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INVESTIGATING THE POTENTIAL TO SUPPLEMENT THE LUSIKISIKI RURAL WATER SUPPLY SCHEME (LRWSS)

LUSIKISIKI GROUNDWATER FEASIBILITY STUDY PHASE 2

FINAL REPORT

May 2009

Prepared by
SRK Consulting (South Africa) (Pty) Ltd

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LUSIKISIKI GROUNDWATER FEASIBILITY STUDY PHASE 2

Investigating the Potential to Supplement the Lusikisiki Rural Water Supply Scheme (LRWSS)

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LUSIKISIKI GROUNDWATER FEASIBILITY STUDY PHASE 2

Investigating the Potential to Supplement the Lusikisiki Rural Water Supply Scheme (LRWSS).

May 2009

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LUSIKISIKI GROUNDWATER FEASIBILITY STUDY PHASE 2

Investigating the Potential to Supplement the Lusikisiki Rural Water Supply Scheme (LRWSS)

EXECUTIVE SUMMARY

The Department of Water Affairs and Forestry, Directorate Options Analysis (hereafter DWAF) appointed SRK Consulting (South Africa) Pty Ltd (hereafter SRK) to conduct a groundwater Feasibility Study Phase 2 to investigate Zalu Dam as possible water supply source to supplement the Lusikisiki Rural Water Supply Scheme (LRWSS) and provide water for agricultural development in the area.

A **Phase 1 Groundwater Feasibility Study for the Lusikisiki Area** was undertaken by SRK Consulting to investigate and verify groundwater potential in order to assess whether the groundwater is the best augmentation source for the Lusikisiki area, town of Lusikisiki and 56 rural villages in the surrounding area. During this study it became evident that the area to the northwest of Lusikisiki has very limited groundwater potential and that surface water potential will be required to be investigated for augmentation of the existing water supply system and expansion of the existing network to the area. Building of the Zalu Dam on the Xura River was found to be the most feasible surface storage scheme option which would be able to provide for present and future (2030) water requirements with 98 % assurance.

Estimated water requirements were calculated taking into consideration population growth and irrigation and forestry in the area and is summarized below.

User Sector	**Low Water Requirements (10^6 m^3/a)**			
	2000	**2010**	**2020**	**2030**
Urban and rural domestic and industrial	0.86	1.42	2.28	3.52
Irrigation	0.009	0.191	0.290	0.378
Stock Watering	1.312	1.312	1.312	1.312
Afforestation	6.110	7.800	9.700	11.510
Total use	**8.300**	**10.723**	**13.591**	**16.720**
Return Flows	0.14	0.18	0.23	0.32
Groundwater supply	0.000	1.231	1.577	2.365
Total use from surface water	**8.16**	**9.312**	**11.784**	**14.035**

The LRWS scheme was originally planned in 1978 as a regional scheme to utilize a dam on the Xura River. To date only phase 1 of the originally planned larger scheme has been implemented. This scheme was commissioned in July 1989 and currently supplies the town of Lusikisiki (about 11 000 people) and 23 villages (about 41 000 people). Lusikisiki town is provided with full water services – house connections and water borne sanitation. The level of services for the villages is limited to bulk supply to village reservoirs. The DWAF has identified projects to upgrade the existing scheme as a part of Community Water Supply and Sanitation Programme as follows:

The design capacity of the bulk water supply infrastructure is 2 760 m^3/day. Raw water is abstracted from the Xura River at the intake that consists of a metal grid with a 500 mm dia. pipe and 300 mm valve. Water is conveyed by gravity to the pump station through a 300 mm dia. pipe. The pump station is located near the weir and consists of 3 centrifugal pumps. During site visit in May 2006 two pumps (combined capacity of 32l/s and design head of 60 m) were working and the third one which was supposed to be a stand-by pump was not operational. The water is pumped to the Water Treatment Works (WTW) through a 650 m long ND 200mm Asbestos Cement (AC) pipe. The existing water supply infrastructure is shown on **Figure 12**.

The WTW are located off the main road to Flagstaff. The treatment process comprises chemical dosing, flocculation, sedimentation, slow and rapid sand filtration and chlorination. The slow sand filtration system consists of three duty and one standby filter bays designed for a maximum head loss of 1.5 m and total duty capacity of 32 l/s. The slow sand filters are in a very bad condition and are clogging on a regular basis. Rapid sand filters were not operational during site visit in May 2006. Subsequently they were repaired and should be operational.

The clear water pump station within the WTW consists of two duty pumps and one stand-by pump, with a total design capacity of 32l/s and pumping head of 80m. The clear water is conveyed by 200m long 200mm diameter AC rising main to bulk storage reservoir A (1 300Kl). This reservoir than gravity feeds a further bulk reservoir C (1 100 Kl) and bulk reservoir B (1,200 Kl) with a booster pump station. Bulk reservoirs A, B and C feed 24 service reservoirs (between 20 and 90 Kl) that supply rural villages. From reservoir 9 water is provided to Mzintlavana Scheme at Port Saint Johns. Most of the pipelines are AC pipes. Existing network and reservoirs are in a poor condition and does not have sufficient capacity. All balls from air valves are removed and air valves blocked, which is creating inefficiency of the system. Full investigation is required to assess condition and capacity of existing systems.

A number of users, including the town, draw water directly from the bulk main between reservoirs A, B and C, although connecting pipelines have very limited capacity.

The level of services in the villages is below RDP standard. The villages are serviced by standpipes located near the service reservoirs.

Cleaning of the reservoirs has to be carried out 2 times a month. Approximately 150mm of mud has to be removed from the reservoirs.

At present the scheme is not able to meet the water requirements and water shortages are frequently being experienced. The low assurance of water supply provided by the system can be attributed to the reasons as follows:

- Insufficient capacity of existing water source at Xura River;
- Inadequate capacity of existing infrastructure;
- The poor condition of existing infrastructure;
- Significant housing development in the area, which has increased the water use.

As an immediate augmentation of the existing system drilled boreholes that can be utilised to supplement the Lusikisiki Existing Supply Scheme to increase assurance of supply. Identified well fields can be summarized to boreholes EC/T60/072, EC/T60/054 and EC/T60/055 to be connected to the Reservoir B and supplement Lusikisiki area and existing network which supplies villages Kwabhumbuta, Mateku, Mataku, Silahia and Mpolweni. Utilising drilled boreholes EC/T60/051, EC/T60/052 and EC/T60/078 the existing network can be extended to provide water for villages Mawotsheni, Njobela and Mjelweni.

Zalu Dam on the Xura River was found to be the most feasible surface storage scheme option which would be able to provide for present and future (2030) water requirements with 98 % assurance. But the following investigations have to be completed at feasibility level.

1. It is assumed that the same centreline can be used for both RCC and earthfill dam options, assuming that the top elevation is similar. One of the likely indications are that the size of the facility may increase. If this is so then a new common impoundment volume needs to be defined.
2. There are a number of development options to be considered. These are RCC only, earthfill embankment with clay core, earthfill with asphalt core, central section of RCC with spillway and earthfill flanks. For each option it must be possible to do a feasibility design sufficient to be able to discount the less favourable options.
3. The current state of the knowledge is that for the RCC option, some foundation drilling took place, but not enough and it is necessary to conduct some more geological investigations specificaly foundation and/or materials investigations.
4. The current state of knowledge for the earthfill option is that for the current dam height sufficient bulk fill materials have been identified. The previous studies have focused on softer earthfill type material solutions. It would equally be possible to construct some portions of the fill walls using harder quality material such as dolerite, more investigation is needed to confirm.
5. Sufficient geotechnical investigations have to be completed for both RCC and earthfill dam options so that both can be compared on a common basis.
6. For RCC the foundation investigation must be sufficient. The available investigation has to be reviewed in the light of the RCC option and then a decision must be made related to the level of additional studies required.
7. For RCC the construction materials investigation must be sufficient. This relates to the coarse and fine RCC aggregates. There is very little available information at this stage. One of the proposed activities must be to assess whether or not it will be possible to develop a suitable dolerite quarry say on the right flank within the dam basin, below full supply level. One of the available options then will be to use the overburden material harvested for portions of the dam construction and then use the high quality dolerite to more effectively construct the RCC option. This is an option which requires investigation.
8. Suitable survey will be required. This is for all the engineering work (dam, spillway, inlet and outlet works) as well as for the reservoir basin.
9. Sufficient geotechnical foundation investigations are required for the defined dam options to be considered in the project. Foundation investigation here specifically refers to founding conditions as well as grouting conditions. As part of this work, attention should be given to whether or not the feeder dolerite dyke related to the dolerite sill is not located in a critical section of the dam.
10. Sufficient geotechnical materials investigations are required for the defined dam options to be considered in the project. Materials investigations here specifically refer to construction materials. RCC materials are aggregates and sand for RCC and the quantum of concrete works for the diversion works, inlet and outlet works; assuming that the spillway section of the dam will be RCC. Earthfill dam materials refer to the core, the shoulders, the filter drains, the rip-rap and the quantum of the concrete works for the diversion works, inlet and outlet works and the spillway. Previous materials investigations have been criticized in the Eastern Pondoland Basin Study report. It seems the original findings on borrow pits by HKS need to be re-assessed (see **paragraph 7.6**). The other sources of materials need to be defined and investigated as well. If higher dams with larger constructed volumes are to be considered, then the additional materials will have to be sourced.
11. If composite dams and or say asphalt core dam is required, then specific investigations for these will also be required if not already covered by the other studies.
12. Specific investigations will also be required for the related facilities such as access roads, construction village if this is relevant.

The existing infrastructure of the LRWS scheme is shown in **Figure 10**. The following sections describe the development schemes considered as options for possible augmentation of the water source for the LRWS. Each scheme consists of a water source and the corresponding primary conveyance system connecting the source to the existing distribution network General layout of project area is attached as Fig 1 appendix 7.

Surface Water Storage Scheme-Zalu Dam (Fig 4, Appendix 2)

All surface water storage option has been sized to meet the total water requirements of the study area as stand-alone schemes. The water will be pumped from the abstraction point to the WTW and then further to a new main storage reservoir located next to the existing reservoir A. The existing capacities of the primary conveyance infrastructure will be utilised and where necessary increased.

Option 1: Zalu Dam, Xura River Rollcrete Dam (Fig 5 & 6 Appendix 2)

Zalu dam has been investigated in the past by HKS (1980). Detailed geological and materials investigations have been undertaken, and it has been proposed that an embankment dam with a gross storage capacity of 13.69 million m3 be constructed. The dam has been sized to supply the domestic requirements for the town of Lusikisiki and five administrative areas (Zalu, Ngobozana, Mevena, Dubana, Xura), as well as the irrigation requirements for an area of approximately 430 ha.
A rollcrete dam structure with a central ogee spillway is considered.
Two main options with regards to the conveyance system from the dam outlet to the water treatment works have been considered:

- **1.1:** The water will be lifted by a new raw water pump station (static head – 6 m), located at the dam outlet works (Fig 7 & 8, Appendix 7), through a 6 000 m long raw water rising main to the upgraded WTW (Fig 3, Appendix 7). An option for conveyance under gravity was also investigated (Fig 2, Appendix 7), but found to be unfavourable (due to the small elevation difference between the dam outlet and the WTW the costs associated with a required largesize gravity main are high). A number of possible conveyance routes were evaluated and the best route selected.
- **1.2:** The water will be released into the river and then abstracted at the existing weir site. The raw water will be lifted by the upgraded raw water pump station (static head 52 m) through a 650 m long raw water rising main to the WTW.

In both cases the water is pumped by an upgraded clear water pump station (static head 57 m) from the upgraded water treatment works to a new bulk storage reservoir, through a 2,120 m long clear water rising main.

Option 2: Zalu Dam, Xura River, Embankment Dam

Due to potential non availability of material for the RCC dam, the embankment dam with a side and central spillway was considered.

The conveyance systems will be the same as per option 1.

Option 2A: Zalu Dam, Xura River, Rockfill Dam (Fig 9 & 10, Appendix 2)

Rockfill Dam with central and side spillway has been taken into consideration. The rockfill dam consists of the clay core with composite filters. Slopes of the upstream face are estimated at 1 :1.75 and downstream face 1 :1.6.

Detailed analysis of most suitable slopes will have to be conducted after materials investigations and laboratory test are completed.

Option 2B: Zalu Dam, Xura River, Earthfill Dam (Fig 12, 13 & 14, Appendix 2)

Earthkfill Dam with central and side spillway has been taken into consideration. The earthfill dam consists of the clay core with composite filters and filter blanket downstream. Slopes of the upstream face are estimated at 1 :1.3 and downstream face 1 :2.5 Rip-Rap to be installed at upstream face for slope protection.

Detailed analysis of most suitable slopes will have to be conducted after materials investigations and laboratory test are completed.

Conjunctive Use of Surface and Groundwater Resources

Groundwater developments can be used to supplement the supply from run of river schemes at times of low flows and in this manner to increase the assurance of supply to acceptable levels. These options offer higher assurance of supply than the run of river schemes, but at higher capital and running costs.

Option 3: Lusikisiki Weir in conjunction with groundwater (98% assurance of supply)

The run of river option has been used as the basis for this scenario. In addition to the infrastructure described in Section 8.2, provision has been made for the development of ground water sources and conveyance infrastructure to supply 40 l/s net, being the difference between total scheme requirements (72 l/s net) and the run of river yield at 90% assurance (32 l/s net). In order to reduce the O&M costs associated with the groundwater supply, the surface water scheme has been sized to supply the full demand at times of high flows. The ground water sources will be used to provide the incremental demand only during drought periods.

The groundwater supply infrastructure will consist of the following components at each borehole (total net supply of 40 l/s): A submersible pump driven by a diesel engine, a pump house, a rising main, a storage reservoir and an access road (track). Due to the uncertainties with regards to the actual position and total yield of the boreholes, certain assumptions have been made with regards to the average characteristics of the conveyance infrastructure per borehole (yield, pumping head, access, conveyance length, storage).

Immediate Augmentation Measures: Lusikisiki Weir in conjunction with Groundwater (95% assurance of supply)

This option is similar to option 3, but the run of river scheme consists only of the existing Lusikisiki weir and its primary conveyance infrastructure. The existing surface water conveyance infrastructure (clear and raw water pump stations and rising mains, water treatment works, and main storage reservoirs) will be utilized to a full potential to supply scheme requirements (32 l/s net). In addition, provision has been made for the development of ground water sources and conveyance infrastructure to supply additional 14.78 l/s net (the full demand, as no yield at 95% assurance is available at the weir).

The groundwater supply infrastructure will consist of the following components at each borehole (total net supply of 20.88 l/s): A submersible pump driven by a diesel engine, a pump house, a rising main, a storage reservoir and an access road (track).

Following boreholes will be equipped and utilized to augment existing network; EC072; EC 055; Ec 054 with a total yiel of 13.7l/s. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir B.
Boreholes EC 052; EC 051 and EC 078 with a total yield of 7.18l/s will be equipped and utilized to augment existing network. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir and new reservoir to be constructed for the extension of the existing network.

Summary of Development Options

Option	Water Source	River	Assu-rance	Primary Conveyance system
1	Zalu dam (RCC) Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPs -CWRM to Res. A -New reservoir adjacent to Reservoir A
2	Zalu dam (Earthfill) Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPs -CWRM to Res. A -New reservoir adjacent to Reservoir A
3	-Lusiksiki weir In conjunction with groundwater (72 l/s) Conjunctive water use scheme	Xura	98%	-RWPS at weir (72 l/s) -RWRM to existing WTW (72 l/s) -Upgrade WTW and CWPS (72 l/s) -CWRM to Res. A (72 l/s) -New reservoir adjacent to Reservoir A -Groundwater infrastructure (total 72 l/s)

Estimated cost of development options

Option No.	Description	Total Capital Cost (R Million)	Total O &M (R Million)	URV of Water at 8% Discounted rate (R/m3)
1	Zalu dam (conv. from dam outlet)	61,136,119	27,898,149	4.28
2	Zalu dam (conv. from weir)	58,995,025	26,972,352	4.14
3	Conjunc. (98%)	68,102,541	21,094,671	4.29

Development Options/Schemes

The Lusikisiki Regional Water Supply Scheme (LRWS) currently serves about 52 000 people in the town of Lusikisiki and 23 surrounding villages, but the existing water source has insufficient assured yield to meet the water requirements. The augmentation of its water source is urgently required.

Various possible supplementary water sources have been considered – surface water storage scheme – Zalu dam, conjunctive use of surface and groundwater. For each of these sources, a number of development options have been investigated, evaluated and the best options selected. The capital cost of each option was estimated. This includes the development of the water source and the primary conveyance system (pump stations, bulk supply pipelines, water treatment works and storage reservoirs).

Based on the findings of this study it can be concluded that the water source of the LRWS scheme can feasibly be augmented by one of the following development options:

Surface storage scheme (capital cost R 71,3 million, URV4.14 R)

This scheme would comprise the Zalu dam with water released down the river and abstracted again at the existing weir on the Xura River. The option includes the upgrading of the existing primary conveyance infrastructure.

This option should be selected by the Department if:

- Assurance levels lower than 98% are not acceptable;

- Possible future extension of the scheme is required or regarded as beneficial. This is the only feasible option if higher demand scenarios are anticipated;
- Particular preference is given to lower operation and maintenance costs and less complicated institutional structures;
- More employment and recreational opportunities are deemed important.

Conjunctive use of surface and groundwater (capital cost R82,3 million, URV4.29 R)

Option upgrading of the conveyance system from the Lusikisiki weir, supplemented by groundwater supply from about 60 boreholes at times of low surface flows was identified as the best conjunctive scheme option. The implementation of this option can be considered if:

- Phased development (less initial capital) is of paramount importance;
- Higher operation and maintenance costs are acceptable;
- The sustainability of the scheme can be guaranteed by the establishment of an adequate institutional structure required for the management of a reasonably complicated system;
- Rejection of borehole based schemes by local water users can be overcome.

Immediate Groundwater Development Option 2 Capital Cost R14,4 million (Feasibility Level)

Boreholes EC072; EC 055; Ec 054 with a total yiel of 13.7l/s. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir B.

Boreholes EC 052; EC 051 and EC 078 with a total yield of 7.18l/s will be equipped and utilized to augment existing network. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir.

No specific preference for any of the development options can be given from an environmental point of view. From the social perspective the development of the Zalu dam involves the inundation of a small area of cultivated land, but this would probably be offset by positive impacts such as recreational opportunities, job creation, etc.

The local population has expressed a definite preference for surface water supply.

Water Source

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

- Without provision for the release of the ecological Reserve, the existing water source (a weir on the Xura River) can supply the present and future (2030) water requirements with assurances of 95% and 65% respectively.
- If provisions for the release of the ecological Reserve are made, the assurance of supply from the existing water source will be reduced to 70% and 40% for the present and future water requirements respectively.
- The above indicates that irrespective of the ecological Reserve requirements, the capacity of the existing water source is insufficient to meet the water requirements at the guideline limit of 98% assurance of supply, and the water source should be augmented.
- The surface and the groundwater resources in the area have high potential for development and can be used for augmentation of the existing water source.
- Based on the results of the reconnaissance study, the following options for augmentation of the water source, capable of meeting the system's requirements at 98% assurance of supply, can be considered for implementation:

- The most feasible storage scheme option is Zalu dam (URV4.14 R). If there is no time for further studies, this option should be implemented.
- The conjunctive surface and groundwater use option (URV4.29 R) includes abstractions from the existing weir, supplemented by the development of boreholes to be operated during times of low river flows.

Bulk Supply System

- The capacity of the existing bulk water conveyance infrastructure is insufficient to supply the present water requirements and a shortage of about 30% is presently experienced. This infrastructure needs to be upgraded urgently.
- The bulk water conveyance system should be upgraded irrespective of whether the supply area of the scheme is extended or not. The requirements for the areas covered by the proposed extensions are relatively low (28%) when compared with those for the full supply area. The proposed future extensions may only influence to a limited extent the sizing parameters for upgrading of the bulk infrastructure, but not the decision to implement the upgrading.

Recommendations

The following recommendations are offered:

- Upgrade the existing bulk supply system from the Lusikisiki weir to the command reservoir to meet the projected water requirements up to the year 2030. This is a common component for all three favourable augmentation options considered and can be regarded as the first phase of the augmentation of the water source. The upgrading will allow increased abstractions from the existing weir at least at times of high river flow. This action, combined with the proposed relaxation of the ecological releases (see bullet below) will result in an immediate improvement of the water supply situation of the existing scheme and will increase the assurance of supply from 70% to 90%.

- Relax temporary the ecological Reserve releases into the Xura River, downstream of the existing weir. This may result in a temporary environmental impact on a river reach of approximately 3 km, which is presently largely modified. The ecological Reserve releases will be compromised only during low flow periods.

During normal flow conditions, sufficient riverine flows will be available. After the augmentation of the water source is completed, the low flow ecological Reserve releases will be made and it is anticipated that the ecosystem in the affected river reach will recover.

- It is recommended that a detailed feasibility study be commissioned in order to obtain more accurate information and to refine the results of the reconnaissance study. This study will allow the selection of the best development option with regards to the water source on the basis of updated information. The proposed feasibility study should include the following main components, and should address the uncertainties identified during the course of the reconna issance study:
    - Ecological aspects (preliminary reserve determination, EIA associated with the proposed relaxation of the Reserve, detailed EIA report for approval of the proposed developments).
    - Engineering aspects and study co-ordination
    - Implementation of immediate groundwater development Option 3 to supplement existing system
    - Identification and confirmation of availability of suitable construction material for Zalu Dam
    - Take the final decision regarding the best development options for implementation on completion of the feasibility study.

- It is recommended to implement immediate emergency measures as soon as possible to augment existing water supply system.

LUSIKISIKI GROUNDWATER FEASIBILITY STUDY PHASE 2

Investigating the Potential to Supplement the Lusikisiki Rural Water Supply Scheme (LRWSS)

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Aquifer: An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials.

Hydrocensus: Field survey of existing boreholes. Information such as borehole depth, water level, equipment, etc. on the borehole is noted. Other relevant groundwater information is also noted (such as springs, possible pollution sources, groundwater use, etc.).

Desk study: Study done mainly in the office and without visiting the project area. The desk study is usually used to collect and evaluate existing information that is relevant to the project.

Pump testing: Technique used to determine the sustainable yield of a borehole and to determine aquifer paramaters such as Transmissivity (T).

Study area: Refers to the area included under the Lusikisiki Groundwater Feasibility project.

Airlift yield: Refers to the yield as measured during drilling by means of air pressure induced by the drilling action.

Vadose zone: The vadose zone, also termed the unsaturated zone, is the portion of earth between the land surface and the zone of saturation (water).

Exploitation potential: The maximum volume of groundwater that can be abstracted per unit area per annum without causing any long-term 'mining' of the aquifer (i.e. without continued long-term declining water levels).

Borehole development: After drilling a new borehole, the borehole is developed by a flushing the inside of the borehole using the air pressure from a compressor.

Transmissivity: Relates to Hydraulic conductivity and is a property of soil or rock that describes the ease with which water can move through pore spaces or fractures.

Outcrop: Visible rock on the surface.

Stepped discharge test: refers to an aquifer test where a borehole is pumped at incremental rates usually 60 minutes each. Each rate change is called a step.

Constant discharge test: Refers to an aquifer test where the borehole is pumped at a constant rate for a given length of time and the water level drawdown is measured

Recovery test: Refers to an aquifer test where the recovery of the water level is measured after a constant discharge test or a stepped discharge test

List of Abbreviations

DWAF	Department of Water Affairs and Forestry
SRK	SRK Consulting (South Africa) Pty Ltd
TOR	Terms of reference
RWSS	Rural water supply study
LRWSS	Lusikisiki rural water supply study
NGDB	National Groundwater Data Bank
WL	water level (groundwater - usually measured as depth from surface)
Ecca	Ecca Group
Dwyka	Dwyka Formation
Mbgl	metres below ground level
M	metre
l/s	litres per second (discharge) - 1000 l/s = 1 m^3/s
GEXP	Groundwater exploration potential
GEP	Groundwater exploitation potential
GDP	Groundwater development potential
GRIP	Groundwater Resource Information Programme
GIS	Geographical Information Systems
w/s	water Supply
w/supply	water supply
GW	ground water
DEV	development
inv	investigation
NGS	Natal Group Sandstone
LGFS	Lusikisiki Groundwater Feasibility Study
GMU	Groundwater Management Unit
EP	Exploitation Potential
DEM	Digital Elevation Model
MAP	Mean Annual Presipitation
T	Transmissivity
K	Hydraulic conductivity
CD	constant discharge test

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LUSIKISIKI GROUNDWATER FEASIBILITY STUDY PHASE 2

Investigating the potential to supplement the Lusikisiki Rural Water Supply Scheme (LRWSS)

1. INTRODUCTION

The Department of Water Affairs and Forestry, Directorate Options Analysis (hereafter DWAF) appointed SRK Consulting (South Africa) Pty Ltd (hereafter SRK) to conduct a groundwater feasibility study Phase 2 to investigate the potential to supplement the Lusikisiki Rural Water Supply Scheme (LRWSS) and provide water for agricultural development in the area.

1.1 Background

The water supply situation in Lusikisiki and surrounding areas has, despite the implementation of a regional surface water scheme by the Transkei Government, which is based on the weir in the Xura River, been unsatisfactory for a number of years. The Department of Water Affairs and Forestry (DWAF) undertook the Eastern Pondoland Basin Study (EPSB) to investigate the water demands and water availability in the region focussing on the Lusikisiki area. Both surface and groundwater development options were indicated to be possible options to supply Lusikisiki and the surrounding villages. It was, however recommended that a more detailed investigation of the groundwater potential be undertaken before a final recommendation on augmentation was made.

A **Phase 1 Groundwater Feasibility Study for the Lusikisiki Area** was undertaken by SRK Consulting to investigate and verify groundwater potential in order to assess whether the groundwater is the best augmentation source for the Lusikisiki area, town of Lusikisiki and 56 rural villages in the surrounding area. During this study it became evident that the area to the northwest of Lusikisiki has very limited groundwater potential and that surface water potential will be required to be investigated for augmentation of the existing water supply system and expansion of the existing network to the area. Building of the Zalu Dam on the Xura River was found to be the most feasible surface storage scheme option which would be able to provide for present and future (2030) water requirements with 98 % assurance.

In order to establish how conjunctive use of groundwater and surface water should optimally be utilised to augment and expand the existing system Investigation of the Potential to Supplement the Lusikisiki Rural Water Supply Scheme was conducted which is the scope of this Report.

2. GENERAL AND BASIC INFORMATION

2.1 Locality

The study area was originally chosen to include an area that stretches from Port St Johns inland to Mabululu (± 15 km west of the town of Lusikisiki), down towards Mkambati at the coast (See **Figure 1**). It therefore included an area of approximately 100 km^2. Although the Mkambati area is situated far from the existing reticulation network, a special request was put forward from the Oliver Tambo District Municipality (OR Tambo) to investigate the potential of finding sufficient groundwater near the Mkambati Nature Reserve to enable the future development of tourism. The Mkambati area was therefore included in the LWRSS. Refer to **Figure 1** for the locality of the project area (study area).

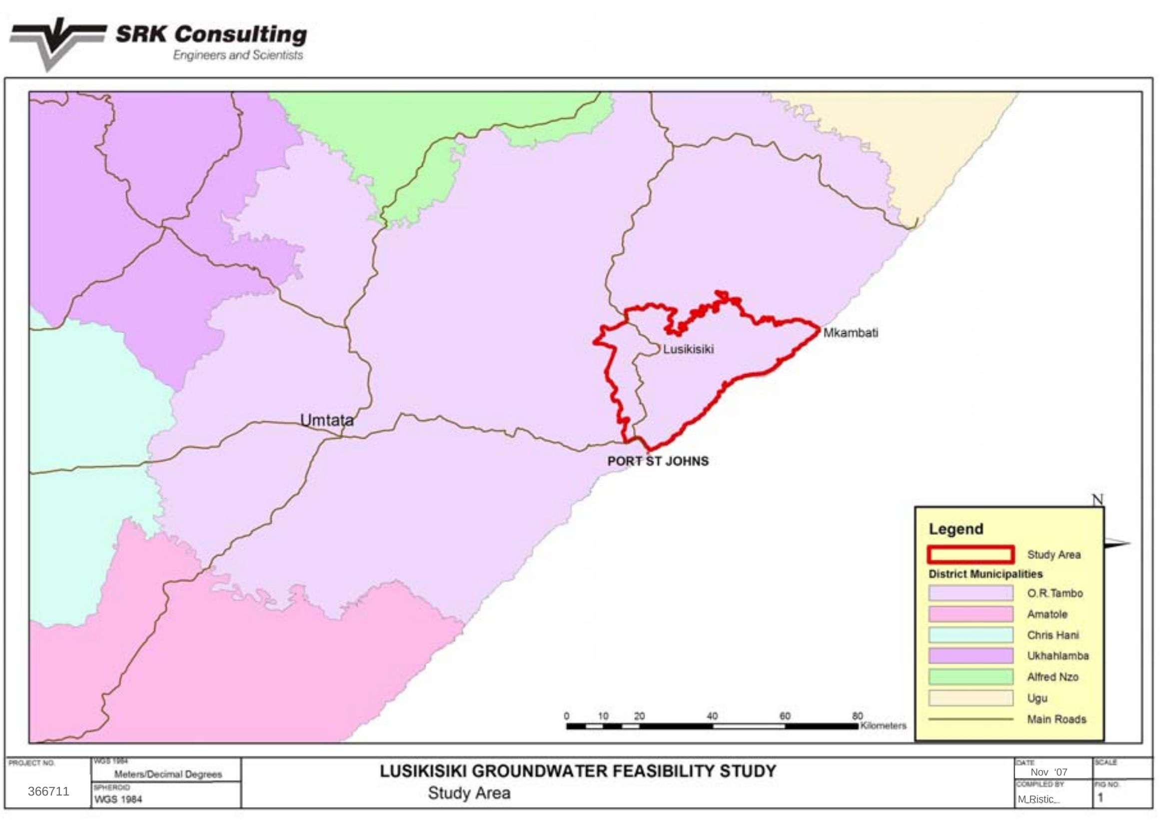

Figure 1: Locality of the study area

2.2 Topography

The topography of the study area varies from very undulating along the main road from Port St Johns to Lusikisiki, to flat-lying areas mainly around Mkambati and the Makwa tea plantation (mainly sandstone). The Natal Group Sandstone Group is however also characterised by large east-west faults, changing direction to north-south as Lusikisiki is approached (near the Makwa tea plantation). The faults caused major displacement and gorges of 100 m + are common. The areas around the town of Lusikisiki form small hills with well developed surface drainage systems.

2.3 Climate and Rainfall

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

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

Table 1: Mean Annual Precipitation

Quaternary catchment	Area (km2)	MAP (mm)
T60F	464	940
T60G	360	1116
T60H	322	1277
T60J	294	1101
T60K	242	1075

2.4 Rivers and Drainage Regions

The rivers in the study area are presently largely under-utilised, and are not regulated by any dams of significant size. The main rivers draining the area are the Ntafufu, Mzintlava, Mkozi and Msikaba. All main rivers are perennial and flow in the south-easterly direction from the elevated inland plateau to the Indian Ocean. The Magwa dam (wall height of 25 m) on the Mkozi River is the only registered dam in the area, but regulates a very small catchment of approximately 5.5 km2. **Table 2** offers a summary of the characteristics of the main rivers.

Table 2: Characteristics of the main rivers within the study area

River	Quaternary Catchment	Catchment Area (km2)	Virgin MAR (106m3/a)
Ntafufu	T60K	186	45.8
Mzintlava	T60J	270	71.2
Mzimpunzi	T60H	24	9.3
Mbotyi (Kobenge)	T60H	29	11.2
Mkozi	T60H	43	16.7
Myekane	T60H	5	1.9
Luphuthana	T60H	20	7.8
Msikaba	T60G / E / F	1022	207.4
Mkweni	T60H	48	18.6

2.5 Geology of the study area

The study area mainly comprises the Ecca Group, Dwyka Formation and the Natal Group Sandstone. The bulk of the current reticulation network is situated on the Ecca and Dwyka as the system runs from north-west of Lusikisiki towards Mkambati, but ending on the edge of the Natal Group Sandstone.

Figure 2 indicates the positions of the Ecca, Dwyka and Natal Group Sandstone relative to the study area. **Figure 3** indicates the position of the existing reticulation system relative to the geological units and the study area.

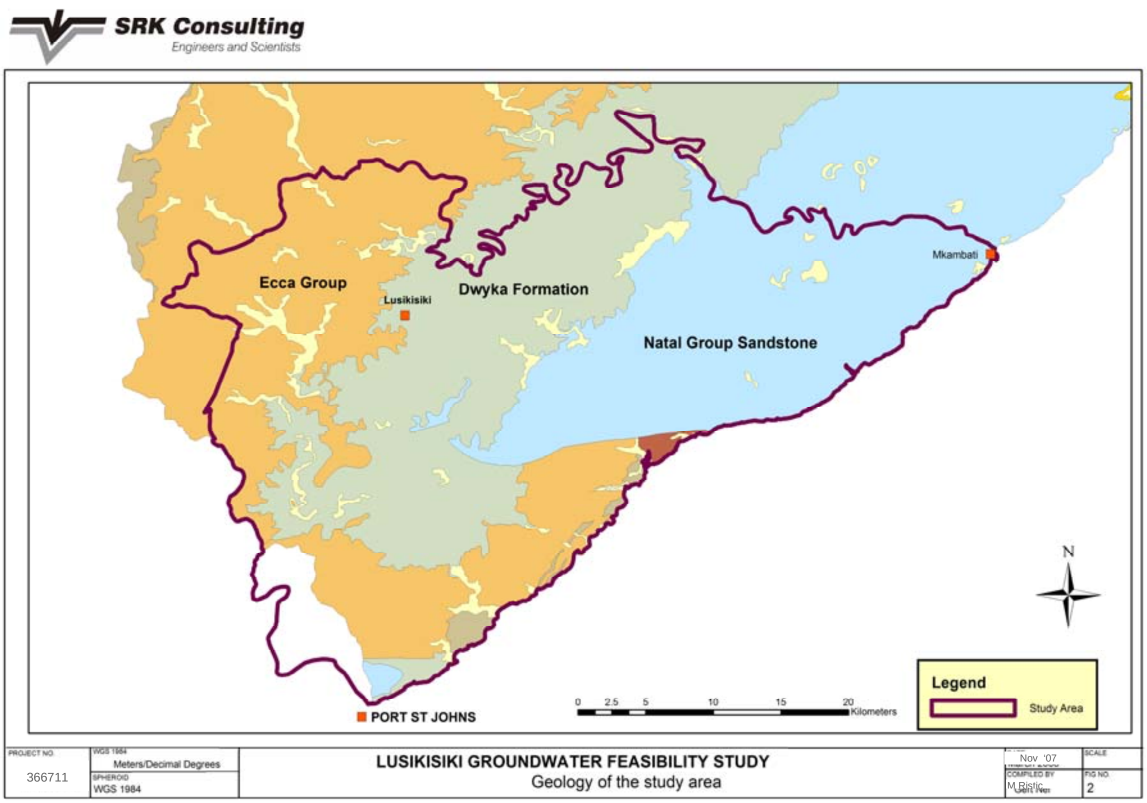

Figure 2: Geology of the study area

2.5.1 Natal Group Sandstone

The Natal Group Sandstone consists of white to grey, siliceous quartzose and subfeldspatic sandstone with subordinate conglomerate. The grain size of the sandstone normally varies between 0.5 mm and 1 mm. Although they seem similar in properties, their geological relationship with the Table Mountain Group sandstones is uncertain.

Further south the sediment is finer grained and forms resistant sandstone cliffs. These give rise to the table top topography seen in the Fraser Gorge near Mbotyi as depicted in **Figure 4**.

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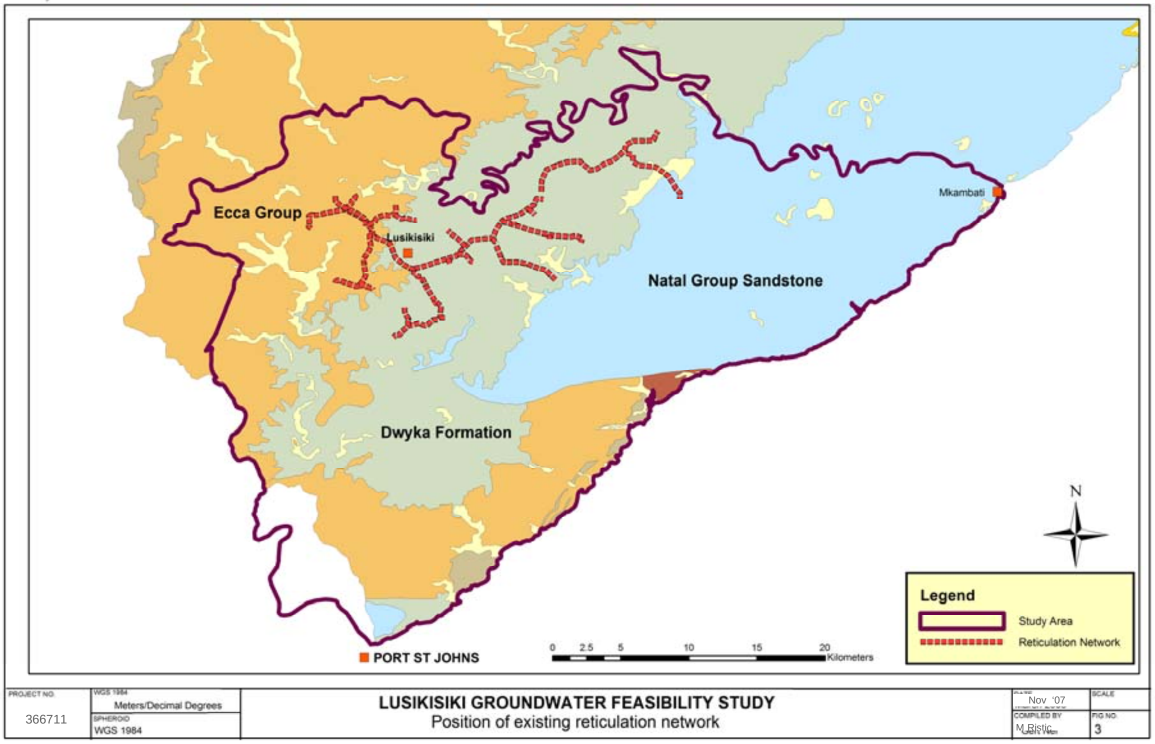


Figure 3: Position of the existing reticulation network

Figure 4: Typical table top topography as seen at Fraser Gorge

2.5.2 Dwyka Formation

The Dwyka Formation overlies the Natal Group Sandstone. It consists of a sequence of coarse diamictites and subordinate laminated mudstones. The diamictites consist of angular to subangular clasts set in a bluish-grey matrix of sand grains and clay, as is shown in **Figure 5**. The diamictites are probably of glacial till origin; hence they are also called Dwyka Diamictite.

Figure 5: Example of diamictite with clasts

In the project area, the Natal Group Sandstone generally dips at 2-3 degrees underneath the Dwyka, but has been structurally disturbed by a series of north-east to south-west striking dyke intruded faults not shown on the 1:250 000 geological map. These faults are however distinguishable on the Landsat image as shown in **Figure 6.**

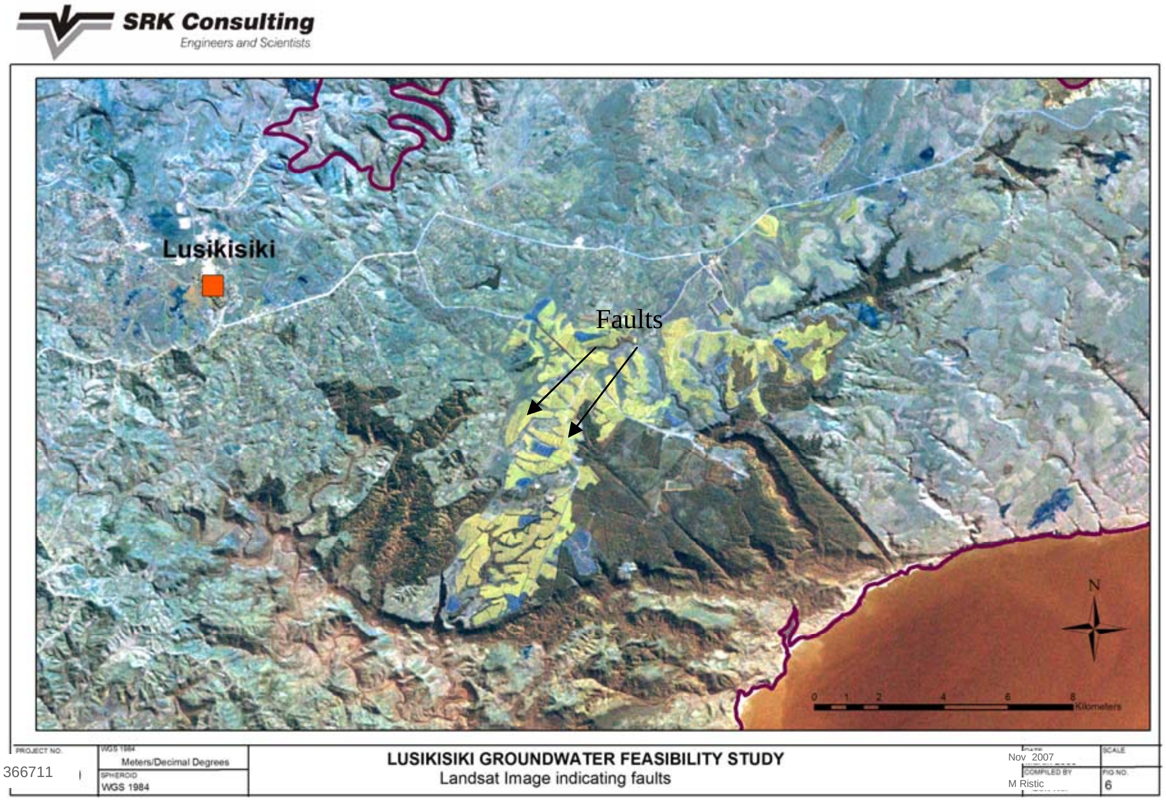


Figure 6: Landsat image showing the positions of the faults not indicated on the 1:250 000 geological map (1:250 000 Umtata Series)

2.5.3 Ecca Group

The Ecca Group occupies approximately a third of the project area and comprises shale and subordinate sandstone. The Ecca is characterised by the widespread presence of dolerite intrusions in the form of dykes and sheets.

The north-west south-east regional faults that are clearly seen in the Natal Group Sandstone and Dwyka are masked in the Ecca by dolerite sheets, making it very difficult to locate the exact position of the gap dykes. **Figure 7** shows how one of the regional dykes disappears when entering the Ecca Group and resurfaces closer to the Beaufort Group (Adelaide sub group - Pa).

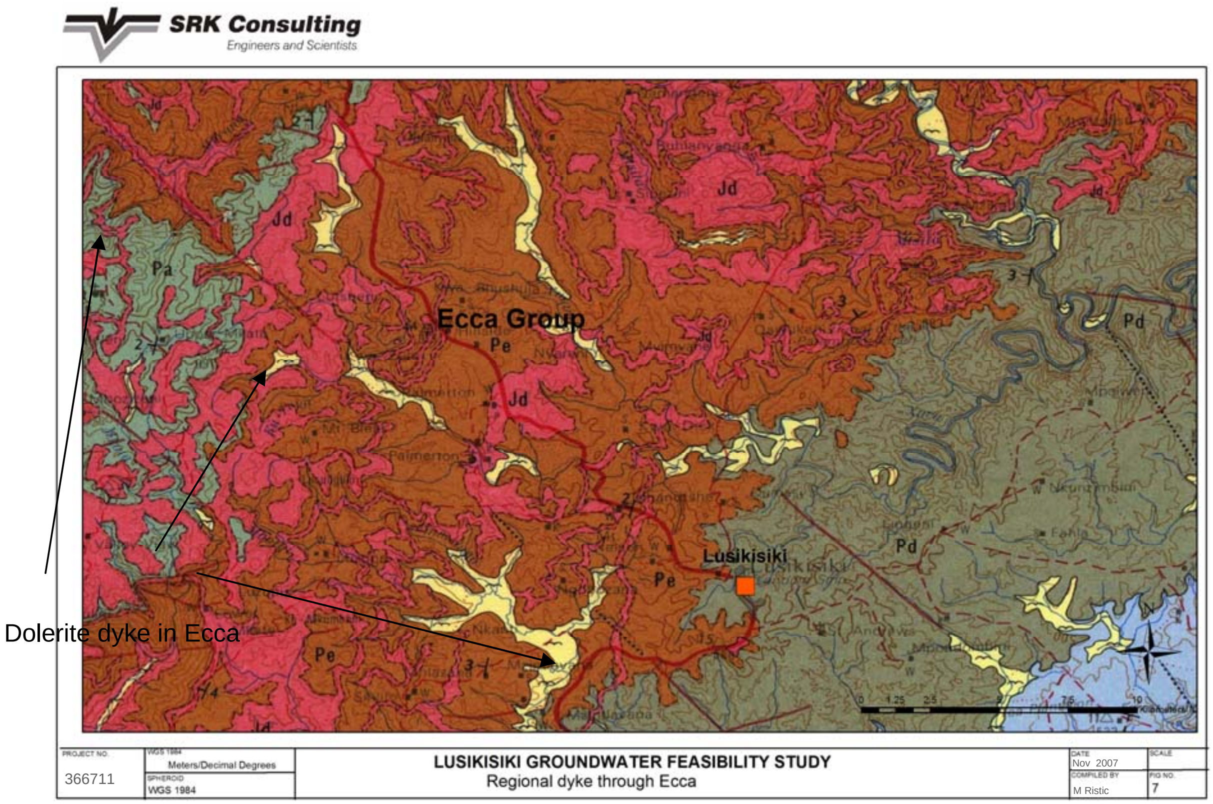


Figure 7: Geology map showing how a dolerite dyke is masked by the Ecca sediments

3. REVIEW AND UPDATE OF EXISTING POPULATION INFORMATION

3.1 Update Population Based on 2001 Census

3.1.1 Eastern Cape's demographic development indicators

The demographic profile of a region gives a first glance of the people potential and their development status. This is necessary as human capital remains the primary driver of economic activity and development – it is the main the starting point and destination of socio-economic development.

The development status of a region is also often measured as a composite index of population size, population growth, infant mortality rate, total fertility rate, life expectancy (age), literacy rate (%) and GDP/GGP per capita. This often forms the basis for a comparison with other regions and countries (see **Table 3**).

Based on these indicators (and more as outlined below), the Eastern Cape's development profile is not very similar to that of South Africa. Whilst there is a higher number of recorded births in the Eastern Cape as compared to the average recorded for South Africa, there also is a high infant mortality and low life expectancy rate. HIV/AIDS seems to be taking its toll on the Eastern Cape population with a visible decrease in the population growth rate. These indicators are outlined below.

Table 3: Eastern Cape Demographic Development Indicators

Indicator	Eastern Cape	SA	Interpretation
Population (000) (2001)	6, 436	44,000	The E C has 14.4% of the country's population residing in it.
Area (sq km)	169, 580	1 223 201	Eastern Cape population density is 37.96 vs 33.2 people per sq km in SA.
Population growth	2.65%	10.4%	The province has a low population growth rate and one of the reasons is that HIV/AIDS has had a serious impact in the province.
Infant mortality rate	72	41.0	Deaths per 1000 births – thus Eastern Cape may have need for better antenatal care. EC also has the highest under 5 mortality rate in the country.
Total Fertility Rate	3.5	2.7	Number of births per woman – thus Eastern Cape has a better fertility rate.
Life Expectancy (Age)	60,7	63.2	Inhabitants seem to have lifespans smaller than that of the avergae South African. (A provincial statistics report highlights that EC has the second lowest life expectancy from all provinces, following the North West which has 59,7 years.)
Literacy Rate (%)	72,3	82.9	The Eastern Cape has a lower literacy rate than the average South African.
Human Development Index	0.654	0.677	0 = a Perfect Score. The Gini Coefficient in the EC worsened from 0.610 in 1995 to 0.654 in 2001, but is still better than the Gini coeficient for SA.

3.1.2 The Eastern Cape's labour and employment profile

The following statistics shown in **Table 4** is obtained from the October Household survey of 1995 and the SA Labour force Survey of February 2002.

Table 4: Employment and economically active population (EAP) shifts, by race and gender, 1995-2002

Category	Employment Change	Economically active population Change	Target Growth Rate (%)	% Change In Employment	Employment Absorption Rate (%)
South Africa					
African	1140684	4524474	74.99	18.91	25.21
Coloured	175665	441040	39.56	15.76	39.83
Asian	137301	227955	64.89	39.08	60.23
White	157923	257578	13.57	8.32	61.31
Other	25576	29625			86.33
Gender					
Male	504585	2143571	37.84	8.91	23.54
Female	1132564	3337101	89.41	30.34	33.94
Total	1637149	5480672	58.32	17.42	29.87
Eastern Cape					
African	329004	827752	127.31	50.6	39.75
Coloured	29446	77111	64.09	24.47	38.19
Asian	18123	20509	278.77	246.34	88.37
White	10422	14653	10.11	7.19	71.13
Other	3515	4434			79.27
Gender					
Male	153932	394880	77.67	30.28	38.98
Female	236578	549580	132.63	57.09	43.05
Total	390510	944460	102.35	42.32	41.35

The economy, in the aggregate, has been creating jobs rather than shedding them. This is also true for the Eastern Cape, where 3900 jobs were created over the period. On the other hand, between 1995 and 2002, the number of new entrants to the labour market nationally increased by over 5 million individuals, which means that about 3.8 million individuals - some of whom were first-time entrants into the labour market - were rendered or remained jobless in this period. As a result of this employment performance, unemployment levels increased to over 7 million individuals in 2002, almost a 100% growth in unemployment over the period. In the Eastern Cape, while almost a million individuals entered the labour force, the province only created 390,000 jobs. Juxtaposed with this, the labour force in the province grew by 61%, employment grew by 42%, and unemployment grew by 88% - which means that although unemployment in this province has grown at a slightly slower rate than is the case nationally, the number of jobs that have been created has not been sufficient to absorb all work-seekers into employment.

A study conducted by the Development Policy Research Unit at the University of Cape Town, rendered an analysis of the current job market in South Africa. The primary data was the October household surveys conducted in 1995 and 1999. The study categorised the SA workforce into skilled, semi-skilled and unskilled, **Table 5**. The following was revealed:

Table 5: Provincial organisation of occupational distribution of employment

Province	Absolute numbers				Percentage			
	Skilled	Semi-skilled	Unskilled	Total	Skilled	Semi-skilled	Unskilled	Total
Western Cape	381 643	535 860	639 421	1 556 924	24.51	34.42	41.07	100
Eastern Cape	219 092	311 953	480 777	1 011 822	21.65	30.83	47.52	100
Northern Cape	33 969	69 650	141 825	245 444	13.84	28.38	57.78	100
Free State	126 568	251 840	362 600	741 008	17.08	33.99	48.93	100
KwaZulu-Natal	422 110	644 224	872 634	1 938 968	21.77	33.23	45.01	100
North-West	125 601	282 845	363 982	772 428	16.26	36.62	47.12	100
Gauteng	731 092	1 115 432	839 860	2 686 384	27.21	41.52	31.26	100
Mpumalanga	112 059	246 720	338 025	696 804	16.08	35.41	48.51	100
Northern Province	155 373	234 412	303 556	693 341	22.41	33.81	43.78	100
Total	**2 307 507**	**3 692 936**	**4 342 680**	**10 343 123**	**22.31**	**35.7**	**41.99**	**100**

Source: Chapter 5, The SA labour market and job opportunities, Published in Monograph No 61, August 2001

Gauteng seems to set the pace and perhaps even the trends in terms of the occupational distribution of employment within the South African labour market. While it may be conceded that Gauteng embodies the fulcrum of economic activity in South Africa, it has the lowest proportion of unskilled occupations within its economic and geographic boundaries and the highest proportion and concentration of skilled and semiskilled occupations among the country's nine provinces. Apart from Gauteng, with an economically active population of approximately 2.6 million people (the largest provincial labour force), three other provinces have a job market that exceeds one million individuals: the Western Cape (1.5 million), Eastern Cape (1 million) and KwaZulu-Natal (1.9 million).

Table 6: Unemployment for degreed workers – African and White, 1995 - 2002

Year	South Africa		Eastern Cape	
	African	White	African	White
Unemployment numbers				
1995	8834	5645	736	230
2002	48658	11386	5727	452
% change	450.8	101.7	678.1	96.5
Unemployment rates				
1995	5.87	2.12	2.73	1.14
2002	16.67	2.57	18.8	1.62

The occupational distribution according to levels of skill (**Table 6**) remains less favourable than that found in Gauteng, but the Western Cape is in the second position with respect to skilled and unskilled occupations. Both the North-West and Mpumalanga have a proportionately larger semiskilled employment category than the Western Cape, but are surpassed by it in terms of the skilled employment categories. Provinces that exhibit the highest concentrations in the unskilled categories and the lowest concentrations in the skilled categories are more likely to exhibit low employment generation in the short term.

The Eastern Cape's Strategy for Growth and Development (2004-2014), report that between 1995 and 2001 South Africa required a GDP growth rate of 6.9% per annum to absorb growth in the labour force and increased labour productivity, actual average growth was 2.9% per annum. Over the 1995 -2001 period, real annual economic growth in the Province averaged 2.4%. Since annual population growth was also about 2.4%, real economic growth per capita was nil (Edwards (2003) in Strategy for Growth and Development (2004-2014)).

Formal employment in the province is estimated to have fallen by 13 000 from 607 000 to 594 000 between 1996 and 2000 (ECDC (2002) in Strategy for Growth and Development (2004-2014)). In this period, the population of the working age (aged between 15 and 64) in the province increased at 4% pa or by about 140 000 a year. It was recorded that unemployment and underemployment during the years 1995-2001 rose sharply. The official definition is that unemployment rose from 23% to 30% between 1995 and 2001.

3.1.3 EC economy compared to other provinces

In the figure **Figure 8** below, we find the public and manufacturing sectors substituting each other for first and second largest sectors in the economy. This indicates that the province is dependent on public sector funding for the sustainability of its economy and it is very likely that a large proportion of this funding comes from national coffers. The overall growth of the Province was still satisfactory, but it can be suggested that higher industrial growth is required to spearhead the private sector of the economy.

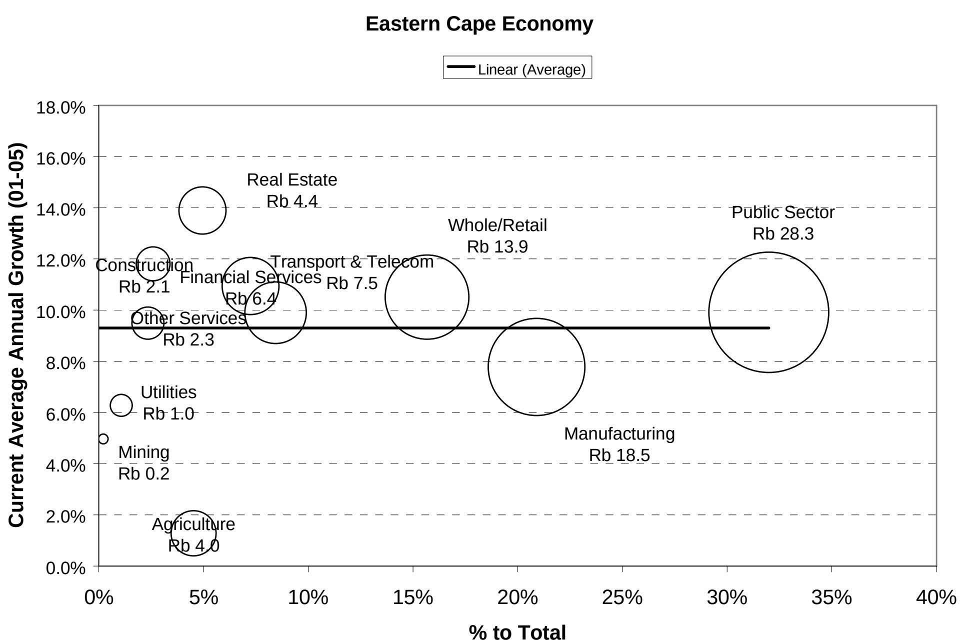


Figure 8: Eastern Cape Economic Structure 2001-2005

3.1.4 Census 2001 for the Project Area

The National South African Census 2001 is still the most credible and 'recent' data that is in use today. To better understand the population figures represented in the Lusikisiki area, an attempt is made to present these figures according the municipal area, the municipal place name and the village/sub-place areas.

It must be noted that since the Government had, post 1994, re-demarcated the municipal boundaries and at the same time done away with Transitional Rural Councils (TRC's), Transitional Local Councils (TLC's) and Magisterial Districts, it is a challenge to find the statistical data for some of the "Admin areas" and "Villages" last recorded.

Information not available from The Census 2001
Data for the following areas could not be found in the Census 2001:

Admin Area	Village Name
Dubana	Maklakane, Ngibe, Dlibona, Ngqungqushe
Gobozana	Gobozana B, Mount Nelson
Mzintlava	Mxelwenkunzi
Malenge	Kunkunzimbibi
Mateko	Mateko B, Matheko
Xura	Kwadick
Malenge	Mpangina
Goso Forest	Kugwexintaba, Gos Forest
Nyosana	Nkanti
Upper Ntafufu	Mampondweni, Ngcenge
Lambasi	Dinfi, Mazize, Ntangeni
Quakeni	Qawukeni B, Qawukeni C
Lower Ntafufu	Ndongeni, Nkondusweni, Isapata

3.1.5 Population

The following tables present population figures using a projected annual growth rate of 2.65%. This is the present calculated growth rate for the Eastern Cape. Due to an insufficient reflection of growth rates at town or village level, 2.65% has been included as the most reliant average projection figure and has thus been used across the board.

It must be noted that the annual growth rate can change depending on a number of variables. For example, the migration patterns of people from towns and villages across provinces, the high death rate attributed to high accident rates, high AIDS rates, and other fatal diseases. Infant mortality and life expectancy rates (which are usually highly dependent on increased professional services, increased basic services and a higher standard of living), also impact on population growth rates.

The average growth rate of 2.65% can be interpreted to be a conservative figure based on existing growth rate calculations between 1996 and 2001.

Table 7: Estimated Population Growth for Places not covered in the Census 2001

Old MGD	Municipal Name	Recognised Municipal place name	Village / SubPlace	Population numbers (projected from 2001 onwards)				
				2001	2005	2010	2020	2030
Bizana	Port St Johns	Mvumelwano	Bizana	756	839	957	1243	1614
Flagstaff/ Siphaqueni	Qaukeni	Flagstaff	None	1759	1953	2226	2891	3756
Flagstaff/ Siphaqueni	Qaukeni	Flagstaff	Flagstaff	1305	1449	1651	2145	2786
Lusikisiki	Qaukeni	Lusikisiki	None	5117	5681	6475	8411	10925
Lusikisiki	Qaukeni	Lusikisiki	Lusikisiki	3957	4393	5007	6504	8448

It was not possible to obtain the urban and rural population figures for the abovementioned places (**Table 7**). Census 2001 does not have this data.

3.1.6 Population Projections for Different Phases of Development

Following tables (**Table 8, 9 and 10**) showing population projections for different phases of development that are as follows:

- Phase 1 (existing phase): Provision of full standpipe services to the 29 villages/subplaces already connected to the scheme, including the installation of reticulation systems and upgrading of the village storage capacities

  This phase also include upgrading of existing bulk supply infrastructure to meet the increased requirements associated with the higher service levels within the existing scheme
- Phase 2: An extension of the existing scheme to supply 32 additional villages/subplaces (about 37 000 people) including the extension of the bulk supply network and the provision of additional village reservoirs and reticulation systems
- Phase 3: A further extension to supply 14 additional villages/subplaces (about 31 000 people) is planned for implementation

Table 8: Phase 1 - Upgrade of existing water supply

Old MGD	Municipal Name	Recognised Municipal place name	Village / SubPlace	Population numbers (projected from 2001 onwards)				
				2001	2005	2010	2020	2030
Lusikisiki	Qaukeni	Lusikisiki	None	5117	5681	6475	8411	10925
Lusikisiki	Qaukeni	Lusikisiki	Lusikisiki	3957	4393	5007	6504	8448
Xura	Qaukeni	Qaukeni	Xura	877	974	1110	1442	1872
Xura	Qaukeni	Qaukeni	Dumasi	1894	2103	2397	3113	4044
Xura	Port St Johns	Mvumelwano	Dumasi	200	222	253	329	427
Xura	Qaukeni	Gunyeni	KuTshandatshi	464	515	587	763	991
Xura	Qaukeni	Qaukeni	KuTshandatshi	447	496	566	735	954
Dubana	Qaukeni	Qaukeni	Mcobotini	4102	4554	5191	6742	8758
Dubana	Qaukeni	Taweni	Mcobotini	753	836	953	1238	1608
Dubana	Qaukeni	Qaukeni	Ngqungqu	64	71	81	105	137
Lower Xura	Qaukeni	Qaukeni	Mdikane	966	1073	1222	1588	2062
Hombe	Qaukeni	Qaukeni	Hombe	75	83	95	123	160
Hombe	Mbizana	Amadiba	Tyeni	484	537	612	796	1033
Hombe	Qaukeni	Qaukeni	Tyeni	1930	2143	2442	3172	4121
Hombe	Qaukeni	Qaukeni	Nqaqhumbe	484	537	612	796	1033
Hombe	Qaukeni	Qaukeni	KuNikhwe	1914	2125	2422	3146	4087
Hombe	Qaukeni	Qaukeni	Nikhwe	678	753	858	1114	1448
Gobozana	Qaukeni	Gunyeni	Ngobozana	2630	2920	3328	4323	5615
Gobozana	Qaukeni	Gunyeni	Gunyeni	2799	3108	3542	4601	5976
Nkunzimbini	Qaukeni	Qaukeni	Nkunzimbini	1249	1387	1580	2053	2667
Nkunzimbini	Qaukeni	Qaukeni	KwaMqezwa	1822	2023	2306	2995	3890
Nkunzimbini	Qaukeni	Qaukeni	Lukhahlambeni	1867	2073	2363	3069	3986
Mdubu	Qaukeni	Gunyeni	Mbudu	221	245	280	363	472
Mzintlava	Port St Johns	Manzamhlophe	Lugaqweni	517	574	654	850	1104
Mevana	Port St Johns	Manzamhlophe	Mevana	98	109	124	161	209
Mevana	Nyandeni	Konjyaoyo	Mevana	787	874	996	1294	1680
Mevana	Qaukeni	Qaukeni	KuMevana	466	517	590	766	995
Nyosana	Port St Johns	Bomvini	Nyosana	244	271	309	401	521

Old MGD	Municipal Name	Recognised Municipal place name	Village / SubPlace	Population numbers (projected from 2001 onwards)				
				2001	2005	2010	2020	2030
Nyosana	Port St Johns	Bomvini	Jambini	2607	2895	3299	4285	5566

Table 9: Phase 2 - An extension of the existing scheme to supply 32 additional villages

Old MGD	Municipal Name	Recognised Municipal place name	Village / SubPlace	Population numbers (projected from 2001 onwards)				
				2001	2005	2010	2020	2030
Malenge	Qaukeni	Qaukeni	Mpolweni	1433	1591	1813	2355	3060
Nkunzimbini	Qaukeni	Qaukeni	Nkunzimbini	1249	1387	1580	2053	2667
Zalu	Port St Johns	Qaukeni	Pamalitoli	586	651	742	963	1251
Zalu	Qaukeni	Qaukeni	Ndimbaneni	1274	1415	1612	2094	2720
Zalu	Mbizana	Amangutyana	Ntsimbini	1673	1858	2117	2750	3572
Zalu	Mbizana	Imizizi	Ntsimbini	77	85	97	127	164
Zalu	Mbizana	Ntlenzi	Ntsimbini	1044	1159	1321	1716	2229
Zalu	Qaukeni	Gunyeni	Ntsimbini	1572	1745	1989	2584	3356
Zalu	Qaukeni	Qaukeni	Ntsimbini	999	1109	1264	1642	2133
Zalu	Port St Johns	Manzamhlophe	Ntsimbini	2562	2845	3242	4211	5470
Zalu	Qaukeni	Qaukeni	Mrhoshozo	647	718	819	1063	1381
Mateko	Qaukeni	Qaukeni	KwaBhumbuta	1102	1224	1394	1811	2353
Mateko	Qaukeni	Ndimakude	Msikaba	483	536	611	794	1031
Mateko	Qaukeni	Sipaqeni	Msikaba	465	516	588	764	993
Mateko	Qaukeni	Qaukeni	Mawotsheni	223	248	282	367	476
Xura	Qaukeni	Qaukeni	Xura	877	974	1110	1442	1872
Lower Xura	Mbizana	Amangutyana	Dumeni	698	775	883	1147	1490
Goso Forest	Qaukeni	Qaukeni	Magwa	250	278	316	411	534
Nyosana	Port St Johns	Bomvini	Jambini	2607	2895	3299	4285	5566
Nyosana	Port St Johns	Bomvini	Nyosana	244	271	309	401	521
Mzintlava	Port St Johns	Gunyeni	Malungeni	914	1015	1157	1502	1951
Mzintlava	Port St Johns	Gunyeni	Matulini	318	353	402	523	679
Mtambalala	Port St Johns	Emtweni	Matane	365	405	462	600	779
Bomvini	Port St Johns	Bomvini	Sihlito	421	467	533	692	899
Bomvini	Port St Johns	Gunyeni	Sihlito	523	581	662	860	1117
Upper Ntafufu	Port St Johns	Gunyeni	Mzintlavana	693	769	877	1139	1480
Upper Ntafufu	Mbizana	Amangutyana	Ntsimbini	1673	1858	2117	2750	3572
Upper Ntafufu	Mbizana	Imizizi	Ntsimbini	77	85	97	127	164
Upper Ntafufu	Mbizana	Ntlenzi	Ntsimbini	1044	1159	1321	1716	2229
Upper Ntafufu	Qaukeni	Gunyeni	Ntsimbini	1572	1745	1989	2584	3356
Upper Ntafufu	Qaukeni	Qaukeni	Ntsimbini	999	1109	1264	1642	2133
Upper Ntafufu	Port St Johns	Manzamhlophe	Ntsimbini	2562	2845	3242	4211	5470

Table 10: Phase 3 - A further extension to supply 14 additional villages

Old MGD	Municipal Name	Recognised Municipal place name	Village / SubPlace	Population numbers (projected from 2001 onwards)				
				2001	2005	2010	2020	2030
Upper Ntafufu	Port St Johns	Gunyeni	Nzondeni	846	939	1071	1391	1806
Mtambalala	Port St Johns	Emtweni	Buchele	1884	2092	2384	3097	4022
Lambasi	Qaukeni	Qaukeni	Ndengane	387	430	490	636	826
Lambasi	Qaukeni	Qaukeni	Cutwini	905	1005	1145	1488	1932
Lambasi	Qaukeni	Qaukeni	Ndindindi	2444	2714	3093	4017	5218

Lambasi	Mbizana	Tsikelo	Ntlamvukazi	424	471	537	697	905
Pumlo	Qaukeni	Qaukeni	Bayi	1002	1113	1268	1647	2139
Lower Ntafufu	Mbizana	Ntlenzi	Taleni	1684	1870	2131	2768	3595
Lower Ntafufu	Qaukeni	Sipaqeni	Taleni	588	653	744	966	1255
Lower Ntafufu	Port St Johns	Bomvini	Taleni	566	628	716	930	1208
Lower Ntafufu	Port St Johns	Emtweni	Kwagingqi	350	389	443	575	747
Lower Ntafufu	Port St Johns	Ndluzula	Kwagingqi	1101	1222	1393	1810	2351
Lower Ntafufu	Port St Johns	Bomvini	Lusubeni	161	179	204	265	344
Lower Ntafufu	Port St Johns	Ndluzula	Mbiza	699	776	885	1149	1492

Phases are the same as proposed in the Eastern Pondoland Basin Study.

4. WATER REQUIREMENTS

4.1 Methodology

Water requirements for the Lusikisiki Regional Water Supply Scheme were calculated based on population data and projections from the National South African Census 2001 (See **Paragraph 3.1**) and the water requirements per capita as detailed in DWAF (2001). A summary of the water requirements methodology and assumptions from DWAF (2001) report is given below.

Water requirements methodology (DWAF 2001)

This section is a summary of the methodology detailed in the report DWAF (2001).

Water use was recorded in the Lusikisiki Regional Water Supply Scheme (LRWSS) between 1993 and 1996. These records were used to estimate water use per capita in the urban and rural areas of the LRWSS. In **Table 11** the maximum daily water use from this data is given. The figures include operational and conveyance system losses (DWAF 2001).

Table 11: Metered gross average daily water usage for the existing LRWS (from DWAF 2001)

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

The value recorded for Lusikisiki town includes certain small businesses, commercial and municipal users. It also includes significant water losses, possibly in excess of 30%, due to the state of the existing system. DWAF (2001) estimated that domestic per capita use was in the order of 110 l/c/d after removing the estimated volumes of losses and municipal and business users from the figures in **Table 11**.

The rural population uses about 10 l/c/d. When the study was done, however, the walking distance to water services in the rural villages did not meet RDP standards. A full standpipe level of service would likely increase the water usage in these areas.

DWAF (2001) suggested caution in dealing with the above figures. Many meters in the area were in bad condition, some bulk meters were inappropriately positioned, meters were read infrequently and most were unable to record low flows.

Based on above information and projections three water use requirement scenarios were proposed by DWAF (2001). These consisted of a high water use estimate, a low water use estimate and a constant estimate.

The high water use estimate was based on a water requirement of above RDP standards for the year 2000 for rural areas. The RDP Rural Water Supply Design Criteria Guidelines (DWAF 1997) recommended a minimum allowance of 25 litres per capita per day (l/c/d) for the case of standpipe levels of service. DWAF (2001) thus conservatively estimated the need for 2000 as 30 l/c/d. The study also recommended sizing all components for a 60 l/c/d for a 10 year projection horizon to allow for growth in water demand (DWAF 2001). Urban water requirements were assumed to grow from 160 l/c/d to 240 l/c/d for the years 2000 to 2030 (DWAF 2001).

As discussed above rural water use in reality has been considerably lower than RDP standards (10l/c/d). Hence DWAF (2001) suggested a lower (yet still conservative) value of 18l/c/d for rural areas in 2000 increasing to 36 l/c/d in 2030. For the same period the urban water requirement were assumed to vary from 110 l/c/d based on historical data to 200 l/c/d. These estimates were used for the low water use scenario.

The constant water use scenario assumed the RDP water requirements of 25 l/c/d were met in rural areas but not improved upon as years went by. The lower estimate of projections of urban water use were also assumed for this scenario.

The water requirements for the various scenarios and planning horizons are given in **Table 13**. These values were used to calculate the water requirements for the area (See results in **Section 4.1**). When calculating the water demand for the year 2001, in order to be in line with the National South African Census Data 2001, the year 2000 water requirement figures were used. Design Annual Average Daily Water Requirements (from DWAF 2001) are shown in the **Table 13** as well.

4.2 Population data

Population data for the area for which water requirements were calculated was obtained from the National South African Census 2001. The population estimates are discussed in **Section 3**.

4.2.1 Urban and rural population division

DWAF (2001) classified only the town of Lusikisiki as urban and the rest of the Lusikisiki area as rural. This was confirmed by data from the National South African Census 2001. The census data was analysed to determine which areas had a significant number of house with full water services (piped dwelling with fully connected flush toilet system). Only Lusikisiki (municipality Qaukeni) had a significant number of such dwellings – 24% flush toilets and 16% fully piped connections for a population of 5117. No other municipalities had more than 7% fully serviced houses and even those which had close to this number had small populations (<1000). One village did have 100% full service but only consisted of 3 households (Old MGD Dubana – Municipal Name Quakeni) and hence was classified as rural. Hence for the calculation of water requirements in this report only the town of Lusikisiki (population 5117) was classified as urban as was done in DWAF (2001).

Final calculation of water requirements

The urban and rural water requirements per capita for various scenarios (high, low and constant) obtained from DWAF (2001) were multiplied by population figures from the National South African Census 2001 to obtain total estimated water requirements for various planning horizons.

4.3 Domestic and Industrial Water Requirements

The water requirements based on the methodology in **Section 4.1** are summarised in **Table 12** and detailed in **Table 13.** The water requirements for 2001 were estimated as 1.35, 0.86 and 1.05 million m^3/annum for high, low and constant water requirements respectively. These grow to 6.4, 3.5 and 2.9 million m^3/annum for high, low and constant scenarios respectively by 2030 **Figure 9**.

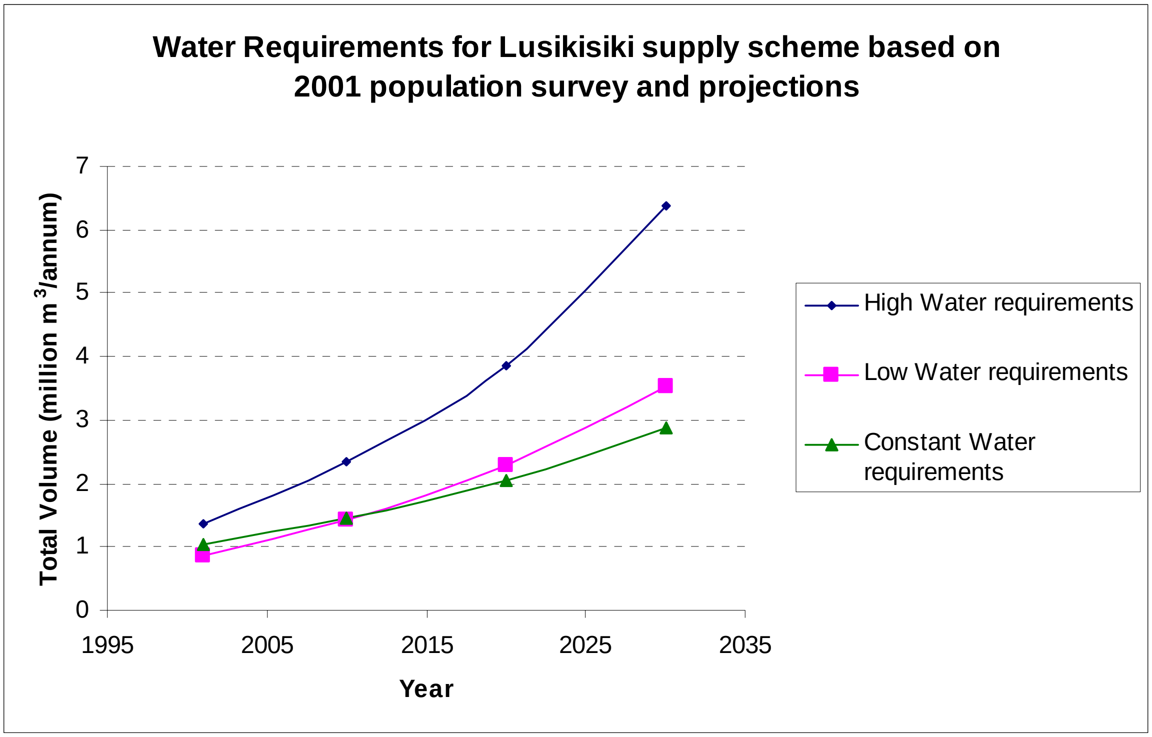


Figure 9: Water Requirements for the Lusikisiki supply scheme based on the 2001 population survey projections

Table 12: Summary of estimated water requirements

Summary of water requirements for Lusikisiki supply scheme based on the 2001 population survey and population projections

	2001*			2010			2020			2030		
Old MGD	High Water requirements	Low Water requirements	Constant Water requirements	High Water requirements	Low Water requirements	Constant Water requirements	High Water requirements	Low Water requirements	Constant Water requirements	High Water requirements	Low Water requirements	Constant Water requirements
Phase 1 (l/d)	2,371,010	1,549,642	1,764,115	3,926,320	2,538,008	2,576,780	6,228,505	4,046,440	3,794,625	9,882,800	6,229,576	5,510,000
Phase 2 (l/d)	936,970	564,197	780,785	1,778,230	952,448	987,940	3,079,835	1,544,020	1,283,345	5,333,760	2,404,344	1,666,925
Phase 3 (l/d)	391,230	234,738	326,025	742,680	396,096	412,600	1,286,160	643,080	535,900	2,227,200	1,002,240	696,000
Total	**3,699,210**	**2,348,577**	**2,870,925**	**6,447,230**	**3,886,552**	**3,977,320**	**10,594,500**	**6,233,540**	**5,613,870**	**17,443,760**	**9,636,160**	**7,872,925**
Phase 1 ($10^6 m^3/a$)	0.87	0.57	0.64	1.43	0.93	0.94	2.27	1.48	1.39	3.61	2.28	2.01
Phase 2 ($10^6 m^3/a$)	0.34	0.21	0.29	0.65	0.35	0.36	1.12	0.56	0.47	1.95	0.88	0.61
Phase 3 ($10^6 m^3/a$)	0.14	0.09	0.12	0.27	0.14	0.15	0.47	0.23	0.20	0.81	0.37	0.25
Total	**1.35**	**0.86**	**1.05**	**2.35**	**1.42**	**1.45**	**3.87**	**2.28**	**2.05**	**6.37**	**3.52**	**2.88**

* Water demand per capita figures for 2000 were used for the 2001 calculations. Water demand figures are from DWAF (2001)

Table 13: Detailed estimated water requirements

Water requirements for Lusikisiki supply scheme based on the 2001 polutation survey and population projections

					2001			2010			2020			2030		
					High Water Requirements	Low Water requirements	Constant Water requirements	High Water Requirements	Low Water requirements	Constant Water requirements	High Water Requirements	Low Water requirements	Constant Water requirements	High Water Requirements	Low Water requirements	Constant Water requirements
Urban water requirement l/c/d					160	110	110	190	140	140	215	170	170	240	200	200
Rural water requirement l/c/d					30	18	25	45	24	25	60	30	25	80	36	25
PHASE 1 (EXISTING PHASE)																
					2001*			**2010**			**2020**			**2030**		
Old MGD	Municipal Name	Recognised Municipal place name	Village / SubPlace	Classification	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)
Lusikisiki	Qaukeni	Lusikisiki	None	Urban	818,720	562,870	562,870	1,230,250	906,500	906,500	1,808,365	1,429,870	1,429,870	2,622,000	2,185,000	2,185,000
Lusikisiki	Qaukeni	Lusikisiki	Lusikisiki	Urban	633,120	435,270	435,270	951,330	700,980	700,980	1,398,360	1,105,680	1,105,680	2,027,520	1,689,600	1,689,600
Xura	Qaukeni	Qaukeni	Xura	Rural	26,310	15,786	21,925	49,950	26,640	27,750	86,520	43,260	36,050	149,760	67,392	46,800
Xura	Qaukeni	Qaukeni	Dumasi	Rural	56,820	34,092	47,350	107,865	57,528	59,925	186,780	93,390	77,825	323,520	145,584	101,100
Xura	Port St Johns	Mvumelwano	Dumasi	Rural	6,000	3,600	5,000	11,385	6,072	6,325	19,740	9,870	8,225	34,160	15,372	10,675
Xura	Qaukeni	Gunyeni	KuTshandatshi	Rural	13,920	8,352	11,600	26,415	14,088	14,675	45,780	22,890	19,075	79,280	35,676	24,775
Xura	Qaukeni	Qaukeni	KuTshandatshi	Rural	13,410	8,046	11,175	25,470	13,584	14,150	44,100	22,050	18,375	76,320	34,344	23,850
Dubana	Qaukeni	Qaukeni	Mcobotini	Rural	123,060	73,836	102,550	233,595	124,584	129,775	404,520	202,260	168,550	700,640	315,288	218,950
Dubana	Qaukeni	Taweni	Mcobotini	Rural	22,590	13,554	18,825	42,885	22,872	23,825	74,280	37,140	30,950	128,640	57,888	40,200
Dubana	Qaukeni	Qaukeni	Ngqungqu	Rural	1,920	1,152	1,600	3,645	1,944	2,025	6,300	3,150	2,625	10,960	4,932	3,425
Lower Xura	Qaukeni	Qaukeni	Mdikane	Rural	28,980	17,388	24,150	54,990	29,328	30,550	95,280	47,640	39,700	164,960	74,232	51,550
Hombe	Qaukeni	Qaukeni	Hombe	Rural	2,250	1,350	1,875	4,275	2,280	2,375	7,380	3,690	3,075	12,800	5,760	4,000
Hombe	Mbizana	Amadiba	Tyeni	Rural	14,520	8,712	12,100	27,540	14,688	15,300	47,760	23,880	19,900	82,640	37,188	25,825
Hombe	Qaukeni	Qaukeni	Tyeni	Rural	57,900	34,740	48,250	109,890	58,608	61,050	190,320	95,160	79,300	329,680	148,356	103,025
Hombe	Qaukeni	Qaukeni	Nqaqhumbe	Rural	14,520	8,712	12,100	27,540	14,688	15,300	47,760	23,880	19,900	82,640	37,188	25,825
Hombe	Qaukeni	Qaukeni	KuNikhwe	Rural	57,420	34,452	47,850	108,990	58,128	60,550	188,760	94,380	78,650	326,960	147,132	102,175
Hombe	Qaukeni	Qaukeni	Nikhwe	Rural	20,340	12,204	16,950	38,610	20,592	21,450	66,840	33,420	27,850	115,840	52,128	36,200
Gobozana	Qaukeni	Gunyeni	Ngobozana	Rural	78,900	47,340	65,750	149,760	79,872	83,200	259,380	129,690	108,075	449,200	202,140	140,375
Gobozana	Qaukeni	Gunyeni	Gunyeni	Rural	83,970	50,382	69,975	159,390	85,008	88,550	276,060	138,030	115,025	478,080	215,136	149,400
Nkunzimbini	Qaukeni	Qaukeni	Nkunzimbini	Rural	37,470	22,482	31,225	71,100	37,920	39,500	123,180	61,590	51,325	213,360	96,012	66,675
Nkunzimbini	Qaukeni	Qaukeni	KwaMqezwa	Rural	54,660	32,796	45,550	103,770	55,344	57,650	179,700	89,850	74,875	311,200	140,040	97,250
Nkunzimbini	Qaukeni	Qaukeni	Lukhahlambeni	Rural	56,010	33,606	46,675	106,335	56,712	59,075	184,140	92,070	76,725	318,880	143,496	99,650
Mdubu	Qaukeni	Gunyeni	Mbudu	Rural	6,630	3,978	5,525	12,600	6,720	7,000	21,780	10,890	9,075	37,760	16,992	11,800
Mzintlava	Port St Johns	Manzamhlophe	Lugaqweni	Rural	15,510	9,306	12,925	29,430	15,696	16,350	51,000	25,500	21,250	88,320	39,744	27,600
Mevana	Port St Johns	Manzamhlophe	Mevana	Rural	2,940	1,764	2,450	5,580	2,976	3,100	9,660	4,830	4,025	16,720	7,524	5,225
Mevana	Nyandeni	Konjyaoyo	Mevana	Rural	23,610	14,166	19,675	44,820	23,904	24,900	77,640	38,820	32,350	134,400	60,480	42,000
Mevana	Qaukeni	Qaukeni	KuMevana	Rural	13,980	8,388	11,650	26,550	14,160	14,750	45,960	22,980	19,150	79,600	35,820	24,875
Nyosana	Port St Johns	Bomvini	Nyosana	Rural	7,320	4,392	6,100	13,905	7,416	7,725	24,060	12,030	10,025	41,680	18,756	13,025
Nyosana	Port St Johns	Bomvini	Jambini	Rural	78,210	46,926	65,175	148,455	79,176	82,475	257,100	128,550	107,125	445,280	200,376	139,150
Total					**2,371,010**	**1,549,642**	**1,764,115**	**3,926,320**	**2,538,008**	**2,576,780**	**6,228,505**	**4,046,440**	**3,794,625**	**9,882,800**	**6,229,576**	**5,510,000**

* Water demand per capita figures for 2000 were used for the 2001 calculations. Water demand figures are from DWAF (2001)

					2001			2010			2020			2030		
					High Water Requirements*	Low Water requirements*	Constant Water requirements*	High Water Requirements	Low Water requirements	Constant Water requirements	High Water Requirements	Low Water requirements	Constant Water requirements	High Water Requirements	Low Water requirements	Constant Water requirements
Urban water requirement l/c/d					160	110	110	190	140	140	215	170	170	240	200	200
Rural water requirement l/c/d					30	18	25	45	24	25	60	30	25	80	36	25

PHASE 2																
Old MGD	Municipal Name	Recognised Municipal place name	Village / SubPlace		**2001***			**2010**			**2020**			**2030**		
				Classification	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)
Malenge	Qaukeni	Qaukeni	Mpolweni	Rural	42,990	25,794	35,825	81,585	43,512	45,325	141,300	70,650	58,875	244,800	110,160	76,500
Nkunzimbini	Qaukeni	Qaukeni	Nkunzimbini	Rural	37,470	22,482	31,225	71,100	37,920	39,500	123,180	61,590	51,325	213,360	96,012	66,675
Zalu	Port St Johns	Qaukeni	Pamalitoli	Rural	17,580	10,548	14,650	33,390	17,808	18,550	57,780	28,890	24,075	100,080	45,036	31,275
Zalu	Qaukeni	Qaukeni	Ndimbaneni	Rural	38,220	22,932	31,850	72,540	38,688	40,300	125,640	62,820	52,350	217,600	97,920	68,000
Zalu	Mbizana	Amangutyana	Ntsimbini	Rural	50,190	30,114	41,825	95,265	50,808	52,925	165,000	82,500	68,750	285,760	128,592	89,300
Zalu	Mbizana	Imizizi	Ntsimbini	Rural	2,310	1,386	1,925	4,365	2,328	2,425	7,620	3,810	3,175	13,120	5,904	4,100
Zalu	Mbizana	Ntlenzi	Ntsimbini	Rural	31,320	18,792	26,100	59,445	31,704	33,025	102,960	51,480	42,900	178,320	80,244	55,725
Zalu	Qaukeni	Gunyeni	Ntsimbini	Rural	47,160	28,296	39,300	89,505	47,736	49,725	155,040	77,520	64,600	268,480	120,816	83,900
Zalu	Qaukeni	Qaukeni	Ntsimbini	Rural	29,970	17,982	24,975	56,880	30,336	31,600	98,520	49,260	41,050	170,640	76,788	53,325
Zalu	Port St Johns	Manzamhlophe	Ntsimbini	Rural	76,860	46,116	64,050	145,890	77,808	81,050	252,660	126,330	105,275	437,600	196,920	136,750
Zalu	Qaukeni	Qaukeni	Mrhoshozo	Rural	19,410	11,646	16,175	36,855	19,656	20,475	63,780	31,890	26,575	110,480	49,716	34,525
Mateko	Qaukeni	Qaukeni	KwaBhumbuta	Rural	33,060	19,836	27,550	62,730	33,456	34,850	108,660	54,330	45,275	188,240	84,708	58,825
Mateko	Qaukeni	Ndimakude	Msikaba	Rural	14,490	8,694	12,075	27,495	14,664	15,275	47,640	23,820	19,850	82,480	37,116	25,775
Mateko	Qaukeni	Sipaqeni	Msikaba	Rural	13,950	8,370	11,625	26,460	14,112	14,700	45,840	22,920	19,100	79,440	35,748	24,825
Mateko	Qaukeni	Qaukeni	Mawotsheni	Rural	6,690	4,014	5,575	12,690	6,768	7,050	22,020	11,010	9,175	38,080	17,136	11,900
Xura	Qaukeni	Qaukeni	Xura	Rural	26,310	15,786	21,925	49,950	26,640	27,750	86,520	43,260	36,050	149,760	67,392	46,800
Lower Xura	Mbizana	Amangutyana	Dumeni	Rural	20,940	12,564	17,450	39,735	21,192	22,075	68,820	34,410	28,675	119,200	53,640	37,250
Goso Forest	Qaukeni	Qaukeni	Magwa	Rural	7,500	4,500	6,250	14,220	7,584	7,900	24,660	12,330	10,275	42,720	19,224	13,350
Nyosana	Port St Johns	Bomvini	Jambini	Rural	78,210	46,926	65,175	148,455	79,176	82,475	257,100	128,550	107,125	445,280	200,376	139,150
Nyosana	Port St Johns	Bomvini	Nyosana	Rural	7,320	4,392	6,100	13,905	7,416	7,725	24,060	12,030	10,025	41,680	18,756	13,025
Mzintlava	Port St Johns	Gunyeni	Malungeni	Rural	27,420	16,452	22,850	52,065	27,768	28,925	90,120	45,060	37,550	156,080	70,236	48,775
Mzintlava	Port St Johns	Gunyeni	Matulini	Rural	9,540	5,724	7,950	18,090	9,648	10,050	31,380	15,690	13,075	54,320	24,444	16,975
Mtambalala	Port St Johns	Emtweni	Matane	Rural	10,950	6,570	9,125	20,790	11,088	11,550	36,000	18,000	15,000	62,320	28,044	19,475
Bomvini	Port St Johns	Bomvini	Sihlito	Rural	12,630	7,578	10,525	23,985	12,792	13,325	41,520	20,760	17,300	71,920	32,364	22,475
Bomvini	Port St Johns	Gunyeni	Sihlito	Rural	15,690	9,414	13,075	29,790	15,888	16,550	51,600	25,800	21,500	89,360	40,212	27,925
Upper Ntafufu	Port St Johns	Gunyeni	Mzintlavana	Rural	20,790	12,474	17,325	39,465	21,048	21,925	68,340	34,170	28,475	118,400	53,280	37,000
Upper Ntafufu	Mbizana	Amangutyana	Ntsimbini	Rural	50,190	30,114	41,825	95,265	50,808	52,925	165,000	82,500	68,750	285,760	128,592	89,300
Upper Ntafufu	Mbizana	Imizizi	Ntsimbini	Rural	2,310	1,386	1,925	4,365	2,328	2,425	7,620	3,810	3,175	13,120	5,904	4,100
Upper Ntafufu	Mbizana	Ntlenzi	Ntsimbini	Rural	31,320	18,792	26,100	59,445	31,704	33,025	102,960	51,480	42,900	178,320	80,244	55,725
Upper Ntafufu	Qaukeni	Gunyeni	Ntsimbini	Rural	47,160	28,296	39,300	89,505	47,736	49,725	155,040	77,520	64,600	268,480	120,816	83,900
Upper Ntafufu	Qaukeni	Qaukeni	Ntsimbini	Rural	29,970	17,982	24,975	56,880	30,336	31,600	98,520	49,260	41,050	170,640	76,788	53,325
Upper Ntafufu	Port St Johns	Manzamhlophe	Ntsimbini	Rural	76,860	46,116	64,050	145,890	77,808	81,050	252,660	126,330	105,275	437,600	196,920	136,750
Total					**936,970**	**564,197**	**780,785**	**1,778,230**	**952,448**	**987,940**	**3,079,835**	**1,544,020**	**1,283,345**	**5,333,760**	**2,404,344**	**1,666,925**

* Water demand per capita figures for 2000 were used for the 2001 calculations. Water demand figures are from DWAF (2001)

					2001			2010			2020			2030		
					High Water Requirements*	Low Water requirements*	Constant Water requirements*	High Water Requirements	Low Water requirements	Constant Water requirements	High Water Requirements	Low Water requirements	Constant Water requirements	High Water Requirements	Low Water requirements	Constant Water requirements
Urban water requirement l/c/d					160	110	110	190	140	140	215	170	170	240	200	200
Rural water requirement l/c/d					30	18	25	45	24	25	60	30	25	80	36	25

PHASE 3																
Old MGD	Municipal Name	Recognised Municipal place name	Village / SubPlace	Classification	**2001***			**2010**			**2020**			**2030**		
					High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)	High Water Requirements (l/d)	Low Water requirements (l/d)	Constant Water requirements (l/d)
Upper Ntafufu	Port St Johns	Gunyeni	Nzondeni	Rural	25,380	15,228	21,150	48,195	25,704	26,775	83,460	41,730	34,775	144,480	65,016	45,150
Mtambalala	Port St Johns	Emtweni	Buchele	Rural	56,520	33,912	47,100	107,280	57,216	59,600	185,820	92,910	77,425	321,760	144,792	100,550
Lambasi	Qaukeni	Qaukeni	Ndengane	Rural	11,610	6,966	9,675	22,050	11,760	12,250	38,160	19,080	15,900	66,080	29,736	20,650
Lambasi	Qaukeni	Qaukeni	Cutwini	Rural	27,150	16,290	22,625	51,525	27,480	28,625	89,280	44,640	37,200	154,560	69,552	48,300
Lambasi	Qaukeni	Qaukeni	Ndindindi	Rural	73,320	43,992	61,100	139,185	74,232	77,325	241,020	120,510	100,425	417,440	187,848	130,450
Lambasi	Mbizana	Tsikelo	Ntlamvukazi	Rural	12,720	7,632	10,600	24,165	12,888	13,425	41,820	20,910	17,425	72,400	32,580	22,625
Pumlo	Qaukeni	Qaukeni	Bayi	Rural	30,060	18,036	25,050	57,060	30,432	31,700	98,820	49,410	41,175	171,120	77,004	53,475
Lower Ntafufu	Mbizana	Ntlenzi	Taleni	Rural	50,520	30,312	42,100	95,895	51,144	53,275	166,080	83,040	69,200	287,600	129,420	89,875
Lower Ntafufu	Qaukeni	Sipaqeni	Taleni	Rural	17,640	10,584	14,700	33,480	17,856	18,600	57,960	28,980	24,150	100,400	45,180	31,375
Lower Ntafufu	Port St Johns	Bomvini	Taleni	Rural	16,980	10,188	14,150	32,220	17,184	17,900	55,800	27,900	23,250	96,640	43,488	30,200
Lower Ntafufu	Port St Johns	Emtweni	Kwagingqi	Rural	10,500	6,300	8,750	19,935	10,632	11,075	34,500	17,250	14,375	59,760	26,892	18,675
Lower Ntafufu	Port St Johns	Ndluzula	Kwagingqi	Rural	33,030	19,818	27,525	62,685	33,432	34,825	108,600	54,300	45,250	188,080	84,636	58,775
Lower Ntafufu	Port St Johns	Bomvini	Lusubeni	Rural	4,830	2,898	4,025	9,180	4,896	5,100	15,900	7,950	6,625	27,520	12,384	8,600
Lower Ntafufu	Port St Johns	Ndluzula	Mbiza	Rural	20,970	12,582	17,475	39,825	21,240	22,125	68,940	34,470	28,725	119,360	53,712	37,300
Total					**391,230**	**234,738**	**326,025**	**742,680**	**396,096**	**412,600**	**1,286,160**	**643,080**	**535,900**	**2,227,200**	**1,002,240**	**696,000**

* Water demand per capita figures for 2000 were used for the 2001 calculations. Water demand figures are from DWAF (2001)

4.4 Agricultural, Stock Watering and Afforestation Requirements

The Department of Water Affairs and Forestry had initiated a study: Eastern Pondoland Basin Study that was finalized in 2001 by UWP Engineers. Relevant information and findings from that study regarding Lusikisiki Area are summarised below.

4.4.1 Agricultural Requirements

Most of the planned irrigation development in the region will be small, community based projects supported by the Department of Public Works. These projects generally vary in size from 1 ha to 25 ha, with the majority below 10 ha.

In general, irrigation is not anticipated to be feasible in the study area. The high mean annual precipitation (above 900 mm) allows high yielding dry-land agriculture. The area is deeply incised by the main river basins, and the potential irrigable land is normally located in the alluvial flood plains within the river valleys.

These valleys are usually not accessible by roads of satisfactory standards, which limits the access to potential markets. The development of irrigation on suitable areas on the plateau is severely restricted by the high pumping head requirements (100 to 300 m) and the associated costs for the water supply infrastructure.

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

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

The total area potentially suitable for irrigation **Figure 10**, based on the aforementioned criteria is estimated to be about 3 700 ha. Irrigation area is taken in full per quaternary, not only what is located in to the study area, because potential water source for irrigation will be supplied from the river. The irrigable land is distributed in small patches across the study area, largely adjacent to the major rivers. The existing and potential irrigation areas and the projected water requirements are shown in **Table 14** and **Table 15** respectively.

Table 14: Existing and Potential Irrigation Areas (ha)

Quaternary sub-catchment	Irrigation Potential	Existing Irrigation	Projected Irrigation Areas (ha)		
			2010	**2020**	**2030**
T60F	1745	1.5	76	115	148
T60G	444	0	7	13	17
T60H	0	0	0	0	0
T60J	906	0	17	29	39
T60K	605	7.5	23	30	37
TOTAL	**3700**	**9**	**123**	**187**	**241**

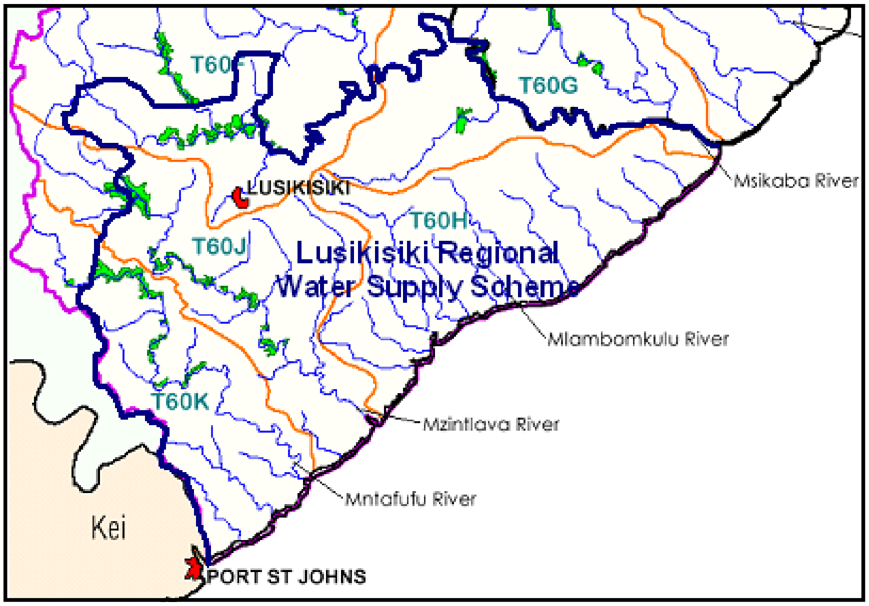


Figure 10: Potential Irrigable Land

Table 15: Estimated Irrigation Water Requirements (10^6 m^3/a)

Quaternary sub-catchment	Potential Demand	Projected Demand			
		2000	**2010**	**2020**	**2030**
T60F	3.270	0.003	0.139	0.210	0.270
T60G	0.490	0.000	0.008	0.013	0.019
T60H	0.000	0.000	0.000	0.000	0.000
T60J	1.102	0.000	0.019	0.032	0.045
T60K	0.776	0.006	0.025	0.035	0.044
TOTAL	**5.638**	**0.009**	**0.191**	**0.290**	**0.378**

4.4.2 Stock Watering Requirements

The available information regarding livestock numbers in the Eastern Pondoland Basin is very limited. An estimate of the livestock population in the region has been made on the basis of the "Revitalization of Agricultural Activities in the Transkei" report prepared by Kula and Nkonki Consortium (1996). The total number of livestock units was proportioned pro rata to the area of the quaternary catchments. An average stocking rate of 1.86 ha per LSU was utilised for the study area (**Table 16**). Livestock requirements of 40 litres per large stock unit per day were used for the determination of the water requirements. Since the region is already overstocked it was assumed that the livestock population and water requirements would remain constant over the projection period.

Table 16: Livestock Numbers and Water Requirements

Quaternary sub-catchment	Gross Area (km^2)	No. of LSU	Water demand (10^6 m^3 /a)
T60F	464	24 946	0.364
T60G	360	19 355	0.283
T60H	322	17 312	0.253
T60J	294	15 806	0.231
T60K	242	13 011	0.190
TOTAL	**1 682**	**90 430**	**1.321**

4.4.3 Afforestation Requirements

Afforestation is one of the fastest growing sectors of the economy in the study area.

The existing and projected afforestation water requirements (reduction of runoff) have been taken into consideration for the determination of the mean annual runoff for all relevant catchments. The existing and projected afforested areas as well as the associated reduction of run off per quaternary catchment are summarised in tables: **Table 17** and **Table 18**.

Table 17: Current and Projected Afforestation Areas (ha)

Quaternary sub-catchment	Afforestation areas (ha)			
	2000	**2010**	**2020**	**2030**
T60F	472	472	472	472
T60G	295	295	295	295
T60H	1 495	2 495	3 495	4 495
T60J	817	817	817	817
T60K	632	632	632	632
TOTAL	**3 711**	**4 711**	**5 711**	**6 711**

Table 18: Estimated Reduction of Runoff due to Afforestation (10^6 m^3/a)

Quaternary sub-catchment	Estimated water requirements (reduction of runoff)			
	2000	**2010**	**2020**	**2030**
T60F	0.58	0.58	0.58	0.58
T60G	0.49	0.49	0.49	0.49
T60H	2.81	4.50	6.40	8.21
T60J	1.27	1.27	1.27	1.27
T60K	0.96	0.96	0.96	0.96
TOTAL	**6.11**	**7.80**	**9.70**	**11.51**

4.4.4 Summary of Consumptive Water Requirements

The results of the estimates for the consumptive water requirements (domestic and industrial, irrigation, stock watering, afforestation) are summarised in **Table 19** and **Table 20** per quaternary catchment and per user sector respectively. For the purposes of modeling of the surface water hydrology, the contributing factors – return flows and groundwater supply have been subtracted. The Ecological Reserve requirements are not included as these are specific for each quaternary. The naturalised incremental MAR per quaternary catchment is provided for reference.

As seen from the **Table 19** the total consumptive water requirements for the study area are estimated to be 8.3 million m^3 for the year 2000 and 16.72 million m^3 for the year 2030. Taking into consideration the estimated contributions from return flows and the supply from groundwater, the total requirements from the surface water resources would be 8.16 million m^3 for the year 2000 and 14.035 million m^3 for the year 2030.

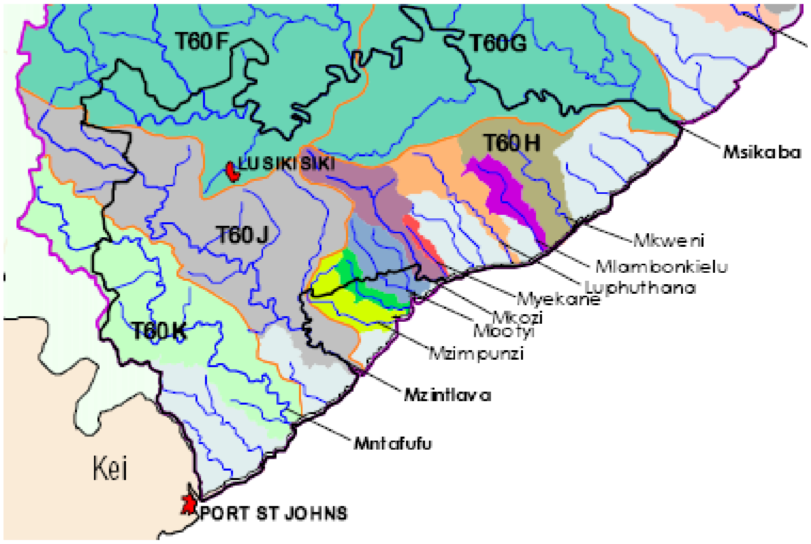


Figure 11: Quaternary Catchments in the Study Area

Table 19: Consumptive Surface Water Requirements per Quaternary

Quaternary sub-catchment	Projected Water Requirements (10^6 m^3/a)				Naturalised MAR
	2000	2010	2020	2030	
T60F	0.876	2.058	2.644	2.941	79.1
T60G	1.005	1.007	1.276	1.862	100.3
T60H	3.511	4.774	6.664	8.466	124.7
T60J	1.517	1.584	1.602	1.747	77.6
T60K	1.391	1.300	1.405	1.704	59.7
TOTAL	**8.300**	**10.723**	**13.591**	**16.720**	**441.4**

Table 20: Total Low Consumptive Water Requirements per User Sector

User Sector	Low Water Requirements (10^6 m^3/a)			
	2000	2010	2020	2030
Urban and rural domestic and industrial	0.86	1.42	2.28	3.52
Irrigation	0.009	0.191	0.290	0.378
Stock Watering	1.312	1.312	1.312	1.312
Afforestation	6.110	7.800	9.700	11.510
Total use	**8.300**	**10.723**	**13.591**	**16.720**
Return Flows	0.14	0.18	0.23	0.32
Groundwater supply	0.000	1.231	1.577	2.365
Total use from surface water	**8.16**	**9.312**	**11.784**	**14.035**

5. LUSIKISIKI REGIONAL WATER SUPPLY SCHEME (LRWS)

5.1 Historical overview and proposed development

The LRWS scheme was originally planned in 1978 as a regional scheme to utilize a dam on the Xura River. To date only phase 1 of the originally planned larger scheme has been implemented. This scheme was commissioned in July 1989 and currently supplies the town of Lusikisiki (about 11 000 people) and 23 villages (about 41 000 people). Lusikisiki town is provided with full water services – house connections and water borne sanitation. The level of services for the villages is limited to bulk supply to village reservoirs. The DWAF has identified projects to upgrade the existing scheme as a part of Community Water Supply and Sanitation Programme as follows:

- Phase 1: Provision of full standpipe services to the 23 villages already connected to the scheme, including the installation of reticulation systems and upgrading of the village storage capacities

  Upgrading of existing bulk supply infrastructure to meet the increased requirements associated with the higher service levels within the existing scheme

- Phase 2: An extension of the existing scheme to supply 34 additional villages (about 37 00 people) including the extension of the bulk supply network and the provision of additional village reservoirs and reticulation systems

- Phase 3: A further extension to supply 22 additional villages (about 31 000 people) is planned for implementation

To date only Phase 1 has been implemented. The other projects have been postponed due to the need for upgrading of the water source to meet the increased water requirements.

5.2 Water Source

The raw water is presently abstracted at the weir on the Xura River. The intake is located under the bridge on the main road between Lusikisiki and Flagstaff, about 7 km northwest from Lusikisiki. Previous studies indicated the following present capacities of the current water source:

Table 21: Estimated runoff at the existing Lusikisiki weir at Xura River

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

5.3 Bulk Water Supply Infrastructure

The design capacity of the bulk water supply infrastructure is 2 760 m^3/day. Raw water is abstracted from the Xura River at the intake that consists of a metal grid with a 500 mm dia. pipe and 300 mm valve. Water is conveyed by gravity to the pump station through a 300 mm dia. pipe. The pump station is located near the weir and consists of 3 centrifugal pumps. During site visit in May 2006 two pumps (combined capacity of 32l/s and design head of 60 m) were working and the third one which was supposed to be a stand-by pump was not operational. The water is pumped to the Water Treatment Works (WTW) through a 650 m long ND 200mm Asbestos Cement (AC) pipe. The existing water supply infrastructure is shown on **Figure 12**.

The WTW are located off the main road to Flagstaff. The treatment process comprises chemical dosing, flocculation, sedimentation, slow and rapid sand filtration and chlorination. The slow sand filtration system consists of three duty and one standby filter bays designed for a maximum head loss of 1.5 m and total duty capacity of 32 l/s. The slow sand filters are in a very bad condition and are clogging on a regular basis. Rapid sand filters were not operational during site visit in May 2006. Subsequently they were repaired and should be operational.

The clear water pump station within the WTW consists of two duty pumps and one stand-by pump, with a total design capacity of 32l/s and pumping head of 80m. The clear water is conveyed by 200m long 200mm diameter AC rising main to bulk storage reservoir A (1 300Kl). This reservoir than gravity feeds a further bulk reservoir C (1 100 Kl) and bulk reservoir B (1,200 Kl) with a booster pump station. Bulk reservoirs A, B and C feed 24 service reservoirs (between 20 and 90 Kl) that supply rural villages. From reservoir 9 water is provided to Mzintlavana Scheme at Port Saint Johns. Most of the pipelines are AC pipes. Existing network and reservoirs are in a poor condition and does not have sufficient capacity. All balls from air valves are removed and air valves blocked, which is creating inefficiency of the system. Full investigation is required to assess condition and capacity of existing systems.

A number of users, including the town, draw water directly from the bulk main between reservoirs A, B and C, although connecting pipelines have very limited capacity.

The level of services in the villages is below RDP standard. The villages are serviced by standpipes located near the service reservoirs

Cleaning of the reservoirs has to be carried out 2 times a month. Approximately 150mm of mud has to be removed from the reservoirs.

5.4 Current Status of the Scheme

At present the scheme is not able to meet the water requirements and water shortages are frequently being experienced. The low assurance of water supply provided by the system can be attributed to the reasons as follows:

- Insufficient capacity of existing water source at Xura River
- Inadequate capacity of existing infrastructure
- The poor condition of existing infrastructure
- Significant housing development in the area, which has increased the water use

5.5 Sources for Augmentation of LRWS

The issues related to potential sources of raw water for augmentation of the existing system are being discussed further in this report (**Sections 6 and 7**). Rehabilitation, improvement and extension of the existing infrastructure will be addressed by other projects.

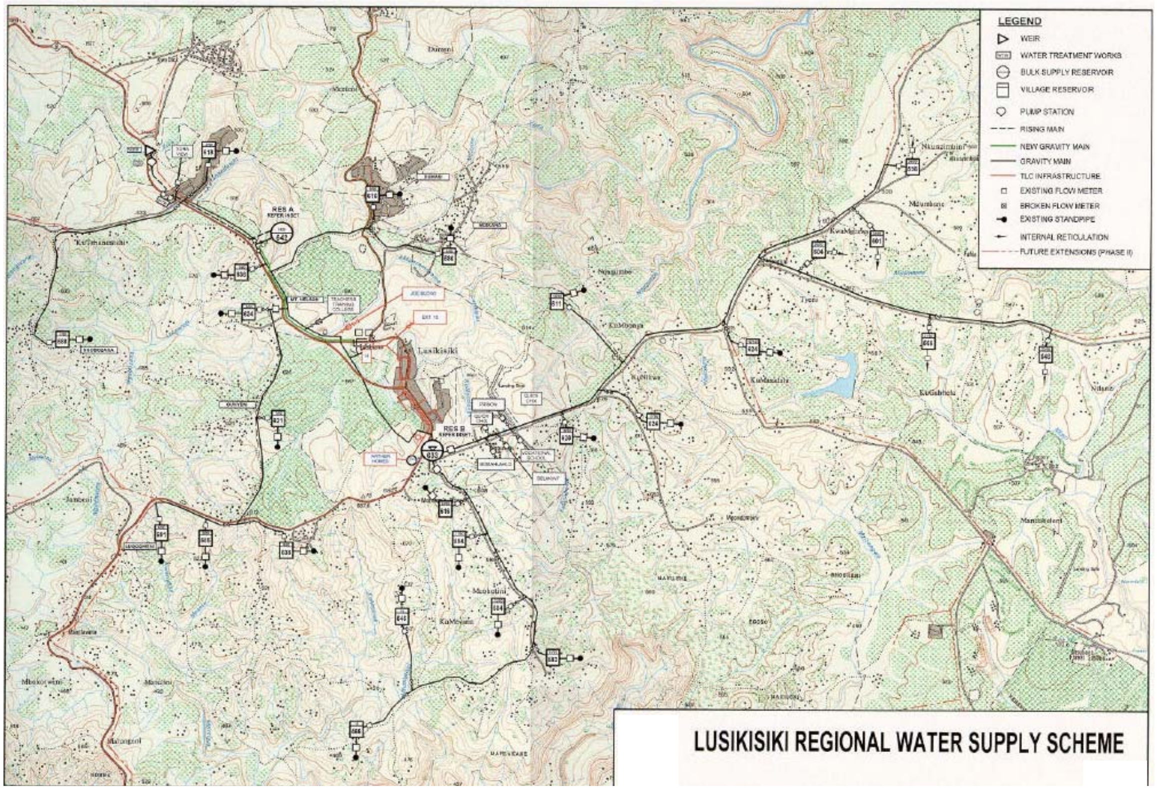


Figure 12: Lusikisiki Regional Water Supply Scheme – Existing Infrastructure

6. GROUNDWATER

6.1 Introduction to Groundwater Determination

SRK Consulting was appointed by the Department of Water Affairs and Forestry (DWAF) in December 2004 to investigate the groundwater potential as a supplementary water source for rural villages in the vicinity of Lusikisiki, Eastern Cape Province and the report **Lusikisiki Groundwater Feasibility Study, P WMA 12/00/00/0706** was compiled. Only the main findings will be summarized from that report.

The study area included the town of Lusikisiki, stretched southwards to Port St Johns and again coastward to Mkambati in the northeast. The north-western boundary was halfway between Lusikisiki and Flagstaff.

6.2 Methodology

The methodology included the following:

- **Desk study**: Information was collected from various data sources such as the NGDB and existing reports (work done previously in the area) and reviewed.
- **Hydrocensus:** The desk study was followed by a hydrocensus whereby field surveys were conducted and borehole and groundwater information collected.
- **Target selection:** The information from the desk study (which included the evaluation of work previously done in the project area) and the hydrocensus was then used in conjunction with further research such as lineament mapping to define targets for groundwater drilling.
- **Geophysical exploration:** With the use of geophysical instruments and field-geological mapping, the selected targets were then further investigated and drilling positions determined.
- **Drilling:** Boreholes were drilled on the selected targets by means of rotary air percussion drilling.
- **Borehole testing (pump testing):** The successful boreholes drilled (those that yielded water) were then pump tested to determine their sustainable yield and also their water quality.

The above information was then used to define the groundwater potential of the area which can further be described in terms of the groundwater exploration potential (GEP - refers to the ease of drilling a successful borehole) and the groundwater development potential (GDP - refers to the possibility of finding a sustainable groundwater source). The GEP focuses on the available structures and geological targets, while the latter also takes into account aspects such as recharge (calculated from rainfall and topography), more on GEP is in the **paragraph 6.3**.

The groundwater potential is then used to determine whether groundwater (boreholes) is suitable for use as sole water supply or in conjunction with other surface water schemes. The groundwater feasibility study is therefore considered a planning tool that can be used by engineers and municipalities to determine the best water source to use for water supply to communities. The feasibility study is therefore completed with a technical report that includes **conclusions** and **recommendations** pertaining to the findings (results) of the study.

6.3 Groundwater potential

As indicated in the set of groundwater potential maps (**Figure 13, Figure 14** and **Figure 15**) of this report, the groundwater potential of the LRWSS can be summarised as follows:

- o the Natal Group Sandstone (NGS) is considered to have the highest groundwater potential, but drilling should still be concentrated on dolerite dykes, faults and major lineaments. High yields in excess of 10 l/s can be expected where dykes are targeted, but lower yields (< 2 l/s) can also be encountered where only lineaments are drilled;
- o the Dwyka Formation is considered to have the second highest groundwater potential and again high borehole yields in excess of 5 l/s can be expected where dolerite dykes are targeted; and
- o the Ecca Group is considered to have the lowest groundwater potential and is also the most difficult to investigate because of the presence of dolerite sheets. The sheets spider-web the Ecca area and make groundwater exploration extremely difficult.

The NGS and the Dwyka Formation are therefore considered areas of high groundwater potential and can be targeted for future groundwater exploration projects.

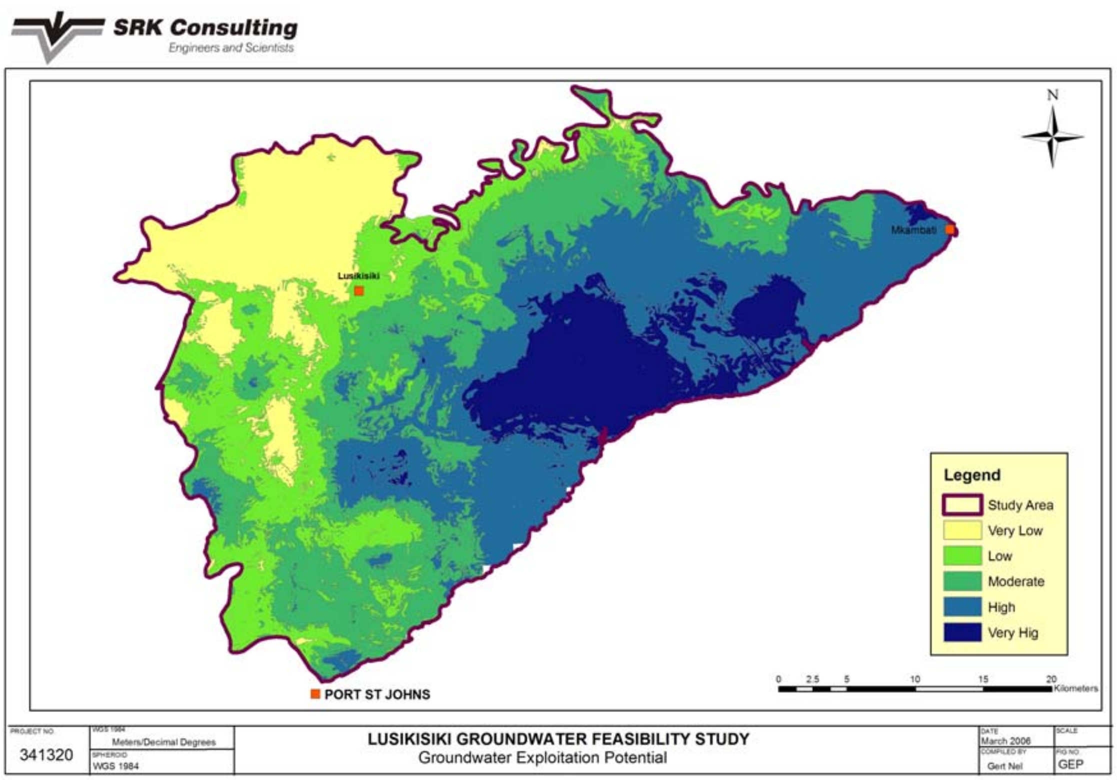


Figure 13: Groundwater Exploitation Potential

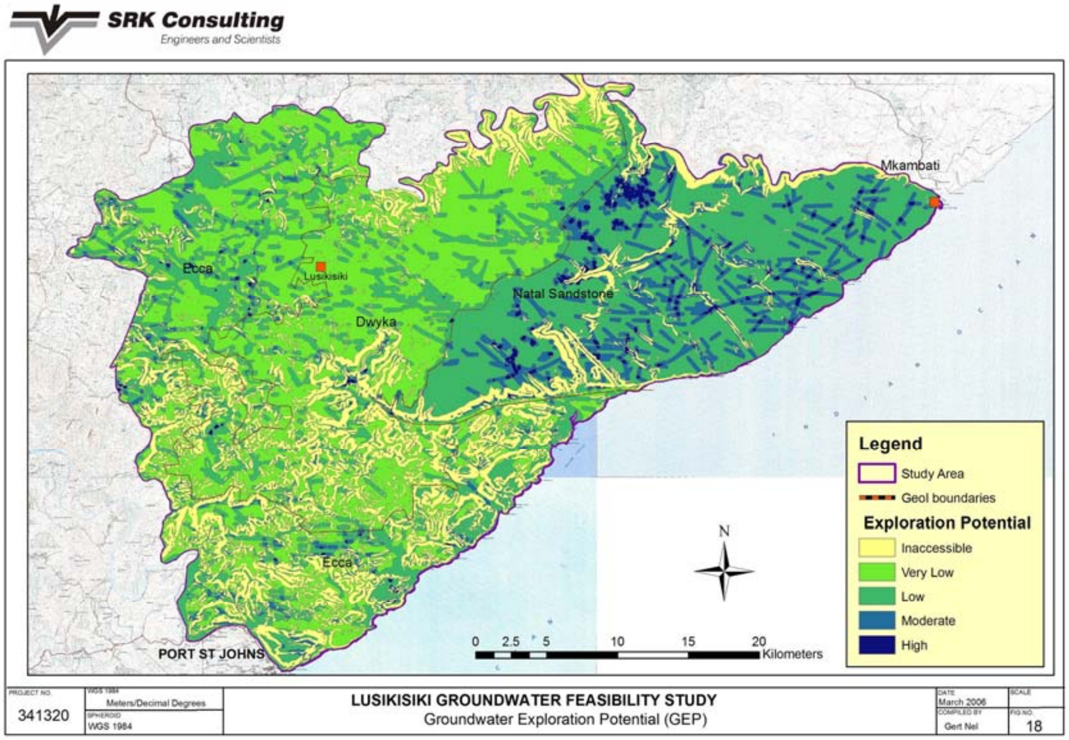


Figure 14: Groundwater Exploration Potential (GEP)

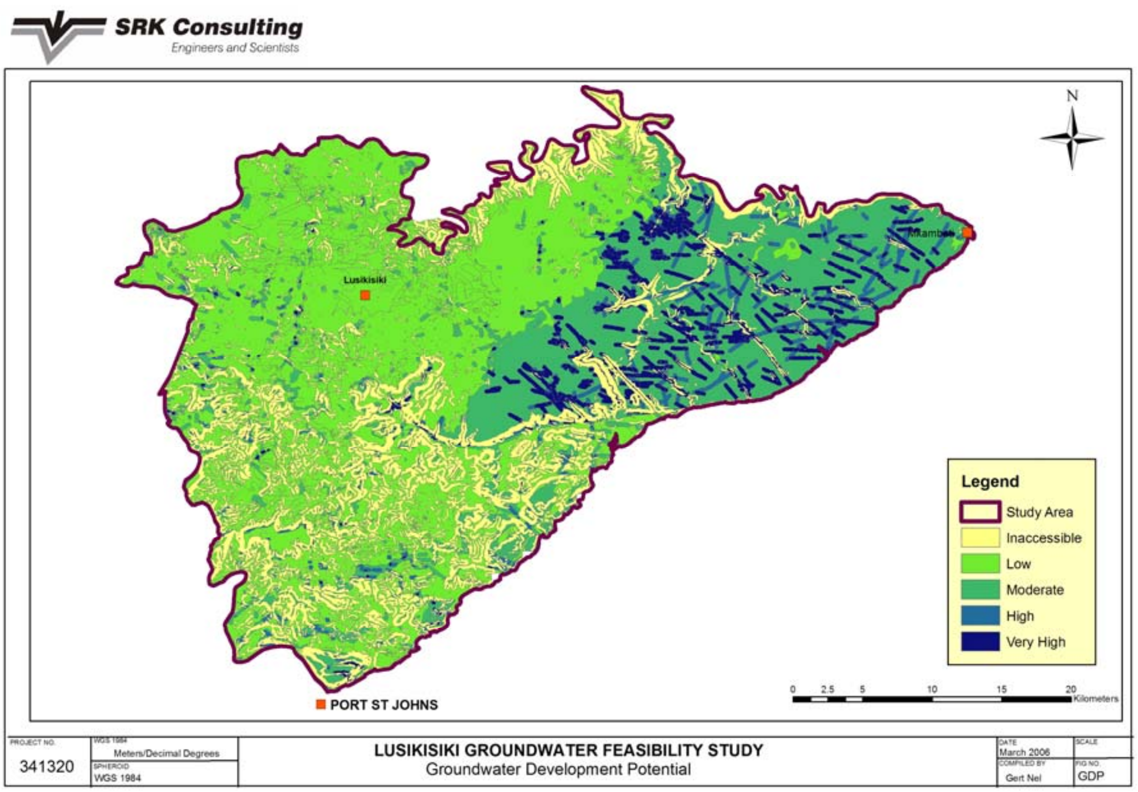


Figure 15: Groundwater Development Potential

6.4 Hydrocensus

6.4.1 Background

The Gateway Hydrocensus Forms were used in the hydrocensus. The information that was gathered included the following:

- borehole coordinates;
- existing equipment;
- borehole identification numbers;
- borehole use;
- current water source of community, including springs;
- borehole information (measured where possible) such as depth, water level, etc. and
- basic sanitation information.

6.4.2 Yield of existing boreholes

Figure 16 indicate the positions of the boreholes that were detected during the hydrocensus and their respective airlift yields indicated by classes. The yield information was obtained from the NGDB (where available).

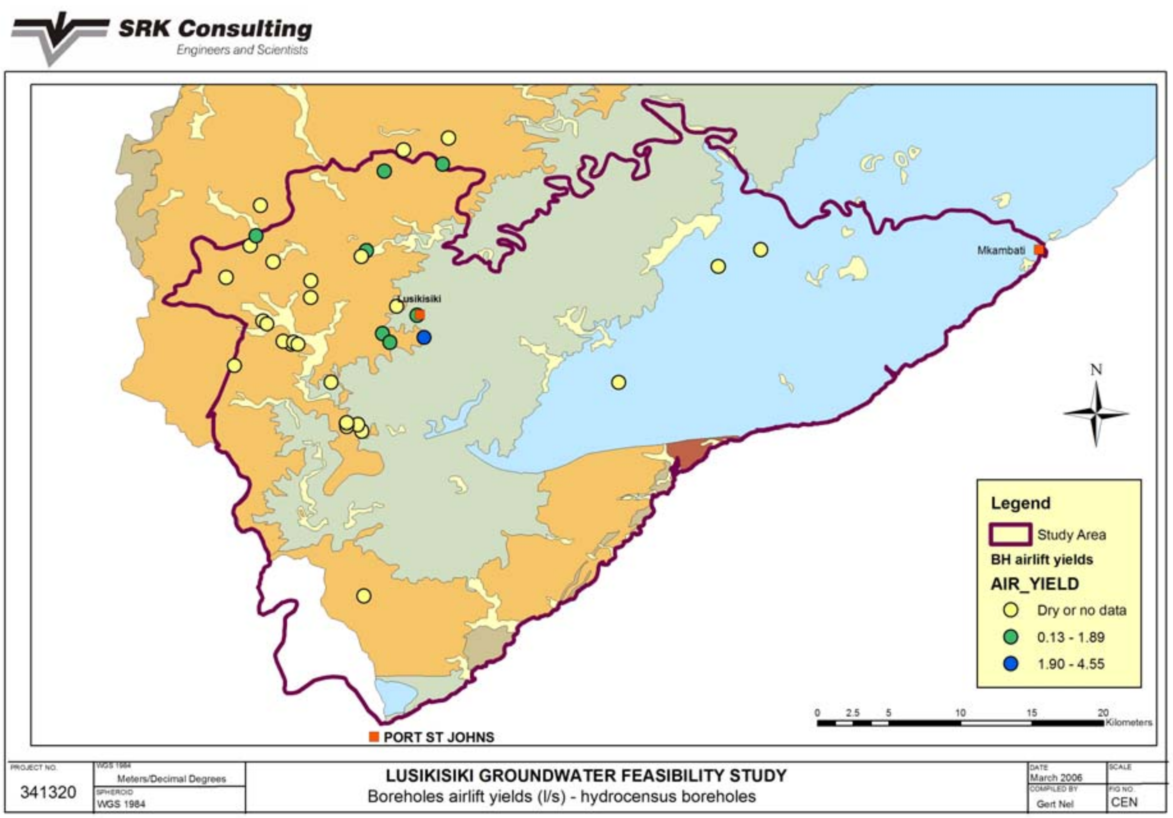


Figure 16: Distribution of the existing boreholes and their respective yields

6.4.3 Springs

During the hydrocensus the current water sources of the communities were also noted. They mostly consist of springs as indicated in **Figure 17**.

The springs were mostly seepages and from varying origin and no spring flow measurements could be taken. Electrical conductivity (EC) was however measured and values were all below 70 mS/m which classifies the water quality as Ideal.

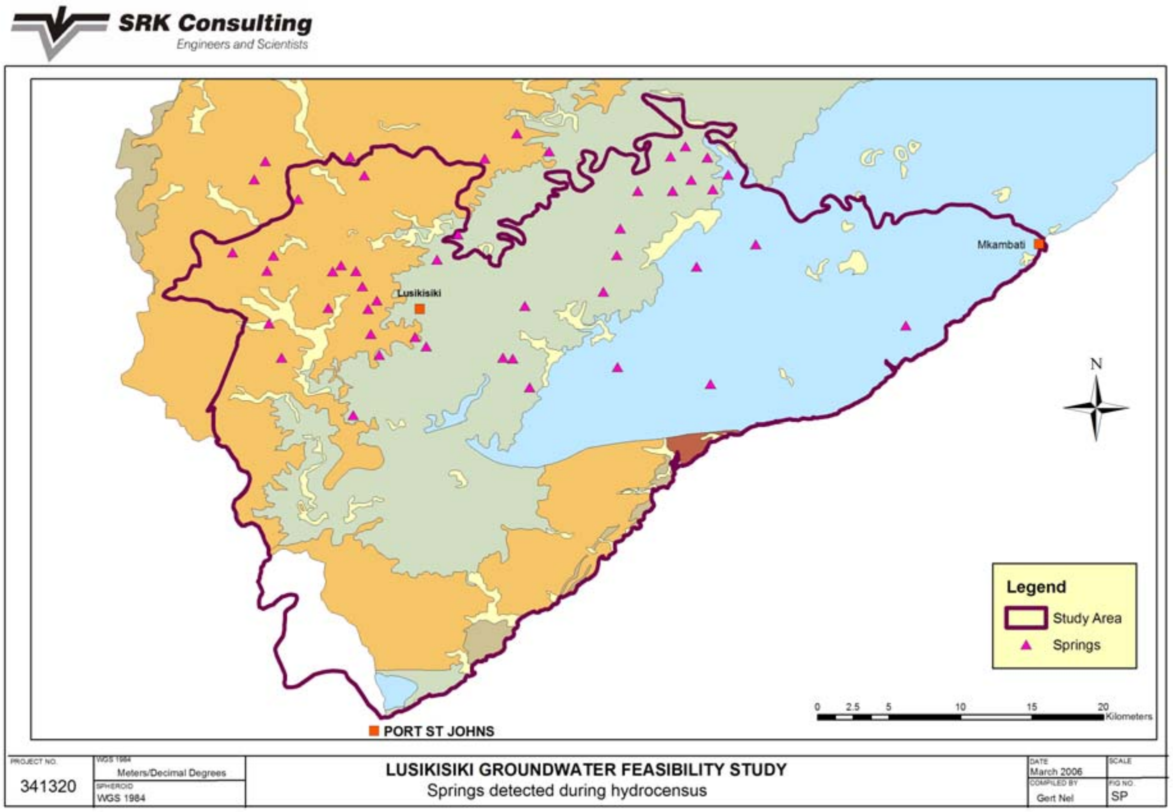


Figure 17: The positions of the springs that were visited during the hydrocensus

Although springs are still widely used by the communities as water supply sources, those communities that were interviewed do not consider the springs as sustainable water sources as they are mostly seasonal.

The springs are not protected and livestock get water from the same springs. In some cases, an effort was made by the community to isolate or protect the eye of the spring, but due to lack of proper construction and knowledge of spring protection measures, it failed.

6.4.4 Location of the villages that formed part of the hydrocensus

Approximately 90 villages were selected for the hydrocensus to include villages that fall within the areas earmarked for the feasibility drilling programme.

Figure 18 indicates the positions of the villages that formed part of the hydrocensus.

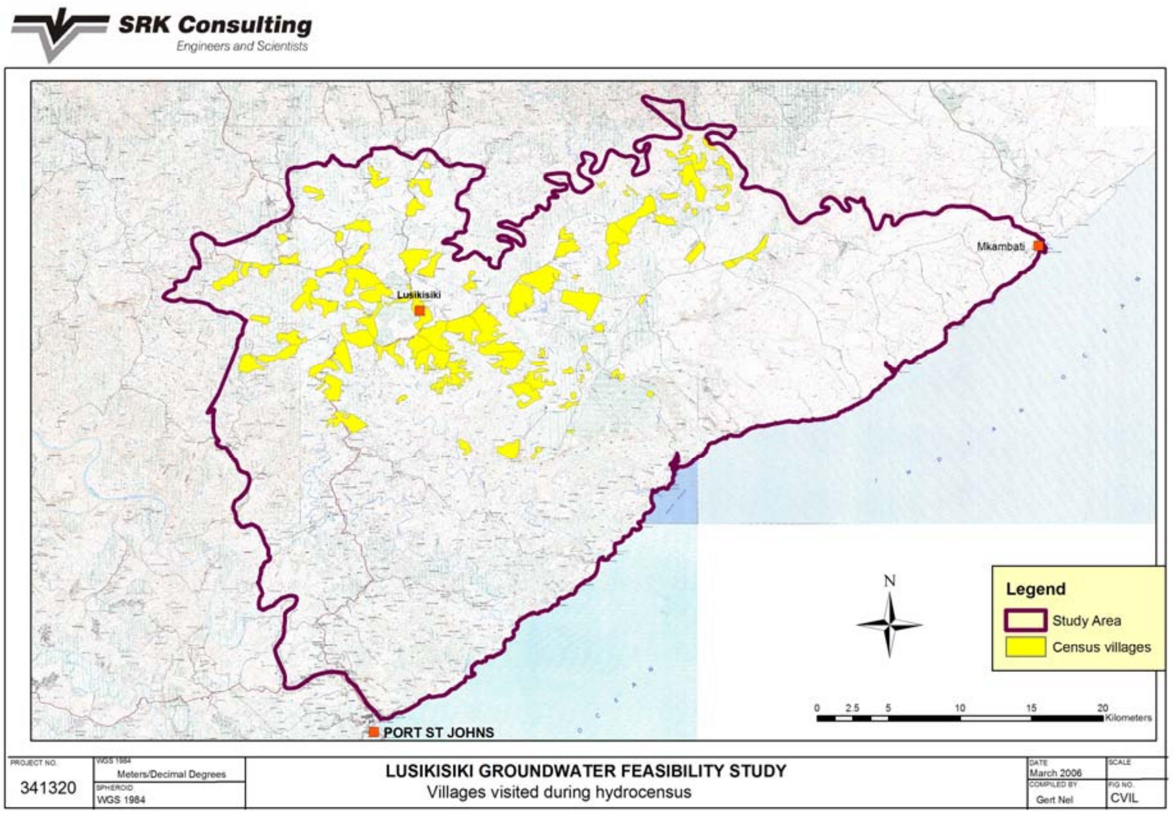


Figure 18: All the villages in the study area. The villages shaded in yellow were included in the hydrocensus

6.4.5 Correlation between NGDB, Desk Study and Hydrocensus

It was difficult to do a direct correlation between the NGDB data, other data bases (e.g. Aquabase), the hydrocensus and the desk study data because of duplications, inconsistent borehole reference numbers and different borehole coordinates. There are very few common references, such as a borehole number, to link the various databases. Where corresponding references such as village names were found, very few boreholes plotted within a radius of 100 m.

In the absence of maps or a GPS, many boreholes were plotted in the middle of the village or ward. Where maps were used, the copies of the maps are faint and the map reference or village name cannot be distinguished. In some cases, the coordinates of boreholes taken from the NGDB plotted up to 7 km away from the position as verified during the hydrocensus (using the T-numbers as reference).

In order to identify boreholes/drilling targets remote sensing, geophysical surveys, etc. were used.

6.5 Drilling and testing results

The geophysical exploration was followed by the drilling of the identified targets. The drilling focussed on a number of sites throughout the area to first establish the expected yields in each of the three geological areas, namely the Ecca Group, Dwyka and Natal Group Sandstone. **Table 22** lists the drilling and pump testing results and **Table 23** compares the drilling results with the different types of targets drilled. The borehole logs are attached in Appendix 3.

Table 22: Drilling and pump testing results

BH No	Latitude	Longitude	Airlift yield (l/s)	12-hr yield (l/s)	24-hr yield (l/s)	BH depth (m)	** Water Quality
EC/T60/051	31.30908000	29.75960000	22	4.6	3.2	110	M - Iron
EC/T60/052	31.30313000	29.75283000	2.75	1.26	0.89	100	M - Bacteria
EC/T60/053	31.34855000	29.70891000	11	1.24	0.87	146	M - Bacteria
EC/T60/054	31.39673000	29.66307000	85	10.5	7.5	100	Good
EC/T60/055	31.39117000	29.65699000	1.1	1.1	0.75	98	Good
EC/T60/056	31.35509000	29.61120000	0.1	Not tested		120	No sample
EC/T60/057	31.31655000	29.48660000	1.6	0.5	0.34	86	M - Iron & chloride
EC/T60/058	31.31135000	29.47263000	1.05	0.2	0.1	98	M - Iron
EC/T60/059	31.31152000	29.47281000	0.4	Not tested		70	U - Iron
EC/T60/060	31.35744000	29.53353000	0	Not tested		110	No sample
EC/T60/061	31.37449000	29.52324000	22	3.3	2.3	120	M - Chloride & Bacteria & Iron
EC/T60/062	31.37458000	29.52327000	5	Not tested		60	No sample
EC/T60/063	31.30420000	29.53667000	0	Not tested		128	No sample
EC/T60/064	31.33744000	29.59236000	2.2	0.84	0.6	86	U - Iron & Bacteria
EC/T60/065	31.42056000	29.54342000	0.1	Not tested		80	No sample
EC/T60/066	31.31145000	29.91935000	0	Not tested		80	No sample
EC/T60/067	31.31104000	29.91933000	0	Not tested		80	No sample
EC/T60/068	31.33211000	29.92446000	0	Not tested		80	No sample
EC/T60/069	31.34969000	29.50047000	0.85	0.2	0.13	80	P-Coliforms
EC/T60/070	31.34958000	29.50069000	0	Not tested		100	No sample
EC/T60/071	31.34960000	29.68408000	0	Not tested		35	No sample
EC/T60/072	31.38769000	29.65072000	5	2.1	1.5	150	U-Coliforms
EC/T60/073	31.39144000	29.65567000	0.3	Not tested		33	No sample
EC/T60/074	31.39164000	29.65579000	0.6	0.48	0.34	120	P - Bacteria
EC/T60/075	31.35328000	29.8214000	0.2	Not tested		74	No sample
EC/T60/076	31.35342000	29.82075000	1.0	0.57	0.4	80	U - Iron, Bac
EC/T60/077	31.31741000	29.77086000	0	Not tested		32	No sample
EC/T60/078	31.31758000	29.7708000	15	1.33	0.94	105	Good
EC/T60/079	31.33893000	29.92912000	0.3	Not Tested		80	No sample
EC/T60/080	31.33175000	29.95383000	2.5	0.72	0.51	80	M - Iron

*** P = Poor, M = Marginal, U = Unacceptable**

Table 23: List of the main types of targets and the drilling results

Feature	Details	Drilled (Yes / No) - Comments
DOLERITE: (ECCA, DWYKA, NGS)	Top contact of dolerite sheet / sill	Yes, no significant water strikes in Dwyka, Ecca. Not drilled in NGS
	Bottom contact of sheet / sill	Yes, no significant water strikes in Dwyka, Ecca. Not drilled in NGS.
	Inside sheet / sill	Yes, no significant water strikes
	Dyke contact	Yes, significant water strikes > 5 l/s in NGS, but not significant in Dwyka when dyke is thin. Thicker dykes yielded 5 l/s shallow strikes. Low yields also when dyke is situated in the Ecca.
	Inside dyke	Yes, but less water than next to dyke (2-3 l/s) - NGS. Low yields where dyke occurs in Dwyka (< 1 l/s)
LINEAMENTS	East west trending lineaments	Yes, significant strikes in Dwyka; none in NGS
	South east trending lineaments	Yes, no strikes in NGS (not drilled in Ecca / Dwyka)
	East north east trending lineaments	Yes, no strikes in NGS (not drilled in Ecca / Dwyka)
FRACTURING/ WEATHERING	In Dwyka	Yes, significant strike where associated with EW lineament
	In thick dolerite sheets	Not targeted, will require resistivity work
	Associated with Dykes (near dykes)	Yes, high yields of up to 85 l/s in NGS in fracturing within 2-20 m from regional dykes.
GEOLOGICAL CONTACTS	Between Ecca / Dwyka	Yes, no significant strikes
	Between Dwyka / NGS	Yes, significant strike but little fracturing. Strikes de-watered.

Notes:
- Significant yields are considered **> 1.5 l/s airlift yield** for the purpose of the above table.
- Lineaments not extensively drilled where they occurred on their own. Those drilled near Mkambati were dry.

6.6 Evaluation of the pump testing results

The evaluation includes a comparison between airlift yield and the calculated 24-hr yield, discussions on the water quality and calculations of the aquifer parameters. Each of the three geological units (Ecca, Dwyka and Natal Group Sandstone) that are found in the project area is discussed individually.

6.6.1 Natal Group Sandstone (NGS)

Table 24 lists the boreholes that were drilled in the Natal Group Sandstone. Two of the boreholes will be discussed, namely borehole EC/T60/054 which was drilled next to a dolerite dyke and borehole EC/T60/080 which targeted a lineament in an area with no dolerite.

Table 24: Boreholes situated in the NGS

BH No	Latitude	Longitude	**Water strike**(m) **and Strike Yield** (l/s)	Airlift yield l/s)	24hr yield (l/s)	BH depth (m)	Water Quality*
EC/T60/051	31.30908000	29.75960000	29(0.34), 57(0.36), 62(1.3), 67(5), 73(3), 96(7)	22	3.41	110	M - Iron
EC/T60/052	31.30313000	29.75283000	17(0.8), 33(0.5), 35(0.5), 38(0.95)	2.75	0.89	100	M - Bacteria
EC/T60/054	31.39673000	29.66307000	26(1.8), 30(0.95), 36(1.65), 84(6.6), 88(74)	85	7.5	100	G
EC/T60/055	31.39117000	29.65699000	52(0.2), 77(0.4), 88(0.5)	1.1	0.72	98	G
EC/T60/066	31.31145000	29.91935000	Dry	0		80	Not tested
EC/T60/067	31.31104000	29.91933000	Dry	0		80	Not tested
EC/T60/068	31.33211000	29.92446000	Dry	0		80	Not tested
EC/T60/075	31.35328000	29.82140000	29(0.2)	0.2		74	Not tested
EC/T60/077	31.31741000	29.77086000	Dry	0		32	Not tested
EC/T60/078	31.31758000	29.7708000	1.33	15	0.94	105	Good
EC/T60/079	31.33893000	29.92912000	43(0.3)	0.3		80	Not tested
EC/T60/080	31.33175000	29.95383000	20(0.1), 42(0.3), 55(1.4)	2.5	0.51	80	M-Iron

Note: M = Marginal; P = Poor; U = Unacceptable

The following statistics can be derived from the testing data:

- ratio of airlift yield to recommended 24-hr yield: 15 - 65%
- average (airlift yield to 24-hr recommendation): 28%
- percentage recovery after testing: (majority = 90% +) 54 - 98%
- highest airlift yield 85 l/s
- lowest airlift yield 0 l/s

The percentage recovery figures can however be misleading as they are dependent on the drawdown that was achieved during the constant discharge test. For example if a borehole recovered to within 4 m of the starting water level after a drawdown of 8 m was achieved, the percentage recovery is only 50 %, while the recovery could measure as 80 % on a borehole where the drawdown was 40 m and the recovery was back to 8 m.

Borehole EC/T60/054 (dyke in NGS)

The highest yielding borehole drilled in the Natal Group Sandstone was EC/T60/054 which measured 85 l/s airlift yield and 7-8 l/s sustainable yield (24-hr pumping). The constant discharge test (CD test) was done at a yield of 25 l/s for a period of 72 hrs. The flow was measured with a calibrated U-Notch as shown in Figure 29a.

A steady drawdown was achieved during the constant discharge test and the percentage recovery as measured equal to the pumping time (72 hours) was 45 % at the time, but when visited in February 2006, it was again flowing artesian. The aquifer parameters as derived from the FC Method are presented below.

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	**Basic FC**	7.84	4.23	32		15.7		2.20E-03	68.2
☐	**Advanced FC**			32		15.7		1.00E-03	68.2
☑	**FC inflection point**	6.74	3.70						66.3
☑	**Cooper-Jacob**	7.17	4.64			15.8		3.01E-03	68.2
☐	**FC Non-Linear**								68.2
☑	**Barker**	7.73	4.09	K_f =	79		S_s =	6.20E-04	68.2
	Average Q_sust (l/s)	**7.37**	**0.52**	b =	0.20	Fractal dimension n =		2.00	

Recommended abstraction rate (L/s)	**7.50**	for 24 hours per day
Hours per day of pumping	12	10.61 L/s for 12 hours per day
Amount of water allowed to be abstracted per month	19440	m^3
Borehole could satisfy the basic human need of	25920	persons
Is the water suitable for domestic use (Yes/No)		

During the pump test of borehole EC/T60/054, borehole EC/T60/055 was used as observation borehole to determine whether the pumping of 054 would have any effect on 055, which at the time was also flowing artesian. Throughout the 72 hours of pumping, no effect was observed on borehole 055 and the flow remained artesian and at a steady rate of approximately 1 l/s.

This led to the conclusion that borehole EC/T60/054 sources its water within the confines of the contact zone between the sandstone and the dolerite dyke and very little water (if anything) was drawn from the sandstone host rock adjacent (>20 m) to the dyke. As the dyke is considered near-impermeable, very little recharge (if any) occurred along the south-western side (contact) of the dyke. The contact zone is considered to be of thickness 5 - 20 m on either side of the dyke and is defined as the zone where the intrusion of the dyke had a direct or indirect effect (heating, cooling, pressure fracturing, etc.) on the quartzitic sandstone host rock. The slow recharge is further proof of the long lateral distance along the north-eastern side of the dyke where the borehole must source water to replace the water that was abstracted. The majority of recharge is therefore not emanating from the adjacent host rock, but mostly along the dyke and the hydraulic water pressure along the contact zone needs to restore itself before the water level rises.

The water quality tested good and although reddish deposits are prominent around the top of the casing of the borehole, it can be ascribed to the low Ph of the water (pH = 6.16) which reacts with the upper steel casing that had to be placed around the inner PVC casing for maximum protection.

Borehole EC/T60/080 (borehole in lineament / fracturing in NGS - near Mkambati)

This borehole was drilled near Mkambati on a north-west south-east striking lineament. The last recorded water strike was at 55 m (1.4 l/s), but the yield increased as drilling progressed to 80 m. The final airlift yield was measured as 2.5 l/s. The Constant Discharge Test (CD test) was done at a yield of 1.3 l/s for a planned period of 24 hrs, but the water level in the borehole reached pump intake after 12 hrs and the test was ended and recovery measurements taken.

The early- T calculated at 2.8 m^2/day and Late-T 1.8 m^2/day.

The water quality tested Marginal with the Iron concentration being 1.17 mg/l. The initial water sample that was taken during the pump test suggested an unacceptable Total Coliform count, but a re-sample with a mobile, sterile sampling unit indicated that there is no significant bacteriological contamination. The initial bacteriological contamination therefore originated from the pumping equipment which was probably not properly disinfected before the test.

6.6.2 Dwyka Formation

Table 25 indicates the boreholes drilled in the Dwyka Formation.

Table 25: Boreholes drilled in the Dwyka Formation

BH No	Latitude	Longitude	**Water strike**(m) **and Strike Yield** (l/s) in brackets	Airlift yield (l/s)	24hr yield (l/s)	BH depth (m)	Water Quality*
EC/T60/053	31.34855000	29.70891000	24(3.14), 32(1.26),71(1.1),95(1.8), 126(3.7)	11	0.87	146	M - Bacteria
EC/T60/055	31.39117000	29.65699000	52(0.2), 77(0.4), 88(0.5)	1.1	0.75	98	Good
EC/T60/056	31.35509000	29.61120000		0.1	Not tested	120	
EC/T60/061	31.37449000	29.52324000	22(22)	22	2.3	120	M - Chloride & Bacteria & Iron
EC/T60/062	31.37458000	29.52327000		5	Not tested	60	
EC/T60/064	31.33744000	29.59236000	23(2.2)	2.2	0.6	86	U - Iron & Bacteria
EC/T60/065	31.42056000	29.54342000		0.1	Not tested	80	
EC/T60/072	31.38769000	29.65072000	17(5)	5	1.5	150	U-Coliforms
EC/T60/073	31.39144000	29.65567000		0.3	Not tested	33	
EC/T60/074	31.39164000	29.65579000	120(0.6)	0.6	0.34	120	P - Bacteria

***Note:** M = Marginal; P = Poor; U = Unacceptable

The following statistics can be derived from the testing data:

- range of airlift yield to recommended 24-hr yield: 6.4 - 68%
- average (airlift yield to 24-hr recommendation): 33%
- percentage recovery after testing: 47 - 98% (average = 83%)
- highest airlift yield 22 l/s
- lowest airlift yield 0.1 l/s

Borehole EC/T60/053

This borehole was drilled through the Dwyka, into the NGS, producing water strikes in the Dwyka, NGS and on the contact between the two.

The airlift yield was 11 l/s and the CD test was conducted at a rate of 4 l/s for a planned 48 hrs, but the yield drastically decreased after 1080 min (18 hrs) and the test was eventually stopped after 1800 min (30 hrs) and recovery taken. After 24 hrs of recovery the water level was still 16 m from the original static water level when the CD test was started, suggesting a 75% recovery.

Even though water strikes were recorded up to 126 mbgl, it seems from the water level drawdown graph shown in **Figure 19** that all the strikes dewatered, except for the strike at ~ 24 mbgl. Available drawdown was taken as 20 m for the purpose of the sustainable yield calculations. The 24-hr yield calculated at a disappointing 0.7 l/s if compared to the original airlift yield of 11 l/s. Early- T was calculated at 7.3 m^2/day and Late-T 0.7 m^2/day. The water quality can be classed as Marginal with slightly elevated levels of bacteria.

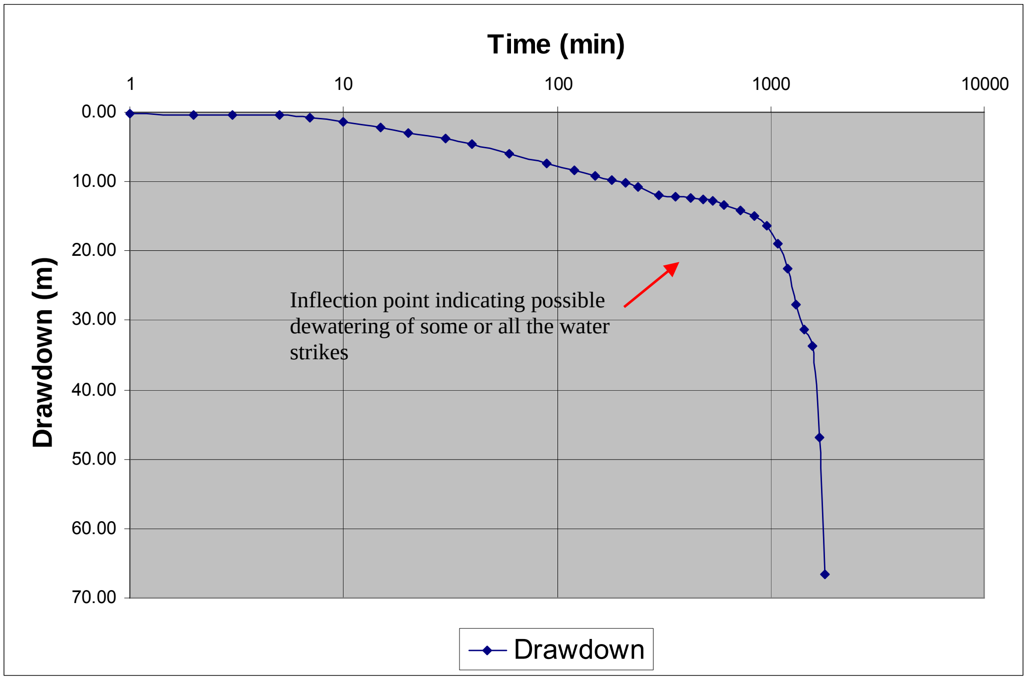


Figure 19: Graphical presentation of the time versus water level drawdown curve during the CD test of borehole EC/T60/053

Borehole EC/T60/061

This borehole as being situated on the Ecca Group at a distance of approximately 2.5 km from the geological contact with the Dwyka and if a dip of 2% is considered, the Dwyka Formation's diamictite should have been intersected at a depth of approximate 50-60m. The drilling logs however confirmed that Dwyka Formation was drilled from the start and no Ecca sediments were encountered. Water was struck at 22 mbgl (22 l/s) and no further water strikes were encountered up to the drilling depth of 120m.

The borehole was yield tested at a constant yield of 7 l/s for a period of 48 hrs. Drawdown was 9.8 m and the borehole recovered to 5 m after 48 hrs which suggests a percentage recovery of only 47%, but it can be misleading as the drawdown was insignificant. If for example, the CD yield was chosen higher and more drawdown was achieved (even resulting in rapid water level drawdown), the recovery percentage would have been higher. Because of the relative poor recovery, the recommended yield calculated 2.3 l/s which might be conservative if the performance of the borehole during the CD test is concerned.

The borehole was drilled along a northeast - southwest lineament which might be a fault if the upwards movement of the Dwyka is considered. The borehole probably sourced its water from the lineament and from weathering in the upper 20 m of the diamictite (confirmed by the drilling logs). The slow recovery is indicative of a low hydraulic water pressure arising from non-confined conditions in the upper 20m.

Early- T was calculated as 50 m^2/day and Late-T 21 m^2/day. Insufficient drawdown to calculate the Late-T value was achieved as the water level reached steady state around 9 mbgl at CD yield of 7 l/s. The water quality can be classed as Marginal with elevated levels of Chloride and Iron.

6.6.3 Ecca

Although the airlift yields were relatively low compared to the Natal Group Sandstone and the Dwyka Formation, the water levels of the tested boreholes recovered well. Transmissivity values were however low which resulted in low recommended yields, despite the good recoveries. Water strikes were relatively shallow and no high yielding boreholes were drilled. On average, Early-T values are in the order of 1.8 m2/day and Late-T = 0.3 m2/day.

The water quality of the boreholes drilled in the Ecca is generally of marginal water quality and can produce unpleasant odours which will aesthetically not be acceptable to the communities unless treated. **Table 26** lists the boreholes drilled in the Ecca.

Table 26: Boreholes drilled in the Ecca Group

BH No	Latitude	Longitude	**Water strike**(m**) and Strike Yield** (l/s) in brackets	Airlift yield l/s)	24hr yield (l/s)	BH depth (m)	Water Quality*
EC/T60/057	31.31655000	29.48660000	29(1.6)	1.6	0.34	86	M - Iron, Chloride
EC/T60/058	31.31135000	29.47263000	20(0.2), 36(0.85)	1.05	0.1	98	M-Iron
EC/T60/059	31.31152000	29.47281000	14(0.4)	0.4	Not tested	70	U-Iron
EC/T60/060	31.35744000	29.53353000	No water strikes	0	0	11	Not tested
EC/T60/063	31.30420000	29.53667000	No water strikes	0	0	128	Not tested
EC/T60/069	31.34969000	29.50047000	35(0.1), 46(0.75)	0.85	0.13	80	P-Coliforms
EC/T60/070	31.34958000	29.50069000	No water strikes	0	0	100	Not tested
EC/T60/071	31.34960000	29.68408000	No water strikes	0	0	35	Not tested

Note: M = Marginal; P = Poor; U = Unacceptable

The following statistics can be derived from the testing data:

- range of airlift yield to recommended 24-hr yield: 9 - 21%
- average (airlift yield to 24-hr recommendation): 15%
- percentage recovery after testing: 92 - 99% (average = 96%)

- highest airlift yield 1.6 l/s
- lowest airlift yield 0 l/s
- average water quality Marginal

6.7 Production boreholes

Table 27 lists the production boreholes that resulted from the feasibility study and that can be utilised as part of the existing water supply scheme or for future water supply purposes.

Where the water quality of a production borehole tested acceptable (i.e. the water quality tested Ideal or Good), the borehole can be used as a stand-alone source. Where the water quality however tested Marginal or worse, it can be used in conjunction with surface water as the surface water will dilute the groundwater and eventually the water will be treated. Boreholes containing water quality classed as Marginal can also be used as stand-alone sources, but their water qualities should be closely monitored for changes and communities should be informed of potential health risks if the water is used long term.

Distinction is therefore made between those boreholes that have potable water quality (Ideal to Marginal) and those that require treatment prior to use. Only boreholes that yielded more than 0.5 l/s (12-hr recommended pumping cycle) have been considered as production boreholes for the purpose of this assessment.

Table 27: Production boreholes

BH No	Latitude	Longitude	Airlift yield (l/s)	12-hr yield (l/s)	24-hr yield (l/s)	** Water Quality
EC/T60/051	31.30908000	29.75960000	22	4.6	3.2	M - Iron
EC/T60/052	31.30313000	29.75283000	2.75	1.26	0.89	M - Bacteria
EC/T60/053	31.34855000	29.70891000	11	1.24	0.87	M - Bacteria
EC/T60/054	31.39673000	29.66307000	85	10.5	7.5	Good
EC/T60/055	31.39117000	29.65699000	1.1	1.1	0.75	Good
EC/T60/057	31.31655000	29.48660000	1.6	0.5	0.34	M - Iron & chloride
EC/T60/061	31.37449000	29.52324000	22	3.3	2.3	M - Chloride & Bacteria & Iron
EC/T60/064	31.33744000	29.59236000	2.2	0.84	0.6	U - Iron & Bacteria
EC/T60/072	31.38769000	29.65072000	5	2.1	1.5	U-Coliforms
EC/T60/076	31.35342000	29.82075000	1.0	0.57	0.4	U - Iron, Bac
EC/T60/078	31.31758000	29.7708000	15	1.33	0.94	Good
EC/T60/080	31.33175000	29.95383000	2.5	0.72	0.51	M - Iron

*** P = Poor, M = Marginal, U = Unacceptable,**

Groundwater Potential

The groundwater potential has been estimated and projected in broad terms for each quaternary catchment and presented in the **Table No. 28.**

Table 28: Total Estimated Usage of Groundwater

Quaternary sub-catchment	Projected Groundwater Usage (10^6 m^3/a)			
	2000	**2010**	**2020**	**2030**
T60F	0.000	0.000	0.000	0.000
T60G	0.000	0.000	0.000	0.000
T60H	0.000	1.231	1.573	2.354
T60J	0.000	0.000	0.004	0.011
T60K	0.000	0.000	0.000	0.000
TOTAL	**0.000**	**1.231**	**1.577**	**2.365**

Exploitation of the boreholes that were drilled as a part of Groundwater Feasibility Study Phase 1

Table 29 indicates a list of drilled boreholes that can be utilised to supplement the Lusikisiki Existing Supply Scheme to increase assurance of supply. Identified well fields can be summarized to boreholes EC/T60/072, EC/T60/054 and EC/T60/055 to be connected to the Reservoir B and supplement Lusikisiki area and existing network which supplies villages Kwabhumbuta, Mateku, Mataku, Silahia and Mpolweni. Utilising drilled boreholes EC/T60/051, EC/T60/052 and EC/T60/078 the existing network can be extended to provide water for villages Mawotsheni, Njobela and Mjelweni.

Where potential targets are indicated near boreholes that have been drilled as part of the Lusikisiki study, they suggest extensions of the existing boreholes to be developed as part of borehole well fields.

Table 29: Boreholes that can be utilised to supplement the Lusikisiki Existing Supply Scheme

BH No	**Latitude**	**Longitude**	**Airlift yield** (l/s)	**12-hr yield** (l/s)	**24-hr yield** (l/s)	**** Water Quality**
EC/T60/051	31.30908000	29.75960000	22	4.6	3.2	M - Iron
EC/T60/052	31.30313000	29.75283000	2.75	1.26	0.89	M - Bacteria
EC/T60/054	31.39673000	29.66307000	85	10.5	7.5	Good
EC/T60/055	31.39117000	29.65699000	1.1	1.1	0.75	Good
EC/T60/072	31.38769000	29.65072000	5	2.1	1.5	U-Coliforms
EC/T60/078	31.31758000	29.7708000	15	1.33	0.94	Good

* **P = Poor, M = Marginal, U = Unacceptable**

Groundwater targets for further drilling

The assessment of the potential targets for future drilling are done on the basis of establishing moderate to high yielding boreholes that can be used as part of a comprehensive water supply scheme and not as part of individual village water supply.

Based on the results of the Lusikisiki Groundwater Feasibility Study, the following target areas are considered the most significant:

- **Dolerite dykes** occurring in the **Natal Group Sandstone (NGS)**, Dwyka and to a lesser extend, the Ecca can be targeted for drilling. The dykes in the Ecca are included as they still have potential, but are difficult to locate and have not extensively been explored as part of the Lusikisiki study. The dykes in the Natal Group Sandstone, especially where they occur inside a fault or extend from a fault, are considered the most promising targets and can be successfully targeted with relatively simple geophysical and field mapping techniques. The physical properties (e.g. thickness) of the dykes in the Dwyka are harder to determine since the Dwyka rock is not so susceptible to fracturing and weathering than the Natal Group Sandstone. The dykes in the Dwyka can produce high yields, but not as high as the NGS. The regional dykes in the Ecca, i.e. those extending from the NGS and the Dwyka, theoretically must produce good yields, but because they are surrounded by dolerite sheets, their exact positions and width are almost impossible to determine. The borehole yields do however seem to increase towards the NGS and the higher rainfall and recharge in the Dwyka and NGS areas can contribute to this scenario (See **Figure 14**: Groundwater Exploitation Potential Map).
- **Lineaments** proved successful in the Dwyka and to a lesser extent the NGS. Mixed results were achieved in the NGS, but drilling on the East - West orientated lineaments proved successful. Not all the different orientations were however drilled and no conclusive statement can be made in this regard.
- The **Faults** that occur mainly in the NGS and Dwyka can be targeted with success, especially where they have been intruded by dykes. The major faults are however very difficult to gain access to and extensive access road construction will have to be done in order to drill them where they occur inside well-developed drainage systems.

Based on the results of the investigation, the following targets did not yield any significant results:

- **Dolerite sheets** (shallow dipping to horizontal) in the **Ecca.** The few dolerite sheets that occur in the Dwyka were not drilled and no conclusion can hence be made on their groundwater potential where they occur in the Dwyka.
- **Small-scale lineaments** in the NGS.

The potential of deep-drilling through the Dwyka into the Natal Group Sandstone was not fully tested in the Lusikisiki study and still is considered a viable option to locate good quality, artesian boreholes. Some of the boreholes that were drilled as part the Lusikisiki study did penetrate the Dwyka into the NGS at shallow depth (~ 70 m) and although the water strikes on the Dwyka / NGS contact did not yield spectacular results, water was found on one of the boreholes. Based on the above criteria, potential target areas have been selected and are shown on **Figure 20**.

The targets as shown on **Figure 20** have been selected from a desk study point of view and have not been investigated. The positions as indicated are merely to show the targets in relation to the geological units and the groundwater development potential. The targets would have to be subjected to full geohydrological and geophysical investigations before they can be drilled. Some of the areas that are indicated might be problematic to gain access to and access roads or tracks might have to be constructed. Where potential targets are indicated near boreholes that have been drilled as part of the Lusikisiki study, they suggest extensions of the existing boreholes to be developed as part of borehole well fields. Depending on the water demand and specific areas where more water is needed, these targets could be extrapolated to the areas in demand if the same or similar structures occur.

The selected targets must also be seen in context with the Groundwater Development Potential Map and the Groundwater Exploitation Potential Map where the targets that plot within the High and Very High zones are more likely to produce good, sustainable yields. In the event that drilling is required to take place in the lower potential zones (e.g. Ecca), the targets still reflect the best options for that specific area.

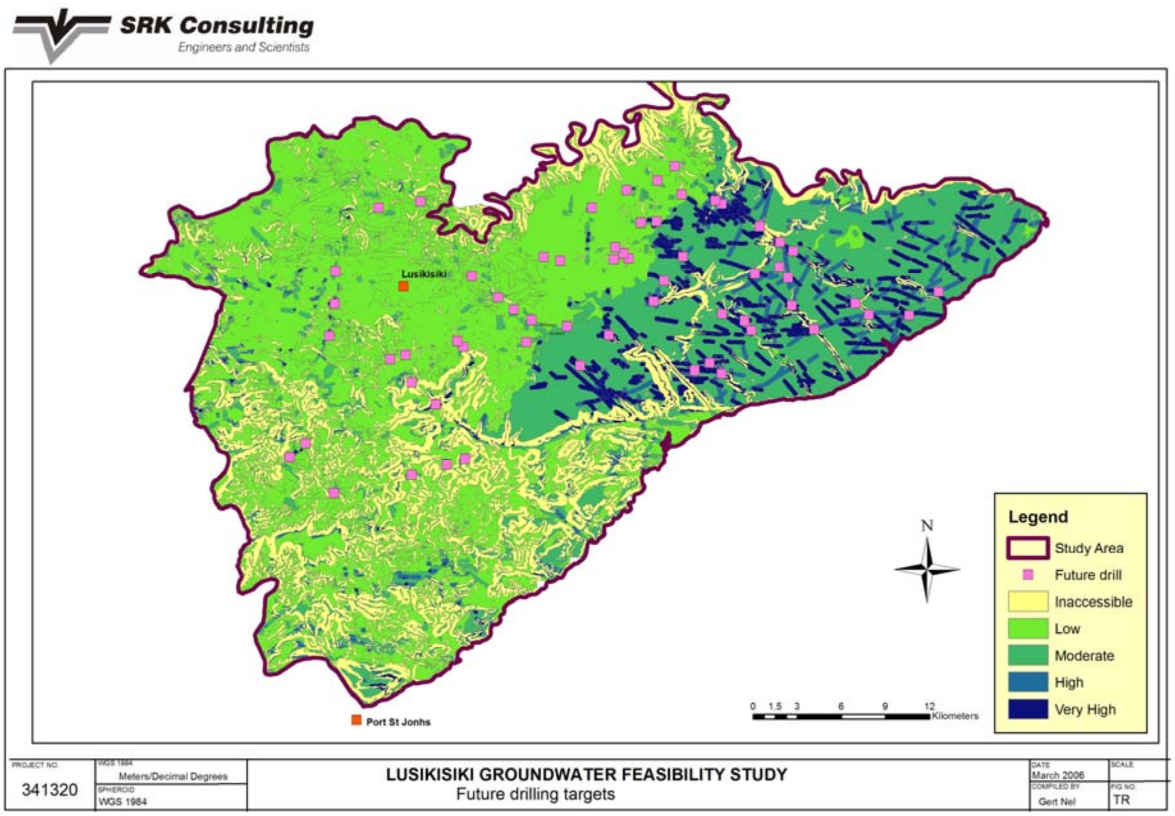


Figure 20: Indication of drilling targets for future groundwater supply

The above targets include:

- o Dolerite dykes
- o Lineaments
- o Contact between Dwyka and Natal Group Sandstone

The boreholes that are targeted on lineaments in the Dwyka and which are situated within approximately 5-7 km from the geological contact (topographically) with the Natal Group Sandstone, should penetrate the Dwyka and intersect the Natal Group Sandstone at depths not exceeding 200 m (taking into consideration a steady dip of 2^0).

In final conclusion it can be stated that the primary objectives of the Lusikisiki Groundwater Feasibility Study have been met and an assessment can now be made to what extent groundwater can be used in conjunction with surface water. The drilling programme was however not extensive enough, nor was it aimed at drilling all the available targets or to drill to meet the current demand. The entire study area covers approximately 900 km^2 and 30 boreholes have been drilled over this entire area.

7. ZALU DAM

7.1 Hydrological Information

7.1.1 Introduction and Catchment Characteristics

The proposed Zalu Dam site is located on the Xura River approximately 11km northwest of Lusikisiki. The proposed dam's catchment area is situated in quaternary drainage region T60F (Fig 000). Vegetation in the catchment includes grassland, thin bush and some bare surfaces. Subsistence agriculture is the predominant land use.

7.1.2 Catchment rainfall

Quaternary drainage region T60F was classified in the WR90 study into Rainfall Zone T6B. The WR2005 study to update the WR90 information is currently under way, with rainfall data collection and patching already completed. The updated patched rainfall stations for Rainfall Zone T6B were obtained and the catchment rainfall record (Appendix 1) was created, starting at October 1920 and ending on September 2005.

The rainfall stations used to derive the catchment rainfall for rainfall zone T6B is shown in **Table 30**.

Table 30: Rainfall Stations used for catchment rainfall

Station No	MAP(mm)	LATITUDE	LONGITUDE	Record Period (Hydro years)
0129007	1276	31.37	29.31	1923 - 2004
0153631	1169	31.01	29.22	1916 - 2004
0153875	819	31.05	29.30	1913 - 1951
0153875	907	31.05	29.30	1956 - 1980
0153875	857	31.05	29.30	1982 - 1989
0154142	1008	31.22	29.35	1909 - 1976
0154142	1541	31.22	29.35	1980 - 1981
0154142	1195	31.22	29.35	1983 - 1989
0154354	1441	31.24	29.42	1914 - 2004
0154796	1181	31.16	29.57	1925 - 1982

7.1.3 Catchment Mean Annual Precipitation

The WR2005 study uses a catchment MAP of 940 mm/a for quaternary drainage region T60F, and this value was also adopted for use in this study.

7.1.4 Point Rainfall at Zalu Dam site

A point rainfall record is required for the yield determination of the proposed Zalu Dam. This point rainfall record was determined from the catchment rainfall and the Catchment MAP. The point rainfall record as well as the results of tests to verify its consistency is attached as **Appendix B**.

7.1.5 Evaporation

Monthly S-pan evaporation data was sourced from the WR2005 dataset. Quaternary catchment T60F is situated in WR2005 Evaporation Zone 30C, with a Mean Annual Evaporation (MAE S_{pan}) of 1151 mm/annum. The monthly S-pan evaporation rates as well as the pan to dam factors to convert the pan evaporation rate to an evaporation rate applicable to large water areas are presented in **Table 31**.

Table 31: Monthly S-pan, pan to dam factors and lake evaporation rates:

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
S-pan	100	101	129	138	120	114	89	73	55	60	83	89	1151
Pan – Dam Factors	0.81	0.82	0.83	0.84	0.88	0.88	0.88	0.87	0.85	0.83	0.81	0.81	
Lake	81	83	107	116	105	101	78	59	46	50	67	72	965

7.1.6 Afforestation

The East Pondoland Basin Study quotes a total existing forest area of 4.72 km^2 for the T60F quaternary catchment. However, Google Earth imagery was studied, and the catchment of Zalu dam contains no afforestation, other than trees for windbreaks as well as what appears to be some natural wooded areas.

The decision was made not to include any afforestation in the rainfall-runoff model setup for the catchment of Zalu Dam.

7.1.7 Irrigation

No irrigation areas could be seen in the catchment area of the proposed Zalu Dam, and was thus not included in the WRSM2000 modelling.

7.1.8 WRSM2000 model setup

The WRSM2000 rainfall-runoff model was set up to simulate inflows into the proposed Zalu Dam for the period October 1920 to September 2005, using the rainfall, evaporation and land use information described above.

7.1.9 Model Calibration / Model parameters

Existing downstream gauging weir T6H004 data was not used for modelling calibration due to reasonsd as follows:

- The existing gauging weir is not a proper flow gauging structure in accordance with TR126- Manual for the planning, design and operation of river gauging stations issued by the Department of Water Affairs, Directorate of Hydrology.
- There was only 10 years of data (monthly volumes were recorded from 1995/1996). The period between 1996 and 1999 has been flagged as “incomplete data”, data exceeding rating table, and “estimated data”.
- Taking into consideration the low confidence of the available data and short period of data available at the gauging weir, it was agreed with DWAF that statistics generated on this record would not be representative of the hydrology of the catchment and therefore regional parameters for the T60F quaternary catchment were adopted using the data from October 1920 to September 2005.

The model parameters are presented in **Table 32**:

Table 32: WRSM2000 Model parameters used

POW	SL	ST	FT	GW	ZMIN	ZMAX	PI	TL	GL	R
3	0	200	15	0	999	999	1.5	0.25	0	0.5

7.1.10 Results

A summary of the results of the WRSM2000 modelling are presented in **Table 33** below.

Table 33: Summary of results: Flow record at Zalu Dam

Catchment Area (km^2)	MAP (mm)	MAR (million m^3)	Std Dev	Seasonal Index
71.35	940	11.86	7.18	16.86

The MAR determined in this study is marginally lower than the MAR determined in the East Pondoland Basin Study of 12.1 million m^3/annum, most probably due to the fact that the longer record period included more serious droughts.

The simulated monthly flow record is attached in **Appendix C**.

7.2 Yield Model

The yield of the proposed Zalu Dam can be determined by using the following information as input into a reservoir model:

- Monthly inflow record
- Monthly point rainfall record at dam site
- Average monthly gross lake evaporation at dam site
- Dam basin stage / area / capacity relationship
- Downstream releases for environmental purposes
- Silt volume

The above information was collected and used as input into the Water Resource Yield Model (WRYM).

7.2.1 Monthly Inflow Record

The flow record determined by the rainfall/runoff modelling (described above) was used as input into the WRYM Model. The flow record is attached in **Appendix B**.

7.2.2 Point Rainfall

The monthly point rainfall record at the dam site has been determined as described in **Table 31**, and is attached in **Appendix A**.

7.2.3 Evaporation

The average gross lake evaporation was determined from the monthly regional S-pan evaporation as described in **Section 7.1.5**, and the monthly lake evaporation values are presented in **Table 31**.

7.2.4 Stage / area / capacity relationship

The stage / area / capacity relationship of the Zalu Dam site used in the WRYM Model setup are presented in **Table 34** below.

Table 34: Stage / area / capacity relationship for Zalu dam:

Stage (m asl)	585.5	589.5	594.5	599.5	601.3	604.5	607.0	609.5	614.5	619.5
Stage (m)	0	4	9	14	15.8	19	21.5	24	29	34
Capacity (million m^3)	0	0.1	0.3	1.3	2	3.3	4.62	6.1	10.3	16.5
Area (km^2)	0	0.05	0.13	0.28	0.48	0.69	1.01	1.43	1.96	2.85

7.2.5 Environmental Flow requirements

The RDM office at DWAF was contacted to obtain the latest available reserve information for the river downstream of Zalu Dam. However, no further work has been carried out in the area, and it was concluded that the Reserve / IFR record used in the East Pondoland Basin Study is the best available information.

However, the Zalu IFR record in the East Pondoland Basin Study range from October 1920 to September 1997, necessitating extending of the IFR. This was done by correlating the monthly inflow record with the IFR time series.

The extended IFR time series used in the yield analyses is attached as **Appendix 2**.

7.2.6 Silt Volume

A 20 year siltation volume of 1.11 million m^3 was used to determine the dead storage volume that need to be allowed for in the proposed Zalu Dam.

This corresponds to a dead storage level of about 12m.

7.2.7 Historical firm yield analysis

The dam yield was determined for various capacities using the historical inflow record as input and the WRYM model with the information described above. The results are presented in **Table 35**. The historical storage / historical firm yield relationship for Zalu Dam is shown in **Figure 21**.

Table 35: Historical firm yield of Zalu Dam

Stage (m asl)	Stage (m)	Gross Storage (10^6 m^3)	Nett Storage* (10^6 m^3)	Historical Yield (10^6 m^3)
585.5	0	0	0	0
589.5	4	0.1	0	0
594.5	9	0.3	0	0
599.5	14	1.3	0.19	0.71
601.3	15.8	2	0.89	1.52
604.5	19	3.3	2.19	2.31
607.0	21.5	4.62	3.51	3.12
609.5	24	6.1	4.99	3.64
614.5	29	10.3	9.19	4.81
619.5	34	16.5	15.39	6.41

* : Include allowance for 20 year silt load of 1.11 million m^3
IFR of 2.72 million m^3/a released

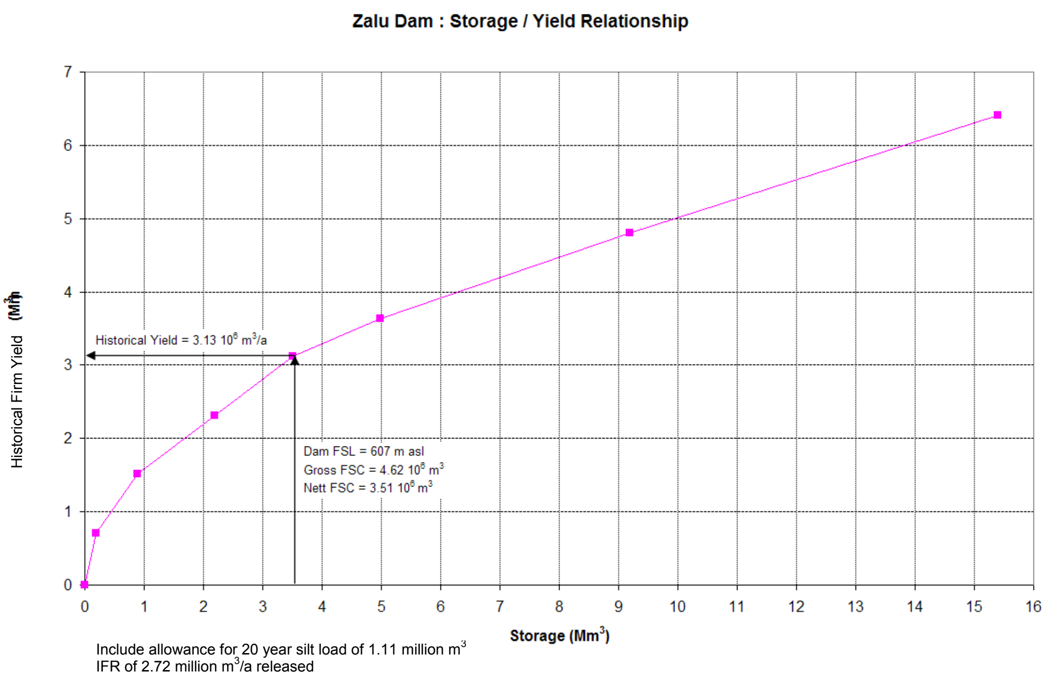


Figure 21: Zalu Dam: Storage/Yield Relationship

Figure 21 and **Figure 22** are presenting Zalu Dam Storage/Historical Firm Yield Relationship and Zalu Dam: Stage/Storage Relationship respectively.

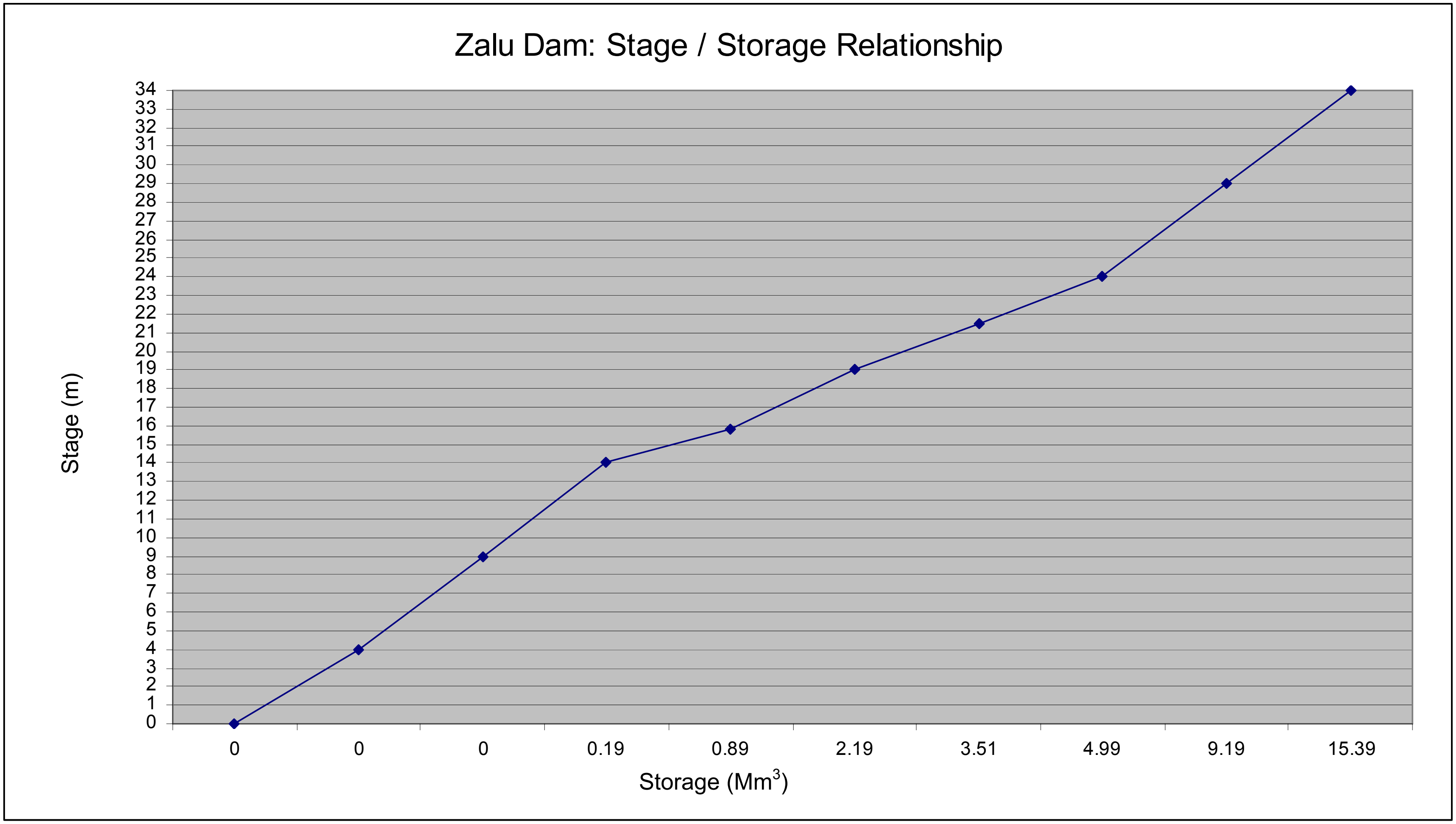


Figure 22: Zalu Dam: Stage/Storage Relationship

7.3 Review and Update Flood Peak Study

Catchment characteristics

The proposed Zalu Dam site is located on the Xura River approximately 11km north west of Lusikisiki. The significant catchment parameters are listed in **Table 36** below.

Table 36: Zalu Dam catchment characteristics

Site	Zalu Dam
River	Xura River
Catchment area (km^2)	71
Longest watercourse (km)	17
Distance to centroid (km)	9
Average catchment steepness (%)	14
Time of concentration (hrs)	3.5

Rainfall

The two closest rainfall gauges to the Zalu site with the longest rainfall record are located at Lusikisiki and Flagstaff. A summary of the rainfall record for each station is described in **Table 37** below together with the area weighted contribution of each gauge to the Zalu catchment.

Table 37: Rainfall stations

Station name	Station number	Period of record	MAP	Zalu representative area
Flagstaff	0153875	87 years	1050	17.5
Lusikisiki	0154142	99	897	53.5

Design rainfall depths for various return period storms were extracted from the *Design Rainfall Estimation in South Africa* software (Smithers and Schulze, 2002) for comparison with the rainfall record presented in Eastern Pondoland Basin Study (2001). This is for various return periods as shown in **Table 38** below.

The data presented in the Eastern Pondoland Basin Study was derived from daily point rainfall data obtained from the Hydrological Information System (HIS) database. Inspection of **Table 38** shows that the rainfall depths determined from the Smithers and Schulze (2002) approach are lower than the Eastern Pondoland Basin Study data up to the 1 in 50-year storm event. From the 1 in 100-year event onwards, however, the rainfall depths are greater. Given the significance of the large rainfall events in the design of the Zalu Dam, the greater depths obtained from the Smithers and Schulze (2002) approach were utilised in determining the peak flows from the Zalu catchment.

Table 38: Comparison of design rainfall depths (mm) for various return periods

	Return Period (years)						
Duration (hrs)	**2**	**5**	**10**	**20**	**50**	**100**	**200**
Design Rainfall Estimation in South Africa(Smithers and Schulze, 2002)							
1.75	36	54	68	84	109	131	157
3	**47**	**70**	**89**	**111**	**144**	**173**	**207**
7	62	93	118	146	189	227	272
24	100	151	192	237	308	370	442
Eastern Pondoland Basin Study							
1.75	54	77	92	107	127	144	159
3	**64**	**91**	**108**	**126**	**150**	**168**	**186**
7	70	100	119	139	164	185	205

Historical floods

There is an absence of reliable, observed flow records for the Xura River. There are thus no historical floods available for the calibration or derivation of design flood estimates.

Previous calculations

The Eastern Pondoland Basin Study undertook a flood frequency analysis for the Xura River. Empirical and Deterministic methods were used to determine the flood peaks. Statistical methods could not be used given the lack of observed flow records of a sufficient length of record.

Empirical methods

The Empirical methods used in the Eastern Pondoland Basin Study included the following:

- MIPI (Midgley and Pitman, 1971)
- HRU 1/71
- CAPA
- Roberts
- TR137 (Ke = 5.2)

It is understood that the Empflo98 software (Van der Spuy, 1998) was used to calculate the flood peaks for these methods. The flood peaks derived by the empirical methods refer to a storm duration of time Tc = 3.5h. **Table 39** below summarises the results of the flood peaks determined by empirical methods.

Table 39: Empirical flood peaks (m^3/s) from Eastern Pondoland Basin Study

Method	Return Period (T) years							
	2	**5**	**10**	**20**	**50**	**100**	**200**	**RMF**
MIPI	27	63	96	136	197	249	307	-
HRU 1/71	29	72	105	141	198	249	309	-
Roberts	33	73	108	145	192	225	256	-
CAPA	45	71	97	133	-	-	-	-
TR 137	-	-	-	-	440	561	697	1088

Deterministic methods

The deterministic methods used in the Eastern Pondoland Basin Study included the following:

Rational

DRH (Bauer and Midgley, 1974)

Synthetic Unit Hydrograph (SUH HRU 1/72)

The design storm rainfall depths presented in **Table 38** for the Eastern Pondoland Basin Study were used in the Detflo 99 software (Rademeyer, 1999) to calculate the flood peaks for the deterministic methods.

The flood peaks were determined for the following storm durations:

$0.5\ T_c = 1.8$ h

$T_c = 3.5$ h

$2\ T_c = 7$ h

The assumed percentage weighting of the soil and vegetation types for the Zalu Dam catchment used in the Eastern Pondoland Basin Study are shown in **Table 40** and **Table 41** below.

Table 40: Soil permeability

Soil Type	Zalu Dam (% of Area)
Semi-permeable	10
Impermeable	90

Table 41: Vegetation cover

Vegetation Type	Zalu Dam (% of Area)
Forest, Dense bush	50
Thin bush	40
Grassland	7
Bare Surface	3

Table 42 below summarises the results of the flood peaks determined by the deterministic methods for the different storm durations.

Table 42: Deterministic flood peaks (m^3/s) from Eastern Pondoland Basin Study

Method	Duration	Return Period (T) years						
	(hrs)	2	5	10	20	50	100	200
Rational	1.8	45	99	145	196	272	342	411
	3.5	55	123	178	242	337	418	503
	7	31	70	101	138	190	238	287
DRH	1.8	51	89	118	150	198	242	283
	3.5	56	97	127	163	216	258	303
	7	44	78	103	132	171	208	244
SUH (***)	1.8	63	109	144	184	242	296	347
	3.5	51	89	117	150	199	238	280
	7	35	61	81	104	136	164	193

(***) Figures taken from output results of the Detflo 99 software presented in Appendix C of Flood Frequency Analysis of Eastern Pondoland Basin Study

Adopted flood peaks from Eastern Pondoland Basin Study for Zalu Dam

After an assessment of the results produced by the empirical and deterministic methods, the authors of the Flood Frequency Analysis report of the Eastern Pondoland Basin Study adopted the Rational method results as the representative flood peaks for the various return period storm events. The flood peaks recommended by the Eastern Pondoland Basin Study are presented in **Table 43** below.

Table 43: Zalu Dam adopted flood peaks (m^3/s) from Eastern Pondoland Basin Study

Duration (hrs)	Return Period (T) years							
	2	5	10	20	50	100	200	RMF
3.5	55	125	180	240	335	420	505	1090

Revised flood peak determination

An assessment of the flood peaks recommended by the Eastern Pondoland Basin Study was undertaken by SRK Consulting by reviewing the flood peak calculations using the following methods:

Empirical methods – MIPI, RMF (TR137), CAPA, Standard Design Flood (SDF)

Deterministic methods – Rational, SUH (using Detflood software (Alexander 2005)

Empirical methods

Empirical methods are generally based on correlations between peak flows and catchment characteristics for comparable flood-producing areas.

MIPI method is based on South Africa being divided into 7 homogenous flood regions accounting for topography, rainfall characteristics, soils, drainage patterns and plant cover. The Zalu Dam catchment is considered to fall within flood region 4.

RMF method is based on Franco-Rodier method assuming that extreme floods in a catchment are caused by rain depths that are large enough to saturate the major proportion of the catchment. The magnitude of the flood is therefore dependent on possible limit on extreme rainfall, general catchment relief and catchment area. South Africa has been divided into rainfall/relief regions with the Zalu Dam catchment falling within region 5.2.

SDF method calibrates the Rational method C-value against Log-Pearson Type III probability distribution return period values for 29 homogenous regions in South Africa. It is based on a series of annual maximum flood records for the 29 areas and is thus considered a conservative approach, as with the RMF method. The Zalu Dam catchment is considered within **region 22**.

The PeakFlows software (Mahlangu 2007) was used to calculate the flood peaks for these methods with Detflood (Alexander 2005) calculating the SDF. The flood peaks derived by the empirical methods refer to a storm duration of time Tc (**Table 44)** below summarises the results of the flood peaks determined by empirical methods.

Table 44: Empirical flood peaks (m^3/s)

Method	Return Period (T) years							
	2	**5**	**10**	**20**	**50**	**100**	**200**	**RMF**
MIPI	27	63	96	136	197	249	307	-
CAPA	43	67	91	124	185	248	332	-
SDF	33	115	192	278	407	516	631	-
RMF (TR 137)	-	-	-	-	415	543	691	1088

Comparison between **Table 43** and **Table 44** reveals that there is a good agreement between the Eastern Pondoland Basin Study results and the current calculated values. This is expected given that the flood regions and catchment area are considered the same.

Deterministic methods

Deterministic methods derive the flood magnitude from an estimate of catchment rainfall for the required return period less catchment retention. The catchment retention is determined through understanding the role of catchment characteristics such as shape, slope, vegetal cover and antecedent moisture condition in converting storm rainfall into catchment runoff. It is also assumed that a T-year return period storm will produce the T-year flood, if the catchment is at an average condition.

A site inspection undertaken during 2006 revealed that there are differences in the vegetation cover and expected soil permeability compared to the values used in the Eastern Pondoland Basin Study as shown in **Table 48**. The revised soil permeability and vegetation cover values are depicted below in **Table 45** and **Table 46.**

Table 45: Soil permeability

Soil Type	Zalu Dam (% of Area)
Semi-permeable	90
Impermeable	10

Table 46: Vegetation cover

Vegetation Type	Zalu Dam (% of Area)
Forest, Dense bush	0
Thin bush	30
Grassland	67
Bare Surface	3

For the Rational method, the total runoff coefficient CT is an integrated value representing the many factors influencing the rainfall-runoff relationship for a catchment. For rural areas such as the Zalu Dam catchment area, this runoff coefficient is affected by catchment slope, permeability of the soil, vegetation, mean annual rainfall and return period where CT = Ch (surface slope) + Cd (permeability) + Cp (vegetation). The calculated figure for CT assuming an average catchment slope of 14% and the above soil permeability and vegetation cover is 0.63.

For the SUH method, the assumed Veld type is Zone 8. Based on the catchment characteristics shown in **Table 45** and **Table 46** above, the following is derived for the SUH method:

- Catchment index = 1315
- Basin lag = 2.5hrs
- Unitgraph peak = 10.3m^3/s

The Detflood software (Alexander 2005) was used to determine the peak flows for the various return periods. These flows are shown in **Table 47** below for various storm durations.

Table 47: Calculated inflow flood peaks (m^3/s) for Zalu Dam

Method	Duration (hrs)	Return Period (T) years						
		2	5	10	20	50	100	200
Rational	1.8	124	203	276	373	586	830	951
	3.5	**81**	**132**	**182**	**246**	**386**	**548**	**625**
	7	54	87	120	162	254	360	412
SUH	1.8	40	63	89	119	170	222	300
	3.5	43	68	97	133	194	260	320
	7	32	51	74	102	153	208	280

Based on a comparison of the results obtained from the empirical and deterministic methods, the inflow flood peaks determined by the Rational method were selected as providing representative flood peaks for the various return periods. The Rational method calculation is based on a deterministic understanding of the Zalu Dam catchment. The calculated flood peaks are considered conservative yet fall within the empirically-based RMF derived flood peaks for the catchment for high return period storm events.

Recommended inflow flood peaks for Zalu Dam

Table 48 provides a comparison between the revised flood peaks and the previous adopted flood peaks from the Eastern Pondoland Basin Study. The comparison is made for a storm duration of 3.5h = T_c.

Table 48: Comparison of Eastern Pondoland Basin Study and current flood peaks (m^3/s)

	Return Period (T) years							
	2	**5**	**10**	**20**	**50**	**100**	**200**	**RMF**
Eastern Pondoland Basin Study	**55**	**125**	**180**	**240**	**335**	**420**	**505**	**1090**
SRK Consulting	**81**	**132**	**182**	**246**	**386**	**548**	**625**	**1090**

A comparison of the results is also depicted in **Figure 23** overpage. Except for the 1 in 2 year flood there is good agreement between the adopted peak flows for storm events up to a 1:50-year return period. For events from the 1:50-year to the 1:200-year return period storms, the currently calculated peak flows are substantially higher than the flows recommended in the Eastern Pondoland Basin Study.

It is suggested that this is due to a combination of factors. These include:

Higher runoff coefficient given the current increased area of grasslands with no dense forests as previously assumed in the Eastern Pondoland Basin Study.

Slightly higher rainfall depths for the high return period storms compared to the rainfall depths used in the Eastern Pondoland Basin Study.

It is also suspected that an additional runoff factor was applied to the runoff coefficient CT in the Rational method for the high return period peak flows during the Eastern Pondoland Basin Study. This is not discussed, however, within the Flood Frequency Analysis Report.

Given that the peak flows calculated within this review are considered more conservative than the flows generated during the previous Eastern Pondoland Basin Study, it is recommended that the peak flows depicted in **Table 49** below be adopted as representative of the inflows to Zalu Dam for various return periods.

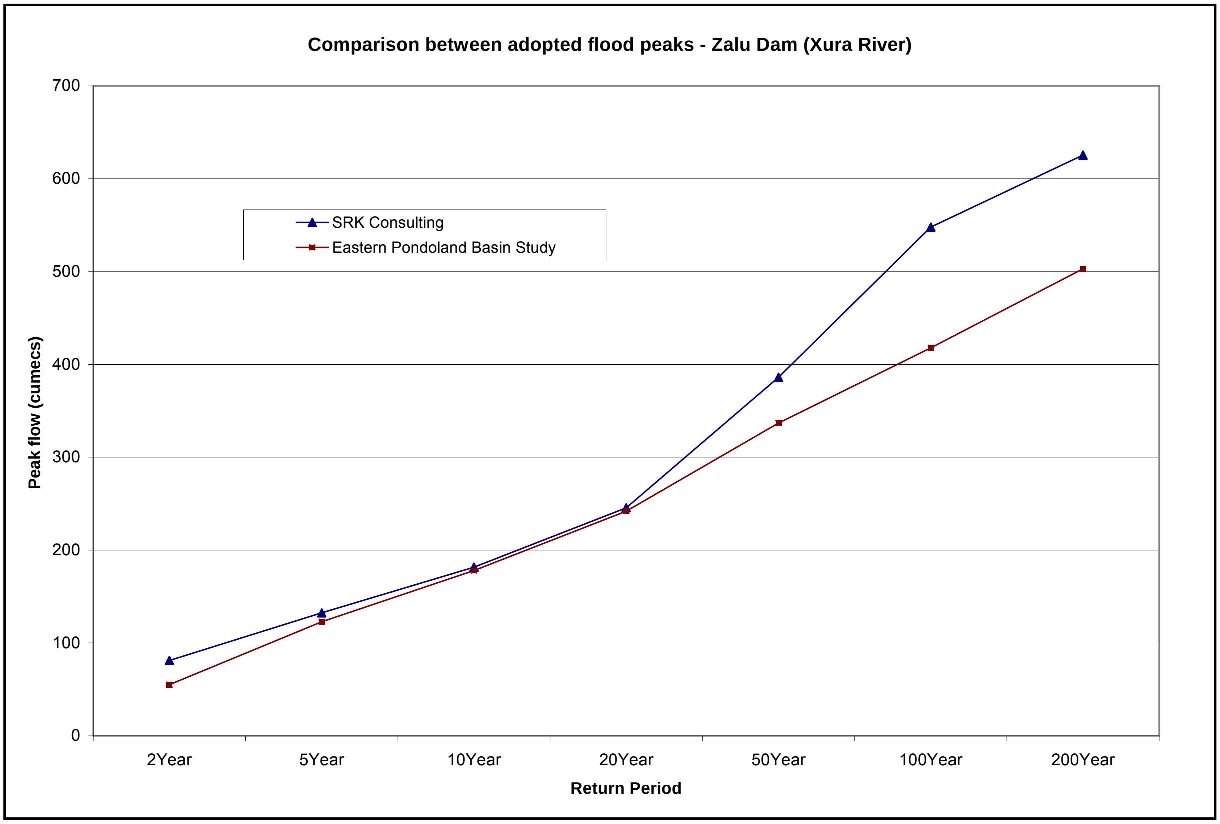


Figure 23: Comparison between Eastern Pondoland Basin Study and current flood peaks (m^3/s)

Table 49: Recommended inflow flood peaks (m^3/s) for Zalu Dam

	Return Period (T) years							
	2	**5**	**10**	**20**	**50**	**100**	**200**	**RMF**
Flow	81	132	182	246	386	548	625	1090

Zalu Dam Hydraulic Assessment

It is understood that the Zalu Dam was designed during the pre-feasibility phase of the Eastern Pondoland Basin Study as a mass roller compacted concrete (RCC) structure with a central spillway.

The sizing of the Zalu Dam during the pre-feasibility phase of the Eastern Pondoland Basin Study is indicated in **Table 50** below. **Table 35** gives yield/storage relationship for different dam sizes to be established for a range of demands. Reasons for revision of these parametars are that this dam is small to meet water requirements that are 5,219 million m^3/year. It is necessary, however, to ensure that the design of the spillway is able to convey the revised flood peaks discussed in **Section 7.3** above.

Table 50: Zalu Dam sizing parameters (Eastern Pondoland Basin Study)

Parameter	Zalu Dam
Type of Dam	Concrete
Type of spillway	Central Overflow
Live storage (10^6 m^3)	3.13
Sediment yield/storage (10^6 m^3)	0.8
Dead storage (10^6 m^3)	0.31
Total storage (10^6 m^3)	4.24
Yield (10^6 m^3/a)	3.12
Bed level (mamsl)	585.5
Freeboard (m)	3.5
FSL (mamsl)	607
NOCL (mamsl)	610.5
Depth from bed to FSL (m)	21.5
Depth from bed to NOCL (m)	25
Depth from rock to NOCL (m)	26.5
NOC length (m)	141
Spillway length (m)	90

Design floods for Zalu Dam spillway

The design floods for sizing the Zalu Dam spillway was established in accordance with the "Guidelines on Safety in Relation to Floods" (SANCOLD, 1991). The Zalu Dam was classified as follows:

Zalu Dam: Category II safety risk (medium size, significant hazard rating)

The SANCOLD guidelines were used to estimate the Safety Evaluation Discharge (SED) and Recommended Design Discharge (RDD). The guidelines require that the capacity of the spillway should be sufficient to pass the SED in such a way that although substantial damage may be sustained, the dam will not fail. The value of the SED recommended for the Zalu Dam with the above size class and hazard rating is as follows:

- SED = RMF
- RDD = 1:200-year flood

Based on the revised flood peaks shown in **Figure 23** this relates to the following flood peaks:

- SED = RMF = 1090m^3/s

- RDD = 1:200-year flood = 625m^3/s

Hydraulics of Zalu Dam spillway

The Zalu Dam spillway designed during the pre-feasibility stage of the Eastern Pondoland Basin Study has the following characteristics:

Table 51: Zalu Dam spillway characteristics (Eastern Pondoland Basin Study)

Spillway type	Concrete ogee crest
Spillway length (m)	90
Spillway freeboard (m)	3.5

The spillway was designed with a smooth vertical upstream face, a conventional reinforced concrete ogee shaped cap and a stepped downstream face with a slope of 1:0.75.

The discharge capacity of the ogee spillway crest is given by the following:

$$Q = 1.8554 \times L \times H^{1.5795}$$

where L = spillway length (m)
H = flow depth (m)

The maximum theoretical discharge capacity of the spillway is 1208m^3/s. This is in excess of the un-attenuated SED = 1090m^3/s.

Freeboard

The maximum available freeboard in the Zalu Dam spillway is 3.5 m. It is necessary to check the required freeboard for the RDD and SED flows.

Assuming a conservative condition of a non-attenuated design discharge, the RDD depth over the spillway is 2.3 m. Allowing for an additional wind wave of 0.4 m, the total required freeboard is 2.7 m. The 3.5 m available freeboard is therefore sufficient to convey the RDD.

In the case of the SED, again assuming a conservative condition of a non-attenuated discharge, the SED depth over the spillway is 3.28m. No additional wave or wind freeboard is required. The freeboard requirement of the spillway is therefore governed by the SED depth. An additional 0.22m of freeboard is available. Given the additional available freeboard coupled with the conservative assumption of the un-attenuated SED discharging over the spillway, the available 3.5m freeboard is considered sufficient.

The current spillway design of Zalu Dam is considered suitable for the conveying of the revised RDD and SED floods. Should the dam be redesigned following this pre-feasibility study, any new spillway configuration will have to be reassessed to ensure that the discharge capacity is maintained. This will also include flood routing of the recommended SED and RDD through the dam to determine the attenuated flood peak requiring discharge through the spillway.

7.4 Review and Update of Sedimentation

Estimates for sediment yields were made in accordance with updated Rooseboom maps (WRC Report No. 297/1/92). The dam catchment is located in the sediment yield region number 9, with erodibility indices in the medium range. The standard average sediment yield within the region is 185t/a/km^2. The yield is estimated for the 20 year horizon and the 80% confidence level to be 0.8 million m^3, which was selected for sizing of the dam. It is considered that the selected sediment yield is conservative and that it actually may be lower.

7.5 Review of the Original Dam Site Investigation Report (HKS, 1979)

The Zalu dam site was previously investigated by HKS Consulting Engineers and reported in October 1979. The dam type assumption on which their investigation was based, was an earthfill dam with full supply level at 618 m and a crest level at 623m.

The investigation was undertaken in two phases:

- A preliminary geological and soils investigation undertaken in February 1979, (**Figure 24**)
- A detailed geological and materials investigation, which is the report currently being reviewed in this document.

The extent of work of the HKS detailed investigation can be summarised as:

- Twenty eight boreholes with total length 651 m. Water testing was undertaken in five boreholes and test grouting in two boreholes.
- Ninety nine trial holes in ten potential borrow areas.

The following aspects were investigated:

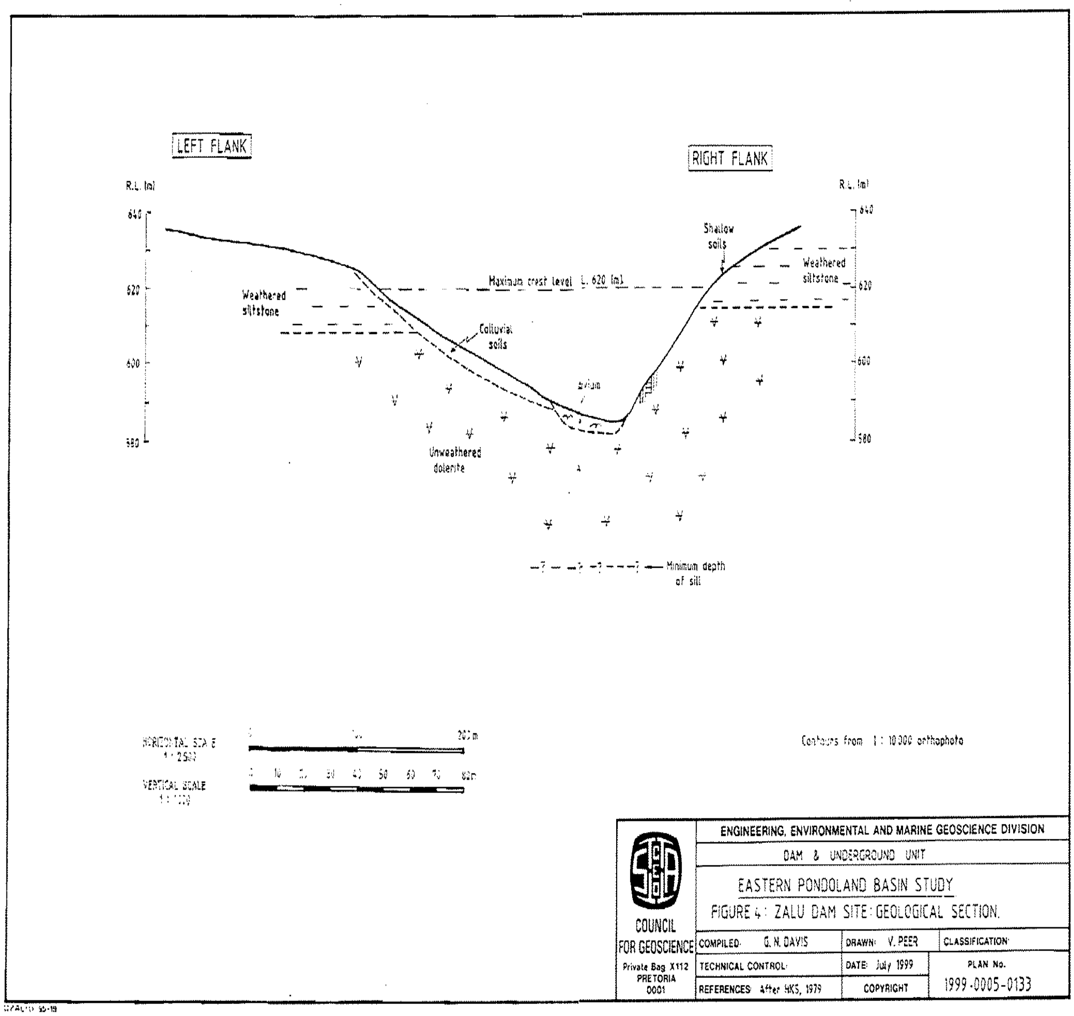
- Dam centreline position
- Spillway position
- Potential borrow materials

The drilling was undertaken in two phases:

- The first phase comprised boreholes LB1, LB2, LB3, RB1 and RB2, which in the opinion of the investigation team at the time confirmed the suitability of the site for the construction of an earthfill dam.
- The balance of the investigation was undertaken to establish the depth to bedrock, rock quality, the nature of the contact between the Ecca shale and the dolerite and the small fault near to borehole LB2.

A schematic of the dam centreline cross section is presented in **Figure 24**. In summary, a dolerite sill is intruded into the Ecca shale on the dam site. The Ecca shale occurs on the left bank above elevation 610 mamsl and above 614 mamsl on the right bank, with dolerite forming the river section below the Ecca shale. The cross section shows that the river section and the left bank is underlain by about 5 m of soil before bedrock is encountered, with a thinner soil cover on the right steeper bank. The summary logs presented in the HKS report indicate in the river section that in all the holes, there is a rapid transition from weathered rock to fresh rock.

Figure 24: Zalu Dam Site: Geological Section



To date no geophysical investigation work has been undertaken to assist in interpolation between borehole locations. However, the boreholes have been placed to achieve very good coverage of the dam centreline.

The engineering geological model of the dam centreline and basin prepared by HKS can be summarised as follows.

- The location of the Ecca shale overlying the dolerite sill in the river section was established.
- The profile of depth of soil cover was established.
- The depth to engineering bedrock / rockhead was established.
- The rock mass joint set directions were established (**Table 52**).

Table 52: Rock Mass Joint Set Directions

Description	Comment
Set 1: 0 - 14^0	Poorly developed
Set 2: 36 - 42^0	Well developed
Set 3: 60 - 70^0	Very well developed
Set 4: 95 - 110^0	Well developed
Set 5: 130 - 140^0	Very well developed
Set 6: 145 - 179^0	Poorly developed

- Other than the small fault on the left bank close to borehole LB2, no major geological structure was identified.
- The presence of no lineament zones were identified or postulated.
- In the river section the transition from alluvium to dolerite bedrock was rapid.
- The alluvium comprised two distinct horizons: a 2m thick sandy silt and clayey silt horizon overlying a 3m thick boulder bed horizon. The conclusion of the HKS investigation is that the behaviour of the boulder bed will be similar to the overlying clayey silt and sandy silt horizon from a basin permeability point of view, as it is hypothesized that the matrix infill will be similar to the overlying soil horizon.
- In the river section, it is concluded that there are no deep erosion gullies within the dolerite bedrock.
- In the river section the quality of the dolerite bedrock improved rapidly with depth. The dolerite was found to extend to a depth of 35 m below river bed level.
- On the left bank, the depth of weathered dolerite extended to 12m where the dolerite is overlain by Ecca shale. It seems that in close proximity to the Ecca shale the quality of the dolerite bedrock is poorer. The Ecca shale seems to be better in close proximity to the dolerite as a result of metamorphism.
- The in situ permeability tests and grouting trials suggest that the rock mass permeability within the influence sphere of the dam has a low permeability; typically the Lugeon values vary between 0 and 5. Some of the higher Lugeon values are associated with open joints within the dolerite.
- The shale was too weathered and weak to undertake grouting trials.
- Limited grouting trials were undertaken in the dolerite as the permeability testing indicated that the grout takes will be low.
- The grouting trails undertaken in the fault zone section in borehole LB5, suggest that the fault can be grouted but that the grout takes will be low.
- The dam basin should be relatively impermeable due to the presence of impervious dolerite and shale and the alluvium cover in the dam basin.
- The reservoir basin side slopes should be stable due to the relatively flat slopes. In the few places where the side slopes are steep, these are heavily wooded and HKS stated that these will also be stable.
- As a result of overgrazing of the catchment area, siltation of the proposed reservoir can be expected. The siltation yield from the catchment is expected to be higher than for the average RSA river.
- The core trench depth within the dolerite zone should typically extend to 5m for a rockfill dam. On the higher flanks where deeper weathered dolerite and shale was encountered the core trench may have to be extended to 12m depth.
- HKS assumed that it would not be necessary to remove the alluvium from the areas where the shoulders of the earthfill dam would be placed – they did confirm that suitable additional investigations would be required to confirm this assumption. The alluvium below any portion of an RCC dam foundation will have to be removed down to suitable bedrock for the case of an RCC dam.

- The shales have slaking properties and the treatment of the shales in excavation will have to be planned for.
- There will be ground water inflows and therefore pumping of the river section excavations will be required.
- HKS recommended that a spillway for a earthfill dam should be placed on the steeper right side, to be founded on dolerite. In the case of an RCC dam the spillway can be placed also on the right side or more to the centre of the dam depending on the layout of the dam selected.
- HKS anticipated that the tower for the outlet works will be placed close to borehole RB3, where fresh dolerite bedrock will be encountered at 4m depth and a bearing capacity of 1000 kPa can be used in the design of the tower foundations. A series of boreholes were drilling along the alignment of the proposed outlet pipe and it was found that these provide for bedrock typically at about 3m depth. An alternative alignment for the outlet pipes was the right side of the river section above the current river level, which will provide easier excavation conditions above water levels. A further alternative was an outlet tunnel on the right side.

HKS undertook a detailed borrow area investigation. The main features of this work are:

- Ten suitable borrow areas were identified.
- Detailed laboratory testing was undertaken but was not included in the Volume 1 report made available for review (the results were however reviewed in the Eastern Pondoland Basin Study).
- It was indicated in the HKS volume I report that the dolerite derived clayey silts could be used for the core and the fine-grained material from the shale for the shoulders. The fine-grained material from the alluvium can be used for the shoulders. If necessary the fine grained soils for the alluvium could be used for the clay core. The review in the Eastern Pondoland Basin Study is however critical of these findings (see further comment below).
- HKS stated in considerable detail where and how the borrow materials could be harvested as well as their assumptions for the exploitation of these various sources. In this regard they highlighted the complications of harvesting alluvium, both from a geometric point of view as well as being low lying and prone to inundation as the water levels rise within the dam basin. HKS also highlighted that the alluvial soils are potentially dispersive and that their use would have to take account of this consideration. Furthermore there are boulders within the alluvium, which would require selective harvesting of the alluvium if the boulders can not be used as part of the alluvium fill.
- HKS highlighted the complication with the provision of filter and concrete aggregates. They stated that locally the shale and dolerite was to too deeply weathered as a source for these aggregates and that the aggregates would have to be imported. Some options were indicated to be commercial sources more than 10 km from the site. Another option was to investigate in detail the existing dolerite quarry lying about 3.5km north of the site.
- HKS recommended that possible natural sand sites be investigated in the area of Lusikisiki.

The review comments are:

- HKS had an earthfill dam in mind when they designed their investigation in 1979. In the Eastern Pondoland Basin Study it was indicated that the site would also be suitable for a roller compacted concrete (RCC) dam. However, it was also indicated that the poor foundation conditions on the left flank may favour a composite dam.

- If more dolerite fill is required than identified by HKS, then it would be possible within a reasonable haul distance to find additional sources. Some of these sources may then be above the full supply level, which is not a first choice solution, but would still be acceptable from an engineering point of view.
- In general terms the HKS geological investigation seems appropriate, as many of the required engineering geological features for a dam project have been determined. Therefore it is only necessary to focus on what could have been missed in the previous investigations.
- The direction of the valley is aligned with major joint set no. 5 (130 - 140^0). Therefore the properties of this joint set are very relevant to the project. Furthermore the conjugate joint sets no. 2 (36 - 42^0) and 3 (60 - 70^0) also have to be carefully considered.
- Chapter 7 of Volume 3 of Engineering Geology of Southern Africa by ABA Brink refers. Mention is made of previous experience (case histories) in drilling in dolerite where the thin clay filled joints were not picked up during drilling as the clay washed out of the joints and the thinness of the joints were not significant enough to be considered a problem during logging of the core. This could have been a problem in 1979; significant advances have been made with drilling equipment and techniques in the last 30 years. In some of the quoted case histories, the depth of the foundation excavation had to be increased to cater for the blockiness of the foundation material which had to be removed. This is of particular relevance if a roller compacted concrete dam is to be constructed.
- At this stage there is no mention of why the valley developed in this location and what geological complications could be expected on site. Although the borehole coverage is good, it is still possible that some geological feature such is fault which could have been missed which could have been instrumental in the development of the valley. The only other possibility is that preferential weathering took place along joint set no. 5 and that this is the reason for the development of the valley.
- No geophysical traverses have been undertaken on the centreline and the line of the spillway and outlet works. Therefore it is essential when a preliminary location / layout of the RCC dam has been determined that such a survey be undertaken.
- No detailed aerial photographic interpretation of faults, lineaments, dykes and joints set were included as part of the engineering geological investigation in 1979. This work may have been undertaken elsewhere, but should also form part of the engineering geological report. It should be noted that a regional structural map assessment is included in the 2001 Eastern Pondoland Basin Study report. This assessment is too regional to be effective for and directly applicable to the Zalu dam site.
- The material investigation of HKS focussed on earthfill construction materials. Although the HKS report giving the results of detailed laboratory tests was not available as part of this review, it seems that it would be possible to develop an earthfill dam on this site. However, it should be noted that the HKS report on the materials investigations was reviewed in the Eastern Pondoland Basin Study and was found inadequate.
- It seems that a RCC dam option may be considered for this site, but that the construction materials for this will require a specific investigation. Furthermore, the layout of an RCC dam will require evaluation / assessment before the materials and specific investigations can be planned.

7.6 The Need for Further Geological/Geotechnical Assessment of Proposed Dam Site and Material Availability

The findings of the HKS materials investigation were reviewd in the Eastern Pondoland Basin Study. The review was critical of some of the findings. For example, the dolerite derived clay soils were found to have very high clay content (generally higher then 45%) suggesting problems with workability. The Atterberg limits were found to exceed normal specifications, dry densities were low and optimum moisture content was high. The review thus queried whether the dolerite derived clay soils were suitable for the semi-peryions zones of an earthfill dam. They appered to be more suitable for the clay core. It was also indicated that the grading of the alluvial clayey silts also made them more suitable for use as core material rather than for the semi-peryions zones. A possible source of semi-peryions material was seen to be soils derived from weathered siltstone but there were reservations since liquid and plastic limits are hish and the materials are potentially dispensive.

The following comments are made:

- No better proposal was presented in the 2001 report regarding possible sources of aggregate, rip-rap and filter material.
- Project costing is strongly impacted by the distance of transportation of the construction materials.
- If the RCC option is to be pursued then it is critical to confirm the quality of the proposed dolerite quarry at 3.5 km from the site and to see if there is no closer suitable aggregate quarry. A similar comment applies to possible sand quarries.
- Although alluvium may be a possible borrow option, this source of material should be considered as a last possible option, specifically taking account of how the material will have to be harvested under possibly quite wet conditions.
- The feasibility of an earthfill dam is significantly dependent on the amount of shoulder foundation excavations to be undertaken. Therefore the actual strength and deformation properties of the alluvium are critical from this perspective. If the overlying fill material is stiffer than the foundation soils, then this could present long-term stability problems. This assessment will be undertaken as part of the next project phase.
- The feasibility of the RCC dam is significantly dependent on the amount of foundation excavation and the distance to the quarries for good quality sand and aggregates.
- The HKS report in terms of its material investigation confirmed in principle that an earthfill dam is feasible. This conclusion is supported, but suitability of borrow pit materials is to be confirmed.
- The UWP report did not indicate where the construction aggregate and sand materials for the RCC dam would come from and therefore the construction materials are critical for any RCC dam design on this site.

From a founding point of view, it will be possible to found both an earthfill dam and an RCC dam on the Zalu dam site. More excavation will be necessaru for the RCC dam. This is not considered critical at this point in time, as it would be possible to provide an earthfill dam on the higher lying shoulders of the dam with a central overflow RCC section. In terms of current available information this is not a critical issue. The most critical issue highlighted in this section of the report is the feasibility of an RCC dam without indicated and / or proven material sources.

It seems that a high level comparison should be undertaken to make the assessment of which of the two options is the most cost effective. This comparison will also highlight what additional investigations will be required to confirm the relevant hypothesis for each of the two options.

The principles of additional geotechnical and engineering geological investigations are proposed which should be undertaken in the next project phase:

- The test results mentioned in the HKS detailed geological and materials investigation report need to be studied.
- The full borehole logs need to be obtained as well as all the other investigation appendices.
- An air photo interpretation needs to be undertaken after the site and surround have been flown.
- In liaison with the dam investigation group of the Council for GeoScience working for DWAF, the next phase of investigation should be planned.
- In order for this team to be sure that the previous logging was sufficient a limited number of boreholes should be drilled using modern equipment. This should be supplemented by a geophysical investigation where suitable traverses are undertaken. This should also focus on the latest dam design proposals.
- The main focus of this new work will be relevant materials investigations to provide design information for the proposed dam designs.

7.7 Water Quality at Zalu Dam Site

This section focuses on the surface water quality (**Appendix 4**) of the area as assessed during a site visit to the area during October 2006.

7.7.1 Methodology

The water quality assessment included:

- identification of potential surface water users in the surrounding area;
- once off grab sampling up- and downstream of the proposed dam site;
- validation and assessment of the data, including available DWAF data.

A surface water monitoring protocol was developed prior to the site visit performed on the 11th and 12th of October 2006 (**Appendix 3**). Five grab samples were taken from the Xura River and tributary according to the protocol. The samples were analysed for general water quality constituents at a laboratory in Port Elizabeth. **Figure 25** gives a schematic representation of the locations of the sampling points, which are described in **Table 53**.

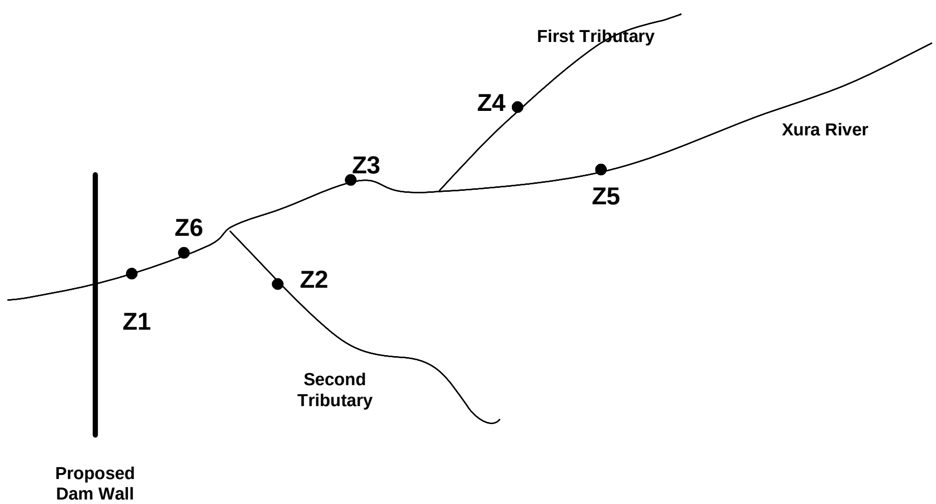


Figure 25: Schematic representation of sampling points (not to scale)

Table 53: Zalu Dam Pre-feasibility study surface monitoring points

Sample name	Relative location	GPS Co-ordinates	
		Longitude	Latitude
Z5	Xura River - Upstream of proposed dam site	44769.20	-3465682.00
Z4	First Tributary	44819.97	-3465776.40
Z3	Xura River - After confluence with Z4	44856.02	-3465775.45
Z2	Second Tributary	45142.56	-3465021.27
Z6	Xura River – After confluence with Z2	45247.00	-3465761.00
Z1	Downstream of proposed dam site (dam wall)	45400.00	-3466000.00

7.7.2 Results and discussion

Surface water users

Potential use of surface water by surrounding communities and the environment is as follows:

- **Domestic use:** As the level of service for the villages (rural settlements) is currently limited to bulk supply at the village reservoirs (below RDP standard) domestic use of water from the Xura River could occur. This includes water used for drinking, food and beverage preparation, bathing and personal hygiene, washing of, for example, dishes and laundry *etc*.
- **Livestock watering:** Surrounding communities may use water for subsistence livestock watering.
- **Irrigation:** Although irrigation water requirements will not be supplied by the Lusikisiki Regional Scheme, the possibility cannot be excluded that water will be used for subsistence irrigation. The requirements for irrigation were, however estimated and taken into account for the assessment of the hydrology of the area performed previously (USP, 2002).
- **Aquatic systems:** Aquatic ecosystems are defined as the abiotic (physical and chemical) and biotic components, habitats and ecological processes contained within rivers and their riparian zones, reservoirs, lakes and their fringing vegetation. Terrestrial biota, other than humans dependent on aquatic ecosystems for survival, are included.

Surface water quality

Table 54 shows the DWAF guideline values for the current uses of water in the area: domestic (washing, drinking etc.), cattle watering, irrigation and aquatic ecosystems. The final column of the same table lists the critical values for water quality, which are the lowest values (highest quality) for each parameter. For the purpose of this study, the water quality data was compared to the critical values to get an overview of the surface water quality in the area. This comparison is presented in **Table 55**. Any exceedences of the critical values are highlighted. DWAF water quality data for the area is shown in **Table 56**.

Table 54: Zalu Comparison of water quality guideline values

Parameter	Unit	Domestic use[1]	Livestock watering[2]	Irrigation use[3]	Aquatic systems[4]	Critical values
(Nitrate and nitrite) as N	mg/l	6	200	5	Ns	5
Cadmium as Cd	mg/l	0.005	0.01	0.01	0.15	0.005
Calcium as Ca	mg/l	150	1000	Ns	Ns	150
Chloride as Cl	mg/l	200	2000	100[#]	Ns	200
Chromium as Cr	mg/l	0.05	1	0.1	0.012	0.012
Cobalt as Co	mg/l	Ns	1	0.05[#]	Ns	1
Conductivity	mS/m	150	Ns	Ns	Ns	150
Copper as Cu	mg/l	1.3	1	0.2[#]	0.003	0.003
E coli	count/100ml	1	200	1	Ns	1
Fluoride	mg/l	1	4	2	1.5	1
Iron (total) as Fe	mg/l	1	10	5	≤10 % variation on background dissolved iron concentration	1
Lead as Pb	mg/l	Ns	0.1	0.2	0.0002[##]	0.1
Manganese as Mn	mg/l	0.4	10	0.02[#]	0.37	0.37
Nickel as Ni	mg/l	Ns	23	0.2	Ns	0.2
pH	pH units	5.0-9.5	Ns	6.5-8.4	No more than 0.5 pH unit of 5% variation on background whichever is more conservative	6.5-8.4
Sodium as Na	mg/l	200	2000	Ns	Ns	200
Sulphate as SO4	mg/l	400	1000	Ns	Ns	400
Total coliform	count/100ml	10	Ns	Ns	Ns	10
Total solids - dissolved	mg/l	1000	1000	1775	No more than 15 % change from normal cycle and no change in amplitude and frequency of cycles	1000
Zinc as Zn	mg/l	3	20	1	0.0036	3

[1]WRC (1998) Quality of Domestic Water Supplies Volume 1: Assessment Guide, WRC Report No.TT101/98

[2] DWAF (1996) South African Water Quality Guidelines Volume 5: Agricultural Water Use: Livestock Water

[3]DWAF (1996) South African Water Quality Guidelines Volume 4: Agricultural Water Use: Irrigation

[4] DWAF (1996) South African Water Quality Guidelines Volume 7: Aquatic Ecosystems

NS Not Specified

[#]Irrigation guideline considered impractical. There are no human health affects associated with the concentrations stated

[##] Aquatic system guideline considered too stringent

Table 55: Surface water quality of the different sampling points

Parameter	Unit	Critical Guideline Value	Samples					
			Z5	Z4	Z3	Z2	Z6	Z1
			Xura River - Upstream of proposed dam site	First Tributary	Xura River - After confluence with Z4	Second Tributary	Xura River – After confluence with Z2	Downstream (Dam wall) of proposed dam site
(Nitrate and nitrite) as N	mg/l	5	2.50	2.40	6.00	1.70	2.80	2.70
Cadmium as Cd	mg/l	0.005	BDL	BDL	BDL	BDL	BDL	BDL
Calcium as Ca	mg/l	150	6.10	3.90	5.70	4.20	4.40	6.10
Chloride as Cl	mg/l	200	20.0	31.0	14.0	25.0	20.0	19.0
Chromium as Cr	ug/l	0.012	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Cobalt as Co	mg/l	1	0.0012	0.0012	0.0012	0.0012	0.0012	0.0013
Conductivity	mS/m	150	14.0	14.0	14.0	16.0	15.0	15.0
Copper as Cu	mg/l	0.003	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
E coli only	count/ 100ml	1	687	ND	770	816	613	ND
Fluoride	mg/l	1	<0.1	<0.1	<0.1	<0.1	<0.1	0.232
Hardness (calcium)	mg/l	Ns	15	9.7	14	10	11	15
Hardness (magnesium)	mg/l	Ns	28	19	26	21	21	28
Hardness (total)	mg/l	Ns	43	29	40	31	32	43
Heterotrophic plate count	cfu/100ml	-	384	272	631	452	608	ND
Iron (total) as Fe*	mg/l	1	5.33	4.36	5.33	4.36	3.41	5.38
Lead as Pb**	mg/l	0.05	0.0015	0.0015	0.0015	0.0015	0.0015	0.0016
Magnesium as Mg	mg/l	Ns	6.7	4.5	6.3	5.2	5.2	6.7
Manganese as Mn	mg/l	0.37	0.025	0.02	0.025	0.02	0.0099	0.027
Nickel as Ni	mg/l	0.2	0.0012	0.0011	0.0012	0.0011	0.0011	0.0012
pH	pH units	6.5-8.4	7.11	6.82	6.54	7.29	7.23	7.5
Potassium as K	mg/l	Ns	1.6	1	0.93	1	0.93	2
Sodium as Na	mg/l	200	12	12	12	14	9.6	13
Sulphate as SO4	mg/l	400	11	7.7	3.5	10	9.4	12
Total coliform	count/ 100ml	10	>2420	ND	>2420	>2420	>2420	ND
Total dissolved solids – (TDS)	mg/l	1000	71	87	73	78	76	73
Zinc as Zn	mg/l	3	0.07	0.06	0.05	0.07	0.04	0.08

ND: not done

BDL: below detection limit

*DWAF Drinking Water Standard: acceptable 1 mg/l; tolerable 5 mg/l

**DWAF Effluent Standard: 0.05 mg/l; International Guideline 0.05 mg/l

Careful consideration should be given to interpreting results from a single set of samples at any given point in time, especially when, as in this case, heavy rains have occurred, prior to sampling. Heavy rains could lead to the dilution of certain anions and cations in the water as well as to increased sedimentation, which could in turn lead to increased concentrations of certain metals *e.g*. iron and aluminium.

Although there are failures of the critical guideline values (**Table 54** and **Table 55**) for E. coli, total coli and iron, the surface water quality in the area is generally of good quality although it is not suitable for human consumption. The water is also not suitable for other domestic uses e.g. bathing and laundry as the E. coli and total coliform counts also exceed the guideline values for these uses. E. coli counts also exceeded the guideline values for livestock watering. The water is however suitable for irrigation. The high counts of E. coli and total coliforms observed could probably be attributed to inadequate sanitation or livestock.

Potentail human health effects from exposure to the level of pollutants present in the water at the time of sampling are given below.

E. coli: more than 20 counts per ml indicate a significant and increasing risk of infectious disease transmission. As faecal coliform levels increase, the amount of water ingested required to cause infection decreases (DWAF, South African Water Quality Guidelines Volume 1: Domestic Use, 1996).

Total coli: more than 100 counts per ml indicate a significant and increased risk of infectious disease transmission to the local community (DWAF, South African Water Quality Guidelines Volume 1: Domestic Use, 1996).

Iron: Concentrations between 1 and 10 mg/l will lead to pronounced aesthetic effects (taste) along with problems with plumbing. Slight health effect expected in young children and sensitive individuals (DWAF, South African Water Quality Guidelines Volume 1: Domestic Use, 1996).

As mentioned previously exceedance of E.coli and total coli counts of the critical guideline values could lead to increased risk of infectious diseases especially when water is used for drinking purposes. Hence treatment before consumption will be required.

As indicated previously, the slightly elevated iron concentrations could be ascribed to higher sediment loads after heavy rains.

A DWAF monitoring point in the Xura River was found downstream of the proposed dam area. When comparing the 90th percentile values of the different parameters contained in the DWAF water quality database for the Xura River (01/01/1970 – 31/12/2006) with the critical guideline values, none of the parameters exceeded the critical guideline values (**Table 56**). Iron, E.coli and total coli levels were not however measured.

Table 56: DWAF water quality of the Xura River (01/01/1970 – 31/12/2005) (http://www.dwaf.gov.za/IWQS/wms/data/pdf/t6h004q01.pdf)

Parameter	Unit	Critical Guideline Value	Number	90th Percentile	Maximum	Minimum	Median
Conductivity	mS/m	150	78	31.0	33.0	9.43	27.6
TDS	mg/l	1000	78	215	234	62.9	189
pH	pH Units	6.5-8.4	78	8.29	8.47	6.72	8.10
Calcium	mg/l	150	78	13.6	18.6	2.76	11.6
Magnesium	mg/l	Ns	78	15.7	16.8	2.74	13.0
Potassium	mg/l	Ns	78	1.27	2.26	0.44	0.95
Sodium	mg/l	200	78	22.3	24.7	7.86	19.8
Alkalinity	mg/l	Ns	78	103	123	16.9	87.5
Chloride	mg/l	200	78	27.0	32.2	5.20	23.4
Fluoride	mg/l	1	78	0.18	0.23	0.10	0.14
Sulphate	mg/l	400	78	12.7	25.1	2.00	6.10
Nitrate as N	mg/l	5	78	1.81	2.15	0.02	1.13

7.8 Water Quality Conclusions and Recommendations

Further monitoring is required to assess the seasonal variation in Iron, E.coli and Total coli of the flows into the proposed Zalu Dam.

It is recommended that sampling of the surface water in the area is performed more frequently prior to construction of the dam to establish background data and verify any seasonal variation.

8. RECONCILIATION OF WATER REQUIREMENTS AND AVAILABILITY

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

MAR for Xura River at Zalu Das site is 11,86 million m^3/annum. The ecological flow requirement for Xura River at Zalu Dam site is calculated to be 2,72 million m^3/annum. Water requirements for Lusikisiki Supply Area is 3,52 million m^3/annum. Total reserve (ecological flow requirement and water requirements for Lusikisiki Supply Area) for year 2030 is 6,24 million m^3/annum that is about 53% of MAR. **This means that in 2030 the surface water resources available at Zalu Dam site will have sufficient capacity to support consumptive requirements after the release of IFR.**

9. SUMMARY OF FINDINGS

9.1 Base Information

- The study area is located from Port St Johns to Mkambati at the coast. It therefore included an area of approximately 1 000 km^2.
- The area includes about 56 villages and town of Lusikisiki with a total estimated population of 120 000 people
- The area has high potential for development of commercial forestry plantation, tourism, and commercial dry-land agriculture. The potential for development of irrigation in the area is considered to be marginal.
- The mean annual precipitation is high, varying between 870mm and 1220 mm per annum.

9.2 Infrastructure

- The Lusikisiki Regional Scheme is the only water supply system in the area and provides water services to approximately 52 000 people.
- The level of water supply for the rural villages is below RDP standard.
- The parts of the scheme are in very poor condition, such as water treatment works and can not provide sufficient quantities of water.

9.3 Total Water Requirements Scenarios for the LRWS Scheme

- The water requirements were estimated for the consumptive users (domestic and industrial, agricultural and livestock) and for non-consumptive users (ecological). Low scenario would better represent the anticipated water use pattern in the study area. Therefore this scenario for the year 2030 horizon was selected for sizing of the scheme options. Based on the assumptions indicated in **chapter 4**, the total water requirements based on low water use scenario are as follows:

User Sector	**Net Water Requirements (10^6 m^3/a)**			
	2000	**2010**	**2020**	**2030**
Urban and rural domestic and industrial	0.86	1.42	2.28	3.52
Stock watering	1.321	1.321	1.321	1.321
Irrigation	0.009	0.191	0.290	0.378
Total use	**2.29**	**2.932**	**3.891**	**5.219**

- The total consumptive water requirements are estimated to be about 2.290 million m^3/a for the year 2000 and 5.219 million m^3/a for the year 2030

- The ecological reserve requirements for Zalu Dam site are conservatively estimated at 2.72 million m^3/a

9.4 Water resources

- The groundwater potential for the study area is estimated to be 2.3 million m^3/a in year 2030.

- The naturalized surface water mean annual runoff from the Xura River at Zalu Dam site is about 11.86 million m^3/a. It can be concluded that the total water requirements for the low water use scenario (consumptive and ecological) are substantially lower than the surface water available at Zalu Dam site. Therefore the proposed surface water resource, Zalu Dam would have sufficient capacity to meet requirements till year 2030 after release of the ecological reserve demand.

9.5 Water Quality

- The water quality in the upper reaches of Xura River is good and suitable for human consumption after treatment

- The water quality of groundwater is generally good

9.6 Accuracy of Study Results and Additional Information Required

- The purpose of this Study was to provide information whether surface water (namely the Zalu dam on the Xura River or a combination of surface water and groundwater) should be developed to augment the water supply for the Lusikisiki area.

- The domestic water requirements have been based on the DWAF water requirements, which are regarded as conservative.

- A total ecological reserve for the river downstream of Zalu Dam was based on the preliminary information obtained from the East Pondoland Basin Study. A Comprenhesive Reserve determination study needs to be conducted.

- Regional parameters for the T60F quaternary catchment are available from the WR90 report and the East Pondoland Basin Study, and were thus selected for rainfall/runoff modelling using WRSM2000. Gauging station T6H004 not far downstream of the site should be used for model calibration during feasibility study.
- The effluent discharges from the sewer treatment facilities should be monitored regulary. Compliance with relevant standards should be imposed.

10. CONCLUSIONS

The findings of the reconnaissance investigations undertaken during the course of the Lusikisiki Groundwater Feasibility Study Phase 2 Study indicate that the water shortages experienced at the LRWSS are due to the inadequate capacities of the two main components of the system – the water source, and the bulk supply infrastructure.

Water source

- Without provision for the release of the ecological Reserve, the existing water source (a weir on the Xura River) can supply the present and future (2030) low growth water requirements with assurances of 90% and 70% respectively.
- If provisions for the release of the ecological Reserve are made, the assurance of supply from the existing water source will be reduced to 70% and 50% for the present and future low growth water requirements respectively.
- The above indicates that irrespective of the ecological Reserve requirements, the capacity of the existing water source is insufficient to meet the water requirements at the guideline limit of 98% assurance of supply, and the water source should be augmented.
- If the ecological Reserve must be released as a matter of urgency, the water source should be augmented immediately, there would be no time for further studies, and a decision should be taken on the basis of the reconnaissance study results. If the ecological Reserve can be relaxed, there would be more time for further studies.
- The surface and the groundwater resources in the area have high potential for development and can be used for augmentation of the existing water source. Based on the results of the reconnaissance study, the following options for augmentation of the water source, capable of meeting the system's requirements at 98% assurance of supply, can be considered for implementation:
    - The most feasible storage scheme option is Zalu Dam.
    - The groundwater use option can be used to augment the system as a immediate short term measure utilizing drilled boreholes during Feasibility study Phase 1
    - The conjunctive surface and groundwater use option includes abstractions from the Zalu Dam, supplemented by the utilasiton of boreholes to be operated during times of low river flows.
- Despite the high MAR from the area, and due to the considerable seasonal variability of runoff, the run of river yields, available for abstraction in and around the study area with assurance levels of 98%, are low. In order to meet the water requirements at 98% assurance of supply, a storage scheme would be required.

Bulk supply system

- The capacity of the existing bulk water conveyance infrastructure is insufficient to supply the present water requirements and a shortage of about 30% is presently experienced. This infrastructure needs to be upgraded urgently.
- The bulk water conveyance system should be upgraded irrespective of whether the supply area of the scheme is extended or not. The requirements for the areas covered by the proposed extensions are relatively low (28%) when compared with those for the full supply area. The proposed future extensions may only influence to a limited extent the sizing parameters for upgrading of the bulk infrastructure, but not the decision to implement the upgrading.

11. RECOMMENDATIONS

- Upgrade the existing bulk supply system from the Lusikisiki weir to the command reservoir to meet the projected water requirements up to the year 2030. This is a common component for favourable augmentation options considered and can be regarded as the first phase of the augmentation of the water source. The upgrading will allow increased abstractions from the existing weir at least at times of high river flow. This action, combined with the proposed relaxation of the ecological releases (see bullet below) will result in an immediate improvement of the water supply situation of the existing scheme and will increase the assurance of supply from 70% to 95%.
- It is recommended that a more detailed feasibility study be commissioned in order to obtain more accurate information and to refine the results of the reconnaissance study. This study will allow the selection of the best development option with regards to the water source on the basis of updated information. The proposed feasibility study should include the following main components, and should address the uncertainties identified during the course of the reconnaissance study:
    - Ecological aspects (preliminary reserve determination, EIA associated with the proposed relaxation of the Reserve, detailed EIA report for approval of the proposed developments).
    - Engineering aspects and study co-ordination

GROUNDWATER RECOMMENDATION

- The successful boreholes that were drilled can be utilised as water supply sources and can be used in conjunction with surface water as part of the Lusikisiki water supply scheme;
- More research is needed to fully understand the geohydrology of the three main geological units, namely the Ecca, Dwyka and NGS. Only 30 boreholes were drilled in a very extensive area and the findings of this report are based on the results of those 30 boreholes. There are still a number of areas and targets that can be investigated and that might also produce high yielding boreholes; and finally
- The Lusikisiki Groundwater Feasibility Study can be seen as a benchmark study for all areas where a decision needs to be taken whether groundwater can be used as water supply source on a regional level. It is therefore recommended that all future groundwater feasibility studies be done in this manner.

Springs

Communities are still using springs despite proposed and existing water schemes and these springs are unprotected and are also being used by livestock for drinking. The communities must be educated in spring protection measures and in the prevention of contamination. In addition to proper education, formal spring protection construction needs to be done in the areas that cannot / will not be served by either borehole or surface water schemes. The villages that were excluded in the hydrocensus need to be included as part of further studies

Areas or aspects that should be considered for further investigation

The areas where there are still exploration options that should be considere for further attention, include:

- **deep drilling** through the Ecca, the Dwyka and into the Natal Group Sandstone. Borehole depths exceeding 150 m are envisaged. The deep drilling could be combined with drilling the regional dolerite dykes to intersect the dykes in depth, for example drilling through the Dwyka to intersect the fractured zones next to the dolerite dykes;

- drilling on **opposite sides of the regional dolerite dykes** and pump testing to determine the degree of impermeability of the dykes. In theory, another borehole can be drilled on opposite side of the dyke where borehole EC/T90/054 was drilled and the two boreholes could theoretically operate without significant impact on each other;
- the regional **dyke** that runs through the **Ecca** could not be located during the geophysical exploration and alternative methods or techniques such as grid drilling or specialised geophysical techniques should be considered to determine its yield and water quality prospects; and
- during the Lusikisiki Groundwater Feasibility Study areas or structures were identified that should be further investigative in more detail, one of which is a possible northeast - southwest fault in the area of borehole EC/T60/072 which is **not indicated on the geological map**. If the dip of the NGS is taken as being 2^0, borehole 072 should have penetrated the Dwyka and entered the NGS at approximately 50 m. The NGS was however only reached at a drilling depth of 148 m. The fault has been intruded by a dolerite dyke. Although successful, borehole EC/T60/072 can produce a higher yield if drilled through the Dwyka and into the NGS, penetrating the regional dyke on which borehole EC/T60/054 was drilled. The fault itself was also not drilled extensively and should also produce high yields.

ZALU DAM RECOMMENDATION

It is recommende that the following investigations have to be completed at feasibility level.

1 It is assumed that the same centreline can be used for both RCC and earthfill dam options, assuming that the top elevation is similar. One of the likely indications are that the size of the facility may increase. If this is so then a new common impoundment volume needs to be defined.

2 There are a number of development options to be considered. These are RCC only, earthfill embankment with clay core, earthfill with asphalt core, central section of RCC with spillway and earthfill flanks. For each option it must be possible to do a feasibility design sufficient to be able to discount the less favourable options.

3 The current state of the knowledge is that for the RCC option, some foundation drilling took place, but not enaugh and it is necessary to conduct some more geological investigations specificaly foundation and/or materials investigations.

4 The current state of knowledge for the earthfill option is that for the current dam height sufficient bulk fill materials have been identified. The previous studies have focused on softer earthfill type material solutions. It would equally be possible to construct some portions of the fill walls using harder quality material such as dolerite, more investigation is needed to confirm.

5 Sufficient geotechnical investigations have to be completed for both RCC and earthfill dam options so that both can be compared on a common basis.

6 For RCC the foundation investigation must be sufficient. The available investigation has to be reviewed in the light of the RCC option and then a decision must be made related to the level of additional studies required.

7 For RCC the construction materials investigation must be sufficient. This relates to the coarse and fine RCC aggregates. There is very little available information at this stage. One of the proposed activities must be to assess whether or not it will be possible to develop a suitable dolerite quarry say on the right flank within the dam basin, below full supply level. One of the available options then will be to use the

overburden material harvested for portions of the dam construction and then use the high quality dolerite to more effectively construct the RCC option. This is an option which requires investigation.

8 Suitable survey will be required. This is for all the engineering work (dam, spillway, inlet and outlet works) as well as for the reservoir basin.

9 Sufficient geotechnical foundation investigations are required for the defined dam options to be considered in the project. Foundation investigation here specifically refers to founding conditions as well as grouting conditions. As part of this work, attention should be given to whether or not the feeder dolerite dyke related to the dolerite sill is not located in a critical section of the dam.

10 Sufficient geotechnical materials investigations are required for the defined dam options to be considered in the project. Materials investigations here specifically refer to construction materials. RCC materials are aggregates and sand for RCC and the quantum of concrete works for the diversion works, inlet and outlet works; assuming that the spillway section of the dam will be RCC. Earthfill dam materials refer to the core, the shoulders, the filter drains, the rip-rap and the quantum of the concrete works for the diversion works, inlet and outlet works and the spillway. Previous materials investigations have been criticized in the Eastern Pondoland Basin Study report. It seems the original findings on borrow pits by HKS need to be re-assessed (see **paragraph 7.6**). The other sources of materials need to be defined and investigated as well. If higher dams with larger constructed volumes are to be considered, then the additional materials will have to be sourced.

11 If composite dams and or asphalt core dam is required, then specific investigations for these will also be required if not already covered by the other studies.

12 Specific investigations will also be required for the related facilities such as access roads, construction village if this is relevant.

12. DESCRIPTION OF THE REGIONAL DEVELOPMENT OPTIONS

The existing infrastructure of the LRWS scheme is shown in **Figure 10**. The following sections describe the development schemes considered as options for possible augmentation of the water source for the LRWS. Each scheme consists of a water source and the corresponding primary conveyance system connecting the source to the users over the enlarged supply area. General layout of project area is attached as Fig 1 appendix 7.

12.1 Surface Water Storage Scheme-Zalu Dam (Fig 4, Appendix 2)

All surface water storage option have been sized to meet the total water requirements of the study area as stand-alone schemes. The water will be pumped from the abstraction point to the WTW and then further to a new main storage reservoir located next to the existing reservoir A. The existing capacities of the primary conveyance infrastructure will be utilised and where necessary increased. The distribution network will be extended.

12.1.1 Option 1: Zalu Dam, Xura River Rollcrete Dam (**Fig 5 & 6 Appendix 2**)

Zalu Dam was investigated in the past by HKS (1980). Detailed geological and materials investigations were undertaken, and it was proposed that an embankment dam with a gross storage capacity of 13.69 million m^3/a be constructed. The dam was sized to supply the domestic requirements for the town of Lusikisiki and five administrative areas (Zalu, Ngobozana, Mevena, Dubana, Xura), as well as the irrigation requirements for an area of approximately 430 ha.

A rollcrete dam structure with a central ogee spillway is considered to meet the 2030 supply requirements of 5.22 mill. m^3/a and the reserve requirements. A dam with live storage 13.69 million m^3 is required.

Two main options with regards to the conveyance system from the dam outlet to the water treatment works have been considered:

- The water will be lifted by a new raw water pump station (static head – 6 m), located at the dam outlet works (Fig 7 & 8, Appendix 7), through a 6 000 m long raw water rising main to the upgraded WTW (Fig 3, Appendix 7). An option for conveyance under gravity was also investigated (Fig 2, Appendix 7), but found to be unfavourable (due to the small elevation difference between the dam outlet and the WTW the costs associated with a required large size gravity main are high). A number of possible conveyance routes were evaluated and the best route selected.
- The water will be released into the river and then abstracted at the existing weir site. The raw water will be lifted by the upgraded raw water pump station (static head 52 m) through a 650 m long raw water rising main to the WTW.

In both cases the water is pumped by an upgraded clear water pump station (static head 57 m) from the upgraded water treatment works to a new bulk storage reservoir, through a 2,120 m long clear water rising main.

12.1.2 Option 2: Zalu Dam, Xura River, Embankment Dam

Due to potential non availability of material for the RCC dam, the embankment dam with a side and central spillway was considered.

The conveyance systems will be the same as per option 1.

12.1.3 Option 2A: Zalu Dam, Xura River, Rockfill Dam (Fig 9 & 10, Appendix 2)

Rockfill Dam with central and side spillway has been taken into consideration. The rockfill dam consists of the clay core with composite filters. Slopes of the upstream face are estimated at 1 :1.75 and downstream face 1 :1.6.

Detailed analysis of most suitable slopes will have to be conducted after materials investigations and laboratory test are completed.

12.1.4 Option 2B: Zalu Dam, Xura River, Earthfill Dam (Fig 12, 13 & 14, Appendix 2)

Earthkfill Dam with central and side spillway has been taken into consideration. The earthfill dam consists of the clay core with composite filters and filter blanket downstream. Slopes of the upstream face are estimated at 1 :1.3 and downstream face 1 :2.5 Rip-Rap to be installed at upstream face for slope protection.

Detailed analysis of most suitable slopes will have to be conducted after materials investigations and laboratory test are completed.

12.2 Conjunctive Use of Surface and Groundwater Resources

Groundwater developments can be used to supplement the supply from run of river schemes at times of low flows and in this manner to increase the assurance of supply to acceptable levels. These options offer higher assurance of supply than the run of river schemes, but at higher capital and running costs.

12.2.1 Option 3: Lusikisiki Weir in conjunction with groundwater (98% assurance of supply)

The run of river option has been used as the basis for this scenario. In addition to the infrastructure described in Section 8.2, provision has been made for the development of ground water sources and conveyance infrastructure to supply 40 l/s net, being the difference between total scheme requirements (72 l/s net) and the run of river yield at 90% assurance (32 l/s net). In order to reduce the O&M costs associated with the groundwater supply, the surface water scheme has been sized to supply the full demand at times of high flows. The ground water sources will be used to provide the incremental demand only during drought periods.

The groundwater supply infrastructure will consist of the following components at each borehole (total net supply of 40 l/s): A submersible pump driven by a diesel engine, a pump house, a rising main, a storage reservoir and an access road (track). Due to the uncertainties with regards to the actual position and total yield of the boreholes, certain assumptions have been made with regards to the average characteristics of the conveyance infrastructure per borehole (yield, pumping head, access, conveyance length, storage).

12.2.2 Imidiate Augmentation Measures: Lusikisiki Weir in conjunction with Groundwater (95% assurance of supply)

This option is similar to option 3, but the run of river scheme consists only of the existing Lusikisiki weir and its primary conveyance infrastructure. The existing surface water conveyance infrastructure (clear and raw water pump stations and rising mains, water treatment works, and main storage reservoirs) will be utilized to a full potential to supply scheme requirements (32 l/s net). In addition, provision has been made for the development of ground water sources and conveyance infrastructure to supply additional 14.78 l/s net (the full demand, as no yield at 95% assurance is available at the weir).

The groundwater supply infrastructure will consist of the following components at each borehole (total net supply of 20.88 l/s): A submersible pump driven by a diesel engine, a pump house, a rising main, a storage reservoir and an access road (track).

Following boreholes will be equipped and utilized to augment existing network; EC072; EC 055; EC 054 with a total yield of 13.7l/s. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir B.

Boreholes EC 052; EC 051 and EC 078 with a total yield of 7.18l/s will be equipped and utilized to augment existing network. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir and new reservoir to be constructed for the extension of the existing network..

Table 29: Summary of Development Options

Option	Water Source	River	Assu-rance	Primary Conveyance system
1	Zalu dam (RCC) Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPs -CWRM to Res. A -New reservoir adjacent to Reservoir A
2	Zalu dam (earthfill) Surface water storage	Xura	98%	-RWPS at dam outlet (all components 72 l/s) -RWRM to existing WTW -Upgrade WTW and CWPs -CWRM to Res. A -New reservoir adjacent to Reservoir A
3	-Lusiksiki weir In conjunction with groundwater (72 l/s) Conjunctive water use scheme	Xura	98%	-RWPS at weir (72 l/s) -RWRM to existing WTW (72 l/s) -Upgrade WTW and CWPS (72 l/s) -CWRM to Res. A (72 l/s) -New reservoir adjacent to Reservoir A -Groundwater infrastructure (total 72 l/s)

13. FACTORS AFFECTING DEVELOPMENT

The reconnaissance level investigations were undertaken as a desktop study, mainly on the basis of existing topographical, geological and environmental information, supplemented by site visits by specialists in all related disciplines (planning, conveyance, dams, geology, materials, environmental and social, water quality). This section outlines the observations from the site visits.

13.1 GEOLOGY AND MATERIALS

Detailed information regarding the engineering geological conditions and the availability of construction material for Zalu Dam is indicated under item 7.5.
The study area is underlain by sedimentary strata of the lower Karoo Supergroup. This group comprises of mudrocks of the Ecca Group, and underlying tillite of the Dwyka Group. This sedimentary sequence has been intruded by younger dolerite dykes and sills, which comprise up to 40 % of the sequence within the Ecca mudrocks, but significantly less within the tillites. The strata are essentially sub-horizontal. No major regional-scale faults are recognized in the area and no economically important mineral deposits occur.

13.1.1 Zalu Dam Site

The geological conditions at Zalu site have been investigated in the past Hill Kaplan Scott [8, 9], when 28 exploration boreholes were drilled and a detailed soil survey of potential borrow pit areas including laboratory testing was conducted. The site is located about 11 km north-west of Lusikisiki. It is asymmetrical; the left flank is relatively gently sloping (1:7), while the right flank is steeper (1:2,5). The river section is approximately 80 m wide, at an elevation of approximately 586 m above msl.

The site is underlain by dolerite sills. Within the river section the dolerite is at least 35 m thick, overlaid by alluvium layer of up to 5 m. The mid to lower left flank and most of the right flank are underlain by this dolerite sill, while the upper left flank is underlain by weathered siltstone. Soil cover is expected to be up to 5 m thick, although extensive dolerite outcrops occur on the lower right flank.Founding conditions are suitable for a concrete gravity structure with a central spillway. Alternatively, the poorer founding conditions on the upper left flank might favour an embankment, with a concrete structure for the remainder of the section. For a concrete structure, excavation depths are likely to vary between 5 m on the left flank (underlain by dolerite), 3 – 4 m in the river section and 1 - 4,5 m on the right flank (where underlain by dolerite). Deeper excavations will be necessary on the upper flank areas underlain by weathered siltstone (up to 15 m). Embankment cut-off depths are expected to vary between 2 – 5 m on the left flank, 3 – 4 m in the river section, and 1 - 4,5 m on the right flank.

A source of coarse aggregate / rip-rap / crusher sand has not yet been investigated. No suitable natural sand reserves were identified. In all likelihood, crusher sand will have to be used. Previous investigations identified the red clayey dolerite soils as a source of impervious core material, and fine-grained soils from siltstone and alluvium as semi-pervious transition material.
A review of these investigations by the Council of Geoscience in the EPBS has however placed some doubt on the original findings. The concerns will have to be resolved.

Table 30: Summary of Geological Characteristics at Dam Site

	Zalu Site
Topography	Asymmetrical gently sloping left flank (1:2.5). River section approximately 80 m wide
Geology	Upper left flank underlain by weatheredsiltstone, mid to lower slopes underlain by dolerite silt. Soil cover 2-5 m Alluvium in river section 5 m thick, overlying unweathered dolerite sill with minimum thickness 35 m. Right flank underlain by unweathered dolerite. Soil cover up to 5 m thick
Dam type	Max height envisaged 35 m. Crest length 320 m. Suitable founding for concrete gravity dam, or composite structure with embankment left flank and concrete river section and right flank
Likely excavation depths	For concrete structure, depths between 5 m on mid to lower left flank. 3-4 m in river section. 1-4.5 m on right flank. Much deeper on upper flanks underlain by siltstone. Cut off depth for embankment 2-5 m
Construction material availability	Possible dolerite body for coarse aggregate, rip-rap, crusher sand. Previous investigations considered clayey dolerite soils for impervious core, soils from siltstone / alluvium for transition zones. Later review by the Council of Geoscience in the EPBS puts these findings in doubt.

13.2 Environmental Impact Assessment of Zalu Dam Site

This section outlines the findings of the investigations related to the assessment of the potential site-specific environmental impacts (and their management) associated with the dam development options. More detailed information is available in the supporting report **Environmental Evaluation: Scoping Report**, (Eastern Pondoland Basin Study) issued in terms of the Environmental Conservation Act, 1989. The proposed plan of study was submitted and approved by the Eastern Cape Department of Economic Affairs, Environment and Tourism (DEAET).

The investigations were based on available data and maps as well as on information obtained during two field visits. A specialist visit to the five proposed dam sites was carried out during the reconnaissance stage of the study. More detailed investigations, including a botanical survey were undertaken during the pre- feasibility phase for the Zalu site.

Information was collected on the habitat integrity of both the riparian and instream components of the affected river reaches along the Xura River. The data was used to determine the ecological importance and sensitivity, as well as the present ecological status of the relevant reaches. These assessments allowed the determination of the ecological management classes of the river reaches within the study area as well as the conservation value of the inundated and affected areas.

The socio-cultural component of the investigation was limited to assessing the dependence of the population on the river and the associated natural resources as well as the cultural and historical value of the sites.The preliminary “socio-cultural“ assessment indicated that dam construction at Zalu site will not result in significant social impacts.

It was found that the natural features at the proposed dam site have been largely modified by the activities of man. The natural riparian vegetation at the site indicates a large to serious degree of degradation due to harvesting of firewood and building material, bush-clearing to create cultivated fields and destructive burning practices. No rare or endangered plant or terrestrial animal species were found at any of the sites. The degree of disturbance and habitat destruction makes it unlikely that any rare or endangered fauna, and possibly even flora, are present in these areas.

The apparent absence of any natural, cultural, or aesthetic features of outstanding value at the dam site indicates that there will be no significant site-specific impacts as a result of the proposed developments. No "fatal flaws" were identified at the site and there were also no distinct "preferred options" from the environmental point of view.

A summary of the evaluation of the negative environmental impacts associated with the construction of dam at the proposed site is provided in **Table 31**. The other options (run of river, conjunctive and ground water) considered during this study, will result in negligible site specific environmental impacts.

More significant potential negative impacts associated with water abstractions applicable to dam from the river will be related to the sensitive and valuable ecosystems downstream of the proposed site. These constraints will probably have a greater influence regarding the choice of a preferred option than any site-specific environmental considerations.

Table 31: Summary evaluation of negative environmental impacts associated with the construction of Zalu dam

L = low; M = medium; H = high; N = negligible; Mitig = extent of impact with mitigation; ? = uncertain, more data required

Environmental Impact Description	Zalu Site	
	Extent	Mitig
Loss of vegetation, particularly rare or endangered species, due to inundation	M	M
Loss of rare or endangered terrestrial fauna, due to inundation	L	L
Loss of rare or endangered aquatic fauna, due to inundation	M	M
Loss of valuable natural riparian resources used by locals, due to inundation	L	L to N
Loss of cultural or historic sites of value	L	L
Loss of special or spectacular natural features, aesthetically valuable areas	L	L
Potential impacts on valuable natural systems downstream (estuary, gorge)	M	L
Impacts of "associated development"	M	L to N
Socio-economic factors, e.g. inundation of cultivated lands, access roads and houses	L	L

13.3 Social Impact Assessment

The potential social impacts associated with the construction of Zalu Dam were initially identified on the basis of desktop studies and literature reviews. The extent of inundation and possible loss of access were initially quantified on the basis of 1:10 000 topographical maps and recent aerial photographs. The information was later refined during field visits and interviews with various institutions and stakeholders with extensive local knowledge.

The following main social impacts for development of Zalu Dam were evaluated.

- **Relocation of people due to inundation:** No relocation is required for construction and inundation of Zalu Dam and lake.
- **Loss of land (arable and grazing):** The loss of grazing land for construction of Zalu Dam and inundation of the lake will be in a range of 100 ha. The loss of arable land is considered to be moderate, varying between 23 and 50 ha.
- **Loss of access:** Low impact on Access. If the road is constructed over the dam the access for the communities will be improved
- **Loss of archaeological and historical sites:** No sites of importance were identified at the proposed development site.
- **Loss of religious and cultural sites:** No sites of importance to the communities will be lost to inundation at the proposed development site.
- **Loss of natural resources:** It has been confirmed that the dependency of the population on natural resources within the inundated areas is insignificant.
- The positive impacts due to the proposed development. These will include the following main benefits:
- Boost of regional economy due to inflow of capital
- Creation of employment opportunities
- Training and empowerment of labour force and local contractors
- Improvement of infrastructure and services (water, roads, electrical, telkom)
- Recreation and conservation opportunities
- The results of the social impact assessment during the reconnaissance stage of the study are summarised in the following table.

Table 32: Significance of negative social impacts due to Zalu Dam development

Dam size	Relocation of people	Loss of land	Loss of access	Loss of natural resources	Loss of historical and cultural sites
Zalu site Xura River	N/A	23 ha arable 5 ha grazing L	L	L	L

In general, the negative social impacts related to the proposed dam development are low to moderate and will most probably be less significant than the positive impacts.

The negative social impacts related to the development of the other option (run of river, conjunctive and ground water) will be even lower than the ones for the dam options. It should however be noted that the local population has had bad experience with groundwater developments in the past (low assurance, frequently malfunctioning, poor water quality, complicated operation and maintenance, etc). It is likely that groundwater options will not be favoured by the local population and may even be opposed.

Table 33: Summary of Negative Social Impacts for Zalu dam site

Impact	Unit	Zalu
Relocation of households	no.	0
Relocation of roads and infrastructure	km/cost	0
Loss of arable (cultivated) land	ha	23
Loss of grazing land	ha	5
Loss of natural resources	L/M/H	Low
Loss of specific religious or cultural sites	L/M/H	Low
Loss of historical / archeological sites	L/M/H	Low
Graveyards and possible relocation	no.	0

13.4 Water Quality Issues

Water quality at Zalu dam Site were indicated in **Item 7.7** of this Report.

Upstream impacts

The upper catchments of river system are well vegetated and rural villages are generally confined to the hilltops. Village water resources are local springs and small catchment dams (earth). Little reliance is placed on groundwater as generally the yields are low (<0.2 l/s), and the boreholes are very deep. In areas where pools form in the rivers, cattle drink and village women congregate to wash clothes. On washdays soap and rinse water may extend for 200 – 300 m downstream, but the total impact on the system appears to be small. Competition for limited water resources (washing by the community and drinking water supplies for a hospital or clinic) has lead to disputes over the right to use the water.

Downstream Impacts

The region adjacent to the Xura River between the Lusikisiki site and the Xura site is more urbanized than the upper catchment. This region consists of the urban town of Lusikisiki and several satellite villages, but other than the abstraction of about 1million m^3/a of raw water from the abstraction weir at the Lusikisiki / Flagstaff road bridge, there are no additional impacts on the river. Return flow from the sludge pond at the water treatment works enters the river, discharging below the intake weir.

Downstream of the Xura dam site, the Lusikisiki River enters the Xura River and, at this point, there is a marked impact on the water quality in the Xura River as a result of urban runoff and a poorly operated sewage treatment works, which impact on the Lusikisiki River water quality. These works are listed in **Table 34**.

Table 34: Site sources of urban runoff and sewerage treatment works

Water User	Capacity	Treatment Facility
Lusikisiki Teachers Training College	90 m³/day	Oxidation ponds
St Elizabeth’s Hospital	120 m³/day	Oxidation ponds
Lusikisiki Transitional Local Council	280 m³/day	Septic tanks and managed wetlands
Lusikisiki old prison	10 m³/day	Oxidation ponds
new prison	60 m³/day	Oxidation ponds
Vocational School	20 m³/day	Septic tank

With the exception of the Lusikisiki Teachers Training College, all works currently discharge effluent into the Lusikisiki River (small tributary of Xura to the north of, and adjacent to the town of Lusikisiki). The effluent does not comply with the general standard for effluent discharges and at low river flows there is likely to be a severe impact on water quality. Any further reduction of the existing downstream flows due to increased abstractions may result in significant degradation of the water quality.

Water Quality Concerns in the Impoundments

Proposed Zalu dam is approximately 25 m in height at the dam wall and it is therefore likely that summer stratification of the reservoirs will take place. In the initial stages of development, this will probably lead to a de-oxygenated hypolimium as the residual vegetation rots. After stabilisation, the degree of de-oxygenation, if any, will depend on the response of the new reservoir to nutrient inputs and release of nutrients from the littoral areas. The available information suggests that the turbidity of the impounded water is likely to be low and as a result light penetration will be good. This will allow numerous algal species to take advantage of any nutrients present. In the initial development of any of the reservoirs there are likely to be severe algal blooms, but after stabilisation the system response will depend on adequate control of nutrients from diffuse runoff.

Proposed Locations of Water Quality Sampling Points

The regular collection and testing of water samples will contribute to obtaining more reliable results from future investigations. To evaluate the water quality for the proposed Zalu dam site, the routine collection of raw water samples at the abstraction weir for the water treatment works will be adequate.

13.5 Institutional Arrangements for O&M

The local government acts as a Water Services Authority. Due to the remoteness and the lack of capacity within the area it will be preferable to select a regional scheme. This may warrant the involvement of a specialised service provider, who will also provide support at village level.

Two Water Services Providers (WSP) are envisaged for this regional scheme. Although the WSPs may be responsible for their own respective portions of the scheme, there would be a need to develop a forum for communication between the respective WSPs. The WSA would need to have representation in this forum. It is envisaged that the two WSPs will be instituted to operate and maintain the regional scheme in the rural areas on the following two levels:

Bulk level: Due to the complexity of the infrastructure to be installed, skilled operators with appropriate support are required to operate and maintain the scheme. It is therefore anticipated that Local Government will transfer the scheme to the WSA. The WSA may elect to operate and maintain the scheme itself or it may instruct a Support Services Agent (SSA) to undertake this task on its behalf.

Village level: It is envisaged that local Water Committees would be responsible for operation and maintenance of the reticulation network within the respective villages.

The number and make-up of these committees would need to be finalised in conjunction with the respective communities and the WSA.

The dam options will be preferable from O&M point of view. The primary infrastructure will be compact in terms of location and number of major components (dam outlet, WTW and main reservoir), requiring less complex institutional structure and lower operating costs.

The groundwater supply options will require the most complex institutional structure in order to ensure the sustainability and reliability of the scheme at the same level as for the other options. It is estimated that a total number of 160 boreholes will be required by the year 2030. The operation and running costs for this option will be substantially higher than for the other options.

14. RECONNAISSANCE SIZING AND COSTING

This section describes the methodology applied for the reconnaissance level of sizing and costing of the development options and should be read in conjunction with **Section 8**, which describes the infrastructure components for each development option. The layouts of the development options are shown in **Figures 1 to 18** Appendix 2.

Initially, all options identified in **Section 12** were evaluated in broad terms based on their technical and economic viability, taking into account the supporting factors affecting the developments (**Section 13**).

All major components of the remaining options have been sized and their costs estimated at a reconnaissance level of detail, in accordance with the criteria specified below. The sizing has been done for the 2030 horizon for water requirements. No optimisation of the system components has been done at this stage.

A summary of the estimated capital costs for all options is provided in **Table 10.5**. The basic schedules of quantities and cost models are attached in **Appendix J**.

14.1 General Sizing Criteria: Design Capacities and Flows

The sizing flows for the main infrastructure components are shown per development node in **Appendix I**. These flows have been established in accordance with the RDP Rural Water Supply Design Criteria Guidelines (DWAF, October 1997). The criteria used are summarised in the table below.

Table 35: Design capacities and flow rates for sizing of infrastructure components

System component	Demand definition	Sizing criteria
	Sizing criteria	
Surface water source: dam	Gross Average Annual Daily Demand (GAADD)	AADD * (1+LFr)
Water treatment works and raw water pump station	Summer Daily Demand (SDD)	SPF * GAADD * (1+LFw)*24/Op Per.
Clear water bulk pipelines, run of river source	Summer Daily Demand (SDD)	SPF * GAADD
System reservoir storage		AADD * Hours
Borehole & clear water pump stations	Summer Daily Demand (SDD)	SPF * GAADD*24/BH operation period
Village reticulation	Design Peak Flow Rate (DPFR)	GAAD*SPF*DPF
	Selected values	
Parameter	**Parameter**	**Selected values**
Conveyance loss	LFr	10%
Water treatment loss	LFw	10%
Summer Peak Factor	SPF	1.5
Operating period: WTW	Hours per day	20
Daily Peak Factor	DPF	2
Reservoir capacity: Single Source	Hours	48
Reservoir capacity: Multiple Source	Hours	36
Min flow per standpipe	Litres per minute	10
Operating period boreholes	Hours per day	12

14.2 Zalu Dam

Sizing

The Zalu Dam was sized and costed in accordance with the "Guidelines for Preliminary Sizing, Costing and Engineering Economic Evaluation of Planning Options" (DWAF, 1996) [33] established for the Vaal Augmentation Planning Study (VAPS). Zalu Dam was sized to meet the total water requirements of the study area at year 2030 design horizon **(Section 4).**

The type of dam was selected on the basis of the geological conditions, topography, possible spillway arrangements and availability of construction material (**Section 8**). The Zalu Dam wall was sized as mass concrete (rollcrete) structures and earth embankment with a side spillway.

The cross section parameters were established in accordance with the VAPS guidelines. For concrete dam sections: crown width at non-overspill crest level (NOCL) 5,0 m, wet slope vertical, dry slope 1: 0,75. For earthfill dam sections: crown width 10 m, wet slope 1: 3, dry slope 1: 2,5. The typical sections for dams and weir s used for costing purposes during the reconnaissance stage of the study are shown in **Appendix 2**.

The excavation depths were determined according to the results of the geological investigations (**Section 9.1**). Allowances for aprons, intake and outlet works, and foundation drilling and grouting were provided for costing purposes in accordance with the VAPS guidelines. In each case, the live storage was determined from the yield-capacity curves derived on the basis of the firm yield analysis **(Section 7.1)**. The total required storage was then= established by adding the necessary sediment capacity (20 year sediment yield) and dead storage (10% of live storage). The full supply level (FSL) for Zalu Dam was determined from the area-capacity relationships.

The design floods for sizing of the spillways were established in accordance with the Guidelines on Safety in Relation to Floods (SANCOLD, Report 4, 1991). Zalu Dam were classified as Category III safety risk: medium size class (12 to 30 m) and high hazard rating, in accordance with Table 2.3. The recommended design discharge (RDD) was determined from Table 5.1 and the safety evaluation discharge (SED) from Tables 5.2 and 5.3. The design floods used for sizing of the spillways are shown in the following table.

Table 36: Design and Extreme Floods for Sizing of Dam Spillways

Flood	Flood Description	Zalu m^3/s
Q_{50}	50 year flood peak discharge	337
Q_{100}	100 year flood peak discharge	420
Q_{200}	200 year flood peak discharge	505
RMF	Regional Maximum Flood	1 000
RDD	Resource Design Discharge	505
SEF	Safety Evaluation Discharge	1 405

The spillway types were determined by site-specific geological and topographical conditions. The freeboards were sized in accordance with the VAPS guidelines, which specify the recommended design discharge (RDD) and safety evaluation flood (SED) to be used for sizing of the wet and total freeboard respectively. The Gorgen's formula was used to make a provision for the flood attenuation effects of the dam basins. The sizing parameters used for costing purposes are summarized in the table below.

Table 37: Sizing Parameters for Dam

Parameter	Zalu
Type of dam	Concrete, Embankment
Type of spillway	Central, side
River	Xura
Catchment area (km²)	71
Live storage (10^6 m³)	3.13
Sediment yield storage (10^6 m³)	0.8
Dead storage (10^6 m³)	0.31
Total storage (10^6 m³)	4.24
Bed level (m above msl)	386.0
Free board (m)	3.5
FSL (m above msl)	606.7
NOCL (m above msl)	610.2
Depth to FSL (m)	242
Spillway length (m)	100

Capital Cost Estimates

The capital costs for Zalu Dam have been estimated on the basis of the cost models established for VAPS [33]. The basic material quantities used in the models (excavation, drilling and grouting, volumes of concrete and earthfill, etc) have been determined in accordance with the sizing criteria described above. Allowances for mechanical items have been made.

The capital costs were estimated at March 2006 price levels. The unit rates were escalated using the published consumer price indices. The cost models for the dams and weirs are attached in **Appendix J2**.

14.3 Groundwater Development

As described in **Sections 12.2**, groundwater resources are being considered for ttwo development options – 1 and 2 (conjunctive use options). The sizing parameters for the groundwater source development Option 1 and 2 as well as for the associated infrastructure are specified in the above-mentioned sections.

Groundwater Development Option 1 (Reconosance level)

Certain assumptions have been made for the purposes of cost estimates. Based on the results of the Lusikisiki Groundwater Feasibility Study Phase 1 studies, it has been assumed that the boreholes in the area will have an average net yield of 1,5 l/s, borehole depth of 80 m, with recommended pumping time of 12 hours per day. The average siting and drilling success rate has been assumed to vary between 65% and 80%. The conveyance infrastructure has been assumed to include the following components at each borehole:

- A submersible positive displacement pump driven by a diesel engine, housed in a pump house
- 3,3 km of rising main connecting the borehole to the secondary conveyance system
- Balancing reservoir with a capacity of 30 m^3 at a command position
- 1,0 km of access tracks

The capital costs associated with the development of the boreholes have been estimated on the basis of information obtained from similar projects. The estimated costs for installation of equipment and conveyance systems have been added. Taking into consideration the sizing criteria (**Section 10.1**), the cost for the supply of 1 l/s of the AADD (72 l/s) by groundwater is estimated to be R800 000. A detailed description of the cost components and assumptions is provided in **Appendix 5**.

Immediate Groundwater Development Option 2 (Feasibility Level)
Boreholes EC072; EC 055; Ec 054 with a total yiel of 13.7l/s. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir B.

Boreholes EC 052; EC 051 and EC 078 with a total yield of 7.18l/s will be equipped and utilized to augment existing network. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir and new reservoir to be constructed for the extension of the existing network.

Estimated costs can be summarized as follows:

14.4 Primary Distribution System

Sizing
The layouts of the primary conveyance system associated development option are shown on **Figures 17 and 18.** The system components are described in detail in **Section 12**. Each option will include some or all of the following components.

- Raw water pump station (RWPS)
- Raw water rising main (RWRM) or raw water gravity main (RWGM)
- Water treatment works (WTW)
- Clear water pump station (CWPS)
- Clear water rising main (CWRM)
- Main storage reservoirs (MSR)
- Clear water gravity man (CWGM)
-

All components have been sized in accordance with the applicable design flow criteria shown in **Table 10.1**. A number of possible route locations for each development option have been investigated and the best route has been selected for sizing. The conceptual longitudinal profiles for selected pipeline routes are shown in **Appendix 2**.

The gravity mains have been sized on the basis of available head, while the pumping mains have been sized on the basis of optimal velocities (in the order of 2 m/s). No optimisation of the pipeline/pump system on economic principles has taken place during the reconnaissance phase. A provision for 50 % standby capacity at all pump stations has been made.

The position of the main storage reservoirs has been selected to be at command points (in terms of elevation) allowing the feeding of the secondary distribution system by gravity.
The reservoirs have been sized for 24 hours of storage capacity.

Capital Cost Estimates
The water treatment process has been assumed to include flocculation, settling, sand filtration and chemical dosing.

The costing of all components has been done using cost models, based on all- in-one costs per metre of pipeline of specific type and size (gravity and rising mans), kW of installed power (pump stations), m^3 of treated water (WTW) and m^3 storage capacity (reservoirs).

The cost models have been established on the basis of actual costs for projects implemented in similar areas and are considered to be reasonably accurate. The cost models are attached in **Appendix 6**.

14.5 Summary of Capital Costs

A summary of the estimated capital costs for the various development options is provided in the table below. More details are available in **Appendix 5 .** The capital costs have been estimated at March 2006 price levels and include provisions for P&G, contingencies, professional fees and VAT.

Table 38: Capital Cost Reconnaissance Phase March 2006

Option No.	Development Option	Capital Cost Water Source (R Millions)	Capital Cost Conveyance (R millions)	Total Capital Costs (R millions)
1	Zalu dam. Conveyance from outlet	52,887.836	25,869,794	78,757,630
2	Zalu dam. Conveyance from weir	52,887.836	18,401,586	71,289,422
3	Conjunctive scheme (98% assurance)	63,893,333	18,401,586	82,294,919
4	Immediate Measures (95% assurance)	14,376,000		

A sensitivity analysis of the capital costs for various demand scenarios (high and medium, **Section 14)** has been undertaken. This has confirmed that the cost rating of the options does not change.
The economic evaluation taking into account the operation and maintenance, running costs and residual values for all options is discussed in **Section 14**. Based on the available information it was not possible to make a decision on the preferred option. More detailed investigations were therefore undertaken, and are described in the following section.

SECTION C: PRE-FEASIBILITY PHASE

The costs (estimated at a preafisibility level of detail) for the Zalu Dam type are very similar. The difference in the capital costs is well within the margin of inaccuracy of the costing models Further geological investigations, availability of material topographical surveys, and more detailed conceptual design and costing will be required to facilitate a more accurate comparison between the two dam type options. The additional studies undertaken for the Zalu dam type options are discussed in this section.

15. FEASIBILITY INVESTIGATIONS FOR ZALU DAM

15.1 Topographical Surveys

A number of possible cross sections at both dam sites were surveyed to a scale of 1:1 000 and the survey plans are attached in **Appendix 7**. This has facilitated the selection of the best dam centreline for each option, and has allowed for more accurate measurement and costing.
Both dam basins were surveyed and maps to a scale of 1:5 000, with contour interval of 1 m were produced (**Appendix 7**). This has facilitated the refinement of the area-capacity relationships, which are attached in **Appendix 7**.

15.2 Geological and Materials Investigations

Detailed geolo gical information, based on extensive exploration drilling (26 boreholes), sampling and laboratory test analysis is available for the Zalu site. The results of the geological investigations are detailed in **item 7.7** of this report.
The river section is wide for the Zalu site approximately 80 m.The founding conditions at the Zalu site, imply great flexibility in terms of structure type and configuration.
The founding conditions at the Zalu site are considered suitable for both embankment and concrete structures. An embankment dam might also be considered at the Zalu site, with spillway options including a side-channel or morning glory and conduit combination,
The founding conditions at the Zalu dam site are also reflected in the expected excavation depths between 3 m and 4 m (which only comprises the removal of alluvium). At higher levels on the left flank, however, a concrete structure would require deeper excavation to ensure founding on unweathered dolerite.
In terms of construction material availability, no hard rock quarry site for coarse aggregate / riprap has yet been proven.
The abandoned dolerite quarry currently recognized as the most likely source is 4 km from the Zalu site. Furthermore, if an embankment dam is favoured at the Zalu site, together with a side-channel spillway, then these spillway excavations might produce suitable material. Sources of embankment construction materials have been identified at the Zalu dam site,

15.3 Stochastic Yield Analysis

The historic yield analyses for all proposed dam site were performed. Stochastic yield analysis for the Zalu site were undertaken in order to confirm the levels of assurance associated with the supply of the yields, which are used for sizing of the dam.
The stochastic yield analyses were performed for three different full supply capacities, and dead storage volumes. Two hundred and one flow sequences with a length of 77 years each were used for the stochastic runs. The results are represented by risk.
The analyses have confirmed that the capacities of the dam used for sizing of 4.24 mill m^3 will generate the required gross yield 2.667 million m^3 with assurance levels exceeding 98%. The results of the firm yield analysis are given in Tables 8.6 and 8.7 (**Section 8**). The yields calculated for the different capacities include the IFR releases.

16. PRE-FEASIBILITY CONCEPTUAL DESIGN AND COSTING

More detailed sizing and costing for the Zalu dam option were undertaken during the pre-feasibility stage. The layouts of the options are shown in **Figures 1 to 15**. More elaborated conceptual designs for all major components of the system were produced **(Appendices 4, 5 and 6).** Certain additional conveyance options were identified and investigated in order to provide a first-order optimisation of the system. The designs were undertaken on the basis of improved geological and topographical information.

16.1 Zalu Dam

Sizing

Similarly to the reconnaissance phase, the dam was sized and costed in accordance with the VAPS Guidelines for the 2030 requirements horizon. The required storage capacities (live, dead and sediment) determined during the reconnaissance stage were used. The corresponding dam levels were then refined using the improved area-capacity relationships.

One option of the type of the Zalu dam was sized as a mass roller compacted concrete (RCC) structure with a central spillway. The cross section parameters recommended by the VAPS Guidelines [33] were used. For concrete dam sections the crown width at NOCL was accepted to be 6,0 m. The wet face - vertical and smooth, and the dry face sloping at 1: 0,75, stepped for the overflow section, but smooth for the NOC section.

The earth embankment type dam was sized for a crown width of 6 m, and both wet and dry faces slopping at 1: 2.5. A central clay core was introduced, assuming that the available material for embankment will be semi-permeable. A side spillway on the right flank was sized to allow 1:100 years floods.

The excavation depths were adjusted according to the results of the more detailed geological investigations. Allowances for foundation drilling and grouting were provided for costing purposes in accordance with the VAPS guidelines.

The design floods for sizing of the spillways were established in accordance with the
"Guidelines on Safety in Relation to Floods" (SANCOLD, Report 4, 1991) similarly to the procedure used during the reconnaissance stage. The dams were classified as follows:

- Zalu dam: Category II safety risk (medium size, significant hazard rating)
- The following design floods have been used for sizing of the spillways:
- Zalu: RDD of 548 m^3/s and SED of 1 090 m^3/s

All major structures related to the dam have been designed at conceptual level of detail: spillway and apron, gallery system, inlet and outlet works, dry well, control room, piping and valve arrangements, etc.

Table 39: Sizing Parameters for Zalu Dam (pre -feasibility phase)

Parameter	Zalu
Type of dam	Concrete
Type of spillway	Central overflow
Live storage (10^6 m³)	3.13
Sediment yield storage (10^6 m³)	0.80
Dead storage (10^6 m³)	0.31
Total storage (10^6 m³)	4.24
Bed level (m above msl)	585.5
Free board (m)	3.5
FSL (m above msl)	607.0
NOCL (m above msl)	610.5
Depth from bed to FSL (m)	21.5
Depth from bed to NOCL (m)	25.0
Depth from rock to NOCL (m)	26.5
NOC length	141
Spillway length (m)	90

Capital Cost Estimates

The capital costs have been estimated on the basis of the cost models established for VAPS. All quantities have been measured from the design plans. Allowances for mechanical items have been made.

16.2 Primary Distribution System

Sizing

The preferred conveyance option is water supplied by gravity from the dam outlet works to the existing WTW

16.3 Summary of Capital Costs

A summary of the estimated capital costs for the options studied during the pre-feasibility phase is provided in the table below. The capital costs are estimated at March 2006 price levels and include provisions for P&G, contingencies, professional fees and VAT.

Table 40: Capital Cost Pre-Feasibility Phase (R million)

Option No.	Development Option	Capital Cost Water Source (R Millions)	Capital Cost Conveyance (R millions)	Total Capital Costs (R millions)
1	Zalu dam. Conveyance from outlet	52,887.836	25,869,794	78,757,630
2	Zalu dam. Conveyance from weir	52,887.836	18,401,586	71,289,422

17. EVALUATION OF DEVELOPMENT OPTIONS

17.1 Economic Analysis Model

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

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

The economics model calculates the NPC at various discount rates, based on the capital costs, and the operational and maintenance costs. The NPV of water has been calculated by applying the same discount rates on the projected annual water supplies. The economic evaluation has been undertaken on the basis of the unit reference value of water (URV = NPC/NPV) established for each option. The economic analysis was performed for a 20- year horizon using the following parameters pertaining to the calculation of the operation, maintenance, energy and chemical costs:

- The following phased implementation of the scheme components has been assumed:
    - Dams, weirs and pipelines for surface water schemes: no phasing
    - Pump statio ns, treatment works and reservoirs: phased at 10 year intervals
    - Development of groundwater infrastructure: boreholes, pumps, pipelines etc. at 10 year intervals, following the demand curve
- A discount rate of 8 % was used, but sensitivity to variation of the rate was tested for 6 % and 10 %.
- The residual values at the end of evaluation period were established for each scheme component, on the basis of the following assumed design life:
    - 45 years for civil works
    - 30 years for M&E items and pipelines
    - 20 years for boreholes
    - 10 years for borehole pumps and diesel engines
- The annual operation and maintenance (O&M) costs were estimated as a percentage of the total capital costs. The following percentages were applied for the various types of schemes and components.

Table 41: O&M costs as a percentage of the capital costs

Development Component	Single Source: Dams	Multiple Source: Weirs	Boreholes
Civil works	0.5%	1%	1%
M & E	4%	8%	10%
Pipelines	1%	1%	2%
Boreholes	-	-	3%

- An estimate of the annual energy costs has been done, and the following rates:
    - Energy charge 20c / kWh
    - Demand charge R38.34 / kVA per month
    - Costs of chemicals 6c / kl

Cost estimates for different type of dams and conveyor system are provided in **Appendix 5**. The economics models, including the calculated NPC and URV are provided in **Appendix 6**. The following tables summarise the results of the economic analysis.

Table 42: Results of the Economic Analysis (for reconnaissance phase)

Option No.	Description	Total Capital Cost (R Million)	Total O &M (R Million)	URV of Water at 8% Discounted rate (R/m^3)
1	Zalu dam (conv. from dam outlet)	61,136,119	27,898,149	4.28
2	Zalu dam (conv. from weir)	58,995,025	26,972,352	4.14
3	Conjunc. (98%)	68,102,541	21,094,671	4.29

17.2 Evaluation of Development Options

The evaluation of the development options has been undertaken on the basis of technical viability, economic feasibility, and ecological and social acceptability, taking into consideration the other factors that may influence the developments such as geological uncertainties, employment opportunities, operation and maintenance implications and institutional arrangements. The estimated capital costs and the unit reference value (URV) of water supplied by each option, are summarized in the following table.

Table 43: Summary capital costs and unit reference value of water

Phase	Water Source	Option No.	Development Option
Pre-feasibility	Dam	1	Zalu dam. Conveyance from outlet
		1.1	Zalu dam. Conveyance from weir
		1.2	Zalu dam. Gravity from site
Feasibility	Conjunctive	2	Conjunctive scheme (98% assurance)

17.2.1 Surface Water Storage Scheme Zalu Dam Options

Selection of the best dam and associated conveyance system option

Zalu dam is preferable for the following reasons:

- The geological foundation conditions are notably more favourable than the other potential sites. Exploration drilling has been undertaken in significant detail. The costs for future exploration drilling (if required at all) will therefore be relatively lower. All this points to less risk due to geological uncertainties than for the Lusikisiki dam.
- The topography at the dam site is more favourable and provides better dam raising opportunities in future. Spillway conditions at Zalu dam are also preferable.
- Preferable from a social impact point of view

- The best conveyance scheme option for Zalu dam is considered to be option water released from the dam outlet and abstracted at the existing Lusikisiki weir. This is the cheapest conveyance option, which also provides greater flexibility in terms of phasing of implementation.
- The dam can be sized to supply water at the required 98% assurance of supply (or higher)
- Flexibility with respect initial development and to future changes in demand pattern. The incremental cost necessary to accommodate higher future demands (than projected during this study) will be lower than for any other source option.
- Less complicated institutional structures and cheaper operation and maintenance, resulting in potentially higher levels of sustainability.
- Potentially higher employment and recreation opportunities

17.2.2 Conjunctive run of river plus groundwater option

Option surface water supply from the Lusikisiki weir, supplemented by groundwater supply from boreholes at times of low surface flows was sized for 98% assurance of supply.

- Opportunity for phased development. The existing primary infrastructure can be upgraded as a first phase, followed by the development of boreholes to be implemented in phases along with the growth of the demand on the system.

Disadvantages of conjunctive water schemes

- Higher URV of water (R3.86), when compared with the best dam option (R3.21)
- Based on previous experience, the local population does not favour and will probably not support a scheme based on groundwater supply (established during interviews with various involved parties)
- High operation and maintenance costs and complicated institutional structures will be required to ensure the sustainability of the scheme (60 boreholes)
- The confidence in the results of these options is lower than in the case of the dam options. No exploration drilling or testing of boreholes has been undertaken.

17.3 Summary of Preferred Options

Based on the comments in the previous sub-chapters, the following best development options for each category of water source are suggested:

Table 44: Summary of recommended schemes per source category

Water Source	Option No.	Development Option	Assurance
Dam+conveyance system	2	Zalu dam. Conveyance from weir	98%+
Conjunctive	3	Conjunctive scheme (Lusiksiki weir plus 60 boreholes)	98%

18. CONCLUSIONS

18.1 Development Options/Schemes

The Lusikisiki Regional Water Supply Scheme (LRWS) currently serves about 52 000 people in the town of Lusikisiki and 23 surrounding villages, but the existing water source has insufficient assured yield to meet the water requirements. The augmentation of its water source is urgently required.

Various possible supplementary water sources have been considered – surface water storage scheme – Zalu dam, conjunctive use of surface and groundwater. For each of these sources, a number of development options have been investigated, evaluated and the best options selected.

The capital cost of each option was estimated. This includes the development of the water source and the primary conveyance system (pump stations, bulk supply pipelines, water treatment works and storage reservoirs).

Based on the findings of this study it can be concluded that the water source of the LRWS scheme can feasibly be augmented by one of the following development options:

Surface storage scheme (capital cost R 71,3 million, URV4.14 R)

This scheme would comprise the Zalu dam with water released down the river and abstracted again at the existing weir on the Xura River. The option includes the upgrading of the existing primary conveyance infrastructure.

This option should be selected by the Department if:

- Assurance levels lower than 98% are not acceptable
- Possible future extension of the scheme is required or regarded as beneficial. This is the only feasible option if higher demand scenarios are anticipated
- Particular preference is given to lower operation and maintenance costs and less complicated institutional structures
- More employment and recreational opportunities are deemed important

Conjunctive use of surface and groundwater (capital cost R82,3 million, URV4.29 R)

Option upgrading of the conveyance system from the Lusikisiki weir, supplemented by groundwater supply from about 60 boreholes at times of low surface flows was identified as the best conjunctive scheme option. The implementation of this option can be considered if:

- Phased development (less initial capital) is of paramount importance
- Higher operation and maintenance costs are acceptable
- The sustainability of the scheme can be guaranteed by the establishment of an adequate institutional structure required for the management of a reasonably complicated system
- Rejection of borehole based schemes by local water users can be overcome.

Immediate Groundwater Development Option 2 Capital Cost R14,4 million (Feasibility Level)

Boreholes EC072; EC 055; Ec 054 with a total yiel of 13.7l/s. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir B.

Boreholes EC 052; EC 051 and EC 078 with a total yield of 7.18l/s will be equipped and utilized to augment existing network. Boreholes will be equipped with a submersible pumps driven by diesel engine, a pump house and rising main which will discharge into the existing reservoir.

No specific preference for any of the development options can be given from an environmental point of view. From the social perspective the development of the Zalu dam involves the inundation of a small area of cultivated land, but this would probably be offset by positive impacts such as recreational opportunities, job creation, etc.

The local population has expressed a definite preference for surface water supply.

18.2 Water Source

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

- Without provision for the release of the ecological Reserve, the existing water source (a weir on the Xura River) can supply the present and future (2030) water requirements with assurances of 95% and 65% respectively.
- If provisions for the release of the ecological Reserve are made, the assurance of supply from the existing water source will be reduced to 70% and 40% for the present and future water requirements respectively.
- The above indicates that irrespective of the ecological Reserve requirements, the capacity of the existing water source is insufficient to meet the water requirements at the guideline limit of 98% assurance of supply, and the water source should be augmented.
- The surface and the groundwater resources in the area have high potential for development and can be used for augmentation of the existing water source.
- Based on the results of the reconnaissance study, the following options for augmentation of the water source, capable of meeting the system's requirements at 98% assurance of supply, can be considered for implementation:

    - The most feasible storage scheme option is Zalu dam (URV4.14 R). If there is no time for further studies, this option should be implemented.
    - The conjunctive surface and groundwater use option (URV4.29 R) includes abstractions from the existing weir, supplemented by the development of boreholes to be operated during times of low river flows.

18.3 Bulk Supply System

- The capacity of the existing bulk water conveyance infrastructure is insufficient to supply the present water requirements and a shortage of about 30% is presently experienced. This infrastructure needs to be upgraded urgently.
- The bulk water conveyance system should be upgraded irrespective of whether the supply area of the scheme is extended or not. The requirements for the areas covered by the proposed extensions are relatively low (28%) when compared with those for the full supply area. The proposed future extensions may only influence to a limited extent the sizing parameters for upgrading of the bulk infrastructure, but not the decision to implement the upgrading.

19. RECOMMENDATIONS

The following recommendations are offered:

- Upgrade the existing bulk supply system from the Lusikisiki weir to the command reservoir to meet the projected water requirements up to the year 2030. This is a common component for all three favourable augmentation options considered and can be regarded as the first phase of the augmentation of the water source. The upgrading will allow increased abstractions from the existing weir at least at times of high river flow. This action, combined with the proposed relaxation of the ecological releases (see bullet below) will result in an immediate improvement of the water supply situation of the existing scheme and will increase the assurance of supply from 70% to 90%.

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

- It is recommended that a detailed feasibility study be commissioned in order to obtain more accurate information and to refine the results of the reconnaissance study. This study will allow the selection of the best development option with regards to the water source on the basis of updated information. The proposed feasibility study should include the following main components, and should address the uncertainties identified during the course of the reconna issance study:

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    - Ecological aspects (preliminary reserve determination, EIA associated with the proposed relaxation of the Reserve, detailed EIA report for approval of the proposed developments).
    - Engineering aspects and study co-ordination
    - Implementation of immediate groundwater development Option 3 to supplement existing system
    - Identification and confirmation of availability of suitable construction material for Zalu Dam
    - Take the final decision regarding the best development options for implementation on completion of the feasibility study.

- It is recommended to implement immediate emergency measures as soon as possible to augment existing water supply system .