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The uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study: Raw Water

WATER REQUIREMENTS AND RETURN FLOWS REPORT

WRITE-UP 2: COMMUNITY SUPPLY FROM SMITHFIELD-COMRIE DAM: PRE-FEASIBILITY STUDY

FINAL

NOVEMBER 2015



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PREAMBLE

1. In June 2014, two years after the commencement of the uMkhomazi Water Project Phase 1 Feasibility Study, a new Department of Water and Sanitation was formed by Cabinet, including the formerly known Department of Water Affairs.

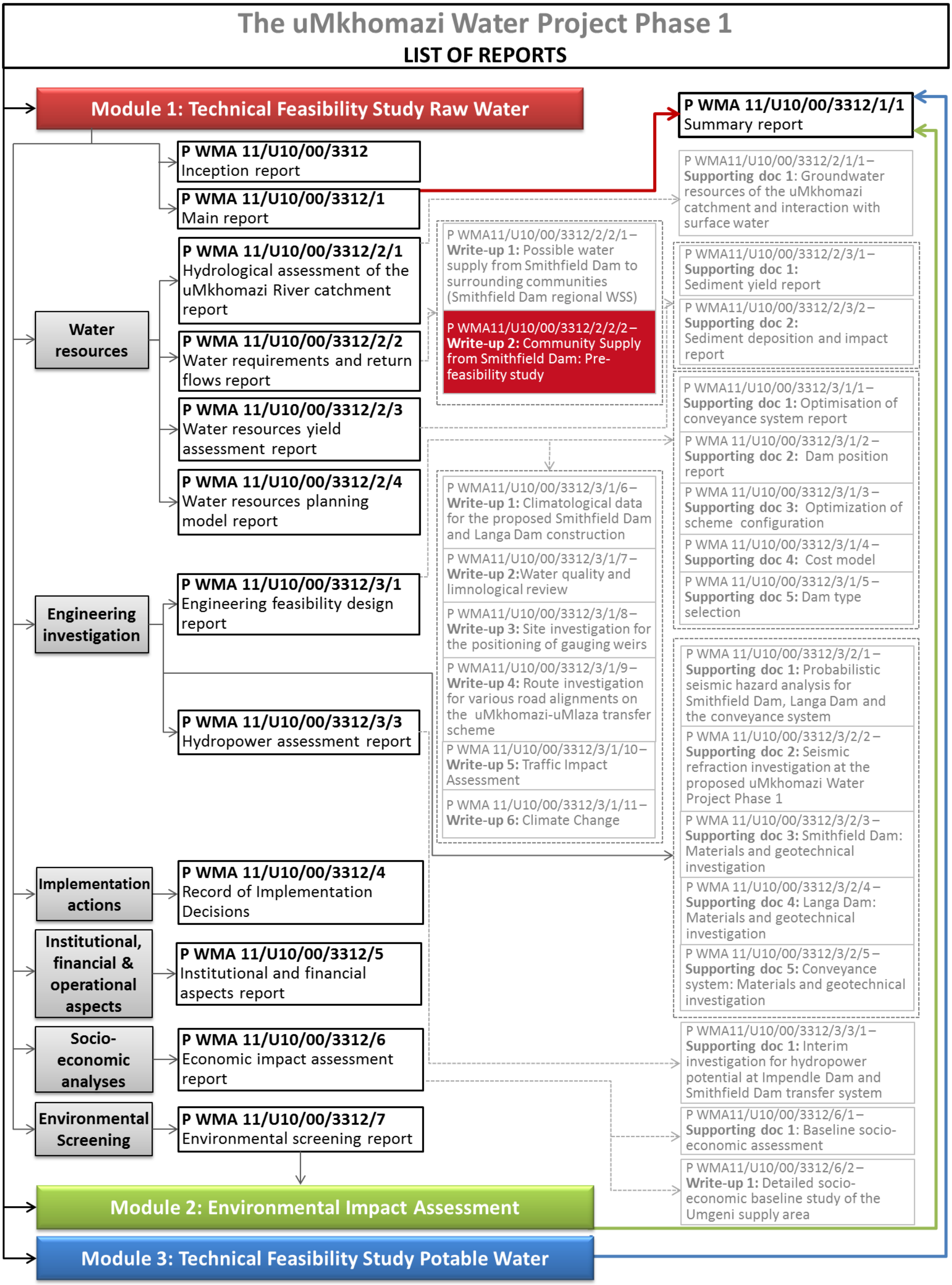
   In order to maintain consistent reporting, all reports emanating from Module 1 of the study will be published under the Department of Water Affairs name.

2. In September 2013, one year after the commencement of the uMkhomazi Water Project Phase 1 Feasibility Study, Sisonke District Municipality was renamed to Harry Gwala District Municipality, as published in the KZN Provincial Gazette 2013.

   The use of Sisonke District Municipality was adopted in numerous reports at the commencement of the study. Reference to Harry Gwala District Municipality was then addressed in reports emanating at a later stage of the study.

3. The dam that is to supply water to the Bulwer Donnybrook Water Supply Scheme (WSS) was initially known as the Bulwer Dam. During the feasibility and detail design of the dam, Bulwer Dam was renamed to Stephen Dlamini Dam.

   The name Stephen Dlamini is used throughout this report and Bulwer Donnybrook WSS refers to the name of the water supply scheme.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Executive summary

The Department of Water and Sanitation previously did a study on the uMkhomazi Water Project which was identified as a long-term solution to augment the Mgeni Water Supply System. This project involves a water transfer scheme from the proposed Smithfield Dam in the uMkhomazi River Catchment to the proposed Langa Dam in the uMlaza River Catchment. It was then decided that a prefeasibility study is necessary to explore the possibility of supplying the communities surrounding Smithfield Dam with potable water.

The purpose of this report is to provide a comprehensive assessment of:

- *A pre-feasibility study to determine the viability to supply the local communities with bulk water from the proposed Smithfield and existing Comrie Dams. This proposed scheme is referred to as the* **Smithfield-Comrie Dam Regional Water Supply Scheme (RWSS)***;*
- *A possibility of integrating the proposed Smithfield-Comrie Dam RWSS with the existing Bulwer-Donnybrook WSS.*
- *Identifying the availability of groundwater within the study area to link with the Bulwer-Donnybrook WSS.*

Based on information from the **2011 Census** *data, about* ***60%*** *of the users surrounding Smithfield Dam currently have access to some form of piped water. The exact source of piped water could however not be confirmed from the 2011 Census information. This water may however, either be sourced from springs, groundwater and/or surface water (i.e. a weir on the Luhane River). It could also not be confirmed whether the water supply to these communities is sufficient and whether the water quality of the current water resources is acceptable.*

In 2015 the estimated current combined water requirement of communities within the Bulwer-Donnybrook WSS was in the order of ***3.45 million m³/a,*** *which will grow to an ultimate future water requirement of* ***4.13 million m³/a*** *in 2045 (assuming a population growth rate of 0.6% per annum). This is based on an average per capita consumption of* ***75 ℓ/capita/day****, which considers a 'piped water inside yard' level of service. This level of service is typical for these types of mixed rural and urban areas. If an increase in the level of service exceeds expectation, an average per capita consumption will increase to approximately* ***100 ℓ/capita/day*** *in 2045, which assumes that households will be* *upgraded to 'piped water inside dwelling', the ultimate water requirement in 2045 is calculated to be* ***5.5 million m³/a****.*

The total estimated capital cost of installing the bulk infrastructure necessary to supply the Bulwer-Donnybrook WSS for the preferred option (Option 5) was estimated at about ***R 252.25 million,*** *including engineering fees as well as environmental and social costs. The capital cost thus excludes the following:*

- Maintenance cost;
- Electrical cost;
- Admin charges; and
- Employment of professional people to manage and maintain the system.

In addition, the operational and maintenance costs that would be ongoing for the duration of the time that water is treated and pumped to the local communities, was estimated at a cost of ***R 2.3 million/annum****. These high costs are mainly due to the fact that the area's extreme topography results in large elevation differences from the Comrie Dam FSL of 1 210 masl and Comrie Dam's end reservoir elevation of 1 568 masl. This large elevation difference results in high operation costs in terms of pumping.*

The URV of the Smithfield-Comrie Dam RWSS for Option 5 is found to be ***R 17.76/m³****. The table below provides the URV values for the various options that were considered.*

	URV (R/m³)	
Description	**Alternative 1**	**Alternative 2**
Option 1. Smithfield via Comrie Dam (excluding Comrie Dam's yield)	**18.80**	**18.04**
Option 2. Smithfield to Sizanenjane and Kwelaba-Ntwana	22.50	23.78
Option 3. Smithfield to Bethlehem and Ncwadi	68.64	-
Option 4. Smithfield Dam supplementing Comrie Dam's shortfall	57.29	53.71
Option 5. Raising of Comrie Dam *	**17.76**	-

It is recommended that the estimated water requirement of approximately ***1 million m³/a*** *is provided from Comrie Dam to supply Bulwer-Donnybrook WSS.*

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c/kWh	cent per kilowatt hour
km	kilometre
kW	kilowatt
ℓ/c/d	litre per capita per day
ℓ/s	litre per second
m	metre
mm	millimetre
m^3	cubic metre
m^3/a	cubic metre per annum
masl	metre above sea level
mbgl	metre below ground level
m^3/d	cubic metre per day
m^3/h	cubic metre per hour
Mℓ	Mega litre
MPa	Mega Pascal
m/s	metre per second
R/m^3	Rand per cubic metre
V	Volt

LIST OF ABBREVIATIONS

AGES	Africa Geo-Environmental Services (Pty) Ltd
AM	Before noon
BKS	BKS (Pty) Ltd
DM	District Municipality
DWA	Department of Water Affairs
DWS	Department of Water and Sanitation
E&M	Electrical and Mechanical
E.O.	Extra and Over
EWR	Environmental Water Releases
FSL	Full Supply Level
GRIP	Groundwater Resource Information Project
GYRM	Groundwater Yield Model for the Reserve
HGL	Hydraulic Grade Line
IAP	Invasive Alien Plants
KZN	KwaZulu-Natal
LCC	Life Cycle Cost
ℓ/c/d	litre per capita per day
LM	Local Municipality
LOS	Level Of Service
masl	metre above sea level
mbgl	metre below ground level
MM&A	Mogoba Maphuthi and Associates
MPa	Mega Pascal
m^3	Cubic meter
NWA	National Water Act
O&M	Operation and Maintenance
PSP	Professional Service Provider
RDP	Reconstruction and Development Programme
SFR	Stream Flow Reduction
ToR	Terms of Reference
URV	Unit Reference Value
VIP	Ventilated Improvement Pit
WC/WDM	Water Conservation/Water Demand Management
WSA	Water Supply Area
WSA	Water Services Authority
WSS	Water Supply Scheme
WTP	Water Treatment Plant

1 INTRODUCTION

The uMkhomazi Water Project (uMWP) has been identified to fulfil the long-term water requirements of the Mgeni Water Supply Scheme (WSS), comprising mostly of eThekwini and Msunduzi municipalities. The first phase of the uMWP comprises a dam on the uMkhomazi River at Smithfield, a 32 km 3.5 m diameter gravity tunnel, a treatment plant, balancing dam and raw and potable water pipelines, as shown schematically in **Figure 1.1**.

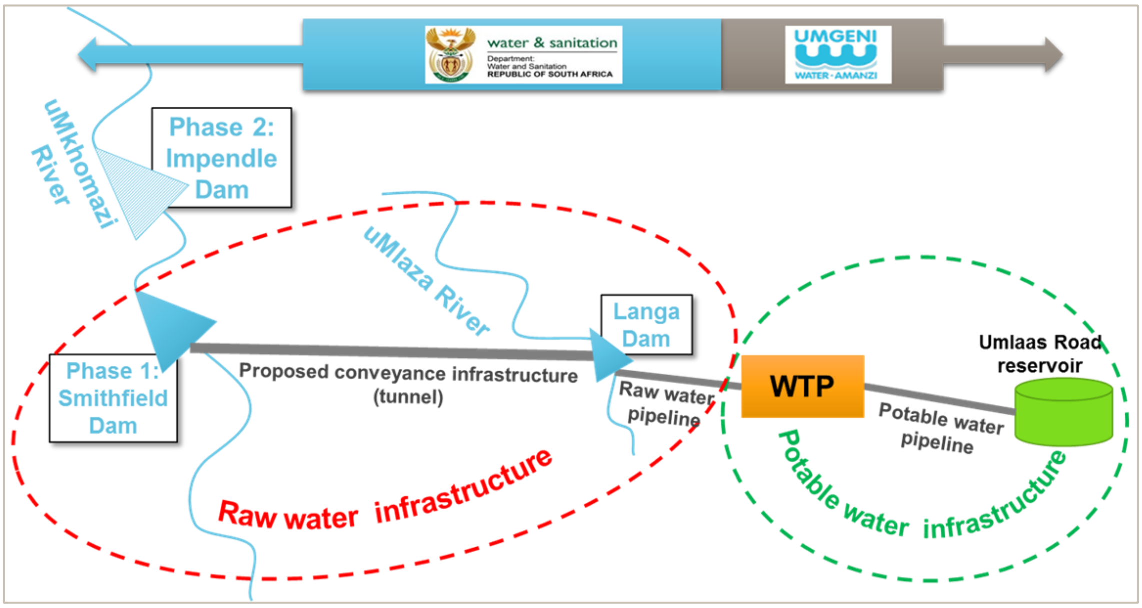

Figure 1.1: Schematic layout of uMWP-1 raw and potable water components

The proposed Smithfield Dam[1] has a 1:100 year stochastic yield of 220 million m³/a that will augment the shortfall of water in the Mgeni WSS. The Smithfield Dam site is located within the Ingwe Local Municipality (LM) which falls within the Harry Gwala[2] District Municipality's (HGDM) area of jurisdiction. The dam wall is located approximately 185 km upstream of the uMkhomazi River mouth. Although a few individual houses will be inundated, there are currently no communities that will be inundated by the proposed dam. However, several scattered communities are located around the dam.

[1] *A name for the dam on the uMkhomazi River at Smithfield has not yet been decided upon, although it is referred to as Smithfield Dam, as per standing policy that dictates a new dam be identified by the farm name on the right flank of the dam wall.*

[2] *Harry Gwala District Municipality was previously Sisonke District Municipality.*

1.1 OBJECTIVE OF THE STUDY

Although the uMWP is earmarked for providing water to the Mgeni WSS, the need for water of the communities around the proposed Smithfield Dam and the municipality are recognised. During the water resource analysis 1 million m^3/a was earmarked for local communities surrounding the proposed Smithfield Dam. Since this area is located within HGDM, the responsible Water Services Authority (WSA), provision was made to align this supply source with the masterplan of the WSA.

Different water sources and schemes were considered to find the most feasible solution to serve the communities surrounding the Smithfield Dam with bulk water. A few of these sources include the proposed Stephen Dlamini Dam and the existing Comrie Dam. The analysis period is 30 years, beginning in the year 2015 to 2045.

Specific objectives for this task are listed below:

- A pre-feasibility study (no geotechnical investigations were included) to determine if it is viable to supply the local communities with bulk water from the proposed Smithfield and Comrie Dams. For ease of reference, this proposed scheme will be referred to as the ***Smithfield-Comrie Dam Regional Water Supply Scheme (RWSS)***;
- Integrate the proposed Smithfield-Comrie Dam RWSS with the existing Bulwer-Donnybrook WSS; and
- Identify the availability of groundwater within the study area.

1.2 STUDY AREA

The focus of the study is to determine the viability of implementing the Smithfield-Comrie Dam RWSS to supply bulk water to communities surrounding the Smithfield Dam. The study area defined is located in the Ingwe (including the towns of Bulwer, Donnybrook and Creighton) and Ubuhlebezwe LM's in the uMkhomazi River catchment as shown in **Figure 1.2**.

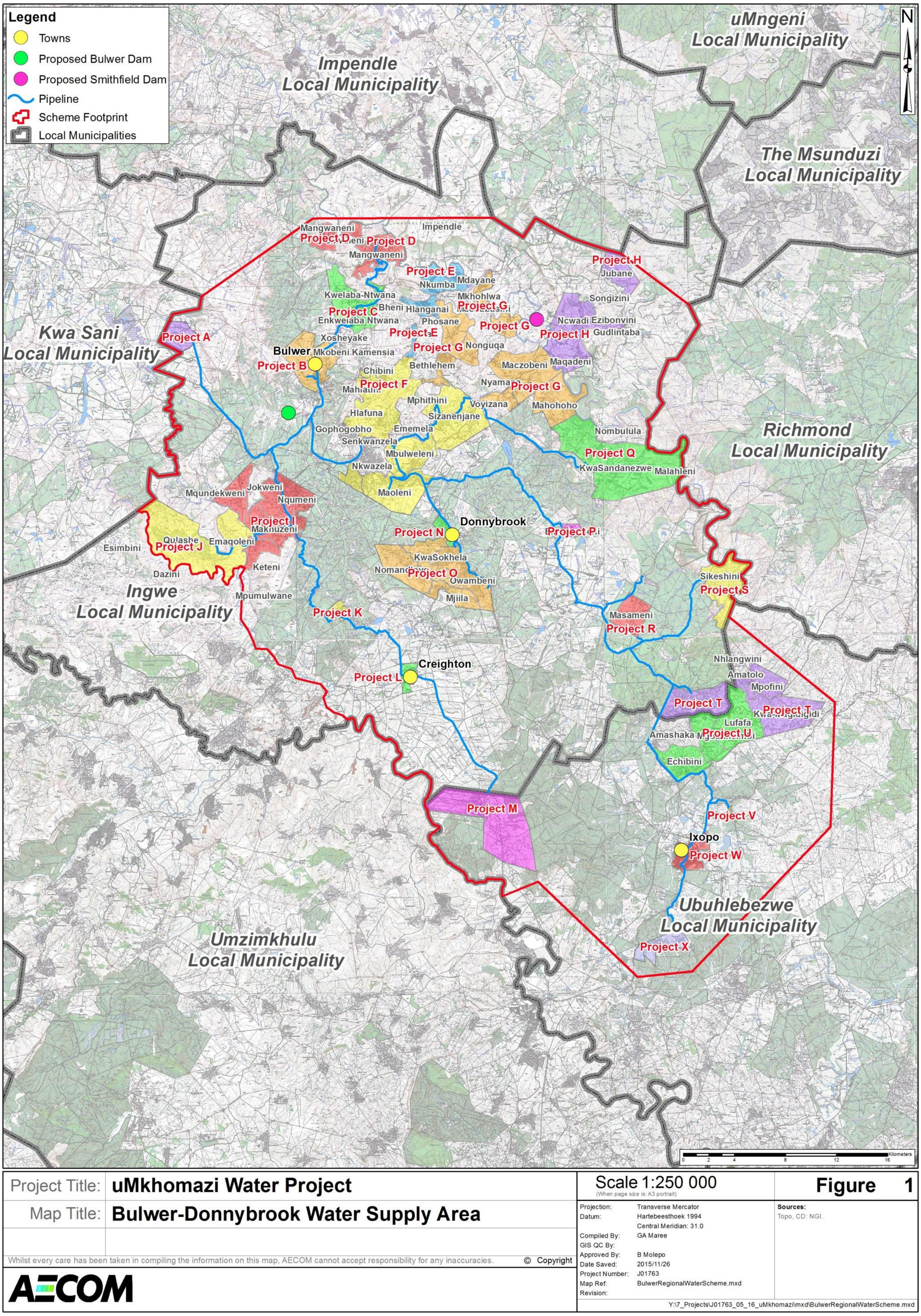

Figure 1.2: Locality map: Study area around the Smithfield Dam

2 POPULATION AND DEMOGRAPHICS

The future population estimate was used to estimate the future water requirements of the study area. In order to determine the most accurate current population numbers in the study area, several sources were used to obtain population data. Settlement data within the study area was grouped per sub place (a sub place is a group of households that form a community). A list of these settlements and their population is provided in **Appendix A**. Population data from *2001 Census* (Statistics South Africa, 2015) data was compared to *2011 Census* (2015) data to obtain an understanding of the population growth/decay within the study area. In this case, a negative growth rate was witnessed for the study area, when comparing 2001 and 2011 census data.

Figure 2.1 shows the historic population numbers and changes from 1996 to 2013 for the Ingwe LM, and the following trends are observed:

- The population declined between 2004 and 2009, followed by a positive growing trend beyond 2009;
- An average negative growth rate of -0.1% is observed between 2001 and 2011;
- The growth between 2009 and 2013 (0.5%) is very similar to the long term trend (1995 – 2013) of ***0.6%***. The long term trend was determined by calculating the average annual population growth from 1995 to 2013; and
- Using the long term growth trend the population is expected to grow from 98 432 people in 2011 to ***120 633*** people in 2045.

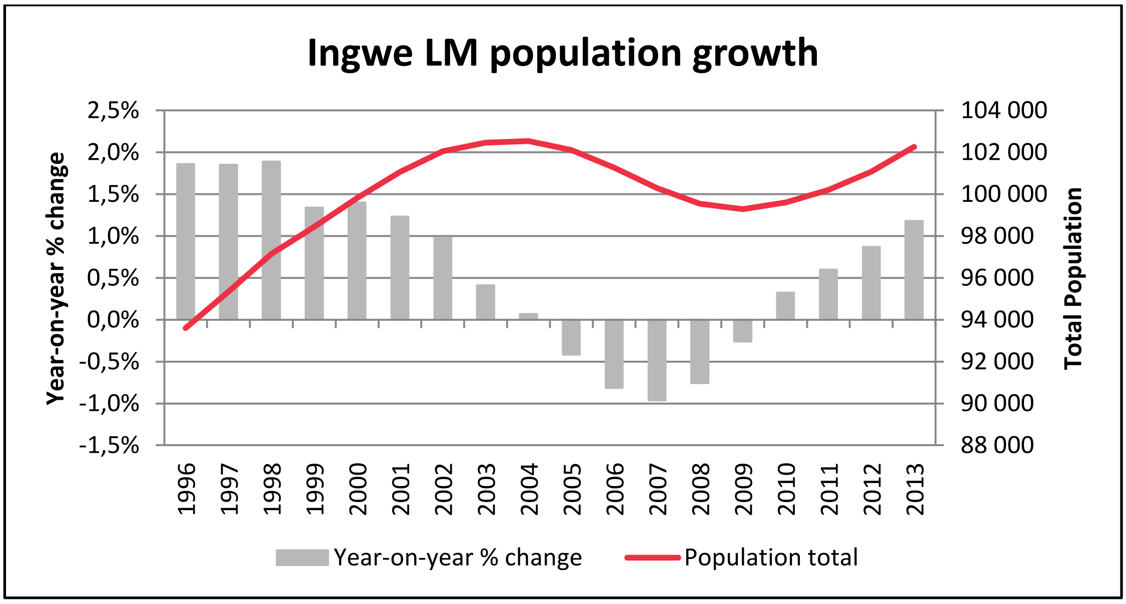

Figure 2.1: Historic population data for Ingwe LM

Future population projections were done based on a constant long-term growth rate of ***0.6%***, as was determined and also recommended by ***Urban Econ's*** *Baseline Socio-economic Assessment report*. For the purpose of this report, no low and high growth scenarios were analysed.

3 WATER REQUIREMENTS AND WATER AVAILABILITY

The Bulwer-Donnybrook WSS is located in the Ingwe and Ubuhlebezwe LM's which fall in the HGDM. The footprint of the Bulwer-Donnybrook WSS is shown in **Figure 1.2** and is mostly comprised of rural settlements. The Bulwer-Donnybrook WSS is the infrastructure that supplies the Bulwer-Donnybrook WSA.

3.1 DOMESTIC WATER REQUIREMENTS

3.1.1 Level of Service (LOS)

The data to determine the level of service (LOS) was obtained from the *2011 Census* (2015). As seen in **Table 3.1** the current LOS in the area is 29.3% of households have a yard and house connection; and 26.1% have a communal stand pipe. With current infrastructure development taking place in the Bulwer-Donnybrook area, it is expected that most of the 26.1% households currently at a communal standpipe LOS, will shift to piped yard connection LOS before 2045. An improved LOS will increase consumption rates and therefore increase water requirements. Considering this change in level of service, an average requirement of 75 ℓ/c/d is used for domestic water requirements for the entire Bulwer-Donnybrook WSS from 2015 to 2045.

Table 3.1: Current level of service in the Bulwer-Donnybrook WSS

Level of service				
House connection	Piped Yard connection	Piped supply < 200m	Piped supply >200m	None/ Own resource eg. boreholes,springs
8.6%	20.6%	18.0%	8.1%	44.6%
29.3%		26.1%		44.6%

3.1.2 Current domestic water requirements

The current domestic water requirement was obtained by multiplying the 2015 population with an average consumption of 75 ℓ/c/d and a peak factor of 1.25. The 75 ℓ/c/d consumption is an average consumption for yard connections in rural areas (CSIR, 2005). The consumption rate and peak factor are constant annually. This calculation is also used to obtain the water requirements in **Table 3.2**. The present (2015) domestic water requirements in the Bulwer-Donnybrook WSS was calculated as **3.45 million m³/a**. The amount of water provided in 2015 to the Bulwer-Donnybrook WSS is 1.54 million m^3/a, and is discussed further in **Section 3.5**.

No water requirements for mining and industries were explored because there were no mines and large industries identified in the study area.

3.1.3 Domestic water requirement projection

Future domestic water requirements are projected up to 2045, as shown in **Table 3.2**. A domestic water requirement of 4.13 million m³/a is expected in the Bulwer-Donnybrook WSS at a 2045 development level. The following assumptions were made during domestic water requirement projections:

- **Population projections:** The projections were done using a constant long-term annual growth rate of ***0.6%*** (refer to **section 2**).
- **Current level of service (LOS):** The current and predicted future levels of service were considered when estimating water requirements (refer to **section 3.1.1**).
- **Future requirement projections:** A peak factor of 1.25 which includes system losses was used to calculate water requirements for the Bulwer-Donnybrook WSS. An average consumption of 75 ℓ/c/d was used.

Table 3.2: Domestic water requirement projections

Year	Population growth	Water requirements (million m³/a)	Water requirements (Mℓ/d)
Actual (2011)	98 432	3.37	9.23
2015	100 816	3.45	9.45
2025	107 031	3.66	10.03
2035	113 629	3.89	10.65
2045	120 633	4.13	11.31

3.2 IRRIGATION AND LIVESTOCK WATER REQUIREMENTS

A previous study *Hydrological Assessment of the uMkhomazi River Catchment* (AECOM, et al., 2014) was used to obtain irrigation and livestock requirements in the Bulwer-Donnybrook WSS. In the study, water requirements were investigated per quaternary catchment. Quaternary catchments U10E, U10F, U10H, U10J and

U10K are located in the uMkhomazi River catchment and form part of the Bulwer-Donnybrook WSS. Although quaternary catchments T51E and T52A are located in the Umzimkhulu River catchment, they were also investigated as they form part of the Bulwer-Donnybrook WSS.

Irrigation and livestock water requirements were area weighted, based on the Bulwer-Donnybrook WSS relative to a quaternary catchment.

Table 3.3 shows irrigation and livestock water requirements per quaternary catchment in the uMkhomazi River catchment, while **Table 3.4** shows the weighted average used for the Bulwer-Donnybrook WSS, including the quaternary catchments T51E and T52A which fall within the Mzimkhulu River Catchment. A total water requirement of 28.2 million m^3/a and 1.1 million m^3/a is estimated for irrigation and livestock, respectively. It should be noted that these values were used to produce the water balance diagrams shown in **Figure 3.4** to **Figure 3.7**.

Table 3.3: Irrigation and livestock water requirements for uMkhomazi quaternary catchments

Quaternary catchment	Area of quaternary catchment (km^2)	Quaternary catchment water use (million m^3/a)			
		Irrigation,from indicated source			Stock watering
		Dams	Run-of-river	Ground-water	
U10E	327	-	-	-	0.23
U10F	379	-	0.59	-	0.26
U10H	458	5.7	6.92	-	0.22
U10J	505	1.83	6.88	0.02	0.3
U10K	364	2.52	3.4	0.13	0.41
Totals:	**2033**	**10.05**	**17.79**	**0.15**	**1.42**

Table 3.4: Irrigation and livestock water requirements for Bulwer-Donnybrook WSS

Bulwer-Donnybrook WSS within quaternary catchment	Area of Bulwer-Donnybrook WSS in quaternary catchment (km^2)	Bulwer-Donnybrook water use (million m^3/a)			
		Irrigation,from indicated source			Stock watering
		Dams	Run-of-river	Ground-water	
U10E	179	-	-	-	0.13
U10F	251	-	0.39	-	0.17
U10H	293	3.65	4.43	-	0.14
U10J	287	1.04	3.91	0.01	0.17
U10K	219	1.52	2.05	0.08	0.25
Subtotal:	**1229**	**6.21**	**10.78**	**0.09**	**0.86**
T51E	214	2.32	3.25	0.00	0.11
T52A	214	2.32	3.25	0.00	0.11
Total:	**1657**	**10.85**	**17.28**	**0.09**	**1.08**
Total water requirement for Bulwer-Donnybrook WSS		**28.22**			**1.08**

3.3 WATER AVAILABILITY

The current water sources being utilised in the Bulwer-Donnybrook WSS are shown in **Figure 3.1**. The exact source of piped water is not known but an assumption was made that piped water may be sourced from boreholes, springs, rivers and dams

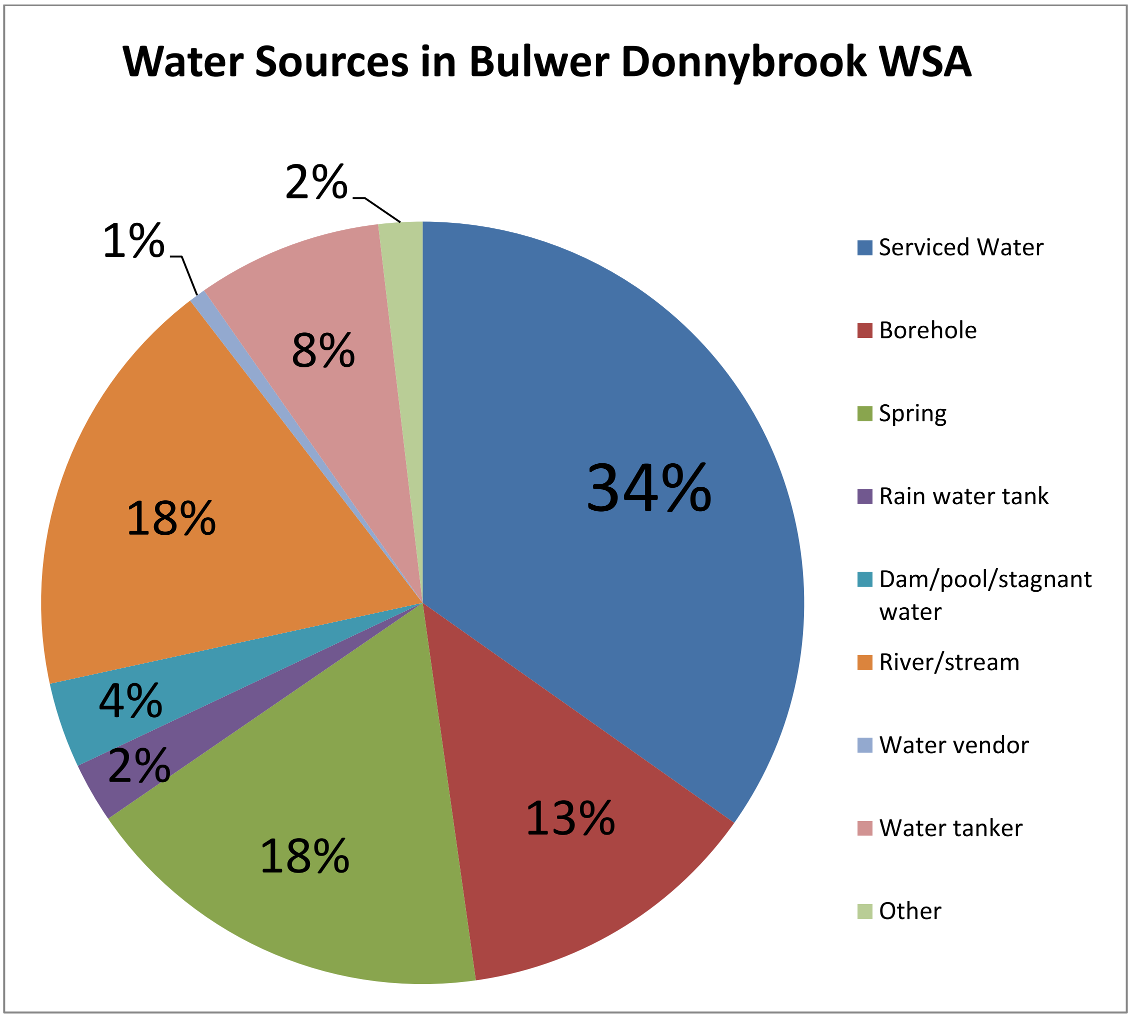

Figure 3.1: Source of water in the Bulwer-Donnybrook WSS

3.3.1 Surface water availability

Based on the water requirements and return flows report, (AECOM, 2014) Bulwer-Donnybrook WSS currently acquires 70% of its water from groundwater and 30% from surface water. Surface water is currently sourced from Ixopo Dam, which has a historic firm yield of 0.6 million m^3/a. River abstraction works on the Luhane River provides Bulwer-Donnybrook WSS with approximately 0.56 million m^3/a. The existing Comrie/Ngudwini Dam has a historic firm yield of 1.81 million m^3/a without considering Environmental Water Releases (EWRs); and 0.85 million m^3/a when releasing EWRs (further discussed in **Section 3.4**).

The proposed Stephen Dlamini Dam has a stochastic yield of 3.07million m^3/a or 8.4 Mℓ/d at a 98% assurance of supply. Stephen Dlamini Dam is currently under construction and was intended to alleviate water shortages in the Bulwer-Donnybrook WSS. The yield of the Stephen Dlamini Dam was overestimated during its feasibility study and it alone will not be able to provide for the water shortage in the Bulwer-Donnybrook WSS. Smithfield Dam or Comrie Dam is the likely solution to eliminate water shortages in the Bulwer-Donnybrook WSS.

3.3.2 Groundwater availability

Groundwater in the Ixopo system has a sustainable yield of 0.383 million m^3/a. No information could be found on the quantity of groundwater abstractions within the rest of the Bulwer-Donnybrook WSS; however, groundwater sales by Umgeni Water show that a total of 0.383 million m^3/a of groundwater is sold in the Ixopo system. **Section 4** provides a detailed discussion on potential groundwater availability.

3.4 HISTORICAL FIRM YIELD ANALYSIS FOR COMRIE DAM

The existing Comrie/Ngudwini Dam is located within the Bulwer-Donnybrook WSS and falls within quaternary catchment U10H. Although the dam is currently owned by Sappi-Saiccor, it was identified as a possible resource to augment the Bulwer-Donnybrook WSS. A study done by WSP Consulting, *Proposed Comrie Dam Expansion* (Konigkramer, 2015), indicates that Comrie Dam has a 12 m high earth fill dam wall. The dam has a gross storage capacity of 1.92 million m^3 and the associated surface area is 71 ha. Comrie Dam can be raised up to 4 m without inundating forestry within the vicinity. Raising the dam by 4 m will result in a gross storage capacity of 6.5 million m^3 and a surface area of 150.2 ha. The capital cost of raising Comrie Dam is estimated as **R 170.86 million** and is discussed further in **Appendix F**.

The hydrology used for the yield analysis of Comrie Dam was derived from the hydrological assessment of the uMkhomazi River Catchment, conducted as part of the uMWP-1. The Water Resources Yield Model (WRYM) was used for the yield analyses and to develop scenarios discussed in this section.

For the yield assessment, land use upstream of Comrie Dam was of interest as seen in **Figure 3.2** and a WRYM schematic representation of the Comrie Dam system is shown in **Figure 3.3**. The lumped dam represents the sum of all the farm dams in the catchment.

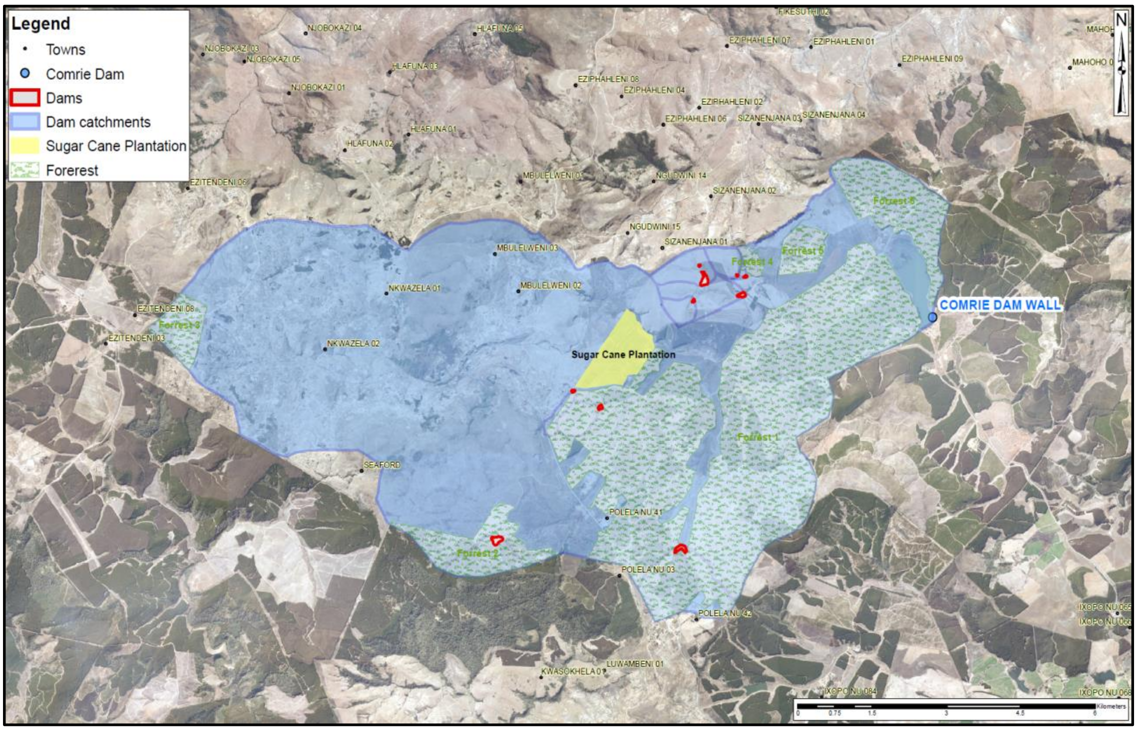

Figure 3.2: Comrie Dam catchment area

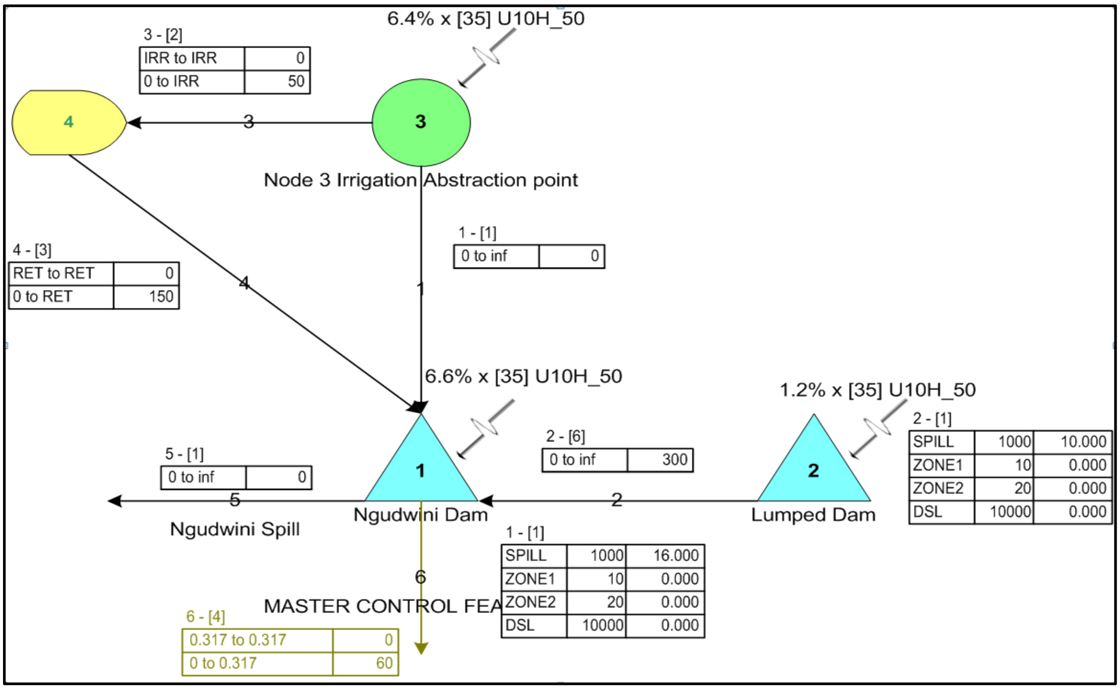

Figure 3.3: Modelled representation of Comrie/Ngudwini Dam catchment

Table 3.5 summarises the runoff and stream flow reduction (SFR) as a percentage of U10H, as used in the WRYM. The runoff percentages are area weighted based on the sub-catchment area relative to the total area of U10H. The forestry percentage is calculated from the area of forestry in the Comrie Dam

Catchment compared to that occurring in U10H. SFRs from invasive alien plants (IAP) were negligible and therefore not included.

Table 3.5: Percentage of the natural runoff and SFR of U10H

Catchment areas	% of the Natural runoff and SFRs of U10H			
	Incremental catchment areas (km²)	Runoff (.INC)	Forestry (.AFF)	Invasive alien plants (.IRR)
Lumped Dam	5.5	1.2%	0.0%	0%
Comrie Dam	30.2	6.6%	16.2%	0%
Irrigation Abs point	29.3	6.4%	0.0%	0%
Downstream Comrie Dam	393.0	75.8%	83.8%	100%
Total	**458.0**	**100%**	**100%**	**100%**

The following four scenarios were modelled for Comrie Dam:

- Base scenario, current 12 m high wall, excluding EWRs releases;
- Base scenario including EWRs releases;
- Base scenario with 4 m dam raising, excluding EWRs releases; and
- Base scenario with 4 m dam raising, including EWRs releases.

The EWR classification information was obtained from EWR estimates of the river desktop biophysical nodes study (Louw, 2014). **Table 3.6** shows the results obtained from the historical yield analysis of Comrie Dam. It should be noted that the implementation of the EWRs reduced the yield of Comrie Dam by 53% for the base scenario and by 63% for the raised dam scenario.

Table 3.6: Results from Comrie Dam historic yield analysis

Catchment Area	Statistics								
	MAR (million m³/a)	SD (million m³/a)	CV	FSC (million m³/a)	MAR/ FSC	HFY(million m³/a)	HFY with EWR(million m³/a)	HFY/ FSC	HFY with EWR /FSC
U10H	82.66	44.09	0.53	-	-	4.00*	-	-	-
Base scenario	11.74	6.26	0.53	1.92	6.11	1.81	0.85	0.94	0.44
Base scenario + raised dam	11.74	6.26	0.53	6.50	1.81	3.66	1.36	0.56	0.21

** Value is derived from the hydrological assessment of the uMkhomazi River Catchment, conducted as part of the uMWP-1.*

3.5 WATER BALANCE

Information from various sources was used to produce water balance scenarios for the Bulwer-Donnybrook WSS. **Table 3.7** provides the inputs that were used to generate the water balance diagrams in **Section 3.5**. It should be noted that only domestic and livestock water requirements were considered in the water balance. Livestock water requirements were considered because it is assumed that farmers in these rural areas use groundwater for livestock watering. Groundwater is a water resource for the Bulwer-Donnybrook WSS. A water use licence is not required for storage for livestock watering for less than 10 000 m^3 per user (NWA, Act 36 of 1998).

Table 3.7: Values used to generate water balance diagrams

Category	Source/Allocation	Reference	Million m3/a	Annual % growth
Availability (2015)	Ixopo Dam HFY	All Towns Study (Tlou, 2011)	0.6	0
	Ixopo Groundwater	All Towns Study (Tlou, 2011)	0.38	0
Requirements (2015)	Domestic	From 2011 census data (75 ℓ/c/d x1.25)	3.45	0.6
	Livestock	2014 Water Requirements Study	1.08	0
Interventions	Luhane River Abstraction	(DWS, 2014)	0.56	0
	Stephen Dlamini Dam	(DWS, 2014)	3.06	0
	Existing Comrie Dam HFY	Yield Model Analysis	0.85	0

Four water balance scenarios were investigated to estimate when Smithfield Dam will be required to augment the Bulwer-Donnybrook WSS. These scenarios are discussed in **Section 3.5.1** to **Section 3.5.4**.

3.5.1 Existing Comrie Dam intervention

Comrie Dam will only augment the Bulwer-Donnybrook WSS if Sappi-Saiccor agrees that HGDM may abstract water from Comrie Dam. The water balance in **Figure 3.4** shows that the existing Comrie Dam is able to provide for the water deficit until the year 2031. The construction of Smithfield Dam will be completed in 2023 and infrastructure to transfer water from Smithfield to Comrie Dam should be constructed and implemented before 2031.

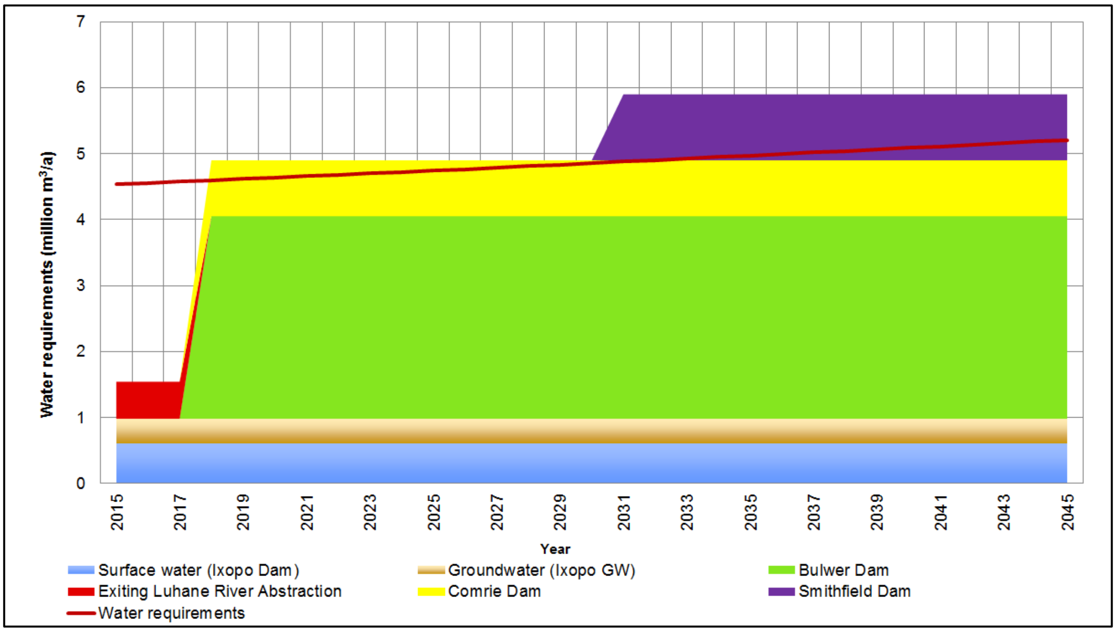

Figure 3.4: Water balance for Bulwer-Donnybrook WSS, using Comrie Dam

3.5.2 Raised Comrie Dam intervention – Raised portion used

A scenario was analysed where Sappi-Saiccor requires Comrie Dam to be raised and the yield of the raised portion should be used by HGDM. This will result in HGDM only having access to the incremental yield, which is 0.51 million m^3/a. The water balance in **Figure 3.5** shows that the raised portion alone is not sufficient to meet the medium-term water requirements. The first delivery of water of the raised Comrie Dam will probably only be in 2021, considering that a feasibility study, a detailed design and construction of the raised dam needs to be done. Augmentation from Smithfield Dam will be required in the year 2023.

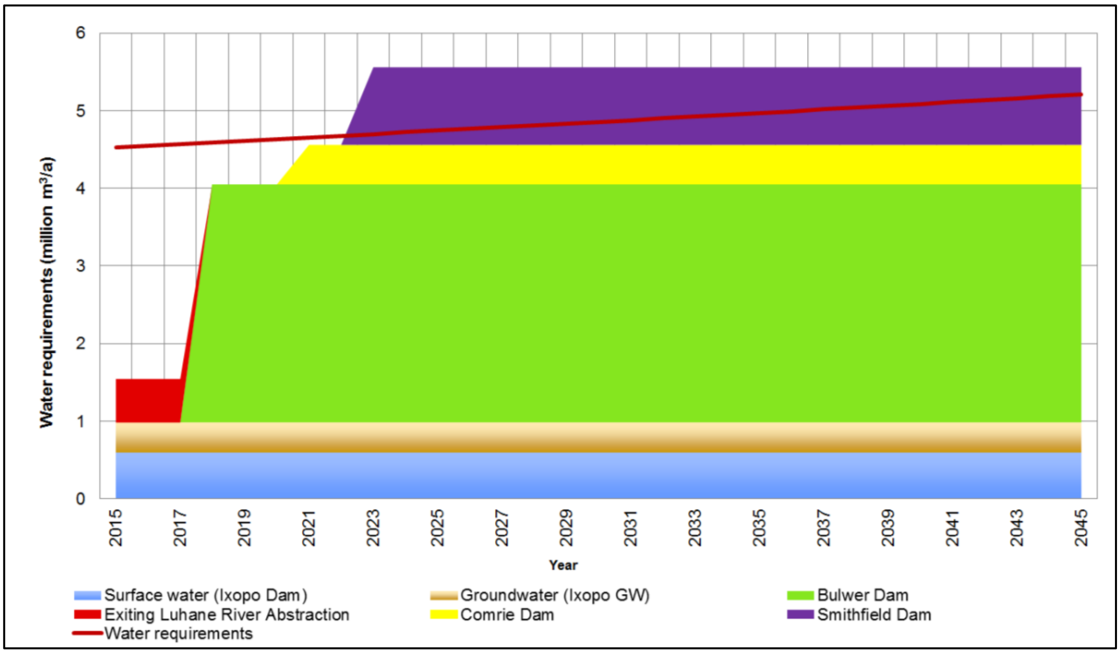

Figure 3.5: Water balance for Bulwer-Donnybrook WSS, using the raised portion of Comrie Dam.

3.5.3 Raised Comrie Dam intervention – total yield used

HGDM may consider to raise Comrie Dam and have full access to its yield, which is 1.36 million m^3/a, if agreed with Sappi-Saiccor. From **Figure 3.6**, it is seen that raising Comrie Dam and using the total yield is sufficient to meet water requirements beyond 2045.

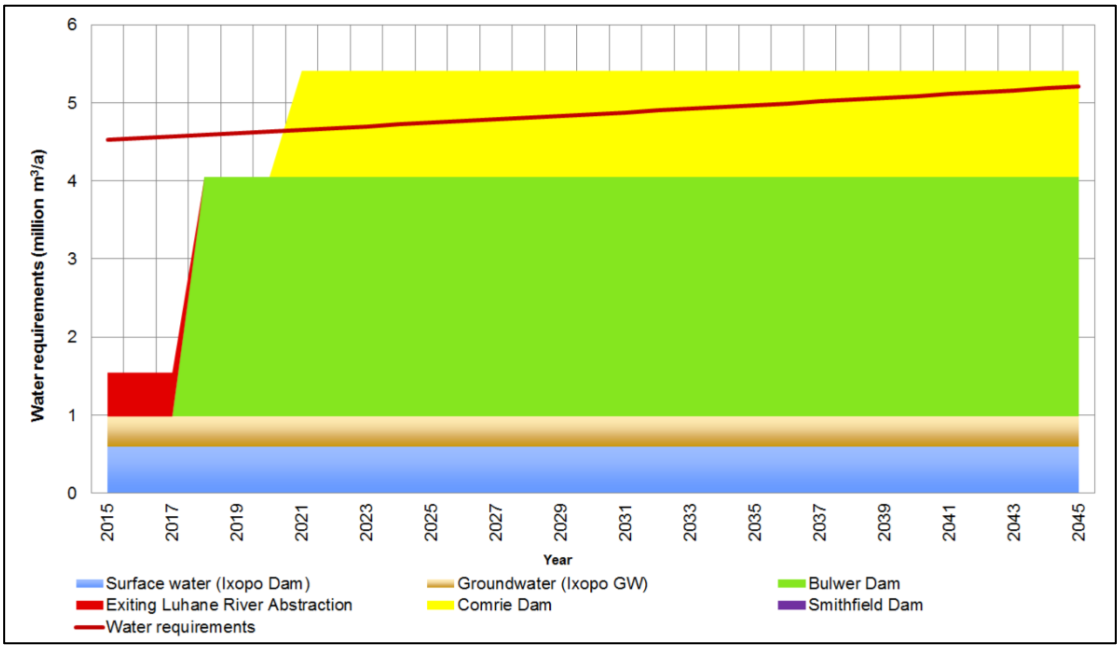

Figure 3.6: Water balance for the Bulwer-Donnybrook WSS, using the total yield of the raised Comrie Dam.

3.5.4 Smithfield Dam intervention without Comrie Dam

A scenario was investigated where Sappi-Saiccor refuses the further use of Comrie Dam water by the HGDM, driving HGDM to use water from Smithfield Dam as next intervention. The water balance in **Figure 3.7** show that as soon as Smithfield Dam is complete in 2023, the infrastructure to transfer bulk water to the Bulwer-Donnybrook WSS should be in place. With a proposed allocation of 1 million m³/a from Smithfield Dam, water shortages will be experienced in the year 2038. An allocation of 1.2 million m³/a from Smithfield Dam will be sufficient until 2045.

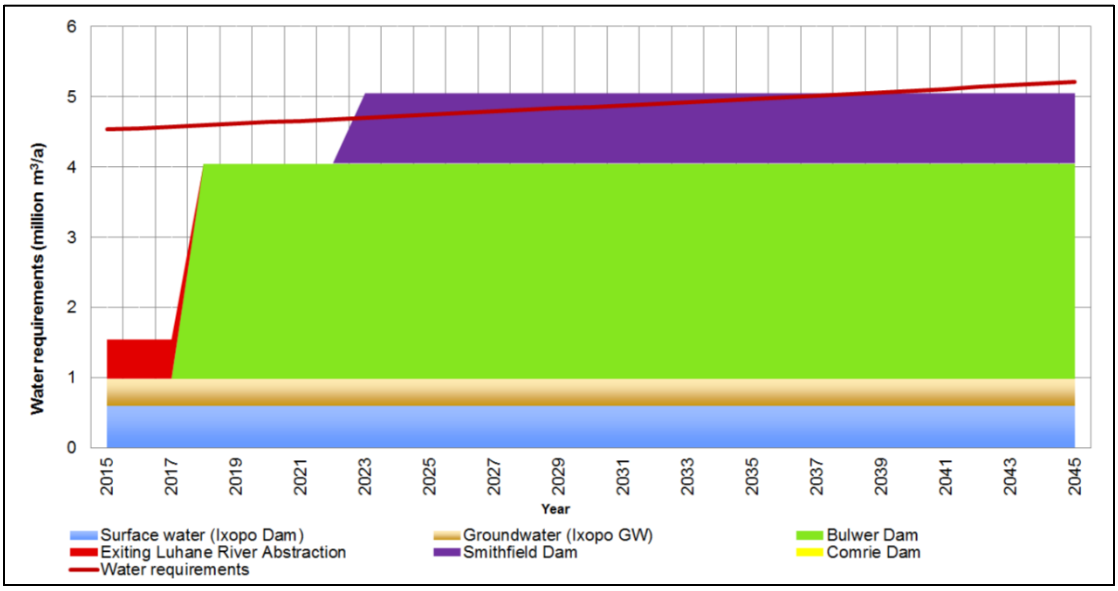

Figure 3.7: Water balance for Bulwer-Donnybrook WSS, using Smithfield Dam

4 POTENTIAL GROUNDWATER RESOURCES

The potential of groundwater exploitation for the communities surrounding Smithfield Dam was investigated as a desktop study and is discussed in **this section**. The information in this section is referenced from the *Hydrological assessment of the uMkhomazi River catchment report* (AECOM, et al., 2014).

4.1 HYDROGEOLOGY

A summary of the three different types of aquifers located in the study area are provided. The aquifers differ in relation to exploitable yield (quantity or volume), the quality and hydraulic characteristics.

4.1.1 Unconfined aquifers (porous aquifers)

The unconfined or porous aquifers are mostly interconnected with unconsolidated sediments, sand and clay, found in the valleys of main river sections that were conveyed by water. The sediment is known as alluvium matter. A greater exploitable yield (volume of ground water) can be obtained from thicker alluvial deposit. The unconsolidated sediment (loose material) allows ground water through stream paths between the material grains. These kinds of aquifers can lead to an exploitable yield of 5 ℓ/s.

4.1.2 Semi-confined aquifers (fractured rock aquifers)

Semi-confined aquifers are mostly interconnected with dolerite sill and dyke intrusions in the Karoo sedimentary rock formations. Fractures often occur along the margins of sedimentary rock and dolerite. Water can convey through the fractured conduits. Boreholes located in these aquifers can have a yield of 2-5 ℓ/s.

4.1.3 Perched aquifers

Perched aquifers are special types of aquifers observed in the study area. This is a type of unconfined aquifer located above another unconfined aquifer. The surface water that infiltrate is trapped on a shallow aquitard. An aquitard is a bed of material with a low permeability along an aquifer. This type of aquifer is unique since it is not actually linked with the groundwater table. Mountainous topography is located in the upper regions of the uMkhomazi catchment area and great variations sedimentary rocks occur with each geological subgroup. Through this multiple perched aquifers are created. Infiltrated water is able to convey through weathered sedimentary rock of higher permeability. Once the water reaches a more impermeable sedimentary rock, the flow is along the rock formation and springs occur on the ground surface. Figure 4.1 provides a visual presentation of the three aquifers discussed above.

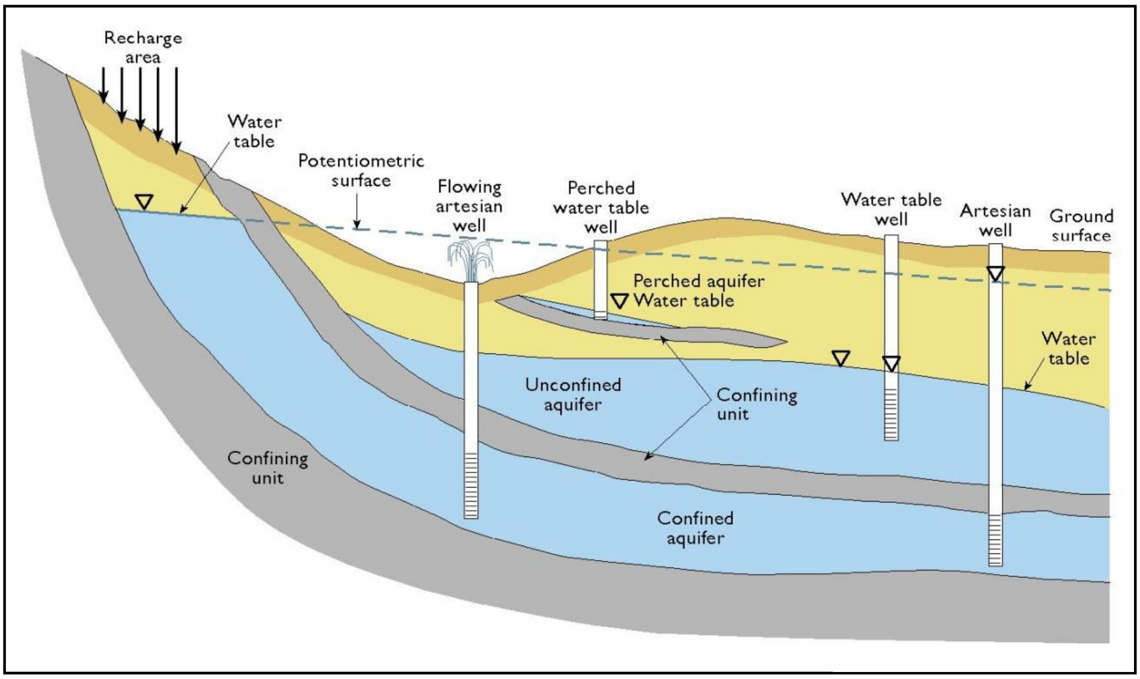

Figure 4.1: Typical visual presentation of discussed aquifers

4.2 GROUNDWATER POTENTIAL

The Groundwater Resource Information Project (GRIP) database, a logical approach to collect, verify, upload and use data to improve management and development of rural groundwater resources in South Africa, was designed to assist and serve water resource management and planning processes.

Data obtained from 806 boreholes in the secondary catchment area U1 were obtained from the KwaZulu-Natal (KZN) GRIP data base (AECOM, et al., 2014). The water level, water quality and the groundwater availability (exploitable yield) obtained from the GRIP data base will be discussed for the following quaternary catchments: U10E, F, G and H. The communities under consideration for this task are mainly located in the quaternary catchment areas mentioned above.

Figure 4.2 presents the quaternary catchment areas in uMkhomazi river catchment area.

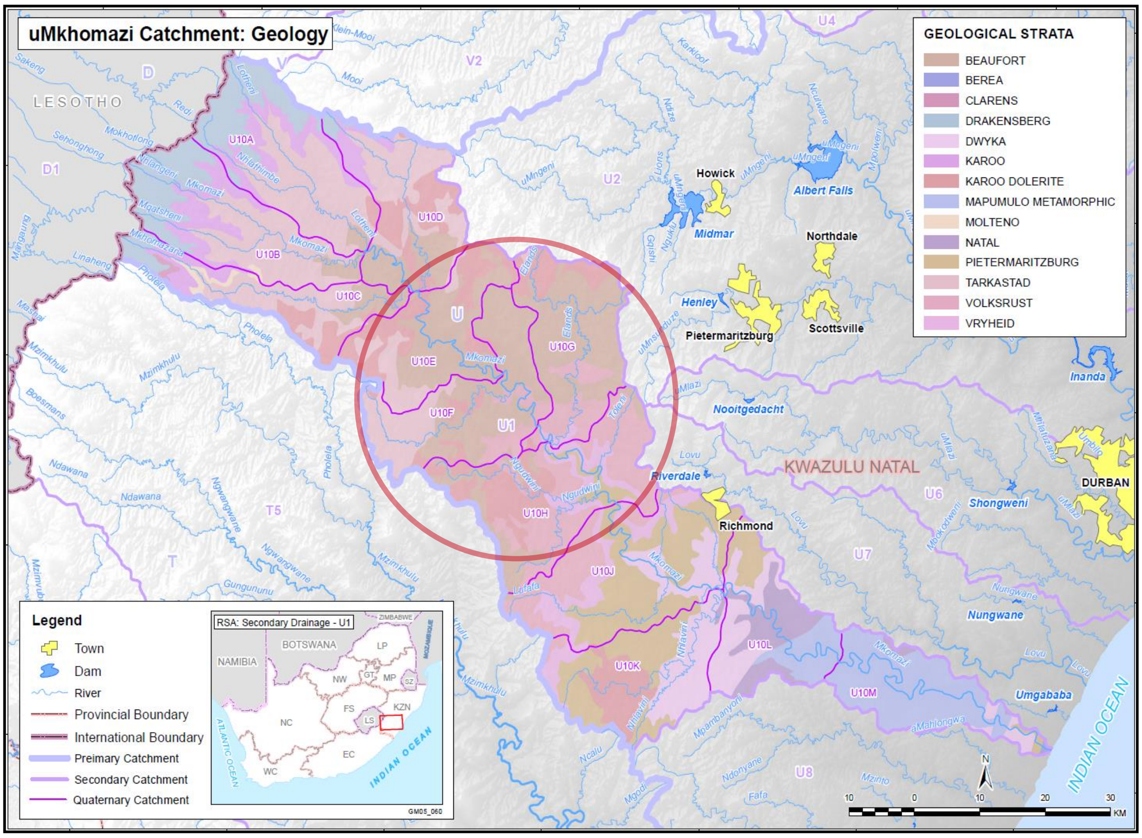

Figure 4.2: Quaternary catchment areas of the uMkhomazi catchment area.

4.2.1 Water levels

Data obtained from the GRIP database was used to identify the representative water levels in the study area. The uMkhomazi River catchment area has a minimum groundwater depth of 0 mbgl (metres below ground level), a maximum groundwater depth of 55 mbgl and a mean groundwater depth of 24 mbgl.

4.2.2 Water quality

The GRIP data was used to evaluate the water quality of the aquifers in the secondary uMkhomazi River catchment area. The results of the groundwater quality of the whole secondary catchment area U1 are available in **Table 4.1**. The water quality guidelines are presented in **Table 4.2**.

Table 4.1: Groundwater quality per quaternary catchment as obtained from the GRIP database (AECOM, et al., 2014)

Catchment	Overall Water Quality Class	pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	CO3 mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	F mg/l	N mg/l	Fe mg/l	Mn mg/l
U10A	Class 0	8.2	23.9	167.3	11.0	1.1	40.2	1.0	0.0	122.0	3.2	4.4	0.18	0.2	0.29	0.02
U10B	Class 1	7.8	27.0	178.1	16.4	6.9	35.3	1.7	0.0	118.2	8.1	11.4	0.49	0.6	0.76	0.06
U10C	Class 1	7.2	15.8	96.9	15.0	2.5	13.8	1.6	0.0	77.8	1.2	4.0	0.06	0.3	0.58	0.15
U10D	Class 1	7.3	64.8	416.0	55.4	23.8	60.4	1.7	0.0	210.0	10.0	124.0	0.31	0.4	0.09	0.14
U10E	Class 2	7.2	25.1	151.2	18.5	10.6	19.0	1.1	0.0	110.7	4.1	9.8	0.07	1.6	1.69	0.38
U10F	Class 2	7.4	23.2	228.8	19.4	6.4	28.5	1.2	0.0	103.4	10.2	19.2	0.36	1.7	1.39	0.09
U10G	Class 2	7.0	10.2	43.0	10.4	4.0	5.9	0.3	0.0	40.7	1.8	1.5	0.06	2.9	1.70	0.05
U10H	Class 0	7.4	25.2	178.8	11.6	6.8	26.0	1.9	0.0	83.2	22.0	1.6	0.11	2.0	0.36	0.04
U10J	Class 3	6.8	20.6	126.6	14.9	12.8	17.1	1.0	0.0	79.3	12.8	16.9	0.93	0.1	6.16	0.70
U10K	Class 0	7.7	24.7	198.1	20.4	8.8	16.2	1.0	0.0	108.5	8.2	7.7	0.37	0.6		
U10L	Class 2	7.7	120.7	818.4	62.1	38.2	132.8	2.6	0.0	227.1	209.5	65.1	0.64	6.9	0.08	0.05
U10M	Class 3	7.3	108.0	802.0	90.5	36.2	155.7	3.1	0.0	231.8	205.2	101.2	1.90	2.2	4.51	0.21

Table 4.2: Water quality guidelines (AECOM, et al., 2014)

DWA drinking WQ guidelines 1998																
Classification	pH	EC mS/m	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	CO3 mg/l	HCO3 mg/l	Cl mg/l	SO4 mg/l	F mg/l	N mg/l	Fe mg/l	Mn mg/l
Class 0: Ideal water quality	5.0<pH<9.5	70	450	80	70	100	25	N/A	N/A	100	200	0.7	6	0.5	0.1
Class 1: Good water quality	5.0>pH>9.5	150	1000	150	100	200	50			200	400	1	10	1	0.4
Class 2: Marginal water quality	4.5>pH>10.0	370	2400	300	200	400	100			600	600	1.5	20	5	4
Class 3: Poor water quality	4.0>pH>10.5	520	3400	300+	400	1000	500			1200	1000	3.5	40	10	10
Class 4: Unacceptable water quality	3.0>pH>11.0	520+	3400+		400+	1000+	500+			1200+	1000+	3.5+	40+	10+	10+

As observed from **Table 4.1** and **Table 4.2** the water quality of the quaternary catchment areas U10E, F and G is classified as Class 2, which is marginal water quality yet save for human consumption. Quaternary catchment U10H has a water quality classification Class 0, which is ideal water quality and suitable for lifetime human consumption. The water quality of the quaternary catchment areas is classified according to the lowest class per measured parameter.

4.2.3 Yield and water availability

The uMkhomazi River catchment is mainly underlain by Karoo Dolerite; this indicates that the area is a good groundwater source with yields ranging between 0.2 ℓ/s to 1.4 ℓ/s. Quaternary catchments U10A to U10G, which includes catchments U10E, F and G, are the most suited catchments for groundwater development according to the Groundwater Yield Model for the Reserve (GYRM). Quaternary catchment area U10H has less potential for groundwater development according to GYRM (AECOM, et al., 2014). One of the biggest limiting factors to abstract groundwater is to construct a network of suitable spaced production boreholes to abstract all the groundwater recharge to an aquifer system or regional scale catchment. The inability to construct such borehole networks are due to factors such as low permeability or transmissivity of the aquifers, aquifer heterogeneity, inaccessibility of drilling rigs and unknown aquifer boundary conditions (AECOM, et al., 2014). **Table 4.3** provides a summary of the estimated storage capacity in the whole secondary catchment area. **Table 4.4** provides a ***more conservative*** utilisable groundwater volume according to GYRM.

Table 4.3: Groundwater storage estimates calculated for each quaternary catchment (AECOM, et al., 2014)

Quaternary catchment	Surface Area (km^2)	Depth to water level GRIP (mbgl)	Min depth to water level GRIP (mbgl)	Max aquifer depth GRAII (mbgl)	Water level management constraint (mbgl)	Aquifer storativity	Groundwater volume in storage (m^3)	Max usable groundwater volume in storage (m^3)	Max usable groundwater volume in storage (million m^3)
U10A	418.2	-7.4	-2.4	-140.9	-42.6	0.0010	33 506 708	16 822 349	16.82
U10B	392.1	-17.8	0.0	-139.6	-52.7	0.0010	28 668 515	20 653 993	20.65
U10C	267.0	-11.1	-7.7	-138.5	-45.7	0.0010	20 414 882	10 161 816	10.16
U10D	337.0	-32.4	-1.0	-136.8	-66.6	0.0010	21 117 983	22 093 268	22.09
U10E	327.2	-24.6	0.0	-136.7	-58.8	0.0010	21 997 264	19 240 044	19.24
U10F	379.0	-29.8	-1.3	-139.9	-64.7	0.0010	25 046 850	24 060 745	24.06
U10G	353.1	-24.3	-4.6	-136.6	-58.4	0.0010	23 812 759	19 009 474	19.01
U10H	457.8	-13.5	0.0	-139.6	-48.4	0.0010	34 652 342	22 140 758	22.14
U10J	505.1	-26.2	-1.1	-156.4	-65.3	0.0010	39 461 440	32 416 315	32.42
U10K	364.4	-25.4	-10.0	-160.1	-65.4	0.0010	29 444 734	20 203 738	20.20
U10L	307.2	-55.1	-2.7	-175.7	-99.0	0.0010	22 236 659	29 584 055	29.58
U10M	280.0	-21.1	0.0	-178.8	-65.8	0.0010	26 488 107	18 428 801	18.43
Total	**4388.1**						**326 848 243**	**254 815 356**	**254.82**

Table 4.4: GYRM usable water from base flow (AECOM, et al., 2014)

Quaternary catchment	*Surface Area (km²)*	*Usable GW component from Base Flow assured 95% (m^3/ km²/ a)*	*Average groundwater exploitation potential (AGEP) (m^3/km^2/a)*	*Utilisable Groundwater Exploitation Potential (UGEP) (m^3/ km²/ a)*	*Final Utilisable Groundwater per catchment (m^3/ km²/a)*	*Final Utilisable Groundwater per catchment (million m^3/a)*
U10A	*418.2*	*103 894*	*51 839*	*46 147*	*46 147*	*19.30*
U10B	*392.1*	*77 613*	*42 848*	*39 398*	*39 398*	*15.45*
U10C	*267.0*	*67 590*	*37 921*	*33 030*	*33 030*	*8.82*
U10D	*337.0*	*63 231*	*35 932*	*31 013*	*31 013*	*10.45*
U10E	*327.2*	*61 873*	*39 568*	*36 441*	*36 441*	*11.92*
U10F	*379.0*	*35 336*	*30 855*	*27 628*	*27 628*	*10.47*
U10G	*353.1*	*40 274*	*33 239*	*29 352*	*29 352*	*10.37*
U10H	*457.8*	*15 801*	*30 633*	*26 747*	*15 801*	*7.23*
U10J	*505.1*	*16 808*	*24 337*	*20 855*	*16 808*	*8.49*
U10K	*364.4*	*-2 094*	*14 035*	*11 836*	*-2 094*	*-0.76*
U10L	*307.2*	*20 292*	*12 528*	*9 847*	*9 847*	*3.03*
U10M	*280.0*	*42 858*	*18 203*	*19 101*	*19 101*	*5.35*
Total	***4388.1***	***543 476***	***371 939***	***331 395***	***302 473***	***110.11***

4.3 ARTIFICIAL GROUNDWATER RECHARGE

Artificial groundwater recharge involves transferring surplus surface water into aquifers. This way the water is not lost during the wet season. During the dry season boreholes causes the water table to drop. It would take many years to replenish the aquifer naturally, thus during the wet season the surplus surface water can be diverted artificially into basins or boreholes to replenish the aquifer.

This causes the water table to rise rapidly. Artificial groundwater recharge is an effective way to maintain a reliable groundwater resource.

4.4 GROUNDWATER CONCLUSION

A volume of 0.38 million m³/a of groundwater is sold to domestic users in the Ixopo area. This is the only known groundwater that is being sold in the Bulwer-Donnybrook WSA.

The groundwater potential in the quaternary areas vary from 11.92 million m³/a to 7.23 million m³/a. This is a substantial amount of water, however further investigation should be done to ensure there is local groundwater sources to supply the communities directly surrounding Smithfield Dam.

General stumbling blocks that occur with groundwater resources in rural areas are:

- Unnoticed and less understood resource;
- Adequate information regarding groundwater is not always obtainable locally;
- Lack of groundwater expertise at a local level;
- Unsustainable groundwater management; and
- The groundwater infrastructure is not maintained.

All this stumbling blocks have to be addressed to ensure a sustainable groundwater source.

4.5 GROUNDWATER RECOMMENDATIONS

A more detailed groundwater investigation has to be done locally around the communities as all the information obtained is at quaternary level. As more data is accumulated around the local communities, better planning and resource management can take place.

The catchments show good supplies and good quality of water which certainly opens an opportunity for maximum exploitation of the resource in the catchment for the supply of communities surrounding Smithfield Dam.

Cost to implement a groundwater scheme was not investigated, therefore it is recommended that a further cost analysis should be done for the implementation of a groundwater scheme.

5 FEASIBILITY OF WATER SUPPLY FROM SMITHFIELD-COMRIE DAM RWSS

As mentioned in **Section 3**, the base year (2015) water requirements for the Bulwer-Donnybrook WSS was calculated as ***3.45 million m³/a*** and the projected water requirements in year 2045 was determined as ***4.13 million m³/a***. The current and planned resources (including the proposed Stephen Dlamini Dam) of the Bulwer-Donnybrook WSS will not be able to supply the water requirements for all the communities in 2045 as can be seen from **Figure 3.4** to **Figure 3.7**. It is therefore necessary to explore the feasibility of other sources, such as sourcing water from either Comrie Dam (current or raised) or the proposed Smithfield Dam, and to determine the feasibility of developing the Smithfield-Comrie Dam RWSS. Although a desktop study was done for groundwater potential, groundwater was not considered as a future source to augment the Bulwer-Donnybrook WSS, because little information is available at a local level (communities around Smithfield Dam).

HGDM stated in a meeting held on 21 April 2015 in Ixopo that an agreement with Sappi-Saiccor is in place for the use of water from Comrie Dam for a period of 10 years to augment the Bulwer-Donnybrook WSS. It is thus assumed that Comrie Dam is an available resource to augment the Bulwer-Donnybrook WSS in the medium term, and a possibility for the long term.

Five water supply options were considered to augment the current Bulwer-Donnybrook WSS from the Smithfield Dam and/or Comrie Dam. The following paragraphs describe the selected options, as well as the assumptions and optimisation.

The five Smithfield-Comrie Dam RWSS options that were considered to augment the current Bulwer-Donnybrook WSS are listed below:

- Option 1: Smithfield Dam via Comrie Dam (excluding Comrie Dam's yield);
- Option 2: Smithfield Dam to the villages Sizanenjane and Kwalaba-Ntwana;
- Option 3: Smithfield Dam to the villages Bethlehem and Ncwadi;
- Option 4: Smithfield Dam supplementing Comrie Dam's shortfall; and
- Option 5: Rising of Comrie Dam.

Figure 5.1 provides the reader with a schematic view of the pipeline layouts. A short description of each option follows:

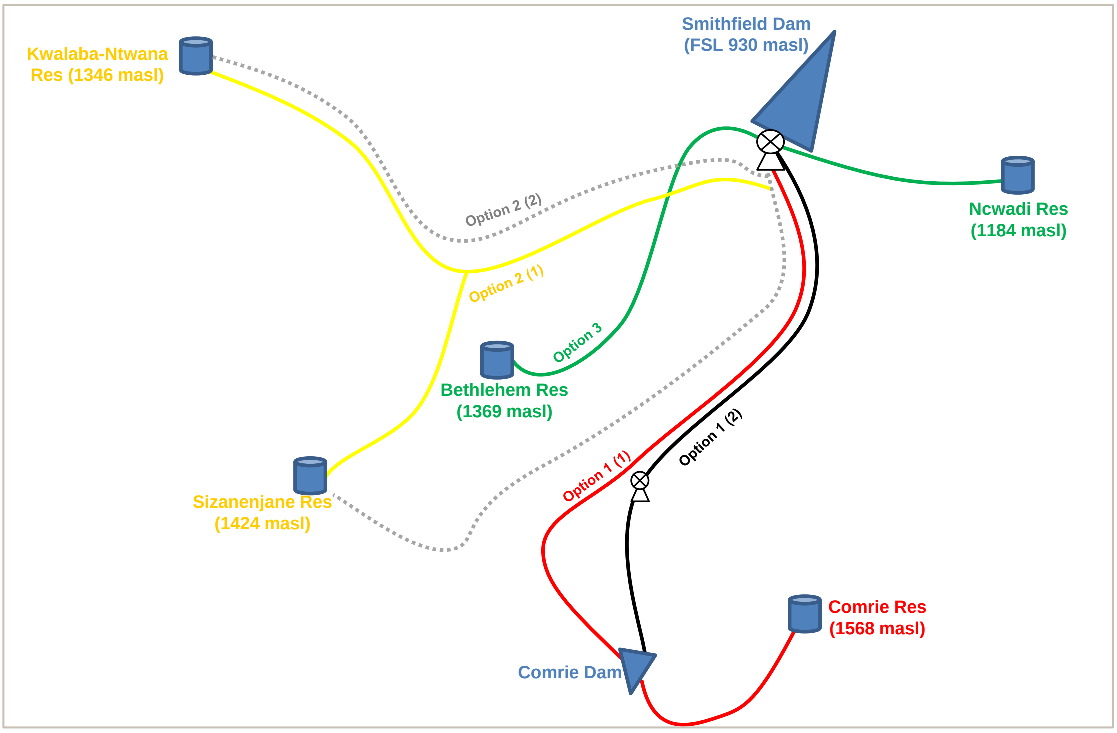

Figure 5.1: Schematic image of possible supply options to communities

- **Option 1 Smithfield via Comrie Dam (excluding Comrie Dam's yield):** Alternative 1 (**red line between Smithfield Dam and Comrie Dam**) is located adjacent to an existing road and follows the layout of the road for most of the system. Alternative 2 **(black line)** follows the shortest practical route from Smithfield Dam to Comrie Dam, but requires an additional head of 111 m to convey water to Comrie Dam. This is due to the topography restraints that the pipeline route of Alternative 2 consists of. These proposed alternatives require water treatment plants (WTP) downstream of Comrie Dam. A pump station is required to pump potable water to a high reservoir and distributed to the communities **(red line downstream of Comrie Dam)**. The yield of Comrie Dam will not be used in this option; Comrie Dam only serves as a medium transporting the water to the point of abstraction.

- **Option 2 Smithfield to Sizanenjane and Kwalaba-Ntwana:** Two pipeline routes, Alternative 1 (**yellow line**) and Alternative 2 (**grey dotted line**) were selected to transfer bulk potable water from the Proposed Smithfield Dam to the two desired destinations. These destinations are reservoirs in Kwelaba-Ntwana and Sizanenjane communities. These reservoirs are situated on the highest elevations that can gravity feed the rest of the communities within the local supply area. A WTP will be located just downstream of the Proposed Smithfield Dam before water is pumped from a pump station.

- **Option 3 Smithfield to Bethlehem and Ncwadi:** This option consists of one alternative which is represented by the **green lines**. Two pipeline routes were selected to transfer bulk water from the Proposed Smithfield Dam to two desired destinations. These destinations are reservoirs in Bethlehem and Ncwadi communities. Bethlehem and Ncwadi are situated on the highest elevations in the surroundings that can gravity feed the communities within the supply area. A water treatment plant will be located downstream of the Proposed Smithfield Dam therefore potable water will be pumped and distributed to the reservoirs at the two communities.

  Option 4 Smithfield Dam supplementing Comrie Dam's shortfall: This option will only be viable if Comrie Dam is a guaranteed resource to be used by the HGDM. Smithfield Dam will supplement Comrie Dam with 0.15 million m³/a since Comrie Dam has a yield of 0.85 million m³/a after environmental releases. Option 1 and Option 4 follow the same routes from the Proposed Smithfield Dam to Comrie Dam. In **Figure 5.1** Alternative 1 is indicated with a **red line** and Alternative 2 is indicated with a **black line.** The water will be treated downstream of Comrie Dam and will be pumped to Comrie reservoir, where distribution of the water will take place.
- **Option 5 Raising of Comrie Dam:** This option will only be viable if Comrie Dam is a guaranteed resource to be used by the HGDM. The yield of Comrie Dam will increase from 0.85 million m³/a to 1.36 million m³/a by raising the dam by 4 m from 12 m to 16 m. The water will be treated and pumped to the Comrie reservoir, from where distribution will take place.

5.1 ROUTE SELECTION

It is necessary to select the optimum route for the pipelines. Various pipeline routes were investigated for the various options and the best alternative was chosen. *Geographical maps* were used to determine the layout of the routes. Once the routes of the different options were fixed, optimisation of the pipelines started.

5.2 ASSUMPTIONS

In the feasibility assessment, the following assumptions were made to determine the optimal diameter of the pipelines for the ***Smithfield-Comrie Dam RWSS***:

- Evaluation period is 30 years (2015 - 2045);
- Initial construction period is 2 years;
- Pumping duration is 20 hours per day;
- Annual pumping down time is calculated to be 60 days;
- The gravity section has an annual down time of 10 days;
- The escalation in energy cost is assumed to be 8% per annum for the life cycle of the project;
- Inflation is 6% per annum;
- The pump efficiency is 69%;
- The long term pipe roughness is 0.5 mm;
- The maximum design velocity is 2.5 m/s, which is less than the allowable 3.0 m/s that the DWS prescribes;
- The dimensionless K-value, representing secondary losses, is 25 for the entire pipeline;
- Steel pipes are used for the analysis;
- Minimum allowable steel pipe wall thickness is 4.5 mm;
- The steel pipe material yield is 290 MPa for the Grade X42 pipe and 350 MPa for the Grade X52 pipe;
- The maximum allowable design stress is 60% of the yield stress of a selected pipe;
- Pipes greater than 600 mm in diameter have a 0.4 mm thick epoxy lining.
- Pipe sections less than 600 mm in diameter have a 10 mm thick cement mortar lining;
- Bitu-guard is used for pipe coating;
- Hard excavation is 15% of the total excavation. Blasting will be required to loosen the material from the in-situ conditions; and
- Intermediate excavation is 30% of the total excavation. Boulders will have to be removed during the excavation process.

The following assumptions were made for the maintenance requirements:

- Annual maintenance cost of the pipeline is 0.5% of the pipeline capital cost;
- Annual maintenance cost of the reservoirs is 0.5% of the reservoir capital cost;

- Pump station civil cost is 30% of the pump station capital cost;
- Pump station Electrical and Mechanical (E&M) cost is 70% of the pump station capital cost;
- Annual maintenance civil cost of the pump stations is 0.25% of the pump station capital civil cost;
- Annual energy and maintenance cost of the pump stations is 4% of the pump station's capital energy and maintenance cost;
- Major overhaul of the pump station is done every 15 years. The overhaul cost is 15% of the initial energy and maintenance cost;
- Annual maintenance cost of the Water Treatment Plant (WTP) is 5% of the WTP capital cost; and
- Vapour pressure, also known as the maximum negative pressure, is equal to 9.1 m.

5.3 OPTIMISATION OF PIPE DIAMETER

A thorough investigation was conducted to select an optimal pipe diameter by using the Life Cycle Cost (LCC) analysis tool. The project life cycle is a 30 year period. The cost of several pipe diameters was compare to find the most economical pipe size. The total cost of each pipeline was determined by adding the capital cost to the energy cost.

5.3.1 Pipe material

It was necessary to select a type of pipe material in order to calculate the LCC to determine the optimal pipe diameter. Advantages and disadvantages of the different pipe materials were weighed against each other. The following criteria were used to decide on which pipe material to implement: the availability of pipe material, client (DWS) requirements, maximum pressure class and pipe cost. After consultation with the HGDM it was found that steel pipes are used for bulk water transfer in the municipality. Steel pipes were identified and selected as the preferred pipe material. Mortar lining will be required and some advantages of mortar lined steel sections are:

- Protection of steel against corrosion
- Easy to repair and low maintenance
- Reduction in roughness coefficients of the pipeline; therefore the cost of pumping energy will reduce.

5.3.2 Energy cost

Eskom's Mega Flex tariffs were used in the LCC analysis to calculate the pumping energy costs. There are different tariffs for various time intervals during the day. The distribution of the time intervals differs between the week and on weekends. The time periods are classified as peak, standard and off-peak periods. The daily distribution of periods is shown in **Figure 5.2**.

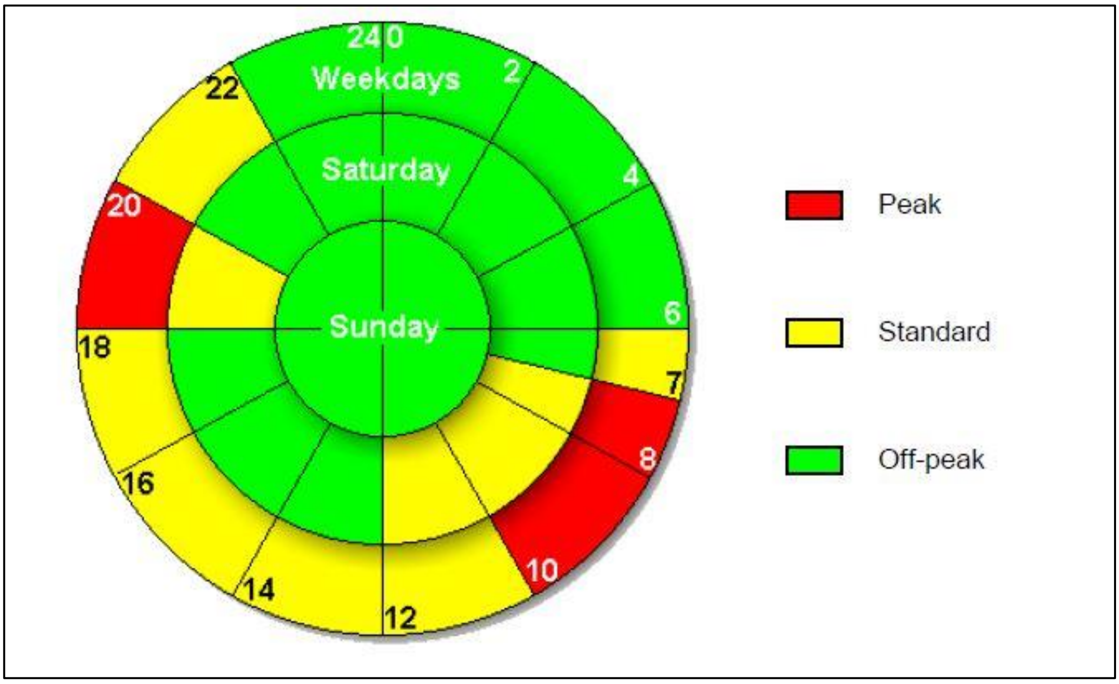

Figure 5.2: Time distribution of energy cost (Eskom, 2014).

An assumption was made that the pump station will be operated at 20 hours per day. Peak hours were avoided as much as possible. It is cheaper to pump water on the weekend as there are no peak periods. The starting time for the pumping hours will be at 11:00 AM and the end time will be 7:00 AM. This will be the most cost efficient time to pump for 20 hours. The Local authority rates in the Eskom document (*Eskom Tariffs and Charges 2014/15*) were used (Eskom, 2014). **Figure 5.3** shows transmission zones across South Africa. Bulwer-Donnybrook WSS falls in Transmission Zone 2, which is a radial interval from 300 km to 600 km from Johannesburg. Rates from Transition Zone 2 and 500V were used to determine energy tariffs. It is important to acknowledge that the energy cost is only an estimate as Eskom may change its tariffs in the future.

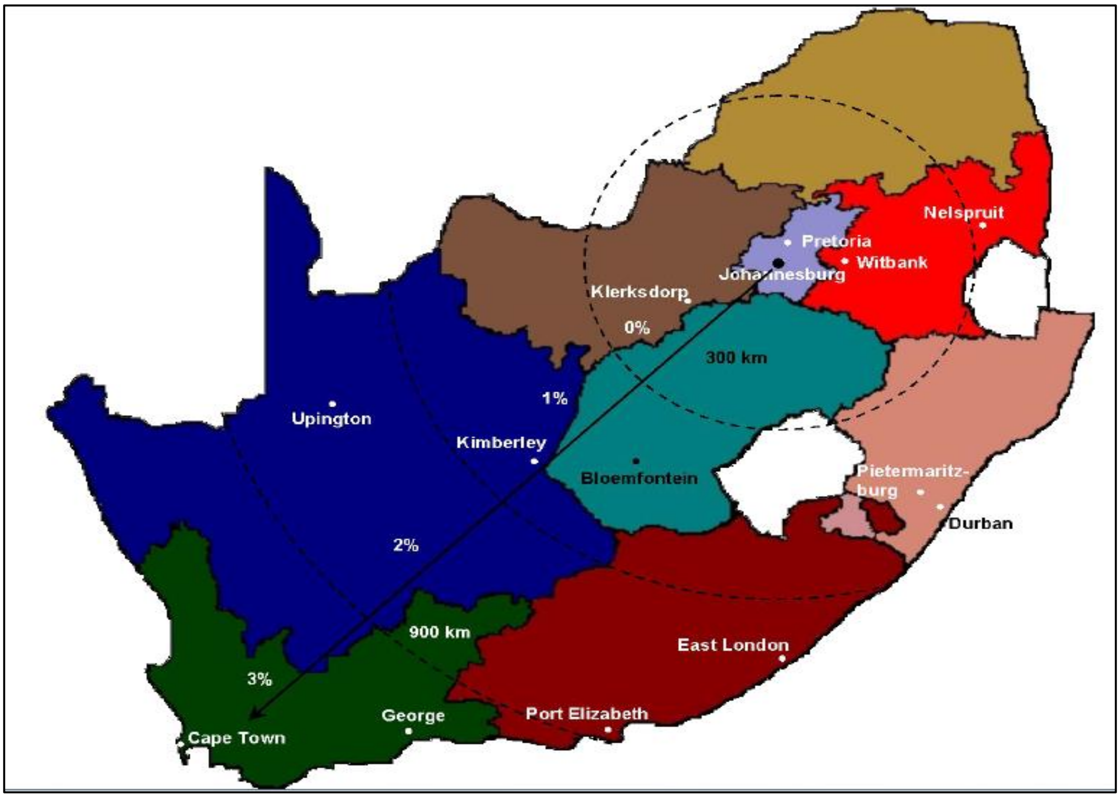

Figure 5.3: Energy cost transmission zones in South Africa (Eskom, 2014).

A summary of the energy rates for the study area are shown in **Table 5.1**. The energy cost was calculated for the high (winter) and low (summer) demand seasons.

Table 5.1: Energy charge for Transmission Zone 2

Season	Summer	Winter
Months per season	9	3
Rate	c/kWh	
Peak	73.39	224.96
Standard	50.51	68.15
Off-peak	32.04	37.01

5.3.3 Optimal diameter

The pipe diameter was selected from the conducted LCC analysis. The total cost of the system includes:

- Capital (construction) cost;
- Energy cost and ; and
- Maintenance cost.

The prices do not include the purchase of valves, the pumps and the construction cost of the valve chambers. All the items mentioned above will be included in a list of quantities in **Appendix B**.

Energy losses has an effect on the LCC of a project, therefore the formulas that were used are presented below.

The Lambda (λ) value was obtained from the Karman-Prandtl formula:

$$\frac{1}{\sqrt{\lambda}} = 2\log(\frac{3.7D}{ks}).$$

- Secondary loss = $h_l = \frac{Kv^2}{2g}$
- Friction loss = $h_f = \frac{\lambda L v^2}{2gD}$

Where:

λ = Friction factor

L = Length of pipe (m)

v = velocity (m/s)

D = Inside diameter (m)

K = secondary loss coefficient

Ks = Absolute roughness of the pipeline (m)

Joukowski's equation, presented below, was used to accommodate for surge in the system. The Hydraulic Grade Line (HGL) was obtained from the sum of the friction loss, secondary loss, static head and 30% of Joukowski's result.

Joukowski's equation:

$$H_{surgeflood} = \frac{a \times \Delta V}{g}$$

Where:

$H_{surgeflood}$ =Calculated surge head (m)

a =Pressure wave velocity (m/s)

ΔV =Fluid velocity change (m/s)

g =Acceleration of gravity (m/s²)

The maximum surge head can be used to see what the required pumping head is for a specific diameter of pipe. It is also a method to check whether the pipeline has the capability to resist the pressure.

5.4 VALVES AND VALVE SELECTION

Valve selection and design is part of detailed design, therefore the cost of valves and valve chambers are estimated as an extra and over costing for all the pipeline options.

Valve selection is dependent on pipe pressure; therefore it is necessary to determine the locations of the valves along the pipeline. Inclusion of valves increases secondary losses and therefore increases pumping costs.

5.4.1 Isolating valves

Isolating valves are used to close off a pipeline for maintenance purposes or limit the loss of water when a burst has occurred in the system. The maximum distance between two isolating valve is 3000 m. Isolating valves should be positioned at either side of scour valves to ensure that maintenance can be done in the scour valve chamber. Isolation valves are also used at the pump stations to make it possible for the labourers to isolate and maintain pumps. It is important to have a bypass around an isolating valve. This operational principal will help reduce surge in the system. A bypass is approximately 30% of the main diameter.

Air valves are used to reduce air pockets in the pipeline during operating conditions. Air pockets usually occur when an empty pipeline is filled with water. Air valves are also needed when water is drained from the system or when a burst occurs. The air valves allow the intake of air into the pipeline, thus preventing vacuum conditions to occur. Vacuum pressures can cause the pipeline to collapse.

5.4.2 Scour valves

Scour valves are placed at the low point to allow the pipeline to drain when maintenance needs to be done on a specific section. Scour valves usually have a diameter 30% of the main pipeline diameter.

5.4.3 Non-return valve

A non-return, check valve, has the function to prevent surge pressure from harming the pipeline through a pressure spike and a negative pressure drop when the wave returns. An air valve will also be installed at the non-return valve.

5.5 SURGE ANALYSIS AND PRESSURE CLASSES

When a variation in pressure occurs it is referred to as surge. It is part of detailed design and furthermore a specialist field of expertise. There are foreseen and unforeseen circumstances that have to be catered for when designing a system to allow for surge. A maximum surge head was obtained by using Joukowski's surge formula. From this pressure, it was evident that the pipe classes are sufficient. The whole pipe section complies with the necessary pipe classes.

6 WATER SUPPLY COST ESTIMATE

An overview of the methodology to calculate the Unit Reference Value (URV) of the pipeline system is illustrated with Option 1 Alternative 1 data. All the pipeline options' cost calculations are available in **Appendix F**. The capital, maintenance and operational cost form part of the URV and will therefore be discussed.

6.1 CAPITAL COST

6.1.1 Pipeline

The total capital cost of the pipeline, including civil works, is approximately **R 71.25 million (excl. VAT)**. An Extra and Over (E.O.) of **R 3.35 million**, for river and donga crossings is included in the capital cost, and an E.O. of **R 3 million** for valves and valve chambers is included in the capital cost of the pipeline.

6.1.2 Pump stations

The proposed pipeline will require two 128 kW pump stations to pump water from Smithfield Dam to Comrie Dam. These comprise of the main pump station and the booster pump station. The proposed pipeline will also need a 199 kW pump station to convey the water from Comrie Dam to the end reservoir. The capital cost of the combined pump stations is estimated as **R 18.66 million (excl. VAT)**, including 30% civil and 70% electrical and mechanical works.

6.1.3 Reservoir storage

A 3 Mℓ, 24 hour storage capacity reservoir is located at the suction side of the booster pump station. A 0.5 Mℓ, 4 hour storage capacity reservoir is used as a break pressure tank just before the gravity section of the system. Another 3 Mℓ, 24 hour storage capacity reservoir is an end reservoir, located downstream of Comrie Dam. Potable water will be pumped from Comrie Dam to the end reservoir from where it will be distributed to the surrounding communities. The total cost of implementation of the reservoirs is estimated to be **R 25.66 million (excl. VAT)**.

6.1.4 Water Treatment Plant (WTP)

Potable water has to be delivered to the communities surrounding the Smithfield Dam and the cost of treating raw water to the required standard is included. The capital cost of a small conventional WTP between 1 Mℓ and 5 Mℓ is approximately **R 3.75 million (excl. VAT)**. The WTP will be located downstream of Comrie Dam.

6.1.5 HGDM's contribution to construct Smithfield Dam

An additional capital cost will have to be earmarked by the HGDM to make provision to acquire water from the proposed Smithfield Dam. A contribution of **R 9.17 million (excl. VAT)** needs to be made to construct Smithfield Dam.

6.1.6 Implementation cost

The total cost of implementing the infrastructure necessary to supply the communities surrounding Smithfield Dam with potable water, is estimated at **R 128.49 million (excl. VAT)**.

Further to this, an additional 10% is added for professional fees and 10% for environmental and social costs, bringing the total cost to **R 154.18 million (excl. VAT)**.

It is important to note that the initial cost to supply electricity to the required sites (pump stations, WTW, etc.) has not been accounted for in this document. The required Eskom infrastructure has been included in the greater ***uMkhomazi Water Project Phase 1: Module 1: Technical Feasibility Study***.

6.2 OPERATIONAL AND MAINTENANCE COST

The latter estimated amount presented in **Section 6.1.6** represents the capital cost to implement the pipeline system. The amount excludes the following:

- Maintenance of pipeline, pumps, pump station and water treatment works;
- Electrical (energy) costs;
- Employment of professional persons to manage, operate and maintain WTW, pump stations and to inspect pipelines; and
- Admin charges.

The operational and maintenance costs are assumed constant per annum for the duration of the time that water is pumped from Smithfield Dam to Comrie Dam, treated and then pumped to the end reservoir downstream of Comrie Dam. The total operational cost for the pipeline, WTPs and pump stations is estimated as **R 1.05 million per annum.** The total maintenance and labour cost for the pipeline, WTPs and pump stations is estimated as **R 1.74 million per annum.** **Table 6.1** provides a summary for the capital and O&M cost for the various pipeline options. **Appendix F** provides a more detailed costing for Smithfield-Comrie Dam RWSS.

Table 6.1: Summary of costs regarding all options

Description	Capital Cost (R)	O&M Cost (R/annum)
Option 1 Alternative 1	154 179 601	2 792 602
Option 1 Alternative 2	144 715 982	3 929 440
Option 2 Alternative 1	170 726 340	2 911 350
Option 2 Alternative 2	192 316 812	2 857 092
Option 3	74 153 391	2 437 431
Option 4 Alternative 1	110 547 984	2 746 280
Option 4 Alternative 2	102 383 628	2 740 468
Option 5	252 253 021	2 283 317

7 FEASIBILITY OF SMITHFIELD-COMRIE DAM RWSS

It is common practise in South Africa to determine URVs of different project options to compare options and to obtain the most feasible option to implement. URVs for all the five options were calculated and compared for the Smithfield-Comrie Dam RWSS. The URV obtained for the Smithfield-Comrie Dam RWSS can be compared to other schemes that are meant to supply communities surrounding the Smithfield Dam.

The physical properties, advantages and disadvantages of the different options are discussed in **Table 7.1** and **Table 7.2** respectively. This information was used to identify the most feasible options.

Table 7.1: Physical properties of the different pipeline options

	Option 1		Option 2		Option 3	Option 4		Option 5
Description	**Alternative 1**	**Alvernative 2**	**Alternative 1**	**Alvernative 2**	**Total system**	**Alternative 1**	**Alvernative 2**	**Raised Comrie Dam**
Route length (m)	19 704	16 696	25 982	**35 541**	15 380	19 704	16 696	***3 655***
Highest elevation (m)	**1 568**	**1 568**	1 424	1 424	***1 367***	**1 568**	**1 568**	**1 568**
Lowest elevation (m)	869	869	869	869	869	869	869	1 212
No. of road crossings	17	12	15	**23**	3	17	12	***0***
No. of river crossings	1	1	1	**2**	1	1	1	0
Average slopes	7.9%, -5%	10.8%, -5.7%	6.3%, -5.7%	6.2%, -6.5%	9.9%, -5.5%	7.9%, -5%	10.8%, -5.7%	13.4%, -3.8%

Table 7.2: Advantages and disadvantages of the different pipeline options

Option 1		Option 2		Option 3	Option 4		Option 5
Alternative 1	**Alternative 2**	**Alternative 1**	**Alternative 2**	**Total system**	**Alternative 1**	**Alternative 2**	**Raising of Comrie Dam**
Advantages							
• 66.7% (13 133 m) of the total pipe length is located next to an existing gravel road. This helps with the construction and maintenance of the pipeline. • Booster pump station is located close to a local community where there is electrical infrastructure in place.	• 50.8% (8 473 m) of the total pipe length is located next to an existing gravel road. This helps with the construction and maintenance of the pipeline. • Booster pump station is located close to a local community where there is electrical infrastructure in place.	• 87.6% (22 760m) of the total pipe length is located next to an existing gravel road. This helps with the construction and maintenance of the pipeline. • Booster pump station is located close to a local community where there is electrical infrastructure in place.	• 66.7% (13 133 m) of the total pipe length is located next to an existing gravel road. This helps with the construction and maintenance of the pipeline. • Booster pump station is located close to a local community where there is electrical infrastructure in place.	• 70.9% (10 923 m) of the total pipe length is located next to an existing gravel road. This helps with the construction and maintenance of the pipeline. • Booster pump station is located close to a local community where there is electrical infrastructure in place.	• 66.7% (13 133 m) of the total pipe length is located next to an existing gravel road. This helps with the construction and maintenance of the pipeline. • Booster pump station is located close to a local community where there is electrical infrastructure in place.	• 50.8% (8 473 m) of the total pipe length is located next to an existing gravel road. This helps with the construction and maintenance of the pipeline. • Booster pump station is located close to a local community where there is electrical infrastructure in place.	• No river crossing. • Only one main pump station required. No booster pump station required. • 32.4% (1 183m) of the pipeline is next to an existing gravel road. • More water will be available after raising the dam; therefore Smithfield Dam will not be required to augment the Bulwer-Donnybrook WSS.
Disadvantages							
• A booster pump will be required, because the system was designed to pump up to 40bar. • The pipeline route has to cross the uMkhomazi River. This requires additional construction costs e.g., pipe jacking.	• A booster pump will be required, because the system was designed to pump up to 40bar. • Very steep topography. Material delivery to site could be problematic • Additional cost will be required to build terraces for safer construction at the steep slopes. • The pipeline route has to cross the uMkhomazi River. This requires additional construction costs e.g., pipe jacking.	• A booster pump will be required, because the system was designed to pump up to 40bar. • The pipeline route has to cross the uMkhomazi River. This requires additional construction costs e.g., pipe jacking.	• A booster pump will be required, because the system was designed to pump up to 40bar. • The pipeline route has to cross the uMkhomazi River. This requires additional construction costs e.g., pipe jacking.	• A booster pump will be required, because the system was designed to pump up to 40bar. • The pipeline route has to cross the uMkhomazi River. This requires additional costs. • Very steep topography. Material delivery to site could be problematic	• A booster pump will be required, because the system was designed to pump up to 40bar. • The pipeline route has to cross the uMkhomazi River. This requires additional construction costs e.g., pipe jacking	• A booster pump will be required, because the system was designed to pump up to 40bar. • Very steep topography, Material delivery to site could be problematic • Additional cost will be required to build terraces for safer construction at the steep slopes. • The pipeline route has to cross the uMkhomazi River. This requires additional construction costs e.g., pipe jacking.	• Very steep topography. • High initial/construction costs are involved if Comrie Dam is raised.

From **Table 7.1** and **Table 7.2** Option 5 is indicated as the most feasible option, because Option 5 has the shortest pipeline length and no infrastructure from Smithfield Dam will be needed. No booster pump station is required and the uMkhomazi River is not crossed. URVs were then used as a tool to compare these options and to obtain the financial feasible option to supply the Bulwer-Donnybrook WSS with potable water.

The URVs for all the options were calculated and compared. **Table 7.3** provides the URVs for the five options under consideration. Options 1 to 5 are discussed in **Appendix B** to **Appendix E**.

Table 7.3: URV values obtained for the various options

	URV (R/m³)	
Description	**Alternative 1**	**Alternative 2**
Option 1. Smithfield via Comrie Dam (excluding Comrie Dam's yield)	**18.80**	**18.04**
Option 2. Smithfield to Sizanenjane and Kwelaba-Ntwana	22.50	23.78
Option 3. Smithfield to Bethlehem and Ncwadi	68.64	-
Option 4. Smithfield Dam supplementing Comrie Dam's shortfall	57.29	53.71
Option 5. Raising of Comrie Dam *	**17.76**	-

** The cost of buying Comrie Dam is not included in the values that were obtained*

Table 7.3 indicates that Option 1 and Option 5 is the most feasible in terms of URVs.

After comparing the URVs, advantages and disadvantages of the different options; it was decided that Option 5 is the most feasible option. It consists of the lowest URV and has good physical conditions (shortest pipeline) to construct and maintain. On the other hand it must be noted that the cost of buying Comrie Dam is not included in the values that is evident in **Table 7.3**.

However, if HGDM does not get permanent access to the water of Comrie Dam, Alternative 1 of Option 1 is the most feasible option to supply the communities with potable water from Smithfield Dam. This decision is supported by the physical properties, advantages and disadvantages of the route. The pipeline is easily accessible from the road, which is ideal for construction and maintenance purposes. The slopes are less steep for Alternative 1 than for Alternative 2. The static pumping head for Alternative 1 is 111 m lower than that of Alternative 2.

8 CONCLUSION AND RECOMMENDATIONS

A pre-feasibility study was conducted to determine the viability of providing the communities surrounding Smithfield Dam with potable water. These five options were analysed:

- Option 1: Smithfield via Comrie Dam (excluding Comrie Dam's yield);
- Option 2: Smithfield to Sizanenjane and Kwalaba-Ntwana;
- Option 3: Smithfield to Bethlehem and Ncwadi;
- Option 4: Smithfield Dam supplementing Comrie Dam's shortfall; and
- Option 5: Rising of Comrie Dam.

Based on information from the ***2011 Census*** data, about **60%** of the users surrounding Smithfield Dam currently have access to some form of piped water. The exact source of piped water could not be confirmed from the 2011 Census information. This water may however, either be sourced from springs, groundwater and/or surface water (i.e. a weir on the Luhane River). It could also not be confirmed whether the water supply to these communities is sufficient and whether the water quality of the current water resources is acceptable.

In 2015 the estimated current combined domestic water requirement of communities within the Bulwer-Donnybrook WSS was in the order of **3.45 million m³/a,** which will grow to an ultimate future water requirement of **4.13 million m³/a** in 2045. This is based on an average per capita consumption of **75 ℓ/capita/day**, which considers a 'piped water inside yard' level of service. This level of service is typical for these types of mixed rural and urban areas. If an increase in the level of service exceeds expectation, an average per capita consumption will increased to approximately **100 ℓ/capita/day** in 2045, which assumes that households will be upgraded to 'piped water inside dwelling', the ultimate water requirement in 2045 is calculated to be **5.5 million m3/a**. Since there are no records of water losses in the Bulwer-Donnybrook WSS, it is recommended that HGDM implement a WC/WDM plan to improve water management in the Bulwer-Donnybrook WSA.

The proposed Smithfield Dam or existing Comrie Dam has been identified as possible resources to eliminate water shortages in the Bulwer-Donnybrook WSS. The total estimated capital cost of installing the bulk infrastructure necessary to supply the Bulwer-Donnybrook WSS from the preferred option (Option 5)was estimated at about **R 252.25 million,** including engineering fees as well as environmental and social costs. It should be noted that the cost for buying Comrie Dam as a source is not included in the cost calculations. In addition the operational and maintenance costs that would be ongoing for the duration of the time that water is treated and pumped to the local communities was estimated at a cost of **R 2.3 million/annum**.

Cost to implement a groundwater scheme was not investigated, therefore it is recommended that a further cost analysis should be done for the implementation of a groundwater scheme.

The URV of the Smithfield-Comrie Dam RWSS Option 5 is **R 17.76/m³**.

It is recommended that the estimated water requirement of approximately **1 million m³/a** is provided from Comrie Dam to supply Bulwer-Donnybrook WSS. This option is feasible if HGDM can negotiate with Sappi Saiccor for ownership or long-term use of Comrie Dam. HGDM may also negotiate with Sappi Saiccor and DWS to exchange a possible allocation from Smithfield Dam, for the use of Comrie Dam, while Sappi Saiccor's requirements are met from Smithfield Dam. This practical solution will reduce operational cost as less pumping will be required.

Smithfield Dam is an alternative source of water if HGDM can reach an agreement with Sappi Saiccor on Comrie Dam. This supply from Smithfield Dam will not have any significant impact on the yield of Smithfield Dam as it is relatively small when compared to the transfer of water to the integrated Mgeni WSS.

In order to determine the way forward, it is recommended that the ***Smithfield-Comrie Dam RWSS*** be included in the uMWP-1. If Option 5 is going to be executed it is recommended that the scheme is implemented and managed by Umgeni Water. The capital cost of implementing Option 5 should then be included in the uMWP-1. However it must be noted that:

- The proposed Smithfield-Comrie Dam RWSS is at least 8 years away from possible completion due to the anticipated possible implementation dates of the uMWP-1;

- The proposed Smithfield-Comrie Dam RWSS should only augment the Bulwer-Donnybrook WSS when no more cost effective local resources are available; and
- Other local sources of water will most likely be available sooner i.e. groundwater and management interventions such as Water Conservation/Water Demand Management (WC/WDM).

It is also recommended that:

- Confirmation of the availability of Comrie Dam as resources for HGDM and possible future raising;
- Water to be supplied from the Smithfield Dam to augment the Bulwer-Donnybrook WSS or supply Sappi Saiccor to the volume of approximately 1 million m^3/a;
- Current water sources utilised by each individual community within the Smithfield-Comrie Dam RWSS/Bulwer-Donnybrook WSS and the portion of the water requirement that could still feasibly be supplied for current, local sources in future (i.e. springs, groundwater and surface water supplies from a weir on the Luhane River). It is highly recommended that communities should continue to use their current water sources for as long as possible;
- The current water available to the communities within the Bulwer-Donnybrook WSS be reconciled with the water requirements of these up to 2023 in order to assess their capacity to await the completion of Smithfield Dam; and
- A feasibility study is performed on the preferred scheme (Option 5).

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Appendix A

List of Communities in the Bulwer-Donnybrook WSS

Table A.1: Communities in the Bulwer-DonnybrookWSS, *2011 Census* (2015)

Sub-place / Community	Total population from Census 2011 (number)	Total households from Census 2011 (Number)	Total Current Population (2015) assuming 0.6 % annual growth (number)	Total Population in 30 years (2045) assuming 0.6 % annual growth (number)	Ultimate total water requirement in 2045 (0.6%) (at a rate 0f 94ℓ/capita /day) (m^3/day)	Ultimate total water requirement in 2045 (0.6%) (at a rate 0f 94ℓ/capita /day) (Kℓ/day)
Supply Zone A						
Project A						
Pevensey	552	150	565	677	63	63
Okhalweni	78	21	80	96	9	9
						72
Project B						
Bulwer	1322	577	1354	1620	152	152
						152
Supply Zone B						
Project I						
Sarnia	39	27	40	48	4	4
Nqumeni	3808	839	3900	4667	438	438
Gala	702	156	719	860	81	81
Mqondekweni	1223	251	1253	1499	141	141
Makhuzeni	1105	257	1132	1354	127	127
Qulashe	2933	599	3004	3595	337	337
Okhetheni	549	127	562	673	63	63
Hlabeni	1323	312	1355	1621	152	152
						1342
Project K						
Tarsvaly	881	220	902	1080	101	101
						101
Project L						
Creighton	899	377	921	1102	103	103
						103
Project M						
Mahehle	5399	1244	5530	6617	620	620
						620
Supply Zone C						
Project C						
Nkelabantwana	3492	754	3577	4280	401	401
Xosheyakhe	1036	240	1061	1270	119	119
MkobeniKamensia	711	153	728	871	82	82
Chibini	677	142	693	830	78	78
Hlafuna	634	137	649	777	73	73
						753

Sub-place / Community	Total population from Census 2011 (number)	Total households from Census 2011 (Number)	Total Current Population (2015) assuming 0.6 % annual growth (number)	Total Population in 30 years (2045) assuming 0.6 % annual growth (number)	Ultimate total water requirement in 2045 (0.6%) (at a rate 0f 94ℓ/capita /day) (m^3/day)	Ultimate total water requirement in 2045 (0.6%) (at a rate 0f 94ℓ/capita /day) (Kℓ/day)
Project D						
KwaSambane/ Mangwaneni	342	97	350	419	39	39
Emvuleni	161	41	165	197	18	18
Amangwane	37	19	38	45	4	4
						62
Project E						
Mqulela	643	130	659	788	74	74
Nkumba/Mdayane	966	235	989	1184	111	111
Mkhohlwa	403	105	413	494	46	46
Hlanganani/Bheni	883	238	904	1082	101	101
Machabasini	452	101	463	554	52	52
Bethlehem	1208	266	1237	1480	139	139
Lubovana	352	60	361	431	40	40
Nonguqa	554	110	567	679	64	64
						627
Supply Zone D						
Project F						
Ezitendeni	1431	352	1466	1754	164	164
Senkwanzela	2336	532	2393	2863	268	268
Ememela	891	174	913	1092	102	102
Sizanenjana	1186	249	1215	1454	136	136
Eziphahleni	623	123	638	764	72	72
Mbulweleni	1581	340	1619	1938	182	182
Nkwezela	2410	480	2468	2954	277	277
Maoleni	1483	8	1519	1817	170	170
						1372
Project G						
Luwambeni	4176	799	4277	5118	480	480
Bhidla	814	178	834	998	94	94
KwaNomandlovu	1065	230	1091	1305	122	122
Umjila	1228	246	1258	1505	141	141
						837
Project H						
Jubane	287	65	294	352	33	33
Siwongozi	348	74	356	426	40	40
Ezibonvini	265	63	271	325	30	30

Sub-place / Community	Total population from Census 2011 (number)	Total households from Census 2011 (Number)	Total Current Population (2015) assuming 0.6 % annual growth (number)	Total Population in 30 years (2045) assuming 0.6 % annual growth (number)	Ultimate total water requirement in 2045 (0.6%) (at a rate 0f 94ℓ/capita /day) (m^3/day)	Ultimate total water requirement in 2045 (0.6%) (at a rate 0f 94ℓ/capita /day) (Kℓ/day)
Ncwadi/ Gudlintaba/ Maqadeni	2199	498	2252	2695	253	253
KwaMnyamana	875	207	896	1072	101	101
Mahohoho	278	56	285	341	32	32
						489
Project N						
Donnybrook	4683		4796	5739	538	538
						538
Project O						
Owambeni	4176		4277	5118	480	480
Nomandlovo	1065		1091	1305	122	122
Umjila	1230		1260	1507	141	141
						743
Project P						
Emnywaneni	609	131	624	746	70	70
						70
Project Q						
KwaSandanezwe	2856	682	2925	3500	328	328
KwaNombulula	227	53	232	278	26	26
						354
Project R						
Sawoti	541	109	554	663	62	62
Masameni	1889	408	1935	2315	217	217
						279
Project S						
Sikeshini	631	141	646	773	72	72
						72
Supply Zone E						
Project T						
Amatolo	472	102	483	578	54	54
Amahlathi	1666	310	1706	2042	191	191
Mpofini	634	153	649	777	73	73
KwaMagidigidi	1849	406	1894	2266	212	212
Nhlangwini	430	94	440	527	49	49
						580
Project U						
Lufafa	1224	256	1254	1500	141	141
Mgobansimbi	577	140	591	707	66	66

Sub-place / Community	Total population from Census 2011 (number)	Total households from Census 2011 (Number)	Total Current Population (2015) assuming 0.6 % annual growth (number)	Total Population in 30 years (2045) assuming 0.6 % annual growth (number)	Ultimate total water requirement in 2045 (0.6%) (at a rate 0f 94ℓ/capita /day) (m^3/day)	Ultimate total water requirement in 2045 (0.6%) (at a rate 0f 94ℓ/capita /day) (Kℓ/day)
Amashaka	1905	379	1951	2335	219	219
Echibini	2026	441	2075	2483	233	233
						659
Project V						
Mariathal	441	117	452	540	51	51
						51
Project W & X						
Ixopo	12461	4657	12763	15272	1432	1432
						1432
Total	**98432**	**21238**	**100816**	**120633**	**11309**	**11309**
Total water requirement in 2045					11309	(m^3/day)
					11.31	(Ml/day)
					4.13	(Mm^3/a)

Appendix B

Smithfield-Comrie Dam RWSS

Options 1 and 4

B.1 GUIDELINES FOR ROUTE SELECTION

B.1.1 LAND RIGHTS AND SERVITUDES

A servitude is a piece of land that has the right to be subjected to an explicit use. Servitudes need to be registered before construction of the designed infrastructure can be initiated. Money should be spent to make the servitude big enough so that it can fulfil future needs. In the case of the Smithfield-Comrie Dam RWSS, enlarging the servitude seems to be negligible since the population growth rate is conservatively estimated at **0.6%** per annum. When existing services are crossed, great care should be taken to prevent any damage to the existing infrastructure.

B.1.2 ALIGNMENT OF PIPE NETWORK

The route selection was done in a way where most of the pipeline is located next to or close to a road for construction and maintenance reasons. During the route selection process, sharp bends were avoided to a feasible extent to reduce system losses. From **Figure B.2.1** and **Figure B.2.2** below, it is evident that no sharp bends occur; the pipes in the system follow gradual bends.

B.1.3 PIPE LENGTH AND DIAMETER

From an energy perspective it is more feasible to use a larger diameter pipe. From hydraulics it is evident as the diameter of the pipe increase for a fixed flow rate, the velocity of the system drop due to an increase in the flow area available. Friction losses reduce and the energy required to convey water also decrease.

From this statement it is reasonable to consider increasing the pipe diameter (capital cost) for the project to save on energy in the future. The pipe length contributes a lot to the cost of the system; therefore the shortest possible routes should be selected.

B.2 ROUTE LAYOUT ALTERNATIVES

Various alternatives were narrowed down to two alternatives that are discussed in the following section. Option 1 has to convey 1 million m³/annum and Option 4 has to convey 0.15 million m³/annum from the proposed Smithfield Dam to Comrie Dam. The two alternatives of Option 1 and Option 4 are presented in **Figure B.2.1** and **Figure B.2.2** respectively. The figures provide the reader with a plan view of the pipeline layout. The longitudinal ground elevation profile of the two alternatives for Option 1 and Option 4 is presented in **Figure B.2.3** and **Figure B.2.4** respectively. Alternative 1 is located adjacent to an existing road and follows the layout of the roadfor most of the system. Alternative 2 follows the shortest practical route from Smithfield Dam to Comrie Dam, but requires an additional head of 111 m, due to topography restraints, to convey water to Comrie Dam.

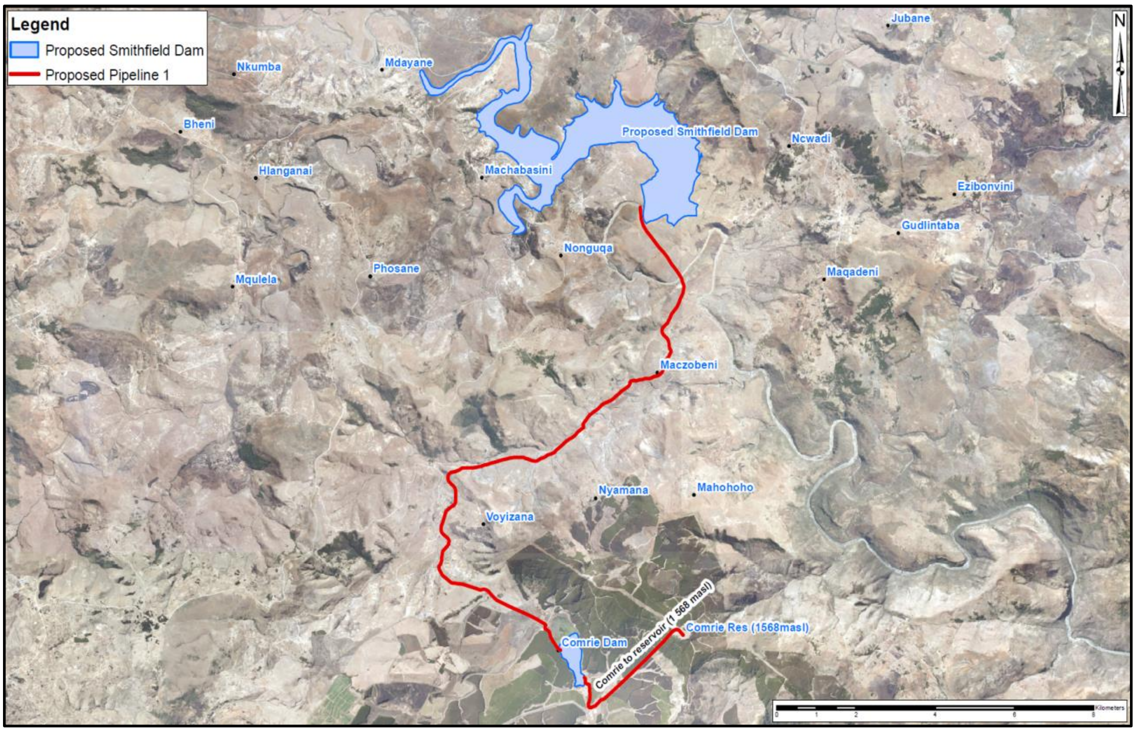

Figure B.2.1: Image of Alternative 1 route layout

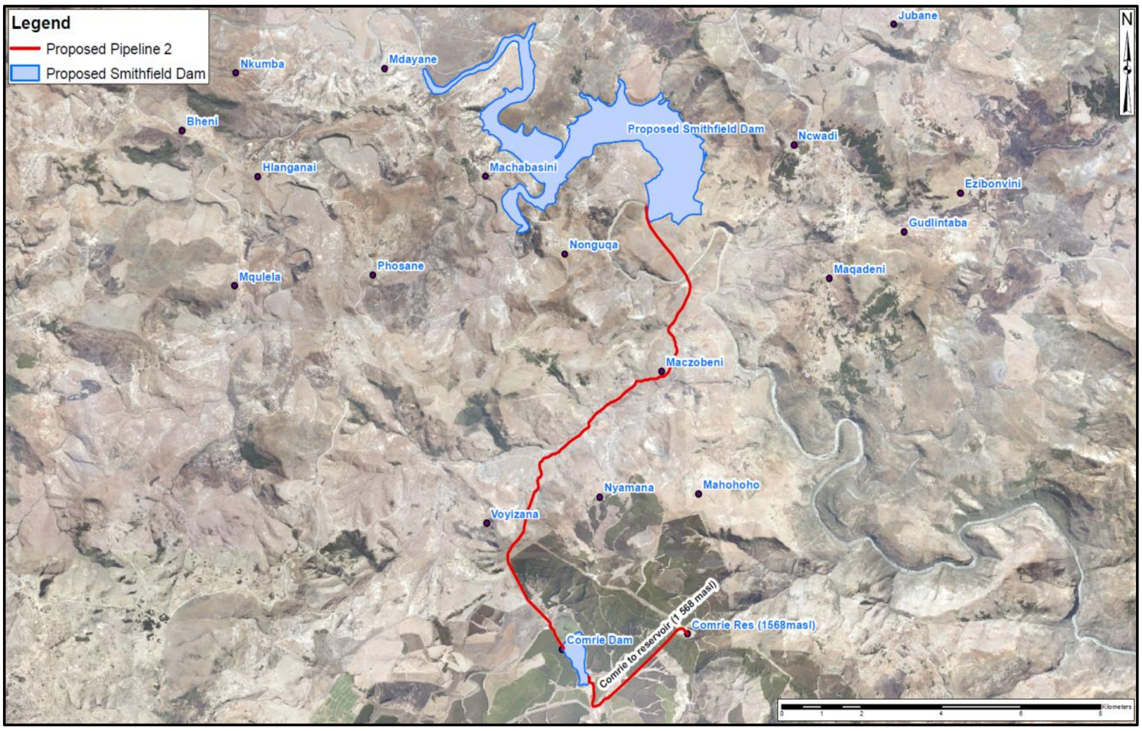

Figure B.2.2: Image of Alternative 2 route layout

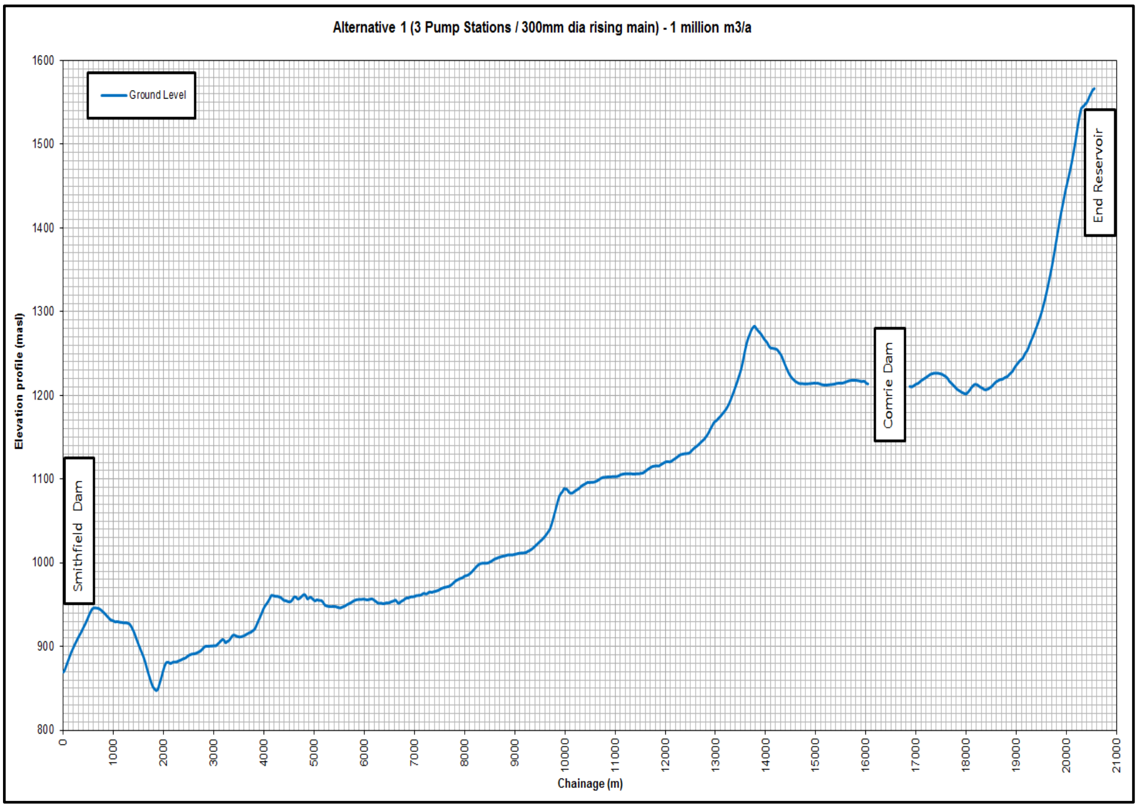

Figure B.2.3: Elevation profile for Alternative 1

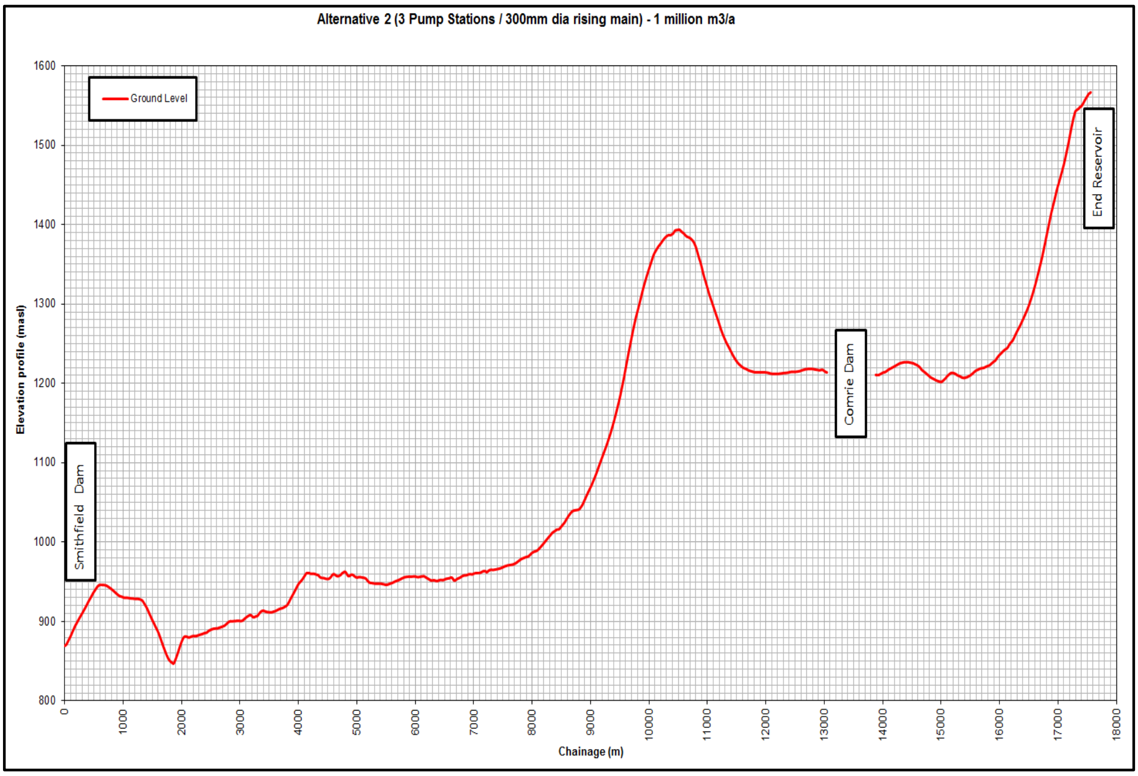

Figure B.2.4: Elevation profile for Alternative 2

B.2.1 OPTIMAL PIPELINE ROUTE

Figure B.2.1 represents Alternative 1 for both options and **Figure B.2.2** represent Alternative 2 for both options. A summary of the alternative routes is presented in **Table B.2.5**.

Table B.2.5: Additional information on both alternatives

Description	Route Alternative 1	Route Alternative 2
Route length (m)	19 704	16 696
Highest elevation (m)	1 568	1 568
Lowest elevation (m)	869	869
No. of road crossings	17	12
Average slopes	7.9%, -5%	10.8%, -7.6%

Some assumptions regarding the crossing of existing services:

- As the area under consideration is classified as a rural area, an assumption was made that no infrastructure (electrical cables, storm water and water pipeline services) exists. Electrical cables are only underground in urban residential areas.

- The term road crossing refers to a pipe section that crosses another service i.e. culverts etc.
- It is assumed that septic tanks and VIP (Ventilated Improved Pit) latrines are used in this area.
- No sewage services are crossed.

B.2.2 EVALUATION OF ALTERNATIVES

The advantages and disadvantages of the two alternatives are discussed in **Table B.2.6**. This is done to verify the most viable alternative.

Table B.2.6: Advantages and disadvantages of Option 1 and Option 4

Alternative 1	Alternative 2
Advantages	
• 66.7% (13 133 m) of the total proposed pipe length is located next to an existing gravel road. This helps with construction and maintenance of the pipeline. • The booster pump station is located close to a local community.	• 50.8% (8 473 m) of the total proposed pipe length is located next to an existing gravel road. • Shorter system length of the two alternatives • Initial construction cost is lower since it is the shorter pipeline section.
Disadvantages	
• Alternative 1 has a longer pipeline section than Alternative 2. • A booster pump will be required. • The UMkhomazi River has to be crossed.	• 111 m additional pumping head required to Comrie Dam. • Booster pump required since the standard for pump stations is <= 40 bar pressure • Very steep topography, pipe delivery could be problematic • Additional cost will be required to build terraces for safer construction at the steep slopes. • Energy cost is higher due to the additional head that has to be pumped. • A river has to be crossed • Maintenance at steep slopes poses as a potential risk factor,

The proposed route for Alternative 1 is 3 008 m longer than that of Alternative 2. A booster pump station will be required to comply with the standards of a pump station; i.e. it may not exceed 40 bar of pressure. An advantage that Alternative 1 has is that 66.7% (13 133 m) of the total length (19 704 m) is next to an existing gravel road. This makes maintenance work much easier.

The route for Alternative 2 has an additional 111 m pumping head requirement to convey the water to Comrie Dam. A booster pump station will be required to comply with the standards of a pump station; i.e. it may not exceed 40 bar of pressure. Only 50.8% (8 473 m) of the total pipe length (16 694 m) is next to an existing gravel road.

After comparing and evaluating the alternatives it was decided that Alternative 1 would be the preferred route for the new pipeline infrastructure. Below are a few factors that determined the outcome of this choice:

- An additional 13.1 km of pipeline is next to an existing gravel road. This is convenient for access to construction and maintenance.
- The pumping head required for Alternative 1 is 111 m less, to convey the water from Smithfield Dam to Comrie Dam, than that of Alternative 2. A lot of savings will occur from an energy perspective.
- Smaller pump stations for Alternative 1 are required due to less static head.

B.2.3 PRELIMINARY NETWORK SYSTEM

Before any calculations were done, a preliminary setup was proposed. **Figure B.2.7** is a schematic showing the components of the two pipeline routes. As shown in the schematic representation of the system, raw water is conveyed from Smithfield Dam to Comrie Dam and then to the required infrastructure to distribute the water. The scheme's main pump station draws water directly from Smithfield Dam pumping it to a reservoir. The reservoir is on the suction side of the booster pump station where water is drawn from. Water is then pumped to a break pressure tank from which water gravitates to Comrie Dam. A water treatment plant (WTP) is located downstream of Comrie Dam. Raw water is than abstracted from Comrie Dam, treated in the WTP and pumped to a reservoir from where the water will be distributed to the surrounding communities.

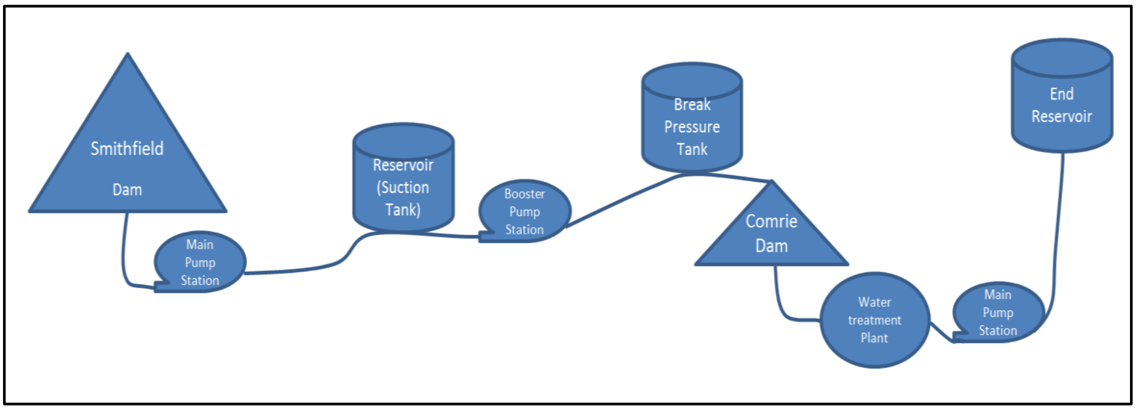

Figure B.2.7: Schematic layout of Smithfield-Comrie Dam supply option - Alternative 1

B.3 SELECTION OF PIPE DIAMETER

The requirements to obtain the optimal diameter for the pipeline and the Life Cycle Cost analysis will be discussed in the following section. Detailed analyses were done to determine the capital, energy, operational and maintenance cost. Various pipe diameters were considered. The diameter that provided the lowest cost over the project life cycle was chosen to be the optimal diameter. The pipeline was divided into three sections namely the main pump station section, booster pump station section and the gravity section.

B.3.1 LIFE CYCLE COST (LCC) ANALYSIS

The pumping head required for the system was obtained for various pipe diameters through hydrological calculations. It was found that a booster pump station will be required since it is good practise for a pump station to not exceed a maximum system pressure rating of 40 bar. To convey the same volume of water through a smaller pipe means that the velocity of the water in the system will increase. Good practise favour a cut-off velocity of 2.5m/s in a system. As the velocity of the water in the system increases the losses of the system also increase since, the losses are a function of the velocity. ***The main pump station section's data of Option 1 Alternative 1 will be used to illustrate how the optimal diameter was determined for both options and there alternatives.*** The velocity for the corresponding pipe diameter is presented in **Table B.3.1**. The flow that should be transferred is 2.8 Mℓ/day with 20hours of pumping daily.

Table B.3.1: Velocities for different pipe diameters from the main pump station

Nominal diameter of the pipeline (mm)	Velocity of the system (m/s)
250	0.84
300	0.56
400	0.34
500	0.21
600	0.13

From **Table B.3.1** it is evident that all the chosen diameters comply with the velocity limitation of 2.5 m/s. The Life Cycle Cost (LCC) analysis on steel pipes was thus conducted to determine the optimal pipe diameter. The flow that should be transferred is 2.8 Mℓ/day with 20 hours of pumping daily. It is thus more feasible to pump longer hours at a low flow rate than more flow at fewer hours. After the analysis, the head was finalised for all the pipe diameters. Joukowski's formula was used to make the design compliant for surge (water hammer). The pipeline will experience a significant variation in pressure when the pumps are suddenly switched off. No further calculations were done to determine the effect of surge since it is a specialist's field of expertise. The required power for the pump station was then determined, as discussed later in this section. The process was repeated for the booster pump station. **Figure B.3.2** represents the hydraulic grade lines along the pipe section.

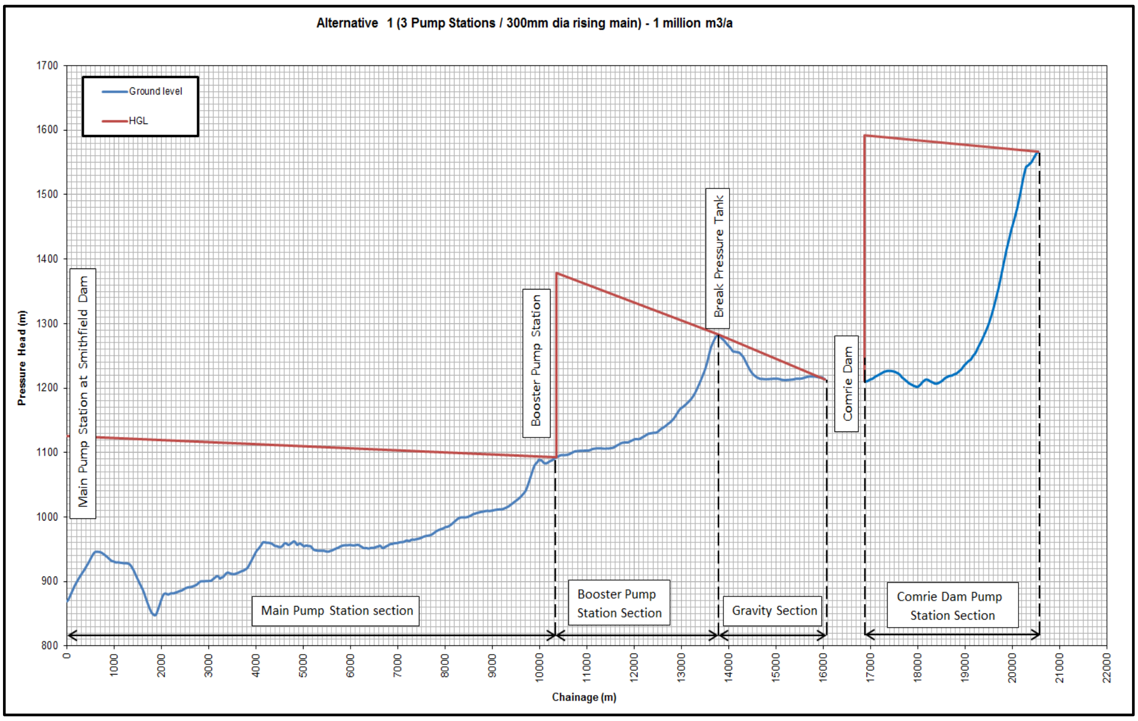

Figure B.3.2: Hydraulic grade lines for the pipeline system

The required pumping head and requisite power, for the main pump station section, are presented in **Table B.3.3** for the various pipe diameters.

Table B.3.3: Required head, flow and power for the various pipe diameters

Nominal diameter (mm)	Required head (m)	Flow (m^3/s)	Power required (kWh)
250	291.0	0.84	142
300	256.7	0.56	128
400	239.2	0.34	123
500	231.8	0.21	121
600	228.3	0.13	121

The required power is calculated by multiplying the required head with the flow rate, gravitational force and the density of water. The product is then divided by the efficiency. The rates for the energy cost were obtained from Eskom's Megaflex- local authority rates. The tariffs per kWh were then multiplied by the installed power of the pump to determine the energy cost of the system. These values were then used to obtain a URV for the different options from which comparisons were done.

The capital cost of the pipeline contains the total cost of the infrastructure. This cost includes the construction of the pipeline. The total LCC was calculated by adding the energy, capital and the maintenance cost of all three pipe sections.

Table B.3.4 provides the simplistic form of the corresponding cost regarding the main pump section.

Table B.3.4: Life Cycle Cost for main pump station section

Nominal diameter (mm)	Energy Cost (R)	Capital Cost (R)	Total Cost (R)
250	23 324 135	36 542 090	59 866 225
300	22 549 580	35 920 531	58 470 111
400	22 246 194	39 657 135	61 903 329
500	22 164 336	45 415 258	67 579 594
600	22 141 248	53 059 175	75 200 423

Figure B.3.5 shows a visual comparison of the pipe diameters in terms of cost. The graph illustrates the energy, capital and the total cost of the pipe section. As previously discussed, the energy cost decrease as the pipe diameter increases. It is also evident that the initial (capital) cost of the larger pipe diameter is higher since the pipe contains more steel. The optimum diameter is where the total cost has a low point. A 300mm diameter pipe will be required for the main pump station section in Alternative 1. The total cost comprises of the following:

Capital cost = R 35 920 531
Energy cost = R 22 549 580
Total cost = R 58 470 111

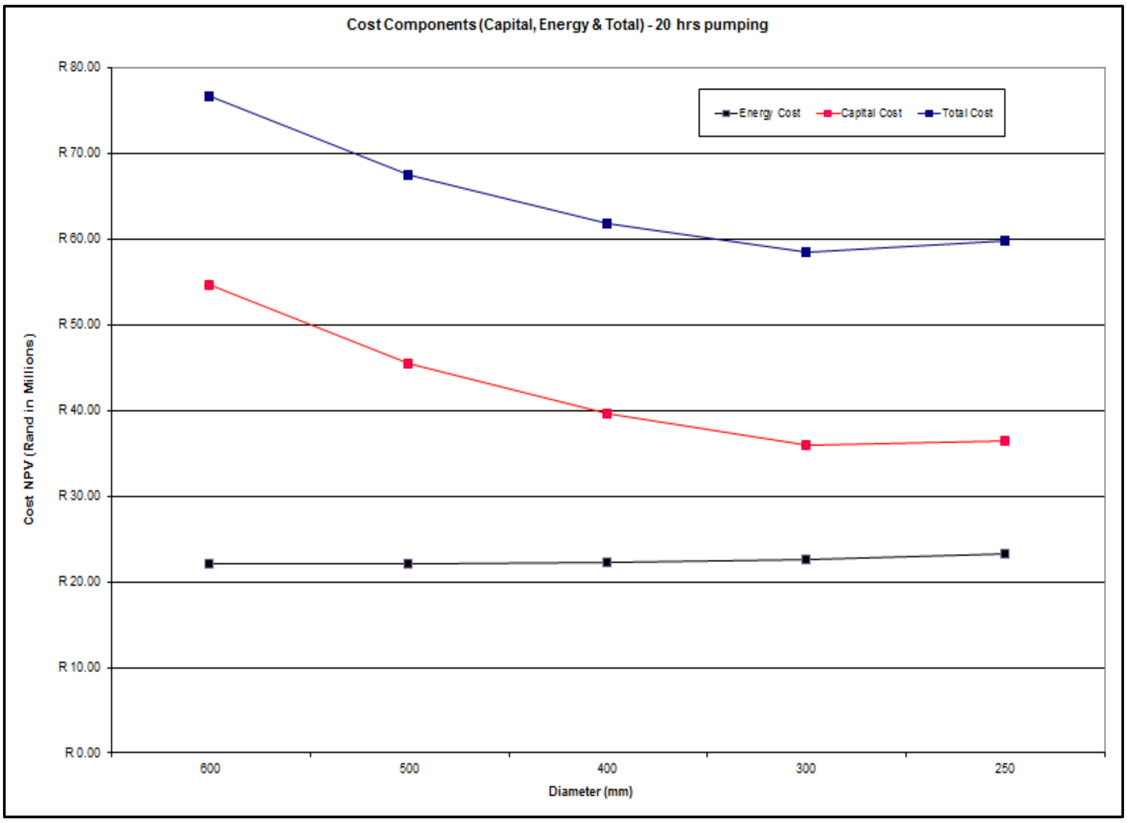

Figure B.3.5: Life Cycle Cost of the main pump station section

B.3.2 VALVE LAYOUT

Scour valves are to be positioned at low points on the pipe section to drain selected parts of the system when maintenance is required. Non-return valves have to be implemented upstream of the pumps to ensure that no water flows back into the pump when the pump is switched off. Isolating valves have to be installed on both sides of the pumps when maintenance is done. A control valve with isolating valves should be installed on both sides of a reservoir to ensure the water stop when the reservoir reaches full supply level (FSL). It is essential to have a bypass around every isolating valve which must be opened before closing or opening the isolating valve.

B.4 CONCLUSION

The evaluation of the alternatives provides the conclusion that Alternative 1 of the Smithfield-Comrie Dam supply option should be used. Alternative 1 does not have the lowest URV yet it has more advantages than Alternative 2. **Table B.4.1** and **Table B.4.2** provide the URV values obtained for different inflation rates. It is seen that Option 1, Alternative 1 has URV value of **R18.80/m³** for an inflation rate of 8% over the life cycle.

Table B.4.1: URVs obtained for Option 1

	URV (R/m³)	
Option 1	**Alternative 1**	**Alternative 2**
NPV 6%	18.10	17.90
NPV 8%	18.80	18.04
NPV 10%	19.70	18.28

Table B.4.2: URVs obtained for Option 4

	URV (R/m³)	
Option 4	**Alternative 1**	**Alternative 2**
NPV 6%	54.43	51.48
NPV 8%	57.29	53.71
NPV 10%	60.68	56.46

Appendix C

Smithfield-Comrie Dam RWSS

Option 2

C.1 GUIDELINES FOR ROUTE SELECTION

C.1.1 EXISTING SERVICES

Existing services such as railway lines, roads, power lines etc. should be considered when selecting a pipeline route. It is desirable to construct a pipeline near existing infrastructure to reduce construction costs and to allow for easier maintenance. The route selection was done in a way where most of the pipeline is adjacent to an existing road. From **Figure C.2.1**, it is evident that no major sharp bends occur along the routes. Minor sharp bends occur where the road was followed at mountainous sections.

C.2 ROUTE LAYOUT ALTERNATIVES

Two pipeline routes were selected to transfer bulk water from the Proposed Smithfield Dam to two desired destinations. These destinations are reservoirs in Kwelaba-Ntwana and Sizanenjane communities. These reservoirs are situated on the highest elevations that can feed the rest of the communities within the local supply area. **Figure C.2.1** illustrates the layout of Alternative 1. Alternative 2 of this option is illustrated in **Figure C.2.2**. Considering that the terrain is very mountainous, existing roads were followed when selecting the pipeline routes.

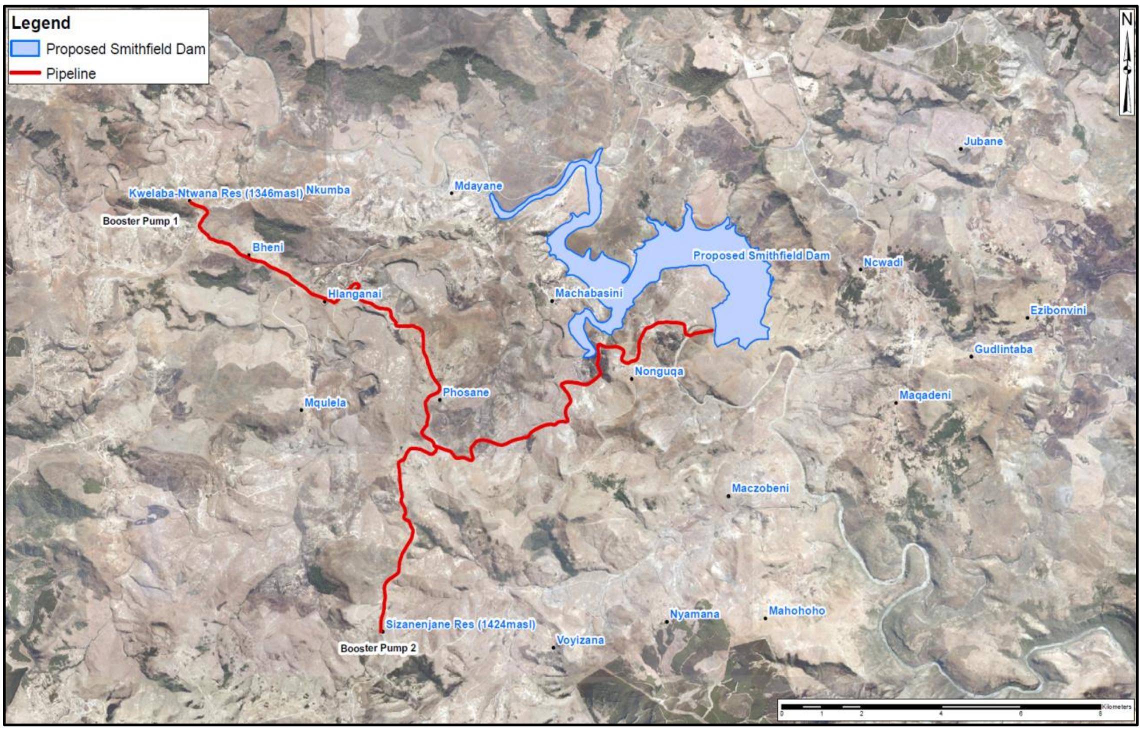

Figure C.2.1: Image for Alternative 1

Longitudinal profiles for Alternative 1's pipeline system are shown in **Figure C.2**.3 and **Figure C.2.4**. The longitudinal profiles for Alternative 2's pipeline system are illustrated in **Figure C.2.5** and **Figure C.2.6**.

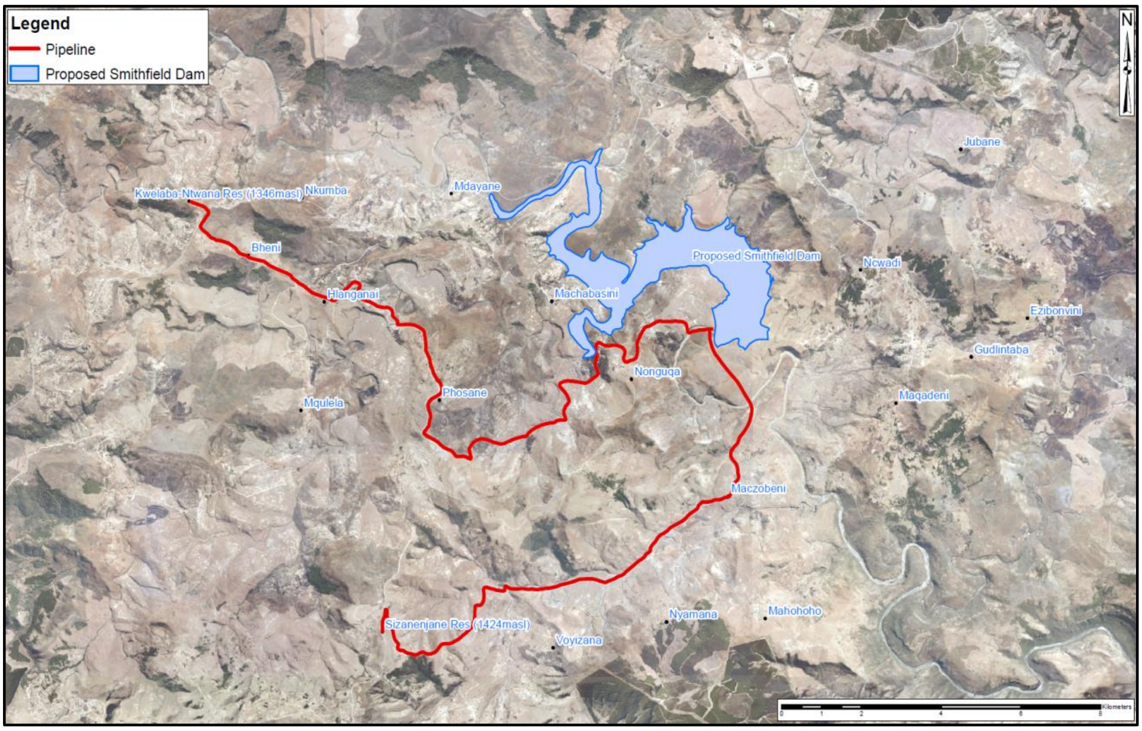

Figure C.2.2: Image for Alternative 2

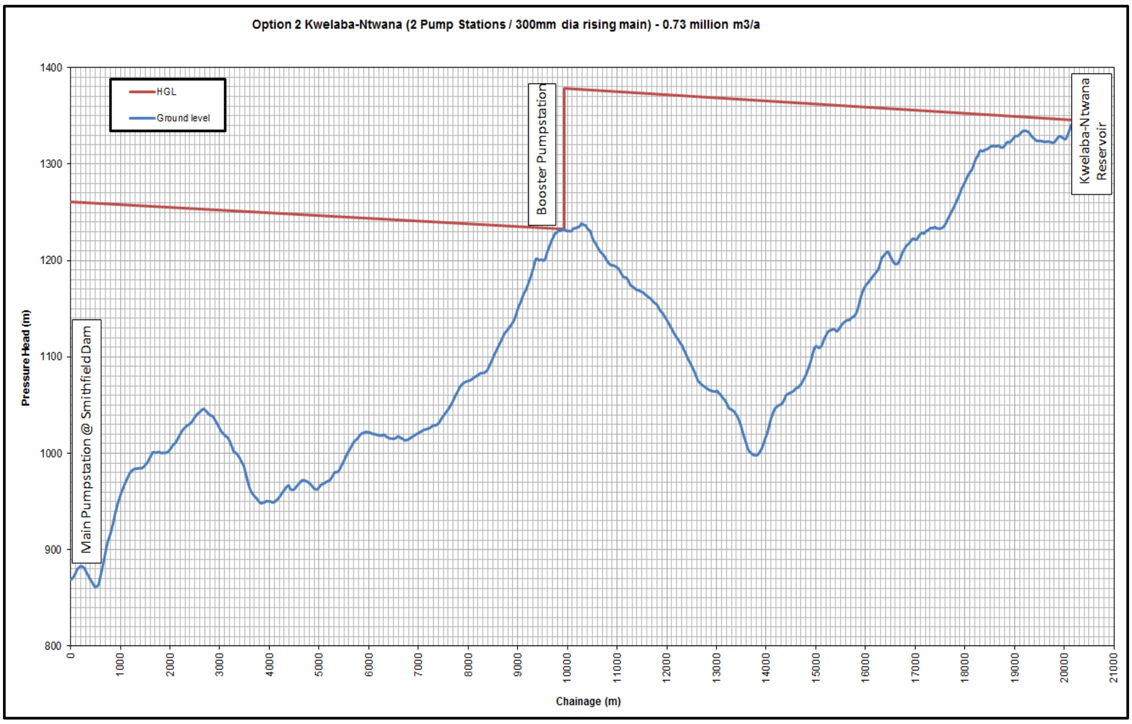

Figure C.2.3: Elevation profile of Alternative 1's Kwelaba-Ntwana pipeline section

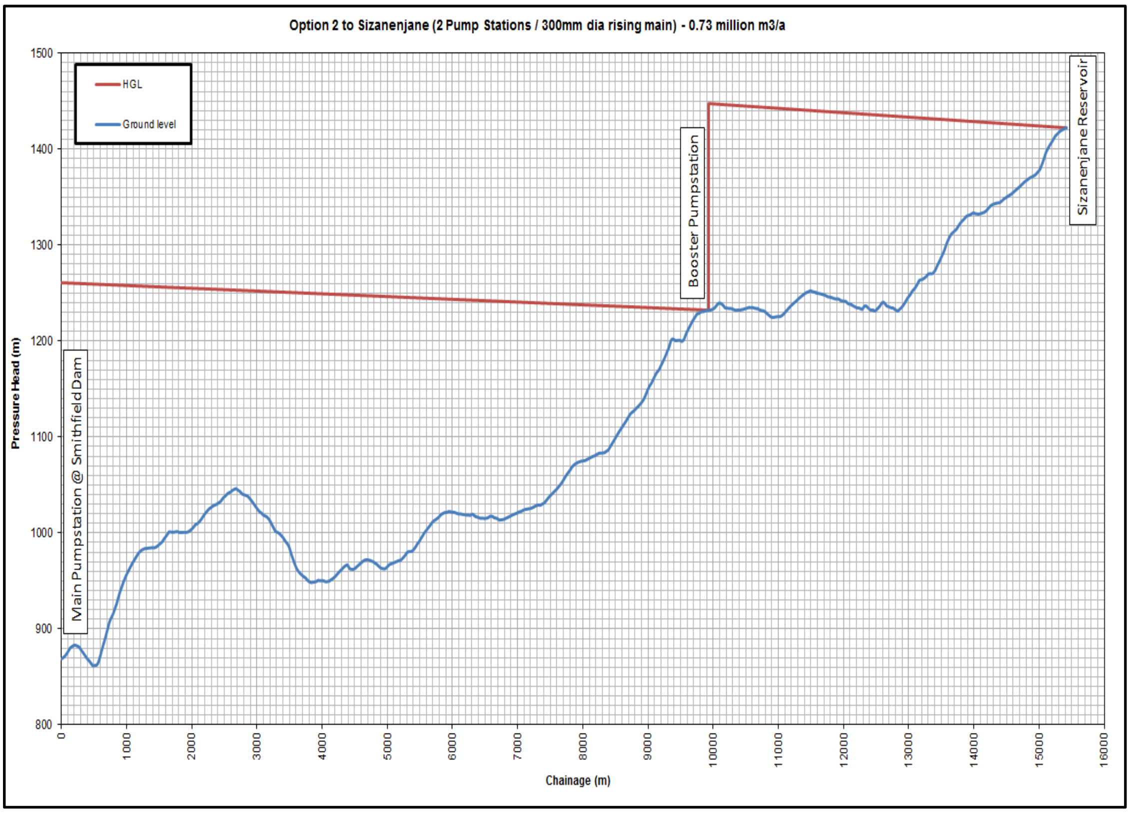

Figure C.2.4: Elevation profile of Alternative 1's Sizanenjane pipeline section

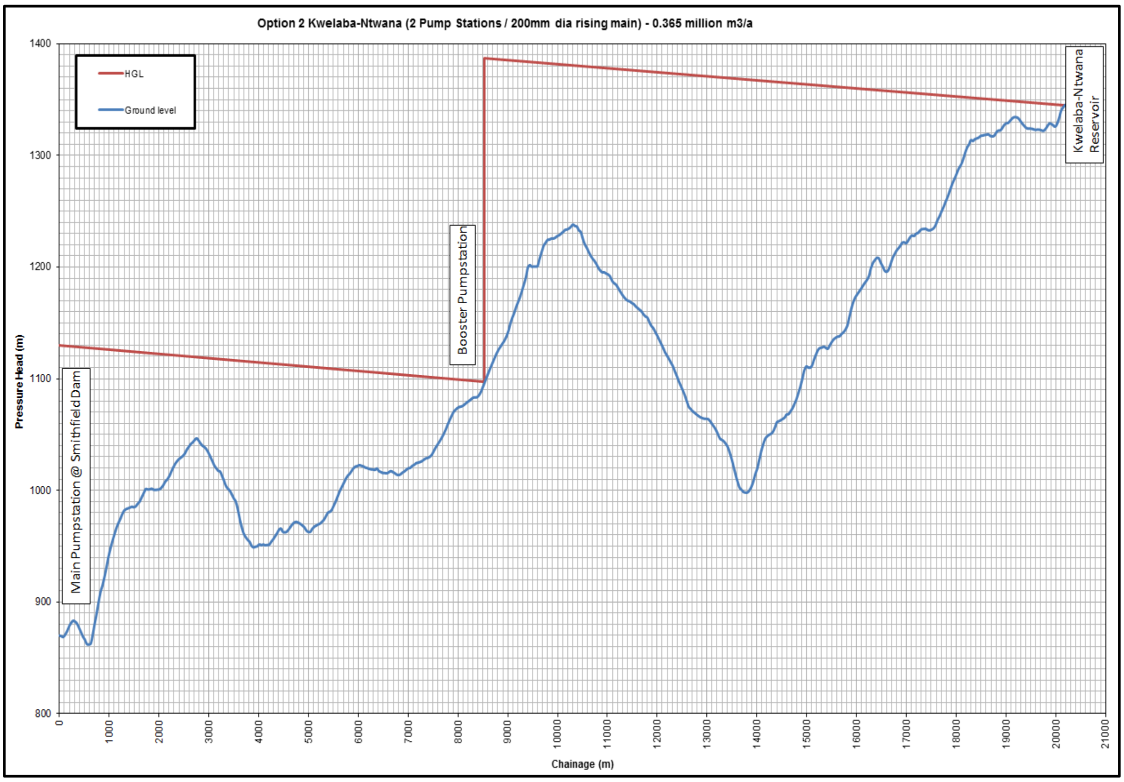

Figure C.2.5: Elevation profile of Alternative 2's Kwelaba-Ntwana pipeline section

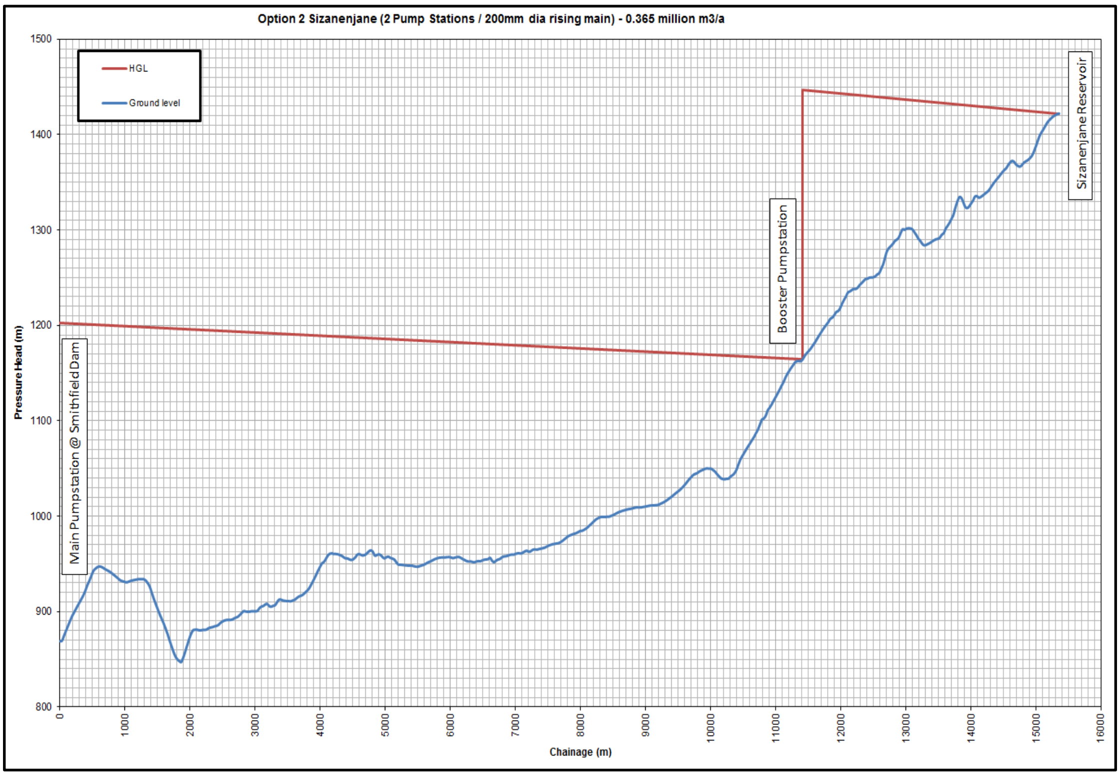

Figure C.2.6: Elevation profile of Alternative 2's Sizanenjane pipeline section

General information is available in **Table C.2.7**, showing the differences between Alternative 1 and Alternative 2.

Table C.2.7: Additional information on Alternatives

Description	Route Alternative 1	Route Alternative 2
Route length (m)	25 982	35 541
Highest elevation (m)	1 422	1 422
Lowest elevation (m)	869	869
No. of road crossings	15	23
No. of river crossings	1	2
Average slopes	6.3%, -5.7%	6.2%, -6.5%

The following assumptions regarding existing services were made:

- The study area is situated in a rural area where there is little development in terms of infrastructure. There is little to no telephone (Telkom) lines installed within the area. Electrical cables have an overhead installation. No sewage disposal pipes are available.
- Road crossings only occur at culverts and bridges.
- It is assumed that septic tanks and VIP (Ventilated Improved Pit) latrines are used in the area.

C.2.1 PIPELINE EVALUATION

The evaluation of the two pipeline routes is discussed in this section. Table C.2.8 reflects the advantages and disadvantages of the proposed alternatives.

Table C.2.8: Advantages and Disadvantages of Option 2

Alternative 1	Alternative 2
Advantages	
• 87.6% of the total proposed pipe length is located next to an existing gravel road, making construction and maintenance simpler • Booster pump station is near Bethlehem local community. • Shorter system of the two alternatives. • Lower capital cost due to shorter section.	• 88.79% of the total proposed pipe length is located next to an existing gravel road, making construction and maintenance simpler. • A booster pump station is located close to a community.
Disadvantages	
• The uMkhomazi River has to be crossed. • Booster pump required since the standard for pump station is <=40Bar pressure. • The system comprise of 15 road crossings.	• Booster pump required since the standard for pump station is <=40 bar pressure. • The uMkhomazi River has to be crossed. • The system comprise of 23 road crossings.

Alternative 1: The system has a length of 25 982 m. A booster pump station will be implemented to comply with the standards of a pump station; it may not exceed 40 bar of pressure. The pipeline is mostly located close to an existing gravel road. This is advantageous for construction and maintenance purposes.

Alternative 2: The system has a length of 35 541 m. A booster pump station will be implemented to comply with the standards of a pump station; it may not exceed 40 bar of pressure. Two river crossings have to be made for this alternative, raising the URV considerably.

From the information above it is evident that Alternative 1 provides more advantages and is thus the better solution between the alternatives.

C.2.2 PRELIMINARY NETWORK SYSTEM

Before any calculations were done, a preliminary setup was proposed for Alternative 1. Figure C.2.9 is a schematic showing the components of the pipeline system. One water treatment plant (WTP) is gravity fed with raw water from the Smithfield Dam. Potable water is conveyed into a clear water tank and distributed by the main pump station to a booster pump station suction tank. Water is then pumped at the two booster pump stations to its respective locations.

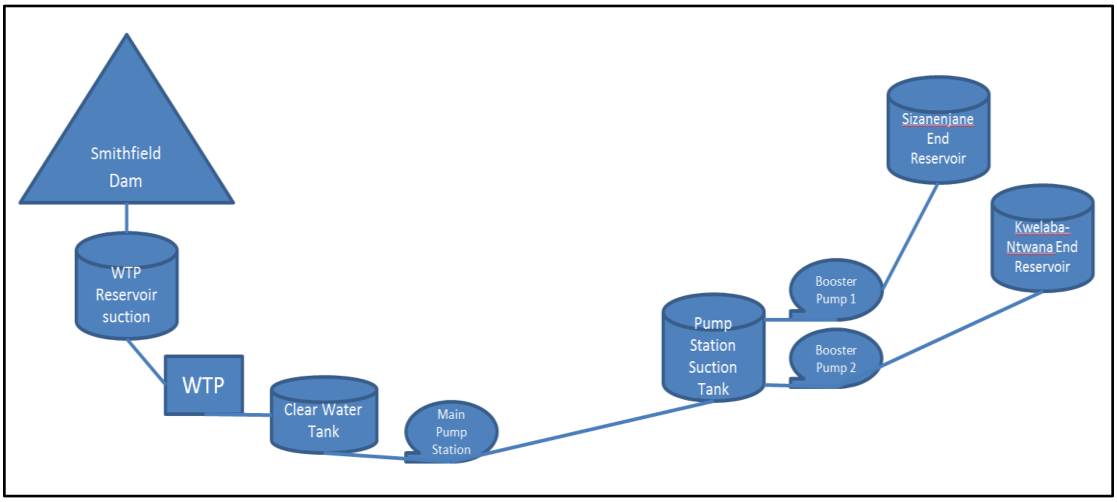

Figure C.2.9: Schematic layout of Sizanenjane and Kwelaba-Ntwana supply

C.3 CONCLUSION

Table C.3.1 provides the URVs obtained for Option 2; it was calculated for three different inflation rates. Option 2 has a URV value of **R22.50/m³** for an inflation rate of 8% over the life cycle. This option will not be discussed any further.

Table C.3.1: URVs obtained for Option 2

	URV (R/m³)	
Options 2	**Alternative 1**	**Alternative 2**
NPV 6%	20.78	21.56
NPV 8%	22.50	23.78
NPV 10%	24.42	26.17

Appendix D

Smithfield-Comrie Dam RWSS

Option 3

D.1 GUIDELINES FOR ROUTE SELECTION

D.1.1 EXISTING SERVICES

Existing services such as railway lines, roads, power lines etc. should be considered when selecting a pipeline route. It is desirable to construct a pipeline near existing infrastructure to reduce construction costs and to allow for easier maintenance. The route selection was done in a way where most of the pipeline is adjacent to an existing road. Sharp bends were avoided to reduce energy losses along the system. From **Figure D.2.1**, it is evident that no major sharp bends occur along the two routes. Minor sharp bends occur where the road was followed at mountainous sections.

D.2 ROUTE LAYOUT ALTERNATIVES

Two pipeline routes were selected to transfer bulk water from the Proposed Smithfield Dam to two desired destinations. These destinations are reservoirs in Bethlehem and Ncwadi communities. Bethlehem and Ncwadi are situated on the highest elevations that can feed the communities within the supply area. The communities that will benefit from the water supply scheme are pinned on the image in **Figure D.2.1**. Route 1 follows in the South Western direction to Bethlehem Reservoir and Route 2follows in the Eastern direction from the abstraction point to Ncwadi Reservoir. Considering that the terrain is very mountainous, existing roads were followed as far as possible when selecting the pipeline routes.

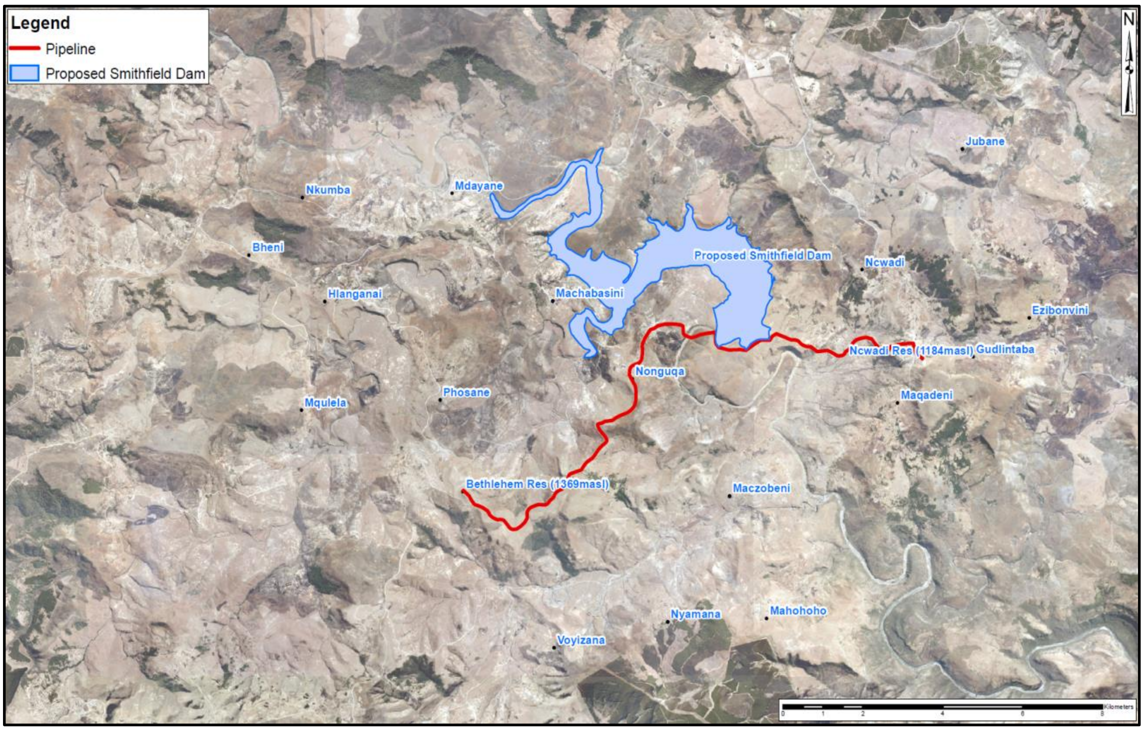

Figure D.2.1: Image for Bethlehem-Ncwadi supply option

Longitudinal profiles for the South Western pipeline and the Eastern pipeline are shown in **Figure D.2.2** and **Figure D.2.3**, respectively.

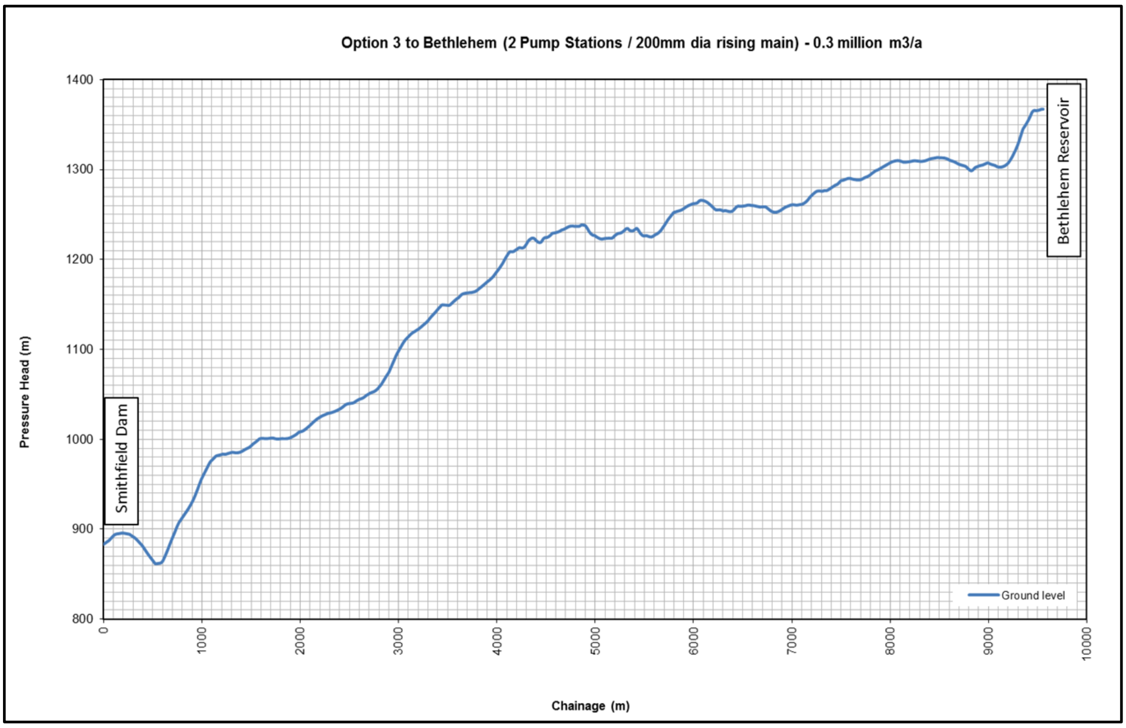

Figure D.2.2: Elevation profile of the South Western pipeline

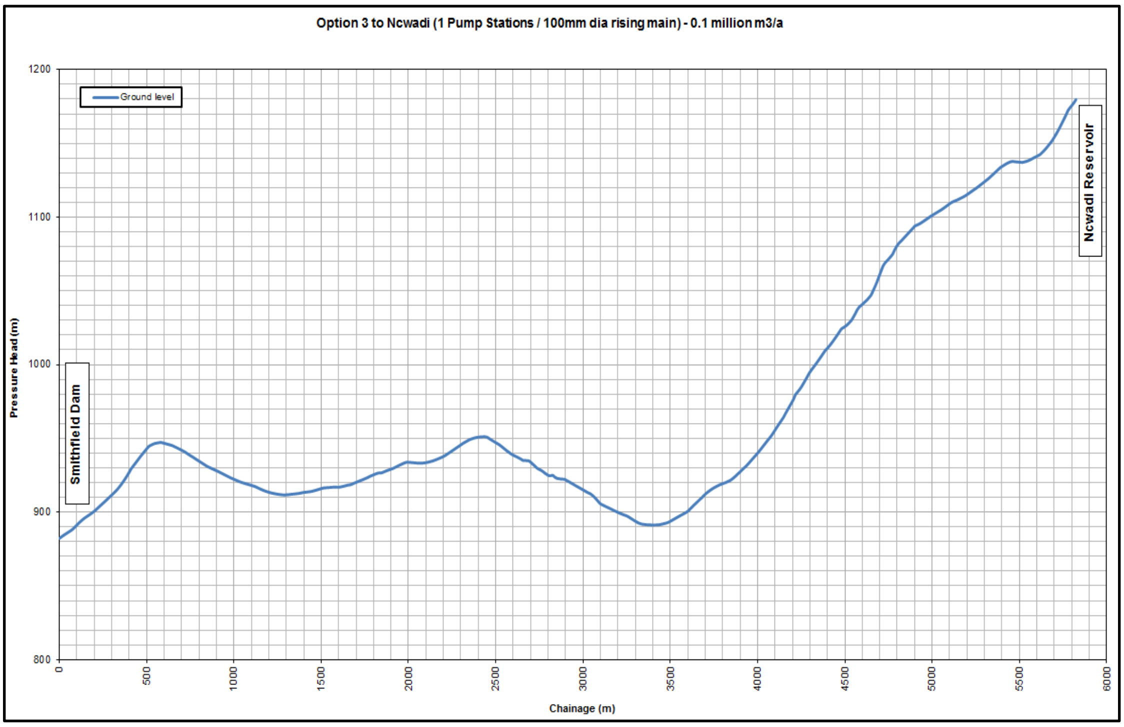

Figure D.2.3: Elevation profile of the Eastern pipeline

General properties of the two pipeline routes are available in **Table D.2.4.**

Table D.2.4: Properties of the two pipeline routes.

Description	South Western Route	Eastern Route
Route length (m)	9 556	5 824
Highest elevation (m)	1 367	1 180
Lowest elevation (m)	869	869
No. of road crossings	0	3
Average slopes	8%, -5.1%	9.9%, -5.5%

The following assumptions regarding existing services were made:

- The study area is situated in a rural area where there is little development in terms of infrastructure. There is little to no telephone (Telkom) lines installed within the area. Electrical cables have an overhead installation. No sewage disposal pipes are available.
- Road crossings only occur at culverts and bridges.
- It is assumed that septic tanks and VIP (Ventilated Improved Pit) latrines are used in the area.

D.2.1 PIPELINE EVALUATION

The evaluation of the two pipeline routes is discussed in this section. **Table D.2.5** reflects the advantages and disadvantages of the South Western and Eastern Pipelines.

Table D.2.5: Advantages and Disadvantages of Bethlehem-Ncwadi supply option

Option 3
Advantages
• 70.9% of the total proposed pipe length is located next to an existing gravel road, making construction and maintenance simpler. • Booster pump station is located close to a community. • No existing services are problematic.
Disadvantages
• The uMkhomazi River has to be crossed. • Booster pump is required because the pumping head exceeds 40 bar. • Required transfer volume is very low for this pipeline. • Topography is steep; pipe delivery will be a challenge.

South Western Pipeline: The South Western pipeline has a length of 9 556 m. A booster pump station will be implemented to comply with the AECOM standards of a pump station; it may not exceed 40bar of pressure. An advantage of this pipe section is that no existing services will be crossed. The pipeline route is located close to an existing gravel road. This is advantageous for construction and maintenance.

Eastern Pipeline: The Eastern pipeline section has a length of 5 824 m. No booster pump station will be required for this section of the pipeline. The topography is steep which is problematic for construction, maintenance and pipe delivery. The water requirements for the pipe section are very little.

D.2.2 PRELIMINARY NETWORK SYSTEM

Before any calculations were done, a preliminary setup was proposed. **Figure D.2**.6 is a schematic showing the components of the two pipeline routes. One water treatment plant (WTP) is gravity fed with raw water from the Smithfield Dam. Potable water is conveyed into a clear water tank and distributed by two pumps to the South Western and Eastern Pipelines.

The South Western Pipeline consists of a pump station suction tank, a booster pump station and an end reservoir at Bethlehem community. The Eastern Pipeline only consists of the end reservoir at Ncwadi community.

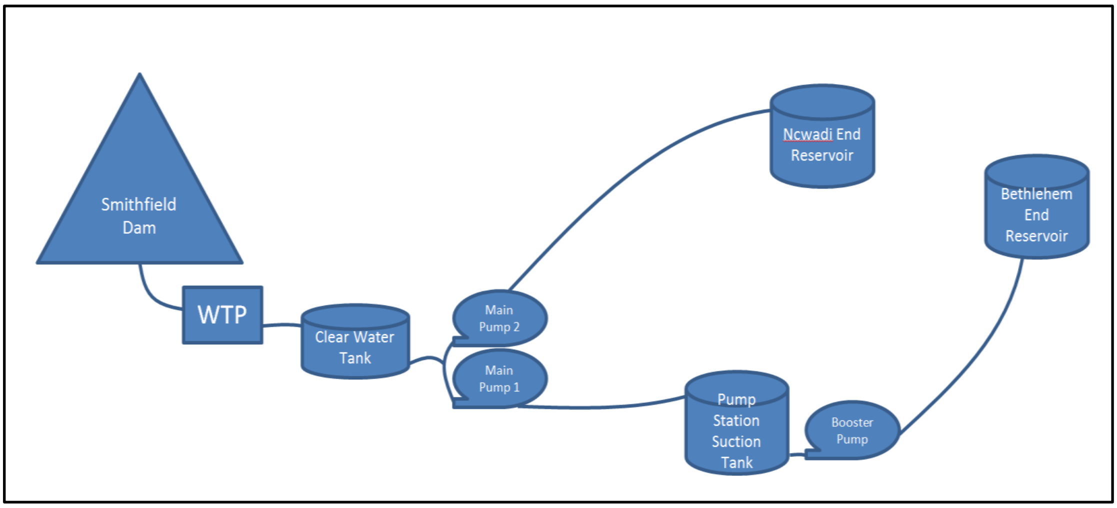

Figure D.2.6: Schematic layout of Bethlehem-Ncwadi supply option

D.3 CONCLUSION

As seen from **Table D.3.1** Bethlehem-Ncwadi supply option has a high URV value of **R 68.64/m³** for an inflation rate of 8% over the life cycle, it was not considered as a viable option. The option will not be discussed any further.

Table D.3.1: URVs obtained for Option 3

	URV (R/m³)
Option 3	**Alternative 1**
NPV 6%	67.80
NPV 8%	68.64
NPV 10%	70.54

Appendix E

Smithfield-Comrie Dam RWSS

Option 5

E.1 GUIDELINES FOR ROUTE SELECTION

E.1.1 EXISTING SERVICES

Existing services such as railway lines, roads, power lines etc. should be considered when selecting a pipeline route. It is desirable to construct a pipeline near existing infrastructure to reduce construction costs and to allow for easier maintenance. The route selection was done in a way where most of the pipeline is adjacent to an existing road. From **Figure E.2.1**, it is evident that a sharp bends occur along the route as the road was followed for this mountainous section.

E.2 ROUTE LAYOUT ALTERNATIVES

The pipeline route was selected to transfer bulk water from the Comrie Dam to the desired destination. The destination is Comrie reservoir. Comrie reservoir is situated on a high point that has the ability to gravitate water to the communities within the supply area. Considering that the terrain is very mountainous, existing roads were followed as far as possible when selecting the pipeline route.

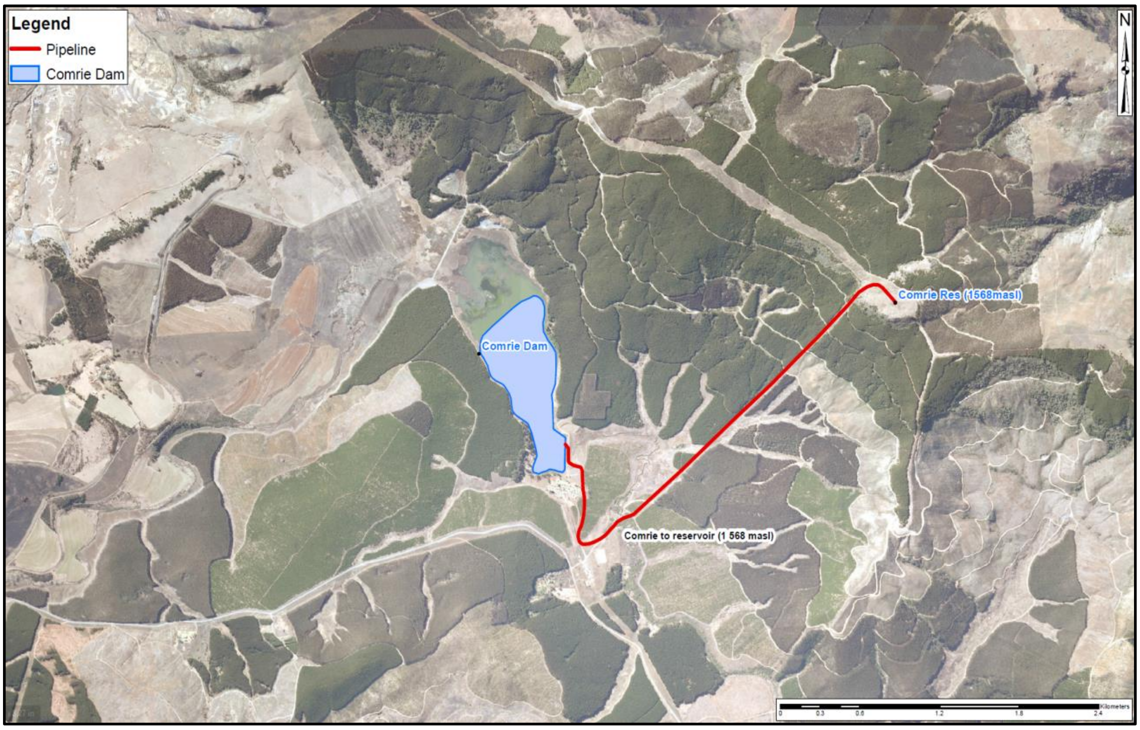

Figure E.2.1: Image for Comrie Dam supply option

A longitudinal profile for the pipeline route is shown in **Figure E.2.2**.

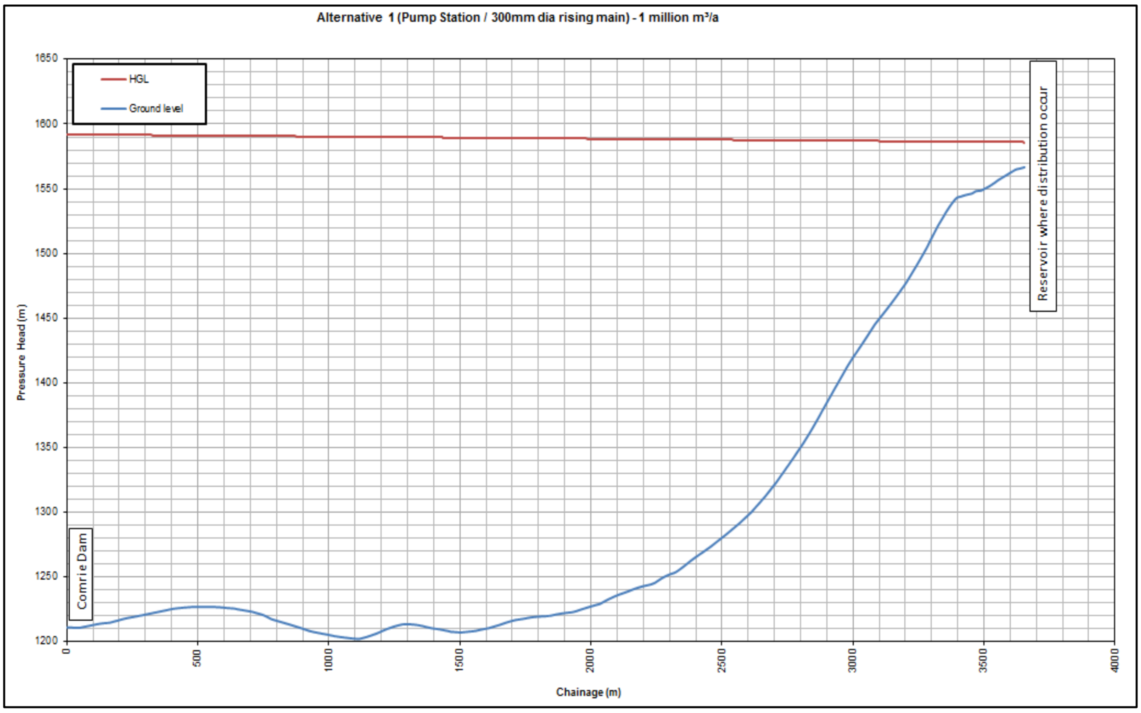

Figure E.2.2: Elevation profile of Option 5

General properties of the two pipeline routes are available in **Table E.2.3.**

Table E.2.3: Properties of Option 5 pipeline route.

Description	South Western Route
Route length (m)	3655
Highest elevation (m)	1568
Lowest elevation (m)	1212
No. of road crossings	0
Average slopes	13.4%, -3.8%

The following assumptions regarding existing services were made:

- The study area is situated in a rural area where there is little development in terms of infrastructure. There is little to no telephone (Telkom) lines installed within the area. Electrical cables have an overhead installation. No sewage disposal pipes are available.
- Road crossings only occur at culverts and bridges.

E.2.1 PIPELINE EVALUATION

The evaluation of the pipeline route is discussed in this section. **Table E.2.4** reflects the advantages and disadvantages of supply Option 5.

Table E.2.4: Advantages and disadvantages of supply Option 5

Option 5
Advantages
• No river crossing. • Only one main pump station required. No booster pump station required. • 32.4% (1 183m) of the pipeline is next to an existing gravel road. • More water will be available after raising the dam; therefore Smithfield Dam will not be required to augment the Bulwer-Donnybrook WSS.
Disadvantages
• Very steep topography. • High initial/construction costs are involved if Comrie Dam is raised.

E.3 CONCLUSION

As seen from **Table E.3.1** Bethlehem-Ncwadi supply option has a high URV value of **R 17.76/m³** for an inflation rate of 8% over the life cycle, it was not considered as a viable option. The option will not be discussed any further.

Table E.3.1: URVs obtained for Option 3

	URV (R/m³)
Option 3	**Alternative 1**
NPV 6%	15.72
NPV 8%	17.76
NPV 10%	20.02

Appendix F

Costing of proposed Smithfield-Comrie Dam RWSS

Table F.1: Summary of Capital Cost (Option 1, Alternative 1)

Pipeline					
Item nr	**Description**	**Diameter (mm)**	**Length (m)**	**Installed pipeline cost per meter (R/m)**	**Cost**
1	Pipeline (main pump station section)	300	10 360	3 467	R 35 918 120.00
2	Pipeline (booster pump station section)	200	3 422	2 870	R 9 821 140.00
3	Pipeline (gravity section)	200	2 260	2 870	R 6 486 200.00
4	Pipeline (Comrie Dam to reservoir)	300	3 655	3 467	R 12 672 736.00
5	E.O. Valves and valve chambers				R 3 000 000.00
6	E.O. River and donga crossings				R 3 350 000.00
				SUB-TOTAL A	***R 71 248 196.00***
Reservoir					
Item nr	**Description**	**Amount**	**Volume (Ml)**	**Construction cost (R)**	**Cost**
7	Reservoir at suction side of booster pump station	1	3	12 377 528	R 12 377 528.00
8	Break pressure tank before gravity section	1	0.5	902 706	R 902 706.00
9	Reservoir at Comrie Dam end point	1	3	12 377 528	12 377 528
				SUB-TOTAL B	***R 25 657 762.00***
Pump stations					
Item nr	**Description**	**Installed KW**	**Cost per KW**		**Cost**
10	Main pump station	128.03		44 231	R 5 662 894.93
11	Booster pump station	128.04		44 231	R 5 663 337.24
12	Comrie to reservoir	198.72		36 882	R 7 329 191.04
				SUB-TOTAL C	***R 18 655 423.21***
Water Treatment Works					
Item nr	**Description**	**Category**	**Category Capacity (Ml/d)**		**Cost**
13	Conventional WTW (Full treatment)	Small		3	R 3 750 000.00
				SUB-TOTAL D	***R 3 750 000.00***

HGDM contribution to construct Smithfield Dam					
Item nr	Description		Construction cost (R)		Cost
14	Contribution to construct Smithfield Dam		9 171 619		R 9 171 619.00
				SUB-TOTAL E	***R 9 171 619.00***
15	TOTAL OF SUB-TOTALS				R 128 483 000.21
Item nr	**Description**		**Unit**	**Rates**	**Cost**
16	Professional fees	(% of 15)	%	10%	R 12 848 300.02
17	Environmental and social cost	(% of 15)	%	10%	R 12 848 300.02
TOTAL CAPITAL COST					**R 154 179 600.25**

Table F.2: Summary of Maintenance Cost (Option 1, Alternative 1)

Maintenance Cost per annum				
Item nr	Description	Total capital cost	O&M cost (%)	Cost
18	Yearly service and admin charges	R 1 059 847.00	-	R 1 059 847.00
19	Yearly network, access and demand charges	R 125 476.00	-	R 125 476.00
20	Pipelines	R 58 575 460.00	0.5	R 292 877.30
21	Reservoirs	R 13 280 234.00	0.5	R 66 401.17
22	Water Treatment Works	R 3 750 000.00	5	R 187 500.00
23	Pump stations (Civil)	R 3 397 902.74	0.25	R 8 494.76
Annual maintenance and labour cost				**R 1 740 596.23**
24	Pump stations (E&M)	R 7 928 439.73	4	R 317 137.59
25	Yearly energy cost	R 734 867.00	-	R 734 867.00
Annual operational cost				**R 1 052 004.59**

Table F.3: Summary of Capital Cost (Option 1, Alternative 2)

Item nr	Description	Diameter (mm)	Length (m)	Installed pipeline cost per meter (R/m)	Cost
Pipeline					
1	Pipeline (main pump station section)	300	9 599	3 467	R 33 281 967.00
2	Pipeline (booster pump station section)	200	919	2 870	R 2 637 817.00
3	Pipeline (gravity section)	200	2 528	2 967	R 7 501 610.00
4	Pipeline (Comrie Dam to reservoir)	300	3 655	3 467	R 12 672 736.00
5	E.O. Valves and valve chambers				R 3 000 000.00
6	E.O. River and donga crossings				R 3 350 000.00
				SUB-TOTAL A	***R 62 444 130.00***
Reservoir					
Item nr	**Description**	**Amount**	**Volume (Ml)**	**Construction cost (R)**	**Cost**
7	Reservoir at suction side of booster pump station	1	3	12 377 528	R 12 377 528.00
8	Break pressure tank before gravity section	1	0.5	902 706	R 902 706.00
9	Reservoir at Comrie Dam end point	1	3	12 377 528	12 377 528
				SUB-TOTAL B	***R 25 657 762.00***
Pump stations					
Item nr	**Description**	**Installed KW**	**Cost per KW**		**Cost**
10	Main pump station	199.63	36 798		R 7 345 984.74
11	Booster pump station	101.34	48 332		R 4 897 964.88
12	Comrie to reservoir	198.72	36 882		R 7 329 191.04
				SUB-TOTAL C	***R 19 573 140.66***
Water Treatment Works					
Item nr	**Description**	**Category**	**Category Capacity (Ml/d)**		**Cost**
13	Conventional WTW (Full treatment)	Small	3		R 3 750 000.00
				SUB-TOTAL D	***R 3 750 000.00***

HGDM contribution to construct Smithfield Dam					
Item nr	**Description**		**Construction cost (R)**		**Cost**
14	Contribution to construct Smithfield Dam			9 171 619	R 9 171 619.00
				SUB-TOTAL E	***R 9 171 619.00***
15	TOTAL OF SUB-TOTALS				R 120 596 651.66
Item nr	**Description**		**Unit**	**Rates**	**Cost**
16	Professional fees	(% of 15)	%	10%	R 12 059 665.17
17	Environmental and social cost	(% of 15)	%	10%	R 12 059 665.17
TOTAL CAPITAL COST					**R 144 715 981.99**

Table F.4: Summary of Maintenance Cost (Option 1, Alternative 2)

Maintenance Cost per annum				
Item nr	**Description**	**Total capital cost**	**O&M cost (%)**	**Cost**
18	Yearly service and admin charges	R 1 059 847.00	-	R 1 059 847.00
19	Yearly network, access and demand charges	R 244 851.00	-	R 244 851.00
20	Pipelines	R 62 444 130.00	0.5	R 312 220.65
21	Reservoirs	R 25 657 762.00	0.5	R 128 289.00
22	Water Treatment Works	R 3 750 000.00	5	R 187 500.00
23	Pump stations (Civil)	R 5 871 942.20	0.25	R 14 680.00
Annual maintenance and labour cost				**R 1 947 387.65**
24	Pump stations (E&M)	R 13 701 198.00	4	R 548 048.00
25	Yearly energy cost	R 1 434 004.00	-	R 1 434 004.00
Annual operational cost				**R 1 982 052.00**

Table F.5: Summary of Capital Cost (Option 2, Alternative 1)

Pipeline					
Item nr	**Description**	**Diameter (mm)**	**Length (m)**	**Installed pipeline cost per meter (R/m)**	**Cost**
1	Pipeline (main pump station section)	300	9 936	3 467	R 34 450 425.00
2	Pipeline (booster pump station section)	200	10 275	2 870	R 29 492 456.00
3	Pipeline (gravity section)	200	5 484	2 870	R 15 740 791.00
4	E.O. Valves and valve chambers				R 3 000 000.00
5	E.O. River and donga crossings				R 3 000 000.00
				SUB-TOTAL A	***R 85 683 672.00***
Reservoir					
Item nr	**Description**	**Amount**	**Volume (Ml)**	**Construction cost (R)**	**Cost**
6	Reservoir at Smithfield Dam	1	2	8 661 344	R 8 661 344.00
7	Reservoir at Booster pump station	1	2	8 661 344	R 8 661 344.00
8	Reservoir at Kwelaba-Ntwana	1	2	8 661 344	R 8 661 344.00
9	Reservoir at Sizanenjane	1	2	8 661 344	R 8 661 344.00
				SUB-TOTAL B	***R 34 645 376.00***
Pump stations					
Item nr	**Description**	**Installed KW**	**Cost per KW**		**Cost**
10	Main pump station	153.15	40 756		R 6 241 781.40
11	Booster pump station	25.89	86 997		R 2 252 352.33
12	Booster pump station	40.21	74 695		R 3 003 485.95
				SUB-TOTAL C	***R 11 497 620.00***
Water Treatment Works					
Item nr	**Description**	**Category**	**Category Capacity (Ml/d)**		**Cost**
13	Conventional WTW (Full treatment)	Small	3		R 3 750 000.00
				SUB-TOTAL D	***R 3 750 000.00***

HGDM contribution to construct Smithfield Dam					
Item nr	**Description**	**Construction cost (R)**			**Cost**
14	Contribution to construct Smithfield Dam	6 695 282			R 6 695 282.00
				SUB-TOTAL E	***R 6 695 282.00***
15	TOTAL OF SUB-TOTALS				R 142 271 950.00
Item nr	**Description**		**Unit**	**Rates**	**Cost**
16	Professional fees	(% of 15)	%	10%	R 14 227 195.00
17	Environmental and social cost	(% of 15)	%	10%	R 14 227 195.00
TOTAL CAPITAL COST					**R 170 726 340.00**

Table F.6: Summary of Maintenance Cost (Option 2, Alternative 1)

Maintenance Cost per annum				
Item nr	**Description**	**Total capital cost**	**O&M cost (%)**	**Cost**
18	Yearly service and admin charges	R 1 059 847.00	-	R 1 059 847.00
19	Yearly network, access and demand charges	R 107 428.00	-	R 107 428.00
20	Pipelines	R 85 683 672.00	0.5	R 428 418.00
21	Reservoirs	R 34 645 376.00	0.5	R 173 227.00
22	Water Treatment Works	R 3 750 000.00	5	R 187 500.00
23	Pump stations (Civil)	R 3 449 286.00	0.25	R 8 623.00
Annual maintenance and labour cost				**R 1 965 043.00**
24	Pump stations (E&M)	R 8 048 334.00	4	R 317 137.59
25	Yearly energy cost	R 629 169.00	-	R 629 169.00
Annual operational cost				**R 946 306.59**

Table F.7: Summary of Capital Cost (Option 2, Alternative 2)

Pipeline					
Item nr	**Description**	**Diameter (mm)**	**Length (m)**	**Installed pipeline cost per meter (R/m)**	**Cost**
1	Pipeline (main pump Kwelaba-Ntwana)	200	8 538	2 870	R 24 506 724.00
2	Pipeline (main pump Sizanenjane)	200	11 420	2 870	R 32 778 964.00
3	Pipeline (Booster Kwelaba-Ntwana)	200	11 646	2 870	R 33 427 654.00
4	Pipeline (Booster Sizanenjane)	200	3 937	2 870	R 11 300 419.00
5	E.O. Valves and valve chambers				R 3 000 000.00
6	E.O. River and donga crossings				R 3 000 000.00
				SUB-TOTAL A	***R 108 013 761.00***
Reservoir					
Item nr	**Description**	**Amount**	**Volume (Ml)**	**Construction cost (R)**	**Cost**
7	Reservoir at Smithfield Dam	1	2	8 661 344	R 8 661 344.00
8	Reservoir at booster pump station	2	0.5	902 706	R 1 805 412.00
9	Reservoir at Kwelaba-Ntwana	1	2	8 661 344	R 8 661 344.00
10	Reservoir at Sizanenjane	1	2	8 661 344	R 8 661 344.00
				SUB-TOTAL B	***R 27 789 444.00***
Pump stations					
Item nr	**Description**	**Installed KW**	**Cost per KW**		**Cost**
11	Main pump station (Kwelaba-Ntwana)	48.99	66 786		R 3 271 846.14
12	Main pump station (Sizanenjane)	64.4	59 345		R 3 821 818.00
13	Booster pump station (Kwelaba-Ntwana)	54.45	64 032		R 3 486 542.40
14	Booster pump station (Sizanenjane)	53.65	64 032		R 3 435 316.80
				SUB-TOTAL C	***R 14 015 523.00***
Water Treatment Works					

Item nr	Description	Category	Category Capacity (Ml/d)		Cost
15	Conventional WTW (Full treatment)	Small	3		R 3 750 000.00
				SUB-TOTAL D	***R 3 750 000.00***
HGDM contribution to construct Smithfield Dam					
Item nr	**Description**	**Construction cost (R)**			**Cost**
16	Contribution to construct Smithfield Dam	6 695 282			R 6 695 282.00
				SUB-TOTAL E	***R 6 695 282.00***
17	TOTAL OF SUB-TOTALS				R 160 264 010.00
Item nr	**Description**		**Unit**	**Rates**	**Cost**
18	Professional fees	(% of 17)	%	10%	R 16 026 401.00
19	Environmental and social cost	(% of 17)	%	10%	R 16 026 401.00
TOTAL CAPITAL COST					**R 192 316 812.00**

Table F.8: Summary of Maintenance Cost (Option 2, Alternative 2)

Maintenance Cost per annum				
Item nr	**Description**	**Total capital cost**	**O&M cost (%)**	**Cost**
20	Yearly service and admin charges	R 1 059 847.00	-	R 1 059 847.00
21	Yearly network, access and demand charges	R 76 974.00	-	R 76 974.00
22	Pipelines	R 108 013 761.00	0.5	R 540 069.00
23	Reservoirs	R 27 789 444.00	0.5	R 138 947.00
24	Water Treatment Works	R 3 750 000.00	5	R 187 500.00
25	Pump stations (Civil)	R 4 204 656.90	0.25	R 10 512.00
Annual maintenance and labour cost				**R 2 013 849.00**
26	Pump stations (E&M)	R 9 810 866.10	4	R 392 435.00
27	Yearly energy cost	R 450 808.00	-	R 450 808.00
Annual operational cost				**R 843 243.00**

Table F.9: Summary of Capital Cost (Option 3)

Pipeline					
Item nr	**Description**	**Diameter (mm)**	**Length (m)**	**Installed pipeline cost per meter (R/m)**	**Cost**
1	Pipeline (main pump Bethlehem)	200	4 863	2 870	R 13 955 744.00
2	Pipeline (booster pump Bethlehem)	200	4 694	2 870	R 13 473 245.00
3	Pipeline (main pump Ncwadi)	100	5 824	2 270	R 13 218 690.00
4	E.O. River and donga crossings				R 3 000 000.00
				SUB-TOTAL A	***R 43 647 679.00***
Reservoir					
Item nr	**Description**	**Amount**	**Volume (Ml)**	**Construction cost (R)**	**Cost**
5	Bethlehem end reservoir	1	1.2	1 820 716	R 1 820 716.00
6	Clear water tank	1	1	1 533 719	R 1 533 719.00
7	Pump station suction tank	1	0.6	1 015 000	R 1 015 000.00
8	Ncwadi end reservoir	1	0.6	1 015 000	R 1 015 000.00
				SUB-TOTAL B	***R 5 384 435.00***
Pump stations					
Item nr	**Description**	**Installed KW**	**Cost per KW**		**Cost**
9	Main pump station (Bethlehem)	54.63	54 190		R 2 960 399.70
10	Booster pump station (Bethlehem)	18.87	87 876		R 1 658 220.12
11	Booster pump station	22	48 332		R 1 063 304.00
				SUB-TOTAL C	***R 5 681 923.82***
Water Treatment Works					
Item nr	**Description**	**Category**	**Category Capacity (Ml/d)**		**Cost**
12	Conventional WTW (Full treatment)	Small	3		R 3 750 000.00
				SUB-TOTAL D	***R 3 750 000.00***

HGDM contribution to construct Smithfield Dam					
Item nr	**Description**		**Construction cost (R)**		**Cost**
13	Contribution to construct Smithfield Dam		3 330 454		R 3 330 454.00
				SUB-TOTAL E	***R 3 330 454.00***
14	TOTAL OF SUB-TOTALS				R 61 794 491.82
Item nr	**Description**		**Unit**	**Rates**	**Cost**
15	Professional fees	(% of 14)	%	10%	R 6 179 449.18
16	Environmental and social cost	(% of 14)	%	10%	R 6 179 449.18
TOTAL CAPITAL COST					**R 74 153 390.18**

Table F.10: Summary of Maintenance Cost (Option 3)

Maintenance Cost per annum				
Item nr	**Description**	**Total capital cost**	**O&M cost (%)**	**Cost**
14	Yearly service and admin charges	R 1 059 847.00	-	R 1 059 847.00
15	Yearly network, access and demand charges	R 46 702.00	-	R 46 702.00
16	Pipelines	R 43 647 679.00	0.5	R 218 238.00
17	Reservoirs	R 5 384 435.00	0.5	R 26 922.00
18	Water Treatment Works	R 3 750 000.00	5	R 187 500.00
19	Pump stations (Civil)	R 1 704 577.15	0.25	R 4 261.00
Annual maintenance and labour cost				**R 1 543 470.00**
20	Pump stations (E&M)	R 3 977 346.67	4	R 159 094.00
21	Yearly energy cost	R 734 867.00	-	R 734 867.00
Annual operational cost				**R 893 961.00**

Table F.11: Summary of Capital Cost (Option 4, Alternative 1)

Pipeline

Item nr	Description	Diameter (mm)	Length (m)	Installed pipeline cost per meter (R/m)	Cost
1	Pipeline (main pump station section)	200	10 360	2 870	R 29 736 433.00
2	Pipeline (booster pump station section)	100	3 422	2 270	R 7 766 889.00
3	Pipeline (gravity section)	200	2 260	2 270	R 5 129 506.00
4	Pipeline (Comrie Dam to reservoir)	300	3 655	3 467	R 12 672 736.00
5	E.O. Valves and valve chambers				R 3 000 000.00
6	E.O. River and donga crossings				R 3 350 000.00
				SUB-TOTAL A	***R 61 655 564.00***

Reservoir

Item nr	Description	Amount	Volume (Ml)	Construction cost (R)	Cost
7	Reservoir at suction side of booster pump station	1	0.5	902 706	R 902 706.00
8	Break pressure tank before gravity section	1	0.3	650 000	R 650 000.00
9	Reservoir at Comrie Dam end point	1	3	12 377 528	R 12 377 528.00
				SUB-TOTAL B	***R 13 930 234.00***

Pump stations

Item nr	Description	Installed KW	Cost per KW	Cost
10	Main pump station	19.10	87 876	R 1 678 431.60
11	Booster pump station	22.14	87 876	R 1 945 574.64
12	Comrie to reservoir	198.72	36 882	R 7 329 191.04
			SUB-TOTAL C	***R 10 953 197.28***

Water Treatment Works

Item nr	Description	Category	Category Capacity (Ml/d)	Cost
13	Conventional WTW (Full treatment)	Small	3	R 3 750 000.00
			SUB-TOTAL D	***R 3 750 000.00***

HGDM contribution to construct Smithfield Dam					
Item nr	**Description**	**Construction cost (R)**			**Cost**
14	Contribution to construct Smithfield Dam	1 834 324			R 1 834 324.00
				SUB-TOTAL E	***R 1 834 324.00***
15	TOTAL OF SUB-TOTALS				R 92 123 319.28
Item nr	**Description**		**Unit**	**Rates**	**Cost**
16	Professional fees	(% of 15)	%	10%	R 9 212 331.93
17	Environmental and social cost	(% of 15)	%	10%	R 9 212 331.93
TOTAL CAPITAL COST					**R 110 547 983.14**

Table F.12: Summary of Maintenance Cost (Option 4, Alternative 1)

Maintenance Cost per annum				
Item nr	**Description**	**Total capital cost**	**O&M cost (%)**	**Cost**
18	Yearly service and admin charges	R 1 059 847.00	-	R 1 059 847.00
19	Yearly network, access and demand charges	R 117 565.00	-	R 117 565.00
20	Pipelines	R 61 655 564.00	0.5	R 308 277.82
21	Reservoirs	R 13 930 234.00	0.5	R 69 651.00
22	Water Treatment Works	R 3 750 000.00	5	R 187 500.00
23	Pump stations (Civil)	R 3 285 959.20	0.25	R 8 215.00
Annual maintenance and labour cost				**R 1 751 055.82**
24	Pump stations (E&M)	R 7 667 238.00	4	R 306 690.00
25	Yearly energy cost	R 688 534.00	-	R 688 534.00
Annual operational cost				**R 995 224.00**

Table F.13: Summary of Capital Cost (Option 4, Alternative 2)

Pipeline					
Item nr	Description	Diameter (mm)	Length (m)	Installed pipeline cost per meter (R/m)	Cost
1	Pipeline (main pump station section)	200	9 599	2 870	R 27 552 126.00
2	Pipeline (booster pump station section)	100	919	2 270	R 2 085 848.00
3	Pipeline (gravity section)	100	2 528	2 270	R 5 737 784.00
4	Pipeline (Comrie Dam to reservoir)	300	3 655	3 467	R 12 672 736.00
5	E.O. Valves and valve chambers				R 3 000 000.00
6	E.O. River and donga crossings				R 3 350 000.00
				SUB-TOTAL A	***R 54 398 494.00***
Reservoir					
Item nr	**Description**	**Amount**	**Volume (Ml)**	**Construction cost (R)**	**Cost**
7	Reservoir at suction side of booster pump station	1	0.5	902 706	R 902 706.00
8	Break pressure tank before gravity section	1	0.3	650 000	R 650 000.00
9	Reservoir at Comrie Dam end point	1	3	12 377 528	R 12 377 528.00
				SUB-TOTAL B	***R 13 930 234.00***
Pump stations					
Item nr	**Description**	**Installed KW**	**Cost per KW**		**Cost**
10	Main pump station	30.00	87 876		R 2 636 280.00
11	Booster pump station	16.40	87 876		R 1 441 166.40
12	Comrie to reservoir	198.72	36 882		R 7 329 191.04
				SUB-TOTAL C	***R 11 406 637.44***
Water Treatment Works					
Item nr	**Description**	**Category**	**Category Capacity (Ml/d)**		**Cost**
13	Conventional WTW (Full treatment)	Small	3		R 3 750 000.00
				SUB-TOTAL D	***R 3 750 000.00***

HGDM contribution to construct Smithfield Dam					
Item nr	**Description**	**Construction cost (R)**			**Cost**
14	Contribution to construct Smithfield Dam	1 834 324			R 1 834 324.00
				SUB-TOTAL E	***R 1 834 324.00***
15	TOTAL OF SUB-TOTALS				R 85 319 689.44
Item nr	**Description**		**Unit**	**Rates**	**Cost**
16	Professional fees	(% of 15)	%	10%	R 8 531 968.94
17	Environmental and social cost	(% of 15)	%	10%	R 8 531 968.94
TOTAL CAPITAL COST					**R 102 383 627.33**

Table F.14: Summary of Maintenance Cost (Option 4, Alternative 2)

Maintenance Cost per annum				
Item nr	**Description**	**Total capital cost**	**O&M cost (%)**	**Cost**
18	Yearly service and admin charges	R 1 059 847.00	-	R 1 059 847.00
19	Yearly network, access and demand charges	R 120 108.00	-	R 120 108.00
20	Pipelines	R 54 398 494.00	0.5	R 271 992.47
21	Reservoirs	R 13 930 234.00	0.5	R 69 651.00
22	Water Treatment Works	R 3 750 000.00	5	R 187 500.00
23	Pump stations (Civil)	R 3 421 991.20	0.25	R 8 555.00
Annual maintenance and labour cost				**R 1 717 653.47**
24	Pump stations (E&M)	R 7 984 646.00	4	R 319 386.00
25	Yearly energy cost	R 703 428.00	-	R 703 428.00
Annual operational cost				**R 1 022 814.00**

Table F.15: Summary of Capital Cost (Option 5)

Pipeline					
Item nr	**Description**	**Diameter (mm)**	**Length (m)**	**Installed pipeline cost per meter (R/m)**	**Cost**
1	Pipeline (Comrie Dam to reservoir)	250	3 655	3 527	R 12 892 021.00
2	E.O. Valves and valve chambers				R 3 000 000.00
				SUB-TOTAL A	***R 15 892 021.00***
Reservoir					
Item nr	**Description**	**Amount**	**Volume (Ml)**	**Construction cost (R)**	**Cost**
3	Reservoir at Comrie Dam end point	1	3	12 377 528	R 12 377 528.00
				SUB-TOTAL B	***R 12 377 528.00***
Pump stations					
Item nr	**Description**	**Installed KW**	**Cost per KW**		**Cost**
4	Comrie to reservoir	198.72		36 882	R 7 329 191.04
				SUB-TOTAL C	***R 7 329 191.04***
Water Treatment Works					
Item nr	**Description**	**Category**	**Category Capacity (Ml/d)**		**Cost**
5	Conventional WTW (Full treatment)	Small		3	R 3 750 000.00
				SUB-TOTAL D	***R 3 750 000.00***
Raising of Comrie Dam					
Item nr	**Description**	**Construction cost (R)**			**Cost**
6	Raising of Comrie Dam			170 862 110	R 170 862 110.00
				SUB-TOTAL E	***R 170 862 110.00***
7	TOTAL OF SUB-TOTALS				R 210 210 850.04
Item nr	**Description**		**Unit**	**Rates**	**Cost**
8	Professional fees	(% of 7)	%	10%	R 21 021 085.00
9	Environmental and social cost	(% of 7)	%	10%	R 21 021 085.00
TOTAL CAPITAL COST					**R 252 253 020.05**

Table F.16: Summary of Maintenance Cost (Option 5)

Maintenance Cost per annum				
Item nr	**Description**	**Total capital cost**	**O&M cost (%)**	**Cost**
10	Yearly service and admin charges	R 1 059 847.00	-	R 1 059 847.00
11	Yearly network, access and demand charges	R 99 744.00	-	R 99 744.00
12	Pipelines	R 15 892 021.00	0.5	R 79 460.00
13	Reservoirs	R 12 377 528.00	0.5	R 61 888.00
14	Water Treatment Works	R 3 750 000.00	5	R 187 500.00
15	Pump stations (Civil)	R 2 198 757.31	0.25	R 5 497.00
Annual maintenance and labour cost				**R 1 493 936.00**
16	Pump stations (E&M)	R 5 130 433.73	4	R 205 217.00
17	Yearly energy cost	R 584 164.00	-	R 584 164.00
Annual operational cost				**R 789 381.00**