water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

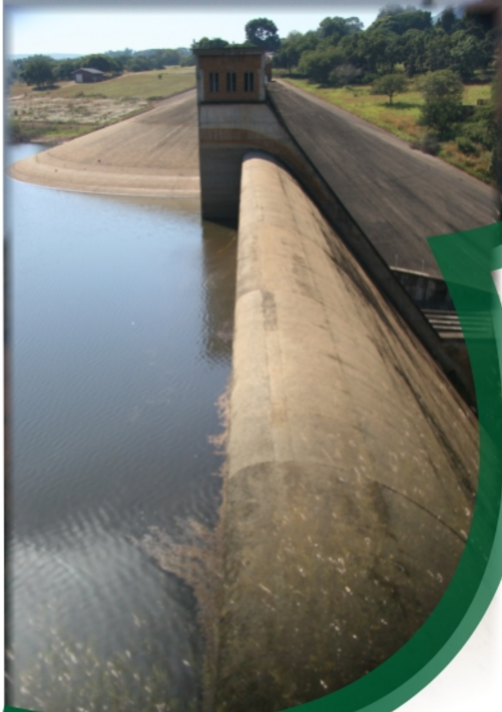
REPORT NO.: P WMA 02/B810/00/0608/3

GROOT LETABA RIVER WATER DEVELOPMENT PROJECT (GLeWaP)

TECHNICAL STUDY MODULE:

Groundwater

VOLUME 3



MAY 2010

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W47_2010/H505701

LIST OF STUDY REPORTS IN GROOT LETABA RIVER WATER DEVELOPMENT PROJECT (BRIDGING STUDIES)

This report forms part of the series of reports, done for the Bridging Study phase of the GLeWaP. All reports for the GLeWaP are listed below.

REPORT NUMBER	REPORT TITLE
P WMA 02/B810/00/0508	**Project Coordination and Management Team**
P WMA 02/B810/00/0508/1	Project Coordination and Management Team: Executive Summary Report: Vol 1
P WMA 02/B810/00/0508/2	Project Coordination and Management Team: Main Report: Vol 2
P WMA 02/B810/00/0508/3	Project Coordination and Management Team: Register of Decisions: Vol 3
P WMA 02/B810/00/0508/4	Project Coordination and Management Team
P WMA 02/B810/00/0508/5	Project Coordination and Management Team
P WMA 02/B810/00/0608	**Technical Study Module**
P WMA 02/B810/00/0608/1	Technical Study Module: Main Report: Vol 1
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P WMA 02/B810/00/0608/6	Technical Study Module: Preliminary Design of Nwamitwa Dam: Vol 6
P WMA 02/B810/00/1110/1	Technical Study Module: Preliminary Design of Nwamitwa Dam: Vol 6 - Annexure 1: Appendices
P WMA 02/B810/00/1110/2	Technical Study Module: Preliminary Design of Nwamitwa Dam: Vol 6 - Annexure 2: Appendix B (Part 1): Geotechnical Investigations
P WMA 02/B810/00/1110/3	Technical Study Module: Preliminary Design of Nwamitwa Dam: Vol 6 - Annexure 3: Appendix B (Part 2): Geotechnical Investigations
P WMA 02/B810/00/1110/4	Technical Study Module: Preliminary Design of Nwamitwa Dam: Vol 6 - Annexure 4: Appendix H: Drawings
P WMA 02/B810/00/0608/7	Technical Study Module: Preliminary Design of the Raising of Tzaneen Dam: Vol 7
P WMA 02/B810/00/0608/8	Technical Study Module: Bulk Water Distribution Infrastructure: Vol 8
P WMA 02/B810/00/1110/5	Technical Study Module: Bulk Water Distribution Infrastructure: Vol 8 - Annexure 1 : Appendices
P WMA 02/B810/00/0708	**Environmental Management Module**
P WMA 02/B810/00/0708/1	Environmental Management Module: Scoping Report: Vol 1
P WMA 02/B810/00/0708/2	Environmental Management Module: Environmental Impact Assessment Report: Vol 2
P WMA 02/B810/00/0708/3	Environmental Management Module: Environmental Management Programme for Borrow Area 1 on the Farm Laborie 515: Vol 3
P WMA 02/B810/00/0708/4	Environmental Management Module: Environmental Management Programme for Borrow Area 2 on the Farm La Parisa 729 (Gubits Farm): Vol 4
P WMA 02/B810/00/0708/5	Environmental Management Module: Environmental Management Programme for Borrow Area 3 on the Farm Letaba Drift 727: Vol 5
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P WMA 02/B810/00/0808/5	Public Involvement Program

REPORT DETAILS PAGE

Project name:	***Groot Letaba River Water Development Project***
Report Title:	***Groundwater : Volume 3***
Author:	***K Morton***
DWA report reference no.:	***P 02/B810/00/0608/3***
PSP project reference no.:	***401775***
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EXECUTIVE SUMMARY

1. INTRODUCTION

1.1 Background to Project

The catchment of the Groot Letaba River has many and varied land-uses with their associated water requirements, for example commercial irrigation, commercial afforestation, tourism, as well as primary requirements by the population in the catchment. The water resources available in the catchment are limited, and considerable pressure has been put on these resources in the past. This situation has been investigated at various levels by the Department of Water Affairs (DWA).

The first major study undertaken for this area was the Letaba River Basin Study in 1985 (DWA, 1990), which comprised the collection and analysis of all available data on water availability and use, as well as future water requirements and potential future water resource developments. This was followed by a Pre-feasibility Study (DWA 1994), which was completed in 1994. The focus of the Pre-feasibility Study was the complete updating of the hydrology of the Basin. The next study undertaken was the Feasibility Study of the Development and Management Options (DWA, 1998), which was completed in 1998.

The Feasibility Study proposed several options for augmenting water supply from the Groot Letaba River. These included some management interventions, as well as the construction of a dam at Nwamitwa and the possible raising of Tzaneen Dam. These options would enable additional water to be allocated to the primary water users, would allow the ecological Reserve to be implemented and could also improve the assurance of supply to the agricultural sector.

This Bridging Study was initiated by the Department of Water Affairs and Forestry in order to re-assess the recommendations contained in the Feasibility Study in the light of developments that have taken place in the intervening 10 years.

*The study area is shown in **Figure E1**. It consists of the catchment of the Letaba River, upstream of its confluence with the Klein Letaba River. The catchment falls within the Mopane District Municipality, which is made up of six local municipalities. The local municipalities that lie within the catchment area are Greater Tzaneen, Greater Letaba and Greater Giyani. The major town in the study area is Tzaneen, with the urban centre of Polokwane located just outside of the catchment to the West.*

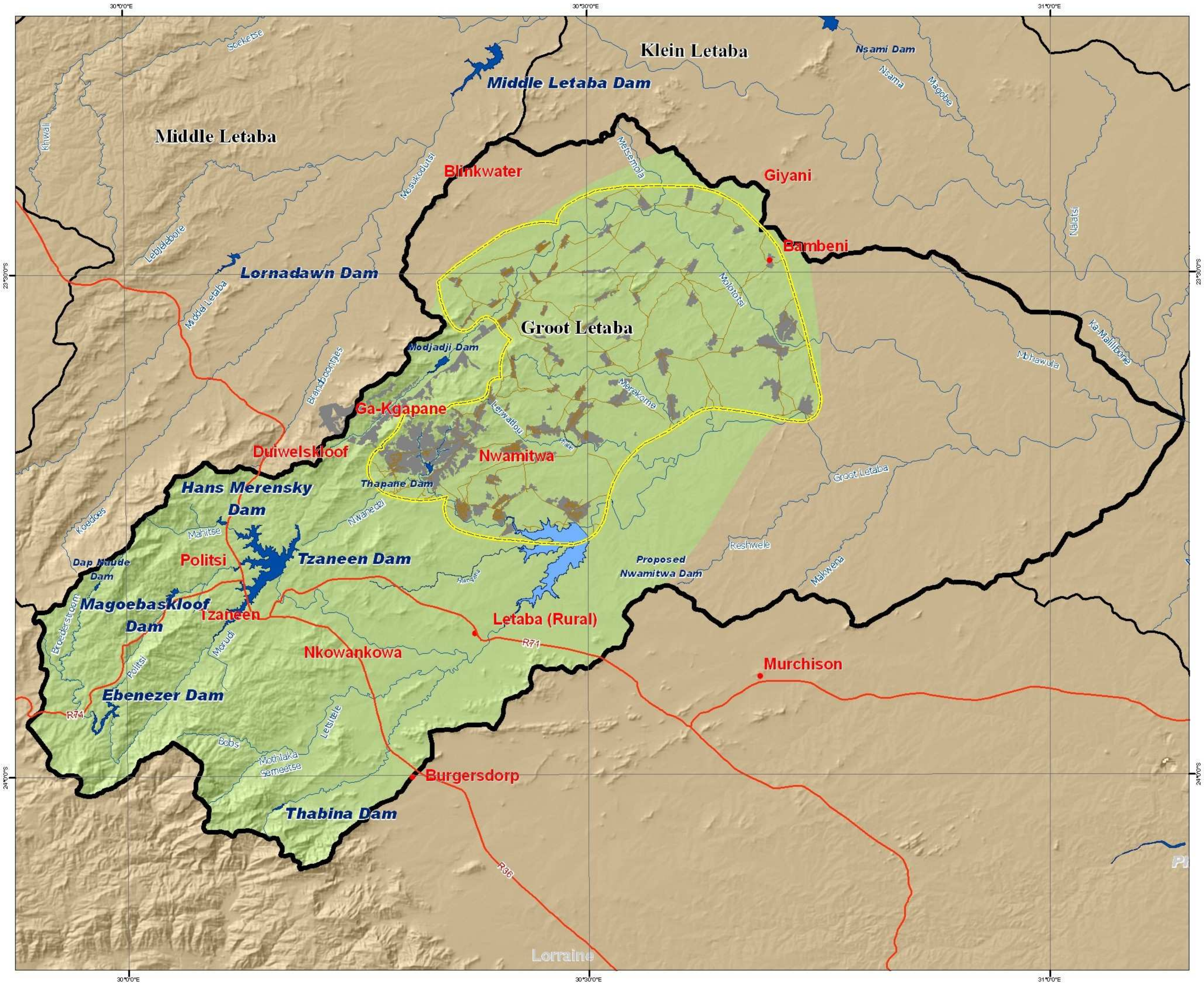
*The site of the proposed Namitwa Dam is also shown on **Figure E1**. The focus of the Feasibility Study was the Groot Letaba Catchment, with the catchments of the other rivers being included to check that environmental flow requirements into the Kruger National Park were met, and international agreements regarding flow entering Mozambique were met. This focus was kept for this Bridging Study.*

1.2 SCOPE AND ORGANISATION OF PROJECT

The Department's Directorate: Options Analysis (OA), appointed Aurecon in Association with a number of sub-consultants to undertake this study. The official title of the study is: "The Groot Letaba River Water Development Project (Bridging Study)".

The Bridging Study comprises a number of modules. This Report focuses on part of the scope of work for the Technical Study Module (TSM). The tasks comprising the TSM are listed below:

TASK 1: WATER REQUIREMENTS
TASK 2: WATER RESOURCE EVALUATION
TASK 3: PRELIMINARY DESIGN OF NWAMITWA DAM
TASK 4: RAISING OF TZANEEN DAM
TASK 5: BULK WATER DISTRIBUTION INFRASTRUCTURE
TASK 6: IMPLEMENTING PROGRAMME
TASK 7: WATER QUALITY



OVERVIEW MAPS :

Study Area

Study Area

LEGEND

- Towns
- National Roads
- Secondary Roads
- Rivers
- Dams
- Villages
- Study Area
- Proposed Supply Area from Nwamitwa Dam

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CONSULTANT :

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TITLES :

GROOT LETABA RIVER WATER DEVELOPMENT PROJECT

PROJECT AREA

FIGURE NO. :

E1

1.3 Scope of this report

This report describes the assessment of the availability of groundwater in the project area, as part of Task 1: Water Requirements. The objectives of the groundwater study were to:

- *determine the present and future use of groundwater in the project area*
- *determine the groundwater potential in the bulk water distribution area, and*
- *determine the groundwater potential for the entire project area.*

2. GROUNDWATER

The use of information from DWA's **Ground Water Information Project (GRIP)** *programme was utilised in the evaluation of groundwater availability and suitability. The information was evaluated in relation to known aquifers or water-bearing geological structures.*

Present and future use of groundwater

The current use of groundwater in the Groot Letaba Catchment for supply to villages is estimated to be 10.6 Mm^3/a. The most recent estimate of groundwater use for irrigation is 29 Mm^3/a (DWAF, 2007), and has been adopted for use in this study. Therefore, the total ***current use*** *of groundwater in the catchment is estimated to be* ***40 Mm^3/a****.*

Groundwater potential

The groundwater development potential in the Groot Letaba Catchment is high.

There is significant rainfall recharge of the groundwater in the project area, and it reduces from west to east across the project area. It is estimated that a total volume of 91 Mm^3/a is added to the groundwater annually from rainfall. This recharge value represents 0.02% to 9.5% of the annual rainfall.

Using the above recharge value, and the current groundwater use of 40 Mm^3/a, approximately 51 Mm^3/a (without accounting for groundwater losses) is available for development.

Recommendations for groundwater development

Since groundwater represents a significant potential water resource for the area, it is recommended that a comprehensive groundwater investigation be undertaken so that *the location and availability of suitable quality groundwater can be determined with greater certainty. These investigations should be focused on specific groundwater supply schemes which could be located in the supply area currently envisaged for the proposed Nwamitwa Dam.*

The potential yields, costs and environmental implications associated with a potential groundwater "Government Water Scheme" should be determined and compared with the yields, costs and environmental implications of the proposed Nwamitwa Dam development.

3. CONCLUSIONS

A summary of the main conclusion emanating from the Groundwater Study is given below:

- *Based on a desktop evaluation, it is estimated that the groundwater potential in the Study Area is 91 Mm^3/a. It is estimated that the current groundwater use is approximately 40 Mm^3/a. This would leave approximately 51 Mm^3/a (without accounting for groundwater losses) available for development. Groundwater is therefore a significant potential water resource for the area. Development on a regional scale is envisaged as an important option for the area.*

4. RECOMMENDATIONS

The following recommendations are made:

- *A comprehensive regional groundwater investigation should be undertaken so that the location and availability of suitable quality groundwater can be determined with greater certainty. These investigations should be focused on developing regional groundwater supply schemes in the supply area currently envisaged for the proposed Nwamitwa Dam.*
- *The potential yields, costs and environmental implications associated with a regional groundwater supply scheme should be determined and compared with the yields, costs and environmental implications of the proposed Nwamitwa Dam development.*

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Aurecon Electronic Reference: I:\HYDRO\401775 Groot Letaba\Reports\Vol 3 Groundwater\Groundwater.doc

ABBREVIATIONS

DME	Department of Mineral and Energy Affairs
DWA	Department of Water Affairs
EMM	Environmental Management Module
GIS	Geographical Information System
GLeWaP	Groot Letaba River Water Development Project
GRIP	DWA's Groundwater Information Project
IFM	Institutional and Financial Module
KLMCS	KLM Consulting Services
l/s	litres per second
m	metres
m^3/a	cubic metres per annum
Mm^3/a	million cubic metres per annum
Mm^3/h	million cubic metres per hour
mbgl	metres below ground level
OA	Options Analysis
PIP	Public Involvement Programme
SABS	South African Bureau of Standards
SEE	Socio-economic evaluation
SOP	Standard Operating Procedure
TSM	Technical Study Module

1. STUDY INTRODUCTION

1.1 BACKGROUND TO PROJECT

The catchment of the Groot Letaba River has many and varied land- uses with their associated water requirements. These include significant use by agriculture in the form of irrigated crops, commercial afforestation, tourism (particularly linked to the Kruger National Park, which lies partially within the catchment), as well as primary requirements by the population in the catchment. The water resources available in the catchment are limited, and considerable pressure has been put on these resources in the past, with periods of severe and protracted water restrictions occurring over the past 25 years. This situation has been investigated at various levels by the Department of Water Affairs (DWA).

The first major study undertaken for this area was the Letaba River Basin Study in 1985 (DWA, 1990), which comprised the collection and analysis of all available data on water availability and use, as well as future water requirements and potential future water resource developments. This was followed by a Pre-feasibility Study (DWA 1994), which was completed in 1994. The focus of the Pre-feasibility Study was the complete updating of the hydrology of the Basin. The next study undertaken was the Feasibility Study of the Development and Management Options (DWA, 1998), which was completed in 1998.

The Feasibility Study proposed several options for augmenting water supply from the Groot Letaba River. These included some management interventions, as well as the construction of a dam at Nwamitwa and the possible raising of Tzaneen Dam. These options would enable additional water to be allocated to the primary water users, would allow the ecological Reserve to be implemented and could also improve the assurance of supply to the agricultural sector.

This Bridging Study was initiated by the (then) Department of Water Affairs and Forestry (DWAF) (now DWA) in 2006 in order to re-assess the recommendations contained in the Feasibility Study in the light of developments that have taken place in the intervening 10 years. Other contributing factors to the DWA's decision to undertake Bridging Studies were the promulgation of the Water Services Act and the National Water Act in 1997 and 1998 respectively, and the recently completed Reserve Study on the Letaba River.

The study area is shown in **Figure 1.1**. It consists of the catchment of the Letaba River upstream of its confluence with the Klein Letaba River. The catchment falls within the Mopane District Municipality, which is made up of six Local Municipalities. The Local Municipalities within the catchment area are Greater Tzaneen, Greater Letaba and Greater Giyane. The major town in the study area is Tzaneen, with the urban centre of Polokwane located just outside of the catchment to the west.

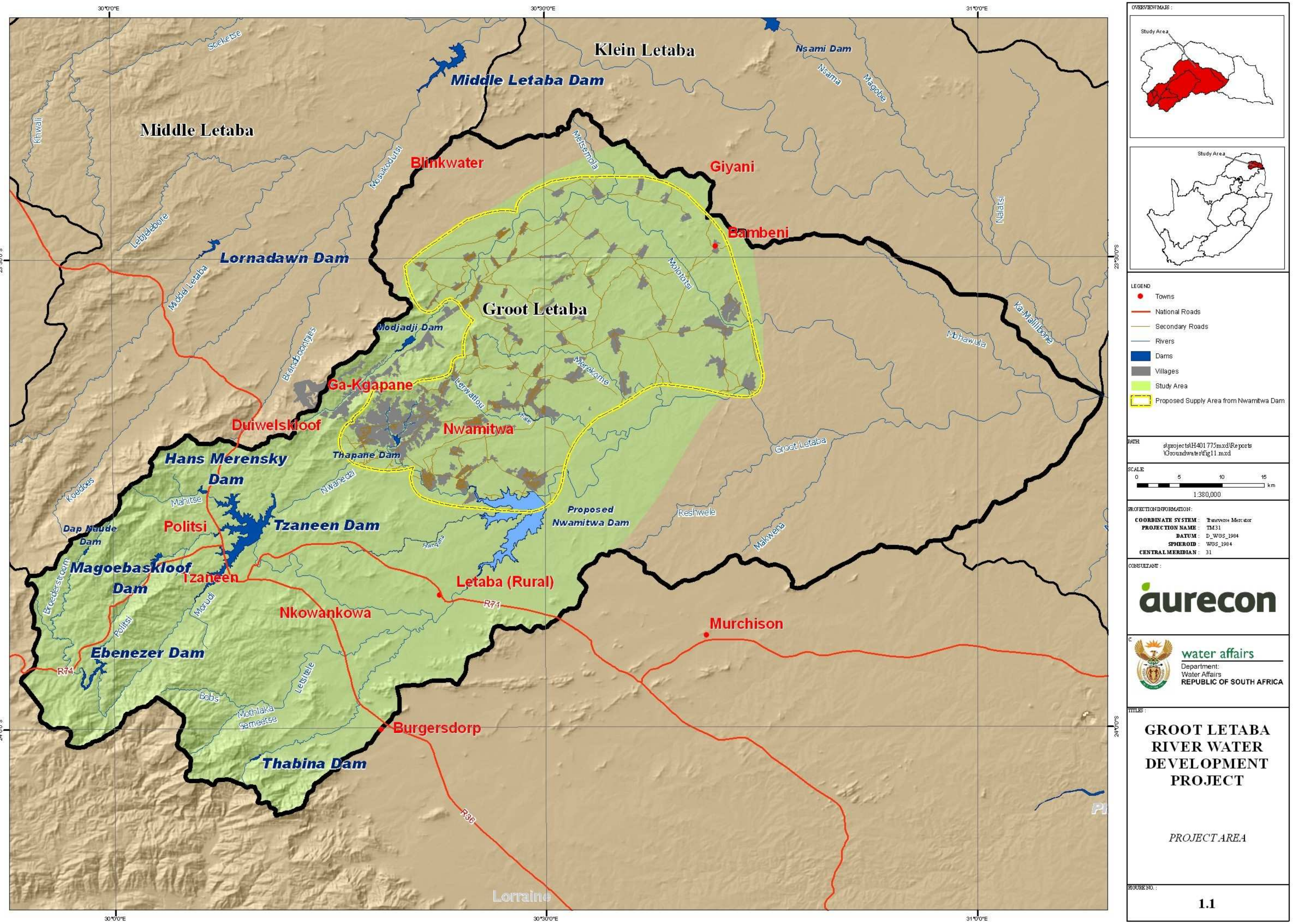
The site of the proposed Namitwa Dam is also shown in **Figure 1.1**. The focus of the Feasibility Study was the Groot Letaba Catchment, with the catchments of the other rivers included to monitor the environmental flow requirements at the Kruger National Park, and check whether international agreements regarding flow entering Mozambique were met. This focus was kept for this Bridging Study.

1.2 SCOPE AND ORGANISATION OF PROJECT

The DWA Directorate: Options Analysis (OA), appointed Aurecon South Africa (Pty) Ltd in association with a number of sub-consultants (listed below) to undertake this study. The official title of the study is "The Groot Letaba River Water Development Project" (Bridging Study).

An association exists between the following consultants for the purposes of this study:

- Aurecon South Africa (Pty) Ltd
- Semenya Furumele Consulting
- KLM Consulting Services (KLMCS)
- Urban-Econ Developmental Economists
- Schoeman & Vennote



Klein Letaba
Middle Letaba Dam
Middle Letaba
Nsami Dam
Blinkwater
Giyani
Bambeni
Lornadawn Dam
Groot Letaba
Modjadji Dam
Ga-Kgapane
Duiwelskloof
Nwamitwa
Thapane Dam
Hans Merensky Dam
Politsi
Tzaneen Dam
Proposed Nwamitwa Dam
Dap Naude Dam
Magoebaskloof Dam
Tzaneen
Letaba (Rural)
Nkowankowa
Murchison
Ebenezer Dam
Burgersdorp
Thabina Dam
Lorraine
R71
R36
Groot Letaba
30°0'0"E
30°30'0"E
31°0'0"E
23°30'0"S
24°0'0"S
OVERVIEW MAPS :
Study Area
LEGEND
Towns
National Roads
Secondary Roads
Rivers
Dams
Villages
Study Area
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CONSULTANT :
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TITLES :
GROOT LETABA RIVER WATER DEVELOPMENT PROJECT
PROJECT AREA
FIGURE NO. :
1.1

The Bridging Study comprises a number of modules, namely: an Environmental Management Module (EMM), a Public Involvement Programme (PIP), a Technical Study Module (TSM), and an Economic Evaluation (EE). This Report focuses on Tasks 1 and 2, discussed below for the TSM.

The tasks comprising the TSM are summarised below:

TASK 1: WATER REQUIREMENTS

The objective of this Task is to:

- review the current estimates of future water requirements in all user sectors,
- establish present levels of water use in these sectors,
- assess the availability of groundwater in the project area.

TASK 2: WATER RESOURCE EVALUATION

The objective of this Task is to:

- assess the present availability of surface water from the Groot Letaba River System.
- assess the increase in yield of the proposed new developments, taking account of the flow regime required to maintain the Ecological Reserve.

TASK 3: PRELIMINARY DESIGN OF NWAMITWA DAM

The objective of this Task is to:

- determine the most suited dam type and position for the proposed Nwamitwa Dam
- optimise the proposed development proposal
- provide an updated estimate of the costs of implementing Nwamitwa Dam.

TASK 4: RAISING OF TZANEEN DAM

The objective of this Task is to:

- determine the benefits from raising Tzaneen Dam, in terms of water availability and security of supply;
- determine the optimum method of raising Tzaneen Dam;
- optimise the proposed development proposal; and
- provide an updated estimate of the costs of raising Tzaneen Dam.

TASK 5: BULK WATER DISTRIBUTION INFRASTRUCTURE

The objective of this Task is to:

- assess infrastructure currently available to make bulk water supplies available to the rural areas,
- undertake conceptual planning for the areas to be supplied from Nwamitwa Dam,
- undertake a preliminary design and cost estimate for the proposed new bulk water distribution infrastructure.

TASK 6: IMPLEMENTING PROGRAMME

The objective of this Task is to determine a realistic programme for the implementation of the proposed developments.

TASK 7: WATER QUALITY

The objective of this Task is to undertake an in-lake water quality analysis of the proposed Nwamitwa Dam, to inform the design of the outlet structure of the dam.

1.3 SCOPE OF THIS REPORT

This report describes a portion of Task 1 : Water Requirements.

The objectives of Task 1 : Water Requirements were as follows :

- review the current estimates of future water requirements in all user sectors,
- establish present levels of water use in these sectors,
- assess the availability of groundwater in the project area.

The third objective is reported on in this report (*Groundwater*), and the first two objectives are reported on in a separate report (*Review of Water Requirements*).

This report deals with the current and potential role of groundwater. The evaluation of groundwater availability and suitability was based on information from DWA's *Ground Water Resource Information Project* (GRIP). This study was undertaken by DWA from 2007 – 2008. The purpose of the study was to determine the present use of groundwater as well as the groundwater potential for the area. The information was evaluated in relation to known aquifers or water-bearing geological structures. No exploration or field testing was undertaken.

Section 2 of this report gives some background to the Groundwater Study. The groundwater resources are described in **Section 3** under the separate topics of borehole depths, water levels, groundwater occurrence, groundwater quality, borehole yields, groundwater recharge and groundwater utilisation.

The groundwater potential is discussed in **Section 4** and groundwater development in **Section 5.** **Section 6** contains discussion on potential conflict of groundwater use.

Sections 7 and **8** of this report summarise the conclusions and recommendations relating to groundwater. The references are contained in **Section 9**.

2. INTRODUCTION AND BACKGROUND TO THE GROUNDWATER STUDY

The groundwater component of this study was undertaken by KLM Consulting Services (KLMS).

The objectives of the groundwater study were to:

- determine the present and future use of groundwater in the project area,
- determine the groundwater potential in the bulk water distribution area, and to
- determine the groundwater potential for the entire project area.

The Department of Water Affairs designed water quality guidelines to serve as the source of information for determining the water quality requirements of different uses. The Volume 1 deals with domestic water usage and water has been classified into five classes, (see **Table 2.1**).

Table 2.1 Classification of water as per DWA classification

DWA CLASSIFICATION	DESCRIPTION
Class 0	Water of an ideal quality
Class I	A good quality water
Class II	Water which is safe for short-term use only
Class III	An unacceptable quality of water
Class IV	Poor water quality

3. GROUNDWATER RESOURCES

During the course of the study, information on groundwater occurrences were deduced from the following sources:

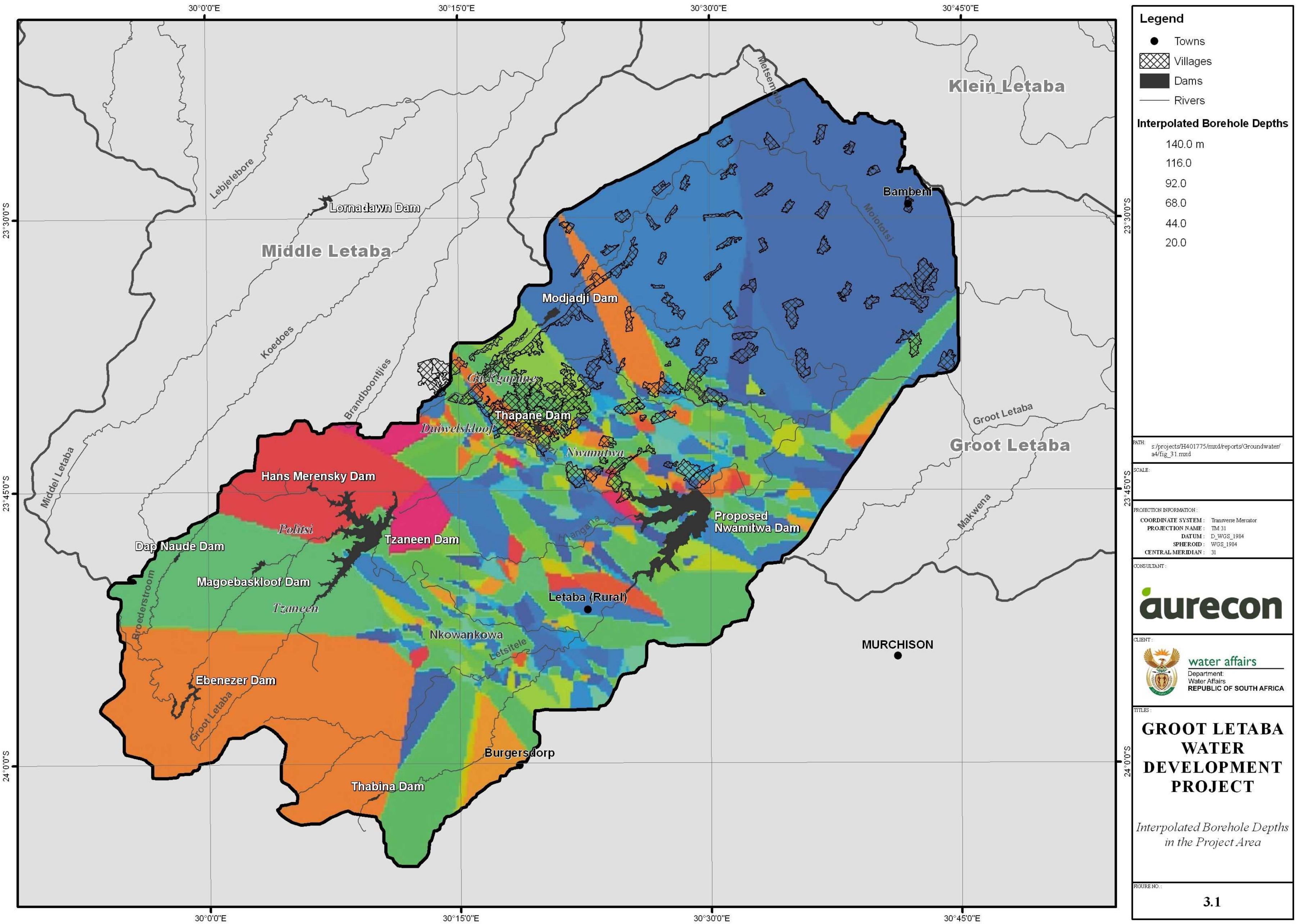
- existing borehole records (DWA's "GRIP" database only),
- hydrochemistry data,
- hydrogeological maps,
- aerial photographic interpretation.

This specifically excludes the analysis of borehole logs, which were not available, so aquifer thickness and type could not be deduced.

Groundwater in the Groot Letaba project area is mainly developed in the alluvium deposits along the river channels and in lineaments and on dykes (DME, 1985). Information on groundwater occurrences has been deduced from existing borehole records, hydrochemistry data, hydrogeological maps and from aerial photographic interpretation.

3.1 BOREHOLE DEPTHS

Figure 3.1 shows the interpolated borehole depths in the project area. Borehole depths in the project area range from 4.5 m to 162 m. They are shallowest in the eastern part of the study area, along the river channels, and deepest in the mountainous area in the west.



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CONSULTANT :

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TITLES :

GROOT LETABA WATER DEVELOPMENT PROJECT

Interpolated Borehole Depths in the Project Area

FIGURE NO. :

3.1

3.2 WATER LEVELS

Figure 3.2 shows the interpolated groundwater levels in the project area. Average water levels recorded during the GRIP were at around 11.8 mbgl, with the deepest being 61.43 mbgl. Water levels are evenly distributed throughout the project area and are not related to aquifer formations. There are some artesian water conditions in some of the irrigation boreholes near the Tzaneen Dam.

3.3 GEOLOGY OF STUDY AREA AND GROUNDWATER OCCURRENCE

The study area is underlain by gneisses and granites of the Archean greenstone belt, basement granite, basement gneiss and bordered on the west by the Transvaal Sequence. The large proportion of the area is underlain by the Turfloop granite. The Mothiba Formation of the Pietersburg Group (ultramafic schist, amphibolite and quartzite) outcrops at Nwamitwa village, Janetsi, Mamokolo and Ga-Modjadji areas.

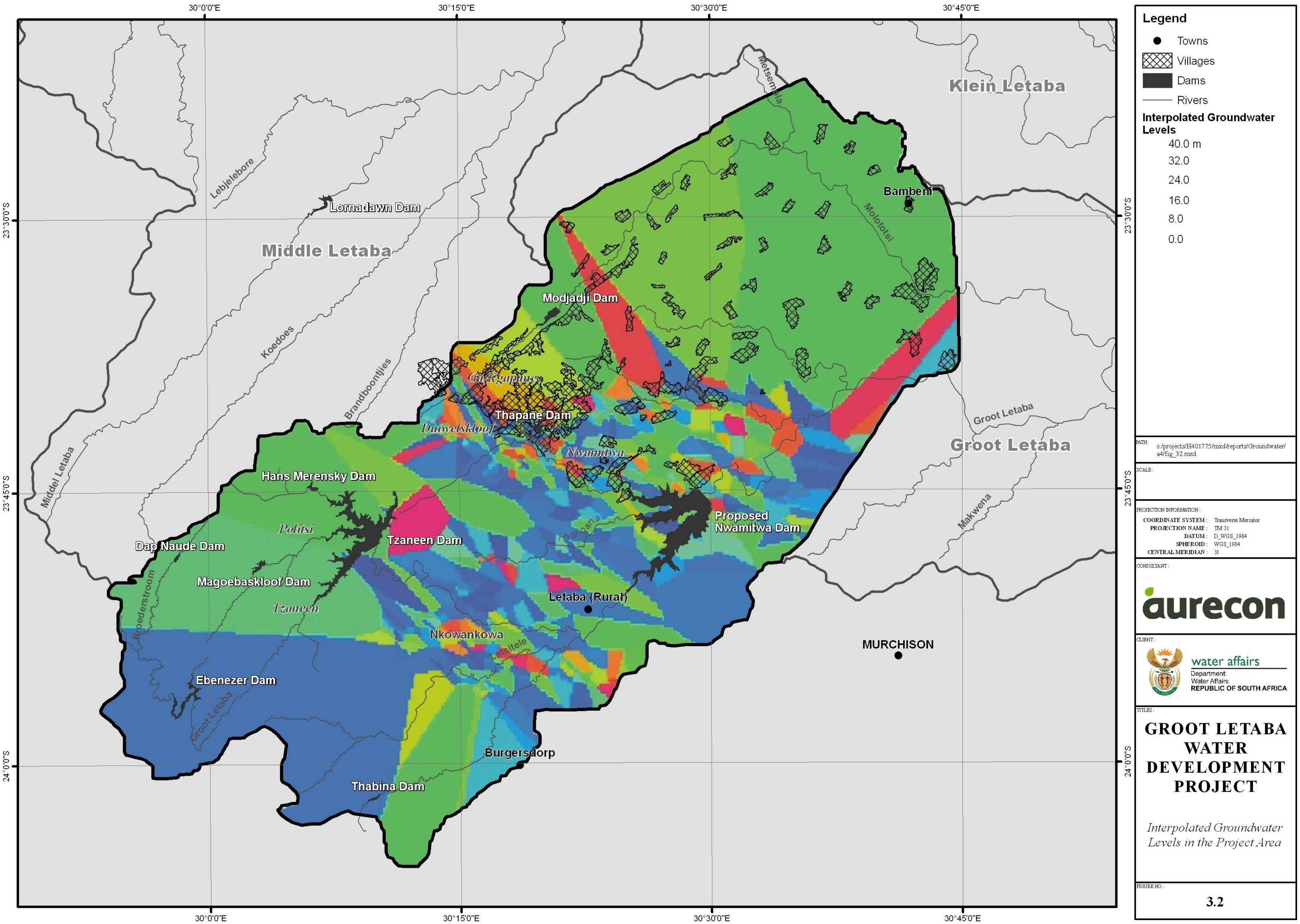
Geological structures were mapped by Brandl in 1987 and confirmed from the aerial photographic interpretation conducted by KLMCS during this study (**Figure 3.3**). The following geological structures were considered to be of hydrogeological significance after analysing groundwater data provided by DWA (collected during GRIP campaign).

a) The Tzaneen Lineament

The Tzaneen Lineament trends in a NE – SW direction. The smaller faults are parallel to the major geological structures.

b) The Koedoes Lineament

The Koedoes River follows the Koedoes Lineament parallel to the Tzaneen Lineament. Even though it does not form part of the study area, it could contribute to the groundwater condition of the project area.



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Dams
Rivers
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Middle Letaba
Groot Letaba
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Modjadji Dam
Thapane Dam
Hans Merensky Dam
Dap Naude Dam
Magoebaskloof Dam
Tzaneen Dam
Proposed Nwamitwa Dam
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Nkowankowa
Ebenezer Dam
Burgersdorp
Thabina Dam
MURCHISON
Bambeni
Ga-Kgapane
Duiwelskloof
Nwamitwa
Politsi
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GROOT LETABA WATER DEVELOPMENT PROJECT
Interpolated Groundwater Levels in the Project Area
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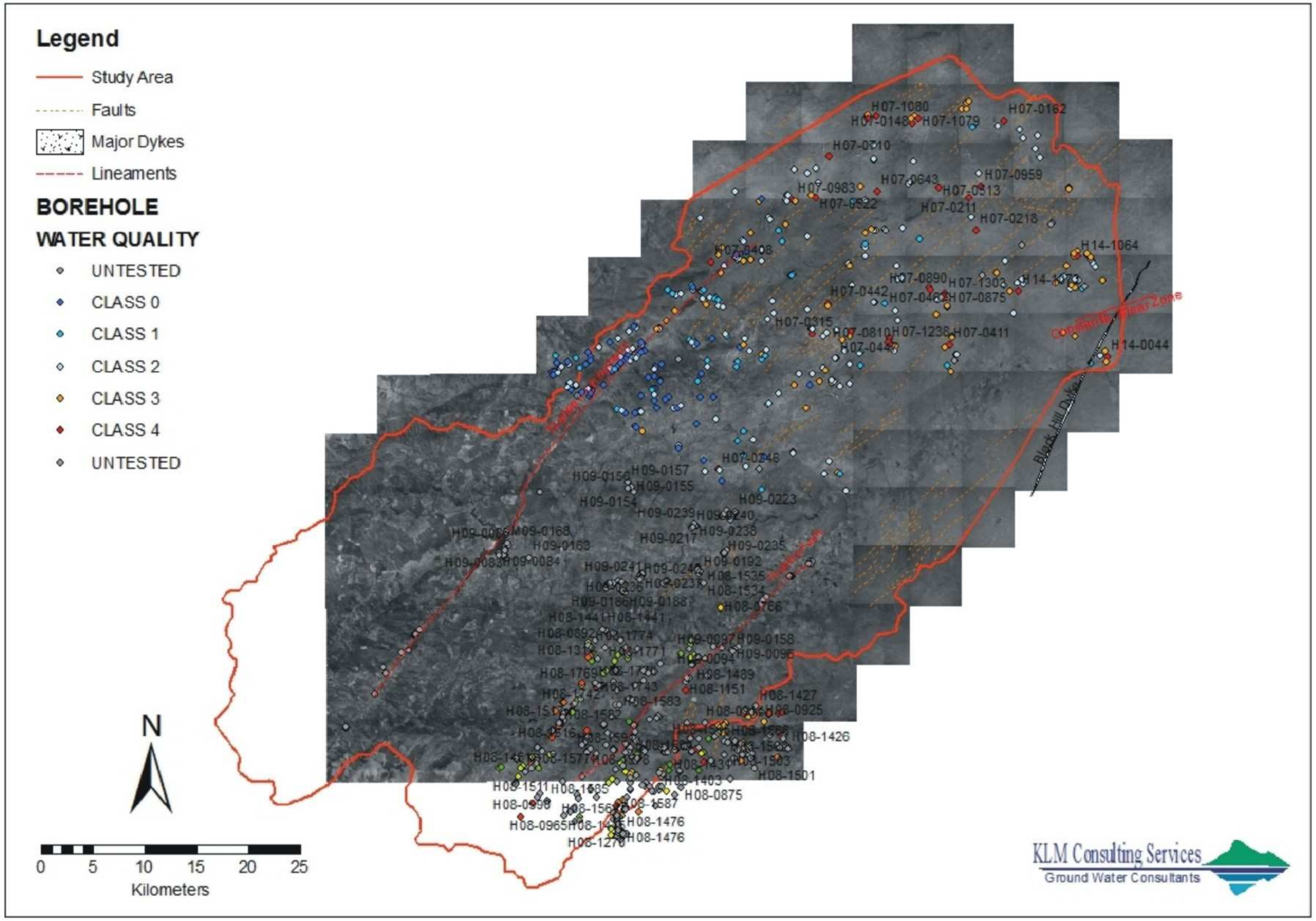

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water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

TITLES:

GROOT LETABA RIVER WATER DEVELOPMENT PROJECT

Aerial Photographic Interpretation Showing Major Geological Structures

FIGURE NO.

3.3

c) Black Hills Dyke

The study area is bound to the east by the NE - SW west trending Black Hills gabbro dyke and to the west by the NE – SW Koedoes Lineament shear zone. The Constantia Fault is trending in NE - SW direction and crosscuts the Black Hills gabbro dyke at Dzumeri area.

d) Thabina Fault

The Thabina Fault is situated south-east of Tzaneen Town and it trends in the SW - NE direction.

The project area is characterized by fractured aquifers. Therefore new boreholes should be drilled targeting the area of structural significance, such as

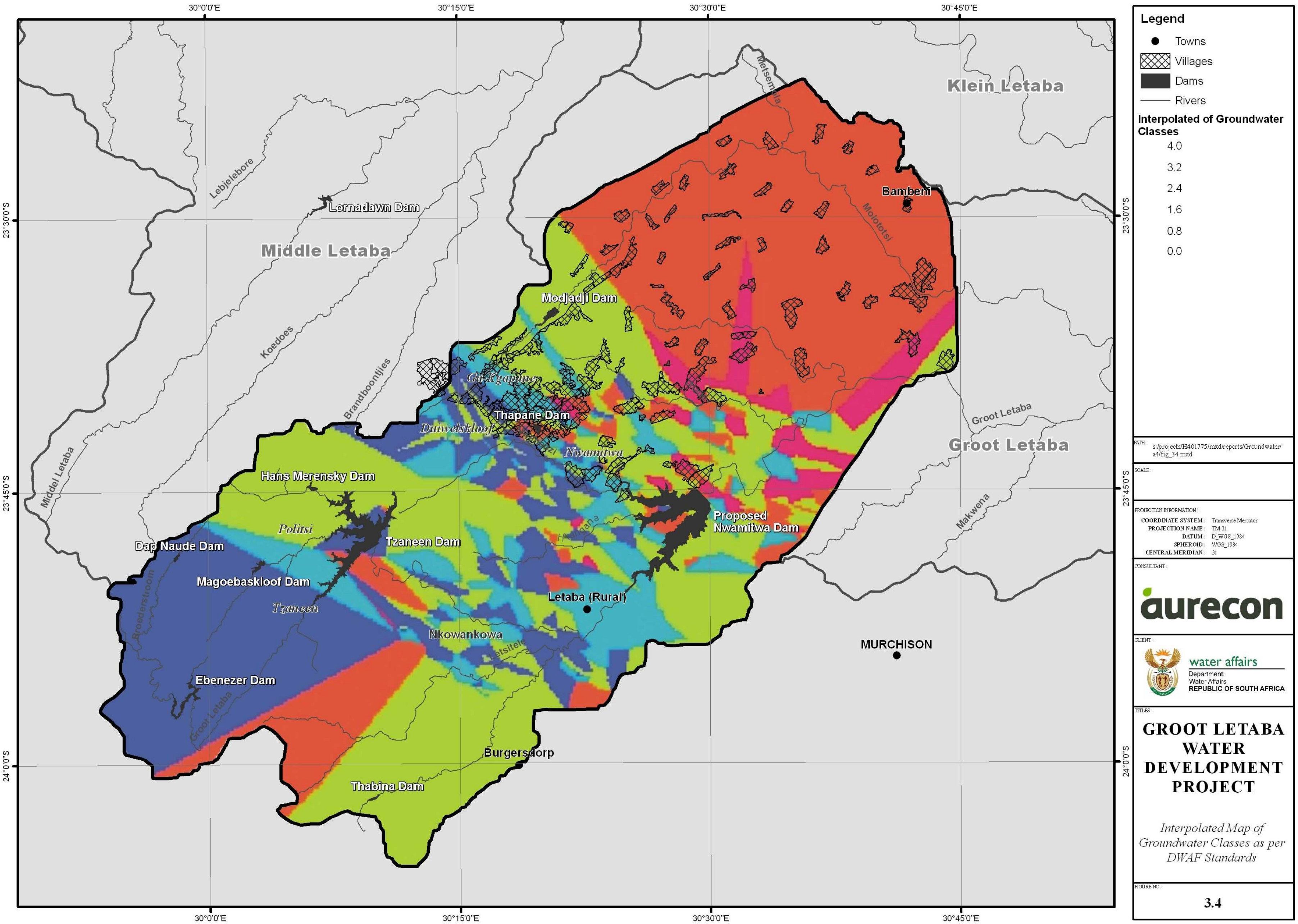
- an area where jointing/faulting is more intense than the surrounding rock,
- fractures along the contact zones caused by the intrusion of dykes and sills,
- saturated unconsolidated alluvial deposits developed along the river channels,
- basins of weathering occurring mostly in the crystalline rocks.

3.4 GROUNDWATER QUALITY

Chemical analysis results from 434 boreholes (in zones H7, H8, H9 and H14) were analysed for suitability for use for domestic purposes. The DWA guidelines (DWA, 1996) (as detailed below) were used as a basis, and the percentage of boreholes with quality in a particular Class is summarised in **Table 3.1**. A spatial representation of where these quality groundwaters occur is given in **Figure 3.4**: Interpolated map of Groundwater Classes as per DWA standards.

Table 3.1 Distribution of groundwater in the study area as per DWA classification

Water Class Type	Description	Percentage of boreholes with this quality
0	Water of ideal quality	21
I	A good quality water	15
II	Water which is safe for short-term use only	38
III	An unacceptable quality of water	18
IV	Poor water quality	8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Groot Letaba
Lebjelebore
Lornadawn Dam
Koedoes
Brandboontjies
Middel Letaba
Metsemola
Molototsi
Bambeni
Modjadji Dam
Thapane Dam
Duiwelskloof
Nwamitwa
Hans Merensky Dam
Politsi
Tzaneen Dam
Proposed Nwamitwa Dam
Dap Naude Dam
Magoebaskloof Dam
Tzaneen
Letaba (Rural)
Nkowankowa
Letsitele
Ebenezer Dam
Groot Letaba
Burgersdorp
Thabina Dam
MURCHISON
Makwena
Legend
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Villages
Dams
Rivers
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CONSULTANT:
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water affairs
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GROOT LETABA WATER DEVELOPMENT PROJECT
Interpolated Map of Groundwater Classes as per DWAF Standards
FIGURE NO.:
3.4

A high percentage (36%) of the water from existing boreholes in the catchment is of acceptable quality, as it falls in the "Ideal" (Class 0 - 21%) and "Good" (Class 1 - 15%) range. There is also a high percentage of boreholes that produced water that can be used for short-term usage (Class II – 38%). Only a total of 26% of the boreholes produced water of unacceptable (18%) or poor (8%) quality water.

Most of the boreholes with acceptable water (Classes 0 and 1) are in the western part of the catchment, as shown in **Figure 3.4**. This area includes the high land areas with high precipitation, Tzaneen town and the other villages with proper reticulation networks. The low lying area (the eastern part of the study area) is dominated by Class III and IV water showing high levels of pollution, probably due to the density of pit latrines in the area. There are however areas in the eastern part of the bulk supply area that have boreholes with acceptable water quality, although they are not as extensive as the western area.

3.5 BOREHOLE YIELDS

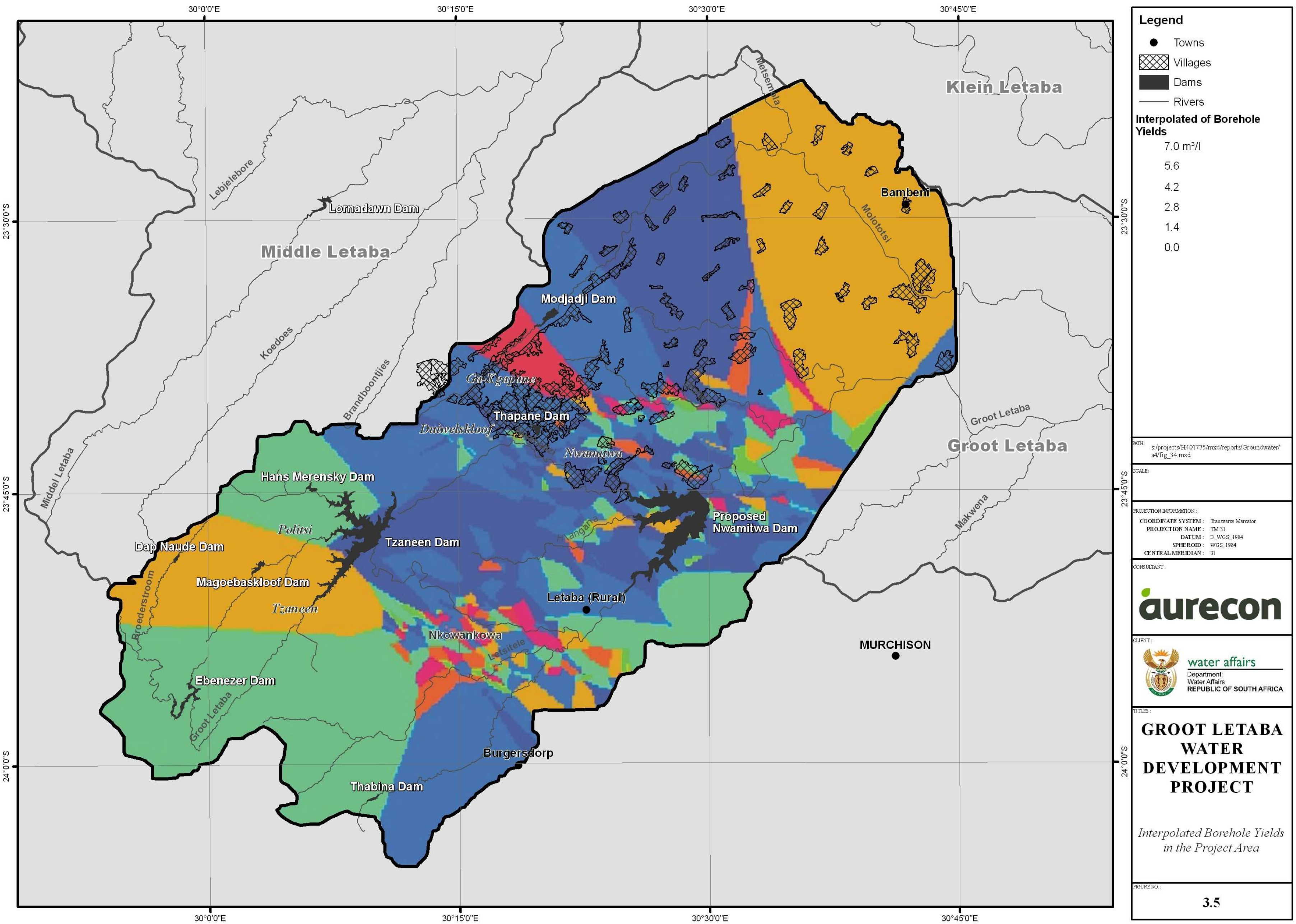
Borehole yields vary from 0 to 28.8 m^3/h, with an average yield of 2.16 m^3/h. The spatial distribution of these yields is shown in **Figure 3.5**. The sustainability of this yield depends on the ongoing maintenance of individual boreholes. This is a concern in the catchment, since 45% of the 1 404 functioning boreholes are currently dry and require rehabilitation.

3.6 GROUNDWATER RECHARGE

Quantitative groundwater recharge can be estimated using hydrological, hydrochemical or isotope data and indirectly by numerical groundwater models. In this study, groundwater recharge was estimated using the chloride profile (mass balance) method. This method has been used in many environments to calculate recharge and requires that chloride in rainfall has to be known.

The following assumptions are used when using this method:

- the only source of chloride is rainfall and there is no other source in the soil or groundwater,
- chloride is conservative in the system,
- there is a steady state relationship between long-term rainfall and chloride concentration,
- there is a downward vertical diffuse flow of soil moisture.



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Proposed Nwamitwa Dam
Bambeni
Letaba (Rural)
Nkowankowa
Burgersdorp
MURCHISON
Ga-Kgapane
Duiwelskloof
Nwamitwa
Politsi
Tzaneen
Lebjelebore
Koedoes
Brandboontjies
Middel Letaba
Metsemola
Molototsi
Groot Letaba
Makwena
Broederstroom
Letsitele
Thabina
Letaba
Legend
Towns
Villages
Dams
Rivers
Interpolated of Borehole Yields
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4.2
2.8
1.4
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GROOT LETABA WATER DEVELOPMENT PROJECT
Interpolated Borehole Yields in the Project Area
FIGURE NO.:
3.5

Recharge was calculated using the equation below:

$$\mathrm{Re} = \frac{Cl_{input} * Rf}{Cl_{gw}}$$

Where: Re is groundwater recharge

Clinput is Chloride in rainfall

Clgw is Chloride in groundwater

Rf is annual rainfall

A linear relationship has been established for inland areas using rainfall chloride and average annual rainfall from the extensive data collected in Botswana and isolated samples in South Africa, Bredenkamp, *et al*, 1995. This linear relationship is plotted in **Figure 3.6** and was used to estimate chloride content in rainfall. This method has been used to determine groundwater recharge in the Pretoria-Rietondale, West Rand, Spring Flats and Kuruman areas in South Africa.

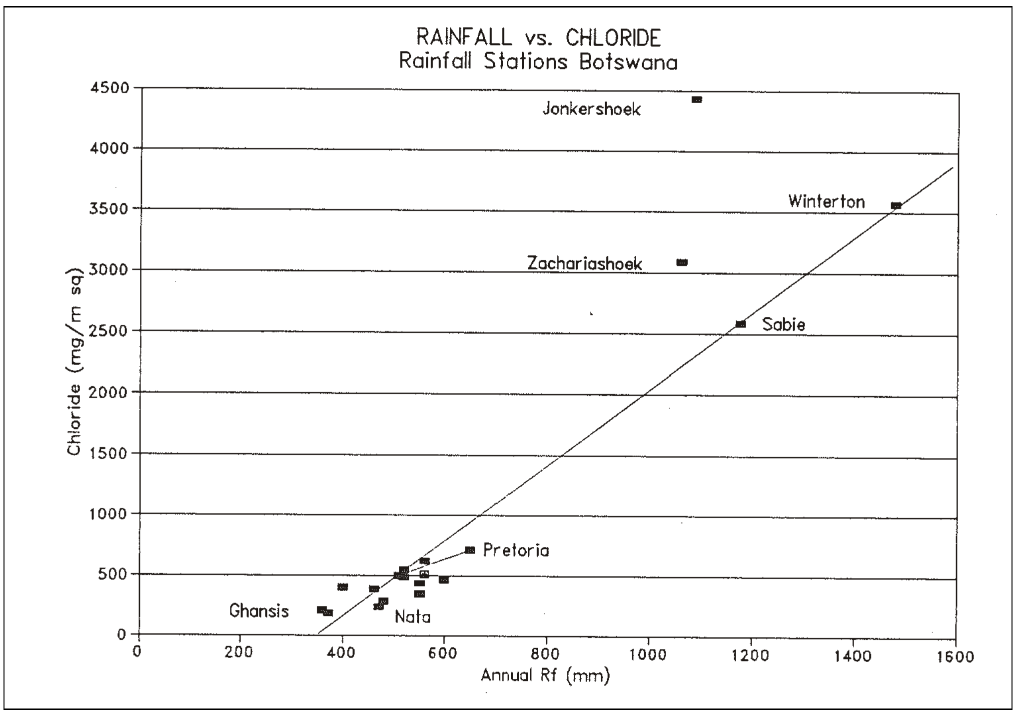


Figure 3.6 Linear relationship between average annual rainfall and chloride input for inland areas, after Bredenkamp, *et al*, 1995

The groundwater chloride values were obtained from the available water chemistry results and the rainfall for the highland and low land were obtained from DWA 2004

(*Luvuvhu/Letaba Water management area* report). The recharge calculations were done in the Microsoft Excel spreadsheet and spatial distribution interpolated in a GIS system. The recharge ranges from a maximum of 175.8 mm/year to a low of 0.1 mm/year, (see **Figure 3.7**). This recharge values represent 0.02% to 9.5% of the annual rainfall. It is highest in the western side of the project area and it reduces in the easterly direction.

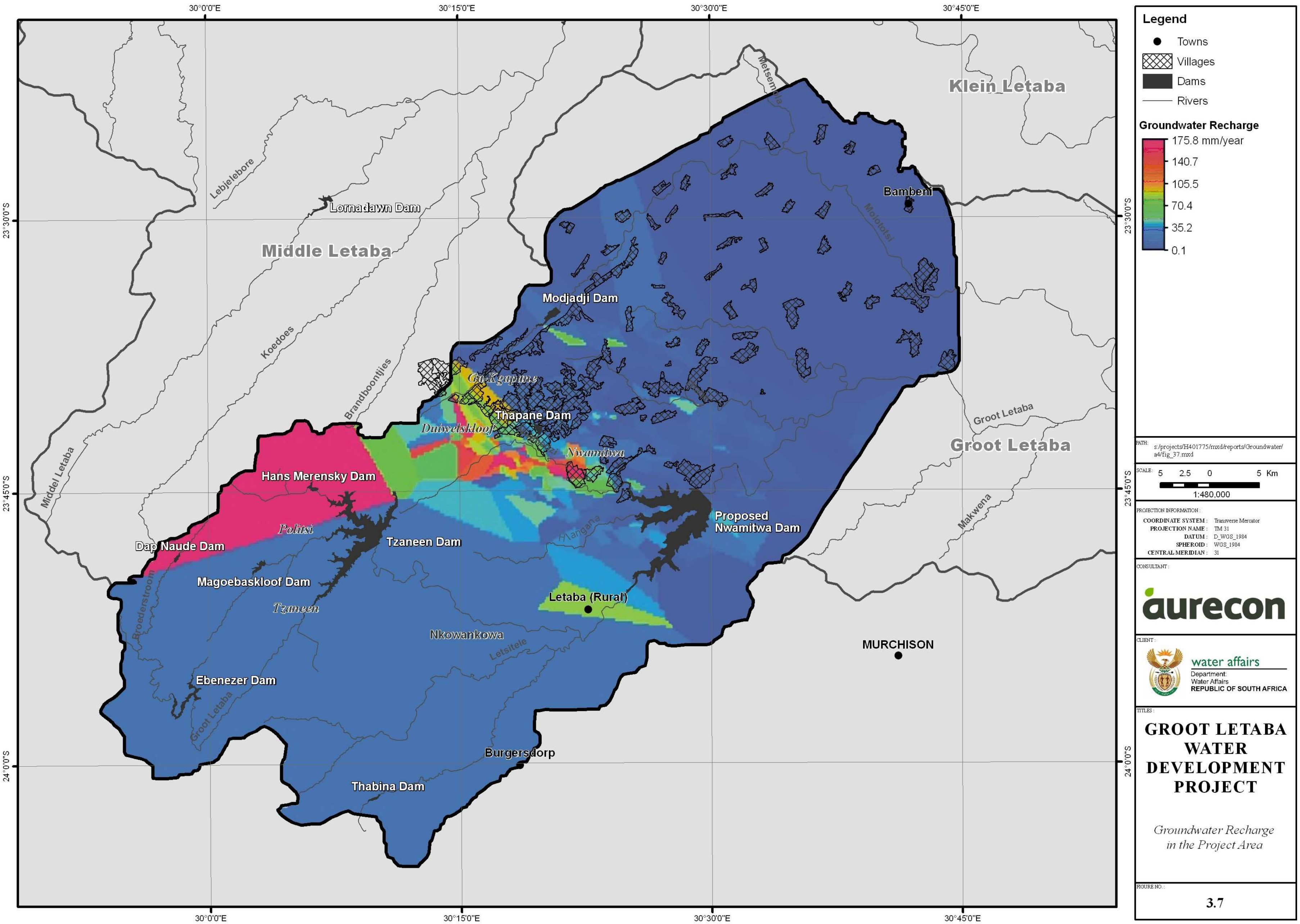
3.7 GROUNDWATER UTILISATION

The groundwater status is based on the data and results from the DWA GRIP study. The groundwater status is summarised as follows:

- Out of 1404 boreholes surveyed during the GRIP campaign in the study area, 635 boreholes (45%) are either dry or blocked,
- 40% of boreholes with DWA Classes III and IV water quality are good yielding. 60% of the good yielding (>1 l/s) boreholes have DWA CLASS 0, I and II water quality. **Table 3.2** lists boreholes with poor quality water and hence yield more than 1 l/s.

Table 3.2 High yielding boreholes with poor water quality

BH No.	YIELD (l/s)	DWA classification	BH No.	YIELD (Mm^3/a)	DWA Classification
H07-0142	1.296	CLASS IV	H07-0085	1.2	CLASS III
H07-0983	5	CLASS IV	H14-1173	1.059	CLASS III
H07-0218	1.2	CLASS IV	H14-1070	1.3	CLASS III
H07-0162	1.1	CLASS IV	H14-0130	1.1	CLASS III
H07-0142	1.3	CLASS IV	H14-0057A	1.99	CLASS III
H14-1073	2.7	CLASS IV	H14-0057	2.4	CLASS III
H14-0044	2	CLASS IV	H14-0045	2.9	CLASS III
H07-0446	1.9	CLASS III	H07-1417	2	CLASS III
H07-0443	1.5	CLASS III	H07-0983A	5	CLASS III
H07-0158	2.5	CLASS III	H07-0799	1.1	CLASS III



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Groot Letaba
Broederstroom
Burgersdorp
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MURCHISON
Makwena
Legend
Towns
Villages
Dams
Rivers
Groundwater Recharge
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105.5
70.4
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CONSULTANT :
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CLIENT :
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Department: Water Affairs
REPUBLIC OF SOUTH AFRICA
TITLES :
GROOT LETABA WATER DEVELOPMENT PROJECT
Groundwater Recharge in the Project Area
FIGURE NO. :
3.7

- The highest yielding borehole, H14-0370 (8 l/s), drilled in Dzumeri area has CLASS II water type.

- Boreholes H07-0983 and H0983A (both yielding 5 l/s), drilled in Femane village, have Class IV and III water quality type, respectively. This is poor water quality, not suitable for any domestic use.

- Borehole H07-0352 yields 3.5 l/s and the water is Class I type.

- Water treatment could increase groundwater contribution to the water supply. The boreholes with poor water quality could contribute to the total groundwater yield by 155,520 l/d if the GRIP lowest recommended sustainable yield of 0.09 l/s is used and 1,278,720 l/d if the GRIP maximum recommended borehole yield of 0.74 l/s is used.

- The borehole yields do not depend on the borehole depth. There are 65 shallow boreholes (0-18 m deep) that yield between 0.08 and 1.3 l/s and 7 deep boreholes (120-180 m deep) that yields between 0.008 and 0.4 l/s.

- The majority of boreholes in region 14 (that falls within the study area) have poor water quality (DWA CLASS II to CLASS IV).

- The water quality deteriorates from west to the east of the study area, (see **Figure 3.3)**.

- The majority of boreholes are concentrated in NE - SW west trending geological structures.

- The hydrogeological map of Phalaborwa (2330) indicates the high groundwater abstraction for irrigational purposes in the area around Tzaneen Town, implying that a total of 2 to 5 Mm^3 of groundwater is abstracted annually for irrigational purposes. A more recent, detailed study (DWAF, 2007) estimated groundwater use for irrigation in the catchment to be 29 Mm^3/a, and this value has been adopted for use in this study. The volume of water pumped from the aquifers for village water supply was estimated from the GRIP data as 10.6 Mm^3/a.

- In summary, it is estimated that a total of 39.6 Mm^3 is abstracted from the aquifer per annum. Therefore; from the recharge of 90.9 Mm^3/a, approximately 51.3 Mm^3/a (without groundwater loses) of the rainfall recharged water is available for future development.

4. GROUNDWATER POTENTIAL

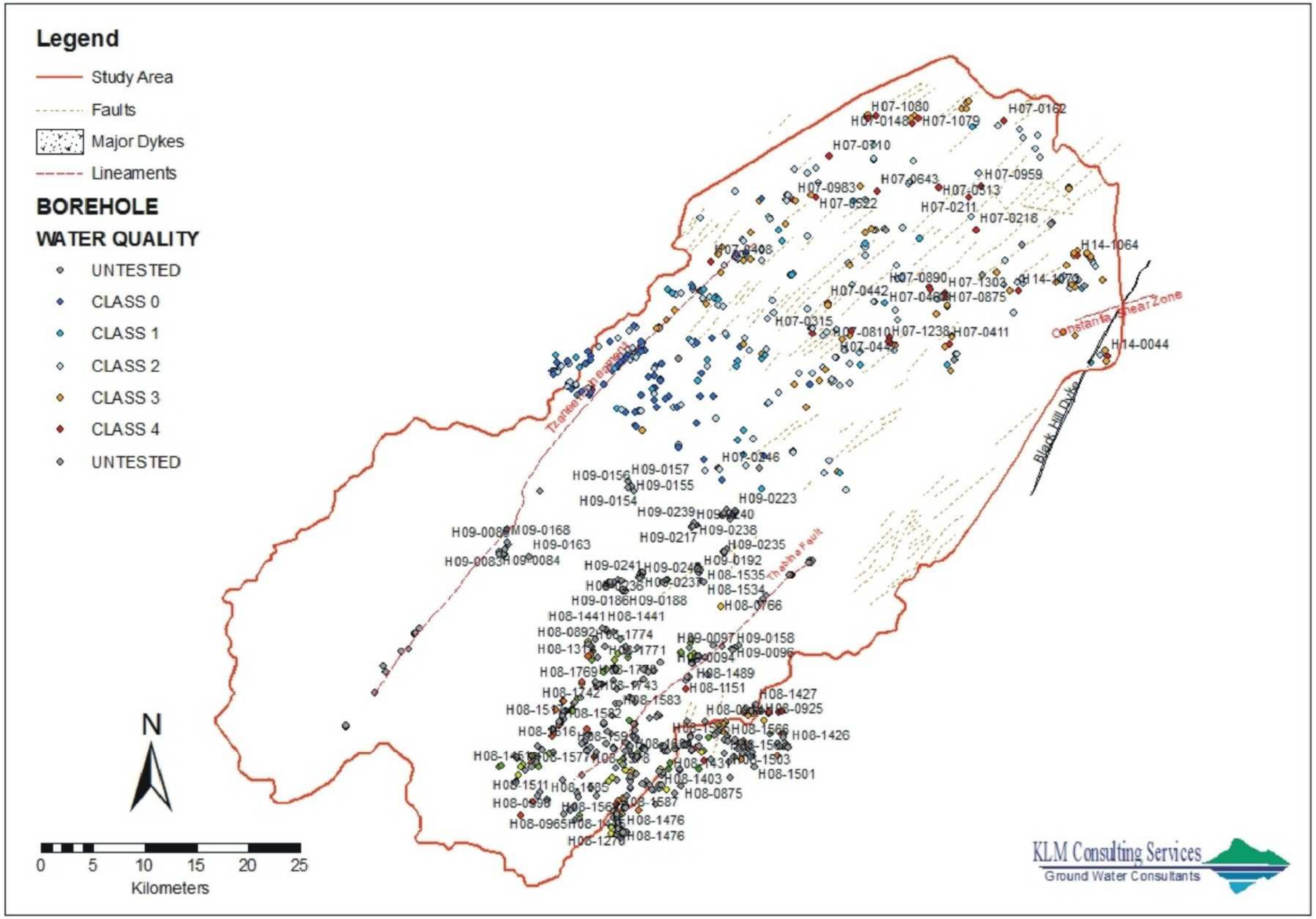
4.1 INTRODUCTION

A detailed structural interpretation of the Project Area was achieved by interpreting available aerial photographs (remote sensing data) in conjunction with published geological mapping information. The interpretation of the remote sensing data set and their integration with existing published geological and structural information has resulted in the development of a structural model of the project area (see **Figure 4.1**).

It is important to understand the geological and hydrogeological significance of structural features identified from aerial photographs, supported by existing information gained from previous drilling and surface mapping. This information was used to identify specific geological features which appear to have the best hydrogeological potential and hence are suggested as areas with high groundwater potential. These areas should be targets for ground geophysical investigations and further drilling of production boreholes. Vegter 1995 recommended the geological structures as the best targets for successful borehole drilling in the project area.

The only information available from borehole records is borehole locations, depths, yields, water levels and water chemistry results. This made it difficult to understand the depth of groundwater strikes and the sources of groundwater.

The groundwater potential in the project area has also been determined qualitatively using GIS modelling.



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CONSULTANT:

aurecon

CLIENT:

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

TITLE:

GROOT LETABA RIVER WATER DEVELOPMENT PROJECT

Structural Model of the Project Area

FIGURE NO.

4.1

4.2 STRUCTURES WITH GROUNDWATER POTENTIAL

4.2.1 Tzaneen Lineament

Tzaneen Lineament seems to have a better groundwater potential in the lowland than in the mountainous area. Boreholes drilled in the highlands have low yields whereas boreholes drilled in the low lying areas have medium to high yields. The high yielding boreholes H07-0749 (7 l/s), H07-0984 (5.5 l/s), H07-0984A (4.6 l/s), H07-0983 (5 l/s) and H07-0983A (5 l/s) are near this lineament and are probably drilled through it. Future geophysical investigation should target the Tzaneen Lineament in the lowland areas.

4.2.2 The Black Hill Dyke and the Constantia Shear Zone

This structure has high groundwater development potential. The Groot Letaba River occupies the Black Hill Dyke in the South of Dzumeri area. The Black Hill Dyke is also cross-cut by the Constantia Fault which is occupied by the Molototsi River in the east of Dzumeri area. There is probably a good groundwater recharge through the Constantia fault zone from the Molototsi River and Groot Letaba River. High yielding boreholes (H14-0370 and H14-0129) in the Dzumeri area are near these structures and were probably drilled through the Black Hills Dyke and the Constantia Fault zone. These boreholes yield 8 l/s and 3.8 l/s, respectively.

4.2.3 Thabina Fault

The Thabina Fault is situated south-east of Tzaneen Town and it trends in the south-west to north-east directions. The boreholes around the Lenyenye and Ramalema area form NE-SW patterns and they were probably drilled targeting this structure. Good yielding boreholes H08-1017 (1.01 l/s) and H08-0844 (1.99 l/s) are near this structure and are probably drilled through this fault. The dip direction and angle of dip of Thabina Fault is not known. This fault is occupied by the Thabina River. Therefore finding an ideal drilling site could be difficult, if it is a vertical structure.

4.3 QUALITATIVE GROUNDWATER POTENTIAL

A GIS model was used to combine spatial data from different sources in order to overlay, query and analyse data to come up with spatial variables that satisfy certain criteria and algorithm.

The groundwater potential of the project area was determined from the available data to have areas of high, moderate and low potential for groundwater development. The potential is defined as the ability of the aquifer to supply potable groundwater of desired quantities and be replenished.

The attributes that were used to determine the groundwater potential are water quality, borehole yields and groundwater recharge. It has to be pointed out that the available borehole records are not distributed entirely through the project area and to cover the entire project area, the data was interpolated. The water quality, borehole yield and recharge maps show areas of high groundwater development potential.

The groundwater potential map was calculated using an algorithm below:

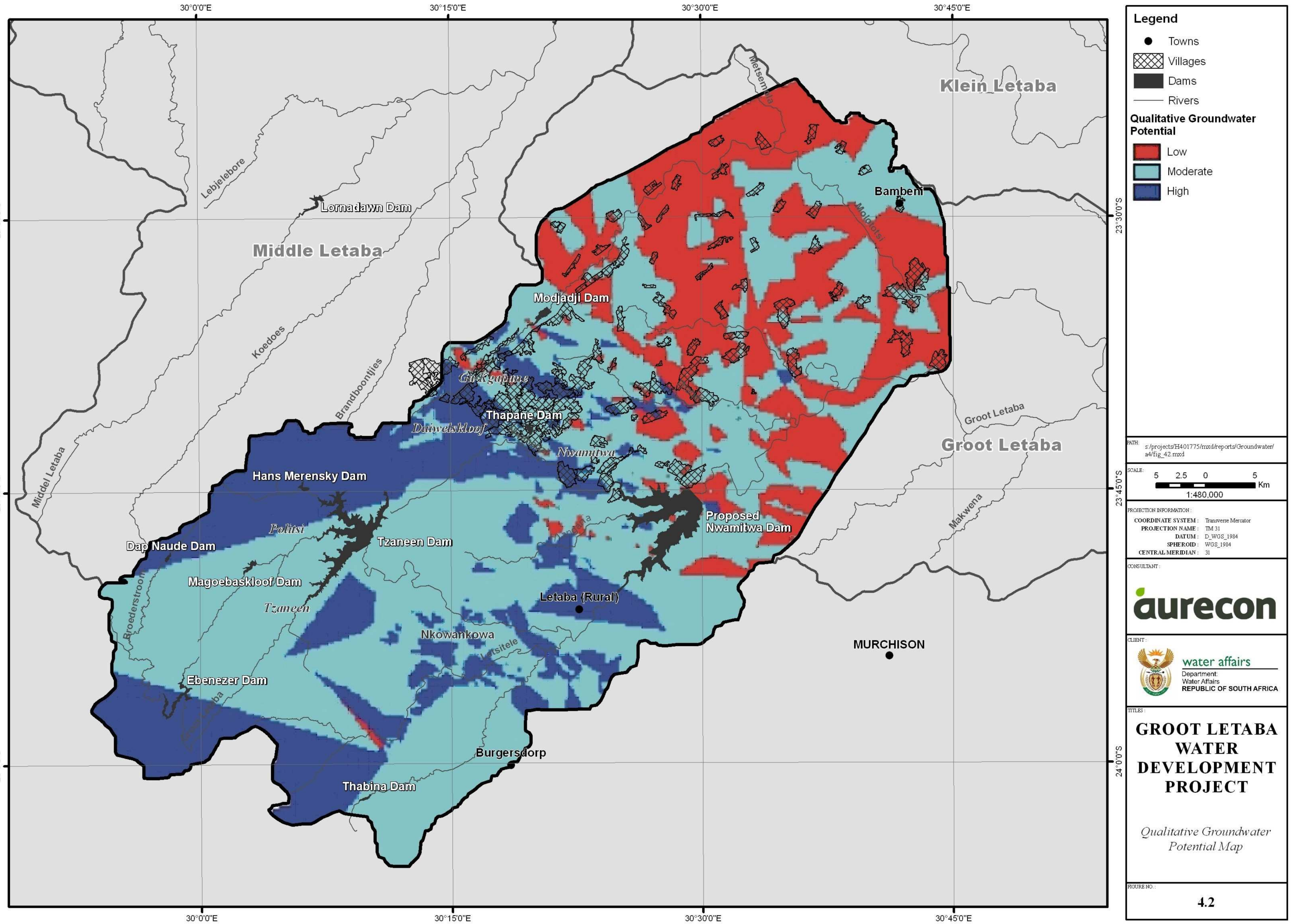
$$Gwpot = \frac{Gwclass_{wght} + Gwyield_{wght} + Gw\mathrm{Re}_{wght}}{W_{Gwclass} + W_{Gwyield} + W_{Gw\mathrm{Re}}}$$

where: $Gwclass_{wght}$, $Gwyield_{wght}$ and $GwRe_{wght}$ are the weighted maps of water quality class, borehole yield and groundwater recharge.

$W_{Gwclass}$, $W_{Gwyield}$ and W_{GwRe} are the weights of each map.

Maps of water quality classes, borehole yields and groundwater recharge were weighted in GIS to determine the groundwater potential. The groundwater quality map was given a high weight score of 7, the borehole yield map was given a weight score of 2.5 and the recharge map was given a weight score of 0.5. High scores were given to the water quality and borehole yields because they are important parameters in determining groundwater potential.

A statistical evaluation was then performed on the map to determine the classes required to slice the image into three classes of high, moderate and low groundwater potential (see **Figure 4.2**). The class of low groundwater potential has values less than 2.5, the class of moderate groundwater potential has values between 2.5 and 5, and the class of high groundwater potential has values of more than 5. Areas with the highest groundwater potential are found throughout the project area and some coincide with the mapped structures in **Figure 4.1**. It has to be noted that some of the areas with good groundwater potential are used for irrigation farming.



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Dams
Rivers
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Water Affairs
REPUBLIC OF SOUTH AFRICA
TITLES :
GROOT LETABA WATER DEVELOPMENT PROJECT
Qualitative Groundwater Potential Map
FIGURE NO. :
4.2

5. GROUNDWATER DEVELOPMENT

5.1 GROUNDWATER DEVELOPMENT STRATEGY

Prior to a full scale groundwater exploration campaign, there should be reconnaissance surveys and a borehole census, as well as confirmation of the populations, as the current figures are not conclusive and hence it is difficult to predict water demands. The borehole census will confirm borehole status, current yields, water qualities, and effects of borehole construction on yields and water quality. These surveys will also carry out vulnerability mapping of groundwater by pollution from pit latrines, septic tanks, grave yards and underground fuel storages.

A ground geophysical investigation should be carried out to determine depths to structures and their orientation. Once the estimated depth where the boreholes would intersect the water bearing structures, the water demand and the number of boreholes to be drilled in each structure is known, then the groundwater development cost can be estimated. A groundwater development strategy is summarised in **Figure 5.1**.

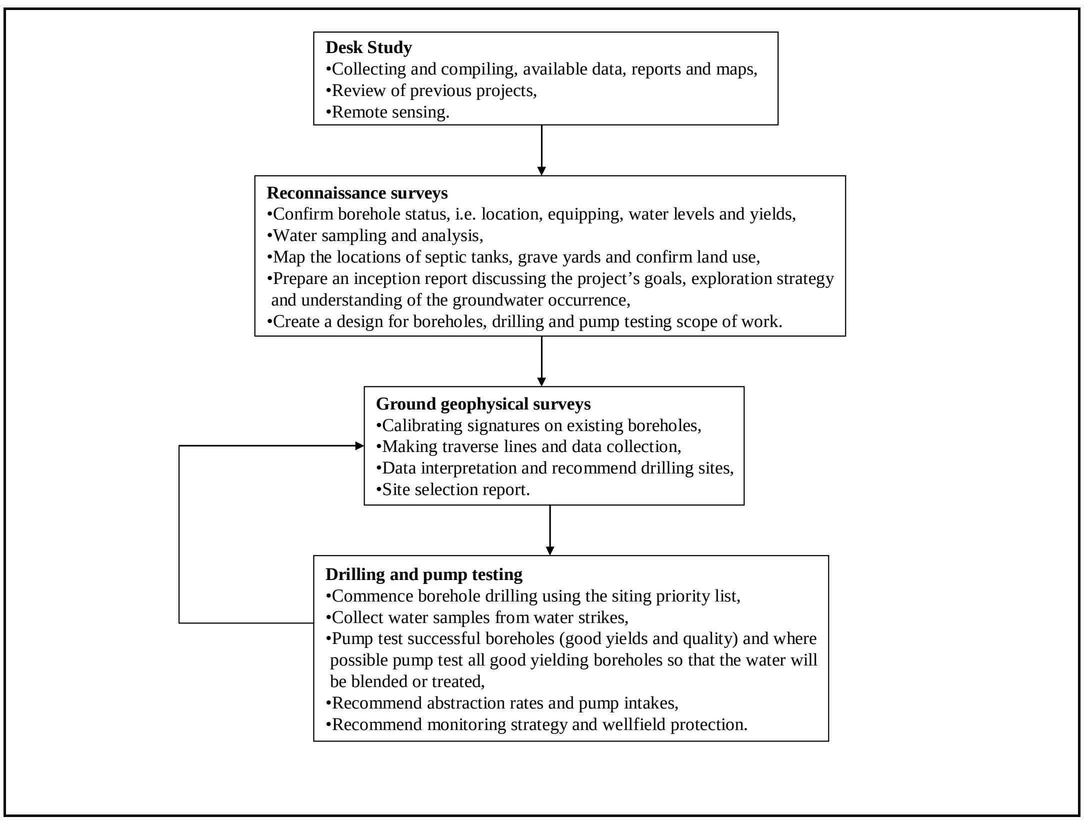


Figure 5.1 Flow chart of groundwater development strategy

In the bulk supply area, there are small areas with good groundwater potential and these have to be developed for village water supply. Since the resources are of small magnitude it will be cheaper to drill boreholes for each village or set of villages to save costs in the reticulation network.

The boreholes should be properly designed to avoid well-head pollution as is reported in some of the existing boreholes. It will also be important to site the boreholes outside the villages to avoid pollution from pit latrines, septic tanks and graveyards. The village development area should be zoned to protect the wellfields. Therefore, the development cost will depend on the potential borehole sites with respect to the village's demand and the infrastructural requirements, which are unknown at this stage.

5.2 QUALITATIVE GROUNDWATER DEVELOPMENT

A qualitative groundwater development analysis was done using GIS modelling. The attributed maps that were used to determine the groundwater development costs are the weighted maps of water quality classes, borehole yield and borehole depths.

The qualitative groundwater development costs were calculated using the algorithm below:

$$Gwdev = \frac{Gwclass_{wght} + Gwyield_{wght} + BHdepth_{wght}}{W_{Gwclass} + W_{Gwyield} + W_{Gw\mathrm{Re}}}$$

where: $Gwclass_{wght}$, $Gwyield_{wght}$ and $BHdepth_{wght}$ are the weighted maps of water class, borehole yield and groundwater recharge.

$W_{Gwclass}$, $W_{Gwyield}$ and $W_{BHdepth}$ are the weights of each map.

A similar procedure to the one used in **Section 4.3** was used to determine three classes of low, moderate and high groundwater development costs (see **Figure 5.1**). Maps of water quality classes, borehole yields and borehole depths were weighted in GIS to determine the groundwater potential. The groundwater quality map was given a high weight score of 5, borehole yield map was given a weight score of 3.5 and borehole depth map was given a weight score of 1.5.

The class of low groundwater development costs has values less than 10, the class of moderate groundwater development costs has values between 10 and 17.5, and the class of high groundwater development costs has values more than 17.5. Most parts of the bulk areas have low to moderate development costs (see **Figure 5.2**). The mountainous areas have the highest groundwater development costs

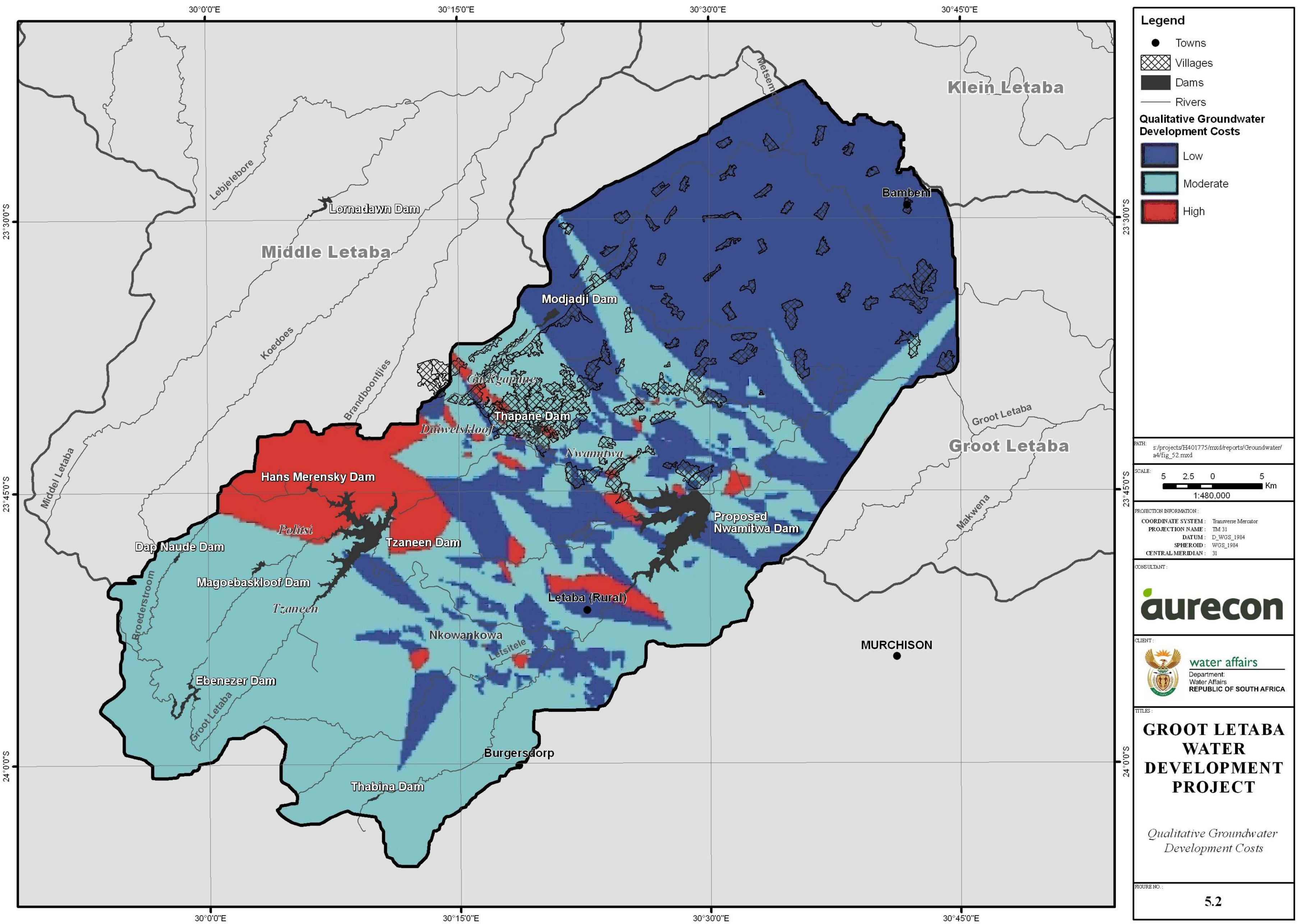
Areas with poor water quality and low yielding deep boreholes have the highest development costs. This is because the water has to be treated to conform to the DWA standards before it can be used for domestic usage. Additional boreholes will have to be drilled to meet a certain water demand and this will result in increasing the development costs.

5.3 CONJUNCTIVE USE OF SURFACE AND GROUNDWATER RESOURCES

The conjunctive use of surface and groundwater resources should be considered as an option in the bulk supply area, to reduce pressure on the groundwater resources. The surface water is potable and can also be used for blending with groundwater and this will have the desired effect of making groundwater conform to the DWA standards in the bulk supply area.

There is a current shortfall in water supply in the project area and the construction of the Nwamitwa Dam will be completed in a period of about 10 years. It is thus important to develop groundwater to meet the current water demands. The required pipeline can be adapted for surface water reticulation.

There is already a water supply infrastructure in the bulk water supply villages and therefore it can also be used for groundwater supply. The problem is that the increases in water demand will necessitate using larger diameter pipes to withstand high pressures associated with high flows.



Legend
Towns
Villages
Dams
Rivers
Qualitative Groundwater Development Costs
Low
Moderate
High
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24°0'0"S
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SCALE: 5 2.5 0 5 Km
1:480,000
PROJECTION INFORMATION :
COORDINATE SYSTEM : Transverse Mercator
PROJECTION NAME : TM 31
DATUM : D_WGS_1984
SPHEROID : WGS_1984
CENTRAL MERIDIAN : 31
CONSULTANT :
aurecon
CLIENT :
water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA
TITLES :
GROOT LETABA WATER DEVELOPMENT PROJECT
Qualitative Groundwater Development Costs
FIGURE NO. : 5.2

6. POTENTIAL CONFLICT OF GROUNDWATER USE

The GRIP data indicates that approximately 10.6 Mm^3/a is pumped from the aquifer from 1404 boreholes for community water supply. The Phalaborwa 2330 hydrogeological map shows that 2 to 5 Mm^3 is abstracted per annum for irrigational use. The most recent detailed study on groundwater use in the catchment (DWAF, 2007) estimated that 29 Mm^3/a of groundwater is used for irrigation purposes in the catchment. If the most recent estimate of groundwater use for irrigation is used, an estimated total of approximately 40 Mm^3/a (10.6 + 29) is abstracted from the aquifer. Increasing the total groundwater yield for community water supply could result in the drying up of boreholes used for irrigation. It is also apparent from the groundwater potential map, (**Figure 4.2**) that the farms are located in the areas with high groundwater potential. To develop these resources might create a conflict between the community and the Farmers.

It is proposed that where possible, some farms should be purchased to allow for the development of public wellfields. This will certainly avoid potential conflicts when it comes to sharing the groundwater resources. It is also possible to prioritise surface water use for farming to avoid conflict in the use of water supply.

7. SUMMARY AND CONCLUSIONS

7.1 PRESENT AND FUTURE USE OF GROUNDWATER

The current use of groundwater in the Groot Letaba Catchment is limited to between 2 and 5 Mm^3/a of irrigation use in the Tzaneen area, and an estimated 10.6 Mm^3/a use for supply to villages. An estimate of 29 Mm^3/a for groundwater use for irrigation was obtained from a more detailed study by Schoeman & Vennote (see separate study report entitled *Review of Water Requirements (DWAF, 2007)*), and has been adopted for use in this study. Therefore the total current use of groundwater in the catchment is estimated to be 39.6 Mm^3/a.

7.2 GROUNDWATER POTENTIAL IN THE BULK WATER DISTRIBUTION AREA

The groundwater development potential in the Groot Letaba Catchment is high :

- There is a significant rainfall recharge of the groundwater in the project area, and it reduces from west to east across the project area. It is estimated that a total volume of 90.9 Mm^3/a is added to the groundwater annually from rainfall. This recharge value represents 0.02% to 9.5% of the annual rainfall.
- Using the above recharge value, and the current groundwater use of 39.63 Mm^3/a, approximately 51.2 Mm^3/a (without accounting for groundwater losses) is available for development.
- Most parts of the project area have low to moderate groundwater development costs (**Figure 5.2**).
- Small areas with good groundwater potential exist in the bulk supply area. These should be developed for village water supply. Since the resources are of small magnitude, separate boreholes supplying individual villages would be more cost effective.
- Most of the existing boreholes in the catchment produce water of acceptable quality for domestic use, as it falls in the "Ideal" (Class 0 - 21%) and "Good" (Class 1 - 15%) range. There is also a high percentage of boreholes that produce water that can be used in the short-term (Class II – 38%).
- Potential borehole sites with suitable quality groundwater exist close to the villages in the bulk supply area. These are widespread in the western part of the bulk supply area, but less so in the eastern part of the bulk supply area. Careful siting

of boreholes will be required in the eastern part of the bulk supply area to ensure that acceptable water quality is obtained.

- Water treatment could increase groundwater contribution to the water supply in the catchment. It was estimated that boreholes with poor quality water could contribute to the total groundwater yield by between 0.06 Mm^3/a – 0.48 Mm^3/a (155 520 l/day – 1 278 720 l/day).
- It is important that alternative groundwater resources are found for the villages that currently have low yielding and poor water quality boreholes. This cannot wait until water from Namitwa Dam is available.

There are some limiting factors with need to be overcome in order to realise this potential groundwater resource :

- There is the need for conjunctive use of surface and groundwater resources for both domestic use and irrigation farming. This is because in some areas of the catchment, the quality of borehole water is not suitable for domestic use without treatment or blending with better quality water. This applies particularly to the low lying, eastern part of the catchment, where potential borehole water quality is dominated with Class III and IV water (**Figure 3.4**).
- Conjunctive use of groundwater and surface water will also be beneficial in those areas of the catchment that have low groundwater potential, for example the extreme eastern part of the catchment.
- Pollution of boreholes by pit latrines, graveyards, petrol and oil stores is a problem in the study area, and needs to be addressed.
- Potential conflict could occur between irrigation users and domestic users if preventative measures are not taken timeously. One such example is the purchase of irrigation farms for the development of wellfields in certain areas.

7.3 OTHER CONCLUSIONS

- The interpreted structures (lineaments) coincide with some of the areas of moderate and high groundwater potential. Some of these structures have been mapped in previous projects. Geophysics and advanced drilling techniques can be used to optimise the abstraction from these sites.

8. GROUNDWATER MANAGEMENT AND RECOMMENDATIONS

Prudent management of water resources is required to sustain the groundwater resources for potable domestic use. This can also be achieved by conjunctive use of surface and groundwater for potable domestic purposes and by blending groundwater with surface water to conform to the DWA standards. There should be regular field visits to monitor groundwater quality, water levels and borehole yields. This monitoring will allow for timely intervention and hence the long-term sustainability of groundwater resources.

8.1 RECOMMENDATIONS TO BE IMPLEMENTED IMMEDIATELY

The following should be implemented immediately to maintain and improve the conditions of the existing groundwater resources in the area:

- Development of the water resources should be carried out as per DWA standards, especially the requirement for environmental impact assessments. This applies particularly to the pristine environments that occur in the project area.

- Potential groundwater pollutants should be identified and mitigated against. Where possible, groundwater vulnerability mapping should be carried out to mitigate against potential and current pollution by changing village development plans (expanding villages away from boreholes and wellfields), location of underground fuel storage and graveyards and also to promote the change from pit latrines to sewer or lined ventilated improved types.

- Those boreholes that are contaminated with diesel need to be investigated in detail, and mitigation strategies must be implemented. The boreholes should be rehabilitated, and a pollution monitoring strategy should be put in place to prevent recontamination.

- Standard Operation Procedure (SOP) for pollution prevention is to drill the boreholes with the correct sanitary seals.

- It is also paramount to have properly designed boreholes to avoid wellhead pollution and the inflow of effluents from pit latrines. There are elevated levels of nitrates in some boreholes and this is attributed to pollution.

- Borehole construction is important in that it allows for maximum use of the aquifer and prevents wellhead contamination from dense non-aqueous liquids (diesels and oils from the pump house) and a properly installed sanitary seal will also avoid pollution from septic tanks and pit latrines.

- Borehole rehabilitation is necessary in high yielding boreholes that were not properly constructed. Some of these boreholes will need to be replaced.

- Water levels and quality monitoring is important and needs to be implemented. This will identify over-pumping and intrusion of poor quality waters.

- The recommended yield in many boreholes was based on the assumption that hand pumps (that do not pump for 24 hours) would be installed. At present, electricity is being used in many boreholes, and therefore pump testing should be conducted to ascertain the correct yields and to determine the optimal pumping rates.

- Groundwater classified under DWA Classes II, II and IV should be considered for blending or treating.

8.2 RECOMMENDATIONS FOR GROUNDWATER DEVELOPMENT

For proper development of groundwater resources in the study area, the following recommendations should be adhered to:

- It is recommended that additional groundwater recharge estimations be done with other methods (e.g. isotopes methods) to validate the results obtained in this study, since data limitations meant that only one method was used. This could be done during the reconnaissance stage of the project.

- Ground geophysical surveys should be conducted in areas of high groundwater potential and across structures to identify sites for production borehole drilling. The survey will also give estimates of borehole depths and prepare for borehole designs. The results of the survey should guide the drilling campaign.

- Pumping tests should be carried out in all the successful boreholes to give the recommended production rates.

- The boreholes and wellfield areas should be zoned to avoid land-usages that will subject them to pollution.

- All boreholes should be completed with sanitary seals as per DWA design and SABS standards.

- A monitoring strategy should be designed and implemented to prevent depletion of potable groundwater resources. This includes monitoring water levels, yields and quality, and adherence to the recommended pumping rates.

- In some cases, the groundwater should be blended with surface water for conformation to the DWA standards in certain high-yielding boreholes. It could also be cheaper to treat water from the polluted high-yielding boreholes.

- In villages located in areas with good groundwater potential, the groundwater resources should be evaluated to determine where boreholes have to be drilled and developed for village water supply. If the resources are of small magnitude it will be cheaper to drill boreholes for each village or set of villages to save costs in the reticulation networks.

- It is also recommended that a provision should be made to connect individual village boreholes to have their own groundwater resources. In situations where a lot of groundwater is available, then multiple villages should be connected to the same boreholes via the central header tanks.

- For each pumping borehole, it is recommended that there should be an equipped standby borehole to supply water in times of crisis.

8.3 SUMMARY OF MAIN RECOMMENDATIONS

- A comprehensive regional groundwater investigation should be undertaken so that the location and availability of suitable quality groundwater can be determined with greater certainty. These investigations should be focused on developing regional groundwater supply schemes in the supply area currently envisaged for the proposed Nwamitwa Dam.

- The potential yields, costs and environmental implications associated with a regional groundwater supply should be determined and compared with the yields, costs and environmental implications of the proposed Nwamitwa Dam development.

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