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The Implementation and Maintenance of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns

Water Resources Report

FINAL
July 2020

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IMPLEMENTATION AND MAINTENANCE OF THE WATER RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

WATER RESOURCES REPORT

FINAL

JULY 2020

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IMPLEMENTATION AND MAINTENANCE OF THE WATER RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

WATER RESOURCES REPORT

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Inception	1	P WMA 04/W100/00/9118
Economic Growth and Demographic Analysis for the Richards Bay Reconciliation Strategy	2	P WMA 04/W100/00/9218
Water Requirements and Return Flows Report	3	P WMA 04/W100/00/9318
Water Conservation / Water Demand Management	4	P WMA 04/W100/00/9218/4
Water Resources	**5**	**P WMA 04/W100/00/9218/5**
Infrastructure and Cost Assessment	6	
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LIST OF ABBREVIATIONS AND ACRONYMS

BJ	Black Jills Engineers Pty Ltd. (BJE)
CoMLM	City of uMhlathuze Local Municipality
CoV	Coefficient of Variance
DWA	Department of Water Affairs (now DWS)
DWAF	Department of Water Affairs and Forestry (now DWS)
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
EWR	Ecological Water Requirement
FSC	Full Supply Capacity
HFY	Historic Firm Yield
IAPs	Invasive Alien Plants
IFR	Instream Flow Requirement
iX	iX Engineers Pty Ltd.
KCDM	King Cetshwayo District Municipality
KZN	KwaZulu-Natal
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MORFP	Mhlathuze Operating Rules and Future Phasing
MWAAS	Mhlathuze Water Availability Assessment Study
NMAR	Natural Mean Annual Runoff
NMMP	National Microbial Monitoring Programme
NWA	National Water Act
NWU	North-West University
Per.	Percentile (%)
RBM	Richards Bay Minerals
RBWSS	Richards Bay Water Supply System
RDM	Resources Directed Measures
RI	Recurrance Interval
SFRA	Streamflow Reduction Activity
St. dev	Standard Deviation
TDS	Total dissolved salts
WRP	WRP Consulting Engineers Pty Ltd.
WR90	Water Resources Study 1990
WRPM	Water Resources Planning Model
WRYM	Water Resources Yield Model
WSS	Water Supply Scheme
WTW	Water Treatment Works

LIST OF UNITS AND SYMBOLS

counts/100 mR	total coliform bacteria/ 100ml
ha	Hectares
km	Kilometre
km^2	Square kilometre
mamsl	Metres above mean sea level
mbmsl	Metres below mean sea level
mg N/l	milligram Nitrogen concentration
mg/l	milligram per liter
Mℓ/day	Mega Litre per Day
m	Metre
mm	Millimetre
mm/a	Millimetre per Annum
m^3/annum (in text)	Cubic Metre per Annum
m^3/a (in tables)	Cubic Metre per Annum
m^3/s	Cubic Metre per Second
Mm^3	Million cubic metres
Mm^3/a	Million cubic metres per annum
mS/m	millisiemens/meter (electrical conductivity)
NTU	Nephelometric
pH	Alkalinity or basic
%	Percentage

EXECUTIVE SUMMARY

Introduction

The Implementation and Maintenance of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns (this Study) follows on from the *Water Reconciliation Strategy for Richards Bay and Surrounding Towns (2013-2015) (DWA, 2015a)*. The overall objective of this Study was to systematically update and improve the Strategy (2015) in order for the Strategy (2015) to remain technically sound, economically feasible, as well as socially acceptable and sustainable. The objective of this report was to determine the water resources availability at the required assurance of supply in the Study Area.

Overview of Study Area

The main focus of this Study was the Richards Bay Water Supply System (RBWSS). The RBWSS supplies water to the City of uMhlathuze Local Municipality (CoMLM), which comprises the towns of Richards Bay, Empangeni, Ngwelezane and Esikhaweni, as well as a number of rural villages. Furthermore, the RBWSS also supplies large well-developed industries, commercial areas and business centres within the Study Area. The RBWSS's supply area is within the Mhlathuze River Catchment, which is the major water resource, and includes the Goedertrouw Dam on the Mhlathuze River main stem. Water is, however, also sourced from various natural lakes within the Catchment such as Lake Nhlabane, Lake Mzingazi and Lake Cubhu. The Catchment also serves as the resource for agriculture, both irrigated and dryland, afforestation, as well as ecological requirements.

The Mhlathuze River Catchment receives inter-catchment transfers from the Umfolozi River and Thukela (Tugela) River Catchments and, as a result, these Catchments are also part of the Study Area. Additional smaller towns not incorporated in the Strategy (2015), namely, Eshowe, Mtunzini, Melmoth, Gingindlovu and Amatikulu, were included in this Study.

Background and Approach

This report provides an overview and summary of the water resources of the Study Area. The report summarises the hydrology used to determine the water resources availability as well as documents the updates carried out to the water resources models used, including updated current water requirements and projections, environmental water requirements (EWRs), infrastructure components and operating rules. Water resources yields were sourced from previous studies and are summarized in this document. Both historical and stochastic yield results are provided and the yields are therefore quoted in terms of assurance of supply. Scenario analyses have then been undertaken including an assessment of the current situation as well as future possibilities of water augmentation options.

Hydrology

The hydrology developed as part of the Mhlathuze Water Availability Assessment Study (MWAAS) (DWAF, 2009) has been used in the water resources analyses Task of this Study. The hydrology covers a period from 1920 to 2004 and has been produced for 24 delineated quinary catchments. The following Table provides a summary of the hydrological data used per tertiary catchment.

Table i: Hydrology Summary

Major River	Tertiary Catchment	MWAAS MAR (million m^3/annum)
Mhlathuze	W12	555.74
Matugulu	W11	109.71
Mlalazi	W13	119.33

Water Requirements

Water requirements determined as part of a previous Task of this Study were used in this water resources analyses Task. The following Table provides a summary of the water requirements per user sector used.

Table ii: Water Requirement Summary

User	2018 Requirement (million m^3/annum)
Urban	45.9
Industrial/Mining	57.4
Irrigation	128.5
Afforestation	58.1
Alien vegetation	16.8
Dryland Sugarcane	20.7
EWR (most downstream site)	40.3

Infrastructure

The main infrastructure components located in the Study Area were simulated in the water resources models. These include major dams, smaller farms dams lumped together as dummy dams as well as potential future dams. The potential future infrastructure options assessed are a new Dam on the Nseleni River and a new Dam on the Mhlathuzana River as well as the raising of Goedertrouw Dam. The inter-catchment transfer linkages have also been included in the simulations, namely, the transfer from the Thukela River to Goedertrouw Dam and the supply from the Umfolozi River for Richards Bay Minerals.

Operating Rules

Operating rules in the form of drought restriction rules and dam release rules were included in the analyses. The rules were tested to ascertain their suitability and impact on the users' assurance of supply. The results for the Mhlathuze system show that additional yield can be extracted from the system if the dam releases are operated efficiently, and the contribution from the tributary flows at the Mhlathuze weir are used to the maximum.

Water Resources Yields

Yield results were obtained from previous studies. The following Tables provide a summary of the yield analyses results.

Table iii: Yield Results Summary

Dam/System	Historic Firm Yield (Mm^3/annum)	1 in 50 year (98%) Long Term Stochastic Yield (Mm^3/annum)
Mhlathuze system*	245	260
Eshlazi/Rutledge Dam	1.29	1.77

*Note this includes the existing Thukela transfer at 1.08 m^3/s (1.2 m^3/s less 10% losses) which is 34 Mm^3/annum

In order to determine the water resources capabilities of the system at various assurance of supply levels, stochastic yield analyses are undertaken. In addition, varying starting storage levels of the dams are analysed ranging from 100% to 10% in order to incorporate the dam storage levels into the determination of the water resources capabilities. This is referred to as the short term yield capabilities of the system, or short term curves.

Table iv: Short Term Yield Results: Mhlathuze System

	Yield Mm^3/annum at indicated RI					
Starting storage (as % of live FSC)	**1:200**	**1:100**	**1:50**	**1:20**	**1:10**	**1:4**
100%	207.33	214.00	227.44	250.46	269.27	297.76
80%	192.48	202.43	217.12	239.02	261.36	295.86
60%	174.18	184.10	198.77	224.01	247.87	289.51
40%	145.33	158.56	170.54	193.71	226.94	270.59
20%	101.50	114.83	126.15	153.84	179.65	212.59
10%	78.39	87.67	95.95	107.61	132.34	164.74

Table v: Short Term Yield Results: Eshlazi/Rutledge Dams

	Yield Mill m^3/annum at indicated RI [(2)]				
Starting storage (as % of live FSC[(1)])	**1:200**	**1:100**	**1:50**	**1:20**	**1:10**
100%	1.53	1.66	1.81	2.08	2.33
80%	1.50	1.60	1.78	2.02	2.30
60%	1.35	1.48	1.64	1.87	2.11
40%	1.15	1.25	1.40	1.50	1.78
5%	0.80	0.84	0.90	1.10	1.28

Scenario Analysis

The Water Resources Planning Model (WRPM) has been used to undertake scenario analyses for the system. The results indicate that the existing Mhlathuze system will not be able to supply the projected requirements at a satisfactory level of assurance from the year 2021 onwards. However, it is anticipated that, from that year, the additional increased Thukela transfer water will be available for further system augmentation. The users will then be supplied satisfactorily until the year 2039 if the system is operated efficiently.

Groundwater

A detailed lake-groundwater interaction assessment was undertaken during the MWAAS (DWAF, 2009). A model was set up at the time, which produced inputs into the Pitman hydrological model for calibration purposes. As part of this study, the Lake model was revisited, refined and updated. The results were again fed into the Pitman model to determine whether the updates would have an impact on the hydrology. Three hydrology files are affected by the lake-groundwater interactions. No significant changes occurred in two of the files, and the third resulted in a small reduction of runoff. The hydrology used for the WRPM scenarios was updated with this new hydrology. A summary of the adjustments is included in Table vi. An analysis was undertaken to determine the contributing portion of the groundwater to the yield of the system. It was found to be 11.1 million m^3/annum.

Table vi: Summary of Groundwater impacts on hydrology

Lake	Quinary	MAR (MWAAS) (Mm^3/a)	This Study			Comparison
			MAR Groundwater (net) (Mm^3/a)	MAR Surface portion (Mm^3/a)	Total MAR (Mm^3/a)	
Mzingazi	W12J1	52.47	12.45	39.98	52.43	Total MAR almost identical, remain with MWAAS
Nhlabane	W12J2	33.18	4.69	25.71	30.40	New MAR lower, adjust to new hydrology for water resources analyses
Cubhu	W12F2	18.04	3.49	18.09	21.58	New MAR higher, remain with MWAAS to be conservative given lack of observed data for validation purposes

Water Quality

A desktop water quality assessment took place as part of this study. Updated water quality data was gathered from various sources, and summarized. The overall physical and chemical water quality is moderate. The microbial data indicates that there are major quality concerns which can cause severe illness for the users making use of raw water for human consumption directly from rivers and dams. Of major concern is the decrease in water monitoring stations over time, and the complete stop of gathering monitoring data since 2017.

Conclusions and Recommendations

It can be concluded from the water resources analyses work undertaken, that the assurance of supply to water users in the Mhlathuze catchment is satisfactory. However, the catchment relies on further augmentation from the increased Thukela transfer which is currently in its final stages of construction. After that is in place, the catchment should enjoy a surplus water balance for at least another 10 years.

1 INTRODUCTION

1.1 Background to this Study

The Department of Water and Sanitation (DWS) commissioned a study on the Water Reconciliation Strategy for Richards Bay and Surrounding Towns (2013-2015) to inform the planning and implementation of water resource management interventions necessary to reconcile future water requirements and water use patterns up to a period of thirty years until 2044.

For the Reconciliation Strategy for Richards Bay and Surrounding Towns (DWS, 2015a), referred to as the Strategy (2015) hereafter, to be implemented, and for the Strategy (2015) to remain relevant in order to properly fulfil its purpose into the future it has to be dynamic. Hence, the water balance has to be continuously monitored and the developed Strategy has to be regularly updated and maintained. This would ensure that planned intervention options to be implemented will also consider any changes, including climate change, that may have potential impacts on the projected water balance.

The DWS commissioned the Implementation and Maintenance of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns Study, referred to as this Study hereafter, to facilitate a process to maintain the relevance of the Strategy (2015).

1.2 Objectives of this Study

The overall objective of this Study was to systematically update and improve the Strategy (2015) in order for the Strategy (2015) to remain technically sound, economically feasible, as well as socially acceptable and sustainable. To assist with this, this Study has been divided into a number of tasks, each focusing on various aspects that will support the updating of the Strategy (2015).

This report provides an overview and summary of the water resources of the Study Area. The report summarises the hydrology used to determine the water resources availability as well as documenting the updates carried out to the water resources models used, including updated current water requirements and projections, environmental water requirements (EWRs), infrastructure components and operating rules. Water resources analyses were undertaken to determine the capability in terms of yield of the existing water resources. Furthermore, scenario analyses were undertaken including an assessment of the current situation as well as future possibilities of water augmentation options. The results of this water resources analyses Task were used as inputs in the formulation of the Final Strategy prepared for the Study Area.

1.3 Study Area

The main focus of this Study was the Richards Bay Water Supply System (RBWSS). The RBWSS supplies water to the City of uMhlathuze Local Municipality (CoMLM), which comprises the towns of Richards Bay, Empangeni, Ngwelezane and Esikhaweni, as well as a number of rural villages. Furthermore, the RBWSS also supplies large well-developed industries, commercial areas and business centres within the Study Area. The RBWSS's supply area is within the Mhlathuze River Catchment, which is the major water resource. Water is, however, also sourced from various natural lakes within the Catchment such as Lake Nhlabane, Lake Mzingazi and Lake Cubhu. The Catchment also serves as the resource for agriculture, both irrigated and dryland, afforestation, as well as ecological requirements.

The Study Area includes the Mhlathuze River Catchment as illustrated in **Figure 1.1**. The Mhlathuze River Catchment receives inter-catchment transfers from the Umfolozi River and Thukela (Tugela) River Catchments and, as a result, these Catchments are also part of the Water Supply System/Study Area. Additional smaller towns not incorporated in the Strategy

(2015), namely, Eshowe, Mtunzini, Melmoth, Gingindlovu and Amatikulu, were included in this Study.

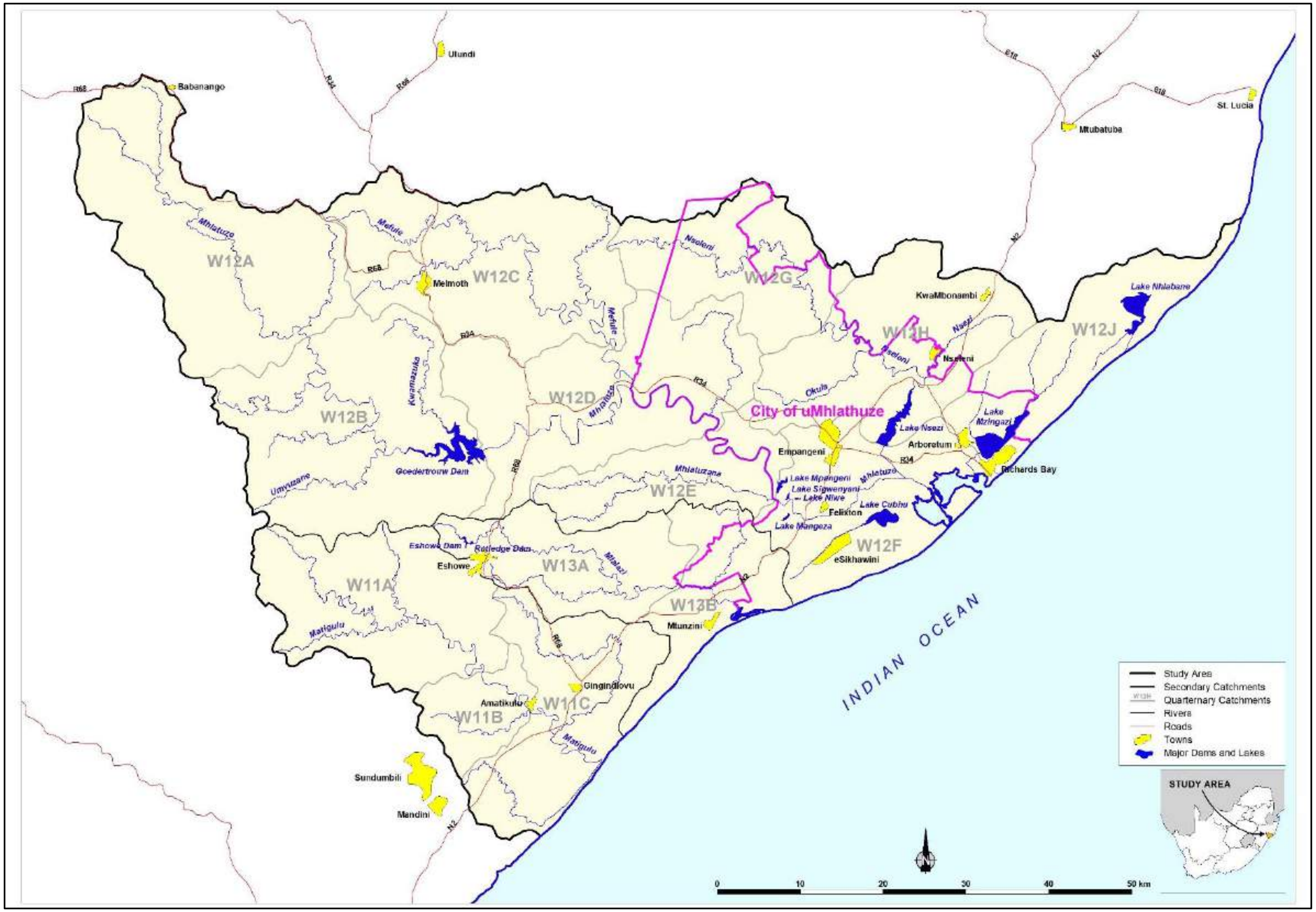


Figure 1.1: Locality map of the Study Area

1.4 Overview of the Reconciliation Strategy (2015)

The Strategy (2015) undertook some yield analyses as presented in the Yield Analyses Report. Various scenarios were assessed and compared with results from the Mhlathuze Water Availability Assessment Study (MWAAS) (DWAF, 2009), which was a detailed hydrological and water resources study carried out in the area prior to the undertaking of the Strategy (2015). However, in the Final Strategy Report, the yields (water availability) used in the water balance plots was the same value as obtained from the MWAAS. The figure used for the existing yield was 247 million m^3/annum which was determined to be 214.3 million m^3/annum from the Mhlathuze system and 32.7 million m^3/annum from the existing Thukela Transfer operational at the time of the Strategy (2015).

1.5 Purpose and Structure of this Report

The Water Resources Planning Model (WRPM) has been updated for use in this study. This report describes the process on updating the WRPM as well as the scenario analyses undertaken and the results obtained.

This Report comprises of the following sections:

- **Section 1** provides a formal overview of the Study Area, this strategy and the purpose and structure of this report.
- **Section 2** presents an overview of previous water resources studies that were undertaken in the Study area over the past ten years and that are relevant to the work undertaken as part of this task.
- **Section 3** provides a summary of all the related aspects that have an effect on the water resources such as, hydrological and climate data, water resources infrastructure, water requirements including Environmental Water Requirements and operating rules.
- **Section 4** presents a summary of the yield analyses that were undertaken in the study area.
- **Section 5** covers the scenario planning analyses that were undertaken.
- **Section 6** provides an overview of the Groundwater assessment that was undertaken.
- **Section 7** provides an overview of the Water Quality assessment that was undertaken.
- **Section 8** contains the conclusions and recommendations to this report.
- **Section 9** indicates the study references.

2 OVERVIEW OF PREVIOUS WATER RESOURCES STUDIES

2.1 Historical

Various studies were undertaken in the Mhlathuze catchment over the years. A Reconnaissance Study undertaken in 1990 indicated that the Mhlathuze River system needs augmentation. This led to the commissioning of a Prefeasibility Study and a subsequent detailed Feasibility Study that recommended the system should be augmented from the Thukela River. Based on this recommendation a White Paper was tabled in Parliament in 1994 with the title "Proposed Tugela-Mhlathuze River Government Water Scheme" (DWAF, 1994). Due to a shortage of funds an emergency drought relief scheme only was built, commonly known as the Thukela-Mhlathuze (Middeldrift) Transfer Scheme, with a transfer capacity of 1.2 m^3/s. Mhlathuze Water commissioned a further study during 1997/98 to assess the feasibility of alternatives to the proposed Phase 1 of the permanent Thukela-Mhlathuze Transfer Scheme.

2.2 MORFP

The Mhlathuze Operating Rules and Future Phases Study (MORFP) (DWAF, 2001) followed on from the work of the previous investigations and was commissioned by the Department of Water Affairs and Forestry and Mhlathuze Water in 1998. The main tasks of the study were to:

- Update the surface hydrological database using all available rainfall data with the aim to improve the confidence of the streamflow time series that are used in the water resource models.
- Undertake an assessment to determine the interaction between the groundwater and lakes. This was undertaken by specialists of the University of Zululand.
- Determine and revise the water demand projections for existing and possible future users supplied from the system.
- Determine the system operating rule and in particular the operation of the transfer from the Thukela River. This also involved the re-evaluation of the yield capability of the system as a whole, as well as of selected components.
- Schedule the implementation of future augmentation schemes based on selected scenarios of demand projections and possible future system configuration.

2.3 MWAAS

The Mhlathuze Water Availability Assessment Study (MWAAS) (DWAF, 2009) was one of five major Studies undertaken by DWAF on selected priority catchment areas throughout South Africa between 2005 and 2009. The Study undertook a detailed hydrological analyses and developed a Water Resources Model to assist with decisions relating to Compulsory Licensing and future water resources planning in the catchment.

2.4 Licensing Support

Subsequent to the MWAAS, a "Maintenance" Study was undertaken to support the Compulsory Licensing Exercise that took place in the catchment between 2010 and 2012 (DWA, 2012a). The Water Resources model was updated using various scenarios of water requirements based on the Verification Study as well as the information that was obtained after the Call for Licenses went out to water users. The output of the Licensing Study was the final Allocation Schedule of water use for various sectors throughout the catchment, which was Gazetted and therefore obtained legal status in 2015.

2.5 Reserve Study

Despite having already included an allocation for the Environmental Reserve in the Final Allocation Schedule produced from the Maintenance Study, further work on the Reserve took place in a Study titled "Reserve Determination Studies for Selected Surface Water, Groundwater, Estuaries and Wetlands in the Usutu/Mhlathuze Water Management Area" (DWS, 2015b). The work included producing Desktop Reserves and extrapolating them to various EWR sites throughout the catchment.

2.6 Reconciliation Strategy

The Reconciliation Strategy Study, which this Study is following on from, was completed in 2015. The Study produced a Water Resources Analyses Report (DWS, 2015d), which summarised work that was carried out to determine the available resources in the catchment. However, it should be noted that in the final reconciliation water balance plots, the existing water resources available value is equal to the yield determined in the MWAAS. It appears that the Reconciliation Strategy therefore made use of the MWAAS results.

2.7 Operational and Other Studies

All Towns Reconciliation Strategies were undertaken on the surrounding towns in the Study Area (Melmoth, Mtunzini, Gingindlovu and Eshowe) (DWA, 2011a,b,c,d). The Stand Alone Dams Operating Rules Project included water resources analyses of Rutledge and Eshlazi Dams (DWS, 2016). An annual operating analyses was undertaken for Goedertrouw Dam in 2017 and in 2019 (DWS, 2017 & DWS, 2019).

3 ASPECTS IMPACTING WATER RESOURCES

3.1 Hydrology

3.1.1 Catchment Delineation and Natural Flows

The catchments included in this Study are summarised in **Table 3.1**. The quinary sub-catchment delineations were maintained since the original MWAAS hydrology subdivisions. **Figure 3.1** presents a map of the catchments and delineations. In total, there are 24 sub-catchments in the study area, and an additional hydrological file that represents the total natural flows in the Umfolozi system. The Mean Annual Runoff (MAR) for each sub-catchment provided in the Table are as per the MWAAS Study and cover the time period 1920 to 2003 (hydrological years).

Table 3.1: Hydrology Summary

Major River	Tertiary Catchment	Quaternary Catchment	Quinary Catchments	Contributing Area (km^2)	MWAAS MAR (Mm^3/annum)
Mhlathuze	W12	W12A	W12A1	624	64.81
		W12B	W12B1	657	91.88
		W12C	W12C1	227	26.88
			W12C2	344	23.92
		W12D	W12D1	278	29.33
			W12D2	293	29.02
		W12E	W12E1	76	8.81
			W12E2	172	23.13
		W12F	W12F1	177	40.55
			W12F2	71	18.04
			W12F3	101	25.02
		W12G	W12G1	326	26.77
		W12H	W12H1	485	61.93
		W12J	W12J1	110	52.47
			W12J2	168	33.18
Amatigulu	W11	W11A	W11A1	445	55.17
		W11B	W11B1	127	17.53
		W11C	W11C1	102	14.98
			W11C2	109	22.03
			W11C3	172	31.47
Mlalazi	W13	W13A	W13A1	36	9.60*
			W13A2	166	44.69*
			W13A3	74	20.24*
		W13B	W13B1	171	44.80
Umfolozi	W21				571.88

Note *: This hydrology was updated as part of the Development of Operating Rules for Water Supply and Drought Management for Stand-Alone Dams and Schemes: Eastern Cluster: The Eshowe Water Supply Scheme: Rutledge and Eshlazi Dams Study (DWS, 2016), and therefore superseded the MWAAS hydrology.

It is important to note that some portions of the catchment do not contribute to any runoff, and therefore the catchment areas presented in **Table 3.1** above do not reflect the total catchment areas but rather the contributing catchment areas.

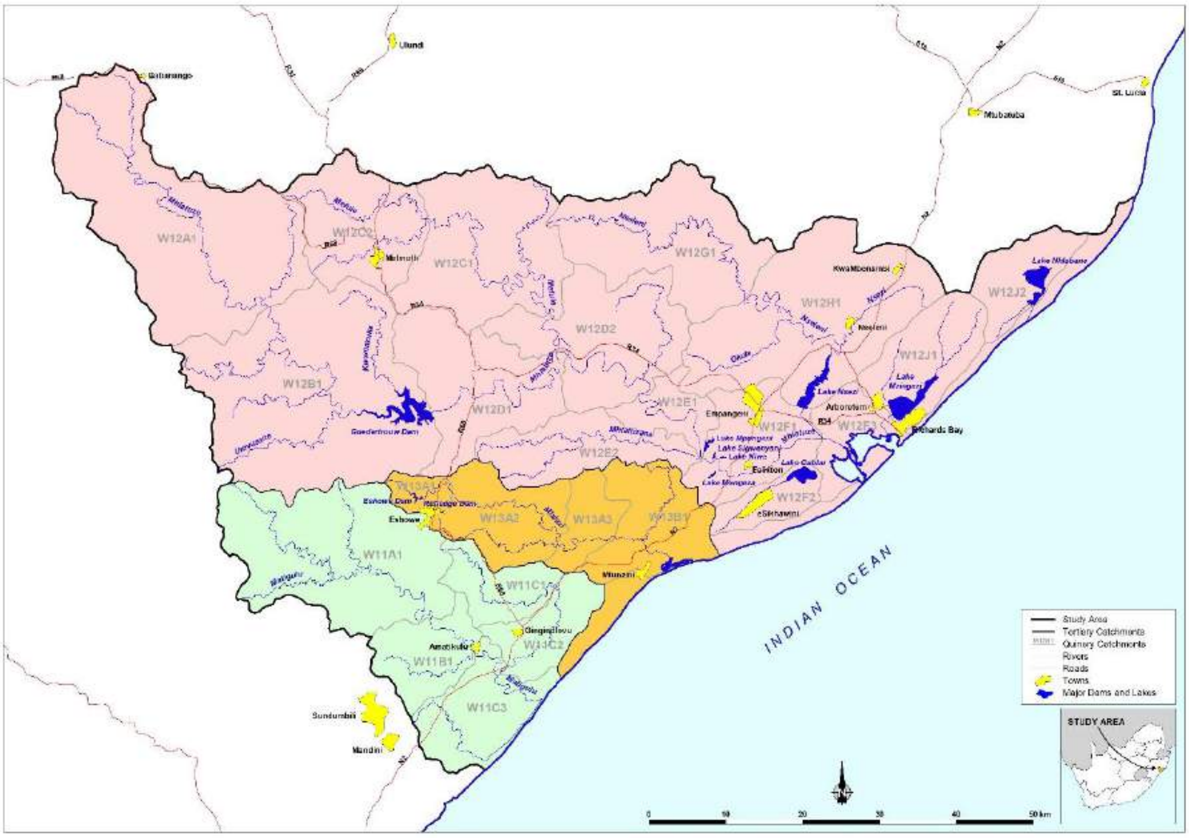


Figure 3.1: Catchment Study Area showing quinary sub-catchments

3.1.2 Rainfall

Each of the 24 sub-catchments have an associated rainfall file. This file represents the rainfall over the historical period (1920 to 2003). **Table 3.2** provides a summary of the Mean Annual Precipitation (MAP) for each sub-catchment. The rainfall data was collected and collated as part of the hydrology assessment of the MWAAS (DWAF, 2009). Detailed evaluation and patching of the rainfall took place as part of that Study.

Table 3.2: Mean Annual Precipitation per sub-catchment (1920-2003)

Rainfall file name	MAP (mm)	Rainfall file name	MAP (mm)	Rainfall file name	MAP (mm)
W11a1.ran	1063.16	W12A1.RAN	811.96	W13A1.RAN	1204.15
W11B1.RAN	1077.11	W12B1.RAN	856.97	W13A2.RAN	1100.05
W11C1.RAN	1103.95	W12C1.RAN	798.95	W13A3.RAN	1166.03
W11C2.ran	1209.97	W12C2.RAN	913.01	W13B1.RAN	1258.03
W11C3.RAN	1172.96	W12D1.RAN	888.03		
		W12D2.ran	869.01		
		W12E1.RAN	1034.97		

Rainfall file name	MAP (mm)	Rainfall file name	MAP (mm)	Rainfall file name	MAP (mm)
		W12E2.RAN	1072.05		
		W12F1.RAN	1191.95		
		W12F2.RAN	1324.00		
		W12F3.RAN	1293.93		
		W12G1.RAN	798.96		
		W12H1.RAN	1058.03		
		W12J1.RAN	1305.98		
		W12J2.RAN	1321.98		

3.2 Water Resources Infrastructure

3.2.1 Large Reservoirs and Lakes

Table 3.3 provides a summary of the large storage reservoirs and lakes simulated explicitly in the Study Area.

Table 3.3: Summary of Lakes and Dams in Study Area

Quaternary Catchment	Details	Full capacity (million m^3)	Minimum Capacity associated with Lake maintenance level* (million m^3)
W12B	Goedertrouw Dam	301.26	1.2
W12H	Lake Nsezi	4.95	0.02
W12F	Lake Cubhu	6.09	2.46
W12J	Lake Nhlabane	39.7	17.1
W12J	Lake Mzingazi	37.6	16.9
W13A	Eshowe & Rutledge Dam	1.12	0.09

Note *: This level is to protect the Lake from an environmental perspective, and the Lake should not be drawn lower than this level except in extreme emergencies.

3.2.2 Transfers, Pipelines and canals

Table 3.4 provides a summary of the infrastructure components included in the water resources model. The associated channel number with reference to the Network Diagrams presented in **Appendix A** is also provided in the Table.

Table 3.4: Summary of transfers and infrastructure capacities

Channel No.	Details	Capacity
170	Thukela (Middledrift) existing transfer and increase capacity as per emergency intervention. Channel enters Umvuzane River upstream of Goedertrouw Dam	1.08 m^3/s till May 2021, thereafter 1.98 m^3/s. This is 1.2 m^3/s and 2.2 m^3/s less 10% for losses and outages
319	Secondary supply from Mhlathuze weir to Esikhaweni WTW, to be used when Lake	Maximum capacity 15000 m^3/day, 0.173 m^3/s

Channel No.	Details	Capacity
	Cubhu drops below maintenance level	
645	Mhlathuze weir directly to Tronox	Maximum capacity 48000 m^3/day, 0.565 m^3/s
108	Mhlathuze weir to Lake Nsezi/Nsezi WTW	Maximum capacity 3.5 m^3/s
140	Secondary supply from Nsezi WTW to Richards Bay, to be used when Lake Mzingazi drops below maintenance level and Mzingazi WTW shuts down	Maximum capacity 48840 m^3/day, 0.555 m^3/s
150	Transfer from Umfolozi to RBM	Maximum capacity 2 m^3/s

3.2.3 Potential New Dams

Three additional resources in terms of dams have previously been mentioned as possible options for the Mhlathuze Catchment. These are as follows, with their locations presented in **Figure 3.2**:

- Nseleni Dam (Strategy (2015) intervention);
- Dam on the Mhlathuzana River (CoMLM proposed option);
- Off Channel storage dam on the Mfolozi River (Strategy (2015) intervention).

Mhlathuze Water is initiating a Study to further ascertain the feasibility of these options. A detailed water resources assessment will therefore be undertaken as part of this Study. For the purpose of this Reconciliation update, however, some assumptions were made in order to include the future options in this Study and to get an understanding of the possible impact they could have on the system. The assumptions are presented in **Table 3.5**.

Table 3.5: Possible Dam options

Option	Location	Capacity	Availability determination methodology
Nseleni Dam	Nseleni River (W12H) upstream of Nseleni, Nsezi River confluence	1 MAR: 55 million m^3	Configured into WRPM and undertook scenario
Mhlathuzana Dam	Outlet of Mhlathuzana River (W12E2) before confluence with Mhlathuze	0.3 MAR: 7 million m^3	Configured into WRPM and undertook scenario
Umfolozi off-channel	Umfolozi Catchment	NA	Made use of result of Reconciliation Strategy (2015)

It should be noted that the Umfolozi River hydrology has never been developed on a detailed level as required before any large capital investment decisions are made, and a study to update the hydrology has been flagged as urgent. Only after this study has been undertaken can the additional availability from an off channel dam on the Umfolozi be stated with confidence.

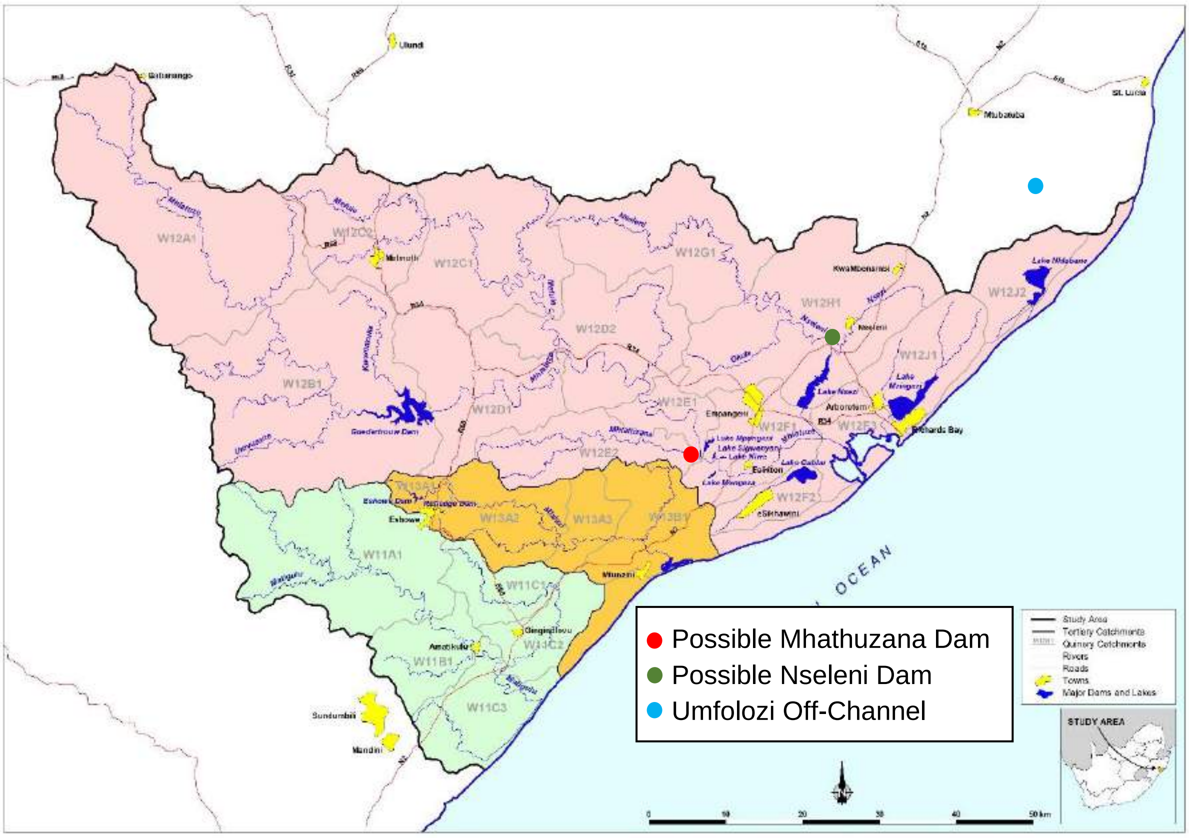


Figure 3.2: Possible New Dam sites

3.3 Water Requirements

The water requirements used in the water resources analyses task were sourced from the water requirements assessment and update completed as part of this Study (DWS, 2018). The following sub-sections provide a summary of the water requirements per user sector.

3.3.1 Urban and Industrial Demands

The water requirement task of this Study (DWS, 2018a) undertook to update current use and future water requirements for the urban demand centres as well as the industrial users included in the Study area. The future requirement projections were determined by considering both population growth determined from the demographic assessment (DWS, 2018b) as well as the projected improvement in level of services supplied to the users. Bulk industrial users were engaged with in order to obtain their projections. **Table 3.6** provides a summary of the urban and industrial water requirements.

Table 3.6: Urban and Industrial water requirement projections

Demand	Channel no.	Requirement (Mm^3/annum)					
		2018	2025	2030	2035	2040	2045
RBM smelter	323	5.6	8.1	8.1	8.1	8.1	8.1
RBM ponds	146	14.4	20.7	20.7	20.7	20.7	20.7
Foskor potable	641	4	5.6	5.6	5.6	5.6	5.6
Rich Bay	167	10.93	12.96	14.63	16.46	18.55	20.93
Foskor clarified	638	3	4.4	4.4	4.4	4.4	4.4

Demand	Channel no.	Requirement (Mm³/annum)					
		2018	2025	2030	2035	2040	2045
Rich Bay	637	6.19	7.34	8.28	9.33	10.51	11.85
Nseleni	118	4.74	5.78	6.56	7.37	8.2	9.3
Ngwelezane	89	2.47	2.95	3.32	3.74	4.18	4.72
Esikhaweni	636	10.86	12.51	13.84	15.29	16.87	18.65
Empangeni	127	8.55	10.57	12.29	14.19	16.36	18.97
Tronox	635	5.80	17.83	17.83	20.26	20.26	20.26
Mondi	644	20.1	20.1	20.1	20.1	20.1	20.1
Bayside	640	0.11	0.21	0.21	0.21	0.21	0.21
Mpact	135	2.48	2.48	2.48	2.48	2.48	2.48
Tongaat	950	1.9	1.9	1.9	1.9	1.9	1.9
Small Industry	642	0.03	0.03	0.03	0.03	0.03	0.03
Goedertrouw direct (Phobane WTW)	301	1.39	11.16	13.95	13.95	13.95	13.95
Lake Nsezi	648	0.16	1.28	1.60	1.60	1.60	1.60
W12A outlet	649	0.12	0.93	1.16	1.16	1.16	1.16
W12B outet	650	0.02	0.13	0.17	0.17	0.17	0.17
W12C outlet	651	0.33	2.63	3.28	3.28	3.28	3.28
W12E Mhlat River	646	0.14	1.15	1.44	1.44	1.44	1.44
Eshowe	503	2.23	2.43	2.64	2.85	3.07	3.33
Mtunzini	547	0.49	0.52	0.56	0.60	0.65	0.70
Gingindlovu	860	0.34	0.36	0.37	0.39	0.41	0.43
Melmoth	670	0.92	1.00	1.09	1.17	1.26	1.36

3.3.2 Irrigation

The volume allocated to the irrigation sector in the catchment is 128.5 million m³/annum. A summary per scheme is presented in **Table 3.7**.

Table 3.7: Summary of Final Allocation Schedule for irrigation (DWS, 2015c)

Location	Allocation (Mm³/a)	Represented by irrigation blocks*
1) Heatonville	43.62	116, 117, 118, 119, 140, 141
2) Lower Mhlathuze	7.73	120, 123, 131
3) Mfuli	5.55	114, 129
4) Nkwaleni	57.00	106, 107, 108, 109, 115, 126, 127, 128, 142
5) Other-irrigation	8.93	121, 122, 124, 132, 133
c) Existing licenses under NWA	4.18	
b) Applications for new water uses	1.54	

Location	Allocation (Mm^3/a)	Represented by irrigation blocks*
Total	**128.5**	

* reference irrigation block numbers to network Diagram presented in Appendix A

Some of these applicants are diffuse irrigators, meaning that they obtain their water from tributaries. While their use is considered when determining the available water resources of the Catchment, they will not specifically form part of the water balance of the main Catchment requirements. Furthermore, these users do not form part of an Irrigation Board. Only the Irrigation Boards indicated in **Table 3.7** (Heatonville, Lower Mhlathuze, Mfuli and Nkwaleni) are dependent on the Goedertrouw Dam for their water. Therefore, the volume allocated to irrigation forming part of the water balance is 113.9 million m^3/annum.

3.3.3 Streamflow Reduction Activities

Afforestation

An extensive investigation into the status of existing afforestation in the Mhlathuze Catchment was undertaken during the MWAAS. Subsequently after Validation, Verification and the determination of the existing lawful use, Compulsory Licensing finalized allocated areas and volumes for afforestation. The DWS KZN Regional office have indicated that there is no longer any unlawful afforestation in the Mhlathuze catchment area. A summary of the afforestation per quaternary catchment is provided in **Table 3.8**.

Table 3.8: Summary of afforestation in the Mhlathuze Catchment

Quaternary	Allocated area (ha)	Allocated use average (Mm^3/a)
W12A	15884	11.96
W12B	4306	3.09
W12C	7780	5.66
W12D	720	0.65
W12E	0	0.00
W12F	2803	2.50
W12G	0	0.00
W12H	12348	13.69
W12J	12131	20.57
Total	**55 971**	**58.12**

Alien Vegetation

Invasive Alien Plants (IAPs) can cause a significant reduction in runoff, especially if these plants are riparian. No further information relating to the extent and use of IAPs in the Catchment was available, and therefore the MWAAS data in used in this Study.

Table 3.9: Summary of IAPs in the Mhlathuze Catchment

Quaternary	IAP area (km^2) MWAAS	IAP water use average (Mm^3/a)
W12A	18	2.01
W12B	21	2.5
W12C	10	0.65
W12D	12	0.97
W12E	10	1.43
W12F	41	5.99
W12G	4	0
W12H	11	1.42
W12J	13	1.84
Total	**140**	**16.81**

Dryland Sugarcane

Though not officially declared a Stream Flow Reduction Activity (SFRA) the extent of dryland sugarcane is large in the Catchment, and it is therefore important to consider the impacts thereof. The areas and estimated volumes used by dryland sugarcane are summarized in **Table 3.10**.

Table 3.10: Summary of dryland sugarcane in the Mhlathuze Catchment

Quaternary	Existing area (km^2)	Existing use average (Mm^3/a)
W12A	1	0
W12B	36	2.28
W12C	32	2.61
W12D	16	1.53
W12E	18	1.96
W12F	85	6.65
W12G	3	0.25
W12H	73	5.4
W12J	0	0
Total	**264**	**20.68**

W11 and W13

The SFRAs applicable to the W11 and W13 (Amatikulu and Mlalazi) catchments are summarized in **Table 3.11**.

Table 3.11: SFRA details: W11 and W13 catchments

	SFR Water Use	SFR Areas

Quaternary	Water Use (Mm^3/a)	As a % of Naturalised MAR	Forest (km^2)	IAPs (km^2)	Dryland sugarcane (km^2)	Total (km^2)
W11A	20	27	30	68	97	195
W11B	5	24	1	16	59	76
W11C	14	16	15	38	230	283
W13A	14	25	0	26	91	117
W13B	5	10	35	7	68	110
Total	**58**		**81**	**155**	**545**	**781**

3.3.4 Environmental Water Requirements

The Environmental Water Requirements (EWRs) were first determined for the Mhlathuze Catchment as part of a study running parallel to the MORFP namely the "Mhlathuze System Ecological Reserve (Quantity) Study" (DWAF, 2000). These requirements, known as Instream Flow Requirements (IFRs) at the time were used in the MORFP assessment. No further work had been done on the EWRs by the time the MWAAS was carried out. As a result of the MWAAS hydrology update, and due to the unavailability of updated EWRs, the MWAAS made use of the original IFRs and sites, and merely scaled these based on factors of the new versus old hydrology.

These scaled EWRs were again used during the Licensing Study. However, towards the end of that Study (after the water resources analyses support task was completed) the RDM office finally produced updated EWRs. These were then titled the Preliminary Reserve. The Preliminary Reserve requires more water than what was used in the final allocation schedules, and therefore when it is included, a system balance is not obtained.

The 2015 EWR Study references the existence of the Preliminary Reserve as presented in **Table 3.12**. These EWRs were incorporated into the systems model and will be supplied as a priority over all other users in the Reconciliation update analyses.

Table 3.12: Mhlathuze system EWRs (DWS, 2015a)

Quaternary Catchment	Water Resources	Ecological Reserve (%) MAR	Ecological Reserve Volume (Mm^3/a)	Basic Human Needs (%NMAR)	Total Reserve (%)	NMAR (Mm^3/a)
W12A	Mhlatuze River: Estimated from IFR site 1	38.1	24.7	0.4	38.5	64.8
W12B	Mhlatuze River: IFR site 1	30.5	54.3	0.06	30.6	156.7
W12C	Mhlatuze River: Estimated from IFR site 2	26.3	13.4	0.16	26.4	50.8
W12D	Mhlatuze River: IFR site 3	26.3	70.8	0.14	26.4	195.2
W12D	Mhlatuze River: IFR site 2	26.6	81.8	0.1	26.7	265.8
W12E	Mhlatuze River: IFR site 4	11.4	40.3	0.11	11.5	278.1

Quaternary Catchment	Water Resources	Ecological Reserve (%) MAR	Ecological Reserve Volume (Mm^3/a)	Basic Human Needs (%NMAR)	Total Reserve (%)	NMAR (Mm^3/a)
W12F	Mhlatuze River: IFR site 4	11.4	40.3	0.23	11.6	332.4
W12G	Nseleni River: Estimated from IFR site 1	38	10.2	0.34	38.3	26.8
W12H	Nseleni River: Estimated from IFR site 4	26.1	22.7	0.63	26.7	87.2

The DWS has recently (March 2020) called for proposals to undertake a study to determine the water resource classes of the Mhlathuze system.

3.4 Operating Rules

The operating rules applicable for the releases and transfers in the system are as follows:

- Rules to supply RBM:
- Supply as much as possible of the 9 million m^3/a required for smelter from Lake Nhlabane as a first resort;
- If Lake Nhlabane cannot supply the full 9 million m^3/a demand, supply difference from Mhlathuze Water via Lake Nsezi;
- Supply the required 23 million m^3/a for the ponds from Mfolozi first;
- If Mfolozi is insufficient, then supply from Lake Nhlabane (up to a total limit of 12 million m^3/a including what is supplied for the smelter); and
- Lastly, if the ponds demand is still not met, then supply from Mhlathuze Water via Lake Nsezi (up to a total limit of 16 million m^3/a including what is supplied for the smelter).
- Eshlazi-Rutledge Dams
- Water is released from the larger Eshlazi Dam into Rutledge Dam, where it is abstracted. There are no rules for releasing water from Eshlazi Dam, the amount of water released is determined by observing dam levels, which are conducted twice daily. When Rutledge Dam has drawn down, a decision is made to release water from Eshlazi Dam and the valve would be opened to allow releases for a few days. Eshlazi Dam has a stage gauge, but the levels are not currently being recorded. Rutledge Dam does not have a gauge plate.
- The transfer from the Thukela is to take place when Goedertrouw Dam drops below 75%.

4 WATER RESOURCES YIELDS

The Water Resources Yield Model (WRYM) developed by the DWS and applied countrywide was applied in previous studies to carry out long term historical and stochastic yield analysis as well as short term analysis to determine the yield available for a range of initial dam storages. A brief description of the terminology relating to the yield analyses is as follows:

- Historic Firm Yield: The maximum volume of water that can be abstracted from a resource over the historical observed time period (1920-2004) such that the resource is able to provide the abstracted volume in full each and every year.
- Long Term Yield at various Recurrence Intervals: 201 natural hydrological time series' (known as stochastic sequences) of 85 year record length are analysed in order to determine the system behavior under different hydrological conditions. The analyses allow for some sequences to fail (not supply the abstraction in full) and the results are quoted in assurance of supply depending on how many sequences fail.
- Short Term Yield at various Recurrence Intervals: 501 natural hydrological time series' (known as stochastic sequences) of 5 year record length are analysed in order to determine the system behavior under different hydrological conditions. In this case the resource's starting storage condition is considered as additional yield is available when the resource is fuller compared with when it starts lower.

More information on yield analyses as well as additional terminology such as assurance of supply, recurrence interval etc. can be found in Basson *et. al*, 1994.

4.1 Mhlathuze System

Detailed yield analyses were undertaken during the MWAAS and subsequent further analyses took place during the Support of Compulsory Licensing. No further updates to the WRYM took place as part of this study as the WRPM was used for the water availability assessment. The required yield inputs to the WRPM in the form of the short term curves had already been undertaken. This section provides a summary of the yields of the system.

The water availability in the Mhlathuze system is determined as a system yield (which also includes the groundwater contribution) and not just the yield of the Goedertrouw Dam and relevant Lake resources added together. This is because of the large amount of tributary runoff that occurs between the Goedertrouw Dam and the point of abstractions of the various users. In order to determine the yield, the individual abstractions at their relative locations are withdrawn from the system and combined together in a single yield node. The excess yield (over and above the total use) is abstracted from the point in the system representing the Mhlathuze weir.

Using this approach, the historic firm yield (HFY) determined for the Mhlathuze system in the MWAAS, including the current available transfer from the Thukela (see **Section 3.2.2**) was determined to be 245 million m^3/a.

The long term stochastic yields obtained from the MWAAS are presented in **Table 4.1** with the curve presented in **Figure 4.1**.

Table 4.1: Long Term Stochastic Yields: Mhlathuze System

Stochastic firm yield at levels of assurance in supply (M m^3/annum)			
99.5 %	**99.0 %**	**98.0 %**	**95.0 %**
1:200 years	**1:100 years**	**1:50 years**	**1:20 years**
243.3	251.6	260.0	272.3

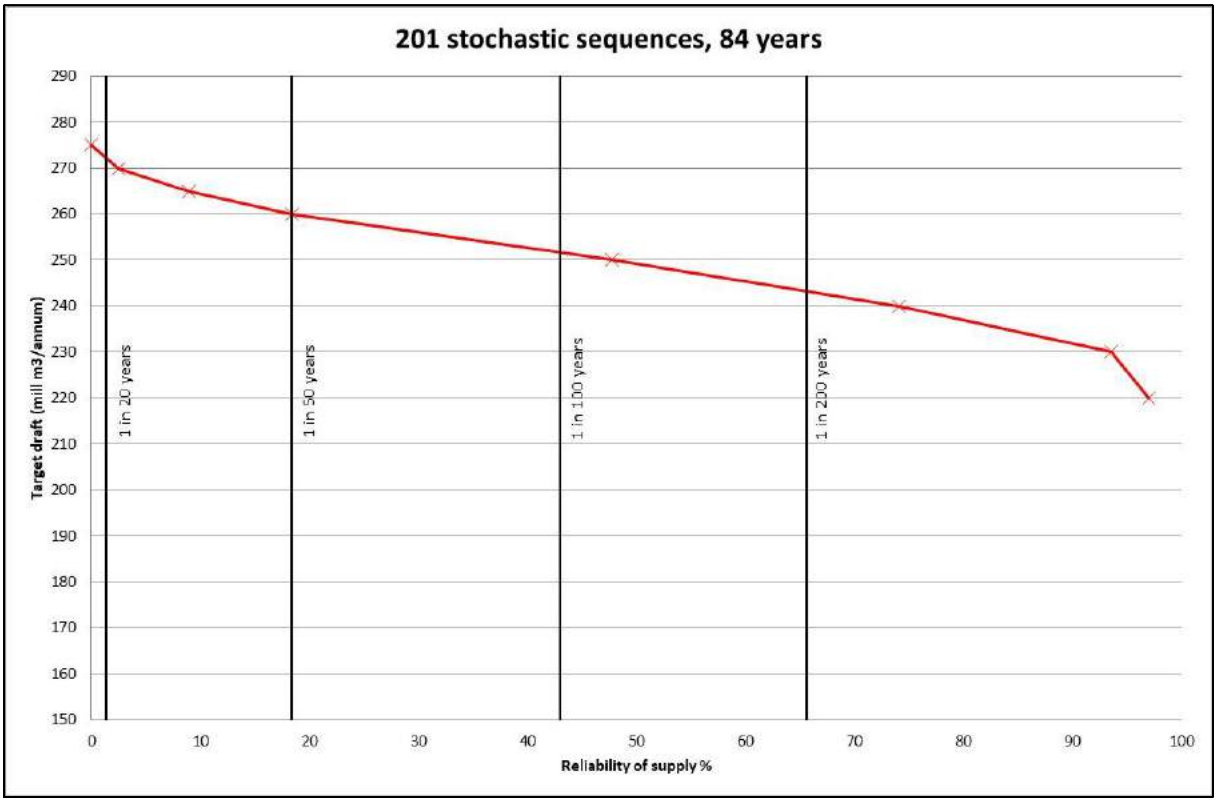


Figure 4.1: Long Term Stochastic Firm Yield: Mhlathuze System

The short term stochastic yield curves were undertaken for the Mhlathuze and Umfolozi systems. These are presented in **Table 4.2** and **Table 4.3**. The individual curves are presented in **Appendix B** and the summary curves in **Figure 4.2** and **Figure 4.3**.

Table 4.2: Short term characteristics: Mhlathuze system

	Yield Mm^3/annum at indicated RI (2)					
Starting storage (as % of live FSC(1))	**1:200**	**1:100**	**1:50**	**1:20**	**1:10**	**1:4**
100%	207.33	214.00	227.44	250.46	269.27	297.76
80%	192.48	202.43	217.12	239.02	261.36	295.86
60%	174.18	184.10	198.77	224.01	247.87	289.51
40%	145.33	158.56	170.54	193.71	226.94	270.59
20%	101.50	114.83	126.15	153.84	179.65	212.59
10%	78.39	87.67	95.95	107.61	132.34	164.74

Note: (1) Live full supply capacity (FSC) of Dam.
(2) Recurrence interval of failure, in years.

Table 4.3: Short term characteristics: Mfolozi system

	Yield Mm^3/annum at indicated RI					
Starting storage (as % of live FSC)	**1:200**	**1:100**	**1:50**	**1:20**	**1:10**	**1:4**
100%	34.36	35.42	38.33	39.60	39.86	40.42
80%	26.60	28.60	30.33	34.55	38.17	39.79

	Yield Mm^3/annum at indicated RI					
Starting storage (as % of live FSC)	**1:200**	**1:100**	**1:50**	**1:20**	**1:10**	**1:4**
60%	17.60	19.40	21.21	24.19	28.22	38.15
40%	7.24	8.01	10.01	13.60	16.10	25.29
20%	1.57	1.71	1.80	2.77	5.99	13.64
10%	0.74	0.85	0.96	1.54	3.10	11.15

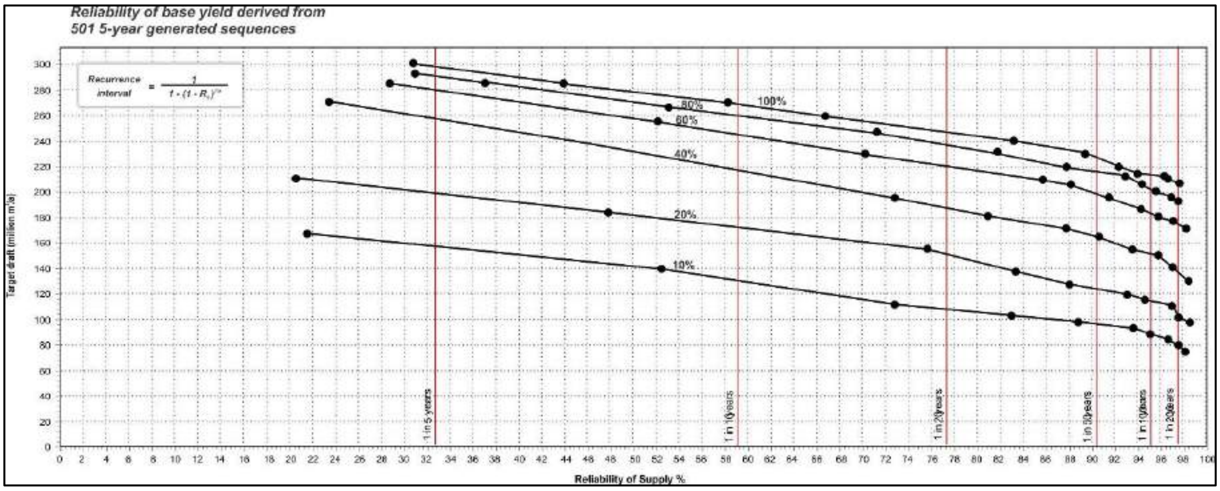


Figure 4.2: Short Term yields: Mhlathuze system

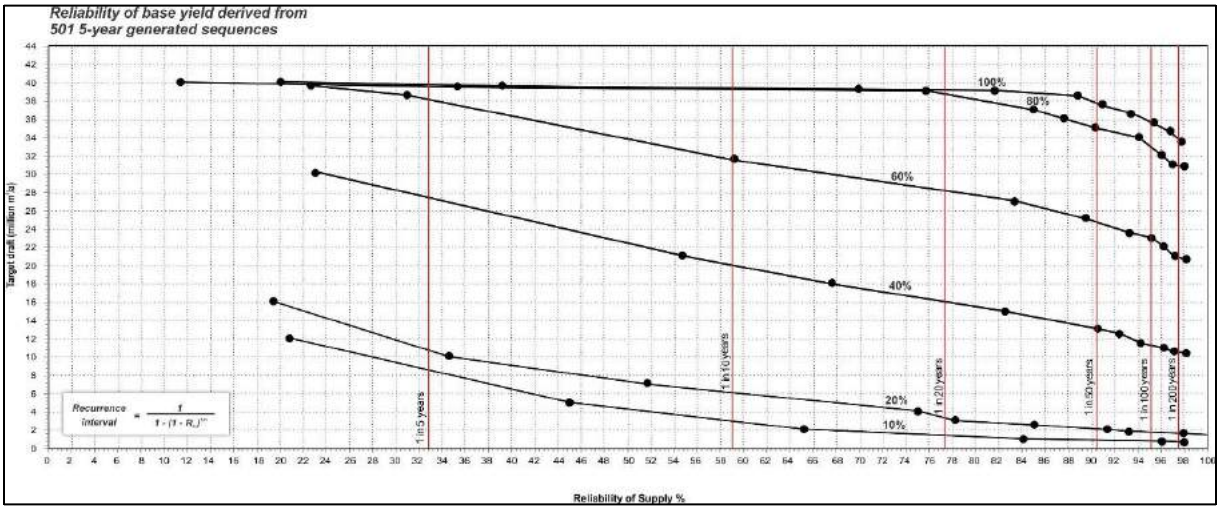


Figure 4.3: Short Term yields: Umfolozi system

4.2 Surrounding Towns

The Eshowe WSS gets its raw water from local dams, Rutledge and Eshlazi, in the Mlalazi River. The system also receives supplementary water from the Goedertrouw Dam in the Mhlathuze River. The Rutledge and Eshlazi (also referred to as Eshowe) dams which supply Eshowe are situated in the upper reaches of the quaternary catchment W13A, namely quinary catchment W13A1, see locality in **Figure 3.1**.

A detailed hydrological, yield and operating rules assessment was carried out as part of the Stand Alone Dams Study (Eastern Cluster) (DWS, 2016). The HFY determined for the combined two dams is 1.29 million m^3/annum. The Long term stochastic yields are presented in **Table 4.4** and the associated yield curve in **Figure 4.4.**

Table 4.4: Long Term Stochastic Yields: Combined Eshlazi and Rutledge Dams

Stochastic firm yield at levels of assurance in supply (Mm^3/annum)		
99.0 %	**98.0 %**	**95.0 %**
1:100 years	**1:50 years**	**1:20 years**
1.58	1.77	2.0

Figure 4.4: Long Term Yield Curve: Combined Eshlazi and Rutledge Dams

The short term yields obtained for the combined dams are presented in **Table 4.5** and the curves are provided in **Appendix B**.

Table 4.5: Short term characteristics: Combined Eshlazi and Rutledge Dams

	Yield Mill m^3/annum at indicated RI (2)				
Starting storage (as % of live FSC(1))	**1:200**	**1:100**	**1:50**	**1:20**	**1:10**
100%	1.53	1.66	1.81	2.08	2.33
80%	1.50	1.60	1.78	2.02	2.30
60%	1.35	1.48	1.64	1.87	2.11
40%	1.15	1.25	1.40	1.50	1.78
5%	0.80	0.84	0.90	1.10	1.28

Note: (1) Live full supply capacity (FSC) of Dam.

(2) Recurrence interval of failure, in years.

Information for the remaining three surrounding towns included in this Study at a Desktop Level Assessment was sourced from the Reconciliation Strategies prepared for each town as part of the All Towns Strategy Study (DWA, 2011a,b,d).

The main source of supply for Gingindlovu Water Supply Scheme is the Matigulu River and Msunduzi River which is a tributary of the Matigulu River. The Gingindlovu Town therefore relies on run of river for its water resources. The Reconciliation Strategy concluded that "During low flow periods the amount of run-off is sufficient to meet the three month peak summer annualised demand of the Gingindlovu WTW, as well as for other water uses, particularly irrigation agriculture." However, it is noted that no water resources analyses took place as part of the study and the conclusion was drawn by comparing average natural flows (from WR90) at the abstraction point.

The main source of supply for the Mtunzini Water Supply Scheme, is the Ntuze River, a tributary of the Mlalazi River and bulk water purchase from CoMLM. The KCDM has a service level agreement for the municipality to supply Mtunzini with bulk water supply. The Reconciliation Strategy stated that "The Mtunzini Water Supply Scheme has a registered water use of 0.5 million m^3/a, from the Ntuze River. The treated bulk water supply infrastructure from the CoMLM, can deliver on average 1.0 Ml/d (0.37 million m^3/a). Therefore the total water available is 0.87 million m3/a."

The main source of supply for the Melmoth Water Supply Scheme is the Mfulazane River, a tributary of the Mfule River. The Reconciliation Strategy concluded that "during low flow periods the run-off at the abstraction point is not sufficient to meet the three month peak summer annualised demand of Melmoth WTW abstraction requirements. This is the reason why boreholes were drilled to supplement the surface water supplies, particularly during low flow periods". Again, however, water resources analyses were not undertaken and the conclusions were drawn using WR90 hydrological flows.

5 WATER RESOURCES SCENARIO ANALYSES

5.1 Overview and methodology

The Water Resources Planning Model (WRPM) has been used in this Study to analyse the behaviour of the systems and to evaluate the water resources capability. The WRPM has additional capabilities to the WRYM in that it performs projection analysis by considering growing demands over time and implements dynamically changing operating rules as opposed to a fixed set of restriction rule levels.

An integrated WRPM system was previously configured as part of the Licensing Support Study (DWA, 2012a). The system was updated as part of this Task to incorporate all the aspects laid out in the opening chapters of this report. The results are provided in the form of boxplots showing the simulated behaviour of selected system elements for 1000 stochastic hydrological sequences indicating the projected probability and risks for the various scenarios described below. Graphical results are given in three main forms, namely:

- Reservoir storage plots;
- User supply plots; and
- Restriction plots.

Conclusions are drawn from the results in terms of the system's behavior resulting from the specific conditions assigned with each varying scenario assessed. **Figure 5.1** provides an example of a boxplot including the probability distribution levels.

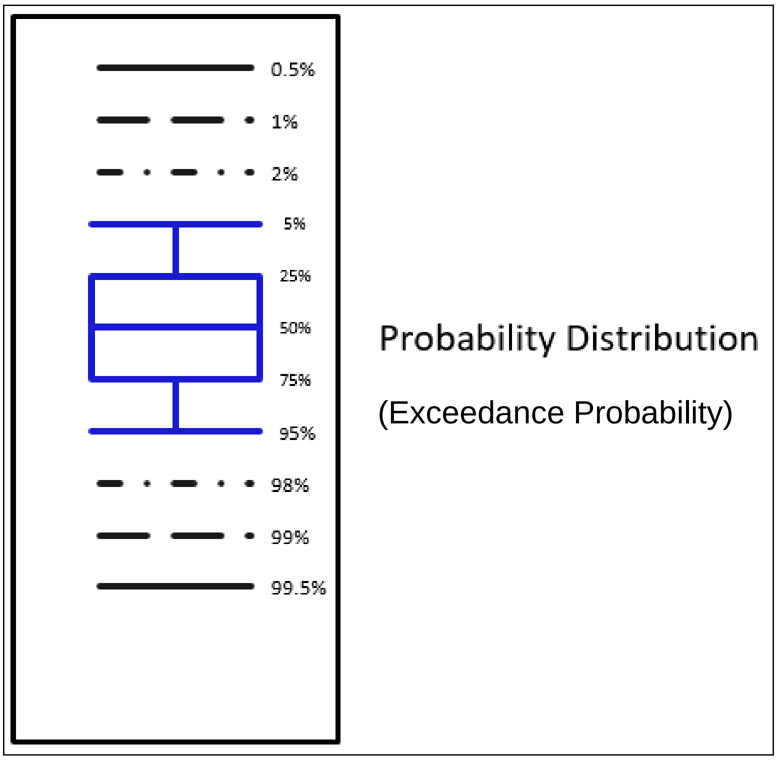


Figure 5.1: Boxplot legend to be applied to all results

5.2 Mhlathuze System

5.2.1 Assurance of Supply Requirements

Assurance of supply criteria have previously been agreed with users in the Mhlathuze system during the Compulsory Licensing Exercise (DWA, 2012a). **Table 5.1** provides a summary of the portion of the users' demands divided into the various assurance of supply categories. This is used as input in the WRPM in order to determine the user restrictions (low priority first, high priority last).

Table 5.1: Priority classification table

Water use sector	% demand at indicated risk of failure				
	1 in 200 years	1 in 100 years	1 in 50 years	1 in 20 years	1 in 4 years
	0.5%	1%	2%	5%	25%
Restriction level	**5**	**4**	**3**	**2**	**1**
Irrigation		20%	40%		40%
Urban	30%	30%		30%	10%
Industrial	70%	20%		10%	

5.2.2 Constant Development Level Scenario

A number of constant development level scenarios were undertaken in order to confirm the system yield capabilities using the WRPM. The demands on the system each have their own individual growths associated with them. A constant development analyses is undertaken by selecting a year in the future and assuming that the demand for each user is set at that year's demand value throughout the simulation period.

The process was iterative, and various years were selected in order to determine whether or not the system could provide all the demands at their required assurance of supply criteria throughout the simulation period. The restriction plot was assessed in each case to check for violations on users' supply criteria. A violation is a situation whereby the system is not able to provide the demands at their required levels of assurance.

The results indicate that the system was unable to supply the demands set at the 2021 development level, however, when the demands were set at the 2020 development level, they were supplied satisfactorily without violations occurring. This is indicated in the following plots. The restriction level is as presented in **Table 5.1**.

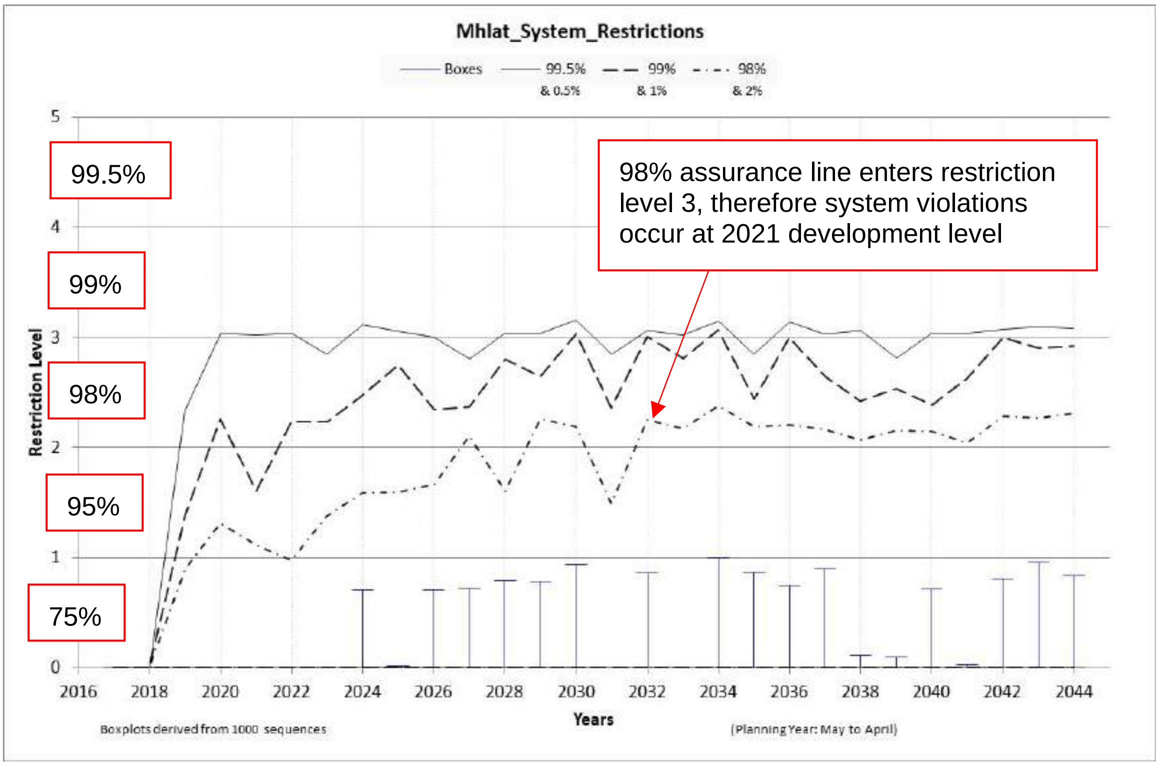


Figure 5.2: Restriction plot: 2021 demands on system

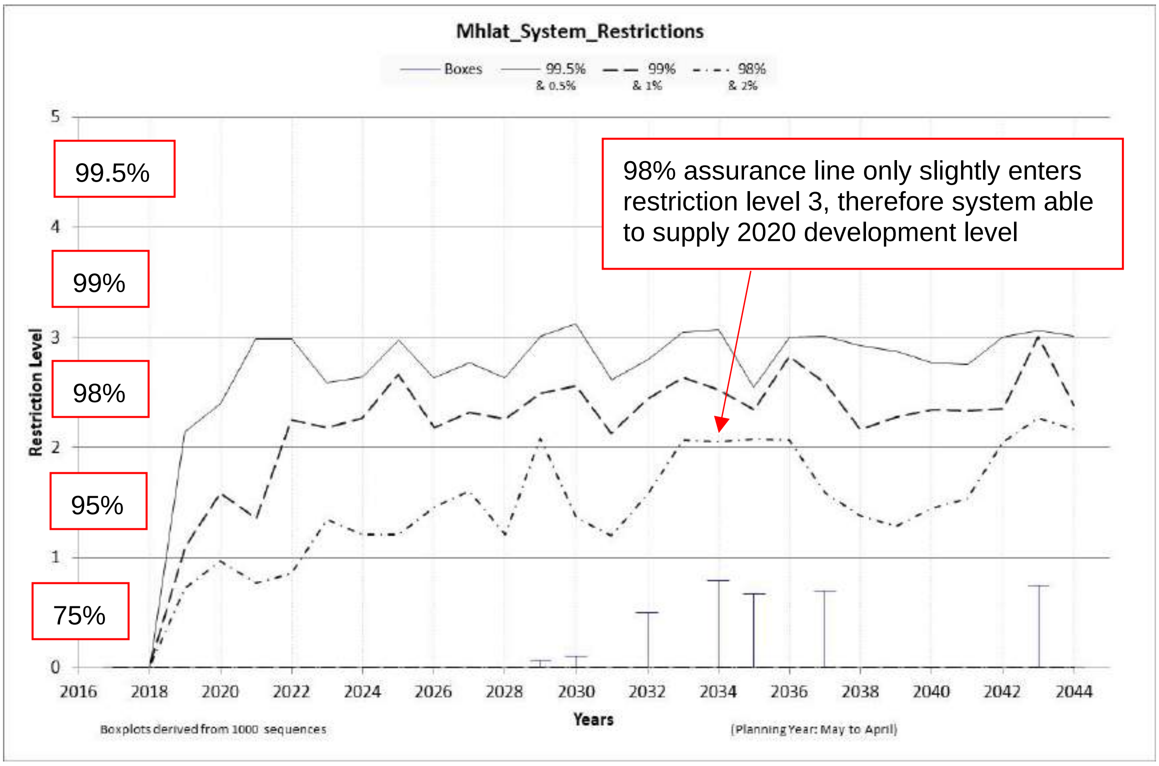


Figure 5.3: Restriction plot: 2020 demands on system

The interpretation of the above result is that the system yield at the required assurance of supply to all users is 247.8 million m^3/annum. It should be noted that this yield is only obtained with efficient system operation, ie. maximising the use of the tributary flows at the

Mhlathuze weir abstraction point prior to making any releases from the Goedertrouw Dam. This additional benefit in yield resulting from improved operation is referred to as the leverage effect, as the system is able to leverage more yield as a result of maximising the tributary flow contribution. The total existing yield of 247.8 million m^3/annum is broken down (approximately) into the following contributing elements:

- Yield from Mhlathuze Resources: 203.2 million m^3/annum
- Existing Thukela transfer: 34.1 million m^3/annum
- Additional yield from efficient operations: 10.5 million m^3/annum.

5.2.3 Growth Scenario

The growing demands scenario was undertaken in order to confirm the result presented in the previous sub-section of the system yield being equivalent to the total 2020 demand on the system. **Figure 5.4** provides the resultant plot for the Richards Bay urban demand centre. As presented in **Table 3.6**, the Richards Bay urban demand is set to grow from the current value of 10.9 million m^3/annum (2018) to 20.9 million m^3/annum (2045). When this was simulated, it can be seen that the demand "fails" in the year 2020. The interpretation of the plot is as follows:

- The colourful bars forming the backdrop of the plot represent the demand and its associated growth into the future. The demand is divided into four sections for each year which represent the size of the demand at the various assurance criteria (see **Table 5.1**). The blue bars represent the highest assurance criteria which is set at 30% of the demand at a 1 in 200 year assurance of supply (99.5%). The pink zone is the 30% portion of the demand that falls in the 1 in 100 year assurance of supply level (99%). The brown is the 30% of the demand that is required to be supplied at a 1 in 20 year assurance of supply criteria (95%) and the purple colour section is the 10% demand portion which lies in a 1 in 4 year assurance of supply criteria zone (75%).
- The boxplot superimposed on the requirements provides the results of the scenario simulation. The complete picture therefore provides a comparison of what is required (coloured bars) with what is supplied (boxplot). A failure of criteria occurs when the specific boxplot line enters the coloured zone area of the requirement bars. In this case, the line representing the 95% assurance of supply (the bottom whisker) enters the brown zone in 2021. This means that the simulation shows that the existing system has not been able to provide all the users at their required assurances from the year 2021 onwards. This is in line with the results presented in **Section 5.2.2** which explains that the existing system yield is equal to the total of the 2020 user requirements.

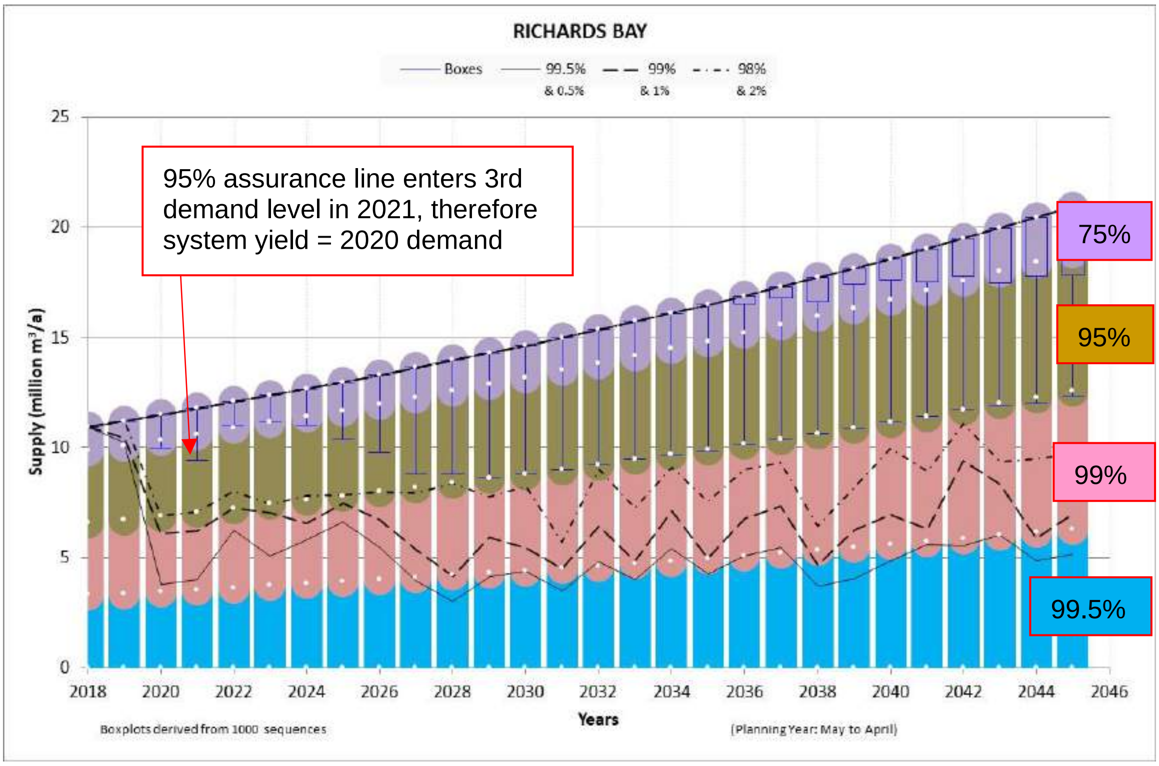


Figure 5.4: Richards Bay urban demand centre simulation result

Figure 5.5 shows the storage plot for Goedertrouw Dam obtained from the WRPM results. The plot shows that the drought operating rule protects the Dam which does not empty at the 98% assurance of supply level criteria.

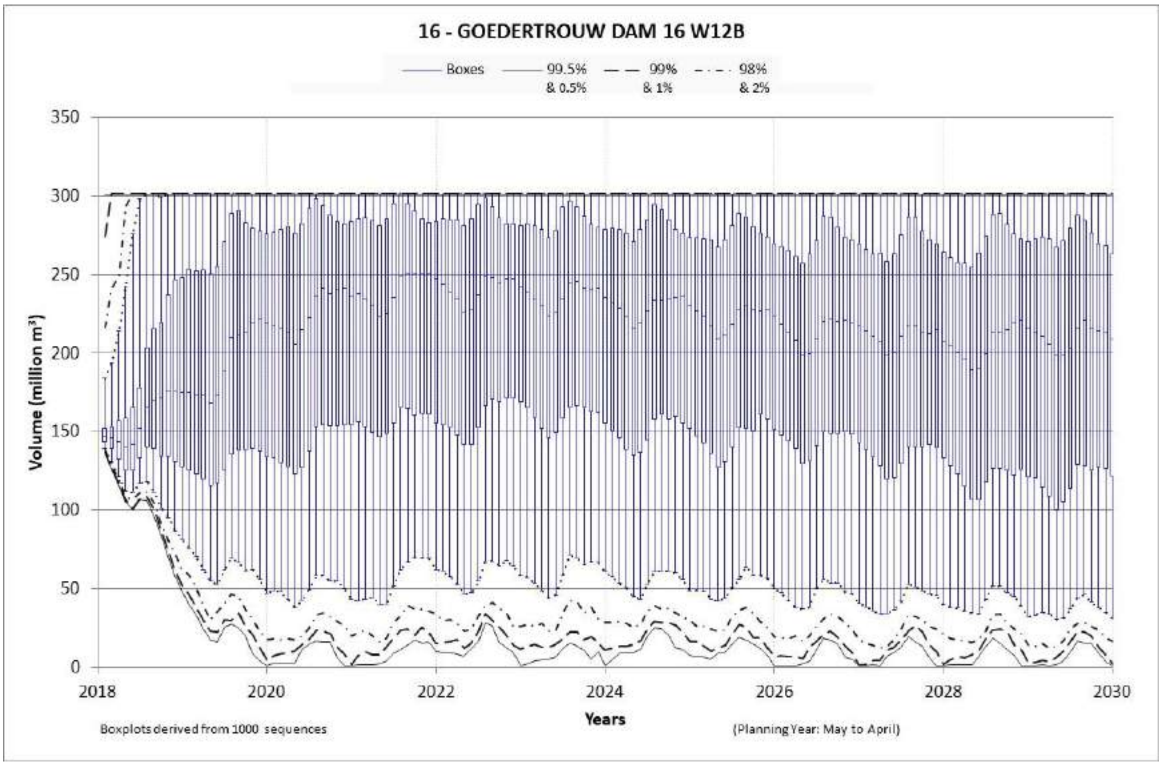


Figure 5.5: Resultant reservoir storage plot: Goedertrouw Dam

5.2.4 Thukela Transfer Phase ii

The increased transfer from the Thukela (Middledrift scheme) was determined to be an important intervention measure during the original Strategy (2015) Study. Shortly after completion of the Strategy, the catchment went into a severe drought situation. As a result of the drought, the intervention was fast tracked, and construction began. The scheme was due to be completed in the middle of 2019, however, various issues have delayed progress. For the purpose of this Study, it was assumed that the scheme would be complete by May 2021, the year which indicated that deficits would start to occur based on the existing system capabilities.

The increased capacity will double the existing transfer (1.2 m^3/s), resulting in the ability to transfer a total of 2.4 m^3/s, which is approximately 68 million m^3/annum if a 10% loss on transferred water is considered. The increased transfer therefore adds 34 million m^3/annum to the system.

The results show that the additional transfer from the Thukela has a total yield increase impact of 44.5 million m^3/annum, which is a combination of the actual additional transfer of 34 million m^3/annum and the leverage benefit of 10.5 million m^3/annum. The leverage effect is, however, only benefitted from if the system is operated to make use of the tributary flows as far as possible, and store water in Goedertrouw Dam for as long as possible. The total water resource capability including the increased Thukela transfer currently under construction is therefore 292.3 million m^3/annum. **Figure 5.6** shows that with the additional transfer, the system is able to satisfy the growing demands until the year 2039, when the first violation occurs.

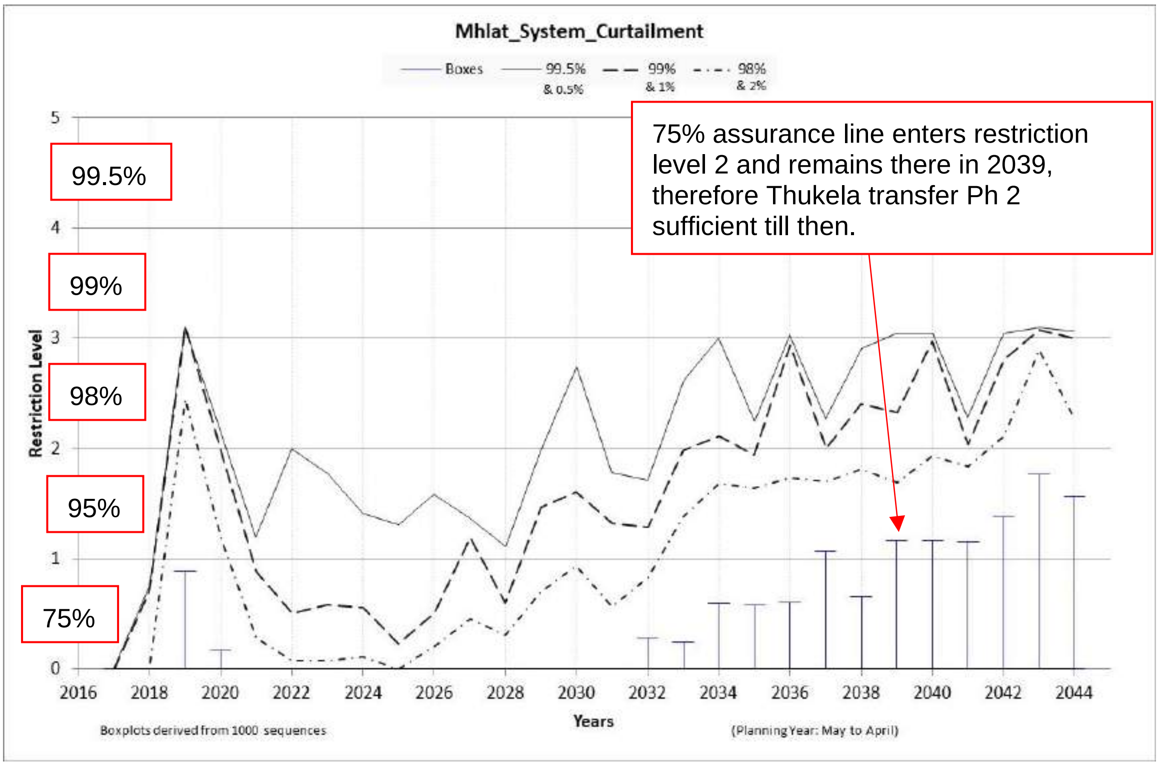


Figure 5.6: Restriction plot: growing demands on system, including additional Thukela transfer

5.2.5 Raising Goedertrouw Dam

A scenario was undertaken to determine the potential benefit of raising Goedertrouw Dam. The dam can be raised by 2.8 metres which will result in an increase in storage capacity from the existing volume of 301 million m^3 to 336 million m^3. The corresponding increase in yield to the system would be 5.8 million m^3/annum.

5.2.6 Increased allocation to Phobane WTW

This scenario was carried out at the request of the DWS RO. The background is as follows:

The King Cetshwayo District Municipality (KCDM) is currently investigating the possibility to upgrade the Phobane Water Treatment Works from 20 Ml/day (7.3 million m^3/annum) to a projected 80 Ml/day (29.2 million m^3/annum) by the year 2040 (based on the 2016 Masterplan for the Goedertrouw Regional Scheme prepared by Aecom for KCDM) for the supply to the Mthonjaneni, Eshowe and KwaHlokohloko sub-supply areas. The project is to be implemented in four phases, and they are currently busy with the Inception stage.

The Phobane WTW is supplied solely by the Goedertrouw Dam. KCDM is currently registered to abstract 13 477 725 m^3 annually (approximately 37 Ml/day). This Licence (which expires in 2035) is adequate for the first two phases, however, will need to be increased for the last two phases.

The Study Team on behalf of the KCDM has been in discussions with DWS's Water Use and Regional Planning divisions regarding the increased allocation requirement from the Goedertrouw Dam for the Phobane WTW, however, the outcome of these discussions is that "the Goedertrouw Dam is constrained and has already been fully allocated. Therefore an increased Licence may not be possible based on the current situation."

The DWS RO therefore recommended that the Team engage with the Reconciliation Strategy Update to see if the requirements can be accommodated.

Technically, the DWS's response that Goedertrouw Dam is over allocated is correct, however, this should be understood in context, with the following two important points:

1. The current yield availability from the system supported by Goedertrouw Dam and the Lakes is 248 million m^3/a. The current allocations in the system are 284 million m^3/a (excluding allocations from tributaries). However, when the increased Thukela transfer scheme which is currently under construction is completed, the system yield will increase to 292 million m^3/annum. It is expected that the scheme will be complete by 2021, after which there will be a surplus of 8 million m^3/annum when comparing yield with existing allocations. An additional 10.7 million m^3/annum has been allocated under the label "volume of water set aside". This has been allocated to future allocations consisting of Government Departments, Community Cooperatives and Traditional Authorities.

2. Despite the catchment having undergone Compulsory Licensing and reallocation, there still appear to be some users who are not making full use of their existing lawful allocations, and do not have plans to, whereas others' projected growths go beyond their allocations. **Table 5.2** provides a summary of the main users within the catchment in terms of their current (2017) actual use, their 2045 projected requirement and their licensed allocation.

Table 5.2: Existing users current, future projected and allocated water use

User	2017 use	2045 projection	Allocation
Richards Bay	11.9	32.8	18.2
Empangeni	6.5	19.0	9.4
Esikhaweni	9.9	18.7	12.5

User	2017 use	2045 projection	Allocation
Ngwelezane	1.7	4.7	2.8
Nseleni	4.5	9.3	5.0
Mondi	18.0	20.1	49.3
Foskor	6.0	10.3	10.3
Tongaat	0.8	1.9	2.8
Mpact	1.5	2.5	2.5
RBM	19.4	28.8	28.8
Tronox	2.7	20.3	8.5
Bayside	0.1	0.2	0.3
Irrigation	114.0	114.0	114.0
Existing small users	4.0	4.0	4.0
New applicants	0.0	15.5	15.5
Total	**201.0**	**302.0**	**283.8**

The users highlighted in red are those where their future projections included in this Reconciliation Strategy update are greater than the current allocations. Those in green are users where the opposite is the case, where allocated water is effectively lying dormant. This is as a result of the users not including the additional water allocated to them in their future plans as provided to this Study Team.

It is important to note that the bulk of the domestic users are set to outgrow their existing allocations. While providing allocations to users is a useful management tool by the DWS, it should not be considered as a cap on future growth. That is precisely why the Reconciliation Strategy studies are carried out, to determine when in the future additional interventions are required.

The “existing small users” and the “new applicants” presented in **Table 5.2** are made up of the users as indicated in **Table 5.3**. The two entries for the existing Phobane WTW license are evident in the Table.

Table 5.3: Breakdown of existing users and new applicants

New applicants	Volume (m^3/annum)
DC28 - UTHUNGULU (ZIMELA WATER WSS)	4 273
DC28 - UTHUNGULU (ZIMELA HLOBANE WSS)	9 612
DC28 - UTHUNGULU (GOEDERTROUW / PHOBANE)	12 397 725
SHAKALAND (PTY LTD	22 028
INTABA INGWE GAME RANCH	108 000
DC28 - UTHUNGULU (OFASIMBA WSS)	141 912
DC28 - UTHUNGULU (OFASIMBA WSS)	2 809 568
Sub-total	**15 493 118**
Existing users	
DC28 - UTHUNGULU (GOEDERTROUW / PHOBANE)	1 080 000
I L PHILLIPS	24 212

SHAKALAND (PTY LTD	8 213
DC28 - UTHUNGULU (OFASIMBA WSS)	1 299 495
INGONYAMA TRUST	1 591 596
EMPANGENI COUNTRY CLUB	10 098
Sub-total	**4 013 614**

The request has been made to consider an additional allocation of 15.7 million m^3/annum for the Phobane WTW. This is over and above the 13.5 million m^3/annum already included in their license, the required total being 29.2 million m^3/a (80 Ml/day). The scenario was undertaken to determine the impacts of allocating an additional licence to KCDM. The scenario was a direct comparison to the growth scenario (including increased Thukela transfer) presented in **Section 5.2.4**, with the only difference being the increase in requirement for Phobane WTW abstracted directly from Goedertrouw Dam.

Figure 5.7 provides the result of the scenario simulation. The impact of providing the additional allocation to the Phobane WTW would mean that additional augmentation of the system would be brought forward from 2039 (as per result presented in **Section 5.2.4**) to 2034.

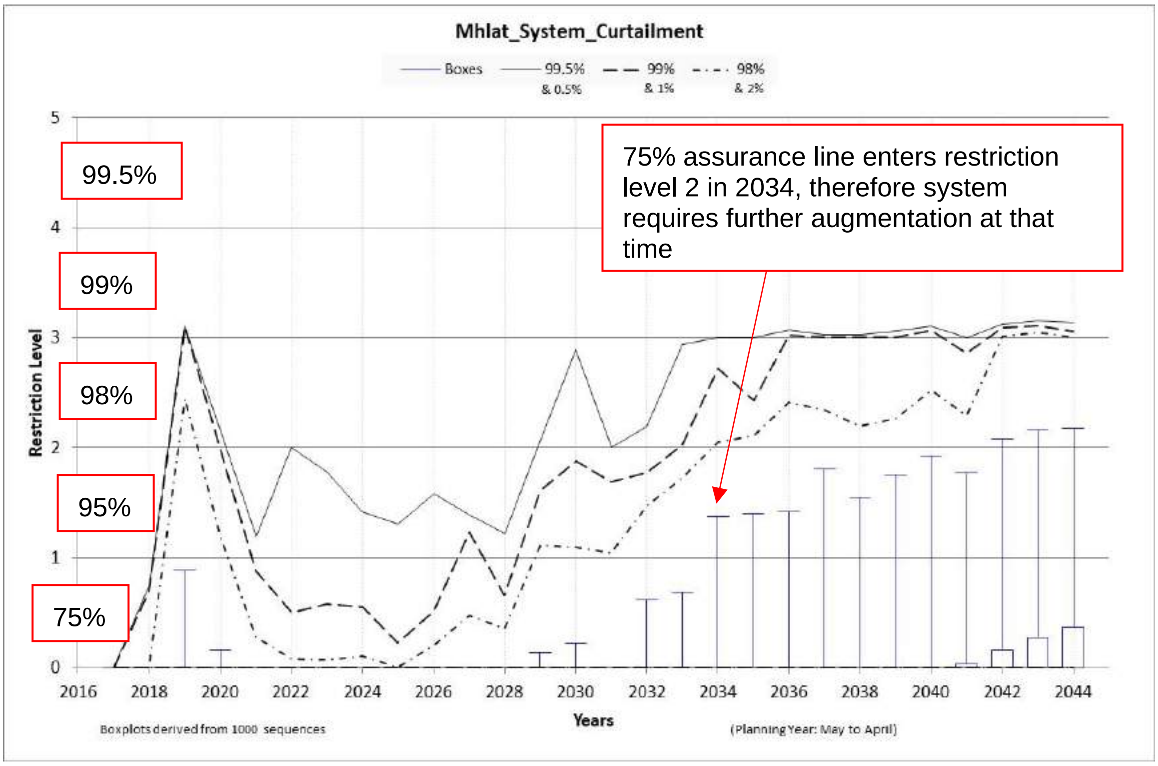


Figure 5.7: Restriction plot: growing demands on system, including additional Thukela transfer and additional use by Phobane WTW

5.3 Additional Resources

The options in terms of new dams as described in **Section 3.2.3** were assessed. **Table 5.4** provides a summary of the additional water these dams could potentially add to the system.

Table 5.4: Summary of additional resources available from indicated new dams

Dam	Additional yield (Mm3/annum)
Mfolozi off channel	36.9
Nseleni Dam	12.0
Mhlathuzana Dam	<1

The dam on the Mhlathuzana River does not appear to be a viable option. The river is currently not contributing to the Mhlathuze system as it ends in a wetland prior to the confluence with the Mhlathuze River. The wetland is likely to be ecologically sensitive, and therefore it is not recommended that this option be explored further.

5.4 Bottle necks

While the main focus in the system analyses task is to determine the system water resources availability, it is important to also consider the individual supply to users and highlight where supply problems may occur. The Mhlathuze system makes use of various resources and infrastructure limitations, referred to as bottlenecks, can come into effect and limit users' supply as the demands grow into the future. The results show that the following infrastructure would need to be increased in capacity by the indicated year, as that current capacity is not large enough to accommodate the growth.

- The secondary supply from Nsezi WTW to Richards Bay which is used when Lake Mzingazi drops below maintenance level and Mzingazi WTW shuts down has a current capacity of 48 840 m^3/day (17.8 million m^3/annum). This will not be sufficient by the year 2036.
- The Esikhaweni WTW has a current design capacity of 13.1 million m^3/annum. Water is abstracted from Lake Cubhu and treated at the Esikhaweni WTW. This water is then supplied to the Esikhaweni domestic area and Mpact. Lake Cubhu has a minimum operating level below which water should not be abstracted. When Lake Cubhu drops below maintenance level a secondary supply from the Mhlathuze weir to Esikhaweni WTW is available which has a current capacity of 15 000 m^3/day (5.5 million m^3/annum). The total demand from Esikhaweni WTW is currently greater than the WTW capacity. In addition, the yield of Lake Cubhu alone, including the minimum maintenance level, is 0.4 million m^3/annum. The Lake Cubhu yield combined with the transfer capacity is not sufficient to supply the demands. This is creating an infrastructure bottle neck in the system.

5.5 Surrounding Towns

The four surrounding towns of Melmoth, Eshowe, Gingindlovu/Amatikulu and Mtunzini were configured into the WRPM and a scenario was undertaken to assess the supply to these towns. The following figures provide the results of the supply to the towns and the interpretations follow.

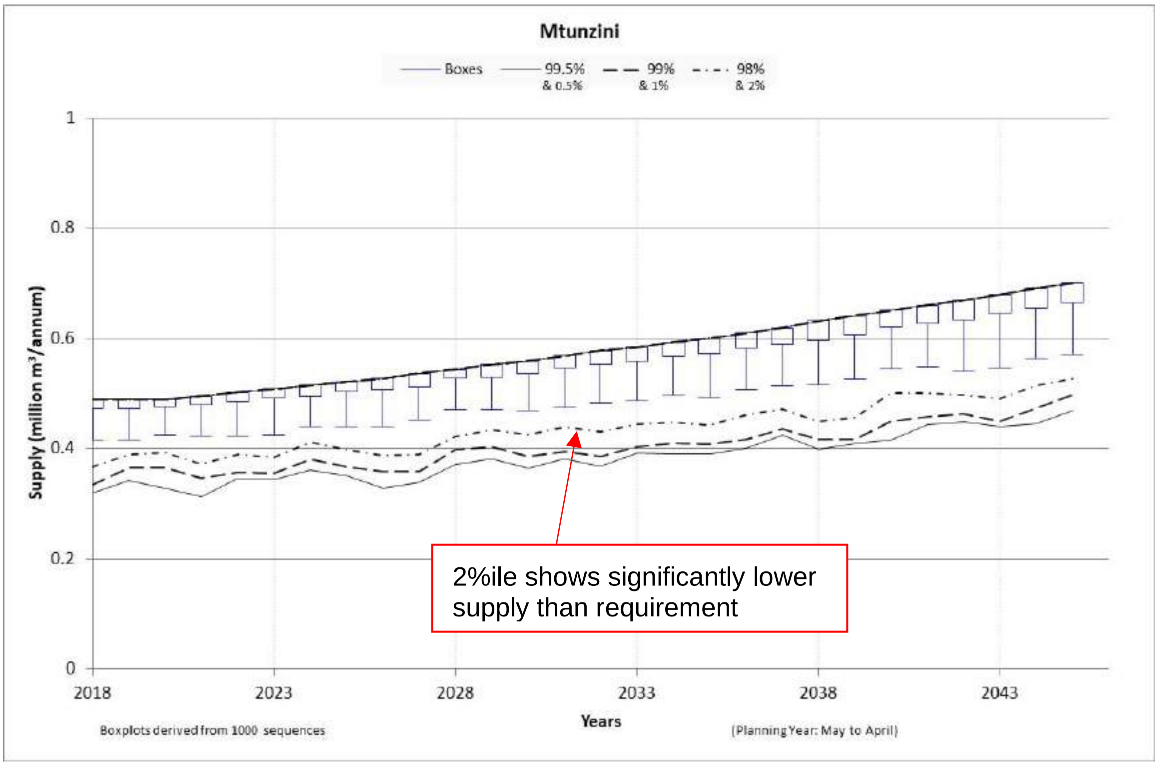


Figure 5.8: Mtunzini Town supply projection (Ntuze source alone)

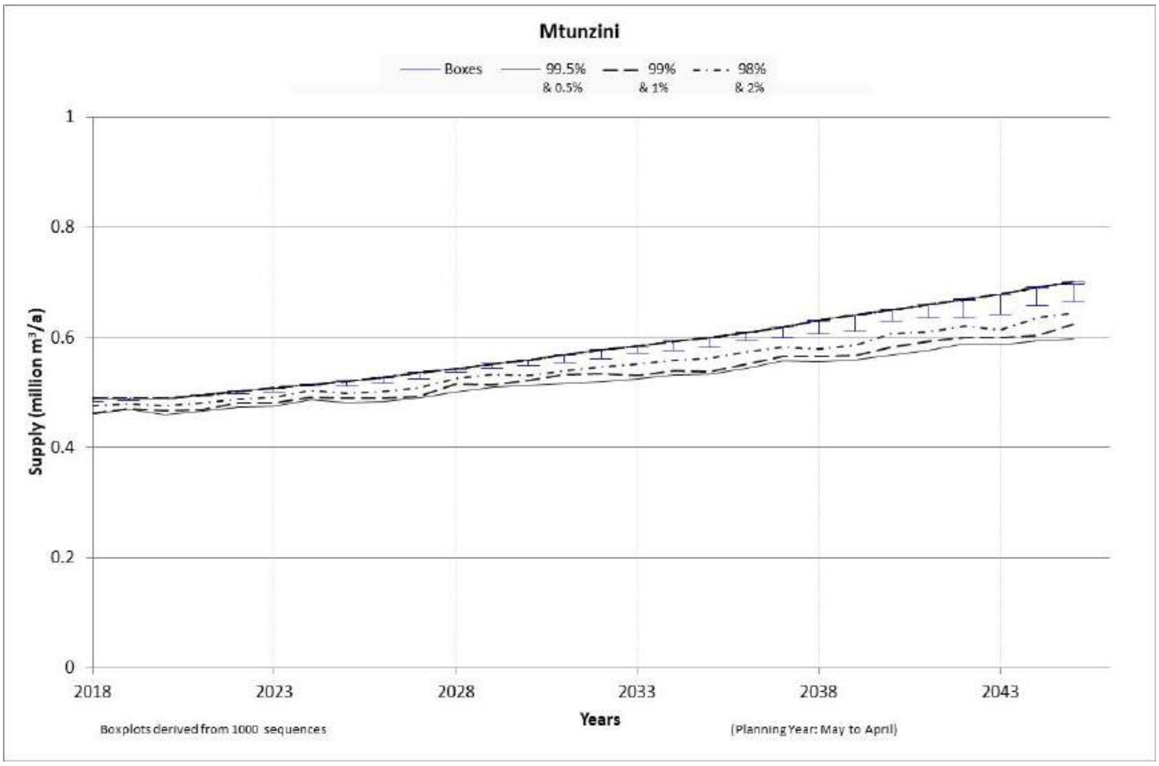


Figure 5.9: Mtunzini Town supply projection (including CoM supply)

The results of the WRPM analyses indicate that the Ntuze River source alone is not sufficient to provide the Mtunzini demand at a satisfactory level of assurance, however, when a portion of demand is supplied by the CoM, the town is supplied at a satisfactory assurance level.

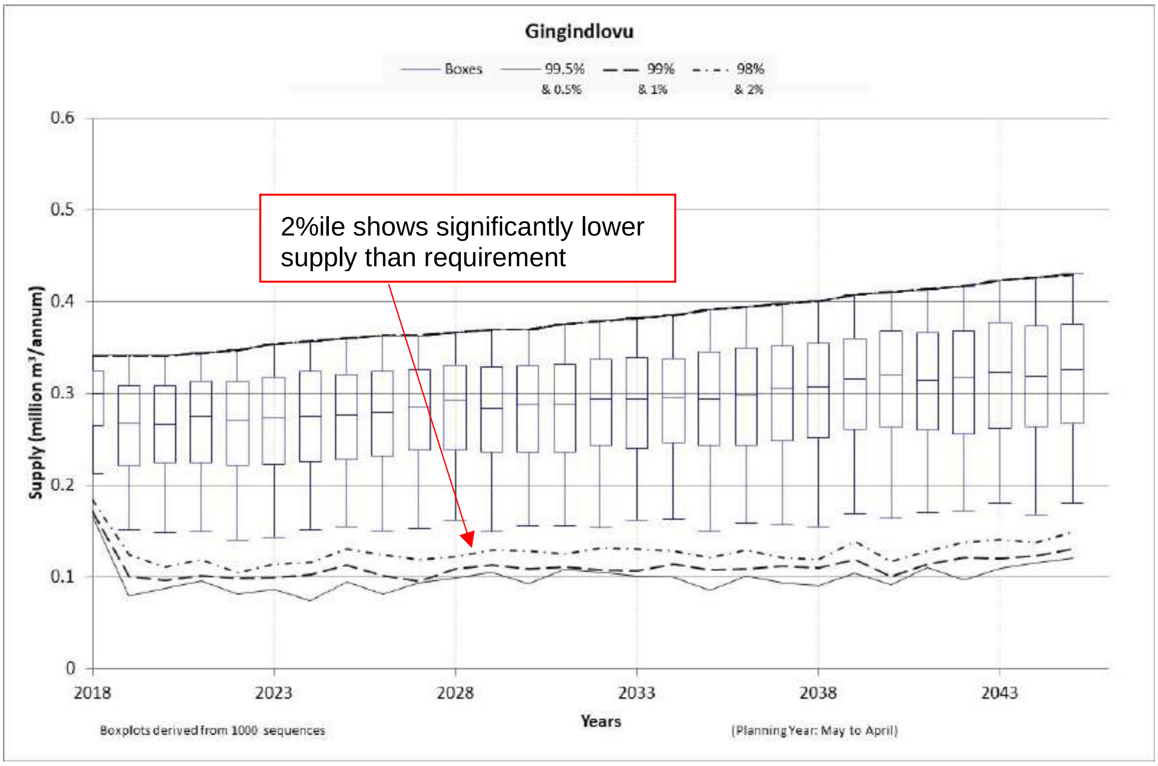


Figure 5.10: Gingindlovu Town supply projection

The results of the WRPM analyses indicate that the town of Gingindlovu is not supplied at an acceptable level of assurance and the run of river resource of the Amatigulu River is not a sufficient resource.

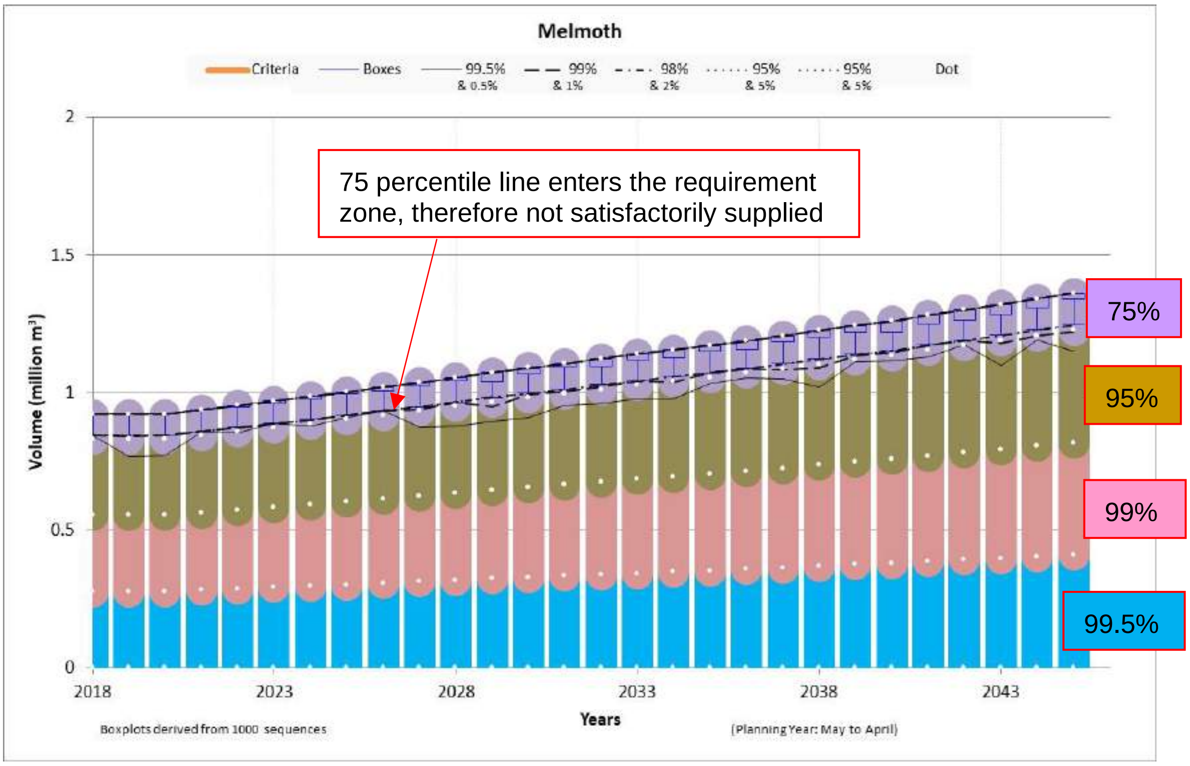


Figure 5.11: Melmoth Town supply projection (surface and ground water resources)

The results of the WRPM analyses indicate that the town of Melmoth is not supplied at an acceptable level of assurance when combining the resources of the Mfulazana River and the estimated production rate of the available boreholes of 1.58 Ml/d, (0.58 million m^3/annum).

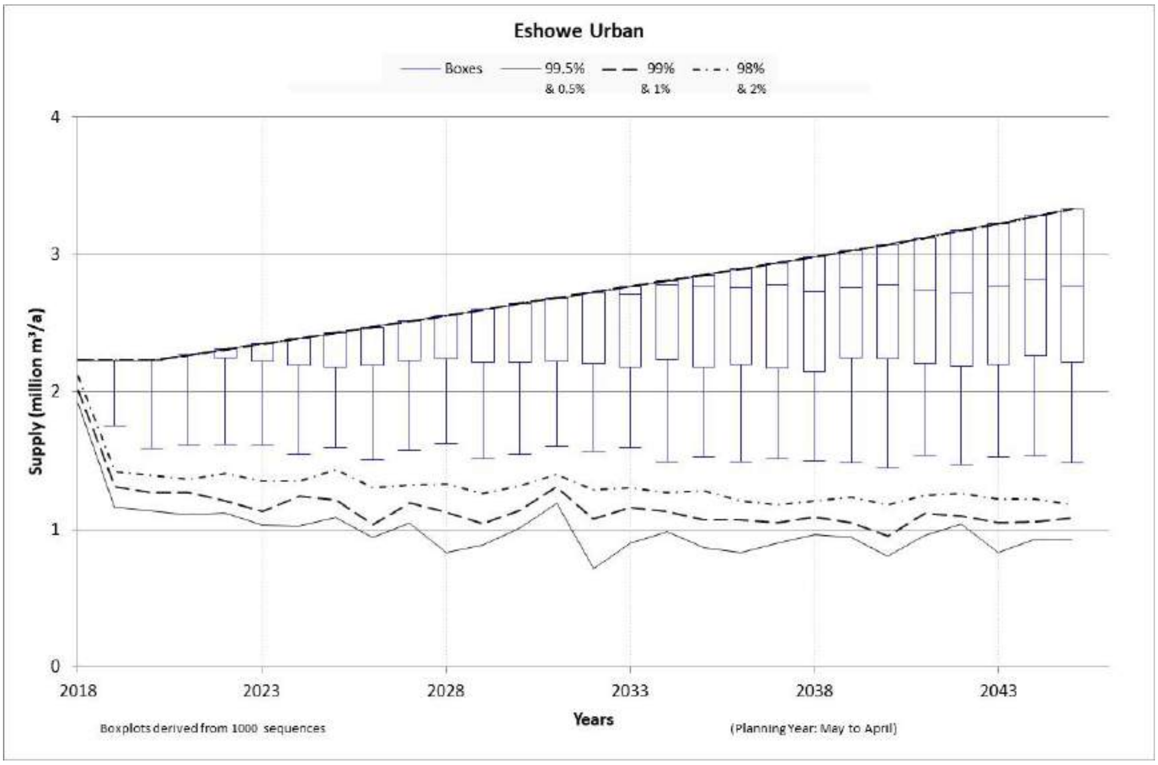


Figure 5.12: Eshowe Town supply projection (local dams only)

The WRPM result confirms that the local dam resources of Rutledge and Eshlazi Dams are not sufficient to supply the growing urban demand of Eshowe Town. However, with the additional augmentation from Goedertrouw Dam available to the town of 5 Ml/d (1.8 million m^3/annum), the Eshowe requirements are supplied at a satisfactory level of assurance as indicated in **Figure 5.13.**

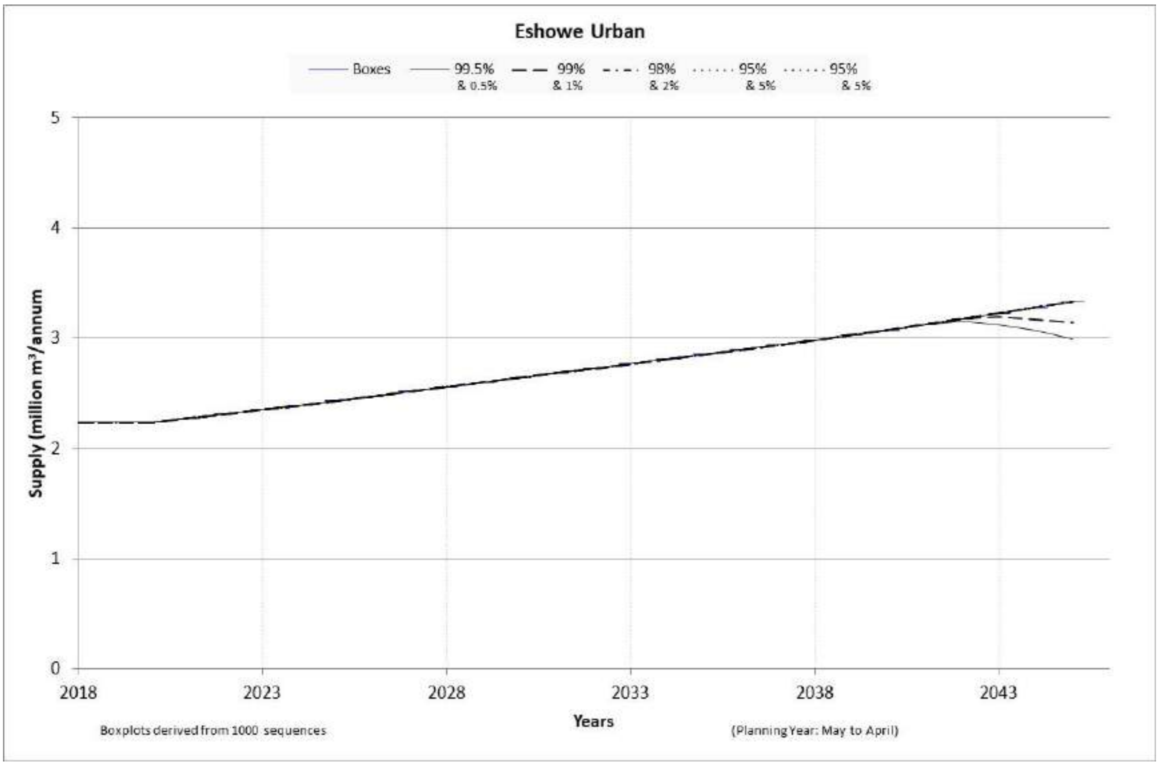


Figure 5.13: Eshowe Town supply projection (local dams and Goedertrouw supply)

6 GROUNDWATER

6.1 Background and Objective

The Yield Analysis Report of the Richards Bay Reconciliation Strategy (DWS, 2015d) found that the confidence in the estimated lake yields presented was very low, as only the surface water component of these yields has historically been taken into account in the modelling. Groundwater contributions to the lakes could not be quantified with an acceptable level of confidence to be included in the lakes' yields estimation. However, this conclusion was based on the findings of the hydrology in the MORFP study. It recommended that in order to improve this assessment in future, the monitoring and quantifying of the groundwater contribution be included, as well as the interaction between groundwater and surface water. Yields for the lakes could then be determined at a more acceptable level of confidence.

The Mhlathuze Water Availability Assessment Study (MWAAS) (DWAF, 2009) subsequent to the MORFP study, had developed a lake water balance model linked to the Pitman Model to simulate lake levels and groundwater inflows and outflows to the lakes. The model did incorporate groundwater inflow to lakes at a coarse level with limited calibration based on existing reports. It simulated and calibrated lake water levels and discharge at existing gauging stations for Lake Mzingazi, however, Lakes Nhlabane and Cubhu were not calibrated. These are the lakes with significant groundwater interaction.

This model incorporated abstractions from the lakes until 2004 and was calibrated against lake water levels reported by Kelbe and Germishuyse (2001) and discharge at the DWS gauging station at the outlet of Lake Mzingazi only. From this model, a time series of groundwater inflows into the lakes was derived for all three lakes.

The MWAAS identified a need to incorporate groundwater interactions from the groundwater lake module into the WRYM to determine a combined system yield. In this study, the Pitman model and the Lake model were updated with revised afforestation estimates and additional lake water level data for calibration and were used to generate both surface water and groundwater inflow and outflow estimates for all three lakes.

6.2 The Coastal Lakes

6.2.1 Types of lakes

On the KwaZulu-Natal coastal plain in the vicinity of Richards Bay, groundwater interacts with a system of lakes. The coastal lakes are lakes Mzingazi, Nhlabane, Nsezi, Cubhu and Mangeza (**Figure 1.1**). The hydrology of the lakes is influenced by the regional groundwater system through baseflow into adjacent streams flowing into the lakes, and for some lakes, by direct seepage from the aquifers into the lakes.

Three types of lake systems exist that function in different manners. The coastal lakes (i) are situated in a topographically flat region with a shallow water table, while the lakes further inland along the Mhlathuze Valley are small water bodies that are formed through the damming of tributaries by sandbars along the flood plain. These off-channel lakes (ii) reside under different geological conditions. They formed in the incised river channels where there are shallow soils and limited groundwater interaction. The third type of lakes are combination lakes (iii) that are fed by rivers and groundwater but are dominated by the stream network.

Although surface water processes dominate the flow regime in Lakes Nsezi and Mangeza, a strong interaction also exists between the local aquifers and these lakes, since they are also fed by baseflow from rivers. Lake Nsezi is controlled by the Nseleni River and lies on the edge of the Zululand Coastal Plain. Lake Mangeza formed as a result of a drowning river valley and is situated at the confluence of the Mangeza and Mhlatuze rivers.

The hydrology of the coastal lakes (i), in particular, is influenced by the groundwater system through baseflow from inflowing rivers and direct seepage from the aquifers into the lakes. The coastal lakes that are controlled by subsurface conditions include Lake Nhlabane, Lake Mzingazi and Lake Cubhu, which are characterised by a very shallow water table intersected by the lakes. They are therefore very sensitive to landuse and large-scale groundwater abstraction that may impact on the water table.

The coastal lakes Cubhu, Mzingazi and Nhlabane are extensions of the local groundwater and have a strong interaction with the aquifer, hence determining their yield requires accounting for surface and groundwater inflows and outflows to the lakes. These are the lakes investigated in this report in terms of the groundwater contribution and its influence on their yields.

6.2.2 Geohydrology of the Lakes region

The Zululand coastal plain has groundwater development potential and could be developed for future water supply. However, it is not recommended that this water be used for large groundwater abstraction schemes in the vicinity of the coastal lakes due to the resulting reduction of inflows into the lakes.

The average borehole yield varies between 0.5-2.0 ℓ/s in the coastal aquifer, however, much higher yields are obtained from boreholes tapping the underlying Miocene conglomerates/coqina. The groundwater quality is very good but the shallow water level and hydraulic conductivity of the coastal aquifer and overlying vadose zone makes the aquifers vulnerable to groundwater contamination.

The Miocene aquifer underlies the coastal sands on the coastal margin and sits above low permeability siltstones of the Zululand Group (**Figure 6.1**). It attains a thickness of up to 35 m and yields of over 15 ℓ/s are possible.

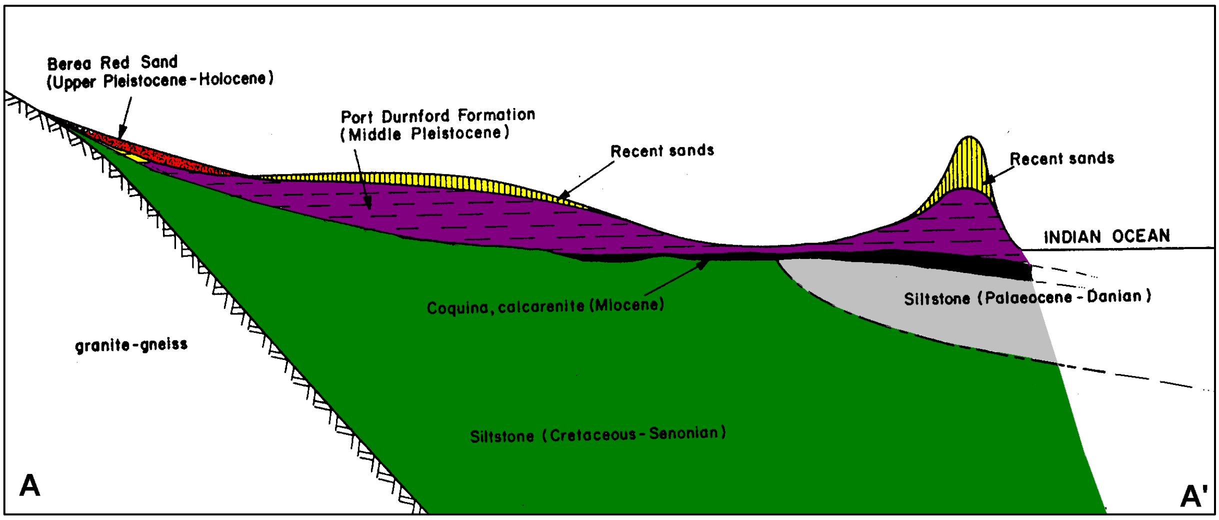


Figure 6.1: Geology of the Zululand coastal plain

The soils and geology of the coastal plain are predominantly composed of recent unconsolidated sands, which are extremely permeable. Most of the rainfall generally infiltrates rapidly into the aquifer and the hydrology of the lakes is influenced by the groundwater system through baseflow and direct seepage from the aquifers. Consequently, groundwater forms an integral part of the water resources.

Groundwater resources on the coastal plain can be seen as complementing surface water resources, since baseflow to the rivers and lakes forms a large part of the water resources and a large proportion of recharge serves to sustain this baseflow. For this reason, it is important to quantify both recharge, its eventual distribution as baseflow and interflow, and inflows and outflows into and out of groundwater fed lakes. The impacts of abstraction are also important to quantify, since groundwater abstraction may deplete both river baseflow and outflow to lakes, thereby affecting surface water resources.

The coastal lakes Cubhu, Mzingazi and Nhlabane are fed by direct rainfall interception, limited surface runoff from riparian zones, streamflow and groundwater inflow. As overland surface runoff is almost non-existent due to the sandy nature of the coastal plain, it is likely that water in streams flowing towards the lakes is also derived from groundwater baseflow; hence groundwater is also a significant component of stream inflows. They are drained by abstraction, evaporation, discharge when lake levels over top the outlet weirs, and groundwater outflow towards the sea.

6.2.3 The Coastal Lakes

Lake Mzingazi

Lake Mzingazi extends to 14 mbmsl. Water levels and discharge from Lake Mzingazi were monitored since August 1978 at a small weir on the southern edge. Lake levels are fairly static and generally remain between 3 - 4 mamsl. During the drought of the early 1990s the lake level dropped to 0.85 mamsl. Peak levels occurred in September 1987 with even greater flooding when the Lake level reached an elevation of 2.85m above the present spillway at 3.03 mamsl.

Relatively good data on storage capacity versus lake level is available (Walmsey and Grobler, 1986). The capacity of the lake, when filled to the level of the spillway (3.03 mamsl) is estimated at approximately 43 Mm^3 (Hattingh, 1998), with an area of 10.57 km^2. At sea level, the lake has a capacity of 16.17 Mm^3 (**Table 6.1**). The minimum capacity associated with lake level maintenance is 16.9 Mm^3, which is approximately 0.1 mamsl.

Table 6.1 Rating table for Lake Mzingazi

Water elevation	Perimeter	Surface Area	Volume
m - *amsl*	Km	10^6*m^2	10^6*m^3
-1	8.30	4.03	10.11
-0.75	17.55	5.62	11.42
-0.5	18.03	6.09	12.89
-0.25	18.51	6.58	14.47
0	18.99	7.08	16.17
0.25	19.17	7.40	17.99
0.5	19.25	7.69	19.88
0.75	19.34	7.97	21.83
1	19.42	8.26	23.86
1.25	19.51	8.55	25.96
1.5	19.57	8.83	28.14
1.75	19.69	9.12	30.38
2	19.77	9.41	32.70
2.25	19.85	9.70	35.08
2.5	19.94	9.99	37.55
2.75	20.03	10.28	40.08
weir @ 3.03	20.11	10.57	42.69

The City of Mhlathuze Local Municipality abstracts water to supply Richards Bay and other users. Water is also used by the Richards Bay Country Club for the golf course and possibly by other small users situated directly next to the lake. Officially, water is only abstracted when the lake level is above a specified minimum stage (storage level) that is set to reduce the impact of saline intrusion.

The lake is only susceptible to saline intrusion under adverse conditions. Several studies were conducted on potential saline intrusion problems for Lake Mzingazi and were presented by Simmonds (1990), van Tonder, Botha and Muller (1986) and Rawlins, Kelbe and Germishuyse (1997).

The position of the sea water interface is dependent on the head of fresh water in the aquifer, and should this head decline the interface moves inland. According to the Ghyben-Herberg concept, the interface is found at a depth below sea level equal to 40 times the head of freshwater above sea level. Consequently, a water level of 1 mamsl, results in the sea water interface being 40 mbmsl. This is well below the base of the lake.

There is also natural groundwater flow towards the coast which depresses the denser sea water interface even further. Simmonds found there is no danger of saline intrusion into the lake if water levels are above 0.4 mamsl, when the interface would be 16 mbmsl. The degree of safety from saline intrusion is substantially higher if tidal waters are prevented from entering the Mzingazi canal. A temporary barrier was constructed in 1992 and later upgraded to a more permanent structure. The barrier acts to retain fresh water approximately 1 m above the saline water level (sea level) in the channel between the lake and the canal. The barrier had a large effect by eliminating the tidal influence between the lake and canal and reducing the salinity levels in this zone. This also reduced the threat of saline intrusion into the lake. During 1994 when the Lake level dropped to 0.85masl at the height of the drought, the water table between the lake and the saltwater canal (0 mamsl) was maintained at approximately the same elevation as the lake during the drought period. Kelbe and Germishuyse (1997) noted that the temporal variation for the electrical conductivity near the lake shows that there were no significant changes in concentration of total dissolved solids (conductivity) at a 5m depth since measurements commenced in 1990.

Lake Nhlabane

The Lake Nhlabane catchment is about 11,886 ha and is a sand catchment intersected by a series of watercourses which formed in the valleys between the inland dunes. To the north is the Mfolozi River catchment and Richards Bay is to the south. The streams and groundwater seepage from the sand aquifer feed directly into Lake Nhlabane. The Lake is 1,258 ha in area when it is at full capacity (**Table 6.2**) and the minimum capacity associated with lake level maintenance is 17.1 Mm^3. With the current weir height and occupies approximately 10% of the catchment area. The Nhlabane Estuary links the lake with the sea via a 2km long channel. This estuary, although very small, is the only estuary in the 60 km of coastline between the Mhlathuze and Mfolozi catchment systems. The connection between the estuary and the lake has been disrupted by the construction of the weir in 1980. Water has not overtopped the weir into the estuary since 2002.

Table 6.2 Rating table for Lake Nhlabane

Water Elevation	Area	Volume
Mamsl	**(km^2)**	**(m^3)**
-1	0	4
-0.75		12469
-0.5		199984
-0.25		700857
0	3	1417778

Water Elevation	Area	Volume
Mamsl	(km^2)	(m^3)
0.25	4	2396829
0.5	5	3588272
0.75		4938411
1	6	6396218
1.25		
1.5	7	9610297
1.75	8	11567843
2		13615807
2.25	9	15741680
2.5		17953381
2.75		
3		22699457
3.25	10	25161015
3.5		27672568
3.75		
4		32844190
4.25		
4.5		38230993
4.75	11	41030524
5		43875761
5.25	12	46720999
5.5		49566236
5.75		52411473
6		55256711

Lake Nhlabane was a former estuary that has been converted to a freshwater lake by the construction of the weir. The lake is shallow and does not extend below sea level. Its volume at the level of the weir (5.75 mamsl) is 52 Mm^3. Lake levels are generally 4.4-4.8 mamsl but have dropped to about 2 mamsl during drought. Abstraction from the lake is approximately 18-22 Mm^3/a.

Lake Nhlabane has been a major source of water supply for RBM for the past 35 years. The increasing demand and utilisation of the water in the region is reducing the reliability of the lake to meet the needs of all the water users. The ability of the lake to provide an adequate and sustainable supply of water is limited by the capacity of the lake to store and release the volumetric quantities of water supplied and lost by natural processes that are affected by anthropogenic impacts in the greater catchment area. The lake and surrounding catchment have changed radically over the past 35 years. These changes have directly and indirectly affected the potential yield of the lake and its ability to sustain water supply under natural hydro-meteorological conditions.

There are no known studies of saline intrusion potential for Lake Nhlabane. The lake volume below mean sea level is less than 11000 m^3 and consequently it is unlikely that there would be saline intrusion.

Lake Cubhu

Lake Cubhu is situated to the south of the Richards Bay Harbour and is isolated from the Mhlathuze. It only overflows when lake levels rise to over 3 mamsl, at which level the storage volume is 10.5 Mm^3. Lake levels are generally just below 3 mamsl but the lake frequently spills (See **Figure 6.2**). The rate of water abstraction at the Esikhaweni Water Treatment Works is about 4.5 Mm^3/a (DWS, 2015d).

The lake has a full supply area and volume of 4.5 km^2 and 9.5 Mm^3. (**Table 6.3**). The minimum capacity associated with lake maintenance is 2.46 Mm^3.

Table 6.3 Rating table for Lake Cubhu

Water elevation	Perimeter	Surface Area	Volume
m - amsl	km	M^2	10^6*m^3
-1	2.045	184310	0.032
-0.75	2.468	295559	0.091
-0.5	4.083	462655	0.184
-0.25	8.914	820273	0.335
0	11.594	1821399	0.676
0.25	12.261	2383110	1.207
0.5	12.004	2860863	1.866
0.75	12.478	3126396	2.614
1	13.605	3438812	3.435
1.25	13.709	3690215	4.327
1.5	13.061	3892080	5.277
1.75	12.804	4072550	6.272
2	12.458	4234005	7.311
2.25	12.231	4390209	8.389
2.5	12.005	4542136	9.506

Lake levels were recorded since October 1995.

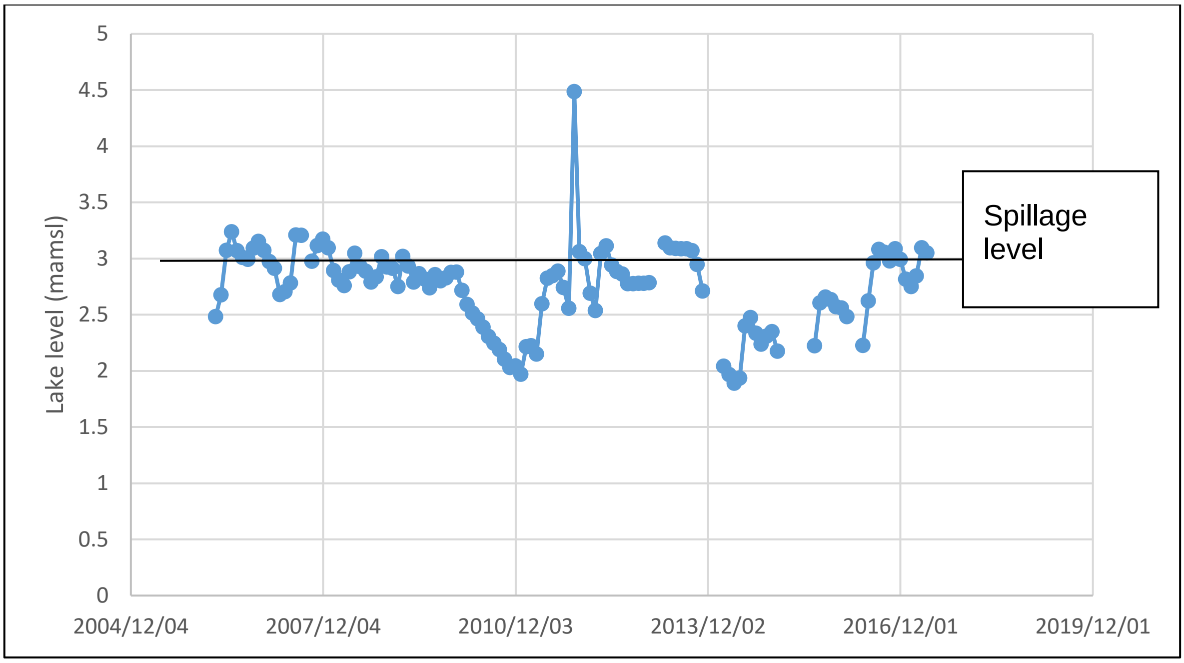


Figure 6.2: Lake Cubhu lake levels

6.3 Reevaluation of data

6.3.1 Lake Mzingazi

A reevaluation of the MWAAS and the Yield Analysis report found that:

- The Kelbe and Germishuyse (2001) water balance data against which the MWAAS lake model was calibrated did not match the existing surface water hydrology from the Pitman Model. It simply assumed that surface runoff into the lake was equal to the excess above the recharge rate, with a reduction of 75% in periods when recharge was less than 4 mm/d. This difference in the surface water hydrology would impact on the lake water balance and consequently could affect required groundwater interactions.
- There was uncertainty in the area of afforestation that was used in the MWAAS. An overestimate of afforestation would reduce the simulated surface water inflow, hence increase the groundwater contribution required to maintain lake levels and discharge over the outflow weir. The area of afforestation also affects recharge and the potential area of evapotranspiration from groundwater, hence also affects the groundwater balance.
- The lake level data used by Kelbe and Germishuyse (2001) does not match the lake level measurements obtained from DWS as they were based on stage at the outlet weir rather than lake levels at the pumping station (DWS station number W1R004) (**Figure 6.3**). In addition, the outlet weir was raised in 1992. The DWS data clearly demonstrate the raising of the outlet weir (**Figure 6.3**), while the Kelbe data do not (**Figure 6.4**). The Kelbe data show a stationary weir outlet at 3.03 mamsl. Kelbe and Germishuyse (2001) state the lake levels were derived from W1H011, which is the outlet weir, and measurements are height above the weir rather than lake level.
- The areas used to define groundwater inflow to the lakes for the Lake Module were the lake catchment due to the catchment resolution of the project. The sub-areas need to be redefined according to the groundwater inflow zone to

the lake, as a portion of the Lake sub-catchments, which could affect the Lake groundwater balances.

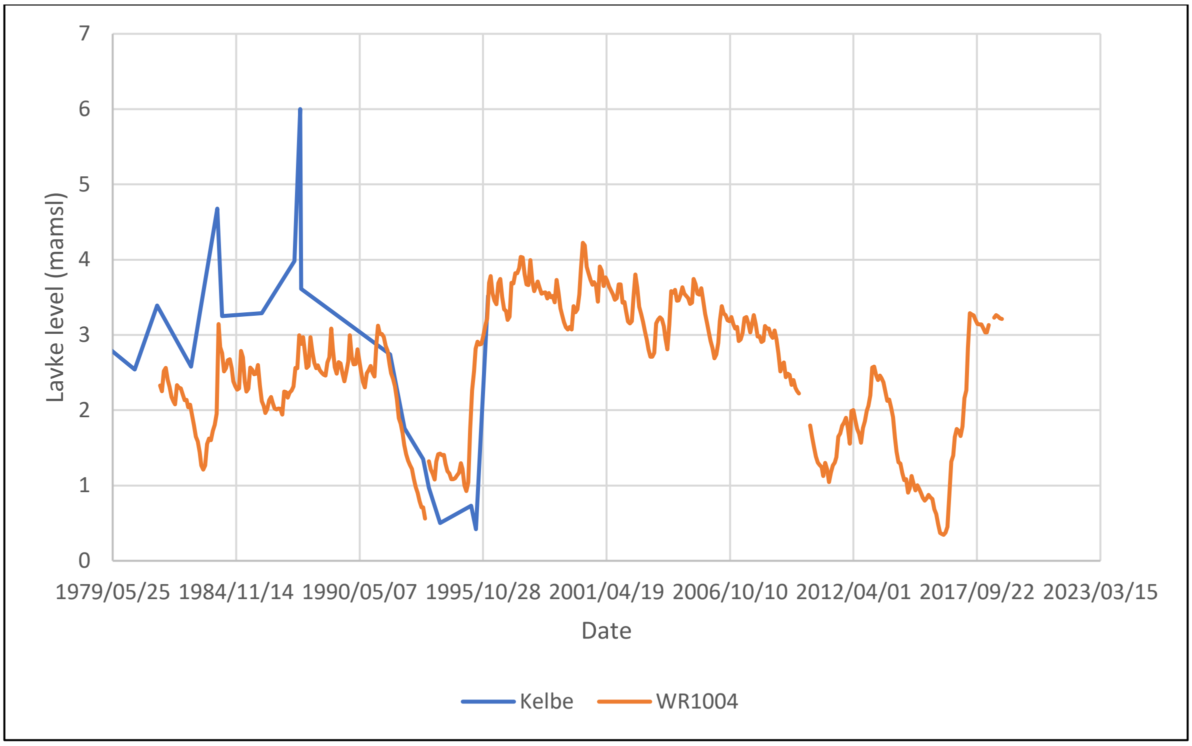


Figure 6.3 Lake water levels from stress periods used by Kelbe and from DWS W1R004 (lake level) Lake Mzingazi

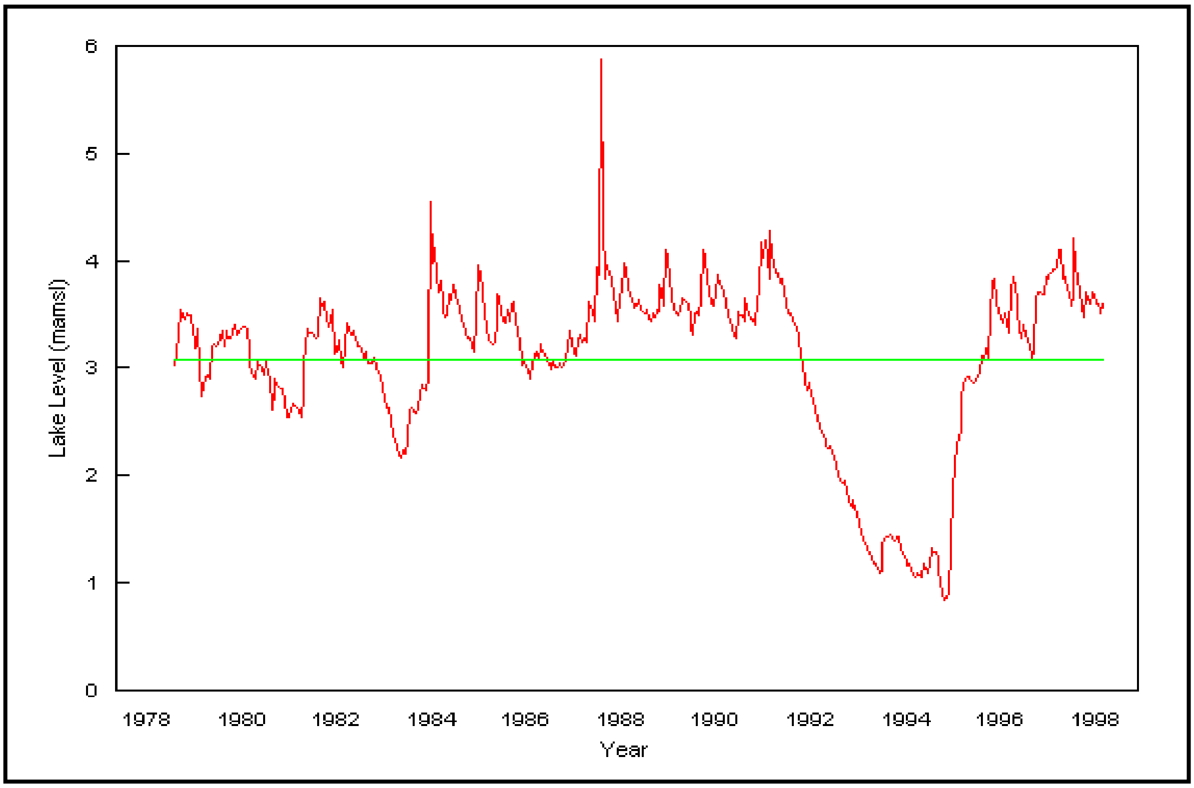


Figure 6.4 Mzingazi lake levels from Kelbe (2001) and level of the outlet weir

The implications of including the lower outlet weir level in simulations is that when the lake storage was lower pre 1992, it would require a significantly higher groundwater contribution to maintain lake water levels as lake storage was lower.

This study found a need to recalibrate the lake model, to fit the lower lake storage balance prior to 1992 and fit water levels before and after this period.

6.3.2 Lake Nhlabane

A reevaluation of the MWAAS and subsequent studies found that:

- The functioning of the lake has been altered by 3 stage raising of the outlet weir in 1980, 1985 and 1998, which was not considered in the MWAAS.
- The bathymetry of the lake, surveyed by EMS (2009), revised the volume-stage and area-stage relationships used by the lake model during the MWAAS.
- Lake level data are available from RBM for the period 1993-2005, which was not available during the MWAAS.
- Afforestation areas were revised.

6.3.3 Lake Cubhu

No new data have become available, except revised afforestation estimates, which potentially alter surface water inflows to the lake.

6.3.4 Groundwater level data

The location of groundwater monitoring boreholes is shown in **Figure 6.5.** Boreholes only exist in the vicinity of Lake Mzingazi and water level data is only post-2004, which falls outside the period for which hydrology is available (1920-2005).

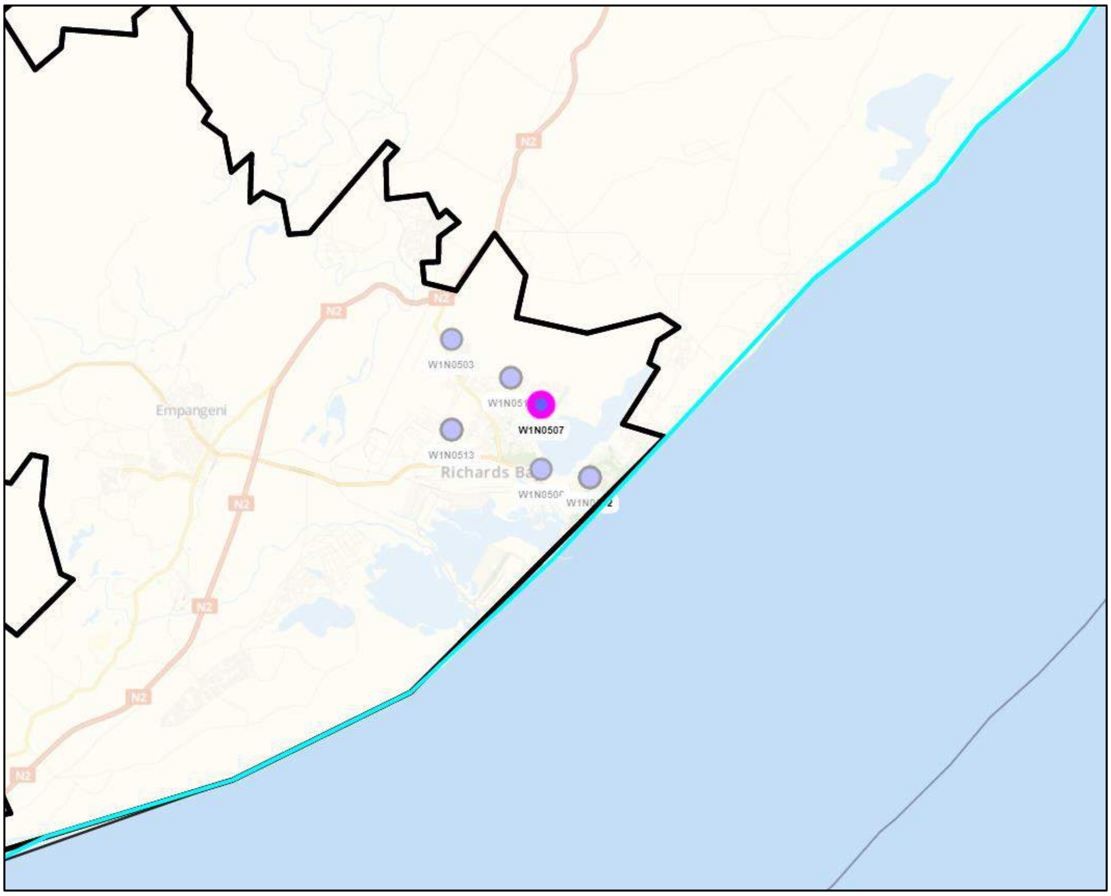


Figure 6.5 Location of monitoring boreholes in the lakes region

6.4 Methodology

The lake water balance model developed during the MWAAS to simulate lake levels, groundwater interactions and lake discharges was updated and utilised as part of this Study. This model is compatible with input data from the Pitman Model, utilising catchment discharge, rainfall, and the Sami module aquifer storage variable to drive the Lake module. The Lake module generates a monthly time series for:

- Lake rainfall
- Groundwater Inflow
- Lake evaporation
- Groundwater outflow
- Lake surface water discharge
- Lake level and storage

It simulates the impacts of lake and groundwater abstractions on the lake water balance and lake levels, which are calibrated against lake level data and discharges. The lake water balance is converted to a lake level and surface area by volume-area-level relationships determined from lake bathymetry.

The model conceptualisation, structure and parameterisation is described in the MWAAS documentation (DWAF, 2009) and are summarised in 2.7.

The model used for the MWAAS was recalibrated based on:

- Revised Pitman model inflow simulations based on afforestation estimates in lake catchments (Quaternaries W12F and W12J).
- The separation of lake catchments into Quinary catchments according to the area considered to contribute surface and groundwater inflow to the lake and that contributing only surface inflow. Consequently, the groundwater inflow zone to each lake is a distinct quinary catchment.
- Utilisation of DWS and RBM data on lake levels and discharge for calibration
-

6.5 Lake Mode Structure

The structure of the lake model is shown in **Figure 6.6**.

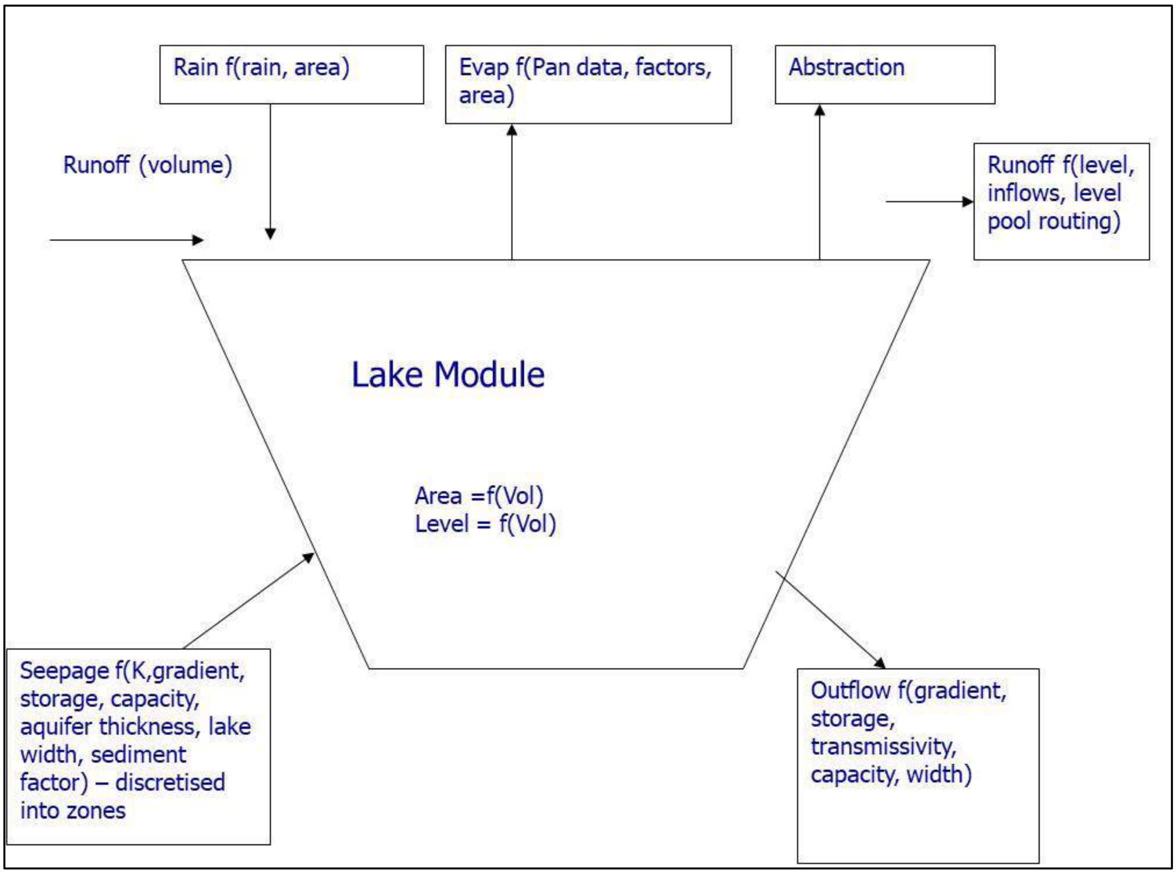


Figure 6.6: Lake module structure

The parameters required for the lake module area shown in **Table 6.4**.

Table 6.4 lake module parameters

Model parameters	Units	Name	Typical Range	Data Source	Uses
Volume-Area slope		A		Bathymetric survey of Area vs volume: AREA=a * Ln VOL - b	Determines area for rainfall and evaporation
Volume-Area Intercept		B			

Model parameters	Units	Name	Typical Range	Data Source	Uses
Volume-Level slope		A		Bathymetric survey of Level vs volume: Level =a * Ln VOL - b	Determines head for level pool routing of outflows. Used for calibration against observed levels
Volume-Level Intercept		B			
Starting Volume	Mm3		Approx. lake full volume	Bathymetric data	Initial condition only
Spill Level	mamsl			Survey of elevation of outflow weir	Used to determine head for level pool routing and level at which outflow takes place
Evaporation pan factors		PAN	0.8-1	WR90, WR2005	12 monthly pan factors to covert pan evaporation data to open water
Lake MAE	mm/a	MAE		WR90	Mean annual S-pan evaporation
Lake half width	m			maps	Used to calculate area of groundwater inflows and outflows
Lake length	m			maps	Used to calculate area of groundwater inflows and conductance
Static water level	mm	LAKESWL	<TAS	Based on aquifer capacity in WRSM2000 and fraction of penetration by the lake	Determines the groundwater storage STORE in WRSM2000 level at which discharge from the lake to the aquifer will stop
Permeability	m/d	K	1-20	Aquifer data	Determines rate of seepage from groundwater into the lake
Sediment factor		SEDFACT	0.1-0.5	Calibration	Determines reduction of permeability due to anisotropy and fine lake bed sediments
Transmissivity	M2/d	T	5-250	Test pumping	Determines rate of loss to the aquifer
Lake MAP	Mm/a	MAP		Rainfall data	Determines rainfall inputs to lake
Rating Curve		C		From rating curve of weir, or estimated so that discharge is less than volume of lake above spill level at various heads	Used to determine routing of outflows
Rating curve Power		POW	1-1.5		

6.6 Lake Mzingazi

6.6.1 Model Setup and surface water inflows

The lake sub-catchments, including the areas contributing groundwater to the lakes, are shown in **Figure 6.7**. The Pitman Model was utilised to simulate runoff into the Lake from the catchment. The parameter set is shown in **Table 6.5**.

Surface runoff into Lake Mzingazi from the Pitman Model for different periods is shown in **Table 6.6** and **Figure 6.8**. There is a decline in MAR over time due to the increasing level of afforestation.

Figure 6.7 Quaternary Catchments and groundwater contribution area lake Quinary catchments

Table 6.5 Lake Mzingazi Pitman model parameters

Parameter	Value	Parameter	Value
MAP (mm/a)	1306	ZMIN	999
POW	3	ZMAX	999
SL	0	PI	1.5
ST	600	TL	0.25
FT	12	GL	2.5
GW	0	R	0.5

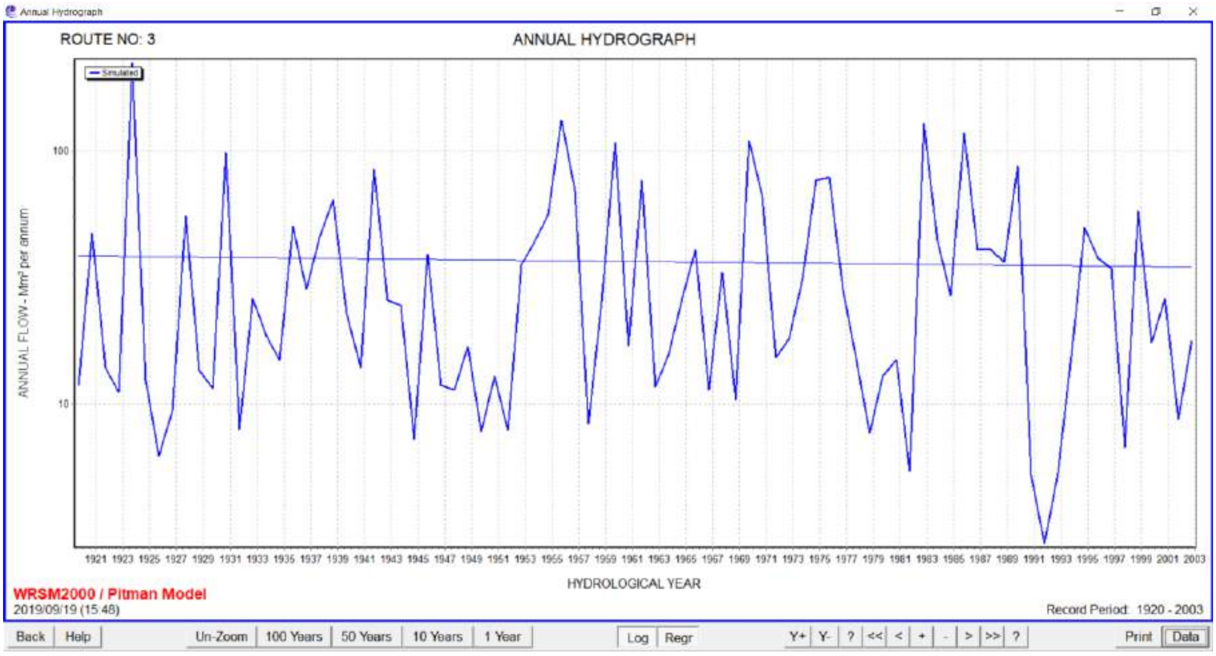


Figure 6.8 Surface water inflow into Lake Mzingazi

Table 6.6 Lake Mzingazi afforestation and simulated runoff

Mzingazi Quinary catchment excluding lake catchment area = 130.5 km²								
		Period						
	Natural	1920-1959	1960-1969	1970-1979	1980-1989	1990-1999	1999-2003	2003
Afforestation at start year (km²)	0	0	29.1	38.3	46	61.3	76.7	76.7
Aliens at start year (km²)	0	0	1.5	2.2	2.8	4.9	4.9	8.6
MAR (Mm³)	33.13	29.62	29.05	37.04	38.83	22.39	20.99	
Lake Mzingazi Groundwater Catchment Area = 27 km²								
Afforestation at start year (km²)	0	0	5.7	7.5	9	12	15	15
MAR (Mm³)	6.85	6.16	6.09	7.79	8.19	4.79	4.63	
Total Inflow to lake (Mm³)	39.98	35.78	35.14	44.83	47.02	27.18	25.63	

6.6.2 Lake Groundwater Interaction parameters

The surface water runoff and aquifer storage time series were input into the Lake Model with the lake abstraction time series (**Figure 6.9**) with the parameter set in **Table 6.7**.

Table 6.7 Lake Mzingazi Parameters for Lake model

Parameter	Value
Transmissivity	76
Spill level (mamsl) 1920/1995	2.1/3.03
Aquifer storage for 0 inflow (mm)	0
Permeability (m/d)	4.6
Sediment factor (fraction of permeability)	0.33
Aquifer thickness (m)	32.6
Lake width (m)	4000
Lake length (m)	2500
MAP (mm/a)	1306
Evaporation (mm/a)	1422

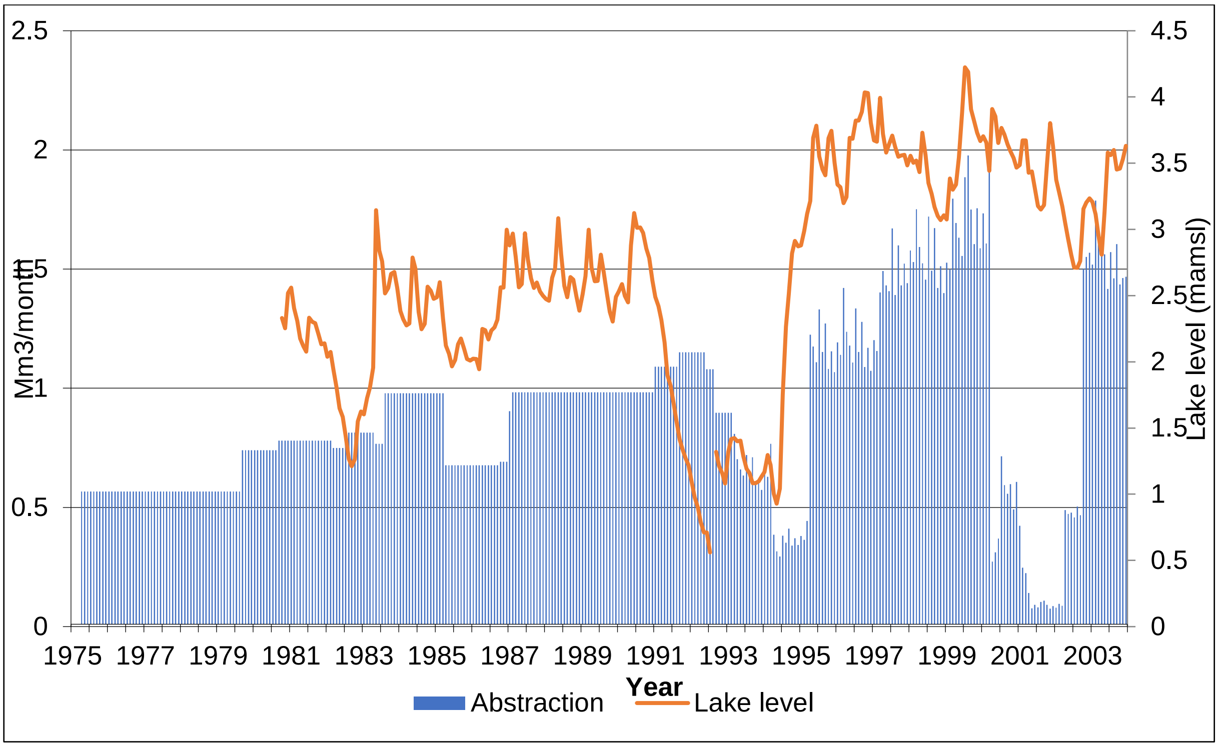


Figure 6.9 Abstraction from Lake Mzingazi

The Lake volume-level-area relationships utilised to convert the lake water balance to a lake level and area are shown in **Figure 6.10** and **Figure 6.11**.

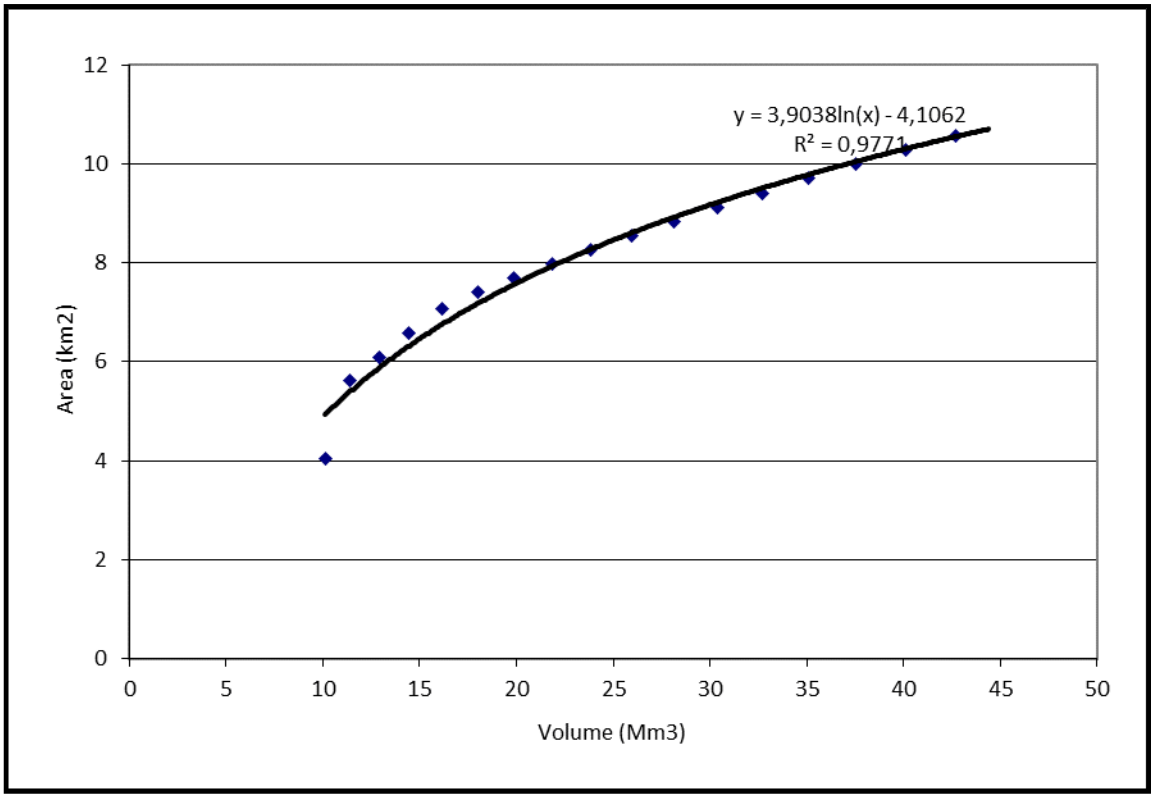


Figure 6.10 Volume-area relationship for Lake Mzingazi

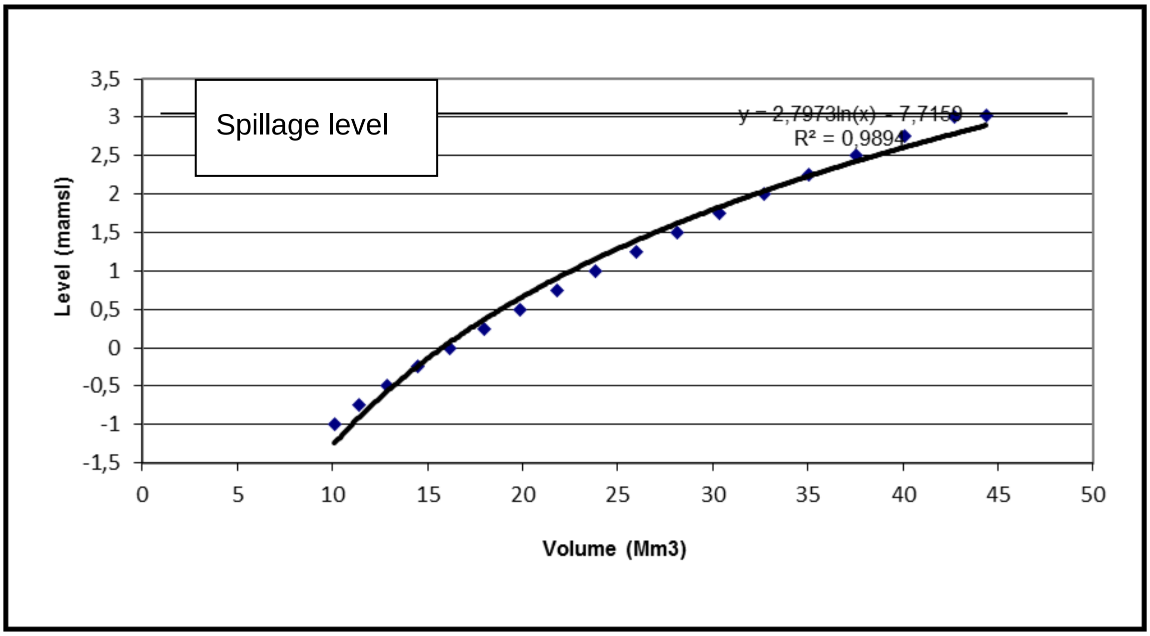


Figure 6.11 Volume–level relationship for Lake Mzingazi

6.6.3 Results

Observed and simulated lake water levels, and naturalised flow with the outlet weir at present level are shown in **Figure 6.12**.

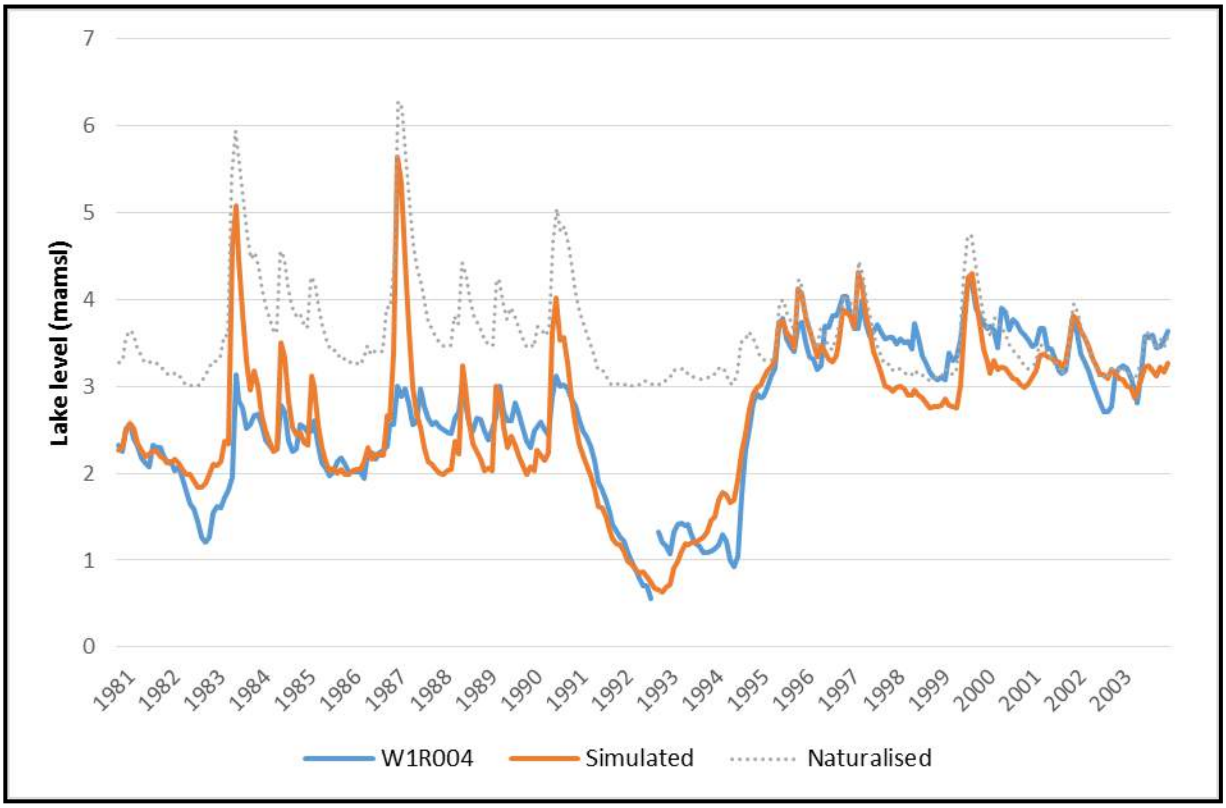


Figure 6.12 Lake Mzingazi simulated, naturalised and observed water levels

The discharge from Lake Mzingazi were monitored since August 1978 at a small weir on the southern edge of the berm wall (W1H011). However, there is uncertainty in over one third of months in the record of discharge. Observed and simulated discharge is shown in **Figure 6.13**.

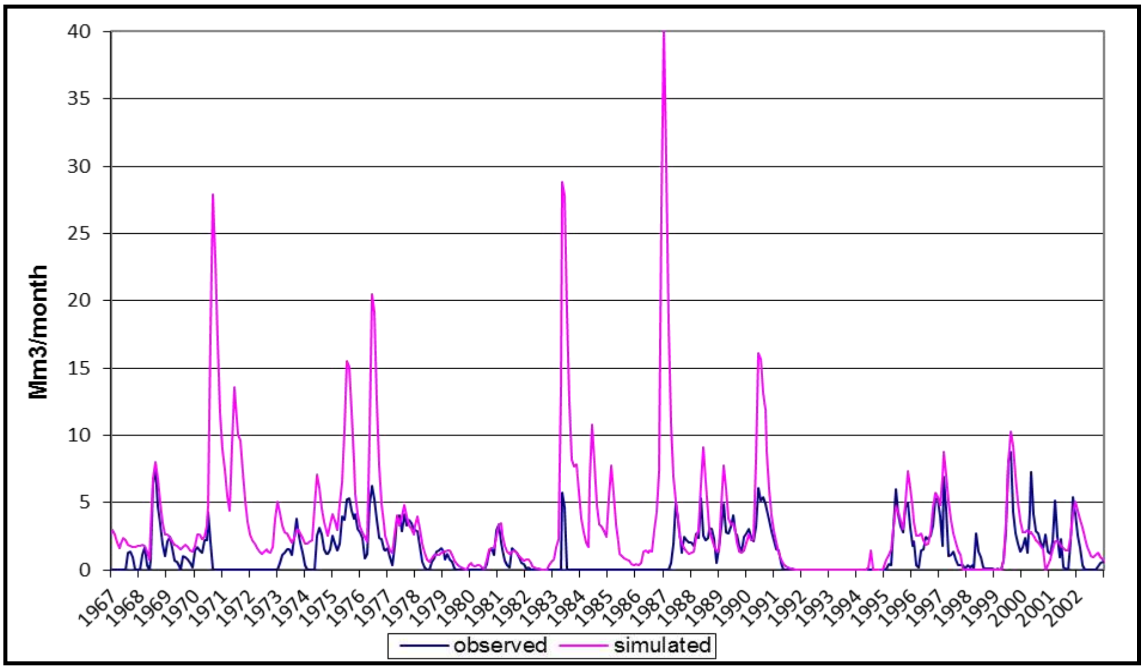


Figure 6.13 Lake Mzingazi simulated and observed discharge

The relationship between simulated and observed lake levels and discharge is shown in **Figure 6.14** and **Figure 6.15**. The relationship is poor for discharge due to the many months with incomplete or missing data, and because the weir cannot measure high flows.

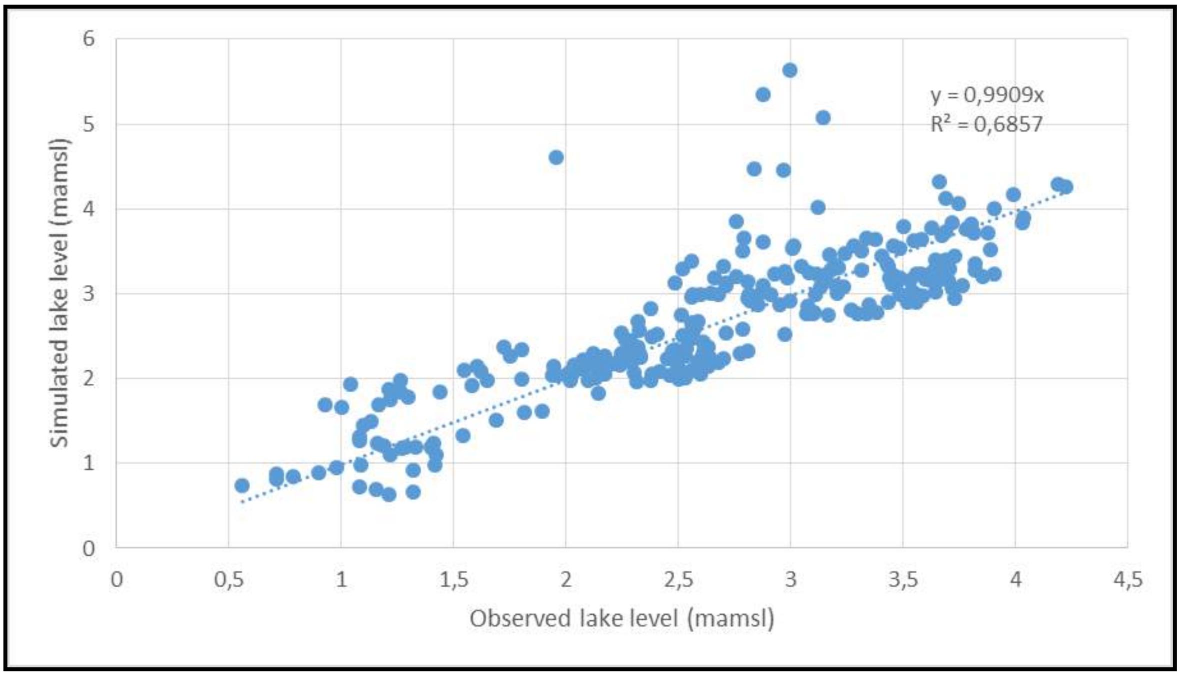


Figure 6.14 Lake Mzingazi observed vs simulated lake level correlation

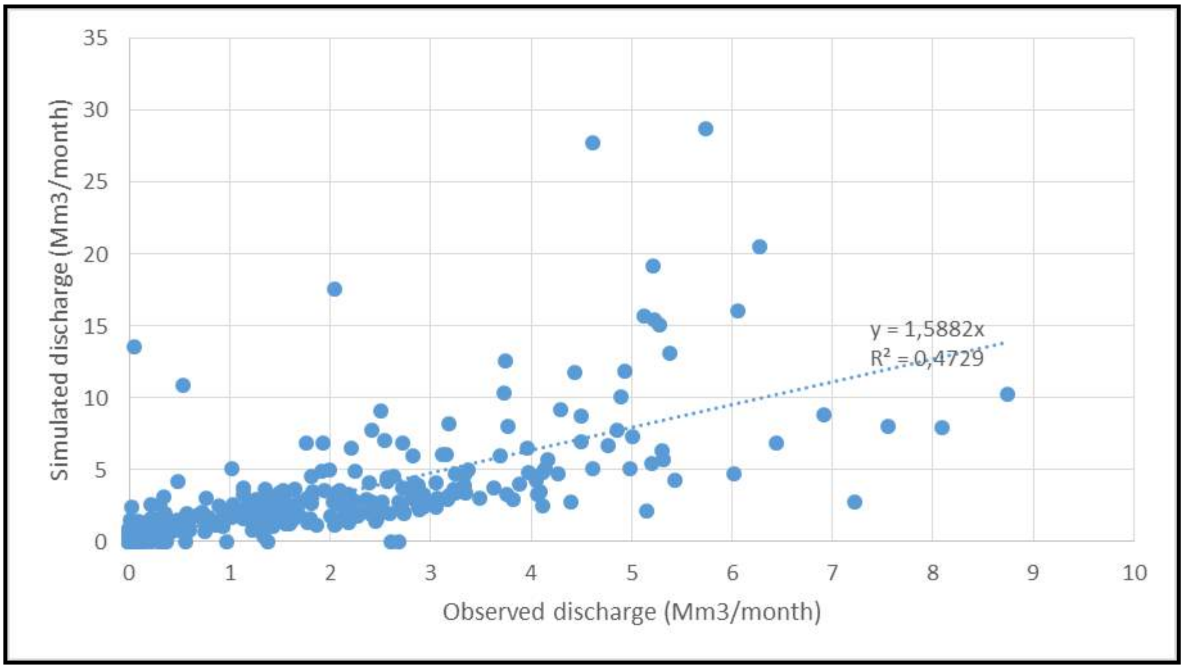


Figure 6.15 Lake Mzingazi observed vs simulated discharge correlation

From the start of the monitoring program until 1992 the lake level remained fairly static between 2-3 mamsl, with the exception of the period between 1981 and 1983 when the lake levels dropped below the spillway. This dip in water level is underestimated by the model.

The major flood event in January 1984 following cyclones Domoina and Imboa showed a significant increase in Lake level, which reached a stage of more than 1.5m above the present spillway is correctly simulated. This was followed three years later in September

1987 with even greater flooding when the Lake level reached an elevation of 2.85m above the present spillway (nearly 5.88 mamsl). Simulated peaks reach 2.65 m above the spill way.

During the severe drought period from 1992 to the 1995, the lake level dropped continuously to a low level of 1.08 mamsl at the end of the winter of 1993. There was a very slight recovery during the summer rainfall of 1994 but the lake level then fell even further to a low of 1.06 mamsl in July 1994, and finally to 0.85 in February 1995. Simulated lake levels drop to 0.63 mamsl during this period.

The lake water balance over the period is shown in **Table 6.8**. In comparison to the water balance provided by Germishuyse (1999), surface water inflows are significantly higher.

Table 6.8 Lake Mzingazi mean annual water balance

	Natural	Germishuyse (1999)	1920-1960	1960-1975	1975-1985	1985-1990	1990-1995	1995-2003
Rainfall	15.42	14.23	13.45	14.19	13.90	14.95	10.26	14.97
Surface Inflow	39.98	12.78	35.78	39.48	41.43	52.67	23.23	28.52
Groundwater Inflow	12.98	14.97	12.97	13.11	13.00	12.95	12.41	13.12
Evaporation	-14.6	-12.78	-12.89	-12.96	-12.67	-13.14	-11.85	-13.80
Abstraction	0	-17.16	0	0	-8.28	-10.47	-10.27	-13.35
Surface water outlfow	-53.13	-15.70	-48.69	-53.05	-47.22	-57.13	-20.55	-28.45
Groundwater Outflow	-0.53	-0.37	-0.53	-0.54	-0.53	-0.53	-0.51	-0.54

Figure 6.16 shows dry season flows for the month of July for surface water, and for groundwater inflow minus outflow (net groundwater contribution). Flows have remained consistent with groundwater contributions exceeding surface water in some years, especially during the drought of the early 1990s. Extended periods of groundwater inflow exceeding surface water by a large margin can be expected to have an impact on water quality, with the lake showing an increasing groundwater signature.

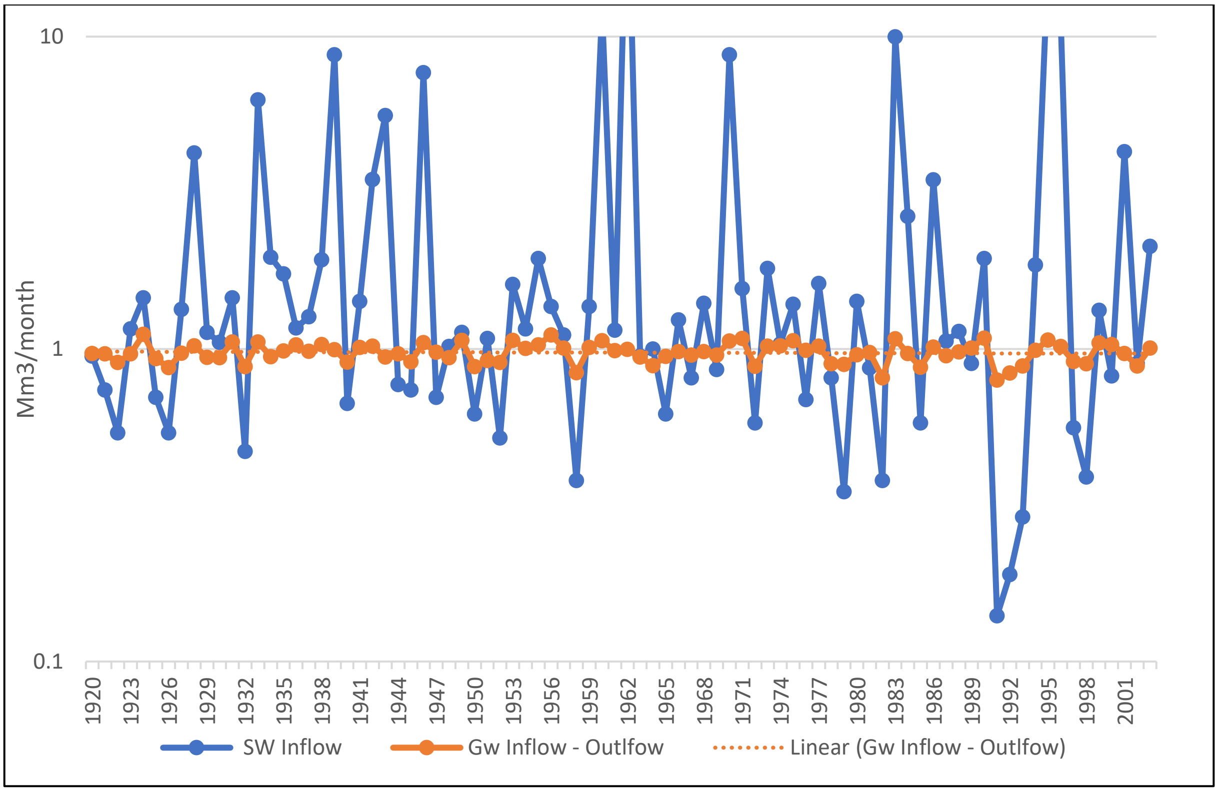


Figure 6.16 Lake Mzingazi surface water and groundwater contributions in July

A double mass plot of cumulative inflow of surface and groundwater (**Figure 6.17**) shows that there is a declining trend in flow relative to natural flow as the surface water inflow line deviates increasingly from the 1:1 line. A decrease in slope towards the end of the plot indicates an increasing rate of runoff reduction. The groundwater plot is linear, suggesting little change in the groundwater regime.

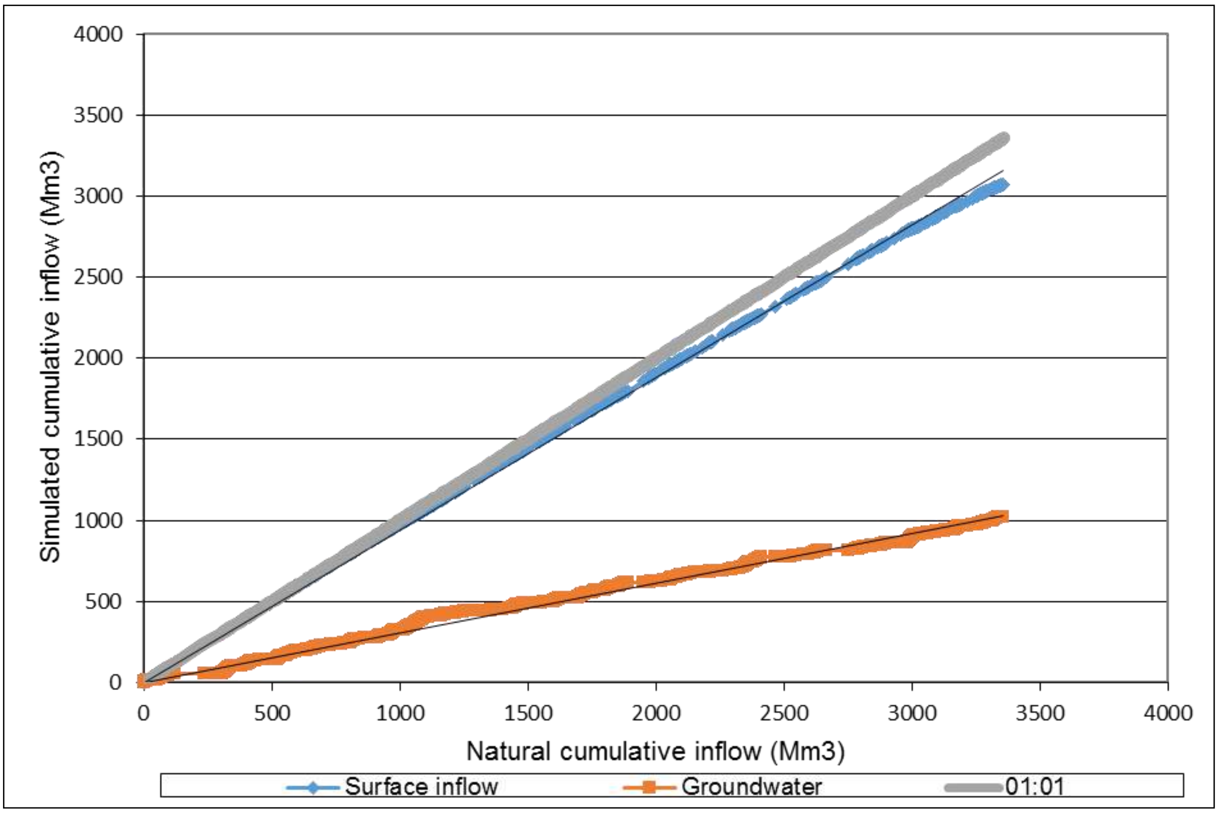


Figure 6.17 Lake Mzingazi Double Mass plots of inflows

6.7 Lake Nhlabane

6.7.1 Model Setup and surface water inflows

The lake sub-catchments are shown in **Figure 6.7**. The Pitman Model was utilised to simulate runoff into the Lake from the catchment. The parameter set is shown in **Table 6.9**.

Surface runoff into Lake Nhlabane from the Pitman Model for different periods is shown in **Table 6.10** and **Figure 6.18**. There is a decline in MAR over time due to the increasing level of afforestation.

Table 6.9 Lake Nhlabane Pitman model parameters

Parameter	Value	Parameter	Value
MAP (mm/a)	1322	ZMIN	999
POW	3	ZMAX	999
SL	0	PI	1.5
ST	600	TL	0.25
FT	12	GL	2.5
GW	0	R	0.5

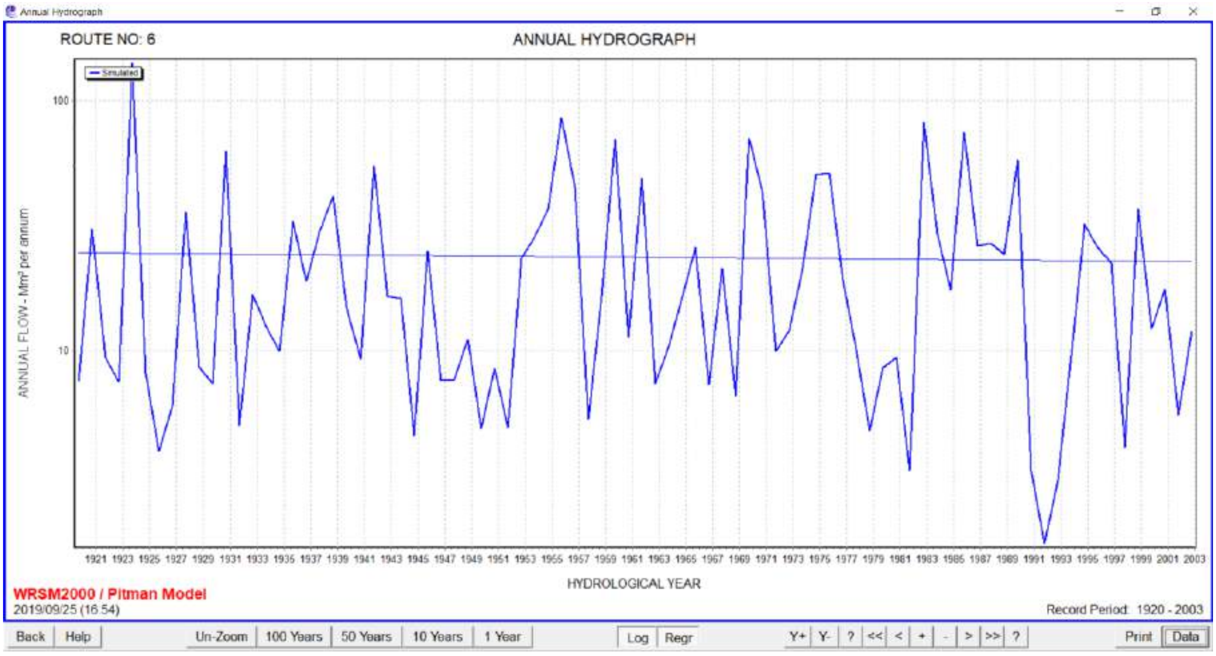


Figure 6.18 Surface inflow into Lake Nhlabane

Table 6.10 Lake Nhlabane afforestation and simulated runoff

Nhlabane Quinary catchment excluding lake catchment area = 72.7 km²							
		Period					
	Natural	1920-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2003	2003
Afforestation at start year (km²)	0	0	13.1	17.2	20.6	27.5	34.4	34.4
Aliens at start year (km²)	0	0	0.7	1.0	1.3	2.3	2.3	4
MAR (Mm³)	19.17	17.26	16.98	21.98	22.81	14.96	9.15	
Lake Nhlabane Groundwater catchment Area = 24. 8km²							
Afforestation at start year (km²)	0	0	7.5	9.9	11.9	15.9	19.8	19.8
MAR (Mm³)	6.54	5.8	5.55	7.25	7.38	4.69	2.61	
Total Inflow to lake (Mm³)	25.71	23.06	22.54	29.24	30.19	19.65	11.77	

6.7.2 Lake Groundwater Interaction parameters

The Pitman Model's runoff and aquifer storage time series, together with the lake abstraction time series (**Figure 6.19**) were entered into the lake model with the parameter set in **Table 6.11**.

Table 6.11 Lake Nhlabane parameters for lake model

Parameter	Value
Transmissivity	76
Spill level (mamsl) 1920/1979/1984/1999	0.5 /3.8 /4.75 /5.85
Aquifer storage for 0 inflow (mm)	250
Permeability (m/d)	4.6
Sediment factor (fraction of permeability)	0.13
Aquifer thickness (m)	32.6
Lake width (m)	4000
Lake length (m)	3000
MAP (mm/a)	1322
Evaporation (mm/a)	1422

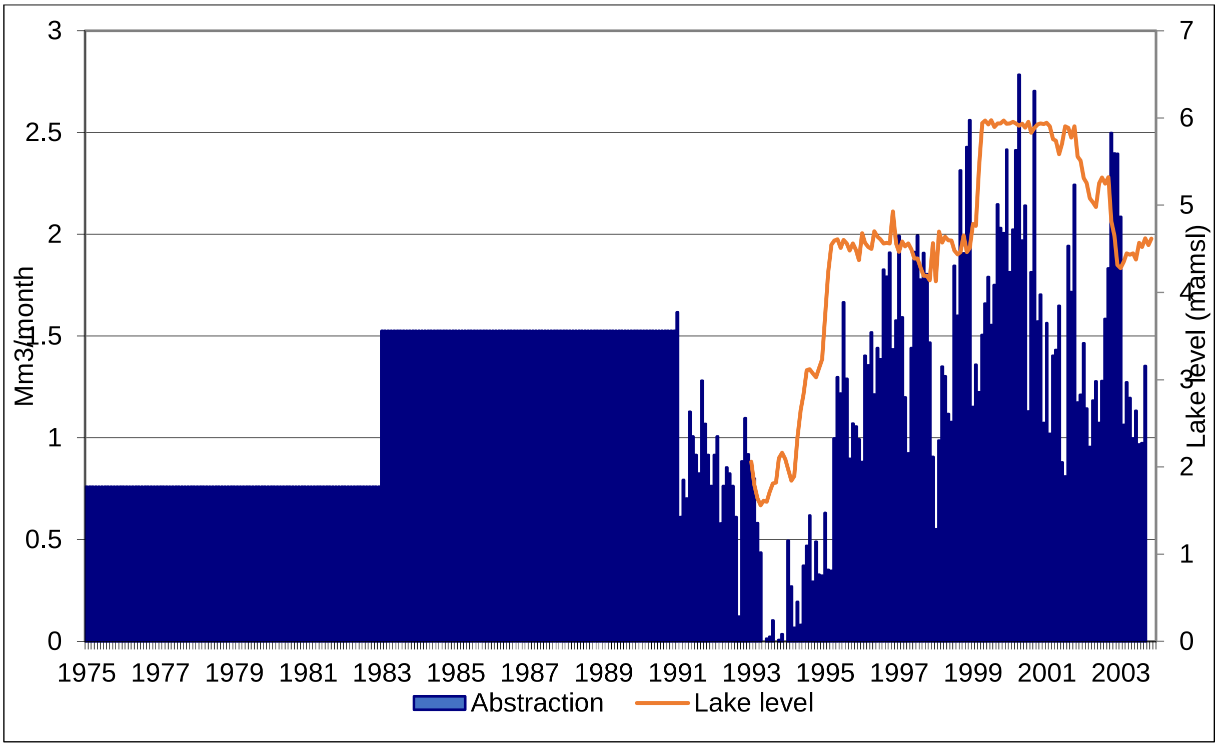


Figure 6.19 Abstraction from Lake Nhlabane

The Lake volume-level-area relationships utilised to convert the lake water balance to a lake level and area are shown in **Figure 6.20** and **Figure 6.21**.

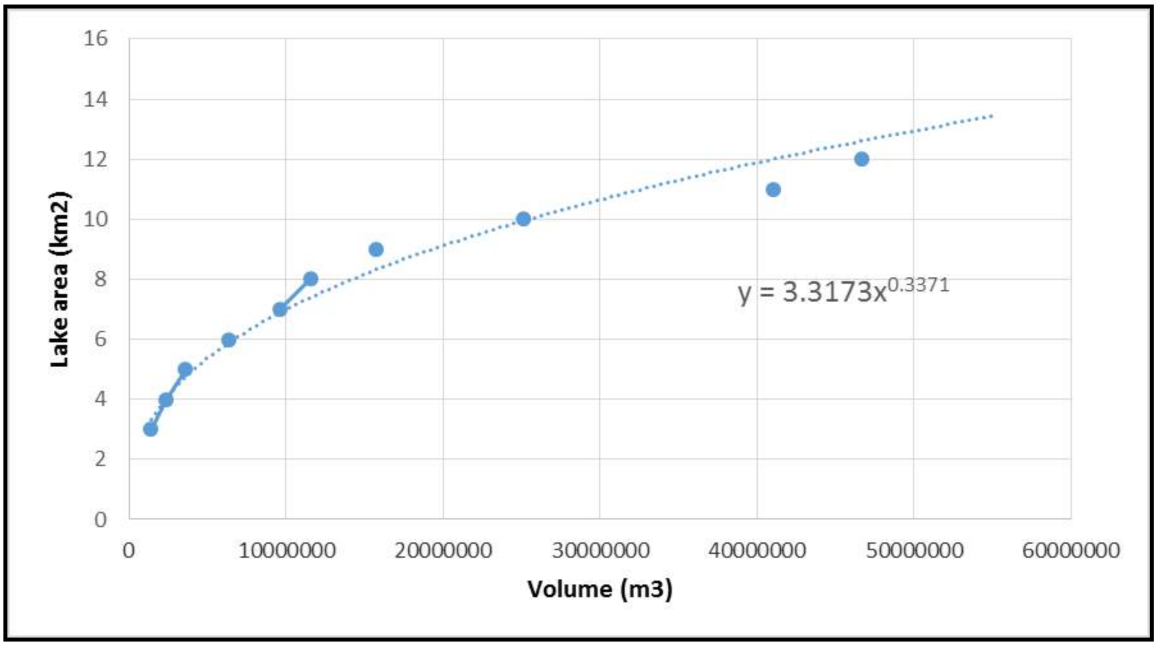


Figure 6.20 Volume-area relationship for Lake Nhlabane

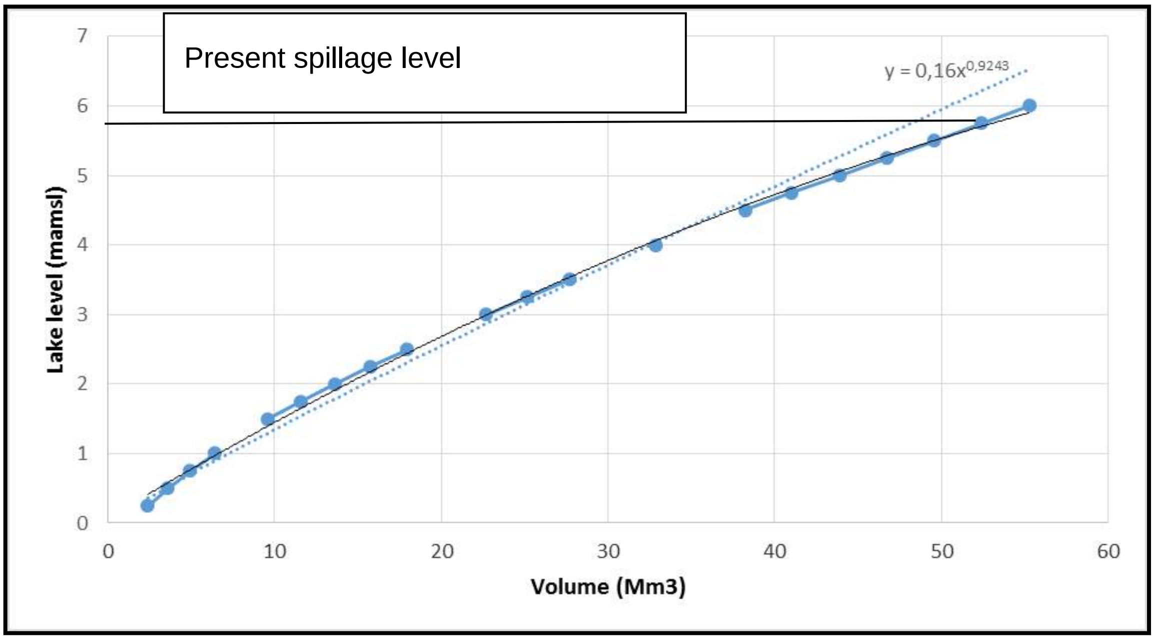


Figure 6.21 Volume–level relationship for Lake Nhlabane

6.7.3 Results

Observed and simulated lake water levels, and naturalised flow with the outlet weir at present level are shown in **Figure 6.22**. The discharge from Lake Nhlabane is not monitored.

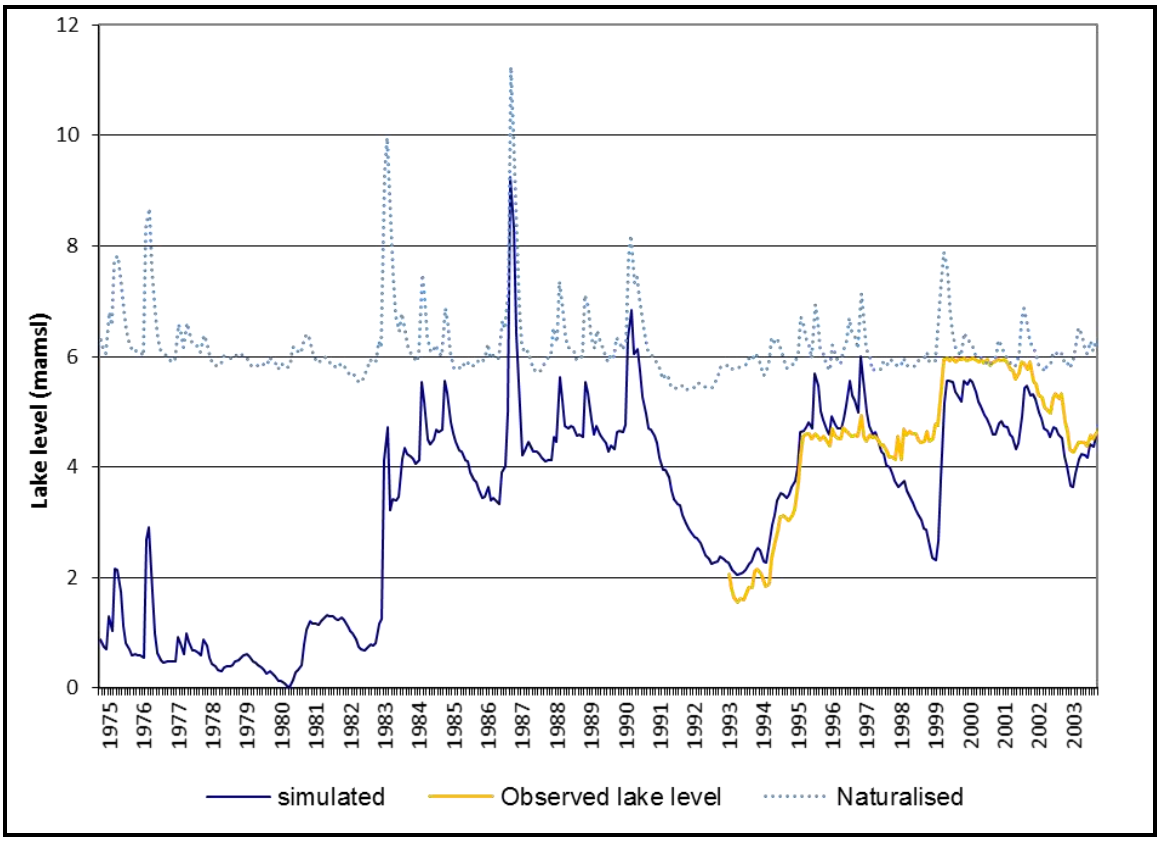


Figure 6.22 Lake Nhlabane simulated, naturalised and observed water levels

The relationship between simulated and observed lake levels is shown in **Figure 6.23**.

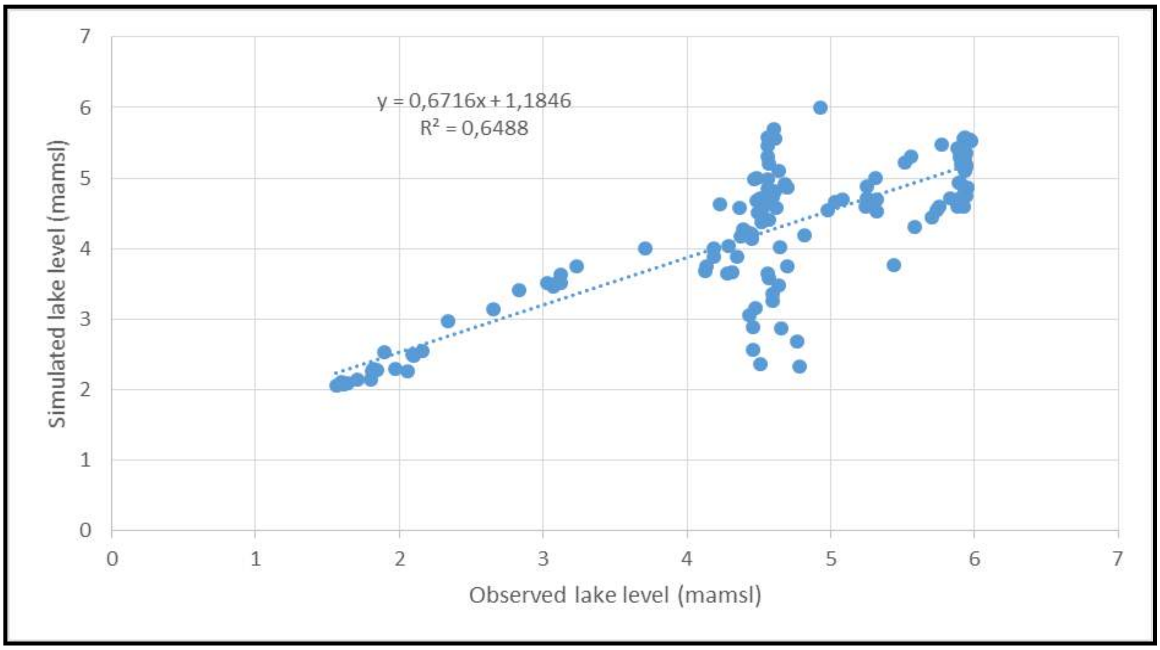


Figure 6.23 Lake Nhlabane observed vs simulated lake level correlation

The monitoring programme began during the drought of 1990-1995 and captures the lowest recorded lake level, which facilitates the calibration of the model. Since 2000 the water level remains below the level of the present weir, and does not spill. Minimum simulated water levels are 2.04 mamsl, while the recorded minimum level is 1.56 mamsl.

The lake water balance over the period is shown in **Table 6.12**. In comparison to the water balance provided by Kelbe et al (2013), surface water inflows are significantly higher.

Table 6.12 Lake Nhlabane mean annual water balance

	Natural	Kelbe et al (2013)	1920-1960	1960-1975	1975-1985	1985-1990	1990-1995	1995-2003
Rainfall	17.12	14.97	8.69	9.04	9.42	16.58	11.50	15.06
Surface Inflow	25.71	10.22	23.06	25.48	26.79	33.90	15.11	18.67
Groundwater Inflow	5.14	4.38	5.80	5.89	5.82	5.87	5.54	5.89
Evaporation	-16.03	-15.33	-8.09	-8.12	-8.37	-14.46	-13.26	-13.82
Abstraction	0	-10.95	0	0	-10.5	-18.3	-9.91	-17.72
Surface water outlfow	-31.44	0	-28.94	-31.61	-19.31	-23.75	-10.13	-6.37
Groundwater Outflow	-0.45	-3.29	-0.50	-0.52	-0.51	-0.51	-0.48	-0.51

Figure 6.24 shows dry season flows for the month of July for surface water, and for groundwater inflow minus outflow. Dry season flows have remained consistent with groundwater contributions exceeding surface water only in very dry years. The lower groundwater contribution relative to lake Mzingazi means the lake is more vulnerable to drought.

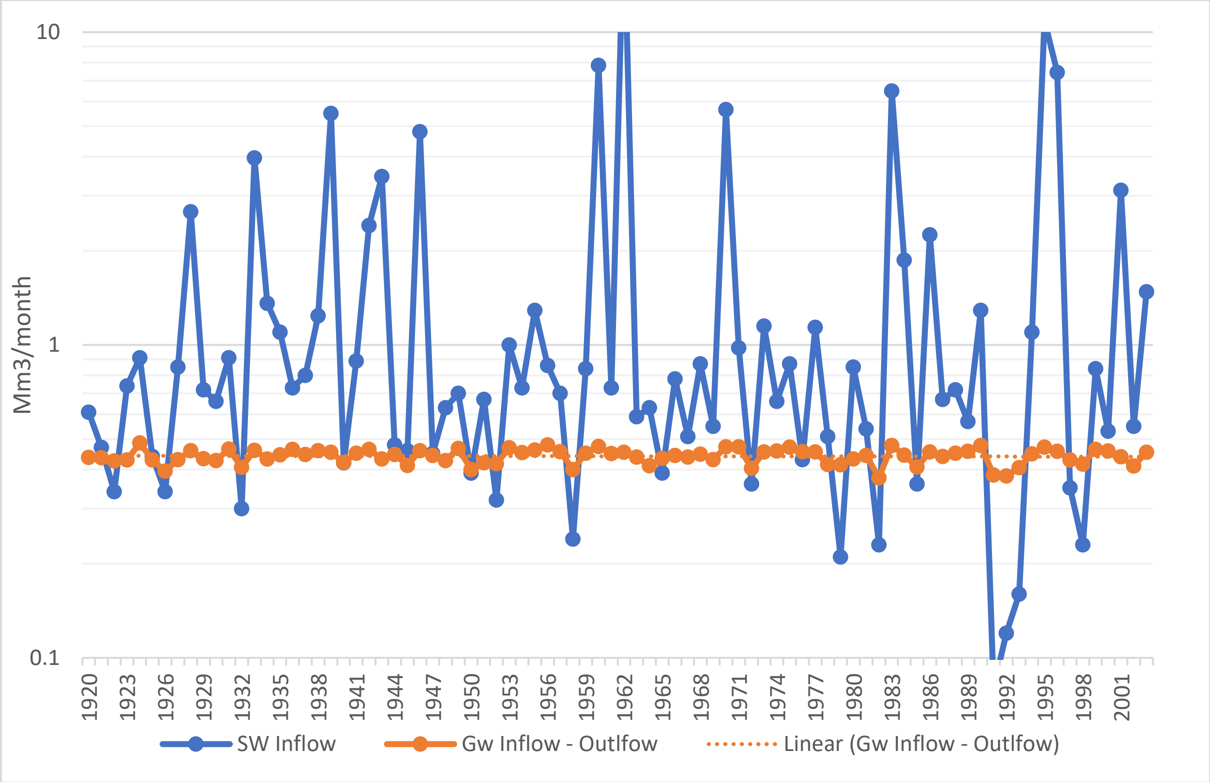


Figure 6.24 Lake Nhlabane surface water and groundwater contributions in July

A double mass plot of cumulative inflow of surface and groundwater (**Figure 6.25**) shows that there is a declining trend in flow relative to natural flow as the surface water inflow line deviates increasingly from the 1:1 line. A decrease in slope towards the end of the plot indicates an increasing rate of runoff reduction. The groundwater plot is linear, suggesting little change in the groundwater regime.

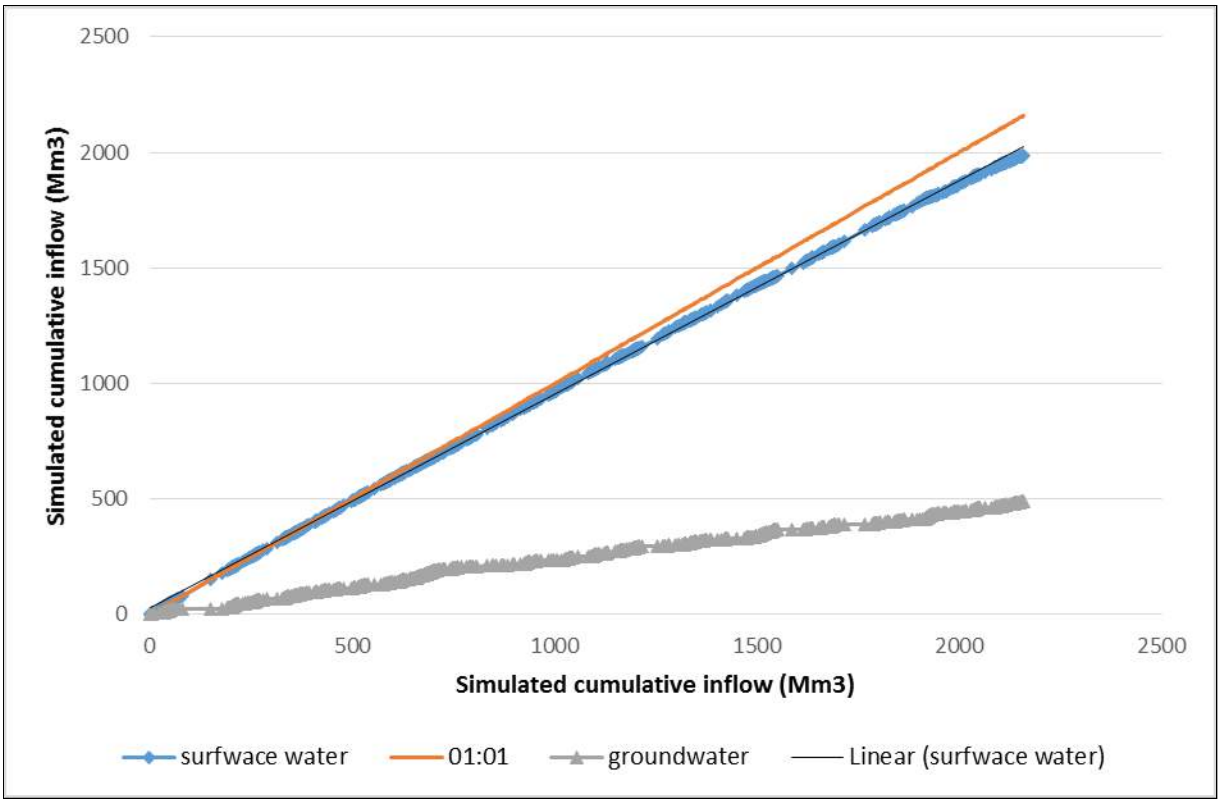


Figure 6.25 Lake Nhlabane Double Mass plots of inflows

6.8 Lake Cubhu

6.8.1 Model Setup and surface water inflows

The lake sub-catchments are shown in **Figure 6.7**. The Pitman Model was utilised to simulate runoff into the Lake from the catchment. The parameter set is shown in **Table 6.13**.

Surface runoff into Lake Cubhu from the Pitman Model for different periods is shown in

Table 6.14 and **Figure 6.26**. There is a decline in MAR over time due to the increasing level of afforestation.

There is a deficiency in lake level monitoring data, which hinders calibration, consequently, some parameters were transferred from Lake Mzingazi.

Table 6.13 Lake Cubhu Pitman model parameters

Parameter	Value	parameter	Value
MAP (mm/a)	1324	ZMIN	999
POW	3	ZMAX	999
SL	0	PI	1.5
ST	600	TL	0.25
FT	12	GL	2.5
GW	0	R	0.5

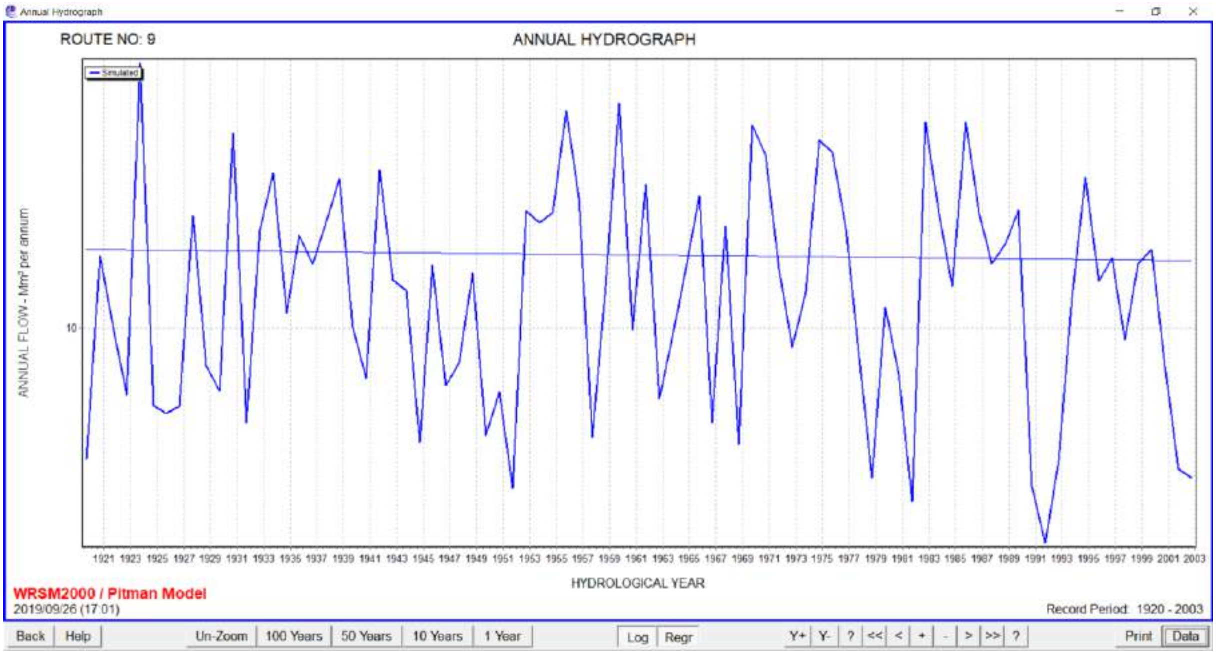


Figure 6.26 Surface inflow into Lake Cubhu

Table 6.14 Lake Cubhu afforestation and simulated runoff

Cubhu Quinary catchment excluding lake catchment area = 43.1 km²								
		Period						
	Natural	1920-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2003	2003
Afforestation at start year (km²)	0	0	5.3	6.9	8.3	11.1	13.9	13.9
Aliens at start year (km²)	0	0	3.2	3	2.3	2.4	2.5	10.5
Dry Cane	0	3.3	3.3	3.3	3.8	4.4	6.3	6.5
MAR (Mm³)	11.73	10.65	11.44	14.54	13.23	8.2	4.77	
Lake Cubhu Groundwater catchment area = 23. 4 km²								
Afforestation at start year (km²)	0	0	0.5	0.6	0.8	1	1.3	
MAR (Mm³)	6.37	6.01	6.63	8.35	7.75	5.07	3.32	
Total Inflow to lake (Mm³)	18.09	16.66	18.07	22.88	20.98	13.27	8.09	

6.8.2 Lake Groundwater Interaction parameters

The Pitman model runoff and aquifer storage time series and the lake abstraction time series (**Figure 6.28**) were entered into the lake model with the parameter set in **Table 6.15**.

Table 6.15 Lake Cubhu parameters for lake model

Parameter	Value
Transmissivity	76
Spill level (mamsl)	2.9
Aquifer storage for 0 inflow (mm)	0
Permeability (m/d)	4.6
Sediment factor (fraction of permeability)	0.2
Aquifer thickness (m)	32.6
Lake width (m)	2000
Lake length (m)	2500
MAP (mm/a)	1324
Evaporation (mm/a)	1422

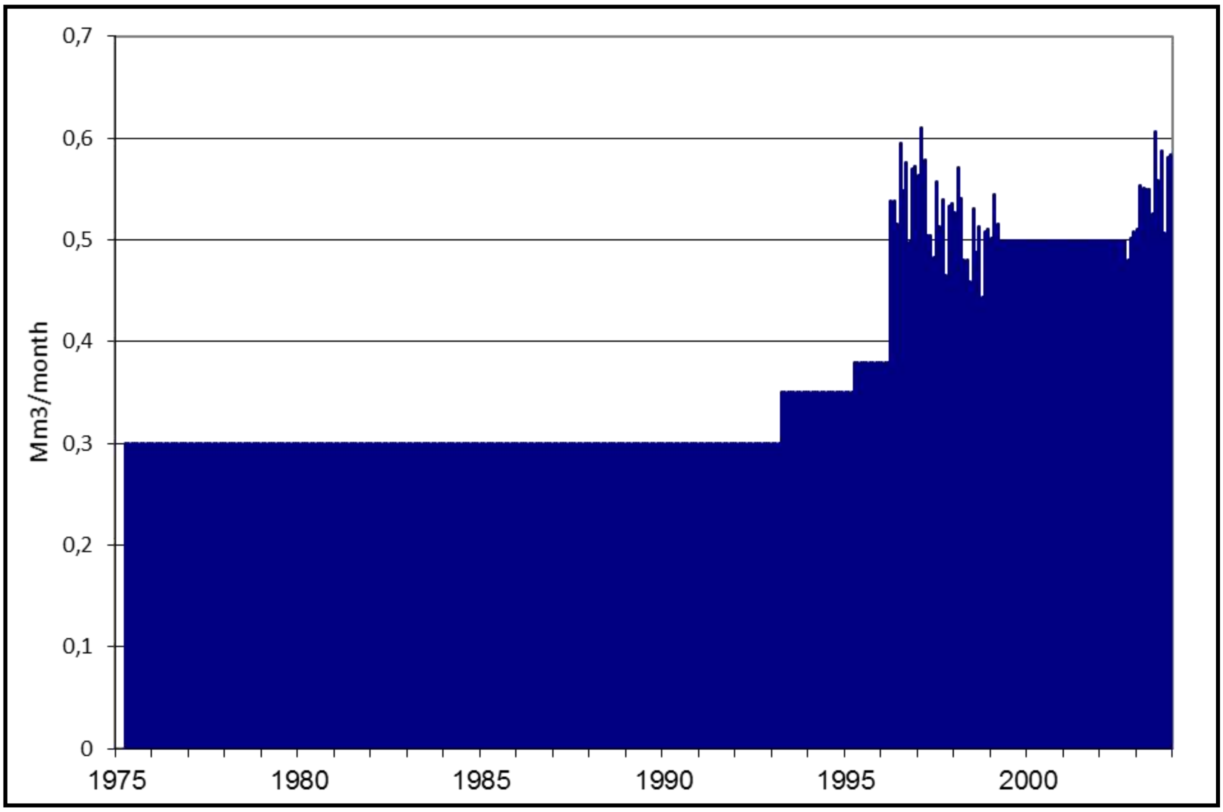


Figure 6.27 Abstraction from Lake Cubhu

The Lake volume-level-area relationships utilised to convert the lake water balance to a lake level and area are shown in **Figure 6.28** and **Figure 6.29**.

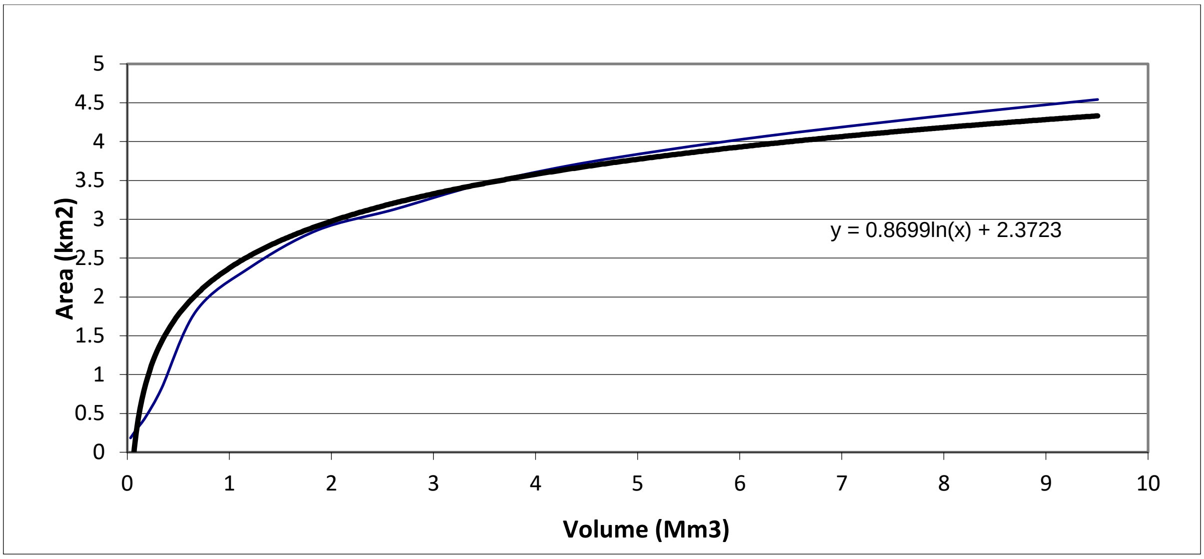


Figure 6.28 Volume-area relationship for Lake Cubhu

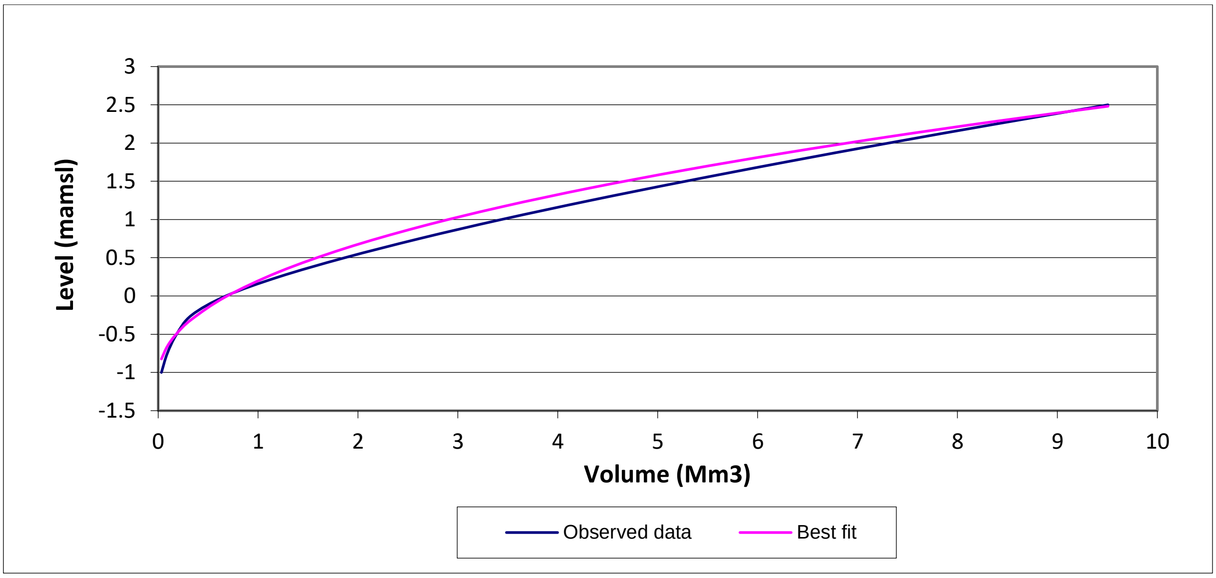


Figure 6.29 Volume – level relationship for Lake Cubhu

6.8.3 Results

Observed and simulated lake water levels, and naturalised flow with the outlet weir at present level with the outlet weir at present level are shown in **Figure 6.30**. The discharge from Lake Cubhu is not monitored.

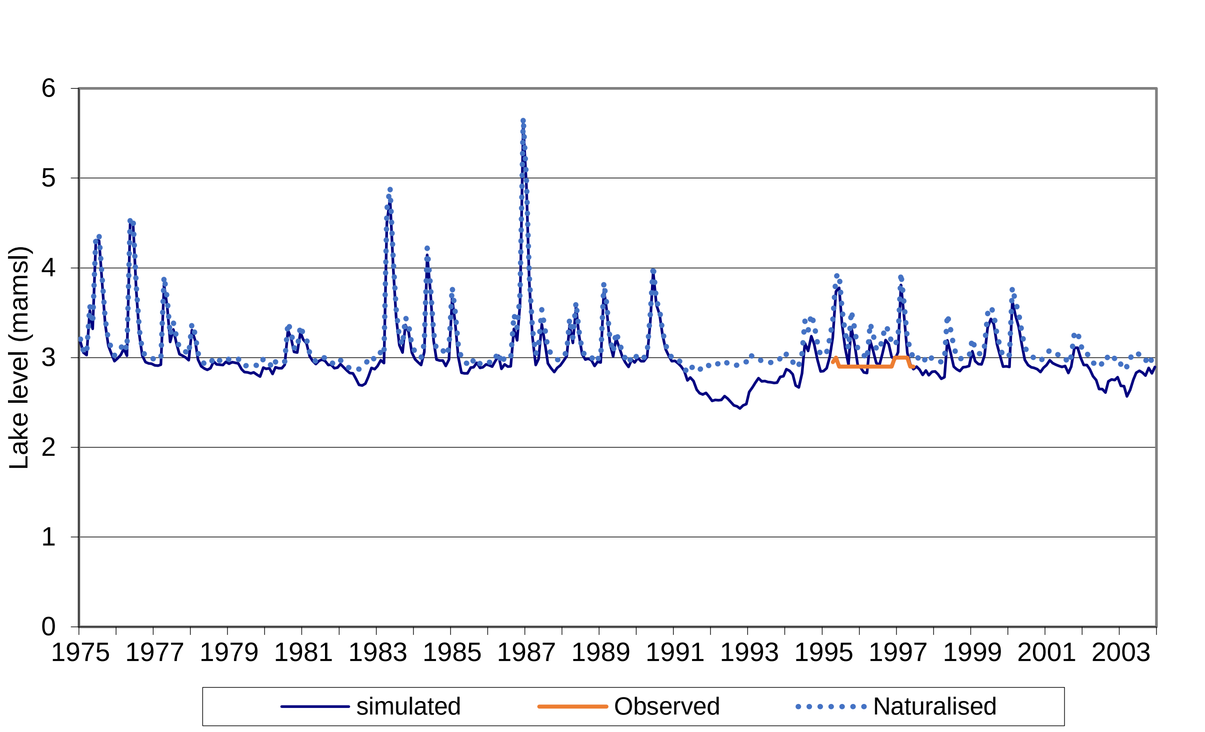


Figure 6.30 Lake Cubhu simulated, naturalised and observed water levels

There is insufficient data on observed water level to evaluate the calibration result. The lake water balance over the period is shown in **Table 6.16**.

Table 6.16 Lake Cubhu mean annual water balance

	Natural	1920-1960	1960-1975	1975-1985	1985-1990	1990-1995	1995-2003
Rainfall	6.28	6.17	6.51	6.39	6.87	5.06	6.20
Surface Inflow	18.09	16.66	19.96	20.17	23.65	9.12	13.27
Groundwater Inflow	3.74	3.75	3.77	3.73	3.75	3.64	3.74
Evaporation	-5.88	-5.88	-5.86	-5.77	-5.91	-5.91	-5.61
Abstraction	0	0	0	-3,51	-3.6	-3.81	-5.97
Surface water outflow	-21.98	-20.45	-24.00	-20.97	-24.55	-7.98	-11.32
Groundwater Outflow	-0.25	-0.25	-0.26	-0.25	-0.25	-0.25	-0.25

Figure 6.31 shows dry season flows for the month of July for surface water, and for groundwater inflow minus outflow. Dry season flows have remained consistent with surface water contributions exceeding groundwater by a large margin except only in severe drought years. The low groundwater contribution means the lake is vulnerable to drought.

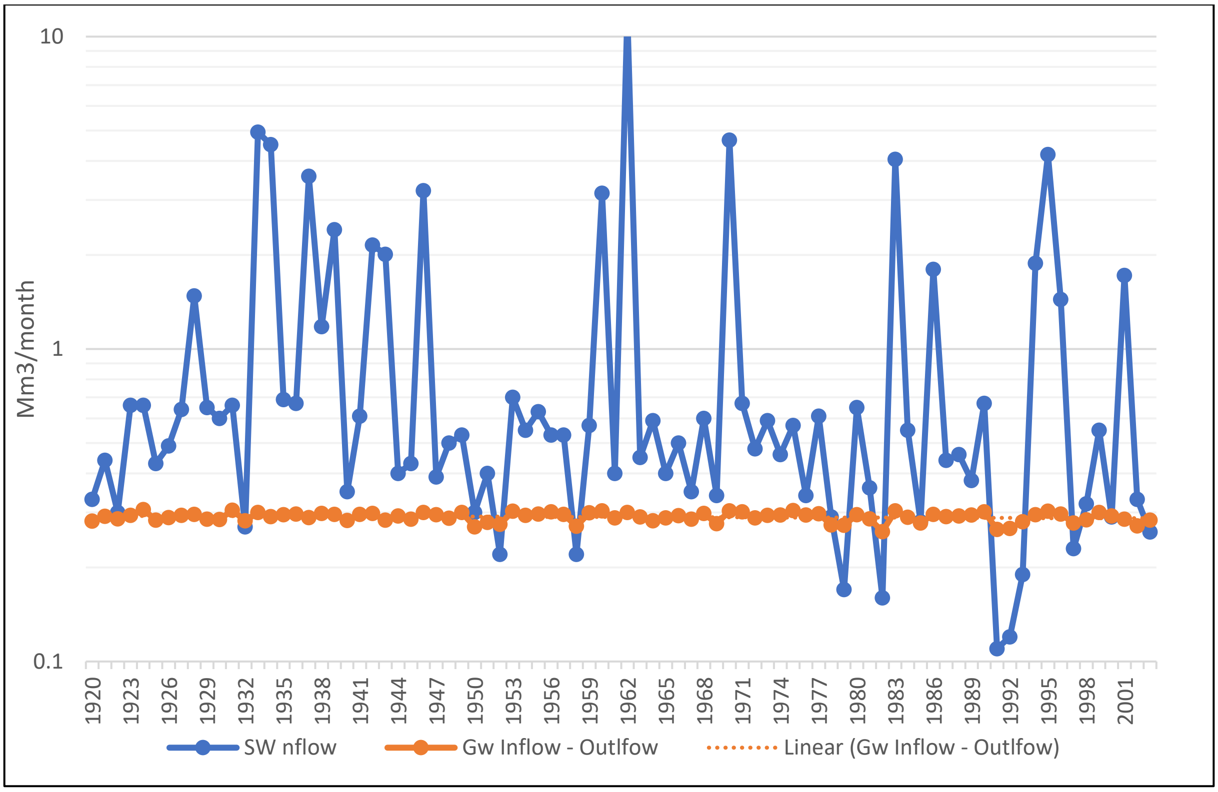


Figure 6.31 Lake Cubhu surface water and groundwater contributions in July

A double mass plot of cumulative inflow of surface and groundwater (**Figure 6.32**) shows that there is a decline in surface flow relative to natural flow as the surface water inflow line deviates increasingly from the 1:1 line. The groundwater plot is linear, suggesting little change in the groundwater regime.

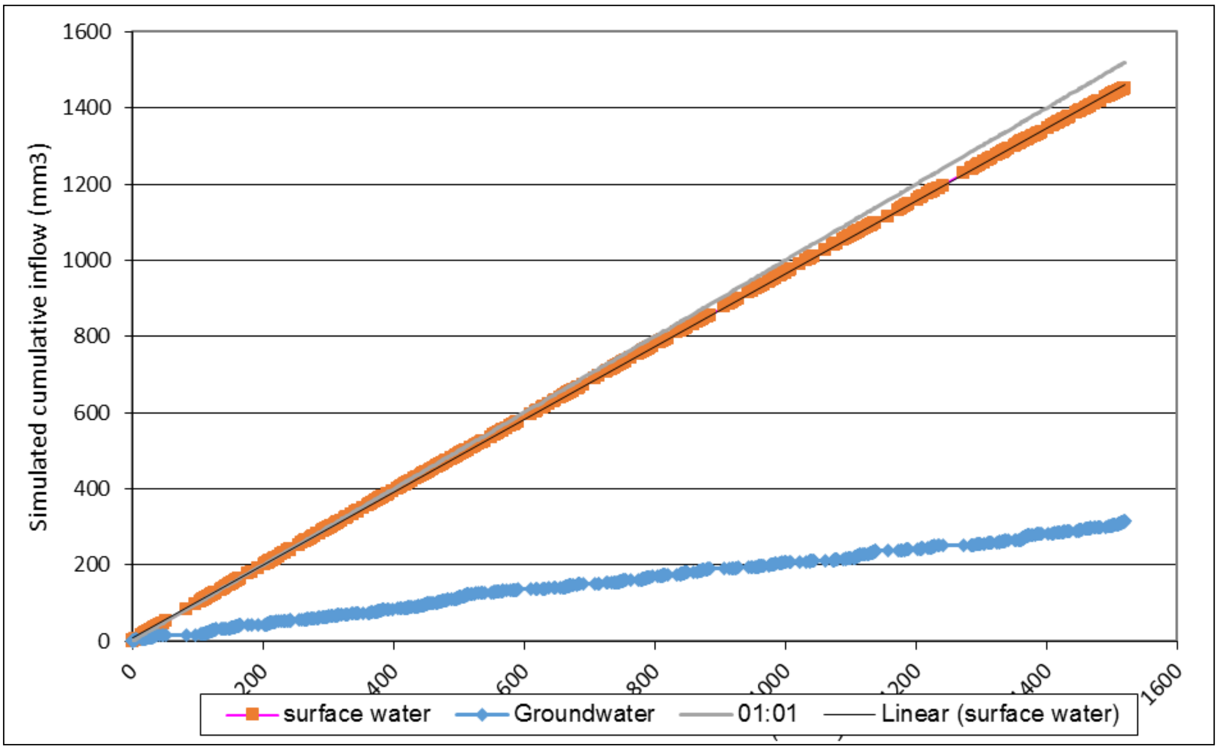


Figure 6.32 Lake Cubhu Double Massplots of inflows

6.9 Conclusions and Recommendations

Table 6.17 provides a summary of the previous natural MARs as determined during the MWAAS for the lake catchments compared with the newly determined MARs resulting from the enhanced groundwater interaction Task undertaken as part of this Study.

Table 6.17: Summary of results

Lake	Quinary	MAR (MWAAS) (Mm^3/a)	This Study			Comparison
			MAR Groundwater (net) (Mm^3/a)	MAR Surface portion (Mm^3/a)	Total MAR (Mm^3/a)	
Mzingazi	W12J1	52.47	12.45	39.98	52.43	Total MAR almost identical, remain with MWAAS
Nhlabane	W12J2	33.18	4.69	25.71	30.40	New MAR lower, adjust to new hydrology for water resources analyses
Cubhu	W12F2	18.04	3.49	18.09	21.58	New MAR higher, remain with MWAAS to be conservative given lack of observed data for validation purposes

Yield is not only dependent on MAR, but is highly influenced by the time period of low flows, ie. the number of sequential months of low flows. It is evident that the MAR for Lake Nhlabane resulting from this Task is less than 10% lower than that from the MWAAS. The updated hydrology was used in the water resources scenarios assessment, however, it was found that it did not have an impact on the results.

Further analyses was undertaken in order to determine the portion of yield contributed to by the groundwater on the coastal lake catchments. This was found to be 11.1 million m^3/annum.

7 WATER QUALITY

7.1 Overview and Objectives

The purpose of this section is to provide information on the current water quality situation of the Mhlathuze Catchment (W12). The scope of the investigation is limited to collecting, collating and analysing water quality data, as well as identifying water quality related problems. The assessment is based on data obtained from DWS and Mhlathuze Water (MW).

The chapter comprises of the following sub-sections:

- An overview of the data available and the location of existing measuring stations;
- An overview of the water quality parameters investigated and a summary of the source documents; and
- Conclusions drawn from the water quality data including a discussion.

7.2 Data

7.2.1 Overview of Available Data and Guidelines

A number of water quality related reports were published, focussing on the Mhlathuze Catchment and its water quality status. Such reports formed part of the MWAAS (DWAF, 2009) and the MORFP (DWAF, 2001).

In addition to the reports specific to the Mhlathuze Catchment, the South African Water Quality Guidelines for Domestic Use, Agricultural Use (irrigation), Industrial Use and Aquatic Ecosystems serve as guideline documents to the assessment of water quality parameters.

The two water quality components that were investigated as part of this Task are (1) physical and chemical parameters and (2) microbial parameters.

The physical and chemical data was obtained from the Centre for Water Science and Management, from the North-West University, for the time period from the 1970s till 2010 (NWU, 2012). More recent information was requested directly from the Department of Water and Sanitation, covering the time period between 2010 and 2017. No information after 2017 could be obtained due to logging activities being halted as a result of a lack of funding. Additional data was obtained from MW.

The station list detailing the sample dates and numbers for the physical and chemical water quality stations are summarised in **Table 7-1** and a map of the study area and monitoring points is shown in **Figure 7.1**. For the water quality assessment 10 out of the 30 stations were selected for further evaluation, as the remainder of stations had too short of a record length and long periods with missing data.

Table 7-1: Chemical and Physical Water Quality Station List DWS and NWU

Sample Station ID	Point ID	Description of Sample Station	Date of first Sample	Date of last Sample	Number of Samples
W1R001-Q01	102825	Goedertrouw dam on Mhlathuze river: near dam wall*	1982/05/11	2010/08/16	681
W1R001-Q05	102829	Goedertrouw dam on Mhlathuze river: point in dam	1986/07/30	1988/03/03	53
W1R002-Q01	102830	Eshowe dam on Mhlalazi river:	1981/05/26	2010/03/16	300

Sample Station ID	Point ID	Description of Sample Station	Date of first Sample	Date of last Sample	Number of Samples
		near dam wall*			
W1H004-Q01	102806	Mhlalazi river at Eshowe*	1977/02/16	2011/06/07	315
W1H005-Q01	102807	Mhlalazi river at Eshowe*	1977/02/09	2010/03/03	417
W1H006-Q01	102808	Mhlathuze river at Normanhurst	1977/01/12	1997/08/26	96
W1H009-Q01	102809	Mhlathuze river at Riverview 11459* [1]	1977/04/06	2010/08/31	416
W1H010-Q01	102810	Matigulu river at reserve no 21 *	1976/10/07	1992/11/09	235
W1H011-Q01	102811	Mzingazi river at arboretum/lake Mzingazi outflow *	1977/01/12	1996/12/04	303
W1H018-Q01	N/A	Amanzamnyama river at the Ranche	1988/07/29	1989/04/21	4
W1H019-Q01	N/A	Siyaya river at the Ranche	1988/07/22	1989/04/21	7
W1H020-Q01	102814	Mfule river at Quneba/Rail (mful)	1984/05/23	1988/04/28	52
W1H021-Q01	102815	Mhlathuze river at Ngoye/road bridge (mtuzc)	1984/05/23	1988/04/28	57
W1H021-Q02	102816	Mhlathuze river at Ngoye/road bridge	1996/03/05	1997/03/10	13
W1H022-Q01	102817	Mbabe river at Nseleni/Earlswood (mbab)	1985/10/24	1997/06/18	64
W1H023-Q01	102818	Nseleni river at Lona Estate/Eseleni Reserve	1984/01/23	1988/05/19	61
W1H024-Q01	102819	Mhlathuze river at Naauwkloof (Mtuza)	1983/08/04	1987/05/21	5
W1H028-Q01	102820	Goedertrouw dam on Mhlathuze river: downstream weir*	1979/11/06	1997/06/23	442
W1H032-Q01	177769	Mhlathuze river @ uMhlathuze valley* [1]	1999/09/22	2011/05/19	111
W1H033-Q01	102821	Mhlathuze river at uMhlathuze valley	1996/03/05	1997/03/10	13
W1H034-Q01	102822	Mhlathuze river at uMhlathuze valley	1996/03/16	1998/11/25	15
W1H035-Q01	102823	Mhlathuze river at uMhlathuze valley/Richard's Bay	1996/03/05	1997/03/10	13
W1H036-Q01	102824	Mhlathuze river at uMhlathuze valley/sugar factory	1996/03/16	1998/12/23	27
N/A	183757	Mdibi river at bridge to RBM[2]	2001/01/23	2017/03/14	10
N/A	187182	Eshakwini WTW extraction from lake Cubhu*	2003/08/27	2016/11/15	138
N/A	189730	Reserve no 10 at Shembe church temple and abstraction point on Lake Cubhu (long gaps)	2001/01/16	2006/08/30	100
N/A	189765	Nhlozane on Mfule[2]	2008/11/05	2017/03/13	114
N/A	187078	Between N2 bridge and Mposa confluence on Nseleni[2]	2003/03/04	2017/03/13	251
N/A	187079	Road bridge downstream of lake Nsezi on Nseleni[2]	2003/03/04	2017/03/13	201

Sample Station ID	Point ID	Description of Sample Station	Date of first Sample	Date of last Sample	Number of Samples
N/A	188841	Maitlands upstream of Nsezi lake on Nseleni	2005/11/30	2017/03/01	54

Notes: * = Used for water quality status quo assessment (16 out of 30)

1 = Additional water quality data received from DWS up to 2017/2018

2 = Only pH and turbidity measured

The MW stations are summarised in Table 7-2

Table 7-2: Chemical and Physical Water Quality Station List MW

Description of Sample Station	Date of first Sample	Date of last Sample	Number of Samples*
Lake Cubu	2010/01/05	2017/05/03	49
Lake Nzesi	2010/10/01	2020/04/30	400
Lake Mzingazi	2014/06/04	2020/04/03	70
Mhlathuze Weir	2011/12/01	2020/04/22	200

Notes: * = Samples not taken consistently, long gaps with intermittent data points.

The preferred physical and chemical water quality source is from the Water Science and Management, as the data has been verified, ensuring that the data quality is acceptable and that there are no major outliers. For two of the stations, W1H009 and W1H032, additional data was received from DWS for the period from 2010 until 2017/2018. The data received from MW had long periods with no sampling data.

The microbial data was downloaded from the National Microbial Monitoring Programme (NMMP) for surface water (DWAF, 2002b). The station list for the microbial water quality parameters is summarised in **Table 7-3**, and a map of the study area microbial stations is shown in **Figure 7.2**. For the water quality assessment 7 out of 12 stations where selected for further evaluation, as the remainder of the stations had an insufficient record length and too many missing values. The microbial data provided my MW was insufficient too short and incomplete to be used for this analysis.

Table 7-3: Microbial Water Quality Station List

Sample Station ID	Point ID	Description of Sample Station	Date of first Sample	Date of last Sample	Number of Samples
W1H009Q01	102809	Mhlathuze River at Riverview 11459	2001/01/16	2017/03/13	36
W1R001A01	103330	Normanhurst 3023 - Goedertrouw Dam on Mhlathuze River: at Dam Wall	2016/09/01	2017/03/01	7
W1H032Q01	177769	Mhlathuze River at UMhlathuze Valley*	2003/03/04	2017/03/13	218
N/A	183757	Midbie River at Bridge to RBM*	2001/01/23	2017/03/14	280
N/A	183761	Mposa River Under Bridge*	2001/01/16	2017/03/13	328
N/A	187078	Between N2 Bridge and Mposa Confluence on Nseleni*	2003/03/04	2017/03/13	250
N/A	187079	at Road Bridge downstream of Lake Nsezi on Nseleni*	2003/03/04	2017/03/13	201

Sample Station ID	Point ID	Description of Sample Station	Date of first Sample	Date of last Sample	Number of Samples
N/A	187183	Mzingazi WTW Extraction Point at Lake Mzingazi	2016/09/01	2017/01/04	4
N/A	188841	Maitlands upstream of Nsezi Lake on Nseleni	2016/09/01	2017/03/01	7
N/A	189730	Reserve no 10 at Shembe Church Temple and Abstraction Point on Lake Cubhu*	2008/11/04	2017/02/13	108
N/A	189765	Nhlozane on Mfule*	2008/11/05	2016/10/17	141
W1R005Q01	192933	Lake Chubu	2016/09/01	2017/03/13	9

Notes: * = Used for water quality status quo assessment (7 out of 12)

The microbial dataset only spans over a short record period from early 2000 until 2017, after which the NMMP project for the catchment was put on hold due to budgetary constraints.

The majority of the water quality stations are located in close proximity to Richard's Bay with only a few stations scattered throughout the catchment.

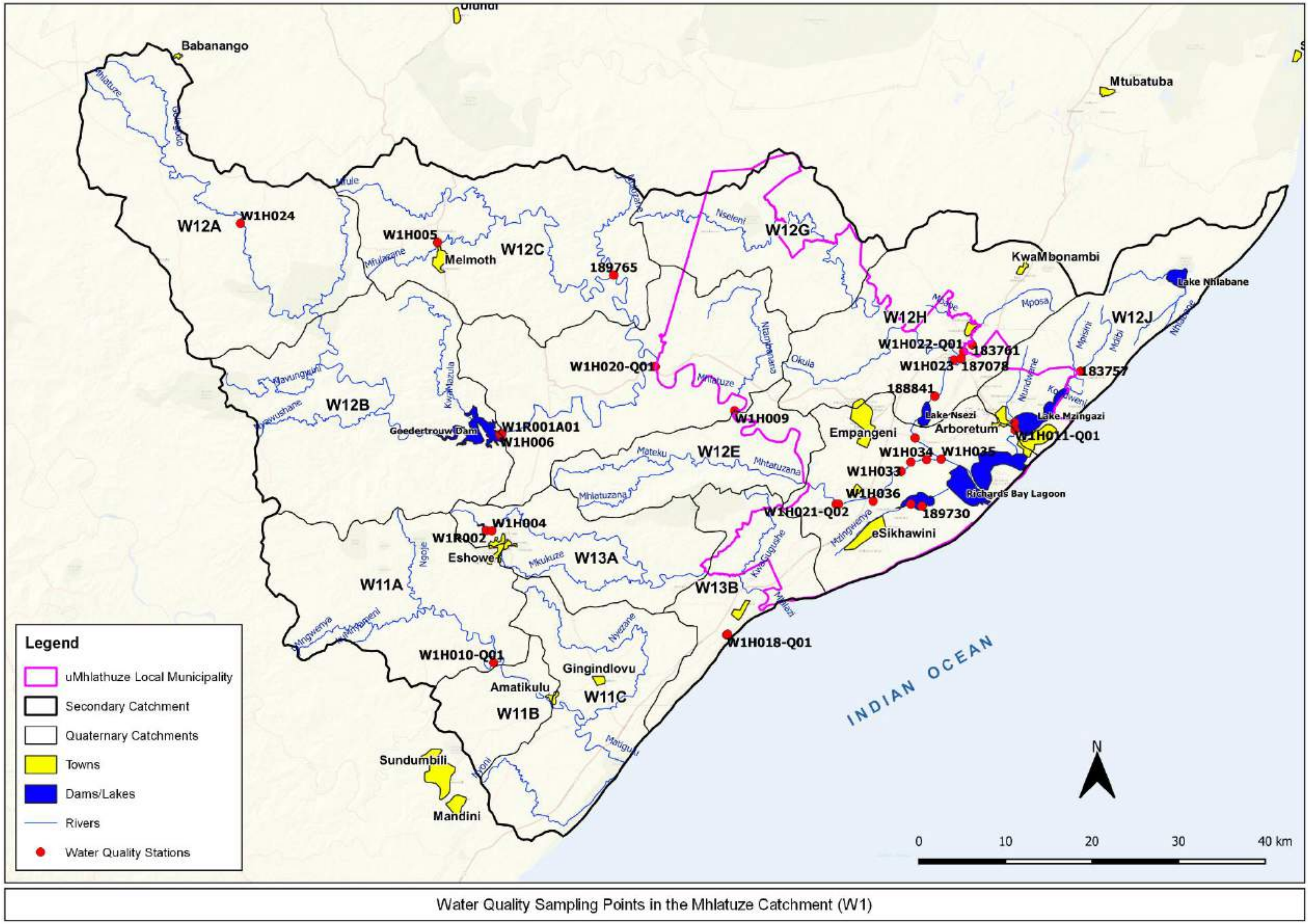
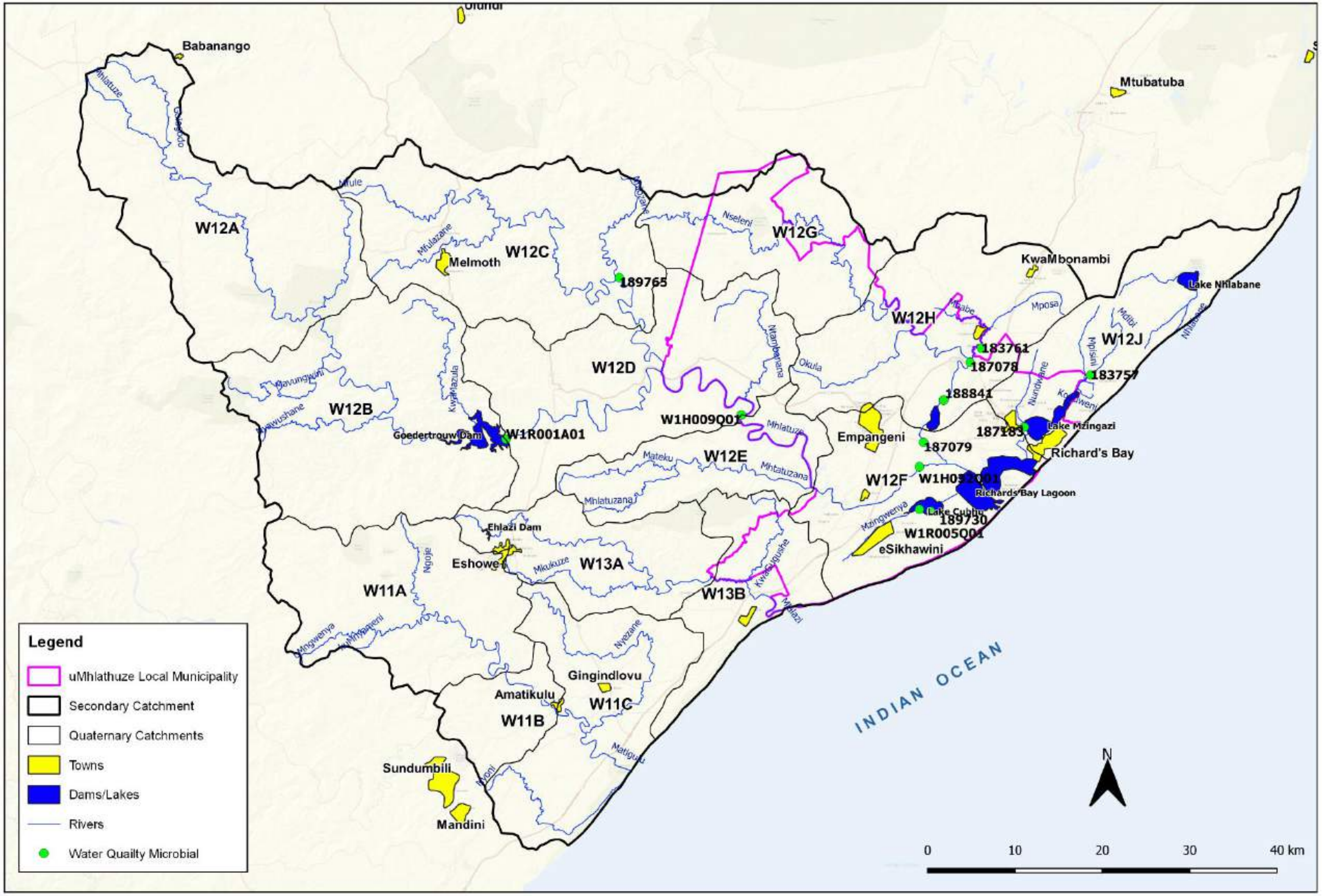


Figure 7.1: Physical and Chemical Water Quality Stations



Water Quality Sampling Points in the Mhlatuze Catchment (W1)

Figure 7.2: Microbial Water Quality Stations

7.3 Water Quality Guidelines

This assessment serves to determine the water quality in the Study Area for domestic, industrial, and agricultural use, as well as for aquatic ecosystems. A number of studies were conducted prior to this assessment highlighting potential water quality issues and trends. In addition, there are various initiatives by DWS to centrally aggregate water quality datasets as discussed in the previous section.

A list of the relevant physical and chemical water quality parameters' guidelines is summarised in **Table 7-4**, for the most sensitive user group, being either, domestic (DWAF, 1996a), industrial (DWAF, 1996c), agricultural users (DWAF, 1996b) or aquatic ecosystems (DWAF, 1996d) (Hohls et. al, 2002). The simplified quality categories assist in the broad assessment of the datasets. The categories and ranges where initially collated during the MWAAS (DWAF, 2009).

Table 7-4: Water Quality Guideline – All User Groups (DWAF, 2008)

Quality Category	Water Quality Parameter						
	TDS (mg/l)	pH (at 25 C)	Nitrate (mg/l as N)	Chloride (mg/l as Cl)	Sulphate (mg/l as SO_4)	un-ionised Ammonia (mg/l as NH_3)	ortho Phosphate (µg/l as PO_4)
Ideal water quality suitable for lifetime use.*	< 260	6.5 – 8.4	< 6	< 100	< 200	< 0.058	< 5
Good water quality suitable for use, rare instances of negative effects.	260 – 600	5 - 9	6 – 10	100 – 175	200–300	0.58 – 1.25	5 – 25
Marginal water quality-conditionally acceptable. Negative effects may occur in some sensitive groups.	600 – 1800	4 – 5 9 – 10	10 – 20	175 – 350	300–500	1.25 – 8.3	25 – 250
Poor water quality unsuitable for use without treatment. Chronic effects may occur.	1800 – 3400	3.5 – 4.0 10 - 11	20 – 40	350 – 700	500-1000	> 8.3	> 250
Dangerous water quality totally unsuitable for use. Acute affects may occur.	> 3400	< 3.5 > 11	> 40	> 700	> 1000	> 8.3	> 250

Notes: * = strict guidelines related to drinking water quality;

In addition to the water quality parameters listed in **Table 7-4**, a comparison of the Resource Water Quality Objective (RWQO) (SA, 2015) and the most sensitive use requirements is shown in **Table 7-5**. The most sensitive user requirements according to the South African Water Quality Guidelines are more stringent than the RWQO for the Mhlathuze Catchment, except for Sulphates (DWAF, 2008).

Table 7-5: Water Quality Guideline Comparison Most Sensitive vs. RWQO (DWAF, 2008)

Water Quality Variable	Most Sensitive User Requirement	DWS RWQO
pH	6.5 – 8.4	6.5 – 8.4
EC (mS/m)	40	90
Chloride (mg/l)	100	138
Sodium (mg/l)	70	93
Sulphate (mg/l)	200	150
Phosphate (µg/l)	0.03	0.03
Nitrates (mg/l)	3.0	6.0
Ammonia (mg/l)	0.058	0.058

Microbial water quality parameter guidelines were summarised, which are also called indicator organisms (DWAF, 2002a).

The indicator organisms consist of pathogenic viruses, protozoa and bacteria which can be transmitted by water. The following indicators are most commonly used to assess the microbiological safety of water by the NMMP:

- **Total coliform bacteria**: Primarily used as a practical indicator of the general hygienic quality of water; mainly used in routine monitoring of drinking water supplies; and
- **Faecal coliform bacteria**: Primarily used as a practical indicator of faecal pollution; more specific for faecal pollution than total coliforms; mainly used for assessment of faecal pollution of wastewater, raw water supplies and natural water environments used for recreational purposes (DWAF, 2002a).

The microbial water quality parameters are summarised in **Table 7-6**, the upper most range per parameter indicates the target range. Both parameters are recorded by the NMMP, with the addition of turbidity (DWAF, 1996a).

Turbidity is caused by the presence of suspended solids, a mixture of inorganic matter, such as clay and soil particles, as well as organic matter. It is measured in nephelometric units (NTU) and ranges from less than 1 NTU, in clear water, to >1000 NTU, in muddy water. A turbidity of >5 NTU has an impact on the aesthetics, colour, and odour of the water, as well as the potential of the water to transmit diseases (DWAF, 1996a).

Table 7-6: Microbial Parameter Guidelines (DWAF, 2002a)

Microbial Parameter	Range	Effects
Total Coliform and Faecal Coliform (counts/100 mR)	0 - 200	Negligible risk of microbial infection
	200 - 1000	Indicative of inadequate treatment, post-treatment contamination or growth in the distribution system. Risk of infectious disease transmission with continuous exposure and a slight risk with occasional exposure
	> 1000	Indicative of poor treatment, post-treatment contamination or definite growth in the water distribution system. Significant and increasing risk of infectious disease transmission

7.4 Results

The physical and chemical water quality statistics are summarised in **Table 7-7**. The water quality parameters investigated are the electrical conductivity (EC), acidity or basic (pH), total dissolved salts (TDS), Sodium, Chloride, Nitrates, Sulphates, Phosphates and Ammonia.

These parameters were investigated in terms of their mean, standard deviation (Std. dev), Coefficient of Variation (CoV), and their statistical distribution, such as the minimum, 5th, 50th 95th percentile and maximum value. The water quality parameters exceeding the guidelines are highlighted in red in the **Table 7-7**.

Table 7-7: Physical and chemical water quality statistics

Station		EC (mS/m)	pH	TDS (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Nitrates (mg N/l)	Sulphate (mg/l)	Phosphate (µg/l)	Ammonia (mg/l)
W1R001Q01	Mean	16.39	7.74	109.30	13.84	15.69	0.29	9.70	0.03	0.05
	Std. dev	3.92	0.32	34.25	3.67	4.41	0.16	4.34	0.05	0.11
	CoV	0.24	0.04	0.31	0.26	0.28	0.55	0.45	1.66	2.21
	Min	12.10	6.17	78.50	6.93	9.50	0.00	0.00	0.00	0.00
	5th per.	14.00	7.05	90.00	11.32	11.10	0.04	3.96	0.00	0.02
	Median	15.90	7.82	104.49	13.30	14.90	0.27	9.24	0.02	0.04
	95th per.	19.20	8.12	134.00	16.90	22.00	0.62	17.10	0.08	0.10
	Max	98.10	8.31	846.00	65.90	55.90	0.85	35.30	0.77	2.66
W1R002Q01	Mean	22.10	7.13	116.01	21.87	43.33	0.20	10.66	0.03	0.09
	Std. dev	8.77	0.74	59.76	13.01	21.24	0.45	17.76	0.09	0.12
	CoV	0.40	0.10	0.52	0.60	0.49	2.23	1.67	2.92	1.31
	Min	7.21	4.39	52.95	3.49	2.00	0.00	0.90	0.00	0.00
	5th per.	15.51	5.41	75.80	14.06	31.74	0.01	2.31	0.00	0.01
	Median	20.50	7.39	107.61	20.22	40.80	0.08	8.40	0.02	0.06
	95th per.	28.90	7.90	176.00	27.89	54.09	0.64	22.40	0.07	0.31
	Max	118.80	8.43	746.00	194.80	367.10	6.64	296.70	1.18	1.17
W1H004Q01	Mean	19.85	7.22	108.60	19.39	37.39	0.20	7.28	0.02	0.15
	Std. dev	3.77	0.56	24.02	4.28	7.82	0.22	5.32	0.06	0.16
	CoV	0.19	0.08	0.22	0.22	0.21	1.09	0.73	2.67	1.07
	Min	9.40	5.32	68.57	4.70	3.80	0.00	0.00	0.00	0.00
	5th per.	14.70	6.08	78.40	14.35	26.98	0.02	1.17	0.00	0.00
	Median	19.70	7.43	106.00	19.10	37.20	0.11	6.40	0.01	0.09
	95th per.	27.00	7.89	150.00	25.76	51.79	0.65	18.52	0.06	0.48
	Max	43.90	8.88	256.28	55.42	71.53	1.42	28.40	1.00	0.83
W1H005Q01	Mean	18.45	7.50	115.56	19.00	23.81	0.26	7.50	0.02	0.04
	Std. dev	6.39	0.55	42.19	6.48	9.33	0.35	6.23	0.03	0.05
	CoV	0.35	0.07	0.37	0.34	0.39	1.34	0.83	1.33	1.27
	Min	7.70	5.58	52.00	7.90	3.40	0.00	0.00	0.00	0.00
	5th per.	11.19	6.39	68.40	12.49	15.69	0.02	0.99	0.00	0.01
	Median	17.80	7.73	111.08	18.40	22.50	0.18	6.90	0.02	0.03
	95th per.	26.25	8.05	159.20	25.52	34.38	0.80	15.61	0.05	0.10

Station		EC (mS/m)	pH	TDS (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Nitrates (mg N/l)	Sulphate (mg/l)	Phosphate (µg/l)	Ammonia (mg/l)
	Max	73.60	8.55	429.00	88.70	155.00	3.11	93.80	0.38	0.89
W1H009	Mean	66.02	7.83	429.33	96.33	135.43	0.26	21.08	0.03	0.05
	Std. dev	180.43	0.50	1194.47	364.93	650.85	0.18	86.37	0.03	0.05
	CoV	2.73	0.06	2.78	3.79	4.81	0.72	4.10	1.19	1.01
	Min	7.70	6.24	73.00	6.14	5.00	0.00	0.00	0.00	0.00
	5th per.	24.60	6.91	149.64	26.35	33.15	0.01	4.51	0.00	0.01
	Median	46.90	7.94	301.93	58.22	72.10	0.24	13.33	0.02	0.04
	95th per.	94.00	8.45	614.45	132.19	170.21	0.57	27.07	0.08	0.14
	Max	2830.0	8.79	18685	5724.1	10275.2	1.24	1369.00	0.37	0.61
W1H010Q01	Mean	27.18	7.13	162.46	31.03	43.12	0.21	7.30	0.02	0.05
	Std. dev	6.46	0.55	41.27	8.52	12.04	0.26	5.38	0.04	0.06
	CoV	0.24	0.08	0.25	0.27	0.28	1.27	0.74	2.13	1.21
	Min	11.10	5.26	73.00	5.00	3.90	0.00	0.00	0.00	0.00
	5th per.	15.90	6.22	90.40	18.30	23.88	0.00	1.66	0.00	0.01
	Median	26.60	7.11	158.00	30.00	42.90	0.10	5.80	0.01	0.04
	95th per.	37.82	8.07	235.20	45.38	61.02	0.63	15.26	0.06	0.14
	Max	57.20	8.92	313.00	75.70	129.10	1.92	37.30	0.37	0.70
W1H011Q01	Mean	34.17	6.86	181.28	36.58	65.69	0.07	19.14	0.02	0.08
	Std. dev	6.35	0.50	35.30	7.12	13.18	0.11	8.67	0.04	0.18
	CoV	0.19	0.07	0.19	0.19	0.20	1.58	0.45	2.29	2.33
	Min	12.40	4.14	84.00	12.70	16.80	0.00	0.70	0.00	0.00
	5th per.	25.64	6.23	133.15	27.10	48.18	0.00	9.62	0.00	0.02
	Median	33.20	6.80	180.00	36.10	65.20	0.04	16.50	0.01	0.06
	95th per.	45.56	7.79	241.55	48.98	89.88	0.23	33.26	0.04	0.16
	Max	53.10	8.47	319.00	57.90	104.10	1.32	66.90	0.52	2.95
W1H028Q01	Mean	19.73	7.47	131.43	18.12	20.69	0.30	8.70	0.03	0.05
	Std. dev	11.10	0.57	75.28	15.13	19.10	0.24	6.33	0.05	0.04
	CoV	0.56	0.08	0.57	0.83	0.92	0.79	0.73	1.77	0.79
	Min	6.10	5.30	53.00	3.10	1.40	0.00	0.00	0.00	0.00
	5th per.	13.40	6.40	82.00	11.42	11.22	0.01	1.80	0.00	0.01
	Median	17.30	7.61	114.00	14.60	17.70	0.29	8.05	0.02	0.04
	95th per.	35.13	8.19	249.55	34.49	34.59	0.67	17.70	0.10	0.13
	Max	110.90	8.42	688.00	156.70	188.30	2.64	79.40	0.91	0.43
W1H032Q01	Mean	50.88	8.04	329.45	60.54	76.26	0.22	19.70	0.04	0.07
	Std. dev	15.12	0.42	110.34	21.62	31.15	0.17	12.92	0.13	0.08
	CoV	0.30	0.05	0.33	0.36	0.41	0.77	0.66	3.22	1.15
	Min	21.90	4.57	109.46	20.38	31.28	0.01	5.34	0.00	0.02
	5th per.	30.60	7.61	171.94	30.02	40.39	0.02	8.56	0.01	0.02
	Median	49.70	8.09	323.67	58.84	74.09	0.21	16.30	0.02	0.05
	95th per.	75.04	8.46	521.04	88.79	109.23	0.48	39.08	0.08	0.20

Station		EC (mS/m)	pH	TDS (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Nitrates (mg N/l)	Sulphate (mg/l)	Phosphate (µg/l)	Ammonia (mg/l)
	Max	140.50	9.03	961.58	201.82	315.36	1.03	110.12	1.42	0.63
187182	Mean	46.08	7.64	242.99	48.96	-	2.00	0.07	0.02	-
	Std. dev	6.10	0.24	39.38	8.72	-	0.00	0.03	0.01	-
	CoV	0.13	0.03	0.16	0.18	-	0.00	0.48	0.76	-
	Min	27.80	6.67	148.96	18.90	-	2.00	0.01	0.01	-
	5th per.	39.40	7.27	206.59	39.11	-	2.00	0.01	0.01	-
	Median	44.70	7.62	235.14	47.69	-	2.00	0.08	0.01	-
	95th per.	61.50	7.95	361.73	72.80	-	2.00	0.11	0.04	-
	Max	69.30	8.43	392.02	82.40	-	2.00	0.11	0.09	-
Lake Cubhu	Mean	55.94	7.17	318.40	69.31	95.64	0.14	58.25	0.06	0.12
	Std. dev	753.17	10.61	0.41	44.10	11.40	17.37	0.13	18.41	0.04
	CoV	13.46	1.48	0.00	0.64	0.12	124.23	0.00	334.78	0.36
	Min	29.40	5.73	237.00	48.90	69.30	0.04	5.63	0.03	0.03
	5th per.	38.60	6.44	239.70	50.97	72.68	0.06	31.49	0.03	0.03
	Median	55.50	7.20	318.00	69.90	97.14	0.08	55.21	0.03	0.06
	95th per.	72.95	7.79	406.10	86.62	124.35	0.49	90.91	0.18	0.64
	Max	75.20	8.21	413.00	87.70	139.44	0.75	91.21	0.21	1.53
Lake Nzesi	Mean	48.46	7.72	272.26	62.42	72.78	0.16	10.22	0.04	0.07
	Std. dev	996.29	10.88	0.42	112.60	20.39	23.53	0.41	6.63	0.01
	CoV	20.56	1.41	0.00	1.80	0.28	151.10	0.04	189.51	0.07
	Min	7.70	6.14	182.00	0.01	5.88	0.08	0.50	0.03	0.05
	5th per.	32.50	6.95	195.30	35.66	41.46	0.08	4.33	0.03	0.05
	Median	47.30	7.83	272.00	61.00	69.87	0.08	8.60	0.04	0.05
	95th per.	68.00	8.18	382.10	94.00	122.39	0.34	20.41	0.04	0.15
	Max	83.90	14.00	990.00	307.00	139.72	12.00	125.71	0.04	0.16
Lake Mzingazi	Mean	68.54	7.27	480.44	76.24	135.28	0.17	122.59	0.03	0.07
	Std. dev	14.15	0.39	55.39	14.48	21.10	0.38	48.95	0.00	0.02
	CoV	0.21	0.05	0.12	0.19	0.16	2.18	0.40	0.00	0.23
	Min	24.50	5.65	400.00	20.20	95.75	0.08	16.63	0.03	0.05
	5th per.	52.85	6.59	-	59.40	109.48	0.08	42.13	0.03	0.05
	Median	65.00	7.30	471.00	75.90	129.28	0.08	128.86	0.03	0.07
	95th per.	96.45	7.78	-	98.60	178.69	0.47	192.05	0.03	0.08
	Max	99.50	8.10	565.00	110.00	179.46	2.89	294.26	0.03	0.08
Mhlathuze Weir	Mean	44.73	7.46	249.41	58.66	46.53	58.75	0.24	11.43	-
	Std. dev	7.93	0.48	42.72	28.50	9.62	28.20	0.07	1.91	-
	CoV	0.18	0.06	0.17	0.49	0.21	0.48	0.29	0.17	-
	Min	0.05	4.00	110.60	5.76	31.40	5.76	0.18	8.88	-
	5th per.	34.30	6.70	114.79	42.18	32.54	42.54	0.19	8.97	-
	Median	45.25	7.54	263.60	56.20	48.80	56.20	0.22	11.29	-
	95th per.	54.10	8.14	303.40	76.16	55.24	76.13	0.34	13.75	-

Station		EC (mS/m)	pH	TDS (mg/l)	Sodium (mg/l)	Chloride (mg/l)	Nitrates (mg N/l)	Sulphate (mg/l)	Phosphate (µg/l)	Ammonia (mg/l)
	Max	93.50	8.47	303.80	366.00	57.10	366.00	0.36	14.25	-

The majority of the stations indicate anomalies in terms of their pH as well as their electrical conductivity. These parameters exceeded the limit only for a small number of samples.

The following conclusion can be drawn from the physical and chemical water quality statistics:

- Stations W1R001 and W1H028 are located at the Goedertrouw Dam indicating that the water quality is generally acceptable except for some occurrences with elevated Phosphate and Ammonia, over drought or low flow periods. There are few occurrences downstream of the dam were chloride and sodium exceeded the guidelines values, this could potentially be a cause of farming activity.
- Stations W1R002 and W1H004 are located at the Eshlazi Dam near the town of Eshowe, there are a few samples which exceed guidelines for Phosphate and Ammonia. There is farming activity and human settlements in the area causing these elevated values.
- The water quality in the Mfulazane River measured at station W1H005 near the town of Melmoth appears to be moderate to good, the river is a tributary of the Mhlathuze River.
- Station W1H009 on the Mhlathuze River has a few samples which significantly exceed the guidelines. Especially concerning are the high EC values, Sodium, Chloride, Phosphate and Ammonia. This measuring point is especially important as it is downstream of all the major tributaries of the Mhlathuze River.
- W1H032, which is on the Mhlathuze River, upstream of the confluence with Nseleni River has similar trends compare to the upstream station W1H009, with elevated EC, Sodium, Chloride, Phosphate and Ammonia. These are indicative of agricultural activity in the catchment due to salt wash-off from irrigators.
- W1H011 which is located downstream of Lake Mzingazi, also indicates water quality issues in terms of the slightly elevated EC and Ammonia. Phosphate exceeds the guidelines excessively over longer periods of time, which is most likely caused by the human settlements and forestry.
- The water quality station at Lake Nsezi unfortunately only had a very short record period with long gaps, therefore it was decided not to use the data for further analysis, as it is not representative of the behaviour of the system.
- The station 187182 is located at Lake Cubhu, to the south of the Richards Bay Lagoon. Similar to Lake Nsezi, the record length and number of samples are limited. Therefore, the statistics for the water quality parameters are likely not representative. Elevated EC, Sodium and Phosphate can be observed, again, due to human settlements in close proximity.
- Data received from MW covers the most recent period, on average the water quality in Lake Cubhu, Mzingazi, Nzesi and Mhalthuze appear to be acceptable except for a few outlier periods in which unacceptable pH, electrical conductivity, and nutrients were present. Unfortunately, there are long periods in which no samples were taken.

The microbial water quality parameters are summarised in **Table 7-8**, indicating the Total Coliforms and the Faecal Coliforms count, as well as the Turbidity of the water, which is a physical water quality parameter. The microbial water quality range is relative to potable water quality; therefore, the majority of the stations appear to indicate large water quality deficiencies. The measuring stations are located within rivers and lakes, therefore the water is of raw quality and should be treated before it is safe for human consumption.

Table 7-8: Microbial Physical water quality statistics

Station		Total Coliform (counts/100 mR)	Faecal Coliform (counts/100 mR)	Turbidity (NTU)
177769	Mean	896.30	722.61	34.98
	Std. dev	1674.03	1773.68	68.61
	CoV	1.87	2.45	1.96
	Min	10.00	7.82	2.20
	5th per.	15.50	68.50	6.90
	Median	264.00	305.00	19.15
	95th per.	6518.40	2912.40	85.04
	Max	8164.00	16300.00	848.00
187079	Mean	2642.79	328.92	48.60
	Std. dev	9072.71	807.44	70.67
	CoV	3.43	2.45	1.45
	Min	10.00	0.00	1.00
	5th per.	10.00	17.80	4.51
	Median	310.00	126.00	23.50
	95th per.	41060.00	1081.00	204.50
	Max	41060.00	10000.00	472.00
189730	Mean	59.59	139.17	10.61
	Std. dev	80.77	310.52	35.40
	CoV	1.36	2.23	3.34
	Min	1.00	0.00	0.05
	5th per.	1.00	0.35	1.30
	Median	31.00	20.00	3.00
	95th per.	312.15	695.45	38.01
	Max	327.00	2187.00	358.00
189765	Mean	8028.07	788.93	29.30
	Std. dev	36076.14	1421.42	98.01
	CoV	4.49	1.80	3.34
	Min	20.00	6.99	0.80
	5th per.	20.00	59.40	1.42
	Median	160.00	384.00	8.20
	95th per.	102559.00	2621.20	104.00
	Max	198630.00	11199.00	1010.00
183757	Mean	1375.14	1716.85	11.14
	Std. dev	5123.24	7077.60	18.02
	CoV	3.73	4.12	1.62
	Min	1.00	0.00	1.00
	5th per.	1.90	68.80	2.81
	Median	31.00	500.00	7.14

Station		Total Coliform (counts/100 mR)	Faecal Coliform (counts/100 mR)	Turbidity (NTU)
	95th per.	21983.00	5620.00	28.18
	Max	24196.00	77010.00	202.00
183761	Mean	4618.37	5101.67	27.33
	Std. dev	7285.79	16930.88	59.33
	CoV	1.58	3.32	2.17
	Min	20.00	1.00	1.60
	5th per.	20.00	28.80	2.86
	Median	971.50	830.00	12.45
	95th per.	24196.00	16020.00	104.75
	Max	24196.00	100000.00	729.00
187078	Mean	137.27	3911.38	39.62
	Std. dev	170.03	27738.52	61.88
	CoV	1.24	7.09	1.56
	Min	10.00	3.00	1.60
	5th per.	10.00	10.00	3.90
	Median	74.50	201.00	17.00
	95th per.	628.35	7180.00	168.75
	Max	740.00	390695.00	455.00

The following conclusions can be drawn from the microbial water quality statistics:

- None of the stations indicate that the water at the station is safe for direct human consumption and can lead to sever illness, stipulate in the NMMP guideline documents (DWAF, 2002a).
- At the confluence of the Nhlozane and Mfule, station 189765, both the total coliform and the faecal coliform counts are high, indicating that the microbial water quality is especially poor.
- Stations 183761 and 187078 are upstream of Lake Nsezi. Stations 183761 is just downstream of the town of Nseleni and Station 187078 is at the confluence of the Mposa and Nseleni rivers. The coliform counts for the station at confluence are lower, due to dilution from the Nseleni River. It is expected that there is significant pollution entering the Mposa River from the town of Nseleni.
- Downstream of Lake Nsezi, station 187079, indicated similar trends to station 187078. However, with slightly higher coliform counts due to potential algae and other biological matter from Lake Nsezi.
- The station 189730 at Lake Cubhu is located close to settlements, therefore it is expected that the water quality in the lake is poor, however, the water quality is not significantly poorer than less populated areas. The station also has a relatively short record period which most likely distorts the microbial water quality parameters.
- Station 177769 is located on the main Mhlathuze River upstream of the confluence with the Nseleni River, over drier months and drought periods the coliform counts are fairly high, in addition to towns and settlements, such as Vulindlela and Felixton, which are in close proximity to the station.

- Upstream of Lake Mzingazi, station 1833757, indicated elevated coliform counts, due to the nearby settlements.
- Data received from MW did not contain microbial water quality timeseries which was sufficiently long for this assessment.

The water quality results are also graphically represented as timeseries plots in **Appendix C** and as boxplots in **Appendix D**.

7.5 Conclusions

The overall physical and chemical water quality is moderate. The microbial data indicates that there are major quality concerns which can cause severe illness for the users making use of raw water for human consumption directly from rivers and dams. The water quality over the past 10 years in the lakes appear to be acceptable, however, the dataset received by MW contained long periods without any samples being taken.

Of concern is the closing of many stations which are required to track the water quality parameters and make adjustments to operating rules to improve the overall water quality situation in the catchment. The microbial assessment has been discontinued since 2017, meaning that currently no microbial data is collected by DWS in the catchment. Most of the stations have short record lengths, less than five years, or few samples, which are spaced over long time periods.

8 CONCLUSIONS AND RECOMMENDATIONS

This report has outlined the work undertaken to determine the water resources availability of the Mhlathuze River Catchment for later use in the water balances to be presented in the updated Reconciliation Strategy. The main objective of the Task was to update the WRPM with the latest available information, specifically related to water requirement projections and the EWR. The hydrology and landuse components of the model were not changed as part of this Task. From the work undertaken, it can be concluded that:

- The existing water resources are sufficient to supply user requirements up till the year 2021 at a satisfactory assurance of supply.
- The existing water resource is equal to 248 million m^3/annum and includes a combination of yields from Goedertrouw Dam, Coastal Lakes, tributary flows captured at the Mhlathuze weir and the existing Thukela transfer.
- The additional water that will be made available to the system when the Thukela transfer is increased is equal to 45 million m^3/annum. This is more than the actual increased transfer volume and can only be benefited from if the system is operated in an efficient manner. This is done by leaving water in the Goedertrouw Dam and making use of tributary flows for as long as possible.
- The impact of raising Goedertrouw Dam by 2.8 m would be to add 5.8 million m^3/annum to the system.
- Additional water resource options of a dam on the Nseleni River and an off channel dam on the Mfolozi River are viable, however, a dam on the Mhlathuzana river is not preferred from an ecological perspective.
- The infrastructure supplying the Esikhaweni users is limiting the supply to those users considering their growth into the future.
- The existing resources available to the surrounding towns of Mtunzini and Eshowe are sufficient to supply their requirements, however, the towns of Gingindlovu and Melmoth are not supplied at a satisfactory level of assurance.
- The existing hydrology used adequately represents the groundwater-coastal lake interaction based on the updated model results.
- The overall physical and chemical water quality is moderate. The microbial data indicates that there are major quality concerns which can cause severe illness for any users making use of raw water for human consumption directly from rivers and dams.

The final Reconciliation Strategy will provide the overall recommendations resulting from this Study. It is recommended that the results of this Task be used to formulate the water balance plots to be developed as part of the Reconciliation Strategy. It is further recommended that the Mhlathuze system continue to be operated on an efficient manner in order to extract the most yield from the resources. The increased Thukela transfer currently under construction should be completed by 2021 in order to provide additional resources to the system. Existing monitoring sites should be maintained, and the water quality monitoring that was stopped in 2017 should be reinstated.

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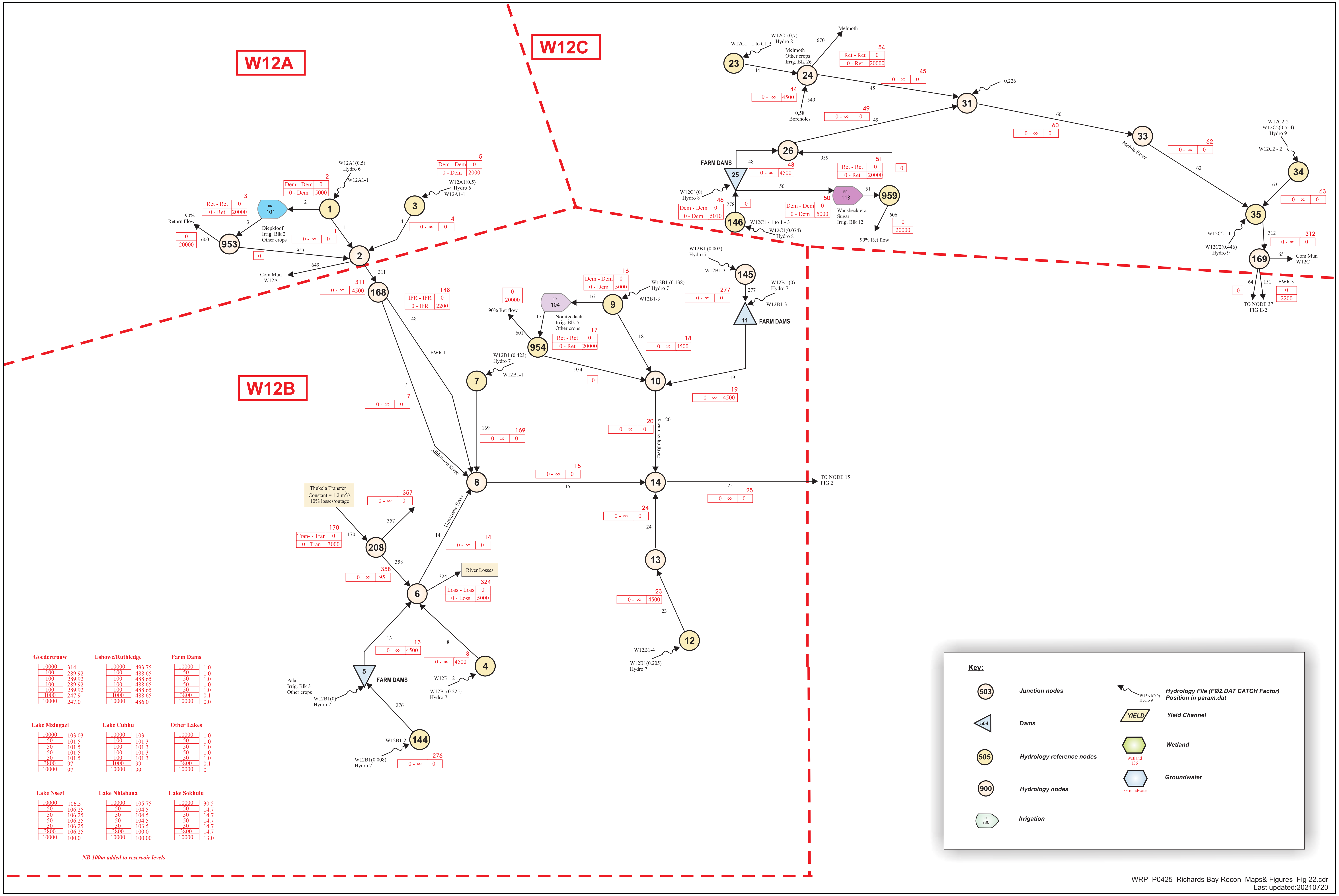
APPENDIX A

MODEL NETWORK DIAGRAMS



Goedertrouw

10000	314
100	289.92
100	289.92
100	289.92
100	289.92
1000	247.9
10000	247.0

Eshowe/Ruthledge

10000	493.75
100	488.65
100	488.65
100	488.65
100	488.65
1000	488.65
10000	486.0

Farm Dams

10000	1.0
50	1.0
50	1.0
50	1.0
50	1.0
3800	0.1
10000	0.0

Lake Mzingazi

10000	103.03
50	101.5
50	101.5
50	101.5
50	101.5
3800	97
10000	97

Lake Cubhu

10000	103
100	101.3
100	101.3
100	101.3
100	101.3
1000	99
10000	99

Other Lakes

10000	1.0
50	1.0
50	1.0
50	1.0
50	1.0
3800	0.1
10000	0

Lake Nsezi

10000	106.5
50	106.25
50	106.25
50	106.25
50	106.25
3800	106.25
10000	100.0

Lake Nhlabana

10000	105.75
50	104.5
50	104.5
50	104.5
50	103.5
3800	100.0
10000	100.00

Lake Sokhulu

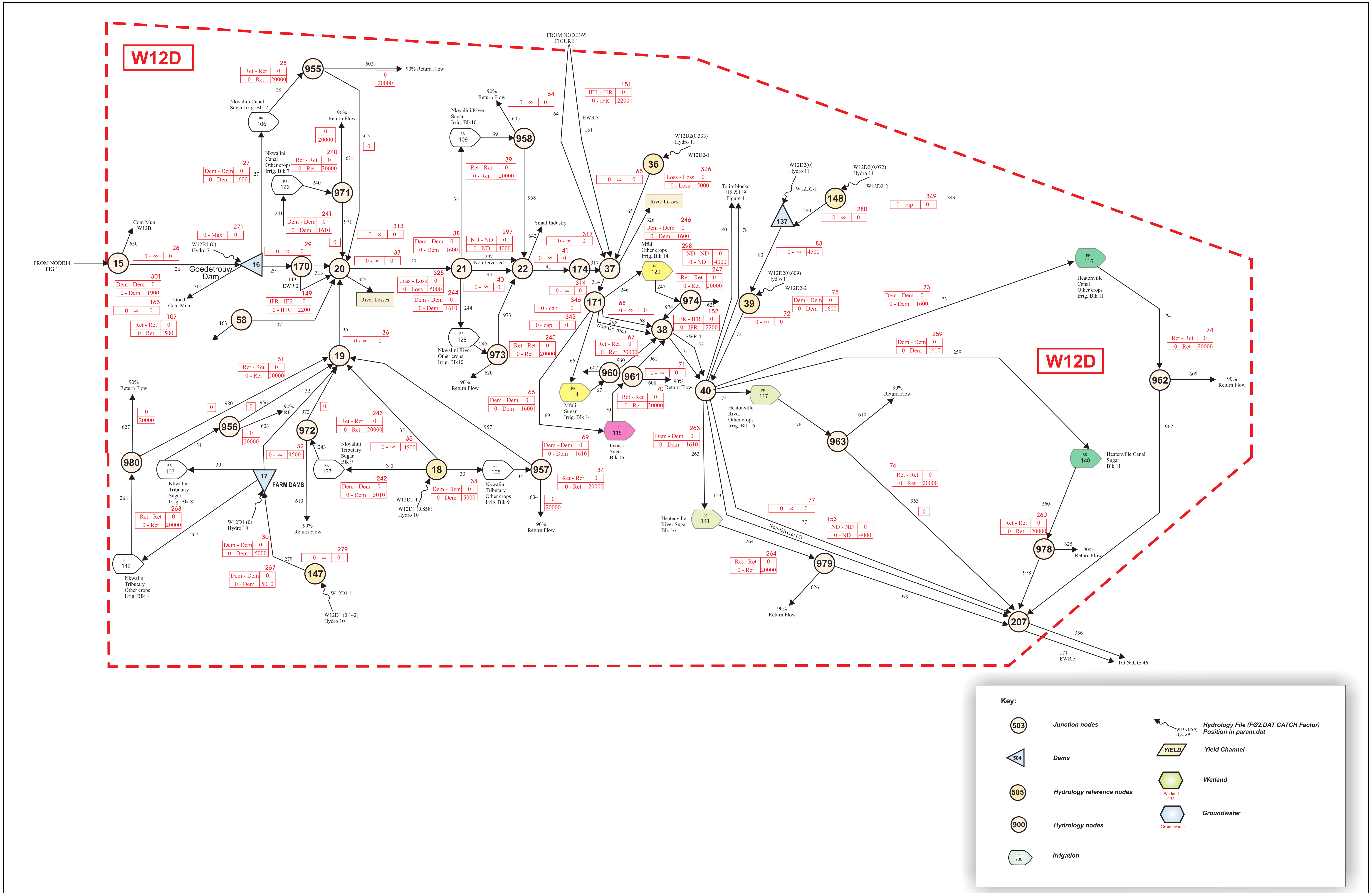
10000	30.5
50	14.7
50	14.7
50	14.7
50	14.7
3800	14.7
10000	13.0

NB 100m added to reservoir levels

IMPLEMENTATION AND MAINTENANCE OF THE WATER RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

W12A, W12B and W12C

A-1



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W12D

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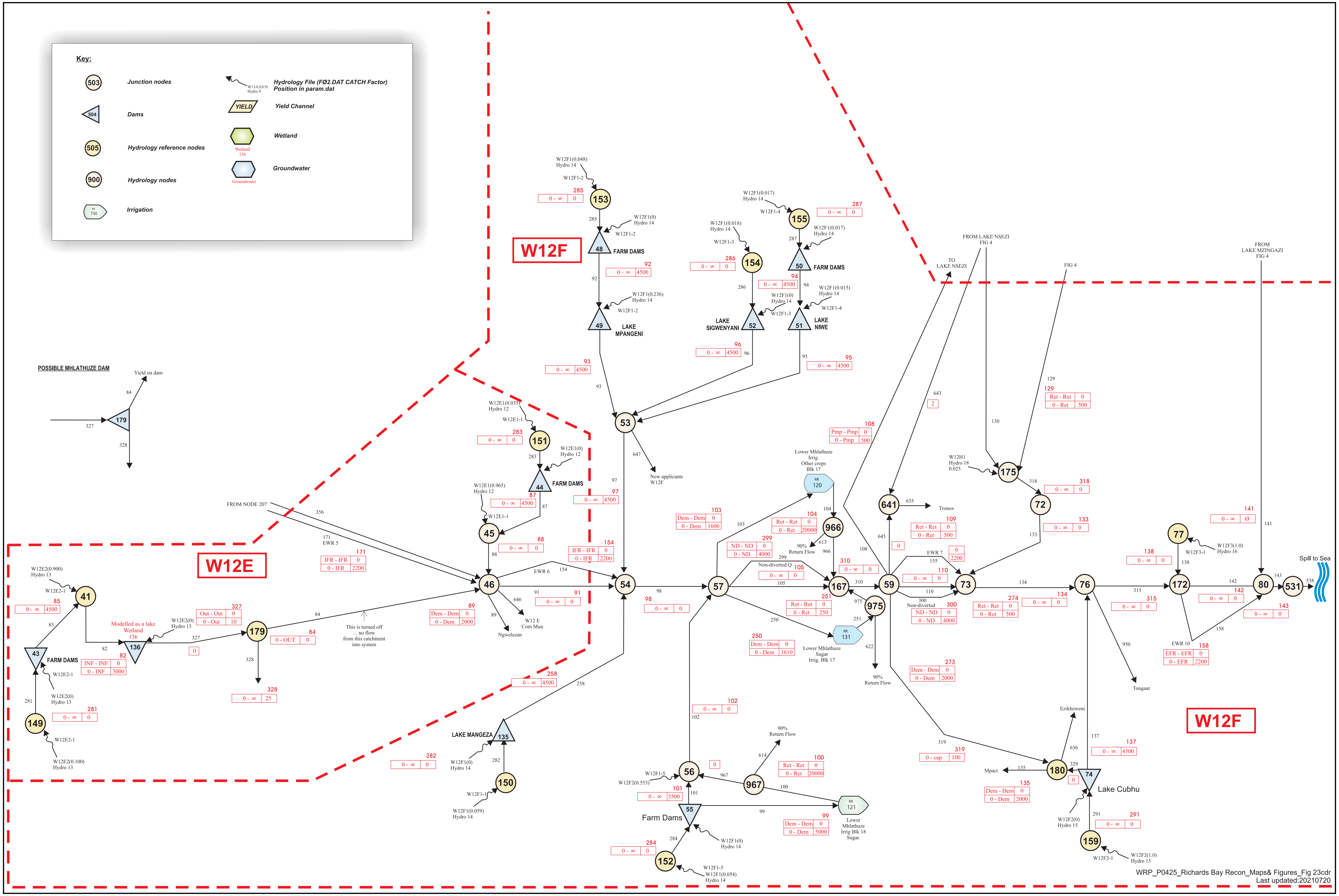

IMPLEMENTATION AND MAINTENANCE OF THE WATER
RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

W12E and W12F

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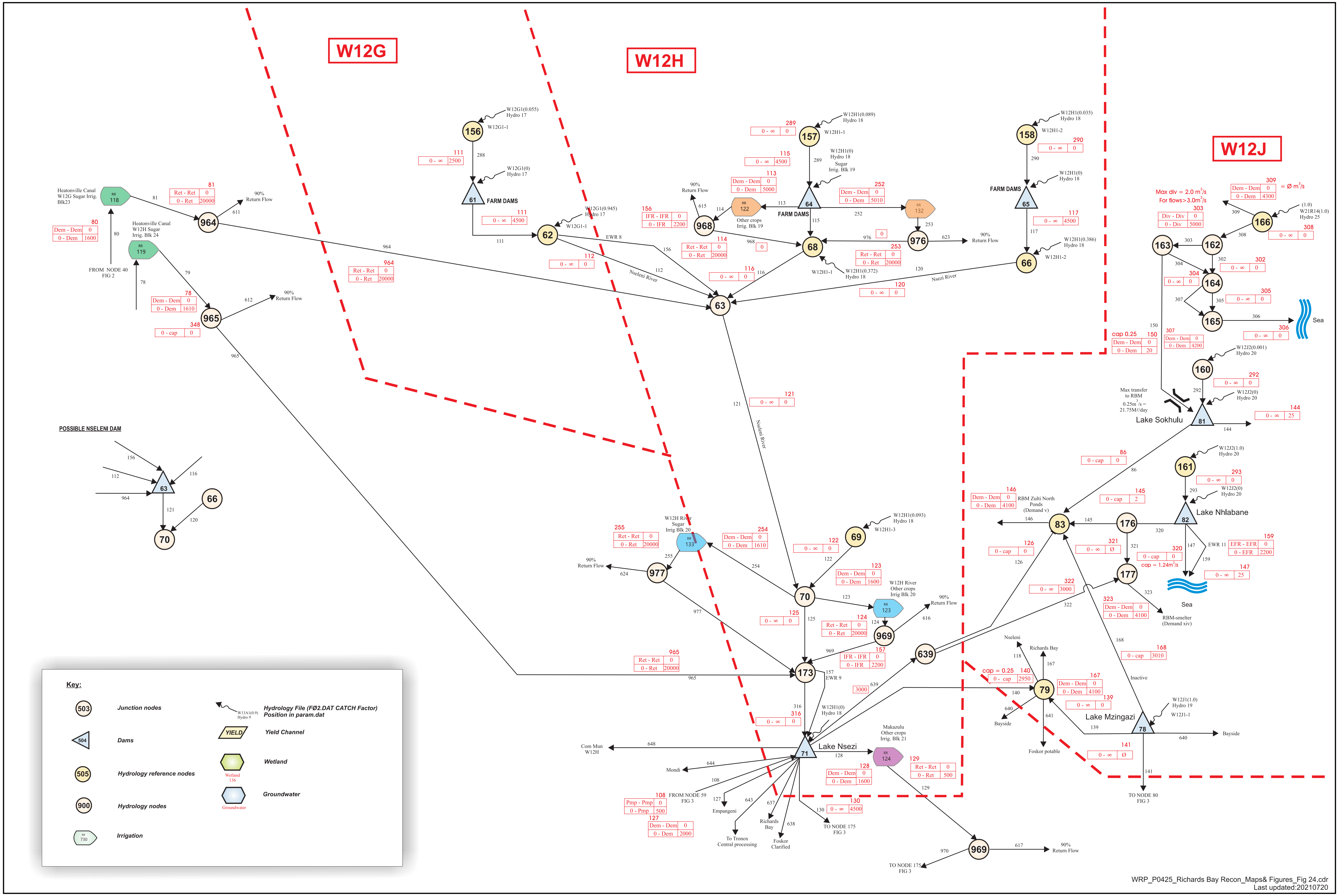

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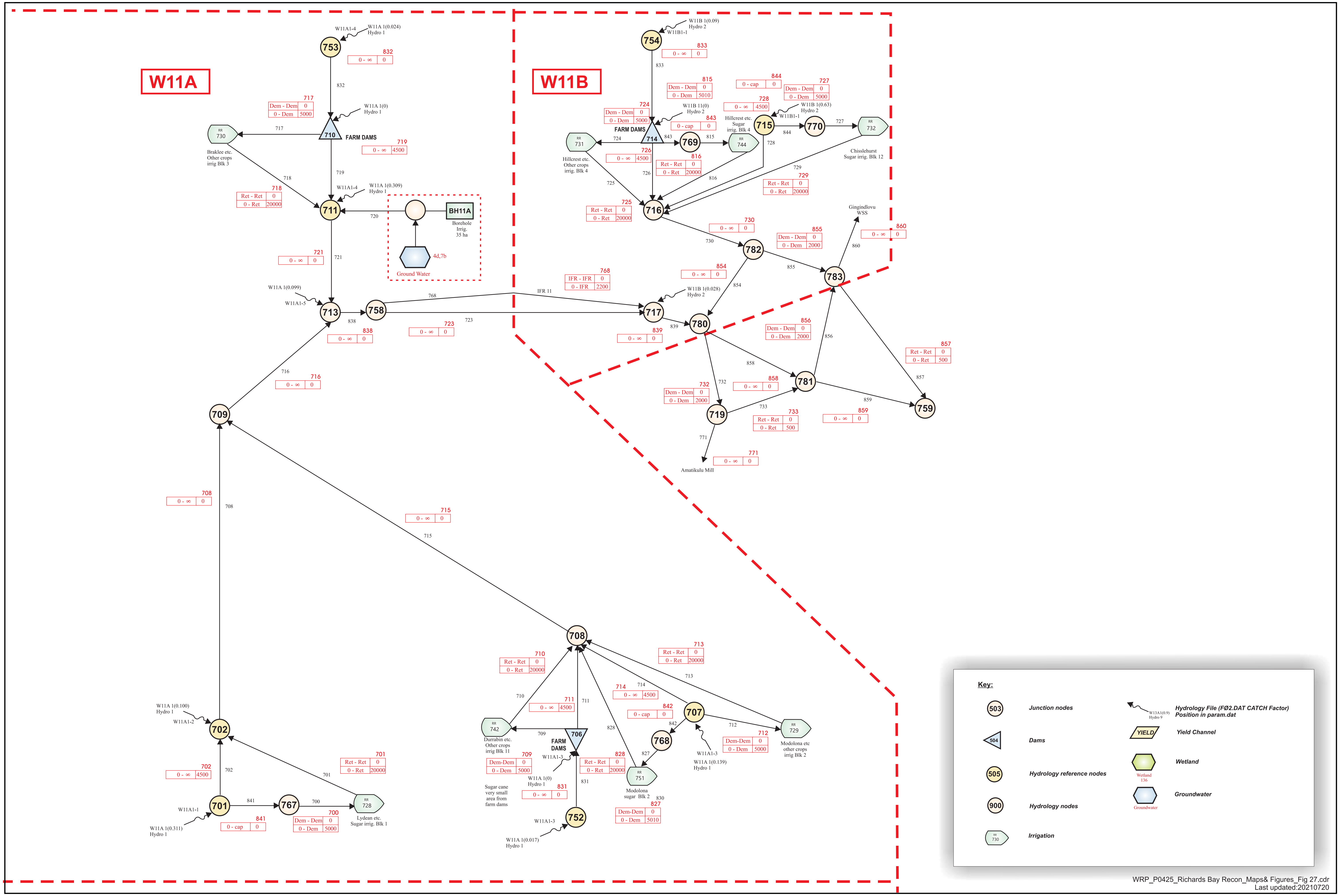
RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

W12G, W12H and W12J

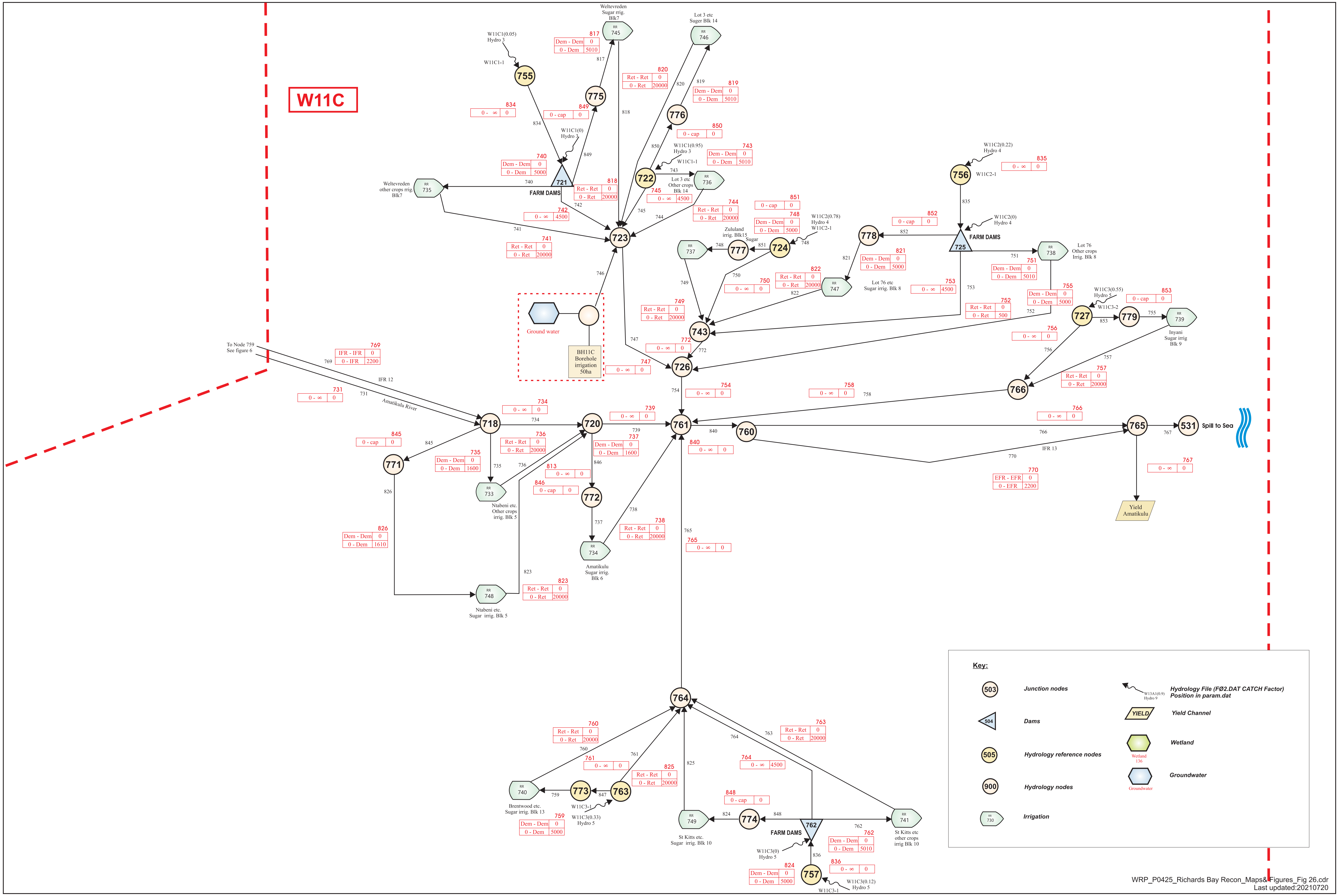
A-4



IMPLEMENTATION AND MAINTENANCE OF THE WATER
RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

W11A and W11B

A-5



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W11C

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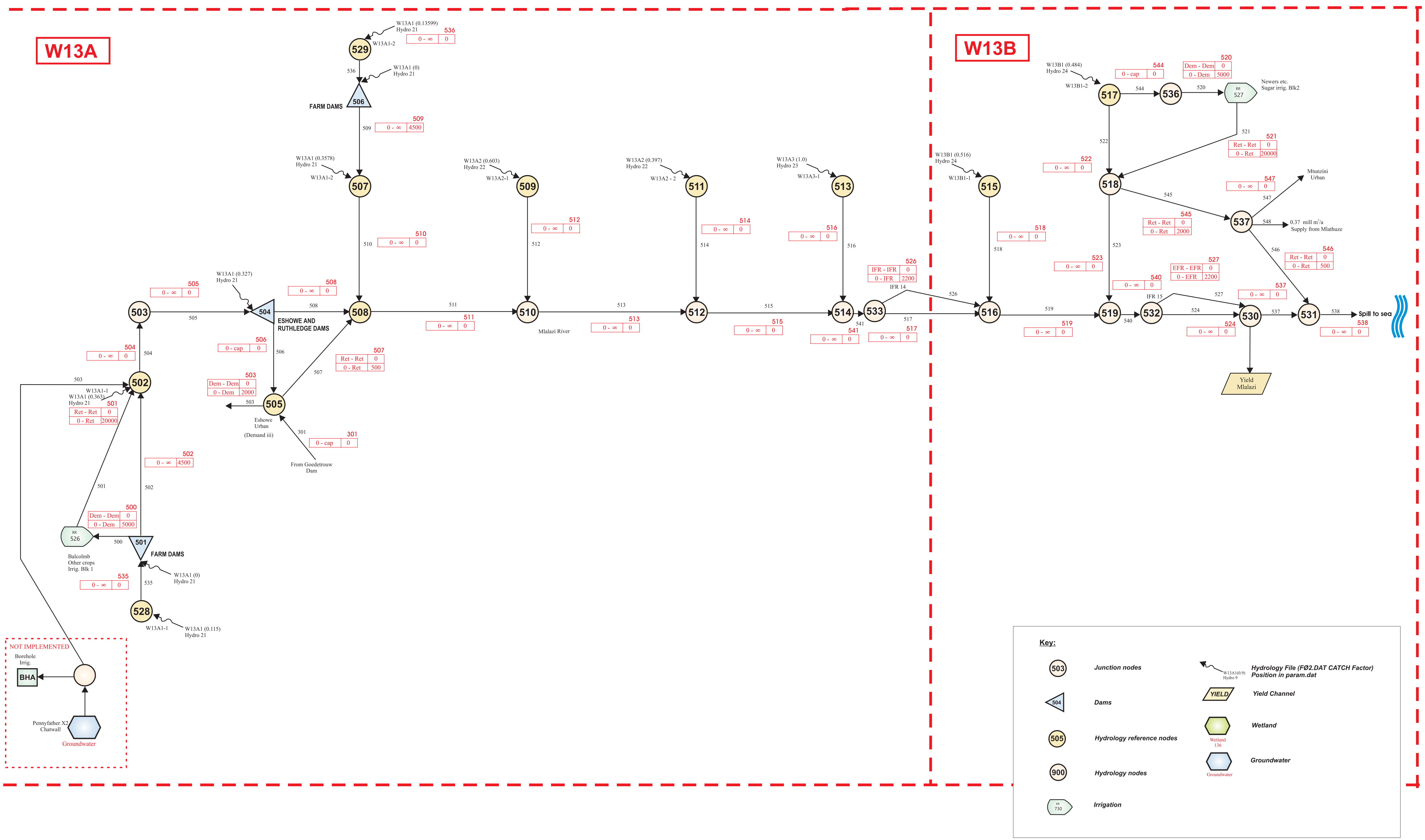

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IMPLEMENTATION AND MAINTENANCE OF THE WATER
RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

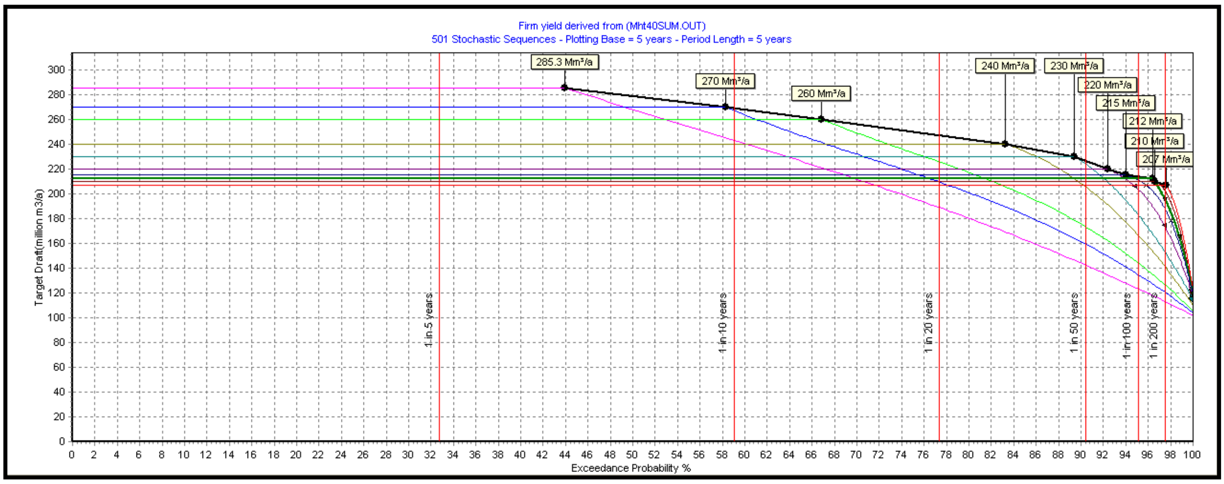
W13A and W13B

A-7

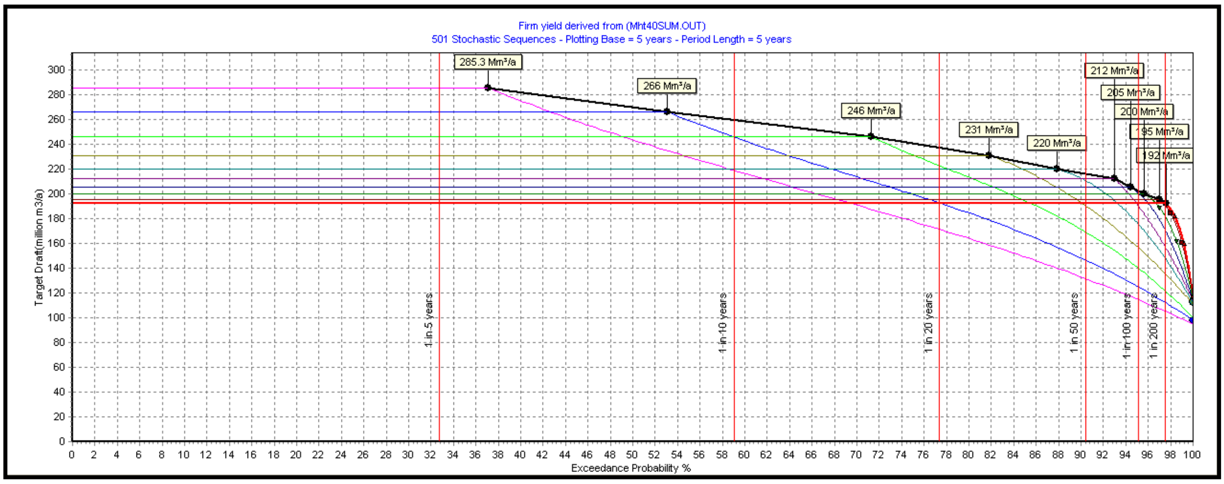
APPENDIX B

SHORT TERM STOCHASTIC YIELD CURVES

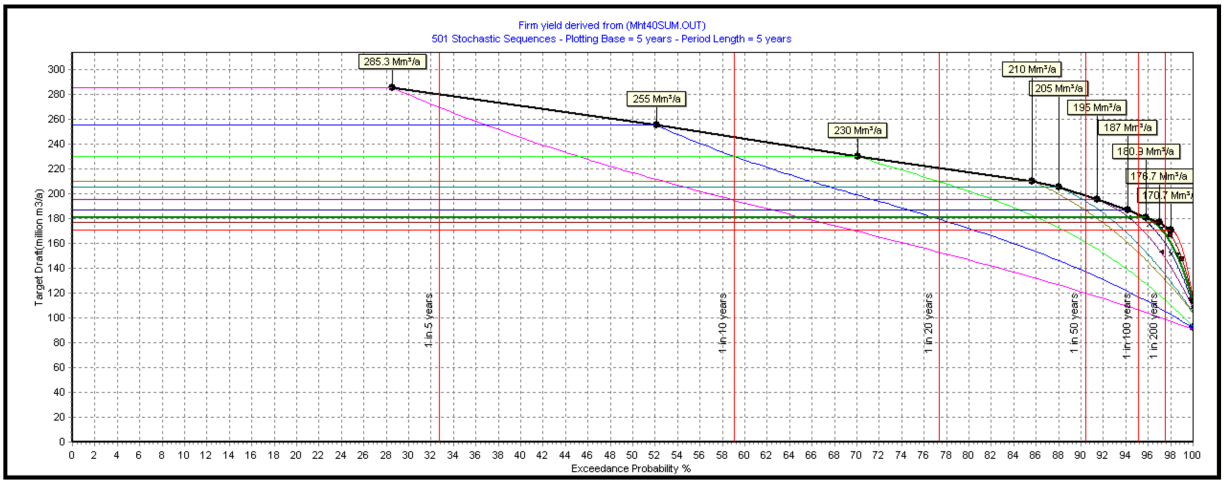
Mhlathuze: 100%



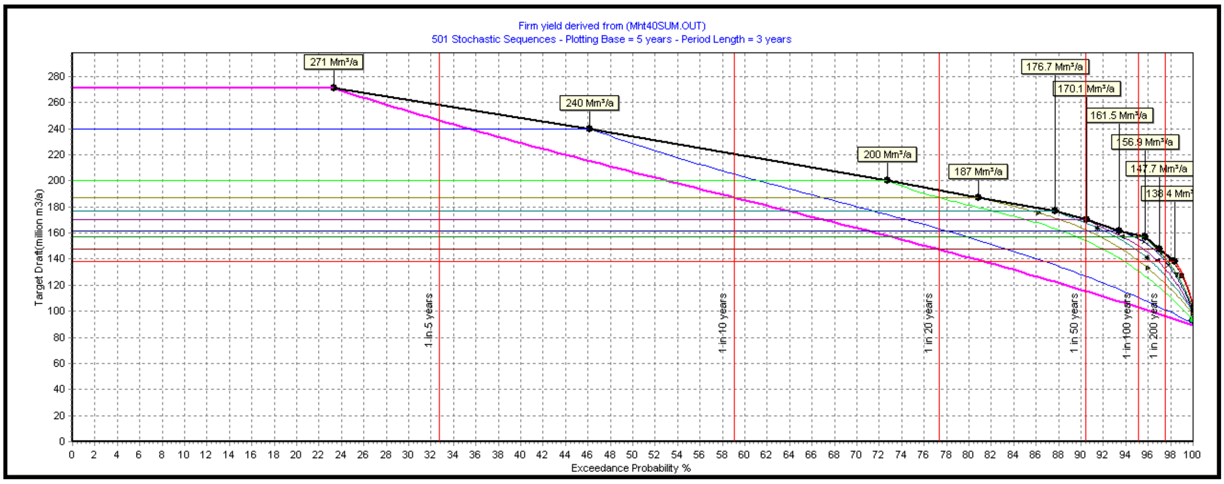
Mhlathuze: 80%



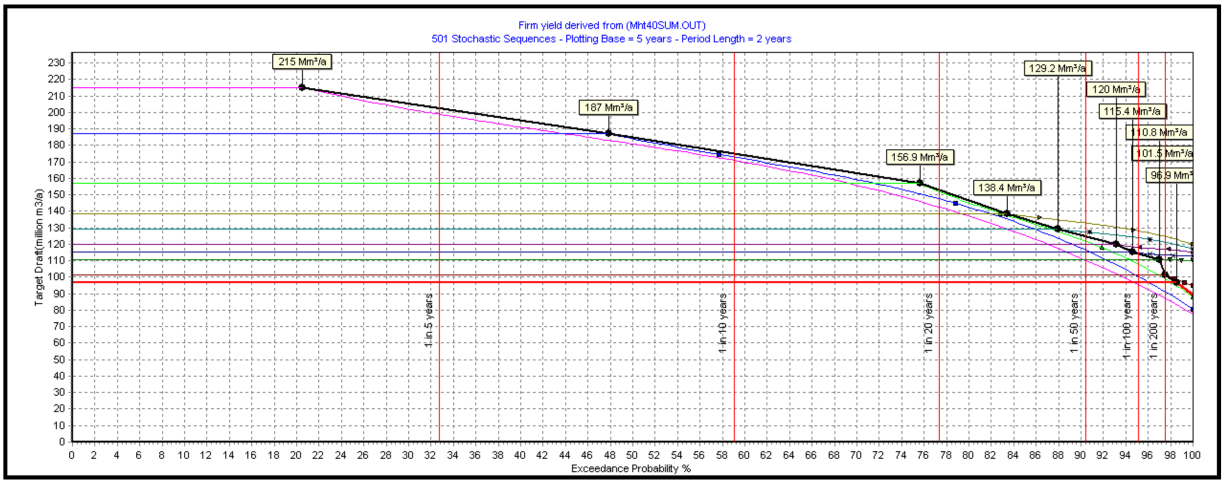
Mhlathuze: 60%



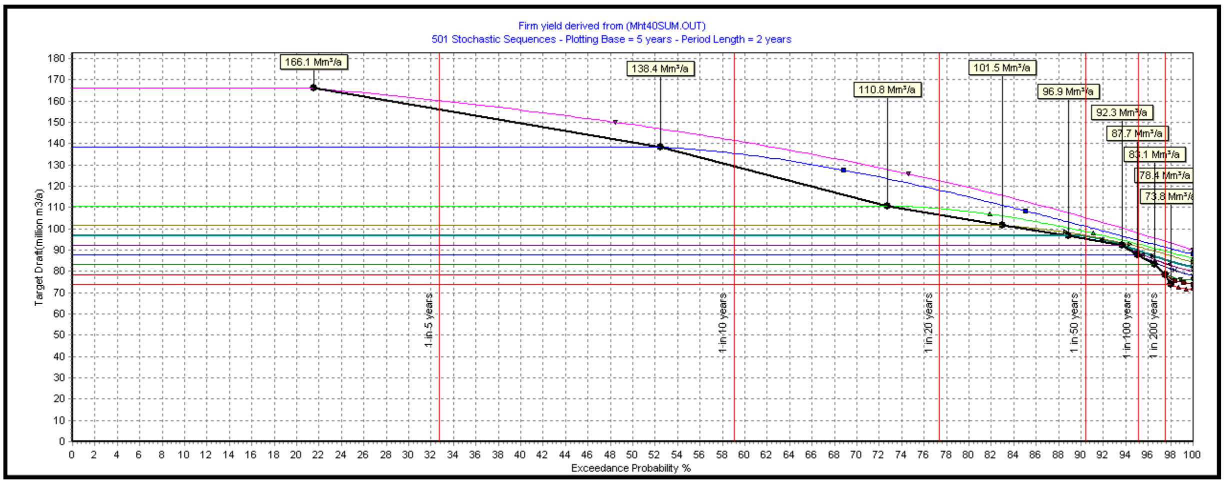
Mhlathuze: 40%



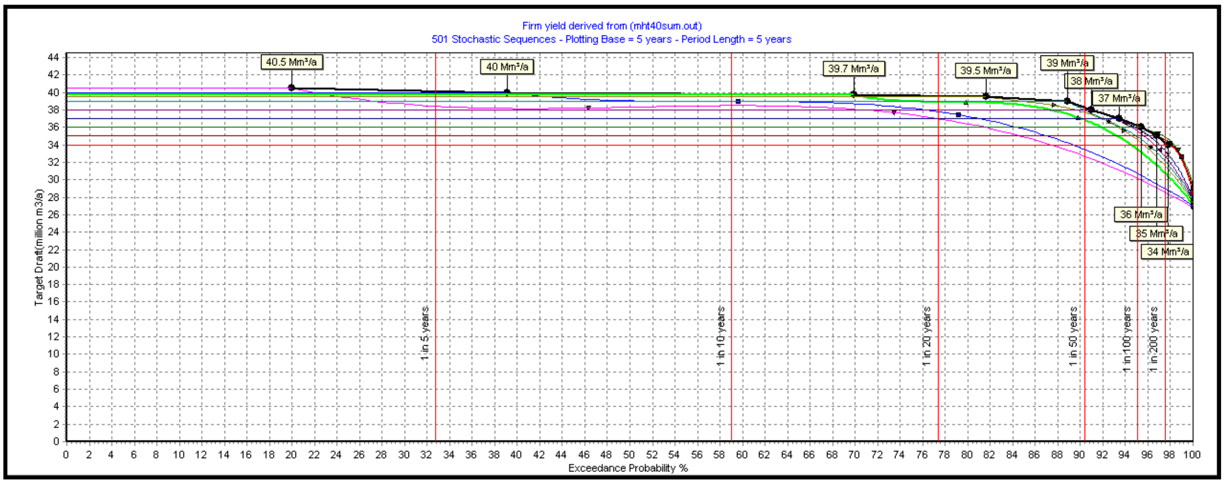
Mhlathuze: 20%



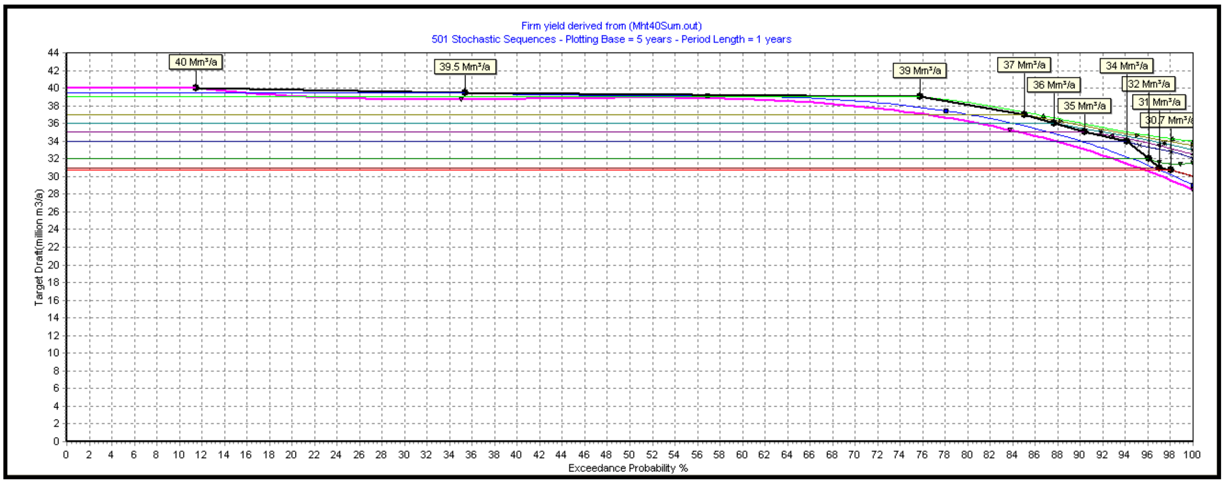
Mhlathuze: 10%



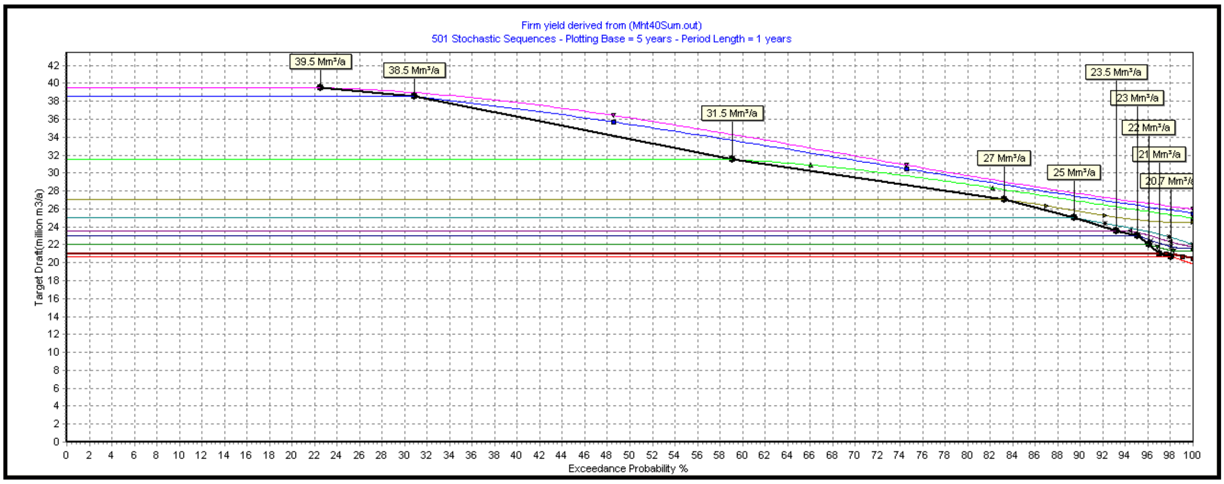
Umfolozi: 100%



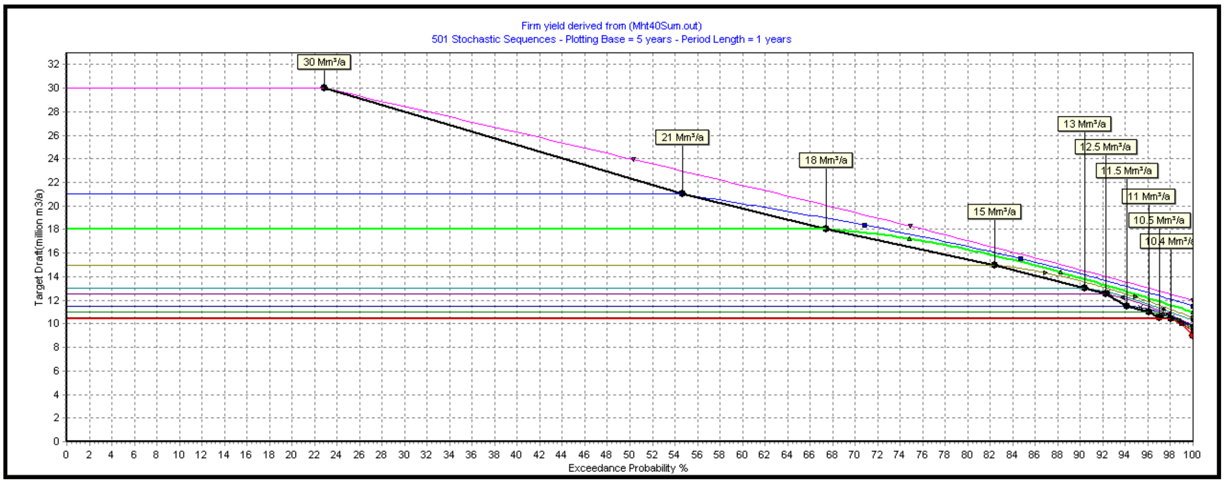
Umfolozi: 80%



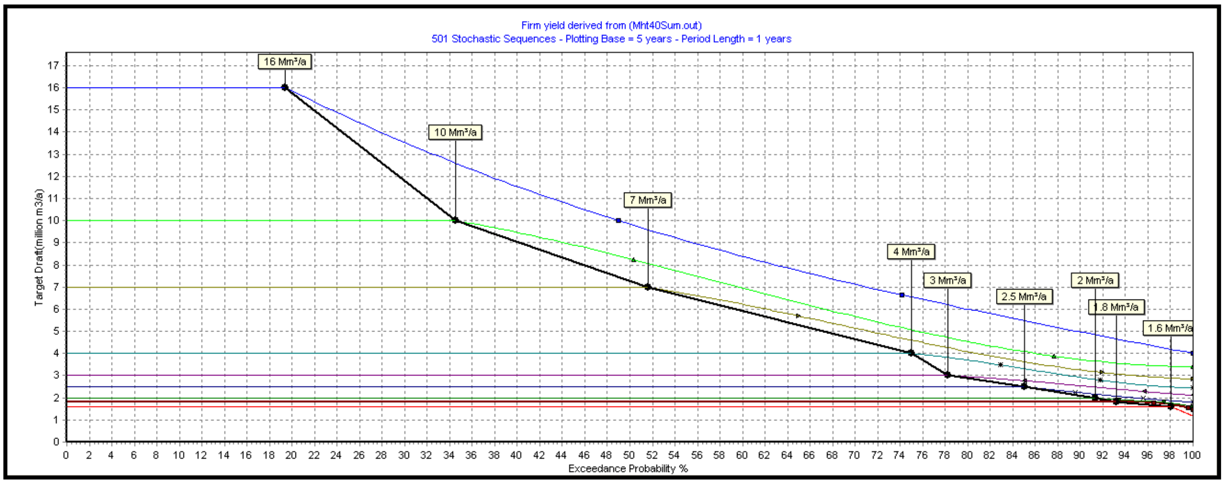
Umfolozi: 60%



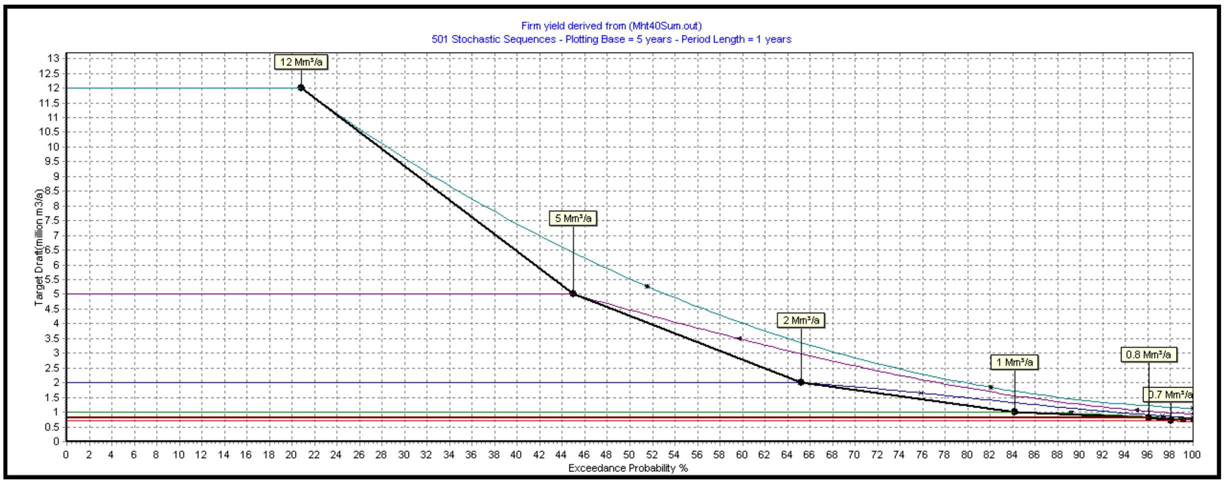
Umfolozi: 40%



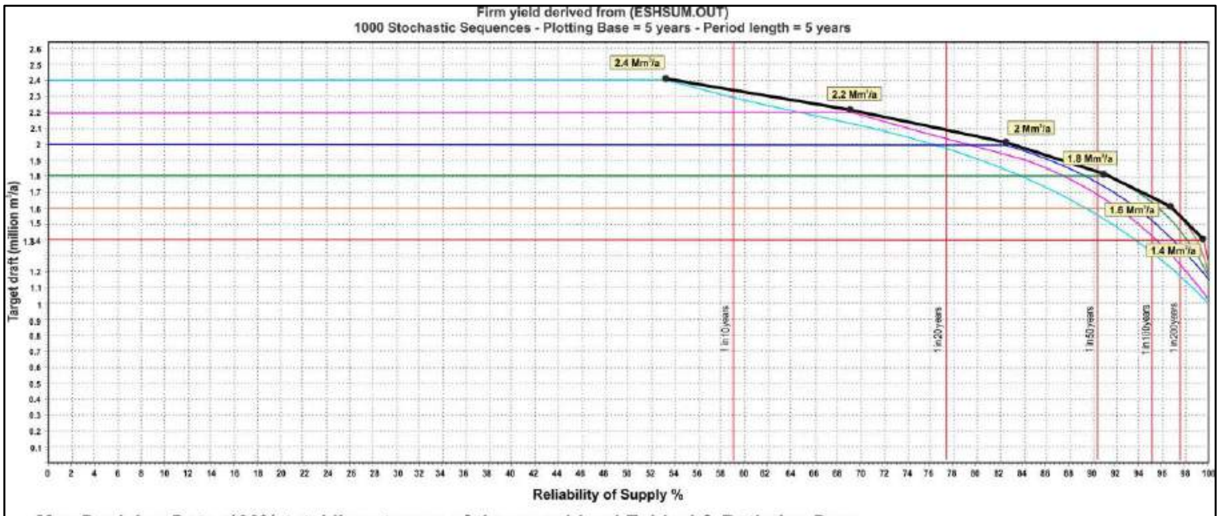
Umfolozi: 20%



Umfolozi: 10%

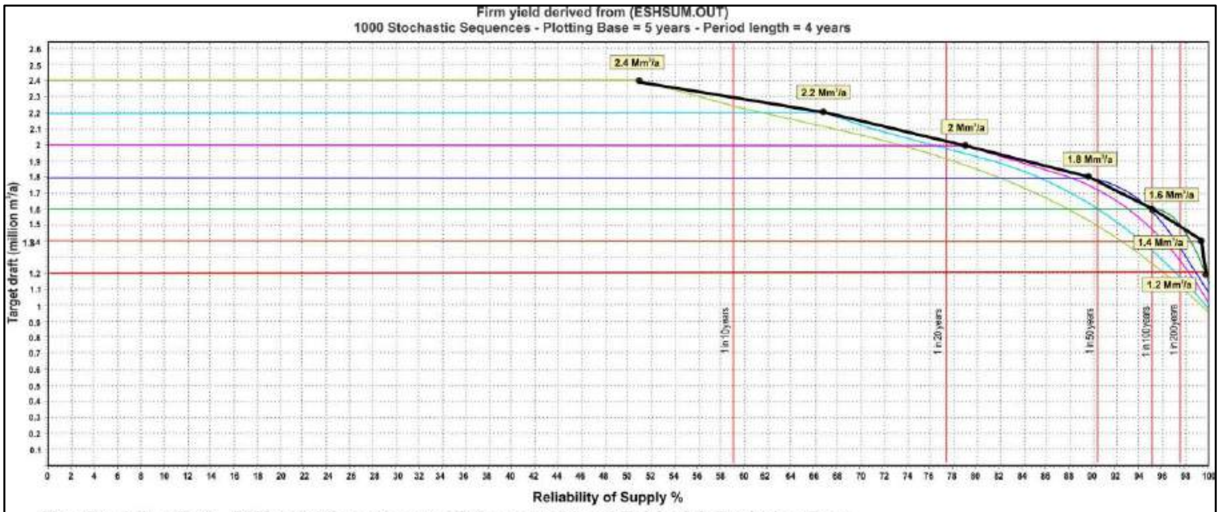


Eshowe and Rutledge: 100%



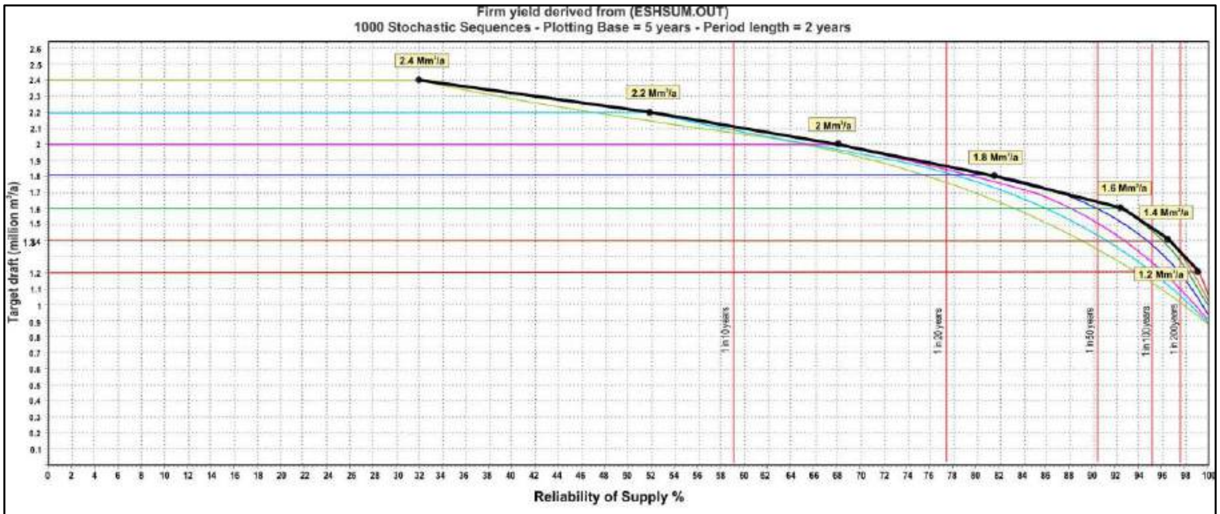
May Decision Date, 100% total live storage of the compbined Eshlazi & Rutledge Dam

Eshowe and Rutledge: 80%



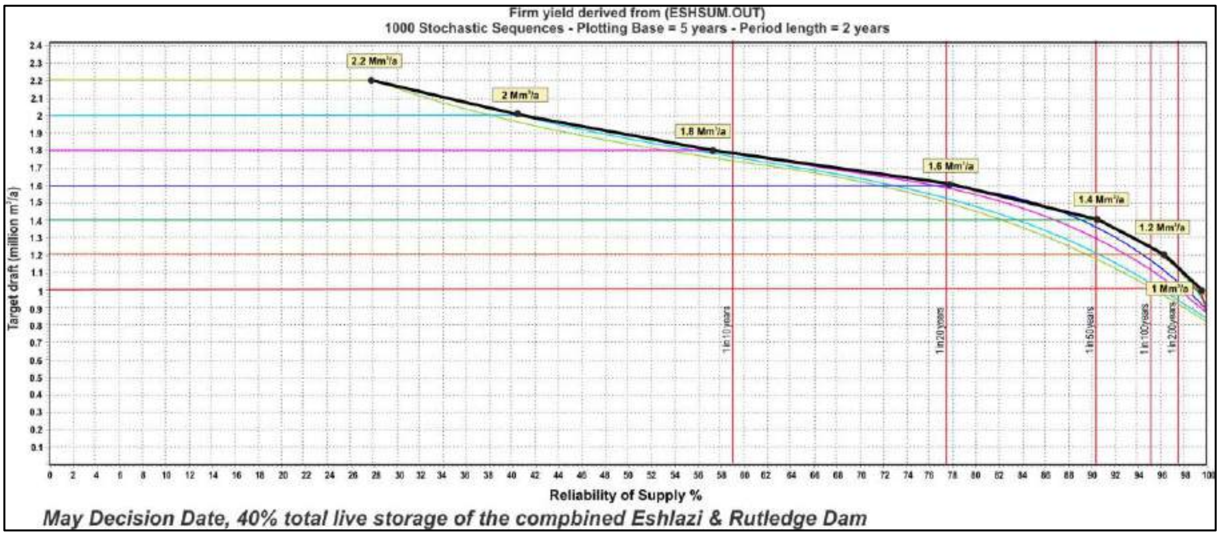
May Decision Date, 80% total live storage of the compbined Eshlazi & Rutledge Dam

Eshowe and Rutledge: 60%

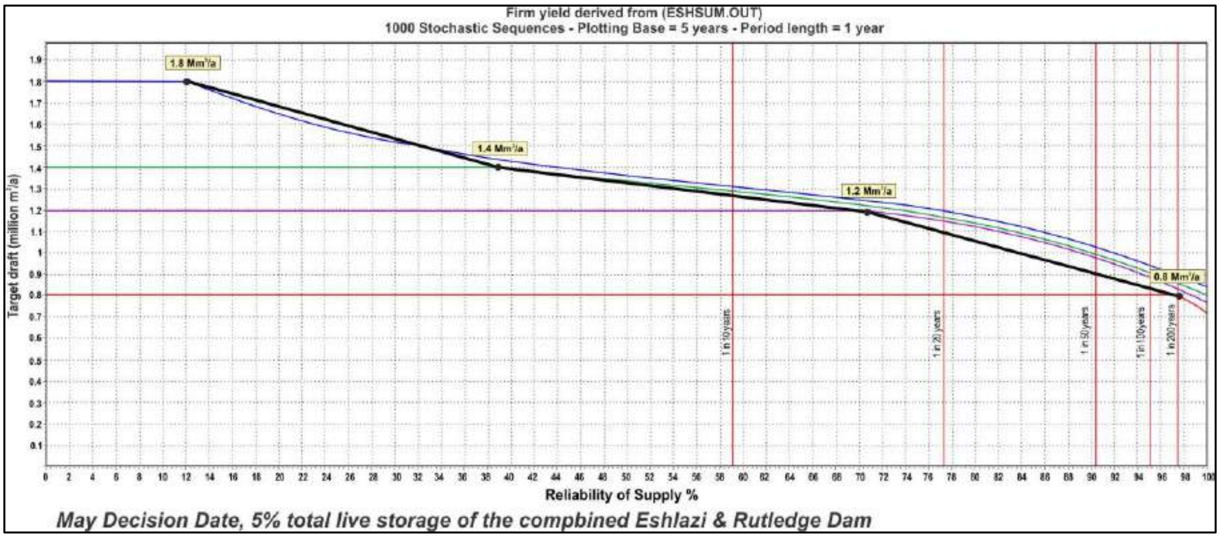


May Decision Date, 60% total live storage of the compbined Eshlazi & Rutledge Dam

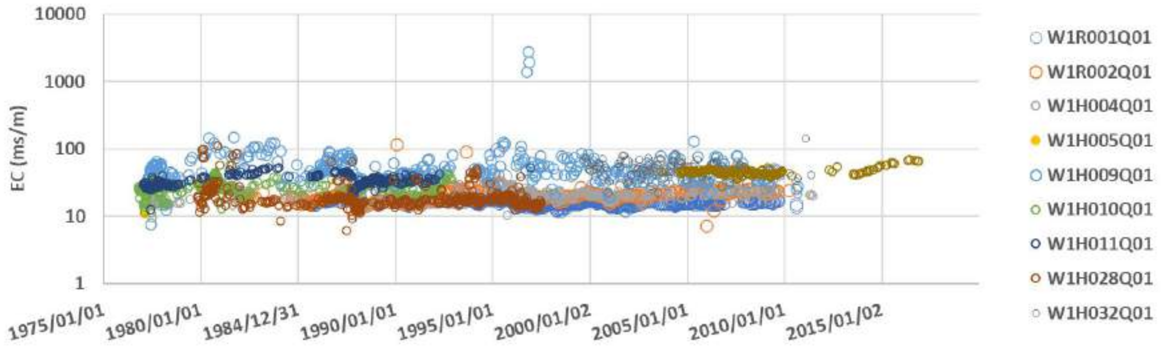
Eshowe and Rutledge: 40%



Eshowe and Rutledge: 5%



APPENDIX C
WATER QUALITY TIME SERIES PLOTS


10000
1000
100
10
1
EC (ms/m)
1975/01/01
1980/01/01
1984/12/31
1990/01/01
1995/01/01
2000/01/02
2005/01/01
2010/01/01
2015/01/02
W1R001Q01
W1R002Q01
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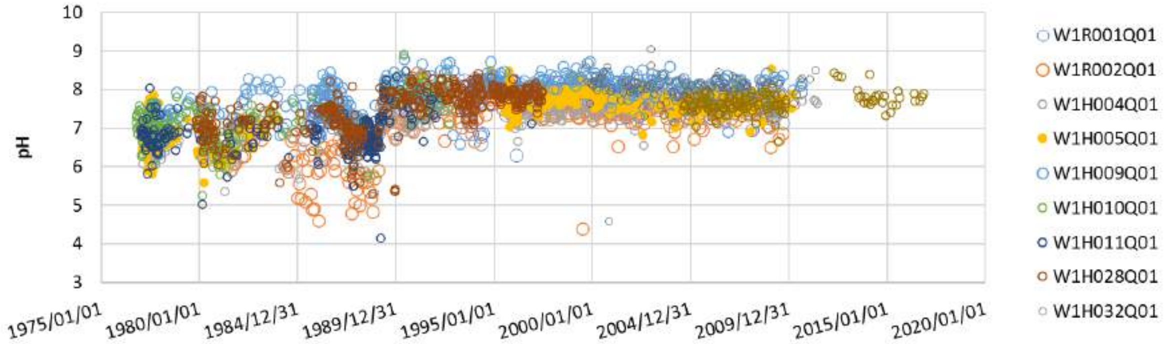
W1H028Q01
W1H032Q01


10
9
8
7
6
5
4
3
pH
1975/01/01
1980/01/01
1984/12/31
1989/12/31
1995/01/01
2000/01/01
2004/12/31
2009/12/31
2015/01/01
2020/01/01
W1R001Q01
W1R002Q01
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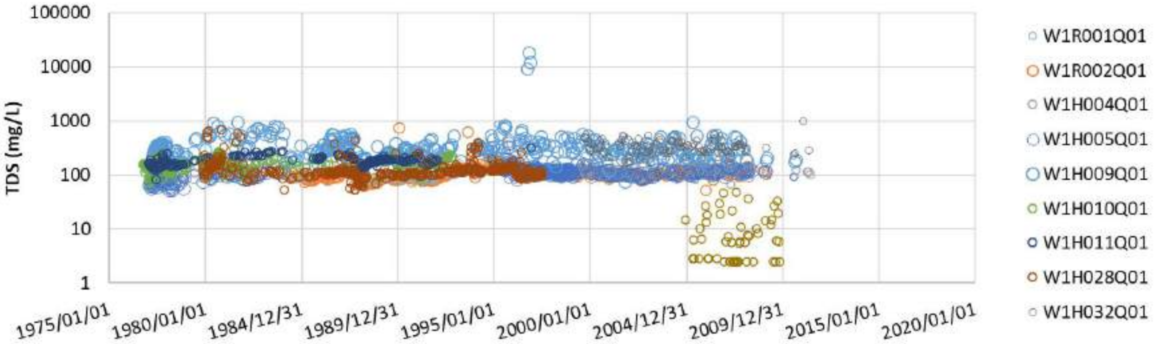
W1H028Q01
W1H032Q01


100000
10000
1000
100
10
1
TDS (mg/L)
1975/01/01
1980/01/01
1984/12/31
1989/12/31
1995/01/01
2000/01/01
2004/12/31
2009/12/31
2015/01/01
2020/01/01
W1R001Q01
W1R002Q01
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W1H028Q01
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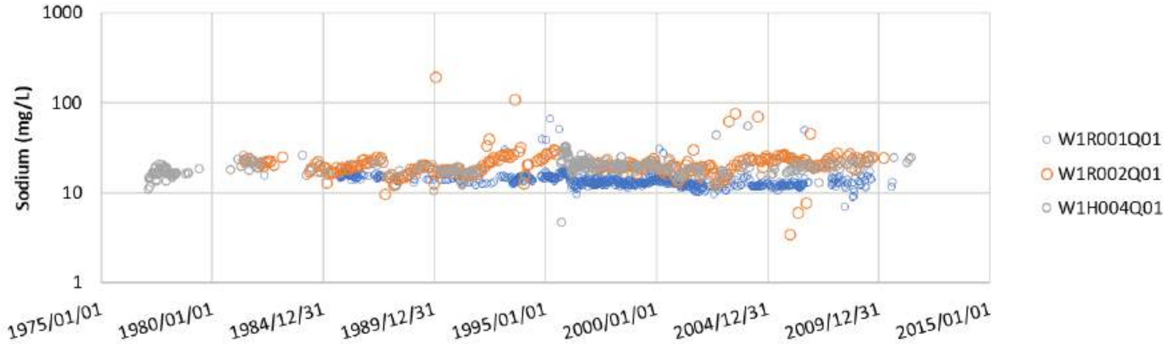
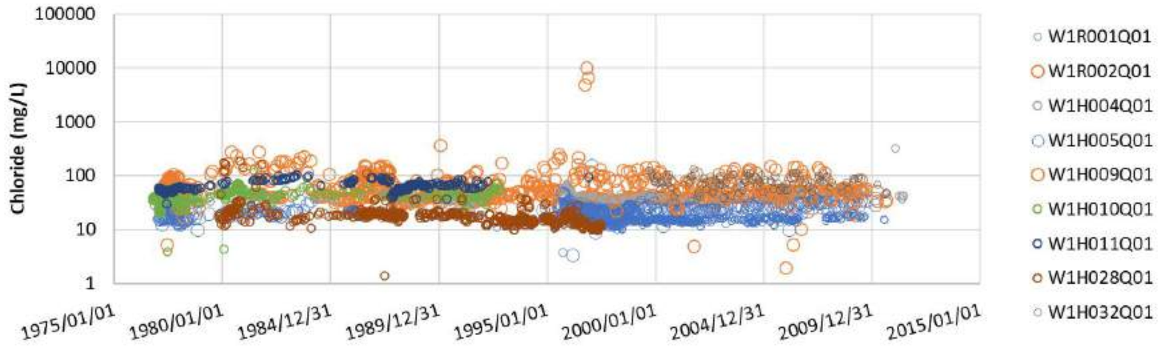

1000
100
10
1
Sodium (mg/L)
1975/01/01
1980/01/01
1984/12/31
1989/12/31
1995/01/01
2000/01/01
2004/12/31
2009/12/31
2015/01/01
W1R001Q01
W1R002Q01
W1H004Q01


Chloride (mg/L)
100000
10000
1000
100
10
1
1975/01/01
1980/01/01
1984/12/31
1989/12/31
1995/01/01
2000/01/01
2004/12/31
2009/12/31
2015/01/01
W1R001Q01
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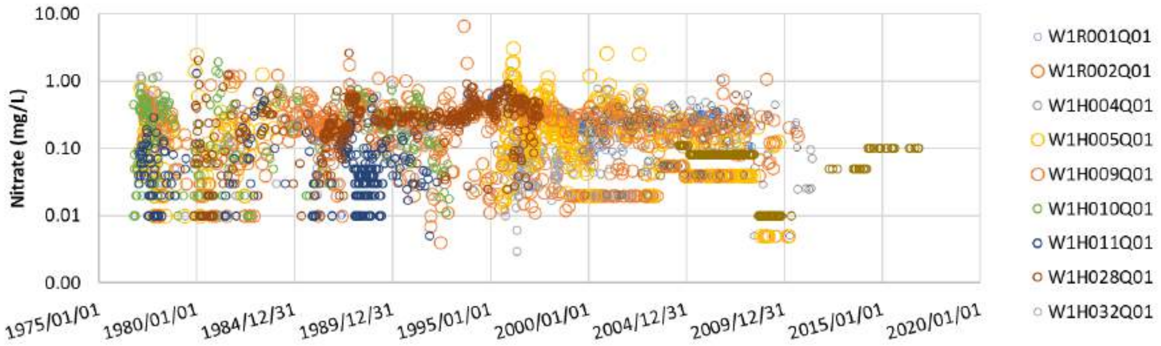
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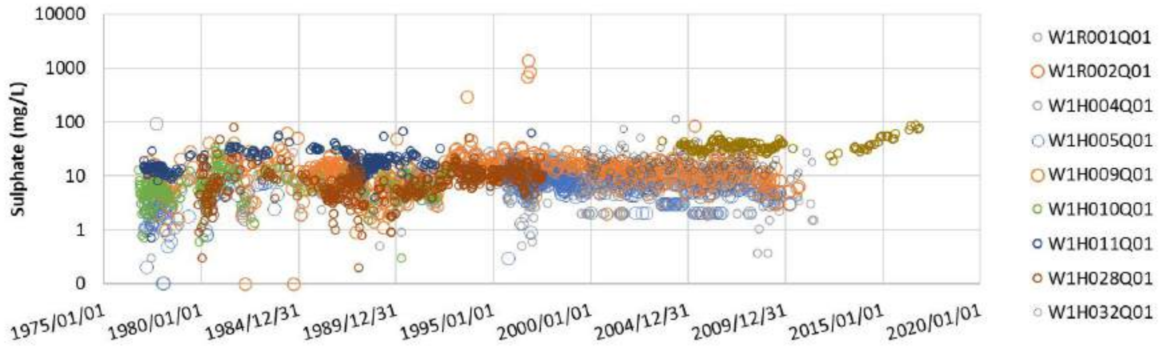
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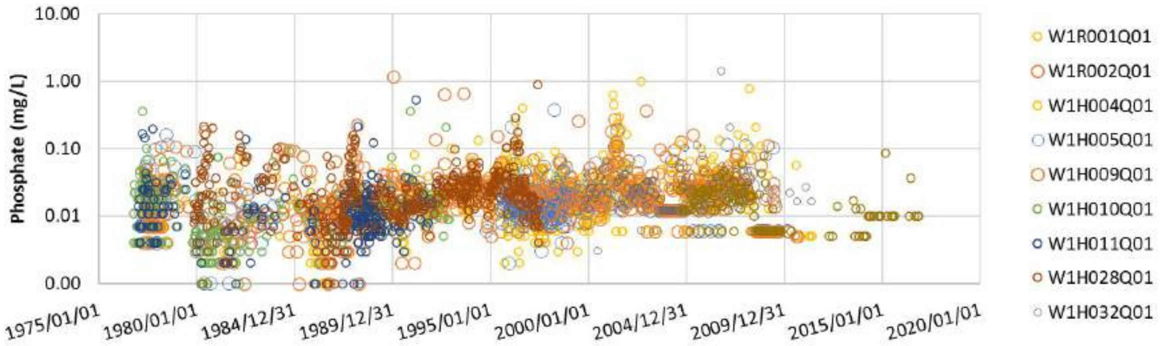
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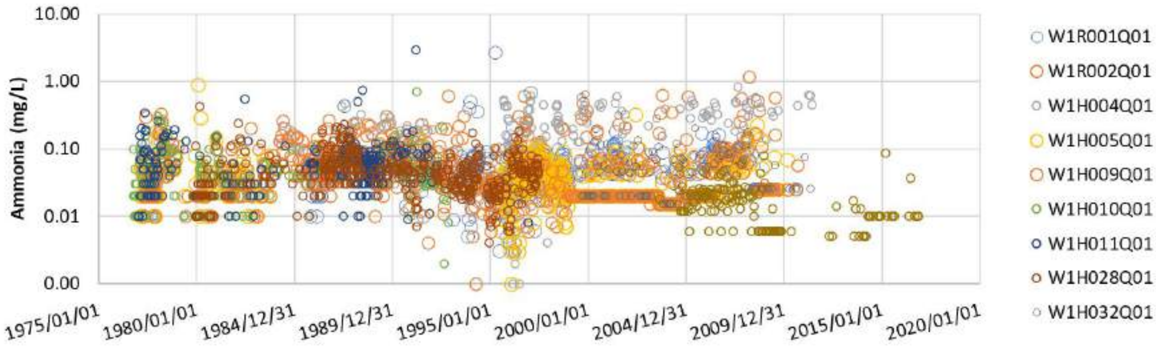
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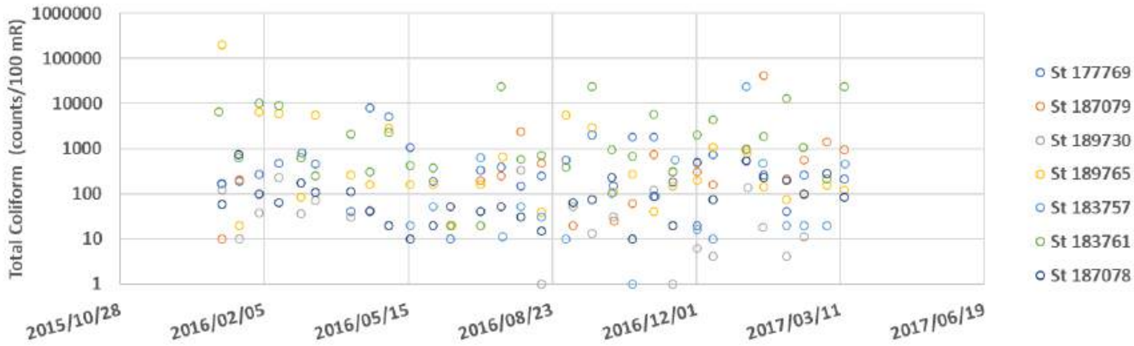
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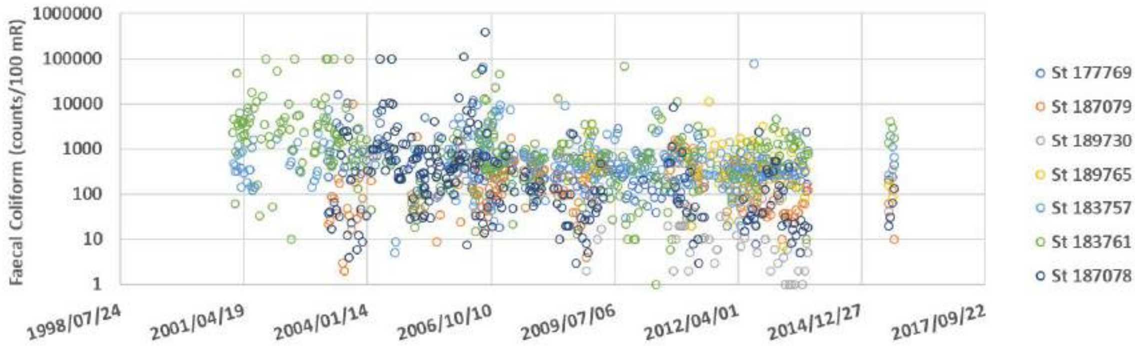
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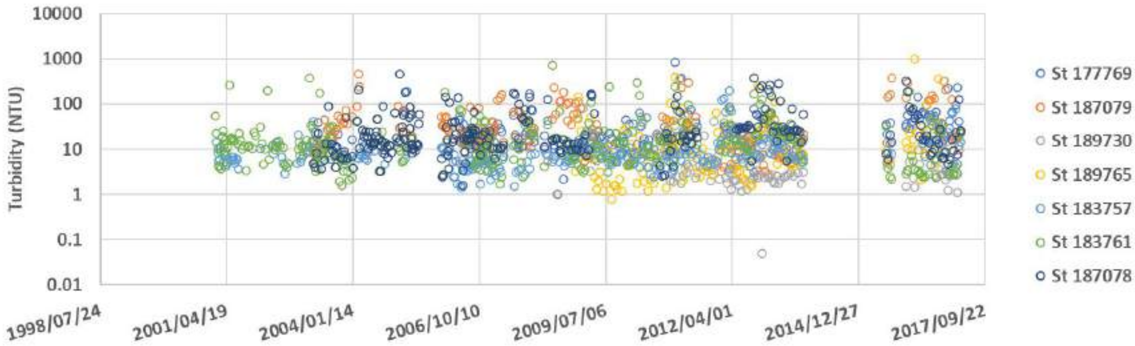
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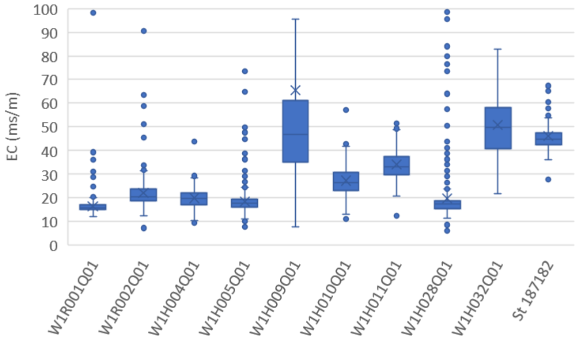
APPENDIX D
WATER QUALITY BOXPLOTS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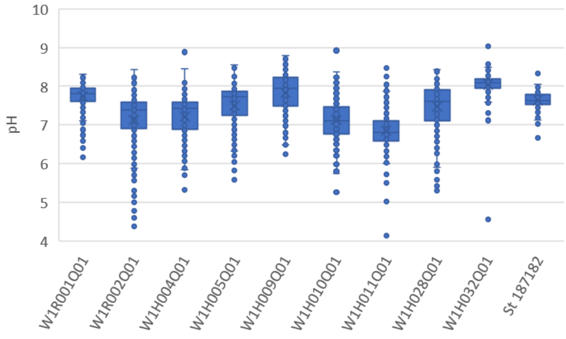
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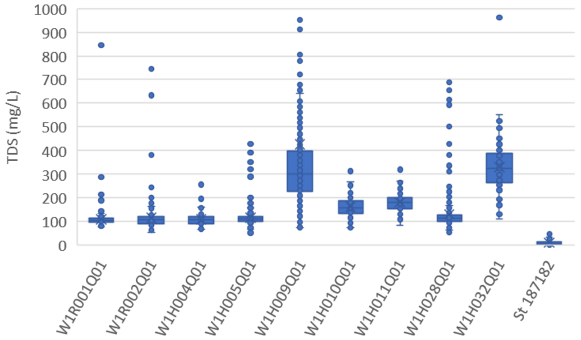
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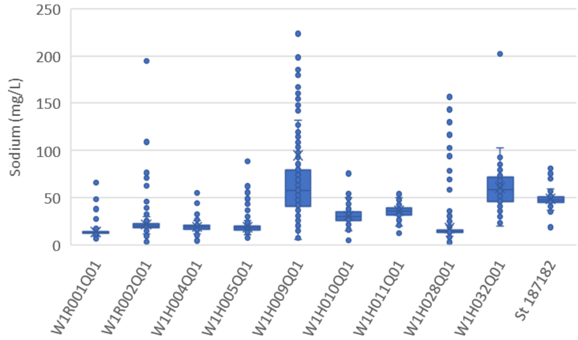
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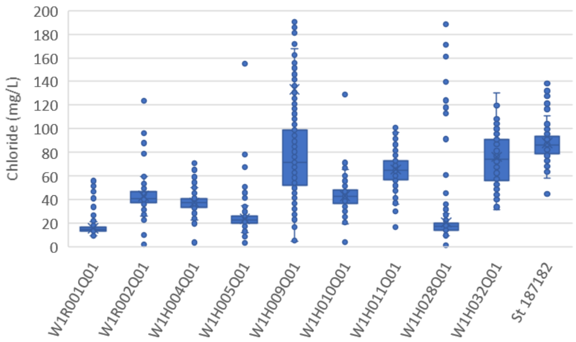
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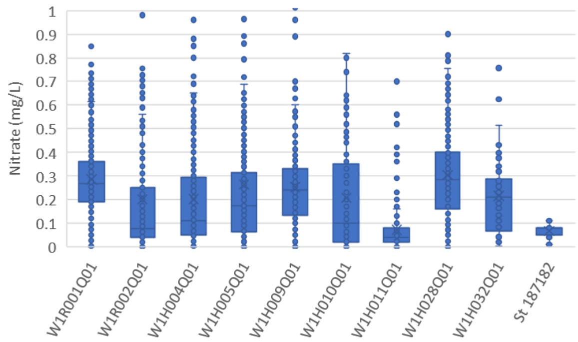
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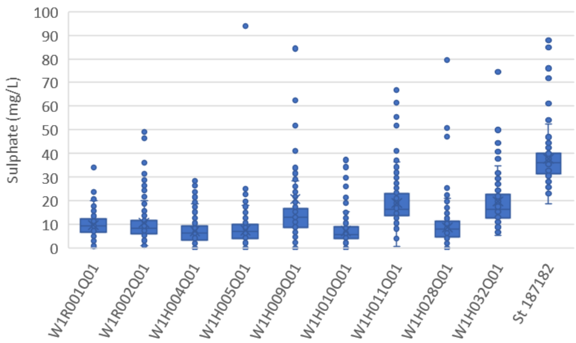
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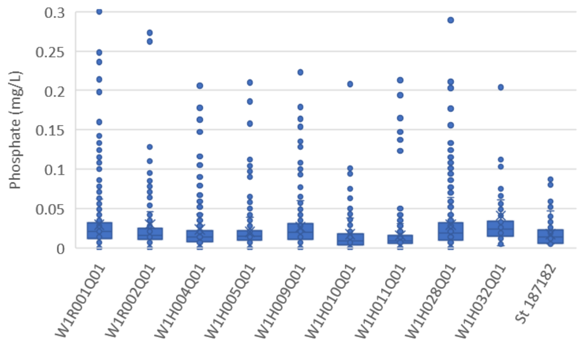
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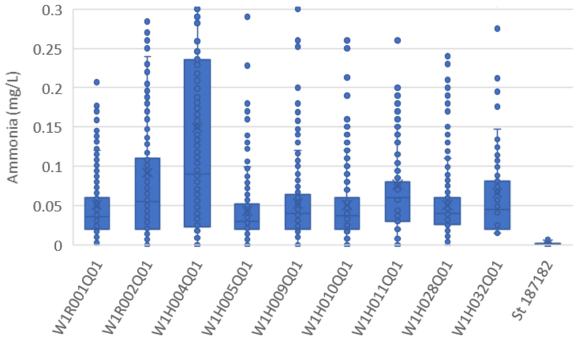
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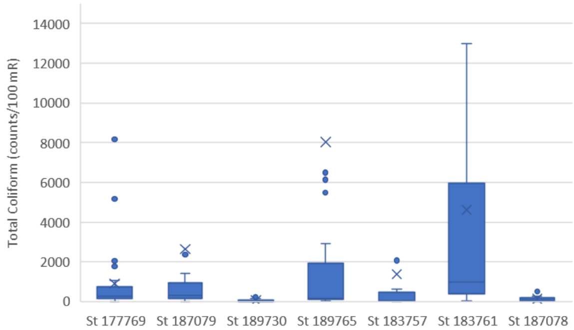
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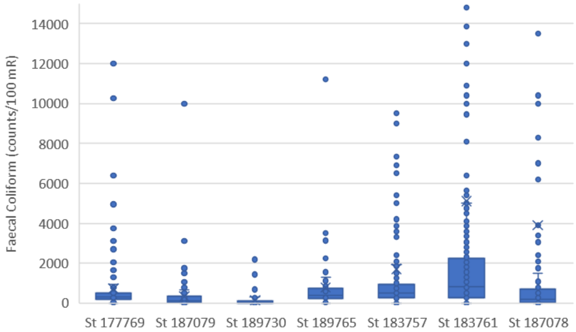
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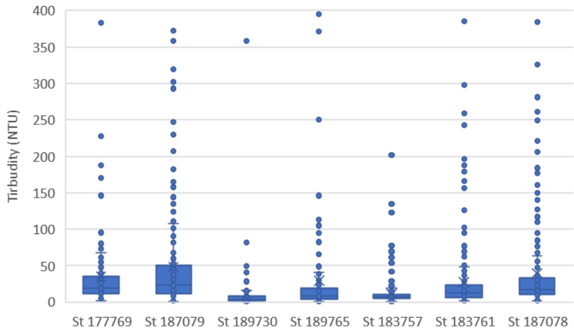
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APPENDIX E
GROUNDWATER ASSESEMENT

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

IMPLEMENTATION AND MAINTENANCE OF THE WATER RECONCILIATION STRATEGY FOR RICHARDS BAY AND SURROUNDING TOWNS

JUNE 2021

COMPILED FOR:	COMPILED BY:
Department of Water and Sanitation Contact person: K Mandaza Private Bag X313, Pretoria 0001 South Africa Telephone: +27(0) 12 336 7670 Email: MandazaK@dws.gov.za	**BJ/iX/WRP Joint Venture** Contact person: K Sami Block 5, Green Park Estate, 27 George Storrar Drive, Pretoria Telephone: +27 (0)12 346 3496 Email: russell@kayamandi.com

THIS MODULE WILL BE INCLUDED IN THE WATER RESOURCES REPORT AS AN APPENDICES, WITH A SUMMARY INCORPORATED INTO THE RECONCILIATION STRATEGY

FINAL MODULE

GROUNDWATER ASSESSMENT

EXECUTIVE SUMMARY

Objective you can take out of my report. Same with what was not covered in previous report. How GW for bulk supply dealt with just say yield of boreholes shows not feasible for bulk supply. Also, that the high yielding areas in the coquina/limestone feed the lakes and abstracting groundwater would impact on the lakes. I said that in report.

Background

The Department of Water and Sanitation (DWS) commissioned a study on the Water Reconciliation Strategy for Richards Bay and Surrounding Towns (2013-2015) to inform the planning and implementation of water resource management interventions necessary to reconcile future water requirements and water use patterns up to a period of thirty years. For the Strategy to remain relevant the water balance has to be continuously monitored and the developed Strategy has to be regularly updated and maintained. The DWS commissioned the Implementation and Maintenance of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns Study, referred to as this Study hereafter, to facilitate a process to maintain the relevance of the Strategy.

During the Implementation and Maintenance of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns Study, (2019), DWS felt that too little attention had been placed on groundwater resources during the Water Reconciliation Strategy for Richards Bay and Surrounding Towns Study (2015).

Objective and Scope of Work

It was decided to commission an additional task to investigate:

- whether groundwater can contribute to the bulk water supply or local supply.
- whether potential exists for increasing the yield from the Coastal lakes through managed aquifer recharge.

Based on a meeting and correspondence between DWS and the Study Team, the following tasks were identified as part of this phase of the Reconciliation Strategy update:

1. Define the Coastal Lake groundwater catchment area boundaries.
2. Clarify the methodology used in the previous Reconciliation Strategy to conclude that there is insufficient yield for bulk water supply from groundwater from the hard rock areas.
3. Use updated information to determine whether the conclusion drawn in 2 is correct, and if not, define scope for further detailed work that is required in order determine if the resource is sufficient.
4. Assess the sand aquifer based on existing data.
5. Look at yield distribution and location of borehole yields determine potential for bulk and local supply. (% > 2 l/s, >5 l/s etc.). Look at recharge and the aquifer stress index.
6. Look at potential for artificial recharge (yield of formation, method) and if viable, to look at further.
7. Produce maps that can be used in future for WSAs to establish where to target groundwater development on a localised level.
8. High level assessment of groundwater abstraction impact on coastal lakes.

Coastal Lake Groundwater Catchment Boundaries

The separation of lake catchments into Quinary catchments according to the area considered to contribute surface and groundwater inflow to the lake and that contributing only surface inflow (as well as groundwater baseflow) were defined by Sami (2019) (Figure 1).

The area contributing groundwater directly to the lakes were defined by the volume of natural groundwater inflow to the lakes obtained from the lake models (Sami 2019), divided the mean annual recharge as defined in Sami (2019). This provides an approximate catchment area required to maintain the lake water balance and water level. This area was then defined spatially from topography, excluding the area of the lakes.

The remainder of the Quaternary catchment also contributes groundwater to the lake via baseflow to surface water courses, which enters the lakes as surface inflow.

Methodology for Groundwater Assessment for the Richards Recon Strategy

Aurecon identified 3 potential wellfields at Mtunzini North, Empangeni West and Lubisana. These had 18-19 production boreholes each and potential yields of 0.71, 0.54, 0.3 Mm^3/a respectively, or a total of 1,55 Mm^3/a. They are all located on the Tugela Terrane of the Natal Metamorphic Province.

The report utilised the combined blow yield of all the most favourable boreholes in each wellfield area and assumed an average abstraction of less than 50% of blow yield, with an average abstraction rate of 1-2.5 l/s, depending on the wellfield. The range of blow yields established is given, but not the distribution of yields so that the proportion of boreholes that can deliver such a yield can be evaluated.

The final yield was based on the average yield of 1-2.5 l/s for a 12-hour pumping day. Since a 12-hr day was assumed, the analysis is based on a sustainable pumping rate of 0.5-1.25 l/s per borehole.

Sami et al. (2000) in a study of the Natal Metamorphic Province near Mapumulo found that the area exhibits a poor historical success rate with about 46% of the holes being dry. Greater than 75% of boreholes yielded more than 1 l/s can be achieved by structural interpretation and strain analysis. An 89% success rate, with 7 of 9 boreholes exceeding 1 l/s and a median yield of between 1.8-3.3 l/s. This suggests that the aquifer can be reconsidered in terms of reticulated water supply if a scientifically appropriate exploration strategy is adhered to.

Consequently, with proper site selection, the Aurecon assessment is a realistic assessment of the yield potential of the aquifer. It would require 50-60 production boreholes to provide 1.5 Mm^3/a. This is not viable for bulk water supply, but the range of yields 23-300 m^3/d per borehole suggests the aquifer is suitable for local stand-alone water supply.

No other geology other than the Tugela Terrane was investigated.

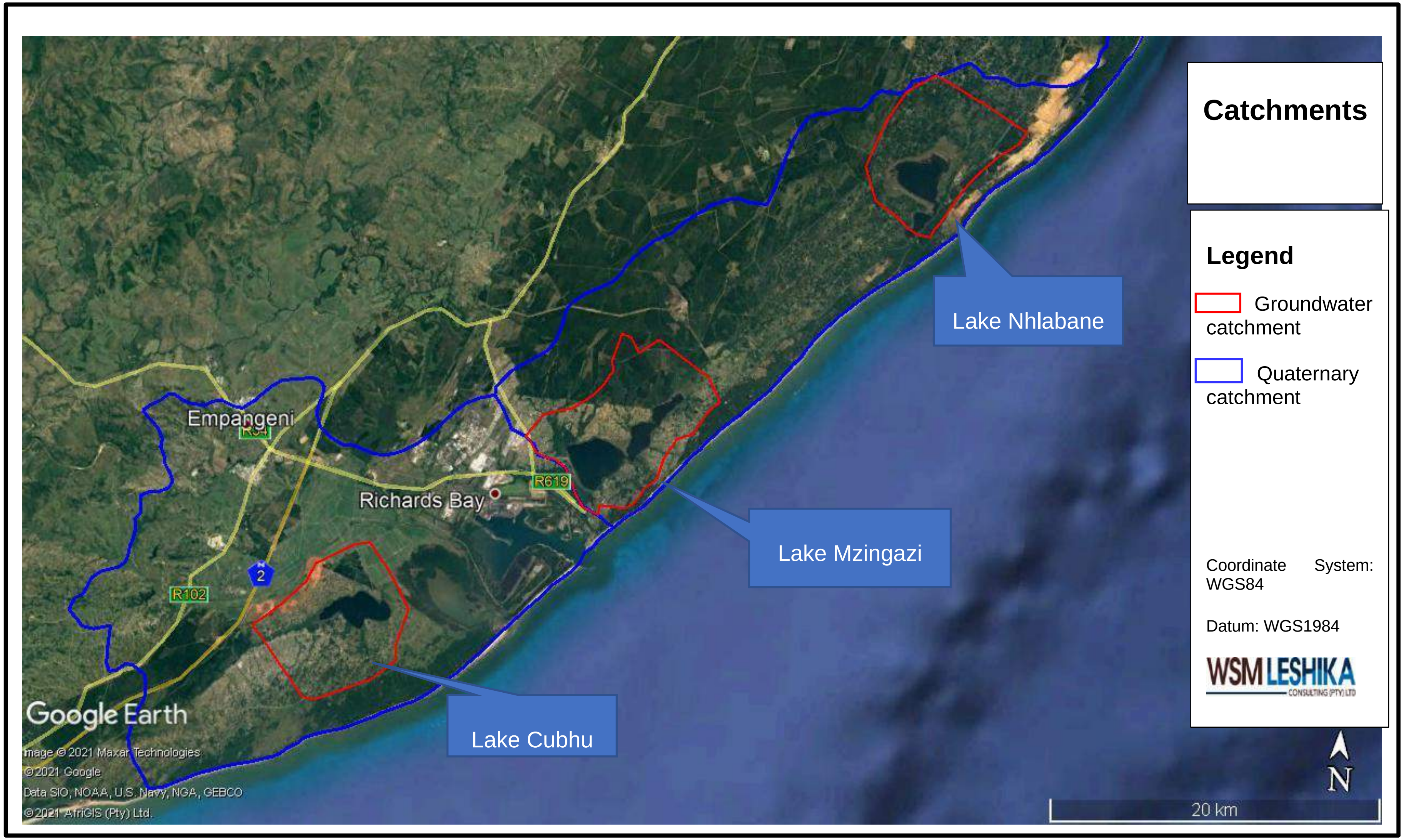

Figure 1 Quaternary and Lake groundwater catchment boundaries

Updated Assessment of Groundwater Resources

Aquifer yield

Aquifer yield is a measure of the available groundwater resources, excluding an assessment of whether they can be economically abstracted. Data was collected on Harvest Potential, Exploitation Potential, and recharge from GRAII (Table 1).

Table 1 Groundwater resources

	Harvest Potential	Recharge	Exploitation Potential	Aquifer recharge	Potable fraction	Baseflow	Abstraction (WARMS)	Stress index
	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a		Mm^3/a	Mm^3/a	
W11A	34.583	43.639	12.226	12.796	0.94	39.271	0.259	0.02
W11B	5.396	12.292	4.506	3.731	0.20	10.980	0.000	0.00
W11C	8.655	40.400	17.241	10.653	0.83	37.143	0.092	0.01
W12A	21.407	35.065	7.476	18.902	0.85	25.170	0.092	0.00
W12B	33.996	42.413	10.836	18.798	0.86	33.160	0.040	0.00
W12C	43.928	32.699	5.939	17.818	0.94	23.233	0.011	0.00
W12D	13.373	29.364	8.005	13.322	0.77	24.833	0.172	0.01
W12E	6.785	21.411	6.461	6.717	0.43	18.485	0.000	0.00
W12F	81.290	84.512	18.684	46.752	0.64	52.001	0.348	0.01
W12G	4.331	18.967	4.705	9.999	0.49	13.774	0.004	0.00
W12H	26.510	41.556	14.980	13.036	0.90	35.852	0.293	0.02
W12J	123.853	70.890	22.701	42.464	1.00	40.200	0.000	0.00
W13A	12.240	30.793	9.756	6.478	0.82	28.239	0.168	0.03
W13B	10.416	32.147	10.260	4.734	0.93	30.364	0.007	0.00
	426.761	536.149	153.776	226.200		412.706	1.486	0.01

It is evident that much of the recharge drives baseflow. Aquifer recharge is a measure of recharge to the regional aquifer after losses for interflow from high lying springs. In mountainous terrain it is a more realistic measure of groundwater resources. The authorised water use from WARMs represents 1% of aquifer recharge, as measured by the stress index. This suggests that groundwater resources are underutilised in the study area.

Borehole yield

Borehole yield is the volume of water that can be abstracted from a borehole. Although aquifer yield may be large, it may not be possible to abstract the groundwater in economically viable volumes for bulk water supply. Borehole yield was assessed by lithology type (Table 2).

Many of the boreholes in the Quaternary deposits are shallow boreholes and do not penetrate to the more permeable Tertiary deposits, which may skew the results for boreholes drilled into the Port Durnford Formation. The boreholes with high yields in this Formation are likely drilled where a thick sequence of the Uloa Formation exists. These channels are the main source of groundwater inflow into the coastal lakes. One such channel coincides with the Mhlatuze river and estuary and another runs through the middle of Lake Mzingazi and has a large impact on the lake hydraulics (Kelbe and Germishuyse, 1999). These would be the most likely positions for high yielding boreholes but would have an impact on the lake.

Table 2 Yields by geological formation

Geology	N	Median (l/s)	% ≥ 2 l/s	% ≥ 5 l/s
Empangeni and Pre Pongola intrusives	71	0.68	11.3	4.2
Natal Metamorphic Province	52	0.5	15.4	0
Natal Group	120	1.1	29.1	5.8
Dwyka Group	67	0.8	23.9	6
Pietermaritzburg Formation	67	1.07	28.36	0
Vryheid Formation	76	1.29	38.15	2.6
Volksrust Formation	16	1.27	25	0
Karoo Argillaceous rocks	64	0.4	10.9	1.6
Karoo Arenaceous rocks	18	0.3	0	0
Letaba Formation	47	0.5	2.12	2.12
Berea red sands	27	0.6	22.2	0
Port Durnford and underlying Formations	87	1.0	24.1	3.4

The distribution of the percent of boreholes with a blow yield greater than 5 l/s, which is considered viable for bulk supply is shown in Figure 2.

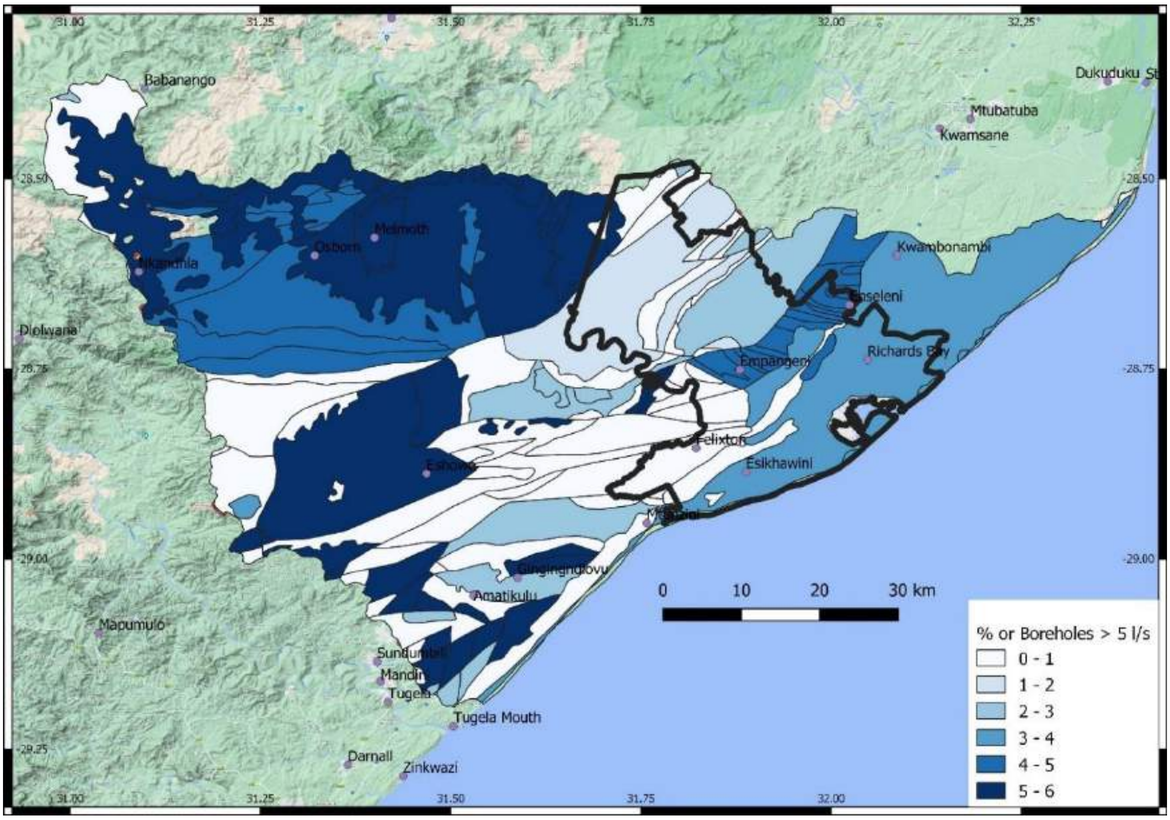

Figure 2 Percent of boreholes with median yield > 5l/s

Impact on Groundwater Abstraction on Coastal Lakes

Groundwater resources on the coastal plain can be seen as complementing surface water resources, since baseflow to the rivers and groundwater inflow directly to the lakes forms a large part of the lake water balance. As overland surface runoff is almost non-existent due to the sandy nature of the coastal plain, it is likely that water in streams flowing towards the lakes is also derived from groundwater as baseflow; hence groundwater is also a significant component of stream inflows. The abstraction of water from the lakes can therefore be considered as the use of groundwater.

The Zululand coastal plain has groundwater development potential and could be developed for future water supply. However, it is not recommended that this water be used for large groundwater abstraction schemes in the vicinity of the coastal lakes due to the resulting reduction of inflows into the lakes.

The determination of impact on the lakes from additional groundwater abstraction would require the development of groundwater models beyond the scope of the project. An attempt was made to determine the impact of abstraction utilising WRSM2000 and the lake model from Lake Mzingazi. A lumped abstraction of 1.2 Mm^3/a and 12 Mm^3/a (approximately equal to current lake abstraction was taken from the lake Mzingazi groundwater catchment. The latter is approximately equal to 65% of recharge. The model run was based on historic land use and lake abstraction from 1920-2004, which had been used for model calibration.

The impact on baseflow to the lake, aquifer storage, and groundwater outflow from the catchment were then used to revise the Lake model water balance. The water balance is shown in table 3 for the 12 Mm^3/a groundwater abstraction. The impacts can be summarised as:

- Reduced baseflow of approximately 1.6 Mm^3/a to the rivers entering the Lake.
- Reduced groundwater flow of approximately 8.5 Mm^3/a towards the lake.
- Reduced groundwater evaporation from the catchment of about 2 Mm^3/a
- Reduced surface water and groundwater inflow to the lake.
- Reduced discharge from the lake.

The impact on lake levels is shown in figure 3**.** During the drought period Lake Mzingazi goes down to -1 mamsl at 12 Mm^3/a, at which point it would contain only 10 Mm^3/a. A low abstraction rate has minimal impact on Lake level.

Given that the median yield of boreholes is 1 l/s, or 31500 m^3/a, approximately 40 boreholes would be required to abstract 1.2 Mm^3/a. However, 3 boreholes yielding 10 l/s in the Uloa Formation could achieve an abstraction of 1.2 Mm^3/a.

Table 3 Water balance of Lake Mzingazi with and without groundwater abstraction

	Natural	**No Groundwater abstraction**				**12 Mm^3/a groundwater abstraction**			
		1980-1985	**1985-1990**	**1990-1995**	**1995-2003**	**1980-1985**	**1985-1990**	**1990-1995**	**1995-2003**
Aquifer water balance from WRSM2000 Sami groundwater module									
Recharge	17.43	17.4	17.8	15.67	17.94	17.4	17.8	15.67	17.94

Baseflow	2.84	2.82	2.87	2.57	2.92	1.24	1.38	1.24	1.33
Groundwater Outflow	12.95	12.27	12.89	11.14	13.42	3.87	4.53	2.7	4.84
Groundwater evaporation	2.0	2.95	3.29	3.24	2.76	0.89	1.20	0.79	1.00
Lake water balance									
Rainfall	15.42	13.93	14.95	10.11	14.93	13.57	14.7	9.12	14.51
Surface Inflow	39.98	41.38	52.62	23.23	28.52	40.7	51.91	22.28	28.16
Groundwater Inflow	13.00	12.29	12.58	11.77	12.82	8.42	8.72	7.88	8.86
Evaporation	14.6	12.66	13.14	11.68	13.77	12.33	12.95	10.33	13.41
Abstraction	0	10.01	10.50	10.38	10.28	10.01	10.50	10.38	10.28
Surface water outflow	53.05	43.87	56.59	20.38	27.83	39.37	51.69	18.67	22.26
Groundwater Outflow	0.63	0.6	0.61	0.57	0.62	0.41	0.42	0.38	0.43

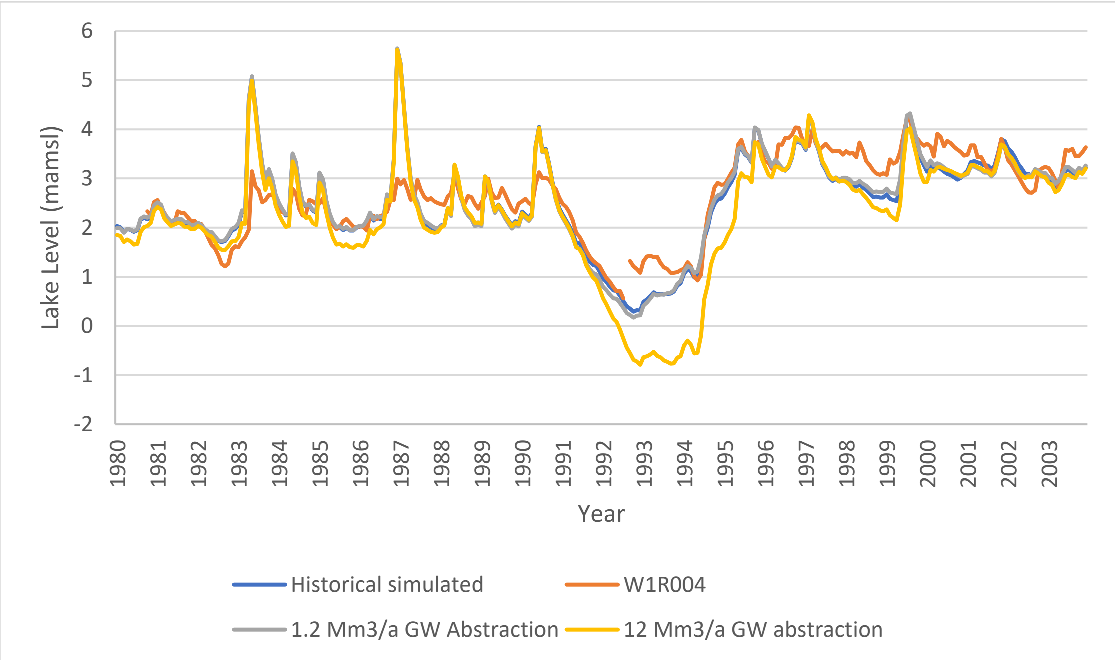

Figure 3 Lake Mzingazi water level with and without groundwater abstraction

Potential for Artificial Recharge

Artificial recharge is the process whereby surface water is transferred underground to be stored in an aquifer. The most common methods used involve injecting water into boreholes and transferring water into spreading basins where it infiltrates the subsurface.

Throughout much of the study area, yields are too low for large scale groundwater abstraction, and the stress index is very low, hence there is no need nor scope for managed aquifer recharge. It is only where thick sequences of Tertiary limestones exist that high abstraction is possible, however, it would interfere with inflows to the coastal lakes, since these are largely fed by groundwater flow through these permeable deposits.

The aquifer has no major groundwater users, and the aquifer is likely to be full most of the time. However, abstraction from the lakes is a groundwater use hence artificial recharge has the potential to allow increased abstraction from the lakes.

The primary objective in the area would be to offset reduced lake inflow from increased lake abstraction since borehole yields are too low to warrant borehole abstraction for bulk supply. Artificial recharge would therefore offset increased abstraction from the lake. The source of water would be treated wastewater, only Lake Mzingazi is a potential option.

Injection Boreholes would be required since the low permeability Port Durnford Formation above the Miocene Formation mitigates against the possible use of a surface spreading basin.

Deep sandy aquifers are potentially major sub-surface storage areas – purely because of the huge volume of water that can be stored in these thick, extensive sandy aquifers. The Richards Bay coastal aquifer is less than 50 m thick, and has average permeability of 2.5 m/d. Germishusye (1999) gives a permeability of 0.5-34.6 m/d for the Miocene aquifer, with an average of 28 m/d with average thickness of 2 m.

Static water levels in the vicinity of the lake are 5-10 mbgl, hence there is little scope for increasing recharge beyond the volumes abstracted from the lake to maintain the groundwater level.

The volume of water that could be recharged given limited yield is unlikely to exceed 1.2 Mm^3/a. This would require 3 x 10 l/s boreholes.

The issues that would need to be evaluated include:

- The sediment load and debris in the recharge water to minimise borehole clogging.
- Mapping of the Miocene Uloa Formation to identify thick deposits upgradient of the Lake, which would the abstraction point.
- Long term duration test pumping to determine the response of the Formation to long term withdrawal/injection due to its discontinuous extent.
- Since the final discharge point is the lake, water quality would have to be of a suitable quality to not alter lake water chemistry.

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LIST OF ABBREVIATIONS AND ACRONYMS

DWS	Department of Water and Sanitation
mbmsl	meters below mean sea level
mamsl	meters above mean sea level
RBM	Richards Bay Minerals
MAR	Mean Annual Runoff
MORFP	Mhlathuze Operating Rules and Future Phasing
MWAAS	Mhlathuze Water Availability Assessment Study

LIST OF UNITS AND SYMBOLS

ha	Hectares
l/s	Litres per second
Mm^3/a	Million m^3 per annum
mamsl	Metres above mean sea level
mbmsl	Metres below mean sea level

1 INTRODUCTION

1.1 Background to this Study

The Department of Water and Sanitation (DWS) commissioned a study on the Water Reconciliation Strategy for Richards Bay and Surrounding Towns (2013-2015) to inform the planning and implementation of water resource management interventions necessary to reconcile future water requirements and water use patterns up to a period of thirty years.

For the Reconciliation Strategy for Richards Bay and Surrounding Towns, referred to as the Strategy hereafter, to be implemented, and for the Strategy to remain relevant in order to properly fulfil its purpose into the future it has to be dynamic. Hence the water balance has to be continuously monitored and the developed Strategy has to be regularly updated and maintained. This would ensure that planned intervention options to be implemented will also consider any changes that may have potential impacts on the projected water balance.

The DWS commissioned the Implementation and Maintenance of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns Study, referred to as this Study hereafter, to facilitate a process to maintain the relevance of the Strategy.

1.2 Objectives of this Study

The overall objective of this Study is to systematically update and improve the Strategy in order for the Strategy to remain technically sound, economically feasible, as well as socially acceptable and sustainable. In addition, smaller towns in the neighbouring catchments were considered at a desktop level of detail, and in so doing the Strategy will be extended to cover selected smaller towns also affected by the Strategy.

1.3 Study Area

The main focus of this Study is the Richards Bay Water Supply Scheme (RBWSS). The RBWSS supplies water to the City of uMhlathuze Local Municipality, which comprises the towns of Richards Bay, Empangeni, Ngwelezane and Esikhaweni, as well as a number of rural villages. Furthermore, the RBWSS also supplies large well-developed industries, commercial areas and business centers within the Study Area. The RBWSS's supply area is within the Mhlathuze River Catchment, which is the major water resource. Water is, however, also sourced from various natural lakes within the Catchment such as Lake Nhlabane, Lake Msingazi and Lake Cubhu.

The Study Area includes the Mhlathuze River Catchment as illustrated in **Figure 1-1**. The Mhlathuze River Catchment receives inter-catchment transfers from the Umfolozi River and Thukela River Catchments and, as a result, these Catchments are also part of the Study Area. Additional smaller towns not incorporated in the Strategy, namely, Eshowe, Mtunzini, Amatikulu, Melmoth and Gingindlovu, have been included in this Study. They will be addressed at a desktop level.

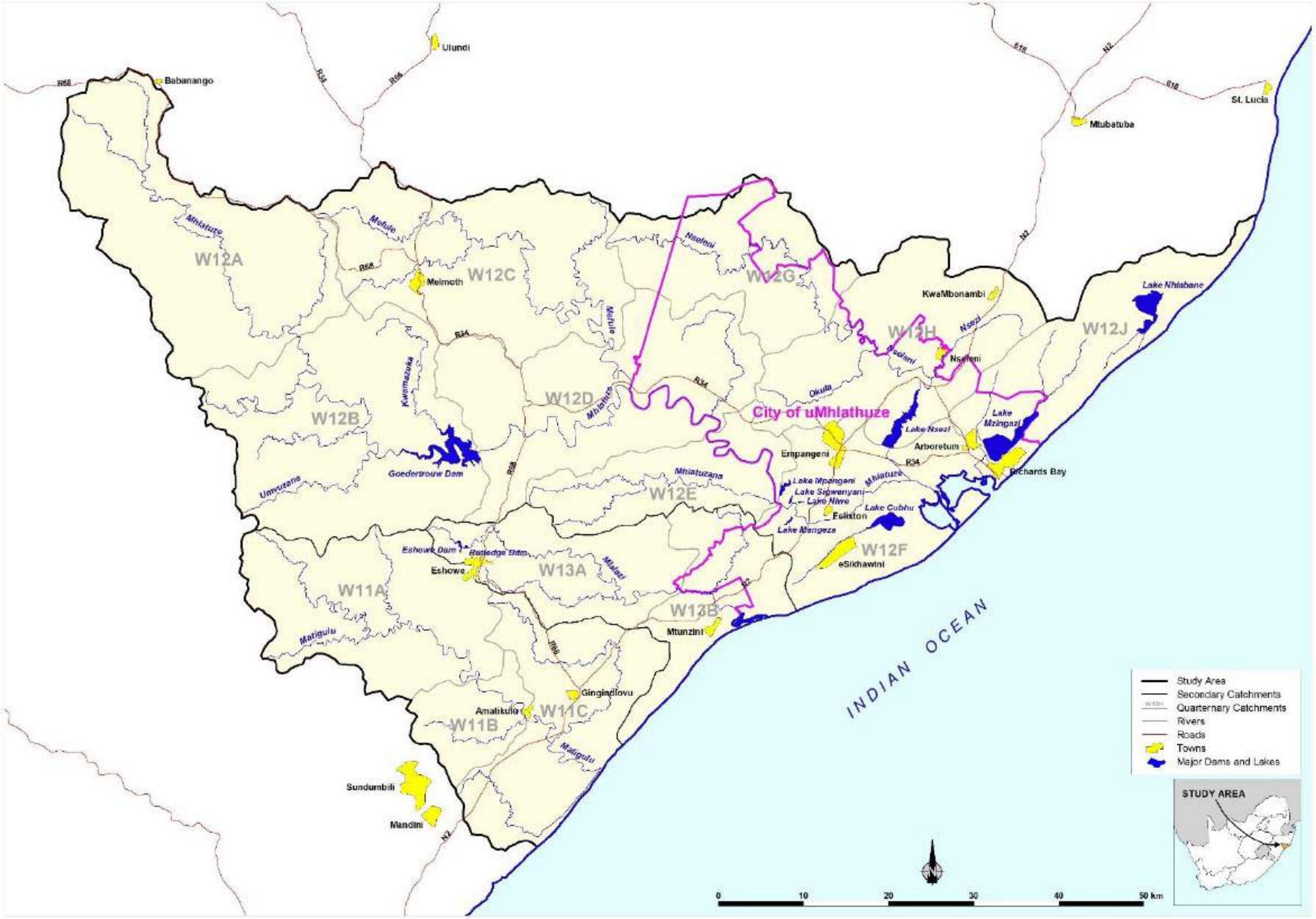


Figure 1-1: Locality map of the Study Area

1.4 Purpose and Structure of this Report

During the Implementation and Maintenance of the Water Reconciliation Strategy for Richards Bay and Surrounding Towns Study, (2019), DWS felt that too little attention had been placed on groundwater resources during the Water Reconciliation Strategy for Richards Bay and Surrounding Towns Study (2015).

It was decided to commission an additional task to investigate:

- whether groundwater can contribute to the bulk water supply or local supply.
- whether potential exists for increasing the yield from the Coastal lakes through managed aquifer recharge.

Based on a meeting and correspondence between DWS and the Study Team, the following tasks were identified as part of this phase of the Reconciliation Strategy update:

9. Define the Coastal Lake groundwater catchment area boundaries.
10. Clarify the methodology used in the previous Reconciliation Strategy to conclude that there is insufficient yield for bulk water supply from groundwater from the hard rock areas.
11. Use updated information to determine whether the conclusion drawn in 2 is correct, and if not, define scope for further detailed work that is required in order determine if the resource is sufficient.
12. Assess the sand aquifer based on existing data.
13. Look at yield distribution and location of borehole yields determine potential for bulk and local supply. (% > 2 l/s, >5 l/s etc.). Look at recharge and the aquifer stress index.
14. Look at potential for artificial recharge (yield of formation, method) and if viable, to look at further.
15. Produce maps that can be used in future for WSAs to establish where to target groundwater development on a localised level.
16. High level assessment of groundwater abstraction impact on coastal lakes.

2 GEOLOGY AND GEOHYDROLOGY

2.1 Stratigraphy and Lithology

The stratigraphy and lithology of the study area is shown in **Table 2-1** and **Figure 2-1.**

Table 2-1 Stratigraphy and Lithology

Group/ Complex	Age	Formation	Lithology
Maputaland	Quaternary	Sibayi	Dune and beach sand
		Kwambonambi	Sand, aeolianite
		Kosi Bay	Sand, calcarenite
		Port Durnford	Sandstone, mudstone
		Berea	sandstone
	Tertiary	Umkwelane	calcarenite
		Uloa	Coquina, conglomerate
Zululand		Richards Bay	siltstone
	Cretaceous	St Lucia	siltstone
	Jurassic		Dolerite
Lebombo	Jurassic	Letaba	Basalt
Karoo Super Group	Triassic	Clarens	Sandstone, siltstone
		Nyoka	Mudstone, sandstone
		Ntabene	Sandstone
Beaufort	Permian	Emakwezini	Mudstone, shale sandstone
Ecca		Volksrust	Shale
		Vryheid	Sandstone, shale coal
		Pietermaritzburg	Shale
Dwyka	Carboniferous		Tillite
Natal	Ordovician		Sandstone
Nogoye	Mokolian		Gneiss
Mlalazi	Mokolian		Serpentinite, Gabbro
Hlobane	Mokolian		Gabbro
Mfongozi	Mokolian		Schist
Tugela	Mokolian	Tuma	Amphibolite, gneiss, schist
Mapumulo	Mokolian		Gneiss, granulite
Nsuze	Randian		Basalt, andesite, quartzite
Unnamed	Swazian		Granite
Empangeni Metamorphic suite	Swazian	Lubana	Greenstones amphibolite, granulite,

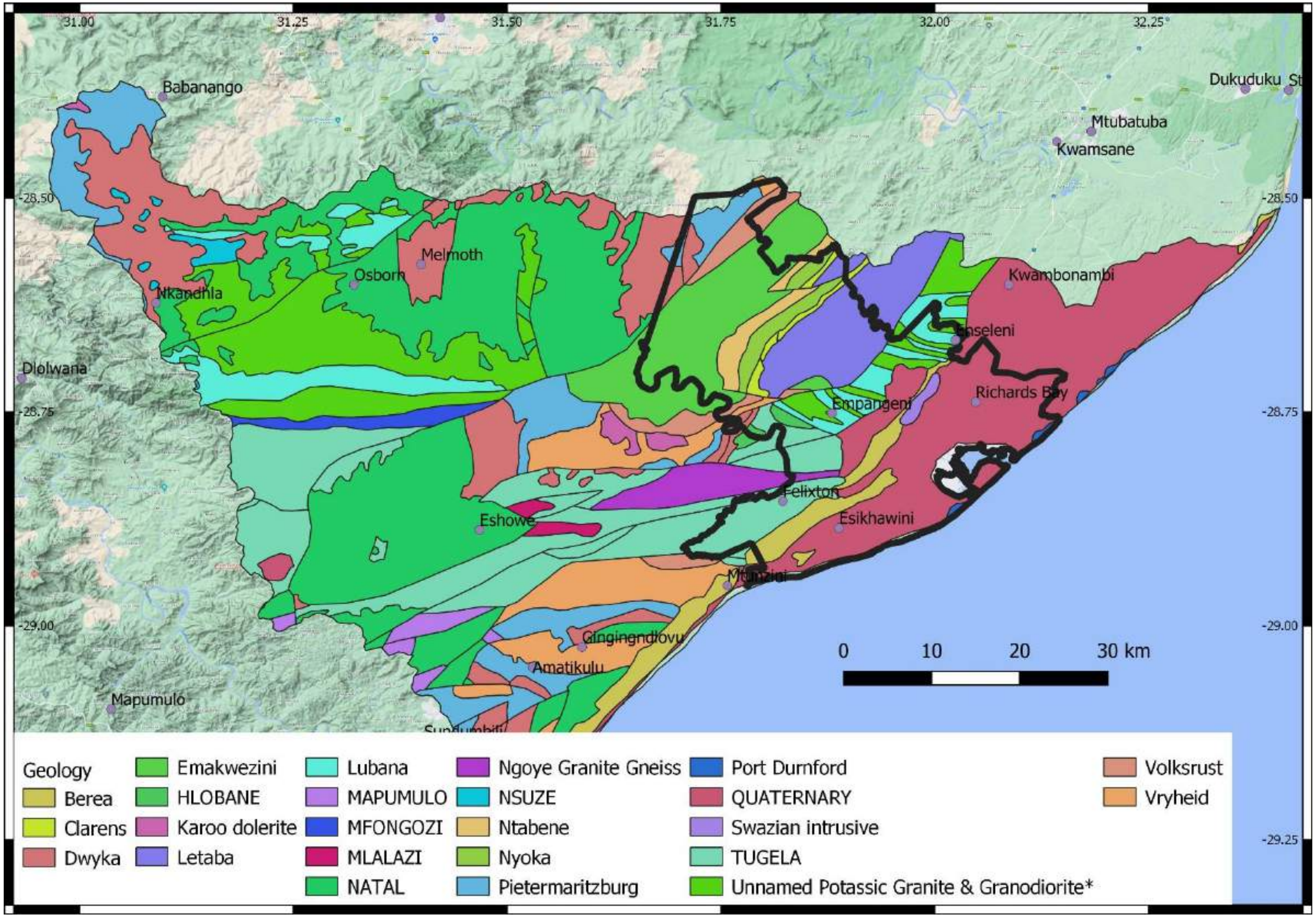


Figure 2-1 Geology of the study area

2.2 Geohydrology

2.2.1 Empageni Metamorphic Suite and Pre-Pongola intrusives.

These are the oldest rocks found in KwaZulu-Natal. They are highly folded and jointed, and form weathered and fractured aquifers with a median yield of 0.8 l/s and 6% yield more than 5 l/s. s. Water quality varies between 23-205 mS/m.

2.2.2 Nsuze Group

These rocks have minimal outcrop where the overlying Karoo Supergroup rocks have been eroded away. They form fractured and weathered aquifers. Borehole yields are between 0.5-2 l/s.

2.2.3 Natal Metamorphic Province

The rocks present in the study belong to the thrust dominated Tugela Terrane of the Natal Metamorphic Province. The northern contact of the Tugela Terrane with the older Swazian rocks coincides with the E-W Tugela fault. This Terrane is expressed as the many geological Groups of Mokolian age.

These rocks are the northernmost terrane of the Natal Metamorphic Province and essentially consist of metamorphosed crystalline rock with lesser amounts of argillaceous metamorphosed rock. For the most part, the rocks of the Natal Metamorphic Province behave hydraulically as typical basement rocks, where the process of weathering play an important role in the development of water-bearing zones. Where the greatest depth of weathering occurs, it can generally be assumed that it has been influenced by a fracture zone. The transition between weathered and solid bedrock is usually a gradual one but can in some instances be a sharp contact. In granite and gneiss lithologies the regolith is mostly comprised of quartz grains, mica, and clay minerals.

The rocks of the Natal Metamorphic Province are characterised by negligible primary porosity and groundwater movement is primarily within hard rock aquifers and controlled by zones of deep weathering, faulting, fracturing, and jointing. Accordingly, water strikes, or seepage encountered in the exploration boreholes drilled during the investigations are either associated with the contact between weathered and solid bedrock, or deep-seated fracture zones of low permeability but high confining pressure. There is no evidence of any additional aquifers at contacts between different lithologies, suggesting that tectonic contacts are more relevant than lithological contacts. Lithological variations are more significant in terms of water quality, with poorer water quality having been recorded in schists and granites (King, 1997).

Weathering in crystalline rocks usually results in a material which has a high porosity but low permeability due to the clay content in the weathered rock. Generally, the regolith system is in hydraulic connectivity with the underlying fractured or solid bedrock. Fractures below regoliths, particularly in the granites and granite gneisses, are the most permeable target but the median yield is generally only 0.3 l/s.

2.2.4 Natal Group

These outcrop west of Mhlatuze and occupy a large tract between Nkandla and Eshowe.

The Natal Group sandstones are one of the best hydrolithological prospects for groundwater in KwaZulu-Natal. There is generally a low percentage of dry boreholes and a large number of boreholes have yields in excess of 1.0 l/s with a median yield of 0.5 l/s.

2.2.5 Dwyka Group

The Dwyka Group is generally not an aquifer. The lithified tillite consists of a fine-grained matrix with inclusions of foreign rock. There is no primary permeability and groundwater flow is restricted to fractures. It is evident from the large number of dry boreholes drilled that it has a low water-bearing potential. Median yields are only 0.1 l/s, however, larger faults intersected do produce greater volumes of water. Smaller faults have lower yields.

The contact with the underlying Natal Group can provide yields of up to 8 l/s, if the contact zone is relatively shallow (< 100m).

2.2.6 Karoo, Ecca and Beaufort Groups

The predominantly argillaceous nature of most of the Karoo sediments results in low primary hydraulic conductivities. Weathering of these rocks is limited, with the products of weathering having a high clay content which further limits permeability. The yield from these aquifers is generally 0.1-2 l/s, with a median yield of 0.5 l/s.

The Vryheid Formation consists mostly of arenaceous rocks with a lesser amount of argillaceous sedimentary rock and coal. The median yield for this Formation is 0.6 l/s.

2.2.7 Lebombo Group

The Letaba Formation lavas form a low to moderate potential aquifer with a median yield of less than 0.5 l/s.

2.2.8 Zululand Group

These do not out crop in the study area but underlie the coastal plain as a low permeability aquiclude tapering out inland towards Lake Nsezi (**Figure 2-2**). Yields are less than 0.1 l/s and groundwater is saline They occur at 20-60 m below sea level at the coast and 20-40 mamsl inland. The St Lucia Formation and the overlying Richards Bay Formation are ltithologically similar, only varying in age.

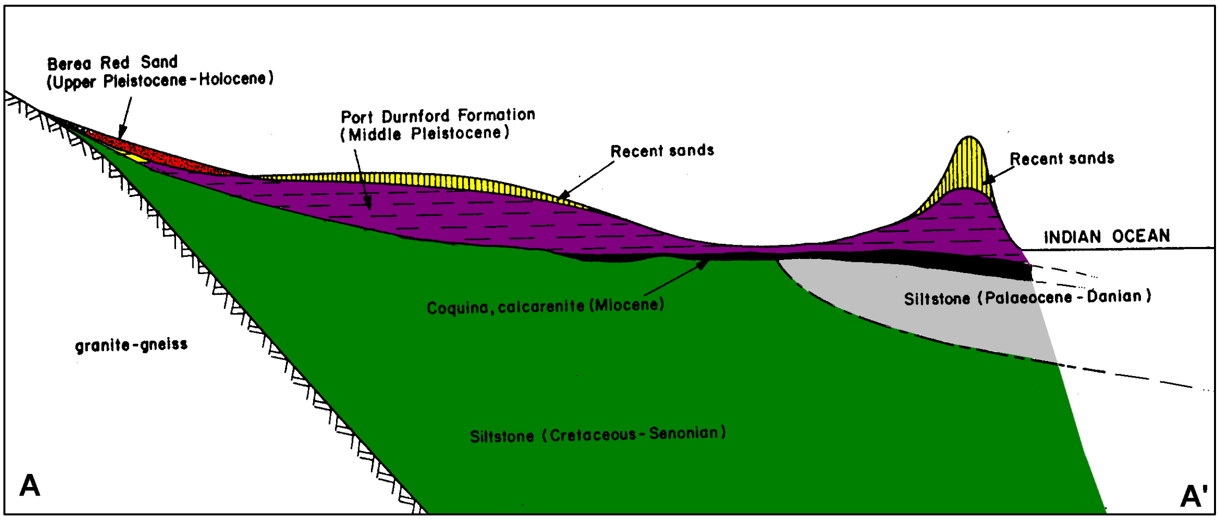


Figure 2-2 Geological cross-section of the Coastal Plain (source: Worthington 1978)

2.2.9 Tertiary limestones

These Formations essentially comprise coquina, conglomerates and calcarenites. They form the principal aquifer of the coastal plain. The Uloa Formation form a thin layer but are not uniformly present. They dip towards the south. They may be up to 19 m thick and absent 1 km away. Outcrop is very limited, and they are buried beneath the Port Durnford Formation.

Borehole yields can exceed 15 l/s; however, the intermittent nature of the formation does not allow them to be extensively developed as sustainable yields are controlled by the bounding low permeability formations.

2.2.10 Quaternary sediments

The Berea-type red sands, often found on dune ridges, are the weathered component of dune sands and are rich in fine-grained material. The groundwater potential in these sands is low due to the elevated position at which they are generally found. However, in places where the dune sand overlies bedrock at shallow depths, groundwater can be encountered at the contact. In this case, the sands are not the aquifer, but they do provide storage to the more permeable contact zone below (limestones).

The Port Durnford Formation varies in thickness from being absent to 40 m. It is not homogenous and consists poorly sorted low permeability fine sands, silts, and clay.

The Sibayi Formation is similar in its hydrogeology to the Berea-type sand, except that the colour of the sand is more yellow brown and is not as fine-grained.

The Kwambonambi Formation for the most part comprises redistributed sands varying from fine- to coarse-grained in places. It is mainly within this formation that shallow hand-dug wells are common.

2.3 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.

The geological history of deformation begins in the beginning at about 1200-1100 Ma, NE directed thrusting and recumbent folding occurred. These are visible as thrust faults in the Tugela Terrane, when the Natal Metamorphic Province Terranes were accreted onto the SE margin of the basement rocks. Subsequently, the area was extensively deformed by numerous NE to ESE trending sinistral, transcurrent ductile shear zones. At least four, and in places five, phases of deformation have been recognised during this tectonic event, as well as four related phases of metamorphism.

An extensive and complex network of faults has been mapped in coastal Natal in a tectonic region known as the Natal Arch or the Natal Monocline. Faulting on the Natal Arch is related to the break-up of Gondwanaland and was caused by a SE oriented tensional regime. This process resulted in a complex pattern of faulting associated with crustal extension normal to the continental margin (SE oriented tension), and/or strain along rotational couples resulting in strike slip movement parallel to the coastline along a transform fault known as the Agulhas Transform Fault. These faults are highly relevant to groundwater exploration.

The regional pattern consists of a series of fault arcs trending from SW-NE to N-S and swinging E-W along the coast. A second band of en echelon curved faults of similar orientation occurs along the coast. At least 4 arcuate fault systems have been identified.

The Tugela Fault is not related to these belts as it is an E-W oriented post Karoo fault that parallels a Precambrian thrust zone. Its origin is probably related to the relaxation of NE thrusting.

From strain analysis, Sami et al (2000) found that E-W or ENE segments of faults may be transtensional, hence the preferred groundwater targets.

3 RESULTS

3.1 Coastal Lake Groundwater Catchment Boundaries

The separation of lake catchments into Quinary catchments according to the area considered to contribute surface and groundwater inflow to the lake and that contributing only surface inflow (as well as groundwater baseflow) were defined by Sami (2019) (**Figure 3-1**).

The area contributing groundwater directly to the lakes were defined by the volume of natural groundwater inflow to the lakes obtained from the lake models (Sami 2019), divided the mean annual recharge as defined in Sami (2019). This provides an approximate catchment area required to maintain the lake water balance and water level. This area was then defined spatially from topography, excluding the area of the lakes.

The remainder of the Quaternary catchment also contributes groundwater to the lake via baseflow to surface water courses, which enters the lakes as surface inflow.

The lake water balance model was originally developed during the MWAAS to simulate lake levels and water balances for these lake groundwater catchment areas. The groundwater interactions and lake discharges were updated during this investigation with revised surface water inputs data from the Pitman Model, utilising catchment discharge, rainfall, and the Sami module aquifer storage variable to drive the Lake module. The Lake module generated a monthly time series for:

- Lake rainfall
- Groundwater Inflow
- Lake evaporation
- Groundwater outflow
- Lake surface water discharge
- Lake level and storage

It simulated the impacts of lake and groundwater abstractions on the lake water balance and lake levels, which are calibrated against lake level data and gauged discharges. The lake water balance was converted to a lake level and surface area by volume-area-level relationships determined from lake bathymetry.

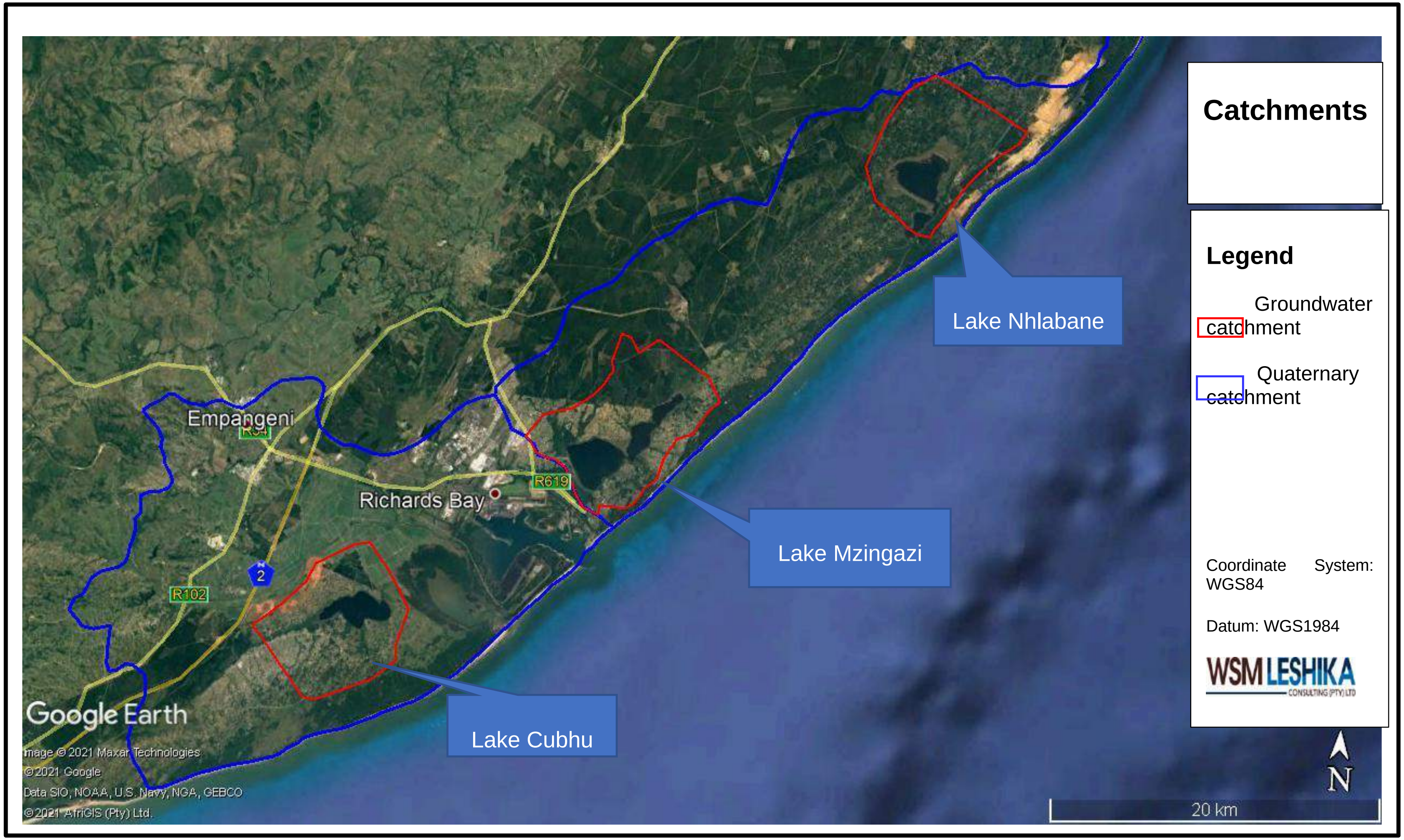


Figure 3-1 Quaternary and Lake groundwater catchment boundaries

3.2 Methodology for Groundwater Assessment for the Richards Recon Strategy

3.2.1 Wellfields Identified by Aurecon

Aurecon identified 3 potential wellfields at Mtunzini North, Empangeni West and Lubisana (**Figure 3-2**). These had 18-19 production boreholes each and potential yields of 0.71, 0.54, 0.3 Mm^3/a respectively, or a total of 1,55 Mm^3/a. They are all located on the Tugela Terrane of the Natal Metamorphic Province.

Figure 3-2 Location of potential wellfields identified by Aurecon

3.2.2 Methodology Uitilised in Recon Study

No literature was available on the identified wellfield sites and they have not been investigated in the field The data utilised was from the NGA, an in-house Geomeasure Group Database, the KwaZulu-Natal Groundwater Resource Information Project Database (KZN GRIP), as well as a limited data from uThungulu DM. No field verification visits were included to the current status of the existing boreholes included in the proposed wellfields. Recommended pump rates were often not included in the datasets, therefore, the borehole blow yields measured during the drilling were used. Blow yield is almost always a much larger volume compared to the recommended pump / discharge rates. Generally sustainable rates are less than 2/3 of the blow yield.

The report utilised the combined blow yield of all the most favourable boreholes in each wellfield area and assumed an average abstraction of less than 50% of blow yield, with an average abstraction rate of 1-2.5 l/s, depending on the wellfield. The range of blow yields established is given, but not the distribution of yields so that the proportion of boreholes that can deliver such a yield can be evaluated.

The final yield was based on the average yield of 1-2.5 l/s for a 12-hour pumping day. Since a 12-hr day was assumed, the analysis is based on a sustainable pumping rate of 0.5-1.25 l/s per borehole.

3.2.3 Evaluation

Sami et al. (2000) in a study of the Natal Metamorphic Province near Mapumulo found that the area exhibits a poor historical success rate with about 46% of the holes being dry. Borehole yields are generally low with only 23% giving a yield greater than 1 l/s. Where only geophysical borehole siting was used, 37% of 27 boreholes drilled in the study area were dry and only 2 had blow yields exceeding 1 l/s. The median yield of successful holes was 0.1 l/s. Dry boreholes as well as high yielding holes have been drilled into all lithologies and are not restricted to any specific rock type; poor and high yielding holes occur within the same lithology and give evidence that structures of tectonic origin are a major factor influencing groundwater occurrence.,

Sami et al (2000) found that greater than 75% of boreholes yielded more than 1 l/s can be achieved by structural interpretation and strain analysis. An 89% success rate, with 7 of 9 boreholes exceeding 1 l/s and a median yield of between 1.8-3.3 l/s. This suggests that the aquifer can be reconsidered in terms of reticulated water supply if a scientifically appropriate exploration strategy is adhered to.

Discharge tests carried out on eight exploration boreholes indicated that at least 4 types of aquifers occur: networks of uniform fractures, sub-vertical fractures with or without leaky weathered overburdens, bedrock contacts with a leaky overburden, and leaky deep seated horizontal fractures. Sustainable yield varied between 26m^3/d and 300m^3/d. High yields are generally derived from aquifers overlain by thick weathered overburden, or large fault zones. Where these are absent or the saturated overburden too thin, small scale fracture zones represent the main target. Transmissivities vary mostly between 1 and 23m^2/d.

A correlation between lineament or fault azimuth and yield shows that successful boreholes are associated with N-S, E-W and NE-SW running structural features, orientations of extensional nature. The only unsuccessful borehole was drilled into a NW-SE fault, the orientation regarded as compressional in nature.

Consequently, with proper site selection, the Aurecon assessment is a realistic assessment of the yield potential of the aquifer. It would require 50-60 production boreholes to provide 1.5 Mm^3/a. This is not viable for bulk water supply, but the range of yields 23-300 m^3/d per borehole suggests the aquifer is suitable for local stand-alone water supply.

No other geology other than the Tugela Terrane was investigated.

3.3 Updated Assessment of Groundwater Resources

3.3.1 Aquifer yield

Aquifer yield is a measure of the available groundwater resources, excluding an assessment of whether they can be economically abstracted. Data was collected on Harvest Potential, Exploitation Potential, and recharge from GRAII (**Table 3-1**).

Table 3-1 Groundwater resources

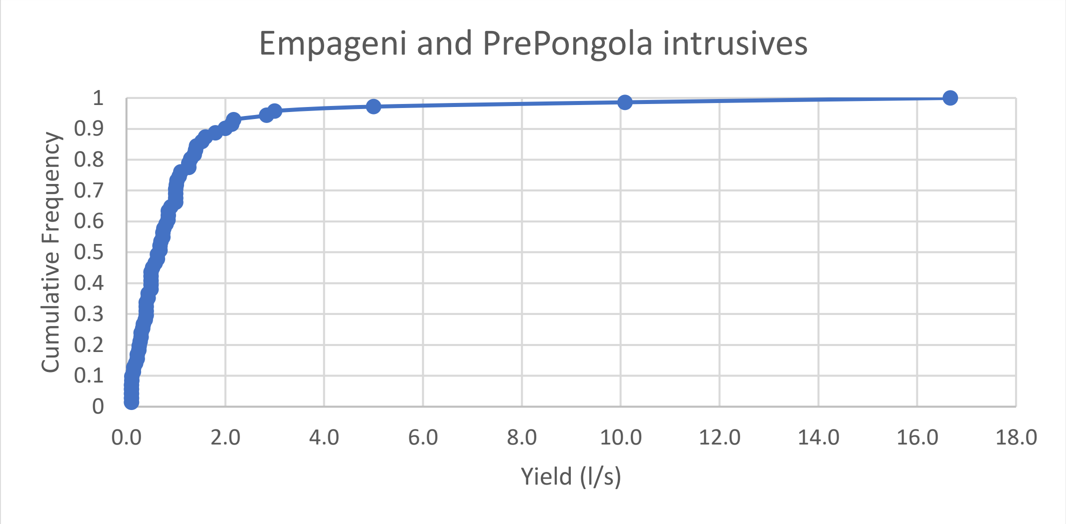
	Harvest Potential	Recharge	Exploitation Potential	Aquifer recharge	Potable fraction	Baseflow	Abstraction (WARMS)	Stress index
	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a		Mm^3/a	Mm^3/a	
W11A	34.583	43.639	12.226	12.796	0.94	39.271	0.259	0.02
W11B	5.396	12.292	4.506	3.731	0.20	10.980	0.000	0.00
W11C	8.655	40.400	17.241	10.653	0.83	37.143	0.092	0.01
W12A	21.407	35.065	7.476	18.902	0.85	25.170	0.092	0.00
W12B	33.996	42.413	10.836	18.798	0.86	33.160	0.040	0.00
W12C	43.928	32.699	5.939	17.818	0.94	23.233	0.011	0.00
W12D	13.373	29.364	8.005	13.322	0.77	24.833	0.172	0.01
W12E	6.785	21.411	6.461	6.717	0.43	18.485	0.000	0.00
W12F	81.290	84.512	18.684	46.752	0.64	52.001	0.348	0.01
W12G	4.331	18.967	4.705	9.999	0.49	13.774	0.004	0.00
W12H	26.510	41.556	14.980	13.036	0.90	35.852	0.293	0.02
W12J	123.853	70.890	22.701	42.464	1.00	40.200	0.000	0.00
W13A	12.240	30.793	9.756	6.478	0.82	28.239	0.168	0.03
W13B	10.416	32.147	10.260	4.734	0.93	30.364	0.007	0.00
	426.761	536.149	153.776	226.200		412.706	1.486	0.01

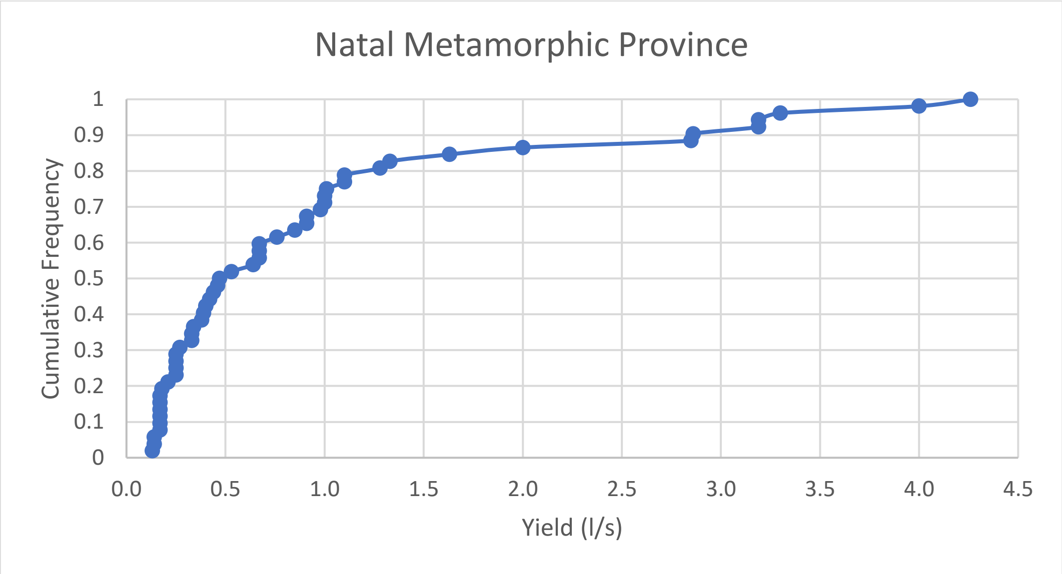
It is evident that much of the recharge drives baseflow. Aquifer recharge is a measure of recharge to the regional aquifer after losses for interflow from high lying springs. In mountainous terrain it is a more realistic measure of groundwater resources. The authorised water use from WARMs represents 1% of aquifer recharge, as measured by the stress index. This suggests that groundwater resources are underutilised in the study area.

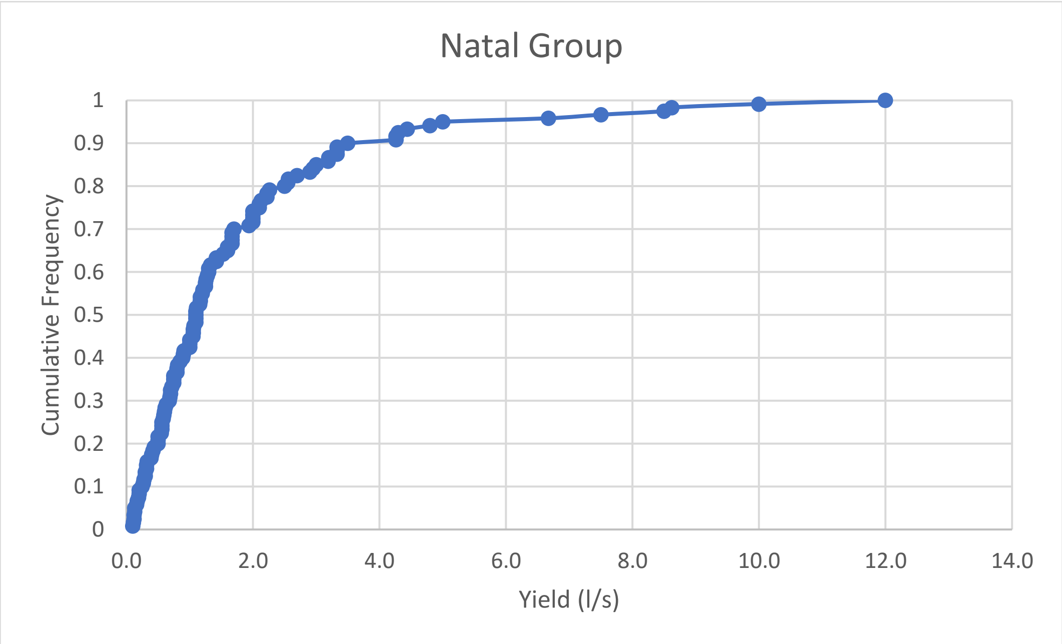
3.3.2 Borehole yield

Borehole yield is the volume of water that can be abstracted from a borehole. Although aquifer yield may be large, it may not be possible to abstract the groundwater in economically viable volumes for bulk water supply. Borehole yield was assessed by lithology type (**Figure 3-3 and Table 3-2**).

Many of the boreholes in the Quaternary deposits are shallow boreholes and do not penetrate to the more permeable Tertiary deposits, which may skew the results for boreholes drilled into the Port Durnford Formation. The boreholes with high yields in this Formation are likely drilled where a thick sequence of the Uloa Formation exists. These channels are the main source of groundwater inflow into the coastal lakes. One such channel coincides with the Mhlatuze river and estuary and another runs through the middle of Lake Mzingazi and has a large impact on the lake hydraulics (Kelbe and Germishuyse, 1999). These would be the most likely positions for high yielding boreholes but would have an impact on the lake.


Empageni and PrePongola intrusives
Cumulative Frequency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0
18.0
Yield (l/s)


Natal Metamorphic Province
Cumulative Frequency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Yield (l/s)


Natal Group
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0.7
0.6
0.5
0.4
0.3
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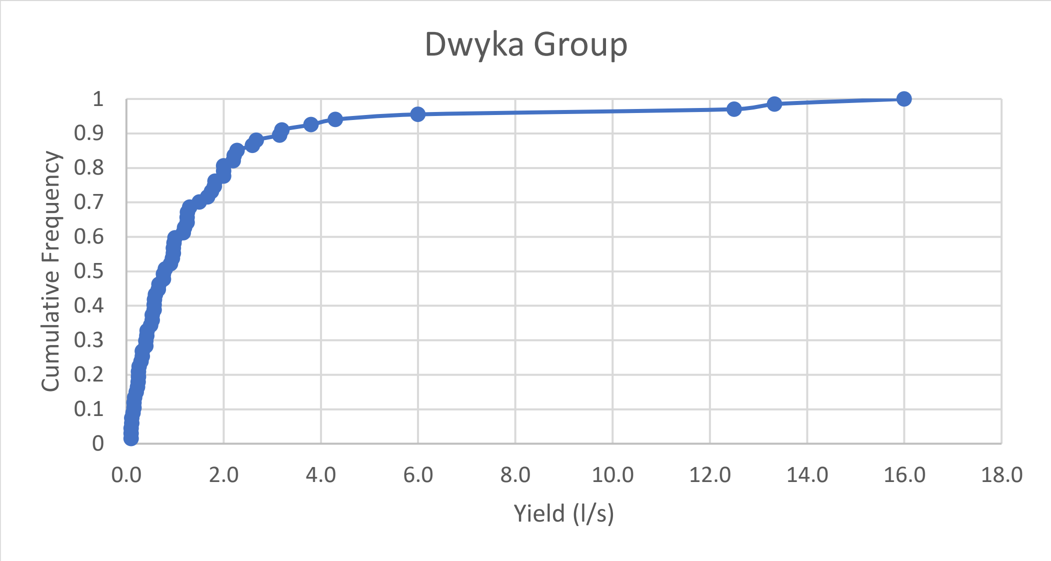
0.0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
Yield (l/s)


Dwyka Group
Cumulative Frequency
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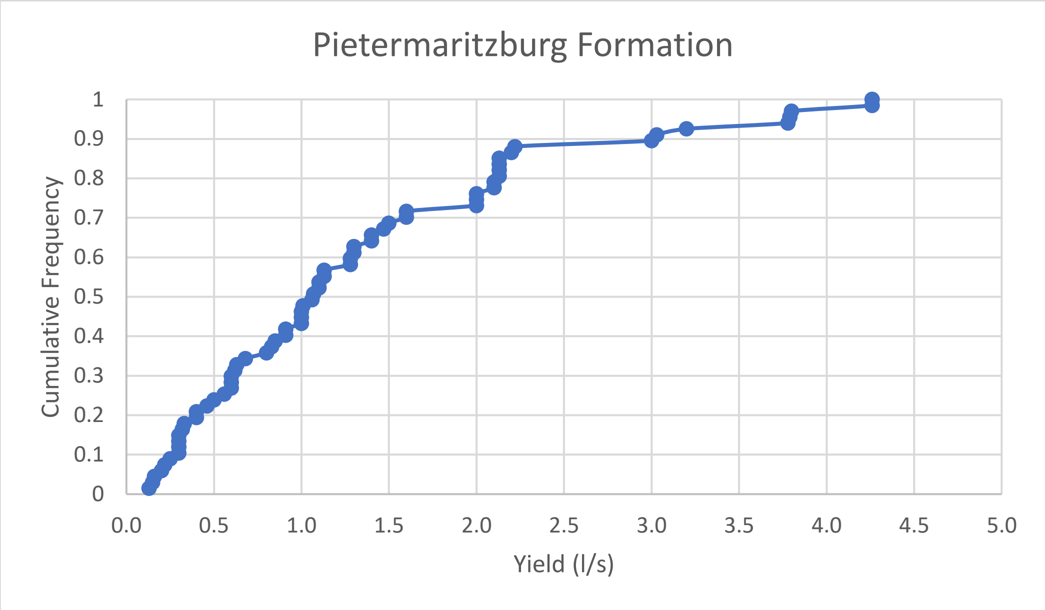
12.0
14.0
16.0
18.0
Yield (l/s)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0
0.0
0.5
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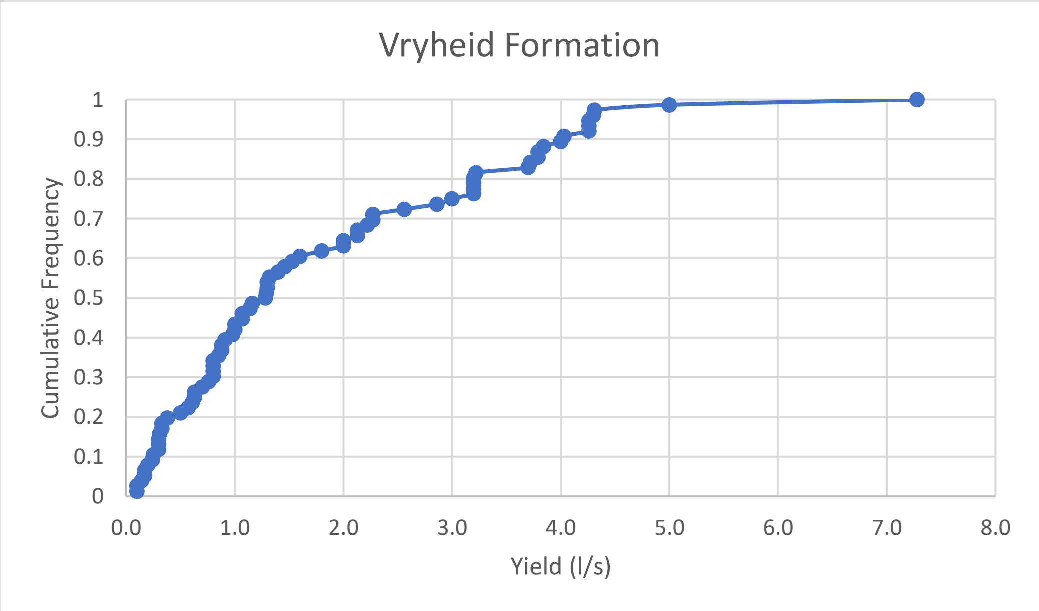
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Yield (l/s)


Vryheid Formation
Cumulative Frequency
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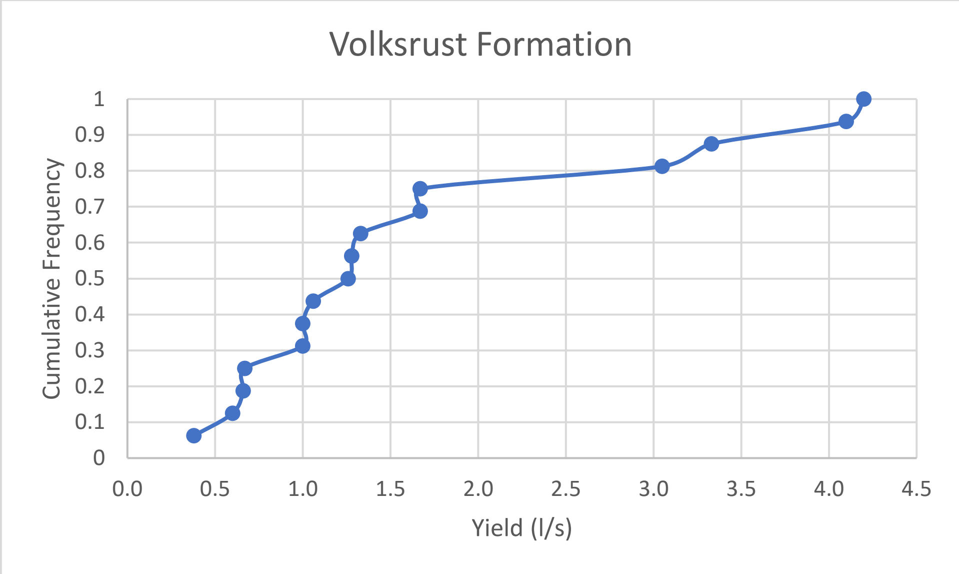
2.0
3.0
4.0
5.0
6.0
7.0
8.0
Yield (l/s)


Volksrust Formation
Cumulative Frequency
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0.6
0.5
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1.0
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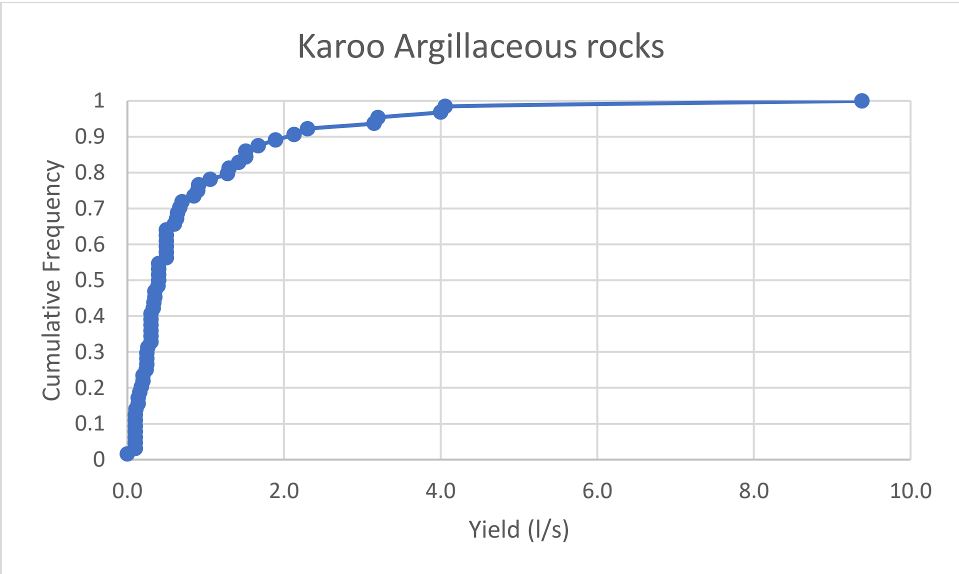
2.0
2.5
3.0
3.5
4.0
4.5
Yield (l/s)


Karoo Argillaceous rocks
Cumulative Frequency
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2.0
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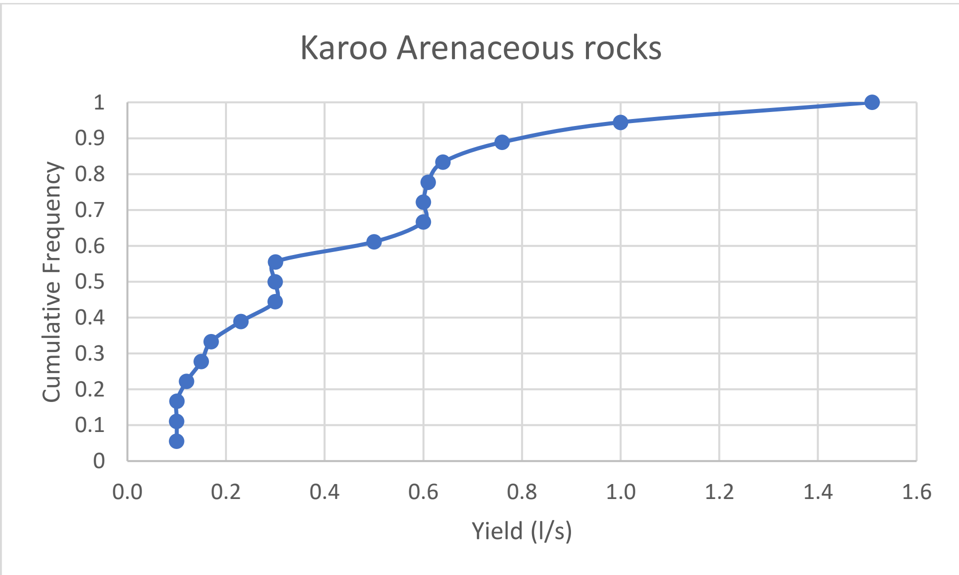
6.0
8.0
10.0
Yield (l/s)


Karoo Arenaceous rocks
Cumulative Frequency
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0.2
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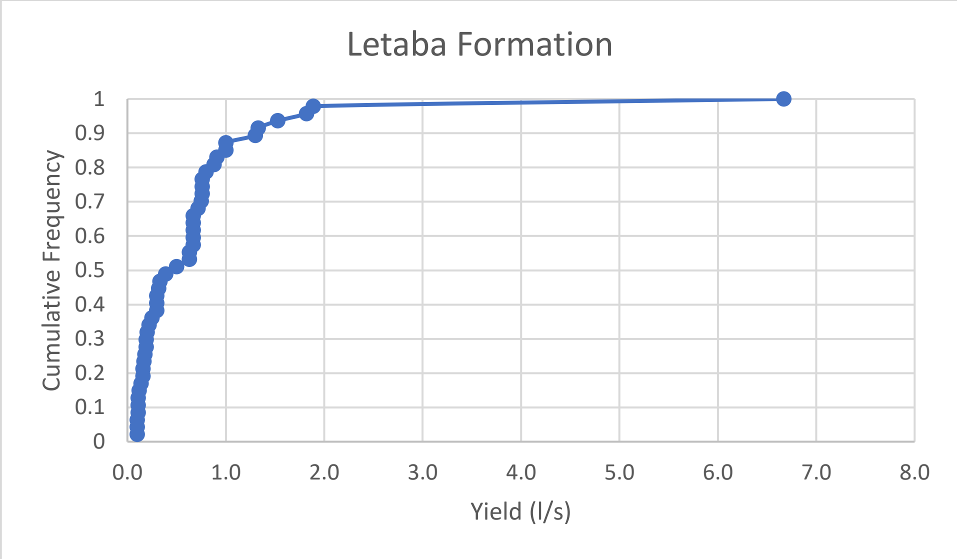
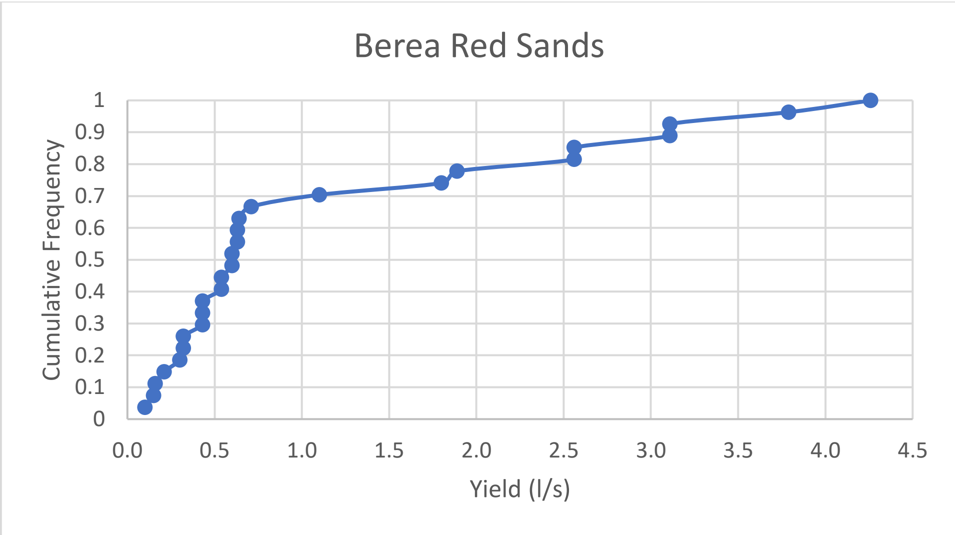
0.6
0.8
1.0
1.2
1.4
1.6
Yield (l/s)





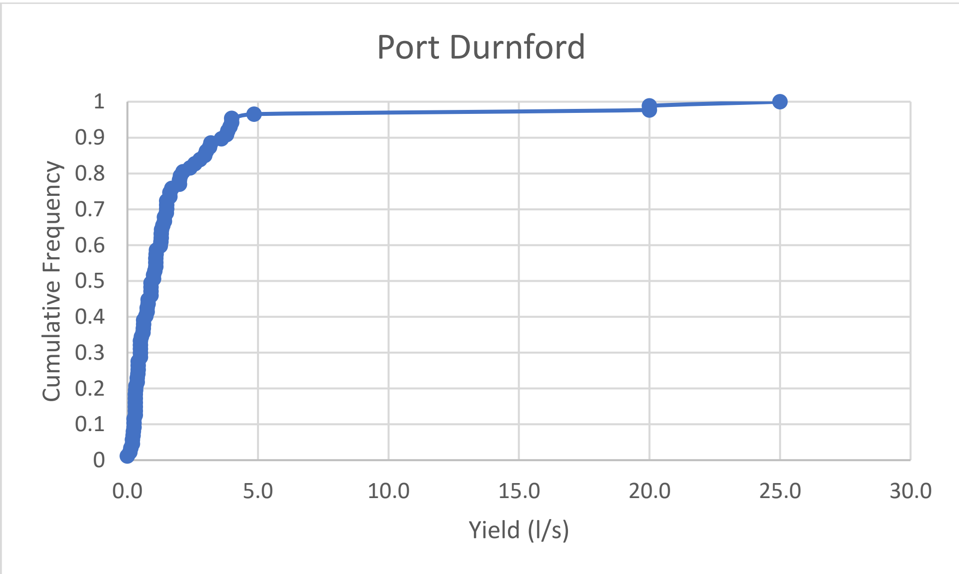


Figure 3-3 Borehole yield distribution by geology

Table 3-2 Yields by geological formation

Geology	N	Median (l/s)	% ≥ 2 l/s	% ≥ 5 l/s
Empangeni and Pre Pongola intrusives	71	0.68	11.3	4.2
Natal Metamorphic Province	52	0.5	15.4	0
Natal Group	120	1.1	29.1	5.8
Dwyka Group	67	0.8	23.9	6
Pietermaritzburg Formation	67	1.07	28.36	0
Vryheid Formation	76	1.29	38.15	2.6
Volksrust Formation	16	1.27	25	0
Karoo Argillaceous rocks	64	0.4	10.9	1.6
Karoo Arenaceous rocks	18	0.3	0	0
Letaba Formation	47	0.5	2.12	2.12
Berea red sands	27	0.6	22.2	0
Port Durnford and underlying Formations	87	1.0	24.1	3.4

The distribution of median yield, and the percent of boreholes with a blow yield greater than 2 and 5 l/s is shown in **Figures 3-4 to 3-6**.

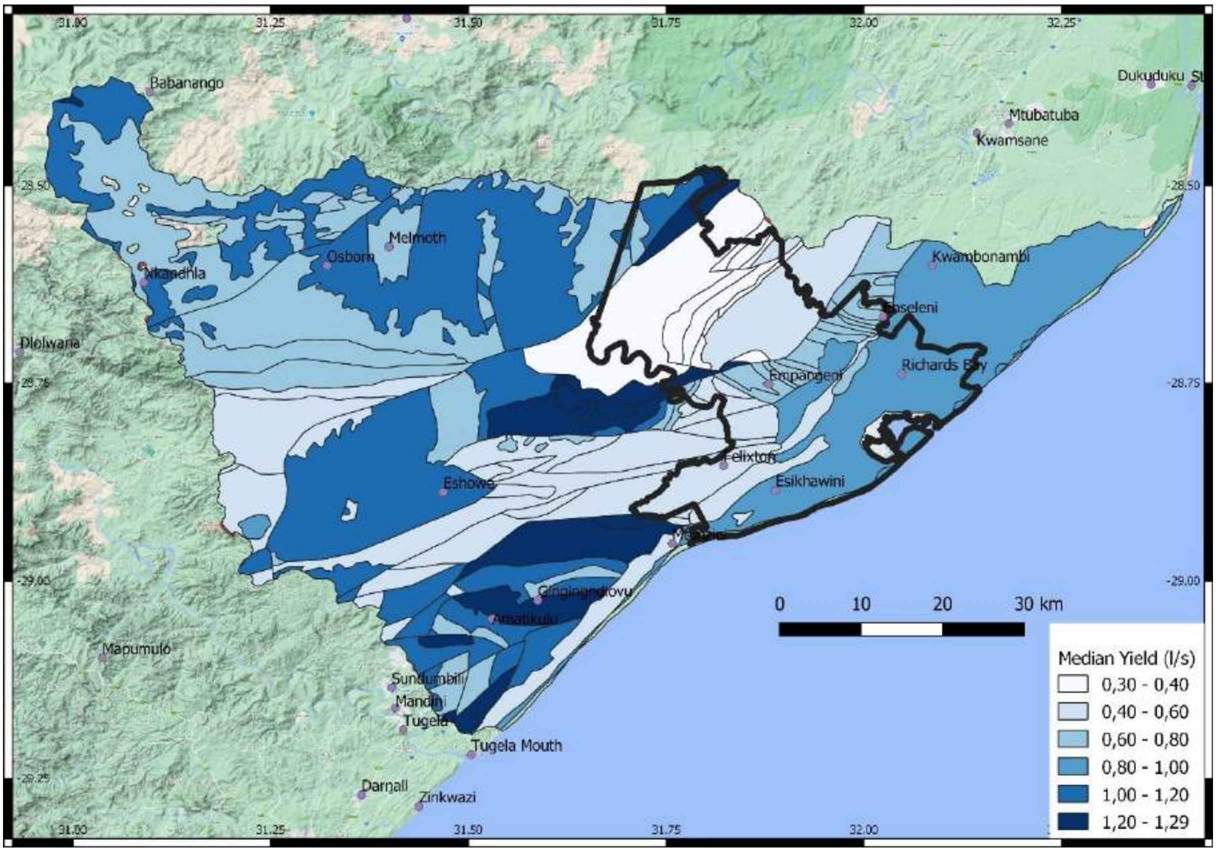


Figure 3-4 Median yield

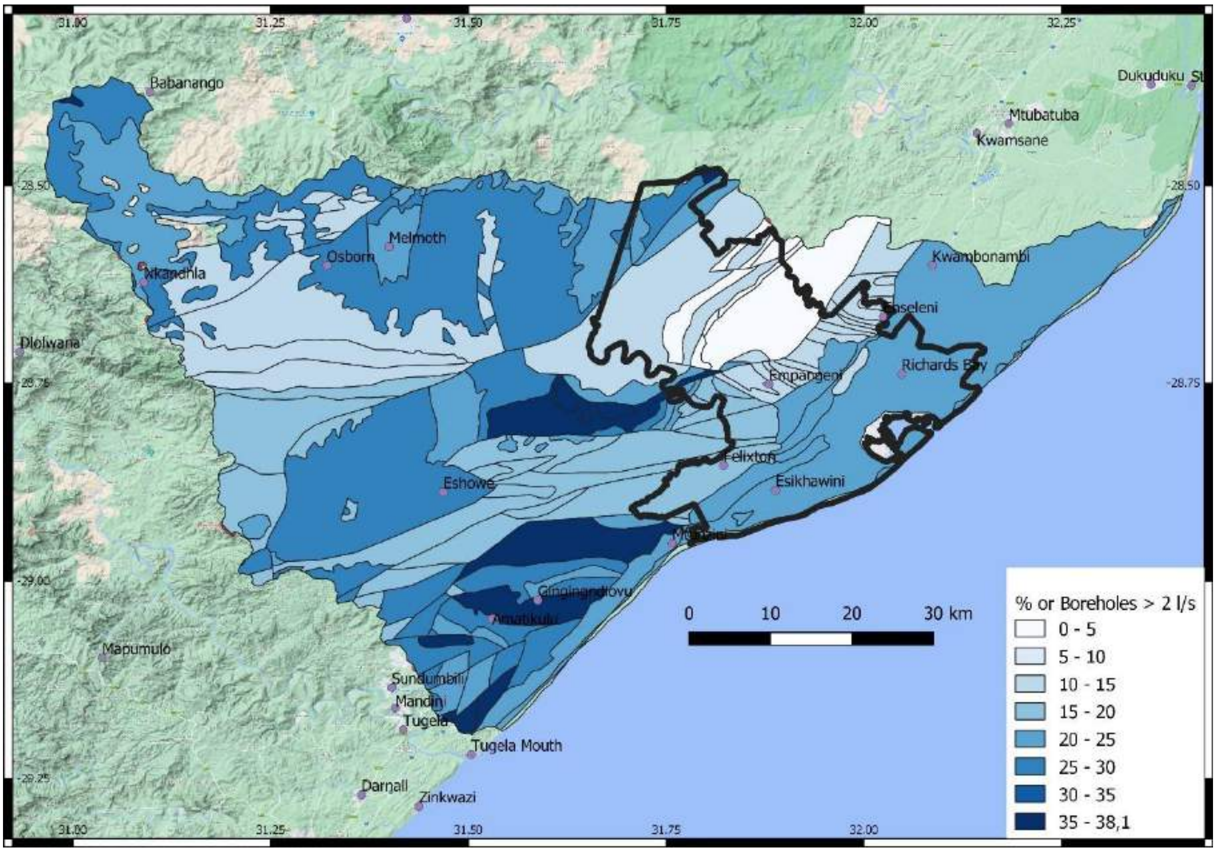


Figure 3-5 Percent of boreholes with median yield > 2 l/s

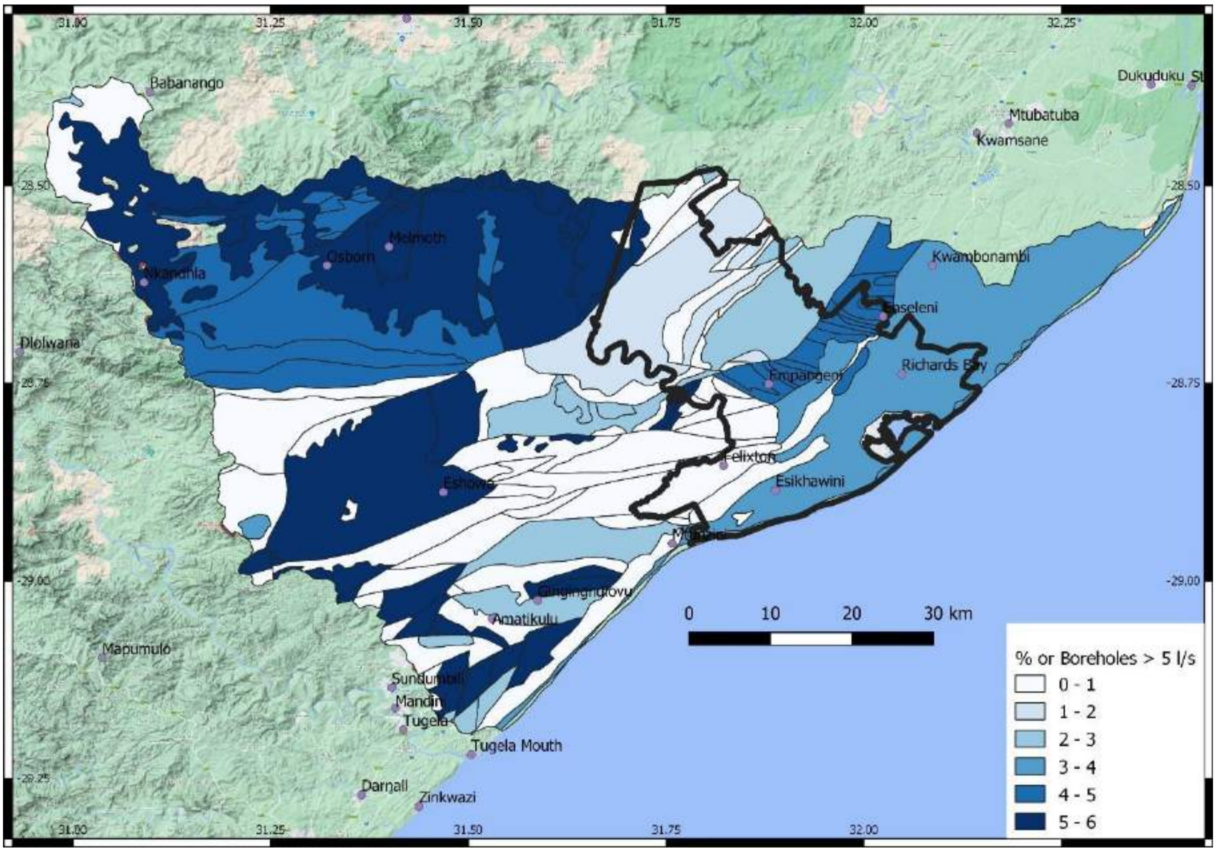


Figure 3-6 Percent of boreholes with median yield > 5l/s

3.4 Impact on Groundwater Abstraction on Coastal Lakes

Groundwater resources on the coastal plain can be seen as complementing surface water resources, since baseflow to the rivers and groundwater inflow directly to the lakes forms a large part of the lake water balance.

The coastal lakes Cubhu, Mzingazi and Nhlabane are fed by direct rainfall interception, limited surface runoff from riparian zones, streamflow and groundwater inflow. The lakes are drained by abstraction, evaporation, discharge when lake levels over top the outlet weirs, and groundwater outflow towards the sea. As overland surface runoff is almost non-existent due to the sandy nature of the coastal plain, it is likely that water in streams flowing towards the lakes is also derived from groundwater as baseflow; hence groundwater is also a significant component of stream inflows. The abstraction of water from the lakes can therefore be considered as the use of groundwater.

The Zululand coastal plain has groundwater development potential and could be developed for future water supply. However, it is not recommended that this water be used for large groundwater abstraction schemes in the vicinity of the coastal lakes due to the resulting reduction of inflows into the lakes.

The determination of impact on the lakes from additional groundwater abstraction would require the development of groundwater models beyond the scope of the project. An attempt was made to determine the impact of abstraction utilising WRSM2000 and the lake model from Lake Mzingazi. A lumped abstraction of 1.2 Mm^3/a and 12 Mm^3/a (approximately equal to current lake abstraction was taken from the lake Mzingazi groundwater catchment (**Figure 3-1**). The latter is approximately equal to 65% of recharge. The model run was based on historic land use and lake abstraction from 1920-2004, which had been used for model calibration.

The impact on baseflow to the lake, aquifer storage, and groundwater outflow from the catchment were then used to revise the Lake model water balance. The water balance is shown in **table 3-3** for the 12 Mm^3/a groundwater abstraction. The impacts can be summarised as:

- Reduced baseflow of approximately 1.6 Mm^3/a to the rivers entering the Lake.
- Reduced groundwater flow of approximately 8.5 Mm^3/a towards the lake
- Reduced groundwater evaporation from the catchment of about 2 Mm^3/a
- Reduced surface water and groundwater inflow to the lake
- Reduced discharge from the lake

The impact on lake levels is shown in **Figure 3-7.** During the drought period Lake Mzingazi goes down to -1 mamsl at 12 Mm^3/a, at which point it would contain only 10 Mm^3/a. A low abstraction rate has minimal impact on Lake level.

Given that the median yield of boreholes is 1 l/s, or 31500 m^3/a, approximately 40 boreholes would be required to abstract 1.2 Mm^3/a. However, 3 boreholes yielding 10 l/s in the Uloa Formation could achieve an abstraction of 1.2 Mm^3/a.

Table 3-3 Water balance of Lake Mzingazi with and without groundwater abstraction

	Natural	**No Groundwater abstraction**				**12 Mm^3/a groundwater abstraction**			
		1980-1985	**1985-1990**	**1990-1995**	**1995-2003**	**1980-1985**	**1985-1990**	**1990-1995**	**1995-2003**
Aquifer water balance from WRSM2000 Sami groundwater module									
Recharge	17.43	17.4	17.8	15.67	17.94	17.4	17.8	15.67	17.94
Baseflow	2.84	2.82	2.87	2.57	2.92	1.24	1.38	1.24	1.33
Groundwater Outflow	12.95	12.27	12.89	11.14	13.42	3.87	4.53	2.7	4.84
Groundwater evaporation	2.0	2.95	3.29	3.24	2.76	0.89	1.20	0.79	1.00
Lake water balance									
Rainfall	15.42	13.93	14.95	10.11	14.93	13.57	14.7	9.12	14.51
Surface Inflow	39.98	41.38	52.62	23.23	28.52	40.7	51.91	22.28	28.16
Groundwater Inflow	13.00	12.29	12.58	11.77	12.82	8.42	8.72	7.88	8.86
Evaporation	14.6	12.66	13.14	11.68	13.77	12.33	12.95	10.33	13.41
Abstraction	0	10.01	10.50	10.38	10.28	10.01	10.50	10.38	10.28
Surface water outflow	53.05	43.87	56.59	20.38	27.83	39.37	51.69	18.67	22.26
Groundwater Outflow	0.63	0.6	0.61	0.57	0.62	0.41	0.42	0.38	0.43

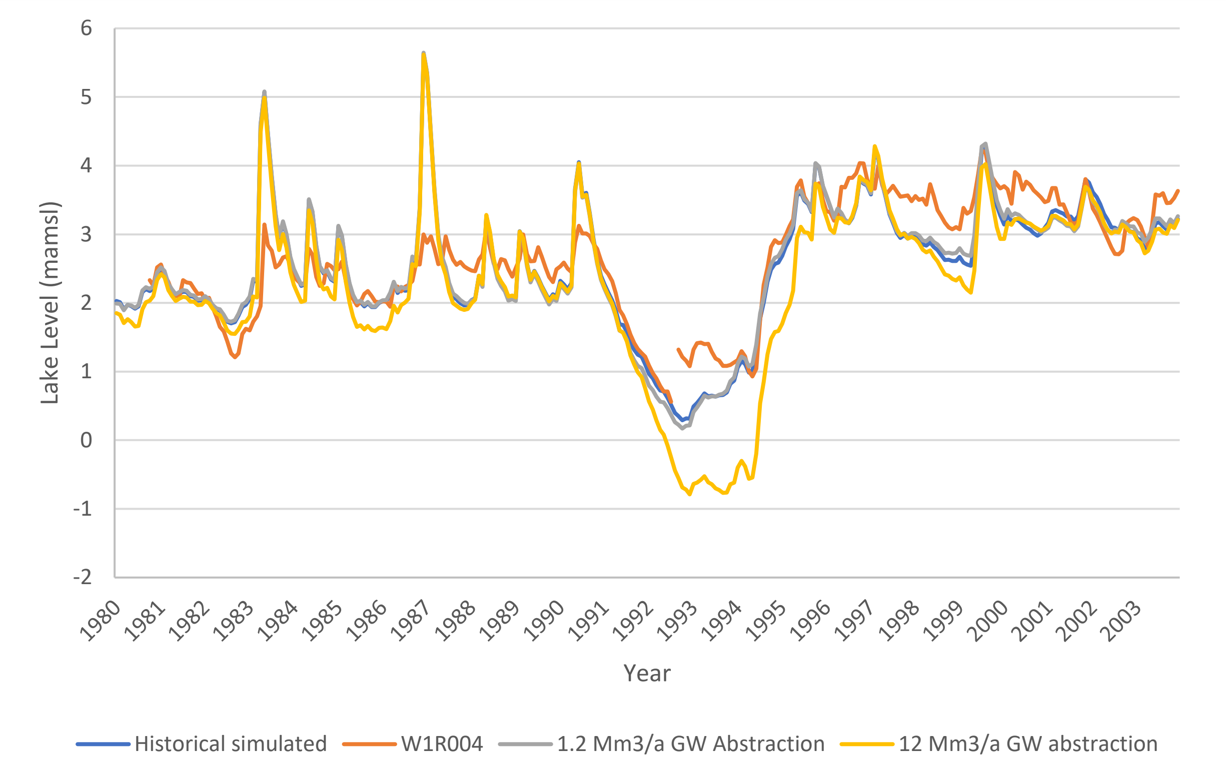


Figure 3-7 Lake Mzingazi water level with and without groundwater abstraction

3.5 Potential for Artificial Recharge

3.5.1 Background

Artificial recharge is the process whereby surface water is transferred underground to be stored in an aquifer. The most common methods used involve injecting water into boreholes and transferring water into spreading basins where it infiltrates the subsurface. Underground water storage is an efficient way to store water because it is not vulnerable to evaporation losses and it is relatively safe from contamination.

The hydrogeological factors to consider include aquifer type and hydraulic conductivity, and the potential aquifer storage Besides a sufficient permeability to inject water, the aquifer must have sufficient storage available to accept water. If groundwater levels have been lowered in and around a wellfield or over the aquifer as a whole, or if the groundwater levels are generally dropping after years of abstraction, then the aquifer has space to be refilled. Alternatively, the aquifer must be s used continually, and at the same time, it is continually recharged with treated wastewater.

A third important factor is the aquifer's hydraulic gradient and the natural geological barriers to flow. These relate mostly to the recovery of the recharged water.

Throughout much of the study area, yields are too low for large scale groundwater abstraction, and the stress index is very low, hence there is no need nor scope for managed aquifer recharge. It is only where thick sequences of Tertiary limestones exist that high abstraction is possible, however, it would interfere with inflows to the coastal lakes, since these are largely fed by groundwater flow through these permeable deposits.

The aquifer has no major groundwater users, and the aquifer is likely to be full most of the time. However, abstraction from the lakes is a groundwater use hence artificial recharge has the potential to allow increased abstraction from the lakes.

Under the South African classification of potential artificial recharge sites, the area is considered an intergranular aquifer of 0.5-2 l/s yield (**Figure 3-8**).

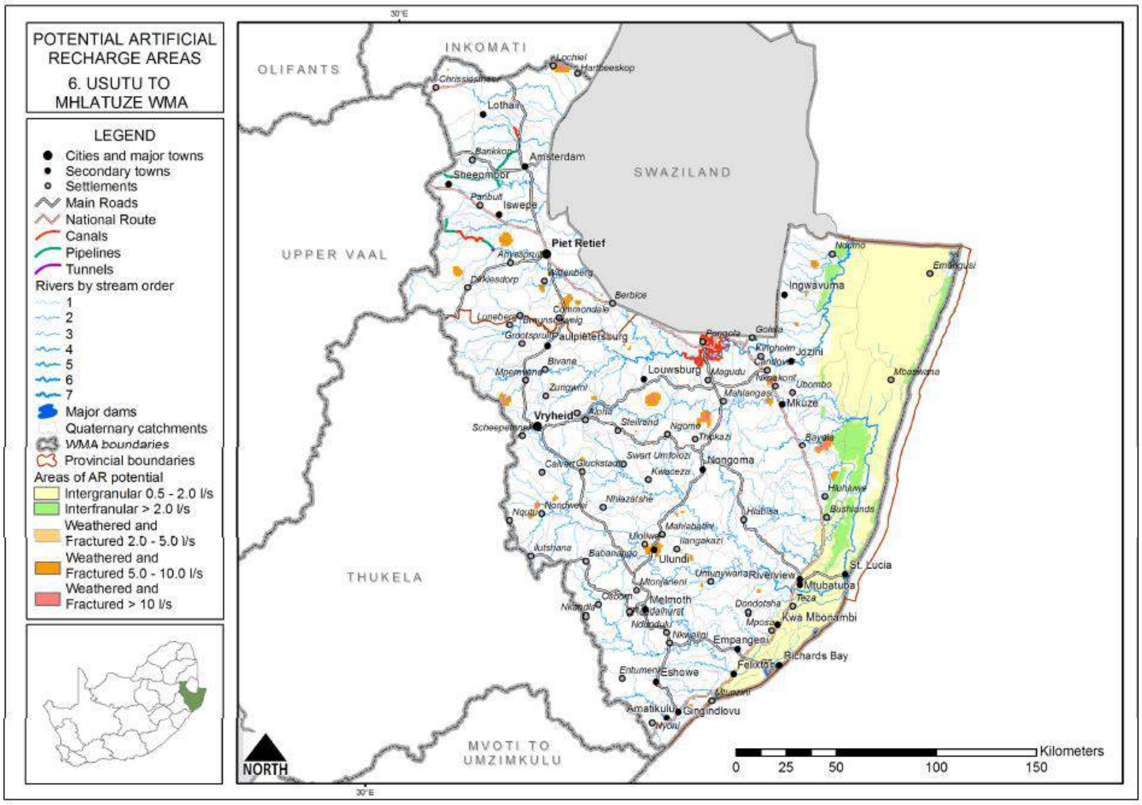


Figure 3-8 Potential artificial recharge sites in WMA11

3.5.2 Objective

The primary objective in the area would be to offset reduced lake inflow from increased lake abstraction since borehole yields are too low to warrant borehole abstraction for bulk supply. Artificial recharge would therefore offset increased abstraction from the lake.

The source of water would be treated wastewater, only Lake Mzingazi is a potential option.

3.5.3 Method

Injection Boreholes would be required, since the low permeability Port Durnford Formation above the Miocene Formation mitigates against the possible use of a surface spreading basin,

3.5.4 Permeability and storage

Deep sandy aquifers are potentially major sub-surface storage areas – purely because of the huge volume of water that can be stored in these thick, extensive sandy aquifers. The Richards Bay coastal aquifer is less than 50 m thick, and has average permeability of 2.5 m/d. Germishusye (1999) gives a permeability of 0.5-34.6 m/d for the Miocene aquifer, with an average of 28 m/d with average thickness of 2 m.

Static water levels in the vicinity of the lake are 5-10 mbgl, hence there is little scope for increasing recharge beyond the volumes abstracted from the lake to maintain the groundwater level.

The volume of water that could be recharged given limited yield is unlikely to exceed 1.2 Mm^3/a. This would require 3 x 10 l/s boreholes.

3.5.5 Potential Issues

The issues that would need to be evaluated include:

- The sediment load and debris in the recharge water to minimise borehole clogging.
- Mapping of the Miocene Uloa Formation to identify thick deposits upgradient of the Lake, which would the abstraction point.
- Long term duration test pumping to determine the response of the Formation to long term withdrawal/injection due to its discontinuous extent.
- Since the final discharge point is the lake, water quality would have to be of a suitable quality to not alter lake water chemistry.

4 CONCLUSIONS

The separation of lake catchments was into Quinary catchments according to the area considered to contribute surface and groundwater inflow to the lake and that contributing only surface inflow. The remainder of the Quaternary catchment also contributes groundwater to the lake via baseflow to surface water courses, which enters the lakes as surface inflow.

Aurecon identified 3 potential wellfields at Mtunzini North, Empangeni West and Lubisana. These had 18-19 production boreholes each and potential yields of 0.71, 0.54, 0.3 Mm^3/a respectively, or a total of 1,55 Mm^3/a. They are all located on the Tugela Terrane of the Natal Metamorphic Province. The Aurecon assessment is a realistic assessment of the yield potential of the aquifer. It would require 50-60 production boreholes to provide 1.5 Mm^3/a. This is not viable for bulk water supply, but the range of yields 23-300 m^3/d per borehole suggests the aquifer is suitable for local stand-alone water supply.

It is evident that much of the recharge drives baseflow. The authorised water use from WARMs represents 1% of aquifer recharge, as measured by the stress index. This suggests that groundwater resources are underutilised in the study area.

The probability of achieving borehole yields of greater than 5 l/s is less than 5% throughout the study area, making groundwater suitable for small scale water supply only, and not bulk supply.

Groundwater resources on the coastal plain can be seen as complementing surface water resources, since baseflow to the rivers and groundwater inflow directly to the lakes forms a large part of the lake water balance. The abstraction of water from the lakes can therefore be considered as the use of groundwater.

The Zululand coastal plain has groundwater development potential and could be developed for future water supply. However, it is not recommended that this water be used for large groundwater abstraction schemes in the vicinity of the coastal lakes due to the resulting reduction of inflows into the lakes. A lumped abstraction of 12 Mm^3/a from the Lake Mzingazi catchment (approximately equal to current lake abstraction was taken from the lake Mzingazi groundwater catchment would result in:

- Reduced baseflow of approximately 1.6 Mm^3/a to the rivers entering the Lake.
- Reduced groundwater flow of approximately 8.5 Mm^3/a towards the lake.
- Reduced groundwater evaporation from the catchment of about 2 Mm^3/a
- Reduced surface water and groundwater inflow to the lake.
- Reduced discharge from the lake.

The impact on lake levels is during drought periods Lake Mzingazi could go down below sea level. A low abstraction rate has minimal impact on Lake level.

Given that the median yield of boreholes is 1 l/s, or 31500 m^3/a, approximately 40 boreholes would be required to abstract 1.2 Mm^3/a. However, 3 boreholes yielding 10 l/s in the Uloa Formation could achieve an abstraction of 1.2 Mm^3/a, hence the potential for over abstraction is low.

Throughout much of the study area, yields are too low for large scale groundwater abstraction, and the stress index is very low, hence there is no need nor scope for managed aquifer recharge. It is only where thick sequences of Tertiary limestones exist that high abstraction is possible, however, it would interfere with inflows to the coastal lakes, since these are largely fed by groundwater flow through these permeable deposits. The aquifer has no major groundwater users, and the aquifer is likely to be full most of the time. However, abstraction from the lakes is a groundwater use hence artificial recharge has the potential to allow increased abstraction from the lakes.

Static water levels in the vicinity of the lake are 5-10 mbgl, hence there is little scope for increasing recharge beyond the volumes abstracted from the lake to maintain the groundwater level. The volume of water that could be recharged given limited yield is unlikely to exceed 1.2 Mm^3/a. This would require 3 x 10 l/s boreholes.

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6 COMMENTS LOG

Sivashni Naicker			
Page number	comment	Response	Changes made
P12	Are these wellfields within the groundwater fed area to the lakes	No, they are not. They are in the NMP	No need to address
P12	Figure is not clear	It comes from Aurecon so I cannot alter it	No
P12	Any hydstra geosites	I was sent this for the previous report but the record start later the period of hydrological record used for the hydrology	No
P21	Is there scope to look at gw abstraction within the primary aquifer outside the groundwater fed catchment area to the lakes?	The yields remain low as shown in the report.	No
P22	Can you look at current gw abstraction within the groundwater fed areas to the lakes (WARMS)	Yes, I can if DWS can send the WARMS data.	