University of the Witwatersrand

Faculty of Engineering and the Built Environment

RESEARCH REPORT:
WATER SUPPLY SYSTEM ASSESSMENT FOR LOMAHASHA INKHUNDLA IN LUBOMBO REGION, SWAZILAND

Bernard Jacques Ndisebuye

A Research Report submitted to the Faculty of Engineering and the Built Environment, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering

Research Supervisor: Prof Adesola Ilemobade
School of Civil & Environmental Engineering

Johannesburg 2014

NOMENCLATURE / LIST OF ACRONYMS

AADD	Annual Average Daily Demand
ADB	African Development Bank
Amsl	Above Mean Sea Level
CLGF	Commonwealth Local Government Forum
CSO	Central Statistics Office
CSR	Corporate Social Responsibility
CSIR	Council for Scientific and Industrial Research
DCP	Dynamic Cone Penetration
DEAT	Department of Environmental Affairs and Tourism
DFID	Department For International Development
DWA	Department of Water Affairs
EIA	Environmental Impact Assessment
EMA	Environmental Management Act
HDPE	High Density Polyethylene
GWP	Global Water Partnership
I&APs	Interested and Affected Parties
JICA	Japanese International Cooperation Agency
KDDP	Komati Downstream Development Project
KOBWA	Komati Basin Water Authority
MOAC	Ministry of Agriculture and Co-operatives
MoPWT	Ministry of Public Works and Transport
NERCHA	National Emergency Response Council on HIV and AIDS
NGO	Non-Government Organisation

O&M	Operation and Maintenance
RDMU	Restructuring and Diversification Management Unit
RSSC	Royal Swaziland Sugar Corporation
RWSB	Rural Water Supply Branch
SABS	South African Bureau of Standards
SANS	South African National Standards
SEA	Swaziland Environment Authority
SEC	Swaziland Electricity Company
SMP	Site Management Plan
SNL	Swazi National Land
SPTC	Swaziland Postal and Telecommunications Corporation
STI	Sexual Transmitted Infection
SWADE	Swaziland Water and Agricultural Development Enterprise
SWALIM	Somalia Water and Land Information Management
SWSC	Swaziland Water Services Corporation
TAC	Technical Advisory Committee
TOR	Terms of Reference
UNCED	United Nations Conference on Environment and Development
UNDP	United Nations Development Programme
uPVC	Unplaticised Polyvinyl Chloride
WTP	Water Treatment Plant
WWTP	Waste Water Treatment Plant

LIST OF MEASURING UNITS

ha	Hectare
kg	kilogram
km	Kilometre
kV	Kilo Volt
kW	Kilo Watt
l	litre
l/s	Litres per second
l/c/d	Litres per capita per day
l/d	Litres per day
m^3	Cubic metre
m^3/s	Cubic metres per second
m^3/d	Cubic metres per day
Mm^3	Million cubic metres
m^3/a	Cubic metres per annun
m a.s.l	Metres Above Sea Level
E	Emalangeni (Swaziland currency = SA Rand)

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

DECLARATION

I declare that this Research Report is my own unaided work. It is being submitted for the Degree of Master of Science in Engineering to the University of the Witwatersrand, Johannesburg.

It has not been submitted before, and is not to be submitted, for any degree or examination to any other University.

Any information used in this Research Report has been obtained by me. I carried out the Research on a part time basis, while employed by BICON Consulting Engineers.

…………………………………………………….

……….. day of …………….., …………………

ABSTRACT

This Research assesses the water supply systems for Lomahasha Inkhundla, located in the north eastern corner of Swaziland. The most favourable option was determined and its supply level was analysed considering other water demands in the same river basin.

The project area is characterised by a history of repetitive drought occurrences and severe food shortages. The area includes Lomahasha 'Town' which is adjacent to the Mozambican city of Namaacha.

For domestic water uses, the people in both Lomahasha and Namaacha generally rely on raw water from rivers and small dams, and during dry months, they travel long distances to reach the few perennial sources available.

Swaziland Water Services Corporation (SWSC) attempted to develop a system to supply water to Lomahasha 'Town' by connecting to the existing system in Simunye, 30km away. This proposal did not cater for the settlements along the 30 km pipeline route and other water deprived localities in the area. This research project was initiated to evaluate the SWSC proposal in comparison with other possible scenarios, and to find the most suitable option to supply water to the whole Lomahasha Inkhundla, including rural areas.

The study was carried out by undertaking site investigations, discussions and interviews with stakeholders, monitoring of water flows and analysis of available documentation and relevant reports.

The study concluded that the most economically and environmentally favourable option for the supply of water to Lomahasha Inkhundla was the option of connecting to the system in place at Simunye.

This source was found to be adequate for the supply of water to Lomahasha Inkhundla, after its evaluation in conjunction with various scenarios of competing water uses in the same river basin.

ACKNOWLEDGEMENTS

This Master of Science Research Report is an outcome of a studious process which is now fulfilled because of the help and support I benefited from many people.

I would like to profoundly thank my supervisor, Prof Adesola Ilemobade, for his kindness and assistance in everything, from research methodology to logistical and administrative guidance. His strong and constant support made the whole process to work out and to reach finality.

I am very proud and grateful of the encouraging support I received from my darling wife and children. They played a crucial role in the success of this process as the work on this report was integrated into our family life.

I express my gratitude to my dear lecturers at the School of Civil and Environmental Engineering for all knowledge acquired from them during the coursework sessions, and which greatly contributed to the success of this research. I would especially like to mention Prof. Ndiritu, Prof. Taigbenu, Prof. James, Prof. Marjanovic, Dr. Fitchett and Mrs. Westraadt. Thanks a lot for your input.

Many thanks to all friendly and caring staff at the School of Civil & Environmental Engineering, and at the Faculty of Engineering and the Built Environment. They made the process to flow and to successfully proceed by welcoming me and attending to all queries I came with. I am particularly grateful to Ms. T. Mtselu for her crucial guidance.

I appreciated the contribution from all the people who supplied information for the preparation of this report, either during field interviews or meetings with stakeholders.

Finally, many thanks to my colleagues at BICON Consulting Engineers for closing the gap at work while I was busy with this research.

1. INTRODUCTION

1.1 Background information

In 2010, the Swaziland Water Services Corporation (SWSC) implemented the first phase of the Lomahasha & Siteki Water Supply System Project which comprised the supply to Siteki and other areas of Lubombo region located to the south west of Simunye including Mpaka and the new King Mswati III International Airport. In this first phase, an intake from Mbuluzi River was constructed together with a purification plant. Also a transmission system was installed, with booster stations and storage reservoirs to supply the areas included in the first phase. The supply to Lomahasha was planned for the second phase. Figure 1 shows the location of the study area on the map of Swaziland.

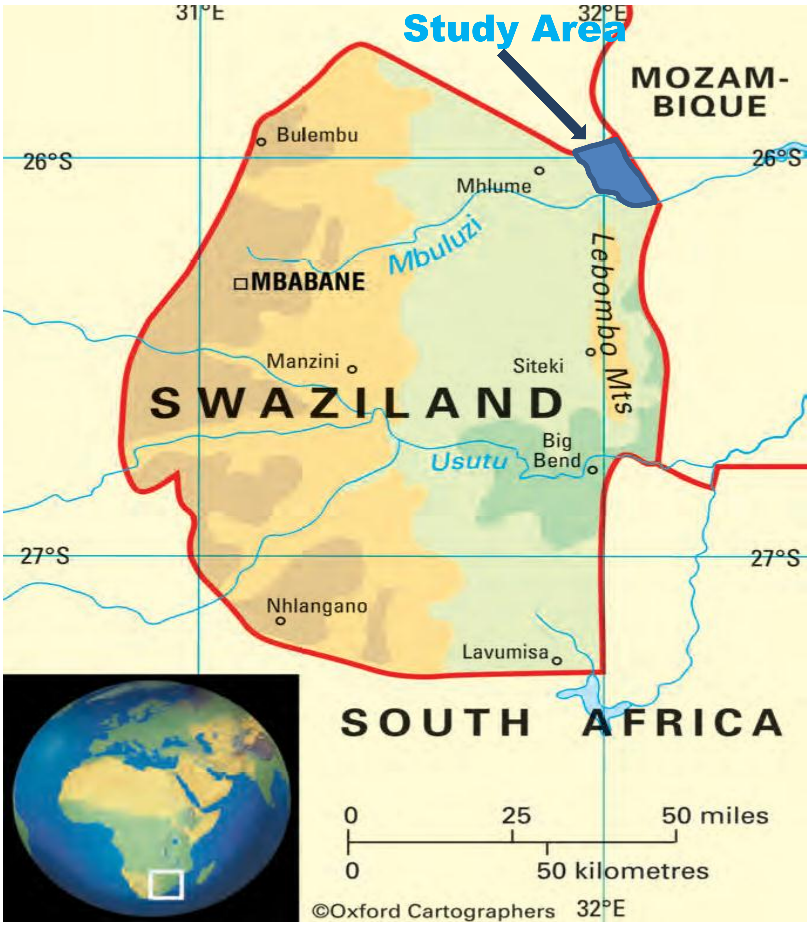


Figure 1: Location of the study area on the map of Swaziland (CLGF, 2009)

In December 2011, SWSC proposed to commence the Lomahasha Water Supply System. The intention was to develop a water supply system for the Lomahasha 'town' which is located 30km away from Simunye where a water purification plant of a capacity of 1200m^3 per hour was constructed in the first phase of the Lomahasha & Siteki water supply project (Figure 2).

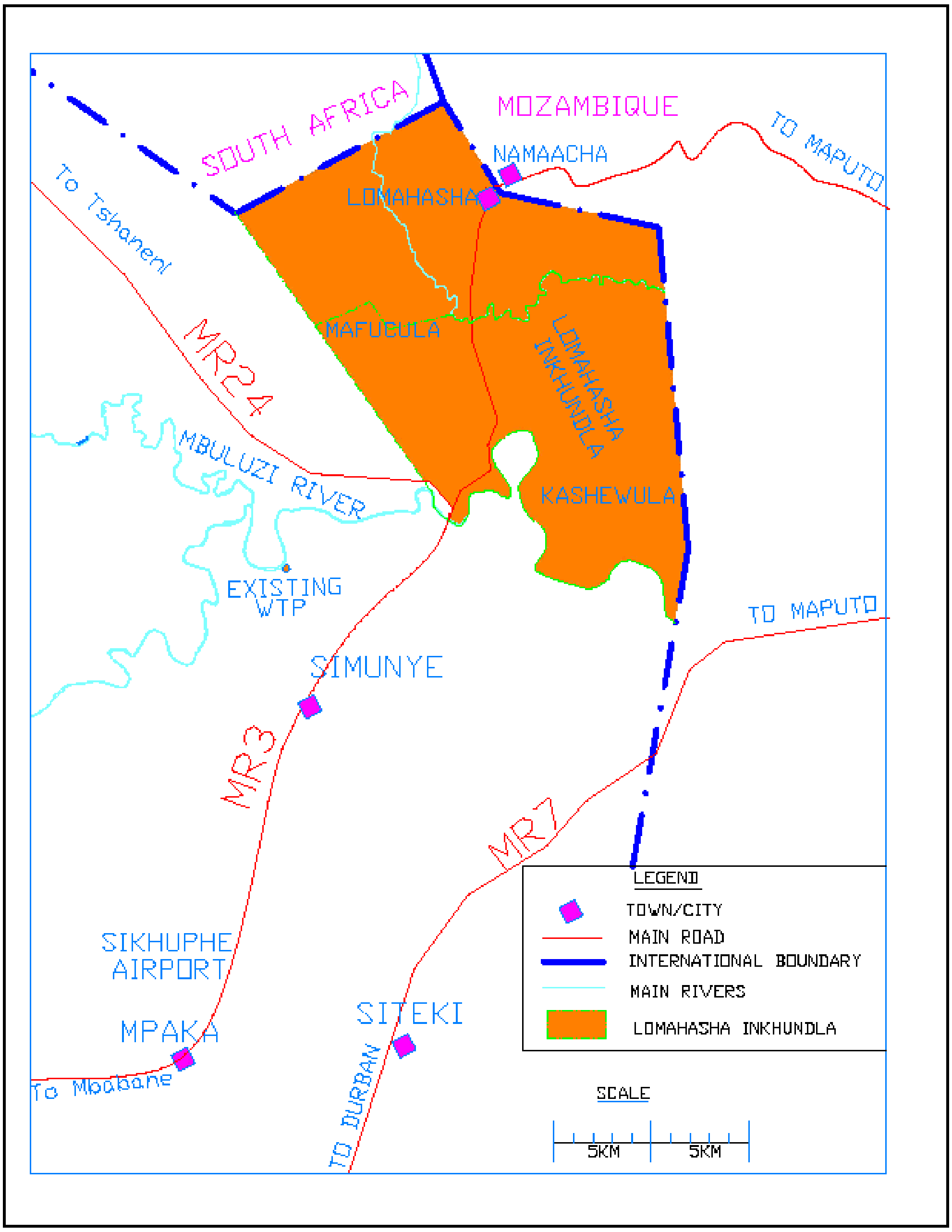


Figure 2: Location of towns included in the Lomahasha & Siteki Water Supply Project

The present study was initiated in order to evaluate the suitability of this proposal, considering other possible source options and other water demands in the project area.

1.2 Problem Statement

The project proposed by SWSC to supply the border post of Lomahasha from the existing water supply system at Simunye raised four fundamental questions which provided inspiration for a research project.

- How much water is needed?
- Is the option to source the water from 30km the most economically viable and environmentally sustainable alternative?
- If water is sourced from Simunye, what will happen to settlements along the route of the transmission line?
- Is the proposed source reliable considering other water uses in the area?

In order to respond to these four questions, the first step required was to determine the boundary of the study area to be able to assess the water demand and the socio-economic impacts of the project. The first challenge encountered was that the town of Lomahasha is not yet gazetted and thus its official boundary does not exist. The second problem is related to the type of rural housing in Swaziland which is characterised by the spreading of homesteads all over the area rather than being concentrated in villages along the road.

It was found to be most practical to make the boundary of the study area the same as that of Lomahasha Inkhundla, which is an administrative entity with a known geographic delimitation. This is also justified by the fact that this Inkhundla is locked between the international border lines and the sugar estates where adequate water supply systems are in place. This study therefore covered all areas of the north eastern corner of Swaziland where people are still deprived of access to adequate source of potable water.

1.3 Objective of the study

1.3.1 Objective Statement

The objective of this study was to identify and evaluate all suitable water source options for a centralised water supply system for Lomahasha, then to determine the best option considering the economic and environmental suitability, and finally to evaluate the supply capability of the chosen source taking into consideration other water demands in the same river basin.

The study would therefore identify the most sustainable solution for the water supply to Lomahasha Inkhundla. The proposed solution should fit into the normal operation of Swaziland Water Services Corporation which is the parastatal responsible for the distribution of water to urban areas and other agglomerations by using centralised systems and pipe reticulation networks with meters at terminal points. Therefore, this research project would exclude home-level and localised systems.

1.3.2 Methodology used to achieve the study objective

This study consisted of the field work to collect the necessary information, and desktop work to compile the information and prepare the research report.

The purpose of the field work undertaken in this study was to collect information related to existing sources of water in the area; to identify potential sources of water for the proposed system and assess their suitability; and to collect information related to water availability and various water uses in Mbuluzi River basin.

The collection of information on existing water sources was carried out by

- Discussions with various organisations and authorities who developed, or who are responsible for the operation, of any of the existing schemes;
- Interviews at household level. Forms were used to record the results of the interviews at household level;

- Site investigation and evaluation of the existing situation.

The identification and the assessment of potential sources for the new system was carried out by

- Gathering of information from local people about the location and the yield of any boreholes or springs in the project area;

- Monitoring of water flows in Nkalashane River. This was carried out by measuring the flow depth at different times in the year to assess if the river could provide enough water to supply the proposed system at any time of the year. During the winter months, the flow was measured using a stopwatch and a container and during summer time, a control section was identified in the river and the flow was measured using the Average Velocity method.

- Gathering of information on Mbuluzi River and on the existing intake and treatment system at Simunye. This was done by inspection of the existing system, interviews with the operators and review of the as-built drawings and operation and maintenance manuals of the equipment.

Finally the assessment of water availability and various water uses in Mbuluzi River basin was achieved by

- Collection of information on gauging stations in Mbuluzi river basin from the records kept by the Department of Water Affairs and from reports in previous studies

- Interviews with authorities and stakeholders dealing with the water resources in Mbuluzi River basin

- Collection of information on water consumption quantities from various users in the Mbuluzi River basin.

1.4 Layout of the Research Report

The report comprises thirteen chapters. The first chapter is an introduction that presents the background, the objective, the methodology and the organisation of the study. The second chapter present the characteristics of the study area and the third chapter deals with the water reconciliation. The fourth chapter elaborates on the assessment of various water source alternatives and the fifth chapter presents the preliminary design of the preferred options. Chapter six presents the economic and environmental evaluations of preferred options. Chapter seven deals with the evaluation of various water demand scenarios in the Mbuluzi River basin and chapter eight presents the conclusions and recommendations. Finally, chapter twelve and thirteen present the list of references and appendices respectively.

2. CHARACTERISTICS OF THE LOMAHASHA INKHUNDLA

2.1 Background

The Lomahasha Inkhundla is in the drainage basin of Mbuluzi River which is the main source of water in the study area. Previous studies carried out on the Mbuluzi River basin were perused to gain information on physical and social characteristics of the study area. These include JTK Associates (2002), Johansson (2006), SWECO & Associates (2005) and Knight Piesold (2011).

JTK Associates (2002) assessed the present and future water availability and water requirements in the lower drainage basin of Mbuluzi River which comprises the study area. The study covered the sugar belt estates in the north east of Swaziland, together with the towns of Mpaka, Siteki and Lomahasha.

Johansson (2006) assessed and reported on how water quality varies in time and in space along the Mbuluzi River, and proposed measures for improving future monitoring.

SWECO & Associates (2005) prepared the Joint Umbeluzi River Basin Study which was the basis for the negotiatiosn between the Governements of Mozambique and Swaziland for an agreement on joint use and management of water in Mbuluzi River.

Knight Piesold (2011) developed an Integrated Water Resources Master Plan for Swaziland. The plan makes provision for the water needs of all sectors of the up to the year 2025.

Journal papers dealing with issues related to water resources availability were consulted during the course of this research. These include the UNISWA Research Journal of Agriculture, Science and Technology; Physics and Chemistry of the Earth and the Journal of the Hydraulics Division.

After the collection of the available data from various authorities, and using the aerial photos of the area, the information obtained from the documentation was physically verified on site. This was done through physical observations and by interviews with local communities.

2.2 Data Sources

2.2.1 Population Data

The basic data on the population of the study area was obtained from the Swaziland Central Statistics Office (CSO, 2007). This is a Government Department which is under the Ministry of Economic Planning and Development and which is the custodian of the national statistics system. The CSO conducts the population census every 10 years and produces thematic reports, statistical tables and population projections. The last population census in Swaziland was conducted in 2007 (CSO, 2007).

The data from the CSO was correlated with the homestead registers obtained from the various chiefdoms of the project area. However, the information from the homestead registers was found to be inconsistent. This can be explained by the fact that people may have supplied wrong information with the intention to maximise their food ratios as these registers are used for food distribution.

2.2.2 Meteorological data

Rainfall and temperature data was obtained from the Swaziland Meteorological Department of the Ministry of Natural Resources (Swaziland Meteorology Department, 2012). This data was needed in order to assess the effect of rainfall and evaporation on water availability in the area.

Monthly data was used to compile tables and graphs showing the variability of weather conditions in the study area.

2.2.3 Geological data

Geological data was obtained from the Swaziland Geology Department and was used in assessing the availability of underground water and the type of rock to encounter when carrying out excavations.

2.2.4 Maps and aerial photos

Maps and aerial photos were generally obtained from the Swaziland Surveyor General Department. Also Google Earth and other internet resources were used to extract various maps and aerial photos of the area.

2.3 Location of the study area

2.3.1 Administrative location

The study area is the Lomahasha Inkhundla in Manzini District. Swaziland is subdivided into four administrative districts (Hhohho, Manzini, Shiselweni and Lubombo) and each district is subdivided into constituencies or “tinkhundla” (plural ‘tinkhundla’; singular ‘inkhundla’). An inkhundla is made of two or several chiefdoms which are the basis of the traditional authority in the country.

In Swaziland, local government is divided into rural and urban councils. The urban councils are municipalities and the rural councils are the Tinkhundla, and in total, there are 12 municipalities and 55 Tinkhundla (CLGF, 2009) (Figure 3).

Lomahasha Inkhundla comprises two chiefdoms namely Lomahasha under Chief Mlongeli Mahlalela and Shewula under Chief Mbandzamane.

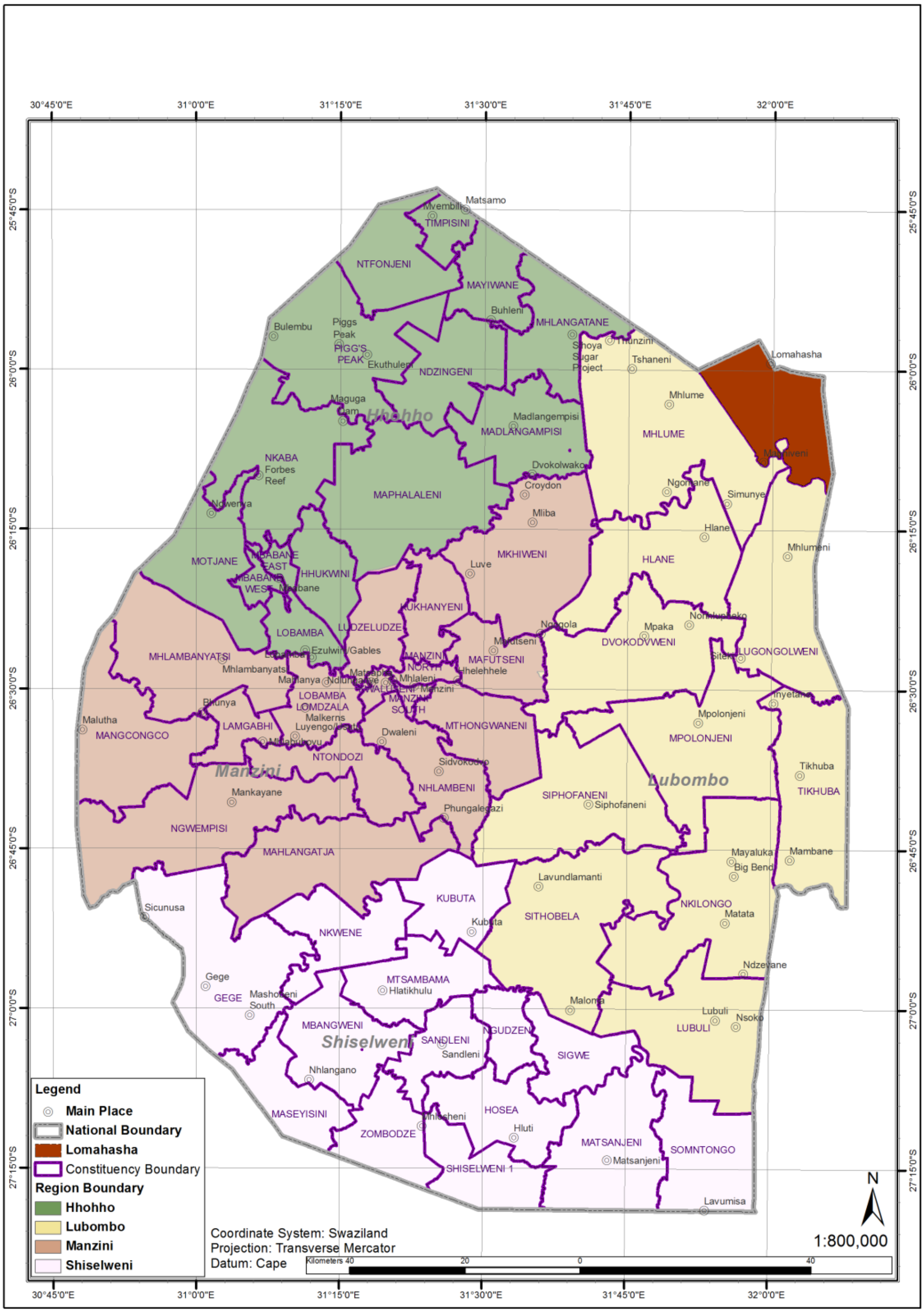


Figure 3: Delimitation of 55 Tinkhundla of Swaziland

2.3.2 Physical location

The Lomahasha Inkhundla is located in the north eastern corner of Swaziland which borders with Mozambique and South Africa (Figure 4).

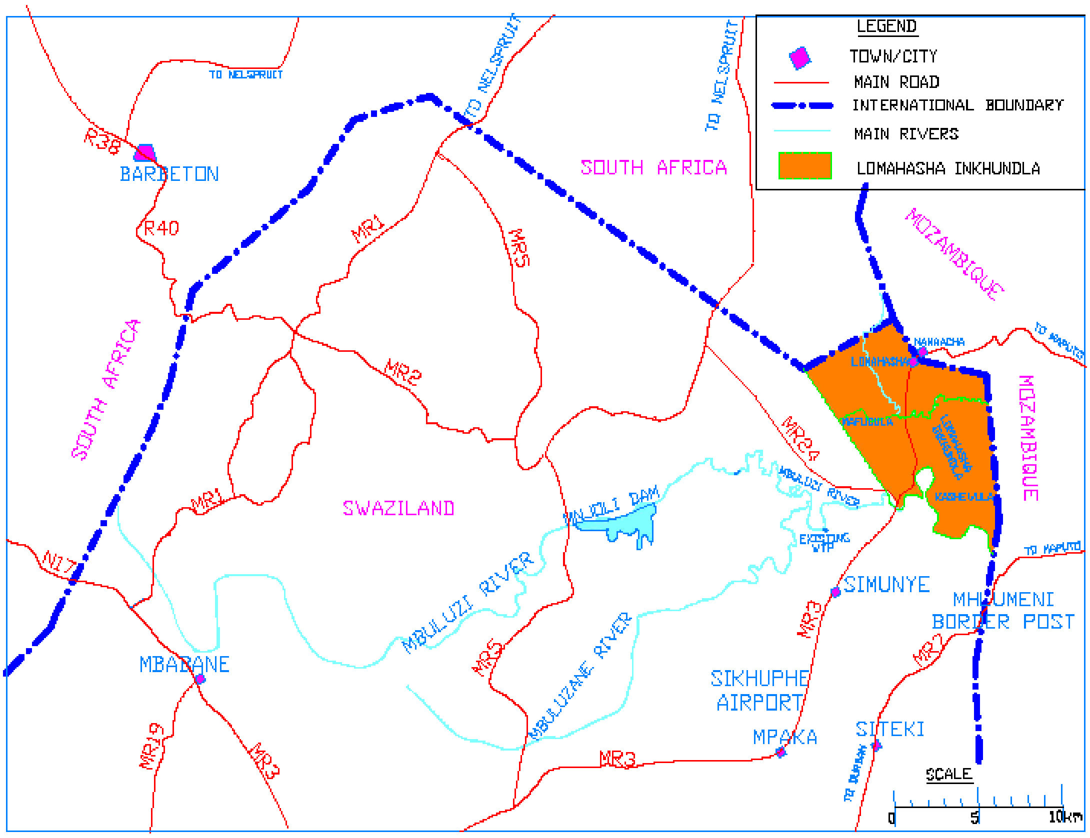


Figure 4: Location of the Study Area

The study area is located in the Lubombo Mountain physiographic region of Swaziland. The country is defined by four main physiographic units, all running in a north-south direction (Johansson, 2006).

- The Highveld to the west. This is a range of mountains that extend into the Drakensberg of South Africa.
- The Middleveld located to the east of the Highveld. This is typically rolling and hilly land of 450-600 amsl;
- The Lowveld further to the east with an average elevation of 150-300 m amsl;

- The Lubombo Mountain Range to the far east, with an average altitude of 600m amsl.

The Lubombo Mountains are a narrow but long range of mountains which stretches on a length of about 800km in South Africa, Swaziland and Mozambique (Johansson, 2006). Depending on local language the range is called ‘Lubombo Mountains’ or ‘Lebombo Mountains’ or ‘Ubombo Montains’. The name is derived from the Zulu word *‘ubombo’* meaning "big nose" (Johansson, 2006).

2.3.3 Socio-economic location

The Study Area includes the Lomahasha Border Gate which is the main point of entry between Swaziland and Mozambique. Swaziland is a landlocked country almost entirely surrounded by South Africa and Mozambique. Lomahasha is separated by a border line from the City of Namaacha which has a population of about 25 000 people and is characterised by active tourism and commercial sectors.

The geographic location of Lomahasha inherently results in the dynamism of informal and formal cross border trading. This has caused the area near the border gate to be occupied by shops and other commercial facilities which provide services to traders and truck drivers travelling from or to Mozambique.

The main activity for communities in remote areas away from the border gate is the cultivation of maize at domestic level and the keeping of cattle. However this is severely affected by the scarcity of water and people generally rely on the food distribution carried out by Government to all poverty stricken areas in the country.

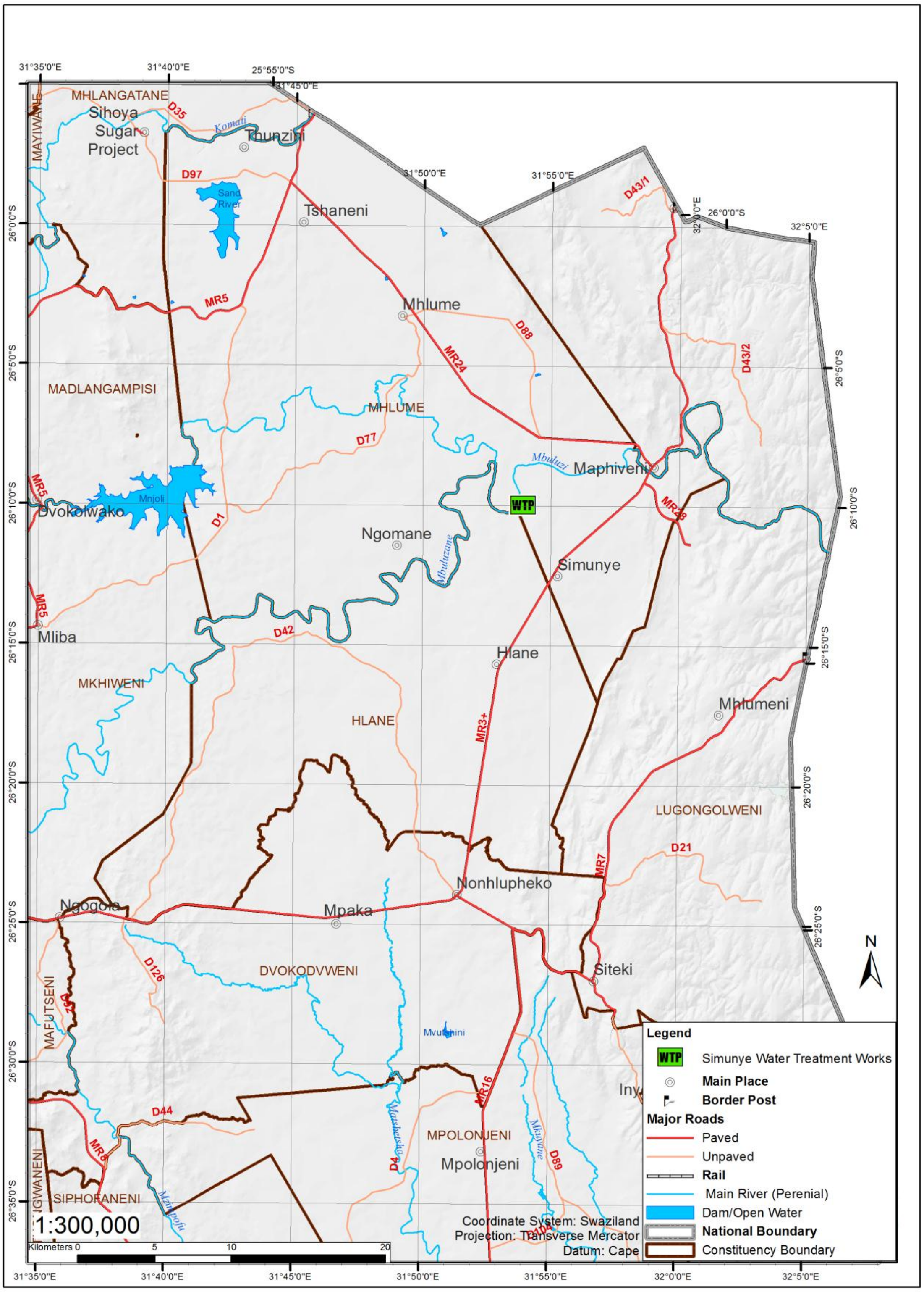


Figure 5: Lomahasha Inkhundla and surrounding areas of Lubombo District

Lack of access to potable water for human consumption, livestock and agriculture is a critical barrier for the socio-economic development of the Study Area. Inadequate access to clean water and sanitation combined with malnutrition threatens the health of the people in the Lomahasha Inkhundla.

Some of the areas along the western boundary of the Lomahasha Inkhundla are occupied by sugarcane farming in the estates of Simunye, Tabankulu, Mhlume and in the fields for the Farmers Association of Mafucula. The southern part of the study area is within the Mlawula Nature Reserve which extends from the boundary of the sugar plantations to the west up to the border with Mozambique to the east.

2.4 Climatic Characteristics

The climate is tropical and semi-arid in the study area. The year can be divided into two distinct seasons, hot and rainy (November to April) and dry and cool (May to October). In general, the climate gets warmer and drier towards the east (Johansson, 2006).

2.4.1 Rainfall

Rainfall information has been obtained from the Swaziland Meteorological Department for the weather station of Mlawula located along Mbuluzi River in the south west of the study area. The data contained monthly rainfall figures for the period from January 1990 to May 2012. It indicates that the rainfall is clearly seasonal with about 65% falling during the four months of November to February. The Mean Annual Precipitation (MAP) is about 678mm/year. The dry period occurs in May to September when a total rainfall for the five months is 50mm, which is less that 7% of the MAP.

Figure 6 below is an illustration of annual trends in MAP, as compiled from the rainfall information for the period of January 1990 to May 2012.

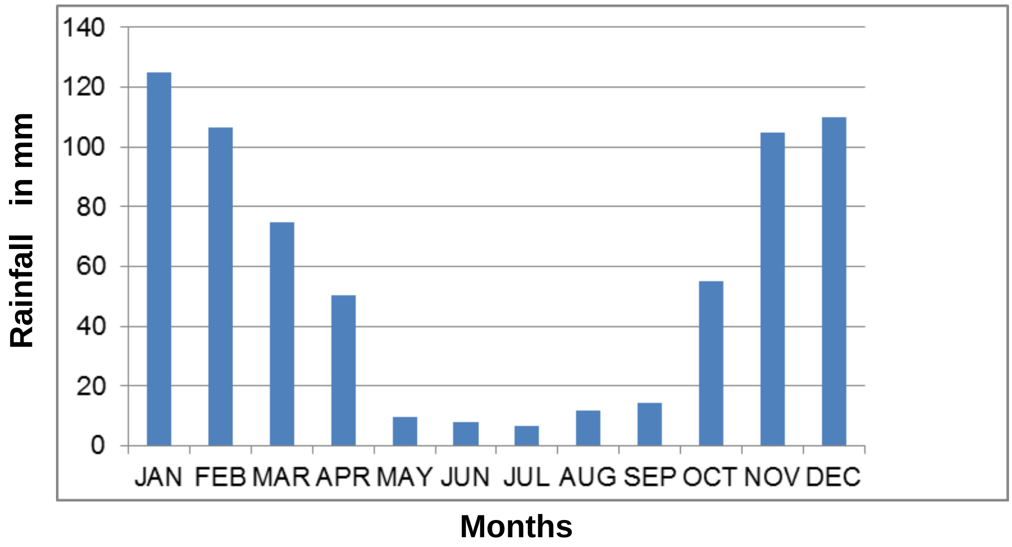


Figure 6: Average monthly rainfall

Annual rainfall from 1990 to 2011 is shown in Figure 7.

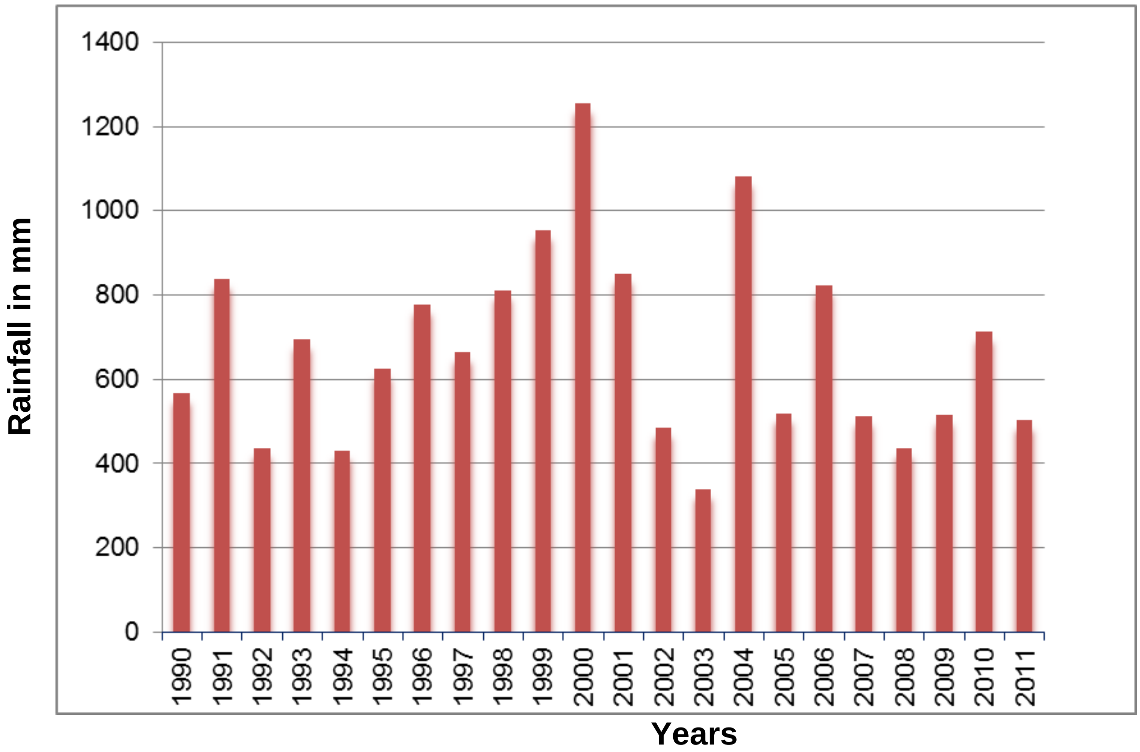


Figure 7: Annual rainfall from 1990 to 2011

The highest rainfall during the period of 1990 to 2011 was experienced in 2000 due to the tropical cyclone 'Eline'. A rainfall of 479.2mm was recorded in the month of February 2000 when the cyclone occurred.

Tropical cyclones occasionally cause extreme flood events in the region. The major floods during the last century have occurred in 1925, 1966, 1984 (cyclone Demoina), 2000 and 2004. During the flood in 1984, river flows of about 5600 m^3/s were recorded at the flow station in Goba (JTK Associates 2003).

The occasional tropical cyclones do not prevent the occurrence of drought events in Swaziland. Ten consecutive years of poor rainfall in parts of the country, including Lomahasha Inkhundla, have substantially impacted on food security as a result of the decline in maize production. The populations in rural areas mostly depend on small-scale farming of maize.

Extreme weather conditions that cause floods or droughts are worsened by the vulnerability of the people in the region resulting from high poverty levels and impacts of HIV/AIDS.

2.4.2 Temperature

The study area is characterised by mild to cold winters and hot summers with temperatures often exceeding 35^{o}C for several consecutive days. The mean annual air temperature is 22^{o}C (Schulze et al, 1997). The average temperature increases by about 0.5^{o}C for every 100mm drop in altitude (JTK Associates 2002).

The average monthly minimum and maximum temperatures have been compiled from the information obtained from the Meteorology Department and are presented in Figure 8.

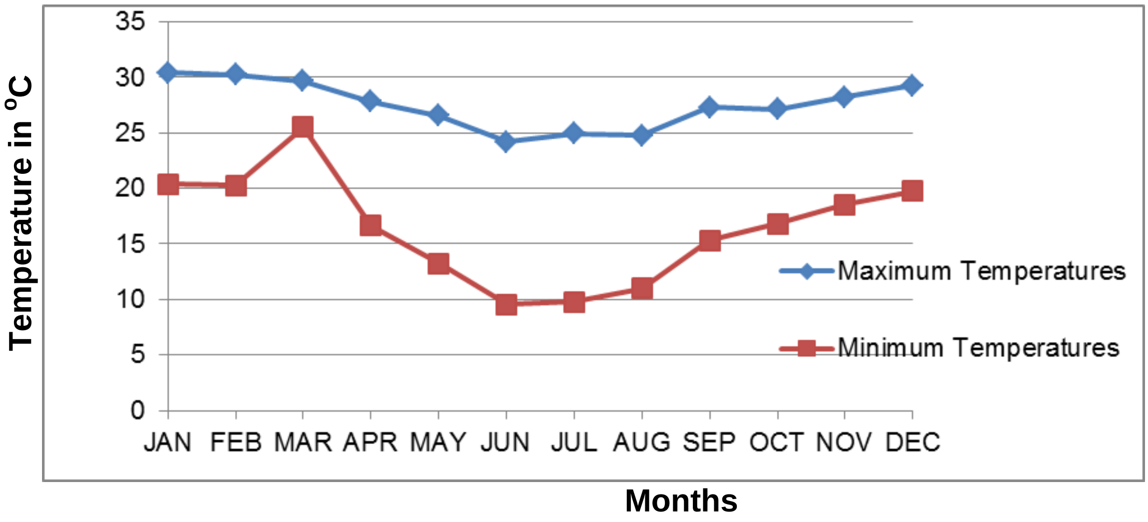


Figure 8: Monthly average minimum and maximum temperatures

2.4.3 Evaporation

Evaporation is measured by various types of pans and there are formulas for converting from one type to another. In Southern Africa, the most common is the Symon's Pan (S-Pan).

The pan evaporation measurement combines the effects of several climatic elements including temperature, humidity, rain fall, drought dispersion, solar radiation and wind. Evaporation is highest on hot, windy, dry, sunny days and is greatly reduced when clouds block the sun and when the air is cool, calm, and humid (JTK Associates, 2002).

The annual S-Pan Evaporation in the study area is 1500mm (JTK Associates 2002). This is above double of the MAP.

2.4.4 Geology

The Swaziland geological map obtained from the Geological Department of Swaziland shows that the study area lies across two major geological formations. These two formations mainly follow the topographical landform regions in roughly parallel bands running in a north-south direction (Figure 9).

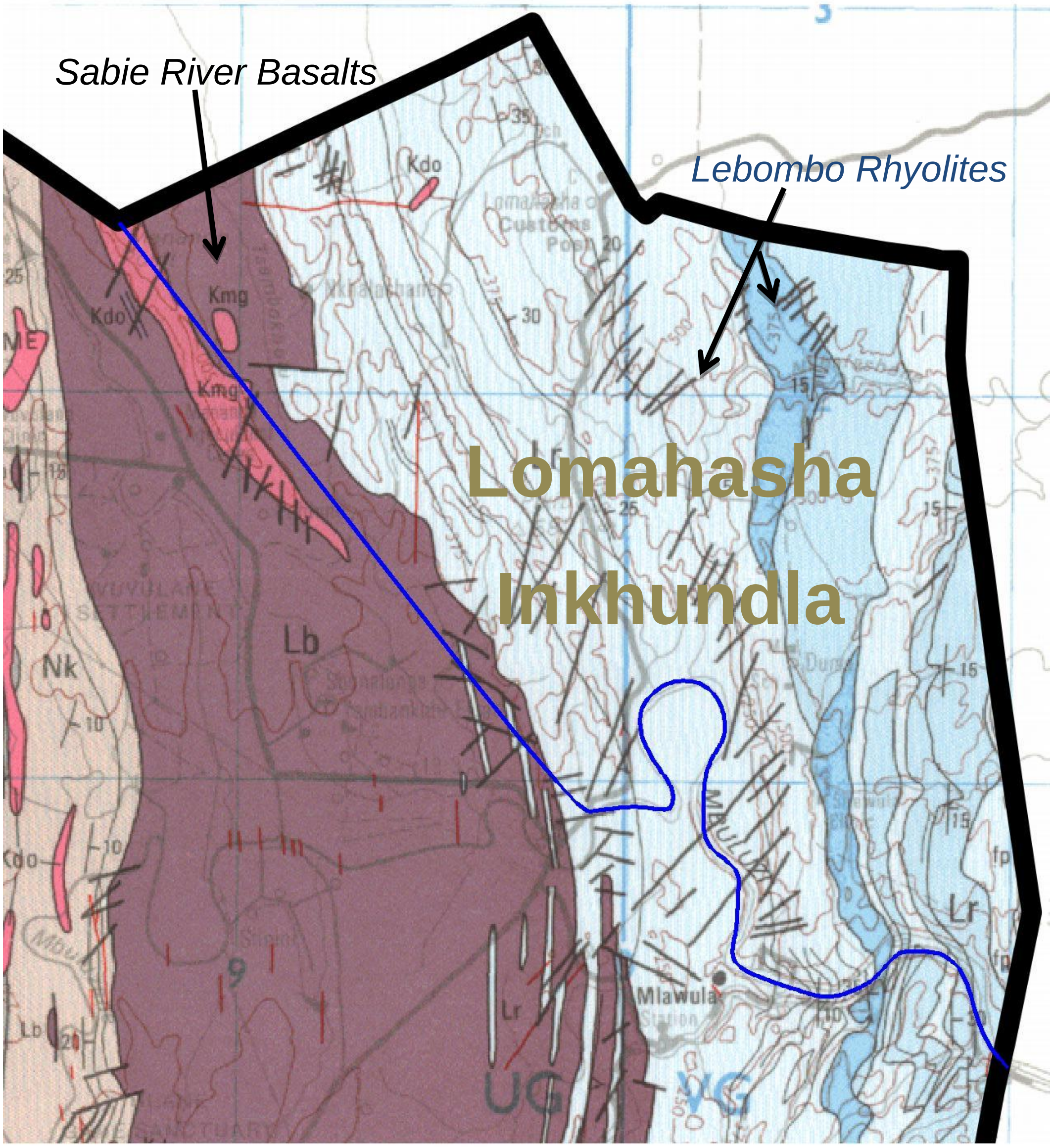


Figure 9: Geological formations of the study area (Geological Department, 1998)

The western part, which is at the edge of the sugar estates, is occupied by the Sabie River Basalt Formation (Geological Department, 1998). Volcanological features observed within the Sabie River Basalt Formation show two basically distinct basaltic magma types, the simultaneous eruption of which presents an intriguing geochemical problem as to their origins (JTK Associates 2002).

The eastern part is within the Lebombo Rhyolites Formation (Geologiocal Map, 1998). This is the youngest Karoo rock type of rhyolite which is made of volcanic rock more acid than basalt (Geological Department, 1998). The rhyolite formation is described as ignimbrite and is made of a very poorly sorted mixture of volcanic ash and pumice lapilli, commonly with scattered lithic fragments (JTK Associates, 2002). The ash is composed of glass shards and crystal fragments. Ignimbrites may be loose and unconsolidated, or solidified rock.

2.5 Water resources

2.5.1 Surface Water

The main source of water in the study area is Mbuluzi River, except for the north western part (Mafucula area) which depends on water transferred from the Komati River Basin

Mbuluzi River rises in Ngwenya Hills in the north-western part of Swaziland close to the border with South Africa, and then flows in an easterly direction into Mozambique where it discharges into the Indian Ocean in the Espirito Santos estuary to the south of Maputo. The length of the River is about 300km with a catchment area of 5400 km^2 of which 58% is located in Swaziland (Figure 10), 40 % in Mozambique and some 2 % in South Africa (Johansson, 2006).

2.5.1.1 Surface water availability

A water balance was carried out for Mbuluzi River basin as part of this study, and the results show that there is a general shortage of water in the basin, mainly due to the water required for irrigation.

JTK Associates (2002) estimated the natural discharge of the Mbuluzi River into Mozambique to be 613 Mm^3/a (Figure 10). The report also noted that in terms of the 1976 Mozambique/Swaziland Agreement on the Mbuluzi River Basin, Swaziland is obligated to release 108Mm^3 per year to Mozambique.

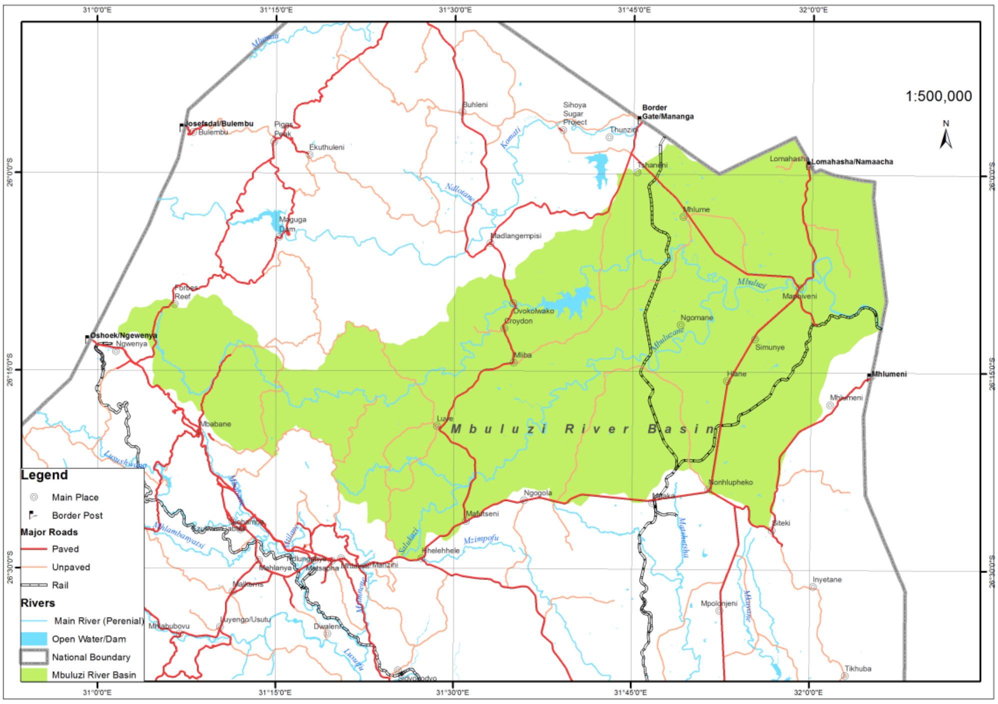


Figure 10: Mbuluzi River basin in Swaziland

The estimated annual environmental flow requirement in the Mbuluzi River as it enters Mozambique is in the range of 79 to 191 Mm^3 per year (SWECO & Associates, 2005) . This represents 13 to 31% of the natural annual discharge.

The main tributary of Mbuluzi River running across Lomahasha Inkhundla is Nkalashane River. This is an important source of water for people in the study area as it traverses the whole Inkhundla from north to south. Nkalashane River supplies drinking water to people and livestock and it is used at a significant scale for irrigation of domestic vegetable gardens. However this river is not perennial and generally dries up in August to September every year.

Mbuluzi River supplies drinking water to almost 3 million people, including the capital cities of both Mozambique and Swaziland. At the same time it supplies irrigation water to Simunye and Tabankhulu sugar estates and industrial agriculture in Libombos Piquenos in Mozambique.

The Mafucula area is supplied with water transferred from the Komati River basin (see Figure 11) for both drinking and irrigation uses. Water is transmitted from Sand River Dam though the canal system supplying Mhlume sugar cane plantation and then through a pipeline up to a balancing dam at Mafucula. The system has been developed by Swaziland Water and Agricultural Development Enteprise (SWADE), and is presently maintained and operated by Mafucula Farmers Association.

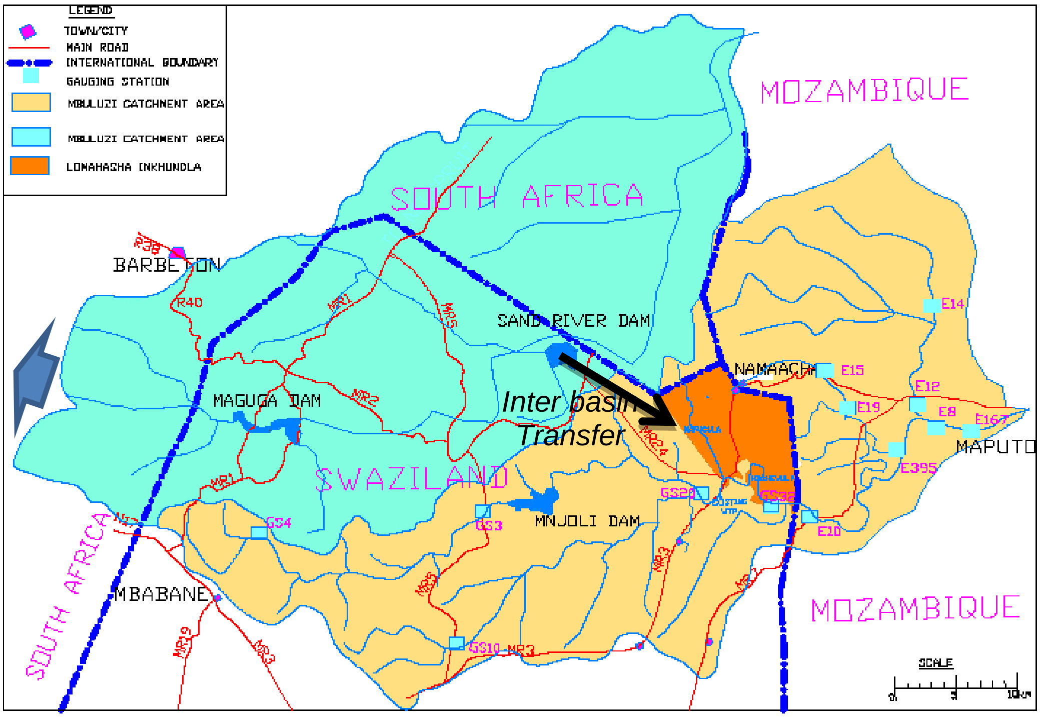


Figure 11: Mbulizi and Komati River Basins

A number of households in the study area rely on stagnant water in ponds and small dams which are also used by cattle (Figure 12).

Figure 12 : Photo of a reservoir supplying drinking water to both the people and the cattle (photo taken on 07 June 2012).

2.5.1.2 Surface water quality

In the general view of the people of Lomahasha, quantity of water available is more important than quality, due to high water scarcity. People take all sorts of risks to obtain water needed for domestic use. They either fetch water from stagnant puddle with visible presence of microbes and mineral loads, or from a river with known risk of being attacked by crocodiles.

However, the water quality in the Mbuluzi River is an important issue particularly because the river supplies potable water to the capital cities of Mozambique and Swaziland and it is severely stressed by intensive sugar cane farming along its lower reaches in Swaziland. Two major storage dams are constructed along the river, Mnjoli Dam in Swaziland and Piquenos Lebombos in Mozambique.

The water quality in the Mbuluzi River basin is generally good for irrigation purposes, and it requires normal level of treatment to attain the quality levels required for domestic use (SWECO & Associates, 2005).

With regard to the contamination of water resources due to irrigation activities, levels of nutrients and minerals running into the river were still within target values, but increased irrigation development in the catchment could cause the surface water quality to deteriorate (JTK Associates, 2002).

Pollution arising from return flows from domestic and industrial water uses in towns and villages are mainly nutrients and bacterial contamination. The load from the towns and villages may therefore contibute to the increase of river contamination, but its input is relatively low in comparison with the agriculture.

Excessive levels of soil erosion in the catchment of Mbuluzi River were noted, up to a value of 352mg/l for Total Suspended Solids (Johansson, 2006). This could be caused by extensive agricultural activities in combination with erodible soils in the river basin. The sediment yield for the Lower Mbuluzi (downstream to the sugar estates) was estimated to 350 t/km^2 per year (SWECO & Associates, 2005).

2.5.2 Groundwater

2.5.2.1 Groundwater availability

The establishment of boreholes could be an important way to curb the endemic water shortages in the study area, but this is generally obstructed by lack of adequate groundwater yield potential.

In hydrogeological terms, the major part of the study area is characterised by crystalline rocks, basalts and consolidated sedimentary rocks with no primary porosity, where groundwater occurrence is restricted to secondary features such as zones of fracturing or deeper weathering (SWECO & Associates, 2005). Siting of boreholes is difficult and yields obtained are typically very low, in the range of 0 to 2 l/s (SWECO & Associates, 2005).

Groundwater was in the past the main source of drinking water in the study area, but in recent years, most of the old boreholes have run dry and the attempts to drill new ones have not been successful (Africon, 2005). However, groundwater still plays an important role in supplying water in the study area as it is, for some communities, the sole source of water for domestic use.

2.5.2.2 Groundwater quality

The Rural Water Supply Branch of the Department of Water Affairs indicated that all water quality tests on boreholes in the area indicated that water quality is good when compared to WHO guidelines (Dlamini A. , 2012), although no test results or reports were available for reference.

There are some localised high fluoride concentrations in some boreholes, but these are not a threat to human health (Knight Piesold , 2011).

3. WATER RECONCILIATION

3.1 Background

For domestic use, people of Lomahasha generally rely on raw water from rivers and small dams or ponds. However, these sources of water are most of the time dry during winter months and people have to travel kilometres to fetch water, as the area is characterised by a severe water scarcity and recurrent drought situations. This problem needs a sustainable remedy. This has been the main motivation which inspired the undertaking of the present study which now intends to propose a solution to end this unacceptable status-quo.

The Government of Swaziland has the duty to ensure that the people of Lomahasha, like any other citizens, have access to required quantity and quality of water for their domestic needs. This is line with the Constitution of Swaziland which was adopted in 2006 and does make mention of issues related to water resources management and fair sharing of natural resources for present and future generations.

The Swaziland Water Services Corporation (SWSC) was established by the Water Services Corporation Act, 1992. The Act gives the Corporation the mandate to supply water to persons residing or carrying on business in areas under its responsibility (Ministry of Natural Resources, 1992). In discharging this mandate, the SWSC prepares plans for the development of water resources and for the supply of water, and construct and maintain the water supply systems.

The present study is destined to assess and indicate the best way to fulfil the SWSC's mission with regard to the sustainable supply of water to Lomahasha. This required a prior evaluation of the water demand needed and the assessment of the capability of existing sources to meet that demand.

3.2 Demographics

An estimate of the population of the study area was carried out on the basis of the Census data of 2007. This information was verified using the homestead lists obtained from the Inkhundla Office and on the basis of physical observations carried out during the time of the study.

It was found that the Census data was close to the reality on the ground while the homestead lists were often biased probably as a consequence of tricks used to increase food ratios.

Population projections were carried out on the basis of an annual growth rate of 2.9% as recommended by the CSO (CSO, 2007), and by the Swaziland Rural Water Design Manual (Rural Water Supply Branch, 2003). However, the population growth is impacted by HIV/AIDS which started to be an epidemic in Swaziland since 1986. Comparison between population totals in the 2007 Population & Housing Census and the 1997 Census, gives a nominal national annual growth rate of 1.1% and an urban growth rate of 1.0%. The figure is 1.4% for the Lubombo region.

3.2.1 Determination of the Analysis Period

The determination of the most appropriate analysis period for a water supply assessment study is mainly based on the following considerations:

- The expected service life of water supply system components;
- The resilience and expected durability of existing infrastructures on which will depend the proposed development;
- Human resources, financial and technical capability of the organization responsible for the operation and maintenance of the system.

Based on these criteria, the analysis period for this study has been set to 15 years from the commissioning of the system. The lead period from the time of this report to the date of commissioning can be estimated to 2 years.

Therefore all projections have been made up to the project horizon of 2029. For illustrating the development of population over time, intermediate years (based on 5 year intervals) are also shown in the projection tables.

3.2.2 2007 Census Data

The study area includes 48 Enumeration Areas as shown in Figure 13 below (CSO, 2007).

The total population of the study area in 2007 was estimated to be 22 239 people (CSO, 2007). The average population density was 69 individuals per km^2, on a total surface area of about $322km^2$. There are 3299 rural homesteads with 4231 households. The males represent 46% of the total population against 54% for the females. The central locality of Lomahasha includes 6 enumeration areas with a total of 2868 people.

In rural Swaziland, it is important to note the number of households in a homestead as, in most of the cases, married children still live with their parents but in different houses within the same homestead. Also, in case of polygamy, each wife has a house within the homestead. A household is understood to be a group of people eating from the same cooking pot. Generally people in one household live under the same roof but they can also sleep in different buildings next to each other, as long as they cook and eat from one pot. A homestead is a group of people living together in one delineated location, and generally linked by a certain level of family relationship. A homestead is made of one or several households.

The location of the Enumeration areas is shown in Figure 13:

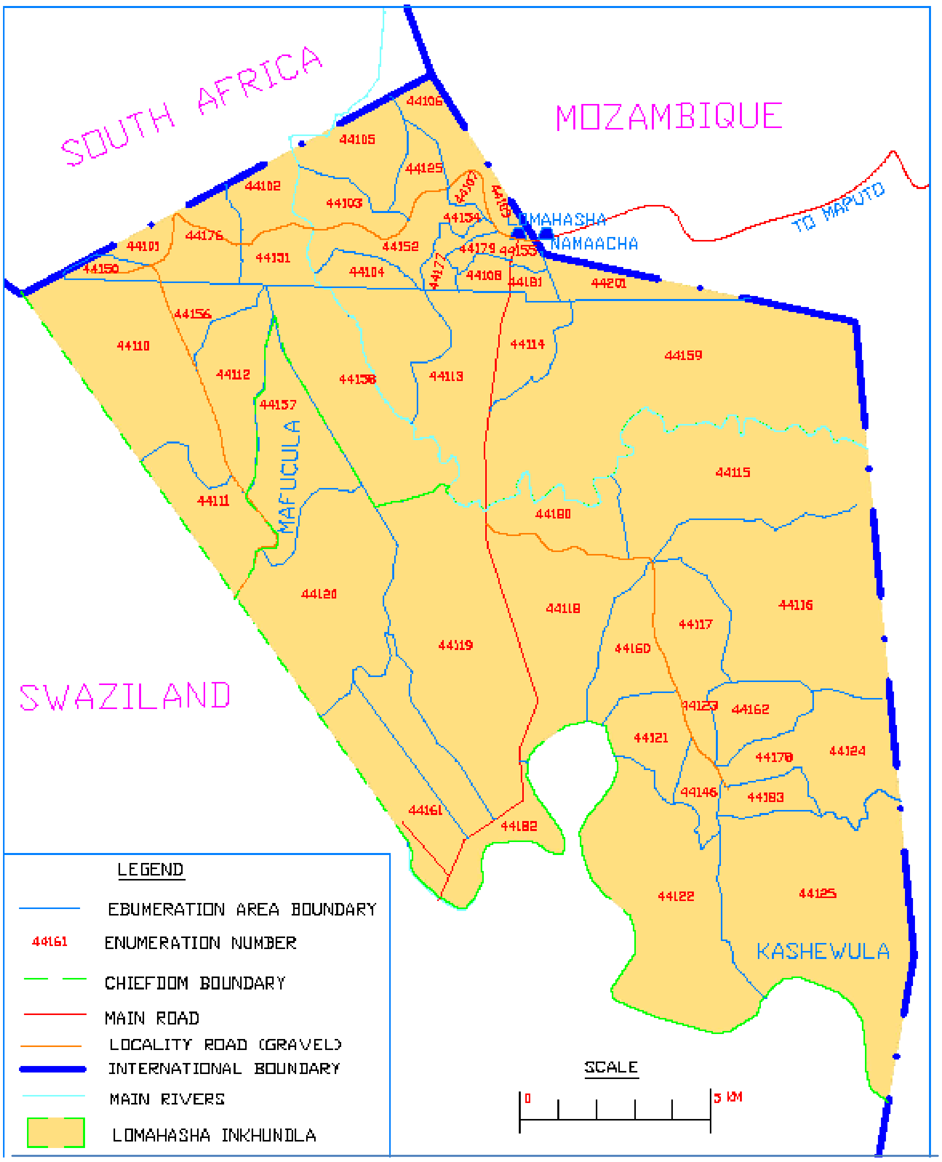


Figure 13: Enumeration Areas of Lomahasha Inkhundla.

3.2.3 Population projections

For the purpose of this study, two scenarios have been considered in the population projections.

- Scenario 1: Normal growth at 2.9% as suggested by (CSO, 2007).
- Scenario 2: Depleted growth of 1.4% due to HIV/AIDS effects.

Assuming a constant growth rate for the whole duration of the design period, the population development has been carried out using the following model.

$$Pop_n = Pop_0\,(1+gr)^n \quad \text{(Equation 1)}$$

Where

- Pop_0: Base Year Population. In this case, population of the year 2007;
- Pop_n: Population in the year 2007+n;
- gr: Annually Population Growth Rate;
- n: number of years after the Base Year of 2007.

The projections have been based on the total population as per the 2007 Census. The two chiefdoms of the Lomahasha Inkhundla have been considered separately in the projections and, starting from 2007, intermediate projection steps of 5 years have been used.

Tables 1 and 2 below present the population projections for the growth without and with depletion due to HIV/AIDS.

Table 1: Growth without depletion due to HIV/AIDS

Chiefdom	2007	2012	2014	2019	2024	2029
Lomahasha	11412	13166	13940	16082	18553	21404
Shewula	10827	12491	13226	15258	17602	20307
Total	22239	25656	27166	31340	36156	41711

Table 2: Growth with depletion due to HIV/AIDS

Chiefdom	2007	2012	2014	2019	2024	2029
Lomahasha	11412	12234	12578	13484	14455	15495
Shewula	10827	11606	11934	12793	13714	14701
Total	22239	23840	24512	26277	28168	30196

Figure 14 presents the population projections in both scenarios (without or with depletion due to HIV/AIDS).

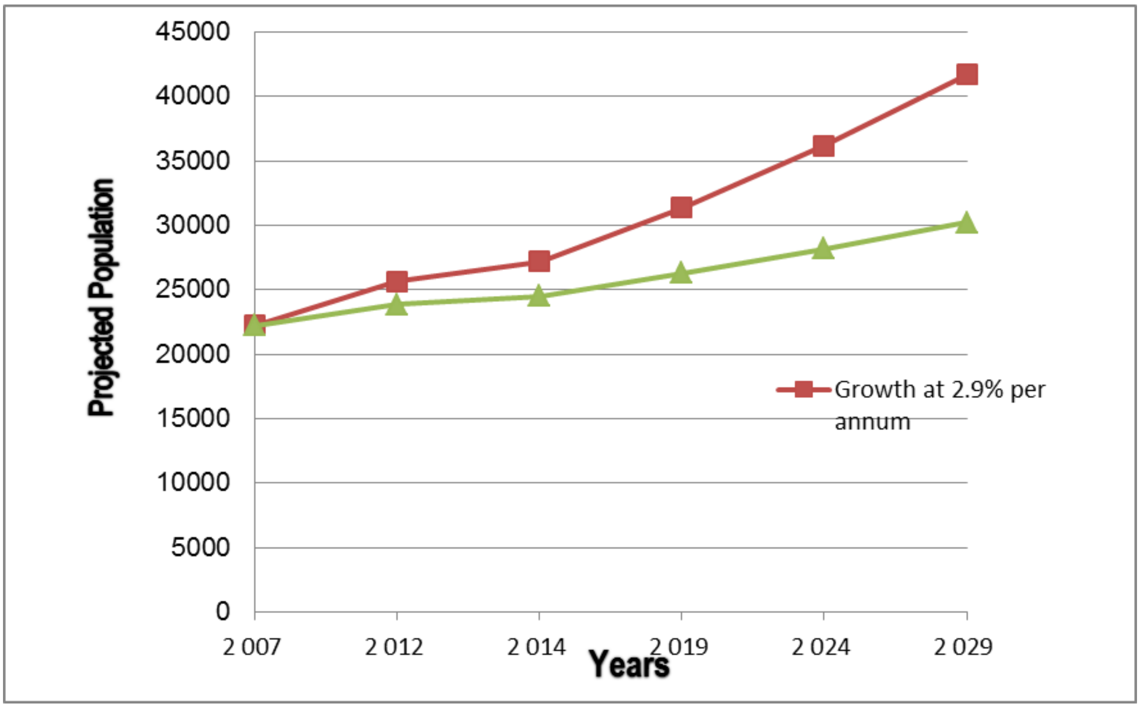


Figure 14: Population projection with and without depletion due to HIV

3.3 Existing Water Supply Systems in Lomahasha

Physical inspections have been carried out as part of this study in order to garner information on the current water supply situation within Lomahasha Inkhundla. Also, as-built drawings were consulted and discussions were held with SWSC operations engineers and technicians, and relevant stakeholders were contacted to gain a clear understanding of the present state of the existing systems.

Interviews were carried out at homestead level to gain information from the people on the ground about various means utilised to source water for domestic use and to understand their feelings with regards to the lack of adequate water supply within the area. Details are presented below.

3.3.1 Discussions with stakeholders

Discussions were held with following stakeholders: Local communities, SWSC Eastern Region Office, Rural Water Supply Branch in Lubombo Region, Lomahasha Border Post, Lomahasha Clinic, Lomahasha High School, Residents and business operators, Microprojects Programme and Ministry of Economic Planning and Development.

From these discussions, it was established that the availability of potable water is a paramount prerequisite not only for the socio-economic development of the area but also for its sustainability as an inhabitable area. The respondents indicated that there is a clear tendency to abandon localities without potable water and build new houses in areas where adequate water supply systems are available or just relocate to neighbouring areas of Mhlume and Dvokodweni where there are no issues related to availability of potable water.

There have been a number of interventions in the past, particularly by Rural Water Supply Branch, Microprojects Programme, World Vision and others, but they generally failed to be efficient due to the lack of adequate water sources (Africon, 2005). The only system which has been installed successful and which is running is the Mafucula Water Supply System installed by SWADE as part of the Komati Downstream Development Project (Dlamini , 2012).

3.3.2 Interviews at homestead level

Interviews at homestead level were carried out to assess the accessibility to various sources of water, and to have a feel of the hardship endured by local people as a result of lack of access to an adequate water source.

In total, 20 homesteads were visited, 10 in Lomahasha Chiefdom and 10 in Ka-Shewula. The interviewed people were presented with a form (see Appendix 1) which was filled up with following information.

- Identification and size of the homestead;

- Water sources for drinking, washing and gardening uses;
- Distance travelled to fetch water;
- Average quantity of water used in a day;
- The family member who generally fetches water;
- Sanitation system used.

The interviews showed that more than 60% of homesteads get drinking water from Nkalashane River, and travel a distance exceeding 2km to fetch water. Generally, the fetching of water is a duty for children and most of the families use between 20 litres and 200 litres in a day for domestic needs.

The majority of the homesteads interviewed have a size between 4 and 10 people and, unfortunately, some families were found to be without any form of sanitation system.

The results of the survey are presented in Figure 15.

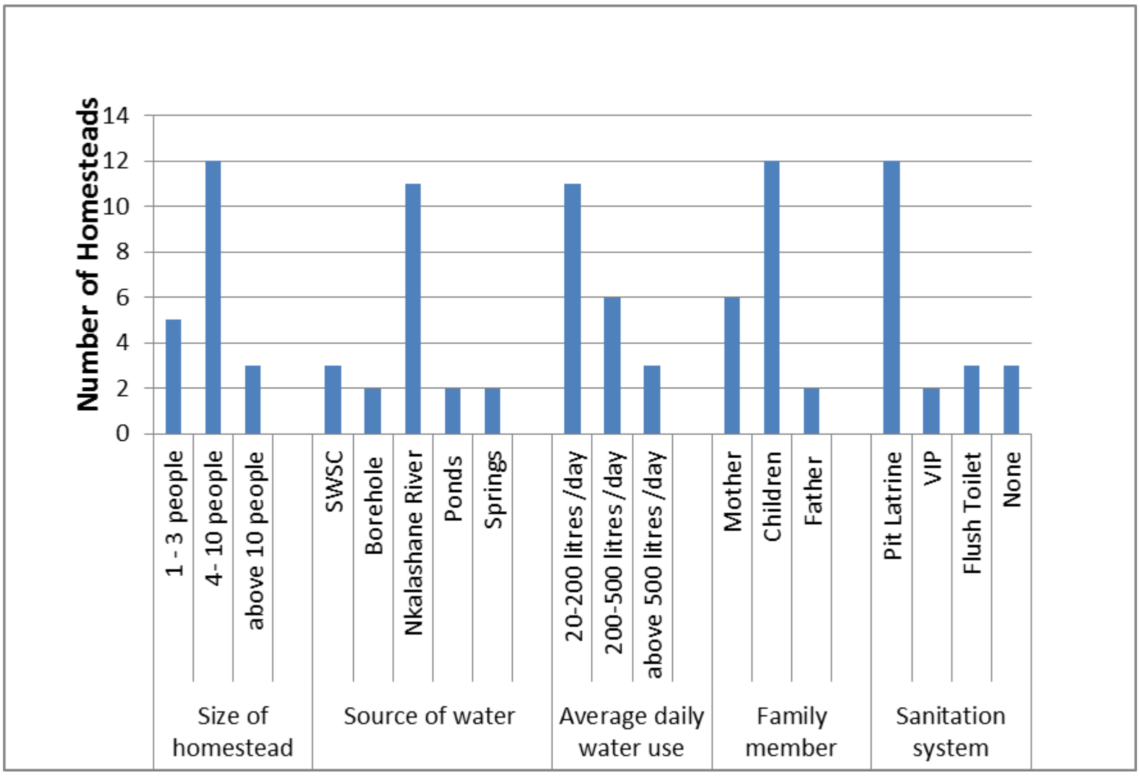


Figure 15: Results of interviews on sources of domestic water in the project area

It is to be noted that the extrapolation of the results of this survey to the overall study area would be erroneous as the 20 homesteads interviewed may not be an adequate representative sample of the whole Lomahasha Inkhundla.

The assessment of existing water sources for the study area was carried out by physical inspection and discussions with various Government organs (Microprojects Programme, Department of Water Affairs, SWSC) and other organisations (World Vision, Save the Children) dealing with water in both Lomahasha and Ka-Shewula chiefdoms.

3.3.3 Lomahasha Chiefdom

People in Lomahasha Chiefdom get drinking water from the following sources:

a) The SWSC water supply system;
b) Small schemes developed by Rural Water Supply Branch or World Vision;
c) Protected springs and handpumps;
d) Rainwater harvesting;
e) Raw water from perennial rivers (Mbuluzi and Nkalashane);
f) Raw water from streams and small dams.

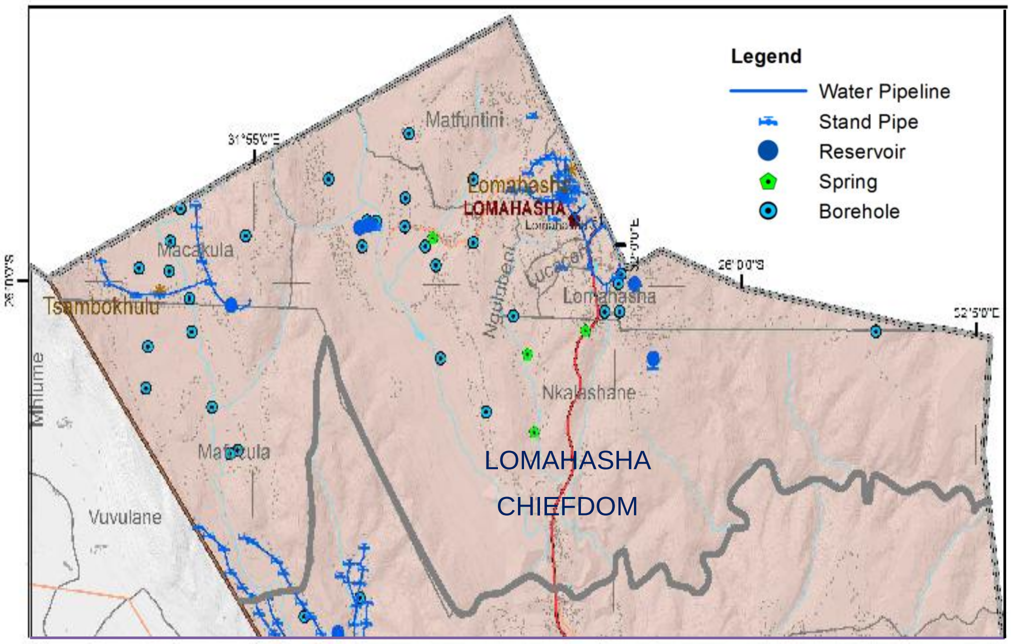


Figure 16: Water Supply Systems in Lomahasha Chiefdom

The information on the SWSC water supply system at Lomahasha was obtained from the Regional Office of the Corporation at Siteki. The information indicated that 76 water connections were in place at Lomahasha and the population supplied was estimated to be 760 people (Dlamini, 2012), which is about 7% of the total population of the study area.

The Regional Rural Water Supply Branch of the Ministry of Natural Resources provided information on the number and locations of small schemes in place in the study area (Dlamini, 2012). This information was supplemented by site inspections to estimate the number of people supplied by these schemes. Also the estimation of people supplied by hand pumps and improved springs was done through physical site inspections. It was found that 2% of the people in Lomahasha were supplied with water from handpumps, small rural schemes and improved springs developed either by Rural Water Supply Branch or by the local communities with assistance from World Vision. The remaining 91% of the population rely on raw water from rivers, streams and small dams.

The distribution of people per source of water is shown in the table below.

Table 3: Distribution of people per type of water source in Lomahasha Chiefdom

No	Water Source	% served
1	SWSC System	7%
2	Raw water	91%
3	Hand pumps	0.4%
4	Improved springs	0.6%
5	Small rural schemes	1%

This distribution shows that more than 90% of the people in Lomahasha get water for their domestic needs from rivers, and other surface water sources including ponds and dams. The SWSC system at the border post supplies 7% of the population and about 2% is supplied by improved springs, hand pumps and small rural water schemes.

3.3.3.1 Existing SWSC system

The SWSC system is perceived to be the most reliable source of water in the area, although with some imperfections. Its coverage is only limited to the area near the border post.

Based on physical inspections and feedbacks received from the contacted stakeholders, the existing SWSC system can be described as follows.

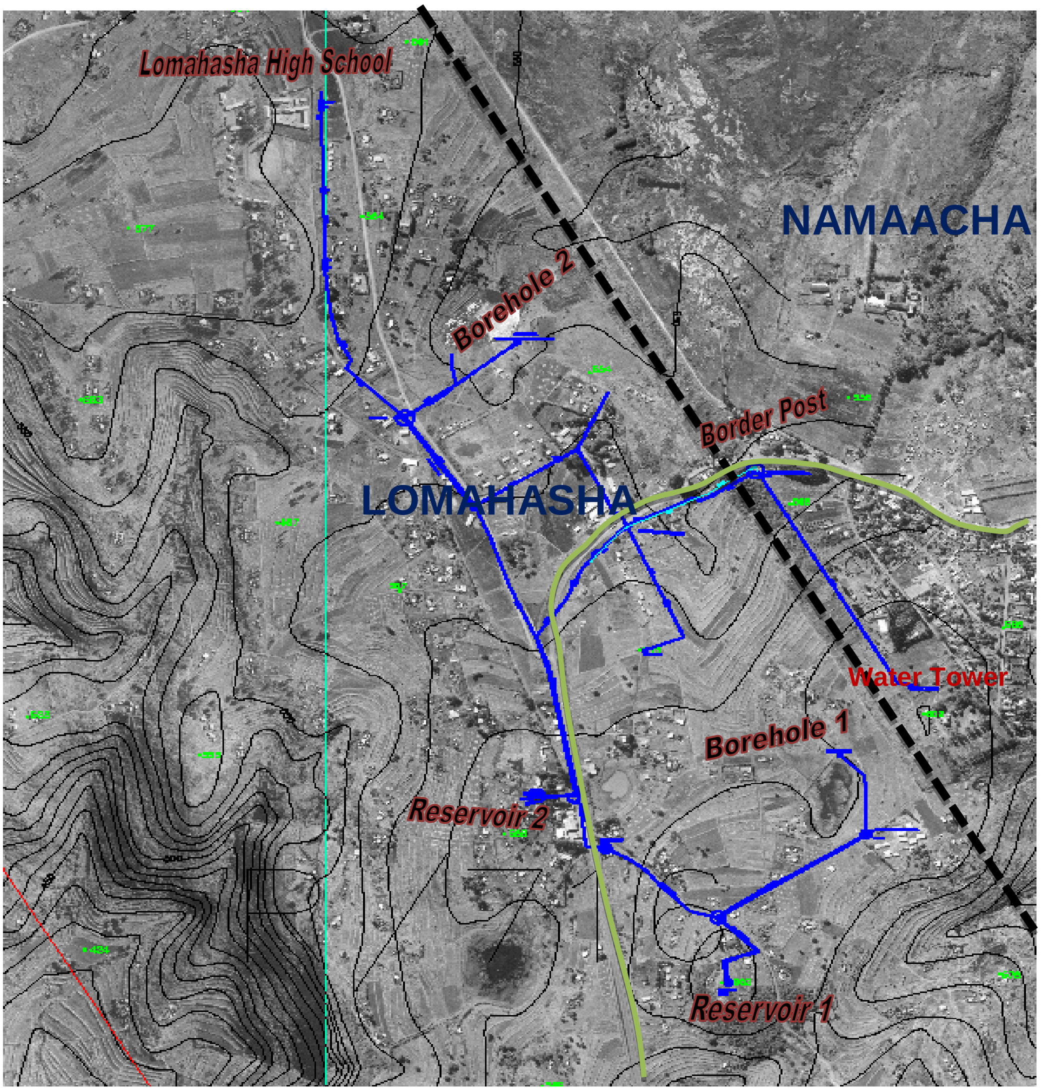
Source of water.

The source of water for the existing SWSC Lomahasha water supply system is mainly boreholes. Presently there are two boreholes in operation.

- ✓ Borehole No.1 located near an earth dam at about 250m north of Emafusini Primary School. It is located at S 25^{o} 59’ 48.1’’ and E 32^{o} 00’ 02.8’’. The pump runs 24 hours per day (Elwyn, 2012) and it was delivering 0.91 l/s at the time of the visit.

- ✓ Borehole No. 2 located along the D43 road at about 700m before the Lomahasha High School when driving northward. It is located at S25^{o} 59’ 10.8’’ and E31^{o} 59’ 34.0’’. The pump runs 7 days per week and 24 hours per day (Elwyn, 2012), and was delivering 0.833l/s as read from the meter at the time of the inspection.

The reliability of the borehole supply in the area is questionable as already some old boreholes were abandoned because of their failure to produce enough yield to supply the system.



Legend

Water Pipeline

Border line, Swaziland / Mozambique

Main Road (MR 3), Mbabane to Maputo

Figure 17: Existing Lomahasha SWSC's Water Supply System

The second source of water to supply the existing SWSC water system is the connection to Namaacha reticulation in Mozambique. As shown on Figure 17, there is a 110mm diameter pipeline supplying the Lomahasha system from the water tower in Mozambique.

In 2007, SWSC and Aquagest Levante from Mozambique signed an agreement to supply water to Lomahasha from Namaacha at a price of R3.75/m^3 (Zizhou, 2012). The implementation of the agreement started in February 2008 and by February 2010 the total quantity of water supplied was about 7,502 m^3 for the two years (Zizhou, 2012). This is an average of 10m^3 per day, which is about 1/6 of the total water consumption of the Lomahasha area.

Water Storage

The water is presently stored in two reservoirs. Reservoir No.1 constructed at an elevation of about 600m (amsl) at 26^o 00' 21.2'' S and 32^o 00' 08.7'' E. This a concrete structure located near a military camp site, with a capacity of 120m^3. At the time of the site visit, this reservoir was overflowing (Figure 18). Considering the condition of the surrounding vegetation, it was evident that the reservoir had been overflowing for an extended period of time. The general condition of the structure is good, except for some leaks observed in the walls.

Some house connections are in a dilapidated condition as it can be seen from the photo in Figure 18. Plastic pipes and fittings are exposed above the ground, in an area where children play.

Concrete reservoir located at Army Camp, Reservoir 1

Pipe work at a house connection at Lomahasha

Figure 18: Concrete reservoir and house connection at Lomahasha

Reservoir No. 2 is constructed with galvanized steel panels (ABECO type). It is made of 7x7 panels in plan with 3 panels in height. Its capacity is about 250m³. This reservoir is constructed at an elevation of 580m (amsl) at S 25^o 59' 51.2'' and E 31^o 59' 36.0''.

In the view of the structural engineer who was approached to seek advice, the structure is in a very bad condition (Magagula, 2012). In order to prevent the collapse of the tank, it was suggested to remove the tree which had grown against the foundation walls (Magagula, 2012). Some panels on the vertical faces have moved causing a general deformation of the structure, as shown on Figure 19.

Deformed panels in the reservoir

Growing tree at foundation

Figure 19: Damaged galvanised steel panel reservoir

The ground levels within the presently supplied area vary from 580m to 550m above sea level. The pipework is generally 110mm and 90mm uPVC class 9 pipes. The total length of the transmission and distribution lines is about 6km.

According to the SWSC Regional Manager in Siteki, the water connections in place in Lomahasha include (Dlamini , 2012): the border post, Lomahsha High School, Emafusini Primary School, Lomahasha clinic, World Vision offices, the police post and the police flats, shops and business centres, residential connections.

3.3.3.2 Water points and small rural schemes

Rural Water Supply Branch (Ministry of Natural Resources and Energy) has developed some protected springs and water points with hand pumps but these are only used by people in their close vicinity. The list of existing schemes was obtained from the Rural Water Supply Branch and a site visit was carried out for those which could be found.

In total 13 springs, 2 dams and 18 boreholes with handpumps are in place as presented in Table 4. Some micro-schemes are supplied by two combined types of source.

Table 4: Existing micro-Schemes in Lomahasha Chiefdom

No	Name of the Scheme	Type of source
1	Makhehla water scheme	Borehole
2	Hlalane water scheme	Borehole
3	Mbokojweni water scheme	Borehole
4	Mashushu water scheme	Spring
5	Mhleleni water shcme	Spring
6	Kumanzini water scheme	Spring and borehole
7	Sicatfula water scheme	Spring and borehole
8	Dzinwane water scheme	Spring and borehole
9	Edamu water scheme	Spring
10	Kasibambo water scheme	Spring
11	Ngulubeni water scheme	Spring and borehole
12	Lasungulo water scheme	Spring and borehole
13	Namshabi water scheme	Spring and borehole

No	Name of the Scheme	Type of source
14	Mahabane water scheme	Spring and dam
15	Bandeni water scheme	2 boreholes
16	Dam Mkangala water scheme	Spring and dam
17	Mkangala water scheme	Spring
18	Tigodzini water scheme	Borehole
19	Timbuti water scheme	Spring and borehole
20	Makhonjwa water scheme	Borehole
21	Mafusini water scheme	Borehole
22	Edvumaneni water scheme	Borehole
23	Majayi water scheme	Borehole
24	Edvumaneni water scheme	Borehole
25	Mbhabubovu water scheme	Borehole
26	Mhlambelo water scheme	Borehole
27	Mkhiweni water scheme	Borehole
28	Ngazini water scheme	Borehole
29	Macabeni water scheme	Borehole

Interviewed people stated that in general, all the protected springs dry up toward the end of July or beginning of August. The majority of the boreholes was found to be non-functional at the time of the site inspection.

Fairly protected spring

Hand pump at Ka-Shewula

Figure 20: Protected spring and hand pump in the project area

There are two small schemes developed by local communities with the assistance of World Vision. They supply four and five public standpipes respectively, without any house connections. They are all supplied by boreholes, which most of the time, dry up toward the end of dry season.

Stand pipe at Lomahasha

Break Pressure Tank

Figure 21: Components of existing water supply systems in Lomahasha

Some boreholes at homesteads or public facilities have been found in the area. Except Lomahasha High School and Lomahasha Clinic which are supplied by SWSC system, other schools and clinics in the area have developed their own boreholes. Boreholes at the homestead level are not common because of their high cost.

3.3.3.3 Raw water from rivers, streams and ponds

More than 90% of the population in Lomahasha rely on rivers, streams and small dams or ponds as sources of drinking water. To make the situation worse, most of these sources of water are not perennial and people have to walk long distances to get water particularly in dry months when flows can be found only in major rivers.

Figure 22 shows two main types of water sources in the area, Nkalashane River and a pond formed in an old borrow pit.

Nkalashane River at the crossing of MR3 in February 2012

Small dam in an old borrow pit along gravel road to Ka-Shewula

Figure 22: Sources of raw water in the project area

The majority of the people in the study area fetch water from Nkalashane River which traverses the whole study area from north to south. During winter time when the river is dry, people dig holes near or in the riverbed to extract water.

The agglomeration of Maphiveni fetches water from Mbuluzi River, which is a perennial river as shown in Figure 23.

Mbuluzi River near Maphiveni, in June 2012 (left) and January 2012 (right)

Figure 23: Difference in water level in Mbuluzi (January and June 2012)

Water quality in rivers, streams and dams is also a problem, particularly in Mbuluzi River as the area is downstream of sugar fields where pesticides and fertilisers are intensively used (Matondo , 2000). Smaller rivers and dams are not better though as the flows are generally too small to dilute the pollution from upstream human activities.

3.3.4 Ka-Shewula Chiefdom

3.3.4.1 Description

Ka-Shewula Chiefdom located on the ridge of a stretch of Lubombo Mountain and is sandwiched between very abrupt slopes and dense bush lands which extend to the border with Mozambique.

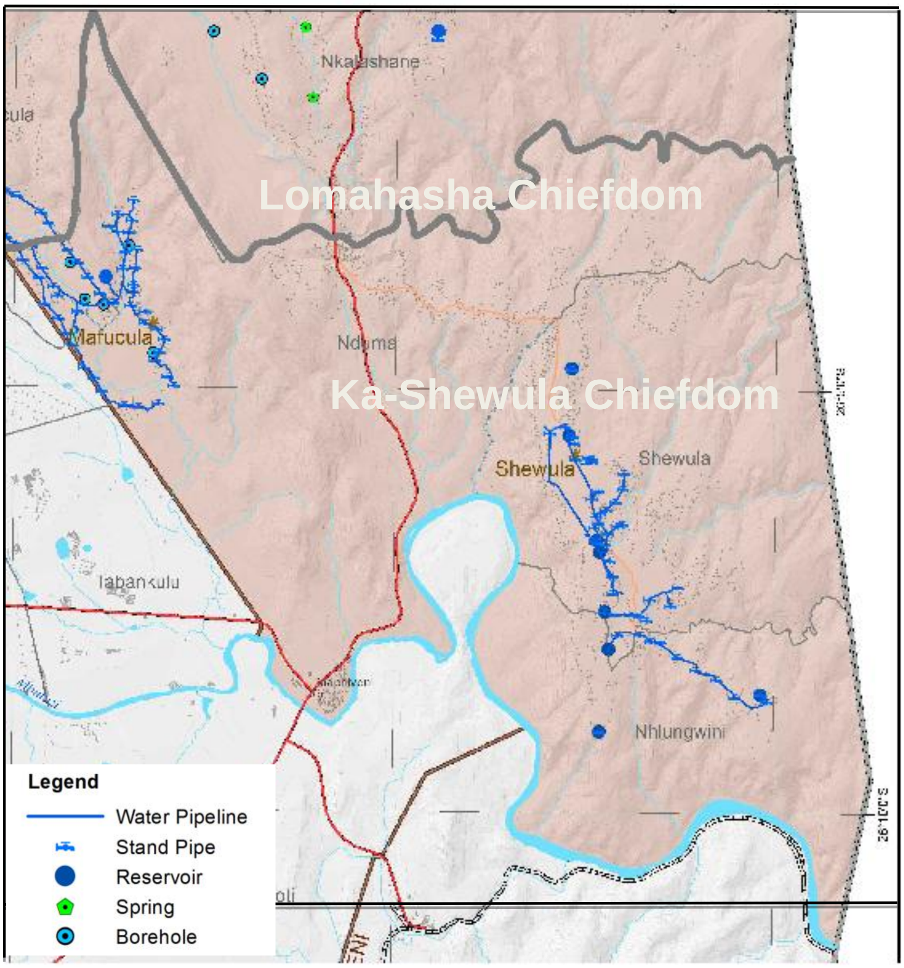


Figure 24: Water supply schemes in Ka-Shewula Chiedfom

The eastern part of the chiefdom has only one access which is the gravel road turning eastward from the MR3 at about 10km south to Lomahasha border post. This is the locality which is commonly known as Ka-Shewula area, and where the Chief's Residence is located. However the chiefdom also includes the localities of Mafucula and Tsambokhulu which are in the north western corner of the Lomahasha Inkhundla and are separated from the main Ka-Shewula by areas under Lomahasha Chiefdom. People from these localities walk across another chiefdom to be able to reach their Chief's residence (or Chief's Kraal).

3.3.4.2 Sources of drinking water in Ka-Shewula Chiefdom

People in Ka-Shewula Chiefdom get drinking water from following sources.

- The Komati Downstream Development Project (KDDP) water supply system in Mafucula area;
- Rural water schemes developed by Rural Water Supply Branch and Microprojects Programme;
- Boreholes;
- Protected springs and handpumps;
- Rainwater harvesting;
- Raw water from perennial rivers (Mbuluzi and Nkalashane);
- Raw water from streams and small dams.

The distribution of people per each source of water is shown in Table 5.

Table 5: Distribution of people per type of water source in Ka-Shewula Chiefdom

No	Water Source	% served
1	Mafucula KDDP	12%
2	Raw water	87%
3	Hand pumps	0.25%
4	Improved springs	0.5%
5	Small rural schemes	0.25%

All the raw water uses are grouped into one category as some sources (streams or ponds) are only used during the rain periods and people revert to perennial rivers after extended dry periods.

The KDDP System supplies the Mafucula community which represents about 12% of the total population of Kashewula Chiefdom. About 87% of the total population of the Chiefdom rely on raw water from rivers, streams and small dams and the remaining 1% source drinking water from handpumps and improved springs developed either by Rural Water Supply Branch or by the Japanese Corporation (JICA). The rural water supply scheme installed by Microprojects Programme in 2006 could not operate as the source (boreholes) dried up before the commissioning of the project.

3.3.4.3 KDDP Water Supply System in Mafucula

The Mafucula Community Water Supply Scheme was constructed as part of the Komati Downstream Development Project. The project was initiated by the Government of Swaziland in 2001 with a fundamental goal of poverty alleviation in the project area (ADB, 2002). This goal was achieved by transforming the farming in the area from subsistence farming into sustainable commercial agriculture. Potable water supply schemes have been incorporated in the project as part of Integrated Water Resources Management, and also as mitigation measures to social impacts caused by the construction of the project infrastructure.

Presently the Mafucula Farmers Association grows sugar cane on an irrigated area of +/- 300 Ha (RDMU, 2007). The water for irrigation and domestic uses is obtained by inter-basin transfer from Komati River, via a canal which supplies Mhlume sugar estate. A 3 kilometre pipeline transmits water from Mhlume Canal to a storage reservoir (dam) at Mafucula (RDMU, 2007).

The Mafucula Potable Water Supply includes the following components (Emmanuel, 2012).

- Raw water intake by gravity from a dam;
- A treatment plant with two slow sand filters and two roughing filters;
- A pump station with two clear water pumps in duty/standby set up;

- A rising main of 1.745km in 75mm diameter uPVC pipes and about 0.5km of 80mm galvanised steel pipe;
- A distribution network of about 25km generally in uPVC and HDPE pipes with galvanised steel pipes at dongas and rock outcrops.

The system supplies water to 260 homesteads, with a total population of about 1700 people (Emmanuel, 2012).

3.3.4.4 Existing infrastructure in main Ka-Shewula area

The Ka-Shewula community has been of interest to a number of initiatives with regard to water supply. However all these end up becoming futile due to lack of suitable water sources.

The existing infrastructure at Ka-Shewula is presented inTable 6.

Table 6: Existing water supply infrastructure in Ka-Shewula

Project Proponent	Year	Type of works	Present Condition
RWSB	1980's	3 protected springs	Out of order
JICA, DFID &RWSB	1990's	8 boreholes	Only two working
RWSB	2001	1 protected spring	Working
RWSB & Italian Government	2004	2 protected springs	Working but incomplete
Microprojects Programme	2006	2 boreholes, 1.3km transmission line, 2x120m^3 reservoirs, 7.5km distribution lines	Construction complete but system not working as sources run dry

Source: (Africon, 2005)

3.4 Water Demand Forecast

3.4.1 Urban and peri-urban areas

Currently, only 76 connections to the SWSC water system are in place at the settlement around the border post at Lomahasha. This is a connection rate of less than 20% for what can be designated as Lomahasha Central area. The low connection rate is mainly caused by the limitations of the existing system in terms of capacity and coverage. The reticulation is basically composed of one pipeline from the reservoir to the border posts with three small branches supplying Lomahasha High School, Emafuseni Primary School and the police flats respectively. Even with these few connections, the supply is not reliable mainly due to lack of adequate water source and distribution system.

Based on experience in similar water supply systems in the same area, and taking into consideration the standard of living of communities in Lomahasha, the connection rate at the commissioning of the new water supply system can be estimated at 50% (Zandamela, 2003). This also takes into consideration the remoteness of some homesteads, especially in the Lomahasha peri-urban area, for which the coverage of the reticulation would be impractical.

The water supply system resulting from this study should follow the full cost-recovery principle, with an operation which should provide a cost-effective and efficient water service. However, the proposed system will be developed in areas where poverty level is high and the issue of affordability should be taken into consideration. Private connections to some potential consumers may be handicapped by the difficult terrain in the study area and the remoteness of some houses in the peri-urban localities.

Therefore public standpipes are considered in this study. These will be located at public facilities including schools, clinics, churches, etc. but also at specific locations where low income and remote communities can fetch water for domestic uses. A pre-paid metering system would be considered to ensure that all water used is paid for.

At the commissioning of the project, all the people in the urban and peri-urban areas should have access to clean potable water. Two levels of service are considered for the urban and peri-urban areas, as follows.

1. Level of Service 1: Private connections (houses): 50%
2. Level of Service 2: Communal Standpipes: 50%

After the commissioning of the project, the percentage of people using house connections is expected to increase with the improvement of living standards of the people. This increase can be estimated at 1% per annum based on the information on connection rate annual increase supplied by the SWSC Regional Office (Dlamini, 2012).

3.4.2 Rural areas

The study area included rural communities, particularly most of those along the main road MR 3, and in remote areas of Ka-Shewula and Lomahasha.

The service level distribution for rural areas would be based on the recommendation of the Design Manual for Rural Water Supply Systems in Swaziland (Rural Water Supply Branch, 2003). It is a requirement in Swaziland to follow this Design Manual for any design of rural eater supply systems.

The three levels of service to be considered for the rural areas is as follows (Rural Water Supply Branch, 2003).

1. Level of Service 1: Communal standpipes 50%
2. Level of Service 2: Private connection (yard tap) 30%
3. Level of Service 3: Private connection (house connection) 20%

It is assumed that if a new water supply system is commissioned in the study area, all the households will have access to clean potable water either by a house connection or via a public stand pipe. After the commissioning of the project, the distribution of the population over various level of service is expected to increase in the favour of private connections as a result of potential improvement of life standards in the area. The Rural Water Supply Branch estimated an annual increase of 1% for yard taps and house connections, and an equivalent decrease in the use of communal standpipes (Dlamini, 2012).

The estimation of the population connected to various levels of services has been carried out as follows:

$Pop_{in} = Pop_n \times f_{in}$ (Equation 2)

Where Pop_{in}= Population connected to level of service i in the year n; Pop_n= Total Population in the year n; and f_{in}= Percentage of people connected to level of service i in the year n.

After the commissioning of the project f_{in} will increase at a rate of 1% per annum for house connections and will decrease at the same rate of 1% for communal stand pipes. Then f_{in} can be calculated as follows.

$f_{in} = f_{i0}\,(1+gr_i)^n$ (Equation 3)

Where f_{in}= Percentage of people connected to level of service i in the year n; f_{i0}= Percentage of people connected to level of service i at the commissioning of the project; gr_i= growth rate of connection percentage for level of service i; and n = number of years after the commissioning of the project.

The project is assumed to be commissioned in 2014, thus 7 years after the Census year of 2007.

The distribution of population to various levels of service is shown in Table 7.

Table 7: Distribution of population to various levels of service

Area	Years					
	2007	**2012**	**2014**	**2019**	**2024**	**2029**
Lomahasha Town						
Total Population	2868	3309	3503	4042	4663	5379
People on House Connection			1752	2124	2575	3123
People on Standpipes			1752	1918	2087	2257
Lomahasha Rural						
Total Population	8544	9857	10437	12041	13891	16025
People on House Connection			2087	2531	3069	3721
People on Yard Connection			3131	3796	4603	5581
People on Standpipes			5218	5713	6219	6723
Shewula						
Total Population	9617	11095	11748	13553	15635	18038
People on House Connection			2350	2849	3454	4188
People on Yard Connection			3524	4273	5181	6282
People on Standpipes			5874	6431	7000	7567
Mafucula						
Total Population	1210	1396	1478	1705	1967	2269
People on House Connection			296	358	435	527
People on Yard Connection			443	538	652	790
People on Standpipes			739	809	881	952
Total	**22239**	**25656**	**27166**	**31340**	**36156**	**41711**

3.4.3 Estimation of the water demand

3.4.3.1 Domestic use

The average daily water demand for house connections in urban and peri-urban areas has been estimated to be 100 litres per person, based on current invoiced water consumption rates for residential areas and taking into consideration the anticipated slight increase of service levels of the water supply system. This correlates well with the figures of 80–145 litres per person per day recommended by the Guidelines for Human Settlement Planning and Design (CSIR , 2003). The Design Manual for Rural Water Supply Systems recommends 80 litres per person per day for rural areas (Rural Water Supply Branch, 2003).

For rural areas, the daily water demand for private connections and public standpipes can be estimated on the basis of the design criteria included in the Design Manual for Rural Water Systems in Swaziland (Rural Water Supply Branch, 2003).

The following average daily demands for various levels of service are to be used (Rural Water Supply Branch, 2003).

Table 8: Average Daily Demand per Capita for various Service Levels

No	Service Level	Average Demand
1	Communal standpipes	30 l/day/capita
2	Private connection (yard tap)	45 l/day/capita
3	House Connection – Rural	80 l/day/capita
4	House Connection – Urban & peri-urban	100 l/day/capita

To estimate the domestic water use, only the population growth scenario without the effects of HIV/AIDS is to be taken into consideration. In the case of population depletion resulting from HIV/AIDS, the water demand per person may increase and this would counterbalance the decrease of the population. Also the long term prediction of the HIV/AIDS effects is difficult to carry out as the continuous research efforts may lead to significant mitigation on population depletion.

The average daily water demand per capita was assumed to remain constant for the duration of the analysis period. The Regional Manager of Swaziland Water Services Corporation in Siteki also confirmed that the records of past water consumption reveal that the billed quantity per connection is on average stable in time, and that the observed variability was due to change in rate of losses as a result of the ageing of the systems (Dlamini, 2012).

The Regional Manager also indicated that seasonal and weather related variations are noticeable but do not translate into any patterns showing a regular increase of water demand per capita with time (Dlamini E. , 2012).

The calculation of Projected Average Daily Demand over the analysis period is presented in Table 9.

Table 9: Estimation of the Domestic Average Daily Demand (in m^3/day)

Area	**Years**			
(Water Demand in m^3/day)	**2014**	**2019**	**2024**	**2029**
Lomahasha Town				
House Connection	175	212	258	312
Standpipes	53	58	63	68
Sub-total for Lomahasha Town	228	270	320	380
Lomahasha Rural				
House Connection	167	202	246	298
Yard Connection	141	171	207	251
Standpipes	157	171	187	202
Sub-total for Lomahasha Rural	464	545	639	751
Ka-Shewula main area				
House Connection	188	228	276	335
Yard Connection	159	192	233	283
Standpipes	176	193	210	227
Sub-total for Ka-Shewula main area	523	613	719	845
Mafucula				
House Connection	24	29	35	42
Yard Connection	20	24	29	36
Standpipes	22	24	26	29
Sub-total for Mafucula	66	77	91	106
Total for Lomahasha Inkhundla	**1281**	**1505**	**1769**	**2082**

The Total average domestic daily water demand for the study area is estimated to be 2082 cubic metres per day.

3.4.3.2 Non-domestic use

The following non-domestic water users have been considered in this study: government and private offices, shops and commercial centres, schools, clinics, border post, industrial water use, churches and Shewula Mountain Camp.

Government and private offices.

The Guidelines for Human Settlement Planning and Design recommends an allocation of 400 litres per 100m^2 of floor area for offices.

The demand for offices in Lomahasha has been estimated as follows.

Table 10: Estimation of Average Daily Demand for Offices

No.	Office	Floor area (m^2)	Demand
1	2 Police Stations	500	2 000 l/day
2	World Vision	250	1 000 l/day
3	Inkhundla	500	2 000 l/day
4	Chief's Residences (2No.)	1250	5 000 l/day
5	Various Private Offices	1250	5 000 l/day
Total		**3750m^2**	**15 000 l/day**

Shops and commercial centres

Two mini-commercial centres are in place in Lomahasha, one near the border post, with about 15 shops, and the other one at the south western entrance of Lomahasha along MR3, with about 25 shops of various sizes. Isolated small shops are also in place within the study area. The information obtained from the Lomahasha Inkhundla indicated that about 78 shops are in place in rural communities outside the border post area (Shongwe, 2014). The total number of shops within the study area was estimated at 118. Assuming four employees per shop, and a water demand of 45 litres per day per person, the demand for all shops and commercial centres within the project area has been estimated to 21 240 litres per day.

Schools

Ten schools are in place in the study area. These are shown in Table 11.

Water demand for the schools has been estimated on the basis of current consumption with an allowance for future increase resulting from the improvement of level of service.

The estimated figures are as follows.

Table 11: Estimation of Average Daily Demand for Schools

No.	Name of School	Floor area (m^2)	Estimated Daily Demand
1	Lomahasha Primary School	1875	7 500 l/day
2	Lomahasha High School	1125	4 500 l/day
3	Emafuseni Primary School	1125	4 500 l/day
4	Nkalashane Primary School	1875	7 500 l/day
5	Nkalashane High School	1125	4 500 l/day
6	Mbokojweni Primary School	1125	4 500 l/day
7	Ka-Shewula Primary School	1875	7 500 l/day
8	Ka-Shewula High School	1875	7 500 l/day
9	Mafucula Primary School	1125	4 500 l/day
10	Saint Gabriel High School	1125	4 500 l/day
11	Shewula Community School	750	3 000 l/day
Total		**15 000**	**60 000** l/day

Clinics

Three clinics are in place in the study area. These are the following: Lomahasha Clinic at Lomahasha, Nkalashane Clinic at Nkalashane and Ka-Shewula Clinic at Ka-Shewula.

(CSIR , 2003) recommends an allowance of 500 litres per day for 100m^2 of floor area for clinic. Considering a floor area in the range of 400m^2, including the outbuildings, the daily water demand for each clinic can be estimated to 2000 litres per day. This fits well with the actual consumption as shown by the present water bills for Lomahasha Clinic.

Churches

Most of the church services in the study area are carried out in informal places, not specifically dedicated to that use. One major church was found in the Lomahasha area along the road to Nkakashane (D43). This is the Pentecostal Assembly of Africa, which also accommodates some social education activities. Four churches of medium size are in place in Ka-Shewula area.

CSIR (2003) recommends an allowance of 2000 litres of water per day per church. The total daily water demand for churches was estimated to be 10 000 litres for Lomahasha Inkhundla.

Border Post

The water demand for the border post has been estimated to 5 000 litres per day, on the basis of the present consumption and taking into account the increase which will result from the improvement of the service delivery.

Water Demand for Industrial use

Based on experience from other industrial water consumption in towns of same size as Lomahasha, an allowance of 100 000 litres per day has been allowed for in the estimation of the total water demand.

3.5 Total Demand Forecast

The water demand forecast has been carried out for both domestic and non-domestic uses. The water demand for non-domestic use is not expected to change from now up to the commissioning of the proposed project, and thereafter it is expected to follow the same growth rate as for the population. The calculation of the total demand at the end of the design period is shown in the Table 12.

Table 12: Estimation of the Total Average Daily Demand

Water uses (Total Daily Water Demand in m^3/day)	Years			
	2014	2019	2024	2029
Domestic	1281	1505	1769	2082
Offices	16	18	21	24
Shops	53	61	70	81
Schools	64	73	85	98
Clinics	6	7	8	10
Churches	11	12	14	16
Border Post	5	6	7	8
Industrial use	106	112	119	126
Total Daily Water Demand	1541	1795	2094	2445

The design of the system components will be based on the average daily demand of **2445m^3 /day** for the year **2029** for the Lomahasha Inkhundla, based on a population growth rate of 2.9% per annum.

3.6 Peak Flow

The peak hourly flow is required for the design of pumping system and hydraulic structures. For the calculation of the peak flow from the daily average demand, a peak factor of 2.5 has been used, as obtained from the CSIR table for peak factors for developing areas (CSIR , 2003). The Peak flow is calculated as follows.

$$Peak\ flow = \frac{\text{Total Daily Demand x 2.5}}{24} \quad \text{(Equation 4)}$$

With Peak flow in m^3/h and Total Daily Demand in m^3/d.

The table below shows various values of the peak flow during the analysis period of the system.

Table 13: Estimation of the Peak Flow

Years	**2014**	**2019**	**2024**	**2029**
Total Daily Water Demand in m^3	1541	1795	2094	2445
Total Hourly Demand in m^3	161	187	218	255

The design peak flow for the project horizon of 2029 is **255m^3** per hour.

4. ASSESSEMENT OF WATER SOURCE OPTIONS

4.1 Listing of possible water source options

Based on discussions with various stakeholders, and on observations made during the site inspections, the following water sources for the supply to Lomahasha were considered.

a) Local springs

b) Boreholes;

c) Namaacha system (Mozambique);

d) Water supply from the Nkalashane River;

e) Connection from Mafucula irrigation system;

f) New intake at Mbuluzi River

g) Connection from existing system at Simunye.

The locations of the above scenarios are presented in *Figure 25*.

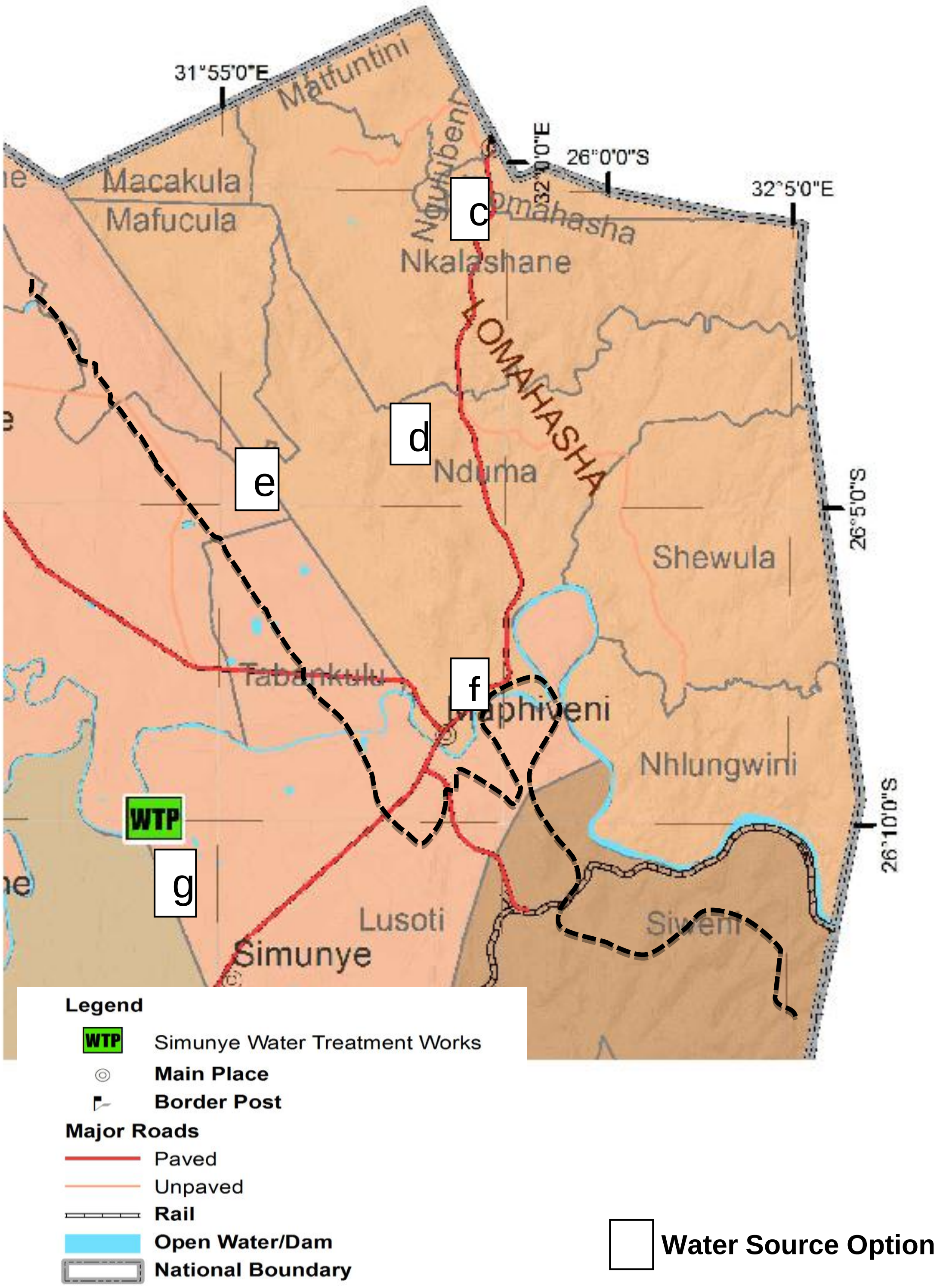


Figure 25: Position of potential water source options to supply the proposed system

Options shown in Figure 25 are: (c) Connection from Namaacha, (d) Intake at Nkalashane River, (e) Connection from Mafucula System, (f) New intake at Mbuluzi River near Maphiveni and (g) connection from existing system at Simunye.

4.2 Screening of water source options

The list of options was screened in order to identify the most suitable to be considered for detailed evaluation. The first step of the screening process was developing goals, based on the main objective of the project, by which the options will be measured.

A suitable source of water to supply the project area should satisfy following goals: (i) supply efficiency; (ii) supply sustainability; (iii) construction; (iv) ease of operation and maintenance; (v) management and (vi) protection to the environment

The options were subsequently rated against the above goals of the project using a descriptive scale of words: *Definite*, *Probable* and *Unlikely*.

A “*Definite*” rating means that the option would certainly meet the given goal to a significant degree;

A “*Probable*” rating means that the option might meet the given goal to a certain degree.

An “*Unlikely*” rating means that in no circumstances, the option would not meet the given goal.

The descriptive scale was further translated into a numerical rating by assigning a score of “0” to an “Unlikely” alternative, “1” to a “Probable” alternative and “2” to a “Definite” alternative.

The rating of the various options considered is shown in Table 14.

Table 14: Rating of various water source options

Alternatives		Goals No. i	ii	iii	iv	v	vi	Total
a	Local springs	0	0	1	1	0	1	**3**
b	Boreholes	0	0	1	1	1	1	**4**
c	Namaacha System	0	0	1	1	1	1	**4**
d	Nkalashane River	1	1	1	1	1	1	**6**
e	Mafucula System	1	1	0	0	1	1	**4**
f	New Intake at Mbuluzi	2	1	1	1	1	1	**7**
g	Existing System at Simunye	2	1	1	1	1	1	**7**

(i) supply efficiency; (ii) supply sustainability; (iii)construction; (iv) ease of operation and maintenance; (v) management and (vi) protection to the environment.

Each alternative was evaluated against all the six project goals, and a score of 0, 1 or 2 was assigned in each case. The total number of points for each alternative in all the goals was calculated and the passing criterion was fixed to a minimum total score of 6 points. Based on this, all the options which are unlikely to meet any of the project goals were eliminated. Only the options for which the fulfilment of any of the project goals is definite or probable were considered for further evaluation.

After the screening process, retained options were compared on the basis of their economic costs and environmental impacts. This required a prior preliminary design of each alternative to determine the main features of the components to be constructed.

4.3 Eliminated options

The following options were eliminated from the analysis as they did not meet one or many project goals: local springs, boreholes, Namaacha system (Mozambique) and connection to Mafucula irrigation system;

4.3.1 Local springs and boreholes

This is the status-quo scenario. Local springs and boreholes failed to provide a reliable source of water in the project area as discussed in Chapter 4. Considering the requirement to provide clean drinking water to all the people, as emphasized in the Millennium Development Goals (MDGs), a more adequate and reliable source of water for Lomahasha needs to be considered to replace the existing inefficient local springs and borehole systems.

4.3.2 Namaacha system (Mozambique)

This option is currently being utilized to complement the borehole water supply in Lomahasha. However, the potable water in Namaacha is very scarce, particularly during the dry weather months, as the town relies on non- perennial streams as sources for the municipal water supply system.

The municipal water supply system is made of an intake from three small dams built on non-perennial streams, a transmission line from the intake to two elevated storage concrete tanks of 60m^3 each (Mabunda, 2012), and a distribution network. The system is managed by a private company, AquaGest LTA, which distributes water to a total of 900 consumer connections (Mabunda, 2012). However, the management of AquaGest LTA indicated that a significant quantity of potable water is not accounted for as it is lost through illegal connections (Mabunda, 2012).

The total potable water supply billed monthly varies from 4 000m^3 to 10 000m^3 (Mabunda, 2012).

At present (October 2013), the Namaacha system does not have any additional capacity as it is not even adequate for its present supply area. An increase in capacity could be achieved by a system upgrading. However, Mabunda (2012), the manager of the system, indicated that no upgrading project implementation was expected in the near future despite the fact that various options had been envisaged at strategic planning levels. The options considered at that time included negotiations with Swaziland for a joint water project for both

Namaacha and Lomahasha with a source at the upper reaches of the Mbuluzi River, or possibly connecting from the existing treated water system in Swaziland (Mabunda, 2012).

Therefore, considering the condition and the present supply capacity of the Namaacha Water Supply system, the capability to supply an additional 255m^3 per hour by 2029, as required by Lomahasha Inkhundla, would not be available.

4.3.3 Mafucula irrigation system

The Mafucula area is located to the north western corner of the Lomahasha Inkhundla as shown in Figure 25. The area is part of Ka-Shewula Chiefdom although it is located far away from the Chief's Residence which is in the south eastern part of the Lomahasha Inkhundla.

The Mafucula area is supplied with water from the Komati basin for both drinking and irrigation uses. Water is conveyed from the Sand River Dam through the canal system supplying Mhlume sugar cane plantation and then through a pipeline up to a balancing dam at Mafucula. The system was developed by SWADE and is presently maintained and operated by the Mafucula Farmers association with the support of SWADE (Mutiro, 2012).

The use of this water for the supply to Lomahasha would present an advantage of shorter transmission pipeline length than sourcing water from Mbuluzi River. However the topography of the area is made of a series of mountains and valleys, as shown in the graph in Figure 26.

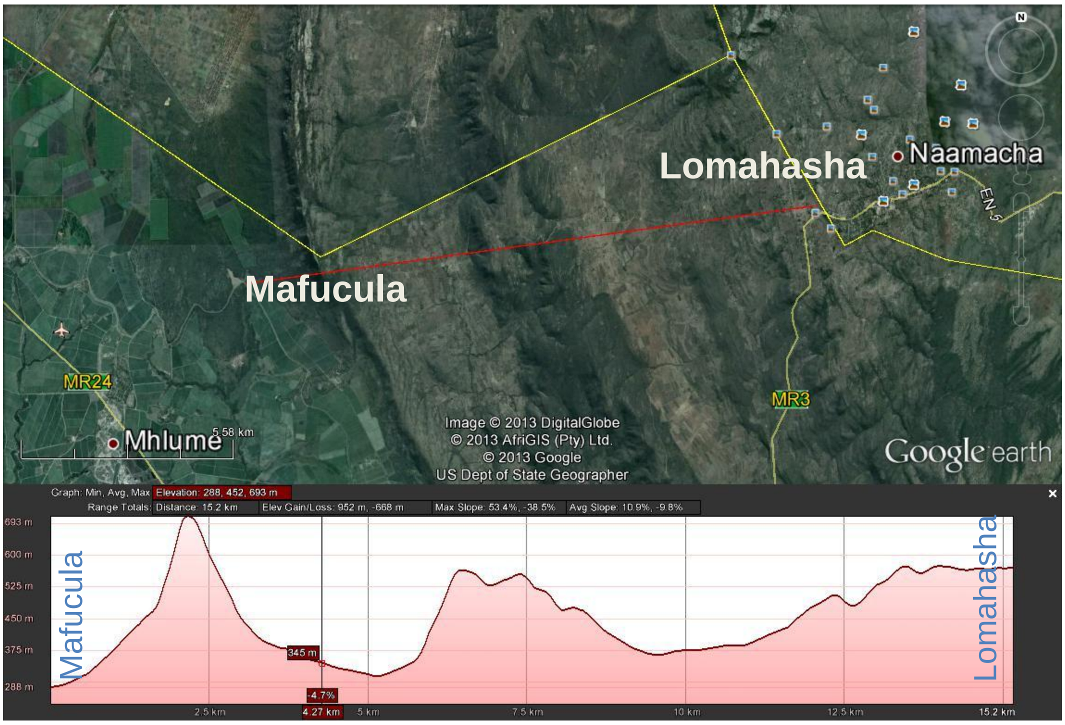


Figure 26: Profile of the topography from Mafucula to Lomahasha (Google earth, 2013)

The other disadvantage of this option is the number of parties which would be involved in the negotiations for using this water source. First is KOBWA for the source of water, second is RSSC for the transmission canal and thirdly is SWADE and Mafucula Farmers Association as owners of the balancing dam, the treatment plant and other water system components located at Mafucula.

This option was not considered for further evaluation as its construction would be impractical considering the topography to go across, and its initiation would require lengthy negotiations between various parties involved in the management of the potential water source.

4.4 Retained scenarios

Three scenarios were retained for further economic and environmental evaluation. The retained scenarios are the following: water supply from the Nkalashane River, new intake at Mbuluzi River and connection to the existing system at Simunye.

4.4.1 Water supply from the Nkalashane River.

The Nkalashane River rises in South Africa in the hills located to the north of Lomahasha. The river crosses the study area in a south easterly direction (Figure 27). All the streams running across the project area drain into this river, which is a tributary of the Mbuluzi River as it discharges into the Pequenos Libombos dam at Boane in Mozambique.

The catchment area upstream to the potential extraction point is about 48km^2 in a mountainous topography with fairly dense vegetation.

The main advantage of this option, in comparison with sourcing water from Mbuluzi River, would be the reduced length of transmission pipeline from the source to the storage reservoir, and consequently the reduced power consumption costs, as a result of the reduction in the length of the rising main.

The river was monitored as part of this study from January 2012 to December 2012, to establish the suitability of the source to supply water to the proposed system. The monitoring was carried out by measuring the flow depth at a particular point where the river traverses a hard rock section and therefore the river bed and sides are not subject to any deformation. This section is at a transition between a sub-critical and supercritical flows as it is located just upstream of a chute.

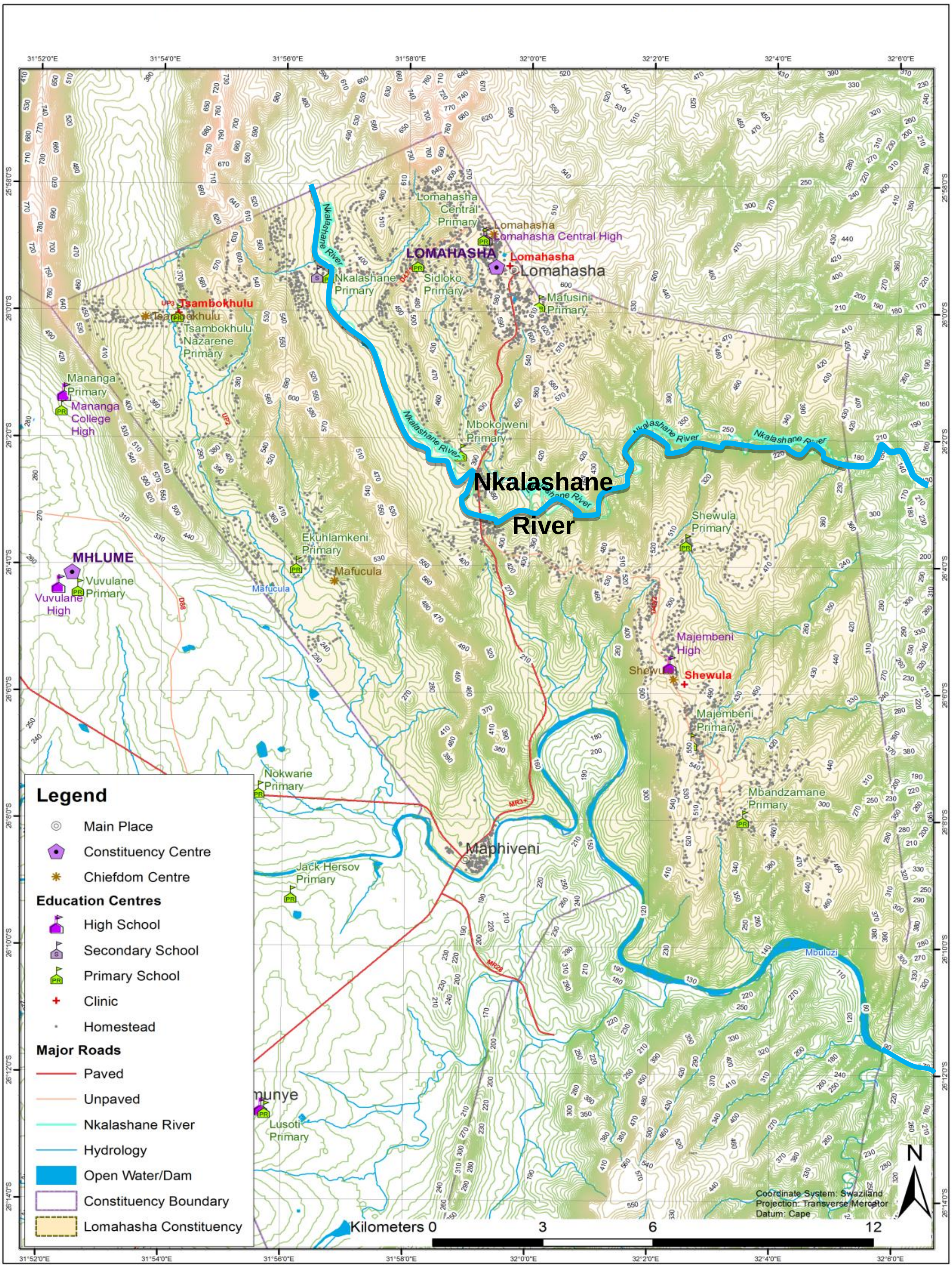


Figure 27: Nkalashane River across the Lomahasha Inkhundla

The river profile shows that the width of the flow area decreases significantly when the water depth is below 300mm. The photos below show the view of the river section in February 2012 and June 2012 respectively.

Nkalashane River in June 2012

Nkalashane River in February 2012

Figure 28: Photos showing Flows in Nkalashane River in June and February 2012.

Flow depth measurements were carried out on a monthly basis. It was ensured that measurements are done during a normal sunny day near the middle of the month to try to have a figure which is representative of the monthly average. The results of the measurements are presented in *Figure 29* below.

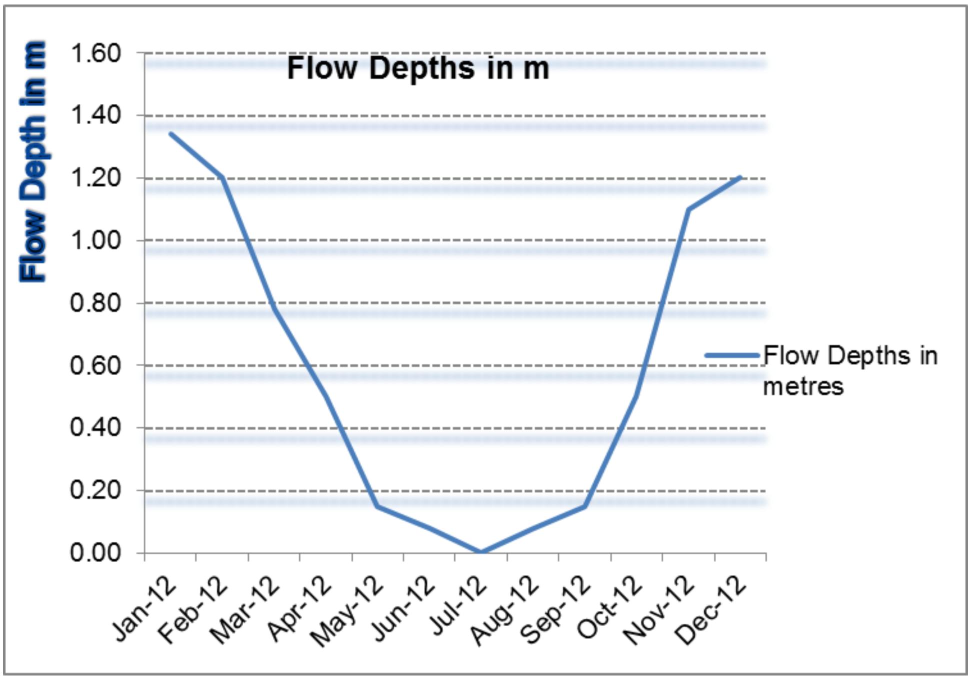


Figure 29: Variability of Flow Depth in Nkalashane River in 2012.

The results of the flow depth measurements prove that Nkalashane River would not reliably supply water during winter months if it was to be relied on for the supply to the study area. This was also confirmed by the residents who use this river as a source of water for domestic needs. They indicated that generally from June to August, the river flow is dry and they have to dig in the river bed to extract some water from the ground (Dlamini, 2012).

The use of Nkalashane River for the supply of water to the study area can be considered only in case a balancing reservoir can be provided. This would involve the construction of a dam of sufficient capacity to cater for high evaporation rates and sometimes prolonged drought periods which characterise the study area.

4.4.2 New intake at Mbuluzi River

A new intake can be developed at Mbuluzi River at a bend located at about 5km from Maphiveni junction, as shown on Figure 30.

Mbuluzi River forms the south eastern boundary of the study area as shown on Figure 30. The closest potential extraction point is located at approximately 15km from Lomahasha Town and is along MR 3 which is the main road linking Swaziland to Mozambique. The rising main can therefore be laid within the road reserve without disturbing the natural vegetation and habitat in the area.

The following components would need to be constructed for the development of this option.

4.4.2.1 Intake

The intake would be located at an elevation of about 130m above sea level. Water would be extracted from the river using submersible pumps. A concrete weir would have to be constructed at the river to provide adequate conditions for the suction of the water.

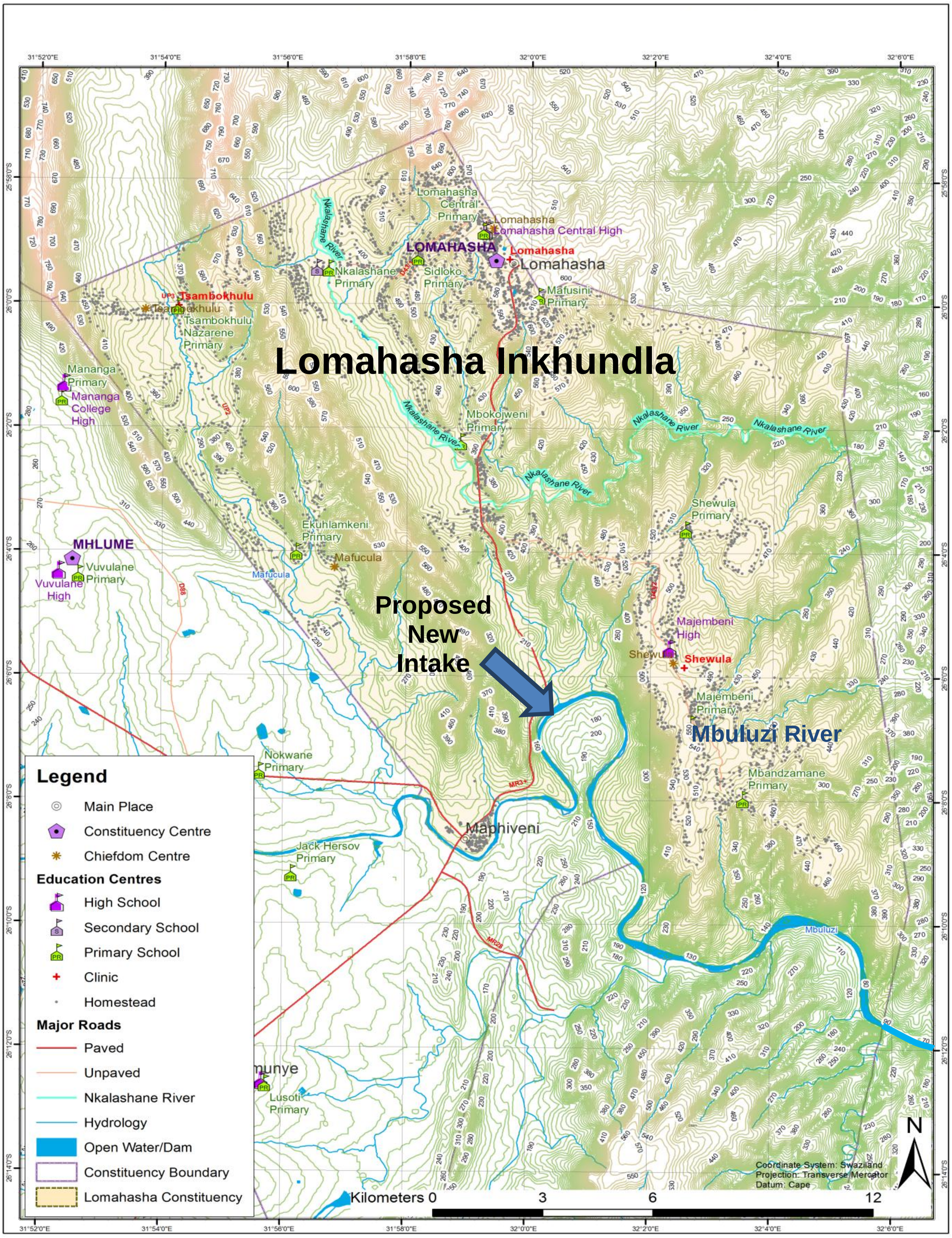


Figure 30: Position of Proposed New Intake at Mbuluzi River

4.4.2.2 Treatment Plant

A package water treatment plant would be provided and installed near the intake. The plant would be similar to the existing treatment plants presently operated by SWSC for ease of maintenance and operation, but with adequate capacity to meet the water demand of the study area. It would include automatic sand separators, static mixers, clarifiers, multimedia pressure filters, dosing plant, with internal pumps and valves.

The quality of water produced by the plant should satisfy the requirements of the WHO Guidelines for drinking water quality.

4.4.2.3 Clear water pumping system/rising main

Clear water would be pumped from the treatment plant to the storage reservoir constructed at Lomahasha. The pumping should be done in two stages to avoid excessive pressures in the pipeline. An intermediate pump station would be constructed halfway along the rising main.

4.4.2.4 Evaluation of the suitability of this option

The source of water for this option is reliable and no problem with regard to extraction permit would be expected. The option will be evaluated on the basis of its economic suitability in comparison with other options retained for further evaluation.

4.4.3 Existing system at Simunye.

The last option considered for the sourcing of water for supply to Lomahasha is the connection to the existing water supply system in Simunye, at about 30km west of Lomahasha town.

The existing water intake, treatment plant and pumping systems were originally designed for both Siteki and Lomahasha areas (Dlamini , 2012). However, it was later recommended to consider other options to ensure that the most suitable solution is used for the supply of water to Lomahasha.

Based on site inspections and interviews with the operators, the components of the existing water supply system in Simunye can be described as follows.

4.4.3.1 Existing raw water intake

The raw water intake works have been installed at a weir previously constructed for irrigation purposes. The water is channelled through a metal screen which blocks reeds and other objects from entering the pump chamber. Four submersible pumps are installed in the chamber with a capacity of 380m^3/hr at 42m total head for each pump (SII Irrigation, 2010). Three pumps suck water from the river to the treatment plant while the fourth one is a standby pump (Gwebu, 2012). A sump pump is also installed in the chamber for cleaning purposes (Gwebu, 2012).

4.4.3.2 Existing treatment process

The existing treatment plant is a combination of several units which carry out the physical and chemical processes required for the treatment of water to the standards recommended by World Health Organisation in the Guidelines for drinking-water quality (WHO, 1993). The design capacity of the plant is 1200m^3 of water /hour (SII Irrigation, 2010).

The main parameters required for the treated water are presented in the table below.

Table 15: WHO drinking water quality guidelines parameters

Parameter	*Unit of Measurement*	*Guideline values*
pH	pH units	6.5-8
Total Dissolved Solids	ppm	< 600
Turbidity	NTU	< 5
Total Hardness	ppm	< 500
Color	TCU	< 15
Iron	ppm	< 0.3
Sulphate	ppm as SO_4	< 250
Nitrite	ppm as NO_2^-	< 3
Total coliform	CFU/100 ml	0
Fecal coliform	CFU/100 ml	0
Fecal streptococci	CFU/100 ml	0

4.4.3.3 Head filtration and sedimentation system

The Head filtration is achieved by a Hydrocyclone which was designed to operate on the basis of free flow principle (SII Irrigation, 2010). Water flows freely on a spiral path along the length of the filter's cylinder and solids particles gravitate downwards to be collected in an underflow chamber, while the purified water rises to emerge from the top end of the filter (Gwebu, 2012). Four hydrocyclone units are installed with a capacity of 300m^3 /hour per each unit (Gwebu, 2012).

A centrifugal sedimentation is used to accelerate the sinking of the particles and their separation from the water. The particles sink to the bottom and the water remains on top for further treatment phases. The water is collected in a balancing tank and then it flows to the next treatment stage. Four centrifugal clarifiers are installed with a capacity of 160m^3 per each, and a balancing tank of a capacity of 300m^3 (SII Irrigation, 2010).

4.4.3.4 Chemical treatment

The chemical treatment is carried out by chlorination and by aluminum sulphate (Gwebu, 2012). The chlorine is used for disinfection and the aluminum sulphate causes the suspended solids to coagulate in larger masses which then fall to the bottom of the sedimentation tank.

4.4.3.5 Multimedia filtration system

The reduction of the turbidity level is achieved by a multi-media filtration process. 34 units of multi- media filters are in pace, with a flow rate of 35m^3/hour per each (SII Irrigation, 2010). The backwash can be operated manually by an operator, or automatically every 24 hours, with an option to adjust the frequency (Gwebu, 2012).

4.4.3.6 Pumping System

Three pump stations are in place in the Simunye Water Supply System.

- An intake pumping system, as described above

- A transfer pumping system made of 4 pumps *KSB ETA 150-400* of a capacity of 400m^3 at 4 bars per each (SII Irrigation, 2010).

- A high lift pumping system to lift the water from the treatment plant to the booster pump station using five pumps *KSB ETA 125-50/2* pumps with a capacity of 250m^3 /hour at 78 m head per each (SII Irrigation, 2010).

- A booster pump station is in place to lift the treated water from Simunye to the Siteki and Lomahasha Supply Systems.The booster pump station consists of three sets of pumps. Each set is composed of one *KSB WKLn 150/4* and one *KSB ETA 150-50* installed in series. The pumping capacity is 320m^3/hr at 160m Head and 320m^3/hr at 60m Head for *WKLn* and *ETA* pumps respectively (SII Irrigation, 2010).

4.4.3.7 Present production of the plant

The following table shows the monthly volume of water extracted from the river and actual production of the plant for the months of April 2011 to March 2012.

Table 16: Production of the existing Simunye Treatment plant

Month	**Intake Volume (m^3)**	**Plant Production Volume (m^3)**	**% production/ Intake**
Apr-11	159 124	155 443	97.7%
May-11	148 636	145 882	98.1%
Jun-11	171 113	166 703	97.4%
Jul-11	177 632	172 539	97.1%
Aug-11	170 889	165 735	97.0%
Sep-11	193 343	189 499	98.0%
Oct-11	195 777	192 480	98.3%
Nov-11	174 078	171 524	98.5%
Dec-11	198 924	195 315	98.2%
Jan-12	182 125	178 847	98.2%
Feb-12	178300	174 556	97.9%
Mar-12	192200	188 548	98.1%

Source: (Gwebu, 2012)

The monthly production for the period of April 2011 to March 2012 varied from 145 882m^3 to 195 315m^3. The minimum production was observed in May 2011 and the maximum in December 2011. The present production is quite below the design capacity of the plant which can be estimated at 720 000 m^3 per month if the plant produces 1 200m^3 per hour and operates 20 hours per day on average to allow for maintenance and any interruption. Presently, the plant is producing less than 30% of its production capacity.

The average daily demand for Lomahasha at the end of the design period was estimated at 1415m^3 per day, or 42 450m^3 per month, which is below 6% of the production capacity of the plant.

4.4.3.8 Provision for the connection for Lomahasha supply

The connection for Lomahasha supply system was allowed for at the time of the design and the commissioning of the existing system. There is a Tee in the rising main at Simunye at the main road MR 3. A 500mm diameter pipe was laid from the booster pump station up to the main road and from there, one line runs to the south west toward Siteki and another one should run to the north east toward Lomahasha.

4.4.3.9 Evaluation of the suitability of this option

This option can be considered for further evaluation as it is technically feasible and it was allowed for at the time of the design of the existing system. This option will be evaluated on the basis of its economic suitability in comparison with other options retained for further evaluation.

5. PRELIMINARY DESIGN OF PREFERRED OPTIONS

After the assessment of all possible options for sourcing the water to supply Lomahasha, three options were retained for further evaluation. These are the following.

- Water supply from the Nkalashane River;
- New intake at Mbuluzi River
- Connection to the existing system at Simunye.

The components to be included in each scenario are described below.

5.1 Option 1: Intake from Nkalashane River

The main components of the system would be the following: balancing dam, intake and water treatment works, storage reservoirs, transmission pipelines, pumping system, distribution reticulation and house connections.

5.1.1 Balancing Dam

5.1.1.1 Proposed position of the balancing dam

The proposed balancing dam would be constructed across Nkhalashane River at a position to the west of the crossing of the MR3 main road (Figure 31). The dam wall will be positioned at 26^{o}03’14.91’’S and 31^{o}58’’22.78’’E. The proposed wall would be constructed with gravel materials with clay core.

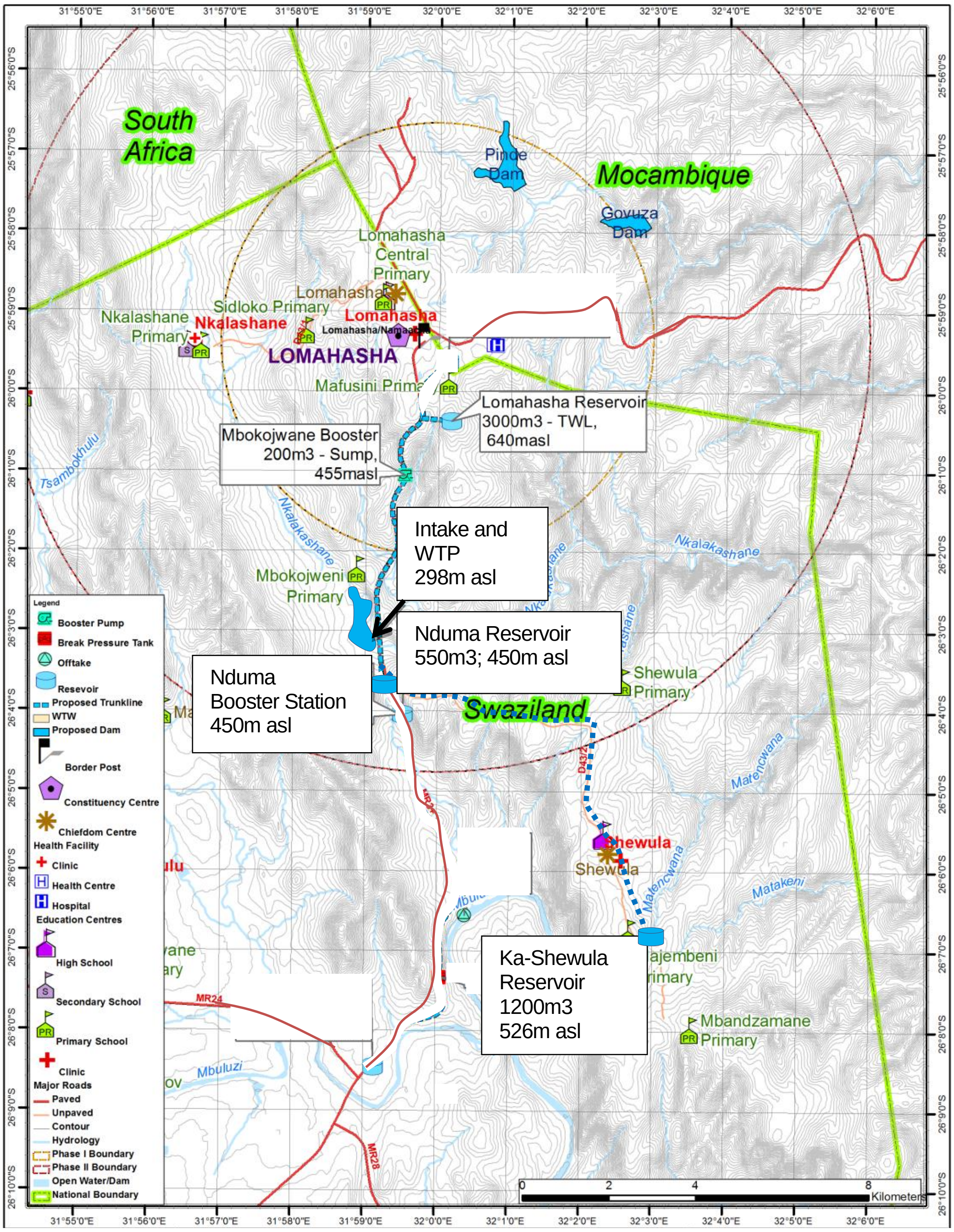


Figure 31: Option 1- Intake at Nkalashane River

5.1.1.2 Catchment area

The catchment area of Nkalashane River up to the point of the proposed dam is $48km^2$, as calculated from the Surveyor General's contour maps.

The catchment is generally in agricultural lands with fair density of population.

5.1.1.3 Rainfall and Runoff

The Mean Annual Rainfall Precipitation (MAP) for the Lomahasha Inkhundla is 678mm as indicated in Chapter 2 above. This was evaluated on the basis of 22 year rainfall records obtained from the Meteorology Department for the Mlawula Rainfall Station.

There is no stream flow gauging stations along Nkalashane River, and no previous study dealt with water availability in this particular river. To convert the annual rainfall records into annual flow records, reference was made to Mitchell (1982). The study analysed the relationship between annual rainfall and runoff for 246 gauging stations in granitic drainage basins in Zimbabwe. It presented curves to use for the derivation of runoff from rainfall.

The annual runoff was extrapolated from the curve for the 22 years covered by the rainfall records as shown below (Table 17).

Table 17: Rainfall and Runoff for the period of 1990 to 2011

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Rainfall (mm)	565.1	837	436	693	430	622	776.5	662.4	810.3	953.2	1253
Runoff (mm)	30.4	119	11.42	63.3	10.83	43.14	93.3	54.006	107.4	179	380.9
Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Rainfall (mm)	849.4	483	338.1	1080	518.4	821.8	511.6	435.4	512.9	710.5	500.8
Runoff (mm)	125.1	16.9	4.247	257	22.05	112.5	20.99	11.36	21.19	69.01	19.37

Mean Rainfall	678mm
Mean Runoff	81mm
Coefficient of Variation	94%

5.1.1.4 Capacity and potential catchment yield

Considering the small size of catchment and the irregular pattern of rainfall and runoff, an 'annual' dam that is refilled and depleted every year would not be adequate (Matondo , 2000). It is therefore necessary to allow for a multi-year storage, for which runoff from high rainfall years is held in storage to provide supply in following years of drought.

The assessment of the reservoir yield can be carried out using the Transition Probability Method (Mitchell, 1977).

The curves proposed by Mitchell (1977) present the relationship between Storage Ratio (capacity/MAR) and Yield Ratio (Yield/MAR). The analysis is based on a 10% risk of supply (Mitchell, 1977).

For a coefficient of Variation of 94% and a Mean Annual Runoff of 81mm as calculated above, the dam to be built at Nkalashane River would have a capacity of 2 x MAR and its yield would be 25% of its capacity.

The main characteristics of the proposed dam are shown below.

Table 18: Characteristics of the proposed dam at Nkalashane River

Catchment area (km^2)	MAR (mm)	MAR (Mm^3)	Storage Capacity (Mm^3)	Yield (Mm^3/year)
48	81	3.888	7.776	1.944

5.1.1.5 Estimation of the supply requirement

The daily water demand for domestic use was estimated to be 2445m^3 for the design horizon of 2029 (Table 12). The demand for 12 months was calculated from the daily demand and an allowance for garden irrigation was made, as residents in the verge of the dam would intend to develop gardens to take advantage of water availability in the vicinity. At the time of the study, a number of vegetable gardens were noticed in the riverine and it was assumed that gardening activity would intensify if a dam was constructed in the area. As recommended in the Design Manual for Rural Water Supply Systems, a factor of 1.5 should be applied to the average daily demand to allow for the use of water for gardening (Rural Water Supply Branch, 2003).

Daily Water Demand for the design horizon of 2029	2 445	m3
Water Demand for 12 months: Daily Demand x 365 days	892 425	m3
Allow for garden irrigation: Domestic Demand x 1.5	1 338 638	m3

The total water demand per year is estimated to 1.339 million cubic metres, which is 68% of the potential yield of the reservoir.

5.1.1.6 Proposed site and dimensions of the reservoir

The topography of the river basin has been analysed on the basis of the contour lines and google mapping. The site to be occupied by the reservoir is presented in Figure 32.

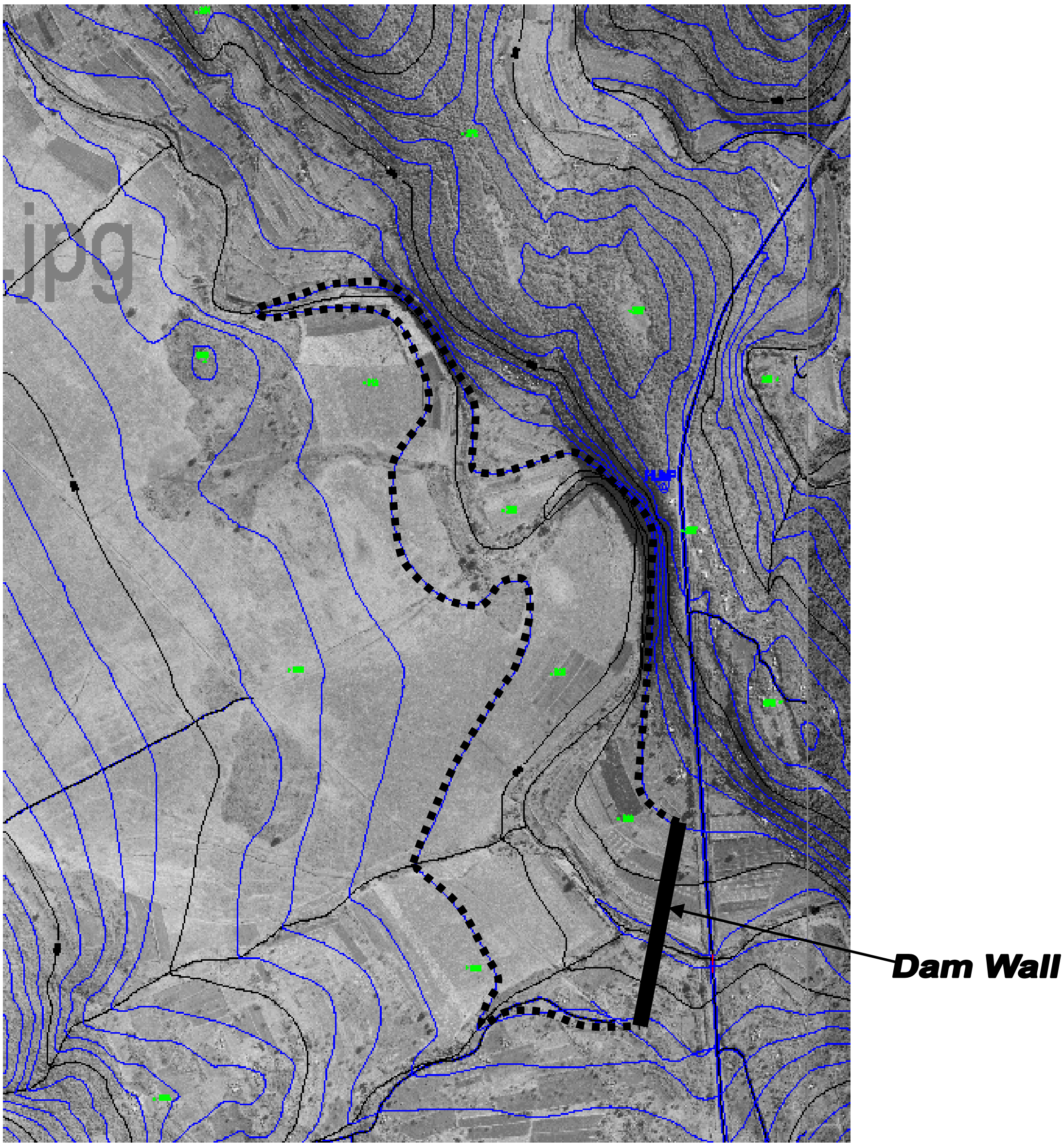


Figure 32: Proposed site for the dam

The height of the dam wall can be determined on the basis of the required storage capacity and using the Stage-Storage relationship (Soil Consercvation Service, 1989).

The double-end area method was used to develop the relationship between the depth of water (stage) and the storage volume. This method uses the areas of the planes at two given elevations to calculate the volume between the two area planes, as expressed in Equation 6 (Soil Consercvation Service, 1989).

$V_{1-2} = \left[\frac{(A1+A2)}{2}\right] d$ (Equation 5)

Where $V_{1\text{-}2}$ = Water volume in m^3 between elevations 1 and 2; A1 and A2 = surface area at elevation 1 and 2; d = change in elevation between points 1 and 2.

The calculations are presented in Table 19.

Table 19 : Development of the stage – storage relationship

Elevation (m)	Surface Area (km^2)	Average Surface Area (km^2)	Incremental Depth (m)	Incremental Volume (Mm^3)	Total Depth (m)	Total Volume (Mm^3)
287	0.00	0.00				
290	0.01	0.00	3	0.01	3	0.01
300	0.22	0.11	10	1.12	13	1.13
310	0.86	0.54	10	5.40	23	6.52
320	1.78	1.32	10	13.22	33	18.63
330	2.92	2.35	10	23.49	43	36.72
340	4.51	3.71	10	37.12	53	60.62
350	6.60	5.55	10	55.55	63	92.67

From Table 19, the Stage-Storage curve was plotted as shown in Figure 33.

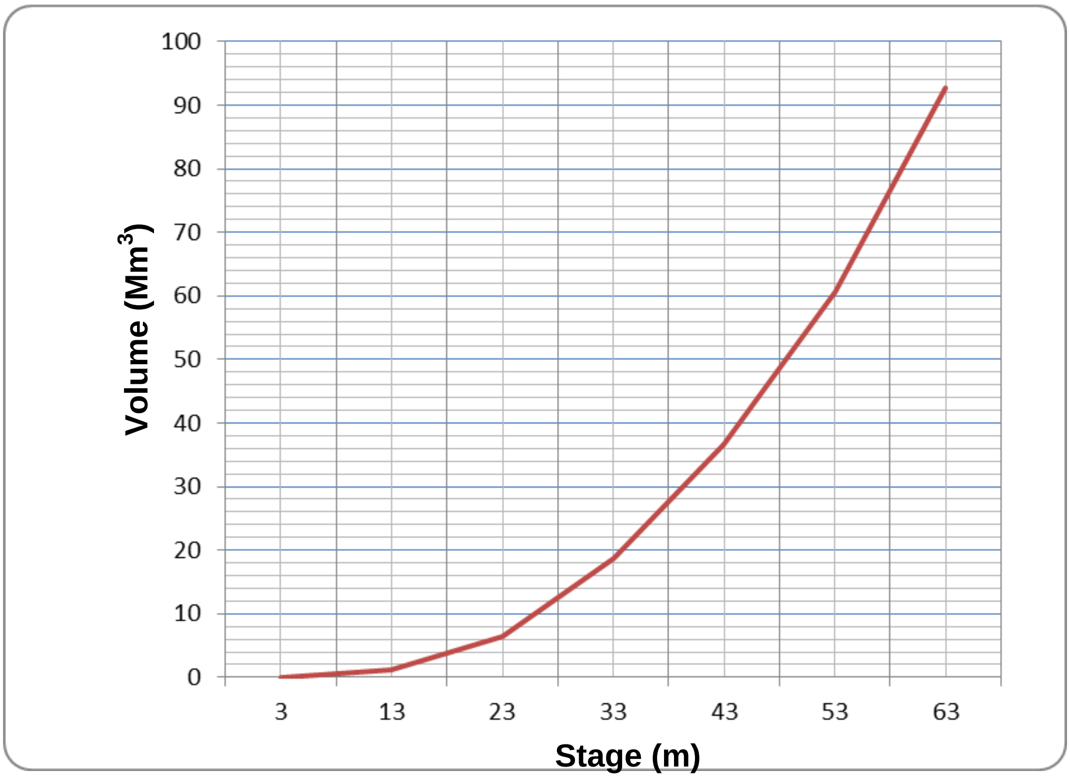


Figure 33: Stage/Volume relationship graph

The water depth for the required storage capacity of 3.888Mm^3 would be 18m (Figure 33). With an allowance of 2m for the free board, a dam wall of 20m in height would need to be constructed.

5.1.2 Intake and Water Treatment Works

Water will be transmitted from the balancing dam to the treatment plant by a gravity transmission pipeline. Water will be transmitted from the balancing dam to the treatment plant by a gravity transmission pipeline. The sizing of the pipeline was carried out using the Darcy-Weisbach equation

$f = \lambda * L/d * V^2/2g$ (Equation 6)

Where f = friction loss; λ= Head loss coefficient; L = Length of the pipeline; d= Diameter of the pipeline and g= gravitational acceleration. The head loss coefficient is a function of Reynolds Number which is given by following relation

$Re = V*d/\mu/\delta$ (Equation 7)

Where V is the velocity, d is the diameter and μ/δ is the kinematic viscosity of water in m^2/s.

The detailed calculations for the sizing of the pipes are included in Appendix 4.

As shown in the calculations (Appendix 4), a uPVC class 9 pipeline of 315mm diameter can be used for a flow rate of $255m^3$ per hour.

A package treatment plant would be provided to treat the raw water to WHO standards for drinking water quality (WHO, 2003). The plant would be made of a sedimentation system, multi-media filters and chemical treatment system using chlorine or aluminium sulphate.

5.1.3 Storage Reservoirs

Three main storage reservoirs will be provided, one at Lomahasha, one at Ka-Shewula, and another one at Nduma to supply the settlements along the main road from Maphiveni to Nduma.

The storage required can be calculated from the Average Daily Demand for the design horizon as estimated in Chapter 3.

The storage reservoir should have the capacity to supply the daily average demand for two days, with an allowance for fire fighting (CSIR , 2003).

The project area can be considered as a low risk category 3 in accordance with the categorization of SABS Code of Practice 090:1972, as it includes residential houses with a floor area generally likely to be less than $100m^2$ but exceeding $55m^2$. The storage required for firefighting is then $21m^3$ (CSIR , 2003).

Table 20: Storage required for Lomahasha and Ka-Shewula Chiefdoms

(Water Demand in m³/day)	Years			
Lomahasha Chiefdom	**2014**	**2019**	**2024**	**2029**
Lomahasha Town Domestic Demand	228	269.9	320.2	380
Lomahasha Rural Domestic Demand	464	544.7	639.2	750.5
Non- Domestic Demand	182	201	222	244
Allow for Fire Fighting	21	21	21	21
Total per day	895	1037	1202	1395
Storage Required for Lomahasha	1790	2073	2405	**2791**
Ka-Shewula Chiefdom				
Ka-Shewula Domestic Demand	523	613.1	719.5	844.8
Non- Domestic Demand	77	89	103	119
Allow for Fire Fighting	21	21	21	21
Total per day	621	723.1	843.5	984.8
Storage Required for Ka-Shewula	1242	1446	1687	**1970**

5.1.3.1 Lomahasha Storage Reservoir

The Lomahasha Chiefdom would be supplied from one main reservoir, which should be constructed at a location 26°00'21.87'' S and 32°00'08.69 E. The floor level should be at 630m amsl. From this position, water will be supplied to the Lomahasha Town and to all inhabited rural areas within Lomahasha Chiefdom. As shown in Table 19, the capacity of the storage should be 2791m^3, rounded off to 3000m^3. The supply to Namaacha in Mozambique could be considered during the early years of the design period, but water would not be enough in the years preceding 2029. This could generate some revenue to SWSC and improve the economic viability of the project.

5.1.3.2 Nduma Storage Reservoir

Nduma Storage Reservoir should be constructed near the junction of Ka-Shewula Road to MR3, at approximately 20km north-east of Simunye. This reservoir would supply the settlement along MR3 which can be grouped as follows: Mapihiveni Settlement; Mlawula Camp and Railway Station; Nduma/Sifundza settlement.

Maphiveni Settlement

The settlement is located along the main road MR3 at about 10km north east to Simunye. It is within the riverine area of Mbuluzi River and it is generally squashed between the main road and the river.

The settlement includes 126 homesteads in a semi-rural set up. Also 3 commercial buildings are in place. The census area code for Maphiveni is 44182, with a population of 663 people in 2007 (CSO, 2007).

The Maphiveni village includes staff houses for the Ministry of Agriculture's workers who are supervising the Foot and Mouth Quarantine Cordon.

Mlawula Camp and Railway Station

The Mlawula Camp and the Railway Station are located at about 5km east to the MR3. The Mlawula Camp is inside the Mlawula Nature Reserve, and the Railway Station is in the same area, along the Mlawula River and the railway line from Mpaka to Maputo.

A total of 86 houses are to be supplied with water in this area, with 3 administration blocks. Based on an average of 6 people per house, the present population at Mlawula can be estimated to 516 people.

Nduma/Sifundza settlement

These are the homesteads located at approximately 20km north-east of Simunye where the road to Ka-Shewula connects to MR3. About 68 homesteads are located to the east of the main road and 156 to the west.

Referring to the 2007 census figures, as obtained from the Central Statistics Offices, these communities are included in three enumeration areas and comprise the following population.

Table 21: Population of Nduma and Sifundza areas (2007 census)

Enumeration area code	Name	Number of homesteads	Number of people
44119	Nduma	68	390
44118	Nduma	70	498
44180	Sifundza	86	581
Total		**224**	**1469**

Source: (CSO, 2007)

The total population for Maphiveni Settlement, Mlawula Camp & Railway Station and Nduma/Sifundza areas was estimated to 2 647 people in 2007. This is 27.5% of the Ka-Shewula population.

The storage required for these areas should be 27.5% of the total storage for the Chiefdom. From the information contained in Table 20, the capacity of the Nduma Storage reservoir can be estimated to 550m^3.

5.1.3.3 Ka-Shewula Storage Reservoir

The Ka-Shewula reservoir should be constructed at a coordinate of 26^{o}06'51.49'' S and 32^{o}02'38.42'' E, with floor level at 526m amsl. The whole Ka-Shewula Chiefdom should be supplied from this reservoir or from Nduma Reservoir, except the Mafucula area where an adequate and efficient system is already in place. Break Pressure Tanks and Pressure Reducing Valves will be required as some areas of the Chiefdom are at an elevation as low as 150m amsl, while the storage reservoir would be at 526m amsl.

The capacity required for Ka-Shewula reservoir should be calculated as follows.

Ka-Shewula Reservoir Capacity = Total Ka-Shewula Chiefdomn Storage – Nduma Storage – Mafucula Storage.

Total Ka-Shewula Chiefdom Storage is 1970m^3 as shown in Table 20; Nduma Storage is 550m^3 and Mafucula Storage is 212m^3. Therefore the Ka-Shewula storage reservoir should have a capacity of 1208m^3, say 1200m^3.

5.1.4 Transmission pipelines

Water will be pumped from the Treatment Plant at Nduma to the main storage reservoirs at Lomahasha and Ka-Shewula.

The pipeline route from Nduma to Lomahasha should generally follow the road reserve of MR3. From the treatment plant, the line follows the road up to about km 4.5 where it would be necessary to deviate from the road reserve to avoid abrupt and rocky escarpment along the road, and to reduce the length of the pipeline. The total length of the transmission pipeline from the Treatment Plant to Lomahasha Reservoir is about 7km, with an intermediate booster station at 4.5km from the Treatment Plant.

The transmission pipeline should have the capacity to deliver the peak hourly demand plus the flow required for fire fighting. The water demand for the Lomahasha Chiefdom is 1395m^3 per day. Using a peak factor of 2.5, the design flow would be 145m^3 per hour, or 40.5 litres per second. This would require the use of a pipe of 250mm to optimise the energy consumption. The detailed calculations for the sizing of the pipelines on the basis of the Darcy-Weisbach head loss equation are included in Appendix 4.

The total length of the rising main from the treatment plant to the Ka-Shewula storage reservoir is about 11km, with an intermediate booster station at Nduma at about 3.3km from the treatment plant. The daily average water demand for the Ka-Shewula Chiefdom is 984.8m^3 per day, thus using a peak factor of 2.5, the design flow would be 102.6m^3 per hour, or 28.50 litres per second. A pipe of 250mm diameter would be used from the treatment plant to Nduma to optimise the energy requirement. From Nduma to Ka-Shewula a pipe of 200mm diameter would be used. The details on the sizing of the pipes are presented in Appendix4.

5.1.5 Pumping System

Three booster pump stations will operate this system including the main booster system at the site of the treatment plant. They are as follows: Main Booster

Station at Treatment Plant; Mbokojwane Intermediate Booster Station and Nduma Intermediate Booster Station.

5.1.5.1 Main Booster Station at Treatment Plant

A pumping station will be provided at the site of the treatment plant to pump the water into the Lomahasha Chiefdom's system and Ka-Shewula Chiefdom's system. The ground level at the site of the booster station is at an elevation of about 298m amsl. The pumping system will be carried out in two stages to minimise the use of high pressure pumps which would require high pressure rising mains.

Calculation of Static Head

The booster pump station at the Treatment Plant would lift a total flow of 69 l/s from an elevation of 298m amsl to 455m amsl for both Lomahasha and Ka-Shewula chiefdoms. The static head would then be 455m-298m = 157m.

Friction Losses

Friction losses were calculated using Equation 11, which is iterative and was resolved using an excel spreadsheet as attached in Appendix 4.

For the Lomahasha line, with a diameter of 250mm, and a flow rate of 40.5 l/s, the friction loss on a length of 4.5km should be 13.34m. The length of the rising main from the Treatment Plant to Nduma Intermediate Booster Station is about 3300m, thus the friction loss for a flow of 28.5 l/sec through a pipe of 250mm diameter would be 4.98m. The friction in the Lomahasha line should be used for the calculation of the total head as it is the highest.

Local Head Losses

Local head losses have been calculated using the following formula.

Local Losses = $\zeta_{tot} * V^2/2g$ (Equation 14)

Where ζ = Local loss coefficient; V = Velocity; g = Gravitational Acceleration.

The calculation has been carried out for the Lomahasha line as the velocity is higher than that in Ka-Shewula line. The details of the calculations are included in Appendix 4.

For V= 0.825m/s; ζ_{tot} = 3.15 and g=9.81m/s^2; Local head loss should be 0.1091m.

The total Head for the pump should be Total Head = Static Head+ Friction loss+ Local losses. Total Head = 157m+13.34m+0.1091m = 170.45m

<u>Pump selection and installation</u>

Two pumps of a capacity per each of 69 litres per second at 170.45m total head will be installed in parallel in a duty/standby set up. KSB WKLn 150/4 pumps can be used for this duty, with an efficiency of 76.1%.

<u>Power Requirement</u>

The power required to drive the pump has been calculated as follows.

Power required $\boldsymbol{P} = \frac{QxH}{367e}$ (Equation 15)

With P= Power required in kW; Q= Flow Rate in m^3/h; H=Total Head in m;

and e = Pump efficiency factor (value between 0 and 1).

For Q = 248.4m^3/h; H= 170.45m; and e=0.761; P should be equal to 151.6kW.

<u>Calculation of Sump Volume</u>

A required minimum sump capacity is to be provided to balance out the supply and the demand flow rates so as to keep the number of stops and starts within an acceptable range. The start/stop frequency was fixed to 4 as recommended in the Design Manual for Rural Water Supply Systems (Rural Water Supply Branch, 2003).

Following formula was used for the calculation of the minimum capacity of the sump.

$V_{min} = T_{min} \times Q$ (Equation 16)

Where V_{min} = Minimum volume between start and stop; T_{min} = Cycle time in seconds = 15x60 = 900 seconds and Q = Pump capacity in litres/second.

For Q = 69 l/s, V_{min} would be 62.10m3.

A rectangular sump with a capacity of 100m^3 will be constructed in reinforced concrete.

5.1.5.2 Mbokojwane Intermediate Booster Station

The Mbokojwane Intermediate Booster Station should be constructed along the main road MR 3, at a distance of 4.5km from the Treatment Plant. The ground level at the site of this booster station is at an elevation of about 455m amsl.

<u>Calculation of Static Head</u>

The Mbokojwane booster station would lift a total flow of 40.5 litres/sec from an elevation of 455m amsl to 630m amsl. The static head would then be 630m - 455m = 175m.

<u>Friction Losses</u>

Friction losses were calculated using Equation 11 and excel calculation spreadsheet as shown in Appendix4.

For a line of 250mm diameter, and a flow rate of 40.5 l/sec, the friction loss on a length of 2.5km is 7.4114m.

5.1.5.2.1 Local Head Losses

Local head losses have been calculated using Equation 13, and the details are included in Appendix 4.

For V= 0.825m/s; ζ_{tot} = 3.00 and g=9.81m/s^2; Local head loss should be 0.1042m.

The total Head for the pump should be Total Head = Static Head+ Friction loss+ Local losses. Total Head = 175m+7.4114m+0.1042m = 182.52m

Pump selection and installation

Two pumps, each of a capacity of 40.5 litres per second at 182.52m total head will be installed in parallel in a duty/standby set up. *KSB WKLn 100/8* pumps can be used for this duty. The efficiency should be 73.81.

A rectangular sump with a capacity of 200m^3 will be constructed in reinforced concrete to allow for the connection of about 5 homesteads in the vicinity of the booster station.

Power Requirement

The power required to drive the pump at the Nduma intermediate booster station has been calculated using Equation 14.

For Q = 145.8m^3/hour; H= 182.52; and e=0.7381; P should be equal to 98.24 kW.

5.1.5.3 Nduma Intermediate Booster Station

The Nduma Intermediate Booster Station should be constructed along the gravel road to Ka-Shewula, at a distance of 3.3km from the Treatment Plant. The ground level at the site of this booster station is at an elevation of about 455m amsl.

Calculation of Static Head

The Ka-Shewula booster pumps would lift a total flow of 20.70 l/s from an elevation of 455m amsl at the booster station to 526m amsl at Ka-Shewula Reservoir. The static head would then be 526m - 455m = 71m.

Friction Losses

Friction losses have been calculated as detailed in 5.1.5.1 above. The rising main from the Nduma booster station to the reservoir is about 7.7km.

For a line of 200mm diameter, and a flow rate of 20.70 l/s, the friction loss is 19.57m.

Local Head Losses

Local head losses have been calculated as detailed above in 5.1.5.1.

For V= 0.659m/s; ζ_{tot} = 3.65 and g=9.81m/s^2; Local head loss should be 0.0720m.

The total Head for the pump should be Total Head = Static Head+ Friction loss+ Local losses. Total Head = 71m+19.57m+0.0720m = 90.64m

Pump selection and installation

Two pumps of a capacity per each of 20.67 litres per second at 90.64m total head will be installed in parallel in a duty/standby set up, with a power requirement of 30.68kW*. Lowara SV 92 04* Vertical multistage pumps can be used for this duty. This efficiency would be 74.3% (Lowara, 2012).

Power Requirement

The power required to drive the Ka-Shewula intermediate booster pump has been calculated as detailed in 5.1.5.1 above.

For Q = 74.52m^3/hour; H= 90.64; and e=0.743; P should be equal to 24.77 kW.

Calculation of Sump Volume

The minimum sump volume was calculated using Equation 15. For a pump capacity of 28.5 l/s, the required minimum sump volume should be 25.65m^3. However, a number of homesteads should be supplied from this storage. These are homesteads at Maphiveni Settlement, Mlawula Camp & Railway Station and Nduma/Sifundza settlement.

A storage reservoir to be used as a sump will be constructed in reinforced concrete, with a storage capacity of 550m^3.

5.1.6 Distribution reticulation and house connections

The detailing of the distribution reticulations and house connections was not covered in this study. These works would not influence the comparison of the options analysed as the difference between various scenarios lies in the type and location of the water source. The water distribution from the storage reservoirs to the water users is expected to be the same for all the scenarios, and therefore does need to be elaborated on by this study.

5.2 Option 2: New intake at Mbuluzi River

The main components of the system would be the following: intake and water treatment works; storage reservoirs; transmission pipelines; pumping system and distribution reticulation and house connections (Figure 33).

The distribution reticulation and the house connections are not assessed in this study as they are the same for all the options, and thus do not influence the comparison between the analysed alternatives.

5.2.1 Intake and Water Treatment Works

The intake and water treatment plant will be provided as described above in 4.4.2.1 and 4.4.2.2. The required capacity of the system should be 255 m^3 per hour.

5.2.2 Storage Reservoirs

The storage reservoirs in this option will be the same as in Option1, except that the Nduma reservoir should have a capacity of 300m^3 only, and another reservoir of 250m^3 capacity should be provided at Maphiveni to supply Mlawula Camp & Railway Station and Maphiveni Settlement. These two reservoirs can be constructed of galvanised steel panels. Four main reservoirs will be provided, the first one of 3000m^3 capacity at Lomahasha, the second one of 300m^3 at Nduma, the third one of 1200m^3 capacity at Ka-Shewula, and the fourth one of 250m^3 at Maphiveni (Figure 34).

5.2.3 Transmission pipelines

Water will be pumped from the Treatment Plant at the new intake at Mbuluzi River to the main storage reservoirs at Lomahasha and Ka-Shewula.

The pipeline route from the Treatment Plant to Lomahasha should generally follow the road reserve of MR3. From the treatment plant, the line follows the road up to about km 5.5km away where an intermediate booster station would be constructed. From this point the line would split in two, with the first branch running toward Lomahasha on a length of 8.3km, and the second one toward Ka-Shewula on a length of 9.7km.

From the Treatment Plant to the Booster Station at km 5.5, a 350mm diameter pipe will be used, and the branches to Lomahasha and to Ka-Shewula will be in 250mm and 200mm diameter pipes as per Option 1.The calculations were carried out using Equation 11 as presented in Appendix 4.

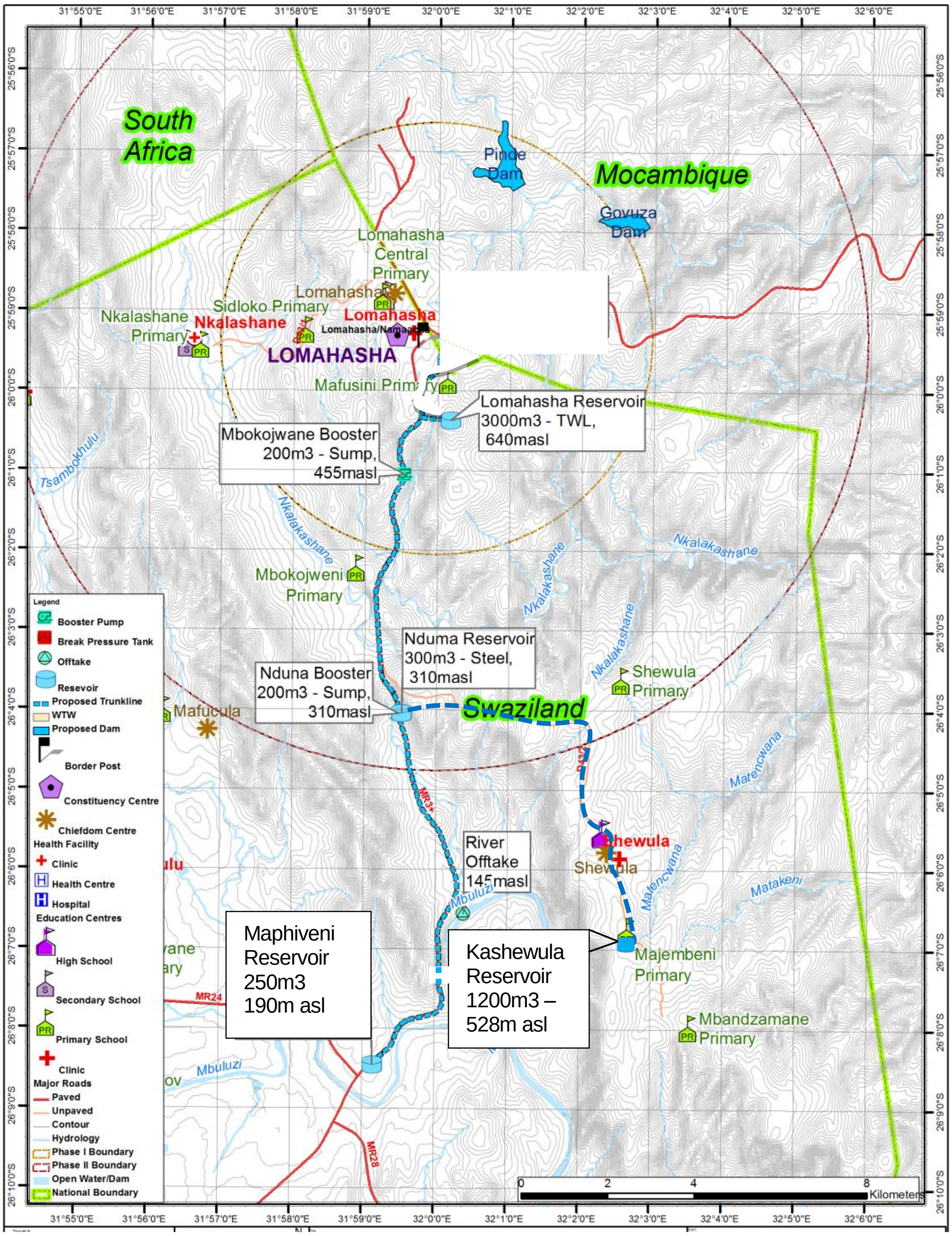


Figure 34: Option 2- New Intake at Mbuluzi River

5.2.4 Pumping System

Five booster pump stations will operate this system including the main booster system at the site of the treatment plant. They are the following: raw water intake pumping system, main clear water pump station at Treatment Plant, Nduma Booster Station and Mbonkojwane Booster Station.

5.2.4.1 Raw water intake pumping system

Raw water intake pumps will be provided to pump the water from the river to the Treatment Plant. The pumps should have a capacity of 85 l/s, or 306m^3/h, at 25m total head. The duty can be achieved by a pump *Lowara FHF 125-200/4*50. The efficiency of the pump should be 71% (Lowara, 2012). The power requirement is calculated by Equation 14. For Q=306m^3/hr; H=25m and e=0.71; P would be 29.36kW.

5.2.4.2 Main Clear Water Pump Station at Treatment Plant

The main clear water pump station will be constructed at the site of the Treatment Plant at the River Intake. This will pump the water into the Lomahasha Chiefdom's system and Ka-Shewula Chiefdom's system. The ground level at the site of the booster station is at an elevation of about 145m amsl. The clear water pumping will be carried out in three stages to minimise the use of high pressure pumps which would require high pressure rising mains.

<u>Calculation of Static Head</u>

The main clear water pumps at the Treatment Plant would lift a total flow of 69 l/s from an elevation of 145m amsl to 310m amsl for both Lomahasha and Ka-Shewula chiefdoms. The static head would then be 310m-145m = 165m.

<u>Friction Losses</u>

Friction losses have been calculated as explained in Option 1 above, by resolving the friction resistance equation using an excel spreadsheet.

For 5.5km of a 350mm diameter pipe, the friction loss for a flow of 69 litres per second would be 9.5m.

Local Head Losses

Local head losses have been calculated as in Option 1. The sum of local losses is as follows.

For V= 0.760m/s; ζ_{tot} = 2.80 and g=9.81m/s^2; Local head loss should be 0.0825m.

The total Head for the pump should be Total Head = Static Head+ Friction loss+ Local losses. Total Head = 165m+9.5m+0.0825m = 174.58m

Pump selection and installation

Two pumps of a capacity per each of 69 litres per second at 170.45m total head will be installed in parallel in a duty/standby set up. *Lowara FHF 125-200/450* pumps can be used for this duty, with an efficiency of 72% (Lowara, 2012).

A rectangular sump with a capacity of 100m^3 will be constructed in reinforced concrete.

Power Requirement

The power required to drive the pump has been calculated as details above in Option 1.

For Q = 248.4m^3/hour; H= 174.58m; and e=0.72; P should be equal to 164.12 kW.

5.2.4.3 Nduma Booster Station

The Intermediate Booster Station at km 5.5 should be constructed along the main road MR 3, at an elevation of 310m amsl.

Calculation of Static Head

The booster pumps would lift a total flow of 69 l/s from an elevation of 310m amsl to 455m amsl. The static head would then be 455m - 310m = 145m.

Friction Losses

Friction losses can be calculated by following relation: $f = \lambda * L/d * V^2/2g$ as detailed in 5.1.5 above. By resolving this equation using an excel calculation spreadsheet (Appendix 4) , for a line of 250mm diameter, and a flow rate of 40.5 l/s, the friction loss on a length of 5.8km is 17.19m. The length of the rising main from the Treatment Plant to Nduma Intermediate Booster Station is about 2km, thus the friction loss for a flow of 28.5 l/s through a pipe of 250mm diameter would be 3.019m. The friction in the Lomahasha line should be used for the calculation of the total head as it is the highest. The detailed calculations for the sizing of the pipeline are included in Appendix 4.

Local Head Losses

Local head losses have been calculated as detailed above in 5.1.5.

For V= 0.825m/s; ζ_{tot} = 3.10 and g=9.81m/s^2; Local head loss should be 0.1077m.

The total Head for the pump should be calculated as follows.

Total Head = 145m+17.19m+0.1077m = 162.30m

Pump selection and installation

Two pumps of a capacity per each of 69 litres per second at 162.30m total head will be installed in parallel in a duty/standby set up *KSB WKLn 150/4* pumps can be used for this duty, with an efficiency of 76% (KSB Pumps, 2012).

Power Requirement

The power required to drive the pump at this intermediate booster station has been calculated as detailed in 9.2.1.5.1.4 above.

For Q = 248.4m^3/hour; H= 162.30; and e=0.76; P should be equal to 144.5 kW.

A rectangular sump with a capacity of 200m^3 will be constructed in reinforced concrete, to allow for the connection of some 4 homesteads in the vicinity of the booster station.

5.2.4.4 Mbokojwane Intermediate Booster Station

The Mbokojwane Intermediate Booster Station should be constructed along the main road MR 3, at the same position as that in Option 1. The pump characteristics would be as detailed above in sub-section 5.1.5.2.

5.3 Option 3: Connection from the existing system in Simunye

As mentioned in sub-section 4.4.3 above, the existing Simunye Water Treatment System was designed to supply Siteki, Lomahasha and surrounding areas. A tee was fitted in the rising main to allow for a future connection to Lomahasha via a 30km transmission pipe. This assessment of other options to providing a supply to the Lomahasha border gate and surrounding areas was motivated due to the extensive resources required to implement the 30 km pipeline.

To connect from Simunye, the following main components would be required: storage reservoirs; transmission pipelines; pumping system and distribution reticulation and house connections.

The distribution reticulation and the house connections were not considered in the analysis as mentioned in sub-section 5.1 above.

5.3.1 Storage Reservoirs

The storage reservoirs in this option will be the same as in Option 2, with the additional reservoir of $250m^3$ capacity provided at Maphiveni to supply Mlawula Camp & Railway Station and Maphiveni Settlement (Figure 35).

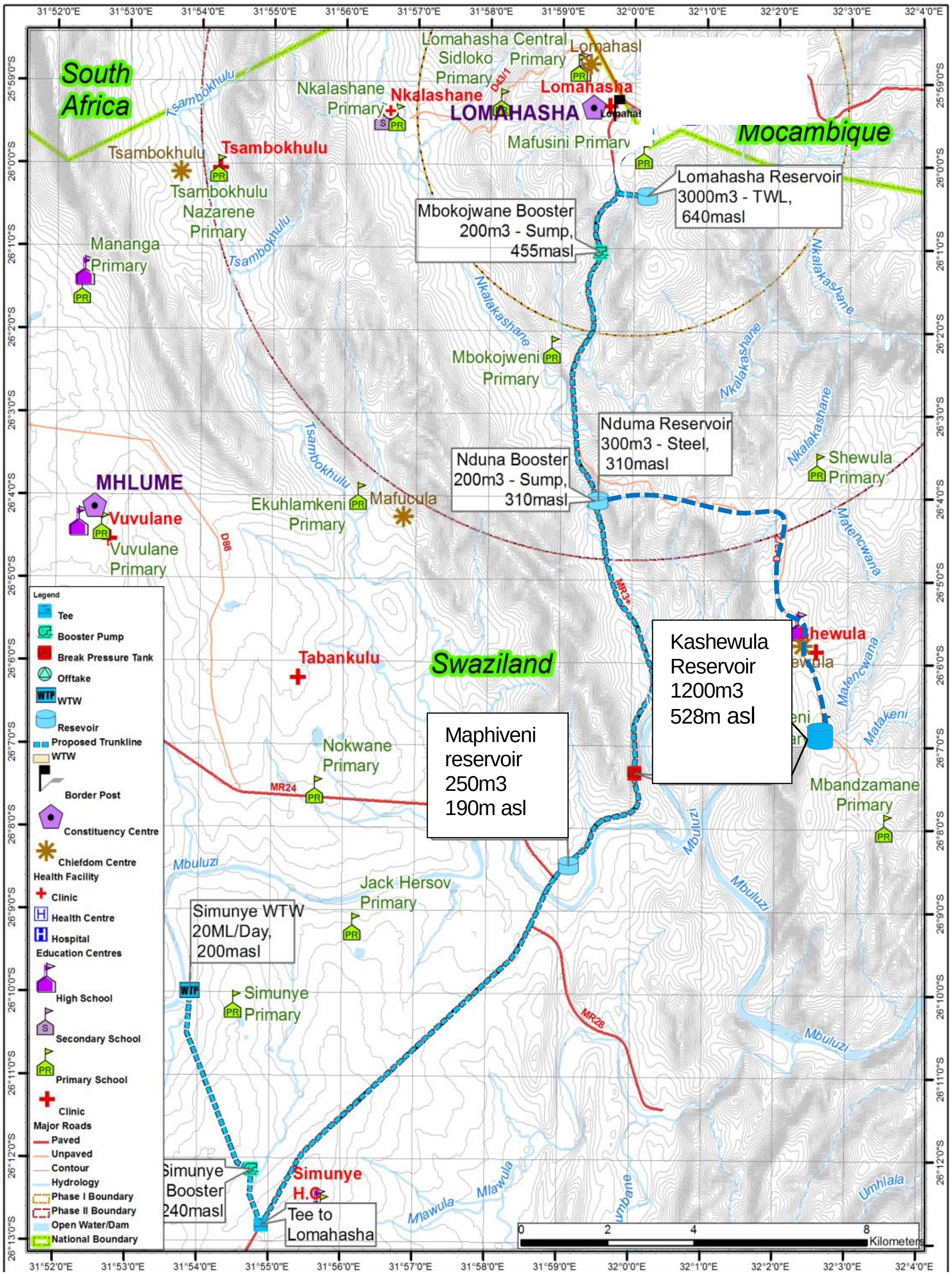


Figure 35: Option 3 - Connection to the existing system in Simunye

5.3.2 Transmission pipelines

The pipeline route from Simunye to Lomahasha generally should follow the road reserve of MR3. The line would start just at the tee which was reserved for the connection to Lomahasha at Simunye, and then follows the alignment of MR3 on the right hand side of the road up to about km 20.3 where if splits in two, with one branch continuing along MR3 toward Lomahasha and another one running along the gravel road toward Ka-Shewula.

The total length of the transmission pipeline from Simunye to the main storage reservoir at Lomahasha would be about 28.6km, and the Ka-Shewula branch would be 9.7km.

From Simunye, water will be transmitted by pressure from the existing booster station in place in the existing system up to a booster station to be constructed at Nduma at the same position as that in Option 2.

From the Treatment Plant to the Nduma Booster Station, a 350mm diameter pipe will be used, and the branches to Lomahasha and to Ka-Shewula will be in 250mm diameter pipes as per Options 1 and 2.

5.3.3 Pumping System

Two booster stations will be provided in this option: Nduma Booster Station and Mbokojwane Booster Station.

The existing booster pumps at Simunye will lift the water up to the Nduma Booster Station, from which water will be pumped into Lomahasha and Ka-Shewula systems.

The existing booster system at Simunye is described in Section 3.3. Details on Nduma Booster Station and Mbokojwane Booster Station are contained in Sections 5.1.5.2 and 5.1.5.3 respectively.

The energy consumption of the existing Simunye system will increase as a result of the new connection to supply the Lomahasha system. This increase can be estimated by calculating the energy required to lift the Lomahasha water demand from the river at Simunye up to the treatment plant, added to the energy required to pump the Lomahasha water demand from the treatment plant at Simunye up to the first booster station at Nduma.

At Simunye, the raw water intake is at an elevation of 196m amsl, then the static head from the intake to Nduma should be 310m – 196m = 114m. The friction losses and the local losses have been calculated as presented in section 5.1.5 above. For a length of 20.5km and a flow rate of 69 litres per second, the total power required should be 169kW, assuming a pumping efficiency of 60%.

The main characteristics of the preferred options are summarised in Table 22.

Table 22: Summary of the main characteristics of the three options

Option	Description	Intake	Total length of transmission line	Storage Reservoirs	Total Power Required
1	Intake at Nkhalashane River	Balancing Dam	18km	3No of 4550m^3 total capacity	274.5kW
2	New Intake at Mbuluzi River	New River Intake	23.5km	4No of 4550m^3 total capacity	461kW
3	Connection to existing line	Pipe Connection	38.3km	4No of 4550m^3 total capacity	440kW

6. ECONOMIC EVALUATION OF PREFERRED OPTIONS

6.1 Preamble

Following the preliminary design of preferred options, an economic evaluation was carried out to compare the various scenarios on the basis of their various costs and beneficial and adverse environmental impacts. For the purposes of this study, the following costs and impacts have been taken into consideration.

- Construction costs,
- Operation and Maintenance costs,
- Beneficial and Adverse Environmental Impacts.

The construction costs were estimated on the basis of the preliminary design of the works as described above, and using average unit prices currently applied by the construction industry in Swaziland.

The operation and maintenance costs were calculated on the basis of estimated annual expenses required for the running of the system and its maintenance. The main cost in this category is for the payment of electricity bills, and this has been evaluated on the basis of predicted power requirements for the pumping system.

The potential environmental impacts have been assessed in terms of land use and disturbance to natural ecology.

6.2 Construction costs

Quantities of works to be constructed have been estimated for each option as described in chapter 5. A bill of quantities was prepared and then cost estimates were compiled using average unit prices obtained from recent contractors' tenders for similar works (BICON, 2012). A construction period of 12 months has been allowed for in all the options with a contractual Defects Liability Period of 12 months.

The detailed cost estimates are attached in Appendix 2. They can be summarised as follows for each option.

6.2.1 Option 1: Intake at Nkalashane River

The construction costs for Option 1 have been estimated as shown in Table 23 below.

Table 23: Estimation of Construction Costs, Option 1

SECTION	DESCRIPTION	AMOUNT (RAND)
1	Section 1: Preliminary And General	6 359 250.00
2	Section 2: Pipe Trenches	2 852 300.00
3	Section 3: Water Pipelines	7 373 900.00
4	Section 4: Bedding	1 093 450.00
5	Section 5: Construction of Balancing Dam	5 785 650.00
6	Section 6: Clear Water Pump House	325 933.00
7	Section 7: Clear Water Pumps	823 050.00
8	Section 8: Booster Pump Station Civil Works	839 559.00
9	Section 9: Booster Pumps	2 021 050.00
10	Section 10: Water Treatment Works	11 100 000.00
11	Section 11: Construction of Sumps	1 365 931.75
12	Section 12: Storage Reservoirs	3 561 220.50
13	Sub-Total	43 501 294.25
14	Add 15% for Contingencies and Price Adjustment	6 525 194.14
15	Sub-Total	50 026 488.39
16	Add 14% VAT	7 003 708.37
TOTAL		**57 030 196.76**

The total estimated cost for Option 1 is **R 57 030 196.76** including an allowance of 14% for VAT and 15% for physical contingencies and price adjustment.

6.2.2 Option 2: New intake at Mbuluzi River

The construction costs for Option 2 have been estimated as shown in Table 24 below.

Table 24: Estimation of Construction Costs, Option 2

SECTION	DESCRIPTION	AMOUNT (RAND)
1	Section 1: Preliminary and General	6 359 250.00
2	Section 2: Pipe Trenches	3 171 550.00
3	Section 3: Water Pipelines	11 061 000.00
4	Section 4: Bedding	1 379 400.00
5	Section 5: Raw Water Intake	1 056 300.00
6	Section 6: Clear Water Pump House	325 933.00
7	Section 7: Clear Water Pumps	823 050.00
8	Section 8: Booster Pump Station Civil Works	839 559.00
9	Section 9: Booster Pumps	2 521 050.00
10	Section 10: Water Treatment Works	11 100 000.00
11	Section 11: Construction of Sumps	1 365 931.75
12	Section 12: Storage Reservoirs	3 561 220.50
13	Sub-Total	43 564 244.25
14	Add 15% For Contingencies and Price Adjustment	6 534 636.64
15	Sub-Total	50 098 880.89
16	Add 14% for Vat	7 013 843.32
	Total	**57 112 724.21**

The total amount for the construction of Option 2 has been estimated to be R**57 112 724.21,** including an allowance of 14% for VAT and 15% for contingencies and price adjustment.

6.2.3 Option 3: Connection to the existing System at Simunye

The construction costs for Option 3 have been estimated as shown in Table 25

Table 25: Estimation of Construction Costs, Option 3

SECTION	DESCRIPTION	AMOUNT (RAND)
1	Section 1: Preliminary And General	6 359 250.00
2	Section 2: Pipe Trenches	3 984 550.00
3	Section 3: Water Pipelines	19 320 900.00
4	Section 4: Bedding	1 379 400.00
5	Section 5: Booster Pump Station Civil Works	839 559.00
6	Section 6: Booster Pumps	2 521 050.00
7	Section 7: Construction of Sumps	1 365 931.75
8	Section 8: Concrete Storage Reservoirs	3 561 220.50
9	Section 9: Nduma and Maphiveni Reservoirs	1 355 356.50
10	Sub-Total	40 687 217.75
11	Add 15% for Contingencies and Price Adjustment	6 103 082.66
12	Sub-Total	46 790 300.41
13	Add 14% For VAT	6 550 642.06
	Total	**53 340 942.47**

As shown in Table 25, the construction of Option 3 would cost R **53 340 942.47,** including an allowance of 14% for VAT and 15% for contingencies and price adjustment. This is the cheapest option when considering the construction costs only. The most preferable option would be determined after the evaluation of all the costs, including the operation and maintenance charges, and the probable impacts to the environment.

6.3 Operation and Maintenance Costs

The main costs required for the running and the maintenance of the system have been evaluated. These include the administrative costs, energy costs and maintenance costs.

6.3.1 Administrative Costs

The administrative costs include all expenses related to personnel and all consumables including office stationery and process chemicals.

With regard to the personnel, it was assumed that each pump station will have a full time security guard, and that there will be one operator for all the pump stations and another one for the treatment plant. There will be one supervisor to oversee the whole system with a bakkie for the transport of personnel and consumables.

Remuneration for the personnel has been extracted from the Government Gazette publication (Government Gazette, 2010).

The administration costs for the various options are summarised below.

Table 26: Summary of annual administration costs for various options

No	Item	Annual costs		
		Option 1	**Option 2**	**Option 3**
1	Salary - Operators	R 84 000.00	R 84 000.00	R 42 000.00
2	Salary - Security	R 63 000.00	R 84 000.00	R 63 000.00
3	Salary - Supervisor	R 60 000.00	R 60 000.00	R 60 000.00
4	Transport	R 180 000.00	R 180 000.00	R 180 000.00
5	Tools	R 6 000.00	R 6 000.00	R 6 000.00
6	Stationery/Sundry	R 6 000.00	R 6 000.00	R 6 000.00
7	Chemicals	R 60 000.00	R 60 000.00	R 60 000.00
TOTAL		**R 459 000.00**	**R 480 000.00**	**R 417 000.00**

6.3.2 Energy Costs

In Swaziland, the electricity is solely distributed by the Swaziland Electricity Company (SEC). There are seven categories of electricity consumers with following tariffs (SEC, 2012):

Table 27: Swaziland Electricity Company tariff categories

No.	Category	Description	Facility Charge (R/Month)	Energy Charge (c/kWh)	Demand Charge (R/kVA)	Access Charge (R/kVA
1	Domestic users	Solely used for residential purposes	None	87.49	None	None
2	General Purpose	Facilities not falling in any other category	143.64	121.31	None	None
3	Small commercial	Commercial, demand below 40kVA	143.64	121.31	None	None
4	Life Line	For poverty alleviation	None	81.23	None	None
5	Small Irrigation	Irrigation with demand below 100kVA	1272.78	46.02	77.28	34.74
6	Large Commercial	Maximum demand over 40kVA	1497.38	54.15	90.92	40.88
7	Large Irrigation	Irrigation with demand exceeding 100kVA	1497.38	54.15	90.92	40.88

Considering the power requirement of the pump stations in this project, all the connections fall under category Six, and would be charged R1497.38 per month for Facility Charge, 54.15 c/kWh for Energy Charge, 90.92 R/kVA for Demand Charge and 40.88 R/kVA for Access Charge.

The annual electricity costs have been calculated based on current charges. The detailed calculations are presented in Appendix 3. The total annual costs for various options can be summarised as follows.

1	Option 1: Intake at Nkalashane River	R 752 576.44
2	Option 2: New Intake at Mbuluzi River	R 1 136 293.37
3	Option 3: Connection to existing system at Simunye	R 1 094 235.66

6.3.3 Maintenance Costs

The maintenance costs have been calculated on the basis of construction costs, considering the life spans of the proposed works and the estimated percentage of maintenance costs over the capital costs, as shown in Table 28 below.

For general civil works and water supply system components, life spans of works and equipment can be projected as follows, as recommended in the Rural Water Supply System (Rural Water Supply Branch, 2003).

Table 28: Service life of components and percentage of maintenance costs over capital costs

No.	Component	Service life (years)	Annual maintenance costs as a % of capital costs
1	Concrete structures	50	1
2	Dams and intakes	45	1
3	uPVC pipes and fittings	20	1
4	Steel galvanised pipes and fittings	25	1
5	Treatment Plant	20	3
6	Pumps with regular maintenance	15	5

The maintenance costs for various options have been estimated as follows.

Table 29: Maintenance costs, Option1

Equipment	Life Cycle (Years)	Annual maintenance costs as a % of Capital Costs	Estimated Cost	Annual Maintenance Cost
Water Pipelines	20	1	R 7 373 900.00	R 73 739.00
Balancing Dam	45	1	R 5 785 650.00	R 57 856.50
Clear Water Pump House	50	1	R 325 933.00	R 3 259.33
Clear Water Pumps	15	5	R 823 050.00	R 41 152.50
Booster Pump Houses	50	1	R 839 559.00	R 8 395.59
Booster Pumps	15	5	R 2 021 050.00	R 101 052.50
Water Treatment Works	25	1	R 11 100 000.00	R 111 000.00
Construction of Sumps	50	1	R 1 365 931.75	R 13 659.32
Storage Reservoirs	50	1	R 3 561 220.50	R 35 612.21
Total				**R 445 726.94**

Table 30: Maintenance costs, Option 2

Equipment	Life Cycle (Years)	Annual maintenance costs as a % of Capital Costs	Estimated Cost	Annual Maintenance Cost
Water Pipelines	20	1	R 11 061 000.00	R 110 610.00
Intake works	50	1	R 1 056 300.00	R 10 563.00
Clear Water Pump House	50	1	R 325 933.00	R 3 259.33
Clear Water Pumps	15	5	R 823 050.00	R 41 152.50
Booster Pump Houses	50	1	R 839 559.00	R 8 395.59
Booster Pumps	15	5	R 2 521 050.00	R 126 052.50
Water Treatment Works	25	1	R 11 100 000.00	R 111 000.00
Construction of Sumps	50	1	R 1 365 931.75	R 13 659.32
Storage Reservoirs	50	1	R 3 561 220.50	R 35 612.21
Total				**R 460 304.44**

Table 31: Maintenance costs, Option 3

Equipment	**Life Cycle (Years)**	**Annual maintenance costs as a % of Capital Costs**	**Estimated Cost**	**Annual Maintenance Cost**
Water Pipelines	20	1	R 19 320 900.00	R 193 209.00
Booster Pump Houses	50	1	R 839 559.00	R 8 395.59
Booster Pumps	15	5	R 2 521 050.00	R 126 052.50
Construction of Sumps	50	1	R 1 365 931.75	R 13 659.32
Storage Reservoirs	50	1	R 3 561 220.50	R 35 612.21
Maphiveni and Nduma reservoirs	25	1	R 1 355 356.50	R 13 553.57
Total				**R 197 273.18**

The total O&M costs for the three options are presented in the table below.

Table 32: Total O&M costs for the three options

No.	**Designation**	**Annual Operation and Maintenance Costs**		
		Option 1	**Option 2**	**Option 3**
1	Administration costs	R 459 000.00	R 480 000.00	R 417 000.00
2	Energy Costs	R 756 683.24	R 1 136 293.37	R 1 094 235.66
3	Maintenance costs	R 445 726.94	R 460 304.44	R 197 273.18
Total		**R 1 661 410.18**	**R 2 076 597.81**	**R 1 708 508.84**

6.4 Total Economic Costs

The total construction and O&M costs can be summarised as shown below.

Table 33: Construction costs and annual O&M costs for various options

Option	Construction Costs	Annual O&M costs
Option 1	R 57 030 196.76	R 1 657 303.38
Option 2	R 57 112 724.21	R 2 076 597.81
Option 3	R 53 340 942.47	R 1 708 508.84

The table above shows that Option 1 and Option 2 have almost the same construction costs but the O&M costs are much higher for Option 2. However, we still have to consider the environmental impacts and therefore all the options should be kept for further evaluation.

In the following analysis, the options should be compared on the basis of their total costs. This would require to calculate the present values of the O&M costs for all the three options.

6.4.1 Calculation of the Annuity Factor

The present value of the operation and maintenance costs can be calculated using the Annuity Factor (Taigbenu, 2011).

$Af= [(1+r)^t-1]/[r(1+r)^t]$ (Equation 11)

Where

Af = Annuity factor

r = Interest rate

t = Design period

Then the Present Value PV is given by

PV = Af x Annual Cost (Equation 12)

The current interest rate recommended by the South African Reserve Bank is 8.5% (South African Reserve Bank, 2012). For a design life of 15 years, the calculated Annuity Factor is 8.306.

6.4.2 Present Value of O&M costs for Option 1

For Af = 8.306 and Annual cost = R 1 657 303.38, the Present Value of O&M costs would be 8.306 x R 1 657 303.38 = R 13 765 561.87

6.4.3 Present Value of O&M costs for Option 2

For Af = 8.306 and Annual cost = R 2 076 597.81, the Present Value of O&M costs would be 8.306 x R 2 076 597.81= R 17 248 221.41.

6.4.4 Present Value of O&M costs for Option 3

For Af = 8.306 and Annual cost = R 1 708 508.84, the Present Value of O&M costs would be 8.306 x R 1 708 508.84 = R 14 190 874.43.

Table 34: Total costs for various options

Option	Construction Costs	Present Value of O&M costs	Total
Option 1	R 57 030 196.76	R 13 765 561.87	R 70 795 758.63
Option 2	R 57 112 724.21	R 17 248 221.41	R 74 360 945.62
Option 3	R 53 340 942.47	R 14 190 874.43	R 67 531 816.90

In terms of economic costs, Option 3 is the most advantageous, followed by Option 1 as shown in Table 38 above. The final option to be adopted for construction should be fixed after the evaluation of the environmental impacts likely to be generated by the various options.

6.5 Beneficial and Adverse Environmental Impacts.

6.5.1 Beneficial Impacts

The main beneficial impact of the proposed water supply system is the improvement of life standards in the area by providing clean drinking water to the people of Lomahasha Inkhundla. Any of the three options would attain this targeted benefit.

The other beneficial impact is the availability of water for irrigation in the area surrounding the dam, in the case of Option 1. The water resource management in Nkalashane River would be improved in case this option was to be implemented and this would impact positively on the ecosystem conservation downstream to the dam.

6.5.2 Negative Impacts

The main negative impacts to be generated by the proposed works are: Land Use; Impacts on Fauna and Flora and Disturbance to the water course

6.5.2.1 Land use

Land will be needed for the construction of the dam, the storage reservoirs, the treatment plant and the pump houses, and for the laying of pipelines. Option 1 is most detrimental when considering the land use issues as it would develop a balancing dam which would occupy a surface area of about 65 hectares. The land to be flooded by the dam is presently used for agriculture and homesteads in the area depend on it for growing maize and vegetables.

Option 1 and Option 2 will also need land for the construction of a treatment plant, while Option 3 would be supplied from an existing plant.

The main work to be carried out in the case of Option 3 is the laying of a pipeline all the way from Simunye to Lomahasha. This work will generally be restricted to the road reserve without requiring the use of new lands.

In terms of land use, Option 3 is most preferable as it involves less use of new lands.

6.5.2.2 Impacts on Fauna and Flora

Fauna and Flora are always impacted on wherever there is a site clearance for construction works. In case of Option 1, species now in place in the area to be flooded by the dam would disappear and would be replaced by aquatic species. Options 1 and 2 would again need site clearance for the construction of the new treatment plant, while Option 3 would be connected to an existing system.

Considering the impacts on Fauna and Flora, Option 3 is most advantageous.

6.5.2.3 Disturbance to the water course

Option 1 and Option 2 will require the construction of a dam or a weir across the normal course of the river. This would disturb the natural flow in the river and could be prejudicial to the water quality and quantity needed by downstream consumers. Moreover the abstraction of water in the case of Options 1 and 2 would require the permit from the Water Apportionment Board, and international agreements would be considered before the issuing of the permit.

On the basis of potential negative impacts to be caused to the water course, Option 3 is most suitable as it does not require any further disturbance of the river course.

6.5.3 Ranking of various options on the basis of environmental aspects

The various options considered can be ranked on the basis of their environmental impacts from the least adverse to the most adverse, as follows.

1. Option 3: Connect to the existing water supply system;
2. Option 2: Build a new intake at Mbuluzi River;
3. Option 1: Build a new intake at Nkalashane River.

Based on the potential beneficial and negative impacts to be generated by the various options analysed, the most favourable scenario is Option 3 which consists of the connection to the existing water supply system in Simunye.

6.6 Selection of the most favourable option

The outcome of the economic analysis and the environmental evaluation as developed in the preceding chapters is summarised in Table 35.

Table 35: Summarised outcome of economic and environmental evaluation

Option	Total Economic Cost	Environmental Ranking
Option 1	R 70 795 758.63	Least Favourable
Option 2	R 74 360 945.62	Medium
Option 3	R 67 531 816.90	Most Favourable

The table above shows that Option 3 is economically and environmentally the most favourable, and therefore should be recommended to proceed with the construction.

After a well dedicated study, which includes the analysis of existing documentation and previous similar studies, site inspections, discussion and interviews with various stakeholders and desktop work, it is concluded that the best option to source water for the supply to Lomahasha is the connection to the water supply system already in place at Simunye.

7. SCENARIO ANALYSIS FOR THE CHOSEN OPTION

7.1 Introduction

This study recommended the supply of water to Lomahasha using the existing system in place at Simunye, which abstracts the water from the Mbuluzi River. The main components of that system are presented in chapter 5.

This section of the study is intended to elaborate on the suitability of the chosen water source, considering all competing water uses in the same river catchment area. This required an assessment of all the water uses which are supplied from the same source and the performance of a water balance operation based on the flow availability in the river at the point of water abstraction. The assessment has been conducted both through review of previous studies and through collection and analysis of new data and information.

The Mbuluzi River has been covered by several water management studies in the past years. These have been reviewed and relevant information extracted. Of the several cited above, the three studies conducted by JTK Associates (2002), SWECO & Associates (2005) and Knightpiesold (2011) have significantly contributed to the present study and provided records relating to hydrology and climate, water consumption and the present physical condition of existing structures.

The emphasis of this section of the study is mainly on the following three aspects: Water availability at intake point, Present and Future Water Demand, and Water Balance Analysis.

7.2 Location of the source

The abstraction point is along Mbuluzi River, at Lusoti Extraction Works, at an existing weir constructed in the 1980’s for the abstraction of irrigation water for sugarcane farming by Royal Swaziland Sugar Corporation (SWECO & Associates, 2005).

It is located at 26°10’02.49’’S and 31°53’48.91’’E. The google image of the intake point is shown in Figure 36.

Figure 36: Lusoti Intake Point along Mbuluzi River

In 2010, the Swaziland Water Services Corporation installed a raw water pump station at the same weir and constructed a water treatment plant nearby. From the treatment works, a bulk supply pipeline takes the water to storage and distribution reservoirs at Mpaka, Siteki, King Mswati III International Airport, and in the future, to Lomahasha.

7.3 Mbuluzi River hydrology

The Mbuluzi river basin extends from the Ngwenya hills in the north west of Swaziland, through the north-central part of Swaziland and into Mozambique (Knight Piesold , 2011). The Mbuluzi river basin covers an area of about 3100 km^2, the altitude ranges from 1500m in the Highveld to about 125m in the Lowveld (Knight Piesold , 2011).

The extraction of drinking water from Mbuluzi River would not be the predominant cause of stream flow depletion in the river but it would be affected if the river flow was to be exhausted by other water uses. In Swaziland, 96% of the water is used for irrigation, while the water used for domestic consumption stands at 2% (Manyatsi, 2009).

7.3.1 Stream flow gauging stations

In total, 13 gauging stations exist in the Mbuluzi River basin as shown in Figure 36 and Table 40. The Department of Water Affairs in the Ministry of Natural Resources and Energy is responsible for the upkeep and the operation of river gauging stations in Swaziland. An official from the Department indicated that they kept reliable records until 1984 when most of the stations were destroyed by the Demoina cyclone (Simelane, 2014). Currently, some of the stations have not been rehabilitated due to economic constraints (Simelane, 2014).

The data coverage varies for the various stations depending on the commencement date of recording at each station. The Goba Montande (E10) and Boane (E8) stations in Mozambique have the longest records starting in the early 1950s (SWECO & Associates, 2005). In Swaziland, the upstream stations GS3, GS4 and GS10 have the longest records (SWECO & Associates, 2005).

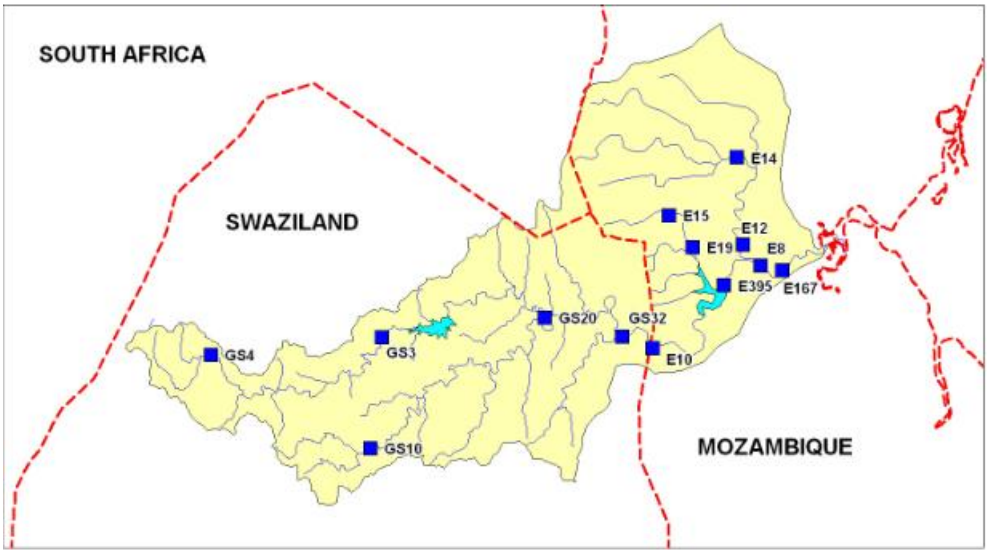


Figure 37: Position of stream gauging station in Mbuluzi River basin

The main characteristics of the gauging stations are presented below.

Table 36: Characteristics of gauging stations in the Mbuluzi River basin

Gauging Station No	Location	River	Latitude	Longitude	Altitude (m amsl)	Catch-ment area (km2)
Swaziland						
G S3	Croydon	Mbuluzi	26 10 15	31 34 45	305	722
GS 4	Leper	Mbuluzi	26 12 30	31 12 00	975	166
GS 10	Mpisi Farm	Mbuluzane	26 21 30	31 31 45	381	223
GS 20	Hlane	Mbuluzi	26 09 30	31 52 45	198	2 429
GS 32	Mlawula	Mbuluzi	26 10 15	32 01 45	122	2 931
Mozambique						
E 10	Goba Montande	Mbuluzi	26 11 48	32 06 59	63	2 986
E 395	Pequenos Libombos Dam	Mbuluzi	26 05 24	32 14 33	17	3 735
E 8	Boane	Mbuluzi	26 03 00	32 19 30	3	5 260
E 167	Captacao	Mbuluzi	26 03 52	32 22 00	13	5 300
E 15	Impaputo	Calichane	25 57 06	32 08 18	125	88
E 19	Calichane	Calichane	26 01 37	32 11 01	55	208
E 12	Movene	Movene	26 00 45	32 17 42	14	1 425
E 14	Movene	Movene	25 50 42	32 16 06	55	709

7.3.2 Rainfall records

Rainfall data are available from 51 rainfall stations within and adjacent to the Mbuluzi River basin as shown on Figure 37 extracted from (Knight Piesold , 2011). The figure also shows that 34 of these stations are located within the Mbuluzi catchment area and the rest are outside its catchment but within its vicinity. Data coverage varies with the longest records extending to the 1920s (SWECO & Associates, 2005).

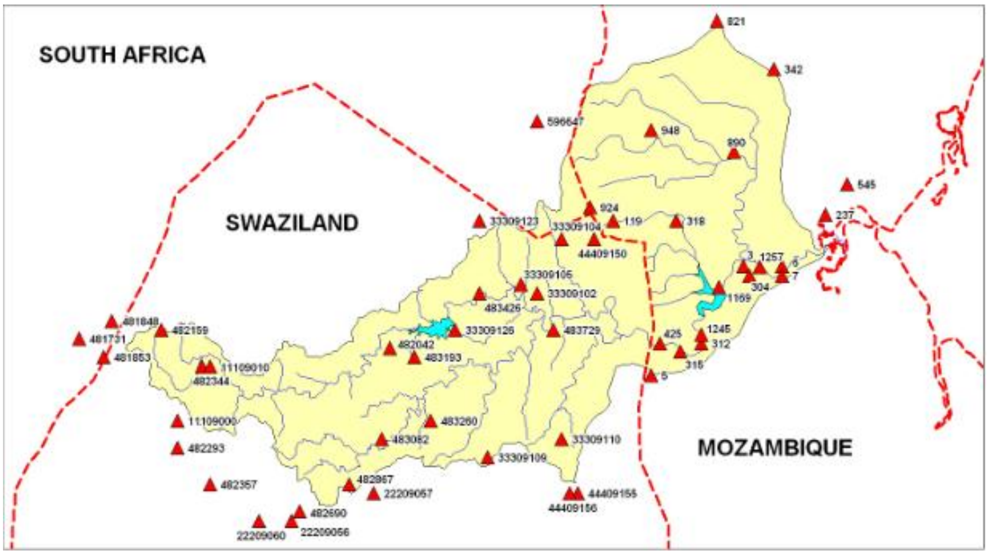


Figure 38: Rainfall stations in Mbuluzi River basin

Rainfall station records, including the location of the rainfall station and monthly rainfall recorded, were obtained from the Swaziland Meteorology services. The climatic information pertinent to this study is presented in chapter 2.

7.3.3 Evaporation

Monthly averages of potential evaporation data for Swaziland are available at the National Meteorological Services of Swaziland. This source provides evaporation figures based on A-pan measurements with formulae to convert from A-pan to S-pan.

The rainfall and potential evaporation data form the basic input to the WRSM2000 model which was used by both JKT & Associates (2002) and SWECO & Associates (2005) to simulate the stream flows in the Mbuluzi River basin.

7.3.4 WRSM 2000 Rainfall-Runoff Model

The WRSM 2000 model was used by previous studies to simulate the stream flows in the Mbuluzi River. The first step in the process of running the model is the subdivision of the river catchment into sub-catchment areas for which the run-off is calculated and compared to the observed stream flows recorded at gauging stations.

In Swaziland, the sub-catchments coincide with the surface water basins defined in Surface Water Resources of South Africa (SWECO & Associates, 2005). The sub-catchments defined for the Mbuluzi River basin are shown in Figure 38. In total, the river basin comprises seventeen sub-catchments, with 11 of them in Swaziland and 6 in Mozambique. Figure 38 also shows that 9 sub-catchment areas are located upstream of the abstraction point at Lusoti Extraction Works (shown by the arrow).

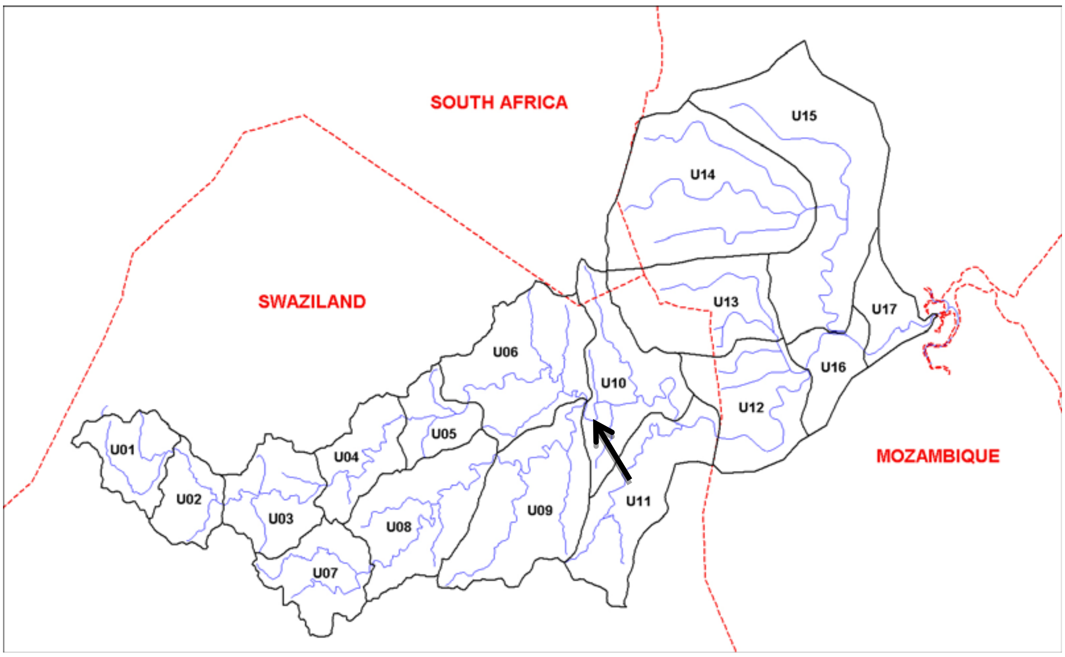


Figure 39: Sub-catchments of the Mbuluzi River basin

The characteristics of the sub-catchments contributing to the flow at Lusoti Extraction Works are as shown in Table 41. The Mean Annual Run-off as simulated by SWECO & Associates (2005) are also presented below.

Table 37: Characteristics of sub-catchments of Mbuluzi River

No	Sub-catchment	Area (km^2)	Cumulative Area (km^2)	MAP (mm)	MAE (mm)	MAR (Mm^3/Year)
1	U01	172	172	1156	1400	73.72
2	U02	143	315	1201	1400	56.88
3	U03	233	548	1161	1400	89.14
4	U04	187	735	937	1400	36.21
5	U05	134	869	806	1400	10.21
6	U06	418	1287	801	1450	29.3
7	U07	222	1509	912	1400	33.44
8	U08	365	1874	796	1450	27.98
9	U09	447	2321	819	1450	22.32

7.3.5 Monthly Stream flow Time Series

Observed stream flows for various gauging stations in the Mbuluzi river basin were obtained from the Department of Water Affairs in Swaziland. These were compared with the simulated stream flow time series generated by JKT & Associates (2002) and SWECO & Associates (2005). Both studies concluded that for most of the stations, the simulated and the observed streamflows compare well for low to medium flows.

Figure 40 shows the comparison for stream gauging station GS20.

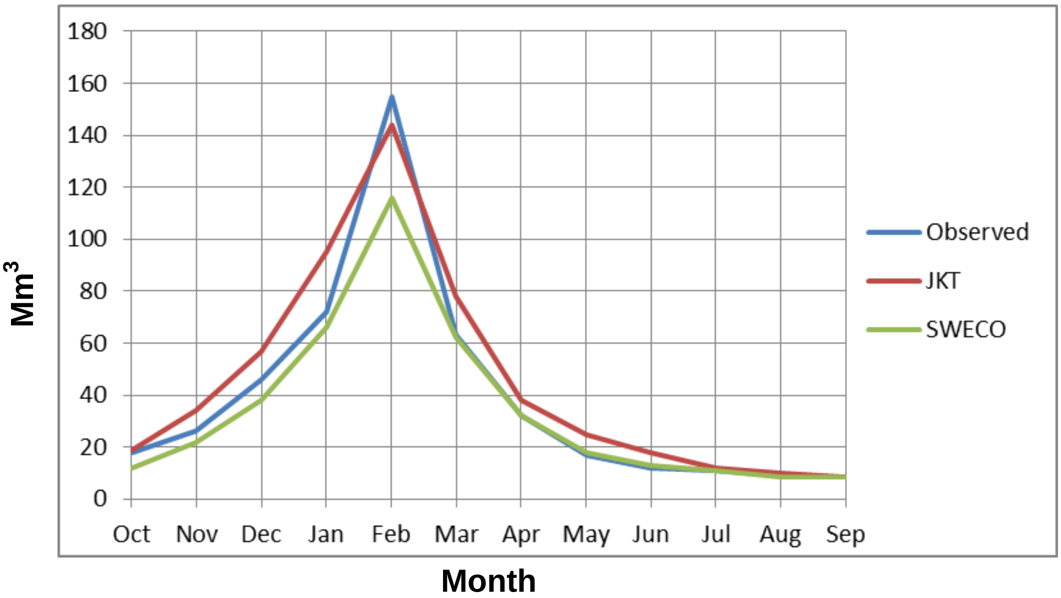


Figure 40: Compared runoff figures for stream gauging station GS 20

The observed stream flows for GS20 are available for the period of 1973 to 1981. The station was destroyed by the Demoina cyclone in 1984 and has not been rehabilitated.

7.4 Water use in the River Basin

7.4.1 Domestic water requirement

The water from Mbuluzi River is mainly used for irrigation and domestic consumption. A study carried out in 2009 indicated that in the Mbuluzi River basin, 180 million of cubic metres were used for irrigation per year, while 25 million cubic metres were used yearly for urban and rural domestic, industry and livestock consumption (Manyatsi, 2009).

The river catchment area upstream of the Lusoti Extraction Works supplies the city of Mbabane, the town of Ngwenya and rural areas within the catchment.

7.4.1.1 Lusoti Water Works

Presently, the Lusoti Water Works supplies water to Siteki, Mpaka, King Mswati III International Airport and rural areas in the central Lubombo Region. The intake and the plant production volumes for the Lusoti Extraction Works were obtained from the Plant Manager for the period of April 2011 to March 2012, as included in Table 42.

Table 38: Intake and plant production volumes for the Lusoti Water Treatment Plant

Month	Intake Volume (m^3/month)	Plant Production Volume (m^3/month)	% production/ Intake
Apr-11	159 124	155 443	97.7%
May-11	148 636	145 882	98.1%
Jun-11	171 113	166 703	97.4%
Jul-11	177 632	172 539	97.1%
Aug-11	170 889	165 735	97.0%
Sep-11	193 343	189 499	98.0%
Oct-11	195 777	192 480	98.3%
Nov-11	174 078	171 524	98.5%
Dec-11	198 924	195 315	98.2%
Jan-12	182 125	178 847	98.2%
Feb-12	178 300	174 556	97.9%
Mar-12	192 200	188 548	98.1%
Total	2 142 141	2 097 071	97.9%

The monthly extraction volume for the period of April 2011 to March 2012 varied from 148 636m^3 to 198 924m^3. The minimum production was observed in May and the maximum in December. The water works extracted for the existing water works was about 2.14Mm^3 in 2012. The present extraction is estimated at 2.27Mm^3 per year based on a normal growth rate of 2.9%. This would increase in the future with the addition of the demand for Lomahasha which has been estimated at 0.88Mm^3 per year. Also, the operation of King Mwasti III International Airport and the development of a new town around the airport would significantly increase the abstraction requirement at the Lusoti Extraction Works.

7.4.1.2 Mbabane and Ngwenya

The water extraction works for the supply to Mbabane are located at Mantjolo in the upper reach of Mbuluzi River. SWSC indicated that the total volume extracted during the year 2013 was 9.24Mm^3 (Zizhou, 2012).

The extraction works for the supply to the town of Ngwenya is located at the Hawane dam wall. SWSC indicated that the total volume extracted during the year 2013 was 0.284Mm^3 (Zizhou, 2012).

7.4.1.3 Small towns and villages in the catchment area

The water requirement for small towns and villages in the Mbuluzi basin was evaluated and projected by JTK Associates (2002) .The requirement in the year 2014 was projected to be about 2.65Mm^3.

The projected water requirements for domestic uses in the catchment area are summarised below.

Table 39: Water requirement for domestic uses

Supply area	Water requirement in Mm^3/year							
	Normal growth: 2.9%				Depleted growth: 1.4%			
	2014	**2019**	**2024**	**2029**	**2014**	**2019**	**2024**	**2029**
Lusoti water works	2.27	2.62	3.02	3.49	2.43	2.81	3.24	3.74
Mbabane	9.51	10.97	12.66	14.60	10.19	11.76	13.57	15.65
Ngwenya	0.29	0.33	0.38	0.44	0.31	0.36	0.41	0.47
Rural areas	2.65	3.06	3.53	4.07	2.84	3.28	3.78	4.36
Total	14.72	16.98	19.59	22.60	15.78	18.20	21.00	24.23

The water supplied to Mbabane and Ngwenya does not return to the Mbuluzi River as it is transferred from the Mbuluzi River catchment to the Lusutfu River catchment.

7.4.2 Industrial water requirement

In general, the industrial water requirement is included in the consumptions for towns, but there are cases where industries source water directly from the river rather than connecting to the municipal system. In the Mbuluzi River basin, industries in the city of Mbabane and Ngwenya extract water from the urban system. Also, the King Mswati III Airport, the Mpaka factory shell and the Lubombo hospital are supplied from the Lusoti Water Works.

The sugar mills at Simunye and Mhlume extract water directly from the river. The Mhlume mill is supplied from the Komati River, while the Mbuluzi River supplies the Simunye plant. The annual water consumption of Simunye plant is 1.75Mm^3 (JTK Associates, 2002).

7.4.3 Irrigation water requirement

Irrigation for sugarcane farming is the major water consumer in the Mbuluzi River basin. The area occupied by sugarcane in this river basin is estimated to be 26 850 ha, with 14 850 ha irrigated with water from the Mbuluzi River and 12 000 ha irrigated with water from Komati River (SWECO & Associates, 2005).

Using the Penman-based method, SWECO & Associates (2005) estimated the projected water requirement for irrigation from the Mbuluzi River in Swaziland for the year 2014 to be 228 Mm^3. The JTK report indicates that small schemes and farms totalling about 4 900 ha could be added up to 2022 and that would increase the irrigation water requirement to 292 Mm^3/year (JTK Associates, 2002).

7.4.4 Other water requirements

The SWECO study estimated the water requirement for livestock in the study area to be 1.16 Mm^3/year, assuming 50 l per day for one Equivalent Large Stock Unit (LSU), and a total population of 64 000 LSUs (SWECO & Associates, 2005). The study also estimated the water requirement for wildlife to be 1.66 Mm^3/year (SWECO & Associates, 2005).

7.4.5 Cross border flow requirement

In terms of the Mbuluzi Agreement signed between the governments of Swaziland and Mozambique, Swaziland is obliged to release 40% of flows as measured at stream flow gauging station GS3 and GS10 (JTK Associates, 2002). The annual cross border requirement was estimated to be 108Mm^3 per year based on the long-term MARs at GS3 and GS10 (JTK Associates, 2002). However, past experience has proven that this agreement was not effective. Firstly, because Mozambique does not need so much water and secondly, the agreement has several limitations particularly with regard to compliance monitoring mechanisms and management of droughts and floods (JTK Associates, 2002).

7.5 Water Balance Analysis

The water balance analysis for the Mbuluzi River basin in Swaziland was performed using the Water Evaluation and Planning System (WEAP) method developed by the Stockholm Environment Institute. This is a water resource planning and management tool which evaluates the suitability of development or management options, taking into account multiple and competing water uses.

Historic mean annual runoffs for existing dams were obtained from the Joint Umbeluzi River Basin study report, and simulated stream flows at GS20 and GS10 were used to determine the streamflows of the Mbuluzi River and the Mbuluzane River respectively.

The information on the two existing dams on the Mbuluzi River in Swaziland is shown in Table 40.

Table 40: Historic mean annual runoffs

Reservoir	FSL (m)	Capacity (Mm^3)	Mean Annual Runoff (Mm^3)	Height of Wall (m)	Mean Annual Precipitation (mm)	Year Constructed
Hawane	1367	3.25	8.7	11.5	1200	1984
Mnjoli	294.5	152.2	167.2	42	800	1980

(SWECO & Associates, 2005)

The streamflow values for GS 20 and GS10 are presented in Table 41.

Table 41: Stream flow values used in WEAP

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mbuluzi GS20 (m^3/s)	25.6	38.9	21.2	10.2	6.75	4.9	3.2	2.7	2.32	5.13	9.19	15.4
Mbuluzane GS10 (m^3/s)	11	16.6	9.03	4.4	2.9	2.08	1.39	1.16	0.99	2.2	3.94	6.6

In order to simulate the various water uses in the Mbuluzi River catchment in Swaziland, nine demand sites were considered as shown in Figure 40.

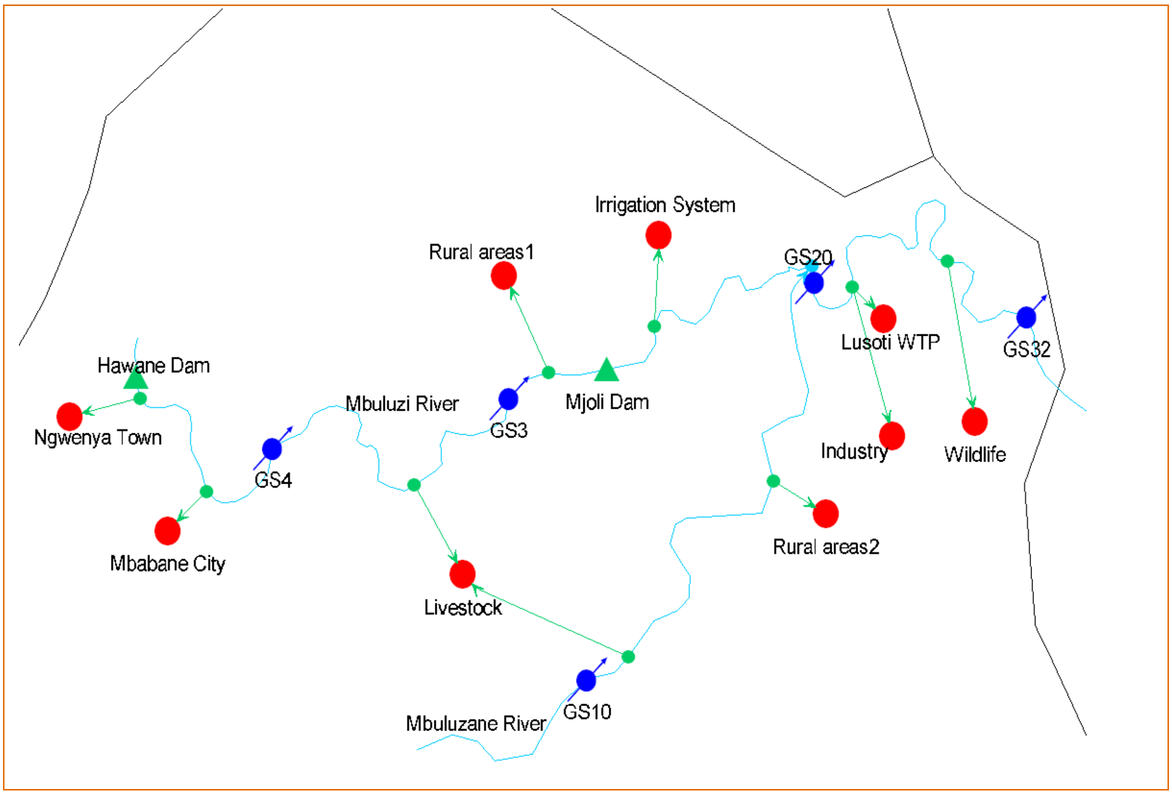


Figure 41: WEAP model schematic

The demand sites are described in Table 42.

Table 42: Demand sites for water balance analysis

No	Name	Description	Present Water Use (Mm^3/year)
1	Ngwenya Town	Water supply to the town of Ngwenya, the main border post between South Africa and Swaziland. Water is extracted from Hawane Dam in the upper reach of the river	0.29
2	Mbabane City	Water supply to the City of Mbabane, the capital city of the Kingdom of Swaziland	9.51
3	Rural areas 1	Small towns and villages in the Mbuluzi River catchment area	1.35

No	Name	Description	Present Water Use (Mm^3/year)
4	Rural areas 2	Small towns and villages in the Mbuluzane River catchment area	1.30
5	Livestock	Water consumed by cattle in the catchment area	1.66
6	Irrigation system	Sugarcane irrigation for the Simunye estate. Water is extracted from Mnjoli Dam	228
7	Lusoti WTP	Water supply to Siteki, Simunye, Lomahasha, Mpaka, the new airport and other areas in the southern parts of Lubombo Region	2.27
8	Industry	Water consumed by the Simunye Sugar Mill and Ethanol Plant	1.75
9	Wildlife	Water consumed by wildlife in Hlane and Mlawula nature reserves	1.16

For the purpose of this study, the priority in water supply to the different users was fixed as follows: (1) Urban Domestic; (2) Rural Domestic; (3) Irrigation; (4) Industry; (5) Wildlife; (6) Livestock.

7.5.1 Scenario analysis

Various scenarios were considered for the supply of water to competing users within the Mbuluzi River catchment in Swaziland. The scenarios were evaluated on an analysis period of 15 years starting from 2014. The scenarios analysed are presented in Table 43.

Table 43: Scenarios considered in the water balance analysis

No	Scenario	Description	Comments
1	Reference Scenario	▪ Normal population growth of 2.9% per annum over the analysis period for rural and urban water demand; ▪ Fixed water consumption rate for wildlife and livestock over the analysis period; ▪ Fixed irrigation water requirement over the analysis period; ▪ Proposed new town at Mpaka not developed, and new airport not fully in operation.	This scenario represents the most probable situation where the population would grow at a rate of 2.9% per annum as predicted by the Statistics Department, and the livestock and wildlife life population would stay the same during the analysis period. The irrigated land would also stay the same during the analysis period. The new airport was inaugurated in March 2014 but its full operation remains sceptical due to the small size of the air transport market of Swaziland.
2	Depleted Population Growth Scenario	▪ Depleted population growth of 1.4% per annum due to the effects of HIV/AIDS; ▪ Fixed water consumption rate for wildlife and livestock over the analysis period; ▪ Fixed irrigation water requirement over the analysis period; ▪ Proposed new town at Mpaka not developed, and new airport not fully in	The population growth could be affected by the effects of HIV/AIDS as predicted by NERCHA (2005). But current interventions being undertaken by Government and NGOs could limit the impacts. This is a modification of the reference scenario by changing the population rate from 2.9% to 1.4%.

		operation.	
3	Increased Irrigated Land Scenario	▪ Normal population growth of 2.9% per annum over the analysis period for rural and urban water demand; ▪ Fixed water consumption rate for wildlife and livestock over the analysis period; ▪ Irrigation water requirement increasing by 2% from the year 2015 up to 2029; ▪ Proposed new town at Mpaka not developed, and new airport not fully in operation.	This is a modification of the reference scenario by allowing for the increase of the irrigated land. JTK Associates (2002) indicated that approximately 4000 hectares suitable for irrigation are still available within the Mbuluzi River catchment in Swaziland. New irrigation schemes are presently being developed by local community farmers associations under projects implemented by SWADE and financed by EU, AfDB and Government of Swaziland. The irrigated area could increase at a rate of 2% until all the suitable land is brought into production.
4	Development of a new town at Mpaka and operation of the new airport	▪ Normal population growth of 2.9% per annum over the analysis period for rural and urban water demand; ▪ Fixed water consumption rate for wildlife and livestock over the analysis period; ▪ Irrigation water requirement increasing by 2% from the year 2015 up to 2029; ▪ Development of a new town at Mpaka, and operation of the new airport at Sikhuphe.	In his speech for the opening of the new airport in March 2014, the King indicated that a town would be developed within a radius of 8km from the airport to provide support services to the new airport. This scenario simulates the situation where the new airport would be fully operational with a town developed around Sikhuphe. The assumed increase of the quantity of water extracted at Lusoti is 6% from 2015 to 2019.

7.5.2 Results of the analysis

As mentioned earlier, the WEAP model was used to evaluate the water supply availability for all the water demands considered and under various scenarios. Figure 41 presents the total quantity of unmet demand for the four scenarios over the analysis period. It can be seen that as from the year 2015, there could be a water shortage of about 6 Mm^3 per year in all the four scenarios. This would be mainly caused by the increase in water required within the city of Mbabane which is supplied by an inter-basin transfer from Mbuluzi to Lusutfu. The inadequacy of the present water source for the city of Mbabane was confirmed by SWSC (Zizhou, 2012). The corporation indicated that it is presently investigating new water sources as the current one is no longer reliable for the capital city (Zizhou, 2012).

Figure 42 shows that unmet demand would stay constant during the analysis period for all the scenarios, except for the Irrigated Land Increase scenario where it would grow up to above 45Mm^3 in 2029.

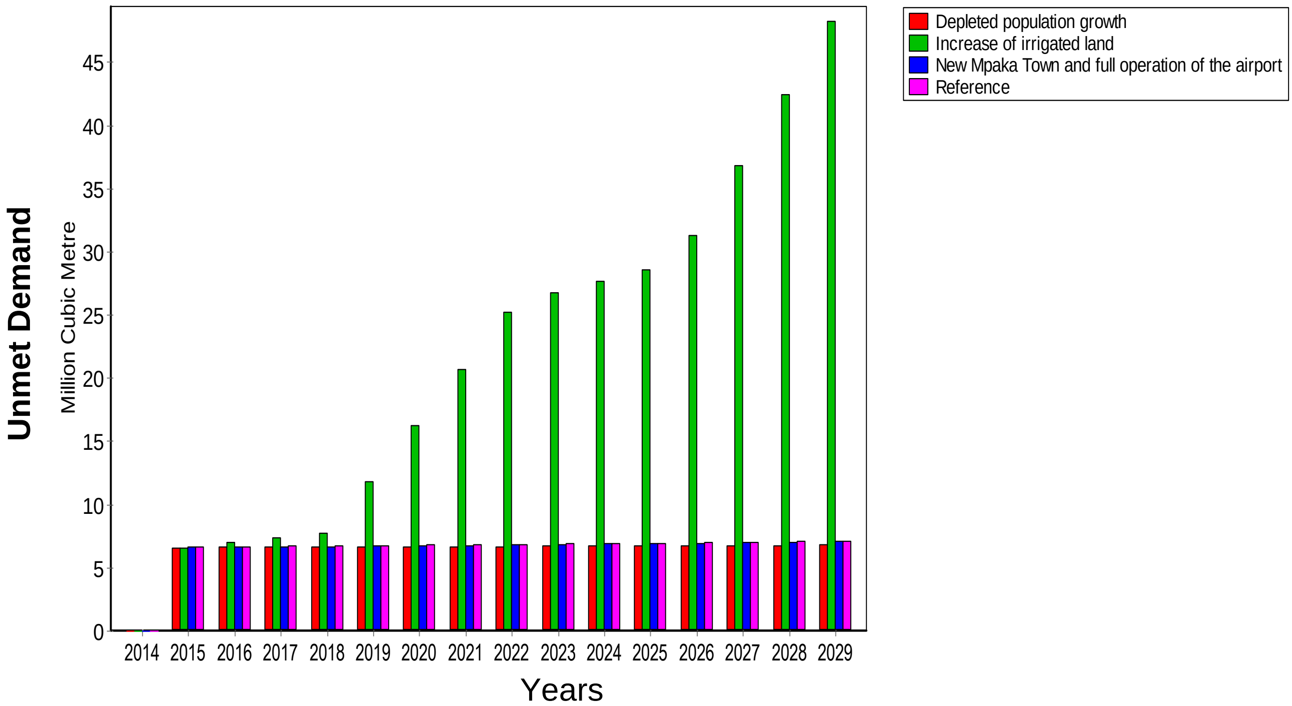


Figure 42: Unmet demand for various scenarios

The unmet demand has been analysed for all the demand sites considered in the study. Table 48 presents the total unmet demand over the 15 years of the analysis period for each demand site for the 4 scenarios. The analysis shows that the Lusoti WTP will not experience water shortages during each of the 4 scenarios. The total unmet demand for the Increased Irrigated Land scenario is estimated to be 338 Mm^3 over 15 years, while it is estimated to be about 100 Mm^3 for the remaining scenarios.

Table 44: Total unmet demand for various demand sites for 4 scenarios

Demand Site	Scenario 1: Reference scenario	Scenario 2: Depleted population growth scenario	Scenario 3: Increased irrigated land scenario	Scenario 4: New Town at Mpaka and Operation of New Airport
Industry	0.00	0.00	0.00	0.00
Irrigation System	95.21	93.98	329.06	95.21
Livestock	0.69	0.68	1.64	0.69
Lusoti WTP	**0.00**	**0.00**	**0.00**	**0.00**
Mbabane City	5.04	4.39	5.04	5.04
Ngwenya Town	0.15	0.13	0.15	0.15
Rural areas1	0.71	0.62	1.62	0.71
Rural areas2	0.00	0.00	0.00	0.00
Wildlife	0.00	0.00	0.00	0.00
Sum (Mm^3)	**101.80**	**99.81**	**337.51**	**101.80**

Table 45 shows the unmet demand per year for each scenario, and Table 46 to Table 49 present the yearly unmet demand for each demand site in various scenarios.

Table 45: Unmet Demand per year for each scenario for the 9 demand sites

(Million cubic metres)

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Scenario 2: Depleted population growth scenario	0	6.56	6.57	6.58	6.60	6.61	6.62	6.64	6.65	6.67	6.68	6.70	6.71	6.72	6.74	6.76
Scenario 3: Increased irrigated land scenario	0	6.55	6.93	7.33	7.74	11.81	16.18	20.64	25.18	26.75	27.65	28.56	31.24	36.82	42.45	48.18
Scenario 4: New Town and Airport	0	6.57	6.60	6.63	6.66	6.68	6.72	6.75	6.78	6.81	6.85	6.88	6.92	6.95	6.99	7.03
Scenario 1: Reference scenario	0	6.61	6.63	6.66	6.69	6.72	6.75	6.78	6.82	6.85	6.88	6.92	6.96	6.99	7.03	7.07

Table 46: Unmet Demand per year for scenario 4 (New Town at Mpaka and Operation of the New Airport) for the 9 demand sites

(Million cubic metres)

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	**Sum**
Industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Irrigation System	0.00	6.21	6.23	6.25	6.27	6.28	6.30	6.32	6.34	6.36	6.38	6.40	6.43	6.45	6.47	6.50	95.21
Livestock	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.69
Lusoti WTP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mbabane City	0.00	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.37	0.38	0.39	0.40	0.42	5.04
Ngwenya Town	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.15
Rural areas1	0.00	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.71
Rural areas2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wildlife	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.00	6.57	6.60	6.63	6.66	6.68	6.72	6.75	6.78	6.81	6.85	6.88	6.92	6.95	6.99	7.03	101.80

Table 47: Unmet Demand per year for Scenario 3 (Increased irrigated land scenario) for the 9 demand sites

(Million cubic metres)

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	**Sum**
Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Irrigation System	0.00	6.20	6.57	6.96	7.35	11.23	15.40	19.67	24.05	25.57	26.45	27.35	29.94	35.31	40.74	46.27	329.06
Livestock	0.00	0.05	0.05	0.05	0.05	0.08	0.10	0.12	0.12	0.12	0.12	0.12	0.13	0.16	0.18	0.20	1.64
Lusoti WTP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mbabane City	0.00	0.26	0.27	0.28	0.29	0.43	0.58	0.73	0.87	0.91	0.92	0.94	1.00	1.16	1.31	1.46	11.42
Ngwenya Town	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.04	0.29
Rural areas1	0.00	0.04	0.04	0.04	0.04	0.06	0.08	0.10	0.12	0.13	0.13	0.13	0.14	0.16	0.19	0.21	1.62
Rural areas2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wildlife	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.00	6.55	6.93	7.33	7.74	11.81	16.18	20.64	25.18	26.75	27.65	28.56	31.24	36.82	42.45	48.18	344.03

Table 48: Unmet Demand per year for Scenario 2 (Depleted population growth scenario) for the 9 demand sites

(Million Cubic Metres)

Year	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**Sum**
Industry	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Irrigation System	0	6.21	6.21	6.22	6.23	6.24	6.25	6.26	6.26	6.27	6.28	6.29	6.30	6.31	6.32	6.33	93.98
Livestock	0	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.68
Lusoti WTP	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mbabane City	0	0.26	0.27	0.27	0.27	0.28	0.28	0.29	0.29	0.30	0.30	0.31	0.31	0.32	0.32	0.33	4.39
Ngwenya Town	0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.13
Rural areas1	0	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.62

Year	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Sum
Rural areas2	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wildlife	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0	6.56	6.57	6.58	6.60	6.61	6.62	6.64	6.65	6.67	6.68	6.70	6.71	6.72	6.74	6.76	99.81

Table 49: Unmet Demand per year for Scenario 1 (Reference scenario) for the 9 demand sites

(Million Cubic Metres)

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	Sum
Industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Irrigation	0.00	6.21	6.23	6.25	6.27	6.28	6.30	6.32	6.34	6.36	6.38	6.40	6.43	6.45	6.47	6.50	95.21
Livestock	0.00	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.69
Lusoti WTP	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mbabane City	0.00	0.27	0.28	0.28	0.29	0.30	0.31	0.32	0.33	0.34	0.35	0.37	0.38	0.39	0.40	0.42	5.04
Ngwenya Town	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.15
Rural areas1	0.00	0.04	0.04	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.71
Rural areas2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wildlife	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sum	0.00	6.57	6.60	6.63	6.66	6.68	6.72	6.75	6.78	6.81	6.85	6.88	6.92	6.95	6.99	7.03	101.80

7.5.3 Analysis of supply levels

Table 50 shows 100% water supply level in all scenarios for the Lusoti WTP, Industry, Rural areas 2 and Wildlife. This is mainly due to the location of these demand sites downstream to the discharge from Mbuluzane River and return flows from irrigation. The water supply level for the Irrigation, Livestock, Mbabane City, Ngwenya Town and Rural areas 1 (in the upper reach of Mbuluzi River) is 92% in the 4 scenarios, except for the Increased Irrigated Land scenario where the supply level is 82%.

Table 50: Levels of supply for demand sites

All Scenarios (Percent)									
Scenarios	**Industry**	**Irrigation System**	**Livestock**	**Lusoti WTP**	**Mbabane City**	**Ngwenya Town**	**Rural areas1**	**Rural areas2**	**Wildlife**
Normal Population Growth	100	92	92	100	92	92	92	100	100
Depleted population growth	100	92	92	100	92	92	92	100	100
Increase of irrigated land	100	82	82	100	82	82	82	100	100
New Town and New Airport	100	92	92	100	92	92	92	100	100

8. CONCLUSION AND RECOMMENDATIONS

The objective of this study was to identify the most suitable option for the supply of water to the Lomahasha Inkhundla and to evaluate the supply effectiveness of the potential source. First, this required the delimitation and the characterisation of the study area. Second, the determination of the water demand of the study area. Third, the identification and evaluation of all possible alternatives for sourcing of water to satisfy the required demand. Fourth, the preliminary design and the economic and environmental evaluation of the various practical options, and lastly the selection of the most favourable option and the evaluation of its supply effectiveness.

Different parts of the study were conducted at different levels of detail based on the targeted objectives and availability of information. Much emphasis was given to aspects related to the assessment of the existing water supply situation, the present and future water demand, preliminary designs, development and operational costs and water balance analysis. Less or no emphasis was given to institutional capacity aspects, environmental studies, water quality, and future infrastructure development.

The final results attained after the water balance analysis show that there could be an overall water shortage in the Mbuluzi River basin. This is demonstrated by the total unmet demand over 15 years which is estimated at 338 Mm^3 for the Increased Irrigated Land scenario and to about 100 Mm^3 for the other scenarios, although the relevant demand for this study (Lusoti WTP) would be met in all the 4 scenarios considered, based on average monthly flows. An overall scarcity of water in the river basin could affect the Lusoti intake, as the Royal Swaziland Sugar Corporation may intend to ration releases from the Mnjoli Dam in order to satisfy irrigation requirements, and this would negatively affect users downstream.

The following measures are recommended for the improvement of the existing situation.

8.1 Recommended measures

During the course of this study, it was very hard to obtain information on water supply and management in Swaziland. There is a pronounced shortage of financial and technical resources in the institutions dealing with the water resource sector. Also, most of the aspects of the Water Act, and a number of cross border agreements signed with Mozambique remain unimplemented due to lack of resources. The following could improve the situation.

- Establishment of the Mbuluzi River Basin Authority as provided for in the Water Act;
- The establishment and the enforcement of a joint river basin management institution between Swaziland and Mozambique to manage all trans-border agreements already in place;
- Capacity building for the SWSC and other government organs or agencies in charge of water supply management;
- Allocation of adequate human and financial resources for the operation and maintenance of water supply and management infrastructure.
- Rehabilitation of the hydrometric network in the Mbuluzi River basin to guarantee sufficient data on river stream flow. This would involve a detailed assessment of the current status of gauging stations as well as the current capacity of the water authorities to operate the network. The assessment should result in the rehabilitation of all hydrometric stations and programmes to build the necessary capacity of the Department of Water Affairs to maintain and operate the network.

8.2 Recommended further studies

The following studies are recommended to complement or confirm the results of this research.

8.2.1 Ground water and small stream assessment

Detailed groundwater and small stream assessment should be carried out for the Mbuluzi River basin. This would determine if alternative supplies for small villages and rural settlements can be provided.

8.2.2 Analysis of return flows from demand sites

The present research used conservative figures for the quantities of water returned to the river. This aspect can be evaluated in depth to ascertain the proportion of water returned to the river from all water consumers.

8.2.3 Assessment of water quality in the Mbuluzi River basin

Several previous studies addressed the issue of water quality in the Mbuluzi River basin and concluded that the water was good enough for human consumption after some level of treatment. A future study could be carried out to provide updated information on water quality.

8.2.4 Water loss analysis

The evaluation of the performance of the system supplied from the Lusoti WTP proved that more than 60% of water extracted from the river is not accounted for. This probably disappears in leaks and illegal connections. An in-depth study on this topic could provide useful tools for the improvement of the water supply system management.

8.2.5 Yield and Reliability Analysis of the System

The WEAP analysis, as carried out in this study, is based on average monthly streamflows and various demand and supply scenarios. A more developed yield and reliability analysis of the Mbuluzi River basin would provide a realistic supply assurance of the system. This would be based on actual time series and stochastically generated streamflows to assess the system performance during drought periods and to account for the uncertainty of the hydrology during the analysis period.

8.2.6 Development of new storage reservoirs

New storage reservoirs could be needed to improve water availability in the basin. Also, the increase of the capacity for existing reservoirs can be considered.

9. REFERENCES

African Developoment Bank. (2002). Komati Downstream Development Appraisal Report. Mbabane: Swaziland Water and Agriculatural Development Enterprise (SWADE).

Africon. (2005). Preliminary Design for the Ka-Shewula Community Water Supply Scheme. Mbabane: Microprojects Programme.

Agricultural Reserch Council - Institute for Agricultural Engineering. (2003). Irrigation Design Manual. Silverton: ARC-LNR.

Banyard, D. A. (2011). Water Distribution Systems. London: Institution of Civil Engineers Publishing.

Bhatti, N. S. (2010). Domestic Water Demand Forecasting and Management Under Changing Socio-Economic. Tokyo - Japan: Society for Social Management Systems.

BICON. (2012). Tender Evaluation Report for Ngcamphalala Water Supply Project. Mbabane: Bicon Consulting Engineers.

Chang, H. H. (2002). Fluvial Processes in River Engineering. Malabar, Florida: Krieger Publishing Company.

Commonwealth Local Government Forum. (2009). Local Government System in Swaziland. Mbabane: CLGF.

Council for Scientific and Industrial Research. (2003). Human Settlement Planning and Design. Pretoria: Department of Housing.

Central Statistics Office. (2007). 2007 Census data. Mbabane: CSO.

Davis, W. Y. (2003). Water Demand Forecast Methodology for California Water Planning Areas - Work Plan and Model Review. California: California Bay-Delta Authority.

Department of Environmental Affairs and Tourism. (2002). National Framework Document: Strengthening Sustainability in the Integrated Development Planning Process. Johannesburg: DEAT.

Dlamini, R. (2012, May 26). Resident. (Bernard, Interviewer)

Dlamini, A. (2012, June 16). Clerk of Works. (Bernard, Interviewer)

Dlamini, E. (2012, June 16). Regional Manager, East Region. (Bernard, Interviewer)

Emmanuel, N. (2012, July 20). Contractor, Project Manager. (Bernard, Interviewer)

Farolfi, S. (2007). Domestic Water Use and Values in Swaziland: A Contingent Valuation Analysis. Agrekon, Vol 46, No 1 (March 2007)

Geologiocal Map. (1998). Ministry of Natural Resources and Energy.

Global Water Partnership. (2000). Integrated Water Resources Management. Stockholm, Sweden: GWP Technical Advisory Committee, Background Paper No.4.

Google earth. (2013). Google Earth. Retrieved from Google earth.

Government Gazette. (2010). Legal Notice No. 184 of 2010, The Regulation of Wages (Building and Construction Order, 2010). Mbabane: Government of Swaziland.

Gwebu. (2012, June 15). Operator. (B. Ndisebuye, Interviewer)

Hope A. (2007). Hydrological Survey and Stage-Volume Relationship. RMC Water and Environment. 0153-001-00

Johansson, A. G. (2006). An investigation of nutrient levels along Mbuluzi River. Sweden: Lund University.

JTK Associates. (2002). Assessment of water resources availability in the Komati and Mbuluzi river basins. Mbabane: Ministry of Natural Resources.

Knight Piesold (2011). Integrated Water Resources Master Plan, Swaziland. Ministry of Natural Resources, Government of Swaziland

Knowledge Base Software. (2011). Pump Catalogue. Cape Town, Cape Town, Cape Town.

KSB Pumps. (2012). Technical Brochures. Johannesburg: KSB Pumps.

Lankford. (2007). The Rise of Large Scale Formal Smallholder Irrigation Schemes in Swaziland. Norwich: University of North Anglia, Working Paper Series.

Lowara. (2012). Technical Catalogues. Johannesburg: Lowara Water Pumps.

Mabunda, S. (2012, February 20). Managing Director. (B. J. Ndisebuye, Interviewer)

Main Industries. (1998). uPVC Pressure Pipe Manual. Johannesburg: Main Industries.

Manyatsi, A.M. (2009). IWRM Survey and Status Report - Swaziland. Global Water Partnership, Sothern Africa.

Matondo, J. (2010). Generating information required in climate change studies in Swaziland. Water International 35 (2), 223-232.

Mitchell , T.B. (1982). Potential Water Yield in Semiarid Regions. IAHS Publication No. 135 July 1982

Mitchell , T.B. (1977). Reservoir Yield Using TPM Method. ASCE , Journal of the Hydraulics Division. Vol 103 No. 2, February 1977, pp 133-150.

Mugabi, B. (2010). Water Utilisation and Population Demography in South Africa. Johannesburg: Wits University.

Muthusi, M. G. (2007). Rural Water Supply Assessment, Technical Report No.08. Nairobi - Kenya: FAO-SWALIM.

Mutiro, J. (2012, July 20). Design Engineer. (B. J. Ndisebuye, Interviewer)

Nasu, A. M. (2010). Domestic Water Demand Forecasting and Management Under Changing Socio-Economic. Tokyo - Japan: Society for Social Management Systems.

Restructuring and Diversification Management Unit. (2007). Technical Audit of Phakama Mafucula Farmers Association. Mbabane: Ministry of Economic Planning and Development.

Rural Water Supply Branch. (2003). Design Manual for Rural Water Supply Systems. Mbabane: Department of Water Affairs, Swaziland.

Schulze R.E., M. M.-T. (1997). South African Atlas of Agrohydrology and Climatology. Pretoria: Water Research Commission.

Swaziland Electricity Company. (2012, December 20). www.sec.co.sz. Retrieved December 20, 2012, from www.sec.co.sz/clients.php.

SII Irrigation. (2010). Simunye Water Treatment Plant Operations and User's Manual. Ezulwini: SWSC.

Soil Conservation Service. (1989). Reservoir Flood Routing. Engineering Hydrology Training Services, Module 111. Washington: United States Department of Agriculture.

South African Government. (1996). South African Government. Retrieved 2013, from South African Constitution: http://www.gov.za

South African Reserve Bank. (2012, December 15). Retrieved December 15, 2012, from www.resbank.co.za.

Steel, E. (1947). Water Supply and Sewerage. New York: Mc Graw-Hill Book Company.

Surveyor General. (2012). Map of Lomahasha Area. Mbabane: Surveyor General Department.

Swaziland Meteorology Department. (2012). Meteorology Information. Mbabane: Ministry of Natural resources.

SWECO. (2005). Joint Umbeluzi River Basin Study. Final Report. Mbabane, Swaziland.

Swaziland Water Act. (2003). Swaziland Water Act. Mbabane: Swaziland Government.

Taigbenu, P. A. (2011). Water Resources Economics - CIVN7059, Water Management. Johannesburg: Wits University.

The World Bank. (2002). Swaziland Urban Development Project, Country Assessment. New York: The World Bank.

United Nations Conference on Environment and Development (UNCED). (1992). Agenda 21 of the UNCED. New York: United Nations.

United Nations Development Programme. (2005). Millenium Development Goals, April 2005 issue of Environment, Science and Policy for Sustainable Development . New York: United Nations.

Uzan, S. (2012, June 15). Managing Director. (B. J. Ndisebuye, Interviewer)

Zandamela, H. (2003). Lessons from Mozambique, Water Mangement Concessions. Maputo.

Zizhou, R. (2012, August 5). Projects Engineer. (B. J. Ndisebuye, Interviewer).

10. LIST OF APPENDICES

1. Forms filled during interviews at homesteads
2. Bills of quantities for construction costs for the preferred option
3. Details of calculations for maintenance and operation costs
4. Calculation of friction losses and local losses in pumping mains
5. Drawing showing the positions of the system components for the preferred option.

N.B: Appendices not herein attached, but included in the CD