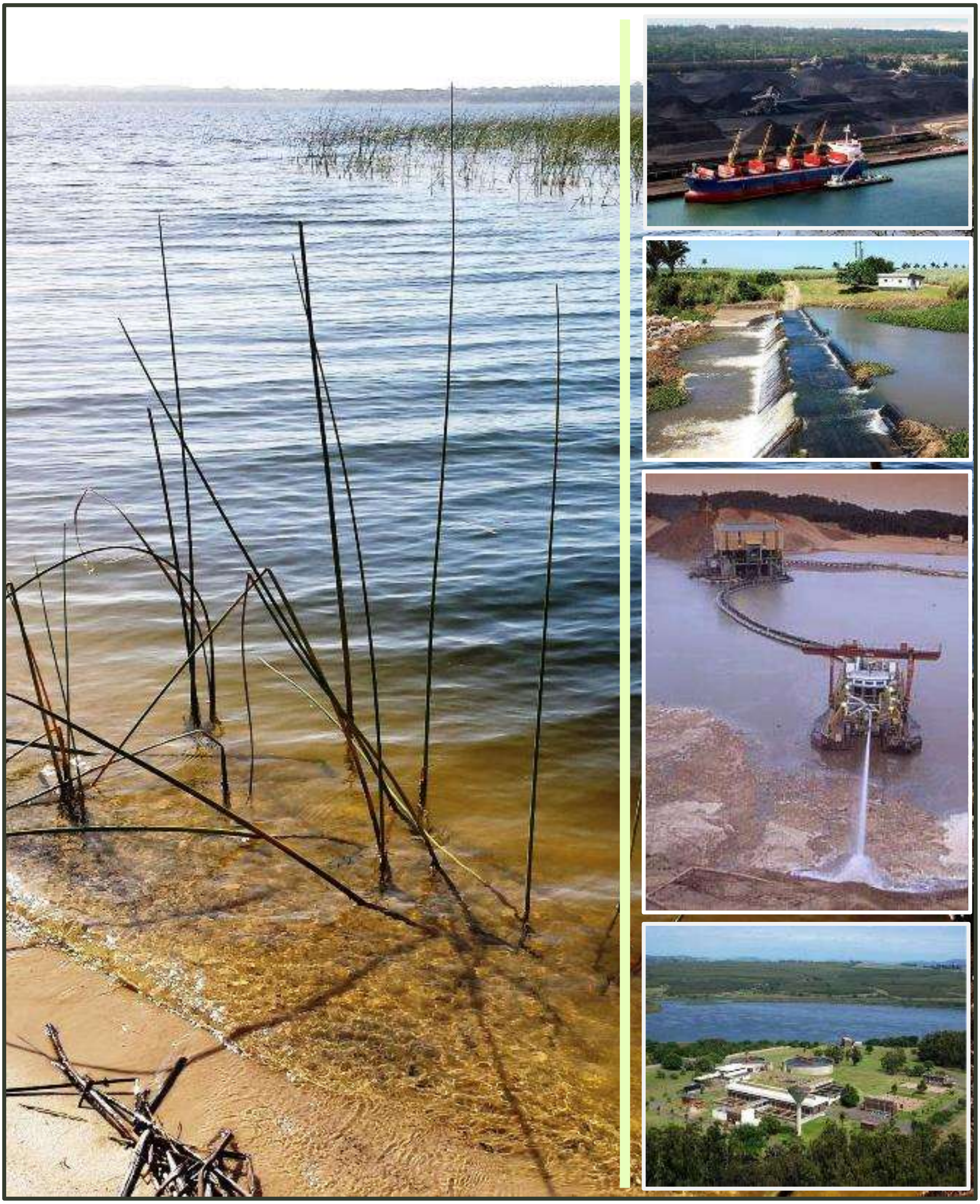

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Water and Sanitation
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Screening of Options Report

Water Reconciliation Strategy for Richards Bay and Surrounding Towns

Department of Water and Sanitation

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Aurecon South Africa (Pty) Ltd

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Aurecon Centre
1 Century City Drive
Waterford Precinct
Century City
Cape Town
7441

PO Box 494
Cape Town
8000
South Africa

T +27 21 526 9400
F +27 21 526 9500
E capetown@aurecongroup.com
W aurecongroup.com

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Approval			
Author signature		Approver signature	
Name	1) Ceridwen Salisbury 2) Erik van der Berg 3) Taryn Swales	Name	Erik van der Berg
Title	1) Civil Engineer 2) Technical Director 3) Hydrogeologist	Title	Technical Director

DEPARTMENT OF WATER AND SANITATION

Directorate: National Water Resources Planning

Water Reconciliation Strategy for Richards Bay and Surrounding Towns

SCREENING OF OPTIONS REPORT

Final: July 2015

Prepared by: Aurecon South Africa (Pty) Ltd
P O Box 494
Cape Town, 8000
South Africa

Tel: 021 526 5790
Fax: 086 526 9500
e-mail: erik.vanderberg@aurecongroup.com

Prepared for: Director: National Water Resources Planning
Department of Water and Sanitation
Private Bag X313
Pretoria 0001
South Africa

Tel: 012 336 8327
Fax: 012 336 8295
E-mail: Niel Van Wyk (CE: NWP East)
vanWykN@dwa.gov.za

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Directorate: National Water Resources Planning

WATER RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

APPROVAL

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STUDY TEAM

Approved for Aurecon South Africa (Pty) Ltd:

....
E VAN DER BERG
Technical Director

DEPARTMENT OF WATER AND SANITATION
Directorate National Water Resources Planning

Approved for Department of Water and Sanitation:

.... 24/08/2015
MR N VAN WYK
CE: NWP (East)

.... 30-Aug-2015
MR T NDITWANI
ACTING D: NWP

Study Reports

Report Name	DWS Report Number	Aurecon Report No
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Water Requirements	P WMA 06/W100/00/3114/1	9168
Water Balance	P WMA 06/W100/00/3114/2	9169
Screening of Options	**P WMA 06/W100/00/3114/3**	**9174**
Scenarios Evaluation	P WMA 06/W100/00/3114/4	9170
Reconciliation Strategy	P WMA 06/W100/00/3114/5	9171

EXECUTIVE SUMMARY

Background

Richards Bay is the economic centre of the uMhlathuze Local Municipality which further comprises Empangeni, Ngwelezane, Nseleni, eSikhaleni and a number of rural villages. Richards Bay is one of the strategic economic hubs of the country. Though the water resources available to the uMhlathuze Municipality are currently sufficient to cater for the existing requirements, should anticipated growth and industrial development materialise the current water sources are likely to come under stress.

The **objective** of the Richards Bay Reconciliation Strategy Study is to develop a strategy to ensure adequate and sustainable reconciliation of future water requirements within the uMhlathuze Local Municipality with potential supply up to 2040, especially that of Richards Bay / Empangeni, their significant industries, as well as the smaller towns and potential external users that may be supplied with water from the system in future.

An **intervention** can be any measure that could potentially make additional water available i.e. that improves the water balance of the Richards Bay WSS. It can therefore be demand-side (lowering water requirements) or supply-side (increasing the water supply) focussed.

It is necessary to identify the potential interventions or groups of interventions that could be implemented to meet the potential future supply shortfalls. The most favourable interventions need to be evaluated to be able to devise the set of best possible alternatives to meet the water requirements of the Richards Bay Water Supply System up to 2040.

The **purpose of this report** is to explain the process followed to identify the potential interventions to augment the water supply system, and to describe the features of the interventions that have been evaluated.

The uMhlathuze Local Municipality area is shown in Figure E1, along with Goedertrouw Dam and the lakes that form part of the Richards Bay Water Supply System. Bulk industries that receive water from the water supply system are further indicated on the map.

Water balance of the Richards Bay WSS

A number of potential future water requirement scenarios were determined for the water supply system, up to 2040, these being dependent on the population and socio-economic growth of the strategy area. Scenarios for Low Growth, Low-Medium growth, Medium growth and High growth were determined.

The Water Resources Yield Model that was configured in the Mhlathuze Water Availability Assessment Study and the subsequent Licensing Support Study was used in the current study as the most representative model configuration of the Mhlathuze catchment to date. The model was refined where appropriate and was updated with current water requirements and allocations. An updated current water balance for the Mhlathuze Water Supply System was determined for the assured (firm*)* yield (i.e. when urban/industrial users can just be supplied fully), which is a conservative indication of water availability from the system.

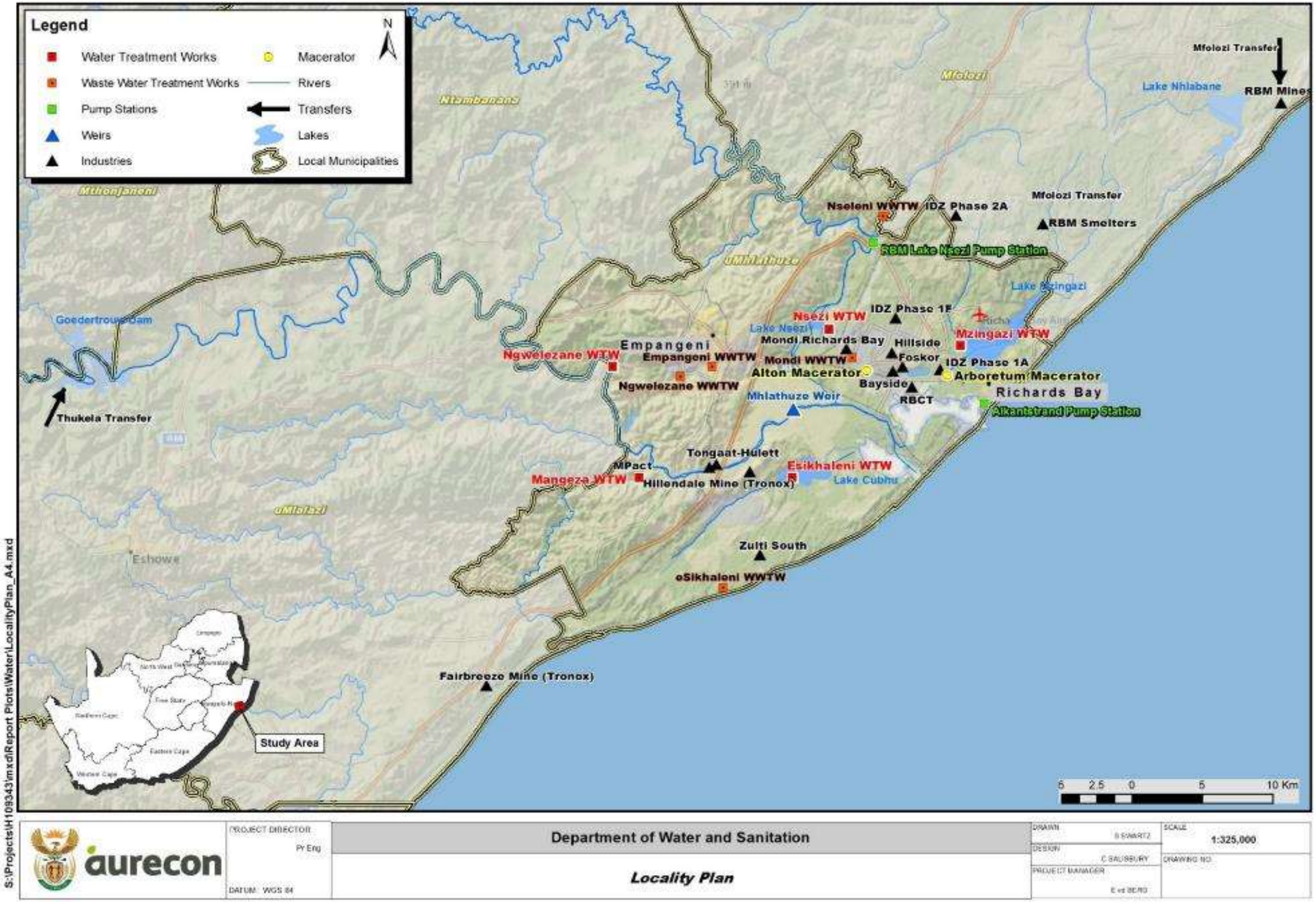

Figure E1: Locality Map of the uMhlathuze Local Municipality

When the water requirements of the high-growth scenario is compared with the assured yield of the water supply system the potential shortage in water supply by 2040 is 143 million m^3/s. This provides an indication of the range of intervention yields to plan for. The potential shortfalls for the various water requirement scenarios will be revisited during the scenario analysis task to follow, and the assured system yield will be superseded by the curtailed (stochastic) system yield values.

Approach and methodology

The following process has been followed:

a) Compilation of a Long List of potential interventions,
b) Screening of the Long List of interventions,
c) Compilation of a Short List of interventions to be evaluated further,
d) Evaluation of short-listed interventions,
e) Documentation of evaluated interventions according to a standard template,
f) Holding an Interventions Workshop with key stakeholders,
g) Preparation of the Interventions Report.

Compilation of the Long List of Interventions

A significant number of potential interventions, which could contribute to meeting the future water requirements of the Richards Bay WSS, were identified from previous and on-going studies, liaison with officials and stakeholders, as well as formulating some new potential interventions. The list of these initial potential interventions has been termed the "*Long List*" of interventions. The Long List describes potential interventions that could be considered for the strategy area, classed under twelve categories of interventions:

About 45 potential interventions in total were identified under the categories of:

- Water conservation and water demand management (WC/WDM),
- Improved operation of the Richards Bay Water Supply System,
- Water reallocation,
- Reducing users' assurances of supply,
- Land care,
- Thukela River inter-basin transfer schemes,
- Mfolozi River inter-basin transfer schemes,
- Mhlathuze River dams,
- Groundwater schemes,
- Use of treated effluent,
- Desalination, and
- Water supply infrastructure.

Screening of potential interventions

Potential interventions in the Long List of interventions were interrogated by the Study Team to ascertain which of these could be seriously considered for further evaluation, and the reasons were documented. The Long List was then circulated for contributions and reviews by key stakeholders, and discussed with stakeholders at the 4th Study Stakeholder Meeting held on 13 August 2014. The outcome of this screening process was the identification of the interventions that should be evaluated further (Short List of interventions).

Selected potential Interventions (Short List)

The following potential augmentation options have been selected for further evaluation:

- Bulk industrial water conservation and water demand management,
- Urban water conservation and water demand management,
- Rainwater harvesting,
- Ensuring sustainable supply from over-abstracted coastal lakes,
- Increased capacity of the Thukela-Mhlathuze Transfer Scheme,
- Coastal pipeline from the lower Thukela River,
- On-channel transfer scheme/s from the Mfolozi River: Kwesibomvu Dam,
- Off-channel transfer scheme/s from the Mfolozi River,
- Raising Goedertrouw Dam,
- Dam on the Nseleni River,
- Groundwater schemes,
- Arboretum Effluent Reuse Scheme, and
- Desalination of seawater.

Evaluation of selected interventions

Pertinent information on technical, financial, ecological and social aspects was assembled or generated and where necessary, improved at desktop level. In so doing, available information from many disparate sources and levels of confidence was brought to a more common level of understanding, in a fairly standard format.

Implementation programmes for interventions were compiled, to ascertain practical dates at which first water from such schemes can be delivered or savings can be made.

Savings to be achieved as a result of WC/WDM measures were drawn from available information, best practice and practical achievable savings. Some yields of interventions were based on assumed scheme size. Diversion curves were developed to determine diversion volumes of off-channel schemes. Indicative yields for surface water schemes were determined using the updated WRYM.

Where possible, capital costs were based on costs available from previous studies or costs of similar sized infrastructure. Costs were escalated to be representative of the base year costs (2013), if such costs were not too dated. In some cases, costs have been estimated from basic principles, as some options have not been evaluated before or the costs were too outdated. An evaluation period of 37 years (2014 to 2050) was selected for all water augmentation schemes, for determination of unit reference values (URV). The URV is a means of comparing different interventions on an equal base by calculating a cost per unit (here R/m^3) for each intervention, based on the same assumptions in terms of evaluation period, equipment replacement periods, electricity costs etc. It provides a comparative indication of the unit cost of water supplied from the scheme during the scheme lifetime. A URV refers to the cost per unit – here, the cost per cubic metre of water. Multiplication factors were added to allow for additional costs.

Interventions Workshop

At the stakeholder workshop held on 4 February 2015 in Richards Bay, the findings of the Interventions evaluation were presented to a group of key stakeholders. The stakeholders provided comment and made suggestions regarding variations of the interventions, or clarified specific facts. The descriptions of the evaluated interventions were refined following the workshop.

Summary of intervention features

The key features of the evaluated interventions are documented in Table E2 and scheme locations are shown in Figure E2.

Table E2: **Summary Interventions Table**

Intervention	Variation	Intervention description	Yield (million m^3/a)	Yield (Mℓ/d)	Capital cost (R million)	URV (8% discount rate)	Environmental and socio-economic impacts	Implementation programme (years)
Bulk industrial WC/WDM	-	WC/WDM applicable to bulk industrial water users, of which Mondi, RBM, Tronox and Foskor accounts for 96%.	2.8	7.7	*Range of costs*	*Range of URVs*	Minimal. Specific to type of WC/WDM	5
Urban WC/WDM	-	WC/WDM applicable to the urban water supply sector (supplied by the City of Mhlathuze) that includes Richards Bay, Empangeni, eSikhaleni, Nseleni and Ngwelezane as well as Uthungulu DM.	4.0	11.0	*Range of costs*	*Range of URVs*	Minimal. Specific to type of WC/WDM	10
Rainwater harvesting	*Non-potable conjunctive uses (garden and flushing toilets) investigated. Yields and costs dependent on a variety of factors, including roof area, tank size and target drawdown volume.*	This is the collection and storage of rainwater for commercial, industrial or domestic use. The focus is on the harvesting of rainwater from roofs for outdoor and indoor non-potable domestic uses	*Up to 200kl/a per household*	-	*R5,000 – R28,000*	*Minimum of R11.04/kl*	Limited. Main concern is that water need to be treated for potable use.	1
Sustainable supply from coastal lakes	*Increase abstraction levels to 50% of the difference between drought maintenance levels (current operation) and management maintenance levels*	This involves the determination of groundwater contributions to lake yields at an acceptable confidence, and revising of the operating rules of abstraction to ensure a sustainable supply from the three coastal lakes of the WSS, Lakes Mzingazi, Cubhu and Nhlabane.	-4.3	-11.8	0	0	Positive environmental impacts. Associated impacts of replacing yield from alternative sources.	4.5
	Increase abstraction levels to management maintenance levels from drought maintenance levels (current operation)		-9.9	-27.1	0	0		4.5
Increased capacity of the Thukela-Mhlatuze Transfer Scheme	**To augment to a final volume of 2.7m³/s**	Increased transfer of water from a weir in the Thukela River at Middledrift to a Mhlatuze River tributary that drains to Goedertrouw Dam. Development has been evaluated for 1, 2 or 3 phases of increased transfers for a variety of infrastructure combinations. Given here are the costs for augmenting the system to 2.7m³/s, 5.7m³/s and 8.7m³/s respectively with the tunnel being included, as it was cheaper in all cases than the corresponding scheme with the pipeline instead. For the options involving multiple phases, the capital cost of each phase is given as well as the sum of those capital costs. The incremental yield is given – i.e. not including the existing 1.2m³/s (37.8 million m³/a) transfer capacity.	**47.3**	**129.6**	**842.39**	**6.43**	Moderate. Generic impacts of inter-basin transfer of water, pipeline construction etc. Weir construction impacts. Pipelines will traverse environmentally sensitive areas, but will follow existing servitude. Options involving tunnel have lower environmental impacts. Outfall into small rivers can cause erosion - mitigatable Increased availability of water to local communities.	8.75
	To augment to a final volume of 5.7m³/s		**141.9**	**388.8**	**2432.29**	**6.72**		10.75
	First phase (augmentation to 2.7m³/s) - incremental		47.3	129.6	1032.51	6.56		8.75
	Second phase (augmentation to 5.7m³/s) - incremental		94.6	259.2	1417.67	4.74		8.75
	To augment to a final volume of 8.7m³/s		**236.5**	**647.9**	**3423.98**	**8.28**		-
	First phase (augmentation to 2.7m³/s) - incremental		47.3	129.6	1225.14	7.07		8.75
	Second phase (augmentation to 5.7m³/s) - incremental		94.6	259.2	1427.99	4.76		8.75
	Third phase (augmentation to 8.7m³/s) - incremental		94.6	259.2	787.90	3.92		7.75
Coastal pipeline from the lower Thukela River	*Raw water pipeline*	This involves shared use of the bulk water abstraction and treatment infrastructure developed in the lower Thukela River at Mandini by Umgeni Water to transfer water to Richards Bay and to supply coastal communities along the way. The pipeline would terminate at the Mhlatuze River, a short distance upstream of the weir. Options of 20 million m³/a and 40 million m³/a transfers were investigated, of which 5 million m³/a would be supplied to coastal communities, and 15 million m³/a and 35 million m³/a respectively to the Richards Bay WSS.	20.0	55	522.84	4.39	Limited to moderate. Pipelines follow existing railway and road servitudes. Outfall of raw water option is into a large river (Mhlatuze), hence limited erosion potential. Use existing infrastructure at abstraction point.	20 Mm³/a: 8.5 40 Mm³/a: 9
			40.0	110	1014.25	4.96		
	Clear water pipeline	Similar to the raw water pipeline except that the pipeline would continue further north to reach the Nsezi WTW, from where it would be distributed to users of treated water. Options of 20 million m³/a and 40 million m³/a transfers were investigated.	20.0	55	584.05	4.28		
			40.0	110	1055.45	5.23		
	Raw Water utilising the Tronox pipeline to Fairbreeze mine	Similar to the previous options except that the pipeline currently being constructed to bring water from the Mhlatuze River to the Fairbreeze mine would be used for that part of the route. Only 40 million m³/a transfer was investigated, taking into account the requirement of the Tronox mines.	40.0	110	1209.47	4.58		
On-channel transfer scheme/s from the Mfolozi River: Kwesibomvu Dam	*26m high (144 million m³ capacity) , 17% MAR dam – pipeline to Nseleni River*	The Kwesibomvu Dam is an on-channel earthfill dam on the Mfolozi River about 7 km upstream of the N2 road bridge that would transfer water to Nsezi WTW and provide a regional water supply to Mtubatuba and other small towns.	66.6	182.5	1764.79	3.52	Significant. Inundation of land, including several pans and social infrastructure. Obstruction of water-course affecting movement of sediment, aquatic species and modification of downstream flow regime.	10.25
	26m high(144 million m³ capacity) , 17% MAR dam – pipeline to Nsezi WTW		66.6	182.5	2272.82	4.21		
	36m high (265 million m³ capacity) , 31% MAR dam– pipeline to Nseleni River		137.3	376.2	2271.29	3.70		-

Intervention	Variation	Intervention description	Yield (million m^3/a)	Yield (Mℓ/d)	Capital cost (R million)	URV (8% discount rate)	Environmental and socio-economic impacts	Implementation programme (years)
	36m high (265 million m^3 capacity) , 31% MAR dam – pipeline to Nsezi WTW		137.3	376.2	2880.56	4.26	Prohibitive, inclusive of flooding of lower portions of the Hluhluwe-iMfolozi Park which probably rules out the scheme.	
Off-channel transfer scheme/s from the Mfolozi River	*2 m^3/s diversion, 28m high, 30 million m^3 dam, pipeline to Nseleni River*	This involves pumping from a weir in the Mfolozi River about 4 km upstream of the Kwesibomvu Dam site to an off-channel earthfill dam at the Nkatha Pan. The scheme could transfer water to Nsezi WTW and provide a regional water supply of 20 million m^3/a to Mtubatuba and other small towns. Different rates of pumping from the Mfolozi River to the dam were investigated, as well as different storage capacities.	33	90.4	941.51	5.36	Moderate to significant. Inundation of one pan (Nkatha Pan).	9.5
	2 m^3/s diversion, 28m high, 30 million m^3 dam, pipeline to Nsezi WTW		33	90.4	1299.40	6.32		
	2 m^3/s diversion, 38m high, 63.2 million m^3 dam, pipeline to Nseleni River		47.1	129.0	1152.79	4.56		
	2 m^3/s diversion, 38m high, 63.2 million m^3 dam, pipeline to Nsezi WTW		47.1	129.0	1565.13	5.36		
	2.5 m^3/s diversion, 32m high, 39 million m^3 dam, pipeline to Nseleni River		40.8	111.8	1131.30	5.97		
	2.5 m^3/s diversion, 32m high, 39 million m^3 dam, pipeline to Nsezi WTW		40.8	111.8	1551.95	6.99		
	2.5 m^3/s diversion, 42m high, 78 million m^3 dam, pipeline to Nseleni River		56.9	155.9	1235.75	5.20		
	2.5 m^3/s diversion, 42m high, 78 million m^3 dam, pipeline to Nsezi WTW		56.9	155.9	1601.93	5.87		
Raising Goedertrouw Dam		A 2.8m raising of the dam wall by building a concrete wave wall on the existing earthfill dam wall, and increasing the capacity of the spillway through a labyrinth spillway configuration.	3.9	10.7	77.6	1.61	Minimal. Small increase in inundated area.	4.5
Dam on the Nseleni River	*1 MAR (43.1 million m^3), 22.5m high*	A new earthfill dam on the Nseleni River tributary of the Mhlatuze River just upstream of the Bhejane township, from where water could be released down to Lake Nsezi for abstraction. Would also increase the assurance of supply to RBM, which has an abstraction point a short way downstream of the proposed dam site.	7.0	19.2	164.39	1.96	Significant, but mitigatable. Inundation of sections of the D857 road. Inundation of farm dam. Disruptions of ecosystems, some inundation of social infrastructure. Impacts as a result of obstruction of the watercourse.	1MAR: 8.5
	1.5 MAR (64.7 million m^3), 26.1m high		10.6	29.0	173.19	1.37		
Groundwater schemes	*Mtunzini-North Groundwater Scheme (wellfield 1)*	Wellfield 1 with 18 production boreholes and 20 exploration boreholes is located in the south western portion of the uMhlathuze LM and extends in a westerly direction over the municipal boundary and into the uMlalazi LM.	0.71	1.95	26.7	6.42	Moderate. Potential over-pumping /over-utilisation during operation impacting on the groundwater table, vegetation, as well as on natural springs and seeps. Construction phase impacts, noise and the influence on the boreholes of other users.	8.5
	Empangeni West Groundwater Scheme (wellfield 2)	Wellfield 2 with 17 production boreholes and 20 exploration boreholes is located to the west of Empangeni and extends westwards towards the boundary of the uMhlathuze and uMlalazi LMs.	0.54	1.48	15.5	4.93		
	Lubisana Groundwater Scheme (wellfield 3)	Wellfield 3 with 19 production boreholes and 20 exploration boreholes is located to the west of Empangeni and extends across the boundary of the uMhlathuze and uMlalazi LMs.	0.30	0.82	19.4	10.69		
Arboretum Effluent Reuse Scheme	*Treated effluent can be reused either directly by supply to industrial users, or indirectly by being taken to the Mzingazi WTW*	This firstly involves construction of a regional activated sludge WWTW and biological nutrient removal process with membrane bioreactors at the Arboretum pump station that can accommodate both the existing and future domestic load of the Arboretum and Alton pump stations. From there the treated effluent will be pumped for discharge into Lake Mzingazi for indirect reuse or sold directly to industrial users.	10.95	30	569	6.97	Moderate. Negative social perceptions of reuse. Mainly sludge disposal. Impacts of indirect use operation on Lake Mzingazi, as yet unquantified.	6.5
Seawater desalination	*Sea intake pipelines*	Seawater will be fed by an intake in the Richards Bay harbour to a site close to the Alkantstrand pump station, where the reverse osmosis desalination plant will be situated. Potable water will be pumped to the Mzingazi WTW for blending.	21.9	60	2243.7	8.47	Limited to moderate. Marine construction and brine outfall. Selection of site(s) will have further specific impacts, as yet unquantified.	Harbour intake: 7.75
	Harbour intake pipelines		21.9	60	2089.7	7.82		

Figure E2: Locality Plan of all schemes

Contents

Figures

Tables

Acronyms

AADD	Average daily demand
AADF	Annual Average Daily Flows
ALC	Active Leakage Control
CBA	Critical Biodiversity Area
CoU	City of uMhlathuze
DEA	Department of Environment Affairs
DM	District Municipality
DMAs	District meter areas
DTMs	Digital terrain models
DML	Drought Minimum Level
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water & Sanitation
EC	Electrical conductivity
EFR	Estuarine Flow Requirement
EIA	Environmental impact assessment
EMC	Environmental Management Categories
ESIA	Environmental and Social Impact Assessment
EWR	Ecological Water Requirement
FSL	Full Supply Level
GDP	Gross Domestic Product
HFY	Historical Firm Yield
IDZ	Industrial Development Zone
IAPs	Invasive alien plants
ISP	Internal Strategic Perspective
IFR	Instream Flow Requirements
KZN	KwaZulu-Natal
KZN GRIP	KwaZulu-Natal Groundwater Resource Information Project Database
LM	Local Municipality
LTBWSS	Lower Thukela Bulk Water Supply Scheme
mamsl	Metres above mean sea level
MAP	Mean Annual Precipitation
MAR	Mean annual runoff
MML	Maintenance Minimum Levels
NFEPA	National Freshwater Ecosystem Priority Area
NGO	Non-Government Organisation
NPAES	National Protected Area Expansion Strategy
NPV	Nett Present Value
NRW	Non-Revenue Water
RAP	Relocation Action Plan
RBCT	Richards Bay Coal Terminal
RBM	Richards Bay Minerals
RO	Reverse Osmosis
RWH	Rainwater harvesting
SFRA	Streamflow Reduction Activities
TDS	Total dissolved solids
UAW	Unaccounted-for Water
URV	Unit reference value
WAAS	Water Availability Assessment Study

WC/WDM	Water Conservation and Water Demand Management
WRYM	Water Resources Yield Model
WSDP	Water Services Development Plan
WSS	Water Supply System
WSSA	Water and Sanitation Services South Africa
WTW	Water Treatment Works
WWTW	Wastewater Treatment Works

1 INTRODUCTION

1.1 Background

Richards Bay is the economic centre of the uMhlathuze Local Municipality which further comprises Empangeni, Ngwelezane, Nseleni, eSikhaleni and a number of rural villages. Richards Bay is one of the strategic economic hubs of the country. Though the water resources available to the uMhlathuze Municipality are currently sufficient to cater for the existing requirements, should anticipated growth and industrial development materialise the current water sources are likely to come under stress. There is a need for long-term planning to ensure that shortfall in water supply is avoided in the long term.

1.2 Objectives of the Reconciliation Strategy

The objective of the study is to develop a strategy to ensure adequate and sustainable reconciliation of future water requirements within the uMhlathuze Local Municipality with potential supply up to 2040, especially that of Richards Bay / Empangeni, their significant industries, as well as the smaller towns and potential external users that may be supplied with water from the system in future.

1.3 Strategy area

Richards Bay is an established city with well-developed industries, commercial areas and business centres. Significant development is currently taking place in the town, particularly in the industrial development zone (IDZ), adjacent to the Richards Bay harbour. Significant growth in water requirements has been experienced in recent years, and this trend is expected to continue, driven primarily by growth in industrial development, but also by growth in domestic water use.

The strategy area considered includes the entire uMhlatuze River catchment, as well as all existing and potential future transfers into and out of the catchment. The focus area of long term supply is however the uMhlathuze Local Municipality area and its significant industries.

In the strategy area, water is sourced from the Mhlatuze River, various natural lakes in the catchment, limited use of boreholes, an inter-basin transfer from the Thukela River (via the Thukela-Mhlatuze (Middledrift) transfer scheme) and the Richards Bay Minerals (RBM) transfer from the lower Mfolozi River for their mining operations.

The strategy focus area is shown on the following page (Figure 1-1).

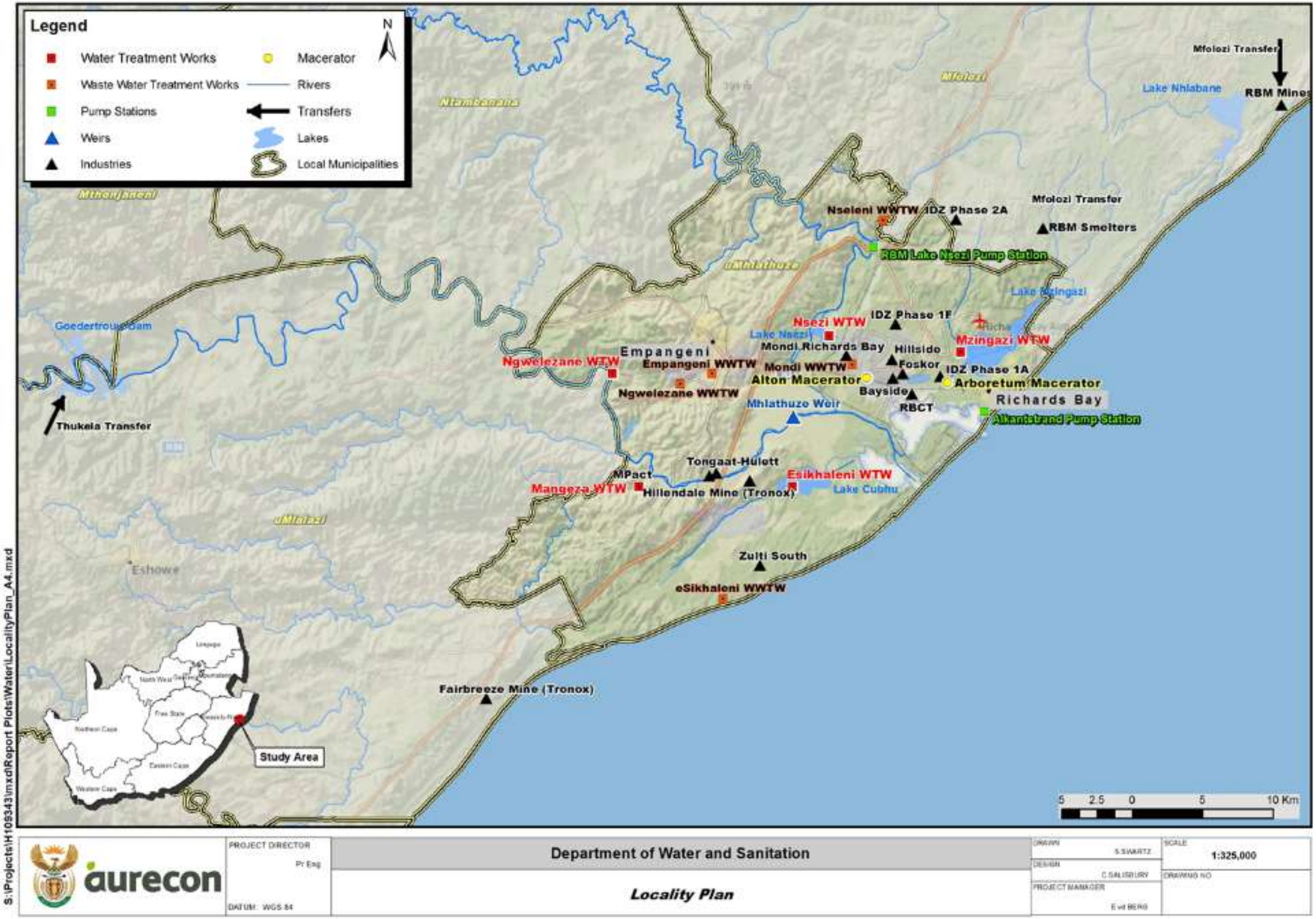

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Figure 1-1: **Locality Map of the uMhlathuze Local Municipality**

1.4 Purpose and scope of this Report

It is necessary to identify the potential interventions or groups of interventions that could be implemented to meet the potential future supply shortfalls. The most favourable interventions need to be evaluated to be able to devise the set of best possible alternatives to meet the water requirements of the Richards Bay Water Supply System (WSS) up to 2040.

The purpose of this report is to explain the process followed to identify the potential interventions to augment the WSS, and to describe the features of the interventions that have been evaluated.

1.5 What is an Intervention?

An Intervention can be any measure that could potentially make additional water available i.e. that improves the water balance of the Richards Bay WSS. It can therefore be demand-side (lowering water requirements) or supply-side (increasing the water supply) focussed.

1.6 Water balance of the Richards Bay WSS

A number of potential future water requirement scenarios were determined for the water supply system, up to 2040, these being dependent on the population and socio-economic growth of the strategy area. Scenarios for Low Growth, Low-Medium growth, Medium growth and High growth were determined.

The Water Resources Yield Model that was configured in the Mhlathuze Water Availability Assessment Study and the subsequent Licensing Support Study was used in the current study as the most representative model configuration of the Mhlathuze catchment to date. The model was refined where appropriate and was updated with current water requirements and allocations. An updated current water balance for the Mhlathuze Water Supply System was determined for the *firm* yield (i.e. when urban/industrial users can just be supplied fully) situation, which is considered to be a conservative indication of water availability from the system.

A system firm yield of 214.3 million m^3/a was used to form an idea of the potential shortfall in supply which the water supply system could face in 2040 for the various future water requirements scenarios. When the firm yield of the water supply system is compared to the future water requirements as a result of high growth in water demands, the water balance indicates that, in 2013, there was a small surplus of 12.7 million m^3/a in the water supply system. When the water allocations are compared with water requirements though, the shortfall in the water supply system is 57.7 million m^3/a.

When the scenario water requirements are compared with the conservative (firm) yield of the water supply system (to be revisited during the scenario analysis task to follow), the potential shortages in water supply by 2040 are as indicated in Table 1-1.

Table 1-1: Potential shortfall by 2040 for various water requirements scenarios

Water Requirement Scenario	Water requirement (million m^3/a)	Potential shortfall (million m^3/a)
Scenario 1: Low growth	244.4	30.1
Scenario 2: Low-Medium growth	267.8	53.5
Scenario 3: Medium growth	298.4	84.1
Scenario 4: High growth	356.9	142.6

1.7 Approach and methodology

The following process has been followed:

h) Compilation of a Long List of potential interventions,
i) Screening of the Long List of interventions,
j) Compiling a list of interventions to be evaluated further – the Short List,
k) Evaluation of short-listed interventions,
l) Documentation of evaluated interventions according to a standard template,
m) Holding an Interventions Workshop with key stakeholders,
n) Preparation of the Interventions Report.

1.8 Structure of this Report

This report is presented in twelve chapters. The contents of these chapters are as follows:

Chapter 1: Introduction (this Chapter) which introduces the reader to the background to and purpose of the Reconciliation Strategy, the Richards Bay WSS and the approach to the Interventions Task.

Chapter 2: Interventions Long List describes the compilation of a Long List of interventions, and the screening process to identify which interventions to evaluate further.

Chapter 3: Interventions Evaluation Process describes the process followed in the screening of the Long List and the evaluation of selected interventions.

Chapter 4: Water Conservation and Water Demand Management (WC/WDM) describes the respective WC/WDM interventions for the Bulk Industrial and Urban water use sectors.

Chapter 5: Limiting Supply from Coastal Lakes describes an intervention that would be aimed at limiting abstraction from the three coastal lakes in the WSS.

Chapter 6: Thukela River Transfer Schemes describes the salient features of either increasing the transfer capacity of the existing Middledrift Transfer Scheme or constructing a new coastal pipeline from the Mandini Weir.

Chapter 7: Mfolozi River Transfer Schemes describes the options for a transfer scheme from the Mfolozi River; notably the Kwesibomvu Dam and an off-channel dam at Lake Nkatha.

Chapter 8: Mhlatuze River Dams describes the options to create additional yield by dam construction in the Mhlatuze River catchment, these being a new dam on the Nseleni tributary or the raising of Goedertrouw Dam.

Chapter 9: Groundwater provides an overview of the high-level potential for groundwater development in the strategy area, and the evaluation of two groundwater options.

Chapter 10: Reuse of Treated Effluent describes the reuse intervention proposed at the Arboretum macerator site.

Chapter 11: Seawater Desalination describes a seawater desalination option that would provide water to Richards Bay.

Chapter 12: Summary of Evaluated Interventions provides a summary of the key features of the evaluated schemes and describes the way forward.

2 INTERVENTIONS LONG LIST

2.1 Compilation of the Long List of Interventions

A significant number of potential interventions, which could contribute to meeting the future water requirements of the Richards Bay WSS, were identified from previous and on-going studies, liaison with officials and stakeholders, as well as formulating some new potential interventions. The list of these initial potential interventions has been termed the "*Long List*" of interventions.

Some potential water supply interventions that have been considered before in other similar strategy studies, such as e.g. mist harvesting, sewer mining, towing of icebergs and catchment management have not been included in the Long List, as these are either untested or are emerging/unknown technology and practices in South Africa, and is either not suited to the strategy area or cannot provide yields at the scale needed.

The Long List describes potential interventions that could be considered for the strategy area, classed under twelve categories of interventions:

The following categories of interventions were identified:

- Water conservation and water demand management (WC/WDM),
- Improved operation of the Richards Bay WSS,
- Water reallocation,
- Reducing users' assurances of supply,
- Land care,
- Thukela River inter-basin transfer schemes,
- Mfolozi River inter-basin transfer schemes,
- Mhlathuze River dams,
- Groundwater schemes,
- Use of treated effluent,
- Desalination, and
- Water supply infrastructure.

Table 2-1 shows the Long List of potential interventions according to the Intervention Categories. The interventions shown in **bold blue font** in the table have been evaluated further.

Table 2-1: Long List of Potential Interventions

Intervention Category	Potential Interventions
WC/WDM	• **Bulk Industrial WC/WDM** • **Urban WC/WDM** • WC/WDM by irrigated agriculture • **Rainwater harvesting** • Stormwater harvesting
Improved operation of the Richards Bay WSS	• **Sustainable supply from "over-abstracted" coastal lakes** *(negative intervention)* • Raising of Lake Nsezi • Artificial recharge and/or raising of WSS coastal lakes • Pipeline from Goedertrouw Dam to Lake Nsezi/Nsezi WTW • Improved abstraction measurement and billing of irrigators • Improved lakes operational procedures
Water reallocation	• Verification and validation of water use • Phasing out of marginal irrigation and allocation for urban/industrial use
Revisiting users' assurances of supply	• Reducing assurances of supply
Land care	• Eradication and control of invasive alien vegetation
Thukela River inter-basin transfer schemes	• **Increased capacity of the Thukela-Mhlathuze Transfer Scheme** • **Coastal pipeline from the lower Thukela River** • Other supply route/s from the Thukela River to Richards Bay WSS
Mfolozi River inter-basin transfer schemes	• **On-channel dam transfer scheme: Kwesibomvu Dam** • **Off-channel dam transfer scheme**
Mhlathuze River dams	• **Raising of Goedertrouw Dam** • Dam on the lower Mhlatuze River / Dam replacing the current weir • Dam on the Mfule River • **Dam on the Nseleni River**
Other surface water supply schemes	• Transfers from the Mlalazi or Matigulu rivers
Groundwater schemes	• **Groundwater schemes**
Use of treated effluent	• Consolidation of supply from WTWs and WWTWs • **Effluent treated to non-potable standards for industrial reuse, urban irrigation or indirect urban reuse** • Effluent treated to non-potable standards for non-potable domestic use • Effluent treated to potable standards for direct use • Exchange of treated effluent with irrigators • Potential reuse of water from a Jindal mine slurry pipeline
Desalination	• Desalination of brackish water • **Desalination of seawater**
Water supply infrastructure	• Upgrades of Nsezi and eSikhaleni WTWs, intakes and conveyance pipelines • Nsezi Mondi/City of Mhlathuze Pump station • Pipeline from Nsezi WTW to eSikhaleni (Forest Hills reservoir) • Water supply to the future Fairbreeze Mine • Water supply to future Zulti-South mine • Water supply to future Port Durnford mine • Future Jindal mine water infrastructure • Middledrift Regional Water Supply Scheme • Ngcebu Regional Water Supply Scheme • Lake Phobane Water Supply Scheme

2.2 Screening of the Long List of interventions

Potential interventions in the Long List of interventions were interrogated by the Study Team to ascertain which of these could be seriously considered for further evaluation, and the reasons were documented. The Long List was then circulated for contributions and reviews by key stakeholders, and discussed with stakeholders at the 4th Study Stakeholder Meeting held on 13 August 2014. The outcome of this screening process was the identification of the interventions that should be evaluated further (termed the "Short List" of interventions).

Following the workshop, one intervention was dropped from the Short List after some investigation (*Artificial recharge of WSS lakes*), one intervention was added after some investigation (*Raising of Goedertrouw Dam*) and another intervention was added after the Interventions Workshop (*Improved lakes operational procedures*). Many of the interventions were refined or were separated into more than one intervention.

The potential interventions that were identified under the various intervention categories are described and discussed in the following Sections. Further actions to be addressed in the Reconciliation Strategy have been noted for the relevant interventions.

2.3 Description of the Interventions in the Long List

2.3.1 WC/WDM

WC/WDM interventions include improved technologies and practices that improve the efficiency of water use (using less water for an activity with the same or improved level of service) or water conservation (doing less with less water). The concept was also broadened to include other non-conventional water sources such as rainwater tanks and stormwater reuse. The potential WC/WDM interventions considered are described below.

Bulk Industrial WC/WDM

This addresses WC/WDM measures implemented by the bulk industrial users. Much has already been achieved in terms of WC/WDM by bulk industries in implementing various WC/WDM initiatives. The largest four industrial water users, namely Mondi, Richards Bay Minerals, Tronox and Foskor account for 96% of the total bulk industrial water use. The balance of the industrial water use is primarily by BHP Billiton, Tongaat Hulett, and the Richards Bay Coal Terminal/Port.

Urban WC/WDM

This addresses WC/WDM measures implemented both upstream and downstream of water meters for urban water use, as well as non-structural educational or institutional WC/WDM measures. It mainly addresses the urban areas supplied by the CoU that includes Richards Bay, Empangeni, eSikhaleni, Nseleni and Ngwelezane The total system losses in the supply area of the various WTWs within the Richards Bay WSS are estimated at approximately 31% of the treated water production. Stopping illegal water use and water leakages are considered to be important WC/WDM measures. Aggressive groundwater conditions negatively impact on the condition of infrastructure, requiring increased levels of maintenance. The responsible authorities for Urban WC/WDM are the CoU and uThungulu DM respectively as the water services authorities.

WC/WDM by irrigated agriculture

This addresses WC/WDM of irrigated agriculture, i.e. more efficient irrigation practices. In terms of irrigators' licences, which are issued volumetrically, farmers may increase their irrigated areas with water saved through their own efficiency measures. Taking into account that the compulsory licensing process has recently been completed, it was not considered worthwhile to evaluate this option further at the time.

Rainwater harvesting

This is the collection and storage of rainwater for commercial, industrial or domestic use. The focus is on the harvesting of rainwater from roofs for outdoor and indoor non-potable domestic uses. Financially viable approaches that warrant further investigation have been identified, e.g. storage for toilet flushing, linked to municipal mains as backup, or for garden watering. This is generally a more expensive option for retrofitting at a scale larger than 1m^3 of storage. This could potentially also be considered as compulsory for new urban development to implement which may require a new bylaw. It could potentially be coupled to artificial recharge of groundwater. The Department of Water and Sanitation (DWS) does not recommend using this source for drinking water.

Stormwater harvesting

Urban stormwater harvesting schemes involve the collection, treatment, storage and use of stormwater runoff from urban areas. It differs from rainwater harvesting as the runoff is collected from drains rather than from roofs. Stormwater can also be used to recharge groundwater. Integrated urban water management refers to the practice of managing freshwater, wastewater, and stormwater as links within the resource management structure, using an urban area as the unit of management (UNEP 2009).

Projects for the capture and reuse of storm water have already been implemented by some bulk industries at local scale. Stormwater harvesting could be considered at a larger scale for implementation by the CoU. The benefits however still tend to be small-scale and localised, and water quality can be an issue. It is probably not worth pursuing as a bulk intervention, but should be encouraged at local scale. It is also still an emerging technology and practice in South Africa.

The Atlantis Water Resource Management Scheme is an example where treated wastewater and storm water is diverted to large basins in urban areas where it infiltrates into a sandy aquifer from where it is abstracted and reused for municipal supplies.

The following actions were recommended for potential WC/WDM interventions:

- Evaluate *Bulk Industrial WC/WDM* further,
- Evaluate *Urban WC/WDM* further,
- Evaluate *Rainwater Harvesting* further, and
- Include a recommendation on local-scale use of *Stormwater Harvesting* in the Strategy.

2.3.2 Improved operation of the RBWSS

This category includes interventions where improvement to existing operational measures could noticeably influence the water balance of the WSS. The potential interventions considered for improved operation of the WSS are described below.

Sustainable supply from "over-abstracted" coastal lakes

(potentially negative intervention)

Three coastal lakes are sources for abstraction in this strategy area: Lake Mzingazi, which supplies Bayside Aluminium and the Mzingazi WTW, Lake Nsezi, which supplies the Nsezi WTW and supplements RBM's supply from other sources, and Lake Cubhu, which supplies the eSikhaleni WTW. There is concern about the accuracy of the historic firm yields (HFY) of these lakes. The science on which the sustainable yields of the lakes were determined is weak so the confidence of the stated sustainable yields is low. Actual abstraction from these lakes is in excess of their stated firm yields. When compared with the stated firm yields of the lakes their ecological Reserve requirements also raises concerns.

This intervention would reduce the system yield. In practice this could potentially mean increasing the minimum levels of abstraction. Should supply from these lakes be reduced, alternative WSS augmentation will be needed to replace the reduction in yield.

Raising of Lake Nsezi

Lake Nsezi is fed by the Nseleni River which originates in the granitic formation further inland. Increasing the capacity of the lake by building/raising its wall to limit seepage and increase storage could be considered in conjunction with water transfers.

Lake Nsezi can currently be topped up from surplus summer flows in the Mhlatuze River, but water is also transferred directly to the Nsezi WTW from Mhlatuze Weir. The lake is generally kept at 6.2 mamsl. Lake Nsezi is largely an artificial lake, with its wall made of rubble and boulders, filled with Berea Red sand. It leaks and water pumped or released into the lake does not get retained for long by this wall.

The raising of Lake Nsezi does not seem attractive owing to the significant expected impacts on the N1 highway, Nsezi WTW intake infrastructure, and impacts on other social infrastructure and on farmland.

Artificial recharge and/or raising of WSS coastal lakes

Consideration could be given to topping up the coastal lakes that form part of the Richards Bay WSS from surplus summer river flows. Increasing the capacities of the lakes by building/raising their walls to increase storage could further be considered in conjunction with water transfers. Lakes Cubhu, Mzingazi and Nhlabane are perceived to be extensions of the local groundwater.

Water is abstracted at the ESikhaleni WTW from Lake Cubhu, but production shortages can be met by transferring water directly from the Mhlatuze Weir to the WTW via the pipeline running under the lake. Because the blending is done in the WTW and not in the lake this allows greater control over the blending process. There is however significant uncertainty whether Lake Cubhu would be able to hold additional storage or whether it would rapidly seep away. This is because there is a serious deficiency in the geological and hydrological data for the Lake Cubhu region. Until this uncertainty is addressed it is not considered worthwhile to further pursue artificial recharge of Lake Cubhu.

Artificial recharge from the Mhlatuze Weir is not considered an option for Lake Mzingazi, given the large distance from the weir to the lake. There is also significant uncertainty whether the lake would be able to hold additional storage or whether it would rapidly seep away. Recharge of this lake with treated wastewater will however be considered under the Arboretum Effluent Reuse Scheme intervention.

Lake Nhlabane was raised by 1m in 1998. Artificial recharge of Lake Nhlabane could only realistically be considered from the Mfolozi River. The RBM Mfolozi run-of-river transfer scheme does not transfer water to the lake. Changes in land use in the Nhlabane catchment have reduced the estimated lake yield to current levels of 30,000m^3/day. This is likely to fall further to about 20,000m^3/day over the next five years, according to the Nhlabane Sustainability Assessment, 2014. The lake could thus be a candidate for artificial recharge, being over-abstracted.

Pipeline from Goedertrouw Dam to Lake Nsezi/Nsezi WTW

Mhlathuze Water has investigated the potential benefits of installing a dedicated gravity pipeline from Goedertrouw Dam directly to the Nsezi WTW. It was found difficult to quantify the savings that can be made on the Mhlatuze Water-only flows component in the Mhlatuze River from losses due to evaporation, evapo-transpiration, infiltration or even possible illegal use. It was found that the pipeline would be expensive.

Specified river flows are needed in the Mhlatuze River to meet the ecological Reserve apart from releases made for irrigators downstream of Goedertrouw Dam. Considering only the river transfer losses for the incremental Mhlathuze Water flow component being released, such losses are probably not very significant.

Such a pipeline, or alternatively a pipeline directly from the discharge of the transfer scheme, could also be considered should the transfer of Thukela water from Middledrift be increased.

Although this scheme would lead to possible energy saving, it will likely result in lost yield. In the summer there are incremental river flows which should be utilised to the maximum by transfer to Lake Nsezi, to reduce weir spillages. In addition, power failures on the irrigation schemes are frequent (as a result of the practice of cane burning), leading to sudden excess flows in the river, which should be utilised at short notice.

Improved abstraction measurement and billing of irrigators

The preferred billing practice is that irrigators pay per m^3 for use from Goedertrouw Dam, which is an efficiency measure in itself and has led to water savings in the past. Water volumes were calculated by calibration with electricity meters. For unknown reasons, this practice has lapsed and irrigators are currently being billed on the full registered volumes, although measurement of ESKOM meter readings has continued. The ESKOM meter readings are converted to water volumes and these 'actuals' are still being submitted to DWS. Re-calibration has not been done for many years. It is strongly recommend that billing per m^3 be reinstated.

Improved operational procedures

From an operational perspective, the lakes of the Richards Bay WSS and Goedertrouw Dam should ideally spill simultaneously to achieve the maximum WSS yield, although this may be difficult to achieve in practice. If operating rules for the lakes forming part of the WSS were revisited, it could potential increase the yield of the WSS. The lakes should be fully exploited while spilling. When spilling stops, abstraction should then preferably be limited to the 98% urban assurance of supply, so that they fail just before Goedertrouw Dam does, i.e. being simultaneously drawn down. Current operation of the lakes is based on minimising costs and not on maximising the yield of the WSS.

The following actions are recommended for *Improved Operation of the RBWSS* interventions:

- Evaluate *Sustainable supply from "over-abstracted" coastal lakes* further,
- Include a recommendation in the Strategy to undertake measurements of the impedance of the sediment layers in the coastal lakes. It is suggested that further detailed studies be conducted on at least one of the coastal lakes (Lake Mzingazi) rather than limited studies on all of them,
- Include a recommendation in the Strategy to investigate the reduction of illegal/commercial afforestation in the immediate vicinity of the coastal lakes,
- Include a recommendation in the Action Plan to reinstate the billing of irrigators for actual water use,
- Consider revisiting the operation of the lakes in the WSS to maximise system yield, instead of the current approach of limiting costs,
- RBM could consider the artificial recharge of Lake Nhlabane from the Mfolozi River to replace lost lake yield.

2.3.3 Water reallocation

Water reallocation refers to the transfer of a water use entitlement from one user to another, often between different types of use, typical from irrigation to urban use. Water reallocation interventions considered are described below.

Verification and validation of water use

Verification and validation of water use (a process aimed at licensing legal water use and eradicating illegal water use in various water use sectors) was recently done in the Mhlatuze catchment as part of the compulsory licensing undertaken by DWS. Some bulk industries however still have allocations that are very significantly in excess of their usage, although this may not be reflected in the Mhlathuze Water allocation for abstraction. The irrigation sector also only uses a low portion of their allocations, even in dry years. There is therefore a very significant difference between total water allocations and actual water use. As the recent verification and validation process is practically complete this is not viewed by DWS as an intervention to pursue further at this time.

Phasing out of marginal irrigation and allocation for urban/industrial use

The compulsory licensing process has addressed the issue of over-allocation of irrigation allocations within the Mhlatuze catchment. Historical irrigation usage patterns are low and many farms are not currently efficiently farmed. The intention in the irrigation sector is to reinstate full capacity on some farms and to use that water that is not being used in other regions where yields (and water use) could be more efficient. To try and reduce irrigation allocations further at this point is not recommended by DWS. It would further be difficult to make a decision on what marginal irrigation is. In addition, Felixton Mill relies on irrigators and needs the cane produced to stay in operation. Phasing out of irrigation therefore does not seem like a good idea, as it would affect the operation and viability of the Felixton Mill. As this is not regarded as a primary intervention, it will not be pursued further in this study.

2.3.4 Revisiting users' assurances of supply

Assurance of supply refers to the assurance, or alternatively the risk at which water can be supplied, and is determined by the hydrological characteristics of the catchment and users' requirements. An assurance of 98% (also called a 1:50 year risk of shortfall) means that for one year in every 50 years the full water allocation could not be supplied to a user. The intervention considered is described below.

Reducing assurances of supply

The area wants to attract especially industrial investors that require good assurances of water supply. Bulk industrial users such as Mondi and RBM need very high assurances of supply to meet their overseas market orders. Assurances of supply to the various user groups were revisited in 2010 as part of the modelling to support compulsory licensing. As this was very recently addressed, it need not be revisited. This is also not regarded as a primary intervention for reconciliation.

Assurance criteria used for the Mhlathuze catchment water users are as follows:

Water use sector	Percent of the water use that must be supplied at the indicated recurrence interval or risk of failure (%)				
	1 in 200 yrs	1 in 100 yrs	1 in 50 yrs	1 in 20 yrs	1 in 4 yrs
	0.5%	1%	2%	5%	25%
Irrigation			50%		50%
Urban	30%	30%		30%	10%
Industrial 1 (1)	70%	20%		10%	
Industrial 2	90%	10%			

(1) Note: Industrial 1 refers only to Tongaat Hulett; all other industrial demands use industrial 2 criteria

From the above table it is evident that assurances of both urban and industrial users are high, when compared to the norm. For metropolitan areas or large towns the norm for urban water supply, which normally includes industrial use is 1:50 years. The urban supply contains some key bulk industrial use, which was the motivation for the high urban assurances of supply used. This explains why average water uses by especially bulk industrial water users are significantly less than their allocations.

Should the water demand start to exceed the water availability, and interventions are not timeously implemented, a situation would develop where the assurances of supply of all users would be reduced. This is however regarded as a situation to avoid.

2.3.5 Land care

Land care, source protection and soil and water conservation are almost synonymous terms, describing an approach of a landholder driven movement towards responsible management aimed at both protecting the environment and improving productivity. The intervention considered is described below.

Eradication and control of invasive alien vegetation

Invasive alien species are plants, animals and microbes that were introduced into the catchment, and are out-competing the indigenous species. They are the single biggest threat to the country's biological biodiversity. Invasive alien plants (IAPs) pose a direct threat not only to biological diversity, but also to water security, the ecological functioning of natural systems and the productive use of land. They intensify the impact of fires and floods and increase soil erosion. IAPs divert water from more productive uses and invasive aquatic plants, such as the water hyacinth, effect agriculture and water supply (http://www.dwaf.gov.za/wfw/). If not addressed, the negative influence of IAPs will increase over time.

Water use by invasive alien plants should be reduced, and the Department of Environmental Affairs (DEA) is addressing this issue in collaboration with stakeholders through projects such as Working for Water. Mhlatuze Water implements an alien eradication program.

The use of additional low flow in the catchment as a result of the clearing of invasive alien plants could be considered for possible allocation. While there are undoubtedly significant benefits as a result of the clearing, the benefits from a water-for-allocation perspective may be limited, The incremental yield from the clearing of alien plants is the additional flow that can be abstracted during the critical hydrological period, which is limited to low flows released as a result of the clearing for run-of-river abstraction.

There is an area of about 290 km^2 of AIPs in the Mhlathuze catchment. The focus on clearing tends to be on riparian IAPs. Clearing alien plants above Goedertrouw Dam is further better from a water perspective.

This intervention is worth supporting, but mainly to prevent further degradation of the catchment. It is unlikely to cause a significant improvement in the water balance.

The following action was recommended for *Land Care*:

- Include a recommendation in the Strategy to support clearing programmes for invasive alien plants, especially in river courses above in-stream dams (currently only Goedertrouw Dam) that supply the RBWSS.

2.3.6 Thukela River Inter-basin Transfer Schemes

The Thukela River has in the past been regarded as the main source to augment the Richards Bay WSS in the future. The other growing requirements for water from the Thukela River mean that this potential source will also increasingly come under pressure in the future. The interventions considered are described below.

Increased capacity of the Thukela-Mhlathuze Transfer Scheme

This intervention involves an increase in the capacity of the Thukela-Mhlathuze Transfer Scheme, or so-called "Middledrift" transfer scheme which augments the Mhlatuze River System from the Thukela River. The current transfer infrastructure was implemented as an emergency scheme. The transfer scheme was originally planned for 3 phases of 3 m^3/s, totalling 9 m^3/s capacity, while the current pumping capacity is only 1.2 m^3/s. In order to increase the capacity of the transfer scheme, a weir in the Thukela River and sedimentation works would be needed. New pump and pipe infrastructure, and/or alternatively the tunnel would need to be constructed. The issue of rural supply schemes that currently share some of the infrastructure would need to be taken into account. The possibility of Mhlathuze Water applying to DWS to move the point of abstraction for their existing 21.23 million m^3/a licence to the Middledrift Weir could be considered.

Coastal pipeline from the lower Thukela River

There is potential to develop a coastal water transfer scheme from the lower Thukela River at Mandini. Such a scheme could potentially provide water for growth in the southern municipal areas and for future mining operations. It could also serve communities along the route. The possibility of sharing infrastructure at the weir and treatment plant being constructed by Umgeni Water at Mandini can be considered.

Mhlathuze Water has an unexercised licence for the abstraction of 21.23 million m^3/a (45% of 47.3 million m^3/a), from the Thukela River at Mandini, which, if not fully utilised by the time of the second 5-yearly review, due in 2015, the volume may be curtailed by DWS.

The original idea was that the mines would pay for a portion of the cost, which is not a current option as bulk water supply infrastructure to Fairbreeze Mine is already under construction. This included supply of irrigation water for 1,400 ha of sugarcane (effectively doubling the water demand). It is now considered unlikely that irrigation could form part of the scheme, as irrigators would have to pay for their portion of the actual scheme costs.

Other supply route/s from the Thukela River to Richards Bay WSS

An assessment can be made as to whether other possible transfer pipeline routes are possible, but finding other suitable routes is considered unlikely.

The following actions were recommended for the *Thukela River Inter-basin Transfer Schemes* interventions:

- Evaluate *Increased capacity of the Thukela-Mhlathuze Transfer Scheme* further,
- Evaluate the *Coastal pipeline from the lower Thukela River* further.

2.3.7 Mfolozi River Inter-basin Transfer Schemes

It is considered prudent to revisit potential transfers from the Mfolozi River, as conditions may have changed since this was last evaluated. There has also been significant growth in urban and rural water requirements in the Mfolozi catchment in and around Mtubatuba. There may potentially be synergy in the development of a bulk water supply scheme. The intervention considered is described below.

On-channel dam transfer scheme: Kwesibomvu Dam

A study was conducted by DWS in the late 1980s, to consider the feasibility of augmentation of the Mhlatuze River System from the Mfolozi River. The findings indicated that, with the sporadic flows, unless major storage was provided on the Mfolozi River, the Mhlatuze River System would ultimately have to be augmented from the Thukela River. Indications at the time were that, viewed on a long-term basis it would be cheaper to build the Thukela Transfer Scheme from the start.

The very silt-laden river poses many problems to the construction of an in-stream dam and a very large spillway would be needed. Previously identified dam sites in the Mfolozi River located upstream of the N2 road bridge could also stabilise the lower Mfolozi River. Ezemvelo KZN Wildlife however had a problem with any dam on the Mfolozi River in the past. A dam on the Mfolozi River might further be able to supply the region with a secure future water supply.

Mfolozi River off-channel dam transfer scheme

Upstream of the N2 road bridge, there are *inter-alia* a number of pans and lakes which could be developed into potential off-channel dam sites. These include the Ntweni and Nkatha pans.

The following actions were recommended for the *Mfolozi River Inter-basin Transfer Schemes* interventions:

- Evaluate all *Mfolozi River Inter-basin Transfer Schemes* further.

2.3.8 Mhlathuze River Dams

This considers the increases that can potentially be gained in the yield of the Richards Bay WSS by providing additional storage on the main stem of the Mhlathuze River, and/or on tributary rivers. The dams considered are described below.

Raising of Goedertrouw Dam

The Goedertrouw Dam which was completed in 1982 consists of an earthfill embankment with a spillway section through a neck. The dam is 89m high with a crest length of 660m and had a storage capacity of 321 million m^3 when it was constructed. It is estimated that the storage capacity of the dam is decreasing by about 1.17 million m^3/a due to siltation. The dam is owned and operated by DWS. The maximum practical height with which the dam can be raised is 2.8 m. Care need to be taken to allow for the extremely large floods experienced.

Dam on the lower Mhlatuze River / Dam replacing the current weir

A dam on the lower Mhlatuze River, if located above the Mhlatuze Weir, may catch incremental flows or excess flows from irrigation releases and increase the yield, as the existing weir does not have much storage capacity, and needs to be replaced. It could also potentially serve as additional in-stream storage for water transferred from the Thukela River. The immediate area upstream of the weir is however very flat and there are no suitable dam sites. Further upstream there are no obvious sites with much storage or without significant impacts, although some sites can be identified.

If the weir had greater storage it might similarly improve “abstraction efficiency” by catching daily surpluses, which will not show up on a monthly model. Should a dam site be available close enough to consider it for replacing the weir, this would provide an elegant solution to limit service risks. Pumping and conveyance infrastructure is already in place at the existing Mhlatuze Weir and it is very unlikely that a dam site exists close enough to replace the existing weir.

Dam on the Mfule River

A dam in the Mfule River will catch summer surpluses just like Goedertrouw Dam does, and could increase the yield if a suitable dam site is available. The dam would have to be at least 0.7 MAR to create meaningful yield and allow for silt loads, which are high in this catchment. Flows from the Mfule River help meet the demand of the Heatonville irrigators. A suitable dam site may be difficult to find.

Dam on the Nseleni River

The Nseleni River flows feed Lake Nsezi, which has limited storage, so an upstream dam could increase the yield and improve operational security. Water from the dam could help improve water quality by dilution or with a direct pipeline to the Nsezi WTW.

The following actions were recommended for the *Mhlatuze River Dams* interventions:

- Evaluate the *Raising of Goedertrouw Dam* further,
- Evaluate a *Dam on the Nseleni River* further.

2.3.9 Other surface water supply schemes

Transfers from other regional rivers have been considered. The interventions considered are described below.

Transfers from the Mlalazi or Matigulu rivers

These are relatively small rivers with sporadic flows which would not provide a long term solution. They should rather be used for irrigation and other local supply.

2.3.10 Groundwater schemes

The Geology and Hydrogeology of the Strategy area indicates that the area holds some potential for groundwater development. The eastern portion of the study area is underlain by quaternary sands, which are considered as primary aquifers, while secondary aquifers are generally located towards the west. Higher-yielding boreholes are mostly located towards the west and south-west of Empangeni. While it was a strong perception that groundwater in the coastal area north of Richards Bay should be fully utilised, the required information for this evaluation could not be obtained from the uThungulu DM. The groundwater schemes considered are described below.

Potential groundwater schemes

Wellfield 1 is located in the south western portion of the LM and extends in a westerly direction over the municipal boundary and into the uMlalazi LM. The borehole located the furthest away from the uMhathuze LM boundary is situated some 3.5 km to the west. Wellfield 2 is located just to the west of Empangeni and extends westwards towards the boundary of the uMlalazi LM. Wellfield 3 is located to the west of Empangeni and extends across the boundary of the uMhlathuze and uMlalazi LMs.

The following actions were recommended for the *Groundwater* interventions:

- Evaluate the *Groundwater interventions* further.

2.3.11 Use of treated effluent

Use of treated effluent, alternatively called water reuse is the use of reclaimed wastewater. As conventional water sources diminish, more attention needs to be given to this possibility. The interventions considered are described below.

Consolidation of supply from WTWs and WWTWs

The possibility of centralising and rationalising the effluent treatment infrastructure in the WSS for potential reuse has been considered in the past. This pertains to improved operation and is unlikely to make more water available.

Effluent treated to non-potable standards for industrial reuse, urban irrigation or indirect urban reuse

This involves the indirect reuse of wastewater effluent by pumping treated effluent to a dam for storage and subsequent reuse. Alternatively, treated wastewater can be used directly by suitable bulk industries.

Reuse of treated effluent would require treatment to a tertiary level. This option could potentially pose a health risk to users, should incorrect operation or poor maintenance arise. Actual risks should therefore be carefully assessed. Potential industrial water users would need to be identified. Non-domestic use could include industrial use, as well as the local irrigation of parks, sports fields and public gardens. Irrigation of the Mzingazi golf course is an option. Foskor could e.g. potentially use the treated effluent in their processes in lieu of clarified water.

Reuse is not considered viable for commercial irrigated agriculture, as apart from the cost of treatment the treated water would have to be pumped back up the valley, which would be too expensive.

The total volume of discharge through the sea-outfall system is estimated to be 11.5 million m^3/a. A possible scheme could pump effluent from a new WWTW to be located at the Arboretum Macerator to the Mzingazi WTW for blending or to Lake Mzingazi for indirect reuse. Instead of pumping directly into Lake Mzingazi, artificial recharge could be considered, to create a barrier to prevent sea water intrusion, such as at the Cape Flats artificial recharge scheme. The quality of water reaching the lake would then be further polished by groundwater filtration.

Effluent treated to non-potable standards for non-potable domestic use

Non-potable domestic use would entail expensive dual distribution system with the risk of misuse and accidental connection. To reduce the risk, effluent might be used only for toilet flushing, thereby eliminating garden taps and other access points. The risks would possibly be too high to consider further.

Effluent treated to potable standards for direct use

This involves the direct use of secondary effluent treated for potable use. There are very few places in the world where this is practised. This requires very stringent control, risks are high and this option is currently not recommended.

Exchange of treated effluent with irrigators

Irrigators are located quite far away from WWTWs with potential for reuse and recycled water would need to be pumped to irrigation farmers willing to trade. This would likely be costly, but costs could potentially be offset. Irrigation with wastewater is however regarded as risky.

Potential reuse of water from a Jindal mine slurry pipeline

This option could only be considered if Jindal decides to go ahead with a slurry pipeline, for pumping pellet slurry should their processing plant be located in Richards Bay. This is currently their alternate approach and may only be revisited should Jindal decide to locate their processing plant in Richards Bay and to make use of a slurry pipeline.

The following actions were recommended for the *Use of Treated Effluent* interventions:

- Evaluate the *Effluent treated to non-potable standards for industrial reuse, urban irrigation or indirect urban reuse* further.

2.3.12 Desalination

Desalination is the process of removing salt from seawater, rendering the water potable. In addition brackish water can be desalinated at lower cost than seawater desalination. Desalination interventions considered are described below.

Desalination of brackish water

This is not considered to be an option in this area, but may potentially be considered for brackish groundwater sources.

Desalination of seawater

The intake/outfall requirements, desalination plant, storage, pump station and distribution infrastructure will need to be considered. The location of the harbour and Alkantstrand Effluent Pump Station may provide an opportunity to limit costs.

The following actions were recommended for *Desalination* interventions:

- Evaluate the *Desalination of Seawater* further.

2.3.13 Water supply infrastructure

Water supply infrastructure in the WSS that is being constructed, is being planned or will need to be planned in future has been included for completeness below, but these are not schemes that will noticeably influence the water balance. These schemes would however need to be taken into account in the system modelling, as well as in the Action Plan that will form part of the Strategy. Water supply infrastructure development is described below.

Upgrades at WTWs and intakes – Nsezi and eSikhaleni WTWs

This is only relevant to this evaluation for improvements being made or planned to be made at WTWs where the capacity of the pump station/treatment plant increases, as it could affect the volumes that can be abstracted. This would only be relevant to the system analysis, as allocation does not increase. Nsezi WTW was recently upgraded to 205Ml/d and is planned to be further upgraded to 250 Ml/d in future. This will be taken into account in the modelling.

Nsezi Mondi/City of Mhlathuze Pump station

This is only relevant to this evaluation as it could affect the volumes that can be abstracted. A feasibility study was completed on the upgrade of the Mondi pumps at Lake Nsezi and augmentation of the supply system to the City of uMhlathuze. Going forward the existing Mondi pumps will be replaced, and a separate pump station is being constructed to supply the City of Mhlathuze. Construction associated with replacement of the Mondi pumps is in progress and the City pump station is also under construction.

Pipeline from Nsezi WTW to eSikhaleni (Forest Hills reservoir)

This planned scheme will pump water from the Mhlatuze Weir to the Nsezi WTW, and pump purified water back to eSikhaleni. The aim is to reduce demand on Lake Cubhu, upgrade eSikhaleni WTW, and to improve utilisation of the supply from Nsezi WTW.

An alternative to supply eSikhaleni and other growth areas in the longer term is the Thukela coastal pipeline supply.

Water supply to the future Fairbreeze Mine

The pipeline has been licensed by DWS with relevance to the streams being crossed and is currently under construction. An alternative future supply to the Fairbreeze mine could be the Thukela coastal pipeline supply.

Water supply to future Zulti-South mine

Mhlathuze Water plans to supply this future RBM mine, as well as eSikhaleni, from the Mhlathuze Weir. The supply is needed by about 2017 should development proceed soon. A new pump station will be constructed at the Mhlatuze Weir with a pipeline to the Zulti-South mine and eSikhaleni.

Water supply to future Port Durnford mine

The pipelines to eSikhaleni and Port Durnford could be considered together. The mine could potentially be supplied by a lower Thukela pipeline.

Future Jindal mine water infrastructure

The future mine would be supplied by pipeline from Goedertrouw Dam. A possibility that Jindal will consider is a slurry pipeline, should they locate their processing plant in Richards Bay.

Middledrift Regional Water Supply Scheme

Separate pumps for rural supply have been installed at the Madungela high-lift pump station. The scheme makes use of the 900mm rising main and therefore reduces the Thukela Scheme capacity very slightly.

Ngcebo Regional Water Supply Scheme

Water is supplied from pumps located at the Madungela high-lift pump station to the Ngcebo communities south of the Thukela River. The scheme is operated by Umgeni Water.

Lake Phobane Water Supply Scheme

The WTW of this rural WSS is located just east of Goedertrouw Dam, below the dam wall. Allowance has been made for this requirement in uThungulu DM water requirements.

The following actions were recommended for *Water Supply Infrastructure* interventions:

- Take any planned changes in capacities at pump stations, treatment plants or conveyance pipelines into account in the yield modelling to be undertaken in the Scenario Evaluation Task.
- Include relevant water supply infrastructure scheme planning and implementation actions in the Action Plan.

3 INTERVENTIONS EVALUATION PROCESS

3.1 Screening of potential interventions

Potential interventions in the Long List of interventions were interrogated by the Study Team to ascertain which of these could be seriously considered for further evaluation, and the reasons were documented. The Long List was then circulated for contributions and reviews by key stakeholders, and discussed with stakeholders at the 4th Study Stakeholder Meeting held on 13 August 2014. The outcome of this screening process was the identification of the interventions that should be evaluated further (Short List of interventions). Following the workshop, one intervention was dropped from the Short List after some investigation (Artificial recharge of WSS lakes) and one intervention was added to the Short List after some investigation (Raising of Goedertrouw Dam). Many of the interventions were refined or were divided into more than one intervention.

3.2 Selected potential Interventions (Short List)

The following potential augmentation options have been selected for further evaluation. The findings following evaluation of these interventions are presented later in this document:

- Bulk industrial WC/WDM
- Urban WC/WDM
- Rainwater harvesting
- Sustainable supply from over-abstracted coastal lakes
- Increased capacity of the Thukela-Mhlathuze Transfer Scheme
- Coastal pipeline from the lower Thukela River
- On-channel transfer scheme/s from the Mfolozi River: Kwesibomvu Dam
- Off-channel transfer scheme/s from the Mfolozi River
- Raising Goedertrouw Dam
- Dam on the Nseleni River
- Groundwater schemes
- Arboretum Effluent Reuse Scheme
- Desalination of seawater

3.3 Evaluation of selected interventions

3.3.1 Technical evaluation

Pertinent information on technical, financial, ecological and social aspects were assembled or generated and where necessary, improved at desktop level. In so doing, available information from many disparate sources and levels of confidence were brought to a more common level of understanding, in a fairly standard format.

It is noted that the current considerations are based mainly on 1:50 000 mapping. Levels between 20 metre contour lines have been interpolated on the mapping. In some cases digital terrain models (DTMs) were generated to obtain more detailed levels. Pipeline long sections, dam wall sections and dam volumes were determined using these levels.

Bulk pipelines and pump stations were sized to cater for modelled or assumed scheme yields to be conveyed. Dam sizes were based on the available topography and an appropriate variation in dam sizes. In-house spreadsheets were used for desktop level design and costing. Run-of-river abstraction rates were determined as a function of the flow regime in the relevant rivers, approximate scheme sizing and size of an off-channel dam, where appropriate. Reservoirs were provided between rising main and gravity main pipelines to allow for some operation flexibility, as well as at the delivery points of some interventions where adequate storage was not available.

Water treatment has been considered, but treatment costs have not included in the technical evaluation. For some interventions such as reuse and desalination where further treatment is not required to attain potable water quality, an allowance has been made to reduce costs of these interventions appropriately so that they can be compared with the other interventions on an equal cost footing.

3.3.2 Ecological and social considerations

A desktop-level assessment of the environmental and socioeconomic impacts of each intervention was carried out. Country-wide maps showing threatened ecosystems, critical biodiversity areas, heritage sites, protected areas and NFEPA wetlands/ rivers were used to identify sensitive areas in the intervention areas, and possible mitigation measures were explored. Specific impacts related to the various interventions are listed in each intervention's section, as well as their predicted severity and any possible mitigation measures. Specific impacts include inter-basin transfer of raw water, which has environmental implications (water quality, transfer of biota between catchments etc.), inundation of environmentally sensitive areas and social infrastructure by dams, as well as impacts of construction on the environment and communities in the area, and also positive impacts such as increased water-supply to rural communities and small towns lacking treated water supply, and socioeconomic benefits arising from access to a higher level of services.

3.3.3 Implementation programmes

Implementation programmes for interventions were compiled, to ascertain practical dates at which first water from such schemes can be delivered or savings can be made. Construction programmes are taken into account in the financial analysis of the options. The implementation programmes for the evaluated options have been included under Chapter 12.

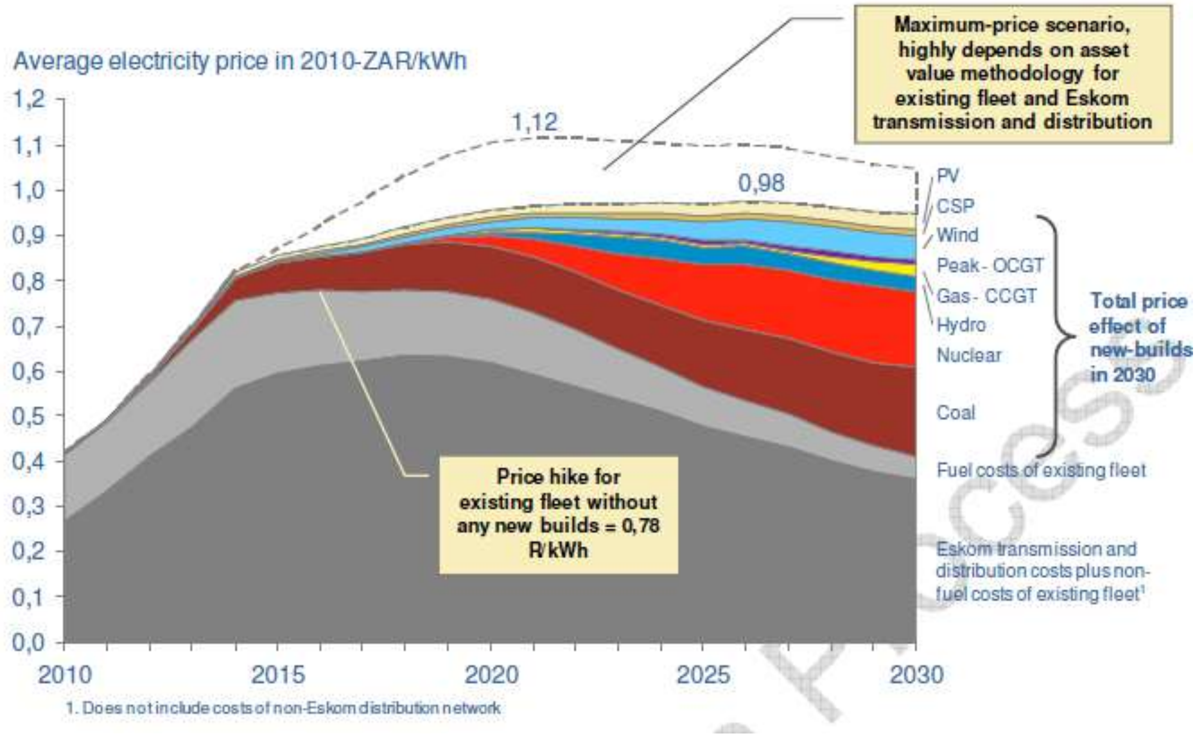
3.3.4 Savings / Yields

Savings to be achieved as a result of WC/WDM measures were drawn from available information, best practice and practical achievable savings. Some yields of interventions were based on assumed scheme size. Diversion curves were developed to determine diversion volumes of off-channel schemes. Indicative yields for surface water schemes were determined using the updated water resources yield model (WRYM). Historical firm yields (HFYs) were determined, which is generally a conservative approach.

3.3.5 Costing

Where possible, capital costs were based on costs available from previous studies or costs of similar sized infrastructure. Costs were escalated to be representative of the base year costs (2013), if such costs were not too dated. In some cases, costs have been estimated from basic principles, as some options have not been evaluated before or the costs were too outdated.

An electricity cost of R1.20/kWh was used, based on the likely future increases in Eskom's tariffs that will be in need to be well excess of inflation.



Breakdown of Anticipated Average Electricity Price Path for Department of Energy's Policy Adjusted Integrated Resource Plan based on Eskom's Average Tariff in 2010.

An evaluation period of 37 years (2014 to 2050) was selected for all water augmentation schemes, for determination of unit reference values (URV). The URV is a means of comparing different interventions on an equal base by calculating a cost per unit (here R/m^3) for each intervention, based on the same assumptions in terms of evaluation period, equipment replacement periods, electricity costs etc. It provides a comparative indication of the unit cost of water supplied from the scheme during the scheme lifetime. A URV refers to the cost per unit – here, the cost per cubic metre of water. Social discount rates of 6%, 8% and 10% were used in the URV calculations.

Equipment replacement periods for e.g. pumps (mechanical and electrical) and desalination membranes were considered. Allowance was made for electricity costs and operation and maintenance costs.

Multiplication factors were added to allow for additional costs as follows:

- *Preliminary and General* costs of 25% was first added to the capital costs.
- A 15% *Contingency* sum was then added to the previous sub-total.
- A 15% Professional *fees/site supervision* sum was further added to the previous sub-total, to get the total construction cost estimate.
- The total construction cost estimate was spread according to a realistic implementation programme in the URV calculation.

3.4 Documentation of interventions

Salient information of each intervention were compiled in a standard format, containing the following information:

- References
- Scheme layout / locality map, where relevant,
- Description of the intervention;
- Saving or yield (with consideration of the Reserve),
- Costing (capital and operating costs and URVs),
- Ecological and socio-economic aspects,
- Findings.

3.5 Interventions Workshop

This stakeholder workshop held on 4 February 2015 in Richards Bay addressed the evaluated potential interventions to achieve a water balance over the evaluation period. Interventions which are appropriate for the Richards Bay Reconciliation Strategy were presented to a group of key stakeholders, in order to consider the interventions in terms of its technical features, potential impacts, strategic value, yield, cost and implementation programme. Specific objectives were to:

- Shortly revisit the screening process undertaken, in terms of the Long List of possible interventions, to select the interventions that were evaluated,
- Present further evaluated interventions in more detail.
- Obtain comment and suggestions regarding the tabled interventions or further potential variants of the interventions,
- Obtain input on the interventions to be evaluated in the Strategy Scenario Planning to follow.

The descriptions of the evaluated interventions were refined following the workshop.

3.6 Following the Interventions Workshop

Figure 3-1 on the following page further illustrates how the workflow of the Interventions Task feeds into the downstream process of scenario evaluation and strategy development.

A scenario planning evaluation (to be undertaken after the Interventions Task) will be done for the identified range of interventions / planning scenarios, using the WRYM and the Water Resource Planning Model, refining yields of groups of interventions. This will be done to identify the most favourable interventions or groups of interventions that could be implemented to meet the potential supply shortfalls for the various water requirement scenarios.

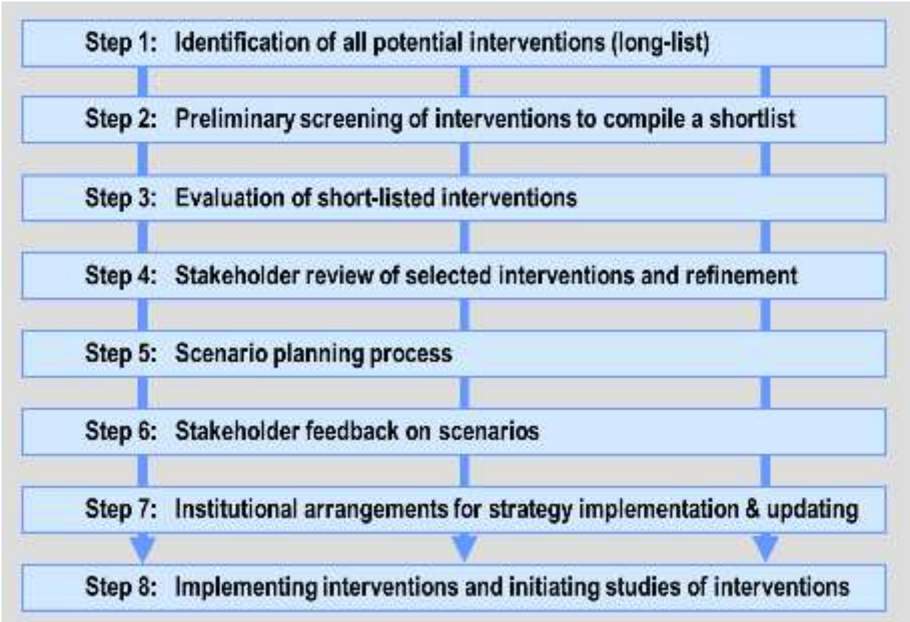


Figure 3-1: Integrated Bulk Water Planning Process

4 WATER CONSERVATION AND WATER DEMAND MANAGEMENT

The following three WC/WDM interventions have been evaluated, and are discussed hereunder:

- Bulk Industrial WC/WDM,
- Urban WC/WDM, and
- Rainwater harvesting.

4.1 Bulk Industrial WC/WDM

4.1.1 Reference Documents

Unless otherwise stated, information presented herein has been taken from the 2008 *Usuthu-Umhlathuze Water Conservation and Water Demand Management Situation Assessment and Business Plan Development Study* (DWS, then the Department of Water Affairs and Forestry (DWAF)).

4.1.2 Scheme Layout

This study covered the areas of Richards Bay, Empangeni, eSikhaleni, Nseleni and Ngwelezane.

To place this in perspective, the total 2013 water use by the urban and industrial sectors was approximately 96 million m^3/a. Of this, the municipal water use totalled 42% (City of Mhlathuze) and that of bulk industry 58%. The largest four industrial water users, namely Mondi, Richards Bay Minerals, Tronox and Foskor (see Figure 1-1) made up 96% of the total bulk industrial water use. The balance of the industrial water use is primarily by BHP Billiton, Tongaat Hulett, and the Richards Bay Coal Terminal. The location of the bulk industrial users within the municipal area is shown on Figure 1-1.

An assessment of WC/WDM at the significant bulk industrial water users follows.

4.1.3 Background

Mondi's Richards Bay mill is supplied with about 65 Mℓ/day (24 million m^3/a) of potable water by Mhlathuze Water. Approximately 47 Mℓ /day (17 million m^3/a) of treated effluent is discharged to sea. Expansion in 2005 (RB720 project) substantially reduced the water consumption, but there are opportunities for improvement.

Richards Bay Minerals (RBM) also utilises approximately 75 Mℓ /day (27 million m^3/a) of raw water from the Mfolozi River, Lake Nhlabane and Lake Nsezi. About 55% is used in sand mining and the balance in processing (smelter). Significant effort has been invested in improving water use efficiency and RBM were awarded first place at the Water Conservation and Water Demand Management Sector Awards (WCWDM) 2013. The sand mining process in particular has consumptive water use of about 50 Mℓ /day (18.3 million m^3/a) through water lost to sand tailings.

Tronox KZN Sands is a heavy mineral sand mining company. This assessment is based on the sand mining activities at their Hillendale mine. This assessment is based on the sand mining activities at their Hillendale mine. Although in the process of being decommissioned, the lessons learned from Hillendale must be taken forward into the development of the new Fairbreeze mine. In 2008 KZN Sands was utilising about 22 Mℓ /day (8 million m^3/a) of raw water supplied from the City of Mhlathuze. 19 Mℓ /day was consumed in the sand mining operation and the balance in the processing complex. Water lost in sand tailings (7 Mℓ /day) and seepage (to sea) and evaporation (collectively 6 Mℓ /day) were the primary drivers of their consumptive use.

Foskor Richards Bay produces sulphuric acid, phosphoric acid and granular fertiliser. The company is supplied with raw and potable water by the City of Mhlathuze at about 23 Mℓ /day (8.4 million m^3/a), of which 55% is raw and 45% potable water.

BHP Billiton currently has two aluminium casting and processing plants in Richards Bay: Hillside and Bayside Aluminium. These are the largest electricity users in the area, but not the largest water users. Hillside produces aluminium ingots, and Bayside deals with further processing. There are indications that Bayside will soon be largely ceasing operation, leading to a reduction in the required water volumes.

Tongaat Hulett Sugar SA – Felixton Mill abstracts its water from the Mhlatuze River, on average about 820 000 m^3/a. Their abstraction requirement is directly dependent on the sugar cane crop size. Felixton's current water allocation is 1 888 000 m^3 per annum. During the 2014 season the mill abstracted 806 000 m^3 of water and discharged approximately 356 000 m^3 water back into the Mhlatuze River.

Richards Bay Coal Terminal is the largest coal export terminal in Africa, and deals with the export of coal from various coal-mines. The coal terminal is the only significant user in the harbour, and was previously one of the large water users in Richards Bay. However, the use has decreased significantly since 2010, when a water conservation and recycling programme was introduced. There are plans for expansion of the port, which will lead to an increased water requirement in the future.

4.1.4 Current WC/WDM Initiatives

Mondi's reduction in water consumption (2005) is attributed to the introduction of improved water efficient technologies. Water recycling takes place during pulping and bleaching processes (evaporators, dewatering and reuse) and during paper making (dewatering). The drivers of water use include the product mix, balance of efficiency against product quality, technology age, raw material selection, and operational efficiency. Bleaching is the most water-intensive process. A Mondi Water Reduction Task Team was formed towards the end of 2012 consisting of members of all the main water consuming business units within the mill. Each business unit has a specific water consumption specification, determined by the respective area's design specifications.

At **RBM** about 20 Mℓ /day (7.3 million m^3/a) of untreated effluent is pumped from the processing complex to the sand mine to supplement the sand mining raw water requirement. In addition to this recycling, RBM also implements a number of positive water use practices. These include the use of cooling towers, water recycling, high efficiency cyclones, recovery of landward-side seepage, seepage recovery from stockpiles and the clarification of water for internal reuse in mining operations. Unfortunately seepage towards the coast is lost to sea.

The **Tronox** Hillendale mining operation (and in future the Fairbreeze Mine) utilizes a wet process, using high pressure water to mine the ore, forming slurry (muddy water). This slurry (Run-of-Mine or ROM) is then pumped to the primary wet plant where the separation of the ore takes place also using water based process. The water is recovered and re-used in the process. Two residue streams emanates from the process being the course fraction (sand minus the ore) and the fine fraction (silt and clay). These streams are pumped using water as a carrier medium to backfill (sand) and to the Residue Storage Facility (RSF). Water is recovered from these pumping operations but the losses are large (mainly evaporation and seepage (recharge of water table) while backfilling sand in the mine pits).

Water from the backfill operation can be captured and returned to the process. This is largely dependent on the mine pit location and topography. The RSF serve as a settling facility for all -45µm particles (slimes) where the solids are dewatered by evaporation. Bleed-off water and rainwater will drain via a penstock tower into the RWD to be re-used in the process, recycled to the PWP.

Foskor implements a number of water saving measures which include closed-loop cooling systems (towers), energy recovery systems (reduced evaporative losses), use of waste water for bi-product disposal, condensate recovery and recycling of water. The 2008 assessment concluded that Foskor's acid production plants operate within international water consumption levels. These are however not necessarily the lowest achievable and there remains scope for improvement. Storm water dams are utilised by Foskor to collect the majority of storm water run-off from their manufacturing site. That water is reused in their two phosphoric acid plants at a monthly average of about 1800m^3. They also have an agreement with **BHP Billiton** (Hillside Aluminium), to recycle their (Hillside's) storm water as a replacement for municipal raw water uptake. An issue here is that using rainwater/ stormwater gives the user a false sense of security, as in times of drought the availability of both the rainwater supply and alternative sources decrease.

Tongaat Hulett Sugar SA – Felixton Mill – The sugar mill implements a number of water saving initiatives. It continues to monitor the day to day activities like washing activities and leaks to conserve water. Most of the water in their process is recovered and is reused in the factory. Large cooling towers cool the water and return it to the factory.

RBCT and harbour

The coal terminal's Environmental Systems Upgrade Project (ESUP) to harness all process water, to prevent pollution of the harbour, and to recycle water was commissioned in 2009. Storm water and water collected from the coal stockpiles is channelled into settling ponds, where contaminants are separated from the water before it can be pumped into the ESUP dam. RBCT uses this recycled water for suppression of dust. This has reduced their overall consumption of potable water over the past 3 years by more than 75%. Potable water is now only used for domestic purposes.

4.1.5 Water Saving Opportunities

Mondi has commenced with a replacement program for all existing on site quench-to-drain flushing and lubricating systems fitted to mechanical seals, with systems incorporating a continuous loop water management design. The continuous loop water management systems will cut water usage at the plant by more than 2 Ml/day, helping to conserve scarce water resources in northern KwaZulu-Natal.

Additional water could possibly be saved through more water efficient processes including energy reduction, reduced cooling requirements and filter replacements opportunities, which are identified, and scoped as part of the Water Reduction task team.

At **RBM** further water use efficiency in the process side is possible but this would in turn reduce the volume of effluent which currently supplements the raw water supply to the sand mining operation. Consequently, a corresponding increased raw water supply would be required, unless reduced water requirements in the sand mining process are also achieved. Opportunities at the mine include possible increased seepage recovery, improved recovery of water from sand tailings, reducing mine pond surface areas (impacts on evaporation and seepage) and increased clarification to remove suspended solids (10 Mℓ /day), subject to the commensurate reduction in water requirement by the sand mining operation.

RBM had an internal target to reduce consumption from 2008 by 10% based on the average consumption from 2008 to 2013.

Water efficiency opportunities at the new Tronox Fairbreeze mine should be incorporated into the design and operation. In 2008 it was estimated that 3 Mℓ /day could be saved through seepage recovery and additional opportunity through changes in the handling of tailings. A 10% increase in tailing solids was estimated to potentially save at least 3.5 Mℓ /day. Effective design of mining pits will improve recovery of water as well as establishment of infrastructure to improve water recovery and recirculation.

Foskor has implemented water efficiency improvements from an operational perspective (notably in the sulphuric acid plants), with opportunity remaining at the phosphoric acid plants of up to 3 Mℓ /day. In 2008 it was identified that there were meter reading discrepancies in the potable supply between the City of Mhlathuze and Foskor, with the municipal meter under-reading by 4 Mℓ /day. Foskor's own internal metering was also estimated to have about 17% unaccounted water and this should be rectified.

Other possible opportunities for reducing the water consumption at Foskor include improved heat recovery (to reduce water cooling requirements), use of sea water for certain cooling processes, optimization of water volume control, flow rates and moisture concentrations, improved control of filter wash volumes and more precise target levels for vacuum development.

Tongaat Hulett Sugar SA – Felixton Mill – The mill will continue to look for opportunities to reduce water consumption by looking at more effective ways of recycling process water back into the factory. This will help the mill in two ways; firstly it would reduce the amount of water abstracted and secondly it would reduce the amount of treated water discharged into the Mhlatuze River. A few changes in the water reticulation system in the factory have been made, but the effect on the water balance has not been established.

4.1.6 Bulk Industrial WC/WDM Saving

It is recommended that a saving of 5% on current bulk industrial water use within the next 5 years be targeted, i.e. 2.8 million m^3/a as these industries are already reasonably water efficient.

4.1.7 Financial Estimates

The URVs for the different industrial WC/WDM option projects are difficult to determine as the costs and savings will vary from area to area and will be dependent on the efficiency of the implementation initiative.

No financial estimates of the potential interventions by **Mondi** have yet been determined. This is required to assess overall viability, including resulting socio-economic impacts.

It was estimated in 2008 that to achieve the possible 10/ Mℓ day saving at **RBM** on the processing side, a R75 million investment would be required, subject to the equivalent reduction in water requirement by the sand mine operation. In 2008, no estimates of the financial investment required to improve water use efficiency were undertaken by **Tronox** or **Foskor**.

4.1.8 Ecological Impacts

Increased reuse by **Mondi** will have no adverse ecological impacts. It will be beneficial in relieving water resource stress through reduced abstractions from the Mhlathuze River by Mhlathuze Water, with possible reduction in releases from Goedertrouw Dam.

Increased reuse by **RBM** will have no adverse ecological impacts. It will be beneficial in reducing the overall water requirement by RBM in the short term, but their expansion program would inevitably drive their increased water requirements into the future.

Increased reuse at Fairbreeze will have no adverse ecological impacts. It will be beneficial in reducing the overall water requirement by **Tronox** from the City of Mhlathuze, which in turn will alleviate stress on the raw water sources. Similarly, increased reuse at **Foskor** and rectification of metering problems will have no adverse ecological impacts. Reducing the overall water requirement from the City of Mhlathuze will be beneficial to the raw water sources.

Increased industrial re-use may result in a more concentrated effluent being discharged to the marine environment. The impact of dilution of the marine outfall should be investigated to determine if effluent discharge conditions could be violated if a more concentrated effluent is discharged.

4.1.9 Socio-Economic Impacts

Mondi is currently unaware of adverse socio-economic impacts which may arise as a result of the implementation of more water efficient measures.

In 2008 it was recommended that the **RBM** Water Management Plan be updated to confirm current and projected water use, water saving opportunities and socio–economic impacts.

No adverse socio-economic impacts are anticipated for improved water efficiency at the new **Tronox** mine at Fairbreeze. The same holds for **Foskor**. Improved revenue to the City of uMhlathuze will be achieved through resolving of metering discrepancies.

4.1.10 Findings

Many of the bulk industries have made significant savings in this area, and have developed management plans to ensure efficient us of water in their processes. This makes determining and implementing blanket savings targets problematic, as the scope for savings is limited by previous savings, and operational efficiency. A possible strategy is to establish benchmarks for industrial use and compare actual use with theoretical usage figures so that realistic savings goals can be established for individual user groups.

4.2 Urban WC/WDM

4.2.1 Reference Documents

The following reference documents have been used:

- City of uMhlathuze Final Bulk Water Master Plan, 2014
- Mhlathuze Water Services Development Plan, 2013
- eSikhaleni Bulk Water Intervention Study, 2013
- eSikhaleni Water Supply System – System Overview, 2013
- 5-Year Strategic Management Plan for the Reduction of Non-Revenue Water in the City of Umhlathuze, 2013
- Mtubatuba and Surrounds All Towns Strategy, 2011
- Usuthu-Umhlathuze Water Conservation and Water Demand Management Situation Assessment and Business Plan Development Study, 2008

4.2.2 Background

Water wastage is generally attributed to distribution losses (leakages) and consumer wastage (e.g. leaks within consumer properties and indiscriminate wastage – e.g. taps left open).

Inefficient usage is attributed to the fact that water is often used for the service derived from it, rather than for the water itself. As gardening and toilet flushing (including continuous toilet leaks into the sewerage system) represent most of the total domestic demand, they are key focus areas for targeting inefficiencies. If a user does not pay for high consumption of water, due to no or inaccurate metering or insufficient credit control, that user tends to waste water.

Various WC/WDM option alternatives are presented in this document. However, one or a combination of the various WC/WDM projects would be appropriate to achieve an objective in a particular area. Therefore the respective WC/WDM options should not be considered individually, but rather as a part of an overall strategy, to achieve a specific objective.

WC/WDM in the urban sector has the objective to minimise water wastage and to ensure the optimal use of water, which often requires a fundamental shift in the perception of consumers of the value of water. The urban sector (supplied by the City of Mhlathuze) includes Richards Bay, Empangeni, eSikhawini, Nseleni and Ngwelezane, which currently amounts to 40 million m^3 per year. The primary focus of this assessment is on the initiatives by the City of Mhlathuze towards implementing WC/WDM opportunities that have been identified in numerous strategic and master planning studies in the area to date.

The key information relating to WC/WDM in the City of uMhlathuze (2012) is outlined in Table 4-1.

Table 4-1: Key WC/WDM information for the City of uMhlathuze (2012)

Area	Length of Mains – Trunk and Reticulation (km)	Registered Water Connections	Total No. of Properties	Total Population	Average Zone Operating Pressure (m)
Richards Bay	666	15 631	30 598	113 349	50
Empangeni	255	7 938	16 451	26 528	84
Esikhaleni	597	6 722	19 776	174 629	58
Ngwelezane	360	4 730	8 450	63 665	43
Totals	**1 878**	**35 021**	**75 275**	**378 171**	**58**

Although the 2008 Situation Assessment mentioned above dates back six years, it is the most detailed assessment of WC/WDM in the study area. As such, the approach to this intervention is to consider the initiatives that were in place in 2008, the recommendations made in terms of potential additional water efficiency measures that should be implemented, and then to assess (from the other references above), which of these recommendations have been implemented, to what extent, and what levels of success have been achieved. As such this serves as a mini "audit" to gauge how WC/WDM in this sector has progressed over the last six years and where it should be focussed in the years ahead.

In 2011, the extent of losses from the Richards Bay water treatment works (WTW) alone was estimated to be approximately 31% of the treated water production, translating to about 14.7 Mℓ /day (5.3 million m^3/a) for that supply area alone. All other areas could be expected to be similar (or potentially worse), depending on the age of the reticulation infrastructure and the extent of metering. 10-15% is considered an acceptable range for system losses in the urban sector and together with the requisite metering and monitoring, and management of system pressures, presents the most significant opportunity for improvement in the urban sector throughout the entire study area. Considering the total current urban water requirement of close to 40 million m^3/a, a 10% reduction in system losses would effectively result in a saving of about 4 million m^3/a.

Figure 4-1 is quite informative as it illustrates the principles of unaccounted for water (UAW) and revenue collection in the municipal situation. The International Water Association Water Loss Task Force produced an international 'best practice' standard approach for water balance calculations, with definitions of all terms involved, as the essential first step in practical management of water losses. The IWA table has been adjusted for the South African situation by adding to and by subdividing the Potential Revenue Water into Free Basic Water, Recovered Revenue and Un-recovered Revenue.

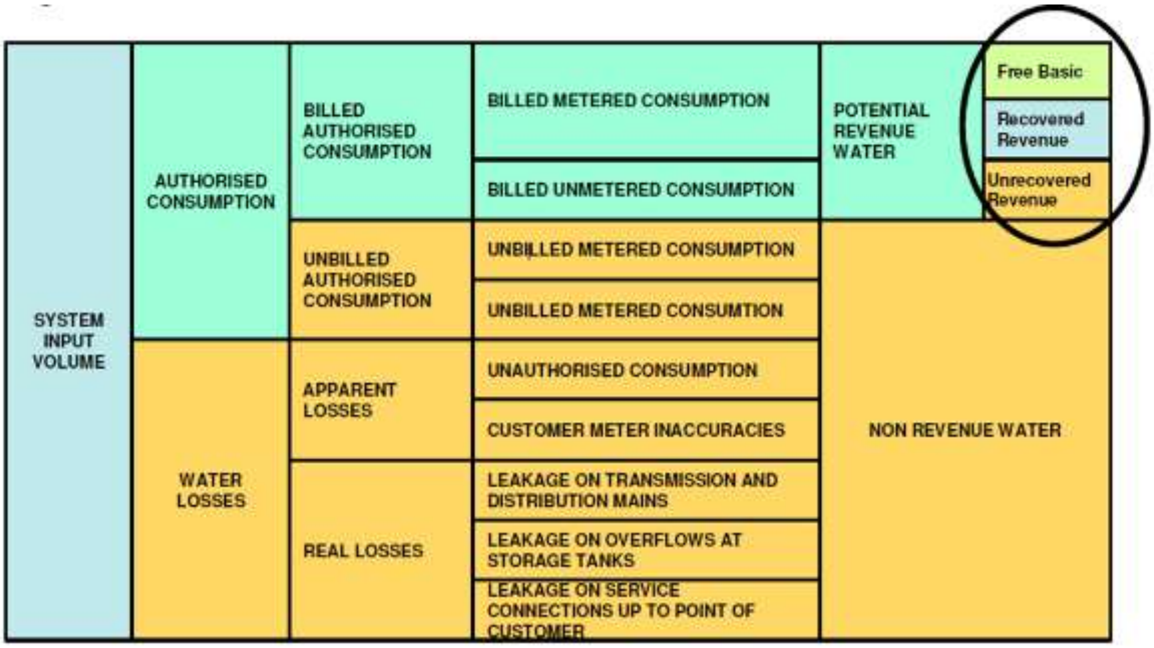


Figure 4-1: International 'best practice' standard approach for water balance calculations

In terms of the adopted international standard for the presentation of water volumes, the projected water balance for the City of uMhlathuze area of supply for the 2011/2012 financial year (within the accepted unit of kl/year) has been included in Figure 4-2. At that stage, non-revenue water by volume was estimated to be 27%.

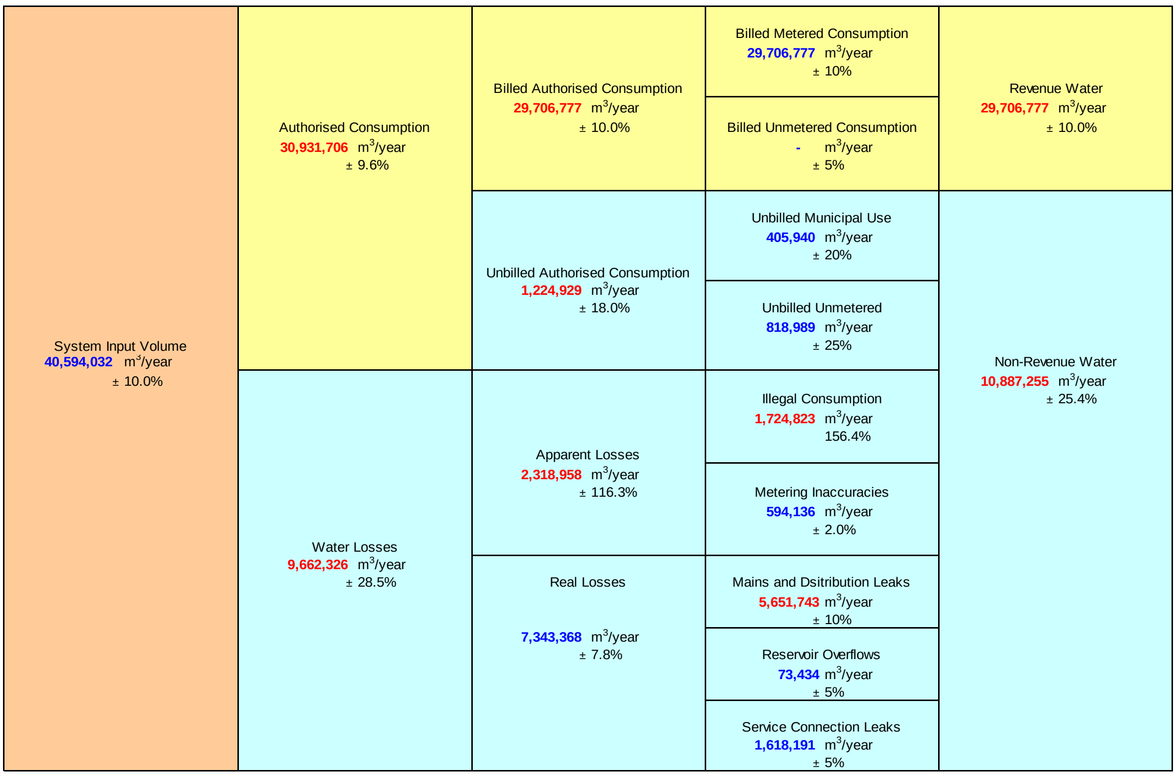


Figure 4-2: City of uMhlathuze – Consolidated Water Balance for 2011/12FY

4.2.3 Current Municipal WC/WDM Initiatives

During recent interviews with the City of uMhlathuze Water Services Department (March 2014), the indication was that the following initiatives are currently being implemented by the municipality:

- Assessment of water reuse options from the 20 Mℓ /day urban effluent volume currently discharged to sea, and the feasibility of one central regional waste water treatment works, although initial indications suggest this will be prohibitively expensive.
- Appointment of a Professional Services Provider to assist with pressure reduction initiatives in a targeted trial area with intention to expand into surrounding areas.
- Investigating a possible reuse plant to supply Foskor with treated effluent from one of the two existing municipal macerator plants, in exchange for potable water supplied.

4.2.4 Prioritisation of WC/WDM Opportunities

Table 4-2 provides a list of prioritised opportunities for implementing WC/WDM in each municipal area within the City of Mhlathuze. These are as identified in the detailed 2008 assessment. The table also provides a summary of the application opportunities of each in the towns and indicates to what extent these have been implemented to date.

Pressure Reduction
Average system pressures are high in some areas (notably Empangeni) with potential for pressure management in such towns. Pressure management control is possible through upgrading and setting of existing pressure reduction valves (PVRs) and installing controllers towards reducing leakages, notably at night when flows are reduced and system pressures are at their highest.

Active Leakage Control without Refurbishment
Active Leakage Control (ALC) without refurbishment was found to be preferential to that with refurbishment because the small marginal increase in water saving through an expensive refurbishment does not appear to be financially viable. The implementation of an effective ALC programme also requires establishing discrete district meter areas (DMAs), of which there were three in 2008 at an average of 3 116 connection. However the discreteness of these zones needed to be confirmed.

Active Leakage Control with Refurbishment
ALC with refurbishment of the infrastructure in order to reduce water losses is a possible option to consider in the longer term. However, the marginal benefit of this option as opposed to ALC without refurbishment is very small, whilst the necessary capital investment is significant.

Tariff Redesign
The cost of water in Richards Bay remains relatively inexpensive, even though a 6-step tariff structure is in place, and it is unlikely that this acts as a deterrent to wasteful water use, particularly by the larger water users, due to the relatively flat tariff steps. The current upper limit of consumption (above 60kl/month) is only R12,90/kl which is significantly less than other coastal municipalities in South Africa such as Cape Town (R28/kl), eThekwini (R30/kl), Buffalo City and George (both R20/kl), in which stepped tariff structures are also in place. Tariff redesign must take cognisance of socio-economic impacts.

Consumer Awareness and Education Programmes
Expansion and continued development of the existing awareness and education programmes offers ongoing opportunity to influence the perceptions of the public on water use, its scarcity and the roles they can play in conserving water. The awareness campaigns should extend into the billing, the media and schools.

Table 4-2: Prioritised Opportunities for WC/WDM Interventions in the Urban Sector

WC/WDM Intervention	RICHARDS BAY	EMPANGENI	eSIKHAWINI	NGWELEZANE	NSELENI
Pressure Management					
Opportunity	Estimated potential saving is moderate (2.5 Mℓ /d) in Richards Bay, but focus should be on reducing the occurrence of expensive pipe burst repairs.	Potential saving of 3 Mℓ /day through installation of dual outlet control PRVs on the bulk supply zones and a focus on reducing night pressure.	Potential saving of 2 Mℓ /day through installation of dual outlet control PRVs on the bulk supply zones and a focus on reducing night pressure.	Potential saving of about 0.4 Mℓ /day through installation of dual PRVs in two proposed DMAs.	Relatively small volume could be potentially saved (0.2 Mℓ /day).
Extent of Implementation	Reducing of excessive pressures helps reduce pipe bursts. 6 existing PRV zones have been optimised and 2 new PRV zones have been designed and shall be implemented in the next 10 months.	Reducing of excessive pressures help reduce pipe bursts. 4 existing PRV zones have been optimised and 8 new PRV zones have been designed and shall be implemented in the next 10 months.	Reducing of excessive pressures help reduce pipe bursts. 12 existing PRV zones have been optimised and no new PRV zones have been designed.	Reducing of excessive pressures help reduce pipe bursts. 4 existing PRV zones have been optimised and 9 new PRV zones have been designed and shall be implemented in the next 10 months.	Reducing of excessive pressures help reduce pipe bursts. No PRV zones have been optimised and 4 new PRV zones have been designed and shall be implemented in the next 10 months.
Active Leakage Control without Refurbishment					
Opportunity	Assess integrity of the three DMAs. Purchase leak detection equipment, identify DMAs with excessive leaks and repair leaks. Estimated potential saving of 7 Mℓ /day.	ALC without refurbishment of the water supply infrastructure in Empangeni is estimated to potentially save about 6 Mℓ /day	Consumer meter management should be implemented first. Then ALC without refurbishment which in Esikhawini is estimated to potentially save about 1 Mℓ /day.	A possible option (saving about 0.5 Mℓ /day) but not considered to be a high priority. Less financially viable than areas.	It would be financially viable to save about 0.2 Mℓ /day through ALC without infrastructure refurbishment.
Extent of Implementation	This area will be the fifth focus area for proactive leak detection and repair activities.	This area will be the fourth focus area for proactive leak detection and repair activities.	490km of reticulation have been surveyed and 212 leaks found and 158 leaks repaired to date.	This area will be the second focus area for proactive leak detection and repair activities.	This area will be the third focus area for proactive leak detection and repair activities.
Tariff Redesign					
Opportunity	Water remains cheap. Tariff redesign offers opportunity to discourage wasteful water use (consumer use reduction) but must take cognisance of socio-economics and not place further burden on low income, low water users. The upper limits of the tariff structure need to be reconsidered. Potential water savings have not been quantified.				
Extent of Implementation	Leak Detection has started to find leaks and repair them	Leak Detection has started to find leaks and repair them	Leak Detection has started to find leaks and repair them	Leak Detection has started to find leaks and repair them	Leak Detection has started to find leaks and repair them

WC/WDM Intervention	RICHARDS BAY	EMPANGENI	eSIKHAWINI	NGWELEZANE	NSELENI
Public Awareness					
Opportunity	Expansion and continued development of the existing awareness and education programmes to be continued through the billing system in the media and through awareness programmes aimed at schools.				
Extent of Implementation	This initiative has begun with media articles and street pole posters in all areas. The schools program shall be started in July 2015.				
Top Consumer Meter Investigation and Replacement					
Opportunity	Assessment of every top 15 meter installation. Meter change outs and billing database monitoring. Focus mainly on industrial consumers. Estimated to potentially save about 4 Mℓ/day	Assessment of every top 15 meter installation. Meter change outs and billing database monitoring. Focus on both, industrial and commercial consumers. Estimated to potentially save about 3 Mℓ /day	Assessment of major commercial consumers. Meter change outs and billing database monitoring. Focus commercial consumers. Estimated to potentially save about 1 Mℓ/day	Assessment of every top 15 meter installation. Meter change outs and billing database monitoring. Focus on both, industrial and commercial consumers. Estimated to potentially save about 2 Mℓ /day	Assessment of major commercial consumers. Meter change outs and billing database monitoring. Focus commercial consumers. Estimated to potentially save about 1 Mℓ/day
Extent of Implementation	This area is the main focus area of this intervention. Four meters have been replaced for more accurate installations. The balance is expected to be finished in April 2015.	This area is the second focus area of this intervention. Two meters have been replaced for more accurate installations. The balance is expected to be finished in March 2015.	This area will be the fourth focus area for top consumer meter replacement. Consumers have been identified and implementation should be conducted in the next 6 months.	This area will be the third focus area for top consumer meter replacement. Consumers have been identified and implementation should be conducted in the next 6 months.	This area will be the fifth focus area for top consumer meter replacement. Consumers have been identified and implementation should be conducted in the next 6 months.
Custody Transfer Meter Investigation and Replacement					
Opportunity	Assessment on current condition of every sale point from the City of uMhlathuze to other Municipalities. Refurbishing and repair of broken meters and/or installations not up to specification. Estimated to potentially save about 1 ℓ/day	Assessment on current condition of every sale point from the City of uMhlathuze to other Municipalities. Refurbishing and repair of broken meters and/or installations not up to specification. Estimated to potentially save about 3 Mℓ/day	Assessment on current condition of every sale point from the City of uMhlathuze to other Municipalities, as well as its location on site. Refurbishing and repair of broken meters and/or installations not up to specification. Estimated to potentially save about 1 Mℓ/day	Assessment on current condition of every sale point from the City of uMhlathuze to other Municipalities, as well as its location on site. Refurbishing and repair of broken meters and/or installations not up to specification.	Assessment on current condition of every sale point from the City of uMhlathuze to other Municipalities, as well as its location on site. Refurbishing and repair of broken meters and/or installations not up to specification. Estimated to potentially save about 3 Mℓ/day

WC/WDM Intervention	RICHARDS BAY	EMPANGENI	eSIKHAWINI	NGWELEZANE	NSELENI
Extent of Implementation	One installation has been identified and civils will be finalised by February 2015.	Three custody transfer meters have been identified and installations modified to suit current standards.	The only custody transfer meter identified in this area will be moved to a better location. Installation is to be completed by the end of February 2015.	No custody transfer meters have been identified thus far. This will be the fifth focus area for this intervention.	Four custody transfer meters have been inspected and installation change outs will be finished by February 2015.
Reservoir Inspection and Inlet Control Valve repairs					
Opportunity	Assessment on the system configuration for each reservoir within the City of uMhlathuze. Identification of inlet control valves that need repairs, as well as confirmation of the reservoirs' structure integrity.				
Extent of Implementation	A total of three reservoirs have been assessed. Schematics have been digitalized for all of them and recommendations been made to the City of uMhlathuze. Inlet control valve repairs will be done in the next 10 months.	A total of six reservoirs have been assessed. Schematics have been digitalized for all of them and recommendations been made to the City of uMhlathuze. Inlet control valve repairs will be done in the next 10 months.	A total of 10 reservoirs have been assessed. Schematics have been digitalized for all of them and recommendations been made to the City of uMhlathuze. Inlet control valve repairs will be done in the next 10 months.	A total of 22 reservoirs have been assessed. Schematics have been digitalized for all of them and recommendations been made to the City of uMhlathuze. Inlet control valve repairs will be done in the next 10 months.	A total of nine reservoirs have been assessed. Schematics have been digitalized for all of them and recommendations been made to the City of uMhlathuze. Inlet control valve repairs will be done in the next 10 months.
Reservoir Outlet Meter repair and District Meter installations					
Opportunity	Design of new zones for meter installations. Identification of reservoir outlet meters in need of repairs. Maximize the length of reticulation under meter control.				
Extent of Implementation	A total of six new meters have been identified thus far and installations will be completed by March 2015.	A total of five new meters have been identified thus far Three installations have been completed and the balance will be completed by March 2015.	A total of five new meters have been identified thus far Three installations have been completed and the balance will be completed by March 2015.	This area is the fourth priority zone. Meter installations will be designed and implemented in the next 12 months.	This area is the fifth priority zone. Meter installations will be designed and implemented in the next 12 months.
Domestic Meter repairs					
Opportunity	A full survey of the area will be conducted to identify old and/or faulty meters. Meters will be replaced for new ones and linked with the billing database. Illegal connection areas will also be identified.				
Extent of Implementation	This initiative will commence in February 2015 and is expected to be implemented in the next 12 months.				

4.2.5 Other WC/WDM Opportunities

Over and above the prioritised interventions tables above, the following additional interventions also offer opportunity to use water more efficiently in the urban sector.

Consumer Metering

A financially optimised meter renewal programme would offer opportunity to not only reduce current leaks and repair costs but also to rectify problems associated with meter-reading errors and consequential shortfalls in income. In some areas, the average age of the meter stock (in 2008) was more than 10 years and it was estimate that consumer meter losses could be in the region of 10%.

Ongoing Public Awareness Programmes

A programme for the municipality needs to be based on a knowledge attitudes and practice survey, which would be the first step to producing education materials and a relevant campaign which should be implemented on an ongoing basis.

Review of Bylaws

The water services bylaws of City of uMhlathuze need to be reviewed and revised into a version that reflects the fundamentals of water conservation and water demand management and how this can be enforced. It is particularly important that the legal instruments for consumer demand management are established. Bylaws could for example specify the requirement for all new and renovated buildings be fitted with water efficient fittings only.

A range of potential WC/WDM measures have been included in **Error! Reference source not found.**.

4.2.6 Urban WC/WDM Saving

The potential saving in water consumption due to the above actions is linked to the Unaccounted for Water (UAW) for a specific area, where UAW is the difference between the bulk input into the area and the measured usage/consumption within that area.

It is generally accepted that UAW cannot generally economically be reduced to below 15% of the annual average daily demand (AADD) in South Africa due to the high costs of identifying and repairing the smaller problems. The potential savings is therefore the difference between actual UAW and the 15% of AADD target.

It is recommended that a saving of 10% on current urban water use within the next 10 years be targeted (8.1% reduction was recommended in the City of uMhlathuze – 5 Year Strategic Management Plan for WC/WDM in 2012), i.e. 4.0 million m^3/a to reduce unaccounted for water to an acceptable level. WC/WDM projects would need to be conceptualised and budgeted for with this target in mind.

4.2.7 Financial Estimates

The URVs for different WC/WDM options are difficult to determine as the costs and savings will vary from area to area and will be dependent on the efficiency of the implementation initiative. The recommended savings would likely require an annual budget of more than R30 million (excluding VAT, and excluding any mains replacement programme. An annual operations budget of about R 750 000 per annum should be set aside to ensure the sustainability of all pressure management intervention as well as targeted leak detection and repair activities.

The impact of savings due to reduced bulk water purchases and/or wastewater treatment and the impact of delayed implementation of capital works infrastructure (water and wastewater), are typically not taken into consideration when evaluating the cost-benefits of WC/WDM projects, but does further support the argument that almost all WC/WDM measures are financially attractive to implement.

4.2.8 Ecological Impacts

Urban WC/WDM will have virtually no adverse ecological impacts. It will be beneficial in relieving water resource stress through reduced abstractions from lakes and the Mhlathuze River, with possible reduction in releases from Goedertrouw Dam.

Increased domestic re-use may result in a more concentrated effluent being discharged to the marine environment. The impact of dilution of the marine outfall may if regarded as necessary be investigated to determine if effluent discharge conditions could be violated if a more concentrated effluent is discharged.

4.2.9 Socio-Economic Impacts

More water efficient measures and processes should not have adverse socio-economic impacts. The possible implementation of WC/WDM measures that will drastically reduce water demand, such as for example the implementation of steeply increased tariffs, would however have to be carefully managed, as it would reduce municipal revenue.

Dual pipeline systems, if considered, should be very carefully managed as they could pose a health risk.

Many of the WC/WDM interventions require capital outlay by home owners such as e.g. grey water systems, private boreholes or more efficient water fittings, which would be prohibitively expensive to the less well-off.

These options are labour intensive by nature, and therefore have the ability to generate a large number of semi-skilled and skilled employment opportunities.

4.2.10 Findings

The main recommendations of the *City of uMhlathuze – 5 Year Strategic Management Plan for WC/WDM*, 2012 are the following:

- *It is of extreme importance that the internal profile of WC/WDM is raised to such a level as to demonstrate Corporate and Financial Department support and buy-in. Without this, the success and impact of the entire programme will be compromised.*
- *If budget permits, all current vacancies need to be filled with qualified people in order to assist with the successful roll-out of a large-scale WC/WDM programme. If budget doesn't allow extending the personnel as proposed, then is imperative that the profile of WC/WDM is elevated to as senior level as possible within the Client organisation.*
- *Use the provided predictive model to prioritize interventions according to available budget.*
- *Investigate Top Consumers per each Local Municipality - ensure that meters are properly installed, registered in the Billing System and meter is read monthly.*
- *All unmetered connections must be metered and registered in the Billing Database as a matter of urgency.*
- *Appropriate metering, illegal connection and real loss reduction policies need to be developed and implemented.*
- *Water mains replacement has not been addressed in this study. Never the less this is an important part of any future program.*
- *The largest impact on WC/WDM is resolving the unregistered consumers in the billing database and implementing advanced pressure management.*
- *An Infrastructure Information Office (CAD & GIS) must be set under the Technical Department. All Technical Data (drawings, plans, maps, etc.) should be captured as a matter of urgency.*
- *New design standards must be formalised and implemented (new pressure regimes, pipe material, etc.)*
- *Start an active leak detection program.*
- *Identify high burst area and high real loss to start a pressure management program.*
- *The recommendations as contained in this Master Plan for the roll-out of the WC/WDM interventions must be approved for implementation.*

Table 4-3: Potential Urban WC/WDM Measures

<table>
<tr>
<td>WC/WDM measures downstream of water meters:
▪ Use of water efficient fittings in new construction
    o By-laws and engagement with certain standard authorities to promote the use of water-efficient fittings in private properties.
▪ Retrofitting of inappropriate plumbing and sanitation fittings
    o Installed water-efficient fittings in management utility buildings
▪ Water wastage at schools in the supply area
▪ Elimination of automatic flushing urinals
    o specific projects
    o promulgation of by-laws for private property
▪ Efficient landscape irrigation (water wise gardening)
▪ Pressure management
▪ Use of private boreholes - promote and regulate their installation and use
▪ Grey water use</td>
<td rowspan="2">WC/WDM measures upstream of water meters:
▪ Domestic /industrial meter replacement programme
▪ Revisit water tariffing structure and credit control (effective billing and pricing)
▪ Address illegal connections
▪ Remove mid-block water supply systems
▪ Tariffs, metering and credit control (consumer, bulk and zone metering)
    o Rising block tariffs
    o An understanding of price elasticity in the area needs to ascertained
    o Volumetric based sanitation tariffs
    o Adopted policy of universal metering
    o Meter audits of high use consumers
    o Replace outdated or old meters
    o Zone Management (sectorisation): programme to establish zones and install zone meters
    o Instituted systems to facilitate the management of meters and the collection, assimilation and analysis of consumption data (monitoring and information management); and
    o Actively pursued credit control.
▪ Leakage detection and repair programme, including hotline
▪ Evaluate water balance and UAW
▪ Pipe replacement prioritisation</td>
</tr>
<tr>
<td>Education / Institutional measures:
▪ Dedicated WC/WDM unit/staff
▪ Updated WC/WDM Strategy/ies
▪ By-laws
▪ Clear rules and implementation procedures for water restrictions management during droughts
▪ Awareness raising, education, communication and marketing campaign
    o A public awareness/ user education programme
    o Consumer education through informative prints with monthly billing
    o Programmes/initiatives to enhance in-house awareness.
    o A schools (educators and learners) awareness programme
    o Support events and develop partnerships with DWS and DoE for the promotion of water efficiency
▪ Asset register and asset management</td>
</tr>
</table>

4.3 Rainwater Harvesting

4.3.1 Scheme Layout

In the evaluation of this intervention reports from several other studies and papers were used for reference. These included:

- Water Reconciliation Strategy Study for the KwaZulu-Natal Coastal Metropolitan Areas: Rainwater Harvesting. This was a short additional study undertaken as part of the Water Reconciliation Strategy Study, and focussed mainly on urban rainwater harvesting and particularly on the potential for harvesting rainwater from roofs for domestic use.

- Rainwater Harvesting: A Neglected Rural Water Supply Option. This paper examines the technologies used in remote areas in South Africa for harvesting rainwater, and demonstrates that rainwater harvesting can be a cost-effective and appropriate option in some situations.

- Climate Change and Rainwater Harvesting in South Africa: A Case Study. The focus of this paper is on harvesting of rainwater from roofs to help alleviate the temporal water supply problems and supplement the conventional water supply type of rainwater harvesting, and models how often a typical family's daily household water needs can be fulfilled under present and future climate change conditions.

- Tank Sizing from Rainfall Records for Rainwater Harvesting under Constant Demand. This study investigates the possibility of simplifying the process of sizing a rainwater tank for optimal results.

  The Rainwater Harvesting study carried out with the KZN Coastal Metropolitan Areas project was used as a primary reference here, being relatively recent and proximate to the study area. Some of the findings were adopted, and some revised, as explained below. One of the main points noted in this report was that rainwater harvesting is more likely to be a successful and feasible option when used in conjunction with an existing supply.

4.3.2 Scheme Description

Rainwater harvesting is a broad term and covers many different methods and approaches. It is defined by Siegert (1994) as 'the concentration, collection and storage (in different structures or in the soil) of rainwater for use either on-site or at a different location, immediately or at a later time.'

Thus, rainwater harvesting may be the collection of rainwater and storage by means of roof-top, surface or underground tanks, for commercial, industrial or domestic use. It may be the storage of rainwater in farm dams for use in irrigation; it may be in an urban or rural environment, and it may be on a small or large scale, as a sole supply option or to supplement an existing system.

In recent years, as awareness of the need for conservation of water resources has grown, more attention has been given to developing innovative methods of using rainwater, especially in urban environments where rainwater runoff is an issue to be dealt with, as well as an untapped resource. This has been incorporated into 'Low Impact Development', 'Green Infrastructure' and other environmentally-oriented design philosophies. The aim is to consider rainwater harvesting and its use, amongst other environmental factors, in the design of new developments and plans. Designs are then aimed at maximising the use of rainwater, minimising the quantity of rainwater runoff that has to be disposed of, and therefore allowing users to save on the quantities of treated water required, especially for non-potable uses, and minimising on environmental effects. Figure 4-3 gives some examples of LID systems.

Figure 4-3: Examples of Low Impact Development Systems for Rainwater Harvesting

Many of the more sophisticated forms of rainwater harvesting are highly unlikely to be feasible in this situation, owing mostly to the lack of local expertise in implementing the systems and availability of the technology in South Africa.

There is currently some harvesting of rainwater by the large industries in the area (RBM, Foskor, BHP Billiton), as they use on-site stormwater runoff in their processes. These plans have been successful and it is likely that other industries in the area will follow suit.

The most common type of rainwater harvesting is collecting rainwater from roofs for domestic purposes (see Figure 4-4. These purposes include for outdoor uses such as watering gardens, washing cars and filling swimming pools etc.; and for indoor purposes such as flushing toilets and running washing machines and dishwashers. If harvested rainwater is to be used for potable purposes it becomes necessary to ensure that the water is adequately filtered and of potable standard. The DWS does not recommend potable use.

Figure 4-4: Conventional Rainwater Harvesting Systems

In this study the feasibility of harvesting of rainwater from roofs for outdoor and indoor non-potable domestic uses will be considered.

4.3.3 Yield

The potential for rainwater harvesting is dependent on the MAP of the area, the catchment size (area collecting rainwater e.g. rooftop size) and the storage available, as well as the rate of use (drawdown), the distribution of the rainfall over the year and the rate of evaporation.

The annual rainfall between 1970 and 2000 is shown below in Figure 3 and the MAP of the quaternary catchments in the uMhlathuze Local Municipality was found to be approximately 1200mm (WRC, 2009).

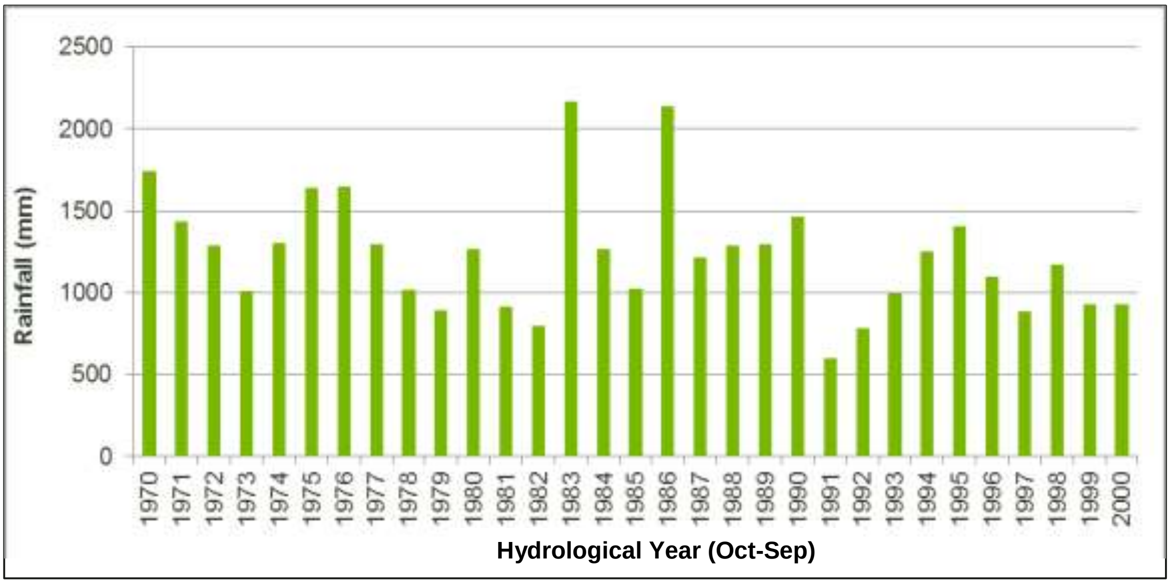


Figure 4-5: **Historical Annual Rainfall Record for the Richards Bay Area (1970-2000)**

There are approximately 86000 households in the uMhlathuze Local Municipality (ref 44 WSDP), of which 66.4% are conventional brick houses on separate stands, the remainder being flats, townhouses (duplexes, simplexes etc.), traditional dwellings and informal housing (ref 32 Key Stats for CoU). Therefore there are about 57,100 houses which can be considered for RWH, excluding innovative systems for rainwater harvesting in rural areas. For roof areas a similar distribution is used as for the eThekwini area. An adjustment that was made was to lower the percentage of larger houses and increase the percentage of smaller houses: the Richards Bay area has a smaller high-income group than the eThekwini area, and this will result in a smaller number of large houses (with roof areas of 150m^2 and over). The distribution of roof sizes is given below in Table 4-4:

Table 4-4: **Properties per Roof Area**

Roof Area (m^2)	Percentage Properties	Number of Properties
40	20	11,420
60	25	14,275
100	20	11,420
150	15	8,565
200	10	5,710
>200	10	5,710
Total	100	57,100

From this it can be calculated that the average roof area is between 100m^2 and 125m^2. The water tariffs for the City of uMhlathuze are based on a rising block system, and are given in Table 4-5.

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Table 4-5: City of uMhlathuze Water Tariffs

Monthly Usage (Kl)	Cost (R/Kl) at 01-Jul-2014
<6	1.6313
6-15	3.2937
15-30	7.4642
30-60	9.8912
>60	12.9012

The monthly and annual household usage according to the size of the dwelling and hence roof-area was taken from the KZN Metros study and is given below in Table 4-6:

Table 4-6: Annual Cost of Water to Consumers

Roof Area (m^2)	Monthly Usage (Kl)	Annual Usage(Kl)	Annual Cost (R)
40	9	108	355.72
60	9	108	355.72
100	22	264	1970.55
150	25	300	2239.26
200	30	360	2687.11
>200	35+	420+	4154.30+

The uses being considered here are indoor and outdoor non-potable uses, as described in Section 2 above. Outdoor purposes are estimated to take up 35% of water use in houses with gardens and around 10% in houses without gardens. Based on the assumption that small houses (40m^2 – 60m^2) will be less likely to have gardens and larger houses (>100m^2) will be more likely to, figures for the target drawdown (abstraction) from rainwater tanks can be calculated.

Of indoor purposes, non-potable uses such as flushing the toilet, baths and showers, washing machines etc. make up 90% of the use of lower-income households and 85% of higher-income houses (as a result of there being more water-using appliances such as dish-washers). Figures for target drawdown of rainwater tanks supplying these non-potable are given below in Table 4-7:

Table 4-7: Target Drawdown Volumes

Roof Area (m^2)	Outdoor Usage (Kl/ month)	Indoor (Non-Potable) Usage (Kl/ month)	Total Non-Potable Usage ‘ (Kl/ month)
40	0.9	7.3	8.20
60	0.9	7.3	8.20
100	7.7	12.2	19.90
150	8.75	13.8	22.55
200	10.5	16.6	27.10

The potential yield per unit (house) is calculated based on the target drawdown from the rainwater tanks, the daily rainfall record for a representative rainfall station in the area, the various roof sizes and the size of the rainfall tank. It is assumed that 90% of the rain falling on the roofs will be collected. The results are shown below in Table 4-8 and Table 4-9.

Table 4-8: Yield for Outdoor Usage

Roof Area (m^2)	Outdoor Usage (Kl/ month)	Tank Size (Kl)	Yield (Kl/a)
40	0.90	0.26	9
		0.5	10
		1	11
		5	11
60	0.90	0.26	10
		0.5	10
		1	11
		5	11
100	7.70	1	52
		5	75
		10	82
150	8.75	1	61
		5	91
		10	99
200	10.50	1	70
		5	109
		10	119

Table 4-9: Yield for Total Non-Potable Usage

Roof Area (m^2)	Non-Potable Usage (Kl/month)	Tank Size (Kl)	Yield (Kl/a)
40	8.20	1	35
		5	45
		10	47
60	8.20	1	43
		5	60
		10	66
100	19.90	1	71
		5	98
		10	109
150	22.55	1	88
		5	131
		10	149
200	27.10	1	105
		5	160
		10	184
		15	197

Ideally the tank that maximised the yield would be chosen, but the relative costs have to be considered. This is discussed below, and the conclusion is that in almost all cases the 5Kl tank is the most cost-effective option. Based on this various scenarios for implementation of the option can be derived. Assumptions of adoption percentages for different house sizes are made. In the base case only the larger houses are likely to adopt RWH, and only a small percentage of those. With increased awareness of the advantages of RWH and the need for conservation, a larger percentage of the different groups might adopt the system, and with a comprehensive implementation programme and possible subsidies, higher percentages could be achieved. The 100% adoption scenario is included for purposes of comparison.

Table 4-10: Total Yield, Base Adoption Scenario

Roof Area (m^2)	Yield (Kl/a)	Number of Houses	% Adoption	Total Yield (Kl/a)
40	45	11,420	0	0
60	60	14,275	0	0
100	98	11,420	5	55,958
150	131	8,565	5	56,101
200	160	5,710	5	45,680
TOTAL				157,739

Table 4-11: Total Yield, Increased Adoption Scenario

Roof Area (m^2)	Yield (Kl/a)	Number of Houses	% Adoption	Total Yield (Kl/a)
40	45	11,420	5	25,695
60	60	14,275	5	42,825
100	98	11,420	10	111,916
150	131	8,565	15	168,302
200	160	5,710	20	182,720
TOTAL				531,458

Table 4-12: Total Yield, 50% Adoption Scenario

Roof Area (m^2)	Yield (Kl/a)	Number of Houses	% Adoption	Total Yield (Kl/a)
40	45	11,420	50	256,950
60	60	14,275	50	428,250
100	98	11,420	50	559,580
150	131	8,565	50	561,008
200	160	5,710	50	456,800
TOTAL				2,262,588

Table 4-13: Total Yield, 100% Adoption Scenario

Roof Area (m^2)	Yield (Kl/a)	Number of Houses	% Adoption	Total Yield (Kl/a)
40	45	11,420	100	513,900
60	60	14,275	100	856,500
100	98	11,420	100	1,119,160
150	131	8,565	100	1,122,015
200	160	5,710	100	913,600
TOTAL				4,525,175

4.3.4 Unit Reference Value

The URV for each option is determined here, based on a number of factors: costs for the tanks themselves as well as gutters, pumps, pipework etc. These costs will vary greatly according to the size of the tank, the amount of guttering etc. that is required to conduct the rainwater to the tank, the power of the pumps required to deliver the water at an acceptable pressure, and, for indoor use, the amount of pipework and fittings required to incorporate the rainwater system into the household system. This last is a significant cost, especially when only selected uses are supplemented with rainwater, and it is not possible to simply tap the rainwater supply into one point. Bearing this in mind, different costs were applied for indoor and outdoor options.

Other factors considered in the determination of the URV are a calculation period of 27 years (2014-2040), and discount rates of 6%, 8% and 10% being used for purposes of comparison, with 8% being the final rate used. Annual cost for maintenance of the components of the rainwater harvesting systems is calculated at 0.5% of the capital cost of civils (tanks, gutters etc.) and 4% of mechanical components (pumps). A lifespan of 10 years for pumps and 20 years for the tanks etc. is assumed. Electricity is included to power the pumps, and it should be noted that this adds significantly to the cost.

The calculated URVs are given below in Table 4-14 (for outdoor use) and Table 4-15 (for total non-potable use).

Table 4-14: URV for Rainwater Harvesting: Outdoor Use (R/Kl)

Roof Area (m^2)	Tank Size (Kl)	Yield (Kl/a)	URV @ 8% (R/Kl)
40	0.5	10	109.55
	1	11	103.52
	5	11	125.08
60	0.5	10	109.55
	1	11	103.52
	5	11	125.08
100	1	52	21.90
	5	75	18.35
	10	82	24.39
150	1	61	19.55
	5	91	15.71
	10	99	20.75
200	1	70	17.04
	5	109	13.12
	10	119	17.26

Table 4-15: URV for Rainwater Harvesting: Non-Potable Use (R/Kl)

Roof Area (m^2)	Tank Size (Kl)	Yield (Kl/a)	URV @ 8% (R/Kl)
40	1	35	43.90
	5	45	39.41
	10	47	51.02
60	1	43	35.73
	5	60	29.56
	10	66	36.33
100	1	71	21.64
	5	98	18.10
	10	109	22.00
150	1	88	17.46
	5	131	13.54
	10	149	16.09
200	1	105	14.63
	5	160	11.09
	10	184	13.03
	15	197	18.97

From the above tables it can be seen that this option is expensive, compared to the price that users pay for municipal water, and to the typical cost of other interventions. It is only for large houses and greater water use that the URV cost begins to approach a competitive price. If the use of rainwater can reduce a consumer's municipal usage to a lower tariff block, this will contribute to the savings incurred. Since outdoor uses contribute a significant proportion of the volume that can potentially be supplied by rainwater, larger houses with larger gardens, pools, ponds etc. will also be more likely to make savings by harvesting rainwater.

Lower-income groups with smaller uses, smaller roof-areas and smaller gardens are much less likely to be able to implement rainwater harvesting feasibly. Besides this, the initial outlay is also expensive for an ordinary householder, and this requires some financial resources. Were the installation of the system to be subsidised, an advantage of the option is that little is required in the way of maintenance and operational costs. There are various possibilities for subsidisation programmes or for providing assistance to householders for the installation costs.

Although the direct costs of this intervention are not generally feasible, it should be noted that there are some indirect savings associated with the implementation of rainwater harvesting. For example, the amount of treated water required by the consumers decreases, and this means that there is less strain on the treatment works and supply thereto. If the implementation of this option can meet growing needs for even a limited period, and the implementation of other interventions can be delayed for this period, the savings in current-day costs can be significant, and this should be taken into account when evaluating the relative merits of each intervention.

As this is not a standard type of intervention, such as the building of a dam, pipeline or treatment works, the multiplication factors that are usually applied to the capital costs are not included here: there will be no need for professional fees, site supervision or other such costs. Should a wholesale approach be adopted and a large programme be implemented, project management costs may be incurred, but these are unlikely to be more than 10% of the total cost, and this is within the expected error margins of the cost estimates.

4.3.5 Ecological Impact

In general the environmental impact of this intervention is positive: harvesting the rainwater contributes to attenuation of peak flows, and there is less runoff to be dealt with in the municipal sewerage system. Furthermore, less treated water is required by households, and therefore the demand on the system is decreased.

Stellenbosch University (Dobrowsky et al, 2014) investigated the suitability of harvested rainwater for household use. They studied a new low-cost development where houses were fitted with 2000 L rainwater tanks to capture runoff from roofs. They tested the chemical and microbial quality of rainwater collected from rainwater tanks of over six months and found that the chemical analyses indicated that the rainwater quality was within potable water quality standards. Metals, cations and anions were all below the recommended drinking water guidelines. However, the microbial analysis showed the presence of waterborne pathogens in numbers that exceeded the drinking water guidelines. The main causes of contamination were windblown dirt and faeces (from birds and small animals) on the roof surface. Other contamination sources included leaf debris and organic material washed into the rainwater tanks, animals or birds that fell into uncovered tanks, as well as breeding mosquitoes. The roofing material affects the quality of the harvested rainwater. For example, elevated zinc levels have been detected in rainwater collected from roofs constructed with galvanised iron sheets, while elevated lead levels were recorded in rainwater collected from painted roofs.

The World Health Organisation strongly discourages the direct consumption of untreated rainwater due to evidence of microbial contamination. Treatment of rainwater is of paramount importance and two approaches for treating harvested rainwater have been applied, namely, treatment directly in the tank, or removing the water and treating the water separately. Low cost treatment techniques include options such as boiling, chlorine or bleach addition, slow sand filtration, and disinfection by using solar technologies.

Rainwater harvesting is a feasible option for household use such as washing, flushing toilets, garden watering, etc. However, treatment and disinfection is required if it is to be used for drinking water. Consumer education is also required to ensure rainwater tanks are protected and managed properly. The Stellenbosch University (Dobrowsky *et al*, 2014) study noted that rainwater tanks are not a 'fit-and-forget' technology and require regular maintenance and upkeep.

4.3.6 Socio-Economic Impact

At a household level the ability to supplement or even replace the municipal water-supply is an advantage financially, as it reduces the expenditure on municipal water-supply. The initial cost of installing storage tanks and any associated fittings is relatively high, and, unless the cost is subsidised, this makes it less likely that lower-income groups will be able to afford it, as well as increasing the NPV of the option. In rural areas where municipal water is more difficult to provide, this is an appropriate supply option when compared with the cost of trucking water in.

Also, changes in weather systems due to climate change could result in droughts occurring more frequently, increasing requirements and pressure on water resources, making this a more attractive option to consumers.

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4.3.7 Findings

The cost of retrofitting a rainwater harvesting system to a house is significantly higher than including it in the building of a new house. Some municipalities in South Africa are implementing by-laws that require new houses to include RWH systems, and this might be implemented in this area.

Overall rainwater harvesting is a sustainable and positive means of increasing the water-supply to an area. The high initial costs associated with retrofitting the hardware to existing houses is counterbalanced by the low running costs and sustainability of the option.

Specific strengths and weaknesses of the option include:

- **Strengths**
    - Quick to implement.
    - Recent reductions in the costs of rainwater tanks have made it more affordable.
    - Recent improved aesthetics of tank designs has made it more attractive for implementation by high income groups, particularly for garden watering and swimming pool top-up, etc.
    - Drought conditions and water restrictions could result in more than the expected number of tanks to be implemented.

- **Weaknesses**
    - The use of untreated rainwater from rainwater tanks for domestic purposes is not recommended by the DWS.
    - The option would largely be driven by the property owner.
    - Limited potential savings.
    - High initial costs.
    - The use of simple rainwater tanks in low income areas for vegetable garden watering may provide socio-economic benefits, provided that this does not lead to increased water usage during periods of low inflow into the dams.

5 SUSTAINABLE SUPPLY FROM COASTAL LAKES

5.1 References

In the evaluation of this intervention reports from several other studies and papers were used for reference. These included:

- Mhlathuze Water Availability Assessment Study, System Analysis Report, 2009
- Mhlathuze Operating Rules and Future Phasing (MORFP), Main Report, 2001
- Mhlathuze Operating Rules and Future Phasing (MORFP), Groundwater (Coastal Lakes) Hydrology Report, 2001
- uMhlathuze Water data of lake levels and abstraction

5.2 Scheme Layout

The lakes that form part of the strategy area water supply system have been presented in Figure 1.1.

5.3 Scheme Description

5.3.1 Overview of the lakes

Lakes Cubhu, Mzingazi and Nhlabane are coastal lakes perceived to be extensions of the local groundwater, with the aquifer formed by extensive sedimentary deposits. Lake Nsezi, on the other hand, is a coastal lake fed by rivers originating in the granitic formation further inland. Lake Nsezi is augmented from the Mhlatuze Weir.

These lakes are sources for abstraction in this strategy area, as follows:

- Lake Mzingazi supplies Bayside Aluminium and the Mzingazi WTW,
- Lake Nsezi supplies the Nsezi WTW and supplements RBM's supply from other sources,
- Lake Cubhu supplies the eSikhaleni WTW, and
- Lake Nhlabane supplies RBM's ponds and smelter.

Water from these lakes is generally of good quality, cheaper to treat than river water and is therefore a preferred source. Lake Nsezi experiences water quality problems though as a result of return flow from the Nseleni WWTW located upstream.

Key information about these lakes is shown in Table 5-1 (MWAAS, 2007).

Table 5-1: Characteristics of the WSS lakes

Location	Live storage above DML[(a)] (million m^3)	Natural inflow (million m^3/a)	Streamflow Reduction water use (million m^3/a)	WRYM modelled inflow (million m^3/a)
Lake Nsezi [(b)]	3.3	88.7	19.1	57.4
Lake Mzingazi	20.2	52.5	13.3	39.7
Lake Cubhu	3.6	18.0	4.0	14.3
Lake Nhlabane[(c)]	22.3	33.2	6.8	26.6

Notes: *(a) DML = drought minimum level*

(b) Levels as per MORFP study, 2001, where the DML was given as 4.5 mamsl and the full capacity as 6.97 mamsl and excludes transfers into the lake

(c) Comprises Lake Nhlabane and RBM storage reservoir supported by inter-catchment transfers from the Mfolozi River, including physical constraints on conveyance channels

5.3.2 Ecological Reserve

The MWAAS study includes estimates for the estuarine flow requirements (EFR) for the quaternary catchments within the Mhlathuze River Catchment, obtained from the MORFP study as summarised in Table 5-2.

Table 5-2: Lakes' Ecological Reserves

Lake	Ecological requirement (million m^3/a)
Lake Nsezi	2.9
Lake Mzingazi	4.5
Lake Cubhu	1.5
Lake Nhlabane[(a)]	14.3

Notes: *(a) Comprises Lake Nhlabane and RBM storage reservoir (being decommissioned) supported by inter-catchment transfers from the Mfolozi River*

The HFYs of the lakes are given in Table 5-3 for drought minimum levels (DML). These results exclude yields resulting from lake-groundwater interaction, about which there is still significant uncertainty.

Table 5-3: Lake Historical Firm Yields

Lake	Historic Firm Yield (million m^3/a)			Ratio of storage to net inflow
	DWS MORFP Study (2001)	*DWS MWAAS Study (2009)*	*This study (2014)*	
Nsezi	13.9	5.7	6.6	0.1
Mzingazi	10.8	8.2	10.5	0.5
Cubhu	5.3	0.3	0.4	0.3
Nhlabane	-	-	7.9	0.8
Nhlabane incl. Mfolozi transfer[a]	30.7	32.7	34.5	

Notes: (a) Comprises Lake Nhlabane and RBM storage reservoir supported by inter-catchment transfers from the Mfolozi River

The MWAAS hydrology was used in this study and therefore the yields obtained should be the same or similar to those obtained in the MWAAS study. There are some differences however which most likely can be attributed to minor changes in the configuration and update of upstream water demands to represent 2013 development levels.

The period of critical drawdown represents the elapsed time from storage full through storage empty and back to storage full. The drawdown of storage represents the imbalance between inflow and outflow, and its duration reflects the magnitude of this imbalance relative to the volume in storage:

- Lake Nsezi has the smallest live storage. Its critical period is relatively short due to the small ratio of storage to net inflow. The lake functions as a balancing storage for water supply through transfers from the Mhlathuze Weir (not included in this simulation of yield). The yield from its own catchment is largely dependent on the characteristics of runoff rather than the volume of storage in the lake. As Lake Nsezi is fed by significant runoff from the Nseleni River and is augmented by transfers from the Mhlatuze Weir, there are not currently concerns about the sustainability of this lake.
- The critical period at Lake Nhlabane is extended by the support in supplying RBM demands through inter-catchment transfers from the Mfolozi River (included in this simulation of yield). The very high proportion of simulated yield (108 per cent of catchment inflow) is significantly in excess of the HFY of the lake on its own.
- The critical periods of Lake Mzingazi and Lake Cubhu are comparable to their relative volumes of storage. Lake Mzingazi has the longer critical period due to its larger storage to inflow ratio compared with that of Lake Cubhu. However, both have similar yields in proportion to their volume of inflow (17 percent).

These findings will change once lake-groundwater interaction is taken into consideration. The modelling of the interchange of groundwater (MORFP Groundwater (Coastal Lakes) Hydrology Report, 2001) could only be undertaken at a low level of confidence, mainly as a result of a lack of field data regarding the impedance of the sediment layers in the lakes. Only the conceptual geological model of Lake Mzingazi is well supported by borehole data. Little data exists for the geology associated with the other lake systems. As a result only the surface water component was hence used in the analysis of lake yields. To change this assumption it would need to be proved through further research that the groundwater contribution from the coastal lakes is significant and can be estimated with reasonable accuracy. This would require measurements of the impedance of the sediment layer in the lakes and obtaining improved water balance measurements that can be used to calibrate the groundwater models of the lakes.

Because the groundwater contribution to lake yields has not been taken into account, it is quite possible that the modelled lake yields may be too low.

Richards Bay Minerals has undertaken an evaluation of the sustainable yield of Lake Nhlabane (*Nhlabane Sustainability Assessment*), and has concluded that the sustainable abstraction from the lake has dropped to 30 000 m^3/d. land use changes, compared to their demand of 29,000m^3/day. This equates to a yield of 10.95 m^3/a. Based on the increasing trend in streamflow reduction, it is estimated that this may within another 5 years drop to 20 000 m^3/d unless there was a substantial increase in rainfall or the land use trends changed.

5.3.3 Abstraction

Annual abstractions from the lakes over the previous five years are as shown in Table 5-4.

Table 5-4: WTW Annual Abstraction Volumes (million m^3)

Year	2008	2009	2010	2011	2012	2013
Nsezi WTW	40.82	44.77	48.25	45.94	43.36	39.67
Lake Nsezi - RBM	5.10	7.80	8.51	8.20	1.62	2.38
Total: Lake Nsezi	**45.92**	**52.57**	**56.76**	**54.14**	**44.98**	**42.05**
Mzingazi WTW	21.26	22.00	16.10	11.92	18.33	22.40
eSikhaleni WTW	10.15	9.98	10.34	11.37	11.36	11.16
Lake Nhlabane - RBM	12.48	8.86	5.23	3.77	11.37	12.95

5.3.4 Concerns about current levels of abstraction

There is concern about the abstraction from these lakes when compared with their HFYs, but there is also concern about the accuracy of the HFYs of these lakes.

The 2013 abstraction from Lake Mzingazi is seemingly *significantly* in excess of its sustainable yield (22.3 million m^3/a vs. 10.5 million m^3/a), and this is an important issue to be addressed. This does however also raise some concerns about the reliability of the determined Lake Mzingazi firm yield, given that the groundwater contribution has not been taken into account.

The 2013 abstraction from Lake Cubhu (11.16 million m^3/a) is very significantly in excess of its firm yield (0.4 million m^3/a). Transfers from the Mhlatuze Weir into the lake have been negligible to date.

RBM has significant concerns about the sustainability of abstraction from Lake Nhlabane (abstraction of 12.95 million m^3/a vs. 7.9 million m^3/a yield, or 10.95 million m^3/a from the RBM study). Note that no abstraction was made from the Mfolozi River in 2013 by RBM, unlike previous years. Diffuse water demands within the lake's catchment can have a marked impact on available inflow to lakes and any changes in their magnitude will affect the lake yield. RBM suggests that changes in land use, notably the increase in plantations in the catchment, reduce runoff and that this has an adverse effect on the lake's water-level and reduces groundwater augmentation potential.

The science on which the sustainable yields of the lakes (especially lakes Mzingazi and Cubhu) were determined is weak and as a result the confidence of the stated sustainable yields is low. The fact that only the surface water component was used in the analysis of the lake yields because of the very low confidence in the groundwater augmentation component (MORFP study) is probably a very significant factor.

5.3.5 Potential intervention

A possible approach to ensure sustainable abstraction from these lakes may be to limit the current extent of abstraction, use water when it is available and then use alternative sources. In practice this would mean increasing the minimum levels of abstraction. Note that the improved operation of the lakes to maximise system yield is not addressed by this intervention, as that is aimed at operational efficiency and not lake sustainability.

Should supply from these lakes be reduced, the pressure on the other available water sources would significantly increase and alternative bulk water sources may even potentially be required. This intervention would noticeably reduce the system yield. Current operating rules, which *inter-alia* try to prevent seawater intrusion, may need to be revisited should the available yield from the lakes be reduced.

Interrogation was therefore done of how the potential revision of the minimum abstraction levels of the coastal lakes influences the yield of the Strategy WSS. This was done for lakes Mzingazi, Cubhu and Nhlabane.

5.4 System Yield for Lakes

The various defined environmental and operational lake levels applicable to all environmental management categories (EMCs) are shown in Table 5. While these various lake operation levels have been defined for environmental operational purposes, it has been assumed that the lakes are managed at DMLs as a norm and not at maintenance minimum level (MMLs) for the evaluation. This however does not seem to be the actual situation, where lakes are drawn down to lower levels. RBM e.g. maintains the level of Lake Nhlabane at 1.8mamsl as the operational level although the actual permitted minimum level is 1.25 mamsl. At Lake Mzingazi abstraction ceases when the water level reaches 40% capacity.

Table 5-5: Environmental lake level requirements (applicable to all EMCs)

Description	Mzingazi (mamsl)	Cubhu (mamsl)	Nhlabane (mamsl)
Actual dead storage level	0.10	0.70	1.06
Drought minimum level (DML)	0.10	0.70	3.50
Maintenance minimum level (MML)	1.40	1.20	4.50
Current full supply level (FSL)	2.40	1.70	6.00

Source: Table 2.9b MORFP study, Systems Analysis Report, 2001

There is little basis for the determination of the revised minimum abstraction levels, given the very low confidence in the current yields. Two hypothetical minimum abstraction levels have therefore been selected to test the influence of increased revised minimum lake abstraction levels. The results of the HFY analysis for the three coastal lakes for their maintenance minimum levels (MML), their drought minimum levels (DML), and a level halfway between the two (50%) are shown in Table 5-6, Table 5-7 and Table 5-8).

Table 5-6: Limiting supply HFYs for Lake Mzingazi

Operating level	Level (mamsl)	Vol. (million m3)	Live storage (million m^3)	HFY (million m3/a)	% Reduction in yield
FSL	2.40	36.6			
MML	1.40	27.3	9.3	4.4	57%
50%	0.75	21.8	14.7	7.6	25%
DML	0.10	16.9	19.7	10.2	-
DSL	0.10	16.9			

Table 5-7: Limiting supply HFYs for Lake Nhlabane

Operating level	Level (mamsl)	Vol. (million m^3)	Live storage (million m^3)	HFY (million m^3/a)	% Reduction in yield
FSL	6.00	39.7			
MML	4.50	25.8	13.9	3.8	50%
50%	4.00	21.2	18.5	6.1	19%
DML	3.50	17.1	22.6	7.5	-
DSL	1.06	1.7			

Table 5-8: Limiting supply HFYs for Lake Cubhu

Operating level	Level (mamsl)	Vol. (million m^3)	Live storage (million m^3)	HFY (million m^3/a)	% Reduction in yield
FSL	1.70	6.1			
MML	1.20	4.2	1.9	0.0	100%
50%	0.95	3.3	2.8	0.14	66%
DML	0.70	2.5	3.6	0.41	-
DSL	0.70	2.5			

It is firstly evident that the total mismatch between the actual abstraction from the three coastal lakes and the apparent HFYs of these lakes means that the findings of this evaluation have to be viewed with great caution.

The evaluation illustrates that the operation of the lakes at higher minimum levels will lead to significant reductions in the HFYs of the lakes, although such yields only take surface flow into account and are by no means complete.

5.5 Unit Reference Value

This intervention does not have any direct cost implication, as it is an operational measure (resulting in negative yield) which only involves limiting the extent of abstraction. As a result a URV cannot currently be determined for this intervention. Should this intervention however result in the need to develop new water sources, the comparable cost of such development (for a similar change in yield) could be used to determine the URV.

5.6 Ecological Impact

The implementation of this intervention is expected to have positive ecological impacts on lake ecology although it is difficult to describe or quantify the specific ecological benefits, given the low confidence in the current estimates of lake yields. Should lake abstraction however be curtailed to the extent that replacement water sources will be required, the new developments would likely be associated with ecological impacts.

Drawdown of a lake has the effect of concentrating sediments and other water quality constituents into a smaller volume of water. This can have a negative impact on water quality and aquatic ecosystems in the lakes. Operating the lakes at a higher operating level will probably have a positive impact on water quality and aquatic biota.

5.7 Socio-Economic Impact

The socio-economic impacts of limiting supply from the lakes could potentially be significant. As it is a cheap source of water, switching some of the supply to more expensive sources would financially affect consumers. Should abstraction from the lakes be further curtailed, this will likely also influence the water balance to the extent that replacement water sources will be required, most likely at significant development and higher operational costs, and the associated impacts.

5.8 Findings

This is the only intervention that could negatively affect the water balance, with the objective to improve sustainable use of these lake resources. The very low confidence in the determined lake yields and the mismatch between current abstraction levels and estimated yields however means that this intervention much be approached with caution. It is recommended that the confidence in lake yields is significantly improved before any measures are introduced. Should this be implemented, an incremental approach would be advisable.

6 THUKELA RIVER TRANSFER SCHEMES

6.1 Increased Capacity of the Thukela-Mhlathuze Transfer Scheme

6.1.1 Scheme Layout

In the evaluation of this intervention as an option for the Richards Bay water-supply area reports from several other studies and papers were used for reference. These included:

- The '*Mhlatuze Basin Augmentation Feasibility Study*' (1993) by WLPU Consulting Engineers: this was the final report in a series of five studies carried out by WLPU between 1990 and 1993. These studies examined the water resources and requirements in the Mhlatuze catchment, as well as the augmentation options. The outcome was the recommendation that the Mhlatuze basin be augmented from the Thukela River.

  The 1993 report concluded that although the lower Thukela (Mandini) scheme had a greater scope for regional benefit (i.e. supplying a number of communities with water en route), the economic viability of the Middledrift scheme outweighed the regional benefits of the Mandini scheme. Layout drawings for the original Middledrift scheme were produced, although the pipeline and tunnel routes used in the cost analysis are those from more recent reports.

- '*Technical Proposal: Design of a Gravitational WSS (Tugela-Mhlatuze*)' (1994) by TMT Consortium. This was an investigation into an alternative scheme for the transfer of water from the Thukela to the Mhlatuze catchment, and it involved a canal and a gravity tunnel to avoid any pumping being required. This scheme was never taken further, but provides an interesting alternative for future investigation, should this option proceed to feasibility level.

- White Paper '*Report on the Proposed Tugela-Mhlathuze River Government Water Scheme*' (1995): this deals mainly with the Middledrift scheme and is based on the recommendation of the 1993 study, that the Mandini scheme be abandoned in favour of the Middledrift scheme.

- The '*Mhlatuze Basin Bulk Water Augmentation – Thukela/Mhlatuze Transfer Scheme*' (1998) by Ninham Shand Consulting Engineers: this study took into account two aspects of the situation that had changed since the earlier evaluations. Firstly, the Middledrift scheme as described in the White Paper had not been built, and the emergency scheme had been put in place instead. Secondly, Iscor Mining (now Tronox) required water for their Hillendale and later Fairbreeze mines, and had undertaken a desktop study to construct a pipeline from the lower Thukela to their mines.

  Based on these developments the Middledrift and Mandini schemes were re-evaluated and different scenarios analysed. The conclusion was that the coastal pipeline was more feasible economically, but this assumed that the supply to Iscor (Tronox) mines was included. It was also noted that the comparison between the Middledrift and Mandini schemes needed to be refined.

- Layout drawings of the existing emergency pipeline and updated tunnel routes produced by Stewart Scott Incorporated (2001) were used in the costing of the options in this study.

- Layout drawings by the then Department of Water Affairs and Forestry (1998) of the proposed weir layout and details were used in the costing of the weir for the various options.

Based on the information from the above reports the following approach was taken to evaluating the Middledrift scheme: a number of options for augmenting the transfer were explored, based on the scenarios described in the 1998 study, and using the pipeline and tunnel routes included in the 2001 report. The details of the various options, as well as the assumptions made, are discussed below.

6.1.2 Scheme Description

The original route for the pipeline and tunnel is shown in Figure 6-1. This route was designed in the early 1990s with the intention of putting in place a 252 million m^3/a (8m^3/s) transfer, as it was predicted at the time that this was the order of the augmentation required in the future. This scheme included a weir, pump-station (Madungela), pipeline and a 3.5m diameter, 7800m-long gravity tunnel, introduced to reduce the pumping head required. The augmentation was planned in three phases of 84 million m^3/a (2.66m^3/s) over a period of fifteen years. Water abstracted from the Thukela River was to be transferred to the Mhlatuze catchment upstream of Goedertrouw Dam, which supplies a large part of the downstream catchment.

During the drought of 1994 an emergency augmentation scheme was put in place (commissioned in 1997) that has the capacity to deliver 37 million m^3/a (1.2m^3/s) to the Mvuzane stream, a tributary of the Mhlatuze River. During the ongoing drought, it was reporting that only about 1.0m^3/s was being delivered through the emergency scheme. This scheme does not include the previously proposed weir or tunnel, and most of the infrastructure was not intended to be permanent. Only the 1,500mm-diameter pipeline between the high-lift pump-station and the future tunnel entrance was intended to remain when the final scheme was built. However, once the capital investment had been made, it became more likely that using the existing infrastructure would be more cost effective than replacing it with the tunnel scheme. It has only been necessary to utilise the scheme on one occasion since it was constructed.

The emergency scheme includes a second high-lift pump-station (Mkhalazi) at the end of the 1,500mm pipeline, to pump the water over the watershed, through an extra rising main and gravity main. The outfall point of that pipeline is higher up in the Mhlatuze catchment, on the Mvuzane stream, than the outfall of both the original and proposed tunnel routes. One implication of this is that the receiving stream has greater erodibility issues as a result of the increased flow. An allowance for riverbank protection was included in the calculation of the construction cost of all scenarios involving the extra pipelines.

For future scenarios this pump-station could be replaced with another of larger capacity, if further pipelines are built over the watershed. If a tunnel is developed the pumping requirements would be lower and hence the pump-station would be smaller, and if a gravity tunnel were put in place, no additional pumping capacity would be required. The Middledrift WTW is located near Mkhalazi (the second) pump-station, and is supplied through the 1,500mm-pipeline from the Thukela River. This WTW serves the local community and would probably remain in operation regardless of the further developments for the transfer scheme. The works were recently upgraded (April 2014) to supply 10Mlday, and in a second phase at some point in the future may supply a further 10 Ml/day.

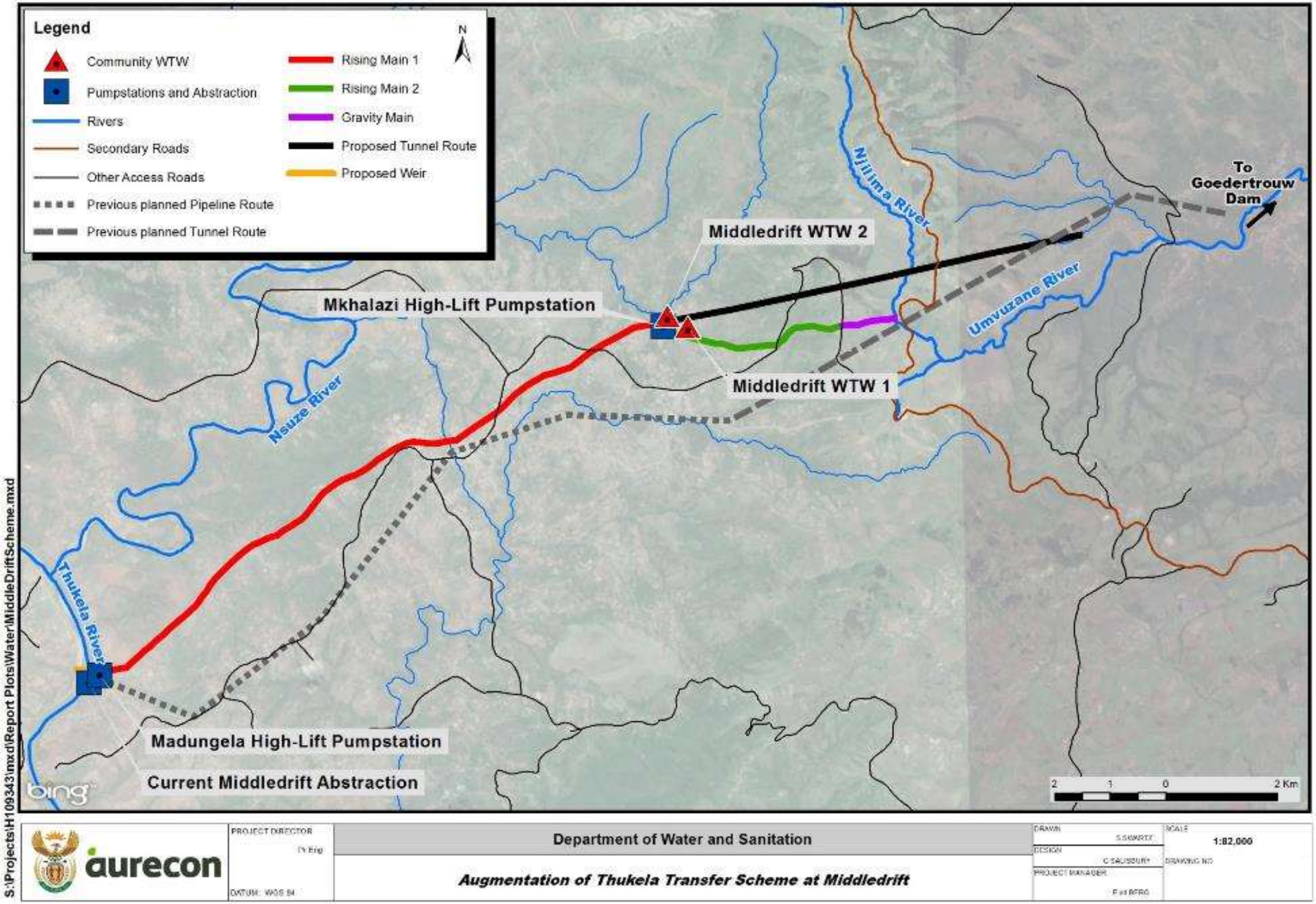

Figure 6-1: Augmentation of Thukela Transfer Scheme at Middledrift

The volume required by the WTW is small relative to the proposed transfer volumes (233Ml/day – 650 Ml/day), and would not have a significant impact on the availability of water to the transfer scheme. Water is also supplied by Umgeni Water from the Middledrift abstraction point to the Ngcebo communities located south of the Thukela River in iLembe District Municipality. The Ngcebo WTW has a capacity of 0.5 Ml/day, with planned upgrades to 4Ml/day. Again, these volumes are not large enough to impact significantly on the availability of water to the transfer scheme.

It would be preferable that the rural infrastructure be separated but there are not currently funds for this, and the impact of the small rural supply schemes is not significant.

Another result of the construction of the emergency scheme is that the route is different from the original planned layout. Therefore any upgrades to the current transfer would probably follow the existing route. The tunnel would begin at the point where the existing 1,500 mm-diameter pipeline ends, which would require that the originally planned route is changed. The original tunnel was intended to be a gravity-tunnel with a slope of 1:800, but the updated layout, although significantly shorter, requires pumping. Should the inclusion of the tunnel be part of further plans, an in-depth investigation of the layout and outfall point would need to be undertaken in order to optimise the route and minimise the cost.

As mentioned above, the emergency scheme has been used only once since its construction, so in reality an additional 37 million m^3/a could be made available to the system without further capital expenditure. This additional transfer was taken into account in determining the water balance which indicates future deficits that will necessitate further augmentation.

The three factors that were varied in the definition of the various scenarios were the amount of water transferred (47 million m^3/a, 142 million m^3/a, or 237 million m^3/a), the presence or absence of the tunnel, and the phasing of the implementation of the intervention.

Assumptions

The assumptions that were made are as follows:

- The existing pipelines, with the exception of the 1500mm-diameter rising main, can supply only 1.2m^3/s, and any additional flow will require an additional pipeline(s).
- The 1500mm-diameter rising main could deliver 2.7m^3/s, and therefore the capacity of the pump station could be increased by 1.5m^3/s from 1.2 m^3/s . The pump-stations are built to accommodate only the current transfer, and new structures would have to be built for further augmentations. In the case of phased schemes the civil components of the pump-stations would be sized to accommodate pumps to deliver the maximum pipeline capacity of 2.7 m^3/s. The marginal pumping costs were also calculated for this increase in the transfer i.e. the pumping costs for a transfer of 2.7 m^3/s less those for the existing 1.2 m^3/s transfer capacity.
- A cost of 40c/m^3 was applied to all schemes to account for the scheme charge for water released from Spioenkop Dam, on the Thukela River.

Alternative pump station and tunnel layouts were also costed.

Costing

In the 1998 report the sizing and costing of the various components of the scheme are given. The general sizing and characteristics of components were used to recalculate the costs using current rates.

All pump-stations and pipelines were entirely re-costed, and in some cases resized where the sizes determined previously were found not to be optimal. The cost of the weir, sedimentation works and tunnel were determined by adjusting the costs determined for recent projects of similar scale.

Scenarios

The construction of a weir is included for each scenario when the total abstraction from the Thukela exceeds 2.7 m^3/s (85.15 million m^3/a). This is based on the original reports which established that no storage was required on the river for abstraction rates of up to 2.7 m^3/s. The height of the weir is limited to approximately 200mamsl to prevent hot-springs upstream from being inundated, as it is of both environmental importance, and social importance to the communities in the area. If and when this scheme is investigated at feasibility level the weir is one component that would need re-evaluation in terms of the abstraction volume for which it would be required, as well as its design characteristics.

The yield of the existing 1.2m^3/s transfer was excluded, i.e. incremental yields were determined, as were costs. The operating costs of the existing pumps were deducted from all scenarios. The design of new pump stations took account of the replacement of the existing 1.2 m^3/s pumping capacity which was included in the capital costs.

The scenarios assumed that yields of schemes would be capped at their maximum transfer capacities. The full yield of the scheme to augment the existing pump station capacity by 1.5 m^3/s would be 47 million m^3/a. This additional yield would be fully utilised by 2018 for the high-growth scenario. The yield of the 142 million m^3/a scheme would be fully utilised by 2034, and the capacity of a 237 million m^3/a scheme would only be exceeded after the end of study period.

6.1.3 System Yield

Depending on the required augmentation to the Mhlatuze system, there is the option of providing an additional 47.3 million m^3/a (1.5 m^3/s), 141.9 million m^3/a (4.5 m^3/a), or 236.5 million m^3/a (7.5m^3/a), in one, two or three phases. Not only the amount of water supplied, but the timing of the implementation and any phasing will be affected by the demand. Therefore the future predicted demands were taken into account in the calculation of the URVs.

The availability of water from the Thukela River will also affect the feasibility of this scheme, and the ultimate capacity that it will be possible to reach. It is not clear how much water is available from the Thukela, and this will need to be clarified if the scheme is investigated at feasibility level. The theoretical yield of the Thukela River is almost completely taken up, but there may be additional yield as a result of over-allocations and intermittent usage. The hydrological modelling of the Thukela River, from which the availability of water can be deduced, assumes that the full potential volume of 530 million m^3 per annum is transferred out of the upper Thukela River to Sterkfontein Dam. In reality, no significant volumes of water have been pumped to Sterkfontein for the last 10 years. Therefore to make 20 or 30 million m^3 available may not impact significantly on the transfers.

6.1.4 Unit Reference Value

A summary of the capital costs, net present values (NPV) of the water supplied and of the costs, and the URVs for each of the different scenarios is given below:

Table 6-1: URVs for Thukela-Mhlatuze Transfer Scheme Options

To augment to a final volume of 2.7m³/s			
URV (R/m³)	***NPV (million R)***	***NPV of Supply (million m³)***	***Capital Cost (million R)***
6.43	3162.68	491.67	842.39

To augment to a final volume of 5.7m³/s (1B)				
	URV (R/m³)	***NPV (million R)***	***NPV of Supply (million m³)***	***Capital Cost (million R)***
In a single phase	***6.72***	***7200.38***	***1072.03***	***2432.29***
First phase (to 2.7m³/s)	6.56	3428.27	522.7	1032.51
Second phase (to 5.7m³/s)	4.74	4017.83	847.36	1417.67

To augment to a final volume of 8.7m³/s (1A)				
	URV (R/m³)	***NPV (million R)***	***NPV of Supply (million m³)***	***Capital Cost (million R)***
In a single phase	***8.28***	***10342.73***	***1249.65***	***3423.98***
First phase (to 2.7m³/s)	7.05	3685.66	522.7	1255.14
Second phase (to 5.7m³/s)	4.76	4031.22	847.36	1427.99
Third phase (to 8.7m³/s)	3.92	3318.28	847.36	787.9

6.1.5 Ecological Impact

The Thukela River is classified as a National Freshwater Ecosystem Priority Area (NFEPA) in terms of rivers and wetlands. Any work undertaken in or on the banks of such rivers requires environmental authorisation and water use licence from the relevant regulatory authorities.

The current abstraction works, without a weir, has a relatively low impact as there is no retention of water. If a weir is built the height and storage capacity would affect the impact: as was found when the weir was designed originally, above a certain level (approximately 210 mamsl) the weir could cause the inundation of a hot-spring upstream, and the weir was designed to avoid this. This would still be a consideration when the weir design was revisited.

The mitigation of construction impacts would be included in the requirements of the project – for example that the disposal of construction materials and waste is carried out responsibly, including excess fill or excavated material.

The proposed transfer scheme is located in a Critical Biodiversity Area (CBA) 1 and 3 (KwaZulu-Natal Terrestrial Systematic Conservation Plan, 2011). The CBA 1 areas are identified as having an irreplaceable biodiversity (niche habitat) which is only located within these areas. CBA 3 indicates the presence of one (or more) features with a low irreplaceability biodiversity habitat. Important species are still located within them and should be accounted for in the EIA process.

The proposed pipeline will traverse four different vegetation types, Dry Coast Hinterland Grassland (Vulnerable), Moist Coast Hinterland Grassland (Endangered), KwaZulu-Natal Hinterland Thornveld (Least Threatened) and Eastern Valley Bushveld (Least Threatened). Botanical assessments will be needed to determine the full impact of the development on vegetation. However, pipelines will follow existing pipeline routes/ servitudes.

At the outfall point of the pipeline options the addition of the extra volume of water into a small stream could cause erosion of the channel. Either the pipeline can be redesigned to have its outfall lower down in the catchment where a larger receiving stream would have lower erosion impacts; or the receiving stream could be protected by, for example, gabions or other erosion-preventing means. This is the option that was preferred in the 1998 Ninham Shand report and costs for 'river training works' were included for these options.

For scenarios including the tunnel the environmental impacts would be lower overall than a pipeline option. This is because the surface area being excavated is smaller, and only at the beginning and end of the tunnel would the area be disturbed. The impact on the geology would need to be investigated to ensure that no adverse impacts on the ground stability etc. would result. The tunnel outfall point is lower down than the pipeline outfall, and the stream is of sufficient volume to receive the extra volume without significant danger of erosion. This would need to be checked if this option were investigated further.

In the long term the impacts of active and abandoned coal mines in the upper catchment of the Thukela River could start to affect the quality of the transfer water. Acid mine drainage is high in salts, sulphates and trace metals and have over time had serious impacts on reservoirs like Loskop Dam in the Olifants River basin. The possible timing of the transfers to Goedertrouw Dam has not been investigated yet. If the transfer is continuous throughout the year then the chemical quality might be poorer (but not the sediment load) during the low-flow periods. If the transfers are scheduled for the high flow periods when there is surplus water in the system, then the chemical quality might be better due to dilution but the sediment loads would be higher. In the Thukela River there is a direct relationship between flow and suspended sediment concentrations, i.e. as the flows increase the suspended sediment concentrations also increase.

6.1.6 Socio-Economic Impact

The existing scheme supplies the Middledrift WTW, and future upgrades would continue to do so. This WTW supplies treated water to communities in the area, and the additional capacity of the transfer would allow for the expansion of the scheme if necessary.

There might be a level of noise pollution as a result of the construction process, as well as from the operation of the pump-stations. However the construction process would be temporary and the pump-stations would merely be an upgrade of the existing pump-stations.

The construction of a large scheme like this would provide temporary jobs in the area as well as income to the area as a result of goods and services required during the construction process. Other socio-economic impacts would be investigated further at the feasibility stage.

6.1.7 Findings

A range of different options were investigated, in terms of phasing and infrastructure. The findings based on the relative costs were that the most cost-effective option is to augment the system by 1.5m^3/s (47 million m^3/a), and to include the tunnel. Even if later phases are to be constructed, building the tunnel at the beginning is still the most economical option.

The options that include the tunnel rather than an additional pipeline are likely to have lower environmental impacts, as well as being cheaper than those with the additional pipeline. However, the pipeline would follow the existing pipeline route, while the tunnel route would need to be investigated effectively from scratch.

It seems unlikely that enough water will be available for the third phase (augmenting by 236 million m^3/a) by the time it is required, and possibly even for the second phase (augmenting by 142 million m^3/a).

There is a possibility that the existing licence for abstraction from the Thukela at Fairbreeze could be transferred to the Middledrift site in this case, which would expedite the implementation process.

Advantages of this intervention include that some of the infrastructure is already in place, and pipeline routes and pump-station sites are already established. The yield of even the first phase is sufficiently large that the system would be adequately supplied for several years, and further interventions could take place later on.

Disadvantages include the higher costs relative to the Lower Thukela scheme, and the likely lack of availability of water for later phases.

6.2 Coastal Pipeline from the Lower Thukela River (Mandini Scheme)

6.2.1 Scheme Layout

In the evaluation of this intervention as an option for the Richards Bay water-supply area reports from several other studies and papers were used for reference. These included:

- The 'Mhlatuze Basin Augmentation Feasibility Study' (1993) prepared by WLPU Consulting Engineers: this was the final report in a series of five studies carried out by WLPU between 1990 and 1993. These studies examined the water resources and requirements in the Mhlatuze catchment, as well as the augmentation options. The outcome was the recommendation that the Mhlatuze basin be augmented from the Thukela River.

  The 1993 report concluded that although the lower Thukela (Mandini) scheme had a greater scope for regional benefit (i.e. supplying a number of communities with water en route), the economic viability of the Middledrift scheme outweighed the regional benefits of the Mandini scheme.
- White Paper 'Report on the Proposed Tugela-Mhlathuze River Government Water Scheme' (1995): this deals mainly with the Middledrift scheme and is based on the recommendation of the 1993 study, that the Mandini scheme be abandoned in favour of the Middledrift scheme.
- The 'Mhlatuze Basin Bulk Water Augmentation' study (1997) prepared by Knight Piésold (Pty) Ltd: this study determined costs for the Mandini pipeline and concluded that it would be worthwhile building the coastal pipeline, supplying rural communities and the mines en route. Three routes for the pipeline were considered, following the old N2 (R102) and N2 respectively, as well as a route partly on either, with a section joining the two, along the railway line that runs perpendicular to the two roads near Gingindlovu township. The third route option was considered most feasible, and it is this route on which the routes considered here are based.
- The 'Mhlatuze Basin Bulk Water Augmentation – Thukela/ Mhlatuze Transfer Scheme' (1998) prepared by Ninham Shand Consulting Engineers: this study took into account two aspects of the situation that had changed since the earlier evaluations. Firstly, the Middledrift scheme as described in the White Paper had not been built, and the emergency scheme had been put in place instead. Secondly, Iscor Mining (now Tronox) required water for their Hillendale and later Fairbreeze mines, and had undertaken a desktop study to construct a pipeline from the lower Thukela to their mines.

  This study re-evaluated the Middledrift and Mandini schemes based on these developments the Middledrift and Mandini schemes were re-evaluated and different scenarios analysed. The conclusion was that the coastal pipeline was more feasible economically, but this assumed that the supply to Iscor (Tronox) mines is included. It was also noted that the comparison between the Middledrift and Mandini schemes needed to be refined.
- Thukela Water Use Licence: In 2005 Mhlathuze Water were granted a licence by the (then) Department of Water Affairs and Forestry to abstract 47.3 million m^3/a from the Thukela 'for household, industrial and irrigation purposes.' 45% of this allocation was intended to be made available to the Tronox mines, 5% to towns and communities between the Mandini site and the

Mhlatuze River, and 50% to a group of farmers, for irrigation purposes. The submission also states that once the mine closes, the water would be transferred to Richards Bay, to augment the stressed Mhlathuze system. The projected water requirements in the Mhlatuze catchment were subsequently re-evaluated and found to be lower than previously predicted and based on these revised projections plans for augmenting the basin were halted.

- The 'Proposed Raw Water Supply to Fairbreeze Mine, KwaZulu-Natal' draft basic assessment report (2011) was submitted by Exxaro KZN Sands to the Department of Agriculture, Environmental Affairs and Rural Development. The route being evaluated here is from the Mhlatuze River to the Tronox mines. This option had originally been evaluated simultaneously with the option of supplying the mines from the Thukela River via a coastal pipeline, and the Thukela River supply option had been preferred at that stage. When the re-evaluation of the water demands in the Mhlatuze catchment led to the postponement of plans to augment the system from the Thukela River, plans to construct the coastal pipeline were set aside. Tronox (then Ticor South Africa, subsequently Exxaro KZN Sands) then undertook a detailed scoping process for the alternative option to supply the planned Fairbreeze mine.

  The alternative option, known as the northern Mhlatuze River option, involved pumping water to the Fairbreeze mine from the current Hillendale mine, which is in turn supplied from the Mhlatuze weir. This included a 27km pipeline mostly running adjacent to the railway line servitude. This option was adopted and is soon to be constructed.

  As noted previously, one of the factors in favour of constructing the coastal pipeline was the possibility of the Tronox' mines benefitting from it and contributing towards the capital cost. With the adoption of the alternative option for supplying the mines this advantage has fallen away. The construction of a parallel pipeline to supply Richards Bay seems less feasible. However, a scenario has been included in this study where some of the synergy that would have resulted from the combined use of the coastal pipeline could possibly be regained.

- The 'Lower Thukela Bulk Water Supply Scheme' (LTBWSS) Detailed Feasibility Study (2012) prepared by Aurecon South Africa (Pty) Ltd: there have been predictions of future water shortages in towns along the KwaZulu-Natal north coast in the KwaDukuza and Mandini Local Municipalities and this report is a detailed feasibility study for one of the two options for augmenting the supply. The scheme involves abstracting water from the lower Thukela River at approximately the same site at Mandini where the planned coastal pipeline to the Mhlatuze River would abstract water.

  The Lower Thukela Bulk Water Supply Scheme will be developed in two phases, the first of which is currently under construction. The scheme is planned to have a capacity of 40.15 million m^3/a (110 Ml/day), and would supply areas both to the north and south of the Thukela River. The first phase of 20.075 million m^3/a) (55 Ml/day) will supply the area to the south of the river. However, it is estimated that by 2020 the second phase scheme will be required to meet the demand.

  The components of the first phase include an abstraction works and a low-lift pump station located on the banks of the Thukela River, a de-silting works, a water treatment works (WTW), potable water storage reservoirs and a high-lift pump-station at the WTW l to supply the bulk pipelines running north and south of the WTW..

  Logically the assessment of the coastal pipeline to the Mhlatuze system will take into account this development. It may be possible to take advantage of the currently unused potential of the scheme – i.e. the scheme could be upgraded to 40 million m^3/a and the additional 20 million m^3/a could be used to supply the Richards Bay system. Alternative options for supplying the KwaDukuza and Mandini areas are also available, and the entire 40 million m^3/a might be available to supply the

Richards Bay system, with off-takes where necessary along the way to supply the towns and communities in the region.

An option that was considered by Mgeni Water for supplementing the supply to the north coast area is a regional bulk water scheme on the Mvoti River, including a new dam. Should this development realise up to 40 million ^{m3}/a might become available for transfer to the Richards Bay system by way of the coastal pipeline.

- 'Water Availability Assessment in the Lower Thukela River' (2010) by WRP Consulting Engineers: this study formed part of the Water Reconciliation Strategy Study for the KwaZulu-Natal Coastal Metropolitan Areas, and concluded that at the time (2010) there were 77 million m^3/a of water available in the Lower Thukela River System. Out of this 77 million m^3/a an allowance of 32 million m^3/a was made for the Fairbreeze Mine licence, and it was concluded that the 40 million m^3/a (110 Ml/day) for the LTBWSS was available. According to these calculations this left only 5 million m^3/a unallocated in the Lower Thukela, which does not allow for much further allocation to other users. However, there may be additional yield as a result of over-allocations and intermittent usage.

  The original licence (Licence No. B191/2/2050/1) issued to Mhlathuze Water in 2005 for abstraction from the lower Thukela River is for 47.3 million m^3/a, for 'household, industrial and irrigation purposes'. The division of the water between these different uses was not specified in the licence.

- Umgeni Water Infrastructure Master-plan (2012/2013 – 2042/2043): this is not the most recent master-plan, but it contains some details for potential plans of dams on the Mvoti River (Mvoti-Poort, Isithundu, Raised Isithundu and Welverdient dams). This river lies approximately 20 km to the south of the Thukela River, and is at the centre of the long-term development strategy for water supply to the KwaZulu-Natal coastal strip between Ballito and the Thukela River. There is potential for the dams to supply a great part of the area that is to be supplied by the LTBWSS, which would free up some or all of the 40 million m^3/a-capacity of that scheme. In that case the full capacity could be transferred to the Mhlatuze system.

Using information from the above reports and current-day costs the feasibility of the coastal pipeline/ Mandini scheme has been re-evaluated. Given the large number of variables and unknowns regarding future water demands and supplies in the area, much of which falls outside of the uMhlathuze Local Municipality and even uThungulu District Municipality, several scenarios were evaluated, based on different assumptions and potential situations.

The various assumptions and scenarios are detailed below.

6.2.2 Scheme Description

The basic scheme will consist of a pipeline from the lower Thukela River at Mandini to the uMhlathuze Local Municipality, terminating either at the Mhlatuze River, if raw water is transferred, or at the Nsezi WTW (potentially with an offtake to the ESikhaleni WTW), if treated water is transferred. Depending on the availability of water from the Thukela River as well as other factors, either 20 million m^3/a or 40 million m^3/a (only in the long-term) could be transferred.

Assumptions
The following general assumptions were made:

The supply to the rural communities along the pipeline route will be 5 million m^3/a, half of which would be abstracted from the northern supply reservoir, and the remaining half at the small town of Gingindlovu. The pipelines and pump-stations were costed accordingly.

The cost estimates for the different scenarios assume that a proportion of the cost of the LTBWSS scheme is borne by this scheme, equivalent to the proportion of the water abstracted there that is used by the scheme in that scenario. The costs for the LTBWSS scheme components were obtained from the design report for the project (Aurecon, 2012) and escalated according to inflation.

The costing of the scenarios deducts from the total cost of the scheme the 5 million m^3/a that would be made available to the local communities along the pipeline route.

In the calculation of the costs of the clear water pipeline the treatment costs were not included, as other options do not include treatment, and the options have to be compared on an equal base.

A cost of 40c/m^3 was applied to all schemes to account for the scheme charge for Spioenkop Dam, on the Thukela River.

Utilization of the Lower Thukela Bulk Water Supply Scheme (LTBWSS)

The Mandini scheme could utilise some of the infrastructure currently being constructed for the LTBWSS, as discussed below. The LTBWSS infrastructure that is already in place or in the process of being constructed includes the weir, abstraction works, low-lift pump-station and pipeline leading to the de-silting works as well as the water treatment works, and a high-lift pump-station but not the high lift pumps.

A rising main and reservoir were planned as part of the LTBWSS for supplying the northern scheme, and this route and layout were used in the scenarios identified below. In addition to the LTBWSS infrastructure, a high-lift pump-station and additional pipeline would be constructed to convey the water to the Mhlatuze system.

Umgeni Water's plan is for a 20 million m^3/a augmentation of the existing 20 million m^3/a WTW to be constructed, when the northern supply is required around 2025-2030. The possibility being considered here is to utilise a percentage of this 20 million m^3/a for transfer to the Mhlatuze WSS. If the water would be treated then it would be delivered to the clear-water reservoirs.

Alternatively, the treatment works at the LTBWSS could be by-passed and raw water pumped to the north. This would simplify matters both in the construction of the pipeline and in the distribution of the water into the Mhlatuze WSS. In this case the water could be transferred directly to the Mhlatuze River where the N2 crosses it near Felixton, approximately 7km upstream of the Mhlatuze Weir. From there the transferred water would be abstracted, treated and distributed as part of the Mhlatuze system. This would mean that water would be treated locally at the other distribution points.

Figure 6-2 shows the raw water options, Figure 6-3 the clear water options and Figure 6-4 the headworks infrastructure.

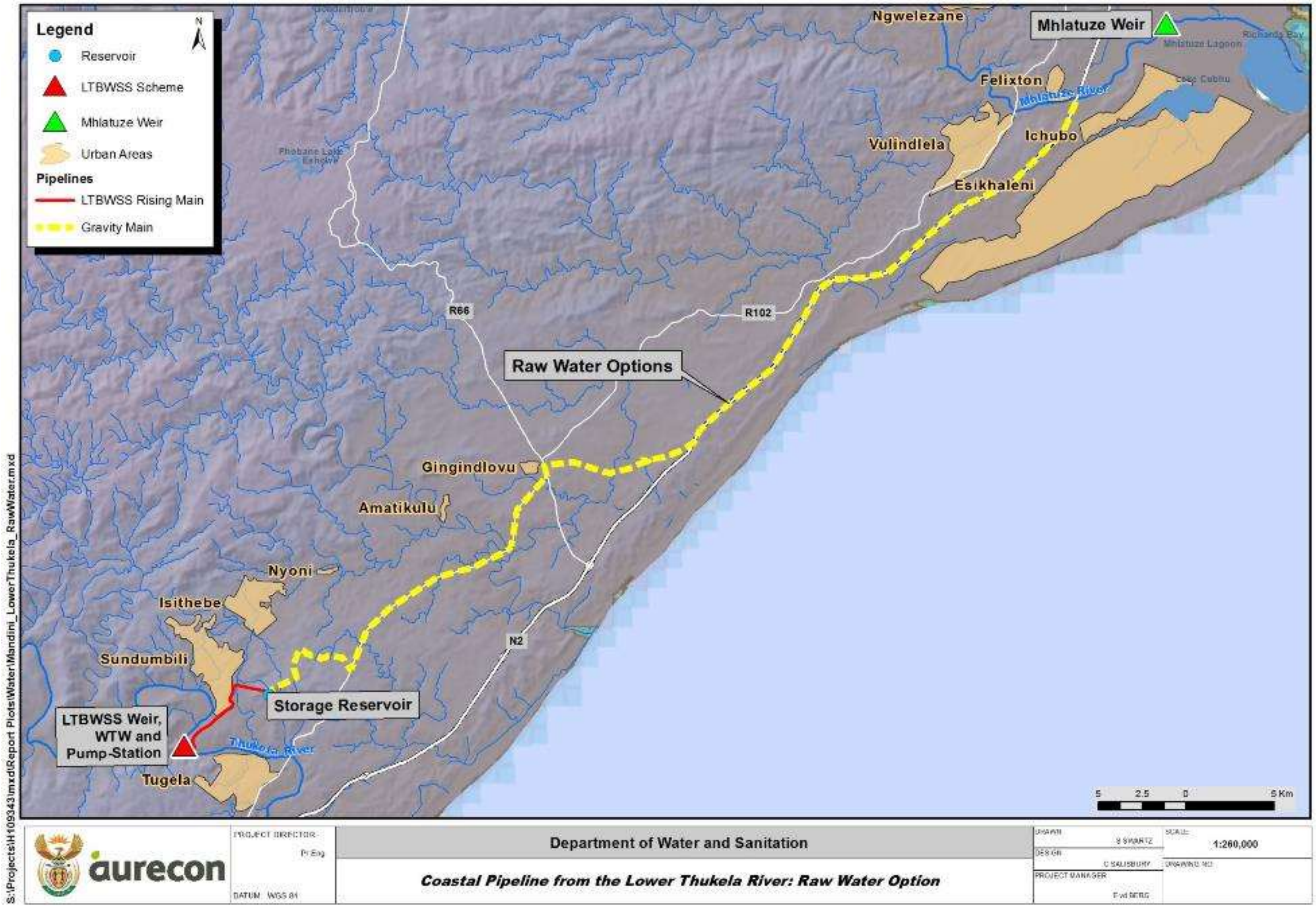

Figure 6-2: **Lower Thukela Transfer Scheme: Raw Water Option**

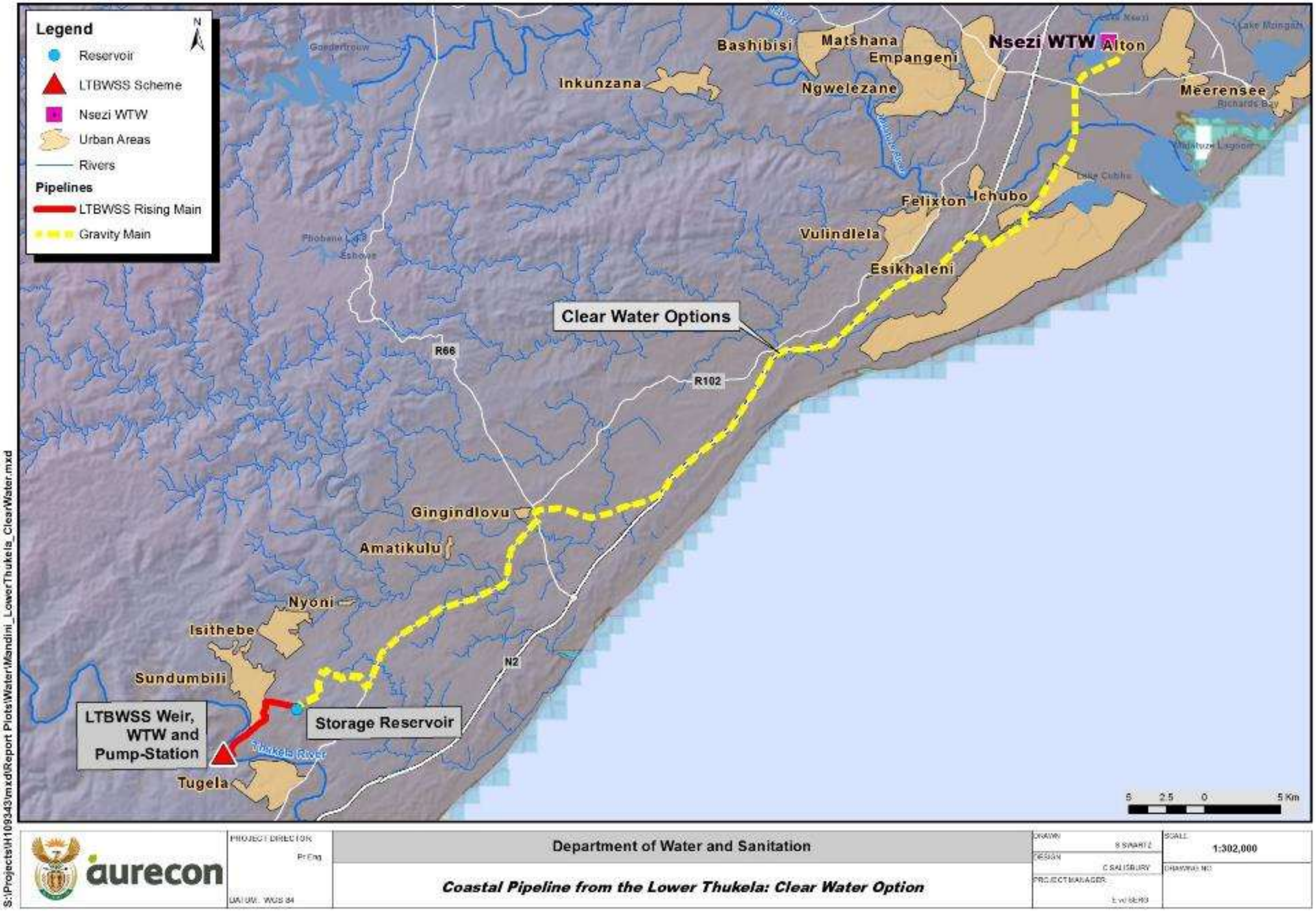

Figure 6-3: Lower Thukela Transfer Scheme: Clear Water Option

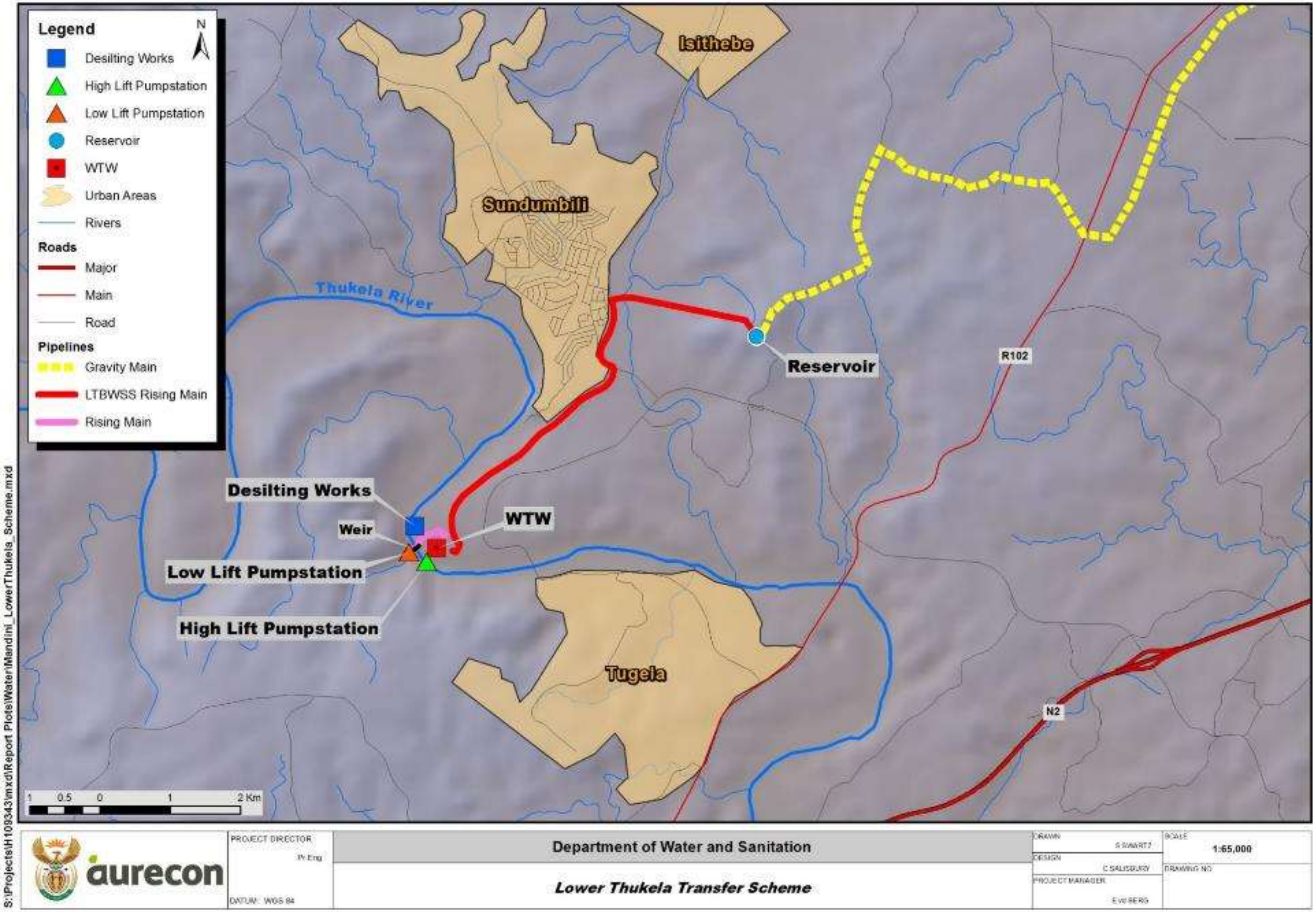

Figure 6-4: Headworks infrastructure of the Lower Thukela Transfer Scheme

If the abstracted water were to be treated at the Mandini WTW there would not be the need for smaller WTWs at the various off-takes en-route to the Mhlatuze River and therefore a slightly smaller volume would need to be transferred, as there would be no further treatment losses. Scenarios with both treated and untreated water are considered here.

Scenarios

Bearing in mind the uncertainty surrounding the quantity of water that will be available for transfer to the Mhlatuze catchment, as well as the timing of its availability, scenarios with both 20 million m^3/a and 40 million m^3/a are included below.

The second major variable is whether the water transferred is to be treated or raw. The advantages of transferring raw water are that the pipeline can be significantly – approximately 16 km - shorter, as it can discharge straight into the Mhlatuze River, while treated water would have to be pumped to the Nsezi WTW for distribution.

Raw Water Option

If untreated water is transferred a larger volume would need to be pumped, as approximately 5% is lost during treatment. Providing a WTW for each small community along the way is unlikely to be either feasible or sustainable. Finally, there will some losses between the discharge of the transferred water into the river and the Nsezi WTW which can be avoided if it is piped directly to the WTW.

Much of the original attraction of the Mandini scheme was based on the incorporation of the supply to the Tronox mines. Although it is not possible to achieve this with the 20 million m^3/a transfer, given that the alternative pipeline from the Mhlatuze River is now being built to supply the Tronox mines, it may be possible to achieve some synergy with the 40 million m^3/a transfer.

Three scenarios are considered under this option: in **Scenario 1** described below 20 million m^3/a of raw water is pumped directly to the Mhlatuze River, in **Scenario 3** described below 40 million m^3/a is pumped directly to the Mhlatuze River, and in **Scenario 5** described below 40 million m^3/a is pumped to the Tronox mines, the mine's requirements is taken off there, and the remaining ~20 million m^3/a is pumped through the existing Tronox pipeline to the Mhlatuze River.

- For Scenario 1, the second phase of the LTBWSS would be built and an additional 20 million m^3/a (55Ml/day) would be made available to the area north of the Thukela. 5 Million m^3/a (13.70 Ml/day) would be supplied to the rural communities along the pipeline route, assuming that 2.5 million m^3/a (6.85 Ml/day) is abstracted at the reservoir and the other half at Gingindlovu. The treatment works at Mandini are by-passed and raw water is pumped north, the outfall being into the Mhlatuze River several kilometres upstream of the Mhlatuze weir.
- Scenario 3 assumes that the full 40 million m^3/a (110 Ml/day) from the Thukela weir is made available to the area north of the Thukela River, and the same off-take to the rural communities at the same points is provided as in the previous scenarios. The water is not treated at the LTBWSS site, and is, as in the first scenario, discharged into the Mhlatuze River upstream of the weir.

  Compared to the previous option, this is obviously more likely to be economically feasible, owing to the larger volume available and hence larger income from tariffs. However, the probability of this volume being available is lower, certainly within the immediate future, until an alternative source of supply to the area south of the Thukela is developed, such as a dam on the Mvoti River is built, if indeed such a project proceeds to implementation.
- In Scenario 5 the full 40 million m^3/a is transferred north, but only as far as the Fairbreeze Mine, some 24 km south of the Mhlatuze River. The water requirement for the mines would then be taken off, and

the remainder then pumped north to the Mhlatuze Weir through the pipeline currently being constructed by Tronox, as described above in Section 1.

The primary advantage of this option is that a significant length of pipeline – approximately 24km – would not need to be constructed as part of the transfer scheme. The abstraction from the Mhlatuze Weir that is made by Tronox for its mines could cease upon mine closure, thereby freeing up water in the Mhlatuze River. The situation present in the other scenarios, where some of the water pumped north to the weir would then pumped a considerable distance back south to the Tronox mines, would be avoided. The pipeline capacity of the mines pipeline would certainly be adequate, as the volume required to be transferred south currently for the Tronox mines is larger than that that would be required to be transferred north after the offtake at the mine.

This scenario is only possible if, firstly, it is possible for the Tronox pipeline to operate in reverse – i.e. to pump water north although it was designed to convey water south and secondly if this arrangement was found to be acceptable by all parties concerned. This also assumes that the full 40 million m^3/a is available to the area north of the Thukela River.

Clear Water Option

The advantages of treating the water at the Mandini site are that the WTW is already in place and merely requires upgrading rather than a complete new development. This would also obviate the need for a regional or small WTW to supply the small towns on the way to Richards Bay.

It is unlikely that additional pumping would be required for the longer pipeline, as after the point of divergence on the two routes the elevation decreases steadily, and a high head would be required up to that point, regardless. The possibility of distributing the treated water to users or to reservoirs closer than the Nsezi WTW also exists, but will not be explored here.

Only two scenarios are considered: in **Scenario 2** a volume of 20 million m^3/a treated water is transferred to the Nsezi WTW and in **Scenario 4** a volume of 40 million m^3/a.

- Scenario 2 is similar to Scenario 1 except that the water transferred to the Mhlatuze catchment would be treated at the Mandini site. The same parameters would apply as for Scenario 1, except that the treated water would be pumped directly to the Nsezi WTW, resulting in a longer pipeline. The treatment cost (i.e. the capital and operating cost of the WTW at the LTBWSS site) is not included, as discussed above, so that the different options can be compared on an equal base.

  The main disadvantage of these two options (Scenarios 1 and 2) is that the lower water quantity will make it less likely to be economically feasible. Unlike the fourth scenario described below, there is no possibility that the Tronox pipeline can be used, as the quantity of water available from the Thukela River is little more than that required by the mine at any point, and supplying that water to the mine would make redundant the pipeline being built from the Mhlatuze Weir.

  Many further sub-scenarios could be investigated, including the distribution directly to reservoirs or to users closer than the Nsezi WTW. However, at the high level of this study the intention is to give an indication only of the relative merits of the various major options, not an in-depth analysis of every permutation.

- Scenario 4 is similar to the previous, but, as in scenario 2, the water is treated in the LTBWSS WTW, and subsequently transferred to the Nsezi WTW.

6.2.3 System Yield

Depending on the amount of water available from the LTBWSS weir and the amount of water supplied to the rural communities and to the mines, along with other factors regarding which assumptions have been made, different yields will be available. In the case of 20 million m^3/a (55 Ml/day) being transferred to the north of the Thukela, 15 million m^3/a (41.25 Ml/day) would be available to the Mhlatuze catchment.

In the case of the full 40 million m^3/a (110 Ml/day) being available, 35 million m^3/a (96 Ml/day) would be available to the Mhlatuze catchment. Were the supply to the Tronox mines to be incorporated, the water available to the other users in the Mhlatuze catchment would vary for the first few years, reducing by 2021 to 17.35 million m^3/a (47.53 Ml/day) until the demand from the Fairbreeze mine is replaced by that from the Port Durnford mine in 2027, whereupon the available water to other users in the Mhlatuze catchment would reduce further to 14.95 million m^3/a (40.96 Ml/day). However, as the requirements of Tronox's mines are part of the water supply system, and the water subtracted from the Mandini scheme would no longer be abstracted at the Mhlatuze Weir, overall the yield of the transfer to the Mhlatuze catchment under that scenario would be almost identical. Losses might vary minimally, but the effect on the yield would be negligible.

6.2.4 Unit Reference Value

Based on the above assumptions the capital cost, net present value of supply and cost, and URVs for the various scenarios are given in Table 6-2:

Table 6-2: URV for the Costal Pipeline from the Lower Thukela Sub-Scheme Options

Intervention variation	URV (R/m^3)	NPV (million R)	NPV of Supply (million m^3)	Capital Cost (million R)
1 (20 Mm^3/a, raw water)	4.39	766.37	174.82	522.84
2 (20 Mm^3/a, treated water	4.28	748.75	174.82	584.05
3 (40 Mm^3/a, raw water)	4.96	1968.62	396.61	1014.25
4 (40 Mm^3/a, treated)	5.23	1965.01	375.69	1055.45
5 (40 Mm^3/a, untreated, using Tronox pipeline)	4.58	1816.67	396.61	1209.47

The quantity of water available for transfer to the north of the Thukela River is of critical importance. When only 20 million m^3/a is available the transfer is less likely to be financially viable, and it is not certain when or if the full 40 million m^3/a will become available.

The benefit of providing treated water to small communities cannot be quantified at this stage, but the qualitative benefits are significant.

6.2.5 Ecological Impact

A large section of the pipeline would run through areas that are 100% transformed, which is preferable to untransformed areas, as natural vegetation will not be lost. Sections of the pipeline, would however, impact on some CBA 1 areas.

The Thukela River is classified as an NFEPA in terms of rivers and wetlands, and it should be noted that an environmental authorisation and a water use licence will be required from the relevant authorities.

Much of the proposed site is located within the Critically Endangered Eshowe-Mtunzini Hilly Grassland threatened ecosystem. This habitat has species of high irreplaceability and high threat, and large areas have already been transformed. As the pipeline runs along an existing servitude and through urban areas, the impact will be limited. A site visit by a botanical specialist will have to determine the extent of the impact.

Impacts resulting from the construction of the weir will have already been considered and addressed in the design of the LTBWSS scheme, and operational considerations only will need to be considered in the coastal pipeline scheme. Impacts such as siltation in the Thukela River and erosion in the Mhlatuze River will be considered.

The ecological reserve will need to be addressed to ensure that the impacts on downstream processes are mitigated.

Raw Water Option
Water quality (biological, chemical and physical) of both rivers should be similar or better in the case of the Thukela River before water is discharged into the Mhlatuze River.

It is expected that the Mhlatuze River is a sufficiently large river that erosion will not occur at the point where the transferred water is added. This will need to be checked for both the 20 million m^3/a and 40 million m^3/a transfers.

In the case of the Tronox pipeline option there will be a lower level of impacts as a result of the shorter length of the new pipeline.

It is assumed that the transfer would take place during elevated flows in the Thukela River when there is excess water available. Studies for the design of the treatment works of the Lower Thukela Bulk Water Supply Scheme found that there was a direct relationship between flow and suspended sediment concentrations, i.e. as flows increase, the suspended sediment concentration and loads increases. If untreated water is transferred, then desilting would be required at the abstraction works on the Thukela River.

If the transferred water is then discharged into the Mhlathuze River, then there will probably be a change in water quality as the quality of the two blends may differ slightly. The resultant water quality would be equivalent to the proportion each of the sources contributes to the blend.

Treated Water Option
A disadvantage of the treated-water pipeline is that it would be longer, as it would need to extend to Nsezi WTW. However, the environmental impact would be only minimally increased, as the pipeline would follow existing roads, railway lines and servitudes

The only water quality impacts in this scenario may be on the Thukela River as a result of the WTW (discharge of sludge from the desilting works and some water treatment chemicals). The increase in impacts would be proportional to the additional volume of water treated for transfer to Richards Bay. The discharge of sludge back into the Thukela River may result in higher silt loads in the lower Thukela River especially when combined with sludge from the new WTW.

6.2.6 Socio-Economic Impact

If water is not treated at the LTBWSS, small WTWs would need to be constructed in order to supply the communities located along the pipeline route with treated water. This would significantly increase the cost of the scheme. If the water is treated at the LTBWSS WTW then communities located along the pipeline route will be supplied with treated water and no additional costs will be incurred for construction of WTWs. There will be significant social benefits associated with supplying these rural communities with water.

6.2.7 Findings

The costs indicate that the treated-water options are more expensive than the raw-water options, although there are other advantages to treating the water that might outweigh the economic considerations.

Along with other considerations such as environmental and social impacts, the various assumptions made will need to be further investigated and verified. These include the feasibility of exchanging use of the Tronox pipeline for water transferred from the Thukela, as well as the division of costs amongst the concerned parties, and factors such as the suitability of the Fairbreeze pipeline for reverse flows.

Other aspects to be further explored include the relative merits of transferring treated and raw water; the distribution and growth of the future requirements in the rural communities between the Thukela and Mhlatuze rivers; the various pipeline routes, as well as the location and duties of the booster pump-stations. The division of costs would need to be thoroughly investigated and discussed amongst the various stakeholders, including the Umgeni and Mhlathuze Water Boards and DWS who might contribute a portion of the capital cost, and users such as Tronox.

Strengths

The existence of Mhlathuze Water's abstraction licence at Mandini would allow the implementation process to be expedited. This is generally a cheaper option than the Middledrift scheme, although it has a similar implementation time. It also has more potential for regional benefit (i.e. the supply to communities en-route).

Weaknesses

It is unlikely that the full 40 million m^3/a would be available in the short-term, and usage of the Tronox pipeline would only be feasible in the short-term if the 40 million m^3/a were available. In the longer term the availability of the 40 million m^3/a is still questionable, but the Tronox pipeline might become available to transfer 20 million m^3/a to the Mhlatuze system once the Fairbreeze mine is completed around 2027.

7 MFOLOZI RIVER TRANSFER SCHEMES

7.1 Background

7.1.1 References

In the evaluation of this intervention as an option for the Richards Bay water-supply area reports from several other studies and papers were used for reference. These included:

- "Ondersoek en eliminasie van damterreine in die Mfolozi-Opvanggebied", First and Second Planning Reports, undertaken in 1977 and 1981 respectively. These evaluations were undertaken by the in-house Planning Department of the then Department of Water Affairs / Directorate of Water Affairs to evaluate and eliminate potential dam sites in the Mfolozi catchment.
- Development of a Reconciliation Strategy for All Towns in the Eastern Region: First Order Reconciliation Strategy for Mtubatuba Town and surrounding areas, DWS 2011. This study assessed the water balance situation for the Mtubatuba water supply area, and made recommendations to meet potential shortfalls in water supply in the medium to long term.
- Umkhanyakhude DM Integrated Development Plan Review, 2013-2014. Because the Mtubatuba Local Municipality is one of the local municipalities falling within this district municipality area, the Mtubatuba and Mpukunyoni water supply situation has been briefly addressed.
- Water Resources Analysis Study: Hydrological Yield Analysis. The study entailed a water resource assessment study of some systems located within the Usutu-Mhlathuze WMA, inclusive of the Mfolozi River System. The yields were use as comparison to the modelled yield.
- Analysis of alternatives to determine the most feasible solution to the hydrological issues of the Lake St Lucia Estuarine system. This is an ongoing investigation by the iSimangaliso Wetland Park Authority). An ACRU river model of the Mfolozi River was set up for the investigation by Aurecon, of which flow sequences were exported for this study.

The evaluations of dam sites in the Mfolozi River undertaken by then Department of Water Affairs (DWA) in 1977 and 1981 were used as the primary reference. Although these evaluations were done some time ago, the information regarding topography and geology are still the same. Some aspects such as dam costs and yields are outdated as well as affected services and people, and these aspects were revisited.

7.1.2 The Mfolozi River

The Mfolozi River is situated downstream of the confluence of the Black and White Mfolozi rivers near the south-eastern boundary of the Hluhluwe-iMfolozi Park, as shown in Figure 7-1.

During the 1950s, the Umfolozi Landowners Association contained and artificially channelled the river through the Monzi Flats to develop sugarcane farms. This new Mfolozi canal resulted in the water depositing its silt load after entering the St. Lucia Estuary. This caused the estuary mouth to rapidly silt up. The government started a costly dredging operation in the estuary mouth area, but it proved ineffective. After years of dredging, the next plan was to prevent the Umfolozi River from entering the St Lucia estuary. The Umfolozi River was canalized straight out to sea at Maphelana. The negative impact of this decision continues and planning is currently underway to allow the Mfolozi River to run its natural course to join the St Lucia Estuary, by incrementally removing the artificial dune.

The low flow available in the catchments upstream of Mtubatuba is fully utilised for domestic use (mainly Vryheid, eMondlo, and Ulundi from the White Mfolozi River) and by the irrigators. Irrigators upstream of Mtubatuba are dependent on either run-of-river abstraction from Mfolozi River or its tributaries and there are several farm dams which reduce the streamflow of the river, particularly during the low flow months. The Mfolozi River cannot sustain the medium to long term water requirements of the area without storage being provided. Taking the ecological Reserve into account, there would be no utilisable run-of-river yield available at all at Mtubatuba, unless the upstream water uses are effectively curtailed.

The high silt load of the river poses many problems for an in-stream dam. A large spillway would also be needed.

A study was conducted by DWS in the late 1980s, to consider the feasibility of augmentation of the Mhlatuze River System from the Mfolozi River. The findings indicated that with the sporadic flows, unless major storage was provided on the Mfolozi, the Mhlatuze River System would ultimately have to be augmented from the Thukela River. Indications at the time were that, viewed on a long-term basis it would be cheaper to build the Thukela Transfer Scheme.

7.1.3 Mtubatuba Water Supply Scheme

Mtubatuba is the main town in the Mtubatuba Local Municipality which is one of five local municipalities making up the Umkhanyakude District Municipality (refer to Figure 7-2). The towns of Mtubatuba, St. Lucia and the surrounding areas are supplied with water from the Mtubatuba Water Treatment Works. Water is abstracted from the Mfolozi River downstream of the N2 highway where it is treated at the (recently upgraded) 20 Ml/d treatment works. The population being supplied has been increasing because of the proximity to the N2 secondary development corridor and the tourism potential of the area.

As a consequence of low river flows between July and October and the fact that the scheme is dependent on run-of-river abstraction from the Mfolozi River, the supply area has over the years seen increasing water restrictions and intermittent water supplies. With the increasing growth in population and extension of the supply area, the magnitude and extent of water restrictions in the supply area have been increasing. The raw water supplies available from the Mfolozi River cannot meet the long term water requirements of Mtubatuba and the surrounding areas on a sustainable basis.

The registered water use for Mtubatuba in 2011 of 10 Ml/d (3.65 million m^3/a) was less than the (then) annual average abstraction of 12.6 Ml/d (4.6 million m^3/a). A licence application will be required to enable the district municipality to continue abstracting from the Mfolozi River. According to the Mtubatuba All-Towns 2012 Strategy the water use from the WSS was 4.35 million m^3 in 2012.

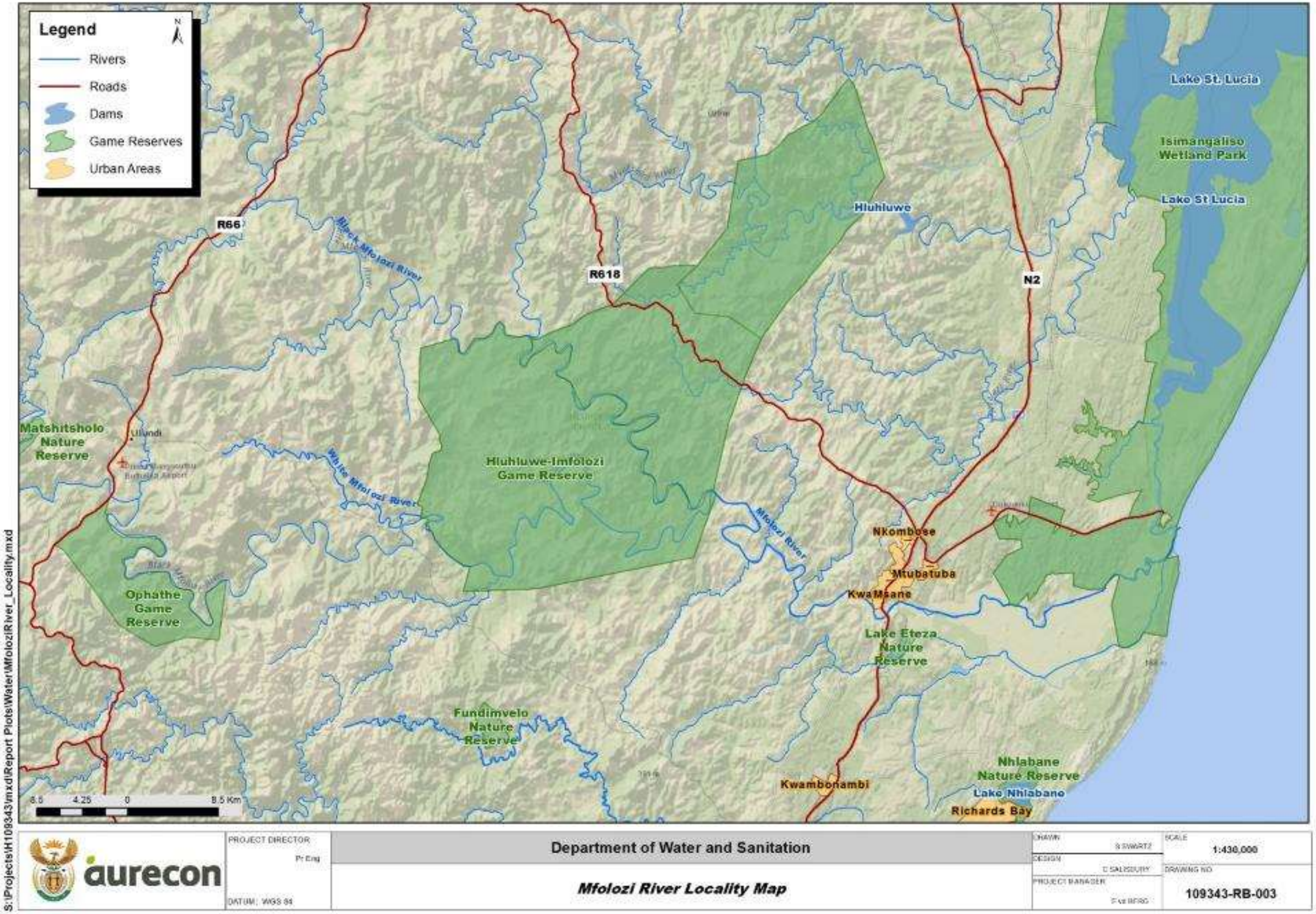

Figure 7-1: **The Mfolozi River**

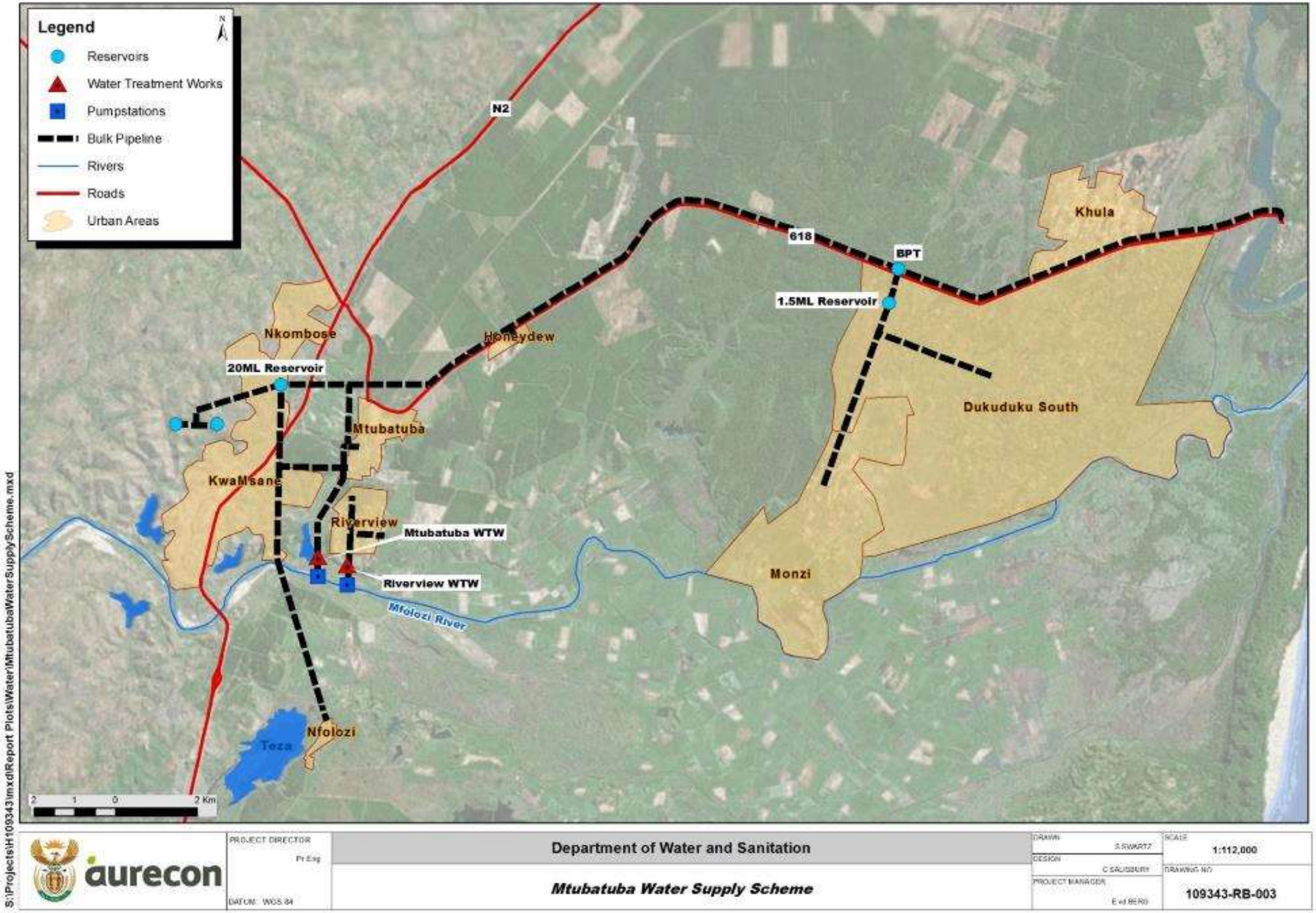

Figure 7-2: **Mtubatuba Water Supply Scheme**

7.1.4 Other future water demands from an Mfolozi Scheme

The *Development of a Reconciliation Strategy for All Towns in the Eastern Region: First Order Reconciliation Strategy for Mtubatuba Town and surrounding areas* study (2011) recommended that "*consideration must then be given to the development of a dam in the Mfolozi River to supply not only Mtubatuba but the whole area down to Richards Bay, if required*."

Not only the Mtubatuba Scheme may benefit from an Mfolozi River regional scheme, but potentially also other water users, as indicated in Table 7-1, apart from users in the Richards Bay WSS.

Table 7-1: Potential further population to be served from an Mfolozi Scheme

Potential future population that could be served	District Municipality	Scenario	Population		
			2011	2025	2045
Mtubatuba Water Supply Scheme	Umkhanyakhude	High	61,860	93,023	138,215
		Low	61,860	78,949	96,811
Mpukunyoni Water Supply Scheme	Umkhanyakhude	High	58,020	69,899	82,178
		Median	58,020	63,498	66,417
Hluhluwe Water Supply Scheme	Umkhanyakhude	High	68,634	88,315	100,772
		Low	68,634	76,565	79,605
Mhlana Somopo Water Supply Scheme	uThungulu	High	100,322	143,045	212,557
		Median	100,322	119,991	124,876

The potential water requirements from these schemes are shown in Table 7-2.

Table 7-2: Potential other water requirements from an Mfolozi Scheme

Water Supply Scheme	District Municipality	Scenario	Demand projection (million m^3/a)						
			2015	2020	2025	2030	2035	2040	2045
Mtubatuba	Umkhanyakhude	High	4.36	5.14	5.92	6.82	7.69	8.58	9.60
		Low	4.10	4.47	4.81	5.47	5.47	5.83	6.22
Mpukunyoni	Umkhanyakhude	High	2.26	2.41	2.56	2.69	2.79	2.90	3.01
		Median	2.22	2.31	2.37	2.45	2.45	2.47	2.49
Hluhluwe	Umkhanyakhude	High	2.93	3.20	3.45	3.63	3.77	3.91	4.06
		Low	2.86	2.97	3.05	3.15	3.15	3.18	3.20
Mhlana Somopo	uThungulu	High	3.66	4.20	4.79	5.39	6.07	6.85	7.74
		Median	3.30	3.59	3.82	3.96	4.11	4.26	4.42
Total Water Requirements		**High** (million m^3/a)	**13.22**	**14.95**	**16.72**	**18.53**	**20.33**	**22.25**	**24.41**
		Low (million m^3/a)	**12.48**	**13.34**	**14.04**	**15.02**	**15.17**	**15.73**	**16.33**
		High (Ml/d)	**36.22**	**40.95**	**45.81**	**50.78**	**55.69**	**60.95**	**66.88**
		Low (Ml/d)	**34.18**	**36.54**	**38.47**	**41.16**	**41.56**	**43.10**	**44.74**

The planning for this study has already made allowance for future water users in Mbonambi and Nseleni, which form part of the Mhlana Somopo WSS.

The Hluhluwe scheme has been included because the existing Hluhluwe Dam has limited capacity to meet the competing demands of the agriculture and domestic water use sectors.

This information does however indicate that, under a high-growth scenario, about 20 million m^3/a could potentially be supplied from a regional Mfolozi River scheme, by 2040, in addition to the supply to the Richards Bay WSS.

7.1.5 Raising of Lake Ntweni

Upstream of the N2 road bridge, there are a number of pans and lakes which could be developed as potential off-channel dams (Figure 7-3). These include the Ntweni and Nkata pans.

Lake Ntweni is situated about 15 km upstream of the N2 bridge on the Northern side of the Mfolozi River. One of the options being considered by Umkhanyakude DM is the raising of Lake Ntweni in order to meet the current and future water requirements of Mtubatuba and its surrounding areas. It is understood that a feasibility study is underway but information on the study could not be obtained. Such a proposed scheme will include construction of a dam wall at the outlet of the lake and a bulk water supply pipeline from the intake works to the Mtubatuba WTW.

The capacity of the proposed Lake Ntweni Dam would be approximately 6 million m^3. It is envisaged that the dam would have a yield of 25 Ml/d over the 3 to 4 month low-flow period. The capital cost of the dam is understood to be approximately R100 million at 2011 prices (Mtubatuba LM, All Towns Reconciliation Strategy, 2011).

7.1.6 Potential large on-channel dams on the Mfolozi River

A big dam (relative to MAR) on the Mfolozi River could provide a regional water supply.

The First and Second Planning Reports "*Ondersoek en eliminasie van damterreine in die Mfolozi-Opvanggebied*" undertaken in 1977 and 1981 respectively identified and evaluated a series of dams throughout the Mfolozi River Basin. In total, 32 potential dam sites were evaluated, not including the seven dam sites that were previously evaluated at two of which dams to supply water to Vryheid were built. The dams were evaluated to potentially supply water to Ulundi, to existing and new irrigators, and to lower the risk of flooding of the Mfolozi floodplain or even supply water directly to the St Lucia estuarine lake. The more feasible dams were evaluated in more detail, following the approach of lowest unit cost over a dam's economic lifetime when taking its yield into consideration.

Considering the more feasible identified dams in the Mfolozi River that could potentially supply not only the greater Mtubatuba area but also the Richards Bay WSS, the following are potential on-channel dam sites to consider:

- Onrust Dam on the White Mfolozi River, located about 56 km south of the Klipfontein Dam (about halfway between Vryheid and Ulundi). This dam had the best cost index of the dam sites on the White Mfolozi River. This dam would have the potential of making releases down the White Mfolozi River for downstream use. A transfer scheme of more than 50 km to an upper tributary of the Mhlatuze River (in the vicinity of Babanango) would be needed, from where water would flow into Goedertrouw Dam to augment the yield of the Richards Bay WSS. Water released from the Onrust Dam would need to flow a very long way to users in the larger Mtubatuba area, through two game reserves. This dam has not been further evaluated, because of the long distance from its intended users, the long transfer pipeline, the expected high operational losses and the expected concern about regulated river flows through the game reserves.

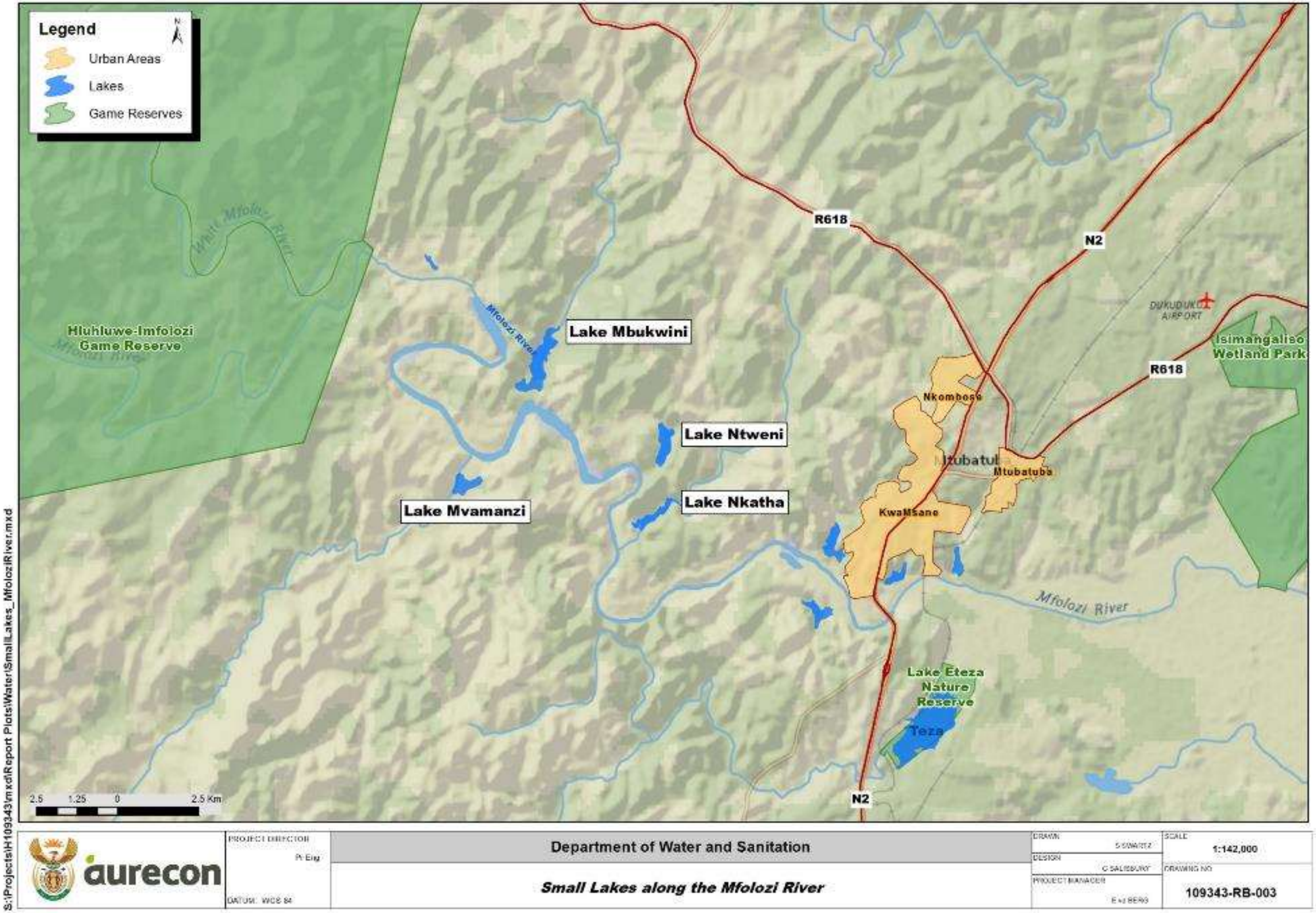

Figure 7-3: Small lakes along the Mfolozi River

- The Harde-arbeid, Doornkop and Ulundi dam sites are located close together near Ulundi on the White Mfolozi River. The issues would be very similar to those for the Onrust Dam. These dams have not been considered further.
- Potential dam sites located within the Hluhluwe-iMfolozi Park are the Ku-Ngqoloti and Tokolwane sites on the White Mfolozi River as well as two sites on the Black Mfolozi River. Ezemvelo KZN Wildlife in the past had a significant problem with any dam on the Mfolozi River that impacts on the game reserve and these sites have not been considered further.
- The previously identified so-called Kwesibomvu and KwaMashaya dam sites on the Mfolozi River below the confluence of the Black and White Mfolozi are located some 7 and 15 km upstream of the N2 road bridge respectively. These dams could stabilise flows in the lower Mfolozi River. The Kwesibomvu site was identified as the better of the two sites, and was further identified as by far the best dam site on the Mfolozi River in terms of unit water cost, and the least impact on the Hluhluwe-iMfolozi Park which would be situated close to the headwaters of the dam.

These sites are shown in Figure 7-4.

The Kwesibomvu Dam has been selected for further evaluation. Preliminary evaluation of the dam yield and structure had already been done and costs were determined, a geological evaluation was done but the dam centre line was not yet drilled in 1981 (one borehole was drilled).

7.1.7 Mfolozi River Yield Analysis

Historical and long-term stochastic yield analyses of the Mfolozi River system were undertaken in the Water Resources Analysis Study: Hydrological Yield Analysis, 2010. According to the 2010 study of the White Mfolozi River the naturalised MAR is 404.7 Mm^3/a (WRC, 2009), and the naturalised MAR for the Black Mfolozi River is 352.1 Mm^3/a. The catchments downstream from the confluence of the two rivers were found to contribute a naturalised MAR of 153.7 Mm^3/a. The total naturalised MAR for the Mfolozi River System was 910.5 Mm^3/a.

Updated WRYM modelled flows in this study, using the flow sequences from the ACRU model compiled for the *Analysis of alternatives to determine the most feasible solution to the hydrological issues of the Lake St Lucia Estuarine system* study, found that the nMAR for the Mfolozi River System is 949 million m^3/a and the current day MAR is 857 million m^3/a.

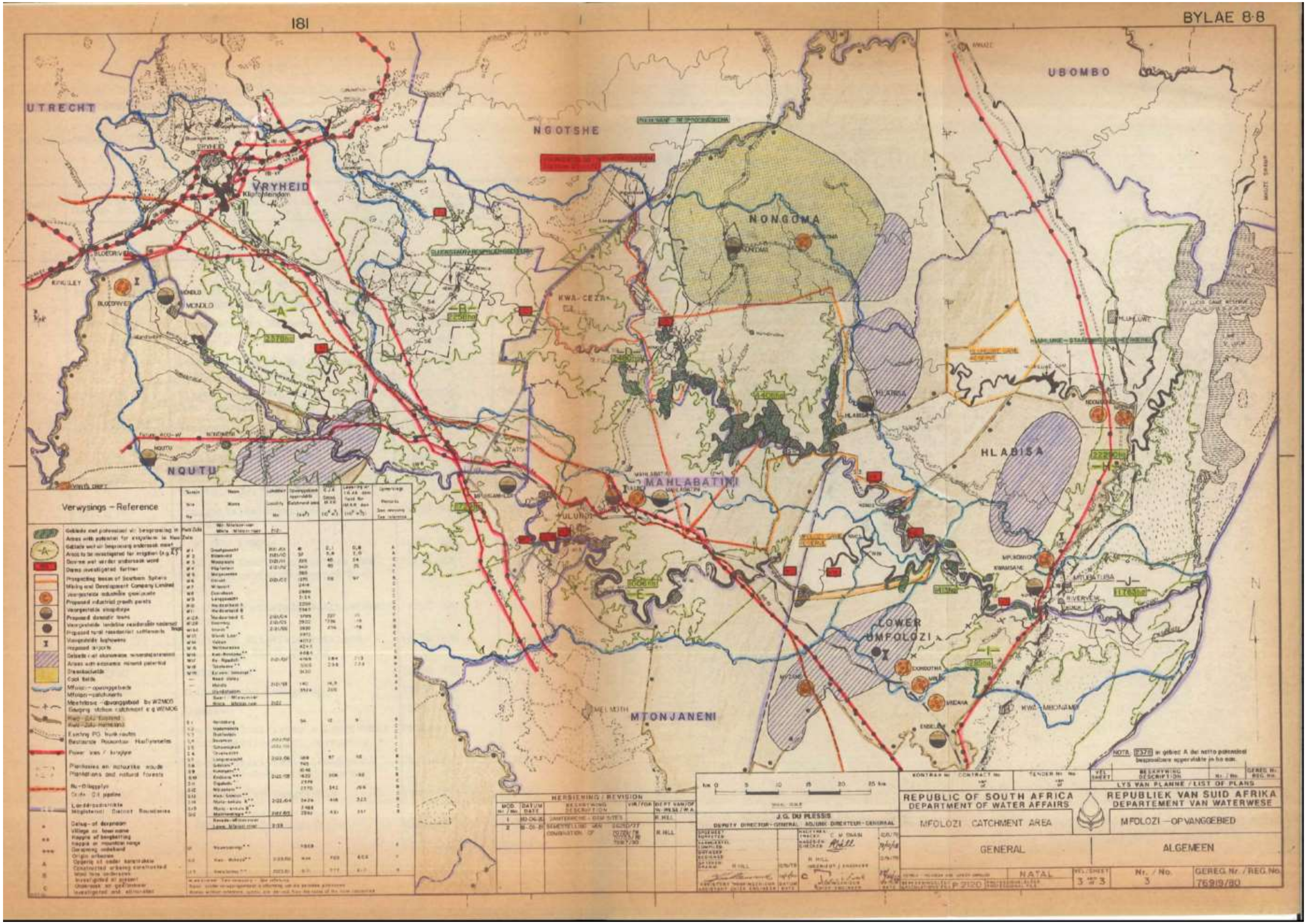

Figure 7-4: **Potential dam sites in the Mfolozi River (1981)**

7.2 Kwesibomvu Dam

7.2.1 Scheme Layout

The Kwesibomvu Dam transfer scheme is shown in Figure 7-5.

7.2.2 Scheme Description

The left flank of the dam centre line consists of basalt weathered to depths of about 2-4m. Alluvium is found in the river channel and the wide alluvial plain. Rock outcrops are seen on the right flank, but the debris at the base of the right flank may be up to 8m deep.

A conventional earth fill dam with a side channel spillway and concrete channel on the left flank is proposed. The biggest challenge at the site is the deep alluvium. This could be mitigated through the provision of a slurry trench to seal the foundation. An outlet tunnel could be provided on the right flank for river releases following construction.

Low flows during construction could be diverted through the outlet tunnel but large floods might have to be discharged over the dam wall. Therefore reinforced rockfill or other flood protection measures would be necessary during construction.

The dam would have to be sized to have as little as possible influence on the game park upstream. A dam with a full supply level in excess of 49 mamsl would start to increase the level of the Mfolozi tributaries within the river channel in the Hluhluwe-iMfolozi Park. For lower full supply levels the damming would be confined to the river channel. The dam level evaluated was therefore at a full supply level of 50 mamsl. With a river bed level of 24 mamsl, the maximum dam height (above river bed level) evaluated would be 26m. A 36m high dam has further been evaluated for reference purposes.

Figure 7-5 shows the scheme location and infrastructure components and Figure 7-6 shows the layout of the dam wall.

Dead storage has been calculated for the volume of sediment that would accumulate after 45 years. It has conservatively been assumed that 100% of sediment would be trapped. Storage capacities for the dam sizes are as shown in Table 7-3.

Table 7-3: Kwesibomvu Dam capacities

Dam height (m)	Storage capacity (million m^3)	Storage capacity as % of MAR (%)	Live Storage capacity (million m^3)
26	144	17%	96
36	265	31%	215

Raw water would be pumped from the dam via a 1.3m dia. 1.7 km long rising main with a pumping capacity of 2.1 m^3/s to a 60 Mℓ balancing reservoir located south-west of the dam wall. From there the water would gravitate 49 km in a 1.4m dia. gravity pipeline with a design capacity of 2.1 m^3/s to the Nsezi water treatment works in Richards Bay for treatment and distribution. An alternative would be to gravitate the water up to a point where the N2 highway crosses the Mposa tributary of the Nseleni River. From there, the water could flow down to Lake Nsezi. This alternative would shorten the gravity line by 19 km, i.e. to 30 km.

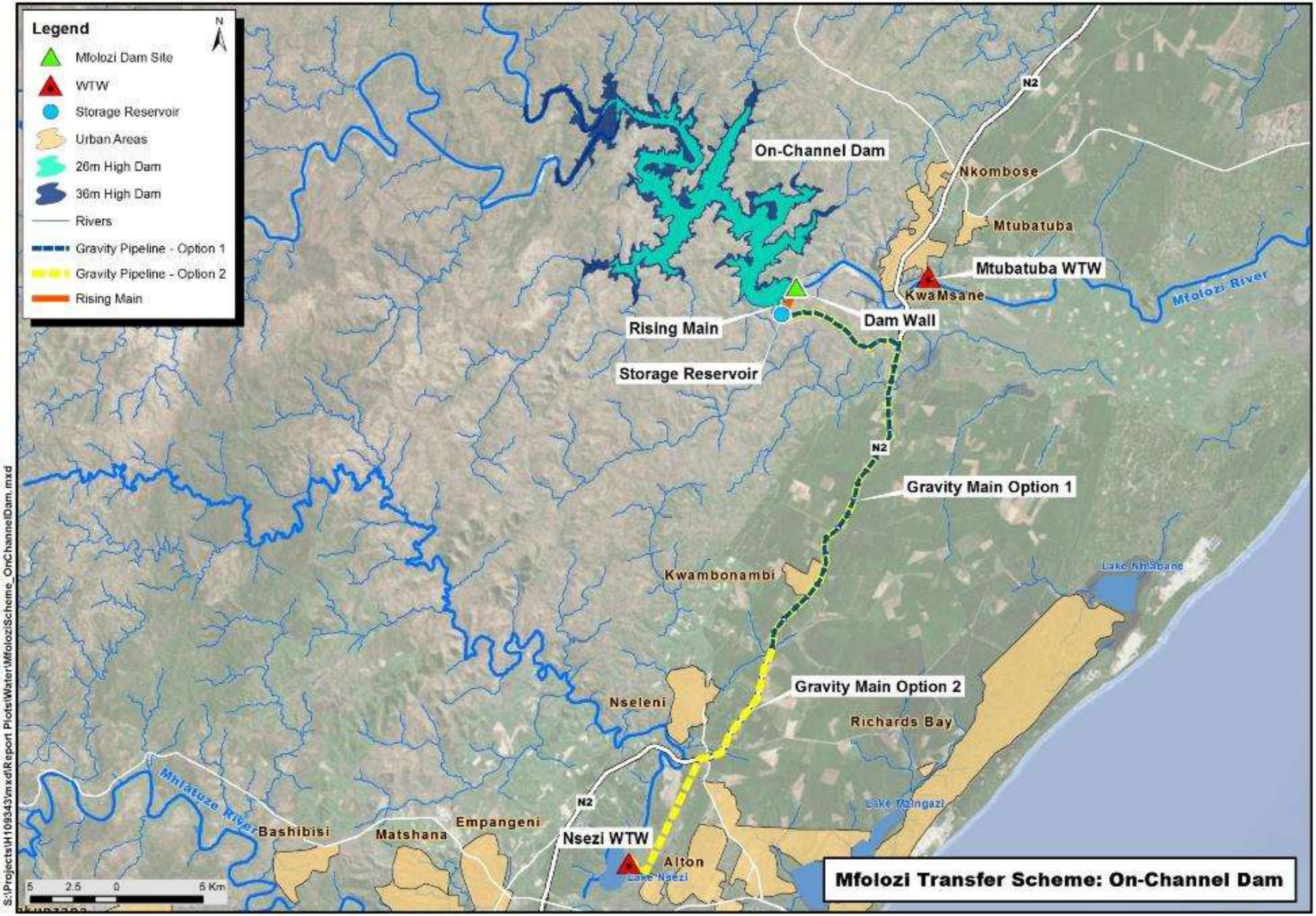

Figure 7-5: Kwesibomvu Dam transfer scheme infrastructure

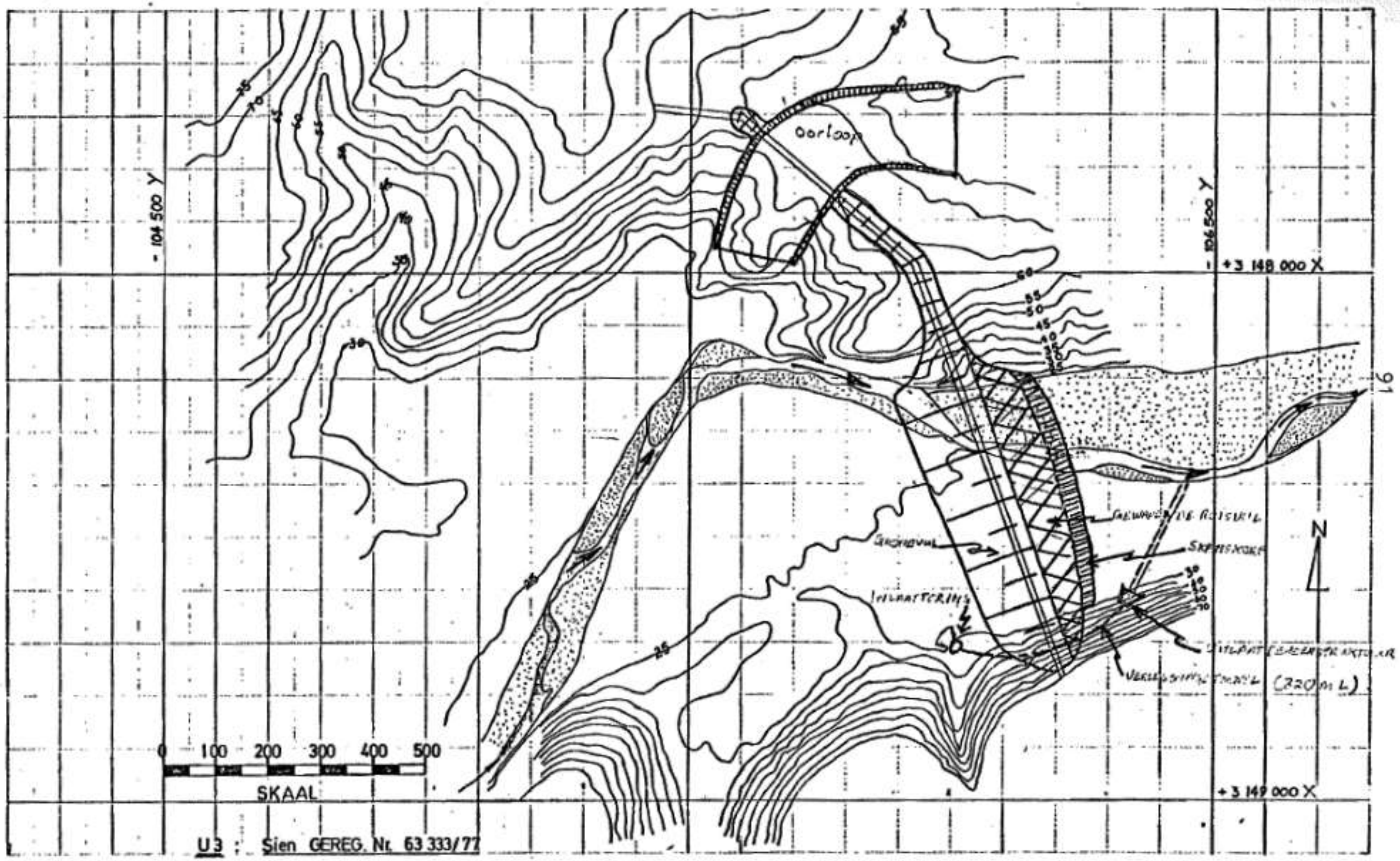

Figure 7-6: **Kwesibomvu Dam plan layout (DWS, 1981)**

7.2.3 Scheme yield

The HFY for the Kwesibomvu on-channel dam based on the current day inflows, taking into account sedimentation (47.8 and 50.5 million m^3/a respectively for the two dam sizes considered) and the requirements downstream for RBM and the estuary IFR (30%) is:

- 26m high (96 million m^3 storage) dam, HFY = 66.6 million m^3/a
- 36m high (215 million m^3 storage) dam, HFY = 137.3 million m^3/a

7.2.4 Unit Reference Value

A summary of the capital costs, net present values of the water supplied and of the costs and URVs for the various sized dams is given below.

Four configurations for an on-channel dam were determined, of which only the costs and URVs for the 26m high dam are reflected here, being considered to be the more feasible dam height. Costs and URVs are shown for transfer to the Nsezi WTW (Table 7-4) as well as to the Mposa River crossing (Table 7-5) respectively.

Table 7-4: URV for 26m high Kwesibomvu Dam (transfer to Nsezi WTW)

ITEM		Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Total capital cost	**(R million)**	2272.8	2272.8	2272.8
Annual operating cost	**(R million/annum)**	76.6	76.6	76.6
NPV Cost	**(R million)**	3310.13	3009.78	2776.63
Unit Reference Value	**(R/m^3)**	**3.69**	**4.21**	**4.75**

Table 7-5: URV for 26m high Kwesibomvu Dam (transfer to Mposa River crossing)

ITEM		Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Total capital cost	**(R million)**	1764.8	1764.8	1764.8
Annual operating cost	**(R million/annum)**	72.3	72.3	72.3
NPV Cost	**(R million)**	2785.08	2513.71	2305.06
Unit Reference Value	**(R/m^3)**	**3.10**	**3.52**	**3.94**

7.2.5 Ecological Impact

Damming the Mfolozi River will result in reduced streamflow downstream of the wall. The dam will block the flow of sediment downstream leading to increased downstream erosion of sedimentary depositional environments (if releases are made) and increased sediment build up in the reservoir. The water released from the dam would probably be quite clear with low turbidity. This improvement in the underwater light climate downstream of the dam would stimulate the growth of filamentous algae attached to suitable substrates and the growth of rooted water plant.

Any natural habit that remains will be lost due to inundation. This includes several pans/wetlands. The Kwesibomvu Dam may potentially flood riverine forest areas and affect rare plant species.

A significant potential impact would be the flooding of lower portions of the Hluhluwe-iMfolozi Park. This could be avoided by limiting the full supply level of the dam. The confluence of the Black and White Mfolozi tributaries further upstream is regarded as unique and should be protected.

The influence of especially the Kwesibomvu Dam on the combined St Lucia/Mfolozi estuary would have to be mitigated by making releases in accordance with the requirements of the ecological Reserve. Canalising of the lower Mfolozi River is now deemed ineffective for the purpose it was designed for and plans are underway to allow the Mfolozi River to return to its natural course and re-join the St Lucia estuary. Sediment that would be trapped by the dam would, however, not proceed downstream to increase siltation of the estuary, and this might assist with the problem there.

A dam acts as a barrier between upstream and downstream migratory aquatic animals. The design of the dam must allow for the migration of such animals downstream of the wall, e.g. fish

Relocated families may have to clear land further up the valley contributing to erosion thereby increasing siltation in the dam and further causing erosion downstream in the Mfolozi River.

When designing the dam, especially determining the area of inundation, consideration must be made to not disrupt or damage sites of heritage or cultural value.

The visual impact of the dam will be high.

A 4 to 5 m thick layer of coal, called the Somkhele coal layer is located in the basin. The impact on potential mining areas would need to be considered, should the mining potential be considered to be economical or near-economical. The Somkhele open-cast coal mine is located 25km north-west of Mtubatuba to the north of the Mfolozi River and the potential for acid-sulphur pollution on the dam should be considered. Some of the impacts may be mitigated by Klipfontein Dam in the upper reaches of the White Mfolozi River near Vryheid. There are good long-term water quality data records available from the DWS for the lower Mfolozi River that can be used to investigate the water quality status and possible water impacts should it be necessary to investigate this intervention in more detail.

The pipeline and weir will be in close proximity to a number of NFEPA wetlands and rivers. This means that environmental authorisation and a water use licence will be required from relevant authorities. The conveyance pipeline to the Nsezi WTW should follow existing roads and railway servitudes as far as possible to minimise habitat destruction.

Much of the proposed development runs through areas that are 100% transformed. Areas such as these are often favoured for development. However, sections classified as CBA 3: Optimal, will also be traversed, meaning features with a low irreplaceability biodiversity habitat. Important species are still located within them and should be accounted for in the EIA process. A small section of CBA 1: Mandatory, will be inundated by the Mfolozi On-Channel Dam. Such areas indicate the presence of units that represent the only localities for which the conservation targets for one or more of the biodiversity features contained within can be achieved, meaning there are no alternative sites available.

The lower reaches of the pipeline, near Richard’s Bay, cross over a threatened ecosystem classified as Critically Endangered. This is the Kwambonambi Hygrophilous Grasslands which is a priority area for meeting explicit biodiversity targets defined in the Kwa-Zulu Natal Systematic Biodiversity Plan. A botanical survey will identify the actual impact on this ecosystem and possible mitigation measures.

7.2.6 Socio-Economic Impact

Rural dwellings/homesteads and farmlands will be inundated and associated relocation and compensation is expected to be costly. Should the dam level be kept under 50 mamsl, the number of affected homesteads is expected to be limited.

The dam could potentially provide recreational activities in the area. The Kwesibomvu Dam might increase fish and waterfowl populations, and if recreational facilities were provided they would be close to population centres.

Building a dam in a valley is more likely to attract people into the area, i.e. local employment (positive) and expansion or establishment of communities usually associated with social problems.

Downstream communities are at higher risk in the event of dam failure due to floods.

Given the severe and continuing problems with water supply in the Mtubatuba area, an ensured long-term water supply would be a positive socio-economic impact development, as the Mfolozi River cannot sustain the water requirements of the area, therefore more water will be made available for water users. There is potential for a number of commercial developments that might take place in the Mtubatuba area/ area south of the Mfolozi, which are currently constrained or rendered infeasible by a lack of assurance of water-supply. The Industrial Development Zone (IDZ) has a large number of developments planned close to Richards Bay (including Nyanza Light Metals and a Solar Water Heater Plant) and might be able to expand their area north should there be water available to support development. Currently future plans do not include any area north of Kwambonambi as having potential for development.

Some projects under development in the Mfolozi/ Kwambonambi area include Moyamara Development, 15ha Commercial Development at the N2-intersection development (Empophomeni Property Investments Holdings cc), Nseleni Mall development (Developer : LST Investments (Pty) Ltd), Nseleni Industrial Node (uThungulu District Municipality), Aluminium Fluoride Production Facility – EIA on hold (Developer : Alfuorco (Pty) Ltd), Fluidised Bed Power Plant (Developer : Umbani Power Company), as well as some commercial, residential and mixed-used developments.

7.2.7 Findings

Strengths

This is a surface water transfer scheme that would add benefit in terms of increased insurance of supply of the Richards Bay Water Supply System, as droughts may occur at different times in the Mfolozi and Mhlathuze catchments. The Mfolozi is currently an under-used river, with significant potential for development. The scheme would in addition provide the bulk water storage which is urgently required for water supply to the Mtubatuba and surrounding areas and provide significant socio-economic benefits for the region. The yield is significant.

Weaknesses

Environmental impacts are significant and a large area of land would be inundated. Aspects relating to the inter-basin transfer of water could be perceived as a barrier, especially if water is transferred for release in the Mposa tributary river.

7.3 Mfolozi Off-Channel Dam

7.3.1 Off-Channel Scheme Layout

The Mfolozi off-channel transfer scheme is shown in Figure 7-7.

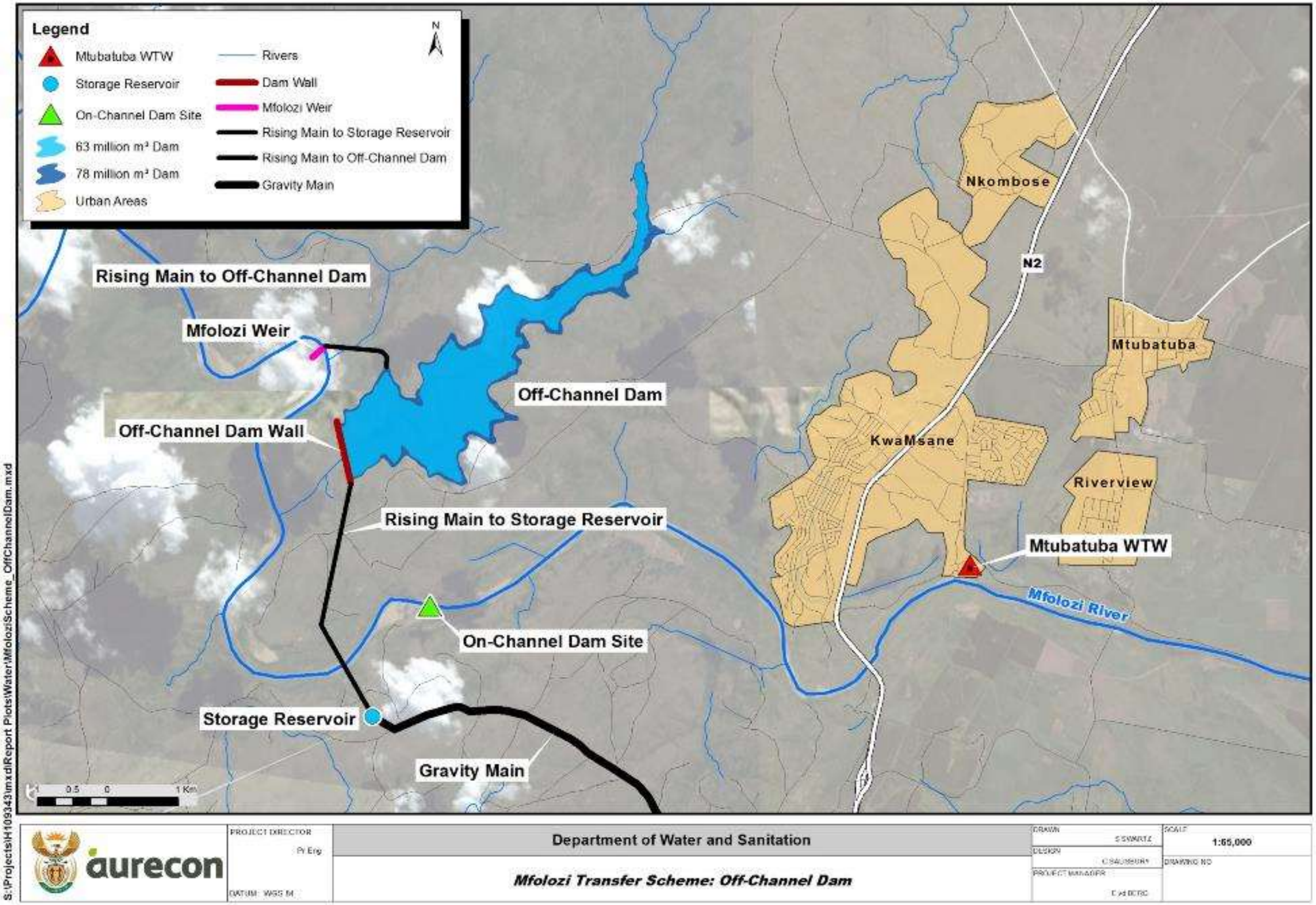

Figure 7-7: Mfolozi off-channel dam transfer scheme infrastructure

7.3.2 Scheme Description

Several potential off-channel dam sites were briefly identified close to the main Mfolozi River channel in the river section upstream of the N2 highway and below the confluence of the White and Black Mfolozi tributaries. From the preliminary characteristics of the potential sites, it was decided to evaluate an off-channel site at the current Nkatha Pan site.

Water would be diverted and pumped from a weir in the Mfolozi River to the off-channel dam via a pipeline of 960m length. Diversion volumes of 2m/s and 2.5m/s were respectively considered. From the off-channel dam water will be pumped to a 60 Mℓ storage reservoir via a pipeline of 3.9km length. Two dam sizes were considered along with each diversion rate, to determine yields and costs. From the reservoir, water will gravitate either to Nsezi WTW, or to the Mposa River crossing. From and including the storage reservoir, the bulk water infrastructure routes are the same as for the Kwesibomvu Dam option.

From the reservoir water would gravitate 49 km to the Nsezi water treatment works in Richards Bay for treatment and distribution. An alternative would be to gravitate the water up to a point where the N2 highway crosses the Mposa tributary of the Nseleni River. From there, the water could flow down to Lake Nsezi. This alternative would shorten the gravity line by 19 km, i.e. to 30 km.

Table 7-6 show the pipeline diameters for the various off-channel dam configurations.

Table 7-6: Pipeline diameters for the Mfolozi Off-Channel Dam Scheme

Transfer Capacity (m^3/s)	Off-channel dam size (million m^3)	Dam height (m)	Pipeline - Weir to Dam (dia, m)	Pipeline - Dam to Reservoir (dia, m)	Pipeline - Reservoir to Mposa crossing (dia, m)	Pipeline - Reservoir to Nsezi WTW (dia, m)
2.0	30	28	1.3	1.2	1.1	1.2
2.0	63	38	1.3	1.4	1.2	1.3
2.5	39	32	1.4	1.3	1.2	1.3
2.5	78	42	1.4	1.6	1.3	1.4

7.3.3 Scheme Yield

The HFY for the Mfolozi off-channel dam based on the current day inflows, taking into account the IFR requirements was determined for the four configurations as shown in Table 7-7.

Table 7-7: Off-channel Dam HFYs

Transfer Capacity (m^3/s)	Off-channel dam size (million m^3)	HFY (million m^3/a)
2.0	30	33
2.0	63	47.1
2.5	39	40.8
2.5	78	56.9

Increasing the transfer rate from the Mfolozi River to the Mfolozi off-channel dam (78 million m^3 dam) to e.g. 5 m^3/s could increase the water transferred by an additional 12.7 million m^3/a.

7.3.4 Unit Reference Value

URVs for the four off-channel dam configurations are shown in the following tables for an 8% discount rate, although URVs were also determined for 6% and 10% for these configurations. Table 7-8 shows the transfer to the Nsezi WTW, while Table 7-9 shows transfers up to the Mposa River crossing.

Table 7-8: Mfolozi off-channel Dam URV (8% discount rate), transfer to Nsezi WTW

ITEM		2m/s diversion 30 million m^3 dam	2m/s diversion 63 million m^3 dam	2.5m/s diversion 39 million m^3 dam	2.5m/s diversion 78 million m^3 dam
Total capital cost	**(R million)**	1299.4	1565.1	1552.0	1601.93
Annual operating cost	**(R million/annum)**	90.3	104.8	111.9	130.9
NPV Cost	**(R million)**	2305.11	2733.14	2805.31	3106.6
Unit Reference Value	**(R/m^3)**	**6.32**	**5.36**	**6.99**	**5.87**

Table 7-9: Mfolozi off-channel Dam URV (8% discount rate), transfer to Mposa crossing

ITEM		2m/s diversion 30 million m^3 dam	2m/s diversion 63 million m^3 dam	2.5m/s diversion 39 million m^3 dam	2.5m/s diversion 78 million m^3 dam
Total capital cost	**(R million)**	941.5	1152.8	1131.3	1235.75
Annual operating cost	**(R million/annum)**	87.5	101.6	108.7	128.1
NPV Cost	**(R million)**	1955.10	2329.43	2394.36	2749.36
Unit Reference Value	**(R/m^3)**	5.36	4.56	5.97	5.20

7.3.5 Ecological Impact

Many of the ecological impacts for the on-channel dam also apply here, although impacts will be less significant as a result of the smaller scale of the dam. The conveyance pipeline from the weir to the dam and then to the storage reservoir will be located in a natural area and therefore effort should be made to ensure that environmental impacts during construction are minimised.

The Mfolozi off-channel scheme would probably have little impact in the water quality in the Mfolozi River. The reduction in flow downstream of the weir where water is diverted and pumped to the off-channel storage dam could possibly result in slightly clearer water in the lower reaches of Mfolozi River. A reduction in streamflow could lead to more sediment settling as the water velocity decreases. This may have a small impact on improving conditions to promote the growth of filamentous algae and rooted water plants.

As in the Thukela River, there is probably a direct relationship between river flow and suspended sediment concentrations in the Mfolozi River. The timing of transfers to the off-channel storage dam would affect the amount of sediments transferred. At low flows little sediment would be transferred and at high flows the sediment loads in the transfer would increase. The transferred sediment would settle in the off-channel storage dam. There may be some evidence of nutrient enrichment in the off-channel dam as a result of diffuse runoff from agricultural lands.

7.3.6 Socio-Economic Impact

Many of the socio-economic impacts as per on-channel dam also apply here. The inundated area is significantly less than the on-channel dam, and the corresponding relocations will be fewer, as well as the general impacts being lower. By the same token, the increased availability of water will be more limited, and the positive effects will be diminished.

7.3.7 Findings

Strengths

This is a surface water transfer scheme that would add benefit in terms of increased insurance of supply of the Richards Bay Water Supply System, as droughts may occur at different times in the Mfolozi and Mhlathuze catchments. The Mfolozi is currently an under-used river, with significant potential for development. The tabled schemes would in addition provide the bulk water storage which is urgently required for water supply to the Mtubatuba and surrounding areas. Development of an Mfolozi River scheme could hold significant socio-economic benefits for the region. The scheme has large potential yield. A strength of the off-channel dam (relative to the on-channel dam) is that it inundates a significantly smaller area ($2km^2$ – $4km^2$) versus ($10km^2$ – $14km^2$).

Weaknesses

Environmental impacts are significant, although it will be less for the off-channel dam than for the on-channel dam. A large area of land would be inundated. Aspects relating to the inter-basin transfer of water could be perceived as a barrier, especially if water is transferred for release in the Mposa tributary river.

8 MHLATUZE RIVER DAMS

8.1 Dam on the Nseleni River

8.1.1 Scheme Layout

This scheme has not been investigated prior to this study, so there is no literature relating directly to it. The location and layout of the dam is shown below in Figure 8-1.

8.1.2 Scheme Description

Although this river has a MAR that is much lower than that of the Mfolozi, Mhlatuze or Thukela rivers, the storage that could be provided is not negligible. Four potential dam sites on the Nseleni River were identified and features of the various sites such as their dam wall sites and basin storage characteristics were briefly compared. The most downstream site was selected for further evaluation, mainly considering storage to earth-fill ratios.

This scheme consists essentially of the dam itself, as well as associated infrastructure such as an outlet tower and outlet pipeline etc. No other pipelines, pump-stations or storage reservoirs are included as releases will be made to the river downstream of the dam and abstractions can be made from Lake Nsezi at Nsezi WTW, as well as by RBM at their abstraction point on Lake Nsezi.

An advantage of the location of this dam is that there is only a short distance (approximately 15 km) between the release point and the abstraction point at Lake Nsezi. This means that there would be relatively low river losses due to infiltration and evaporation along the route, as well as limited opportunity for contamination of the water downstream of the dam – although the existing water quality issues as described below would be a problem that would need to be addressed.

The capital cost of this scheme is the only significant cost, as recurring costs due to maintenance and operation would be negligible. In turn, the capital cost depends largely on the size of the dam, and the URV depends on the cost and yield for each dam size.

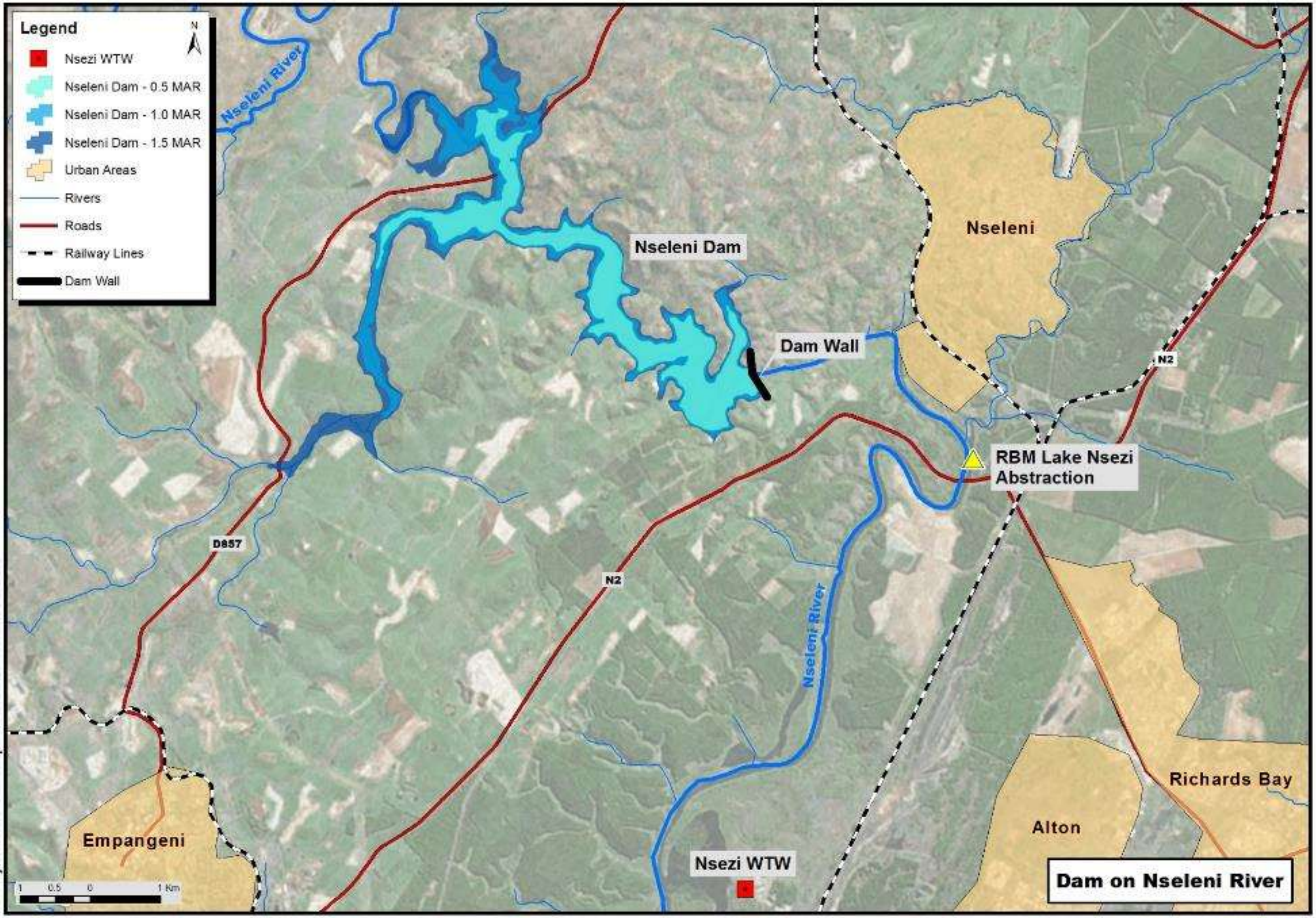

Figure 8-1: **Dam on the Nseleni River**

8.1.3 System Yield

The 0.5MAR, 1MAR and 1.5MAR dam volumes were investigated. The storage volumes of these dams correspond to a volume equal to the relevant fraction of the current-day MAR at the damming point.

From the Yield Model the natural and current-day MAR volumes were calculated, taking into account the effects of sedimentation and provision for the reserve, amongst other factors. The current-day MAR was found to be 43.1 million m^3/a and the characteristics of the three dam sizes investigated are given below in Table 8-1:

Table 8-1: Characteristics of Nseleni Dam options

Dam size (fraction of current-day MAR)	Capacity (million m^3)	Height (m)	Surface Area (million m^2)	Yield (million m^3/a)
0.5	21.555	17.2	3.02	0.0
1	43.110	22.5	5.24	7.0
1.5	64.665	26.1	7.18	10.6

As the 0.5MAR dam was found to not have an incremental yield, it is not described further in this section, although the cost of this dam has been determined.

8.1.4 Unit Reference Value

The dams were costed according to a simple spreadsheet model. An earth-fill dam with a spillway was designed, and features such as an outlet tower and pipeline were included. A full and detailed design of the dam, taking into account other infrastructure such as access roads etc. would be carried out if this project proceeded to feasibility study stage.

Adjustments to the exact location of the dam site, based on geological or geophysical factors and optimisation of the storage to fill ratio for the dam would be made, but the results of the financial analysis, given below in Table 8-2, are reasonable approximations to the final figures.

Table 8-2: URVs for Nseleni Dam Options (8%)

ITEM		1.0MAR Dam (43.1Mm³)	1.5MAR Dam (64.7Mm³)
Total capital cost	**(R million)**	164.39	173.19
Annual Cost	**(R million)**	1.07	1.13
NPV Cost	**(R million)**	157.04	165.44
NPV Supply	**(million m^3)**	79.96	121.08
Unit Reference Value	**(R/m^3)**	1.96	1.37

8.1.5 Ecological Impact

The environmental impact of the dam would mostly relate to the inundation of an area of between 3 km^2 and 7 km^2, depending on the size of the dam. The area to be inundated is mostly commercial agricultural land (sugar-cane) on the western bank of the river, with some small agricultural plots on the eastern bank. Most of the area that would be inundated by the dam is developed in one way or another, so from an environmental perspective the impact would be lower than for an undeveloped area.

The impact on the ecological processes in the river as a result of the dam construction would be temporary. Releases for the environmental Reserve would be made once the dam was completed, and the resolution of water-quality issues downstream of the dam would have a positive impact on the environmental situation there.

The Nseleni River is an NFEPA river and is listed as Class A: Unmodified and Natural. The Okula River flows into the Nseleni River and its lower reaches will also be flooded as a result of the dam. The Okula River is also an NFEPA River and is also a Class A river; thus, any work undertaken within the river or on the banks of the river requires an environmental authorisation and water use licence from the regulatory authorities.

A loss of vegetation will occur through inundation of three indigenous forest patches of KwaZulu-Natal Coastal Forest which are classified as Endangered by the KZN Systematic Conservation Plan: Zululand Coastal Thornveld is classified as Endangered, the Maputaland Coastal Belt (location of the proposed dam wall) is classified as Vulnerable and Northern Coastal Forest may also be lost due to inundation of land.

A large part of the area of inundation will be located within the Critically Endangered Kwambonambi Hygrophilous Grasslands. This is a priority area for meeting explicit biodiversity targets as described by the KZN Systematic Biodiversity Plan. This vegetation type is of very high irreplaceability and of high threat.

The area just upstream and immediately downstream of the intended dam wall is listed as a Natural Floodplain Wetland. The wetland ecosystem type is Indian Ocean Coastal Belt Group 1 which is listed as Least Threatened and is Well Protected. In the Okula River, an Artificial Wetland has been identified which has been classified as having a wetland ecosystem type of Lowveld Group 11. This ecosystem type is largely listed as Least Threatened and Well Protected, but small sections are classified as Vulnerable and Critically Endangered.

8.1.6 Socio-Economic Impact

As with the environmental impact of the dam, the socio-economic impacts are mostly related to the inundation of the area of the dam. Depending on the size of the dam, there are one or two sections of the D857 road that would be inundated. This would require a diversion of the road, which has been allowed for in the costing of the dam, but which would also have impacts in terms of construction of the new route. Impacts as a result of the dam construction (noise pollution, disposal of materials etc.) would be fully investigated and mitigation measures put in place during the feasibility stage of the project.

The surrounding area is mostly agricultural, with some houses. The cost of purchasing the land has been included in the dam cost estimate, but ensuring that the acquisition process and any relocations are carried out with full stakeholder participation and support would be a primary objective of the process. A Relocation Action Plan (RAP) will be required. Amongst the social infrastructure that would be inundated, an agricultural college would be partly flooded, and the impacts and mitigation of this would need to be addressed.

A farm dam – Crystal Dam - is located on one of the tributaries of the Nseleni River, a short way upstream of the planned dam site. Both the 1MAR and 1.5MAR dams would cause the complete inundation of this dam, and the 0.5MAR dam would inundate an area that, while not overtopping the dam wall from downstream, would inundate most of the area below it. In any case this would have to be discussed with the landowner and an agreement reached as to the approach to this impact. Either water rights to an equivalent abstraction volume from the proposed dam could be granted, as well as compensation for the additional area inundated, or the farm dam could be protected by raising the dam wall, which would lead to the loss of a portion of the proposed dam's capacity, as well as the additional cost of raising the farm dam. This would need to be investigated fully at a later stage.

Increased assurance of supply to users in the area would lead to positive social benefits, especially taking into account the requirement of the Nsezi WTW downstream, from Lake Nsezi.

8.1.7 Findings

The costing carried out here was based on a number of assumptions, given the best information available. If this intervention were to be evaluated at feasibility level more information would have to be obtained. A geological investigation would need to be carried out at the site to evaluate the founding conditions for the dam. An EIA would need to be carried out to evaluate the environmental impacts fully and investigate mitigation measures. The water-quality issues would need to be investigated and mitigation measures implemented.

The maximum yield of this intervention would likely be taken up by the predicted increase in demand within a short space of time (likely two years). Other interventions would then need to be implemented to meet the increasing demand. In the analysis of various scenarios this would need to be taken into account.

However, this dam would increase the assurance of supply to both the Nsezi WTW and RBM, which would be of indirect benefit to the system as a whole. The alternative source of water for Nsezi WTW is the Mhlatuze River; greater abstraction from Lake Nsezi would result in increased availability of water from the river for other users. Similarly, RBM abstracts water from the Mfolozi River and from Lake Nhlabane, and the pressure on those sources could be reduced by increased availability of water from Lake Nsezi.

The dam would capture and store floods, providing both attenuation and increased yield to the system.

8.2 Raising of Goedertrouw Dam

8.2.1 References

In the evaluation of this intervention as an option for the Richards Bay water supply area the following documents and sources were used as reference:

- *"Goedertrouw Dam: Third Dam Safety Inspection Report"* by DWS, dated March 2011. This report is the latest safety evaluation of the dam on record.
- *"Goedertrouw Dam Operation and Maintenance Manual"* by the then DWAF dated November 2003. The manual was compiled by the then DWAF to comply with dam safety regulations.
- "*Mhlathuze Operating Rules and Future Phasing (MORFP), Main Report*" dated 2001. The study was undertaken by the then DWAF.
- Personal communication with Mr Jan Nortje and Dr Chris Oosthuizen of the DWS Dam Safety Office and with Mr Abdulla Sayed of the KwaZulu-Natal Regional Office, Oct 2014 and Jan 2015.

8.2.2 Scheme Layout

The location of the dam is shown below in Figure 8-2.

8.2.1 Scheme Description

Introduction

The Goedertrouw Dam is located on the Mhlatuze River near Eshowe. The dam was completed in 1982 and consists of an earthfill embankment with a spillway section through a neck (see layout in Figure 8-3. The 160m long uncontrolled spillway is situated about 230m from the wall on the right flank. The dam is 88m high with a crest length of 660m and had a storage capacity of 321 million m^3 when it was constructed. The storage capacity of the dam has decreased to an estimated 301 million m^3 (year 2000) due to siltation. The 1.7 MAR dam is owned and operated by DWS.

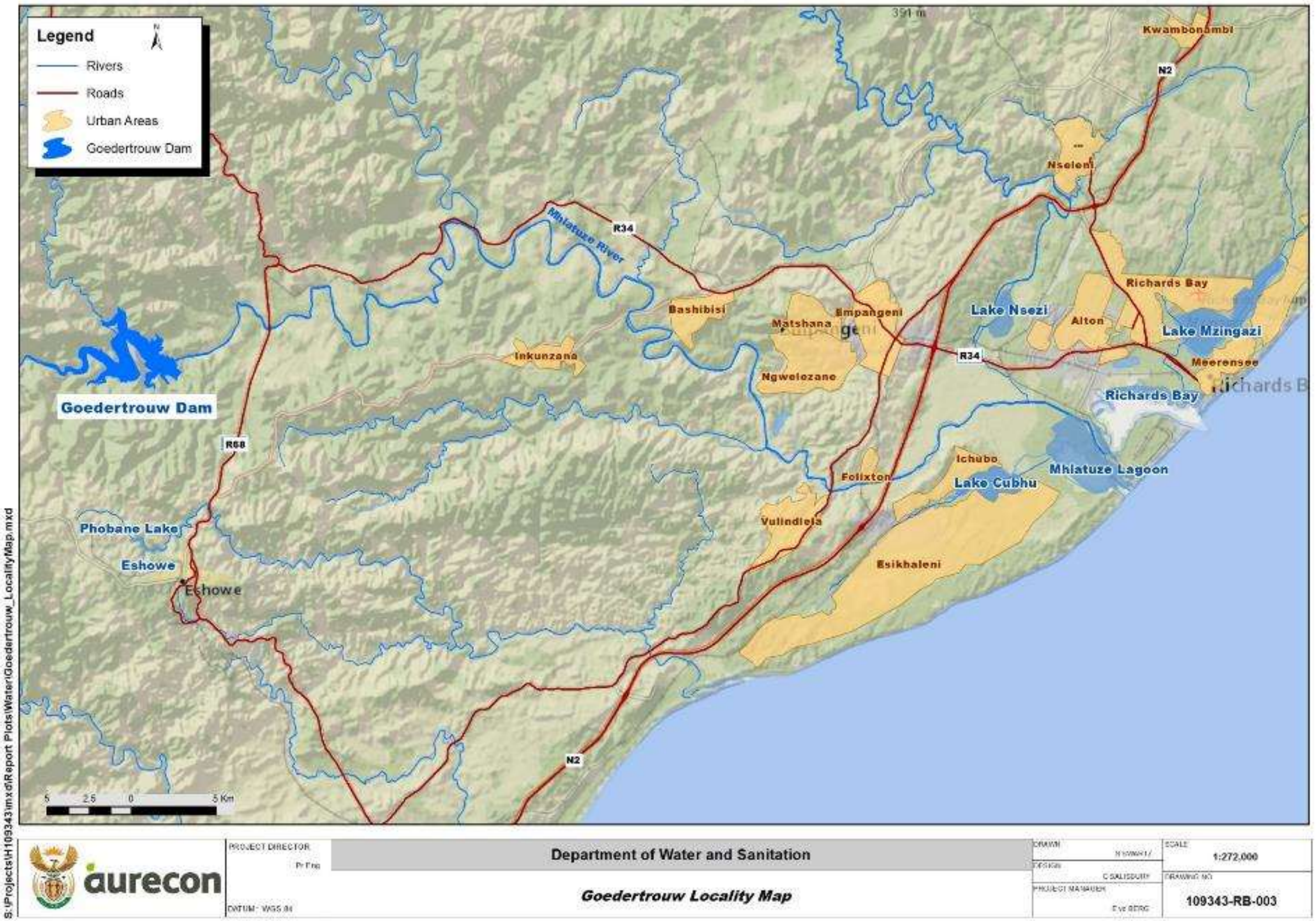

Figure 8-2: **Location of Goedertrouw Dam**

Figure 8-3: **Layout of Goedertrouw Dam**

The dam regulates the flow of the Mhlatuze River to make water available to downstream irrigators as well as urban and industrial users in the Richards Bay area.

The Mhlathuze Operating Rules and Future Phasing (MORFP), Main Report, 2001 made the statement: "*Results of analyses to investigate the possibility of raising Goedertrouw Dam showed that an increase in yield of 6.1 million m^3/a can be achieved when the dam is raised by 2.8 m, given the current Thukela-Mhlathuze transfer scheme. The 2.8 m is the maximum practical height with which the dam can be raised*".

The possibility of raising the dam was discussed with the DWS Dam Safety Office (personal communication Jan Nortje, Dr Chris Oosthuizen and Abdulla Sayed, Oct 2014) and the following points were made:

- *Some 8 years ago, a Licence to Alter was issued by the Dam Safety Office, which included a provision to raise the non-overspill crest of the dam by 0.5 m to ensure a minimum total freeboard of 8.0 m. With this work having been done, the Safety Evaluation Flood (SEF) can just be handled with 8 m of freeboard, and there is no spare freeboard. This means that in addition to raising the spillway, the non-overspill crest level of the Dam wall will also have to be raised.*
- *Despite the fairly flat downstream slope, the raising may have to be done from the downstream toe, which will be expensive (assuming a fixed raising). Test pits will need to be excavated in order to check the level of the core.*
- *No chances can be taken, as the Dam is in the eastern region of KZN where the Kovacs "K" flood values are the highest in the country, leading to extremely large floods.*
- *The impact of a potential dam raising on land or infrastructure is expected to be minimal.*
- *The estimated R 9 million in the quoted MORFP Report is extremely low and provides no indication of what the current cost of raising the dam will be.*
- *The dam is already sized large relative to MAR and raising of the dam is expected to be relatively expensive if conventionally raised.*

As advised in the MORFP Report, a 2.8m high raising was considered. The raising height was confirmed by DWS staff.

Present condition of dam

The third safety evaluation of the dam in 2011 concluded that the dam is in good condition requiring no major upgrading work other than routine maintenance. Further investigations and monitoring were recommended with the most significant being:

- Conduct numerical or model tests of the outlet system to verify that no unwanted flow regimes are present.
- Evaluation of the ungrouted rock bolts in the outlet tunnel.
- Monitor erosion of the rock mass below the spillway flip bucket as it is blocky in nature and susceptible to headward erosion.

Existing spillway capacity of dam

As stated above the freeboard of the dam was increased around 2009. The third safety evaluation report list the freeboard as 7.5 m. The report also recommended a SEF of 7 030 m^3/s (= RMF peak with K=5.6) and concluded that after flood routing was carried out the SEF could be accommodated by the spillway with a dry freeboard of 0.7 m. The existing spillway capacity of the dam is therefore sufficient. Figure 8-4 shows the dam spilling in 1987.

Figure 8-4: Goedertrouw Dam spilling in 1987

Raising of spillway

It is proposed that the existing ogee shaped spillway be raised by 2.8 m by means of a labyrinth or piano key weir (PKW) spillway. As this type of spillway increases the effective length of the spillway the unit discharge per straight length of spillway is increased and the total required freeboard decreases. It is estimated at this reconnaissance level that the total required freeboard will decrease to approximately 6 m. The existing spillway will have to be demolished. A typical PKW spillway is shown in Figure 8-5.

Figure 8-5: Typical Piano Key Weir

Embankment raising

It is anticipated that the embankment crest will be raised by 1 to 1.5 m depending on the final raised spillway configuration. As the embankment crest is 10 m wide (which allows sufficient space) and was reportedly raised and reconstructed with an access road around 2009 it is considered least disruptive to do the raising in a wave/parapet wall. Such typical curved wall is shown in the Figure 8-6.

Outlet works

It is assumed that the outlet tower is structurally capable of being raised by such minor margin and allowance has therefore only been made to raise the walls and re-construct the roof.

It is understood that the present ecological flow releases from the dam will continue and therefore that no additional allowances for such releases will have to be made.

Land acquisition and relocations

An allowance for land acquisition and relocations has been made. We are not aware of any major relocations required at present.

Figure 8-6: Typical wave/parapet wall on embankment crest

8.2.2 Yield of the Raised Dam

The nMAR at the dam is 156.7 million m^3/a and the current day MAR is 136 million m^3/a, taking into account the effects of sedimentation and provision for the Reserve, and updated downstream water demands.

The additional yield of the raised dam was found to be 3.9 million m^3/a. The characteristics and yield of the current and raised dams are shown in Table 8-3.

Table 8-3: Characteristics and yield of the raised dam

	Volume (million m^3)	Yield (million m^3/a)	Height (m)	Surface Area (ha)
Existing dam	301.3 (2000)	51.1	88.0	1194
Raised dam	336	55	90.8	1279

8.2.3 Unit Reference Value

Capital and operational and maintenance costs have been determined for the raising of the dam and ancillary infrastructure. These are shown in Table 8-4 along with the URVs.

Table 8-4: URVs for the Raising of Goedertrouw Dam

ITEM		Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Total capital cost	**(R million)**	77.6	77.6	77.6
Annual operating cost	**(R million/annum)**	0.19	0.19	0.19
NPV Cost	**(R million)**	75.13	72.98	71.06
Unit Reference Value	**(R/m^3)**	1.33	1.61	1.89

Water treatment costs have been excluded in the URV calculation.

8.2.4 Ecological Impact

Most of the impacts, social and ecological, will be as a result of the greater area of inundation caused by the dam wall being raised and the capacity being increased. Possible ecological impacts stem largely from a loss of vegetation and habitat for fauna.

Ecological releases would be maintained, and any ecological impact is expected to be minimal.

A loss of vegetation, specifically Eastern Valley Bushveld (SVs 6) will result. This vegetation type is listed as Least Threatened and has a conservation target of 25%. However only 0.8% is statutorily conserved and about 15% in this area has been transformed, mainly by cultivation.

The Mhlatuze River is classified as a NFEPA. Thus any work undertaken within the river or on the banks of the river requires an environmental authorisation and water use licence from the regulatory authorities

The current dam is proximate to a number of CBA (KwaZulu-Natal Terrestrial Systematic Conservation Plan, 2011). It is upstream of a CBA 1 and certain areas of inundation are located within a CBA 3. By increasing the dam wall, more CBA 3 areas will be inundated. CBA 3 indicates the presence of one (or more) features with a low irreplaceability biodiversity habitat. Important species are still located within them and should be accounted for in the EIA process. The current dam itself is listed as 100% transformed in the KZN Systematic Conservation Plan.

The downstream impacts associated with the raising of the dam wall is considered marginal as the impacts already exists however, with increased water storage capacity, comes increased siltation capacity.

With the raising of Goedertrouw Dam, the water residence time in the reservoir would, on average, increase from about 2.2 years to 2.4 years. Water residence affects how quickly water is flushed from the reservoir. This affects rate dependent processes such as the rate of sediment deposition and algal growth rate. An increase in water residence time of two months would probably not have a significant impact on the current physical and biological processes in the reservoir and water quality would probably change little from its present state.

8.2.5 Socio-Economic Impact

As the FSL will be raised by only 1-1.5m, the impact on infrastructure or houses are expected to be minimal. The socio-economic impact would largely be positive as a result of the additional water made available for socio-economic growth.

The dam may flood sites of heritage importance, such as graves or memorials, or of archaeological importance where fossils are present,

A positive socio-economic impact is that additional water will be available for farming and household use in the Richards Bay/Empangeni area and perhaps locally too.

Recreational users of the dam may view the increase in size as a positive impact, unless it means the flooding of recreational buildings, camps sites or picnic sites.

If the area to be inundated includes a rural settlement, farm house or crops therefore, relocation or compensation may be required.

Greater risk of dam failure due to floods as the dam is in the eastern region of KZN where the Kovacs “K” flood values are the highest in the country, leading to extremely large floods. Communities downstream of the dam would be most at risk.

8.2.6 Findings

This is a relatively straightforward option, in that there are few additional impacts or peripheral infrastructure required to implement it. The additional yield is limited, but the related costs are correspondingly low, and the implementation is likely to be quicker than other options that require identification and/or investigation of a new site. Raising the dam would allow some of the ‘dead’ storage lost to siltation of the dam to be recovered.

9 GROUNDWATER

9.1 Overview

9.1.1 General Study Area Information

Groundwater Study Area

The study area for the groundwater evaluation is roughly defined by the uMhlathuze LM border, as presented on Figure 1-1 – Locality Plan, although there was an attempt to look at a slightly wider area.

Topography and Drainage

The topography of the study area can be described as planar to slightly undulating in the eastern regions near the coast, whilst the western regions can be described as slightly to steeply undulating.

Since the study area encompasses the entire uMhlathuze LM, the drainage direction is area specific. However, drainage tends to be towards the major rivers running through the study area, such as the Mhlatuze River, Mhlatuzana River and their tributaries. These major rivers flow in an east south east direction towards the Indian Ocean.

9.1.2 Geology and Geohydrology

Geology

The 1 : 250 000 Dundee and St. Lucia Geological sheets indicate that a variety of geological units are present within the study area, as presented on Figure 2 – Geological Plan on a following page.

The study area is predominantly underlain by unconsolidated Quaternary-age sediments which are generally located in the eastern region of the study area, whilst the western region is underlain by various geological units, which predominantly belong to the Natal Sector of the Namaqua-Natal Province.

The general descriptions of the geology identified within the proposed wellfields, namely Proposed Wellfield 1 (PW 1), Proposed Wellfield 2 (PW 2) and Proposed Wellfield 3 (PW 3), are included below:

Quaternary-age sediments

The Quaternary-age sediments include the unconsolidated sediments deposited by fluvial action of the Mhlatuze River and its tributaries. The Quaternary sands also include the coastal dunes evident in the eastern portion of the site. Given that these sands underlie the eastern portion of the study area, they are highly susceptible to pollution. Due to the high level of industry located in the Richards Bay area, the chance of pollution impacting upon these sands is very high. These sands include those belonging to the Berea and Port Durnford Formations.

Namaqua-Natal Province

The Namaqua-Natal Province is comprised mainly of intrusive gneisses, including the gneisses which form part of the Matigulu Steep Belt (Cornell *et al*., 2006). These gneisses include quartz feldspar gneisses, biotite gneisses and amphibole gneisses and underlie the southern portion of the study area which includes PW 1 and the southern portion of PW 3.

The northern portion of the study area, which includes PW 2 and the northern portion of PW 3 are underlain by intrusive gneisses, including the gneisses of the Ngoye Complexes, which form part of the Tugela Group (Cornell *et al*., 2006). These lithologies include gneisses, olivine norites, granitic gneisses and amphibolites.

9.1.3 Structural Geology

The study area has been subjected to differing tectonic forces, as part of various tectonic events, which has hence resulted in the formation of different geological structures orientated in a variety of directions. Given that the eastern parts of the study area are underlain by unconsolidated sediments, these structures have been mapped mainly toward the west.

The formation of the Namaqua-Natal Province represents the earliest possible tectonic / formation event that resulted in some of the structures evident in the region. Early-stage syn-emplacement deformation occurred as a result of northeast – southwest orientated convergence characterized by north-east verging, recumbent and assymetrical folds that are transposed along southerly (south-westerly) dipping, geometrically-related, thrust faults and ductile (sinistral transcurrent) shear zones (McCourt *et al*., 2006; Cornell *et al*., 2006). Such tectonic movements allowed for the formation of the west-southwest – east-northeast structures (faults) seen in the region.

The greater study area also coincides with a region of complex faulting which is associated with crustal extension that is related to the Mesozoic breakup of Gondwana (Watkeys and Sokoutis, 1998). This faulting is best explained through Watkeys' (2002) five stage model describing the breakup of Gondwana, which accounts for the north – south and north-northeast – south-southwest structures seen in the area. The former were likely formed through the Lebombo 'monocline' undergoing east – west extension, as a result of movement along the Agulhas-Falkland Fracture Zone (Watkeys and Sokoutis, 1998), whilst the latter can be attributed to the extraction of the Falklands Plateau from the Natal Valley, when during coast-parallel shearing, right-lateral strike-slip movement occurred (Watkeys, 2002).

It should be noted though that the ability of a structure to transmit groundwater is typically dependent upon its mode of formation, the variation in the stress regime of the region since its formation and its current orientation with respects to the orientation of present σ_1 (maximum compression stress), σ_2 (intermediate compression stress) and σ_3 (minimum compression stress).

Anderson's (1951) theory of faulting, although possibly simplistic, aids in identifying the original orientation of σ_1, σ_2 and σ_3, in relation to the formation of the structures evident in the region. Those structures orientated perpendicular to σ_3, or parallel to σ_2, are deemed to have possibly been open during their formation, and hence were able to transmit greater amounts of groundwater. Although the transmissivity state of structures typically varies since their formation, as a result of various deformation events, an assessment of the information incorporated by Gravelét-Blondin (2013) suggests that during the present time, all three (3) of the detailed structure orientations have the ability to transmit elevated amounts of groundwater, due to extensional tectonics.

9.1.4 Geohydrology

The underlying gneisses, amphibolites and norites are considered secondary aquifers which are described as weathered and fractured rock aquifers with negligible primary porosity since groundwater movement is confined to joints, fractures and geological contacts, therefore groundwater development options are often limited to these zones.

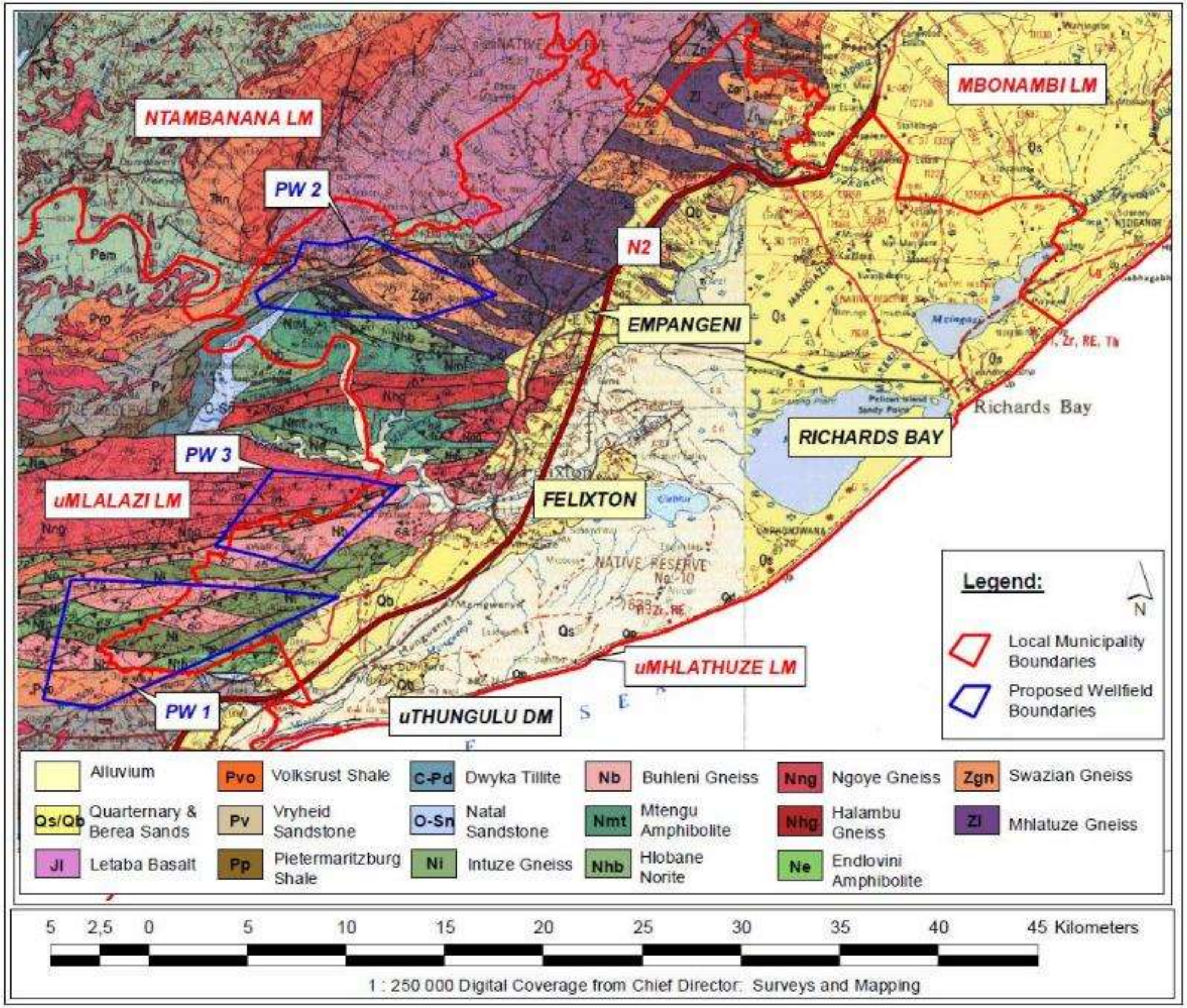

Figure 9-1: **Geological Plan**

According to *"Characterisation and Mapping of the Groundwater Resources, Mapping Unit 3"* May 1995, as prepared by Groundwater Development Services, borehole yields can be described as poor to moderate and usually range between 0.1 l/sec and 3.0 l/sec. Most water-strikes are encountered in the transition / contact zone between the weathered and un-weathered units.

Boreholes geophysically sited to intersect the major geological structures identified within the study area can produce borehole yields in excess of 3.0 l/sec.

Ambient groundwater quality in this region is generally moderate to poor due to elevated total dissolved solids (TDS) concentrations, which raise electrical conductivity (EC) levels to between 100 mS/m and 150 mS/m. Sporadically-elevated concentrations of fluoride (F), nitrate (NO_3) and sodium (Na) also occur in these geological environments, whilst elevated total coliforms and *E. coli* levels are common, and are usually attributed to anthropogenic activities and livestock grazing.

The hydrochemical characteristics classify the groundwater quality in the fresh water to slightly saline range.

9.2 Groundwater Schemes

9.2.1 Scheme Layout and Limitations

These schemes have not, as far as known, been investigated prior to this study, so there is no known literature relating directly to it. The borehole data available for this specific area have been obtained from historical databases, including our Geomeasure Group In-house Databases, the DWS National Groundwater Archive Database (NGA), the KwaZulu-Natal Groundwater Resource Information Project Database (KZN GRIP), as well as a limited uThungulu Database which was populated using the hard copy reports provided by the uThungulu DM.

It must be noted that during the data gathering process, the uThungulu DM indicated that their more recent (< 5 years old) borehole data were available electronically in a database format, however, despite numerous requests, this was not provided to us. The uThungulu DM did however provide us with hard copy reports for capturing purposes.

It must also be noted that a number of limitations arise when undertaking this type of project, and this should be kept in mind while assessing this intervention.

One of the important limitations is that since the data has been attained from historical databases, the data are often outdated and therefore may not represent the true current status of the boreholes in the field. Furthermore, since no field verification visits were included in the current scope of work, the current status of the existing boreholes included in the proposed wellfields / schemes could not be confirmed at this stage.

In addition, borehole entries into a database are generally undertaken using the drilling logs from when the boreholes were installed and therefore pump test data and management recommendations are often not included. Furthermore, many of the boreholes in this specific area were installed with the aim of equipping them with hand pumps and therefore recommended pump rates are not often included in the datasets. Therefore, since the pump rates / recommended aquifer yields are often absent, the borehole blow yields measured during the drilling are used instead. However, this in itself is a significant limitation since a blow yield is almost always a much larger volume compared to the recommended pump / discharge rates and is not a true representation of the aquifer / borehole yield.

Despite the identification of numerous existing boreholes in the study area, it is recommended that new production boreholes be installed in these areas in order to develop wellfields which are economically viable by being capable of supplying significant groundwater volumes in a sustainable manner.

The location and layout of the proposed wellfields, hence called Project Wellfield (PW) 1, PW 2 and PW 3 are described below and have been shown on the Figures included on the following pages of this report.

9.2.2 Scheme Description

Since geophysical and field investigations have not been carried out at this stage, the proposed borehole locations represent suggested drilling target areas. From this it is inferred that following field investigations, the locations of the boreholes as well as the delineated proposed wellfields may change.

The proposed production borehole locations have been chosen according to the presence of geological structures, dolerite dykes and geological lineaments which are targeted when undertaking geophysical investigations and borehole sitings. In addition, the assumed current land use has also been taken into account, whereby areas showing agricultural farmland have not been included. Furthermore, an estimated 500 m spacing between each new production borehole in each cluster has also been taken into account when deciding on the proposed borehole locations. Further still, access to a drilling rig has also been taken into account by positioning the wellfields close to access roads (observed a desktop level) and in the general vicinity of existing boreholes, which indicate areas where drilling rigs have been able to access in the past.

At this stage of the investigation, however, only the locations of the proposed production boreholes have been included. Due to the high density of existing boreholes in the area, it is suggested that a hydrocensus be undertaken to determine which existing boreholes could possibly be viable for use as monitoring boreholes, which will be used to monitor aquifer conditions during the operational phase.

Mtunzini-North Groundwater Scheme (PW 1)

PW 1 is located in the south western portion of the uMhlathuze LM and extends in a westerly direction over the municipal boundary and into the uMlalazi LM, as shown on Figure 9-2 on the following page. The existing borehole located the furthest away from the uMhathuze LM boundary is identified to be BH ONG 15, which is situated some 3.5 km to the west. A total of 14 existing boreholes have been included within the delineated PW 1 boundary, which has an approximate extent of 12 km in a west – east direction and 6.3 km in a north – south direction.

Despite the identification of existing boreholes in the area, a new proposed wellfield comprising approximately 18 production boreholes and 20 exploration boreholes is recommended. If feasible, existing boreholes will be integrated. The production boreholes have been grouped into 3 main clusters as shown on Figure 9-3.

Since all three proposed wellfields are underlain by gneisses and amphibolites of the Matigulu Steep Belt and Tugela Groups, elevated concentrations of F, Na, EC, iron (Fe), manganese (Mn), NO_3 and chloride (Cl) can occur in some of the units. In addition, elevated concentrations of total coliforms and *E. coli* are possible, since they are usually attributed to anthropogenic activities which are prevalent throughout the study area.

With the installation of "in-line" treatment systems, specific determinants elevated in specific boreholes can be treated before the groundwater is pumped into the Municipal reservoirs, using "in-line" treatment methods which could include the following:

- Reverse Osmosis systems for the treatment of elevated EC, Na, total coliforms, Cl, NO_3 and F concentrations
- Chlorination systems for the treatment of elevated total coliform and *E. Coli* concentrations
- Ozone generator systems for the treatment of Fe and Mn concentrations

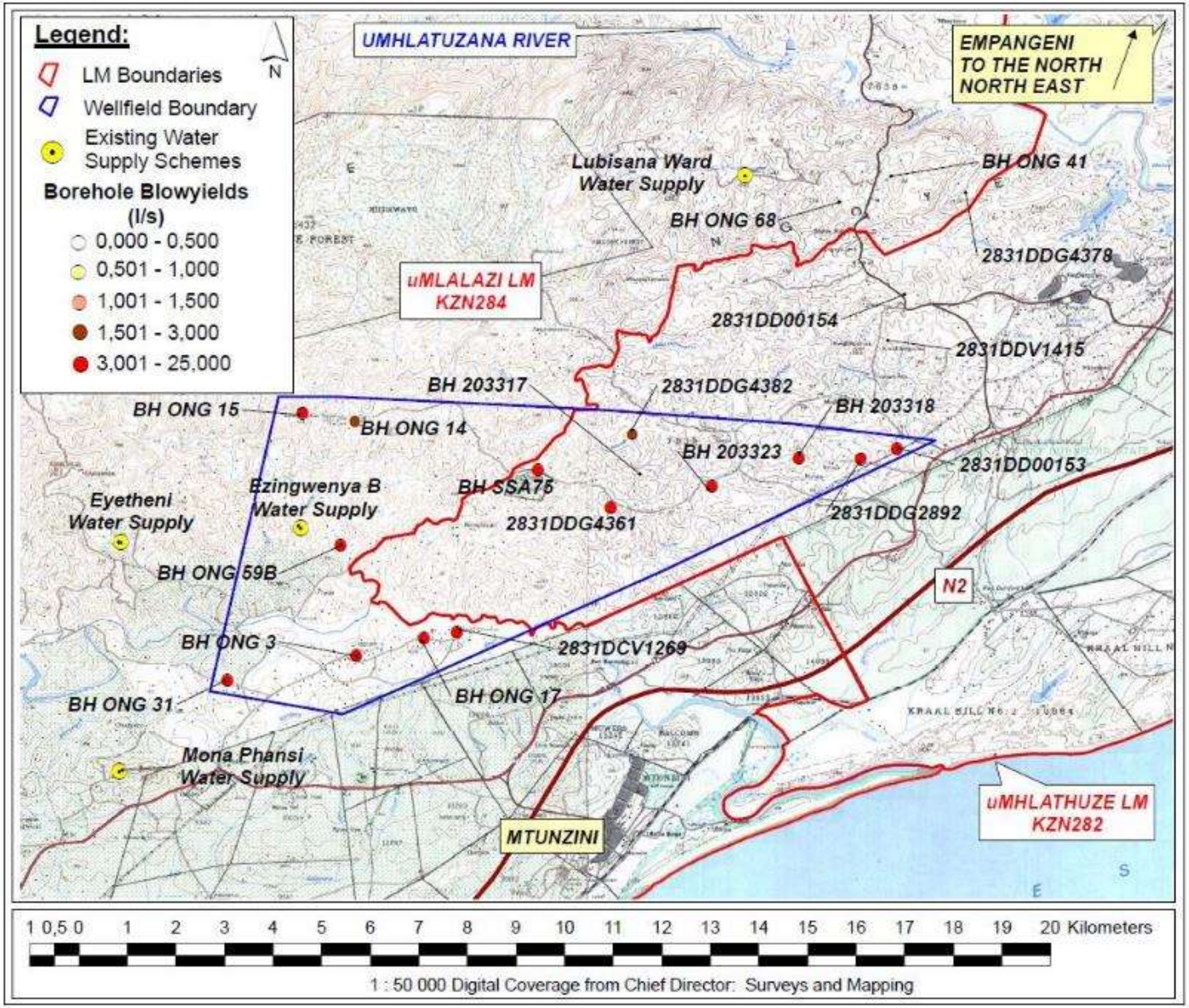

Figure 9-2: Location and Layout of Existing Boreholes within Proposed Wellfield 1

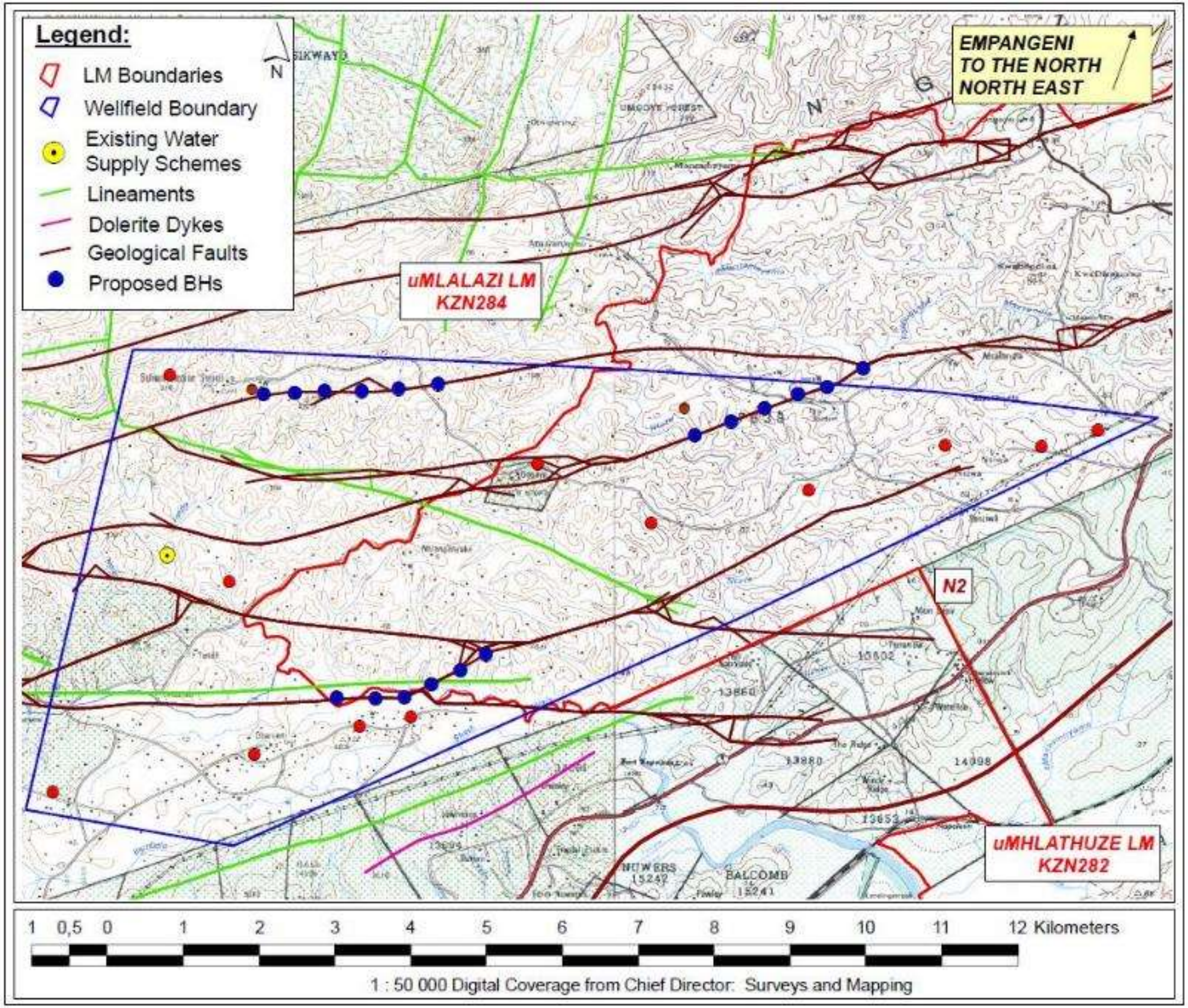

Figure 9-3: **Locations of Proposed New Production Boreholes within Proposed Wellfield 1**

Empangeni West Groundwater Scheme (PW 2)

PW 2 is located to the west of Empangeni and extends westwards towards the boundary of the uMhlathuze and uMlalazi LMs, as shown on Figure 9-4. A total of 15 boreholes have been included within the delineated PW 2 boundary, which has an approximate extent of 10.7 km in a west – east direction and 4 km in a north – south direction.

Despite the identification of existing boreholes in the area, a new proposed wellfield comprising approximately 17 production boreholes and 20 exploration boreholes is recommended. If feasible, existing boreholes will be integrated. The production boreholes have been grouped into 3 main clusters as shown on Figure 9-5.

Lubisana Groundwater Scheme (PW 3)

PW 3 is located to the west of Empangeni and extends across the boundary of the uMhlathuze and uMlalazi LMs, as shown on Figure 9-6. A total of 5 boreholes have been included within the delineated PW 3 boundary, which has an approximate extent of 6 km in a west – east direction and 6 km in a north – south direction.

Despite the identification of existing boreholes in the area, a new proposed wellfield comprising approximately 19 production boreholes and 20 exploration boreholes is recommended. If feasible, existing boreholes will be integrated. The production boreholes have been grouped into 3 main clusters as shown on Figure 9-7.

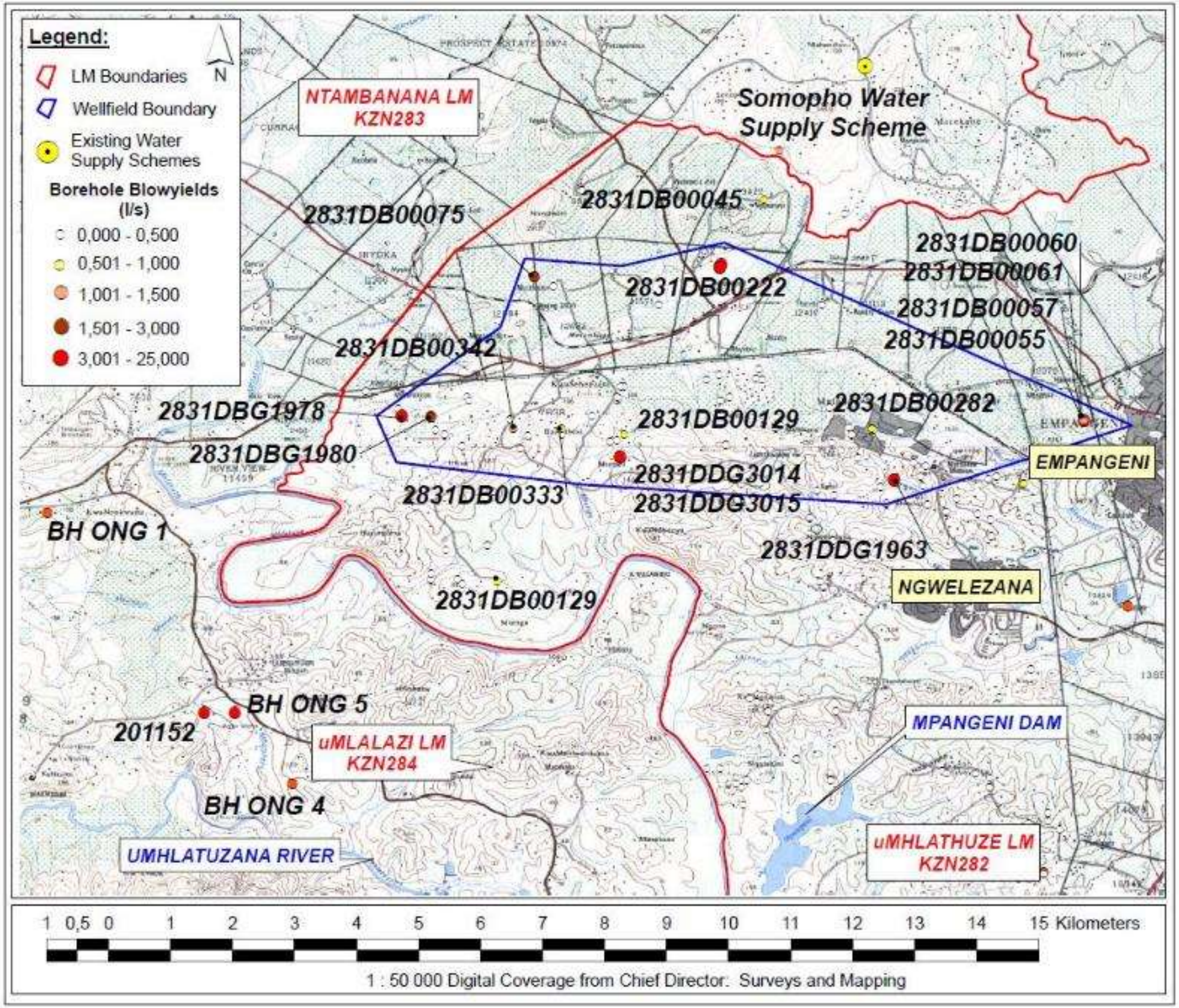

Figure 9-4: **Location and Layout of Existing Boreholes within Proposed Wellfield 2**

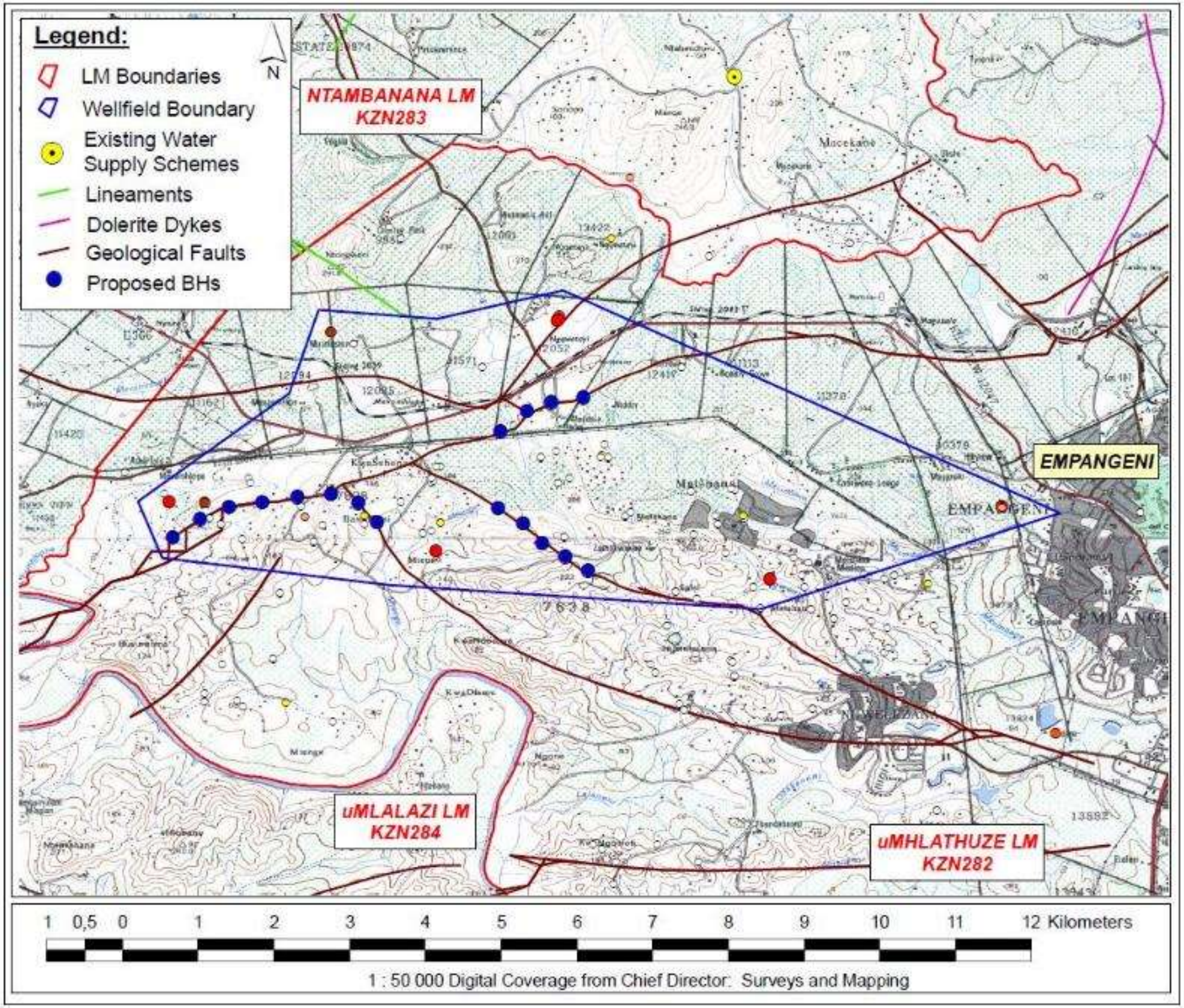

Figure 9-5: **Locations of Proposed New Production Boreholes within Proposed Wellfield 2**

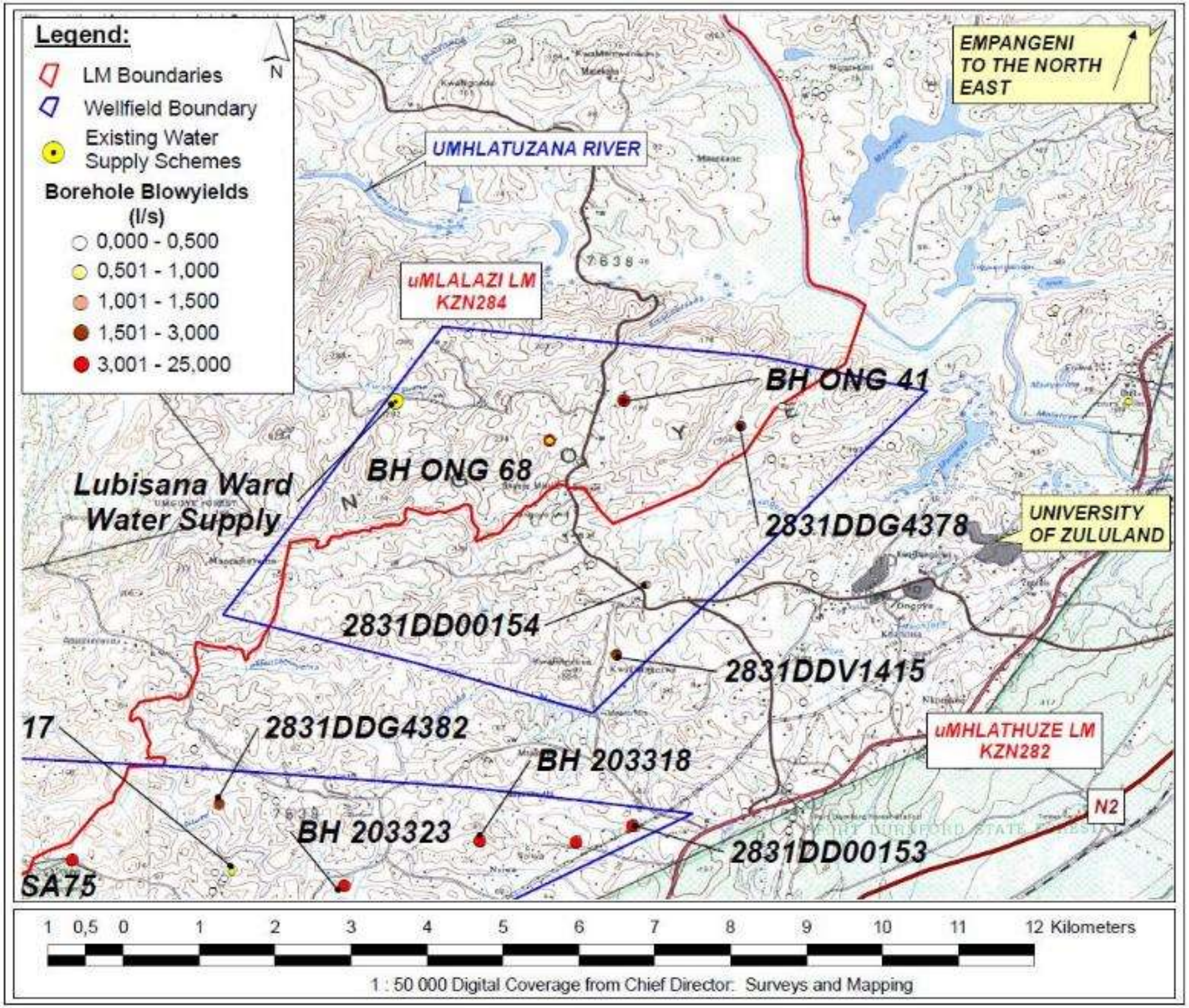

Figure 9-6: **Location and Layout of Existing Boreholes within Proposed Wellfield 3**

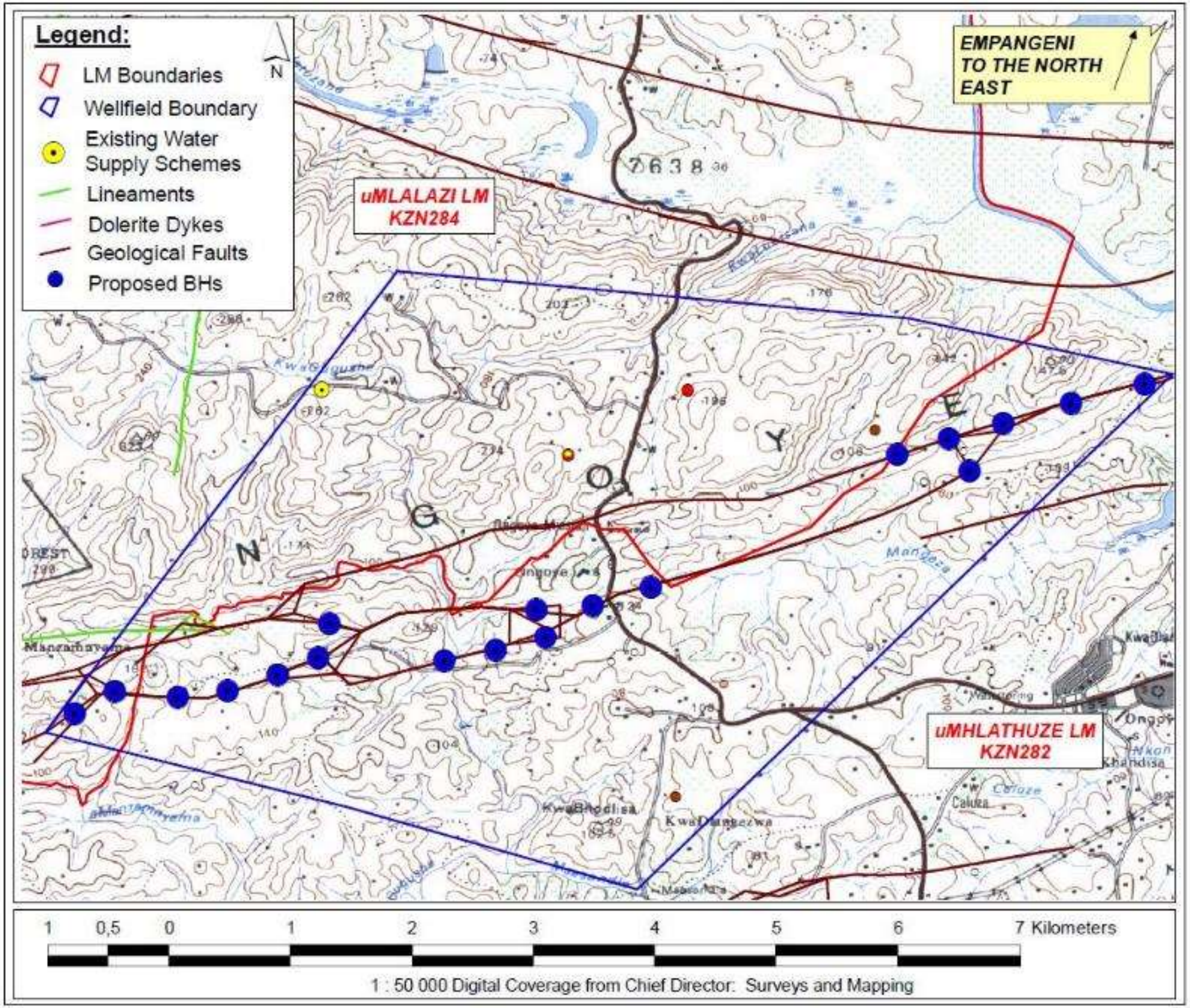

Figure 9-7: **Locations of Proposed New Production Boreholes within Proposed Wellfield 3**

9.2.3 System Yield

Despite the high density of boreholes located predominantly in and around the western portion of the uMhlatuze LM, the majority of boreholes were identified to be very low yielding with blow yields in the range of 0 l/sec to 0.5 l/sec.

Therefore only boreholes with yields in excess of 0.5 l/sec were included. Since blow yields are only basic indications of possible water supply, the sustainable borehole yields can be as little as half of the blow yield volume, therefore, it is extremely difficult to determine the true yields of the boreholes selected to form part of the proposed wellfields.

For the purpose of this study and for the estimation of reasonable possible borehole yields, the following assumptions have been made:

- All boreholes identified in this desk top study level do still exist in the field.
- All boreholes are still capable of yielding volumes similar to the volumes measured when the boreholes were first installed.
- The borehole yields equate to half of the blow yield measured during the borehole installations.

Table 9-1: Boreholes and Their Respective Blow yields Included in Proposed Wellfield 1 (PW 1)

Borehole Number	Measured Blow yield (l/sec)	Measured Blow yield (l/hr)	Estimated BH Yields (l/sec)	Estimated BH Yields (l/hr)
ONG15	11,10	39960	5,550	19980
2831DDG4361	10,00	36000	5,000	18000
ONG3	10,00	36000	5,000	18000
2831DDG2892	9,17	33012	4,585	16506
SSA75	8,95	32220	4,475	16110
B 203323	6,67	24012	3,335	12006
ONG17	6,67	24012	3,335	12006
B 203318	5,00	18000	2,500	9000
2831DCV1269	4,00	14400	2,000	7200
ONG31	4,00	14400	2,000	7200
ONG59B	4,00	14400	2,000	7200
2831DD00153	3,30	11880	1,650	5940
2831DDG4382	2,83	10188	1,415	5094
ONG14	2,00	7200	1,000	3600
TOTALS	***87,69***	***315684***	***43,845***	***157842***

The data in Table 9-1 above indicate that the final combined blow yields of all 14 boreholes are estimated to be in the order of 315 684 l/hr. Since the existing borehole records suggest possible borehole yields ranging between 1 l/sec and 5.5 l/sec, a conservative figure of 2.5 l/sec is used for the estimations of the groundwater volumes which could be attained from this wellfield.

Based on the estimated yield of approximately 2.5 l/sec (9000 l/hr) per borehole, and by using a standard pump cycle of 12 hrs (per day), the estimated abstraction volumes from the 18 proposed production boreholes in PW 1 could be in the order of 1 944 000 l/day. This equates to 0.73 million m^3/a.

The groundwater from PW 1 would ideally be pumped to tanks within the wellfield and / or then pumped to the closest reservoir, the Forest Hills Reservoir.

Table 9-2: Boreholes and respective blow yields included in Proposed Wellfield 2 (PW 2)

Borehole Number	Measured Blow yield (l/sec)	Measured Blow yield (l/hr)	Estimated BH Yields (l/sec)	Estimated BH Yields (l/hr)
2831DB00129	0,76	2736	0,380	1368
2831DB00061	0,50	1801	0,250	901
2831DB00055	10,09	36324	5,045	18162
2831DB00057	0,84	3024	0,420	1512
2831DB00060	1,01	3636	0,505	1818
2831DB00075	1,51	5436	0,755	2718
2831DB00222	3,33	11988	1,665	5994
2831DB00282	0,76	2736	0,380	1368
2831DB00333	0,76	2736	0,380	1368
2831DB00342	1,01	3636	0,505	1818
2831DBG1978	5,00	18000	2,500	9000
2831DBG1980	2,00	7200	1,000	3600
2831DDG1963	3,06	11016	1,530	5508
2831DDG3014	1,39	5004	0,695	2502
2831DDG3015	25,00	90000	12,500	45000
TOTALS	***57,020***	***205273***	***28,510***	***102637***

The data in Table 9-2 above indicates that the final combined blow yields of all 15 boreholes are estimated to be in the order of 205 273 l/hr.

Since the existing borehole records suggest possible borehole yields ranging between 0.2 l/sec and 12.5 l/sec, a conservative figure of 2.0 l/sec is used for the estimations of the groundwater volumes which could be attained from this wellfield.

Based on the estimated yield of approximately 2.0 l/sec (7200 l/hr) per borehole, and by using a standard pump cycle of 12 hrs (per day), the estimated abstraction volumes from the 17 proposed production boreholes in PW 2 could be in the order of 1 468 800 l/day. This equates to 0.54 million m^3/a.

The groundwater from the boreholes within PW 2 would ideally be pumped to the Empangeni Reservoir, which is located just to the south of PW 2 between the PW 2 boundary and the uMhlathuze LM boundary.

Table 9-3: Boreholes and Their Respective Blow yields Included in Proposed Wellfield 3 (PW 3)

Borehole Number	Measured Blow yield (l/sec)	Measured Blow yield (l/hr)	Estimated BH Yields (l/sec)	Estimated BH Yields (l/hr)
ONG 41	15.00	54000	7.50	27000
ONG 68	1.00	3600	0.50	1800
2831DDV1415	1.67	6012	0.84	3006
2831DDG4378	2.00	7200	1.00	3600
2831DD00154	1.11	3960	0.55	1980
TOTALS	***20,770***	***74772***	***10,39***	***37386***

The data in Table 9-3 above indicates that the final combined blow yields of all 5 boreholes are estimated to be in the order of 74 772 l/hr.

Since the existing borehole records suggest possible borehole yields ranging between 0.50 l/sec and 7.5 l/sec, a conservative figure of 1.0 l/sec is used for the estimations of the groundwater volumes which could be attained from this wellfield.

Based on the estimated yield of approximately 1.0 l/sec (3600 l/hr) per borehole, and by using a standard pump cycle of 12 hrs (per day), the estimated abstraction volumes from the 19 proposed production boreholes in PW 3 could be in the order of 820 800 l/day. This equates to 0.30 million m^3/a.

The groundwater from PW 3 would ideally be pumped to tanks within the wellfield and / or then pumped to the closest reservoir, the Forest Hills Reservoir.

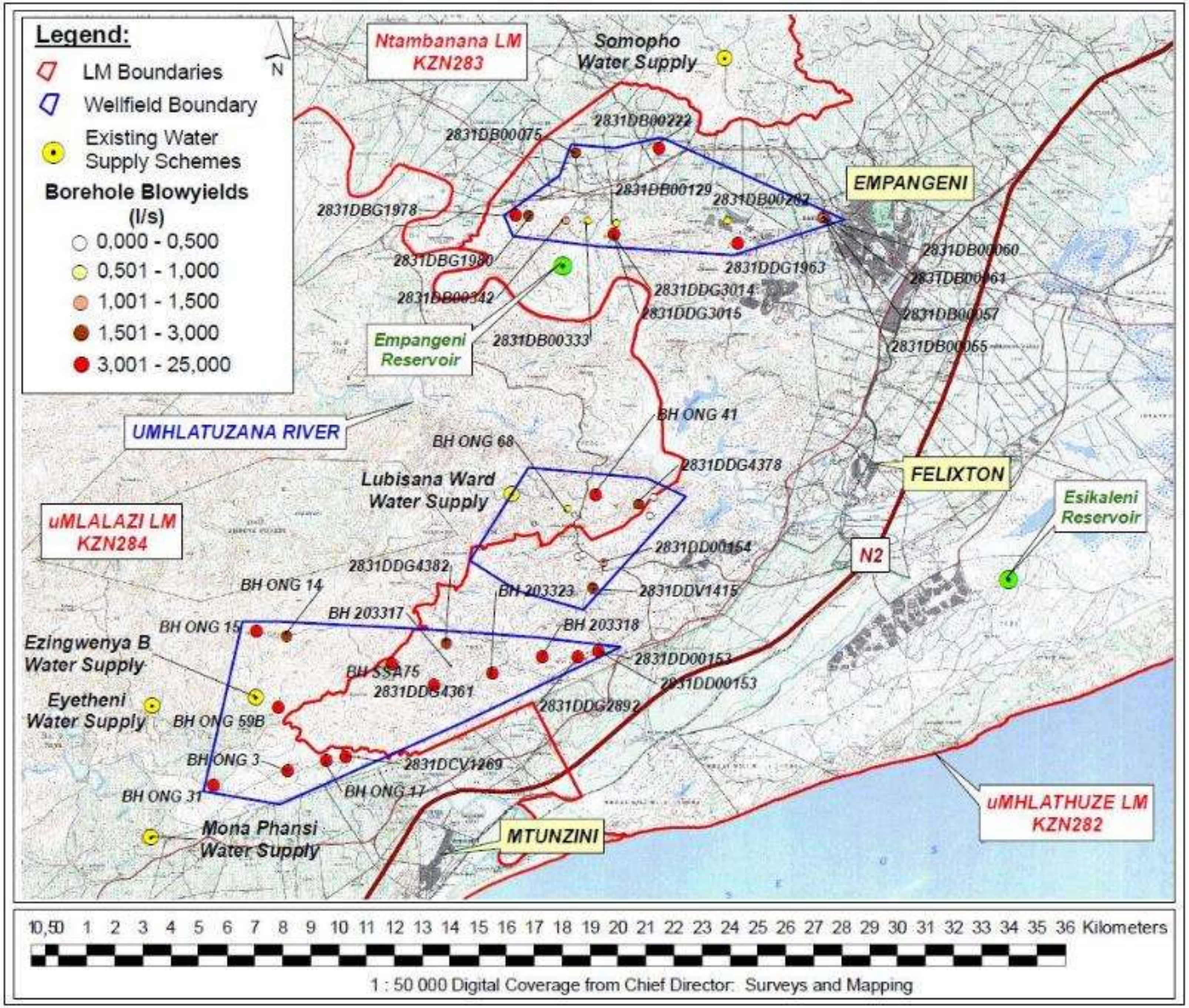

Figure 9-8: Locations of PW 1 – PW 3 in Relation to Existing Reservoirs

9.2.4 Unit Reference Value

The URVs for this option are based on the costing performed and on assumed average yields per borehole.

Table 9-4: URVs for Wellfield 1

ITEM	Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Total capital cost (R million)	26.7	26.7	26.7
Annual Cost (R million)	1.31	1.31	1.31
NPV Cost (R million)	57.56	52.35	48.35
NPV Supply (million m^3)	10.21	8.15	6.71
Unit Reference Value (R/m^3)	**5.64**	**6.42**	**7.21**

Table 9-5: URVs for Wellfield 2

ITEM	Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Total capital cost (R million)	15.5	15.5	15.5
Annual Cost (R million)	0.98	0.98	0.98
NPV Cost (R million)	34.08	30.57	27.95
NPV Supply (million m^3)	7.77	6.20	5.10
Unit Reference Value (R/m^3)	**4.39**	**4.93**	**5.48**

Table 9-6: URVs for Wellfield 3

ITEM	Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Total capital cost (R million)	19.4	19.4	19.4
Annual Cost (R million)	0.96	0.96	0.96
NPV Cost (R million)	40.57	36.85	34.01
NPV Supply (million m^3)	4.32	3.45	2.83
Unit Reference Value (R/m^3)	**9.40**	**10.69**	**12.00**

9.2.5 Ecological Impact

Ecological and environmental impacts associated with this type of scheme could occur during both the construction phase as well as the operational phase.

Impacts associated with the construction phase could include the destruction of vegetation and habitats of any small fauna living within the vegetation through which a drilling rig would be required to access.

The most important ecological and environmental impacts would occur during the operational phase, whereby the boreholes and aquifers are over pumped / over utilised which would result in the lowering of the groundwater table which would in turn impact on vegetation, as well as on natural springs and seeps which may dry up. The lowering of the groundwater table could also impact on wetlands and rivers, by reducing the baseflow which is provided by groundwater,

9.2.6 Social Impact

Social impacts possibly related to the groundwater intervention would also be related to the over-utilisation of the groundwater aquifers. The over-pumping would lead to the lowering of the groundwater table and depletion of the aquifer, which would result in boreholes of existing users being affected. The decrease in groundwater for domestic and commercial purposes would affect the existing users' lives and businesses.

The identified wellfields lie within heavily farmed areas with many rural low-density settlements. It may prove a challenge to get access to land, acquire land and to locate boreholes far enough away from settlements. Operation and maintenance may also prove challenging in this setting.

9.2.7 Findings

The respective strengths and weaknesses of groundwater development are as follows:

Strengths

- The clustering of production boreholes within the wellfields will assist in minimising abstraction from just one area.
- Existing bulk infrastructure is located within reasonable distances from the wellfields. New reticulation to feed into the municipal supply would not be too long.
- Newly installed production boreholes are usually more efficient than older boreholes and recent pump test data can be used to more-accurately determine safe, sustainable abstraction yields.
- Boreholes drilled into secondary weathered and fractured-rock aquifers are less susceptible to contamination as opposed to primary sand aquifers.
- Ecological impacts are limited to groundwater levels being lowered if the groundwater resource is over-utilised.
- Technology allows for electronic record keeping and automated systems to ensure the aquifers are not over-utilised.

Weaknesses

- Blow yields, which are not indicative of the true aquifer yields, have had to be used for yield estimations due to the lack of current and recommended abstraction rates data.
- No recent borehole data were available for the investigation.
- The viability of the existing boreholes is not known without having undertaken field visits
- Over-utilisation of boreholes and aquifers lower groundwater levels.

- Extremely limited data are available for the primary (unconsolidated sediment) aquifers.
- Access to land and acquiring land is expected to be a challenge.
- Operation and maintenance may be challenging as the wellfields would be located close to settlements.

10 REUSE OF TREATED EFFLUENT

10.1 Reference Documents

In the evaluation of this intervention as an option for the Richards Bay water supply area the following documents were used for reference:

- "*Feasibility Study for the Reuse of Effluent (waste water) in the City of uMhlathuze*" draft report, dated December 2014. This evaluation was undertaken by the CSIR for the City of uMhlathuze to determine the feasibility of using waste water from its two macerator stations Alton and Arboretum. The investigation *inter-alia* proposed beneficial use opportunities and methods of disposal of sludge and waste water. This intervention option is based to a very large extent on the recommendations made in this report.
- Letter from the City of uMhlathuze, dated 5 June 2014 to potential water users requesting their requirements for the uptake of treated waste water. The feedback from potential users to the municipality has not yet been obtained.

10.2 Scheme Layout

The preliminary recommended location (Figure 10-1) is where the emergency pond is currently located at the Arboretum macerator. A distinct advantage is that the proposed area is within the boundary of the pump station and is therefore on property that is owned by the municipality.

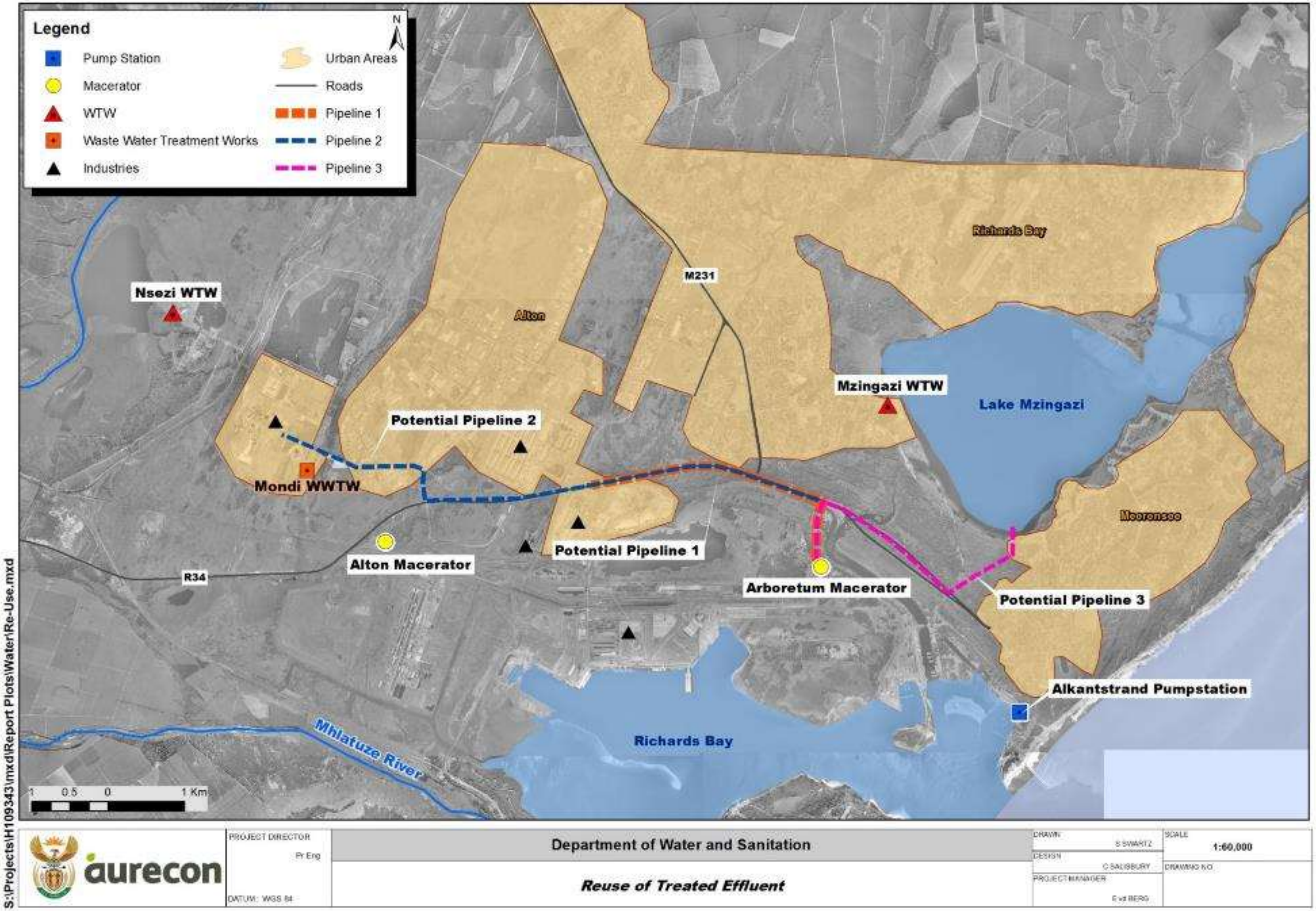

Figure 10-1: Proposed treatment works location and pipeline route

10.3 Scheme Description

10.3.1 Existing Richards Bay wastewater infrastructure

All industrial and domestic effluent from Richards Bay is pumped via Alkantstrand pump station (owned and operated by Mhlathuze Water) out to sea, thus there is no municipal WWTW in Richards Bay. Some elementary screening takes place beforehand at the Alton and Arboretum macerators (owned and operated by the municipality), but there is no further treatment beyond screening.

Sewage and waste water emanating from urban and industrial areas of Richards Bay are disposed of via the marine outfall-pumping scheme after screening at the Arboretum and the Alton Macerator Pump stations, and dilution of effluent with seawater. There are three sea-outfall pipelines from Alkantstrand, which extend more than 4km out to sea. The outfall discharge is approximately 140 Ml/d or 51 million m^3/a, which includes seawater that is added prior to discharge of effluent to the marine environment.

The Arboretum Macerator pump station receives predominantly domestic sewage from surrounding areas including the central business district of Richards Bay and the Alton Macerator pump station receives a combination of domestic and industrial waste water.

The preliminary treatment at both pump stations consists of a series of course and fine hand-raked screens to remove large objects such as rags, bottles, etc. Following the screens are the horizontal flow grit chambers which are alternated for the removal of sand, gravel and other inorganic material that may have passed through the screening process. The screenings and grit are disposed of by an external service provider (Wasteman). In previous years the two pump stations were each equipped with macerator/choppers before the screened sewage/waste water was pumped into the marine outfall sewer, but these macerators were subsequently removed. The screened waste water from the Alton Macerator Pump station combines with the screened sewage from the Arboretum Macerator Pump station before it is discharged into the marine outfall sewer.

10.3.2 Scheme description

The flow rate through the Arboretum pump stations is on average almost 12 Mℓ/d and the Alton pump station handles approximately 8 Mℓ of wastewater per day. The CSIR adopted a flow of 20Mℓ/d as the combined current flow through the two pump stations. The City of uMhlathuze Water Services Development Plan (WSDP) estimated that the combined flow at the two pump stations would increase by approximately 2 Mℓ/d by 2020 and 6 Mℓ/d by 2030.

The two pump stations are only designed for the pre-treatment (i.e. screening and grit removal) of the wastewater/sewage before it is discharged to the sea. Therefore in essence the effluent discharged is raw sewage or screened sewage/wastewater that require further treatment if it is to be considered for reuse.

Various options for reuse have been considered and the recommended option is to construct a regional wastewater treatment works at the Arboretum pump station that can accommodate both the existing and future load of the Arboretum and Alton pump stations. The flows from the Alton pump station already combine at the Arboretum pump station.

An activated sludge plant with a design capacity of about 30 Mℓ/d is proposed for the regional WWTW as this takes into account the existing and future loads projected for after 2030. The City of uMhlathuze could build this in a phased process as 2 modules, each treating 15 Mℓ/d.

A proper geotechnical investigation and topographical survey is required to determine the suitability of the Arboretum macerator site for such a facility, as well as an EIA and licencing process.

10.3.3 Indirect effluent reuse

Treated effluent could be discharged to Lake Mzingazi for indirect potable and industrial reuse. The inlet would need to be located sufficiently far away from the Mzingazi WTW intake works.

A pipeline of about 600 mm diameter of 2.5 km (CSIR estimation) would be required to convey the treated effluent to the lake. It is proposed to follow the same route as the potable water lines that supply the area.

10.3.4 Uptake by industrial users

The treated effluent could alternatively be utilised by bulk industry immediately surrounding the Arboretum macerator. Some potential industries to investigate re-use are listed below.

- RBIDZ
- Kynoch Fertilizer (Fermentech)
- Hillside Aluminium
- Foskor
- Shincel wood chips
- Transnet port authority

It will be necessary to determine what level of treatment these stakeholders require, however it is recommended that the municipality endeavours to meet (or exceed) requirements for disposal to surface water bodies. Industrial users located further away such as Mondi could also potentially also be considered.

The route of the conveyance pipeline of about 600 mm diameter would depend on the specific industrial users that will take up the treated effluent. It is assumed that the water would be conveyed to the edge of the industrial properties.

10.3.5 Biological nutrient removal process

The recommended components for the biological nutrient removal process include the following:

- A balancing tank that has sufficient storage to accommodate a peak flow of 2 to 3 times the Annual Average Daily Flow (AADF). The balancing tank can be included ahead of the reactor and its main function is to even out the organic and hydraulic load variations on the plant.
- Two primary settling tanks.
- Two bioreactors, each able to treat 15 Mℓ/d.
- Two secondary settling tanks.
- A chlorine contact chamber for disinfection.
- A sludge handling facility that comprises of digesters to stabilise the raw sludge from the primary settling tanks.
- Drying beds to dewater the digested sludge.

Brine could potentially be discharged into the ocean via the outfall pipelines. No changes have been allowed for in the current infrastructure to pump the wastewater to Alkantstrand.

Further investigation or engineering design is required to determine the sizes of various structures listed above and whether these structures would physically fit on the proposed site.

10.3.6 Process configuration

Various process configurations have been developed for the removal of nutrients, such as carbon, phosphorus and nitrogen. The reactor is divided into different zones that are either aerobic (free oxygen present), anaerobic (no forms of oxygen present) and anoxic (containing no free oxygen, only nitrates). The various systems in common use in South Africa are the Phoredox, Bardenpho, UCT and Johannesburg process configurations. The selection of these is dependent on the TKN/COD (Total Kjedahl Nitrogen/Chemical Oxygen Demand) ratio of the wastewater being treated.

10.4 Effluent Reuse Yield

The design capacity is 30 Mℓ/d (10.95 million m^3/a) to be developed in 2 modules, each treating 15 Mℓ/d (5.48 million m^3/a).

10.5 Unit Reference Value

Capital and operational and maintenance costs have been determined for the required infrastructure components to treat the effluent and to pump the effluent to either industrial users or to Lake Mzingazi. The costs are based on an assumed treated volume of 30 Mℓ/day. Escalation has been excluded and all costs are present day values (2014). Membrane life for the MBR system has been assumed to be 7 years.

The URVs (Table 10-1) includes the WWTW, pump station, pipeline and operating capital and operating costs. Provision for infrastructure to dispose of the brine has been excluded as it has been assumed that brine could be pumped to the Alkantstrand pump station for disposal to sea utilising existing infrastructure.

The effluent that will be treated under this scheme would otherwise have to be pumped out to sea, and the cost saving is taken into account below, although the actual cost is relatively small (less than R 500 000/a).

The unit cost is quite high, which is explained by the fact that a full WWTW needs to be constructed as part of the reuse infrastructure.

For the surface and groundwater options, water treatment costs have been excluded in the URV calculations. This resulted in a reduced URV of between 20% and 30% for those options. An equivalent saving is therefore applicable to the reuse URVs as no further water treatment process is applicable. The total URV of the reuse process (which is assumed to supply water to approximately potable standard) was therefore reduced by R1.50/m^3 to bring the treated effluent to a raw water basis.

Table 10-1: URVs for Reuse of Treated Effluent Option

ITEM		Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Total capital cost	**(R million)**	569	569	569
Annual operating cost	**(R million/annum)**	34.2	34.2	34.2
NPV Cost	**(R million)**	1177.4	968.7	861.1
Unit Reference Value *No adjustment for treatment saving*	**(R/m^3)**	7.92	8.47	9.15
Unit Reference Value *Adjusted for treatment and pumping saving*	**(R/m^3)**	6.42	6.97	7.65

10.6 Ecological Impact

The proposed site is located on previously-developed land that is owned by the municipality. Furthermore, the proposed pipeline/s would be routed adjacent to existing pipeline, road and rail reserves in areas that are already disturbed. This would reduce the extent of new areas of disturbance.

The reuse of sewage effluent has a positive ecological impact as it delays the development of other sources that may impact on the environment.

The removal of sludge will impact on landfill areas. The continued use of the sea outfall pipelines to dispose of some brine will limit new impacts associated with the scheme.

One of the concerns with discharging treated wastewater effluent into Lake Mzingazi is nutrient enrichment. Domestic wastewater effluent is rich in nutrients (phosphates and nitrates). When discharged to a lake with low nutrient concentrations and high water clarity, these nutrients would stimulate the growth of phytoplankton (free-floating algae). If the nutrients load being discharged to the lake is sufficiently high, it could stimulate the proliferation of blue-green algae. These are responsible for taste and odour problems in treated potable water and can under certain circumstances produce algal toxins that could be harmful to consumers.

Other problems associated with eutrophication include unsightly algal blooms that affect the recreational and aesthetic appeal of the lake, wide fluctuations in dissolved oxygen concentrations of the water creating stress for biota, and a change in the fish species composition. To prevent enrichment of the lake with nutrients and the development of eutrophication problems in Lake Mzingazi stringent nutrient standards may be required to be met at the proposed regional WWTW. This may be quite costly and may make direct re-use for non-potable purposes a more attractive option.

Further concerns associated with direct or indirect re-use of treated domestic wastewater are the presence of endocrine disrupting chemicals (EDCs) and partially metabolised pharmaceuticals. These compounds are generally not removed during the wastewater treatment process and can interfere with the endocrine systems of aquatic biota and humans. EDCs can originate from the breakdown products of pesticides, plastics, phytoestrogens and synthetic and natural hormones.

10.7 Socio-Economic Impact

The assumption is made that the discharge into the catchment would be a permissible water use in terms of the Water Act and in addition, that this practice would be socially acceptable for the affected and interested parties. Especially indirect potable reuse has the potential to trigger opposition from the public.

Additional water provided by this scheme would contribute to the development of Richards Bay. In addition, this water resource is not dependent on rainfall, providing the Municipality with a strategic advantage.

Visual impacts associated with the development would be minimal since the plant would be located opposite an existing industrial area. Furthermore, the plant would not release odours or gases that could be a nuisance or have any other negative social impacts on the public

10.8 Findings

Possible positive impacts of this system include:

- Utilisation of a potential water source previously “lost” by being discharged into the sea at Alkantstrand;
- Reduced demand on natural resources by industrial users;

- Augmentation of the Municipality's potable water resources through a source capable of producing a constant reliable output, influenced to a limited extent by drought cycles, as water demand is expected to slightly decrease when water restrictions are implemented.

Possible negative impacts include:

- High concentrations of reject water/brine disposal into the sea;
- Impacts related to the construction of the scheme;
- Institutional implications regarding the operation and maintenance of the WWTW/ reclamation plant;
- A large component of the project requires the importation of specialist equipment. The cost of equipment is thus dependent on the Rand exchange rate.

11 SEAWATER DESALINATION

11.1 References

In the evaluation of this intervention as an option for the Richards Bay water supply area the following documents and sources were used as reference:

- *Nelson Mandela Bay Municipality Desalination Plant Feasibility Study*, 2013. The study was undertaken to identify the most suitable location for the proposed 60 Ml/day desalination plant and to undertake the preliminary design.
- Algoa Reconciliation Strategy Study, 2011. A desalination plant of 100 Mℓ/d (36.5 million m^3/a) was evaluated by the DWS, situated in the Coega Industrial Development Zone.
- *Desalination Engineer: Planning and Design*, USA Voutchkov/McGraw Hill, 2013.
- *Desalination*. Crisp, 2005. University of Western Australia.
- *A Desalination Guide for South African Municipal Engineers*, South Africa, 2006. Department of Water Affairs and Forestry and Water Research Commission.

11.2 Scheme Layout

The identification of available and appropriate land is essential to the planning of a desalination plant. The size of the site depends on the capacity of the desalination plant and the method of desalination to be implemented. For the purpose of the study an approximate area of 2.5 ha was considered for the plant footprint.

The initial identification and screening of potential locations for the proposed desalination plant should be based primarily on the exclusion of sensitive areas and identified existing and planned built up land use areas. Opportunities to utilize existing brown fields sites situated within the existing or planned development areas should however also be considered.

The location and layout of the scheme is shown in Figure 11-1.

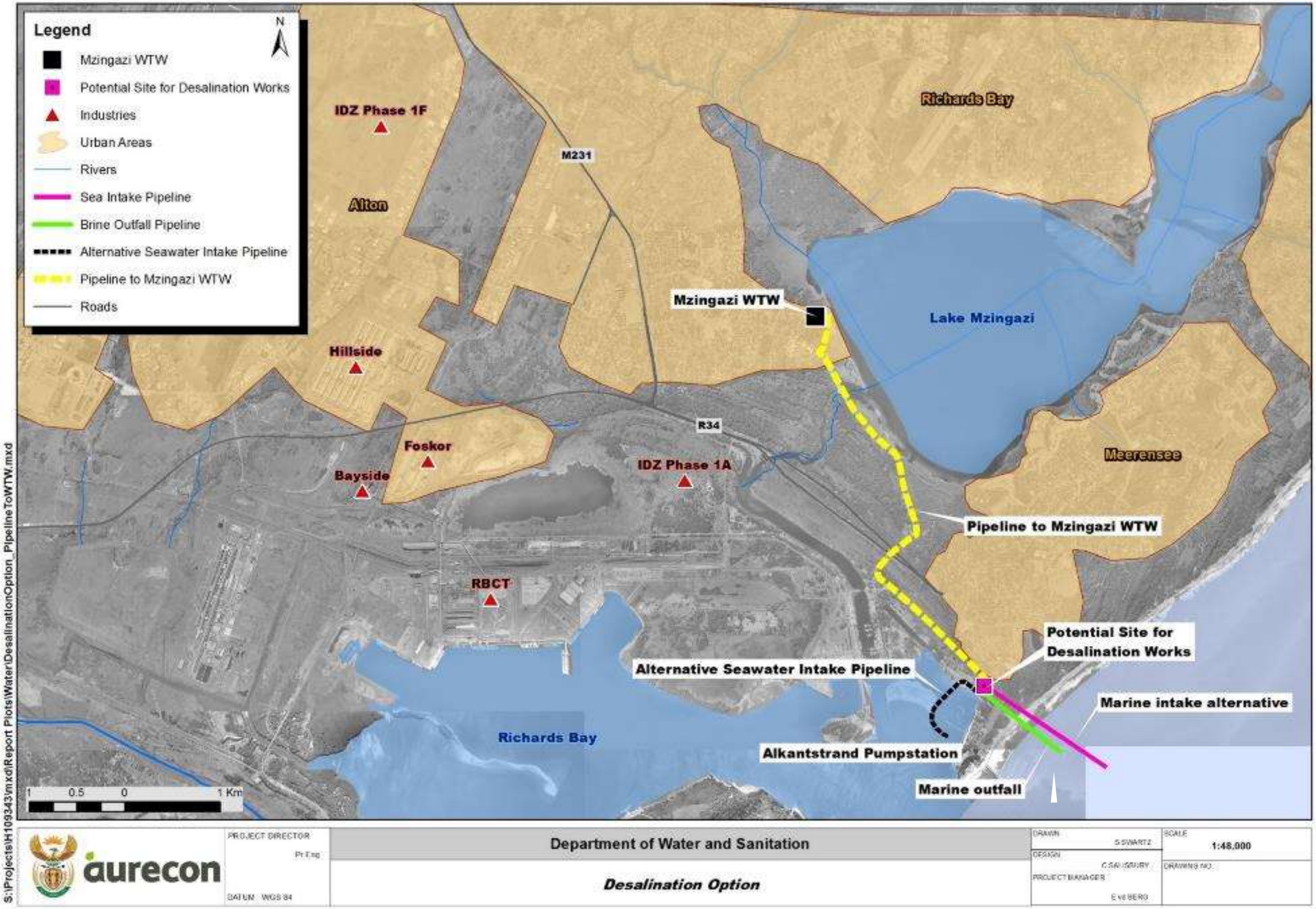

Figure 11-1: Layout of Desalination Option Infrastructure

11.3 Scheme Description

11.3.1 Selection of desalination technology

Reverse Osmosis (RO) is currently the most widely implemented desalination process globally. RO technology has been applied in over 90% of the municipal desalination plants built over the past two decades (Voutchkov) and RO is the recommended desalination process.

The costs of operating RO plants have been lowered by two significant developments over the past decade: (1) the development of membranes that can operate under lower pressures, and (2) the incorporation of an energy recovery device in the brine stream leaving the pressure vessel.

Membrane desalination is based on the ability of semi-permeable membranes to separate mineral salts and water by allowing the selective migration of water (but almost no salts) from one side of the membrane to the other side.

The preferred technologies and final process configurations chosen for the plant components are informed by the preferred site location.

11.3.2 Desalination Scheme

The components of the desalination plant include the following:

- The **marine intake** (intake structure, pipeline, pump station and energy requirements);
- The **desalination plant** (including pre-treatment, post-treatment, energy requirements, chemicals, labour and maintenance requirements);
- The **brine outfall** pipeline (operating under gravity);
- The **produce water delivery system** (including pipeline, pump stations and reservoirs required to deliver the product water to the point of distribution);
- **Additional costs** (including land acquisition, extending the power supply lines and constructing access roads).

The marine intake and desalination plant are the two most significant components.

The **marine intake** consists of a seawater collection structure, an intake pipeline, intake screens and an intake pump station. It has been assumed that the spare capacity in the current sea outfall pipelines is too limited to try and make use of the existing sea outfall pipelines. The preferred marine option is based on the expected conditions of the near shore environment and whether micro-tunnelling would be required. The most suitable marine intake structure to use must be assessed on a site specific basis. This could be an underwater open ocean intake using either an intake tower or wedge-wire screens depending on the presence of undersea currents. In this case however, the proximity of the harbour may offer a significant advantage to limit the marine intake costs. Allowance has to be made for adequate water depth for the Richards Bay harbour traffic zone.

Seawater will be pumped (harbour intake) from an onshore bulk head to the proposed RO plant site.

For the harbour intake the intake was costed assuming a pipe intake length of 1000 m and a brine pipe length of 500m (1000m total) from the shore out to sea. This would need to be revisited.

For a sea intake *alternative* the intake was costed assuming a pipe intake length of 1000 m from the shore (1500m total) and a brine pipe length of 500m (1000m total) from the shore via a 1.0m dia. pipeline to the proposed RO plant site. This would need to be revisited. Installation of two sea intake pipelines should be considered to allow for maintenance and cleaning without interrupting the supply. The most probable intake system will be an underground collector pipe system installed by directional drilling, a more capital intensive intake than open sea intakes, but far more environmentally acceptable and thus to be approved with less environmental mitigation factors and probably in a shorter EIA timeframe.

For successful desalination one or two stage **pre-treatment** may be required to handle the suspended solids, chlorophyll and other contaminants prior to desalination. The extent of pre-treatment will depend on the source water quality and the type of desalination technology being used. Source water quality would need to be established by monitoring over an adequate period. Like most process systems, desalination plants operate most efficiently and predictably when feed water characteristics remain relatively constant and are not subject to rapid or dramatic water quality fluctuations. Some factors that may influence the turbidity and the presence of colloidal, organic and biological matter include: sea currents, the presence of marine life, human activity, effluent outfalls, the presence of estuaries and river deltas, the traffic path of tankers and cargo ships, and the likelihood of algal blooms (Du Plessis et al, 2006).

The **desalination process** is used to separate the saline feed water from the fresh product water.

Post-treatment is generally required after desalination to stabilize and disinfect the water in order to ensure it meets the required quality standards of the intended users. Water will be lime stabilised at the RO site before being pumped via a 4.8km x 0.8m dia pipeline to the Mzingazi WTW site, where it may be blended with water supplied from the lake.

Typically, a desalination plant **waste discharge system** is required to discharge (1) brine concentrate, (2) used filter backwash water from pre-treatment processes, (3) used chemicals and cleaning water containing chemicals from routine membrane cleaning, (4) DAF sludge if a DAF clarifier is used in pre-treatment, and (5) sludge from the lime clarifiers. Debris collected on the intake screens can also be moved to the deck level where it is conveyed to collection bins and disposed as solid waste or is recycled back to the source water body. It is important that the waste streams are released in an environmentally safe and controlled manner. Brine concentrate makes up the largest volume of discharged waste and also holds the greatest potential risk to the environment. If a downstream user for the brine discharge cannot be found, then the brine stream will be discharged into the ocean, via a sea outfall sewer sea discharge pipeline.

An underwater pipeline with brine diffusers is recommended, but a surface or shallow water discharge directly into the surf zone could be considered, given the high energy and dynamic nature of most of the coastline. Diluting the brine with effluent from a waste water treatment works should also be considered. It is recommended that the synergy between this option and the Alkantstand Pump Station be further interrogated. The waste discharge system will require modelling of the potential brine dispersal plume and consideration of neutral buoyancy.

It has been assumed that the **energy supply** could be provided as the pump station and RO plant would be situated within the electricity supply area of the municipality in a heavily industrialised area. The cost of extending power supply lines as well as the potential need for a new substation was considered.

An **energy recovery system** is an efficient way of minimising the energy requirements of a plant and hence overall operational costs. The use of various renewable energy types to supplement energy supply from the grid may also be viable. Energy costs are likely to be significant given the potential future ESKOM price increases of up to 16% annually over the next 5 years. Therefore, special attention should be given to the design of an efficient energy system and energy recovery system. The potential for a cogeneration plant should be investigated. The potential use of cooling water from a nearby industrial development, and the association with a renewable energy (wind or wave) plant must also not be overlooked. Integration with renewable energy sources could have a positive impact on carbon credits for the desalination plant.

To reduce the risks associated with a sudden break in electrical supply, such as membrane damage due to water hammer, consideration should be given to the installation of a **backup energy supply** in the form of strategically located generators and double supply lines from different substations.

Product delivery is the final step in the desalination process. Once the saline water has been collected by the marine intake, pre-treated, desalinated and post-treated, it is ready for delivery to the intended users. The product water is pumped to an elevated reservoir from where the product water is gravity fed through the bulk water distribution system. It is important to consider delivery costs when choosing an appropriate site for the plant as this aspect of desalination could have a large influence on the overall cost. The product water will need to meet various criteria for potable water. The criteria for potable water in South Africa are defined in SANS 241 of 2005: Drinking Water Quality Management Guide for Water Services Authorities.

There may be an added benefit in utilising potable water from RO, as the blending of this water with water supplied from Lake Mzingazi would likely improve the final water quality supplied to end users.

11.4 Yield

Seawater could yield a limitless volume. The water demand versus available sources at the time of implementation will determine the yield of the scheme to be developed. For the purposes of this assessment, a treated water output of 60 Ml/d (21.9 million m^3/a) was considered to be comparable with some of the other potential interventions. Phased development would be considered.

11.5 Unit Reference Value

Economics of scale dictates that the larger the plant the lower the unit cost of the water produced. It is estimated that the overall cost of water production through desalination reduce further in the future.

Comparative cost estimates for the different options were developed based on the conceptual design considerations. Capital and operational and maintenance costs have been determined, to a large extent using costs developed in the Nelson Mandela Bay Municipality Desalination Plant Feasibility Study for a similar sized plant. Such costs were inflated to take into account inflation and the change in the R/$ exchange rate.

It was assumed that the plant would be constructed in two 30 Mℓ/d phases. These are shown in Table 11-1 and Table 11-2 along with the URVs.

Table 11-1: URVs for the Desalination Option: Marine Intake

ITEM		Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Total capital cost	**(R million)**	2243.7	2243.7	2243.7
Annual operating cost	**(R million/annum)**	56.47	56.47	56.47
NPV Cost	**(R million)**	2600.87	2383.07	2217.81
Unit Reference Value *No adjustment for treatment saving*	**(R/m^3)**	8.60	9.97	11.40
Unit Reference Value *Adjusted for treatment saving*	**(R/m^3)**	**7.10**	**8.47**	**9.90**

Table 11-2: URVs for the Desalination Option: Harbour Intake

ITEM		Discount Rate 6%	Discount Rate 8%	Discount Rate 10%
Total capital cost	**(R million)**	2089.71	2089.71	2089.71
Annual operating cost	**(R million/annum)**	42.28	42.28	42.28
NPV Cost	**(R million)**	2403.38	2226.61	2090.13
Unit Reference Value *No adjustment for treatment saving*	**(R/m³)**	7.95	9.32	10.74
Unit Reference Value *Adjusted for treatment saving*	**(R/m³)**	**6.45**	**7.82**	**9.24**

Note that the URVs exclude escalation and any income stream for utilisation of the brine stream by others. The URV includes operating costs including conveyance to the Mzingazi WTW and including balancing storage at the same site.

For the surface and groundwater options, water treatment costs have been excluded in the URV calculations. This resulted in a reduced URV of between 20% and 30% for those options. An equivalent saving is therefore applicable to desalination as no further water treatment process is applicable. The total URV of desalination (which is assumed to supply water to approximately potable standard) was therefore reduced by R1.50/m^3 to bring the desalinated water to a raw water basis.

11.6 Ecological Impact

There are numerous environmental impacts that need to be carefully considered during the implementation of a desalination plant (Crisp, 2005). Some of the main aspects that require attention are: the construction process, the energy requirements, the intake process, the discharge process and inland sited plants.

Desalination plants are known for their large energy requirement and should be designed to minimise energy consumption. Impacts associated with the production of additional energy for a desalination plant are:

- Cumulative secondary environmental impacts associated with the development of power stations for electricity generation. These impacts are not borne by the beneficiaries of the water, but are concentrated in the areas of abundant coal resources, giving rise to equitability issues.

The intake process can cause harmful environmental effects in the following ways:

- Constructing the intake by means of drilling, dredging or excavating can disturb the natural sands and bedrock and thus the habitat of various species;
- Operation can lead to impingement and entrainment of marine species if not designed adequately.

Desalination plants need to discharge waste streams and this can also lead to adverse environmental impacts if not designed carefully, as the waste stream often contains harmful contaminants

Diluting the discharge stream with sewage treatment plant discharges or power plant cooling water discharges may reduce the negative environmental impacts of the desalination waste streams.

Pipeline routes should as far as possible follow roads or existing pipeline servitudes to minimise construction impacts.

11.7 Socio-Economic Impact

Additional water provided by this scheme would contribute to the development of Richards Bay. In addition, this water resource is not dependent on rainfall, providing the Municipality with a strategic advantage.

The disruption that the scheme could cause to the coastline in the view of the public should be minimised. The intake pump station on the coast should have minimal visible impact. While a specific site for the desalination plant has not yet been determined, the social impacts would be limited if the site was located in an industrially zoned area that would go mostly unnoticed to the general public.

The high capital and operating cost would likely lead to increased water tariffs, depending on the extent to which the capital costs are subsidised. The very high operational cost would likely also lead to an operational practice where the desalination plant is utilised for less than 5% of the time, i.e. a significantly underused, yet strategically important asset.

11.8 Findings

Possible positive impacts of this system include:

- Utilisation of a potential previously unused water source;
- It provides a 100% reliable source of water that is not subject to climate variability or changes in allocation policies as with other surface water sources.
- It is not subject to the impacts of droughts or restrictions.
- It is not subject to water quality concerns particular from emerging contaminants or social concerns with the use of treated effluent.
- The operator will have complete control of the supply from the desalination plant.
- Reduced demand on natural resources.

Possible negative impacts include:

- Very high energy requirements.
- High capital and operating costs.
- High concentrations of reject water/brine disposal into the sea.
- Impacts related to the construction of the scheme.
- Specialist skills required to operate the desalination plant.
- Institutional implications regarding the operation and maintenance of the desalination plant.

A large component of the project requires the importation of specialist equipment. The cost of equipment is thus dependent on the Rand exchange rate.

12 SUMMARY OF EVALUATED INTERVENTIONS

12.1 Preliminary Implementation Programmes

The preliminary implementation programmes, as shown in Table 12-1 on the following page, are notably dependent on the implementing organisation.

The implementation of interventions such as WC/WDM, rainwater harvesting, local groundwater schemes, effluent reuse and desalination would typically be the responsibility of the City of uMhlathuze. Implementation decisions could potentially be quickly taken, although this would likely be dependent on the availability of funds for implementation.

Bulk schemes that have a regional nature will be used by various water supply sectors or have a strong Reserve-related component are typically the domain of the DWS, and may also typically take longer to implement.

The implementation programmes presented here are preliminary, and can be adjusted to suit actual circumstances. Project implementation could further be fast-tracked, if circumstances require it.

Table 12-1: Preliminary Implementation Programmes (years)

INTERVENTION	Pre-Feasibility	Feasibility			Implementation / Construction							TOTAL Time to develop yield	
		Budget/ TOR / Appoint Consultant	Feasibility Study/ EIA/ Monitoring	DWS Reserve determination	Budget/ TOR / Appoint Consultant	DWS licensing process (incl Reserve)	DEA&DP approval process	Design / tender preparation & award	Construct /Implement/Council Bylaw	Warm up / first filling			
			Simultaneous	Simultaneous		Simultaneous	Simultaneous			Start	End	Start	End
Bulk industrial WC/WDM								1	4	0	5	0	5
Urban WC/WDM								1	9	0	10	0	10
Rainwater harvesting									1				1
Sustainable supply from coastal lakes		1	3	2					0.5				4.5
Increased capacity of the Thukela-Mhlathuze Transfer Scheme Ph 1		1	2	1	0.75	0.5	1.5	1.5	2				8.75
Increased capacity of the Thukela-Mhlathuze Transfer Scheme Ph 2		1	1.5	1	0.75	1	1.5	1.5	2.5				8.75
Thukela-Mhlathuze Transfer Scheme Ph 1 + Ph 2		1	2.5	1	0.75	1	1.5	2	3				10.75
Increased capacity of the Thukela-Mhlathuze Transfer Scheme Ph 3		1	1	1	0.75	1.5	1.5	1	2.5				7.75
Coastal pipeline from the lower Thukela River (20Mm^3/a))		1	1.75	1	0.75	0.5	1.5	1.5	2				8.5
Coastal pipeline from the lower Thukela River (40Mm^3/a)		1	1.75	1	0.75	1.5	1.5	2	2				9
Mfolozi River on-channel transfer scheme: Kwesibomvu Dam		1	2	2	0.75	1.5	1.5	2	3	0	1	9.25	10.25
Mfolozi River off-channel transfer scheme		1	1.75	1.75	0.75	1.5	1.5	2	2.5	0	1	8.5	9.5
Raising Goedertrouw Dam		1	0.5	0	0.75	0.5	0.5	0.5	1.25				4.5
Dam on the Nseleni River		1	1.5	1.5	0.75	1.5	1.5	1.5	2.25	0	1	7.5	8.5
Groundwater scheme	0.75	0.75	1.5	1	0.75	1.5	1.5	2	1.25				8.5
Arboretum Effluent Reuse Scheme		0.75	0.75	0	0.75	1	1.5	1	1.75				6.5
Desalination of seawater Ph 1		0.75	2	0	0.75	1	1.5	1	1.75				7.75
Desalination of seawater, Ph 2 & further phases		0.75	1	0	0.75	1	1	0.75	1.5				5.75
Desalination of seawater double size Ph 1		0.75	2	0	0.75	1	1.5	1.25	2.25				8.5
Desalination of seawater, double size, Ph 2 & further phases		0.75	1	0	0.75	1	1	1	2.5				7
Thukela-Mhlathuze Transfer Scheme Ph 1 Fast Track		0.25	1.25	1	0.25	1	1	1.25	2				6
Coastal pipeline from the lower Thukela River (20Mm^3/a) Fast Track		0.25	1	1	0.25	0.5	0.75	1	1.75				5
Mfolozi River off-channel transfer scheme Fast Track		0.75	1.25	1.25	0.5	1	1	1.5	2	0	1	6	7
Desalination of seawater Ph 1 Fast Track		0.5	1.5	0	0.25	1	1	0.75	1.5				5.5
Desalination of seawater Ph 1 + Ph 2 Fast Track		0.5	1.5	0	0.25	1	1	1	1.75				6

12.2 Summary of intervention features

The key features of the evaluated interventions are documented in Table 12-2 on the following page and scheme locations are shown in Figure 12-1.

The following aspects are shown:

- Intervention name,
- Intervention variation – several intervention variations have been tested in some cases, although this has been limited by the extent and nature of this study,
- Intervention description: A succinct explanation of the intervention,
- Yield: HFY or assumed scheme yields are shown for previous evaluations or assumed scheme sizes. These have been shown in both million m^3/a and Mℓ/d,
- Capital cost: This shows a scheme capital costs in R million or a range of costs in some cases,
- URV, being a particularly useful indicator to compare bulk water schemes over their lifetimes,
- Identifiable significant environmental and socio-economic impacts and an indication to what extent these can be mitigated or may potentially limit the development of a scheme,
- Preliminary implementation programme in years.

Of particular interest is that there are a number of interventions that provide limited yield. While these schemes should be considered to improve the water balance, they would not provide the significant increase in yield needed over the longer term. These interventions include:

- Bulk industrial WC/WDM (2.8 million m^3/a yield),
- Urban WC/WDM (4 million m^3/a yield),
- Rainwater harvesting (up to 200kl/a per household),
- Sustainable supply from over-abstracted coastal lakes (potentially negative yield),
- Raising Goedertrouw Dam (3.9 million m^3/a yield),
- Dam on the Nseleni River (6.1 million m^3/a yield),
- Groundwater schemes (1.55 million m^3/a yield),
- Arboretum Effluent Reuse Scheme (11.0 million m^3/a yield).

Then there are the schemes that can significantly increase the yield of the WSS, these being:

- Increased capacity of the Thukela-Mhlathuze Transfer Scheme (up to 236.5 million m^3/a yield), but dependent on the future availability of water from the Thukela River at a feasible cost, which would likely be a limiting factor,
- Coastal pipeline from the lower Thukela River (15.0 or 35.0 (long-term only)) million m^3/a yield), taking into account 5 million m^3/a water to be supplied to small coastal towns and communities.
- On-channel transfer scheme/s from the Mfolozi River: Kwesibomvu Dam (46.6 million m^3/a yield), taking into account water to be supplied to the Mtubatuba WSS and surrounding areas.
- Off-channel transfer scheme/s from the Mfolozi River (36.9 million m^3/a yield), taking into account water to be supplied to the Mtubatuba WSS and surrounding areas.
- Desalination of seawater (virtually unlimited).

Table 12-2: Summary Interventions Table

Intervention	Variation	Intervention description	Yield (million m^3/a)	Yield (Mℓ/d)	Capital cost (R million)	URV (8% discount rate)	Environmental and socio-economic impacts	Implementation programme (years)
Bulk industrial WC/WDM	-	WC/WDM applicable to bulk industrial water users, of which Mondi, RBM, Tronox and Foskor accounts for 96%.	2.8	7.7	*Range of costs*	*Range of URVs*	Minimal. Specific to type of WC/WDM	5
Urban WC/WDM	-	WC/WDM applicable to the urban water supply sector (supplied by the City of Mhlathuze) that includes Richards Bay, Empangeni, eSikhaleni, Nseleni and Ngwelezane as well as Uthungulu DM.	4.0	11.0	*Range of costs*	*Range of URVs*	Minimal. Specific to type of WC/WDM	10
Rainwater harvesting	*Non-potable conjunctive uses (garden and flushing toilets) investigated. Yields and costs dependent on a variety of factors, including roof area, tank size and target drawdown volume.*	This is the collection and storage of rainwater for commercial, industrial or domestic use. The focus is on the harvesting of rainwater from roofs for outdoor and indoor non-potable domestic uses	*Up to 200kl/a per household*	-	*R5,000 – R28,000*	*Minimum of R11.04/kl*	Limited. Main concern is that water need to be treated for potable use.	1
Sustainable supply from coastal lakes	*Increase abstraction levels to 50% of the difference between drought maintenance levels (current operation) and management maintenance levels*	This involves the determination of groundwater contributions to lake yields at an acceptable confidence, and revising of the operating rules of abstraction to ensure a sustainable supply from the three coastal lakes of the WSS, Lakes Mzingazi, Cubhu and Nhlabane.	-4.3	-11.8	0	0	Positive environmental impacts. Associated impacts of replacing yield from alternative sources.	4.5
	Increase abstraction levels to management maintenance levels from drought maintenance levels (current operation)		-9.9	-27.1	0	0		4.5
Increased capacity of the Thukela-Mhlatuze Transfer Scheme	**To augment to a final volume of 2.7m³/s**	Increased transfer of water from a weir in the Thukela River at Middledrift to a Mhlatuze River tributary that drains to Goedertrouw Dam. Development has been evaluated for 1, 2 or 3 phases of increased transfers for a variety of infrastructure combinations. Given here are the costs for augmenting the system to 2.7m³/s, 5.7m³/s and 8.7m³/s respectively with the tunnel being included, as it was cheaper in all cases than the corresponding scheme with the pipeline instead. For the options involving multiple phases, the capital cost of each phase is given as well as the sum of those capital costs. The incremental yield is given – i.e. not including the existing 1.2m³/s (37.8 million m^3/a) transfer capacity.	**47.3**	**129.6**	**842.39**	**6.43**	Moderate. Generic impacts of inter-basin transfer of water, pipeline construction etc. Weir construction impacts. Pipelines will traverse environmentally sensitive areas, but will follow existing servitude. Options involving tunnel have lower environmental impacts. Outfall into small rivers can cause erosion - mitigatable Increased availability of water to local communities.	8.75
	To augment to a final volume of 5.7m³/s		**141.9**	**388.8**	**2432.29**	**6.72**		10.75
	First phase (augmentation to 2.7m³/s) - incremental		47.3	129.6	1032.51	6.56		8.75
	Second phase (augmentation to 5.7m³/s) - incremental		94.6	259.2	1417.67	4.74		8.75
	To augment to a final volume of 8.7m³/s		**236.5**	**647.9**	**3423.98**	**8.28**		-
	First phase (augmentation to 2.7m³/s) - incremental		47.3	129.6	1225.14	7.07		8.75
	Second phase (augmentation to 5.7m³/s) - incremental		94.6	259.2	1427.99	4.76		8.75
	Third phase (augmentation to 8.7m³/s) - incremental		94.6	259.2	787.90	3.92		7.75
Coastal pipeline from the lower Thukela River	*Raw water pipeline*	This involves shared use of the bulk water abstraction and treatment infrastructure developed in the lower Thukela River at Mandini by Umgeni Water to transfer water to Richards Bay and to supply coastal communities along the way. The pipeline would terminate at the Mhlatuze River, a short distance upstream of the weir. Options of 20 million m^3/a and 40 million m^3/a transfers were investigated, of which 5 million m^3/a would be supplied to coastal communities, and 15 million m^3/a and 35 million m^3/a respectively to the Richards Bay WSS.	20.0	55	522.84	4.39	Limited to moderate. Pipelines follow existing railway and road servitudes. Outfall of raw water option is into a large river (Mhlatuze), hence limited erosion potential. Use existing infrastructure at abstraction point.	20 Mm³/a: 8.5 40 Mm³/a: 9
			40.0	110	1014.25	4.96		
	Clear water pipeline	Similar to the raw water pipeline except that the pipeline would continue further north to reach the Nsezi WTW, from where it would be distributed to users of treated water. Options of 20 million m^3/a and 40 million m^3/a transfers were investigated.	20.0	55	584.05	4.28		
			40.0	110	1055.45	5.23		
	Raw Water utilising the Tronox pipeline to Fairbreeze mine	Similar to the previous options except that the pipeline currently being constructed to bring water from the Mhlatuze River to the Fairbreeze mine would be used for that part of the route. Only 40 million m^3/a transfer was investigated, taking into account the requirement of the Tronox mines.	40.0	110	1209.47	4.58		
On-channel transfer scheme/s from the Mfolozi River: Kwesibomvu Dam	*26m high (144 million m³ capacity) , 17% MAR dam – pipeline to Nseleni River*	The Kwesibomvu Dam is an on-channel earthfill dam on the Mfolozi River about 7 km upstream of the N2 road bridge that would transfer water to Nsezi WTW and provide a regional water supply to Mtubatuba and other small towns.	66.6	182.5	1764.79	3.52	Significant. Inundation of land, including several pans and social infrastructure. Obstruction of water-course affecting movement of sediment, aquatic species and modification of downstream flow regime.	10.25
	26m high(144 million m³ capacity) , 17% MAR dam – pipeline to Nsezi WTW		66.6	182.5	2272.82	4.21		
	36m high (265 million m³ capacity) , 31% MAR dam– pipeline to Nseleni River		137.3	376.2	2271.29	3.70		-

Intervention	Variation	Intervention description	Yield		Capital cost (R million)	URV (8% discount rate)	Environmental and socio-economic impacts	Implementation programme (years)
			(million m^3/a)	(Mℓ/d)				
	36m high (265 million m^3 capacity) , 31% MAR dam – pipeline to Nsezi WTW		137.3	376.2	2880.56	4.26	Prohibitive, inclusive of flooding of lower portions of the Hluhluwe-iMfolozi Park which probably rules out the scheme.	
Off-channel transfer scheme/s from the Mfolozi River	*2 m^3/s diversion, 28m high, 30 million m^3 dam, pipeline to Nseleni River*	This involves pumping from a weir in the Mfolozi River about 4 km upstream of the Kwesibomvu Dam site to an off-channel earthfill dam at the Nkatha Pan. The scheme could transfer water to Nsezi WTW and provide a regional water supply of 20 million m^3/a to Mtubatuba and other small towns. Different rates of pumping from the Mfolozi River to the dam were investigated, as well as different storage capacities.	33	90.4	941.51	5.36	Moderate to significant. Inundation of one pan (Nkatha Pan).	9.5
	2 m^3/s diversion, 28m high, 30 million m^3 dam, pipeline to Nsezi WTW		33	90.4	1299.40	6.32		
	2 m^3/s diversion, 38m high, 63.2 million m^3 dam, pipeline to Nseleni River		47.1	129.0	1152.79	4.56		
	2 m^3/s diversion, 38m high, 63.2 million m^3 dam, pipeline to Nsezi WTW		47.1	129.0	1565.13	5.36		
	2.5 m^3/s diversion, 32m high, 39 million m^3 dam, pipeline to Nseleni River		40.8	111.8	1131.30	5.97		
	2.5 m^3/s diversion, 32m high, 39 million m^3 dam, pipeline to Nsezi WTW		40.8	111.8	1551.95	6.99		
	2.5 m^3/s diversion, 42m high, 78 million m^3 dam, pipeline to Nseleni River		56.9	155.9	1235.75	5.20		
	2.5 m^3/s diversion, 42m high, 78 million m^3 dam, pipeline to Nsezi WTW		56.9	155.9	1601.93	5.87		
Raising Goedertrouw Dam		A 2.8m raising of the dam wall by building a concrete wave wall on the existing earthfill dam wall, and increasing the capacity of the spillway through a labyrinth spillway configuration.	3.9	10.7	77.6	1.61	Minimal. Small increase in inundated area.	4.5
Dam on the Nseleni River	*1 MAR (43.1 million m^3), 22.5m high*	A new earthfill dam on the Nseleni River tributary of the Mhlatuze River just upstream of the Bhejane township, from where water could be released down to Lake Nsezi for abstraction. Would also increase the assurance of supply to RBM, which has an abstraction point a short way downstream of the proposed dam site.	7.0	19.2	164.39	1.96	Significant, but mitigatable. Inundation of sections of the D857 road. Inundation of farm dam. Disruptions of ecosystems, some inundation of social infrastructure. Impacts as a result of obstruction of the watercourse.	1MAR: 8.5
	1.5 MAR (64.7 million m^3), 26.1m high		10.6	29.0	173.19	1.37		
Groundwater schemes	*Mtunzini-North Groundwater Scheme (wellfield 1)*	Wellfield 1 with 18 production boreholes and 20 exploration boreholes is located in the south western portion of the uMhlathuze LM and extends in a westerly direction over the municipal boundary and into the uMlalazi LM.	0.71	1.95	26.7	6.42	Moderate. Potential over-pumping /over-utilisation during operation impacting on the groundwater table, vegetation, as well as on natural springs and seeps. Construction phase impacts, noise and the influence on the boreholes of other users.	8.5
	Empangeni West Groundwater Scheme (wellfield 2)	Wellfield 2 with 17 production boreholes and 20 exploration boreholes is located to the west of Empangeni and extends westwards towards the boundary of the uMhlathuze and uMlalazi LMs.	0.54	1.48	15.5	4.93		
	Lubisana Groundwater Scheme (wellfield 3)	Wellfield 3 with 19 production boreholes and 20 exploration boreholes is located to the west of Empangeni and extends across the boundary of the uMhlathuze and uMlalazi LMs.	0.30	0.82	19.4	10.69		
Arboretum Effluent Reuse Scheme	*Treated effluent can be reused either directly by supply to industrial users, or indirectly by being taken to the Mzingazi WTW*	This firstly involves construction of a regional activated sludge WWTW and biological nutrient removal process with membrane bioreactors at the Arboretum pump station that can accommodate both the existing and future domestic load of the Arboretum and Alton pump stations. From there the treated effluent will be pumped for discharge into Lake Mzingazi for indirect reuse or sold directly to industrial users.	10.95	30	569	6.97	Moderate. Negative social perceptions of reuse. Mainly sludge disposal. Impacts of indirect use operation on Lake Mzingazi, as yet unquantified.	6.5
Seawater desalination	*Sea intake pipelines*	Seawater will be fed by an intake in the Richards Bay harbour to a site close to the Alkantstrand pump station, where the reverse osmosis desalination plant will be situated. Potable water will be pumped to the Mzingazi WTW for blending.	21.9	60	2243.7	8.47	Limited to moderate. Marine construction and brine outfall. Selection of site(s) will have further specific impacts, as yet unquantified.	Harbour intake: 7.75
	Harbour intake pipelines		21.9	60	2089.7	7.82		

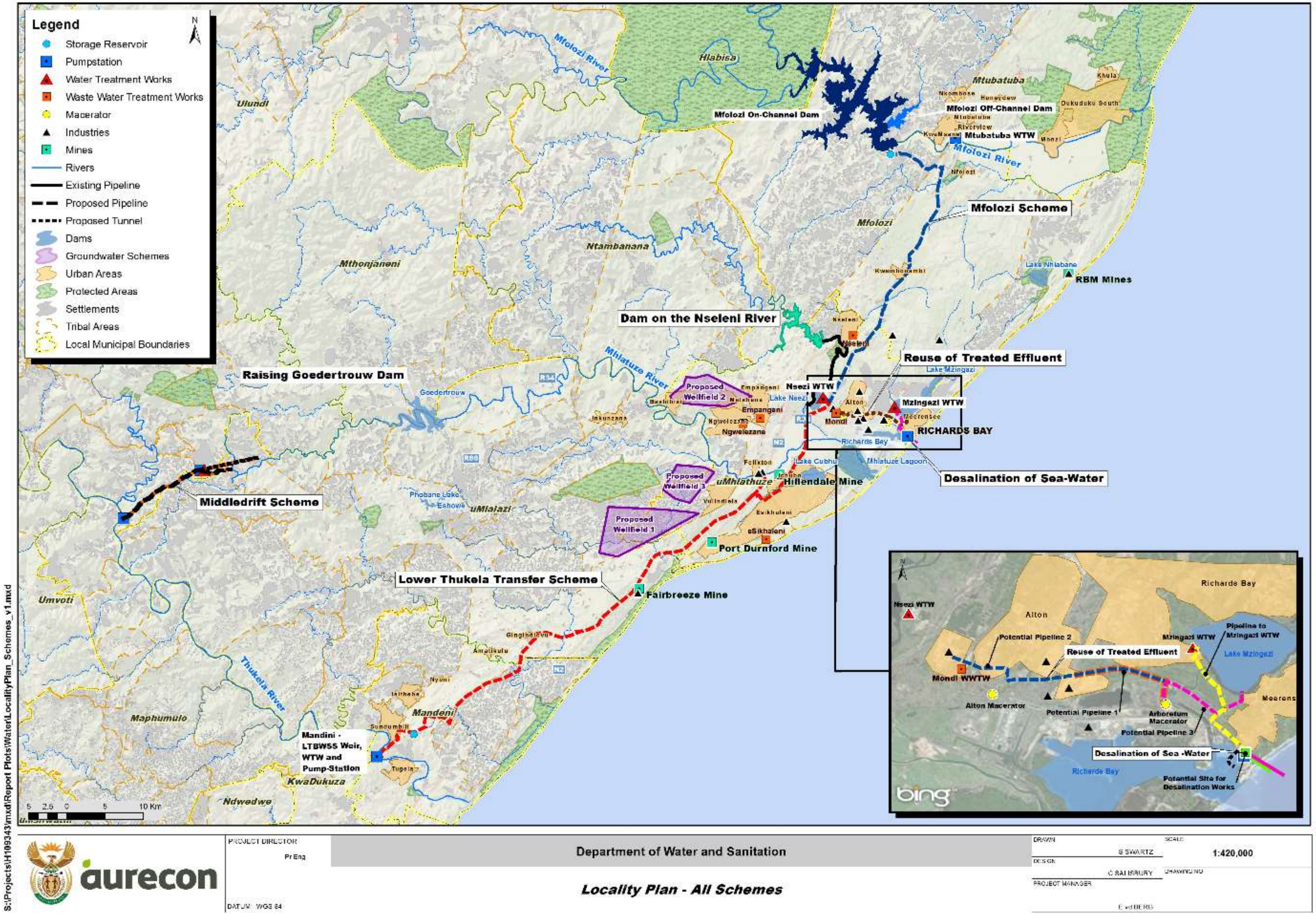

Figure 12-1: Locality Plan of all schemes

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Appendix A

Unit Reference Value Calculation Sheets

Net Present Value and Unit Reference Value Calculation

Rainwater Harvesting: 200m² roof, 5Kl tank, non-potable indoor uses

System Yield:	160.00	m³/a		Implementation period:	1	year	
CAPITAL COST COMPONENTS (R)				**ANNUAL COST COMPONENTS (R)**			
	CIVIL	**MECH/ELEC**	**TOTAL**				
Storage tank	5,000		5,000	Maintenance	Civil	0.50%	40
Pumps, gutters, pipework	3,000	3,500	6,500		Mech	4.00%	140
Total cost	**8,000**	**3500**	**11,500**	Operating cost			360
Calendar Year	**Year No**	**Supply (m³/a)**	**Storage tank**	**Pumps, gutters, pipework**	**Maint cost**	**Elec cost**	
2014	1	160	5,000	6,500	180	360	
2015	2	160	0	0	180	360	
2016	3	160	0	0	180	360	
2017	4	160	0	0	180	360	
2018	5	160	0	0	180	360	
2019	6	160	0	0	180	360	
2020	7	160	0	0	180	360	
2021	8	160	0	0	180	360	
2022	9	160	0	0	180	360	
2023	10	160	0	0	180	360	
2024	11	160	0	3,900	180	360	
2025	12	160	0	0	180	360	
2026	13	160	0	0	180	360	
2027	14	160	0	0	180	360	
2028	15	160	0	0	180	360	
2029	16	160	0	0	180	360	
2030	17	160	0	0	180	360	
2031	18	160	0	0	180	360	
2032	19	160	0	0	180	360	
2033	20	160	0	0	180	360	
2034	21	160	5,000	3,900	180	360	
2035	22	160	0	0	180	360	
2036	23	160	0	0	180	360	
2037	24	160	0	0	180	360	
2038	25	160	0	0	180	360	
2039	26	160	0	0	180	360	
2040	27	160	0	0	180	360	
2041	28	160	0	0	180	360	
2042	29	160	0	0	180	360	
2043	30	160	0	0	180	360	
2044	31	160	0	3,900	180	360	
2045	32	160	0	0	180	360	
2046	33	160	0	0	180	360	
2047	34	160	0	0	180	360	
2048	35	160	0	0	180	360	
2049	36	160	0	0	180	360	
2050	37	160	0	0	180	360	
NPV of supply @	6%	2,358	6,188	9,974	2,653	5,305	
NPV of supply @	8%	1,884	5,623	8,825	2,120	4,239	
NPV of supply @	10%	1,553	5,221	8,006	1,747	3,494	
URV @	6%	10.23					
URV @	8%	11.04					
URV @	10%	11.89					

Net Present Value and Unit Reference Value Calculation

Thukela-Mhlathuze Transfer Scheme: Augmentation of 47.3 million m³/a (1.5m³/s), tunnel option

System Yield:	**47.304**	**million m³/a**	**Implementation period:**	**2**	**years**	**Spioenkop Dam tariff:**		**0.4**	**R/m³**
CAPITAL COST COMPONENTS (R million)						**ANNUAL COST COMPONENTS (R MILLION)**			
		CIVIL	**MECH/ELEC**	**DAMS**	**TOTAL**				
Tunnel		190.86			190.86	Maintenance	Civil	0.50%	1.50
Pump-stations		107.20	432.14		539.33		Mech	4.00%	17.29
Pipelines		2.20	0.12		2.32		Dams	0.25%	0.00
Consulting fees					109.88	Operating cost			133.58
Total cost		**300.26**	**432.25**	**0.00**	**842.39**	Other costs			3.66

Calendar Year	Year No.	Supply (million m³)	Pump-stations	Pipelines	Tunnel	Consulting fees	Maint cost	Elec cost	Other costs
2014	1	0.00	269.67	1.16	95.43	54.94			
2015	2	0.00	269.67	1.16	95.43	54.94			
2016	3	11.50					18.79	133.58	8.26
2017	4	22.80					18.79	133.58	12.78
2018	5	40.40					18.79	133.58	19.82
2019	6	47.30					18.79	133.58	22.58
2020	7	47.30					18.79	133.58	22.58
2021	8	47.30					18.79	133.58	22.58
2022	9	47.30					18.79	133.58	22.58
2023	10	47.30					18.79	133.58	22.58
2024	11	47.30					18.79	133.58	22.58
2025	12	47.30					18.79	133.58	22.58
2026	13	47.30					18.79	133.58	22.58
2027	14	47.30					18.79	133.58	22.58
2028	15	47.30					18.79	133.58	22.58
2029	16	47.30					18.79	133.58	22.58
2030	17	47.30	259.28				18.79	133.58	22.58
2031	18	47.30					18.79	133.58	22.58
2032	19	47.30					18.79	133.58	22.58
2033	20	47.30					18.79	133.58	22.58
2034	21	47.30					18.79	133.58	22.58
2035	22	47.30		0.07			18.79	133.58	22.58
2036	23	47.30					18.79	133.58	22.58
2037	24	47.30					18.79	133.58	22.58
2038	25	47.30					18.79	133.58	22.58
2039	26	47.30					18.79	133.58	22.58
2040	27	47.30					18.79	133.58	22.58
2041	28	47.30					18.79	133.58	22.58
2042	29	47.30					18.79	133.58	22.58
2043	30	47.30					18.79	133.58	22.58
2044	31	47.30					18.79	133.58	22.58
2045	32	47.30	259.28				18.79	133.58	22.58
2046	33	47.30					18.79	133.58	22.58
2047	34	47.30					18.79	133.58	22.58
2048	35	47.30					18.79	133.58	22.58
2049	36	47.30					18.79	133.58	22.58
2050	37	47.30					18.79	133.58	22.58
NPV of supply	6%	624.44	917.48	2.18	174.96	100.72	272.38	1936.67	302.88
NPV of supply	8%	491.67	877.30	2.12	170.18	97.97	218.95	1556.81	239.35
NPV of supply	10%	398.22	839.91	2.06	165.62	95.35	181.18	1288.26	194.61
URV @	6%	5.94							
URV @	8%	6.43							
URV @	10%	6.95							

Net Present Value and Unit Reference Value Calculation

Thukela-Mhlathuze Transfer Scheme: Augmentation of 141.9 million m³/a (4.5m³/s), tunnel option

System Yield:	141.912	million m³/a	Implementation period:	3	years	Spioenkop Dam tariff:	0.4	R/m³

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	MECH/ELEC	DAMS	TOTAL				
Tunnel		190.86			190.86	Maintenance	Civil	0.50%	3.29
Pump-stations		231.89	934.83		1166.72		Mech	4.00%	37.39
Pipelines		236.03	12.42		248.45		Dams	0.25%	1.27
Weir				509.00	509.00				
Consulting fees					317.26	Operating cost			282.55
Total cost		658.79	947.25	509.00	**2432.29**	Other costs			10.58

Calendar Year	Year No.	Supply (million m³)	Pump-stations	Pipelines	Tunnel	Weir	Cons fees	Maint cost	Elec cost	Other costs
2014	1		388.91	82.82	63.62	169.67	105.75			
2015	2		388.91	82.82	63.62	169.67	105.75			
2016	3		388.91	82.82	63.62	169.67	105.75			
2017	4	40.40						41.96	282.55	26.74
2018	5	50.80						41.96	282.55	30.90
2019	6	53.70						41.96	282.55	32.06
2020	7	56.80						41.96	282.55	33.30
2021	8	63.60						41.96	282.55	36.02
2022	9	78.80						41.96	282.55	42.10
2023	10	82.60						41.96	282.55	43.62
2024	11	86.50						41.96	282.55	45.18
2025	12	90.60						41.96	282.55	46.82
2026	13	94.80						41.96	282.55	48.50
2027	14	99.10						41.96	282.55	50.22
2028	15	105.60						41.96	282.55	52.82
2029	16	110.40						41.96	282.55	54.74
2030	17	115.30	560.90					41.96	282.55	56.70
2031	18	120.50						41.96	282.55	58.78
2032	19	135.10						41.96	282.55	64.62
2033	20	140.70						41.96	282.55	66.86
2034	21	141.91						41.96	282.55	67.34
2035	22	141.91		7.45				41.96	282.55	67.34
2036	23	141.91						41.96	282.55	67.34
2037	24	141.91						41.96	282.55	67.34
2038	25	141.91						41.96	282.55	67.34
2039	26	141.91						41.96	282.55	67.34
2040	27	141.91						41.96	282.55	67.34
2041	28	141.91						41.96	282.55	67.34
2042	29	141.91						41.96	282.55	67.34
2043	30	141.91						41.96	282.55	67.34
2044	31	141.91						41.96	282.55	67.34
2045	32	141.91	560.90					41.96	282.55	67.34
2046	33	141.91						41.96	282.55	67.34
2047	34	141.91						41.96	282.55	67.34
2048	35	141.91						41.96	282.55	67.34
2049	36	141.91						41.96	282.55	67.34
2050	37	141.91						41.96	282.55	67.34
NPV of	6%	1407.56	1902.97	227.28	170.06	453.52	282.68	602.88	4059.79	714.97
NPV of	8%	1072.03	1796.26	218.91	163.96	437.25	272.53	486.18	3273.94	551.35
NPV of	10%	841.56	1698.52	211.05	158.21	421.93	262.99	403.17	2714.95	438.24
URV @	6%	5.98								
URV @	8%	6.72								
URV @	10%	7.50								

Net Present Value and Unit Reference Value Calculation

Thukela-Mhlathuze Transfer Scheme: Augmentation of 141.9 million m^3/a (4.5m^3/s) PHASE 1

System Yield:	47.304	million m^3/a	Implementation period:	2	years	Spioenkop Dam tariff:	0.4	R/m^3

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	MECH/ELEC	DAMS	TOTAL				
Tunnel		190.86			190.86	Maintenance	Civil	0.50%	2.08
Pump-stations		222.73	482.19		704.92		Mech	4.00%	19.29
Pipelines		1.95	0.10		2.05		Dams	0.25%	0.00
									21.37
Consulting fees					134.68	Operating cost			133.41
Total cost		415.54	482.29	0.00	**1032.51**	Other costs			4.49

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Tunnel	Weir	Consulting fees	Maint cost	Elec cost	Other costs
2014	1		352.46	1.03	95.43		67.34			
2015	2		352.46	1.03	95.43		67.34			
2016	3	22.80						21.37	133.41	13.61
2017	4	40.40						21.37	133.41	20.65
2018	5	47.30						21.37	133.41	23.41
2019	6	47.30						21.37	133.41	23.41
2020	7	47.30						21.37	133.41	23.41
2021	8	47.30						21.37	133.41	23.41
2022	9	47.30						21.37	133.41	23.41
2023	10	47.30						21.37	133.41	23.41
2024	11	47.30						21.37	133.41	23.41
2025	12	47.30						21.37	133.41	23.41
2026	13	47.30						21.37	133.41	23.41
2027	14	47.30						21.37	133.41	23.41
2028	15	47.30						21.37	133.41	23.41
2029	16	47.30						21.37	133.41	23.41
2030	17	47.30	289.31					21.37	133.41	23.41
2031	18	47.30						21.37	133.41	23.41
2032	19	47.30						21.37	133.41	23.41
2033	20	47.30						21.37	133.41	23.41
2034	21	47.30						21.37	133.41	23.41
2035	22	47.30		0.06				21.37	133.41	23.41
2036	23	47.30						21.37	133.41	23.41
2037	24	47.30						21.37	133.41	23.41
2038	25	47.30						21.37	133.41	23.41
2039	26	47.30						21.37	133.41	23.41
2040	27	47.30						21.37	133.41	23.41
2041	28	47.30						21.37	133.41	23.41
2042	29	47.30						21.37	133.41	23.41
2043	30	47.30						21.37	133.41	23.41
2044	31	47.30						21.37	133.41	23.41
2045	32	47.30	289.31					21.37	133.41	23.41
2046	33	47.30						21.37	133.41	23.41
2047	34	47.30						21.37	133.41	23.41
2048	35	47.30						21.37	133.41	23.41
2049	36	47.30						21.37	133.41	23.41
2050	37	47.30						21.37	133.41	23.41
NPV of supply	6%	656.56	1118.27	1.93	174.96		123.46	309.76	1934.26	327.71
NPV of supply	8%	522.70	1070.85	1.88	170.18		120.08	249.00	1554.87	261.40
NPV of supply	10%	428.23	1026.68	1.83	165.62		116.87	206.05	1286.66	214.58
URV @	6%	6.08								
URV @	8%	6.56								
URV @	10%	7.05								

Net Present Value and Unit Reference Value Calculation

Thukela-Mhlathuze Transfer Scheme: Augmentation of 141.9 million m^3/a (4.5m^3/s) PHASE 2

System Yield: **94.608** **million m^3/a** **Implementation period:** **2.5** **years** **Spioenkop Dam tariff:** **0.4** **R/m^3**

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	MECH/ELEC	DAMS	TOTAL				
						Maintenance	Civil	0.50%	1.24
Pump-stations		11.85	463.45		475.30		Mech	4.00%	18.54
Pipelines		236.03	12.42		248.45		Dams	0.25%	1.27
Weir				509.00	509				**21.05**
Consulting fees					184.91	Operating cost			155.37
Total cost		247.88	475.87	509.00	**1417.67**	Other costs			6.16

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Tunnel	Weir	Cons fees	Maint cost	Elec cost	Other costs
2014	1		190.12	99.38		203.60	73.97			
2015	2		190.12	99.38		203.60	73.97			
2016	3	11.40	95.06	49.69		101.80	36.98	10.52	77.69	7.64
2017	4	40.40						21.05	155.37	22.32
2018	5	50.80						21.05	155.37	26.48
2019	6	53.70						21.05	155.37	27.64
2020	7	56.80						21.05	155.37	28.88
2021	8	63.60						21.05	155.37	31.60
2022	9	78.80						21.05	155.37	37.68
2023	10	82.60						21.05	155.37	39.20
2024	11	86.50						21.05	155.37	40.76
2025	12	90.60						21.05	155.37	42.40
2026	13	94.61						21.05	155.37	44.01
2027	14	94.61						21.05	155.37	44.01
2028	15	94.61						21.05	155.37	44.01
2029	16	94.61						21.05	155.37	44.01
2030	17	94.61						21.05	155.37	44.01
2031	18	94.61	278.07					21.05	155.37	44.01
2032	19	94.61						21.05	155.37	44.01
2033	20	94.61						21.05	155.37	44.01
2034	21	94.61						21.05	155.37	44.01
2035	22	94.61						21.05	155.37	44.01
2036	23	94.61		7.45				21.05	155.37	44.01
2037	24	94.61						21.05	155.37	44.01
2038	25	94.61						21.05	155.37	44.01
2039	26	94.61						21.05	155.37	44.01
2040	27	94.61						21.05	155.37	44.01
2041	28	94.61						21.05	155.37	44.01
2042	29	94.61						21.05	155.37	44.01
2043	30	94.61						21.05	155.37	44.01
2044	31	94.61						21.05	155.37	44.01
2045	32	94.61						21.05	155.37	44.01
2046	33	94.61	278.07					21.05	155.37	44.01
2047	34	94.61						21.05	155.37	44.01
2048	35	94.61						21.05	155.37	44.01
2049	36	94.61						21.05	155.37	44.01
2050	37	94.61						21.05	155.37	44.01
NPV of supply	6%	1100.53	856.43	229.83	0.00	458.75	166.66	295.26	2179.37	526.67
NPV of supply	8%	847.36	808.14	222.15	0.00	443.88	161.26	235.58	1738.89	407.92
NPV of supply	10%	671.44	763.97	214.91	0.00	429.84	156.16	193.44	1427.83	325.22
URV @	6%	4.28								
URV @	8%	4.74								
URV @	10%	5.23								

Net Present Value and Unit Reference Value Calculation

Thukela-Mhlathuze Transfer Scheme: Augmentation of 236.5 million m^3/a ($7.5m^3/s$), tunnel option

System Yield: 236.52 million m^3/a | **Implementation period:** 4 years | **Spioenkop Dam tariff:** 0.4 R/m^3

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	MECH/ELEC	DAMS	TOTAL				
Tunnel		190.86			190.86	Maintenance	Civil	0.50%	5.08
Pump-stations		354.38	1428.59		1782.97		Mech	4.00%	57.14
Pipelines		469.82	24.73		494.55		Dams	0.25%	1.27
Weir				509.00	509.00				
Consulting fees					446.61	Operating cost			431.80
Total cost		1015.06	1453.31	509.00	**3423.98**	Other costs			14.89

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Tunnel	Weir	Cons fees	Maint cost	Elec cost	Other costs
2014	1		445.74	123.64	47.72	127.25	111.65			
2015	2		445.74	123.64	47.72	127.25	111.65			
2016	3		445.74	123.64	47.72	127.25	111.65			
2017	4		445.74	123.64	47.72	127.25	111.65			
2018	5	50.80						63.49	431.80	35.21
2019	6	53.70						63.49	431.80	36.37
2020	7	56.80						63.49	431.80	37.61
2021	8	63.60						63.49	431.80	40.33
2022	9	78.80						63.49	431.80	46.41
2023	10	82.60						63.49	431.80	47.93
2024	11	86.50						63.49	431.80	49.49
2025	12	90.60						63.49	431.80	51.13
2026	13	94.80						63.49	431.80	52.81
2027	14	99.10						63.49	431.80	54.53
2028	15	105.60						63.49	431.80	57.13
2029	16	110.40						63.49	431.80	59.05
2030	17	115.30						63.49	431.80	61.01
2031	18	120.50	857.15					63.49	431.80	63.09
2032	19	135.10						63.49	431.80	68.93
2033	20	140.70						63.49	431.80	71.17
2034	21	146.20						63.49	431.80	73.37
2035	22	152.10						63.49	431.80	75.73
2036	23	158.30		14.84				63.49	431.80	78.21
2037	24	165.00						63.49	431.80	80.89
2038	25	172.10						63.49	431.80	83.73
2039	26	179.90						63.49	431.80	86.85
2040	27	188.40						63.49	431.80	90.25
2041	28	201.60						63.49	431.80	95.53
2042	29	215.90						63.49	431.80	101.25
2043	30	231.30						63.49	431.80	107.41
2044	31	236.52						63.49	431.80	109.49
2045	32	236.52						63.49	431.80	109.49
2046	33	236.52	857.15					63.49	431.80	109.49
2047	34	236.52						63.49	431.80	109.49
2048	35	236.52						63.49	431.80	109.49
2049	36	236.52						63.49	431.80	109.49
2050	37	236.52						63.49	431.80	109.49
NPV of supply	6%	1668.71	2789.31	439.50	165.34	440.93	386.88	903.50	6144.56	879.33
NPV of supply	8%	1249.65	2599.87	419.60	158.04	421.47	369.80	731.03	4971.65	671.27
NPV of supply	10%	967.08	2429.00	401.13	151.25	403.36	353.92	607.58	4132.05	529.29
URV @	6%	7.28								
URV @	8%	8.28								
URV @	10%	9.31								

Net Present Value and Unit Reference Value Calculation

Thukela-Mhlathuze Transfer Scheme: Augmentation of 236.5 million m^3/a ($7.5m^3/s$), PHASE 1

System Yield: 47.304 million m^3/a | **Implementation period:** 2 years | **Spioenkop Dam tariff:** 0.4 R/m^3

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	MECH/ELEC	DAMS	TOTAL				
Tunnel		190.86			190.86	Maintenance	Civil	0.50%	2.66
Pump-stations		338.90	532.78		871.68		Mech	4.00%	21.31
Pipelines		2.66	0.14		2.80		Dams	0.25%	0.00
Consulting fees					159.80	Operating cost			133.33
Total cost		532.42	532.92	0.00	1225.14	Other costs			5.33

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Tunnel	Consulting fees	Maint cost	Elec cost	Other costs
2014	1		435.84	1.40	95.43	79.90			
2015	2		435.84	1.40	95.43	79.90			
2016	3	22.80					23.97	133.33	14.45
2017	4	40.40					23.97	133.33	21.49
2018	5	47.30					23.97	133.33	24.25
2019	6	47.30					23.97	133.33	24.25
2020	7	47.30					23.97	133.33	24.25
2021	8	47.30					23.97	133.33	24.25
2022	9	47.30					23.97	133.33	24.25
2023	10	47.30					23.97	133.33	24.25
2024	11	47.30					23.97	133.33	24.25
2025	12	47.30					23.97	133.33	24.25
2026	13	47.30					23.97	133.33	24.25
2027	14	47.30					23.97	133.33	24.25
2028	15	47.30					23.97	133.33	24.25
2029	16	47.30					23.97	133.33	24.25
2030	17	47.30	319.67				23.97	133.33	24.25
2031	18	47.30					23.97	133.33	24.25
2032	19	47.30					23.97	133.33	24.25
2033	20	47.30					23.97	133.33	24.25
2034	21	47.30					23.97	133.33	24.25
2035	22	47.30		0.08			23.97	133.33	24.25
2036	23	47.30					23.97	133.33	24.25
2037	24	47.30					23.97	133.33	24.25
2038	25	47.30					23.97	133.33	24.25
2039	26	47.30					23.97	133.33	24.25
2040	27	47.30					23.97	133.33	24.25
2041	28	47.30					23.97	133.33	24.25
2042	29	47.30					23.97	133.33	24.25
2043	30	47.30					23.97	133.33	24.25
2044	31	47.30					23.97	133.33	24.25
2045	32	47.30	319.67				23.97	133.33	24.25
2046	33	47.30					23.97	133.33	24.25
2047	34	47.30					23.97	133.33	24.25
2048	35	47.30					23.97	133.33	24.25
2049	36	47.30					23.97	133.33	24.25
2050	37	47.30					23.97	133.33	24.25
NPV of supply	6%	656.56	1320.67	2.63	174.96	146.49	347.57	1933.09	339.85
NPV of supply	8%	522.70	1265.95	2.56	170.18	142.48	279.40	1553.93	271.16
NPV of supply	10%	428.23	1214.93	2.49	165.62	138.67	231.20	1285.88	222.66
URV @	6%	6.50							
URV @	8%	7.07							
URV @	10%	7.62							

Net Present Value and Unit Reference Value Calculation

Thukela-Mhlathuze Transfer Scheme: Augmentation of 236.5 million m^3/a ($7.5 m^3/s$), PHASE 2

System Yield:	**94.608**	**million m^3/a**	**Implementation period:**	**2.5**	**years**	**Spioenkop Dam tariff:**		**0.4**	**R/m^3**
CAPITAL COST COMPONENTS (R million)						**ANNUAL COST COMPONENTS (R MILLION)**			
		CIVIL	**MECH/ELEC**	**DAMS**	**TOTAL**				
						Maintenance	Civil	0.50%	1.27
Pump-stations		18.09	466.18		484.28		Mech	4.00%	18.65
Pipelines		236.03	12.42		248.45		Dams	0.25%	1.27
Weir				509.00	509				**21.19**
Consulting fees					186.26	Operating cost			155.37
Total cost		254.13	478.60	509.00	**1427.99**	Other costs			6.21

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Weir	Consulting fees	Maint cost	Elec cost	Other costs
2014	1		193.71	99.38	203.60	74.50			
2015	2		193.71	99.38	203.60	74.50			
2016	3	11.40	96.86	49.69	101.80	37.25	10.60	77.69	7.66
2017	4	40.40					21.19	155.37	22.37
2018	5	50.80					21.19	155.37	26.53
2019	6	53.70					21.19	155.37	27.69
2020	7	56.80					21.19	155.37	28.93
2021	8	63.60					21.19	155.37	31.65
2022	9	78.80					21.19	155.37	37.73
2023	10	82.60					21.19	155.37	39.25
2024	11	86.50					21.19	155.37	40.81
2025	12	90.60					21.19	155.37	42.45
2026	13	94.61					21.19	155.37	44.05
2027	14	94.61					21.19	155.37	44.05
2028	15	94.61					21.19	155.37	44.05
2029	16	94.61					21.19	155.37	44.05
2030	17	94.61	279.71				21.19	155.37	44.05
2031	18	94.61					21.19	155.37	44.05
2032	19	94.61					21.19	155.37	44.05
2033	20	94.61					21.19	155.37	44.05
2034	21	94.61					21.19	155.37	44.05
2035	22	94.61		7.45			21.19	155.37	44.05
2036	23	94.61					21.19	155.37	44.05
2037	24	94.61					21.19	155.37	44.05
2038	25	94.61					21.19	155.37	44.05
2039	26	94.61					21.19	155.37	44.05
2040	27	94.61					21.19	155.37	44.05
2041	28	94.61					21.19	155.37	44.05
2042	29	94.61					21.19	155.37	44.05
2043	30	94.61					21.19	155.37	44.05
2044	31	94.61					21.19	155.37	44.05
2045	32	94.61	279.71				21.19	155.37	44.05
2046	33	94.61					21.19	155.37	44.05
2047	34	94.61					21.19	155.37	44.05
2048	35	94.61					21.19	155.37	44.05
2049	36	94.61					21.19	155.37	44.05
2050	37	94.61					21.19	155.37	44.05
NPV of supply	6%	1100.53	867.04	229.83	458.75	167.87	297.23	2179.37	527.30
NPV of supply	8%	847.36	818.28	222.15	443.88	162.43	237.15	1738.89	408.43
NPV of supply	10%	671.44	773.68	214.91	429.84	157.29	194.73	1427.83	325.63
URV @	6%	4.30							
URV @	8%	4.76							
URV @	10%	5.25							

Net Present Value and Unit Reference Value Calculation

Thukela-Mhlathuze Transfer Scheme: Augmentation of 236.5 million m^3/a (7.5m^3/s), PHASE 3

System Yield:	94.608	million m^3/a	Implementation period:	2.5	years	Spioenkop Dam tariff:	0.4	R/m^3

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	MECH/ELEC	DAMS	TOTAL				
						Maintenance	Civil	0.50%	1.17
Pump-stations		0.00	439.04		439.04		Mech	4.00%	17.56
Pipelines		233.79	12.30		246.10		Dams	0.25%	0.00
									18.73
Consulting fees					102.77	Operating cost			148.86
Total cost		233.79	451.34	0.00	**787.90**	Other costs			3.43
Calendar Year	**Year No.**	**Supply (million m^3)**	**Pump-stations**	**Pipelines**		**Consulting fees**	**Maint cost**	**Elec cost**	**Other costs**
2014	1		175.61	98.44		41.11			
2015	2		175.61	98.44		41.11			
2016	3	11.40	87.81	49.22		20.55	9.37	74.43	6.27
2017	4	40.40					18.73	148.86	19.59
2018	5	50.80					18.73	148.86	23.75
2019	6	53.70					18.73	148.86	24.91
2020	7	56.80					18.73	148.86	26.15
2021	8	63.60					18.73	148.86	28.87
2022	9	78.80					18.73	148.86	34.95
2023	10	82.60					18.73	148.86	36.47
2024	11	86.50					18.73	148.86	38.03
2025	12	90.60					18.73	148.86	39.67
2026	13	94.61					18.73	148.86	41.27
2027	14	94.61					18.73	148.86	41.27
2028	15	94.61					18.73	148.86	41.27
2029	16	94.61					18.73	148.86	41.27
2030	17	94.61	263.42				18.73	148.86	41.27
2031	18	94.61					18.73	148.86	41.27
2032	19	94.61					18.73	148.86	41.27
2033	20	94.61					18.73	148.86	41.27
2034	21	94.61					18.73	148.86	41.27
2035	22	94.61		7.38			18.73	148.86	41.27
2036	23	94.61					18.73	148.86	41.27
2037	24	94.61					18.73	148.86	41.27
2038	25	94.61					18.73	148.86	41.27
2039	26	94.61					18.73	148.86	41.27
2040	27	94.61					18.73	148.86	41.27
2041	28	94.61					18.73	148.86	41.27
2042	29	94.61					18.73	148.86	41.27
2043	30	94.61					18.73	148.86	41.27
2044	31	94.61					18.73	148.86	41.27
2045	32	94.61	263.42				18.73	148.86	41.27
2046	33	94.61					18.73	148.86	41.27
2047	34	94.61					18.73	148.86	41.27
2048	35	94.61					18.73	148.86	41.27
2049	36	94.61					18.73	148.86	41.27
2050	37	94.61					18.73	148.86	41.27
NPV of supply	6%	1100.53	801.19	227.65	0.00	92.62	262.72	2087.93	488.26
NPV of supply	8%	847.36	755.78	220.04	0.00	89.62	209.62	1665.93	377.28
NPV of supply	10%	671.44	714.24	212.87	0.00	86.79	172.13	1367.92	300.06
URV @	6%	3.60							
URV @	8%	3.92							
URV @	10%	4.25							

Net Present Value and Unit Reference Value Calculation

Coastal Pipeline from the Lower Thukela River: Scenario 1 (55Ml/day transfer of untreated water)

System Yield: 15 million m^3/a | **Implementation period:** 2 years | **Spioenkop Dam tariff:** 0.4 R/m^3

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	**MECH/ELEC**	**DAMS**	**TOTAL**				
Access Road		1.95			1.95	Maintenance	Civil	0.50%	1.94
Weir/Abstr. Works		29.47	23.32		52.78		Mech	4.00%	2.03
Pump stations		5.98	27.51		33.50		Dams	0.25%	0.00
Pipelines		309.40	16.28		325.68				**3.97**
Desilting Works		4.24			4.24				
Northern Reser		36.49			36.49				
						Oper. cost			10.06
Cons. fees					68.20				
Total cost		387.53	67.11	0.00	**522.84**	Other costs			2.27

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Access Road	Weir/Abstr	Desilting Wks	Reservoir	Cons fees	Maint cost	Elec cost	Other costs
2014	1		16.75	162.84	1.95	52.78	4.24	18.25	34.10			
2015	2		16.75	162.84				18.25	34.10			
2016	3	15.00								3.97	10.06	8.27
2017	4	15.00								3.97	10.06	8.27
2018	5	15.00								3.97	10.06	8.27
2019	6	15.00								3.97	10.06	8.27
2020	7	15.00								3.97	10.06	8.27
2021	8	15.00								3.97	10.06	8.27
2022	9	15.00								3.97	10.06	8.27
2023	10	15.00								3.97	10.06	8.27
2024	11	15.00								3.97	10.06	8.27
2025	12	15.00								3.97	10.06	8.27
2026	13	15.00								3.97	10.06	8.27
2027	14	15.00								3.97	10.06	8.27
2028	15	15.00								3.97	10.06	8.27
2029	16	15.00								3.97	10.06	8.27
2030	17	15.00	16.51			13.99				3.97	10.06	8.27
2031	18	15.00								3.97	10.06	8.27
2032	19	15.00								3.97	10.06	8.27
2033	20	15.00								3.97	10.06	8.27
2034	21	15.00								3.97	10.06	8.27
2035	22	15.00		9.77						3.97	10.06	8.27
2036	23	15.00								3.97	10.06	8.27
2037	24	15.00								3.97	10.06	8.27
2038	25	15.00								3.97	10.06	8.27
2039	26	15.00								3.97	10.06	8.27
2040	27	15.00								3.97	10.06	8.27
2041	28	15.00								3.97	10.06	8.27
2042	29	15.00								3.97	10.06	8.27
2043	30	15.00								3.97	10.06	8.27
2044	31	15.00								3.97	10.06	8.27
2045	32	15.00	16.51			13.99				3.97	10.06	8.27
2046	33	15.00								3.97	10.06	8.27
2047	34	15.00								3.97	10.06	8.27
2048	35	15.00								3.97	10.06	8.27
2049	36	15.00								3.97	10.06	8.27
2050	37	15.00								3.97	10.06	8.27
NPV of supply	6%	217.47	57.64	306.75	1.84	74.00	4.00	33.45	62.52	57.57	145.82	119.95
NPV of supply	8%	174.82	55.10	298.14	1.81	71.98	3.92	32.54	60.81	46.28	117.22	96.42
NPV of supply	10%	144.66	52.74	289.96	1.78	70.06	3.85	31.67	59.18	38.30	97.00	79.79
URV @	6%	3.97										
URV @	8%	4.39										
URV @	10%	5.01										

Net Present Value and Unit Reference Value Calculation

Coastal Pipeline from the Lower Thukela River: Scenario 2 (55Ml/day transfer of treated water)

System Yield: 15 million m³/a **Implementation period:** 2 years **Spioenkop Dam tariff:** 0.4 R/m³

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	MECH/ELEC	DAMS	TOTAL				
Access Road		1.95			1.95	Maintenance	Civil	0.50%	2.19
Weir / Abstr Works		29.47	23.32		52.78		Mech	4.00%	2.03
Pump stations		5.98	27.51		33.50		Dams	0.25%	0.00
Pipelines		359.96	18.95		378.91				**4.22**
Desilting Works		4.24			4.24				
Northern Reser		36.49			36.49				
						Oper. cost			10.06
Cons. fees					76.18				
Total cost		438.10	69.77	0.00	**584.05**	Other costs			2.54

Calendar Year	Year No.	Supply (million m³)	Pump-stations	Pipelines	Access Road	Weir & Abstr	Desilting Wks	Reservoir	Consulting fees	Maint cost	Elec cost	Other costs
2014	1		16.75	189.46	1.95	52.78	4.24	18.25	38.09			
2015	2		16.75	189.46				18.25	38.09			
2016	3	15.00								4.22	10.06	8.54
2017	4	15.00								4.22	10.06	8.54
2018	5	15.00								4.22	10.06	8.54
2019	6	15.00								4.22	10.06	8.54
2020	7	15.00								4.22	10.06	8.54
2021	8	15.00								4.22	10.06	8.54
2022	9	15.00								4.22	10.06	8.54
2023	10	15.00								4.22	10.06	8.54
2024	11	15.00								4.22	10.06	8.54
2025	12	15.00								4.22	10.06	8.54
2026	13	15.00								4.22	10.06	8.54
2027	14	15.00								4.22	10.06	8.54
2028	15	15.00								4.22	10.06	8.54
2029	16	15.00								4.22	10.06	8.54
2030	17	15.00	16.51			13.99				4.22	10.06	8.54
2031	18	15.00								4.22	10.06	8.54
2032	19	15.00								4.22	10.06	8.54
2033	20	15.00								4.22	10.06	8.54
2034	21	15.00								4.22	10.06	8.54
2035	22	15.00		11.37						4.22	10.06	8.54
2036	23	15.00								4.22	10.06	8.54
2037	24	15.00								4.22	10.06	8.54
2038	25	15.00								4.22	10.06	8.54
2039	26	15.00								4.22	10.06	8.54
2040	27	15.00								4.22	10.06	8.54
2041	28	15.00								4.22	10.06	8.54
2042	29	15.00								4.22	10.06	8.54
2043	30	15.00								4.22	10.06	8.54
2044	31	15.00								4.22	10.06	8.54
2045	32	15.00	16.51			13.99				4.22	10.06	8.54
2046	33	15.00								4.22	10.06	8.54
2047	34	15.00								4.22	10.06	8.54
2048	35	15.00								4.22	10.06	8.54
2049	36	15.00								4.22	10.06	8.54
2050	37	15.00								4.22	10.06	8.54
NPV of supply	6%	217.47	57.64	356.89	1.84	74.00	4.00	33.45	69.83	61.24	145.82	123.81
NPV of supply	8%	174.82	55.10	346.87	1.81	71.98	3.92	32.54	67.93	49.22	117.22	99.52
NPV of supply	10%	144.66	52.74	337.35	1.78	70.06	3.85	31.67	66.11	40.73	97.00	82.35
URV @	6%	3.82										
URV @	8%	4.28										
URV @	10%	4.76										

Net Present Value and Unit Reference Value Calculation

Coastal Pipeline from the Lower Thukela River: Scenario 3 (110Ml/day transfer of untreated water)

System Yield: **35** **million m^3/a** **Implementation period:** **2 years** **Spioenkop Dam tariff:** **0.4 R/m^3**

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	MECH/ELEC	DAMS	TOTAL				
Access Road		4.56			4.56	Maintenance	Civil	0.50%	3.35
Weir / Abstr Works		68.75	54.50		123.26		Mech	4.00%	7.62
Pump stations		31.97	135.90		167.87		Dams	0.25%	0.00
Pipelines		534.21	28.12		562.33				**10.97**
Desilting		9.88			9.88				
Northern Res.		21.29			21.29				
						Oper. cost			45.41
Cons. fees					125.06				
Total cost		670.67	218.52	0.00	**1014.25**	Other costs			4.45

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Access Road	Weir & Abstr	Desilting Wks	Reservoir	Cons fees	Maint cost	Elec cost	Other costs
2014	1		83.93	281.16	4.56	123.26	9.88	10.64	62.53			
2015	2		83.93	281.16				10.64	62.53			
2016	3	22.80								10.97	45.41	13.57
2017	4	35.00								10.97	45.41	18.45
2018	5	35.00								10.97	45.41	18.45
2019	6	35.00								10.97	45.41	18.45
2020	7	35.00								10.97	45.41	18.45
2021	8	35.00								10.97	45.41	18.45
2022	9	35.00								10.97	45.41	18.45
2023	10	35.00								10.97	45.41	18.45
2024	11	35.00								10.97	45.41	18.45
2025	12	35.00								10.97	45.41	18.45
2026	13	35.00								10.97	45.41	18.45
2027	14	35.00								10.97	45.41	18.45
2028	15	35.00								10.97	45.41	18.45
2029	16	35.00								10.97	45.41	18.45
2030	17	35.00	81.54			32.70				10.97	45.41	18.45
2031	18	35.00								10.97	45.41	18.45
2032	19	35.00								10.97	45.41	18.45
2033	20	35.00								10.97	45.41	18.45
2034	21	35.00								10.97	45.41	18.45
2035	22	35.00		16.87						10.97	45.41	18.45
2036	23	35.00								10.97	45.41	18.45
2037	24	35.00								10.97	45.41	18.45
2038	25	35.00								10.97	45.41	18.45
2039	26	35.00								10.97	45.41	18.45
2040	27	35.00								10.97	45.41	18.45
2041	28	35.00								10.97	45.41	18.45
2042	29	35.00								10.97	45.41	18.45
2043	30	35.00								10.97	45.41	18.45
2044	31	35.00								10.97	45.41	18.45
2045	32	35.00	81.54			32.70				10.97	45.41	18.45
2046	33	35.00								10.97	45.41	18.45
2047	34	35.00								10.97	45.41	18.45
2048	35	35.00								10.97	45.41	18.45
2049	36	35.00								10.97	45.41	18.45
2050	37	35.00								10.97	45.41	18.45
NPV of supply	6%	495.93	286.93	529.65	4.30	172.84	9.32	19.51	114.64	159.04	658.32	262.83
NPV of supply	8%	396.61	274.34	514.78	4.22	168.13	9.15	18.98	111.51	127.84	529.20	210.46
NPV of supply	10%	326.45	262.63	500.65	4.15	163.65	8.98	18.47	108.52	105.79	437.91	173.46
URV @	6%	4.47										
URV @	8%	4.96										
URV @	10%	5.47										

Net Present Value and Unit Reference Value Calculation

Coastal Pipeline from the Lower Thukela River: Scenario 4 (110Ml/day transfer of treated water)

System Yield: 35 million m^3/a **Implementation period:** 2 years **Spioenkop Dam tariff:** 0.4 R/m^3

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
		CIVIL	MECH/ELEC	DAMS	TOTAL				
Access Road		4.56			4.56	Maintenance	Civil	0.50%	3.52
Weir/Abstr Works		68.75	54.50		123.26		Mech	4.00%	7.36
Pump stations		30.04	129.37		159.41		Dams	0.25%	0.00
Pipelines		569.28	29.96		599.24				**10.87**
Desilting Works		9.88			9.88				
Northern Reser		21.29			21.29				
Consulting fees					137.81	Oper. cost			43.05
Total cost		703.80	213.84	0.00	1055.45	Other costs			4.59

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Access Road	Weir & Abstr	Desilting Wks	Reservoir	Cons fees	Maint cost	Elec cost	Other costs
2014	1		79.70	299.62	4.56	123.26	9.88	10.64	68.91			
2015	2		79.70	299.62				10.64	68.91			
2016	3	11.50								10.87	43.05	9.19
2017	4	22.80								10.87	43.05	13.71
2018	5	35.00								10.87	43.05	18.59
2019	6	35.00								10.87	43.05	18.59
2020	7	35.00								10.87	43.05	18.59
2021	8	35.00								10.87	43.05	18.59
2022	9	35.00								10.87	43.05	18.59
2023	10	35.00								10.87	43.05	18.59
2024	11	35.00								10.87	43.05	18.59
2025	12	35.00								10.87	43.05	18.59
2026	13	35.00								10.87	43.05	18.59
2027	14	35.00								10.87	43.05	18.59
2028	15	35.00								10.87	43.05	18.59
2029	16	35.00								10.87	43.05	18.59
2030	17	35.00	77.62			32.70				10.87	43.05	18.59
2031	18	35.00								10.87	43.05	18.59
2032	19	35.00								10.87	43.05	18.59
2033	20	35.00								10.87	43.05	18.59
2034	21	35.00								10.87	43.05	18.59
2035	22	35.00		17.98						10.87	43.05	18.59
2036	23	35.00								10.87	43.05	18.59
2037	24	35.00								10.87	43.05	18.59
2038	25	35.00								10.87	43.05	18.59
2039	26	35.00								10.87	43.05	18.59
2040	27	35.00								10.87	43.05	18.59
2041	28	35.00								10.87	43.05	18.59
2042	29	35.00								10.87	43.05	18.59
2043	30	35.00								10.87	43.05	18.59
2044	31	35.00								10.87	43.05	18.59
2045	32	35.00	77.62			32.70				10.87	43.05	18.59
2046	33	35.00								10.87	43.05	18.59
2047	34	35.00								10.87	43.05	18.59
2048	35	35.00								10.87	43.05	18.59
2049	36	35.00								10.87	43.05	18.59
2050	37	35.00								10.87	43.05	18.59
NPV of supply @	6%	474.41	272.79	564.42	4.30	172.84	9.32	19.51	126.33	157.66	624.21	256.29
NPV of supply @	8%	375.69	260.81	548.57	4.22	168.13	9.15	18.98	122.88	126.73	501.78	203.75
NPV of supply @	10%	306.10	249.67	533.51	4.15	163.65	8.98	18.47	119.59	104.87	415.22	166.69
URV @	6%	4.65										
URV @	8%	5.23										
URV @	10%	5.83										

Net Present Value and Unit Reference Value Calculation

Coastal Pipeline from the Lower Thukela River: Scenario 5

(110Ml/day transfer of untreated water using Tronox pipeline)

System Yield: 35 million m³/a | **Implementation period:** 2 years | **Spioenkop Dam tariff:** 0.4 R/m³

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)						
		CIVIL	MECH/ELEC	DAMS	TOTAL							
Access Road		4.56			4.56	Maintenance	Civil	0.50%	4.46			
Weir/Abstr. Works		68.75	54.50		123.26		Mech	4.00%	4.76			
Pump stations		13.96	64.58		78.54		Dams	0.25%	0.00			
Pipelines		773.34	40.70		814.04				**9.22**			
Desilting Works		9.88			9.88							
Northern Reservoir		21.29			21.29							
Consulting fees					157.90	Operating cost			23.47			
Total cost		891.79	159.78	0.00	**1209.47**	Other costs			5.26			
Calendar Year	**Year No.**	**Supply (million m³)**	**Pump-stations**	**Pipelines**	**Access Road**	**Weir & Abstr**	**Desilting Wks**	**Reservoir**	**Cons. fees**	**Maint cost**	**Electr cost**	**Other costs**
2014	1		39.27	407.02	4.56	123.26	9.88	10.64	78.95			
2015	2		39.27	407.02				10.64	78.95			
2016	3	22.80								9.22	23.47	14.38
2017	4	35.00								9.22	23.47	19.26
2018	5	35.00								9.22	23.47	19.26
2019	6	35.00								9.22	23.47	19.26
2020	7	35.00								9.22	23.47	19.26
2021	8	35.00								9.22	23.47	19.26
2022	9	35.00								9.22	23.47	19.26
2023	10	35.00								9.22	23.47	19.26
2024	11	35.00								9.22	23.47	19.26
2025	12	35.00								9.22	23.47	19.26
2026	13	35.00								9.22	23.47	19.26
2027	14	35.00								9.22	23.47	19.26
2028	15	35.00								9.22	23.47	19.26
2029	16	35.00								9.22	23.47	19.26
2030	17	35.00	38.75			32.70				9.22	23.47	19.26
2031	18	35.00								9.22	23.47	19.26
2032	19	35.00								9.22	23.47	19.26
2033	20	35.00								9.22	23.47	19.26
2034	21	35.00								9.22	23.47	19.26
2035	22	35.00		24.42						9.22	23.47	19.26
2036	23	35.00								9.22	23.47	19.26
2037	24	35.00								9.22	23.47	19.26
2038	25	35.00								9.22	23.47	19.26
2039	26	35.00								9.22	23.47	19.26
2040	27	35.00								9.22	23.47	19.26
2041	28	35.00								9.22	23.47	19.26
2042	29	35.00								9.22	23.47	19.26
2043	30	35.00								9.22	23.47	19.26
2044	31	35.00								9.22	23.47	19.26
2045	32	35.00	38.75			32.70				9.22	23.47	19.26
2046	33	35.00								9.22	23.47	19.26
2047	34	35.00								9.22	23.47	19.26
2048	35	35.00								9.22	23.47	19.26
2049	36	35.00								9.22	23.47	19.26
2050	37	35.00								9.22	23.47	19.26
NPV of supply	6%	495.93	135.22	766.73	4.30	172.84	9.32	19.51	144.75	133.70	340.26	274.60
NPV of supply	8%	396.61	129.26	745.21	4.22	168.13	9.15	18.98	140.79	107.48	273.52	219.92
NPV of supply	10%	326.45	123.73	724.75	4.15	163.65	8.98	18.47	137.02	88.94	226.34	181.29
URV @	6%	4.04										
URV @	8%	4.58										
URV @	10%	5.14										

Net Present Value and Unit Reference Value Calculation

Mfolozi (Kwesibomvu) On-Channel Dam: 26m-high, pipeline to Nsezi WTW

System Yield: 66.6 million m^3/a **Implementation period:** 3 years

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)				
		CIVIL	MECH/ELEC	DAMS	TOTAL					
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	4.91	
Pump stations		43.38	175.60		218.99		Mech	4.00%	7.02	
Pipelines		887.04	46.69		933.73		Dams	0.25%	1.93	
Dam				772.65	772.65				**13.86**	
Consulting fees					296.45	Oper. cost			52.86	
Total cost		981.43	222.29	772.65	**2272.82**	Other costs			9.88	

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Dam	Reservoir	Cons fees	Maint cost	Electr cost	Other costs
2014	1		73.00	311.24	257.55	17.00	98.82			
2015	2		73.00	311.24	257.55	17.00	98.82			
2016	3		73.00	311.24	257.55	17.00	98.82			
2017	4	40.40						13.86	52.86	9.88
2018	5	50.80						13.86	52.86	9.88
2019	6	53.70						13.86	52.86	9.88
2020	7	56.80						13.86	52.86	9.88
2021	8	63.60						13.86	52.86	9.88
2022	9	66.60						13.86	52.86	9.88
2023	10	66.60						13.86	52.86	9.88
2024	11	66.60						13.86	52.86	9.88
2025	12	66.60						13.86	52.86	9.88
2026	13	66.60						13.86	52.86	9.88
2027	14	66.60						13.86	52.86	9.88
2028	15	66.60						13.86	52.86	9.88
2029	16	66.60						13.86	52.86	9.88
2030	17	66.60						13.86	52.86	9.88
2031	18	66.60	105.36					13.86	52.86	9.88
2032	19	66.60						13.86	52.86	9.88
2033	20	66.60						13.86	52.86	9.88
2034	21	66.60						13.86	52.86	9.88
2035	22	66.60						13.86	52.86	9.88
2036	23	66.60		28.01				13.86	52.86	9.88
2037	24	66.60						13.86	52.86	9.88
2038	25	66.60						13.86	52.86	9.88
2039	26	66.60						13.86	52.86	9.88
2040	27	66.60						13.86	52.86	9.88
2041	28	66.60						13.86	52.86	9.88
2042	29	66.60						13.86	52.86	9.88
2043	30	66.60						13.86	52.86	9.88
2044	31	66.60						13.86	52.86	9.88
2045	32	66.60						13.86	52.86	9.88
2046	33	66.60	105.36					13.86	52.86	9.88
2047	34	66.60						13.86	52.86	9.88
2048	35	66.60						13.86	52.86	9.88
2049	36	66.60						13.86	52.86	9.88
2050	37	66.60						13.86	52.86	9.88
NPV of supply	6%	897.30	357.31	854.15	688.43	45.44	264.14	199.18	759.49	141.98
NPV of supply	8%	714.40	337.27	822.70	663.73	43.81	254.66	160.63	612.48	114.50
NPV of supply	10%	584.81	318.91	793.15	640.49	42.28	245.75	133.20	507.90	94.95
URV @	6%	3.69								
URV @	8%	4.21								
URV @	10%	4.75								

Net Present Value and Unit Reference Value Calculation

Mfolozi (Kwesibomvu) On-Channel Dam: 26m-high, pipeline to the Nseleni River

System Yield: 66.6 million m³/a **Implementation period:** 3 years

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)				
		CIVIL	MECH/ELEC	DAMS	TOTAL					
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	2.81	
Pump stations		43.38	175.60		218.99		Mech	4.00%	7.02	
Pipelines		467.36	24.60		491.96		Dams	0.25%	1.93	
Dam				772.65	772.65				**11.76**	
Consulting fees					230.19	Oper. cost			52.86	
Total cost		561.75	200.20	772.65	**1764.79**	Other costs			7.67	

Calendar Year	Year No.	Supply (million m³)	Pump-stations	Pipelines	Dam	Reservoir	Cons fees	Maint cost	Elec cost	Other costs
2014	1		73.00	163.99	257.55	17.00	76.73			
2015	2		73.00	163.99	257.55	17.00	76.73			
2016	3		73.00	163.99	257.55	17.00	76.73			
2017	4	40.40						11.76	52.86	7.67
2018	5	50.80						11.76	52.86	7.67
2019	6	53.70						11.76	52.86	7.67
2020	7	56.80						11.76	52.86	7.67
2021	8	63.60						11.76	52.86	7.67
2022	9	66.60						11.76	52.86	7.67
2023	10	66.60						11.76	52.86	7.67
2024	11	66.60						11.76	52.86	7.67
2025	12	66.60						11.76	52.86	7.67
2026	13	66.60						11.76	52.86	7.67
2027	14	66.60						11.76	52.86	7.67
2028	15	66.60						11.76	52.86	7.67
2029	16	66.60						11.76	52.86	7.67
2030	17	66.60						11.76	52.86	7.67
2031	18	66.60	105.36					11.76	52.86	7.67
2032	19	66.60						11.76	52.86	7.67
2033	20	66.60						11.76	52.86	7.67
2034	21	66.60						11.76	52.86	7.67
2035	22	66.60						11.76	52.86	7.67
2036	23	66.60		14.76				11.76	52.86	7.67
2037	24	66.60						11.76	52.86	7.67
2038	25	66.60						11.76	52.86	7.67
2039	26	66.60						11.76	52.86	7.67
2040	27	66.60						11.76	52.86	7.67
2041	28	66.60						11.76	52.86	7.67
2042	29	66.60						11.76	52.86	7.67
2043	30	66.60						11.76	52.86	7.67
2044	31	66.60						11.76	52.86	7.67
2045	32	66.60						11.76	52.86	7.67
2046	33	66.60	105.36					11.76	52.86	7.67
2047	34	66.60						11.76	52.86	7.67
2048	35	66.60						11.76	52.86	7.67
2049	36	66.60						11.76	52.86	7.67
2050	37	66.60						11.76	52.86	7.67
NPV of supply	6%	897.30	357.31	450.03	688.43	45.44	205.10	169.03	759.49	110.25
NPV of supply	8%	714.40	337.27	433.46	663.73	43.81	197.74	136.31	612.48	88.91
NPV of supply	10%	584.81	318.91	417.89	640.49	42.28	190.82	113.04	507.90	73.73
URV @	6%	3.10								
URV @	8%	3.52								
URV @	10%	3.94								

Net Present Value and Unit Reference Value Calculation

Mfolozi Off-Channel Dam: 2m³/s transfer, 30 million m³, pipeline to the Nseleni River

System Yield: **33 million m³/a** **Implementation period:** **2.5 years**

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)					
		CIVIL	MECH/ELEC	DAMS	TOTAL						
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	2.00		
Pump stations		30.07	122.67		152.75		Mech	4.00%	4.91		
Pipelines		319.59	16.82		336.41		Dams	0.25%	0.22		
Dam				86.28	86.28				**7.13**		
Weir		123.44	97.68		221.12						
Consulting fees					93.96	Operating cost			76.14		
Total cost		400.66	139.49	86.28	**941.51**	Other costs			4.24		

Calendar Year	Year No.	Supply (million m³)	Pump-stations	Pipelines	Dam	Reservoir	Weir	Cons. fees	Maint cost	Elec cost	Other costs
2014	1		61.10	134.56	34.51	20.40	88.45	37.59			
2015	2		61.10	134.56	34.51	20.40	88.45	37.59			
2016	3	11.40	30.55	67.28	17.26	10.20	44.22	18.79	3.56	38.07	2.12
2017	4	33.00							7.13	76.14	4.24
2018	5	33.00							7.13	76.14	4.24
2019	6	33.00							7.13	76.14	4.24
2020	7	33.00							7.13	76.14	4.24
2021	8	33.00							7.13	76.14	4.24
2022	9	33.00							7.13	76.14	4.24
2023	10	33.00							7.13	76.14	4.24
2024	11	33.00							7.13	76.14	4.24
2025	12	33.00							7.13	76.14	4.24
2026	13	33.00							7.13	76.14	4.24
2027	14	33.00							7.13	76.14	4.24
2028	15	33.00							7.13	76.14	4.24
2029	16	33.00							7.13	76.14	4.24
2030	17	33.00							7.13	76.14	4.24
2031	18	33.00	73.60						7.13	76.14	4.24
2032	19	33.00							7.13	76.14	4.24
2033	20	33.00							7.13	76.14	4.24
2034	21	33.00							7.13	76.14	4.24
2035	22	33.00							7.13	76.14	4.24
2036	23	33.00		10.09			58.61		7.13	76.14	4.24
2037	24	33.00							7.13	76.14	4.24
2038	25	33.00							7.13	76.14	4.24
2039	26	33.00							7.13	76.14	4.24
2040	27	33.00							7.13	76.14	4.24
2041	28	33.00							7.13	76.14	4.24
2042	29	33.00							7.13	76.14	4.24
2043	30	33.00							7.13	76.14	4.24
2044	31	33.00							7.13	76.14	4.24
2045	32	33.00							7.13	76.14	4.24
2046	33	33.00	73.60						7.13	76.14	4.24
2047	34	33.00							7.13	76.14	4.24
2048	35	33.00							7.13	76.14	4.24
2049	36	33.00							7.13	76.14	4.24
2050	37	33.00							7.13	76.14	4.24
NPV of supply	6%	458.06	250.97	311.19	77.76	45.97	245.71	84.69	99.95	1068.03	59.44
NPV of supply	8%	364.60	237.40	300.79	75.24	44.48	235.91	81.94	79.75	852.16	47.43
NPV of supply	10%	298.62	224.96	290.98	72.86	43.07	226.76	79.35	65.48	699.73	38.94
URV @	6%	4.90									
URV @	8%	5.36									
URV @	10%	5.83									

Net Present Value and Unit Reference Value Calculation

Mfolozi Off-Channel Dam: 2m^3/s transfer, 30 million m^3, pipeline to Nsezi WTW

System Yield: 33 million m^3/a **Implementation period:** 2.5 years

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)					
		CIVIL	MECH/ELEC	DAMS	TOTAL						
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	3.38		
Pump stations		30.07	122.67		152.75		Mech	4.00%	4.91		
Pipelines		594.15	31.27		625.42		Dams	0.25%	0.22		
Dam				86.28	86.28				**8.50**		
Weir		123.44	97.68		221.12						
Cons. fees					162.84	Oper. cost			76.14		
Total cost		675.23	153.94	86.28	1299.40	Other costs			5.68		

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Dam	Reservoir	Weir	Cons. fees	Maint cost	Elec cost	Other costs
2014	1		61.10	250.17	34.51	20.40	88.45	65.13			
2015	2		61.10	250.17	34.51	20.40	88.45	65.13			
2016	3	11.40	30.55	125.08	17.26	10.20	44.22	32.57	4.25	38.07	2.84
2017	4	33.00							8.50	76.14	5.68
2018	5	33.00							8.50	76.14	5.68
2019	6	33.00							8.50	76.14	5.68
2020	7	33.00							8.50	76.14	5.68
2021	8	33.00							8.50	76.14	5.68
2022	9	33.00							8.50	76.14	5.68
2023	10	33.00							8.50	76.14	5.68
2024	11	33.00							8.50	76.14	5.68
2025	12	33.00							8.50	76.14	5.68
2026	13	33.00							8.50	76.14	5.68
2027	14	33.00							8.50	76.14	5.68
2028	15	33.00							8.50	76.14	5.68
2029	16	33.00							8.50	76.14	5.68
2030	17	33.00							8.50	76.14	5.68
2031	18	33.00	73.60						8.50	76.14	5.68
2032	19	33.00							8.50	76.14	5.68
2033	20	33.00							8.50	76.14	5.68
2034	21	33.00							8.50	76.14	5.68
2035	22	33.00							8.50	76.14	5.68
2036	23	33.00		18.76			58.61		8.50	76.14	5.68
2037	24	33.00							8.50	76.14	5.68
2038	25	33.00							8.50	76.14	5.68
2039	26	33.00							8.50	76.14	5.68
2040	27	33.00							8.50	76.14	5.68
2041	28	33.00							8.50	76.14	5.68
2042	29	33.00							8.50	76.14	5.68
2043	30	33.00							8.50	76.14	5.68
2044	31	33.00							8.50	76.14	5.68
2045	32	33.00							8.50	76.14	5.68
2046	33	33.00	73.60						8.50	76.14	5.68
2047	34	33.00							8.50	76.14	5.68
2048	35	33.00							8.50	76.14	5.68
2049	36	33.00							8.50	76.14	5.68
2050	37	33.00							8.50	76.14	5.68
NPV of supply	6%	458.06	250.97	578.54	77.76	45.97	245.71	146.76	119.21	1068.03	79.71
NPV of supply	8%	364.60	237.40	559.21	75.24	44.48	235.91	142.00	95.11	852.16	63.60
NPV of supply	10%	298.62	224.96	540.97	72.86	43.07	226.76	137.51	78.10	699.73	52.22
URV @	6%	5.70									
URV @	8%	6.32									
URV @	10%	6.95									

Net Present Value and Unit Reference Value Calculation

Mfolozi Off-Channel Dam: $2m^3/s$ transfer, 63 million m^3, pipeline to the Nseleni River

System Yield:	**47.12**	**million m^3/a**			**Implementation period:**		**2.5**	**years**			
CAPITAL COST COMPONENTS (R million)						**ANNUAL COST COMPONENTS (R MILLION)**					
		CIVIL	**MECH/ELEC**	**DAMS**	**TOTAL**						
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	2.39		
Pump stations		39.19	159.43		198.62		Mech	4.00%	6.38		
Pipelines		388.24	20.43		408.67		Dams	0.25%	0.38		
Dam				151.86	151.86				**9.15**		
Weir		123.44	97.68		221.12						
Consulting fees					121.52	Operating cost			87.25		
Total cost		478.43	179.86	151.86	**1152.79**	Other costs			5.16		
Calendar Year	**Year No.**	**Supply (million m^3)**	**Pump-stations**	**Pipelines**	**Dam**	**Reservoir**	**Weir**	**Cons. fees**	**Maint cost**	**Elec cost**	**Other costs**
2014	1		79.45	163.47	60.74	20.40	88.45	48.61			
2015	2		79.45	163.47	60.74	20.40	88.45	48.61			
2016	3	11.40	39.72	81.73	30.37	10.20	44.22	24.30	4.57	43.63	2.58
2017	4	40.40							9.15	87.25	5.16
2018	5	47.12							9.15	87.25	5.16
2019	6	47.12							9.15	87.25	5.16
2020	7	47.12							9.15	87.25	5.16
2021	8	47.12							9.15	87.25	5.16
2022	9	47.12							9.15	87.25	5.16
2023	10	47.12							9.15	87.25	5.16
2024	11	47.12							9.15	87.25	5.16
2025	12	47.12							9.15	87.25	5.16
2026	13	47.12							9.15	87.25	5.16
2027	14	47.12							9.15	87.25	5.16
2028	15	47.12							9.15	87.25	5.16
2029	16	47.12							9.15	87.25	5.16
2030	17	47.12							9.15	87.25	5.16
2031	18	47.12	95.66						9.15	87.25	5.16
2032	19	47.12							9.15	87.25	5.16
2033	20	47.12							9.15	87.25	5.16
2034	21	47.12							9.15	87.25	5.16
2035	22	47.12							9.15	87.25	5.16
2036	23	47.12		12.26			58.61		9.15	87.25	5.16
2037	24	47.12							9.15	87.25	5.16
2038	25	47.12							9.15	87.25	5.16
2039	26	47.12							9.15	87.25	5.16
2040	27	47.12							9.15	87.25	5.16
2041	28	47.12							9.15	87.25	5.16
2042	29	47.12							9.15	87.25	5.16
2043	30	47.12							9.15	87.25	5.16
2044	31	47.12							9.15	87.25	5.16
2045	32	47.12							9.15	87.25	5.16
2046	33	47.12	95.66						9.15	87.25	5.16
2047	34	47.12							9.15	87.25	5.16
2048	35	47.12							9.15	87.25	5.16
2049	36	47.12							9.15	87.25	5.16
2050	37	47.12							9.15	87.25	5.16
NPV of supply	6%	643.48	326.26	378.04	136.87	45.97	245.71	109.53	128.33	1223.86	72.33
NPV of supply	8%	510.33	308.63	365.40	132.43	44.48	235.91	105.98	102.39	976.51	57.71
NPV of supply	10%	416.41	292.46	353.49	128.24	43.07	226.76	102.62	84.08	801.82	47.38
URV @	6%	4.14									
URV @	8%	4.56									
URV @	10%	4.99									

Net Present Value and Unit Reference Value Calculation

Mfolozi Off-Channel Dam: 2m^3/s transfer, 63 million m^3, pipeline to Nsezi WTW

System Yield: 47.12million m^3/a **Implementation period:** 2.5 years

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)					
		CIVIL	MECH/ELEC	DAMS	TOTAL						
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	3.99		
Pump stations		39.19	159.43		198.62		Mech	4.00%	6.38		
Pipelines		707.79	37.25		745.04		Dams	0.25%	0.38		
Dam				151.86	151.86				**10.75**		
Weir		123.44	97.68		221.12						
Consulting fees					197.50	Operating cost			87.25		
Total cost		797.98	196.68	151.86	**1565.13**	Other costs			6.84		

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Dam	Reservoir	Weir	Cons. fees	Maint cost	Elec cost	Other costs
2014	1		79.45	298.02	60.74	20.40	88.45	79.00			
2015	2		79.45	298.02	60.74	20.40	88.45	79.00			
2016	3	11.40	39.72	149.01	30.37	10.20	44.22	39.50	5.37	43.63	3.42
2017	4	40.40							10.75	87.25	6.84
2018	5	47.12							10.75	87.25	6.84
2019	6	47.12							10.75	87.25	6.84
2020	7	47.12							10.75	87.25	6.84
2021	8	47.12							10.75	87.25	6.84
2022	9	47.12							10.75	87.25	6.84
2023	10	47.12							10.75	87.25	6.84
2024	11	47.12							10.75	87.25	6.84
2025	12	47.12							10.75	87.25	6.84
2026	13	47.12							10.75	87.25	6.84
2027	14	47.12							10.75	87.25	6.84
2028	15	47.12							10.75	87.25	6.84
2029	16	47.12							10.75	87.25	6.84
2030	17	47.12							10.75	87.25	6.84
2031	18	47.12	95.66						10.75	87.25	6.84
2032	19	47.12							10.75	87.25	6.84
2033	20	47.12							10.75	87.25	6.84
2034	21	47.12							10.75	87.25	6.84
2035	22	47.12							10.75	87.25	6.84
2036	23	47.12		22.35			58.61		10.75	87.25	6.84
2037	24	47.12							10.75	87.25	6.84
2038	25	47.12							10.75	87.25	6.84
2039	26	47.12							10.75	87.25	6.84
2040	27	47.12							10.75	87.25	6.84
2041	28	47.12							10.75	87.25	6.84
2042	29	47.12							10.75	87.25	6.84
2043	30	47.12							10.75	87.25	6.84
2044	31	47.12							10.75	87.25	6.84
2045	32	47.12							10.75	87.25	6.84
2046	33	47.12	95.66						10.75	87.25	6.84
2047	34	47.12							10.75	87.25	6.84
2048	35	47.12							10.75	87.25	6.84
2049	36	47.12							10.75	87.25	6.84
2050	37	47.12							10.75	87.25	6.84
NPV of supply	6%	643.48	326.26	689.19	136.87	45.97	245.71	178.00	150.74	1223.86	95.92
NPV of supply	8%	510.33	308.63	666.16	132.43	44.48	235.91	172.23	120.27	976.51	76.53
NPV of supply	10%	416.41	292.46	644.44	128.24	43.07	226.76	166.78	98.76	801.82	62.84
URV @	6%	4.81									
URV @	8%	5.36									
URV @	10%	5.92									

Net Present Value and Unit Reference Value Calculation

Mfolozi Off-Channel Dam: 2.5m³/s transfer, 39 million m³, pipeline to the Nseleni River

System Yield: **40.82** **million m³/a** **Implementation period:** **2.5** **years**

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)					
		CIVIL	MECH/ELEC	DAMS	TOTAL						
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	2.35		
Pump stations		37.34	151.96		189.30		Mech	4.00%	6.08		
Pipelines		381.78	20.09		401.88		Dams	0.25%	0.25		
Dam				101.23	101.23				**8.68**		
Weir		154.30	122.10		276.40						
Consulting fees					111.51	Operating cost			94.87		
Total cost		470.12	172.05	101.23	**1131.32**	Other costs			5.10		

Calendar Year	Year No.	Supply (million m³)	Pump-stations	Pipelines	Dam	Reservoir	Weir	Cons fees	Maint cost	Elec cost	Other costs
2014	1		75.72	160.75	40.49	20.40	110.56	44.60			
2015	2		75.72	160.75	40.49	20.40	110.56	44.60			
2016	3	3.10	37.86	80.38	20.25	10.20	55.28	22.30	4.34	47.44	2.55
2017	4	11.50							8.68	94.87	5.10
2018	5	22.80							8.68	94.87	5.10
2019	6	40.40							8.68	94.87	5.10
2020	7	40.82							8.68	94.87	5.10
2021	8	40.82							8.68	94.87	5.10
2022	9	40.82							8.68	94.87	5.10
2023	10	40.82							8.68	94.87	5.10
2024	11	40.82							8.68	94.87	5.10
2025	12	40.82							8.68	94.87	5.10
2026	13	40.82							8.68	94.87	5.10
2027	14	40.82							8.68	94.87	5.10
2028	15	40.82							8.68	94.87	5.10
2029	16	40.82							8.68	94.87	5.10
2030	17	40.82							8.68	94.87	5.10
2031	18	40.82	91.18						8.68	94.87	5.10
2032	19	40.82							8.68	94.87	5.10
2033	20	40.82							8.68	94.87	5.10
2034	21	40.82							8.68	94.87	5.10
2035	22	40.82							8.68	94.87	5.10
2036	23	40.82		12.06			73.26		8.68	94.87	5.10
2037	24	40.82							8.68	94.87	5.10
2038	25	40.82							8.68	94.87	5.10
2039	26	40.82							8.68	94.87	5.10
2040	27	40.82							8.68	94.87	5.10
2041	28	40.82							8.68	94.87	5.10
2042	29	40.82							8.68	94.87	5.10
2043	30	40.82							8.68	94.87	5.10
2044	31	40.82							8.68	94.87	5.10
2045	32	40.82							8.68	94.87	5.10
2046	33	40.82	91.18						8.68	94.87	5.10
2047	34	40.82							8.68	94.87	5.10
2048	35	40.82							8.68	94.87	5.10
2049	36	40.82							8.68	94.87	5.10
2050	37	40.82							8.68	94.87	5.10
NPV of supply	6%	514.68	310.96	371.76	91.24	45.97	307.14	100.50	121.78	1330.71	71.52
NPV of supply	8%	401.06	294.15	359.33	88.28	44.48	294.89	97.25	97.17	1061.76	57.07
NPV of supply	10%	321.33	278.75	347.61	85.49	43.07	283.45	94.17	79.79	871.83	46.86
URV @	6%	5.35									
URV @	8%	5.97									
URV @	10%	6.63									

Net Present Value and Unit Reference Value Calculation

Mfolozi Off-Channel Dam: 2.5m³/s transfer, 39 million m³, pipeline to Nsezi WTW

System Yield:	40.82 million m^3/a	Implementation period:	2.5	years

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)					
		CIVIL	MECH/ELEC	DAMS	TOTAL						
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	3.95		
Pump stations		37.34	151.96		189.30		Mech	4.00%	6.08		
Pipelines		701.34	36.91		738.25		Dams	0.25%	0.25		
Dam				101.23	101.23				**10.28**		
Weir		154.30	122.10		276.40						
Consulting fees					195.78	Oper. cost			94.87		
Total cost		789.67	188.87	101.23	**1551.95**	Other costs			6.78		

Calendar Year	Year No.	Supply (million m^3)	Pump-stations	Pipelines	Dam	Reservoir	Weir	Cons fees	Maint cost	Elec cost	Other costs
2014	1		75.72	295.30	40.49	20.40	110.56	78.31			
2015	2		75.72	295.30	40.49	20.40	110.56	78.31			
2016	3	3.10	37.86	147.65	20.25	10.20	55.28	39.16	5.14	47.44	3.39
2017	4	11.50							10.28	94.87	6.78
2018	5	22.80							10.28	94.87	6.78
2019	6	40.40							10.28	94.87	6.78
2020	7	40.82							10.28	94.87	6.78
2021	8	40.82							10.28	94.87	6.78
2022	9	40.82							10.28	94.87	6.78
2023	10	40.82							10.28	94.87	6.78
2024	11	40.82							10.28	94.87	6.78
2025	12	40.82							10.28	94.87	6.78
2026	13	40.82							10.28	94.87	6.78
2027	14	40.82							10.28	94.87	6.78
2028	15	40.82							10.28	94.87	6.78
2029	16	40.82							10.28	94.87	6.78
2030	17	40.82							10.28	94.87	6.78
2031	18	40.82	91.18						10.28	94.87	6.78
2032	19	40.82							10.28	94.87	6.78
2033	20	40.82							10.28	94.87	6.78
2034	21	40.82							10.28	94.87	6.78
2035	22	40.82							10.28	94.87	6.78
2036	23	40.82		22.15			73.26		10.28	94.87	6.78
2037	24	40.82							10.28	94.87	6.78
2038	25	40.82							10.28	94.87	6.78
2039	26	40.82							10.28	94.87	6.78
2040	27	40.82							10.28	94.87	6.78
2041	28	40.82							10.28	94.87	6.78
2042	29	40.82							10.28	94.87	6.78
2043	30	40.82							10.28	94.87	6.78
2044	31	40.82							10.28	94.87	6.78
2045	32	40.82							10.28	94.87	6.78
2046	33	40.82	91.18						10.28	94.87	6.78
2047	34	40.82							10.28	94.87	6.78
2048	35	40.82							10.28	94.87	6.78
2049	36	40.82							10.28	94.87	6.78
2050	37	40.82							10.28	94.87	6.78
NPV of supply @	6%	514.68	310.96	682.91	91.24	45.97	307.14	176.45	144.19	1330.71	95.11
NPV of supply @	8%	401.06	294.15	660.08	88.28	44.48	294.89	170.73	115.05	1061.76	75.89
NPV of supply @	10%	321.33	278.75	638.56	85.49	43.07	283.45	165.33	94.47	871.83	62.31
URV @	6%	6.19									
URV @	8%	6.99									
URV @	10%	7.85									

Net Present Value and Unit Reference Value Calculation

Mfolozi Off-Channel Dam: 2.5m^3/s transfer, 78 million m^3, pipeline to the Nseleni River

System Yield: **56.87** **million m^3/a** **Implementation period:** **2.5** **years**

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)					
		CIVIL	**MECH/ELEC**	**DAMS**	**TOTAL**						
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	2.12		
Pump stations		51.50	207.62		258.76		Mech	4.00%	8.30		
Pipelines		321.66	16.93		338.59		Dams	0.25%	0.46		
Dam				185.87	185.87				10.89		
Weir		154.30	122.10		276.40						
Consulting fees					125.13	Operating cost			111.69		
Total cost		423.80	224.55	185.87	1235.75	Other costs			5.55		
Calendar Year	**Year No.**	**Supply (million m^3)**	**Pump-stations**	**Pipelines**	**Dam**	**Reservoir**	**Weir**	**Cons. fees**	**Maint cost**	**Elec cost**	**Other costs**
2014	1		103.51	135.44	74.35	20.40	110.56	50.05			
2015	2		103.51	135.44	74.35	20.40	110.56	50.05			
2016	3	3.10	51.75	67.72	37.17	10.20	55.28	25.03	5.44	55.85	2.78
2017	4	11.50							10.89	111.69	5.55
2018	5	22.80							10.89	111.69	5.55
2019	6	40.40							10.89	111.69	5.55
2020	7	50.80							10.89	111.69	5.55
2021	8	53.70							10.89	111.69	5.55
2022	9	56.80							10.89	111.69	5.55
2023	10	56.87							10.89	111.69	5.55
2024	11	56.87							10.89	111.69	5.55
2025	12	56.87							10.89	111.69	5.55
2026	13	56.87							10.89	111.69	5.55
2027	14	56.87							10.89	111.69	5.55
2028	15	56.87							10.89	111.69	5.55
2029	16	56.87							10.89	111.69	5.55
2030	17	56.87							10.89	111.69	5.55
2031	18	56.87	124.57						10.89	111.69	5.55
2032	19	56.87							10.89	111.69	5.55
2033	20	56.87							10.89	111.69	5.55
2034	21	56.87							10.89	111.69	5.55
2035	22	56.87							10.89	111.69	5.55
2036	23	56.87		10.16			73.26		10.89	111.69	5.55
2037	24	56.87							10.89	111.69	5.55
2038	25	56.87							10.89	111.69	5.55
2039	26	56.87							10.89	111.69	5.55
2040	27	56.87							10.89	111.69	5.55
2041	28	56.87							10.89	111.69	5.55
2042	29	56.87							10.89	111.69	5.55
2043	30	56.87							10.89	111.69	5.55
2044	31	56.87							10.89	111.69	5.55
2045	32	56.87							10.89	111.69	5.55
2046	33	56.87	124.57						10.89	111.69	5.55
2047	34	56.87							10.89	111.69	5.55
2048	35	56.87							10.89	111.69	5.55
2049	36	56.87							10.89	111.69	5.55
2050	37	56.87							10.89	111.69	5.55
NPV of supply	6%	685.21	424.98	313.21	167.52	45.97	307.14	112.78	152.73	1566.67	77.89
NPV of supply	8%	528.98	402.00	302.74	162.09	44.48	294.89	109.13	121.86	1250.03	62.15
NPV of supply	10%	419.79	380.95	292.87	156.96	43.07	283.45	105.67	100.06	1026.42	51.03
URV @	6%	4.62									
URV @	8%	5.20									
URV @	10%	5.81									

Net Present Value and Unit Reference Value Calculation

Mfolozi Off-Channel Dam: 2.5m^3/s transfer, 78 million m^3, pipeline to Nsezi WTW

System Yield: 56.87 million m^3/a **Implementation period: 2.5 years**

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)					
		CIVIL	**MECH/ELEC**	**DAMS**	**TOTAL**						
Reservoir		51.00			51.00	Maintenance	Civil	0.50%	3.49		
Pump stations		51.15	207.62		258.76		Mech	4.00%	8.30		
Pipelines		596.23	31.38		627.61		Dams	0.25%	0.46		
Dam				185.87	185.87				12.26		
Weir		154.30	122.10		276.40						
Consulting fees					202.30	Operating cost			111.69		
Total cost		698.37	239.00	185.87	1601.93	Other costs			7.00		
Calendar Year	**Year No.**	**Supply (million m^3)**	**Pump-stations**	**Pipelines**	**Dam**	**Reservoir**	**Weir**	**Cons. fees**	**Maint cost**	**Elec cost**	**Other costs**
2014	1		103.51	251.04	74.35	20.40	110.56	80.92			
2015	2		103.51	251.04	74.35	20.40	110.56	80.92			
2016	3	3.10	51.75	125.52	37.17	10.20	55.28	40.46	6.13	55.85	3.50
2017	4	11.50							12.26	111.69	7.00
2018	5	22.80							12.26	111.69	7.00
2019	6	40.40							12.26	111.69	7.00
2020	7	50.80							12.26	111.69	7.00
2021	8	53.70							12.26	111.69	7.00
2022	9	56.80							12.26	111.69	7.00
2023	10	56.87							12.26	111.69	7.00
2024	11	56.87							12.26	111.69	7.00
2025	12	56.87							12.26	111.69	7.00
2026	13	56.87							12.26	111.69	7.00
2027	14	56.87							12.26	111.69	7.00
2028	15	56.87							12.26	111.69	7.00
2029	16	56.87							12.26	111.69	7.00
2030	17	56.87							12.26	111.69	7.00
2031	18	56.87	124.57						12.26	111.69	7.00
2032	19	56.87							12.26	111.69	7.00
2033	20	56.87							12.26	111.69	7.00
2034	21	56.87							12.26	111.69	7.00
2035	22	56.87							12.26	111.69	7.00
2036	23	56.87		18.83			73.26		12.26	111.69	7.00
2037	24	56.87							12.26	111.69	7.00
2038	25	56.87							12.26	111.69	7.00
2039	26	56.87							12.26	111.69	7.00
2040	27	56.87							12.26	111.69	7.00
2041	28	56.87							12.26	111.69	7.00
2042	29	56.87							12.26	111.69	7.00
2043	30	56.87							12.26	111.69	7.00
2044	31	56.87							12.26	111.69	7.00
2045	32	56.87							12.26	111.69	7.00
2046	33	56.87	124.57						12.26	111.69	7.00
2047	34	56.87							12.26	111.69	7.00
2048	35	56.87							12.26	111.69	7.00
2049	36	56.87							12.26	111.69	7.00
2050	37	56.87							12.26	111.69	7.00
NPV of supply	6%	685.21	424.98	580.56	167.52	45.97	307.14	182.33	171.98	1566.67	98.16
NPV of supply	8%	528.98	402.00	561.16	162.09	44.48	294.89	176.42	137.22	1250.03	78.32
NPV of supply	10%	419.79	380.95	542.86	156.96	43.07	283.45	170.83	112.68	1026.42	64.31
URV @	6%	5.17									
URV @	8%	5.87									
URV @	10%	6.63									

Net Present Value and Unit Reference Value Calculation

Nseleni Dam: 1MAR Dam (43.110 million m^3)

System Yield:	7.00	million m^3/a	Implementation period:		2.25	years
CAPITAL COST COMPONENTS (R million)			**ANNUAL COST COMPONENTS (R MILLION)**			
	DAMS	**TOTAL**				
Dam	142.95	142.95	Maintenance	Dams	0.25%	0.36
						0.36
Consulting fees		21.44				
Total cost	142.95	**164.39**	Other costs			0.71
Calendar Year	**Year No.**	**Supply (million m^3)**	**Dam**	**Consulting fees**	**Maint cost**	**Other costs**
2014	1		63.53	9.53		
2015	2		63.53	9.53		
2016	3	5.25	15.88	2.38	0.27	0.54
2017	4	7.00			0.36	0.71
2018	5	7.00			0.36	0.71
2019	6	7.00			0.36	0.71
2020	7	7.00			0.36	0.71
2021	8	7.00			0.36	0.71
2022	9	7.00			0.36	0.71
2023	10	7.00			0.36	0.71
2024	11	7.00			0.36	0.71
2025	12	7.00			0.36	0.71
2026	13	7.00			0.36	0.71
2027	14	7.00			0.36	0.71
2028	15	7.00			0.36	0.71
2029	16	7.00			0.36	0.71
2030	17	7.00			0.36	0.71
2031	18	7.00			0.36	0.71
2032	19	7.00			0.36	0.71
2033	20	7.00			0.36	0.71
2034	21	7.00			0.36	0.71
2035	22	7.00			0.36	0.71
2036	23	7.00			0.36	0.71
2037	24	7.00			0.36	0.71
2038	25	7.00			0.36	0.71
2039	26	7.00			0.36	0.71
2040	27	7.00			0.36	0.71
2041	28	7.00			0.36	0.71
2042	29	7.00			0.36	0.71
2043	30	7.00			0.36	0.71
2044	31	7.00			0.36	0.71
2045	32	7.00			0.36	0.71
2046	33	7.00			0.36	0.71
2047	34	7.00			0.36	0.71
2048	35	7.00			0.36	0.71
2049	36	7.00			0.36	0.71
2050	37	7.00			0.36	0.71
NPV of supply @	6%	99.84	129.82	19.47	5.10	10.19
NPV of supply @	8%	79.96	125.91	18.89	4.08	8.16
NPV of supply @	10%	65.92	122.20	18.33	3.37	6.73
URV @	6%	1.65				
URV @	8%	1.96				
URV @	10%	2.29				

Net Present Value and Unit Reference Value Calculation

Nseleni Dam: 1.5MAR Dam (64.665 million m^3)

System Yield:	10.60	million m^3/a		Implementation period:		2.25	years
CAPITAL COST COMPONENTS (R million)			**ANNUAL COST COMPONENTS (R MILLION)**				
	DAMS	**TOTAL**					
Dam	150.60	150.60	Maintenance	Dams		0.25%	0.38
							0.38
Consulting fees		22.59					
Total cost	150.60	**173.19**	Other costs				0.75
Calendar Year	**Year No.**	**Supply (million m^3)**	**Dam**	**Consulting fees**		**Maint cost**	**Other costs**
2014	1		66.93	10.04			
2015	2		66.93	10.04			
2016	3	7.95	16.73	2.51		0.28	0.56
2017	4	10.60				0.38	0.75
2018	5	10.60				0.38	0.75
2019	6	10.60				0.38	0.75
2020	7	10.60				0.38	0.75
2021	8	10.60				0.38	0.75
2022	9	10.60				0.38	0.75
2023	10	10.60				0.38	0.75
2024	11	10.60				0.38	0.75
2025	12	10.60				0.38	0.75
2026	13	10.60				0.38	0.75
2027	14	10.60				0.38	0.75
2028	15	10.60				0.38	0.75
2029	16	10.60				0.38	0.75
2030	17	10.60				0.38	0.75
2031	18	10.60				0.38	0.75
2032	19	10.60				0.38	0.75
2033	20	10.60				0.38	0.75
2034	21	10.60				0.38	0.75
2035	22	10.60				0.38	0.75
2036	23	10.60				0.38	0.75
2037	24	10.60				0.38	0.75
2038	25	10.60				0.38	0.75
2039	26	10.60				0.38	0.75
2040	27	10.60				0.38	0.75
2041	28	10.60				0.38	0.75
2042	29	10.60				0.38	0.75
2043	30	10.60				0.38	0.75
2044	31	10.60				0.38	0.75
2045	32	10.60				0.38	0.75
2046	33	10.60				0.38	0.75
2047	34	10.60				0.38	0.75
2048	35	10.60				0.38	0.75
2049	36	10.60				0.38	0.75
2050	37	10.60				0.38	0.75
NPV of supply	6%	151.18	136.76	20.51		5.37	10.74
NPV of supply	8%	121.08	132.64	19.90		4.30	8.60
NPV of supply	10%	99.82	128.74	19.31		3.55	7.09
URV @	6%	1.15					
URV @	8%	1.37					
URV @	10%	1.59					

Net Present Value and Unit Reference Value Calculation

Groundwater Scheme 1 (0.71 million m³)

System Yield: **0.71** **million m³/a** — **Implementation period:** **1.25 years**

CAPITAL COST COMPONENTS (R Million)		ANNUAL COST COMPONENTS (R Million)		
Boreholes drilling	3.80	Dams	0.25%	0.00
Borehole equipping	2.60	Civils	0.50%	0.070
Borehole pump testing	0.76	M&E	4.0%	0.141
Collector wellfield sump	1.80	Borehole operation		0.501
Pipelines & pump station	17.70	Borehole maintenance	5.0%	0.130
		PL&PS Op costs		0.351
Total cost	**26.67**	Other costs (Admin)		0.113

Calendar Year	Year No	Supply (million m³)	Boreholes Installation	Pipelines & pump station	Borehole Operation	Borehole Maintenance	PL&PS Maint cost	PL&PS Op costs	Other cost
2014	1		7.17	14.16					
2015	2	0.53	1.79	3.54	0.38	0.10	0.16	0.26	0.09
2016	3	0.71			0.50	0.13	0.21	0.35	0.11
2017	4	0.71			0.50	0.13	0.21	0.35	0.11
2018	5	0.71			0.50	0.13	0.21	0.35	0.11
2019	6	0.71			0.50	0.13	0.21	0.35	0.11
2020	7	0.71			0.50	0.13	0.21	0.35	0.11
2021	8	0.71			0.50	0.13	0.21	0.35	0.11
2022	9	0.71			0.50	0.13	0.21	0.35	0.11
2023	10	0.71			0.50	0.13	0.21	0.35	0.11
2024	11	0.71			0.50	0.13	0.21	0.35	0.11
2025	12	0.71			0.50	0.13	0.21	0.35	0.11
2026	13	0.71			0.50	0.13	0.21	0.35	0.11
2027	14	0.71			0.50	0.13	0.21	0.35	0.11
2028	15	0.71			0.50	0.13	0.21	0.35	0.11
2029	16	0.71			0.50	0.13	0.21	0.35	0.11
2030	17	0.71		8.50	0.50	0.13	0.21	0.35	0.11
2031	18	0.71			0.50	0.13	0.21	0.35	0.11
2032	19	0.71			0.50	0.13	0.21	0.35	0.11
2033	20	0.71			0.50	0.13	0.21	0.35	0.11
2034	21	0.71			0.50	0.13	0.21	0.35	0.11
2035	22	0.71			0.50	0.13	0.21	0.35	0.11
2036	23	0.71			0.50	0.13	0.21	0.35	0.11
2037	24	0.71			0.50	0.13	0.21	0.35	0.11
2038	25	0.71			0.50	0.13	0.21	0.35	0.11
2039	26	0.71			0.50	0.13	0.21	0.35	0.11
2040	27	0.71			0.50	0.13	0.21	0.35	0.11
2041	28	0.71			0.50	0.13	0.21	0.35	0.11
2042	29	0.71			0.50	0.13	0.21	0.35	0.11
2043	30	0.71			0.50	0.13	0.21	0.35	0.11
2044	31	0.71			0.50	0.13	0.21	0.35	0.11
2045	32	0.71		8.50	0.50	0.13	0.21	0.35	0.11
2046	33	0.71			0.50	0.13	0.21	0.35	0.11
2047	34	0.71			0.50	0.13	0.21	0.35	0.11
2048	35	0.71			0.50	0.13	0.21	0.35	0.11
2049	36	0.71			0.50	0.13	0.21	0.35	0.11
2050	37	0.71			0.50	0.13	0.21	0.35	0.11
NPV of supply @	6%	10.21	8.36	30.38	7.21	1.87	3.06	5.05	1.63
NPV of supply @	8%	8.15	8.18	29.14	5.76	1.49	2.44	4.03	1.30
NPV of supply @	10%	6.71	8.00	27.99	4.74	1.23	2.01	3.32	1.07
URV @	6%	5.64							
URV @	8%	6.42							
URV @	10%	7.21							

Net Present Value and Unit Reference Value Calculation
Groundwater Scheme 1 (0.54 million m^3)

System Yield: **0.54** **million m^3/a** — **Implementation period:** **1.25 years**

CAPITAL COST COMPONENTS (R Million)		ANNUAL COST COMPONENTS (R Million)		
Boreholes drilling	3.70	Dams	0.25%	0
Borehole equipping	2.53	Civils	0.50%	0.028
Borehole pump testing	0.74	M&E	4.00%	0.056
Collector wellfield sump	1.44	Borehole operation		0.474
Pipelines & pump station	7.06	Borehole maintenance	5.00%	0.126
		PL&PS Op costs		0.231
Total cost	**15.47**	Other costs (Admin)		0.066

Calendar Year	Year No	Supply (million m^3)	Boreholes Installation	Pipelines & pump station	Borehole Operation	Borehole Maintenance	PL&PS Maint cost	PL&PS Op costs	Other cost
2014	1		6.73	5.65					
2015	2	0.41	1.68	1.41	0.36	0.10	0.06	0.17	0.05
2016	3	0.54			0.47	0.13	0.08	0.23	0.07
2017	4	0.54			0.47	0.13	0.08	0.23	0.07
2018	5	0.54			0.47	0.13	0.08	0.23	0.07
2019	6	0.54			0.47	0.13	0.08	0.23	0.07
2020	7	0.54			0.47	0.13	0.08	0.23	0.07
2021	8	0.54			0.47	0.13	0.08	0.23	0.07
2022	9	0.54			0.47	0.13	0.08	0.23	0.07
2023	10	0.54			0.47	0.13	0.08	0.23	0.07
2024	11	0.54			0.47	0.13	0.08	0.23	0.07
2025	12	0.54			0.47	0.13	0.08	0.23	0.07
2026	13	0.54			0.47	0.13	0.08	0.23	0.07
2027	14	0.54			0.47	0.13	0.08	0.23	0.07
2028	15	0.54			0.47	0.13	0.08	0.23	0.07
2029	16	0.54			0.47	0.13	0.08	0.23	0.07
2030	17	0.54		3.39	0.47	0.13	0.08	0.23	0.07
2031	18	0.54			0.47	0.13	0.08	0.23	0.07
2032	19	0.54			0.47	0.13	0.08	0.23	0.07
2033	20	0.54			0.47	0.13	0.08	0.23	0.07
2034	21	0.54			0.47	0.13	0.08	0.23	0.07
2035	22	0.54			0.47	0.13	0.08	0.23	0.07
2036	23	0.54			0.47	0.13	0.08	0.23	0.07
2037	24	0.54			0.47	0.13	0.08	0.23	0.07
2038	25	0.54			0.47	0.13	0.08	0.23	0.07
2039	26	0.54			0.47	0.13	0.08	0.23	0.07
2040	27	0.54			0.47	0.13	0.08	0.23	0.07
2041	28	0.54			0.47	0.13	0.08	0.23	0.07
2042	29	0.54			0.47	0.13	0.08	0.23	0.07
2043	30	0.54			0.47	0.13	0.08	0.23	0.07
2044	31	0.54			0.47	0.13	0.08	0.23	0.07
2045	32	0.54		3.39	0.47	0.13	0.08	0.23	0.07
2046	33	0.54			0.47	0.13	0.08	0.23	0.07
2047	34	0.54			0.47	0.13	0.08	0.23	0.07
2048	35	0.54			0.47	0.13	0.08	0.23	0.07
2049	36	0.54			0.47	0.13	0.08	0.23	0.07
2050	37	0.54			0.47	0.13	0.08	0.23	0.07
NPV of supply @	6%	7.77	7.85	12.11	6.81	1.82	1.22	3.32	0.95
NPV of supply @	8%	6.20	7.68	11.62	5.44	1.46	0.97	2.65	0.76
NPV of supply @	10%	5.10	7.51	11.16	4.47	1.20	0.80	2.18	0.62
URV @	6%	4.39							
URV @	8%	4.93							
URV @	10%	5.48							

Net Present Value and Unit Reference Value Calculation

Groundwater Scheme 1 (0.30 million m^3)

System Yield: **0.30** **million m^3/a** **Implementation period:** **1.25 years**

CAPITAL COST COMPONENTS (R Million)		ANNUAL COST COMPONENTS (R Million)		
Boreholes drilling	3.90	Dams	0.25%	0.00
Borehole equipping	2.67	Civils	0.50%	0.044
Borehole pump testing	0.78	M&E	4.00%	0.089
Collector wellfield sump	0.90	Borehole operation		0.529
Pipelines & pump station	11.13	Borehole maintenance	5.00%	0.133
		PL&PS Op costs		0.079
Total cost	**19.38**	Other costs (Admin)		0.082

Calendar Year	Year No	Supply (million m^3)	Boreholes Installation	Pipelines & pump station	Borehole Operation	Borehole Maintenance	PL&PS Maint cost	PL&PS Op costs	Other cost
2014	1		6.60	8.90					
2015	2	0.23	1.65	2.23	0.40	0.10	0.10	0.06	0.06
2016	3	0.30			0.53	0.13	0.13	0.08	0.08
2017	4	0.30			0.53	0.13	0.13	0.08	0.08
2018	5	0.30			0.53	0.13	0.13	0.08	0.08
2019	6	0.30			0.53	0.13	0.13	0.08	0.08
2020	7	0.30			0.53	0.13	0.13	0.08	0.08
2021	8	0.30			0.53	0.13	0.13	0.08	0.08
2022	9	0.30			0.53	0.13	0.13	0.08	0.08
2023	10	0.30			0.53	0.13	0.13	0.08	0.08
2024	11	0.30			0.53	0.13	0.13	0.08	0.08
2025	12	0.30			0.53	0.13	0.13	0.08	0.08
2026	13	0.30			0.53	0.13	0.13	0.08	0.08
2027	14	0.30			0.53	0.13	0.13	0.08	0.08
2028	15	0.30			0.53	0.13	0.13	0.08	0.08
2029	16	0.30			0.53	0.13	0.13	0.08	0.08
2030	17	0.30		5.34	0.53	0.13	0.13	0.08	0.08
2031	18	0.30			0.53	0.13	0.13	0.08	0.08
2032	19	0.30			0.53	0.13	0.13	0.08	0.08
2033	20	0.30			0.53	0.13	0.13	0.08	0.08
2034	21	0.30			0.53	0.13	0.13	0.08	0.08
2035	22	0.30			0.53	0.13	0.13	0.08	0.08
2036	23	0.30			0.53	0.13	0.13	0.08	0.08
2037	24	0.30			0.53	0.13	0.13	0.08	0.08
2038	25	0.30			0.53	0.13	0.13	0.08	0.08
2039	26	0.30			0.53	0.13	0.13	0.08	0.08
2040	27	0.30			0.53	0.13	0.13	0.08	0.08
2041	28	0.30			0.53	0.13	0.13	0.08	0.08
2042	29	0.30			0.53	0.13	0.13	0.08	0.08
2043	30	0.30			0.53	0.13	0.13	0.08	0.08
2044	31	0.30			0.53	0.13	0.13	0.08	0.08
2045	32	0.30		5.34	0.53	0.13	0.13	0.08	0.08
2046	33	0.30			0.53	0.13	0.13	0.08	0.08
2047	34	0.30			0.53	0.13	0.13	0.08	0.08
2048	35	0.30			0.53	0.13	0.13	0.08	0.08
2049	36	0.30			0.53	0.13	0.13	0.08	0.08
2050	37	0.30			0.53	0.13	0.13	0.08	0.08
NPV of supply @	6%	4.32	7.70	19.10	7.61	1.92	1.92	1.14	1.18
NPV of supply @	8%	3.45	7.53	18.32	6.08	1.53	1.53	0.91	0.95
NPV of supply @	10%	2.83	7.36	17.60	5.00	1.26	1.26	0.75	0.78
URV @	6%	9.40							
URV @	8%	10.69							
URV @	10%	12.00							

Net Present Value and Unit Reference Value Calculation
Raising Goedertrouw Dam

System Yield:	3.90	million m^3/a	Implementation period:		1.25
CAPITAL COST COMPONENTS (R million)			**ANNUAL COST COMPONENTS (R MILLION)**		
	DAMS	TOTAL			
Dam	77.56	77.56	Maintenance	0.25%	0.19
Calendar Year	**Year No.**	**Supply (million m^3)**	**Dam**	**Maint cost**	
2014	1		62.05		
2015	2		15.51		
2016	3	3.9		0.15	
2017	4	3.9		0.19	
2018	5	3.9		0.19	
2019	6	3.9		0.19	
2020	7	3.9		0.19	
2021	8	3.9		0.19	
2022	9	3.9		0.19	
2023	10	3.9		0.19	
2024	11	3.9		0.19	
2025	12	3.9		0.19	
2026	13	3.9		0.19	
2027	14	3.9		0.19	
2028	15	3.9		0.19	
2029	16	3.9		0.19	
2030	17	3.9		0.19	
2031	18	3.9		0.19	
2032	19	3.9		0.19	
2033	20	3.9		0.19	
2034	21	3.9		0.19	
2035	22	3.9		0.19	
2036	23	3.9		0.19	
2037	24	3.9		0.19	
2038	25	3.9		0.19	
2039	26	3.9		0.19	
2040	27	3.9		0.19	
2041	28	3.9		0.19	
2042	29	3.9		0.19	
2043	30	3.9		0.19	
2044	31	3.9		0.19	
2045	32	3.9		0.19	
2046	33	3.9		0.19	
2047	34	3.9		0.19	
2048	35	3.9		0.19	
2049	36	3.9		0.19	
2050	37	3.9		0.19	
NPV of supply @	6%	56.5	72.34	2.79	
NPV of supply @	8%	45.5	70.75	2.23	
NPV of supply @	10%	37.6	69.23	1.83	
URV @	6%	1.33			
URV @	8%	1.61			
URV @	10%	1.89			

Net Present Value and Unit Reference Value Calculation

Effluent Reuse

System Yield: 10.95 million m³/a **Implementation period:** 1.75 years

CAPITAL COST COMPONENTS (R million)					ANNUAL COST COMPONENTS (R MILLION)		
	CIVIL	MECH/ELEC	TOTAL				
Pump-stations	6.6	9.9	16.5	Maintenance	Civil	0.50%	1.02
Pipelines	7.0		7.0		Mech	4.00%	14.58
WWTW	190.9	354.6	545.5		Dams	0.25%	0.00
Consulting fees			236.16				**15.60**
Total cost	204.5	364.5	**569.0**	Operating cost			2.47
Calendar Year	**Year No.**	**Supply (million m³)**	**Pump-stations and Pipelines**	**WWTW**	**Overhaul**	**Maint cost**	**Elec cost**
2014	1		13.43	311.71	0.00	0.00	0.00
2015	2		10.07	233.79	0.00	11.70	1.85
2016	3	3.10	0.00	16.50	0.00	15.60	2.47
2017	4	11.50	0.00	16.50	0.00	15.60	2.47
2018	5	22.80	0.00	16.50	0.00	15.60	2.47
2019	6	40.40	0.00	16.50	0.00	15.60	2.47
2020	7	50.80	0.00	16.50	0.00	15.60	2.47
2021	8	53.70	0.00	16.50	0.00	15.60	2.47
2022	9	56.80	0.00	16.50	80.00	15.60	2.47
2023	10	56.87	0.00	16.50	0.00	15.60	2.47
2024	11	56.87	0.00	16.50	0.00	15.60	2.47
2025	12	56.87	0.00	16.50	0.00	15.60	2.47
2026	13	56.87	0.00	16.50	0.00	15.60	2.47
2027	14	56.87	0.00	16.50	0.00	15.60	2.47
2028	15	56.87	0.00	16.50	0.00	15.60	2.47
2029	16	56.87	0.00	16.50	80.00	15.60	2.47
2030	17	56.87	0.00	16.50	10.00	15.60	2.47
2031	18	56.87	0.00	16.50	0.00	15.60	2.47
2032	19	56.87	0.00	16.50	0.00	15.60	2.47
2033	20	56.87	0.00	16.50	0.00	15.60	2.47
2034	21	56.87	0.00	16.50	0.00	15.60	2.47
2035	22	56.87	0.00	16.50	0.00	15.60	2.47
2036	23	56.87	0.00	16.50	80.00	15.60	2.47
2037	24	56.87	0.00	16.50	0.00	15.60	2.47
2038	25	56.87	0.00	16.50	0.00	15.60	2.47
2039	26	56.87	0.00	16.50	0.00	15.60	2.47
2040	27	56.87	0.00	16.50	0.00	15.60	2.47
2041	28	56.87	0.00	16.50	0.00	15.60	2.47
2042	29	56.87	0.00	16.50	0.00	15.60	2.47
2043	30	56.87	0.00	16.50	80.00	15.60	2.47
2044	31	56.87	0.00	16.50	0.00	15.60	2.47
2045	32	56.87	0.00	16.50	10.00	15.60	2.47
2046	33	56.87	0.00	16.50	0.00	15.60	2.47
2047	34	56.87	0.00	16.50	0.00	15.60	2.47
2048	35	56.87	0.00	16.50	0.00	15.60	2.47
2049	36	56.87	0.00	16.50	0.00	15.60	2.47
2050	37	56.87	0.00	16.50	0.00	15.60	2.47
NPV of supply @	6%	148.60	22.53	715.04	194.59	211.73	33.55
NPV of supply @	8%	116.45	21.63	653.92	118.98	165.92	26.29
NPV of supply @	10%	94.06	20.80	608.10	76.98	134.02	21.24
URV @	6%	7.92					
URV @	8%	8.47					
URV @	10%	9.15					

Net Present Value and Unit Reference Value Calculation

Desalination of Seawater: Marine Intake

System Yield: 21.9 million m³/a **Implementation period:** 1.75 years

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
	OTHER	CIVIL	MECH /ELEC	DAMS	TOTAL				
Reservoir		59.00			59.00	Maint	Civil	0.50%	4.41
Pump station to Mzingazi		1.48	5.98		7.46		Mech	4.00%	0.24
Pipeline to Mzingazi		25.89	1.36		27.25		Dams	0.25%	0.00
Marine works		299.20	52.80		352.00				**4.65**
Desal plant		497.00	497.00		994.00				
Power supply			20.00		20.00				
Land & site	5.50				5.50		Labour desal		0.76
Access roads	5.50				5.50		Chem cost		0.55
Prof services & cons. fees					773.00		Oper cost		15.80
Total cost	11	882.57	577.14	0.00	2243.71		Other costs		7.35

Calendar Year	Year No.	Supply (Mm³)	Pump-stations	Pipelines	Reservoir	Desal plant	Power supply	Land acq	Access Roads	Cons fees	Desal Labour	Chem Cost	Maint cost	Elec cost	Other cost
2014	1		4.26	15.57	33.71	568.00	11.43	3.14	3.14	441.71	0.00	0.00			
2015	2	2.88	3.20	11.68	25.29	426.00	8.57	2.36	2.36	331.29	2.18	1.58	1.16	3.95	1.84
2016	3	21.90									16.62	12.05	4.65	15.80	7.35
2017	4	21.90									16.62	12.05	4.65	15.80	7.35
2018	5	21.90									16.62	12.05	4.65	15.80	7.35
2019	6	21.90									16.62	12.05	4.65	15.80	7.35
2020	7	21.90									16.62	12.05	4.65	15.80	7.35
2021	8	21.90				24.78					16.62	12.05	4.65	15.80	7.35
2022	9	21.90									16.62	12.05	4.65	15.80	7.35
2023	10	21.90									16.62	12.05	4.65	15.80	7.35
2024	11	21.90									16.62	12.05	4.65	15.80	7.35
2025	12	21.90									16.62	12.05	4.65	15.80	7.35
2026	13	21.90									16.62	12.05	4.65	15.80	7.35
2027	14	21.90				24.78					16.62	12.05	4.65	15.80	7.35
2028	15	21.90									16.62	12.05	4.65	15.80	7.35
2029	16	21.90									16.62	12.05	4.65	15.80	7.35
2030	17	21.90	3.59								16.62	12.05	4.65	15.80	7.35
2031	18	21.90									16.62	12.05	4.65	15.80	7.35
2032	19	21.90									16.62	12.05	4.65	15.80	7.35
2033	20	21.90				24.78					16.62	12.05	4.65	15.80	7.35
2034	21	21.90									16.62	12.05	4.65	15.80	7.35
2035	22	21.90		0.82							16.62	12.05	4.65	15.80	7.35
2036	23	21.90									16.62	12.05	4.65	15.80	7.35
2037	24	21.90									16.62	12.05	4.65	15.80	7.35
2038	25	21.90									16.62	12.05	4.65	15.80	7.35
2039	26	21.90				24.78					16.62	12.05	4.65	15.80	7.35
2040	27	21.90									16.62	12.05	4.65	15.80	7.35
2041	28	21.90									16.62	12.05	4.65	15.80	7.35
2042	29	21.90									16.62	12.05	4.65	15.80	7.35
2043	30	21.90									16.62	12.05	4.65	15.80	7.35
2044	31	21.90									16.62	12.05	4.65	15.80	7.35
2045	32	21.90	3.59			24.78					16.62	12.05	4.65	15.80	7.35
2046	33	21.90									16.62	12.05	4.65	15.80	7.35
2047	34	21.90									16.62	12.05	4.65	15.80	7.35
2048	35	21.90									16.62	12.05	4.65	15.80	7.35
2049	36	21.90									16.62	12.05	4.65	15.80	7.35
2050	37	21.90									16.62	12.05	4.65	15.80	7.35
NPV of supply	6%	302.25	12.72	25.77	54.31	1007.89	18.41	5.06	5.06	711.55	216.42	156.83	64.72	219.80	102.31
NPV of supply	8%	238.99	12.17	25.08	52.90	975.98	17.93	4.93	4.93	693.02	167.96	121.71	51.28	174.14	81.06
NPV of supply	10%	194.62	11.66	24.42	51.55	946.06	17.47	4.81	4.81	675.35	134.29	97.31	41.84	142.10	66.14
URV @	6%	8.60													
URV @	8%	9.97													
URV @	10%	11.40													

Net Present Value and Unit Reference Value Calculation

Desalination of Seawater: Harbour Intake

System Yield: 21.9 million m³/a   Implementation period: 1.75 years

CAPITAL COST COMPONENTS (R million)						ANNUAL COST COMPONENTS (R MILLION)			
	OTHER	CIVIL	MECH /ELEC	DAMS	TOTAL				
Reservoir		59.00			59.00	Maint	Civil	0.50%	3.76
Pump station to Mzingazi		1.48	5.98		7.46		Mech	4.00%	0.24
Pipeline to Mzingazi		25.89	1.36		27.25		Dams	0.25%	0.00
Marine works		168.30	29.70		198.00				
Desal plant		497.00	497.00		994.00				**4.00**
Power supply			20.00		20.00				
Land & site	5.50				5.50		Labour desal		0.759
Access roads	5.50				5.50		Chem cost		0.55
Prof services & cons. fees					773.00		Oper cost		6.37
Total cost	11.00	751.67	554.04	0.00	**2089.71**		Other costs		7.24

Calendar Year	Year No.	Supply (Mm^3)	Pump-stations	Pipelines	Reservoir	Desal plant	Power supply	Land acq	Access Roads	Cons fees	Labour	Chem Cost	Maint cost	Elec cost	Other cost
2014	1		4.26	15.57	33.71	568.00	11.43	3.14	3.14	441.71	0.00	0.00			
2015	2	2.88	3.20	11.68	25.29	426.00	8.57	2.36	2.36	331.29	2.18	1.58	0.00	1.59	1.81
2016	3	21.90									16.62	12.05	0.00	6.37	7.24
2017	4	21.90									16.62	12.05	0.00	6.37	7.24
2018	5	21.90									16.62	12.05	0.00	6.37	7.24
2019	6	21.90									16.62	12.05	0.00	6.37	7.24
2020	7	21.90									16.62	12.05	0.00	6.37	7.24
2021	8	21.90				24.78					16.62	12.05	0.00	6.37	7.24
2022	9	21.90									16.62	12.05	0.00	6.37	7.24
2023	10	21.90									16.62	12.05	0.00	6.37	7.24
2024	11	21.90									16.62	12.05	0.00	6.37	7.24
2025	12	21.90									16.62	12.05	0.00	6.37	7.24
2026	13	21.90									16.62	12.05	0.00	6.37	7.24
2027	14	21.90				24.78					16.62	12.05	0.00	6.37	7.24
2028	15	21.90									16.62	12.05	0.00	6.37	7.24
2029	16	21.90									16.62	12.05	0.00	6.37	7.24
2030	17	21.90	3.59								16.62	12.05	0.00	6.37	7.24
2031	18	21.90									16.62	12.05	0.00	6.37	7.24
2032	19	21.90									16.62	12.05	0.00	6.37	7.24
2033	20	21.90				24.78					16.62	12.05	0.00	6.37	7.24
2034	21	21.90									16.62	12.05	0.00	6.37	7.24
2035	22	21.90		0.82							16.62	12.05	0.00	6.37	7.24
2036	23	21.90									16.62	12.05	0.00	6.37	7.24
2037	24	21.90									16.62	12.05	0.00	6.37	7.24
2038	25	21.90									16.62	12.05	0.00	6.37	7.24
2039	26	21.90				24.78					16.62	12.05	0.00	6.37	7.24
2040	27	21.90									16.62	12.05	0.00	6.37	7.24
2041	28	21.90									16.62	12.05	0.00	6.37	7.24
2042	29	21.90									16.62	12.05	0.00	6.37	7.24
2043	30	21.90									16.62	12.05	0.00	6.37	7.24
2044	31	21.90									16.62	12.05	0.00	6.37	7.24
2045	32	21.90	3.59			24.78					16.62	12.05	0.00	6.37	7.24
2046	33	21.90									16.62	12.05	0.00	6.37	7.24
2047	34	21.90									16.62	12.05	0.00	6.37	7.24
2048	35	21.90									16.62	12.05	0.00	6.37	7.24
2049	36	21.90									16.62	12.05	0.00	6.37	7.24
2050	37	21.90									16.62	12.05	0.00	6.37	7.24
NPV of supply	6%	302.25	12.72	25.77	54.31	1007.89	18.41	5.06	5.06	711.55	216.42	156.83	0.00	88.59	100.76
NPV of supply	8%	238.99	12.17	25.08	52.90	975.98	17.93	4.93	4.93	693.02	167.96	121.71	0.00	70.18	79.83
NPV of supply	10%	194.62	11.66	24.42	51.55	946.06	17.47	4.81	4.81	675.35	134.29	97.31	0.00	57.27	65.14
URV @	6%	7.95													
URV @	8%	9.32													
URV @	10%	10.74													

Aurecon South Africa (Pty) Ltd
1977/003711/07
Aurecon Centre
1 Century City Drive
Waterford Precinct
Century City
Cape Town
7441
PO Box 494
Cape Town
8000
South Africa
T +27 21 526 9400
F +27 21 526 9500
E capetown@aurecongroup.com
W aurecongroup.com