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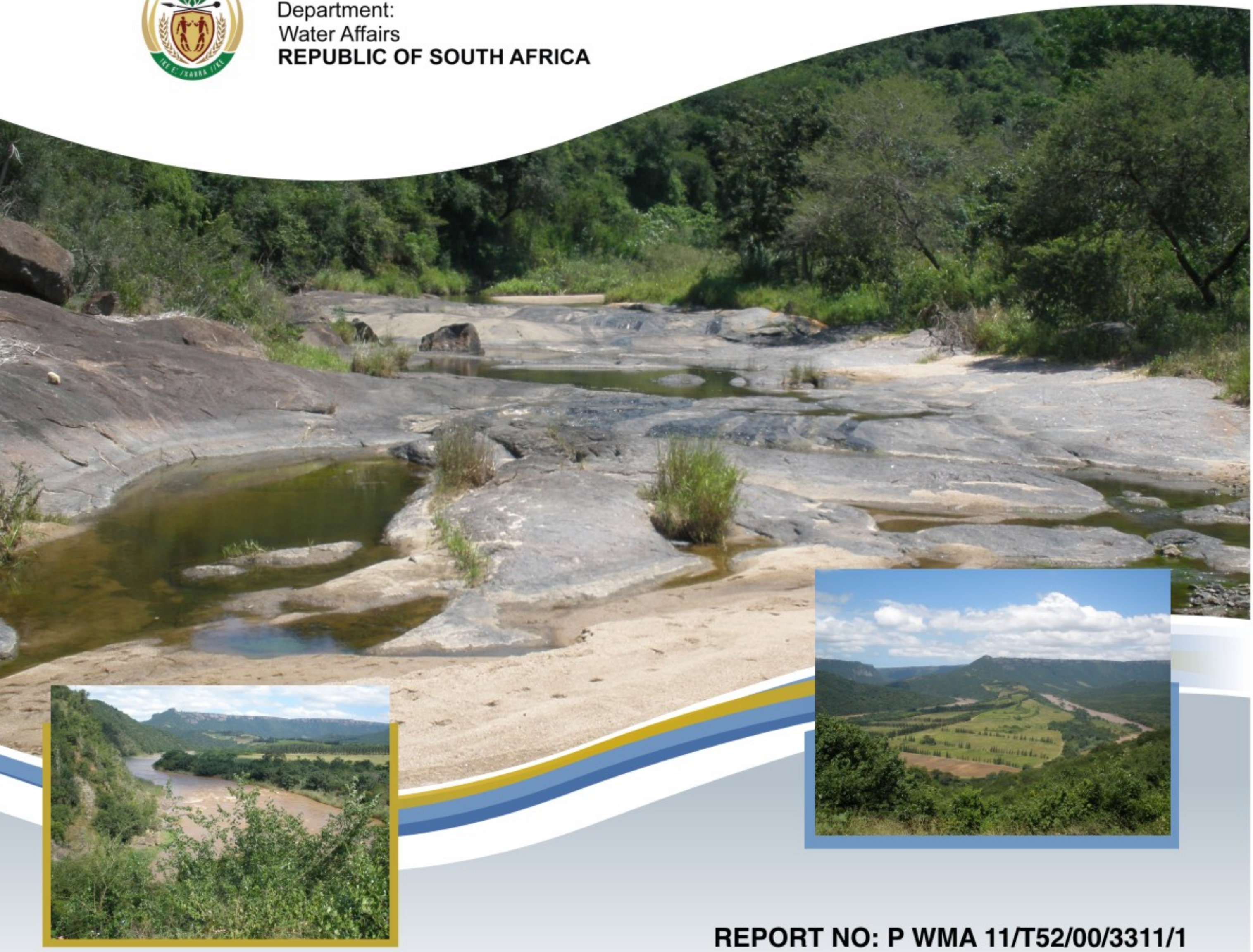

REPORT NO: P WMA 11/T52/00/3311/1

Ncwabeni Off-Channel Storage Dam Feasibility Study: Module 1: Technical Study

SUPPORTING REPORT 1: WATER REQUIREMENTS AND WATER RESOURCES

JULY 2012

W103_2012/J01494

NCWABENI OFF-CHANNEL STORAGE DAM FEASIBILITY STUDY: MODULE 1: TECHNICAL STUDY

SUPPORTING REPORT 1:

WATER REQUIREMENTS AND WATER RESOURCES

July 2012

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Report Details Page

Project name:	Ncwabeni Off-Channel Storage Dam Feasibility Study: Module 1: Technical Study
Report Title:	Supporting Report 1: Water Requirements and Water Resources
Author:	Jonathan Schroder; Kagiso Kwele; Johan Rossouw
PSP project reference no.:	J01494
Status of report:	Final
First issue:	20 May 2012
Final issue:	31 July 2012

Consultants: *BKS (Pty) Ltd.*

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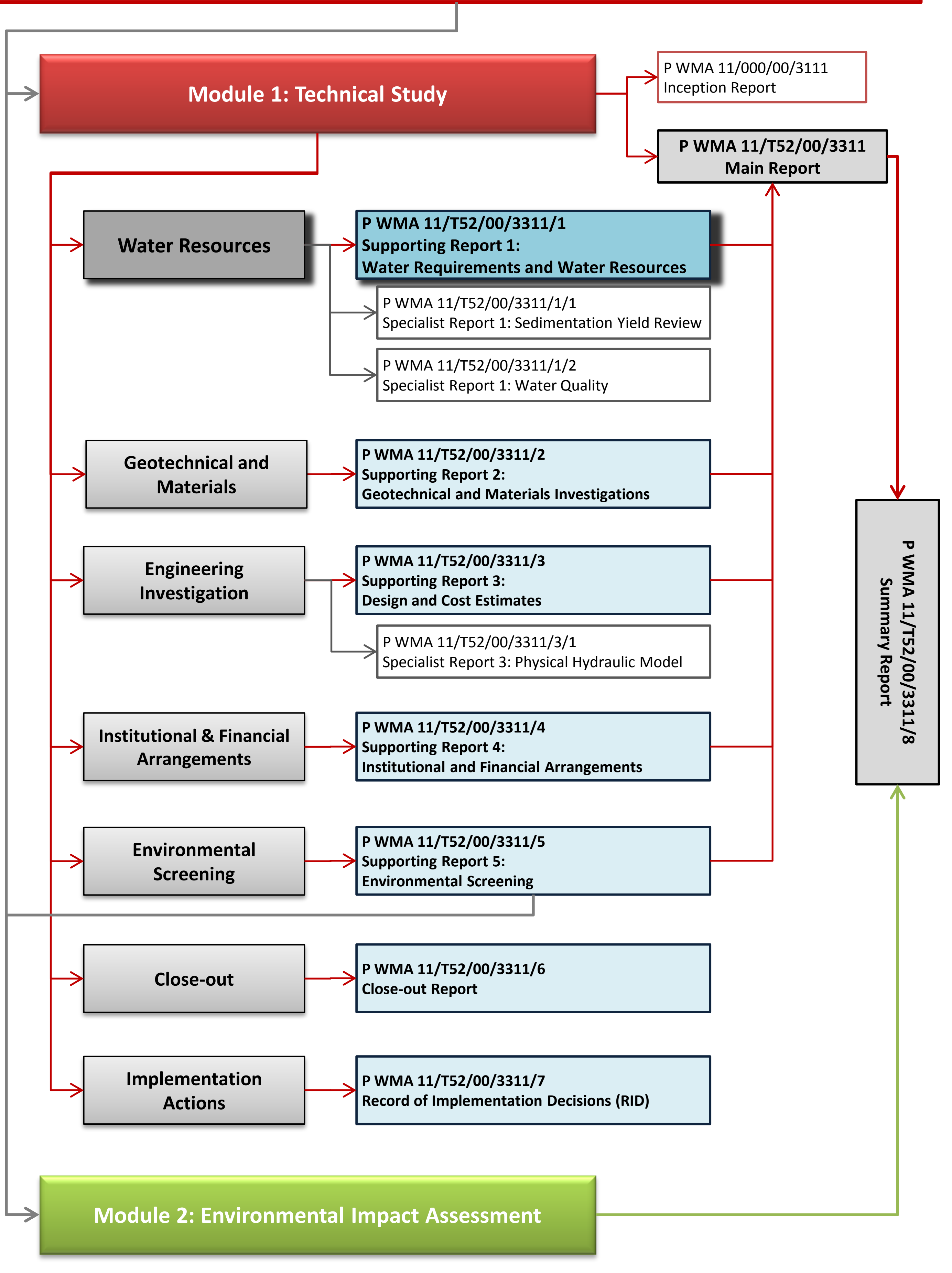
Ncwabeni Off-Channel Storage Dam Feasibility Study – List of Study Reports



EXECUTIVE SUMMARY

Background

The Umzimkhulu Regional Water Supply Scheme (RWSS), which forms part of the KwaZulu Natal's Lower South Coast System, supplies water to the coastal region from Hiberdeen to Margate, including Port Shepstone. The water is presently sourced from non-regulated river flows in the Umzimkhulu River. Abstraction is at the St. Helen's Rock (SHR) works near Port Shepstone where water is treated and from where it is distributed to various users.

The Southern KwaZulu-Natal Water Resources Pre-feasibility Study Phase 1 (DWA, 2002), concluded that during dry periods, the river flow is insufficient to meet the water requirements, even without provision for the ecological Reserve. The study recommended that, in order to provide for the water supply to all user sectors, including the Reserve, the construction of an off-channel storage (OCS) dam in one of the tributaries to the Umzimkhulu River should be considered. The reservoir can be filled from its incremental catchment, supplemented by pumping from the Umzimkhulu River during times of high river flows. During times of low flows water can be released back into the Umzimkhulu River for abstraction downstream at the existing St. Helen's Rock abstraction works.

The 2nd phase of the Southern KwaZulu-Natal Water Resources Pre-feasibility Study (SKZNFS PH2), as well as the Mzimkhulu River Off-Channel Storage Pre-feasibility Study, investigated various sites for an OCS dam along the Lower Umzimkhulu River. The most favourable two sites were found on the Ncwabeni and Gugamela Rivers, which join the main river about 25 km upstream of the St Helen's Rock Abstraction.

Subsequently the Ncwabeni Off-channel Storage Dam Feasibility Study: Module 1: Technical Study (this study) was initiated to conduct a comprehensive engineering investigation at the feasibility level for the proposed Ncwabeni Off-Channel Storage Scheme. This was supported by the Ugu Municipality Council Resolution accepting the need for the scheme. The possible dam on the Ncwabeni River was to be considered first and if a fatal flaw is found, the site on the Gugamela River should then be considered. As part of the Feasibility study, the water requirements for the Umzimkhulu RWSS have been updated, together with the water requirements for the region surrounding the dam site. Water resources yield analyses were conducted to determine the yield of the system with a dam added, and for sizing and timing of the proposed dam.

Water Requirements:

- *The current (2010) demand for water in the Umzimkhulu Regional Water Supply Scheme (RWSS) area is in the order of 18.5 million m^3/a.*
- *Future water requirements of approximately 28 million m^3/a have been projected up until 2040 for the RWSS. Reduction of water losses and more efficient use of water is assumed.*
- *Water conservation and water demand management (WC/WDM) is an essential part of ensuring the efficient use of the water resource, as well as reducing the water balance deficit and likelihood of water shortages up until the water resource can be augmented in about 2018.*

- *The Umzumbe area that is planned to be supplied from the Mhlabatshane Scheme needs to be augmented by about 1.4 million m^3/a with water from the Umzimkhulu River and the OCS dam, if the full desired level of water services of 60 L/c/d is to be achieved by 2030.*
- *The Umzimkhulu Regional Water Supply Scheme area was thus expanded for planning purposes to include the lower portion of Umzumbe.*
- *The total water requirement which needs to be supplied from the lower Umzimkhulu River system including an off-channel storage dam is in the order of 30 million m^3/a.*

Water Availability:

- *The water resources of the Umzimkhulu River were simulated using the water resources yield model (WRYM).*
- *The hydrology and WRYM configuration developed by the Mzimkhulu River Catchment Water Resources Study (MRCWRS) conducted by the DWA in 2011, was adopted and refined for this feasibility study.*
- *The hydrology and the ecological water requirements included in the WRYM were reviewed by the Feasibility Study team before yield analyses were conducted.*
- *Firm yields were conducted to determine water available at St Helen's Rock abstraction. The current yield is in the order of 18.3 million m^3/a. This yield is already slightly lower than the 2010 water requirement, and does not account for ecological water requirements.*
- *The water resource of the Umzimkhulu River needs urgent augmentation if the growing water requirements of the Umzimkhlulu RWSS are to be met, and ecological reserve is to be improved.*
- *The yields at St Helen's Rock with various sizes of both the Ncwabeni and Gugamela dams included were calculated. This was done for a range of off-channel pumping rates of between 0.2 m^3/s and 1.5 m^3/s, and dam sizes between 12 and 27 million m^3.*
- *For each dam size an optimal pumping rate was found above which no increase in firm yield is achieved. The optimal pumping rate for dam sizes that could meet the 2040 water requirement of 30 million m^3/a, were in the order of 0.7 to 0.8 m^3/s.*
- *An optimisation exercise was conducted to determine the best size of dam to be taken further into feasibility design. A dam size for the Ncwabeni site with a full supply level of 167.5 mamsl or greater was proposed, or a dam on the Gugamela of 177 masl. This equates to dams with capacities of approximately 16 million m^3.*
- *A desktop assessment was made of possible supply to the Umzumbe area directly from the dam or by extending the pipelines of the Umzimkhulu RWSS. The assessment can be utilised as a starting point for further bulk water planning form the dam. The assessment also assisted the study team in identifying a realistic limitation in how far water from the Ncwabeni dam can be supplied into the Mhlabatshane supply area for augmentation purposes.*
- *An off-channel storage dam in the Lower Umzimkhulu River is the preferred solution to the water resources problem experienced during the low flow months. A larger dam on the Bisi River, a major tributary of the Mzimkhulu River was investigated at a desktop level of detail and was found to be a less favourable, even if developed as a multi-purpose dam.*

System operation:

- *The proposed dam will be filled in the summer months and will require on average 3.5 months of continuous pumping at a rate of 0.75 m^3/s to be filled. In the driest years up to 5.5 months of pumping may be needed.*
- *Water shall only be abstracted when the flows in the river are greater than the sum of the downstream ecological water requirement and the demand for water at St Helen's Rock. Water should also not be abstracted during high flow periods when the sediment load in the river is high, to reduce the load of silt pumped into the dam.*
- *When required water shall be released in the winter months to supply the shortfall in water available in the Umzimkhulu River. The flows of the Umzimkhuluwana River that join just above the St Helen's Rock abstraction will also need to be taken into account.*
- *Releases from the dam are not made directly for the reserve but, do allow the reserve to be supplied first by available flows in the Umzimkhulu River.*
- *Flows at the off-channel abstraction weir shall be gauged for the purposes of operation of the proposed scheme. Gauging of flows at the outlet of the Umzimkhuluwana River will also need to be conducted. The flow measurements will need to feed into an operating system that calculates the releases needed for St Helen's Rock. A framework for the operating system has been proposed.*
- *Good operating rules will be a very important part of successful implementation of the scheme.*

RECOMMENDATIONS

The following recommendations are made based on the water requirements and water resources availability assessments:

- *A dam of 16 million m^3 on the Ncwabeni River (FSL of 167.5 masl or greater), or a dam on the Gugamela (FSL of 177 masl or greater) be considered when selecting the best scheme.*
- *An abstraction weir for off-channel pumping of 0.75 m^3/s.*
- *Flows at the abstraction weir on the Umzimkhulu River as well as the flows at the outlet of the Umzimkhulwana River need to be gauged and measured for operation of the scheme.*
- *The project needs to be implemented as soon as possible as the water requirement already exceeds the water resource.*
- *A validation and verification exercise needs to be conducted in the catchment to confirm legal water users both above the project site as well as between the dam and the water abstraction point.*
- *The possibility of using water directly from the dam should be investigated further by the water services authority.*
- *An additional study is required to investigate mitigation dams in the catchment to off-set afforestation development.*
- *WC/WDM measures needs to be implemented by the Water Services Authority.*

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LIST OF ABBREVIATIONS

DM	District Municipality
Du/ha	Dwelling units per hectare
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EIA	Environmental impact assessment
EWR	Ecological water requirements
FSL	full supply level
IDP	Integrated development plan
L/c/d	Litres per capita per day
LM	Local Municipality
masl	meters above sea level
MRCWRS	Mzimkhulu River Catchment Water Resources Study
OCS	off-channel storage
PSP	Professional services provider
RCC	Roller compacted concrete
RWSS	Regional Water Supply Scheme
SKZNFS PH1	Southern KwaZulu-Natal Water Resources Pre-feasibility Study Phase 1
SKZNFS PH2	Southern KwaZulu-Natal Water Resources Pre-feasibility Study Phase 2
UFW	Unaccounted for Water
VIP	Ventilated improved pit latrine
WC/WDM	Water conservation and Water Demand Management
WRYM	Water Resources Yield Model
WSA	Water Services Authority
WTW	Water treatment works

1. INTRODUCTION

1.1 BACKGROUND TO THE PROJECT

The Umzimkhulu Regional Water Supply Scheme (RWSS), which forms part of the KwaZulu Natal's Lower South Coast System, supplies water to the coastal region from Hiberdeen to Margate, including Port Shepstone. The water is presently sourced from non-regulated river flows in the Umzimkhulu River. Abstraction is at the St. Helen's Rock abstraction works near Port Shepstone where water is treated and from where it is distributed to various users.

The *Southern KwaZulu-Natal Water Resources Pre-feasibility Study Phase 1* (DWAF, 2002), concluded that during dry periods, the river flow is insufficient to meet the water requirements, even without provision for the release of the ecological Reserve. The study recommended that, in order to provide for the water supply to all user sectors, including the Reserve, the construction of an off-channel storage (OCS) dam in one of the tributaries to the Umzimkhulu River should be considered. The reservoir can be filled from its incremental catchment, supplemented by pumping from the Umzimkhulu River during times of high river flows. During times of low flows water can be released back into the Umzimkhulu River for abstraction downstream at the existing St. Helen's Rock abstraction works.

The *Southern KwaZulu-Natal Water Resources Pre-feasibility Study Phase 2* (DWA, 2005), investigated numerous options with regard to the position of the potential OCS dams. Four competitive sites, which are located about 20 km north-west of Port Shepstone, were selected as the most feasible potential OCS dam sites. Two of the sites (D2 and D2A) are located on the Ncwabeni River while the other two (D3 and D3A) are on the Gugamela River. Conceptual designs for dams at these sites were undertaken as part of the afore-mentioned study.

Following on the above, the *Reconnaissance Phase of the Umzimkhulu River Off-Channel Storage Pre-feasibility Study* (DWA, 2007), re-assessed all four OCS dam options on the basis of more detailed hydrological modelling and updated information regarding water requirements, topographical surveys, geotechnical and flood hydrology data, which became available after completion of the *SKZNFS PH2*. It was established that the D3 site on the Gugamela River and the D2A site on the Ncwabeni River were distinctly less favourable than the other two sites and were therefore not investigated further. The study concluded that the social impacts of the site on the Ncwabeni River appeared less problematic than that on the Gugamela River and that the construction of a Roller Compacted Concrete (RCC) dam at the D2 site on the Ncwabeni River appeared the most feasible option.

Subsequently the *Ncwabeni Off-channel Storage Dam Feasibility Study: Module 1: Technical Study* (this study) was initiated to conduct a comprehensive engineering investigation at the feasibility level for the proposed Ncwabeni Off-Channel Storage Scheme. The possible dam at site D2 on the Ncwabeni River was to be considered first and if a fatal flaw or substantial increase in cost was identified, site D3A on the Gugamela River should then be considered.

The proposed dam options and project area is provided in **Figure A1** in **Annexure A**.

1.2 SCOPE AND ORGANISATION OF THE STUDY

The **key objectives** of the study are to:

- Recommend the optimum scheme configuration;
- Undertake feasibility level dam foundation, reservoir slope stability and construction material investigations including quarries;
- Undertake the necessary supporting investigations and studies to support the feasibility study required for the implementation of the scheme;
- Do sufficient design of infrastructure to obtain cost estimates;
- Collaboration with the appointed PSP that will be responsible for the EIA process;
- Optimise the engineering and economic parameters and determine cost estimates for the following components of the scheme; the dam, pipeline, pump station, abstraction works, diversion weir and access roads; and
- Provide institutional arrangements for the smooth implementation of the scheme.

The **sequence of activities** in order from beginning to end followed in this feasibility study included the following:

- Water resource including yield analysis for both the Gugamela and Ncwabeni Dam sites;
- Foundation and construction materials investigation;
- Cost comparison of dam types for both Gugamela and Ncwabeni Dams for the yield associated with the most likely water requirements;
- Selection of site and dam type;
- Cost comparison of scheme for incremental yield to the highest water requirement;
- Hydraulic model study of Umzimkhulu River to identify three possible sites for abstraction works;
- Selection of the best layout for abstraction works and diversion weir;
- Selection and cost comparison of abstraction work, diversion weir, pump station, pipeline and access road layouts for the three identified sites;
- Hydraulic model study of selected abstraction work, diversion weir and pump station for optimisation;

- Optimization and cost comparison analysis of selected scheme;
- Conceptual design of selected scheme; and
- Determination of URV of water supplied.

The activities specific to the ***Water resources task*** included:

- Determine the water requirements both current and future projections of the Lower South Coast system and areas surrounding the proposed scheme;
- Review and update the hydrology developed by the *Mzimkhulu River Catchment Water Resources Study (MRCWRS)* conducted by the Department of Water affairs (DWA, 2011);
- Conduct yield analyses to determine historic firm yields for the different scheme configurations in aid of selecting the best scheme;
- Conduct detailed stochastic yield analyses to determine the assurance of supply of the final selected scheme;
- Conduct scenario analyses to determine the required intervention date for which the proposed scheme and augmentation of existing water supply should come on line; and;
- Review the ecological water requirement information from the DWA's *Umzimkhulu River Catchment Water Resources Study*, and the implementation thereof in the WRYM.

1.3 PURPOSE OF THE REPORT

The purpose of the report is to present the methodology, assumptions made and results of the water resources task of the study. This information is required input into the engineering, financial and institutional investigations tasks, and this report is thus a supporting report to the main study report.

1.4 LAYOUT OF THE REPORT

Section 1 of the report presents the background information on the proposed project and the region.

Section 2 introduces the Umzimkhulu River catchment and the Umzimkhulu Regional Water Supply Scheme.

Section 3 presents the historical and current water requirements, and water requirement projections.

Section 4 presents the hydrology review and sedimentation information that feeds into the water resources availability assessment

Section 6 covers the yield analyses and operation of the off-channel storage dam.

Section 7 is a summary of the limnology assessment.

Sections 8 and **9** present the conclusions and recommendations respectively.

2. PROJECT AREA

2.1 THE UMZIMKHULU RIVER CATCHMENT

The Umzimkhulu River is one of the few major rivers in the country that is still largely unregulated with no major dams. Current and future water use as well as possible infrastructure developments in the catchment, have been have been recently investigated by the *Mzimkhulu River Catchment Water Resources Study (MRCWRS*) (DWA, 2011). Future catchment development levels/scenarios as determined by the *MRCWRS* have been adopted by this study for the catchment upstream of the proposed OCS dam. This feasibility study has focused in more detail on the lower Umzimkhulu River. The proposed off-channel storage (OCS) dam in the lower reaches of the Umzimkhulu River is intended to solve the specific water resource shortages experienced by the Umzimkhulu Regional Water Supply Scheme in the dry months, and augment water supply for future water requirement growth in and around Port Shepstone.

2.2 THE UMZIMKHULU REGIONAL WATER SUPPLY SCHEME

The orientation and layout of the existing Umzimkhulu RWSS supply area and infrastructure are shown in **Figures A2** and **A3** of **Annexure A** respectively.

The Umzimkhulu Regional Water Supply Scheme supply area (Bhobhoyi Supply Zone) for the requirement projection encompasses the following urban centres:

- Hibberdene
- Port Shepstone
- Louisiana
- Margate
- Shelly Beach
- Southbroom
- Gamalakhe
- Ramsgate

This system also supplies Nsimbini Tribal Authority, the KwaMdlala Tribal Authority, the Murchison-Bhobhoyi rural and peri-urban area as well as the Kwandwalane tribal authority.

Currently, the only source of water for the Umzimkhulu RWSS is un-regulated run-of-river abstractions from the Umzimkhulu River at the St Helen’s Rock abstraction, which is positioned 9 km upstream from the River Mouth. The abstracted water is then pumped to the Umzimkhulu Water Treatment Works (WTW), which includes a recently constructed dam for operational purposes, known as the Umzimkhulu off-channel storage dam. Due to the studies and construction associated with the operations dam, the DWA have changed the name of the proposed off-channel storage dam, to the Ncwabeni OCS dam to avoid confusion. Any further references to off-channel storage (OCS) dams during this study will pertain to the proposed OCS dam to augment the water resource, and not the recently constructed operations dam at the WTWs, unless otherwise stated. The existing Umzimkhulu OCS operations/ balancing dam and the proposed Ncwabeni OCS dam for water resource augmentation are shown in **Figure A1** of **Annexure A**.

During low flow periods the shallow water depths and a meandering flow in the sandy river bed make abstraction at St Helen's Rock difficult. To improve the abstraction efficiency during low flow periods, a weir has been proposed at the St Helen's Abstraction. This weir is a necessary part of the overall plans for upgrading water supply system, and needs to be developed in parallel to the proposed OCS dam. The weir at St Helen's Rock will be investigated by the Ugu District Municipality, the Water Services Authority, and will not be focused on further during this study. This proposed weir at St Helen's Rock must also not be confused with the abstraction weir which will be required for off-channel pumping to the Ncwabeni OCS dam higher upstream.

3. UPDATING OF WATER REQUIREMENT PROJECTIONS

The growing water requirements in the Umzimkhulu River catchment over the past decade have been documented in previous studies as summarised in the introduction of this report. The situation of water requirements beginning to exceed local water resources was further highlighted by recent occurrences during very dry months, whereby salt water was intruding back up the estuary of the Umzimkhulu River to the point of the St Helen's Abstraction. To better understand the current and future situation, updated water requirements and water requirement projections are needed.

The water requirement projections for the Umzimkhulu RWSS as determined by the *Mzimkhulu Off-channel Storage Dam Pre-feasibility Study* conducted by the DWA (2007), are more than five years old and require comparison with actual supply records and updating. Subsequent to the pre-feasibility study, other studies in the region have been conducted which need to be considered. The need for water supply services outside of the Umzimkhulu RWSS supply area has also been identified, and all these factors were considered when updating the water requirements that need to be reconciled by the proposed OCS dam. The updated water requirements will form the basis for a revised current water balance of the Umzimkhulu RWSS, as well as for sizing the proposed OCS dam.

The first part of updating the water requirement projections is to verify current water supply and requirements. Furthermore, in additional to the water requirements of the existing supply area, other potential water users in the region were also assessed from a needs perspective as well as their potential of being supplied from the proposed project.

3.1 DATA COLLECTION

3.1.1. Stakeholder awareness and liaison

As a starting point for information gathering, a database of stakeholders for the project as part of the public liaison task was compiled. Key stakeholders were consulted during the data collection phase to ensure a comprehensive database of existing reports and relevant information was constructed for assessment and analysis.

Further to this the main role players including Ugu DM, DWA, Umgeni Water and BKS (Pty) Ltd attended Study Steering Committee meetings, during which various issues and concerns were discussed, which included the water supply area, water requirement projections, and water losses and water use efficiency.

3.1.2. Sources of data

3.1.2.1 Water supply records

The basis for water requirement projections is accurate historical information and data. Bulk meter readings and billed consumption were received from Ugu DM which reflected water production figures as well as water supply for the Umzimkhulu RWSS. This information were compared with the previous water requirement projections and used as the base point of the revised future water requirement projection. The actual supply records are discussed and processed in **Section 3.2**.

3.1.2.2 Previous studies

Together with the actual recent water supply records, water requirement information and water requirement projections were collected from previous studies. A number of previous studies were available, but the three most recent and relevant studies are:

- The *Mzimkhulu Off-channel Storage Dam Pre-feasibility Study* conducted by UWP on behalf of the Department of Water Affairs and Forestry (2007);
- The *Bulk Water Services Master Plan* conducted by SSI (Pty) on behalf of Ugu District Municipality (2006); and
- The *Mzimkhulu River Catchment Water Resources Study* conducted by Aurecon on behalf of the Department of Water Affairs (2011).

3.1.2.3 Population and level of service

Where existing information on water supply was not available, i.e. the areas in the region currently not part of the Umzimkhulu RWSS, other sources of data were used to determine current water requirements. This included household counts to establish population and settlement classification, as well as establishing the required level of service.

Settlement classification:

The settlement classification into which the households were distributed was used to determine the required level of service.

Settlement areas within the Ugu district range from high density urban areas, predominantly located on the coast, to dispersed rural settlements inland. There are three types of residential areas, which are identified in the 2011 district Spatial Development Framework (SDF).

A sector wide infrastructure audit was performed and an audit report complied by the Hibiscus Coast Local Municipality (2011). The spatial distribution of the various settlement types in the Ugu District Municipality is shown in **Table 3.1**, illustrates the distribution of the settlement types.

Table 3.1: Settlement classification in the Ugu District Municipality

Settlement classification	Definition/example	Density	Notes
Middle/high income formal urban	Formal urban settlement with formal layout plan and use of conventional building materials. Individual units value at > R100 000	> 2 du/ha	This type of settlement primarily located in the coastal strip in formally proclaimed towns where planning schemes are in place.
Low income formal urban	Low cost formal urban settlement established through township establishment processes. Individual units valued at < R100 000.	> 10 du/ha	Although substantial low cost housing developments, these are difficult to identify and generally included in category above or below.
Informal residential (linked to urban) upgrade	Informal settlement established without any formal layout design or township establishment processes.	> 10 du/ha	Primarily "squatter" areas within proclaimed urban areas, but dense and informal. Not a strong feature of Ugu urban landscape.
Linked rural upgrade	Settlement directly adjacent or linked to a Convenience or higher level node (as defined by the SDF)	> 2 du/ha	
Good access rural upgrade	Settlement not linked to node but located on a District Road (within 15 min walk from District Road)	> 2 du/ha	
Limited access rural upgrade	Settlement further than a 15 min walk from a District Road	<1 du/ha	
Scattered	Low density settlement	< 1du/ha	

Note: Density of du/ha stands for dwelling units per hectare

<u>Level of service:</u>

The level of service for a public utility is generally defined by the qualitative and quantitative standards adopted for the design, installation and operation of the utility. In regard to water requirement projection, the overall quantitative level of service is described here, only in so far as it will impact on future requirements.

<u>Water supply service</u>

The Ugu district consists of varying demographics, from dense formal urban settlements to scattered rural settlements. Using "CSIR Guidelines for Human Settlement Planning and Design" Ugu (2011) determined the water delivery standards for each settlement category as indicated in **Table 3.2**.

Table 3.2: Water delivery standards per settlement category

Settlement category	Average daily per capita consumption	Description of level of service
Formal urban	200 ℓ/c/d	Medium/high income, with waterborne sanitation
Informal residential upgrade	100 ℓ/c/d	Moderate income, with waterborne sanitation
Linked rural upgrade	60 ℓ/c/d	Yard connections, dry pit latrines/septic tanks
Good access rural upgrade	60 ℓ/c/d	Yard connections, dry pit latrines/septic tanks

Rural area per capita requirements were based on the initial design figure of 60 ℓ/c/d as required by Ugu. This standard is being adopted by Ugu and is the benchmark that they are aiming to achieve within the greater District Municipality. It was assumed that economic growth in rural areas (including Umzumbe) would lead to a progressive requirement for full domestic connections in place of standpipe supplies.

Rural sanitation

The standard for a basic level of rural sanitation in Ugu is a ventilated, improved pit latrine (VIP) comprising pre-cast concrete "C" sections, *Sanitation Services Master Plan* (Ugu, 2005), and therefore water for sanitation is not included in the 60 ℓ/c/d for rural areas within the requirement calculations.

3.2 WATER SUPPLY RECORDS

The annual average daily abstraction and 7 day peak abstraction have historically been recorded for the Umzimkhulu Water Treatment Works (WTW). The recorded data in the **Table 3.3** was documented within the *Bulk Water Services Master Plan* (Ugu, 2006). For the purposes of water requirements and water requirement projections the annual volumes were determined based on the annual average daily abstraction figures.

Table 3.3: Historical abstraction figures to the Umzimkhulu Water Works

Umzimkulu Water Works				
Year ending 30 June	**Annual average daily abstraction *(Mℓ/d)***	**7 day peak abstraction in December *(Mℓ/d)***	**Peak factor**	**Annual abstraction *(Mℓ/annum)***
1995	28.57	37.11	1.30	10 435
1996	29.44	36.93	1.25	10 753
1997	29.58	37.95	1.28	10 804
1998	28.55	33.71	1.18	10 428
1999	28.75	34.57	1.20	10 501
2000	32.81	42.96	1.31	11 984
2001	30.96	36.06	1.16	11 308
2002	30.50	38.62	1.27	11 140
2003	32.48	36.59	1.13	11 863
2004	36.38	42.17	1.16	13 288
2005	38.72	45.52	1.18	14 142

The capacity of the Umzimkhulu WTW's capacity is currently 54 Mℓ/d. A report conducted by (Ugu, 1999) concluded that the capacity of the WTW's would need to be increased from 54 to 108 Mℓ/d in two 27 Mℓ/d stages and that this would most likely be needed by 2019. Although the upgrade of the WTW's is not part of the scope of this feasibility, it is an essential part of upgrading of the water supply system that will need to accompany increasing the water resource availability.

Additional to the information available in the *Bulk Water Master Plan* up to 2005, Ugu was able to supply detailed production figures over the past six year period along with billed consumer usage for the Umzimkhulu supply area. These production figures were extracted from detailed records of meter readings from the Umzimkhulu WTW.

Table 3.4 presents the recorded water production and consumption data for the Umzimkhulu RWSS, from July 2004 to June 2010 as well as the distribution of water consumption to the various water users of the Umzimkhulu RWSS. A graphical representation of Table 3.4 is illustrated in **Figure 3-1**.

Some anomalies were noted in the data presented in **Table 3.4**, notably the large drop in unbilled authorised consumption in 2008/2009 and the duplication of the same volume for metered standpipes for 2007/2008 and 2008/2009. Though these present some concern about the volumes of these specific components of the total supply, these are assumed to be problems in getting the split into these componenets correct, and the total volume supplied is assumed to be correct.

Table 3.4: Historic production and consumption data: Umzimkhulu supply area

Umzimkulu system: Production and consumption						
Component	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
	kℓ/annum	kℓ/annum	kℓ/annum	kℓ/annum	kℓ/annum	kℓ/annum
System input volume	**14 145 884**	**15 074 284**	**16 173 356**	**16 982 024**	**16 269 419**	**18 259 187**
1) Billed metered consumption-domestic	6 504 763	6 890 565	7 144 878	7 161 604	5 624 813	7 326 739
2) Billed metered consumption-commercial	765 467	791 346	802 365	2 928 565	2 820 087	1 701 465
3) Metered municipal consumption	67 968	67 968	67 968	63 935	63 935	485 654
4) Metered standpipes	1 336 464	1 336 464	1 336 464	506 710	506 710	1 770 020
5) Billed authorised consumption (1+2+3+4)	**8 674 662**	**9 086 343**	**9 351 675**	**10 660 815**	**9 015 546**	**11 283 878**
6) Unmetered municipal use	141 459	150 743	161 734	38 639	2 093	116 256
7) Unmetered standpipes	671 604	671 604	671 604	92 912	-	589 962
8) Unbilled authorised consumption (6+7)	**813 063**	**822 347**	**833 338**	**131 551**	**2 093**	**706 218**
9) Unauthorised consumption	720 474	817 623	989 216	440 387	562 772	1 056 622
10) Metering inaccuracies	303 613	318 022	327 309	241 628	206 451	441 824
11) Apparent losses (9+10)	**1 024 087**	**1 135 645**	**1 316 525**	**682 015**	**769 223**	**1 498 445**
12) Mains and distribution leaks	2 694 399	3 086 318	3 721 768	4 406 114	5 186 046	3 816 517
13) Reservoir overflows	36 341	40 299	46 718	55 076	64 826	47 706
14) Service connection leaks	903 332	903 332	903 332	1 046 452	1 231 686	906 423
15) Real losses (12+13+14)	3 634 072	4 029 949	4 671 818	5 507 643	6 482 558	4 770 647
Unaccounted for water (11+15)	**4 658 159**	**5 165 594**	**5 988 343**	**6 189 658**	**7 251 781**	**6 269 092**
Real losses %	**25.7%**	**26.7%**	**28.9%**	**32.4%**	**39.8%**	**26.1%**
Non-revenue water %	**32.9%**	**34.3%**	**37.0%**	**36.4%**	**44.6%**	**34.3%**

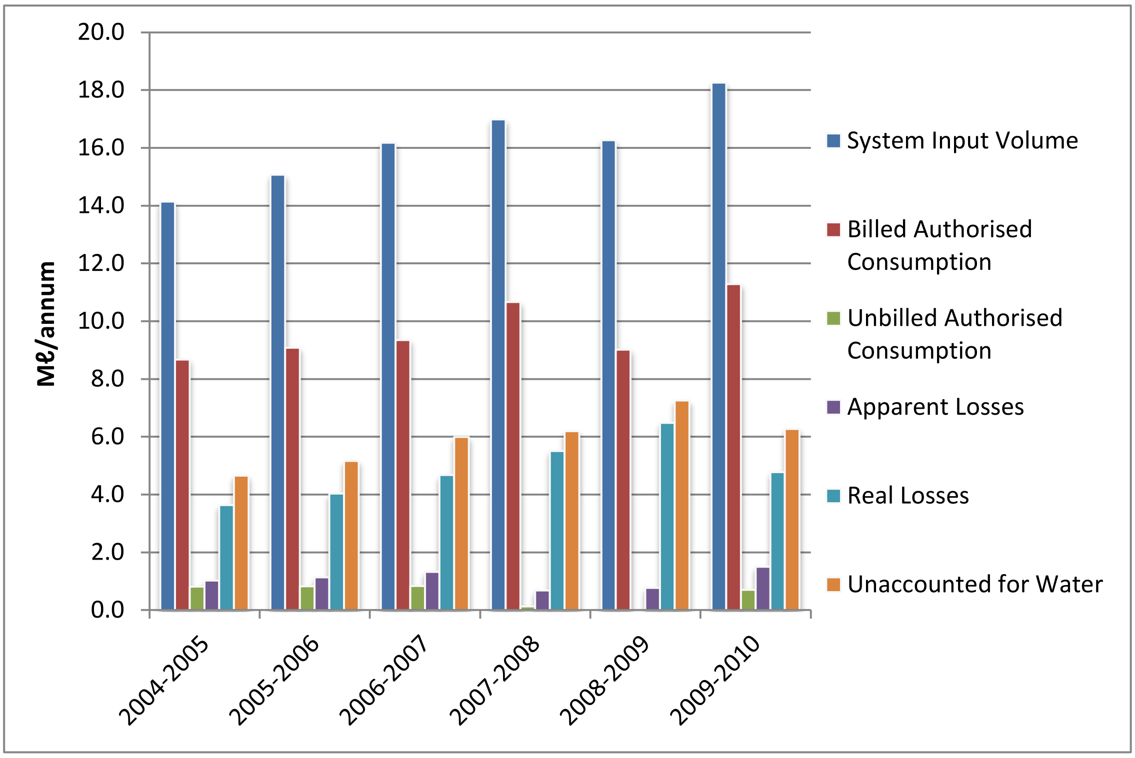

Figure 3-1: Umzimkhulu Regional Supply Scheme water production volumes, consumption volumes and losses

From **Table 3.5** and **Figure 3-1** it can be seen that over the past six years the unaccounted for water (UFW) and real losses have fluctuated (as expected), with non-revenue water averaging about 35% and real losses in the order of about 30%. According to Ugu, water conservation and water demand management (WC/WDM) measures have been introduced to reduce losses and un-accounted for water in the system. This may or may not be reflected in the drop in losses shown in the most recent data for 2009/2010.

Before a significant and costly new scheme is implemented to augment the water resource, it will be prudent to use the existing resource wisely and efficiently. As such realistic reductions in water losses and unaccounted for water through the implementation of WC/WDM measures will be accounted for in projecting the current water requirements.

To better understand the possible reduction in losses the unaccounted for water (UFW) was broken down into it's constituents as indicated in **Table 3.5**.

These percentages are based on total treated water production at the main Water Works and billed consumer metering measurements

Table 3.5: Unaccounted for water constituents

Umzimkhulu system	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010
Unauthorised consumption	5.09%	5.42%	6.12%	2.59%	3.46%	5.79%
Leakage on mains	19.05%	20.47%	23.01%	25.95%	31.88%	20.90%
Leakage on reservoirs	0.26%	0.27%	0.29%	0.32%	0.40%	0.26%
Leakage in reticulation	6.39%	5.99%	5.59%	6.16%	7.57%	4.96%
Metering Inaccuracies	2.15%	2.11%	2.02%	1.42%	1.27%	2.42%
TOTAL	**32.93%**	**34.27%**	**37.03%**	**36.45%**	**44.57%**	**34.33%**

A water loss strategy can embrace one or more of the following initiatives, based on an economic analysis of costs and benefits:

- Introduction of active leakage control.
- Mains renewal.
- Introduction of pressure management.
- Bulk, large consumer and domestic metering renewal.
- Improving capacity of system maintenance resources.
- A campaign to reduce unauthorised use.

3.2.1. Estimated impact on requirements with reduction in UFW

The estimated impact on water loss reduction was discussed in the Bulk water services master plan Ugu (2006), where it was stated that the two primary benefits gained through water loss reduction would be:

- "The most efficient use of scarce water resources and is therefore environmentally proactive."
- "The reduction in the size and delay in the implementation of all components throughout the whole water system including dams, water works, pipelines, pump stations and reservoirs."

With regards to the practical level of water loss reduction, the *Bulk Water Services Master Plan* (Ugu, 2006) states:

"*the major cost saving accrues from lower capital expenditures on smaller capital components and from delays in such expenditures due to lower water requirements and that there is an economic balance between the costs of implementing "loss reduction" against the cash flow of the savings that accrue from "loss reduction". A point is reached when it is uneconomic to pursue further loss reduction. Large sums* *of money need to be expended to achieve effective loss reduction as opposed to on-going inspection, maintenance and repairs*."

These statements raise some important points. These being:

- WC/WDM measures are needed to made sustainable use of the existing and future water resource
- WC/WDM measures will be a very important tool in helping delay the need for the next scheme and the expenditure of significant capital required for the next scheme. In the case of earliest possible completion date of the proposed Ncwabeni OCS dam, and the current growing level of utilisation of the existing resource, this is likely to be very important as will be shown later on in **Section 3.3.4.2**.
- Expectations of the impacts of WC/WDM measures on water losses need to be practical and within the realistic framework of diminishing returns on money spent.

The expected impact of the water loss reduction strategies on requirement and consumption are illustrated in **Table 3.6**.

Table 3.6: Expected impact of water loss reduction strategies

Component of UFW	%	Expected impact of water loss strategies	
		Reduce requirement	Increase metered consumption
Unauthorised consumption (illegal connections)	5.79	Large impact	Large impact
Leakage on reservoirs	0.26	Little or no impact	Small Impact
Metering inaccuracies	2.42	Little or no impact	Large Impact
Leakage on mains	20.9	Large impact	Little or no impact
Leakage in reticulation	4.96	Large impact	Little or no impact
Current total NRW as a percentage of water produced	**34.33 %**		

The UFW volume for the year 2010 shows that 34.33% of water produced is unaccounted for. A recommendation was made within *The Bulk water Services Master Plan* (Ugu, 2006), that water loss can be reduced down to approximately 20% and could be accomplished over the period 2006/2015 in the Umzimkhulu/Umtamvuna systems. This is approximately 2%/a.

After consulting with role players (DWA, UGU, BKS), and considering the current UFW figures, it was established that UGU can achieve a UFW target of 24% (of water requirement) to be attained between 2010 to 2015, which would be a 2.07% annual decrease in UFW, as illustrated in **Table 3.7**.

Table 3.7: Water loss strategy for requirement scenarios

	Reduction in base year (2010) leakage and unauthorised water usage (%)						
Year	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2034**
Unaccounted for water (%)	34.33	32.3	30.2	28.1	26	24	24

3.3 WATER REQUIREMENT PROJECTIONS

The current water supply and requirements have been established and provide a reliable base from which to project water requirements into the future.

3.3.1. The broader purpose and nature of water requirement projections

Forecasting water requirements from a rational base aims at quantify the impact of changes by population demographics, business and industrial management and technical interventions that can alter water requirement in the supply area.

The approach to projecting water requirements is also a function of the available data and the specific demographics and water user profiles for the areas, as well as the intended use of the water requirement projection.

3.3.2. Methodology and model for water requirement projections

A model was developed considering two water requirement projection methodologies (trend extrapolation and per capita method) that would best suit the planning objectives, available data and available resources. This model is graphically represented in **Figure 3-2**.

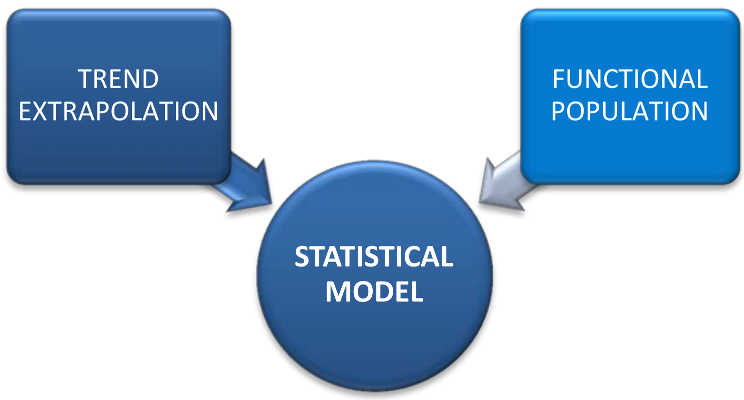

Figure 3-2: Requirement projection statistical model

3.3.3. Population within the Umzimkhulu Regional Water Supply Scheme

Population and is a key driver in water requirement growth as well as the funding arrangements of water supply schemes. Various sources of data on the population and demographics of the region exist. Much of this data is based on the 2001 Census data. The information is generally assimilated at a Municipal level. Ugu District Municipality's IDP estimates that there are 50 650 households in the Hibiscus Coast area. The IDP estimates a population of 222 281 giving 4.7 persons per household on average.

The footprint of the Umzimkhulu RWSS is similar but not the same as the Hibuscus Coast LM. The Umzimkhulu RWSS footprint does not include the lower portion of the Hibuscus Coast LM, and does cover small portions of the Umzumbe LM (see Umzimkulu/Bhobhoyi supply area **Figure A2** in **Appendix A**). Due to this mismatch in footprints and the fact that the base of much of the available data is generally about ten years old (2001 census information), the study team performed a household count for the existing Umzimkhulu RWSS area. The household count was based on 2010 aerial photography. The information gathered from the household count is reflected in **Table 3.8**.

Table 3.8: House count for the Umzimkhulu RWSS supply area (2010)

Household type	Households		
	Urban	Rural	Total
Houses	16 944	7 472	24 416
Dwellings/huts		22 546	22 546
Total	16 944	30 018	46 962
Schools	16	52	68
Hospitals	6	1	7
Clinics	0	21	21

The household count conducted for this feasibility study did not verify the number of people living in the different household types through any ground truthing exercises. As such information of average persons per household from previous studies was adopted to estimate the current population being supplied water by the Umzimkhulu RWSS. An average of 4.7 persons per household was used for households in the urban areas based on the average persons per household identified in IDP for the Hibuscus Coast Municipality. The number of persons per household and per hut in rural parts of the Umzimkhulu RWSS was based on the Water Master Plan for the Mhlabatshane Sub-Regional Water Supply Scheme conducted by SBA for the Ugu

DM (2006)[2], as well as conversations with the engineers planning the bulk water infrastructure in rural areas in Umzube. An average of 6.6 persons per house hold and 3.06 persons per hut was adopted for the rural areas of the Umzimkhulu RWSS. These estimated persons per household were used to calculate an indicative population for the Umzimkhulu RWSS. The population estimated for the Umzimkhulu RWSS is shown in **Table 3.9**.

Table 3.9: Estimated population of the Umzimkhulu Regional Water Supply Scheme based on household count

Household type	Households			Population		
	Urban	Rural	Total	Urban	Rural	Total
Houses	16 944	7 472	24 416	79 637	49 315	128 952
Dwellings/huts		22 546	22 546		68 991	68 991
Total	**16 944**	**30 018**	**46 962**	**79 637**	**118 306**	**197 943**
Schools	16	52	68			
Hospitals	6	1	7			
Clinics	0	21	21			

As can be seen, the population as estimated for the Umzimkhulu RWSS in Table 3.9 is about 25 000 people less that that indicated for the whole Hibuscus Coast LM. This is expected due to the portion of the Hibuscus Coast LM that is not covered by the Umzimkhulu RWSS. The *Development of a reconciliation strategy for All Towns in the Eastern Region* (DWA, 2011), recently estimated the population for the Umzimkhulu RWSS at about 153 000 people. This is lower than that estimated in Table 3.9. The most likely difference lies in estimating the average person per household of the urban area along the coast. Due to the popularity of the area as a holiday destination and an associated number of holiday homes, the permanent population is likely to be lower than 4.7 persons per household. The fluctuating population in the region with holiday seasons does complicate population demographic estimates. This dynamic population and associated water requirement will be accounted for when applying a monthly distribution to the annual water requirements.

Another source of information for comparison is the recent Sector Wide Infrastructure Audit by the Hibiscus Coast Municipality (2011). This report showed that approximately 50% of the households in the Municipality are urban and 50% rural. The population household demographics as determined by the Sector Wide audit for the Hibuscus Coast are presented in **Table** 3.10.

Table 3.10: Distribution of households in settlement types - Sector Wide Infrastructure Audit (Hibuscus Coast LM, 2011)

	Percentage of households					
Local municipality	Formal urban	Informal residential upgrade	Linked rural upgrade	Good access rural upgrade	Limited access rural upgrade	Scattered
Hibiscus Coast	50.0	0.49%	29.45%	13.32%	1.90%	4.78%

This is a lower portion of rural households than determined by the household count as presented in Tables 3.9 and 3.10. The difference again is attributed to the differences in footprint of the Hibuscus Coast LM and the Umzimkhulu RWSS. The Umzimkhulu RWSS includes some small but dense rural and semi-rural areas of the Umzumbe LM, while the lower parts of the Hibuscus Coast LM that are not covered by the Umzimkhulu RWSS have significant urban development along the coast.

In summary, the current population within the Umzimkhulu RWSS supply area is between 153 000 and 197 000. The household population demographics are approximately half rural, and half urban and peri-urban.

3.3.4. Water requirement projections for the Umzimkhulu RWSS

3.3.4.1 Water requirement projections of the pre-feasibility study

As suggested in the TOR, the water requirement projections as determined by the *Mzimkhulu Off-channel Storage Dam Pre-feasibility Study* (DWA, 2007) are now dated and need to be updated based on actual recorded supply figures, as well as most likely current situation. The planning water requirement projection scenario from the pre-feasibility study has been plotted together with the actual historical supply information obtained for 1995 up until 2010 in **Figure 3-3**. The actual supply recorded from 1995 until 2005 appears to display two different trends: lower growth between 1995 to 2003 (*Trend line 1*), and higher growth from 2003 until 2010 (*trend line 2*). From the trend lines of the recorded supply in Figure 3-3 it can be seen that the water requirement growth recorded over the last five years (2003 to 2010 - *trend line 2*) is higher that projected by the planning scenario of the pre-feasibility study, and also higher than the previous ten years on record (1995 to 2003 – *trend line 1*). This may be due various factors affecting the period from 2003 to 2010 such as:

- An increase in water service delivery levels to as well as the possible addition of new supply areas due to the backlog in water service delivery; and/or
- Increasing water losses over the past six years (except for the last year on record 2010) as highlighted by increasing unaccounted for water in **Table 3.4**.

The average growth over the total record period from 1995 until 2010 (*trend line 3*) is, however, similar to the growth projected by the planning scenario by the pre-feasibility study. As such over the longer term the planning scenario of the pre-feasibility study appears to be in-line with the actual water requirement recorded at the Umzimkhulu WTWs. The planning scenario of the pre-feasibility study, however does need to be adjusted based on the current water requirement levels as well as refined to account for a reduction in water losses reduction required as per **Section 3.1.3**, as well as to incorporate additional information that has emanated from other recent studies.

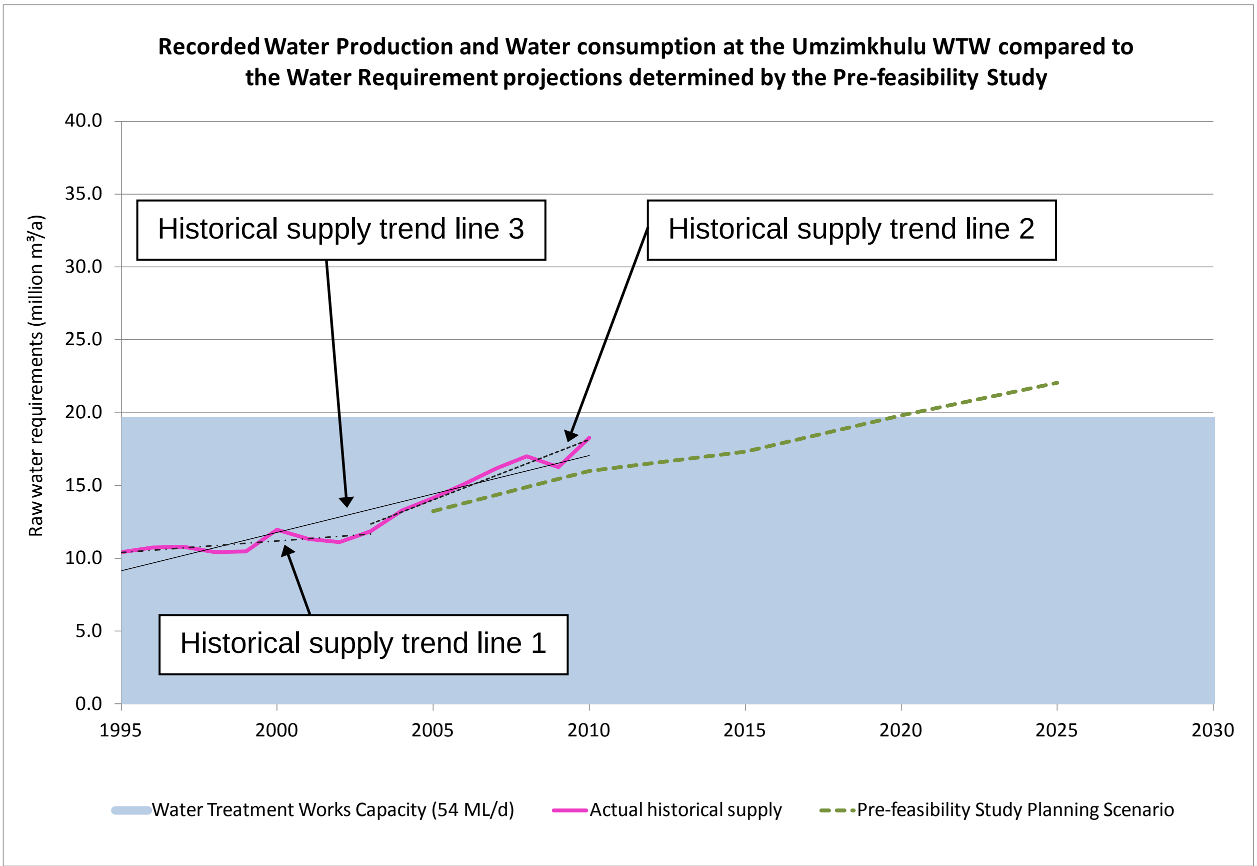

Figure 3-3: Comparison of water supply record with projected water requirements from the pre-feasibility study

3.3.4.2 Water requirement projections additional information

Water requirement growth scenarios from the *Water Resources Planning Study* (Ugu, 2004) where also plotted for comparison. This included a high medium and low growth rates of 3.3%, 2.3% and 1.3% respectively. The water requirement projections of the *Water Resources Planning Study* (Ugu, 2004) are shown in **Figure 3-4**. From **Figure 3-4**, the growth rate of the medium requirement scenario (2.3%) is closest to the growth in historical water consumption between 1995 and 2010, and the planning scenario of the *Pre-feasibility Study* (DWAF, 2007).

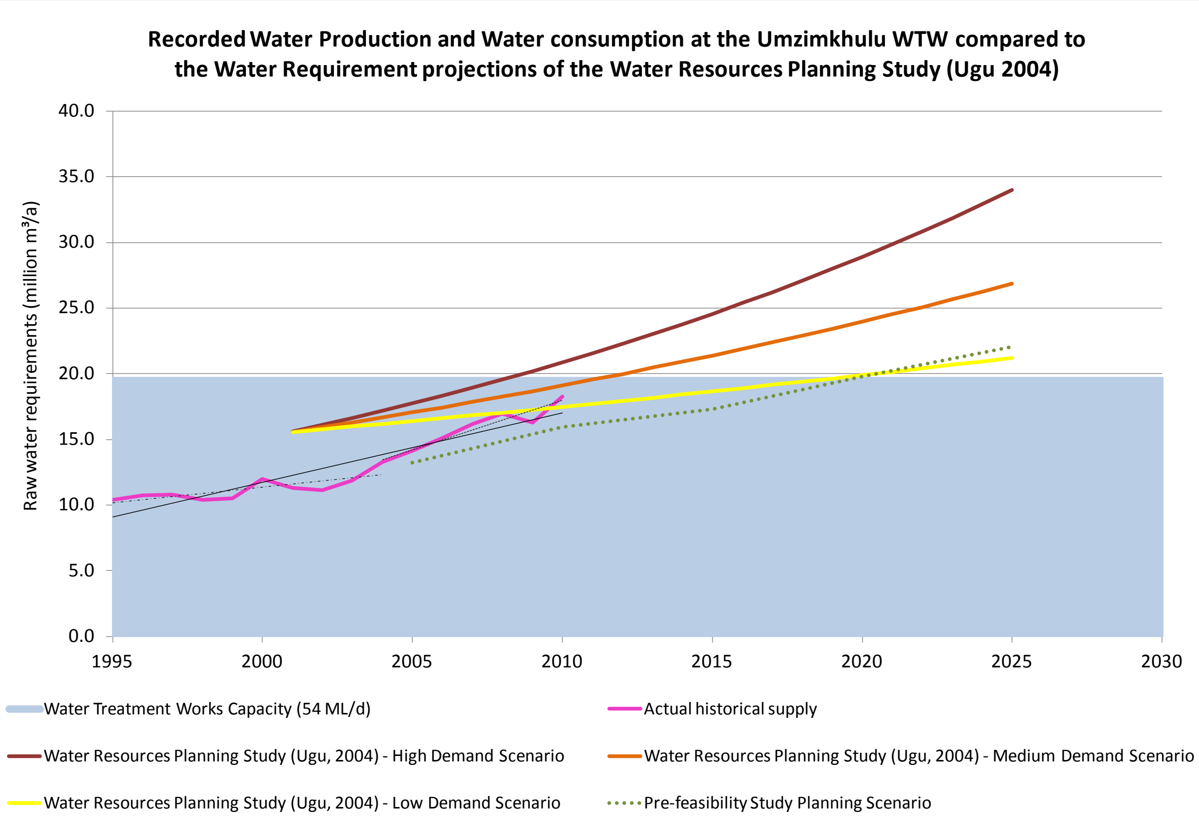

Figure 3-4: Comparison of water supply record with projected water requirements from Water Resources Planning Study (Ugu, 2004)

The exponential growth of the water requirement scenarios as determined by the *Water Resources Planning Study* (Ugu, 2004), does however result in the water requirement growth increasing with time into the future. While this may be realistic over the short term with eradication of backlogs in water services delivery, it is unlikely over the longer term. The water requirement curves of most of the larger centres appear to be either growing in a linear fashion or are flattening as the uptake of increasingly expensive water slows e.g. Johannesburg (DWA, 2011). Furthermore there are no economic drivers identified for this region such as ports or development corridors. The majority of the development in KZN is currently occurring on the north coast with the re-location of Durban's Airport to King Shaka International.

As such growth is likely to be gradual and based on the same drivers that have promoted growth over the past 15 years, e.g. urbanisation. Linear growth is thus believed to be most representative of likely future growth in the area than exponential growth as suggested in the *Water Resources Planning Study* (Ugu, 2004).

Recently the DWA conducted reconciliation studies for a number of smaller centres/towns around the country, namely The *Development of a reconciliation strategy for All Towns in the Eastern Region* (DWA, 2011). The report was prepared by the DWA (2011). The high, medium and low water requirement projection scenarios for the Umzimkhulu water supply scheme adopted linear growth rates of 2.7%, 1.7% and 0.7% respectively. These growth rates are similar in magnitude and to those developed by the *Water Resources Planning Study* (Ugu, 2004), but also adopt linear growth as apposed to exponential growth. The water requirement growth rates developed by the *Development of a Reconciliation Strategy for All Towns in the Eastern Region* (DWA, 2011), also make allowance for expansion in the supply footprint of the Umzimkhulu RWSS to areas with a backlog is water supply services and for increased levels of water services into the future. The Water requirement projections scenarios as determined by the *Development of a Reconciliation Strategy for All Towns in the Eastern Region* (DWA, 2011), are presented in **Figure 3-5**.

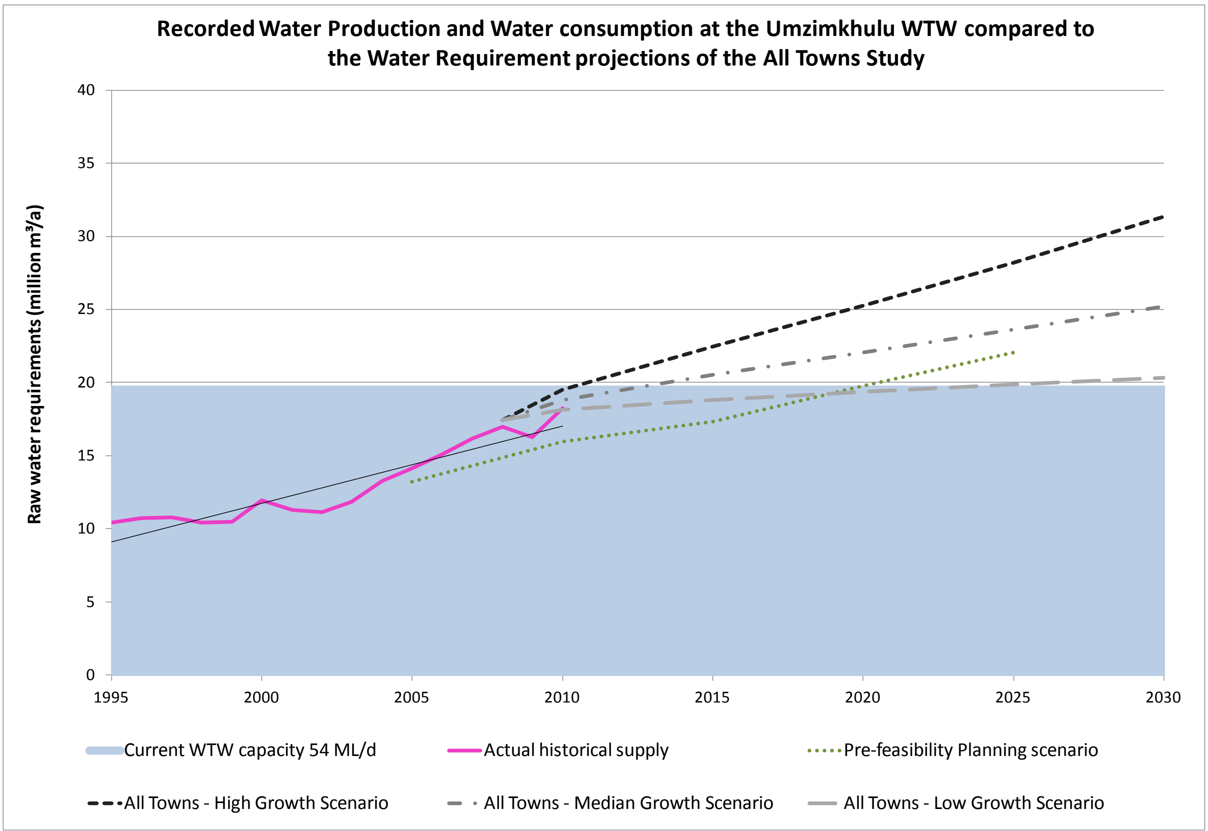

Figure 3-5: Comparison of water supply record with projected water requirements from the All Towns Study (DWA, 2011)

High, medium and low growth rates of 3.3%, 2.3% and 1.3% applied in a linear manner where thus adopted by this feasibility to cover the range of likely water requirement growth expected for the Umzimkhulu RWSS. Furthermore the medium growth scenario was selected as the planning scenario, and the high and low growth scenarios selected as the upper and lower bounds of the water requirement projection envelope. These water requirement projection scenarios where discussed and accepted by the key role players (DWA, UGU, and BKS). The three scenarios of water requirement projections presented in **Figure 3-6** and **Table 3.11**.

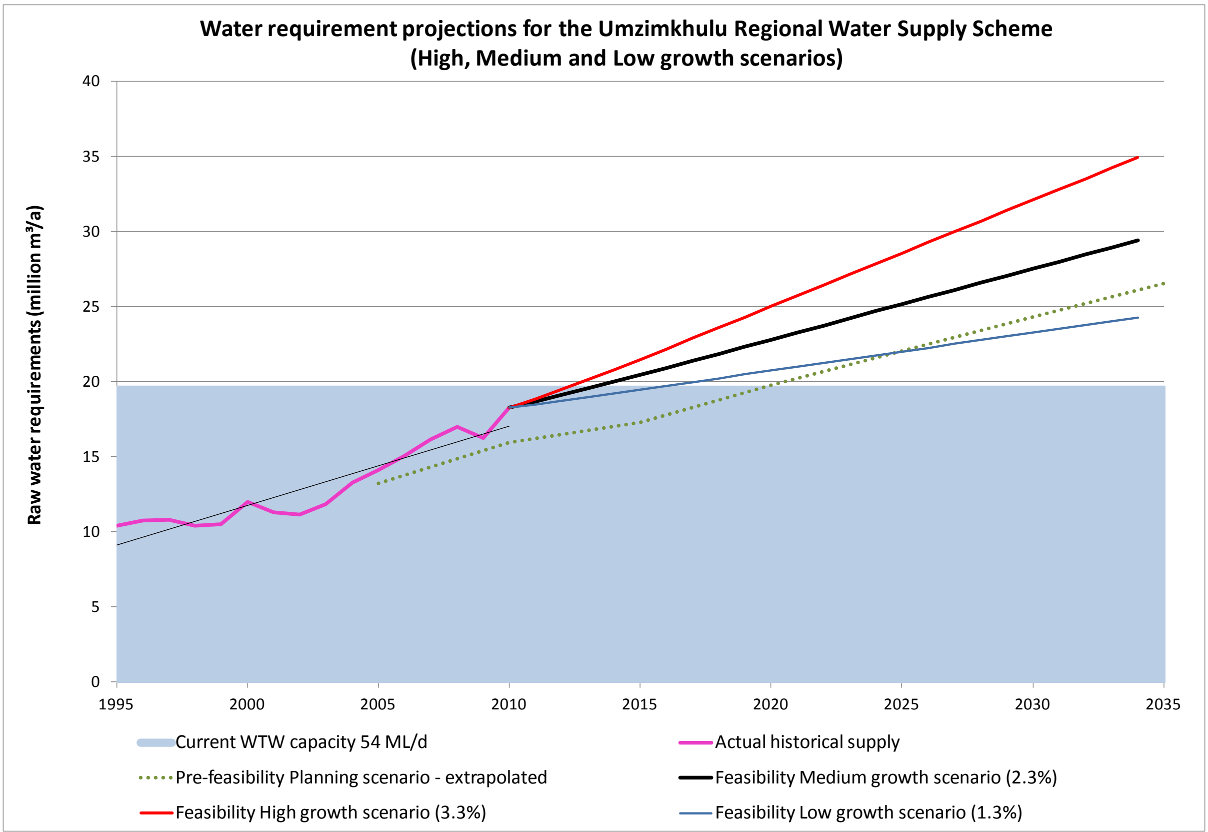

Figure 3-6: Water requirement projections scenarios adopted for the feasibility study

Table 3.11: Production Growth rate scenarios

Requirement projection assumptions	
Scenarios	**Umzimkhulu production growth rate**
Lower bound	1.3 %/a
Medium growth	2.3 %/a
Upper bound	3.3 %/a

Due to the current high level of water losses included within the water consumption figures, the water loss reduction through WC/WDM measures as described in **Section 3.2.1** should be added to the water requirement projection scenarios to account for more efficient use existing and future water resources. The impact of water loss reduction (2010 to 2015) on the water requirement projection of the planning scenario is presented in **Figure 3-7**. Apart from more efficient and sustainable use of the water resource, the successful reduction of water losses through WC/WDM measures will also have the very important impact of delaying the need for upgrading the Umzimkhulu WTW's capacity by about four years.

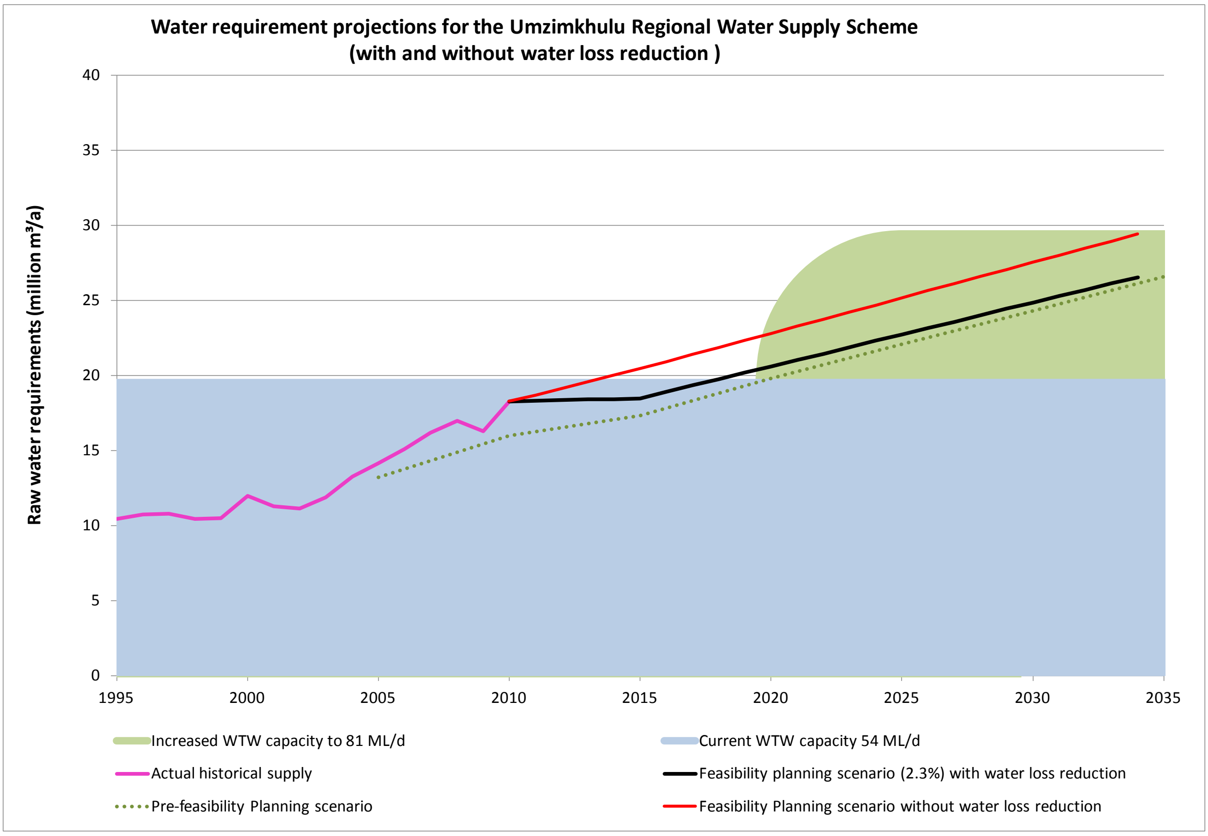

Figure 3-7: Water requirement projection planning scenario adopted for the feasibility study, with and without WC/WDM

Population and water requirements have been determined for the existing Umzimkhulu RWSS supply area. There are however, areas outside of the existing supply area that are in need of water services delivery and could be supplied water from the proposed OCS dam through an expansion of the Umzimkhulu RWSS supply area.

3.4 UMZUMBE SUPPLY AREA

3.4.1. Mlhabatshane Regional Water Supply Scheme

As introduced in Section 3.1.3.3, the portion of the Umzumbe Local Municipality around the proposed OCS dam has limited or no water supply services. Currently there are smaller stand-alone schemes within the Umzumbe rural area that draw water from the Umzumbe River, namely the Phungashe, the Ndwebu and Assissi schemes. Some of these stand-alone schemes are planned to be incorporated in phases into a larger Mlhabatshane Regional Water Supply Scheme (RWSS). Various studies have been conducted on the planning of the Mlhabatshane RWSS by the Ugu DM. Currently Umgeni Water is busy implementing the Mlhabatshane Dam and first phase of the bulk water scheme which will incorporate the existing Phungashe scheme. Ultimately the Mhlabatshane water supply scheme is planned to supply the full area between the Umzimkhulu and Mzumbe rivers, from Phungashe in the North-west to Frankland in the South-east. This would cover ten tribal authorities and forty-nine tribal wards, which also includes the Shabeni and KwaMadladla areas that are located in the Hibiscus Coast Municipality. The areas to be supplied within the Umzumbe Municipality are the Bhekani, Nhlangwini, Mabhaleni, Hlubi, KwaCele 1, KwaCele K, Qwabe P and Frankland areas.

Initial plans were for the Mlhabatshane RWSS to supply the full supply area with a level of service of 32.5 ℓ/c/d. Subsequent to the *Mlhabatshane Pre-feasibility Study*, the Ugu DM requested that various options be investigated to bring this level of water service up to the desired 60 ℓ/c/d. This was conducted as a follow up study namely the *Mlhabatshane Regional Water Supply Scheme Report – Bulk Supply Options* (Ugu, 2009). The study concluded that the yield of a practical sized Mlhabatshane Dam of 1.56 million m^3/a, will not have sufficient water to supply the planned area in its entirety with the desired level of service of 60 ℓ/c/d. The option of abstracting water from the Umzimkhulu River adjacent to Phungashe in summer to augment the yield of the dam was proposed. This option could yield sufficient water to meet the water requirement of 2.79 million m^3/a for the population of the Umzumbe area earmarked for supply of about 101 000 people at 60 ℓ/c/d.

3.4.1.1 Umzumbe – Mhlabatshane supply area population

The population and household count used to determine the water requirement of 2.79 million m^3/a by the *Mlhabatshane Regional Water Supply Scheme Report – Bulk Supply Options* (Ugu, 2009) is included in **Table 3.14**, was based predominantly on the Census 2001 data. As a significant portion of the base data behind the water requirements for the Umzumbe area were now more than 10 years old, the study team felt it necessary to update the information. As such a household count was conducted for the whole Umzumbe supply area. This was conducted using recent aerial photography and GIS software. The revised household count for 2010 is included in **Table 3.13**. Through discussions with the Ugu DM, it became apparent that the KwaMdlala was already serviced by the Umzimkhulu RWSS and as such would not be a part of the Planned Mhlabatshane RWSS. Excluding the KwaMdlala population for the potential Mlhabatshane supply area was in the order of 90 500 using predominantly 2001 census data. Using the 2010 information the population stands at about 97 000.

The household count identified the area to be rural or semi-rural. This was confirmed by the resent sector wide infrastructure audit performed by Ugu (2011), which provided the percentage distribution for settlements types in the Umzumbe Municipality shown in **Table 3.14**. This confirms the population as essentially rural.

Table 3.12: Population and household count from Mlhabatshane Regional Water Supply Scheme Report – Bulk Supply Options Study (2009)

Tribal authority	Estimated no. of houses	Household occupancy	Population estimate	Source of data
Bhekani	261	5	1 197	Census 2001
Nhlangwini (West)	3 175	8	25 401	Census 2001/ Hut Count
KwaCele 1	1 989	6	11 723	Census 2001
Hlubi	976	5	4 826	Census 2001
Mabhaleni (West)	1 304	8	10 426	Census 2001/Hut Count
KwaCele K	2 253	4	9 519	Census 2001
Frankland	600	7	4 200	Business Plan
Qwabe P	795	8	6 360	Business Plan
Shabeni	1 845	8	16 605	Business Plan
KwaMadlala	2 100	5	10 705	Census 2001 + 1.5% p.a. growth
Total	**15 298**	**6.5**	**101 062**	

Table 3.13: Population based on 2010 aerial photography house count

Area	Houses	Dwellings	Population	Schools	Clinics	Hospitals
Mlabatshane supply area (*excl. KwaMdlala*)	957	29 653	97 054	46	7	0
Assisi supply area	198	3 177	11 028	2	1	0

Table 3.14: Distribution of households in settlement types

LM	Percentage of households					
	Formal urban	Informal residential	Linked rural	Good access rural	Limited access rural	Scattered
Umzumbe	0.08%	0.00%	28.49%	25.67%	17.83%	27.93%

3.4.1.2 Umzumbe – Mhlabatshane supply area population

Although a number of studies on rural areas have show very little or even negative growth, the increase in population based on the revised population count for 2010 suggests that the population may well be growing albeit slowly. This is particularly likely for the areas closer to Port Shepstone and the coast, which are becoming denser through migrations from deeper rural areas to be closer to urban centre.

Three growth rates, namely low, medium and high, with annual growth rates of 0.0%, 1.0% and 1.3% respectively were adopted for the water requirement projections. These growth rates accommodate both a small increase in population as well as possible increases in level of service above the current 60 ℓ/c/d target. The medium growth scenario was assumed as the most likely growth rate for the area, as it is more in line with the estimated growth between 2001 and 2010 of about 0.9% based on the two different household counts.

3.4.1.3 Umzumbe – Mhlabatshane supply area water requirements

For the current population of 97 000 for the Mhlabatshane Supply area in Umzumbe at a level of water service of 60 ℓ/c/d (with reasonable bulk conveyance losses of 25%) the 2010 requirement is in the order of 2.85 million m^3/a.

The yields of the Mhlabatshane Scheme are given in **Table 3.15**.

Table 3.15: Yields of the Mhlabatshane scheme phases

Mhlabatshane Scheme	Yield (million m^3/a)
Phase 1 – Dam only	1.56
Phase 2 – with abstraction from the Umzimkhulu in summer	2.79

Based on the medium growth scenario of 1.1% per annum, the water requirements for the planning horizon of 2035 increase to 3.64 million m^3/a. This is greater than the yield that the Mlhabatshane scheme with abstraction from the Umzimkhulu River in summer (phase 2) can yield 2.79 million m^3/a. The projected water balance for the Umzumbe-Mhlabatshane Supply Area with only the Mhlabatshane Scheme is shown in **Figure 3-8**.

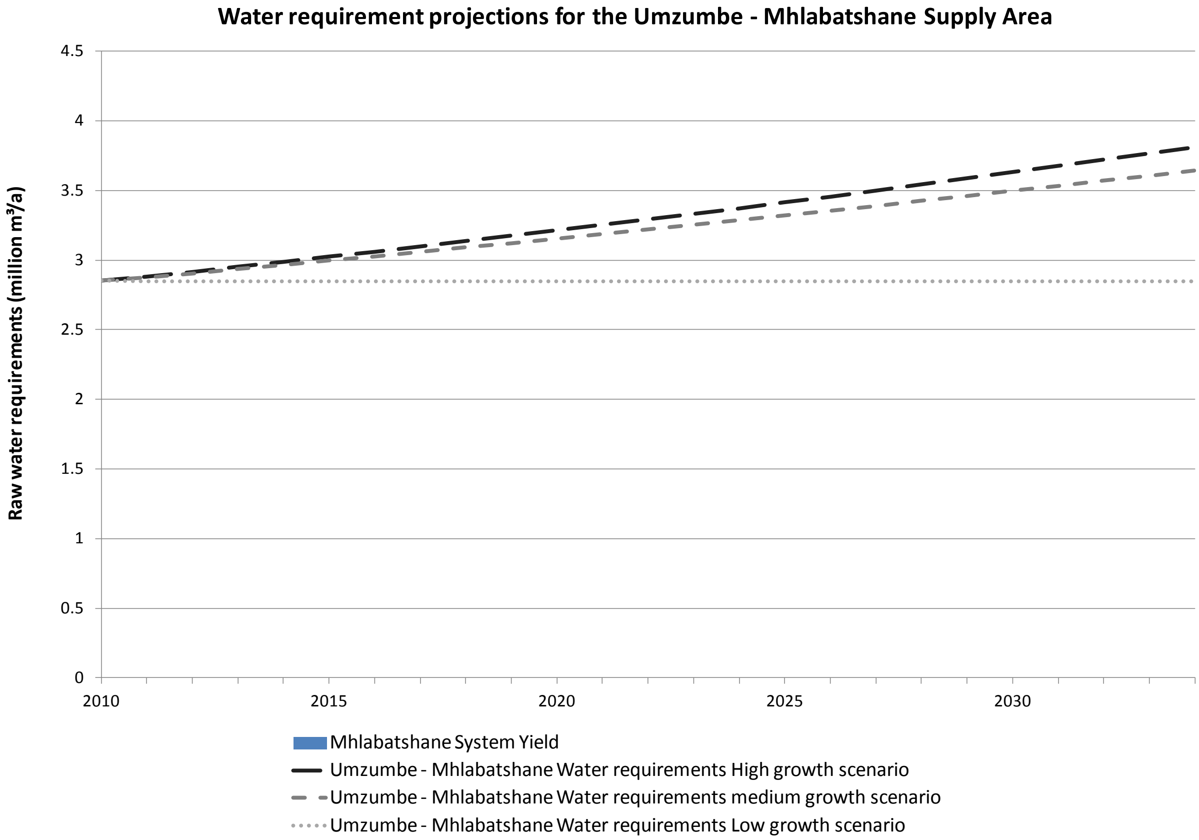

Figure 3-8: Mhlabasthane Water Supply Scheme projected water balance

As such, through discussions with the Ugu DM, it is proposed that the water supply to the Umzumbe area is augmented by the proposed OCS dam, so that the full desired level of service of 60 ℓ/c/d can be achieved. The lower lying areas furthest from the Mhlabatshane Dam could be supplied by the proposed OCS dam, leaving the higher lying areas closer to the Mlhabatshane Dam to be supplied by the Mhlabatshane WSS. The split was based both on the yield available at the Mhlabatshane Scheme and the total area it could supply (southwards), as well as how far Ncwabeni could supply northwards by taking practical pumping height limitations into account. These two criteria aligned well, and resulted in the split as presented in **Figure A4** of **Annexure A.** The proposed supply to each of these areas is thus linked to a specific population and growth thereof. This is shown in **Figure 3-9**. Note, the colours for each supply area used in **Figure 3-9**, are the same as the colours used in **Figure A4** in **Annexure A**.

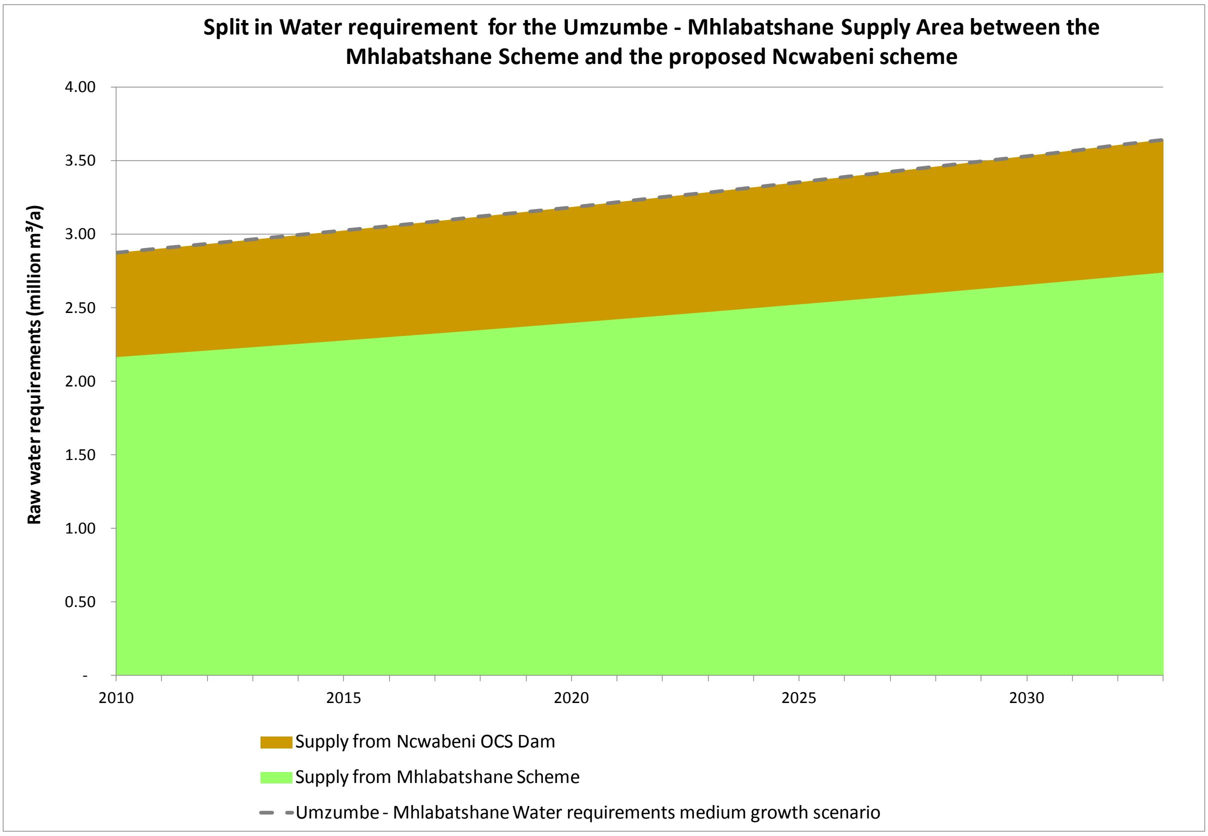

Figure 3-9: Mhlabasthane Water Supply Scheme projected water balance

3.4.2. Assisi Water Supply Scheme

The Assissi Scheme which is in the lower South East portion of Umzumbe, services a dense rural area closer to the coast with a population of about 11 000 people. The Assisi scheme is supplied by water abstracted, run-of-river from the Umzumbe River. Currently the Assissi scheme and local water resource is only capable of achieving about half the desired service level. Previous plans to increase the level of service included linking the Assissi scheme to either the Mlhabatshane scheme as an ultimate phase of the Mhlabatshane Scheme, or to the Umzimkhulu RWSS. As already indicated the Mhlabatshane scheme does not have sufficient yield for this additional water requirement, and it is proposed that the Assissi Scheme becomes part of the Umzimkhulu RWSS supply area. This could either be direct supply from the OCS dam, or by extending the existing Umzimkhulu RWSS pipelines to link with the Assisi scheme. It is further proposed that the full water requirement of the Assisi scheme supply area be allocated to the proposed OCS dam and the Umzimkhulu RWSS. This will allow the water resource of the Umzumbe River to be used for supply northwards into the Hlokozi/Vulamehlo Water Supply Area of Umzumbe, which Ugu DM have indicated needs further water supply augmentation due to limited water resources.

The addition of the Assisi Supply Area Water requirements to the Umzimkhulu RWSS as well as the portion of the Mhlabatshane supply area water requirements also being assigned to the Umzimkhulu RWSS is shown in **Figure 3-10**.

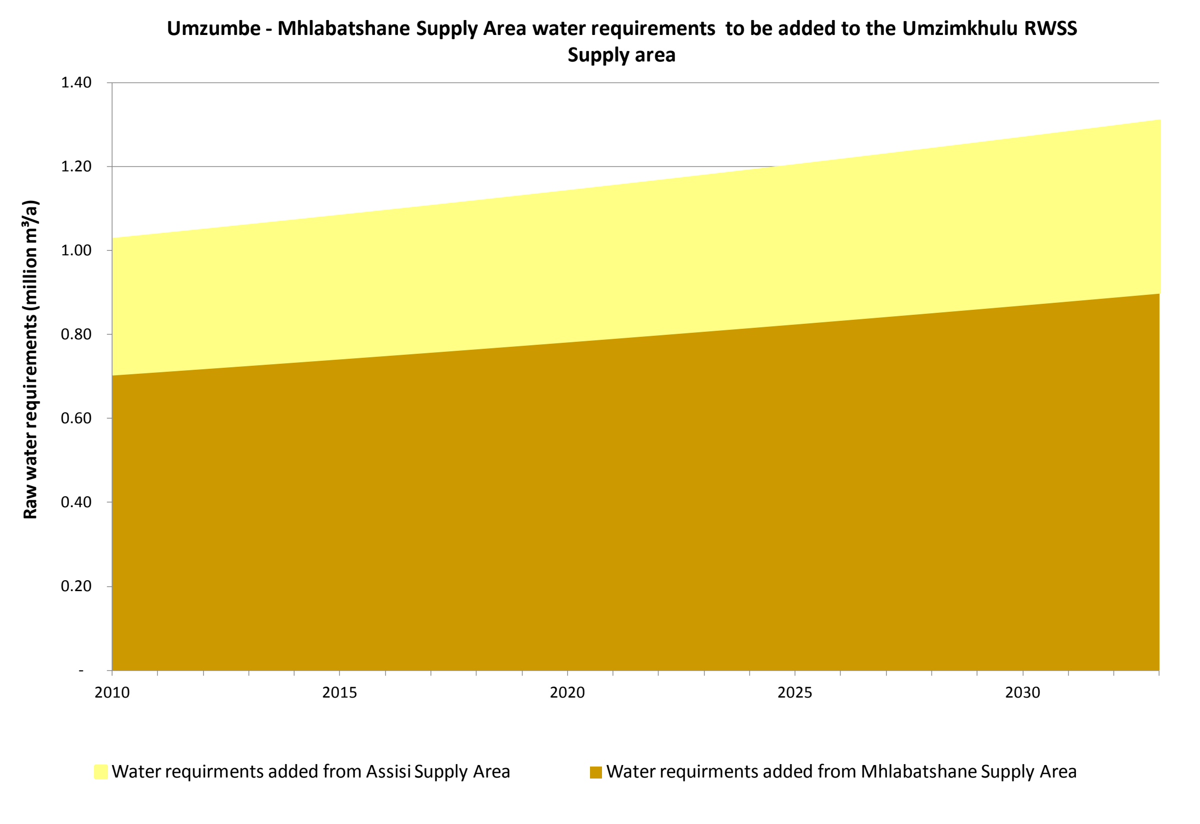

Figure 3-10: Umzumbe water requirements to be added to the Umzimkhulu RWSS

The total water requirement to be added to the Umzimkhulu RWSS for Umzumbe is thus about 1.0 million m^3/a in 2010, growing to about 1.3 million m^3/a by 2035.

3.4.3. Supply into the Umzumbe area from the proposed OCS dam

The final proposed supply split of Umzumbe into the Mlhabatshane Supply area and the Umzimkhulu RWSS is shown in **Figure A3** of **Appendix A**. It is important to note that this study by the DWA is focused on the development of the water resource, and identifying the likely future water requirements that will need to be reconciled with the new water resource development. The future water requirement projections thus inform the sizing and timing of the proposed OCS dam. The final detailed bulk water infrastructure planning, layout and optimisation will be conducted by Ugu DM, the Water Services Authority for the area. However, to facilitate a realistic supply area for the proposed OCS dam, some basic planning of possible bulk water infrastructure was conducted as touched on in **Section 3.3.1.3**. This pre-feasibility level information may also assist Ugu DM in revising the bulk water plans for the area considering the inclusion of the proposed OCS dam.

Supply route options

There are two options for supply into the Umzumbe area from the propose Ncwabeni OCS dam. Either direct abstraction from the dam, treatment at a new works near the dam and distribution, or extension of the existing Umzimkhulu RWSS pipelines and supply of water abstracted at St Helen's Rock and treated at the Umzimkhulu WTWs. These two supply options are shown in **Figure A3** in **Appendix A**.

For comparison purposes, pre-feasibility level capital costs as well as URV's including pumping costs were determined for the two options. Option A would constitute the direct supply from the OSC dam, with the provision of a new treatment works and pump station. Option B entails the supply from the WTW at St Helens rock. Some upgrading to the WTW and existing pipeline infrastructure may be required.

Table 3.16 indicates the estimated cost for the implementation of each option as well as the calculated URV's. From the table it can be seen that the two options are similar in magnitude and considering the low level of detail involved in the design and cost estimates, the relatively small differences indicate further investigation of both options is needed by Ugu DM.

Table 3.16: Estimated cost breakdown for bulk infrastructure Option A and Option B

Estimated cost		
Infrastructure	**Option A**	**Option B**
Pipelines	R 11 178 230	R 49 354 250
Pump stations	R 9 729 011	R 17 160 722
Reservoirs	R 28 682 380.215	R 32 984 737.247
Water treatment works	R 45 115 328	R 24 813 431
Total	**R 94 704 949**	**R 124 313 140**
URV - R/m^3 (1)	**3.29**	**3.97**

(1) URV includes O&M costs

3.5 TOTAL WATER REQUIREMENT PROJECTIONS FOR THE UMZIMKHULU RWSS

The total water requirements for the Umzimkhulu RWSS are the combination of the water requirement projections for the Existing supply area and the water requirements identified in the new Umzumbe supply area. These water requirements are presented in **Figure 3-11**. The water requirement projection was extended until

2040, to allow for a 20 to 25 year supply window if the OCS dam is to be constructed between 2015 and 2020. Based on this planning horizon, the OCS dam will thus be sized to yield about 30 million m^3/a, to be able to meet the planning horizon water requirements.

The water availability of the Umzimkhulu RWSS will now be assessed, both without and then with the OCS dam to determine both the timing and size of the dam required.

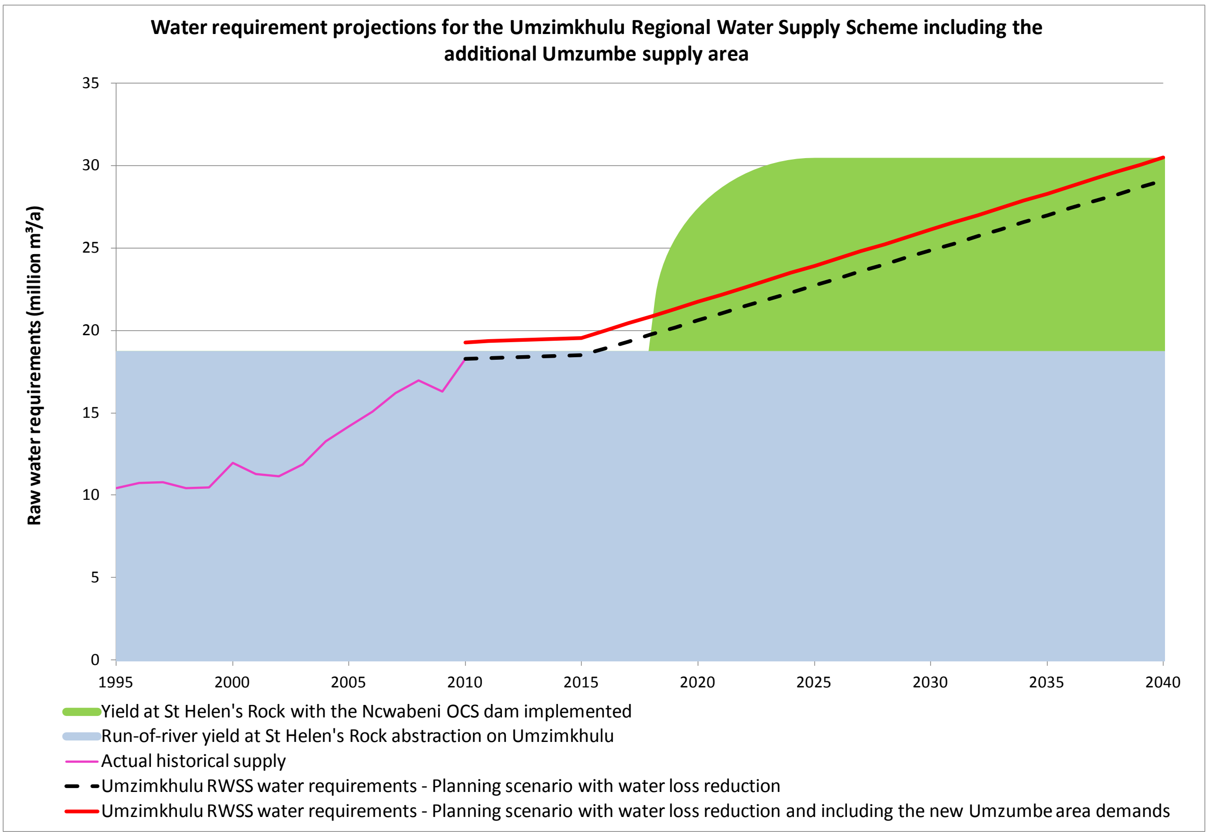

Figure 3-11: Planning scenario Water requirement projection to be used for sizing the off-channel storage dam

4. HYDROLOGY

As part of assessing the water availability of the proposed OCS dam, the hydrology available for the Umzimkhulu River catchment is to be updated.

4.1 ASSESSMENT OF THE HYDROLOGY

Due to the limited time available for the execution of this task, the terms of reference indicated that the study only extends the rainfall and runoff records of the hydrology by a year, and does not perform a full general hydrology update. The Umzimkulu River hydrological data were recently updated to the end of the 2007 hydrological year (September 2008) by the *Mzimkhulu River catchment Water Resource Study*

(MRCWRS), DWA (2011). The scope of this task was therefore to review the hydrology to the end of the 2008 hydrological year (September 2009).

The following was noted:

- The Mzimkhulu EWR assessment, a parallel task to the hydrology task of the *MRCWRS*, expressed some concerns with regards to the flow data.
- Preliminary comparisons between the pre-feasibility study and the *MRCWRS* showed significant differences in mean annual runoff (MAR) for both the Ncwabeni River as well as the greater Umzimkhulu River at St Helen's Rock. The differences were, however, not consistent as can be seen in **Table 4.1**.

Table 4.1: Comparison of naturalised mean annual runoff for selected points in the catchment by previous studies

Location/catchment	MAR - Natural (million m^3/a)			
	MRCWRS (1)	SKZN (2)	WR90 (3)	WR2005 (4)
Ncwabeni Dam	4	5.5	6.3	6.25
T52M	33	43.3	49.2	48.9
St Helen's Rock	1 450	1 346	1 382	1 373

As such the study team, in consultation with the DWA, found it necessary to review the hydrology. Furthermore the value of updating the hydrology by a year was assessed with an initial review of the 2008 hydrological year data. Unless the 2008 hydrological year was particularly dry it will have little effect on the yields of the system.

4.2 2008 HYDROLOGICAL YEAR

As a starting point for assessing the 2008 hydrological data, rainfall data was reviewed. Naturally there is a link between extreme rainfall and runoff, and very high or very low rainfall will result in very high or very low flow in the Mzimkhulu River. Rainfall data is easier to analyse against historical records since it is not affected by land-use. Fewer gaps are usually found in the rainfall data. Patching of flow data can be quite problematic and time-consuming. The reasons for gaps are numerous, including floods, human error, measuring error, electronic problems, vandalism, etc.

4.2.1. Rainfall

Figure 4-1 was published by the South African Weather Services and shows the rainfall deviation from the normal for the 2008 hydrological season for the entire South Africa.

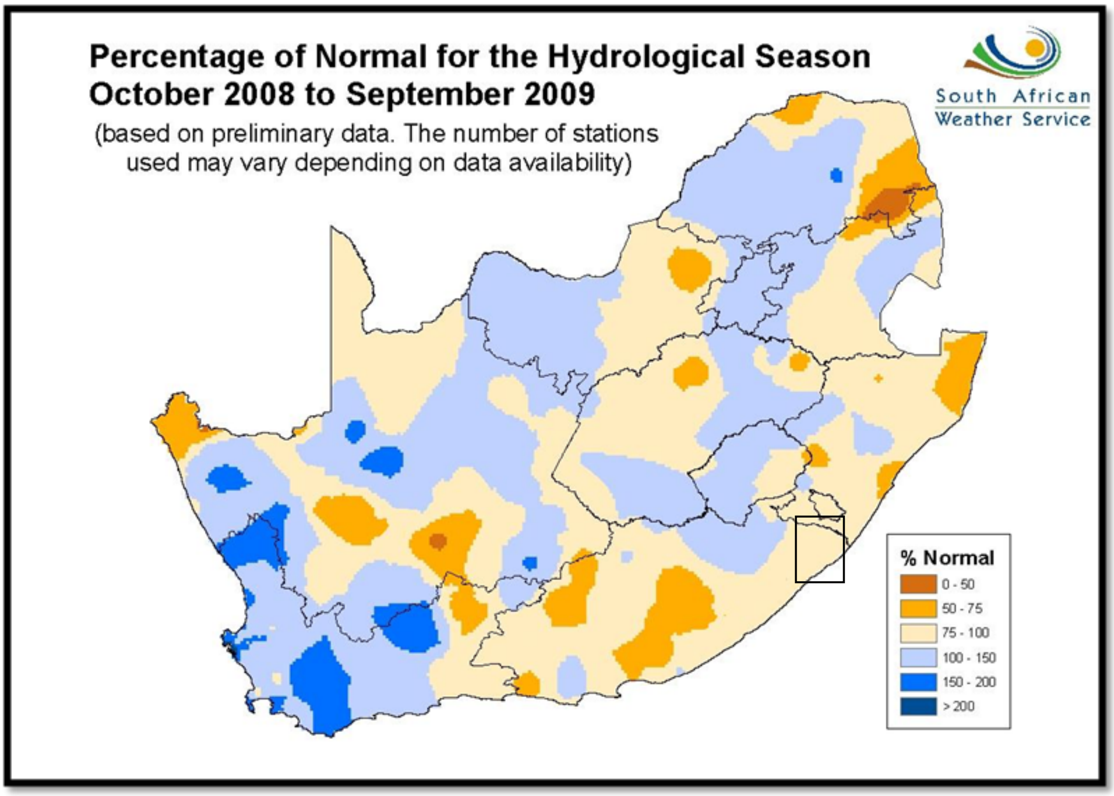

Figure 4-1: Rainfall deviation from average for the 2008 hydrological year

The Umzimkhulu River catchment lies within the rectangle indicated in **Figure 4-1**. This area falls in the 75% to 100% zone of deviation from normal rainfall. This indicates that the annual rainfall measured for the 2008 hydrological season was average, or just below average.

4.2.2. Flow data

Flow data that was patched during the *MRCWRS*, were extended with observed flow from the DWA website to include the 2008 hydrological year for three flow gauging stations on the Umzimkhulu and Umzimkhulwana (tributary of the Umzimkhulu River) rivers. These three gauges were selected due to their spatial distribution covering most of the catchment, and the fact that these stations were also selected by the *MRCWRS* for calibrating flow against rainfall. Details of the flow gauging stations used to calibrate the hydrology and also selected for analyses of the 2008 hydrological year are shown in **Table 4.2** and **Figure 4-2**. **Note:** T5H007 was not used for 2008 data but is an important reference gauge in the catchment.

Table 4.2: Selected stations to be analysed for the hydrological year 2008

Station	River	Calibration period	MAR (excl. 2008) (million m^3/a)	2008 total run-off (million m^3/a)	Comments
T5H004	Umzimkhulu	1949 - 2008	242	250	
T5H007	Umzimkhulu	1956 -1978	1 003	800[1]	Last portion of record not used in calibration as the MAR's are much lower. Gauge underestimates low flow, probably land-use impact.
T5H012	Umzimkhulwana	1970 - 2008	33	48	

[1]Roughly patched by inspection of daily values

Figure 4-3 shows that for the three gauges with 2008 hydrological year data, the 2008 runoff of T5H012 was 40 % higher than average, the 2008 runoff of gauge T5H004 was average, and the 2008 runoff for T5H007 was about 24% lower than average. The relative difference of T5H007 is skewed by the statistics being based on a record period from 1956 to 1977, when land use in the catchment was lower. The 2008 year with high land use is expected to be lower even for an average year. This effect of differences in land use development is less noticeable for the other two gauges where the record period extended all the way up to 2008, and as such the statistics include recent land use development levels. Based on the MAR of the gauges the runoff for the 2008 hydrological year does not seem more than usually different.

Figure 4-4 shows the relative position of the observed 2008 monthly flows for T5H012, against the range of flows (percentiles) for each month on record. The focus on T5H012 was on at a monthly level as it is the lowest gauge of the three in the catchment and closest to the abstraction points. T5H012 also has a complete record for the past 20 years. Figure 4-4 shows that 2008 does have three drier winter months where flows are approximately equal to the 25% percentile. These winter flows, although lower than average, are not extreme even with the high level of land use in 2008 versus the historical record. The summer months have good higher flows and this would allow an off-channel dam to be filled to support the drier winter months. As such no failures as a result of the 2008 hydrological year flows are expected, and the 2008 year would most likely have no effect on the firm yield of the system.

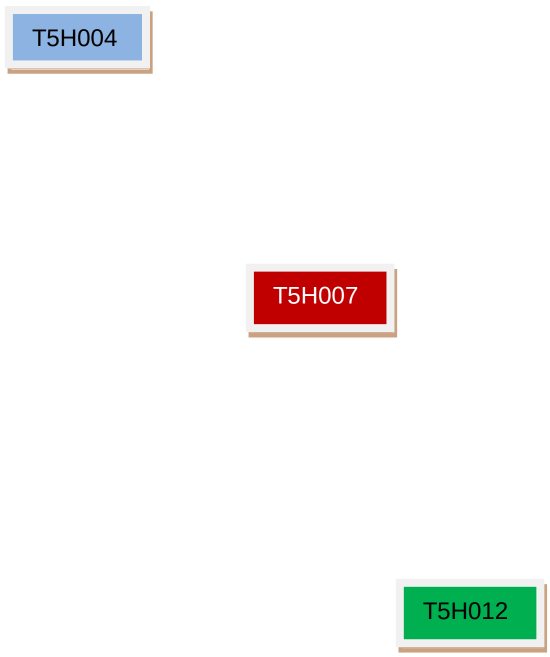

Figure 4-2: Flow gauges reviewed in the Umzimkhulu River catchment

Figure 4-3: Deviation from average of recorded flow for select gauging stations in the Umzimkhulu River catchment

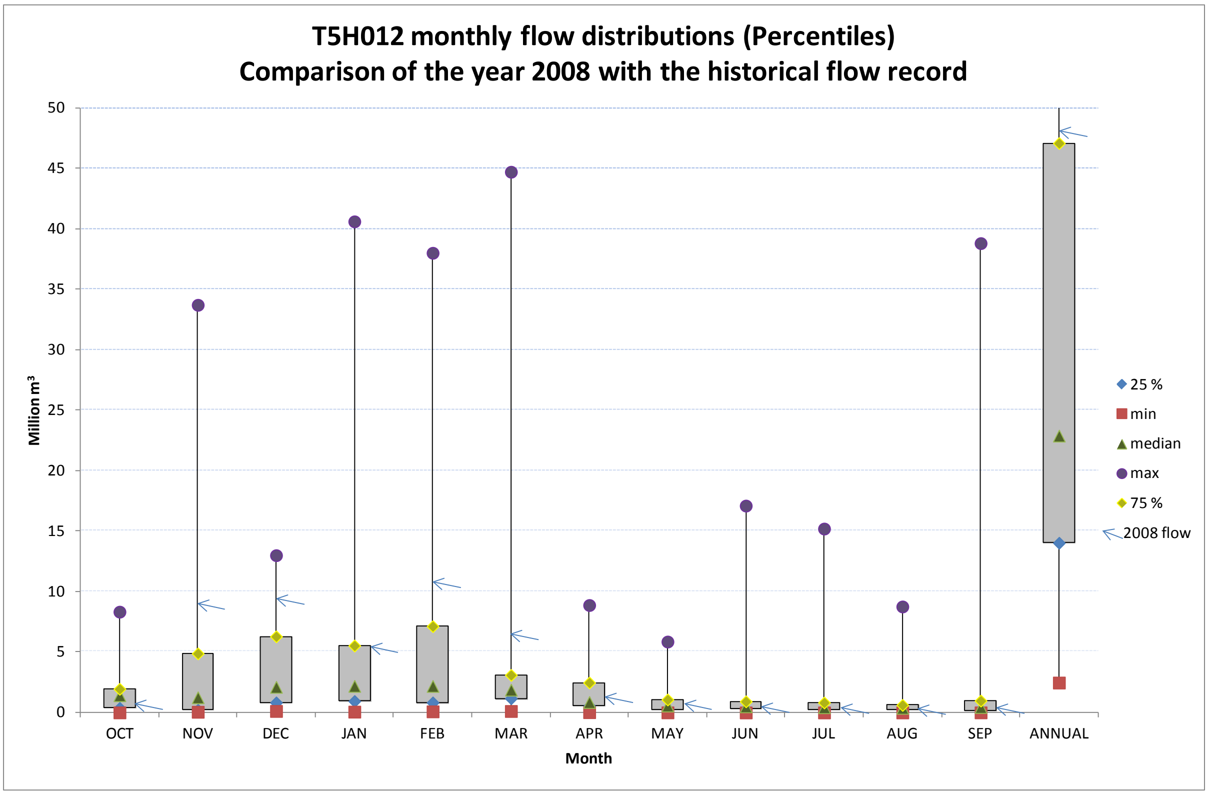

Figure 4-4: Boxplots showing relative percentiles of 2008 flows for T5H012

4.2.3. Conclusion on extension of hydrological data

Based on a review of both rainfall and runoff records the 2008 hydrological year was about average in nature. The updating of the hydrology with this year, which would have taken some effort, will therefore not change the yield calculations. It was therefore not deemed necessary or effective to update/extend the hydrology with one year. The review of the hydrology was presented to the Study Steering Committee who agreed that it was not necessary to update the hydrology, but to rather focus the effort on reviewing the inconsistent differences in the hydrology from the previous studies, placing particular emphasis on the results of the *MRCWRS*.

4.3 REVIEW OF THE HYDROLOGY OF THE UMZIMKHULU RIVER CATCHMENT WATER RESOURCES STUDY

As shown in **Table 4.1**, the naturalised hydrology of the *Umzimkhulu River Catchment Water Resources Study* (MRCWRS) which is to be used for the water availability assessment of this study, differs from that of previous studies, namely the *Southern KwaZulu Natal Water Resources Pre-feasibility Study* (SKZN), the WR90 study and the WR2005 study. As such the task team undertook to review the hydrology of the *MRCWRS* to determine the cause for the differences, and whether the hydrology should be used further in this study.

4.2.4. Approach for the review

The hydrology review consisted of a detailed assessment of the WRSM2000-model's input data, followed by some sensitivity analyses and discussions with a specialist Hydrologists from DWA (Mr Elias Nel) with regards to the official models and also with specialists on the WRSM2005-model, i.e. SSI (Allan Bailey), and Dr Bill Pitman. The results and inputs from the recently completed *WRSM2005* study were also used for comparison purposes.

4.2.5. Input data and methodology of the MRCWRS

Rainfall data was patched and aggregated using the Rain-IMS. The level of the WRSM2005 model configuration was detailed, and afforestation, alien invasive plants, farm dams, dry land sugarcane, irrigation, wetlands, abstractions and return flows were addressed per quaternary catchment, and even finer, where necessary.

An in-depth assessment of the input data and parameters, i.e. looking for typing errors, found two parameters in the present day set-up that were a result of typing mistakes. The values of FT of "20" in T51D should have been "30" and the value of ST should have been "140" but was input as "1 400". These parameters will only affect the run-off from 8% of the total catchment area. This error will have no effect on the calibration and natural flow. This error was corrected in this study. Comparisons of land-use data against the data input in the WRSM2000 showed no discrepancies.

It was interesting to note that the WRSM2000 model, without the SAMI groundwater module, was used for the calibration and simulation of the flow data. The SAMI module for groundwater was, however, used in the *WRSM2005* study. Unfortunately there are too many flaws in the *WRSM2005* study, one being the total exclusion of farm dams. It is therefore not clear what the effect of the inclusion of the SAMI groundwater module is on the hydrology. Official sources at DWA indicated that the SAMI model is still in its infancy and it is not necessarily the prescribed method to use for DWA projects.

The calibration parameters for the WRSM2000 model used by the *MRCWRS* appeared to be unconventional at first, as the parameters Zmin and Zmax were changed. Discussions with various hydrology specialists, however, confirmed that this is not a problem and it is quite acceptable to change the values of these parameters.

The *MRCWRS* opted to use the user-defined method for calculating afforestation water usage. Initial results were not favourable, but the *MRCWRS* conducted further work on the afforestation water use that corrected the initial problems. The *MRCWRS* went into far more detail on afforestation than had been conducted in previous studies.

4.2.6. Sensitivity analyses

A sensitivity analysis was conducted to test the effect of changes in other parameters on the hydrology calibration, particularly those related to afforestation which is a major water user in the catchment. The incremental flow data in T52G was selected for this exercise as the *Reserve Study* indicated some initial concern with the data in this catchment. (Note: The revision of the afforestation water use methodology by the *MRCWRS* has subsequently solved the issues with regards to low flow concerns).

The following scenarios were selected for the sensitivity analysis:

- Scenario 1: Natural
- Scenario 2: present day, no Sami-groundwater, user-defined afforestation
- Scenario 3: Scenario 2, but with Gush afforestation
- Scenario 4: Scenario 2, but with CSIR afforestation
- Scenario 5: Scenario 2, but with SAMI module and WR2005 parameters.

The results of the sensitivity analysis are presented in **Figure 4-5**. The graph shows that the type of afforestation water use calculation method has negligible impact on the runoff. This is confirmed in **Figure 4-6** that shows very similar water use by afforestation calculated by the user-defined method chosen in the *MRCWRS*, and the industry norm of the Gush method. The inclusion of the SAMI-groundwater module does change the flow regime somewhat. Inclusion of the SAMI-groundwater component in the WRSM2000 reduces the medium to high flows and increases the low flows. This is not unexpected, as the groundwater module creates more base-flow. Through discussions with the Strategy Steering Committee, it was decided that the hydrology without the inclusion of the SAMI-groundwater module should be used as this is more conservative with regards to the low flows, which have a big impact on the yield at St Helen's Rock.

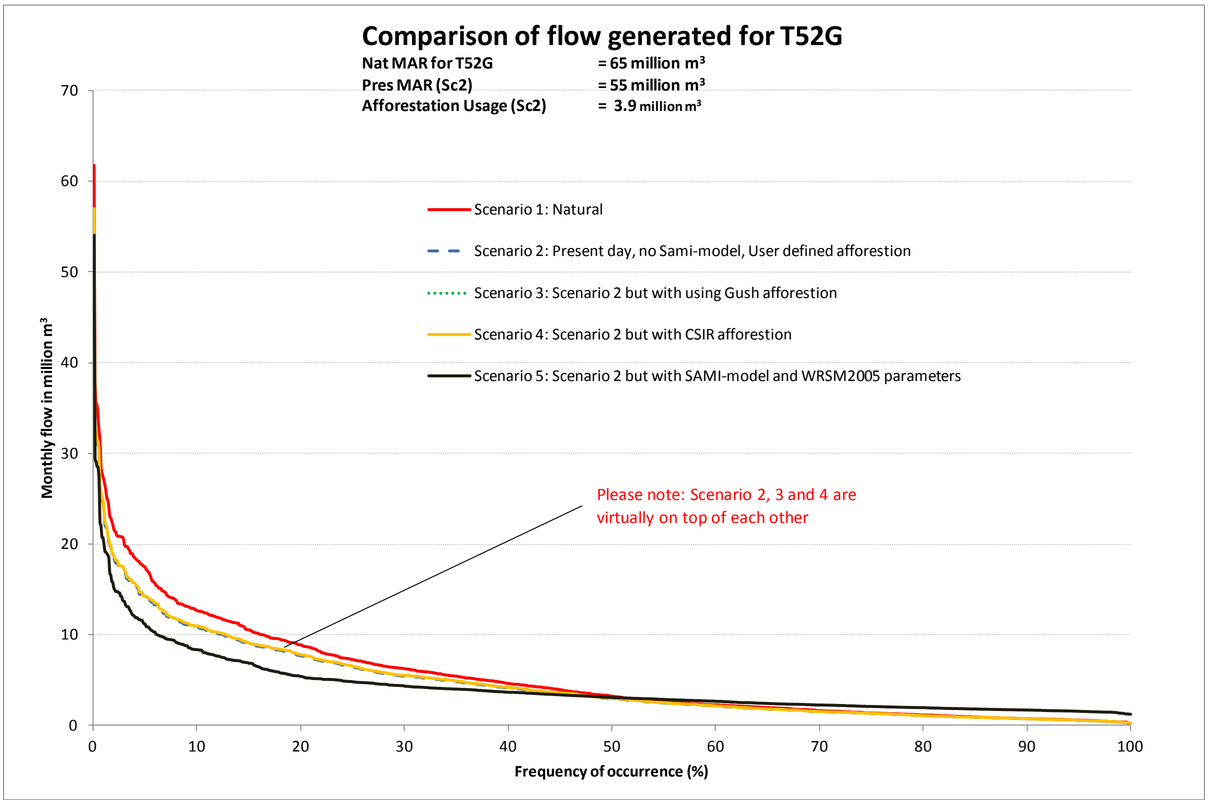

Figure 4-5: Sensitivity analysis for gauge T52G

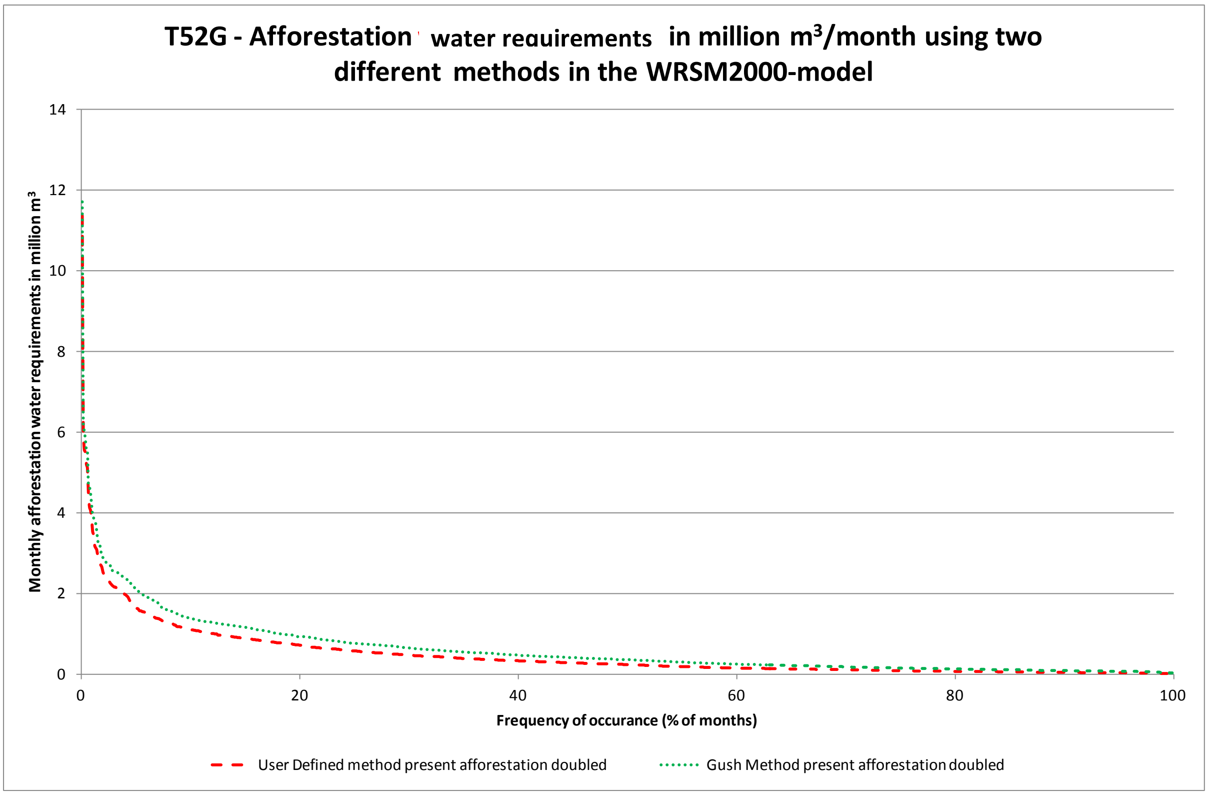

Figure 4-6: Comparison of afforestation water requirements for two methods

4.2.7. Hydrology conclusions

Based on the hydrology review, it appears that there are no fatal flaws in the hydrology as determined by the *MRCWRS*. Initial concerns about afforestation water use have subsequently been resolved. The study was done on a detailed basis focused on the Umzimkhulu River catchment, and is more detailed than previous studies such as the WR90 and WR2005, which most likely explains the differences in the hydrology from the previous studies.

The naturalised hydrology with the revised user-defined afforestation water use, excluding the SAMI-groundwater module, up to the end September 2008 will be used for the water availability analyses.

The future land-use scenarios that have been considered for the yield analyses are discussed in further detail in **Section 6.2**.

5. THE PROPOSED PROJECT

Before the yield analyses are presented the basic layout and functioning of the proposed OCS dam, must be explained. The layout of the two possible OCS dam options, namely the Ncwabeni and Gugamela OCS dams are shown in Figure A2 in Appendix A. In this section the operation of the proposed OCS dam within the greater Umzimkhulu RWSS are discussed further.

The OCS dam will provide releases of water back into the Umzimkhulu River to augment the low flows often experienced in the Umzimkhulu River during the winter months. The water is then abstracted at the existing St Helen’s Rock works about 25 km downstream of the proposed OCS dam sites. St Helen’s Rock itself is about 8 km from the estuary mouth. Although there may be some direct abstraction for communities surrounding the dam site, the majority of the water will be for abstraction at St Helen’s Rock. As such the yield from the dam itself is of less importance than how it increases the yield of the system at St Helen’s Rock. The focus of the yield assessment will thus be at St Helen’s Rock.

The increased yield of the system with the addition of the OCS dam will be derived from:

- Primarily the abstraction, pumping and storage of water from a weir on the Umzimkhulu River into the OCS dam during the summer months when there is surplus water in the river; and
- Incremental runoff directly into the dam from the tributary on which the dam is positioned.

The incremental catchments of the two possible OCS dams are very similar in size and runoff. The likely abstraction points for diverting and pumping water into the OCS dams are also very close together on the Umzimkhulu River main stem (approximately within a kilometre). As such the water resources of the two OCS dam sites are essentially the same. The preferred OCS dam site from a technical perspective will thus be a function of the size and cost of dam for which the required yield can be generated (dam storage characteristics), and the operational costs (pumping height and distance).

The yields analyses provide the yield information for dam size and pumping rate options, also provide an indication of the timing of the required OCS dam project as well as the assurance of water supply to the projected water users. This information will feed into the engineering and cost investigations for the sizing and optimisation of the dam.

5.1 SEDIMENTATION

Reduced sedimentation is an advantage of an off-channel storage dam. Some sedimentation of the off-channel storage dams is still expected from the incremental catchment of the tributary on which the dam lies, as well as some finer particles of sediment being pumped from the abstraction weir and works. Before determining the yields, the anticipated long term sedimentation of the off-channel storage dams need to be taken into account. As a starting point, the sedimentation volumes calculated by the Pre-feasibility Study will be utilised. Once the Sedimentation Yield Review Report and the Physical Hydraulic Model Study is completed, the sedimentation of the OCS dam will be refined. The information obtained from the Pre-fesibility study is included in **Table 5.1.**

Table 5.1: Sedimentation volumes determined by the Pre-feasibility Study

Dam site	Sedimentation volume (million m^3)	
	No off-channel pumping)	*With off-channel pumping*
Ncwabeni (D2)	1.1	2.1
Gugamela (D3A)	1.0	1.8

6. YIELD ANALYSIS

Various yield analyses were performed to determine the water availability of Umzimkhulu Regional Supply Scheme with the addition of OCS dam options. The yields analyses consisted of three phases, namely:

1. Set-up and testing of the Water Resources Yield Model (WRYM)
2. Historic firm yield analyses to determine yields for various sizes of OCS dams and abstraction rates, for the purposes of selecting the best scheme; and
3. Stochastic yields of the final selected scheme to confirm the assurance of supply.

The methodologies, assumptions and results of the yield analyses are summarised in the following sections.

6.1 WRYM SETUP AND TESTING

To simulate the water resources of the Umzimkhulu River and determine the yields of the potential off-channel storage dam options, the Water Resources Yield Model (WRYM) was utilised. The WRYM is a monthly time-step model developed and used extensively on water resource analyses in Southern Africa. This study built on the existing WRYM system configuration developed for the *MCWRS* conducted by the

DWA in 2010/2011. Some enhancements that were made to the configuration of the *MCWRS* are as follows:

- Gugamela OCS Dam (referred to as D3A in the pre-feasibility study) was added to the system as an alternative option to Ncwabeni OCS Dam (D2);
- The elevation-area and elevation-storage curves for Ncwabeni OCS Dam were updated based on new topographical survey information;
- The penalty system was refined, particularly with regards to the prioritisation of ecological water requirements (EWRs);
- The configuration of the Lower Umzimkhulu River was refined, particularly the details such as the position of the EWR sites, as well as the portion of the incremental flow of quaternary T52M entering above and below the abstraction points;
- An application to DWA for the pumping of water from the Umzimkhulu River during summer months to the Mhlabatshane Scheme in the neighbouring Umzumbe River catchment has been made. This was refined based on discussions with Umgeni Water; and
- The inclusion of a hydropower scheme near the project site. This was only done after initial runs and once the information was obtained through discussions with stakeholders.

Further to this the daily abstraction efficiencies included in the model for both the existing run-of-river abstraction at St Helens Rock and the proposed abstraction weir for the OCS dams were tested and confirmed. The daily abstraction efficiencies are discussed in more detail in **section 6.3.2**. After these updates and tests to the WRYM system configuration were made, various basic tests were conducted to confirm the correct functioning of the model. This included comparisons of the flows of the updated configuration and the original *MCWRS* configuration, such as the flow at the estuary.

6.1.1. Setup and penalty structure

The penalty structure was refined for this study, particularly with regard to the EWR channels. The reason for this is that the *MRCWRS* approached the modelling of the water availability with a different method and purpose. The approach used by the *MRCWRS* was to use a low penalty (priority) for the EWR channels and then increase upstream land use until the EWR could not longer be met. This was done in particular to determine how much afforestation development could be added to the catchment before negatively affecting the EWR.

When determining the yields of the possible dam options in this feasibility study, the EWR channels were given high penalties (priorities) and the yields were then determined after the EWR's were satisfied.

6.1.1.1 Ecological Water Requirements

The ecological water requirements (EWR) were reviewed by the study team to confirm their appropriate inclusion and application in the WRYM.

This was done by obtaining the information determined by the reserve team of the *MRCWRS* and comparing this against the information as included in the WRYM configuration of the MRCWRS. Discussions were also held with the Reserve team of the MRCWRS.

The full EWR review is included in **Annexure B**. The key outcomes of the review are:

- The EWR's are generally correctly implemented in the WRYM (one small amendment was needed for an EWR site which lies on a tributary of the main river).
- The EWR for the Gibraltar site should be adopted for just below the abstraction weir on the Umzimkhulu River.
- The inclusion of an off-channel storage dam and off-channel pumping in the summer months, together with releases of water for St Helen's Rock in the winter months, does not negatively impact the EWR below the proposed project. EWR compliance actually improves compared to that of the Gibraltar site just upstream.

6.1.2. Present day flows

The present day flows were determined at St Helen's Rock abstraction and at the proposed Ncwabeni abstraction weir site. The requirements of the Gibraltor and estuary EWR channels were also determined. These results were then compared against the present day flows in the pre-feasibility study as well as the *MRCWRS*. **Table 6.1** and **Table 6.2** show the mean annual runoff (MAR) flows at key points in the catchment.

Table 6.1: Present day flows (million m^3/a) at selected EWR sites

	Feasibility study setup flows	
	Requirement	Supply
Gibraltor EWR	359.29	358.73
Estuary EWR	357.98	357.98

Table 6.2: Present day flows (million m^3/a) at selected abstraction points

	Feasibility study	Pre-feasibility study	MRCWRS
St Helen's Rock abstraction	1 203.4	1 220.4	1 236.0
Ncwabeni abstraction	1 162.1	1 148.9	1 174.8

The results show that the flows at key points in the system are similar for the three studies. The small differences, particularly between the feasibility study configuration and that of the *MRCWRS*, are a result of the refinements made to the lower Umzimkhulu River during this study.

6.1.3. Present day yield

Having refined and tested the system configuration, the present day yields were determined for the Umzimkhulu RWSS with the unregulated run-of-river abstraction at St Helen's Rock as per the current situation. The yields were compared to those stated in the pre-feasibility study and are summarised in **Table 6.3**.

Table 6.3: Present day run-of-river firm yields at St Helen's Rock

	Feasibility study (million m^3/a)	Pre-feasibility study (million m^3/a)
Yield with EWR	3.3	0.0
Yield without EWR	18.3	49.0

The present day firm yields determined by this feasibility study are approximately the same in magnitude as the 2010 water requirement. This is to be expected as the water resource is being fully utilised, as was highlighted by salt water being pumped at the St Helen's Abstraction in recent very dry winter months. This figure is also more in line with the current situation than the 49 million m^3/a as determined by the pre-feasibility study. The difference in results is most likely due to the more recent hydrology of the *MRCWRS* used by this feasibility study.

If the Reserve is to be implemented the yield drops significantly as all the water in the river during the dry months needs to be reserved for ecological purposes. It must be noted that the EWRs utilised are preliminary and still need to refined through the classification process, but provide a good initial indication of the significant impact that implementation of the Reserve will have on the current run-of-river abstraction yield. The small increase in yield of 3.3 million m^3/a determined for the feasibility study for the scenario with EWR can be attributed to the inclusion of the small operations off-channel storage dam at St Helen's Rock in the feasibility study, that was not yet considered by the Pre-feasibility Study. This small operations dam has limited storage, but does provide some yield support for a month or two during lower winter flows.

6.2 FUTURE PLANNING SCENARIOS

The present day scenario was used to determine the current system yields and to test the system configuration. When sizing the dam for future water requirements, the yield analyses must take into account the future catchment development levels, particularly that of the upstream catchment. The *MRCWRS* postulated various future development level scenarios. These future scenarios included various levels of expansion in afforestation and irrigation as well as different possible infrastructure developments. All future scenarios included domestic water requirements at an estimated 2030 level. No further increase in irrigation levels is considered.

6.2.1. Scenarios 1: All small growers

Future Scenario 1 (FS1) has increased forestry areas of 29 400 ha for small growers throughout the catchment. FS1 had the further options, the inclusion or exclusion of a mitigation dam on the Ngwangwane River, to mitigate the impacts of the afforestation development on low flows.

6.2.2. Scenarios 2: Small growers in the Bisi catchment

Future Scenario 2 (FS2) is similar to FS1, but only has increased forestry areas of 21 050 ha for small growers in the Bisi and Middle Umzimkhulu river catchments. Again, there is no increase in irrigated agriculture above current areas.

Similarly the inclusion or exclusion of a mitigation dam on the Bisi River, to mitigate the impacts of the afforestation development on low flows was considered.

6.2.3. Scenario 5: No afforestation growth

This scenario although not included in the *MRCWRS* has been included in this feasibility study as an option with no further growth in afforestation over the present day scenario, but includes growth for domestic water requirements. This scenario was called Scenario 5 to avoid confusion with the *MRCWRS* which included Scenarios 1 to 4.

6.3 HISTORIC FIRM YIELD ANALYSES

Historic firm yields (HFY) were determined for various OCS dam sizes and pumping rates utilising the WRYM configuration tested on the present day scenario. As the

OCS dam will fit into a greater scheme, the focus of the HFY analyses was the available yield at the St Helen's Rock abstraction point.

6.3.1. Conveyance losses

As water stored in the dam is to be released back into the river in winter months to augment the low flows in the river, there is a likelihood of some losses between the release point at the dam and the St Helen's Rock abstraction downstream. There is also the reality of practical system operation and the possibility of some inefficiency. As such a conveyance loss of 20 % of the water released was assumed up until the St Helen's Rock abstraction about 20 km downstream. This is the same loss as assumed in the Pre-feasibility Study. As not better information was available, no reason to deviate from the 20 % loss could be substantiated.

6.3.2. Historic firm yields with no pumping

As a starting point, the yields were determined for the system with an OCS dam, with no pumping from the Umzimkhulu River to fill the dam in the wet season. This was done for the most conservative scenario (FS1) and the least conservative scenario (FS5), to determine the range of possible yields. A single dam size was chosen (the dam size suggested by the pre-feasibility study) as a starting point. Due to the limited incremental flows into the dam, the impact of assessing a different dam size without pumping is likely to be small. **Table 6.4** shows the yields for the Ncwabeni OCS dam and **Table 6.5** for Gugamela OCS dam.

Table 6.4: Historic firm yields at St Helen's Rock abstraction with Ncwabeni off-channel storage dam added to the system and no pumping

	Ncwabeni off channel storage dam		
Future scenario	**FSL (m)**	**Capacity (million m^3)**	**Yield at St Helen's (million m^3/a)**
FS1	167.5	15.5	13.57
FS5	167.5	15.5	14.75

Table 6.5: Historic firm yields at St Helen's Rock abstraction with Gugamela off-channel storage dam added to the system and no pumping

	Gugamela off channel storage dam		
Future scenario	**FSL (m)**	**Capacity (million m3)**	**Yield at St Helen's (million m^3/a)**
FS1	175.0	16.0	10.45
FS5	175.0	16.0	13.67

What can be deduced from the previous two tables is that the addition of an OCS dam without abstraction and pumping from the Umzimkhulu River to fill the dam, does not provide sufficient yield to meet current or future water requirements with the inclusion of EWRs. However, the increase from 3.3 million m^3/a to about 13 million m^3/a shows that the addition of the OCS dam in the system will increase the yield by about 10 million m^3/a, even without off-channel pumping. This is the impact of utilisation of the incremental flows of the Ncwabeni or Gugamela tributaries. The net impact on yield as St Helen's Rock is greater than the MAR of these tributaries as the water in the OCS dam is only used to augment low flows.

Off-channel pumping in conjunction with a OCS dam is necessary, which was expected based on the results of the pre-feasibility study.

6.3.3. Daily abstractions

Before determining the yields of the system with an OCS dam included, the abstraction efficiency for pumping water from the Umzimkhulu River into the OCS dam needed to be determined. Daily flows were used to determine the percentage of the monthly flows that can be reliably abstracted. This was done as the WRYM is a monthly time step model and utilises monthly average flows. Peak flows within a month are often greater than practical pumping capacities, and skew the average flow values which can cause over-estimation of the flow that can be abstracted with a pumping capacity constraint. Refer to DWAF (2006) for more detail on the daily abstraction methodology.

The daily flows at two key flow gauges were obtained and assessed:

- T5H007 on the Umzimkhulu River; and
- T5H002 on the Bisi River, a major tributary of the Umzimkhulu River

The daily flows were ranked for each month. The flow that can be abstracted for each day was then calculated as the lesser of either the abstraction/pumping capacity or the actual daily flow. This was done for a range of possible abstraction/pumping rates. This way a relationship between average monthly flow and maximum abstraction possible (hereafter referred to as the daily abstraction efficiency relationship) for each month was established.

The pre-feasibility study utilised an abstraction rate of 0.5 m^3/s. For this study a range of possible pumping rates from 0.3 m^3/s to 1.2 m^3/s were considered. The maximum rate of 1.2 m^3/s was chosen, as at this rate the recommended size of dam in the pre-feasibility study can be filled from empty within three months. No improvement in firm yield is expected for abstraction/pumping rates higher than 1.2 m^3/s.

When analysing the data of the two gauges, it was noted that the trends were different for the two gauges. While the high and medium flows of gauge T5H007 on the Umzimkhulu River main stem where significantly higher than those of gauge T5H002 on the Bisi River, the low flows in the Bisi River where greater. This can be seen in **Figure 6-1**. The trend is not unexpected as although gauge T5H007 (on the Umzimkhulu River) has a larger catchment which creates the high flows, there is greater development in the form of irrigation, afforestation and farm dams in the Umzimkhulu River which impacts on the low flows. As such the Bisi River contributes more relatively during particularly dry periods and should be focused on for the run-of-river abstraction at St Helen's Rock. The abstraction of water for pumping to the proposed OCS dam is to occur during medium to high flows in the summer months when there is surplus water in the river. As such, the flows for gauge T5H007 are more relevant for the OCS dam abstraction.

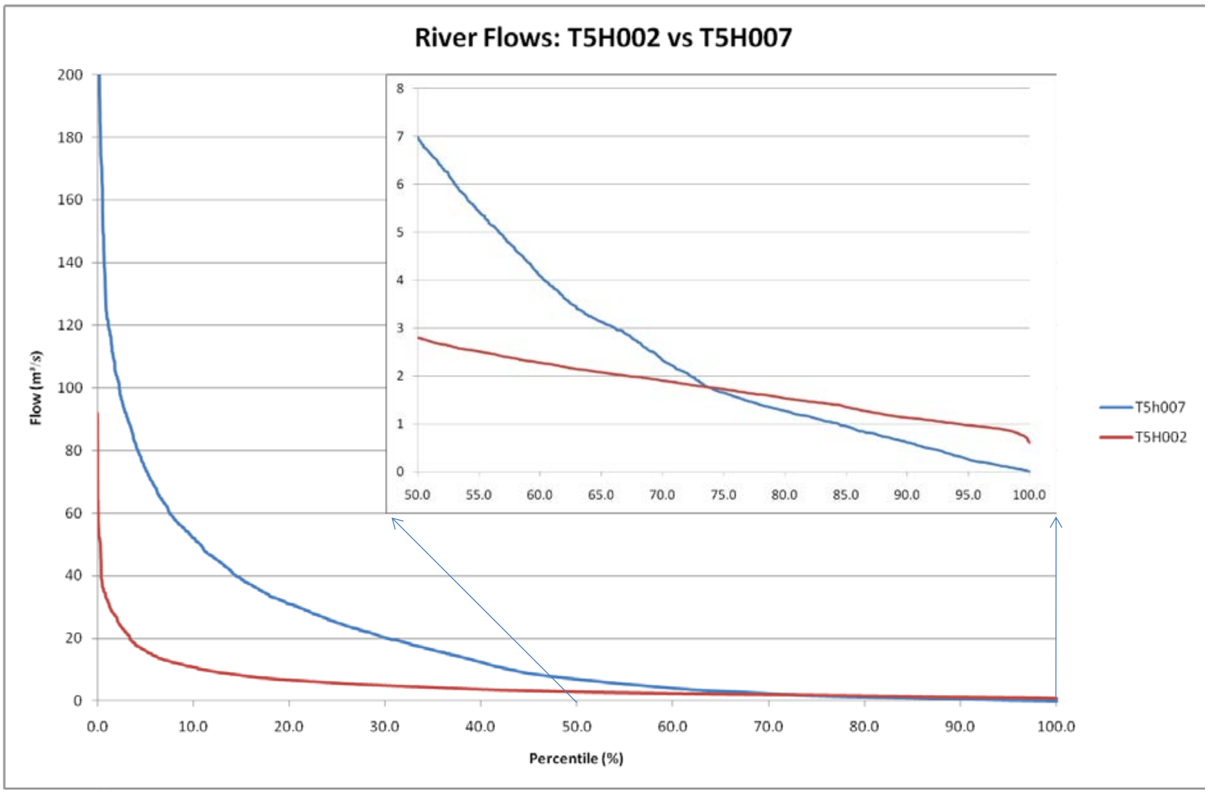

Figure 6-1: Comparison of flows at gauges T5H002 and T5H007 in the Umzimkhulu River catchment

The possible abstractions vs. the monthly average flows were plotted for a maximum abstraction rate of 1.2 m^3/s, for T5H007 and for T5h002 in **Figure 6-2** and **Figure 6-3** respectively. What can be seen is that there is some scatter in the relationship, as months with similar average monthly flows do not necessarily have the same daily distribution of flows. The abstraction efficiency curve plotted in Figure 6.2 is the same curve used in the *MRCWRS* and is a good fit of the scattered points. This abstraction efficiency relationship curve was used in the WRYM. The same curve is plotted in Figure 6.3 and is slightly more conservative for the scatter of points for gauge T5H002. The decision was taken to use the same curve and to be more conservative for the St Helen's Rock abstraction, to account for operational imperfections and difficulties associated with run-of-river abstractions without a weir.

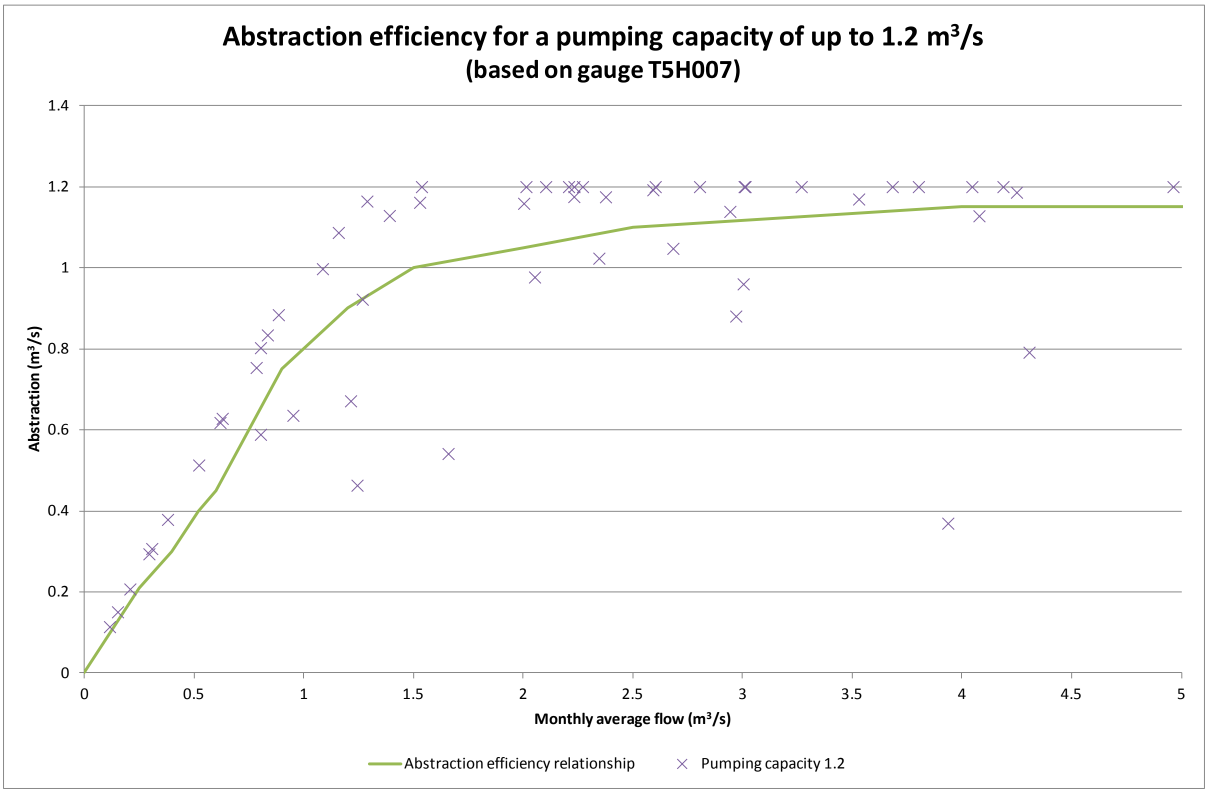

Figure 6-2: Daily abstraction relationship for the off-channel pumping based on gauge T5H007

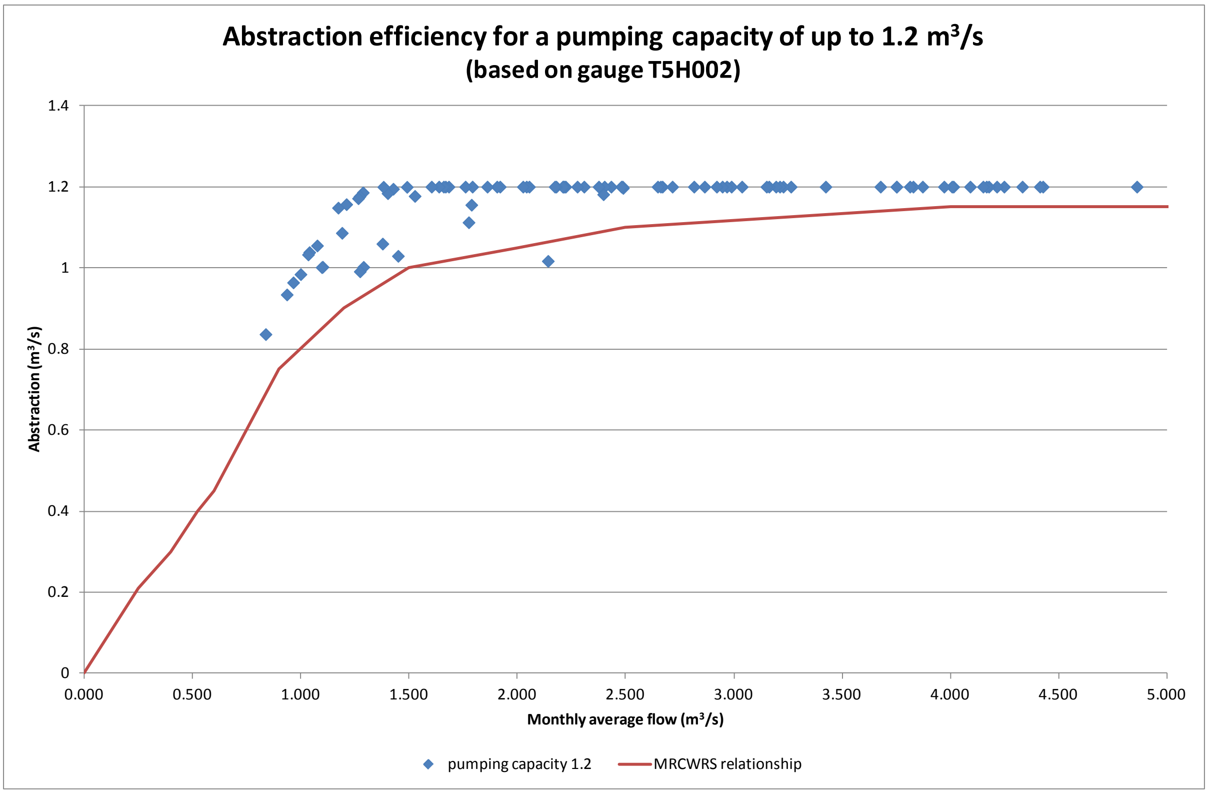

Figure 6-3: Daily abstraction relationship for the off-channel pumping based on gauge T5H007

6.3.4. Historic firm yields with off-channel pumping

The historic firm yield at St Helen's Rock for Ncwabeni and Gugamela OCS dam options were determined for a range of dam sizes and pumping rates. This was done for future Scenarios 1, 2 and 5. A wide range of pumping and dam sizes were considered. The initial dam sizes chosen were those recommended by the pre-feasibility study. Additional dam sizes were then selected to give yields both higher and lower than the projected water requirements. The Historic firm yields determined for Future Scenario 1, 2 and 5 are shown in **Figure 6-4, Figure 6-5** and **Figure 6-6** respectively.

The dam capacities range from 13.5 million m^3 to 23.5 million m^3 for the range of FSL levels of 165 to 175 masl for the Ncwabeni site.

Dam capacities range from 14 million m^3 to 24.5 million m^3 for the range of FSL levels of 165 to 175 masl for the Gugamela site.

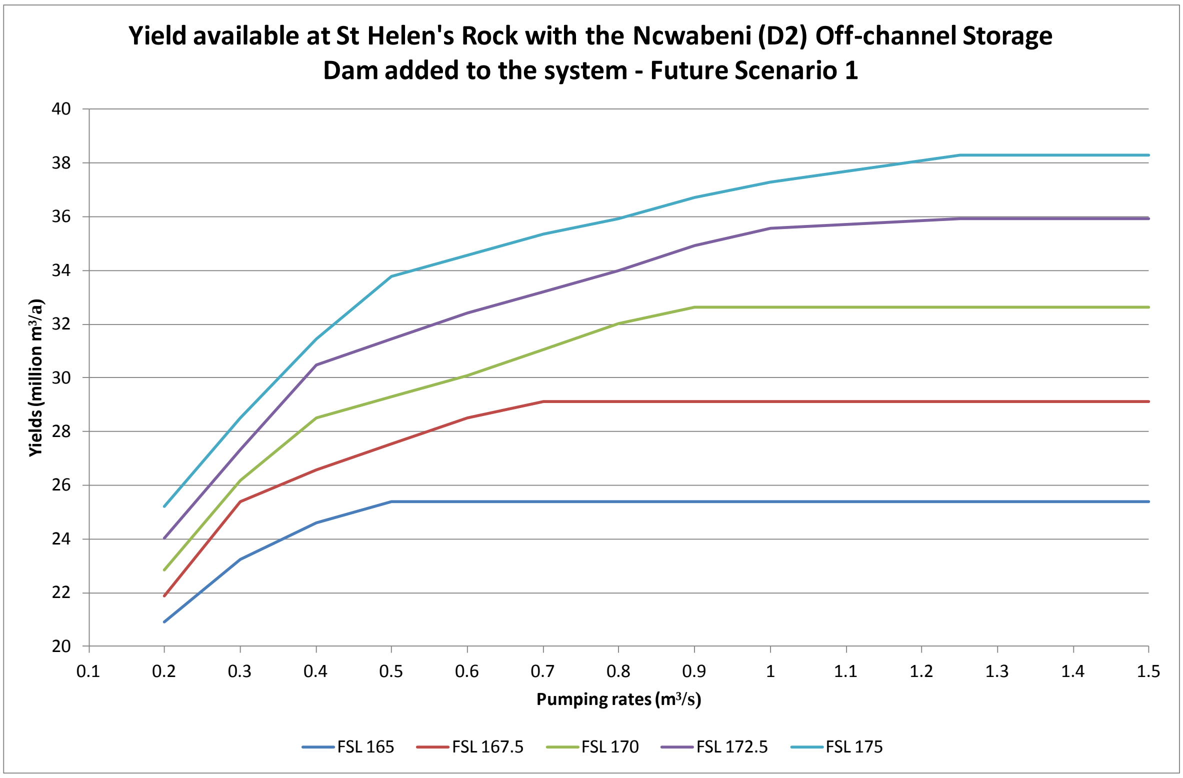

Figure 6-4: Firm yields at St Helen's Rock for various Ncwabeni dam sizes and different pumping rates and Future Scenario 1

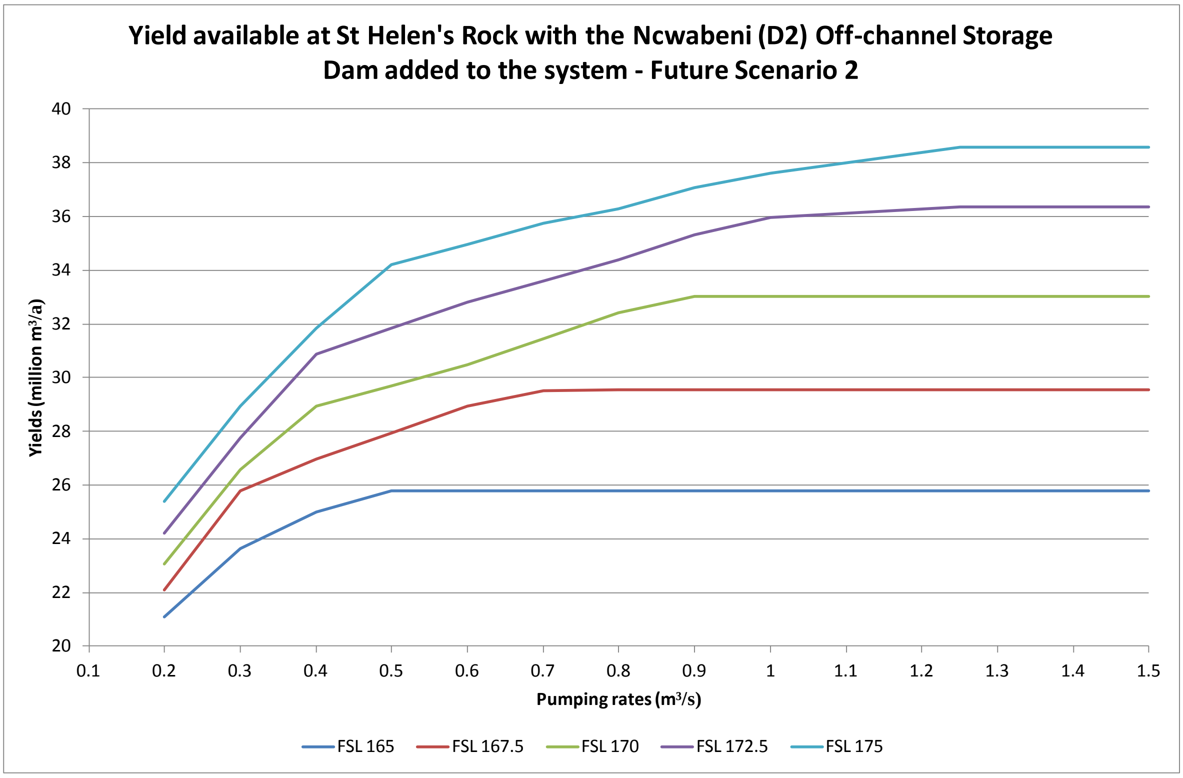

Figure 6-5: Firm yields at St Helen's Rock for various Ncwabeni dam sizes and different pumping rates and Future Scenario 2

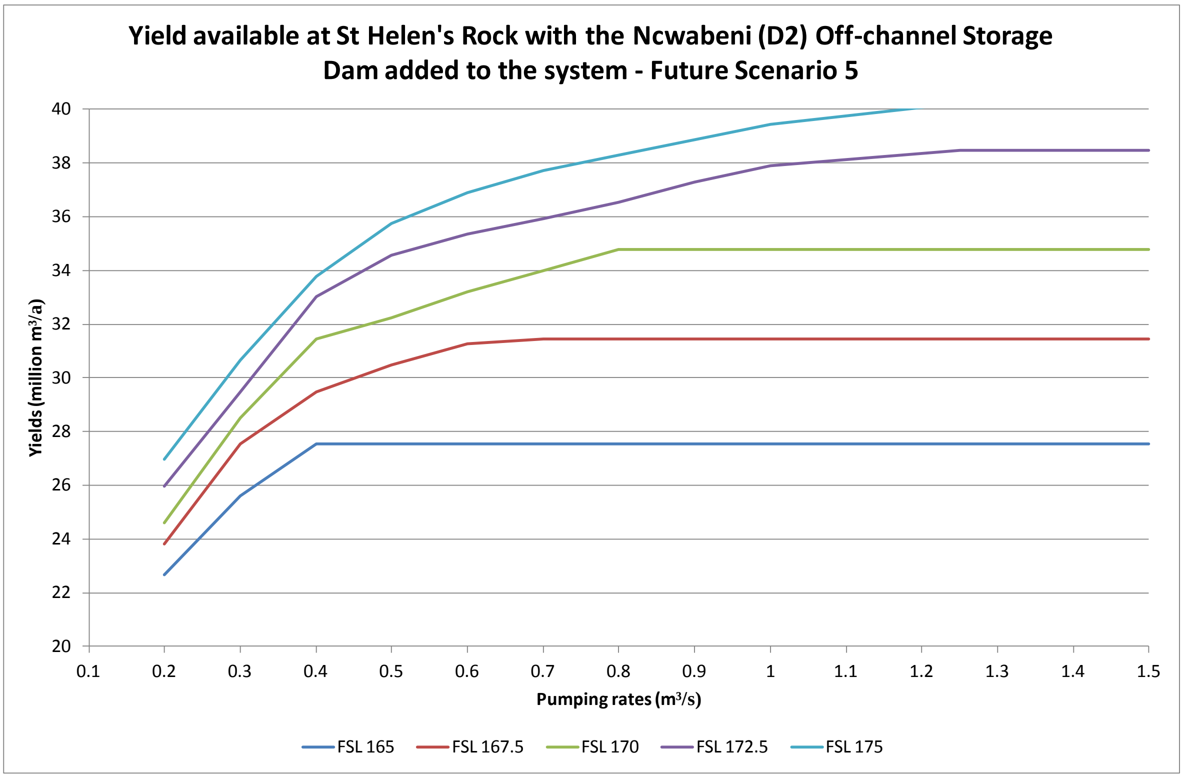

Figure 6-6: Firm yields at St Helen's Rock for various Ncwabeni dam sizes and different pumping rates and Future Scenario 5

As can be seen from **Figure 6-4**, **Figure 6-5** and **Figure 6-6**, the firm yield for the three future scenarios does not differ significantly. The difference between FS1 and FS2 is about 0.4 million m^3/a, and the difference between FS1 and FS5 is about 2 million m^3/a. Future scenario 5 without any future expansion in forestry may well underestimate the level of development in the catchment and therefore overestimate the low flows. FS1, with the highest level of afforestation development in the catchment, may overestimate the future development levels. As such FS2 is chosen to be used as indicative of future development levels in the catchment while being sufficiently conservative for planning purposes. The difference between FS1 and FS2 is also relatively small. Further yield analyses will be conducted using FS2.

Historic firm yield was thus determined for the proposed Gugamela OCS dam for various dam sizes and pumping rates using FS2. The results are presented in **Figure 6-7**.

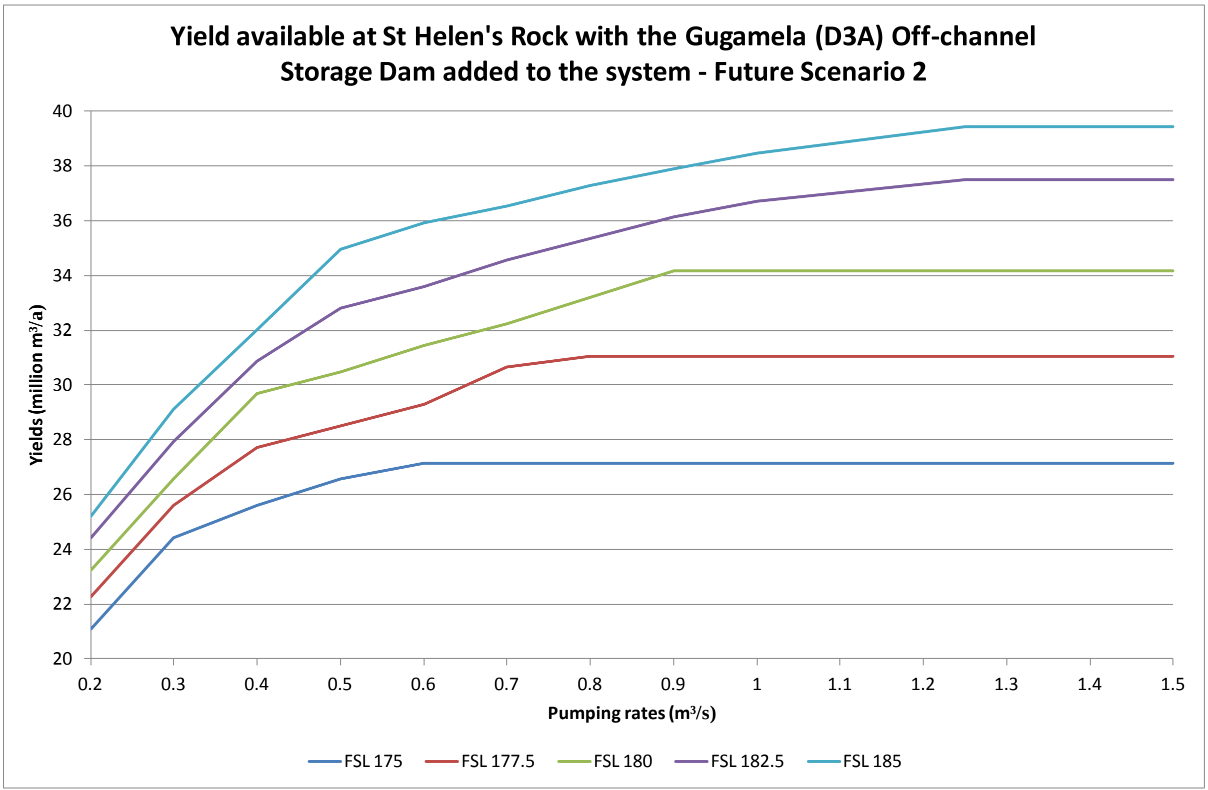

Figure 6-7: Firm yield curves for the Umzimkhulu RWSS for different configurations of the Gugamela OCS Dam

The firm yield curves for the various dam and pumping options all display a common characteristic. The yield for a particular size of dam increases with increasing pumping capacity up to a point. Thereafter increasing the pumping capacity does not increase the yield any further. The point at which each yield curve flattens (inflection point) is the pumping rate that can reliably fill the OCS dam sufficient during the summer months. Increases in pumping rates above this point will result in the OCS dam being filled more rapidly, but not more reliably. These inflection points on the yield curves are also expected to be close to the optimal pumping rates for a particular dam size, as the capital cost for increasing the pumping capacity is likely to be much less than the capital cost for building a bigger dam. The pumping capacity should therefore be maximised up to the point that no meaningful benefit in yield is achieved.

Based on the initial firm yield curves the optimal pumping rates where plotted against dam size for both Ncwabeni and Gugamela Dam options (see **Figure 6-8**).

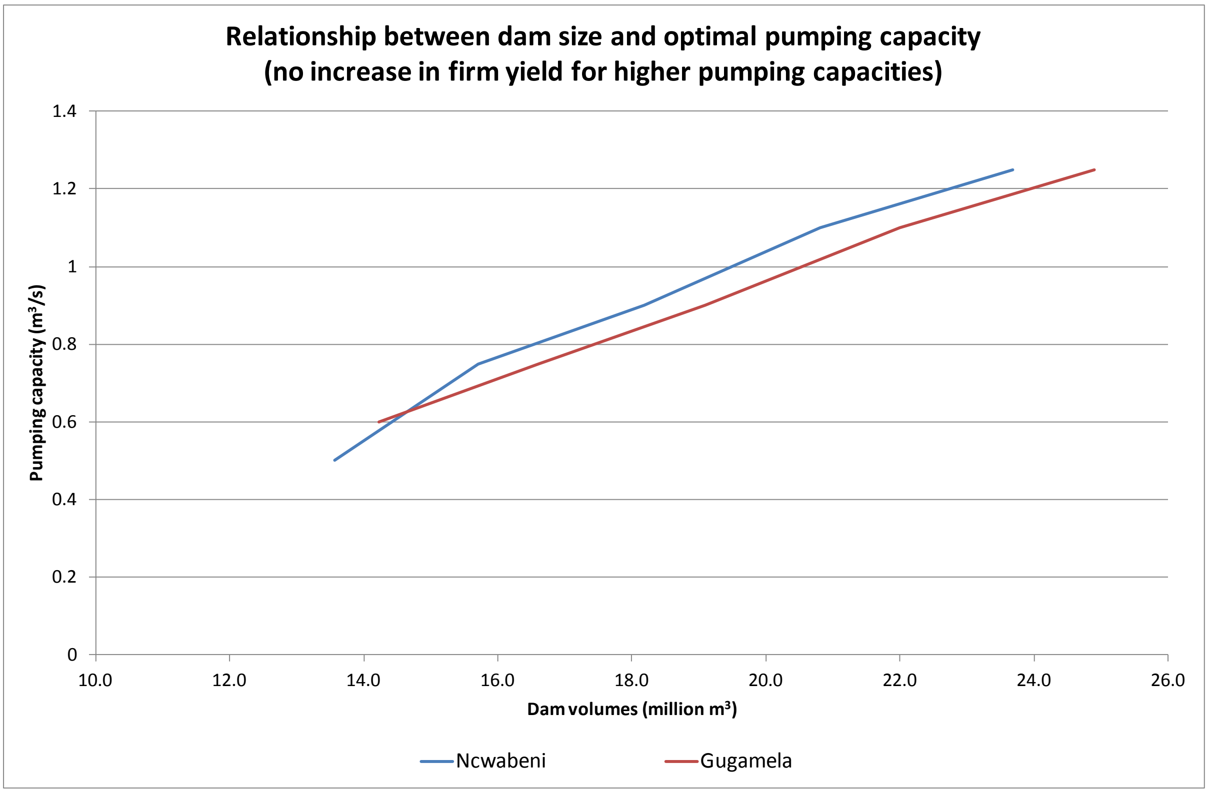

Figure 6-8: Relationship between off-channel dam size and pumping capacity

Based on the future projected water requirement of 30 million m^3/a (see Section 2 of the report), a dam with a full storage level (FSL) of 167.5 mamsl or greater will be considered further for the Ncwabeni site and a dam size of 177 mamsl or greater for the Gugamela site. Pumping rates of 0.7 m^3/s or greater achieve sufficient yield. Larger dams with smaller pumping rates can achieve the same yield, but as mentioned earlier, this is likely to be a more costly solution. Larger dams, however, will still be considered further as they may be more optimal from a unit cost perspective.

The pre-feasibility study recommended a pumping rate of 0.5 m^3/s. The recommended pumping rate as determined by this feasibility study is likely to be larger. This is due to the higher water requirements projected for a later planning horizon, and as such the difference is expected.

The next step in assessing the water availability of the system would be to calculate the long-term stochastic yields for the possible dams and determine the volumes that can be yielded at different assurance levels. However, before this was done, some additional information on an existing run-of-river hydropower plant near the project site was received.

6.3.5. Camero Estates Hydropower

During a site visit to the landowners with the study team of Module 2: The Environmental Impact Assessment Study, it was confirmed that a hydropower plant existed at Camero Estates and been in operation for some years. The hydropower plant diverts water through a tunnel across the narrow part of the peninsula on which the estate is positioned. The head difference of the natural drop in the river as it flows around the peninsula is used to generate power. The layout of the hydropower plant is shown in **Figure 6-9**.

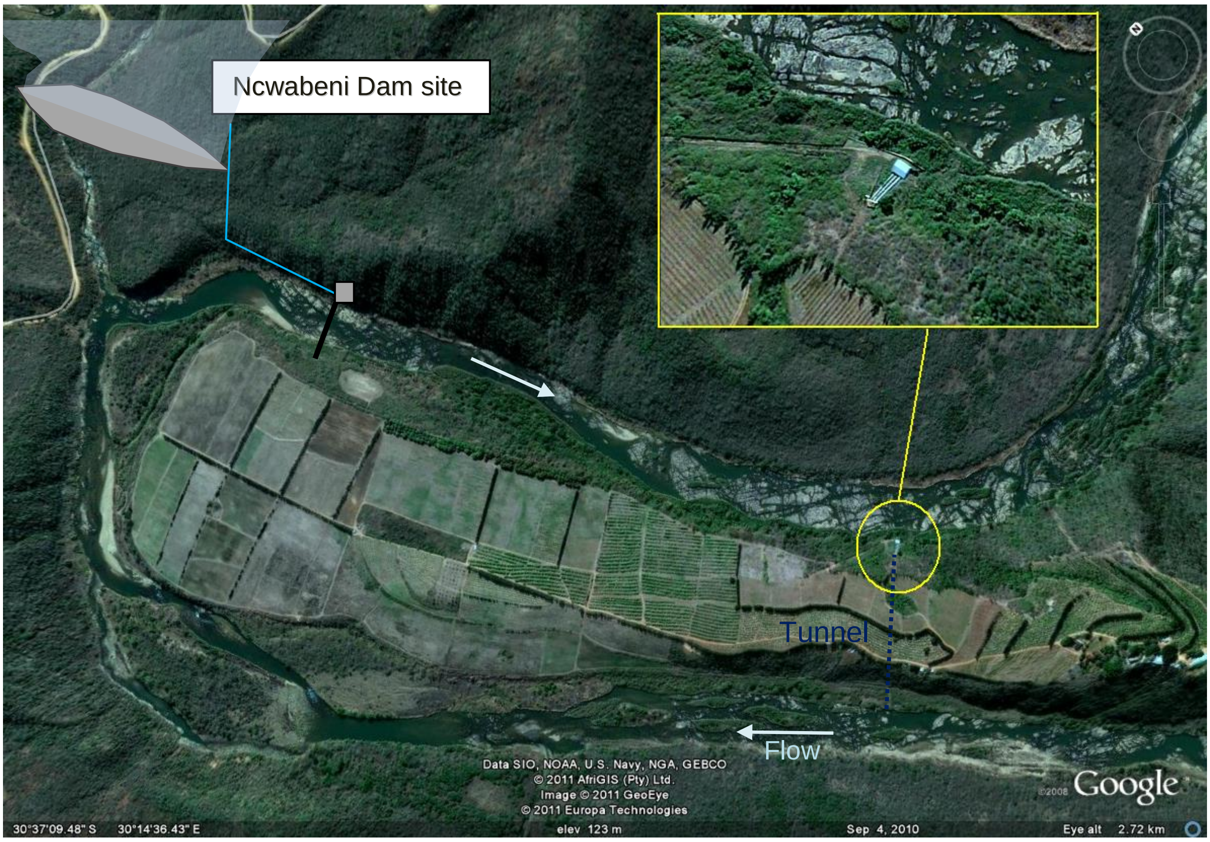

Figure 6-9: Existing hydropower plant at Camero Estates and relation to the off channel storage dam project site

Currently Camero Estates operates the hydropower plant to drive their irrigation pumps. The land owner has indicated that he is interested in operating the hydropower to its full potential in the future and sell the generated electricity. This could be a potential energy source for the pumping water to the OCS dam. This possibility is explored further in Supporting Report 3: Engineering design and cost estimates.

The water diverted through the tunnel of the hydropower plant will not pass the abstraction weir for off-channel pumping, and as such this must be taken into account when determining yields of the system.

The characteristics of the hydropower plant were obtained from the land owner. Fully developed the hydropower can reportedly develop in the order of 600 kW of power with a flow of 15 m^3/s through the plant, and a static head of 10 m.

The yields of the system with the Ncwabeni OCS dam included were thus recalculated taking into account a flow of 15 m^3/s bypassing the off-channel pumping abstraction point. The yields for this assessment are presented in **Figure 6-10**.

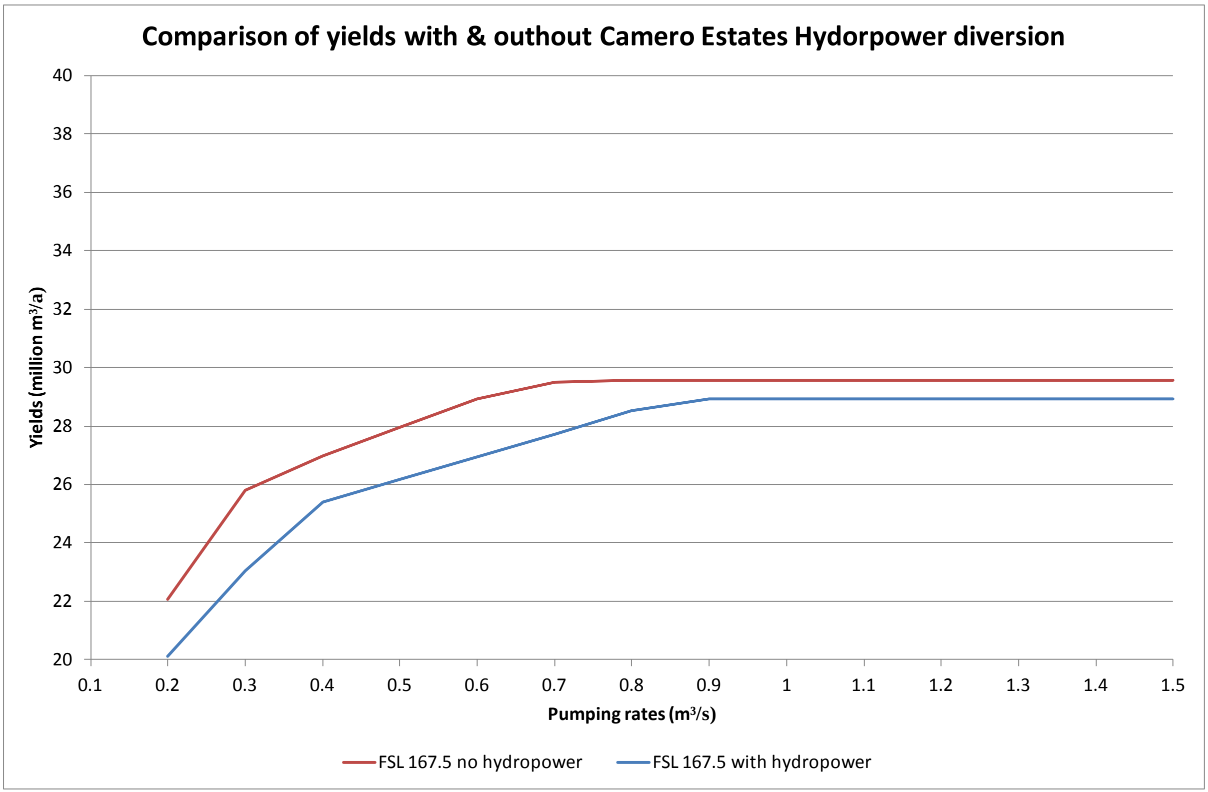

Figure 6-10: Impact of Camero Estates hydropower diversion on yield with Ncwabeni OCS dam

It appears that the impact of the full 15 m^3/s diversion is a reduction in yield of between 1.8 and 0.6 million m^3/a depending on the pumping rate. The results can also be viewed as a bigger pumping rate is required to achieve the same yield once the hydropower diversion is included.

In assessing and discussing these results, it became apparent that the inclusion of a 15 m^3/s diversion for the hydropower plant is not as simple as adding a channel that diverts all flows up to 15 m^3/s. There is no diversion weir, and therefore the diversion efficiency will not be 100% of the flows. It will also be in the interest of the ecology of the river section around the peninsula to maintain some level of flows. Thirdly, if hydropower is to be used to supply electricity for pumping, then at least 1 m^3/s of flow should not be diverted. More regular flow past the off-channel abstraction point increases the amount of time in a year that off-channel pumping is possible and thereby reduces the required pumping rate. From first order estimates the hydropower that can be generated will only be able to provide electricity for a pumping rate of up to 0.8 m^3/s.

Based on these points, it appears that neither can the hydropower divert all the flow in the river, nor should it divert all the flow in the river, from an ecological or business case perspective. The off-channel pumping will also be conducted during the summer months when flows in the river are higher. Diversion of lower flows in the winter months will have little impact on the off-channel pumping, but will need to be factored into the releases from the OCS dam.

As such the impact of the existing hydropower plant, even if developed to its full potential, should have little impact on the yield of the system.

6.4 LONG-TERM STOCHASTIC YIELDS

Long-term stochastic yields were calculated to determine the assurance of supply for the Umzimkhulu RWSS with the inclusion of an OCS dam. Long-term stochastic yield curves were generated for Ncwabeni OCS dam for FS2 and for four dam sizes with FSLs from 167.5 mamsl to 175.0 mamsl, and a pumping rate of 0.75 m^3/s. The long term stochastic yields were provided as input into the task of determining unit reference values (URVs) and sizing of the dam. The results of the long-term stochastic yield analyses are presented in **Table 6.6**, for key assurance levels. Although the impact of the Camero Estates hydropower scheme is most likely small, it was included to be conservative in estimating yield.

Table 6.6: Long-term stochastic yields for the Umzimkhulu RWSS with an off-channel storage dam included, and the reserve included

Long-term stochastic yield (million m^3/a)					
Dam size		Assurance of supply			
FSL	Volume	95%	98%	99%	99.5%
(mamsl)	*(million m^3)*	*1:20 years*	*1:50 years*	*1:100 years*	*1:200 years*
167.5	15.7	31.5	30.5	29.0	27.5
170.0	18.2	34.0	32.7	31.2	29.5
172.5	20.8	36.5	35.0	33.5	32.0
175.0	23.7	37.0	36.3	35.0	33.5

The long-term stochastic yield curves are very flat and as such the 95% or 98% assurance of supply volume is likely to be critical. The single assurance of supply level often used for domestic supply is an average of 98%, or 1:50 year failure. Due to this standard and the flat curves, the 98% assurance level yields in Table 6.6 will thus be taken as the yield that can be achieved for supply to the Umzimkhulu RWSS at a reliable level for the water users.

6.5 SIZING OF SCHEME

For the calculation of URVs and the optimisation of the best scheme, the following summary of information was provided:

- Four dam sizes to be considered, namely a dam with a FSL of 167.5 mamsl which meets the planning horizon future water requirements, as well as three larger dams with FSL of 170.0, 172.5 and 175.0 mamsl. These dams were considered to derive the unit cost curve, as the minimal unit cost may occur for a larger dam
- A pumping rate of 0.75 m^3/s or greater should be considered for off-channel pumping. Pumping rates greater than 0.75 m^3/s, however, are not likely to provide any benefits within the 2040 planning horizon. A larger pumping rate may also be considered for off-peak hours pumping.

6.6 OPERATION OF THE SCHEME

It is important to determine how the scheme should be operated so that the operational, and in particular the pumping costs of the different scheme sizes, can be factored into the URVs and selection of the best scheme.

The operation of the off-channel abstraction and release of water from the off-channel storage dam is as follows:

Off-channel pumping:

- Off channel pumping occurs during the summer months when the river flows are higher. This is typically November to March.
- Pumping into the dam can only commence once the flows in the Umzimkhulu River are greater than required abstraction at St Helen's Rock or the ecological water requirements for the stretch of the Umzimkhulu River below the dam and weir, whichever is larger.
- Abstraction should not occur when the river is in flood and carries a large sediment load.
- If the dam levels are sufficiently high pumping can be confined to off-peak hours to reduce energy costs of power supply from Eskom. If hydropower from the Camero Estates is to be used this may not be a factor.

Releases of water from the Dam:

- Water is released from the off-channel dam back into the Umzimkhulu River to augment low flows in the winter months.
- The volume of water that needs to be released is the difference between the total water requirements of the Umzimkhulu Regional Water Supply Scheme and the

flows in the river after allocating water to the Reserve and lawful downstream users.

- In this way water in the dam will not directly supply the Reserve, but will supply the shortfall to domestic users after flows in the river are used to meet the Reserve. If the Reserve has not been implemented through the classification process then a compensation flow for the estuary could be maintained in the river below St Helen's Rock.
- It is recommended that required releases be determined on a monthly or weekly basis.

As can be seen from the operation of the dam, measuring of flows in the Umzimkhulu River will be an integral part of both off-channel pumping and releases from the dam. As such the weir for off-channel pumping has been identified to also be a gauging weir, and is being designed accordingly by the engineering investigation task team. When releasing water from the OCS dam, the flows in the Umzimkhulwana River which join the Umzimkhulu River just upstream of St Helen's Rock will also need to be gauged and factored in to release volumes.

The gauged and measured flows at the abstraction weir on the Umzimkhulu river and the outflow of the Umzimkhulwana River will need to be input into an operating system that calculates water releases based on current water requirements and ecological flow requirements. The operating system and release calculation will also need to take into account Camero Estates Hydropower flows, and water users between the dam and St Helen's Rock. A framework for the operating system and release calculation has been included in **Annexure C**. A real-time system will most likely be needed with the appropriate telemetry to convey flow measurements.

For the benefit of the OCS dam to be fully appreciated and the maximum system yield achieved, a weir is also required for abstraction at St Helen's Rock to increase the water depth and abstraction efficiency during low flow months. Further studies and design of this weir will need to be conducted by the Water Service Authority.

By operating the scheme this way, monthly average pumping and release volumes were determined from a 88 year historic simulation of the system operating at full capacity. The average monthly off-channel pumping is shown in **Figure 6-11** as a percentage of time pumped with a 0.75 m^3/s pumping rate. The average monthly releases are shown in **Figure 6-12**. Actual abstraction and pumping will vary from year to year and greater abstractions from the Umzimkhulu River will be needed to refill the OCS dam during dry years, and only a few months of pumping will be required during wet years.

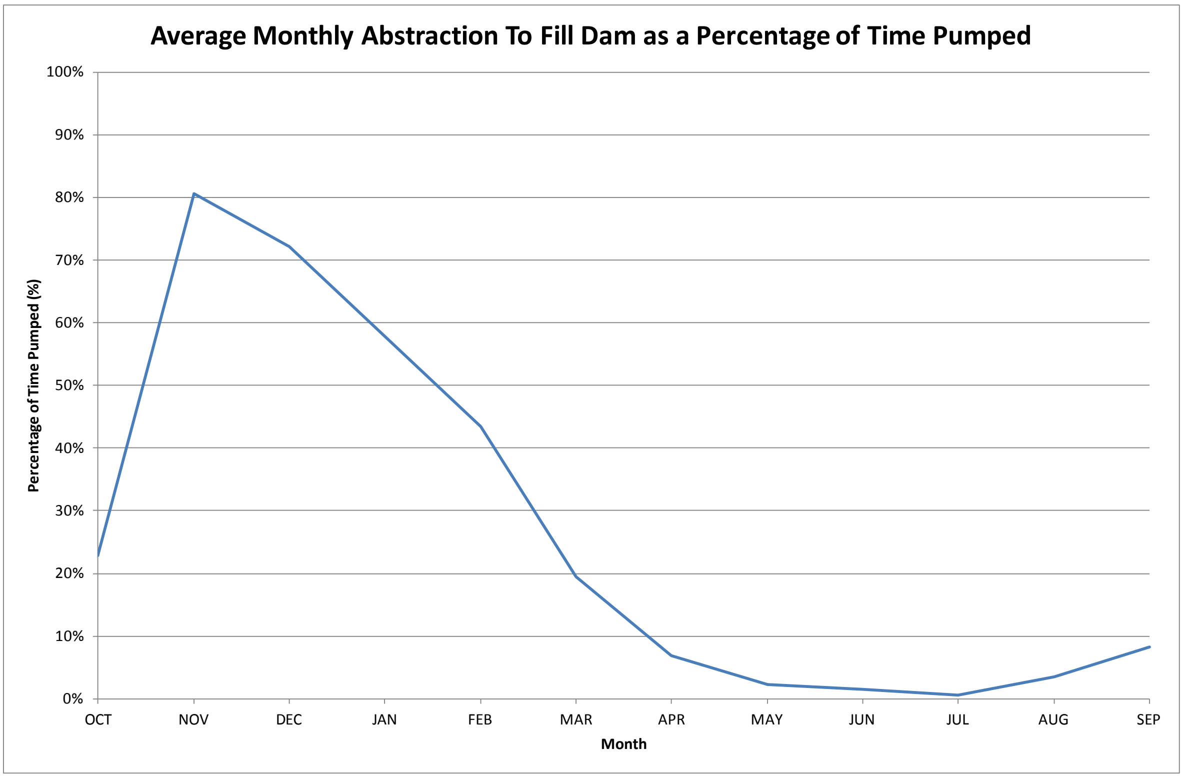

Figure 6-11: Average monthly pumping to fill off-channel storage dam in summer months

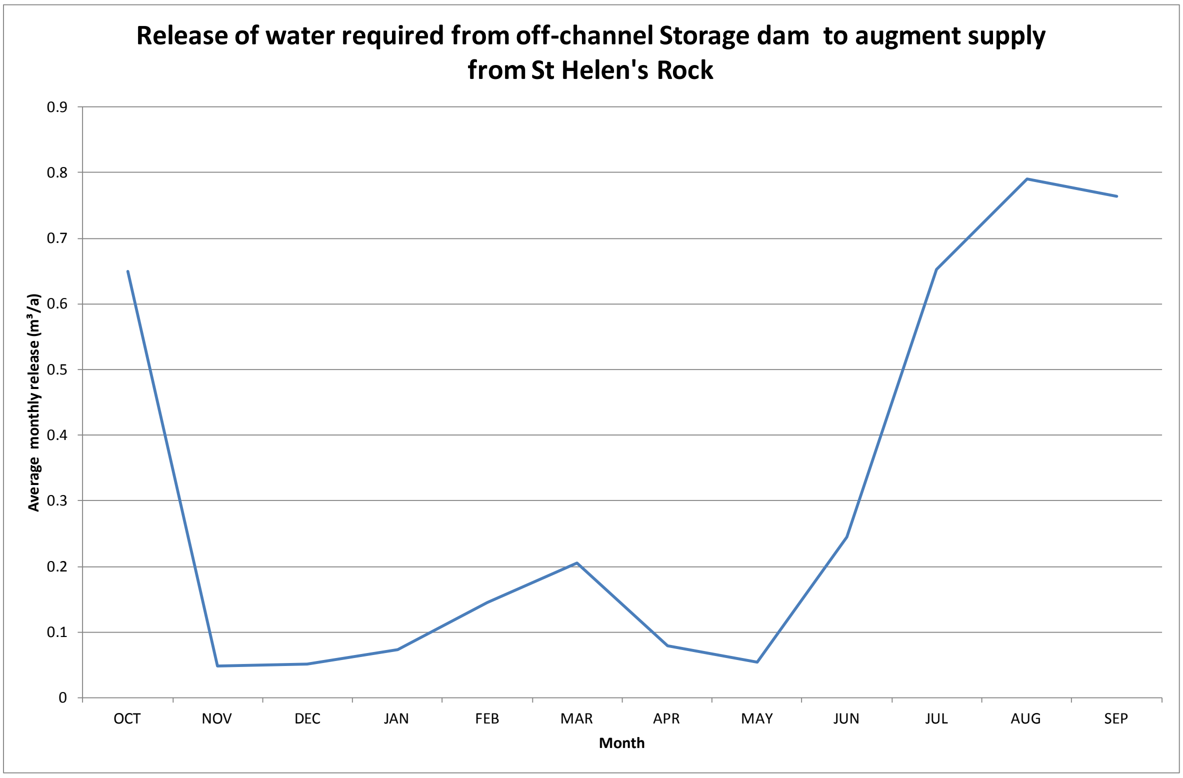

Figure 6-12: Average monthly releases from off-channel storage dam to augment supply of the Umzimkhulu RWSS

The pumping in Figure 6.11 shows the monthly average of all 88 years which includes some years with no pumping in for a month, as well as pumping in the summer months beginning in different months over the 88 year period. For the purposes of URV calculations, the average pumping in the summer months was consolidated into the number of months continuous pumping, to better capture how the system will be operated, i.e. pump continuously until the dam is full. This information is included in **Table 6.7**.

Table 6.7: Average number of month's continuous pumping required to fill OCS dams of different sizes with a pumping rate of 0.75 m^3/s

Dam size	Number of months pumping continuous	Dam yield
167.5	3.25	30.5
170.0	3.76	32.7
172.5	4.38	35.0
175.0	5.06	36.3

6.7 DAM ALTERNATIVES HIGHER UP IN THE UMZIMKHULU RIVER CATCHMENT

As mentioned in **Section 6.2**, the *MRCWRS* identified possible afforestation development in the catchment as well as possible infrastructure developments such as dams on the main channel of the Umzimkhulu River and its major tributaries.

Various dam sizes were considered for different water uses. The most likely development was for dams to mitigate low flow reduction caused by afforestation developments. The possibility of adding domestic water use was raised, thereby effecting a multi-purpose dam development.

At a reconnaissance level, the supply from a multi-purpose dam to Port Shepstone was investigated as an alternative to the proposed OCS dam. A multi-purpose dam would need to be close enough to the afforestation to effectively mitigate the reduction in flows without losing significant stretches of river. A dam in the Bisi River catchment, a major tributary of the Umzimkhulu, was considered, as it is lower than other dam sites identified by the *MRCWRS*, which is advantageous for releases down to St Helen's Rock. This dam is still more than 80 km upstream of St Helen's Rock. The position of this dam is shown in **Figure 6-13**.

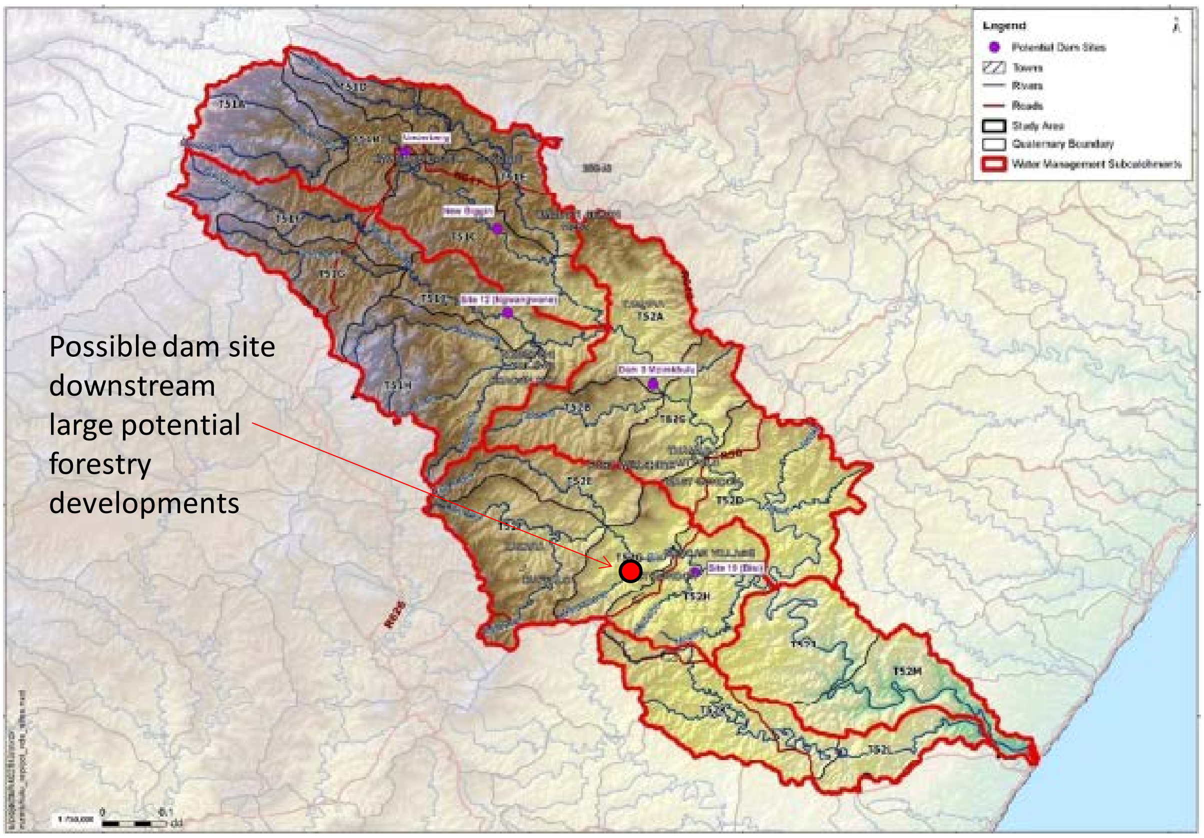

Figure 6-13: Dam site in the Bisi River

The dam on the Bisi River was sized to supply the EWR and mitigate low flows, as well as yield an additional 30 million m^3/a for St Helen's Rock. Conveyance losses of 20% where included. The findings of this exercise were:

- A dam on the Bisi River of approximately 45 million m^3 storage would be required. Of this volume approximately 17 million m^3 will be lost to sedimentation.
- This is significantly more storage than is needed for the OCS dam.
- Practical operation of a dam much higher upstream needs to be questioned, as well as the possible losses between the release and abstraction point.
- The multi-purpose component of the dam is only about 18% for afforestation (i.e. the afforestation could build a smaller 9 million m^3 "large farm dam" upstream for their purposes of mitigation).
- A multi-purpose scheme, which is at the beginning of the project development life-cycle, would take longer to study further and implement, delaying water delivery and increasing the likelyhood of water shortages and impacts on economic growth for the region.

As such a multi-purpose dam upstream is a less favorable solution to resolve the water resource shortages experienced by the Umzimkhulu RWSS.

6.8 REFINEMENT OF SEDIMENTATION ESTIMATES

As a starting point, sedimentation volumes determined by the Pre-feasibility Study were used for the yield analyses. This information was presented in **section 5.1**.

The expected sediment loads of both the incremental catchment as well as the total Umzimkhulu catchment that may be pumped into the dam were refined based the Sedimentation Yield Review Report (**Annexure D**), and the Physical Hydraulic model Study Report (**Specialist Report 3: Physical Hydraulic Model Study**).

The sediment yield from the Incremental catchment of the Ncwabeni or gugamela catchments is approximately the same due to similar catchment areas. The sediment yield for the Ncwabeni D2 site is 1336 t/km^2/a for the 40 km^2 catchment giving a total load of 53 440 t/a (**Annexure D**).

The predicted sediment yield for the Umzimkhulu River at the proposed abstraction point for off-channel pumping (5657 km^2) is 807 t/km^2/a, which gives a mean annual load of 4.565 million t/a.

Based on the results of the Physical Hydraulic model Study, if the coarser sediment (typical bed load) is trapped at the river abstraction works, an estimated 83 % of the abstracted sediment would be pumped to the Ncwabeni Off-channel Storage Dam. Based on the daily flow record and the above mentioned sediment yield the average sediment concentration in the river from low flow to floods is estimated to be 1236 mg/l. This concentration was determined from the simulated daily flow record and sediment transport in the river based on ACRU model simulations adjusted to the proposed sediment yield, as part of the sediment yield study (**Annexure D**).

If different abstraction rates are considered the average daily sediment loads would be pumped to the Ncwabeni Off-channel Storage Dam as indicated in **Table 6.8**.

Table 6.8: Sediment loads pumped into off-channel storage dam for different abstraction rates and pumping scenarios

River abstraction pumping rate (m^3/s)	Sediment load diverted based on pumping all year (t/day)*	Sediment load pumped to off-channel dam based on pumping all year (t/day)*	Sediment diverted during summer months (Nov to Mar) (t/day)	Sediment load pumped to dam during summer months (Nov to Mar) (t/day)*
0.75 (monthly value in yield model)	80	66	111	92
0.90 (physical model average daily design)	96	79	134	110
1.08 (physical model design peak daily)	115	95	160	132

The abstracted sediment loads are based on the simulated daily data of sediment concentrations in the river based on ACRU model simulations adjusted to the proposed sediment yield (Basson, 2011).Assuming that the pumping is to be conducted in the summer months from November to March, the sediment load pumped into the proposed Ncwabeni dam with an abstraction rate of 0.75 m^3/s is 92 t/day based on **Table 6.8**. Using a long term average number of consecutive months pumping of 3.25 months for a 167.5 mamsl FSL dam from **Table 6.7**, the sediment load pumped is calculated to be 8 970 t/a. The combine total load of sediment into the dam from the incremental catchment and pumping is thus 62 410 t/a. Assuming a density of 1.2 t/m^3, the total accumulated sediment over 50 years is calculated to be 2.6 million m^3/a. This is slightly higher than the pre-feasibility study value of 2.1 million m^3 used as a starting point **(Table 5.1)**. The small increase can be attributed to the increased pumping rate and higher level of detailed information on pumped sediment from the physical hydraulic model study. The impact of the small increase in sediment volumes is likely to be negligible, but long-term stochastic yields were re-calculated to confirmed this. The impact the small change in long-term sedimentation volumes from 2.1 to 2.6 million m^3 is a reduction of only about 1% in yield from 30.5 million m^3/a to 30.2 million m^3/a.

7. WATER QUALITY

For the purposes of assessing water quality of the planned resource with an off-channel dam included, a water quality and limnology assessment was conducted. The limnology task report is included in **Annexure E**. The limnology assessment included 10 months of water sampling to determine the quality of the water in the main Umzimkhulu River as well as the Ncwabeni and Gugamela tributaries. This information will also be provided to the specialist Studies of Module 2: the EIA study.

The following are the main findings of the Limnology assessment:

7.1 CURRENT WATER QUALITY STATUS

Water quality measured in the Mzimkhulu and Ncwabeni Rivers is generally good, with low concentrations of dissolved salts, turbidity and nutrients for the majority of the time. Iron and some bacterial counts are, however, above domestic standards.

7.2 PREDICTED IMPACT OF IMPOUNDING THE NCWABENI RIVER

Algal counts are predicted to be low and blooms of nuisance algal species are unlikely to occur. Stratification of the proposed impoundment is likely to result in anoxic water at a depth of 5 - 15 m from the surface during the hottest summer months. In-dam processes such as sedimentation of suspended material and bacteriological removal are likely to significantly improve surface water quality between the inflow and the wall of the proposed impoundments.

7.3 MANAGEMENT OF PROPOSED IMPOUNDMENTS TO OPTIMISE WATER QUALITY

Scouring (as opposed to spilling) is the recommended release mechanism during low rainfall and low inflow conditions when algal numbers are high to avoid release of algal-laden water into the downstream riverine ecosystems. It is recommended that spill-abstraction-scour releases be managed to minimise the impact on aquatic life. From a water quality planning perspective, there appear to be no significant water quality problems that preclude the construction of the proposed Ncwabeni impoundment.

8. CONCLUSIONS

The water resources task conducted a detailed water requirements assessment of the historical, current and future expected demand for water in Port Shepstone and surrounds. The water availability of the Umzimkhulu River was determined for the current situation, and for the system with various options of off-channel storage dams included. The following conclusions have been drawn from the work conducted:

Water Requirements:

- The current (2010) demand for water in the Umzimkhulu Regional Water Supply Scheme area is in the order of 18.5 million m^3/a.
- Future water requirements have been projected up until 2040 of approximately 38 million m^3/a, which includes the reduction of water losses and more efficient use of water.
- WC/WDM is an essential part of ensuring the efficient use of the current water resource before the dam can be built, as well as the augmented water resource including the dam.
- The Umzumbe area that is planned to be supplied from the Mhlabatshane Scheme needs to be augmented with 1.4 million m^3/a water from the Umzimkhulu River and the Ncwabeni dam, if the full desired level of water services of 60 L/c/d is to be achieved by 2030.
- The Umzimkhulu RWSS area was thus expanded for planning purposes to include the lower portion of Umzumbe.
- The total water requirement which needs to be supplied from the lower Umzimkhulu River system with an off-channel storage dam included is in the order of 30 million m^3/a.

Water Availability:

- The water resources of the Umzimkhulu River were simulated using the WRYM

- The WRYM system configuration from the *Mzimkhulu River Catchment Water Resources Study* conducted by the DWA in 2011, was updated and refined for this Feasibility Study.
- The hydrology and the ecological water requirements included in the WRYM were reviewed by the Feasibility Study team.
- Firm yields were conducted to determine water available at St Helen's Rock abstraction. The current yield is in the order of 18.3 million m^3/a. This is already lower than the 2010 water requirement, and does not account for ecological water requirements.
- The water resource of the Umzimkhulu River needs urgent augmentation if the growing water requirements of the Umzimkhulu RWSS are to be met and the improvement of the ecological reserve is to be possible.
- The yields at St Helen's Rock with various sizes of both the Ncwabeni and Gugamela dams included were calculated. This was done for a range of off-channel pumping rates to fill the dams between 0.2 m^3/s and 1.5 m^3/s.
- For each dam size an optimal pumping rate was found above which no increase in firm yield is achieved. The optimal pumping rate for dam sizes that can meet the 2040 water requirement is in the order of 0.7 to 0.8 m^3/s.
- An optimisation exercise was conducted to determine the best size of dam to be taken further into feasibility design. A dam size for the Ncwabeni site with a full supply level of 167.5 masl or greater was proposed, or a dam on the Gugamela of 177 msal. This equates to dams with capacities of approximately 16 million m^3.
- A desktop assessment was made of possible supply to the Umzumbe area directly from the dam or by extending the pipelines of the Umzimkhulu RWSS.
- An off-channel storage dam in the Lower Umzimkhulu River is the preferred solution to the water resources problem experienced in winter. A larger dam on the main channel was investigated at a desktop level of detail and was found to be a less favourable, even if developed as a multi-purpose dam.

System operation:

- The proposed dam will be filled in the summer months and will require on average 3.5 months of continuous pumping at a rate of 0.75 m^3/s to be filled.
- Water shall be released in the winter months to supply the shortfall in water available in the Umzimkhulu River.
- Releases from the dam are not made directly for the reserve but, allow the reserve to be supplied first by available flows in the Umzimkhulu River.
- The possibility of gauging of flows at the weir that is required for off-channel abstraction and pumping should be investigated for the purposes of operation of the proposed scheme.
- An operational releases calculation framework was developed.

9. RECOMMENDATIONS

The following recommendations are made based on the water requirements and water resources availability assessments:

1. A dam on the Ncwabeni of 167.5 mamsl or greater, or a dam on the Gugamela of 177 mamsl or greater be considered when selecting the best scheme.
2. The abstraction weir should be used to gauge flows if possible for operation of the scheme.
3. The project needs to implemented as soon as possible as the water requirement already exceeds the water resource without allowing for the implementation of the ecological reserve.
4. A validation and verification exercise needs to be conducted in the catchment to confirm legal water users both above the project site as well as between the dam and the water abstraction point.
5. The possibility of using water directly from the dam should be investigated further by the water services authority.
6. WC/WDM measures need to be implemented by the WSA.
7. An additional study is needed to investigate mitigation dams for afforestation developments in the catchment.

10. REFERENCES

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Annexure A

Figures

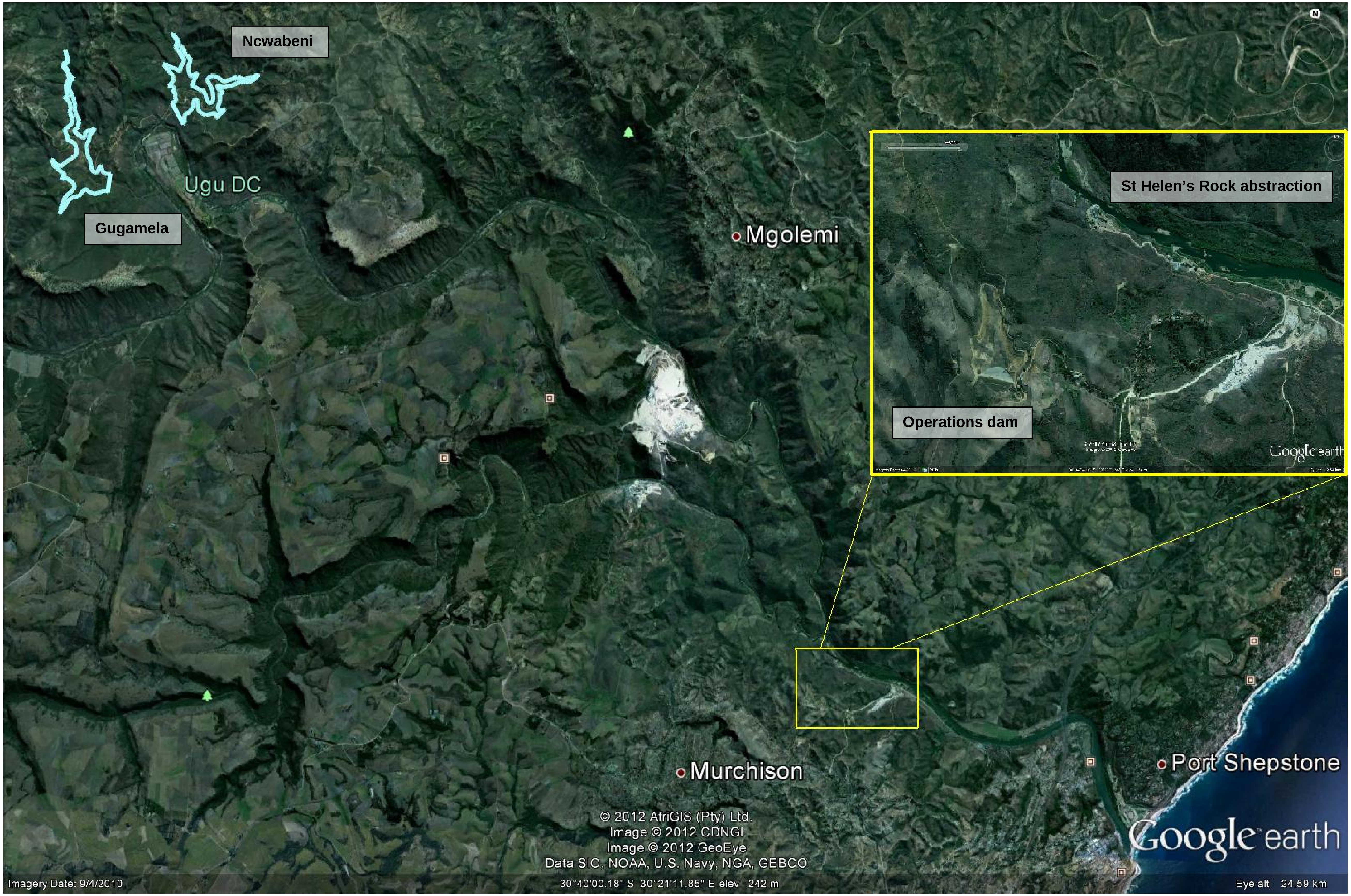


Figure A1: Location of Ncwabeni and Gugamela off-channel storage dam sites and the St Helen's Rock abstraction

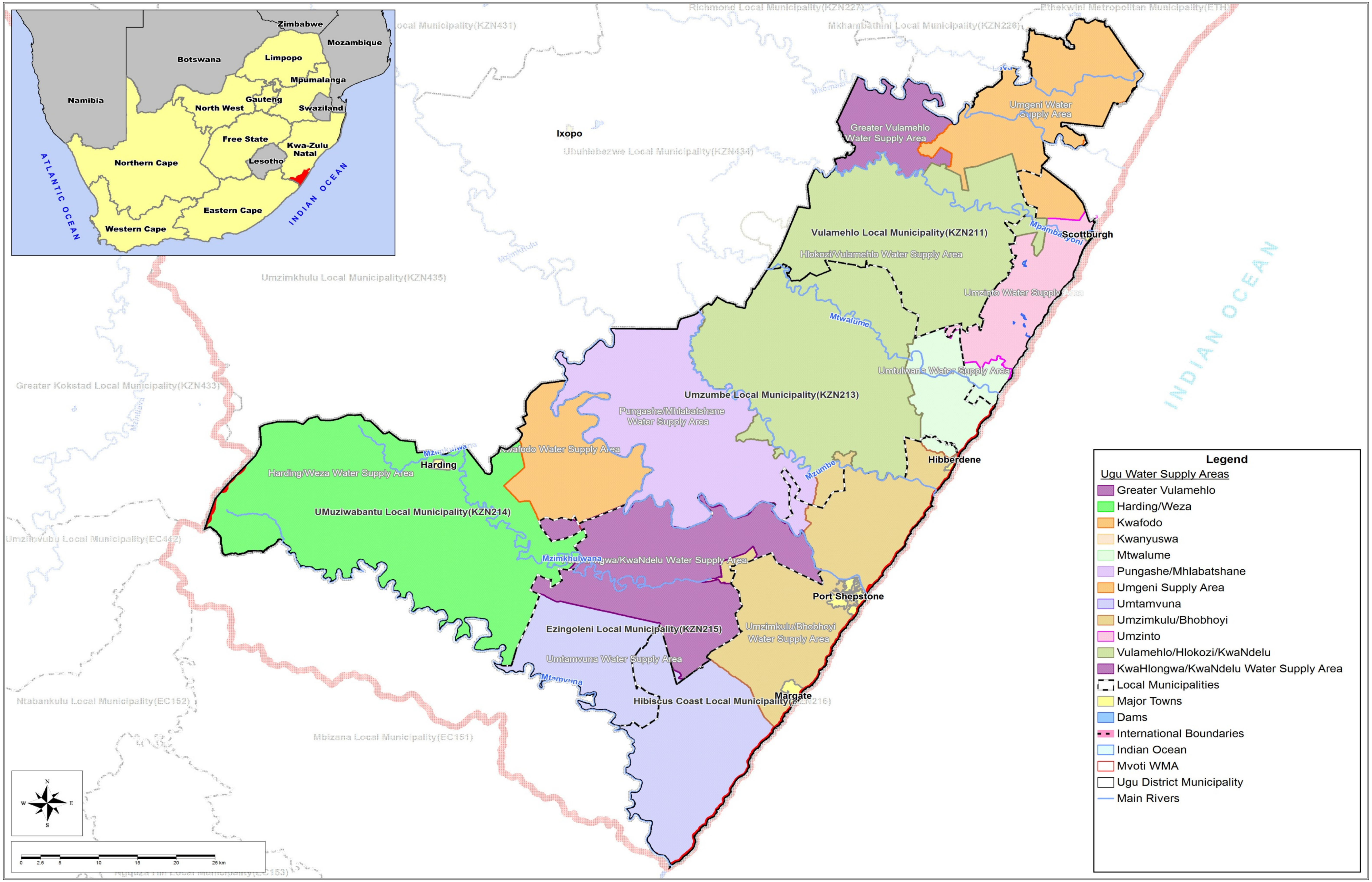


Figure A2: Water supply areas and local government boundaries of the Lower South Coast (adopted from DWA, 2001)

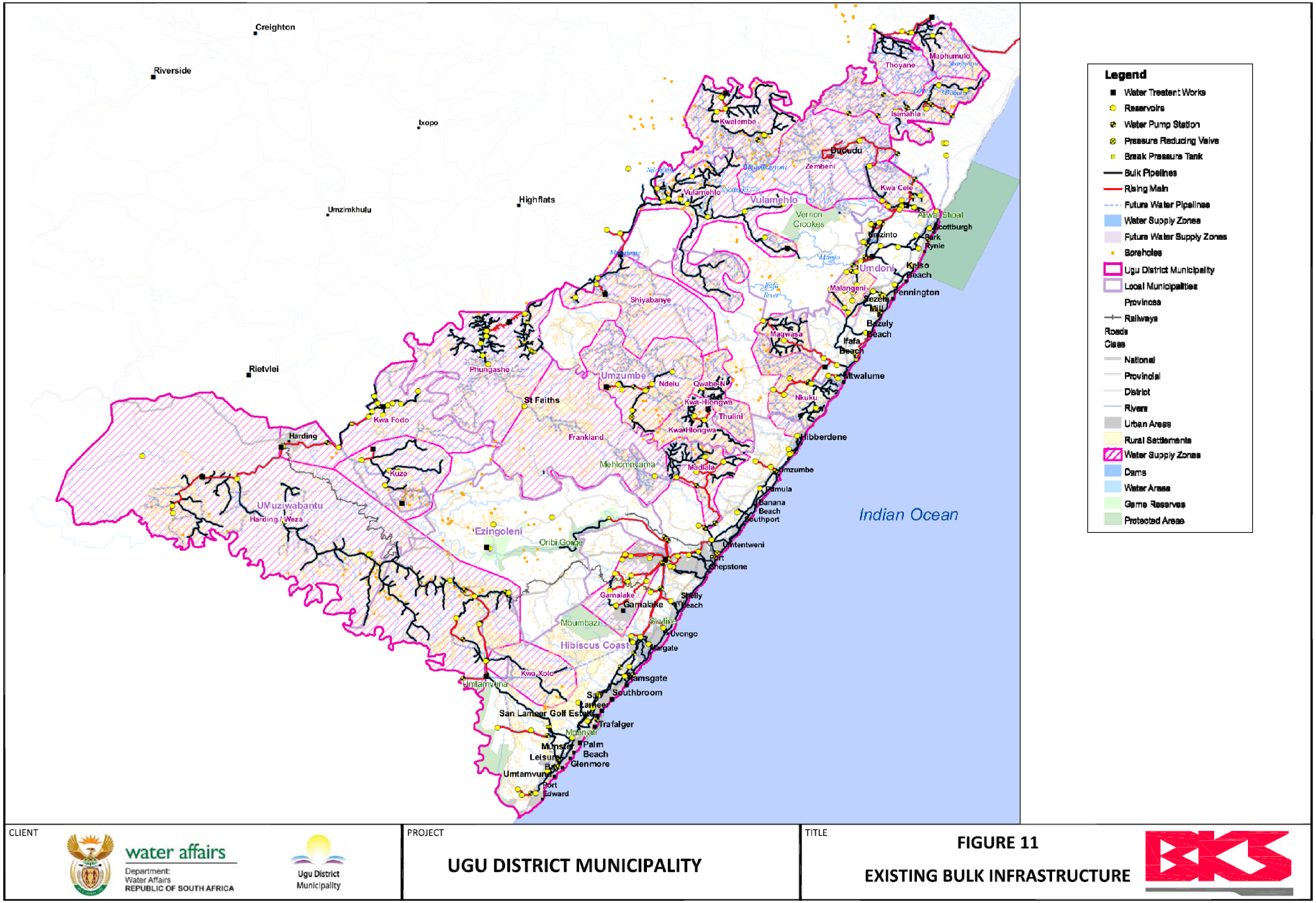


Figure A3: Existing water supply infrastructure in the Ugu District Municipality

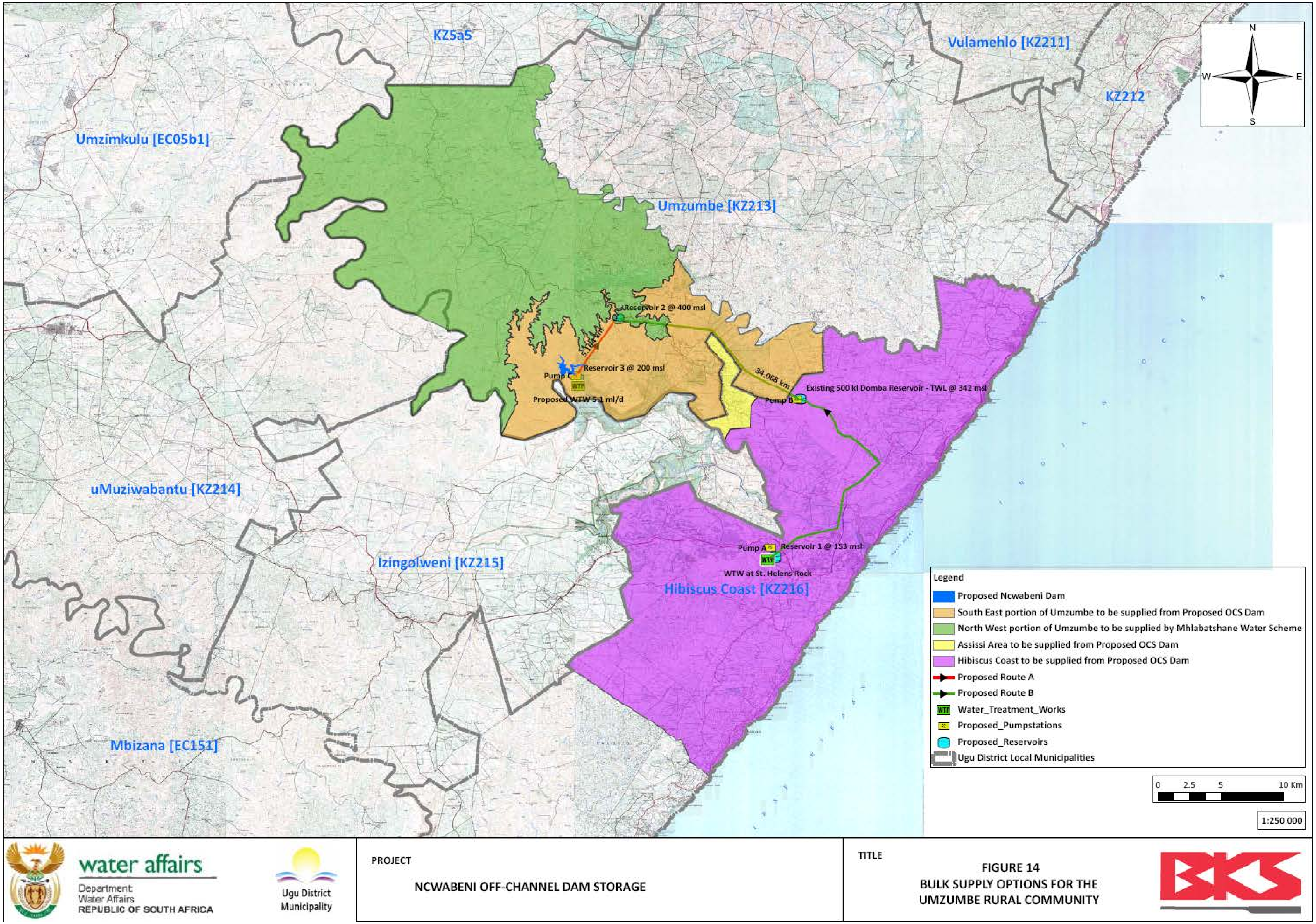


Figure A4: Proposed split in water supply to Umzumbe from Mhlabatshane WSS and the Umzimkhulu RWSS, and bulk supply options to Umzumbe

Annexure B

Ecological Water Requirements Implementation Review

1 Ecological Reserve: Review

1.1 Background

The *Mzimkhulu River Catchment Water Resource Study (WP 9900) - Mzimkulu Riverine Ecological Water Requirements (2011)*, was done as part of a larger project viz. the *Mzimkhulu Catchment Water Resources Study*, with the Ecological Water Requirements (EWR) of the river and estuary forming necessary components of the overall water resources investigation.

In the EWR study, the Intermediate Reserve determination approach has been applied to five sites and the Rapid III applied to the remaining three sites in the Umzimkhulu River and tributaries. A detailed description of the EWRs is attached as ***Appendix A***. These EWR has been extrapolated by the Reserve Team to every quaternary catchment where no high level reserves were done. The EWR points derived are given in ***Appendix B***.

The overall conclusion of this EWR investigation was that the state of the ecosystem in the Umzimkulu catchment is generally good, with the present ecological state (PES) of the main river ranges from a Category A/B to B. The PES of the tributaries ranges from a category A/B to C, with the Nwangwane River in T51F in the lowest ecological state. The Reserve report cautioned on some uncertainty around the accuracy of the hydrology, especially in the Bisi catchment. The report also warned about uncertainties about the extent of the ecological impacts that would occur in smaller tributaries at a local scale.

1.2 Review of EWRs in the WRYM

This aim of this document is to review the hydrology and to ensure that the Reserve is correctly incorporated in the WRYM.

The uncertainty around the Hydrology was resolved by the *Mzimkhulu River Catchment Water Resource Study,* hydrology task team. The problem was solved through adjustment of the percentages between water use of high flows and low flows in the afforestation model of the WRSM2000-model. The new flow data was collected and evaluated by this study. The uncertainty in the hydrology was related to the application of the afforestation model in the WRSM2000. The feasibility study team reviewed the hydrology and found that afforestation problem was resolved and that the reduction of high flow because of afforestation were now acceptable.

The correct implementation of the EWR was analysed through:

- the collection of the updated and extrapolated EWRs;
- the analysis of the WRYM configuration to verify the correct implementation of the EWR in the model;
- ensure that the reserve team recommendations for the EWR below the proposed Ncwabeni Dam, are implemented;
- Compliance with the recommended EWR for the yield analyses (WRYM) of the proposed dam(s).

The Reserve Report stated that a large dam on the main stem Mzimkhulu River will have a big potential impact on the ecosystem but a dam on any tributary will be preferred, having much less impact.

The Recommended Ecological Category (REC) was considered by the Reserve Study Team to be the same as the Present Ecological State (PES), which would thus suggest that no loss or improvement in the present condition of the river is recommended.

Consultation with the Reserve team indicated that the EWR at Gibraltar (EWR6i) was the preferred EWR to be used for the proposed Ncwabeni Dam yield analyses.

A number of EWR sites were included on the tributaries of the Umzimkhulu River. The EWR site positions reflect the direct impact of the upstream forestry and irrigation activities in the tributary catchments. The position and correctness of the EWR's in the WRYM was assessed. The position of all the EWR channels in the WRYM model but one was found to be correct. The small EWR on a tributary that was not in the correct place was noted and corrected.

The EWR flow requirements in the WRYM were reviewed, as well as the compliance to these flows when simulating yields for the system in the WRYM. Focus on EWR compliance was above and below the off-channel abstraction point as well as below the St Helen's Rock Abstraction. The results of compliance at these key points is shown in Table 1.

Table 1: EWR compliance at key points in the Lower Umzimkhulu River with an OCS dam included

EWR site	Demand	Supply	Shortfall
	m^3/s average flow		
EWR Gibraltar (above weir)	11.385	11.364	0.021
EWR below Ncwabeni Weir	11.385	11.385	0.000
EWR T52L (Umzimkhulwana)	0.356	0.317	0.039
EWR below St Helen's	11.344	11.344	0.000

As can be seen from Table 1, the EWR at Gibraltar just above the Ncwabeni and Gugamela Rivers is not fully supplied. Some shortfalls to exist in the winter months. This is a result of landuse impacts upstream. With the inclusion of an OCS dam, the augmentation of flows in the winter months through release downstream to St Helen's Rock increases the low flows and actually increases compliance with the Gibraltar EWR just below the weir and hydropower site. It must be noted that an existing hydropower plant at Camero Estates diverts water through a tunnel bypassing a stretch of river of about 3 to 4 km. The outlet of the hydropower plant is below the Ncwabeni weir. Water diverted through the hydropower plant tunnel will affect this stretch of river.

A subsequent project contracted by the Chief Directorate Resource Directed Measures (CD: RDM) office has sought to extend the number and location of sites to include small tributaries of the Umzimkhulu River. The updated EWRs were sourced from the study team. The updated EWR's included additional rapid reserves. The information was however only received after the majority of the yield analyses were already completed. As such a check was made to determine the change in the Gibraltar EWR using the new information from that already included in the WRYM.

The comparison showed that the total average flow requirements are very similar with an average difference of less than 1 million m^3/a for an EWR with an annual average flow of about 360 million m^3/a. The differences were also predominantly in the higher flow months. As such it is not deemed necessary to re-run the yields with the newer information received. The update EWR's also highlights the process of refinement of EWR flow requirements and how further changes to EWR flow requirements are likely until the classification process and the setting of the river classes and EWR flow requirements has been finalised for the Umzimkhulu River. The yields of the system with an off-channel storage dam will need to be revised once the classification process for the Umzimkhulu River is completed.

The small non-compliance events at Gibraltar EWR site just above the proposed project site also highlight the need for a validation and verification exercise to determine the lawful use in the catchment upstream.

Appendix A

Summary of the Ecological Water Requirements for the Mzimkhulu River and Tributaries

Quaternary catchment	River	EWR site number	EWR site name	Level	PES	REC	EIS	Natural MAR (106m3)	%Maintenance Low Flow	%Maintenance High Flow	%EWR	%Drought Low Flow
T51C	Mzimkhulu	EWR2i	Callaway	Intermediate	B	B	M	261	12.5	12.1	24.6	4.6
T52A	Mzimkhulu	EWR3i	Creighton	Intermediate	B	B	M	870	19.9	3.1	23.0	4.4
T52D	Mzimkhulu	EWR5i	Middle Mzimkhulu	Intermediate	B	B	M	1 085	15.8	5.5	21.3	5.3
T52M	Mzimkhulu	EWR6i	Gibraltar	Intermediate	A/B	A/B	M	1 384	25.5	4.7	30.2	5.7
T51E	Pholela	EWR9r	Pierr	Rapid 3	B/C	B/C	M	110	18.7	9.7	28.4	7.0
T51F	Nwangwane	EWR8r	Coleford	Rapid 3	C	C	M	117	11.7	9.8	21.4	5.6
T52G	Bisi	EWR14r	Welverdiend	Rapid 3	A/B	A/B	M	195	31.2	11.6	42.8	11.9
T52L	Mzimkulwana	EWR17i	Oribi	Intermediate	B	B	H	43	17.6	12.4	30.0	5.9

Appendix B

Summary of the Ecological Water Requirements for the Mzimkhulu River and Tributaries per quaternary catchment (including extrapolated data)

Quat	River/ description	Site name	Level	Latitude	Longitude	MAR (million m³)	EWR (million m³)	Used in the WRYM
T51A	Mzimkhulu	MzRap1	Rapid 3	29.7545	29.3265	108.35	50.26	Y
T51B	Mzimkhulu	T51Be	Extrapolation	Outlet of T51B		244.39	60.11	Y
T51C	Mzimkhulu	MzEWR2i	Intermediate	29.8318	29.5221	260.77	66.07	Y
T51D	Pholela	MzRap2	Rapid 3	29.7009	29.4158	32.31	16.21	Y
T51E	Pholela	MzEWR9r	Rapid 3	29.8915	29.6601	110.28	31.31	Y
T51F	Bushmans	MzRap3	Rapid 3	29.8835	29.2809	54.84	17.56	N
T51F	Nwangwane	MzEWR8r	Rapid 3	29.9552	29.4773	116.67	25.01	Y
T51G	Ndawana	MzRap4	Rapid 3	29.9251	29.2548	16.46	6.49	Y
T51H	Upper Gungununu	MzRap5	Rapid 3	30.0399	29.4668	25.92	8.71	N
T51H	Lower Gungununu	MzRap6	Rapid 3	30.1219	29.6493	116.03	48.11	Y
T51J	Ngwangwane	T51Je	Extrapolation	Outlet of T51J		383.23	107.94	Y
T52A	Mzimkhulu	MzEWR3i	Intermediate	30.0601	29.8028	870.45	199.78	Y
T52A	Nkonzo	MzRap7	Rapid 3	29.9889	29.8509	27.25	7.26	N
T52B	Cabane	MzRap8	Rapid 3	30.1738	29.8413	44.21	25.77	Y
T52C	Mzimkhulu	MzRap13	Rapid 3	30.2588	29.9441	1062.72	435.13	Y
T52D	Mzimkhulu	MzEWR5i	Intermediate	- 30.3565	30.0486	1084.96	231.28	Y
T52E	Upper Bisi	MzRap9	Rapid 3	30.3010	29.7069	27.68	12.77	Y
T52F	Little Bisi	T52Fe	Extrapolation	Outlet of T52F		96.55	42.50	Y
T52G	Bisi	MzEWR14i	Intermediate	30.4193	29.8594	194.63	83.28	Y
T52H	Lower Bisi	T52He	Extrapolation	Outlet of T52H		245.64	82.90	Y
T52H	Mahobe	MzRap10	Rapid 3	30.4775	29.8856	5.80	1.42	N
T52J	Mzimkhulu	MzRap11	Rapid 2	30.5509	30.1106	1357.27	566.26	Y
T52K	Mzimkulwana	MzRap12	Rapid 3	30.7116	30.0757	28.28	8.36	Y
T52L	Mzimkulwana	MzEWR17i	Intermediate	- 30.7074	30.2707	42.53	12.60	Y
T52M	Hlokohloko	Hloko	Rapid 3	30.6486	30.3226	0.95	0.17	N
T52M	Mzimkhulu	MzEWR6i	Intermediate	30.6285	30.2437	1384.13	417.62	Y

Annexure C

Dam release calculation framework

$$Q_{release} = Q_{st\ helen's\ demand} - Q_{surplus\ at\ st\ helen's} \qquad \text{Equation 1}$$

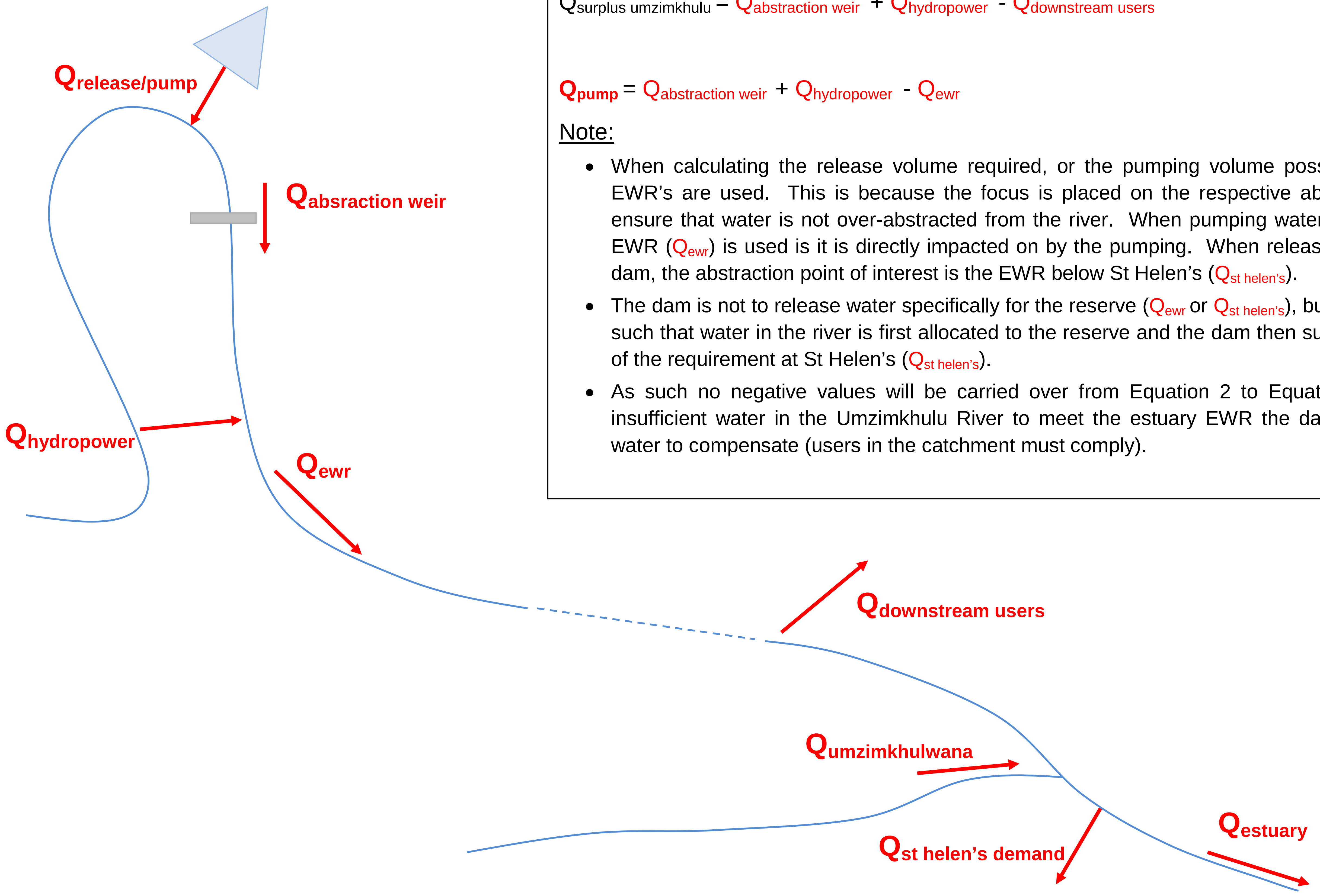
$$Q_{surplus\ at\ st\ helen's} = Q_{surplus\ umzimkhulu} + Q_{umzimkhulwana} - Q_{estuary} \qquad \text{Equation 2}$$

$$Q_{surplus\ umzimkhulu} = Q_{abstraction\ weir} + Q_{hydropower} - Q_{downstream\ users} \qquad \text{Equation 3}$$

$$Q_{pump} = Q_{abstraction\ weir} + Q_{hydropower} - Q_{ewr} \qquad \text{Equation 4}$$

Note:

- When calculating the release volume required, or the pumping volume possible, two different EWR's are used. This is because the focus is placed on the respective abstraction points to ensure that water is not over-abstracted from the river. When pumping water into the dam, the EWR (Q_{ewr}) is used is it is directly impacted on by the pumping. When releasing water from the dam, the abstraction point of interest is the EWR below St Helen's ($Q_{st\ helen's}$).
- The dam is not to release water specifically for the reserve (Q_{ewr} or $Q_{st\ helen's}$), but is to be operated such that water in the river is first allocated to the reserve and the dam then supplies the balance of the requirement at St Helen's ($Q_{st\ helen's}$).
- As such no negative values will be carried over from Equation 2 to Equation 1. If there is insufficient water in the Umzimkhulu River to meet the estuary EWR the dam will not release water to compensate (users in the catchment must comply).



Annexure D

Sedimentation Yield Review

NCWABENI OFF-CHANNEL DAM FEASIBILITY STUDY

SEDIMENT YIELD REPORT

FINAL

MAY 2011

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NCWABENI OFF-CHANNEL STORAGE DAM-FEASIBILITY STUDY
SEDIMENTATION REPORT

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1. Introduction

The northern part of the Lower South Coast Water Supply System (from Hibberdene to Ramsgate, including Port Shepstone) is presently supplied from non-regulated river flow from the Mzimkhulu River. The water is abstracted at the St. Helen's Rock (SHR) abstraction works near Port Shepstone and is pumped to the water treatment works.

The Southern KwaZulu-Natal Water Resources Pre-feasibility Study Phase 1 (SKZNFS PH1), completed in 2002, concluded that during dry periods, the river flow is insufficient to meet the water requirements, even without provision for the release of the ecological Reserve. It was recommended that, in order to provide for the water requirements for all user sectors, including the Reserve, the construction of an off-channel storage reservoir (OCSR) in one of the tributaries to the Mzimkhulu River, should be considered. The reservoir can be filled from its incremental catchment, supplemented by pumping from the Mzimkhulu River during times of high river flows. During times of low flows, the water can be released back into the Mzimkhulu River for abstraction downstream at the existing St. Helen's Rock abstraction works.

The Southern KwaZulu-Natal Water Resources Pre-Feasibility Study Phase 2 (SKZNFS PH2), which was completed in February 2005, investigated numerous options with regards to the position of the potential OCSR. Four potential sites, which are located between 15 and 20 km north-west of Port Shepstone were selected as the most feasible dam sites. Two of the sites (D2 and D2A) are located on the Ncwabeni River, while the other two (D3 and D3A) are on the Gugamela River. During 2006 another pre-feasibility study was initiated by the Department of Water Affairs (DWA) which proposed an off-channel dam at site D2.

ASP Technology (Pty) Ltd was appointed during 2011 by BKS (Pty) Ltd to carry out the hydraulic design of the river abstraction works on the Mzimkhulu River with the aid of a hydraulic physical model study. One of the tasks was to determine the sediment yield of the Mzimkhulu River at the proposed abstraction works on the Mzimkhulu River and at the possible off-channel dam site D2. This report describes the sediment yield determination.

The Mzimkhulu River catchment is shown in Figure 1-1. The sediment yield prediction was required to determine the possible impact of sedimentation on the operation and design of the proposed river abstraction works on the Mzimkhulu River and the loss in storage capacity at the off-channel dam.

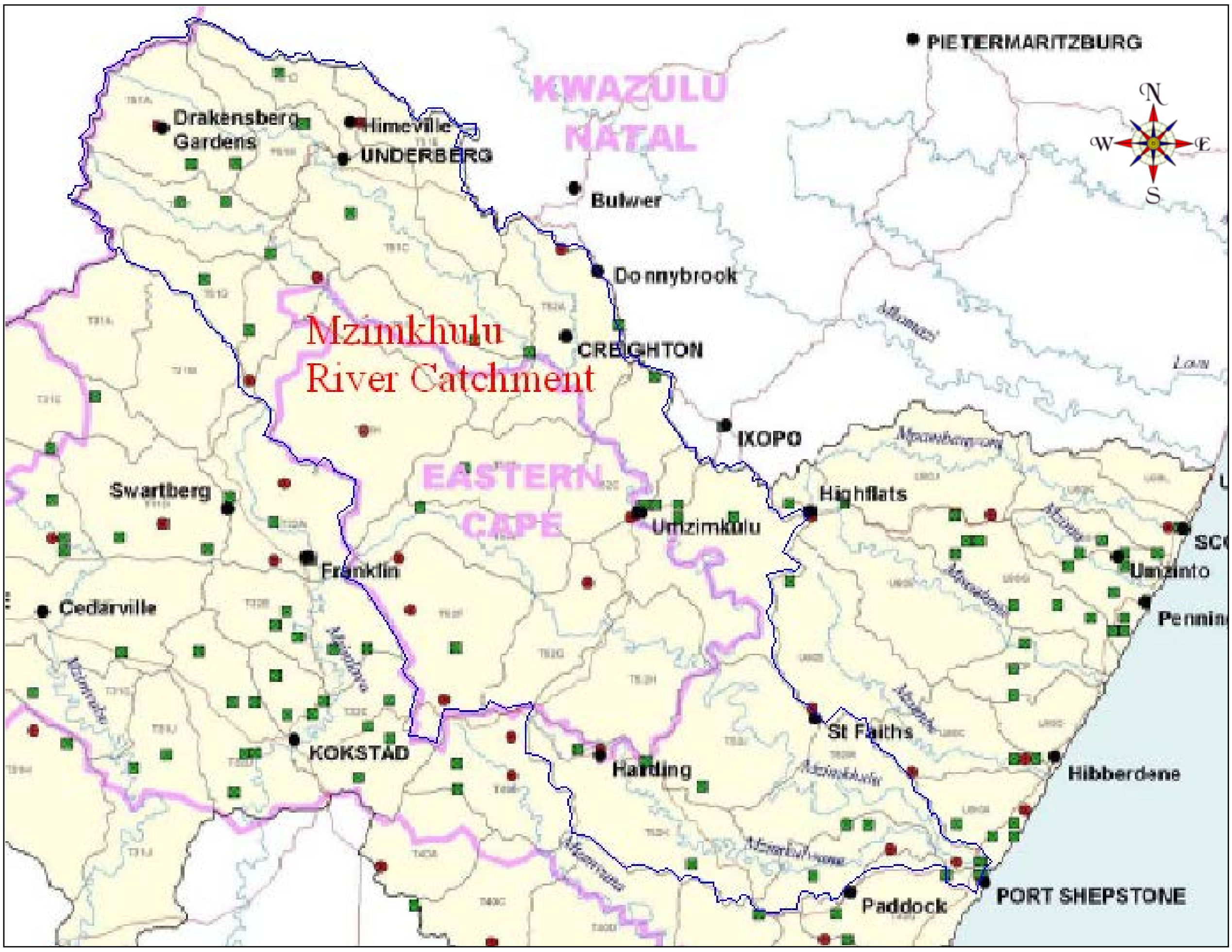

Figure 1-1 General layout of Mzimkhulu River catchment

2 Scope of study

The scope of work of this study included:

a) Field visit to obtain river sediment characteristics
b) Sediment yield prediction of the Mzimkhulu River and the proposed dam site sub-catchment by using the ACRU model with the Modified Universal Soil Loss Equation (MUSLE), considering land use, soil types, hydrology, etc.
c) Comparison of ACRU sediment yield with a regional sediment yield prediction methodology.
d) Design layouts and positioning of the proposed river abstraction works.
e) Calculation of abstracted sediment loads.
f) Evaluation of sediment deposition at the proposed dam site.
g) Hydraulic physical model tests of the river abstraction works
h) Analysis of the weir sedimentation at the abstraction works

3. Methodology to determine sediment yield

The methodology followed during this study to determine the sediment yield involved:

a) Catchment sediment yield modelling by daily hydrological model ACRU and soil erosion module MUSLE.
b) Sediment yield prediction by using a regional empirical method based on the WRC(2010) methodology.

4. Sediment yield modelling by mathematical model

The ACRU model simulates runoff from sub-catchments from rainfall data, and routes the flow through the system. When the MUSLE Module is added, the model routes daily sediment loads. The prediction accuracy depends on the reliability of the input data and available calibration data.

In this study the following assumptions were made:

a) Topographical data were obtained from 1:50 000 scale topographical maps
b) Land use was based on a field visit, 1:50 000 topographical maps and a report by Schäfer and Botha (2002).

Figure 4-1 shows the dense vegetation in the steep D2 site catchment, while Figure 4-2 shows the Mzimkhulu River in the valley downstreamof the proposed dam site.

Figure 4-1 View of Site D2 catchment

Figure 4-2 View of Mzimkhulu River from site D2 catchment on left bank

The general soil type of the Mzimkhulu River catchment was taken as sandy clay loam (80.7 %) and sandy loam (19.3 %).

The land use of the Mzimkhulu River catchment was taken as woodland (31 %), mixed crops (32 %), standveld (30 %) and wetland grasses (7 %) on average (sub-catchment values varied).

The soil erodibility class was taken as medium high (38 %) and medium low (62 %).

The Mzimkhulu River catchment was sub-divided into 27 sub-catchments based on the topography and river network (refer to Figure 4-3).

Calibration against the flow record at gauging station Nooitgedacht on the Mzimkhulu River was carried out mainly for the floods, since they transport most of the sediment. The flow record used for calibration was for the period 1966 to 1975 (refer to Figure 4-4). The model was also calibrated against the flow record at Bezweni (Figure 4-5) for the period 1966 to 1975.

Model simulation of the sediment yield at the proposed abstraction works was carried out for the period 1966 to 1998 (refer to Figures 4-6 and 4-7). The predicted sediment yield could not be calibrated against suspended sediment data (none available).

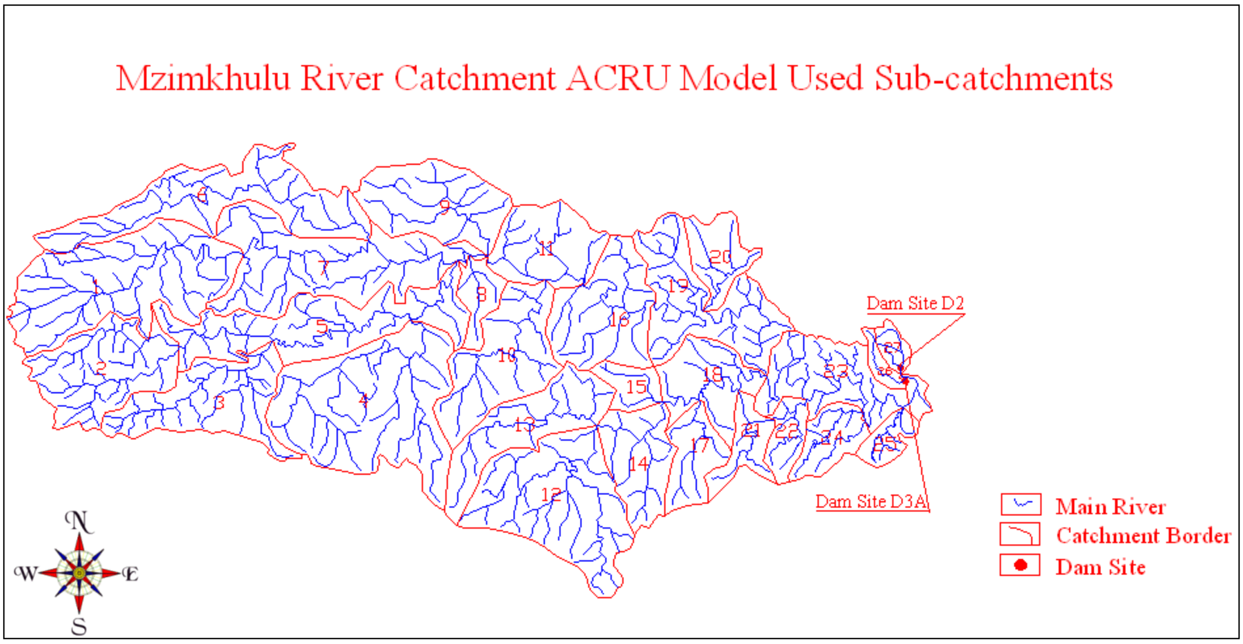

Figure 4-3 ACRU model sub-catchments

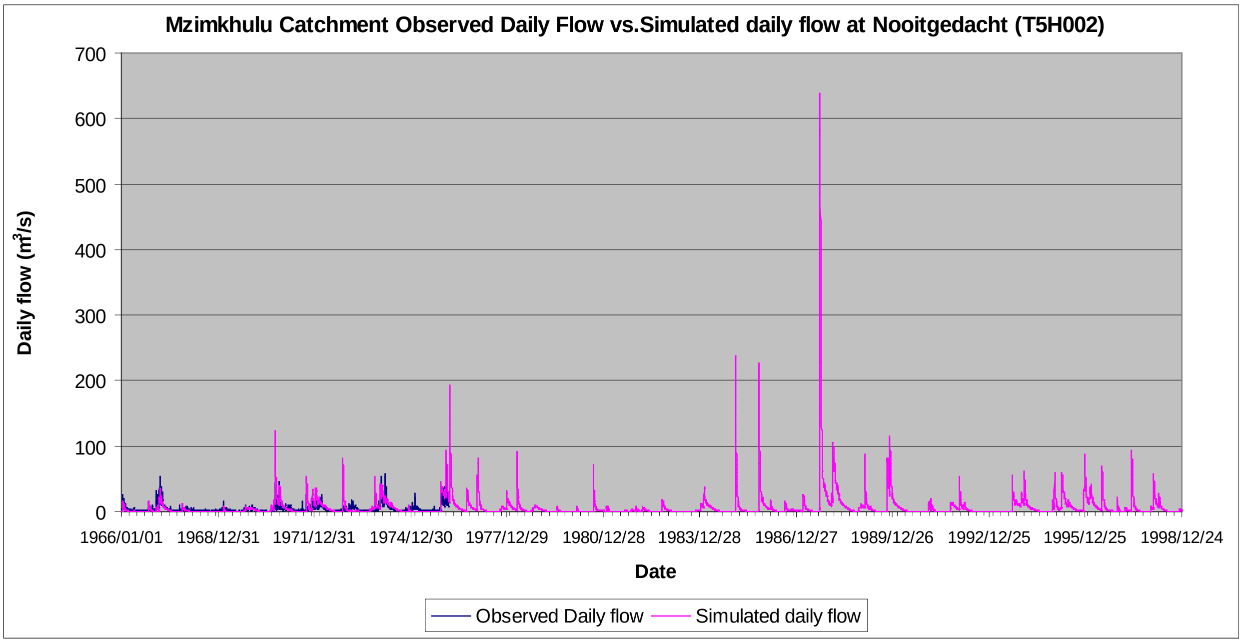

Figure 4-4 Runoff calibration at Nooitgedacht

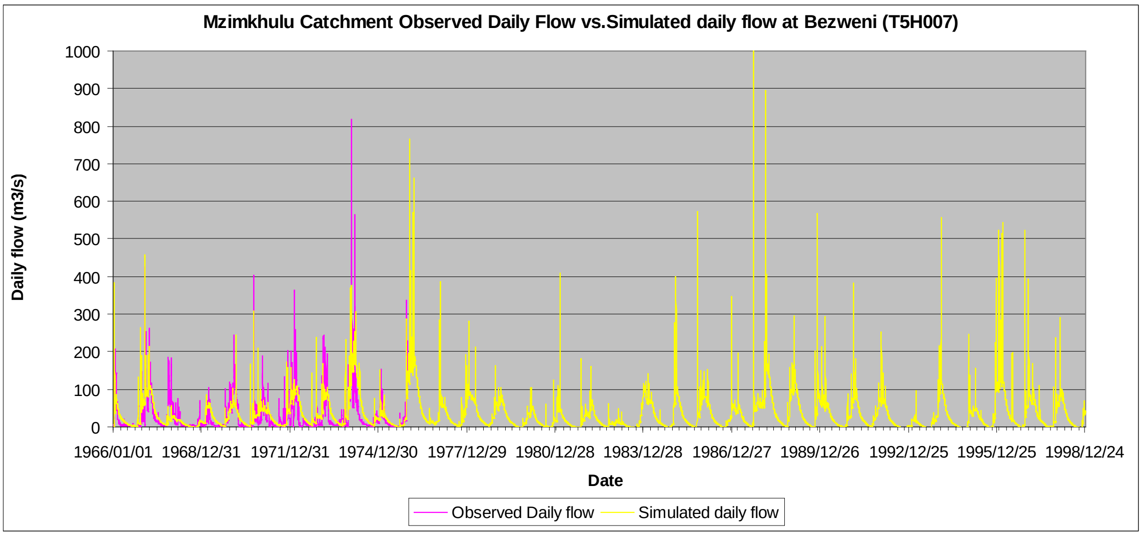

Figure 4-5 Runoff calibration at Bezweni

A sediment yield of 477 t/km^2.year was simulated by ACRU for the 5657 km^2 catchment area at the proposed abstraction works. The highest sub-catchment yield was 2479 t/km^2.a (No 24) and the lowest was 80 t/km^2/a (No 7) (refer to Table 4.1). Figure 4-6 shows the simulated sediment yields graphically. This large difference in sediment yields is typical of South African catchments and is often related to soil types, catchment slope and land use. In this specific case the high sediment yield of sub catchment 24 is due to farming activity.

At the off-channel dam site D2, the sediment yield predicted is 1303 t/km^2/annum.

The dam site sediment yield is relatively high, but take into account possible future land degradation, often encountered with development of water resources.

Figure 4-7 shows the simulated annual sediment loads. During wetter periods the sediment loads were the highest. The simulated sediment yield per year is in agreement with the rainfall pattern (refer to Figure 4-8).

Table 4.1 Sub-catchment sediment yields

Sub-catchment No.	Catchment area (km^2)	Sediment yield ($ton/km^2/annum$)
1	464	207
2	271	302
3	260	305
4	530	208
5	354	86
6	356	151
7	405	80
8	63	720
9	244	454
10	265	892
11	187	552
12	406	469
13	224	996
14	164	576
15	57	788
16	248	337
17	108	628
18	159	557
19	288	571
20	99	392
21	77	1458
22	63	1793
23	226	802
24	89	2479
25	49	1994
Total sub-catchments 1 to 25	5657	477
27 (site D2)	40	1303

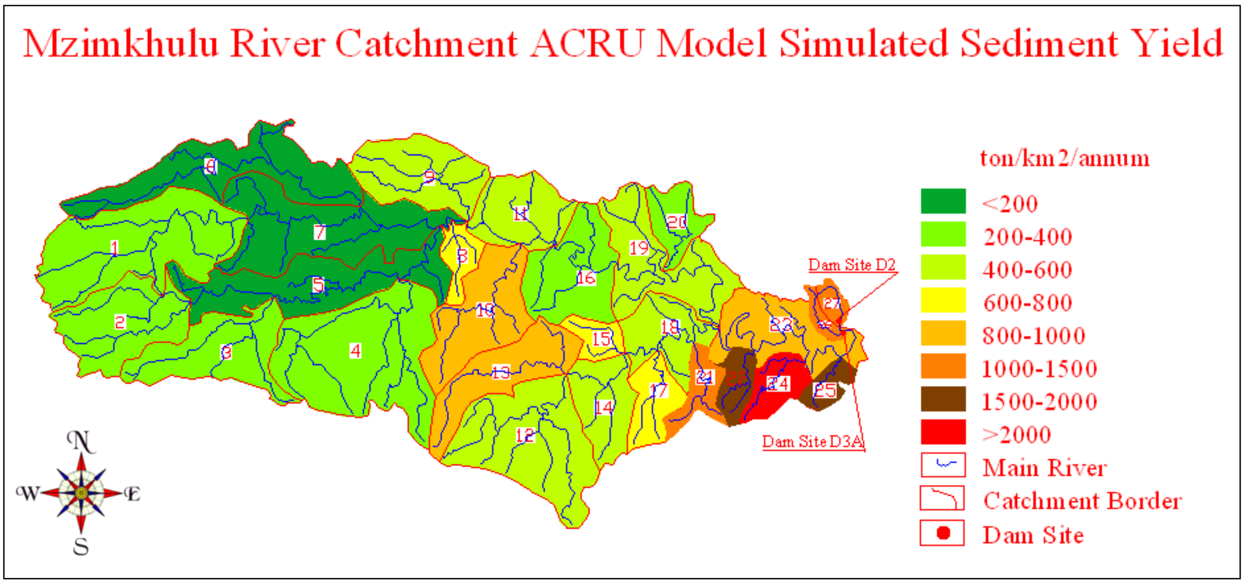

Figure 4-6 Simulated sub-catchment sediment yields

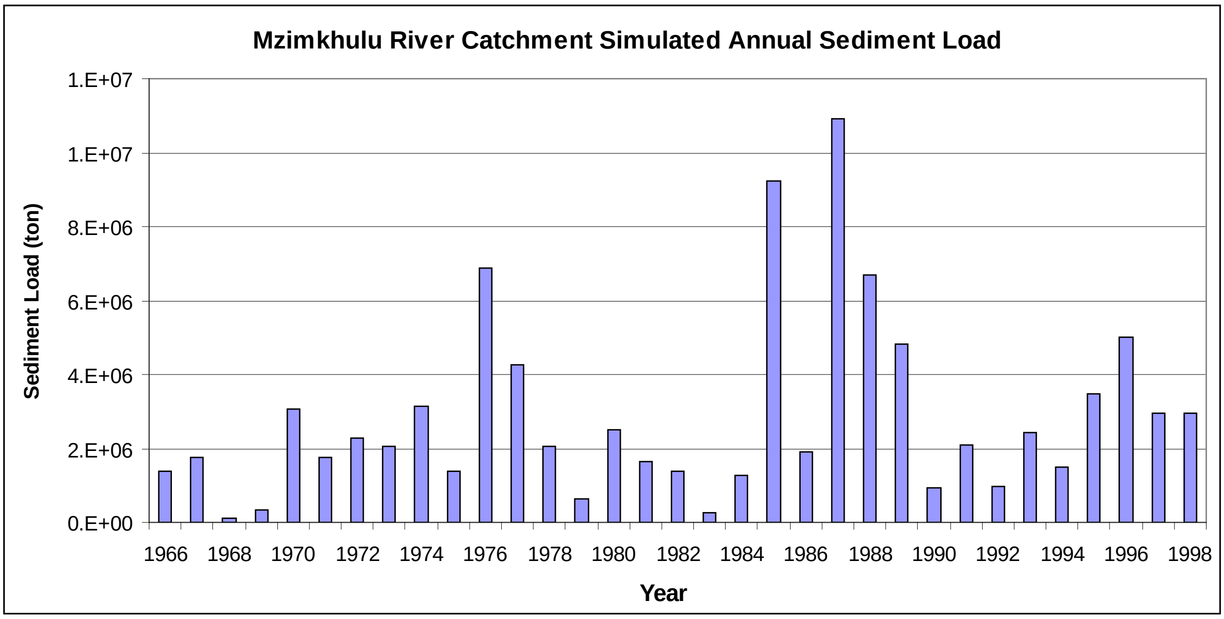

Figure 4-7 Simulated annual sediment loads for sub-catchments 1 to 25

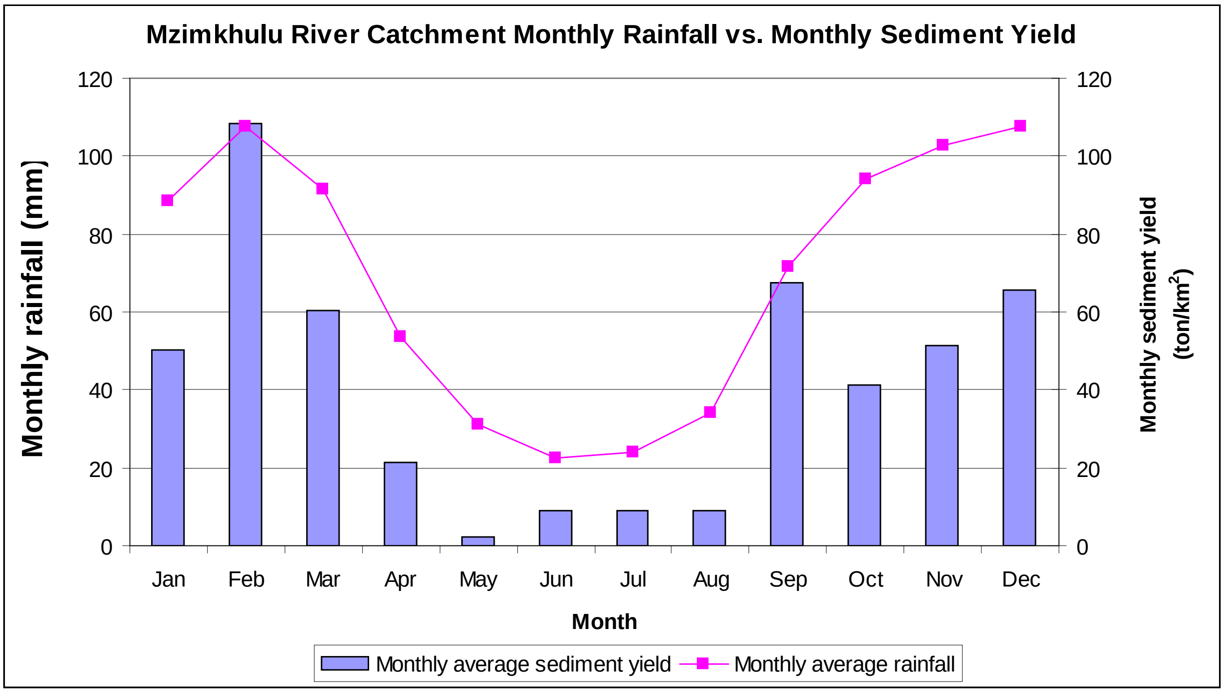

Figure 4-8 Monthly rainfall and simulated monthly sediment yield

5. Regional sediment yield prediction methodology

The sediment yields from the catchments upstream of the proposed dam site and diversion weirs were estimated in accordance with the revised Sediment Yield Prediction Methodology (WRC, 2010). The yields were estimated for 50%, 80%, 90% and 95% confidence levels, and were used for sizing of the off-channel dam. A summary of the results is provided in Table 5.1.

Table 5.1 Estimated sediment yields at proposed sites by WRC (2010) methodology

Site	Confidence level (%)	Sediment yield (t/km^2/a)
D2 dam site	50	424
	80	721
	90	1060
	95	1336
Mzimkhulu River at abstraction works	50	256
	80	436
	90	641
	95	807

6. Comparison of sediment yield predictions

In summary the predictions by the methods used on the Mzimkhulu River were as follows:

a) ACRU model: 477 t/km^2/a
b) WRC (2010) 807 t/km^2/a

The prediction at the proposed off-channel dam site was as follows:

a) ACRU model : 1303 t/km^2/a
b) WRC (2010) method (95%): 1336 t/km^2/a

On the Mzimkhulu River the 80 percentile WRC method sediment yield is comparable with the value of the ACRU model. It is, however, proposed that the WRC 95 percentile sediment yield is used in the design of the abstraction works. The ACRU model is mainly a soil erosion model (MUSLE) with many assumptions made on the land use and degradation, while the WRC (2010) method uses observed empirical regional sediment yield data. Considering possible future land degradation with development in the catchment, a 95 percentile sediment prediction value is proposed (WRC, 2010).

At the dam site the ACRU and WRC (2010) predictions are similar and again the 95 percentile value is proposed of the WRC method.

The ACRU model needs calibration for reliable prediction, while the WRC (2010) offers a regionally calibrated empirical method. Local river suspended sediment transport data or reservoir sedimentation would be more reliable than the ACRU and WRC predictions. No long term records could however be found of suspended sediment data on the river. The dams in the Mzimkhulu River catchment are relatively small and no sediment survey data are available. The Gilbert Eyles Dam is located 14 km south east of the Ncwabeni Dam site on the Mzimkhulwana River. It was constructed in 1951 and has lost 77 % of the original storage capacity by 1986, the last survey on record. The Gilbert Eyles Reservoir is however small (original storage capacity was 1.44 million m^3, which decreased to 0.34 million m^3 by 1986), with a small sediment trap efficiency and it is therefore not possible to estimate the sediment yield at the dam.

7. Conclusions and recommendations

The following are key conclusions:

Sediment yields have been predicted by the WRC (2010) empirical regional method and the ACRU model. No reliable local reservoir sediment survey or long term river suspended sediment data was available. Sediment yields based on the WRC (2010) method are proposed, while the daily time series of flows and sediment loads could be used to determine the abstracted sediment loads at the river pumpstation. The proposed sediment yields and loads are:

- Mzimkhulu River at the proposed abstraction works (5657 km^2): 807 $t/km^2/a$, which gives a mean annual load of 4.565 million t/a.
- D2 dam site (40 km^2): 1336 $t/km^2/a$, with a mean annual load of 53440 t/a.

The proposed dam sub-catchment sediment yield is relatively high, but takes into account possible future land degradation and the steepness of the catchment. Only a fraction of the river sediment would be abstracted, and the dam site annual sediment load is small because of the small catchment area. Limited sedimentation is a key benefit of the off channel dam.

8. References

Schafer, W. and Botha, J. (2002). Southern Kwazulu-Natal Water Resources Prefeasibility Study. Supporting Report 3: Hydrology. DWAF Report no. P U000-00-0501.

WRC. (2010). Sediment yield prediction for South Africa – 2010 edition. To be published.

APPENDIX A

Sediment yield calculations for the Mzimkhulu River

Catchment T51

Subcatchment	Area	length	Dns	CSlp	RSlp	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9	EI10	Total
	[km^2]	[m]	[km/km^2]	[%]	[%]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	
T51A	327.3	36105.5	0.11	11.84	5.07				39.0	264.3	24.0					
T51B	210.0	13783.1	0.07	6.26	2.72			19.0	123.6	67.4						
T51C	461.4	69988.0	0.15	6.82	4.75		33.2	256.9	171.2							
T51D	141.3	33675.4	0.24	8.68	6.70			0.7	65.3	75.3						
T51E	255.4	45215.2	0.18	6.66	3.73			61.7	193.8							
T51F	306.2	67490.0	0.22	8.24	4.58		31.1	65.6	145.1	64.5						
T51G	255.3	36400.0	0.14	7.33	4.85		80.8	120.1	54.4							
T51H	519.2	113322.5	0.22	8.15	5.42		53.3	340.7	125.1							
T51J	264.7	52470.9	0.20	7.49	4.17		9.8	124.1	130.8							
Total	2740.8	468450.6	0.17		4.67	0.0	208.2	988.8	1048.3	471.5	24.0	0.0	0.0	0.0	0.0	2740.8

Catchment T52 *K and L not included, branch joining behind the abstraction works*

Subcatchment	Area	length	Dns	CSlp	RSlp	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9	EI10	Total
	[km^2]	[m]	[km/km^2]	[%]	[%]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	
T52A	381.8	20648.3	0.05	6.94	5.56				335.5	46.3						
T52B	255.4	38852.4	0.15	6.45	4.23			5.2	249.3	0.9						
T52C	260.5	40251.8	0.15	7.60	2.26				143.7	116.8						
T52D	530.0	104565.4	0.20	7.75	6.94				196.9	327.6	5.4					
T52E	232.6	40721.6	0.18	6.55	4.41			65.0	133.0	34.6						
T52F	416.8	57591.5	0.14	7.55	4.43			272.8	144.0							
T52G	220.7	33527.3	0.15	9.13	4.00				132.7	88.0						
T52H	343.6	75515.4	0.22	6.66	5.20				0.3	343.3						
T52J	366.8	49646.6	0.14	9.92	7.82					356.0	10.8					
T52M	311.8	59067.0	0.19	9.79	6.85			6.3	28.6	186.5	90.5					
Total	3320.0	520387.3	0.16		5.17	0.0	0.0	349.3	1364.0	1500.0	106.7	0.0	0.0	0.0	0.0	3320.0

Total	**6060.8**	**988837.9**				**0.0**	**208.2**	**1338.1**	**2412.3**	**1971.5**	**130.7**	**0.0**	**0.0**	**0.0**	**0.0**	**6060.8**
weighting							0.03	0.22	0.40	0.33	0.02					1.00
							0.07	0.66	1.59	1.63	0.13					4.08

Q_{10} =	1930	m^3/s		A flood of a recurrecence interval 1 in 10 years
R_{nd} =	163.2	m/km^2		River Network Density
A_e =	6060.8	km^2		Effective Catchment Area
EI_w =	4.08			Weighted Erodibility Index according to sub-catchment areas
S_0 =	4.9	%		Average River Slope
Q_s =	1553524	t/a		Sediment load
Q_s =	**256.3**	**$t/km^2.a$**		50%
	435.7	$t/km^2.a$	x1.7	80%
	640.8	$t/km^2.a$	x2.5	90%
	807.4	$t/km^2.a$	x3.15	95%

APPENDIX B

Sediment yield calculations for the off-channel dam site D2

Subcatchment	Area	length	Dns	CSlp	RSlp	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9	EI10	Total
	[km^2]	[m]	[km/km^2]	[%]	[%]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	[km^2]	
T52M	311.8	59067.0	0.19	9.79	6.85			6.3	28.6	186.5	90.5					311.9
weighting								0.02	0.09	0.60	0.29					1.00
								0.06	0.37	2.99	1.74					5.16

Q_{10} =	140.55	m^3/s		A flood of a recurrecence interval 1 in 10 years
R_{nd} =	190.0	m/km^2		River Network Density
A_e =	311.9	km^2		Effective Catchment Area
EI_w =	5.16			Weighted Erodibility Index according to sub-catchment areas
S_0 =	6.9	%		Average River Slope
Q_s =	132297.2	t/a		Sediment load
Q_s =	**424.2**	**$t/km^2.a$**		50%
	721.1	$t/km^2.a$	x1.70	80%
	1060.4	$t/km^2.a$	x2.50	90%
	1336.1	$t/km^2.a$	x3.15	95%

1:10 year flood *(Drainage Manual)*

Q =	140.6	peak flow [m^3/s]	T_C =	2.1	time of concentration [hours]
C =	0.476	run-off coefficient [-]	L =	13	hydraulic length of catchment [km]
I =	26.63486	average rainfall intensity over catchment [mm/hour]	S_{av} =	0.022	average slope [m/m]
A =	39.91	effective area of catchment [km^2]			
			$H_{0,85L}$ =	395	elevation height at 85% of length [m]
C_S =	0.26	Surface slope	$H_{0,10L}$ =	177	elevation height at 10% of length [m]
C_P =	0.26	Permeability			
C_V =	0.04	Vegetation			
F_t =	0.85				
C_{PMF} =	0.86				
P_T =	55	Point rainfall [mm]			

Annexure E

Limnology Assessment

NCWABENI OFF-CHANNEL STORAGE DAM

FEASIBILITY STUDY: MODULE 1: TECHNICAL STUDY

WATER QUALITY

JANUARY 2012

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TITLE	***:***	***NCWABENI OFF-CHANNEL STORAGE DAM FEASIBILITY STUDY: MODULE 1: TECHNICAL STUDY - WATER QUALITY***
Project Team	***:***	*BKS (Pty) Ltd*
Client	***:***	*Department of Water Affairs*
BKS Project No	***:***	*J01494*
Status of Report	***:***	*Draft*
Date of this Issue	***:***	*January 2012*

For BKS (Pty) Ltd

Compiled by	:	B le Roux		15 December 2011
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Approved by	:			
		Initials & Surname	Signature	Date

EXECUTIVE SUMMARY

The Mzimkhulu Regional Water Supply Scheme, which forms part of the KwaZulu Natal's Lower South Coast System, supplies water to the coastal region from Hiberdeen to Margate, including Port Shepstone. Subsequently the Ncwabeni Off-channel Storage Dam Feasibility Study: Module 1: Technical Study was initiated to conduct a comprehensive engineering investigation at the feasibility level for the proposed Ncwabeni Off-Channel Storage Scheme (OCSS).

The aim of this feasibility water quality assessment is to guide the design and planning of the proposed Ncwabeni impoundment and its operation to optimise water quality. The findings of the Water Quality Assessment of the proposed Ncwabeni impoundment are as follows:

***Catchment Assessment - Overview of pollution potential**: Water will be pumped from the Mzimkhulu River to be stored in the Ncwabeni Off-Channel Storage Dam, Located on the Ncwabeni Tributary. The catchments of the Ncwabeni and Mzimkhulu Rivers will therefore both impact on the water quality of the Ncwabeni Dam. The upper Mzimkhulu catchment is utilised for agricultural purposes, forestry, tourism and informal residential settlement. Population density in the catchment is low and is unlikely to have significant water quality impacts. There are no industries in the catchment, and no mining activities are known. In general, catchment quality is good to very good, and very few water quality problems are anticipated.*

***Current water quality status**: Water quality measured in the Mzimkhulu and Ncwabeni Rivers is generally good, with low concentrations of dissolved salts, turbidity and nutrients for the majority of the time. Iron and some bacterial counts are, however, above domestic standards.*

***Predicted impact of impounding the Ncwabeni River**: Algal counts are predicted to be low and blooms of nuisance algal species are unlikely to occur. Stratification of the proposed impoundment is likely to result in anoxic water at a depth of 5 - 15 m from the surface during the hottest summer months. In-dam processes such as sedimentation of suspended material and bacteriological removal are likely to significantly improve surface water quality between the inflow and the wall of the proposed impoundments.*

***Management of proposed impoundments to optimise water quality**: Scouring (as opposed to spilling) is the recommended release mechanism during low rainfall and low inflow conditions when algal numbers are high to avoid release of algal-laden water into the downstream riverine ecosystems. It is recommended that spill-abstraction-scour releases be managed to minimise the impact on aquatic life. From a water quality planning perspective, there appear to be no significant water quality problems that preclude the construction of the proposed Ncwabeni impoundment.*

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LIST OF ACRONYMS

SKZNFS:	Southern KwaZulu-Natal Pre-feasibility Study
OCSS:	Off-Channel Storage Scheme
EC:	Electrical Conductivity
TDS:	Total Dissolved Solids
TP:	Total Phosphates
OP:	Ortho-Phosphates
FC:	Faecal Coliform
IDP:	Integrated Development Plan
ENPAT:	Environmental Protection Atlas
DWAF:	Department of Water Affairs and Forestry (prior to 2009)
MAR:	Mean Annual Runoff
MAP:	Mean Annual Precipitation
FSC:	Full Supply Capacity
FSL:	Full Supply Level
DO:	Dissolved Oxygen
mamsl:	metres above mean sea level.

1. INTRODUCTION

1.1. BACKGROUND TO THE PROJECT

The Mzimkhulu Regional Water Supply Scheme, which forms part of the KwaZulu Natal's Lower South Coast System, supplies water to the coastal region from Hiberdeen to Margate, including Port Shepstone. The water is presently sourced from non-regulated river flows in the Mzimkhulu River. The water is abstracted at the St. Helen's Rock (SHR) abstraction works near Port Shepstone and is pumped into a water treatment works. From there the water is distributed to the various user nodes.

The *Southern KwaZulu-Natal Water Resources Pre-feasibility Study Phase 1* [(1)] *(SKZNFS PH1)*, completed in 2002, concluded that during dry periods, the river flow is not sufficient to meet the water requirements, even without provision for the release of the ecological Reserve. The study recommended that, in order to provide for the water requirements for all user sectors, including the Reserve, the construction of an off-channel storage (OCS) dam in one of the tributaries to the Mzimkhulu River, should be considered. The reservoir can be filled from its incremental catchment, supplemented by pumping from the Mzimkhulu River during times of high river flows. During times of low flows water can be released back into the Mzimkhulu River for abstraction downstream at the existing St. Helen's Rock abstraction works.

The *Southern KwaZulu-Natal Water Resources Pre-feasibility Study Phase 2* [(2)] *(SKZNFS PH2)*, which was completed in February 2005, investigated numerous options with regard to the position of the potential OCS dams. Four competitive sites which are located about 20 km north-west of Port Shepstone were selected as the most feasible potential OCS dam sites. Two of the sites (D2 and D2A) are located on the Ncwabeni River while the other two (D3 and D3A) are on the Gugamela River. Conceptual designs for dams at these sites were undertaken as part of the afore-mentioned study.

Following on the above, the Reconnaissance Phase of the *Mzimkhulu River Off-Channel Storage Pre-feasibility Study* [(3)], completed in October 2007, re-assessed all four OCS dam options on the basis of more detailed hydrological modelling and updated information regarding water requirements, topographical surveys, geotechnical and flood hydrology data, which became available after completion of the *SKZNFS PH2*. It was established that the D3 site on the Gugamela River and the D2A site on the Ncwabeni River were distinctly less favourable than the other two sites and were therefore not investigated further. The study concluded that the geological conditions for the sites on the Ncwabeni River are superior to those on the Gugamela River and that the construction of a Roller Compacted Concrete (RCC) dam at the D2 site on the Ncwabeni River appeared the most feasible option.

Subsequently the *Ncwabeni Off-channel Storage Dam Feasibility Study: Module 1: Technical Study* (this study) was initiated to conduct a comprehensive engineering investigation at the feasibility level for the proposed Ncwabeni Off-Channel Storage Scheme (OCSS). The possible dam at site D2 on the Ncwabeni River was to be considered first and if a fatal flaw or substantial increase in cost is identified, site D3A on the Gugamela River should then be considered.

Figure 1-1 indicates the location of this proposed OCSS and **Figure 1-2** indicates the preliminary layout of the scheme configurations at the time of conducting the investigation.

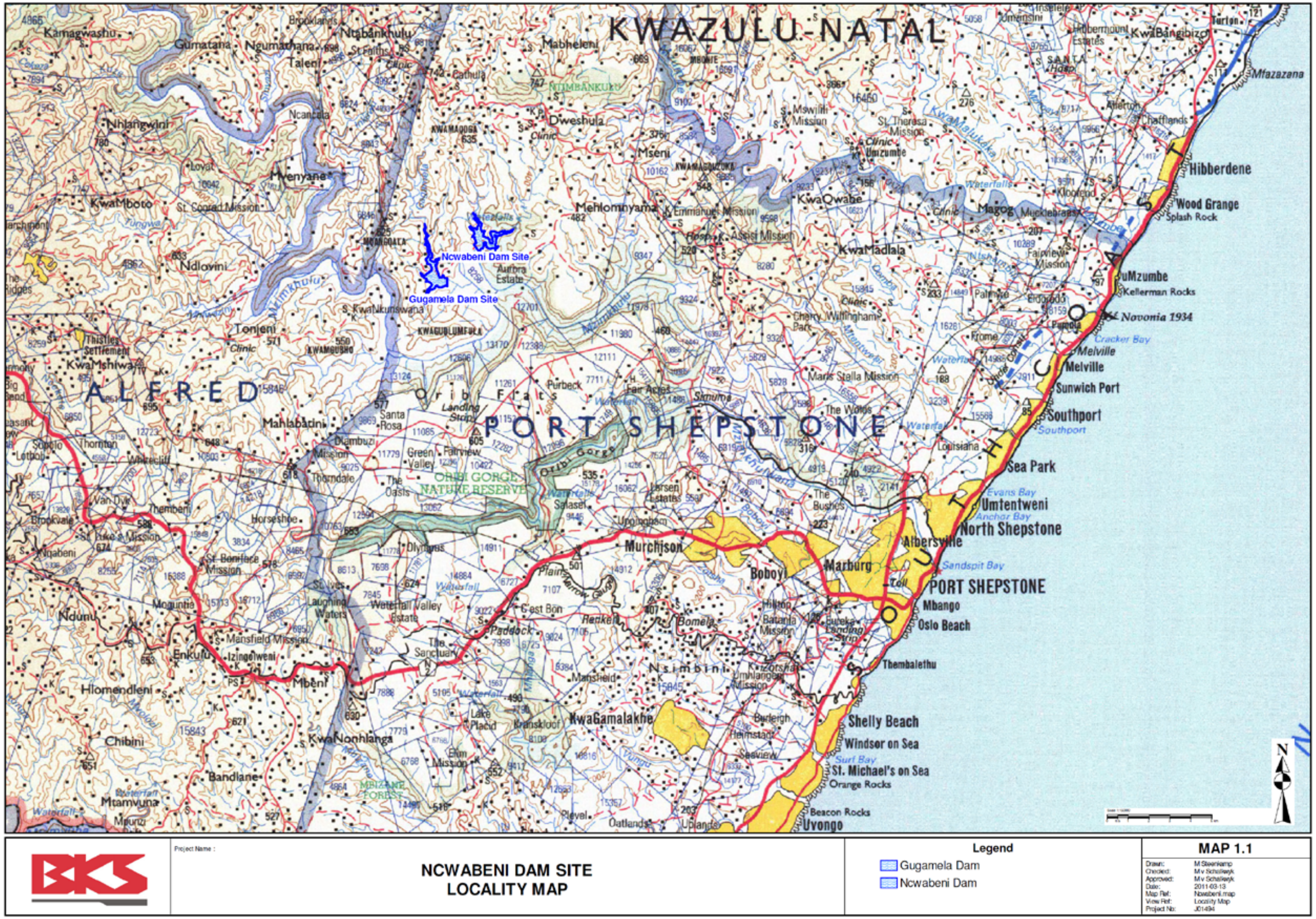


Figure 1-1: Location of the proposed OCSS

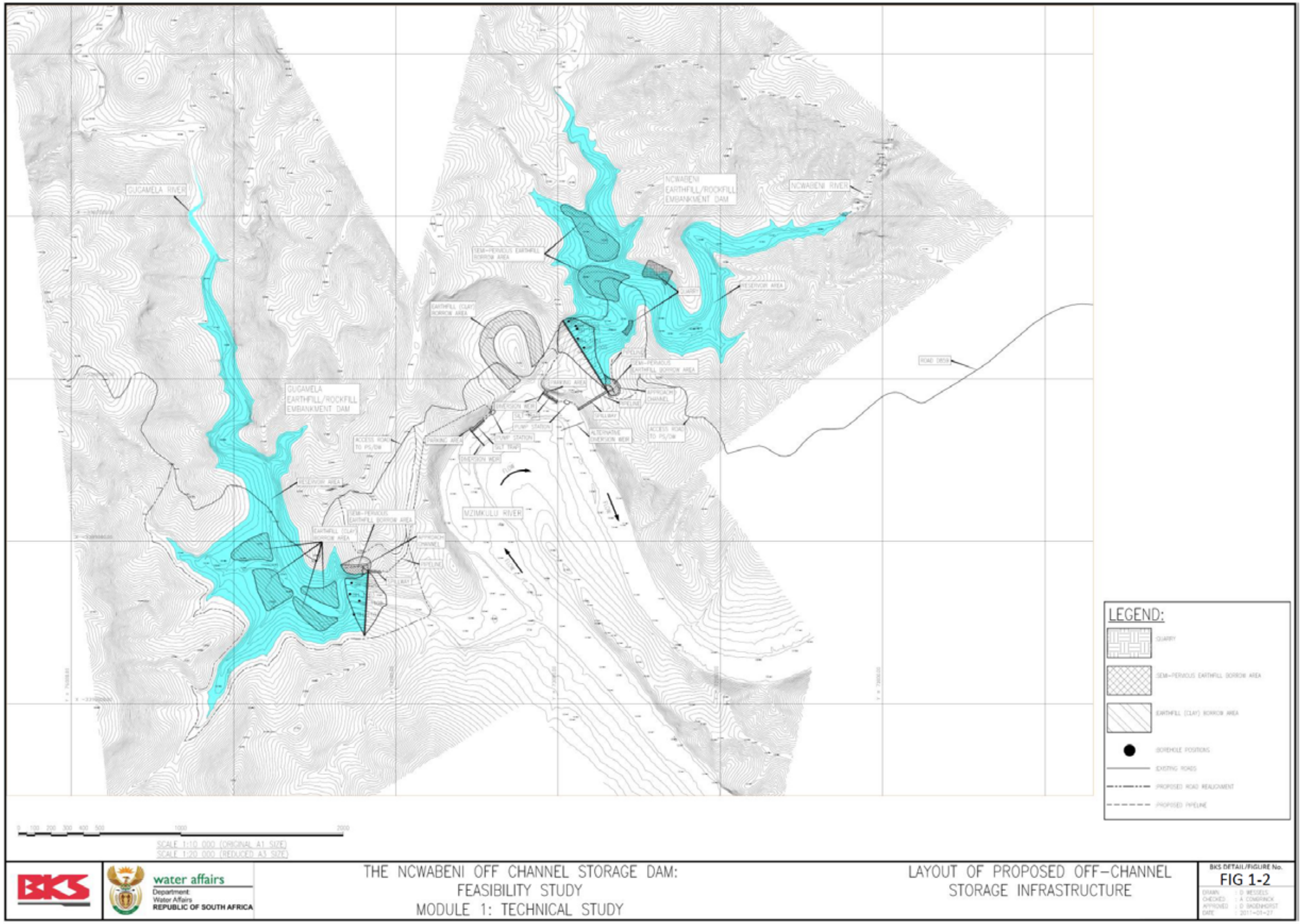


Figure 1-2: Preliminary layout of the scheme configuration

1.2. Purpose of the Water Quality Assessment

The aim of the water quality assessment is to guide the design and operation of the proposed Ncwabeni impoundment to optimise abstraction water quality. Specific objectives are to:

- Assess the quality of the raw water source and land use activities upstream of the impoundment
- Predict the quality of the impounded water
- Recommend best water quality management practices for abstraction and release
- Provide data for advising on storage infrastructure

1.3. Purpose and Layout of this Report

This report documents the results of a water quality assessment for the proposed Ncwabeni OCSS. The assessment considered the following factors:

- Land uses in the Mzimkhulu and Ncwabeni River catchments
  - Agricultural activities
  - Residential and rural settlements
  - Forestry
  - Tourism
  - Nature reserves and wetlands
- Water quality data of the Mzimkhulu and Ncwabeni Rivers
  - pH
  - Electrical Conductivity (EC) and Total Dissolved Solids (TDS)
  - Suspended solids and turbidity
  - Iron and manganese
  - Orthophosphates
  - Nitrates
  - Microbiological
  - Chlorophyll a
- Predicted water quality impacts of impoundment
  - Algal blooms
  - Stratification of reference impoundments (Hazelmere & Nagle Dams)
  - Reduced metal problems
  - Reduced water quality problems

2. CATCHMENT ASSESSMENT – OVERVIEW OF POLLUTION POTENTIAL

Water will be pumped from the Mzimkhulu River to be stored in the Ncwabeni OCSS on the Ncwabeni River. The catchments of the Ncwabeni and Mzimkhulu Rivers will therefore both impact on the water quality of the proposed Ncwabeni Dam.

The available land cover data (**Figure 2-1**) for the Mzimkhulu and Ncwabeni River catchments were sourced from ENPAT (2000). More detailed information on activities in these catchments was obtained from Integrated Development Plans (IDPs) of the Umzimkhulu and Ingwe Local Municipalities which fall within the relevant catchment areas.

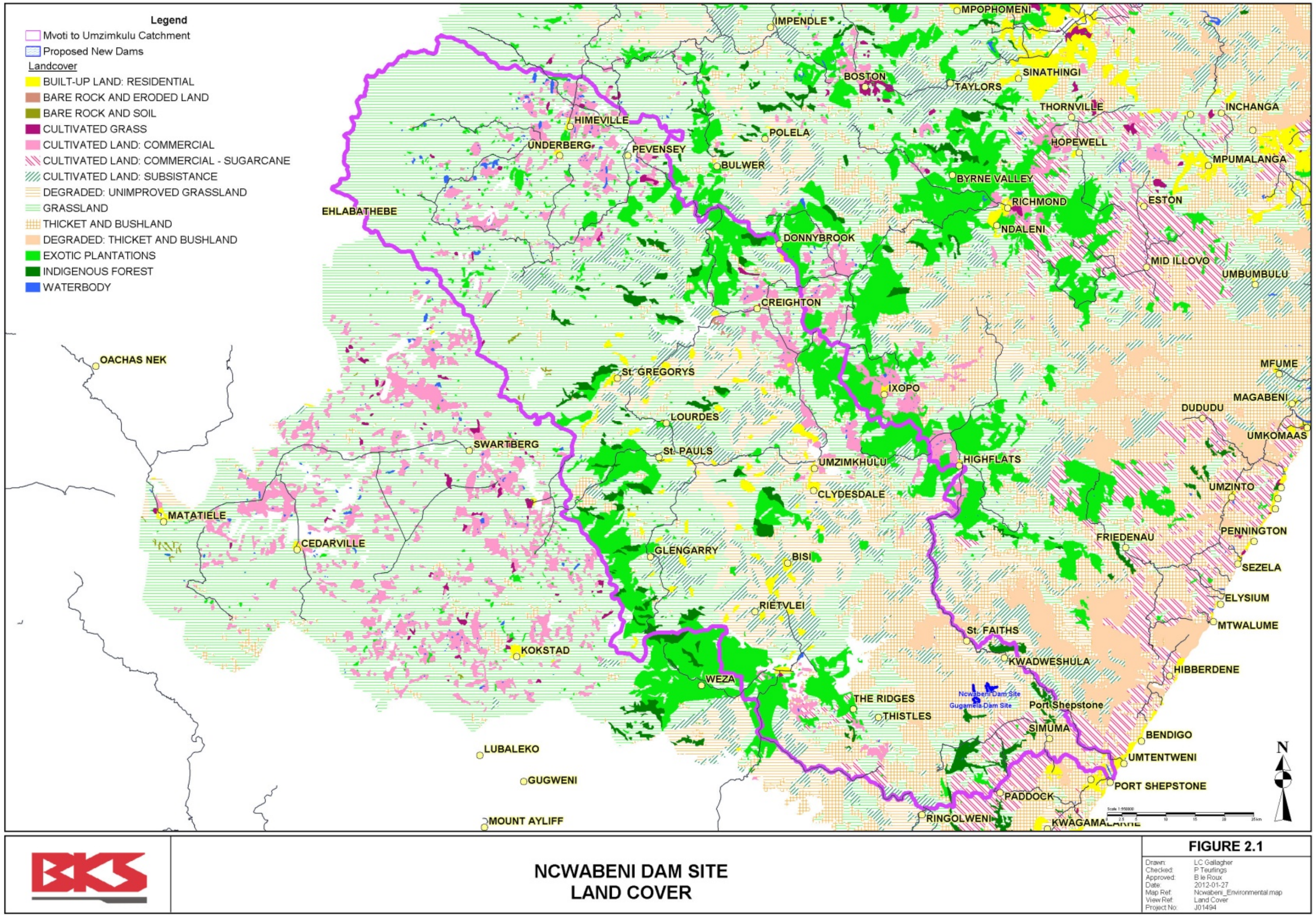


Figure 2-1: Land cover of the Mzimkhulu and Ncwabeni River catchments

2.1. CATCHMENT UPSTREAM OF THE PROPOSED NCWABENI DAM AND MZIMKHULU RIVER

The majority of the catchments of the Ncwabeni and Mzimkhulu Rivers are vacant with unspecified land use while large parts are under conservation. Land uses such as cultivated lands, forestry, subsistence farming and residential areas also cover a significant part of the Mzimkhulu catchment:

- **Forestry** is extensively practised in the Mzimkhulu River catchment and the footprint of current forests is expected to increase significantly in the future (Umzimkhulu IDP, 2011/2012). Pine forests are planted for furniture, building materials and chemicals, while *Eucalypthus* and *Acacia* species (wattles) are planted for the production of paper (Umzimkhulu IDP, 2011/2012). Forestry could result in future water quantity problems and could also impact on water quality through erosion. The species that are used in forestry mentioned above are invasive plants and could threaten the ecological integrity of the water resources downstream.
- **Agriculture** the Mzimkhulu River catchment is practiced on both large and small scale and consists of cattle and sheep, poultry and crop farming. These are the most common ways of sustaining livelihood in the area (Umzimkhulu IDP, 2011/2012). According to the Ingwe IDP (2009/2010) over-grazing and soil erosion occurs and this reduces agricultural outputs. Cultivated lands are often associated with the use of fertilisers and biocides and irrigation return flows, which could have an impact on the water quality. Dairy farming is the largest generator of income in the agricultural sector of Kwasani Local Municipality, which falls within the upper reaches of the Mzimkhulu River catchment. Beef farming also contributes substantially to the agricultural income of the same area.
- Overall **population density** in the Mzimkhulu River catchment is low, but insufficient sanitation services or leaking sewage pipes could result in increased water pollution.
- Quite extensive riparian wetland areas exist and appear to be in reasonable to good condition. These would undoubtedly improve water quality when downstream of problem inputs. According to the 2011/2012 Umzimkhulu IDP (Umzimkhulu IDP, 2011/2012) the Mzimkhulu River floodplain is an important hydrogeomorphic (HGM) unit in the catchment of the Mzimkhulu River. The most important functions of this HGM are sediment trapping and the enhancement of water quality through

phosphate, nitrate and toxicant removal. Other important HGM units in the catchment provides stream flow regulation and erosion control.

- A number of small farm dams exist in the headwaters of the Mzimkhulu River catchment and some are stocked with trout.
- Several nature reserves are found within the Mzimkhulu River catchment including Sani Pass and the Mzimkhulu Wilderness Area.

Considering the relatively low nature of the agricultural practices, together with the existence of many functional wetland areas, few significant water quality issues arise. Of concern is the afforestation that could take place in this catchment and destruction of wetland areas.

2.2. NCWABENI DAM SITE

The Ncwabeni impoundment site is in a pristine condition, with a high diversity of species. The vegetation associated with the banks of the Ncwabeni River is mostly woody plants growing densely within the river valley. This woody vegetation will be removed before the area is inundated by the proposed Ncwabeni impoundment. No human settlements or agricultural lands are found within the impoundment site and no roads will be inundated either. **Table 2-1** summarises the potential water quality issues.

Table 2-1: Summary of potential water quality issues

Land Use	Potential Problems
Forestry	Quantity issues, increasing area under plantations. Environmental degradation. Encroachment into wetlands. Poor harvesting practices/erosion. Forest roads and related erosion.
Intensive crop/silage agriculture	Fertiliser application, irrigation return flows, biocide applications and runoff, wetland encroachment.
Grazing	Erosion, direct input of faecal matter during cattle watering.
Farm worker populations	Inadequate sanitation and other services.
Trout hatchery/ trout dams	Possible nutrient and organic inputs. Trout dams may be established to promote this introduced species, flooding wetlands.
Wetland	Encroachment by agricultural activities and subsequent reduction in water quality and quantity.

3. WATER QUALITY AND HYDROLOGY DATA

3.1. WATER QUALITY DATA

Monthly water quality samples have been collected since March 2011 from the Ncwabeni, Mzimkhulu and Gugamela Rivers. While this is a short monitoring period, it provides an indication of both the summer high rainfall period and the drier winter period, which is necessary to provide an indication of the average and poorest water quality conditions.

3.1.1. pH

The pH values in the Ncwabeni River ranges between 7.7 and 8.3 (**Figure 3-1).** These pH values fall within the range of most natural waters. At these ranges, no adverse effects are expected for all users.

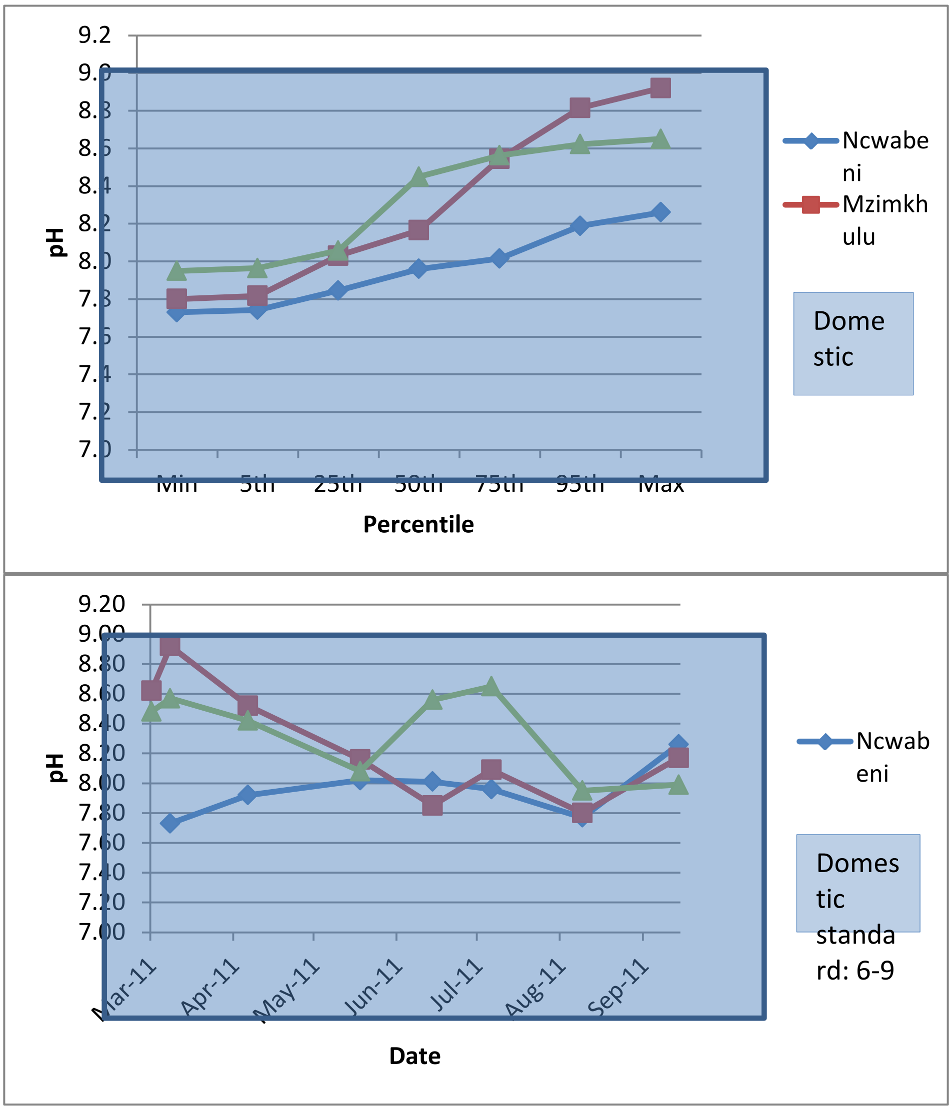


Figure 3-1: pH for the Ncwabeni, Mzimkhulu and Gugamela Rivers

3.1.2. Electrical Conductivity (EC) and dissolved salts

The range of EC results recorded (6-30 mS/m) reflect a soft water with low dissolved salt concentrations. These concentrations are within the DWA water quality standards for domestic water (**Figure 3-2** and **Figure 3-3**). The increase in EC and TDS during June and July could be due to low flow conditions during these months. This would have a greater impact on the water in the Ncwabeni River, as there are impoundments where the flow of water is reduced and evaporation of water can occur.

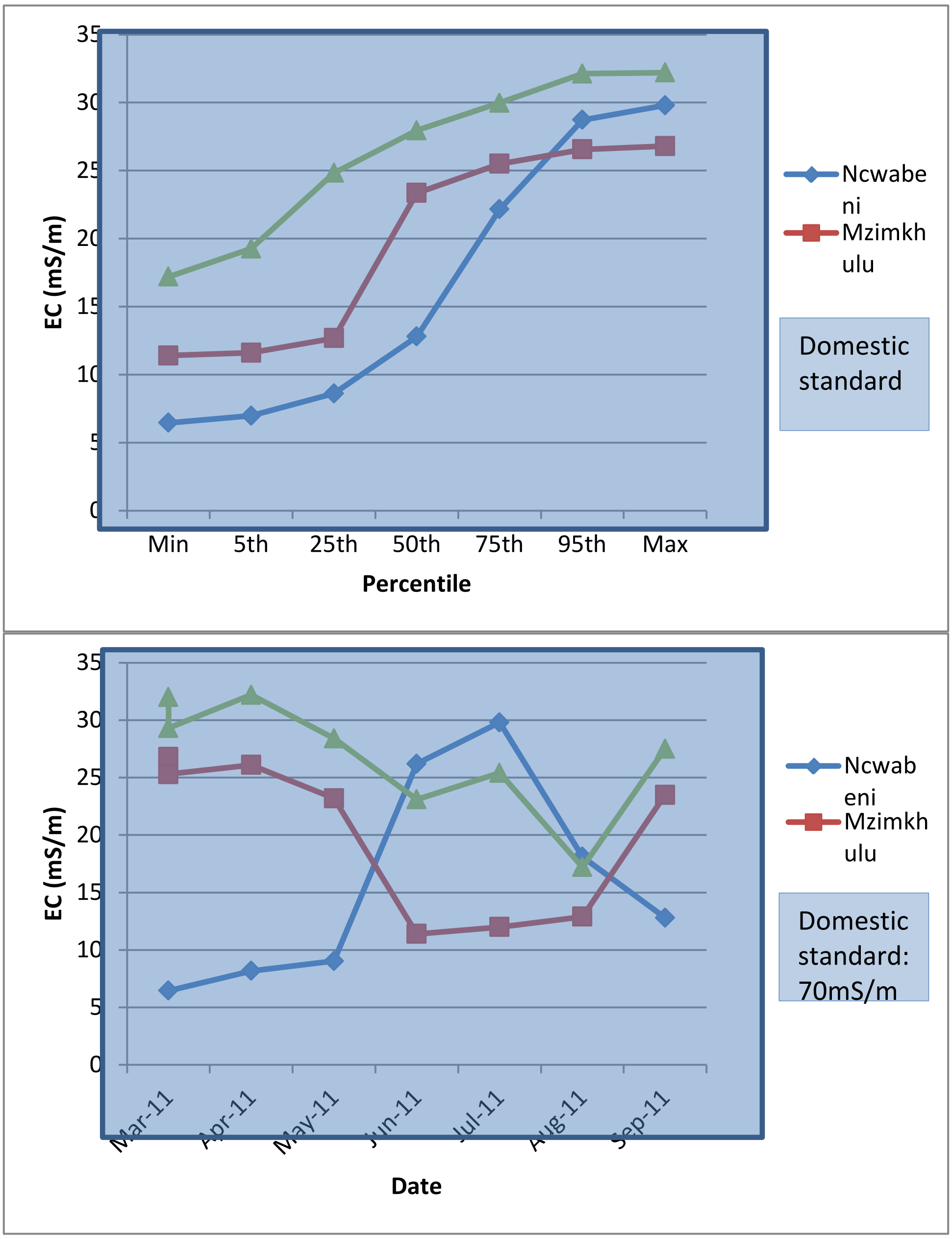


Figure 3-2: Electrical conductivity for the Ncwabeni, Mzimkhulu and Gugamela Rivers

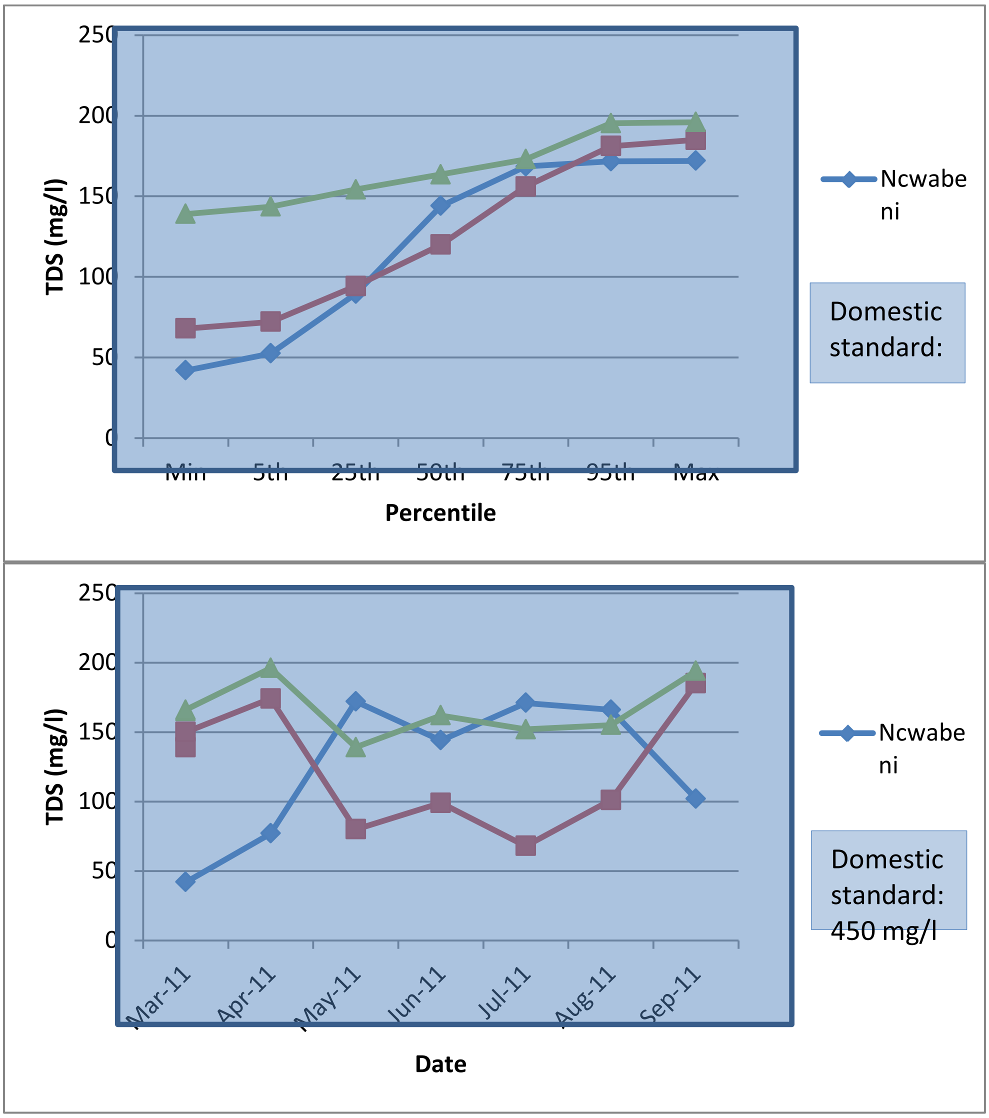


Figure 3-3: Total Dissolved Solids concentration for the Ncwabeni, Mzimkhulu and Gugamela Rivers

3.1.3. Suspended solids and turbidity

The median suspended solid concentration in the Ncwabeni River is low, at 6 mg/l. An increase in the suspended solids during March and August is indicated in **Figure 3-4** and could be ascribed on higher rainfall during these times. The Ncwabeni catchment is in a natural state and not used for agricultural purposes, which is a major source of suspended materials. The higher value of suspended sediment in March 2011 was probably a result of exploration activities taking place upstream of the sampling point.

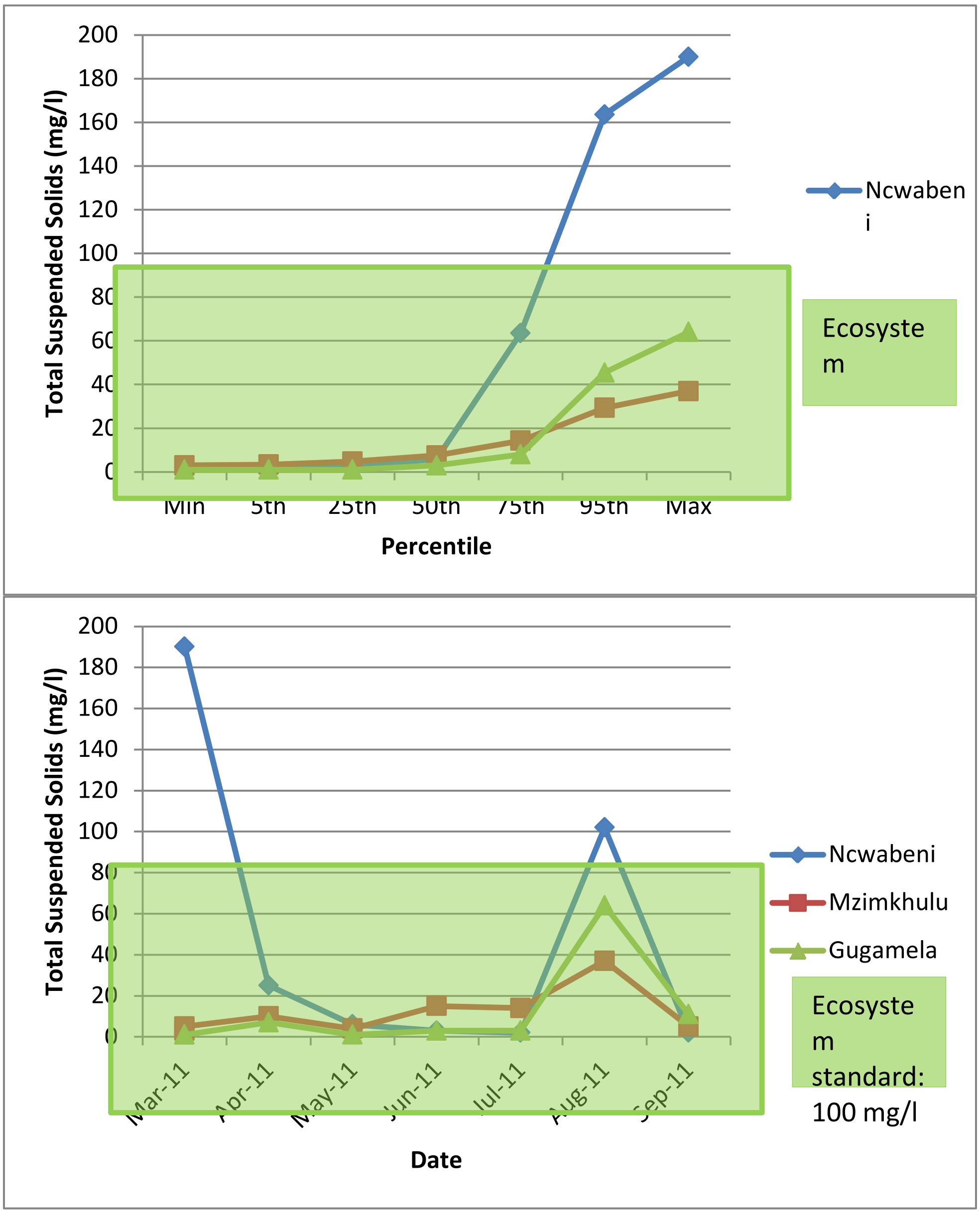


Figure 3-4: Total suspended solids for the Ncwabeni, Mzimkhulu and Gugamela Rivers

3.1.4. Iron and manganese

Metal concentrations, like suspended solids, display higher concentrations during storm flows in August. Median iron and manganese concentrations for the Ncwabeni River were 0.219 mg/l and 0.013 mg/l respectively. Iron concentrations are mostly above drinking standards (DWAF domestic guidelines, 1996), while manganese concentrations are within domestic limits (**Figure 3-5** and **Figure 3-6**).

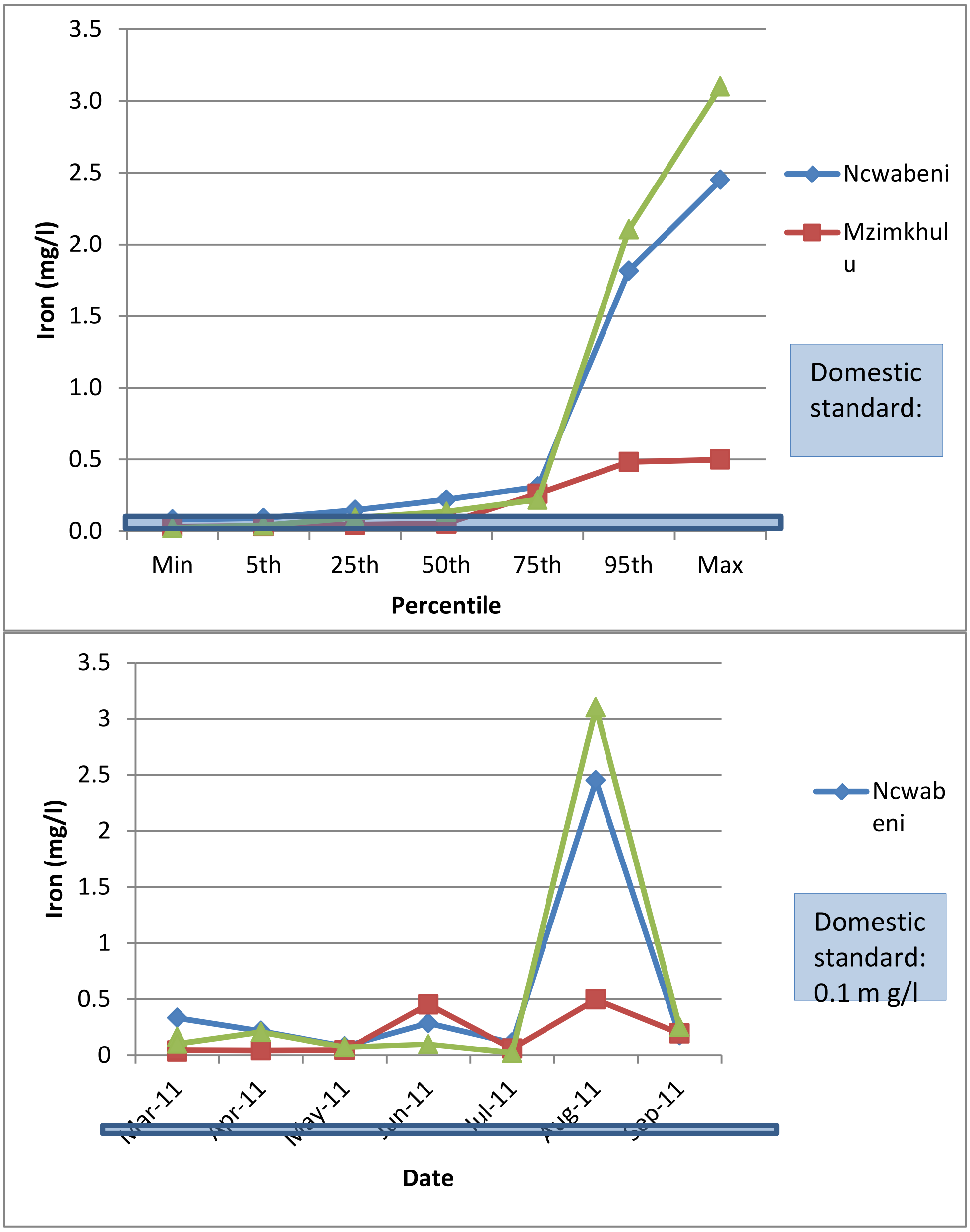
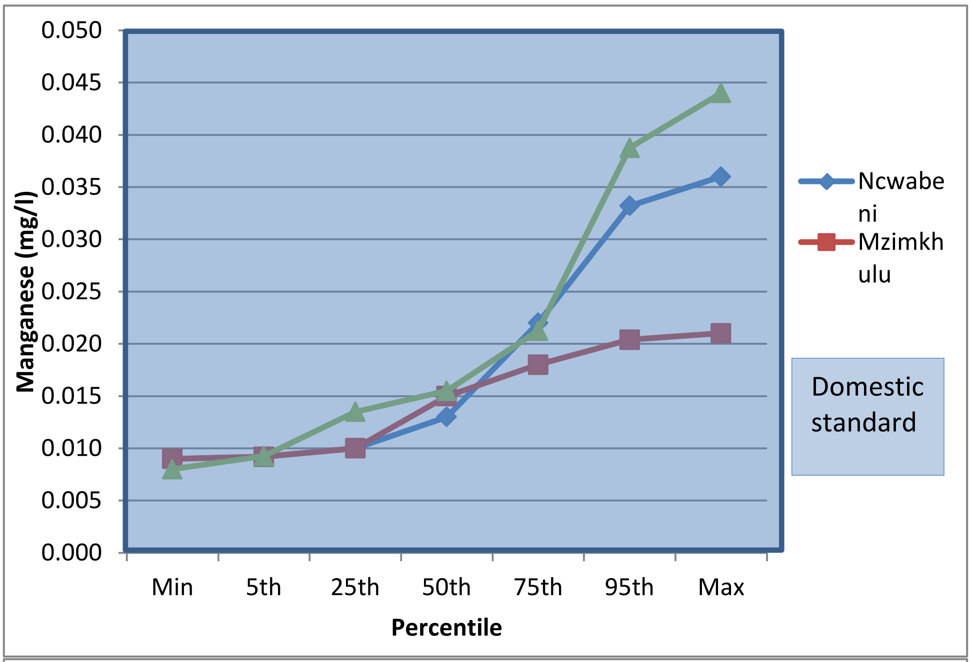


Figure 3-5: Iron concentration for the Ncwabeni, Mzimkhulu and Gugamela Rivers



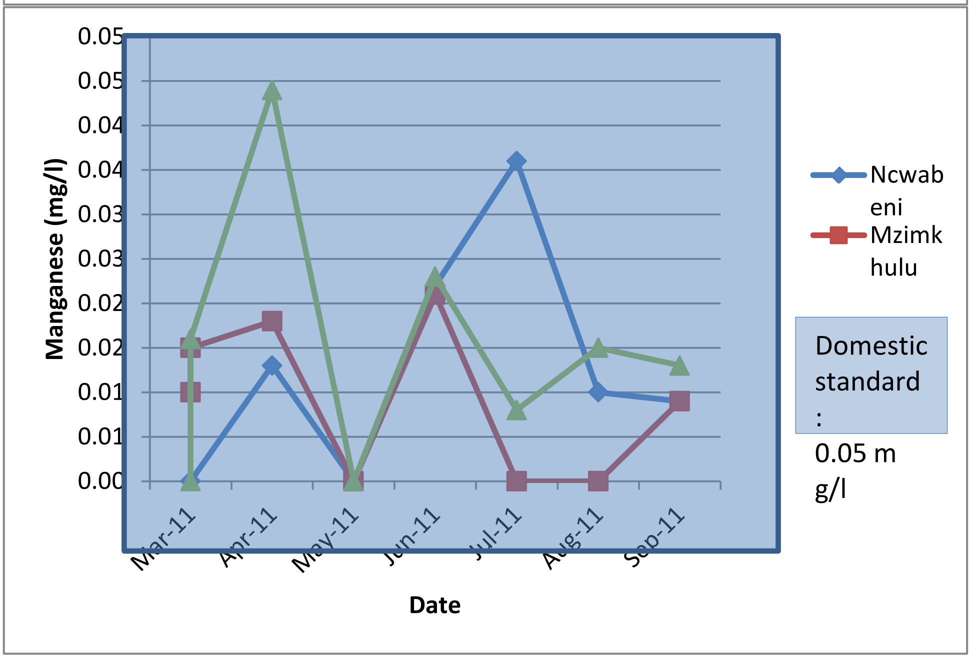


Figure 3-6: Manganese concentration for the Ncwabeni, Mzimkhulu and Gugamela Rivers

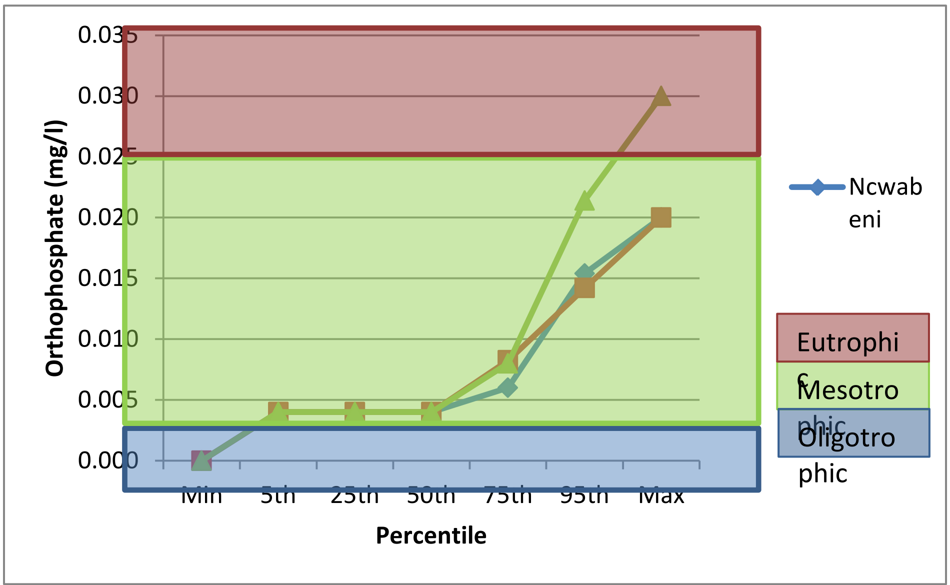
3.1.5. Nutrients – Phosphorus

Phosphorus concentrations for the Ncwabeni, Mzimkhulu and Gugamela Rivers are described in terms of orthophosphate concentrations, because:

- The accuracy of available Total Phosphorus (TP) concentrations were too poor to be used and

- Orthophosphates (OP) are the only form of phosphates that are readily available to algae. Orthophosphates are therefore a driving force behind algal growth in water (Jones & Lee, 1982).

Median concentrations of orthophosphates in the Ncwabeni and Mzimkhulu Rivers are below 0.004 mg/l at which the water is classified as oligotrophic. The maximum concentration of orthophosphates in these rivers is 0.02 mg/l, which causes mesotrophic conditions in the rivers (**Figure 3-7**).



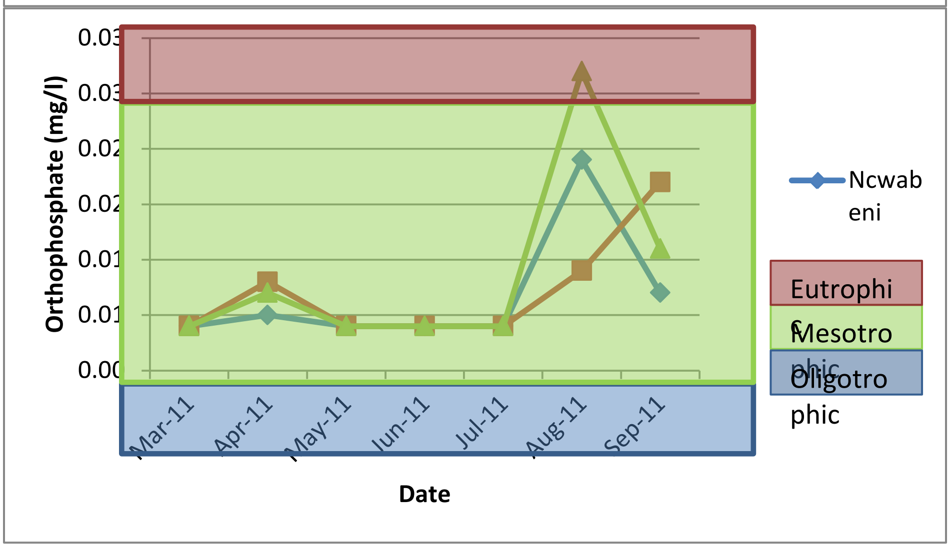
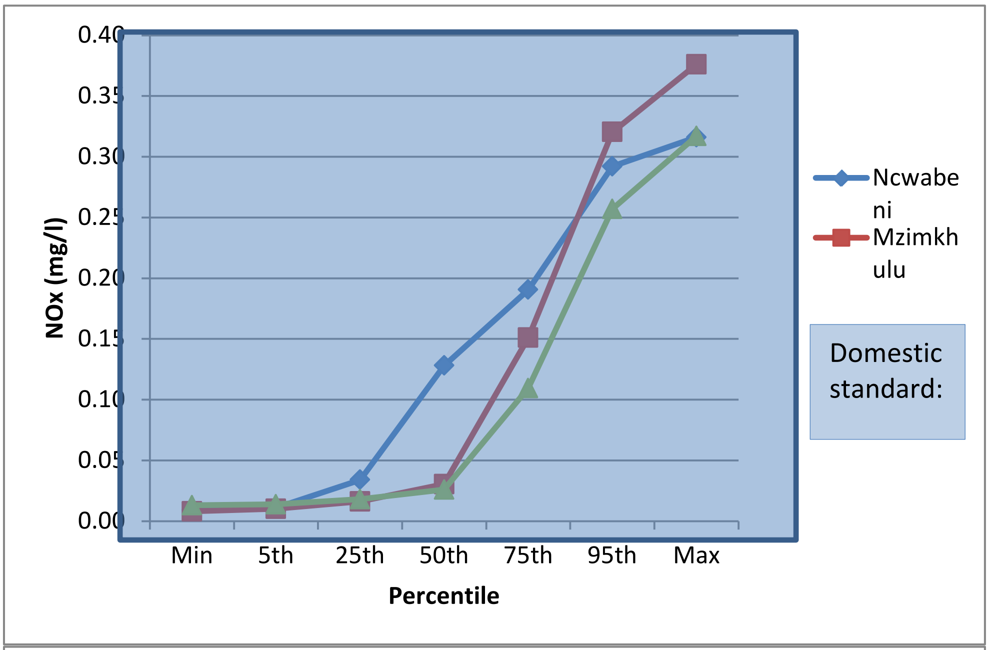


Figure 3-7: Orthophosphate concentration for the Ncwabeni, Mzimkhulu and Gugamela Rivers

3.1.6. Nutrients – Nitrogen

As indicated in **Figure 3-8** median summer inorganic nitrogen concentrations, which is the sum of nitrite, nitrate and ammonia, were calculated to be 0.128 mg/l indicating oligotrophic conditions (DWAF Aquatic Ecosystem guidelines, 1996). Oligotrophic systems usually have moderate levels of biodiversity and are low productivity systems with rapid nutrient cycling. These systems do generally not have nuisance growths of aquatic plants or a significant presence of blue-green algal blooms.



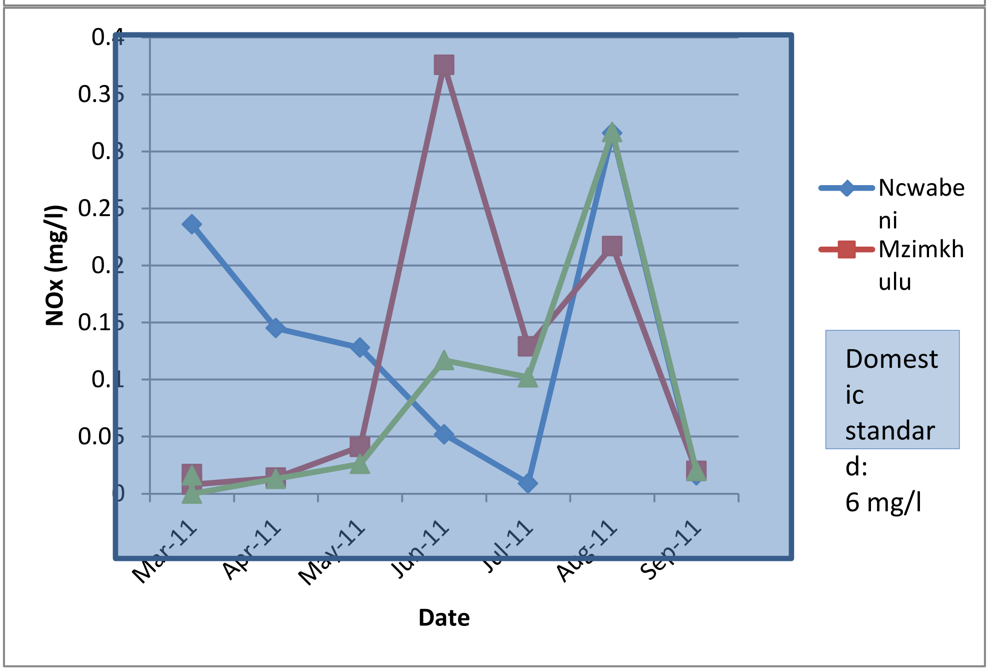


Figure 3-8: Nitrate and nitrite concentration for the Ncwabeni, Mzimkhulu and Gugamela Rivers

3.1.7. Microbiological

The median *E. coli* count at the proposed Ncwabeni impoundment site is low, with 50 cells/100ml recorded. As the Ncwabeni River catchment is a natural system, the maximum result of 579 cells/100ml in the Ncwabeni River is regarded as an outlier and is probably due to faecal contamination immediately upstream of the sampling point. The median *E. coli* statistic in the Mzimkhulu River (200 *E. coli* per 100ml) exceeds the DWAF *E. coli* target water quality guideline for full contact recreation (130 *E. coli* per 100ml), thus posing a slight risk of gastrointestinal illnesses among swimmers and bathers. **Figure 3-9** indicates the faecal coliform counts and **Figure 3-10** indicates the *E. coli* counts from March to September 2011.

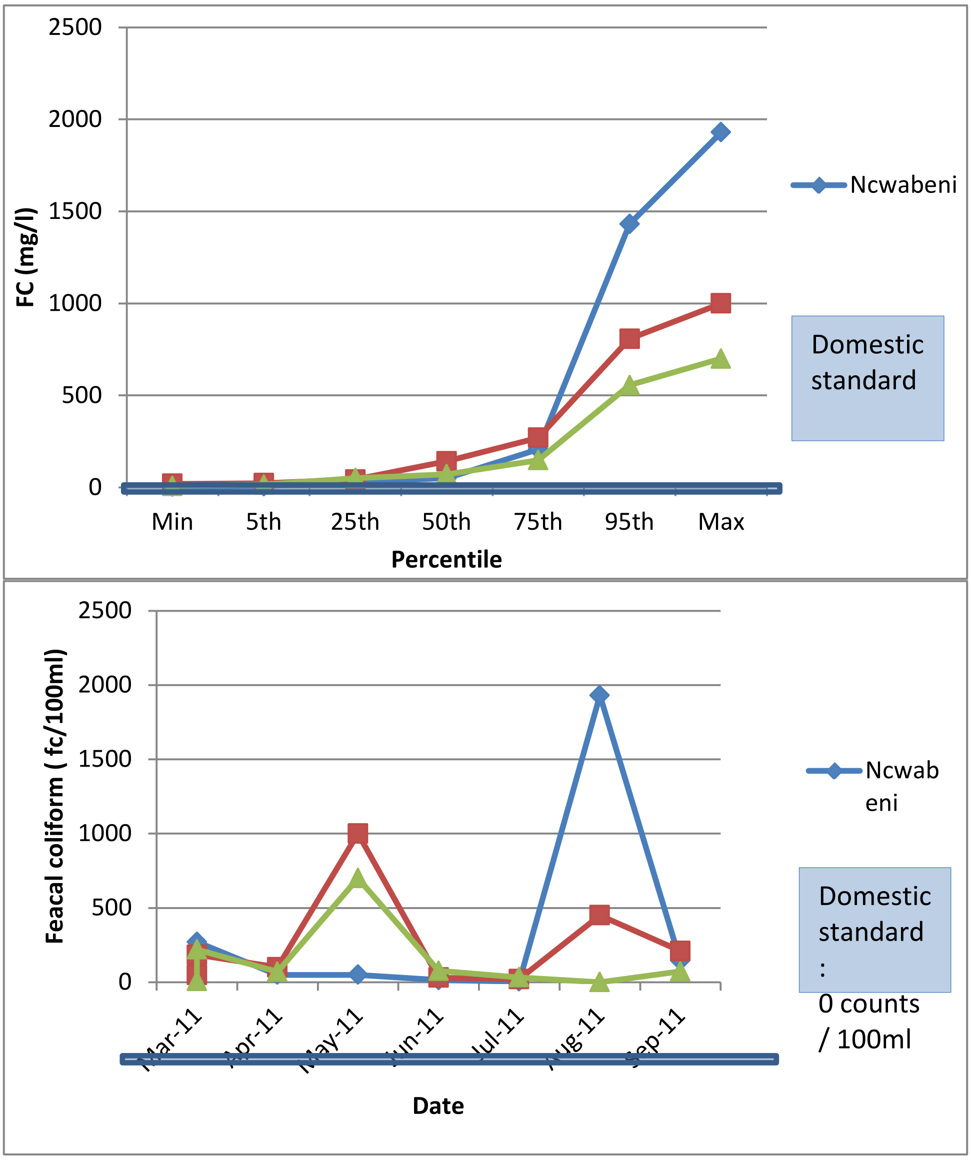


Figure 3-9: Feacal coliform for the Ncwabeni, Mzimkhulu and Gugamela Rivers

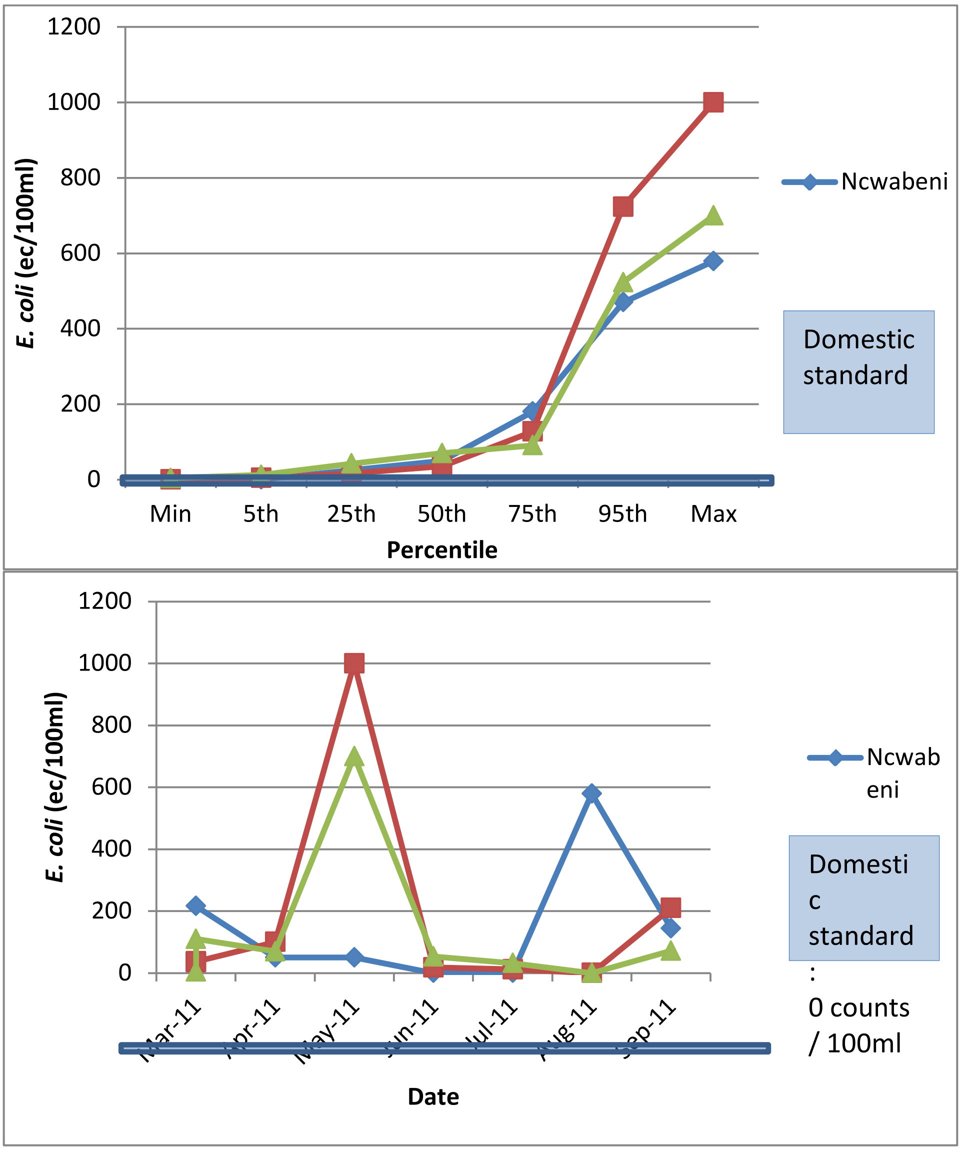


Figure 3-10: *E. coli* for the Ncwabeni, Mzimkhulu and Gugamela Rivers

3.1.8. Chlorophyll a

Algal biomass is usually measured in terms of chlorophyll a concentrations. Chlorophyll a, which is present in most algae, constitutes approximately one to two percent of the dry weight of organic material in all planktonic algae and is the most convenient indicator of algal biomass estimates. The median value of Chlorophyll a in the Ncwabeni and Mzimkhulu Rivers are within limits of aesthetic standards (DWAF domestic guidelines, 1996). Maximum concentrations of Chlorophyll a are well above the standards (**Figure 3-11**) for aesthetic use of water, and the water is expected to be murky and green with taste and odour problems. Secondary growth of bacteria in the distribution systems can also be expected at these concentrations.

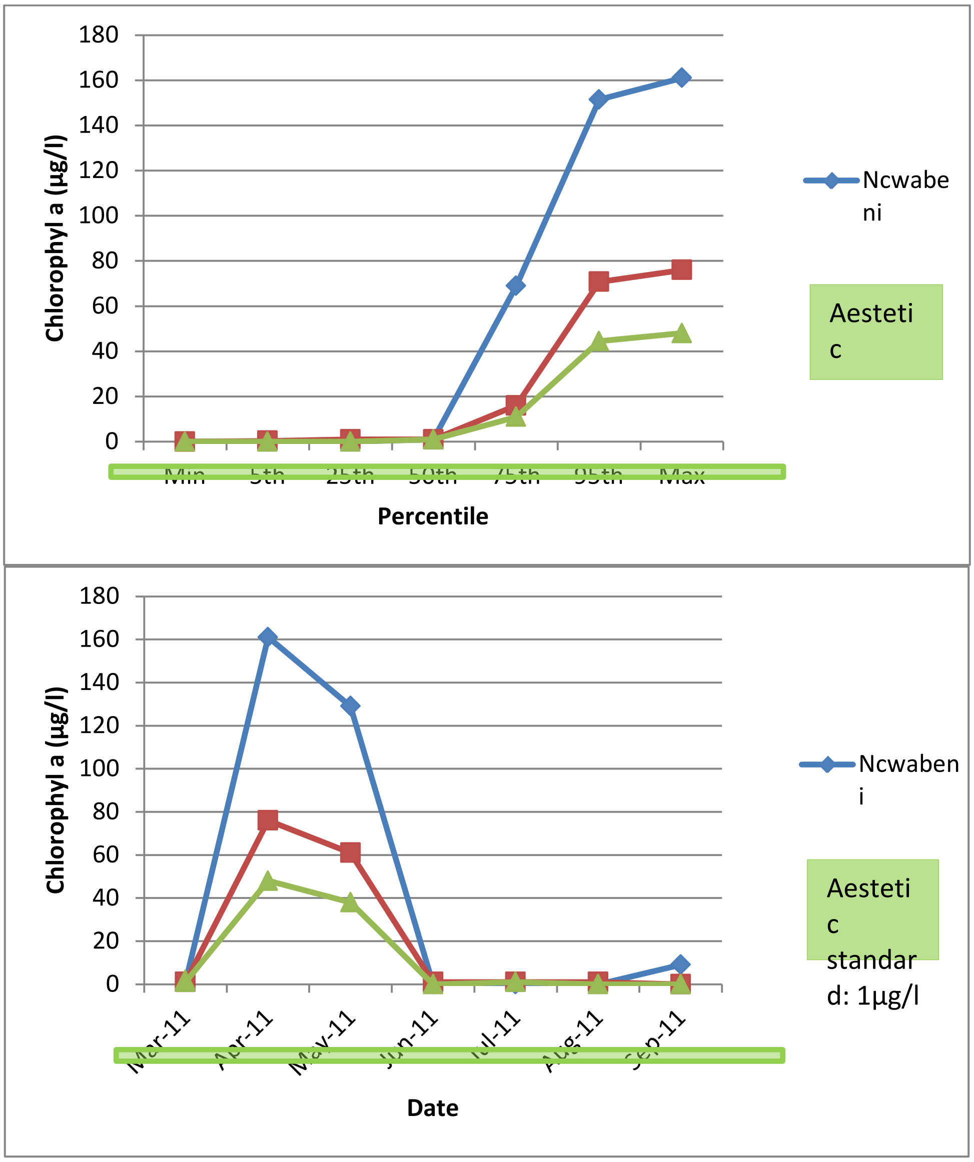


Figure 3-11: Chlorophyll a concentration for the Ncwabeni, Mzimkhulu and Gugamela Rivers

3.2. Hydrological Data

The Mzimkhulu River catchment has an area of 6 678 km^2 and a natural Mean Annual Runoff (MAR) of 1 373 million m^3/annum (DWAF, 2004a). Quaternary T52M contributes only 3% of the cumulative MAR at the Mzimkhulu River mouth (DWAF, 2002). A hydrological and yield assessment was undertaken as part of the Mzimkhulu River Off-Channel Storage pre-feasibility study (DWAF, 2007b) and the results are summarised below. A summary of the MAR at key sites is provided in **Table 3-1**.

Table 3-1: Stream flow hydrology at key locations in the study area (DWAF, 2007b)

Site Name	Catchment size (km2)	Naturalised MAR (million m3/a)	Present Day MAR (million m3/a)
D2 (Ncwabeni River)	39.8	5.5	5.5
D3A (Gugamela River)	34.6	4.8	4.8
Mzimkhulu at confluence with Gugamela River	5 919.0	1 254.0	1 143.0
Mzimkhulu at confluence with Ncwabeni River	5 960.0	1 259.0	1 149.0
Mzimkhulu at St Helen's Rock	6 657.0	1 346.0	1 220.0

A historical firm yield analysis was performed for the Ncwabeni dam site and for a range of dam heights and pump rates (pumping from the Mzimkhulu River into the Ncwabeni OCS dam). The dam size for the Ncwabeni Dam at Full Supply Level (FSL) of 167.5 metres above mean sea level (mamsl) was selected because for this size the yield of the dam will be able to supply (supplemented by pumping from the Mzimkhulu River at various pumping rates) the full range of water requirement scenarios in year 2025 and beyond (lower limit scenario: 16 million m^3/a, planning scenario: 22 million m^3/a and upper limit scenario: 26 million m^3/a). At these sizes and at a pumping rate of 0.5 m^3/s the dam can meet the water requirements for the planning scenario in 2025 (DWAF, 2007b).

Table 3-2 displays summary statistics for the simulated inflow volumes and impoundment storage, based on the dam operated for full Yield, for the proposed impoundment between 1920 and 2007. **Figure 3-12** shows time series plots of this monthly hydrograph data.

Table 3-2: Hydrological characteristics of the proposed Ncwabeni impoundment

Hydrological characteristics	Ncwabeni
Catchment (km^2)	39.8
Natural MAR (million m^3)	4
MAP (mm)	88.2
Average volume augmented from Mzimkhulu River (million m3 / annum)	6.3
Gross full supply capacity (million m^3)	16
Live full supply capacity (million m^3)	14
Storage as a % MAR	155
Surface area as FSL (km^2)	0.95
Maximum water depth at FSL (m)	42
Maximum impounded river distance (km)	3.4

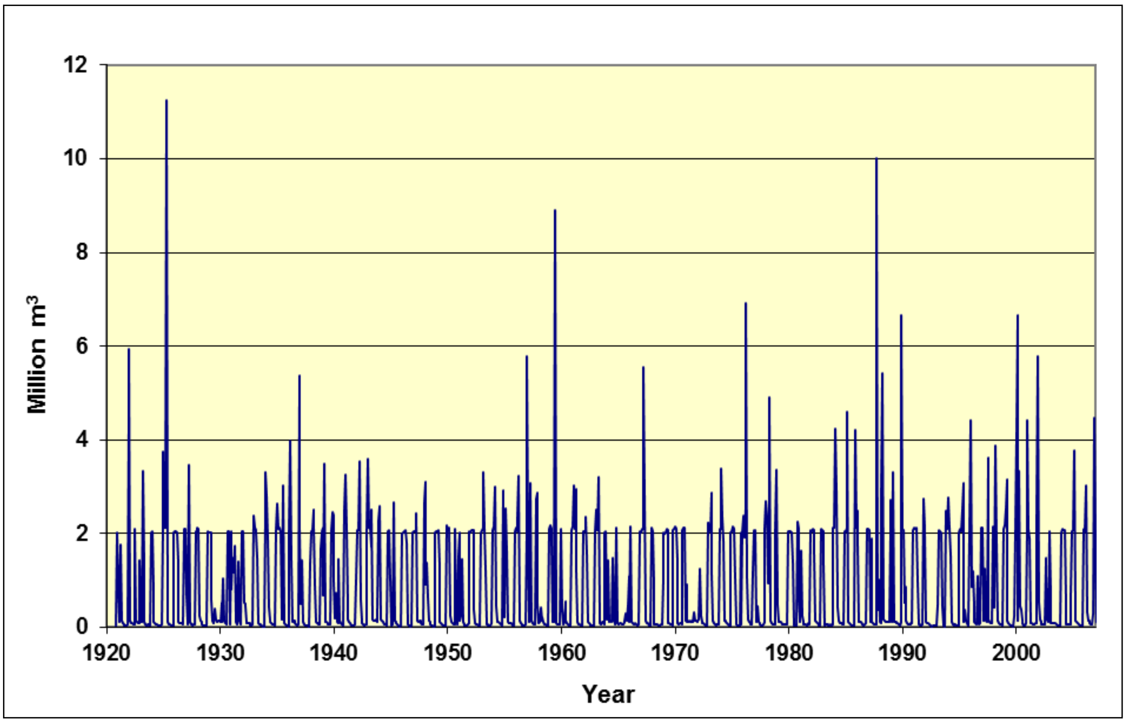


Figure 3-12: Simulated hydrological data (monthly inflow)

4. PREDICTED IMPACT OF IMPOUNDMENT

4.1. ALGAL BLOOMS WITH LIKELIHOOD OF TREATMENT PROBLEMS IN SUMMER

Although the proposed Ncwabeni impoundment is not within the same latitude as the Nagle and Hazelmere impoundments east and north of Durban, the proposed Ncwabeni can be compared to these impoundments for the following reasons:

- Both impoundments fall within the same temperature zone as Ncwabeni (refer to **Figure 4-1**).
- Both impoundments fall within the same rainfall zone as Ncwabeni, receiving between 700 and 800 mm annually (refer to **Figure 4-2**)
- The Full Supply Capacity (FSC) of the impoundments is within the same range as the proposed Ncwabeni, being relatively small. Hazelmere has a FSC of 17.9 million m^3, Nagle Dam has a FSC of 23.3 m^3 whilst Ncwabeni will have a FSC of approximately 15-16 million m^3 (DWA, 2011)
- Water quality for the Ncwabeni River corresponds to water quality for the Hazelmere and Nagle impoundments.

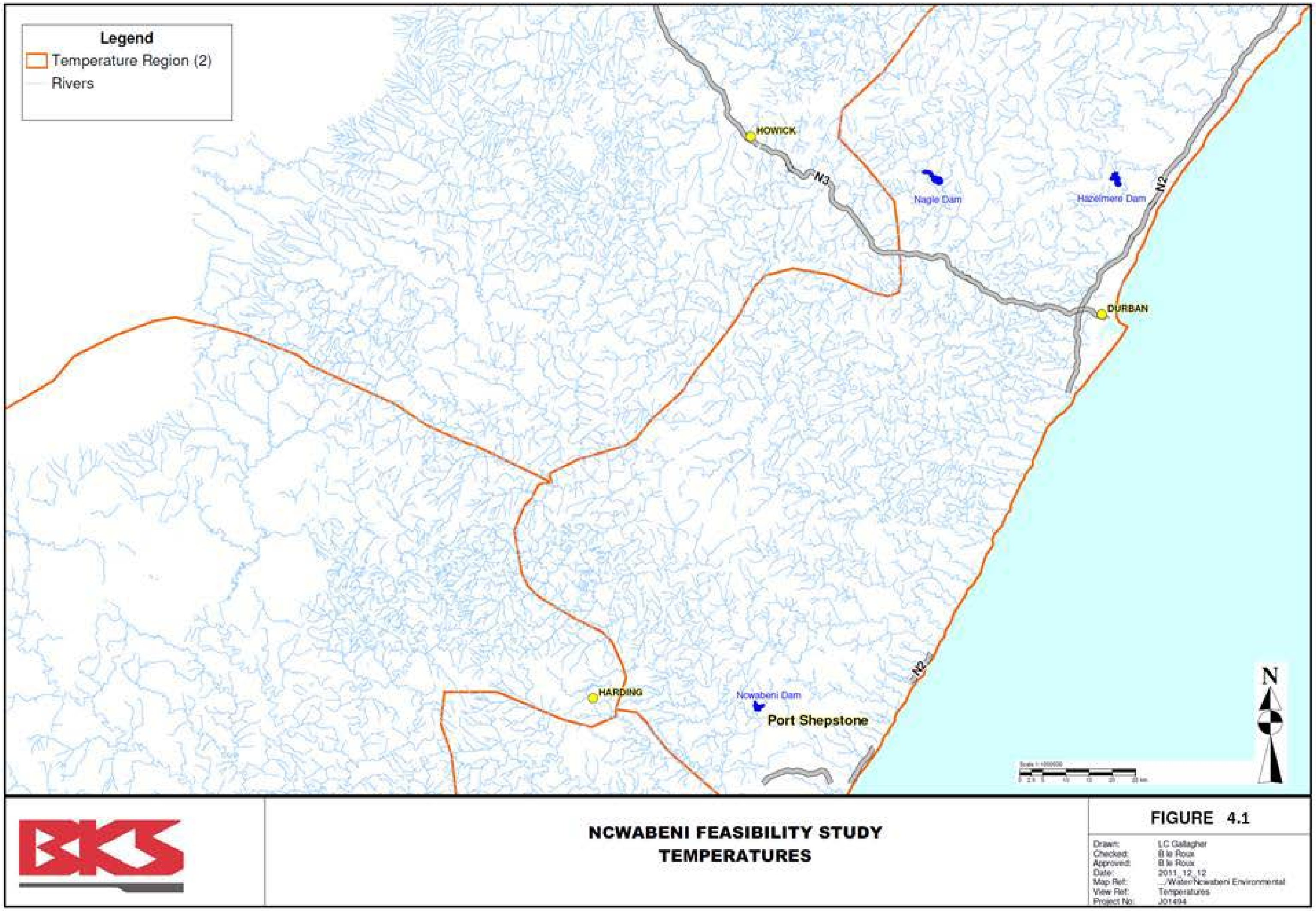


Figure 4-1: Temperature zone of Hazelmere and Nagle impoundments and proposed Ncwabeni impoundment site (Schulze *et al*., 2008)

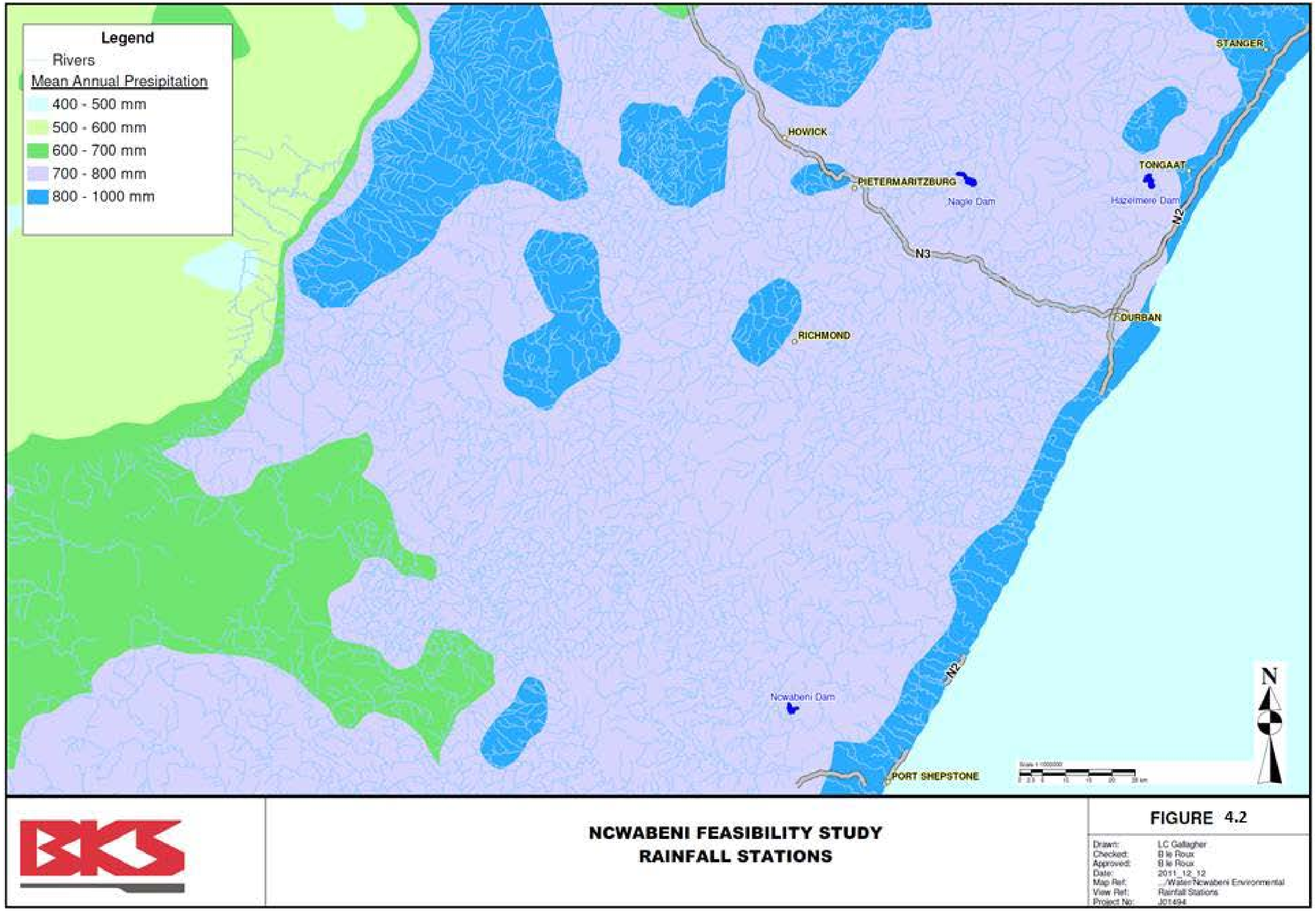


Figure 4-2: Rainfall of Hazelmere and Nagle impoundments and proposed Ncwabeni impoundment site (ENPAT, 2000)

Due to the similarities, the current water quality of the Hazelmere and Nagle impoundments can be used to predict the expected water quality of the Ncwabeni impoundment.

Algal growth in the Hazelmere impoundment has significant potential to become eutrophic, while the Nagle impoundment has moderate potential to become eutrophic. Although summer data are not available, winter measurements in 2011 indicated that both the Hazelmere and Nagle impoundments were in an oligotrophic condition. Hazelmere had a chlorophyll a value of 1.25 µg/l and a total phosphate concentration of 0.057mg/l. Nagle had a chlorophyll a value of 1.25 µg/l and a total phosphate concentration of 0.0405 mg/l (NEMP, 2011).

However, the amount of phosphorus available for uptake and flushing or retention time is also considered to play a major role in limiting algal growth in the impoundment. The empirical OECD (Organisation for Economic and Cooperative Development) model that predicts average and peak chlorophyll a concentrations from the inflow total phosphorus concentration and retention time in the impoundment were used to predict the algal response in the proposed Ncwabeni impoundment (OECD, Eutrophication of Waters, 1982). However, the available total phosphorus concentration data for the Ncwabeni Dam is not sufficiently accurate, and Ortho-Phosphate (OP) concentrations were used instead. Ortho-P is expected to give a better indication of algal growth, as that is the only form of phosphates that is available for algae. The predictive equations and results are shown in **Table 4-1.**

Table 4-1: Results of the OECD modelling exercise

Average inflow OP concentration (OP_{in})	6.7 µg/l
Retention time (T_w)	1.55 years
Chlorophyll a = 0.37 x [OP_{in}, µg/l / (1+ (T_w, year) $^{0.5}$)] $^{0.79}$	0.88 µg/l
Peak Chlorophyll a = 0.74 x [OP_{in}, µg/l / (1+ (T_w, year)$^{0.5}$)] $^{0.89}$	1.96 µg/l

The predicted average chlorophyll a concentration for the proposed Ncwabeni impoundment is 0.88µg/l and the predicted peak chlorophyll a concentration is 1.96 µg/l. Based on the OECD classification, the trophic status of the proposed Ncwabeni impoundment would be mesotrophic. Mesotrophic systems are moderately enriched with nutrients and have occasional blooms of nuisance algal species (average chlorophyll a concentration 2.5 - 8.0 µg/l, maximum chlorophyll a concentration 8.0 - 25.0 µg/l).

A chlorophyll a / algal count relationship was developed using ten years of historical data from the Nagle and Hazelmere impoundment. This average relationship identified 1 µg/l chlorophyll a to be equivalent to approximately 625 cells/ml of total algae. The algal counts in the proposed Ncwabeni impoundment were predicted by applying this relationship to the predicted chlorophyll a concentrations (**Table 4-2**).

Table 4-2: Predicted algal counts in the proposed Ncwabeni impoundment

Average annual algal count (cells/ml)	550
Peak annual algal count (cells/ml)	1225

These predicted algal counts are considered to be low. Should there be blue green algae present in the water, this number of algae per ml may have chronic effects with long-term ingestion. However, no acute health effects are expected. Taste and odour problems are also not expected at this algal count. **Figure 4-3** indicates chlorophyll a concentrations for the Nagle and Hazelmere impoundments. **Figures 4-4** and **4-5** indicate the change in algal numbers in Hazelmere and Nagle Dams respectively. High levels of the problematic algae, *Microcystis*, are found in both impoundments between January and March.

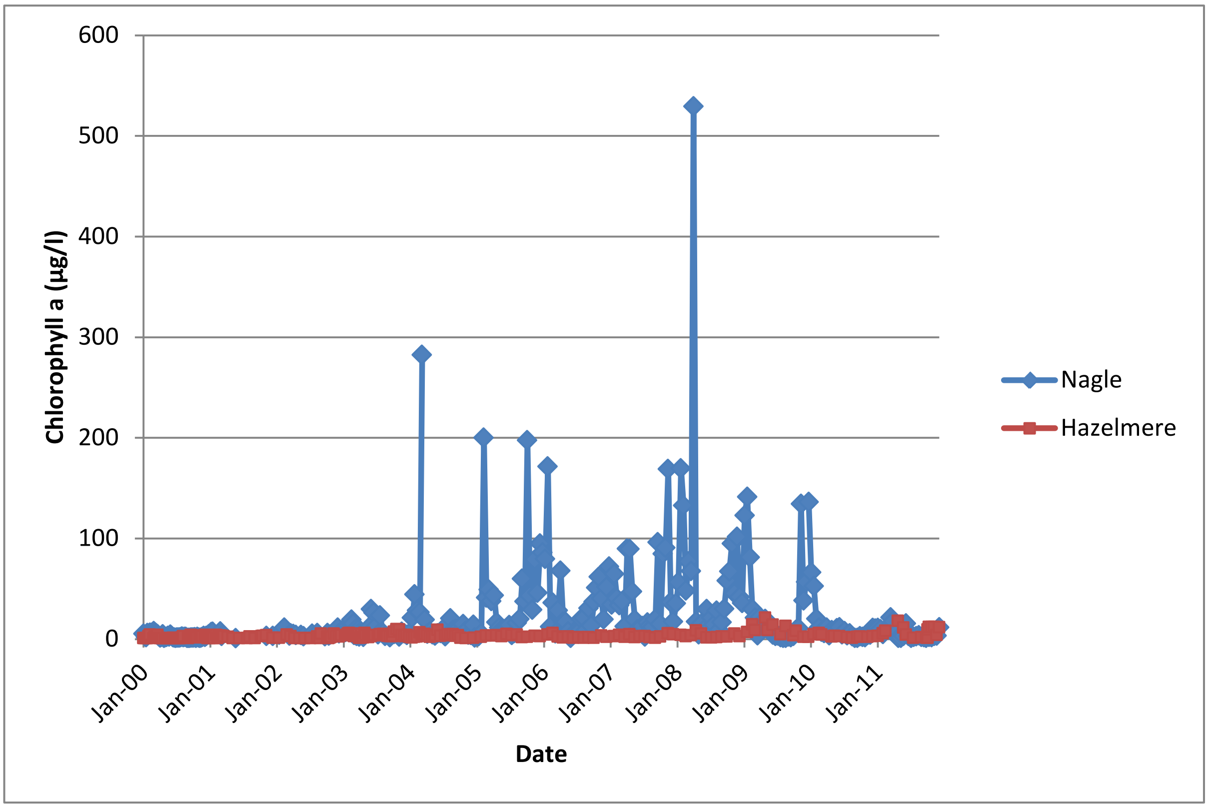


Figure 4-3: Chlorophyll a concentrations in Nagle and Hazelmere impoundments (Umgeni Water, 2011)

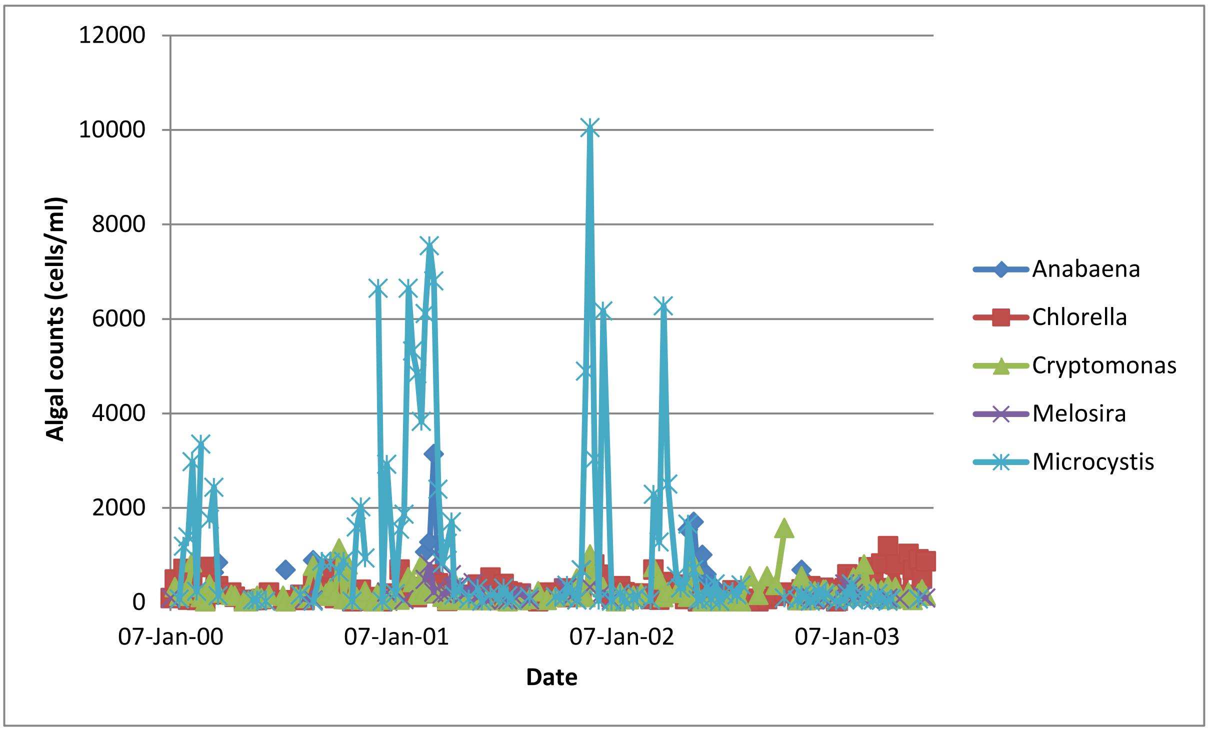


Figure 4-4: Hazelmere Dam algal species and count (Umgeni Water, 2011)

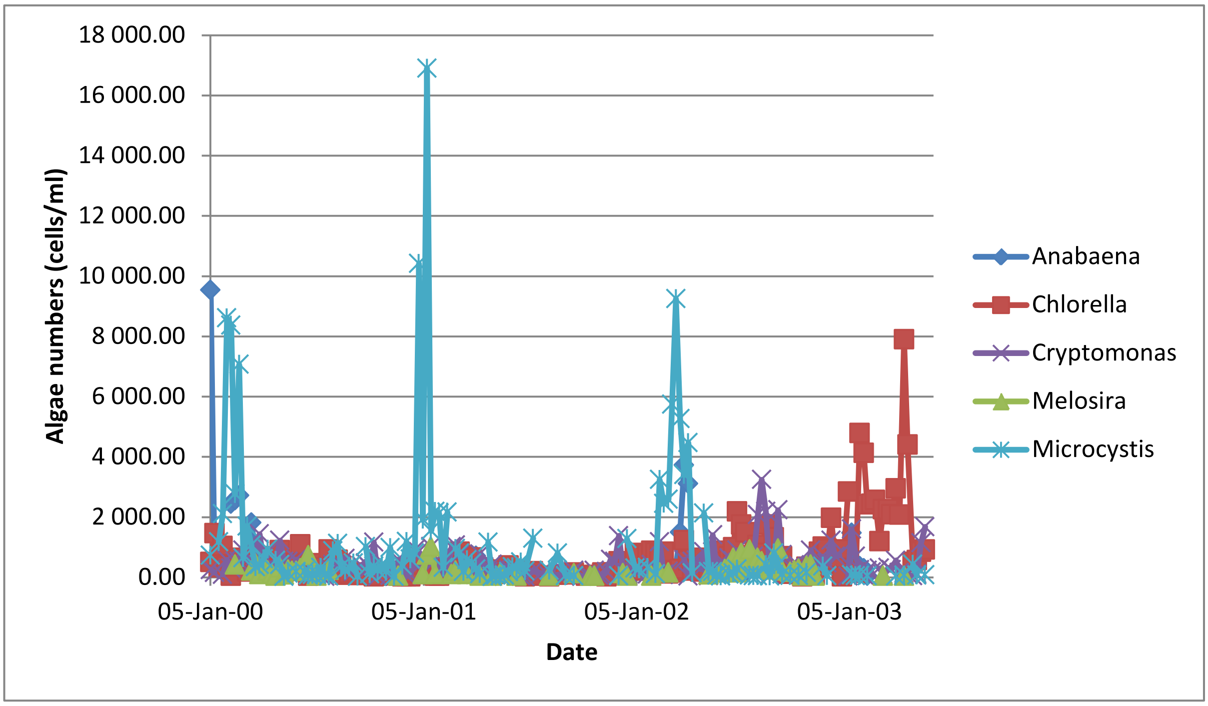


Figure 4-5: Nagle Dam algal species and count (Umgeni Water, 2011)

The following are likely to apply to the proposed Ncwabeni Dam:

- The maximum counts are likely to occur during the January to April period, particularly after the main input of nutrients and when impoundment spilling and flushing have reduced somewhat.

- During the higher rainfall period, problem blue-green genera such as Microcystis and Anabaena may occur.

It should be noted that during the filling phase of impoundments, algal counts might be relatively higher than predicted due to the decay of vegetation and flooding of soils, and subsequent release of nutrients.

4.2. PREDICTED STRATIFICATION PATTERNS

Knowledge of temperature and Dissolved Oxygen (DO) stratification patterns in proposed impoundments is important from the water treatment perspective as it will guide the positioning of abstraction levels to abstract aerobic water for treatment. Although anoxic water can be treated, it is more difficult and expensive to treat to potable water standards (Hodgson, 2011).

Since the Ncwabeni impoundment is proposed to be a storage impoundment, this knowledge will be used to guide the siting of drawoffs to ensure that compensation releases are not detrimental to downstream aquatic life. The stratification patterns in the proposed impoundment were predicted using experience gained from monitoring other impoundments in the Umgeni Water operational area. The Hazelmere and Nagle impoundments were selected to provide an indication of the stratification patterns expected to occur in Ncwabeni. Hazelmere impoundment displays strong stratification patterns both in terms of DO and temperature and represents the worst case scenario (**Figure 4-6**). Nagle impoundment, on the other hand, has weak stratification patterns and is regarded to be the best case scenario (**Figure 4-7**).

In the worst case scenario (**Figure 4-6**), stratification is likely to result in anoxic water at a depth of 5 - 15 m from the surface during the hottest summer months (January - March). The most severe stratification can be expected during February and will result in approximately 14 m depth of aerobic water being available. Impoundment turnover is predicted to occur in late March - early April, dependent on air temperatures and impoundment drawdown.

Between May and October, the water column will generally be isothermal and oxygenated throughout. Restratification is likely to commence in October and by the end of December, the anoxic zone should be 10 - 15 m below the surface during the end of the year. Under the optimal conditions (**Figure 4-7**) stratification patterns are likely to be similar to what was described above, but during stratification oxygenated water can be found up to 30m from the surface.

Four abstraction levels are recommended to be constructed at the following depths below Full Supply Level (FSL):

- 3 m
- 6 m
- 10 m
- 18 m

This will allow aerobic water to be abstracted for treatment at all times, and allow selection to reduce the algal load abstracted. Selecting the most favourable abstraction level will ensure the optimal quality of raw water at the water works, reducing water treatment costs and facilitate compliance with potable water quality standards. It is also recommended that a scour is constructed at approximately 40 m below FSL in order to release bottom water of the impoundment during high summer inflows. Using sleeve valves with dispersers will ensure the oxygenation of this scour water for environmental releases.

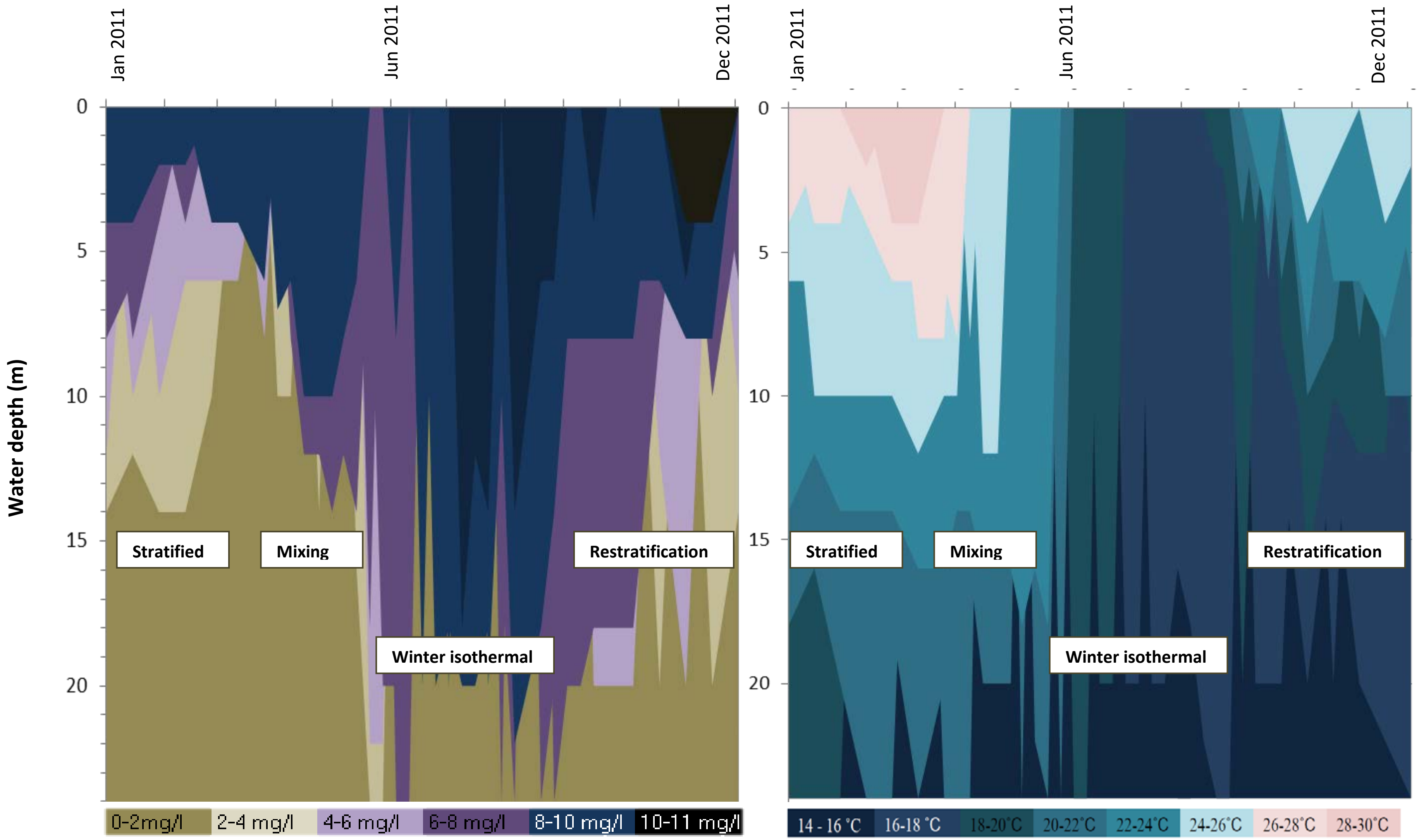


Figure 4-6: Hazelmere impoundment oxygen concentration (mg/l) and temperature (˚C) stratification for the year 2011 (Umgeni Water, 2011)

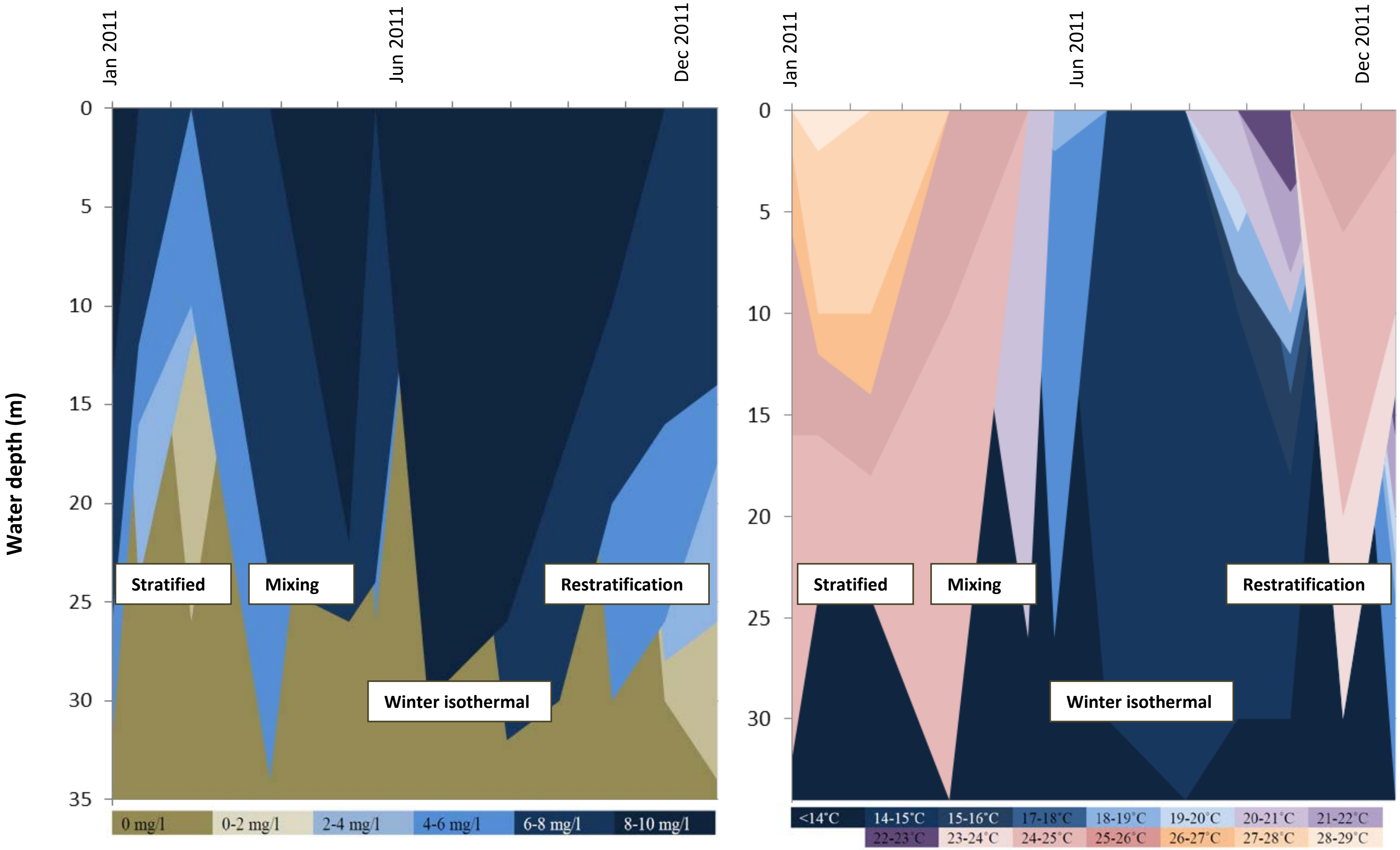


Figure 4-7: Nagle impoundment oxygen concentration (mg/l) and temperature (˚C) stratification for the year 2011 (Umgeni Water, 2011)

The Ncwabeni impoundment only differs from the Hazelmere and Nagle impoundments in that it will be an off-channel storage dam. Depending on the operating strategies, pumping water from the Mzimkhulu River can disrupt the stratification of the Ncwabeni impoundment. However, the water will only be pumped into the Ncwabeni impoundment during high flow events and it is not expected to create more disruption to the stratification over what would happen under natural circumstances. If the thermocline is stable, it is expected that the impoundment will return to the normal stratification soon after the pumps are shut down.

4.3. Reduced Metal Problems After Impoundment Destratification

At the onset of impoundment turnover in the proposed Ncwabeni impoundment, anoxic water will be mixed into the water column, reducing dissolved oxygen concentrations throughout the water column. Elevated concentrations of metals that are liberated from the sediments under anoxic conditions are then mixed through the water column at turnover. Manganese concentrations are not expected to cause any problems, since manganese concentrations are generally low in the Ncwabeni and Mzimkhulu Rivers. However, iron concentrations are high in both the Ncwabeni and Mzimkhulu Rivers and this must be managed appropriately.

4.4. Water Quality Improvement on Impoundment

The low median value for suspended solids in both the Ncwabeni and Mzimkhulu Rivers indicates no marked erosion-related problems in either catchment. The provision of a stilling basin at the off-take point in the Mzimkhulu River means that sedimentation in the impoundment is not anticipated to be a serious problem. In-dam processes such as sedimentation of suspended material will significantly improve surface water quality between the inflow and the wall. Significant reductions in concentrations of suspended materials as indicated by suspended solids, iron and manganese are expected with the impoundment. However, this will be true for surface waters, but not for scour release. At times, suspended material concentrations in the scour release could be higher than the inflow.

5. MANAGEMENT OF THE PROPOSED NCWABENI IMPOUNDMENT TO OPTIMISE WATER QUALITY

5.1. Reduction of Algal Numbers

When algal numbers are high (greater than 10 000 cells/ml), the recommended operating rule for compensation releases would be to release water at 3 m from FSL during summer rainfall, high inflow conditions. During this time, enough water is available to reduce the impact of algal numbers on downstream ecosystems.

5.2. Compensation Releases

To provide optimal quality water for aquatic life and downstream users, it is recommended that when the impoundment is 100% full, spill - abstraction - scour releases be managed to minimise the impact on aquatic life since the release of scour water only may have a detrimental effect on aquatic life for a short river distance before full aeration.

6. CONCLUSIONS

The findings of the Water Quality Assessment of the proposed Ncwabeni impoundment are as follows:

6.1. Catchment Assessment – Overview of Pollution Potential

The upper Mzimkhulu catchment is utilised for agricultural, tourism and residential purposes, but the activities are limited and the pollution potential is expected to be low. Population density in the catchment is low and is unlikely to have significant water quality impacts. There are no industries in the catchment, and no mining activities are known, other than some quarrying for road materials. In general, catchment quality is good to very good, and very few water quality problems are anticipated.

6.2. Current Water Quality Status

Water quality measured in the Mzimkhulu and Ncwabeni Rivers is generally good, with low concentrations of dissolved salts, turbidity and nutrients. Of concern is that iron concentrations, faecal coliform and *E. coli* counts are above DWA standards for domestic use and chlorophyll a concentrations are above DWA aquatic standards.

6.3. PREDICTED IMPACTS

Impounding the Ncwabeni River is expected to result in the following impacts:

- Algal counts are predicted to be low – moderate and blooms of nuisance algal species are unlikely to occur.
- Stratification of the proposed impoundment is likely to result in anoxic water at a depth of 5 - 15 m from the surface during the hottest summer months.
- In-dam processes such as sedimentation of suspended material and bacteriological removal are likely to significantly improve surface water quality between the inflow and the wall of the proposed impoundments.

6.4. MANAGEMENT OF PROPOSED IMPOUNDMENTS TO OPTIMISE WATER QUALITY

Scouring (as opposed to spilling) is the recommended release mechanism during low rainfall and low inflow conditions when algal numbers are high to avoid release of algal-laden water into the downstream riverine ecosystems.

It is recommended that spill-abstraction-scour releases be managed to minimise the impact on aquatic life.

From a water quality planning perspective, there appear to be no significant water quality problems that preclude the construction of the proposed Ncwabeni impoundment.

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