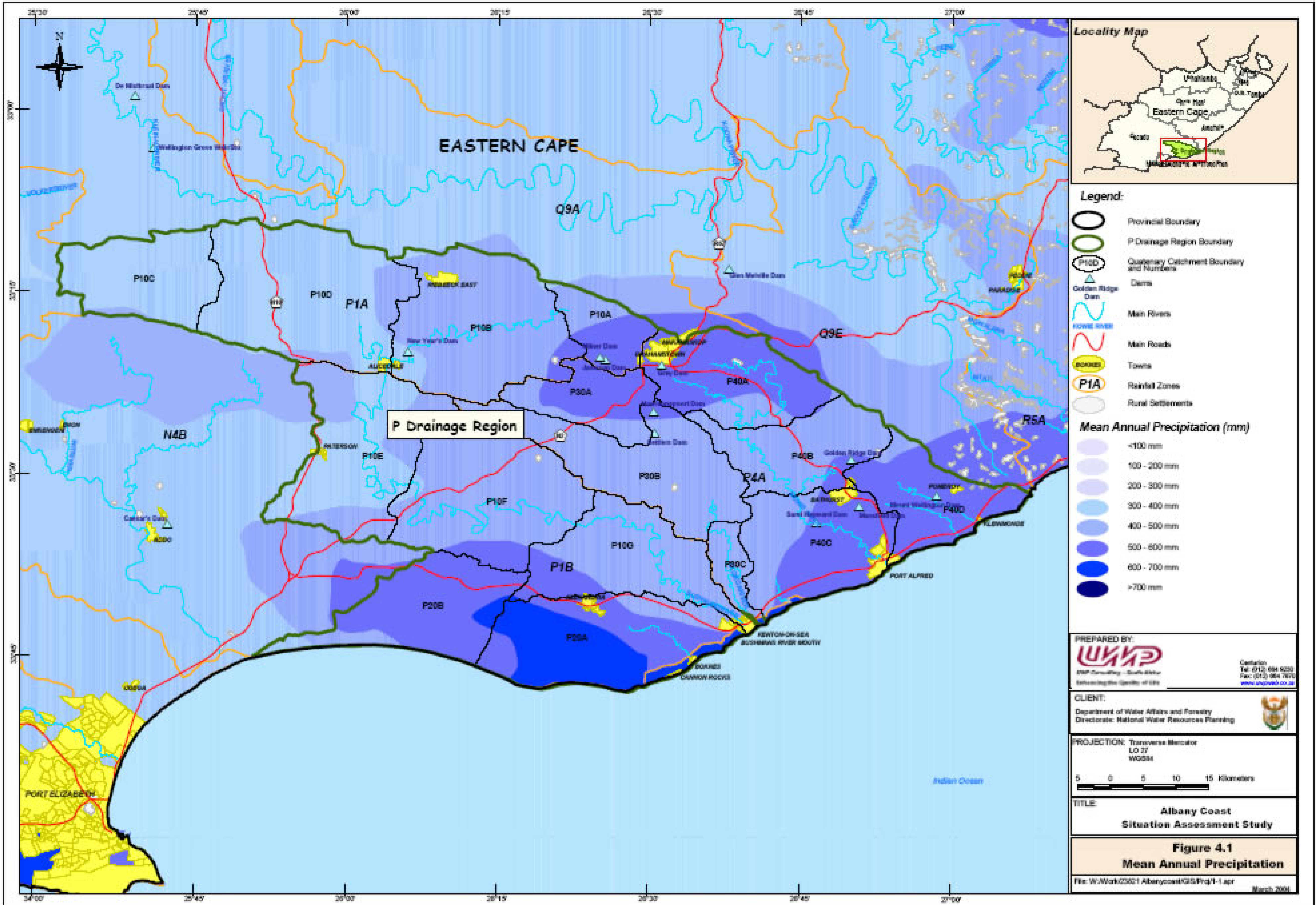
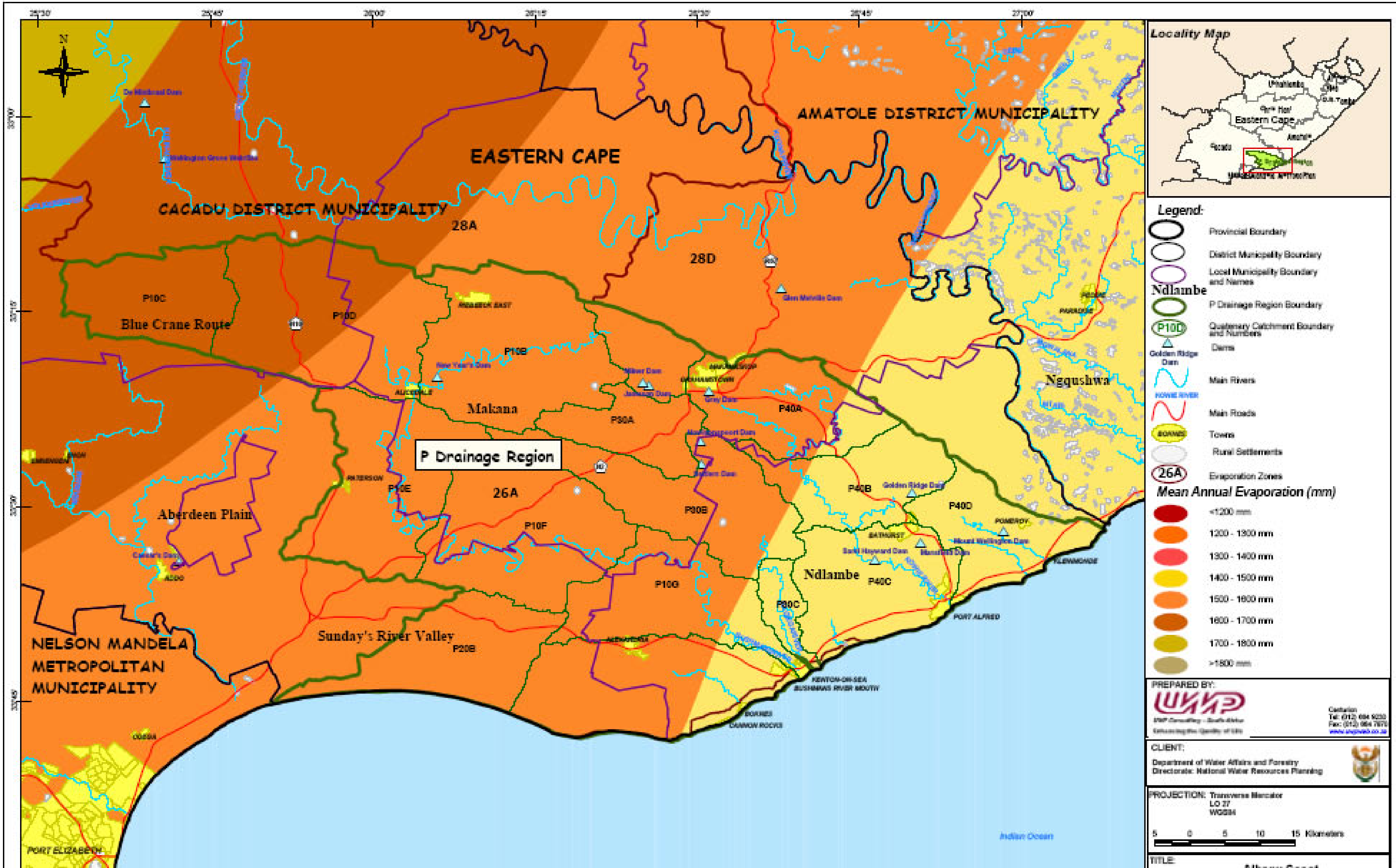


Figure 4.1
Mean Annual Precipitation

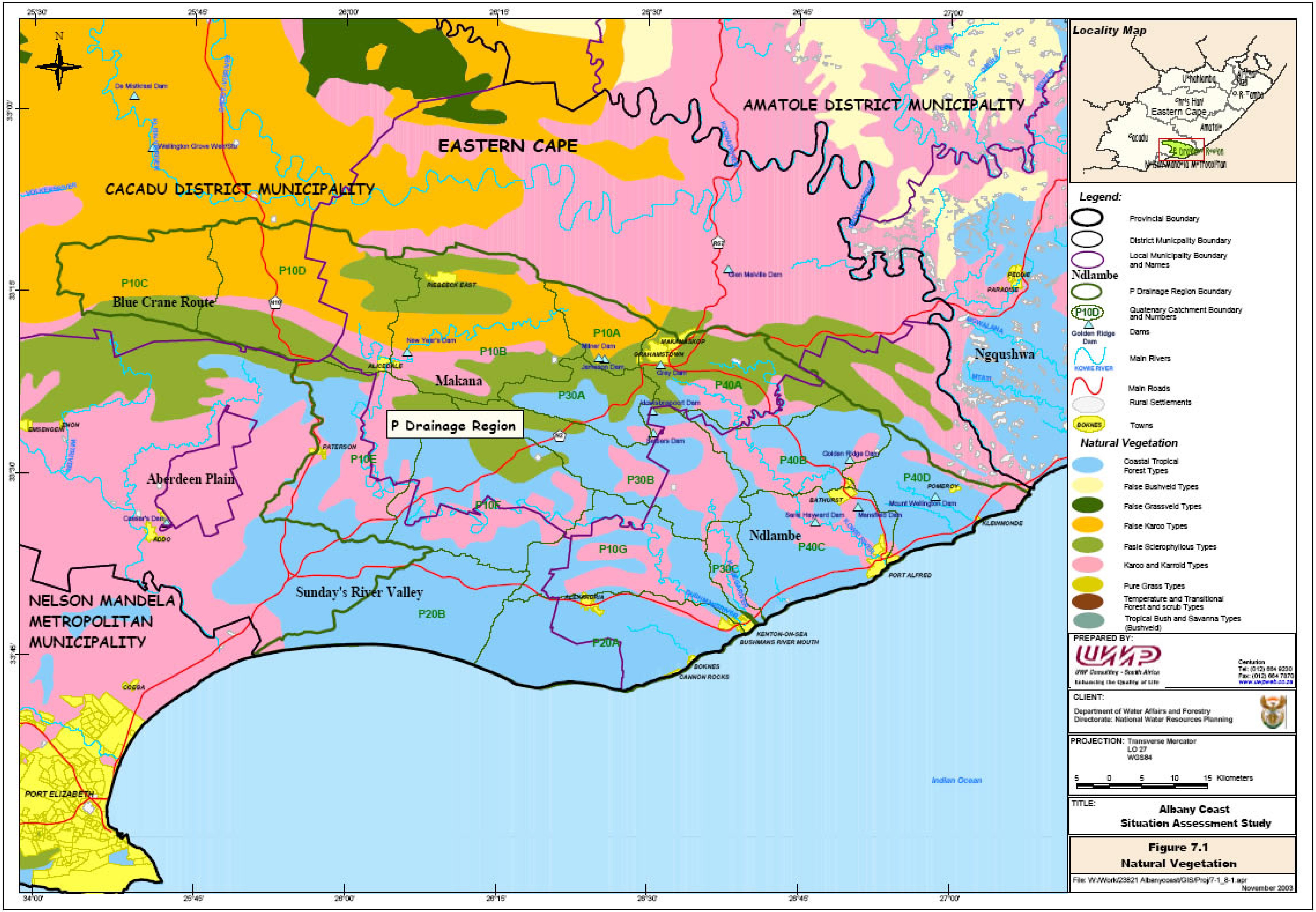
March 2004



EASTERN CAPE
AMATOLE DISTRICT MUNICIPALITY
CACADU DISTRICT MUNICIPALITY
NELSON MANDELA METROPOLITAN MUNICIPALITY
P Drainage Region
Blue Crane Route
Makana
Aberdeen Plain
Sunday's River Valley
Ndlambe
Ngqushwa
28A
28D
26A
P10C
P10D
P10B
P10E
P10F
P10G
P20B
P30A
P30B
P30C
P40A
P40B
P40C
P40D
Locality Map
Eastern Cape
Legend:
Provincial Boundary
District Municipality Boundary
Local Municipality Boundary and Names
Ndlambe
P Drainage Region Boundary
Quaternary Catchment Boundary and Numbers
P10D
Dams
Main Rivers
Main Roads
Towns
Rural Settlements
Evaporation Zones
26A
Mean Annual Evaporation (mm)
<1200 mm
1200 - 1300 mm
1300 - 1400 mm
1400 - 1500 mm
1500 - 1600 mm
1600 - 1700 mm
1700 - 1800 mm
>1800 mm
PREPARED BY:
CLIENT:
Department of Water Affairs and Forestry
Directorate: National Water Resources Planning
PROJECTION: Transverse Mercator
LO 27
WGS84
5 0 5 10 15 Kilometers
TITLE:
PORT ALFRED
PORT ELIZABETH
GRAHAMSTOWN
Indian Ocean

Figure 5.1
Geology

Locality Map
Eastern Cape
Legend:
Provincial Boundary
District Municipality Boundary
Local Municipality Boundary and Names
Ndlambe
P Drainage Region Boundary
Quaternary Catchment Boundary and Numbers
P10D
Dams
Golden Ridge Dam
Main Rivers
KOWIE RIVER
Main Roads
Towns
BOKNES
Rural Settlements
Soils
Depth
Texture
Relief
Moderate to Deep
Clay Loam
Flat
Moderate to Deep
Sandy Loam
Steep
Moderate to Deep
Clay Loam
Undulating
Moderate to Deep
Sandy Loam
Steep
Moderate to Deep
Sandy Loam
Undulating
Shallow
Sandy Loam
Undulating
Moderate to Deep
Sandy Soil
Steep
Moderate to Deep
Sandy Soil
Undulating
PREPARED BY:
CLIENT:
Department of Water Affairs and Forestry
Directorate: National Water Resources Planning
PROJECTION: Transverse Mercator
LO 27
WGS84
5 0 5 10 15 Kilometers
TITLE:
Albany Coast
Situation Assessment Study
Figure 6.1
Soils
November 2003
CACADU DISTRICT MUNICIPALITY
EASTERN CAPE
AMATOLE DISTRICT MUNICIPALITY
NELSON MANDELA METROPOLITAN MUNICIPALITY
P Drainage Region
Blue Crane Route
Makana
Aberdeen Plain
Sunday's River Valley
Ndlambe
Ngqushwa
P10C
P10D
P10B
P10A
P30A
P40A
P10E
P30B
P40B
P40D
P10F
P10G
P30C
P40C
P20B
P20A
RIEBEECK EAST
GRAHAMSTOWN
ALICEDALE
PATERSON
ADDO
ALEXANDRIA
BATHURST
PORT ALFRED
KENTON-ON-SEA
BUSHMANS RIVER MOUTH
BOKNES
CANNON ROCKS
PORT ELIZABETH
COEGA
PEDDIE
PARADISE
KLEINMONDE
New Year's Dam
Milner Dam
Jameson Dam
Glen Melville Dam
Golden Ridge Dam
Mount Wellington Dam
Indian Ocean



EASTERN CAPE
AMATOLE DISTRICT MUNICIPALITY
CACADU DISTRICT MUNICIPALITY
NELSON MANDELA METROPOLITAN MUNICIPALITY
P Drainage Region
Blue Crane Route
Makana
Aberdeen Plain
Sunday's River Valley
Ndlambe
Ngqushwa
P10A
P10B
P10C
P10D
P10E
P10F
P10G
P20A
P20B
P30A
P30B
P30C
P40A
P40B
P40C
P40D
GRAHAMSTOWN
ALICEDALE
PATERSON
ADDO
ALEXANDRIA
BATHURST
PORT ALFRED
KENTON-ON-SEA
BUSHMANS RIVER MOUTH
BOKNES
CANNON ROCKS
KLEINEMONDE
PEDDIE
PORT ELIZABETH
Indian Ocean
N
Locality Map
Eastern Cape
Legend:
Provincial Boundary
District Municipality Boundary
Local Municipality Boundary and Names
Ndlambe
P Drainage Region Boundary
P10D
Quaternary Catchment Boundary and Numbers
Golden Ridge Dam
Dams
KOWIE RIVER
Main Rivers
Main Roads
Rural Settlements
BOKNES
Towns
Natural Vegetation
Coastal Tropical Forest Types
False Bushveld Types
False Grassveld Types
False Karoo Types
Fasle Sclerophyllous Types
Karoo and Karroid Types
Pure Grass Types
Temperature and Transitional Forest and scrub Types
Tropical Bush and Savanna Types (Bushveld)
PREPARED BY:
CLIENT:
Department of Water Affairs and Forestry
Directorate: National Water Resources Planning
PROJECTION: Transverse Mercator
LO 27
WGS84
5 0 5 10 15 Kilometers
TITLE:
Albany Coast
Situation Assessment Study
Figure 7.1
Natural Vegetation
November 2003

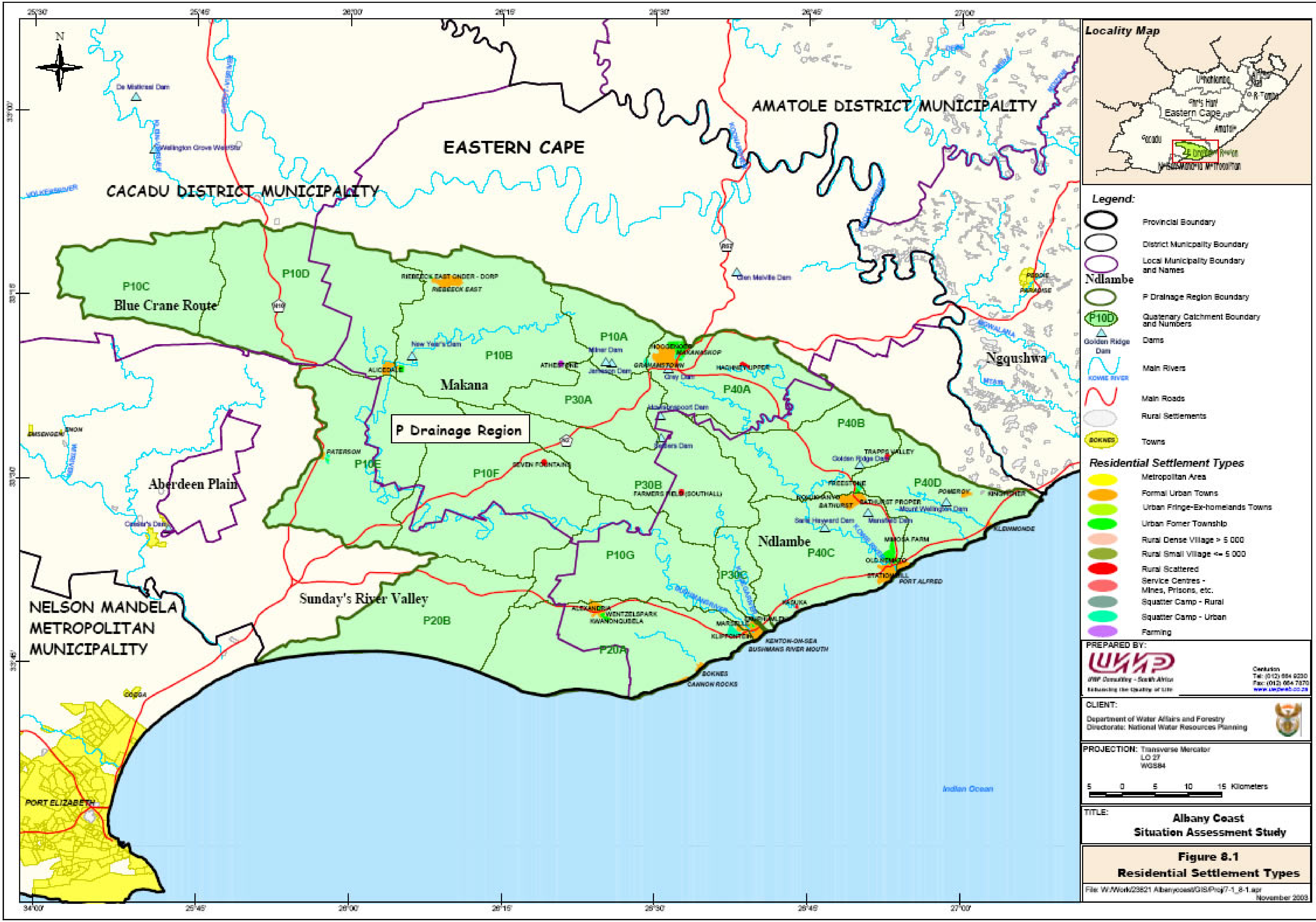
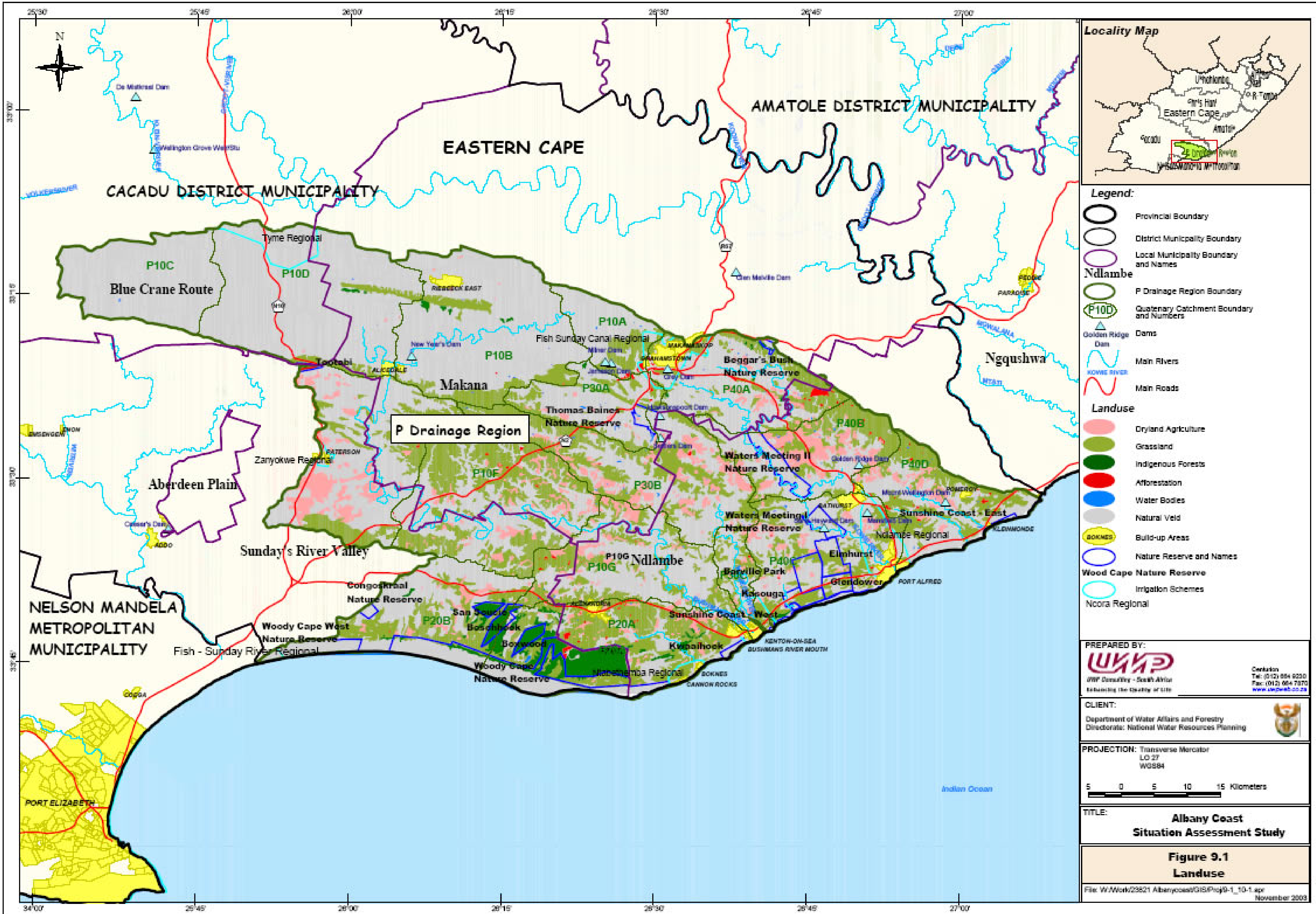


Figure 8.1
Residential Settlement Types



Locality Map
Eastern Cape
Legend:
Provincial Boundary
District Municipality Boundary
Local Municipality Boundary and Names
Ndlambe
P Drainage Region Boundary
P10D
Quaternary Catchment Boundary and Numbers
Golden Ridge Dam
Dams
KOWIE RIVER
Main Rivers
Main Roads
Landuse
Dryland Agriculture
Grassland
Indigenous Forests
Afforestation
Water Bodies
Natural Veld
BOKNES
Build-up Areas
Nature Reserve and Names
Wood Cape Nature Reserve
Irrigation Schemes
Ncora Regional
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Directorate: National Water Resources Planning
PROJECTION: Transverse Mercator
LO 27
WGS84
5 0 5 10 15 Kilometers
TITLE:
Albany Coast
Situation Assessment Study
Figure 9.1
Landuse
November 2003
EASTERN CAPE
AMATOLE DISTRICT MUNICIPALITY
CACADU DISTRICT MUNICIPALITY
NELSON MANDELA METROPOLITAN MUNICIPALITY
P Drainage Region
Blue Crane Route
Makana
Ndlambe
Ngqushwa
Aberdeen Plain
Sunday's River Valley
P10A
P10B
P10C
P10D
P10F
P10G
P20A
P20B
P30A
P30B
P40A
P40B
P40D
Tyme Regional
Fish Sunday Canal Regional
Zanyokwe Regional
Fish - Sunday River Regional
Ndlambe Regional
Thomas Baines Nature Reserve
Beggar's Bush Nature Reserve
Waters Meeting II Nature Reserve
Waters Meeting I Nature Reserve
Sunshine Coast - East
Sunshine Coast - West
Congoskraal Nature Reserve
Woody Cape West Nature Reserve
Woody Cape Nature Reserve
San Souci
Boschhoek
Boxwood
Kwaaihoek
Barville Park
Kasouga
Elmhurst
Glendower
PORT ALFRED
PORT ELIZABETH
Indian Ocean

Figure 10.1
Water Supply Schemes

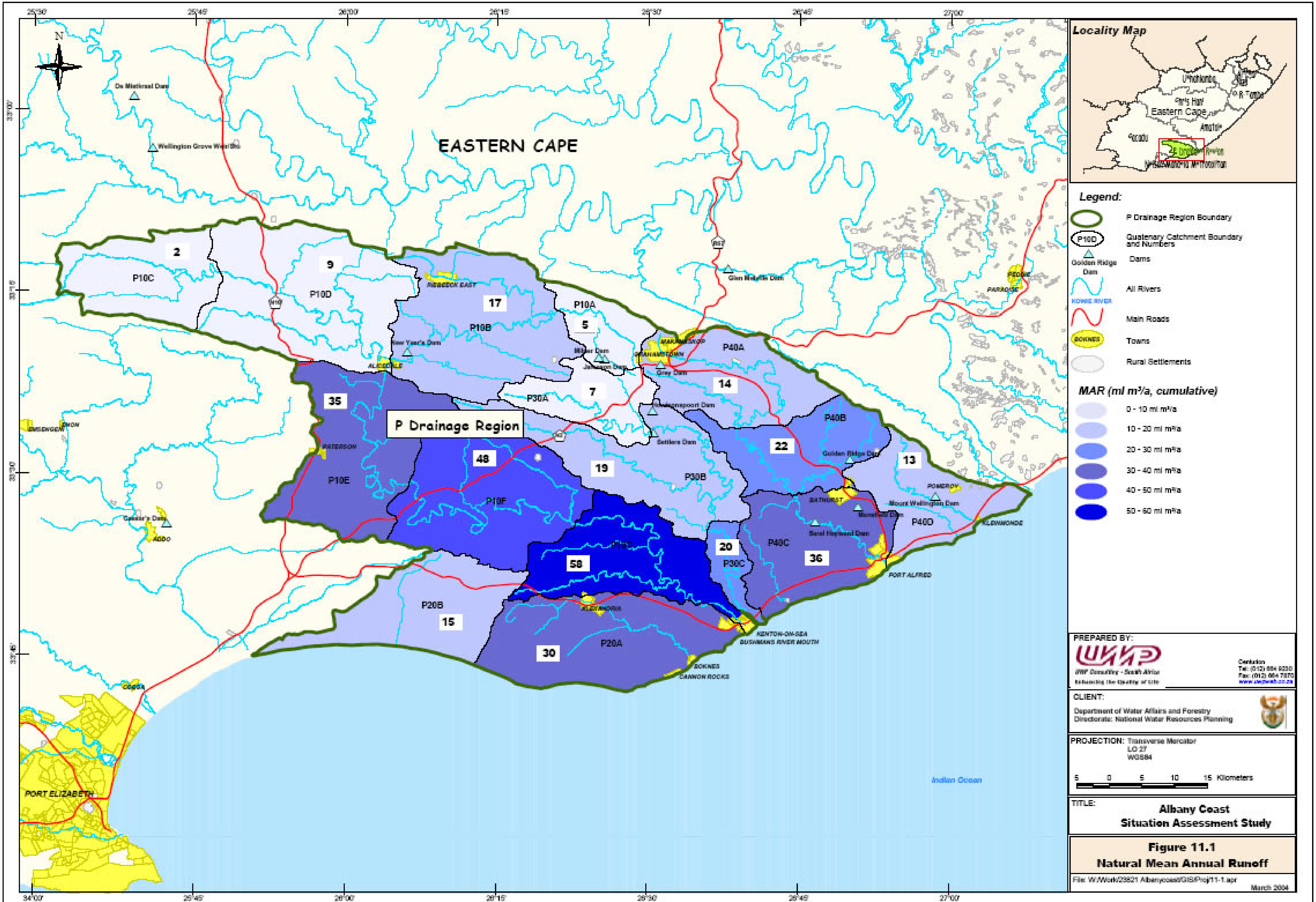


Figure 11.1
Natural Mean Annual Runoff

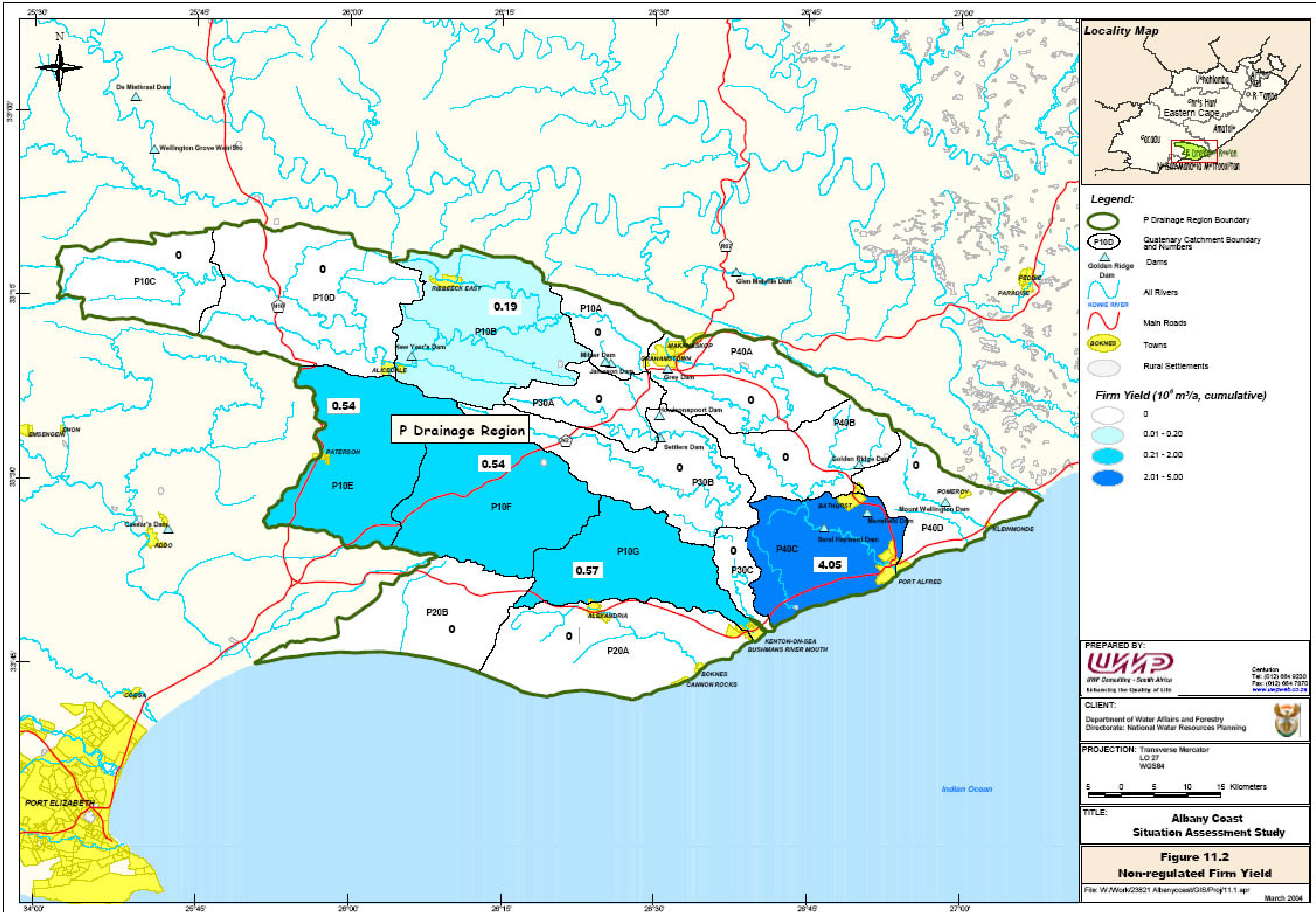


Figure 11.2
Non-regulated Firm Yield

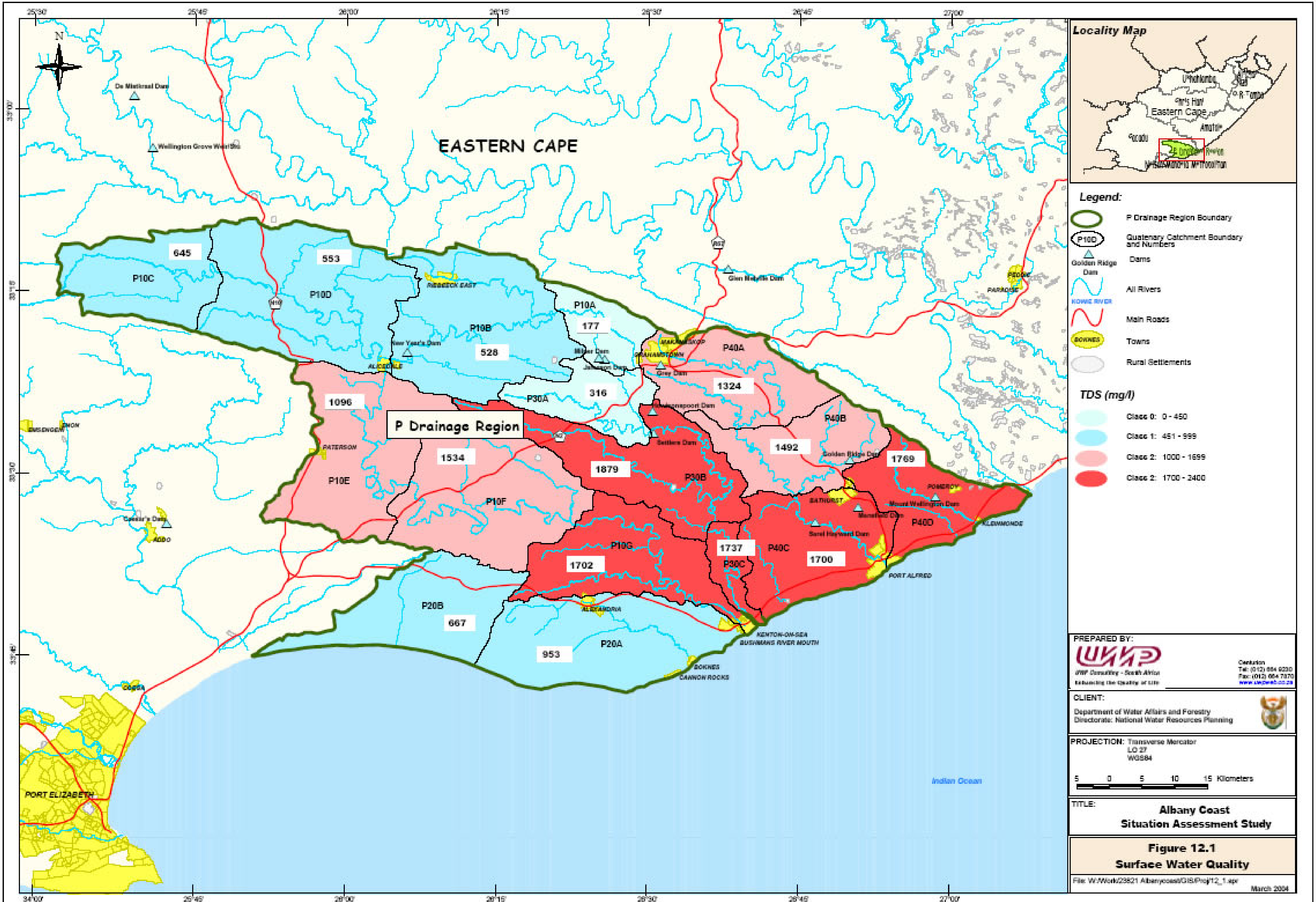
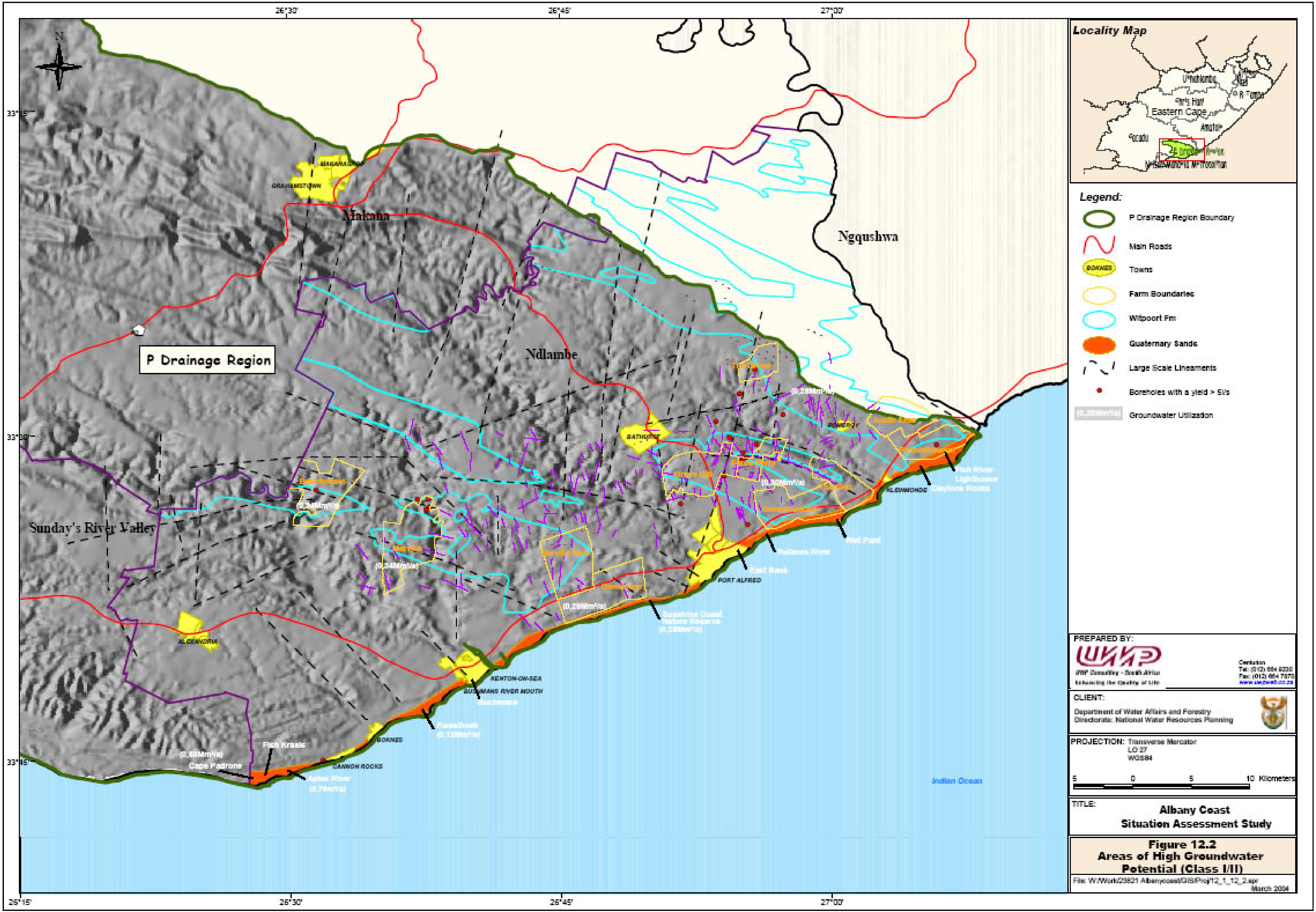


Figure 12.1
Surface Water Quality



26°30'
26°45'
27°00'
26°15'
33°15'
33°30'
33°45'
N
Locality Map
Eastern Cape
Legend:
P Drainage Region Boundary
Main Roads
Towns
Farm Boundaries
Witpoort Fm
Quaternary Sands
Large Scale Lineaments
Boreholes with a yield > 5l/s
Groundwater Utilization
P Drainage Region
Makana
Ndlambe
Ngqushwa
Sunday's River Valley
GRAHAMSTOWN
BATHURST
PORT ALFRED
ALEXANDRIA
KENTON-ON-SEA
BUSHMANS RIVER MOUTH
BOKNES
CANNON ROCKS
KLEINMONDE
Bushmans
Kwaaihoek
Fish Kraals
Cape Padrone
Aplas River
East Bank
Rufanes River
Riet Punt
Claytons Rocks
Fish River Lighthouse
Sunshine Coast Nature Reserve
Indian Ocean
PREPARED BY:
WRP Consulting - South Africa
Enhancing the Quality of Life
Centurion
CLIENT:
Department of Water Affairs and Forestry
Directorate: National Water Resources Planning
PROJECTION: Transverse Mercator
LO 27
WGS84
5 0 5 10 Kilometers
TITLE:
Albany Coast
Situation Assessment Study
Figure 12.2
Areas of High Groundwater Potential (Class I/II)
March 2004

Legend:

- P Drainage Region Boundary
- Dams
- Elevation (meter)

Infrastructure

- Pump Main
- Gravity Main
- Break Pressure Tank
- Groundwater Source
- Pumpstation
- Reservoir
- Water Treatment Works

PREPARED BY:

UWP Consulting - South Africa
Enhancing the Quality of Life

Centurion
Tel: (012) 664 9230
Fax: (012) 664 7870
www.uwpweb.co.za

CLIENT:

Department of Water Affairs and Forestry
Directorate: National Water Resources Planning

PROJECTION: Transverse Mercator
LO 27
WGS84

5 0 5 10 Kilometers

TITLE:

Albany Coast
Situation Assessment Study

Figure 13.1
Proposed Scheme Layouts

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March 2004

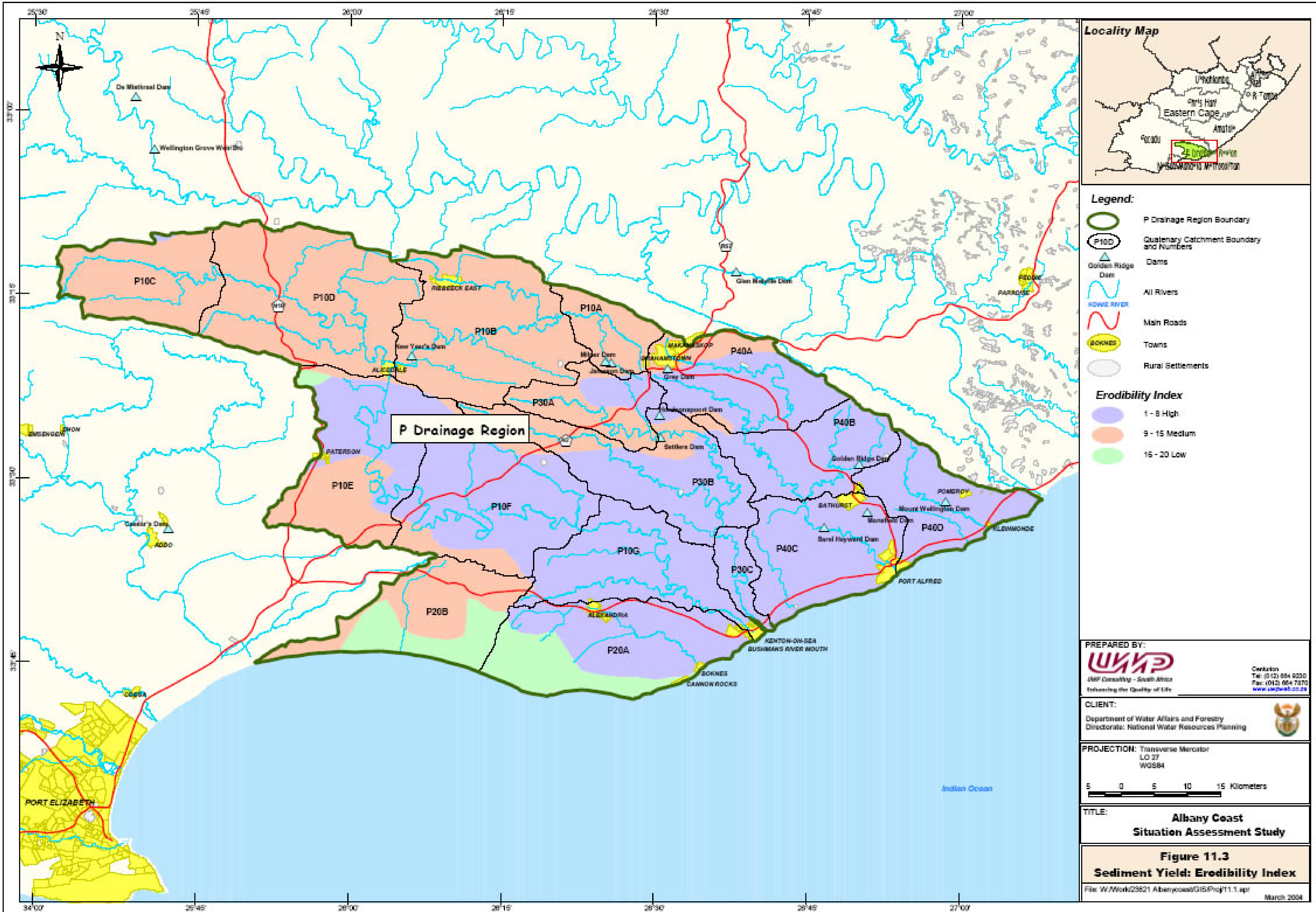
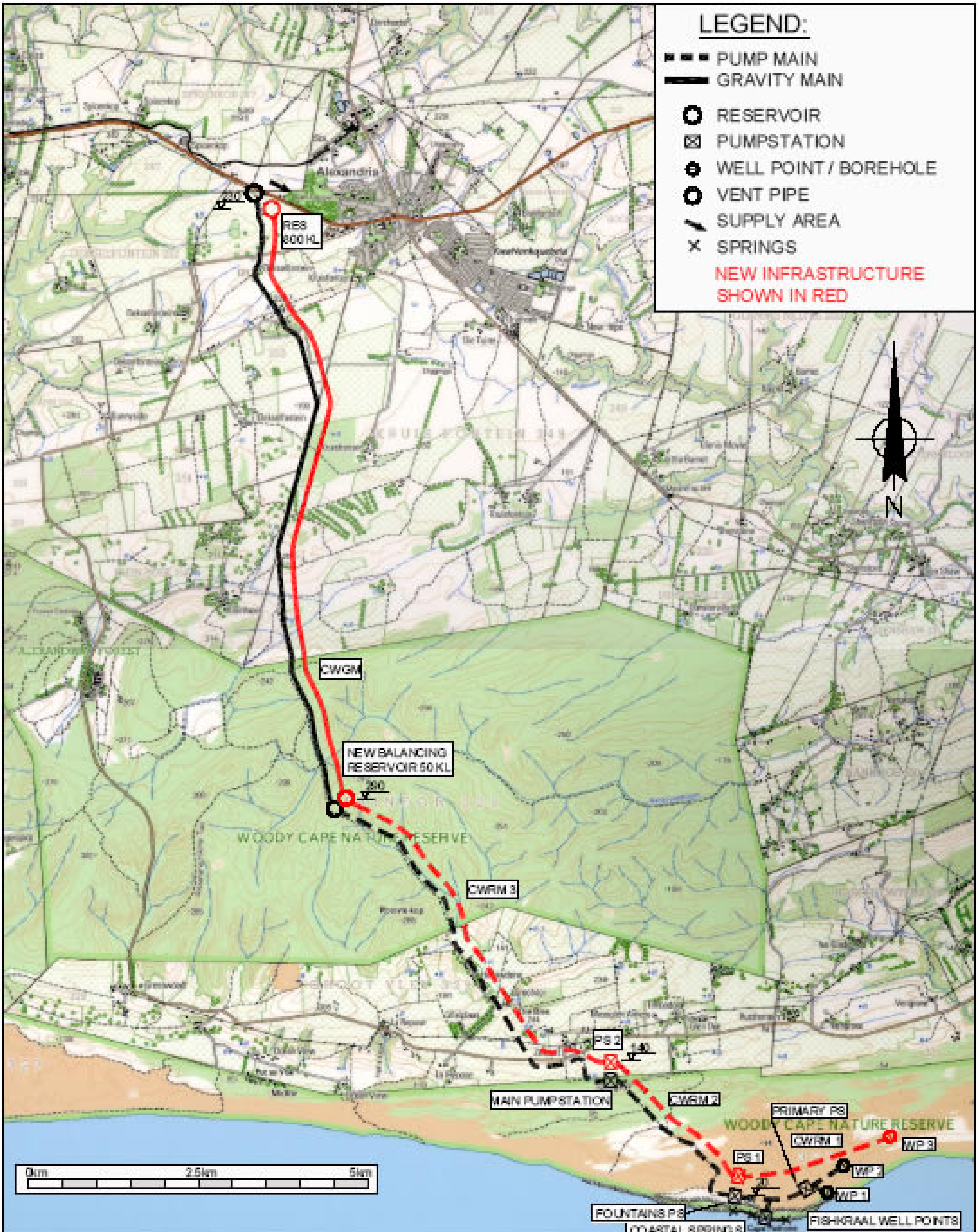


Figure 11.3
Sediment Yield: Erodibility Index



UWP Consulting

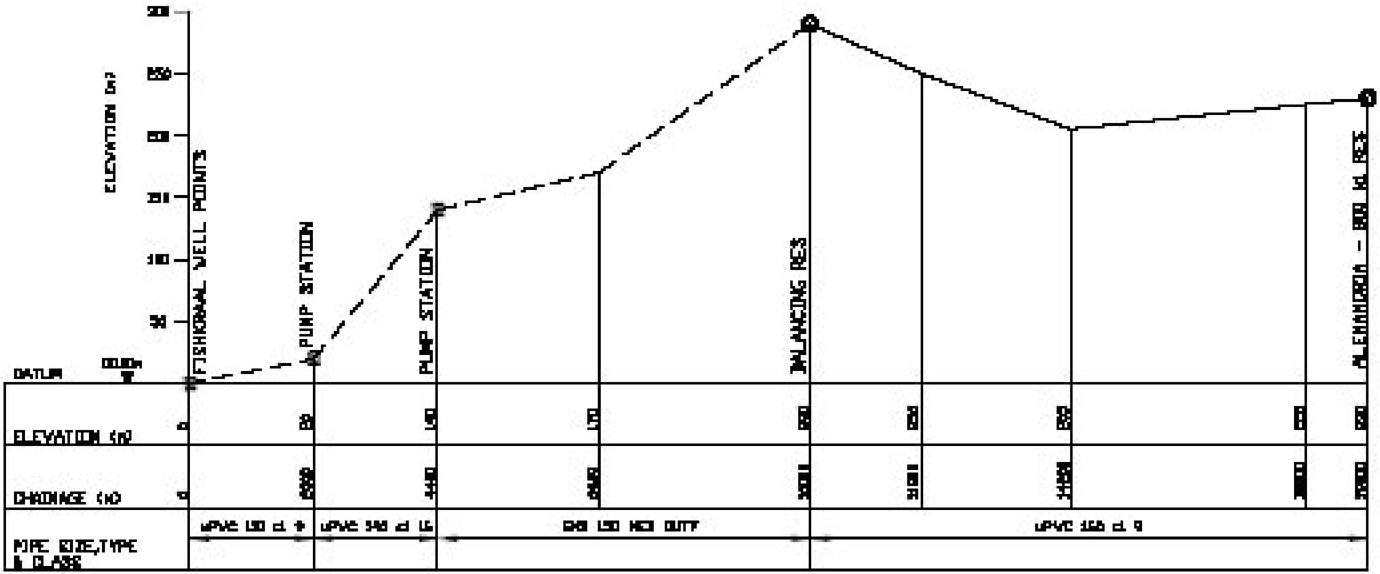
Project

ALBANY COAST
SITUATION ASSESSMENT STUDY

Description

ALEXANDRIA LAYOUT

Designed: R.L.
Sheet: 1 of 1
Drawn: R.L.
Scale: AS SHOWN
Checked: H.V.D.
No.
Fig. S1



FISHKRAAL WELL POINTS TO ALEXANDRIA - LONGITUDINAL SECTION

UWP Consulting

Project	ALBANY COAST SITUATION ASSESSMENT STUDY
Description	ALEXANDRIA - LONGITUDINAL SECTION

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Sheet	1 of 1
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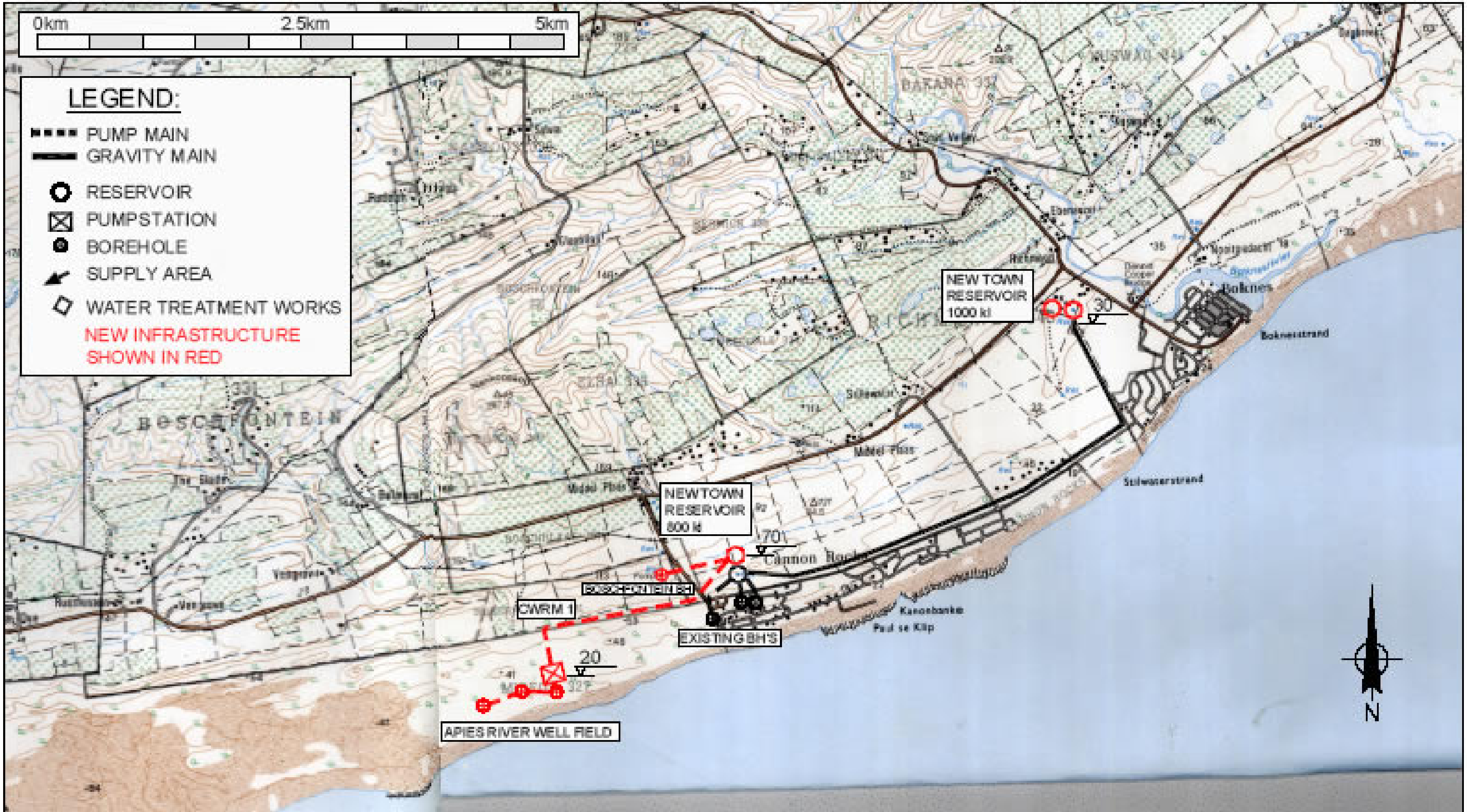
Scale	AS SHOWN
Checked	H.V.D.
No	Fig. L1



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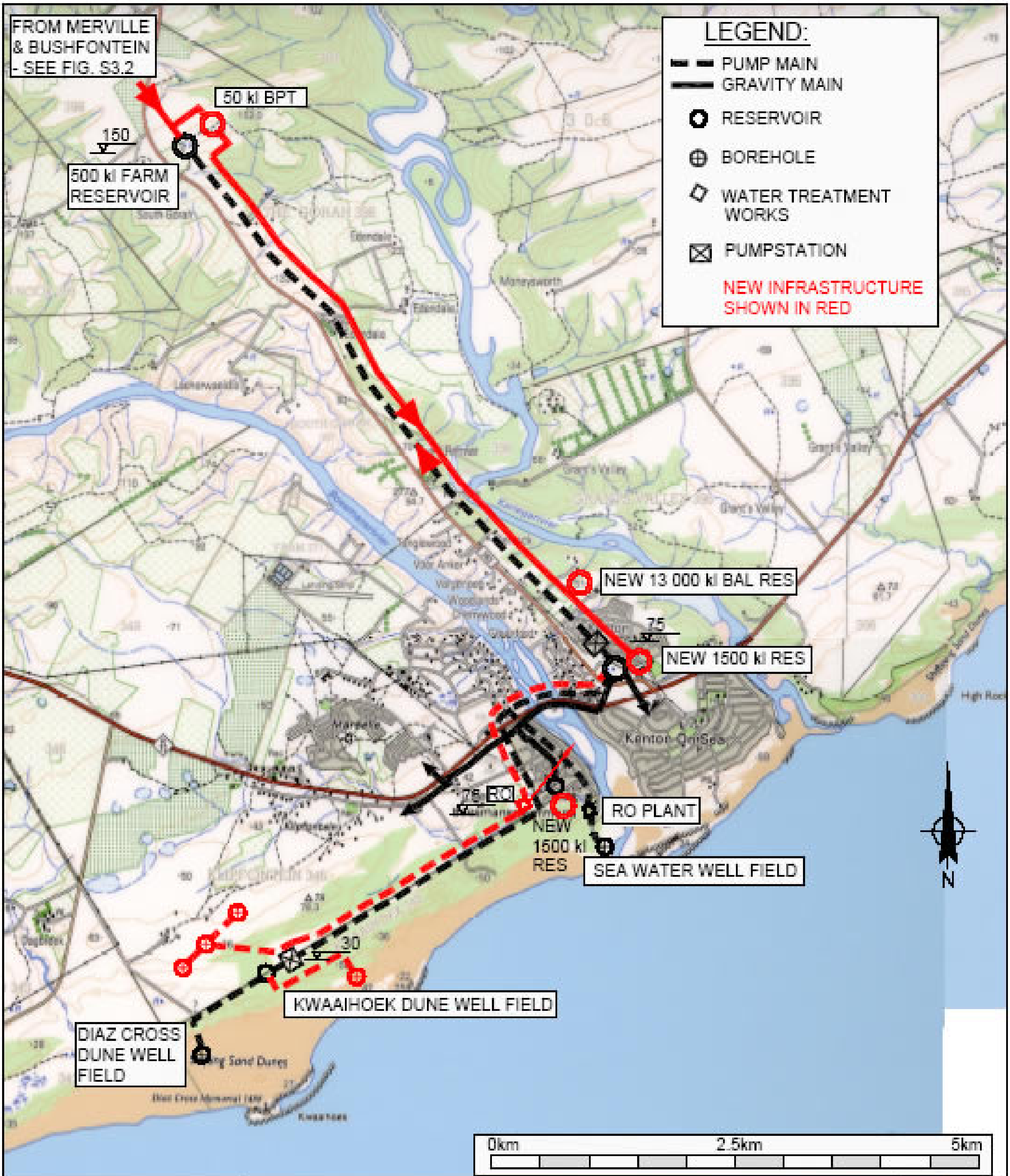
Project
ALBANY COAST
SITUATION ASSESSMENT STUDY

Description
CANNON ROCKS & BOKNES

Designed:	R.L.
Sheet:	1 of 1
Drawn:	R.L.
Scale:	AS SHOWN
Checked:	H.V.D.
No.	Fig. S2



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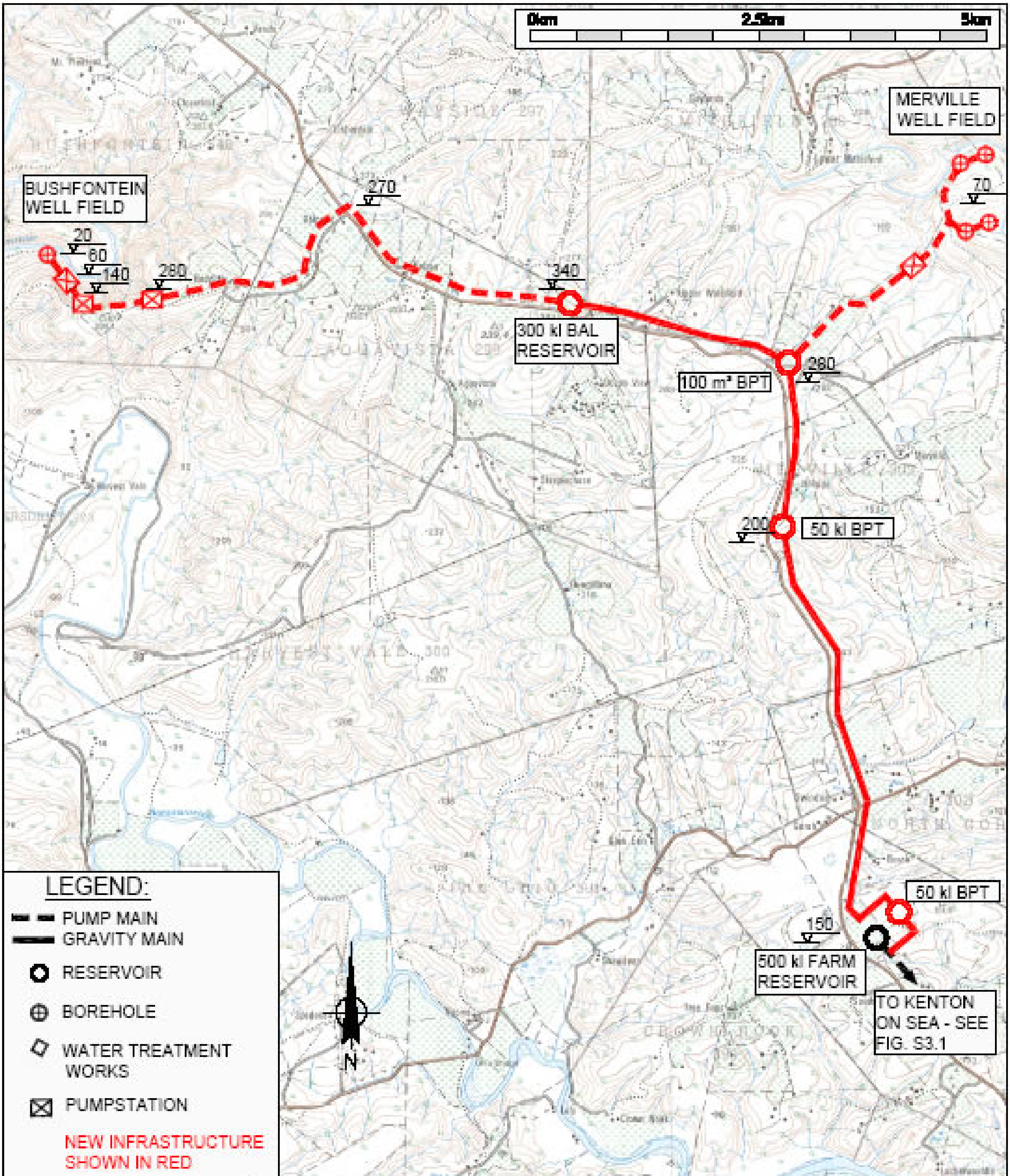
Project

ALBANY COAST
SITUATION ASSESSMENT STUDY

Description

KENTON ON SEA SCHEME LAYOUT

Designed:	R.L.
Sheet:	1 of 1
Drawn:	R.L.
Scale:	AS SHOWN
Checked:	H.V.D.
No.	Fig. S3.1



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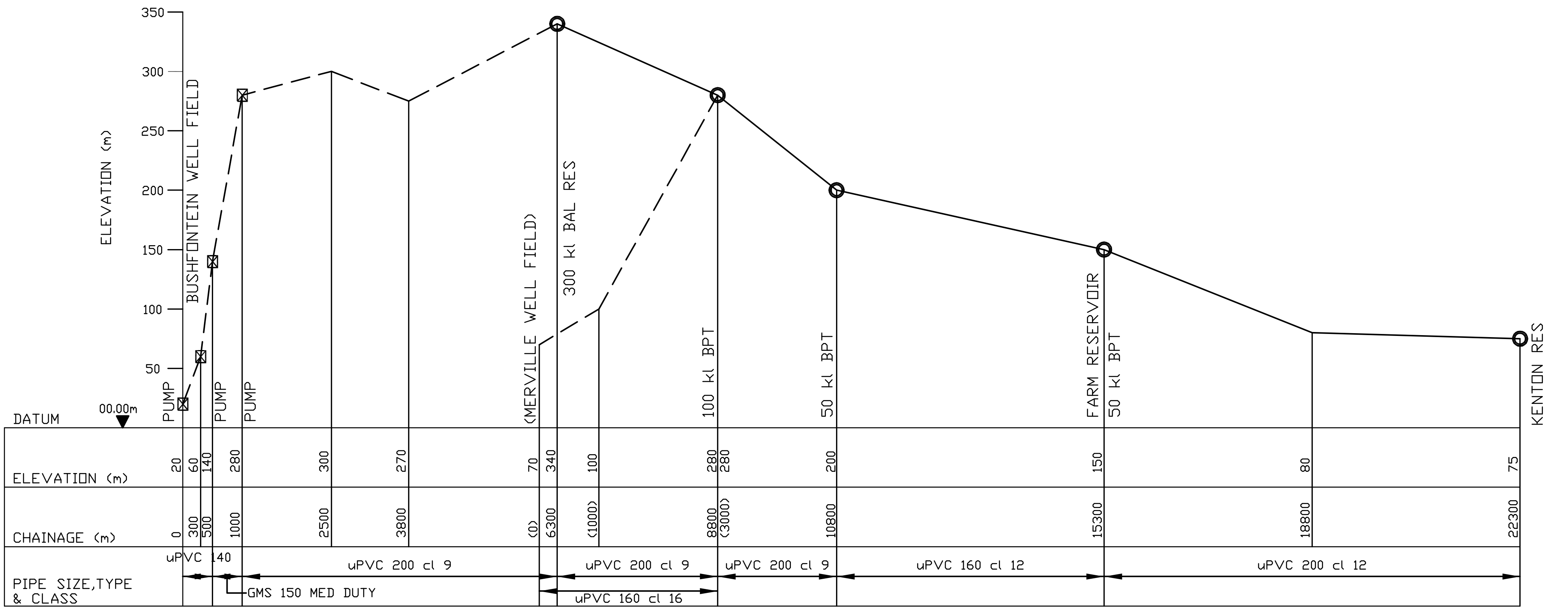
Project

ALBANY COAST
SITUATION ASSESSMENT STUDY

Description

KENTON ON SEA SCHEME LAYOUT

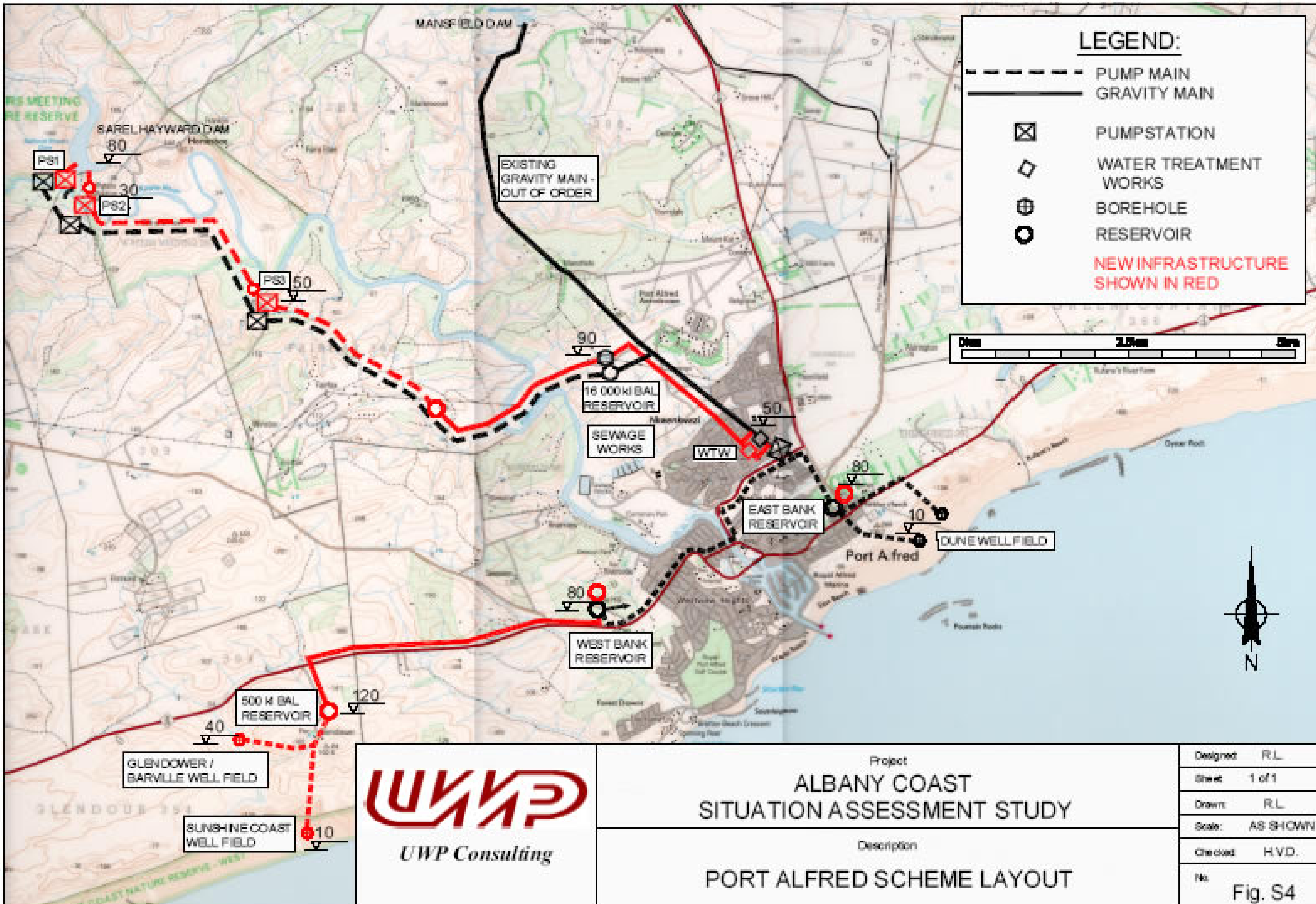
Designed:	R.L.
Sheet:	1 of 1
Drawn:	R.L.
Scale:	AS SHOWN
Checked:	H.V.D.
No.	Fig. S3.2



BUSHFONTEIN & MERVILLE TO KENTON ON SEA - LONGITUDINAL SECTION

HORIZONTAL : 1:100 000
VERTICAL : 1:5 000

UWP Consulting	Project ALBANY COAST SITUATION ASSESSMENT STUDY	Designed: R.L. Sheet: 1 of 1 Drawn: R.L. Scale: AS SHOWN Checked: H.V.D.
	Description KENTON ON SEA - LONGITUDINAL SECTION	No. Fig. L3



UWP Consulting

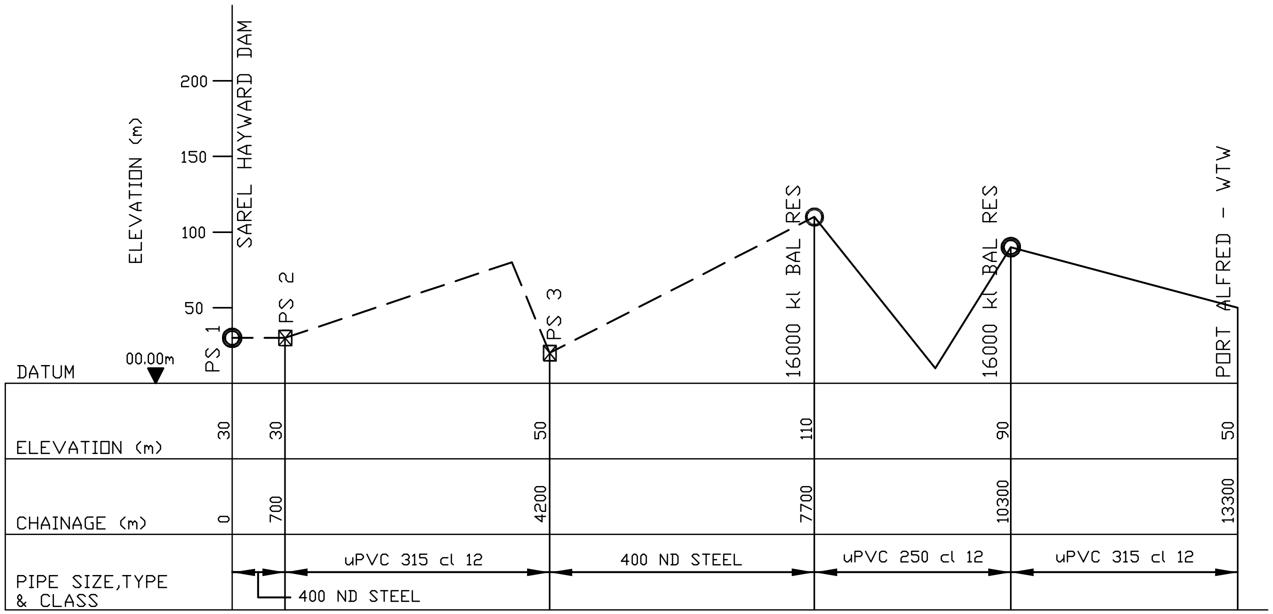
Project

ALBANY COAST
SITUATION ASSESSMENT STUDY

Description

PORT ALFRED SCHEME LAYOUT

Designed:	R.L.
Sheet:	1 of 1
Drawn:	R.L.
Scale:	AS SHOWN
Checked:	H.V.D.
No.	Fig. S4



LONGITUDINAL SECTION

HORIZONTAL : 1:100 000
VERTICAL : 1:5 000

UWP Consulting

Project

ALBANY COAST
SITUATION ASSESSMENT STUDY

Description

SAREL HAYWARD DAM TO PORT ALFRED - LONGITUDINAL SECTION

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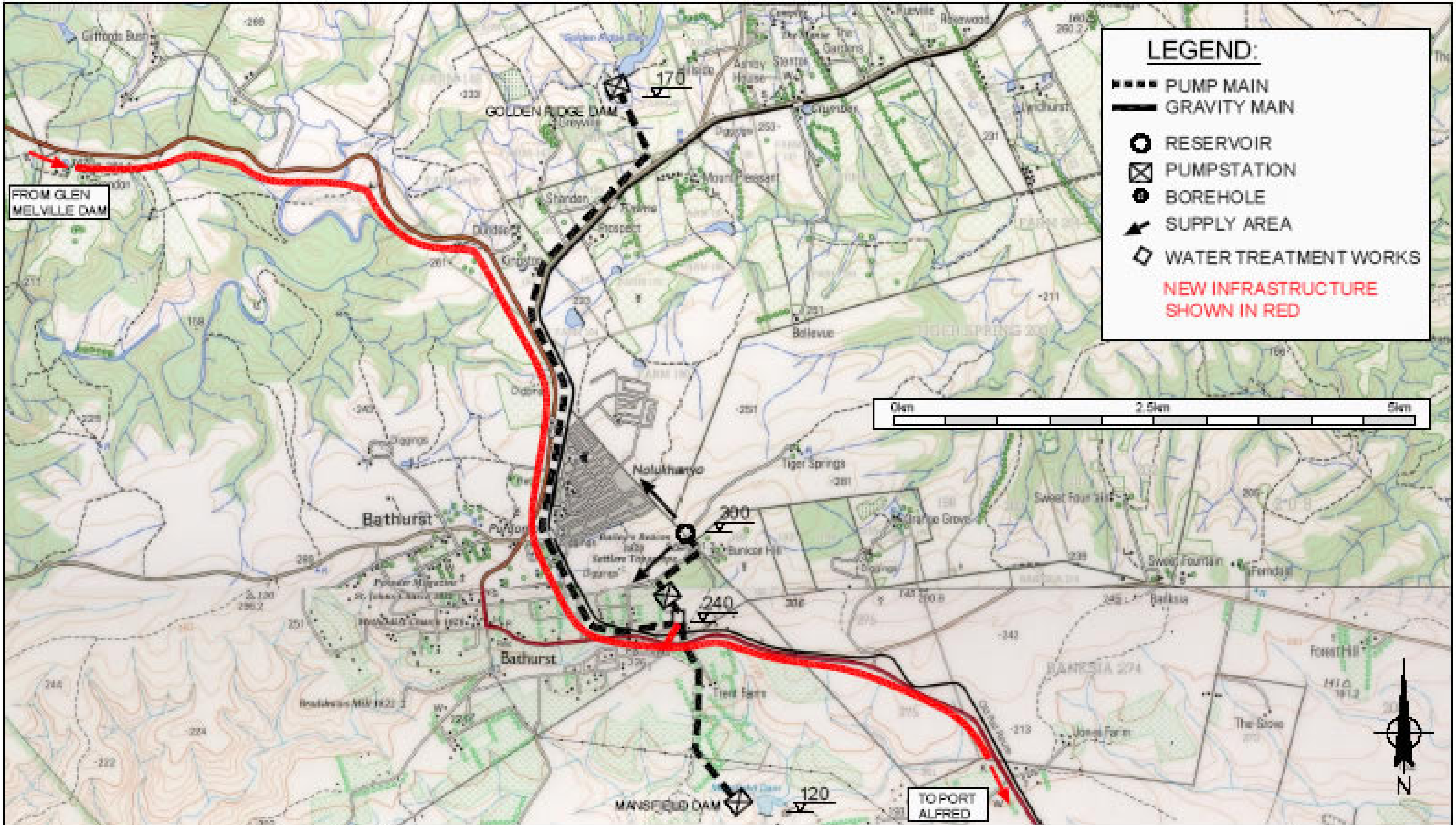
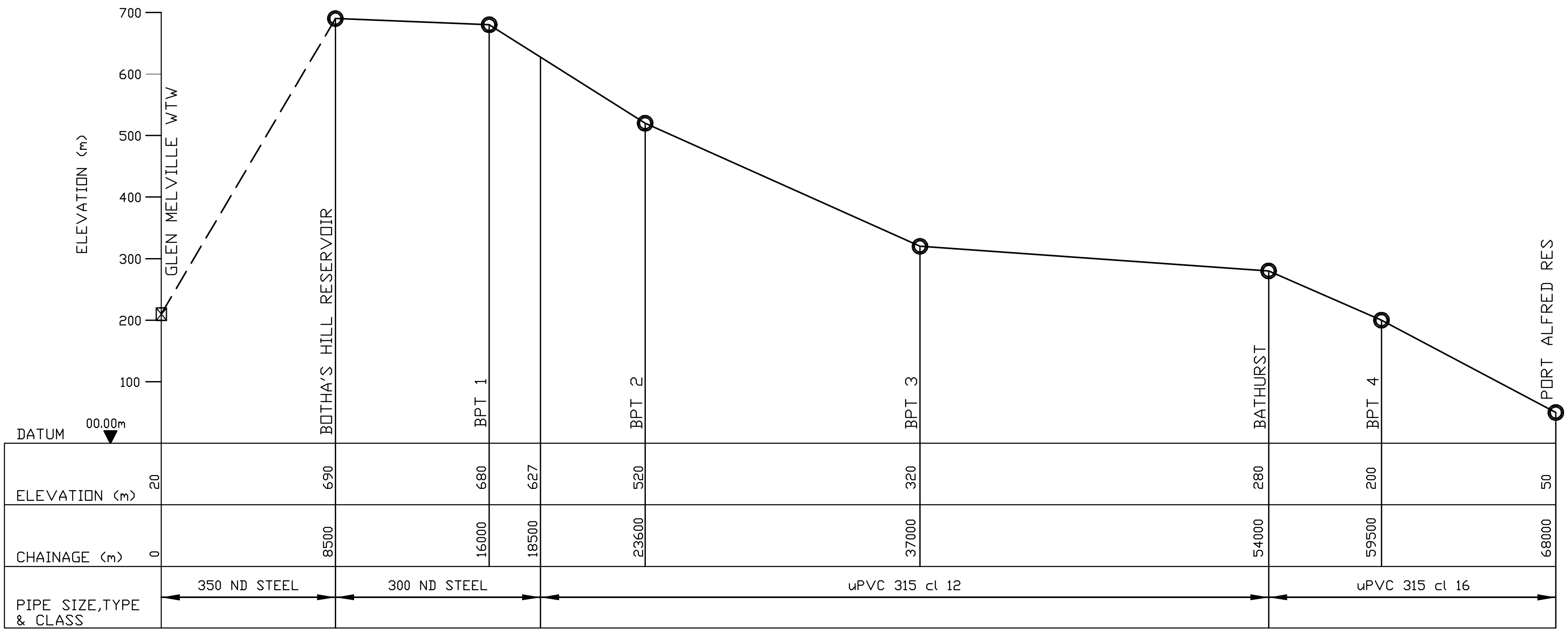
Sheet:	1 of 1
Drawn:	R.L.
Scale:	AS SHOWN
Checked:	H.V.D.
No.	Fig. L4



UWP Consulting

Project	
ALBANY COAST SITUATION ASSESSMENT STUDY	
Description	
BATHURST LAYOUT	

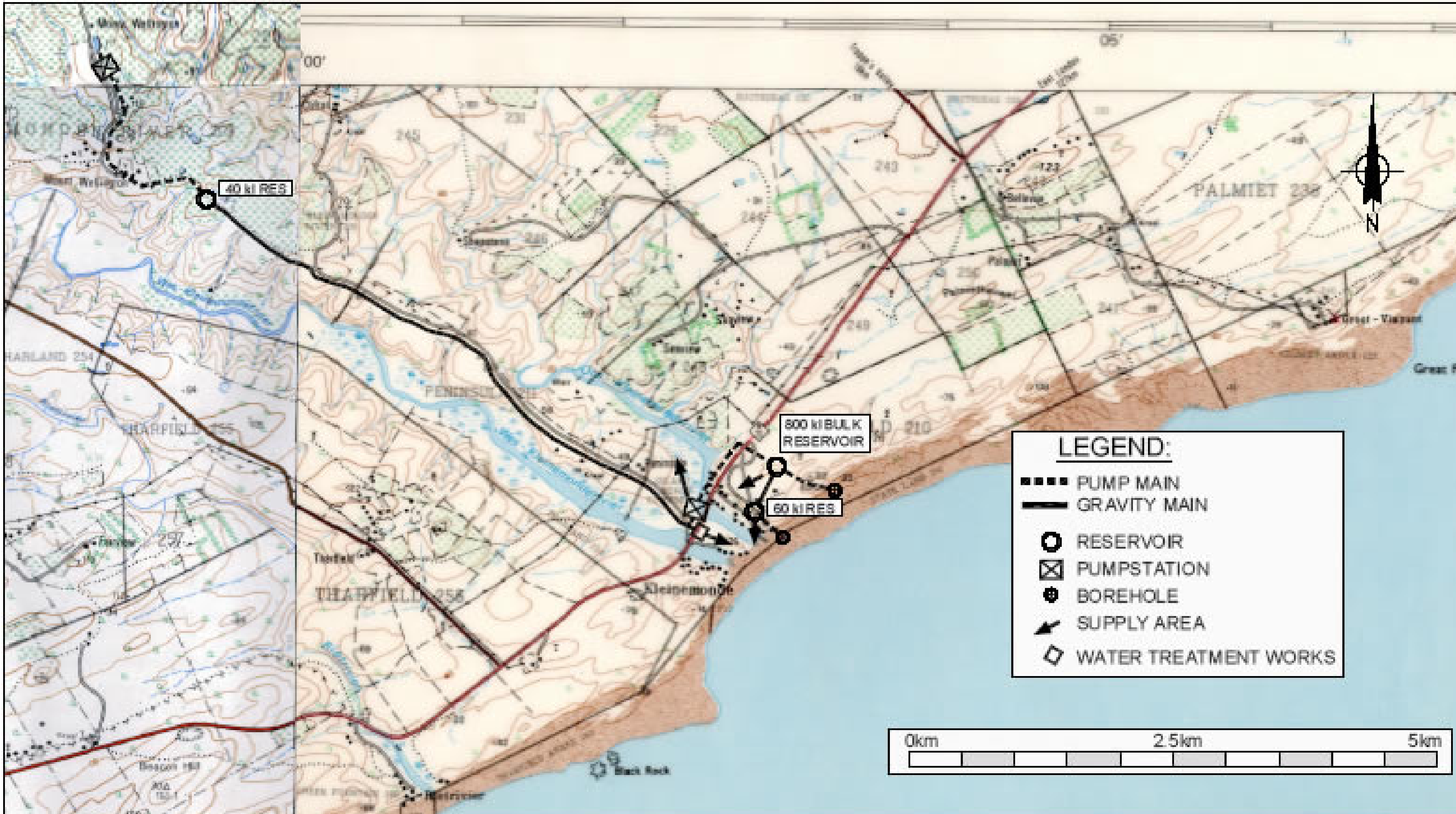
Designed:	R.L.
Sheet:	1 of 1
Drawn:	R.L.
Scale:	AS SHOWN
Checked:	H.V.D.
No.	Fig. S5



GLEN MELVILLE DAM TO PORT ALFRED – LONGITUDINAL SECTION

HORIZONTAL : 1:300 000
VERTICAL : 1:10 000

UWP Consulting	Project ALBANY COAST SITUATION ASSESSMENT STUDY	Designed: R.L. Sheet: 1 of 1 Drawn: R.L. Scale: AS SHOWN Checked: H.V.D.
	Description GLEN MELVILLE DAM TO PORT ALFRED - LONGITUDINAL SECTION	No. Fig. L5

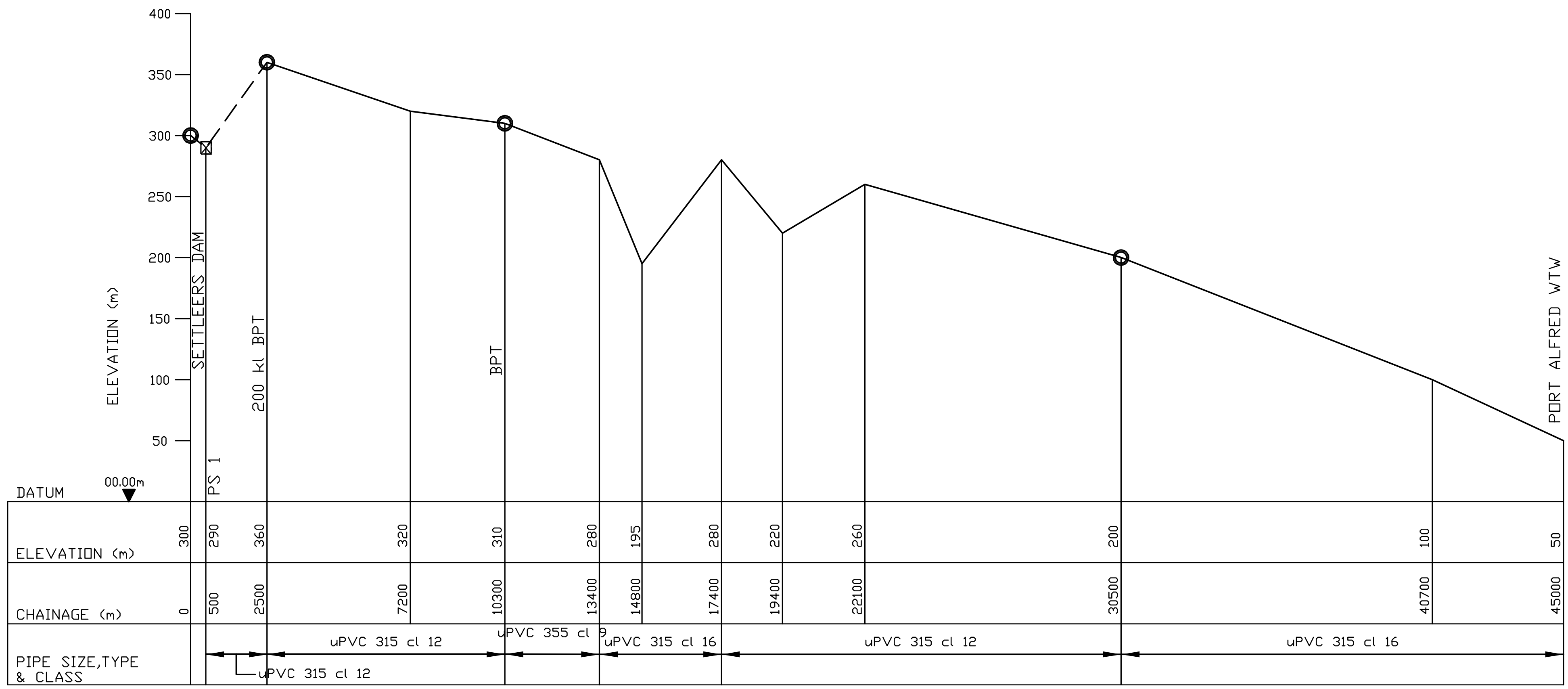


UWP Consulting

Project
ALBANY COAST
SITUATION ASSESSMENT STUDY

Description
KLEINEMONDE / SEAFIELD SCHEME LAYOUT

Designed:	W.S.K.
Sheet	1 of 1
Drawn:	W.K.
Scale:	AS SHOWN
Checked:	W.S.K.
No.	Fig. S6



SETTLERS DAM TO PORT ALFRED - LONGITUDINAL SECTION

HORIZONTAL : 1:200 000
VERTICAL : 1:5 000

UWP Consulting

Project

ALBANY COAST
SITUATION ASSESSMENT STUDY

Description

SETTLERS DAM TO PORT ALFRED - LONGITUDINAL SECTION

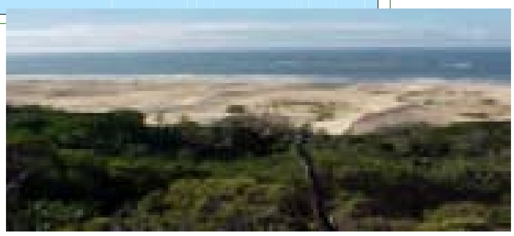
Designed:	R.L.
Sheet:	1 of 1
Drawn:	R.L.
Scale:	AS SHOWN
Checked:	H.V.D.
No.	Fig. L7

P WMA 15/000/00/0407

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate: National Water Resource Planning

ALBANY COAST SITUATION ASSESSMENT STUDY



Main Report: Volume 2

Appendices 3 to 10

Final

December 2004

Prepared by :

UWP Consulting (Pty) Ltd

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CENTURION
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DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

PROJECT NAME	:	Albany Coast Situation Assessment Study
TITLE	:	Main Report: Volume 2 - Final
AUTHOR	:	HV Doudenski
REPORT STATUS	:	Final
DWAF REPORT NO	:	P WMA 15/000/00/0407
DATE	:	December 2004

Submitted on behalf of UWP Consulting by:

…………………………………………………………………………………

HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

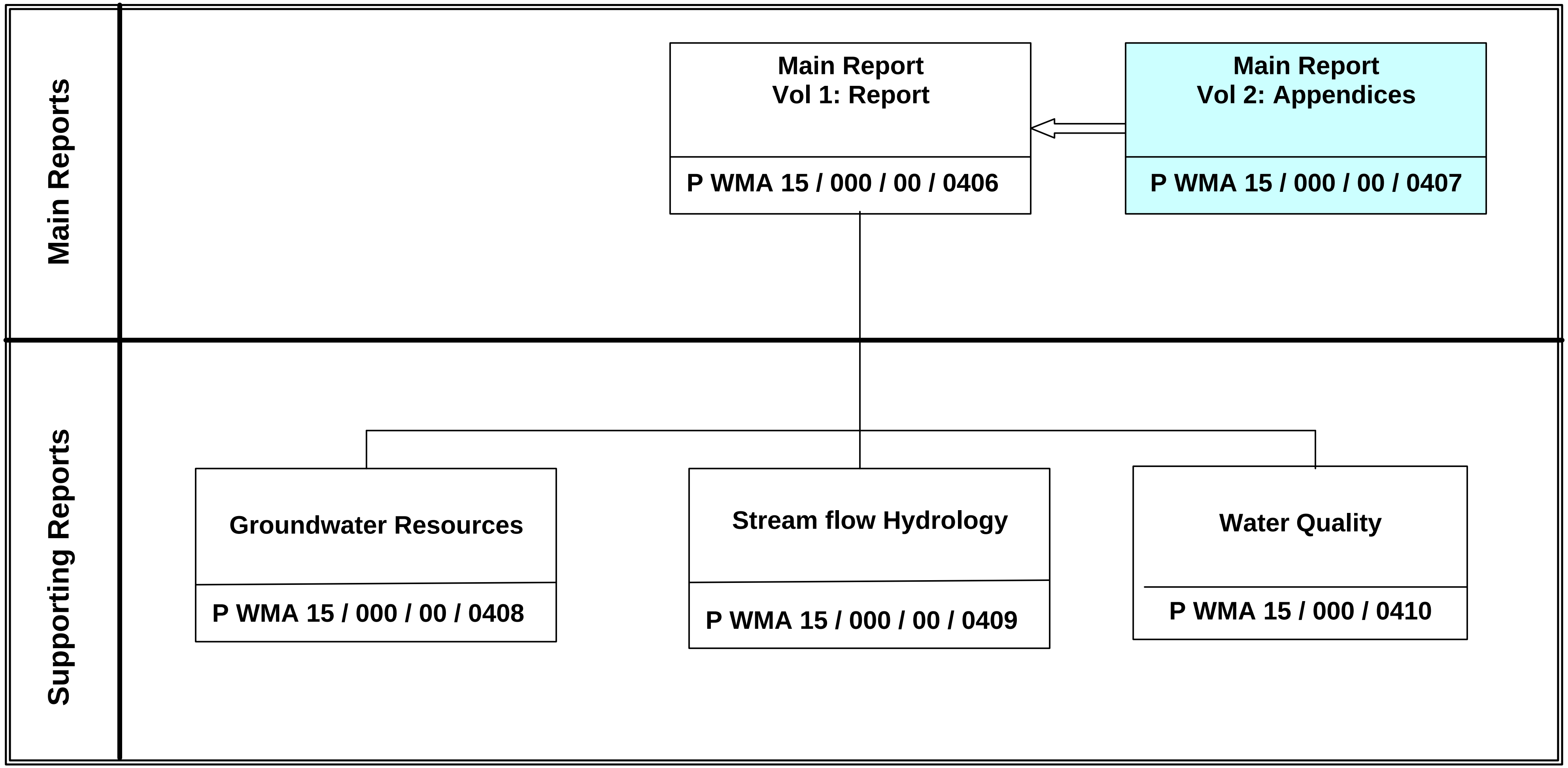
Directorate: National Water Resource Planning

Approved for Department of Water Affairs and Forestry by:

………………………………………………	………………………………………………
FA STOFFBERG	**JA VAN ROOYEN**
Chief Engineer: National Water Resource Planning	Director: National Water Resource Planning

ALBANY COAST SITUATION ASSESSMENT STUDY

Structure of Reports



DEPARTMENT OF WATER AFFAIRS & FORESTRY

DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

ALBANY COAST SITUATION ASSESSMENT STUDY

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APPENDIX 3: DEMOGRAPHIC DATA

Contents

APPENDIX 3. 1: CENSUS 2001 URBAN POPULATIONA NUMBERS PER QUATERNARY CATCHMENT AND PER SUBPLACE

Quaternary	Town	Water sourse	Census		Population No.		Service levels: No of households				Total	Pop No.
			sub-place code	Sub-place Name	Sub - Place	Total town	House Connect	Yard Connect	Communal Stand pipe	No service / or other	No of H. holds	per H. hold
P10B	Riebeeck East	GW P10B	20406000	Riebeeck East	517		0	136	0	3	139	3.7
			20401000	Albany	172		15	22	6	15	58	3.0
				Total		689						
P10D	Alicedale	NY dam P10B	Not listed	Alicedale		-						
P10E	Paterson	GW P10E	20609000	Paterson	671		0	126	15	0	141	4.8
			20607000	KwaZenzele SP	3,652		90	577	202	39	908	4.0
			20607001	KwaZenzele	81		3	0	26	0	29	2.8
				Total		4,404						
P10G	Kenton on sea	GW P10G	20507000	Kenton on Sea	856		377	18	9	0	404	2.1
			20505000	Ekuphumieni	2,023		12	498	3	0	513	3.9
			20505001	Ekuphumieni	1,602		0	180	334	0	514	3.1
			20507001	Tot Kenton Marselle	4,399		470	413	411	0	1294	3.4
				Total		8,880						
P20A	Alexandria	GW P20A	20501000	Alexandria	1,820		357	99	18	12	486	3.7
			20501001	Wentzel Park	1,263		170	30	85	0	285	4.4
			20509000	Kwanonqubela	4,632		122	1006	81	6	1215	3.8
				Total		7,715						
	Boknes	GW P20A	20503000	Boknes	216	216	71	12	9	9	101	2.1
	Canon Rocks	GW P20A	20504000	Canon Rocks	215	215	65	22	9	3	99	2.2

P40A	Grahamstown	Milner dam P10A	20403000	Grahamstown	14,854		2614	786	149	9	3558	4.2
		Jameson dam P10A		Institutions above	751						0	
		Holson's dam P30A	20403001	Ford E Hospital	291			3			3	97.0
		Settlers dam P30A	20403002	Gr Military Base	393		61	3			64	6.1
		Glen Melville Q	20403003	Mayfield	1,728		3	3	423		429	4.0
			20403004	Rhodes university	806		0				0	
			20403005	Silvertown	541			3	167		170	3.2
			20403006	Vukani	2,061			21	447	31	499	4.1
			20402000	Fingo Village	3,072		20	706	51	18	795	3.9
			20405001	Eluxolveni	796				210		210	3.8
			20405002	Glen Graig	847				282		282	3.0
			20405003	Kopke	1,681			374	36		410	4.1
			20405004	Xolani	33,938		597	6500	1069	81	8247	4.1
				Total		61,759						
P40C	Bathurst	GW private supplies	20502000	Bathurst	597		142	21	24	79	266	2.2
		Golden ridge P40B	20512000	Freestone	3,382		38	872	12	12	934	3.6
		Mansfield dam P40C	20512001	Nolukhanyo	1,570		9	136	301	0	446	3.5
				Total		5,549						
	Port Alfred	Sarel Hayword P40C	20513000	Port Alfred	4,578		1356	169	57	6	1588	2.9
		Mansfield dam P40C	20513001	Station Hill	1,714		412	69	42	6	529	3.2
		GW P40C	20511000	Nkwenkwezi	14,673		27	1659	2042	175	3903	3.8
				Thornhil	-							
				Total		20,965						
	Kasuka	GW	20506000	Kasuka	102	102	15	6	12	12	45	2.3
P40D	Kleinmonde	Wellington dam P40D	20508000	Kleinmonde	12	12		3			3	4.0
TOTAL URBAN POPULATION					110,506	110,506	7,046	14,473	6,532	516	28,567	3.9

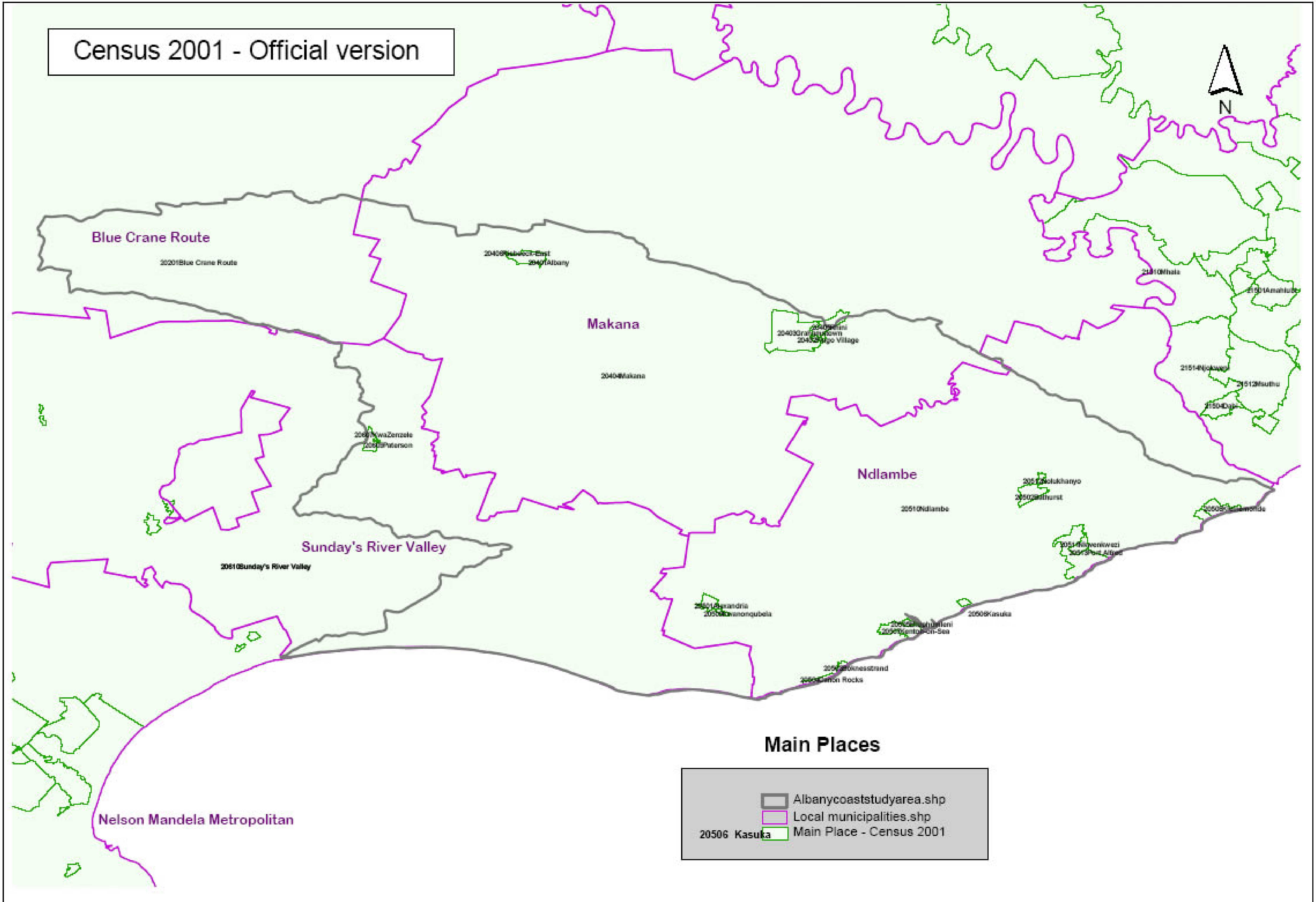
APPENDIX 3.2: Comparison of population data

Quaternary	Town	Pop Number Comparison				Accepted
		Mark Data	***Census***	***WSDP***	***WRSA***	***Base***
		1995	***2001***	***2001***	***1995***	***2001***
P10A						
1) Urban		-	-		-	-
2) Rural			363		246	363
	Total: Urban + Rural	-	363		246	363
P10B						
1) Urban	**Riebeeck East**	650	689	689	650	689
2) Rural			1,452		972	1,452
	Total: Urban + Rural	650	2,141		1,622	2,141
P10C						
1) Urban		-	-		-	-
2) Rural			310		282	310
	Total: Urban + Rural	-	310		282	310
P10D						
1) Urban	**Alicedale**	5,950	-	5,064	5,950	5,950
2) Rural			977		904	977
	Total: Urban + Rural	5,950	977		6,854	6,927
P10E						
1) Urban	**Paterson**	3,251	4,404	7,335	3,250	4,404
2) Rural			1,328		1,594	1,328
	Total: Urban + Rural	3,251	5,732		4,844	5,732
P10F						
1) Urban		-	-		-	-
2) Rural			1,344		2,517	1,344
	Total: Urban + Rural	-	1,344		2,517	1,344
P10G	**Kenton-on-Sea and Bushmans River Mouth**					
1) Urban		8,598	8,880	9,500	8,168	8,880
	Kenton/Ekuphuleni	4,199	4,481	5,000		4,481
	Marselle/Bushmans	4,399	4,399	4,500		4,399
2) Rural			2,488		2,497	2,488
	Total: Urban + Rural	8,598	11,368		10,665	11,368
P20A	**Alexandria, Canon Rocks, Boknesrand**					
1) Urban		7,649	8,146	8,620	8,080	8,146
	Alexandria	7,649	7,715	8,189	7,649	7,715
	Boknes	-	216	216	216	216
	Canon Rocks	-	215	215	215	215
2) Rural			3,242		3,999	3,242
	Total: Urban + Rural	7,649	11,388		12,079	11,388
P20B						
1) Urban		-	-		-	-
2) Rural			894		1,434	894
	Total: Urban + Rural	-	894		1,434	894
P30A						
1) Urban		-	-		-	-
2) Rural			484		1,119	484
	Total: Urban + Rural	-	484		1,119	484
P30B						
1) Urban		-	-		-	-
2) Rural			1,575		3,325	1,575
	Total: Urban + Rural	-	1,575		3,325	1,575
P30C						
1) Urban		-	-		-	-
2) Rural			328		562	328
	Total: Urban + Rural	-	328		562	328
P40A						
1) Urban	**Grahamstown**	59,357	61,759	81,600	59,350	61,759
2) Rural			997		2,378	997
	Total: Urban + Rural	59,357	62,756		61,728	62,756
P40B						
1) Urban		-	-		-	-
2) Rural		-	1,228		1,772	1,228
	Total: Urban + Rural	-	1,228		1,772	1,228
P40C						
1) Urban	**Port Alfred, Buthurst**	22,001	26,514	43,200	22,000	26,514
	Port Alfred	17,400	20,965	37,000	17,400	20,965
	Bathurst	4,601	5,549	6,200	4,600	5,549
2) Rural			1,511		2,014	1,511
	Total: Urban + Rural	22,001	28,025		24,014	28,025
P40D						
1) Urban	**Kleinmonde**	1,450	12	200	1,450	1,450
2) Rural			1,117		1,289	1,117
	Total: Urban + Rural	1,450	1,129		2,739	2,567
Total Urban		**108,906**	**110,404**	**156,208**	**108,898**	**117,792**
Total Rural			**19,638**		**26,904**	**19,638**
TOTAL STUDY			**130,042**		**135,802**	**137,430**

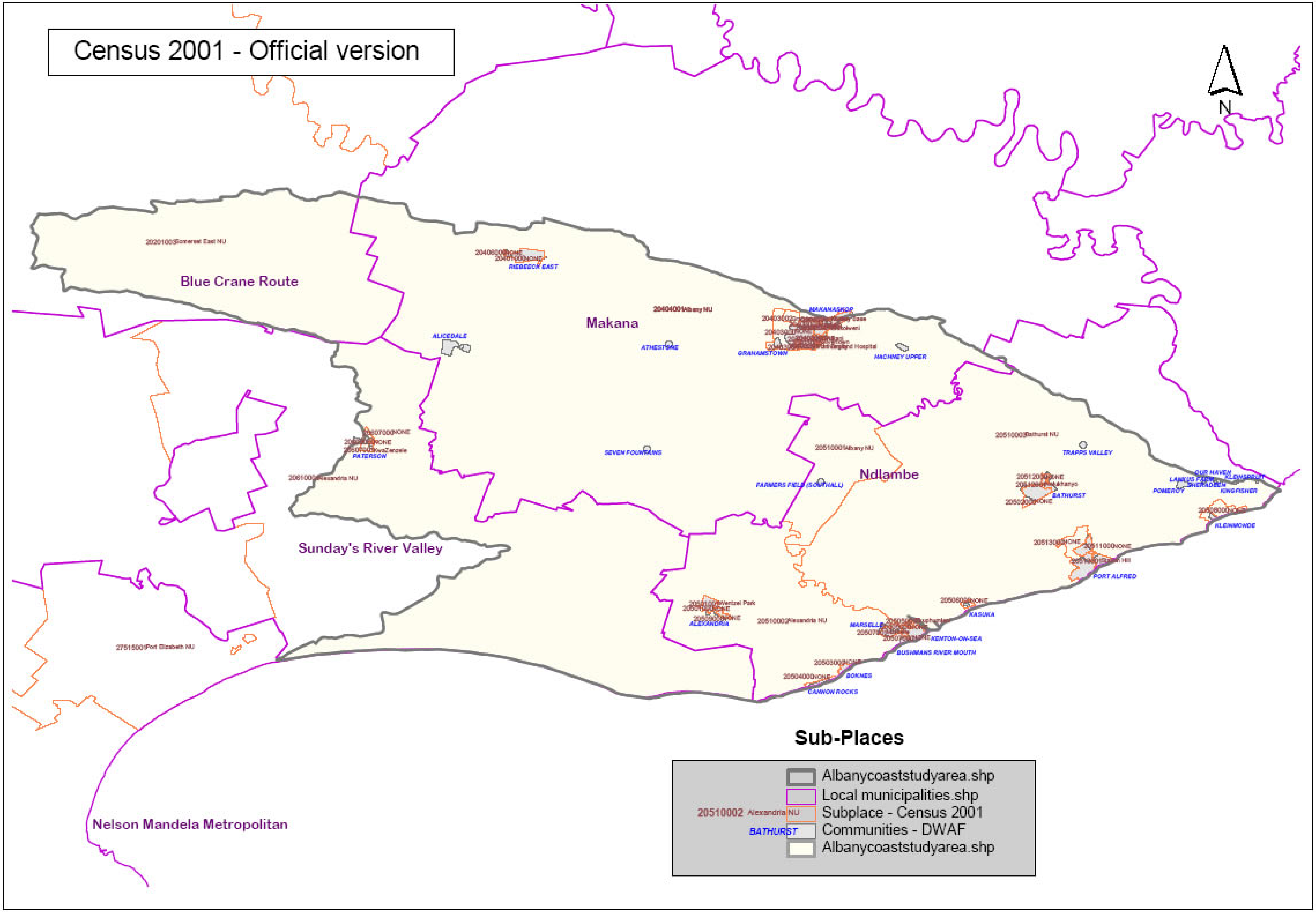
APPENDIX 3.3: Urban and rural population numbers per quaternary catchment

Quaternary	Town	Accepted	Planned new developments				MD Growth rates, % per annum			Projected population numbers			
		Base					*High scenario*						
		2001	*2001*	*2005*	*2015*	*2025*	2005	2015	2025	*2001 Base*	*2005*	*2015*	*2025*
P10A													
1) Urban		-				-				-	-	-	-
2) Rural		363					0.3718	-0.2974	-1.0859	363	368	358	321
	Total: Urban + Rural	363								363	368	358	321
P10B													
1) Urban	**Riebeeck East**	689					0.4965	-0.2218	-0.5210	689	703	687	652
2) Rural		1,452					0.3718	-0.2974	-1.0859	1,452	1,474	1,430	1,283
	Total: Urban + Rural	2,141								2,141	2,177	2,118	1,935
P10C													
1) Urban		-								-	-	-	-
2) Rural		310					0.2520	-0.9677	-1.2250	310	313	284	251
	Total: Urban + Rural	310								310	313	284	251
P10D													
1) Urban	**Alicedale**	5,950					0.5012	-0.2326	-0.5090	5,950	6,070	5,930	5,635
2) Rural		977					0.3718	-0.2974	-1.0859	977	992	963	863
	Total: Urban + Rural	6,927								6,927	7,062	6,893	6,498
P10E													
1) Urban	**Paterson**	4,404					0.4994	-0.2367	-0.5028	4,404	4,493	4,387	4,172
2) Rural		1,328					0.3715	-0.5357	-0.8486	1,328	1,348	1,277	1,173
	Total: Urban + Rural	5,732								5,732	5,840	5,665	5,345
P10F													
1) Urban		-								-	-	-	-
2) Rural		1,344					0.3718	-0.2974	-1.0859	1,344	1,364	1,324	1,187
	Total: Urban + Rural	1,344								1,344	1,364	1,324	1,187
P10G	**Kenton-on-Sea and Bushmans River Mouth**												
1) Urban		8,880								9,480	12,745	13,734	14,539
	Kenton/Ekuphuleni	4,481	300	1,200			2.3709	1.6370	1.3724	4,781	6,451	7,588	8,696
	Marselle/Bushmans	4,399	300	1,500			0.5003	-0.2376	-0.5041	4,699	6,294	6,146	5,843
2) Rural		2,488					0.3715	-0.5357	-0.8486	2,488	2,525	2,393	2,198
	Total: Urban + Rural	11,368								11,968	15,270	16,127	16,737
P20A	**Alexandria, Canon Rocks, Boknesrand**												
1) Urban		8,146								8,646	9,793	11,751	11,669
	Alexandria	7,715	0	500	1,000	-	0.5010	-0.2325	-0.5105	7,715	8,371	9,178	8,720
	Boknes	216	250	200	450	-	2.3709	1.6370	1.3724	466	712	1,287	1,475
	Canon Rocks	215	250	200	450	-	2.3709	1.6370	1.3724	465	711	1,286	1,474
2) Rural		3,242					0.3715	-0.5357	-0.8486	3,242	3,290	3,118	2,864
	Total: Urban + Rural	11,388								11,888	13,084	14,870	14,533

P20B													
1) Urban		-								-	-	-	-
2) Rural		894					0.3715	-0.5357	-0.8486	894	907	860	790
	Total: Urban + Rural	894								894	907	860	790
P30A													
1) Urban		-								-	-	-	-
2) Rural		484					0.3718	-0.2974	-1.0859	484	491	477	428
	Total: Urban + Rural	484								484	491	477	428
P30B													
1) Urban		-								-	-	-	-
2) Rural		1,575					0.3714	-0.5358	-0.8476	1,575	1,599	1,515	1,391
	Total: Urban + Rural	1,575								1,575	1,599	1,515	1,391
P30C													
1) Urban		-								-	-	-	-
2) Rural		328					0.3714	-0.5358	-0.8476	328	333	315	290
	Total: Urban + Rural	328								328	333	315	290
P40A													
1) Urban	**Grahamstown**	61,759					1.0405	0.3091	0.0306	61,759	64,370	66,387	66,591
2) Rural		997					0.3718	-0.2974	-1.0859	997	1,012	982	881
	Total: Urban + Rural	62,756								62,756	65,382	67,370	67,471
P40B													
1) Urban		-								-	-	-	-
2) Rural		1,228					0.3714	-0.5358	-0.8476	1,228	1,246	1,181	1,085
	Total: Urban + Rural	1,228								1,228	1,246	1,181	1,085
P40C													
1) Urban	**Port Alfred, Buthurst**	26,514								26,514	34,023	41,821	46,769
	Port Alfred	20,965	-	4,500	3,000		2.3716	1.6362	1.3723	20,965	27,526	35,376	40,542
	Bathurst	5,549		800			0.6605	-0.0797	-0.3438	5,549	6,497	6,445	6,227
2) Rural		1,511					0.3714	-0.5358	-0.8476	1,511	1,534	1,453	1,335
	Total: Urban + Rural	28,025								28,025	35,556	43,275	48,104
P40D													
1) Urban	**Kleinmonde**	1,450		-			2.3716	1.6362	1.3730	1,450	1,833	2,156	2,471
2) Rural		1,117					0.3714	-0.5358	-0.8476	1,117	1,134	1,074	987
	Total: Urban + Rural	2,567								2,567	2,967	3,230	3,458
Total Urban		**117,792**	**1,100**	**8,900**	**4,900**	**-**				**118,892**	**134,029**	**146,855**	**152,499**
Total Rural		**19,638**								**19,638**	**19,930**	**19,006**	**17,324**
TOTAL FOR STUDY AREA		**137,430**	**1,100**	**8,900**	**4,900**	**-**				**138,530**	**153,959**	**165,861**	**169,822**



Census 2001 - Official version
N
Blue Crane Route
20201Blue Crane Route
20401Albany
Makana
20404Makana
Ndlambe
20510Ndlambe
20506Kasuka
Sunday's River Valley
20610Sunday's River Valley
Nelson Mandela Metropolitan
Main Places
Albanycoaststudyarea.shp
Local municipalities.shp
20506 Kasuka
Main Place - Census 2001


Census 2001 - Official version
N
Blue Crane Route
Makana
Ndlambe
Sunday's River Valley
Nelson Mandela Metropolitan
ALICEDALE
GRAHAMSTOWN
BATHURST
PORT ALFRED
KENTON-ON-SEA
BUSHMANS RIVER MOUTH
CANNON ROCKS
Sub-Places
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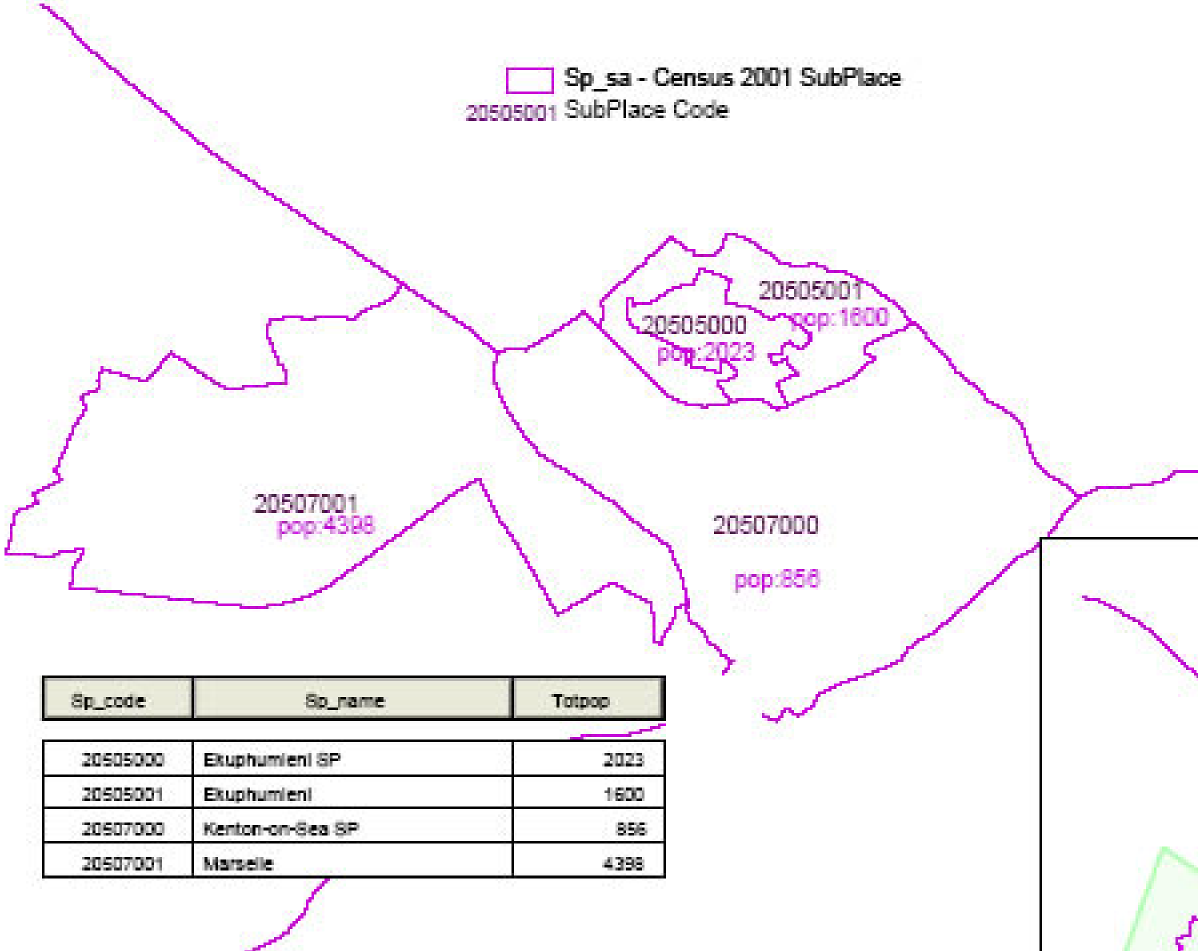
Local municipalities.shp
20510002 Alexandria NU
Subplace - Census 2001
BATHURST
Communities - DWAF
Albanycoaststudyarea.shp



Sp_code	Sp_name	Totpop
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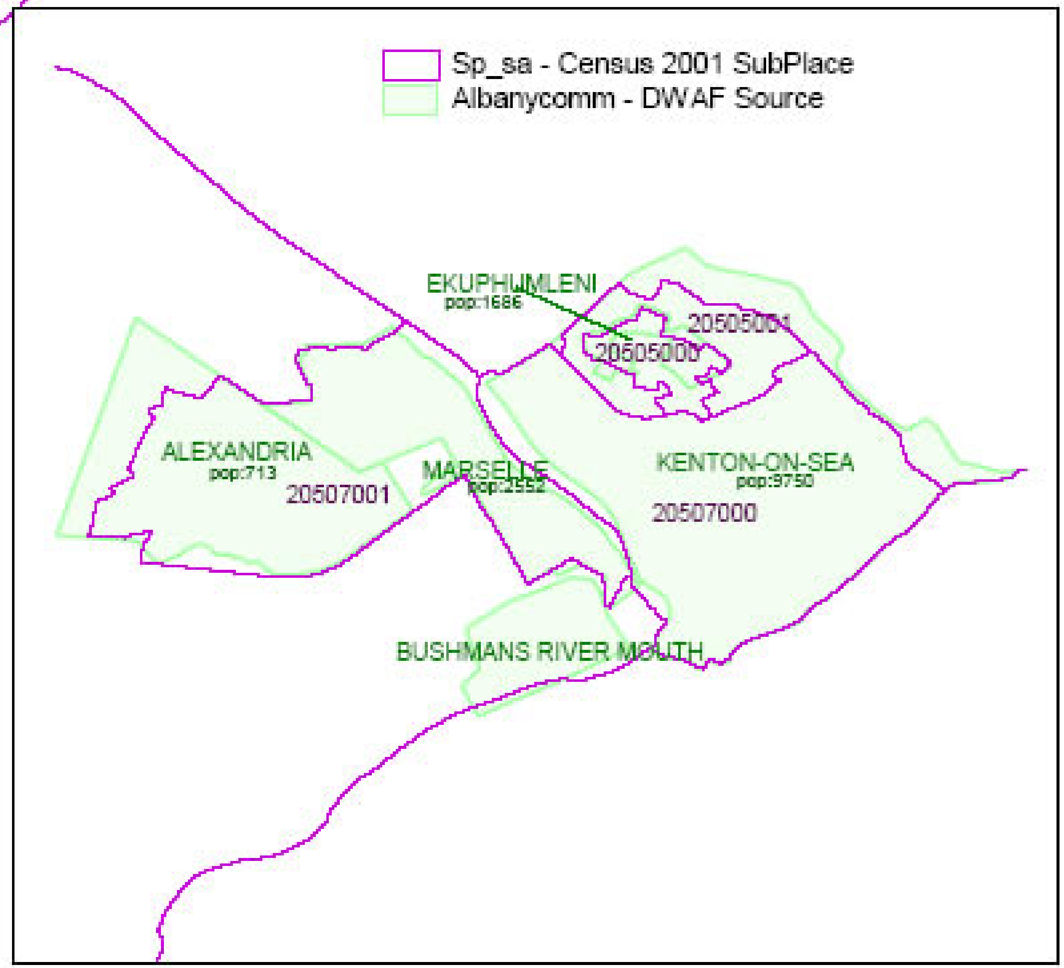
20505001	Ekuphumleni	1600
20507000	Kenton-on-Sea SP	856
20507001	Marselle	4398



Albany Coast Basin Study - Census 2001
Main Water Supply as Number of Households per SubPlace

Total for all intersecting Albany Coast Municipalities	11,782	25,778	5,401	5,635	524	45	1,952	1,591	485	54	944	54,199

Local Municipalit EC102 - Blue Crane Route Municipality

SubPlace Code	SubPlace Name	Piped water inside dwelling	Piped water inside yard	Piped water on community stand within 200m	Piped water on community stand not within 200m	Borehole	Spring	Rainwater tank	Dam/Pool/Stagnant water	River/Stream	Water vendor	Other	Total
20201001	Bedford NU	109	137	24	126	38	0	27	83	65	6	12	627
20201002	Pearston NU	76	236	33	9	21	0	6	6	0	0	3	391
20201003	Somerset East NU	428	675	179	211	66	3	134	123	153	9	59	2,041
20202000	NONE	306	500	21	15	0	0	0	0	0	0	26	868
20202001	Bongweni	0	146	0	0	0	0	0	0	0	0	0	146
20203000	NONE	46	85	0	0	0	0	0	0	0	0	0	131
20203001	Newtown	9	120	54	0	0	0	0	0	0	0	30	213
20204000	NONE	6	408	0	0	0	0	3	0	0	0	3	420
20205000	NONE	185	1,007	184	198	3	0	0	0	0	0	15	1,592
20205001	KwaNojoli	0	366	6	92	0	0	3	0	0	0	12	478
20206000	NONE	98	24	0	3	0	0	0	0	0	0	3	128
20206001	Nelsig	62	374	13	3	0	0	0	0	0	0	0	451
20207000	NONE	996	719	18	30	0	0	6	0	3	0	3	1,775
20207001	Clevedon	0	118	0	0	0	0	0	0	0	0	0	118
20207002	Westview	0	167	9	0	0	0	0	0	0	0	0	176

Summary for 'LM' = Blue Crane Route Municipality (15 detail records)

Total	2,321	5,082	541	687	128	3	179	212	221	15	166	9,555

Local Municipalit EC104 - Makana Municipality

SubPlace Code	SubPlace Name	Piped water inside dwelling	Piped water inside yard	Piped water on community stand within 200m	Piped water on community stand not within 200m	Borehole	Spring	Rainwater tank	Dam/Pool/Stagnant water	River/Stream	Water vendor	Other	Total
20401000	NONE	15	22	3	3	0	0	15	0	0	0	0	58
20402000	NONE	20	706	9	42	0	0	0	0	0	0	18	795
20403000	NONE	2,614	786	87	62	0	0	0	0	0	0	9	3,558
20403001	Fort England Hospital	0	3	0	0	0	0	0	0	0	0	0	3
20403002	Grahamstown Military Base	61	3	0	0	0	0	0	0	0	0	0	64
20403003	Mayfield	3	3	221	202	0	0	0	0	0	0	0	429
20403004	Rhodes University	0	0	0	0	0	0	0	0	0	0	0	0
20403005	Silvertown	0	3	91	76	0	0	0	0	0	0	0	170
20403006	Vukani	0	21	28	419	0	0	0	0	0	0	31	499
20404001	Albany NU	702	1,171	360	318	84	9	275	269	63	3	45	3,300
20405001	Eluxolweni	0	0	210	0	0	0	0	0	0	0	0	210
20405002	Glen Graig	0	0	71	211	0	0	0	0	0	0	0	283
20405003	Kopke	0	374	0	36	0	0	0	0	0	0	0	410
20405004	Xolani	597	6,500	705	364	0	0	3	0	6	0	72	8,247
20406000	NONE	0	136	0	0	0	0	0	0	0	0	3	139

Summary for 'LM' = Makana Municipality (15 detail records)

Total		*4,012*	*9,728*	*1,785*	*1,733*	*84*	*9*	*293*	*269*	*69*	*3*	*178*	*18,165*

Local Municipalit EC105 - Ndlambe Municipality

SubPlace Code	SubPlace Name	Piped water inside dwelling	Piped water inside yard	Piped water on community stand within 200m	Piped water on community stand not within 200m	Borehole	Spring	Rainwater tank	Dam/Pool/Stagnant water	River/Stream	Water vendor	Other	Total
20501000	NONE	357	99	3	15	0	0	0	3	0	0	9	486
20501001	Wentzel Park	170	30	73	12	0	0	0	0	0	0	0	286
20502000	NONE	142	21	12	12	29	3	44	0	0	0	3	265
20503000	NONE	71	12	3	6	0	0	9	0	0	0	0	101
20504000	NONE	65	22	6	3	0	0	0	0	0	3	0	99
20505000	NONE	12	498	3	0	0	0	0	0	0	0	9	522
20505001	Ekuphumleni	0	180	241	93	0	0	0	0	0	0	37	551
20506000	NONE	15	6	9	3	0	0	12	0	0	0	0	45
20507000	NONE	377	18	0	9	0	0	6	0	0	0	0	410
20507001	Marselle	470	413	94	317	0	0	6	0	0	0	6	1,306
20508000	NONE	0	3	0	0	0	0	0	0	0	0	0	3
20509000	NONE	122	1,006	18	63	0	0	0	0	0	0	6	1,215
20510001	Albany NU	27	72	12	6	0	0	45	32	18	0	0	213
20510002	Alexandria NU	113	144	325	191	30	3	280	86	6	3	33	1,214
20510003	Bathurst NU	346	315	110	321	109	3	267	286	75	3	3	1,837
20511000	NONE	27	1,659	1,261	781	0	3	30	0	0	0	142	3,904
20512000	NONE	38	872	9	3	0	0	0	0	0	0	12	934
20512001	Nolukhanyo	9	136	57	244	0	0	0	0	0	0	0	446
20513000	NONE	1,356	169	24	33	0	0	0	0	0	0	6	1,588
20513001	Station Hill	412	69	15	27	0	0	3	0	0	0	3	528

Summary for 'LM' = Ndlambe Municipality (20 detail records)

Total		*4,129*	*5,744*	*2,275*	*2,139*	*168*	*12*	*702*	*407*	*99*	*9*	*269*	*15,953*

Local Municipalit EC106 - Sunday's River Valley Municipality

SubPlace Code	SubPlace Name	Piped water inside dwelling	Piped water inside yard	Piped water on community stand within 200m	Piped water on community stand not within 200m	Borehole	Spring	Rainwater tank	Dam/Pool/Stagnant water	River/Stream	Water vendor	Other	Total
20601000	NONE	33	6	6	6	0	0	0	15	0	0	6	72
20601001	Valencia	18	180	9	122	0	0	0	0	0	0	3	332
20602000	NONE	0	18	0	0	0	0	0	0	0	0	0	18
20603000	NONE	3	104	0	0	0	0	0	0	0	0	9	116
20604000	NONE	24	922	30	79	0	0	73	6	3	0	112	1,249
20604001	Bontrug	70	236	41	0	0	0	0	0	0	0	6	353
20605000	NONE	83	64	3	9	0	0	6	0	0	0	0	166
20606000	NONE	181	152	3	0	0	0	0	0	0	0	6	342
20606001	Bergsig	55	186	0	0	0	0	3	0	0	0	12	256
20607000	NONE	90	577	64	138	21	0	0	3	0	0	15	907
20607001	KwaZenzele	3	0	26	0	0	0	0	0	0	0	0	29
20608000	NONE	9	1,647	188	325	3	3	0	98	3	0	30	2,306
20609000	NONE	0	126	9	6	0	0	0	0	0	0	0	142
20610001	Alexandria NU	243	266	166	194	84	15	228	157	24	3	0	1,381
20610002	Kirkwood NU	386	682	230	188	30	3	450	394	60	15	114	2,554
20610003	Kirkwood SH	122	58	25	9	6	0	18	30	6	9	18	303

Summary for 'LM' = Sunday's River Valley Municipality (16 detail records)

Total	*1,320*	*5,224*	*800*	*1,076*	*144*	*21*	*778*	*703*	*96*	*27*	*331*	*10,526*

Albany Coast Basin Study - Census 2001
Population per Main Place Type

Total for all intersecting Albany Coast Municipalities	*117*	*0*	*47,038*	*1,737*	*142,525*	*12,340*	*90*	*57*	*2,688*	*33*	*206,625*

Local Municipalit EC102 - Blue Crane Route Municipality

Main Place Code	Main Place Name	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20201	Blue Crane Route	0	0	9,196	0	0	0	0	0	0	0	9,196
20202	Bongweni	0	0	0	0	3,344	432	0	0	0	0	3,776
20203	Cookhouse	0	0	0	0	1,415	0	0	0	0	0	1,415
20204	Khayanisho	0	0	0	0	1,448	0	0	0	0	0	1,448
20205	KwaNojoli	0	0	0	0	6,442	1,690	0	0	0	0	8,132
20206	Pearston	0	0	0	0	2,596	0	0	0	0	0	2,596
20207	Somerset East	0	0	0	195	8,261	0	0	0	0	0	8,456

Summary for 'LM' = Blue Crane Route Municipality (7 detail records)

Total	*0*	*0*	*9,196*	*195*	*23,506*	*2,122*	*0*	*0*	*0*	*0*	*35,019*

Local Municipalit EC104 - Makana Municipality

Main Place Code	Main Place Name	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20401	Albany	0	0	0	0	172	0	0	0	0	0	172
20402	Fingo Village	0	0	0	0	3,072	0	0	0	0	0	3,072
20403	Grahamstown	0	0	0	604	14,244	4,318	0	0	2,237	0	21,403
20404	Makana	0	0	12,102	0	0	0	0	0	0	0	12,102
20405	Rhini	0	0	0	0	35,622	1,643	0	0	0	0	37,265
20406	Riebeeck-East	0	0	0	0	517	0	0	0	0	0	517
Summary for 'LM' = Makana Municipality (6 detail records)												
Total		*0*	*0*	*12,102*	*604*	*53,627*	*5,961*	*0*	*0*	*2,237*	*0*	*74,531*

Local Municipalit EC105 - Ndlambe Municipality

Main Place Code	Main Place Name	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20501	Alexandria	0	0	0	0	3,030	0	0	57	0	0	3,087
20502	Bathurst	0	0	0	0	600	0	0	0	0	0	600
20503	Boknesstrand	0	0	0	0	216	0	0	0	0	0	216
20504	Canon Rocks	0	0	0	0	209	0	0	0	0	0	209
20505	Ekuphumleni	0	0	0	0	2,020	1,599	0	0	0	0	3,619
20506	Kasuka	0	0	0	0	96	0	0	0	0	0	96
20507	Kenton-on-Sea	0	0	0	0	4,253	1,013	0	0	0	0	5,266
20508	Kleinemonde	18	0	0	0	0	0	0	0	0	0	18
20509	Kwanonqubela	0	0	0	0	4,626	0	0	0	0	0	4,626
20510	Ndlambe	0	0	11,833	0	0	0	0	0	0	0	11,833
20511	Nkwenkwezi	0	0	0	0	14,673	0	0	0	0	0	14,673
20512	Nolukhanyo	0	0	0	0	3,382	1,579	0	0	0	0	4,961
20513	Port Alfred	0	0	0	0	6,287	0	0	0	0	0	6,287

Summary for 'LM' = Ndlambe Municipality (13 detail records)

Total	*18*	*0*	*11,833*	*0*	*39,392*	*4,191*	*0*	*57*	*0*	*0*	*55,491*

Local Municipalit EC106 - Sunday's River Valley Municipality

Main Place Code	Main Place Name	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20601	Addo	99	0	0	0	1,653	0	0	0	0	0	1,752
20602	Addo Elephant National Park	0	0	0	0	0	0	90	0	0	0	90
20603	Barsheba	0	0	0	0	517	0	0	0	0	0	517
20604	Bontrug	0	0	0	0	6,806	0	0	0	0	0	6,806
20605	Enon	0	0	0	0	782	0	0	0	0	0	782
20606	Kirkwood	0	0	0	0	2,671	0	0	0	78	0	2,749
20607	KwaZenzele	0	0	0	0	3,634	66	0	0	0	33	3,733
20608	Nomathamsanqa	0	0	0	0	9,266	0	0	0	0	0	9,266
20609	Paterson	0	0	0	0	671	0	0	0	0	0	671
20610	Sunday's River Valley	0	0	13,907	938	0	0	0	0	373	0	15,218

Summary for 'LM' = Sunday's River Valley Municipality (10 detail records)

Total	*99*	*0*	*13,907*	*938*	*26,000*	*66*	*90*	*0*	*451*	*33*	*41,584*

Albany Coast Basin Study - Census 2001
Population per SubPlace Type

Total for all intersecting Albany Coast Municipalities		99	0	47,034	1,737	142,532	12,349	90	51	2,707	33	206,632

Local Municipalit EC102 - Blue Crane Route Municipality

SubPlace Code	SubPlace Name	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20201001	Bedford NU	0	0	1,953	0	0	0	0	0	0	0	1,953
20201002	Pearston NU	0	0	1,046	0	0	0	0	0	0	0	1,046
20201003	Somerset East NU	0	0	6,204	0	0	0	0	0	0	0	6,204
20202000	Bongweni SP	0	0	0	0	3,344	0	0	0	0	0	3,344
20202001	Bongweni	0	0	0	0	0	432	0	0	0	0	432
20203000	Cookhouse SP	0	0	0	0	499	0	0	0	0	0	499
20203001	Newtown	0	0	0	0	914	0	0	0	0	0	914
20204000	Khayanisho SP	0	0	0	0	1,445	0	0	0	0	0	1,445
20205000	KwaNojoli SP	0	0	0	0	6,436	0	0	0	0	0	6,436
20205001	KwaNojoli	0	0	0	0	0	1,687	0	0	0	0	1,687
20206000	Pearston SP	0	0	0	0	495	0	0	0	0	0	495
20206001	Nelsig	0	0	0	0	2,102	0	0	0	0	0	2,102
20207000	Somerset East SP	0	0	0	204	6,729	0	0	0	0	0	6,933
20207001	Clevedon	0	0	0	0	652	0	0	0	0	0	652
20207002	Westview	0	0	0	0	861	0	0	0	0	0	861

Summary for 'LM' = Blue Crane Route Municipality (15 detail records)

Total		*0*	*0*	*9,203*	*204*	*23,477*	*2,119*	*0*	*0*	*0*	*0*	*35,003*

Local Municipalit EC104 - Makana Municipality

SubPlace Code	SubPlace Name	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20401000	Albany SP	0	0	0	0	172	0	0	0	0	0	172
20402000	Fingo Village SP	0	0	0	0	3,075	0	0	0	0	0	3,075
20403000	Grahamstown SP	0	0	0	598	14,247	0	0	0	751	0	15,596
20403001	Fort England Hospital	0	0	0	0	0	0	0	0	291	0	291
20403002	Grahamstown Military Base	0	0	0	0	0	0	0	0	393	0	393
20403003	Mayfield	0	0	0	0	0	1,728	0	0	0	0	1,728
20403004	Rhodes University	0	0	0	0	0	0	0	0	806	0	806
20403005	Silvertown	0	0	0	0	0	541	0	0	0	0	541
20403006	Vukani	0	0	0	0	0	2,061	0	0	0	0	2,061
20404001	Albany NU	0	0	12,102	0	0	0	0	0	0	0	12,102
20405001	Eluxolweni	0	0	0	0	0	796	0	0	0	0	796
20405002	Glen Graig	0	0	0	0	0	847	0	0	0	0	847
20405003	Kopke	0	0	0	0	1,681	0	0	0	0	0	1,681
20405004	Xolani	0	0	0	0	33,938	0	0	0	0	0	33,938
20406000	Riebeeck-East SP	0	0	0	0	517	0	0	0	0	0	517
Summary for 'LM' = Makana Municipality (15 detail records)												
Total		*0*	*0*	*12,102*	*598*	*53,630*	*5,973*	*0*	*0*	*2,241*	*0*	*74,544*

Local Municipalit EC105 - Ndlambe Municipality

SubPlace Code	SubPlace Name	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20501000	Alexandria SP	0	0	0	0	1,769	0	0	51	0	0	1,820
20501001	Wentzel Park	0	0	0	0	1,263	0	0	0	0	0	1,263
20502000	Bathurst SP	0	0	0	0	597	0	0	0	0	0	597
20503000	Boknesstrand SP	0	0	0	0	216	0	0	0	0	0	216
20504000	Canon Rocks SP	0	0	0	0	215	0	0	0	0	0	215
20505000	Ekuphumleni SP	0	0	0	0	2,023	0	0	0	0	0	2,023
20505001	Ekuphumleni	0	0	0	0	0	1,602	0	0	0	0	1,602
20506000	Kasuka SP	0	0	0	0	102	0	0	0	0	0	102
20507000	Kenton-on-Sea SP	0	0	0	0	856	0	0	0	0	0	856
20507001	Marselle	0	0	0	0	3,395	1,004	0	0	0	0	4,399
20508000	Kleinemonde SP	12	0	0	0	0	0	0	0	0	0	12
20509000	Kwanonqubela SP	0	0	0	0	4,632	0	0	0	0	0	4,632
20510001	Albany NU	0	0	764	0	0	0	0	0	0	0	764
20510002	Alexandria NU	0	0	4,493	0	0	0	0	0	0	0	4,493
20510003	Bathurst NU	0	0	6,570	0	0	0	0	0	0	0	6,570
20511000	Nkwenkwezi SP	0	0	0	0	14,673	0	0	0	0	0	14,673
20512000	Nolukhanyo SP	0	0	0	0	3,382	0	0	0	0	0	3,382
20512001	Nolukhanyo	0	0	0	0	0	1,570	0	0	0	0	1,570
20513000	Port Alfred SP	0	0	0	0	4,578	0	0	0	0	0	4,578
20513001	Station Hill	0	0	0	0	1,714	0	0	0	0	0	1,714

Summary for 'LM' = Ndlambe Municipality (20 detail records)

Total	*12*	*0*	*11,827*	*0*	*39,415*	*4,176*	*0*	*51*	*0*	*0*	*55,481*

Local Municipalit EC106 - Sunday's River Valley Municipality

SubPlace Code	SubPlace Name	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20601000	Addo SP	87	0	0	0	162	0	0	0	0	0	249
20601001	Valencia	0	0	0	0	1,500	0	0	0	0	0	1,500
20602000	Addo Elephant National Park SP	0	0	0	0	0	0	90	0	0	0	90
20603000	Barsheba SP	0	0	0	0	523	0	0	0	0	0	523
20604000	Bontrug SP	0	0	0	0	5,349	0	0	0	0	0	5,349
20604001	Bontrug	0	0	0	0	1,458	0	0	0	0	0	1,458
20605000	Enon SP	0	0	0	0	785	0	0	0	0	0	785
20606000	Kirkwood SP	0	0	0	0	1,144	0	0	0	78	0	1,222
20606001	Bergsig	0	0	0	0	1,536	0	0	0	0	0	1,536
20607000	KwaZenzele SP	0	0	0	0	3,619	0	0	0	0	33	3,652
20607001	KwaZenzele	0	0	0	0	0	81	0	0	0	0	81
20608000	Nomathamsanqa SP	0	0	0	0	9,263	0	0	0	0	0	9,263
20609000	Paterson SP	0	0	0	0	671	0	0	0	0	0	671
20610001	Alexandria NU	0	0	4,969	0	0	0	0	0	0	0	4,969
20610002	Kirkwood NU	0	0	8,933	0	0	0	0	0	388	0	9,321
20610003	Kirkwood SH	0	0	0	935	0	0	0	0	0	0	935

Summary for 'LM' = Sunday's River Valley Municipality (16 detail records)

Total	*87*	*0*	*13,902*	*935*	*26,010*	*81*	*90*	*0*	*466*	*33*	*41,604*

Albany Coast Basin Study - Census 2001
Population per SubPlace Type

Quaternary P10A

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20403000	Grahamstown SP	**0.29**	0	0	0	598	14,247	0	0	0	751	0	15,596
20403002	Grahamstown Military Base	**0.75**	0	0	0	0	0	0	0	0	393	0	393
20404001	Albany NU	**0.03**	0	0	12,102	0	0	0	0	0	0	0	12,102

Summary for 'QUAT' = P10A (3 detail records)

Total											
Total	*0*	*0*	*12,102*	*598*	*14,247*	*0*	*0*	*0*	*1,144*	*0*	*28,091*

Quaternary P10B

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20401000	Albany SP	**1.00**	0	0	0	0	172	0	0	0	0	0	172
20404001	Albany NU	**0.12**	0	0	12,102	0	0	0	0	0	0	0	12,102
20406000	Riebeeck-East SP	**1.00**	0	0	0	0	517	0	0	0	0	0	517

Summary for 'QUAT' = P10B (3 detail records)

Total											
Total	*0*	*0*	*12,102*	*0*	*689*	*0*	*0*	*0*	*0*	*0*	*12,791*

Quaternary P10C

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20201003	Somerset East NU	**0.05**	0	0	6,204	0	0	0	0	0	0	0	6,204

Summary for 'QUAT' = P10C (1 detail record)

Total											
Total	*0*	*0*	*6,204*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*6,204*

Quaternary P10D

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20201003	Somerset East NU	**0.06**	0	0	6,204	0	0	0	0	0	0	0	6,204
20404001	Albany NU	**0.05**	0	0	12,102	0	0	0	0	0	0	0	12,102
20610001	Alexandria NU	**0.00**	0	0	4,969	0	0	0	0	0	0	0	4,969

* This ratio represents the area of the subplace which falls within the quaternary boundary:1 = 100%
This was not applied to the population figures in this report

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Quaternary P10D

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
Summary for 'QUAT' = P10D (3 detail records)													
Total			*0*	*0*	*23,275*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*23,275*

Quaternary P10E

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20404001	Albany NU	**0.04**	0	0	12,102	0	0	0	0	0	0	0	12,102
20607000	KwaZenzele SP	**0.97**	0	0	0	0	3,619	0	0	0	0	33	3,652
20607001	KwaZenzele	**1.00**	0	0	0	0	0	81	0	0	0	0	81
20609000	Paterson SP	**1.00**	0	0	0	0	671	0	0	0	0	0	671
20610001	Alexandria NU	**0.17**	0	0	4,969	0	0	0	0	0	0	0	4,969
Summary for 'QUAT' = P10E (5 detail records)													
Total			*0*	*0*	*17,071*	*0*	*4,290*	*81*	*0*	*0*	*0*	*33*	*21,475*

Quaternary P10F

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20404001	Albany NU	**0.07**	0	0	12,102	0	0	0	0	0	0	0	12,102
20610001	Alexandria NU	**0.10**	0	0	4,969	0	0	0	0	0	0	0	4,969
Summary for 'QUAT' = P10F (2 detail records)													
Total			*0*	*0*	*17,071*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*17,071*

Quaternary P10G

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20404001	Albany NU	**0.01**	0	0	12,102	0	0	0	0	0	0	0	12,102
20501000	Alexandria SP	**0.08**	0	0	0	0	1,769	0	0	51	0	0	1,820
20505000	Ekuphumleni SP	**1.00**	0	0	0	0	2,023	0	0	0	0	0	2,023
20505001	Ekuphumleni	**1.00**	0	0	0	0	0	1,602	0	0	0	0	1,602
20507000	Kenton-on-Sea SP	**0.88**	0	0	0	0	856	0	0	0	0	0	856
20507001	Marselle	**0.10**	0	0	0	0	3,395	1,004	0	0	0	0	4,399
20510001	Albany NU	**0.10**	0	0	764	0	0	0	0	0	0	0	764
20510002	Alexandria NU	**0.40**	0	0	4,493	0	0	0	0	0	0	0	4,493
20510003	Bathurst NU	**0.06**	0	0	6,570	0	0	0	0	0	0	0	6,570
20610001	Alexandria NU	**0.02**	0	0	4,969	0	0	0	0	0	0	0	4,969

* This ratio represents the area of the subplace which falls within the quaternary boundary:1 = 100%
This was not applied to the population figures in this report

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Quaternary P10G

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total

Summary for 'QUAT' = P10G (10 detail records)

Total			*0*	*0*	*28,898*	*0*	*8,043*	*2,606*	*0*	*51*	*0*	*0*	*39,598*

Quaternary P20A

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20501000	Alexandria SP	**0.92**	0	0	0	0	1,769	0	0	51	0	0	1,820
20501001	Wentzel Park	**1.00**	0	0	0	0	1,263	0	0	0	0	0	1,263
20503000	Boknesstrand SP	**1.00**	0	0	0	0	216	0	0	0	0	0	216
20504000	Canon Rocks SP	**1.00**	0	0	0	0	215	0	0	0	0	0	215
20507000	Kenton-on-Sea SP	**0.11**	0	0	0	0	856	0	0	0	0	0	856
20507001	Marselle	**0.90**	0	0	0	0	3,395	1,004	0	0	0	0	4,399
20509000	Kwanonqubela SP	**1.00**	0	0	0	0	4,632	0	0	0	0	0	4,632
20510002	Alexandria NU	**0.60**	0	0	4,493	0	0	0	0	0	0	0	4,493
20510003	Bathurst NU	**0.00**	0	0	6,570	0	0	0	0	0	0	0	6,570
20610001	Alexandria NU	**0.11**	0	0	4,969	0	0	0	0	0	0	0	4,969

Summary for 'QUAT' = P20A (10 detail records)

Total			*0*	*0*	*16,032*	*0*	*12,346*	*1,004*	*0*	*51*	*0*	*0*	*29,433*

Quaternary P20B

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20610001	Alexandria NU	**0.18**	0	0	4,969	0	0	0	0	0	0	0	4,969

Summary for 'QUAT' = P20B (1 detail record)

Total			*0*	*0*	*4,969*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*4,969*

Quaternary P30A

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20404001	Albany NU	**0.04**	0	0	12,102	0	0	0	0	0	0	0	12,102

Summary for 'QUAT' = P30A (1 detail record)

Total			*0*	*0*	*12,102*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*12,102*

* This ratio represents the area of the subplace which falls within the quaternary boundary:1 = 100%
This was not applied to the population figures in this report

Quaternary P30B

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20404001	Albany NU	**0.05**	0	0	12,102	0	0	0	0	0	0	0	12,102
20510001	Albany NU	**0.84**	0	0	764	0	0	0	0	0	0	0	764
20510003	Bathurst NU	**0.05**	0	0	6,570	0	0	0	0	0	0	0	6,570

Summary for 'QUAT' = P30B (3 detail records)

Total	*0*	*0*	*19,436*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*19,436*

Quaternary P30C

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20510003	Bathurst NU	**0.05**	0	0	6,570	0	0	0	0	0	0	0	6,570

Summary for 'QUAT' = P30C (1 detail record)

Total	*0*	*0*	*6,570*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*6,570*

Quaternary P40A

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20402000	Fingo Village SP	**1.00**	0	0	0	0	3,075	0	0	0	0	0	3,075
20403000	Grahamstown SP	**0.71**	0	0	0	598	14,247	0	0	0	751	0	15,596
20403001	Fort England Hospital	**1.00**	0	0	0	0	0	0	0	0	291	0	291
20403002	Grahamstown Military Base	**0.25**	0	0	0	0	0	0	0	0	393	0	393
20403003	Mayfield	**1.00**	0	0	0	0	0	1,728	0	0	0	0	1,728
20403004	Rhodes University	**1.00**	0	0	0	0	0	0	0	0	806	0	806
20403005	Silvertown	**1.00**	0	0	0	0	0	541	0	0	0	0	541
20403006	Vukani	**1.00**	0	0	0	0	0	2,061	0	0	0	0	2,061
20404001	Albany NU	**0.06**	0	0	12,102	0	0	0	0	0	0	0	12,102
20405001	Eluxolweni	**0.62**	0	0	0	0	0	796	0	0	0	0	796
20405003	Kopke	**0.00**	0	0	0	0	1,681	0	0	0	0	0	1,681
20405004	Xolani	**0.60**	0	0	0	0	33,938	0	0	0	0	0	33,938
20510001	Albany NU	**0.01**	0	0	764	0	0	0	0	0	0	0	764
20510003	Bathurst NU	**0.04**	0	0	6,570	0	0	0	0	0	0	0	6,570

Summary for 'QUAT' = P40A (14 detail records)

Total	*0*	*0*	*19,436*	*598*	*52,941*	*5,126*	*0*	*0*	*2,241*	*0*	*80,342*

Quaternary P40B

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total

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Quaternary P40B

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20404001	Albany NU	**0.00**	0	0	12,102	0	0	0	0	0	0	0	12,102
20502000	Bathurst SP	**0.00**	0	0	0	0	597	0	0	0	0	0	597
20510001	Albany NU	**0.06**	0	0	764	0	0	0	0	0	0	0	764
20510003	Bathurst NU	**0.18**	0	0	6,570	0	0	0	0	0	0	0	6,570
20512000	Nolukhanyo SP	**0.89**	0	0	0	0	3,382	0	0	0	0	0	3,382
20512001	Nolukhanyo	**0.39**	0	0	0	0	0	1,570	0	0	0	0	1,570

Summary for 'QUAT' = P40B (6 detail records)

	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
Total	*0*	*0*	*19,436*	*0*	*3,979*	*1,570*	*0*	*0*	*0*	*0*	*24,985*

Quaternary P40C

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20502000	Bathurst SP	**0.76**	0	0	0	0	597	0	0	0	0	0	597
20506000	Kasuka SP	**1.00**	0	0	0	0	102	0	0	0	0	0	102
20510003	Bathurst NU	**0.23**	0	0	6,570	0	0	0	0	0	0	0	6,570
20511000	Nkwenkwezi SP	**1.00**	0	0	0	0	14,673	0	0	0	0	0	14,673
20512000	Nolukhanyo SP	**0.03**	0	0	0	0	3,382	0	0	0	0	0	3,382
20512001	Nolukhanyo	**0.61**	0	0	0	0	0	1,570	0	0	0	0	1,570
20513000	Port Alfred SP	**0.99**	0	0	0	0	4,578	0	0	0	0	0	4,578
20513001	Station Hill	**0.26**	0	0	0	0	1,714	0	0	0	0	0	1,714

Summary for 'QUAT' = P40C (8 detail records)

	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
Total	*0*	*0*	*6,570*	*0*	*25,046*	*1,570*	*0*	*0*	*0*	*0*	*33,186*

Quaternary P40D

SubPlace Code	SubPlace Name	Area ratio in quat*	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
20502000	Bathurst SP	**0.23**	0	0	0	0	597	0	0	0	0	0	597
20508000	Kleinemonde SP	**1.00**	12	0	0	0	0	0	0	0	0	0	12
20510003	Bathurst NU	**0.17**	0	0	6,570	0	0	0	0	0	0	0	6,570
20512000	Nolukhanyo SP	**0.08**	0	0	0	0	3,382	0	0	0	0	0	3,382
20513000	Port Alfred SP	**0.01**	0	0	0	0	4,578	0	0	0	0	0	4,578
20513001	Station Hill	**0.74**	0	0	0	0	1,714	0	0	0	0	0	1,714

Summary for 'QUAT' = P40D (6 detail records)

	Sparce: 10 or fewer HH	Tribal settlement	Farm	Smallholding	Urban settlement	Informal settlement	Recreational area	Industrial area	Institution	Hostel	Total
Total	*12*	*0*	*6,570*	*0*	*10,271*	*0*	*0*	*0*	*0*	*0*	*16,853*
Grand Total	*12*	*0*	*227,844*	*1,196*	*131,852*	*11,957*	*0*	*102*	*3,385*	*33*	*376,381*

* This ratio represents the area of the subplace which falls within the quaternary boundary:1 = 100%
This was not applied to the population figures in this report

APPENDIX 4

WATER REQUIREMENTS

APPENDIX 4: WATER REQUIREMENTS

Contents

APPENDIX 4.1

DIRECT WATER USE

Categories and default unit water use rates as per the National Demographic Study

CATEGORY	WATER USE *l*/c/d
1. Full service: Houses on large erven > 500m^2	320
2. Full service: Flats, Town Houses, Cluster Houses	320
3. Full service: Houses on small erven > 500m^2	160
4. Small houses, RDP houses and shanties with water connection but minimal or no sewerage service	90
5. Informal houses and shanties with service by communal tap only	10
6. No service from any water distribution system	6
7. Other/Miscellaneous (hostels, etc)	90

APPENDIX 4.2

INDIRECT WATER USE

Classification of Urban Centres as per the National Demographic Study

CLASSIFI-CATION	TYPE OF CENTRE	DESCRIPTION
1.	Long established Metropolitan centres (M)	Large conurbation of a number of largely independent local authorities generally functioning as an entity.
2.	City (c)	Substantial authority functioning as a single entity isolated or part of a regional conurbation.
3.	Town: Industrial (Ti)	A town serving as a centre for predominantly industrial activity.
4.	Town: Isolated (Tis)	A town functioning generally as a regional centre of essentially minor regional activities.
5.	Town: Special (Ts)	A town having significant regular variations of population consequent on special functions. (Universities, holiday resorts, etc.)
6.	Town: Country (Tc)	A small town serving essentially as a local centre supporting only limited local activies.
New Centres		
7.	Contiguous (Nc)	A separate statutory authority, or number of authorities adjacent to, or close to, a metropolis or city and functioning as a component part of the whole conurbation.
8.	Isolated (Nis)	A substantial authority or group of contiguous authorities not adjacent to an established metropolis or city.
9.	Minor (Nm)	Smaller centres with identifiable new or older established centres not constituting centres of significant commercial or industrial activity.
10.	Rural (Nr)	All other areas not having significant centres.

APPENDIX 4.3

INDIRECT WATER USE

Indirect Water Use as a Fraction of the Total Direct Water Use

<table>
<tr><th>URBAN CENTRE CLASSIFICATION</th><th>COMMERCIAL</th><th>INDUSTRIAL</th><th>INSTITUTIONAL</th><th>MUNICIPAL</th></tr>
<tr><td>Metropolitan</td><td rowspan="4">0.2</td><td rowspan="4">0.3</td><td rowspan="4">0.15</td><td rowspan="4">0.08</td></tr>
<tr><td>Cities</td></tr>
<tr><td>Towns Industrial</td></tr>
<tr><td>Towns Isolated</td></tr>
<tr><td>Towns Special</td><td>0.30</td><td>0.15</td><td>0.08</td><td>0.03</td></tr>
<tr><td>Towns Country</td><td>0.10</td><td>0.15</td><td>0.03</td><td>0.10</td></tr>
<tr><td>New Centres</td><td>0.15</td><td>0.08</td><td>0.08</td><td>0.08</td></tr>
</table>

Population numbers per category of water use. Direct water use

Quat	Town	Town	Population numbers				Water requirements, 10^6 m^3/a				Indirect	
		Category	Per category of water use								Instit	Loss
			2001	2005	2015	2025	1995	2005	2015	2025	%	%
P10A												
P10B	**Riebeeck East**	**Riebeeck East**	**689**	**703**	**687**	**652**	**0.023**	**0.027**	**0.027**	**0.029**	**18%**	**25%**
		Category 1	-				-	-	-	-		
		Category 2	22	22	22	20	0.003	0.003	0.003	0.002		
		Category 3	22	91	120	232	0.001	0.005	0.007	0.014		
		Category 4	571	590	545	400	0.019	0.019	0.018	0.013		
		Category 5	18				0.000	-	-	-		
		Category 6	56				0.000	-	-	-		
		Category 7	-	-			-	-	-	-		
			689	703	687	652						
P10C												
P10D	**Alicedale**	**Alicedale**	**5,950**	**6,070**	**5,930**	**5,635**	**0.136**	**0.216**	**0.269**	**0.268**	**18%**	**25%**
		Category 1	307	361	390	380	0.036	0.042	0.046	0.044		
		Category 2	-	42	42	40	-	0.005	0.005	0.005		
		Category 3	570	1,570	1,980	1,860	0.033	0.092	0.116	0.109		
		Category 4	1,446	1,970	2,951	3,297	0.048	0.065	0.097	0.108		
		Category 5	3,110	1,949	450	-	0.011	0.007	0.002	-		
		Category 6	293	-	-	-	0.001	-	-	-		
		Category 7	224	178	117	58	0.007	0.006	0.004	0.002		
			5,950	6,070	5,930	5,635						

P10E	**Paterson**	**Paterson**	**4,404**	**4,493**	**4,387**	**4,172**	**0.121**	**0.138**	**0.136**	**0.130**	**18%**	**25%**
		Category 1	-				-	-	-	-		
		Category 2	-				-	-	-	-		
		Category 3	362	366	368	368	0.021	0.021	0.021	0.021		
		Category 4	2,921	3,463	3,419	3,244	0.096	0.114	0.112	0.107		
		Category 5	964	664	600	560	0.004	0.002	0.002	0.002		
		Category 6	157				0.000	-	-	-		
		Category 7					-	-	-	-		
			4,404	4,493	4,387	4,172						
P10F												
P10G	**Kenton On Sea/ Bushmans/Ekuphu**	**Kenton On Sea/ Bushmans/Ekuphu**	**4,781**	**6,451**	**7,588**	**8,696**	**0.168**	**0.257**	**0.359**	**0.482**	**38%**	**25%**
		Category 1	399	430	830	960	0.047	0.050	0.097	0.112		
		Category 2	108	242	262	382	0.013	0.028	0.031	0.045		
		Category 3	338	1,000	1,694	3,282	0.020	0.058	0.099	0.192		
		Category 4	2,563	3,500	3,900	4,000	0.084	0.115	0.128	0.131		
		Category 5	1,373	1,259	859	-	0.005	0.005	0.003	-		
		Category 6	-	-	-	-	-	-	-	-		
		Category 7	-	20	43	72	-	0.001	0.001	0.002		
			4,781	6,451	7,588	8,696						
	Marselle	**Marselle**	**4,699**	**6,294**	**6,146**	**5,843**	**0.188**	**0.238**	**0.299**	**0.329**	**38%**	**25%**
		Category 1	385	385	396	396	0.045	0.045	0.046	0.046		
		Category 2	62	62	75	86	0.007	0.007	0.009	0.010		
		Category 3	1,451	1,792	2,900	3,798	0.085	0.105	0.169	0.222		
		Category 4	1,404	2,240	2,192	1,520	0.046	0.074	0.072	0.050		
		Category 5	1,397	1,800	552	-	0.005	0.007	0.002	-		
		Category 6	-	-	-	-	-	-	-	-		
		Category 7	-	15	31	43	-	0.000	0.001	0.001		
			4,699	6,294	6,146	5,843						

P20A	**Alexandria**	**Alexandria**	**7,715**	**8,371**	**9,178**	**8,720**	**0.327**	**0.392**	**0.500**	**0.483**	**18%**	**25%**
		Category 1	520	560	882	878	0.061	0.065	0.103	0.103		
		Category 2	60	98	496	486	0.007	0.011	0.058	0.057		
		Category 3	1,931	2,950	3,260	3,200	0.113	0.172	0.190	0.187		
		Category 4	4,383	4,190	4,446	4,081	0.144	0.138	0.146	0.134		
		Category 5	753	464	-	-	0.003	0.002	-	-		
		Category 6	68	-	-	-	0.000	-	-	-		
		Category 7	-	113	94	75	-	0.004	0.003	0.002		
			7,715	8,375	9,178	8,720						
	Boknes	**Boknes**	**466**	**712**	**1,287**	**1,475**	**0.048**	**0.069**	**0.126**	**0.143**	**38%**	**25%**
		Category 1	242	408	746	867	0.028	0.048	0.087	0.101		
		Category 2	160	109	225	230	0.019	0.013	0.026	0.027		
		Category 3	-	114	164	186	-	0.007	0.010	0.011		
		Category 4	26	41	88	102	0.001	0.001	0.003	0.003		
		Category 5	19	40	64	90	0.000	0.000	0.000	0.000		
		Category 6	19				0.000	-	-	-		
		Category 7	-				-	-	-	-		
			466	712	1,287	1,475						
	Canon Rocks	**Canon Rocks**	**465**	**711**	**1,286**	**1,474**	**0.047**	**0.068**	**0.126**	**0.143**	**38%**	**25%**
		Category 1	230	400	746	867	0.027	0.047	0.087	0.101		
		Category 2	160	109	225	230	0.019	0.013	0.026	0.027		
		Category 3	-	114	164	186	-	0.007	0.010	0.011		
		Category 4	48	48	88	102	0.002	0.002	0.003	0.003		
		Category 5	20	40	63	89	0.000	0.000	0.000	0.000		
		Category 6	7				0.000	-	-	-		
		Category 7	-				-	-	-	-		
			465	711	1,286	1,474						
P20B												
P30A												

P30B												
P30C												
P40A	**Grahamstown**	**Grahamstown**	**61,759**	**64,370**	**66,387**	**66,591**	**2.868**	**3.177**	**3.594**	**3.793**	**18%**	**25%**
		Category 1	6,913	7,543	8,642	9,533	0.807	0.881	1.009	1.113		
		Category 2	4,000	4,766	5,852	6,809	0.467	0.557	0.684	0.795		
		Category 3	10,350	13,646	18,401	20,563	0.604	0.797	1.075	1.201		
		Category 4	22,280	21,959	19,809	17,024	0.732	0.721	0.651	0.559		
		Category 5	11,090	10,235	9,568	8,852	0.040	0.037	0.035	0.032		
		Category 6	569	672	899	1,086	0.001	0.001	0.002	0.002		
		Category 7	6,557	5,549	4,216	2,724	0.215	0.182	0.138	0.089		
			61,759	64,370	67,387	66,591						
P40B												
P40C	**Port Alfred**	**Port Alfred**	**20,965**	**27,526**	**35,376**	**40,542**	**0.691**	**1.173**	**1.653**	**2.119**	**38%**	**25%**
		Category 1	1,200	2,984	3,978	5,151	0.140	0.349	0.465	0.602		
		Category 2	860	1,342	2,083	2,965	0.100	0.157	0.243	0.346		
		Category 3	3,286	3,713	5,806	8,802	0.192	0.217	0.339	0.514		
		Category 4	6,947	12,325	16,903	18,396	0.228	0.405	0.555	0.604		
		Category 5	7,977	6,232	5,430	3,267	0.029	0.023	0.020	0.012		
		Category 6	694	242	255	775	0.002	0.001	0.001	0.002		
		Category 7	-	688	921	1,186	-	0.023	0.030	0.039		
			20,964	27,526	35,376	40,542						

	Buthurst	**Buthurst**	**5,549**	**6,497**	**6,445**	**6,227**	**0.165**	**0.213**	**0.249**	**0.263**	**18%**	**25%**
		Category 1	120	180	280	360	0.014	0.021	0.033	0.042		
		Category 2	60	81	91	94	0.007	0.009	0.011	0.011		
		Category 3	309	343	584	801	0.018	0.020	0.034	0.047		
		Category 4	3,683	4,823	5,173	4,925	0.121	0.158	0.170	0.162		
		Category 5	1,157	882	207	-	0.004	0.003	0.001	-		
		Category 6	220	169	76	-	0.000	0.000	0.000	-		
		Category 7	-	19	34	47	-	0.001	0.001	0.002		
			5,549	6,497	6,445	6,227						
P40D	**Kleinmonde**	**Kleinmonde**	**1,450**	**1,833**	**2,156**	**2,471**	**0.029**	**0.046**	**0.065**	**0.086**	**38%**	**25%**
		Category 1	114	139	157	174	0.013	0.016	0.018	0.020		
		Category 2	37	44	47	49	0.004	0.005	0.005	0.006		
		Category 3	90	180	289	420	0.005	0.011	0.017	0.025		
		Category 4	64	298	606	988	0.002	0.010	0.020	0.032		
		Category 5	1,113	1,078	882	568	0.004	0.004	0.003	0.002		
		Category 6	31	87	159	247	0.000	0.000	0.000	0.001		
		Category 7	1	7	15	25	0.000	0.000	0.000	0.001		
			1,450	1,833	2,155	2,471						
TOTAL STUDY AREA			**118,892**	**134,029**	**146,855**	**152,499**	**4.812**	**6.014**	**7.404**	**8.268**		

APPENDIX 4.5: Urban Water Requirements per Town

Quat	Town	2001 water requirements				2005 water requirements				2015 water requirements				2025 water requirements				Total water requirements			
		million m^3/a				*million m^3/a*				*million m^3/a*				*million m^3/a*				*million m^3/a*			
		Direct	Indirect	Losses	Total	Direct	Indirect	Losses	Total	Direct	Indirect	Losses	Total	Direct	Indirect	Losses	Total	2001	2005	2015	2025
P10B	Riebeeck East	0.023	0.004	0.009	0.036	0.027	0.005	0.011	0.043	0.027	0.005	0.011	0.043	0.029	0.005	0.011	0.046	0.036	0.043	0.043	0.046
P10D	Alicedale	0.136	0.024	0.053	0.214	0.216	0.039	0.085	0.341	0.269	0.048	0.106	0.422	0.268	0.048	0.105	0.421	0.214	0.341	0.422	0.421
P10E	Paterson	0.121	0.022	0.048	0.190	0.138	0.025	0.054	0.216	0.136	0.024	0.053	0.214	0.130	0.023	0.051	0.205	0.190	0.216	0.214	0.205
P10G	Kenton On Sea/ Bushmans/Ekuphu	0.168	0.064	0.077	0.309	0.257	0.098	0.118	0.473	0.359	0.136	0.165	0.661	0.482	0.183	0.222	0.887	0.309	0.473	0.661	0.887
	Marselle	0.188	0.072	0.087	0.346	0.238	0.090	0.109	0.437	0.299	0.114	0.138	0.551	0.329	0.125	0.152	0.606	0.346	0.437	0.551	0.606
P20A	Alexandria	0.327	0.059	0.129	0.515	0.392	0.071	0.154	0.617	0.500	0.090	0.197	0.787	0.483	0.087	0.190	0.759	0.515	0.617	0.787	0.759
	Boknes	0.048	0.018	0.022	0.088	0.069	0.026	0.032	0.126	0.126	0.048	0.058	0.232	0.143	0.054	0.066	0.263	0.088	0.126	0.232	0.263
	Canon Rocks	0.047	0.018	0.022	0.087	0.068	0.026	0.031	0.125	0.126	0.048	0.058	0.232	0.143	0.054	0.066	0.263	0.087	0.125	0.232	0.263
P40A	Grahamstown	2.868	0.516	1.128	4.512	3.177	0.572	1.250	4.999	3.594	0.647	1.413	5.654	3.793	0.683	1.492	5.968	4.512	4.999	5.654	5.968
P40C	Port Alfred	0.691	0.263	0.318	1.272	1.173	0.446	0.540	2.158	1.653	0.628	0.760	3.041	2.119	0.805	0.975	3.899	1.272	2.158	3.041	3.899
	Buthurst	0.165	0.030	0.065	0.259	0.213	0.038	0.084	0.335	0.249	0.045	0.098	0.392	0.263	0.047	0.104	0.414	0.259	0.335	0.392	0.414
P40D	Kleinmonde	0.029	0.011	0.013	0.054	0.046	0.017	0.021	0.085	0.065	0.025	0.030	0.119	0.086	0.033	0.040	0.159	0.054	0.085	0.119	0.159
TOTAL STUDY AREA																		7.88	9.95	12.35	13.89

APPENDIX 4.6: Total urban water requirements per quaternary catchment

Quaternary	Urban population numbers				Total urban requirements			
	Million m^3/a				*Million m^3/a*			
	2001	***2005***	***2015***	***2025***	***2001***	***2005***	***2015***	***2025***
P10A	-	-	-	-	-	-	-	-
P10B	689	703	687	652	0.036	0.043	0.043	0.046
P10C	-	-	-	-	-	-	-	-
P10D	5,950	6,070	5,930	5,635	0.214	0.341	0.422	0.421
P10E	4,404	4,493	4,387	4,172	0.190	0.216	0.214	0.205
P10F	-	-	-	-	-	-	-	-
P10G	9,480	12,745	13,734	14,539	0.656	0.910	1.212	1.493
P20A	8,646	9,793	11,751	11,669	0.690	0.868	1.252	1.285
P20B	-	-	-	-	-	-	-	-
P30A	-	-	-	-	-	-	-	-
P30B	-	-	-	-	-	-	-	-
P30C	-	-	-	-	-	-	-	-
P40A	61,759	64,370	66,387	66,591	4.512	4.999	5.654	5.968
P40B	-	-	-	-	-	-	-	-
P40C	26,514	34,023	41,821	46,769	1.531	2.493	3.434	4.313
P40D	1,450	1,833	2,156	2,471	0.054	0.085	0.119	0.159
Total	**118,892**	**134,029**	**146,855**	**152,499**	**7.883**	**9.955**	**12.350**	**13.889**

APPENDIX 4.7: Rural water requirements

Quaternary	Accepted	MD Growth rates, % per annum			Projected population numbers				Water use	Projected domestic requirements			
	Base	*High scenario*							*l/c/d*	*Million m3/a*			
	2001	2005	2015	2025	*2001 Base*	*2005*	*2015*	*2025*	*2001*	*2001*	*2005*	*2015*	*2025*
P10A	363	0.3718	-0.2974	-1.0859	363	368	358	321	127	0.017	0.018	0.018	0.016
P10B	1,452	0.3718	-0.2974	-1.0859	1,452	1,474	1,430	1,283	47	0.025	0.026	0.027	0.024
P10C	310	0.2520	-0.9677	-1.2250	310	313	284	251	129	0.015	0.015	0.015	0.013
P10D	977	0.3718	-0.2974	-1.0859	977	992	963	863	46	0.016	0.017	0.018	0.016
P10E	1,328	0.3715	-0.5357	-0.8486	1,328	1,348	1,277	1,173	47	0.023	0.024	0.024	0.022
P10F	1,344	0.3718	-0.2974	-1.0859	1,344	1,364	1,324	1,187	120	0.059	0.062	0.064	0.057
P10G	2,488	0.3715	-0.5357	-0.8486	2,488	2,525	2,393	2,198	41	0.037	0.039	0.040	0.036
P20A	3,242	0.3715	-0.5357	-0.8486	3,242	3,290	3,118	2,864	39	0.046	0.049	0.049	0.045
P20B	894	0.3715	-0.5357	-0.8486	894	907	860	790	124	0.040	0.043	0.043	0.039
P30A	484	0.3718	-0.2974	-1.0859	484	491	477	428	118	0.021	0.022	0.023	0.020
P30B	1,575	0.3714	-0.5358	-0.8476	1,575	1,599	1,515	1,391	16	0.009	0.010	0.010	0.009
P30C	328	0.3714	-0.5358	-0.8476	328	333	315	290	119	0.014	0.015	0.015	0.014
P40A	997	0.3718	-0.2974	-1.0859	997	1,012	982	881	38	0.014	0.015	0.015	0.013
P40B	1,228	0.3714	-0.5358	-0.8476	1,228	1,246	1,181	1,085	42	0.019	0.020	0.020	0.018
P40C	1,511	0.3714	-0.5358	-0.8476	1,511	1,534	1,453	1,335	43	0.024	0.025	0.025	0.023
P40D	1,117	0.3714	-0.5358	-0.8476	1,117	1,134	1,074	987	43	0.018	0.019	0.019	0.017
Total	**19,638**				**19,638**	**19,930**	**19,006**	**17,324**		**0.396**	**0.419**	**0.424**	**0.386**

Appendix 4.8: Irrigation water requirements in 2001

Quaternary	Average area	Maximum area	Field edge req.	Net requirement	Conv. losses	Conv. losses	Gross requir.
	ha	ha	m^3/ha/a	$x10^6$ m^3/a	%	$x10^6$ m^3/a	$x10^6$ m^3/a
P10A	22	44	8,500	0.372	12%	0.051	0.423
P10B	83	165	8,500	1.404	12%	0.191	1.595
P10C	47	94	8,500	0.795	12%	0.108	0.903
P10D	94	187	8,500	1.590	12%	0.217	1.806
P10E	77	153	8,500	1.302	12%	0.178	1.480
P10F	77	153	8,500	1.302	12%	0.178	1.480
P10G	55	109	8,500	0.930	12%	0.127	1.057
P20A	0	0	8,500	0.000	12%	0.000	0.000
P20B	0	0	8,500	0.000	12%	0.000	0.000
P30A	53	105	8,500	0.896	12%	0.122	1.018
P30B	119	237	8,500	2.012	12%	0.274	2.287
P30C	20	40	8,500	0.338	12%	0.046	0.384
P40A	6	12	8,500	0.101	12%	0.014	0.115
P40B	3	6	8,500	0.051	12%	0.007	0.058
P40C	6	12	8,500	0.101	12%	0.014	0.115
P40D	3	6	8,500	0.051	12%	0.007	0.058
Total	**665**	**1,323**		**11.246**		**1.533**	**12.779**

Appendix 4.9: Stock Watering, Afforestation and Alien Vegetation Water Requirements

	Stock Watering		Afforestation		Alien Vegetation	
Quaternary	**No. ELSU**	**Water requirements**	**Average area**	**Net requirement**	**Average area**	**Reduction runoff**
		$x10^6\ m^3/a$	**km^2**	**$x10^6\ m^3/a$**	**km^2**	**$x10^6\ m^3/a$**
P10A	849	0.032	2.14	0.050	5.27	0.38
P10B	3,436	0.126			4.51	0.30
P10C	822	0.032			0.00	0.00
P10D	2,535	0.095			0.26	0.04
P10E	9,982	0.158			0.78	0.06
P10F	7,392	0.126			11.20	0.51
P10G	8,851	0.126			0.41	0.04
P20A	12,476	0.189			51.10	4.60
P20B	9,812	0.152			57.19	3.64
P30A	1,188	0.032	3.40	0.090	22.12	1.64
P30B	4,082	0.095			5.49	0.29
P30C	1,861	0.032			0.38	0.01
P40A	3,211	0.063	0.75	0.020	40.11	3.22
P40B	6,994	0.126			5.62	0.32
P40C	9,469	0.158			10.98	0.69
P40D	6,797	0.126			13.51	1.07
Total	**89,757**	**1.666**	**6.29**	**0.160**	**228.93**	**16.81**

Appendix 4.10: Water requirements summary

Water requirements per user sector

User Sector	Water Requirements ($10^6m^3/a$)				Distribution, %	
	2001	2005	2015	2025	2001	2025
Urban domestic and industrial	7.88	9.95	12.35	13.89	19.9	30.4
Rural domestic	0.40	0.42	0.42	0.39	1.0	0.8
Stock watering	1.67	1.67	1.67	1.67	4.2	3.6
Irrigation	12.78	12.78	12.78	12.78	32.2	28.0
Afforestation	0.16	0.16	0.16	0.16	0.4	0.4
Alien vegetation	16.81	16.81	16.81	16.81	42.3	36.8
Total consumptive requirements	**39.70**	**41.79**	**44.19**	**45.69**	**100.0**	**100.0**
Return Flows	-2.35	-2.69	-3.08	-3.20	-5.9	-7.0
Interbasin transfer	-2.31	-2.80	-3.45	-3.65	-5.8	-8.0
Groundwater supply	-1.97	-2.60	-2.73	-3.11	-5.0	-6.8
Total inflows	-6.63	-8.09	-9.26	-9.96	-16.7	-21.8
Total use from surface water	**33.07**	**33.70**	**34.93**	**35.73**	**83.3**	**78.2**

Water requirements per quaternary catchment

Quaternary Sub-catchment	Projected Water Requirements ($10^6m^3/a$)				Naturalised MAR
	2001	2005	2015	2025	
P10A	0.88	0.88	0.88	0.88	4.54
P10B	2.01	2.00	2.00	2.00	12.19
P10C	0.93	0.93	0.93	0.93	2.39
P10D	2.07	2.14	2.19	2.19	6.77
P10E	1.70	1.63	1.52	1.42	8.85
P10F	2.12	2.12	2.12	2.12	13.60
P10G	1.88	2.13	2.43	2.72	9.60
P20A	4.27	3.90	4.22	3.96	30.38
P20B	3.79	3.79	3.79	3.79	15.27
P30A	2.78	2.78	2.78	2.78	6.86
P30B	2.67	2.67	2.67	2.67	11.69
P30C	0.43	0.43	0.43	0.43	1.70
P40A	3.77	3.57	3.30	3.29	13.73
P40B	0.50	0.50	0.50	0.50	8.18
P40C	1.99	2.92	3.84	4.71	14.02
P40D	1.28	1.30	1.31	1.33	13.28
TOTAL	**33.07**	**33.70**	**34.93**	**35.73**	**173.05**

APPENDIX 5

EXISTING INFRASTRUCTURE

APPENDIX 5: EXISTING INFRASTRUCTURE

Contents

ALEXANDRIA
WATER SERVICES DATA SHEET

1. DESCRIPTION OF THE SUPPLY AREA

The supply area includes the town of Alexandria and the former townships of Wentzel Park and KwaNonqubela.

2. DESCRIPTION OF THE INFRASTURUCTURE

2.1 Water

Raw water is obtained from a series of coastal springs near Cape Padrone and from 2No. well points near Fishkraal. Both sources are located some 16 km south east of Alexandria near the coastline.

The water from the boreholes and the springs is pumped to a balancing reservoir located some 10km from Alexandria and then pumped to the main storage reservoir located to the west of Alexandria. Water is then gravity fed through the reticulation network to consumers.

See the layout schematic of the scheme at the end of the data sheets.

2.2 Sanitation

The wastewater from these areas drain into an oxidation pond system, complete with irrigation system.

3. DATA ON THE SUPPLY AREA

No	Name	Households	Population	Level of Service	Comment
1	Alexandria	486	1820	100% yard connection 100% sewered	40 low income households
2	Wentzel Park	285	1263	100% yard connection 80% sewered	200 low income households
3	KwaNonqubela	1215	4632	100% yard connection 40% sewered	1450 low income households
4	New Developments	500	1500	100% yard connection 100% sewered	

(Census 2001)

4. INFRASTRUCTURE COMPONENTS REF: KWEZI V3

4.1 Water

Component	Capacity	Comment
Fountains /Springs	Drought : 7l/s (24) Normal : 16 l/s (1382 m³/day)	1 x spare BH at 3 l/s (12)
Fountains pump station and pumping mains	Q=18l/s (1555 m³/day) L=2320m h= 122 m (static) Ø= 100/125mm AC	Adequate capacity
Boreholes / well points (Fishkraal)	Q=2 x 6 l/s = 12l/s (1037 m³/day)	Adequate yield if used conjunctively with the springs to beyond 2005 Qtotal = 22 l/s Qpeak = 20 l/s (2005)
Primarily pump station and pumping main	Q=15 l/s (1296 m³/day) L= ? m h= ? m (static) Ø= ? mm AC	Adequate capacity
Balancing Reservoir	265m³	4 hours of AADD $_{2000}$
Main pump station and pumping main to air vent	Q=19l/s (1642 m³/day) L= 6220 m h= ? m Q= 150 mm AC L= 900 m Ø= 150 mm (ductile iron)	Limiting factor to meet peak demands Operating in parallel with the existing main. Part of ongoing upgrade.
Gravity main air vent reservoir	Q= ? L=8500 m h= ? m Ø= 150 mm AC L=1900 m h= 66 m Ø= 200 uPVC	Limiting factor to meet peak demands Operating in parallel Part of ongoing upgrade.
Reservoirs Total	3400 m³	50 hours AADD $_{2005}$ storage

Notes:

- AADD (current) = 1380 m³/day (16 l/s)
- Peak demands 1660 m³/day (19.2 l/s) ; SPF=1.2
- Current capacity of system = 19 l/s plus spare BH at springs: 3 l/s (12)
- GAADD (2025) = 2100 m³/day (Gross Annual Average Daily Demand – including losses)
- GGSDD (2025) = 2500 m³/day
- Only chlorination takes place
- Total storage capacity of existing reservoirs: 1 x 1.5 Ml, 1 x 1.0 Ml, 2 x 0.45 Ml

4.2 Sanitation

Component	Capacity	Comments
Oxidation ponds	Primarily ponds : 5400 m ² Secondary ponds : 46 300m²	Capacity of the system is unknown

5. KEY ISSUES

5.1 Water

- The conveyance system from the balancing reservoir to the bulk storage reservoir has limited capacity and is unable to meet the peak summer demands (19 l/s (24 h))
- Low pressures are being experienced in Wentzel Park.
- 643 erven and 20 small holdings still required, access to a formal water supply in KwaNonqubeka.
- Main industry: Chicory factory

5.2 Sanitation

- The adequacy of the wastewater system is not known.
- Sewer infrastructure is required for 643 households in KwaNonqubela and 80 erven in Phokoza valley.
- 20 households in KwaNonqubela require VIP's

6. ONGOING PROJECTS

- Investigation into the capacity of the oxidation pond

7. IDENTIFIED PROJECT

7.1 Water

	excluding VAT
• In-line booster pumps for Wentzel Park :	R 80 000
• 150 mm pumping main on bulk delivery system	R 1 700 000
• 200 mm gravity main on bulk delivery system	R 3 100 000
• Extension to main pump station on bulk delivery system	R 950 000
• Reticulation to 643 erven in KwaNonqubela	R 1 050 000
• Reticulation to 20 small holdings in KwaNonqubela	R 100 000

7.2 Sanitation

	excluding VAT
• Upgrading of the oxidation pond system	R 4 800 000
• Sewer infrastructure for Phokoza Valley	R 560 000
• Sewer infrastructure for KwaNonqubela	R 2 800 000
• VIP's for KwaNonqubela	R 40 000

8. SOURCE OF INFORMATION

- Mr. G. Kruger Kwezi V3 Engineers (PE)
- Mr S. Fick P&S Consulting (Alexandria) – (046) 653 0770
- Mr W. Patterson Ndlambe Municipality – 082 572 1517
- Eastern Cape Water Resources Situation Assessment
- DWAF National Database

CANNON ROCKS / BOKNES
WATER SERVICES DATA SHEET

1. DESCRIPTION OF THE SUPPLY AREA

The supply area includes the coastal resorts of Cannon Rocks and Boknes. This area does fall within the area of jurisdiction of the Albany Coast Water Board, although they are currently not active in the area.

2. DESCRIPTION OF THE INFRASTRUCTURE

2.1 Water

Water is obtained from 3No boreholes located to the west of Cannon Rocks and pumped through the linked reticulation network, to 2No. storage reservoirs.

2.2 Sanitation

All households have septic tanks with soakaways.

3. DATA OF THE SUPPLY AREA

NO	Name	Household	Population	Level of service	Comment
1	Cannon Rocks	99	215	• 100% yard connection • 100% septic tanks	
2	Boknes	101	216	• 100% septic tanks • 100% yard connections	
Notes: • The IDP indicates a permanent population of 372 with an additional seasonal population of 2500 • The DWAF National Database indicates a permanent population of 3873					

4. DATA ON INFRASTRUCTURE

4.1 Water

Component		Capacity	Comment
3No boreholes Pumping main Reservoir	No 1&2: 10 l/s (12) No 3: 5 l/s (12) 650 m³/d	Q= 3-6l/s(±390m³/day) Into Reticulation H= 170 ‘ (CR), 130 ‘ (B) Ø=100mm(CR), 225mm(B)	Poor water quality see note 2
Cannon Rock Reservoir		470 m³	48 hours of AADD
Boknes Reservoir		530m³	48 hours of AADD

Notes:

- 1No borehole is used out of season
- **The water quality in the boreholes is unpalatable, apparently as a result of sea water intrusion due to over pumping.**
- AADD (current) : = 500 m³/day
- Current peak demands = 1300 m³/day; PF = 2.6
- AADD (2025) : = 1400 m³/day
- GSDD (2025) : = 2000 m³/day
- Water is currently used primarily for gardening.

4.2 Sanitation

All households have owner built septic tanks with soakaways.

5. KEY ISSUES

5.1 Water

- The quality of the water is poor, apparently as a result of sea water intrusion due to over pumping.
- 100 new plots at CR and a settlement of Stillwater (180 erven), in the vicinity of Boknes is currently being planned.
- Water loses could be high as water is pumped thorough the reticulation networks to the storage reservoirs.

5.2 Sanitation

- Nil

6. ONGOING PROJECTS

6.1 Water

- Although there are currently no ongoing projects, attempts are being made to utilise CDM funds to augment the supply to the area from the Fishkraal boreholes, which are currently used to supply Alexandria
- 5.5 km pipeline from Fishkraals to Cannon Rocks
- New source development at Cannon Rocks (Apies River well field)
- Proposed to secure BH's that supply farmers with irrigation to supply Cannon Rocks community

6.2 Sanitation

- Nil.

7. IDENTIFIED PROJECTS

7.1 Water

- 2 possible alternative boreholes sites have been identified to augment supply to the area.

7.2 Sanitation

- Nil

8. SOURCE OF INFORMATION

- Mr S. Fick P&S Consulting
- Mr R. Ball Albany Coast Water Board
- Mr W. Patterson Ndlambe Municipality
- Eastern Cape Water Resources Situation Assessment
- Western District Council WSDP

BUSHMANS RIVER / KENTON-ON-SEA
WATER SUPPLY DATA SHEET

1. DESCRIPTION OF THE SUPPLY AREA

The supply area includes the towns of Kenton-on-Sea and Bushmans River Mouth and the former townships of Klipfontein, Marselle and Ekuphumleni.

2. DESCRIPTION FO THE INFRASTRUCTURE

2.1 Water

Raw water is obtained from the following sources.

- 6No. boreholes near Dias Cross.
- 5No "fresh" water boreholes located near the Albany Coast Board offices.
- 8 No. sea water boreholes located near the mouth of the Bushmans River.

Water from the Dias Cross boreholes is pumped to a balancing reservoir from where it is pumped directly to the bulk supply reservoirs located at a high point behind Kenton-on-Sea (north of the R72).

Water from the other boreholes is pumped to plastic tanks near the Albany Coast Water Board Offices and then pumped through a reverse osmosis desalination plant before going into local storage. Brine from the desalination plant is returned to the sea via the Bushmans River, whilst the treated water is pumped to the bulk storage reservoirs.

Potable water from the bulk reservoirs is gravity fed directly to Kenton-on-Sea, eKuphumleni, Marselle, Klipfontein and a reservoir which feeds Bushmans River Mouth. A pumped supply system also feeds some farmers and a balancing reservoir to the north of Kenton-on-Sea.

It can be noted that most households in these areas augment their supplies with rainwater tanks.

See the layout schematic of the scheme end of the data sheets.

6 x 10 m deep boreholes are responsible for 60 % of the bulk supply – these are vulnerable during low rainfall periods.

2.2 Sanitation

Both Kenton-on-Sea and Bushmans River Mouth have septic tanks and soakaways whilst Klipfontein, Marselle and eKuphumleni have waterborne sewer systems which drain to activated sludge wastewater treatment works in Bushmans River Mouth and Kenton-on-Sea respectively.

3. DATA ON THE SUPPLY AREA

NO	Name	Households	Population	Level of service	Comments
1	Klipfontein & Marselle	1294	4399	100% yard connections 100% water borne sewer	
2	Kenton-on-sea	404	856	100% yard connections 100% septic tanks	
3	eKuphumleni	1027	3625	100% yard connections 100% water borne sewer	
Notes: • Population figures from DWAF National database					

4. INFRASTRUCTURE DATA

4.1 Water

Component	Capacity	Comments
Dias Cross boreholes and conveyance system - 19 l/s (12) Pipeline rated: 25 l/s	Q=34 m³/h (24) 820 m³/d ø= 200 PVC	Only licensed to abstract 300 000 m³/a (average of ±34 m³ /h) (24) or 822 m³/d
Balancing reservoir	100 m³	1.3 hours storage at peak capacity
Pumping system to bulk storage reservoir	Q=90 m³/h L= ± 9000m ø= 200 PVC	
Brackish boreholes	Q=21 m³/h	
Sea water boreholes	Q=110 m³/h	Total capacity from all 3 sources = 165 m³/hour

Component	Capacity	Comment
Plastic Tanks	7 x 15 = 95m³	0.75 hours of storage at peak capacity
Desalination Plant • No.1 • No 2 • No 3 Only 2 x RO's operate simultaneously	 20m³/hour 20m³/hour 10m³/hour	Plant No1 is currently functional. Only 50% of the capacity has been installed in plant No.3. The figures quoted are the final outputs. The desalination plants are ± 38% efficient.
Storage reservoir	100 m³	
Pumping system to bulk storage reservoir	Q=58 m³/h	
Bulk Reservoir	2 x 2 Ml	64 hours of AADD at current levels.
Bushmans reservoir	100 m³	
Farmers pump system	Q=15 m³/h	
Farmers Reservoir	200 m³	

Notes:

- Current AADD = 1200 – 1500 m³/day (63m³/hour)
- Current peak demand = 2800 m³/day (117m³/hour); PF = 1.86;
- Current capacity of system = 114 m³ / hour (when plant No. 1 is functional)
- The annual average capacity of the system currently stands at 64m³/hour
- AADD (2005) = 1960 m³/day
- AADD (2005) = 3150 m³/day
- Restrictions are often imposed on garden watering during peak seasons (Dec and Jan).
- Growth is currently around 10% p.a.
- Klipfontein: 200 RDP houses with sewer services
- Marselle: 230 completed RDP houses, plus 700 planned RDP houses

4.2 Sanitation

Component	Capacity	Comments
Ekuphumleni WWTW	Q=? m³/day	
Klipfontein / Marselle WWTW	Q=? m³/day	

Notes:

5. KEY ISSUES

5.1 Water

- The peak demands can only be sustained by stress pumping the Dias Cross boreholes beyond their permitted annual average abstraction rate.
- The water quality is sub-standard (class II –see typical analysis sheet attached), (currently 1400 mg/l TDS).
- The bulk storage capacity is inadequate for the peak season (4 Ml = 1.4 days).

- The Eskom supply is erratic, which further limits the supply capacity of the scheme.
- Desalinated water is expensive.
- The brine from the desalination plant is returned to the river, near the river mouth, which may have some negative environmental impact.

5.2 Sanitation

- Some septic tanks are overloaded during peak season resulting in some spillages.

6. ONGOING PROJECTS

6.1 Water

Upgrading of bulk infrastructure R3.4 million (CMIP), which includes:

- Refurbishing plant No1 (completed in November 2003)
- Augmentation of supply via run-of-river abstraction and filtration (100m³/hour), scoping report in progress.
- Upgrading desalination plant No.3 to its full capacity.
- Upgrading the brine disposal system, scoping report in progress.
- Upgrading the Eskom supply.

6.2 Sanitation

- Nil

7. IDENTIFIED PROJECTS

1.1 Water

- Upgrading the bulk storage capacity systems – additional 2 Ml reservoir
- Develop new Kwaaihoek well field – 12 l/s (12)

1.2 Sanitation

- Nil

8. SOURCE OF INFORMATION

Mr R Ball – Albany Coast Water Board

Mr W Patteson – Ndlambe Municipality

Eastern Cape Water Resources Situation Assessment

PORT ALFRED
WATER SERVICES DATASHEET

1. DESCTIPTION OF THE SUPPLY AREA

The supply area includes the town of the Port Alfred, the former townships of Nemato and Minosa Farm and the proposed township of Thornhill.

2. DESCRIPTION OF THE INFRASTRUCTURE

2.1 Water

Raw water is obtained from a weir on the Kowie River and pumped to an off channel storage dam (Sarel Haywood Dam) on the Bathurst stream. Water is then pumped from main linking the weir pumping system to the dam, to the sump of a third pump station, from where the water is pumped to a balancing dam near the hospital. From there the water is gravity fed to the water treatment works located to north of town in the vicinity of the school.

Potable water is then pumped from the bulk storage reservoir to 4No distribution reservoirs located on the East Bank, West Bank, Nemato township and a high level supply zone reservoir. Water is then reticulated by gravity to households.

Port Alfred also used to obtain water front the Mansfield Dam located to the south of Bathurst and from coastal sand dunes near the town. The dune system is still used during the peak seasons whilst the gravity main from the Mansfield is said to be broken in many places.

See the layout schematic of the scheme at the end of the datasheets.

2.2 Sanitation

Parts of Port Alfred and parts of Nemato have waterborne sanitation, which drains into ponds treatment system, complete with an irrigation system, located on the banks of the Kowie River near, just upstream of Centenary Park.

The balance of Port Alfred has conservancy tanks whilst the balance of Nemato has pit latrines.

3. DATA ON THE SUPPLY SYSTEM

No	Name	Households	Population	Level of service	comments
1	Port Alfred	1588	4578	100% erf connections 40% water borne 60% conservancy tank	
2	Nemato: Station Hill Nkwnkwezi	4432	16387	60% yard connection 20% communal standpipe; 20% water borne 50% digestive systems with French drains 50% VIP's	Phased upgrading of digestive system to a waterborne sewer system
3	Thornhill				Proposed development to cater for over crowding in Nemato

Notes:

- Population figures from DWAF National database.

4. INFRASTRUCTURE DATA

4.1 Water

Component	Capacity	Comments
Sarel Haywood Dam	Live storage =2.5 x10^6 m³ Yield = 1.5 x 10^6 m³/a (4.1 Ml/day)	1:50 year yield
Mansfield Dam	Live storage = 0.2 x 10^6 m³	No longer used
Dune system	yield = 0.13 x 10^6 m³/a (356 m³/day)	Used in peak season
Weir abstraction system (pump system No.1)	Q=12 960 m³/day (150 l\s) L= 700 m Ø= 350 mm	Cannot abstract from the weir if the water level reaches 1.0 m below the crest of the weir
Pump system No 1	Q=4320 m³/day (50l/s) L= 4200 m Ø= 300 mm	
Pump system No 2	Q=4320 m³/day (50l/s) L= 6800 m Ø= 250 mm	
Balancing Dam	16 000 m³	± 8 days of AADD at current levels
Gravity system		Capacity recently upgraded
Water treatment works	5 Ml/day	Recently upgraded

Bulk reservoir	2 Ml	± 24 hours AADD at current demands
Distribution reservoirs West Bank East Bank Nemato	 2.8 Ml 0.8 Ml 1.0 Ml	
Notes: • AADD (current) = 1.8 - 2.0 Ml/day • Current peak demand = 5 Ml/day • Current capacity of system = 4.3 Ml/day • AADD = (2005) = 2.3 Ml/day • AADD = (2010) = 2.4 Ml/day		

4.2 Sanitation

Component	Capacity	Comments
Ponds system	1.8 Ml/day	Average inflows = ± 94% of wwtw capacity. Peak inflows = +/- 236% of wwtw capacity
Notes: 1. The original design of the wwtw never catered for Nemato 2. The capacity of the ponds are exceeded during the summer peaks and spillage into the Kowie River probably occur		

5. KEY ISSUES

5.1 Water

- The reliability (assurance of supply) of the raw water supply is questionable.
- The raw water quality is poor (high saline content) due to the marine origins of the soils underlying the dam basin. See potable water analysis sheet attached.
- The capacity of the bulk supply system needs to be upgraded to meet the peak seasonal demands.
- Bulk water supply infrastructure is required to support the proposed Thornhill development.
- Not all households in Nemato have access to yard connections.

5.2 Sanitation

- The existing oxidation ponds are inadequate to meet the current demands,
- Bulk infrastructure is required to support the proposed Thornhill development.
- Some households in Nemato do not have access to even a basic level of service.
- Not all households have access to the water borne sewer system.

6. ONGOING PROJECTS

6.1 Water

- Refurbishment of the water treatment work and gravity conveyance system R2.0 million (CMIP).

6.2 Sanitation

- None

7. IDENTIFIED PROJECTS

The following projects are recommended.

7.1 Water

- A water resources study of the area with a view to improving the assurance and quality of supply to the Ndlambe area in general and Port Alfred in particular.
- Upgrading of the bulk supply infrastructure.
- Provision of bulk water services to Thornhill and Nemato.

7.2 Sanitation

- Investigation and possible upgrading of the wastewater treatment works.
- Investigation with regard the use of partly treated sewerage to irrigate the golf course.
- Provision of services to Thornhill and sewers to the remaining portions of Port Alfred and Nemato.

8. SOURCE OF INFORMATION

- Mr. W Patterson – Ndlambe Municipality
- Eastern Cape Water Resources Situation Assessment
- Operating and Maintenance Manual for the Safety of the Sarel Hayward Dam.

KLEINENONDE /SEAFIELD
WATER SERVICES SUPPLY SHEET

1. DESCRIPTION OF THE SUPPLY SHEET

The supply area includes East Kleinemonde and Seafield. West Kleinemonde is a share block and the owners are responsible for their own services provision.

2. DESCRIPTION OF THE INFRASTRUCTURE

2.1 Water

Water is obtained from Wellington Dam (a farm dam) located some 8 km north west of the town and from 2No. coastal boreholes located in the Seafield area. The boreholes are generally used as a standby capacity and during peak seasons.

Raw water is pumped from Wellington Dam, via a balancing reservoir, to a water treatment works located on East Kleinemonde peninsula, where it is treated and pumped to a storage reservoir in Seafield. Water is also pumped from the works directly into the Peninsula and South Island reticulation networks, which are connected to the pumping main to the Seafield reservoir.

The Seafield Reservoir gravity feeds a portion of Seafield and a lower laying storage reservoir, which in turn gravity feeds a supply zone within Seafield.

The borehole located to the east of Seafield supplies the Seafield reservoir whilst the borehole near the East Kleinemonde River mouth, supplies the lower zone reservoir.

See the layout schematic of the scheme at the end of the data sheets.

2.2 Sanitation

All households have septic tanks with soakaways.

3. DATA ON THE SUPPLY AREA

NO	Name	Households	Population	Level of Service	Comments
1	East Kleinemonde Seafield	632	1450	50% yard connection 50% septic tanks	± 300 erf are developed ± 200 households are permanently occupied

Notes:

- Population figure from DWAF National database.
- Household figures from NLM

4. INFRASTRUCTURE COMPONENTS

4.1 Water

Component	Capacity	Comments
Wellington Dam		Yield of the dam has not been ascertained.
Wellington pump station and pumping main	Q=360 m³/day L= ± 2000m Ø= 75 mm uPVC	
Balancing reservoir	40 m³	5 hours of AADD at current development
Gravity main	L=± 6000 m Ø= 75mm uPVC	
Water treatment works	90 m³/day	
Pump station and pump main	Q=360 m³/day L= 2000 m Ø= 75 mm U PVC	Capacity is said to be adequate.
Reservoir	800 m³	± 106 hours AADD at current development
Seafield borehole	48 m³/day	
River mouth borehole	50 m³/day	
Zone reservoir	60 m ³	

Notes:

- Winter demand 60 – 100 m³/day
- Summer demands 100 – 150 m³/day
- December demand 360 m³/day; PF= 3.6
- Current capacity of system = 408 m³/day
- AADD (2005) @2%p.a = 268 m³/day
- AADD (2010) @2%p.a = 316 m³/day
- Development of the area is happening fast.
- System appears to be adequate to 207

4.2 Sanitation

All households have owner built septic and soakaways. A tanker service is provided by Ndlambe Municipality if required.

5. KEY ISSUES

5.1 Water

- The reliability of the yield from Wellington dam is not known.
- The frequent Eskom power outages negatively impact on the continuity of supply.
- Bulk and reticulation systems are interconnected (high possibility of water losses/unaccounted for water).
- Telemetry control system negatively impacts on the operational efficiency of the system.
- Water quality of Wellington Dam is poor after heavy rains, TDS goes up to 2500 ppm. The purification plant has a capacity of 90 m³/d, while the Seafield Boreholes can yield 48 m³/d. This results in a maximum system capacity of 138 m³/d during worst case scenarios when water quality is poor.

5.2 Sanitation

- Poorly constructed soakaways result in sewerage spillage into the river during peak holiday season.

6. ONGOING PROJECTS

6.1 Water

- Nil

6.2 Sanitation

- Nil

7. IDENTIFIED PROJECTS

No projects have been identified for this area but the following are recommended:

- Assessment of the reliability of the scheme is general and the dam in particular, taking cognisance of the current growth rate.
- Installation of a dedicated bulk supply system and the upgrading of the reticulation network to ensure an equitable supply through Kleinemonde.

- Review and possible upgrade of the control system
- Establishment of design standards for septic tanks and soakaways

8. SOURCE OF INFORMATION

- Mr Lionel Wilson – Ndlambe Municipality

BATHURST
WATER SERVICES DATA SHEET

1. DESCRIPTIION OF THE SUPPLY AREA

The supply area includes the town of Bathurst and the former townships of Nolukhanyo and Freestone.

2. DESCRIPTION OF THE INFRASTRUCTURE

2.1 Water

The town of Bathurst is dependent on private supplies (boreholes) and rainwater tanks, whilst Nolukhanyo and Freestone are supplied from the Goldenridge Dam. The area used to be supplied with water from the Mansfield Dam, but it ran dry some years ago, necessitating an alternate supply. Raw water is pumped from the dam to a package treatment within the town from where potable water is pumped to the Toposcope reservoir. The reservoir then gravity feeds the respective reticulation networks.

2.2 Sanitation

Bathurst is serviced by a mixture of septic and conservancy tanks whilst Nolukhanyo and Freestone are service with septic tanks and soakaways.

3. DATA ON THE SUPPLY AREA

No	Name	Households	Population	Level of Service	Comment
1	Bathurst		5000	100% yard connections 100% septic tanks	
2	Nolukhanyo		3832	100% yard connections 100% septic tanks	
3	Freestone		1808	100% yard connections 100% septic tanks	
Notes: • Population figures from the DWAF National Database					

4. INFRASTRUCTURE COMPONENTS

4.1 Water

Component	Capacity	Comments
Goldenridge Dam	Storage=400 000 m³ Yield=0.002 x 10^6 m³/a	
Pump stations pumping main	Q=16l/s (1382m³/day) L=8000m Ø=200pVC 2 x 66 kW pumps	
Mansfield Dam	Storage = 165 000 m³ Yield=45 000 m³/a	
Pump station and pumping main	Q=5l/s	
Water treatment works	Q= 18m³/hour (432 m³/day)	Plant has been designed to be progressively upgraded to 28m³/hour and 42m³/hour.
Potable water pumping main	L=1300m Ø=110mm uPVC	
Toposcope Reservoir	1.0 Ml	
Notes: • AADD current = 710 m²/day AADD (2025) = 1134 m³/day (50 % supplied by private BH's, including Bathurst)		

4.2 Sanitation

Conservancy and septic tanks

5 KEY ISSUES

- The scheme does not service the entire area.
- The treatment work is near or at capacity.
- Inadequate bulk storage
- The Mansfield Dam is no longer in use

6 ONGOING PROJECTS

6.1 Water

- Nil

6.2 Sanitation

- Nil

7 INDENTIFIED PROJECTS

- Upgrading of the water treatment works and command reservoir.
- Investigation regarding the adequacy of the scheme to feed the entire town including the possible re-commissioning of the supply from the Mansfield Dam.
- Investigation into the adequacy of the sanitation facilities.

8 SOURCE OF INFORAMTION

Mr J. Nel – Africon (PE)

Mr W Patterson – Ndlambe Municipality

Eastern Cape Water Resources Situation Assessment

HOLIDAY RESORTS AND RURAL SETTLEMENTS WATER SERVICES DATASHEETS

Holiday Resorts

The settlements of Kasuku and Fish River Mouth are holiday resorts and it is reported that they have access to a level of service above RDP standards.

Rural Settlements

These settlements are predominantly located on privately owned farmlands to the east of Ndlambe on the banks of the Fish River.

The following settlements are reported to have access to services below RDP standards

- Glassmere (± 60 people) = have access to sub-RDP services (groundwater)
- Wilmington (±90 people)= have access to sub-RDP services (groundwater)
- Gross Roads (± 20 people) = have access to sub-RDP services (groundwater)
- Tappes Valley (± 4 people) = rain water tanks

WATER SERVICES DEVELOPMENT PLAN: KLEINEMONDE/SEAFIELD WATER SERVICES SUPPLY SHEET

1. The above document, circulated to the Seafield Resident's and Rate Payers' Association for comments, refers.

My comments are based on a table, which was used by Haldene, Kleyn & Association in 1998, which I find fairly accurate.

2. WATER DEMAND

Year Ended	Number of Dwellings	Gross A.A.D.D.	Average Year Round Demand	Average Summer Peak Demand	Probable Maximum S.P.D.D.	Required from Wellfield	Number of BH's
1998	207	211.53	84/61	384.98	481.23	121.23	2
1999	214	218.46	88.48	395.41	494.27	134.27	2
2000	222	226.38	92.82	407.48	509.36	149.36	2
2005	264	267.96	112.54	468.93	586.16	226.16	3
2010	313	316.47	136.40	538.00	672.50	312.50	4
2015	372	374.88	165.70	618.55	773.19	413.19	5
2020	442	444.18	201.21	710.69	888.36	528.36	6
2025	525	527.35	244.23	815.84	1019.80	659.80	8
2030	623	623.37	296.72	935.06	1168.82	808.82	10

3. WATER SOURCES

3.1 Wellington Dam. Although seen as the main source, it is my contention that this source of supply is at best, a supplementary source of the other sources of supply for the following reasons:

The Wellington dam is situated in the center of pine fields some of them come to within 20 m of the high water level. This causes to soil and pesticides to wash into the dam, especially during heavy rains.

The T.D.S. then rises up to 2,500 parts per million which is too high for drinking water. In fact the water becomes so bad that normal washing of clothes is not possible without staining your clothes.

The purification plant cannot coupe with the filtration once there is a down-pour and the output is only 90 m³ per day.

3.2 Seafield Borehole. This borehole produced 80 m³ per day for 4 weeks then the borehole ran dry and the motor burned out.

It is felt that 48 m³ per day is the maximum that could safely be pumped on a continuous basis.

3.3 River Mouth Borehole. This borehole supplies a zone reservoir of 60 m³.

The borehole is:

- highly subject to contamination due to household septic tanks being on a higher level than the borehole;
- supplies 32 dwellings which could rise to 40 due to subdivisions of stands;
- a closed system and does not contribute to the current overall capacity of the system;
- is highly susceptible to saline infiltration if this system is used at its peak demand.

4. WATER SUPPLY CAPACITY

Based on the above the current supply capacity of the system is:

Best scenario:

Wellington Dam	-	360 m^3
Seafield Borehole	-	48 m^3
TOTAL	-	408 m^3 per day

Using the above table, there will be a water shortage by 2007 and the supply will not be adequate until 2010 as indicated in the report. Based on 591 stands (632 minus 32 stands fed from River Mouth Borehole).

Worst scenario: (Refer to paragraph 3.1)

Wellington Dam	-	90 m^3
Seafield Borehole	-	48 m^3
TOTAL	-	138 m^3 per day

In the event of such a situation occurring (heavy rainfall) – a common yearly occurrence – the system capacity will be barely adequate to supply present demand.

5. RECOMMENDATION

It is recommended that an alternative main source of water be found.

Although Wellington Dam might have the water capacity, problems mentioned in paragraph 3.1 makes this source unreliable and not worth spending money on increasing filtration capacity.

The exploitation of the Palmiet Welfield – or any closer underground source – should be developed as a matter of urgency.

…………………………………………………
J STRYDOM (PR.ENG)
Committee Member 2004

23 January 2003

Registered Dams within P - Drainage Region

APPENDIX 5.2

Dam number	Name	Longitude			Latitude			Completion Date	Type of wall	Wall height	Capacity (1000m3)	Area (ha)
P100-01	NUWEJAARS DAM (NEW YEARS)	26	6	50	33	18	10	1959		22	4700	96
P100-02	JAMESON DAM	26	26	15	33	18	55	1906	EARTHFIL	13	575	15
P100-03	MILNER DAM	26	25	40	33	18	45	1898	EARTHFIL	13	255	7.7
P101-14	GREY DAM	26	31	45	33	19	25	1861	EARTHFIL	12	68	1
P101-17	KAREELEEGTE DAM	25	44	1	33	12	1	1962	EARTHFIL	6	64	7
P101-18	BLACKBURN DAM	26	1	5	33	11	45	1970	EARTHFIL	10	150	0
P101-19	TEAFONTEIN RESERVOIR	26	16	30	33	13	25	1906	EARTHFIL	8	204	3
P102-14	TABLE HILL BIG DAM	26	25	1	33	16	1	1951	EARTHFIL	12	364	8
P102-15	OAKWELL DAM	26	20	15	33	17	30	1969	EARTHFIL	10	82	2
P102-16	MOSSLANDS DAM	26	27	15	33	24	10	1962	EARTHFIL	15	571	18
P102-17	BRAKKLOOF RIVER DAM	26	22	50	33	13	30	1960	EARTHFIL	7	75	4
P102-18	STROWAN DAM	26	28	10	33	17	45	1950	EARTHFIL	9	139	6
P102-19	HILTON DAM	26	20	50	33	14	50	1954	EARTHFIL	6	60	3
P102-20	SHENFIELD CAMP DAM	26	12	0	33	13	35	1952	EARTHFIL	10	60	2
P102-21	MOUNTAIN VIEW DAM	26	19	40	33	28	10	1988	EARTHFIL	11	250	1
P102-22	SPRINGVALE DAM (ZUUR KLOOF 271)	26	12	40	33	21	5	1983	EARTHFIL	9	163	6
P102-23	PROCTORSFONTEIN DIPPING TANK DAM	26	11	55	33	22	28	0	EARTHFIL	9	126	3
P102-24	PROCTORSFONTEIN HOUSE DAM	26	12	23	33	22	32	1950	EARTHFIL	11	299	4
P300-01	HOWISONSPOORT DAM	26	30	57	33	23	15	1930		24	883	16.3
P300-02	SETTLERS DAM	26	31	1	33	25	1	1962		21	5620	101
P300-03	LAKE GUM TREE	26	14	55	33	23	20	1984	EARTHFIL	9	251	7
P300-04	BIRMINGHAM NEW DAM	26	25	41	33	23	55	1948	EARTHFIL	13	414	10
P300-05	DOGPLUM DAM	26	39	50	33	32	7	1986	EARTHFIL	15	101	32
P300-06	YELLOW WOOD DAM	26	40	2	33	31	35	1985	EARTHFIL	12	130	5
P300-07	NEW YEAR PARK DAM	26	26	0	33	28	0	0	EARTHFIL	8	79	0
P300-08	ARNHEM DAM	26	27	25	33	19	35	0	EARTHFIL	17	80	2
P300-09	ROCHESTER DAM	26	18	1	33	25	1	1985	EARTHFIL	8	202	0
P300-10	LINDALE DAM	26	27	20	33	26	55	1977	EARTHFIL	10	260	17
P300-11	ALL'S WELL DAM	26	20	18	33	24	49	1983	EARTHFIL	8	492	18
P300-12	ASSEGAAI DAM	26	31	50	33	29	15	1989	EARTHFIL	9	224	8
P300-13	DORINGKLOOF DAM	26	31	10	33	29	35	1988	EARTHFIL	11	198	7

P300-14	LE GRANGE DAM	26	25	5	33	29	15	1983	EARTHFIL	8	130	0
P300-16	LANGLEY PARK DAM	26	19	1	33	22	1	1979	EARTHFIL	7	90	5
P300-17	YARROW DAM	26	23	25	33	24	40	1985	EARTHFIL	11	462	8
P300-19	ENDWELL FARM DAM	26	37	30	33	28	0	1986	EARTHFIL	9	60	1
P300-20	FAIRFIELD DAM	26	19	30	33	24	40	1980	EARTHFIL	8.5	79	6
P300-21	HOPELEIGH DAM	26	29	10	33	27	25	1960		6	136	34
P300-22	HOMELEIGH DAM	26	31	25	33	30	50	1987	EARTHFIL	9	82	2
P300-23	AVONDALE DAM	26	30	45	33	29	0	1971		7	272	7
P300-24	WELTEVREDE DAM	26	27	20	33	29	1	1987	EARTHFIL	8	205	10
P400-04	ROSSLYN DAM	26	46	1	33	24	6	1983	EARTHFIL	14	150	4
P400-05	KENKELE DAM	26	46	5	33	23	3	1974	EARTHFIL	13	160	4
P400-06	PINEDALE DAM	26	45	8	33	23	5	1986	EARTHFIL	16	300	7
P400-07	MANSFIELD DAM	26	51	8	33	31	10	1942	EARTHFIL	14	165	4
P400-08	SAREL HAYWARD DAM (BATHURST STREAM I	26	46	55	33	32	25	1986	EARTHFIL	40	2522	25
P400-09	WILLOW PARK DAM	26	41	5	33	19	35	1983	EARTHFIL	11	150	4
P400-10	GLENIFFER DAM 1	26	42	28	33	31	0	1982	EARTHFIL	8	50	3
P400-11	THE HOME DAM	26	42	40	33	25	5	1985	EARTHFIL	10	110	4
P400-13	GLENIFFER DAM NO 2	26	43	25	33	30	45	1985	EARTHFIL	12	200	6
P400-14	MOUNT WELLINGTON DAM	26	58	45	33	30	18	1984	EARTHFIL	11.9	250	2
P400-15	LANPETER DAM	26	50	0	33	25	0	1988	EARTHFIL	10	120	5
P400-17	ROCKWOODVALE DAM	26	38	0	33	17	0	1985	EARTHFIL	6	135	3
P400-18	RHEMA DAM	26	42	10	33	19	0	1987	EARTHFIL	13	150	2
P400-19	FAIRVIEW DAM	26	48	1	33	24	5	1985	EARTHFIL	7.9	218	4
P400-20	THE GROVE DAM	26	57	1	33	27	1	1984	EARTHFIL	11	70	2
P400-21	OLD MILL DAM	26	38	0	33	32	10	1984	EARTHFIL	8	76	4
Q110-02	HEUNINGKRANS DAM	25	26	0	31	14	0	1956	EARTHFIL	8	220	150

Dam number	Name	Owner	Person in control	Designer
P100-01	NUWEJAARS DAM (NEW YEARS)	ALICEDALE - MUNISIPALITEIT	ALICEDALE - MUNISIPALITEIT	STEWART,SVIRIDOV & OLIVER
P100-02	JAMESON DAM	GRAHAMSTAD-MUNISIPALITEIT	GRAHAMSTAD-MUNISIPALITEIT	D. GERRAND
P100-03	MILNER DAM	GRAHAMSTAD-MUNISIPALITEIT	GRAHAMSTAD-MUNISIPALITEIT	ONBEKEND
P101-14	GREY DAM	GRAHAMSTAD-MUNISIPALITEIT	GRAHAMSTAD-MUNISIPALITEIT	ONBEKEND
P101-17	KAREELEEGTE DAM	GREEFF M.J.	GREEFF M.J.	ONBEKEND
P101-18	BLACKBURN DAM	DELPORT W.M.	DELPORT W.M.	ONBEKEND
P101-19	TEAFONTEIN RESERVOIR	POHL D.B.	POHL D.B.	UNKNOWN
P102-14	TABLE HILL BIG DAM	WHITE F.C.D. & S. ST L.	WHITE F.C.D. & S. ST L.	PALMER E.W. (DECEASED)
P102-15	OAKWELL DAM	THOMPSON P J	THOMPSON P J	R.H. STEPHENSON
P102-16	MOSSLANDS DAM	MOSS M.N. & B.E.	MOSS M.N. & B.E.	STATE (DWA)
P102-17	BRAKKLOOF RIVER DAM	BROWN G.S.	BROWN G.S.	UNKNOWN
P102-18	STROWAN DAM	PALMER M.G.	PALMER M.G.	G.W. PALMER
P102-19	HILTON DAM	WHITE T.C.	WHITE T.C.	G. PALMER
P102-20	SHENFIELD CAMP DAM	POHL J.B.	POHL J.B.	ONBEKEND
P102-21	MOUNTAIN VIEW DAM	SCHEEPERS M.E.J.	SCHEEPERS M.E.J.	MBB INC
P102-22	SPRINGVALE DAM (ZUUR KLOOF 271)	RIPPON C.P.	RIPPON C.P.	STATE - DWA
P102-23	PROCTORSFONTEIN DIPPING TANK DAM	RIPPON C.P.	RIPPON C.P.	UNKNOWN
P102-24	PROCTORSFONTEIN HOUSE DAM	RIPPON C.P.	RIPPON C.P.	UNKNOWN
P300-01	HOWISONSPOORT DAM	GRAHAMSTAD-MUNISIPALITEIT	GRAHAMSTAD-MUNISIPALITEIT	STEWART SVIRIDOV & OLIVER
P300-02	SETTLERS DAM	GRAHAMSTAD-MUNISIPALITEIT	GRAHAMSTAD-MUNISIPALITEIT	STEWART SVIRIDOV & OLIVER
P300-03	LAKE GUM TREE	ASSEGAAI RIVER TRUST	ASSEGAAI RIVER TRUST	MBB INC.
P300-04	BIRMINGHAM NEW DAM	MOSS H.C. & SONS	MOSS H.C. & SONS	STATE (DWA)
P300-05	DOGPLUM DAM	STIRK L.G.	STIRK L.G.	L G STIRK & SONS
P300-06	YELLOW WOOD DAM	STIRK L.G.	STIRK L.G.	LG STIRK & SONS
P300-07	NEW YEAR PARK DAM	EMSLIE D.W.	EMSLIE D.W.	M KOLESKY
P300-08	ARNHEM DAM	TREMEER A.R.	TREMEER A.R.	DRMIN EXISTANSTANCE
P300-09	ROCHESTER DAM	BALL V.V.	BALL H.S.	H.L.S. BALL (LATE)
P300-10	LINDALE DAM	AMM R.G.	AMM R.G.	DWA
P300-11	ALL'S WELL DAM	HOWARTH G.H.	HOWARTH G.H.	MCNICOL
P300-12	ASSEGAAI DAM	KING A.C.	KING A.C.	D.M. VAN DER BERG
P300-13	DORINGKLOOF DAM	KING A.C.	KING A.C.	D. VAN DER BERG

P300-14	LE GRANGE DAM	SCHEEPERS B.S.	SCHEEPERS A.W.	M. BRADFIELD
P300-16	LANGLEY PARK DAM	CURRIE J.	CURRIE J.	ONBEKEND
P300-17	YARROW DAM	MOSS H.S.	MOSS H.S.	STATE - DWA
P300-19	ENDWELL FARM DAM	RIGBY J.V.	RIGBY J.V.	ONBEKEND
P300-20	FAIRFIELD DAM	EMSLIE S.J.	FAIRFIELD SEVENFOUNTAINS	M. BRADFIELD
P300-21	HOPELEIGH DAM	AMM R.G.	AMM R.G.	ONBEKEND
P300-22	HOMELEIGH DAM	THOMSON E.A.	THOMSON E.A.	ONBEKEND
P300-23	AVONDALE DAM	MULLINS A.L.	MULLINS A.L.	ONBEKEND
P300-24	WELTEVREDE DAM	SCHOONBEE E.C.	SCHOONBEE E.C.	UNKNOWN
P400-04	ROSSLYN DAM	PURDON R.K.	PURDON R.K.	OWNER
P400-05	KENKELE DAM	PURDON R.K.	PURDON R.K.	OWNER
P400-06	PINEDALE DAM	PURDON R.K.	PURDON R.K.	OWNER
P400-07	MANSFIELD DAM	PORT ALFRED-MUNISIPALITEIT	PORT ALFRED-MUNISIPALITEIT	J.C. HAWKINS
P400-08	SAREL HAYWARD DAM (BATHURST STREAM I	PORT ALFRED-MUNISIPALITEIT	PORT ALFRED-MUNISIPALITEIT	NINHAM SHAND (KAAP) ING.
P400-09	WILLOW PARK DAM	HORNE D.C.	HORNE D.C.	MBB INC.
P400-10	GLENIFFER DAM 1	BLADEN G.	BLADEN G.	M. BRADFIELD
P400-11	THE HOME DAM	TIMM N.	TIMM N.	STATE (AGRICULTURE)
P400-13	GLENIFFER DAM NO 2	BLADEN G.	BLADEN G.	M. BRADFIELD
P400-14	MOUNT WELLINGTON DAM	BRADFIELD J.	BRADFIELD J.	MBB INC
P400-15	LANPETER DAM	BADENHORST B.J.	BADENHORST B.J.	M. KOLESKY - NINHAM SHAND
P400-17	ROCKWOODVALE DAM	LEACH T.R.	LEACH T.R.	ONBEKEND
P400-18	RHEMA DAM	LONG J.A.	LONG J.A.	LANDBOU TEGNIESE DIENSTE
P400-19	FAIRVIEW DAM	HANDLEY G.L.	HANDLEY G.L.	DAVE PALMER
P400-20	THE GROVE DAM	LANDBANK	LANDBANK	UNKNOWN
P400-21	OLD MILL DAM	STIRK D.N.	STIRK D.N.	OWNER
Q110-02	HEUNINGKRANS DAM	JOUBERT A.J.	JOUBERT A.J.	STATE (AGRICULTURE)

APPENDIX 6

PHOTOGRAPHS AND PLATES

Plate 1: Sarel Hayward Dam

Plate 2: Fishkraal Dune Ground Water Development

Plate 3: Diaz Cross Well Field

Plate 4: Coastal Springs at Cape Padrone

Plate 5: Coastal Springs at Cape Padrone

Plate 6: Fishkraal Dune Ground Water Development

Plate 7: Coastal Springs at Cape Padrone

Plate 8: Well Field at Coastal Dunes at Port Alfred

Plate 10: Well Fields at Cape Padrone

Plate 12: Well Field at Cape Padrone

Plate 15: Dune Aquifer Exploration Drilling

Plate 17: RO Plant at Kenton on Sea

APPENDIX 7

LEGAL ASPECTS AND INSTITUTIONAL ARRANGEMENTS FOR WATER ASPECTS

1.1 LEGAL ASPECTS AND INSTITUTIONAL ARRANGEMENTS FOR WATER ASPECTS

National Water Act

The NWA does away with and introduces some far-reaching concepts. These concepts have both economic and social features. The former to address water management by conservation and pricing strategy and the latter by ensuring that past discriminatory principles are not continued in the NWA. The most important of these can be summarised as follows:

- The riparian principle is done away with. The nation's water resources become common property, belonging to the nation as a whole. Therefore the previous concept of private ownership in water is done away with;
- The national government, through the Minister of Water Affairs and Forestry, becomes responsible as the public trustee of all water resources to ensure that water resources are protected and water allocated equitably and used beneficially in the public interest. Therefore the NWA reflects the constitutional right of access to sufficient water (Section 27 of the Constitution);
- All right to use water derives from the NWA;
- Water must be available for the Reserve. The Reserve is a new concept and consists of two legs, namely the quantity and quality of water required to satisfy basic human needs as prescribed by the Water Services Act (Act no 108 of 1997) for people who now or will in future require water and to protect the aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource. Thus environmental considerations are anchored in the NWA;
- Setting out the purposes of the Act that institutions which have appropriate community, racial and gender representation must be developed to give effect to the NWA;
- Shifts the emphasis from the traditional "supply management" approach towards "demand management", that is conservation of the nation's water resources by lessening the demand and providing for an innovative pricing system.
- Providing for extensive public participation. Virtually no decision can be made without public participation;
- The abolishment of the Water Courts and introducing a Water Tribunal where administrative final decisions can be appealed to; and
- Recognition of international obligations.

Licensing

Whereas the Water Act of 1956 divided water into different categories, in the NWA all water has the same status. Section 21 of the NWA sets out what is regarded as water use. These include, amongst other uses, taking water from a water resource, storage of water, diverting water, discharging waste into a watercourse, disposing of waste in a manner that may detrimentally impact on a water resource and recreational use.

Two new concepts of water use are created. The first is that the Minister can declare any activity to be a stream flow reduction activity, if that activity reduces the availability of water. Afforestation has already been declared a stream flow reduction activity. The second new concept is that the Minister can declare any activity to be a controlled activity if that activity impacts on a water resource. Activities such as irrigation on any land with waste, recharging of an aquifer are examples of activities that are already controlled activities.

All water use requires a licence unless it falls into a Schedule 1 use (this deals with the *de minimus* use, such as water for reasonable domestic use, small gardening and animal watering (excluding feedlots); or was permissible as an existing lawful use (water use permitted under previous laws and which were exercised during the period of two years before the date that Section 32 came into effect; namely 1 October 1998); and under a general authorisation.

An important innovation is that a licence can only be for a maximum period of 40 years and is subject to a review period, which may not be at intervals of more than five years. A licence can be increased at each review period but not for more than the review period. This is known as the "revolving licence".

If a person who has an existing lawful use applies for a licence under Section 43 of the NWA (compulsory licensing), and the application has been refused or has been granted for a lesser amount, which results in severe economic prejudice, the applicant may claim compensation. Compensation cannot be claimed if the reduction is to provide for the Reserve, rectify a previous over-allocation or a previous unfair allocation.

Compensation must be claimed from the Water Tribunal.

The Minister has the right to attach conditions to any licence as well as to make regulations on various topics set out in section 26 of the NWA.

Other Legislation

It is important to note that although the Water Services Act (Act no 108 of 1997) deals with water services, the actual water use is controlled under the NWA.

The NWA is aligned with other laws in order to prevent, for example, duplication of applications, unnecessary expenses and where possible, a "one stop" can be issued. Specific examples are as follows:

- Environment assessments in terms of the Environmental Conservation Act of 1989 can be taken into account by the responsible authority when issuing a licence;
- If a licence is issued under other acts that meet the purpose of the NWA, the responsible authority can dispense with the issuing of a licence for water under the NWA; and
- Provisions in the Constitution of the Republic of South Africa must be complied with.

Further, there is a close connection between the Water Services Act (Act no 108 of 1997) and the NWA.

The Abolition of Racially Based Land Measures Act repealed laws that previously restricted black persons from owning or occupying land. These acts had the effect of preventing black persons from having any water rights or under certain circumstances, limited water entitlements.

Notwithstanding the NWA there are other acts to which a water user and indeed the State must comply.

These Acts are the following:

Physical Planning Act (Act No. 125 of 1991)

Under this act no land use, development or subdivision may be permitted unless in accordance with an approved plan.

Development Facilitation Act (Act No. 67 of 1995)

This act prescribes the set of principles with which all development projects and all land use and land use planning should comply, and which will serve as guidelines for the administration of land use and development schemes.

Restitution of Land Rights (Act No. 22 of 1994)

This act is aimed at the restitution of land to those who have been deprived thereof in terms of discriminatory laws. Claims are lodged with the Land Claims Commission. It is because of this act that when a transfer of water entitlements is approved in terms of the NWA an indemnity is required from the transferor that a claim was not lodged against the land in terms of the Restitution of Land Rights Act.

Environmental Conservation Act (Act No. 73 of 1989)

This act provides for the effective protection and control of the environment. It makes provision for the declaration of an environmental conservation policy.

In terms of this act the state has a responsibility to act as trustee of the natural environment and to consider all activities that may have an influence on the environment.

Activities, which may have a detrimental effect on the environment, have been published in terms of Section 21 of this act. To undertake any of these activities, authorisation is required, which can only be obtained from the Minister of Environmental Affairs and Tourism after the prescribed procedure has been complied with. The construction of various forms of water works (dams, water diversions, water transfer schemes, etc.) is subject to the new process.

Through a consultative process a White Paper for Sustainable Coaster Development in South Africa was prepared. In terms thereof it is the joint responsibility of the Departments of Water Affairs and Forestry and of Environmental Affairs and Tourism to protect the in-shore marine environment.

In terms of this act the Department of Environmental Affairs and Tourism is responsible for issuing waste permits under this act and has published a Government Notice 1986 of 24 August 1990 relating to the identification of waste. This government notice needs drastic amendment to bring it in line with the NWA.

In May 2000 the Department of Environment Affairs and Tourism published a White Paper on Integrated Pollution and Waste Management for South Africa. Aspects included water pollution; diffuse water pollution, marine pollution; and land pollution.

National Environmental Management Act (Act No. 107 of 1998)

This act lays a new foundation for environmental management. The act includes 20 principles that serve as a general framework within which environmental management and implementation plans must be formulated and guide any other law concerned with the protection or management of the environment. Environment is defined as the natural environment and the physical chemical, aesthetic and cultural properties of it that influence human well being.

To give effect to these principles this act creates the National Environmental Forum and the Committee for Environmental Co-ordination and defines the procedure for the establishment of a Coastal Management Subcommittee of the Committee for Environmental Co-ordination in order to achieve better inter-governmental co-ordination of coastal management.

This act provides for the drawing up of environmental implementation plans by certain scheduled national Government Departments and the Provinces. In addition, environmental management plans are to be drawn up by certain national Departments. The two sets of plans do not have to be drawn up by the private sector and may be consolidated. The purpose of the plans is set out in detail and must co-ordinate and harmonise environmental policies, plans, decisions of the three spheres to prevent duplication; give effect to co-operative governance and enable monitoring the achievement.

Chapter 7 of this act relates to environmental damage, duty of care, emergencies and remediation.

Conservation of Agriculture Resources Act (Act No. 43 of 1983)

This act is to provide for control over the utilisation of the natural agricultural resources in order to promote the conservation of the soil; the water resources and vegetation and the combating of weeds and invader plants. Except for weeds and invader plants, this act does not apply to land in an urban area.

Institutions Responsible for Community Water Supplies

The Water Services Act, No. 108 of 1997, deals with the provision of water supply services and sanitation services in a manner consistent with the broader goals of water resource management. The institutional structure provided for in the Act includes, in addition to the National Government, represented by the Department of Water Affairs and Forestry, the following bodies:

(i) Water Services Authorities, which are municipalities, including district or rural councils, that are responsible for ensuring access to water services.

(ii) Water Boards, which may be established by the Minister of Water Affairs and Forestry, after due consultation with stakeholders, for the primary purpose of providing water services to other water services institutions.

(iii) Water Services Committees, which may be established by the Minister of Water Affairs and Forestry to provide water services to communities within their own service area where the Water Services Authorities having jurisdiction in the areas in question are unable to provide water services effectively.

(iv) The Provincial Government, which may take over the functions of a Water Services Committee or a Water Board, if requested to do so by the Minister of Water Affairs and Forestry.

Advisory Committees, which may be appointed by the Minister of Water Affairs and Forestry, to provide advice on matters falling within the scope of the Act.

The municipalities are the Water Services Authorities responsible for water services in the WMA. The municipalities were restructured in the year 2000. As this report deals with the period prior to that, mainly the institutional arrangements prior to the restructuring are reported on here.

The Fish to Tsitsikamma WMA was fortunate in that most of the transitional local councils had the resources and the technical skills to be Water Services Authorities. Therefore, they became the Water Service Authorities responsible for the water and sanitation services of their own towns and the surrounding areas. The areas of jurisdiction of the transitional local councils are shown on Figure 3.4.9.1.

The areas that did not fall within the jurisdiction of the transitional local council fell under the transitional regional councils that are also shown on Figure 3.4.9.1. These areas are generally nature reserves or privately owned farmland where the owners of the land are responsible for their own water supplies. In these areas, neither the transitional rural councils nor the district councils were Water Services Authorities.

In the south-eastern corner of the WMA, between the Great Fish River and the eastern boundary of the WMA, where there are areas of tribal land that were part of the former Republic of Ciskei. When the Ciskei was re-incorporated into South Africa, DWAF took over the responsibility for community water supplies in these areas, and was the Water Services Authority until the year 2001, when the responsibility passed to the new Amatole District Municipality. The boundaries of the supply area of the Amatole Water Board, which provides water services mainly in the Mzimvubu to Keiskamma WMA, have recently been extended to include this area.

APPENDIX 8

POTENTIAL FOR WATER CONSERVATION AND DEMAND MANAGEMENT

1.1 POTENTIAL FOR WATER CONSERVATION AND DEMAND MANAGEMENT

The value of water is largely unrecognised by many water users in South Africa and inefficient water usage is evident. South Africa is a developing country with relatively scarce water resources and is therefore forced to improve the management thereof. All water use sectors including agriculture, forestry, industry, recreational, ecological and water services are encouraged to conserve and manage the limited sources available.

Water conservation is the minimisation of loss or waste, the prevention, care and protection of water resources and the efficient and effective use of water. Water conservation should be both an objective in water resource and water services management as well as a strategy.

Water demand management is the adaptation and implementation of a strategy (policies and initiatives) by a water institution to influence the water requirements and use of water in order to meet any of the objectives of economic efficiency, social development, social equity, environmental protection, sustainability of water supply and services and political acceptability. Water supply institutions should set water demand goals and targets by managing the distribution system and consumer requirements in order to achieve the above objectives.

Water demand management is deemed to include the entire water supply chain – from the point of abstraction at the source to the point of use. This includes all levels of water distribution management and consumer demand management. The conservation measures related to the water resources and return flow are part of water resource management and return flow management respectively. Various obstacles and constraints have to be overcome before the full potential of water conservation and demand management can be achieved.

Existing Water Services

50% of the total quantity of water that is supplied is not accounted for in many of the urban areas. This unaccounted for water consists of a combination of reticulation system leaks, unauthorised water connections, faulty water meters and domestic plumbing leaks. These factors, combined with low level of payment and institutional problems of local authorities, affect the sustainability of water services. Current indications are that levels of unaccounted for water are growing despite the formulation of several water conservation strategies in the past.

Water Resources and Supply

The sustainability of the limited water resources is threatened in terms of quantity and quality. Unless the current water use pattern is changed, future water requirements will greatly exceed existing available fresh water resources. Frequently the water supply and quality are unreliable or improperly managed, leading to the wasteful use of water by consumers in anticipation of possible supply failure.

Environment

Environmental degradation and the prevention thereof is a key focus in the current policy and legislation. Measures such as providing for water of suitable quality in sufficient quantity in the Reserve to protect the integrity, health and productivity of the rich and diverse ecosystems have become necessary.

Basic Water Supply Needs

By the application of water demand management measures to existing water services, water resources and bulk infrastructure can be reallocated for the provision of new services where adequate services do not yet exist. Water demand management is also essential in ensuring the sustainability of the new water service delivery projects and can help to ensure that water remains affordable.

Water Restrictions

Experience from past water restrictions that have proved to be the most effective during times of drought, which are relevant to future water conservation efforts are:

- The overall reduction in water use depends on a number of factors. However, when water use is reduced beyond 30% it can be detrimental to user from a financial and motivational perspective.
- Voluntary reduction in water use fails to achieve the savings possible with mandatory steps.
- The most effective methods of reducing water use are higher tariffs, restriction of garden water times, the banning of domestic hose pipe usage and allotting quotas to industry, bulk consumers and irrigators.
- The most effective motivations are pamphlets/newsletters, higher tariffs and punitive measures.
- The major interventions required to reduce both physical and non-physical losses from pipe networks are leak detection/monitoring, replacing old plumbing and the repair/monitoring of meters.
- The most effective methods of saving water used by commerce and industry are technical adjustments, recycle/re-use and promotion campaigns.
- The ratio of return flow to water use is not materially changed by changes in water use.

APPENDIX 9

SIZING FLOWS

Appendix 9: Sizing Flows

Option No	Option Name	Towns Supplied	Water Source	Primary Conveyance System
1	Alexandria – GW (1 A : GW)	Alexandria	- Fishkraal GW	- Develop GW with 6 BH’s (11 l/s, 12 hr) & 2 PS’s (12,5 l/s) - CWRM of 10.5 km (12,5 l/s) - 50 m³ Bal Res, 150 m³ BPT - CWGM of 8.5 km (12,5 l/s) - 800 m³ reservoir
2	Cannon Rocks – GW (2 CR : GW)	Cannon Rocks and Boknes	- Apies River mouth GW	- Devlp GW with 12 BH’s (34 l/s) - 1 PS (34 l/s) - CWRM of 2.5 km (34 l/s) - 2 town reservoirs (1 800 m³)
3	Kenton on Sea – GW (3 KOS : GW)	Kenton on Sea Boesmansriviermond	- Upgrade RO - Kwaaihoek GW - Merville GW - Bushfontein GW	- Upgrade existing RO plant to 60 m³/hr - Devlp Kwaaihoek GW with 4 BH’s (6.9 l/s) - CWRM1 of 1 km to existing PS (6.9 l/s) - Devlp Merville GW with 5 BH’s (18.5 l/s) - 1 CWPS & 3 km CWRM with a 100 m³ Bal Res - Devlp Bushfontein GW with 3 BH’s (18.5 l/s) - 3 CWPS & 9 km CWRM with a 300 m³ Bal Res - CWGM of 13.5 km & 3 BPT’s - New PE lined Bal Dam of 13 000 m³ & new Res’s of 3 000 m³
4a	Kenton on Sea – RO1 (4a KOS : RO1)	Kenton on Sea Boesmansriviermond	- Upgrade existing RO - Kwaaihoek - New RO (seawater)	- Upgrade existing RO plant to 60 m³/hr - Devlp Kwaaihoek GW with 4 BH’s (6.9 l/s) - CWRM1 of 1 km to existing PS (6.9 l/s) - New RO (seawater) plant – 2 400 m³/d - 1 CWPS with a 100 m³ Bal Res & CWRM of 3.5 km - New PE lined Bal Dam of 13 000 m³ & new Res’s of 3 000 m³

4b	Kenton on Sea – RO2 (4b KOS : RO2)	Kenton on Sea Boesmansriviermond	- Upgrade existing RO - Kwaaihoek - New RO (brackish water)	- Upgrade existing RO plant to 60 m³/hr - Devlp Kwaaihoek GW with 4 BH's (6.9 l/s) - CWRM1 of 1 km to existing PS - Devlp brackish water source (3 800 m^3/d) & RWRM of 3.3 km - New RO (brackish) plant – 2 400 m³/d - 1 CWPS with a 200 m³ Bal Res & CWRM of 2.5 km - New PE lined Bal Dam of 13 000 m³ & new Res's of 3 000 m³
5	Kenton on Sea – SW (5 KOS : SW)	Kenton on Sea Boesmansriviermond	- SW from Glen Melville Dam	- Upgrade existing RO plant to 60 m³/hr - Devlp Kwaaihoek GW with 4 BH's (6.9 l/s) - CWRM1 of 1 km to existing PS - Surface water (2 400 m³/d) from Glen Melville Dam via PA - New PE lined Bal Dam of 13 000 m³ & new Res's of 3 000 m³
6	Port Alfred – GM 1 (6 PA : GM1: PA, BT, KoS)	Port Alfred Bathurst Kenton on Sea	- Barville / Glendower - Sunshine Coast - SW from Glen Melville Dam	- Devlp Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Devlp Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Glen Melville Dam (144 l/s) & 1 CWPS - CWRM of 8.5 km & a 2 500 m³ Bal Res - CWGM of 83 km with 4 x 250 m³ BPT's - Bathurst Res 1 200 m³ & PA Res 15 000 m³
7	Port Alfred – GM2 (7 PA : GM 2: PA, BT)	Port Alfred Bathurst	- Barville / Glendower - Sunshine Coast - SW from Glen Melville Dam	- Devlp Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Devlp Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Glen Melville Dam (112 l/s) & 1 CWPS - CWRM of 8.5 km & a 2 000 m³ Bal Res - CWGM of 59 km with 4 x 150 m³ BPT's - Bathurst Res 1 200 m³ & PA Res 15 000 m³

8a	Port Alfred – SH (8a PA : SH)	Port Alfred	- Barville / Glendower - Sunshine Coast - SW from Sarel Hayward Dam	- Devlp Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Devlp Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to the 500 m³ Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Port Alfred (106 l/s) - 1 RWPS (250 l/s) at river abstraction - 2 RWPS's (106 l/s) with Bal Res's - RWRM of 7.7 km (93 l/s) & a 200 m³ Bal Res - RWGM of 2.6 km (93 l/s) with a 200 m³ Bal Res - RWGM of 3 km (93 l/s) to WTW - Port Alfred Res 15 000 m³ - Raise Sarel Hayward Dam wall by 12 m, from FSL 38.9 to 50.9
8b	Port Alfred – SH & RO (8b PA : SH & RO)	Port Alfred	- Barville / Glendower - Sunshine Coast - SW from Sarel Hayward Dam - Treat 4 000m³/d by RO	- Devlp Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Devlp Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to the 500 m³ Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Port Alfred (106 l/s) - 1 RWPS (250 l/s) at river abstraction - 2 RWPS's (106 l/s) with Bal Res's - RWRM of 7.7 km (93 l/s) & 1 200 m³ Bal Res - RWGM of 2.6 km (93 l/s) with 1 200 m³ Bal Res - RWGM of 3 km (93 l/s) to WTW - Port Alfred Res 15 000 m³ - Raise Sarel Hayward Dam wall by 12 m, from FSL 38.9 to 50.9 - Treat 4 000 m³/d of SW through 14 RO units - 1 CWPS (56 l/s) with a 300 m³ Bal Res at RO plant - RWGM of 0.5 km (76 l/s) from WTW to RO plant - CWRM of 1.3 km (56 l/s) from RO to town Res

9	Port Alfred – SD (9 PA : SD)	Port Alfred	- Barville / Glendower - Sunshine Coast - SW from Settlers Dam	- Devlp Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to a 500 m³ Bal Res - Devlp Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to the 500 m³ Bal Res - CWGM of 5 km to PA (54 l/s) - WTW at Port Alfred (106 l/s) - 1 RWPS (106 l/s) at Settlers Dam - RWRM of 2 km (93 l/s) & 1 200 m³ Bal Res - RWGM of 42.5 km with 4 x 200 m³ BPT's - WTW at Glen Melville Dam (106 l/s) - 1 CWPS (96 l/s) with Bal Res from WTW to Botha's Hill Res - CWRM of 8.5 km (93 l/s) from GM WTW to Botha's Hill Res - CWGM of 10.5 km (93 l/s) from Botha's Hill Res to GTown Res - Port Alfred Res 15 000 m³
10	Port Alfred – RO (10 PA : RO)	Port Alfred	- Barville / Glendower - Sunshine Coast - RO plant (seawater)	- Devlp Barville/Glendower GW with 5 BH's (23 l/s) - CWRM of 2 km (30 l/s) to 1 x 500 m³ Bal Res - Devlp Sunshine Coast GW with 9 BH's (18 l/s) - CWRM of 2 km (24 l/s) to the 500 m³ Bal Res - CWGM of 5 km to PA (54 l/s) - Devlp GW source at coast with 15 BH's (155 l/s) - 1 RWPS (155 l/s) with a 250 m³ Bal Res - RWRM of 2.1 km (155 l/s) & 1 250 m³ Bal Res - New RO (seawater) plant – 7 650 m³/d - 1 CWPS (110 l/s) with a 200 m³ Bal Res - CWRM of 0.5 km (110 l/s) to the town Res - Port Alfred Res 15 000 m³

Bal Dam	balancing dam
Bal Res	balancing reservoir
BH	borehole
BPT	break pressure tank
CLRM	clean water raising main
CWGM	clean water gravity main
CWPS	clean water pump station
GW	groundwater
hr	hour
m^3	cubic metre
m^3/d	cubic metre per day
m^3/h	cubic metre per hour
km	kilometre
l/c/d	litre per capita per day
l/day	litre per day
l/s	litre per second
mamsl	metres above mean sea level
m^3/a	cubic metre per year
m^3/d	cubic metre per day
m^3/h	cubic metre per hour
ND	nominal diameter
PE	polyethylene
PS	pump station
Res	reservoir
RO	reverse osmosis
RWGM	raw water gravity main
RWPS	raw water pump station
RWRM	raw water raising main
WTW	water treatment works

APPENDIX 10

COSTING

APPENDIX 10: COSTING

Contents

APPENDIX 10.1

COST MODELS

ALBANY COAST SITUATION ASSESEMENT STUDY

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Appendix 10.1

DESCRIPTION OF THE CONVEYANCE SYSTEM

1

ALEXANDRIA
SUPPLY FROM GW
(1 A : GW)

GAADD	2082.00	m3/d
SDD	2499.00	m3/d

Description : Develop additional Fishkraal dune GW source, upgrade conveyance to Alex Res

No	Description	unit	Quantity	Rate	Sub-tot	Total for component
1	**Ground Water Source**					**673,521**
1.1	Develop source: 11 l/s (12hr), 1.83 l/s/bh, 6 No bh	sum			196,333	
1.2	Equip bh: Q 1.83 l/s, H 70 m	no	6	50750	304,500	
1.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,200	89.74	107,688	
1.4	Electrical connection	m	1,000	65.00	65,000	
2	**Clear Water Raising/Gravity Mains**					**5,342,902**
2.1	CWRM 1: uPVC 110, cl 9	m	2,000	126.30	252,600	
2.2	CWRM 2: uPVC 140, cl 16	m	2,320	304.39	706,185	
2.3	CWRM 3: GMS 150, med duty	m	6,220	402.19	2,501,622	
2.4	CWGM: uPVC 160, cl 9	m	8,500	221.47	1,882,495	
3	**Pump Station**					**1,269,879**
3.1	CWPS 1: one duty, one standby	no	1	601379.00	601,379	
	WKLn 80/9, motor 37 kW (1450 RPM)					
3.2	CWPS 2: 1xduty, 1 x standby	no	1	668500.00	668,500	
	WKLn 80/13, motor 45 kW (1450 RPM)					

No	Description	unit	Quantity	Rate	Sub-tot	Total
4	**Reservoirs**					**875,000**
4.1	Balancing Reservoir and BPT 50 kl	no	2	112,000	224,000	
4.2	Additional town Res 800 kl	no	1	651,000	651,000	
	Total for scheme					**8,161,302**

BH Source				196,333
BH Equipm				369,500
CWRM				3,568,095
CWGM				1,882,495
CWPS				1,269,879
Storage				875,000
TOTAL				**8,161,302**

ALBANY COAST SITUATION ASSESEMENT STUDY

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DESCRIPTION OF THE CONVEYANCE SYSTEM

2

CANON ROCKS/BOKNES
SUPPLY FROM GW
(2 CR : GW)

GAADD	1420.00	m3/d
SDD	2130.00	m3/d

Description : Develop additional resources at Apies River GW source, conveyance to Res

No	Description	unit	Quantity	Rate	Sub-tot	Total for component
1	**Ground Water Source: Apies River**					**1,597,580**
1.1	Develop source: 34 l/s (12hr), 2.85 l/s/bh, 12 No bh	sum			561,404	
1.2	Equip bh: Q 2.85 l/s, H 60 m	no	12	52150	625,800	
1.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	2,400	89.74	215,376	
1.4	Electrical connection	m	3,000	65.00	195,000	
2	**Clear Water Raising/Gravity Mains**					**797,975**
2.1	CWRM 1: uPVC 200, cl 9	m	2,500	319.19	797,975	
3	**Clear Water Pump Station**					**425,000**
3.1	CWPS: one duty, one standby WKLn	no	1	425000.00	425,000	
	100/4 Motor 45 kW (1450 RPM)					

No	Description	unit	Quantity	Rate	Sub-tot	Total
4	**Reservoirs**					**1,502,000**
4.1	Town reservoir 800 kl	no	1	650,000	650,000	
4.2	Town reservoir 1000 kl	no	1	740,000	740,000	
4.3	Balancing Reservoir at CWPS 50 kl	no	1	112,000	112,000	
	Total for scheme					**4,322,555**

BH Source				561,404
BH Equipm				820,800
CWRM				1,013,351
CWGM				0
CWPS				425,000
Storage				1,502,000
TOTAL				**4,322,555**

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

3

For Year 2015:

GAADD	3320.00	m3/d
SDD	4980.00	m3/d

KENTON ON SEA/BUSHMANS RIVER MOUTH
SUPPLY FROM GW
(3 KOS : GW)

Description : Keep existing RO plant & Dias Cross well field, upgrade seawater intake and **RO**, develop **Kwaaihoek** dune source, develop **Merville** and **Bushfontein** well fields
Provide necessary conveyance, reservoirs and balancing reservoir
Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total for component	Total for sub-system
A	**Upgrade RO plant**					**4,100,000**	**4,100,000**
	Build sea water intake and filtration	sum		1,400,000	1,400,000		
	Upgrade Eskom supply	sum		700,000	700,000		
	Upgrade brine disposal	sum		600,000	600,000		
	Expand R0 3 plant (add 10 kl/hr)	sum		1,400,000	1,400,000		
B	**Develop Kwaaihoek dune well field**						**628,372**
B1	**Ground Water Source**					**516,462**	
	Develop source: 6.9 l/s (12hr), 1.72 l/s/bh, 4 No bh	sum			178,070		
	Equip bh: Q 1.72 l/s, H 60 m	no	4	50400	201,600		
	Collector pipes, ND 75, cl 9, 200 m/bh	m	800	89.74	71,792		
	Electrical connection	m	1,000	65.00	65,000		
B2	**Clear Water Raising/Gravity Mains**					**111,910**	
	CWRM 1: uPVC 90, cl 9	m	1,000	111.91	111,910		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
C	**Develop Merville and Bushfontein well fields**						**14,351,578**
C1	**Ground Water Source: Bushfontein**					**6,073,674**	
C1.1	Develop source: 18.5 l/s (12hr), 6.2 l/s/bh, 3 No bh	sum			776,316		
C1.2	Equip bh: Q 6.2 l/s, H 85 m	no	3	58800	176,400		
C1.3	Collector pipes, ND 90, cl 9, 300 m/bh	m	900	111.91	100,719		
C1.4	Electrical connection	m	4,000	65.00	260,000		
C1.5	Balancing Reservoir Bushfontein 300 kl	no	1	330,000	330,000		
C1.6	Balancing Reservoir at CWPS's 50kl	no	3	112,000	336,000		
C1.7	CWRM 2: uPVC 140, cl 9	m	300	204.32	61,296		
C1.8	CWRM 3: uPVC 140, cl 12	m	200	245.33	49,066		
C1.9	CWRM 4: GMS 150 Med Duty	m	500	402.19	201,095		
C1.10	CWRM 5: uPVC 200, cl 9	m	5,300	319.19	1,691,707		
C1.11	CWGM 1: uPVC 200, cl 9	m	2,500	319.19	797,975		
C1.12	CWPS 1: one duty, one standby WKLn	no	1	340100.00	340,100		
	100/3 Motor 18.5 kW (1450 RPM)						
C1.13	CWPS 2: one duty, one standby WKLn	no	1	602000.00	602,000		
	100/10 Motor 37 kW (1450 RPM)						
C1.14	CWPS 3: one duty, one standby WKLn	no	1	351000.00	351,000		
	65/4 Motor 55 kW (1450 RPM)						
C2	**Ground Water Source: Merville**					**3,187,829**	
C2.1	Develop source: 18.5 l/s (12hr), 3.7 l/s/bh, 5 No bh	sum			750,219		
C2.2	Equip bh: Q 3.7 l/s, H 135 m	no	5	56000	280,000		
C2.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,000	89.74	89,740		
C2.4	Electrical connection	m	2,000	65.00	130,000		
C2.5	Balancing Reservoir Merville 100 kl	no	1	176,000	176,000		
C2.6	CWRM 5: uPVC 160, cl 16	m	1,500	339.29	508,935		
C2.7	CWRM 6: uPVC 160, cl 16	m	1,500	339.29	508,935		
C2.7	CWPS 4: one duty, one standby WKLn	no	1	744000.00	744,000		
	100/8 Motor 45 kW (1450 RPM)						

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
C3	**Clear Water Raising/Gravity Mains**					**5,090,075**	
C3.1	CWGM 2: uPVC 200, cl 9	m	4,500	319.19	1,436,355		
C3.2	CWGM 3: uPVC 160, cl 12	m	2,000	266.48	532,960		
C3.3	CWGM 4: uPVC 200, cl 12	m	7,000	388.68	2,720,760		
C3.4	BPT 50kl	no	2	112,000	224,000		
C3.5	BPT 100kl	no	1	176,000	176,000		
D	**Reservoirs**					**1,946,000**	**1,946,000**
	Add capacity to town reservoirs 2 x 1500 kl	no	2	973,000	1,946,000		
E	**Balancing dam**					**600,000**	**600,000**
	PE lined dam: 13 000 kl	no	1	600,000	600,000		
	Total for scheme					**21,625,950**	**21,625,950**

RO Plant			1,400,000
BH Source			1,704,605
BH Equipm			1,113,000
CWRM			3,995,195
CWGM			5,488,050
CWPS			2,037,100
WTW (Sea water intake and filter)			2,100,000
Storage			3,788,000
TOTAL			**21,625,950**

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

4a

KENTON ON SEA/BUSHMANS RIVER MOUTH
SUPPLY FROM GW & RO (SEAWATER)
(4a KOS : RO1)

For year 2015:

GAADD	3320.00	m3/d
SDD	4980.00	m3/d

Description : Keep existing RO plant & Dias Cross well field, upgrade seawater intake and **RO**,
develop **Kwaaihoek** dune source, develop additional **seawater RO** plant to make up deficit (2400 m³/d)
Provide necessary seawater intake, brine disposal, RO units and clean water pump station
Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total for component	Total for sub-system
A	**Upgrade RO plant**					**4,100,000**	**4,100,000**
	Build sea water intake and filtration	sum			1,400,000		
	Upgrade Eskom supply	sum			700,000		
	Upgrade brine disposal	sum			600,000		
	Expand R0 3 plant (add 10 kl/hr)	sum			1,400,000		
B	**Develop Kwaaihoek dune well field**						**628,372**
B1	**Ground Water Source**					**516,462**	
	Develop source: 6.9 l/s (12hr), 1.72 l/s/bh, 4 No bh	sum			178,070		
	Equip bh: Q 1.72 l/s, H 60 m	no	4	50400	201,600		
	Collector pipes, ND 75, cl 9, 200 m/bh	m	800	89.74	71,792		
	Electrical connection	m	1,000	65.00	65,000		
B2	**Clear Water Raising/Gravity Mains**					**111,910**	
	CWRM 1: uPVC 90, cl 9	m	1,000	111.91	111,910		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
C	**Additional RO equipment (90 m3/hr)**					**17,200,000**	**17,200,000**
	RO Unit complete	no	8	1,300,000	10,400,000		
	Housing for RO equipment	m2	800	2,000	1,600,000		
	Upgrade Eskom supply	no	8	300,000	2,400,000		
	Upgrade sea abstraction and filtration	no	8	300,000	2,400,000		
	Upgrade brine disposal	sum	8	50,000	400,000		
D	**Clear Water Pump Station**					**760,430**	**760,430**
G1.1	Pump sump / balancing reservoir (1 hr storage) (100 kl)	no	1	176,000	176,000		
G1.2	CWPS: one duty, one standby: WKLn 100/6 Motor 45 kW (1450 RPM)	no	1	584,430	584,430		
E	**Clear Water Raising Main**					**1,416,170**	**1,416,170**
	Pumping main to town Res: uPVC 250, cl 12	m	3,500	404.62	1,416,170		
F	**Reservoirs**					**1,946,000**	**1,946,000**
	Add capacity to town reservoirs 2 x 1500 kl	no	2	973,000	1,946,000		
G	**Balancing dam**					**600,000**	**600,000**
	PE lined dam: 13 000 kl	no	1	600,000	600,000		
	Total for scheme					**26,650,972**	**26,650,972**

RO Plant			14,900,000
BH Source			178,070
BH Equipm			266,600
CWRM			2,599,872
CWGM			0
CWPS			584,430
WTW (Sea water intake and filter)			3,800,000
Storage			4,322,000
TOTAL			**26,650,972**

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

4b

KENTON ON SEA/BUSHMANS RIVER MOUTH
SUPPLY FROM GW & RO (BRACKISH)
(4b KOS : RO2)

For year 2015:

GAADD	3320.00	m3/d
SDD	4980.00	m3/d

Description : Keep existing RO plant & Dias Cross well field, upgrade seawater intake and **RO**,
develop **Kwaaihoek** dune source, develop additional **brackish water RO** plant to make up deficit (2400 m³/d)
Provide necessary brackish water intake, brine disposal, RO units and clean water pump station
Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total for component	Total for sub-system
A	**Upgrade RO plant**					**4,100,000**	**4,100,000**
	Build sea water intake and filtration	sum			1,400,000		
	Upgrade Eskom supply	sum			700,000		
	Upgrade brine disposal	sum			600,000		
	Expand R0 3 plant (add 10 kl/hr)	sum			1,400,000		
B	**Develop Kwaaihoek dune well field**						**628,372**
B1	**Ground Water Source**					**516,462**	
	Develop source: 6.9 l/s (12hr), 1.72 l/s/bh, 4 No bh	sum			178,070		
	Equip bh: Q 1.72 l/s, H 60 m	no	4	50400	201,600		
	Collector pipes, ND 75, cl 9, 200 m/bh	m	800	89.74	71,792		
	Electrical connection	m	1,000	65.00	65,000		
B2	**Clear Water Raising/Gravity Mains**					**111,910**	
	CWRM 1: uPVC 90, cl 9	m	1,000	111.91	111,910		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
C	**New RO equipment (2400 m3/d)**					**6,100,000**	**6,100,000**
	RO Unit complete	no	8	400,000	3,200,000		
	Housing for RO equipment	m2	800	2,000	1,600,000		
	Eskom supply	no	8	100,000	800,000		
	New brine disposal (1000m @ 200 cl 9 uPVC plus civils)	sum	1	500,000	500,000		
D1	**Ground Water Source (Brackish)**					**5,191,100**	**5,191,100**
D1.1	Develop source: 88 l/s (12hr), 4 l/s/bh, 22 No bh	sum			2,000,000		
D1.2	Equip bh: Q 4 l/s, H 50 m	no	22	54600	1,201,200		
D1.3	Collector pipes, uPVC 250, cl 9, 5000 m	m	5,000	332.98	1,664,900		
D1.4	Electrical connection	m	5,000	65.00	325,000		
D2	**Raw Water Raising Main**					**1,663,740**	**1,663,740**
D2.1	RWRM to RO: uPVC 315, cl 9	m	3,250	511.92	1,663,740		
D3	**Clear Water Pump Station**					**1,067,000**	**1,067,000**
D3.1	Pump sump / balancing reservoir (1 hr storage) (200 kl)	no	1	270,000	270,000		
D3.2	CWPS: one duty, one standby: ETA 125-200	no	1	797,000	797,000		
	Motor 11 kW (1450 RPM)						
D4	**Clear Water Raising Main**					**832,450**	**832,450**
D4.1	CWRM 2 Pumping main to town Res: uPVC 250, cl 9	m	2,500	332.98	832,450		
E	**Reservoirs**					**1,946,000**	**1,946,000**
	Add capacity to town reservoirs 2 x 1500 kl	no	2	973,000	1,946,000		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
F	**Balancing dam**					**600,000**	**600,000**
	PE lined dam: 13 000 kl	no	1	600,000	600,000		
	Total for scheme					**22,128,662**	**22,128,662**

RO Plant			7,700,000
BH Source			2,178,070
BH Equipm			1,792,800
RWRM			4,428,640
CWRM			1,016,152
CWGM			0
CWPS			797,000
WTW (Sea water intake and filter)			1,400,000
Storage			2,816,000
TOTAL			**22,128,662**

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

5

KENTON ON SEA/BUSHMANS RIVER MOUTH
SUPPLY FROM GW & SW (GLEN MELVILLE)
(5 KOS : SW)

For Year 2015:

GAADD	3320.00	m3/d
SDD	4980.00	m3/d

Description : Keep existing RO plant & Dias Cross well field, upgrade seawater intake and **RO**, develop **Kwaaihoek** dune source, supply deficit from **Glen Melville Dam** (2300 m³/d)
Provide necessary conveyance, reservoirs and balancing reservoir
Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total for component	Total for sub-system
A	**Upgrade RO plant**					**4,100,000**	**4,100,000**
	Build sea water intake and filtration	sum			1,400,000		
	Upgrade Eskom supply	sum			700,000		
	Upgrade brine disposal	sum			600,000		
	Expand R0 3 plant (add 10 kl/hr)	sum			1,400,000		
B	**Develop Kwaaihoek dune well field**						**628,372**
B1	**Ground Water Source**					**516,462**	
	Develop source: 6.9 l/s (12hr), 1.72 l/s/bh, 4 No bh	sum			178,070		
	Equip bh: Q 1.72 l/s, H 60 m	no	4	50400	201,600		
	Collector pipes, ND 75, cl 9, 200 m/bh	m	800	89.74	71,792		
	Electrical connection	m	1,000	65.00	65,000		
B2	**Clear Water Raising/Gravity Mains**					**111,910**	
	CWRM 1: uPVC 90, cl 9	m	1,000	111.91	111,910		

C	**Reservoirs**					**1,946,000**	**1,946,000**
	Add capacity to town reservoirs 2 x 1500 kl	no	2	973,000	1,946,000		
E	**Supply 2300 m³/d from Glen Melville Dam to KOS**					**25,127,190**	**25,127,190**
	Total sum	sum			25,127,190		
	Total for scheme					**31,801,562**	**31,801,562**

RO Plant			2,100,000
BH Source			178,070
BH Equipm			266,600
CWRM			183,702
RWRM			2,000,000
Additional costs of SW: GM Opt1 - GM 0pt 2			25,127,190
Storage			1,946,000
TOTAL			**31,801,562**

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

6

KENTON ON SEA & PORT ALFRED
SUPPLY FROM GW & SW (GLEN MELVILLE)
(6 PA : SW1)

GAADD	15906.00	m3/d
SDD	26724.00	m3/d

Description : Keep existing dune source. **Develop Barville / Glendower** well field, develop **Sunshine Coast** well field, develop **SW** supply from **Glen Melville Dam** to Bathurst, Port Alfred & Kenton On Sea
Provide necessary pump stations, conveyance, reservoirs and balancing reservoir
Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total for component	Total for sub-system
(I)	**GROUND WATER SOURCE**						
A	**Develop Barville / Glendower well field**						**2,137,200**
A1	**Ground Water Source**					**2,137,200**	
A1.1	Develop source: 23 l/s (12hr), 5 l/s/bh, 5 No bh	sum			1,015,000		
A1.2	Equip bh: Q 5 l/s, H 150 m	no	5	60900	304,500		
A1.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,000	89.74	89,740		
A1.4	Electrical connection	m	3,000	65.00	195,000		
A1.5	Pumping main to balancing Res: uPVC 160, cl 12	m	2,000	266.48	532,960		
A2	**Develop Sunshine Coast well field**						**1,867,812**
A2	**Ground Water Source**					**1,867,812**	
A2.1	Develop source: 18 l/s (12hr), 2 l/s/bh, 9 No bh	sum			495,000		
A2.2	Equip bh: Q 2 l/s, H 145 m	no	9	52500	472,500		
A2.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,800	89.74	161,532		
A2.4	Electrical connection	m	2,000	65.00	130,000		
A2.6	Pumping main to balancing Res: uPVC 140, cl 16	m	2,000	304.39	608,780		
A3	**Balancing reservoir 500 kl**	no	1	**470,000**	**470,000**	**470,000**	**470,000**

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
B	**Clear Water Gravity Main from GW source to PA**						**1,664,900**
B1	**Gravity Main from Balancing Reservoir to PA**					**1,664,900**	
B1.1	CWGM 1: uPVC 250, cl 9	m	5,000	332.98	1,664,900		
(II)	**SURFACE WATER**						
C	**Water Treatment Works**					**8,784,000**	**8,784,000**
	Build new WTW with a capacity of 144 l/s	l/s	144	61,000	8,784,000		
D	**Clear Water Pump Station at WTW**					**7,592,543**	**7,592,543**
D1.1	CWPS: one duty, one standby Sulzer HPH 50/20 Motor 900 kW (1450 RPM)	no	1	7,592,543	7,592,543		
E1	**Clear Water Raising/Gravity Mains**					**68,290,155**	**68,290,155**
E1.1	CWRM 1: Steel 400 ND, 6mm wall thickness	m	8,500	749.79	6,373,215		
E1.2	CWGM 1: to BT, steel 400 ND, 6 mm wall	m	10,000	749.79	7,497,900		
E1.3	CWGM 2: to BT, uPVC 400 ND, cl 12	m	35,500	976.60	34,669,300		
E1.4	CWGM 3: From BT to PA, steel 300 ND	m	14,000	591.41	8,279,740		
E1.5	CWGM 5: From PA to KOS, steel 200 ND	m	23,000	450.00	10,350,000		
E1.10	BPT 250kl	no	4	280,000	1,120,000		
G	**Reservoirs**					**9,891,000**	**9,891,000**
	Balancing reservoir at GT 1 x 2 500 kl		1	1,425,000	1,425,000		
	Add capacity at Bathurst 1 x 1200 kl		1	840,000	840,000		
	Add capacity at Port Alfred 3 x 5000 kl	no	3	2,542,000	7,626,000		
	Total for scheme					**100,697,610**	**100,697,610**

WTW			8,784,000
GW Source			1,835,000
BH Equipment			777,000
CWRM			7,766,227
CWGM			62,461,840
RWPS			0
CWPS			7,592,543
Storage			11,481,000
TOTAL			**100,697,610**

0

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

7

PORT ALFRED
SUPPLY FROM GW & SW (GLEN MELVILLE)
(7 PA : SW2)

GAADD	11815.00	m3/d
SDD	20587.00	m3/d

Description : Keep existing dune source. **Develop Barville / Glendower** well field, develop **Sunshine Coast** well field, develop **SW** supply from **Glen Melville Dam** to Bathurst & Port Alfred
Provide necessary pump stations, conveyance, reservoirs and balancing reservoir
Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total for component	Total for sub-system
(I)	**GROUND WATER SOURCE**						
A	**Develop Barville / Glendower well field**						**2,137,200**
A1	**Ground Water Source**					**2,137,200**	
A1.1	Develop source: 23 l/s (12hr), 5 l/s/bh, 5 No bh	sum			1,015,000		
A1.2	Equip bh: Q 5 l/s, H 150 m	no	5	60900	304,500		
A1.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,000	89.74	89,740		
A1.4	Electrical connection	m	3,000	65.00	195,000		
A1.5	Pumping main to balancing Res: uPVC 160, cl 12	m	2,000	266.48	532,960		
A2	**Develop Sunshine Coast well field**						**1,867,812**
A2	**Ground Water Source**					**1,867,812**	
A2.1	Develop source: 18 l/s (12hr), 2 l/s/bh, 9 No bh	sum			495,000		
A2.2	Equip bh: Q 2 l/s, H 145 m	no	9	52500	472,500		
A2.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,800	89.74	161,532		
A2.4	Electrical connection	m	2,000	65.00	130,000		
A2.6	Pumping main to balancing Res: uPVC 140, cl 16	m	2,000	304.39	608,780		
A3	**Balancing reservoir 500 kl**	no	1	**470,000**	**470,000**	**470,000**	**470,000**

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
B	**Clear Water Gravity Main from GW source to PA**						**1,664,900**
B1	**Gravity Main from Balancing Reservoir to PA**					**1,664,900**	
B1.1	CWGM 1: uPVC 250, cl 9	m	5,000	332.98	1,664,900		
(II)	**SURFACE WATER**						
C	**Water Treatment Works**					**6,832,000**	**6,832,000**
	Build new WTW with a capacity of 112 l/s	l/s	112	61,000	6,832,000		
D	**Clear Water Pump Station at WTW**					**7,592,543**	**7,592,543**
D1.1	CWPS: one duty, one standby Sulzer HPH 50/20 Motor 900 kW (1450 RPM)	no	1	7,592,543	7,592,543		
E1	**Clear Water Raising/Gravity Mains**					**45,339,965**	**45,339,965**
E1.1	CWRM 1: Steel 350 ND, 6 mm wall thickness	m	8,500	637.94	5,422,490		
E1.2	CWGM 1: to BT, steel 300 ND	m	10,000	591.41	5,914,100		
E1.3	CWGM 2: to BT, uPVC 315 ND, cl 12	m	35,500	631.69	22,424,995		
E1.4	CWGM 3: From BT to PA, uPVC 315 ND, cl16	m	14,000	764.17	10,698,380		
E1.5	BPT 150kl	no	4	220,000	880,000		
G	**Reservoirs**					**9,666,000**	**9,666,000**
	Balancing reservoir at GT 1 x 2 000 kl	no	1	1,200,000	1,200,000		
	Add capacity at Bathurst 1 x 1200 kl	no	1	840,000	840,000		
	Add capacity at Port Alfred 3 x 5000 kl	no	3	2,542,000	7,626,000		
	Total for scheme					**75,570,420**	**75,570,420**

WTW			6,832,000
GW Source			1,835,000
BH Equipment			777,000
CWRM			6,815,502
CWGM			40,702,375
RWPS			0
CWPS			7,592,543
Storage			11,016,000
TOTAL			**75,570,420**

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

8a

PORT ALFRED
SUPPLY FROM GW & SW (SAREL HAYWARD)
(8a PA : SW3)

GAADD	10682.00	m3/d
SDD	19228.00	m3/d

Description : Keep existing dune source. **Develop Barville / Glendower** well field, develop **Sunshine Coast** well field. Raise Sarel Hayward Dam and develop **SW** supply from **Sarel Hayward Dam** to Port Alfred
Supply Bathurst from Golden Ridge Dam. Provide necessary PS's, conveyance, Res's and Bal Res's
Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total for component	Total for sub-system
(I)	**GROUND WATER SOURCE**						
A	**Develop Barville / Glendower well field**						**2,137,200**
A1	**Ground Water Source**					**2,137,200**	
A1.1	Develop source: 23 l/s (12hr), 5 l/s/bh, 5 No bh	sum			1,015,000		
A1.2	Equip bh: Q 5 l/s, H 150 m	no	5	60900	304,500		
A1.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,000	89.74	89,740		
A1.4	Electrical connection	m	3,000	65.00	195,000		
A1.5	Pumping main to balancing Res: uPVC 160, cl 12	m	2,000	266.48	532,960		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
A2	**Develop Sunshine Coast well field**						**1,867,812**
A2	**Ground Water Source**					**1,867,812**	
A2.1	Develop source: 18 l/s (12hr), 2 l/s/bh, 9 No bh	sum			495,000		
A2.2	Equip bh: Q 2 l/s, H 145 m	no	9	52500	472,500		
A2.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,800	89.74	161,532		
A2.4	Electrical connection	m	2,000	65.00	130,000		
A2.6	Pumping main to balancing Res: uPVC 140, cl 16	m	2,000	304.39	608,780		
A3	**Balancing reservoir 500 kl**	no	1	**470,000**	**470,000**	**470,000**	**470,000**
B	**Clear Water Gravity Main from GW source to PA**						**1,664,900**
B1	**Gravity Main from Balancing Reservoir to PA**					**1,664,900**	
B1.1	CWGM 1: uPVC 250, cl 9	m	5,000	332.98	1,664,900		
(II)	**SURFACE WATER**						
C	**Water Treatment Works**					**6,466,000**	**6,466,000**
	Build a new WTW at PA with a capacity of 106 l/s	l/s	106	61,000	6,466,000		
D	**Develop Raw Water Pump Stations**					**1,844,000**	**1,844,000**
D1.1	RWPS 1: one duty, one standby	no	1	738000.00	738,000		
	WKLn 150/2 Motor 75 kW (1450 RPM)						
D1.2	RWPS 2: one duty, one standby WKLn	no	1	553000.00	553,000		
	100/5 Motor 45 kW (1450 RPM)						
D1.3	RWPS 3: one duty, one standby WKLn	no	1	553000.00	553,000		
	100/5 Motor 45 kW (1450 RPM)						

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
E1	**Clear Water Raising/Gravity Mains**					**8,469,285**	**8,469,285**
E1.1	RWRM 1: Steel 400 ND (PS 1 to dam)	m	700	749.79	524,853		
E1.2	RWRM 2: uPVC 315/12 (PS 2 to PS 3)	m	3,500	631.69	2,210,915		
E1.3	RWRM 3: uPVC 315/12 (PS 3 to BPT)	m	3,500	631.69	2,210,915		
E1.4	RWGM 1: uPVC 315/16	m	2,600	764.17	1,986,842		
E1.5	RWGM 2: uPVC 315/9 (BAL RES to WTW)	m	3,000	511.92	1,535,760		
F	**Reservoirs**					**8,166,000**	**8,166,000**
F1.1	Bal RES at PS 3 and at high point CH 7700 (200kl)	no	2	270,000	540,000		
F1.2	Add capacity to PA reservoirs : 3 x 5 000 kl	no	3	2,542,000	7,626,000		
G	**Raising of Sarel Hayward Dam**					**11,363,751**	**11,363,751**
	Raising of wall by 12 m	sum			11,363,751		
	Total for scheme					**42,448,948**	**42,448,948**

GW Source			1835000.00
GW Equipment			777000.00
WTW			6,466,000
CWRM			1,393,012
CWGM			1,664,900
RWGM			1,535,760
RWRM			6,933,525
RWPS			1,844,000
Storage			8,636,000
Raising Dam wall			11,363,751
TOTAL			**42,448,948**

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

8b

PORT ALFRED
SUPPLY FROM GW & SW (SAREL HAYWARD)
(8b PA : SW4)

GAADD	10682.00	m3/d
SDD	19228.00	m3/d

Description : Keep existing dune source. **Develop Barville / Glendower** well field, develop **Sunshine Coast** well field. Raise Sarel Hayward Dam and develop **SW** supply from **Sarel Hayward Dam** to Port Alfred
Treat 4 000 m³/d of Sarel Hayward's SW through RO, supply Bathurst from Golden Ridge Dam.
Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total for component	Total for sub-system
(I)	**GROUND WATER SOURCE**						
A	**Develop Barville / Glendower well field**						**2,128,226**
A1	**Ground Water Source**					**2,128,226**	
A1.1	Develop source: 23 l/s (12hr), 5 l/s/bh, 5 No bh	sum			1,015,000		
A1.2	Equip bh: Q 5 l/s, H 150 m	no	5	60900	304,500		
A1.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	900	89.74	80,766		
A1.4	Electrical connection	m	3,000	65.00	195,000		
A1.5	Pumping main to balancing Res: uPVC 160, cl 12	m	2,000	266.48	532,960		
A2	**Develop Sunshine Coast well field**						**1,813,968**
A2	**Ground Water Source**					**1,813,968**	
A2.1	Develop source: 18 l/s (12hr), 2 l/s/bh, 9 No bh	sum			495,000		
A2.2	Equip bh: Q 2 l/s, H 145 m	no	9	52500	472,500		
A2.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,200	89.74	107,688		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
A2.4	Electrical connection	m	2,000	65.00	130,000		
A2.6	Pumping main to balancing Res: uPVC 140, cl 16	m	2,000	304.39	608,780		
A3	**Balancing reservoir 500 kl**	no	1	**470,000**	**470,000**	**470,000**	**470,000**
B	**Clear Water Gravity Main from GW source to PA**						**1,664,900**
B1	**Gravity Main from Balancing Reservoir to PA**					**1,664,900**	
B1.1	CWGM 1: uPVC 250, cl 9	m	5,000	332.98	1,664,900		
(II)	**SURFACE WATER**						
C	**Water Treatment Works**					**6,466,000**	**6,466,000**
	Build a new WTW at PA with a capacity of 106 l/s	l/s	106	61,000	6,466,000		
D	**Develop Raw Water Pump Stations**					**1,844,000**	**1,844,000**
D1.1	RWPS 1: one duty, one standby	no	1	738000.00	738,000		
	WKLn 150/2 Motor 75 kW (1450 RPM)						
D1.2	RWPS 2: one duty, one standby WKLn	no	1	553000.00	553,000		
	100/5 Motor 45 kW (1450 RPM)						
D1.3	RWPS 3: one duty, one standby WKLn	no	1	553000.00	553,000		
	100/5 Motor 45 kW (1450 RPM)						
E1	**Clear Water Raising/Gravity Mains**					**8,469,285**	**8,469,285**
E1.1	RWRM 1: Steel 400 ND (PS 1 to dam)	m	700	749.79	524,853		
E1.2	RWRM 2: uPVC 315/12 (PS 2 to PS 3)	m	3,500	631.69	2,210,915		
E1.3	RWRM 3: uPVC 315/12 (PS 3 to BPT)	m	3,500	631.69	2,210,915		
E1.4	RWGM 1: uPVC 315/16	m	2,600	764.17	1,986,842		
E1.5	RWGM 2: uPVC 315/9 (BAL RES to WTW)	m	3,000	511.92	1,535,760		
F	**Reservoirs**					**8,166,000**	**8,166,000**
F1.1	Bal RES at PS 3 and at high point CH 7700 (200kl)	no	2	270,000	540,000		
F1.2	Add capacity to PA reservoirs : 3 x 5 000 kl	no	3	2,542,000	7,626,000		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
G	**Raising of Sarel Hayward Dam**					**11,363,751**	**11,363,751**
	Raising of wall by 12 m	sum			11,363,751		
H	**New RO equipment (4000 m³/d)**					**12,900,000**	**12,900,000**
	RO Unit complete	no	14	400,000	5,600,000		
	Housing for RO equipment	m2	1,400	2,000	2,800,000		
	Supply Eskom power	no	14	300,000	4,200,000		
	Brine disposal (1200 m @ uPVC 200 cl 9 plus civils)	sum			300,000		
I	**Clear Water Pump Station**					**1,121,960**	**1,121,960**
I1.1	Pump sump/balancing reservoir (1 hr storage) (300 kl)	no	1	228,000	228,000		
I1.2	CWPS: one duty, one standby: ETA 125-250	no	1	638,000	638,000		
	Motor 15 kW (1450 RPM)						
I1.3	RWGM - uPVC 315 cl 9, PS to RO Plant	m	500	511.92	255,960		
J	**Clear Water Raising Main**					**166,490**	**166,490**
	Pumping main RO to town Res: uPVC 250, cl 9	m	500	332.98	166,490		
	Total for scheme					**56,574,580**	**56,574,580**

GW Source			1835000.00		
GW Equipment			777000.00		
WTW			6,466,000		
RO Plant			12,600,000		
CWPS			638,000		
CWRM			1,496,684		
CWGM			1,664,900		
RWGM			1,791,720		
RWRM			7,233,525		
RWPS			1,844,000		
Storage			8,864,000		
Raising Dam wall			11,363,751		
TOTAL			**56,574,580**		0

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

9

PORT ALFRED
SUPPLY FROM GW & SW (SETTLERS)
(9 PA : SW5)

GAADD	10682.00	m3/d
SDD	19228.00	m3/d

Description : Keep existing dune source. **Develop Barville / Glendower** well field, develop **Sunshine Coast** well field. Develop **SW** supply from **Settlers Dam** to Port Alfred, supply Bathurst from **Golden Ridge Dam**. Develop **SW** supply from **Glen Melville Dam** to Grahamstown-West

Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total for component	Total for sub-system
(I)	**GROUND WATER SOURCE**						
A	**Develop Barville / Glendower well field**						**2,137,200**
A1	**Ground Water Source**					**2,137,200**	
A1.1	Develop source: 23 l/s (12hr), 5 l/s/bh, 5 No bh	sum			1,015,000		
A1.2	Equip bh: Q 5 l/s, H 150 m	no	5	60900	304,500		
A1.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,000	89.74	89,740		
A1.4	Electrical connection	m	3,000	65.00	195,000		
A1.5	Pumping main to balancing Res: uPVC 160, cl 12	m	2,000	266.48	532,960		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
A2	**Develop Sunshine Coast well field**						**1,867,812**
A2	**Ground Water Source**					**1,867,812**	
A2.1	Develop source: 18 l/s (12hr), 2 l/s/bh, 9 No bh	sum			495,000		
A2.2	Equip bh: Q 2 l/s, H 145 m	no	9	52500	472,500		
A2.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,800	89.74	161,532		
A2.4	Electrical connection	m	2,000	65.00	130,000		
A2.6	Pumping main to balancing Res: uPVC 140, cl 16	m	2,000	304.39	608,780		
A3	**Balancing reservoir 500 kl**	no	1	**470,000**	**470,000**	**470,000**	**470,000**
B	**Clear Water Gravity Main from GW source to PA**						**1,664,900**
B1	**Gravity Main from Balancing Reservoir to PA**					**1,664,900**	
B1.1	CWGM 1: uPVC 250, cl 9	m	5,000	332.98	1,664,900		
(II)	**SURFACE WATER**						
C	**Water Treatment Works**					**12,932,000**	**12,932,000**
	Build a new WTW at PA with a capacity of 106 l/s	l/s	106	61,000	6,466,000		
	Build new WTW at Glen Melville Dam, cap of 106 l/s	l/s	106	61,000	6,466,000		
D	**Develop Raw Water Pump Stations**					**7,784,000**	**7,784,000**
D1.1	RWPS 1: one duty, one standby WKLn	no	1	553000.00	553,000		
	100/5 Motor 45 kW (1450 RPM)						
D1.2	CWPS: Glen Melville Dam - one duty, one standby	no	1	7231000.00	7,231,000		
	Sulzer HPH 50/20 Motor 900 kW (1450 RPM)						

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
E1	**Clear Water Raising/Gravity Mains**					**41,712,153**	**41,712,153**
E1.1	RWRM 1: uPVC 315/12	m	2,000	631.69	1,263,380		
E1.2	RWGM 1: uPVC 315/9	m	7,800	511.92	3,992,976		
E1.3	RWGM 2: uPVC 355/9	m	3,100	641.38	1,988,278		
E1.4	RWGM 3: uPVC 315/16	m	4,000	764.17	3,056,680		
E1.5	RWGM 4: uPVC 315/12	m	13,100	631.69	8,275,139		
E1.6	RWGM 5: uPVC 315/16	m	14,500	764.17	11,080,465		
E1.7	CWRM 1: Steel 350, GM Dam WTW to Botha's Res	m	8,500	637.94	5,422,490		
E1.8	CWGM 8: uPVC 315/12, From Botha's Res to Gtown	m	10,500	631.69	6,632,745		
F	**Reservoirs**					**8,706,000**	**8,706,000**
F1.1	BPT 200kl	no	4	270,000	1,080,000		
F1.2	Add capacity to PA reservoir : 3 x 5 000 kl	no	3	2,542,000	7,626,000		
	Total for scheme					**77,274,065**	**77,274,065**

GW Source			1835000.00
GW Equipment			777000.00
WTW			12,932,000
CWRM			6,815,502
CWGM			8,297,645
RWGM			28,393,538
RWRM			1,263,380
RWPS			553,000
CWPS			7,231,000
Storage			9,176,000
TOTAL			**77,274,065**

0

ALBANY COAST SITUATION ASSESMENT STUDY

02-Sep-04

DESCRIPTION OF THE CONVEYANCE SYSTEM

10

PORT ALFRED
SUPPLY FROM GW & RO (SEAWATER)
(10 PA : RO)

GAADD	10682.00	m3/d
SDD	19228.00	m3/d

Description : Keep existing dune source. **Develop Barville / Glendower** well field, develop **Sunshine Coast** well field. Develop **RO** plant at Port Alfred, supply Bathurst from **Golden Ridge Dam**.
Provide necessary pump stations, conveyance, reservoirs and balancing reservoir
Prices exclude VAT and professional fees (total of 30%)

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
						for	for
						component	sub-system
(I)	**GROUND WATER SOURCE**						
A	**Develop Barville / Glendower well field**						**2,137,200**
A1	**Ground Water Source**					**2,137,200**	
A1.1	Develop source: 23 l/s (12hr), 5 l/s/bh, 5 No bh	sum			1,015,000		
A1.2	Equip bh: Q 5 l/s, H 150 m	no	5	60900	304,500		
A1.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,000	89.74	89,740		
A1.4	Electrical connection	m	3,000	65.00	195,000		
A1.5	Pumping main to balancing Res: uPVC 160, cl 12	m	2,000	266.48	532,960		
A2	**Develop Sunshine Coast well field**						**1,867,812**
A2	**Ground Water Source**					**1,867,812**	
A2.1	Develop source: 18 l/s (12hr), 2 l/s/bh, 9 No bh	sum			495,000		
A2.2	Equip bh: Q 2 l/s, H 145 m	no	9	52500	472,500		
A2.3	Collector pipes, ND 75, cl 9, 200 m/bh	m	1,800	89.74	161,532		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
A2.4	Electrical connection	m	2,000	65.00	130,000		
A2.6	Pumping main to balancing Res: uPVC 140, cl 16	m	2,000	304.39	608,780		
A3	**Balancing reservoir 500 kl**	no	1	**470,000**	**470,000**	**470,000**	**470,000**
B	**Clear Water Gravity Main from GW source to PA**						**1,664,900**
B1	**Gravity Main from Balancing Reservoir to PA**					**1,664,900**	
B1.1	CWGM 1: uPVC 250, cl 9	m	5,000	332.98	1,664,900		
C	**Reservoirs**					**7,626,000**	**7,626,000**
C1.2	Add capacity to PA reservoirs : 3 x 5 000 kl	no	3	2,542,000	7,626,000		
(II)	**RO PLANT**						
D	**GW Source Development**					**3,623,675**	**3,623,675**
D1.1	Develop a GW source, 15 x BH's total of 155 l/s	no	15	110,000	1,650,000		
D1.2	Pump sump/balancing Res (½ hr storage) (250 kl)	no	1	300,000	300,000		
D1.3	Collector pipes, ND 160, cl 9	m	2,500	221.47	553,675		
D1.4	Supply Eskom power	no	5	90,000	450,000		
D1.5	RWPS: (Beach) one duty, one standby: WKLn 100/7 Motor 45 kW (1450 RPM)	no	1	670,000	670,000		

No	Description	unit	Quantity	Rate	Sub-tot	Total	Total
E	**New RO equipment (2000 m³/d)**					**44,350,000**	**44,350,000**
	RO Unit complete	no	26	1,300,000	33,800,000		
	Housing for RO equipment	m2	2,600	2,000	5,200,000		
	Supply Eskom power	no	26	100,000	2,600,000		
	Brine dispsl (1200 m @ uPVC 250 cl 9 plus civils)	sum			2,750,000		
I	**Clear Water Pump Station**					**1,387,690**	**1,387,690**
I1.1	Pump sump/balancing Res (½ hr storage) (200 kl)	no	1	270,000	270,000		
I1.2	CWPS: (RO) one duty, one standby: WKLn 150/2 Motor 90 kW (1450 RPM)	no	1	797,000	797,000		
I1.3	CWRM - uPVC 355 cl 9, PS to RO Plant	m	500	641.38	320,690		
J	**Raw Water Raising Main**					**1,574,559**	**1,574,559**
	Pumping main BH's to town RO: Steel 400, 5 mm	m	2,100	749.79	1,574,559		
	Total for scheme					**64,701,836**	**64,701,836**

GW Source			3935000.00
GW Equipment			777000.00
WTW			-
RO Plant			41,600,000
CWPS			797,000
CWRM			1,713,702
CWGM			1,664,900
RWGM			-
RWRM			4,878,234
RWPS			670,000
Storage			8,666,000
TOTAL			**64,701,836**

APPENDIX 10.2

SUMMARY OF COSTS

Economic Comparison:

APPENDIX 10.2

No.	DAM/OPTION	Capital	URV	Note
		R mil	R/kl	
1	Alexandria: Ground Water (GW)	R10.61	R15.22	Recommend
2	Canon Rocks / Boknes: GW	R5.62	R5.02	Recommend
3	KOS / Bushmans River Mouth: GW	R28.11	R10.08	Recommend: short term
4a	KOS / Bushmans River Mouth: RO sea W	R34.65	R13.56	Not recommended
4b	KOS / Bushmans River Mouth: RO brack W	R28.77	R11.33	Not recommended
5	KOS: SW from GM Dam	R41.34	R10.21	Recommended: long term
6	PA: Glen Melville Dam: Opt 1: PA, BT, KOS	R130.91	R10.68	Recommended: long term
7	PA: Glen Melville Dam: Opt 2: PA, BT	R98.24	R9.97	Comparison
9	PA: Settlers Dam: Opt 1: PA	R100.46	R10.91	Comparison
8a	PA: Sarel Hayward Dam: Opt 1: PA	R55.18	R5.70	Recommended: long term
8b	PA: Sarel Hayward Dam: Opt 1: PA and RO	R73.53	R8.27	To improve water quality
10	PA: GW and RO only	R84.11	R10.85	Comparison

ALBANY COAST SITUATION ASSESSMENT STUDY **22-Sep-04**

Cost Estimates of Bulk Conveyance Options

Notes:-

Infrastructure sized for 2025

Pipelines installed in 2005 but sized for 2025

Costs given in April 2004 Rands (millions)

PEAK SUMMER DEMAND - FULL SCHEME

INPUT DATA

Construction 2005, capital costs R million

DATA INPUT TABLE: INFO OBTAINED FROM THE COST MODEL TABLES

Opt No	OPTION	RO PLANT	SW SOURCE	GW SOURCE	BH EQUIPMENT	RAW WATER PUMP STATION	RAW WATER GRAVITY MAIN	RAW WATER RISING MAIN	WATER TREATMENT	CLEAR WATER PUMP STATION	CLEAR WATER RISING MAIN	STORAGE	CLEAR WATER GRAVITY MAINS	TOTAL
1	Alexandria: Ground Water (GW)	R0.00	R0.00	R0.20	R0.37	R0.00	R0.00	R0.00	R0.00	R1.27	R3.57	R0.88	R1.88	R8.16
2	Canon Rocks / Boknes: GW	R0.00	R0.00	R0.56	R0.82	R0.00	R0.00	R0.00	R0.00	R0.43	R1.01	R1.50	R0.00	R4.32
3	KOS / Bushmans River Mouth: GW	R1.40	R0.00	R1.71	R1.11	R0.00	R0.00	R0.00	R2.10	R2.04	R4.00	R3.79	R5.49	R21.63
4a	KOS / Bushmans River Mouth: RO sea W	R14.90	R0.00	R0.18	R0.27	R0.00	R0.00	R0.00	R3.80	R0.58	R2.60	R4.32	R0.00	R26.65
4b	KOS / Bushmans River Mouth: RO brack W	R7.70	R0.00	R2.18	R1.79	R0.00	R0.00	R4.43	R1.40	R0.80	R1.02	R2.82	R0.00	R22.13
5	KOS: SW from GM Dam	R2.10	R0.00	R0.18	R0.27	R0.00	R0.00	R2.00	R1.95	R0.40	R0.18	R1.95	R22.77	R31.80
6	PA: Glen Melville Dam: Opt 1: PA, BT, KOS	R0.00	R0.00	R1.84	R0.78	R0.00	R0.00	R0.00	R8.78	R7.59	R7.77	R11.48	R62.46	R100.70
7	PA: Glen Melville Dam: Opt 2: PA, BT	R0.00	R0.00	R1.84	R0.78	R0.00	R0.00	R0.00	R6.83	R7.59	R6.82	R11.02	R40.70	R75.57
8a	PA: Sarel Hayward Dam: Opt 1: PA	R0.00	R11.36	R1.84	R0.78	R1.84	R1.54	R6.93	R6.47	R0.00	R1.39	R8.64	R1.66	R42.45
9	PA: Settlers Dam: Opt 1: PA	R0.00	R0.00	R1.84	R0.78	R0.55	R35.03	R1.26	R12.93	R7.23	R6.82	R9.18	R1.66	R77.27
8b	PA: Sarel Hayward Dam: Opt 1: PA and RO	R12.60	R11.36	R1.84	R0.78	R1.84	R1.54	R7.24	R6.47	R0.64	R1.97	R8.64	R1.66	R56.57
10	PA: GW and RO only	R42.60		R4.19	R1.78	R0.67		R2.32		R0.80	R2.01	R8.67	R1.66	R64.70
	Total all schemes	**R26.10**	**R11.36**	**R12.34**	**R7.74**	**R2.40**	**R36.56**	**R14.63**	**R44.27**	**R27.93**	**R35.17**	**R55.56**	**R136.63**	**R410.68**

All above costs exclude VAT (14%) and professional fees (16%). These are added into the summary tables

PEAK SUMMER DEMAND - FULL SCHEME
Construction 2005, capital costs R million

No.	OPTION	RO PLANT	SW SOURCE	GW SOURCE	BH EQUIPMENT	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL
1	Alexandria: Ground Water (GW)	R0.000	R0.000	R0.255	R0.480	R1.651	R0.000	R1.138	R7.085	R10.609
2	Canon Rocks / Boknes: GW	R0.000	R0.000	R0.729	R1.067	R0.553	R0.000	R1.953	R1.317	R5.619
3	KOS / Bushmans River Mouth: GW	R1.820	R0.000	R2.217	R1.447	R2.648	R2.730	R4.924	R12.328	R28.114
4a	KOS / Bushmans River Mouth: RO sea W	R19.370	R0.000	R0.231	R0.347	R0.760	R4.940	R5.619	R3.380	R34.646
4b	KOS / Bushmans River Mouth: RO brack W	R10.010	R0.000	R2.831	R2.331	R1.036	R1.820	R3.661	R7.078	R28.767
5	KOS: SW from GM Dam	R2.730	R0.000	R0.231	R0.347	R0.520	R2.538	R2.530	R32.440	R41.335
6	PA: Glen Melville Dam: Opt 1: PA, BT, KOS	R0.000	R0.000	R2.386	R1.010	R9.870	R11.419	R14.925	R91.296	R130.907
7	PA: Glen Melville Dam: Opt 2: PA, BT	R0.000	R0.000	R2.386	R1.010	R9.870	R8.882	R14.321	R61.773	R98.241
8a	PA: Sarel Hayward Dam: Opt 1: PA	R0.000	R14.773	R2.386	R1.010	R2.397	R8.406	R11.227	R14.985	R55.184
9	PA: Settlers Dam: Opt 1: PA	R0.000	R0.000	R2.386	R1.010	R10.119	R16.812	R11.929	R58.201	R100.456
8b	PA: Sarel Hayward Dam: Opt 1: PA and RO	R16.380	R14.773	R2.386	R1.010	R3.229	R8.406	R11.227	R16.125	R73.535
10	PA: GW and RO only	R55.380	R0.000	R5.441	R2.310	R1.907	R0.000	R11.266	R7.804	R84.108
	Total all schemes	**R33.930**	**R14.773**	**R16.037**	**R10.059**	**R39.424**	**R57.546**	**R72.225**	**R289.884**	**R533.878**

Construction 2005, annual O&M costs, R million

No.	OPTION	RO PLANT	SW SOURCE	GW SOURCE	BH EQUIPMENT	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL
	O&M as % of capital costs	**3.00%**	**0.85%**	**1.00%**	**5.50%**	**2.78%**	**1.73%**	**0.50%**	**1.00%**	
1	Alexandria: Ground Water (GW)	R0.000	R0.000	R0.003	R0.026	R0.046	R0.000	R0.006	R0.071	R0.151
2	Canon Rocks / Boknes: GW	R0.000	R0.000	R0.007	R0.059	R0.015	R0.000	R0.010	R0.013	R0.104
3	KOS / Bushmans River Mouth: GW	R0.055	R0.000	R0.022	R0.080	R0.073	R0.047	R0.025	R0.123	R0.425
4a	KOS / Bushmans River Mouth: RO sea W	R0.581	R0.000	R0.002	R0.019	R0.021	R0.085	R0.028	R0.034	R0.771
4b	KOS / Bushmans River Mouth: RO brack W	R0.300	R0.000	R0.028	R0.128	R0.029	R0.031	R0.018	R0.071	R0.606
5	KOS: SW from GM Dam	R0.082	R0.000	R0.002	R0.019	R0.014	R0.044	R0.013	R0.324	R0.499
6	PA: Glen Melville Dam: Opt 1: PA, BT, KOS	R0.000	R0.000	R0.024	R0.056	R0.274	R0.197	R0.075	R0.913	R1.538
7	PA: Glen Melville Dam: Opt 2: PA, BT	R0.000	R0.000	R0.024	R0.056	R0.274	R0.153	R0.072	R0.618	R1.196
8a	PA: Sarel Hayward Dam: Opt 1: PA	R0.000	R0.126	R0.024	R0.056	R0.067	R0.145	R0.056	R0.150	R0.622
9	PA: Settlers Dam: Opt 1: PA	R0.000	R0.000	R0.024	R0.056	R0.281	R0.290	R0.060	R0.582	R1.292
8b	PA: Sarel Hayward Dam: Opt 1: PA and RO	R0.491	R0.126	R0.024	R0.056	R0.090	R0.145	R0.056	R0.161	R1.148
10	PA: GW and RO only	R1.661	R0.000	R0.054	R0.127	R0.053	R0.000	R0.056	R0.078	R2.030
	Total all schemes	**R1.018**	**R0.126**	**R0.160**	**R0.553**	**R1.094**	**R0.993**	**R0.361**	**R2.899**	**R7.204**

Residual values as at 2025, R million

No.	OPTION	RO PLANT	SW SOURCE	GW SOURCE	BH EQUIPMENT	PUMP STATIONS	WATER TREATMENT	RESERVOIRS	PIPELINES	TOTAL
	Residual values after 20 years as % of capital	**40.00%**	**54.00%**	**0.00%**	**0.00%**	**43.00%**	**50.00%**	**55.00%**	**33.00%**	
1	Alexandria: Ground Water (GW)	R0.000	R0.000	R0.000	R0.000	R0.710	R0.000	R0.626	R2.338	R3.674
2	Canon Rocks / Boknes: GW	R0.000	R0.000	R0.000	R0.000	R0.238	R0.000	R1.074	R0.435	R1.746
3	KOS / Bushmans River Mouth: GW	R0.728	R0.000	R0.000	R0.000	R1.139	R1.365	R2.708	R4.068	R10.008
4a	KOS / Bushmans River Mouth: RO sea W	R7.748	R0.000	R0.000	R0.000	R0.327	R2.470	R3.090	R1.115	R14.750
4b	KOS / Bushmans River Mouth: RO brack W	R4.004	R0.000	R0.000	R0.000	R0.446	R0.910	R2.013	R2.336	R9.709
5	KOS: SW from GM Dam	R1.092	R0.000	R0.000	R0.000	R0.224	R1.269	R1.391	R10.705	R14.681
6	PA: Glen Melville Dam: Opt 1: PA, BT, KOS	R0.000	R0.000	R0.000	R0.000	R4.244	R5.710	R8.209	R30.128	R48.291
7	PA: Glen Melville Dam: Opt 2: PA, BT	R0.000	R0.000	R0.000	R0.000	R4.244	R4.441	R7.876	R20.385	R36.947
8a	PA: Sarel Hayward Dam: Opt 1: PA	R0.000	R7.977	R0.000	R0.000	R1.031	R4.203	R6.175	R4.945	R24.331
9	PA: Settlers Dam: Opt 1: PA	R0.000	R0.000	R0.000	R0.000	R4.351	R8.406	R6.561	R19.206	R38.524
8b	PA: Sarel Hayward Dam: Opt 1: PA and RO	R6.552	R7.977	R0.000	R0.000	R1.389	R4.203	R6.175	R5.321	R31.617
10	PA: GW and RO only	R22.152	R0.000	R0.000	R0.000	R0.820	R0.000	R6.196	R2.575	R31.744
	Total all schemes	**R13.572**	**R7.977**	**R0.000**	**R0.000**	**R16.952**	**R28.773**	**R39.724**	**R95.662**	**R202.660**

ALBANY COAST OPTIONS

Annual Electricity charges and chemical costs

No	Component	Unit	Op 1 Alex: GW 1	Op 2 CR: GW 2	KOS: GW Kwaaihoek	KOS: GW Merville	KOS: GW Bushfontein	KOS: GW RO	Op 3 KOS: GW Total	KOS: RO Kwaaihoek	KOS: RO RO Plant	Op 4a KOS: RO Total	KOS: RO Kwaaihoek	KOS: RO RO sea W	KOS: RO RO brack W	Op 4b KOS: RO Total	KOS: GM Dam Kwaaihoek	KOS: GM Dam RO sea W	KOS: GM Dam GM Dam	Op 5 KOS: GM Dam Total
1	GAADD: min	l/s	0	0	0	0	0	0		0	0		0	0	0		0	0	0	
	: max	l/s	5.2	8.9	2.4	6.4	6.4	6.8	22	2.4	19.6	22	2.4	6.8	12.8	22	2.4	6.8	21.8	31
	SPF		1.2	1.5	1.5	1.5	1.5	1.5		1.5	1.5		1.5	1.5	1.5		1.5	1.5	1.5	
2	Design SDD: min	l/s	0	0	0	0	0	0		0	0		0	0	0		0	0	0	
	: max	l/s	6.24	13.35	3.6	9.6	9.6	10.2		3.6	29.4		3.6	10.2	19.2		3.6	10.2	32.7	
3	Static head	m	280	80	85	245	350			85			85				85		480	
4	Local losses	m	10	10	10	10	10			10			10				10		10	
5	Friction losses: min	m	0	0	0	0	0	0		0	0		0	0	0		0	0	0	
	: max	m	100	50	45	25	40			45			45				45		20	
6	Total head: min	m	290	90	95	255	360	0		95	0		95	0	0		95	0	490	
	: max	m	390	140	140	280	400	0		140	0		140	0	0		140	0	510	
7	Energy: min	kW	0	0	0	0	0	0		0	0		0	0	0		0	0	0	
	: max	kW	23	14	4	20	29	0		4	0		4	0	0		4	0	127	
8	Installed capacity: min	kW	0	0	0	0	0	0		0	0		0	0	0		0	0	0	
	: ma	kW	28	21	6	31	44	0		6	0		6	0	0		6	0	190	
9	kVA Rating: min	kVA	14	11	3	16	23	0		3	0		3	0	0		3	0	99	
	: max	kVA	29	22	6	32	46	0		6	0		6	0	0		6	0	198	
10	Energy unit cost	R/kwh	0.2222	0.2222	0.2222	0.2222	0.2222	0.2222		0.2222	0.2222		0.2222	0.2222	0.2222		0.2222	0.2222	0.2222	
11	Demand unit cost	R/kwa/m	5.43	5.43	5.43	5.43	5.43	5.43		5.43	5.43		5.43	5.43	5.43		5.43	5.43	5.43	
12	Energy charge: min	R mil	-	-	-	-	-			-			-				-		-	
	: max	R mil	0.054	0.041	0.011	0.060	0.085	0.186		0.011	0.536		0.011	0.186	0.152		0.011	0.186	0.370	
13	Demand charge: min	R mil	0.001	0.001	0.000	0.001	0.001	-		0.000	-		0.000	-	-		0.000	-	0.006	
	: max	R mil	0.002	0.001	0.000	0.002	0.003	-		0.000	-		0.000	-	-		0.000	-	0.013	
14	Chemicals unit cost	R/kl	-	-				0.63		-	0.63		-	0.63	0.63			0.63		
15	Total chem. cost: min	R mil	-	-	-	-	-	-		-	-		-	-	-		-	-	-	
	: max	R mil	-	-	-	-	-	0.135		-	0.389		-	0.135	0.254		-	0.135	-	
16	Total electr & chemicals																			
	: Min	R mil	0.001	0.001	0.000	0.001	0.001	-	0.003	0.000	-	0.000	0.000	-	-	0.000	0.000	-	0.006	0.007
	: Max	R mil	0.056	0.043	0.012	0.062	0.088	0.321	0.483	0.012	0.925	0.937	0.012	0.321	0.407	0.739	0.012	0.321	0.383	0.716

No	Component	Unit	GM Dam 1 GW	GM Dam 1 SW	Op 6 GM Dam 1 Total	GM Dam 2 GW	GM Dam 2 SW	Op 7 GM Dam 2 Total	GH Dam 1 GW	SH Dam 1 SW	Op 8 SH Dam 1 Total	Settlers Dam GW	Settlers Dam SW	Op 9 Settlers Dam Total	GH Dam 1 GW	SH Dam 1 SW	SH Dam RO brack W	Op 8b SH Dam 1 Total	GW & RO GW	GW & RO RO	Op 10 GM Dam 2 Total
1	GAADD: min	l/s	0	0		0	0		0	0		0	0		0	0	0		0	0	
	: max	l/s	20	71	91	20	53.5	73.5	20	49.2	69.2	20	49.2	69.2	20	49.2	25	69.2	20	49.2	69.2
	SPF		1.7	1.7		1.7	1.7		1.7	1.7		1.7	1.7		1.7	1.7	1.5		1.7	1.5	
2	Design SDD: min	l/s	0	0		0	0		0	0		0	0		0	0	0		0	0	
	: max	l/s	34	120.7		34	90.95		34	83.64		34	83.64		34	83.64	37.5		34	73.8	
3	Static head	m	120	480		120	480		120	140		120	550		120	140			120		
4	Local losses	m	10	10		10	10		10	10		10	10		10	10			10		
5	Friction losses: min	m	0	0		0	0		0	0		0	0		0	0	0		0	0	
	: max	m	30	20		30	30		30	43		30	42		30	43			30		
6	Total head: min	m	130	490		130	490		130	150		130	560		130	150	0		130	0	
	: max	m	160	510		160	520		160	193		160	602		160	193	0		160	0	
7	Energy: min	kW	0	0		0	0		0	0		0	0		0	0	0		0	0	
	: max	kW	37	413		37	317		37	108		37	338		37	108	0		37	0	
8	Installed capacity: min	kW	0	0		0	0		0	0		0	0		0	0	0		0	0	
	: ma	kW	62	702		62	539		62	184		62	574		62	184	0		62	0	
9	kVA Rating: min	kVA	32	366		32	281		32	96		32	299		32	96	0		32	0	
	: max	kVA	65	731		65	562		65	192		65	598		65	192	0		65	0	
10	Energy unit cost	R/kwh	0.2222	0.2222	0.2222	0.2222	0.2222		0.2222	0.2222		0.2222	0.2222		0.2222	0.2222	0.2222		0.2222	0.2222	
11	Demand unit cost	R/kwa/m	5.43	5.43	5.43	5.43	5.43		5.43	5.43		5.43	5.43		5.43	5.43	5.43		5.43	5.43	
12	Energy charge: min	R mil	-	-		-	-		-			-	-		-				-		
	: max	R mil	0.121	1.367		0.121	1.050		0.121	0.358		0.121	1.118		0.121	0.358	0.298		0.121	1.345	
13	Demand charge: min	R mil	0.002	0.024		0.002	0.018		0.002	0.006		0.002	0.019		0.002	0.006	-		0.002	-	
	: max	R mil	0.004	0.048		0.004	0.037		0.004	0.012		0.004	0.039		0.004	0.012	-		0.004	-	
14	Chemicals unit cost	R/kl	-	-					-			-	-		-		0.63			0.63	
15	Total chem. cost: min	R mil	-	-		-	-		-	-		-	-		-	-	-		-	-	
	: max	R mil	-	-		-	-		-	-		-	-		-	-	0.497		-	0.977	
16	Total electr & chemicals																				
	: Min	R mil	0.002	0.024	0.026	0.002	0.018	0.020	0.002	0.006	0.008	0.002	0.019	0.022	0.002	0.006	-	0.008	0.002	-	0.002
	: Max	R mil	0.125	1.414	1.539	0.125	1.087	1.212	0.125	0.371	0.496	0.125	1.157	1.282	0.125	0.371	0.795	1.290	0.125	2.322	2.447

APPENDIX 10.3

COST MODEL FOR RAISING SAREL HAYWARD DAM

RAISING OF SAREL HAYWARD DAM: COST MODEL

App. 10.3 **Reconnaissance** March 2004 price levels

No.	Pay ref.	Description	Unit	Rate	Quantity	Amount
1.	1.0	*Site and basin clearing*				
	1.1	(a) sparse	ha	2,980	2.0	R5,960
	1.2	(b) bush	ha	8,940	1.00	R8,940
	1.3	(c) trees	ha	14,899	0.40	R5,960
2.	2.0	*River diversion*	Sum		50,000	R50,000
3.	3.0	*Excavation*				
	3.1	(a) Bulk				
		(i) all materials	m^3	21	12,200	R259,673
		(ii) extra over for rock	m^3	38	1,220	R46,741
	3.2	(b) Confined				
		(i) all materials	m^3	32	50	R1,596
4.		*Embankment*				
	4.1	(a) Earthfill	m^3	26	195,000	R4,980,609
	4.2	(b) Filters	m^3	94	50	R4,683
	4.3	(c) Rip-rap	m^3	46	800	R37,187
	4.3	(d) Overhaul beyond 2km	m^3km	2.1	39,000	R83,010
5.		*Concrete Works*				
	5.0	(a) Formwork				
	5.1	(i) Gang formed	m^2	107	0	R0
	5.2	(ii) Intricate	m^2	170	120	R20,433
	5.3	(b) Concrete				
	5.4	(i) mass	m^3	387	250	R96,776
	5.5	(ii) structural	m^3	498	67	R33,360
	5.6	(c) Reinforcing	t	5,321	7	R36,383
6.	6.0	*Mechanical items*				
	6.1	(a) Valves & gates	Sum	8%	Civil	R423,395
	6.2	(b) Cranes & hoists				
	6.3	(c) Structural steelwork				
7.	7	*Fencing*	km	14,899	4	R59,597
		SUB TOTAL				**R6,154,303**
8.	8.0	*Landscaping (% of 1 to 7)*	%	5		R307,715
9.	9.0	*Miscellaneous (% of 1 to 7)*	%	10		R615,430
		SUB TOTAL A				**R7,077,448**

No.	Pay ref.	Description	Unit	Rate	Quantity	Amount
10.	10.0	*Preliminary & General*	%	30		R2,123,234
		(% of sub total A)				
11.	11.0	*Preliminary works*				
	11.1	(a) Access road	km	90,000	9	R810,000
	11.2	(b) Electricity to site	km	50,000	6	R300,000
	11.3	(c) Water to site - Construction	Sum			R20,000
		(included in miscellaneous)				
	11.4	(d) Railhead & materials handling	Sum		miscellan.	R0
		(included in miscellaneous)				
12.	12.0	*Accommodation*	Sum		miscellan.	R0
		(included in miscellaneous)				
		SUB TOTAL B				**R10,330,682**
13.	13.0	*Contingencies (% of sub total B)*	%	10		R1,033,068
		SUB TOTAL C				**R11,363,751**
14	14.0	*Planning, design & supervision,*	%	15		R1,704,563
		fees, time, cost & transport				
		(% of sub total C)				
		SUB TOTAL D				**R13,068,313**
15.	15.0	*VAT (% of sub total D)*	%	14		R1,829,564
		TOTAL PROJECT COST				**R14,897,877**

Current NOCL = **46.7 masl**
New proposed NOCL = **58.7 masl**
Total elevation raised = **12 m**

APPENDIX 10.4

ECONOMIC MODELS FOR NPC AND URV

ECONOMICS MODEL **Appendix 10.4**

1. A: GW

1: Alexandria Groundwater Option

YEAR	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	TOTAL ANNUAL COST Capital	TOTAL ANNUAL COST M & O	TOTAL ANNUAL COST Energy cost	NET PRESENT COST AT 4% Capital	NET PRESENT COST AT 4% M & O	NET PRESENT COST AT 4% Energy cost	NET PRESENT COST AT 6% Capital	NET PRESENT COST AT 6% M & O	NET PRESENT COST AT 6% Energy cost	NET PRESENT COST AT 8% Capital	NET PRESENT COST AT 8% M & O	NET PRESENT COST AT 8% Energy cost
	Min	0.151	0	0.001	0	0												
	Max			0.056	0	0												
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	10.609						10.609	0.000	0.000	9.809	0.000	0.000	9.442	0.000	0.000	9.096	0.000	0.000
2006		0.151	0.000	0.001	0.000	0.000	0.000	0.151	0.001	0.000	0.134	0.001	0.000	0.127	0.001	0.000	0.120	0.001
2007		0.151	0.000	0.004	0.000	0.000	0.000	0.151	0.004	0.000	0.129	0.003	0.000	0.120	0.003	0.000	0.111	0.003
2008		0.151	0.000	0.007	0.000	0.000	0.000	0.151	0.007	0.000	0.124	0.006	0.000	0.113	0.005	0.000	0.103	0.005
2009		0.151	0.000	0.010	0.000	0.000	0.000	0.151	0.010	0.000	0.119	0.008	0.000	0.106	0.007	0.000	0.095	0.006
2010		0.151	0.000	0.013	0.000	0.000	0.000	0.151	0.013	0.000	0.115	0.010	0.000	0.100	0.008	0.000	0.088	0.007
2011		0.151	0.000	0.015	0.000	0.000	0.000	0.151	0.015	0.000	0.110	0.011	0.000	0.095	0.010	0.000	0.082	0.008
2012		0.151	0.000	0.018	0.000	0.000	0.000	0.151	0.018	0.000	0.106	0.013	0.000	0.089	0.011	0.000	0.076	0.009
2013		0.151	0.000	0.021	0.000	0.000	0.000	0.151	0.021	0.000	0.102	0.014	0.000	0.084	0.012	0.000	0.070	0.010
2014		0.151	0.000	0.024	0.000	0.000	0.000	0.151	0.024	0.000	0.098	0.016	0.000	0.080	0.013	0.000	0.065	0.010
2015	0.000	0.151	0.000	0.027	0.000	0.000	0.000	0.151	0.027	0.000	0.094	0.017	0.000	0.075	0.013	0.000	0.060	0.011
2016		0.151	0.000	0.030	0.000	0.000	0.000	0.151	0.030	0.000	0.091	0.018	0.000	0.071	0.014	0.000	0.056	0.011
2017		0.151	0.000	0.033	0.000	0.000	0.000	0.151	0.033	0.000	0.087	0.019	0.000	0.067	0.015	0.000	0.051	0.011
2018		0.151	0.000	0.036	0.000	0.000	0.000	0.151	0.036	0.000	0.084	0.020	0.000	0.063	0.015	0.000	0.048	0.011
2019		0.151	0.000	0.039	0.000	0.000	0.000	0.151	0.039	0.000	0.081	0.021	0.000	0.059	0.015	0.000	0.044	0.011
2020		0.151	0.000	0.042	0.000	0.000	0.000	0.151	0.042	0.000	0.078	0.021	0.000	0.056	0.015	0.000	0.041	0.011
2021		0.151	0.000	0.044	0.000	0.000	0.000	0.151	0.044	0.000	0.075	0.022	0.000	0.053	0.016	0.000	0.038	0.011
2022		0.151	0.000	0.047	0.000	0.000	0.000	0.151	0.047	0.000	0.072	0.022	0.000	0.050	0.016	0.000	0.035	0.011
2023		0.151	0.000	0.050	0.000	0.000	0.000	0.151	0.050	0.000	0.069	0.023	0.000	0.047	0.016	0.000	0.032	0.011
2024		0.151	0.000	0.053	0.000	0.000	0.000	0.151	0.053	0.000	0.066	0.023	0.000	0.044	0.016	0.000	0.030	0.011
2025	-3.674	0.151	0.000	0.056	0.000	0.000	-3.674	0.151	0.056	-1.550	0.064	0.024	-1.020	0.042	0.016	-0.676	0.028	0.010
TOTAL	**6.935**	**3.020**	**0.000**	**0.570**	**0.000**	**0.000**	**6.935**	**3.020**	**0.570**	**8.258**	**1.897**	**0.311**	**8.422**	**1.541**	**0.235**	**8.420**	**1.271**	**0.180**

	NPC	NPV water	URV, R/kl
AT 4%	**10.5**	**0.9**	**11.76**
AT 6%	**10.2**	**0.7**	**15.22**
AT 8%	**9.9**	**0.5**	**19.31**

Net present value of water supplied

Low demand scenario

Min	0	l/s
Max	5.2	l/s

YEAR	TOTAL SUPPLY (x1000 m3)	NPV of water supplied at 4% (x1000 m3)	NPV of water supplied at 6% (x1000 m3)	NPV of water supplied at 8% (x1000 m3)
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.009	0.007	0.007	0.006
2008	0.017	0.014	0.013	0.012
2009	0.026	0.020	0.018	0.016
2010	0.035	0.026	0.023	0.020
2011	0.043	0.032	0.027	0.023
2012	0.052	0.036	0.031	0.026
2013	0.060	0.041	0.034	0.028
2014	0.069	0.045	0.036	0.030
2015	0.078	0.049	0.039	0.031
2016	0.086	0.052	0.040	0.032
2017	0.095	0.055	0.042	0.032
2018	0.104	0.058	0.043	0.033
2019	0.112	0.060	0.044	0.033
2020	0.121	0.062	0.045	0.033
2021	0.129	0.064	0.045	0.032
2022	0.138	0.066	0.046	0.032
2023	0.147	0.067	0.046	0.031
2024	0.155	0.068	0.046	0.031
2025	0.164	0.069	0.046	0.030
TOTAL	**1.640**	**0.890**	**0.670**	**0.511**

ECONOMICS MODEL

2. A: GW

2: Canon Rocks/Boknes Groundwater Option

	Min	0.104	0	0.001	0	0												
	Max			0.043	0	0												
YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 4%			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	5.619						5.619	0.000	0.000	5.195	0.000	0.000	5.001	0.000	0.000	4.817	0.000	0.000
2006		0.104	0.000	0.001	0.000	0.000	0.000	0.104	0.001	0.000	0.092	0.001	0.000	0.087	0.001	0.000	0.083	0.001
2007		0.104	0.000	0.003	0.000	0.000	0.000	0.104	0.003	0.000	0.089	0.003	0.000	0.082	0.003	0.000	0.076	0.002
2008		0.104	0.000	0.005	0.000	0.000	0.000	0.104	0.005	0.000	0.085	0.004	0.000	0.078	0.004	0.000	0.071	0.004
2009		0.104	0.000	0.008	0.000	0.000	0.000	0.104	0.008	0.000	0.082	0.006	0.000	0.073	0.005	0.000	0.066	0.005
2010		0.104	0.000	0.010	0.000	0.000	0.000	0.104	0.010	0.000	0.079	0.007	0.000	0.069	0.007	0.000	0.061	0.006
2011		0.104	0.000	0.012	0.000	0.000	0.000	0.104	0.012	0.000	0.076	0.009	0.000	0.065	0.008	0.000	0.056	0.007
2012		0.104	0.000	0.014	0.000	0.000	0.000	0.104	0.014	0.000	0.073	0.010	0.000	0.062	0.008	0.000	0.052	0.007
2013		0.104	0.000	0.016	0.000	0.000	0.000	0.104	0.016	0.000	0.070	0.011	0.000	0.058	0.009	0.000	0.048	0.008
2014		0.104	0.000	0.019	0.000	0.000	0.000	0.104	0.019	0.000	0.068	0.012	0.000	0.055	0.010	0.000	0.045	0.008
2015	0.000	0.104	0.000	0.021	0.000	0.000	0.000	0.104	0.021	0.000	0.065	0.013	0.000	0.052	0.010	0.000	0.041	0.008
2016		0.104	0.000	0.023	0.000	0.000	0.000	0.104	0.023	0.000	0.062	0.014	0.000	0.049	0.011	0.000	0.038	0.008
2017		0.104	0.000	0.025	0.000	0.000	0.000	0.104	0.025	0.000	0.060	0.015	0.000	0.046	0.011	0.000	0.035	0.009
2018		0.104	0.000	0.028	0.000	0.000	0.000	0.104	0.028	0.000	0.058	0.015	0.000	0.043	0.011	0.000	0.033	0.009
2019		0.104	0.000	0.030	0.000	0.000	0.000	0.104	0.030	0.000	0.056	0.016	0.000	0.041	0.012	0.000	0.030	0.009
2020		0.104	0.000	0.032	0.000	0.000	0.000	0.104	0.032	0.000	0.053	0.016	0.000	0.039	0.012	0.000	0.028	0.009
2021		0.104	0.000	0.034	0.000	0.000	0.000	0.104	0.034	0.000	0.051	0.017	0.000	0.036	0.012	0.000	0.026	0.009
2022		0.104	0.000	0.036	0.000	0.000	0.000	0.104	0.036	0.000	0.049	0.017	0.000	0.034	0.012	0.000	0.024	0.008
2023		0.104	0.000	0.039	0.000	0.000	0.000	0.104	0.039	0.000	0.047	0.018	0.000	0.032	0.012	0.000	0.022	0.008
2024		0.104	0.000	0.041	0.000	0.000	0.000	0.104	0.041	0.000	0.046	0.018	0.000	0.031	0.012	0.000	0.021	0.008
2025	-1.746	0.104	0.000	0.043	0.000	0.000	-1.746	0.104	0.043	-0.737	0.044	0.018	-0.485	0.029	0.012	-0.321	0.019	0.008
TOTAL	**3.873**	**2.080**	**0.000**	**0.440**	**0.000**	**0.000**	**3.873**	**2.080**	**0.440**	**4.458**	**1.307**	**0.241**	**4.516**	**1.062**	**0.182**	**4.496**	**0.875**	**0.139**

	NPC	NPV water	URV, R/kl
AT 4%	**6.0**	**1.5**	**3.94**
AT 6%	**5.8**	**1.1**	**5.02**
AT 8%	**5.5**	**0.9**	**6.30**

Net present value of water supplied

Low demand scenario

Min	0	l/s
Max	8.9	l/s

YEAR	TOTAL SUPPLY (x1000 m3)	NPV of water supplied at 4% (x1000 m3)	NPV of water supplied at 6% (x1000 m3)	NPV of water supplied at 8% (x1000 m3)
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.015	0.013	0.012	0.011
2008	0.030	0.024	0.022	0.020
2009	0.044	0.035	0.031	0.028
2010	0.059	0.045	0.039	0.034
2011	0.074	0.054	0.046	0.040
2012	0.089	0.062	0.052	0.044
2013	0.103	0.070	0.058	0.048
2014	0.118	0.077	0.062	0.051
2015	0.133	0.083	0.066	0.053
2016	0.148	0.089	0.069	0.054
2017	0.162	0.094	0.072	0.055
2018	0.177	0.098	0.074	0.056
2019	0.192	0.103	0.076	0.056
2020	0.207	0.106	0.077	0.056
2021	0.222	0.109	0.078	0.055
2022	0.236	0.112	0.078	0.055
2023	0.251	0.115	0.078	0.054
2024	0.266	0.117	0.078	0.053
2025	0.281	0.118	0.078	0.052
TOTAL	**2.807**	**1.524**	**1.147**	**0.875**

ECONOMICS MODEL

3. KOS: GW

3: Kenton On Sea/Bushmans River mouth: GW

YEAR	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	TOTAL ANNUAL COST Capital	M & O	Energy cost	NET PRESENT COST AT 4% Capital	M & O	Energy cost	NET PRESENT COST AT 6% Capital	M & O	Energy cost	NET PRESENT COST AT 8% Capital	M & O	Energy cost
Min		0.425	0	0.003	0	0												
Max				0.483	0	0												
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	28.114						28.114	0.000	0.000	25.993	0.000	0.000	25.021	0.000	0.000	24.103	0.000	0.000
2006		0.425	0.000	0.003	0.000	0.000	0.000	0.425	0.003	0.000	0.378	0.003	0.000	0.357	0.003	0.000	0.337	0.002
2007		0.425	0.000	0.028	0.000	0.000	0.000	0.425	0.028	0.000	0.363	0.024	0.000	0.337	0.022	0.000	0.312	0.021
2008		0.425	0.000	0.054	0.000	0.000	0.000	0.425	0.054	0.000	0.349	0.044	0.000	0.318	0.040	0.000	0.289	0.036
2009		0.425	0.000	0.079	0.000	0.000	0.000	0.425	0.079	0.000	0.336	0.062	0.000	0.300	0.056	0.000	0.268	0.050
2010		0.425	0.000	0.104	0.000	0.000	0.000	0.425	0.104	0.000	0.323	0.079	0.000	0.283	0.069	0.000	0.248	0.061
2011		0.425	0.000	0.129	0.000	0.000	0.000	0.425	0.129	0.000	0.311	0.094	0.000	0.267	0.081	0.000	0.230	0.070
2012		0.425	0.000	0.155	0.000	0.000	0.000	0.425	0.155	0.000	0.299	0.109	0.000	0.252	0.091	0.000	0.213	0.077
2013		0.425	0.000	0.180	0.000	0.000	0.000	0.425	0.180	0.000	0.287	0.121	0.000	0.237	0.100	0.000	0.197	0.083
2014		0.425	0.000	0.205	0.000	0.000	0.000	0.425	0.205	0.000	0.276	0.133	0.000	0.224	0.108	0.000	0.182	0.088
2015	0.000	0.425	0.000	0.230	0.000	0.000	0.000	0.425	0.230	0.000	0.265	0.144	0.000	0.211	0.114	0.000	0.169	0.091
2016		0.425	0.000	0.256	0.000	0.000	0.000	0.425	0.256	0.000	0.255	0.154	0.000	0.199	0.120	0.000	0.156	0.094
2017		0.425	0.000	0.281	0.000	0.000	0.000	0.425	0.281	0.000	0.245	0.162	0.000	0.188	0.124	0.000	0.145	0.096
2018		0.425	0.000	0.306	0.000	0.000	0.000	0.425	0.306	0.000	0.236	0.170	0.000	0.177	0.128	0.000	0.134	0.097
2019		0.425	0.000	0.331	0.000	0.000	0.000	0.425	0.331	0.000	0.227	0.177	0.000	0.167	0.130	0.000	0.124	0.097
2020		0.425	0.000	0.357	0.000	0.000	0.000	0.425	0.357	0.000	0.218	0.183	0.000	0.158	0.132	0.000	0.115	0.096
2021		0.425	0.000	0.382	0.000	0.000	0.000	0.425	0.382	0.000	0.210	0.189	0.000	0.149	0.134	0.000	0.106	0.096
2022		0.425	0.000	0.407	0.000	0.000	0.000	0.425	0.407	0.000	0.202	0.193	0.000	0.140	0.135	0.000	0.098	0.094
2023		0.425	0.000	0.432	0.000	0.000	0.000	0.425	0.432	0.000	0.194	0.197	0.000	0.133	0.135	0.000	0.091	0.093
2024		0.425	0.000	0.458	0.000	0.000	0.000	0.425	0.458	0.000	0.187	0.201	0.000	0.125	0.135	0.000	0.084	0.091
2025	-10.008	0.425	0.000	0.483	0.000	0.000	-10.008	0.425	0.483	-4.223	0.179	0.204	-2.777	0.118	0.134	-1.841	0.078	0.089
TOTAL	**18.106**	**8.500**	**0.000**	**4.860**	**0.000**	**0.000**	**18.106**	**8.500**	**4.860**	**21.770**	**5.340**	**2.644**	**22.244**	**4.338**	**1.992**	**22.262**	**3.577**	**1.522**

	NPC	NPV water	URV, R/kl
AT 4%	**29.8**	**3.8**	**7.90**
AT 6%	**28.6**	**2.8**	**10.08**
AT 8%	**27.4**	**2.2**	**12.65**

Net present value of water supplied

Low demand scenario

Min	0	l/s		
Max	22	l/s		
YEAR	**TOTAL SUPPLY (x1000 m3)**	**NPV of water supplied at 4% (x1000 m3)**	**NPV of water supplied at 6% (x1000 m3)**	**NPV of water supplied at 8% (x1000 m3)**
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.037	0.031	0.029	0.027
2008	0.073	0.060	0.055	0.050
2009	0.110	0.087	0.077	0.069
2010	0.146	0.111	0.097	0.085
2011	0.183	0.133	0.115	0.099
2012	0.219	0.154	0.130	0.110
2013	0.256	0.173	0.143	0.118
2014	0.292	0.190	0.154	0.125
2015	0.329	0.205	0.163	0.131
2016	0.365	0.219	0.171	0.134
2017	0.402	0.232	0.178	0.137
2018	0.438	0.243	0.183	0.138
2019	0.475	0.253	0.187	0.139
2020	0.511	0.262	0.190	0.138
2021	0.548	0.270	0.192	0.137
2022	0.584	0.277	0.193	0.135
2023	0.621	0.283	0.194	0.133
2024	0.657	0.288	0.193	0.131
2025	0.694	0.293	0.193	0.128
TOTAL	**6.938**	**3.766**	**2.835**	**2.163**

ECONOMICS MODEL

4A. KOS: RO SEA WATER

4: Kenton on Sea/ Bushmans River Mouth: RO Option

	Min	0.771	0	0	0	0												
	Max			0.937	0	0												
YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 4%			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	34.646						34.646	0.000	0.000	32.032	0.000	0.000	30.835	0.000	0.000	29.703	0.000	0.000
2006		0.771	0.000	0.000	0.000	0.000	0.000	0.771	0.000	0.000	0.685	0.000	0.000	0.647	0.000	0.000	0.612	0.000
2007		0.771	0.000	0.049	0.000	0.000	0.000	0.771	0.049	0.000	0.659	0.042	0.000	0.611	0.039	0.000	0.567	0.036
2008		0.771	0.000	0.099	0.000	0.000	0.000	0.771	0.099	0.000	0.634	0.081	0.000	0.576	0.074	0.000	0.525	0.067
2009		0.771	0.000	0.148	0.000	0.000	0.000	0.771	0.148	0.000	0.609	0.117	0.000	0.544	0.104	0.000	0.486	0.093
2010		0.771	0.000	0.197	0.000	0.000	0.000	0.771	0.197	0.000	0.586	0.150	0.000	0.513	0.131	0.000	0.450	0.115
2011		0.771	0.000	0.247	0.000	0.000	0.000	0.771	0.247	0.000	0.563	0.180	0.000	0.484	0.155	0.000	0.417	0.133
2012		0.771	0.000	0.296	0.000	0.000	0.000	0.771	0.296	0.000	0.542	0.208	0.000	0.456	0.175	0.000	0.386	0.148
2013		0.771	0.000	0.345	0.000	0.000	0.000	0.771	0.345	0.000	0.521	0.233	0.000	0.431	0.193	0.000	0.357	0.160
2014		0.771	0.000	0.395	0.000	0.000	0.000	0.771	0.395	0.000	0.501	0.256	0.000	0.406	0.208	0.000	0.331	0.169
2015	0.000	0.771	0.000	0.444	0.000	0.000	0.000	0.771	0.444	0.000	0.482	0.277	0.000	0.383	0.221	0.000	0.306	0.176
2016		0.771	0.000	0.493	0.000	0.000	0.000	0.771	0.493	0.000	0.463	0.296	0.000	0.361	0.231	0.000	0.283	0.181
2017		0.771	0.000	0.542	0.000	0.000	0.000	0.771	0.542	0.000	0.445	0.313	0.000	0.341	0.240	0.000	0.262	0.185
2018		0.771	0.000	0.592	0.000	0.000	0.000	0.771	0.592	0.000	0.428	0.329	0.000	0.322	0.247	0.000	0.243	0.187
2019		0.771	0.000	0.641	0.000	0.000	0.000	0.771	0.641	0.000	0.412	0.342	0.000	0.304	0.252	0.000	0.225	0.187
2020		0.771	0.000	0.690	0.000	0.000	0.000	0.771	0.690	0.000	0.396	0.354	0.000	0.286	0.256	0.000	0.208	0.187
2021		0.771	0.000	0.740	0.000	0.000	0.000	0.771	0.740	0.000	0.381	0.365	0.000	0.270	0.259	0.000	0.193	0.185
2022		0.771	0.000	0.789	0.000	0.000	0.000	0.771	0.789	0.000	0.366	0.375	0.000	0.255	0.261	0.000	0.179	0.183
2023		0.771	0.000	0.838	0.000	0.000	0.000	0.771	0.838	0.000	0.352	0.383	0.000	0.240	0.261	0.000	0.165	0.180
2024		0.771	0.000	0.888	0.000	0.000	0.000	0.771	0.888	0.000	0.338	0.390	0.000	0.227	0.261	0.000	0.153	0.176
2025	-14.750	0.771	0.000	0.937	0.000	0.000	-14.750	0.771	0.937	-6.224	0.325	0.395	-4.093	0.214	0.260	-2.713	0.142	0.172
TOTAL	**19.896**	**15.420**	**0.000**	**9.370**	**0.000**	**0.000**	**19.896**	**15.420**	**9.370**	**25.808**	**9.688**	**5.087**	**26.742**	**7.871**	**3.829**	**26.990**	**6.490**	**2.921**

	NPC	NPV water	URV, R/kl
AT 4%	**40.6**	**3.8**	**10.77**
AT 6%	**38.4**	**2.8**	**13.56**
AT 8%	**36.4**	**2.2**	**16.83**

Net present value of water supplied

Low demand scenario

Min	0	l/s
Max	22	l/s

YEAR	TOTAL SUPPLY (x1000 m3)	NPV of water supplied at 4% (x1000 m3)	NPV of water supplied at 6% (x1000 m3)	NPV of water supplied at 8% (x1000 m3)
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.037	0.031	0.029	0.027
2008	0.073	0.060	0.055	0.050
2009	0.110	0.087	0.077	0.069
2010	0.146	0.111	0.097	0.085
2011	0.183	0.133	0.115	0.099
2012	0.219	0.154	0.130	0.110
2013	0.256	0.173	0.143	0.118
2014	0.292	0.190	0.154	0.125
2015	0.329	0.205	0.163	0.131
2016	0.365	0.219	0.171	0.134
2017	0.402	0.232	0.178	0.137
2018	0.438	0.243	0.183	0.138
2019	0.475	0.253	0.187	0.139
2020	0.511	0.262	0.190	0.138
2021	0.548	0.270	0.192	0.137
2022	0.584	0.277	0.193	0.135
2023	0.621	0.283	0.194	0.133
2024	0.657	0.288	0.193	0.131
2025	0.694	0.293	0.193	0.128
TOTAL	**6.938**	**3.766**	**2.835**	**2.163**

ECONOMICS MODEL

4B. KOS: RO BRACKISH WATER

4: Kenton on Sea/ Bushmans River Mouth: RO Option

	Min	0.606	0	0	0	0
	Max			0.739	0	0

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 4%			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	28.767						28.767	0.000	0.000	26.597	0.000	0.000	25.603	0.000	0.000	24.663	0.000	0.000
2006		0.606	0.000	0.000	0.000	0.000	0.000	0.606	0.000	0.000	0.539	0.000	0.000	0.509	0.000	0.000	0.481	0.000
2007		0.606	0.000	0.039	0.000	0.000	0.000	0.606	0.039	0.000	0.518	0.033	0.000	0.480	0.031	0.000	0.445	0.029
2008		0.606	0.000	0.078	0.000	0.000	0.000	0.606	0.078	0.000	0.498	0.064	0.000	0.453	0.058	0.000	0.412	0.053
2009		0.606	0.000	0.117	0.000	0.000	0.000	0.606	0.117	0.000	0.479	0.092	0.000	0.427	0.082	0.000	0.382	0.074
2010		0.606	0.000	0.156	0.000	0.000	0.000	0.606	0.156	0.000	0.461	0.118	0.000	0.403	0.103	0.000	0.354	0.091
2011		0.606	0.000	0.194	0.000	0.000	0.000	0.606	0.194	0.000	0.443	0.142	0.000	0.380	0.122	0.000	0.327	0.105
2012		0.606	0.000	0.233	0.000	0.000	0.000	0.606	0.233	0.000	0.426	0.164	0.000	0.359	0.138	0.000	0.303	0.117
2013		0.606	0.000	0.272	0.000	0.000	0.000	0.606	0.272	0.000	0.409	0.184	0.000	0.338	0.152	0.000	0.281	0.126
2014		0.606	0.000	0.311	0.000	0.000	0.000	0.606	0.311	0.000	0.394	0.202	0.000	0.319	0.164	0.000	0.260	0.133
2015	0.000	0.606	0.000	0.350	0.000	0.000	0.000	0.606	0.350	0.000	0.379	0.219	0.000	0.301	0.174	0.000	0.241	0.139
2016		0.606	0.000	0.389	0.000	0.000	0.000	0.606	0.389	0.000	0.364	0.234	0.000	0.284	0.182	0.000	0.223	0.143
2017		0.606	0.000	0.428	0.000	0.000	0.000	0.606	0.428	0.000	0.350	0.247	0.000	0.268	0.189	0.000	0.206	0.146
2018		0.606	0.000	0.467	0.000	0.000	0.000	0.606	0.467	0.000	0.336	0.259	0.000	0.253	0.195	0.000	0.191	0.147
2019		0.606	0.000	0.506	0.000	0.000	0.000	0.606	0.506	0.000	0.324	0.270	0.000	0.239	0.199	0.000	0.177	0.148
2020		0.606	0.000	0.545	0.000	0.000	0.000	0.606	0.545	0.000	0.311	0.280	0.000	0.225	0.202	0.000	0.164	0.147
2021		0.606	0.000	0.583	0.000	0.000	0.000	0.606	0.583	0.000	0.299	0.288	0.000	0.212	0.204	0.000	0.152	0.146
2022		0.606	0.000	0.622	0.000	0.000	0.000	0.606	0.622	0.000	0.288	0.295	0.000	0.200	0.206	0.000	0.140	0.144
2023		0.606	0.000	0.661	0.000	0.000	0.000	0.606	0.661	0.000	0.277	0.302	0.000	0.189	0.206	0.000	0.130	0.142
2024		0.606	0.000	0.700	0.000	0.000	0.000	0.606	0.700	0.000	0.266	0.307	0.000	0.178	0.206	0.000	0.120	0.139
2025	-9.709	0.606	0.000	0.739	0.000	0.000	-9.709	0.606	0.739	-4.097	0.256	0.312	-2.694	0.168	0.205	-1.786	0.111	0.136
TOTAL	**19.058**	**12.120**	**0.000**	**7.390**	**0.000**	**0.000**	**19.058**	**12.120**	**7.390**	**22.500**	**7.614**	**4.012**	**22.908**	**6.186**	**3.020**	**22.877**	**5.101**	**2.304**

	NPC	NPV water	URV, R/kl
AT 4%	**34.1**	**3.8**	**9.06**
AT 6%	**32.1**	**2.8**	**11.33**
AT 8%	**30.3**	**2.2**	**14.00**

Net present value of water supplied

Low demand scenario

Min	0	l/s		
Max	22	l/s		
YEAR	**TOTAL SUPPLY (x1000 m3)**	**NPV of water supplied at 4% (x1000 m3)**	**NPV of water supplied at 6% (x1000 m3)**	**NPV of water supplied at 8% (x1000 m3)**
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.037	0.031	0.029	0.027
2008	0.073	0.060	0.055	0.050
2009	0.110	0.087	0.077	0.069
2010	0.146	0.111	0.097	0.085
2011	0.183	0.133	0.115	0.099
2012	0.219	0.154	0.130	0.110
2013	0.256	0.173	0.143	0.118
2014	0.292	0.190	0.154	0.125
2015	0.329	0.205	0.163	0.131
2016	0.365	0.219	0.171	0.134
2017	0.402	0.232	0.178	0.137
2018	0.438	0.243	0.183	0.138
2019	0.475	0.253	0.187	0.139
2020	0.511	0.262	0.190	0.138
2021	0.548	0.270	0.192	0.137
2022	0.584	0.277	0.193	0.135
2023	0.621	0.283	0.194	0.133
2024	0.657	0.288	0.193	0.131
2025	0.694	0.293	0.193	0.128
TOTAL	**6.938**	**3.766**	**2.835**	**2.163**

ECONOMICS MODEL

5. KOS: from GM Dam

5: Kenton on Sea/ Bushmans River Mouth: from Glen Melville dam

	Min	0.499	0	0.007	0	0
	Max			0.716	0	0

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 4%			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	41.355						41.355	0.000	0.000	38.235	0.000	0.000	36.806	0.000	0.000	35.455	0.000	0.000
2006		0.499	0.000	0.007	0.000	0.000	0.000	0.499	0.007	0.000	0.444	0.006	0.000	0.419	0.006	0.000	0.396	0.006
2007		0.499	0.000	0.044	0.000	0.000	0.000	0.499	0.044	0.000	0.427	0.038	0.000	0.395	0.035	0.000	0.367	0.033
2008		0.499	0.000	0.082	0.000	0.000	0.000	0.499	0.082	0.000	0.410	0.067	0.000	0.373	0.061	0.000	0.340	0.056
2009		0.499	0.000	0.119	0.000	0.000	0.000	0.499	0.119	0.000	0.394	0.094	0.000	0.352	0.084	0.000	0.314	0.075
2010		0.499	0.000	0.156	0.000	0.000	0.000	0.499	0.156	0.000	0.379	0.119	0.000	0.332	0.104	0.000	0.291	0.091
2011		0.499	0.000	0.194	0.000	0.000	0.000	0.499	0.194	0.000	0.365	0.141	0.000	0.313	0.121	0.000	0.270	0.105
2012		0.499	0.000	0.231	0.000	0.000	0.000	0.499	0.231	0.000	0.351	0.162	0.000	0.295	0.137	0.000	0.250	0.116
2013		0.499	0.000	0.268	0.000	0.000	0.000	0.499	0.268	0.000	0.337	0.181	0.000	0.279	0.150	0.000	0.231	0.124
2014		0.499	0.000	0.306	0.000	0.000	0.000	0.499	0.306	0.000	0.324	0.198	0.000	0.263	0.161	0.000	0.214	0.131
2015	0.000	0.499	0.000	0.343	0.000	0.000	0.000	0.499	0.343	0.000	0.312	0.214	0.000	0.248	0.170	0.000	0.198	0.136
2016		0.499	0.000	0.380	0.000	0.000	0.000	0.499	0.380	0.000	0.300	0.228	0.000	0.234	0.178	0.000	0.183	0.140
2017		0.499	0.000	0.417	0.000	0.000	0.000	0.499	0.417	0.000	0.288	0.241	0.000	0.221	0.185	0.000	0.170	0.142
2018		0.499	0.000	0.455	0.000	0.000	0.000	0.499	0.455	0.000	0.277	0.253	0.000	0.208	0.190	0.000	0.157	0.143
2019		0.499	0.000	0.492	0.000	0.000	0.000	0.499	0.492	0.000	0.266	0.263	0.000	0.196	0.194	0.000	0.146	0.144
2020		0.499	0.000	0.529	0.000	0.000	0.000	0.499	0.529	0.000	0.256	0.272	0.000	0.185	0.197	0.000	0.135	0.143
2021		0.499	0.000	0.567	0.000	0.000	0.000	0.499	0.567	0.000	0.246	0.280	0.000	0.175	0.199	0.000	0.125	0.142
2022		0.499	0.000	0.604	0.000	0.000	0.000	0.499	0.604	0.000	0.237	0.287	0.000	0.165	0.200	0.000	0.116	0.140
2023		0.499	0.000	0.641	0.000	0.000	0.000	0.499	0.641	0.000	0.228	0.293	0.000	0.156	0.200	0.000	0.107	0.138
2024		0.499	0.000	0.679	0.000	0.000	0.000	0.499	0.679	0.000	0.219	0.298	0.000	0.147	0.200	0.000	0.099	0.135
2025	-14.681	0.499	0.000	0.716	0.000	0.000	-14.681	0.499	0.716	-6.195	0.211	0.302	-4.074	0.138	0.199	-2.700	0.092	0.132
TOTAL	**26.674**	**9.980**	**0.000**	**7.230**	**0.000**	**0.000**	**26.674**	**9.980**	**7.230**	**32.040**	**6.270**	**3.937**	**32.732**	**5.094**	**2.968**	**32.755**	**4.200**	**2.269**

	NPC	NPV water	URV, R/kl
AT 4%	**42.2**	**5.3**	**7.96**
AT 6%	**40.8**	**4.0**	**10.21**
AT 8%	**39.2**	**3.0**	**12.87**

Net present value of water supplied

Low demand scenario

Min	0	l/s		
Max	31	l/s		
YEAR	**TOTAL SUPPLY (x1000 m3)**	**NPV of water supplied at 4% (x1000 m3)**	**NPV of water supplied at 6% (x1000 m3)**	**NPV of water supplied at 8% (x1000 m3)**
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.051	0.044	0.041	0.038
2008	0.103	0.085	0.077	0.070
2009	0.154	0.122	0.109	0.097
2010	0.206	0.156	0.137	0.120
2011	0.257	0.188	0.161	0.139
2012	0.309	0.217	0.183	0.154
2013	0.360	0.243	0.201	0.167
2014	0.412	0.267	0.217	0.177
2015	0.463	0.289	0.230	0.184
2016	0.515	0.309	0.241	0.189
2017	0.566	0.327	0.250	0.193
2018	0.617	0.343	0.258	0.195
2019	0.669	0.357	0.263	0.195
2020	0.720	0.370	0.268	0.195
2021	0.772	0.381	0.270	0.193
2022	0.823	0.391	0.272	0.191
2023	0.875	0.399	0.273	0.188
2024	0.926	0.406	0.272	0.184
2025	0.978	0.413	0.271	0.180
TOTAL	**9.776**	**5.307**	**3.995**	**3.048**

ECONOMICS MODEL

6. GM Dam: Option 1

6: Port Alfred, Bathurts, Kenton on Sea: from Glen Melville dam

YEAR	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	TOTAL ANNUAL COST Capital	TOTAL ANNUAL COST M & O	TOTAL ANNUAL COST Energy cost	NET PRESENT COST AT 4% Capital	NET PRESENT COST AT 4% M & O	NET PRESENT COST AT 4% Energy cost	NET PRESENT COST AT 6% Capital	NET PRESENT COST AT 6% M & O	NET PRESENT COST AT 6% Energy cost	NET PRESENT COST AT 8% Capital	NET PRESENT COST AT 8% M & O	NET PRESENT COST AT 8% Energy cost
Min		1.538	0	0.026	0	0												
Max				1.539	0	0												
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	130.907						130.907	0.000	0.000	121.031	0.000	0.000	116.507	0.000	0.000	112.232	0.000	0.000
2006		1.538	0.000	0.026	0.000	0.000	0.000	1.538	0.026	0.000	1.367	0.023	0.000	1.291	0.022	0.000	1.221	0.021
2007		1.538	0.000	0.106	0.000	0.000	0.000	1.538	0.106	0.000	1.315	0.090	0.000	1.218	0.084	0.000	1.130	0.078
2008		1.538	0.000	0.185	0.000	0.000	0.000	1.538	0.185	0.000	1.264	0.152	0.000	1.149	0.138	0.000	1.047	0.126
2009		1.538	0.000	0.265	0.000	0.000	0.000	1.538	0.265	0.000	1.216	0.209	0.000	1.084	0.187	0.000	0.969	0.167
2010		1.538	0.000	0.345	0.000	0.000	0.000	1.538	0.345	0.000	1.169	0.262	0.000	1.023	0.229	0.000	0.897	0.201
2011		1.538	0.000	0.424	0.000	0.000	0.000	1.538	0.424	0.000	1.124	0.310	0.000	0.965	0.266	0.000	0.831	0.229
2012		1.538	0.000	0.504	0.000	0.000	0.000	1.538	0.504	0.000	1.081	0.354	0.000	0.910	0.298	0.000	0.769	0.252
2013		1.538	0.000	0.583	0.000	0.000	0.000	1.538	0.583	0.000	1.039	0.394	0.000	0.859	0.326	0.000	0.712	0.270
2014		1.538	0.000	0.663	0.000	0.000	0.000	1.538	0.663	0.000	0.999	0.431	0.000	0.810	0.349	0.000	0.660	0.284
2015	0.000	1.538	0.000	0.743	0.000	0.000	0.000	1.538	0.743	0.000	0.961	0.464	0.000	0.764	0.369	0.000	0.611	0.295
2016		1.538	0.000	0.822	0.000	0.000	0.000	1.538	0.822	0.000	0.924	0.494	0.000	0.721	0.386	0.000	0.566	0.302
2017		1.538	0.000	0.902	0.000	0.000	0.000	1.538	0.902	0.000	0.888	0.521	0.000	0.680	0.399	0.000	0.524	0.307
2018		1.538	0.000	0.982	0.000	0.000	0.000	1.538	0.982	0.000	0.854	0.545	0.000	0.642	0.410	0.000	0.485	0.309
2019		1.538	0.000	1.061	0.000	0.000	0.000	1.538	1.061	0.000	0.821	0.567	0.000	0.605	0.418	0.000	0.449	0.310
2020		1.538	0.000	1.141	0.000	0.000	0.000	1.538	1.141	0.000	0.790	0.586	0.000	0.571	0.424	0.000	0.416	0.308
2021		1.538	0.000	1.220	0.000	0.000	0.000	1.538	1.220	0.000	0.759	0.602	0.000	0.539	0.428	0.000	0.385	0.305
2022		1.538	0.000	1.300	0.000	0.000	0.000	1.538	1.300	0.000	0.730	0.617	0.000	0.508	0.430	0.000	0.356	0.301
2023		1.538	0.000	1.380	0.000	0.000	0.000	1.538	1.380	0.000	0.702	0.630	0.000	0.480	0.430	0.000	0.330	0.296
2024		1.538	0.000	1.459	0.000	0.000	0.000	1.538	1.459	0.000	0.675	0.640	0.000	0.452	0.429	0.000	0.306	0.290
2025	-48.291	1.538	0.000	1.539	0.000	0.000	-48.291	1.538	1.539	-20.377	0.649	0.649	-13.401	0.427	0.427	-8.883	0.283	0.283
TOTAL	**82.616**	**30.760**	**0.000**	**15.650**	**0.000**	**0.000**	**82.616**	**30.760**	**15.650**	**100.654**	**19.325**	**8.541**	**103.106**	**15.700**	**6.448**	**103.349**	**12.946**	**4.936**

	NPC	NPV water	URV, R/kl
AT 4%	**128.5**	**15.6**	**8.25**
AT 6%	**125.3**	**11.7**	**10.68**
AT 8%	**121.2**	**8.9**	**13.55**

Net present value of water supplied

Low demand scenario

Min	0	l/s		
Max	91	l/s		

YEAR	TOTAL SUPPLY (x1000 m3)	NPV of water supplied at 4% (x1000 m3)	NPV of water supplied at 6% (x1000 m3)	NPV of water supplied at 8% (x1000 m3)
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.151	0.129	0.120	0.111
2008	0.302	0.248	0.226	0.206
2009	0.453	0.358	0.319	0.286
2010	0.604	0.459	0.402	0.353
2011	0.755	0.552	0.474	0.408
2012	0.906	0.637	0.536	0.453
2013	1.057	0.714	0.590	0.490
2014	1.208	0.785	0.637	0.518
2015	1.359	0.849	0.676	0.540
2016	1.510	0.907	0.708	0.555
2017	1.661	0.959	0.735	0.566
2018	1.812	1.006	0.756	0.571
2019	1.964	1.048	0.773	0.573
2020	2.115	1.086	0.785	0.572
2021	2.266	1.118	0.794	0.567
2022	2.417	1.147	0.799	0.560
2023	2.568	1.172	0.801	0.551
2024	2.719	1.193	0.800	0.540
2025	2.870	1.211	0.796	0.528
TOTAL	**28.698**	**15.580**	**11.726**	**8.947**

ECONOMICS MODEL

7. GM Dam: Opt 2

7: Port Alfred, Bathurst: from Glen Melville dam

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 4%			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%		
	Min	1.196	0	0.02	0	0												
	Max			1.212	0	0												
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	98.241						98.241	0.000	0.000	90.829	0.000	0.000	87.434	0.000	0.000	84.226	0.000	0.000
2006		1.196	0.000	0.020	0.000	0.000	0.000	1.196	0.020	0.000	1.063	0.018	0.000	1.004	0.017	0.000	0.949	0.016
2007		1.196	0.000	0.083	0.000	0.000	0.000	1.196	0.083	0.000	1.022	0.071	0.000	0.947	0.066	0.000	0.879	0.061
2008		1.196	0.000	0.145	0.000	0.000	0.000	1.196	0.145	0.000	0.983	0.120	0.000	0.894	0.109	0.000	0.814	0.099
2009		1.196	0.000	0.208	0.000	0.000	0.000	1.196	0.208	0.000	0.945	0.165	0.000	0.843	0.147	0.000	0.754	0.131
2010		1.196	0.000	0.271	0.000	0.000	0.000	1.196	0.271	0.000	0.909	0.206	0.000	0.795	0.180	0.000	0.698	0.158
2011		1.196	0.000	0.334	0.000	0.000	0.000	1.196	0.334	0.000	0.874	0.244	0.000	0.750	0.209	0.000	0.646	0.180
2012		1.196	0.000	0.396	0.000	0.000	0.000	1.196	0.396	0.000	0.840	0.279	0.000	0.708	0.235	0.000	0.598	0.198
2013		1.196	0.000	0.459	0.000	0.000	0.000	1.196	0.459	0.000	0.808	0.310	0.000	0.668	0.256	0.000	0.554	0.213
2014		1.196	0.000	0.522	0.000	0.000	0.000	1.196	0.522	0.000	0.777	0.339	0.000	0.630	0.275	0.000	0.513	0.224
2015	0.000	1.196	0.000	0.585	0.000	0.000	0.000	1.196	0.585	0.000	0.747	0.365	0.000	0.594	0.291	0.000	0.475	0.232
2016		1.196	0.000	0.647	0.000	0.000	0.000	1.196	0.647	0.000	0.718	0.389	0.000	0.561	0.304	0.000	0.440	0.238
2017		1.196	0.000	0.710	0.000	0.000	0.000	1.196	0.710	0.000	0.691	0.410	0.000	0.529	0.314	0.000	0.407	0.242
2018		1.196	0.000	0.773	0.000	0.000	0.000	1.196	0.773	0.000	0.664	0.429	0.000	0.499	0.322	0.000	0.377	0.244
2019		1.196	0.000	0.836	0.000	0.000	0.000	1.196	0.836	0.000	0.639	0.446	0.000	0.471	0.329	0.000	0.349	0.244
2020		1.196	0.000	0.898	0.000	0.000	0.000	1.196	0.898	0.000	0.614	0.461	0.000	0.444	0.334	0.000	0.323	0.243
2021		1.196	0.000	0.961	0.000	0.000	0.000	1.196	0.961	0.000	0.590	0.474	0.000	0.419	0.337	0.000	0.299	0.241
2022		1.196	0.000	1.024	0.000	0.000	0.000	1.196	1.024	0.000	0.568	0.486	0.000	0.395	0.338	0.000	0.277	0.237
2023		1.196	0.000	1.087	0.000	0.000	0.000	1.196	1.087	0.000	0.546	0.496	0.000	0.373	0.339	0.000	0.257	0.233
2024		1.196	0.000	1.149	0.000	0.000	0.000	1.196	1.149	0.000	0.525	0.504	0.000	0.352	0.338	0.000	0.238	0.228
2025	-36.947	1.196	0.000	1.212	0.000	0.000	-36.947	1.196	1.212	-15.590	0.505	0.511	-10.253	0.332	0.336	-6.796	0.220	0.223
TOTAL	**61.294**	**23.920**	**0.000**	**12.320**	**0.000**	**0.000**	**61.294**	**23.920**	**12.320**	**75.239**	**15.028**	**6.722**	**77.181**	**12.209**	**5.075**	**77.430**	**10.067**	**3.884**

	NPC	NPV water	URV, R/kl
AT 4%	**97.0**	**12.6**	**7.71**
AT 6%	**94.5**	**9.5**	**9.97**
AT 8%	**91.4**	**7.2**	**12.65**

Net present value of water supplied

Low demand scenario

Min	0	l/s		
Max	73.5	l/s		
YEAR	**TOTAL SUPPLY (x1000 m3)**	**NPV of water supplied at 4% (x1000 m3)**	**NPV of water supplied at 6% (x1000 m3)**	**NPV of water supplied at 8% (x1000 m3)**
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.122	0.104	0.097	0.090
2008	0.244	0.201	0.182	0.166
2009	0.366	0.289	0.258	0.231
2010	0.488	0.371	0.325	0.285
2011	0.610	0.446	0.383	0.330
2012	0.732	0.514	0.433	0.366
2013	0.854	0.577	0.477	0.396
2014	0.976	0.634	0.514	0.419
2015	1.098	0.686	0.546	0.436
2016	1.220	0.733	0.572	0.449
2017	1.342	0.775	0.594	0.457
2018	1.464	0.813	0.611	0.461
2019	1.586	0.847	0.624	0.463
2020	1.708	0.877	0.634	0.462
2021	1.830	0.903	0.641	0.458
2022	1.952	0.926	0.645	0.452
2023	2.074	0.947	0.647	0.445
2024	2.196	0.964	0.646	0.436
2025	2.318	0.978	0.643	0.426
TOTAL	**23.179**	**12.583**	**9.471**	**7.226**

ECONOMICS MODEL

8. Sarrel Hayword Dam

8: Port Alfred from Sarrel Hayword dam

		Maintenance	Operation	Energy Charge	Demand Charge	Chemicals
Min		0.622	0	0.008	0	0
Max				0.496	0	0

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 4%			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	55.184						55.184	0.000	0.000	51.021	0.000	0.000	49.114	0.000	0.000	47.311	0.000	0.000
2006		0.622	0.000	0.008	0.000	0.000	0.000	0.622	0.008	0.000	0.553	0.007	0.000	0.522	0.007	0.000	0.494	0.006
2007		0.622	0.000	0.034	0.000	0.000	0.000	0.622	0.034	0.000	0.532	0.029	0.000	0.493	0.027	0.000	0.457	0.025
2008		0.622	0.000	0.059	0.000	0.000	0.000	0.622	0.059	0.000	0.511	0.049	0.000	0.465	0.044	0.000	0.423	0.040
2009		0.622	0.000	0.085	0.000	0.000	0.000	0.622	0.085	0.000	0.492	0.067	0.000	0.438	0.060	0.000	0.392	0.054
2010		0.622	0.000	0.111	0.000	0.000	0.000	0.622	0.111	0.000	0.473	0.084	0.000	0.414	0.074	0.000	0.363	0.065
2011		0.622	0.000	0.136	0.000	0.000	0.000	0.622	0.136	0.000	0.454	0.100	0.000	0.390	0.086	0.000	0.336	0.074
2012		0.622	0.000	0.162	0.000	0.000	0.000	0.622	0.162	0.000	0.437	0.114	0.000	0.368	0.096	0.000	0.311	0.081
2013		0.622	0.000	0.188	0.000	0.000	0.000	0.622	0.188	0.000	0.420	0.127	0.000	0.347	0.105	0.000	0.288	0.087
2014		0.622	0.000	0.213	0.000	0.000	0.000	0.622	0.213	0.000	0.404	0.139	0.000	0.328	0.112	0.000	0.267	0.092
2015	0.000	0.622	0.000	0.239	0.000	0.000	0.000	0.622	0.239	0.000	0.388	0.149	0.000	0.309	0.119	0.000	0.247	0.095
2016		0.622	0.000	0.265	0.000	0.000	0.000	0.622	0.265	0.000	0.374	0.159	0.000	0.292	0.124	0.000	0.229	0.097
2017		0.622	0.000	0.291	0.000	0.000	0.000	0.622	0.291	0.000	0.359	0.168	0.000	0.275	0.129	0.000	0.212	0.099
2018		0.622	0.000	0.316	0.000	0.000	0.000	0.622	0.316	0.000	0.345	0.176	0.000	0.260	0.132	0.000	0.196	0.100
2019		0.622	0.000	0.342	0.000	0.000	0.000	0.622	0.342	0.000	0.332	0.183	0.000	0.245	0.135	0.000	0.182	0.100
2020		0.622	0.000	0.368	0.000	0.000	0.000	0.622	0.368	0.000	0.319	0.189	0.000	0.231	0.137	0.000	0.168	0.099
2021		0.622	0.000	0.393	0.000	0.000	0.000	0.622	0.393	0.000	0.307	0.194	0.000	0.218	0.138	0.000	0.156	0.098
2022		0.622	0.000	0.419	0.000	0.000	0.000	0.622	0.419	0.000	0.295	0.199	0.000	0.206	0.138	0.000	0.144	0.097
2023		0.622	0.000	0.445	0.000	0.000	0.000	0.622	0.445	0.000	0.284	0.203	0.000	0.194	0.139	0.000	0.133	0.095
2024		0.622	0.000	0.470	0.000	0.000	0.000	0.622	0.470	0.000	0.273	0.206	0.000	0.183	0.138	0.000	0.124	0.093
2025	-24.331	0.622	0.000	0.496	0.000	0.000	-24.331	0.622	0.496	-10.267	0.262	0.209	-6.752	0.173	0.138	-4.475	0.114	0.091
TOTAL	**30.853**	**12.440**	**0.000**	**5.040**	**0.000**	**0.000**	**30.853**	**12.440**	**5.040**	**40.754**	**7.815**	**2.750**	**42.362**	**6.349**	**2.076**	**42.836**	**5.236**	**1.589**

	NPC	NPV water	URV, R/kl
AT 4%	**51.3**	**11.8**	**4.33**
AT 6%	**50.8**	**8.9**	**5.70**
AT 8%	**49.7**	**6.8**	**7.30**

Net present value of water supplied

Low demand scenario

Min	0	l/s
Max	69.2	l/s

YEAR	TOTAL SUPPLY (x1000 m3)	NPV of water supplied at 4% (x1000 m3)	NPV of water supplied at 6% (x1000 m3)	NPV of water supplied at 8% (x1000 m3)
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.115	0.098	0.091	0.084
2008	0.230	0.189	0.172	0.156
2009	0.345	0.272	0.243	0.217
2010	0.459	0.349	0.306	0.268
2011	0.574	0.420	0.360	0.310
2012	0.689	0.484	0.408	0.345
2013	0.804	0.543	0.449	0.372
2014	0.919	0.597	0.484	0.394
2015	1.034	0.646	0.514	0.411
2016	1.149	0.690	0.538	0.422
2017	1.263	0.730	0.559	0.430
2018	1.378	0.765	0.575	0.434
2019	1.493	0.797	0.588	0.436
2020	1.608	0.826	0.597	0.435
2021	1.723	0.850	0.604	0.431
2022	1.838	0.872	0.607	0.426
2023	1.953	0.891	0.609	0.419
2024	2.067	0.907	0.608	0.411
2025	2.182	0.921	0.606	0.401
TOTAL	**21.823**	**11.847**	**8.917**	**6.803**

ECONOMICS MODEL

8. Sarrel Hayword Dam

8: Port Alfred from Sarrel Hayword dam

YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 4%			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%		
	Min	0.622	0	0.008	0	0												
	Max			0.496	0	0												
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	55.184						55.184	0.000	0.000	51.021	0.000	0.000	49.114	0.000	0.000	47.311	0.000	0.000
2006		0.622	0.000	0.008	0.000	0.000	0.000	0.622	0.008	0.000	0.553	0.007	0.000	0.522	0.007	0.000	0.494	0.006
2007		0.622	0.000	0.034	0.000	0.000	0.000	0.622	0.034	0.000	0.532	0.029	0.000	0.493	0.027	0.000	0.457	0.025
2008		0.622	0.000	0.059	0.000	0.000	0.000	0.622	0.059	0.000	0.511	0.049	0.000	0.465	0.044	0.000	0.423	0.040
2009		0.622	0.000	0.085	0.000	0.000	0.000	0.622	0.085	0.000	0.492	0.067	0.000	0.438	0.060	0.000	0.392	0.054
2010		0.622	0.000	0.111	0.000	0.000	0.000	0.622	0.111	0.000	0.473	0.084	0.000	0.414	0.074	0.000	0.363	0.065
2011		0.622	0.000	0.136	0.000	0.000	0.000	0.622	0.136	0.000	0.454	0.100	0.000	0.390	0.086	0.000	0.336	0.074
2012		0.622	0.000	0.162	0.000	0.000	0.000	0.622	0.162	0.000	0.437	0.114	0.000	0.368	0.096	0.000	0.311	0.081
2013		0.622	0.000	0.188	0.000	0.000	0.000	0.622	0.188	0.000	0.420	0.127	0.000	0.347	0.105	0.000	0.288	0.087
2014		0.622	0.000	0.213	0.000	0.000	0.000	0.622	0.213	0.000	0.404	0.139	0.000	0.328	0.112	0.000	0.267	0.092
2015	0.000	0.622	0.000	0.239	0.000	0.000	0.000	0.622	0.239	0.000	0.388	0.149	0.000	0.309	0.119	0.000	0.247	0.095
2016		0.622	0.000	0.265	0.000	0.000	0.000	0.622	0.265	0.000	0.374	0.159	0.000	0.292	0.124	0.000	0.229	0.097
2017		0.622	0.000	0.291	0.000	0.000	0.000	0.622	0.291	0.000	0.359	0.168	0.000	0.275	0.129	0.000	0.212	0.099
2018		0.622	0.000	0.316	0.000	0.000	0.000	0.622	0.316	0.000	0.345	0.176	0.000	0.260	0.132	0.000	0.196	0.100
2019		0.622	0.000	0.342	0.000	0.000	0.000	0.622	0.342	0.000	0.332	0.183	0.000	0.245	0.135	0.000	0.182	0.100
2020		0.622	0.000	0.368	0.000	0.000	0.000	0.622	0.368	0.000	0.319	0.189	0.000	0.231	0.137	0.000	0.168	0.099
2021		0.622	0.000	0.393	0.000	0.000	0.000	0.622	0.393	0.000	0.307	0.194	0.000	0.218	0.138	0.000	0.156	0.098
2022		0.622	0.000	0.419	0.000	0.000	0.000	0.622	0.419	0.000	0.295	0.199	0.000	0.206	0.138	0.000	0.144	0.097
2023		0.622	0.000	0.445	0.000	0.000	0.000	0.622	0.445	0.000	0.284	0.203	0.000	0.194	0.139	0.000	0.133	0.095
2024		0.622	0.000	0.470	0.000	0.000	0.000	0.622	0.470	0.000	0.273	0.206	0.000	0.183	0.138	0.000	0.124	0.093
2025	-24.331	0.622	0.000	0.496	0.000	0.000	-24.331	0.622	0.496	-10.267	0.262	0.209	-6.752	0.173	0.138	-4.475	0.114	0.091
TOTAL	**30.853**	**12.440**	**0.000**	**5.040**	**0.000**	**0.000**	**30.853**	**12.440**	**5.040**	**40.754**	**7.815**	**2.750**	**42.362**	**6.349**	**2.076**	**42.836**	**5.236**	**1.589**

	NPC	NPV water	URV, R/kl
AT 4%	**51.3**	**11.8**	**4.33**
AT 6%	**50.8**	**8.9**	**5.70**
AT 8%	**49.7**	**6.8**	**7.30**

Net present value of water supplied

Low demand scenario

Min	0	l/s
Max	69.2	l/s

YEAR	TOTAL SUPPLY (x1000 m3)	NPV of water supplied at 4% (x1000 m3)	NPV of water supplied at 6% (x1000 m3)	NPV of water supplied at 8% (x1000 m3)
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.115	0.098	0.091	0.084
2008	0.230	0.189	0.172	0.156
2009	0.345	0.272	0.243	0.217
2010	0.459	0.349	0.306	0.268
2011	0.574	0.420	0.360	0.310
2012	0.689	0.484	0.408	0.345
2013	0.804	0.543	0.449	0.372
2014	0.919	0.597	0.484	0.394
2015	1.034	0.646	0.514	0.411
2016	1.149	0.690	0.538	0.422
2017	1.263	0.730	0.559	0.430
2018	1.378	0.765	0.575	0.434
2019	1.493	0.797	0.588	0.436
2020	1.608	0.826	0.597	0.435
2021	1.723	0.850	0.604	0.431
2022	1.838	0.872	0.607	0.426
2023	1.953	0.891	0.609	0.419
2024	2.067	0.907	0.608	0.411
2025	2.182	0.921	0.606	0.401
TOTAL	**21.823**	**11.847**	**8.917**	**6.803**

ECONOMICS MODEL

9. Settlers Dam

9: Port Alfred from Settlers Dam

	Min	1.292	0	0.022	0	0												
	Max			1.282	0	0												
YEAR	COSTS						TOTAL ANNUAL COST			NET PRESENT COST AT 4%			NET PRESENT COST AT 6%			NET PRESENT COST AT 8%		
	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost	Capital	M & O	Energy cost
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	100.456						100.456	0.000	0.000	92.877	0.000	0.000	89.405	0.000	0.000	86.125	0.000	0.000
2006		1.292	0.000	0.022	0.000	0.000	0.000	1.292	0.022	0.000	1.149	0.020	0.000	1.085	0.018	0.000	1.026	0.017
2007		1.292	0.000	0.088	0.000	0.000	0.000	1.292	0.088	0.000	1.104	0.075	0.000	1.023	0.070	0.000	0.950	0.065
2008		1.292	0.000	0.155	0.000	0.000	0.000	1.292	0.155	0.000	1.062	0.127	0.000	0.965	0.116	0.000	0.879	0.105
2009		1.292	0.000	0.221	0.000	0.000	0.000	1.292	0.221	0.000	1.021	0.175	0.000	0.911	0.156	0.000	0.814	0.139
2010		1.292	0.000	0.287	0.000	0.000	0.000	1.292	0.287	0.000	0.982	0.218	0.000	0.859	0.191	0.000	0.754	0.168
2011		1.292	0.000	0.354	0.000	0.000	0.000	1.292	0.354	0.000	0.944	0.258	0.000	0.811	0.222	0.000	0.698	0.191
2012		1.292	0.000	0.420	0.000	0.000	0.000	1.292	0.420	0.000	0.908	0.295	0.000	0.765	0.249	0.000	0.646	0.210
2013		1.292	0.000	0.486	0.000	0.000	0.000	1.292	0.486	0.000	0.873	0.328	0.000	0.721	0.271	0.000	0.598	0.225
2014		1.292	0.000	0.553	0.000	0.000	0.000	1.292	0.553	0.000	0.839	0.359	0.000	0.681	0.291	0.000	0.554	0.237
2015	0.000	1.292	0.000	0.619	0.000	0.000	0.000	1.292	0.619	0.000	0.807	0.387	0.000	0.642	0.308	0.000	0.513	0.246
2016		1.292	0.000	0.685	0.000	0.000	0.000	1.292	0.685	0.000	0.776	0.411	0.000	0.606	0.321	0.000	0.475	0.252
2017		1.292	0.000	0.751	0.000	0.000	0.000	1.292	0.751	0.000	0.746	0.434	0.000	0.571	0.332	0.000	0.440	0.256
2018		1.292	0.000	0.818	0.000	0.000	0.000	1.292	0.818	0.000	0.717	0.454	0.000	0.539	0.341	0.000	0.407	0.258
2019		1.292	0.000	0.884	0.000	0.000	0.000	1.292	0.884	0.000	0.690	0.472	0.000	0.509	0.348	0.000	0.377	0.258
2020		1.292	0.000	0.950	0.000	0.000	0.000	1.292	0.950	0.000	0.663	0.488	0.000	0.480	0.353	0.000	0.349	0.257
2021		1.292	0.000	1.017	0.000	0.000	0.000	1.292	1.017	0.000	0.638	0.502	0.000	0.453	0.356	0.000	0.323	0.254
2022		1.292	0.000	1.083	0.000	0.000	0.000	1.292	1.083	0.000	0.613	0.514	0.000	0.427	0.358	0.000	0.299	0.251
2023		1.292	0.000	1.149	0.000	0.000	0.000	1.292	1.149	0.000	0.590	0.525	0.000	0.403	0.358	0.000	0.277	0.247
2024		1.292	0.000	1.216	0.000	0.000	0.000	1.292	1.216	0.000	0.567	0.533	0.000	0.380	0.358	0.000	0.257	0.242
2025	-38.524	1.292	0.000	1.282	0.000	0.000	-38.524	1.292	1.282	-16.255	0.545	0.541	-10.691	0.359	0.356	-7.086	0.238	0.236
TOTAL	**61.932**	**25.840**	**0.000**	**13.040**	**0.000**	**0.000**	**61.932**	**25.840**	**13.040**	**76.622**	**16.234**	**7.117**	**78.715**	**13.189**	**5.373**	**79.039**	**10.875**	**4.113**

	NPC	NPV water	URV, R/kl
AT 4%	**100.0**	**11.8**	**8.44**
AT 6%	**97.3**	**8.9**	**10.91**
AT 8%	**94.0**	**6.8**	**13.82**

Net present value of water supplied

Low demand scenario

Min	0	l/s		
Max	69.2	l/s		

YEAR	TOTAL SUPPLY (x1000 m3)	NPV of water supplied at 4% (x1000 m3)	NPV of water supplied at 6% (x1000 m3)	NPV of water supplied at 8% (x1000 m3)
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.115	0.098	0.091	0.084
2008	0.230	0.189	0.172	0.156
2009	0.345	0.272	0.243	0.217
2010	0.459	0.349	0.306	0.268
2011	0.574	0.420	0.360	0.310
2012	0.689	0.484	0.408	0.345
2013	0.804	0.543	0.449	0.372
2014	0.919	0.597	0.484	0.394
2015	1.034	0.646	0.514	0.411
2016	1.149	0.690	0.538	0.422
2017	1.263	0.730	0.559	0.430
2018	1.378	0.765	0.575	0.434
2019	1.493	0.797	0.588	0.436
2020	1.608	0.826	0.597	0.435
2021	1.723	0.850	0.604	0.431
2022	1.838	0.872	0.607	0.426
2023	1.953	0.891	0.609	0.419
2024	2.067	0.907	0.608	0.411
2025	2.182	0.921	0.606	0.401
TOTAL	**21.823**	**11.847**	**8.917**	**6.803**

ECONOMICS MODEL

10. PA: GW AND RO only

10: Port Alfred from RO

YEAR	Capital	Maintenance	Operation	Energy Charge	Demand Charge	Chemicals	TOTAL ANNUAL COST Capital	M & O	Energy cost	NET PRESENT COST AT 4% Capital	M & O	Energy cost	NET PRESENT COST AT 6% Capital	M & O	Energy cost	NET PRESENT COST AT 8% Capital	M & O	Energy cost
	Min	2.03	0	0.002	0	0												
	Max			2.447	0	0												
SHADOW	1.00	1.00	1.00	1.00	1.00	1.00												
2003							0	0	0	0	0	0	0	0	0	0	0	0
2004							0	0	0	0	0	0	0	0	0	0	0	0
2005	84.108						84.108	0.000	0.000	77.763	0.000	0.000	74.856	0.000	0.000	72.109	0.000	0.000
2006		2.030	0.000	0.002	0.000	0.000	0.000	2.030	0.002	0.000	1.805	0.002	0.000	1.704	0.002	0.000	1.611	0.002
2007		2.030	0.000	0.131	0.000	0.000	0.000	2.030	0.131	0.000	1.735	0.112	0.000	1.608	0.104	0.000	1.492	0.096
2008		2.030	0.000	0.259	0.000	0.000	0.000	2.030	0.259	0.000	1.669	0.213	0.000	1.517	0.194	0.000	1.382	0.177
2009		2.030	0.000	0.388	0.000	0.000	0.000	2.030	0.388	0.000	1.604	0.307	0.000	1.431	0.274	0.000	1.279	0.245
2010		2.030	0.000	0.517	0.000	0.000	0.000	2.030	0.517	0.000	1.543	0.393	0.000	1.350	0.344	0.000	1.184	0.302
2011		2.030	0.000	0.645	0.000	0.000	0.000	2.030	0.645	0.000	1.483	0.472	0.000	1.274	0.405	0.000	1.097	0.349
2012		2.030	0.000	0.774	0.000	0.000	0.000	2.030	0.774	0.000	1.426	0.544	0.000	1.202	0.458	0.000	1.016	0.387
2013		2.030	0.000	0.903	0.000	0.000	0.000	2.030	0.903	0.000	1.371	0.610	0.000	1.134	0.504	0.000	0.940	0.418
2014		2.030	0.000	1.031	0.000	0.000	0.000	2.030	1.031	0.000	1.319	0.670	0.000	1.069	0.543	0.000	0.871	0.442
2015	0.000	2.030	0.000	1.160	0.000	0.000	0.000	2.030	1.160	0.000	1.268	0.725	0.000	1.009	0.577	0.000	0.806	0.461
2016		2.030	0.000	1.289	0.000	0.000	0.000	2.030	1.289	0.000	1.219	0.774	0.000	0.952	0.604	0.000	0.746	0.474
2017		2.030	0.000	1.418	0.000	0.000	0.000	2.030	1.418	0.000	1.172	0.819	0.000	0.898	0.627	0.000	0.691	0.483
2018		2.030	0.000	1.546	0.000	0.000	0.000	2.030	1.546	0.000	1.127	0.859	0.000	0.847	0.645	0.000	0.640	0.487
2019		2.030	0.000	1.675	0.000	0.000	0.000	2.030	1.675	0.000	1.084	0.894	0.000	0.799	0.659	0.000	0.593	0.489
2020		2.030	0.000	1.804	0.000	0.000	0.000	2.030	1.804	0.000	1.042	0.926	0.000	0.754	0.670	0.000	0.549	0.487
2021		2.030	0.000	1.932	0.000	0.000	0.000	2.030	1.932	0.000	1.002	0.954	0.000	0.711	0.677	0.000	0.508	0.484
2022		2.030	0.000	2.061	0.000	0.000	0.000	2.030	2.061	0.000	0.964	0.978	0.000	0.671	0.681	0.000	0.470	0.478
2023		2.030	0.000	2.190	0.000	0.000	0.000	2.030	2.190	0.000	0.926	0.999	0.000	0.633	0.683	0.000	0.436	0.470
2024		2.030	0.000	2.318	0.000	0.000	0.000	2.030	2.318	0.000	0.891	1.017	0.000	0.597	0.682	0.000	0.403	0.461
2025	-31.744	2.030	0.000	2.447	0.000	0.000	-31.744	2.030	2.447	-13.395	0.857	1.033	-8.809	0.563	0.679	-5.839	0.373	0.450
TOTAL	**52.364**	**40.600**	**0.000**	**24.490**	**0.000**	**0.000**	**52.364**	**40.600**	**24.490**	**64.368**	**25.507**	**13.299**	**66.047**	**20.723**	**10.011**	**66.270**	**17.087**	**7.639**

	NPC	NPV water	URV, R/kl
AT 4%	**103.2**	**11.8**	**8.71**
AT 6%	**96.8**	**8.9**	**10.85**
AT 8%	**91.0**	**6.8**	**13.38**

Net present value of water supplied

Low demand scenario

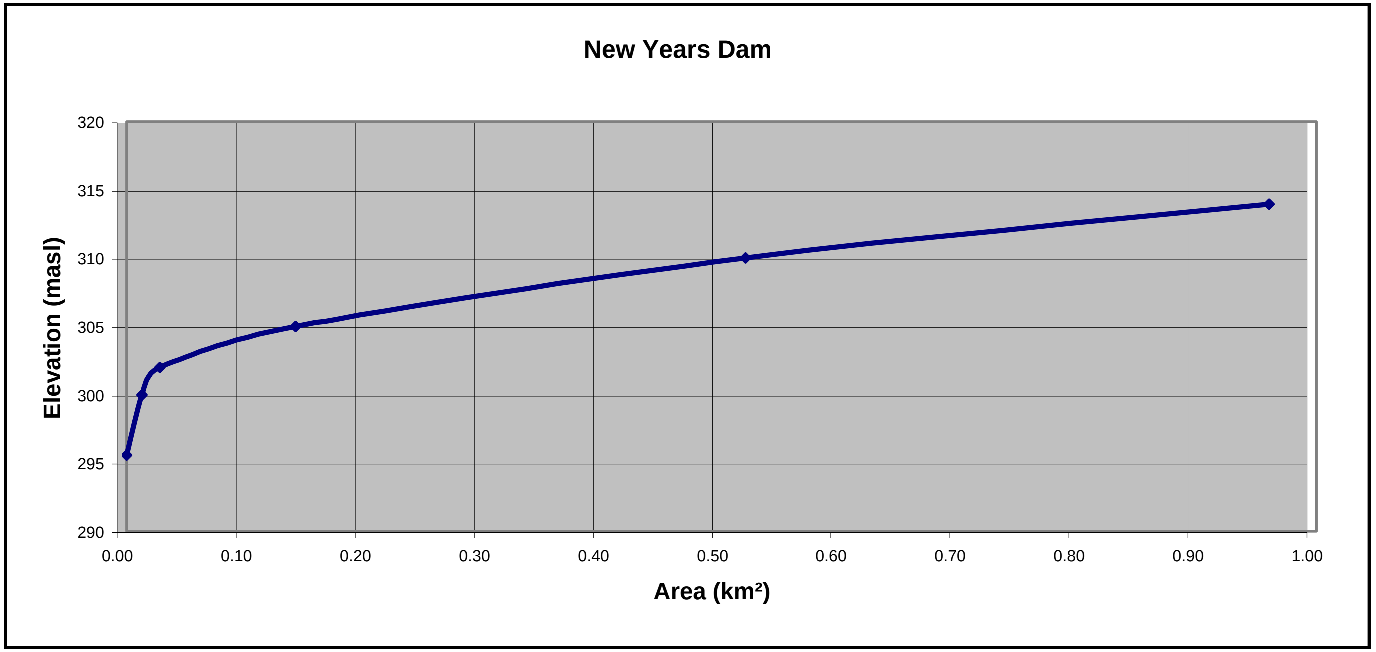
Min	0	l/s		
Max	69.2	l/s		

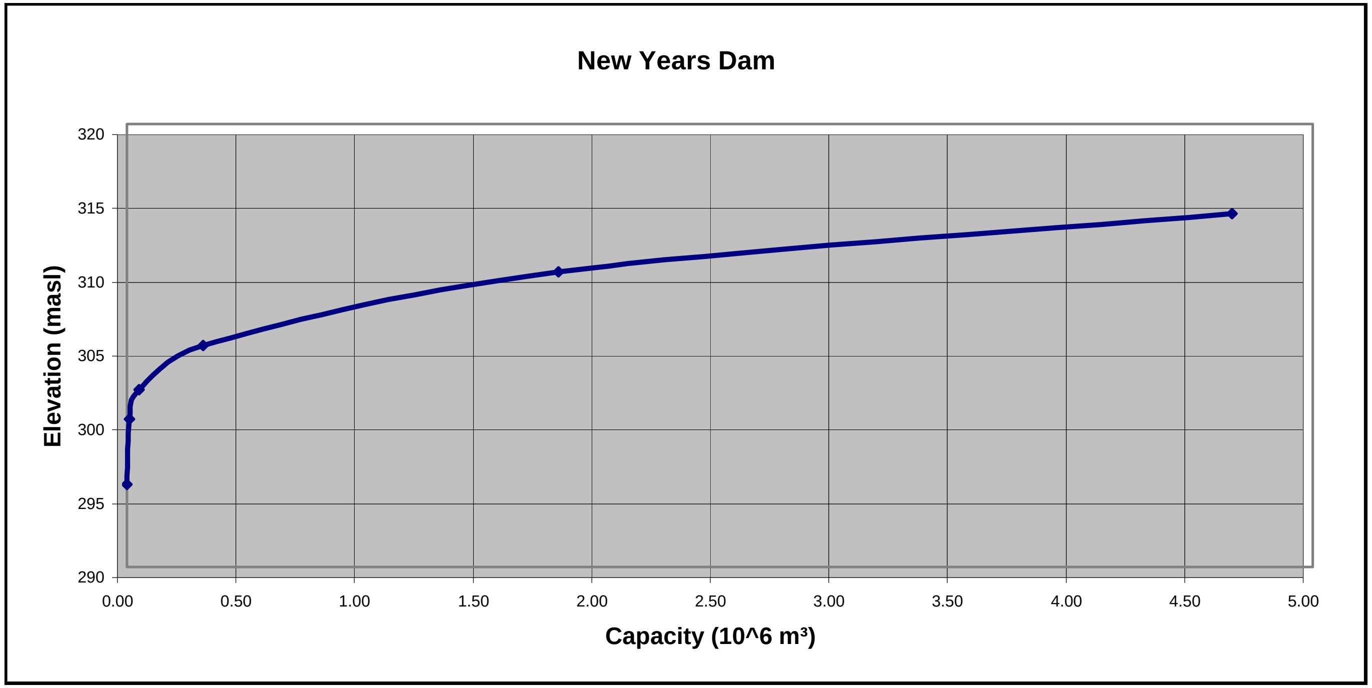
YEAR	TOTAL SUPPLY (x1000 m3)	NPV of water supplied at 4% (x1000 m3)	NPV of water supplied at 6% (x1000 m3)	NPV of water supplied at 8% (x1000 m3)
2003				
2004				
2005				
2006	0.000	0.000	0.000	0.000
2007	0.115	0.098	0.091	0.084
2008	0.230	0.189	0.172	0.156
2009	0.345	0.272	0.243	0.217
2010	0.459	0.349	0.306	0.268
2011	0.574	0.420	0.360	0.310
2012	0.689	0.484	0.408	0.345
2013	0.804	0.543	0.449	0.372
2014	0.919	0.597	0.484	0.394
2015	1.034	0.646	0.514	0.411
2016	1.149	0.690	0.538	0.422
2017	1.263	0.730	0.559	0.430
2018	1.378	0.765	0.575	0.434
2019	1.493	0.797	0.588	0.436
2020	1.608	0.826	0.597	0.435
2021	1.723	0.850	0.604	0.431
2022	1.838	0.872	0.607	0.426
2023	1.953	0.891	0.609	0.419
2024	2.067	0.907	0.608	0.411
2025	2.182	0.921	0.606	0.401
TOTAL	**21.823**	**11.847**	**8.917**	**6.803**

APPENDIX 11

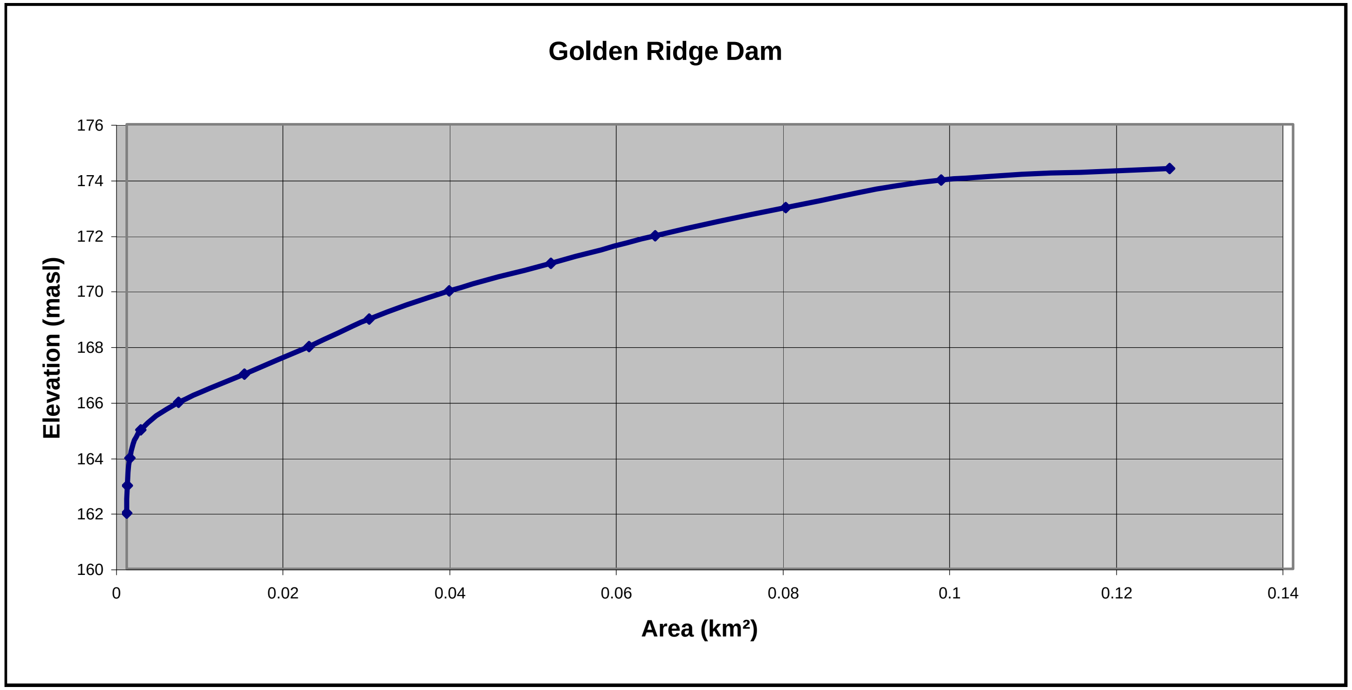
ELEVATION – AREA/CAPACITY CURVES FOR DAMS

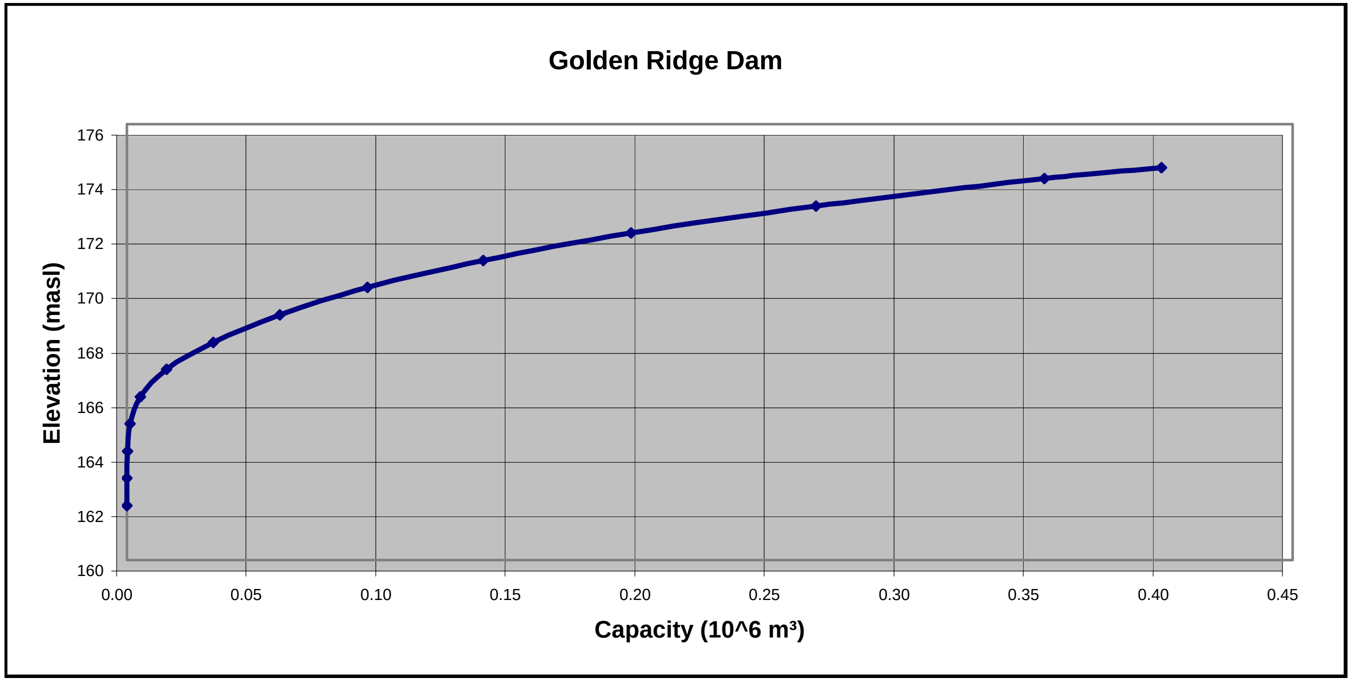
Elevation (masl)	Area (km²)	Capacity (10^6 m^3)
New Years Dam		
295.6	0	0.000
300	0.013	0.010
302	0.028	0.050
305	0.142	0.320
310	0.520	1.820
313.94	0.960	4.660



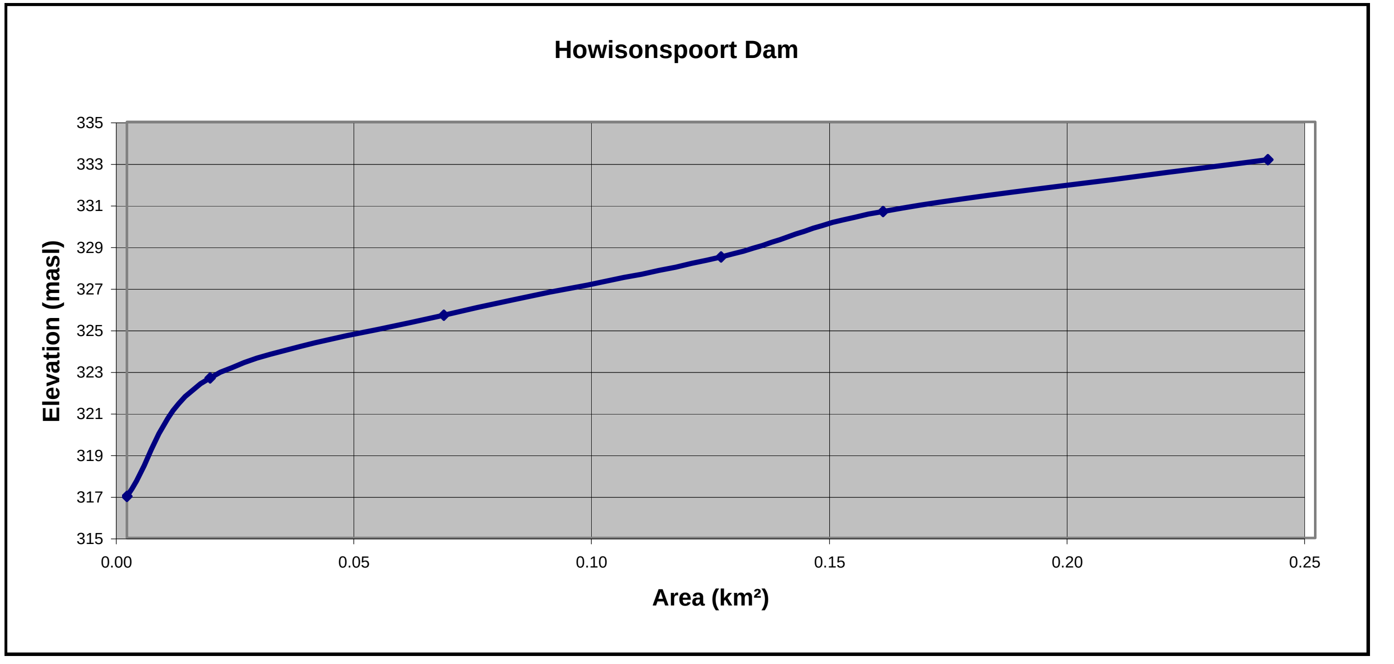


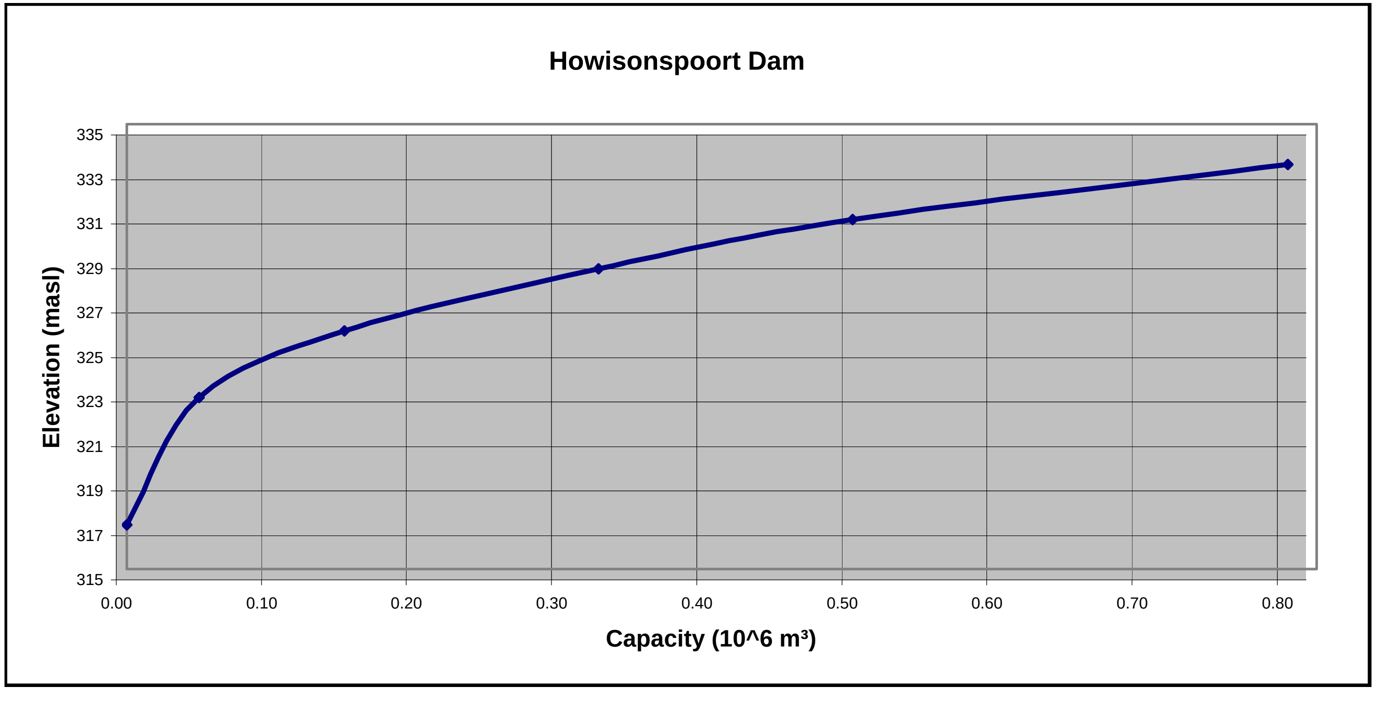
Elevation (masl)	Area (km²)	Capacity (10^6 m^3)
Golden Ridge Dam		
162	6.10E-07	0.000
163	9.27E-05	0.000
164	0.0004	0.000
165	0.0017	0.001
166	0.0062	0.005
167	0.0141	0.015
168	0.0219	0.033
169	0.0291	0.059
170	0.0387	0.093
171	0.0509	0.138
172	0.0634	0.195
173	0.0791	0.266
174	0.0978	0.354
FSL 174.41	0.1252	0.399



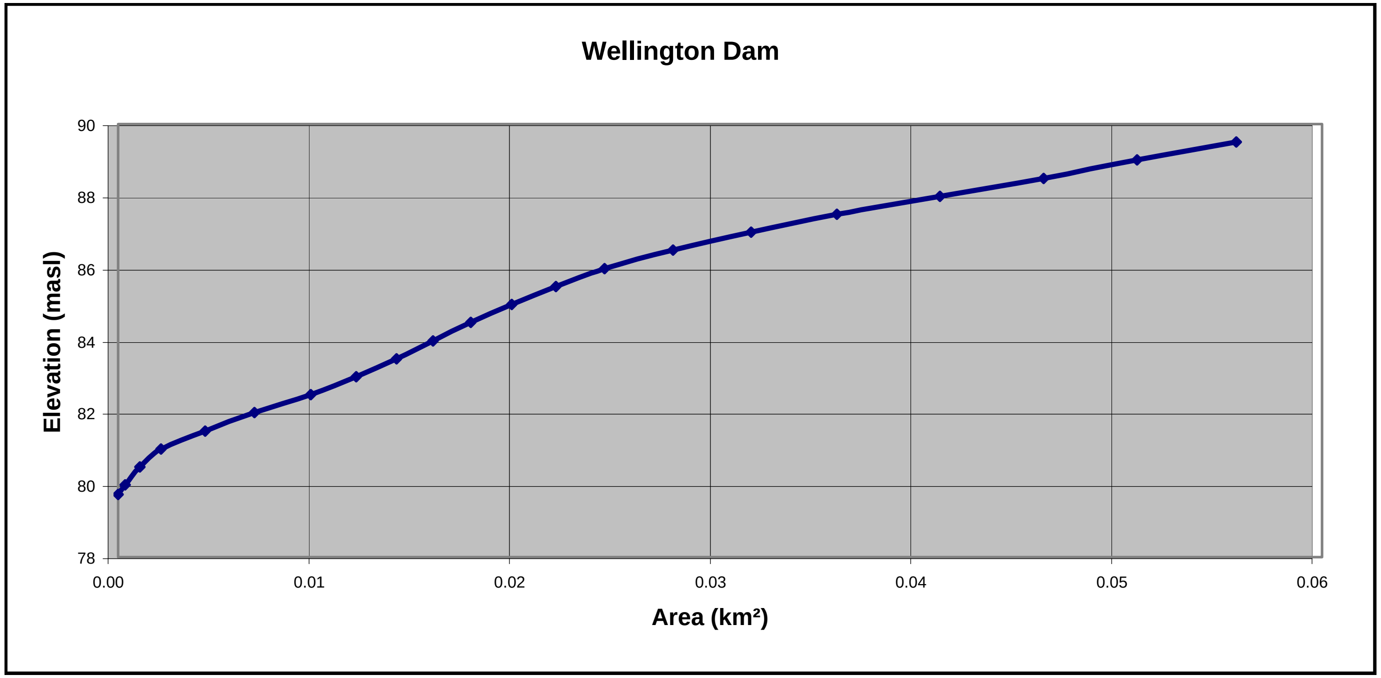


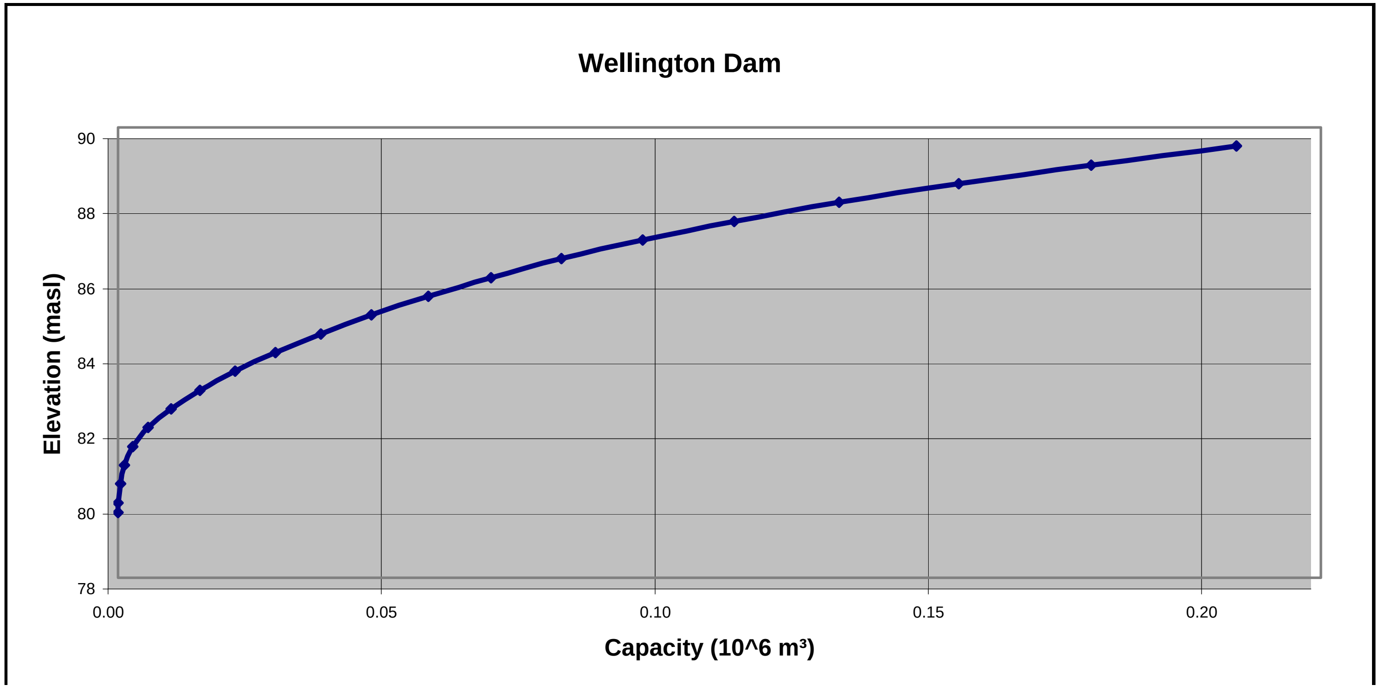
Elevation (masl)	Area (km²)	Capacity (10^6 m^3)
Howisonspoort Dam		
317	0	0.0000
322.7	0.0175	0.0500
325.7	0.0667	0.1500
328.5	0.1250	0.3250
330.7	0.1591	0.5000
333.2	0.2400	0.8000



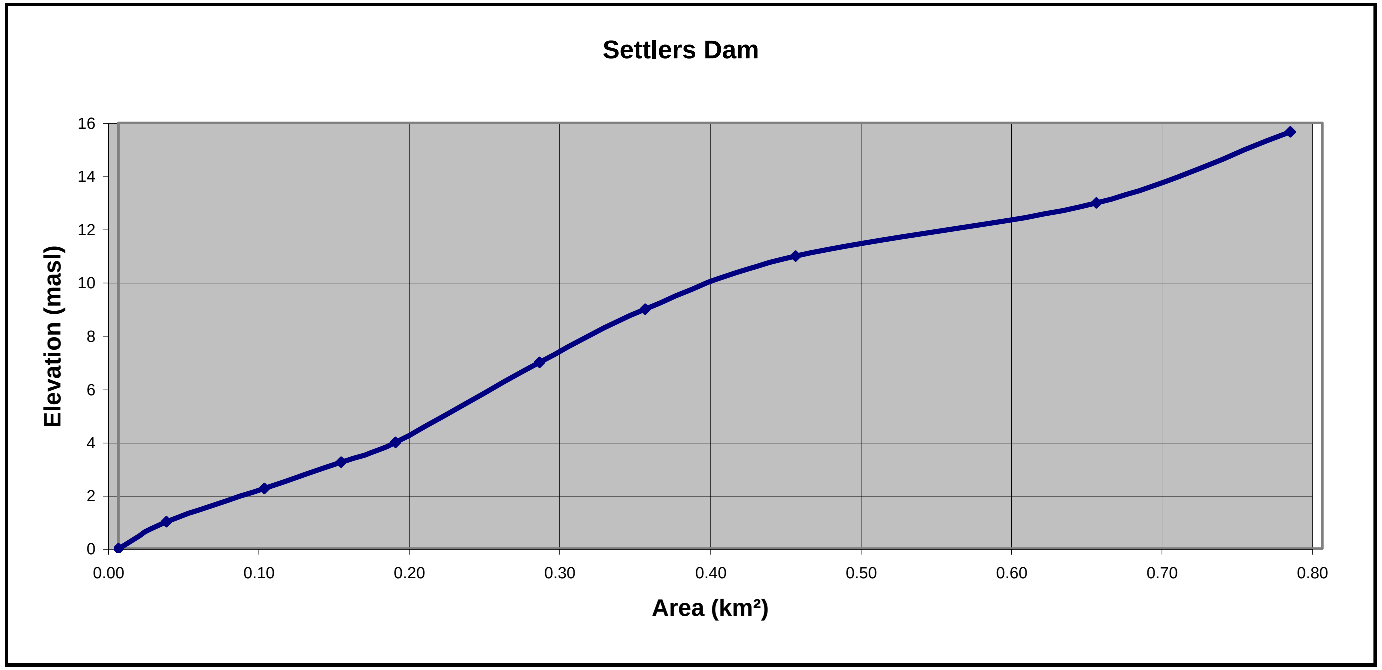


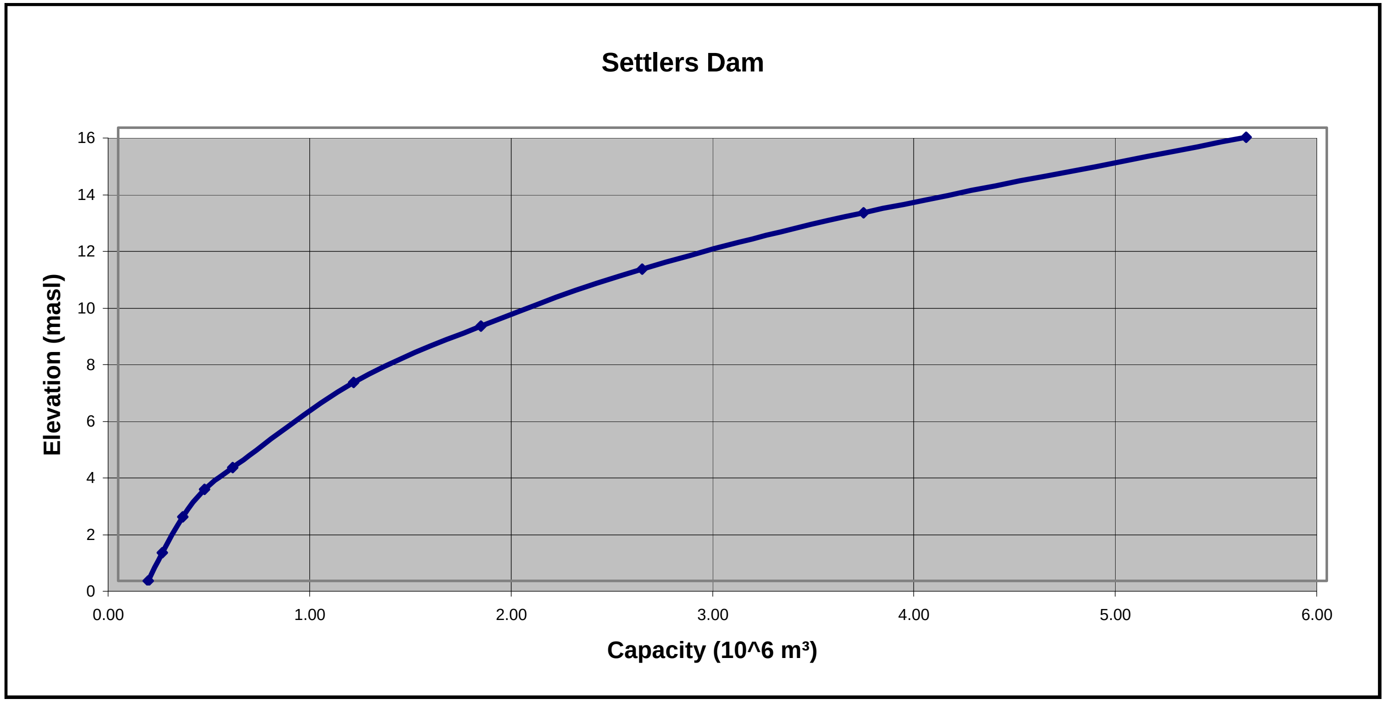
Elevation (masl)	Area (km²)	Capacity (10^6 m^3)
Wellington Dam		
79.74	0	0.000
80.0	0.000	0.000
80.5	0.001	0.000
81.0	0.002	0.001
81.5	0.004	0.003
82.0	0.007	0.005
82.5	0.010	0.010
83.0	0.012	0.015
83.5	0.014	0.021
84.0	0.016	0.029
84.5	0.018	0.037
85.0	0.020	0.046
85.5	0.022	0.057
86.0	0.024	0.068
86.5	0.028	0.081
87.0	0.032	0.096
87.5	0.036	0.113
88.0	0.041	0.132
88.5	0.046	0.154
89.0	0.051	0.178
89.5	0.056	0.205



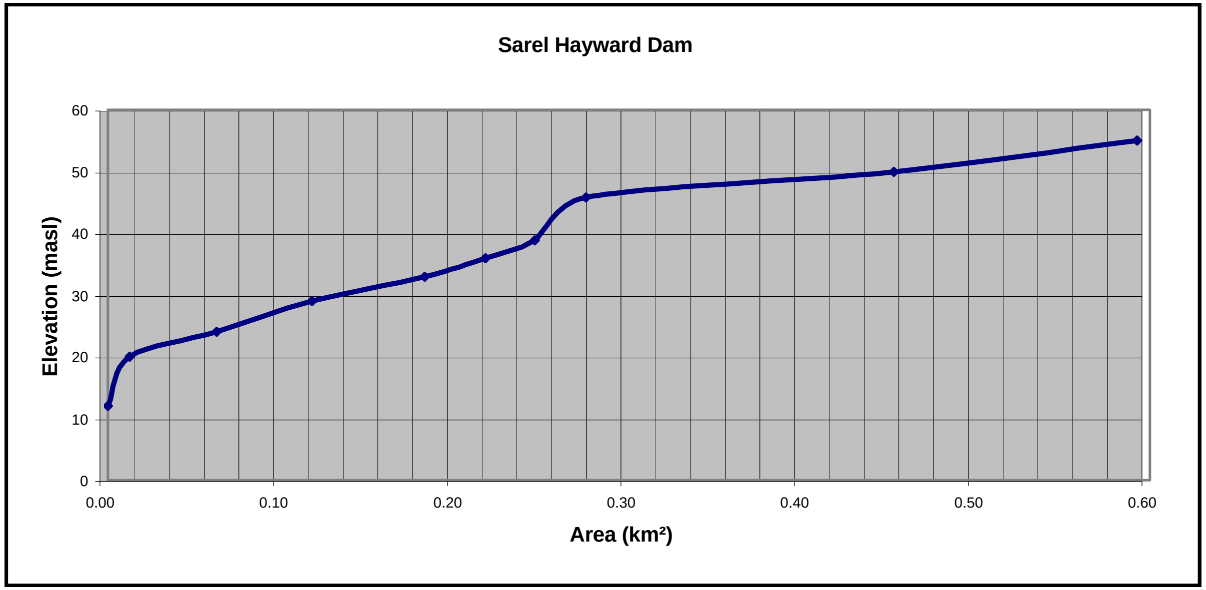


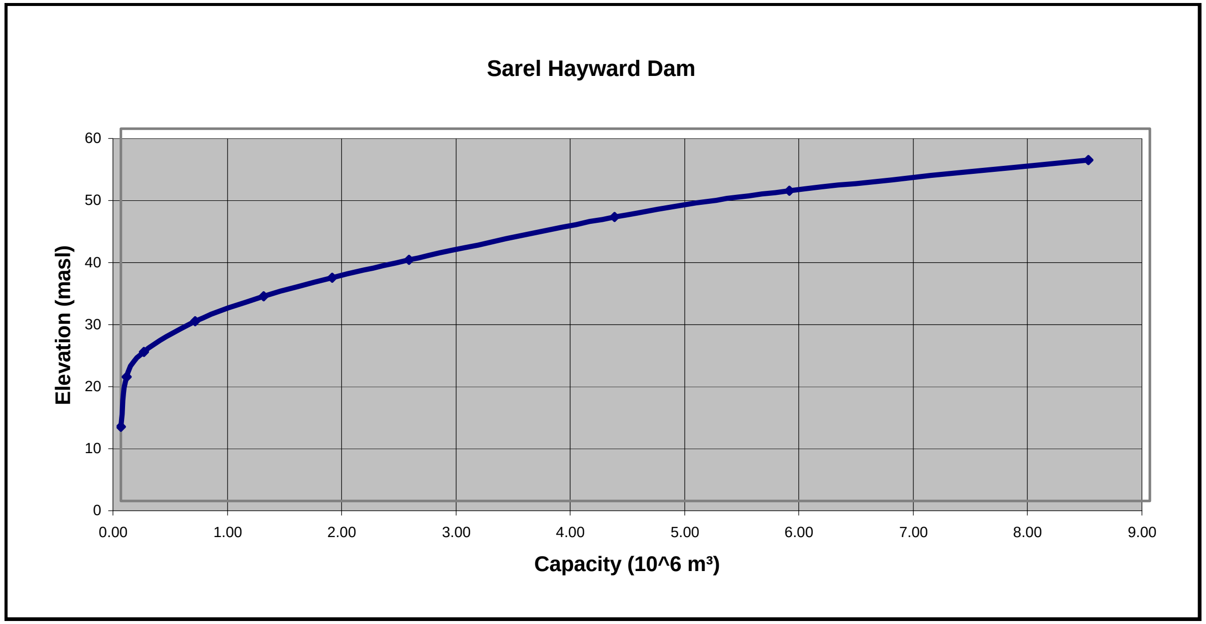
Elevation (masl)	Area (km²)	Capacity (10^6 m^3)
Settlers Dam		
0	0	0.150
1	0.032	0.220
2.25	0.097	0.320
3.24	0.148	0.430
4	0.184	0.570
7	0.280	1.170
9	0.350	1.800
11	0.450	2.600
13	0.650	3.700
15.66	0.779	5.600



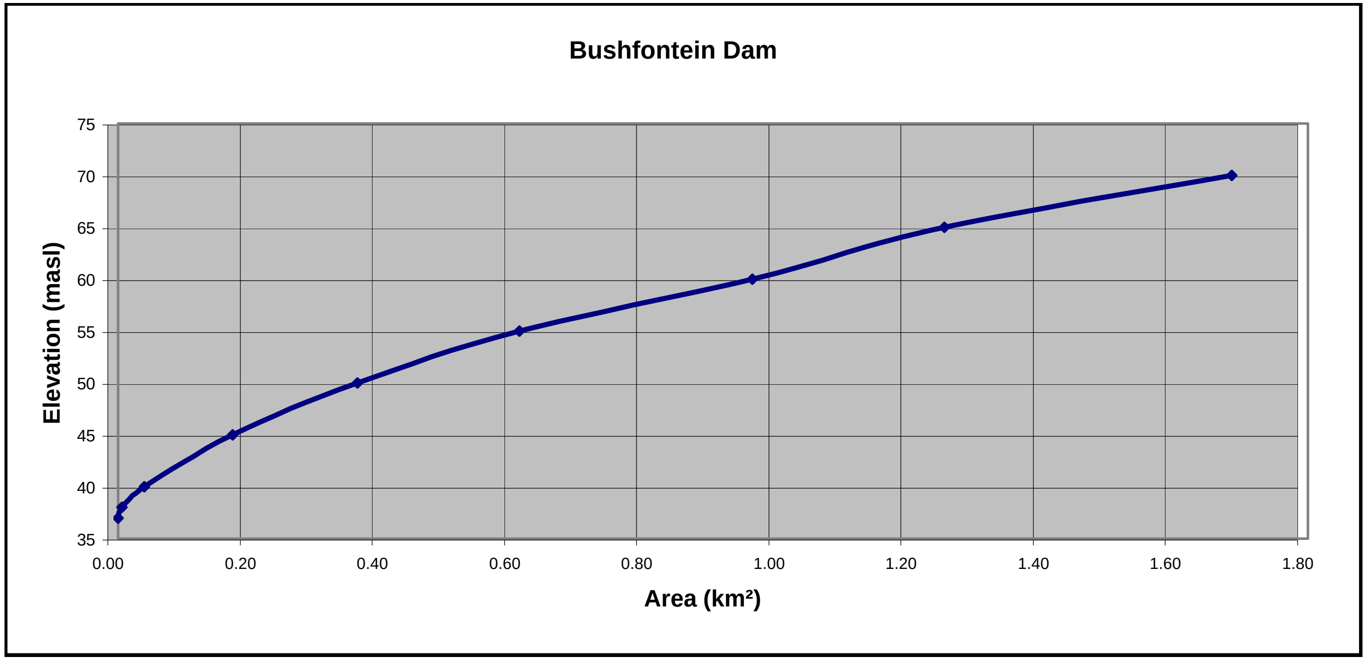


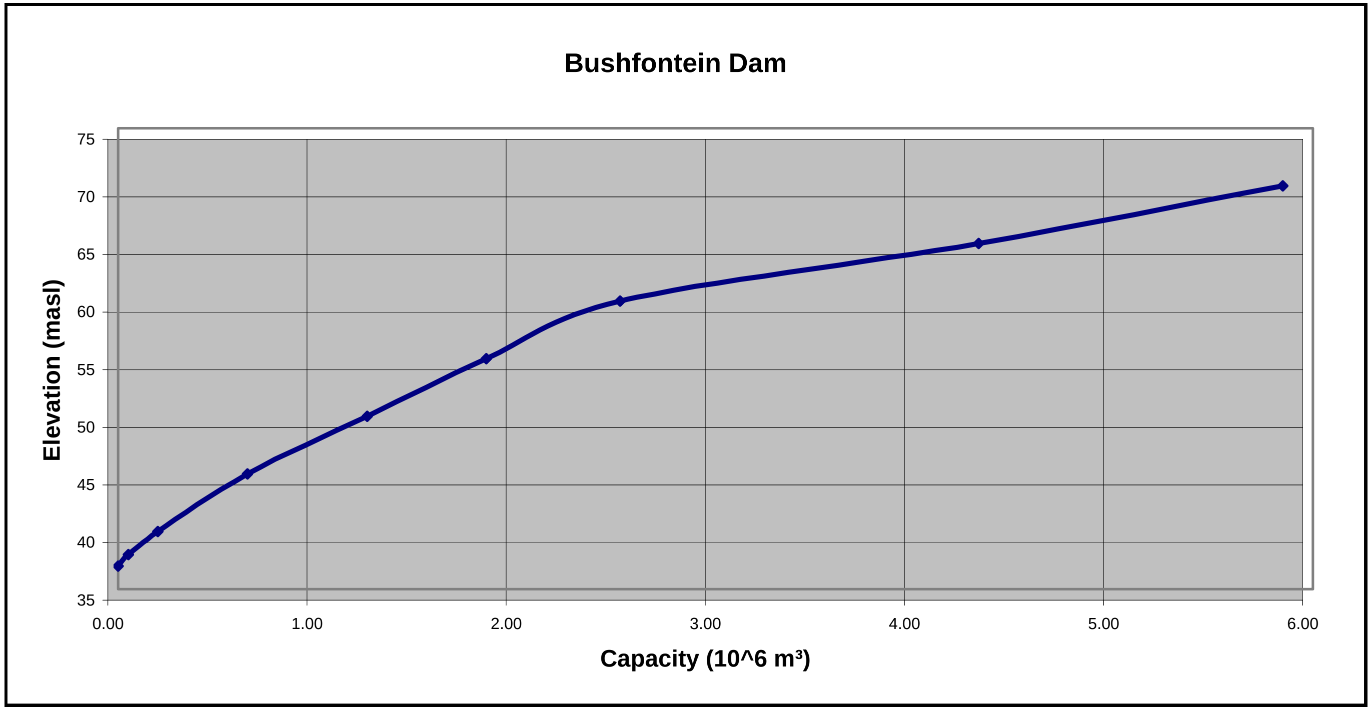
	Elevation (masl)	Area (km²)	Capacity (10^6 m^3)
	Sarel Hayward Dam		
	12	0	0.0000
	20	0.0125	0.0500
	24	0.0625	0.2000
	29	0.1175	0.6500
	33	0.1825	1.2500
	36	0.2175	1.8500
FSL	38.9	0.2459	2.5220
	45.8	0.2752	4.3200
	50	0.4524	5.8480
	55	0.5926	8.4600





Elevation (masl)	Area (km²)	Capacity (10^6 m^3)
Bushfontein Dam		
37	0	0.000
38	0.006	0.050
40	0.040	0.200
45	0.173	0.650
50	0.362	1.250
55	0.607	1.850
60	0.960	2.522
65	1.250	4.320
70	1.685	5.848





APPENDIX 12

STAKEHOLDER MEETINGS

Department of Water Affairs & Forestry
Directorate Water Resources Planning

Albany Coast Situation Assessment Study

Stakeholder Meeting

30 October 2003

UWPEngineers

Agenda

- Introduction by DWAF: TG
- Project team
- Scope of study
- Lines of communication
- Inputs by stakeholders
- Closure

2 UWPEngineers

Purpose of meeting

- To launch the study
- To introduce the stakeholders
- To present the scope of services and program
- To obtain inputs from the stakeholders
- To establish the channels for communication

3 UWPEngineers

Study Team

Client - DWAF

- Directorate : Water Resources Planning
- Chief Directorate : EC Region

Consultants

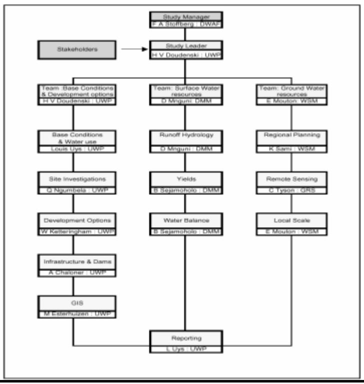
UWP Consulting - lead consultant

In association with:

Water Systems Management
DMM Development Consultants

4 UWPEngineers

Study organisational chart



5 UWPEngineers

Main Stakeholders

- DWAF
- Cacadu DM
- Ndlambe LM
- Albany Coast Water Board
- Department of Environmental Affairs
- Various consultants and service providers
- Beneficiaries: DM, LM, water users

6 UWPEngineers

Purpose of study

- To provide a solution to the water supply problems of the coastal towns:

  Port Alfred, Bathurst, Kleinemonde, Kenton-on-Sea, Bushmans River Mouth, Boknes, Cannon Rock, and Alexandria

- Problems currently experienced relate to:

  Inadequate water sources, or poor water quality, and/or infrastructure capacity

7 UWPEngineers

Scope of services

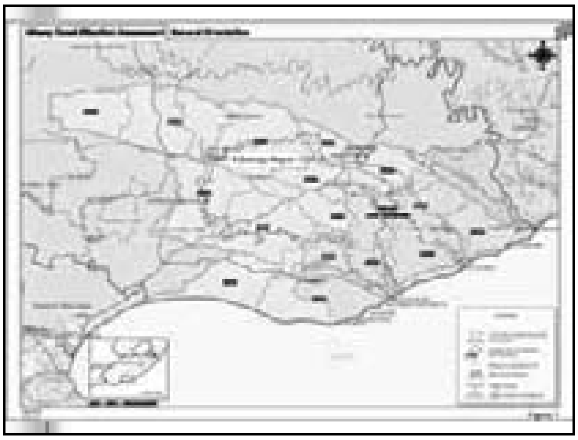
- Investigate at reconnaissance level the water supply problems in the study area
- Consider relevant conditions in catchment
- Consider possible solutions suitable for immediate implementation
- Compile an implementation strategy
- If necessary, outline the scope of further investigations or studies

8 UWPEngineers

Study area

- Focus on coastal belt (Ndlambe)
- But, consider water resources situation in entire P catchment

9 UWPEngineers



Methodology

- Study to be undertaken in two phases:
  - Situation assesment study
  - Development option study

11 UWPEngineers

Situation Assessment

- Obtain and collate information
- Overview of water supply at coastal towns
- Surface water resources for P catch.
- Ground water resouces
- Conceptual level development options for coastal belt
- Presentation of interim results

12 UWPEngineers

Development Options

- More detailed studies on development options
  - Water requirements
  - Demand management and conservation
  - Water sources: surface and ground
  - Infrastrure
  - Evaluate options
- Implementation strategy
- Recommendations and reports

13 UWPEngineers

Base Conditions: General

- Study and verify information
- Development status of study area
- Water supply infrastructure
- Agricultural developments and afforestation
- Overview of water conservation and demand management measures

14 UWPEngineers

Water Requirements

- Urban and industrial
- Rural domestic
- Agricultural
- Afforestation and alien vegetation
- Ecological
- Return flows

15 UWPEngineers

Surface Water Resources

- Stream flow hydrology for the entire catchment based on WR90
- Base flows hydrology for specific development sites
- Yield analysis for selected dam development sites

16 UWPEngineers

Ground Water Resources

- Regional scale study (desk study)
  Estimate reserve, use, assess option for development
- Local scale study: hydrocensus
  Field work, local scale exploration potential, siting of potential targets
- GIS and remote sensing
  Assessment of seepage and fructured zones exploration potential based on satellite immagery

17 UWPEngineers

Development Options

- Estimate and project requirements
- Assess existing water sources and bulk infrastructure
- Review previously identified options
- Identify new development options
- Consider water demand mnmgt
- Conceptual sizing and costing
- Evaluate options and select best
- Compile implementation strategy

18 UWPEngineers

Study programme

- Study staretd in October 2003
- Situation assessment and interim results - end February 2004
- Development options study and draft report – end May 2004
- Copmletion of study – end Sep 2004

19 UWPEngineers

Stakeholder Imputs

- Imputs and co-operation from stakeholders will be very valuable
- Consultants to approach stakeholders for information and comments
- Channels of communication

20 UWPEngineers

Thank you

21 UWPEngineers

ALBANY COAST WATER RESOURCE SITUATION ASSESSMENT: STAKEHOLDER MEETING, 30 OCTOBER 2003, NLAMBE MUNICIPALITY COUNCIL CHAMBERS, PORT ALFRED

	NAME	ORGANISATION	TEL. No.	FAX No.	E-MAIL	SGN/INIT.
	T.J. GELDENHUYS	DWAF, S. REGION	048-881 3005	048-881 3545	geldent@dwaf.gov.za	[signature]
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4	B.B. SWAYENA	D.W.A.F (K.W.T)	043-6045451	043-6045587	swayenb@dwaf.gov.za	[signature]
5	H.H. GOOSSENS	DWAF (KWT)	043-6045445	043-6045587	GoosseH@kwt.dwaf.gov.za	[signature]
6	F.S. Botha	DWAF (H.O.)	012 336 8835	012 336 7774	IFK@dwaf.gov.za	[signature]
7	Z.T Peteni-Kave	DWAF (HO)	(012) 3368526	(012) 3368295	ifj@dwaf.gov.za	[signature]
8	F.A. STOFFBERG	DWAF_NWRP (South)	012.336.8319	012.336.8295	ica@dwaf.gov.za	[signature]
9	P SNYMAN	CDM	041-5087335	041-5087276	psnyman@cacadu.co.za	[signature]
10	V. RAPIYA	CDM (CMIP)	041-5087264	041-5087276	cmip@cacadu.co.za	[signature]
11	E. Moulton	WSM (Pty) Ltd	(083)573-5805 (046)648-1181	(046)648-1181	wsmec@mweb.co.za	[signature]
12	R. BALL	ALBANY COAST WATER	046-6481233	046 6481552	ALBWATER@BORDER.CO.ZA	[signature]
13	W. KETTERINGHAM	UWP - EAST LONDON	043-7030186	043-7030288	wayne.k@uwp.co.za	[signature]
14	D. Bahrmann	DWAF(Pta) NWRP	012-3368195	012-3368295	icf@dwaf.gov.za	[signature]
15	Christo Dordenski	UWP Consulting	012 6649232	012 6647870	christo.d@uwp.co.za	[signature]
16						

23821/4

Rudi Louwrens

From: Geldenhuys Theo (CDK) [GeldenT@dwaf.gov.za]

Sent: 28 July 2004 16:04

To: psnyman@cacadu.co.za; crenze@cacadu.co.za; dcockcroft@ndlambe.co.za; bpatterson@ndlambe.co.za; dklassen@ndlambe.co.za; gngesi@ndlambe.co.za; Coetzee Dewald (KWT); Botha Fanie; Peteni-Kave Zimkitha; Baron Jane (PLZ); Cobban Dale (KWT); Van Vliet Henk (KWT); Mbambisa Galelo (KWT); Behrmann Dennis; Keke Zolile Hamilton (KWT); KETTERINGHAM WAYNE (wayne.k@uwp.co.za); Lucas Andrew (East London); Stoffberg Frans; ALBANY COAST WB (albwater@border.co.za); MOUTON ETIENNE (wsmec@telkomsa.net); sfick@intekom.co.za; deedeejp@telkomsa.net; agouws@ndlambe.co.za; mktshungu@makana.gov.za; Goossens Herman (KWT); luciusm@sanparks.org; luciusm@parks-sa.co.za; nollieb@parks-sa.co.za; nollieb@sanparks.org; sholness@upe.ac.za; coastal@upe.ac.za; tom.bornman@upe.ac.za; scarrn@eetrepc.ecape.gov.za

Cc: christo.d@uwp.co.za; rudi.l@uwp.co.za

Subject: ALBANY COAST WATER RESOURCES SITUATION ASSESSMENT STUDY: STAKEHOLDER MEETING, REPORT BACK

ALBANY COAST WATER RESOURCES SITUATION ASSESSMENT STUDY: STAKEHOLDER MEETING, REPORT BACK

1. **BACKGROUND**: - Consultants for the Department of Water Affairs and Forestry (DWAF) are in the process of completing a water situation assessment study of the Albany Coast Region to identify, for further detailed investigation by the Ndlambe Local and/or Cacadu District Municipality, the best possible options for augmenting the water supplies t the coastal towns in the area. This study has been necessitated as a result of the periodic shortages in an acceptable quality of water, especially during the holiday seasons and particularly during summer. The area identified for investigation stretches from Kleinemonde to Cannon Rocks/Alexandria … the Albany Coast.

2. This proposed meeting, to be held with all the relevant stakeholders in the study area, is in order to inform those involved persons on, and to present, the results of the study and to accept for consideration any final comments.

3. The **meeting of stakeholders** is to be held in the **NDLAMBE MUNICIPAL COUNCIL CHAMBERS, BERGAM BUILDING, PORT ALFRED on Thursday 26 August 2004 at 10:00** and should be completed by 13:00.

4. Travel arrangements to and from the meeting will be each attendees own responsibility.

5. **RSVP** to e-mail: - christo.d@uwp.co.za or to Tel. No. 012-664 9232 or to Fax 012-664 7870 … **by Friday 13 August 2004**.

6. All are also requested to accordingly inform, or invite, any other person who may be interested and/or affected by the outcomes of this study.

Theo Geldenhuys, Water Use Management
Department of Water Affairs & Forestry, Eastern Cape Region
Private Bag X 68, CRADOCK, 5880
Fax:- 048-881 3545 Tel.:- 048-881 3005
Cell.:- 082-808 0499 E-mail:- geldent@dwaf.gov.za

Department of Water Affairs & Forestry
Directorate National Water Resources Planning

Albany Coast Situation Assessment Study

Presentation to Stakeholders

26 August 2004

UWPEngineers

Agenda

- Introduction
- Presentation of interim results
- Inputs by stakeholders
- Way forward

2 UWPEngineers

Study Team

Client - DWAF

- Directorate : Water Resources Planning
- Chief Directorate : EC Region

Consultants

UWP Consulting - lead consultant

In association with:

Water Systems Management (Geohydrology)
DMM Development Consultants (Hydrology)

3 UWPEngineers

Purpose of study

- To provide a solution to the severe water supply problems at certain coastal towns:
  Alexandria, Boknes, Canon Rocks, Kenton-on-Sea, Port Alfred, Kleinemonde and Bathurst
- Current problems relate to:
  - High growth rates in coastal areas
  - High holiday peak water usage
  - Inadequate sources: quality and quantity
  - Limited infrastructure capacity

4 UWPEngineers

Scope of Study

- Water resources situation assessment for the entire P drainage region
- Assess in detail the water supply situation at the coastal towns
- Evaluate possible solutions that can lead to fast-track implementation

5 UWPEngineers

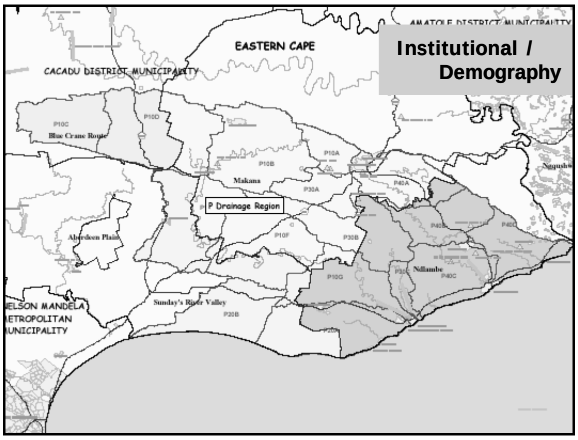
Purpose of presentation

- To present the interim results from this reconnaissance study
- To obtain guidance and input from the stakeholders in terms of the way forward

6 UWPEngineers

WATER RESOURCES SITUATION ASSESSMENT

7

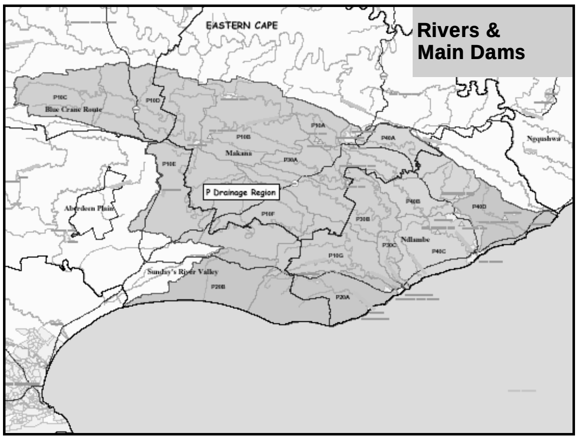


Basic info

- Total area of P region is 5 300 km^2.
- Elevation from 0 to 1000 m amsl
- MAP from 400 to 715 mm/a
- 3 main rivers and 4 main dams
- Geology: saline shales affect quality
- Land use: dry land agric and grazing
- Population 140 000 growing to 170 000 in 20 years, mostly urban
- Coastal areas of high ecological value

9

UWPEngineers



Water requirements per user sector in P drainage region

User Sector	Water Requirements ($10^6 m^3/a$) 2001	2005	2015	2025	Distribution, % 2001	2025
Urban domestic and industrial	7.88	9.95	12.35	13.89	34.7	48.4
Rural domestic	0.40	0.42	0.42	0.39	1.7	1.3
Stock watering	1.67	1.67	1.67	1.67	7.3	5.8
Irrigation	12.78	12.78	12.78	12.78	56.2	44.5
Total consumptive requirements	**22.73**	**24.82**	**27.22**	**28.72**	**100.0**	**100.0**
Total usage from inter basin transfers, return flows & GW	-6.63	-8.09	-9.26	-9.96	-29.2	-34.7
Total use from surface water	**16.10**	**16.73**	**17.96**	**18.76**	**-70.8**	**-65.3**

11

UWPEngineers

Surface Water yield per tertiary catchment

Tertiary Catchment	River	Area	Naturalised MAR	Yield no prov for ER	Yield prov for ER
		km^2	$x10^6 m^3$	$x10^6 m^3$	$x10^6 m^3$
P10	Bushmans	2757	57.94	2.740	0.570
P20	Boknes	754	45.64	0.103	0.006
P30	Kariega	647	20.25	0.000	0.000
P40	Kowie	1164	49.21	4.170	4.050
TOTAL		**5322**	**173.04**	**7.013**	**4.626**

12

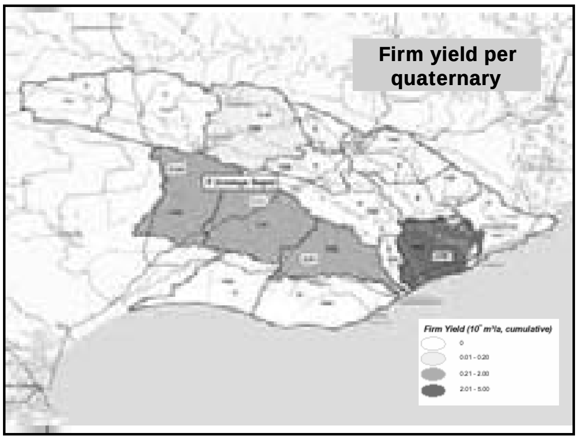
UWPEngineers

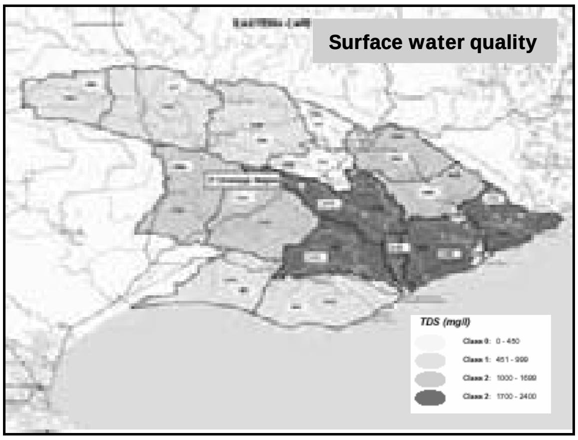
Surface Water Resources

- The total natural MAR is 173 x10^6 m^3/a
- Area has a positive water balance, but total available yield is only 4 x10^6 m^3/a
- Surface water quality in middle / lower reaches is poor: TDS 1000 to 2500
- RoR schemes not feasible due to low yield and poor water quality
- Development of local SW is not favourable

13

UWPEngineers





Ground Water

- Existing use of groundwater is low
- Coastal aquifers are currently used. Yields are low to moderate 3 l/s to 5 l/s
- Drilling depths vary 100 m to 180 m
- Success rates 30% to 60%
- Water quality varies: TDS 700 to 2000
- Areas with high potential for GW development identified during study and exploration drilling done
- In cases GW development is favourable

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UWPEngineers

DEVELOPMENT OPTIONS

17

Water requirements per affected town

- Based on the Mark Data methodology
- Population data as per Census 2001
- Known new developments accounted for
- No data about losses in the distribution systems is available
    - Due to source deficit water is being used wisely: rainfall harvest tanks, etc
    - Assumed best water demand management practices

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UWPEngineers

Population numbers per town

Quaternary	Town	Urban Population			
		2001	2005	2015	2025
P10B	Riebeeck East	689	703	687	652
P10D	Alicedale	5,950	6,070	5,930	5,635
P10E	Paterson	4,404	4,493	4,387	4,172
P10G	Kenton/Bushmans	9,480	12,745	13,734	14,539
P20A	Alexandria	7,715	8,371	9,178	8,720
	Canon Rocks/ Boknes	931	1,422	2,573	2,949
P40A	Grahamstown	61,759	64,370	66,387	66,591
P40C	Port Alfred	20,965	27,526	35,376	40,542
	Bathurst	5,549	6,497	6,445	6,227
P40D	Kleinmonde	1,450	1,833	2,156	2,471
Total urban population		**118,892**	**134,029**	**146,855**	**152,499**

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Water requirements per town

Town	Total gross water requirements				Exist. source	Growth	Deficit
	million m^3/a				mil m^3/a	%	%
	2001	2005	2015	2025	2005	05 to 25	in 2005
Kenton On Sea/ Bushmans	0.66	0.91	1.21	1.49	0.58	64%	-56%
Alexandria	0.52	0.62	0.79	0.76	0.60	23%	-3%
Canon/Boknes	0.18	0.25	0.46	0.53	0.24	109%	-5%
Port Alfred	1.27	2.16	3.04	3.90	1.73	81%	-25%
Buthurst	0.26	0.34	0.39	0.41	0.30	23%	-12%
Kleinmonde	0.05	0.08	0.12	0.16	0.11	88%	23%
SUBTOTAL	**2.93**	**4.36**	**6.02**	**7.25**	**3.56**	66%	-22%
Grahamstown	4.51	5.00	5.65	5.97	8.60	19%	42%
TOTAL STUDY AREA	**7.44**	**9.35**	**11.67**	**13.22**	**12.16**	41%	23%

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Development Options: Assumptions

- Existing source and infrastructure used
- New infrastructure includes: source, bulk conveyance system, WTW, and reservoirs
- System sized to supply summer peaks
- System has not been optimised (conveyance – balancing reservoirs)
- Where possible all development options based on conjunctive GW/SW use
- This will allow the necessary time for further studies related to larger SW development

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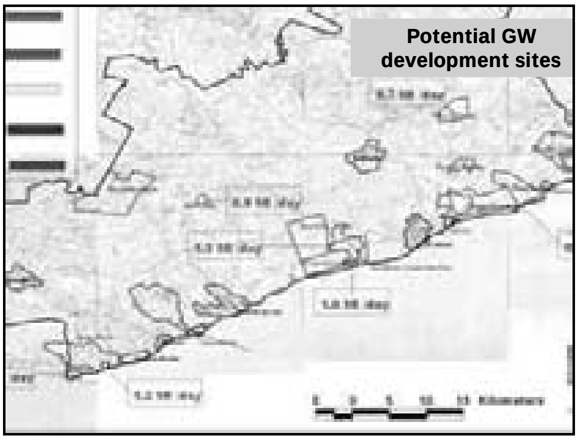

Alexandria

- Moderate growth in water use
- Situation is not critical yet
- Existing source (Fishkraal) and conveyance adequate until 2007
- Additional GW source can be developed and used for future. Environmental constraints
- Conveyance system needs to be upgraded
- SW scheme not required
- EIA has been done, outcome awaited

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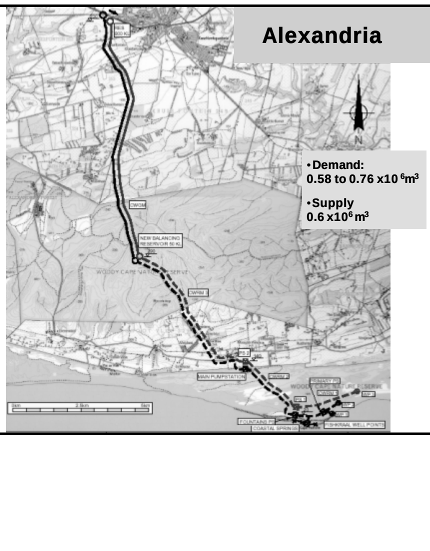

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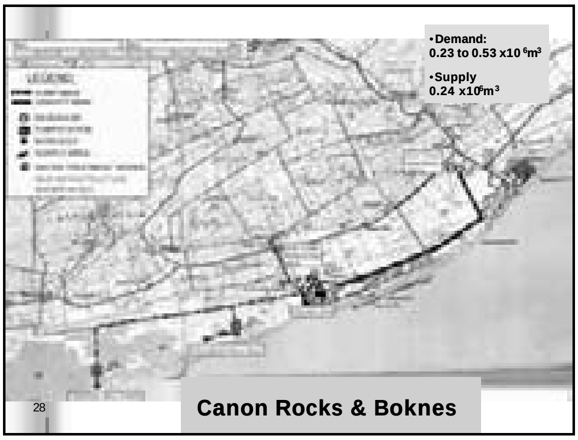
Canon Rocks & Boknes

- High growth in water use is expected
- Situation critical during peak
- Sufficient GW resources at the Apies River mouth are available, but
- Environmental constraints to be resolved with Sandpark
- New conveyance system to be built
- SW resources not favourable
- EIA has been prepared, results pending
- Implementation can start

27 UWPEngineers



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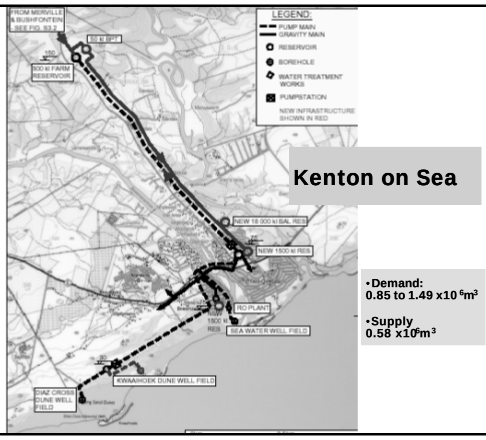
Kenton on Sea / Bushmans

- High growth in water use is expected
- Situation critical even during low demand
- Additional dune GW source at Kwaaihoek can be developed subject to EIA
- Potential GW sources at Merville and Bushfontein can be explored
- Alternatively expansion of the RO plant or supply from SW can be considered
- A problem with the position with the RO plant being experienced
- EIA for Kwaaihoek well field to be done

29 UWPEngineers



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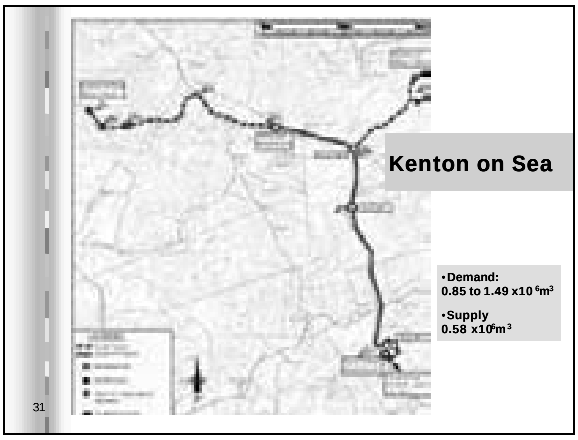
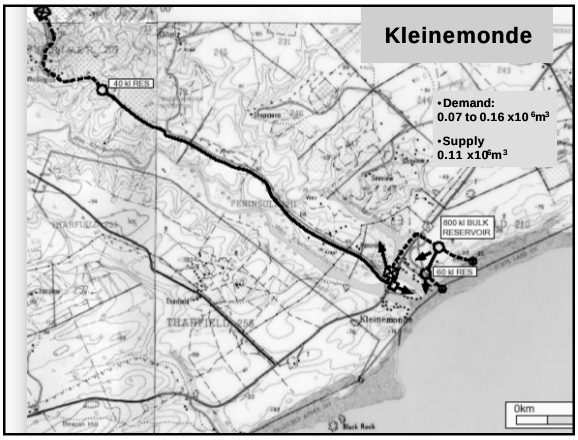


Kleinemonde

- High growth in water use is expected
- Situation not critical yet
- Supply from Wellington dam has poor water quality TDS up to 2 500
- Source has sufficient capacity until 2007
- Additional GW sources investigated and should be developed

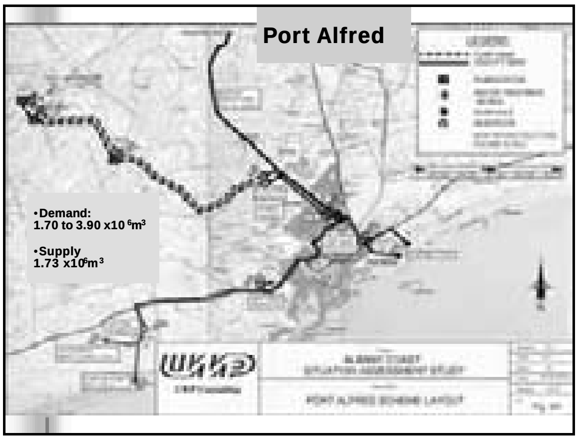
33 UWPEngineers



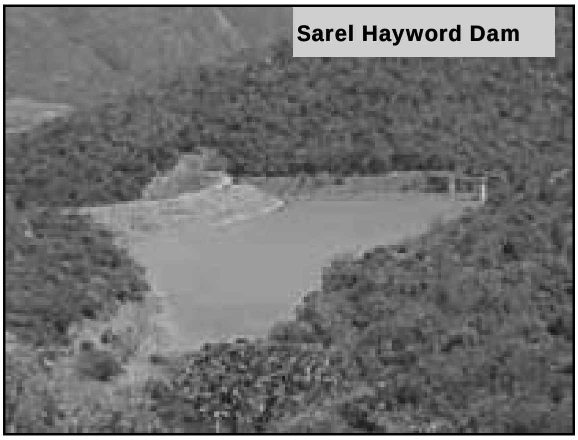
Port Alfred

- High growth in water use is expected
- Situation is critical during peak. Available sources will be adequate until 2005
- Existing source: poor water quality tds 1700
- GW resources not sufficient to supply full future requirement, but can postpone development until 2011
- SW scheme is required: Sources considered: Glen Melville, Settlers, Sarel Hayword, New Years dam, all in conjunction with GW

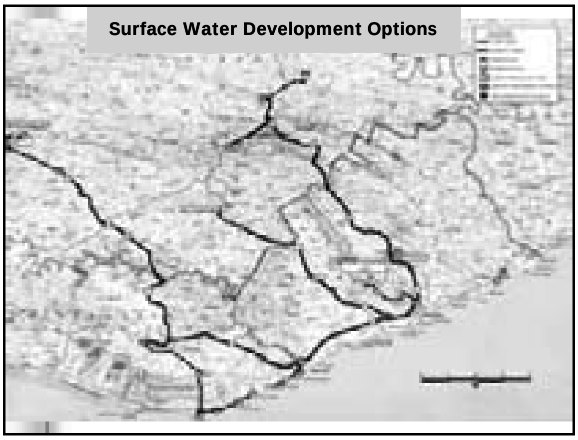
35 UWPEngineers



Sarel Hayword Dam



Surface Water Development Options



Bathurst

- Moderate growth is expected
- Portions of town rely on private sources – not reticulated.
- Existing sources: Golden Ridge (a private dam) will be adequate until 2006
- A study on the IFR releases from the dam needs to be done
- No feasible GW resources identified yet.
- Sources can be augmented as follows:
  - Supply from GM Dam if considered for PA
  - Investigate GW sources

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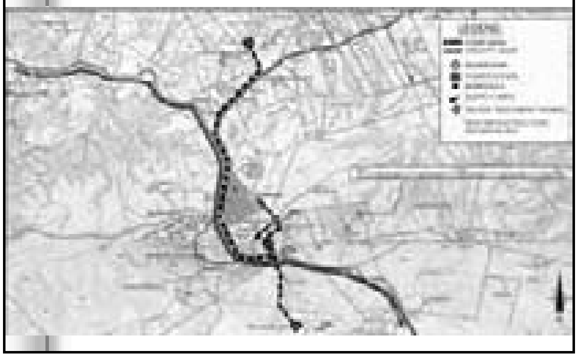
Bathurst

- Demand: 0.34 to 0.41 x10 ^{6}m^3
- Supply 0.30 x10^{6}m^3



Development Options

- Water source
  - Ground water stand alone
  - Conjunctive use of surface and ground water
  - Surface water storage schemes
  - Sea and brackish water desalination plants
- Conveyance systems
  - Pump stations
  - Mains
  - Treatment plants
  - Bulk storage

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Summary Options

- Ground water stand alone schemes:
  - Alexandria, Canon Rocks and Kleinemonde
- Conjunctive GW, RO or SW scheme
  - Kenton on Sea/Bushmans River
- Conjunctive GW and SW scheme
  - Port Alfred and Bathurst: Supply from G Melville, or Settlers, or Sarel Hayward

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Economic Evaluation
Selected Schemes

No.	DAM/OPTION	Capital	URV	Note
		R mil	R/kl	
1	Alexandria: Ground Water (GW)	R10.61	R15.22	Recommend
2	Canon Rocks / Boknes : GW	R5.62	R5.02	Recommend
3	KOS / Bushmans River Mouth: GW	R28.11	R10.08	Recommend: short term
4a	KOS / Bushmans River Mouth: RO sea W	R34.65	R13.56	Not recommended
4b	KOS / Bushmans River Mouth: RO brackW	R28.77	R11.33	Not recommended
5	KOS: SW from GM Dam	R41.34	R10.21	Recommended: long term
6	PA: Glen Melville Dam: Opt 1: PA, BT, KOS	R130.91	R10.68	Recommended: long term
7	PA: Glen Melville Dam: Opt 2: PA, BT	R98.24	R9.97	Comparison
9	PA: Settlers Dam: Opt 1: PA	R100.46	R10.91	Comparison
8a	PA: Sarel Hayward Dam: Opt 1: PA	R55.18	R5.70	Recommended: long term
8b	PA: Sarel Hayward Dam: Opt 1: PA and RO	R73.53	R8.27	To improve water quality
10	PA: GW and RO only	R84.11	R10.85	Comparison

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CONCLUSIONS

- **Alexandria, Canon Rocks and Boknes** can be supplied with GW from additional sources at Cape Padrone, Fish Kraals and Apies River:
  - Ecological sensitivity is an issue
  - EIA report has been prepared
  - If ecological impact is unacceptable, further GW investigations to be done
  - DWAF to be approached for assistance
- If this is not acceptable a regional scheme should be developed

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CONCLUSIONS

- **Kenton on Sea and Bushmans River Mouth.** Water source to be augmented in the following sequence:
  - Produce EIA report and develop Kwaaihoek well field subject to acceptance of EIA
  - Upgrade supporting infrastructure for the existing RO plant: electrical, intake, disposal
  - Develop GW sources at Merville and Bushfontein together with conveyance system
  - Furthers studies to confirm the anticipated yields of the GW sources are recommended, but implementation process can commence
- Regional scheme will be the solution in long term

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CONCLUSIONS

Port Alfred

- Develop GW resources at Sunshine coast and Glendour to postpone SW scheme
- SW development would possibly be required in long term. Available GW resources would probably not be sufficient
- Undertake further studies to determine best surface water scheme: Glen Melville, Settlers, or Sarel Hayward
- Sarel Hayward water quality is poor
- Undertake further GW studies to firm up on GW development potential of the Witteberg

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CONCLUSIONS

- **Bathurst**
  - carry out Reserve determination study for Golden Ridge dam. Supply from this source can continue
  - Commence GW investigation to identify GW sources for augmentation of the source
- **Kleinemonde**
  - Water supply situation is not critical
  - Identify suitable GW resources for future augmentation

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Recommendations

- The results of the reconnaissance study indicate that most of the towns in the coastal area can be supplied from GW (Alex, CR/B, KoS/Bush, KlM) in short tem
- Possible positions for GW development sites have been identified
- EIA studies need to be done for proposed sites to confirm acceptability
- LA to commence implementation process

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Recommendations

- For Port Alfred: develop GW resources at Sunshine Coast and Glendour, subject to acceptable EIA
- The GW resources in the region are not sufficient in long term. A SW scheme would eventually be required
- Undertake further studies to finalise the best regional scheme option

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Thank you

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UWPEngineers

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

ALBANY COAST SITUATION ASSESSMENT STUDY

STAKEHOLDER MEETING NO 2

Date: 26 August 2004 **Time:** 10:00 **Venue:** Port Alfred

LIST OF ATTENDANTS

No	Initials and surname	Organisation/position	E-mail address	Tel. No.	Fax No.
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26/8/04

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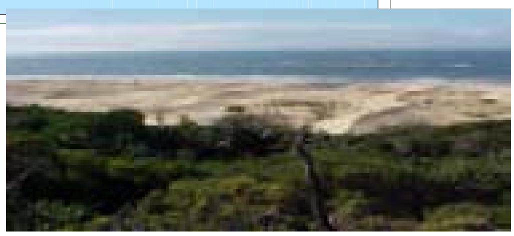
DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate: National Water Resource Planning

ALBANY COAST SITUATION ASSESSMENT STUDY



Groundwater Resource

Final

December 2004

Lead Consultant:

UWP Consulting

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DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

PROJECT NAME	:	Albany Coast Situation Assessment Study
TITLE	:	Groundwater Resource – Final
AUTHOR	:	E Mouton
REPORT STATUS	:	Final
DWAF REPORT NO	:	P WMA 15/000/00/0408
DATE	:	December 2004

Submitted on behalf of WSM Leshika (Pty) Ltd by:

……………………………………………………………………………….
HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate: National Water Resource Planning

Approved for Department of Water Affairs and Forestry by:

………………………………..…………..
FA STOFFBERG
Chief Engineer: National Water Resource Planning

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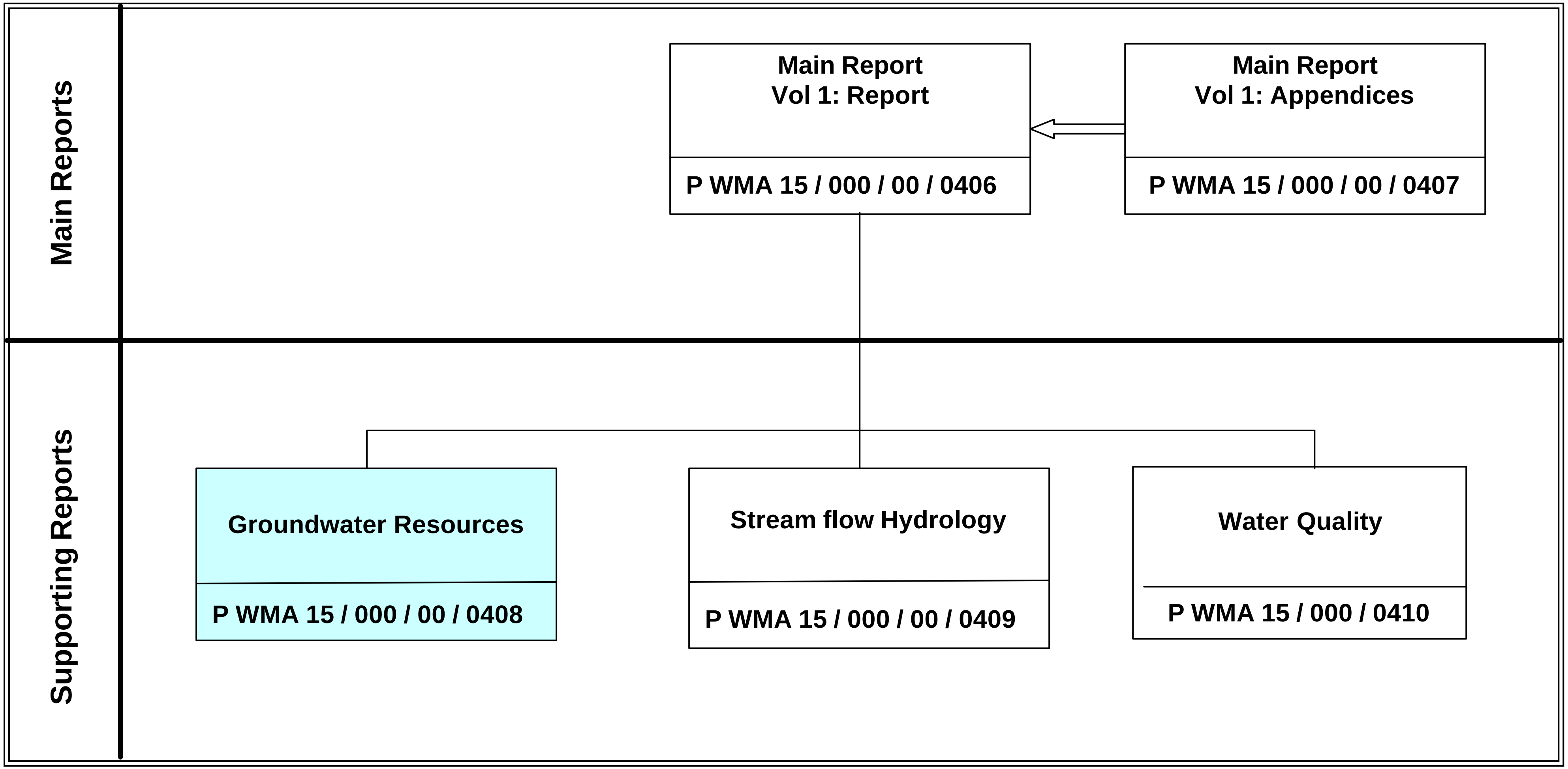
JA VAN ROOYEN
Director: National Water Resource Planning

ALBANY COAST SITUATION ASSESSMENT STUDY

Structure of Reports



EXECUTIVE SUMMARY

INTRODUCTION AND RESEARCH OBJECTIVES

The Albany Coast drainage region (‘P’) falls under the jurisdiction of the Cacadu District Municipality, and includes the entire administrative area of Ndlambe Local Municipality, where all the affected towns are located. Essentially all the coastal and inland towns situated within Ndlambe experience serious, periodic water supply problems, mainly because of inadequate resources, poor water quality and insufficient capacity of their bulk supply infrastructure. These towns are Port Alfred, Seafield/Kleinemonde, Kenton-on-Sea, Bushmans River, Boknes, Cannon Rocks and Alexandria. DWAF appointed UWP Consulting Engineers as a lead consultant to conduct a Water Situation Assessment for the coastal zone of the Albany Coast Basin, corresponding roughly to Ndlambe. Due to the multi-disciplinary nature of the project, UWP Consulting invited DMM and ***WSM*** to offer specialist services in the fields of surface hydrology and hydrogeology respectively.

WSM were asked to evaluate the groundwater resources of which the development potential will be conducted in two scales viz., regionally as a desk study and locally as a hydrocensus. This report serves primarily to define the hydrogeological characteristics of Ndlambe on a regional scale in order that planning can be undertaken by DWAF. More specifically, the availability of groundwater in terms of spatial distribution, quality and quantity needs to be evaluated where the resources can serve as a primary water supply or augment surface water.

HYDROGEOLOGY

The geology is dominated by the sedimentary deposits of the Cape Supergroup, which underlie almost the entire area. Some Karoo Supergroup sediments are preserved in he Fish River floodplain. Rocks of the Algoa Group and Quaternary form a thin veneer along the coastal zone, but are nevertheless, an important component of the geology.

The Cape Supergroup rocks are represented by the Bokkeveld Group shales and the Witteberg Group shales and quartzites. Whereas the former is largely undifferentiated, the latter comprises the basal Weltevrede Formation (largely shale); the central Witpoort Formation (largely orthoquartzite), which is in turn overlain by the Lake Mentz Formation (largely shale). Although orthoquartzites of the Witpoort Formation, have much in common with the Table Mountain Group Rocks, its aquifer potential has been largely ignored - mainly because of the ease (and low-cost) in developing coastal aquifers.

The Algoa Group 'limestone's' constitute near shore, marine, fluvial and aeolian sediments. Their formation and distribution was related to sea-level changes during the recent past. These rocks generally young towards the present-day coastline and are represented by the Bathurst, Alexandria, and Nanaga formations. The Quaternary (10 000 years to present) is represented by the Schelmhoek Formation and comprises modern beach and dune sand and found along the entire 75-Km long Ndlambe coastline. These fossil and modern dune aquifers combine to act as primary aquifers and are responsible for groundwater targets where optimally developed.

The entire southern Cape region, originally part of southern Gondwanaland, was subject to increasing compression from a southerly direction – some 290 million years ago. This resulted in folding and uplift of mainly Cape Supergroup rocks to form the east-west trending Cape Fold Belt. During the Mesozoic period, the fragmentation of Gondwanaland began to process of marginal rift faulting. Cape Supergroup rocks within Ndlambe are folded into asymmetric folds and faulted, including thrust, normal and strike-slip varieties.

Prevailing stress conditions have a significant impact on the water bearing potential of a fault, as it determines whether the structure will be open or closed, thereby affecting permeability. Structural mapping and geodynamics analysis from this study suggests that south-southeast and east-northeast trending structures form the most suitable drilling targets for high yielding boreholes. This was complemented by a first-pass lineament analysis, which showed similar directions.

Borehole data exists in the national Groundwater Database (NGBD) and 755 boreholes are listed for the area. The NGDB is nether comprehensive or complete and it is estimated that less than half the actual boreholes drilled and/or utilized are reflected. Nevertheless, the NGDB has been able to provide a regional assessment of background hydrogeological conditions. Limited hydrocensus work was also conducted around each of the affected towns in Ndlambe. An additional 24 boreholes have been appended to the NGDB. The vast majority of these boreholes are low-yielding and serve rural communities.

In fractured aquifers, the sand:clay ratio plays a noticeable role both quantitatively and qualitatively in the occurrence of groundwater, causing borehole yields and chemistry to vary widely. A high proportion of clays resulted in these rocks deforming without inducing secondary fracturing. Clay-rich rocks also impart a marine (or sodium chloride) character to the groundwater, giving it a brackish taste.

The Bokkeveld, Weltevrede and Lake Mentz aquifers, which make up 56 % of the surface geology of Ndlambe, cannot be economically exploited as they generally possess low to moderate yields and are mostly saline.

Of the fractured aquifers, the Witpoort orthoquartzites have the highest potential of an assumed 2.55 Mm^3/a. The Witpoort Formation is present as three discrete, southeast trending belts, which make up 25 % of the surface geology. These three belts have a cumulative strike length of 45 Km, which fortuitously, arcs behind each of the affected towns.

Targets for exploitation in these belts are restricted to major fault zones. Thirty percent of scientifically boreholes sited and drilled are expected to yield between ~ 5 ℓ/s of Class I and Class II quality groundwater. Poorer quality groundwater is expected where marine shales bound faults. Water strikes can be expected as deep as 70 m bgl, and deep drilling will be required to accommodate the high expected draw downs

The western belt trends behind Kenton-on-Sea/Bushmans River i.e., the area of greatest need. Up to 1 Mm^3/a could be exploited from this belt. Obvious targets are situated in and around the farms Bushfontein, Merville, Barville Park and Glendower. Recent drilling on Merville by DWAF on the farm Merville produced very encouraging results viz., a 100 % success rate with 4 boreholes with a cumulative blow yield of ~ 36 ℓ/s. Some of these boreholes are artesian.

A thrust fault bisects the central belt and coincides with a cluster of high-yielding boreholes. Farms in and around Grove Hill, Fords Party and Tharfield are obvious targets for groundwater to benefit Bathurst, Port Alfred or the Seafield/Kleinemonde respectively. Potentially, another 0,3 Mm^3/a could be abstracted from the central belt.

Up to 1.28 Mm^3/a could be exploited from the Eastern Belt, which trends from the Fish River Lighthouse to Grahamstown and beyond. Potential targets occur in and around farms corresponding to Palmietheuval, Southseas and The Grove. The Seafield/Kleinemonde communities could benefit by as much as 3 507 Kℓ/day from this groundwater resource.

With respect to the much younger, coastal aquifers, which occur as a narrow strip along the 75 Km long Ndlambe coastline. Here, approximately 75 % of boreholes drilled are expected to yield ~ 2 ℓ/s of Class I and Class II quality groundwater. Water strikes can vary from 5 to 10 m bgl with a maximum borehole depth of ~ 20 m.

The exploitation potential of the modern dune aquifer were calculated separately for areas where the dune cordon is sufficiently wide to exploit sustainably. These aquifers are composite in nature and are recharged directly from MAP and benefit from lateral inflow from the back dune area. Targets of high potential are presented from the west to the east.

The under utilized Cape Padrone/Fishkraals aquifer could contribute 0.83 Mm^3/a, whereas the undeveloped Apies River aquifer an additional 0.76 Mm^3/a to benefit the Alexandria, Cannon Rocks/Boknes communities.

For the greater Kenton-on-Sea/Bushmans River communities, development of the Kwaaihoek aquifer (0.12 Mm^3/a) makes sense as groundwater from this source would make use of the under optimised Dias Cross pipeline, which passes nearby. Drawing groundwater from this source will do much to reduce the seasonal peak demands. The Dias Cross (0.22 Mm^3/a) and the Bushmans River Mouth (0.07 Mm^3) well fields are fully developed.

All the above-mentioned coastal aquifers are developed in ground managed by SanParks, who do not sanction further exploitation of coastal aquifers. SanParks's jurisdiction extends only as far as the west bank of the Bushmans River.

Port Alfred could benefit by augmenting their East Bank well field (0.12 Mm^3) by considering the Sunshine Coast Nature Reserve (0.28 Mm^3/a); Rufanes River (0.12 Mm^3/a) and Riet River (0.11 Mm^3) aquifers, all of which are undeveloped. By utilizing these resources, Port Alfred could improve water quality by blending and cope with peak demands.

The Seafield/Kleinemonde community could develop the Clayton's Rocks (0.11 Mm^3/a) and/or the Fish River Lighthouse (0.11 Mm^3/a) coastal aquifers to help cope with their peak demands.

CONCLUSIONS AND RECOMMENDATIONS

Existing borehole use is low and it is favourable to develop well fields in both the Witpoort fractured aquifer and the coastal, intergranular aquifer. No other aquifers need to be considered. The groundwater abstracted will augment by conjunctive use, the severe water supply problem in the coastal towns. Areas of high potential within these aquifers have been identified close to affected towns. Although the groundwater quality will be largely marginal, it will be significantly better that water derived from most dams. The TDS is currently 2 500 mg/ℓ at the Sarel Hayward dam.

Initial exploration drilling done in the Witpoort aquifer was encouraging and needs to be expanded to all three belts. All towns (with the possible exception of Bathurst at this stage) can benefit from exploiting this aquifer. Follow-up hydrogeological work is recommended for the proposed sites ahead of the requisite EIA's for any possible groundwater development.

Under optimal conditions, the coastal aquifer can be relied upon to bring relief to each of the coastal towns, almost without exception. Detailed hydrogeological feasibility studies are recommended for the area in and around the proposed sites in support of the EIA's, which will confirm acceptability. Issues regarding developing groundwater resources in the ecologically sensitive coastal zone need to be resolved.

No other aquifers need to be considered as a potential groundwater resource.

It is accepted that groundwater resources will not be sufficient in the long term and ultimately, a surface water scheme will be required for Ndlambe.

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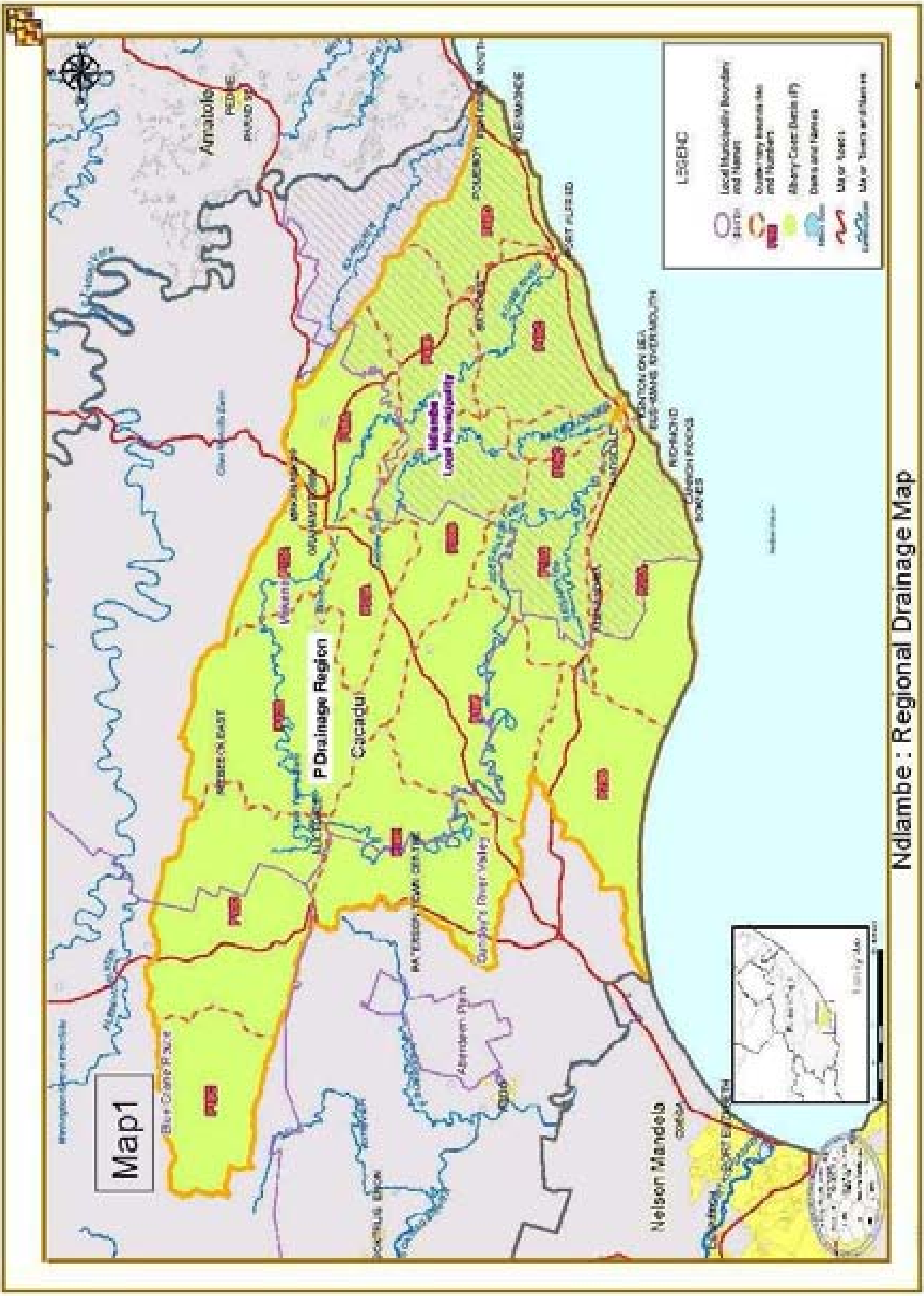
ADDENDUM TO REPORT

1. INTRODUCTION

The Albany Coast primary drainage region ('P') falls under the jurisdiction of the Cacadu District Municipality, and includes the entire administrative area of Ndlambe Local Municipality, where all the affected towns are located (Map 1). For the sake of brevity, the study area will be referred to as 'Ndlambe' hereafter. The study area is situated between the catchments of the Great Fish River, the Sundays River and the Indian Ocean and covers ~ 2 006 Km². The main rivers in the study area are the Bushmans, Kariega and the Kowie, with the Fish River (and its tributary, the Kap River) forming the eastern boundary with primary drainage region 'Q'. These drainage regions were defined in the Water Research Commission Report No.298 of 1994.

Funding has been made available through DWAF's National Resources Planning sub-directorate to undertake a Water Situation Assessment of Ndlambe. A number of coastal and inland towns situated within Ndlambe experience serious periodic water supply problems, mainly because of inadequate resources, poor water quality and insufficient capacity of their bulk supply infrastructure. These towns are Port Alfred, Bathurst, Kleinemonde, Kenton-on-Sea, Bushmans River Mouth, Boknes, Cannon Rocks and Alexandria (Map 1).

At present, the Ndlambe Municipality is the water service authority and service provider for all affected towns, except for Bushmans /Kenton and Alexandria. The Albany Coast Water Board (ACWB) is the service provider for the former towns whereas P&S Consulting is a support services agent for the latter town and the resorts of Boknes and Cannon Rocks.


Map1
Ndlambe : Regional Drainage Map
P Drainage Region
Cacadu
Nelson Mandela
Amatole
LEGEND

Map 1

2. TERMS OF REFERENCE

DWAF appointed UWP Consulting Engineers as a lead consultant to conduct a Water Situation Assessment for the coastal zone of the Albany Coast basin, corresponding roughly to Ndlambe. Due to the multi-disciplinary nature of the project, UWP Consulting invited DMM and ***WSM*** to offer specialist services in the fields of hydrology and hydrogeology respectively. In addition, a specialist sub-consultant – Geospatial and Remote Sensing Specialists, were co-opted to undertake remote sensing interpretation.

Background to the study is contained in the Albany Coast Situation Assessment (Tender No.: 2003-123) and the subsequent Inception Report, both compiled by UWP Consulting.

WSM were asked to evaluate the groundwater resources of which the development potential will be conducted in two scales – regionally as a desk study and locally as a hydrocensus. This report serves primarily to define the hydrogeological characteristics of Ndlambe on a regional scale in order that planning can be undertaken by DWAF. More specifically, the availability of groundwater in terms of spatial distribution, quality and quantity needs to be evaluated where the resources can serve as a primary water supply or augment surface water resources.

3. MAIN AIMS AND OBJECTIVES

The purpose of the study is to investigate, at a reconnaissance level, the water supply problems of the area, with specific reference to the afore-mentioned towns, through a broad review of existing information, and to consider possible solutions that may present themselves for ready implementation. The study will also produce a situation overview from which, if necessary, DWAF can draw up a framework for further studies and infrastructure development.

The study included consultations with officials from DWAF, consulting engineers and local authorities in order to obtain a full understanding of the water supply situation. The primary focus is to identify resources to resolve water supply problems for the specified towns (urban sector) with due consideration given to rural domestic, agricultural, afforestation, ecological Reserve etc.

The purpose of the hydrogeological investigation is to provide an overall assessment of the situation, to identify readily available solutions, and based on this, to refine the scope for the successive phase(s). The following approach was followed:

Regional Scale – Desk Study: A literature study was conducted for all relevant geological and hydrogeological information and maps available for Ndlambe. The groundwater resources included an overall assessment of the resources within Ndlambe, based on available data. This phase drew heavily on interrogating the NGDB.

Local Scale – Hydrocensus: Here detailed, site-specific investigations targeted affected towns. This phase was largely field-based and included remote sensing, hydrocensus and sampling. From this work, the exploration potential of the groundwater resources of the towns was assessed.

The final product will be compiled into a single report.

4. NETWORKING

The study is reliant on the interaction and networking between various organizations including: various DWAF departments, ACWB, agricultural extension officers, consulting engineers, municipal officials, nature conservation officials (including SanParks), rate-payers associations, Chamber of Business, commercial farmers and unions and tertiary institutions. This is required in order that all data is received for the study area, enabling an inclusive overview of the groundwater resources to be put forward. Reference is made to all data received and source(s) of this data. In summary, the following organizations, technical reports and networking activities are listed below:

Interaction with ongoing Projects:

- GRIP (EC) – Groundwater Resources Information Project
- DWAF Directorate Geohydrology –Witpoort Research Drilling
- ACWB: Bulk Water Supply Upgrades, Bushmans/Kenton
- P&S Consulting: Bulk Supply Upgrades – Boknes/Cannon Rocks

Technical Reports:

- Refer References

Liaison and Meetings:

- Ndlambe Municipality (Mr. George Ngesi, Mr. Bill Patterson and Mr. Anton Gouws)
- ACWB (Mr. Ron Ball)
- P&S Consulting (Mr. Paul Fick and Mr. Stephen Fick)
- Bathurst and Alexandria Agricultural Extension Officers (Mr. Ray Hageman and Ms Jenny Potgieter)
- DWAF Directorate Geohydrology – Ms Jane Baron and Mr. Herman Goossens
- Rhodes University (Prof Julian Marsh and Prof Etienne Nel)
- Chamber of Business Kenton – Mr. Walther Kitkat
- Kleinemonde Ratepayers – Mr. Des Forward and Mr. Christo Bezuidenhout
- Various commercial/game farmers and farmers' representatives and unions
- SanParks and Nature Conservation officials

5. SITE LOCALITY AND DESCRIPTION

5.1 LOCATION

The study area is located in the southwestern portion of the Eastern Cape Province and is situated more or less midway between Port Elizabeth and East London and about 50 Km south of Grahamstown (Map 1).

5.2 CLIMATE

On the basis of the Koppen system of climate classification, the coastal zone is regarded as sub-tropical, all months having temperatures of between 10 and 22.2 ºC and having at least 60 mm of rainfall. The temperature is mild in both winter and summer, with wind reducing both the heat and humidity.

The area receives a bi-modal rainfall distribution with a larger peak in spring and a somewhat smaller peak in autumn. This is a transitional zone, as further east, the pattern changes to a more abundant summer rainfall, whereas further west, the pattern changes to mainly winter rainfall.

Table 1: Mean Monthly and Mean Annual Precipitation

Monthly Rain	Alexandria Forest Stn	Bathurst	Bushmans/ Kenton	Seafield/ Kleinemonde	Port Alfred
January	61	55	42	44	41
February	58	59	45	53	52
March	78	80	68	71	69
April	66	55	49	52	53
May	77	43	54	62	58
June	72.5	40	50	48	44
July	69	41	48	37	39
August	73	57	53	43	41
September	91	55	63	50	63
October	97	76	65	61	66
November	86	79	64	58	57
December	61	61	45	42	44
MAP (mm)	**885**	**703**	**636**	**621**	**627**

The Mean Annual Precipitation (MAP) for the region varies around 640 mm (± s = 140) and decreases in a northerly (inland direction). The area around the Alexandria Forest Station benefits from rain-bearing clouds being orographically uplifted, inducing higher rainfall over a localized area.

The most rain that fell in Port Alfred was 175 mm in 24 hours. This event coincided with above average rainfall in 2003.

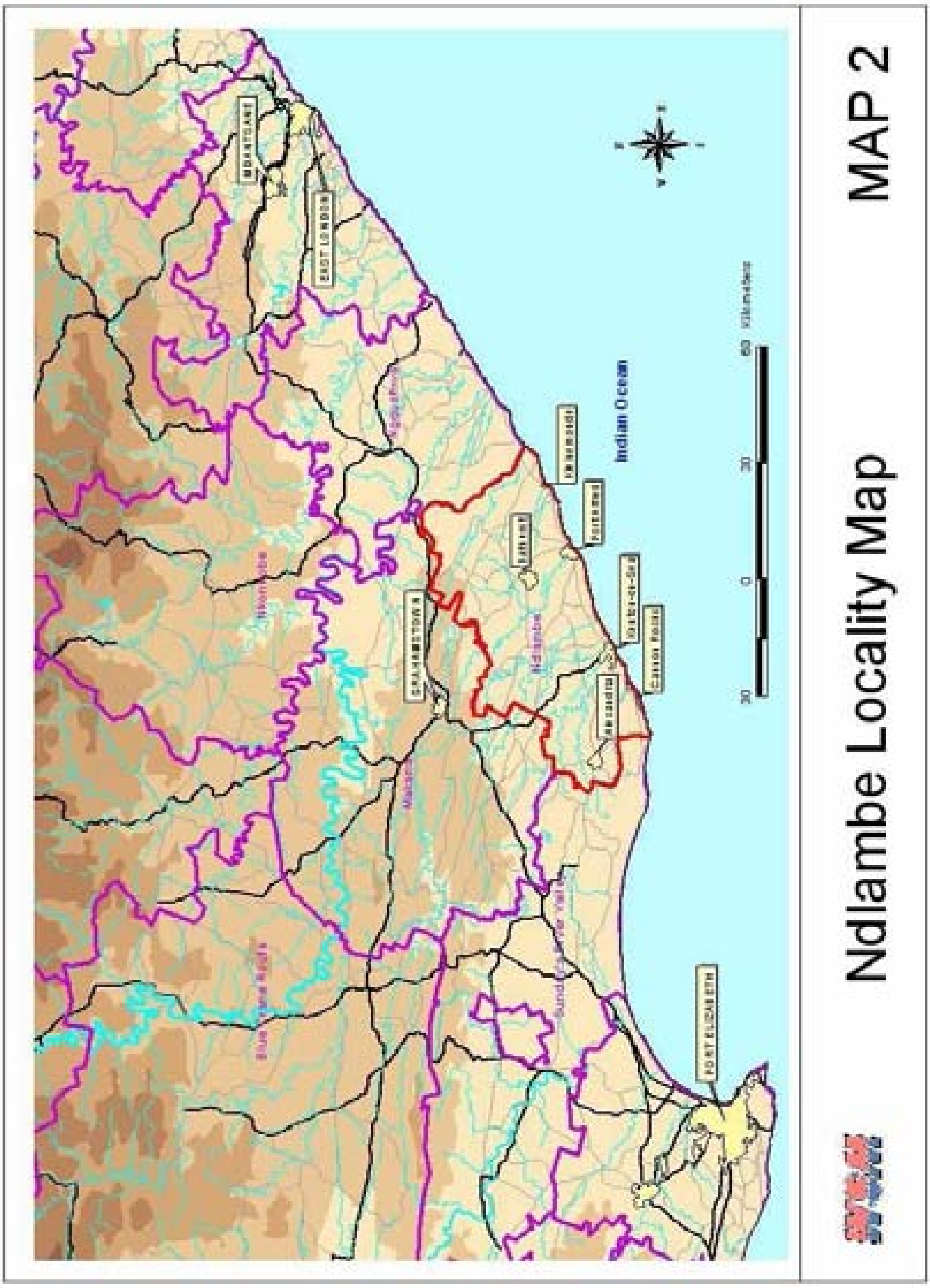
The average monthly evaporation rates for the region ranges seasonally from 104.5 mm in winter to 210.7 mm in summer, following a similar trend to the mean temperatures. Runoff volumes can be estimated from rainfall and evaporation data, and indicate that the maximum runoff should occur in the summer months. Rainfall runoff never exceeds evaporation in this region. According to DWAF criteria, runoff should be managed where rainfall runoff exceeds evaporative water loss for more than 20 % of the time. The annual relative humidity in the area shows seasonal fluctuations and ranges from a maximum of 80 % to a minimum of 40 % for summer and winter, respectively. The mean relative humidity of the air is 72 %.

Wind is dominated by a southwesterly and to a lesser extent, a southeasterly – which predominate in winter and summer respectively. In the winter months, occasional berg winds blow. Winds with a velocity of > 30 m/s occur most frequently in the summer months.

5.3 PHYSIOGRAPHY AND DRAINAGE

The study area extends from sea level along the coastal belt, with elevations increasing inland to ~ 550 m amsl in the vicinity of Grahamstown and the Kap River mountain range (Map 2).

The region consists of a gently undulating coastal plain, through which at least 10 significant rivers and estuaries flow in a southeasterly direction. Adjacent to the coastline, the area is bounded by high, vegetated dunes. The primary drainage regions in the area are indicated on Map 1 and Table 2:



Map 2

Table 2: Primary Drainage Regions and Associated Rivers

Drainage Region	Primary River
Q93	Great Fish
P40	Kowie
P30	Kariega
P10	Bushmans
P20	Boknes

5.4 SOILS AND VEGETATION

There is a gradation from coastal fynbos to coastal thicket and Ultimately coastal forest as the rainfall changes from a winter to a summer pattern, with the temperatures becoming more moderate.

- **Fynbos**: Although dominant in the southwest, Cape fynbos occurs in the study area as occasional pockets at Woody Cape, Port Alfred and as far as the Fish River Mouth. Proteas are particularly abundant on the acid soils developed on the Witpoort quartzites.

- **Coastal Thicket**: Thicket vegetation is the dominant vegetation and consists of woody shrubs and trees, which are fairly impenetrable. Dune thicket is common along the coastline, whereas valley bushveld penetrates into the interior up the river valleys.

- **Coastal Forest**: In areas of high orographic rainfall, coastal forests are developed and are predominantly Afromontane.

- **Coastal Grassland and Savannah**: Interior to the coastal thicket or forest, sour grassland is common, which is particularly well developed on the Witpoort quartzite. These farms mainly support dairy and beef cattle.

5.5 DEMOGRAPHICS

Ndlambe is home to some 80 000 people residing in 5 main urban areas, 5 coastal resorts and 21 rural settlements. It is primarily an agricultural area, but also has a strong tourism base (Map 2). Almost half the population resides in and around Port Alfred. The rural areas account for close to 17 000 people. The twin resorts of Bushmans/Kenton (9 500) and the agricultural communities of Alexandria (9 000) and Bathurst (6 200) have significant populations. According to DWAF's national database, there are 14 701 people in greater Bushmans/Kenton. The balance is spread in the resorts of Seafield/Kleinemonde and Cannon Rocks/Boknes.

The popularity of the coastal resorts is clearly evident as a major influx of people occurs during the summer holiday periods. The additional seasonal population is estimated at around 35 000, with 15 000 visiting both Port Alfred and Bushmans/Kenton respectively. The balance visits the resorts of Seafield/Kleinemonde or Boknes/Cannon Rocks.

5.6 WATER SERVICES OVERVIEW

There are six local water supply schemes, which service the settlements within the area. Port Alfred, Seafield/Kleinemonde and parts of Bathurst are supplied from surface water schemes, whilst the balance of the area (viz., 45 % of the population) is reliant on groundwater. There is a component of conjunctive utilization of groundwater in both Port Alfred and Seafield/Kleinemonde. Bushmans/Kenton augment their groundwater supplies with desalinated water via the reverse osmosis process. The rural areas, private coastal resorts (e.g. Kasouga and Riet River) and parts of Bathurst (e.g. 'Monkey Town' adjacent to the commonage) are generally serviced through private supply systems (rain water tanks and boreholes).

The reliability of the yields and the quality of the water from the respective water sources is in general inadequate. Furthermore, the capacity of the bulk infrastructure of many of the schemes is in general inadequate, especially to meet peak season demands. Many of the households in the area therefore augment the municipal supplies by rain water harvesting and rain water storage tanks. This is currently a prerequisite for new developments stipulated by the former Western District Council.

5.7 SANITATION

The bulk of Alexandria and portions of Port Alfred and Bushmans/Kenton (primarily the former townships of the latter areas) all have reticulated sewer systems; whilst the balance of the coastal resorts all have soak away or conservancy tanks. The rural settlements tend to have pit latrines of sub-RDP standard.

6. GEOLOGICAL DESCRIPTION

6.1 INTRODUCTION

This section deals with geological and geomorphologic aspects of the study area. Following geological tradition, the oldest rock formations are described first, the youngest last. The same will apply to the various landforms that make up the landscape. The standard geological map of the area is the 1:250 000 Grahamstown 3326 which covers the area between Alicedale and East London. Map 3 is a cropped geological plan of the area whereas a schematic cross section is presented as Figure 1. A generalized stratigraphic column is included as Table 3.

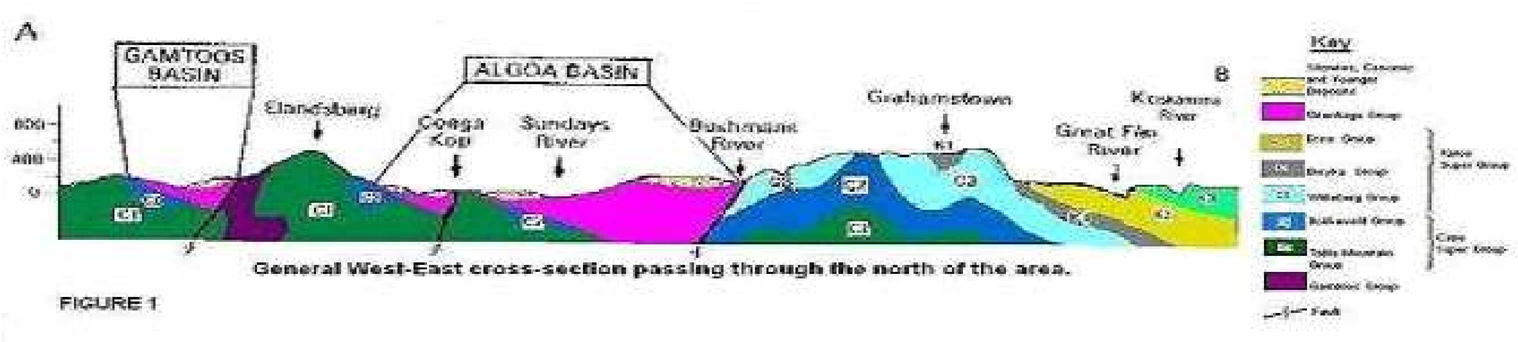


Figure 1: East-West section across the Eastern Cape

Table 3: Stratigraphic Table

Era	Epoch/Period Age (million years)	(Super)Group	Formation	Rock Type
CENOZOIC	HOLOCENE **0.01**	Algoa	Schelmhoek	modern dunes
CENOZOIC	PLEISTOCENE **2**	Algoa	Nahoon Salnova	aeolianite,beach deposits
CENOZOIC	PLIOCENE MIOCENE **25**	Algoa	Nanaga Alexandria	aeolianites beach deposits
MESOZOIC	OLIGOCENE EOCINE PALAEOCENE **65**	Algoa	Bathurst	sandy limestone, marine mud
MESOZOIC (GONDWANA	CRETACEOUS BREAK-UP) **140**	Uitenhage	Sundays River Kirkwood Enon	marine mud fluvial sand conglomerate
MESOZOIC	JURASSIC **210**	Karoo S'Gp	Suurberg Intrusives	basalt, dolerite
MESOZOIC	TRIASSIC **250**	Karoo S'Gp	'Stormberg'	'red beds'
PALAEOZOIC	PERMIAN **290**	Karoo S'Gp	Beaufort Ecca	shale, mud, sandstone
PALAEOZOIC	CARBONIFEROUS **360**	Karoo S' Gp	Dwyka	tillite, shale
PALAEOZOIC	DEVONIAN **410**	Cape S' Gp	Witteberg Bokkeveld	quartzite, shale
PALAEOZOIC	SILURIAN **440**	Cape S'Gp	Table Mountain	quartzite, shale
PALAEOZOIC	ORDOVICIAN **500**	Cape S'Gp		
PALAEOZOIC	CAMBRIAN **590**		Cape Granite	Granite
PALAEOZOIC	PRE-CAMBRIAM **800**	Pre-Cape	Kaaimans Kango Gamtoos	quartzite, marble, skarn

The geology is dominated by the sedimentary deposits of the Cape Supergroup, which underlie almost the entire area. Some Karoo Supergroup sediments are preserved in the Fish River floodplain. Rocks of the Algoa Group (i.e., Cenozoic) and Quaternary form a thin veneer along the coastal zone, but are nevertheless an important component of the geology. No igneous rocks whatsoever occur in the area.

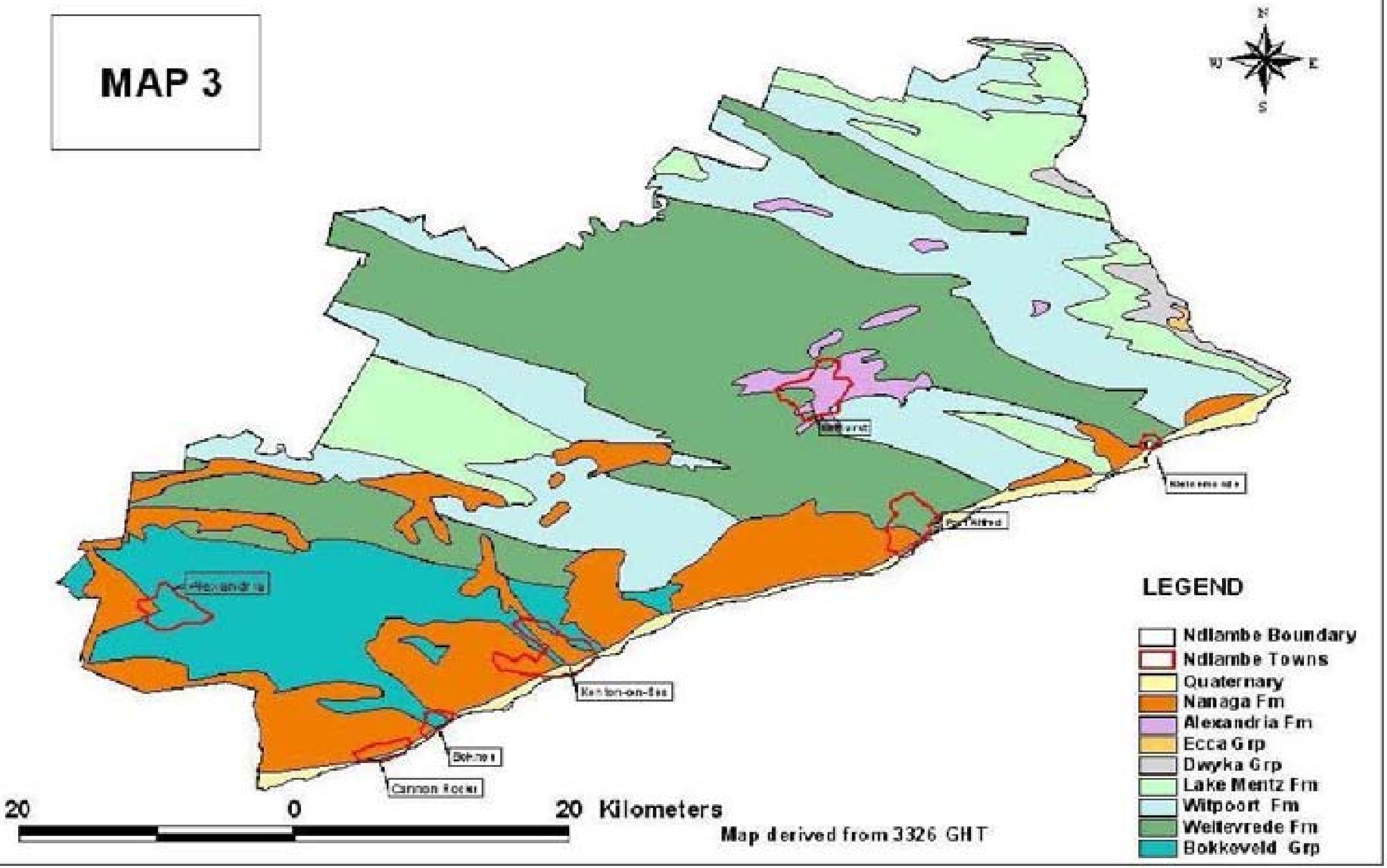
Two major features control the structural fabric, viz., the Cape Fold Belt (CFB) and the fracture system formed during the break-up of Gondwanaland – 140 to 160 million years ago. Sea level fluctuations and erosion has peneplained the fringes of these ancient rocks, unconformably depositing fossil and modern dunes adjacent to the present-day coastal zone.

6.2 CAPE SUPERGROUP

The Cape Supergroup is the backbone of the CFB and is divided into the Table Mountain, Bokkeveld and Witteberg Groups. Outcrops are limited to narrow stretches of the coast, riverbanks and naturally eroded steep cliffs. Artificial exposures are in quarries and road cuttings. These rocks become younger towards the interior.

The **Table Mountain Group** is a thick succession of mostly orthoquartzite. Although there are no outcrops within the study area, Bird Island (off Woody Cape) consists of Table Mountain quartzite. These rocks have attracted much interest as hard rock, fractured aquifers with significant groundwater potential. Only recently, towns such as Jeffreys Bay, Oudtshoorn, Plettenberg Bay, Bredasdorp and Citrusdal have benefited by exploiting this deep, groundwater resource. The Table Mountain Group will not be discussed further in this report.

MAP 3



Ndlambe Geological Map

The Bokkeveld Group is composed largely of black shales, compact siltstone and subordinate sandstones, representative of an ancient deltaic environment of deposition (Plate 1). Minor sandstone units constitute roughly 10 % of the entire sedimentary package. These rocks are restricted to the area west of the Kasouga River. Bokkeveld rocks weather away relatively rapidly, forming valleys and low rolling hills. The Bokkeveld shales occur as a low amplitude, southeast plunging anticline in the southwestern portion of Ndlambe. Dip is variable and can, over short distances, alternate from vertical to shallow dipping. Outcrop is poor and as a result of the absence of marker beds, no attempt has been made to sub-divide the Bokkeveld Group into discrete formations.

Plate 1: Exposure of Bokkeveld Shale in the Kariega River.

The **Witteberg Group** comprises the basal Weltevrede Formation (predominantly black shale), the central Witpoort Formation (predominantly quartzites) overlain by the uppermost Lake Mentz Formation (predominantly shale). Through a combination of folding, faulting and erosion, rocks of the Witteberg Group occur as three discrete, southeast trending belts in Ndlambe.

The Weltevrede Formation consists of a series of greyish-black phyllite grading upwards into buff-coloured quartzite (Plate 2). The former shows a pronounced cleavage and often weathers into a red-grey or olive-grey colour.

Plate 2 : Exposure of Weltevrede Shales near the Wellington Dam.

The Witpoort Formation has a high proportion of arenaceous rocks interbedded with lesser phyllite beds (Plate 3). Quartzite rocks consist mainly of recrystallised, polygonal-shaped quartz grains with minor feldspar and biotite. Beds have variable dips and display a well-developed joint pattern. Although the Witpoort has much in common with the Table Mountain Group rocks, its aquifer potential has been largely ignored - mainly because of the ease (and low-cost) in developing coastal aquifers.

Plate 3 : Exposure of highly veined Witpoort Quartzites.

The Lake Mentz Formation overlies the Witpoort Formation. Its lower and upper contacts are composed largely of argillaceous (or clay-rich) units, some 200 and 340 m thick respectively. The central portion is an 80 m thick arenaceous unit, which may have moderate aquifer potential due to its thickness.

6.3 KAROO SUPERGROUP

Karoo Supergroup rocks unconformably overlie those of the Cape Supergroup and only have a very limited occurrence in the extreme eastern portion of Ndlambe.

The **Dwyka Group** is an approximately 600 m thick mass of diamictite, which contains a dark grey argillaceous matrix. Subordinate lenses of shale and sandstone occur sporadically. Due to their dense, impervious nature, the rocks of the Dwyka Group generally offer limited groundwater potential. These rocks have an extremely limited sub-outcrop distribution in the area, being limited to the floodplain of the Fish River in the extreme east.

The **Ecca Group** consists predominantly of laminated and platy argillaceous rocks and subordinate inter-bedded sandstones.

Rocks of the Dwyka and Ecca Group are not considered as potential aquifers in Ndlambe area and will not be discussed further.

6.4 ALGOA GROUP

These Cenozoic deposits form a discontinuous veneer of variable but generally thin thickness in the coastal zone and constitute near shore, marine, fluvial and aeolian sediments. The major driving force controlling their formation and distribution was sea-level changes during the recent past. The interaction between landscape development and contemporary sedimentary record is complex and poorly understood. These rocks generally become younger towards the present day coastline.

The **Bathurst Formation** occurs roughly 300 m amsl and is a 65 million year old (fossiliferous) limestone with a negligible sub-outcrop distribution. It will not be discussed further.

The **Alexandria Formation** (24.6 to 1.8 million years old) is well represented in the area. It is mostly of marine origin, deposited during intermittent regressions of sea level after an initial high stand at about 250 m above present sea level. Sediments of this formation were deposited on wave-cut platforms. The base is marked by a thin (0 to 2 m), discontinuous conglomerate, whereas the overlying coarse-grained ‘limestone’ makes up the balance of its ~ 7 m thickness (Plate 4). The Alexandria Formation typically forms bench-like cliffs, e.g. at Cape Padrone and Woody Cape. Being a limestone, the Alexandria Formation is a good aquifer and is responsible for some karst topography in the coastal zone.

Plate 4 : Exposure of Alexandria Conglomerate in Port Alfred.

The aeolian deposits of the **Nanaga Formation** overlie the marine deposits of the Alexandria Formation. The oldest deposits are found as far inland as Paterson. These wind-derived deposits take the form of fossil dune cordons (i.e., parallel to the present coast line) that developed successively along an old shoreline (Plate 5). The Nanaga (and Alexandria) sediments are better developed in the western portion of Ndlambe. The preferential erosion of the Bokkeveld basement rocks governs their thickness and distribution.

Plate 5 : Exposure of Nanaga Aeolanite in Port Alfred.

The **Nahoon Formation** (1,8 to 0,01 million years old) is a younger, semi-cemented aeolianite, with spectacular cross beds marking the slip faces of the fossil dunes. A distinctly textured rock, which forms isolated rocky headlands (or promontories) all along the present coast, such as Dias Cross, Kwaaihoek, Three Sisters and Bats Cave at Fish River. The present-day Alexandria coastal dune field is a modern-day equivalent of the Nahoon and Nanaga Formations. The Nahoon Formation has a very limited sub-outcrop distribution and shall not be discussed further.

6.5 QUATERNARY

The **Schelmhoek Formation** (10 000 years old to present) represents modern beach and dune sands (Plate 6). It is composed largely of well-sorted quartz grains and may contain 30 to 35 % shell and algal fragments. Typically these sediments contain sand, which may be interbedded with mud and lenses of calcrete. Depending on the palaeo-topography of the basement rocks, a highly transmissive shell conglomerate (or ‘shingle’) may be developed at its base.

Plate 6 : Exposure of Schelmhoek (Quarternary) Coastal Sands.

These are the youngest deposits and are still currently being deposited. The Schelmhoek Formation forms a strip of variable thickness (0 to 40 m) and width (100 to 1 000 m) above the high tide mark. This, along with the Alexandria and Nanaga Formations, constitutes the coastal aquifer, which is exploited intermittently along the 75 Km-long Ndlambe coastline.

6.6 STRUCTURE AND GEODYNAMICS

The presently exposed structure of the region can be attributed to two major tectonic events: thrusting that occurred during the Permo -Triassic Cape Orogeny and extension resulting from the fragmentation of southwestern Gondwanaland during Mesozoic times. The Cape Orogeny tectonically thickened the rock sequence of the CFB by thrusting, while the later, extensional faulting disrupted the sequence. As a result, the region displays northeasterly verging, first order folds sliced by thrusts and shears and extensional normal faults, all striking roughly southeast.

6.6.1 Regional Structure

The entire southern Cape region, originally part of southern Gondwanaland, was subject to increasing compression from a southerly direction - some 290 million years ago. This resulted in folding and the uplift of (mainly) Cape Supergroup rocks, to form the east-west trending Cape Fold Belt (CFB). Subsequent erosion, especially of the weak shales of the

Bokkeveld Group produced broad valleys, whereas the resistant sandstones of the Table Mountain and Witteberg Groups formed the longitudinal east-west mountain ranges.

During the Mesozoic period, the fragmentation of Gondwanaland began with the extrusion of the Drakensburg basalts and injection of the Karoo dolerites due to the initiation of tensional stresses. These did not intrude into the CFB region due to the prevailing compressional stresses, and the occurrence of dolerites is restricted to the region north of 33° S. The southern portion of Gondwana subsequently began to break-up by a process of marginal rift faulting. The structure of the coastline of the Eastern Cape was determined by the Agulhas-Falklands fracture zone – essentially a linear tear-fault, which extends offshore from the Eastern Cape coast and along the southern margin of the Agulhas Bank. With the break-up of Gondwanaland, the sea flooded into the new margins of the subcontinent and thus marine rocks of the Cretaceous age (i.e., 144 to 65 million years ago) are found fringing the continental margin in places. In the Eastern Cape Province, these are rocks belonging mainly to the Uitenhage Group.

After the break-up of Gondwana, erosion commenced on the newly formed high and steep margins of the newly formed subcontinent and operated to base level of the newly formed ocean. It was the continuance of this head-ward working erosion, which has given rise to the ‘escarpment’ as we know it today.

6.6.2 Local Structure

Rocks of the Witteberg Group, in the vicinity of Port Alfred, are folded into asymmetric folds and thrust faulted. Medium-sized folds are prevalent with the majority being close folds (i.e., interlimb angle 54 º). Further inland, these folds plunge shallowly to the northwest, whereas closer to the coast, they plunge southeast. Vergence, based on the asymmetry of folded limbs, is from the southwest.

Bedding parallel thrusting, duplexing and piggy back trusting have disrupted strata, giving rise to variable bed thickness and stacking of beds one upon another. These complexities make the correlation of rock units in the field extremely dubious. Problems of correlation are compounded where thrusting, folding and normal faulting occurs together. Furthermore, it is difficult to distinguish between the Weltevrede and the underlying Bokkeveld Group.

Northwest-striking normal faults are commonly developed in the proximity of the Kowie River, forming horst and graben structures. Strike-slip faults occur approximately parallel to the strike of normal faults. The normal and strike-slip faults are the product of the break-up of Gondwanaland. At least four pulses of tectonics took place with the style of folding and thrusting showing a decrease in deformation northwards.

Deformation and metamorphism is imprinted on the Cape Supergroup rocks and interpreted to have reached greenschist facies i.e., low-grade regional metamorphism. Granoblastic polygonal textures are commonly developed in arenaceous rocks, whereas chlorite/stilpnomelane assemblages occur in metapelites.

The conflicting interpretations regarding the stratigraphic positions of the rocks in the area may be attributable to the lack of appreciation of the significant deformation, including thrust, normal and strike-slip faulting recorded in these rocks.

6.6.3 Geodynamic Analysis of Faulting

Faults can be divided into normal or dip-slip (extensional), thrust-slip (compressional) and strike-slip (shear) categories, depending on the orientation of rock movement. The direction of movement is dependent on prevailing stress conditions at the time the fault was formed. It is also important to note that stress conditions change over geological time so that faults formed under one stress-regime, such as shear stress, can be rejuvenated as another type of fault, such as normal faults, if stress conditions change.

The prevailing stress conditions have significant impact on the water bearing potential of a fault, as it determines whether the structure will be open or closed, thereby affecting permeability. Prevailing stress conditions can only be determined by seismic data, but where this is lacking, faults and resulting conjugate fracture sets can be used to interpret stress conditions that occurred at the time the structures were formed. The assumption is then made that the stress condition that prevailed at the time that the most recent structures were formed is similar to those of the present day.

Faults can be categorised either by field observations of rock movement and slickenside orientations, or alternatively by their dip angle. Due to the stress conditions under which rocks break in combinations with Coulomb's law of rock failure, strike-slip faults are predominantly vertical, normal faults dip at ~ 60^0 and thrust-slips dip at approximately 30^0. The dynamic analysis of faults and/or conjugate fracture sets allows the stress conditions under which they formed to be predicted. Therefore, from the orientation of fractures and slip directions, the orientation of their causal stresses can be predicted. By determining the age relationship of faults, variations in stress conditions over time can also be determined. For hydrogeological investigations, present day stress conditions, or the most recent stress conditions, and their impact on existing structures are the most relevant.

Joint sets are similar to faults, except a fracture is classified as a joint when there is no observed rock movement. Joints commonly occur parallel to conjugated fault planes. Secondary joint sets, known as Mode 1 tension joints, may also develop perpendicular to the direction of principal stress, however at a much steeper dip, resulting in a network of intercepting fractures. In the dip-slip and strike-slip settings these are sub-vertical.

During field structural investigations, a plunging anticline in a zone not disturbed by faulting was observed with a dip direction and dip of $166^{\circ}/18^{\circ}$, suggesting that folding and thrusting occurred due to stresses from the west-southwest. The folds and thrusts within the CFB are attributable to compression and uplift during the Cape Orogeny.

The observed presence of regional southeast to south-southeast trending normal faults implies that the thrust-slip, compressional setting present during the Cape Orogeny, was subsequently altered to a dip-slip setting. Thrusts were subsequently inverted to normal faults due to the initiation of tensional stresses. This shift in the stress regime can be attributed to tensional stresses that prevailed during the early Mesozoic break-up of Gondwanaland.

Tension was probably caused by extension of the Southern Outeniqua Basin and the related rotation of the Falkland Platform due to wrench or transform faulting that developed offshore along the Aghulhas Marginal Fracture Zone, which forms the boundary between continental and oceanic crust.

This east-southeast trending wrench fault resulted from right-lateral shear stresses. Associated stresses from wrenching would have resulted in northeast oriented maximum extensional stress (southeast trending normal faults); northwest oriented maximum compressional stress (northeast trending thrusting, and east-southeast and south-southeast to south shearing (Figure 2).

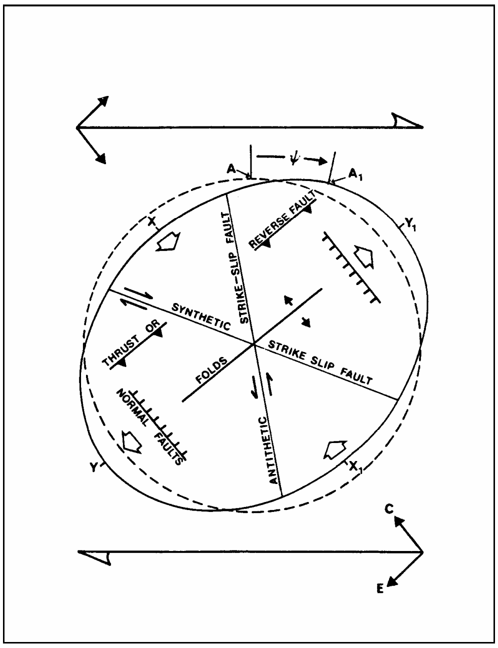


Figure 2: Strain ellipse arising from wrench or transform faulting

It is possible that subsequent uplift of the coastal margin could have resulted in tensional stresses oriented perpendicular to the coast line (i.e., northwest) and reactivated some of the existing structures since late-Mesozoic times.

6.6.4 Local Structure and Field Observations

A total of 18 outcrops were mapped with 7 fault orientations and 121 joint orientation measured (Figure 3). The following faults were observed in the field and classified as follows:

Thrust-slip setting (Dip direction/dip of fault planes)

- 23°/33°: Back-thrust – Kowie Quarry, Port Alfred
- 44°/40°: Back-thrust - Kowie Quarry, Port Alfred
- 234°/13°: Low-angle thrust – Marselle Quarry, Kenton-on-Sea

Thrusts generally strike northwest to southeast and represent stresses that arose from thrusting from the southwest during the Cape Orogeny.

Dip-slip setting (Dip direction/dip of fault planes)

- 66º/78º
- 229º/73º
- 67º/48º
- 249/79º
- 266º/70º

The normal faults strike northwest to southeast to north-northwest to south-southeast and opposing dips suggest a horst and graben structure developed. However, this cannot be observed on an outcrop scale. The faults 229°/73° and 67°/48° represent a conjugate set recorded on one outcrop. The relatively steep dip of southwest dipping fault and the shallow dip of the northeast dipping fault may be the result of tilting that occurred during continental uplift subsequent to faulting.

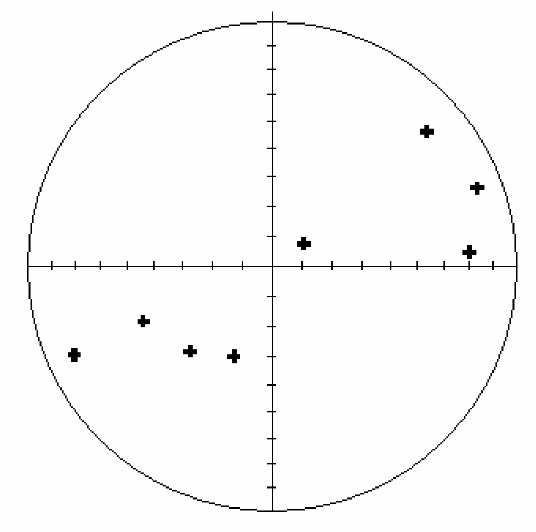


Figure 3: Equal area stereonet of poles of faults

The joint sets mapped are shown in Figures 4 and 5. Several prominent joint sets can be observed:

1. The most obvious features in the study area are sub-vertical joints dipping at more than 70° to the north or south and striking east-northeast to east-southeast. These could be associated with shear stresses related to east-southeast wrenching, or could represent Mode 1 tension joints due to north-south extension.
2. A second prominent set can be observed striking south-southeast to north-northwest and dipping at 60° - 80°, predominantly to the northeast. These indicate extension to the west-southwest resulting from east-southeast wrenching.
3. Low-angle thrust related joints are predominantly oriented to the north-northwest to south-southeast and can be attributed to thrusting during the Cape Orogeny.

The pattern of faulting and jointing indicates a dip-slip fault setting with shear stresses related to wrench faulting. The primarily northeast dip of joints appears to indicate that the northeast side of the faults is commonly the downthrown side.

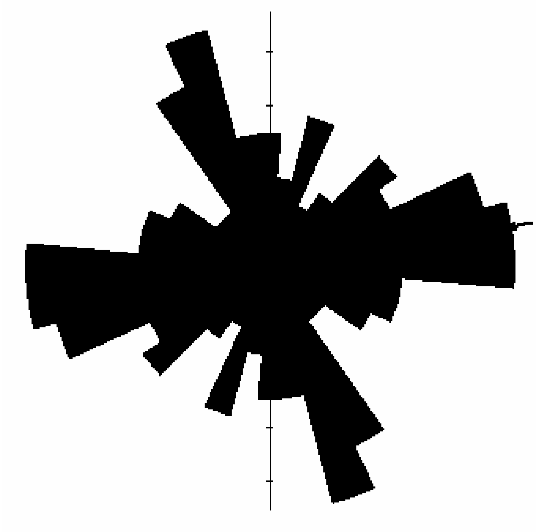


Figure 4: Rose diagram of frequency of strike orientations of joints

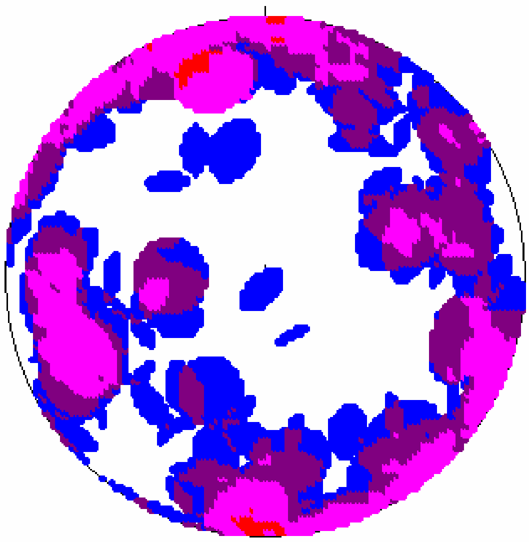


Figure 5: Equal area stereonet plot of pole of all fractures

To identify the different stress fields responsible for the observed fracture pattern, fractures were plotted into dip degree categories of:

- 90º-80º
- 80º-61º
- 60º-46º
- <45º

<u>Fractures dipping 90-80°</u>

The cluster of fractures dipping steeper than 80^0 can be considered to be shear related or Mode 1 tension joints, related to dip-slip or strike slip stresses and are expected to be parallel to the strike of potential faulting. Consequently, joints are expected to range from east-southeast to south-southeast striking. However, the dominant orientation observed is south-southwest to north-northeast to west-east striking (Figure 6), parallel to the coastline.

This suggests that north-south to northwest-southeast tensional forces have been present, which cannot be explained by wrenching on the Aghulas Fracture Zone, since structures with a northeast orientation would have been subject to maximum compressional stress.

Northwest tension could be attributable to coastal uplift, since this orientation is sub-perpendicular to the coastline, however no corresponding northeast striking normal faulting has been observed.

Another explanation may be that oblique or divergent movement was created on the Aghulas Fracture Zone due to the change in orientation of movement on the Master Transform Fault, resulting in transtension. The increasingly southwest to westerly trend of the Transform Fault as it curves around the coast of the Eastern Cape, suggests that such stresses may have taken place. In a transtensile regime, divergent movement results in a combination of tensional and transcurrent faulting perpendicular to the axis of tension. Oblique shear motion is taken up by high angle strike-slip faults that curve away from normal faults until they strike almost perpendicular to the normal fault (Figure 7).

Transtension would result in extension oriented to the northwest and maximum transtensional stress being located between the Algoa Basin and East London. Very limited lateral displacement is usually observed on transcurrent faults; hence they appear as high-angle normal faults.

The high observed dip angles of northeast to east trending joints and the large variation in strike in these joints suggests they may have a transtensile origin and may represent tension features with a shear origin.

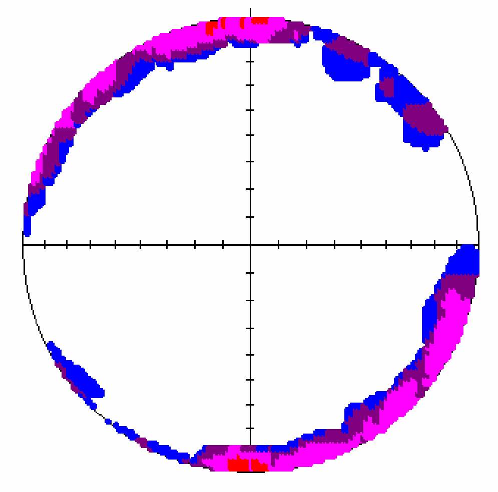


Figure 6: Stereonet plot of all fractures dipping $>80^{0}$

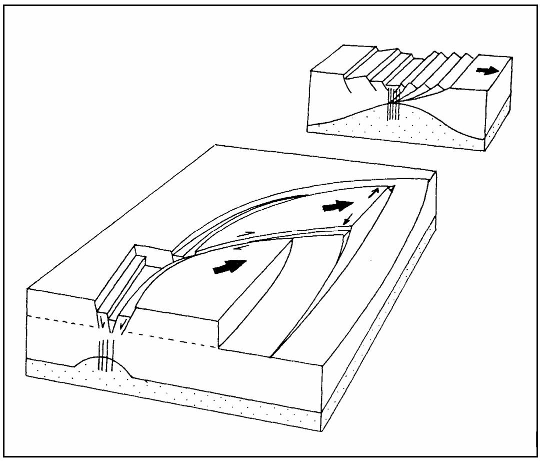


Figure 7: Block diagram of transtension

The stresses responsible for the observed joint sets are shown in Table 4.

Table 4: Orientation of stresses responsible for observed fracture sets

Dip (degrees)	Setting	Orientation Strike°/dip°	Compression Strike°/dip°	Neutral Strike°/dip°	Extension Strike°/dip°
80° - 90°	Dip-slip	198/86 24/90	199/85	213/71	109/-5
	Dip-slip	225/86 50/89	228/89	224/37	138/-1
	Dip-slip	251/85 75/89	73/90	231/71	343/0
	Dip-slip	272/85 90/89	272/89	92/10	182/-1
	Dip-slip	326/80 143/85	143/88	144/6	53/2
	Dip-slip	117/82 296/87	117/86	296/14	27/4
61° - 80°	Dip-slip	337/70 163/70	337/81	337/3	247/-9
	Dip-slip	360/71 179/69	360/80	179/3	270/-10
	Dip-slip	275/68 90/71	90/86	91/19	360/4
	Dip-slip	69/75 234/68	67/80	242/27	337/10
	Dip-slip 3D	338/69 1/70 303/62 119/65 143/73 165/68	340/82	157/20	250/-8
45° - 60°	Dip-slip	161/50 338/56	161/63	340/2	71/27
<45°	Thrust slip	353/34 162/41	266/-67	169/1	353/16

Fractures dipping between 80-60^{0}

These fracture sets are considered to be related to dip-slip stresses (Figure 8). Prominent sets strike east-northeast, east-southeast, south-southeast, south-southwest, southwest, west, and north-northwest respectively. The most prominent conjugate sets are those striking north-northwest and east-northeast, which suggests two dominant extension orientations at perpendicular angles: one to the north-northwest and one to the east-northeast. These stresses confirm a model of west-southwest oriented tension arising from wrenching on the Aghulas Fracture Zone, and uplift or transtension causing northwest to southeast oriented tension. The stresses responsible for these fractures are shown in Table 4.

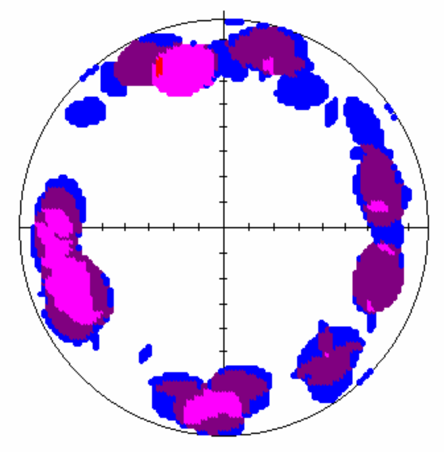


Figure 8: Stereonet plot of all fractures dipping 60-80^0

<u>Fractures dipping between 60-45°</u>

Only one conjugate set strikes to the north-northwest to south-southeast (Figure 9). These can be attributed to dip-slip stresses, or joints with a thrust slip origin that have subsequently been tilted.

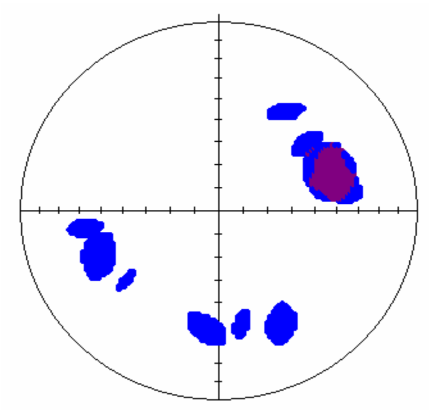


Figure 9: Stereonet plot of all fractures dipping 45-60^0

Fractures dipping less than 45°

The orientation of thrust-slip fractures is shown in Figure 10. The most prominent set strikes north to south and dips to the east. In general, few fractures with a thrust-slip origin can be observed.

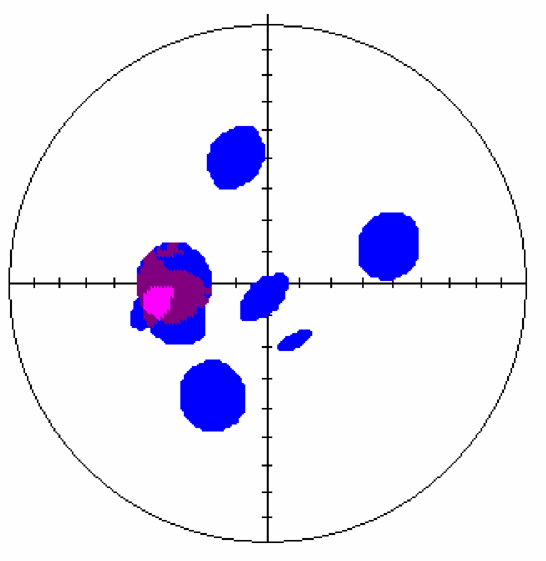


Figure 10: Stereonet plot of all fractures dipping <45^0

6.6.5 Orientation of stress fields

Dip-slip setting

Figure 11 shows the stereonet of the direction of maximum extension for the dip-slip setting based on the data in Table 1. Extension structures generally strike at 140 -160°, dipping steeply to the southwest (Figure 12). Another cluster strikes from 70 - 90° and dip steeply southward. This suggests tension stresses oriented to the west-southwest and to south-southeast to south.

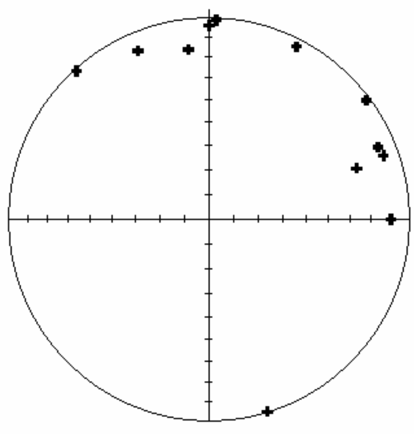


Figure 11: Directions of maximum extension for the dip-slip setting

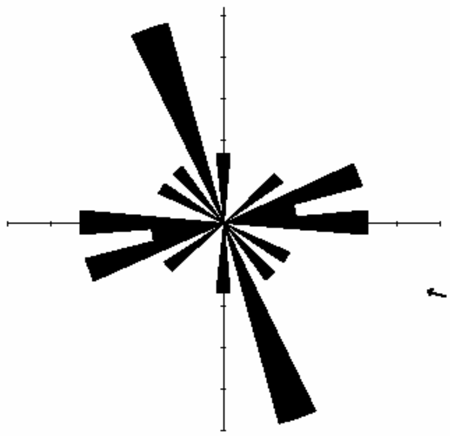


Figure 12: Rose Diagram of the orientation of maximum extension

6.6.6 Structural Interpretation

Analysis of joint orientations suggest that structures oriented to the south-southeast and dipping steeply to the west-southwest have a tensional origin, however, available seismic data has not been able to confirm that this stress orientation exists today due to the low density of seismic stations in the region.

East-northeast to east striking and south dipping structures also have a tensional origin, however the nature of this stress cannot be confirmed. North-northwest tensional stress may have originated from transtension related to movement on the Aghulas Fracture Zone, or due to differential stresses resulting from continental uplift.

The present day drainage network follows a south-southeast orientation, with significant east-northeast kinks on major rivers. This confirms that these orientations represent zones of major weaknesses in the rock, exploited by major river channels.

South-southeast and east-northeast trending structures therefore form the most suitable drilling target for high yielding boreholes. A lineament analysis is required to identify the location of these structures.

6.7 EROSION SURFACES

Sea level fluctuations and erosion has peneplained the fringes of the Cape Supergroup rocks, unconformably depositing fossil and modern dunes in the present-day coastal zone.

The African erosion surface, which was developed both above and below the escarpment, was initiated by the break-up of Gondwanaland. The escarpment was pushed progressively further into the interior by head-ward erosion of rivers, a broad plain developed in the coastal margin, while offshore, a marine cut bench developed on the more resistant rock-types. This erosion persisted to ‘Old Age’ and caused the Bushmans and Fish Rivers to meander in their upper reaches. Because of the resistance to erosion, sandstone and quartzite rocks of the CFB have always stood high above younger erosion surfaces developed on surrounding softer rocks.

The development of silcrete on the African erosion surface: Deep weathering caused silica to migrate into the upper portions of the soil profile that underlay low points in the landscapes. Nevertheless, because of the resistance of silcrete to erosion and the later dissection of the African erosion surface by younger erosion, silcrete remnants now usually form the highest points of the landscape. Consequently, an inversion of the topography has taken place as far as silcrete deposits are concerned. This has positive implications with respect to groundwater potential, as drilling will invariably be restricted to valleys.

Development of the early Post-African erosion surface: About 18 million years ago, epeirogenic uplift of some 100 to 200 m took place in the Eastern Cape. The axis of uplift was parallel to and ~ 70 Km inland of the coastline. As a result, the coastal areas were tilted seaward. This initiated a new cycle of erosion as rejuvenated rivers cut down to new erosion base levels. The seaward tilting of the proto-Eastern Cape on the coastal side of the axis of uplift led to an invasion of the land by the sea. A major embayment formed between Port Elizabeth and Port Alfred – similar to the present day Algoa Bay. Limited coastal areas northeast of Port Alfred were also submerged.

Sedimentary deposits associated with submergence now form beach deposits, comprising the Alexandria Formation, in which large fossil oysters predominate.

Development of the later Post-African erosion surfaces: The early erosion cycle was terminated by major uplift and seaward tilting of the coastal hinterland about 4 million years ago. This uplift raised the Alexandria Formation beach sediments to an altitude of some 300 m at Paterson. The later erosion surface developed mainly as a valley incision cycle as there has not been enough time to reduce the land to a plain. Where the later erosion cycle has penetrated into the interior, it has operated to local base levels resulting from variations in rock hardness and resistance to erosion.

Recent events: These lasted from 1,8 million to 10 000 years ago and were characterized by sea level movements, resulting from worldwide climate fluctuations. In overall terms, the sea level declined. These fluctuations in sea level gave rise to a number of well-developed marine terraces. During this time, sandy limestone of aeolian origin, corresponding to the Nahoon Formation, were deposited. About 18 000 years ago, during the peak of the world wide Last Glacial stage, sea level was about 120 m below its present level. As a result the lower courses of rivers in the Eastern Cape, such as the Bushmans, Kowie and Fish rivers, became deeply incised. Subsequent rises in sea level some 5 000 years ago have caused alluvial infilling of these incised valleys to depths of up to 40 m or more.

Modern events: During the last 10 000 years, climatic changes and sea level movements gave rise to extensive dune fields around Algoa Bay, producing the Alexandria dune fields. Sea level rose about 2 m above its present level some 5 000 years ago, as evidenced by raised beach deposits near the mouths of many rivers. By 3 700 years ago sea level had reached its present level.

6.8 REMOTE SENSING

The principle objectives of using remote sensing are to:

- To define geological boundaries

- To identify on a regional scale internal tectonic structures that represent potential groundwater targets
- To undertake the pattern of fracture orientation and density over a range of characteristic length scales

Aster images, including digital elevation and topographic data, were acquired for the project. The reader is referred to the comprehensive digital dataset entitled 'Ndlambe Geospatial Digital Atlas' compiled by Tyson (2004), which has been included as Addendum A to this report.

6.8.1 Digital Elevation Model Analysis

Using the DEM and elevation modelling procedures the following data sets were created:

- slope and aspect raster as well as a sun-shaded DEM data set
- drainage vector and basins/catchment areas and raster for flow directions and flow accumulations.

Utilising 1: 50 000 Topographical sheets covering Ndlambe, the following infrastructure and ancillary data was incorporated: Municipal boundary, roads, railway line and towns.

6.8.2 Satellite Image Processing

Two ASTER Image Maps were acquired to provide satellite coverage of the region. The images were received in geotiff format and the following procedures were run on the data in order to make it suitable for processing:

- Accurate georeferencing and resampling to fit the 1:50 000 Topographical sheets and other data.
- Image decomposition to separate the image into three bands representing the original data. These bands cover the green, red and near-infrared portions of the electromagnetic spectrum and have a 15 m pixel size
- Hue/Intensity/Saturation analysis to enhance the details visible on the image
- Principal Components Analysis to enhance information available in the image dataset and to search for anomalies
- A Normalized Difference Vegetation Index (NDVI) to highlight vegetation cover and patterns

- A Lap Lace edge enhancement filter was run on the red and infrared bands of the image to highlight linear features within the dataset.

A script was also run to try and de-vegetate the red and near-infrared bands. These attempts were conducted to strip the image of vegetation and emphasize the ground below. This script was designed for semi-arid/sparsely vegetated regions, and in this case, Ndlambe is fairly heavily vegetated – in particular farmland, forests and grasslands. Although the procedure was not as successful as in other areas, it did reveal some additional patterns in the landscape.

6.8.3 Lineament Mapping and Interpretation

Many landform patterns are visible from both the DEM and ASTER image datasets. The additional analyses provide valuable support information in mapping out the drainage networks and catchment's areas; assessing the pour points between basins and flow accumulations along the drainage network; assessing the slopes and aspects of sites of interest; assessing relationships between existing boreholes and potential sites; assessing distances and access routes; and many other features.

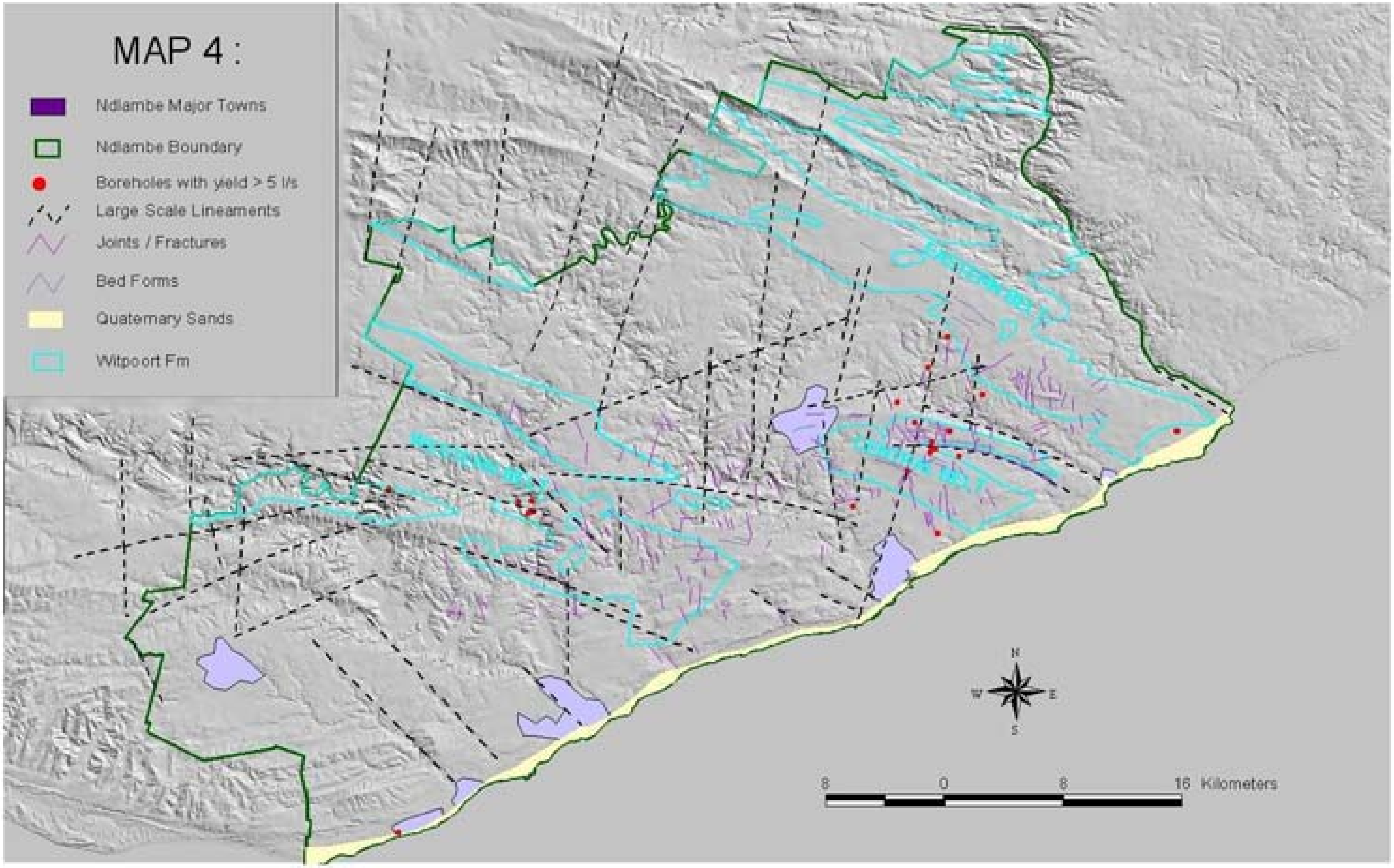
The Digital Atlas (Addendum A) contains all the data specified above with styled and annotated legends. These have been produced to provide easy access to view and explore the entire dataset. Many tools are included for the user to conduct further interpretations of the data. These tools include querying databases, measurements, drawing cross-sections, sketching and annotating and printing displays. Also included are instructions on how to use the Atlas. The data has been exported to ArcView and geotiff files for use by a range of GIS software packages.

The present day drainage network follows a south-southeast orientation, with significant east-northeast kinks on major rivers. This confirms that these orientations represent zones of major weaknesses in the rock resulting from tensional stress that have been exploited by major river channels (Map 4). Other obvious lineaments include the north-northeast to south-southwest and southeast to northwest directions. This could represent conjugate strike-slip structures associated with the south-southeast normal faulting.

There is a general paucity of data in the coastal zone owing to the blanketing effect that fossil and modern dunes have on the Cape Supergroup rocks. It was concluded that the scale of the dataset is such that large/medium scale structures become very clear and are highlighted by many of the data layers. However, small-scale features are not visible due to the resolution of the datasets. In order to produce detailed fracture maps of the small areas requested, high-resolution aerial photography would be required in combination with field investigations.

6.8.4 Aerial Photographs

Limited aerial photographs (in stereo-pairs) have been purchased to cover select areas of interest to this study and the concomitant Witpoort drilling project and include Bushmans/Kenton, Merville farm and Port Alfred. Stereoscopic interpretation of the area around the farm Merville located a strong structural fabric trending southeast-northwest. This feature was ground-truthed and found to be a significant fault, with a 5 m thick crush zone separating vertical dipping rocks (north) from horizontal dipping rocks (south).



NDLAMBE: LINEAMENTS, JOINTS AND BEDDING FROM SUN-SHADED DEM

7. HYDROGEOLOGICAL DESCRIPTION

7.1 BOREHOLE INFORMATION AND STATISTICS

Borehole data exists in the National Groundwater Database (NGDB) and 755 boreholes are listed for the area. The NGDB is neither comprehensive nor complete. It is estimated that less than half the actual boreholes drilled and/or utilized are reflected in the NGDB (pers. obs. and pers. comm. Walter Penny, Agricultural Extension Officer, Grahamstown). Nevertheless, the NGDB can be used to perform a regional assessment of background hydrogeological conditions.

Limited hydrocensus work has also been conducted around each of the affected towns in Ndlambe. Initially this fieldwork involved visits to DWAF officials, consulting engineers, municipal staff, ratepayers, agricultural extension officers and commercial farmers to obtain an overview of groundwater resources and potential problems. Subsequent visits were geared at collecting hard hydrogeological and geological data. An additional 24 boreholes have been appended to the NGDB for statistical analysis. All the borehole information is tabulated in Appendix A and summarized in Table 5. Map 5 shows borehole localities and yields of boreholes within Ndlambe. These boreholes are superimposed over Topographical sheets in much more detail as Appendices B to G.

Table 5: Median borehole data from the NGDB for Ndlambe

Aquifer	(n)	Depth (mbgl)	SWL (mbgl)	Water Strike	Yield (ℓ/s)	Max Yield		EC (mS/m) (n)	Remarks (Area)
						ℓ/s	Location		
FRACTURED									
Bokkeveld	41	76.5	25	49.07	0.07	2.71	Ghio	405 (15)	223 Km²
Weltevrede	224	73.15	30.2	56.5	0.37	25	Mansfield	244 (9)	661 Km²
Witpoort	272	65.5	22.2	55.6	0.49	25	The Grove	305 (21)	502 Km²
Lake Mentz	51	73.15	30.0	56.0	0.55	25	Pinelands	364 (7)	220 Km²
Dwyka & Ecca	1	44	19	23.0	0.81	0.81	Spanish Reeds		21 Km²

INTERGRANULAR									
Alexandria	17	91.4	20.0	43.0	0.7	3.4	Bathurst	307	35 Km²
Nanaga	145	87.1	25.6	50.9	0.29	76.8	Palmiet	(43)	306Km²
Schelmhoek	4	8	2.5	6.0	1.5	5.0	Dias	213 (8)	39 Km²
TOTAL	**755**								**2007 Km²**

7.2 BOKKEVELD AQUIFER

The sand:clay ratio plays a noticeable role both quantitatively and qualitatively in the occurrence of groundwater, causing borehole yields and chemistry to vary widely. A high proportion of clay results in these rocks deforming without inducing secondary fracturing. Within Ndlambe, the Bokkeveld aquifer (n=41) produces a median yield of 0.07 ℓ/s, while a maximum yield of 2.71 ℓ/s has been recorded on the farm The Ghio, north of Kenton. Figure 13 shows the distribution of borehole yields in the Bokkeveld aquifer.

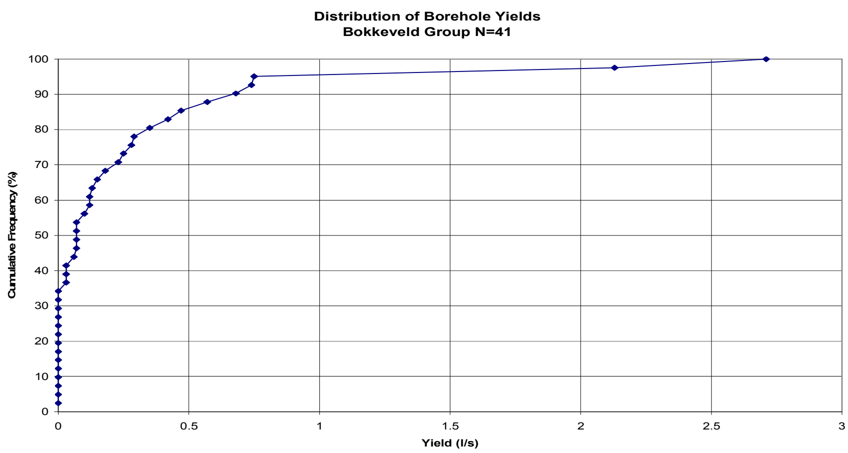


Figure 13: Distribution of borehole yields-Bokkeveld Group

A spring, which supplies water to the development of Natures Landing, is reputed to yield ~ 2.5 ℓ/s (pers. comm. K Wilmot) of Marginal (Class II) quality water. According to Meyer (1980), where sandstone units have been targeted, 5 % of boreholes yield > 5 ℓ/s. This phenomenon may be responsible for the high yield recorded in the centre-pivot equipped borehole on the farm Boschfontein, immediately west of Cannon Rocks.

Water strikes are encountered from 5 -100 m (Figure 14), but few strikes occur below 85 m. The median water strike is 49 m. The highest yielding water strikes occur above 40 m (Figure 15).

Static water levels (Figure 16) are variable and range from 5 - 95 m, with a median of 25 m. This reflects the varied topography of the region.

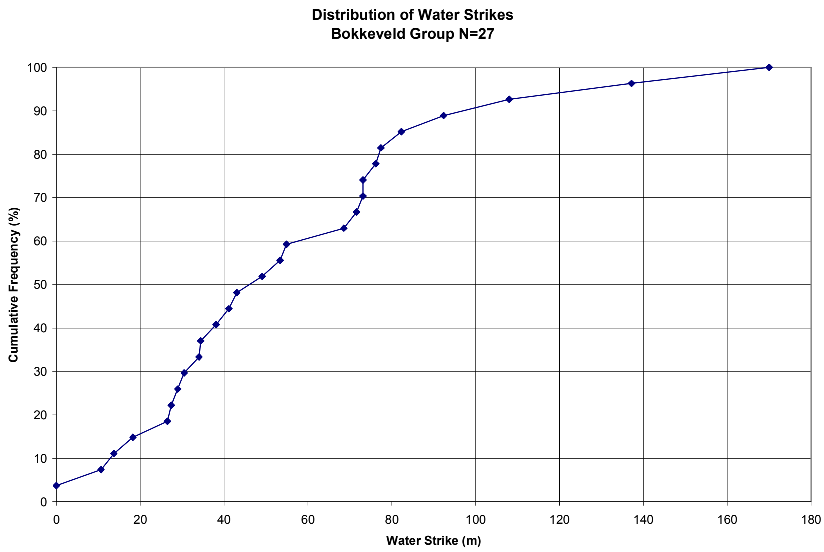


Figure 14: Distribution of water strikes-Bokkeveld Group

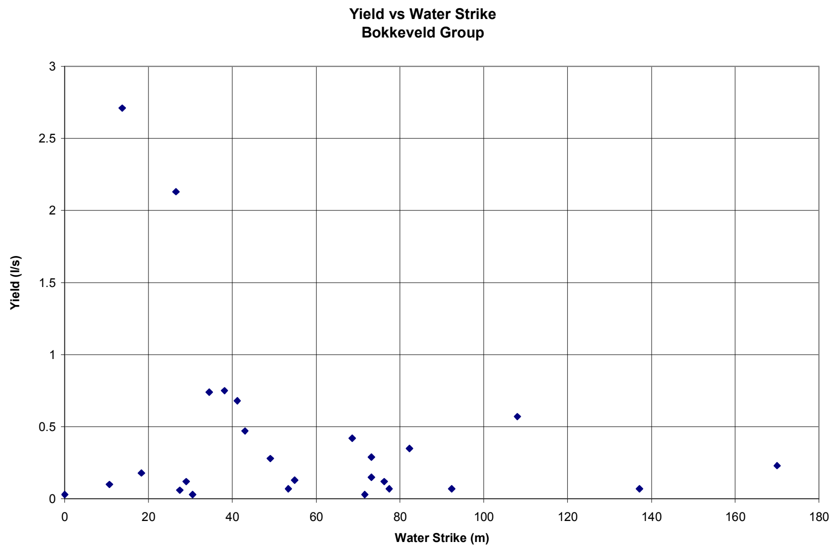


Figure 15: Water strike depth versus yield-Bokkeveld Group

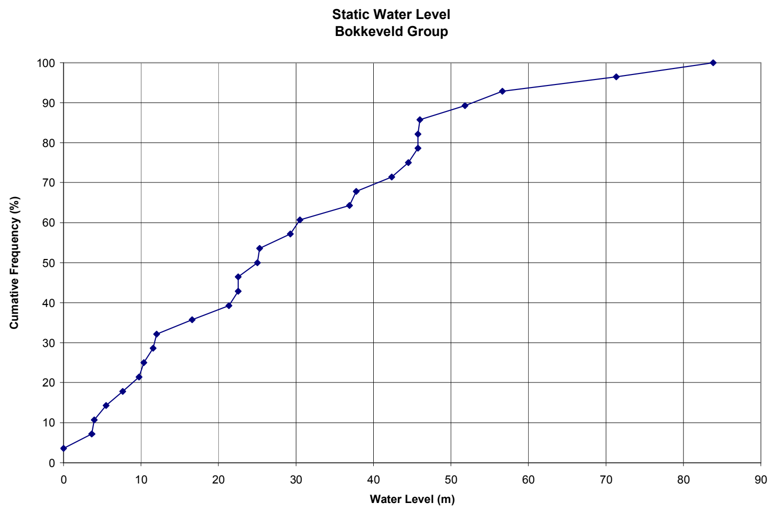
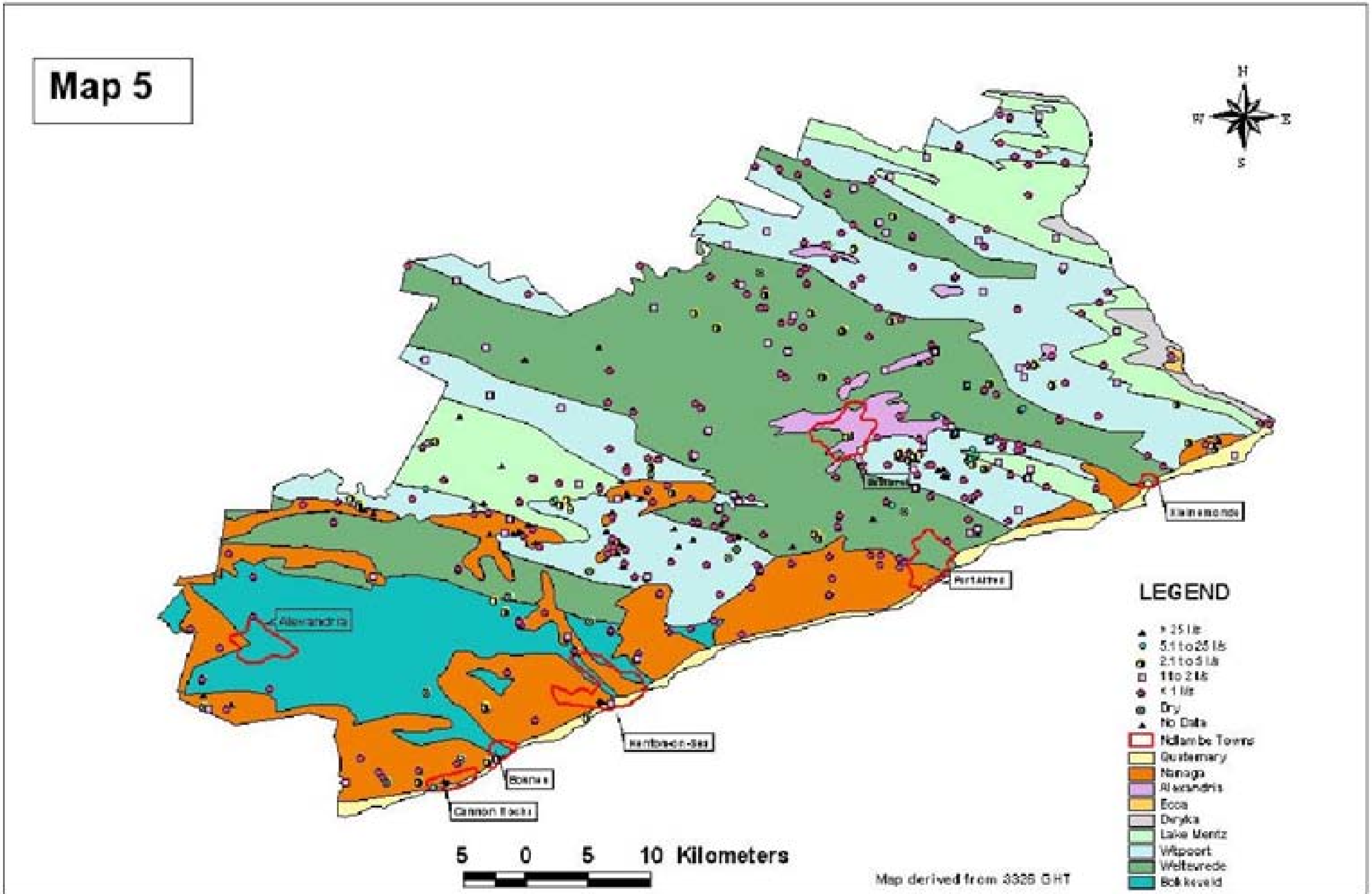


Figure 16: Distribution of static water level-Bokkeveld Group



Ndlambe : Borehole Localities & Yields

Bokkeveld shale is associated with poorer water quality and electrical conductivities (EC's) commonly exceed 200 to 400 mS/m i.e., Marginal (Class II) water quality to Poor (Class III) water quality. Sodium, chloride and sulphate often exceed maximum recommended and/or allowable limits. Groundwater in the Bokkeveld is generally of a sodium-chloride nature with its character taking on the chemistry of the ancient environment of deposition.

Through the preferential erosion of the Bokkeveld shale, an irregular, impermeable basement to a thin succession of recent and modern dune sands has developed. This basement (or wave-cut platform) slopes seaward at ~ 1.5º and controls the specific flow of groundwater towards the sea. An understanding of the trends in the buried landscape is important in the exploration of water in the coastal environment. Obvious targets are ancient, buried depressions or valleys, which are in turn blanketed by large, permeable catchment areas. These buried structures can be mapped or located geophysically.

The importance of the Bokkeveld is not for its aquifer potential - but rather for the role it plays as an aquiclude. The aquifer can be developed locally to serve domestic water to small homesteads, stock watering and smaller water supply schemes.

The Bokkeveld aquifer makes up 12 % of the surface area of Ndlambe, yet accounts for less than 6 % of recorded boreholes – suggestive of a low groundwater potential.

7.3 WELTEVREDE AQUIFER

The Weltevrede Formation consists of shale and subordinate sandstone. A median borehole yield of 0.37 ℓ/s was determined (n=224). The distribution of borehole yields is shown in Figure 17. Of this sub-population, six boreholes recorded yields > 5 ℓ/s. High yields have been recorded on the farms of Mansfield (25 ℓ/s), Port Alfred Park (16 ℓ/s) and Sweet Fountain (10 ℓ/s), which may have intersected sandstone units. These boreholes are also located topographically below prominent Witpoort Formation outcrop, which may also help explain the high yields encountered.

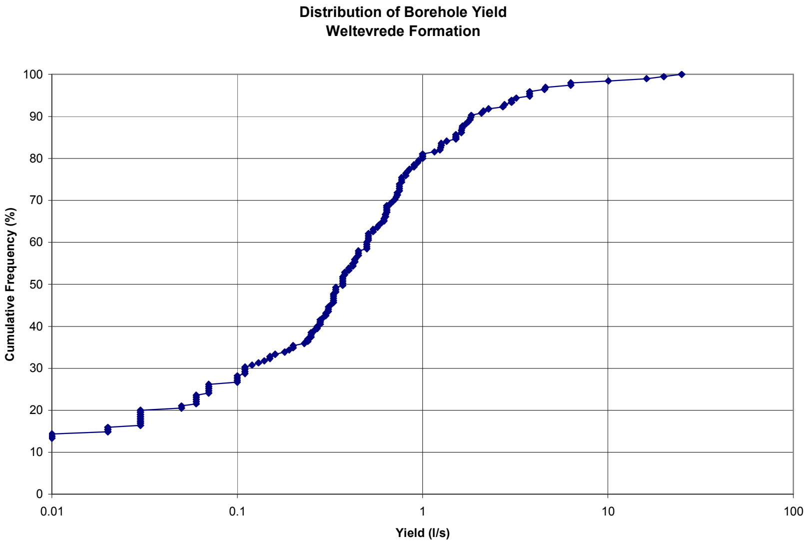


Figure 17: Distribution of borehole yields-Weltevrede Formation

Water strikes generally occur down to 100 m, suggesting that prevalent tectonic related fracturing occurs (Figure 18). No relationship exists between yield and water strike depth due to the tectonic nature of fracture zones. This implies fracture zones are not weathering related (Figure 19).

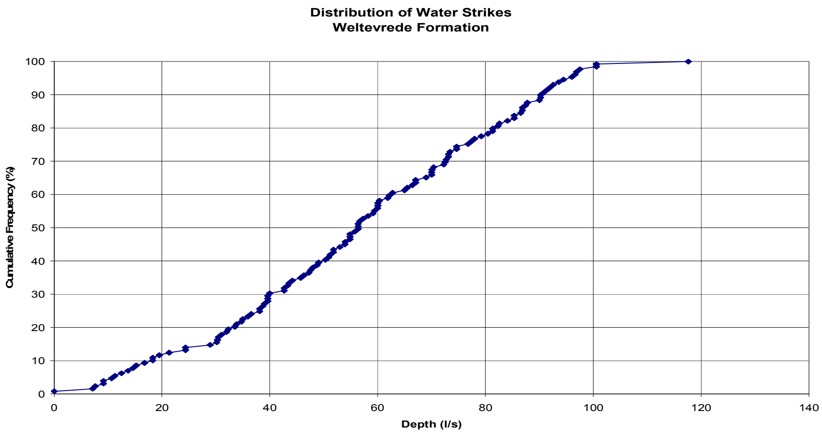


Figure 18: Distribution of water strikes – Weltevrede Formation

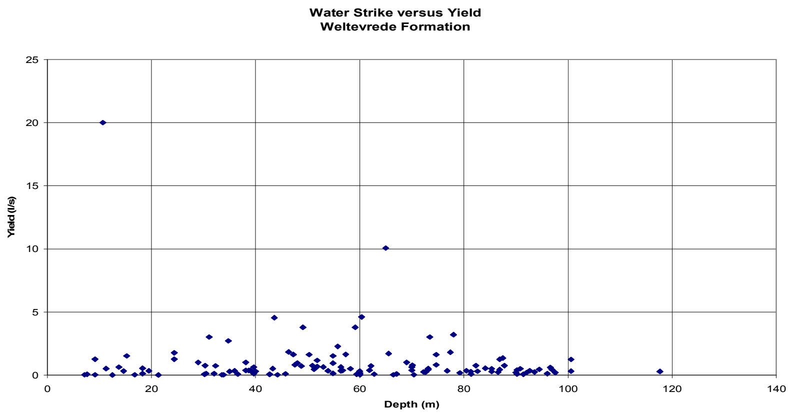


Figure 19: Water strike versus yield – Weltevrede Formation

Static water levels range form 0-70 m, and are generally topographic position dependent (Figure 20).

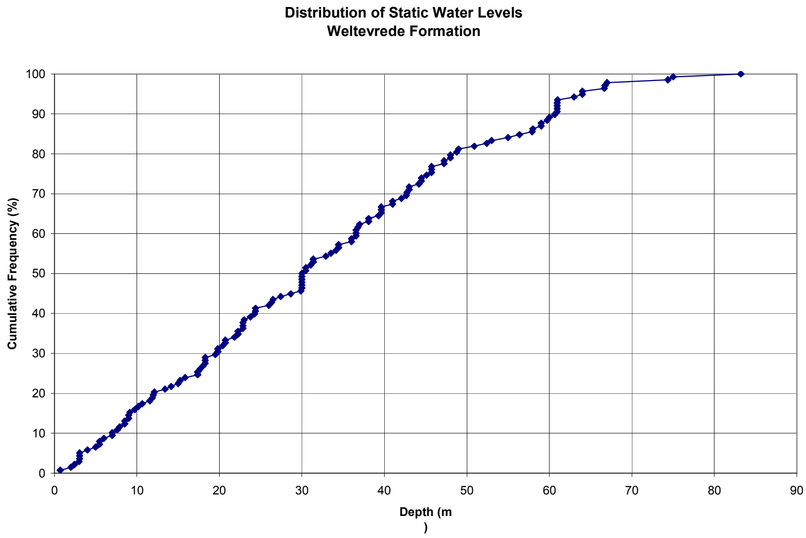


Figure 20: Distribution of static water levels – Weltevrede Formation

Brackish groundwater, with EC's ranging between 40 - 1 400 mS/m can be expected, with higher salinities from the shale components. Some 50 % of the water quality is Class II and 25 % is Class III (Figure 21).

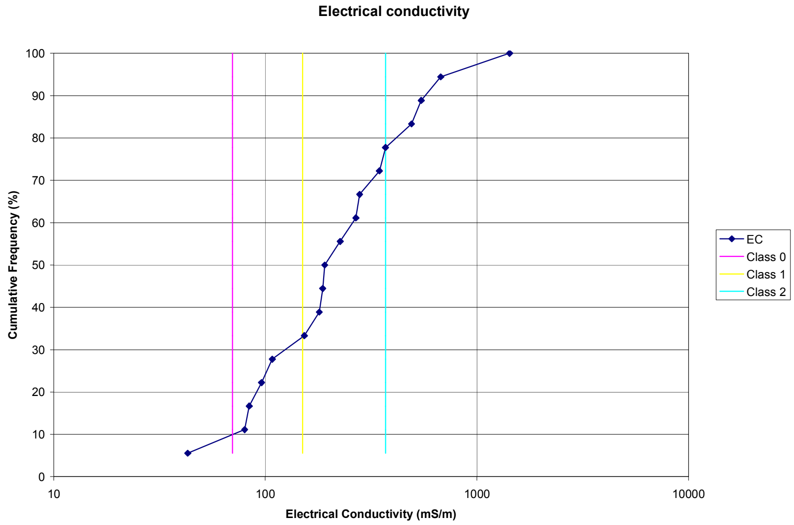


Figure 21: Electrical conductivity of borehole water – Weltevrede Formation

The following determinants often exceed the maximum allowable limits in the shale's viz., sodium, magnesium, chloride and sulphate. Groundwater in the shale is generally of a sodium-chloride nature. Groundwater associated with the Weltevrede sandstone is expected to be of better quality.

The Weltevrede Formation posses a moderate groundwater potential, with 55 % of boreholes yielding 0.2 – 2 ℓ/s and 35 % yielding less than 0.2 ℓ/s. Hence the aquifer can only be used for small water schemes.

The Weltevrede aquifer makes up 33 % of the surface area of Ndlambe, and accounts for 30 % of recorded boreholes.

7.4 WITPOORT AQUIFER

The ~ 300 m thick Witpoort Formation is an orthoquartzite unit, which overlies the Weltevrede Formation. A borehole analysis (n = 272) indicates that the median yield is 0.49 ℓ/s (Figure 22). Of this sub-population, 10 % yield more 2.8 ℓ/s. Of these 21 boreholes, 4 of them were drilled at Merville during this investigation. This suggests that the database may under represent the potential of the Witpoort, since most of the boreholes did not target high yielding structures and/or were to shallow.

High yields have been recorded in each of the three belts within Ndlambe viz., at The Grove (2 x 25 ℓ/s), Merville (7 & 20 ℓ/s) and Dundas (15 ℓ/s). The spectacular yields (viz., an unconfirmed 77 ℓ/s) recorded at Palmietheuwel, behind the Fish River Lighthouse, should be defaulted to the Witpoort, despite being collared in Nanaga Formation.

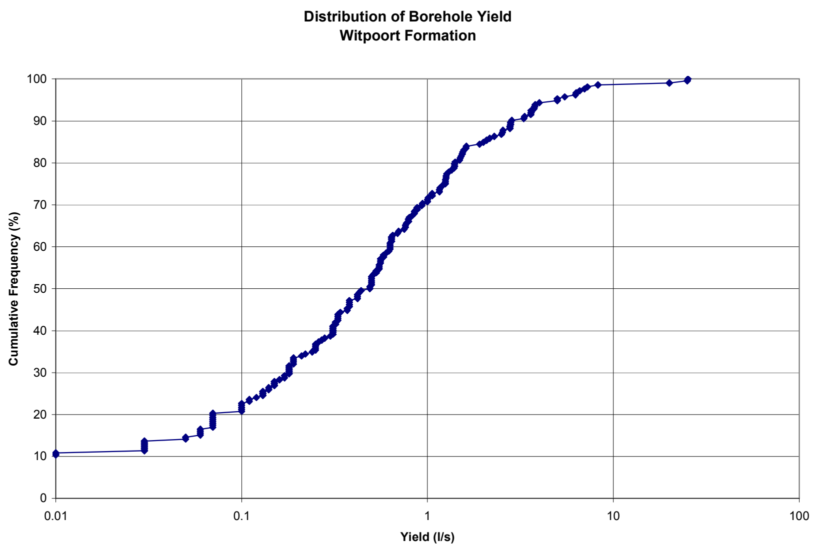


Figure 22: Distribution of borehole yield- Witpoort Formation

Water strikes generally occur down to 90 m (Figure 23). However, it can be noted that the distribution of drilling is only approximately 10 m deeper than water strikes, suggesting in many cases boreholes have not been drilled deep enough to encounter additional water strikes. It is also significant to note that the average water strike depths (viz., 74 m) recorded under very favourable conditions at Merville exceeds the median drilling depth recorded in the NGDB.

No relationship exists between yield and water strike depth due to the tectonic nature of the water bearing fracture zones (Figure 24).

The Witpoort can also be exploited through the presence of many springs. One such spring, the Kariega Spring, on the farm Merville is thought to be tapping a southeast-northwest fracture. This spring has been estimated by Reynders (1987) to yield between 15 to 20 ℓ/s. The reported strategy was to pump the spring for 18 hours at 20 ℓ/s, followed by a period of recovery of 6 hours, to produce 473 040 m³ per annum of marginal quality (i.e., Class II) water. This volume is 1.5 times greater than the production of the Dias Cross well field and is of a similar quality. As the upper reaches of the Kariega River flows through weathered rocks with a marine origin, runoff and leaching from these rocks is responsible for introducing salts into the spring. Depending on seasonal rainfall, the EC's of the Merville Spring can vary between 160 and 320 mS/m.

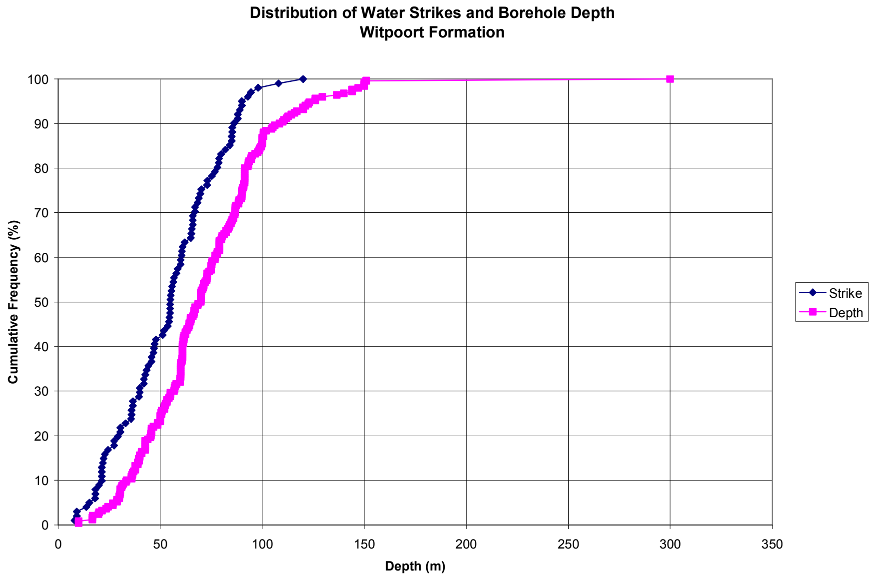


Figure 23: Distribution of water strikes and borehole depth – Witpoort Formation

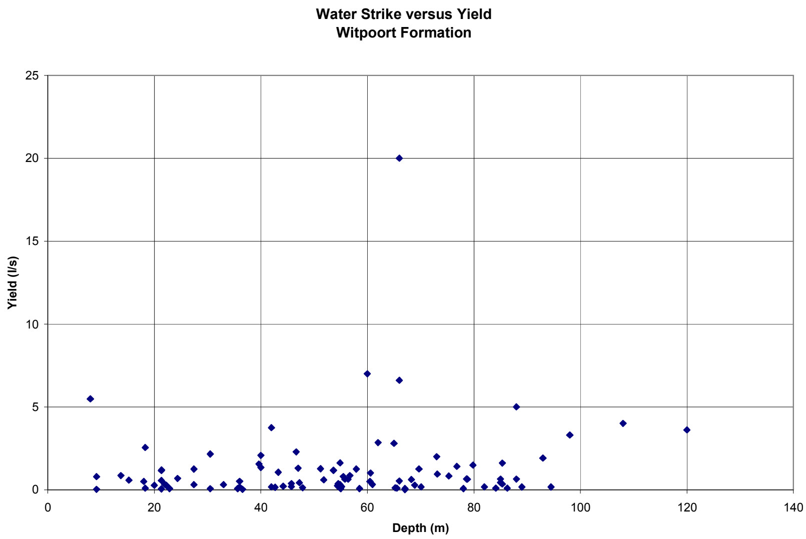


Figure 24: Water strike depth versus borehole yield – Witpoort Formation

Static water levels generally range from 0 – 50 m depending on topographic setting (Figure 25).

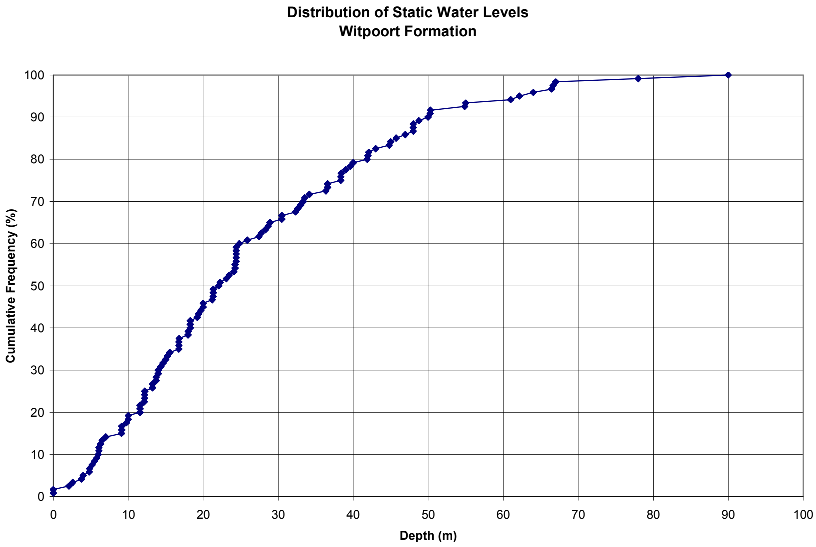


Figure 25: Distribution of static water levels – Witpoort Formation

EC's of groundwater from these quartzite's ranges between 5 – 314 mS/m i.e., Ideal (Class 0) or Marginal (Class II) quality water. Some 50 % of the water quality samples are of Class II, but only 5 % are of Class III (Figure 26).

The following determinants might occasionally exceed maximum recommended limits: sodium, chloride and total alkalinity. Groundwater from the sandstone and orthoquartzite units is invariably of a magnesium-chloride nature. Poorer quality water is associated with unfavourable recharge conditions and/or abundant black phyllite encountered during drilling. The phyllite acts as a conduit, drawing in poorer quality water from the enclosing shale formations.

Some of the highest yielding boreholes, such as the artesian boreholes at The Grove, in close proximity to the Cuylerville Cricket Club, have EC values in the range 60 mS/m.

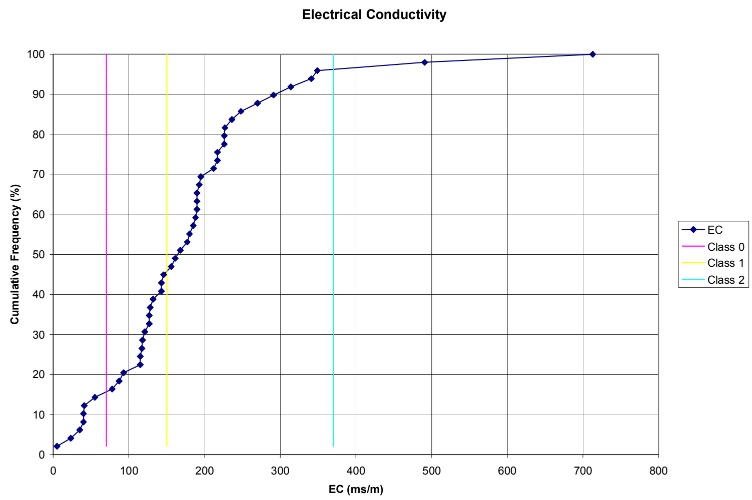


Figure 26: Distribution of borehole water quality - Witpoort Formation

A characteristic of groundwater derived from the Witpoort aquifer is that it is often sweet to taste, slightly acidic and iron-rich. Once a borehole is functional, the action of iron bacteria can set in under certain circumstances, due to the iron titanium oxides present on cross-bed foresets in the quartzite matrix. Iron bacteria problems often occur when formations with substantial levels of iron and manganese are exposed to oxidising conditions due to pumping. Slimy material is created which may plug screen pores and perforated slotted casing and may even retard fracture permeability, rendering a once productive borehole much less effective. Borehole rehabilitation is possible with chemical treatment, however, controlling fluctuations in draw down is preferable to avoid the problem.

The low pH of the groundwater is also a problem due to the consequent corrosive action that makes relatively inexpensive steel unsuitable for well screens and casing. The use of uPVC can be used to overcome these problems.

DWAF recently undertook drilling in Ndlambe to test the potential of the Witpoort aquifer as a groundwater resource. Drilling started on the farm Merville on a southeast to northwest trending fault with encouraging results, with the third borehole drilled among the best ever drilled in Ndlambe. The structure of the locality is complex and represents a significant tectonically deformed zone. A Rhodes University honours (geology) student is currently mapping the structure of the general area.

Subsequent drilling took place in the vicinity of Kleinemonde, behind the Fish River lighthouse. The results (up to end March 2004) are summarized in the Table 6.

Table 6: Summary of Witpoort Drilling on Merville & Kleinemonde

Borehole Number	Depth (mbgl)	Water Strike	SWL (mbgl)	Blow Yield (ℓ/s)	EC (mS/m)	TDS (mg/ℓ)
ECP 3001	151	88	Artesian	5.0	127	636
ECP 3002	150	98	Artesian	3.3	118	603
ECP 3003	91	66	2.1	20.0	314	1906
ECP 3004	147	60		7.0	212	1090
ECP 3005	126	108		4	92.9	604
ECP 3006	71	40	14.34	1.35	156.0	1014
ECP 3007	123	47		1.3	87.1	566

Another southeast-northwest trending fault was mapped in Potgieter Quarries, immediately south of Merville. This fault displays a 5 m thick crush zone, which separates vertical beds from horizontal beds in the north and south respectively. This fault trends towards the farm Bushfontein, which has a gorge 2 Km long and 240 m deep, through which the Bushmans River flows. Geological structures, observed in the sheer walls, can be utilized to site boreholes with confidence (Plate 7). While the terrain is relatively flat, accessibility, owing to extremely thick vegetation, would pose a problem. The same gorge has been mooted by DWAF to be a potential dam site. An extremely high yielding borehole (viz., an unconfirmed 76 ℓ/s) is mentioned in the NGDB on the farm Ettrick, north of the gorge, but is immediately outside the Ndlambe municipal boundary and not reflected in Figure 21. This gorge is ~ 15 Km from each of the following towns: Alexandria, Boknes/Cannon Rocks and Bushmans/Kenton and represents an obvious groundwater target for these communities and should be considered in conjunction with Merville.

Plate 7 : Gorge on the farm Harvestvale/Boschfontein

In summary, the Witpoort aquifer has high groundwater potential and is largely undeveloped, except by private individuals. Two centre-pivot irrigation systems are known to exist in the vicinity of the Cuylerville Cricket Club, on the Eastern Belt. At least one derives its water from a borehole. The Witpoort Formation has much in common with the Table Mountain Group aquifer that supplies significant groundwater to Jeffreys Bay, where seven boreholes (130 to 150 m deep) and yielding 11 to 28 ℓ/s, supply roughly 50 % of the bulk supply during peak season. Out of season, their contribution is higher as this borehole water is cheaper than piped water from the Churchill Dam.

Large groundwater schemes can be developed within this aquifer although the water may be slightly acidic and aggressive. Some high yielding boreholes also experience salinity problems due to leakage of poor quality water from surrounding formations, especially when marine sediments bound faults.

Access to potential targets may also be problematic, particularly in densely vegetated ravines and valley gorges. In addition, some of the land is occupied by private game reserves not amenable to the development of groundwater within their property. The following game reserves are developed on the Witpoort Formation in Ndlambe: Western Belt – Emlanjeni, Kariega, Sibuya; Central Belt – Nyala Valley and Oceana; Eastern Belt – Kap River, Round Hill/ Oribi and Safari Park/ Fort D'Acre.

DWAF plans to drill additional boreholes to further test the Witpoort aquifer, for the benefit of all towns within Ndlambe.

The Witpoort aquifer makes up 25 % of the surface area of Ndlambe, and accounts for 36 % of recorded boreholes – suggesting high groundwater potential.

7.5 LAKE MENTZ AQUIFER

The Lake Mentz aquifer occurs as three discrete belts within Ndlambe (Map 3). An analysis of NGDB data suggests a median yield of 0.55 ℓ/s. Figure 27 shows the distribution of borehole yields in the Lake Mentz aquifer. Less than 5% of boreholes yield more than 2 ℓ/s. In theory, the Lake Mentz aquifer should not be a prolific producer of groundwater. While this is largely true, some boreholes yield as much as 25 ℓ/s, which can be attributed to the fact that the Lake Mentz rocks overlie those of the Witpoort Formation. While some boreholes may have been collared in the former, they may have intersected groundwater in the latter. Alternatively, the 80 m thick quartzite in the central portion of the Lake Mentz may have aquifer potential. An example of a prolific borehole, which supplies groundwater to the centre-pivot irrigation system, occurs on the farm Goodwoods, roughly 20 Km north of Kenton.

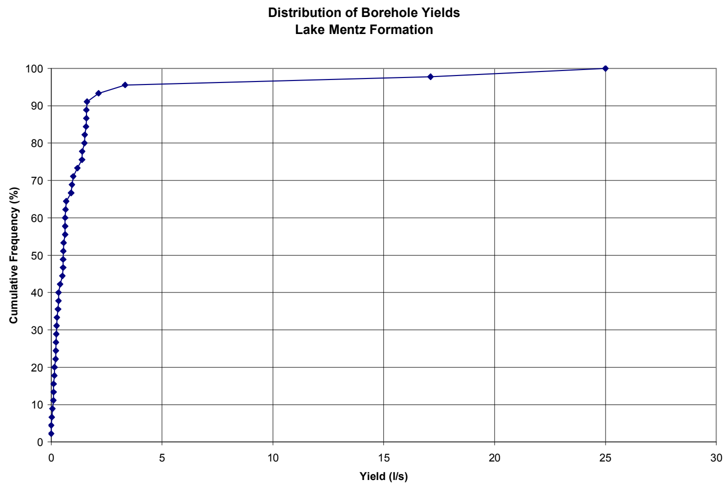


Figure 27: Distribution of borehole yields - Lake Mentz Formation

The competency contrast between the two formations also appears to be a productive groundwater target. Map 5 shows several high yielding boreholes drilled on the geological contact between the Witpoort and the Lake Mentz Formations especially in the central belt. A southeast trending thrust fault has been mapped in this locality (pers. comm. Marc Goedhardt).

Water strikes in the Lake Mentz Formation range from 15 – 110 m, with a median of 56 m (Figure 28). Water strikes are uniformly distributed with depth and water strike frequency does not decline with depth. Yield is also not correlated with depth (Figure 29), suggesting that water bearing horizons are primarily fractured and not related to weathering. Static water levels range from less than 5 m to 100 m, reflecting topographic controls (Figure 30).

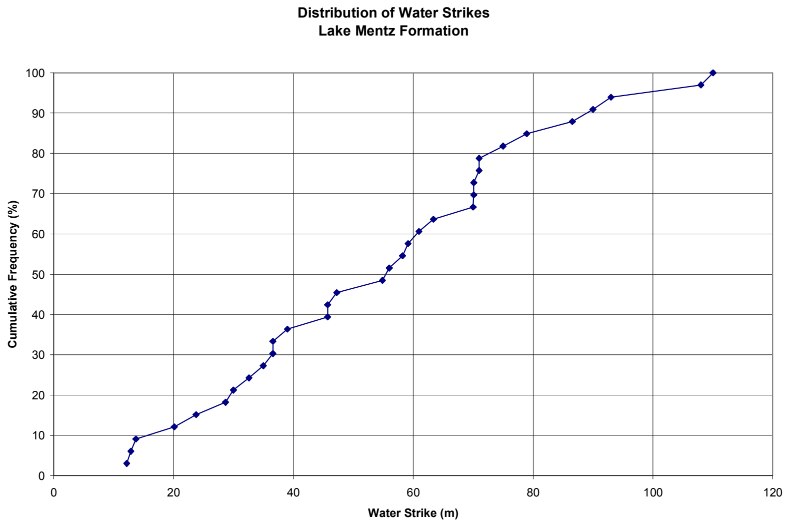


Figure 28: Distribution of water strikes – Lake Mentz Formation

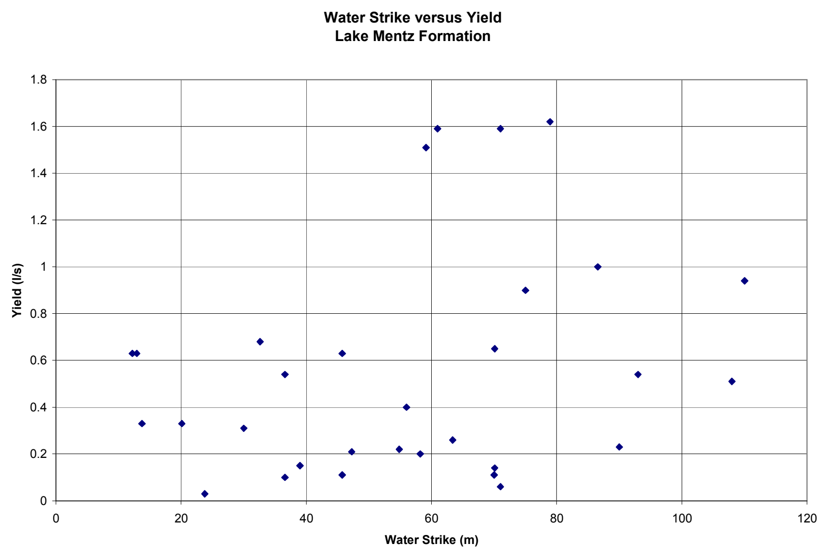


Figure 29: Water strike depth versus yield – Lake Mentz Formation

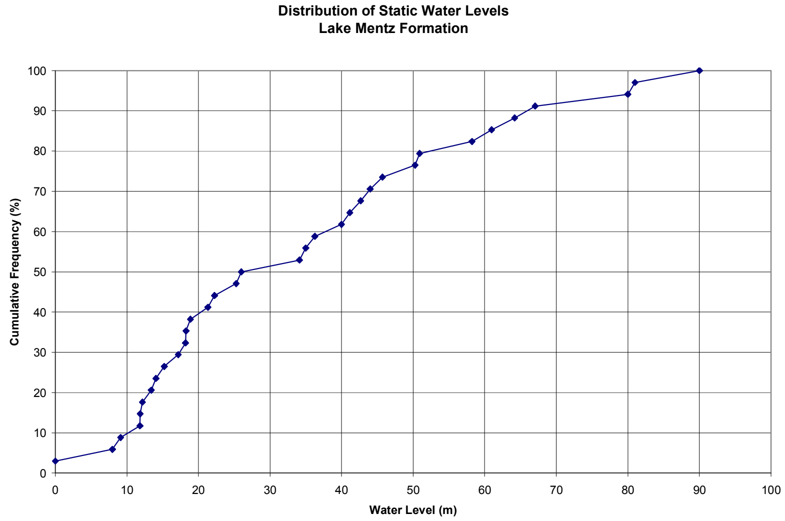


Figure 30: Distribution of Static water levels – Lake Mentz Formation

Groundwater quality is significantly worse than the lithologically similar, Weltevrede aquifer. Groundwater EC's range from 100-400 mS/m (Figure 31) and are generally Class II.

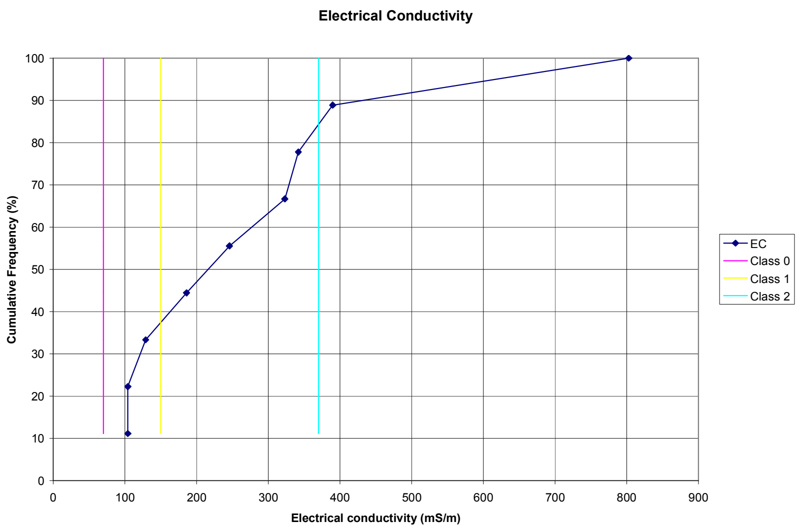


Figure 31: Distribution of borehole water quality – Lake Mentz Formation

The Lake Mentz aquifer makes up 11 % of the surface area of Ndlambe, yet accounts for 7 % of recorded boreholes – suggesting low groundwater potential.

7.6 ALEXANDRIA AND NANAGA AQUIFERS

Coastal primary aquifers are geological formations adjacent to the coastline comprising sufficient water-saturated permeable material to produce significant volumes of water in boreholes and wells. The underlying material may be semi-consolidated (i.e., fossil dunes) to unconsolidated (i.e., modern dunes) belonging to the Nanaga and Schelmhoek formations respectively. Porous rocks account for 19 % of all lithologies within Ndlambe. Relevant NGDB data is summarized in Appendix A, whilst Map 5 shows localities and yields of boreholes in Ndlambe. These boreholes are superimposed over Topographical sheets in much more detail as Appendices B to G.

Collectively, fossil dunes corresponding to the Alexandria and Nanaga Formations form a unique intergranular aquifer. The Nanaga can be considered an aquitard; it stores a significant volume of water but does not transmit water at an economic rate due to its relatively low permeability. In general, the Nanaga drains via springs that emerge at the contact with underlying low permeability formations. When the underlying formation is relatively permeable and is pumped, it can transmit water via vertical leakage to the underlying aquifer.

The basal Alexandria Formation conglomerate is not laterally persistent – its occurrence is governed primarily by the ancient topography of the underlying Cape Supergroup. The conglomerate is best developed in ancient depressions where it contains and transports significant quantities of water. From a hydrogeological perspective, the Alexandria Formation is a thin transmissive zone overlying the Post-African erosion surface through which groundwater draining from the Nanaga Formation flows towards the sea, frequently emerging as springs near sea level (e.g. Cape Padrone).

At Cape Padrone, three wells produce 7 ℓ/s of water on a near continuous basis for the partial requirement of the Alexandria community (Plate 8). A spare borehole is held as a reserve for times of peak demand and produces 3 ℓ/s over a 12-hour pump cycle. These springs have been providing Class 0 and Class I water to Alexandria since 1967 via a 20 Km pipeline. Shutdowns are restricted to routine maintenance and those occasions where spring high tides are accompanied by gale force on-shore winds, causing waves to break over the wells. Abstraction continues as soon as the wind has abated.

Recharge conditions are favourable for the springs at Cape Padrone and are related to a large catchment area of porous Nanaga 'limestone' and generous orographic rainfall.

The distribution of borehole yields is shown in Figure 32. The median yield is 0.3 ℓ/s however, it is often uncertain whether the yield is obtained from the Nanaga and Alexandria Formations, or from an underlying aquifer. The high yielding borehole immediately behind the Fish River Lighthouse with an unconfirmed yield of 76 ℓ/s is almost certainly related to underlying Witpoort quartzite. For this reason, the yield of boreholes collared in the Nanaga and Alexandria Formations must be seen in light of the underlying geology.

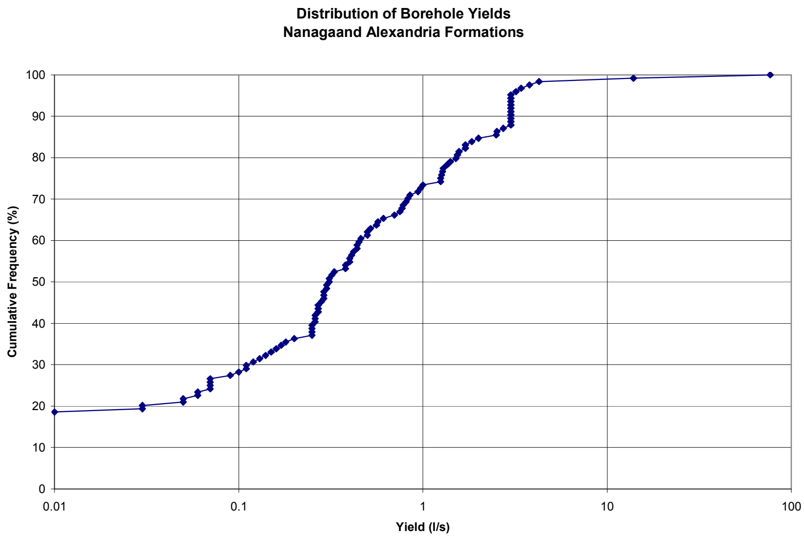


Figure 32: Distribution of Borehole Yields – Nanaga and Alexandria Formations

Additional untapped springs occur beneath the limestone cliffs of Woody Cape and are well known by recreational fishermen. Both the Cape Padrone and Woody Cape springs occur in the Alexandria Forest Reserve – now part of the Addo Elephant Park.

Another high yielding borehole, which derives its yield and favourable water chemistry from similar aquifer conditions, is the centre-pivot equipped borehole on the farm Boschfontein owned by Mr. Christo Potgieter. This borehole is on the western periphery of Cannon Rocks and has been considered as a potential source of bulk water for this community. This borehole has been registered with DWAF and has been licensed to abstract 70 200 m^3/annum for irrigation of pasturage for dairy cattle. This borehole struck water at 36 m, which corresponds to the Bokkeveld sandstone/Alexandria conglomerate contact. This borehole is currently pumped at 10 ℓ/s for three to four days and then rested for a week during late autumn-early spring with no ill effects according to the owner. Recently this borehole was subjected to a constant rate test (72-hours at 10.47 ℓ/s) and reached 1.65 m draw down on completion of the test. Recovery reached 93.3 % after 72-hours. The test indicated that a sustainable rate of 2.5 ℓ/s on a 24-hour cycle could be pumped from this borehole – equivalent to 216 Kℓ/day. This borehole has, in the Ndlambe context, a fairly spectacular yield. The water quality is Marginal (Class II), with a TDS analysis of 1 820 mg/ℓ.

Water strikes generally range from 2 – 90 m, reflecting the variable thickness of this composite aquifer (Figure 33). Water strikes above 1 ℓ/s can occur at any depth, depending on the thickness of the Nanaga Formation (Figure 34).

Static water levels range from less than 1 to 60 m below ground (Figure 35).

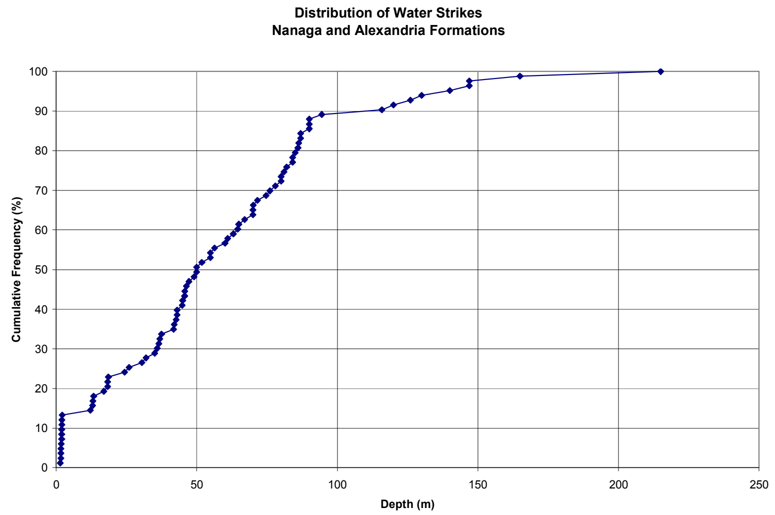


Figure 33: Distribution of Water strikes – Nanaga and Alexandria Formations

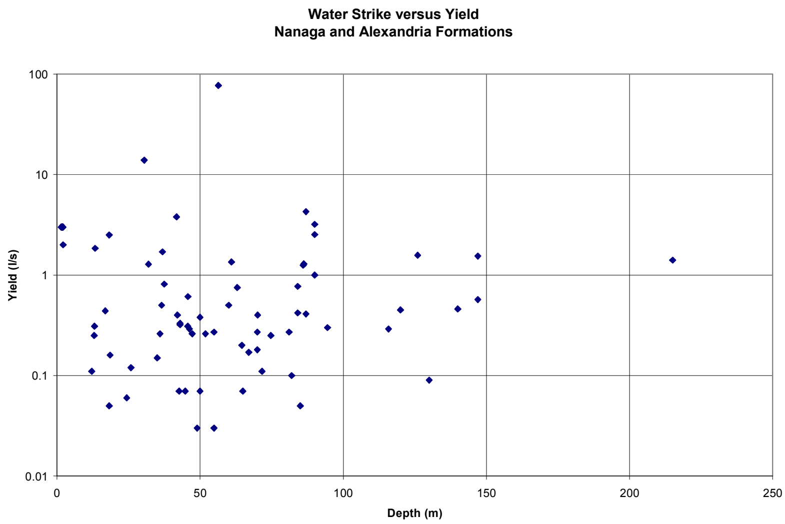


Figure 34: Water strike depth versus yield – Alexandria and Nanaga Formations

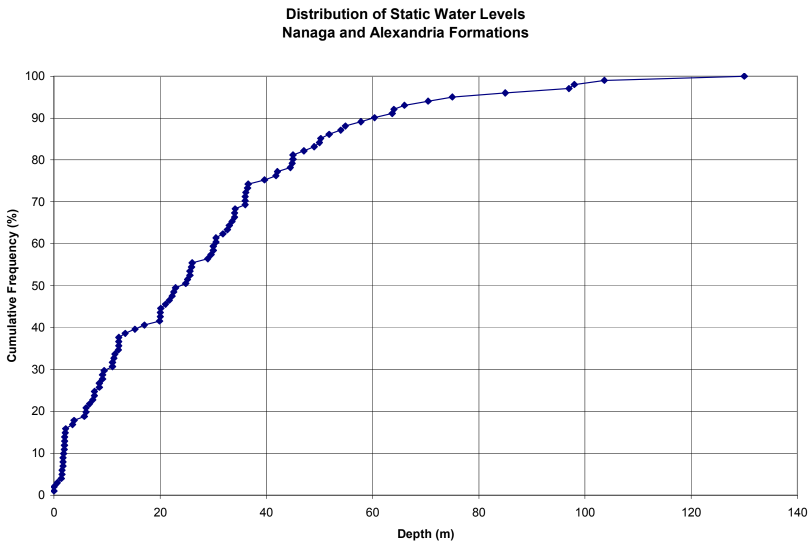


Figure 35: Distribution of static water levels – Alexandria and Nanaga Formations

Plate 8 : Cape Padrone Well Field.

Water quality ranges from 100 – 400 mS/m (Figure 36) and is generally Class II or Marginal quality water. Sodium, calcium and chloride may exceed maximum recommended limits. Groundwater from the Alexandria and Nanaga aquifers frequently displays a sodium–chloride-calcium nature.

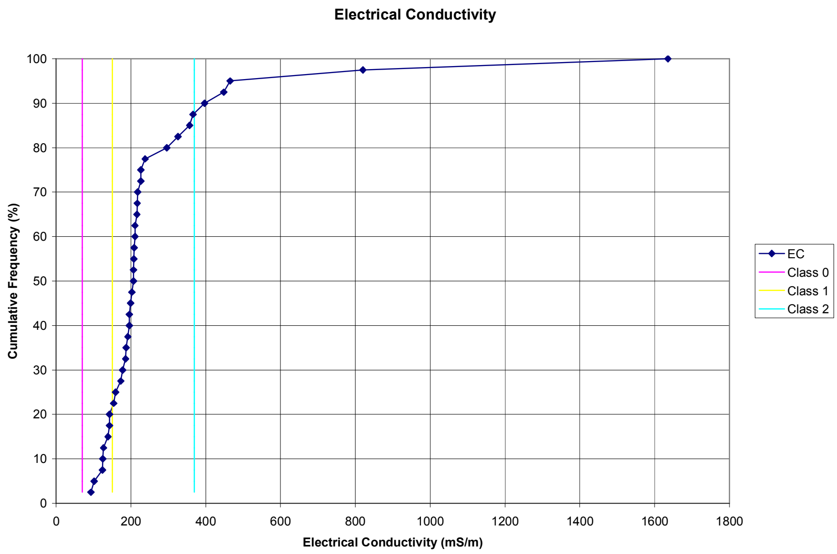


Figure 36: Distribution of borehole water quality – Alexandria and Nanaga Formations

The combined Alexandria/Nanaga aquifers makes up 17 % of the surface area of Ndlambe, and account for 22 % of recorded boreholes – indicative of its moderate groundwater potential.

7.7 SCHELMHOEK AQUIFER

This Quaternary (modern) sand aquifer occurs sporadically along the coast and is exploited at the Fish Kraals, Dias Cross, Bushmans River Mouth, Port Alfred (Freshwater Estates and East Bank) and Kleinemonde. The Apies River sand aquifer (immediately west of Cannon Rocks) is currently being investigated as a possible source of bulk water for this community (Mouton, 2004).

Borehole yields are generally 1 – 2 ℓ/s but can reach 5 ℓ/s, depending on aquifer thickness. Test pump data from available reports suggest transmissivity values ranging between 150 and 180 m^2/day. Storativity values are in the order of 2.8×10^{-1}. Porosity in the upper saturated sand is in the order 12 % and in the lower shingle considerably higher at 26 %.

Boreholes situated within the modern sand aquifers are recharge dependent and their exploitation must be adjusted accordingly to prevent degradation through salt water intrusion. Ideally they must be developed where the sand cordon is thick, broad, and free of pockets of highly salinized mud and associated with favourable recharge conditions.

The locality where the Schelmhoek aquifer is exploited is discussed from west to east.

The Fish Kraals: The Fish Kraals West and East well fields are situated between Cape Padrone and Cannon Rocks and currently produce a combined 12 ℓ/s (over a 24 hour pump cycle) of Good/Marginal quality water (Class I/II). This groundwater augments the Cape Padrone springs, which supply bulk water to Alexandria. These were established in 2002 and, according to the DWAF license agreement, the full quota is utilized. The manifold-type abstraction points utilize a strong suction to draw fresh water from ~ 4 m of dune sand – some 200 m from the high tide mark (Plate 10).

Plate 10 : Fish Kraals Well Field.

This well field is managed by P & S Consulting Engineers who have an agreement with the Ndlambe municipality to deliver bulk water to the storage reservoirs outside Alexandria. The current daily demand of Alexandria is 1 350 m³/day (equivalent to 15.6 ℓ/s) with the current capacity of the system just coping with the peak demand of 1 500 m³/day (equivalent to 19.1 ℓ/s).

Additional groundwater is available for exploitation in the modern dune sands between Fish Kraals East and Cannon Rocks. The Apies River aquifer has high groundwater potential and feasibility study has just been completed. Plate 9 is a false colour infrared image of the area around the Apies River aquifer.

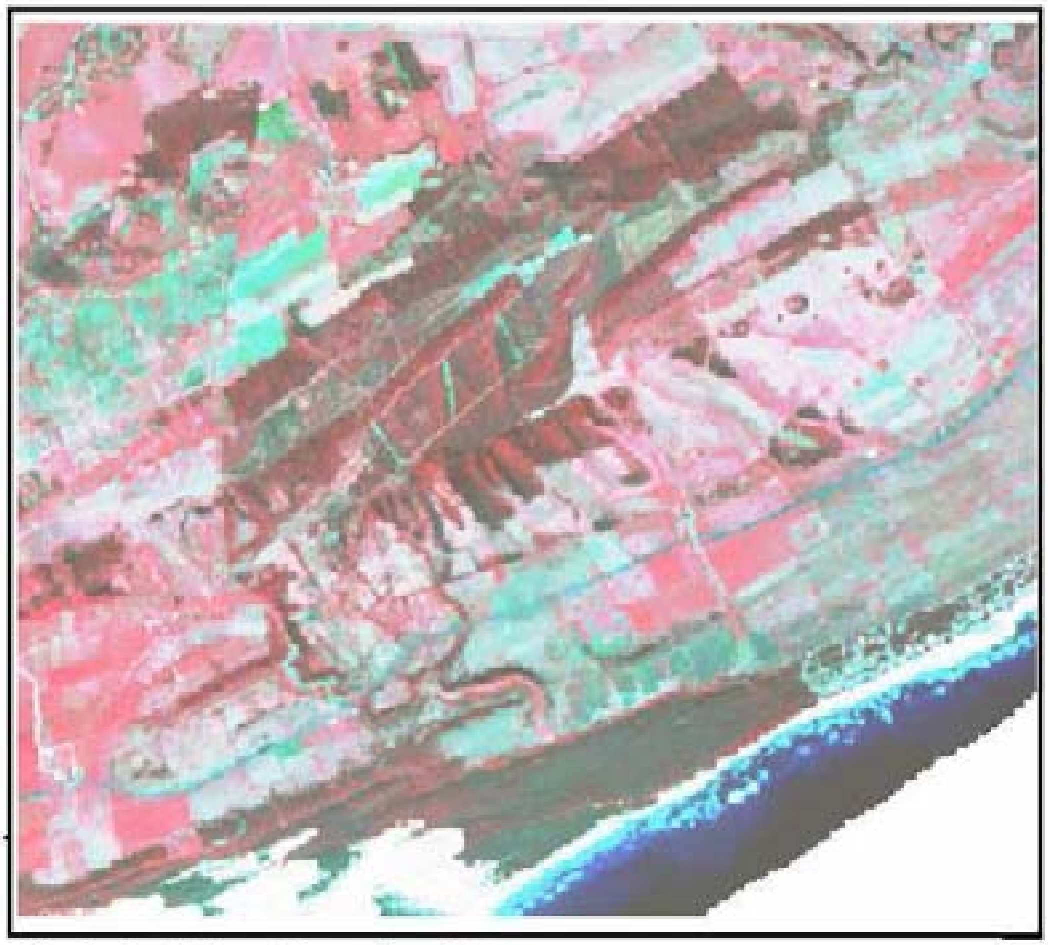


Plate 9 : Apies River Aquifers.

This environmentally sensitive land forms part of the Alexandria Forest Reserve and is managed ultimately by the Addo Elephant Park. SanParks have intimated that they will not consider any new well field development in ground under their jurisdiction.

Dias Cross: The Dias Cross well field is situated midway between the resort towns of Boknes and Bushmans River (Plate 11). In 1984, a Water Affairs investigation identified the area behind the Dias Cross rock promontory suitable for development as a production well field for the greater Bushmans/Kenton communities. The long term safe yield of this 1250 m (long) x 800 m (wide) aquifer was set at 300 000 m³/annum. Recharge by direct rainfall was calculated at 60 % for rainfall events exceeding 10 mm – which may be an over estimation.

The Dias Cross well field is currently producing 19 ℓ/s over a 12-hour pump cycle, equivalent to 821 m³/day. The water from the Dias aquifer is pumped via a 9 Km pipeline (rated at 25 ℓ/s) to 2 x 2 Mℓ storage reservoirs overlooking Ekuphumleni Township to the north of Kenton. Groundwater from Dias Cross (@ R0.70/m³) is blended in the ratio 63:37 with better quality Reverse Osmosis water (@ R4.85/m³) to produce an end product of an acceptable quality and cost profile.

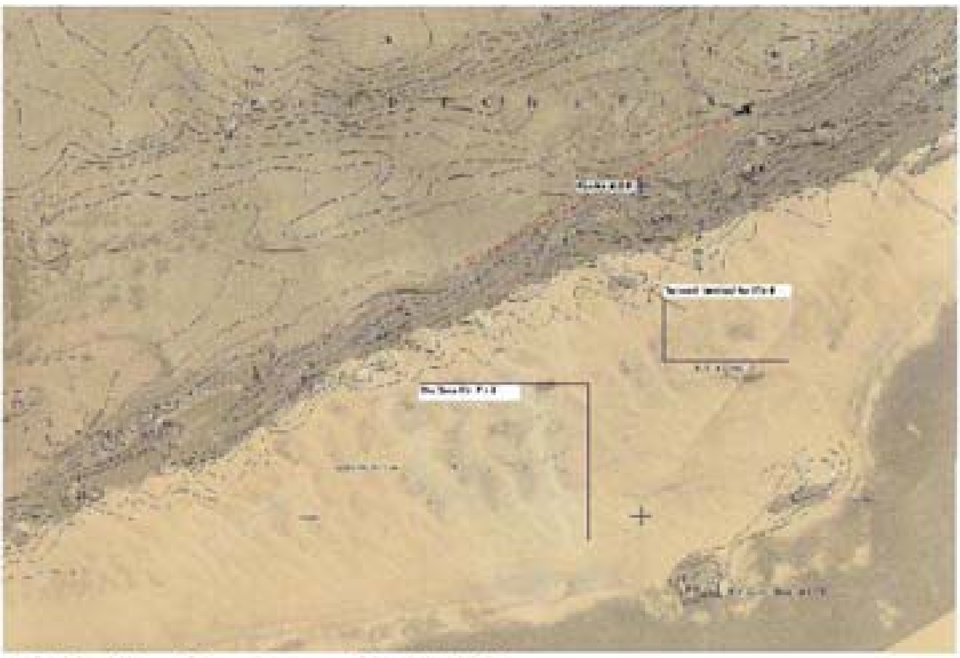


Plate 11 : Dias Cross Well Field.

Any demand for bulk water in excess of 1 900 m³/day results in a decline in the level of the storage reservoirs. During the 2003/04 Xmas holiday season, demand peaked at 2 800 m³/day, causing the water level in the storage reservoirs to drop for 14 consecutive days.

The stressing of the Dias Cross aquifer has caused the EC's to degenerate from around 100 mS/m (initial production 1990), to 200 mS/m (late 2003) to 250 mS/m (early 2004). Despite the many reversals in water quality based on seasonal rainfall patterns, the overall trend has seen a steady decline in the groundwater quality. This is due to the ACWB not being able to reduce abstraction during times of stress and drought conditions. In the absence of spare capacity, the ACWB has little option but to draw water from this stressed source. Locally the water table is depressed with the result that the pumps in the production boreholes began sucking air intermittently on the 18 March 23, 2004, interrupting the supply of bulk water. ***Due to the drought conditions, over 60 % of the bulk supply to the greater Bushmans/Kenton is extremely vulnerable at present.***

Based on the influx of people into the surrounding townships and current developments in the Bushmans/Kenton, soon the ACWB will face serious shortfalls in the delivery of bulk water. It is proposed to develop an additional well field in the modern dunes behind Kwaaihoek, some 800 m east of the existing Dias Cross well field. A linear array of approximately 6 additional boreholes (ø = 10 to 12") will be required to produce an additional 12 ℓ/s over a 12-hour pump cycle. The groundwater can be reticulated through the existing pipeline, located in close proximity to the envisaged expansion. As a result, the unit cost of producing this water will be low. Outside the peak holiday season, pumping schedules from Dias and the proposed Kwaaihoek aquifer can be rotated to prevent degradation of water quality and ensure the longevity of both well fields. However, SanParks have stressed that they will oppose the development of any new well fields in ground under their jurisdiction.

Direct recharge of the depleted Dias Cross well field by the Boknes lagoon (EC's of 100 – 200 mS/m) in the back dune area, may result in hyper-saline water migrating down hydraulic gradient to degrade the groundwater quality. It is likely, that intrusion of salt water from the south is also down grading the Dias Cross well field.

Bushmans River Mouth: Here groundwater has historically been abstracted from shallow boreholes situated in the dunes in close proximity to the mouth of the Bushmans River (Plate 12). In 1983, the Bushmans Municipality and the ACWB were abstracting 104 000 m³/annum from five boreholes for the Bushmans/Kenton bulk supply. On average, these boreholes yielded 2 – 3 ℓ/s each. Ten years later, supply had essentially doubled to 202 726 m³/annum. In 1984, Water Affairs were commissioned to conduct a detailed hydrogeological investigation from the mouth of the Bushman River up to and including the state land immediately west of Dias Cross. Their investigation condemned this area due to low yield and poor quality, due to pockets of mineralized mud in the sand profile.

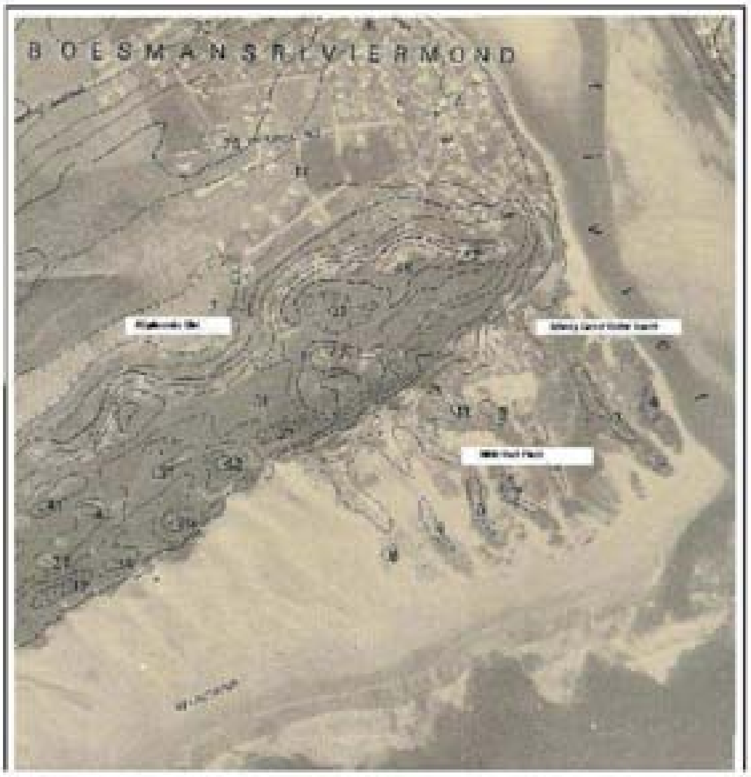


Plate 12 :Bushman 's River Mouth Well Field

Direct recharge from the aquifer beneath the Klipfontein Vlei in the back dune area (EC's ranging from 300 to 400 mS/m) resulted in brack water migrating down the hydraulic gradient to degrade the water quality over time. Later in 1986, it was noted that yields and water quality had deteriorated significantly. The Bushmans River well field was abandoned in favour of the newly commissioned Dias Cross well field in 1990.

Four brackish boreholes are currently being pumped and provide around 20 % of the raw input water to the ACWB's desalination plant.

Fresh Water Estates, Port Alfred: Numerous shallow wells and springs characterize this secluded, low density development on the western peripheries of Port Alfred (Plate 13). Historically, the general area served as a camping ground with holidaymakers exploiting the shallow water table for domestic use. This aquifer consists of unconsolidated coastal sand (0 to 10 m thick) overlying relatively impervious Witpoort quartzite.

Plate 13 : Spring on Fresh Water Estates.

The development of the Forest Downs suburb (hydraulically up-gradient) and the popularity of these sea-fronting properties, poses a risk of sterilizing this groundwater resource. DEAT are currently looking at the environmental implications of further developments in the area.

The general area to the west of Fresh Water Estates, viz., the Sunshine Coast Nature Reserve, possesses all the salient characteristics of having high aquifer potential.

East Bank, Port Alfred: Here water is also abstracted at a low-rate on an almost continuous basis from this coastal aquifer on the East Bank of the Kowie River (Plate 14). The scheme was devised and implemented by Water Affairs in 1985. The cumulative yield is in the order of 130 000 m³/annum. Five boreholes have been developed in a line mid-way between the high-tide mark and the vegetated, back dunes. The dune cordon is 800 m's wide at this location. The aquifer consists of recent coastal sands (4 to 5 m's thick) in contact with impermeable Weltevrede shale. Current field measurements of the water quality reveal the EC's to be 230 mS/m i.e., Class II or Marginal quality water. This water is used conjunctively with water from the Sarel Hayward dam.

Plate 14 : East Bank Well Field at Port Alfred.

Recharge conditions are not ideal at this location owing to the East Bank suburb being located nearby and hydraulically up gradient of this well field.

7.8 WATER QUALITY

The main phenomenon affecting the quality of the water is the mineralisation or salinization of groundwater in the main catchments due to the marine origin of the geology in the region. Shale-dominated lithologies account for 56 % of the surface area by outcrop, whereas 'limestones' make up an additional 17 %. Together these two 'marine' lithologies account for 73 % of the surface area by outcrop, whereas chemically inert quartzites make up only 25 %. The underlying Weltevrede shales and overlying Lake Mentz shales enclose the Witpoort quartzites. In the near coastal zone, the Nanaga limestones often blanket the Witpoort. Leakage from these rocks introduces a marine character to the groundwater in the Witpoort aquifer.

Other factors affecting the natural chemistry of groundwater include:

- Volume and rate of recharge
- Exchange of water between the bedrock and the overlying sediments
- Residence time/response time (varies with saturated thickness, spatial extent, specific yield)

- Depth to water table (aquifers with shallow water tables tend to have a close correlation between groundwater quality and climate)
- Abstraction
- Evapo-transpiration.
- Seawater intrusion (either close to the sea as a natural condition, or farther inland through over-exploitation).
- Salt leaching (most of the sediments of coastal aquifers are of marine origin and have both a high calcareous content and a high alkalinity. The calcareous component is derived mainly from shells and calcareous algal fragments. Leaching and dissolution of these compounds into groundwater produces a high salt content. Deposition of salt by sea spray is a factor in the near, marine environment
- Weathering and erosion of the parent material, especially Bokkeveld shales, have been shown to release large quantities of salts on leaching
- Selective retention of salts by plants, e.g. Tamarisk, which concentrates the salts in leaves. When the leaves fall off annually, the salts leach out with the following rains causing a relocation of the salt in the profile.

As water moves from the recharge area to the discharge area, various geochemical processes alter the quality of the water. When rain water enters the unsaturated zone it is pure (very low TDS) and is slightly to moderately acidic. The water also has a high carbon dioxide and oxygen content. Interactions of the water with mineral constituents and organic matter bring about active leaching and transport of dissolved salts. As the groundwater moves through the sand, plant root reactions decrease the oxygen and increase the carbon dioxide content. This results in the formation of carbonic acid, making the groundwater more acidic. Furthermore the TDS content increases as water moves away from the recharge area.

A total of n = 103 groundwater samples from the NGDB, were clipped according to the various lithologies within the Ndlambe municipal boundary. These are listed along with their analyses in Appendices H along with additional groundwater samples collected during the course of this study. The following is a generalized description of the expected groundwater chemistry.

Fifty-two groundwater analyses are presented to describe groundwater from the various fractured aquifers and a further 51 from the two intergranular aquifers. Median concentrations per lithotype for both classes of aquifer are presented in Table 7.

pH is consistently and comfortably in the ideal (Class 0) category for all aquifers. Slightly more acidic water (viz., ph of 6.2) is often associated with the Witpoort Formation rock-types. The low pH of the groundwater and consequent corrosion makes relatively inexpensive steel unsuitable for well screens and casings. The use of uPVC can be used to overcome these problems.

Electrical Conductivity is, as expected, poor quality (Class III) for groundwater derived from the Bokkeveld Group. Here the median value is 405 mS/m. Groundwater emanating from the Lake Mentz Formation narrowly escapes the poor quality classification by falling just within the upper limits of marginal quality classification with an EC value of 364 mS/m. The median concentration for all the other lithotypes, plots essentially in the middle of the marginal quality (Class II) category. Anomalously, groundwater from the Weltevrede Formation (EC = 244 mS/m) appears to be significantly better than that derived from the Witpoort Formation (EC = 305 mS/m). In general, EC's from the modern coastal sands are the best with median values around 213 mS/m.

Total Dissolved Salts for all lithotypes span the range of marginal water quality (Class II), with the Bokkeveld Group defining the worst (TDS = 2 333 mg/ℓ) and anomalously, the Weltevrede Formation the better with a TDS = 1 245 mg/ℓ. It is apparent that there is significant leakage between the aquifers in the various lithotypes. As the Witpoort Formation occurs stratigraphically and topographically above the Weltevrede Formation, the latter may be benefiting from the 'leakage' of higher quality groundwater generally anticipated in the former. Further work should be done to establish the generally disappointing water quality of the Witpoort Formation.

Table 7: Median Hydrochemistry of the various aquifers

ANALYSES	UNIT	Fractured Aqufers				Primary Aquifers		CLASSIFICATION			
		Bokkeveld Group	Weltevrede Fm	Witpoort Fm	Lake Mentz Fm	Alexandria & Nanaga Fm's	Schelm Hoek Fm	Class 0	Class I	Class II	Class III
(n = x)		15	9	21	7	43	8	Ideal	Good	Marginal	Poor
pH								5.5 - 9.5	4.5 - 10	4 - 10.5	3 - 11
Conductivity	mS/m	405	244	305	364	307	213	< 70	70 - 150	150 - 370	370 - 520
TDS	mg/l	2333	1245	1745	1976	1633	1342	< 450	450 - 1000	1000 - 2400	2400 - 3400
Sulphate	mg/l	181	102	110	103	122	71	< 200	200 - 400	400 - 600	600 - 1000
Nitrate (N)	mg/l	0.5	0.34	0.29	0.68	1.06	0.3	< 6	6 - 10	10 - 20	20 - 40
Chloride	mg/l	1089	644	828	981	747	542	< 100	100 - 200	200 - 600	600 - 1200
Fluoride	mg/l	0.26	0.39	0.29	0.35	0.36	0.43	< 0.7	0.7 - 1	1 - 1.5	1.5 - 3.5
P - Alkalinity		273	245	295	292	275	284				
M - Alkalinity											
Carbonate											
Bicarbonate		333	299	360	356	336	346				
Total Hardness	CaCo3	697	381	543	282	470	408	< 200	200 - 300	300 - 600	> 6
Ca - Hardness											
Mg - Hardness											
Calcium	mg/l	159	78	133	170	112	114	< 80	80 - 150	150 - 300	> 3
Magnesium	mg/l	79	41	53	79	42	30	< 70	70 - 100	100 - 200	200 - 400
Sodium	mg/l	590	365	429	438	473	348	< 100	100 - 200	200 - 400	400 - 1000
Potassium	mg/l	9.06	4.62	8	9.37	7.41	6.2	< 25	25 - 50	50 - 100	100 - 500
Iron	mg/l	0.02	0.02	0.02	0.02	0.02	0.02	< .5	.5 - 1	1 - 5	5 - 10
Manganese	mg/l	0	0	0	0	0	0	< .1	.1 - .4	.4 - 4	4 - 10

Drinking Water Quality Criteria (WRC, 1988)

Class 0: Ideal water quality - suitable for lifetime use
Class I: Good water quality - suitable for use, rare instances of negative impact.
Class II: Marginal water quality - unsuitable for use without treatment.
Class III: Poor water quality - unsuitable for use without treatment. Chronic effects may occur.
Class IV: Dangerous water quality - totally unsuitable for use. Acute effects may occur.

Sulphate is variable and generally plots in the middle of ideal (Class 0) water quality. The concentration of sulphate in the Bokkeveld Group generally tests the good (Class I) classification.

Nitrate concentrations are generally low with most values comfortably within ideal (Class 0) water quality. The highest values (viz., up to 10.10 mg/ℓ corresponding to Class II) occur within the Alexandria/Nanaga Formations and appear to be associated with intensive dairy farming in the near coastal zone of western Ndlambe.

Chloride, with the exception of marginal (Class II) quality water associated with the modern, sands, reports largely to poor water quality (Class III). Groundwater from the Bokkeveld Formation, is often unacceptably close to dangerous quality water classification (Class IV), with a median value of 1 089 mg/ℓ.

Fluoride is consistently and comfortably within ideal (Class 0) water quality for all aquifer and lithotypes.

Hardness covers the range in classification from good (Class I) water quality for the Lake Mentz formation to poor (Class III) water quality for the Bokkeveld Group rocks. The rest, viz., the Weltevrede, Witpoort, Alexandria/Nanaga and Schelmhoek Formations, all default to marginal (Class II) water quality. On average, most groundwater will have a 'brack' after taste. Where recharge conditions are favourable, Class 0 and/or Class I water quality is known to exist e.g. the artesian borehole at 'The Grove.' Some farmers sell this water commercially as 'whiskey water'.

Calcium spans the range from ideal (Class 0) for the Weltevrede aquifer to marginal (Class II) for the Bokkeveld and Lake Mentz aquifers. The Witpoort, Alexandria/Nanaga and Schelmhoek aquifers on average, all report to good (Class I) water quality.

Magnesium, on average, either reports to ideal (Class 0) or to good (Class I) water quality.

Sodium defaults largely to poor (Class III) water for the Bokkeveld, Witpoort, Lake Mentz and Alexandria/Nanaga lithotypes. Marginal (Class II) water quality, on average characterizes the Weltevrede and Schelmhoek formations.

Potassium is consistently and comfortably well within the ideal (Class 0) water quality classification for all lithotypes.

Iron is, on average, falls well within the ideal (Class 0) water quality classification. Problems do occur with individual boreholes within the Witpoort Formation, where concentrations consistent with poor (Class III) water quality are recorded e.g. high-yielding borehole on Merville has a Fe concentration of 8.59 mg/ℓ.

Manganese concentrations, on average, report largely to the ideal (Class 0) and good (Class I) water quality classification. Occasionally, some boreholes in the Witpoort Formation may be elevated to marginal (Class II) water quality with respect to Mn.

Different graphical techniques are presented to characterize the groundwater occurring within each of the lithotypes making up the hydrogeology of Ndlambe. These are Shoeller, Piper and Expanded Durov diagrams and are presented as Figures 37, 38 and 39 respectively.

The Shoeller diagram (Figure 37) represents different types of water in a quick and easy manner.

For the Piper diagrams (Figure 38), the major cations (Ca, Mg and Na+K) are plotted in one trilinear diagram by calculating the percentage contribution that each represents of the major cations. The same is done for the major anions (Cl, SO_4 and HCO_3 + CO_3) and the results are plotted as one point in the anion trilinear field. These two points are then extended into the main diamond –shaped field of the Piper diagram to plot as one point. The water is classified depending on the position of this point. Piper diagrams can be used to imply certain chemical processes such as mixing, chemical evolution along a flow path or ion exchange. Piper diagrams can also be used to identify certain types of water.

Expanded Durov diagrams (Figure 39) use similar ratio techniques to plot the concentrations of the major ions, however six triangular diagrams are used, three for the anions and three for the cations, on each triangle the sum of the ions add up to 50 % and the ions are plotted in different combinations. The result is nine fields for classification, giving better splitting than the Piper diagram.

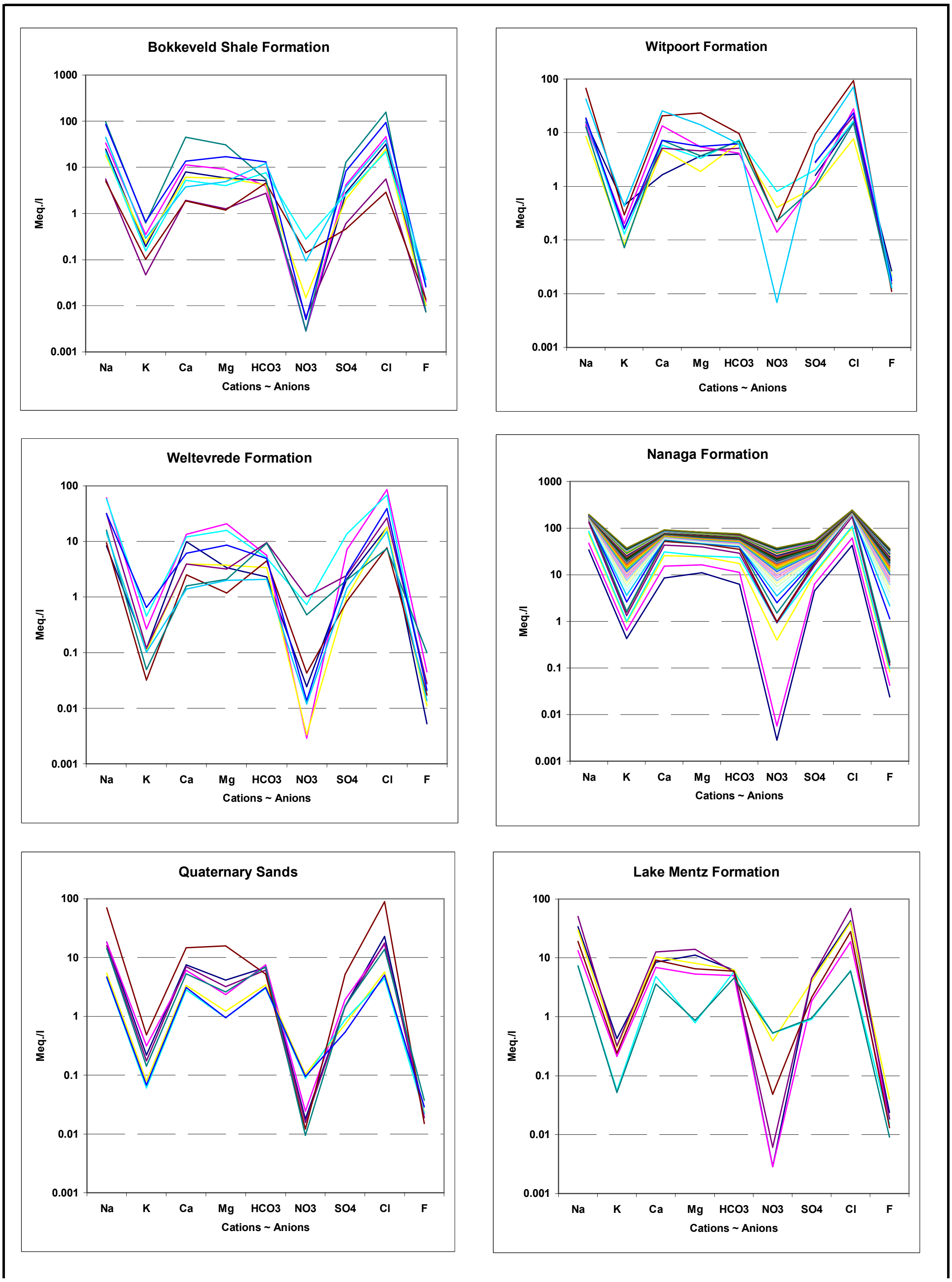


Figure 37: Schoeller Diagrams

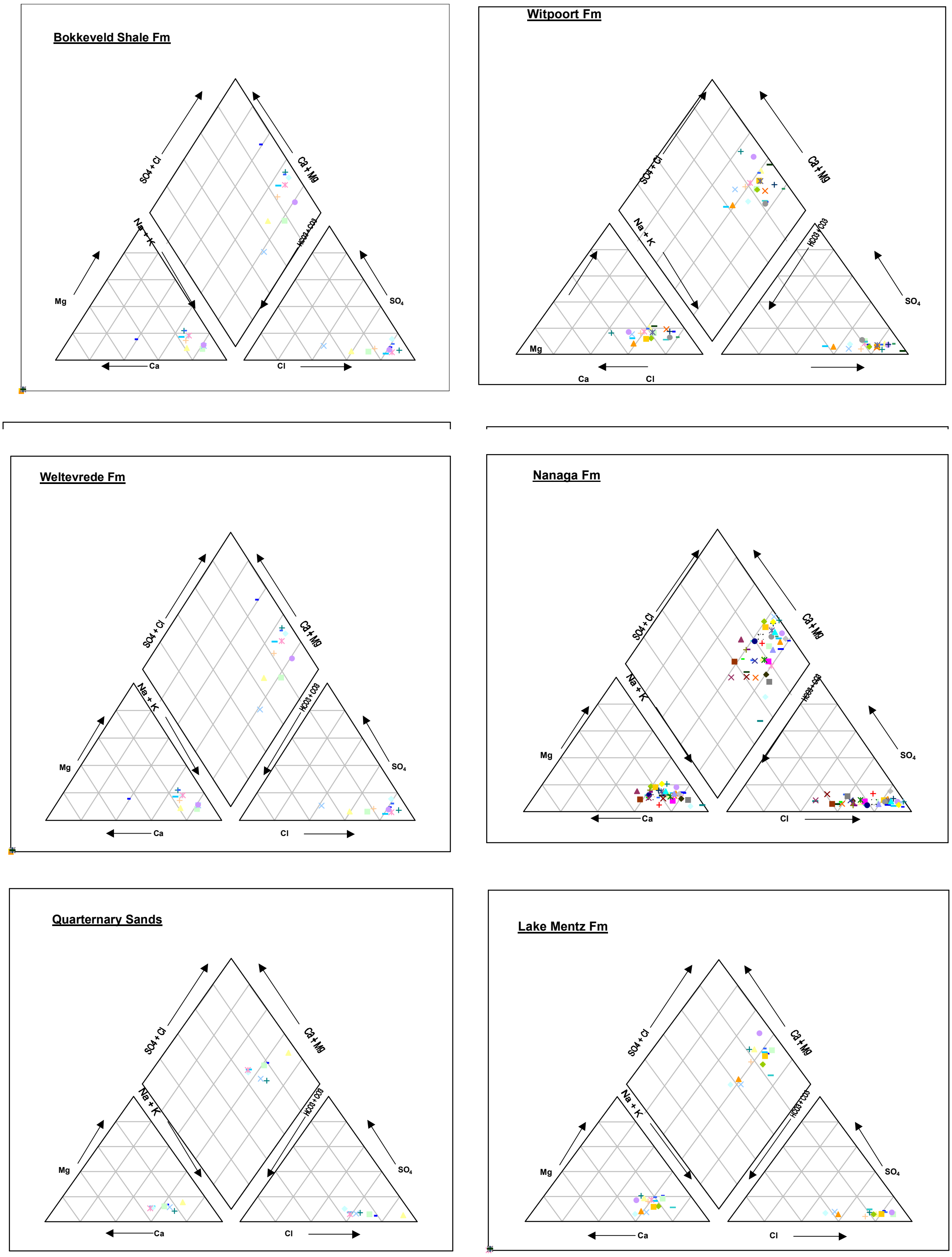


Figure 38: Piper Diagrams

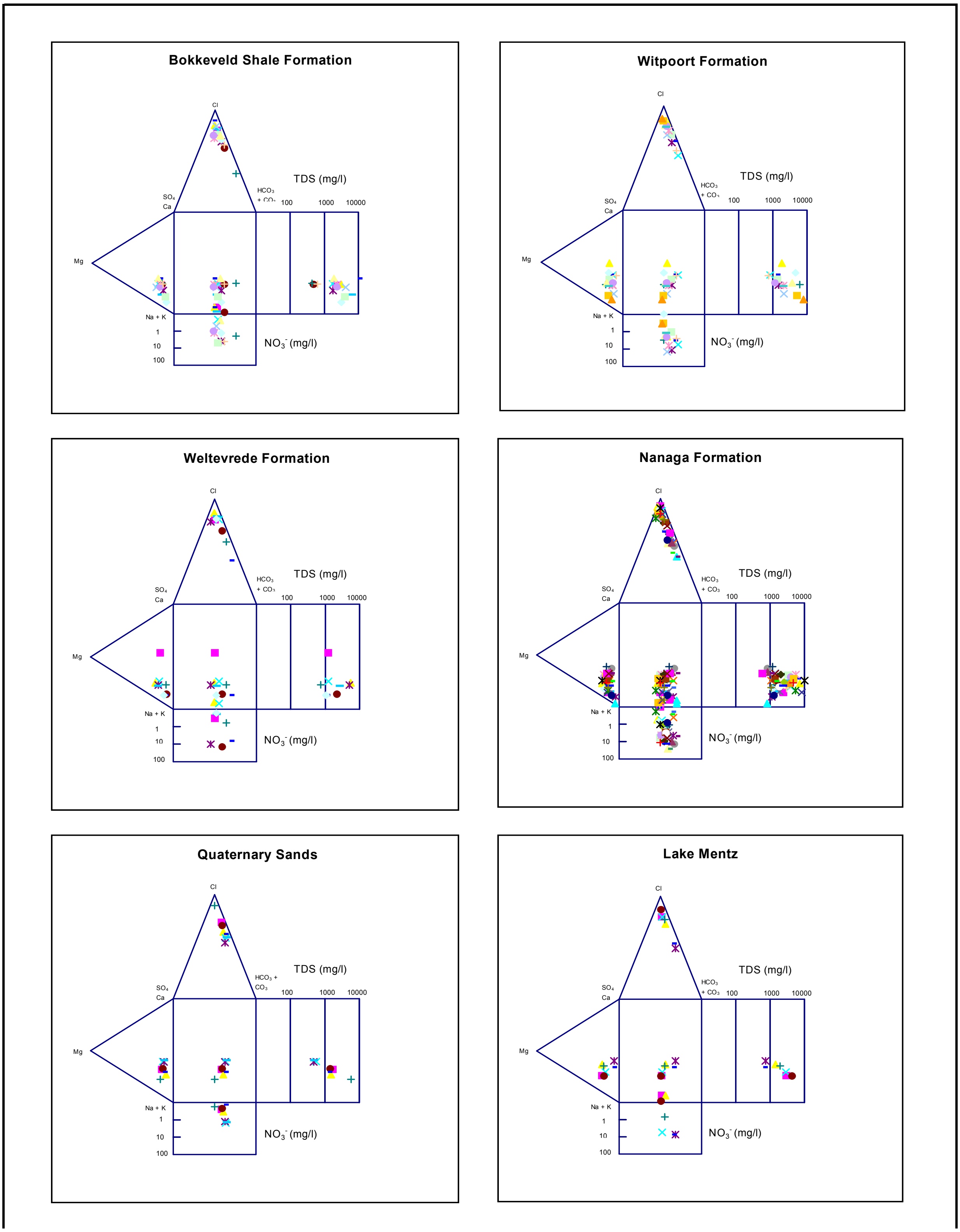


Figure 39: Durov Diagrams

The marine imprint on the groundwater in the study area is clearly indicated on all three hydrochemical representations i.e., Schoeller, Piper and Expanded Durov. The hydrochemical signatures of the various aquifer units are very similar and are suggestive of leakage from shales, which dominate the geology.

7.9 CONTAMINATION AND POLLUTION

For the purposes of this report, contamination is considered to be due to natural causes, whereas pollution refers to human influences. The following natural sources of contamination may affect the quality of groundwater:

- Groundwater/surface water interactions
- Natural leaching
- Saline intrusion
- Brackish water up-coning

These sources may be created and/or exacerbated by human activity.

Pollution occurs as a result of deleterious substances and waste products produced by humans adversely affecting aquifers. Some examples include:

- Discharge of substances into the earth by wastewater treatment plants and/or septic tanks.
- Unplanned release by sources designed to store, treat and/or dispose of substances. These may be landfills and waste disposal sites, illegal dumping, graveyards, materials stockpiles, storage tanks and storm water detention centres.
- Transport or transmission of substances, viz., pipelines and materials transport operations.
- Discharging of substances as a consequence of planned activities, viz., animal wastes, irrigation, fertilizer application, urban runoff and percolation of atmospheric pollutants.
- Inducing discharge by altered flow patterns or conduits, viz., boreholes and wells and construction excavation.
- Uncontrolled development hydraulically up-gradient of existing well fields and/or potential aquifers should be avoided as a matter of routine.

7.10 SEA WATER INTRUSION

Groundwater input to coastal waters has been shown to account for as much as 65 % of the total fresh water inflow (Campbell et. al., 1992). Alteration of this groundwater flow through abstraction can result in salt water intrusion into wells, which also affects the salinity status of the whole aquifer system, and ultimately the ecological stability of the area. Under natural conditions, salt water intrusion must be very rare.

The most important and immediately apparent source of contamination is that of saline water intrusion. Salt water has a higher density than fresh water, so salty water always occurs below fresh water. The salt wedge below and along coastlines prevents downward mixing of low salinity water, so that fresh groundwater discharges closer to the shore.

Saline intrusion occurs when coastal aquifers are in direct contact with the sea and when over pumping reverses the normal seaward flow of fresh water. The presence of a salt wedge has important implications since deepening wells for increased abstraction will increase the danger of intrusion of salt water. This is not a factor in Ndlambe as boreholes in the coastal aquifer are only drilled as deep as the Cape Supergroup contact.

Classical salt water intrusion from the south has been mentioned as the reason for the steady degradation in water quality of the Bushmans River and Dias Cross well fields over time. However, it is more likely, given the impermeable Bokkeveld ‘basement’ and the salinities of groundwater in the back dune area, that this degradation has an inland source. Long-term and comprehensive monitoring is required to resolve the issue unambiguously.

7.11 ACCESSIBILITY AND DRILLING

In general, accessibility is not a problem. However problems may arise in attempting to place a drilling rig on a known geological fault – the surface expression of which may be a steep, thickly, wooded ravine. Mobilizing drilling rigs onto modern sand dunes also poses problems, as light, 4 x 4 driven vehicles are required. Drilling in the Apies River, Kwaaihoek and/or Sunshine Coast Nature Reserves will have to be cleared with DEAT and SanParks. The latter have indicated, that in future, no new well fields may be developed in ground under their management or control. SanParks have agreed to allow maintenance drilling to repair or replace existing boreholes under strict conditions. This decision has effectively sterilized all untapped groundwater resources in the coastal zone west of the Bushmans River mouth.

Boreholes in the Witpoort aquifer should be cased throughout with uPVC casings and screens. This is necessary to stabilize the brittle formation and to prevent corrosion of metal casings by aggressive (acidic) groundwater.

Drilling in unconsolidated sand requires more advanced methods to penetrate without disrupting the aquifer. Despite its relatively high cost, mud rotary drilling, ODEX or Simcase is recommended.

Borehole construction is important and must take cognisance of unique aquifer characteristics.

Most of the drilling terrain in fractured aquifers will comprise private farmland, whereas drilling in the coastal aquifers will involve DEAT, SanParks and/or Nature Conservation.

8. OVERVIEW OF AQUIFER POTENTIAL

In broad terms, the physiological, geological and hydrogeological characteristics of the area have been described. These are based on existing borehole data, literature surveys, technical reports and local experience of the area. The ensuing sections provide an interpretation of this data to ensure effective development and exploitation of the groundwater resources.

8.1 HARVEST POTENTIAL

The quantification of the groundwater resources is probably one of the most difficult aspects to assess. Information on recharge to the groundwater systems, storage capacity of the groundwater systems, the hydraulic conductivity and thickness of these groundwater systems, the interaction with surface water and water quality is required. Once the groundwater resources are quantified a groundwater balance is established, comparing the resource with the existing use, to determine areas of over exploitation and identify areas that have a potential for further groundwater exploitation.

The Groundwater Harvest Potential (Seward and Seymour, 1996) was used as the basis for the evaluation. The Harvest Potential is defined as the maximum volume of groundwater that is available for abstraction without depleting the aquifer systems, and takes into account recharge, storage and drought periods. The minimum groundwater harvest potential along the coastal zone varies between 25 000 – 100 000 $m^3/a/Km^2$, depending on whether the underlying geology is comprised of fossil or modern dunes. Farther inland, harvest potential decreases sharply, to vary between a minimum of 10 000 – 15 000 $m^3/a/Km^2$, depending on whether the underlying geology is comprised of shale or quartzite. For the purpose of this study, the following estimates of harvest potential have been used and tabulated in Table 8 below.

Table 8 : Estimates of Minimum Harvest Potential

AQUIFER	Dimension Km^2	Harvest Potential $m^3/a/Km^2$	Supply Mm^3/a	Supply/Day M^3/day
UNCONSOLIDATED				
Schlemhoek Formation	39.17	100 000	3.92	10 700
SEMI-CONSOLIDATED				
Nanaga & Alexandria Fms	340.27	25 000	8.51	23 300
ARENACEOUS FRACTURED ROCKS				
Witpoort Formation	501.55	15 000	7.52	20 600
ARGILLACEOUS FRACTURED ROCK				
Bokkeveld, Lake Mentz, Weltevrede, Ecca, Dwyka Fm	1125.72	10 000	11.26	30 800
TOTAL	**2006.71**		**31.21**	**85 500**

It must be noted that the water resource volumes noted in Table 8 might not be economically exploitable due to water quality limitations, low yields, limited aquifer extent in outcrop areas, and land ownership issues:

- The argillaceous aquifers are generally of poor quality and low yielding, hence their exploitation potential is extremely limited.
- The semi-consolidated dunes can only be exploited where underlain by a permeable horizon, such as the Alexandria Formation. Consequently, a large fraction of this resource is not economically exploitable.
- The unconsolidated dunes can only be exploited where accessible, and where a sufficiently wide dune cordon exists to provide recharge and storage.
- Significant portions of the arenaceous Witpoort Formation are rugged and difficult to access due to adverse topography and the existence of Nature and Game Reserves. In addition, sufficient permeability is restricted to major fault zones.

Consequently, economically accessible groundwater reserves are restricted to portions of the unconsolidated modern dunes and the arenaceous Witpoort Formation.

8.2 EXPLOITATION POTENTIAL

It is generally not possible to abstract all the groundwater considered available in the Harvest Potential concept. This is mainly due to economic and/or environmental considerations. The main contributing factor is the hydraulic conductivity or transmissivity of the aquifer systems. As no regional information on transmissivity is available, borehole yield information was used, as there is a good relationship between borehole yield and transmissivity.

The groundwater resources were estimated using Harvest Potential data from WSAM (Table 9) in order to quantify exploitable groundwater resources. These Harvest Potential values are based on gridded median Harvest Potential values, accounting for rainfall variability and variations in geological exposure, hence are more spatially integrated than those in Table 8.

The Harvest Potential was reduced by an exploitation factor, determined from borehole yield data, to obtain an exploitation potential i.e. the portion of the Harvest Potential that can practically be exploited. Where average yields were above 1.5 ℓ/s, an exploitation factor of 0.6 was utilized, where average yield was 0.7-1.5 ℓ/s a factor of 0.5 was utilized, and where yield was 0.3-0.7 ℓ/s a factor of 0.4 was utilized.

This factor was multiplied by the Harvest Potential of each quaternary catchment to obtain the exploitation potential. The Exploitation Potential is considered to be a conservative estimate of the groundwater resources available for exploitation.

The interaction of the groundwater and the surface water was assessed by evaluating the base flow component of the surface water, or more specifically the contribution of the Harvest Potential to base flow. From this, the extent to which groundwater abstraction will reduce base flow component of the surface water was evaluated and the Exploitable Portion was calculated in order to avoid impacts on the Environmental Reserve.

Where the contribution of groundwater to the base flow component of the surface flow is zero the impact will be negligible. Where the contribution is less than 30 % of the base flow the impact will be low, where the contribution is between 30 % and 80 % of the base flow the impact will be moderate, and where the contribution to base flow is more than 80 % the impact will be high.

Existing groundwater use was also estimated and the balance of the Exploitation Potential was calculated. The portion of the groundwater resources considered potable (Class 0, I and II) was utilized to account for the portion of Exploitation Potential that cannot be utilized for water supply due to poor quality in order to determine maximum utilisable groundwater resources (Table 9).

The Exploitation Potential is 19.7 Mm^3/a, however, it is estimated that the maximum utilisable groundwater is 7.3 Mm^3/a due to the prevalence of poor water quality. Current use is approximately 20 % of these utilisable resources.

Quat Catch	A Km^2	Harvest Pot m^3/Km^2/a	Harvest Potential x10^6 m^3/a	Ave yield Bh's ℓ/s, 8hrs/d	Expl Factor	Exploitation Potential x10^6 m^3/a	Total Use x10^6 m^3/a	Contribution to Base flow (10^6 m^3/a	Gwater only portion (10^6 m^3/a	Exploitable Portion x10^6 m^3/a	Balance Harvest Potential x10^6 m^3/a	Balance Exploitation Potential x10^6 m^3/a	Use % Exp. Pot	Portion Potable	Max Utilize Gwater x10^6 m^3/a
P10G	256	15116	3.87	1.40	0.5	1.93	0.0822	0.00	3.87	1.93	3.79	1.85	4.25	0.00	0.00
P20A	270	35206	9.51	1.17	0.5	4.75	0.4954	0.06	9.45	4.72	9.01	4.26	10.49	0.39	1.87
P30B	195	12700	2.48	0.88	0.5	1.24	0.0532	0.00	2.48	1.24	2.42	1.19	4.30	0.13	0.15
P30C	68	29229	1.99	1.02	0.5	0.99	0.0163	0.00	1.99	0.99	1.97	0.98	1.64	0.50	0.50
P40A	51	12700	0.65	0.59	0.4	0.26	0.0406	0.12	0.53	0.21	0.61	0.22	19.33	0.30	0.08
P40B	257	12700	3.26	0.90	0.5	1.63	0.0623	0.00	3.26	1.63	3.20	1.57	3.82	0.70	1.14
P40C	342	38324	13.11	0.69	0.4	5.24	0.4118	0.03	13.08	5.23	12.69	4.83	7.87	0.39	2.04
P40D	246	12779	3.14	1.76	0.6	1.89	0.2038	0.03	3.12	1.87	2.94	1.68	10.90	0.33	0.63
Q93D	321	11842	3.80	1.09	0.5	1.90	0.0825	0.00	3.80	1.90	3.72	1.82	4.34	0.47	0.89
TOTAL	**2006**		**41.80**			**19.84**	**1.45**	**0.24**	**41.56**	**19.73**	**40.35**	**18.39**			**7.31**

Table 9: Groundwater Resources of Ndlambe by Quaternary Catchment

8.3 RECHARGE

To confirm the Exploitation Potential of individual geological formations, recharge was estimated. Recharge is the portion of rainfall that contributes directly to aquifer replenishment on an annual basis. A figure of 2 % has generally been regarded as a conservative estimate for ancient fractured aquifers, however, recharge to quartzites of the Cape Supergroup has been estimated at 15 – 25 %. These estimates are primarily derived from regions with winter rainfall, hence are probably an overestimate for the Witpoort quartzites. Consequently, a recharge value of 5 % has been tentatively used.

According to Reynders (1987), recharge to the coastal sands can be as high as 30 %. Sami (2004) calculated recharge of over 35 % based on steady state flow conditions at the Bushmans River Mouth and Dias Cross dune well fields. Recharge into the fossil dunes of the Nanaga Formation was estimated by Sami (2004) at around 3.6 % of MAP based on hydraulic gradients and permeabilities of the back dune areas. An estimate of groundwater recharge is given in Table 10.

AQUIFER	Dimension Km^2	Recharge % @ 640 mm MAP	Supply/Annum Mm^3/a
UNCONSOLIDATED			
Schlemhoek Formation	39.17	35	8.77
SEMI-CONSOLIDATED			
Nanaga & Alexandria Formations	340.27	3.6	7.84
ARENACOUES FRACTURED ROCK			
Witpoort Formation	501.55	5	16.05
ARGILLACEOUS FRACTURED ROCK			
Bokkeveld, Lake Mentz, Weltevrede, Ecca, Dwyka	1125.72	2	14.41
TOTAL			**47.06**

The estimates of recharge are slightly higher than Harvest Potential as the latter is based on drought rainfall. Recharge must also be reduced by an exploitation factor to determine Exploitation Potential.

8.4 AQUIFER UNITS AND UTILISABLE GROUNDWATER

An attempt has been made to subdivide the broad aquifer units into discrete aquifers or well fields (Table 11) where these are within economic distance to towns and communities.

Estimated aquifer storage was calculated by multiplying the area of outcrop by aquifer thickness and storativity. Aquifer thickness was determined from the difference in the median values of water strike and static water level for each aquifer.

Exploitation Potential was calculated as the exploitable fraction of recharge using exploitation factors in a similar manner to Table 9. Exploitation Potential therefore only considers recharge and aquifer permeability. For the Witpoort aquifer, potential recharge is higher than the storage potential, hence a fraction of recharge is lost as base flow, discharge to springs, and evapo-transpiration. In addition, during years of less than average recharge, storage limits exploitation potential. For this reason, Exploitation Potential was calculated as the product of the exploitation factor and storage.

Maximum utilisable groundwater resources were calculated by multiplying recharge or storage capacity, which ever is least, by the fraction of boreholes yielding more than 2 ℓ/s and the fraction of boreholes of water quality Class 0 and I (Exp. Factor * Class I), and the fraction of boreholes of Class II (Exp. Factor * Class II). These data attempt to exclude poor quality water and potential low yielding portions of aquifers that cannot be economically exploited.

For the intergranular coastal dune aquifer, the exploitation factor was also multiplied by the fraction of the area where the dune cordon is sufficiently wide to exploit (71 %).

Table 11 : Utilisable Groundwater Resources by Aquifer

Lithology	Area (Km^2)	Aquifer thickness (m)	Storativity	Storage (Mm^3)	Recharge (%)	Recharge (Mm^3/a)	Exploitation Factor	Exploitation Potential	Exp. Factor * Class 1	Util. Resources (Mm^3/a)	Exp. Factor* Class 2	Util. Resources (Mm^3/a)
Witpoort Fm Western Belt	190.47	30	0.001	5.71	5%	6.10	0.50	2.86	0.080	0.46	0.170	0.97
Witpoort Fm Central Belt	59.22	30	0.001	1.78	5%	1.90	0.50	0.89	0.080	0.14	0.170	0.30
Witpoort Fm Eastern Belt	251.77	30	0.001	7.55	5%	8.06	0.50	3.78	0.080	0.60	0.170	1.28
Weltevrede Formation	660.97	25	0.005	82.62	2%	8.46	0.30	2.54	0.033	0.28	0.075	0.63
Bokkeveld Group	222.7	20	0.005	22.27	2%	2.85	0.20	0.57	0.000	0.00	0.000	0.00
Lake Mentz Formation	220.33	30	0.005	33.05	2%	2.82	0.30	0.85	0.027	0.08	0.044	0.12
Nanaga & Alexandria Formations	340.27	25	0.01	85.07	4%	7.84	0.30	2.35	0.033	0.26	0.127	1.00
Karoo Super Group	21.72	20	0.005	2.17	2%	0.28	0.30	0.08	0.020	0.01	0.075	0.02
Schlemhoek Formation	39.17	5	0.1	19.59	35%	8.77	0.65	5.70	0.090	0.79	0.360	3.16
TOTAL	**2006.62**			**259.81**		**47.07**		**19.61**		**2.61**		**7.49**

Groundwater resources are approximately 7.5 Mm^3/a, of which 1.45 Mm^3/a is already being exploited, primarily from the coastal intergranular and Witpoort fractured aquifers. Over 42 % are found in the coastal dune belt. A total of 2.55 Mm^3/a can be exploited from the Witpoort aquifers. Portions of the Witpoort western and eastern belts are also too far removed from population centres, hence will not be economically exploitable. Other portions are either difficult to access or occupied by National Parks and/or private game reserves. To take into account these factors, exploitable resources in the Witpoort would have to be reduced by as much as 50 % Mm^3/a.

8.5 LOCAL AREAS OF HIGH GROUNDWATER POTENTIAL

Areas of high groundwater potential occur throughout Ndlambe and their occurrences are given on Map 6. The description pertaining to each area gives generalisations of expected conditions such as expected yield, drilling success and anticipated water chemistry. These should be used for planning purposes only.

8.5.1 Witpoort Fractured Aquifers

With respect to the Witpoort fractured aquifer, areas of high groundwater potential shall be discussed for each of the three main areas of outcrop: the western, central and eastern belts. Targets for exploitation in these belts are restricted to major fault zones. Thirty percent of scientifically–sited boreholes drilled are expected to yield between 5 and 10 ℓ/s of Class I or Class II quality groundwater. Poorer quality water is expected where marine shales bound faults. The main water strikes can be expected as deep as 70 m bgl. Since fracture zones are tectonic in origin, fracturing at depth is expected and boreholes can be drilled to 150 m to increase yield and the available draw down of boreholes. However, it must be noted that deep-water strikes are only high yielding due to the effect of the hydraulic pressure head as the fracture For the intergranular coastal dune aquifer, the exploitation factor was also multiplied by the fraction of the area where the dune cordon is sufficiently wide to exploit (71 %).

are generally low. As a result, deep-water strikes generally incur high draw downs when pumped at high rates, resulting in high pumping costs. Large available draw downs are required to accommodate the high-expected draw downs arising from low fracture permeabilities.

Deep fracture zones also contain water in a reduced geochemical environment, hence when these fracture zones are exposed to oxidation resulting from draw down, iron bacteria clogging results due to the iron-rich matrix of the quartzites.

No reliable pump testing data is available to determine potential sustainable yields from boreholes, however, it can be assumed that yields could be 30 – 50 % of blow yields. Based on assumed exploitation potential of 2.55 Mm^3/a, 50 % of which can be accessed economically, a yield of 40 ℓ/s would be achieved, which would require blow yields of 133 ℓ/s.

Target regions consist of brittle fracture zones associated with major south-southeast and east-northeast trending fault structures. These have not been thoroughly documented as yet. Figure 40 shows the orientation and length of identified lineaments. Long regional lineaments appear to be oriented north-northeast and east-northeast.

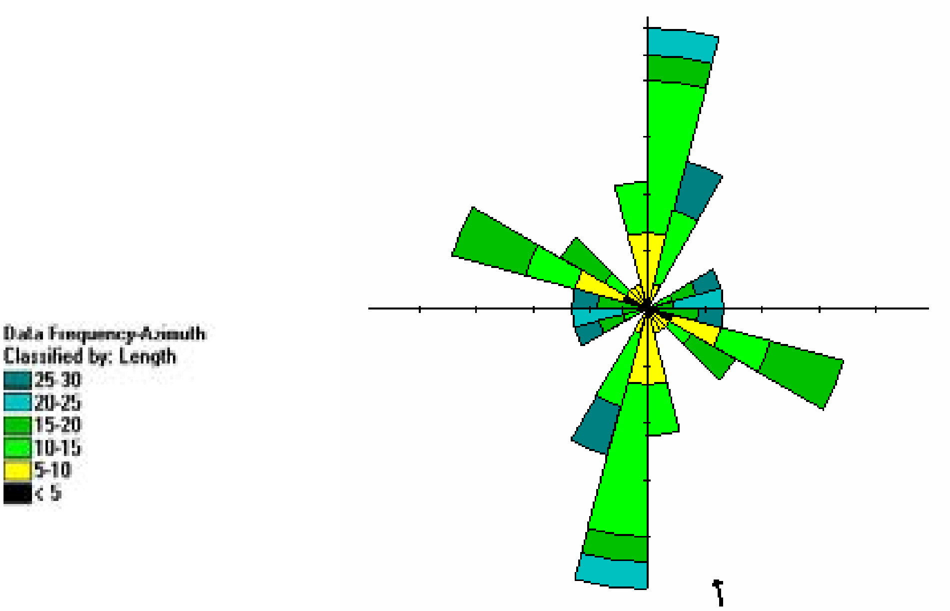


Figure 40 : Classified Rose Diagram of Lineaments According to Length (Km)

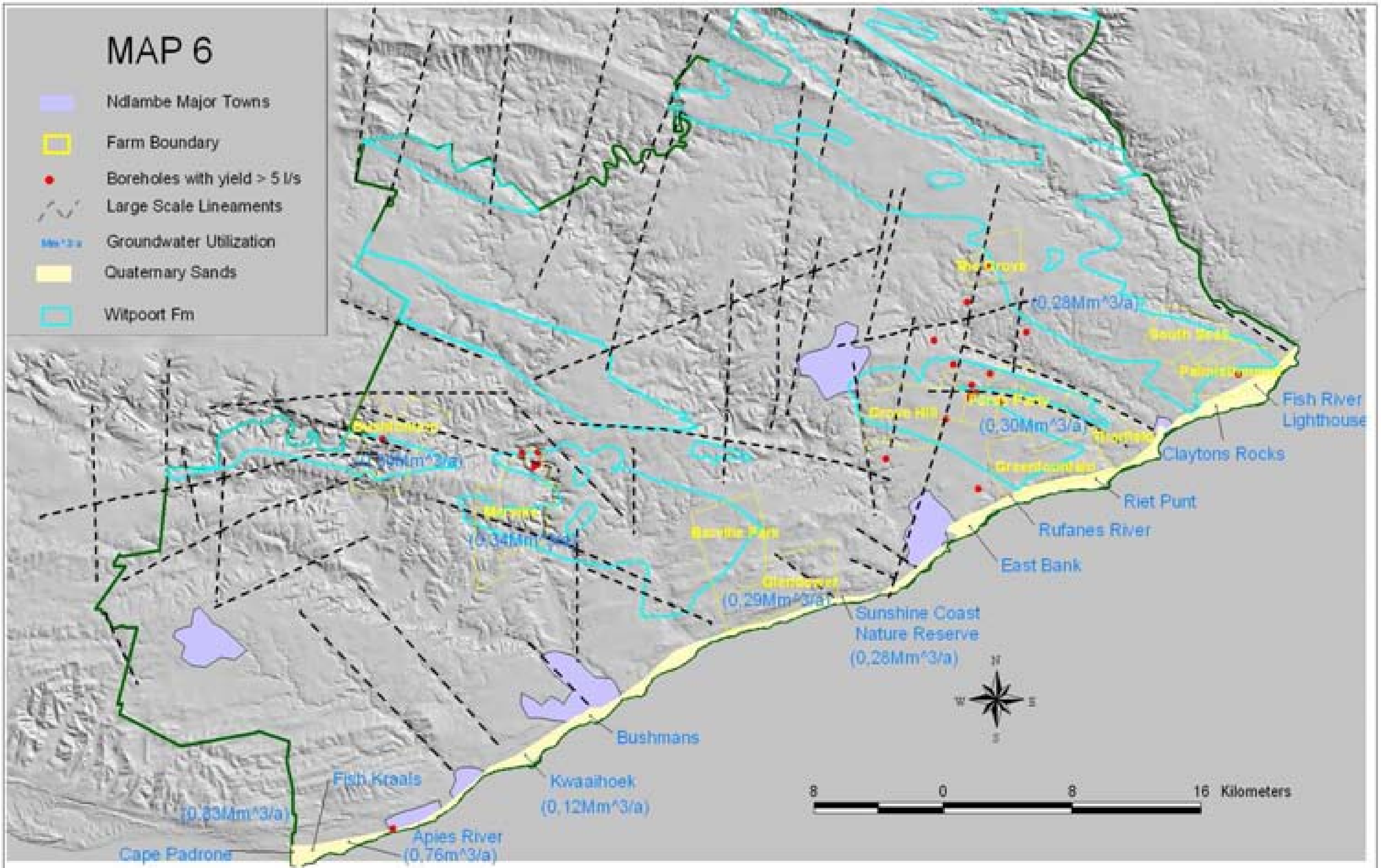
Western Belt: Up to 1 Mm^3/a could be exploited from this belt, however a significant portion may occur too far away from population centres to be economically viable. This belt corresponds to the area of greatest need and fortuitously arcs behind Kenton-on-Sea/Bushmans River and ultimately, behind Alexandria.

Obvious targets in the western belt are found in and around the farms Bushfontein, Merville, Barville Park and Glendower. Groundwater (and spring water) resources have been proven on Merville, which could be utilized to augment the bulk supply of Bushmans/Kenton. DWAF drilled exploration boreholes on Merville with very encouraging results viz., a 100 % success rate with 4 boreholes having an average blow yield of ~ 9 ℓ/s. These boreholes alone could provide 900 m^3/d, or 0.34 Mm^3/a.

The gorge on Bushfontein has many of the salient characteristics of Merville (i.e., lithology, structure, topography etc.) with obvious groundwater potential. Bushfontein is equidistant (~ 15 Km) from Alexandria, Boknes/Cannon Rocks and Bushmans/Kenton. Bushfontein has also been mooted as a potential dam site by DWAF. Potentially, another 900 m^3/d, or 0.34 Mm^3/a could be obtained from this target.

The recharge potential at Glendower is particularly attractive as blind rivers bring surface runoff into the back of fossil dunes, which in turn overlie the Witpoort aquifer. Here geophysics would be required to site boreholes with confidence. Glendower is 5 Km west of Port Alfred and immediately inland of the Sunshine Coast Nature Reserve coastal aquifer. Potentially another 0.32 Mm^3/a could be abstracted from this target.

Central Belt: Conveniently, this belt arcs behind Port Alfred and terminates at Bathurst. A large southeast trending thrust bisects the northern portion of this belt and this portion coincides with a cluster of high yielding boreholes. Farms in and around Grove Hill, Fords Party and Tharfield are obvious targets for groundwater for the Bathurst, Port Alfred and Seafield/Kleinemonde communities respectively. Potentially 0.3 Mm^3/a could be exploited from this belt.



NDLAMBE: AREAS OF HIGH GROUNDWATER POTENTIAL (CLASS I/II)

Eastern Belt: This belt outcrops neat the fish River Lighthouse and trends towards Grahamstown and beyond. Up to 1.28 Mm^3/a could be exploited. Potential groundwater targets occur in and around the farms Palmietheuval, Southseas and The Grove, where up to 1.28 Mm^3/a could be exploited The Seafield/Kleinemonde community would benefit from boreholes drilled on these farms. DWAF drilled three boreholes behind the Fish River lighthouse with moderate success.

8.5.2 Lake Mentz, Weltevrede and Bokkeveld aquifers

The Bokkeveld, Weltevrede or Lake Mentz Formations cannot be economically exploited as they generally possess a low to moderate potential and are mostly saline with respect to water quality. Up to 0.75 Mm^3/a can be exploited if sufficiently high yielding fault structures are present in sandstone beds.

These formations may serve to supply local homesteads, stock watering and small local supplies schemes.

8.5.3 Intergranular Aquifers

With respect to the intergranular coastal aquifers, areas of high potential will be discussed from west to east. Approximately 75 % of boreholes drilled are expected to yield 2 ℓ/s of Class I and Class II quality groundwater. The main strikes can vary between 5 and 10 m bgl with a maximum borehole depth of ~ 20 m.

The exploitation potential of the dune intergranular aquifers was calculated separately for zones where the dune cordon is sufficiently wide to exploit economically (Table 12). These aquifers are composite in nature and are recharged by direct recharge into the coastal dunes and lateral inflow from the back dune area. Recharge to these aquifers was assumed to be 35 % of rainfall for the area coastal dunes, and 3.6 % for the back dune area (Table 10). The exploitation factor utilized was 0.54, based on borehole yields of 1.5 – 3 ℓ/s and 90 % of boreholes having a water quality of Class II or better. For Cape Padrone and Apies River the exploitation factor was reduced to 0.3 since it is unlikely the large areas involved can be fully exploited.

Table 12 : Groundwater Availability in Dune Aquifer Systems

Well field / Aquifer	Area Km²		Storage Capacity Mm³	Recharge	Utilisable Groundwater		Current Status	Priority Status
	Dunes	Back Dune		Mm³/a	Factor	Mm³/a		
Cape Padrone - Fish kraals	11	13	12.00	2.76	0.30	0.83	Under Developed. ± 50% spare capacity	High Priority. Supply to Alex & Can Rocks
Apies River	9.7	15.3	6.25	2.53	0.30	0.76	Under Developed. ± 80% spare capacity	High Priority. Supply to Can Rocks/Boknes
Dias Cross	1.08	7	4.00	0.40	0.54	0.22	Fully Developed	High Priority. Supply to BRM/KOS
Kwaaihoek	0.52	4.5	2.5	0.22	0.54	0.12	Undeveloped. 100% spare capacity	High Priority. Augment Dias Cross supply
Sunshine Coast Nature Reserve	1.3	10.2	3.0	0.53	0.54	0.28	Undeveloped. 100% spare capacity	High Priority. Supply for Port Alfred.
Bushmans River Mouth	0.42	1.2	0.81	0.12	0.54	0.07	Fully developed	Water supply to ACWB
Port Alfred East Bank	0.8	1.76	1.28	0.22	0.54	0.12	Limited Spare Capacity	Low Potential
Rufanes River	0.8	1.65	0.61	0.22	0.54	0.12	Undeveloped	Moderate Potential
Riet River	0.8	1.3	0.52	0.21	0.54	0.11	Undeveloped	Moderate Potential
Claytons Rocks	0.8	0.95	0.43	0.20	0.54	0.11	Undeveloped	Moderate Potential
Fish River Lighthouse	0.8	1.15	0.49	0.21	0.54	0.11	Undeveloped	Moderate Potential
TOTAL	**28**	**58**	**31.89**	**7.61**		**2.84**		

The aquifers at Cape Padrone, Fishkraals, Kwaaihoek and Apies River are largely in the control of SanParks, who do not sanction further exploitation.

Pump testing data suggests the aquifers are leaky, with a thin transmissive basal conglomerate overlain by fine sands. Optimum pumping schedules would require long duration pumping at low rates due to the limited available draw down.

Apies River: Serious consideration should be given to developing the Apies River aquifer, immediately west of Cannon Rocks. Favourable recharge conditions suggest a groundwater Harvest Potential of around 2 000 m³/day. This assumption is based on the thick occurrence of both fossil and recent dunes, a wide dune cordon of around 1 000 m, generous orographic recharge (MAP = 788 mm) and flushing received from the Apies

River. As this area forms part of the Addo National Park, any bush clearing and access roads will first have to be cleared with DEAT and SanParks.

The resources at Apies River are sufficient to meet the current peak demand of the combined Boknes/Cannon Rocks communities.

Alternative options are to approach the landowner of the farm Boschhoek (Mr. Christo Potgieter) regarding the use of his borehole to the benefit of the Boknes/Cannon Rocks community. This borehole, licensed for 70 200 m^3/annum and would be able to provide Class II water at a rate of 2.5 ℓ/s over a 24-hour pump cycle. This augmentation would also serve to upgrade the existing poor quality of water by blending with higher quality water.

Kwaaihoek: The modern dune aquifer (800 m east of Dias Cross) has moderate groundwater development potential and should be considered to augment the Dias Cross well field. Approximately 6 wide diameter boreholes, each estimated at 14 m deep, would be sufficient to supply an additional 300 m^3/d of Class II quality water towards the bulk supply of ACWB. Water from this source could conveniently utilise the existing pipeline, which passes directly behind this aquifer. Developing this well field could resolve the peak demand crisis often experienced by the Bushmans/Kenton communities over holiday periods. This well field can be pumped below capacity on a rotational basis with the Dias Cross well field.

Both DEAT and SanParks need to be informed of the urgency to develop this aquifer.

Sunshine Coast Nature Reserve: This aquifer west of Port Alfred, coincides with the eastern portion of the Sunshine Coast Nature Reserve, has a high groundwater development potential. A well field developed in these coastal sands could provide 750-1000 m^3/d for the western suburbs of Port Alfred. This water could be utilized to cope with the peak demand. Alternatively, this water could be judiciously blended with the bulk supply from the Sarel Hayward dam, on a continual basis, to upgrade the existing poor quality water endured by the residents of Port Alfred.

This aquifer is served by a pristine catchment area and also has a blind river focusing recharge into the back dune area, enhancing the sustainability of the resource. This aquifer has much in common with the Apies River aquifer.

DEAT should be informed of the need to develop this aquifer.

Rufanes River: Consideration should also be given to augment the East Bank well field with a new well field developed on the west bank of the Rufanes River. This area is undeveloped, has a broad dune cordon and is periodically recharged by the Rufanes River, which introduces runoff into the back-dune area.

Riet River: Here, a broad dune cordon is developed on a plunging anticline of Witpoort quartzites, at Riet Punt, immediately west of Riet River. Although some distance from Port Alfred, this source can deliver potable water to the local residents, if required.

Clayton's Rocks: The ongoing development and expansions at Seafield/ Kleinemonde has resulted in water shortages that will be compounded in the future. An option is to develop the modern dune cordon, located immediately behind Clayton's Rocks in preference to the current coastal borehole, which supplies poor quality water to a small portion of the community.

Fish River Lighthouse: At this locality, a broader zone of fossil dunes, hydraulically up-gradient, complements a broad expanse of modern dunes, thus providing additional significant storage potential to the latter aquifer. This option should be investigated further as the Kleinemonde community requires additional water to cope with peak demand.

8.5.4 Anticipated Hydrogeological Conditions and Costs

Anticipated hydrogeological drilling conditions and costs are presented in Tables 13 and 14 respectively.

Table 13 : Anticipated Hydrogeological Conditions

Locality Farm/Area	Tot. Yield (12 hours) (kℓ/day)	Yield per borehole (ℓ/s)	No. of bh's	Average drill depth (m bgl)	Metres drilled	Cost per (m)	Av. Dynamic Water Level (m)	Drill Success Rate (%)	Assumptions/Remarks
HIGH POTENTIAL: FRACTURED									
Harvestvale/Bushfontein	800	7.5	10	150	1 500	400	30	50	Boreholes near artesian.
Merville	800	4	10	150	1 500	400	35	50	Boreholes near artesian, excludes contribution from spring.
Barville/Glendower	1 000	5	12	180	2 160	400	50	35	Witpoort fractured will receive vertical leakage from the overlying, intergranular Nanaga aquifer.
Tharfield/Greenfountain	1 000	4	12	150	1800	400	40	30	
Fords Party	1 000	4	12	150	1 800	400	40	30	
South Seas/Palmietheuval	800	3	12	150	1 800	400	40	30	
The Grove	800	5	10	150	1 500	400	35	50	Has potential but fairly remote.
HIGH POTENTIAL: INTERGRANULAR									
Cape Padrone/Fish Kraals	1 100	2	15	12	180	1 200	8	60	Excludes current abstraction (~ 19ℓ/s)
Apies River	2 000	3	20	20	400	1 200	10	70	Blind river feeding dune cordon
Kwaaihoek	300	2	5	12	60	1 200	8	60	Satellite well field to Dias Cross
Sunshine Coast Nature Reserve	750	2	12	20	240	1 200	10	70	Blind river feeding dune cordon
TOTAL (kℓ/day)	**9 350**	**37.5**			**11 140**				

Table 14 : Anticipated Borehole Costs

Locality Farm/Area	Scoping/ EIA	Water Licences	Hydrogeo Study	Test Pumping	Sub Total	Contingencies	VAT	TOTAL	Cost/m³/d	URV/m³/d
HIGH POTENTIAL: FRACTURED										
Harvestvale/Bushfontein	45 000	35 000	25 000	100 000	805 000	80 500	123 970	885 500	1 106.88	0.28
Merville	35 000	25 000	17 500	100 000	777 500	77 750	119 735	855 250	1 069.06	0.27
Barville/Glendower	35 000	25 000	17 500	120 000	1 061 500	106 150	163 471	1 167 650	1 167.65	0.30
Tharfield/Greenfountain	35 000	20 000	17 500	120 000	1 070 000	107 000	164 780	1 341 780	1 341.78	0.34
Fords Party	30 000	20 000	17 500	120 000	907 500	90 750	139 755	998 250	998.25	0.26
South Seas/Palmietheuval	30 000	20 000	17 500	120 000	907 500	90 750	139 755	998 250	1 247.81	0.32
The Grove	25 000	17 500	17 500	100 000	760 000	76 000	117 040	836 000	1 045.00	0.27
HIGH POTENTIAL: INTERGRANULAR										
Cape Padrone/Fish Kraals	45 000	35 000	25 000	150 000	471 000	47 100	72 534	518 100	471.00	0.12
Apies River	45 000	35 000	25 000	200 000	785 000	78 500	120 890	863 500	431.75	0.11
Kwaaihoek	30 000	15 000	17 500	50 000	184 500	18 450	28 413	202 950	676.50	0.17
Sunshine Coast Nature Reserve	45 000	35 000	25 000	120 000	513 000	51 300	79 002	564 300	752.40	0.19
TOTAL (kℓ/day)	**400 000**	**282 500**	**222 500**	**1 300 000**	**7 172 500**	**7 818 100**	**1 269 345**	**9 231 530**	**987.33**	**0.22**

Drilling costs include assumed mobilization, site setup, PVC casing and screens, gravel packs etc.
Site supervision is included in drilling and test costs
URV's are based on 25 year design life and 0.08 discount rate. They include borehole establishment only.

9. CONCLUSIONS

A number of coastal and inland towns situated within the coastal belt of the study area experience serious periodic water supply problems, mainly because of inadequate sources, poor water quality and insufficient capacity of their bulk supply infrastructure.

There is a general lack of understanding of groundwater resources and a lack of capacity and funding to perform basic maintenance and monitoring.

Around 45 % of the population is reliant on groundwater schemes as a source for bulk supply. This is particularly prevalent in the western portion of Ndlambe, which has a thicker succession of fossil and modern dunes, allowing exploitation of primary (porous) aquifers.

The study has identified the potential of several regional aquifers to supplement existing water supply, and has identified several localities that can be targeted for more detailed groundwater investigation.

Conclusions pertaining to the hydrogeological potential of Ndlambe are as follows:

9.1 COASTAL AQUIFERS

- Exploitation of the fossil (Alexandria and Nanaga) and modern (Schelmhoek) coastal aquifers has application in the Ndlambe context. Both these primary aquifers are capable of storing and releasing significant volumes of water. These aquifers are invariably in contact with one another, with the latter occurring down the hydraulic gradient and receiving groundwater from the former. Their optimal development coincides with large, present-day catchments superimposed over ancient channels.
- Intergranular aquifers are best developed along the coast where thicker deposits of Alexandria, Nanaga and Schelmhoek Formation have been preserved. The contact between these rocks and the underlying 'basement' is an obvious target. The permeable Nanaga Formation also plays a significant role in storing significant volumes of groundwater, where leakage occurs to the lower aquifer. The aquifers are

currently exploited at Cape Padrone, Fishkraals, Dias Cross, Bushmans River Mouth and Port Alfred, East Bank.

- Potential target areas where a thick and wide succession of these deposits exist have been identified at Cape Padrone/Fishkraals, Apies River, Sunshine Coast Nature Reserve, Kwaaihoek, Rufanes River, Riet River, Clayton's Rocks and Fish River Lighthouse.
- The potential groundwater resources of these coastal aquifers is 2.84 Mm^3/a.
- The Apies River, Kwaaihoek and the Sunshine Coast Nature Reserve coastal aquifers represent the most attractive to develop due to potential large water resources of suitable quality in the vicinity of population centres. The preferred method of abstraction is from shallow (generally < 15 m) boreholes or caissons. These potential well fields would benefit the Boknes/Cannon Rocks, Bushmans/Kenton and the Port Alfred communities respectively.
- Coastal aquifers are vulnerable to degradation through over pumping and drought conditions – a situation currently affecting Ndlambe and the ACWB in particular.
- Severe draw down causes localized flow gradients, inducing brack water in the back-dune area to surge into the well field. Under certain conditions, sea water is capable of intruding from the south to infiltrate the well field.

9.2 FRACTURED AQUIFERS

- Competent rocks, especially quartzites of the Witpoort Formation underwent brittle failure during the Cape Orogeny and during the break-up of Gondwanaland, resulting in numerous faults, fractures and joints, thus creating secondary fracture porosity. Many of these structures are tensional in nature, hence are potentially high yielding groundwater targets.
- The Witpoort Formation is a potential aquifer due to its proximity to population centres. Conveniently, the Witpoort aquifer arcs behind Bushmans/Kenton, Port Alfred and Seafield/Kleinemonde as three discrete belts.

- The median yield of the Witpoort aquifer is less than 0.5 ℓ/s, unless regional structures are targeted. Recent drilling suggests a moderate to high groundwater potential on fault structures. Drilling on the farm Merville has provided significant yields of 5.0; 3.3, 20.0 and 7.0 ℓ/s of Class I and II quality water – confirming the attractiveness of the aquifer. These boreholes have not, as yet, been subjected to long duration test pumping. The two high yielding boreholes are artesian. Similar structures are located elsewhere in the Witpoort Formation.

- Sustainable groundwater resources of the Witpoort aquifer are approximately 2.5 Mm^3/a.

- South-southeast and east-northeast trending structures form the most suitable drilling target for high yielding boreholes. These can be detected using a combination of Landsat imagery and aerial photography.

- Incompetent rocks (i.e., shale's) are more flexible and less inclined to break, thereby inhibiting fracture porosity. As a possible groundwater resource, the Bokkeveld, Weltevrede and Lake Mentz aquifers generally have a low groundwater potential. Low median yields and the paucity of brittle deformations structures result in few obvious groundwater targets. In addition, water quality is generally poor. Some high yielding boreholes in the Lake Mentz Formation may be related to the underlying Witpoort Formation.

10. RECOMMENDATIONS

A sustainable solution to the perennial bulk water supply problems of Ndlambe needs to be sought as a matter of urgency. The interruptions to supply and poor water quality (often Class II or Marginal) endured by the residents have become an emotive issue. An erosion of business and/or investment confidence (particularly as a retirement location or tourist destination) has been forecast should the situation not improve. The popularity of the area and the upgrading of infrastructure to RDP standards will place additional demands on the suppliers of bulk water.

The following recommendations are made based on the findings and evaluation of the available data and an understanding of the demographics, hydrogeology and economic potential of the region.

- Although the NGDB lists 755 boreholes in Ndlambe, it is estimated that at least half the actual boreholes drilled and/or utilized are not reflected in the NGDB. It is recommended to conduct a thorough hydrocensus over he entire local municipality to confirm borehole densities and actual usage.

- Community and private boreholes make up an important contribution (~ 45 %) to the supply of bulk water in Ndlambe. Boreholes, as much as possible, should not be used in isolation as a source of bulk supply. Rather, they should be used in conjunction with surface water, desalinated water (via reverse osmosis) and/or recycled water to spread the load on the various resources. Water from diverse sources will allow an element of proactive management to reduce risk and to achieve the right cost and quality profiles through judicious blending.

- The Witpoort aquifer has much in common with the heavily exploited Table Mountain Group aquifer in the southern Cape region, however, it is relatively unexploited within Ndlambe. The Bushmans/Kenton communities can benefit from this aquifer, however, the extent of resources remains unproven.

- Target areas within the Witpoort need additional remote sensing to confirm anomalies ahead of ground-truthing properties for the scoping/EIA process.

- The boreholes drilled into the Witpoort by DWAF on Merville should be test pumped and equipped. Groundwater could then be piped 20 Km into the ACWB's storage reservoirs at Ekuphumleni.

- DWAF could extend their drilling programme to test the high groundwater potential in and around the following farms locate on the Witpoort aquifer. Western belt: Bushfontein, Barville Park and Glendower. Central belt: farms corresponding to Grove Hill, Fords Party and Tharfield. Eastern belt: Palmietheuval, Southseas and The Grove. Successful boreholes in these belts would be to the benefit of all towns within the affected area. Mapping and geophysical surveys should precede drilling to increase success rates.

- Geophyisical surveys, utilising the electrical ('Res') and electro-magnetic ('EM') methods should be considered along the gravel roads, developed on Witpoort quartzite, trending towards the interior.

- Satellite telemetry system is required to monitor water quality, water level and flow rate on a continual basis in the coastal aquifers, relaying information to a dedicated computerized data capture system. Although the Dias Cross aquifer has served the area for several years, limited performance data is available which would enable a model to be produced and calibrated to similar aquifers in the Ndlambe. In addition, such data is required as an early warning system of potential aquifer failure. Environmental monitoring of well fields is a requisite by DWAF in terms of their licence agreement to abstract groundwater.

- Given the severe water shortages in Ndlambe, an aggressive 'Water Conservation and Demand Programme' must be instituted without delay. DWAF expect this of municipalities in dire need, as the data produced provides a stimulus for their intervention.

- Agricultural property is widely sought after in Ndlambe and attracts premium prices from individuals (often foreigners) who are keen to develop the land into a housing estate or game reserve. This often makes it difficult to utilize a potential groundwater resource. Ndlambe should consult with affected landowners as soon as possible about its future bulk water requirements and come to a commercial agreement regarding developing well fields and abstraction of groundwater.

- In light of all the developments occurring in Ndlambe, care should be taken to ensure that potential aquifers are not sterilized and/or contaminated through injudicious planning. At present, bulk water resources are severely stretched and any new development is essentially 'fatally flawed' until the situation improves significantly. Alternatively, new developments should develop their own sustainable water source.

- Rain water tanks should be installed as a matter of routine to all future RDP houses. This should be extended with retro-fitting of rain tanks to all older houses in the townships. Rain tanks should be made compulsory in the affluent communities, with the tank capacity based on a sliding-scale according to the roof area.

- DWAF should inform DEAT and SanParks of the bulk water problems of the region and the need to develop coastal aquifers.

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APPENDIX A

National Groundwater Database of Ndlambe Local Municipality

APPENDIX A : BOKKEVELD (1)

NUMBER	28	BASIC SITE	LATEST DEPTH	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO
1	3.571428571	3326DA00158	0.00000	0.01000	0.03000	<1 l/s	0.03	0.01
2	7.142857143	3326DA00099	35.35000	10.66000	0.10000	<1 l/s	0.10	3.65
3	10.71428571	3326DA00100	17.98000	13.71000	2.71000	2.1 to 5 l/s	2.71	3.96
4	14.28571429	3326DA00064	70.71000	18.28000	0.18000	<1 l/s	0.18	5.48
5	17.85714286	3326DA00012	33.52000	26.51000	2.13000	2.1 to 5 l/s	2.13	7.62
6	21.42857143	3326DA00025	117.04000	27.43000	0.06000	<1 l/s	0.06	9.75
7	25	3326DA00028	109.72000	28.95000	0.12000	<1 l/s	0.12	10.36
8	28.57142857	3326DA00026	76.20000	30.48000	0.03000	<1 l/s	0.03	11.58
9	32.14285714	3326DA00109	122.00000	34.00000		No Data		12
10	35.71428571	3326DA00132	44.80000	34.44000	0.74000	<1 l/s	0.74	16.61
11	39.28571429	3326DA00027	57.91000	38.10000	0.75000	<1 l/s	0.75	21.33
12	42.85714286	3326DA00091	44.50000	41.14000	0.68000	<1 l/s	0.68	22.55
13	46.42857143	3326CB00017	66.00000	43.00000	0.47000	<1 l/s	0.47	22.55
14	50	3326DA00114	49.07000	49.07000	0.28000	<1 l/s	0.28	25
15	53.57142857	3326DA00065	76.20000	53.34000	0.07000	<1 l/s	0.07	25.29
16	57.14285714	3326DA00023	68.58000	54.86000	0.13000	<1 l/s	0.13	29.26
17	60.71428571	3326DA00090	83.21000	68.58000	0.42000	<1 l/s	0.42	30.48
18	64.28571429	3326DA00110	115.82000	71.62000	0.03000	<1 l/s	0.03	36.88
19	67.85714286	3326DA00089	76.80000	73.15000	0.15000	<1 l/s	0.15	37.79
20	71.42857143	3326DA00024	98.14000	73.15000	0.29000	<1 l/s	0.29	42.36
21	75	3326DA00102	91.13000	76.20000	0.12000	<1 l/s	0.12	44.5
22	78.57142857	3326DA00131	133.19000	77.41000	0.07000	<1 l/s	0.07	45.72
23	82.14285714	3326DA00066	97.23000	82.29000	0.35000	<1 l/s	0.35	45.72
24	85.71428571	3326DA00111	155.14000	92.35000	0.07000	<1 l/s	0.07	46
25	89.28571429	3326CB00024	111.00000	108.00000	0.57000	<1 l/s	0.57	51.81
26	92.85714286	3326DA00006	191.10000	137.16000	0.07000	<1 l/s	0.07	56.63
27	96.42857143	3326CB00158	180.00000	170.00000	0.23000	<1 l/s		71.32
28	100	3326CB00016	60.00000		0.00000	DRY		83.82
29	103.5714286	3326CB00018	90.00000		0.00000	DRY		DRY
30	107.1428571	3326CB00019	48.00000		0.00000	DRY		DRY
31	110.7142857	3326DA00005	146.30000		0.00000	DRY		DRY
32	114.2857143	3326DA00007	70.10000		0.00000	DRY		DRY
33	117.8571429	3326DA00022	105.76000		0.00000	DRY		DRY
34	121.4285714	3326DA00092	36.57000		0.00000	DRY		DRY
35	125	3326DA00093	129.54000		0.00000	DRY		DRY
36	128.5714286	3326DA00103	170.38000		0.00000	DRY		DRY
37	132.1428571	3326DA00104	33.52000		0.00000	DRY		DRY
38	135.7142857	3326DA00112	118.87000		0.00000	DRY		DRY
39	139.2857143	3326DA00113	127.40000		0.00000	DRY		DRY
40	142.8571429	3326DA00133	73.45000		0.00000	DRY		DRY
41	146.4285714	3326DA00147	66.63000		0.00000	DRY		DEPTH
42	150	3326CB00081	72.00000		0.25000	<1 l/s	0.25	
Median			**76.50000**	**49.07**	**0.07**			

APPENDIX A: WELTEVREDE (2)

NUMBER	138	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL
1	0.724637681	3326DA00160	WOLFS CRAG	20.00000			0.51	<1 l/s	0.51		12.00000
2	1.449275362	3326DA00039	WOLFS CRAG GED. GLENNIFFER	70.10000		7.14000	0.03	<1 l/s	0.03		7.01000
3	2.173913043	3326DA00041	WOLFS CRAG GED. GLENNIFFER	33.83000		7.62000	0.06	<1 l/s	0.06		3.04000
4	2.898550725	3326DA00060	WOLFS CRAG GED. HOPEDALE GED. 4	25.90000		9.14000	1.26	1 to 2 l/s	1.26		5.48000
5	3.623188406	3326DA00040	WOLFS CRAG GED. GLENNIFFER	53.34000		9.14000	0.03	<1 l/s	0.03		8.53000
6	4.347826087	3326BD00057	KLEIN MONDEN RIVIER GED. PENINSULA PARK	18.58000	0.00000	10.66000	20	5.1 to 25 l/s	20.00		9.14000
7	5.072463768	3326BC00036	YENDALLA GED. NORTH END	69.18000		11.27000	0.51	<1 l/s	0.51		2.00000
8	5.797101449	3326BC00026	GLENFILLAN GED. GLENFILLAN PARK	74.98000		12.49000	0.01	<1 l/s	0.01		9.00000
9	6.52173913	3326BD00004	KAP RIVER FARM GED. ALLANDALE	17.06000	0.00000	13.71000	0.63	<1 l/s	0.63		2.43000
10	7.246376812	3326BC00027	GLENFILLAN GED. GLENFILLAN PARK	30.78000		14.63000	0.32	<1 l/s	0.32		3.00000
11	7.971014493	3326DA00042	WOLFS CRAG GED. GLENNIFFER	24.07000		15.24000	1.51	1 to 2 l/s	1.51		3.04000
12	8.695652174	3326BC00032	HOLLINGROVE GED. GLEN HOPE	66.14000		16.76000	0.03	<1 l/s	0.30		9.00000
13	9.420289855	3326DA00043	WOLFS CRAG GED. GLENNIFFER	33.83000		18.28000	0.54	<1 l/s	0.54		7.92000
14	10.14492754	3326DA00045	WOLFS CRAG GED. GLENNIFFER	28.04000		18.28000	0.11	<1 l/s	0.11		8.53000
15	10.86956522	3326DA00071	THEOPOLIS GED. LINCOLN	57.91000		19.50000	0.33	<1 l/s	0.33		17.37000
16	11.5942029	3326DA00067	THEOPOLIS GED. LINCOLN	35.66000		21.33000	0.01	<1 l/s	0.01		19.81000
17	12.31884058	3326BD00103	MARTINDALE GED. FOREST VIEW	63.39000	0.00000	24.38000	1.76	1 to 2 l/s	1.76		7.01000
18	13.04347826	3326BD00042	LANGHOLM GED. LANGHOLM ESTATES	42.67000	0.00000	24.38000	1.26	1 to 2 l/s	1.26		24.38000
19	13.76811594	3326DA00095	MOSSAY CRAG	39.77000		28.95000	1	1 to 2 l/s	1.00		17.37000
20	14.49275362	3326BD00032	FARM 61 GED. HOPEWELL	67.66000	0.00000	30.17000	0.06	<1 l/s	0.06		20.42000
21	15.2173913	3326BD00182	ARMAGH GED. TRAPPE'S VALLEY	36.36000	0.00000	30.30000	0.75	<1 l/s	0.75		12.12000
22	15.94202899	3326BC00030	HOLLINGROVE GED. GLEN HOPE	138.98000		30.48000	0.12	<1 l/s	0.12		23.00000
23	16.66666667	3326BD00088	FARM 55 GED. CLIFFTON	45.72000	0.00000	31.08000	3.02	2.1 to 5 l/s	3.02		18.28000
24	17.39130435	3326BD00146	FARM 55 GED. CLIFTON	61.57000	0.00000	32.00000	0.11	<1 l/s	0.11		19.51000
25	18.11594203	3326BD00106	MARTINDALE GED. FOREST VIEW	37.79000	0.00000	32.30000	0.73	<1 l/s	0.73		22.25000
26	18.84057971	3326BD00055	FARM 195 GED. ORANGE GROVE	108.81000	0.00000	33.52000	0.03	<1 l/s	0.03		22.25000
27	19.56521739	3326BD00066	FARM 202 GED. SWEET FOUNTAIN	46.63000	0.00000	33.83000	0.02	<1 l/s	0.02		28.65000
28	20.28985507	3326BD00089	FARM 55 GED. CLIFFTON	39.62000	0.00000	34.74000	2.71	2.1 to 5 l/s	2.71		20.72000
29	21.01449275	3326BD00050	FARM 67 GED. NOTTINGHAM	50.00000	0.00000	35.00000	0.28	<1 l/s	0.28		18.00000
30	21.73913043	3326BC00035	YENDALLA GED. NORTH BEND	83.51000		35.96000	0.33	<1 l/s	0.33		36.00000
31	22.46376812	3326DA00030	WOLFS CRAG GED. GLENNIFFER	123.74000		36.57000	0.07	<1 l/s	0.07		9.75000
32	23.1884058	3326BD00046	MARTINDALE	45.56000	0.00000	38.10000	1	1 to 2 l/s	1.00		5.48000
33	23.91304348	3326BD00128	FARM 163 GED. PINEDON	47.24000	0.00000	38.10000	0.37	<1 l/s	0.37		34.44000
34	24.63768116	3326DA00129	WOLFS CRAG	62.48000		38.70000	0.37	<1 l/s	0.37		7.62000
35	25.36231884	3326BD00125	FARM 159 GED. SPRINGFIELD	62.78000	0.00000	39.01000	0.37	<1 l/s	0.37		33.52000
36	26.08695652	3326BD00045	MARTINDALE	46.93000	0.00000	39.62000	0.63	<1 l/s	0.63		3.04000
37	26.8115942	3326BD00007	KLEIN MONDEN RIVIER GED. MOUNT WELLINGTON	63.70000	0.00000	39.62000	0.11	<1 l/s	0.11		15.24000
38	27.53623188	3326AB00042	LATON GED. LAYTON	84.73000		39.62000	0.16	<1 l/s	0.16		30.00000
39	28.26086957	3326BD00193	FARM 67	114.00000	0.00000	40.00000	0.29	<1 l/s		BLOWTEST	15.00000
40	28.98550725	3326BD00039	FARM 61 GED. HOPEWELL	52.73000	0.00000	42.67000	0.06	<1 l/s	0.06		34.13000
41	29.71014493	3326BD00114	BANANA GROVE	47.24000	0.00000	42.67000	0.05	<1 l/s	0.05		36.57000
42	30.43478261	3326BC00029	HOLLINGROVE GED. GLEN HOPE	84.42000		43.28000	0.51	<1 l/s	0.51		30.00000
43	31.15942029	3326BD00129	FARM 193 GED. PINEDON	49.68000	0.00000	43.58000	4.54	2.1 to 5 l/s	4.54		24.38000
44	31.88405797	3326BD00037	FARM 61 GED. HOPEWELL	110.33000	0.00000	44.19000	0.03	<1 l/s	0.03		30.48000
45	32.60869565	3326BD00134	FARM 163 GED. PINEDON	95.70000	0.00000	45.72000	0.1	<1 l/s	0.10		39.62000
46	33.33333333	3326AB00041	LATON GED. LAYTON	53.95000		46.33000	1.83	1 to 2 l/s	1.83		41.00000
47	34.05797101	3326BC00092	KLIP FONTEIN GED. WINDY RIDGE	73.15000		47.24000	1.63	1 to 2 l/s	1.63		41.00000
48	34.7826087	3326DA00121	WALSINGHAM	48.46000		47.54000	0.81	<1 l/s	0.81		13.41000
49	35.50724638	3326BC00003	KLIP FONTEIN GED. ORANGE GROVE	102.00000		48.00000	0.95	<1 l/s	0.95		4.00000
50	36.23188406	3326BD00006	KLEIN MONDEN RIVIER GED. MOUNT WELLINGTON	58.82000	0.00000	48.76000	0.71	<1 l/s	0.71		17.67000
51	36.95652174	3326BD00043	FARM 150 GED. LUSHINGTON VALLEY	52.88000	0.00000	49.07000	3.78	2.1 to 5 l/s	3.78		36.57000

APPENDIX A: WELTEVREDE (2)

NUMBER	138	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL
52	37.68115942	3326BD00118	FARM 42 GED. KLIPKOP	64.00000	0.00000	50.29000	1.62	1 to 2 l/s	1.62		31.39000
53	38.4057971	3326BD00112	BANANA GROVE	52.42000	0.00000	50.90000	0.75	<1 l/s	0.75		26.51000
54	39.13043478	3326BD00054	FARM 195 GED. ORANGE GROVE	60.35000	0.00000	51.20000	0.45	<1 l/s	0.45		11.88000
55	39.85507246	3326BD00015	GIFFORDS BUSH	57.30000	0.00000	51.81000	1.16	1 to 2 l/s	1.16		27.43000
56	40.57971014	3326BD00079	BIRBURY	60.96000	0.00000	51.81000	0.67	<1 l/s	0.67		34.44000
57	41.30434783	3326BD00011	ARMAGH GED. TRAPPE'S VALLEY	91.00000	0.00000	53.00000	0.64	<1 l/s	0.64		6.00000
58	42.02898551	3326BD00078	FARM 46 GED. BEAUFORTVALE	63.09000	0.00000	53.91000	0.33	<1 l/s	0.33		38.10000
59	42.75362319	3326DA00210	WALSINGHAM GED. LOMBARDY	124.00000		54.00000		No Data			26.33000
60	43.47826087	3326BD00133	FARM 163 GED. PINEDON	60.96000	0.00000	54.86000	1.51	1 to 2 l/s	1.51		30.48000
61	44.20289855	3326BD00110	KAP RIVER FARM GED. ALLANDALE	61.56000	0.00000	54.86000	0.94	<1 l/s	0.94		44.19000
62	44.92753623	3326BD00065	FARM 202 GED. SWEET FOUNTAIN	100.58000	0.00000	54.86000	0.13	<1 l/s	0.13		44.50000
63	45.65217391	3326BD00113	BANANA GROVE	68.58000	0.00000	55.77000	2.27	2.1 to 5 l/s	2.27		10.66000
64	46.37681159	3326BC00028	GLENFILLAN GED. GLENFILLAN PARK	64.00000		56.38000	0.34	<1 l/s	0.34		30.00000
65	47.10144928	3326BD00016	GLENCAIRN GED. GLEN CAIRN	60.35000	0.00000	56.38000	0.64	<1 l/s	0.64		42.67000
66	47.82608696	3326BD00144	FARM 55 GED. CLIFTON	60.35000	0.00000	56.39000	0.33	<1 l/s	0.33		39.62000
67	48.55072464	3326BC00018	CURRIE'S DRIFT OUTSPAN GED. CURRIESDRIFT	77.41000		56.69000	0.37	<1 l/s	0.37		48.00000
68	49.27536232	3326BC00041	HOME GED. THE HOME	71.62000		57.30000	1.64	1 to 2 l/s	1.64		53.00000
69	50	3326BD00124	BANANA GROVE GED. ROSSLYN	76.20000	0.00000	58.21000	0.5	<1 l/s	0.50		45.11000
70	50.72463768	3326BD00111	BANANA GROVE	66.14000	0.00000	59.13000	3.78	2.1 to 5 l/s	3.78		39.31000
71	51.44927536	3326BD00127	ELLINGTON GED. THE ORCHARD	85.95000	0.00000	59.43000	0.06	<1 l/s	0.06		57.91000
72	52.17391304	3326BD00179	FARM 159 GED. SPRINGFIELD	70.00000	0.00000	60.00000	0.31	<1 l/s	0.31		60.00000
73	52.89855072	3326DA00130	WOLFS CRAG	96.62000		60.04000	0.15	<1 l/s	0.15		31.39000
74	53.62318841	3326BD00038	FARM 61 GED. HOPEWELL	119.48000	0.00000	60.04000	0.03	<1 l/s	0.03		56.38000
75	54.34782609	3326BC00038	ROCKEBY PARK	65.83000		60.35000	4.6	2.1 to 5 l/s	4.60		49.00000
76	55.07246377	3326BD00049	FARM 68 GED. NEW GLOUCESTER	73.45000	0.00000	61.87000	0.38	<1 l/s	0.38		22.86000
77	55.79710145	3326DA00070	THEOPOLIS GED. LINCOLN	67.66000		62.17000	0.72	<1 l/s	0.72		23.77000
78	56.52173913	3326BD00019	FARM 46 GED. HAMILTON	85.34000	0.00000	62.78000	0.07	<1 l/s	0.07		39.62000
79	57.24637681	3326BD00135	FARM 202 GED. SWEET FOUNTAIN	90.00000	0.00000	65.00000	10.06	5.1 to 25 l/s	10.06		
80	57.97101449	3326BD00094	FARM 28 GED. ESKDALE	74.37000	0.00000	65.53000	1.71	1 to 2 l/s	1.71		47.24000
81	58.69565217	3326BC00019	CURRIE'S DRIFT OUTSPAN GED. CURRIESDRIFT	96.01000		66.44000	0.02	<1 l/s	0.02		63.00000
82	59.42028986	3326BD00020	FARM 46 GED. HAMILTON	70.71000	0.00000	67.05000	0.07	<1 l/s	0.07		36.57000
83	60.14492754	3326DA00116	WALSINGHAM	77.72000		67.05000	0.1	<1 l/s	0.10		60.96000
84	60.86956522	3326DB00184	BIRBURY	84.00000	0.00000	69.00000	1	1 to 2 l/s	1.00		10.17000
85	61.5942029	3326BC00002	KLIP FONTEIN GED. ORANGE GROVE	100.00000		70.00000	0.64	<1 l/s	0.64		43.00000
86	62.31884058	3326BD00156	BIRBURY	70.00000	0.00000	70.00000	0.38	<1 l/s	0.38		55.00000
87	63.04347826	3326DA00063	WALSINGHAM GED. IRINGA	82.29000		70.10000	0.77	<1 l/s	0.77		29.87000
88	63.76811594	3326BD00036	FARM 61 GED. HOPEWELL	97.23000	0.00000	70.40000	0.03	<1 l/s	0.03		45.72000
89	64.49275362	3326BD00172	FARM 42 GED. KLIPKOP	75.75000	0.00000	72.27000	0.25	<1 l/s	0.25		24.24000
90	65.2173913	3326BD00116	DUNDEE	84.73000	0.00000	72.54000	0.24	<1 l/s	0.24		48.76000
91	65.94202899	3326BD00180	HAV-A-LUCK	83.33000	0.00000	72.72000	0.25	<1 l/s	0.25		42.72000
92	66.66666667	3326BC00029	HOLLINGROVE GED. GLEN HOPE	84.42000		73.15000	0.51	<1 l/s	0.51		30.00000
93	67.39130435	3326BC00040	HOME GED. THE HOME	85.34000		73.15000	0.42	<1 l/s	0.42		59.00000
94	68.11594203	3326BC00037	ROKEBY GED. PROSPECT	77.72000		73.45000	3.02	2.1 to 5 l/s	3.02		48.00000
95	68.84057971	3326BD00107	MARTINDALE GED. FOREST VIEW	88.39000	0.00000	74.67000	1.62	1 to 2 l/s	1.62		38.10000
96	69.56521739	3326BD00018	FARM 151 GED. GRANDON	82.60000	0.00000	74.67000	0.81	<1 l/s	0.81		60.96000
97	70.28985507	3326BC00035	YENDALLA GED. NORTH BEND	83.51000		76.80000	0.33	<1 l/s	0.33		36.00000
98	71.01449275	3326BD00052	FARM 67 GED. NOTTINGHAM	82.60000	0.00000	77.41000	1.8	1 to 2 l/s	1.80		66.75000
99	71.73913043	3326BD00051	FARM 67 GED. NOTTINGHAM	84.00000	0.00000	78.00000	3.2	2.1 to 5 l/s	3.20		61.00000
100	72.46376812	3326BC00022	GLENFILLAN GED. GLENFILLAN PARK	92.96000		79.24000	0.18	<1 l/s	0.18		26.00000
101	73.1884058	3326DA00120	WALSINGHAM	92.35000		80.46000	0.34	<1 l/s	0.34		47.24000

APPENDIX A: WELTEVREDE (2)

NUMBER	138	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL
102	73.91304348	3326BD00053	FARM 195 GED. ORANGE GROVE	93.26000	0.00000	81.33000	0.27	<1 l/s	0.27		22.86000
103	74.63768116	3326BD00014	GIFFORDS BUSH	99.97000	0.00000	81.38000	0.07	<1 l/s	0.07		60.96000
104	75.36231884	3326AB00040	LATON GED. LAYTON	91.44000		82.30000	0.75	<1 l/s	0.75		67.00000
105	76.08695652	3326BD00056	PARK FARM	86.25000	0.00000	82.60000	0.3	<1 l/s	0.30		52.42000
106	76.8115942	3326BD00117	DUNDEE	94.48000	0.00000	84.12000	0.54	<1 l/s	0.54		64.00000
107	77.53623188	3326BC00031	HOLLINGROVE GED. GLEN HOPE	102.10000		85.34000	0.5	<1 l/s	0.50		58.00000
108	78.26086957	3326BC00017	BLAAUWKRANTZ	96.62000		85.34000	0.28	<1 l/s	0.28		59.00000
109	78.98550725	3326BC00033	HOLLINGROVE GED. GLEN HOPE	91.44000		86.56000	0.23	<1 l/s	0.23		30.00000
110	79.71014493	3326BC00021	WESLEY WOOD GED. DENVER	95.40000		86.86000	0.44	<1 l/s	0.44		37.00000
111	80.43478261	3326BD00115	FARM 133 GED. CLUMBER	96.01000	0.00000	86.86000	1.25	1 to 2 l/s	1.25		83.21000
112	81.15942029	3326BD00090	CONSTANCEVILLE	94.48000	0.00000	87.47000	1.35	1 to 2 l/s	1.35		60.96000
113	81.88405797	3326DA00123	WALSINGHAM	92.35000		87.78000	0.75	<1 l/s	0.75		20.72000
114	82.60869565	3326CB00039	CORAL DENE GED. 1	120.00000	0.00000	90.00000	0.2	<1 l/s	0.20		43.00000
115	83.33333333	3326DA00138	WALSINGHAM GED. LOMBARDY	96.01000		90.22000	0.4	<1 l/s	0.40		31.08000
116	84.05797101	3326DA00059	WOLFS CRAG GED. HOPEFIELD GED. 4	107.28000		90.22000	0.07	<1 l/s	0.07		45.72000
117	84.7826087	3326BD00126	ELLINGTON GED. THE ORCHARD	107.89000	0.00000	90.83000	0.5	<1 l/s	0.50		50.90000
118	85.50724638	3326BD00105	MARTINDALE GED. FOREST VIEW	121.92000	0.00000	91.44000	0.06	<1 l/s	0.06		74.37000
119	86.23188406	3326DA00128	WOLFS CRAG	122.52000		92.04000	0.2	<1 l/s	0.20		64.00000
120	86.95652174	3327CA00012	SEAFIELD	96.62000	0.00000	92.62000	0.34	<1 l/s	0.34		19.81000
121	87.68115942	3326BC00025	GLENFILLAN GED. GLENFILLAN PARK	103.32000		93.57000	0.24	<1 l/s	0.24		30.00000
122	88.4057971	3326DA00072	THEOPOLIS GED. LINCOLN	106.68000		94.48000	0.45	<1 l/s	0.45		18.28000
123	89.13043478	3326DA00044	WOLFS CRAG GED. GLENNIFFER LOT B	148.74000		96.01000	0.11	<1 l/s	0.11		15.84000
124	89.85507246	3326DA00122	WALSINGHAM	113.69000		96.62000	0.6	<1 l/s	0.60		32.91000
125	90.57971014	3326DA00143	WOLFSKRAG GED. COWLEY	102.41000		96.93000	0.43	<1 l/s	0.43		59.74000
126	91.30434783	3326BD00143	FARM 55 GED. CLIFTON	107.90000	0.00000	97.54000	0.19	<1 l/s	0.19		42.06000
127	92.02898551	3326BD00031	FARM 61 GED. HOPEWELL	119.78000	0.00000	100.58000	0.31	<1 l/s	0.31		18.28000
128	92.75362319	3326BD00104	MARTINDALE GED. FOREST VIEW	106.07000	0.00000	100.58000	1.24	1 to 2 l/s	1.24		44.50000
129	93.47826087	3326BC00020	CURRIE'S DRIFT OUTSPAN	146.60000		117.65000	0.28	<1 l/s	0.28		75.00000
130	94.20289855	3326BD00170	KAP RIVIER FARM GED. HEATHER GLEN	16.66000			0.26	<1 l/s	0.26		0.70000
131	94.92753623	3326BD00164	MARTINDALE GED. FOREST VIEW	150.00000	0.00000		3.78	2.1 to 5 l/s	5.05		5.00000
132	95.65217391	3326DB00182	BIRBURY	120.00000			6.3	5.1 to 25 l/s	6.30		11.58000
133	96.37681159	3326DB00183	BIRBURY	37.00000				No Data			14.16000
134	97.10144928	3326DB00181	BIRBURY	85.00000			6.3	5.1 to 25 l/s	6.30		21.82000
135	97.82608696	3326BD00059	KLEIN MONDEN RIVIER GED. PENINSULA PARK	102.71000	0.00000		0.62	<1 l/s	0.62		22.86000
136	98.55072464	3326DA00206	THEOPOLIS GED. LINCOLN	91.44000			0.3	<1 l/s	0.30		36.81000
137	99.27536232	3326DA00055	HARVEST VALE	121.61000			0.1	<1 l/s	0.10		45.72000
138	100	3326BD00168	FARM 151 GED. GRANDON	90.90000			0.64	<1 l/s	0.64		60.66000
139	100.7246377	3326BD00153	FARM 142 GED. BRADVILLE	90.90000			0.27	<1 l/s	0.27		66.66000
140	101.4492754	3326BD00033	FARM 61 GED. HOPEWELL	124.66000	0.00000		0	DRY		DRY	
141	102.173913	3326BD00034	FARM 61 GED. HOPEWELL	101.49000	0.00000		0	DRY		DRY	
142	102.8985507	3326BD00058	KLEIN MONDEN RIVIER GED. PENINSULA PARK	106.98000	0.00000		0	DRY		DRY	
143	103.6231884	3326BD00077	FARM 46 GED. BEAUFORTVALE	78.02000	0.00000		0	DRY		DRY	
144	104.3478261	3326BD00080	BIRBURY	61.56000	0.00000		0	DRY		DRY	
145	105.0724638	3326BD00095	FARM 28 GED. ESKDALE	92.04000	0.00000		0	DRY		DRY	
146	105.7971014	3326BD00108	MARTINDALE GED. FOREST VIEW	93.87000	0.00000		0	DRY		DRY	
147	106.5217391	3326DA00033	GLEN GHIO GED. GLEN ERIN	45.41000			0	DRY		DRY	
148	107.2463768	3326DA00034	GLEN GHIO GED. GLEN ERIN	64.60000			0	DRY		DRY	
149	107.9710145	3326DA00038	WOLFS CRAG GED. GLENNIFFER	62.78000			0	DRY		DRY	
150	108.6956522	3326DA00054	HARVEST VALE	121.92000			0	DRY		DRY	
151	109.4202899	3326DA00061	WOLFS CRAG GED. HOPEDALE GED. 4	122.83000			0	DRY		DRY	
152	110.1449275	3326DA00062	WOLFS CRAG GED. HOPEFIELD GED. 4	44.19000			0	DRY		DRY	

APPENDIX A: WELTEVREDE (2)

NUMBER	138	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL
153	110.8695652	3326DA00068	THEOPOLIS GED. LINCOLN	4.26000			0	DRY		DRY	
154	111.5942029	3326DA00069	THEOPOLIS GED. LINCOLN	12.19000			0	DRY		DRY	
155	112.3188406	3326DA00094	MOSSAY CRAG	122.22000			0	DRY		DRY	
156	113.0434783	3326DA00127	WOLFS CRAG	92.65000			0	DRY		DRY	
157	113.7681159	3326DA00145	WOLFSKRAG GED. COWLEY	152.40000			0	DRY		DRY	
158	114.4927536	3326BD00062	PINEDALE	64.00000	0.00000		0	DRY		DRY	
159	115.2173913	3326BD00109	MARTINDALE GED. FOREST VIEW	64.00000	0.00000		0	DRY		DRY	
160	115.942029	3326DB00013	FAIRFAX	105.76000			0	DRY		DRY	
161	116.6666667	3326DB00014	FAIRFAX	38.10000			0	DRY		DRY	
162	117.3913043	3326DB00040	FAIRFAX GED. WINSTON	73.45000			0	DRY		DRY	
163	118.115942	3326DB00041	FAIRFAX GED. WINSTON	92.04000			0	DRY		DRY	
164	118.8405797	3326DB00066	PORT ALFRED GED. ROSE HILL	61.56000			0	DRY		DRY	
165	119.5652174	3326DB00042	FAIRFAX GED. WINSTON	123.74000			0.01	<1 l/s	0.01		
166	120.2898551	3326DB00011	FAIRFAX	53.03000			0.02	<1 l/s	0.02		
167	121.0144928	3326DB00015	SUMMERHILL PARK GED. FAIRY GLEN	123.13000			0.03	<1 l/s	0.03		
168	121.7391304	3326DB00056	SUMMERHILL PARK GED. GLAZENWOOD	73.15000			0.05	<1 l/s	0.05		
169	122.4637681	3326DB00010	FAIRFAX	66.44000			0.1	<1 l/s	0.10		
170	123.1884058	3326DA00009	PORT ALFRED PARK	46.32000			0.14	<1 l/s	0.14		
171	123.9130435	3326DB00055	SUMMERHILL GED. GLAZENWOOD	53.34000			0.15	<1 l/s	0.15		
172	124.6376812	3326DB00074	BARVILLE PARK	75.00000			0.25	<1 l/s	0.25		
173	125.3623188	3326DB00131	MANSFIELD	0.01000			0.31	<1 l/s	0.31		
174	126.0869565	3326DB00165	GROVE HILL	27.27000			0.37	<1 l/s	0.37		
175	126.8115942	3326DB00142	WALSINGHAM	40.00000			0.4	<1 l/s	0.40		
176	127.5362319	3326DA00010	PORT ALFRED PARK	18.89000			0.42	<1 l/s	0.42		
177	128.2608696	3326DB00069	WALSINGHAM	0.00000			0.43	<1 l/s	0.43		
178	128.9855072	3326DB00064	PORT ALFRED GED. ROSE HILL	67.66000			0.45	<1 l/s	0.45		
179	129.7101449	3326DB00028	PORT ALFRED	76.20000			0.5	<1 l/s	0.50		
180	130.4347826	3326DB00179	BARVILLE PARK	75.00000			0.57	<1 l/s	0.57		
181	131.1594203	3326DB00128	FAIRFAX	197.00000			0.58	<1 l/s	0.58		
182	131.884058	3326DB00032	FARM 262 GED. ROCKLANDS	70.00000			0.62	<1 l/s	0.62		
183	132.6086957	3326DB00065	PORT ALFRED GED. ROSE HILL	40.53000			0.69	<1 l/s	0.69		
184	133.3333333	3326BD00154	FARM 46 GED. BEAUFORTVALE	64.00000			0.73	<1 l/s	0.73		
185	134.057971	3326DB00012	FAIRFAX	67.66000			0.77	<1 l/s	0.77		
186	134.7826087	3326DB00044	FAIRFAX GED. WINSTON	63.70000			0.77	<1 l/s	0.77		
187	135.5072464	3326DB00133	FARM 388 GED. LOLEN	52.00000			0.83	<1 l/s	0.83		
188	136.2318841	3326DB00045	PORT ALFRED PARK GED. ALDRINGTON	61.56000			0.85	<1 l/s	0.85		
189	136.9565217	3326DB00080	FAIRFAX	61.57000			0.9	<1 l/s	0.90		
190	137.6811594	3326DB00127	FAIRFAX	157.00000			0.9	<1 l/s	0.90		
191	138.4057971	3326DB00033	THE DUNES	72.54000			1.51	1 to 2 l/s	1.51		
192	139.1304348	3326DB00016	GROVE HILL GED. THORNDALE	47.24000			1.82	1 to 2 l/s	1.82		
193	139.8550725	3326DB00124	FAIRFAX	61.57000			2.08	2.1 to 5 l/s	2.08		
194	140.5797101	3326DB00043	FAIRFAX GED. WINSTON	61.56000			2.13	2.1 to 5 l/s	2.13		
195	141.3043478	3326BD00155	BIRBURY GED. HARMONY	9999.99000			2.77	2.1 to 5 l/s	2.77		
196	142.0289855	3326DA00008	PORT ALFRED PARK	52.42000			16.15	1 to 2 l/s	16.15		
197	142.7536232	3326DB00039	MANSFIELD	60.00000			25	5.1 to 25 l/s	25.00		
198	143.4782609	3326BC00016	WESLEY WOOD GED. BRIGHTON	65.00000				No Data			
199	144.2028986	3326BC00023	GLENFILLAN GED. GLENFILLAN PARK	1.82000				No Data			
200	144.9275362	3326BC00024	GLENFILLAN GED. GLENFILLAN PARK	5.48000				No Data			
201	145.6521739	3326BC00039	HOME GED. THE HOME	121.92000				No Data			
202	146.3768116	3326BC00055	FAIRFIELD	109.12000				No Data			
203	147.1014493	3326BC00091	KLIP FONTEIN GED. WINDY RIDGE	51.82000				No Data			

APPENDIX A: WELTEVREDE (2)

NUMBER	138	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL
204	147.826087	3326BD00044	FARM 122 GED. LYNDHURST	75.28000				No Data			
205	148.5507246	3326BD00142	FARM 55 GED. CLIFTON	121.92000				No Data			
206	149.2753623	3326BD00145	FARM 55 GED. CLIFTON	37.49000				No Data			
207	150	3326BD00147	FARM 55 GED. CLIFTON	107.90000				No Data			
208	150.7246377	3326BD00148	FARM 55 GED. CLIFTON	42.37000				No Data			
209	151.4492754	3326BD00192	FAIRFAX	157.00000				No Data			
210	152.173913	3326DA00144	WOLFSKRAG GED. COWLEY	9999.99000				No Data			
211	152.8985507	3326DA00211	WALSINGHAM GED. LOMBARDY	0.01000				No Data			
212	153.6231884	3326DB00002	PORT ALFRED GED. THE HAVEN	44.90000				No Data			
213	154.3478261	3326DB00029	PORT ALFRED	76.20000				<1 l/s			
214	155.0724638	3326DB00030	WALSINGHAM GED. DUIKERBOS	0.00000				No Data			
215	155.7971014	3326DB00076	FAIRFAX	197.00000				No Data			
216	156.5217391	3326DB00077	FAIRFAX	157.00000				No Data			
217	157.2463768	3326DB00078	FAIRFAX	60.96000				No Data			
218	157.9710145	3326DB00079	FAIRFAX	60.96000				No Data			
219	158.6956522	3326DB00125	FAIRFAX	60.96000				No Data			
220	159.4202899	3326DB00126	FAIRFAX	60.96000				No Data			
221	160.1449275	3326DB00136	HONEY DAWN BEE FARM THORNHILL BEIN	0.01000				No Data			
222	160.8695652	3326DB00186	FRM 309 GED. ELMHURST	50.00000				No Data			
223	161.5942029	3327CA00010	SEAFIELD	36.57000				No Data			
224	162.3188406	3327CA00011	SEAFIELD	79.85000				No Data			
225											
Median				**73.15000**		**56.38500**	**0.37000**				**30.24000**

APPENDIX A: WITPOORT (3)

NUMBER	120	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL	0.00000	
1	0.833333333	3326DA00152	SMITHFIELD	66.00000		8.00000	5.48000	5.1 to 25 l/s	5.48		14.00000	10.00000	0.4
2	1.666666667	3326BD00091	DUNDAS	36.57000	0.00000	9.14000	0.03000	<1 l/s	0.03		5.48000	10.00000	0.8
3	2.5	3326DA00157	WOODLANDS	57.30000		9.15000	0.79000	<1 l/s	0.79		13.23000	16.76000	1.2
4	3.333333333	3326BD00008	KAP RIVER FARM GED. HEATHER GLEN	24.38000	0.00000	13.71000	0.85000	<1 l/s	0.85		2.59000	16.76000	1.6
5	4.166666667	3326BC00046	BRAKFONTEIN GED. BUFFALO KLOOF	68.28000		15.24000	0.58000	<1 l/s	0.58		18.00000	16.90000	2
6	5	3326DA00242	WALSINGHAM	86.60000		18.00000	0.50000	<1 l/s	0.50		13.72000	19.81000	2.4
7	5.833333333	3326BD00024	HOPE FARM	39.01000	0.00000	18.28000	2.55000	2.1 to 5 l/s	2.55		5.79000	20.00000	2.8
8	6.666666667	3326DA00217	THEOPOLIS	68.58000		18.29000	0.10000	<1 l/s	0.10			21.52000	3.2
9	7.5	3326BD00158	COOMBS VALE	90.00000	0.00000	20.00000	0.27000	<1 l/s	0.27		6.00000	23.46000	3.6
10	8.333333333	3326BD00121	RADIES VLEY	28.95000	0.00000	21.33000	1.16000	1 to 2 l/s	1.16		9.14000	24.38000	4
11	9.166666667	3326BD00028	HOPE FARM	63.39000	0.00000	21.33000	0.56000	<1 l/s	0.56		15.54000	26.82000	4.4
12	10	3327CA00014	FARM 248 GED. SEAVIEW	70.71000	0.00000	21.33000	0.05000	<1 l/s	0.05		17.98000	26.82000	4.8
13	10.83333333	3326DA00153	WALSINGHAM	39.62000		21.34000	1.20000	1 to 2 l/s	1.20		27.43000	28.78000	5.2
14	11.66666667	3326DA00019	THEOPOLIS GED. CHARLGROVE	81.38000		21.94000	0.33000	<1 l/s	0.33		16.76000	28.95000	5.6
15	12.5	3327AC00012	FARM 225 GED. POMEROY	32.00000	0.00000	22.25000	0.26000	<1 l/s	0.26		19.20000	30.00000	6
16	13.33333333	3326BD00097	DONKIN MOUNT GED. FERNROCK	83.82000	0.00000	22.86000	0.07000	<1 l/s	0.07		15.24000	30.00000	6.4
17	14.16666667	3326BD00030	HOPE FARM	33.52000	0.00000	24.38000	0.69000	<1 l/s	0.69		11.58000	30.30000	6.8
18	15	3326BD00096	DONKIN MOUNT GED. FERNROCK	50.90000	0.00000	27.43000	0.31000	<1 l/s	0.31		16.76000	30.48000	7.2
19	15.83333333	3326DA00200	WALSINGHAM	39.62000		27.43000	1.25000	1 to 2 l/s	1.25		21.34000	30.48000	7.6
20	16.66666667	3326BD00131	FARM 101 GED. WHITE BUSH	35.96000	0.00000	29.26000		No Data			24.38000	30.48000	8
21	17.5	3327AC00013	FARM 225 GED. POMEROY	90.52000	0.00000	30.48000	0.06000	<1 l/s	0.06		21.33000	31.08000	8.4
22	18.33333333	3327AC00006	SOUTHSEAS GED. SOUTH SEAS	56.80000	0.00000	30.50000	2.16000	2.1 to 5 l/s	2.16		16.80000	31.39000	8.8
23	19.16666667	3326BD00178	RADIES VLEY GED. HELENDENE	39.00000	0.00000	33.00000	0.31000	<1 l/s	0.31		9.09000	32.00000	9.2
24	20	3326BD00025	HOPE FARM	61.26000	0.00000	35.66000	0.07000	<1 l/s	0.07		27.73000	33.22000	9.6
25	20.83333333	3326BD00012	LANPETER GED. CYPRESS GROVE	79.00000	0.00000	36.00000	0.16000	<1 l/s	0.16		7.00000	33.52000	10
26	21.66666667	3326DA00191	WALSINGHAM GED. FEATHERS FARM	86.60000		36.00000	0.51000	<1 l/s	0.51		23.09000	35.96000	10.4
27	22.5	3326BD00075	GREATHEAD GED. WHITE HEATH	75.59000	0.00000	36.57000	0.03000	<1 l/s	0.03		36.57000	35.96000	10.8
28	23.33333333	3326DA00195	WOODLANDS	80.16000		36.58000		No Data			24.08000	36.27000	11.2
29	24.16666667	3326BD00026	HOPE FARM	52.73000	0.00000	39.62000	1.55000	1 to 2 l/s	1.55		23.46000	36.57000	11.6
30	25	3327AC00007	SOUTHSEAS GED. SOUTH SEAS	53.30000	0.00000	40.00000	2.08000	2.1 to 5 l/s	2.08		4.80000	37.00000	12
31	25.83333333	ECP30006		71.00000		40	1.35				14.34000	37.79000	12.4
32	26.66666667	3326DA00201	WOLFS CRAG GED. GLENNIFFER	60.00000		42.00000	0.18000	<1 l/s	0.18		4.00000	37.80000	12.8
33	27.5	3326DA00011	FARM 85 PORTION 1	60.00000		42.00000	3.75000	2.1 to 5 l/s	3.75		10.00000	37.80000	13.2
34	28.33333333	3326BD00048	FARM 58 GED. NEW BRISTOL	110.64000	0.00000	42.67000	0.15000	<1 l/s	0.15		22.25000	39.00000	13.6
35	29.16666667	3326BD00072	WAAI PLAATZ	64.92000	0.00000	43.28000	1.06000	1 to 2 l/s	1.06		9.75000	39.01000	14
36	30	3326BD00061	PERCIVAL	86.86000	0.00000	44.19000	0.21000	<1 l/s	0.21		33.52000	39.62000	14.4
37	30.83333333	3326DA00193	WOODLANDS	57.00000		45.72000	0.19000	<1 l/s	0.19		6.10000	39.62000	14.8
38	31.66666667	3326DA00198	LOMBARDS POST GED. WOODLANDS	88.39000		45.72000	0.38000	<1 l/s	0.38		41.85000	40.00000	15.2
39	32.5	3327CA00008	FARM 242 GED. BELLEVUE	50.59000	0.00000	46.63000	2.29000	2.1 to 5 l/s	2.29		30.48000	40.00000	15.6
40	33.33333333	ECPp30007		123.00000		47	1.3					41.00000	16
41	34.16666667	3326BD00092	DUNDAS	50.59000	0.00000	47.24000	0.42000	<1 l/s	0.42		32.30000	41.00000	16.4
42	35	3327CA00013	FARM 248 GED. SEAVIEW	85.34000	0.00000	47.85000	0.12000	<1 l/s	0.12		34.13000	42.67000	16.8
43	35.83333333	3326DA00018	THEOPOLIS GED. CHARLGROVE	53.34000		51.20000	1.27000	1 to 2 l/s	1.27		16.76000	42.67000	17.2
44	36.66666667	3326BD00035	HOPE FARM	54.25000	0.00000	51.81000	0.60000	<1 l/s	0.60		38.40000	42.67000	17.6
45	37.5	3326BC00064	FARM 460 GED. HOWARD'S GRANT	71.93000		53.64000	1.17000	1 to 2 l/s	1.17		40.00000	42.67000	18
46	38.33333333	3327CA00015	FARM 248 GED. SEAVIEW ANNEX	80.46000	0.00000	54.36000	0.24000	<1 l/s	0.24		24.38000	42.67000	18.4
47	39.16666667	3326BD00183	FARM 90 GED. UPPER CAXTON	60.60000	0.00000	54.54000	0.37000	<1 l/s	0.37		24.24000	42.67000	18.8
48	40	3327CA00001	FARM 242 GED. BELLEVUE	93.26000	0.00000	54.86000	0.10000	<1 l/s	0.10		5.18000	44.00000	19.2
49	40.83333333	3326BD00064	FARM 107 GED. SWALLOW FIELD	59.74000	0.00000	54.86000	1.62000	1 to 2 l/s	1.62		18.28000	45.11000	19.6
50	41.66666667	3326DA00057	MERVILLE GED. HILLSIDE	100.58000		54.86000	0.31000	<1 l/s	0.31		28.65000	45.45000	20

APPENDIX A: WITPOORT (3)

NUMBER	120	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL	0.00000	
51	42.5	3326DA00215	WALSINGHAM GED. SIESTA	60.00000		55.00000	0.06000	<1 l/s	0.06		39.00000	45.45000	20.4
52	43.33333333	3326DA00096	NEWTON	62.48000		55.16000	0.19000	<1 l/s	0.19		45.72000	45.72000	20.8
53	44.16666667	3327CA00002	FARM 242 GED. BELLEVUE	62.48000	0.00000	55.47000	0.80000	<1 l/s	0.80		18.28000	45.72000	21.2
54	45	3326BD00073	DUNDAS GED. WILLOW GLEN	66.44000	0.00000	55.77000	0.63000	<1 l/s	14.63		14.63000	45.72000	21.6
55	45.83333333	3326BD00119	FARM 102 GED. LIMESTONE HILL	82.29000	0.00000	56.38000	0.63000	<1 l/s	0.63		44.80000	46.63000	22
56	46.66666667	3326BC00095	SPARKS PLACE GED. YONDER	71.32000		56.69000	0.85000	<1 l/s	0.85		43.00000	48.76000	22.4
57	47.5	3327AC00008	FARM 221 GED. DELAMERE	73.15000	0.00000	57.91000	1.25000	1 to 2 l/s	1.25		6.09000	48.76000	22.8
58	48.33333333	3326DA00029	FAITHFUL FONTAIN	100.58000		58.52000	0.07000	<1 l/s	0.07		39.62000	50.00000	23.2
59	49.16666667	ECP30004	MERVILLE	147.00000		60	7					50.00000	23.6
60	50	3326DA00212	WALINGHAM GED. SIESTA	120.00000		60.00000		No Data				50.00000	24
61	50.83333333	3326BD00159	CHERTSEY GED. CLAY PITS	63.00000	0.00000	60.50000	0.50000	<1 l/s	0.50		28.30000	50.00000	24.4
62	51.66666667	3326BD00185	DUNDAS GED. WILLOW GLEN	66.66000	0.00000	60.60000	1.01000	1 to 2 l/s	1.01		12.12000	50.59000	24.8
63	52.5	3327CA00007	FARM 242 GED. BELLEVUE	74.06000	0.00000	60.96000	0.32000	<1 l/s	0.32		3.76000	50.59000	25.2
64	53.33333333	3326CB00141	UNION	150.00000	0.00000	62.00000	2.84000	2.1 to 5 l/s	2.84	7H PUMPTEST	45.00000	50.90000	25.6
65	54.16666667	3326BD00186	FARM 102 GED. LIMESTONE HILL	72.70000	0.00000	65.00000	2.80000	2.1 to 5 l/s	2.80		6.50000	52.00000	26
66	55	3326BD00069	PERCIVAL GED. SPORTSVALE	88.39000	0.00000	65.22000	0.11000	<1 l/s	0.11		49.98000	52.12000	26.4
67	55.83333333	3326BD00076	GREATHEAD GED. WHITE HEATH	71.32000	0.00000	65.53000	0.10000	<1 l/s	0.10		11.58000	52.42000	26.8
68	56.66666667	ECP30003	MERVILLE	91.00000		66	20				2.10000	52.73000	27.2
69	57.5	3326DA00014	BUSCHFONTEIN	100.00000		66.00000	0.53000	<1 l/s	0.53		48.00000	53.30000	27.6
70	58.33333333	3326DA00015	BUSHFONTEIN GED. A	100.00000		66.00000	6.60000	5.1 to 25 l/s	6.60		48.00000	53.34000	28
71	59.16666667	3326BD00029	HOPE FARM	75.28000	0.00000	67.05000	0.07000	<1 l/s	0.07		54.86000	54.25000	28.4
72	60	3326BD00082	PERCIVAL GED. BLYGEMOED	97.84000	0.00000	67.05000	0.01000	<1 l/s	0.01		64.00000	54.86000	28.8
73	60.83333333	3326DA00058	MERVILLE GED. HILLSIDE	78.94000		68.27000	0.62000	<1 l/s	0.62		62.17000	55.00000	29.2
74	61.66666667	3326BD00047	FARM 58 GED. NEW BRISTOL	76.80000	0.00000	68.88000	0.28000	<1 l/s	0.28		42.06000	55.00000	29.6
75	62.5	3326BD00177	FARM 78 GED. ROCKVILLE	70.30000	0.00000	69.69000	1.26000	1 to 2 l/s	1.26		19.69000	56.80000	30
76	63.33333333	3326BD00084	BOTANY	75.28000	0.00000	70.10000	0.18000	<1 l/s	0.18		9.14000	57.00000	30.4
77	64.16666667	3326BC00062	LONGRIDGE	102.00000		73.00000	2.00000	1 to 2 l/s	1.54	BLOWTEST	33.00000	57.00000	30.8
78	65	3326BC00043	SPRING GROVE GED. BROOKLANDS	78.02000		73.15000	0.94000	<1 l/s	0.94		78.00000	57.30000	31.2
79	65.83333333	3326BD00017	GLENCAIRN GED. GLEN CAIRN	83.21000	0.00000	75.28000	0.83000	<1 l/s	0.83		36.57000	57.91000	31.6
80	66.66666667	3326BD00120	FARM 102 GED. LIMESTONE HILL	108.50000	0.00000	76.80000	1.41000	1 to 2 l/s	1.41		30.48000	59.74000	32
81	67.5	3326BD00071	WAAI PLAATZ	94.79000	0.00000	78.02000	0.07000	<1 l/s	0.07		18.28000	59.74000	32.4
82	68.33333333	3326BD00021	RADIES VLEY GED. HELENDENE	85.95000	0.00000	78.63000	0.65000	<1 l/s	0.65		48.76000	59.74000	32.8
83	69.16666667	3326BD00184	WIDCOMBE	121.21000	0.00000	78.78000	0.63000	<1 l/s	1.51		66.66000	60.00000	33.2
84	70	3326BC00044	SPRING GROVE GED. BROOKLANDS	96.62000		79.85000	1.49000	1 to 2 l/s	1.49		67.00000	60.00000	33.6
85	70.83333333	3326BD00060	PERCIVAL	93.57000	0.00000	81.99000	0.18000	<1 l/s	0.18		50.29000	60.00000	34
86	71.66666667	3326BD00098	DONKIN MOUNT GED. FERNROCK	90.22000	0.00000	84.12000	0.10000	<1 l/s	0.10		12.19000	60.00000	34.4
87	72.5	3326BD00010	GREATHEAD GED. WHITE HEATH	91.00000	0.00000	85.00000	0.64000	<1 l/s	0.64		20.00000	60.00000	34.8
88	73.33333333	3326DA00186	THEOPOLIS	88.80000		85.00000	0.43000	<1 l/s	0.43		55.00000	60.00000	35.2
89	74.16666667	3326BD00132	FARM 101 GED. WHITE BUSH	104.54000	0.00000	85.34000	0.34000	<1 l/s	0.34		24.38000	60.00000	35.6
90	75	3326BC00098	SPARKS PLACE GED. YONDER	89.92000		85.34000	1.61000	1 to 2 l/s	1.61		61.00000	60.00000	36
91	75.83333333	3326BD00101	FOREST CLIFF	93.26000	0.00000	86.25000	0.10000	<1 l/s	0.10		46.93000	60.25000	36.4
92	76.66666667	ECP30001	MERVILLE	151.00000		88	5				0.00000	60.60000	36.8
93	77.5	3326BD00009	GREATHEAD GED. WHITE HEATH	95.00000	0.00000	88.00000	0.64000	<1 l/s	0.64		90.00000	60.60000	37.2
94	78.33333333	3326BD00157	LANPETER GED. CYPRESS GROVE	93.00000	0.00000	89.00000	0.17000	<1 l/s	0.17		48.00000	60.96000	37.6
95	79.16666667	3326DA00185	THEOPLIS	117.00000		90.00000		No Data			4.85000	60.96000	38
96	80	3326DA00173	WAYSIDE	140.00000		90.00000		No Data				60.96000	38.4
97	80.83333333	3326BD00063	FARM 104 GED. ROMANCE	98.75000	0.00000	92.96000	1.91000	1 to 2 l/s	1.91		13.71000	60.96000	38.8
98	81.66666667	3326DA00056	MERVILLE GED. HILLSIDE	111.86000		94.48000	0.17000	<1 l/s	0.17		32.61000	61.00000	39.2
99	82.5	ECP30002	MERVILLE	150.00000		98	3.3				0.00000	61.00000	39.6
100	83.33333333	ECP30005		126.00000		108	4					61.00000	40

APPENDIX A: WITPOORT (3)

NUMBER	120	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL	0.00000	
101	84.16666667	3326DA00174	SMITHFIELD	126.00000		120.00000	3.61000	2.1 to 5 l/s	3.61		14.00000	61.00000	40.4
102	85	3326DA00188	THEOPOLIS	90.00000				No Data			6.33000	61.26000	40.8
103	85.83333333	3326BD00174	MARTINDALE	55.00000			2.53000	2.1 to 5 l/s	2.53		10.00000	61.26000	41.2
104	86.66666667	3326DA00197	WOLFS CRAG GED. SOUTHWELL CAFE	19.81000			0	DRY		DRY	11.58000	61.54000	41.6
105	87.5	3326BD00130	FARM 101 GED. WHITE BUSH	31.08000	0.00000		0.00000	DRY		DRY	12.19000	61.56000	42
106	88.33333333	3326BD00181	HOPE FARM GED. THE HOPE	30.30000			0.19000	<1 l/s	0.19		12.21000	61.87000	42.4
107	89.16666667	3326DA00192	WOODLANDS	45.72000			0.13000	<1 l/s	0.13		13.23000	62.48000	42.8
108	90	3326DA00224	WOLFS CRAG	91.44000			0.32000	<1 l/s	0.32		15.00000	62.48000	43.2
109	90.83333333	3326DA00214	WALSINGHAM GED. SIESTA	60.00000			0.06000	<1 l/s	0.06		19.39000	63.00000	43.6
110	91.66666667	3326BD00169	FARM 88 GED. KINGSMEAD	50.00000			1.57000	1 to 2 l/s	1.57		20.00000	63.39000	44
111	92.5	3326BD00173	FARM 102 GED. LIMESTONE HILL	106.09000			0.55000	<1 l/s	0.55		21.21000	64.00000	44.4
112	93.33333333	3326DA00241	WALSINGHAM	42.67000			0.76000	<1 l/s	0.76		21.34000	64.31000	44.8
113	94.16666667	3326DA00189	WALSINGHAM GED. FEATHERS FARM	42.67000				No Data			22.07000	64.31000	45.2
114	95	3326BD00161	DUNDAS	66.66000			0.88000	<1 l/s	0.88		24.24000	64.92000	45.6
115	95.83333333	3326DA00190	AQUAVISTA GED. OCEAN VIEW	100.00000			1.50000	1 to 2 l/s	1.50		24.38000	65.00000	46
116	96.66666667	3326DA00146	AQUAVISTA	100.00000			1.52000	1 to 2 l/s	1.52	DEPTH	24.38000	65.00000	46.4
117	97.5	3326DA00223	NEWTON	91.44000			0.70000	<1 l/s	0.70		24.82000	66.00000	46.8
118	98.33333333	3326BD00149	GREATHEAD	55.00000				No Data			25.88000	66.44000	47.2
119	99.16666667	3326DA00218	NEWTON GED. NEWTON FARM	57.00000			0.93000	<1 l/s	0.93		28.90000	66.66000	47.6
120	100	3326BD00165	GREATHEAD GED. WHITE HEATH	60.60000			0.88000	<1 l/s	0.88		33.33000	66.66000	48
121	100.8333333	3326BD00167	GLEN HOPE	45.45000			0.15000	<1 l/s	0.15		36.36000	67.05000	48.4
122	101.6666667	3326DA00155	THEOPOLIS	44.00000			0.07000	<1 l/s	0.07	DEPTH	38.35000	67.05000	48.8
123	102.5	3326DA00202	THEOPOLIS GED. THEOPHILIS	52.00000			0.07000	<1 l/s	0.07		38.35000	68.28000	49.2
124	103.3333333	3326DA00216	THEOPOLIS	54.86000				No Data			41.95000	68.58000	49.6
125	104.1666667	3326CB00094	VOGELFONTEIN GED. ROOI DAM	60.25000			2.50000	2.1 to 5 l/s	2.50		50.25000	70.00000	50
126	105	3326DA00221	THEOPOLIS GED. CHARLGROVE	75.00000			0.15000	<1 l/s	0.15		66.45000	70.00000	50.4
127	105.8333333	3326BD00083	BOTANY	64.00000	0.00000		0	DRY		DRY		70.00000	50.8
128	106.6666667	3326DA00238	THEOPOLIS	78.00000			0	DRY		DRY		70.00000	51.2
129	107.5	3326DA00237	THEOPOLIS	150.00000			0	DRY		DRY		70.00000	51.6
130	108.3333333	3326BD00005	KAP RIVER FARM GED. ALLENDALE	84.73000	0.00000		0.00000	DRY		DRY		70.00000	52
131	109.1666667	3326BD00022	RADIES VLEY GED. HELENDENE	105.15000	0.00000		0.00000	DRY		DRY		70.30000	52.4
132	110	3326BD00023	RADIES VLEY GED. HELENDENE	33.22000	0.00000		0.00000	DRY		DRY		70.71000	52.8
133	110.8333333	3326BD00027	HOPE FARM	35.96000	0.00000		0.00000	DRY		DRY		71.00000	53.2
134	111.6666667	3326BD00040	FARM 88 GED. KINGSMEAD	73.15000	0.00000		0.00000	DRY		DRY		71.32000	53.6
135	112.5	3326BD00041	FARM 88 GED. KINGSMEAD	45.11000	0.00000		0.00000	DRY		DRY		71.32000	54
136	113.3333333	3326BD00074	WHITE HEATH	67.05000	0.00000		0.00000	DRY		DRY		71.93000	54.4
137	114.1666667	3326BD00081	PERCIVAL GED. BLYGEMOED	37.79000	0.00000		0.00000	DRY		DRY		72.70000	54.8
138	115	3326BD00099	DONKIN MOUNT GED. FERNROCK	86.56000	0.00000		0.00000	DRY		DRY		73.00000	55.2
139	115.8333333	3326BD00102	FOREST CLIFF	67.05000	0.00000		0.00000	DRY		DRY		73.00000	55.6
140	116.6666667	3326BD00122	RADIES VLEY	61.54000	0.00000		0.00000	DRY		DRY		73.15000	56
141	117.5	3326DA00020	THEOPOLIS GED. CHARLGROVE	98.45000			0.00000	DRY		DRY		73.15000	56.4
142	118.3333333	3326DA00097	NEWTON	94.48000			0.00000	DRY		DRY		74.06000	56.8
143	119.1666667	3326DA00124	NEWTON GED. WATERSMEET	99.66000			0.00000	DRY		DRY		75.00000	57.2
144	120	3326DB00021	FARM 208 GED. FOREST HILL	31.39000			0	DRY		DRY		75.00000	57.6
145	120.8333333	3326DB00052	BARVILLE PARK	91.44000			0	DRY		DRY		75.00000	58
146	121.6666667	3326DB00141	WALSINGHAM	30.00000			0	<1 l/s	0.01			75.28000	58.4
147	122.5	3326DB00023	FARM 208 GED. FOREST HILL	59.74000			0	<1 l/s	0.03			75.28000	58.8
148	123.3333333	3326DB00024	FARM 208 GED. FOREST HILL	36.27000			0	<1 l/s	0.03			75.59000	59.2
149	124.1666667	3326DB00048	BARVILLE PARK	112.77000			0	<1 l/s	0.03			76.80000	59.6
150	125	3326DB00050	BARVILLE PARK	78.94000			0	<1 l/s	0.03			77.00000	60

APPENDIX A: WITPOORT (3)

NUMBER	120	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL	0.00000	
151	125.8333333	3326DB00049	BARVILLE PARK	82.29000			0	<1 l/s	0.05			77.00000	60.4
152	126.6666667	3326DB00146	PORT ALFRED PARK	45.45000			0	<1 l/s	0.06			78.00000	60.8
153	127.5	3326DB00025	FARM 208 GED. FOREST HILL	48.76000			0	<1 l/s	0.07			78.02000	61.2
154	128.3333333	3326DB00070	WALSINGHAM	0.00000			0	<1 l/s	0.11			78.94000	61.6
155	129.1666667	3326DB00099	FORDS PARTY	0.00000			0	<1 l/s	0.13			78.94000	62
156	130	3326DB00167	FORDS PARTY	23.46000			0	<1 l/s	0.13			79.00000	62.4
157	130.8333333	3326DB00090	BANKSIA	40.00000			0	<1 l/s	0.14			79.00000	62.8
158	131.6666667	3326DB00177	BANKSIA	40.00000			0	<1 l/s	0.14			79.00000	63.2
159	132.5	3326DB00026	FARM 208 GED. FOREST HILL	61.26000			0	<1 l/s	0.18			79.00000	63.6
160	133.3333333	3326DB00075	BARVILLE PARK	75.00000			0	<1 l/s	0.18			80.00000	64
161	134.1666667	3326DB00178	BARVILLE PARK	75.00000			0	<1 l/s	0.19			80.16000	64.4
162	135	3326DB00144	PORT ALFRED PARK	10.00000			0	<1 l/s	0.22			80.46000	64.8
163	135.8333333	3326DB00046	BARVILLE PARK	87.17000			0	<1 l/s	0.25			81.38000	65.2
164	136.6666667	3326DB00120	GROVE HILL	61.00000			0	<1 l/s	0.25			82.29000	65.6
165	137.5	3326DB00145	PORT ALFRED PARK GED. PLOT NO. 1	28.78000			0	<1 l/s	0.25			82.29000	66
166	138.3333333	3326DB00189	GROVE HILL	61.00000			0	<1 l/s	0.25			83.21000	66.4
167	139.1666667	3326DB00051	BARVILLE PARK	129.54000			0	<1 l/s	0.30			83.82000	66.8
168	140	3326DB00095	FARM 269 GED. FORD'S PARTY	26.82000			0	<1 l/s	0.31			84.00000	67.2
169	140.8333333	3326DB00171	FARM 269 GED. FORD'S PARTY	26.82000			0	<1 l/s	0.31			84.73000	67.6
170	141.6666667	3326DB00018	GROVE HILL GED. FERNEY	61.87000			0	<1 l/s	0.33			85.00000	68
171	142.5	3326DB00083	GROVE HILL	16.76000			0	<1 l/s	0.33			85.34000	68.4
172	143.3333333	3326DB00162	GROVE HILL	79.00000			0	<1 l/s	0.33			85.95000	68.8
173	144.1666667	3326BD00176	PERCIVAL GED. BLYDEMOED	9999.99000			0.37000	<1 l/s	0.37			85.95000	69.2
174	145	3326DB00117	GROVE HILL	61.00000			0	<1 l/s	0.38			86.56000	69.6
175	145.8333333	3326DB00166	GROVE HILL GED. GED. 5 DELMORE	80.00000			0	<1 l/s	0.38			86.60000	70
176	146.6666667	3326DB00192	GROVE HILL	61.00000			0	<1 l/s	0.38			86.60000	70.4
177	147.5	3326DB00093	FORDS PARTY	42.67000			0	<1 l/s	0.42			86.86000	70.8
178	148.3333333	3326DB00169	FORDS PARTY	42.67000			0	<1 l/s	0.42			86.86000	71.2
179	149.1666667	3326DB00132	THARFIELD	45.72000			0	<1 l/s	0.44			87.17000	71.6
180	150	3326DB00047	BARVILLE PARK	85.95000			0	<1 l/s	0.49			88.39000	72
181	150.8333333	3326DB00100	FORDS PARTY	0.00000			0	<1 l/s	0.49			88.39000	72.4
182	151.6666667	3326DB00022	FARM 208 GED. FOREST HILL	110.03000			1	<1 l/s	0.50			88.80000	72.8
183	152.5	3326DB00112	GROVE HILL	0.00000			1	<1 l/s	0.50			89.61000	73.2
184	153.3333333	3326DB00168	FORDS PARTY	21.52000			1	<1 l/s	0.50			89.92000	73.6
185	154.1666667	3326DB00156	GROVE HILL	0.01000			1	<1 l/s	0.53			90.00000	74
186	155	3326DB00151	GREENFOUNTAIN	91.44000			1	<1 l/s	0.55			90.00000	74.4
187	155.8333333	3326DB00152	GREENFONTEIN GED. RUFANE RIVER FAR	20.00000			1	<1 l/s	0.55			90.00000	74.8
188	156.6666667	3326DB00034	SUMMERHILL PARK GED. TRENT FARM	122.52000			1	<1 l/s	0.56			90.22000	75.2
189	157.5	3326DB00121	GREENFOUNTAIN	91.44000			1	<1 l/s	0.56			90.52000	75.6
190	158.3333333	3326DB00019	FORDS PARTY	59.74000			1	<1 l/s	0.58			91.00000	76
191	159.1666667	3326DB00035	FORDS PARTY GED. VECTIS	89.61000			1	<1 l/s	0.63			91.00000	76.4
192	160	3326DB00020	FORDS PARTY	52.42000			1	<1 l/s	0.64			91.44000	76.8
193	160.8333333	3326DB00118	GROVE HILL	70.00000			1	<1 l/s	0.75			91.44000	77.2
194	161.6666667	3326DB00198	HYEMANS PARTY	60.96000			1	<1 l/s	0.76			91.44000	77.6
195	162.5	3326DB00054	GROVE HILL GED. FERNEY	61.56000			1	<1 l/s	0.77			91.44000	78
196	163.3333333	3326DB00193	GROVE HILL	73.00000			1	<1 l/s	0.79			91.44000	78.4
197	164.1666667	3326DB00091	BANKSIA	70.00000			1	1 to 2 l/s	1.00			91.44000	78.8
198	165	3326DB00176	BANKSIA	70.00000			1	1 to 2 l/s	1.00			91.44000	79.2
199	165.8333333	3326DB00036	GREENFOUNTAIN	99.36000			1	1 to 2 l/s	1.06			91.44000	79.6
200	166.6666667	3326DB00027	FARM 208 GED. FOREST HILL	52.12000			1	1 to 2 l/s	1.16			91.44000	80

APPENDIX A: WITPOORT (3)

NUMBER	120	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL	0.00000	
201	167.5	3326DB00170	FORDS PARTY	65.00000			1	1 to 2 l/s	1.25			93.00000	80.4
202	168.3333333	3326DB00017	GROVE HILL GED. FERNEY	46.63000			1	1 to 2 l/s	1.26			93.26000	80.8
203	169.1666667	3326DB00115	GROVE HILL	41.00000			1	1 to 2 l/s	1.39			93.26000	81.2
204	170	3326DB00139	WALSINGHAM	42.67000			1	1 to 2 l/s	1.40			93.57000	81.6
205	170.8333333	3326DB00153	GROVE HILL	41.00000			1	1 to 2 l/s	1.40			94.48000	82
206	171.6666667	3326DB00122	FARM 272 GED. STANDERWICK	79.00000			2	1 to 2 l/s	1.54			94.79000	82.4
207	172.5	3326DB00113	GROVE HILL	50.00000			3	2.1 to 5 l/s	2.78			95.00000	82.8
208	173.3333333	3329DB00088	HEYMANS PARTY	91.44000			3	2.1 to 5 l/s	2.78			96.62000	83.2
209	174.1666667	3326DB00155	GROVE HILL	50.00000			3	2.1 to 5 l/s	2.80			97.84000	83.6
210	175	3326DB00087	HEYMANS PARTY	60.96000			3	2.1 to 5 l/s	3.33			98.45000	84
211	175.8333333	3326DB00154	GROVE HILL	60.00000			4	2.1 to 5 l/s	3.60			98.75000	84.4
212	176.6666667	3326DB00114	GROVE HILL	60.00000			4	2.1 to 5 l/s	3.61			99.36000	84.8
213	177.5	3326DB00119	GROVE HILL	70.00000			4	2.1 to 5 l/s	3.77			99.66000	85.2
214	178.3333333	3326DB00172	FARM 269 GED. FORD'S PARTY	144.00000			4	2.1 to 5 l/s	3.80			100.00000	85.6
215	179.1666667	3326DB00123	FARM 272 GED. STANDERWICK	60.00000			5	2.1 to 5 l/s	5.00			100.00000	86
216	180	3326DB00092	SWEETWATER	85.00000			6	5.1 to 25 l/s	6.25			100.00000	86.4
217	180.8333333	3326DB00104	FARM 208 GED. FOREST HILL	120.00000			6	5.1 to 25 l/s	6.31			100.00000	86.8
218	181.6666667	3326DB00101	FORDS PARTY	65.00000			7	5.1 to 25 l/s	7.25			100.58000	87.2
219	182.5	3326DB00197	HYEMANS PARTY	91.44000			8	5.1 to 25 l/s	8.27			100.58000	87.6
220	183.3333333	3326DB00159	GROVE HILL	0.01000			25	5.1 to 25 l/s	25.00			100.58000	88
221	184.1666667	3326DB00108	GROVE HILL	0.00000			25	25.1 to 77 l/s	25.25			102.00000	88.4
222	185	3326BC00042	SPRING GROVE GED. BROOKLANDS	48.76000				No Data				104.54000	88.8
223	185.8333333	3326BC00096	SPARKS PLACE GED. YONDER	136.55000				No Data				105.15000	89.2
224	186.6666667	3326BC00097	SPARKS PLACE GED. YONDER	100.58000				No Data				106.09000	89.6
225	187.5	3326BD00067	PERCIVAL GED. SPORTSVALE	115.82000				No Data				108.50000	90
226	188.3333333	3326BD00068	PERCIVAL GED. SPORTSVALE	114.30000				No Data				110.03000	90.4
227	189.1666667	3326BD00100	DONKIN MOUNT GED. FERNROCK	9999.99000				No Data				110.64000	90.8
228	190	3326DA00187	THEOPLIS	90.00000				No Data				111.86000	91.2
229	190.8333333	3326DA00194	WOODLANDS	0.01000				No Data				112.77000	91.6
230	191.6666667	3326DA00203	WOLFS CRAG GED. GLENNIFFER	0.01000				No Data				114.30000	92
231	192.5	3326DA00204	THEOPOLIS GED. LINCOLN	30.48000				No Data				115.82000	92.4
232	193.3333333	3326DA00205	THEOPOLIS GED. LINCOLN	0.01000				No Data				117.00000	92.8
233	194.1666667	3326DA00209	LOMBARDS POST GED. WESTLANDS	0.01000				No Data				120.00000	93.2
234	195	3326DA00213	WALSINGHAM GED. SIESTA	60.00000				No Data				120.00000	93.6
235	195.8333333	3326DA00220	NEWTON	57.91000				No Data				121.21000	94
236	196.6666667	3326DB00001	GROVE HILL	50.00000				No Data				122.52000	94.4
237	197.5	3326DB00067	OLIVE BURN	45.72000				No Data				123.00000	94.8
238	198.3333333	3326DB00071	WALSINGHAM	77.00000				No Data				126.00000	95.2
239	199.1666667	3326DB00072	WALSINGHAM	42.67000				No Data				126.00000	95.6
240	200	3326DB00081	GROVE HILL	79.00000				No Data				129.54000	96
241	200.8333333	3326DB00082	GROVE HILL	91.44000				No Data				136.55000	96.4
242	201.6666667	3326DB00084	GROVE HILL	64.31000				No Data				140.00000	96.8
243	202.5	3326DB00085	GREENFOUNTAIN	30.48000				No Data				144.00000	97.2
244	203.3333333	3326DB00086	GREENFOUNTAIN	0.00000				No Data				144.00000	97.6
245	204.1666667	3326DB00088	HEYMANS PARTY	91.44000				No Data				147.00000	98
246	205	3326DB00094	FARM 269 GED. FORD'S PARTY	144.00000				No Data				150.00000	98.4
247	205.8333333	3326DB00098	FORDS PARTY	60.96000				No Data				150.00000	98.8
248	206.6666667	3326DB00102	FARM 208 GED. CONISTON	84.00000				No Data				150.00000	99.2
249	207.5	3326DB00103	FARM 208 GED. CONISTON	37.00000				No Data				151.00000	99.6
250	208.3333333	3326DB00105	GROVE HILL	37.80000				No Data				300.00000	100

APPENDIX A: WITPOORT (3)

NUMBER	120	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	WATER LEVEL	0.00000	
251	209.1666667	3326DB00106	GROVE HILL	0.00000				No Data					
252	210	3326DB00107	GROVE HILL	0.00000				No Data					
253	210.8333333	3326DB00110	GROVE HILL	0.00000				No Data					
254	211.6666667	3326DB00111	GROVE HILL	0.00000				No Data					
255	212.5	3326DB00116	GROVE HILL	73.00000				No Data					
256	213.3333333	3326DB00138	WALSINGHAM	0.00000				No Data					
257	214.1666667	3326DB00140	WALSINGHAM	77.00000				No Data					
258	215	3326DB00143	CRAB CREEK	10.00000				No Data					
259	215.8333333	3326DB00149	GREENFOUNTAIN	16.90000				No Data					
260	216.6666667	3326DB00150	GREENFOUNTAIN	30.48000				No Data					
261	217.5	3326DB00157	GROVE HILL	30.00000				No Data					
262	218.3333333	3326DB00158	GROVE HILL	0.01000				No Data					
263	219.1666667	3326DB00161	GROVE HILL	37.80000				No Data					
264	220	3326DB00163	GROVE HILL	64.31000				No Data					
265	220.8333333	3326DB00164	GROVE HILL	16.76000				No Data					
266	221.6666667	3326DB00175	FORDS PARTY	60.96000				No Data					
267	222.5	3326DB00188	GROVE HILL	300.00000				No Data					
268	223.3333333	3326DB00190	GROVE HILL	70.00000				No Data					
269	224.1666667	3326DB00191	GROVE HILL	70.00000				No Data					
270	225	3326DB00194	GROVE HILL	0.01000				No Data					
271	225.8333333	3326DB00195	GROVE HILL	0.01000				No Data					
272	226.6666667	3327CA00016	FARM 248 GED. SEAVIEW ANNEX	86.86000				No Data					
Median				**65.50000**		**55.00000**	**0.49000**				**22.16000**		

APPENDIX A: LAKE MENTZ (4)

NUMBER	34	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	ABSTRACTION	TRANSMISSION	STORATIVITY	WATER LEVEL
1	2.941176471	3327AC00004	THORN HILL	88.39		12.2	0.63	<1 l/s	0.63					25.29
2	5.882352941	3326CA00005	THARFIELD	88.39		12.9	0.63	<1 l/s	0.63					22.25
3	8.823529412	3326DA00021	SMITHFIELD GED. CRANWELL	18.29		13.72	0.33	<1 l/s	0.33					36.27
4	11.76470588	3326DA00239	GROOT MASSERSDRIFT	45.73	0	20.12	0.33	<1 l/s	0.33	BLOWT				90
5	14.70588235	3326DA00088	KLIPHEUWEL GED. MAYFAIR	54.55		23.77	0.03	<1 l/s	0.03					18.28
6	17.64705882	3326DA00172	WAYSIDE	48		28.67		No Data						
7	20.58823529	3327AC00011	FARM 215 GED. GRASSMERE	51.8		30	0.31	<1 l/s	0.31					18.2
8	23.52941176	3327AC00002	FARM 94 GED. KAFFIRSDRIFT SAP	0	0.68	32.6	0.68	<1 l/s	0.68					60.96
9	26.47058824	3326DA00240	SALEM	100		35		No Data		BLOWT				
10	29.41176471	3326DA00199	GOODWOODS	60.04		36.57	0.54	<1 l/s	0.54					9.14
11	32.35294118	3327CA00017	THARFIELD	95.7		36.57	0.1	<1 l/s	0.1					45.72
12	35.29411765	3326DA00087	KLIPHEUWEL GED. MAYFAIR	45		39	0.15	<1 l/s	0.15					11.82
13	38.23529412	3326DA00177	SMITHFIELD	96.31	0	45.72	0.11	<1 l/s	0.11					0.01
14	41.17647059	3327AC00268	FISH RIVER MOUTH BORDER POST	53.34	0	45.72	0.63	<1 l/s	0.63					14.06
15	44.11764706	3326BD00013	WIDCOMBE	55.93		47.24	0.21	<1 l/s	0.21					80
16	47.05882353	3326DA00148	BUSCHFONTEIN	92.96	0	54.86	0.22	<1 l/s	0.22	DEPTH				64.2
17	50	3326BD00189	WIDCOMBE GED 3	88.69		56	0.4	<1 l/s	0.4	BLOWTEST				81
18	52.94117647	3327CA00019	THARFIELD	121.92	0	58.21	0.2	<1 l/s	0.09					42.67
19	55.88235294	3326BD00085	CHERTSEY GED. CLAY PITS	122.52	0	59.13	1.51	1 to 2 l/s	1.51					50.9
20	58.82352941	3326DA00266	KLIPHEUWEL	65.83	0	60.96	1.59	1 to 2 l/s	1.59					
21	61.76470588	3326DA00149	MOUNT PLEASANT	81.99	0	63.39	0.26	<1 l/s	0.26		2			11.86
22	64.70588235	3327AC00005	FARM 94 GED. ALLENBY	100	0	70	0.11	<1 l/s	0.11					67.05
23	67.64705882	3326BD00190	WIDCOMBE GED 1	73.15	0	70.1	0.65	<1 l/s	0.65	BLOWTEST				26
24	70.58823529	3327AC00001	FARM 94 GED. ALLENBY	116.73	0	70.1	0.14	<1 l/s	0.14					58.21
25	73.52941176	3326BD00162	KAFFIR DRIFT FARM GED. ERYTHNIA	83.82	0	71.01	0.06	<1 l/s	0.06					40
26	76.47058824	3327AC00009	THORN HILL GED. ENTERPRISE	80.77	0	71.01	1.59	1 to 2 l/s	1.59					41.14
27	79.41176471	3326DA00046	GOODWOODS	78	0	75	0.9	<1 l/s						13.41
28	82.35294118	3326BC00050	KLIP HEUVEL GED. FARMER FIELD	78.94	0	78.94	1.62	1 to 2 l/s	1.62					
29	85.29411765	3326BD00160	CHERTSEY GED. CLAY PITS	90.52		86.56	1	1 to 2 l/s	1					44
30	88.23529412	3326BD00087	CHERTSEY GED. CLAY PITS	96	0	90	0.23	<1 l/s	0.23					18.89
31	91.17647059	3326DA00156	GOODWOODS	156	0	93	0.54	<1 l/s			1			35
32	94.11764706	3326DA00101	SMITHFIELD	120		108	0.51	<1 l/s						21.33
33	97.05882353	3327AC00010	THORN HILL GED. ENTERPRISE	110.03	0	110.03	0.94	<1 l/s	0.94					34.13
34	100	3326DA00084	KLIPHEUWEL GED. MAYFAIR	100			0.25	<1 l/s	0.25					8
35	102.9411765	3326DA00086	KLIPHEUWEL GED. MAYFAIR	70			0	DRY						12.19
36	105.8823529	3326BD00093	ELEPHANT PARK	55			1.57	1 to 2 l/s	1.57					15.24
37	108.8235294	3326DA00150	WAYSIDE	122.22				No Data			1			17.19
38	111.7647059	3326BD00086	CHERTSEY GED. CLAY PITS	120			0	DRY						50.29
39	114.7058824	3326DB00096	FARM 258 GED. FAIRVIEW	50			0.55	<1 l/s	0.55		4.2	0	0	
40	117.6470588	3326DB00097	FARM 258 GED. FAIRVIEW	50			0.56	<1 l/s	0.56		1	0	0	
41	120.5882353	3326DB00068	FARM 258 GED. OLIVE BURN	60.96			1.18	1 to 2 l/s	1.18		1.5	0	0	
42	123.5294118	3326DB00109	GROVE HILL	70			1.39	1 to 2 l/s	1.39					
43	126.4705882	3326DB00160	GROVE HILL	70			1.4	1 to 2 l/s	1.4					
44	129.4117647	3326DB00135	THARFIELD	50			1.5	1 to 2 l/s	1.5					
45	132.3529412	3326DA00085	KLIPHEUWEL GED. MAYFAIR	72			2.13	2.1 to 5 l/s	2.13	DRY				
46	135.2941176	3326DB00089	HEYMANS PARTY	62.18			3.33	2.1 to 5 l/s	3.33		25.3	0	0	
47	138.2352941	3326DB00031	FARM 269 GED. PINELANDS	70.71			17.11	1 to 2 l/s	17.11					
48	141.1764706	3326DB00196	HYEMANS	62.18			25	5.1 to 25 l/s	25					
49	144.1176471	3326DB00134	THARFIELD	50				No Data						
50	147.0588235	3326DB00137	THARFIELD	60.96				No Data						
51	150	3327CA00018	THARFIELD	1.82				No Data						
Median				**73.15**	**0**	**56**	**0.55**		**0.595**		**1.5**			**30.065**

APPENDIX A: NANAGA (6)

NUMBER	101	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	ABSTRACTION	WATER LEVEL
1	0.990099	3326DA00115	BOESMANSRIVIERMOND	13.00000		1.50000	3.00000	2.1 to 5 l/s				1.50000
2	1.980198	3326DA00235	BOESMANSRIVIERMOND	8.00000		1.70000	3.00000	2.1 to 5 l/s	1.28			1.50000
3	2.970297	3326CB00142	BOESMANSRIVIERMOND	7.00000		1.70000	3.00000	2.1 to 5 l/s				1.70000
4	3.960396	3326DA00050	BOESMANSRIVIERMOND	8.00000		1.70000	3.00000	2.1 to 5 l/s				1.70000
5	4.950495	3326CB00154	BOESMANSRIVIERMOND	8.00000		1.80000	3.00000	2.1 to 5 l/s	3.00			1.80000
6	5.9405941	3326DA00105	BOESMANSRIVIERMOND	12.00000		2.00000	3.00000	2.1 to 5 l/s				1.90000
7	6.9306931	3326DA00049	BOESMANSRIVIERMOND	9.00000		2.00000	3.00000	2.1 to 5 l/s				2.00000
8	7.9207921	3326DA00077	BOESMANSRIVIERMOND	57.00000		2.00000	3.00000	2.1 to 5 l/s				2.00000
9	8.9108911	3326DA00004	BOESMANSRIVIERMOND	11.00000		2.05000	3.00000	2.1 to 5 l/s	3.50			
10	9.9009901	3326DA00079	BOESMANSRIVIERMOND	10.20000		2.10000	3.00000	2.1 to 5 l/s				2.10000
11	10.891089	3326DA00052	BOESMANSRIVIERMOND	13.00000		2.20000	2.00000	1 to 2 l/s	3.50			2.20000
12	11.881188	3326DA00078	THEOPOLIS	102.10000		12.19000	0.11000	<1 l/s	0.11			11.27000
13	12.871287	3326DA00076	KLEIN HOEK	91.00000	0.00000	13.00000	0.25000	<1 l/s	0.25			17.00000
14	13.861386	3326DA00137	LOMBARDS POST GED. WESTLANDS	46.02000		13.10000	0.31000	<1 l/s	0.31			9.14000
15	14.851485	3326DA00051	SOUTH GORAH GED. LOCHERWAELDLE	107.50000		13.35000	1.84000	1 to 2 l/s	1.84			3.50000
16	15.841584	3326DA00080	GRANTS VALLEY	67.60000		16.90000	0.44000	<1 l/s	0.44			11.00000
17	16.831683	3326DA00032	THEOPOLIS	117.34000		18.28000	0.05000	<1 l/s	0.05			25.60000
18	17.821782	3326CB00156	LOMBARDS POST	30.48000		18.29000	2.50000	2.1 to 5 l/s	2.50		2.00000	12.19000
19	18.811881	3326DA00163	GRANTS VALLEY	51.20000		18.59000	0.16000	<1 l/s	0.16			7.31000
20	19.80198	3326DB00062	LOMBARDS POST	44.50000		24.38000	0.06000	<1 l/s	0.06			20.11000
21	20.792079	3326DB00063	LOMBARDS POST GED. WALSYBVILLE	81.99000		25.90000	0.12000	<1 l/s	0.12			13.41000
22	21.782178	3326DA00180	CANNON RO	35.38000	0.00000	30.50000	13.90000	5.1 to 25 l/s	13.90			29.59000
23	22.772277			68.00000		32.00000	1.28					20.00000
24	23.762376	3326CB00040	LOMBARDS POST GED. WALSYBVILLE	41.60000		35.05000	0.15000	<1 l/s	0.15			8.53000
25	24.752475	3326DA00035	DEKSELFONTEIN GED. 9	48.00000	0.00000	36.00000	0.26000	<1 l/s	0.26			6.00000
26	25.742574	3326DA00107	LOMBARDS POST GED. WESTLANDS	76.20000		36.57000	0.50000	<1 l/s	0.50			28.95000
27	26.732673			40.84000		36.88000	1.7					1.37000
28	27.722772	3326CB00022	LOMBARDS POST GED. GLENRETHA	72.23000		37.49000	0.81000	<1 l/s	0.81			25.90000
29	28.712871	3326DA00082	BOSCHFONTEIN	45.75000		41.79000	3.79000	2.1 to 5 l/s	3.79			41.79000
30	29.70297	3326DA00001	LOMBARDS POST	46.63000		42.06000	0.40000	<1 l/s	0.40			15.24000
31	30.693069	3326DA00053	GRANTS VALLEY	97.22000		42.67000	0.07000	<1 l/s	0.07			9.44000
32	31.683168			61.00000		43.00000	0.32					20.00000
33	32.673267	3326DA00003	KLIEN HOEK	60.00000	0.00000	43.00000	0.33000	<1 l/s	0.33			21.00000
34	33.663366	3326DA00075	GRANTS VALLEY	89.00000		44.80000	0.07000	<1 l/s	0.07			9.14000
35	34.653465	3326CB00023	MERVILLE GED. HILLSIDE	65.00000		45.00000		No Data				45.00000
36	35.643564	3326CB00025	PALMIET	61.87000	0.00000	45.72000	0.31000	<1 l/s	0.31			12.19000
37	36.633663	3326DA00106	KLEIN HOEK	61.92000	0.00000	45.75000	0.61000	<1 l/s	0.61			22.88000
38	37.623762	3326DA00073	AQUAVISTA GED. BELTON	114.60000		46.32000	0.29000	<1 l/s	0.29			42.06000
39	38.613861	3326DA00117	THEOPOLIS	100.58000		47.24000	0.26000	<1 l/s	0.26			32.64000
40	39.60396	3326DA00159	BOSCHFONTEIN GED. VENGROVE	125.00000	0.00000	49.00000	0.03000	<1 l/s	0.03			49.00000
41	40.594059	3326DA00118	GRANTS VALLEY	90.00000		50.00000	0.07000	<1 l/s	0.07			45.00000
42	41.584158	3326DA00047	UNION	80.00000	0.00000	50.00000	0.38000	<1 l/s	0.38		0.40	47.05000
43	42.574257	3326CB00157	FICKS	70.46000	0.00000	51.85000	0.26000	<1 l/s	0.26			36.00000
44	43.564356	3326DA00074	LOMBARDS POST GED. GLENRETHA	102.10000		54.86000	0.27000	<1 l/s	0.27			39.62000
45	44.554455	3326DA00184	GLEN HEATH	123.74000		54.86000	0.03000	<1 l/s	0.03			51.81000
46	45.544554	3326CB00027	PALMIET	97.53000	0.00000	56.38000	76.80000	25.1 to 77 l/s	76.80			44.50000
47	46.534653	3326CB00148	LOMBARDS POST	82.90000		60.04000	0.50000	<1 l/s	0.50			34.13000
48	47.524752	3326CB00091	AQUAVISTA GED. OCEAN VIEW	102.10000		60.96000	1.35000	1 to 2 l/s	1.35			54.86000
49	48.514851	3326DA00183	PALMIET	90.00000	0.00000	63.00000	0.75000	<1 l/s	0.75			26.00000
50	49.50495	3326CB00038	SOUTH GORAH GED. LACKERWAELDLE	73.15000		64.61000	0.20000	<1 l/s	0.20			12.19000

APPENDIX A: NANAGA (6)

NUMBER	101	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	ABSTRACTION	WATER LEVEL
51	50.49505	3326DA00108	SOUTH GORAH GED. LACKERWAELDLE	74.98000		64.92000	0.07000	<1 l/s	0.07			63.70000
52	51.485149	3326CB00064	BOSCHFONTEIN GED VENGROVE GED. 1	114.00000	0.00000	67.00000	0.17000	<1 l/s		1 UUR TOETS		54.00000
53	52.475248	3326DA00031	WAYSIDE	100.00000		70.00000	0.18000	<1 l/s	0.18			31.80000
54	53.465347	3326DA00179	WAYSIDE	100.00000		70.00000	0.27000	<1 l/s	0.27			44.85000
55	54.455446	3326BC00102	SOUTH GORAH GED. LACHERWAELDLE	91.74000		70.10000	0.40000	<1 l/s	0.40			7.62000
56	55.445545	3326DA00017	SOUTH GORAH GED. LACKERWAELDLE	115.82000		71.62000	0.11000	<1 l/s	0.11			36.57000
57	56.435644	3326CB00053	SCHIET RUG GED. THE LOMONDS	120.00000	0.00000	74.70000	0.25000	<1 l/s	0.25		0.30	30.48000
58	57.425743			76.00000		76.00000	0					
59	58.415842	3326DA00222	AQUAVISTA GED. OCEAN VIEW	102.00000		78.00000		No Data				0.60000
60	59.405941	3326DA00119	UNION	150.00000	0.00000	80.00000		No Data			0.40	
61	60.39604	3326DA00154	LOMBARDS POST GED. WESTRANDS	100.00000		80.00000		No Data				
62	61.386139			82.29000		81.07000	0.27					22.55000
63	62.376238	3326DA00126	KLEIN HOEK	101.00000	0.00000	82.00000	0.10000	<1 l/s	0.10			50.00000
64	63.366337	3327CA00009	LOMBARDS POST GED. ROYVILLE	88.39000		84.12000	0.42000	<1 l/s	0.42			33.52000
65	64.356436	3326CB00030	AQUAVISTA GED. BELTON	89.00000		84.12000	0.77000	<1 l/s	0.77			60.35000
66	65.346535	3326CB00103	BOSCHFONTEIN GED. RUSFONTEIN	145.00000	0.00000	85.00000	0.05000	<1 l/s	0.05			85.00000
67	66.336634	3326DA00083	PALMIET	100.00000	0.00000	86.00000	1.25000	1 to 2 l/s	1.25			36.00000
68	67.326733	3326DA00135	GRANTS VALLEY	96.62000		86.25000	1.29000	1 to 2 l/s	1.29			22.25000
69	68.316832	3326DA00139	PALMIET	96.00000	0.00000	87.00000	4.27000	2.1 to 5 l/s	4.27		112.00	30.00000
70	69.306931	3326CB00041	BOSCHFONTEIN GED. VENGROVE	110.00000	0.00000	87.00000	0.41000	<1 l/s	0.41			64.00000
71	70.29703	3326DA00002	VOGELFONTEIN GED. ROOIDAM GED. 2	114.00000	0.00000	90.00000	1.00000	1 to 2 l/s	1.00			21.70000
72	71.287129	3326DA00168	PALMIET	120.00000	0.00000	90.00000	3.20000	2.1 to 5 l/s	3.20		112.00	34.00000
73	72.277228	3326CB00084	UNION	120.00000	0.00000	90.00000	2.52000	2.1 to 5 l/s	2.52		2.50	50.25000
74	73.267327	3326CB00026	LOMBARDS POST GED. WALSYBVILLE	105.46000		94.48000	0.30000	<1 l/s	0.30			57.81000
75	74.257426	3326DA00125	BOSCHFONTEIN GED. BALMORAL	121.92000	0.00000	115.82000	0.29000	<1 l/s	0.29			103.63000
76	75.247525	3326DA00081	BOSCHFONTEIN	135.00000		120.00000	0.45000	<1 l/s	0.45			66.00000
77	76.237624	3326CB00029	BOSCHFONTEIN GED. RUSFONTEIN	130.00000	0.00000	126.00000	1.57000	1 to 2 l/s	1.57			75.00000
78	77.227723	3326CB00079	BOSCHFONTEIN GED. RUSFONTEIN	134.00000	0.00000	130.00000	0.09000	<1 l/s	0.09			98.00000
79	78.217822	3326DA00223	KLEIN HOEK	203.00000	0.00000	140.00000	0.46000	<1 l/s	0.46			36.00000
80	79.207921	3326DA00016	KLEINHOEK	160.00000	0.00000	147.00000	1.54000	1 to 2 l/s	1.54			6.00000
81	80.19802	3327CA00022	KLEIN HOEK	160.00000	0.00000	147.00000	0.57000	<1 l/s	0.57			30.00000
82	81.188119	3326DA00162	UNION GED. MELODY	180.00000	0.00000	165.00000		No Data			0.70	130.00000
83	82.178218	3326DA00037	BOSCHFONTEIN GED. RUSFONTEIN GED. 6	250.00000	0.00000	215.00000	1.41000	1 to 2 l/s				97.00000
84	83.168317	3326DA00230	MERVILLE GED. HILLSIDE	65.00000			0.01000	<1 l/s	0.01			0.01000
85	84.158416	3326DA00176	AQUAVISTA	0.01000				No Data				0.01000
86	85.148515	3326DA00142	BOESMANSRIVIERMOND MEENT	15.00000				No Data				1.70000
87	86.138614	3326DA00036	BOESMANSRIVIERMOND	14.00000				No Data				1.98000
88	87.128713	3326DA00175	KROONGENOT GED. DAGBREEK	30.00000			0.97000	<1 l/s	0.97	DEPTH	1.00000	3.77000
89	88.118812	3326DA00234	LANGE HOOP	30.00000			0.13000	<1 l/s	0.13	DEPTH	0.00000	5.71000
90	89.108911	3326DA00207	BOKNES MEENT	32.64000			1.70000	1 to 2 l/s	1.70	DEPTH		6.71000
91	90.09901	3326DA00219	NEWTON	31.27000				No Data				7.62000
92	91.089109	3326CB00100	RICHMOND	38.43000			2.73000	2.1 to 5 l/s	2.73	DEPTH		8.54000
93	92.079208	3326CB00102	LOMBARDS POST GED. WESTLANDS	100.00000			1.25000	1 to 2 l/s	1.25			11.00000
94	93.069307	3327CA00020	NEWTON	24.38000			0.28000	<1 l/s	0.28	DEPTH	0.00000	11.47000
95	94.059406			45.45000			1.51					12.12000
96	95.049505	3326DC00001	GEELHOUTBOOM	90.00000			0.44000	<1 l/s	0.44			19.87000
97	96.039604	3327CA00003	NEWTON	91.44000			0.70000	<1 l/s	0.70			24.82000
98	97.029703	3326DA00166	NEWTON	67.06000			0.29000	<1 l/s	0.29			25.11000
99	98.019802	3326DA00196	LOMBARDS POST GED. CRANE'S NEST	70.41000				No Data				25.60000
100	99.009901	3326DA00232	SCHIET RUG GED. THE LOMONDS	100.58000			0.25000	<1 l/s	0.25			30.48000
101	100	3326DA00013	CANNON ROCKS	43.39000				No Data				33.00000

APPENDIX A: NANAGA (6)

NUMBER	101	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	ABSTRACTION	WATER LEVEL
102	100.9901	3327CA00006	THE GORAH	47.00000			0.30000	<1 l/s	0.30			34.00000
103	101.9802	3326DA00178	SMITHFIELD	90.00000				No Data				36.12000
104	102.9703	3326DA00134	CANNON ROCKS TOWN	46.00000				No Data				36.45000
105	103.9604	3326DA00231	MERVILLE GED. HAPPY HAVEN	85.00000			0.25000	<1 l/s	0.25			70.45000
106	104.9505	3326DA00161	LOMBARDS POST GED. WALSYBVILLE	2.89000			0.00000	DRY		DRY		
107	105.94059	3326CB00020	BOESMANSRIVIERMOND	29.00000			0.00000	DRY		DRY		
108	106.93069	3327CA00021	KLEIN HOEK	64.00000	0.00000		0.00000	DRY		DRY		
109	107.92079	3326DA00208	GRANTS VALLEY	65.83000			0.00000	DRY		DRY		
110	108.91089	3326DA00048	BOSCHFONTEIN GED VENGROVE GED. 1	66.00000	0.00000		0.00000	DRY				
111	109.90099	3326DA00098	THEOPOLIS	77.41000			0.00000	DRY		DRY		
112	110.89109	3326CB00012	GRANTS VALLEY	86.86000			0.00000	DRY		DRY		
113	111.88119	3326CB00028	SOUTH GORAH GED. LACHERWAELDLE	86.86000			0.00000	DRY		DRY		
114	112.87129	3326CB00021	GRANTS VALLEY	90.00000			0.00000	DRY		DRY		
115	113.86139	3326DA00165	SOUTH GORAH GED. LACKERWAELDLE	97.53000			0.00000	DRY		DRY		
116	114.85149	3326DA00136	GRANTS VALLEY	97.71000			0.00000	DRY		DRY		
117	115.84158	3326DA00236	SOUTH GORAH GED. LACKERWAELDLE	116.73000			0.00000	DRY		DRY		
118	116.83168	3326DA00151	SOUTH GORAH GED. LACHERWAELDLE	122.52000			0.00000	DRY		DRY		
119	117.82178	3326CB00101	SOUTH GORAH GED. LACKERWAELDLE	122.52000			0.00000	DRY		DRY		
120	118.81188	3326DA00164	GRANTS VALLEY	141.73000			0.00000	DRY		DRY		
121	119.80198	3326DA00233	SOUTH GORAH GED. LACKERWAELDLE	144.17000			0.00000	DRY		DRY		
122	120.79208	3326DA00228	GLEN HEATH	161.54000			0.00000	DRY		DRY		
123	121.78218	3326DA00226	BOSCHFONTEIN GED VENGROVE GED. 1	228.00000	0.00000		0.00000	DRY				
124	122.77228	3326DA00227	RICHMOND	91.80000			0.00000	DRY		DEPTH		
125	123.76238	3326DA00229	GLENDOUR GED. GLENDOWER	103.63000			0.00000	DRY		DRY		
126	124.75248	3326DA00225	GLENDOUR GED. GLENDOWER	87.17000			0.00000	DRY		DRY		
127	125.74257			109.72000			0.06					
128	126.73267			111.25000			0.14					
129	127.72277			91.44000			0.38					
130	128.71287			76.20000			0.52					
131	129.70297			122.52000			0.56					
132	130.69307	3326DA00182	RICHMOND GED. STILLEWATER	24.00000			0.78000	<1 l/s	0.78	DEPTH		
133	131.68317			117.65000			0.83					
134	132.67327			129.54000			0.85					
135	133.66337			110.94000			0.94					
136	134.65347			92.35000			1.26					
137	135.64356			122.00000			3.41					
138	136.63366	3326CB00078	KLEIN HOEK	100.65000	0.00000			No Data		DEPTH ?		
139	137.62376	3326CB00080	FARM 252	91.20000	0.00000			No Data		DEPTH ?		
140	138.61386	3326CB00095	VOGELFONTEIN GED. ROOI DAM	128.00000				No Data			0.40	
141	139.60396	3326DA00167	BOSCHFONTEIN	114.00000				No Data				
142	140.59406	3326DA00170	CANNON ROCKS TOWN	9999.99000				No Data				
143	141.58416	3326DA00171	CANNON ROCKS TOWN	9999.99000				No Data				
144	142.57426	3326DA00181	MERVILLE GED. HILLSIDE	65.00000				No Data				
145	143.56436	3326DA00265	BOESMANSRIVIERMOND	11.00000				No Data				
146	144.55446	3326DB00053	FARM 309 GED. ELMHURST	64.00000				<1 l/s	0.50			
147	145.54455	3326DB00057	GLENDOUR GED. GLENDOWER	80.77000				<1 l/s	0.51			
148	146.53465	3326DB00058	GLENDOUR GED. GLENDOWER	30.48000				<1 l/s	0.49			
149	147.52475	3326DB00059	GLENDOUR GED. GLENDOWER	106.68000				<1 l/s	0.41			
150	148.51485	3326DB00060	GLENDOUR GED. GLENDOWER	67.66000				<1 l/s	0.30			
151	149.50495	3326DB00061	GLENDOUR GED. GLENDOWER	95.70000				<1 l/s	0.03			
152	150.49505	3326DB00073	BARVILLE PARK	45.00000				<1 l/s	0.14		0.20	

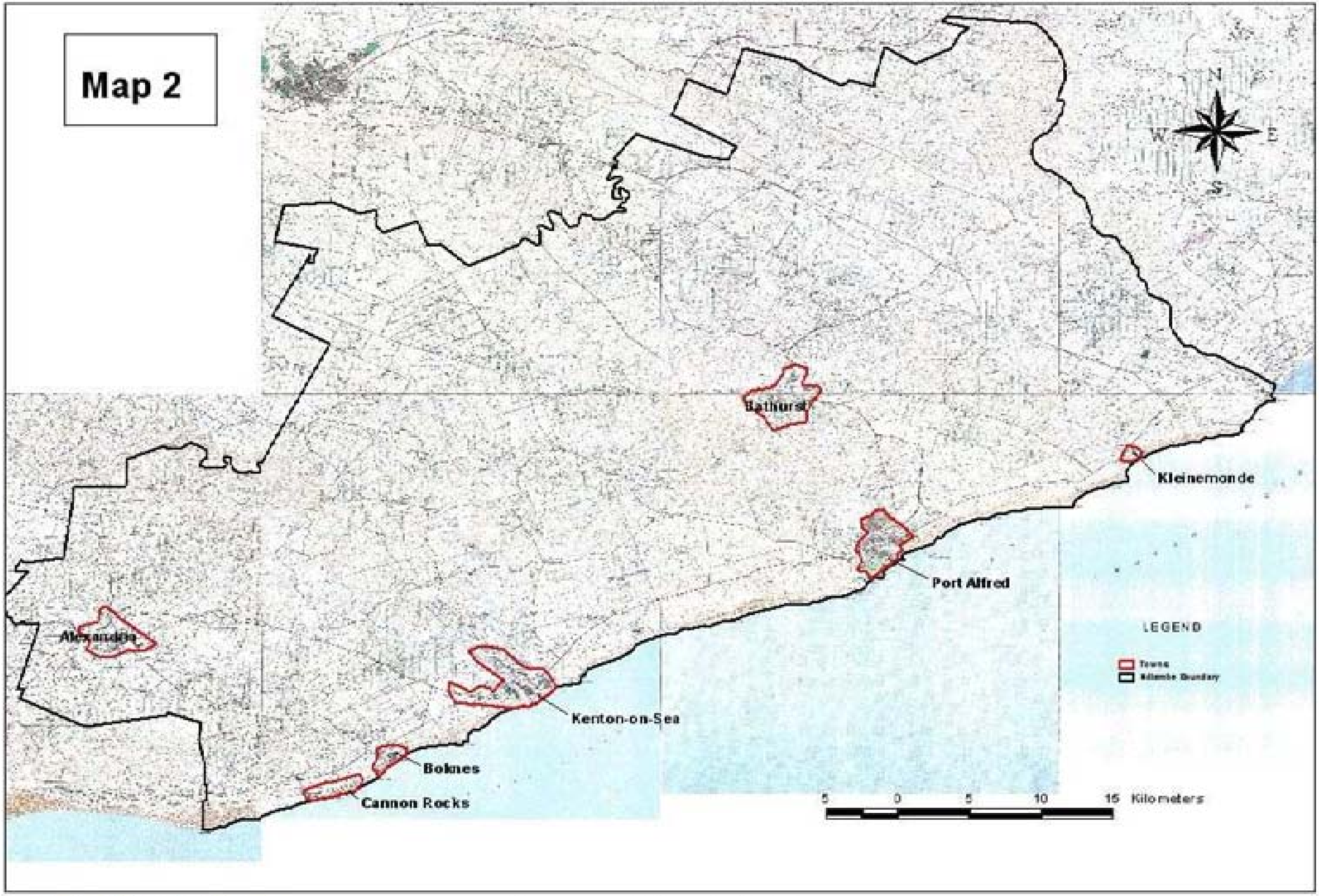
NUMBER	101	BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	AQUIFER CO	ABSTRACTION	WATER LEVEL
153	151.48515	3326DB00129	PORT ALFRED GED. SEAWAYS	60.60000				<1 l/s	0.15			
154	152.47525	3326DB00130	PORT ALFRED GED. ROSE HILL	114.00000				<1 l/s	0.63			
155	153.46535	3326DB00147	GLENDOUR	30.30000				<1 l/s	0.49			
156	154.45545	3326DB00148	GLENDOUR	0.00000				<1 l/s	0.31			
157	155.44554	3326DB00173	BLINKKLIP	75.75000				<1 l/s	0.25			
158	156.43564	3326DB00174	BLINKKLIP	60.60000				<1 l/s	0.12			
159	157.42574	3326DB00180	BARVILLE PARK	75.00000				<1 l/s	0.30			
160	158.41584	3326DB00185	FARM 309 GED. ELMHURST	110.00000				<1 l/s	0.12			
161	159.40594	3326DB00187	FARM 309 GED. ELMHURST	2.00000				<1 l/s	0.60			
				40.00000								
Median				**90.00000**	**0.00000**	**50.00000**	**0.31000**		**0.39**			**24.82000**

APPENDIX A: QUARTERNARY (7)

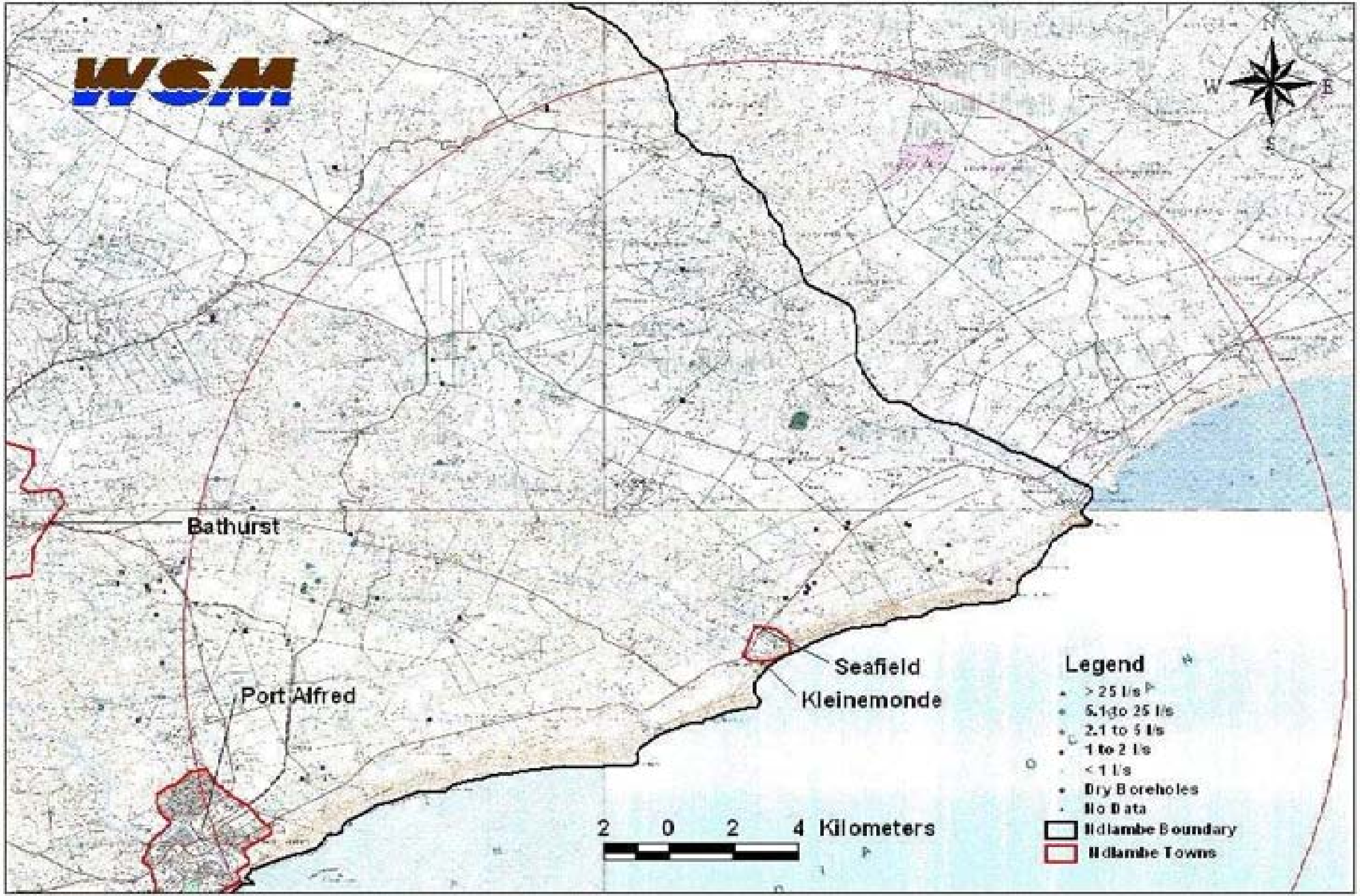
BASIC SITE	ORIGINAL SITE	LATEST DEPTH	TOTAL YIELD	DEPTH TO TOP	CONTRIBUTION	YIELD	DISCHARGE	DATE MEASURED	WATER LEVEL
3326DA00169	KWAAIHOEK	6.00000			2.00000	1 to 2 l/s	2.00	2002.10.02	0.81000
3326DA00259	KWAAIHOEK DIAZ CROSS	9.00000		2.00000	1.00000	1 to 2 l/s		1983.09.19	2.00000
3326DA00260	KWAAIHOEK DIAZ CROSS	9.00000		1.90000	0.60000	<1 l/s		1983.09.22	1.90000
3326DA00261	KWAAIHOEK DIAZ CROSS	11.20000				No Data		1983.09.25	1.70000
3326DA00262	KWAAIHOEK DIAZ CROSS	12.00000		1.20000	2.50000	2.1 to 5 l/s		1983.09.28	1.20000
3326DA00263	KWAAIHOEK DIAZ CROSS	6.00000		0.80000	0.50000	<1 l/s		1983.09.30	0.80000
3326DA00264	KWAAIHOEK DIAZ CROSS	12.00000				No Data			
3327AC00021	FISH RIVER MOUTH TOWN	38.00000	0.00000	32.00000	0.07000	<1 l/s	0.07	1982.07.31	14.40000
3327CA00004	FARM 240 GED. GROOT VISPUNT LIGTORING	108.00000	0.00000	96.00000		No Data		1984.07.10	39.00000
3327CA00005	FARM 240 GED. GROOT VISPUNT LIGTORING	102.00000			1.72000	1 to 2 l/s	1.72		

APPENDICES B to G

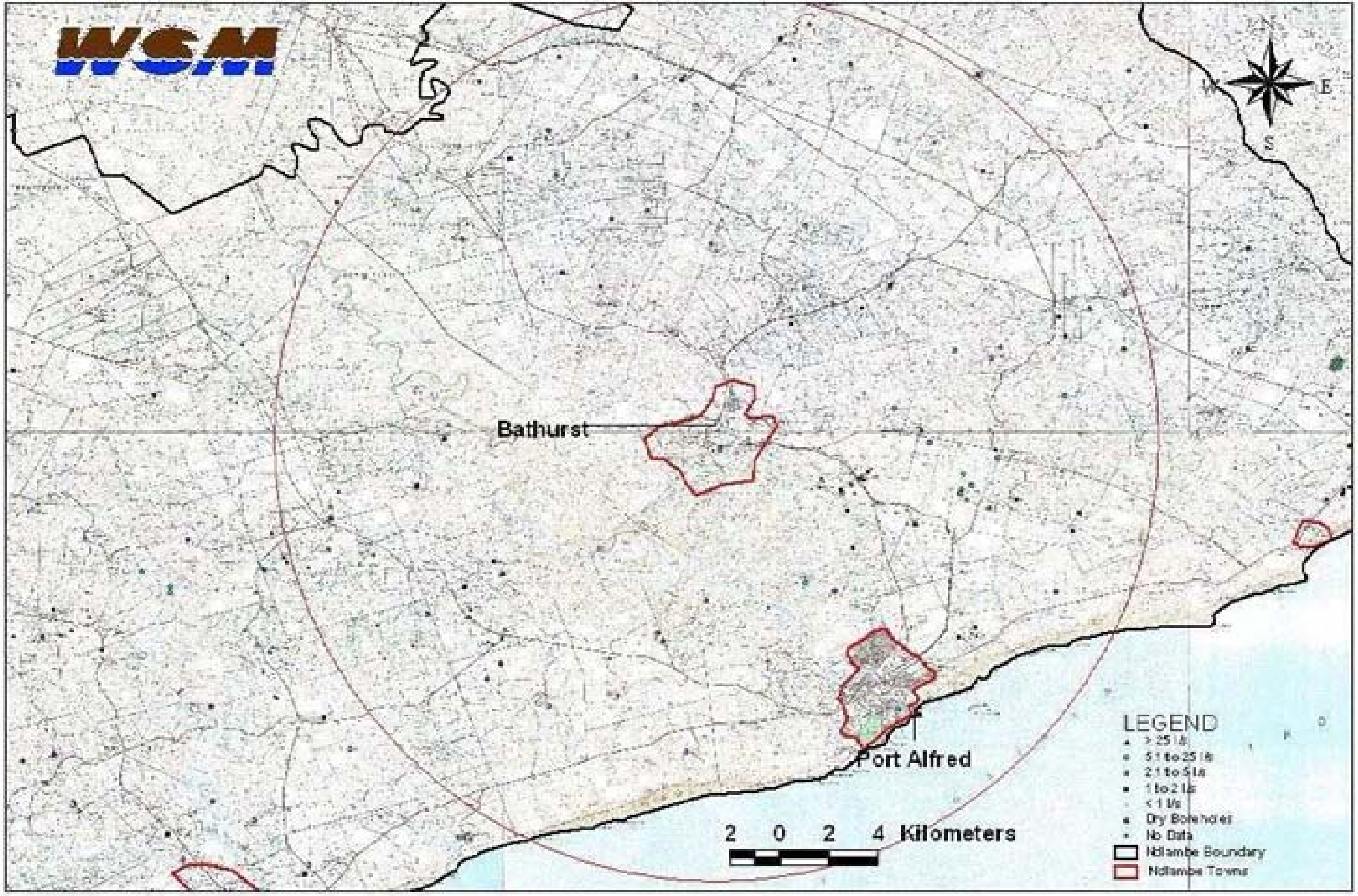
NGDB Boreholes Superimposed on Relevant Topographical Sheets



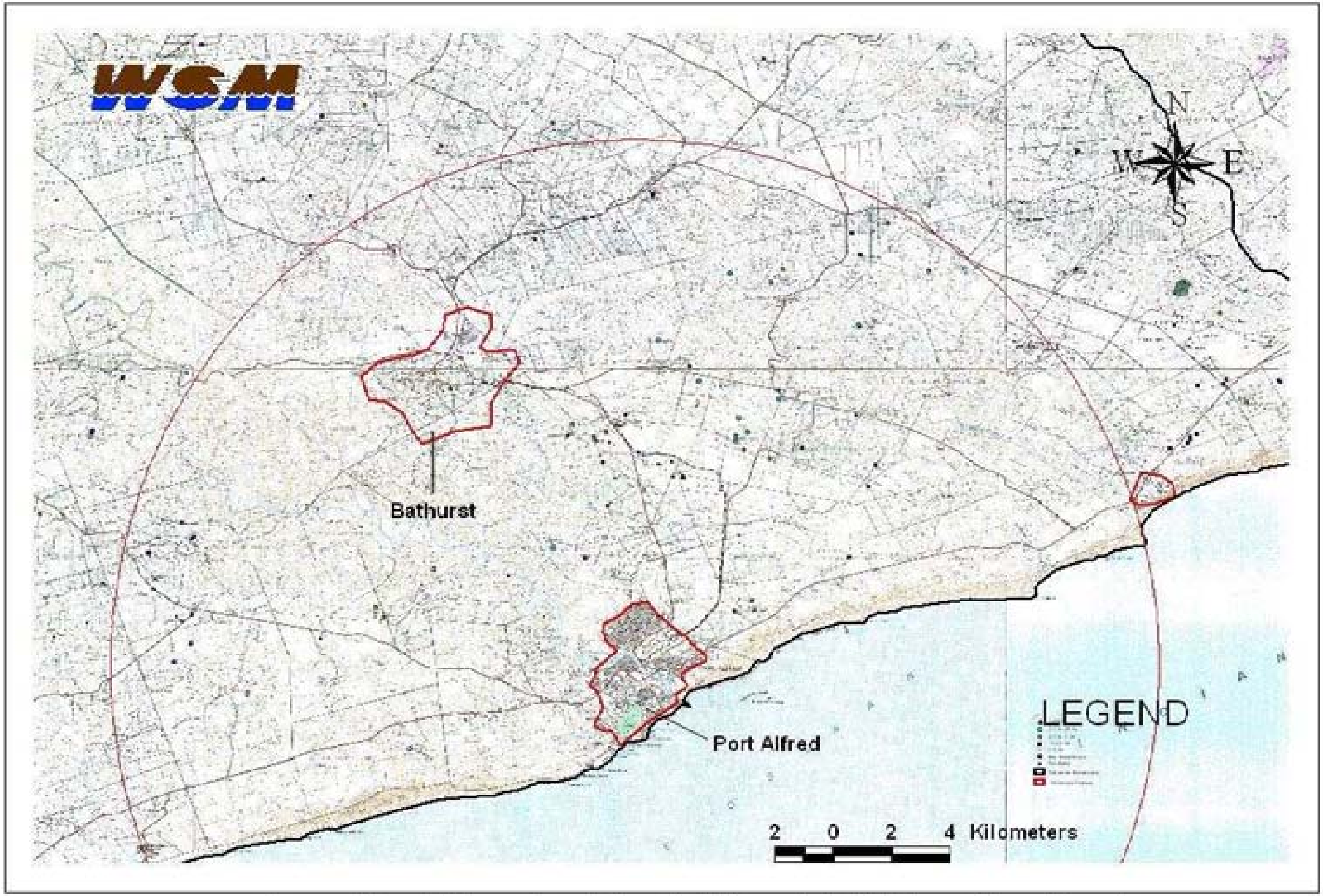
Locality Map



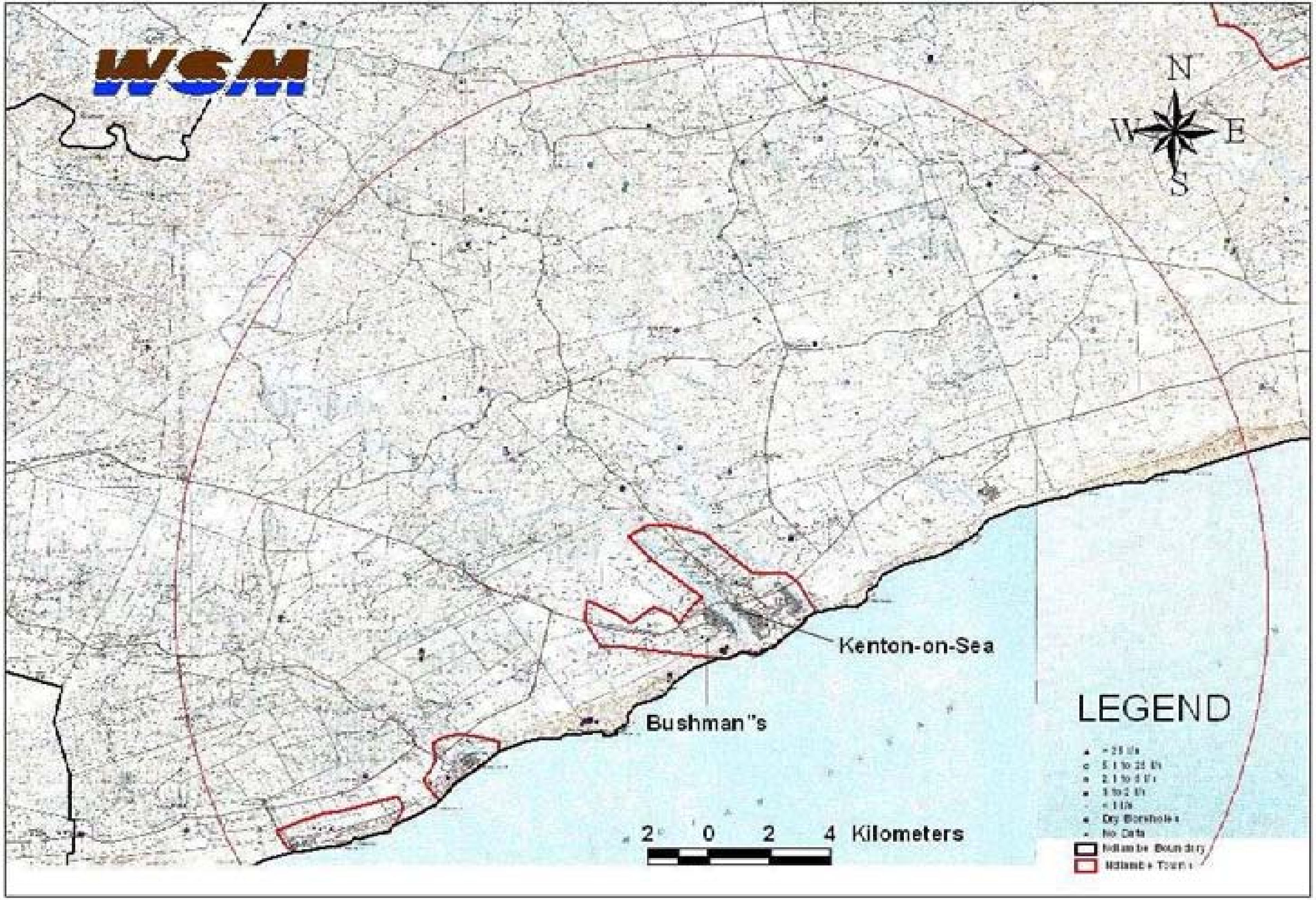
Locality Map for the Seafield and Kleinemonde Area(15 km Radius)



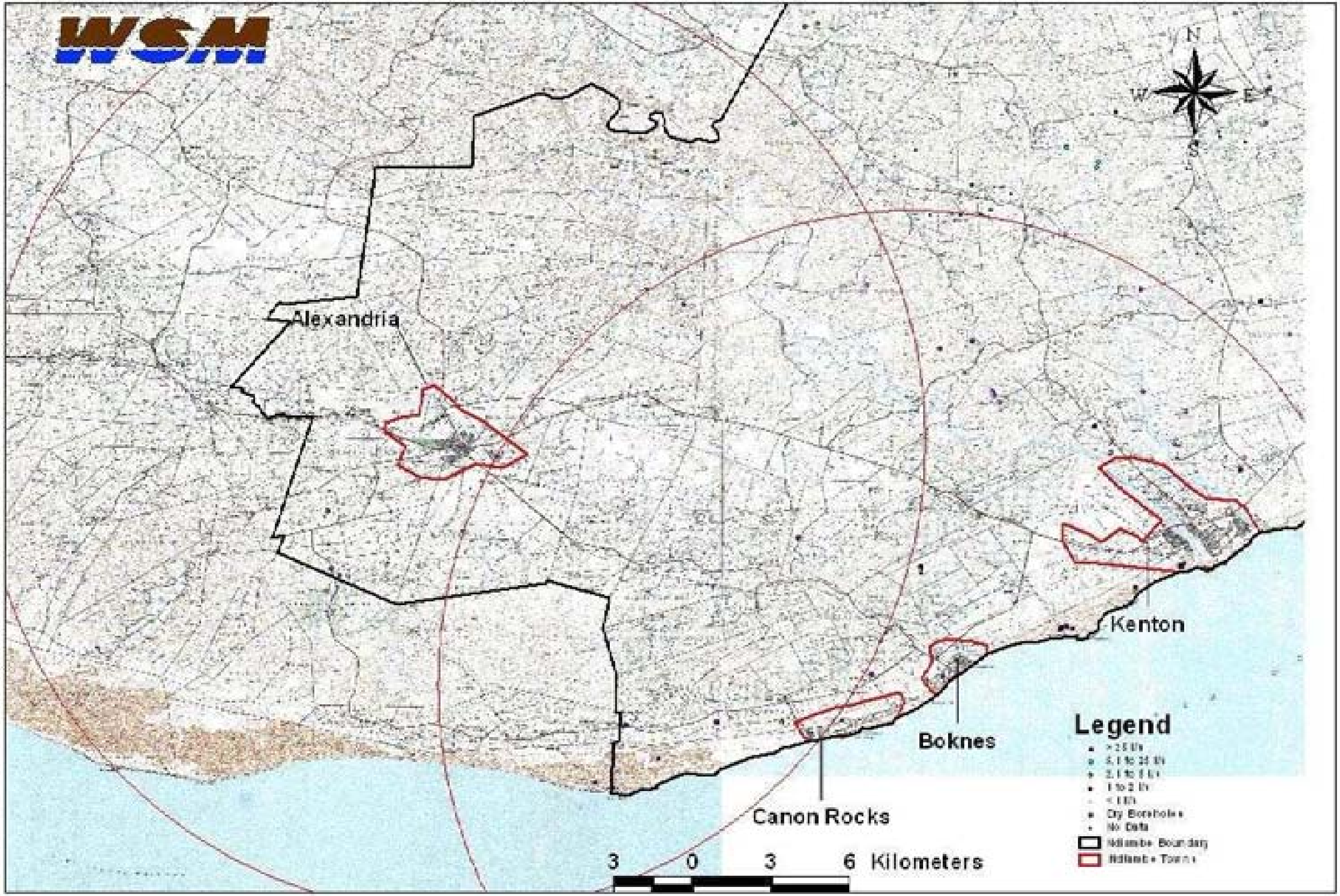
Locality Map for the Bathhurst Area (15 km Radius)



Locality Map for Port Alfred (15 km Radius).



Locality Map for Bushman's and Kenton (15 km Radius).



Locality Map for Alexandria, Boknes and Cannon Rocks (15 km Radius).

APPENDIX H

NGDB Hydrochemistry Listed

Per Lithotype

Bokkeveld Water Quality: ex-NGDB (1)

Macro hydrochemical data input file (mg/l)				TOTAL				Major Ions (mg/l or ppm)							
15	BH NO	Latitude(x)	Longitude(y)	EC(mS/m)	TDS(mg/l)	HARDNESS	TAL(mg/l)	Na	K	Ca	Mg	HCO_3	SO_4	Cl	NO_3
1	170238	-33.63194	26.40167	325.00	2234.08	690.22	257.80	571.80	7.48	159.00	71.20	314.52	135.40	1131.90	0.04
2	170239	-33.63361	26.40472	462.00	3052.04	1018.91	196.10	766.00	13.68	224.50	111.30	239.24	201.90	1615.00	0.04
3	170284	-33.68472	26.52667	327.00	1734.23	595.32	211.50	424.10	9.01	123.30	69.80	258.03	97.40	881.40	0.21
4	170740	-33.64278	26.70111	271.00	1790.02	461.31	377.30	498.70	6.03	104.10	48.90	460.31	123.10	775.10	3.94
5	170918	-33.69028	26.47694	97.10	492.15	158.98	136.30	128.10	1.83	38.60	15.20	166.29	29.20	196.00	0.08
6	170925	-33.68139	26.35833	84.20	437.40	153.69	229.50	114.80	3.95	37.80	14.40	279.99	22.10	102.40	1.96
7	170992	-33.69139	26.47028	1590.00	9822.17	3791.16	272.90	2196.50	24.16	897.70	376.30	332.94	623.20	5537.80	0.04
8	170994	-33.63889	26.63306	1077.00	6504.13	1529.19	652.70	1931.20	25.51	270.70	207.20	796.29	394.00	3277.30	0.07
9	170995	-33.63222	26.62694	539.00	3116.66	432.21	613.40	1030.50	11.38	74.80	59.60	748.35	180.50	1384.40	1.30
10	171003	-33.71611	26.56722	631.00	4010.54	750.43	564.20	1212.80	10.57	162.00	84.00	688.32	281.70	1910.40	4.90
11	171004	-33.68222	26.52972	340.00	1916.64	758.49	334.20	429.30	8.64	174.30	78.50	407.72	102.50	919.30	0.24
12	171013	-33.61500	26.40972	757.00	4250.10	1380.94	367.00	1070.00	20.03	229.80	196.00	447.74	238.80	2271.10	0.50
13	171021	-33.66806	26.46611	411.00	2402.91	760.13	278.40	590.00	9.32	171.00	80.90	339.65	296.70	1083.90	1.27
14	171022	-33.65778	26.46944	405.00	2333.31	697.05	222.00	591.30	9.06	145.90	80.80	270.84	280.40	1089.40	1.03
15	176237	-33.65694	26.58833	120.50	623.50	207.53	158.60	169.40	2.42	52.60	18.50	193.49	31.40	248.30	4.13
(n=15)			**MEDIAN (mg/l)**	**405.00**	**2333.31**	**697.05**	**272.90**	**590.00**	**9.06**	**159.00**	**78.50**	**332.94**	**180.50**	**1089.40**	**0.50**
			STD DEV	**400.15**	**2471.95**	**895.87**	**163.51**	**618.19**	**7.24**	**207.79**	**94.78**	**199.48**	**160.44**	**1393.73**	**1.67**

Weltevrede Water Quality: ex-NGDB (2)

Macro hydrochemical data input file (mg/l)				TOTAL				Major Ions (mg/l or ppm)								
9	BH NO	Latitude(x)	Longitude(y)	EC(mS/m)	TDS(mg/l)	HARDNESS	TAL(mg/l)	Na	K	Ca	Mg	HCO_3	SO_4	Cl	NO_3	F^-
1	163377	-33.50833	26.80000	244.10	1241.87	662.17	115.10	190.40	4.62	197.90	40.80	140.42	102.20	635.40	0.34	0.10
2	170733	-33.51833	26.71778	884.00	5471.35	1708.29	280.90	1396.90	10.46	266.40	253.30	342.70	340.80	3032.10	0.04	0.85
3	170999	-33.50556	26.69111	232.00	1245.41	380.90	167.00	323.10	4.19	78.00	45.20	203.74	49.20	643.80	0.05	0.21
4	171124	-33.46972	26.93167	819.00	5038.33	1383.50	252.90	1350.30	17.83	239.40	190.80	308.54	655.70	2419.80	10.24	0.39
5	171125	-33.47667	26.93694	384.00	2211.29	354.13	474.40	732.50	4.73	78.00	38.70	578.77	116.80	936.80	14.37	0.52
6	171126	-33.48333	26.90000	143.00	736.71	184.90	222.70	219.50	1.25	50.30	14.40	271.69	40.30	274.50	0.61	0.33
7	171133	-33.44278	26.89000	158.00	1075.98	183.25	463.50	365.10	1.94	31.50	25.40	565.47	98.80	263.80	6.70	1.90
8	175929	-33.55222	26.85694	469.00	2635.90	737.55	244.90	730.20	25.42	123.20	104.40	298.78	128.20	1374.90	0.19	0.40
9	175933	-33.58278	26.78944	194.00	1054.86	169.73	103.90	331.30	4.01	27.90	24.30	126.76	68.50	535.30	0.17	0.26
(n=9)			**MEDIAN (mg/l)**	**244.10**	**1245.41**	**380.90**	**244.90**	**365.10**	**4.62**	**78.00**	**40.80**	**298.78**	**102.20**	**643.80**	**0.34**	**0.39**
			STD DEV	**281.474**	**1781.89**	**557.87**	**133.92**	**466.74**	**8.22**	**91.14**	**84.94**	**163.38**	**200.15**	**980.78**	**5.45**	**0.55**

Witpoort Water Chemistry: ex-NGDB (3)

Macro hydrochemical data input file (mg/l)				TOTAL				Major Ions (mg/l or ppm)								
21	BH NO	Latitude(x)	Longitude(y)	EC(mS/m)	TDS(mg/l)	HARDNESS	TAL(mg/l)	Na	K	Ca	Mg	HCO_3	SO_4	Cl	NO_3	F^-
1	170730	-33.55139	26.61833	239.00	1230.86	266.80	200.40	360.60	17.42	32.80	44.90	244.49	76.90	575.00	1.00	0.50
2	170731	-33.58222	26.58222	321.00	1836.31	942.08	204.70	318.20	8.00	269.10	65.60	249.73	59.10	989.50	1.94	0.33
3	170734	-33.53111	26.67083	159.00	840.25	335.85	321.50	195.20	3.19	96.90	22.80	392.23	46.40	274.00	5.65	0.41
4	170737	-33.54722	26.74667	241.00	1476.87	459.50	364.00	401.20	5.09	116.90	40.70	444.08	98.00	581.60	11.34	0.38
5	170739	-33.59639	26.72806	248.00	1590.25	484.08	254.50	419.70	6.50	102.50	55.40	310.49	139.20	710.70	1.00	0.29
6	170987	-33.61778	26.59139	1087.00	6287.91	2177.34	482.30	1552.00	11.56	408.40	281.10	588.41	447.10	3290.50	3.04	0.21
7	170993	-33.57889	26.66778	240.00	1289.98	542.66	349.50	293.00	2.80	144.10	44.40	426.39	48.80	540.50	3.19	0.24
8	170996	-33.59306	26.73139	305.00	1798.53	632.98	312.20	428.80	6.39	143.00	67.00	380.88	133.80	828.10	1.00	0.34
9	170997	-33.55250	26.73611	795.00	4662.31	1972.54	304.50	962.00	16.67	510.10	169.70	371.49	289.30	2528.70	0.10	0.25
10	171000	-33.58306	26.60694	249.00	1375.53	512.44	290.60	331.00	4.60	125.40	48.40	354.53	49.10	638.70	1.07	0.24
11	171007	-33.48611	26.60556	657.00	3703.73	1290.48	376.10	881.00	20.15	263.50	153.60	458.84	237.50	1916.90	1.66	0.43
12	171011	-33.54917	26.42278	381.00	2127.35	468.17	347.80	627.10	5.58	105.20	49.90	424.32	178.10	934.40	14.91	0.27
13	171014	-33.56944	26.40556	364.00	2049.41	605.44	333.50	537.00	9.06	154.40	53.40	406.87	103.00	982.70	6.41	0.47
14	171127	-33.46944	26.98583	212.00	1187.64	370.36	144.70	298.00	5.04	100.00	29.30	176.53	62.10	602.80	2.13	0.26
15	171128	-33.45639	26.95944	146.00	754.08	282.40	253.00	184.40	1.76	90.50	13.70	308.66	38.40	268.50	2.49	0.22
16	171137	-33.37250	26.79889	99.30	545.65	139.69	70.10	154.40	2.89	19.00	22.40	85.52	24.70	278.50	1.00	0.44
17	175931	-33.56556	26.94528	364.00	2068.85	635.27	241.30	524.20	14.94	133.20	73.50	294.39	127.00	1047.60	1.22	0.22
18	175932	-33.53278	26.87972	278.00	1541.60	327.16	257.00	467.80	9.93	60.60	42.70	313.54	140.30	662.50	1.00	0.35
19	176232	-33.59833	26.53861	892.00	5235.23	1241.80	311.50	1569.00	18.79	168.80	199.20	380.03	333.20	2755.90	0.33	0.36
20	176234	-33.62972	26.64056	1283.00	7941.65	1457.71	295.10	2495.40	89.19	214.70	223.80	360.02	526.40	4211.80	0.34	0.15
21	176235	-33.55667	26.52000	887.00	5004.68	1694.65	78.90	1313.80	33.25	283.20	239.80	96.26	109.50	2976.00	1.00	0.27
(n=21)			**MEDIAN (mg/l)**	**305.00**	**1798.53**	**542.66**	**295.10**	**428.80**	**8.00**	**133.20**	**53.40**	**360.02**	**109.50**	**828.10**	**1.22**	**0.29**
			STD DEV	**339.48**	**2044.22**	**597.51**	**97.99**	**594.83**	**18.89**	**120.95**	**81.76**	**119.55**	**137.64**	**1147.35**	**3.79**	**0.10**

Lake Mentz Water Chemistry: ex NGDB (4)

Macro hydrochemical data input file (mg/l)				TOTAL				Major Ions (mg/l or ppm)								
7	BH NO	Latitude(x)	Longitude(y)	EC(mS/m)	TDS(mg/l)	HARDNESS	TAL(mg/l)	Na	K	Ca	Mg	HCO_3	SO_4	Cl	NO_3	F^-
1	170727	-33.51361	26.52417	521.00	3021.50	977.11	311.20	780.80	16.83	169.50	134.50	379.66	215.40	1514.60	0.04	0.45
2	170728	-33.52667	26.58056	253.00	1424.13	609.52	249.20	306.30	8.38	137.40	64.70	304.02	89.00	666.30	0.04	0.35
3	170729	-33.53694	26.53917	478.00	2837.21	932.05	315.00	695.60	12.00	210.00	99.00	384.30	190.00	1433.00	5.46	0.76
4	170735	-33.54139	26.65167	123.90	722.96	283.40	291.90	168.60	2.18	97.50	9.70	356.12	43.70	215.80	7.42	0.29
5	170989	-33.52667	26.53528	777.00	4416.91	1331.11	288.70	1151.90	12.62	251.90	170.50	352.21	215.90	2437.90	0.09	0.35
6	170990	-33.52500	26.58083	364.00	1975.73	782.26	298.00	438.40	9.37	182.50	79.30	363.56	102.80	980.90	0.68	0.25
7	170991	-33.53889	26.65444	128.50	657.99	224.68	229.00	168.00	2.04	72.50	10.60	279.38	45.60	212.10	7.46	0.17
(n=7)			**MEDIAN (mg/l)**	**364.00**	**1975.73**	**782.26**	**291.90**	**438.40**	**9.37**	**169.50**	**79.30**	**356.12**	**102.80**	**980.90**	**0.68**	**0.35**
			STD DEV	**235.332**	**1365.68**	**394.786**	**32.1813**	**364.502**	**5.45991**	**62.7364**	**59.8675**	**39.2612**	**76.6546**	**799.69**	**3.58053**	**0.19147**

Nanaga Groundwater Quality: ex-NGDB (5)

Macro hydrochemical data input file (mg/l)				TOTAL				Major Ions (mg/l or ppm)								
43	BH NO	Latitude(x)	Longitude(y)	EC(mS/m)	TDS(mg/l)	HARDNESS	TAL(mg/l)	Na	K	Ca	Mg	HCO_3	SO_4	Cl	NO_3	F^-
1	100608	-33.69333	26.65083	460.80	2466.10	440.13	74.30	772.50	13.38	56.70	72.50	90.65	75.60	1430.00	0.10	0.32
2	100609	-33.71389	26.60861	1282.00	7367.40	2180.63	26.70	2030.10	35.07	323.30	333.50	32.57	461.10	4167.50	0.54	0.39
3	161376	-33.68333	26.65000	676.47	3881.99	903.28	254.10	1150.08	25.68	171.69	115.24	310.00	138.48	2125.21	0.60	0.28
4	161442	-33.73333	26.50000	200.30	1127.39	116.91	364.88	402.60	4.06	30.58	9.85	445.15	53.63	399.58	4.53	0.82
5	161443	-33.75000	26.50000	307.18	1632.47	414.15	223.28	473.30	6.62	96.80	41.88	272.40	100.18	770.08	7.43	0.47
6	161509	-33.75000	26.53333	233.43	1279.08	310.83	272.20	366.30	9.43	66.93	34.90	332.08	77.85	556.25	1.39	0.40
7	161510	-33.70000	26.60000	1032.00	6110.18	1982.86	100.90	1544.93	29.82	388.23	246.10	123.10	369.33	3470.10	0.11	0.33
8	161511	-33.73333	26.53333	247.70	1367.42	238.08	261.30	426.40	13.25	46.20	29.80	318.79	92.70	598.80	0.88	0.39
9	161665	-33.68056	26.60056	250.20	1206.98	276.49	39.40	350.30	7.65	34.70	46.10	48.07	75.30	668.20	0.70	0.72
10	170232	-33.74083	26.49250	519.00	3371.91	1054.16	262.10	858.40	5.22	290.40	79.90	319.76	262.30	1709.70	6.11	0.23
11	170243	-33.55528	26.47778	256.00	1554.80	474.93	422.60	437.10	7.54	130.50	36.20	515.57	167.70	491.20	26.78	0.31
12	170244	-33.55417	26.43778	250.00	1401.99	497.01	275.20	355.70	5.94	137.20	37.50	335.74	59.30	631.90	6.58	0.37
13	170246	-33.60639	26.49083	827.00	5558.95	2019.12	444.60	1346.20	35.30	433.10	227.70	542.41	313.20	2927.90	4.34	0.37
14	170247	-33.60500	26.48806	617.00	4027.94	1347.91	371.60	1014.00	21.73	279.90	157.60	453.35	296.30	2027.40	4.34	0.40
15	170248	-33.58833	26.38444	470.00	2977.03	629.93	205.80	895.20	10.41	111.60	85.30	251.08	234.30	1514.60	0.09	0.46
16	170281	-33.66556	26.35889	174.00	985.27	212.07	306.90	303.30	1.87	43.70	25.00	374.42	51.30	372.70	0.19	0.43
17	170282	-33.73556	26.54833	438.00	2956.73	857.30	210.80	797.60	11.00	186.00	95.40	257.18	204.10	1534.00	0.04	0.36
18	170468	-33.58639	26.39583	452.00	2583.19	686.41	243.00	706.20	10.78	151.70	74.70	296.46	159.10	1331.30	1.18	0.33
19	170487	-33.63806	26.35611	794.00	4947.29	1490.67	211.00	1267.70	18.52	325.20	164.80	257.42	405.00	2637.30	0.06	0.16
20	170489	-33.63917	26.37611	597.00	3577.70	877.93	265.40	998.00	16.07	200.20	91.80	323.79	200.70	1909.00	0.04	0.18
21	170491	-33.66000	26.36639	195.00	1057.05	292.62	359.10	296.90	1.49	72.00	27.40	438.10	52.20	387.60	0.41	0.31
22	170732	-33.62972	26.61194	317.00	1864.59	318.28	460.00	594.00	9.43	64.30	38.30	561.20	128.50	746.60	2.86	0.66
23	170736	-33.54500	26.70278	163.00	861.81	337.47	316.40	217.80	1.37	105.30	18.10	386.01	44.30	267.80	14.14	0.31
24	170738	-33.58333	26.66083	187.00	1164.34	488.52	296.10	259.50	2.46	130.50	39.50	361.24	66.00	484.70	1.06	0.36
25	170741	-33.67167	26.58444	228.00	1434.19	405.00	377.20	411.60	7.41	92.60	42.20	460.18	105.50	518.80	25.99	0.81
26	170919	-33.74667	26.48972	381.00	2037.41	661.96	300.90	521.70	3.75	186.60	47.60	367.10	124.90	959.90	9.41	0.19
27	170920	-33.74778	26.46806	380.00	2036.10	654.59	300.50	526.10	3.69	185.30	46.60	366.61	127.30	954.00	9.80	0.20
28	170988	-33.56639	26.59028	269.00	1405.48	410.82	230.50	373.40	4.93	97.90	40.40	281.21	62.20	683.10	2.95	0.21
29	170998	-33.54528	26.70250	161.00	827.80	302.68	262.50	218.00	2.17	88.40	19.90	320.25	51.70	277.30	10.20	0.22
30	171001	-33.67361	26.63694	1320.00	8338.49	1554.48	745.80	2648.90	24.61	202.00	255.00	909.88	351.40	4401.60	0.04	1.33
31	171002	-33.69778	26.59750	1550.00	9922.48	3099.31	378.80	2579.10	29.56	516.40	439.50	462.14	431.20	5694.60	1.05	0.47
32	171005	-33.73667	26.52389	343.00	1853.82	370.60	355.20	560.60	4.81	96.80	31.30	433.34	117.30	823.10	3.24	0.51
33	171006	-33.59111	26.44306	834.00	4711.01	1256.45	298.40	1277.70	35.25	253.50	151.40	364.05	309.80	2490.00	11.34	0.47
34	171008	-33.55694	26.48028	259.00	1403.13	371.15	480.00	405.40	6.37	99.00	30.10	585.60	153.30	415.90	0.26	0.35
35	171009	-33.56000	26.48444	414.00	2368.36	532.18	493.00	687.40	10.25	121.60	55.50	601.46	181.60	997.60	13.68	0.40
36	171010	-33.55250	26.44083	258.00	1387.01	470.15	270.70	346.30	5.19	127.10	37.10	330.25	56.90	643.00	6.29	0.30
37	171019	-33.69972	26.43722	110.00	604.70	213.41	162.30	147.10	2.96	51.00	20.90	198.01	24.60	259.10	0.04	0.35
38	171020	-33.70028	26.42222	115.40	602.57	211.57	156.10	149.20	3.01	52.90	19.30	190.44	24.80	258.10	0.04	0.27
39	171701	-33.62583	26.76056	137.00	816.00	40.33	349.50	310.30	0.76	2.30	8.40	426.39	54.70	226.30	0.04	0.24
40	175928	-33.59750	26.86667	854.00	5519.48	1038.35	178.20	1636.10	26.70	171.10	148.40	217.40	695.10	2733.20	0.18	0.10
41	175930	-33.64444	26.75333	233.00	1292.82	175.46	319.50	446.00	4.41	29.70	24.60	389.79	121.60	470.80	0.82	0.38
42	176236	-33.66889	26.59444	216.00	1071.81	239.52	139.80	322.40	5.79	44.80	31.00	170.56	52.80	529.70	0.04	0.40
43	175934	-33.50722	26.82722	185.00	1045.63	361.35	450.00	275.80	2.96	105.30	23.90	549.00	76.50	281.70	4.97	0.27
(N=43)			**MEDIAN (mg/l)**	**307.18**	**1632.47**	**470.15**	**275.20**	**473.30**	**7.41**	**111.60**	**41.88**	**335.74**	**121.60**	**746.60**	**1.06**	**0.36**
			STD DEV	**342.733**	**2180.27**	**643.444**	**131.399**	**600.302**	**10.244**	**114.276**	**92.1524**	**160.307**	**143.021**	**1264.48**	**6.29955**	**0.21122**

Quaternary Water Chemistry: ex-NGDB (6)

Macro hydrochemical data input file (mg/l)				TOTAL				Major Ions (mg/l or ppm)								
8	BH NO	Latitude(x)	Longitude(y)	EC(mS/m)	TDS(mg/l)	HARDNESS	TAL(mg/l)	Na	K	Ca	Mg	HCO_3	SO_4	Cl	NO_3	F^-
1	89921	-33.69306	26.65861	320.52	1720.99	585.90	339.45	422.90	8.64	151.56	50.38	414.12	71.84	808.37	0.25	0.44
2	89922	-33.69306	26.65861	28.80	1496.56	419.34	376.50	417.30	12.35	121.10	28.40	459.33	92.80	594.60	0.34	0.42
3	89957	-33.77083	26.46250	188.03	552.59	229.89	171.53	123.83	3.10	67.41	14.95	209.26	35.43	201.78	1.46	0.45
4	100720	-33.76667	26.46667	88.00	466.31	188.19	150.50	104.70	2.35	56.40	11.50	183.61	42.30	156.00	1.25	0.43
5	100960	-33.69139	26.66000	272.10	1436.79	507.85	304.30	365.80	6.85	138.90	39.10	371.25	70.30	630.00	0.22	0.36
6	100961	-33.69111	26.65861	973.20	5683.71	1525.10	262.73	1616.10	18.97	293.97	192.10	320.53	249.43	3152.70	0.17	0.29
7	171532	-33.69306	26.65861	237.00	1247.68	396.72	347.70	329.80	5.55	106.60	31.70	424.19	72.40	489.40	0.13	0.71
8	171533	-33.77083	26.46250	95.30	481.80	202.33	153.30	107.00	2.65	61.90	11.60	187.03	25.70	178.10	1.34	0.55
(N=8)			**Median**	**212.51**	**1342.24**	**408.03**	**283.52**	**347.80**	**6.20**	**113.85**	**30.05**	**345.89**	**71.07**	**542.00**	**0.30**	**0.43**
			Std Dev	**299.15**	**1710.27**	**436.52**	**93.09**	**496.39**	**5.73**	**77.28**	**60.06**	**113.57**	**71.11**	**989.78**	**0.59**	**0.13**

ADDENDUM A

Ndlambe Geospatial Data Digital Atlas

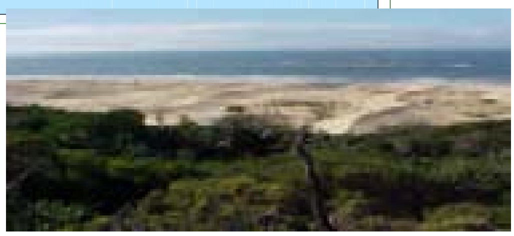
On CD-ROM

P WMA 15/000/00/0409

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate: National Water Resource Planning

ALBANY COAST SITUATION ASSESSMENT STUDY



Stream Flow Hydrology

Final

December 2004

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DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

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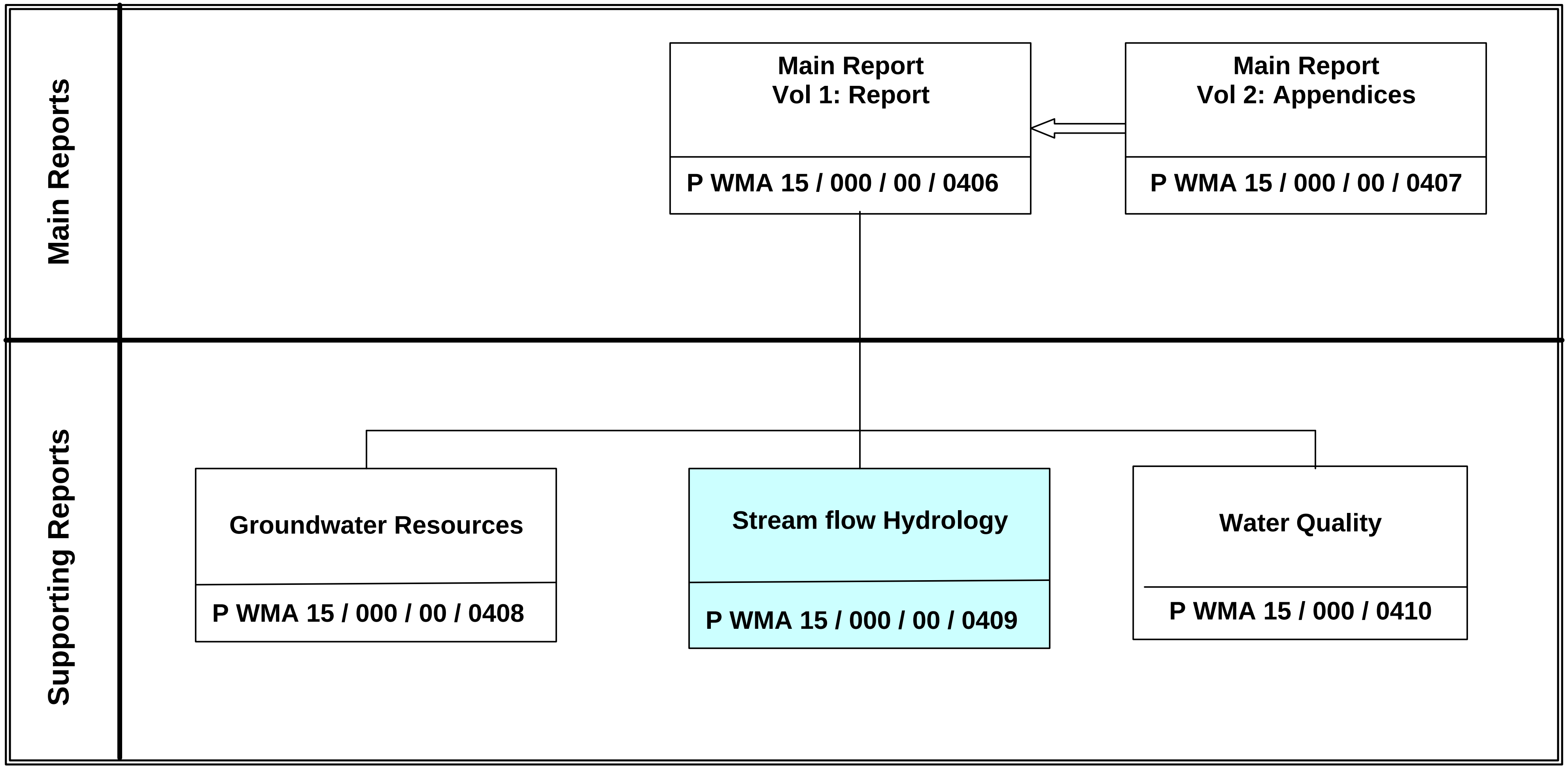
ALBANY COAST SITUATION ASSESSMENT STUDY

Structure of Reports



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EXECUTIVE SUMMARY

The objectives of the hydrology and yield analysis work module were to generate streamflow sequences and to determine water availability at the outlet of all quaternary catchments within the P Region and to determine yield at selected strategic points, which include existing dam sites (Sarel Hayward and Golden Ridge) under current and raised dam conditions, as well as at a new proposed dam site (Bushfontein Dam).

The water resources situation assessment study was carried out at a reconnaissance level of detail. The hydrology and yield were supposed to be determined at the same level. However, due to the current and future benefits of using a system model, the Water Resources Yield Model was configured to determine available surplus in the study area (P region). This robust WRYM configuration is available for scenario analyses and for future use in studies of the same or better level of investigation.

The P Drainage Region has a natural and present day MAR of 173 X $10^6 m^3$ and 135 X $10^6 m^3$, respectively. The Region has an excess historic firm yield of 4.626 X $10^6 m^3$, mainly available in quaternary catchment P10G, P20A, P20B, P40C and P40D. The characteristics of the study area and the summary of the results of the study are captured in ***Table I*** *overleaf*

Three of the development options that were assessed include the raising of the Sarel Hayward and Golden Ridge dams and the development of a new Bushfontein Dam on the Bushmans River. The yield analysis results of the dams are shown below. Sarel Hayward Dam can be raised to get the required yield to cater for increased water requirements. A storage capacity of about 5.12 x $10^6 m^3$ will provide the maximum required yield of 4.28 x $10^6 m^3$. The current storage capacity is 2.522 x $10^6 m^3$ and has a yield of 2.96 x $10^6 m^3$. Golden Ridge Dam options proved to be totally undesirable.

Sarel Hayward Dam Historical Firm Yield ($10^6 m^3$/a) after provision for IFR

PUMP RATE Kowie River (l/s)	FSL=38.9 m VOL=2.52 X $10^6 m^3$	FSL=42.3 m VOL=3.41X$10^6 m^3$	FSL=48.0 VOL=5.12X$10^6 m^3$	FSL=55.0 m VOL=8.46X$10^6 m^3$
150	2.96	3.14	3.49	3.85
200	3.3	3.52	3.9	4.48
250	3.3	3.8	4.17	4.76
300	3.3	3.97	4.36	5

Proposed Bushfontein Dam yield ($10^6 m^3$/a)

DSL (m)	FSL (m)	Capacity (X$10^6 m^3$)	Yield Without IFR (X$10^6 m^3$)	Yield With IFR (X$10^6 m^3$)
290.2	298	1.919	6.11	4.51
286.3	288	0.049	4.35	2.32

Table I: P Drainage Region Characteristics and Study Results

Quaternary	AREA (km^2)	MAP (mm)	Natural MAR (10^6m^3)	Present day MAR (10^6m^3)	Affore Station (10^6m^3)	Alien Veg. (10^6m^3)	Irrigation (10^6m^3)	Urban (10^6m^3)	Stock (10^6m^3)	Total Consumptive Use (10^6m^3)	Return flow (10^6m^3)	Dam net evap. Losses (10^6m^3)	IFR (accum) average (10^6m^3)	Excess yield (10^6m^3)
P10A	126	600	4.54	3.66	0.05	0.38	0.42	0.00	0.03	0.88	0.00	0.19	0.82	**0.00**
P10B	508	531	12.19	9.92	0.00	0.30	1.60	0.25	0.13	2.27	0.03	0.79	3.53	**0.19**
P10C	281	386	2.39	1.46	0.00	0.00	0.90	0.00	0.03	0.93	0.00	0.03	0.41	**0.00**
P10D	564	432	6.77	4.83	0.00	0.04	1.81	0.00	0.09	1.94	0.00	0.03	3.16	**0.00**
P10E	466	493	8.85	7.15	0.00	0.06	1.48	0.00	0.16	1.70	0.19	0.00	7.07	**0.54**
P10F	469	557	13.60	11.48	0.00	0.51	1.48	0.00	0.13	2.12	0.00	0.13	11.24	**0.54**
P10G	343	550	9.60	8.38	0.00	0.04	1.06	0.00	0.13	1.22	0.28	0.00	14.80	**0.57**
P20A	422	715	30.38	25.59	0.00	4.60	0.00	0.00	0.19	4.79	0.29	0.00	3.82	**0.003**
P20B	332	635	15.27	11.48	0.00	3.64	0.00	0.00	0.15	3.79	0.00	0.00	1.93	**0.003**
P30A	176	623	6.86	4.08	0.09	1.64	1.02	0.00	0.03	2.78	0.00	0.19	1.29	**0.00**
P30B	403	559	11.69	4.54	0.00	0.29	2.29	4.48	0.09	7.15	0.00	1.64	4.10	**0.00**
P30C	68	536	1.70	1.27	0.00	0.01	0.38	0.00	0.03	0.43	0.00	0.00	6.06	**0.00**
P40A	312	635	13.73	10.31	0.02	3.22	0.12	0.00	0.06	3.42	2.18	0.13	2.68	**0.002**
P40B	264	570	8.18	7.68	0.00	0.32	0.06	0.00	0.13	0.50	0.00	0.16	5.08	**0.002**
P40C	342	616	14.02	11.51	0.00	0.69	0.12	1.55	0.16	2.51	0.66	0.22	1.67	**4.05**
P40D	246	666	13.28	11.96	0.00	1.07	0.06	0.06	0.13	1.32	0.03	0.00	1.42	**0.00**
Total			**173.05**	**135.29**	**0.16**	**16.81**	**12.78**	**6.34**	**1.67**	**37.76**	**3.66**	**3.50**		***4.63**

1 INTRODUCTION

1.1 Scope of Report

The report outlines the streamflow hydrology and system yield analysis for the P Region as a deliverable of the hydrology and yield analysis work module. It is a supporting report for the Albany Coast Water Resources Situation Assessment Study.

The objectives of the hydrology and system yield yield analysis were to generate streamflow sequences and determine water availability at the outlet of all quaternary catchments within the P Region and to determine yield at selected strategic points, which include existing dam sites under current and raised dam conditions, as well as at new proposed dam sites.

The water resources situation assessment study was carried out at a reconnaissance level of detail. The hydrology and yield analysis were supposed to be determined at the same level. However, due to the current and future benefits of using a system model, the Water Resources Yield Model (WRYM) was configured to determine available surplus in the study area (P region). This was undertaken at the consultants' cost to provide realistic estimates and facilitate future water resources assessments for the P region. The hydrology was determined at a reconnaissance level using available WR90 data.

This report, Work Module Streamflow Hydrology and Yield Supporting Report has the following sections:

- Section 2: Hydrometereological Data, which discusses the rainfall, evaporation and streamflow records data for the area and how they were used in the work module study.
- Section 3: Landuse, which discusses the irrigation and afforestation data sources and requirements, and impoundments data.
- Section 4: Natural Streamflow and Present Day Streamflow, which presents the natural and present day streamflow traits at the outlets of all quaternary catchments within the P Region.
- Section 5: Reserve, which presents the results of the desktop Reserve determination at the outlets of each quaternary catchment within the P Drainage Region.

- Section 6: System Yield Analysis, which discusses the approach used in configuring the WRYM and presents the yield results at the quaternary catchment outlets, selected specific points and for different scenarios at the selected points.
- Section 7: Reconciliation with the National Water Resources Strategy (NWRS), which compares the results from this study and that from the NWRS. Reasons for the differences are given.
- Section 8: The conclusions from the above tasks.

1.2 Description of the study area

The entire P Drainage Region forms the study area. It is located to the north east of Port Elizabeth and comprises the DWAF Quaternary catchments P10 A-G, P20 A-B, P30 A-C and P40 A-D, **Figure 1 of Annexure A** The study area is located between the catchments of the Great Fish River, the Sundays River and the Indian Ocean.

The P drainage Region has a total catchment area of 5322 km^2. The natural Mean Annual Runoff (MAR) is quoted as 174 X 10^6 m^3 in the recent overview of Water Resources Availability and Utilisation Study by BKS (2003). The present day MAR is 135 X 10^6 m^3.

The area has several small dams, with Settlers Dam, Sarel Hayward and New Years Dam being the biggest with full supply capacities of 5.6, 2.5 and 4.7 X 10^6 m^3, respectively. Other small dams include Jameson / Milner, Golden Ridge, Mansfield, and Mt Wellington, each with a capacity of less than 1 X 10^6 m^3.

The towns of Alicedale, Grahamstown, Riebeck East, Paterson and Alexandria are located inland while Richmond, Cannon Rocks, Bathurst, Kenton on Sea and Port Alfred are located on the east coast of the region. Kowie, Kariega and Bushmans rivers are the three major rivers in the catchment, with the latter being the biggest of the three. The small towns in the catchment rely on these rivers with additional water coming from the Fish River through the existing transfer scheme augmenting the supply to Grahamstown.

The year 2001 rural and urban population for the catchment was 19 638 and 118 892 as per Census 2001, respectively. Urban water consumption is 6.34 X 10^6 m^3 per annum. Alien vegetation impact on runoff and irrigation water requirements are the highest in the area standing at 16.81 X 10^6 m^3 per annum and 12.8 X 10^6 m^3 per annum, respectively. The total annual water requirements (inclusive of evaporation losses) of 41.3 X 10^6 m^3 in the area represent about 24% of the MAR.

2 HYDROMETEOROLOGICAL DATA

2.1 Rainfall

The Mean Annual Precipitation (MAP) for the quaternary catchment is shown in Table 2.1. This is based on the Surface Water Resources of South Africa Study (WRC, 1990). The MAP ranges from 386 to 715 mm. It is lowest in inland areas and highest in the coastal areas. Quaternary catchment P20A has the highest MAP.

Table 2.1: Rainfall

Quaternary	MAP (mm	Quaternary	MAP (mm)	Quaternary	MAP (mm)	Quaternary	MAP (mm)
P10A	600	P20A	715	P30A	623	P40A	635
P10B	531	P20B	635	P30B	559	P40B	570
P10C	386			P30C	536	P40C	616
P10D P10E	432 493					P40D	666
P10F	557						
P10G	550						

The figures in the above table were used in subsequent tasks for determining the yield of each quaternary catchment and at selected points. The rainfall data covers the record period from 1920 to 1990.

However, a search of rainfall stations in and around the study area was carried out, stations with long records of rainfall data were identified. The data could not be sourced due to cost and study limitations. The rainfall figures used in the study could be improved with acquisition of the rainfall data from these stations. **Figure 2** of **Annexure A** shows some of the good rainfall stations, which are located inside the study area

2.2 Streamflow

There are three streamflow gauging stations within the study area with significant records, **Figure 4 of Annexure A**. These are P1H003, P3H001 and P4H001 with data starting from 1957, 1970 and 1969, respectively. The records are above 90% or more complete for all three stations from the recording commencement dates, see **Annexure E**.

These stations are important for the P drainage region and have significant record lengths. The earlier years of measurements are marked by significant missing records. Nevertheless, the records are considered useable for calibration. However, since the hydrology component of the study did not include any extension of hydrology, these were not used for calibration and were also not patched. Studies that will be undertaken at a higher level of detail than this one could use these streamflow records.

2.3 Evaporation

The WRYM was used to determine the available yield at the outlets of all quaternary catchments, Section 7. The WRYM requires the mean monthly S-pan evaporation and S-pan conversion factors to determine lake evaporation. The figures used in the study were obtained from WR90 and are presented in **Table 2.2**.

Table 2.2: Evaporation

Quaternary	Average S-pan evaporation for indicated quaternary catchment (mm)												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Ma	Jun	Jul	Aug	Sep	Total
P10A	147	174	208	214	171	148	107	76	55	59	81	109	1550
P10B	147	174	208	214	171	148	107	76	55	59	81	109	1550
P10C	157	185	222	228	182	157	114	81	58	63	86	116	1650
P10D	152	180	215	221	177	153	111	78	57	61	84	112	1600
P10E	147	174	208	214	171	148	107	76	55	59	81	109	1550
P10F	147	174	208	214	171	148	107	76	55	59	81	109	1550
P10G	143	168	202	207	166	143	104	73	53	57	78	105	1500
P20A	159	183	207	198	151	130	90	65	51	58	86	122	1500
P20B	168	181	209	197	153	133	92	72	54	63	93	135	1550
P30A	147	174	208	214	171	148	107	76	55	59	81	109	1550
P30B	143	168	202	207	166	143	104	73	53	57	78	105	1500
P30C	143	168	202	207	166	143	104	73	53	57	78	105	1500
P40A	143	168	202	207	166	143	104	73	53	57	78	105	1500
P40B	143	168	202	207	166	143	104	73	53	57	78	105	1500
P40C	138	163	195	200	160	138	100	71	51	56	76	102	1450
P40D	138	163	195	200	160	138	100	71	51	56	76	102	1450

Pan factors for converting S-pan to lake evaporation

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
0.81	0.82	0.83	0.84	0.88	0.88	0.88	0.87	0.85	0.83	0.81	0.81

3 LANDUSE

3.1 Irrigation

Irrigation within the study area comprises private irrigation and irrigation schemes. The following regional irrigation schemes are in the study area:

- Ndlambe
- Ntabethemba
- Ncora
- Fish-Sunday Canal (extends outside the study area)
- Zanyokwe and
- Tyme (small portion inside the study area)

The details of the areas under irrigation were provided by UWP. They obtained the figures from Fish to Tsitsikama Water Management Area Overview of Water Resources Availability and Utilisation Report (BKS, 2003) and are shown in **Figures 3 and 5 of Annexure A** According to the report, an area of 13.2 km^2 is irrigated in a year with sufficient water and this may reduce to 6.65 km^2 in an average year. Landsat (CSIR) gave an irrigation area of 27.09 km^2. It was decided to use the figure of 13.2 km^2 until this could be checked with reliable Water Use Authorisation and Management System (WARMS) information. However, the scenarios with an irrigation area of 6.65 km^2 were also assessed using the WRYM model to determine the available yields of the quaternary catchments.

The programme Irrdem was used to generate irrigation demand distributions for different quaternary catchments. There were no limits on irrigation that were allowed for in the programme. The irrigation was assumed to be 75% efficient. It was also assumed that the current development levels applied over the entire simulation period. The irrigation demands were calculated using the irrigation distribution in **Figure 3.1**. The irrigation requirements are presented in **Table 3.1** below.

Table 3.1: Irrigation Water Requirements

Quaternary	Irrigation (10^6m^3)	Quaternary	Irrigation (10^6m^3)	Quaternary	Irrigation (10^6m^3)	Quaternary	Irrigation (10^6m^3)
P10A	0.42	P20A	0	P30A	1.02	P40A	0.12
P10B	1.60	P20B	0	P30B	2.29	P40B	0.06
P10C	0.90			P30C	0.38	P40C	0.12
P10D	1.81					P40D	0.06
P10E	1.48						
P10F	1.48						
P10G	1.06						

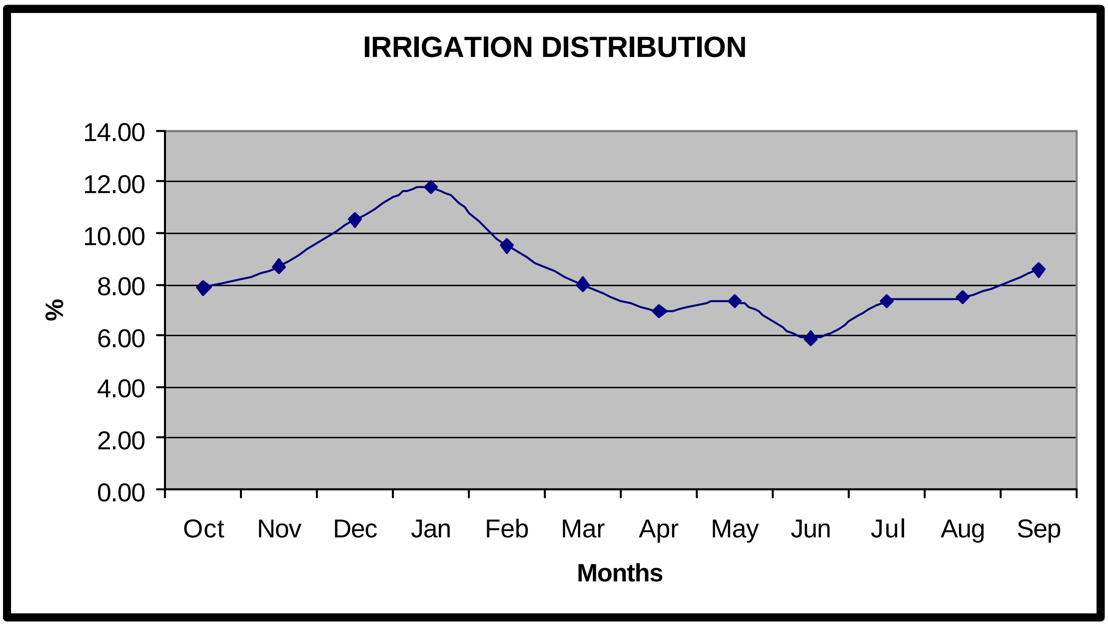


Figure 3.1: Irrigation Distribution used for the P Drainage Region

3.2 Dams

The study area has several dams, all of which have a capacity smaller than 6 X 10^6m^3. The details of these are shown in Table 3.3 below per quaternary catchment and their spatial distribution depicted in **Figure 5 of Annexure A** The farms dams were all lumped together as a dummy dam, one for each quaternary catchment, except P40C and P40D, which had 2 dummy dams each. UWP provided the Full Supply Areas and Full Supply Volumes for all the farm dams. An arbitrary bottom level point (also dead storage level) was estimated and the dam depth calculated by dividing volume by area.

Table 3.2: Dam Details

Quaternary	Dam name	Live Depth (m)	Full Supply Volume (10^6 m^3)	Full Supply Area (km^2)
P10A	Jameson / Milner	3.00	0.84	0.28
P10A	P10A Dummy	4.80	0.72	0.15
P10B	New Years Dam	15.30	4.7	0.96
P10B	P10B Dummy	3.50	0.56	0.16
P10C	P10C Dummy	1.86	0.06	0.07
P10D	P10D Dummy	3.50	0.21	0.06
P10F	P10F Dummy	4.32	0.82	0.19
P10G	P10G Dummy	4.30	0.08	0.02
P30A	P30A Dummy	4.45	1.38	0.31
P30B	Settlers Dam	17.81	5.6	1.01
P30B	P30B Dummy	2.74	6.3	2.3
P40A	P40A Dummy	4.45	0.89	0.20
P40B	P40B Dummy	3.75	0.6	0.16
P40B	Golden Ridge	5.38	0.399	0.125
P40C	P40C Dummy 1	2.67	0.12	0.05
P40C	P40C Dummy 2	2.67	0.12	0.05
P40C	Sarel Hayward	13.90	2.522	0.301
P40C	Mansfield	4.25	0.17	0.04
P40D	Mt Wellington Dam	12.50	0.25	0.02
P40D	P40D Dummy 1	3.50	0.04	0.01
P40D	P40D Dummy 2	3.50	0.04	0.01

3.3 Afforestation

According to the BKS (2003) report and Water situation Assessment Model (WSAM) there are only three quaternaries that contain afforestation / commercial timber, P10A, P30A and P40A. The area under afforestation is 6.29 km^2. A third source, the CSIR satellite imagery, gives a figure of 16.88 km^2 under commercial timber, which is spread throughout the P Drainage Region, **Figure 6 of Annexure A** The BKS and WSAM figures were used in this study. Like irrigation, the complete and reliable WARMS data should be used to check these figures.

The WRYM requires monthly afforestation runoff reduction figres for the entire simulation period. To produce these, the Affdem programme was used. The rotation period was fixed at 20 years since the catchment is not a high potential area. The rotation periods of

30 years in slow growing areas and 15 years in fast growing areas are generally used as default in South Africa. It was assumed that the current development levels applied on the entire simulation period. The runoff reductions due to afforestation are shown in Table 3.3 below.

Table 3.3: Afforestation Requirements

Quaternary	Afforestation ($10^6 m^3$)
P10A	0.05
P30A	0.09
P40A	0.02
Total	**0.16**

3.4 Alien Vegetation

The condensed areas under alien vegetation were used to calculate the runoff reduction due to alien vegetation. The areas were taken from the Water Situation Assessment Model (WSAM) and are shown below in Table 3.4, together with the runoff reductions for each quaternary catchment. The SHELL model was used to determine the runoff reductions. The alien vegetation type was considered to be tall shrubs of age varying from 4 to 20 years. These were further split into % riparian short and % upland long for each quaternary catchment. The current development was assumed to be applicable throughout the simulation period.

Table 3.4: Alien Vegetation Runoff Reductions

QUAT	Area (km^2)	Age	Runoff Reductions ($10^6 m^3$)
P10A	5.27	10	0.38
P10B	4.51	10	0.30
P10D	0.26	5	0.04
P10E	0.78	5	0.06
P10F	11.2	10	0.51
P10G	0.41	4	0.04
P20A	51.1	10	4.60
P20B	57.19	20	3.64
P30A	22.12	20	1.64
P30B	5.49	10	0.29
P30C	0.38	5	0.01
P40A	40.11	20	3.22
P40B	5.62	10	0.32
P40C	10.98	10	0.69
P40D	13.51	10	1.07
Total	**228.93**		**16.81**

3.5 Urban and stock water requirements and return flows

The urban and stock water requirements and return flows are shown in Table 3.5 below. These exclude the supply from groundwater, which is the main source for meeting rural water requirements. Abstractions from quaternary P30B for Grahamstown (P40A) represent 70% of urban requirements in the P drainage Region. P40A has the highest return flows of 2.18 X 10^6 m^3 due to the effluent from Grahamstown and the surrounding areas. The return flows from the coastal towns flow into the Indian Ocean and have little impact on water available for use.

Table 3.5: Urban and stock water requirements

Quaternary	Urban $10^6 m^3/a$)	Stock ($10^6 m^3/a$)	Return flow ($10^6 m^3/a$)
P10A	0.00	0.03	0.00
P10B	0.25	0.13	0.03
P10C	0.00	0.03	0.00
P10D	0.00	0.09	0.00
P10E	0.00	0.16	0.19
P10F	0.00	0.13	0.00
P10G	0.00	0.13	0.28
P20A	0.00	0.19	0.29
P20B	0.00	0.15	0.00
P30A	0.00	0.03	0.00
P30B	4.48	0.09	0.00
P30C	0.00	0.03	0.00
P40A	0.00	0.06	2.18
P40B	0.00	0.13	0.00
P40C	1.55	0.16	0.66
P40D	0.06	0.13	0.03
Total	**6.34**	**1.67**	**3.66**

4 NATURAL AND PRESENT DAY STREAMFLOW

The monthly natural streamflow sequences were obtained from WR90 and the present day streamflow sequences for each quaternary catchment outlet are presented in **Annexure C** of this report. The electronic flow duration curves for the sequences are also available in the accompanying report on CD . The MARs of the natural and present day flow sequences are shown below in Table 4.1.

The present day sequences were taken at the outlet of each quaternary using the WRYM, which is discussed in Section 6. Incremental naturalised flow sequences were input into the catchment, all development requirements taken out and the quaternary outlet channel flow sequences then used to give present day flow sequences.

Table 4.1: Natural and Present Day Runoff (Incremental)

Quaternary	Natural MAR (mm)	Natural MAR ($10^6 m^3/a$)	Present day MAR ($10^6 m^3/a$)
P10A	36	4.54	3.66
P10B	24	12.19	9.91
P10C	8.5	2.39	1.46
P10D	12	6.77	4.83
P10E	19	8.85	7.15
P10F	29	13.60	11.48
P10G	28	9.60	8.38
P20A	72	30.38	25.59
P20B	46	15.27	11.48
P30A	39	6.86	4.08
P30B	29	11.69	4.54
P30C	25	1.70	1.27
P40A	44	13.73	10.31
P40B	31	8.18	7.68
P40C	41	14.02	11.51
P40D	54	13.28	11.96
Total		**173.05**	**135.29**

5 RESERVE

The Reserve was determined by the RDM Office of DWAF at the outlet of each quaternary catchment using SPATSIM. The produced Reserve Flow Duration Curves were used in the WRYM model. These are shown in **Annexure D**. The location of the Instream Flow Requirements is shown in the WRYM Schematics.

The Reserve figures used in this study are therefore based on the desktop level of determination. There is no Reserve implementation plan that has been drafted for the P Region. Consequent thereof, quarternary catchment yields were determined with and without Reserve implementation.

6 SYSTEM YIELD ANALYSIS

6.1 Approach

6.1.1 Quaternary catchments

The WRYM was used to determine the yield at the outlet of the quaternary catchments and at three dam sites. The WRYM is widely used in South Africa for systems analysis and once configured, it provides a robust tool for scenario analysis characteristic of water resources planning. The model was configured using the information discussed in Section 3 above and two scenarios, with and without the reserve, were configured and analysed.

The system configuration schematics are shown in **Annexure B** for the P10, P20, P30 and P40 tertiary catchments / systems. These depict the characteristics of each system, showing where dams are located, irrigation takes place, abstractions occur and IFR sites are located. The digital 1:50 000 maps for the study area were used to augment information discussed above, and to identify where various water use activities and abstractions were taking place.

The incremental historic firm yield of the uppermost catchment in each distinct system was first calculated. Once this was done the yield channel was moved to the next downstream catchment outlet to calculate the cumulative yield. This was repeated until the bottom quaternary catchment outlet was reached. The Instream Flow Requirements (IFR) were given priority over other uses for the scenario that included the supply of IFR.

In addition the WRYM was setup to determine the historic firm yield at three dam sites, namely the existing Sarel Hayward and Golden Ridge dams, and the proposed Bushfontein Dam, which were identified as potential development options.

6.1.2 Sarel Hayward Dam

The dam is an existing off-channel storage dam in P40C and is fed by a pump scheme from Kowie River. Yield was determined for a range of pump rates: 150, 200, 250 and 300 litres/second. The objective was to determine the new storage level required to give a yield , with the Reserve supplied, in the range of 2.95 – 4.28 X $10^6 m^3$ at an optimum pump rate and not raising the dam by more than say 10-15 m. The historic firm yield was therefore determined for the current storage capacity of 2.52 X $10^6 m^3$ and future raised dam with 3.41 and 5.12 X $10^6 m^3$ capacity. The elevation-capacity and area curves for the dam are in **Annexure F** and were provided by UWP.

6.1.3 Bushfontein Dam

Bushfontein Dam is a proposed dam on the Bushmans River in quaternary catchment P10G and has a catchment area of 2 465 km^2. The objective was to determine the storage capacity required to give a yield in the range of 1.35 – 2.68 X $10^6 m^3/a$ with the reserve supplied. The yield results are reported in Section 6.2. The elevation-capacity and area curves for the dam are in **Annexure F** and were provided by UWP.

6.1.4 Golden Ridge Dam

Golden Ridge Dam is on the Lushington River and has a 32 km^2 catchment. The objectives were to determine its historic firm yield at present Full Supply Level and the required storage to give a historic firm yield of 0.42 X $10^6 m^3$. The elevation-capacity and area curve for the dam is in Annexure E and was provided by UWP.

6.2 Results

The WRYM was run for the scenarios described in the approach above and historic firm yield determined. The yield results for the quaternary catchments, Sarel Hayward, and Bushfontein dams are given below in **Tables 6.2, 6.3** and **6.4.** The P drainage region / Bushmans catchment has an excess available yield of 7.013 X $10^6 m^3/a$ if the Reserve is not supplied and 4.626 X $10^6 m^3/a$ if the Reserve is supplied.

The catchments that have no excess yield are depicted in **Table 6.2** and in **Figures 7.1a** and **7.1b** of **Annexure A**. These are P10A, P10C, P10D, P30A, P30B, P30C and P40D. The total excess yield is made up of the excess determined at P10G, P20A, P20B, P40C and P40D.

Table 6.2: Yield Results

Quaternary Catchment	Cummulative Yield (X $10^6 m^3/a$)	
	With IFR	Without IFR
P10A	0.00	0.00
P10B	0.19	1.00
P10C	0.00	0.00
P10D	0.00	0.00
P10E	0.54	2.49
P10F	0.54	2.62
P10G	0.57	2.74

P20A	0.003	0.10
P20B	0.003	0.003
P30A	0.00	0.00
P30B	0.00	0.00
P30C	0.00	0.00
P40A	0.002	0.002
P40B	0.002	2.76
P40C	4.05	4.14
P40D	0.00	0.03
TOTAL FOR P DRAINAGE REGION	**4.63**	**7.01**

The historic firm yield of the existing Sarel Hayward Dam is 2.96 X 10^6 m^3/a, which is above the minimum required yield of 2.95 X 10^6 m^3, which is based on the current water requirements. To get a yield of 4.2 X $10^6 m^3$ in order to meet future water requirements, the dam will have to be raised by 9.1 m to a Full Supply Level of 48.0 m.a.s.l. at a pump rate of 250 ls^{-1}, **Figure 6.2**.

A storage capacity of 0.049 X $10^6 m^3$ and 1.919 X $10^6 m^3$ will be required for the proposed Bushfontein Dam to produce yields of 2.32 X 10^6 m^3 and 4.51 X $10^6 m^3$, respectively.

The historic firm yields of Golden Ridge Dam are 0.002 and 0.23 X 10^6 m^3/a with and without Reserve being supplied. The figures are below the required 0.42 X 10^6 m^3/a to meet the water requirements that could be supplied from the Golden Ridge Dam (Main Report). The catchment area for the dam is very small. The stochastic yield was not determined and may possibly be higher for a 98% assurance of supply. However, the results indicate that the Golden Ridge Dam should not be considered for future development options, as this is likely not to be cost effective.

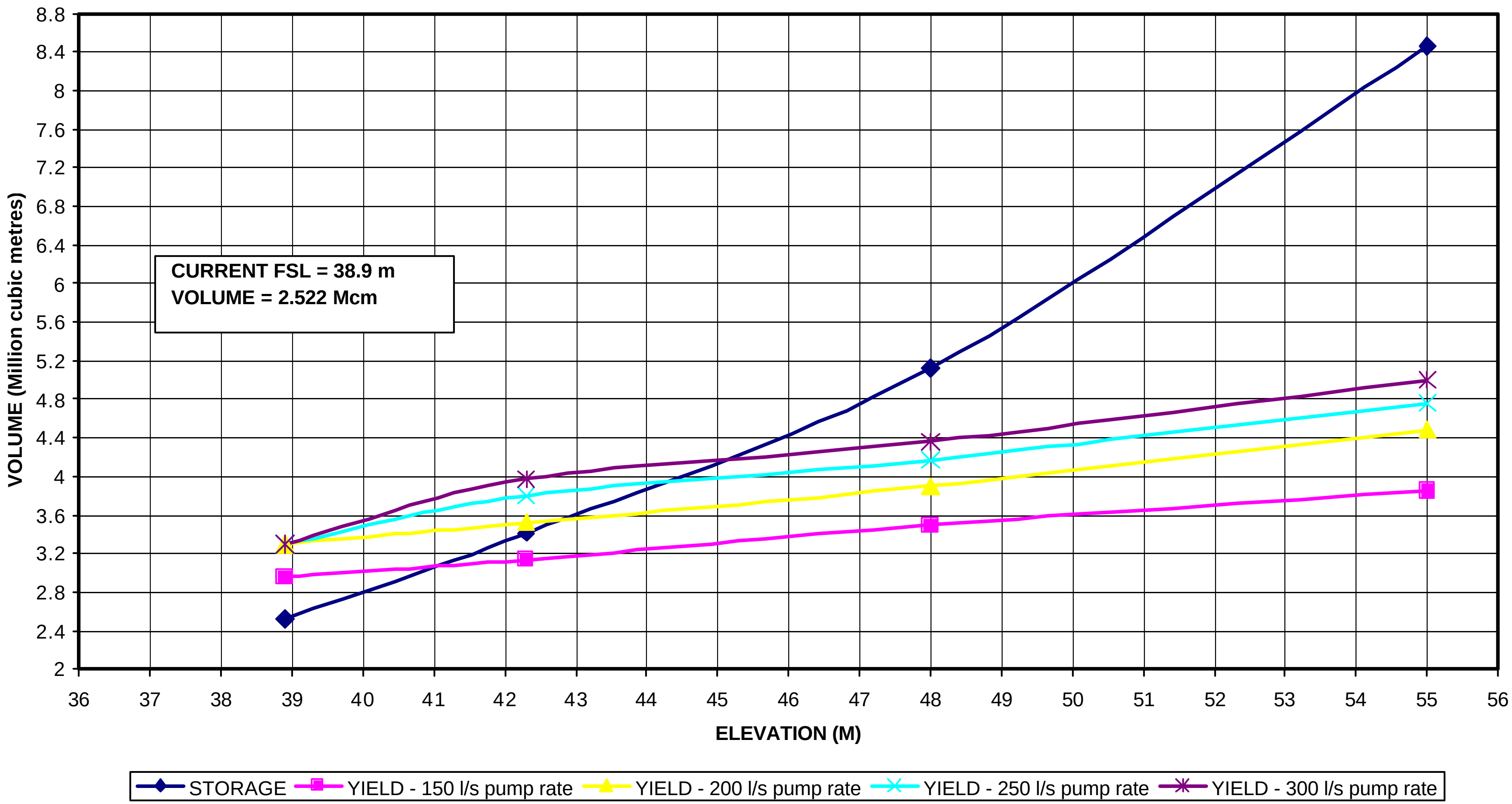
Table 6.3: Sarel Hayward Dam Yield (10^6 m^3/a) after provision for IFR

PUMP RATE	FSL=38.9 m VOL=2.52 X 10^6 m^3	FSL=42.3 m VOL=3.41X10^6 m^3	FSL=48.0 VOL=5.12X10^6 m^3	FSL=55.0 m VOL=8.46X10^6 m^3
150	2.96	3.14	3.49	3.85
200	3.30	3.52	3.90	4.48
250	3.30	3.80	4.17	4.76
300	3.30	3.97	4.36	5.00

Table 6.4: Proposed Bushfontein Dam yield ($10^6 m^3/a$)

DSL (m)	FSL (m)	Capacity ($X10^6 m^3$)	Yield Without IFR ($X10^6 m^3$)	Yield With IFR ($X10^6 m^3$)
290.2	298	1.919	6.11	4.51
286.3	288	0.049	4.35	2.32

Fig 6.2: SAREL HAYWARD DAM - YIELD @ DIFFERENT RAISED LEVELS AND PUMP RATES



7 RECONCILIATION WITH NWRS

The P Drainage Region, the study area, is referred to as the Bushmans catchment in the Fish to Tsitsikama Water Management Area Overview of Water Resources and Utilisation as well as in the National Water Resources Strategy Document.

The figures used in this study and results thereof are different from those in the NWRS. This study used the WRYM to model each quaternary catchment using the actual urban water requirements. Furthermore, the Shell Model, Irrdem and Affdem programmes were used to determine the alien vegetation, irrigation and afforestation requirements and distribution. The Reserve flow duration curves were also used at the outlet of each quaternary catchment as opposed to using a single monthly or annual Reserve estimate. The NWRS requirements are at year 2000 development levels and include the human Reserve component at 25 l/c/d whereas the urban requirements for this study are at 2001 development levels.

The irrigation water requirements are reported to be 11 X $10^6 m^3$ in the NWRS and were determined to be about 13 X $10^6 m^3$ in this study.

The yield figures given at the outlet of each quaternary are the historic firm yield, whereas those in the NWRS are at 98% assurance levels.

The comparison of the results is presented in **Table 7.1**. The NWRS reports that the Bushmans catchment is in balance, with 0 excess / deficit after adding the groundwater yield. According to **Table 6.2**, the results of this study, the Bushmans Catchment has an overall surplus yield of 4.63 X 10^6 m^3. This surplus yield is specifically available at the quaternaries shown in **Figure 7.1** of **Annexure A**, P10G, P20A, P20B, P40C and P40D. The quaternary catchments that have no surplus yield are also shown in **Table 6.2**. The figures of this study have not added the groundwater yield, as the focus was surface water hydrology. It is logical that the excess yield will increase if groundwater yield is added. The groundwater yield is covered in a separate Groundwater Work Module Supporting Report for the same parent study.

Table 7.1: Comparisons of NWRS and This Study Figures

Description	NWRS	This Study	Comments
Irrigation (X 10^6m^3)	11	12.78	
Urban (X 10^6m^3)	9	6.34	NWRS figure includes human reserve component @ 25 l/c/d, This Study figure is actual abstractions and excludes supply from groundwater.
Rural (X 10^6m^3.)	2	1.67	NWRS figure includes human reserve component @ 25 l/c/d, This Study figure is only stock watering. Rural requirements were assumed to be diffuse and supplied from groundwater
Total requirements	**22**	**20.79**	
REDUCTION IN RUNOFF (X 10^6m^3)			
Alien vegetation	17	16.81	
Afforestation	0	0.16	
RESERVE ((X 10^6m^3/a)			
Reserve	15	Reserve Flow Duration Curves	Quaternary Reserve Flow Duration Curves at all quarternary catchment outlets were used in this Study's WRYM to determine yield
BALANCE			
Surplus/ Deficit (X 10^6m^3)	**0**	**4.63**	Reserve supplied in both cases, In NWRS Excess yield = yield determined before supplying requirements minus requirements and impact on yield by runoff reduction activities , whereas in this study Excess yield = yield at the catchment outlet after supplying all requirements including Runoff Reduction Activities and Reserve using Reserve Flow Duration Curves

The biggest difference between the NWRS and this Study's results is the available yield. The water requirements are fairly similar. The difference is attributed to the approaches and level of detail used in determining the yield, as explained in **Table 7.1** above.

8 CONCLUSIONS

The P Drainage Region has a natural and present day MAR of 173 X 10^6 m^3 and 135 X 10^6 m^3, respectively. The Region has an excess yield of 4.63 X 10^6 m^3, mainly available in quaternary catchments P10 and P40C. The surplus yield in P40C accounts for 87% of the total surplus yield. The summary of the results of the study are captured in **Table 8.1** overleaf

One of the development options that was assessed was the raising of the Sarel Hayward Dam. The Dam can be raised and the required yield attained to cater for increased water requirements. A storage capacity of about 5.12 x 10^6 m^3 will provide the maximum required yield of 4.28 x 10^6 m^3/a. The current storage capacity is 2.522 x 10^6 m^3 and has a yield of 2.96 x $10^6 m^3$/a.

A robust WRYM configuration for the Region was created for the study and is available for scenario analyses, improvement and future use in studies of the same and better level of investigation.

Table 8.1: Results summary(Figures in $10^6 m^3$/annum unless specified otherwise)

Quaternary	AREA (km^2)	MAP (mm)	Natural MAR	Present day MAR	Affore station	Alien Veg.	Irrigation	Urban	Stock	Total Consumptive Use	Return flow	Dam net evap. losses	IFR (accum) average	Balance
P10A	126	600	4.54	3.66	0.05	0.38	0.42	0.00	0.03	0.88	0.000	0.189	0.82	**0.00**
P10B	508	531	12.19	9.92	0.00	0.30	1.60	0.25	0.13	2.27	0.032	0.789	3.53	**0.19**
P10C	281	386	2.39	1.46	0.00	0.00	0.90	0.00	0.03	0.93	0.000	0.032	0.41	**0**
P10D	564	432	6.77	4.83	0.00	0.04	1.81	0.00	0.09	1.94	0.000	0.032	3.156	**0**
P10E	466	493	8.85	7.15	0.00	0.06	1.48	0.00	0.16	1.70	0.189	0.000	7.069	**0.54**
P10F	469	557	13.60	11.48	0.00	0.51	1.48	0.00	0.13	2.12	0.000	0.126	11.235	**0.54**
P10G	343	550	9.60	8.38	0.00	0.04	1.06	0.00	0.13	1.22	0.284	0.000	14.801	**0.57**
P20A	422	715	30.38	25.59	0.00	4.60	0.00	0.00	0.19	4.79	0.287	0.000	3.818	**0.003**
P20B	332	635	15.27	11.48	0.00	3.64	0.00	0.00	0.15	3.79	0.000	0.000	1.925	**0.003**
P30A	176	623	6.86	4.08	0.09	1.64	1.02	0.00	0.03	2.78	0.000	0.189	1.294	**0**
P30B	403	559	11.69	4.54	0.00	0.29	2.29	4.48	0.09	7.15	0.000	1.641	4.102	**0**
P30C	68	536	1.70	1.27	0.00	0.01	0.38	0.00	0.03	0.43	0.000	0.000	6.059	**0**
P40A	312	635	13.73	10.31	0.02	3.22	0.12	0.00	0.06	3.42	2.178	0.126	2.682	**0.002**
P40B	264	570	8.18	7.68	0.00	0.32	0.06	0.00	0.13	0.50	0.000	0.158	5.081	**0.002**
P40C	342	616	14.02	11.51	0.00	0.69	0.12	1.55	0.16	2.51	0.663	0.221	1.673	**4.05**
P40D	246	666	13.28	11.96	0.00	1.07	0.06	0.06	0.13	1.32	0.032	0.000	1.42	**0**
Total	**5322**		**173.05**	**135.29**	**0.16**	**16.81**	**12.78**	**6.34**	**1.67**	**37.76**	**3.66**	**3.50**	***29.69**	***4.626**

* added tertiary outlets figures

9 REFERENCES

BKS (2003) Fish to Tsitsikama Water Management Area, Overview of Water Resources and Utilisation. Department of Water affairs and Forestry Report No. WMA 15/000/00/0203.

DWAF (2004). Personal communications with Mr E Nel.

UWP (2004), UWP. Personal communications with Messrs R Louwrens and C Doudenski

Water Research Commission, 1994. Surface Water Resources of South Africa 1990. WRC Report No 298/6.1/9.4

ANNEXURE A

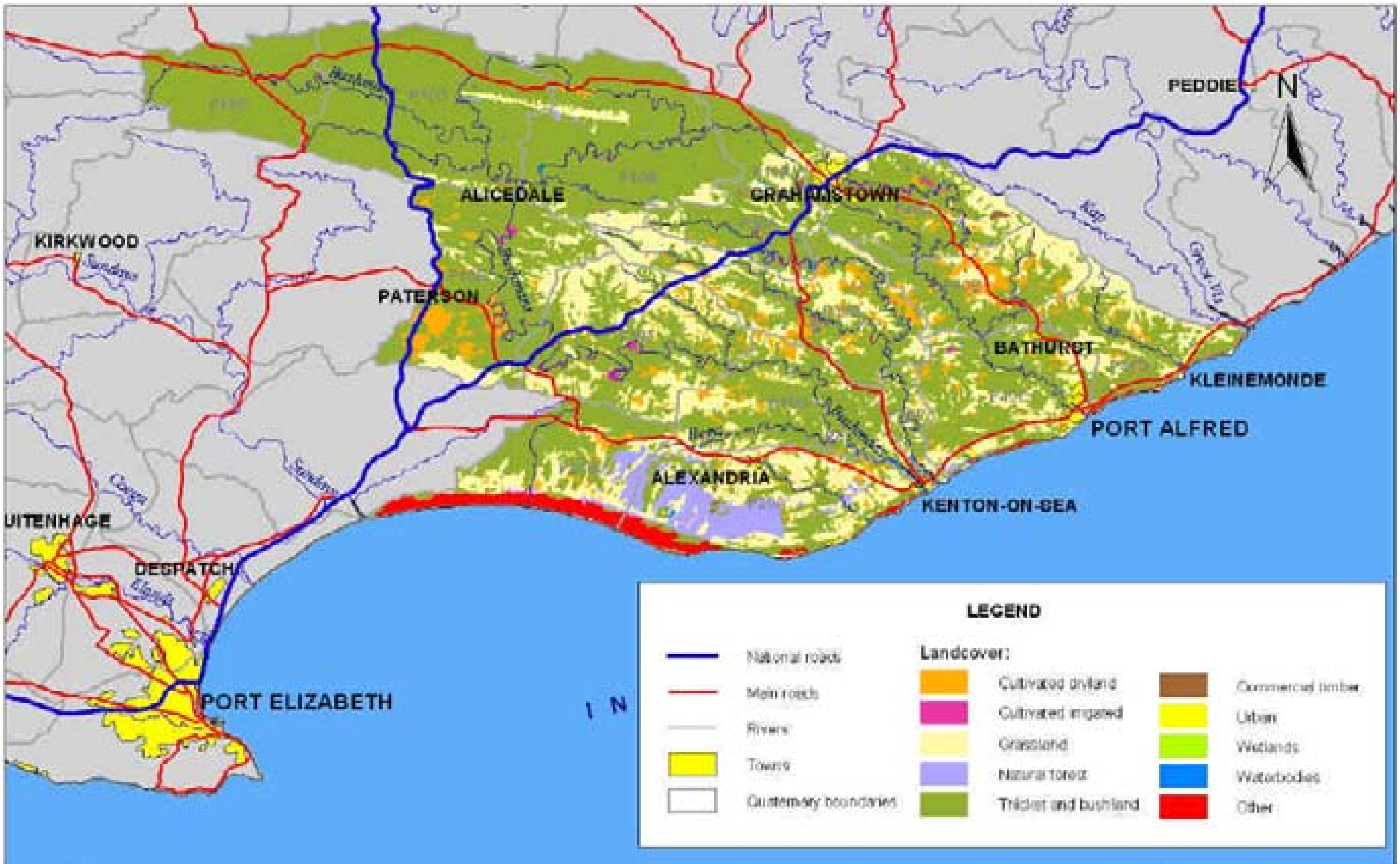
MAPS

ALBANY COAST SITUATION ASSESSMENT STUDY

FIG 1 : GENERAL LOCALITY MAP OF STUDY AREA

ALBANY COAST SITUATION ASSESSMENT STUDY

FIG 2 : POSITION OF RAINFALL STATIONS



ALBANY COAST SITUATION ASSESSMENT STUDY

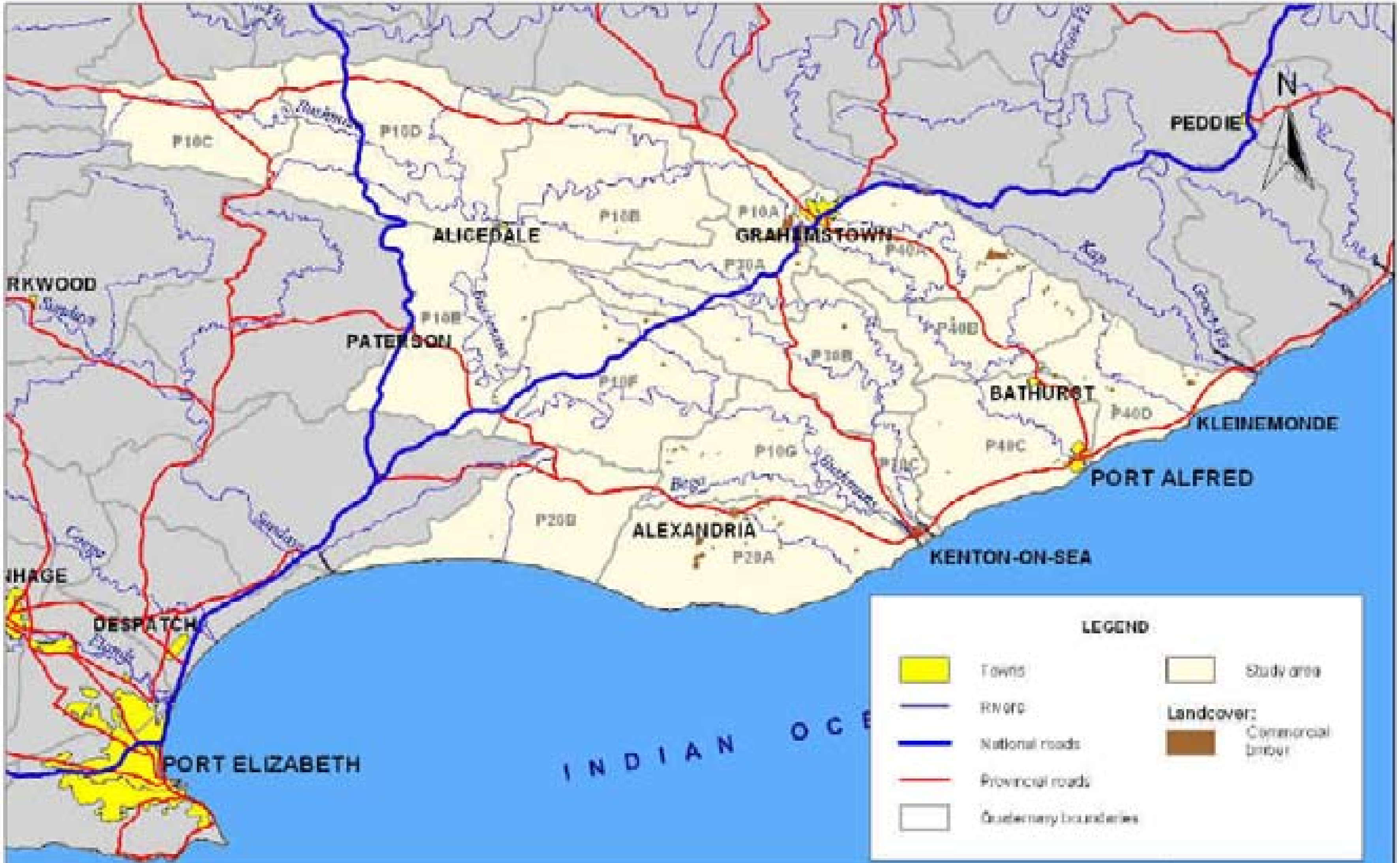
FIG 3 : LANDCOVER

ALBANY COAST SITUATION ASSESSMENT STUDY

FIG 4 : POSITION OF STREAMFLOW GUAGING STATIONS

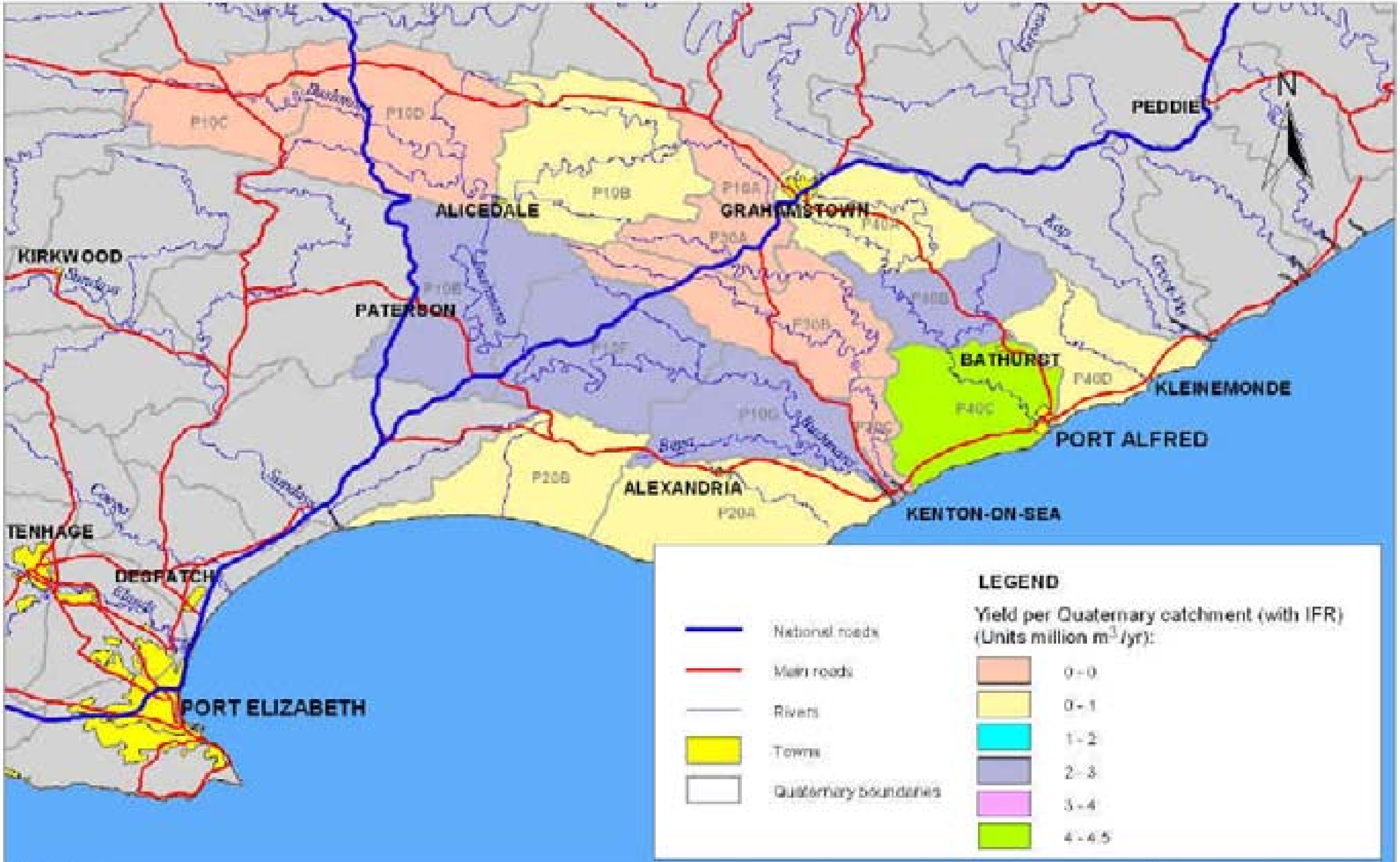
ALBANY COAST SITUATION ASSESSMENT STUDY

FIG 5 : WATERBODIES AND IRRIGATION



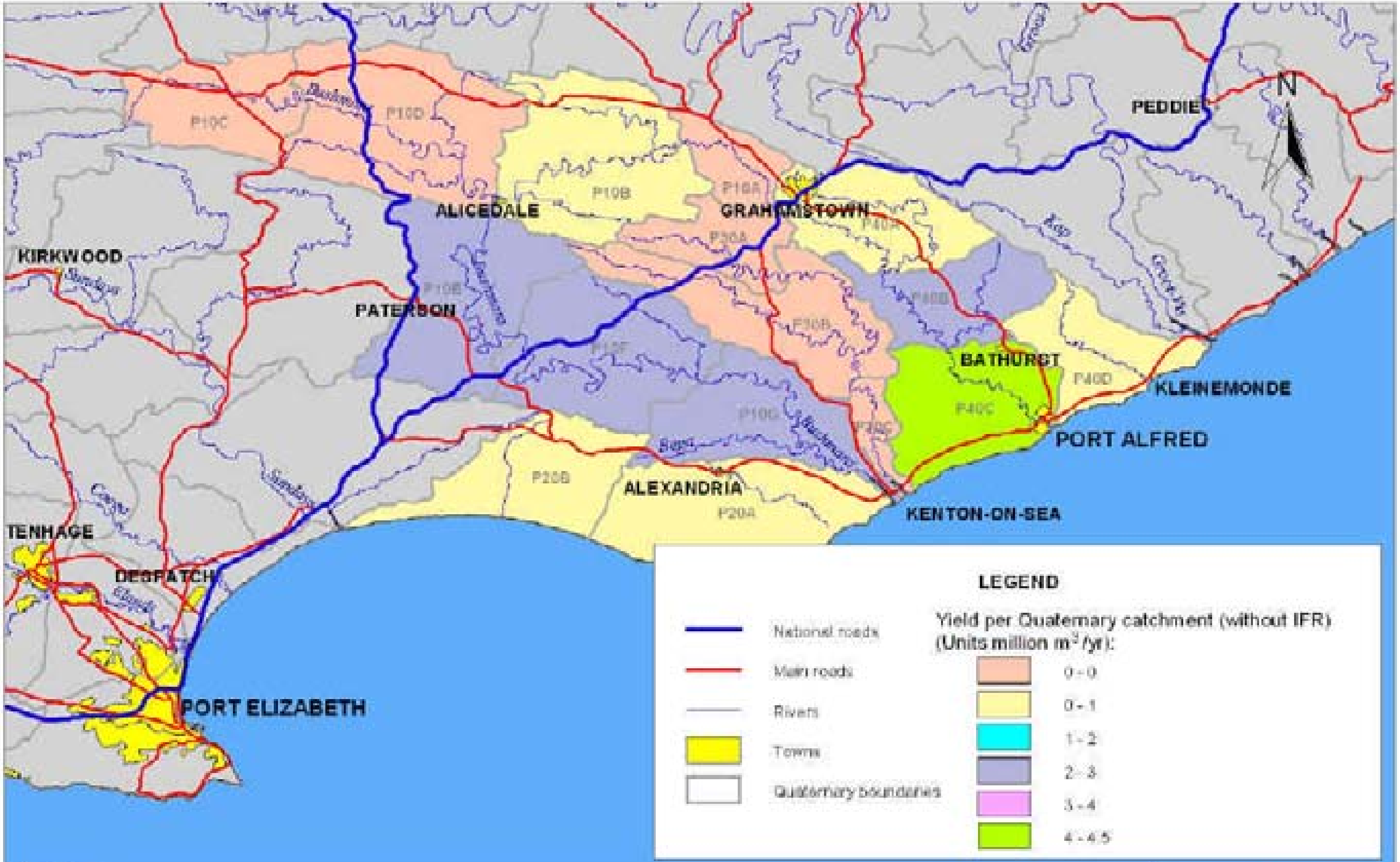
ALBANY COAST SITUATION ASSESSMENT STUDY

FIG 6 : COMMERCIAL TIMBER



ALBANY COAST SITUATION ASSESSMENT STUDY

FIG 7.1a SURPLUS YIELD PER QUATERNARY CATCHMENT (WITH IFR)

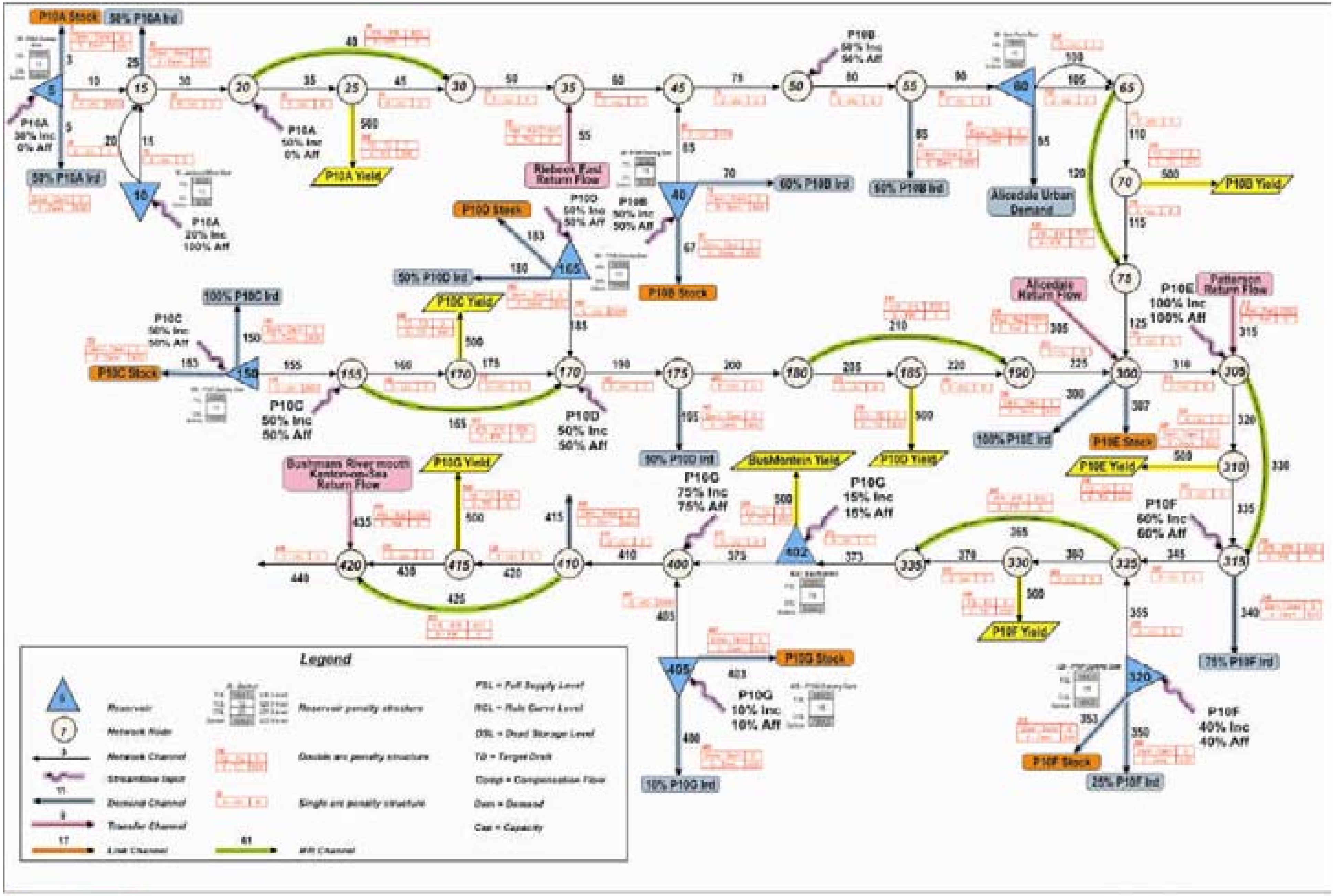


ALBANY COAST SITUATION ASSESSMENT STUDY

FIG 7.1b SURPLUS YIELD PER QUATERNARY CATCHMENT (WITHOUT IFR)

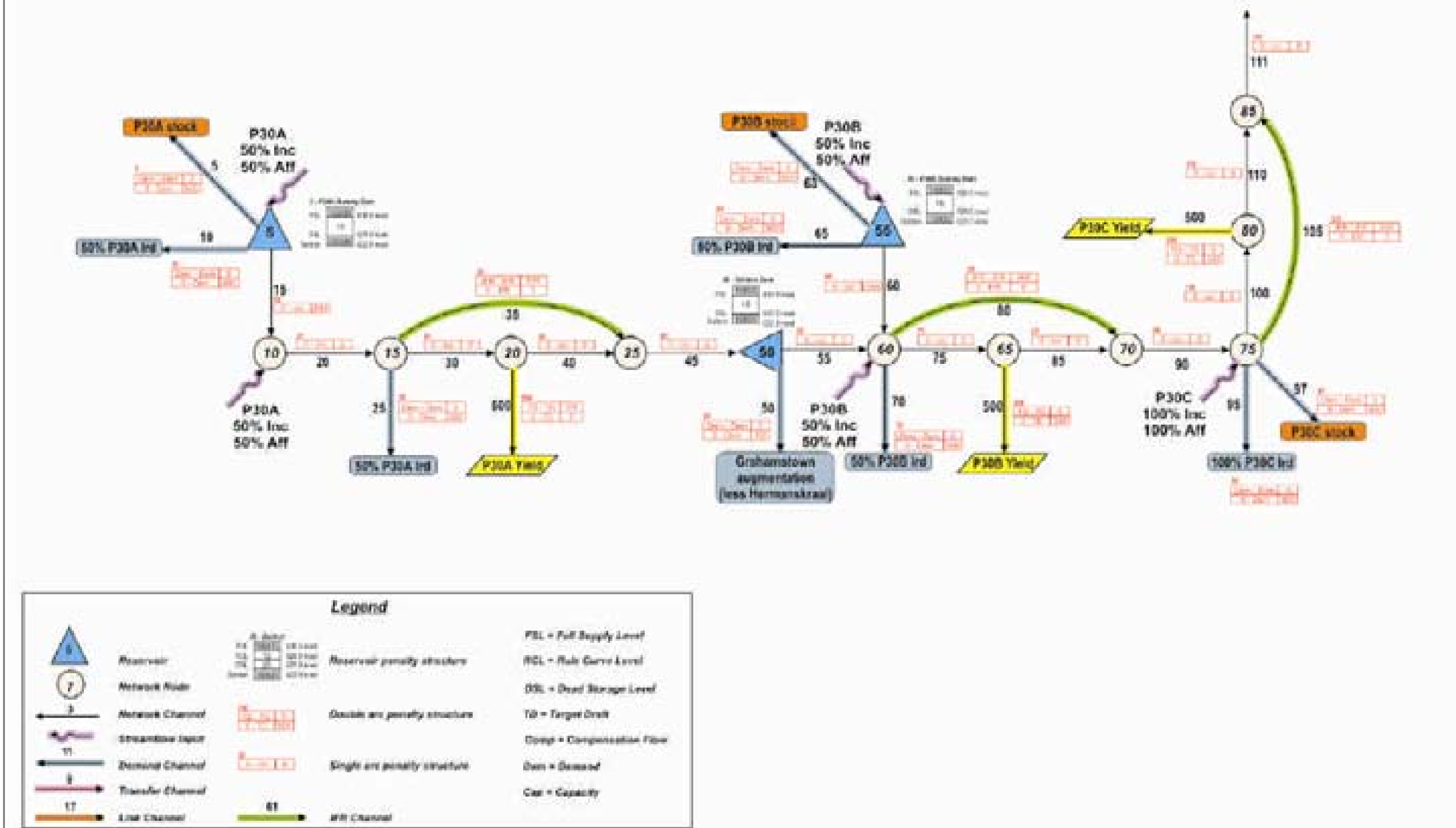
ANNEXURE B

WRYM SCHEMATICS

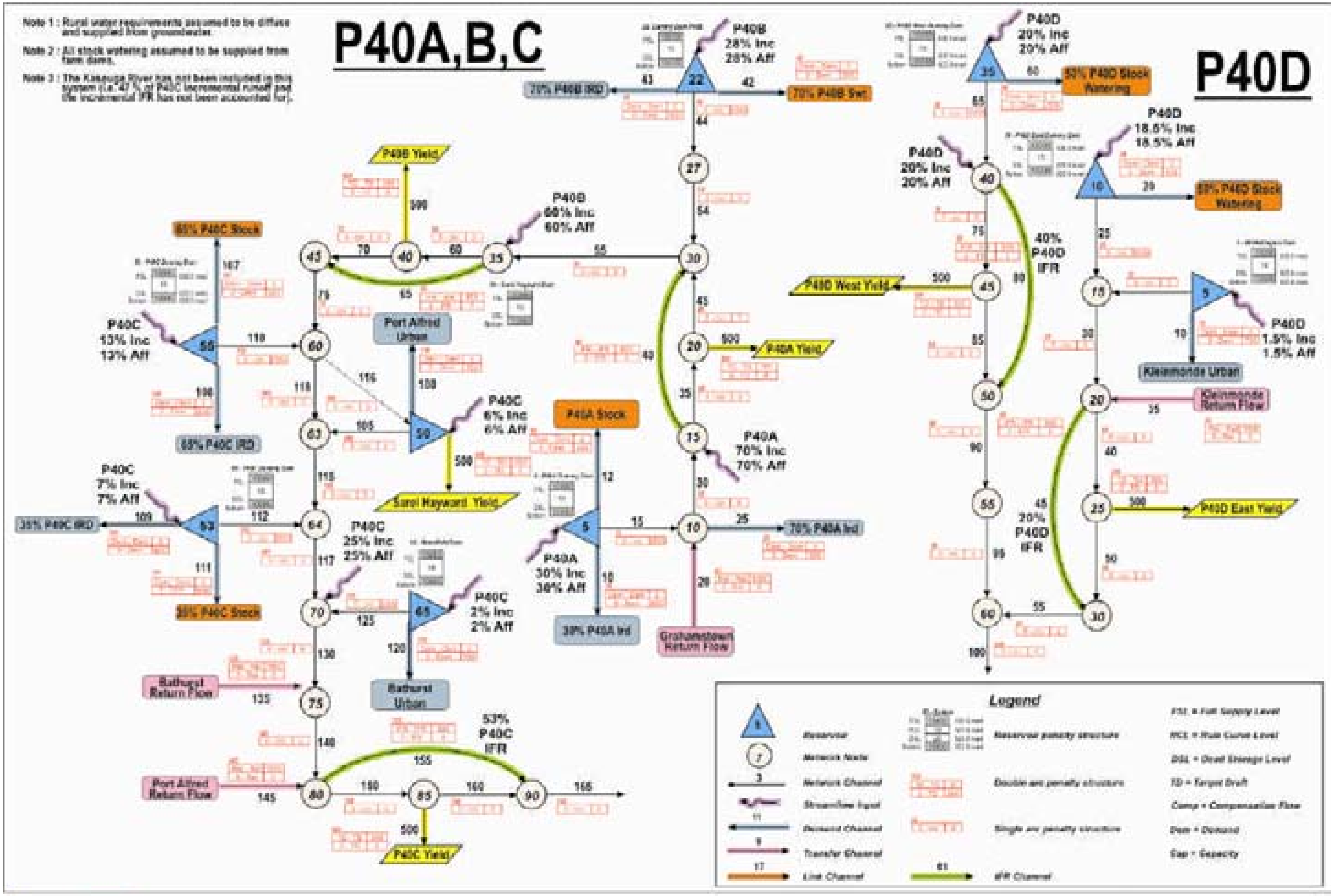


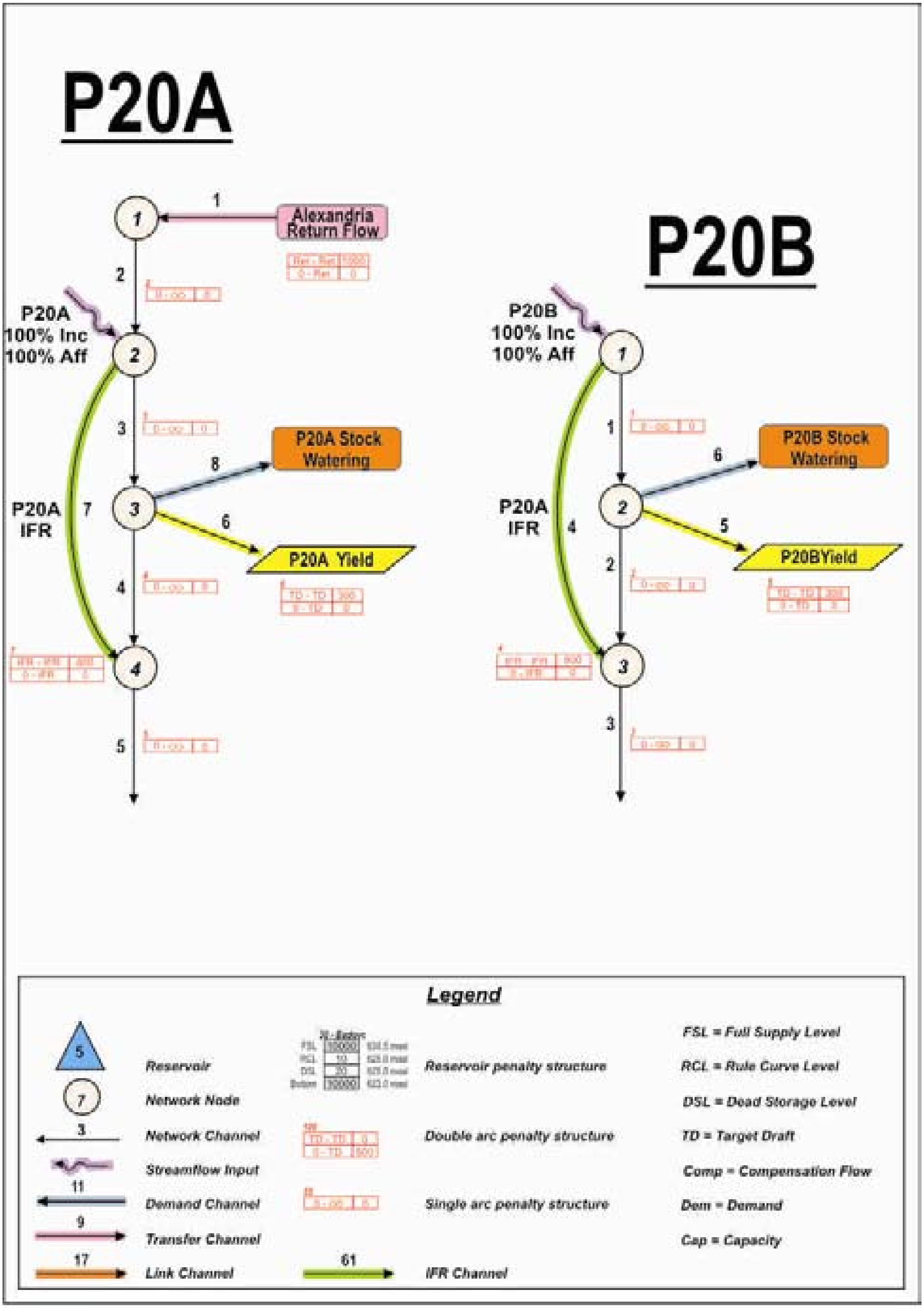
ALBANY COAST SITUATION ASSESSMENT STUDY

SYSTEM SCHEMATIC FOR P10 TERTIARY CATCHMENT



P30A stock
P30A
50% Inc
50% Aff
50% P30A Ird
P30A
50% Inc
50% Aff
50% P30A Ird
P30A Yield
P30B stock
P30B
50% Inc
50% Aff
50% P30B Ird
Grahamstown augmentation (less Hermanskraal)
P30B
50% Inc
50% Aff
50% P30B Ird
P30B Yield
P30C Yield
P30C
100% Inc
100% Aff
100% P30C Ird
P30C stock
Legend
Reservoir
Network Node
Network Channel
Streamflow Input
Demand Channel
Transfer Channel
Loss Channel
Reservoir penalty structure
Double arc penalty structure
Single arc penalty structure
IFR Channel
FSL = Full Supply Level
RCL = Rule Curve Level
DSL = Dead Storage Level
TD = Target Draft
Ccomp = Compensation Flow
Dem = Demand
Cap = Capacity


Note 1 : Rural water requirements assumed to be diffuse and supplied from groundwater.
Note 2 : All stock watering assumed to be supplied from farm dams.
Note 3 : The Kasouga River has not been included in this system (i.e. 47 % of P40C incremental runoff and the incremental IFR has not been accounted for).
P40A,B,C
P40D
P40B 28% Inc 28% Aff
70% P40B IRR
70% P40B Swt
P40B Yield
P40D 60% Inc 60% Aff
60% P40C Stock
P40C 13% Inc 13% Aff
Port Alfred Urban
P40C 6% Inc 6% Aff
60% P40C IRR
P40C 7% Inc 7% Aff
30% P40C IRR
Sarel Hayward Yield
P40C 25% Inc 25% Aff
P40C 2% Inc 2% Aff
30% P40C Stock
Bathurst Return Flow
Bathurst Urban
Port Alfred Return Flow
53% P40C IFR
P40C Yield
P40A Stock
P40A 30% Inc 30% Aff
30% P40A Ind
P40A 70% Inc 70% Aff
70% P40A Ind
Grahamstown Return Flow
P40A Yield
P40D 20% Inc 20% Aff
50% P40D Stock Watering
P40D 20% Inc 20% Aff
P40D 18.5% Inc 18.5% Aff
50% P40D Stock Watering
40% P40D IFR
P40D West Yield
P40D 1.5% Inc 1.5% Aff
Kleinmonde Urban
Kleinmonde Return Flow
20% P40D IFR
P40D East Yield
Legend
Reservoir
Network Node
Network Channel
Streamflow Input
Demand Channel
Transfer Channel
Link Channel
Reservoir penalty structure
Double arc penalty structure
Single arc penalty structure
IFR Channel
FSL = Full Supply Level
RCL = Rule Curve Level
DSL = Dead Storage Level
TD = Target Draft
Comp = Compensation Flow
Dem = Demand
Cap = Capacity



ALBANY COAST SITUATION ASSESSMENT STUDY

SYSTEM SCHEMATIC FOR TERTIARY CATCHMENT P20

ANNEXURE C

PRESENT DAY FLOW SEQUENCES

C1. P10 A FLOW SEQUENCES

C2. P10B FLOW SEQUENCES

C3. P10C FLOW SEQUENCES

C4. P10D FLOW SEQUENCES

C5. P10E FLOW SEQUENCES

C6. P10F FLOW SEQUENCES

C7. P10G FLOW SEQUENCES

C8. P20A FLOW SEQUENCES

C9. P20B FLOW SEQUENCES

C10. P30A FLOW SEQUENCES

C11. P30B FLOW SEQUENCES

C12. P30C FLOW SEQUENCES

C13. P40A FLOW SEQUENCES

C14. P40B FLOW SEQUENCES

C15. P40C FLOW SEQUENCES

C16. P40D FLOW SEQUENCES

P10A : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0	0.005	0.065	0.017	0.03	0.101	0.192	0.061	0.011	0.008	0	0	0.041
1921	0	0.21	0.095	0.011	0.011	0	0	0.023	0.325	0.896	0.177	0.008	0.147
1922	0	1.369	0.407	0.03	0.016	0	0	0.002	0.004	0.017	0.006	0	0.153
1923	0	0	0.019	0.019	0.027	0	0	0.002	0.002	0.003	0	0	0.006
1924	0	0.006	0.022	0.011	0.023	0.027	0.042	0.017	0.015	0.012	0.002	0.01	0.015
1925	0.006	0	0.009	0.013	0.002	0	0.003	0.001	0.008	0.006	0	0	0.004
1926	0.011	0.061	0.015	0.009	0.002	0	0	0	0.001	0.002	0	0	0.008
1927	0	0.001	0	0.002	0.002	0.711	0.447	0.004	0.004	0.004	0	0.031	0.101
1928	0.056	0.007	0.004	0.015	0.007	0	0.009	0.01	0.004	0.008	0.006	0	0.011
1929	0.11	0.007	0	0.01	0.027	0.062	0.03	0.001	0.017	0.012	0.016	0.011	0.025
1930	0.17	0.049	0.009	0.023	0.013	0	0.056	0.019	0.004	0.058	0.022	0.002	0.036
1931	0.091	0.02	0.475	0.226	0.024	0	0	0.002	0.001	0.005	0	0.792	0.136
1932	0.389	0.122	0.017	0.026	0.024	0	0.009	0.006	0.002	0.003	0	0.02	0.052
1933	0	0.026	0.009	0.043	0.097	0.106	0.08	0.006	0.006	0.052	0.021	0	0.037
1934	0.096	0.028	0.009	0.03	0.021	0.01	0.079	1.403	0.534	0.025	0.029	0.05	0.194
1935	0.021	0.069	0.014	0.019	0.165	0.066	0.008	0.008	0.006	0.017	0.004	0	0.032
1936	0.182	0.933	0.253	0.018	0.023	0	0	0.01	0.004	0.002	0	0	0.118
1937	0	0.011	0.079	0.063	0.022	0.014	0.027	0.006	0.004	0.005	0	0	0.019
1938	0.035	0.115	0.021	0.01	0.187	0.128	0.042	0.004	0.004	0.022	0.04	0.035	0.053
1939	0.101	0.022	0.003	0.024	0.047	0.022	0.104	0.004	0.004	0.005	0	0.011	0.029
1940	0.006	0	0.018	0.01	0.02	0	0.067	0.027	0.004	0.004	0	0	0.013
1941	0.297	0.121	0.021	0.024	0.011	0	0	0.001	0.004	0.004	0	0	0.041
1942	0.052	0.026	0.002	0.012	0.021	0	0	0.002	0.071	0.045	0.015	0.004	0.021
1943	0	0.207	0.119	0.012	0.016	0.034	0.016	1.302	0.511	0.035	0.008	0.012	0.191
1944	0.004	0	0.019	0.01	0.016	0	0.009	0.012	0.019	0.012	0	0	0.008
1945	0	0	0.021	0.032	0.023	0	0.091	0.002	0.002	0.004	0	0	0.014
1946	0.033	0.009	0	0.013	0.005	0.025	0.019	0.001	0.004	0.014	0.002	0	0.01
1947	0.028	0.018	0.002	0.015	0.032	0	0.747	0.256	0.01	0.014	0.002	0	0.093
1948	0	0	0.019	0.018	0.018	0	0.007	0.002	0.001	0.004	0	0	0.006
1949	0	0.086	0.027	0.021	0.002	0	0	0.008	0.006	0.004	0.002	0	0.013
1950	0.121	0.181	0.127	0.351	0.082	0	0	0.01	0.001	0.01	0.002	0	0.074
1951	0.079	0.005	0.018	0.011	0.095	0.015	0.005	0.006	0.006	0.005	0.006	3.899	0.341
1952	1.248	0.003	0.003	0.024	0.009	0	0.011	0.012	0.001	0.004	0.02	0	0.113
1953	4.171	1.603	0.052	0.008	0.028	0.039	0.096	0.006	0.006	0.008	0.006	0.015	0.507
1954	0.004	0.007	0.001	0.011	0.024	0	0.005	0.002	0.001	0.003	0	0	0.005
1955	0	0.103	0.031	0.028	0.028	0	0	0.006	0.004	0.003	0	0	0.017
1956	0.073	0.079	0.062	0.012	0.078	0.03	0.006	0.001	0.002	0.004	0	0	0.029
1957	0	0.006	0.021	0.011	0.006	0	0	0.081	0.032	0.008	0	0	0.014
1958	0.013	0.002	0.012	0.036	0.02	0.017	0.078	0.024	0.008	0.169	0.023	0.01	0.035
1959	0	0	0.011	0.013	0.005	0	0.014	0.01	0.008	0.006	0	0.004	0.006
1960	0.006	0.009	0	0.021	0.022	0.039	0.03	0.038	0.017	0.006	0.002	0	0.016
1961	0	0	0.011	0.002	0.013	0.037	0.117	0.014	0.006	0.004	0	0	0.017
1962	0.036	0.023	0	0.18	0.058	0.479	0.978	0.213	0.013	0.017	0.006	0	0.167
1963	0.027	0.009	0.006	0.01	0.184	0.033	0	0.002	0.21	0.073	0.028	0.059	0.052
1964	0.017	0	0.004	0.013	0.023	0.004	0	0.004	0.019	0.018	0.006	0.002	0.009
1965	0.203	0.277	0.058	0.007	0.013	0.013	0.009	0.002	0.001	0.002	0	0	0.049
1966	0	0.024	0.004	0.026	0.011	0.017	0.031	0.619	0.237	0.038	0.016	0.004	0.086
1967	0	0	0.018	0.032	0.03	0	0.047	0.02	0.13	0.058	0.009	0.8	0.094
1968	0.268	0	0.011	0.032	0.022	0.079	0.046	0.002	0.006	0.005	0	0	0.04
1969	0	0	0.019	0.034	0.024	0	0.011	0.012	0.006	0.004	0.215	0	0.027
1970	0.021	0.007	0.677	0.191	0.084	0.013	0.05	0.027	0.011	0.015	2.343	0.505	0.333
1971	0.037	0.009	0	0.007	0.013	0	0.007	0.002	0.002	0.003	0	0	0.007
1972	0	0	0.018	0.032	0.042	0.001	0.028	0.015	0.008	0.004	0.006	0	0.013
1973	0	0.039	0.036	0.121	0.352	2.362	0.978	0.073	0.041	0.014	0.048	0.058	0.344
1974	0.009	0.045	0.008	0.015	0.049	0.013	0.003	0.004	0.004	0.004	0	0.899	0.086
1975	0.315	0.007	0.105	0.024	0.027	0.347	0.28	0.022	0.011	0.027	0.008	0	0.099
1976	0.247	0.1	0.006	0.021	0.921	0.128	0.023	0.185	0.073	0.014	0	0	0.138
1977	0	0.089	0.064	0.012	0.023	0	0.028	0.014	0.006	0.005	0	0	0.02
1978	0.033	0.022	0.028	0.04	0.036	0	0	0.006	0.008	5.045	5.038	0.82	0.937
1979	0.006	0	0.018	0.036	0.024	0.002	0.007	0.01	0.001	0.003	0	0	0.009
1980	0	0.031	0.008	0.012	0.047	0.05	0.156	0.225	0.093	0.017	0.023	0.015	0.056
1981	0.1	0.038	0.015	0.005	0.025	0.01	0.036	0.015	0.004	0.017	0.006	0.016	0.024
1982	0.009	0	0.019	0.032	0.025	0.015	0.009	0.01	0.001	0.086	0.001	0.004	0.018
1983	0.031	0.033	0.004	0.018	0.023	0	0	0	0.002	0.004	0	0	0.009
1984	0	0.003	0	0.012	0.029	0	0	0.001	0.002	0.003	0	0	0.004
1985	0.135	0.182	0.078	0.016	0.013	0.004	0.009	0.012	0.006	0.004	0	0	0.038
1986	0.191	0.117	0.004	0.028	0.007	0	0	0	0.002	0.003	0	0.016	0.031
1987	0.006	0	0	0	0.108	0.01	0.001	0.002	0.002	0.003	0	0.008	0.011
1988	0.008	0.016	0.018	0.005	0.005	0	0.084	0.034	0.006	0.005	0	0	0.015
1989	0.213	2.643	0.855	0.011	0.007	0	0	0.002	0.002	0.003	0	0.003	0.31
AVERAGE	0.133	0.132	0.06	0.033	0.051	0.072	0.075	0.071	0.037	0.1	0.117	0.116	0.083

P10B : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
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1920	0	0	0.316	0.031	0.158	0.699	0.995	0.312	0.067	0.034	0	0	0.218
1921	0	1.178	0.539	0	0.04	0	0	0	1.314	3.651	0.82	0.123	0.643
1922	0	7.321	2.23	0.163	0.021	0.068	0	0.018	0.01	0	0	0	0.814
1923	0	0	0.133	0.072	0	0	0.023	0.018	0.014	0.014	0	0	0.023
1924	0	0.053	0	0.006	0.058	0	0	0	0	0	0	0.041	0.013
1925	0	0	0	0.048	0.115	0	0	0.018	0	0	0	0	0.014
1926	0	0.089	0.03	0.126	0.105	0.084	0.083	0.019	0.017	0.019	0	0.109	0.056
1927	0	0.058	0.123	0.126	0.105	5.498	2.731	0.003	0	0.002	0	0.877	0.797
1928	0	0	0	0.05	0.033	0.041	0.083	0.046	0.014	0	0	0.069	0.028
1929	0.298	0.013	0.007	0.048	0	0.484	0.172	0.017	0.066	0.065	0.121	0.121	0.119
1930	0.772	0.279	0.036	0	0.014	0	0.309	0.102	0.005	0.327	0.149	0.041	0.171
1931	0.419	0.114	2.798	1.329	0.078	0	0	0.019	0.016	0.007	0	4.188	0.749
1932	0.491	0.643	0.051	0.098	0	0	0	0.009	0.011	0.014	0	0.571	0.157
1933	0	0	0	0	0.5	0.923	0.462	0.012	0.012	0.32	0.143	0	0.196
1934	0.442	0.163	0.036	0.135	0.094	0.111	0	6.424	2.355	0.182	0.177	0.795	0.917
1935	0	0	0.015	0.064	0.887	0.524	0.015	0.031	0.019	0.118	0.019	0	0.137
1936	0.822	4.741	1.299	0.05	0.105	0	0	0.046	0.02	0.018	0	0.001	0.589
1937	0	0	0.018	0.384	0.073	0.19	0.157	0.009	0.005	0	0	0.009	0.071
1938	0.124	0.633	0.099	0.023	1.07	0.853	0.24	0.011	0.002	0.153	0.166	0.491	0.316
1939	0.274	0.141	0.021	0.089	0.002	1.23	0.563	0.011	0.006	0.002	0	0.056	0.201
1940	0	0	0.061	0.046	0	0	0.117	0.175	0.007	0.002	0	0.122	0.044
1941	0.301	0.667	0.119	0.118	0.024	0	0	0.018	0.008	0.005	0	0.033	0.108
1942	0	0.133	0	0.048	0.047	0	0	0.019	0.135	0.269	0.115	0.055	0.068
1943	0	1.13	0.714	0	0.01	0.372	0.093	6.036	2.289	0.217	0.077	0.14	0.93
1944	0	0	0.133	0.021	0	0	0.083	0	0	0	0	0.059	0.025
1945	0	0	0.143	0.154	0.105	0	0.027	0.016	0.01	0.008	0	0.077	0.045
1946	0	0	0.006	0.048	0.105	0	0.093	0.017	0.002	0.04	0.006	0	0.026
1947	0.133	0.113	0	0.05	0	0	4.359	1.486	0.051	0.091	0.006	0	0.521
1948	0	0	0.133	0.055	0	0	0.06	0.019	0.017	0.02	0.015	0.164	0.04
1949	0.01	0	0	0.081	0.049	0.111	0.083	0.007	0.008	0.007	0	0	0.03
1950	0	0.664	0.767	2.028	0.478	0	0.033	0.046	0.017	0	0	0.252	0.358
1951	0.363	0	0.112	0.003	0.388	0.201	0	0.012	0.016	0.004	0.051	23.276	2.006
1952	5.281	0	0.012	0.089	0.031	0.076	0.092	0.068	0.015	0.01	0	0.318	0.507
1953	20.992	8.828	0.302	0.04	0.129	0.6	0.532	0.012	0.02	0.032	0.048	0.144	2.662
1954	0	0	0.008	0.014	0	0	0	0.019	0.015	0.014	0	0.09	0.013
1955	0	0.317	0.17	0.126	0.129	0	0	0.01	0.008	0.014	0	0.081	0.07
1956	0.33	0.438	0.342	0	0.463	0.299	0.011	0.018	0.01	0.008	0	0.005	0.158
1957	0	0.059	0.151	0.014	0.039	0.079	0.028	0	0	0	0	0	0.031
1958	0	0	0	0.257	0.046	0.226	0.453	0.134	0.029	1.034	0.237	0.111	0.213
1959	0	0	0.077	0	0.036	0	0	0	0	0	0	0	0.009
1960	0	0	0.006	0	0	0.368	0.176	0.224	0.104	0.014	0.018	0	0.077
1961	0	0	0.086	0.126	0.016	0.257	0.65	0.07	0.016	0.006	0	0.07	0.108
1962	0.022	0.145	0.007	1.012	0.262	5.215	4.509	0.871	0.097	0.122	0.059	0	1.031
1963	0.114	0.025	0	0.048	0.994	0.319	0	0.018	1.153	0.448	0.159	0.654	0.321
1964	0	0	0	0.048	0.105	0.1	0.027	0.012	0	0	0	0	0.024
1965	0	1.355	0.325	0.036	0.041	0.112	0.083	0.018	0.015	0.017	0	0	0.166
1966	0	0	0	0.117	0.04	0	0	2.321	1.093	0.252	0.134	0.075	0.339
1967	0	0	0.112	0.154	0.137	0	0	0	0.517	0.337	0.083	4.486	0.48
1968	0.168	0	0.075	0.148	0	0.37	0.265	0.017	0.002	0	0	0.001	0.088
1969	0	0	0.133	0.155	0	0	0.099	0.068	0.024	0.02	0.722	0.446	0.14
1970	0.093	0.011	3.932	1.13	0.495	0.189	0.294	0.164	0.059	0.104	12.073	3.643	1.868
1971	0.174	0.027	0.003	0.036	0.017	0	0.06	0.019	0.014	0.012	0	0.033	0.033
1972	0	0	0.112	0.154	0	0	0	0	0	0.002	0	0	0.023
1973	0	0	0	0.761	2.059	14.41	4.994	0.37	0.223	0.082	0.342	0.343	1.971
1974	0	0.259	0	0.049	0.121	0.185	0	0.02	0.013	0.007	0	4.656	0.436
1975	0.255	0.031	0.62	0.078	0.127	3.942	1.506	0.116	0.07	0.157	0.06	0	0.586
1976	0.49	0.519	0	0.081	4.869	0.906	0.121	0.962	0.402	0.075	0	0.005	0.676
1977	0	0.42	0.357	0	0.105	0	0	0	0.008	0	0	0.048	0.078
1978	0.046	0.14	0.156	0.246	0.19	0	0.024	0.009	0	28.32	28.52	6.047	5.388
1979	0	0	0.112	0	0.074	0.084	0.052	0.037	0.016	0.015	0	0	0.032
1980	0	0	0	0	0	1.91	0.893	1.311	0.575	0.117	0.184	0.913	0.495
1981	0	0	0	0.04	0.115	0.111	0	0	0.001	0	0	0.151	0.034
1982	0.006	0	0.133	0.154	0.105	0.112	0.083	0.046	0.016	0	0	0	0.055
1983	0	0.128	0	0.052	0.105	0	0.003	0.023	0.014	0.008	0	0.013	0.028
1984	0	0	0.01	0	0	0	0	0.018	0.014	0.013	0	0.129	0.015
1985	0	0	0.328	0.029	0.041	0.093	0.083	0.057	0.024	0.02	0	0	0.057
1986	0	0.088	0	0.126	0.034	0.015	0.06	0.023	0.014	0.013	0	0	0.031
1987	0	0	0.086	0.148	0	0.045	0	0.017	0.011	0.014	0	0	0.027
1988	0	0	0.058	0.04	0.038	0	0.376	0.209	0.016	0	0	0.076	0.067
1989	0.275	14.387	4.381	0.001	0.034	0	0	0.018	0.014	0.015	0.008	0.177	1.599
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AVERAGE	0.467	0.647	0.315	0.157	0.224	0.592	0.375	0.318	0.159	0.527	0.636	0.777	0.434

P10C : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0.006	0.005	0.021	0.008	0.013	0.026	0.095	0.027	0.013	0.01	0.007	0.006	0.02
1921	0.005	0.117	0.036	0.005	0.001	0	0	0.016	0.089	0.086	0.046	0.022	0.035
1922	0.01	0.826	0.243	0.009	0.006	0	0	0.002	0.006	0.014	0.011	0.005	0.094
1923	0.006	0.002	0	0.002	0.011	0	0	0.002	0.004	0.005	0.005	0.005	0.004
1924	0.005	0.001	0.01	0.005	0	0.014	0.021	0.013	0.013	0.014	0.009	0.012	0.01
1925	0.008	0.002	0.002	0.002	0	0.001	0.001	0.004	0.008	0.008	0.005	0.005	0.004
1926	0.01	0.033	0.007	0	0	0	0	0.001	0.002	0.003	0.003	0.003	0.005
1927	0.003	0.001	0	0	0	0.679	0.324	0.007	0.008	0.007	0.005	0.027	0.089
1928	0.027	0.007	0.002	0.002	0.002	0	0	0.001	0.004	0.008	0.009	0.037	0.008
1929	0.067	0.008	0	0.002	0.011	0.018	0.013	0.004	0.013	0.014	0.014	0.014	0.015
1930	0.087	0.024	0	0.008	0.006	0	0.023	0.013	0.006	0.029	0.018	0.01	0.019
1931	0.037	0.012	0.272	0.12	0.01	0	0	0.002	0.002	0.007	0.004	0.297	0.064
1932	0.186	0.064	0.01	0.002	0.01	0	0.005	0.005	0.006	0.005	0.029	0.018	0.029
1933	0.006	0.012	0.004	0.014	0.027	0.044	0.04	0.007	0.008	0.027	0.018	0.006	0.018
1934	0.039	0.014	0	0	0	0	0.046	0.4	0.168	0.036	0.024	0.037	0.064
1935	0.019	0.025	0.007	0.002	0.072	0.026	0.005	0.005	0.008	0.014	0.009	0.005	0.016
1936	0.094	0.482	0.12	0.002	0	0	0	0.001	0.002	0.004	0.003	0.004	0.059
1937	0.005	0.005	0.046	0.019	0.008	0.002	0.01	0.007	0.006	0.007	0.005	0.005	0.01
1938	0.021	0.039	0.011	0.004	0.08	0.069	0.016	0.005	0.006	0.018	0.023	0.026	0.026
1939	0.056	0.016	0	0.002	0.018	0	0.053	0.005	0.006	0.007	0.005	0.01	0.015
1940	0.008	0.002	0	0.002	0.008	0	0.033	0.017	0.008	0.007	0.004	0.003	0.008
1941	0.191	0.069	0.011	0.008	0.004	0	0	0.004	0.006	0.007	0.004	0.004	0.026
1942	0.032	0.016	0.001	0.002	0	0	0	0.002	0.044	0.032	0.014	0.01	0.013
1943	0.006	0.109	0.052	0.007	0.006	0.009	0.008	0.552	0.236	0.036	0.016	0.016	0.088
1944	0.008	0.002	0	0.004	0.006	0	0	0.007	0.015	0.014	0.006	0.004	0.006
1945	0.005	0.002	0	0	0	0.024	0.047	0.005	0.006	0.007	0.004	0.004	0.009
1946	0.019	0.007	0	0.002	0	0.012	0.01	0.004	0.008	0.012	0.007	0.005	0.007
1947	0.017	0.01	0.001	0.002	0.013	0	0.477	0.171	0.013	0.014	0.009	0.005	0.061
1948	0.005	0.002	0	0.002	0.008	0	0	0.002	0.002	0.004	0.003	0.002	0.002
1949	0.003	0.06	0.014	0.002	0.001	0	0	0.005	0.006	0.007	0.006	0.005	0.009
1950	0.1	0.108	0.059	0.195	0.03	0	0	0.001	0.002	0.008	0.006	0.041	0.046
1951	0.052	0.007	0	0.005	0.033	0.003	0.003	0.005	0.008	0.008	0.009	2.068	0.181
1952	0.664	0.012	0	0.002	0.002	0	0	0.001	0.002	0.005	0.014	0.042	0.063
1953	1.683	0.662	0.022	0.004	0	0.016	0.05	0.007	0.008	0.01	0.009	0.016	0.209
1954	0.008	0.005	0	0.004	0.01	0.002	0.003	0.002	0.004	0.005	0.004	0.003	0.004
1955	0.003	0.063	0.014	0	0	0	0	0.005	0.006	0.005	0.003	0.036	0.011
1956	0.049	0.035	0.019	0.007	0.024	0.007	0.005	0.004	0.006	0.007	0.004	0.005	0.014
1957	0.005	0.001	0	0.004	0.001	0	0	0.052	0.033	0.01	0.006	0.005	0.01
1958	0.012	0.003	0.006	0.015	0.008	0.003	0.024	0.014	0.01	0.084	0.05	0.018	0.021
1959	0.007	0.002	0	0.007	0.002	0	0.006	0.009	0.01	0.008	0.006	0.008	0.005
1960	0.008	0.007	0	0.008	0.008	0.018	0.013	0.017	0.015	0.01	0.007	0.005	0.01
1961	0.005	0.002	0	0	0.004	0.027	0.059	0.011	0.008	0.007	0.004	0.004	0.011
1962	0.021	0.012	0	0.075	0.021	0.394	0.434	0.073	0.017	0.018	0.013	0.006	0.091
1963	0.015	0.007	0.002	0.002	0.083	0.008	0	0.002	0.112	0.056	0.018	0.036	0.028
1964	0.015	0.003	0.001	0.002	0	0	0	0.005	0.013	0.018	0.011	0.008	0.006
1965	0.142	0.182	0.021	0.004	0.001	0	0	0.002	0.004	0.004	0.004	0.005	0.031
1966	0.004	0.012	0.002	0	0.001	0.009	0.016	0.218	0.108	0.036	0.02	0.012	0.037
1967	0.007	0.002	0	0	0	0	0.023	0.013	0.071	0.045	0.014	0.135	0.026
1968	0.097	0.007	0	0	0.01	0.038	0.018	0.004	0.008	0.008	0.006	0.005	0.017
1969	0.006	0.002	0	0	0.01	0	0	0.001	0.001	0.003	0.165	0.062	0.021
1970	0.015	0.007	0.408	0.104	0.025	0.002	0.018	0.016	0.012	0.014	0.389	0.081	0.092
1971	0.034	0.008	0.001	0.004	0.004	0	0	0.002	0.004	0.005	0.004	0.004	0.006
1972	0.004	0.002	0	0	0.018	0.002	0.013	0.011	0.01	0.007	0.007	0.006	0.006
1973	0.006	0.022	0.017	0.042	0.2	1.345	0.536	0.038	0.031	0.018	0.046	0.042	0.195
1974	0.014	0.018	0.004	0.002	0.021	0.002	0.001	0.002	0.004	0.007	0.004	0.285	0.03
1975	0.155	0.008	0.027	0.008	0.011	0.209	0.162	0.013	0.013	0.018	0.013	0.005	0.054
1976	0.123	0.048	0.002	0.002	0.546	0.046	0.008	0.076	0.045	0.016	0.007	0.006	0.074
1977	0.005	0.035	0.019	0.007	0	0	0.013	0.009	0.008	0.008	0.005	0.004	0.009
1978	0.019	0.012	0.012	0.013	0.015	0	0	0.005	0.008	3.684	4.635	1.059	0.8
1979	0.023	0.003	0	0.015	0.011	0	0	0.001	0.002	0.004	0.003	0.005	0.006
1980	0.006	0.016	0.002	0.005	0.021	0.059	0.094	0.137	0.066	0.019	0.034	0.018	0.04
1981	0.055	0.018	0.007	0.004	0	0	0.016	0.011	0.006	0.014	0.011	0.016	0.013
1982	0.012	0.002	0	0	0	0	0	0.001	0.002	0.067	0.04	0.01	0.011
1983	0.017	0.014	0.002	0.002	0	0	0	0.002	0.004	0.007	0.005	0.005	0.005
1984	0.004	0.003	0	0.005	0.011	0	0	0.002	0.004	0.005	0.003	0.003	0.003
1985	0.151	0.11	0.025	0.007	0.001	0	0	0.001	0.001	0.003	0.003	0.004	0.026
1986	0.147	0.064	0.002	0	0.002	0	0	0.002	0.004	0.005	0.004	0.014	0.021
1987	0.008	0.002	0	0	0.072	0.007	0.001	0.004	0.006	0.005	0.004	0.008	0.009
1988	0.01	0.01	0.009	0.004	0.001	0	0.034	0.019	0.008	0.008	0.004	0.004	0.009
1989	0.123	1.498	0.44	0.005	0.002	0	0	0.002	0.004	0.005	0.003	0.002	0.173
AVERAGE	0.069	0.072	0.029	0.011	0.022	0.045	0.04	0.03	0.02	0.068	0.085	0.067	0.047

P10D : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0	0	0.111	0	0	0	0.461	0.151	0.036	0.035	0.016	0.016	0.069
1921	0	0.535	0.204	0	0	0	0	0.013	0.524	0.442	0.024	0.025	0.147
1922	0.006	4.247	1.304	0.026	0	0	0	0	0.004	0	0	0.01	0.463
1923	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0.061	0.025	0.041	0.045	0.011	0.018	0.017
1925	0.001	0	0	0	0	0	0	0	0.004	0.01	0	0	0.001
1926	0	0.003	0	0	0	0	0	0	0	0	0	0	0
1927	0	0	0	0	0	4.38	1.666	0.005	0.016	0.006	0	0	0.511
1928	0	0.014	0	0	0	0	0	0	0	0.01	0	0.197	0.018
1929	0	0.024	0	0	0	0	0.027	0	0.029	0.042	0	0.012	0.011
1930	0	0.013	0	0	0	0	0.059	0.029	0.008	0.139	0	0.032	0.023
1931	0	0.019	1.533	0.699	0	0	0	0	0	0.001	0	2.041	0.359
1932	0	0.086	0	0	0	0	0	0	0.002	0	0	0	0.007
1933	0	0.01	0	0.083	0.218	0.102	0.13	0.003	0.017	0.122	0	0.019	0.058
1934	0	0.017	0	0	0	0	0.192	2.011	0.852	0.134	0	0	0.269
1935	0.016	0.009	0	0	0.482	0	0	0	0.014	0.028	0.001	0.01	0.044
1936	0	2.522	0.673	0	0	0	0	0	0	0	0	0	0.264
1937	0	0	0.291	0.156	0	0	0.017	0	0.008	0.01	0	0	0.041
1938	0	0.038	0	0	0.539	0	0.043	0	0.01	0.042	0	0	0.053
1939	0	0.029	0	0	0.038	0.406	0.196	0	0.006	0.006	0	0.007	0.057
1940	0	0	0	0	0	0	0.081	0.072	0.016	0.006	0	0	0.015
1941	0	0.1	0	0	0	0	0	0	0.005	0.003	0	0	0.009
1942	0	0.021	0	0	0	0	0	0	0.259	0.122	0	0.031	0.036
1943	0	0.485	0.301	0	0	0	0.016	2.847	1.191	0.134	0	0.006	0.418
1944	0.002	0	0	0	0	0	0	0	0.015	0.015	0.005	0	0.003
1945	0	0	0	0	0	0.09	0.151	0	0.004	0.001	0	0	0.02
1946	0	0.01	0	0	0	0	0.021	0	0.009	0.035	0.01	0.01	0.008
1947	0	0.014	0	0	0	0	2.481	0.886	0.039	0.04	0.014	0.001	0.288
1948	0	0	0	0	0	0	0	0	0	0	0	0	0
1949	0	0.039	0.001	0	0	0	0	0	0.004	0.001	0	0	0.004
1950	0	0.332	0.335	1.077	0.203	0	0	0	0	0.008	0	0.085	0.171
1951	0	0.009	0	0	0.245	0	0	0	0.013	0.018	0	12.489	1.048
1952	2.907	0.046	0	0	0	0	0	0	0	0	0	0.058	0.255
1953	9.822	4.213	0.114	0	0	0.161	0.17	0.001	0.017	0.032	0	0.001	1.221
1954	0	0.001	0	0	0	0	0	0	0	0	0	0	0
1955	0	0.098	0.005	0	0	0	0	0	0.005	0	0	0.18	0.024
1956	0	0.004	0.078	0	0.169	0	0	0	0.004	0.001	0	0	0.02
1957	0	0	0	0	0	0	0	0.31	0.177	0.035	0.011	0.01	0.046
1958	0.011	0	0	0.106	0	0	0.089	0.041	0.019	0.551	0.095	0.019	0.079
1959	0	0	0	0	0	0	0	0	0.005	0.01	0	0.015	0.003
1960	0	0.01	0	0	0	0	0.03	0.073	0.053	0.026	0.01	0.01	0.018
1961	0	0	0	0	0	0.075	0.232	0.019	0.017	0.002	0	0	0.029
1962	0	0.015	0	0.532	0.072	3.023	2.214	0.394	0.067	0.044	0	0.016	0.534
1963	0	0.01	0	0	0.54	0	0	0	0.654	0.268	0	0	0.119
1964	0.011	0	0	0	0	0	0	0	0.012	0.002	0	0.028	0.004
1965	0	0.877	0.104	0	0	0	0	0	0	0	0	0	0.081
1966	0	0	0	0	0	0	0.04	1.212	0.554	0.131	0	0.032	0.165
1967	0	0	0	0	0	0	0	0.028	0.476	0.197	0	1.062	0.145
1968	0	0.01	0	0	0	0	0.05	0	0.007	0.016	0.01	0	0.008
1969	0	0	0	0	0	0	0	0	0	0	0.96	0.122	0.092
1970	0.006	0.008	2.195	0.622	0.173	0	0.048	0.057	0.029	0.034	2.693	0.812	0.563
1971	0.045	0.023	0	0	0	0	0	0	0	0	0	0	0.006
1972	0	0	0	0	0	0	0.025	0.02	0.019	0.006	0	0.015	0.007
1973	0	0.007	0.04	0.385	1.1	7.596	2.688	0.203	0.151	0.048	0.113	0	1.03
1974	0.028	0.009	0	0	0.032	0	0	0	0	0.001	0	2.001	0.17
1975	0	0.027	0.218	0	0	2.173	0.852	0.027	0.035	0.044	0	0.013	0.285
1976	0	0.032	0	0	2.817	0.155	0.016	0.47	0.243	0.045	0.016	0.017	0.301
1977	0	0.009	0.084	0	0	0	0	0	0.017	0.018	0	0	0.011
1978	0	0.014	0	0.073	0	0	0	0	0.003	18.737	22.131	5.373	3.917
1979	0.063	0	0	0.073	0	0	0	0	0	0	0	0	0.012
1980	0	0	0	0	0.03	1.082	0.455	0.714	0.354	0.057	0	0	0.226
1981	0	0.017	0	0	0	0	0	0.004	0.011	0.03	0	0	0.005
1982	0.016	0	0	0	0	0	0	0	0	0.382	0	0.029	0.036
1983	0.001	0.014	0	0	0	0	0	0	0	0.001	0	0	0.001
1984	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0	0.347	0.139	0	0	0	0	0	0	0	0	0	0.04
1986	0	0.081	0	0	0	0	0	0	0	0	0	0	0.007
1987	0	0	0	0	0.444	0	0	0	0.002	0	0	0	0.035
1988	0.003	0.015	0	0	0	0	0.127	0.088	0.017	0.015	0	0	0.022
1989	0	7.439	2.259	0	0	0	0	0	0	0	0	0	0.803
AVERAGE	0.185	0.313	0.143	0.055	0.101	0.275	0.181	0.139	0.087	0.317	0.373	0.355	0.211

P10E : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0.171	0.167	1.482	0.319	0.518	1.897	3.247	1.124	0.325	0.233	0.182	0.104	0.815
1921	0.165	4.751	2.13	0.139	0.036	0.055	0.051	0.473	4.05	7.818	2.423	0.385	1.882
1922	0.285	26.361	8.421	0.89	0.282	0.025	0.01	0.031	0.088	0.346	0.276	0.033	3.07
1923	0.233	0.027	0.071	0.048	0.333	0.099	0.016	0.031	0.065	0.06	0.119	0.03	0.093
1924	0.108	0.031	0.422	0.147	0.023	1.06	0.797	0.296	0.376	0.313	0.226	0.228	0.338
1925	0.331	0.101	0.205	0.072	0.068	0.334	0.122	0.079	0.138	0.139	0.104	0.069	0.148
1926	0.448	1.249	0.31	0.075	0.062	0.039	0.041	0.031	0.038	0.029	0.025	0.029	0.197
1927	0.05	0.036	0.067	0.075	0.062	24.81	9.785	0.116	0.112	0.094	0.108	0.439	3.006
1928	1.057	0.28	0.185	0.073	0.094	0.02	0.041	0.026	0.207	0.218	0.251	0	0.206
1929	1.995	0.275	0.036	0.055	0.344	1.605	0.667	0.064	0.387	0.345	0.399	0.338	0.545
1930	3.337	1.179	0.028	0.488	0.169	0.112	1.646	0.631	0.092	1.505	0.498	0.271	0.835
1931	2.302	0.71	9.278	4.801	0.472	0.071	0.023	0.023	0.042	0.153	0.115	12.858	2.577
1932	6.652	2.1	0.381	0.06	0.319	0.084	0.392	0.178	0.072	0.06	1.513	0.65	1.046
1933	0.206	0.463	0.153	0.811	1.847	3.419	1.577	0.14	0.139	2.02	0.589	0.084	0.952
1934	1.974	0.687	0.028	0.081	0.056	0.064	2.082	26.172	9.635	0.825	0.601	0.482	3.587
1935	0.585	1.008	0.323	0.043	3.222	1.625	0.19	0.185	0.165	0.471	0.261	0.063	0.663
1936	3.347	15.616	4.552	0.043	0.062	0.082	0.027	0.026	0.022	0.034	0.012	0	1.979
1937	0.134	0.222	1.986	1.475	0.361	0.759	0.568	0.133	0.096	0.106	0.108	0	0.5
1938	0.921	2.21	0.566	0.095	4.454	2.648	0.856	0.105	0.103	0.651	0.695	0.311	1.112
1939	2.149	0.742	0.022	0.056	0.9	4.897	2.008	0.105	0.096	0.105	0.087	0.256	0.954
1940	0.303	0.097	0.022	0.058	0.271	0.048	1.666	0.839	0.123	0.094	0.059	0.037	0.299
1941	7.09	2.446	1.16	0.813	0.133	0.016	0.027	0.064	0.099	0.094	0.074	0	1.012
1942	1.493	0.77	0.063	0.082	0.021	0.066	0.043	0.027	1.828	1.115	0.395	0.21	0.511
1943	0.21	4.484	2.611	0.173	0.223	1.303	0.429	18.966	7.454	0.887	0.376	0.386	3.146
1944	0.346	0.03	0.071	0.097	0.205	0.016	0.041	0.359	0.711	0.349	0.141	0.01	0.198
1945	0.191	0.019	0.078	0.088	0.062	2.631	1.218	0.083	0.08	0.086	0.074	0.017	0.389
1946	0.76	0.239	0.042	0.049	0.062	1.207	0.634	0.061	0.153	0.347	0.224	0.055	0.322
1947	0.75	0.485	0.063	0.043	0.359	0.153	14.461	5.104	0.298	0.386	0.228	0.004	1.851
1948	0.216	0.031	0.071	0.039	0.224	0.025	0.032	0.023	0.038	0.028	0.018	0.07	0.067
1949	0.035	2.339	0.731	0.052	0.032	0.064	0.041	0.13	0.107	0.239	0.25	0.056	0.339
1950	2.805	3.825	2.938	7.058	2.027	0.006	0.021	0.026	0.038	0.205	0.195	0.016	1.6
1951	1.76	0.209	0.062	0.115	2.246	0.826	0.109	0.123	0.148	0.135	0.31	82.368	7.26
1952	27.523	0.268	0.019	0.056	0.109	0.032	0.045	0.042	0.069	0.079	0.267	0	2.418
1953	69.999	28.065	1.436	0.063	0.074	3.716	1.898	0.385	0.253	0.22	0.313	0.388	8.981
1954	0.291	0.204	0.026	0.106	0.302	0.373	0.116	0.027	0.053	0.06	0.042	0.02	0.134
1955	0.045	2.595	0.877	0.075	0.074	0.048	0.018	0.219	0.134	0.06	0.028	0.106	0.355
1956	1.729	1.421	1.255	0.147	2.084	1.209	0.191	0.057	0.08	0.086	0.074	0	0.687
1957	0.116	0.037	0.087	0.106	0.051	0.035	0.016	3.111	1.356	0.195	0.146	0.04	0.445
1958	0.42	0.121	0.207	1.369	0.371	0.97	1.49	0.551	0.199	3.854	1.569	0.362	0.966
1959	0.243	0.007	0.043	0.193	0.086	0.066	0.249	0.183	0.156	0.139	0.137	0.211	0.143
1960	0.348	0.231	0.036	0.428	0.284	1.492	0.66	1	0.537	0.173	0.219	0.036	0.456
1961	0.173	0.058	0.052	0.075	0.154	3	2.286	0.349	0.158	0.09	0.074	0.013	0.542
1962	0.945	0.629	0.036	3.69	1.125	19.856	14.271	2.757	0.455	0.499	0.368	0.075	3.743
1963	0.696	0.256	0.115	0.058	3.625	1.116	0.036	0.031	4.101	1.832	0.461	0.038	1.01
1964	0.635	0.093	0.074	0.049	0.062	0.054	0.019	0.149	0.392	0.368	0.297	0.123	0.194
1965	4.341	6.14	1.486	0.079	0.028	0.066	0.041	0.031	0.053	0.045	0.254	0.052	1.053
1966	0.095	0.43	0.105	0.07	0.036	0.807	0.64	10.066	4.289	1.057	0.46	0.259	1.539
1967	0.227	0.045	0.062	0.088	0.08	0.126	0.76	0.347	5.184	2.242	0.385	9.293	1.556
1968	4.088	0.156	0.046	0.087	0.277	1.649	0.996	0.068	0.123	0.136	0.142	0	0.654
1969	0.199	0.03	0.071	0.091	0.283	0.044	0.054	0.042	0.017	0.025	6.088	0.256	0.608
1970	0.653	0.236	17.089	5.447	1.672	0.713	1.097	0.731	0.322	0.422	28.257	6.232	5.302
1971	1.008	0.312	0.042	0.077	0.185	0.016	0.032	0.023	0.069	0.071	0.074	0	0.159
1972	0.057	0.04	0.062	0.088	0.514	0.491	0.511	0.268	0.167	0.094	0.244	0.083	0.216
1973	0.21	0.826	0.817	2.843	6.596	46.28	16.098	2.004	3.97	1.324	5.407	0.165	7.238
1974	0.428	0.88	0.144	0.053	0.931	0.743	0.111	0.02	0.088	0.094	0.083	13.422	1.396
1975	5.399	0.298	2.113	0.518	0.459	14.73	5.509	0.428	0.335	0.815	0.381	0.062	2.615
1976	4.156	1.82	0.127	0.052	16.17	3.474	0.454	3.865	1.764	0.398	0.182	0.099	2.63
1977	0.161	1.903	2.061	0.335	0.062	0.034	0.753	0.306	0.161	0.134	0.087	0.005	0.501
1978	1.049	0.714	0.636	0.996	0.617	0.081	0.017	0.131	0.147	98.773	106.435	21.908	19.582
1979	0.51	0.085	0.062	0.83	0.383	0.039	0.023	0.021	0.045	0.053	0.051	0.045	0.179
1980	0.223	0.61	0.15	0.216	0.776	11.225	4.286	4.604	2.18	0.529	1.762	0.968	2.309
1981	1.488	0.605	0.264	0.073	0.068	0.064	0.963	0.382	0.103	0.326	0.291	0.39	0.42
1982	0.399	0.07	0.071	0.088	0.058	0.066	0.041	0.026	0.042	4.167	1.471	0.144	0.563
1983	0.598	0.624	0.102	0.036	0.062	0.02	0.009	0.016	0.126	0.105	0.108	0	0.151
1984	0.065	0.152	0.019	0.142	0.327	0.057	0.027	0.042	0.065	0.064	0.023	0.04	0.083
1985	5.143	3.626	1.823	0.272	0.04	0.048	0.041	0.033	0.017	0.025	0.115	0.007	0.939
1986	4.928	1.739	0.113	0.075	0.094	0.004	0.032	0.016	0.088	0.071	0.073	0.191	0.624
1987	0.299	0.054	0.052	0.087	2.696	0.852	0.073	0.068	0.072	0.06	0.047	0.147	0.361
1988	0.359	0.354	0.375	0.076	0.071	0.153	1.799	0.845	0.159	0.119	0.074	0.016	0.367
1989	6.887	46.46	14.099	0.127	0.138	0.155	0.067	0.034	0.084	0.06	0.013	0.087	5.661
AVERAGE	2.693	2.505	1.212	0.54	0.865	2.342	1.409	1.272	0.785	1.976	2.392	2.216	1.69

P10F : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
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1920	0.246	0.3	2.535	0.61	0.853	2.61	5.072	1.753	0.507	0.383	0.279	0.195	1.279
1921	0.261	8.178	3.746	0.253	0.017	0.099	0.101	1.011	6.813	12.719	3.942	0.337	3.138
1922	0.445	46.568	14.97	1.772	0.564	0.002	0.014	0.038	0.16	0.71	0.335	0.062	5.439
1923	0.409	0.06	0.024	0.015	0.602	0.18	0	0.036	0.109	0.103	0.239	0.072	0.152
1924	0.152	0	0.841	0.294	0	1.721	1.467	0.528	0.813	0.588	0.304	0.256	0.584
1925	0.587	0.195	0.473	0.102	0.028	0.705	0.262	0.181	0.27	0.254	0.18	0.123	0.283
1926	0.892	2.19	0.556	0.031	0.024	0.006	0.013	0.04	0.045	0.032	0.059	0	0.324
1927	0.056	0	0.023	0.031	0.024	43.732	16.59	0.203	0.198	0.169	0.192	0	5.15
1928	2.075	0.592	0.473	0.112	0.13	0	0.013	0.004	0.605	0.522	0.313	1.287	0.512
1929	3.345	0.47	0.042	0.035	0.68	2.289	1.105	0.101	0.698	0.568	0.589	0.328	0.858
1930	6.062	2.092	0	0.922	0.303	0.185	3.77	1.401	0.162	2.885	0.896	0.349	1.595
1931	4.439	1.455	15.145	8.461	0.982	0.107	0.027	0.02	0.063	0.394	0.234	25.893	4.774
1932	11.974	3.215	0.647	0.023	0.572	0.15	1.089	0.446	0.124	0.103	3.797	0.102	1.871
1933	0.298	0.844	0.261	1.462	2.894	5.757	2.633	0.243	0.235	4.913	1.539	0.125	1.767
1934	3.251	1.161	0	0.035	0.021	0.017	4.762	58.418	20.886	1.253	1.422	0.012	7.67
1935	0.978	2.089	0.677	0.012	4.915	2.194	0.347	0.389	0.299	0.799	0.336	0.11	1.071
1936	5.698	25.491	7.504	0.016	0.024	0.134	0.046	0.004	0.023	0.052	0.023	0.022	3.243
1937	0.19	0.416	3.676	2.402	0.608	1.307	0.962	0.248	0.17	0.193	0.188	0.017	0.872
1938	1.54	3.841	1.046	0.111	8.578	4.517	1.346	0.187	0.184	1.185	1.178	0	1.933
1939	3.931	1.382	0	0.02	1.716	8.681	3.478	0.183	0.169	0.192	0.153	0.275	1.685
1940	0.51	0.239	0	0.037	0.51	0.089	3.824	1.624	0.221	0.172	0.104	0	0.607
1941	12.846	4.274	3.226	1.787	0.208	0.017	0.036	0.121	0.186	0.169	0.13	0.006	1.939
1942	3.233	1.465	0.088	0.136	0.007	0.095	0.08	0.03	3.679	1.897	0.597	0.285	0.969
1943	0.305	7.654	4.36	0.323	0.421	2.077	0.765	32.968	12.705	1.337	0.512	0.129	5.333
1944	0.643	0.047	0.024	0.101	0.376	0.023	0.013	0.998	2.016	0.81	0.235	0	0.44
1945	0.297	0.027	0.027	0.04	0.024	4.917	2.301	0.137	0.139	0.16	0.131	0	0.689
1946	1.375	0.456	0.046	0.025	0.024	2.194	1.332	0.099	0.365	0.664	0.316	0.09	0.586
1947	1.201	0.777	0.084	0.015	0.712	0.273	23.917	8.368	0.469	0.598	0.309	0.032	3.045
1948	0.401	0.071	0.024	0.009	0.35	0.031	0.007	0.019	0.053	0.035	0	0.029	0.084
1949	0	5.516	1.737	0.018	0.006	0.017	0.013	0.23	0.199	0.706	0.392	0.113	0.743
1950	5.403	7.623	5.206	12.378	3.753	0	0	0.004	0.064	0.478	0.304	0.642	2.992
1951	2.97	0.402	0.02	0.154	4.183	1.397	0.192	0.235	0.258	0.237	0.368	154.091	13.506
1952	51.18	0.442	0	0.02	0.148	0.006	0.013	0.011	0.161	0.159	0.635	0.274	4.499
1953	116.018	47.183	2.628	0.047	0.031	6.893	3.319	1.167	0.592	0.37	0.37	0.342	15.048
1954	0.464	0.411	0.029	0.14	0.535	0.686	0.208	0.027	0.091	0.102	0.078	0	0.229
1955	0.045	5.347	1.757	0.031	0.031	0.053	0.022	0.614	0.313	0.103	0.053	1.77	0.84
1956	3.067	2.101	1.946	0.238	4.16	2.095	0.388	0.086	0.14	0.155	0.131	0.031	1.195
1957	0.169	0	0.036	0.12	0.044	0	0	8.151	3.247	0.34	0.256	0.077	1.046
1958	0.708	0.221	0.401	2.692	0.702	1.761	2.583	0.936	0.321	6.796	2.765	0.322	1.7
1959	0.374	0.004	0.007	0.416	0.145	0.096	0.464	0.372	0.291	0.255	0.231	0.287	0.246
1960	0.652	0.418	0.037	0.908	0.528	2.109	1.052	2.081	1.019	0.293	0.315	0.069	0.794
1961	0.298	0.107	0.013	0.031	0.223	5.747	4.057	0.63	0.262	0.161	0.131	0	0.976
1962	1.879	1.104	0.04	6.148	1.952	35.219	24.076	4.427	0.702	0.773	0.416	0.111	6.436
1963	1.097	0.45	0.203	0.044	5.676	1.674	0.052	0.034	6.906	2.989	0.688	0	1.619
1964	1.287	0.16	0.107	0.025	0.024	0.007	0	0.346	0.856	0.699	0.342	0.19	0.34
1965	7.393	10.948	2.666	0.079	0.005	0.027	0.013	0.026	0.076	0.073	0.493	0.174	1.834
1966	0.132	0.787	0.173	0.029	0.017	1.513	1.211	21.35	8.489	2.716	0.951	0.317	3.169
1967	0.349	0.066	0.02	0.04	0.037	0.164	1.396	0.623	13.43	5.141	0.476	18.432	3.318
1968	7.499	0.272	0.01	0.039	0.452	3.213	1.679	0.109	0.242	0.252	0.235	0.021	1.181
1969	0.293	0.043	0.024	0.042	0.427	0.063	0.015	0.011	0	0.014	11.836	0.781	1.144
1970	1.084	0.445	35.227	11.463	2.598	1.128	2.01	1.414	0.568	0.68	43.072	9.775	9.236
1971	1.669	0.569	0.054	0.077	0.38	0.043	0.007	0.02	0.118	0.124	0.131	0.002	0.266
1972	0.076	0.058	0.02	0.04	0.919	1	0.941	0.482	0.284	0.169	0.325	0.136	0.367
1973	0.312	1.655	1.585	4.766	10.385	76.415	26.517	4.502	13.521	4.282	15.844	1.782	13.515
1974	0.711	1.351	0.242	0.045	1.651	1.271	0.232	0.011	0.155	0.182	0.159	27.066	2.716
1975	10.096	0.486	3.284	0.871	0.684	25.444	9.433	0.683	0.534	1.82	0.615	0.098	4.553
1976	7.023	2.96	0.221	0.018	26.649	5.791	0.781	7.731	3.315	0.621	0.278	0.153	4.494
1977	0.236	3.622	4.82	0.975	0.024	0.069	1.852	0.754	0.302	0.246	0.153	0	1.092
1978	2.322	1.433	1.033	1.606	1.057	0.138	0	0.28	0.29	166.868	178.747	37.51	33.094
1979	0.848	0.159	0.02	1.443	0.576	0.006	0	0	0.091	0.095	0.091	0.12	0.287
1980	0.396	1.224	0.29	0.576	1.473	24.58	9.08	8.044	3.669	0.813	5.698	0	4.69
1981	2.596	1.091	0.49	0.075	0.028	0.017	2.434	0.947	0.186	0.561	0.335	0.338	0.761
1982	0.672	0.121	0.024	0.04	0.021	0.027	0.013	0.004	0.047	11.098	3.713	0.21	1.356
1983	1.01	0.989	0.161	0.008	0.024	0.016	0	0.005	0.334	0.23	0.187	0.015	0.249
1984	0.088	0.333	0.02	0.241	0.585	0.082	0.049	0.061	0.11	0.111	0.042	0	0.14
1985	9.436	8.639	3.56	0.511	0.042	0.002	0.013	0.007	0	0.016	0.233	0.047	1.886
1986	9.022	3.355	0.191	0.031	0.12	0	0.007	0.003	0.211	0.143	0.169	0.093	1.122
1987	0.493	0.083	0.013	0.039	5.389	1.557	0.123	0.109	0.124	0.103	0.086	0.225	0.666
1988	0.641	0.66	0.65	0.083	0.109	0.274	3.37	1.453	0.264	0.214	0.129	0	0.653
1989	17.514	78.67	23.323	0.208	0.308	0.378	0.151	0.046	0.196	0.116	0	0.031	10.046
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AVERAGE	4.788	4.387	2.183	0.942	1.461	4.073	2.473	2.54	1.633	3.502	4.143	4.083	3.028

P10G : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0.344	0.453	3.807	0.985	1.249	3.782	7.133	2.438	0.705	0.546	0.32	0.274	1.837
1921	0.396	12.528	5.754	0.443	0.022	0.174	0.179	1.674	10.087	18.813	5.912	0.313	4.714
1922	0.626	71.45	23.052	2.923	0.928	0	0.036	0.061	0.24	1.156	0.466	0.103	8.372
1923	0.643	0.13	0	0	0.982	0.303	0.003	0.055	0.16	0.157	0.337	0.126	0.237
1924	0.222	0.01	1.399	0.553	0.008	2.42	2.286	0.778	1.373	0.913	0.331	0.294	0.888
1925	0.887	0.326	0.849	0.178	0	1.213	0.452	0.328	0.427	0.384	0.26	0.161	0.46
1926	1.459	3.336	0.845	0	0	0	0	0.095	0.083	0.055	0.109	0.006	0.499
1927	0.09	0.003	0	0	0	66.597	24.719	0.305	0.291	0.258	0.276	0.04	7.789
1928	3.339	0.995	0.899	0.202	0.188	0.002	0	0	1.179	0.915	0.394	3.481	0.967
1929	4.908	0.697	0.075	0.043	1.122	3.152	1.615	0.152	1.064	0.819	0.82	0.388	1.242
1930	9.496	3.264	0.003	1.445	0.473	0.293	6.731	2.442	0.241	4.645	1.534	0.224	2.581
1931	7.31	2.489	21.97	12.945	1.714	0.169	0.049	0.033	0.094	0.718	0.34	43.459	7.609
1932	18.857	4.473	0.953	0	0.969	0.254	2.053	0.82	0.185	0.159	7.097	0	3.014
1933	0.414	1.29	0.406	2.183	4.016	8.736	3.905	0.359	0.339	8.906	2.883	0.156	2.806
1934	4.682	1.746	0.003	0	0	0	8.343	102.134	36.019	1.707	2.766	0	13.233
1935	1.41	3.519	1.148	0	6.655	2.698	0.53	0.653	0.46	1.191	0.406	0.155	1.535
1936	8.506	37.063	10.978	0.011	0	0.238	0.09	0	0.037	0.082	0.053	0.049	4.745
1937	0.27	0.647	5.602	3.469	0.932	1.931	1.413	0.383	0.253	0.294	0.268	0.047	1.303
1938	2.247	5.983	1.726	0.167	13.812	6.955	1.929	0.282	0.273	1.863	1.75	0.012	3.014
1939	6.209	2.234	0.006	0	2.645	13.687	5.278	0.274	0.252	0.293	0.231	0.32	2.625
1940	0.753	0.447	0.023	0.045	0.783	0.163	6.641	2.64	0.333	0.269	0.166	0.001	1.015
1941	20.04	6.652	6.278	3.114	0.314	0.039	0.062	0.206	0.287	0.259	0.202	0.037	3.16
1942	5.426	2.405	0.144	0.253	0.033	0.147	0.138	0.053	5.929	2.825	0.851	0.301	1.546
1943	0.425	11.559	6.452	0.543	0.646	2.666	1.167	50.067	19.038	1.806	0.686	0.033	7.979
1944	1.01	0.094	0	0.157	0.572	0.058	0	1.887	3.818	1.427	0.298	0.025	0.778
1945	0.432	0.066	0	0	0	0	7.819	3.569	0.206	0.208	0.25	0.203	0.018	1.073
1946	2.089	0.727	0.075	0.024	0	4.412	2.289	0.154	0.652	1.058	0.354	0.13	1.005
1947	1.704	1.111	0.134	0.01	1.114	0.435	34.987	12.156	0.655	0.824	0.336	0.07	4.435
1948	0.649	0.152	0	0	0.504	0.058	0	0.031	0.081	0.058	0.017	0	0.127
1949	0.015	9.677	3.099	0	0	0	0	0.377	0.299	1.372	0.708	0.166	1.306
1950	8.488	12.778	8.05	18.882	5.935	0.016	0	0	0.102	0.816	0.349	2.097	4.796
1951	4.348	0.647	0	0.241	6.52	2.051	0.29	0.37	0.381	0.352	0.415	245.126	21.406
1952	81.028	0.644	0.007	0	0.222	0	0	0	0.297	0.258	1.202	1.285	7.202
1953	170.315	70.093	4.169	0.06	0	11.482	5.074	2.297	1.063	0.537	0.427	0.367	22.357
1954	0.659	0.672	0.065	0.218	0.856	1.048	0.321	0.043	0.14	0.158	0.13	0.015	0.358
1955	0.077	8.859	2.915	0	0	0.118	0.051	1.163	0.553	0.159	0.096	4.573	1.537
1956	4.616	2.88	2.712	0.377	6.861	2.796	0.636	0.13	0.209	0.237	0.203	0.075	1.782
1957	0.249	0.003	0	0.185	0.062	0.004	0.007	14.975	5.766	0.499	0.333	0.126	1.868
1958	1.032	0.352	0.642	4.393	1.221	2.522	3.948	1.385	0.457	10.388	4.244	0.354	2.603
1959	0.526	0.028	0	0.734	0.247	0.15	0.701	0.595	0.445	0.385	0.294	0.187	0.359
1960	1.03	0.638	0.063	1.555	0.843	2.713	1.486	3.519	1.639	0.426	0.35	0.118	1.204
1961	0.47	0.191	0	0	0.34	9.517	6.241	0.971	0.378	0.247	0.203	0.022	1.556
1962	3.05	1.705	0.076	8.996	2.958	54.282	35.825	6.341	0.964	1.074	0.54	0.145	9.713
1963	1.536	0.681	0.335	0.061	7.851	2.256	0.085	0.053	10.191	4.316	0.935	1.095	2.403
1964	2.129	0.253	0.17	0.024	0	0	0.003	0.626	1.441	1.077	0.433	0.224	0.536
1965	10.948	16.872	4.17	0.108	0.002	0	0	0.049	0.118	0.113	0.945	0.287	2.805
1966	0.194	1.201	0.276	0	0.022	2.057	1.936	36.482	14.02	5.358	1.902	0.356	5.367
1967	0.501	0.112	0	0	0	0.291	2.117	0.92	24.845	9.08	0.629	31.607	5.789
1968	11.975	0.406	0	0	0.658	5.28	2.571	0.164	0.384	0.386	0.301	0.053	1.868
1969	0.409	0.082	0	0	0.597	0.104	0	0	0.004	0.03	18.926	2.155	1.883
1970	1.58	0.705	59.103	19.418	3.598	1.575	3.23	2.295	0.865	0.973	59.402	14.381	14.105
1971	2.447	0.882	0.093	0.105	0.618	0.099	0	0.033	0.172	0.189	0.203	0.03	0.406
1972	0.12	0.1	0	0	1.403	1.593	1.434	0.713	0.415	0.258	0.411	0.173	0.546
1973	0.439	2.697	2.519	7.013	14.602	111.873	38.712	7.886	28.034	8.768	30.961	5.258	21.648
1974	1.03	1.897	0.375	0.073	2.464	1.866	0.397	0.02	0.229	0.291	0.25	45.74	4.486
1975	16.47	0.703	4.59	1.291	0.989	38.593	14.163	0.962	0.75	3.187	1.01	0.136	6.981
1976	10.403	4.363	0.355	0	38.82	8.723	1.166	12.782	5.28	0.862	0.32	0.187	6.744
1977	0.337	5.991	8.689	1.951	0	0.149	3.396	1.349	0.467	0.376	0.231	0.026	1.922
1978	3.975	2.421	1.542	2.294	1.57	0.227	0.003	0.468	0.459	247.915	264.439	56.776	49.229
1979	1.234	0.27	0	2.1	0.796	0	0	0	0.157	0.152	0.143	0.192	0.42
1980	0.626	2.018	0.491	1.111	2.29	42.61	15.454	12.236	5.43	1.118	12.037	0.948	8.097
1981	3.788	1.669	0.747	0.109	0	0	4.498	1.704	0.275	0.813	0.414	0.292	1.196
1982	0.982	0.206	0	0	0	0	0	0	0.078	20.636	6.977	0.227	2.469
1983	1.46	1.399	0.252	0.002	0	0.053	0.016	0.011	0.613	0.393	0.268	0.043	0.377
1984	0.135	0.566	0.053	0.393	0.908	0.135	0.093	0.098	0.164	0.171	0.081	0.001	0.228
1985	14.933	15.662	5.816	0.813	0.079	0	0	0	0.004	0.033	0.32	0.099	3.161
1986	14.171	5.444	0.306	0	0.194	0.019	0	0.009	0.365	0.241	0.287	0.037	1.771
1987	0.719	0.137	0	0	8.612	2.217	0.189	0.164	0.185	0.16	0.142	0.283	1.02
1988	0.972	1.019	0.972	0.125	0.185	0.435	5.295	2.183	0.38	0.322	0.201	0.018	1.008
1989	32.392	117.213	34.16	0.341	0.567	0.713	0.276	0.071	0.342	0.199	0.021	0	15.485
AVERAGE	7.381	6.714	3.42	1.467	2.18	6.228	3.789	4.202	2.759	5.385	6.305	6.65	4.723

P20A : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0.004	0.003	0.405	0.118	0.122	0.434	0.498	0.134	0.007	0.011	0.003	0	
1921	0.028	1.72	0.802	0.079	0.003	0.021	0.047	0.35	4.634	4.721	0.806	0.003	
1922	0.004	8.281	2.669	0.572	0.27	0	0.018	0.013	0.022	0.222	0.022	0.003	
1923	0.118	0.03	0.003	0.003	0.159	0.023	0.003	0.01	0.007	0.003	0.04	0	
1924	0.003	0.008	0.229	0.167	0.041	0.525	0.246	0.032	0.343	0.114	0.003	0	
1925	0.114	0.034	0.258	0.074	0.003	0.237	0.095	0.137	0.063	0.011	0.003	0	
1926	0.33	0.427	0.085	0.003	0.003	0.003	0.003	0.076	0.029	0.003	0.008	0.003	
1927	0.003	0.003	0.003	0.003	0.003	6.045	2.424	0.003	0.011	0.007	0.004	0.085	
1928	0.663	0.222	0.338	0.094	0.003	0.003	0.003	0.003	0.51	0.276	0.011	2.29	
1929	1.717	0.01	0.008	0.004	0.202	0.472	0.157	0.003	0.16	0.054	0.038	0	
1930	2.421	0.787	0.003	0.13	0.061	0.003	1.895	0.659	0.003	1.012	0.148	0.334	
1931	3.869	1.317	2.117	2.023	0.409	0	0.003	0.003	0.003	0.258	0.033	5.479	
1932	3.026	0.318	0.07	0.003	0.206	0.023	0.744	0.264	0.003	0.003	2.688	0.535	
1933	0.003	0.117	0.029	0.094	0.145	0.998	0.445	0.003	0.007	5.067	1.334	0.003	
1934	0.608	0.218	0.005	0.003	0.003	0.003	1.892	19.904	8.233	0.514	2.644	0.65	
1935	0.276	0.883	0.243	0.003	0.03	0.093	0.033	0.18	0.063	0.168	0.013	0	
1936	1.228	3.406	0.968	0.003	0.003	0.046	0.018	0.003	0.003	0.014	0.003	0.003	
1937	0.003	0.034	0.433	0.234	0.188	0.26	0.186	0.039	0.007	0.003	0.003	0.003	
1938	0.217	1.123	0.284	0.002	2.726	0.904	0.146	0.013	0.007	0.363	0.089	0.254	
1939	2.933	0.94	0.003	0.003	0.223	1.38	0.699	0.006	0.003	0.003	0.003	0.001	
1940	0.051	0.162	0.035	0.003	0.163	0.011	1.556	0.548	0.037	0.014	0.003	0.003	
1941	3	1.062	2.135	0.712	0.006	0.003	0.003	0.065	0.037	0.007	0.003	0	
1942	1.469	0.479	0.006	0.127	0.057	0.003	0.033	0.017	1.084	0.348	0.06	0	
1943	0.003	1.561	0.679	0.06	0.141	0.428	0.16	8.109	2.781	0.007	0.003	0.17	
1944	0.173	0.004	0.003	0.003	0.077	0	0.003	0.692	3.153	0.922	0.003	0.003	
1945	0.013	0.003	0.005	0.003	0.003	0.898	0.397	0.006	0.003	0.021	0.003	0.003	
1946	0.254	0.072	0.004	0.003	0.003	1.142	0.561	0.028	0.222	1.647	0.314	0.003	
1947	0.118	0.049	0.006	0.004	0.119	0.008	3.66	1.237	0.003	0.003	0.003	0	
1948	0.155	0.034	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	
1949	0.003	2.248	0.708	0.003	0.003	0.003	0.003	0.083	0.033	0.572	0.503	0.003	
1950	1.368	2.526	1.191	2.893	0.906	0.003	0.003	0.003	0.029	0.229	0.036	0.806	
1951	1.221	0.068	0.003	0.005	0.902	0.224	0.003	0.065	0.022	0.007	0.003	25.486	
1952	8.712	0.003	0.003	0.003	0.006	0.003	0.003	0.003	0.145	0.054	0.17	0.767	
1953	14.69	6.552	0.635	0.003	0.003	1.368	0.72	0.935	0.321	0.028	0.003	0	
1954	0.004	0.102	0.022	0.008	0.137	0.043	0.008	0.003	0.026	0.011	0.003	0	
1955	0.003	1.812	0.558	0.003	0.003	0.017	0.011	0.469	0.163	0.003	0.003	0.77	
1956	0.869	0.083	0.101	0.01	1.456	0.692	0.106	0.003	0.011	0.007	0.003	0	
1957	0.003	0.003	0.003	0.003	0.003	0.004	0.003	4.297	1.464	0.003	0.012	0	
1958	0.058	0.015	0.096	0.848	0.304	0.575	0.656	0.17	0.007	4.673	2.641	0.175	
1959	0.003	0.003	0.007	0.161	0.069	0.003	0.025	0.097	0.037	0.007	0.003	0.179	
1960	0.184	0.021	0.006	0.287	0.17	0.214	0.08	0.946	0.325	0.007	0.007	0	
1961	0.088	0.026	0.005	0.003	0.006	1.194	0.997	0.141	0.003	0.003	0.003	0.003	
1962	0.622	0.28	0.012	0.877	0.317	5.672	4.826	0.823	0.007	0.046	0.003	0.003	
1963	0.066	0.041	0.059	0.011	0.277	0.043	0.003	0.003	1.295	0.417	0.008	1.09	
1964	1.138	0.003	0.005	0.003	0.003	0.003	0.003	0.242	0.339	0.096	0.003	0	
1965	1.372	2.242	0.564	0.004	0.002	0.003	0.003	0.017	0.011	0.003	0.379	0.011	
1966	0.003	0.095	0.018	0.003	0.006	0.277	0.299	10.08	3.426	3.809	0.969	0	
1967	0.011	0.003	0.003	0.003	0.003	0.013	0.117	0.039	8.951	2.857	0.003	4.365	
1968	2.557	0.003	0.003	0.003	0.077	0.836	0.344	0.006	0.071	0.024	0.003	0.003	
1969	0.002	0.003	0.003	0.003	0.006	0.003	0.003	0.003	0.003	0.003	2.903	0.548	
1970	0.158	0.087	10.448	3.45	0.134	0.05	0.681	0.559	0.115	0.082	6.681	0.712	
1971	0.294	0.106	0.015	0.004	0.17	0.013	0.003	0.01	0.014	0.007	0.003	0.003	
1972	0.003	0.003	0.003	0.003	0.069	0.254	0.142	0.032	0.007	0.003	0.033	0	
1973	0.005	0.544	0.322	0.723	1.024	8.326	3.098	2.795	10.363	2.998	8.065	1.336	
1974	0.337	0.095	0.018	0.034	0.181	0.23	0.073	0.003	0.007	0.043	0.008	6.906	
1975	3.213	0.003	0.2	0.054	0.069	3.507	1.587	0.065	0.029	3.78	0.959	0.003	
1976	1.404	0.6	0.042	0.003	4.013	0.878	0.157	3.662	1.337	0.035	0.003	0	
1977	0.002	1.453	2.476	0.623	0.003	0.05	1.032	0.397	0.078	0.021	0.003	0.003	
1978	1.092	0.625	0.132	0.112	0.203	0.015	0.003	0.126	0.074	22.709	20.348	1.71	
1979	0.111	0.023	0.003	0.004	0.014	0.003	0.005	0.01	0.071	0.024	0.003	0	
1980	0.129	0.369	0.088	0.349	0.213	7.236	2.813	1.98	0.766	0.035	6.947	0.724	
1981	0.354	0.15	0.084	0.011	0.003	0.003	1.372	0.48	0.007	0.007	0.003	0	
1982	0.073	0.015	0.003	0.003	0.014	0.003	0.003	0.006	0.011	7.765	2.214	0	
1983	0.069	0.034	0.015	0.004	0.003	0.006	0.003	0.003	0.263	0.096	0.003	0.003	
1984	0.003	0.136	0.032	0.039	0.069	0	0.021	0.017	0.011	0.007	0.003	0.003	
1985	2.639	3.726	1.019	0.097	0.057	0	0.003	0.003	0.015	0.007	0.04	0	
1986	2.539	0.962	0.032	0.003	0.041	0.001	0.003	0.003	0.149	0.05	0.038	0	
1987	0.025	0.003	0.003	0.003	1.202	0.311	0.003	0.006	0.003	0.003	0.003	0	
1988	0.136	0.11	0.109	0.016	0.073	0.012	0.846	0.3	0.003	0.003	0.003	0.003	
1989	7.48	12.405	3.048	0.042	0.231	0.217	0.088	0.013	0.134	0.046	0.003	0.003	
AVERAGE	1.084	0.87	0.485	0.218	0.255	0.661	0.515	0.878	0.737	0.948	0.876	0.792	

P20B : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0	0	0.155	0.04	0.041	0.169	0.202	0.05	0	0	0	0	0.055
1921	0.003	0.727	0.332	0.023	0	0	0.007	0.139	1.337	2.002	0.339	0	0.411
1922	0	4.369	1.391	0.237	0.103	0	0	0	0.003	0.085	0	0	0.512
1923	0.037	0	0	0	0.058	0	0	0	0	0	0	0	0.008
1924	0	0	0.079	0.054	0.01	0.211	0.096	0.003	0.139	0.042	0	0	0.053
1925	0.037	0.004	0.089	0.02	0	0.083	0.029	0.05	0.018	0	0	0	0.028
1926	0.125	0.168	0.025	0	0	0	0	0.024	0.003	0	0	0	0.029
1927	0	0	0	0	0	3.109	1.243	0	0	0	0	0	0.366
1928	0.269	0.08	0.127	0.028	0	0	0	0	0.213	0.107	0	0.117	0.079
1929	0.518	0	0	0	0.072	0.182	0.058	0	0.059	0.013	0	0	0.076
1930	0.791	0.257	0	0.043	0.018	0	0.839	0.291	0	0.442	0.039	0	0.228
1931	1.091	0.355	0.943	0.899	0.168	0	0	0	0	0.1	0	2.383	0.495
1932	1.317	0.121	0.018	0	0.076	0	0.313	0.107	0	0	0.841	0	0.235
1933	0	0.038	0.002	0.026	0.048	0.388	0.191	0	0	1.704	0.379	0	0.235
1934	0.248	0.08	0	0	0	0	0.839	10.998	4.098	0.128	0.877	0	1.452
1935	0.013	0.372	0.089	0	0.002	0.022	0.003	0.067	0.021	0.06	0	0	0.054
1936	0.525	1.545	0.435	0	0	0.006	0	0	0	0	0	0	0.209
1937	0	0	0.167	0.084	0.069	0.093	0.065	0.01	0	0	0	0	0.041
1938	0.08	0.477	0.108	0	1.243	0.357	0.05	0	0	0.15	0.005	0	0.199
1939	0.588	0.178	0	0	0.082	0.531	0.306	0	0	0	0	0	0.141
1940	0.013	0.052	0.004	0	0.058	0	0.686	0.24	0.007	0	0	0	0.088
1941	1.319	0.477	0.95	0.31	0	0	0	0.017	0.007	0	0	0	0.26
1942	0.633	0.202	0	0.04	0.014	0	0.003	0.003	0.473	0.15	0.005	0	0.127
1943	0	0.656	0.276	0.015	0.048	0.165	0.058	3.572	1.218	0	0	0	0.504
1944	0.062	0	0	0	0.022	0	0	0.294	0.608	0.157	0	0	0.095
1945	0	0	0	0	0	0.353	0.167	0	0	0.003	0	0	0.044
1946	0.093	0.023	0	0	0	0.444	0.24	0.003	0.085	0.082	0	0	0.081
1947	0.037	0.008	0	0	0.037	0	1.723	0.582	0	0	0	0	0.198
1948	0.051	0.004	0	0	0	0	0	0	0	0	0	0	0.005
1949	0	0.964	0.305	0	0	0	0	0.024	0.007	0.24	0.045	0	0.132
1950	0.591	1.102	0.509	1.321	0.412	0	0	0	0.003	0.089	0	0	0.336
1951	0.258	0.019	0	0	0.384	0.083	0	0.017	0.003	0	0	14.833	1.28
1952	5.02	0	0	0	0	0	0	0	0.051	0.013	0.045	0	0.435
1953	7.977	3.494	0.267	0	0	0.529	0.313	0.407	0.135	0.003	0	0	1.103
1954	0	0.03	0.002	0	0.048	0.003	0	0	0.003	0	0	0	0.007
1955	0	0.765	0.229	0	0	0	0	0.193	0.063	0	0	0	0.104
1956	0.334	0.023	0.028	0	0.641	0.275	0.036	0	0	0	0	0	0.109
1957	0	0	0	0	0	0	0	2.071	0.704	0	0	0	0.234
1958	0.013	0	0.025	0.358	0.121	0.231	0.268	0.064	0	1.403	0.653	0	0.264
1959	0	0	0	0.052	0.022	0	0	0.032	0.007	0	0	0	0.009
1960	0.066	0	0	0.11	0.058	0.074	0.025	0.411	0.135	0	0	0	0.074
1961	0.023	0	0	0	0	0.463	0.425	0.053	0	0	0	0	0.081
1962	0.255	0.104	0	0.373	0.128	2.896	2.019	0.269	0	0.01	0	0	0.507
1963	0.016	0.004	0.01	0	0.103	0.006	0	0	0.573	0.179	0	0	0.073
1964	0.214	0	0	0	0	0	0	0.093	0.135	0.031	0	0	0.04
1965	0.591	0.947	0.235	0	0	0	0	0.003	0	0	0.124	0	0.159
1966	0	0.027	0	0	0	0.103	0.115	4.778	1.622	1.518	0.318	0	0.715
1967	0	0	0	0	0	0	0.036	0.01	4.091	1.306	0	1.735	0.593
1968	1.094	0	0	0	0.022	0.331	0.144	0	0.021	0.003	0	0	0.136
1969	0	0	0	0	0	0	0	0	0	0	1.325	0	0.112
1970	0.055	0.023	5.662	1.866	0.044	0.006	0.285	0.233	0.04	0.024	2.509	0	0.911
1971	0.114	0.034	0	0	0.058	0	0	0	0	0	0	0	0.017
1972	0	0	0	0	0.018	0.09	0.05	0.003	0	0	0	0	0.013
1973	0	0.222	0.117	0.299	0.436	4.438	1.652	1.045	5.387	1.604	4.269	0.087	1.636
1974	0.013	0.027	0	0.002	0.065	0.08	0.022	0	0	0.01	0	3.201	0.281
1975	1.461	0	0.068	0.013	0.018	1.645	0.763	0.017	0.003	0.889	0.156	0	0.425
1976	0.605	0.25	0.007	0	1.899	0.361	0.054	1.397	0.47	0	0	0	0.412
1977	0	0.611	1.1	0.274	0	0.006	0.442	0.164	0.025	0.003	0	0	0.22
1978	0.466	0.257	0.041	0.034	0.068	0	0	0.046	0.021	12.216	11.677	0.686	2.162
1979	0.034	0	0	0	0	0	0	0	0.021	0.003	0	0	0.005
1980	0.041	0.144	0.025	0.134	0.079	3.814	1.48	0.893	0.303	0	2.966	0	0.833
1981	0.139	0.049	0.017	0	0	0	0.598	0.211	0	0	0	0	0.084
1982	0.02	0	0	0	0	0	0	0	0	3.439	0.939	0	0.373
1983	0.016	0	0	0	0	0	0	0	0.103	0.035	0	0	0.013
1984	0	0.041	0.001	0.005	0.018	0	0	0.003	0	0	0	0	0.006
1985	1.111	1.692	0.449	0.025	0.014	0	0	0	0	0	0	0	0.275
1986	1.059	0.418	0.001	0	0.01	0	0	0	0.051	0.013	0	0	0.13
1987	0.003	0	0	0	0.527	0.123	0	0	0	0	0	0	0.051
1988	0.044	0.034	0.03	0.001	0.022	0	0.359	0.125	0	0	0	0	0.051
1989	3.896	6.102	1.462	0.008	0.082	0.074	0.025	0	0.048	0.013	0	0	0.976
AVERAGE	0.477	0.394	0.225	0.096	0.107	0.311	0.232	0.414	0.319	0.404	0.393	0.329	0.31

P30A : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
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1920	0	0	0	0	0	0	0.179	0.075	0.002	0	0	0	0.021
1921	0	0.155	0.04	0.003	0.003	0	0	0.018	0.851	2.075	0.458	0.012	0.304
1922	0.005	3.7	1.137	0.191	0.02	0	0	0	0	0.001	0	0	0.419
1923	0	0	0	0.002	0.003	0	0	0	0.002	0.001	0	0	0.001
1924	0	0	0.012	0.002	0.001	0.006	0.054	0.013	0.009	0.006	0	0	0.009
1925	0.009	0	0	0	0.001	0	0	0	0.006	0.004	0	0	0.002
1926	0.024	0.04	0.006	0.001	0.001	0	0	0	0	0	0	0	0.006
1927	0	0	0	0	0.001	0.028	0.235	0	0	0	0	0.011	0.023
1928	0.188	0.057	0.004	0.002	0	0	0	0	0.026	0.028	0.014	0.09	0.034
1929	0.374	0	0	0	0	0.012	0.016	0	0.017	0.01	0.018	0	0.038
1930	0.236	0.045	0	0.005	0	0	0.019	0.006	0	0.045	0.024	0	0.032
1931	0.327	0.079	0.085	0.109	0.011	0	0	0	0	0.001	0	0.399	0.084
1932	0.448	0.068	0	0	0	0	0.01	0	0	0	0	0.001	0.045
1933	0	0.008	0.001	0	0.014	0.074	0.052	0	0.002	0.712	0.144	0	0.085
1934	0.02	0.01	0	0.001	0.001	0	0.225	5.489	1.858	0.031	0.062	0.017	0.649
1935	0.025	0	0	0	0	0	0	0	0.002	0.004	0	0	0.003
1936	0.097	0.217	0.034	0	0.001	0.005	0.001	0	0	0.001	0	0	0.03
1937	0	0.002	0.131	0.065	0.009	0.017	0.042	0.006	0.004	0.002	0	0	0.023
1938	0	0.139	0.03	0.004	1.706	0.295	0.066	0	0	0	0.002	0.02	0.178
1939	0.129	0.005	0	0	0.024	0.147	0.105	0	0	0.002	0	0	0.035
1940	0	0.072	0.01	0	0.011	0	0.117	0.063	0.015	0.006	0	0	0.024
1941	0.162	0.075	0.073	0.027	0.008	0	0	0.01	0.007	0.002	0	0	0.031
1942	0.053	0.016	0	0	0.008	0	0.01	0.004	0.017	0.01	0.013	0	0.011
1943	0	0.047	0.022	0.002	0.01	0.09	0.063	0.13	0.074	0.03	0.002	0.023	0.041
1944	0.058	0	0	0.002	0.001	0	0	0.004	0.034	0.021	0	0	0.01
1945	0.02	0	0	0.001	0.001	0.011	0.014	0	0	0.002	0	0	0.004
1946	0.005	0	0	0	0.001	0.009	0.028	0.004	0.021	0.037	0.014	0	0.01
1947	0	0.002	0	0.001	0.011	0	0.347	0.17	0	0	0	0	0.044
1948	0.1	0.023	0	0.001	0	0	0	0	0	0	0	0	0.01
1949	0	0.175	0.112	0	0.001	0	0	0.038	0.023	0.017	0.013	0	0.032
1950	0.119	0.144	0.239	0.588	0.102	0	0	0	0	0.008	0	0.397	0.133
1951	0.417	0	0	0	0	0	0	0	0	0.004	0	3.87	0.354
1952	1.35	0	0	0	0	0	0	0	0	0	0.008	0	0.115
1953	3.189	1.236	0.03	0	0	0.038	0.044	0.029	0.008	0.003	0.006	0	0.385
1954	0	0.014	0	0.005	0.012	0	0	0	0	0.001	0	0	0.003
1955	0	0.053	0.012	0.001	0	0	0	0.023	0.011	0.002	0	0	0.009
1956	0.125	0.024	0.02	0.002	0.015	0.033	0.001	0	0.002	0.002	0	0	0.019
1957	0.003	0	0	0	0.001	0	0	0.78	0.325	0.003	0	0	0.094
1958	0	0	0.013	0.014	0.009	0.006	0.062	0.029	0.007	0.121	0.073	0	0.028
1959	0.002	0	0	0.003	0.003	0	0	0.031	0.017	0.006	0	0	0.005
1960	0.031	0.016	0	0.003	0.009	0	0	0.045	0.03	0.013	0.007	0	0.013
1961	0	0	0	0	0.003	0	0.111	0.01	0.002	0.002	0	0	0.01
1962	0.098	0.051	0	0.032	0.011	1.588	1.643	0.298	0.006	0.03	0.003	0	0.314
1963	0	0	0	0	0.017	0.003	0	0	0.054	0.042	0.012	0	0.011
1964	0.195	0	0	0	0.001	0	0	0.022	0.032	0.021	0.002	0	0.023
1965	0.099	0.153	0.002	0.002	0.003	0	0	0.006	0.004	0.001	0.022	0	0.024
1966	0	0.012	0	0.001	0.006	0.009	0.021	1.577	0.575	0.226	0.054	0	0.209
1967	0	0	0	0	0	0	0.001	0.006	1.254	0.423	0.004	0.025	0.142
1968	0.01	0	0	0	0	0.011	0.015	0	0.006	0.006	0	0	0.004
1969	0	0	0	0.001	0	0	0	0	0	0.001	1.938	0.006	0.165
1970	0.138	0.021	0.819	0.213	0.009	0	0.024	0.024	0	0.003	0.536	0	0.151
1971	0.012	0	0	0	0	0	0	0	0	0.002	0	0	0.001
1972	0	0	0	0	0.008	0	0	0	0	0.001	0.002	0	0.001
1973	0	0.044	0.013	0.015	0.05	2.849	1.043	0.107	1.634	0.483	1.093	0	0.614
1974	0	0	0	0	0	0	0	0	0	0	0.002	1.385	0.114
1975	0.617	0	0	0	0	0.032	0.049	0	0	0.183	0.054	0	0.079
1976	0.124	0.073	0.002	0.001	0.158	0.031	0.009	0.245	0.094	0.019	0	0	0.063
1977	0	0.097	0.132	0	0	0	0.929	0.337	0.043	0.019	0	0	0.129
1978	0.181	0.058	0	0	0.012	0	0	0.006	0.007	4.786	4.298	0.096	0.801
1979	0.014	0	0	0	0	0	0	0	0	0	0	0	0.001
1980	0.003	0.016	0.001	0.017	0.01	0.496	0.286	0.237	0.101	0.013	0.252	0.003	0.121
1981	0.012	0	0	0	0	0	0.07	0.057	0.01	0.006	0	0	0.013
1982	0	0	0	0	0.001	0	0	0	0	0.471	0.125	0	0.051
1983	0.031	0	0	0.001	0	0	0	0	0.034	0.029	0.003	0	0.008
1984	0	0	0	0.002	0.013	0	0	0	0	0.002	0	0	0.001
1985	0.093	0.565	0.218	0	0	0	0	0	0	0.001	0.013	0	0.074
1986	0.105	0.069	0	0.001	0.006	0	0	0	0.009	0.006	0.007	0	0.017
1987	0.002	0	0	0	0.148	0.058	0	0	0.002	0.001	0	0	0.017
1988	0.003	0.002	0.006	0.002	0.003	0	0.039	0.018	0	0.002	0	0	0.006
1989	0.398	2.685	0.725	0	0	0	0	0	0	0	0	0	0.316
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AVERAGE	0.138	0.147	0.056	0.019	0.035	0.084	0.085	0.142	0.103	0.143	0.133	0.091	0.098

P30B : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	1.014	0	0	0	0	0	0.785	0.296	0	0	0	0	0.176
1921	0	0.228	0.179	0	0	0	0	0.002	1.851	8.309	2.361	0	1.092
1922	0	20.372	6.224	1.056	0.132	0.013	0.008	0	0	0	0	0	2.303
1923	0	0	0	0	0	0	0	0	0	0	0	0	0
1924	0	0	0	0	0	0	0.1	0.002	0	0	0	0	0.008
1925	0	0	0	0	0	0	0	0	0	0	0	0	0
1926	0.023	0.035	0	0	0	0	0	0	0	0	0	0	0.005
1927	0	0	0	0	0	0.097	1.335	0	0	0	0	0	0.118
1928	0.684	0.061	0	0	0	0	0	0	0.024	0	0	0.501	0.106
1929	0.731	0	0.009	0.014	0	0	0.036	0	0	0	0	0	0.067
1930	0.768	0.105	0	0	0	0	0.021	0	0	0.141	0	0	0.088
1931	1.009	0.245	0.427	0.523	0	0	0	0	0	0	0	4.329	0.542
1932	1.383	0.127	0	0.017	0	0.013	0.053	0.005	0	0	0	0	0.135
1933	0	0	0	0	0	0	0.076	0	0	1.95	0.338	0	0.2
1934	0.011	0	0	0	0	0	1.196	24.564	8.709	0	0	0	2.899
1935	0	0	0	0.014	0	0	0	0	0	0	0	0	0.001
1936	0.397	1.087	0.161	0.002	0	0	0	0	0	0	0	0	0.137
1937	0	0	0.817	0.386	0	0	0.055	0	0	0	0	0	0.107
1938	0	0.258	0.032	0	8.623	0.907	0.24	0	0	0	0	0.016	0.789
1939	0.374	0.004	0	0.013	0.148	0	0.384	0	0	0	0	0	0.076
1940	0	0.065	0	0	0	0	0.614	0.291	0	0	0	0	0.081
1941	0.739	0.164	0.356	0.063	0	0	0	0	0	0	0	0	0.112
1942	0.121	0.005	0	0	0	0	0	0	0	0	0	0	0.011
1943	0	0.113	0	0	0	0	0.209	0.524	0.159	0	0	0	0.084
1944	0.074	0	0	0	0	0	0	0	0.047	0	0	0	0.01
1945	0.017	0	0	0	0	0	0.023	0	0	0	0	0	0.003
1946	0	0	0	0	0	0	0.092	0	0	0	0	0	0.008
1947	0	0	0	0	0	0	1.754	0.879	0	0	0	0	0.219
1948	0.195	0.01	0	0	0	0	0	0	0	0	0	0	0.017
1949	0	1.728	0.693	0.014	0	0	0	0.1	0.014	0	0	0	0.211
1950	0.267	0.339	1.193	2.916	0.588	0.011	0.003	0.005	0	0	0	2.981	0.691
1951	0.955	0	0.015	0.006	0.045	0	0	0.002	0	0	0	19.197	1.663
1952	6.427	0	0.015	0.017	0.01	0.013	0.011	0.01	0	0	0	0	0.552
1953	12.445	6.289	0.136	0.014	0.016	0	0.2	0.071	0	0	0.008	0	1.61
1954	0	0	0	0	0	0	0	0	0	0	0	0	0
1955	0	0.073	0	0	0	0	0	0.015	0	0	0	0	0.007
1956	0.169	0	0	0	0.025	0	0	0	0	0	0	0	0.016
1957	0	0	0	0	0	0	0	3.67	1.495	0	0	0	0.434
1958	0	0	0	0	0	0	0.066	0	0	0.378	0	0	0.037
1959	0	0	0	0	0	0	0	0.034	0	0	0	0	0.003
1960	0.037	0	0	0	0	0	0	0.132	0.026	0	0	0	0.016
1961	0	0	0	0	0	0	0.149	0	0	0	0	0	0.012
1962	0.301	0.07	0	0.135	0	7.296	7.495	0.943	0	0	0.006	0	1.358
1963	0	0	0	0.013	0.169	0	0.007	0	0.093	0	0	0.417	0.057
1964	0.401	0	0	0	0	0	0	0.013	0.025	0	0	0	0.037
1965	0.268	0.447	0	0	0	0	0	0	0	0	0	0	0.06
1966	0	0	0	0	0	0	0.029	5.038	1.903	0.323	0	0	0.614
1967	0	0.003	0.016	0.018	0.016	0	0.01	0	3.451	1.208	0.004	0.059	0.396
1968	0.002	0	0.016	0.018	0	0	0.027	0	0	0	0	0	0.005
1969	0	0	0	0	0	0	0	0	0	0	6.527	1.904	0.71
1970	0.467	0.021	4.996	1.295	0.053	0	0.043	0.037	0	0	1.081	0	0.678
1971	0	0	0	0.001	0	0	0.008	0	0	0	0	0	0.001
1972	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0.061	0	0.054	0.204	13.101	5.831	0.392	6.42	1.747	4.925	0.76	2.805
1974	0	0	0	0.014	0	0	0.003	0.005	0	0	0	6.478	0.534
1975	2.44	0	0	0	0.003	0	0.239	0	0	0.775	0	0	0.293
1976	0.374	0.11	0	0	0.838	0	0	1.123	0.335	0	0	0	0.228
1977	0	0.171	0.63	0	0	0	4.868	1.625	0.017	0	0	0	0.607
1978	0.637	0.129	0	0.001	0	0	0	0	0	19.394	20.629	3.009	3.709
1979	0	0	0.015	0.014	0.003	0.013	0.008	0.005	0	0	0	0	0.005
1980	0	0	0	0.075	0	1.954	1.547	1.076	0.337	0	0.573	0.057	0.472
1981	0	0	0	0	0.014	0.001	0.145	0.089	0	0	0	0	0.021
1982	0	0	0	0	0	0	0	0	0	1.875	0.581	0	0.208
1983	0.017	0	0	0	0	0	0	0	0.079	0	0	0	0.008
1984	0	0	0	0	0	0	0	0	0	0	0	0	0
1985	0.371	3.5	1.182	0	0	0	0	0	0	0	0	0	0.419
1986	0.232	0.051	0	0	0	0	0	0	0	0	0	0	0.024
1987	0	0	0	0	0.854	0.08	0	0	0	0	0	0	0.073
1988	0	0	0	0	0	0	0.101	0.013	0	0	0	0	0.009
1989	2.163	11.798	3.376	0.014	0	0	0	0	0	0	0	0.014	1.441
AVERAGE	0.507	0.681	0.293	0.096	0.168	0.336	0.397	0.585	0.357	0.516	0.529	0.567	0.42

P30C : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
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1920	1.008	0.001	0.108	0.008	0.014	0.043	2.342	0.77	0.028	0.024	0.018	0.031	0.366
1921	0.018	1.322	0.714	0.013	0	0	0.04	0.103	4.333	16.911	4.99	0.022	2.4
1922	0.092	40.171	12.614	2.459	0.639	0	0	0	0.009	0.045	0.019	0.014	4.643
1923	0.036	0.085	0.023	0	0.003	0	0	0.024	0.016	0.007	0	0	0.016
1924	0	0	0.124	0	0	0	0.631	0.07	0.028	0.024	0.008	0.04	0.077
1925	0.089	0	0.006	0	0	0	0.047	0.013	0.023	0.02	0	0.02	0.018
1926	0.218	0.356	0.045	0	0	0	0	0	0	0	0	0	0.052
1927	0	0	0	0	0	5.66	3.268	0.006	0.019	0.015	0.027	0	0.754
1928	1.4	0.318	0.023	0	0	0	0	0	0.209	0.14	0	2.925	0.416
1929	1.369	0.082	0	0	0.019	0	0.285	0.003	0.077	0.036	0	0.047	0.161
1930	1.58	0.456	0	0	0	0	0.238	0.053	0.009	0.735	0.084	0.037	0.269
1931	2.446	0.465	1.291	1.433	0.184	0	0	0	0	0.018	0	11.236	1.416
1932	3.768	0.442	0.046	0	0.018	0	0.313	0.091	0.009	0.011	0.5	0.026	0.441
1933	0.021	0.113	0.025	0.159	0.094	0	0.349	0.009	0.012	4.317	1.103	0.026	0.526
1934	0.175	0.143	0.023	0	0	0	3.61	48.068	16.624	0.052	0.204	0	5.792
1935	0.113	0.106	0.02	0	0.008	0.021	0.009	0.049	0.022	0.023	0.002	0	0.031
1936	1.201	3.359	0.716	0	0	0.019	0.075	0	0	0.007	0	0	0.447
1937	0	0.083	2.968	1.168	0.013	0.048	0.265	0.049	0.019	0.018	0.002	0	0.392
1938	0.057	1.435	0.413	0	18.815	5.021	0.559	0.031	0.021	0.034	0.002	0	2.093
1939	0.955	0.157	0.023	0	0.988	1.817	1.058	0.028	0.019	0.018	0.002	0.052	0.423
1940	0.054	0.355	0.1	0	0.005	0	2.201	0.799	0.031	0.025	0	0	0.296
1941	1.542	0.495	1.116	0.465	0.014	0	0	0.057	0.031	0.018	0.008	0	0.316
1942	0.622	0.159	0.001	0.197	0.009	0	0.136	0.049	0.081	0.036	0.015	0.027	0.112
1943	0	0.425	0.456	0.038	0.004	0	0.507	1.235	0.441	0.028	0.021	0.315	0.29
1944	0.316	0.013	0	0	0	0	0	0.049	0.315	0.081	0.017	0	0.066
1945	0.196	0.065	0	0	0	0	0.244	0	0	0.011	0	0	0.043
1946	0.087	0.04	0	0	0	0	0.396	0.024	0.082	0.188	0.002	0.014	0.069
1947	0.033	0.068	0.01	0	0.006	0	5.515	2.09	0.021	0.02	0.014	0	0.645
1948	0.766	0.174	0	0	0	0	0	0	0	0	0	0	0.079
1949	0	5.813	1.964	0	0	0	0	0.53	0.172	0.043	0	0.016	0.708
1950	0.985	1.001	2.953	6.481	1.678	0	0	0	0.005	0.039	0.024	8.209	1.776
1951	2.338	0.015	0	0	0.619	0.06	0.013	0.07	0.034	0.02	0.014	39.395	3.501
1952	12.947	0.015	0	0	0	0	0	0	0.031	0.018	0.493	0.459	1.184
1953	25.91	12.693	0.67	0	0	0.152	0.504	0.223	0.063	0.035	0	0.04	3.383
1954	0.036	0.139	0.026	0	0.015	0	0	0	0.005	0.007	0	0.02	0.021
1955	0.021	0.52	0.188	0	0	0	0	0.177	0.06	0.018	0.021	1.377	0.197
1956	0.736	0.134	0.144	0	0.552	0.125	0.057	0.003	0.016	0.018	0	0.052	0.151
1957	0.067	0	0	0	0	0	0	8.991	3.379	0.03	0.01	0.026	1.052
1958	0.083	0.033	0.26	0.307	0.007	0.024	0.333	0.093	0.022	1.04	0.219	0.033	0.207
1959	0.043	0	0	0.039	0.015	0	0	0.284	0.092	0.023	0.008	0.052	0.047
1960	0.282	0.128	0.01	0	0.012	0	0.024	0.657	0.222	0.03	0.004	0.008	0.116
1961	0.021	0.024	0	0	0.003	0	0.904	0.05	0.016	0.011	0	0	0.085
1962	1.023	0.328	0	0.78	0.184	18.683	14.559	1.95	0.031	0.076	0	0.026	3.152
1963	0.081	0.043	0.023	0	1.074	0.114	0	0	0.512	0.137	0.01	1.916	0.317
1964	1.03	0.036	0.008	0	0	0	0	0.167	0.221	0.053	0.025	0.018	0.131
1965	0.992	1.769	0.34	0	0	0	0	0.052	0.024	0.015	0.07	0.048	0.276
1966	0.016	0.134	0.025	0	0.018	0.034	0.263	11.46	4.162	0.772	0.099	0.024	1.431
1967	0.018	0	0	0	0	0.031	0.195	0.053	8.148	2.769	0	0	0.929
1968	0.141	0.002	0	0	0.168	0	0.258	0.006	0.023	0.024	0.017	0	0.052
1969	0.032	0	0	0	0	0	0	0	0.005	0.001	15.529	4.831	1.718
1970	1.114	0.206	10.329	3.067	0.422	0.041	0.263	0.15	0.031	0.031	2.721	0.343	1.583
1971	0.118	0.054	0.03	0	0.396	0.04	0	0	0.009	0.011	0.002	0	0.053
1972	0.001	0.011	0	0	0.014	0	0.004	0.013	0.005	0.001	0.008	0.015	0.006
1973	0.026	0.366	0.126	0.554	1.201	30.417	11.806	0.923	11.765	3.457	9.506	2.164	6.057
1974	0.083	0.1	0.018	0	0.035	0.009	0	0	0.025	0.023	0.021	15.58	1.306
1975	5.376	0.009	0.116	0.01	0	0.338	0.575	0.006	0.012	1.862	0.375	0.024	0.737
1976	1	0.419	0.024	0	2.509	0.046	0.094	2.513	0.843	0.028	0.022	0.027	0.616
1977	0.021	0.483	1.739	0.289	0	0	11.03	3.681	0.101	0.029	0.016	0.028	1.446
1978	1.371	0.474	0.057	0	0.015	0	0	0.053	0.029	38.629	39.238	7.153	7.365
1979	0.094	0.029	0	0	0	0	0	0	0.022	0.015	0	0.052	0.018
1980	0.067	0.138	0.025	0.623	0.184	8.23	3.739	2.404	0.845	0.026	1.595	0	1.503
1981	0.118	0.054	0.114	0.008	0	0	1.154	0.411	0.025	0.024	0.017	0.013	0.161
1982	0.04	0	0	0	0	0	0	0	0	5.265	1.677	0.026	0.595
1983	0.2	0.082	0	0	0	0	0	0	0.46	0.143	0.016	0.003	0.075
1984	0.001	0.024	0	0	0.028	0	0	0	0.005	0.011	0	0	0.006
1985	1.15	9.36	2.995	0.098	0.019	0.034	0.033	0	0	0.001	0.032	0.048	1.143
1986	0.945	0.36	0.02	0	0.018	0	0	0	0.044	0.027	0	0.05	0.123
1987	0.06	0	0	0	3.352	0	0	0.009	0.012	0.015	0	0.035	0.27
1988	0.067	0.065	0.032	0	0.003	0	0.456	0.158	0.009	0.011	0	0	0.066
1989	6.417	24.486	6.987	0	0.01	0.062	0.05	0	0.044	0.026	0.004	0	3.165
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AVERAGE	1.189	1.578	0.716	0.26	0.477	1.015	0.977	1.268	0.771	1.11	1.126	1.385	0.991

P40A : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0.067	0.063	0.13	0.084	0.092	0.2	0.554	0.279	0.116	0.107	0.077	0.046	0.151
1921	0.072	0.479	0.232	0.086	0.074	0.053	0.083	0.15	2.147	4.18	0.994	0.16	0.731
1922	0.141	7.408	2.411	0.525	0.198	0.051	0.056	0.059	0.074	0.136	0.096	0.045	0.928
1923	0.082	0.109	0.074	0.074	0.076	0.053	0.061	0.079	0.077	0.073	0.068	0.048	0.073
1924	0.068	0.063	0.13	0.083	0.065	0.325	0.338	0.129	0.119	0.106	0.075	0.122	0.135
1925	0.126	0.061	0.063	0.07	0.068	0.1	0.081	0.075	0.103	0.091	0.071	0.049	0.08
1926	0.192	0.257	0.096	0.067	0.066	0.057	0.062	0.06	0.067	0.067	0.065	0.054	0.093
1927	0.066	0.064	0.061	0.068	0.063	1.002	0.586	0.073	0.092	0.079	0.087	0.176	0.202
1928	0.488	0.226	0.096	0.072	0.065	0.053	0.059	0.063	0.15	0.197	0.15	0.786	0.2
1929	0.932	0.109	0.056	0.07	0.087	0.256	0.166	0.067	0.144	0.113	0.137	0.09	0.187
1930	0.583	0.247	0.059	0.08	0.066	0.079	0.174	0.103	0.071	0.312	0.189	0.079	0.171
1931	0.949	0.361	0.316	0.372	0.14	0.053	0.061	0.062	0.067	0.074	0.067	1.406	0.327
1932	1.003	0.277	0.107	0.068	0.082	0.053	0.181	0.122	0.078	0.075	0.222	0.134	0.201
1933	0.076	0.125	0.081	0.104	0.132	0.325	0.201	0.077	0.083	1.766	0.474	0.044	0.294
1934	0.173	0.163	0.071	0.068	0.065	0.057	0.757	10.58	3.687	0.187	0.269	0.175	1.366
1935	0.176	0.14	0.077	0.069	0.082	0.069	0.062	0.096	0.089	0.093	0.073	0.048	0.09
1936	0.543	0.589	0.222	0.069	0.063	0.123	0.092	0.059	0.067	0.073	0.07	0.051	0.169
1937	0.071	0.102	0.692	0.294	0.103	0.174	0.18	0.103	0.091	0.083	0.073	0.047	0.169
1938	0.093	0.514	0.181	0.082	3.44	0.689	0.267	0.112	0.101	0.124	0.121	0.167	0.471
1939	0.375	0.159	0.086	0.072	0.303	0.407	0.336	0.102	0.089	0.085	0.073	0.068	0.179
1940	0.092	0.291	0.116	0.068	0.098	0.052	0.521	0.259	0.119	0.098	0.073	0.05	0.153
1941	0.53	0.257	0.293	0.176	0.094	0.053	0.06	0.119	0.106	0.083	0.077	0.045	0.159
1942	0.309	0.149	0.063	0.109	0.093	0.053	0.132	0.096	0.144	0.113	0.144	0.049	0.121
1943	0.071	0.331	0.218	0.092	0.11	0.338	0.229	0.366	0.239	0.156	0.099	0.144	0.199
1944	0.219	0.071	0.059	0.069	0.071	0.059	0.062	0.086	0.199	0.158	0.085	0.044	0.099
1945	0.17	0.082	0.059	0.066	0.063	0.215	0.15	0.06	0.069	0.075	0.073	0.048	0.094
1946	0.113	0.077	0.058	0.068	0.065	0.308	0.222	0.094	0.158	0.23	0.151	0.047	0.133
1947	0.089	0.101	0.065	0.068	0.099	0.054	1.187	0.457	0.094	0.092	0.073	0.045	0.201
1948	0.34	0.156	0.055	0.068	0.068	0.06	0.062	0.063	0.068	0.069	0.067	0.048	0.094
1949	0.068	0.923	0.379	0.07	0.065	0.065	0.062	0.221	0.161	0.143	0.144	0.042	0.195
1950	0.412	0.413	0.614	1.277	0.357	0.057	0.057	0.063	0.07	0.106	0.085	1.334	0.403
1951	0.964	0.059	0.059	0.08	0.219	0.112	0.073	0.136	0.113	0.092	0.08	7.54	0.786
1952	2.711	0.06	0.059	0.067	0.069	0.06	0.066	0.063	0.082	0.077	0.188	0	0.296
1953	6.38	2.516	0.22	0.07	0.065	0.312	0.21	0.171	0.133	0.123	0.132	0.09	0.876
1954	0.095	0.148	0.073	0.08	0.115	0.089	0.062	0.062	0.071	0.069	0.073	0.047	0.082
1955	0.078	0.357	0.145	0.066	0.066	0.054	0.06	0.147	0.12	0.085	0.083	0	0.105
1956	0.453	0.156	0.153	0.085	0.214	0.184	0.092	0.067	0.092	0.084	0.074	0.084	0.145
1957	0.107	0.061	0.061	0.068	0.063	0.053	0.067	2.184	0.818	0.125	0.113	0.051	0.317
1958	0.127	0.076	0.167	0.152	0.093	0.153	0.229	0.148	0.105	0.481	0.223	0.089	0.171
1959	0.103	0.061	0.063	0.092	0.077	0.057	0.067	0.197	0.144	0.099	0.076	0.091	0.094
1960	0.225	0.151	0.065	0.077	0.094	0.085	0.079	0.297	0.197	0.134	0.124	0.043	0.131
1961	0.079	0.074	0.059	0.07	0.077	0.358	0.37	0.118	0.085	0.075	0.071	0.047	0.124
1962	0.392	0.205	0.059	0.25	0.135	3.128	3.615	0.812	0.128	0.173	0.123	0.045	0.757
1963	0.112	0.081	0.078	0.074	0.329	0.148	0.06	0.059	0.255	0.177	0.113	0.182	0.138
1964	0.601	0.088	0.065	0.069	0.063	0.059	0.062	0.128	0.208	0.156	0.1	0.045	0.138
1965	0.445	0.468	0.174	0.084	0.074	0.051	0.056	0.09	0.09	0.081	0.187	0.081	0.157
1966	0.076	0.141	0.071	0.066	0.087	0.153	0.187	3.595	1.298	0.763	0.233	0.054	0.565
1967	0.073	0.06	0.06	0.065	0.066	0.075	0.131	0.104	2.987	1.017	0.127	0.177	0.41
1968	0.158	0.061	0.06	0.067	0.113	0.27	0.16	0.074	0.104	0.1	0.082	0.047	0.108
1969	0.078	0.061	0.06	0.067	0.066	0.06	0.062	0.063	0.07	0.07	4.362	0.203	0.442
1970	0.389	0.186	1.71	0.586	0.179	0.097	0.177	0.166	0.112	0.124	1.424	0	0.435
1971	0.154	0.088	0.097	0.085	0.185	0.094	0.056	0.06	0.069	0.076	0.077	0.048	0.09
1972	0.074	0.066	0.055	0.067	0.092	0.054	0.068	0.071	0.071	0.069	0.095	0.047	0.069
1973	0.081	0.281	0.14	0.214	0.387	5.998	2.209	0.322	3.503	1.144	2.328	0	1.39
1974	0.135	0.125	0.065	0.072	0.106	0.063	0.056	0.063	0.079	0.088	0.098	3.116	0.335
1975	1.416	0.062	0.135	0.085	0.071	0.338	0.233	0.075	0.083	0.748	0.237	0.058	0.299
1976	0.364	0.255	0.088	0.068	0.566	0.182	0.117	0.586	0.3	0.135	0.089	0.056	0.232
1977	0.077	0.331	0.398	0.127	0.066	0.066	1.974	0.764	0.19	0.159	0.107	0.047	0.358
1978	0.479	0.258	0.123	0.085	0.115	0.054	0.061	0.099	0.107	9.392	8.284	0.37	1.646
1979	0.153	0.075	0.059	0.072	0.068	0.06	0.057	0.059	0.082	0.072	0.067	0.051	0.073
1980	0.111	0.152	0.077	0.225	0.14	1.344	0.673	0.571	0.306	0.142	0.919	0.026	0.393
1981	0.15	0.088	0.135	0.085	0.063	0.053	0.388	0.206	0.107	0.099	0.082	0.046	0.125
1982	0.093	0.061	0.06	0.065	0.065	0.06	0.066	0.063	0.069	1.55	0.411	0.047	0.22
1983	0.184	0.108	0.059	0.066	0.065	0.056	0.062	0.062	0.217	0.189	0.112	0.045	0.102
1984	0.074	0.074	0.058	0.086	0.117	0.052	0.06	0.06	0.071	0.074	0.069	0.053	0.07
1985	0.504	1.59	0.577	0.095	0.091	0.099	0.078	0.059	0.069	0.07	0.14	0.083	0.287
1986	0.422	0.251	0.073	0.066	0.082	0.053	0.056	0.059	0.098	0.097	0.122	0.122	0.125
1987	0.097	0.06	0.06	0.068	0.822	0.244	0.072	0.079	0.078	0.081	0.072	0.052	0.145
1988	0.112	0.105	0.1	0.074	0.077	0.053	0.255	0.149	0.071	0.076	0.067	0.048	0.099
1989	1.194	5.624	1.668	0.077	0.096	0.13	0.089	0.063	0.115	0.09	0.069	0.054	0.77
AVERAGE	0.403	0.416	0.21	0.123	0.172	0.287	0.28	0.378	0.312	0.397	0.371	0.271	0.303

P40B : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0.063	0.06	0.26	0.101	0.147	0.578	1.99	0.769	0.194	0.178	0.129	0.094	0.38
1921	0.097	1.226	0.741	0.121	0.086	0.051	0.136	0.307	5.713	12.955	3.458	0.25	2.113
1922	0.285	25.663	8.289	1.81	0.632	0.047	0.061	0.065	0.096	0.263	0.175	0.051	3.102
1923	0.139	0.222	0.116	0.083	0.092	0.052	0.059	0.113	0.111	0.092	0.074	0.068	0.102
1924	0.067	0.052	0.265	0.107	0.061	1.071	0.917	0.252	0.201	0.175	0.109	0.247	0.295
1925	0.257	0.072	0.081	0.077	0.077	0.233	0.138	0.108	0.167	0.141	0.082	0.091	0.128
1926	0.454	0.621	0.178	0.068	0.067	0.057	0.061	0.07	0.07	0.07	0.064	0.051	0.153
1927	0.063	0.06	0.06	0.07	0.063	5.436	2.256	0.095	0.136	0.114	0.156	0.225	0.733
1928	1.461	0.549	0.16	0.08	0.061	0.051	0.061	0.059	0.32	0.399	0.283	3.438	0.575
1929	2.225	0.217	0.054	0.075	0.115	0.808	0.421	0.087	0.278	0.204	0.272	0.202	0.417
1930	1.833	0.634	0.063	0.088	0.069	0.16	0.424	0.189	0.091	0.899	0.323	0.186	0.417
1931	2.676	1.019	1.085	1.223	0.296	0.051	0.059	0.063	0.07	0.099	0.076	7.28	1.163
1932	3.266	0.655	0.194	0.07	0.105	0.053	0.482	0.252	0.104	0.101	0.618	0.249	0.517
1933	0.119	0.275	0.132	0.248	0.225	0.971	0.537	0.108	0.118	4.867	1.477	0.1	0.774
1934	0.403	0.372	0.103	0.07	0.061	0.057	2.859	33.676	11.586	0.339	0.712	0.235	4.242
1935	0.371	0.292	0.118	0.075	0.102	0.119	0.078	0.165	0.135	0.146	0.101	0.052	0.146
1936	1.743	2.481	0.725	0.075	0.063	0.288	0.174	0.065	0.07	0.092	0.07	0.05	0.492
1937	0.078	0.204	2.587	0.998	0.156	0.421	0.425	0.18	0.138	0.125	0.097	0.05	0.46
1938	0.174	1.347	0.512	0.092	12.447	4.019	0.733	0.183	0.158	0.22	0.228	0.249	1.628
1939	1.014	0.375	0.137	0.08	1.055	2.074	0.958	0.163	0.134	0.129	0.09	0.186	0.53
1940	0.167	0.756	0.232	0.07	0.152	0.05	1.945	0.743	0.206	0.159	0.09	0.048	0.383
1941	1.711	0.672	0.98	0.554	0.147	0.063	0.067	0.227	0.18	0.126	0.113	0.053	0.411
1942	0.83	0.354	0.077	0.272	0.152	0.054	0.285	0.165	0.278	0.203	0.289	0.122	0.258
1943	0.081	0.974	0.661	0.136	0.183	1.076	0.634	1.073	0.567	0.28	0.177	0.052	0.493
1944	0.524	0.109	0.058	0.076	0.082	0.057	0.061	0.132	0.479	0.314	0.143	0.048	0.174
1945	0.407	0.156	0.058	0.068	0.063	0.689	0.368	0.07	0.073	0.096	0.085	0.051	0.183
1946	0.231	0.127	0.058	0.07	0.061	1.022	0.623	0.148	0.296	0.456	0.281	0.096	0.291
1947	0.149	0.195	0.086	0.07	0.15	0.061	4.457	1.566	0.143	0.145	0.102	0.069	0.596
1948	0.921	0.373	0.055	0.07	0.074	0.059	0.061	0.059	0.069	0.071	0.064	0.043	0.161
1949	0.064	4.245	1.447	0.075	0.061	0.064	0.061	0.613	0.339	0.272	0.279	0.097	0.633
1950	1.229	1.146	2.217	4.529	1.291	0.077	0.064	0.059	0.078	0.187	0.149	6.14	1.427
1951	2.668	0.08	0.058	0.088	0.733	0.261	0.101	0.266	0.196	0.144	0.127	27.107	2.621
1952	9.089	0.083	0.058	0.068	0.072	0.059	0.065	0.061	0.12	0.106	0.538	0.64	0.927
1953	20.297	8.707	0.704	0.075	0.061	1.04	0.602	0.369	0.249	0.216	0.251	0.199	2.754
1954	0.165	0.338	0.112	0.091	0.191	0.161	0.078	0.063	0.085	0.083	0.087	0.097	0.129
1955	0.122	1.076	0.323	0.068	0.067	0.07	0.066	0.33	0.227	0.129	0.14	1.179	0.315
1956	1.215	0.348	0.329	0.103	0.684	0.467	0.165	0.083	0.136	0.127	0.092	0.212	0.329
1957	0.209	0.059	0.06	0.07	0.063	0.059	0.08	7.371	2.69	0.218	0.212	0.117	0.943
1958	0.26	0.122	0.416	0.434	0.152	0.361	0.597	0.298	0.17	1.359	0.496	0.19	0.408
1959	0.182	0.066	0.078	0.138	0.095	0.057	0.081	0.462	0.283	0.158	0.111	0.218	0.161
1960	0.539	0.335	0.085	0.085	0.142	0.162	0.124	0.84	0.424	0.236	0.231	0.082	0.275
1961	0.123	0.118	0.067	0.075	0.091	1.577	1.051	0.212	0.121	0.101	0.078	0.046	0.306
1962	1.177	0.521	0.067	0.84	0.271	12.827	11.229	2.209	0.216	0.336	0.234	0.071	2.511
1963	0.23	0.14	0.124	0.083	1.134	0.359	0.065	0.065	0.674	0.368	0.212	1.79	0.429
1964	1.545	0.15	0.083	0.075	0.063	0.057	0.061	0.275	0.452	0.293	0.176	0.103	0.28
1965	1.358	1.607	0.468	0.096	0.086	0.046	0.061	0.161	0.143	0.117	0.331	0.198	0.39
1966	0.12	0.316	0.11	0.068	0.115	0.371	0.458	10.89	3.893	1.798	0.517	0.123	1.58
1967	0.1	0.048	0.058	0.065	0.066	0.12	0.334	0.188	8.55	2.855	0.235	0.211	1.064
1968	0.354	0.065	0.058	0.068	0.211	0.823	0.394	0.102	0.167	0.163	0.139	0.062	0.218
1969	0.127	0.06	0.058	0.068	0.067	0.059	0.061	0.059	0.078	0.077	13.716	2.3	1.413
1970	1.081	0.446	6.4	2.134	0.506	0.205	0.427	0.341	0.191	0.224	3.944	0	1.343
1971	0.309	0.155	0.164	0.099	0.478	0.182	0.061	0.07	0.088	0.105	0.098	0.059	0.154
1972	0.09	0.096	0.055	0.068	0.126	0.071	0.097	0.094	0.085	0.075	0.191	0.085	0.094
1973	0.135	0.73	0.289	0.686	1.305	21.76	7.683	0.893	10.096	3.24	7.372	0.865	4.61
1974	0.267	0.26	0.088	0.08	0.179	0.103	0.061	0.059	0.115	0.14	0.181	12.502	1.154
1975	4.352	0.072	0.273	0.106	0.082	1.198	0.682	0.099	0.118	2.165	0.623	0.131	0.837
1976	1.015	0.615	0.147	0.07	2.04	0.538	0.231	1.93	0.83	0.239	0.156	0.134	0.654
1977	0.119	0.979	1.401	0.362	0.067	0.108	7.379	2.632	0.346	0.289	0.193	0.092	1.161
1978	1.484	0.643	0.219	0.101	0.193	0.061	0.059	0.177	0.181	29.042	26.583	3.081	5.235
1979	0.31	0.119	0.058	0.08	0.074	0.059	0.063	0.065	0.115	0.096	0.067	0.159	0.106
1980	0.217	0.345	0.123	0.734	0.301	6.532	2.564	1.868	0.842	0.255	2.596	0	1.378
1981	0.302	0.156	0.248	0.103	0.063	0.054	1.182	0.519	0.174	0.162	0.138	0.091	0.266
1982	0.165	0.059	0.058	0.065	0.061	0.059	0.065	0.061	0.071	4.979	1.528	0.105	0.616
1983	0.43	0.215	0.065	0.068	0.061	0.074	0.071	0.063	0.574	0.388	0.202	0.072	0.191
1984	0.091	0.122	0.06	0.107	0.197	0.05	0.066	0.07	0.087	0.093	0.07	0.05	0.088
1985	1.626	6.59	2.17	0.207	0.132	0.2	0.121	0.065	0.073	0.079	0.297	0.202	0.978
1986	1.249	0.608	0.109	0.068	0.105	0.065	0.062	0.065	0.178	0.159	0.24	0.232	0.263
1987	0.181	0.048	0.058	0.07	3.022	0.787	0.099	0.111	0.108	0.118	0.083	0.139	0.386
1988	0.218	0.203	0.176	0.084	0.093	0.053	0.732	0.326	0.092	0.103	0.069	0.048	0.183
1989	4.563	18.371	5.334	0.084	0.149	0.293	0.153	0.075	0.205	0.143	0.069	0.051	2.45
AVERAGE	1.16	1.294	0.609	0.281	0.457	1.018	0.843	1.082	0.801	1.07	1.043	1.046	0.894

P40C : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0.123	0.139	0.485	0.18	0.226	1.059	3.51	1.17	0.251	0.235	0.212	0.269	0.654
1921	0.177	2.519	1.464	0.243	0.123	0.121	0.21	0.427	8.658	20.657	5.966	0.703	3.469
1922	0.406	42.517	13.942	3.23	1.285	0.13	0.109	0.108	0.138	0.343	0.27	0.189	5.191
1923	0.23	0.342	0.19	0.12	0.132	0.116	0.101	0.16	0.155	0.138	0.149	0.211	0.17
1924	0.144	0.119	0.502	0.202	0.092	2.576	1.538	0.342	0.259	0.232	0.188	0.621	0.571
1925	0.376	0.151	0.143	0.107	0.112	0.411	0.222	0.154	0.221	0.193	0.159	0.265	0.21
1926	0.65	0.955	0.301	0.091	0.101	0.105	0.096	0.113	0.109	0.108	0.113	0.113	0.238
1927	0.113	0.1	0.094	0.099	0.095	11.312	4.065	0.139	0.181	0.161	0.247	1.104	1.488
1928	2.307	0.821	0.25	0.115	0.092	0.121	0.106	0.1	0.469	0.571	0.426	9.879	1.263
1929	3.806	0.331	0.112	0.104	0.166	1.655	0.655	0.131	0.376	0.272	0.406	0.433	0.711
1930	2.952	0.997	0.122	0.138	0.104	0.298	0.641	0.264	0.134	1.425	0.657	0.396	0.683
1931	4.896	1.596	2.106	2.145	0.634	0.118	0.101	0.105	0.109	0.146	0.152	16.576	2.379
1932	6.211	1.008	0.329	0.099	0.149	0.111	0.745	0.349	0.147	0.147	1.262	0.657	0.944
1933	0.201	0.412	0.214	0.53	0.46	2.151	0.833	0.152	0.162	7.103	2.475	0.279	1.263
1934	0.571	0.541	0.173	0.099	0.092	0.106	5.041	53.554	18.46	0.466	1.38	0.943	6.842
1935	0.511	0.428	0.191	0.107	0.144	0.232	0.137	0.231	0.184	0.199	0.179	0.17	0.227
1936	2.838	4.722	1.451	0.107	0.095	0.535	0.277	0.108	0.109	0.138	0.139	0.14	0.89
1937	0.155	0.303	4.612	1.802	0.232	0.765	0.636	0.246	0.185	0.174	0.176	0.168	0.797
1938	0.274	2.717	1.058	0.149	20.709	9.326	1.137	0.242	0.207	0.29	0.338	0.8	2.992
1939	1.547	0.549	0.218	0.115	1.965	5.353	1.725	0.219	0.181	0.179	0.167	0.406	1.049
1940	0.264	1.181	0.434	0.099	0.246	0.134	3.478	1.161	0.269	0.213	0.167	0.138	0.645
1941	2.795	1.062	1.905	1.054	0.224	0.15	0.123	0.309	0.239	0.176	0.193	0.191	0.709
1942	1.29	0.523	0.139	0.584	0.241	0.108	0.425	0.231	0.38	0.271	0.441	0.31	0.413
1943	0.158	1.541	1.306	0.3	0.296	2.519	0.986	1.695	0.857	0.363	0.269	1.615	0.994
1944	0.756	0.192	0.104	0.109	0.118	0.1	0.096	0.183	0.725	0.429	0.228	0.18	0.269
1945	0.582	0.261	0.104	0.094	0.095	1.348	0.574	0.113	0.115	0.142	0.161	0.168	0.315
1946	0.337	0.219	0.117	0.099	0.092	2.474	0.977	0.202	0.401	0.685	0.433	0.271	0.53
1947	0.238	0.306	0.15	0.099	0.233	0.148	7.712	2.57	0.191	0.196	0.18	0.223	1.015
1948	1.434	0.553	0.107	0.099	0.109	0.095	0.096	0.1	0.101	0.105	0.123	0.14	0.257
1949	0.141	7.755	2.789	0.104	0.092	0.093	0.096	0.935	0.485	0.365	0.413	0.278	1.125
1950	1.949	1.969	4.001	7.553	2.406	0.166	0.117	0.1	0.12	0.241	0.235	14.575	2.774
1951	4.918	0.16	0.104	0.143	1.424	0.455	0.163	0.361	0.259	0.195	0.209	47.991	4.642
1952	15.634	0.162	0.104	0.091	0.107	0.095	0.093	0.095	0.165	0.154	1.127	3.779	1.822
1953	33.332	14.945	1.419	0.104	0.092	2.529	0.957	0.526	0.334	0.281	0.37	0.42	4.648
1954	0.256	0.497	0.188	0.144	0.327	0.294	0.138	0.105	0.126	0.129	0.163	0.267	0.218
1955	0.205	1.701	0.65	0.094	0.101	0.157	0.122	0.471	0.306	0.179	0.226	5.081	0.768
1956	1.814	0.504	0.635	0.187	1.344	0.85	0.259	0.127	0.18	0.176	0.169	0.463	0.555
1957	0.315	0.138	0.094	0.099	0.095	0.144	0.138	11.632	4.278	0.283	0.314	0.301	1.499
1958	0.377	0.211	0.837	0.855	0.24	0.65	0.91	0.41	0.223	2.037	0.991	0.396	0.684
1959	0.275	0.144	0.139	0.316	0.137	0.106	0.139	0.677	0.39	0.211	0.19	0.482	0.268
1960	0.778	0.488	0.149	0.125	0.214	0.3	0.196	1.292	0.621	0.306	0.339	0.248	0.423
1961	0.206	0.207	0.128	0.104	0.129	4.123	1.874	0.286	0.166	0.147	0.154	0.143	0.643
1962	1.876	0.772	0.128	1.524	0.6	23.321	18.589	3.434	0.277	0.457	0.347	0.227	4.316
1963	0.345	0.233	0.201	0.12	2.093	0.652	0.119	0.108	1.06	0.525	0.314	6.304	0.988
1964	2.308	0.24	0.146	0.107	0.095	0.1	0.096	0.389	0.658	0.39	0.267	0.286	0.427
1965	2.161	3.129	0.963	0.161	0.124	0.129	0.109	0.221	0.194	0.165	0.645	0.426	0.704
1966	0.202	0.467	0.186	0.094	0.166	0.682	0.69	16.775	6.131	2.843	1.072	0.306	2.492
1967	0.179	0.126	0.099	0.086	0.087	0.233	0.509	0.261	13.076	4.524	0.344	1.089	1.708
1968	0.501	0.144	0.099	0.091	0.5	1.651	0.608	0.147	0.219	0.218	0.223	0.208	0.384
1969	0.214	0.139	0.099	0.091	0.101	0.095	0.096	0.1	0.12	0.123	21.048	7.824	2.527
1970	1.716	0.653	11.386	3.812	1.034	0.365	0.644	0.477	0.25	0.295	6.275	2.456	2.473
1971	0.447	0.255	0.265	0.169	1.023	0.338	0.109	0.113	0.13	0.152	0.174	0.201	0.277
1972	0.167	0.18	0.11	0.091	0.188	0.158	0.16	0.138	0.127	0.119	0.289	0.251	0.165
1973	0.222	1.141	0.561	1.262	2.353	37.259	13.006	1.391	16.001	5.158	12.143	4.747	7.97
1974	0.38	0.39	0.155	0.114	0.323	0.207	0.109	0.1	0.159	0.189	0.275	24.548	2.216
1975	8.093	0.151	0.518	0.195	0.118	2.991	1.088	0.144	0.161	3.28	1.261	0.315	1.549
1976	1.588	0.947	0.234	0.099	3.618	1.014	0.35	3.195	1.319	0.311	0.243	0.327	1.089
1977	0.203	1.55	2.637	0.759	0.101	0.215	12.911	4.443	0.468	0.376	0.288	0.265	2.013
1978	2.382	1.004	0.378	0.173	0.33	0.148	0.101	0.244	0.241	45.467	42.648	9.658	8.69
1979	0.434	0.206	0.104	0.115	0.109	0.095	0.114	0.108	0.16	0.144	0.143	0.347	0.173
1980	0.32	0.505	0.204	1.348	0.643	13.064	4.75	3.112	1.329	0.332	4.299	1.673	2.653
1981	0.438	0.255	0.487	0.188	0.095	0.108	2.214	0.778	0.228	0.216	0.222	0.264	0.457
1982	0.258	0.138	0.099	0.086	0.092	0.095	0.093	0.095	0.106	7.742	2.719	0.285	1
1983	0.607	0.331	0.125	0.094	0.092	0.163	0.128	0.105	0.903	0.554	0.299	0.229	0.303
1984	0.169	0.212	0.12	0.194	0.343	0.134	0.12	0.113	0.129	0.139	0.138	0.119	0.16
1985	2.634	11.52	3.948	0.443	0.193	0.354	0.195	0.108	0.114	0.125	0.453	0.436	1.707
1986	1.967	0.932	0.179	0.094	0.15	0.152	0.111	0.108	0.233	0.213	0.361	0.565	0.424
1987	0.28	0.126	0.099	0.099	5.179	1.566	0.16	0.157	0.151	0.165	0.16	0.339	0.679
1988	0.326	0.313	0.279	0.123	0.132	0.11	1.155	0.468	0.134	0.15	0.142	0.145	0.289
1989	8.731	29.617	8.879	0.122	0.227	0.505	0.241	0.119	0.268	0.197	0.137	0.113	4.088
AVERAGE	1.938	2.167	1.089	0.487	0.793	1.994	1.43	1.698	1.228	1.643	1.701	2.513	1.56

P40D EAST : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
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1920	0.001	0	0.007	0	0.002	0.019	0.169	0.052	0.001	0.001	0.001	0	0.021
1921	0	0.097	0.054	0	0	0	0	0.012	0.528	0.908	0.195	0.004	0.151
1922	0.002	1.848	0.583	0.172	0.046	0	0.001	0.001	0.001	0	0	0.001	0.22
1923	0	0.001	0	0	0	0	0.001	0.001	0.001	0.001	0.001	0	0
1924	0	0.001	0	0	0.001	0.027	0.071	0.008	0.001	0.001	0.001	0	0.009
1925	0.005	0	0	0	0	0	0.002	0.001	0.001	0.001	0.001	0	0.001
1926	0.016	0.039	0.006	0.001	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.006
1927	0.001	0.001	0.001	0	0.001	0.236	0.185	0.001	0.001	0.001	0	0.004	0.036
1928	0.118	0.034	0	0	0.001	0	0	0.001	0.007	0.01	0	0.362	0.044
1929	0.192	0.002	0.001	0	0	0.032	0.027	0.001	0.004	0	0	0	0.022
1930	0.169	0.048	0	0	0	0	0.023	0.006	0.001	0.061	0.002	0	0.026
1931	0.237	0.08	0.094	0.105	0.011	0	0.001	0.001	0.001	0.001	0.001	0.54	0.089
1932	0.239	0.038	0.006	0.001	0	0	0.03	0.012	0.001	0.001	0.027	0.005	0.03
1933	0.001	0.008	0.001	0.007	0.009	0.035	0.035	0.001	0.001	0.356	0.084	0.001	0.046
1934	0.013	0.016	0	0.001	0.001	0	0.266	2.304	0.825	0.015	0.083	0.013	0.297
1935	0.005	0.007	0	0	0	0	0	0.004	0.001	0	0	0.001	0.002
1936	0.143	0.212	0.057	0.001	0.001	0	0.005	0.001	0.001	0.001	0.001	0.001	0.035
1937	0	0	0.234	0.082	0.001	0.011	0.021	0.003	0.001	0.001	0.001	0.001	0.03
1938	0	0.103	0.035	0	1.156	0.129	0.049	0.001	0.001	0	0	0.001	0.116
1939	0.063	0.016	0	0	0.083	0.049	0.085	0.001	0.001	0.001	0.001	0	0.025
1940	0	0.052	0.011	0.001	0.001	0	0.168	0.057	0.001	0	0.001	0.001	0.024
1941	0.143	0.046	0.08	0.035	0.002	0	0	0.006	0.001	0.001	0.001	0.001	0.027
1942	0.049	0.018	0	0.009	0.004	0	0.01	0.004	0.007	0	0	0	0.008
1943	0.001	0.073	0.044	0.001	0.005	0.032	0.044	0.078	0.024	0.001	0.001	0.01	0.026
1944	0.024	0	0.001	0	0	0	0.001	0.001	0.016	0.004	0.001	0.001	0.004
1945	0.013	0.004	0.001	0.001	0.001	0.02	0.023	0.001	0.001	0.001	0.001	0.001	0.006
1946	0	0	0	0.001	0.001	0.017	0.046	0.001	0.005	0.035	0	0	0.009
1947	0	0	0	0.001	0	0	0.413	0.133	0.001	0.001	0.001	0	0.046
1948	0.056	0.019	0.001	0.001	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.007
1949	0	0.372	0.124	0.001	0.001	0.001	0.001	0.037	0.014	0.002	0	0	0.046
1950	0.093	0.093	0.197	0.465	0.117	0	0	0.001	0.001	0	0	0.473	0.12
1951	0.202	0.001	0.001	0	0.046	0.002	0	0.009	0.002	0.001	0.001	1.803	0.17
1952	0.535	0.001	0.001	0.001	0	0.001	0.001	0.001	0	0	0.018	0.091	0.055
1953	1.366	0.624	0.052	0.001	0.001	0.029	0.048	0.017	0.004	0	0	0	0.18
1954	0	0.013	0.001	0	0.007	0	0	0.001	0.001	0.001	0	0	0.002
1955	0	0.073	0.018	0.001	0	0	0	0.013	0.005	0.001	0	0.109	0.018
1956	0.072	0.012	0.014	0	0.046	0.013	0.003	0.001	0.001	0.001	0.001	0	0.013
1957	0.001	0	0.001	0	0.001	0	0	0.582	0.195	0.001	0	0	0.066
1958	0	0	0.024	0.021	0.005	0.008	0.037	0.01	0.001	0.141	0.022	0	0.023
1959	0	0.001	0	0	0	0	0	0.024	0.008	0.001	0.001	0	0.003
1960	0.026	0.012	0	0	0	0	0	0.059	0.018	0	0	0	0.01
1961	0	0	0	0	0	0.004	0.084	0.003	0.001	0.001	0.001	0.001	0.008
1962	0.083	0.033	0	0.064	0.012	0.81	0.926	0.153	0.001	0.001	0	0.001	0.174
1963	0.001	0	0	0	0.091	0.009	0	0.001	0.04	0.01	0	0.212	0.029
1964	0.115	0	0	0	0.001	0.001	0.001	0.004	0.018	0.001	0.001	0	0.012
1965	0.102	0.12	0.03	0	0	0	0	0.001	0.001	0.001	0	0	0.021
1966	0.001	0.011	0	0.001	0	0.008	0.024	0.883	0.303	0.196	0.032	0.001	0.123
1967	0.001	0.001	0.001	0.001	0.001	0	0.015	0.005	0.67	0.214	0.001	0.007	0.076
1968	0.01	0.001	0.001	0.001	0	0.034	0.024	0.001	0.001	0.001	0.001	0.001	0.006
1969	0	0	0.001	0.001	0	0.001	0.001	0.001	0.001	0.001	0.814	0.166	0.083
1970	0.076	0.021	0.636	0.2	0.032	0	0.023	0.013	0.001	0	0.334	0.029	0.115
1971	0.008	0	0.003	0	0.032	0	0.001	0.001	0.001	0.001	0.001	0	0.004
1972	0	0	0	0.001	0	0	0	0.001	0.001	0.001	0	0	0
1973	0	0.04	0.012	0.046	0.102	1.307	0.543	0.059	0.8	0.237	0.515	0.113	0.315
1974	0.013	0.008	0	0	0.006	0	0	0.001	0.001	0	0	0.876	0.074
1975	0.285	0.001	0.009	0	0	0.029	0.056	0.001	0.001	0.148	0.024	0.001	0.047
1976	0.071	0.038	0	0.001	0.191	0.022	0.007	0.175	0.051	0.001	0.001	0	0.046
1977	0	0.069	0.115	0.019	0.001	0	0.705	0.232	0.001	0.001	0.001	0	0.095
1978	0.113	0.043	0.007	0	0.007	0	0.001	0.003	0.001	1.881	1.725	0.231	0.34
1979	0.002	0	0.001	0	0	0.001	0	0.001	0.001	0.001	0.001	0	0.001
1980	0	0.013	0	0.053	0.012	0.342	0.227	0.167	0.051	0.001	0.231	0.022	0.094
1981	0.008	0	0.012	0	0.001	0	0.098	0.035	0.001	0.001	0.001	0	0.013
1982	0	0	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.364	0.09	0	0.039
1983	0.015	0.004	0	0.001	0.001	0	0	0.001	0.03	0.01	0	0.001	0.005
1984	0.001	0	0	0	0.002	0	0	0.001	0.001	0.001	0.001	0.001	0.001
1985	0.128	0.582	0.192	0.003	0	0	0	0.001	0.001	0.001	0	0	0.076
1986	0.092	0.036	0	0.001	0	0	0	0.001	0	0	0	0.002	0.011
1987	0	0.001	0.001	0	0.279	0.034	0	0.001	0.001	0.001	0.001	0	0.025
1988	0	0	0.004	0	0	0	0.054	0.017	0.001	0.001	0.001	0.001	0.007
1989	0.395	1.259	0.343	0	0	0.002	0.002	0.001	0	0	0.001	0.001	0.167
AVERAGE	0.076	0.089	0.043	0.019	0.033	0.047	0.065	0.074	0.052	0.066	0.06	0.073	0.058

P40D WEST : AVERAGE CHANNEL FLOW (M3/S)
PRESENT DAY

YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	AVE
1920	0	0	0.024	0.001	0.008	0.049	0.359	0.109	0	0	0	0	0.046
1921	0	0.234	0.118	0.003	0	0	0	0.028	1.085	1.819	0.395	0.011	0.31
1922	0.006	3.702	1.174	0.35	0.098	0	0	0	0.001	0.002	0	0	0.442
1923	0	0.012	0.002	0	0	0	0	0.003	0.002	0	0	0	0.002
1924	0	0	0.017	0.002	0	0.087	0.158	0.018	0.002	0	0	0.008	0.024
1925	0.012	0	0	0	0	0.003	0.007	0.001	0.002	0	0	0	0.002
1926	0.042	0.088	0.017	0	0	0	0	0	0	0	0	0	0.012
1927	0	0	0	0	0	0.6	0.409	0	0.001	0	0	0.026	0.087
1928	0.258	0.077	0.004	0	0	0	0	0	0.03	0.023	0	0.813	0.1
1929	0.39	0.007	0	0	0.001	0.09	0.06	0	0.012	0.002	0	0	0.048
1930	0.369	0.109	0	0	0	0	0.051	0.013	0	0.137	0.008	0	0.058
1931	0.523	0.17	0.194	0.217	0.029	0	0	0	0	0	0	1.126	0.188
1932	0.482	0.083	0.016	0	0.001	0	0.073	0.026	0	0	0.072	0.015	0.065
1933	0	0.022	0.006	0.02	0.023	0.095	0.079	0	0	0.747	0.175	0	0.098
1934	0.034	0.037	0.002	0	0	0	0.576	4.609	1.653	0.034	0.171	0.031	0.6
1935	0.012	0.016	0.002	0	0.001	0	0	0.009	0.002	0.001	0	0	0.004
1936	0.322	0.475	0.119	0	0	0.014	0.014	0	0	0	0	0	0.079
1937	0	0.006	0.521	0.179	0.006	0.03	0.047	0.006	0	0	0	0	0.067
1938	0.001	0.245	0.08	0	2.327	0.263	0.104	0	0	0.001	0	0.013	0.239
1939	0.137	0.036	0.003	0	0.188	0.116	0.176	0.001	0.001	0	0	0	0.054
1940	0.001	0.118	0.026	0	0.011	0	0.372	0.127	0.005	0.001	0	0	0.055
1941	0.321	0.104	0.169	0.078	0.007	0	0	0.016	0.005	0	0	0	0.059
1942	0.117	0.041	0	0.025	0.012	0	0.026	0.009	0.017	0.003	0	0	0.021
1943	0	0.166	0.1	0.007	0.015	0.092	0.098	0.173	0.053	0	0	0.041	0.062
1944	0.052	0	0	0	0	0	0	0.006	0.049	0.011	0	0	0.01
1945	0.037	0.01	0	0	0	0.068	0.052	0	0	0	0	0	0.014
1946	0.006	0	0	0	0	0.078	0.102	0.001	0.012	0.079	0	0	0.023
1947	0	0.005	0	0	0.01	0	0.902	0.293	0	0	0	0	0.1
1948	0.135	0.045	0	0	0	0	0	0	0	0	0	0	0.015
1949	0	0.844	0.275	0	0	0	0	0.096	0.031	0.007	0	0	0.104
1950	0.206	0.207	0.422	0.935	0.24	0	0	0	0	0.002	0	0.991	0.25
1951	0.409	0	0	0	0.112	0.01	0	0.021	0.006	0	0	3.651	0.346
1952	1.076	0	0	0	0	0	0	0	0.004	0.001	0.061	0.221	0.115
1953	2.738	1.253	0.112	0	0	0.083	0.102	0.039	0.011	0.001	0	0	0.364
1954	0	0.032	0.006	0	0.019	0	0	0	0	0	0	0	0.005
1955	0	0.177	0.043	0	0	0	0	0.037	0.012	0	0	0.267	0.044
1956	0.158	0.028	0.034	0.001	0.105	0.035	0.008	0	0.001	0	0	0	0.03
1957	0.004	0	0	0	0	0	0	1.275	0.424	0	0	0	0.143
1958	0.005	0	0.057	0.052	0.014	0.024	0.082	0.024	0.001	0.311	0.053	0	0.052
1959	0	0	0	0	0.003	0	0	0.056	0.018	0	0	0.001	0.007
1960	0.058	0.028	0	0	0.006	0	0	0.13	0.039	0.001	0	0	0.022
1961	0	0	0	0	0	0.065	0.186	0.008	0	0	0	0	0.021
1962	0.196	0.074	0	0.146	0.03	1.751	1.854	0.312	0	0.007	0	0	0.365
1963	0.007	0.001	0.003	0	0.204	0.025	0	0	0.094	0.023	0	0.465	0.067
1964	0.234	0	0	0	0	0	0	0.028	0.039	0.004	0	0	0.026
1965	0.228	0.274	0.069	0	0	0	0	0.007	0.003	0	0.005	0.001	0.049
1966	0	0.029	0.004	0	0.001	0.027	0.055	1.838	0.609	0.397	0.07	0	0.255
1967	0	0	0	0	0	0	0.04	0.011	1.411	0.433	0	0.027	0.159
1968	0.024	0	0	0	0.016	0.088	0.054	0	0.002	0	0	0	0.015
1969	0	0	0	0	0	0	0	0	0	0	1.729	0.338	0.174
1970	0.157	0.049	1.278	0.409	0.07	0.002	0.051	0.03	0.002	0.002	0.685	0.064	0.237
1971	0.02	0.003	0.011	0	0.075	0.002	0	0	0	0	0	0	0.009
1972	0	0	0	0	0.003	0	0	0	0	0	0	0	0
1973	0	0.104	0.03	0.106	0.228	2.738	1.09	0.122	1.602	0.479	1.033	0.23	0.649
1974	0.029	0.019	0.002	0	0.019	0	0	0	0.003	0.001	0	1.82	0.155
1975	0.577	0	0.026	0.001	0	0.085	0.117	0	0	0.313	0.053	0	0.099
1976	0.153	0.083	0.004	0	0.403	0.051	0.018	0.356	0.107	0	0	0	0.096
1977	0	0.162	0.252	0.046	0	0	1.436	0.47	0.005	0	0	0	0.197
1978	0.253	0.092	0.018	0	0.019	0	0	0.011	0.005	3.798	3.454	0.467	0.687
1979	0.006	0	0	0	0	0	0	0	0.003	0	0	0	0.001
1980	0.002	0.034	0.004	0.121	0.03	0.768	0.459	0.337	0.105	0	0.474	0.05	0.2
1981	0.02	0.003	0.029	0.001	0	0	0.226	0.076	0.002	0	0	0	0.03
1982	0	0	0	0	0	0	0	0	0	0.809	0.197	0	0.085
1983	0.037	0.01	0	0	0	0	0	0	0.079	0.023	0	0	0.012
1984	0	0	0	0	0.015	0	0	0	0	0	0	0	0.001
1985	0.297	1.279	0.392	0.011	0.004	0	0	0	0	0	0	0.003	0.165
1986	0.201	0.082	0	0	0.001	0	0	0	0.004	0.001	0	0.008	0.025
1987	0.001	0	0	0	0.624	0.086	0	0	0	0	0	0	0.056
1988	0.001	0.007	0.012	0	0	0	0.123	0.039	0	0	0	0	0.015
1989	0.886	2.591	0.694	0	0.006	0.011	0.006	0	0.005	0.001	0	0	0.349
AVERAGE	0.161	0.19	0.091	0.039	0.071	0.106	0.137	0.154	0.108	0.135	0.123	0.153	0.122

ANNEXURE D
RESERVE

ANNEXURE E
GAUGING STATIONS STREAMFLOW

E1. **P1H003**

E2. **P3H001**

E3. **P4H001**

P1H003 (Million cubic metres)													
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1956/1957	#	#	#	#	#	0.771	#	#	#	0.006	0.004	0.001	#
1957/1958	0	0	0	0	0	0	0	29.3	0.002	0.002	0.002	0.002	29.3
1958/1959	0.001	0	0.001	2.64	2.44	0.464	0.515	0.027	0.016	1.13	0.303	0.23	7.76
1959/1960	0.013	0.006	0.004	0.02	0.287	0.045	0.269	0.028	0.015	0.017	0.009	0.025	0.737
1960/1961	0.015	0.009	0.006	0.005	0.09	3.38	0.366	0.013	0.002	0.002	6.8	0.045	10.7
1961/1962	0.011	0.006	0.002	0	0.35	0.446	0.014	0.008	0.005	0.004	0.004	0.003	0.854
1962/1963	0.006	0.022	0	0.082	0.004	3.06	11.6	0.439	0.036	0.171	0.057	0.009	15.5
1963/1964	0.011	0.009	0.078	0.003	0.008	0.003	0.003	0.002	0.007	0.005	0.01	2.45	2.59
1964/1965	0.095	1.55	0.005	0.001	0.002	0.001	0.007	0.005	0.011	0.017	0.01	0.009	1.71
1965/1966	1.18	4.26	#	0	0	0	0	0.003	0.004	0.004	0.01	0.003	#
1966/1967	0	0.002	0	0	0	0.001	0.369	3.2	1.83	1.64	0.364	0.046	7.45
1967/1968	0.011	#	#	#	#	#	#	#	#	#	#	#	#
1968/1969	#	#	0.007	0.004	0	1.24	0.02	0.01	0.019	0.01	0.018	0.015	#
1969/1970	0.007	0.004	#	#	0.003	0.004	0.002	0.004	0.006	0.005	1.45	0.049	#
1970/1971	0.275	#	#	#	#	#	11.5	0.737	#	0.051	26.1	3.87	#
1971/1972	1.34	0.083	0.012	0.011	0.008	0.006	#	#	0.016	0.011	0.01	0.006	#
1972/1973	0.004	0.005	0.001	#	#	0.01	#	0.011	0.007	0.007	0.011	0.005	#
1973/1974	0.007	0.916	0.424	0.152	0.149	21.7	3.7	3.33	1.77	0.742	20.4	11.4	64.6
1974/1975	1.5	0.13	0.11	0.009	0.147	0.205	0.029	#	0.037	#	0.014	4.43	#
1975/1976	1.2	0.023	0.018	0.014	0.015	#	2.2	0.839	#	0.35	0.423	0.074	#
1976/1977	0.35	2.56	0.036	0.009	1.09	0.147	0.166	4.1	0.398	0.153	0.076	0.017	9.1
1977/1978	0.018	0.046	#	#	0.085	0.011	0.017	0.012	0.028	0.031	0.024	0.022	#
1978/1979	0.027	0.022	0.011	0.047	#	0.017	0.009	0.011	0.011	#	#	12.1	#
1979/1980	2.02	0.241	0.016	0.012	0.276	0.037	0.013	0.012	0.014	0.018	0.018	0.016	2.69
1980/1981	0.014	0.094	0.475	0.009	0.363	4.63	1.37	3.93	7.66	1.04	0.68	4.45	24.7
1981/1982	0.904	0.235	4.05	0.36	0.013	0.014	0.046	0.04	0.031	0.036	0.022	0.041	5.79
1982/1983	0.016	0.018	0.014	#	#	#	0.012	0.01	0.01	25.2	2.77	0.373	#
1983/1984	3.97	1.09	0.135	0.031	0.02	0.033	0.031	0.014	0.013	0.006	0.022	0.015	5.38
1984/1985	0.015	0.012	0.013	0.011	0.013	0.012	0.011	0.024	0.012	0.016	0.014	0.009	0.162
1985/1986	0.325	7.73	9.54	0.728	0.013	0.016	0.012	0.011	0.012	0.015	#	0.012	#
1986/1987	0.02	0.014	0.008	0.006	0.01	0.017	0.008	0.011	0.012	0.01	0.01	#	#
1987/1988	0.008	0.004	#	0.002	1.23	0.045	0.011	0.016	0.011	0.019	0.012	0.009	#
1988/1989	0.008	0.013	0.025	0.005	#	0.045	0.085	0.012	0.011	0.011	0.012	0.008	#

P1H003 (Million cubic metres)													
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1989/1990	0.051	19.1	0.632	0.283	0.015	0.015	0.01	0.012	0.011	0.012	0.01	0.011	20.2
1990/1991	0.011	0.01	0.008	0.007	0.006	0.008	0.007	0.007	0.007	0.003	0.007	0.007	0.089

P3H001 (Million cubic metres)													
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1968/1969	#	#	#	#	#	#	#	#	#	#	0	0	#
1969/1970	0	0	0	0	0	0	0	0	0	0	0.156	0.096	0.253
1970/1971	3.54	0.261	62.4	0.416	1.4	0.81	4.62	0.675	0.179	0.099	7.25	0.917	82.6
1971/1972	0.511	0.158	0.068	0.014	0.011	0.03	0	0	0	0	0	0	0.792
1972/1973	0	0	0	0	0	0	0	0	0	0	0	0	0
1973/1974	0	0	0	0	0	0.123	0.61	2.19	#	#	#	#	#
1974/1975	#	#	0.037	0	0.016	0	0	0	0.01	#	#	#	#
1975/1976	#	0.047	0.165	0.257	0.003	1.19	0.869	#	0.027	0.616	0.388	0.063	#
1976/1977	0.405	3.23	0.055	0.002	0.003	0.007	0.039	4.21	0.333	0.186	0.04	0.036	8.55
1977/1978	0.087	0.425	0.548	2.99	0.027	0.003	0.512	0.648	0.293	0.16	0.082	0.06	5.83
1978/1979	0.633	1.33	0.074	0.005	0	0.074	0	0	0.014	35.2	49.6	7.14	94.1
1979/1980	1.12	0.276	0.009	0.003	0.005	0.005	0.005	0.004	0.005	0.005	0.006	0.006	1.45
1980/1981	0.005	0.007	0.016	0.008	0.039	8.01	2.51	1.97	5.95	0.736	0.488	2.71	22.5
1981/1982	0.499	0.112	0.086	0.065	0.002	0.001	0.006	0.006	0.009	0.008	0.038	0.007	0.838
1982/1983	0.001	0	0	0	0	0	0	0	0	3.25	0.86	0.06	4.18
1983/1984	0.414	0.09	0.004	0.001	0	0.01	0.004	0.003	0.005	0.003	0.01	0.009	0.554
1984/1985	0.003	0	0	0	0	0	0	#	0	0	#	0	#
1985/1986	0.001	7.59	8.71	1.18	0.066	0.106	0.025	0.012	0.021	0.008	0.037	0.048	17.8
1986/1987	0.321	0.339	0.204	0.004	0.003	0.002	0.001	0.001	0	0.002	0.003	0.002	0.883
1987/1988	#	0	0	#	0.441	0.421	#	0.009	0.007	0.054	0.018	0.012	#
1988/1989	0.009	#	0.006	0.001	#	0.008	0.004	0.004	0.002	0.002	0.002	0.001	#
1989/1990	0.959	19.6	0.928	0.019	0.021	0.099	0.03	0.023	0.025	0.047	0.02	0.015	21.8
1990/1991	0.016	0.009	0.004	0.002	0	0	0	0	0	0	0	0	0.031
1991/1992	0.002	0.003	0.002	0	0	0	0	0	0	0	0	0	0.007
1992/1993	0	0.001	0	0	0	0	0	0	0	0	0	0.074	0.076
1993/1994	0.005	0.003	0.038	0.124	0.129	0.054	0.004	0.003	0.003	0.003	0.006	0.008	0.38
1994/1995	0.128	0.005	1.89	10.1	0.252	0.12	0.135	0.112	0.025	0.016	0.011	0.008	12.8
1995/1996	0.006	0.005	0.005	0.003	0.003	0.001	0.002	0	0	0.002	0.002	0.003	0.033
1996/1997	0.003	2.91	0.41	0.259	0.007	0.005	0.024	0.142	3.29	1.57	0.423	0.171	9.22
1997/1998	0.029	0.012	0.007	0.007	0.004	0.047	0.045	0.036	0.013	0.012	0.016	0.028	0.256
1998/1999	0.021	0.011	0.208	0.028	0.006	0.008	0.007	0.005	0.006	0.007	0.008	0.007	0.323
1999/2000	0.009	0.007	0.005	0.003	0.003	0.007	0.011	0.009	0.01	0.008	0.009	0.009	0.089
2000/2001	0.007	1.72	0.127	0.043	0.011	0.009	0.015	0.022	0.012	0.012	0.078	0.407	2.46
2001/2002	0.375	0.812	0.49	0.06	0.014	0.01	0.01	0.008	0.009	0.014	6.84	26	34.6

P3H001 (Million cubic metres)													
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
2002/2003	1.31	0.155	0.039	0.014	0.949	0.025	#	#	#	#	#	#	#
No of #	4	3	1	2	2	1	3	4	3	4	4	3	34
Total # elements	35	35	35	35	35	35	35	35	35	35	35	35	420
Total # 0	4	6	7	8	10	8	10	10	10	7	6	6	92
% complete	91.9047619												
% zero	21.9047619												

P1H003 (Million cubic metres)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1991/1992	0.013	0.007	0.003	0.003	0.006	0.008	0.004	0.004	0.003	0.004	0.009	0.01	0.074
1992/1993	0.014	0.01	0.006	0.007	0.006	0.006	0.008	0.009	0.012	0.009	0.021	0.025	0.133
1993/1994	0.672	0.014	1.48	1.03	0.043	0.393	0.015	0.017	0.015	0.015	0.017	0.013	3.72
1994/1995	0.022	0.01	0.021	3.81	0.033	0.02	0.017	0.019	0.017	0.016	0.02	0.016	4.02
1995/1996	0.013	0.014	0.374	0.02	0.013	0.017	0.014	0.012	0.011	0.011	0.014	0.012	0.526
1996/1997	0.018	12.4	3.66	1.97	0.026	0.015	3.84	0.53	3.5	2.56	0.565	0.081	29.1
1997/1998	0.018	0.017	0.014	0.013	0.011	0.02	0.02	0.018	0.013	0.015	0.015	0.016	0.19
1998/1999	0.015	0.009	0.011	0.38	0.013	0.019	0.017	0.016	0.013	0.021	0.015	0.017	0.547
1999/2000	0.015	0.012	0.012	0.012	0.013	0.265	2.28	0.06	0.024	0.021	0.023	0.023	2.76
2000/2001	0.016	6.19	0.179	0.091	0.02	0.023	1.56	0.151	0.033	0.028	0.037	0.206	8.53
2001/2002	0.196	0.61	0.931	0.07	0.028	0.025	0.03	0.025	0.027	0.03	8.09	24.9	35
2002/2003	1.36	0.088	0.264	0.024	#	#	#	#	#	#	#	#	#
No of #	2	4	7	7	8	5	5	5	5	4	4	3	59
Total # elements	47	47	47	47	47	47	47	47	47	47	47	47	564
Total # 0	2	2	3	4	4	2	2	0	0	0	0	0	19
% complete	89.53901												
% zero	3.368794												

P4H001 (Million cubic metres)													
Year	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
1968/1969	#	#	#	#	#	#	#	#	#	#	0.059	0.044	#
1969/1970	0.002	0	0	0	0	0	0	0	0	0	11.1	2.58	13.7
1970/1971	12.6	0.943	#	#	1.68	#	4.65	0.82	0.375	0.231	17.7	2.01	#
1971/1972	2.18	1.05	1.16	#	0.219	0.293	0.067	0.05	0.074	#	0.027	0.116	#
1972/1973	0.004	0.019	0	0	0	0	0	0	0	0	0	0	0.023
1973/1974	0	0	0	0	1.05	53.8	5.37	4.82	7.63	#	#	3.55	#
1974/1975	1.37	0.359	0.38	0.047	0.01	0.044	0.018	0	0.082	0.108	0.067	27.0m	29.5m
1975/1976	3.07	0.325	0.714	0.253	0.243	2.23	1.18	0.709	0.195	#	0.975	0.333	#
1976/1977	2.55	6.59	0.289	#	#	0.62	0.237	17.1	0.823	0.587	0.315	0.261	#
1977/1978	0.315	1.93	0.658	5.25	0.33	0.009	20.9	3.75	1.34	0.807	0.426	0.26	36
1978/1979	2.32	2.73	0.386	0.127	0.021	1.08	0.137	0.201	0.412	52.1	60	8.17	128
1979/1980	2.07	0.561	#	0.021	0.015	0.021	0.004	0	0	0.046	0.038	0.091	#
1980/1981	0.145	0.043	0.353	0.094	1.17	12.4	2.58	1.29	3.03	0.592	0.961	3.22	25.9
1981/1982	2.73	1.48	0.416	0.09	0	#	0	0	0	0	0	0	#
1982/1983	0	0	0	0	0	0	0	0	0	1.29	0.61	0.057	1.95
1983/1984	2.01	0.375	0.071	0.002	0	0	0	0	0	0	0	0	2.46
1984/1985	#	0	0	0	0	0	0	0	0	0	0	0	#
1985/1986	0	64	22.1	#	0.54	0.675	0.211	0.071	0.073	0.055	0.059	0.177	#
1986/1987	2.36	2.17	0.622	0.025	0	#	0	0	0	0	0	#	#
1987/1988	0.018	0	0	0	0.136	3.07	0.876	0.145	0.083	0.037	0.011	0.121	4.5
1988/1989	0.283	0.215	0.12	0.231	0	0	0.06	0.256	0.064	0.047	0.027	0.001	1.31
1989/1990	6.16	69.5	1.79	0.218	0.232	0.848	0.684	0.305	0.065	0.148	0.046	0.105	80.1
1990/1991	0.101	0.039	0	0	0	0	0	0	0	0	0	0	0.14
1991/1992	0	0.474	0.073	0	0	0.097	0.011	0	0	0	0.064	0.002	0.721
1992/1993	0.005	0.179	0.004	0	0	0	0	0	0	0	0	0.172	0.361
1993/1994	0.202	0.034	2.4	2.34	4.42	1.57	0.156	0.019	0.024	0.02	0.454	0.2	11.8
1994/1995	0.145	0.018	19.7	8.31	0.94	2.03	1.54	0.739	0.276	0.126	0.05	0.025	33.8
1995/1996	0.027	0.037	0.116	0.098	0	0	0.002	0	0	0	0	0	0.279
1996/1997	0	7.62	2.23	1.52	0.055	0.014	1.97	1.69	10.1	3.04	0.97	0.696	30
1997/1998	0.546	0.199	0.024	0	0	0.002	0.063	0.031	0.011	0.002	0.026	0.205	1.11
1998/1999	0.161	0.023	1.85	0.585	0.052	0.039	0.322	0.084	0.053	0.05	0.244	0.085	3.55
1999/2000	0.161	0.074	0.001	0	0	1.09	4.76	0.808	0.252	0.092	0.063	0.08	7.37
2000/2001	0.089	7.15	0.801	0.398	0.062	0.043	0.929	0.394	0.118	0.169	0.827	0.669	11.6
2001/2002	0.708	3.49	2.59	0.548	0.191	0.034	0.055	0.113	0.046	#	20.5	30.4	#
No of #	2	1	3	5	2	4	1	1	1	5	1	1	27
Total #	34	34	34	34	34	34	34	34	34	34	34	34	408
Total # 0	5	5	7	11	14	9	9	13	12	10	8	6	109

P4H001 (Million cubic metres)													
Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
% complete	93.38235												
% zero	26.71569												

ANNEXURE F

ELEVATION – CAPACITY AND AREA CURVES

F1. SAREL HAYWARD DAM

F2. BUSHFONTEIN DAM

F3. GOLDEN RIDGE DAM

ELEVATION - CAPACITY & AREA CURVES

Bushfontein Dam (New proposed)

RL (m)	Area (km^2)	Cumulative Volume (Million m^3)
37	0.000	0.000
38	0.006	0.003
40	0.040	0.049
45	0.173	0.582
50	0.362	1.919
55	0.607	4.342
60.29	0.960	8.259
65	1.250	13.784
70	1.685	21.122

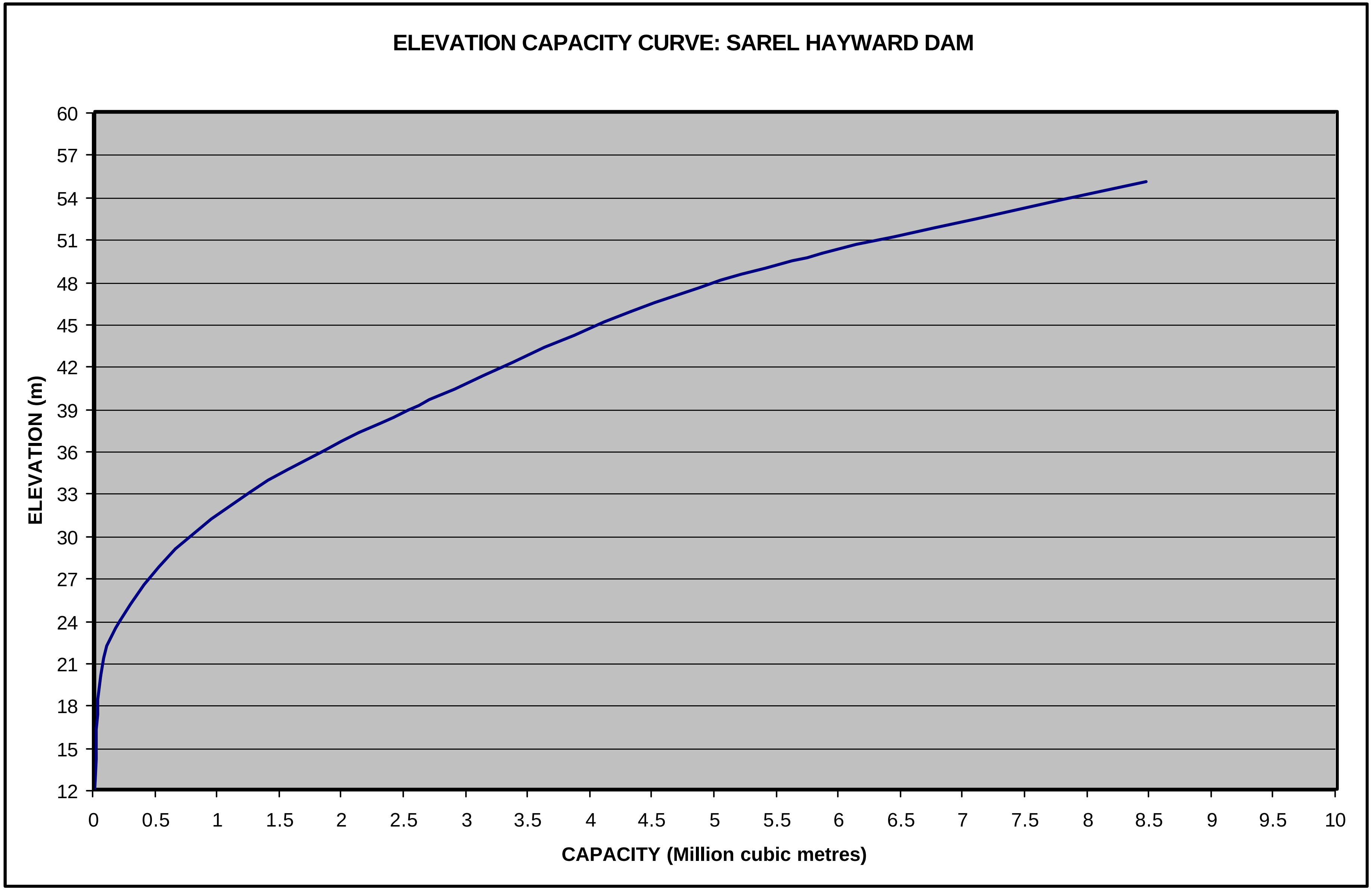
Sarel Hayward Dam

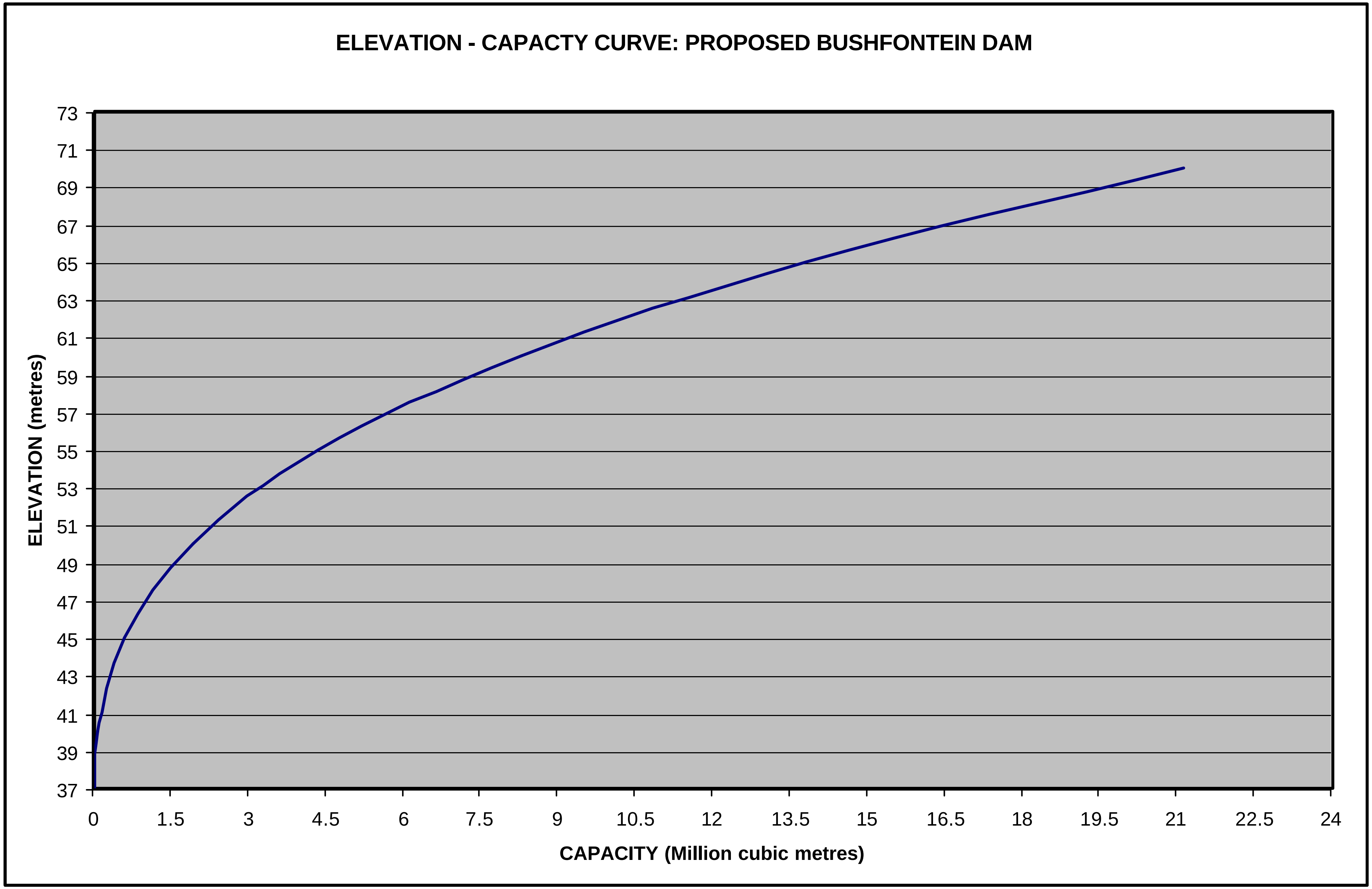
RL (m)	Cumulative Volume (Million m^3)	RL (m)	Area (km^2)
12	0.000	12	0.000
20	0.050	15	0.007
24	0.200	19.7	0.022
29	0.650	25	0.054
33	1.250	30	0.105
36	1.850	35.6	0.164
39	2.522	40	0.225
46	4.320	45.3	0.341
50	5.848	50	0.456
55	8.461	55	0.589

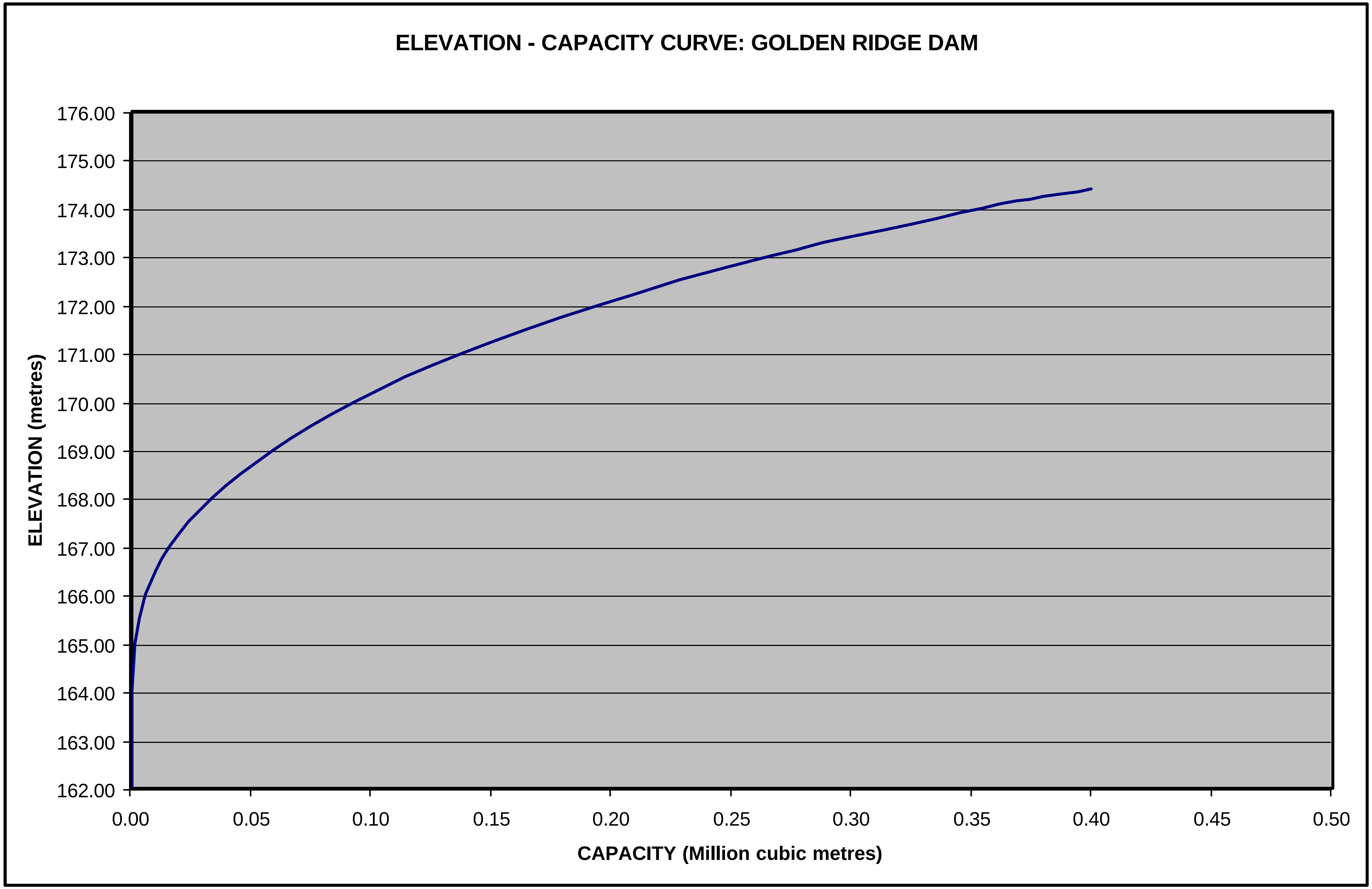
Golden Ridge Dam

RL (m)	Area (km^2)	Cumulative Volume (Million m^3)
162.00	0.000	0.000
163.00	0.000	0.000
164.00	0.000	0.000
165.00	0.002	0.001
166.00	0.006	0.005
167.00	0.014	0.015
168.00	0.022	0.033
169.00	0.029	0.059
170.00	0.039	0.093
171.00	0.051	0.138
172.00	0.063	0.195
173.00	0.079	0.266
174.00	0.098	0.354
174.41	0.125	0.399

Provided by UWP


ELEVATION CAPACITY CURVE: SAREL HAYWARD DAM
ELEVATION (m)
60
57
54
51
48
45
42
39
36
33
30
27
24
21
18
15
12
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
CAPACITY (Million cubic metres)


ELEVATION - CAPACTY CURVE: PROPOSED BUSHFONTEIN DAM
ELEVATION (metres)
73
71
69
67
65
63
61
59
57
55
53
51
49
47
45
43
41
39
37
0
1.5
3
4.5
6
7.5
9
10.5
12
13.5
15
16.5
18
19.5
21
22.5
24
CAPACITY (Million cubic metres)

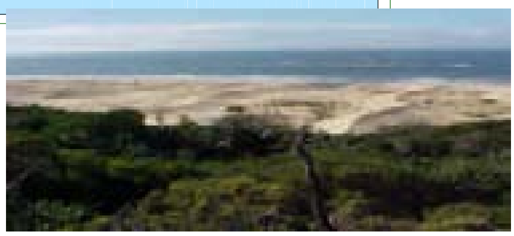

ELEVATION - CAPACITY CURVE: GOLDEN RIDGE DAM
ELEVATION (metres)
176.00
175.00
174.00
173.00
172.00
171.00
170.00
169.00
168.00
167.00
166.00
165.00
164.00
163.00
162.00
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
CAPACITY (Million cubic metres)

P WMA 15/000/00/0410

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate: National Water Resource Planning

ALBANY COAST SITUATION ASSESSMENT STUDY



Water Quality

Final

December 2004

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DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE: NATIONAL WATER RESOURCE PLANNING

PROJECT NAME	:	Albany Coast Situation Assessment Study
TITLE	:	Water Quality – Final
AUTHOR	:	K Sami
REPORT STATUS	:	Final
DWAF REPORT NO	:	P WMA 15/000/00/0410
DATE	:	December 2004

Submitted on behalf of WSM Leshika (Pty) Ltd by:

……………………………………………………………………………..
HV DOUDENSKI
Project Leader

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate: National Water Resource Planning

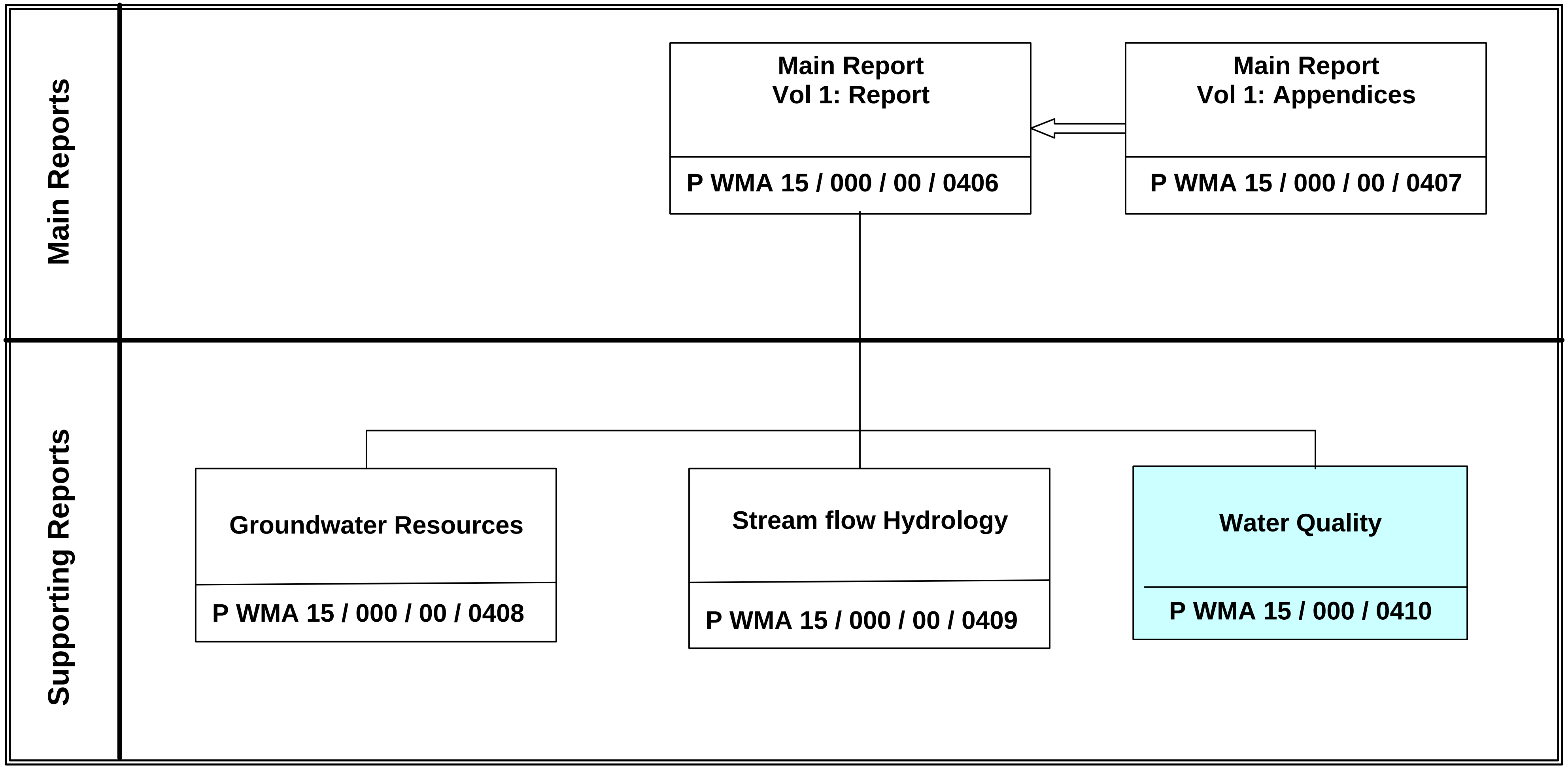
Approved for Department of Water Affairs and Forestry by:

……………………………………...…………..
FA STOFFBERG
Chief Engineer: National Water Resource Planning

…………………………………………..….
JA VAN ROOYEN
Director: National Water Resource Planning

ALBANY COAST SITUATION ASSESSMENT STUDY

Structure of Reports



EXECUTIVE SUMMARY

Introduction: Much of Region P is underlain by rocks of marine origin that contribute a significant salt load to runoff, especially during low flow periods. TDS levels in the rivers can exceed 2 000 mg/l due to leaching of these salts. As a result, dams with catchment areas in these strata provide poor quality water. *The purpose of the desk top study* is to calculate the expected salt loads and TDS levels in the proposed dam reservoirs.

Study area geology: The strata in the area belong to the Cape Supergroup (Bokkeveld and Witteberg Groups) the Karoo Supergroup (Dwyka Group), Cretaceous age silcretes of the Grahamstown Formation, and Quaternary sediments of the Algoa Group.

Study area drainage: The main rivers draining the region are the Bushman's (P10), Boknes (P20), Kariega (p30), Kowie (P40A-C), and the Kleinemonde (P40D). There is no significant groundwater baseflow in the rivers and runoff consists of storm runoff and throughflow from drainage of the weathered zone immediately following rain events.

Surface water quality: Rainfall on the Bokkeveld and other marine terrains results in flushing of surficial salts released by weathering, and the leaching of salts by water percolating through the soil and weathered zone. In general, water leaching over Bokkeveld shales results in 0.3 g salt/kg of rock, whereas soils developed over Bokkeveld yield 0.8-4 g/kg. As a result, 25-50 tons of salt are expected to be leached per mm of rain, resulting in surface runoff having a TDS of over 2 200 mg/l, given rainfalls of 600 mm/a.

Over 73% of the salt load is derived from the coastal Nanaga and inland Weltevrede Formations, which occupy 70% of the area. By comparison, nearly 16% of the salt load is derived from Bokkeveld shales, which occupy only 2.3 % of the area. The Dwyka tillites, although containing saline groundwater, contribute only 2% of the salt load and generate primarily fresh surface runoff in the headwater catchments due to their low permeability.

High salt loads for the Weltevrede Formations in Quaternary catchments P30B and P40B can be attributed to significant irrigation return flows on the Kariega and Bloukrans rivers. Over much of catchments P20A, P20B, P30B, P10E and P10F the

Nanaga Formation overlies Bokkeveld shales, hence produces more saline than elsewhere. High salinities are also recorded in boreholes drilled in the Nanaga in these catchments. As a result, runoff from the Nanaga in these catchments generally produces high salt loads.

The quality of runoff is categorised according to the DWAF drinking water classification. In general, only the Witpoort quartzites, and the Dwyka tillites in the headwater region, produce Class 0 water.

Predicted runoff quality: In the Bushman's river, good water quality (Class 1) can be expected down stream to include Quaternaries P10A-D, which are the New Year's and upper Bushman's rivers to Alicedale. *South of Alicedale*, water quality deteriorates rapidly due to significant salt loads originating from the Nanaga and Weltevrede Formations. Runoff continues to become progressively more saline downstream.

In the Kariega catchment acceptable water quality is only present in the head waters of the Kariega, P10A and the headwaters of the Assegai, P30B, which is partially underlain by Witpoort quartzites. *Below the Settler's dam* in catchment P30B water quality deteriorates rapidly due to salt loads from the Weltevrede shales and irrigation return flows.

In the Kowie River, water quality is acceptable in the headwaters, which are underlain by Dwyka, Lake Mentz and Witpoort rocks (P40A). Water quality deteriorates once the *river flows over Weltevrede rocks* north of Bloukrans pass. Salinisation is also expected due to irrigation in the Belmont valley of the Bloukrans, SE of Grahamstown.

In the Boknes catchment, good quality water can only be expected from springs emanating from the Alexandria Formation at the base of the Nanaga Formation at its contact with the Bokkeveld. The Boknes River itself flows over Bokkeveld rocks and *water quality deteriorates rapidly down channel*.

The Diepkloof is an intermittent river with internal drainage into the back dunes regions. Water quality of springs draining the Nanaga is *generally poor*.

Conclusion: The development of dams to produce acceptable quality water is generally not possible, except in those upstream areas underlain by Witpoort quartzites and Dwyka tillites.

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1 INTRODUCTION

1.1 BACKGROUND

Much of Region P is underlain by rocks of marine origin that contribute a significant salt load to runoff, especially during low flow periods. TDS levels in the rivers can exceed 2000 mg/l due to leaching of these salts. This problem is exacerbated where the natural geological profile has been disturbed by agricultural practice, where tillage exposes more of the profile to leaching, or where removal of vegetation increases infiltration.

As a result, dams in the region that have their catchments underlain by marine sediments provide poor quality water due to excessive salt loads in the inflow water. In order to quantify salt loads at potential dam sites, the water quality of groundwater seepage and natural runoff is characterised by lithology and by Quaternary catchment in order to provide a means to characterise water quality at potential dam sites underlain by variable portions of marine lithologies.

1.2 TERMS OF REFERENCE

WSM was approached by UWP regarding potential water quality problems that could arise in proposed dam sites for Ndlambe Municipality in the Eastern Cape. WSM was appointed by UWP Ref. No. 23821/RW/06.

1.3 SCOPE OF WORK

The scope of work includes calculating salt loads and approximate TDS in water at a reconnaissance scale for proposed dam sites when varying proportions of the dam catchment are underlain by marine deposits. This objective requires:

- Characterising surface and subsurface water quality for the Bokkeveld and Witteberg Groups.
- Estimating runoff coefficients and groundwater seepage for the above geological Groups
- Estimate final water quality for varying proportions of Bokkeveld catchment area using a geochemical mixing model.

- Determining maximum proportions of a catchment that could be underlain by saline marine deposits before unacceptable water quality occurs.

1.4 DATA SOURCES

The study will be at a desk top level based on available data and limited field investigation. Data sources consulted include:

- Water quality from local dams established on Bokkeveld and Witteberg Group rocks
- Local borehole and surface runoff collected while undertaking the Albany Coast Water Situation Assessment
- Water quality data from the DWAF ZQM data base
- Runoff coefficients derived from WSAM

2 THE STUDY AREA

2.1 GEOLOGY

The strata in the area belong to the Cape Supergroup (Bokkeveld and Witteberg Groups) the Karoo Supergroup (Dwyka Group), Cretaceous age silcretes of the Grahamstown Formation, and Quaternary sediments of the Algoa Group (Table 1 and Map 1).

The oldest rocks are of the Bokkeveld Group that lies conformably over the Table Mountain Group and comprises the lower Ceres subgroup, which consists of 3 inter-bedded mudrock and 3 thin sandstone layers, and the upper Traka subgroup, which consist of shales and siltstones. These are overlain by the Witteberg Group, of which the lowest member is the Weltevrede Formation, consisting of shale, phyllite and sandstone, and the Witpoort Formation, consisting of quartzite.

The Bokkeveld Group generally lies in synclinal valleys in between mountain ranges consisting of quartzite. Resistant steeply folded beds of shales and siltstones and sandstones form sharp hogsback ridges V ridges at the noses of anticlines and synclines and elongated basins and domes that trends ESE parallel to river valleys.

The shales are generally dark grey to black and have a high carbon content, seen as graphite flakes in cleavage zones. They contain a high iron sulphide fraction in the form of pyrite and sericite. Although these rocks have a low permeability, groundwater from these rocks can have a TDS exceeding 4000 mg/l and up to 9000 mg/l.

Sandstone formations are generally thin and fine grained and also contain sericite mica. The sandstones contain much sericite mica and have well developed jointing that provide channels for groundwater movement, therefore the sandstone beds are of significantly lower salinity.

The Bokkeveld is of marine origin and formed under deltaic conditions. Rocks are generally of very low permeability due to the high degree of rock induration, and pore spaces have been effectively sealed due to secondary crystallisation during periods of dynamic metamorphism, orogenesis and tectogenesis. The presence of well developed micaceous cleavage and graphite confirms high pressures were active in sealing these rocks.

Groundwater flow is restricted to joints, fractures and faults that have a variable degree of openness and marine salts have therefore not been leached from the rock matrix over geological time. Shales of the Bokkeveld Group therefore contain highly saline connate water due to high concentrations of sodium chloride sorbed on to clays micas and graphite platlets, or held immobile in pores until weathering of the rock matrix allows leaching and drainage. Salts are generally released from broken fragments in the weathered zone from material rich in sericite mica and graphite.

When leached, magnesium, calcium, iron and aluminium oxides are leached out of the rock, co-releasing sorbed Cl. Oxidation of sulphide minerals also produces large amounts of sulphate. Cation exchange from weathered clays sorbs the released magnesium and calcium in exchange for sodium, resulting in strongly sodium-chloride type water.

The Witteberg Group consists of the Weltevrede and, Witpoort Formations, and the Lake Mentz Subgroup. The Weltevrede consists of shales deposited under similar conditions to the Bokkeveld, hence is expected to have a similar saline character. The Witpoort quartzites represent deltaic or fluviatile deposits and do not produce saline marine water. The Lake Mentz subgroup represent offshore marine deposits, hence also yield brackish water. Te Witteberg Group lies conformably over the Bokkeveld and builds a series of foothills.

The Dwyka Group consists of glacial tills deposited in deep marine water by ice-rafting. It is generally present in valley bottoms of the New Years and Bloukrans rivers near Grahamstown.

The Nanaga Formation consists of Pliocene-Pleistocene Aeolian deposits deposited in coastal dune fields; hence do not have a marine origin.

Table 1 Stratigraphy of Region P.

Supergroup	Group	Subgroup	Formation	Lithology
	Algoa		Nanaga	Calcareous sandstone, sandy limestone
			Grahamstown	Silcrete
	Uitenhage		Kirkwood	Mudstone
Karoo	Dwyka		Elandsvlei	Diamictite
Cape	Witteberg	Lake Mentz	Waaipoort	Mudrock, sandstone

			Floriskraal	Mudrock, sandstone
			Kweekvlei	Mudrock
			Witpoort	Quartzite
			Weltevrede	Shale, quartzite
	Bokkeveld	Traka	Sandpoort Adolphspoort Karies	Shale, siltstone
		Ceres	BoPlaas Tra-Tra Hex River Voorstehoek Gamka Ghydo	Mudrock, shale, sandstone

2.2 DRAINAGE

The main rivers draining the region are the Bushman's (P10), Boknes (P20), Kariega (p30), Kowie (P40A-C), and the Kleinemonde (P40D). The Quaternary catchments, runoff and baseflow, as given in WSAM, are listed in Table 2 and shown on Map 1.

Table 2 Runoff and baseflow

Quaternary	Area (km^2)	MAP (mm)	MAR (Mm^3/a)	Baseflow (mm/a)	MAR (mm/a)
P10A	126	600	4.51	11.31	35.79
P10B	508	531	12.25	8.07	24.11
P10C	281	386	2.38	2.99	8.47
P10D	564	432	7.01	4.48	12.43
P10E	466	493	8.71	0.75	18.69
P10F	469	557	13.67	2.21	29.15
P10G	343	550	9.76	1.79	28.45
P20A	422	715	30.27	12.91	71.73
P20B	332	635	15.43	5.14	46.48
P30A	176	623	6.95	12.72	39.49
P30B	403	559	11.67	2.30	28.96
P30C	68	536	1.69	0.00	24.85
P40A	312	635	13.58	14.23	43.53
P40B	264	570	8.17	2.03	30.95
P40C	342	616	14.18	4.20	41.46
P40D	246	666	13.36	6.24	54.31

There is no significant groundwater baseflow in the rivers and runoff consists of storm runoff and throughflow from drainage of the weathered zone immediately following rain events.

Due to the widespread presence of alien invasive vegetation and farm dams, significant runoff reduction has occurred. Estimated runoff due to runoff reduction is given in table 3.

Table 3 Runoff due to runoff reduction by alien invasives

Quaternary	Alien Invasives (km^2)	Estimated runoff (Mm^3)
P10A	5.27	3.09
P10B	4.51	9.78
P10C	0	1.54
P10D	0.26	4.60
P10E	0.78	8.56
P10F	11.2	12.63
P10G	0.41	9.23
P20A	51.10	24.82
P20B	57.19	13.72
P30A	22.12	4.71
P30B	5.49	10.74
P30C	0.38	1.69
P40A	40.11	9.14
P40B	5.62	7.63
P40C	10.98	12.71
P40D	13.51	11.83

2.3 QUATERNARY CATCHMENT GEOLOGY

The proportion of each Quaternary catchment underlain by the various geological Formations is given in table 4.

Due to the difficulties in establishing the contacts between some of the various Formations, the areas underlain by the various lithologies must be considered approximate.

2.4 QUATERNARY CATCHMENT GROUNDWATER QUALITY

Borehole and surface water quality data found in the National ZQM water quality data base was clipped using Quaternary and geological formation boundaries to identify the range of TDS values in each Formation per quaternary catchment. The average TDS value was used to categorise each Formation (table 5). Where no data was present, TDS was extrapolated from an adjacent Quaternary catchment. A weighted mean catchment groundwater TDS was subsequently derived according to lithological type areas and their percentage distribution. The results are shown in table 5.

2.5 QUATERNARY CATCHMENT SURFACE WATER QUALITY

Rainfall on Bokkeveld and other marine terrains results in flushing of surficial salts released by weathering, and the leaching of salts by water percolating through the soil and weathered zone. In general, water leaching over Bokkeveld shales results in 0.3 g salt/kg of rock, whereas soils developed over Bokkeveld yield 0.8-4 g/kg. As a result, 25-50 tons of salt are expected to be leached per mm of rain, resulting in surface runoff having a TDS of over 2200 mg/l, given rainfalls of 600 mm/a.

Peak TDS is encountered during the first flush of runoff, with a lowering of TDS generally appearing several days after peak flows. The recorded TDS of runoff is shown in figures 1-7.

2.5.1 Bushman's River – P10

In the headwater regions of the New Year's river (P10A, figure 1), TDS is generally less than 200 mg/l and has a mean value of 140 mg/l, except during rainfall events, when a first flush of higher TDS of up to 500 mg/l can be expected. Following these events, lower TDS values are recorded.

Higher TDS values are recorded downstream in catchment P10B (figure 2), where TDS averages approximately 500 mg/l. During flood events, TDS rises to over 3500 mg/l.

TDS continues to rise downstream (P10E, figure 3), and the Bushman's river has an average TDS of 2200 mg/l, rising to over 4000 mg/l during flood events. Immediately after floods flush salts from the catchment TDS values drop to as low as 500 mg/l.

Pools sampled in the Bushman's and the Bega river tributary that originates on Bokkeveld shales had TDS values of 4400 mg/l, and over 10 000 mg/l respectively.

2.5.2 Kariega River – P30

The headwaters of the Kariega (P30A figure 4) generally have an average TDS of 250-400 mg/l, which rises up to 1400 mg/l during floods. Downstream in P30B the Kariega has an average TDS of 2500 mg/l, rising to over 5500 mg/l during floods (figure 5).

2.5.3 Kowie River – P40

In the headwaters of the Kowie (P40A figure 6) average TDS values are 750-900 mg/l, rising to over 1300 mg/l during floods. TDS values increase downstream to an average of 1700 mg/l in P40C (figure 7).

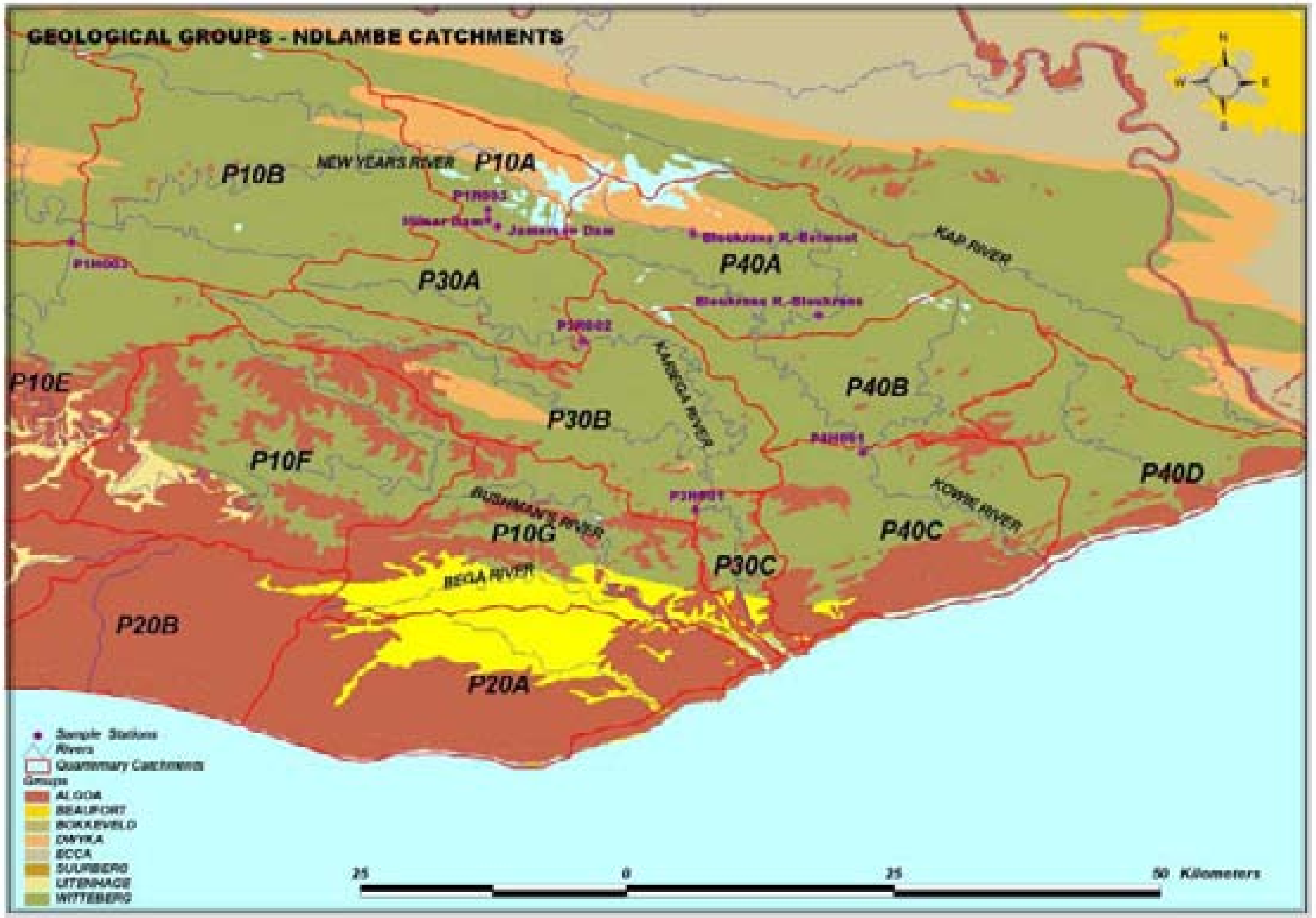
2.6 SALT LOADS

To calculate salt loads, the average TDS of runoff was obtained from the WSAM model. The weighted mean groundwater TDS times baseflow volumes were used to calculate the annual salt load contributed by subsurface drainage. The remainder of the total salt load was attributed to the flushing of salts by surface runoff (table 6). TDS values for runoff in catchments P10E, F and G were not available from WSAM and were estimated based on recorded discharges (figure 3).

Salt loads per mm of rainfall and runoff are shown in table 7, together with the estimated weighted mean TDS in runoff calculated from runoff and estimated total salt loads.

Quaternary	Weltevrede	Witpoort	Nanaga	Grahamstown	Lake Mentz	Bokkeveld	Dwyka	Basalt	Kirkwood	Sand	Limestone
P10A	10.57	27.00		8.73	13.40		40.30				
P10B	18.38	50.00			18.81		12.81				
P10C	43.50				44.09		12.40				
P10D	53.50				32.52		13.98				
P10E	39.95		49.00	0.09	1.67			2.15	7.12	0.02	
P10F	10.62		70.00	0.38	6.18	6.00	3.00	1.13	0.84	1.85	
P10G	26.64		46.00		12.36	15.00					
P20A			84.26			10.96				4.78	
P20B			90.21			3.94				5.15	
P30A	60.00		40.00		0.00						
P30B	71.00		19.00		6.00		4.00				
P30C	26.00		60.60		10.80	1.10				1.50	
P40A	57.00			3.80	23.50		15.10				0.60
P40B	94.40				0.00						5.60
P40C	42.20		42.10		8.70	1.80				4.80	0.40
P40D	50.20		33.30		13.80					1.90	0.80

Table 4 Percentage distribution of Formations by Quaternary catchment



Map 1 Geological Map of region P, showing Quaternary catchments and water quality sampling points.

Quaternary	Weltevrede	Witpoort	Nanaga	Grahamstown	Lake Mentz	Bokkeveld	Dwyka	Basalt	Kirkwood	Sand	Limestone	Mean TDS (mg/l)
P10A	600	552		106	666		106					353.66
P10B	900	963			1192		3677					1342.07
P10C	800	963			1400		992					1088.38
P10D	800				1014		992					896.43
P10E	3761	1394	2629	1394	1394			1520	1520	2629		2956.64
P10F	3188	3188	2838	1394	1600	3929	3188	600	1520	2600		2828.33
P10G	2557		1881		1875	3929				2360		2641.93
P20A			2417			2358				819		2334.15
P20B			2578			3828				819		2536.66
P30A	600		600									600.00
P30B	2498	2498	915		2489		2498					2196.69
P30C	1233	1420	994		927	8123				2600		1151.41
P40A	2600	588		1394	2400		2500				800	2481.27
P40B	2609	656					2500				800	2507.70
P40C	2442	2255	2255		2500	2034				2600	1337	2364.14
P40D	2509	1473	1473		2500					2600	813	2150.93

Table 5 Average TDS in mg/l per Formation and weighted mean groundwater TDS in mg/l per Quaternary catchment.

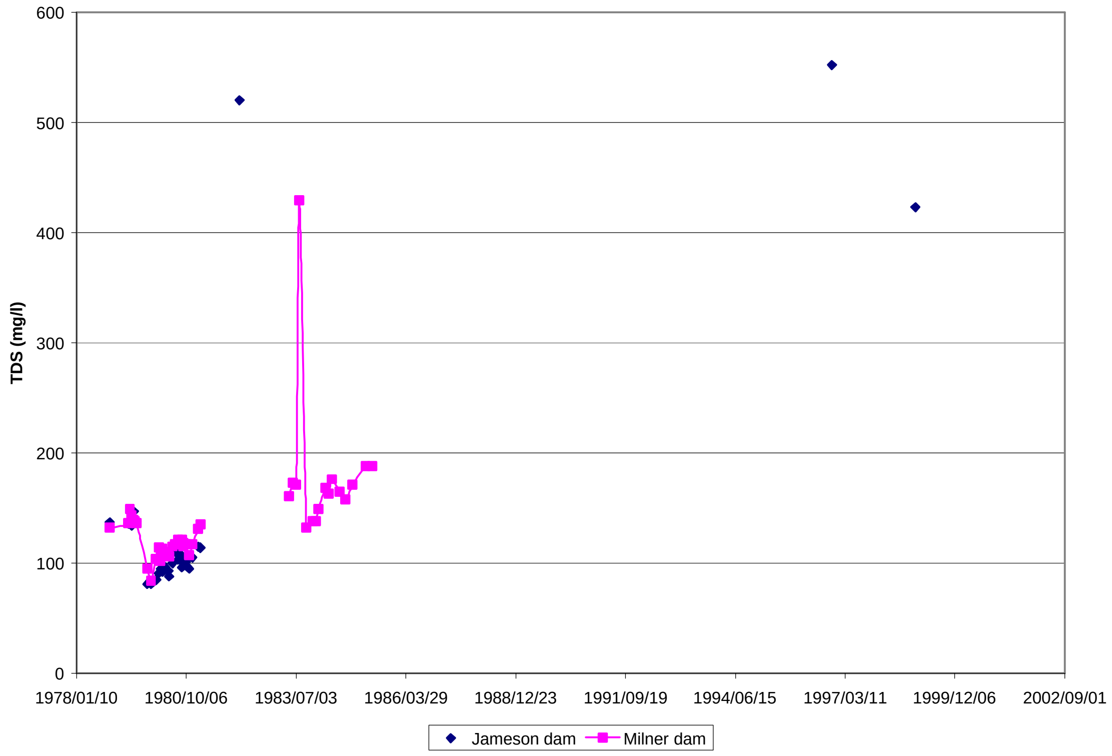


Figure 1 TDS values in Jameson and Milner dams, P10A

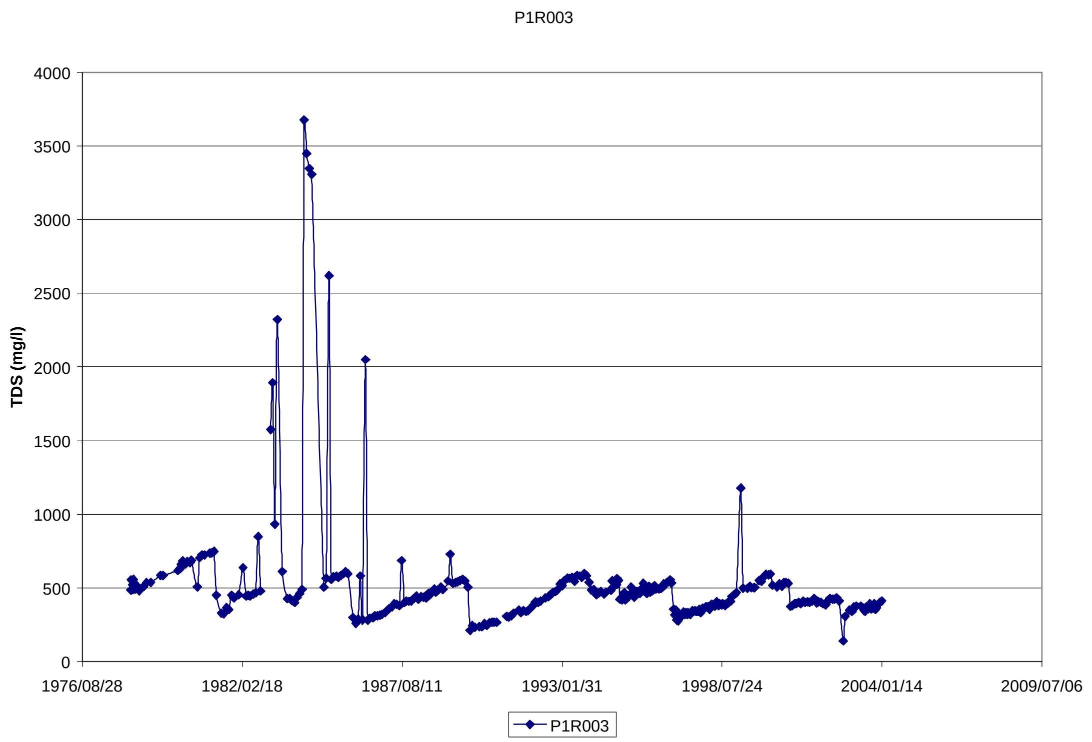


Figure 2 TDS values at gauge P1R003, P10B.

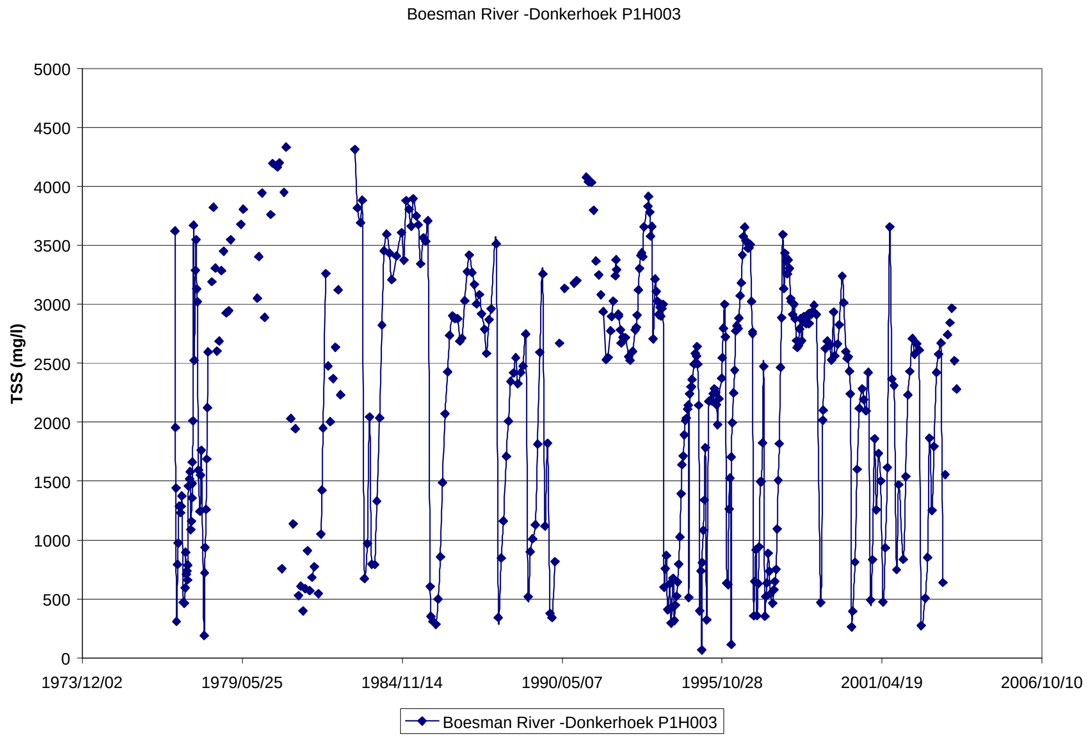


Figure 3 TDS values in the Bushman's river, P10E

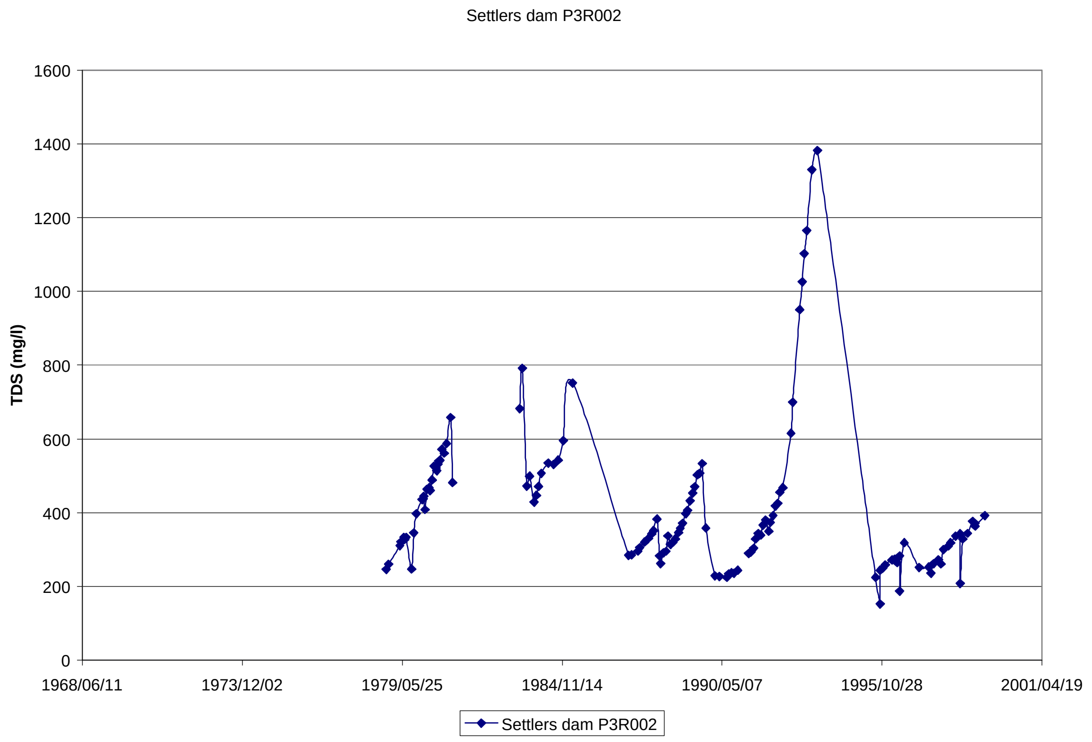


Figure 4 TDS values in Settler's dam, P30A

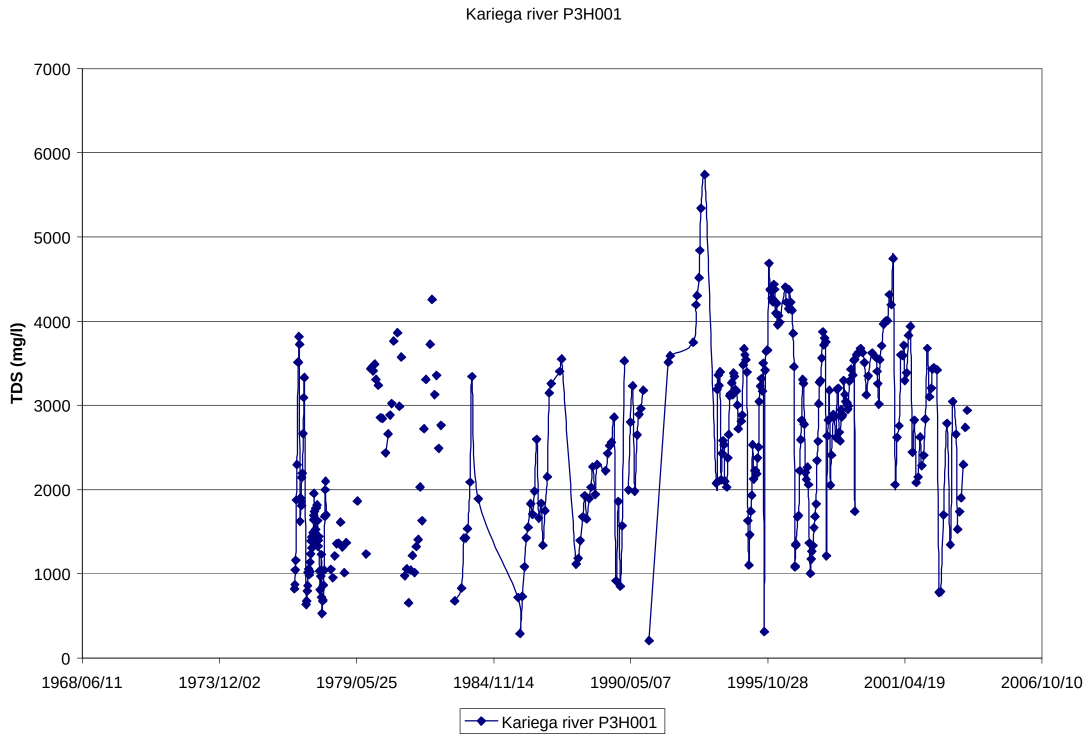


Figure 5 TDS values in the Kariega river, P3H001, P30B

Figure 6 TDS values in the Blaukrans river, P40A

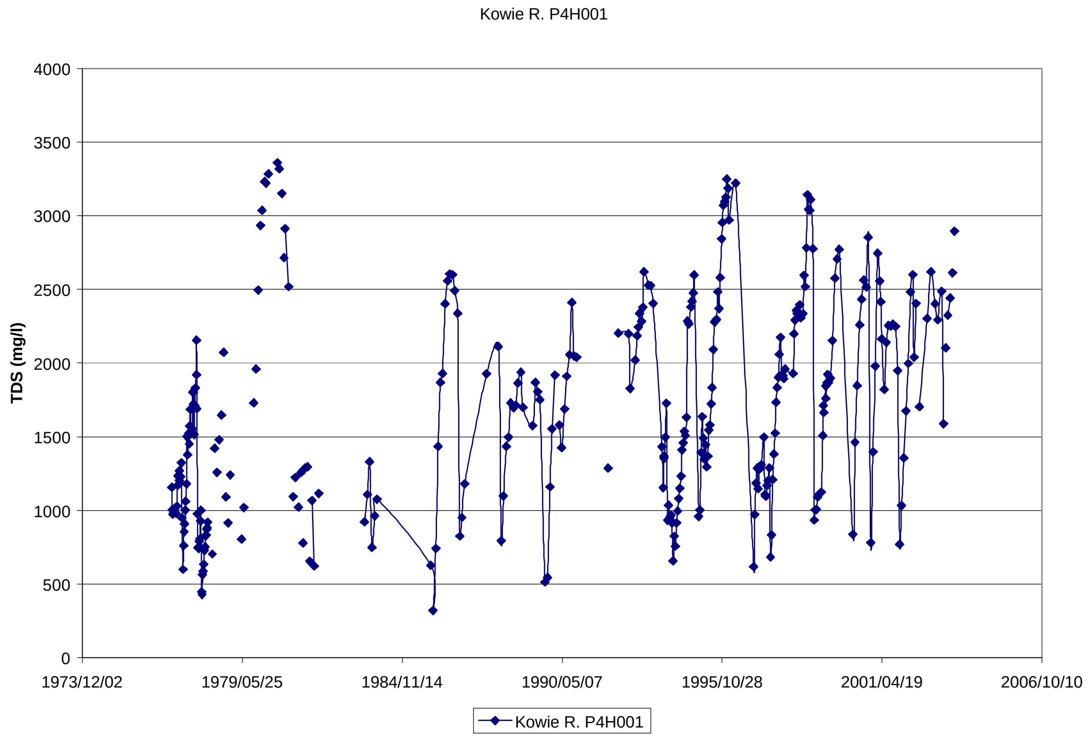


Figure 7 TDS values in the Kowie River, P4H001, P40C.

Table 6 Surface and subsurface runoff salt loads by Quaternary catchment

Quaternary	Runoff TDS (mg/l)	Groundwater TDS(mg/l)	Groundwater load (tonnes/a)	Surface runoff load (tonnes/a)	Surface runoff TDS (mg/l)	Total load (tonnes/a)
P10A	121	353	503	43	26	546
P10B	510	1342	5502	746	131	6248
P10C	418	1088	914	80	114	994
P10D	343	896	2264	139	67	2403
P10E	2300	2956	1033	19000	2315	20033
P10F	2300	2858	2962	28479	2456	31441
P10G	2300	2641	1621	20827	2418	22448
P30A	214	580	1298	192	77	1490
P30B	2361	2196	2035	25513	2599	27548
P30C	442	1151	0	747	442	747
P40A	891	2481	11015	1085	231	12100
P40B	1582	2507	1344	11579	1631	12922
P40C	1770	2364	3396	21697	1924	25093

P40D	1566	2150	3300	17620	1712	20920
P20A	781	2334	12716	10934	564	23650
P20B	593	2536	4325	4829	402	9154

Table 7 Estimated salt loads per unit rainfall and runoff.

Quaternary	Tonnes/ mm rain/a	Tonnes/ mm runoff/a	Discharge (Mm3/a)	Est. average TDS (mg/l)
P10A	0.9	22.3	3.09	177
P10B	11.8	324.4	12.87	528
P10C	2.6	181.3	1.54	645
P10D	5.6	294.5	6.14	553
P10E	40.6	1091.1	27.57	1096
P10F	56.4	1167.3	40.20	1534
P10G	40.8	834.4	49.43	1702
P30A	2.4	55.6	4.71	316
P30B	49.3	1033.4	15.46	1879
P30C	1.4	30.0	17.15	1737
P40A	19.1	413.0	9.14	1324
P40B	22.7	446.9	16.77	1492
P40C	40.7	675.0	29.49	1700
P40D	31.4	435.2	11.83	1769
P20A	33.1	402.1	24.82	953
P20B	14.4	221.4	13.72	667

2.7 RUNOFF COEFFICIENTS

Runoff coefficients for both surface and subsurface drainage as a percentage of rainfall per Formation and per Quaternary were derived to estimate salt loads from each Formation. Runoff coefficients (table 8) were calibrated against total Quaternary runoff (table 3) to derive an estimate of runoff per Formation (table 9).

Quaternary	Weltevrede	Witpoort	Nanaga	Grahamstown	Lake Mentz	Bokkeveld	Dwyka	Basalt	Kirkwood	Sand	Limestone
P10A	2.1	4.9		2.5	1.0		5.5			10.0	
P10B	2.1	4.9			1.0		5.5			10.0	
P10C	1.2				1.0		4.0			10.0	
P10D	1.8				1.0		4.5			10.0	
P10E	2.0		5.8	2.5	1.0			2.0	0.0	10.0	
P10F	1.7		5.8	2.5	1.0	4.0	4.0	2.0	0.0	10.0	
P10G	2.1		6.2	2.5	1.0	9.0	4.5	2.0	0.0	10.0	1.0
P20A			8.0			9.0				10.0	
P20B			6.3			9.0				10.0	
P30A	3.0		6.2							10.0	
P30B	4.0		8.0		3.0	9.0	5.7	2.0	0.0	10.0	3.0
P30C	3.0		5.8		1.5	9.0	5.7	2.0	0.0	10.0	3.0
P40A	5.5	7.0	7.0	3.0	2.0	13.0	5.7	2.0	0.0	10.0	3.0
P40B	5.2	7.0	7.0	3.0	2.0	13.0	5.7	2.0	0.0	10.0	3.0
P40C	4.6	7.0	7.0	3.5	5.0	13.0	5.7	2.0	0.0	10.0	3.0
P40D	7.5	8.0	8.0	4.0	5.0	13.0	5.7	2.0	0.0	10.0	3.0

Table 8 Calibrate runoff coefficients per Formation

Quaternary	Weltevrede	Witpoort	Nanaga	Grahamstown	Lake Mentz	Bokkeveld	Dwyka	Basalt	Kirkwood	Sand	Limestone	Total (Mm^3/a)
P10A	0.17	1.00	0.00	0.17	0.10	0.00	1.68	0.00	0.00	0.00	0.00	3.11
P10B	1.04	6.61	0.00	0.00	0.51	0.00	1.90	0.00	0.00	0.00	0.00	10.06
P10C	0.57	0.00	0.00	0.00	0.48	0.00	0.54	0.00	0.00	0.00	0.00	1.58
P10D	2.35	0.00	0.00	0.00	0.79	0.00	1.53	0.00	0.00	0.00	0.00	4.67
P10E	1.84	0.00	6.53	0.01	0.04	0.00	0.00	0.10	0.00	0.00	0.00	8.51
P10F	0.47	0.00	10.61	0.02	0.16	0.63	0.31	0.06	0.00	0.48	0.00	12.75
P10G	1.06	0.00	5.38	0.00	0.23	2.55	0.00	0.00	0.00	0.00	0.00	9.22
P20A	0.00	0.00	8.48	0.00	0.00	1.24	0.00	0.00	0.00	0.60	0.00	10.33
P20B	0.00	0.00	14.66	0.00	0.00	0.91	0.00	0.00	0.00	1.32	0.00	16.88
P30A	0.76	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.81
P30B	4.95	0.00	2.65	0.00	0.31	0.00	0.40	0.00	0.00	0.00	0.00	8.32
P30C	1.10	0.00	4.97	0.00	0.23	0.14	0.00	0.00	0.00	0.21	0.00	6.66
P40A	6.81	0.00	0.00	0.25	1.02	0.00	1.87	0.00	0.00	0.00	0.04	9.98
P40B	6.88	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	7.12
P40C	5.05	0.00	7.66	0.00	1.13	0.61	0.00	0.00	0.00	1.25	0.03	15.73
P40D	8.32	0.00	5.89	0.00	1.53	0.00	0.00	0.00	0.00	0.42	0.05	16.21

Table 9 Mean annual runoff per Formation in Mm^3/a.

2.8 ORIGIN OF SALTS

Estimated runoff from each Formation (table 9) and the water quality of runoff from each Formation (table 10) were used to estimate salt loads emanating from each Formation per Quaternary (Table 11). Runoff water quality was calibrated against total salt loads from each catchment (table 6). Water quality from each Formation is expressed as a percentage of the total Quaternary and Region P salt load in table 12.

Over 73% of the salt load is derived from the coastal Nanaga and inland Weltevrede Formations, which occupy 70% of the area. By comparison, nearly 16% of the salt load is derived from Bokkeveld shales, which occupy only 2.3 % of the area. The Dwyka tillites, although containing saline groundwater, contribute only 2% of the salt load and generate primarily fresh surface runoff in the headwater catchments due to their low permeability.

Salt loads expressed as tonnes/a/km^2 per Formation are given in Table 13. High salt loads for the Weltevrede Formations in Quaternary catchments P30B and P40B can be attributed to significant irrigation return flows on the Kariega and Bloukrans rivers. Over much of catchments P20A, P20B, P30B, P10E and P10F the Nanaga Formation overlies Bokkeveld shales, hence produces more saline than elsewhere. High salinities are also recorded in boreholes drilled in the Nanaga in these catchments (Table 5). As a result, runoff from the Nanaga in these catchments generally produces high salt loads.

The quality of runoff is categorised according to the DWAF drinking water classification in table 14. In general, only the Witpoort quartzites, and the Dwyka tillites in the headwater region, produce Class 0 water.

Quaternary	Weltevrede	Witpoort	Nanaga	Grahamstown	Lake Mentz	Bokkeveld	Dwyka	Basalt	Kirkwood	Sand	Limestone
P10A	750	150		200	700		100				
P10B	1500	300			1500		1000				
P10C	850	150			850		200				
P10D	750	150			700		100				
P10E	2950	300	2200	1394	2500			1520	1520	2629	
P10F	3000	300	2200	1394	2500	7000	1000	600	2000	2600	
P10G	3000		700		1875	6000				2360	
P20A			1450			8000				2600	
P20B			500			1200				800	
P30A	1000	150	700								
P30B	4100	300	2200		3000		1000				
P30C	250	100	100		250	1000				200	
P40A	1350	150		1394	1300		700				800
P40B	1850	150					700			2600	800
P40C	1700	100	1100		1200	6000				2600	1337
P40D	1550	100	900		1200					2400	1300

Table 10 Calibrated TDS of weighted surface and subsurface runoff in mg/l per Formation and Quaternary catchment

Quaternary	Weltevrede	Witpoort	Nanaga	Grahamstown	Lake Mentz	Bokkeveld	Dwyka	Basalt	Kirkwood	Sand	Limestone	Total (tonnes/a)
P10A	126	150	0	33	71	0	168	0	0	0	0	547
P10B	1562	1983	0	0	761	0	1900	0	0	0	0	6206
P10C	481	0	0	0	407	0	108	0	0	0	0	995
P10D	1760	0	0	0	555	0	153	0	0	0	0	2468
P10E	5415	0	14364	8	96	0	0	150	0	10	0	20043
P10F	1415	0	23333	34	403	4389	313	35	0	1255	0	31179
P10G	3166	0	3766	0	437	15281	0	0	0	0	0	22650
P20A	0	0	12300	0	0	9930	0	0	0	1564	0	23794
P20B	0	0	7328	0	0	1089	0	0	0	1054	0	9472
P30A	763	0	735	0	0	0	0	0	0	0	0	1498
P30B	20308	0	5832	0	942	0	398	0	0	0	0	27480
P30C	276	0	497	0	57	140	0	0	0	42	0	1013
P40A	9191	0	0	345	1327	0	1308	0	0	0	31	12203
P40B	12734	0	0	0	0	0	0	0	0	0	188	12922
P40C	8579	0	8427	0	1357	3650	0	0	0	3244	42	25298
P40D	12904	0	5301	0	1831	0	0	0	0	1008	69	21113

Table 11 Estimated annual salt load per Formation and Quaternary in tonnes/a.

Quaternary	Weltevrede	Witpoort	Nanaga	Grahamstown	Lake Mentz	Bokkeveld	Dwyka	Basalt	Kirkwood	Sand	Limestone
P10A	22.98	27.41		6.03	12.96		30.62				
P10B	25.17	31.95			12.26		30.62			0.00	
P10C	48.35				40.84		10.81			0.00	
P10D	71.31				22.48		6.21			0.00	
P10E	27.02		71.67	0.04	0.48			0.75		0.05	
P10F	4.54		74.84	0.11	1.29	14.08	1.01	0.11		4.03	
P10G	13.98		16.63		1.93	67.46				0.00	
P20A			51.69			41.73				6.57	
P20B			77.37			11.50				11.13	
P30A	50.90		49.10							0.00	
P30B	73.90		21.22		3.43		1.45			0.00	
P30C	27.24		49.09		5.66	13.83				4.19	
P40A	75.32			2.83	10.87		10.72			0.00	0.26
P40B	98.54									0.00	1.46
P40C	33.91		33.31		5.36	14.43				12.82	0.16
P40D	61.12		25.11		8.67					4.78	0.33
% of total load (Region P)	35.95	0.97	37.41	0.19	3.77	15.75	1.99	0.08	0.00	3.74	0.15

Table 12 Percent of total salt load derived from each Formation for each Quaternary catchment.

Quaternary	Weltevrede	Witpoort	Nanaga	Grahamstown	Lake Mentz	Bokkeveld	Dwyka	Basalt	Kirkwood	Sand	Limestone
P10A	1.00	1.19		0.26	0.56		1.33				
P10B	3.07	3.90			1.50		3.74				
P10C	1.71				1.45		0.38				
P10D	3.12				0.98		0.27				
P10E	11.62		30.82	0.02	0.21			0.32		0.02	
P10F	3.02		49.75	0.07	0.86	9.36	0.67	0.08		2.68	
P10G	9.23		10.98		1.27	44.55					
P20A			69.89			56.42				8.89	
P20B			18.18			2.70				2.62	
P30A	11.21		10.82								
P30B	65.09		18.69		3.02		1.27				
P30C	1.05		1.88		0.22	0.53				0.16	
P40A	26.87			1.01	3.88		3.83				0.09
P40B	51.76										0.77
P40C	20.33		19.97		3.22	8.65				7.69	0.10
P40D	38.87		15.97		5.51					3.04	0.21

Table 13 Salt loads in tonnes/a/km^2 per Formation.

Quaternary	Weltevrede	Witpoort	Nanaga	Grahamstown	Lake Mentz	Bokkeveld	Dwyka	Basalt	Kirkwood	Sand	Limestone
P10A	1	0		0	1		0				
P10B	2	0			2		2				
P10C	1				1		0				
P10D	1				1		0				
P10E	3		3	2	3			2		3	
P10F	4		3	2	3	4	2	1		3	
P10G	4		1		2	4					
P20A			2			4				3	
P20B			1			2				1	
P30A	2		1								
P30B	4		3		4		2				
P30C	0		0		0	2				0	
P40A	2			2	2		1				1
P40B	2										1
P40C	2		2		2	4				3	2
P40D	2		1		2					3	2

Table 14 Category of runoff TDS in terms of DWAF classification

3 PREDICTED RUNOFF QUALITY AND CONCLUSIONS

Estimated salt loads from each Quaternary were incremented down channel to derive estimates of mean water quality that could be expected in dams (table 15).

Table 15 Predicted water quality in main river channels of Quaternary catchments

Quaternary	Discharge Mm^3/a	TDS Mg/l
P10A	3.09	177
P10B	12.87	528
P10C	1.54	645
P10D	6.14	553
P10E	27.57	1096
P10F	40.20	1534
P10G	49.43	1702
P30A	4.71	316
P30B	15.46	1879
P30C	17.15	1737
P40A	9.14	1324
P40B	16.77	1492
P40C	29.49	1700
P40D	11.83	1769
P20A	24.82	953
P20B	13.72	667

3.1 BUSHMAN'S RIVER - P10

In the Bushman's river, good water quality (class 1) can be expected down stream to include Quaternaries P10A-D, which are the New Year's and upper Bushman's rivers to Alicedale. South of Alicedale, water quality deteriorates rapidly due to significant salt loads originating from the Nanaga and Weltevrede Formations. Runoff continues to become progressively more saline downstream.

3.2 KARIEGA RIVER – P30

In the Kariega catchment acceptable water quality is only present in the head waters of the Kariega, P10A and the headwaters of the Assegai, P30B, which is partially underlain by Witpoort quartzites. Below the Settler's dam in catchment P30B water quality deteriorates rapidly due to salt loads from the Weltevrede shales and irrigation return flows.

3.3 KOWIE RIVER - P40

In the Kowie River, water quality is acceptable in the headwaters, which are underlain by Dwyka, Lake Mentz and Witpoort rocks (P40A). Water quality deteriorates once the river flows over Weltevrede rocks north of Bloukrans pass. Salinisation is also expected due to irrigation in the Belmont valley of the Bloukrans, SE of Grahamstown.

3.4 BOKNES AND DIEPKLOOF RIVERS – P20

In the Boknes catchment, good quality water can only be expected from springs emanating from the Alexandria Formation at the base of the Nanaga Formation at its contact with the Bokkeveld. The Boknes River itself flows over Bokkeveld rocks and water quality deteriorates rapidly down channel.

The Diepkloof is an intermittent river with internal drainage into the back dunes regions. Water quality of springs draining the Nanaga is generally poor.

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