Groundwater Resource Directed Measures: Mvoti to Umzimkhulu Water Management Area

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Groundwater Resource Directed Measures: Mvoti to Umzimkhulu Water Management Area

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Cover Photograph:

Photograph taken in Mshwati Local Municipality on route to Greytown past the town of Seven Oaks showing extensive areas under pine forestation which is characteristic of the landuse practiced in the northern regions of the Mvoti to Mzimkhulu Water Management Area.

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Disclaimer

The opinions expressed in this Report have been based on the information supplied to SRK Consulting (South Africa) (Pty) Ltd (SRK) by Department of Water Affairs (DWA). The opinions in this Report are provided in response to a specific request from DWA to do so. SRK has exercised all due care in reviewing the supplied information. Whilst SRK has compared key supplied data with expected values, the accuracy of the results and conclusions from the review are entirely reliant on the accuracy and completeness of the supplied data. SRK does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them. Opinions presented in this report apply to the site conditions and features as they existed at the time of SRK's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which SRK had no prior knowledge nor had the opportunity to evaluate.

List of Abbreviations

BFI	:	Baseflow Index
BHN	:	Basic Human Needs
CMA	:	Catchment Management Agency
CRD	:	Cumulative Rainfall Departure
DWA	:	Department of Water Affairs
DWAF	:	Department of Water Affairs and Forestry
EARTH	:	Extended Model for Aquifer Recharge and Soil Moisture Transport through the Saturated Hardrock
EC	:	Electrical Conductivity
ER	:	Ecological Reserve
EWR	:	Ecological Water Requirements
GRAII	:	Groundwater Resource Assessment Phase II
GRDM	:	Groundwater Resource Directed Measures
GRIP	:	Groundwater Resource Information Project
GRU	:	Groundwater Resource Unit
GYM	:	Groundwater Yield Model
ICP	:	Inductively Coupled Plasma
ISP	:	Internal Strategic Perspective
K	:	Hydraulic Conductivity
MAE	:	Mean Annual Evaporation
MAP	:	Mean Annual Precipitation
MAR	:	Mean Annual Rainoff
MLF	:	Maintenance Low Flow
mamsl	:	meters above mean sea level
mbgl	:	metres below ground level
NGA	:	National Groundwater Archive

NWA : National Water Act (Act 36 of 1998)

NWRS : National Water Resource Strategy

RDM : Resource Directed Measures

RQO : Resource Quality Objectives

S : Storativity

SA : South Africa

SFR : Stream Flow Reduction

Stats SA: Statistics South Africa

T : Transmissivity

ToR : Terms of Reference

WARMS: Water Use Authorisation & Registration Management System

WMA : Water management Area

WMS : Water Management System

WR2005: Water Resources of South Africa 2005

WRC : Water Research Commission

Units of Measurement

a	annum
cm	centimetre
d	day
i	gradient
km^2	square kilometre
L	Litre
m	metre
m^2	square metre
m^3	cubic metre
mamsl	metres above mean sea level
mbgl	metres below ground level
mm	millimetre
mS	millisiemens
q	flux
s	second

Glossary

Abstraction: The removal of water from a groundwater resource e.g. the pumping of groundwater from an aquifer.

Allocable Groundwater: The volume of groundwater available to allocate or distribute.

Alluvial Aquifer: An aquifer formed of unconsolidated material deposited by water, typically occurring adjacent to river channels and in buried or paleo channels.

Aquifer: An aquifer is defined as a saturated permeable geological formation of group of formations that is permeable enough to yield economic quantities of water.

Aquifer Testing: Aquifer testing involves the withdrawal of measured quantities of water from or the addition of water to, a borehole(s); and the measurement of resulting changes in head in the aquifer both during and after the period of abstraction or addition.

Available Drawdown: Is the difference between the static water level or piezometric surface and the main water strike (in fractured aquifers) and the pump depth (in porous aquifers) in a borehole.

Baseflow: Sustained low flow in a river during dry or fair weather conditions, but not necessarily all contributed by groundwater; includes contributions from delayed interflow and groundwater discharge.

Baseflow Index (BFI): The ratio of annual baseflow in a river to the total annual run-off. BFI greater than 2, requires specialist hydrologist input for EWR estimates.

Basic Human Needs (BHN): The least amount of water required to satisfy basic water requirements; this is currently set at 25 ℓ/person/d.

Borehole: Includes a well, excavation, or any other artificially constructed or improved groundwater cavity which can be used for the purpose of intercepting, collecting or storing water from an aquifer; observing or collecting data and information on water in an aquifer; or recharging an aquifer [from National Water Act (Act No. 36 of 1998)].

Catchment: The area from which any rainfall will drain into the watercourse, contributing to the runoff at a particular point in a river system; synonymous with the term river basin.

Classification: The classification system prescribed under the National Water Act (1998) provides guidelines on how to set appropriate levels of protection for water resources.

Confined Aquifer: An aquifer where the groundwater is isolated from the atmosphere at the point of discharge by impermeable geological formation. Confined groundwater is generally subject to pressure greater than atmospheric.

Contamination: The introduction of any substance into groundwater systems by the action of man which may become harmful to both humans and the environment.

Desired Ecological Status: The future desired status of groundwater within the resource unit as used in setting the groundwater component of the ecological Reserve.

Dissolved Solids: Minerals and organic matter dissolved in water.

Drawdown: The distance between the static water level and the surface of the cone of depression.

Ecological Water Requirement (EWR): The quantity and quality of water of that resource that is required to maintain the said water resource in its assigned ecological category.

Effluent Stream: A stream fed directly by groundwater; the surrounding water table or piezometric surface is above the stream surface; opposite of influent stream.

Electrical Conductivity (EC): Electrical conductivity is a measure of how well a material accommodates the transport of electric charge. The more salts dissolved in the water, the higher the EC value. It is used to estimate the amount of total dissolved salts, or the total amount of dissolved ions in the water.

Ephemeral Streams: These rivers are generally storm-event driven and flow occurs less than 20% of the time; these rivers have a limited (if any) baseflow component with no groundwater discharge.

Exploitation Potential: The volume of harvest potential that can practically be exploited due to borehole yield constraints.

Fault: A zone of displacement in rock formations resulting from forces of tension or compression in the earth's crust.

Fracture: Any break in a rock including cracks, joints and faults.

Fractured Aquifer: An aquifer that owes its water-bearing properties to fracturing

Groundwater: Water found in the subsurface in the saturated zone below the water table

Groundwater Allocation: That volume of groundwater that can be allocated for use after consideration of the Reserve and Resource Quality Objectives.

Harvest Potential: The harvest potential is the maximum amount of groundwater that can be abstracted per square kilometre per annum in South Africa without depleting the aquifers.

Hydraulic Conductivity: Measure of the ease with which water will pass through earth material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).

Hydraulic Gradient: The rate of change in the total hydraulic head per unit distance of flow in a given direction.

Hydraulic Head: Hydraulic head is the height above a datum plane such as sea level of the column of water that can be supported by the hydraulic pressure at a given point in a groundwater system.

Hydrograph: A graph which displays specific hydrological measurements over time, including water levels and discharges.

Hydrological Year: A continuous 12-month period from 1 October to 30 September.

Infiltration: The downward movement of water from the atmosphere into the ground.

Influent Stream: An influent stream is positioned above the watertable and discharges into the underlying groundwater system.

Interflow: The rapid flow of water along essentially unsaturated flow paths, water that infiltrates the subsurface and moves both vertically and laterally before discharging into other water bodies.

Integranular Aquifer: A term used in the South African map series referring to aquifers in which groundwater flows in openings and void space between grains or weathered rock.

Karst Aquifer: Limestone and dolomite areas that possess a topography peculiar to and dependent upon underground solution and the diversion of surface waters to underground routes.

Leachate: Any liquid, including any suspended components in the liquid that has percolated through or drained from human-emplaced materials.

Lithology: Lithology refers to the physical characteristics of rock.

Major Aquifer System: Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (less than 150 mS/m).

Minor Aquifer System: These can be fractured or potentially fractured rocks which do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable.

Non Aqueous Phase Liquids (NAPLs): Organic compounds that do not readily dissolve in water.

Perched Aquifer: Aquifers that contain perched groundwater, i.e. bodies of groundwater separated from an underlying body of groundwater by an unsaturated zone.

Perennial Streams: Streams where surface flow persists throughout the year.

Permeability: The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (expressed as $m^3/m^2/d$ or m/d); it is an intrinsic property of the porous medium and is dependent of the properties of the saturating fluid.

Piezometric Surface: An imaginary or hypothetical surface of the piezometric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer; analogous to the watertable of an unconfined aquifer.

Porosity: Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.

Potable Water: Water that is safe and palatable for human use.

Preferential Flow: The preferential movement of water through more permeable zones in the subsurface.

Primary Aquifer: An aquifer in which water moves through the original interstices of the geological formation

Quaternary catchment: A fourth order catchment in a hierarchal classification system in which a primary catchment is the major unit.

Recharge: Recharge is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation, or indirectly by way of another formation.

Reserve: The quantity and quality of water required to supply basic needs of people to be supplied with water from that resource, and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of water resources.

Resource: A resource is a substance or item available for use. A natural resource is a resource that man can use, but cannot manufacture or create.

Resource Quality Objectives (RQOs): A term used but not defined by the National Water Act. Resource Quality Objectives are used to put a Classification and Reserve into practice by specifying conditions that will ensure that the Class is not compromised and the Reserve can be met. Resource quality may relate to critical flows, groundwater levels and quality that must be maintained. The objectives are to articulate goals that result from the catchment visioning process, but must be based on DWAF policy statements and methodologies and aligned with the National Water Resource Strategy.

Resource Unit: Areas of similar physical or ecological properties that are grouped or typed to simplify the Reserve determination process

Rest Water Level: The groundwater level in a borehole not influenced by abstraction or artificial recharge.

Riparian Habitat: Area of land directly adjacent to a stream or river, influenced by stream-induced or related processes.

Runoff: All surface and subsurface flow from a catchment, but in practice refers to the flow in a river, i.e. excludes groundwater not discharged into a river.

Saline Intrusion: The replacement of fresh groundwater by saline water in an aquifer, usually as a result of groundwater abstraction.

Saturated Zone: The subsurface zone below the watertable where interstices are filled with water under pressure greater than that of the atmosphere.

Secondary aquifer: An aquifer in which water moves through secondary openings and interstices, which developed after the rocks were formed i.e. weathering, fracturing, faulting.

Semi-confined Aquifer: An aquifer that is partly confined by layers of lower permeability material through which recharge and discharge may occur.

Sole Source Aquifer: An aquifer that is needed to supply 50% or more of the domestic water for a given area, and for which there are no reasonably available alternative water sources should the aquifer be impacted upon or depleted.

Specific Yield (Sy): The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.

Storage Coefficient (S): The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Stream Flow Reduction (SFR): The process whereby any land based activity decreases/diminishes the amount of water that would normally be available. These activities include afforestation and alien vegetation.

Sustainable Yield: Is defined as the maximum rate of withdrawal that can be sustained by an aquifer without causing an unacceptable decline in the hydraulic head or deterioration in water quality in the aquifer.

Transmissivity (T): The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.

Unconfined Aquifer: An aquifer where the watertable is the upper boundary and with no confining layer between the watertable and the ground surface. The watertable is free to fluctuate up and down.

Unsaturated Zone: That part of the geological stratum above the watertable where interstices and voids contain a combination of air and water, synonymous with zone of aeration or vadose zone.

Vulnerability: The vulnerability of groundwater to contaminants generated by human activities taking into account the inherent geological, hydrological, hydrogeological characteristics of an aquifer.

Water Management Area (WMA): An area established as a management unit in the National Water Resource Strategy within which a Catchment Management Agency will conduct the protection, use, development, conservation, management and control of water resources in South Africa.

Wellfield: A group or cluster of boreholes in an area used collectively to supply sufficient groundwater to a user or users.

Wetland: Land which is transitionary between terrestrial and aquatic systems, where the watertable is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil.

Yield: The quantity of water removed from a water resource e.g. yield of a borehole

1 Introduction

SRK Consulting was appointed by the Department of Water Affairs (DWA), Chief Directorate Resource Directed Measures on contract WP10260, to determine the groundwater component of the Reserve, otherwise known as Groundwater Resource Directed Measures (GRDM) for the Mvoti to Umzimkhulu Water Management Area (WMA) 11, which is the entire study area.

The DWA has the responsibility of managing water resources (taking into account the interdependency of all the components of the hydrological cycle) on behalf of the people of South Africa. The National Water Act (NWA) (Act 36 of 1998) provides a legal framework for the effective and sustainable management of South Africa’s water resources. The NWA therefore provides decision-making tools to achieve a balance between protecting and using South African water resources. Chapter 3 of the NWA focuses on protecting the health of South Africa’s water resources. The aim of protecting water resources is to ensure that water is available for current and future use. Protection therefore involves the sustaining of a certain quantity and quality of water to maintain the overall ecological functioning of rivers, wetlands, groundwater and estuaries. This Chapter (parts 1, 2 and 3) of the NWA therefore introduces series of measures which together are intended to protect all water resources. These measures are referred to as Resource Directed Measures (RDM), and in the case of where it is related to Groundwater, as GRDM. These measures include Classification, Quantification of the Reserve and Resource Quality Objectives (DWA, 2011). Guidelines to undertake GRDM assessments are prescribed in DWAs GRDM Manuals.

The “Reserve” as defined in the National Water Act (NWA) (Act No. 36 of 1998), constitutes the quantity and quality of groundwater required to:

- Satisfy Basic Human Needs (BHN) by securing a basic water supply for people who are now or who will in the foreseeable future be dependent on groundwater; and
- Protect aquatic ecosystems, to ensure ecologically sustainable development and use of the relevant water resource. This is known as an Ecological Water Requirement (EWR) and is essentially the contribution from groundwater towards maintaining baseflow to rivers.

An important outcome of the GRDM is the determination of the allocable groundwater portion (groundwater available after consideration of the BHN and EWR Reserves and existing use) that will be used to address current as well as future water use license applications.

1.1 Terms of Reference (ToR)

The determination of GRDM for the Mvoti to Umzimkhulu WMA was requested in accordance with the procedure as set out in the ToR supplied by CD: RDM (May 2009), subdividing the study into three phases, namely:

- Phase 1 Inception Phase,
- Phase 2 Study Implementation, and
- Phase 3 Project Termination

The objective of Phase 1 was for the project team to review all relevant available information including reports, datasets, maps, aerial photographs etc. that were available for the study area, develop a project plan, including scheduled tasks and activities to meet the requirements of the terms of reference. These were done and integrated with the Inception Report (SRK Report 411183/1, August 2011).

Phase 2, would comprise:

- Description of study area;
- Delineation of Groundwater Resource Units (GRUs);
- Preliminary groundwater resource classification in the absence of the gazetted National Water Resources Classification System (NWRCS);
- Quantification of the Reserve;
- Setting of Resource Quality Objectives (RQO's); and
- Recommending a groundwater monitoring program.

Phase 3 would commence once the objectives of the study had been achieved.

1.2 Scope of work

The Scope of Work (SoW) also emanates from the TOR document issued by CD: RDM (May 2009) and is as follows:

1.2.1 Level of confidence required

- An intermediate to comprehensive level GRDM (medium to high confidence level), maximum of 18 month duration, is proposed for the Mvoti to Umzimkhulu GRDM determination. Where available, detailed site specific information must be included in the assessment;
- Field verification of existing groundwater information is required. If groundwater resource units are under-represented in terms of groundwater quality aspects, then groundwater samples must be collected during the fieldwork phase and analysed for major cation and trace elements. The design and planning for the fieldwork phase is one of the outcomes of the Inception phase;
- A comprehensive literature review and desktop GRDM determination are required during the Inception phase to identify those areas where a higher level of detail GRDM is required;
- Specific areas requiring comprehensive GRDM determinations must be identified and prioritised. During project termination a detailed, subsequent site specific studies may include groundwater dependent ecosystems severely impacted or under threat;
- The delineation of groundwater resource units, and associated hydrogeological aspects, should be given preference where major aquifer systems extend across more than one water management area;
- The appointed PSP must take into account the recommendations of GRDM determinations completed in neighbouring water management areas; and
- The appointed PSP must also interact with the surface water Reserve determination team (s).

1.2.2 Groundwater quality

- Groundwater quality issues are not addressed under the Reserve. As a result, no method is provided to address the groundwater quality component of the Reserve; and
- However, groundwater quality aspects are generally addressed as part of the Description of the Study Area, Water Resource Classification and Resource Quality Objective (RQO's).

1.2.3 Groundwater information

The following suggested literature sources and databases may be accessed for groundwater information: Manual-Groundwater Resource Directed Measures; National Water Resource Strategy (NWRS); WARMS Database; Groundwater Resource Assessment Phase I and II; Internal Strategic Perspective (ISP's) – Groundwater Reports; Catchment Management Studies/Reports; GH Reports, WRC Reports and Post-graduate research thesis; EIA's and EMPR's; and Consultants Reports.

Data (i.e. available data) integrity, reliability and representivity are key requirements to set the confidence levels and implement the GRDM methodology. The latter aspects must be considered when evaluating available groundwater data and designing a hydrocensus phase to gather groundwater abstraction and groundwater quality data for different aquifers

1.3 Revised GRDM Approach

Following a Project Steering Committee (PSC) Workshop held on 2 September 2011, DWA requested that SRK attempt to align the project approach with the new gazetted GRDM methodology which is consistent with the prescribed Water Resource Classification System (WRCS) promulgated in September 2010. A summary of the new methodology is presented below:

"*The Water Resource Classification System and other measures laid down by the Act are together intended to ensure the ecological sustainability of all the significant water resources by taking into consideration the social and economic needs of competing interests by all who rely on the water resources.*

1.3.1 Procedure for determining different classes of water resources

The class of a water resource must describe:

- *the extent of use of the water resource;*
- *the Reserve;*
- *the resource quality objectives; and*
- *the determination of the allocable portion of a water resource for use.*

Water resources must be classified into one of the following classes –

a) ***Class I water resource**: This is one:*

   (i) which is minimally used; and

   (ii) in which the configuration of the ecological categories of the water resources within a catchment results in an overall condition of that water resource that is minimally altered from its pre-development condition.

b) ***Class II water resource**: This is one:*

   (i) which is moderately used; and

   (ii) in which the configuration of ecological categories of the water resources within a catchment results in an overall condition of that water resource that is moderately altered from its pre-development condition.

c) ***Class III water resource**: This is one:*

   (i) which is heavily used; and

   (ii) in which the configuration of ecological categories of the water resources within a catchment results in an overall condition of that water resource that is significantly altered from its pre-development condition.

The procedure to determine the different classes of water resources must comprise of the following seven steps:

a) ***Step 1**: Delineate the units of analysis and describe the status quo of the water resource or water resources.*

*b) **Step 2**: Link the socio-economic and ecological value and condition of the water resource or water resources.*

*c) **Step 3**: Quantify the ecological water requirements and changes in non-water quality ecosystem goods, services and attributes.*

*d) **Step 4**: Determine an ecologically sustainable base configuration scenario.*

*e) **Step 5**: Evaluate scenarios within the integrated water resource management process.*

*f) **Step 6**: Evaluate the scenarios with stakeholders.*

*g) **Step 7**: Gazette and implement the class configuration.*

1.3.2 Procedure for determining the Reserve

For each water resource class, the procedure for the determination of the Reserve must comprise of the following eight steps:

*a) **Step 1**: Initiate the basic human needs and ecological water requirements assessment.*

*b) **Step 2**: Determine eco-regions, delineate resource units, select study sites and, where appropriate, align with Step 1 of the water resource classification procedure set out in Regulation 2(4).*

*c) **Step 3**: Determine the reference conditions, present ecological status and the ecological importance and sensitivity of each of the selected study sites.*

*d) **Step 4**: Determine the basic human needs and ecological water requirements for each of the selected study sites and, where appropriate, align with Step 3 of the water resource classification procedure set out in Regulation 2(4).*

*e) **Step 5**: Determine operational scenarios and its socio-economic and ecological consequences.*

*f) **Step 6**: Evaluate the scenarios with stakeholders and align with Step 6 of the water resource classification procedure set out in Regulation 2(4).*

*g) **Step 7**: Design an appropriate monitoring programme.*

*h) **Step 8**: Gazette and implement the Reserve.*

1.3.3 Procedure for determining Resource Quality Objectives

For each water resource class, the procedure for establishing resource quality objectives must comprise of the following six steps:

*a) **Step 1**: Identify water users within each water resource management unit, and where appropriate, align with Step 1 of the water resource classification procedure set out in Regulation 2(4).*

*b) **Step 2**: Determine the present state per water user and, where appropriate, align with Step 5 of the water resource classification procedure set out in Regulation 2(4).*

*c) **Step 3**: Determine the desired water quality per user and, where appropriate, align with Step 6 of the water resource classification procedure set out in Regulation 2(4).*

*d) **Step 4**: Determine water user specifications and, where appropriate, align with Step 6 of the water resource classification procedure set out in Regulation 2(4).*

e) ***Step 5****: Determine water quality requirements of water uses and, where appropriate, align with Step 6 of the water resource classification procedure set out in Regulation 2(4).*

f) ***Step 6****: Gazette and implement the resource quality objectives.*

These regulations shall be called the Regulations for the Establishment of the Classification System, 2010" (DWA, 2011).

It must be noted that although SRK has attempted to align the project outcomes to a level that can be used within the framework of the WRCS, this does not include any involvement beyond:

- Step 5 of Water Resource Classification;
- Step 5 of Determining the Reserve;
- Step 2 of Resource Quality Objectives; and
- Any public participation beyond the Final GRDM Workshop.

1.4 Background to Study Area (From Inception Phase)

The Mvoti to Umzimkhulu WMA 11 extends from the town of Zinkwazi in the north to Port Edward on the south along the KwaZulu-Natal coastline and envelopes the inland towns of Underberg and Greytown up until the Drakensberg escarpment. The water management area spans across the primary catchment "U" and incorporates the secondary drainage areas of T40 (Mtamvuna River in Port Shepstone) and T52 (Umzimkhulu River). Ninety quaternary catchments constitute the water management area (Midgeley, et.al, 1994) and the major rivers draining this area include the Mvoti, Mgeni, Mkomazi, Umzimkhulu and Mtamvuna.

According to DWAF, (2004), 5.1 Million people inhabit the WMA. Nearly 70% of the population is concentrated within the Mgeni River catchment of which ~ 85% of the population is situated in the Ethekweni and Pietermaritzburg metropolitan area.

The main land use activities include manufacturing, agriculture (predominantly sugarcane), forestry and mining to a lesser degree (DWAF, 2008). Activities contributing to the Gross Domestic Product include manufacturing (highest contributor largely centred in Durban and surrounding industrial areas), trade, government and finance. Additional scope for timber farming has been reported. The urban population represents 68% and the rural, 32 % of the total population for the Water Management Area (DWAF2, 2003).

The degree to which water resources are developed in the WMA vary. The Mngeni River, which is the main source of water for the Durban/Pietermaritzburg area, is fully regulated by several large dams in the catchment and is augmented with transfers from the Thukela WMA. A substantial volume of water is transferred through the Thukela WMA through the Mooi-Mgeni transfer scheme (~50 million m^3/a).

The requirements for water in this area already exceed its availability and further growth is anticipated.

There are a number of game reserves and nature parks. The largest of these is the Drakensberg Reserve area and others are Umgeni Valley, Karkloof, Krantzkloof, Vernon Crookes, Oribi Gorge, Mtamvuna and Coleford.

The geology consists of a diverse assemblage of rock types ranging from highly metamorphosed Proterozoic rocks to the sedimentary deposits of the Natal Group, glacial deposits of the Karoo Supergroup, dolerite intrusions and alluvium deposits of Quaternary Age. The tectonic history of these geological formations has influenced the present hydrological systems observed in the catchment.

Three principal aquifer types occur in this water management area, namely integranular, integranular and fractured; and fractured (structural). A single occurrence of a karst aquifer (carbonate rock) is recorded near the town of Port Shepstone where marble is being mined.

Groundwater abstraction is fairly low and there is high potential for a significant surface water/ groundwater interaction component. According to DWAF (2004) groundwater usage is estimated at ~6 Mm^3/a (GRAII estimate). Groundwater utilisation in the catchment is fairly poor with an additional 380 Mm^3/a available for abstraction however groundwater quality (total dissolved solids, nitrates and fluoride) is one of the major factors hindering the utilisation of this resource. The ecological requirement for the WMA is very high at 1,152.6 Mm^3/a which equates to 18% of the total water requirement. Of this the Umzimkhulu catchment represents 47-62 % (DWAF1, 2003).

For desktop GRDM assessment figures, the GRA II database provided for the WMA a total recharge estimate at 2006 Mm^3/a, baseflow at 405 Mm^3/a and current use (groundwater abstraction) at 5.92 Mm^3/a. These values appeared to be more conservative estimates when compared to GRDM data. The groundwater abstraction data compared well with available literature.

On termination of the Inception phase of the study and to improve the data confidence levels for the BHN Reserve and groundwater use components, the WARMS, GRIP and NGA databases were refined and used in a revised GRDM Assessment. In addition annual population growth figures obtained through Stats SA were used to project 2001 population census data to 2010 to determine the BHN Reserve. For the entire WMA, BHN Reserve is estimated at 43.96 Mm^3/a, and groundwater use was calculated at 48 Mm^3/a.

2 Catchment Description

The Mvoti to Umzimkhulu Water Management Area (WMA 11) extends from the town of Zinkwazi to Port Edward along the KwaZulu-Natal (KZN) coastline and envelopes the inland towns of Underberg and Greytown up until Drakensberg escarpment. A small portion of the WMA straddles across the provincial KZN boundary with the Eastern Cape. The WMA spans across the primary catchment “U” and incorporates the secondary drainage areas of T40 (Mtamvuna River in Port Shepstone) and T52 (Umzimkhulu River). Ninety quaternary catchments form this WMA (Midgeley, et.al, 1994). The location of the WMA is displayed in Figure 2-1. All GIS data and additional sources of data are tabled in Appendix A.

2.1 Physiography

The Drakensberg Mountain range in the western portion of the WMA is at an altitude of 3000 metres above mean sea level (mamsl) (Figure 2-2). The gradient sharply decreases and is at around 150 mamsl along the coast (DWAF, 2004) thereby giving rise to deeply incised ravines and major fluvial systems such as the Mkomazi and Umzimkhulu Rivers which are in close proximity of the mountainous region. The landscape across the interior of KZN allows for the development of medium size river systems (Mgeni and Mvoti Rivers) however smaller and shorter rivers characterise the coastal areas due to the pervasive gentle topography.

2.2 Surface water and drainage

The Mvoti to Umzimkhulu WMA encompasses a total catchment area of ~27,000 km^2 and occurs largely within KZN however a small portion of the Mtamvuna River and the upper and lower segments of the Umzimkhulu River straddles the Eastern Cape, close to the Mzimvubu and Keiskama WMAs in the south. Across border rivers are absent from the WMA ([1]DWAF, 2003).

The hydrological characteristics of WMA 11 are observed in Figure 2-3. The WMA is characterised by several parallel rivers which arises in the escarpment and discharges into the Indian Ocean. The water courses in the study area display a prominent southeasterly flow direction.

The major rivers within the catchment are discussed below:

- Umzimkhulu River which arises in the Drakensberg escarpment is observed in the southern portion of the WMA and discharges at the town of Port Shepstone. The Umzimkhulu River incorporates the tertiary catchments T51 and T52 ([2]DWAF, 2003);
- Mkomazi River which arises close to the Lesotho Border, drains in a southeasterly direction and discharges into the Indian Ocean at the coastal town of Umkomaas. The Mkomazi River forms the U10 catchment;
- Mgeni River which evolves in the interior of KZN (above the metropolis of Pietermaritzburg) forms the U20 catchment;
- Mdloti River found in the northern region of the WMA is located within the secondary catchment U30;
- Mvoti River also located in the northern parts of the KZN stems from Greytown and flows through the U40 and U50 secondary catchments; and
- Several smaller rivers occur within the coastal region of WMA e.g. Mlazi, Lovu and Mtamvuna Rivers.

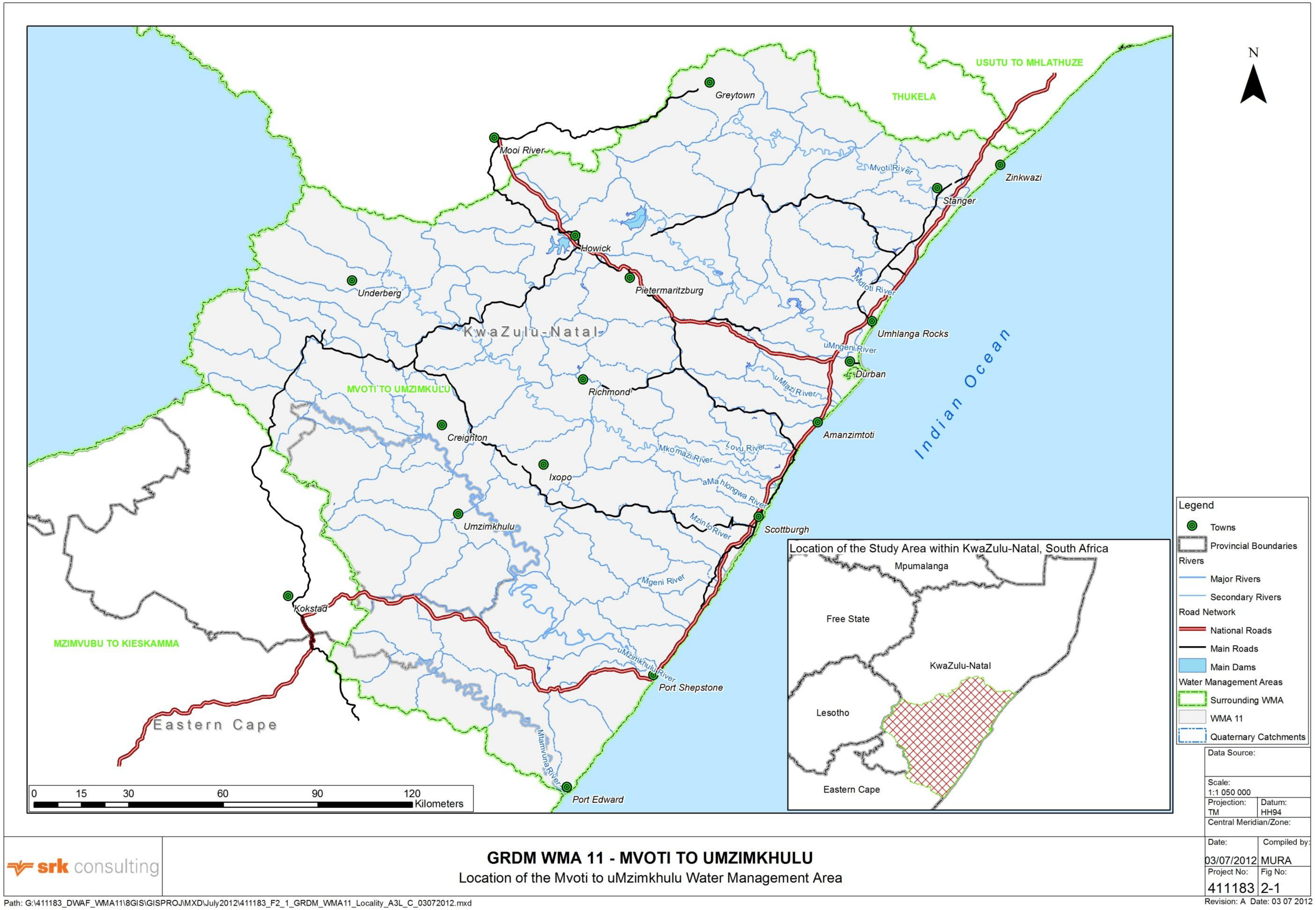


Figure 2-1: Location of the Mvoti to Umzimkhulu Water Management Area.

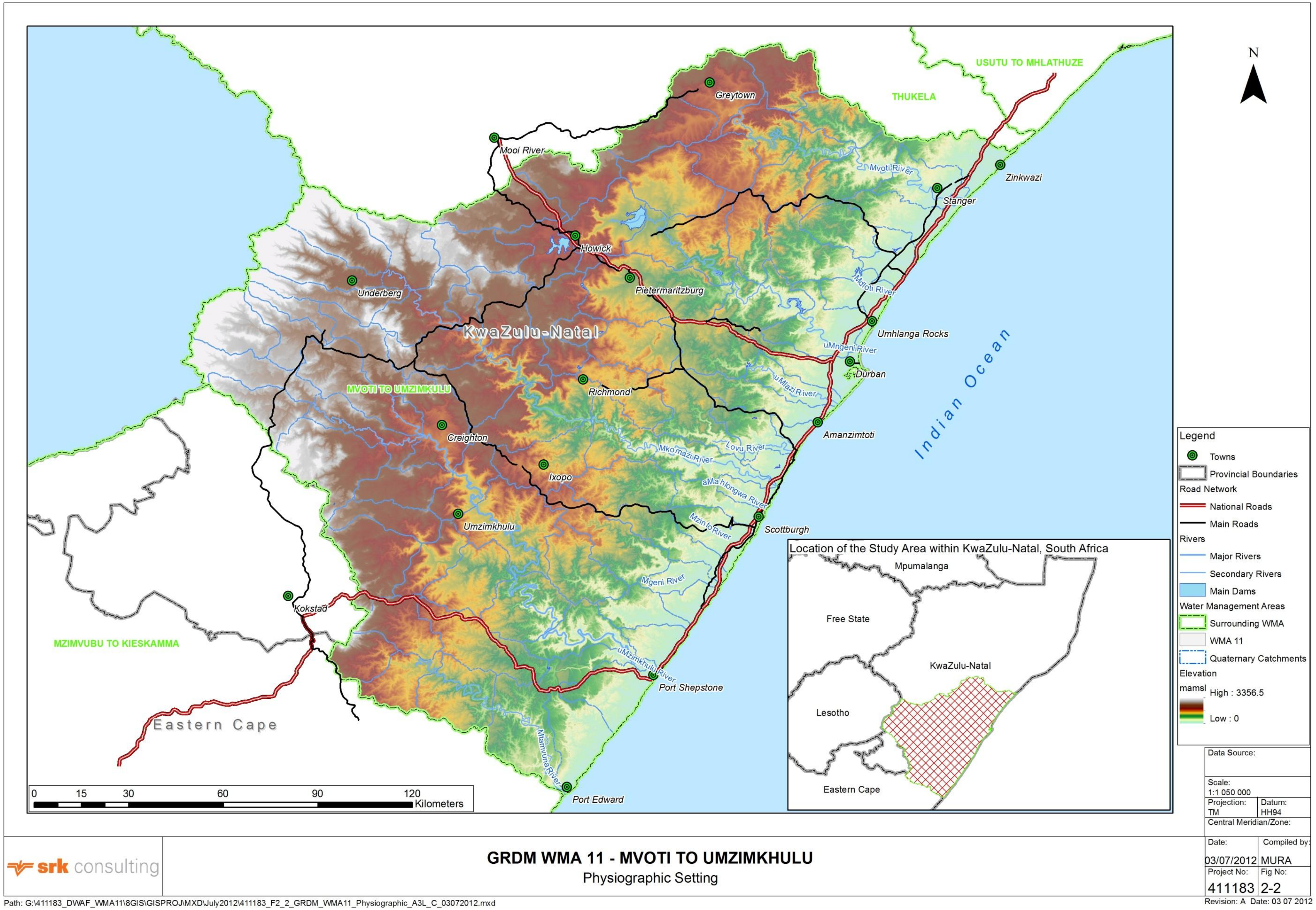


Figure 2-2: Physiographic Setting of the Study Area

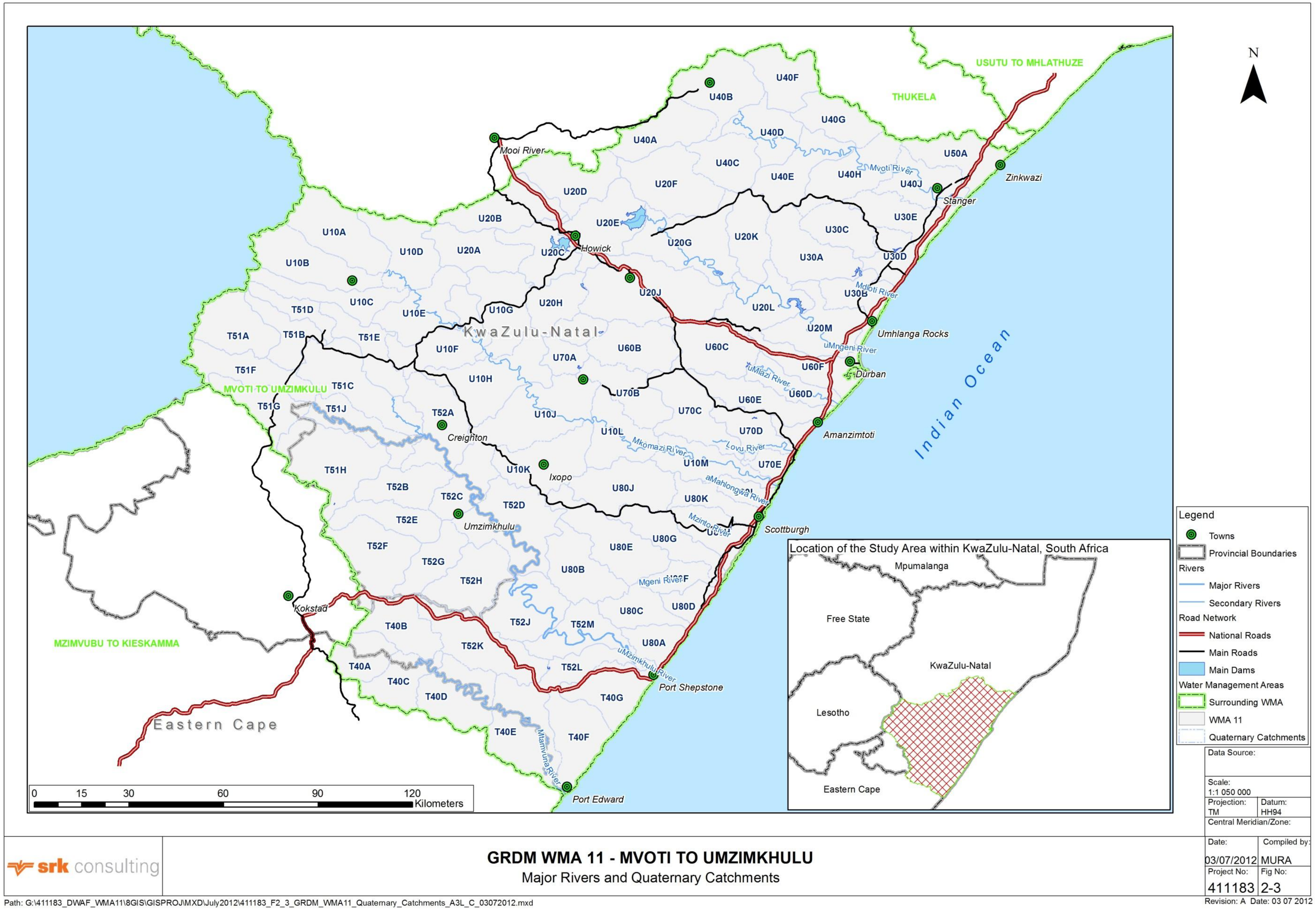


Figure 2-3: Major Rivers and Quaternary Catchments of the WMA 11

2.3 Climate

The climate across the WMA ranges from sub-tropical climatic conditions along the coastal areas to a temperate climate closer to the mountainous terrane. Temperatures vary between 16°C to 25°C in winter while warm to hot conditions (23°C to 33°C) are prevalent in the summer months. The average temperature for the WMA is reported as 21°C. Snow occurs frequently on the Drakensburg mountain peaks during winter; however heavy snowfall, which is a rare phenomenon, is experienced in these parts due to the combination of low winter temperatures and the expansion of a strong cold front arising from the Western Cape.

The Mozambique Ocean Current which flows along the southeast coast of South Africa and Mozambique is a warm surface current with high moisture content. The vapour content of the Mozambique Current plays a pivotal role in influencing the climate in that the humidity increases the temperature hence sub-tropical weather conditions are experienced in areas closer to the coast (Jury, 1998).

In addition, the sea breeze laden with moisture generates conditions that advocate high precipitation (convective rainfall) hence the high volumes of precipitation (Mean Annual Precipitation (MAP)) is recorded along the coastline (1000 to 1200 mm/a). Precipitation gradually decreases from the coast to the interior with the exception of Drakensberg Mountain which acts as a significant topographic barrier thus giving rise to orographic rainfall normally in excess of 1000 mm, increasing >1200 mm in parts. Precipitation recorded across the WMA generally varies between 800-100 mm/a with sporadic areas (interior river basins) receiving between 600-800 mm/a of rainfall. The highest volume of rainfall is recorded in the summer months whilst winter tends to be dry. The MAP) for the study area is presented in Figure 2-4.

The highest MAE is observed in the vicinity of the Drakenberg Escarpment (1300-1400 mm/yr) whilst areas between the escarpment and Creighton, Howick, Greytown and from the coastal town of Tongaat to Zinkwazi indicate a MAE between 1200-1300 mm/yr whilst the rest of the WMA records MAE at a rate of <1200 mm/yr (Figure 2-5).

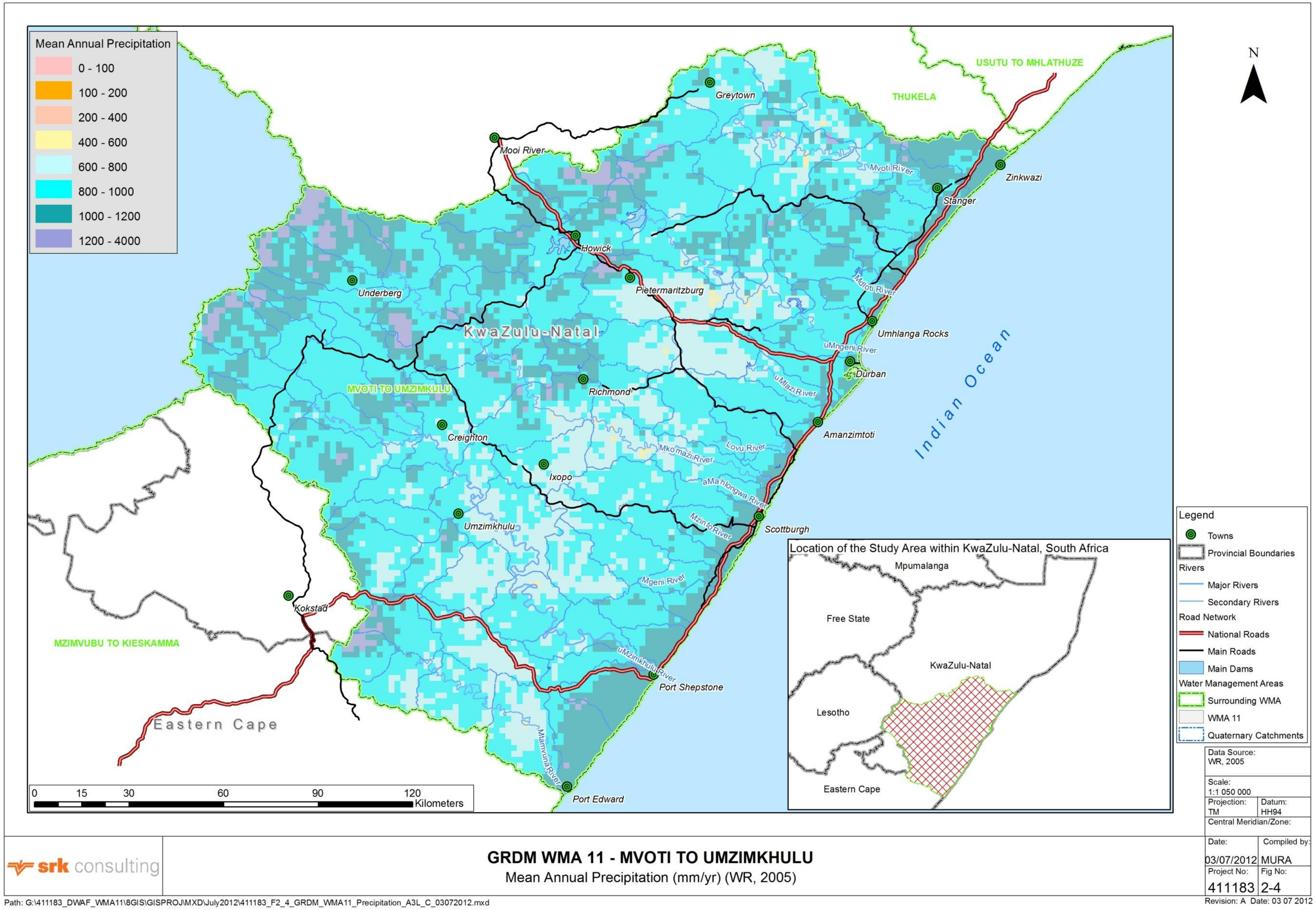


Figure 2-4: Mean Annual Precipitation (mm/a) of the Study Area

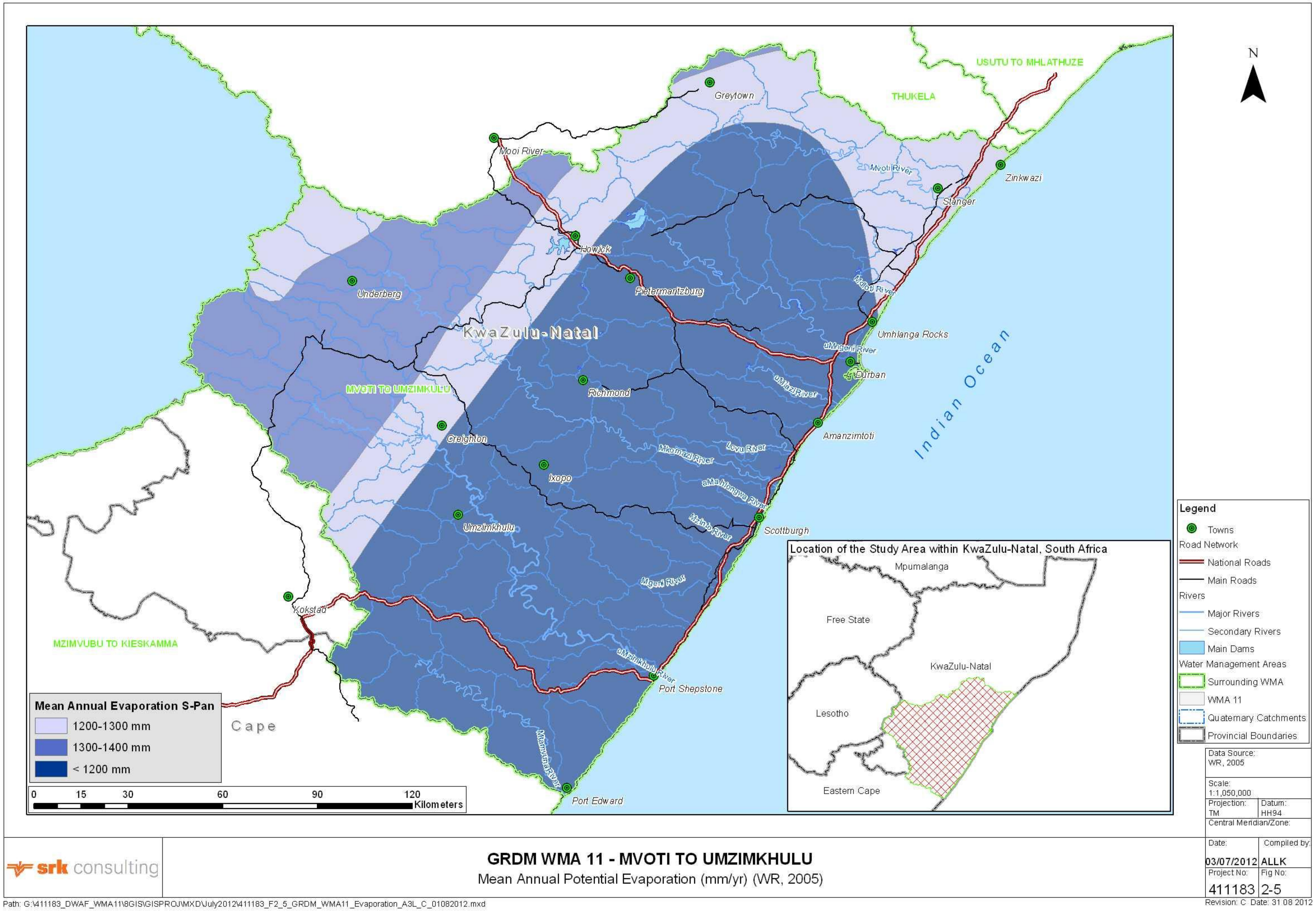


Figure 2-5: Mean Annual Potential Evaporation (mm/yr) of the Study Area.

2.4 Vegetation

The Mvoti to Umzimkhulu WMA is characterised by various veld types and is depicted in Figure 2-6. The vegetation types found in the WMA are discussed below:

- ***Coastal forest and thornveld*** extends as a ~15 km to 65 km belt along the coastal areas and from sea level to 450 mamsl. Mangroves and beach forests occur along the sheltered coastlines below the high water level of spring tides whilst the growth of *thornveld* vegetation occurs at an elevation of ~450 mamsl. This vegetation type occurs in areas with an annual rainfall that ranges from 800 mm to >1000 mm (Acocks, 1998);
- ***Ngongoni Veld*** comprises grass covered hills intermingled with patches of forest and bush and predominantly occurs inland of the coast at elevations of 450 mamsl to 900 mamsl. The annual rainfall ranges from 850 mm to 1300 mm;
- ***Ngongoni Veld of Natal Mist Belt*** spans as an uninterrupted belt extending from Hilton to Eshowe and occurs at altitudes of 900 mamsl to 1400 mamsl. Due to the high moisture content in the atmosphere (precipitation recorded at 800 mm to 1600 mm per annum), this area supports the growth of fairly large forests;
- ***Southern Tall Grassveld*** occurs sporadically in the interior of KZN and consists of grass in excess of 1 m and acacia thorn trees. Growth of this vegetation types occurs at elevations of 900 mamsl and 1400 mamsl with the annual rainfall in the range of 800 mm to 1000 mm;
- ***Highland Sourveld*** occupies the high-lying western section of the WMA at elevations of 1400 mamsl and 2000 mamsl and is characterised by short grass (<0.5 m). Annual rainfall in this region ranges from 800 mm to 1500 mm; and
- ***Valley Bushveld*** is a common vegetation type found in the valleys of major rivers of the WMA. The topography is steep and rugged with the altitude ranging from 300 mamsl to 900 mamsl. The annual rainfall ranges from 600 mm to 700 mm per annum (Philips, 1973).

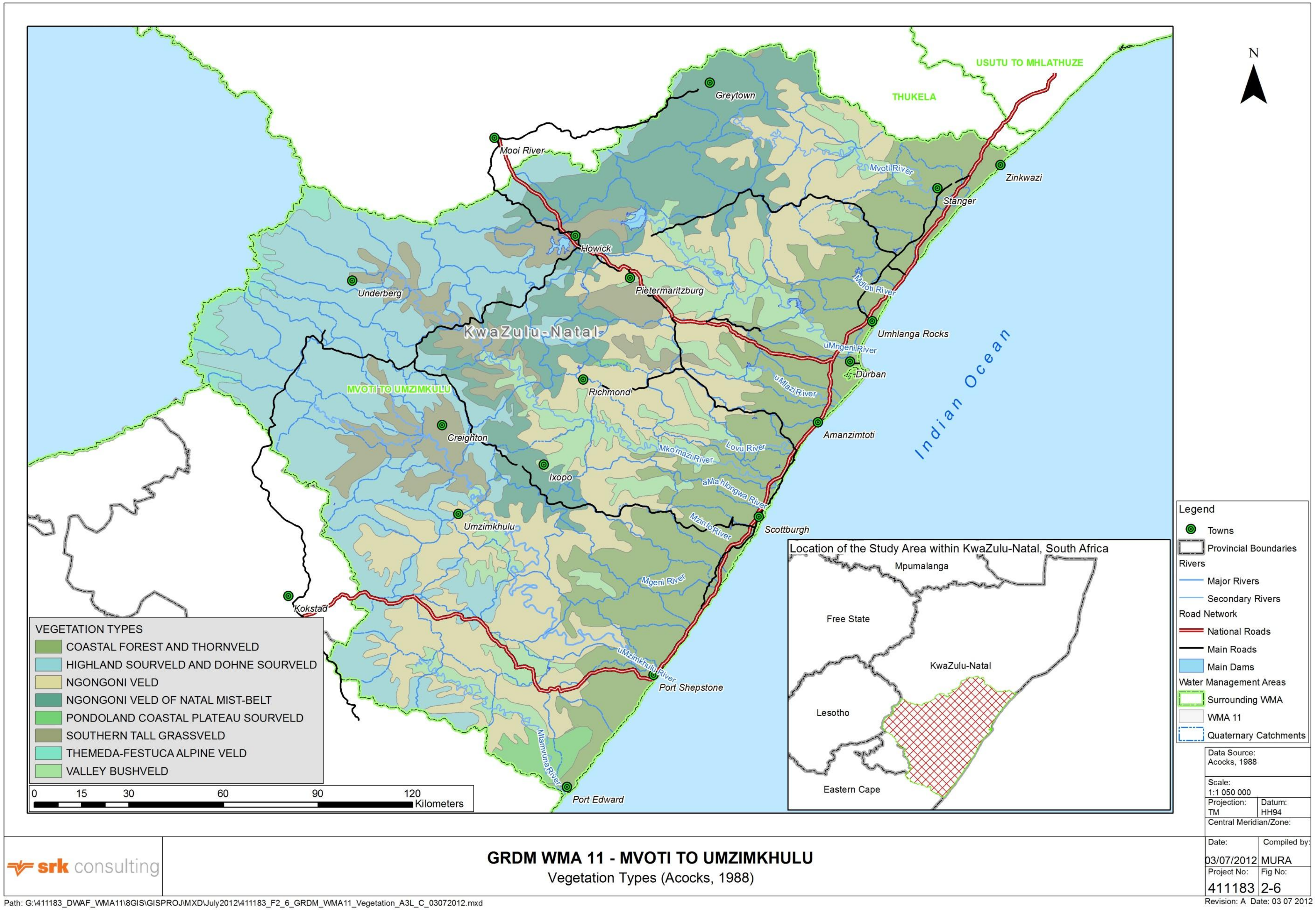


Figure 2-6: Vegetation Types (Acocks, 1998)

2.5 Soils

Soil cover is an important consideration in groundwater recharge estimation. There are currently two soil classification systems that have surfaced during this study. That proposed by the Soil Classification Working Group (1991) (the distribution area is shown in Figure 2-7) which is normally referred to in agriculture and by MacVicars et al (1977) (the distribution area is shown in Figure 2-8) which is normally used by soil scientists and engineers. These have effectively the same distribution area and have been conjunctively used to describe the soils in the WMA.

MacVicar (1977) compiled a binomial soil classification system for South Africa and classifies soil types according to the percentage Sand (Sa), Loam (Lm) and Clay (Cl) compositions. Hence soils comprising essentially Sand and Clay with a dominant Clay component is referred to as a Sandy Clay and take on the nomenclature SaCl. A Sandy Loam would according be represented as SaLm. In order to compensate for variation in relative percentage compositions, soil types are described within a certain range, for example, SaLm to SaCl.

The coastal belt of the WMA is dominated by the Glenrosa Soil Type (SaClLm/SaLm-SaCl/SaLm-SaClLm) which consists of an Orthic A-horizon[1] and an overlying lithocutanic B-Horizon which displays distinct features which are listed below:

- It merges into the underlying weathered strata;
- Has a general organisation with regards to colour, structure or consistency that has apparent affinities with the underlying parent rock;
- Has cutanic character expressed generally as either tongues or prominent colour variations caused by residual soil formation and illuviation resulting in the mobilisation of one or more of the clay, iron and manganese oxides;
- Is laterally discontinuous; and
- If the horizon displays >25% moisture, then is displays a saprolite character.

The interior of the WMA is underlain by the Hutton Soil Type (SaClLm-SaCl) which is categorised as agricultural soil. This formation is massive and appears as a “red” B horizon that is vertically pervasive. The Hutton soil type has a penetrative drainage configuration thus making it favourable for cultivation.

The Kroonstad and Plinthic Soil Type (SaClLm-SaCl) are prominent in the semi-arid areas of the WMA and are observed in areas preceding the pedimont of the Drakensberg Mountain. Plinthic soils are associated with fluctuating water tables. The Kroonstad Soil Type comprises an Orthic A-horizon overlying a diagnostic E-horizon and a basal G-horizon. The basal G-horizon has prominent features which are discussed below:

- It is saturated with water for long periods unless drained;
- Is dominated by grey, low chroma matrix colours, with or without mottling;
- Accumulation of colloid material occurs in this horizon;
- Has consistency of one grade firmer than the overlying horizon; and
- Lacks saprolitic and plinthic character.

Mispah Soils (SaCl) occur exclusively in a small segment along the northwestern boundary of the WMA. This formation is characterised by Orthic A-horizon overlying hard bedrock.

[1] Orthic A Horizon: Is a surface horizon lacking fine stratification and contains free iron oxide which imparts a bleached colouration to the formation. This horizon has a crusty appearance and remains relatively dry after precipitation and is very unstable.

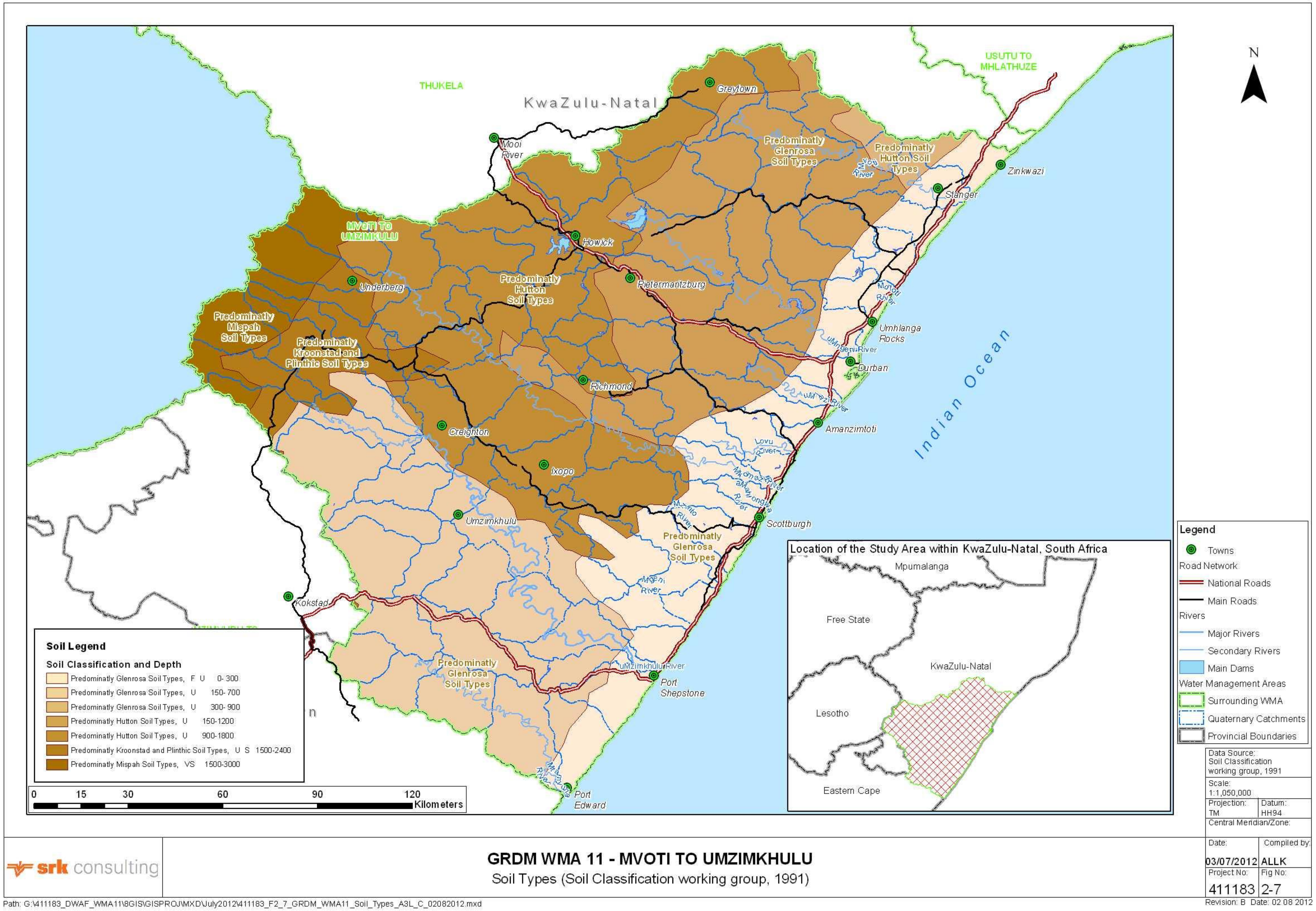


Figure 2-7: Soil Types (Soil Classification, Working Group, 1991)

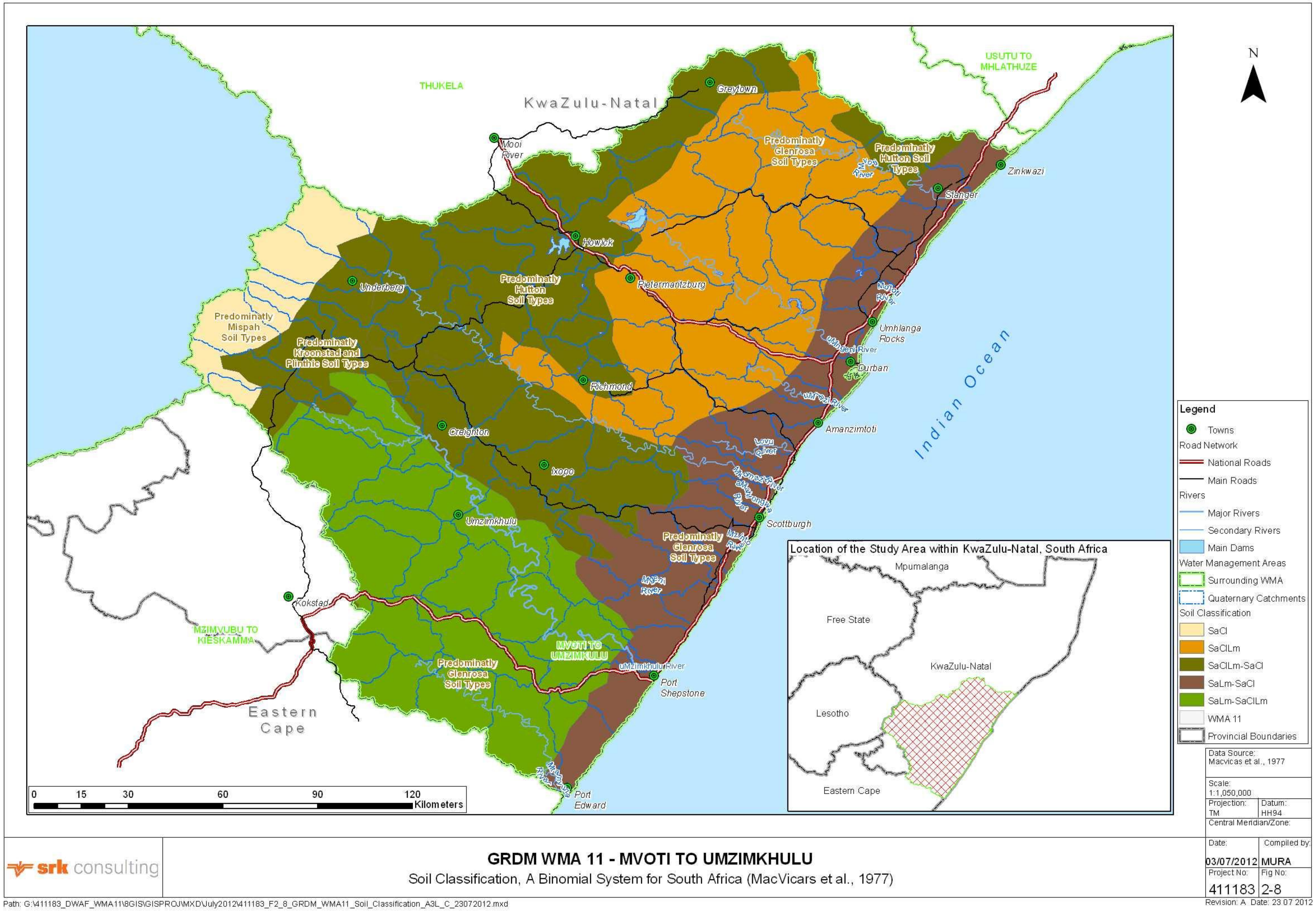


Figure 2-8: Soil Types (MacVicar, 1977)

2.6 Geology

The geology of the WMA consists of a diverse assemblage of rock types ranging from highly metamorphosed Proterozoic rocks to the sedimentary deposits of the Natal Group, glacial deposits of the Karoo Supergroup, dolerite intrusions and alluvium deposits of Quaternary age. The tectonic history of these geological formations has influenced the present hydrological systems observed in the catchment. The stratigraphy of the catchment is tabulated in Table 2-1 and a regional geological map for the WMA is presented in Figure 2.8. The stratigraphic units discussed below are in chronological order (oldest to youngest).

The Proterozoic age Namaqua-Natal Province is a structurally deformed and highly metamorphosed suite of rocks which formed between ~1000 Ma to 1200 Ma and forms the basement rocks of the WMA. The rocks outcrop extensively in the Northern Cape and KwaZulu-Natal therefore they are referred to as the Namaqua and Natal Sector of the Namaqua-Natal Province respectively. The Natal Sector of the Namaqua-Natal Province in KZN spans across 20 000 km^2 and is subdivided into three discontinuity-bound tectonostratigraphic terranes (Tugela Terrane which falls beyond the WMA, Mzumbe Terrane and Margate Terrane) with distinct formations and varying degrees of metamorphism. The WMA encompasses the Mzumbe and Margate Terranes and these tectonostratigraphic packages are discussed below.

- Mzumbe Terrane extends from the Mkomazi River at the coast to the town of Port Shepstone and comprises upper amphibolites facies rocks (medium to coarse grain tonalities, trondhjemites and granodiorites) which have undergone polyphase metamorphism and migmitisation hence they form severely deformed, multiple sheet-like bodies which outcrop along the Mkomazi, Mpambanyoni, Fafa, Mtwalume, Mgeni, Mzimayi and Mzumbe River’s; and
- Margate Terrane which spans across Port Shepstone and Port Edward and transects the Umzimkhulu River comprises granulite facies rocks (which include the economically important Marble Delta Formation near Port Shepstone) which also display a high degree of structural deformation.

The early Palaezoic Natal Group comprises sedimentary formations overlying the Proterozoic basement rocks and extends from Hlabisa (outside WMA) in the north to Hibberdene in the south. The attitude of the basin indicates that the western margin is roughly parallel to and ~60-70 km inland of the KZN coastline. The geology of the Natal Group consists of reddish-brown arenaceous rocks interbedded with mudstone and conglomerate units and is fractured in certain regions which can be related to the fragmentation of Gondwanaland (the super-continent).

The Late Carboniferous to Middle Jurassic Karoo Supergroup consists of an assemblage of glacial deposits, sedimentary units and dolerite intrusions. The Karoo Supergroup is divided into the following stratigraphic units:

- Dwyka Group unconformably overlies the Natal Group sediments in KZN and predominantly consists of glacial deposits (diamictite), conglomerate (boulder beds and poorly sorted pebbles) and mudstone (silty rhythmite);
- Ecca Group in the WMA encompasses the Pietermaritzburg, Vryheid and Volkrust Formations. Mudstone, siltstone, coal and shale are the dominant lithologies and aquatic reptile fossils were common in this Group;
- Beaufort Group comprises interbedded sandstone and mudstone; and
- Drakensberg Group is subdivided into the Molteno, Elliot and Clarens Formations which are dominated by medium to coarse grain sandstone, grey and red mudstone and are capped by aeolian deposits.

The Mesozoic Karoo Igneous Province encompasses both intrusive and extrusive igneous rocks, dolerite and basalt respectively. Sedimentation in the Karoo basin ceased due to the extrusion of flood basalt which conformably overlies the Clarens Formation and caps the Drakensberg Mountain.

Dolerite dyke and sill intrusions into the sedimentary formations of the Karoo Supergroup are a common feature of the Karoo magmatism.

Cenozoic deposits of marine, fluvial and aeolian derivation overlie a broad coastal plain (some 60 km in places) in southern Mozambique and northern KwaZulu-Natal (outside WMA), which progressively constricts southwards towards Mtunzini. From this locality southwards to Port Edward, Cenozoic deposits are compressed into a narrow belt. This is referred to as the Maputaland Group. The Isipingo Formation of the Maputaland Group (which is a shallow marine deposit consisting of unconsolidated sand, silt and clayey material) in the WMA extends along the shoreline from Umdloti Beach (north of Durban) to south of the Umlaas Canal). The Berea-type red sand is considered an informal unit as it is derived from an older aeolian deposit also occurs along coastal areas from Mnini (40 km south of Durban) and follows the distribution areas of the Maputaland Group to the north (Johnson & Thomas, 2006).

Table 2-1: Stratigraphy of the Mvoti to Umzimkhulu Catchment.

Lithostratigraphic unit		Era	Characteristics	Hydrogeological Significance
Dolerite and Basalt		Jurassic	Intrusions and extrusions	Structural features are important for siting of boreholes
Quaternary Deposits Maputaland Group		Cenozoic	Unconsolidated sands, silt and clayey material.	High yielding primary (integranular) aquifers. Alluvial aquifers likely recharge from streams.
Karoo Supergroup	Drakensberg Group	Late Triassic	Sandstone and grey-red mudstone.	Moderate yielding aquifer, structural feature usually higher yielding.
	Beaufort Group	Late Permian	Inter-bedded sandstone and mudstone.	
	Ecca Group	Permian	Mudstone, sandstone, coal and shale.	Deep weathering which stores water and recharges underlying aquifer.
	Dwyka Group	Late Carboniferous	Diamictite, conglomerate and mudstone.	Groundwater is associated with the fractures in the diamictite. The aquifer has very low storativity.
Natal Group		Palaeozoic	Arenaceous rocks inter-bedded with mudstone and conglomerate units.	Groundwater is associated with fractures, joints and fissures in the sandstone.
Namaqua-Natal Province	Margate Terrane	Proterozoic	Plutonic gneisses, granodiorites, tonalities, limestone and granitoid plutons.	Structural features are important for siting of boreholes. Karstic aquifers are likely to develop in the limestone.
	Mzumbe Terrane			
	Tugela Terrane			

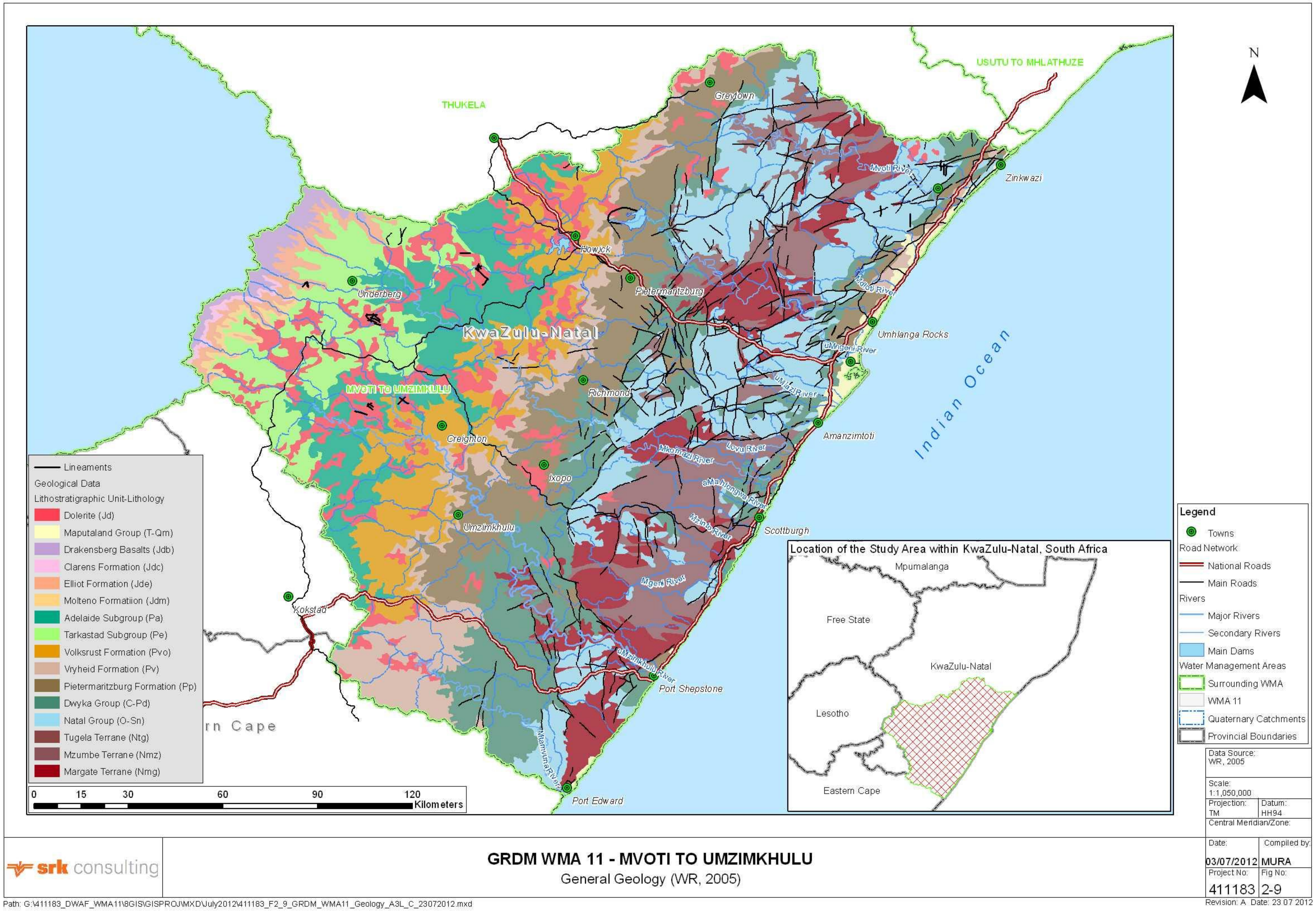


Figure 2-9: General geology of the study area (WR2005)

2.7 Hydrogeology

2.7.1 Background to aquifer types and locality

Three principal aquifer types are found in WMA 11, namely; Integranular, Integranular and Fractured and Fractured (Structural). These are individually discussed below.

Integranular Aquifers

Integranular aquifers principally occur along the coastline and major rivers and are associated with unconsolidated deposits of sand, silt, clayey material and coarse gravel to boulders which has a high degree of permeability and is typically recharged by streams. According to King (2002), the only integranular aquifer depicted on the 1:500 000 hydrogeological mapsheet for Durban 2928, occurs south of Durban Harbour comprising of sands, estuarine clay and silts. Groundwater levels are shallow ranging from 2 to 7m and yields as high as 50 L/s have been documented in these formations. Groundwater quality is influenced by the depositional environment, proximity to the coast and industrial activities and is on average, 100 mS/m. The Berea type red sands are common around the Durban Area and not considered a true aquifer as groundwater is only intercepted at the base of the red sands on the contact with the underlying bedrock.

Alluvial aquifers are not represented on the 1:500 000 hydrogeological mapsheet due to their limited extent. Alluvials along the Mvoti and Fafa Rivers are examples of such aquifers. The yield ranges are similar to that of the Maputaland Group aquifers, however yields are in the majority <2 L/s. Groundwater derived from alluvial aquifers usually take on the chemical signature of the associated surface water body (King, 2002).

Integranular and Fractured Aquifers

The sedimentary deposits of the Karoo Supergroup including the metamorphic rocks of the Namaqua-Natal Province give rise to integranular and fractured aquifers which characterise most of the WMA. The weathering of the sedimentary formations and crystalline rocks gives rise to weathered aquifers where groundwater is stored in the interstices in the weathered saturated zone and in joints and fractures of competent rocks. Borehole yields range from 0.5-2.0 L/s.

Fractured Aquifers

Fractured aquifers in the WMA are common in the sandstone and diamictite of the Natal Group (Msikaba Formation) and Dwyka Group respectively. Fractured rock aquifers are structurally controlled as they are a function of post-depositional events and are associated with faults, fractures, dykes and lithological contacts. Shallow weathering occurs at the surface and the fractures are saturated with groundwater. The dimension of the fractures/faults is highly variable and therefore influences the borehole yield which ranges from 0.5-2.0 L/s. Dolerite dykes often represent barriers to the flow of groundwater and serve as important targets when siting boreholes.

Karstic Aquifers

A single occurrence of a karstic aquifer has been documented near the town of Port Shepstone which is underlain by carbonate rocks (Marble Delta Formation) of the Margate Terrane (Namaqua-Natal Province). Karstic aquifers develop in chemically soluble rocks such as limestone and and is characterised by a network of conduits which allow for turbulent flow of groundwater. Borehole yields at the site locality according to the hydrogeological; mapsheet vary between 0.5 L/s to 2.0 L/s although yields intercepted in karstic aquifer can easily exceed100 L/s.

Figure 2-10 shows the aquifers present in the WMA.

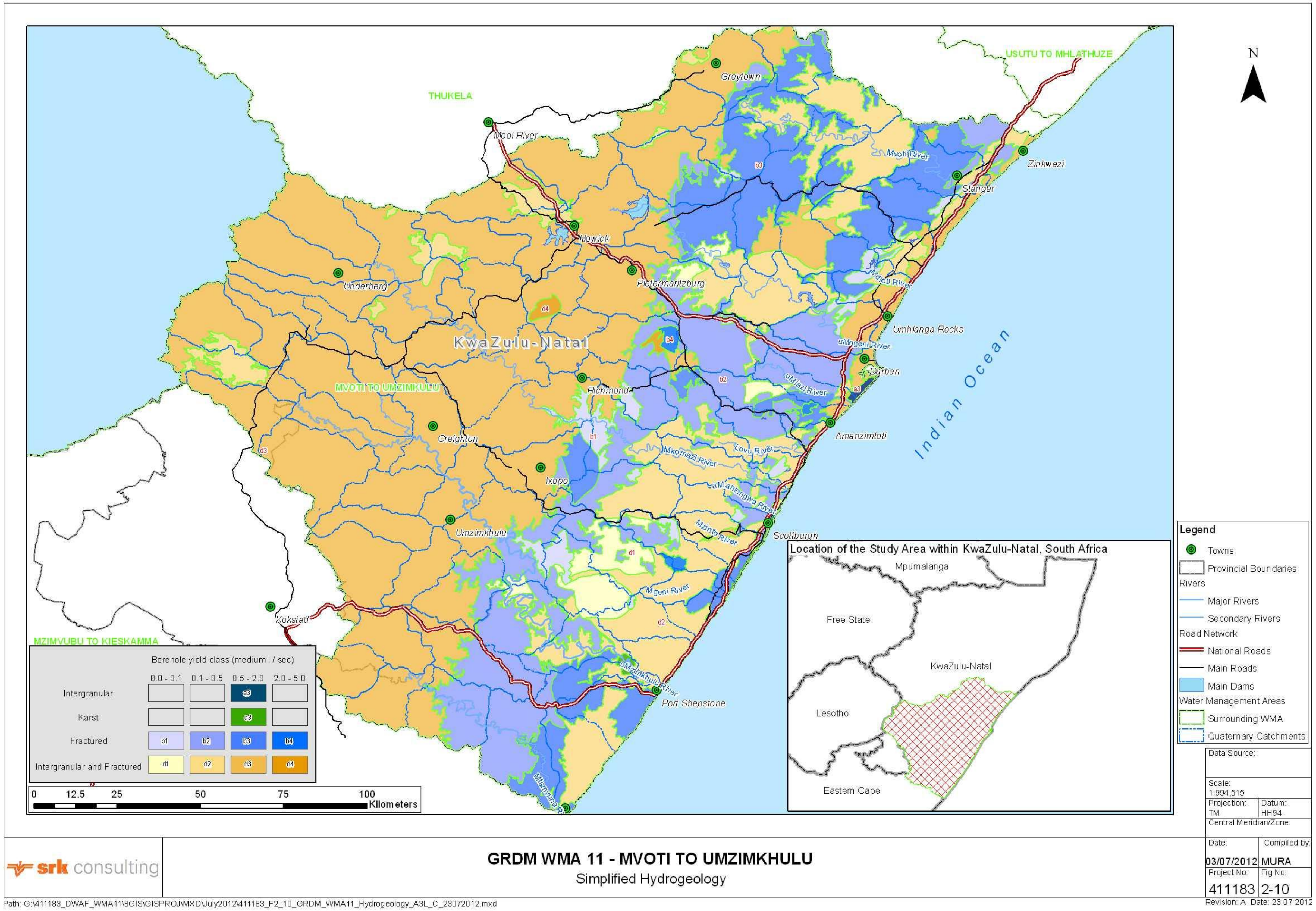


Figure 2-10: Simplified Hydrogeology

2.7.2 Available hydrogeological data

Borehole records obtained from DWA included the following:

- National Groundwater Archive (NGA) and Water Management System (WMS) for groundwater quality records;
- Groundwater Resource Information Project (GRIP);
- Water Use Authorisation & Registration Management System (WARMS);
- Groundwater Resource Assessment (GRA) II data sets.

These datasets when combined provide good spatial coverage of the WMA (Figure 2-11).

2.7.3 Field Work

Objectives

In order to update hydrogeological data for the WMA, an extensive field program was designed and implemented with the following objectives in mind:

- To visit all locality municipalities in the WMA that lie within the six district municipalities namely; eThekwini, uMgungundlovu, Sisonke, Ugu, uMzinyathi, iLembe, to better understand groundwater dependency and stresses and physically visit and document all groundwater fed schemes and future development scenarios;
- Spatial representation of groundwater level data;
- In communication with the municipalities to update al desktop information on potential sources of contamination to groundwater; and
- Update aquifer hydraulic characteristics through short duration aquifer tests at select sites; and
- Following data gap analysis on water quality records, conduct additional sampling and analysis of major anions, cations and trace metals where data is lacking.

Hydrocensus

The positions of the verified hydrocensus boreholes are shown on Figure 2-11. These boreholes were labelled according to the local municipality in which they were verified. A summary of the groundwater use per municipality (verified through hydrocensus) is provided as Table 2-2. Detailed hydrocensus data and information is detailed per Local Municipality in Appendix B.

From interviews with key technical municipal managers, potential sources of contamination to groundwater that included landfills, waste water treatment works, and industrial sites were identified for the various municipalities within the WMA. This information is summarised in Section 2.7.6. Groundwater Quality and Appendix C provides a detailed register of these sites.

Table 2-2: Hydrocensus verified groundwater use (Mm^3/a) per municipality

District Municipality	Local Municipality	Groundwater Use (Mm^3/a)
eThekwini	eThekwini	0.0084096
uMgungundlovu	Mkhambatini	
	Richmond	0.02415935
	uMgeni	0.0365
	Mshwati	0.0252799
	Impendle	0.1118944
	Msunduzi	
Umzinyathi	Umvoti	0.440555
iLembe	Kwadukuza	6.5916153
	Maphumulo	0.27959
	Ndwedwe	0.014746
Ugu	Vulamehlo	0.009636
	Umdoni	
	Umzumbe	0.000876
	Ezingoleni	
	Hibiscus Coast	0.0004745
	Umuzibantu	
Sisonke	Ubushlebezwe	0.23528265
	Mzimkulu	
	Ingwe	
	Kwa Sani	
	Total	**7.7790187**

Aquifer Testing

On compilation of the hydrocensus data, additional data required from a gap analysis were supplemented by limited aquifer testing and sampling. Aquifer testing comprised short duration discharge tests followed by recovery monitoring to estimate aquifer hydraulic parameters such as Transmissivity (T) and Storativity (S) although scarcity in observation wells largely restricted the estimate of S to typical values associated with the aquifer. A total of six aquifer tests were conducted.

A single opportunity to estimate storativity from water level responses at an observation borehole presented itself at Hammarsdale Landfill Site in eThekwini Municipality , however the two boreholes (H_ETEK02 a & b) targeted two different aquifers (evident in the construction depth and measured Static Water Level (SWL) in the respective boreholes).Rendering data acquired unsuitable for use.

A summary of the aquifer testing data and results is presented as Table 2-3 and the field data is provided as Appendix D.

Table 2-3: Summary of aquifer hydraulic characteristics T and S

Site ID	Longitude	Latitude	Quaternary	Pump depth mbgl	SWL mbgl	Discharge Rate L/s	Maximum Drawdown m	Transmissivity (Average) m^2/d	Storativity (Estimate)
H_MSHW02	30.466472	-29.344083	U20F	existing pump used	8.02	0.2	6.81	1 to 3	0.005*
H_RICH05	30.183417	-29.828417	U70A	existing pump used	5.32	0.88	2.35	22.6	0.005*
H_ETEK 02	30.67244	-29.79431	U60C	52	42	1.33	8.45	15 to 16.6	0.00000139**
H_ETEK 02_Obs	30.67244	-29.79431	U60C	7.05	3.94	Obs Well	0.3217	Not determined	0.00000139**
H_UMD 004	30.736289	-30.323317	U80K	existing pump used	3.1	0.18	2.98	1 to 2	0.005*
H_MGEN02	29.99349	-29.35816	U20B/V20D	existing pump used	9	0.5	65	0.1 to 0.5	0.005*

* Estimate. S cannot be accurately determined at a single pumping well

** Observation monitoring well data used for S estimate. Data not very reliable as wells ETEK 02 and ETEK 02 Obs intercepting different aquifers and hydraulic connectivity observed in the water level responses is very low

Groundwater Sampling

A total of eleven boreholes were sampled in accordance with approved sampling procedures and methods. Groundwater samples were submitted for analysis of major anions and cations and trace metals. It must be borne in mind that the aim of the groundwater sampling was not to be site specific but rather to obtain and add to the hydrochemical database in order to perform a regional hydrochemical assessment of the WMA. Samples were analysed for pH, EC, TDS, alkalinity, SO4, Cl, Ca, Mg, Na, K, Fe, Mn, NO3, F, Free and Saline Ammonia, Ortho Phosphate. ICP Metal Scan for trace metals was requested on six of these groundwater samples. The results have been integrated in the discussion on groundwater quality at a later stage in the report. Appendix E contains the certified laboratory analytical certificates.

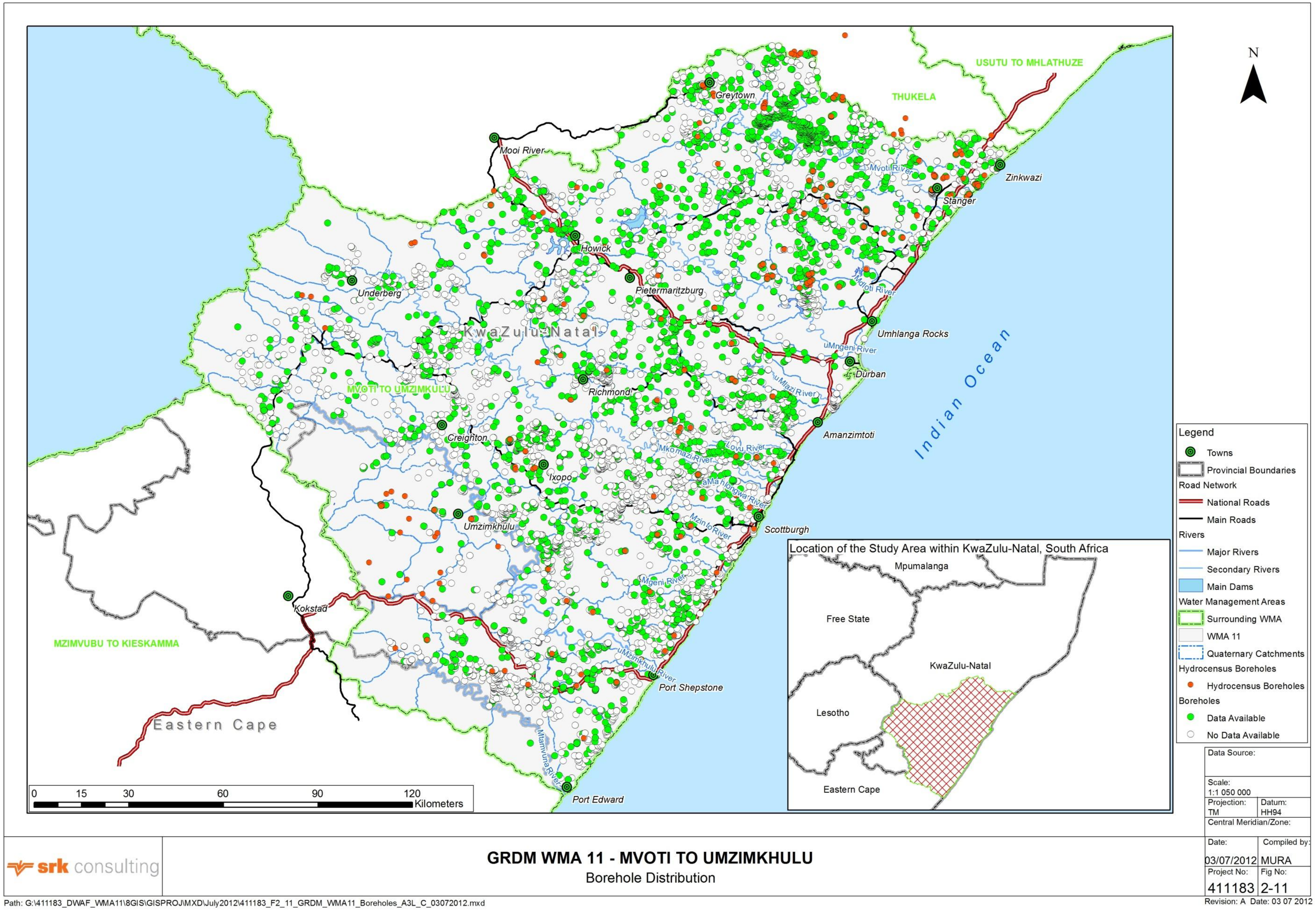


Figure 2-11: Borehole Distribution

2.7.4 Groundwater Levels

In areas straddling the coastline, groundwater levels range from 2 to 10 metres below ground level (mbgl) and can be traced alongside major rivercourses such as the uMzimkhulu, Mkomazi, uMngeni and Mvoti. Groundwater levels in the range from 10 – 20 mbgl also radiate inland from some areas along the coastline and have a distribution area that is roughly parallel to the coastline up to the towns of uMzimkhulu, Howick and Greytown. Areas further west record groundwater levels >20 mbgl with areas bordering Lesotho being >30 mbgl.

Groundwater levels (mamsl) display a roughly Bayesian relationship with the topographical surface (correlation co-efficient of 0.9965) implying that majority of the boreholes largely intercept the integranular and weathered aquifer which are unconfined to semi-confined in nature.

TRIPOL, an Institute for Groundwater Studies (IGS) developed software, uses the linear relationship between the measured water levels and topographical elevations to interpolate water level data for areas lacking data. The simulated groundwater levels (Figure 2-12) indicates groundwater elevations of >2000 mamsl (western areas of WMA) decrease to 1001-1500 mamsl (areas to the west of the towns of Creighton and Howick) decreasing further to between 501-1000 mamsl (broad zone ~30 km west of the coastline decreasing further east to sea level. Figure 2-19, the Topographical/Groundwater elevation difference map, in essence displays groundwater level distribution in mbgl across the WMA.

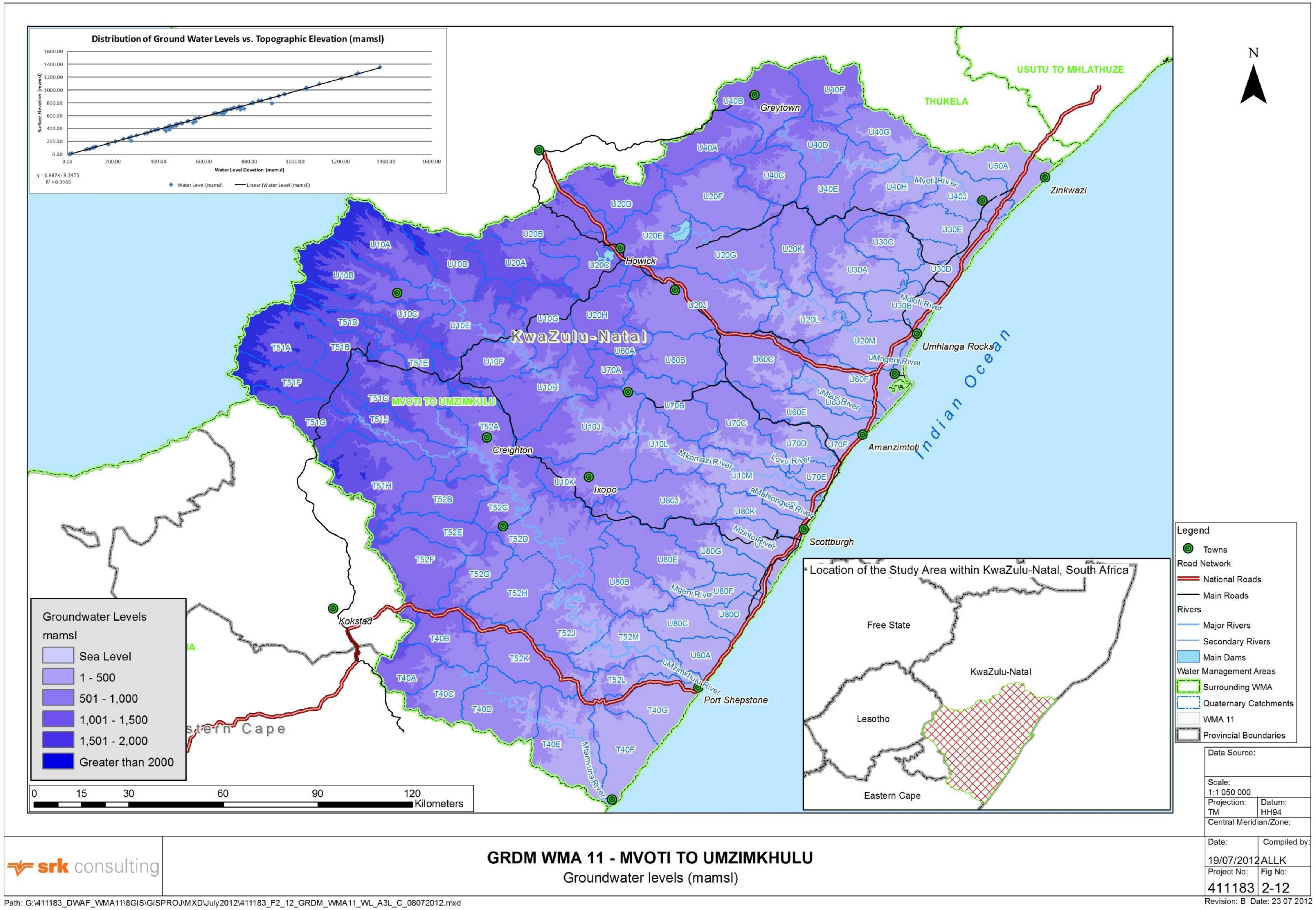


Figure 2-12: Groundwater levels (mamsl)

2.7.5 Groundwater Abstraction and Use

The GRA II database (the source of which is the National Groundwater Archive (NGA) dated to 2004) indicated groundwater abstraction at 5.92 Mm^3/a. This estimate of groundwater abstraction compared well with available literature at the time which indicated total groundwater abstraction in the WMA at 6 Mm^3/a (DWAF, 2004). During the Inception Phase of this study and to improve the data confidence levels for the groundwater abstraction component, the available groundwater databases were refined (duplication and erroneous data removed) and collated and groundwater abstraction was calculated at 42.4 Mm^3/a constituted by NGA (10.7 Mm^3/a), WARMS (7.8 Mm^3/a) and GRIP (29.46 Mm^3/a). According to the WARMS database, the agricultural (irrigation), industrial and municipal sectors account for the bulk of the registered groundwater users. Schedule 1 usage constitutes only one percent of registered users indicating that information on private groundwater users is limited (See Table 2-4). Information regarding the water use sector is not detailed in the GRIP and NGA datasets.

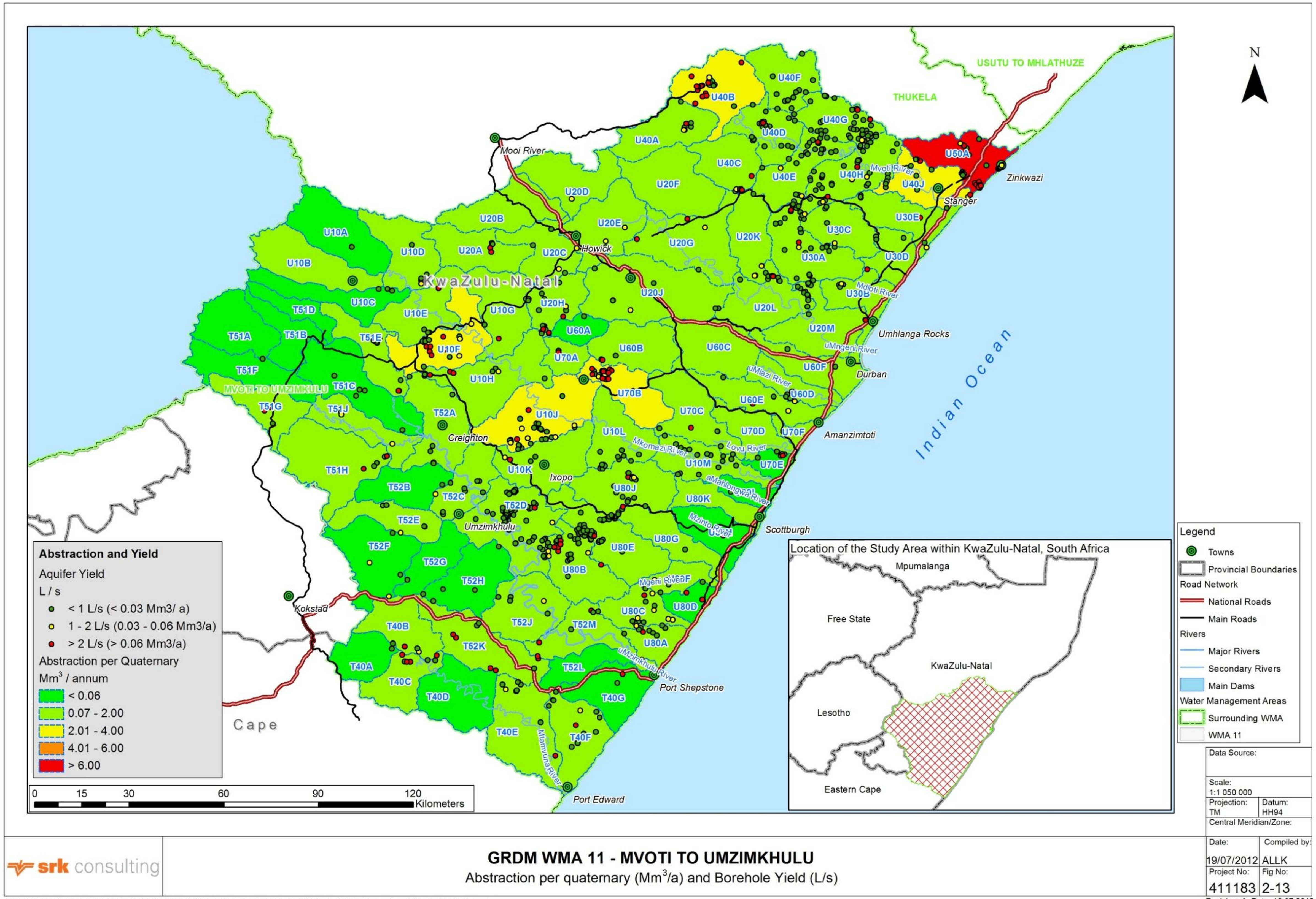
Table 2-4: Summary of WARMS Groundwater Use

Sector	Groundwater Use (Mm^3/a)	Percentage (%)
Schedule 1 Usage	0.078	1
Agriculture (Irrigation)	3.381	43
Agriculture (Livestock)	0.139	2
Industry (Urban & Non-Urban)	1.816	23
Recreational	0.027	0.4
Urban (Incl Urban & Domestic)	0.001	0.1
Water Supply Service (Municipal)	2.402	30.5
Total	**7.846**	**100**

Hydrocensus data verified groundwater users in various sectors which include private use, agriculture (irrigation and stock watering) and municipal water supply. These users totalled 7.77 Mm^3/a.

The total groundwater abstraction calculated through this study is 50.2 Mm^3/a which includes NGA, GRIP, WARMS and additional groundwater users verified through hydrocensus.

Groundwater abstraction has been summed per quaternary and is shown as Figure 2-13. Groundwater use occurs largely in the range from 0.07 to 2 Mm^3/a. Groundwater use is <0.06 Mm^3/a and the distribution area within the WMA is patchy and restricted to; some coastal quaternaries south of Amanzimtoti, (U70, U80 and T40), southern WMA boundary quaternaries (T40), quaternaries on the western WMA boundary (T52 and T51) and a single quaternary U60A centrally positioned in the WMA. Groundwater use occurs in the range from 2.01 to 4 Mm^3/a in centrally positioned quaternaries in the WMA which include U10J, U10F and U70B and in the northern boundary quaternaries U40B (Greytown) and U40J (Stanger). The highest groundwater use was recorded in quaternary U50A >6 Mm^3/a which intercepts the coastal town of Zinkwazi on the Natal North Coast.



Path: G:\411183_DWAF_WMA11\8GIS\GISPROJ\MXD\July2012\411183_F2_13_GRDM_WMA11_Abstraction_A3L_C_19072012.mxd

Figure 2-13: Abstraction per quaternary (Mm^3/a) and Borehole Yields (L/s)

2.7.6 Groundwater Quality

The DWAF hydrogeological map of Durban (2928) indicates that electrical conductivity was recorded between 0-70 mS/m across a large portion of the WMA however certain areas close to the coast and sporadically dispersed inland have elevated levels of electrical conductivity of 70 to 300 mS/m e.g. at Stanger/KwaDukuza and Mooi River.

Large areas of the WMA are under sugarcane farming and forestry. These (particularly sugarcane farming) represent a diffuse source of pollution in the WMA. Stock farming is intensively practiced in Mshwati, Richmond and Mkhambatini Local Municipalities.

Point sources of pollution include, waste disposal sites or landfill sites, Waste Water Treatment Works (WWTWs), industrial and chemical sites, feedlots etc. The WMA has recorded a total of thirty nine (39) landfill sites and sixty seven (67) WWTWs. The hazardous landfill sites currently in operation the WMA include Shongweni Landfill Site H:h (located in Shongweni off the N3 Highway) and Kwadukuza Landfill Site H:H (approximately 10 km outside Stanger/ KwaDukuza which has only recently started accepting waste).

The industrial areas are mainly concentrated in the Durban (includes Pinetown) and Pietermaritzburg Metropolitan Areas and the distribution area (seen in Figure 2-15) occurs within close proximity of the road and rail networks. Durban South Basin (includes the Lanxess site for which groundwater monitoring data was received), Island View Complex and Harbour Area, Umbogintwini Industrial Complex (the 2011 groundwater monitoring report was made available to the project team), Pinetown Industrial Complex and Pietermaritzburg Industrial Complex appear to be the dominant industrial areas in the WMA although most towns have industrial areas on a smaller scale in the outer areas or fringe of the developed areas.

Appendix C presents a detailed account of potential sources of contamination to groundwater in the WMA, based on available data.

Data received from DWAs Water Management System (WMS) (a total of 1174 records) indicate good spatial coverage for the WMA, however there are obvious data gaps when viewed on a quaternary scale. The existing data date from 1970 to 2010. Figure 2-14 shows the distribution of water quality records and hydrocensus positions sampled, across the WMA.

Sampling of spatially representative boreholes (identified during the hydrocensus) was conducted and analysed (between 2011 and 2012) in order to update and supplement the existing datasets. These samples were analysed for:

- Physical parameters, pH and Electrical Conductivity (EC) in mS/m and Total Dissolved Solids (TDS) in mg/L;
- Anions, Chloride (Cl), Sulfate (SO_4), Nitrate (NO_3), Fluoride (F); and
- Cations, Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K)

All hydrochemical data were collated and were assessed for potability using the South African National Standard (SANS) 241 for Drinking Water (Abbreviated) (Table 2-5). SANS 241 is also one of the guidelines recommended with the new GRDM methodology for classification of water resources.

Almost 30% (two samples) of the total samples (eleven samples) record Fluoride concentrations that occur in the SANS Class II category. These elevated concentrations can be typically associated with the geological formations intercepted by these boreholes. These concentrations range from 1.1 to

1.7 mg/L. All other parameters analysed for, occur within the SANS Class I concentration range. The chemical data for the physical parameters, major anions and cations is presented as Table 2-6.

A Quantitative Inductively Coupled Plasma (ICP) Metal Scan for trace metals was conducted on eight spatially representative samples. The ICP Metal Scan targeted the following trace metals: Arsenic (As), Selenium (Se), Titanium (Ti), Aluminium (Al), Nickel (Ni), Manganese (Mn), Iron (Fe), Vanadium (V), Zinc (Zn), Antimony (Sb), Lead (Pb), Cobalt (Co), Copper (Cu), Total Chromium (Cr), Silicon (Si), Tin (Sn), Zirconium (Zr), Bismuth (Bi), Thallium (Tl), Beryllium (Be), Cadmium (Cd), Strontium (Sr), Boron (B), Phosphorus (P), Uranium (U), Molybdenum (Mo), Barium (Ba), Silver (Ag), Thorium (Th), Mercury (Hg).

Of these boreholes sampled, two boreholes KWDK07 and UMZI21 record As concentrations in the SANS Class II range. These sites occur on relatively undeveloped land and are likely to represent naturally occurring concentrations in the groundwater. Al occurs in the SANS Class II for two samples (MNGENI02 and UMDO04) at concentrations' of 0.32 and 0.33 µg/L which is likely to be naturally occurring Al. Mn and Fe appear to co-exist at four boreholes (ETEK02, KWDK07, MNGENI02 and UMDO04) at concentrations varying between a Class II and Class III with Fe concentrations predominantly in the Class III range. These may be attributed to a combination of sensitivity to pH (low pH increases solubility of metals) as well as water levels stabilising/occurring within the mild steel casing length which may potentially leach these metals into the groundwater. All other parameters analysed for, occur within the SANS Class I concentration range. These data are presented as Table 2-7.

Existing data on trace metal concentrations in the WMA include Fe and Mn concentrations to a large extent and very patchy Al concentration data. The locations of sites for which Quantitative ICP Metal Scan was undertaken are indicated on Figure 2-14.

Table 2-5: SANS 241 Drinking Water Standards

1	2	3	4	5
Determinand	**Unit**	**Class I (recommended operational limit)**	**Class II (max. allowable for limited duration)**	**Class II water consumption period,[a] max.**
Physical and organoleptic requirements				
Colour (aesthetic)	mg/L Pt	< 20	20 – 50	No limit[b]
Conductivity at 25 °C (aesthetic)	mS/m	< 150	150 – 370	7 years
Dissolved solids (aesthetic)	mg/L	< 1 000	1 000 – 2 400	7 years
Odour (aesthetic)	TON	< 5	5 – 10	No limit[b]
pH value at 25 °C (aesthetic/ operational)	pH units	5,0 – 9,5	4,0 – 10,0	No limit[c]
Taste (aesthetic)	FTN	< 5	5 – 10	No limit
Turbidity (aesthetic/operational/ indirect health)	NTU	< 1	1 – 5	No limit[d]
Chemical requirements — macro-determinand				
Ammonia as N (operational)	mg/L	< 1,0	1,0 – 2,0	No limit[d]
Calcium as Ca (aesthetic/operational)	mg/L	< 150	150 – 300	7 years
Chloride as Cl^- (aesthetic)	mg/L	< 200	200 – 600	7 years
Fluoride as F^- (health)	mg/L	< 1,0	1,0 – 1,5	1 year
Magnesium as Mg (aesthetic/ health)	mg/L	< 70	70 – 100	7 years
(Nitrate and nitrite) as N (health)	mg/L	< 10	10 – 20	7 years
Potassium as K (operational/health)	mg/L	< 50	50 – 100	7 years
Sodium as Na (aesthetic/health)	mg/L	< 200	200 – 400	7 years
Sulfate as $SO_4^{=}$ (health)	mg/L	< 400	400 – 600	7 years
Zinc as Zn (aesthetic/health)	mg/L	< 5,0	5,0 – 10	1 year

Sans 241 Drinking Water Standard continued…..

1	2	3	4	5
Determinand	**Unit**	**Class I (recommended operational limit)**	**Class II (max. allowable for limited duration)**	**Class II water consumption period,[a] max.**
Chemical requirements — micro-determinand				
Aluminium as Al (health)	µg/L	< 300	300 – 500	1 year
Antimony as Sb (health)	µg/L	< 10	10 – 50	1 year
Arsenic as As (health)	µg/L	< 10	10 – 50	1 year
Cadmium as Cd (health)	µg/L	< 5	5 – 10	6 months
Total Chromium as Cr (health)	µg/L	< 100	100 – 500	3 months
Cobalt as Co (health)	µg/L	< 500	500 – 1 000	1 year
Copper as Cu (health)	µg/L	< 1 000	1 000 – 2 000	1 year
Cyanide (recoverable) as CN^- (health)	µg/L	< 50	50 – 70	1 week
Iron as Fe (aesthetic/ operational)	µg/L	< 200	200 – 2 000	7 years[b]
Lead as Pb (health)	µg/L	< 20	20 – 50	3 months
Manganese as Mn (aesthetic)	µg/L	< 100	100 – 1 000	7 years
Mercury as Hg (health)	µg/L	< 1	1 – 5	3 months
Nickel as Ni (health)	µg/L	< 150	150 – 350	1 year
Selenium as Se (health)	µg/L	< 20	20 – 50	1 year
Vanadium as V (health)	µg/L	< 200	200 – 500	1 year
Chemical requirements — organic determinand				
Dissolved organic carbon as C (aesthetic/health)	mg/L	< 10	10 – 20	3 months[e]
Total trihalomethanes (health)	µg/L	< 200	200 – 300	10 years[f]
Phenols (aesthetic/health)	µg/L	< 10	10 – 70	No limit[b]

[a] The limits for the consumption of class II water are based on the consumption of 2 L of water per day by a person of mass 70 kg over a period of 70 years. Columns 4 and 5 shall be applied together.
[b] The limits given are based on aesthetic aspects.
[c] No primary health effect – low pH values can result in structural problems in the distribution system.
[d] These values can indicate process efficiency and risks associated with pathogens.
[e] When dissolved organic carbon is deemed of natural origin, the consumption period can be extended.
[f] This is a suggested value because trihalomethanes have not been proven to have any effect on human health.

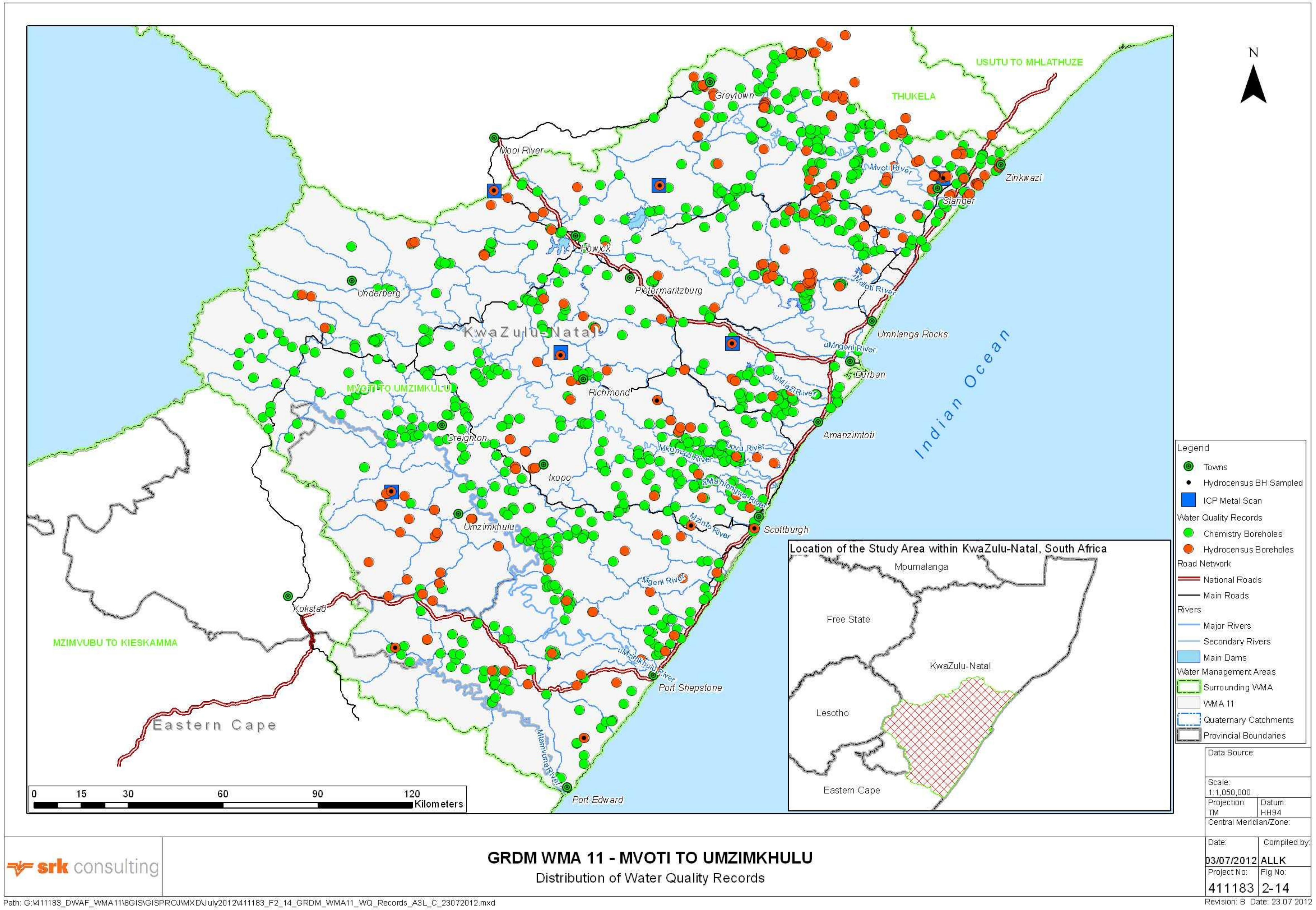


Figure 2-14: Distribution of Water Quality Records

Table 2-6: Major Anion and Cation Analysis for Hydrocensus Boreholes

	SITE ID		H_ETEK02	H_KWDK07	H_RICH03	H_RICH05	H_MGEN02	H_HIBI04	H_UMZI21	H_UMDO04	H_UMDO04_DUPLICATE	H_HIBI03	H_MSHW02	H_UMUZ03	TRIP BLANK
	LATITUDE		-29.794310	-29.322830	-29.956583	-29.828417	-29.358160	-29.344083	-30.217000	-30.323317	-30.323317	-30.921080	-30.696590	-30.664070	NA
	LONGITUDE		30.672440	31.275500	30.459333	30.183417	29.993490	30.466472	29.700361	30.736289	30.736289	30.250130	30.413910	29.711740	NA
	DATE OF SAMPLING		20111219	20111219	20111219	20111219	20111219	20111219	20111219	20111219	20111219	20111219	20111219	20111219	NA
PARAMETERS (mg/L where applicable)	SANS 241 DRINKING WATER STANDARDS (mg/L)														
	CLASSI	CLASSII													
pH Value @ 25°C	5-9.	4-10.	6.60	6.30	5.60	6.80	6.30	7.20	7.70	6.40	6.30	7.50	3.50	6.80	6.30
Conductivity mS/m @ 25°C	<150	150-300	128.00	43.10	15.70	17.70	21.50	45.70	14.30	41.20	41.70	31.50	25.70	5.13	0.31
Total Dissolved Solids	<1000	1000-2400	782.00	310.00	132.00	114.00	222.00	305.00	141.00	286.00	260.00	176.00	124.00	30.00	24.00
Calcium,Ca	<150	150-300	82.00	6.20	3.30	19.30	13.20	12.00	12.80	21.00	22.00	17.80	10.00	1.40	4.50
Magnesium, Mg	<70	70-100	35.00	3.30	3.60	4.70	11.10	9.00	4.70	9.80	9.50	5.20	6.10	1.10	1.10
Sodium,Na	<200	200-400	123.00	79.00	25.00	11.10	16.80	72.00	15.10	41.00	41.00	45.00	12.50	7.10	0.20
Potassium,K	<50	50-100	5.90	1.80	3.90	0.80	2.60	1.60	2.00	7.80	7.50	3.60	0.70	0.80	1.20
Free and Saline Ammonia as N	<1	1-2.	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.20	0.10	<0.1	<0.1
Total Alkalinity as $CaCO_3$	No Standard		284.00	103.00	17.00	80.00	90.00	130.00	67.00	76.00	57.00	114.00	-	29.00	3.00
P Alk as $CaCO_3$	No Standard		0.00	0.00	0.00	Nil	0.00	Nil	0.00	0.00	0.00	0.00	-	0.00	0.00
Bicarbonate,HCO_3	No Standard		346.00	126.00	21.00	98.00	110.00	158.00	82.00	93.00	69.00	139.00	-	35.00	4.00
Carbonate, CO_3	No Standard		0.00	0.00	0.00	Nil	0.00	Nil	0.00	0.00	0.00	0.00	-	0.00	0.00
Chloride,Cl	<200	200-600	211.00	53.00	33.00	4.50	18.40	60.00	1.20	75.00	75.00	26.00	47.00	3.50	0.70
Sulfate,SO^4	<400	400-600	65.00	8.20	6.40	3.80	8.30	18.00	6.20	16.30	24.00	4.20	47.00	7.30	4.20
Nitrate as N	<10	10-20.	0.10	0.30	5.40	<0.1	0.20	0.70	1.00	1.40	0.90	0.40	<0.1	0.20	0.20
Fluoride,F	<1	1-1.5	1.70	0.40	0.20	0.50	0.30	1.60	0.20	0.30	0.30	1.10	<0.1	0.50	0.10

Concentrations represented as mg/L except for physical chemical parameters pH and EC

-Not requested

No Standard- means no guideline value prescribed under SANS 241 Drinking Water Standard

Table 2-7: ICP Metal Scan for Hydrocensus Boreholes

CHEMICAL PARAMETERS (mg/L)	SANS 241 DRINKING WATER STANDARDS (mg/L)		RICH05	HIBI04	MSHW02	ETEK02	KWDK07	MGENI02	UMZI21	UMDO04
	CLASS I	CLASSII								
Arsenic, As	<0.01	0.01-0.05	<0.001	<0.001	<0.001	<0.001	0.02	<0.001	0.015	0.001
Selenium, Se	<0.02	0.02-0.05	<0.001	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	<0.001
Titanium, Ti	No standard		0.001	0.002	0.001	0.001	0.009	0.003	0.002	0.003
Aluminium, Al	<0.3	0.3-0.5	<0.009	0.035	0.01	0.094	0.1	0.32	0.26	0.33
Nickel, Ni	<0.15	0.15-0.35	0.005	0.003	0.007	<0.003	0.009	0.004	<0.003	0.011
Manganese, Mn	<0.1	0.1-1	0.025	0.004	1.4	0.18	0.4	0.32	0.002	0.28
Iron, Fe	<0.2	0.2-2	0.088	0.23	0.12	0.32	10.2	14.9	0.12	14.9
Vanadium, V	<0.2	0.2-0.5	0.011	0.018	0.014	0.007	0.044	0.008	0.012	0.007
Zinc, Zn	<5	5-10.	0.041	<0.005	0.22	0.54	0.5	0.55	0.51	0.52
Antimony, Sb	<0.01	0.01-0.05	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Lead, Pb	<0.02	0.02-0.05	<0.001	<0.001	<0.001	<0.001	<0.001	0.004	<0.001	0.003
Cobalt, Co	<0.5	0.5-1	<0.001	<0.001	0.002	0.001	0.006	0.001	<0.001	0.003
Copper, Cu	<1	1-2.	0.01	0.014	0.012	0.017	0.013	0.073	0.008	0.01
Total Chromium, Cr	<0.1	0.1-0.5	0.01	0.009	0.01	0.004	0.014	0.004	0.004	0.004
Silicon, Si	No standard		16.5	37	6.7	11.1	37	16.4	15.2	10.3
Tin, Sn	No standard		<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Zirconium, Zr	No standard		<0.001	0.001	<0.001	0.001	0.003	0.002	0.002	0.002
Bismuth, Bi	No standard		<0.005	<0.005	<0.005	<0.005	0.037	0.007	<0.005	0.023
Thallium, Tl	No standard		<0.009	<0.009	<0.009	0.014	0.01	0.024	0.015	0.01
Beryllium, Be	No standard		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cadmium, Cd	<0.005	0.005-0.01	<0.001	0.001	<0.001	0.001	<0.001	<0.001	0.001	<0.001
Strontium, Sr	No standard		0.14	0.034	0.014	0.76	0.028	0.15	0.087	0.059
Boron, B	No standard		<0.006	0.006	0.018	0.3	0.33	0.32	0.3	0.34
Phosphorus, PO4	No standard		<0.12	0.25	<0.04	<0.04	0.09	2	0.07	0.24
Uranium, U	No standard		<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Molybdenum, Mo	No standard		<0.001	<0.001	<0.001	0.001	<0.001	<0.001	0.002	<0.001
Barium, Ba	No standard		0.007	0.026	0.092	0.63	0.7	0.79	0.73	0.92
Silver, Ag	No standard		<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004
Thorium, Th	No standard		<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Mercury, Hg	<0.001	0.001-0.005	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

According to [1]DWAF (2004), groundwater utilisation in the catchment is fairly poor with an additional 380 million m^3/a available for abstraction however groundwater quality (total dissolved solids, fluoride and nitrates) is one of the major factors hindering the utilisation of this resource.

Total Dissolved Solids (TDS) and Fluoride (F) were identified as the main CoCs for the WMA. These parameters have been superimposed on maps referenced as Figure 2-15 and 2-16 respectively. In an attempt to correlate potential sources of contamination with TDS, Figure 2-15 also show the spatial distribution of waste water treatment works, waste storage facilities and recovery facilities and Landfill facilities. Figure 2-16 shows F concentrations superimposed on a geological map (as these are naturally occurring concentrations attributed to the geological formations that constitute these aquifers).

Where TDS concentrations were not recorded in the datasets, a constant value of 6.5 was multiplied with the EC concentration (where available) to derive an estimate of a TDS concentration. A total of 868 records (representing 74 % of the total records) recorded TDS concentrations. Of these, 90 % were of Class I ideal quality (0-1000 mg/L), 5% were of Class II marginal quality (>1000-2400 mg/L) and 5% were of Class III unsuitable quality (>2400 mg/L). The distribution area for Class II and Class II water quality based on TDS concentrations is largely recorded in quaternaries of the Mkomazi River near the coast as well as in the quaternaries immediately south. Other distribution areas in Class II and III are sporadic and in instances represented by single datapoints. Two areas where small clusters occur that classify as either Class II or III is in a coastal quaternary along the

Mzimkhulu River to the south of the WMA and the other area along the Mvoti River to the north. However, the elevated TDS concentrations show little or no correlation with the potential sources of contamination which occur in defined areas along the coast between the town of Scottburgh to south of the town of Stanger (located along the coast to the north of the WMA). TDS concentrations are scarce around the potential sources of contamination presented in Figure 2-15.

Fluoride concentrations (733 records constituting 62 % of the total chemical records) are largely in the Class I range (<1 mg/L) which represents 80% of the available records. Class II (1.1-1.5 mg/L) and Class III (>1.5 mg/L) represent 8% and 12 % of the available records, respectively. Fluoride concentrations in the Class II and Class III range typically occur in lithogies of the Natal Metamorphic Province, specifically the Mzumbe and Margate Terrane Formations, which can be observed in Figure 2-16.

All laboratory analytical certificates containing results for the various parameters described are included as Appendix E.

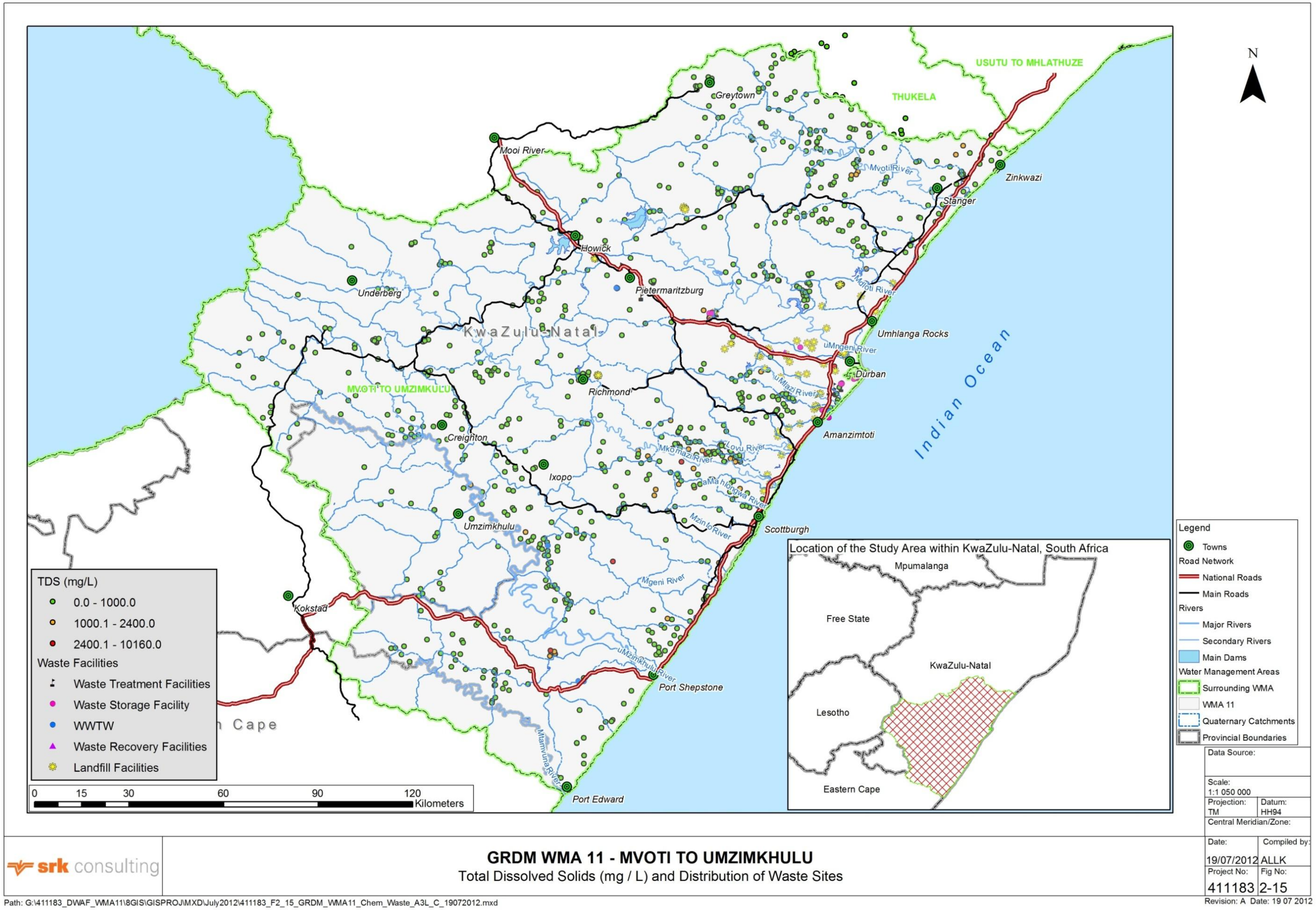


Figure 2-15: Total Dissolved Solids (mg/L) and Distribution of Waste Sites

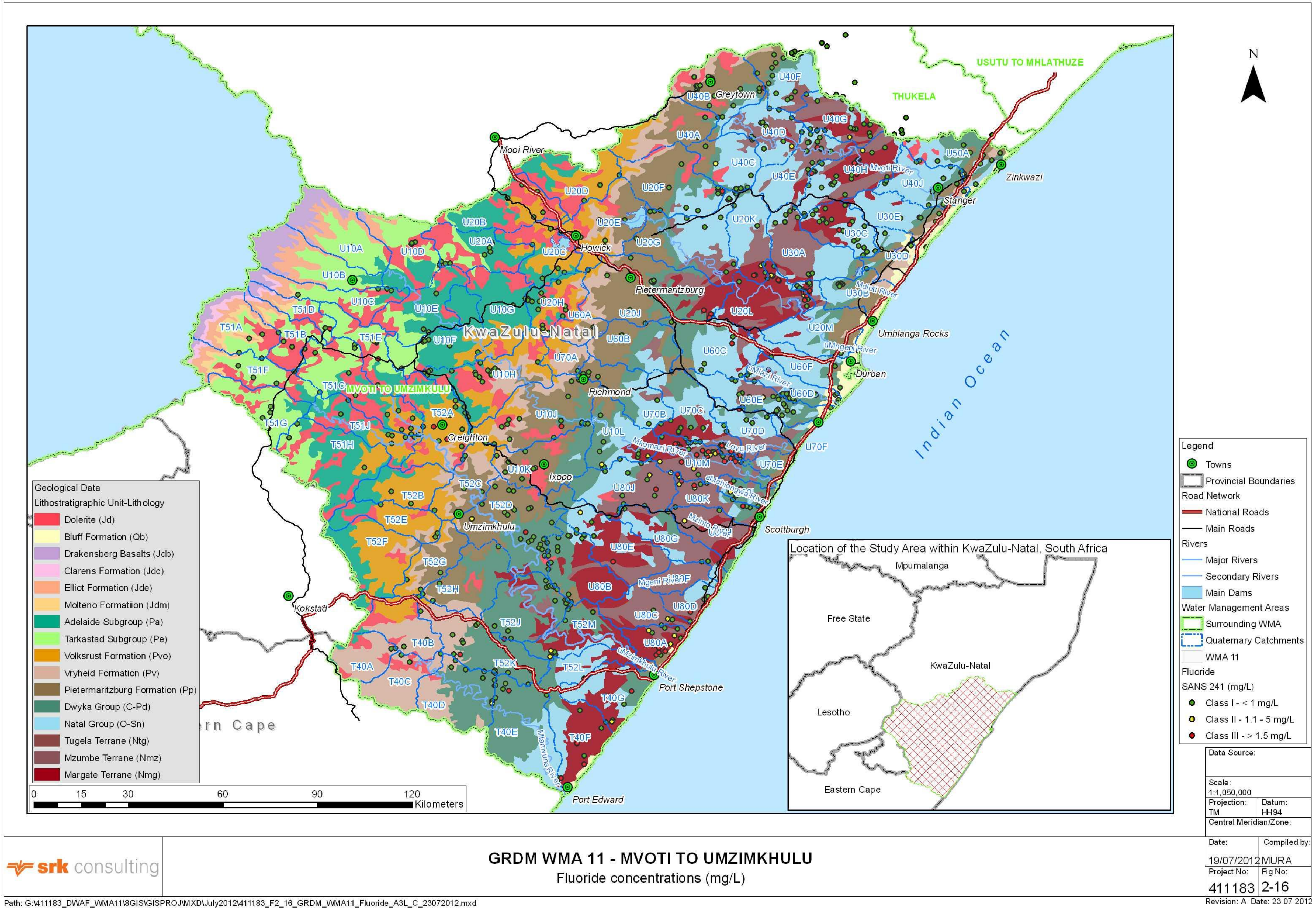


Figure 2-16: Fluoride concentrations (mg/L)

2.7.7 Aquifer Vulnerability

Aquifers that are susceptible to surface contamination are usually characterised by shallow groundwater tables, thin soil cover, coarse soils with low clay content, unconfined and are associated with low pH groundwater (IGS, 1996). These aquifers are typically associated with piston recharge models. Fractured aquifers allow rapid entry and migration of contaminants via preferred pathways and have the potential to contaminate vast areas along the fracture network. (

The assessment of aquifer vulnerability relies on readily available data to ascertain the movement of surface contaminants vertically through the vadose zone to the groundwater table. The DRASTIC Approach which is effectively a Geographical Information System (GIS) driven process, superimposing various layers of data with a prescribed ratings. The final outcome/rating is then used to categorise the rating. Higher ratings are associated with aquifers that have higher vulnerability and susceptibility to contamination from surface. The term DRASTIC originates from:

D - Depth to groundwater,

R - Recharge rate (net),

A - Aquifer media,

S - Soil media,

T - Topography,

I - Impact on vadose zone, and

C – Conductivity (Hydraulic Conductivity).

Each of these layers is assigned a value based on a rating. These factors are adjusted by a weighting factor and summed to calculate the DRASTIC index. The aquifer vulnerability is calculated using Groundwater Level (mbgl), Slope of the area (%), Recharge (%), Soil Media, Aquifer Media, Vadose Zone.

The DRASTIC formula for groundwater in South Africa according to Lynch *et al.* (1984) is as follows:

DRASTIC INDEX = $D_rD_w + R_rR_w + A_rA_w + S_rS_w + T_rT_w + I_rI_w$

The weights of each of the above-mentioned terms are:

Depth to groundwater (D_w) = 5
Recharge (R_w) = 4
Aquifer media (A_w) = 3
Soil media (S_w) = 2
Topography (% slope) (T_w) = 1
Impact of vadose zone (I_w) (I_w) = 5

A guideline for the ratings is provided in Table 2-7.

For the WMA, the data for the various layers was grouped per quaternary making it easier to represent the final ratings (as a %) on a quaternary level. Accordingly the following groupings were derived:

- <25% - Low Aquifer Vulnerability;

- 25%-50% - Moderate Aquifer Vulnerability;
- 50%-75% - High Aquifer Vulnerability;
- >75% - Very High Aquifer Vulnerability;

The main criteria driving the above categories in the WMA appear to be largely related to D, R, A and I. Generally, quaternaries occurring along the coast of the WMA tend to be more vulnerable and susceptible to contamination (on account of shallower groundwater tables, higher recharge, the occurrence of fractured aquifers and the vadose zone associated with the geology distributed in these areas) as well as quaternaries U40C to U40F, U20G and U20K that are located in the northern WMA that have high ratings for recharge, fractured aquifers and the vadose zone associated with the geology in these areas. Figure 2-17 shows these relationships.

With the exception of the above, quaternaries generally display moderate aquifer vulnerability in the interior of the WMA. The DRASTIC indices are presented in Appendix F where GIS derived indices are compared with excel based solutions.

Table 2-8: Rating Values for DRASTIC Approach (After GRDM, 2011)

Depth to groundwater (D_R)		**Net recharge (R_R)**	
Range (m)	**Rating**	**Range (mm)**	**Rating**
0 – 5	10	0 – 5	1
5 – 15	7	5 – 10	3
15 – 30	3	10 – 50	6
>30	1	50 – 100	8
		>100	8
Aquifer media (A_R)		**Soil media (S_R)**	
Range (m)	**Rating**	**Range (mm)**	**Rating**
Dolomite	10	Sand	8 – 10
Intergranular	8	Shrinking and/or aggregated clay	7 – 8
Fractured	6	Loamy sand	6 – 7
Fractured and weathered	3	Sandy loam	5 – 6
Topography (T_R)		Sandy clay loam and loam	4 – 5
Range (% slope)	**Rating**	Silty clay loam, sandy clay and silty loam	3 – 4
0 – 2	10	Clay loam and silty clay	2 – 3
2 – 6	9		
6 – 12	5		
12 – 18	3		
>18	1		
Impact of the vadose zone (I_R)			
Range			**Rating**
Gneiss, Namaqua metamorphic rocks			3
Ventersdorp, Pretoria, Griqualand West, Malmesbury, Van Rhynsdorp, Uitenhage, Bokkeveld, Basalt, Waterberg, Soutpansberg, Karoo (northern), Bushveld, Olifantshoek			4
Karoo (southern)			5
Table Mountain, Witteberg, Granite, Natal, Witwatersrand, Rooiberg, Greens one, Dominion, Jozini			6
Dolomite			9
Beach sands and Kalahari			10

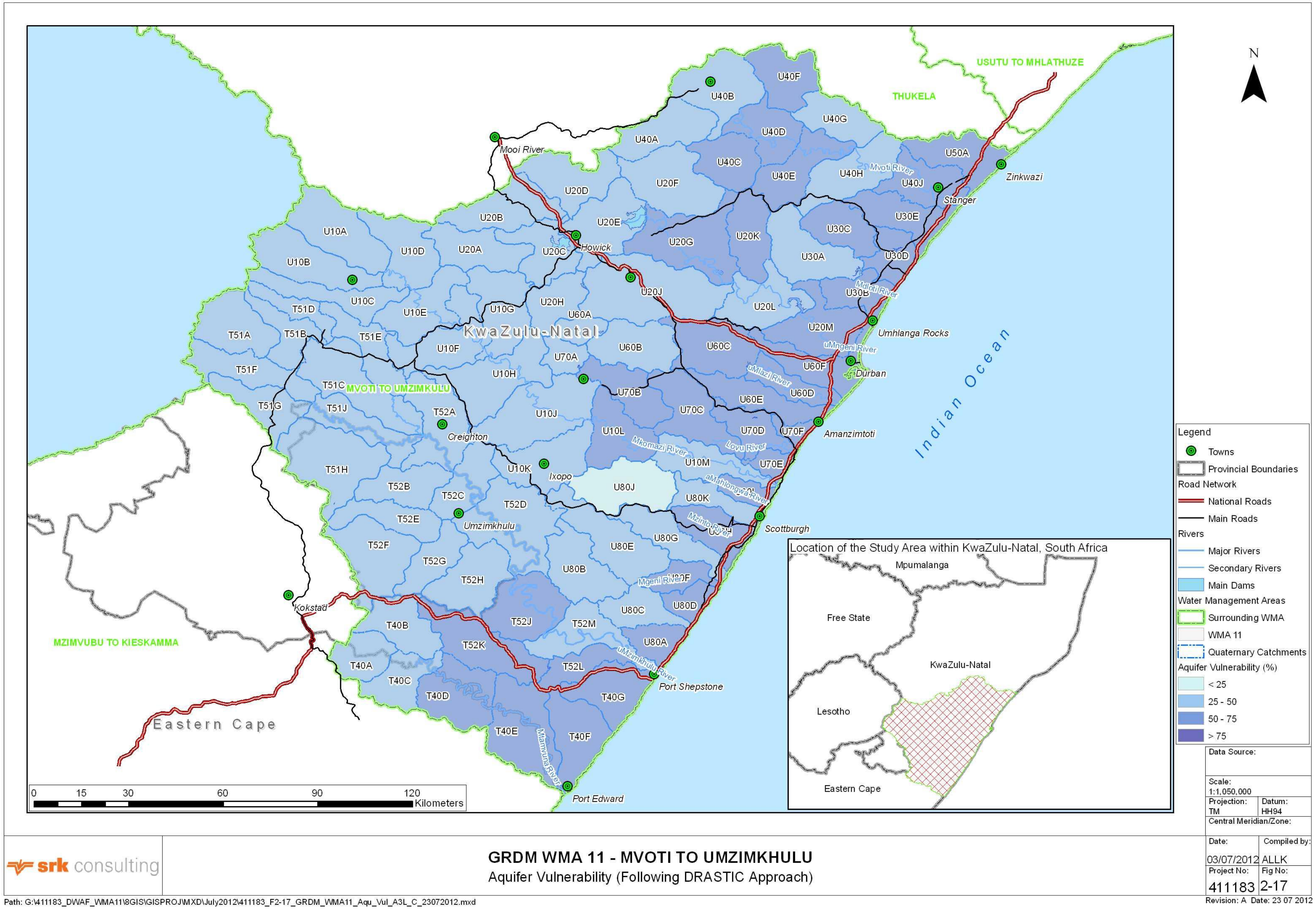


Figure 2-17: Aquifer Vulnerability (Following DRASTIC Approach)

2.7.8 Surface Water/ Groundwater Interaction and Baseflow

Background (GRDM, 2011)

The interaction of groundwater with surface water depends on the physiographic and climatic setting of the landscape. For example, a stream in a wet climate might receive groundwater inflow, but a stream in an identical physiographic setting in an arid climate might lose water to groundwater.

Based on the literature review of surface–groundwater interaction methodologies, the following characteristics of rivers emerged as most important for the application of mathematical models:

- Gradient between piezometric surface and river stage (either side);
- Occurrence and characterisation of clogging layers in the riverbed;
- Hydrogeological characteristics of the strata along the river stretches; and
- Regional groundwater gradients.

It is proposed that in order to understand the relationship between surface water and groundwater that firstly, the river classification is well understood i.e whether the river is flowing in its upper, middle or lower course. Secondly, the geological classification needs to be considered which differentiates between rivers flowing in porous media or over bedrock. A third class accounts for valley trains underlain by aquitards, a typical situation of an alluvial aquifer along a river stretch underlain by impervious hard rocks.

Hydrographs are another way of ascertaining some of these relationships. A river hydrograph consists of three components: direct runoff, interflow through the unsaturated zone and groundwater discharge from the saturated zone. Although a baseflow is often defined as the groundwater discharge from the saturated zone in classic hydrogeological textbooks the word *baseflow* is generally known to many hydrologists as delayed flow components (mainly groundwater), as opposed to a quick, direct runoff. Thus, baseflow itself is not indicative of origins of water sources. The baseflow is normally separated by removing the direct runoff from a hydrograph. As a result, such a baseflow component may still contain some interflow component.

The Herold method is one of the common methods in South Africa to determine the groundwater contribution to flow in a river. The method is based on the total flow in the river being equal to the groundwater contribution and surface runoff. The assumption is then made that all flow below a certain value (called *GGMAX*) is groundwater flow. The value of GGMAX is adjusted each month according to the surface runoff during the preceding month and is assumed to decay with time.

The link between groundwater and wetlands is still poorly understood (and researched) in South Africa. However, it is suspected that many wetlands depend – at least to some degree (both spatially and temporally) – on a contribution from groundwater. This is especially true during the dry season where the groundwater contribution is critical in sustaining the ecology of the wetland.

In order to assess wetlands the following must be considered:

- Gradient between piezometric surface and the water level in the wetland; and
- Occurrence and characterisation of clogging layers in the wetland.

Surface water bodies in WMA verified during hydrocensus

During the field hydrocensus undertaken in the last quarter of 2011, there was an opportunity to record the locations of numerous surface water bodies in various terrains on route to verify groundwater supply infrastructure. A photographic log is presented below showing tributaries and rivers flowing in various geomorphological environments.

Additional visualisations of river systems and geomorphological environments for a selection of the major river systems sourced through google earth have been included as Appendix G, which provides a first indication of the potential for hydraulic connectivity between surface water and groundwater systems.

Groundwater level data for boreholes in close proximity to surface water bodies was very limited, which was largely due to lack of access, to be able to assess hydraulic gradients, as was field data on clogging clay layers and hydrogeological characteristics of the river geological formations.

Generally, where tributaries and rivers flow across relatively impermeable strata, the potential for hydraulic connectivity with the surrounding aquifers is reduced. It is likely that groundwater contribution to these surface water bodies will be largely through interflow. The potential for hydraulic connectivity between shallow aquifer systems and rivers/tributaries that flow in geomorphological terrains consisting of sandy to gravelly formations (highly porous media) is greater. These relationships must however be confirmed with proper conceptualization of the physical elements that have an influence e.g. interflow, geomorphology, riparian vegetation, channel aquifers along river, riparian aquifer and then the terrestrial aquifer. Water level measurements need to be made in piezometers or boreholes transecting the river course where these relationships are suspected. River flow and chemistry measurements also need to be considered along the river length investigated.

Plate 2-1: Sandy, flat alluvial type environment along riverbanks (Mvoti River, 2.5 km northwest of KwaDukuza)

Plate 2-2: Wide flat sandy riverbanks (Mvoti River, with the river diversion approximately 500 m southeast of Sappi (Pty) Ltd in KwaDukuza

Plate 2-3: Unnamed tributaries flowing over bedrock (Ndwedwe Area)

Plate 2-4: Unnamed tributary flowing over sandy/gravelly riverbed (Mapumolo Area)

Plate 2-5: Unnamed tributary flowing through deeply incised channel in Sappi forestry area in Mshwati

Plate 2-6: Unnamed tributary flowing over bedrock in Msunduzi Area.

Plate 2-7: Unnamed tributary in a high energy depositional environment (Kwadwengu,Mkhambatini Area).

Plate 2-8: Unnamed tributary flowing over bedrock (Gulube, Mkhambatini Area)

Available Surface Water Data

The EWR data including locations of sites and surface water reserve determinations for these sites was made available by DWA. Stream flow data (WR2005) was downloaded from the DWA website for the generation of hydrographs and estimation of the baseflow component of river flow contributed by groundwater. Figure 2-18 shows the EWR sites and the location of the streamflow gauges in the WMA. The surface water reserve determinations for the EWR sites are included as Appendix H and streamflow hydrographs using Herolds Baseflow Separation Method are included as Appendix I.

Topographical Elevation & Groundwater Elevation Difference

Groundwater levels were interpolated using the Bayesian method (due to good correlation between topographical elevation data and groundwater level elevation data). The interpolated groundwater levels (in mamsl) were deducted from the topographical elevations. The resulting difference data was mapped (contoured) across the WMA, and GIS layers for rivers, dams and wetlands were superimposed. This surface effectively mapped groundwater levels (in mbgl) across the catchment.

Where groundwater levels are observed to shallow towards surface water bodies, may represent areas of potential surface water/groundwater interaction. Groundwater levels between 2 and 10 mbgl are observed in a roughly parallel alignment with the coastline of the WMA and tend to follow the major river courses upstream e.g. Mvoti River, Mdloti River, Mngeni River, Lovu River, Mkomazi River, Mzimkhulu River, Mtamvuna River etc. Figure 2-19 shows these relationships.

Selection of Sites for Assessment of Potential Surface Water/Groundwater Interaction

The groundwater level data distribution was scrutinised around major surface water bodies which included rivers and wetlands. The following sites were selected where groundwater level data was more available than the remainder of the WMA, transecting both sides of the surface water body with the exception of the cross section for the Allerthorpe Wetland which only transects one side:

- Allerthorpe Wetland (U20C);
- Mvoti Vlei (U40A);
- Unnamed tributaries of Nonoti River (U50A);
- Wetland alond the Ntshambili River (U80A); and
- Wetland along the Mzumbe River (U80C).

The Allerthorpe Wetland is located in the U20C quaternary catchment in close proximity of Midmar Dam. The cross section extends across a distance of 500 m with the groundwater elevation ranging from 1055 mamsl (A) to 1060 mamsl (B). The groundwater gradient is at 0.01 and slopes towards the wetland indicating potential for hydraulic connectivity between groundwater and the wetland. Figure 2-20 shows these relationships.

The Mvoti Vlei is located in the U40A quaternary catchment near Greytown and the cross section (which extends across a distance of 4 km) transects both sides of the wetland. The groundwater level decreases from 965 mamsl (A) to 935 mamsl (centre of the wetland) and rises to 1045 mamsl (B). The gradient slopes towards the centre of the wetland from both directions indicating good potential for hydraulic connectivity between the groundwater and the wetland. Refer to Figure 2-21.

For the unknown tributaries of the Nonoti River (site located in U50A quaternary catchment), the cross section extends across a distance of 900 m and transects the tributaries on both sides (before the confluence). The groundwater level decreases from 110 mamsl (B) to 70 mamsl (A). A steeper gradient is observed from B towards the confluence of the tributaries where the gradient becomes very flat, indicating good potential for hydraulic connectivity between the groundwater and the tributaries. Refer to Figure 2-22.

The cross section for the Ntshambili River (located in the U80A quaternary catchment) near Port Shepstone extends across a distance of 350 m. The groundwater level ranges from 15 mamsl (A) to 20 mamsl (B), however the difference between the topographic and the groundwater elevation surface occurs in the range between 60 to 80 m, thereby reducing the potential for hydraulic connectivity between groundwater and the river. Figure 2-23 shows these relationships.

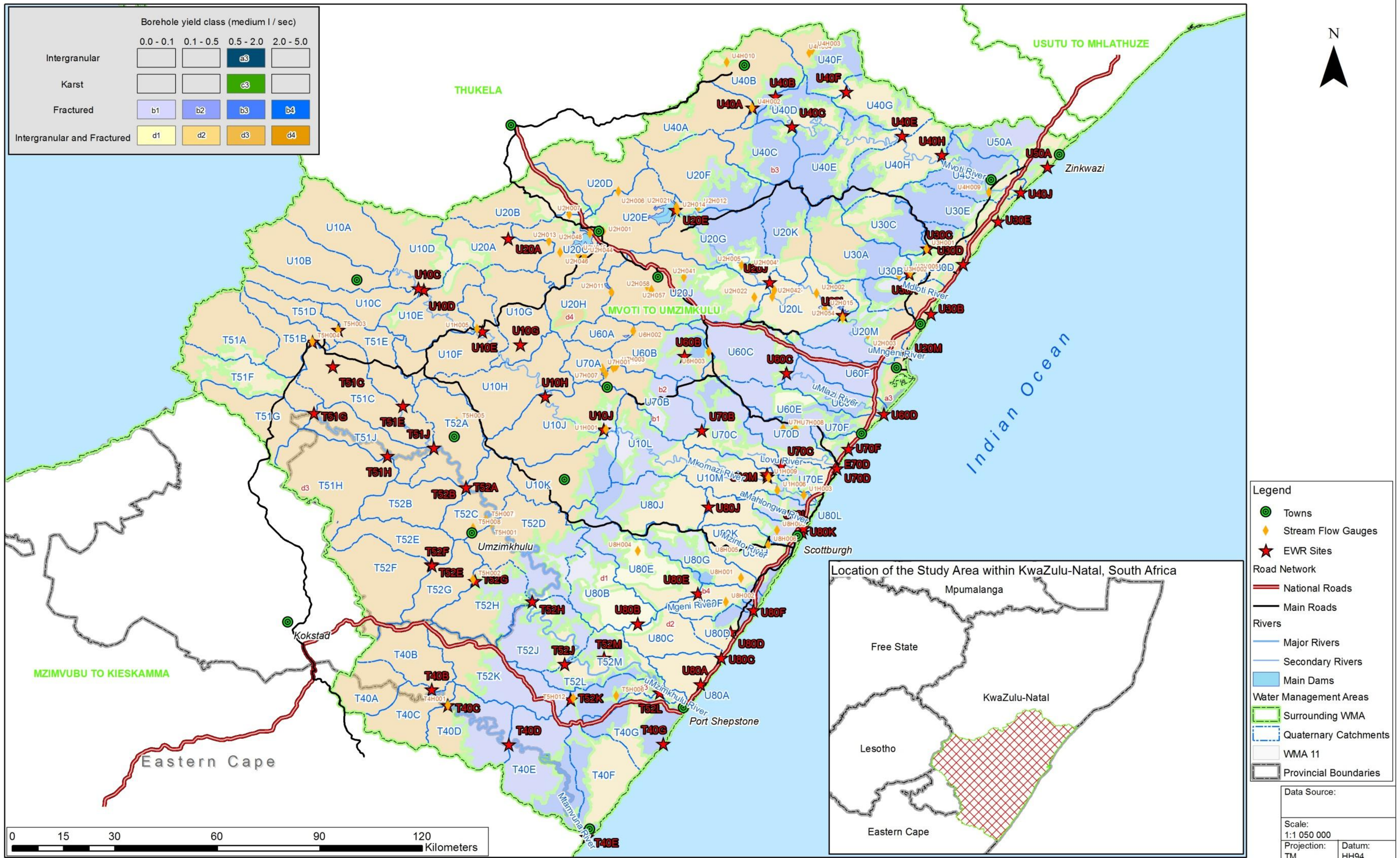
The cross section across a wetland along the Mzumbe River (U80C quaternary catchment) extended 750 m and transected both sides of the wetland. The groundwater elevation surface is observed to shallow significantly towards the wetland from both sides indicating good potential for hydraulic connectivity between the groundwater and the wetland. Refer to Figure 2-24.

Baseflow Estimation per Quaternary

Various sources of data were considered for the estimation of baseflow for the WMA. These included:

- Surface Water Reserve Determinations for EWR Sites;
- Assessment of stream flow data using Herold's baseflow separation method;
- Baseflow estimates made during the GRAII Assessment,
- Baseflow estimates included in the GRDM software, and
- Estimates Hughes, Pitman, Schultz and Van Tonder.

For consideration of average baseflow figures, only GRAII, GRDM, Hughes, Pitman, Schultz and Van Tonder estimates were used. The EWR and Herold's baseflow estimate were inconsistent and were often in orders of magnitude of the total recharge available for the quaternary. The average baseflow were represented on a quaternary scale for the entire WMA, in order to quickly assess the dependence of surface water systems on groundwater. The average baseflow (Mm^3/a) per quaternary is 12.5 Mm^3/a. Estimates range from 2.68 Mm^3/a (U70F) to 34.57 Mm^3/a (U10A).The higher baseflow values can be observed in the middle to upper reaches of the Mkomazi, Mzimkhulu, Mngeni and Mvoti Rivers and quaternaries T40G and T40F located between Port Shepstone and Port Edward along the coastline. Figure 2-24 shows the baseflow estimates per quaternary in the WMA.



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GRDM WMA 11 - MVOTI TO UMZIMKHULU

EWR Sites and Stream Flow Gauges

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Figure 2-18: EWR Sites And Streamflow Gauges

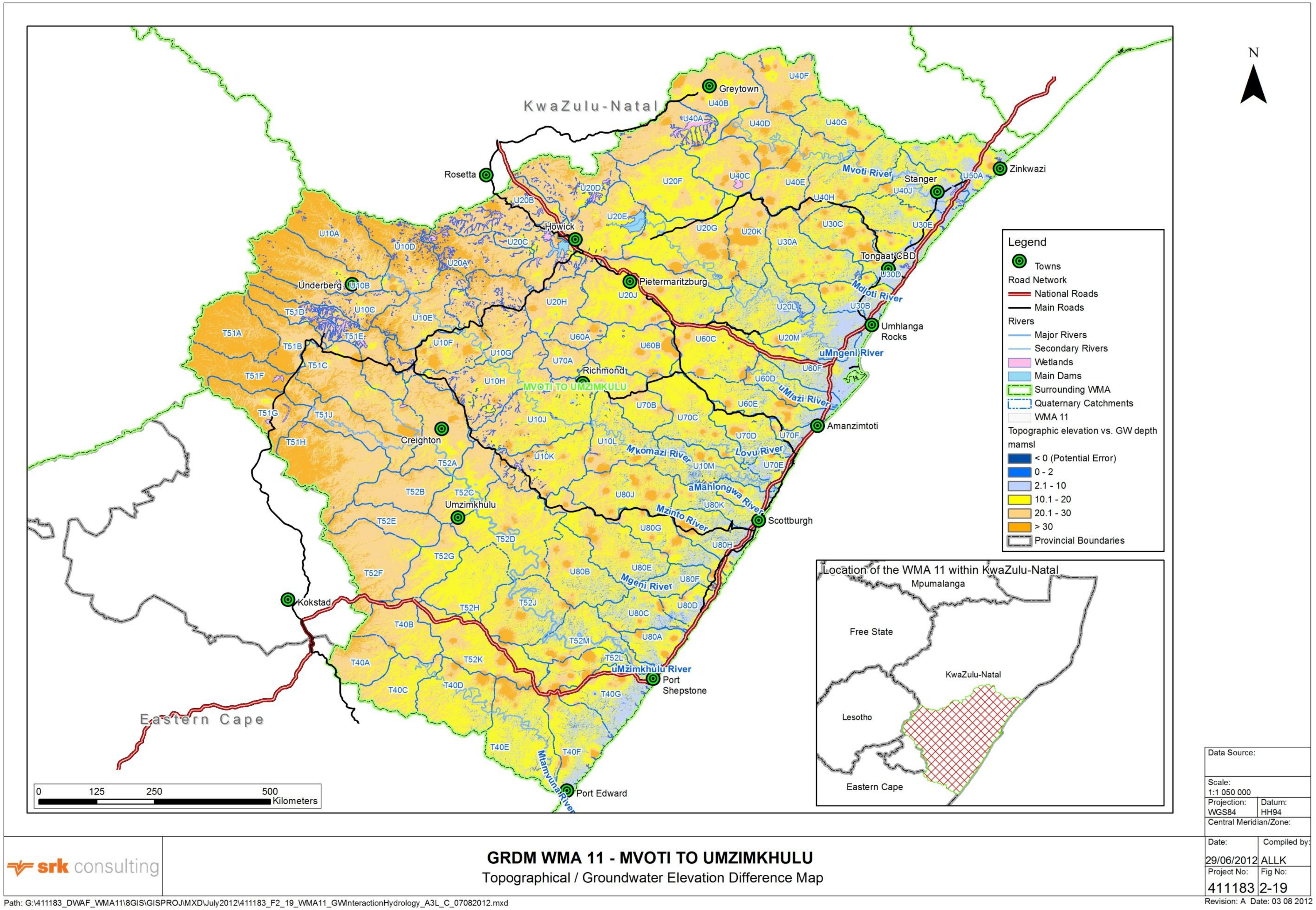

Figure 2-19: Topographical / Groundwater Elevation Difference Map

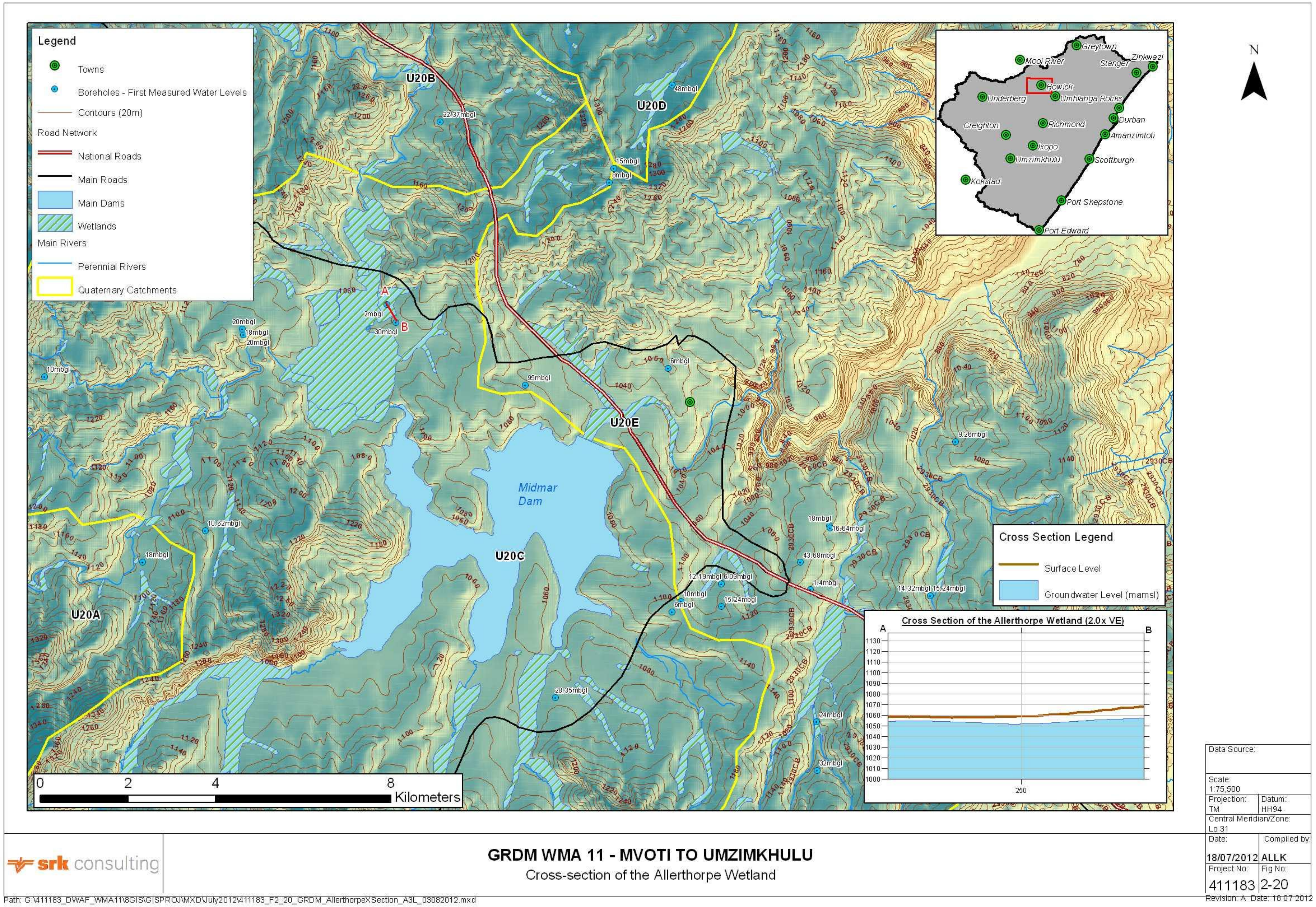

Figure 2-20: Cross-section of the Allethorpe Wetland-U20C

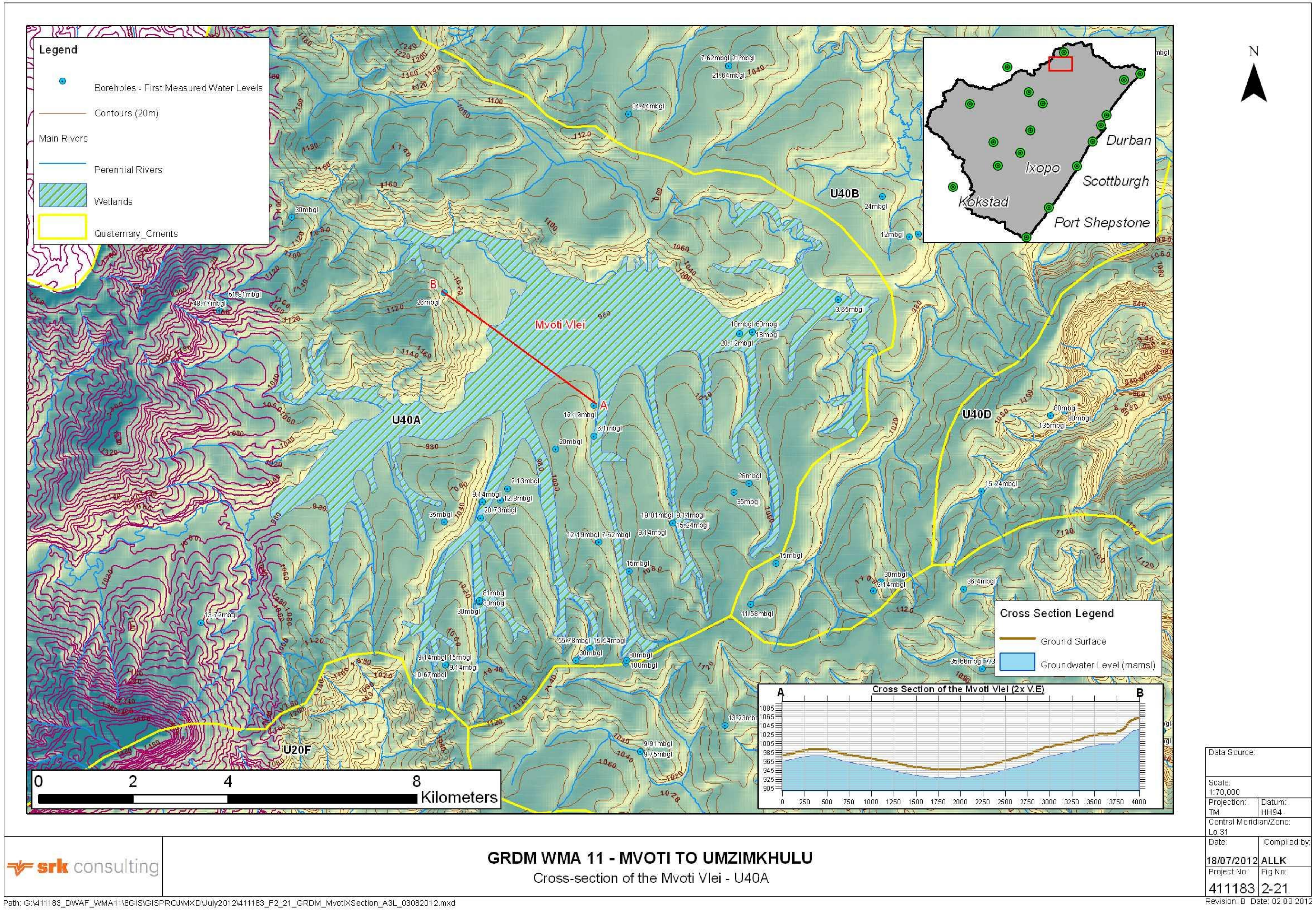

Figure 2-21: Cross-section of the Mvoti Vlei-U40A

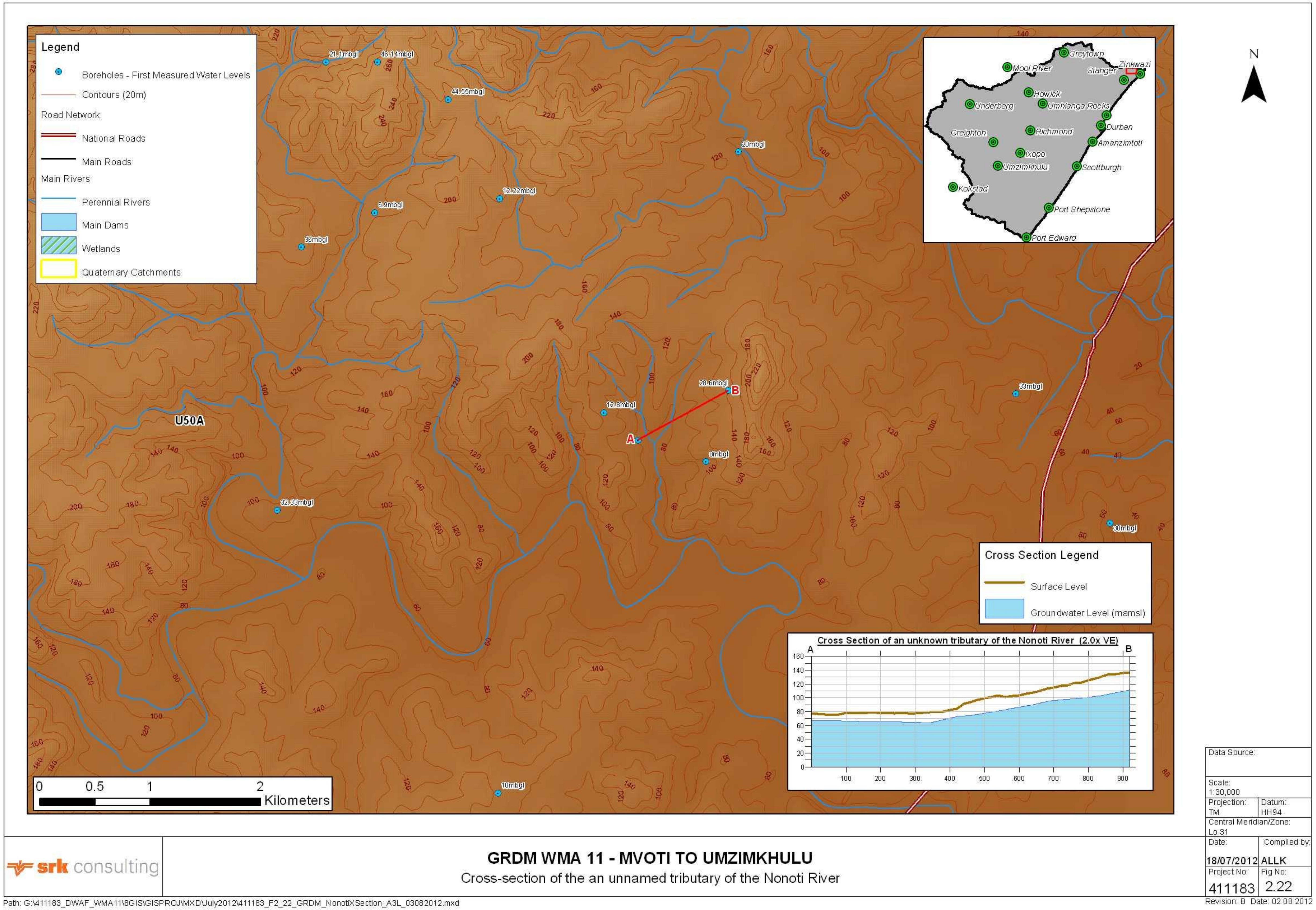

Figure 2-22: Cross-section of an unnamed tributary of the Nonoti River - U50A

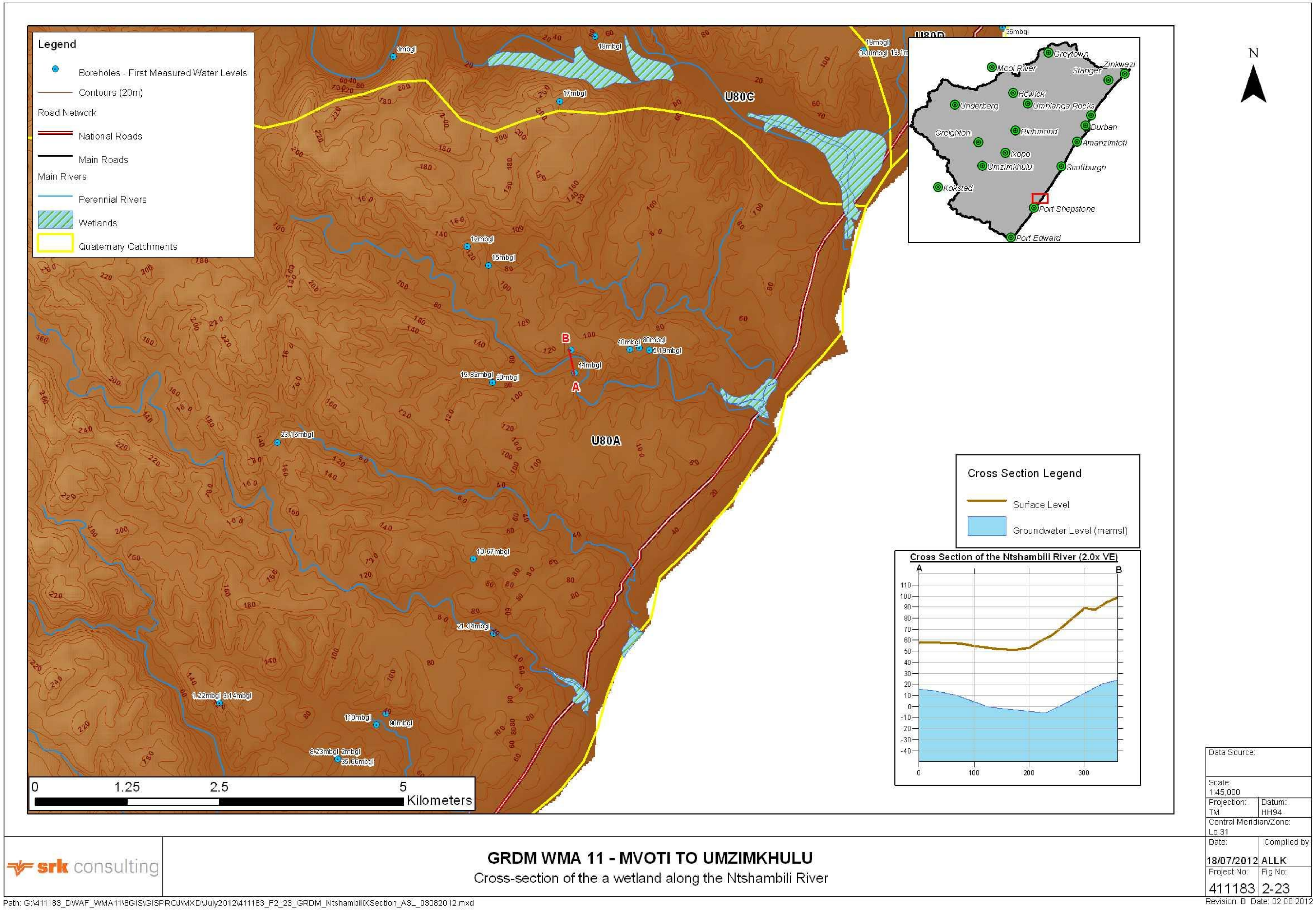

Figure 2-23: Cross-section along the Ntshambili River - U80A

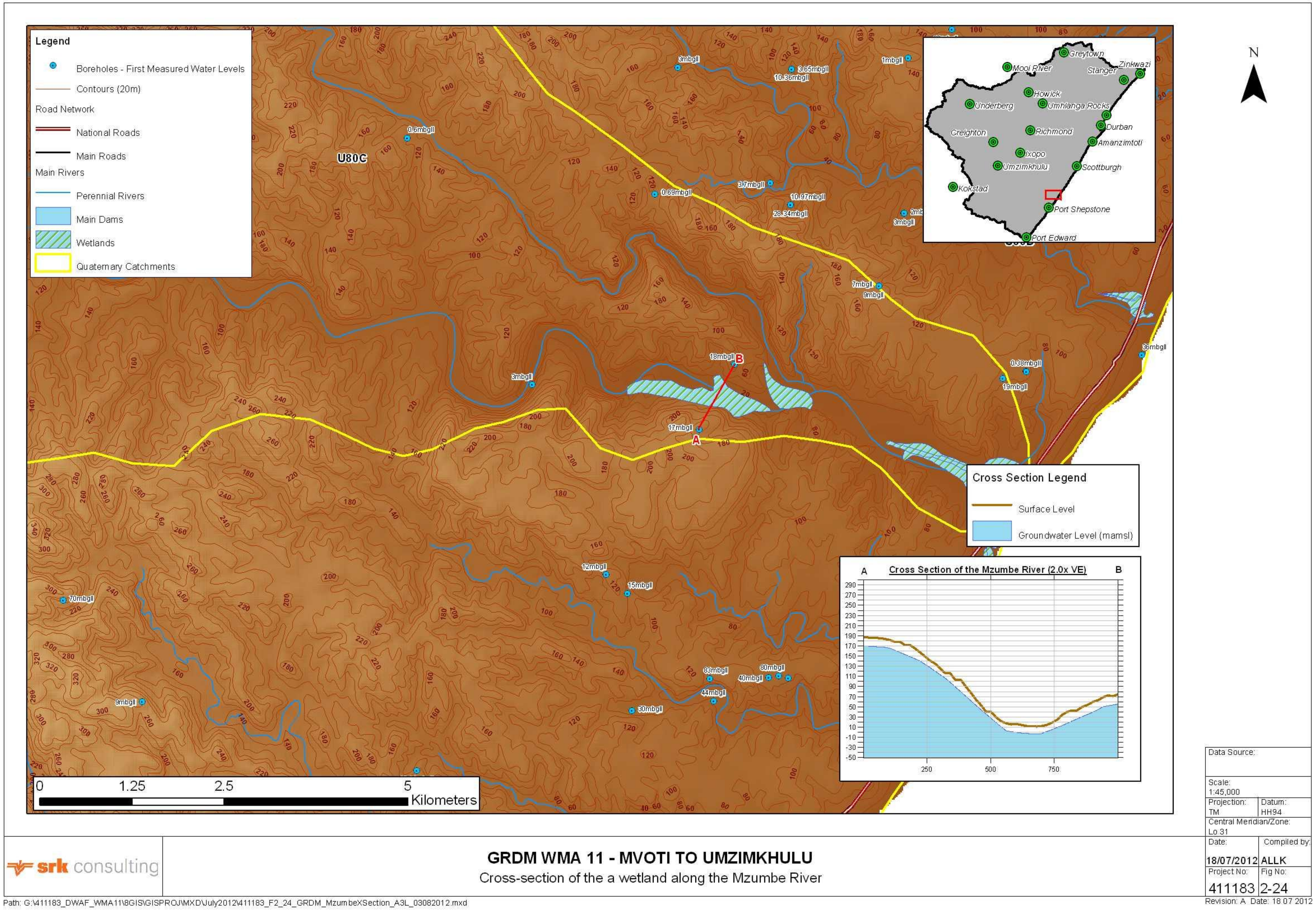

Figure 2-24: Cross-section of the wetland along the Mzumbe River - U80C

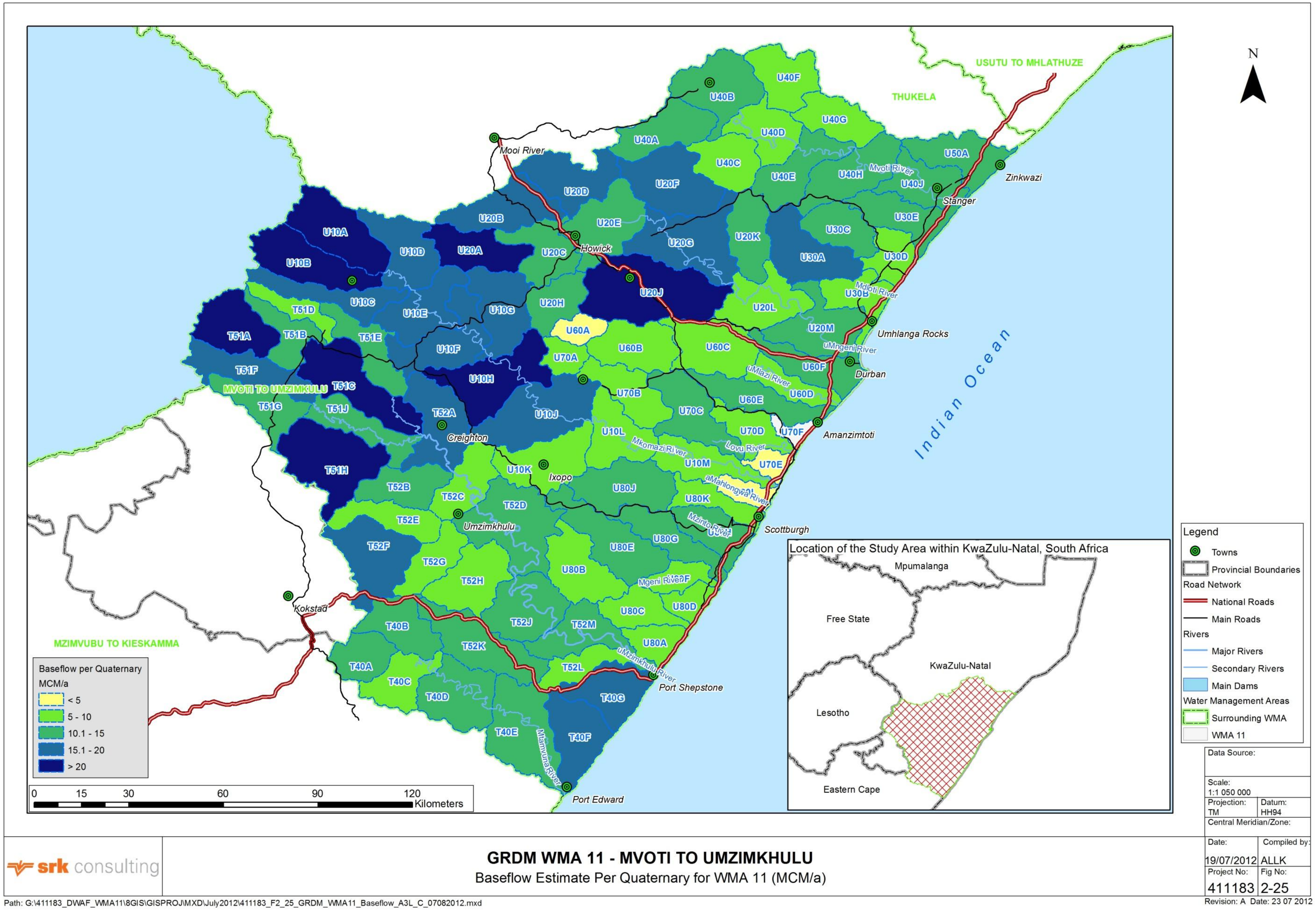

Figure 2-25: Baseflow Estimate Per Quaternary for WMA 11 (MCM/a)

2.8 Land Use

The Mvoti to Umzimkhulu WMA comprises grasslands and is largely undeveloped (rural land use). Urban land use in the WMA is concentrated along the coast from Umhlanga Rocks in the north to Port Edward in the south and the metropolitan areas of Durban and Pietermaritzburg. Agricultural farming in the form of sugar cane plantations are predominantly cultivated along the coast (Tongaat-Stanger) and intermittently in the interior. Afforestation is practised in the vicinity of Greytown-Howick, Richmond and the southeastern portion of the WMA. Indigenous forests and wetlands are sparse and sporadically distributed across the WMA. The different land use sectors in the WMA are presented in Figure 2-26.

2.9 Stream Flow Reduction (SFR)

2.9.1 Background

Stream Flow Reduction (SFR) can be defined as the process whereby any land based activity decreases/diminishes the amount of water that would normally be available. These activities include afforestation and alien vegetation.

Initial studies were done by CSIR Division of Water, Environment and Forestry Technology to address concerns regarding the impact of afforestation (pine, wattle and eucalyptus) on the amount of water available to rivers and streams. Studies did show that plantations do reduce the total runoff from catchments in proportion to the area planted and depending on the tree type. Studies also showed that the reduction in low (dry season) runoff is somewhat greater than for the total annual runoff. Commercial forestry is estimated to reduce total runoff in South Africa by 3.2% (1 417 x 106 m3/yr) and Mean Annual Low flow, ((MALf) the flow in the driest three months of the average year)) by7.8% (101 x 106 m3/yr). The stream flow reduction curves were developed around non-riparian conditions by use of an adjustment factor. (Scott & Le Maitre, 1998). Estimates of runoff reduction are tabled below (Table 2-9) for the primary catchments and thereafter on a provincial level (Table 2-10). The relevant areas are highlighted. Table 2-11 provides estimates of reduction in total annual and low flow according to the plantation species.

Table 2-9: Reduction in MAR for commercial plantations (Scott & Le Maitre, 1980)

TABLE 5
THE AREA OF COMMERCIAL PLANTATIONS IN EACH PRIMARY CATCHMENT AND THE REDUCTION IN MAR (PERCENTAGE OF TOTAL AND LOW FLOW) ATTRIBUTED TO PLANTATIONS. THE IMPACTS OF FORESTRY IN SWAZILAND HAVE BEEN EXCLUDED AND CATCHMENTS AFFECTED BY THIS ARE INDICATED BY AN ASTERISK (*) IN THE TABLE
(ADAPTED FROM LE MAITRE ET AL., 1997)

Primary catch-ment	River system	Catchment area (ha)	Mean annual (mm)			Plantation area (ha)	Runoff reduction (%)	
			Precipitation	Total flow	Low flow		Total flow	Low flow
A	Limpopo	10 873 287	528	22	0.783	20 994	0.886	1.817
B	Olifants	7 350 308	625	40	1.576	88 055	3.712	11.228
C	Vaal	19 628 409	525	23	0.298	1 666	0.013	0.014
D	Orange	37 824 180	254	7	0.085	957	0.015	0.009
E	Olifants (W Cape)	4 906 252	213	21	0.078	1 000	0.152	0.205
F	Namaqualand	2 850 622	128	1	0.000	0	0.000	0.000
G	W Cape coast	2 524 374	477	81	0.877	16 442	1.732	3.205
H	Breede & SW Cape coast	1 551 872	544	135	1.916	5 031	0.428	1.159
J	Gouritz	4 513 434	260	15	0.107	184	0.030	0.012
K	S Cape coast	716 825	756	181	9.659	75 616	9.446	12.327
L	Gamtoos	3 473 106	283	14	0.166	9 027	1.373	1.681
M	Port Elizabeth region	261 157	555	57	0.508	6 055	2.746	2.816
N	Sundays	2 122 532	330	13	0.025	0	0.000	0.000
P	E Cape coast	530 807	561	33	0.123	628	0.080	0.251
Q	Gt Fish	3 022 811	410	17	0.162	7 640	0.549	1.875
R	Border coast	791 831	675	73	1.306	14 891	1.359	2.869
S	Great Kei	2 048 308	610	51	1.386	23 385	1.600	2.762
T	Transkei region	4 648 239	857	158	4.908	203 045	2.813	3.367
U	S KwaZulu-Natal	1 829 157	928	171	6.898	199 994	4.848	5.810
V	Tugela	2 902 399	824	137	3.126	22 628	0.392	0.468
W*	N KwaZulu-Natal & Mpumalanga highveld	4 507 461	825	105	4.133	403 150	5.929	8.820
X*	Mpumalanga escarpment	2 857 158	769	100	6.901	336 294	14.801	22.383
South Africa		121 734 527	448	37	1.069	1 436 684	3.162	7.795

Table 2-10: Reduction in MAR for commercial plantations per province(Scott & Le Maitre, 1980)

TABLE 7
SUMMARY TABLE BY PROVINCE OF THE AREA OF COMMERCIAL PLANTATIONS AND THE REDUCTION IN MEAN TOTAL RUNOFF AND LOW FLOW (PERCENTAGE OF VIRGIN) ATTRIBUTED TO PLANTATIONS IN EACH PROVINCE. THE NORTH WEST AND NORTHERN CAPE PROVINCES HAVE NO AREAS UNDER COMMERCIAL PLANTATIONS (FROM LE MAITRE ET AL., 1997)

Province	Area (ha)	Mean annual (mm)			Plantation area		Runoff reduction (%)	
		precipi-tation	total flow	low flow	(ha)	(%)	total flow	low flow
Eastern Cape	16 974 730	552	61	1.675	232 288	1.368	2.312	3.583
Free State	12 993 572	532	27	0.265	2 413	0.019	0.026	0.031
Gauteng	1 651 904	670	33	2.134	17	0.001	0.001	0.001
KwaZulu-Natal	9 212 465	844	131	4.324	468 208	5.082	2.826	4.469
Mpumalanga	7 957 055	730	79	4.001	575 882	7.237	9.867	18.150
North West	11 601 009	451	9	0.193	0	0.000	0.000	0.000
Northern Cape	36 198 066	202	3	0.000	0	0.000	0.000	0.000
Northern Province	12 214 309	534	28	0.864	78 169	0.640	2.477	8.980
Western Cape	12 931 417	346	51	0.796	79 706	0.616	1.959	6.024
South Africa	121 734 527	448	37	1.069	1 436 684	1.180	3.162	7.795

Table 2-11: Reduction in Total Flow and Low Flow according to Plantation Species (Scott & Le Maitre, 1980)

TABLE 9
AN ANALYSIS OF THE SENSITIVITY OF THE MODELLING RESULTS TO DIFFERENT ALLOCATIONS OF THE FLOW REDUCTION CURVES TO PLANTATION AREAS (PLANTATION AREA AND ROTATION LENGTHS ARE FIXED)

Species group	Forestry potential	Rainfall class mm	Reduction model	Applicable plantation area (ha)	Reduction in total flow (mm)	Reduction in low flow (mm)
Using current rules: recommended						
Wattle	<80%	<1 000	Short-lag	74 592	50.37	2.3383
Wattle	<80%	>1 000	Long-lag	2 460	11.75	0.5790
Wattle	≥80%	all	Short-lag	33 952	51.67	2.3780
Pine	<80%	<1 000	Short-lag	434 363	98.11	5.6533
Pine	<80%	>1 000	Long-lag	57 671	106.65	5.8568
Pine	≥80%	all	Short-lag	327 862	151.22	12.1334
Eucalypt	<80%	<1 000	Short-lag	285 278	64.70	4.4699
Eucalypt	<80%	>1 000	Long-lag	20 075	44.15	7.3779
Eucalypt	≥80%	all	Short-lag	200 432	92.26	8.4570
Total				1 436 684	98.65	7.06
Scenario 1: If forestry potential ≥80% then use short-lag curve, otherwise use long-lag curve						
Wattle	<80%	all	Long-lag	77 051	6.79	0.4528
Wattle	≥80%	all	Short-lag	33 952	51.67	2.3780
Pine	<80%	all	Long-lag	492 034	47.82	3.1549
Pine	≥80%	all	Short-lag	327 862	151.22	12.1334
Eucalypt	<80%	all	Long-lag	303 353	20.28	2.6556
Eucalypt	≥80%	all	Short-lag	200 432	92.26	8.4570
Total				1 436 684	69.72	5.68
Scenario 2: Use the short-lag curves for all commercial plantations						
Wattle	all	all	Short-lag	111 003	51.82	2.3706
Pine	all	all	Short-lag	819 895	128.11	8.6181
Eucalypt	all	all	Short-lag	505 785	78.51	6.4114
Total				1 436 684	104.76	7.36

2.9.2 Mvoti to Mzimkhulu Area

For this Mvoti to Mzimkhulu Study, the percentage cover of forestry per quaternary has been determined. Approximately13.78% of the total WMA area is under forestry although the plantation species data for these areas was not available for this study, in order to better assess the potential impact from stream flow reduction activities.

Table 2-12: Summary of forestry cover per quaternary

Forestry Cover	No of QCs	% of QCs
<1%	13	14.4
>1-10%	42	46.6
>10-20%	15	16.6
>20-30% (T52A, U80E, U10K, T52K, T52E, T52C, U10J)	7	7.7
>30-40% (T52F, U10H, U20E, U20D,U40C)	5	5.55
>40-50% (U70B, U60A, U20F)	3	3.33
>50% (U40F,T40B,U40B,U40A,U70A)	5	5.55

2.9.3 WR2005 (Middleton & Bailey, 2009)

The Water Research Commission (WRC) commissioned the Water Resources of South Africa, 2005 Study (WR2005) in 2004 which had project duration of three years. Besides an update of WR90 data, WR2005 has incorporated various other organisations and user groups and developed tools through WRSM2005 that are essential for water resources management, planning and operational practitioners, researchers and decision makers.

Stream Flow Reduction (SFR) was identified as a water resource issue and the WRSM2005 allowed for catchment absorption processes such as alien vegetation and afforestration.

A comparative assessment of WR90 and WR2005 naturalised MAR was made for all WMAs in South Africa. Differences in the naturalised flows between 1990 and 2005 were ascribed to amongst others:

- The effect of climate variations with WR2005 rainfall being extended from 1989 to 2004;
- The use of flow records in WR2005 that were not available or too short in the WR90 study; and
- Enhanced methods for analysing irrigation, afforestation and alien vegetation.

Flows showed a percentage change for Mzimkhulu (T50) and Mkomaas (U10) catchments at -1% and -4% respectively. However, the remaining catchments show increased flows across this period and the net change in naturalised flow for the WMA is zero.

The flow data for Mvoti to Mzimkhulu WMA are shown below (Table 2-13).

Table 2-13: Comparison of Naturalised MAR between WR90 and WR2005 Studies

Catchment	MAR (Mm^3/a)		
	1990	2005	% change
T40-Mtamvuna	419.40	437.63	4
T50-Mzimkhulu	1381.80	1372.60	-1
U10-Mkomaas	1089.5	1045.4	-4
U20-Mngeni	739.9	738.03	0
U30-Mdloti	240.2	246.54	3
U40-Mvoti	352.60	358.54	2
U50-Nonoti	59.50	59.73	0
U60-Mlazi	172.60	181.51	5
U70-Lovu	138.60	142.06	2
U80-Mtwalume	334.80	340.38	2
Total	**4928.90**	**4922.42**	**0**

In order to better gauge the impacts of stream flow reduction activities on the Mvoti to Mzimkhulu WMA, there needs to be closer interaction with the relevant working groups addressing these concerns.

2.10 Population

According to DWAF, (2004), 5.1 Million people inhabit the WMA. Nearly 70% of the population is concentrated within the Mgeni River catchment of which ~ 85% of the population is situated in the Ethekweni and Pietermaritzburg metropolitan area. With regards to the entire WMA, 68% and 32% of the population are classified as urban and rural respectively. Census data will be available for 2011 following the national July 2011 census. However, it is unlikely that the results will be released during the course of this project. Two approaches were taken in attempting to estimate the population figures for 2010. Firstly population growth rates estimated and projected by Statistics South Africa (Stats SA) up to 2010 were used and projected a population estimate of 8.24 Million in the year 2010 which can be considered an overestimate. These data are provided in Table 2-14.

Table 2-14: Projected population growth rates (Stats SA, 2010)

Period	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009-2010
Male	1,53	1,43	1,34	1,30	1,27	1,25	1,26	1,25	1,18
Female	1,29	1,18	1,08	1,03	1,00	0,99	1,00	1,01	0,94
Total	**1,40**	**1,30**	**1,21**	**1,16**	**1,13**	**1,11**	**1,13**	**1,12**	**1,06**

Secondly, Census 2007 data (this data is used by the respective municipalities for planning purposes, as part of their Integrated Development Plan (IDP)) placed the population estimate at 6.23 Million in the WMA, however this was a sum of the population figures in the respective municipalities. The population per quaternary was estimated using Census 2007 data and using the DWAF 2004 estimate as a startpoint, the average growth rate per quaternary was calculated and used to project population figures to 2011. The population growth rates ranged across the quaternaries from 1.8 to 5.6 % (U40A,B and F). The population based on this approach has been projected to 6.84 Million which has been used to determine the Basic Human Needs Reserve per quaternary. Figure 2-27 shows the population distribution per quaternary. The largest populations are easily observed to lie within the Durban – Pietermaritzburg Metropolitan Areas.

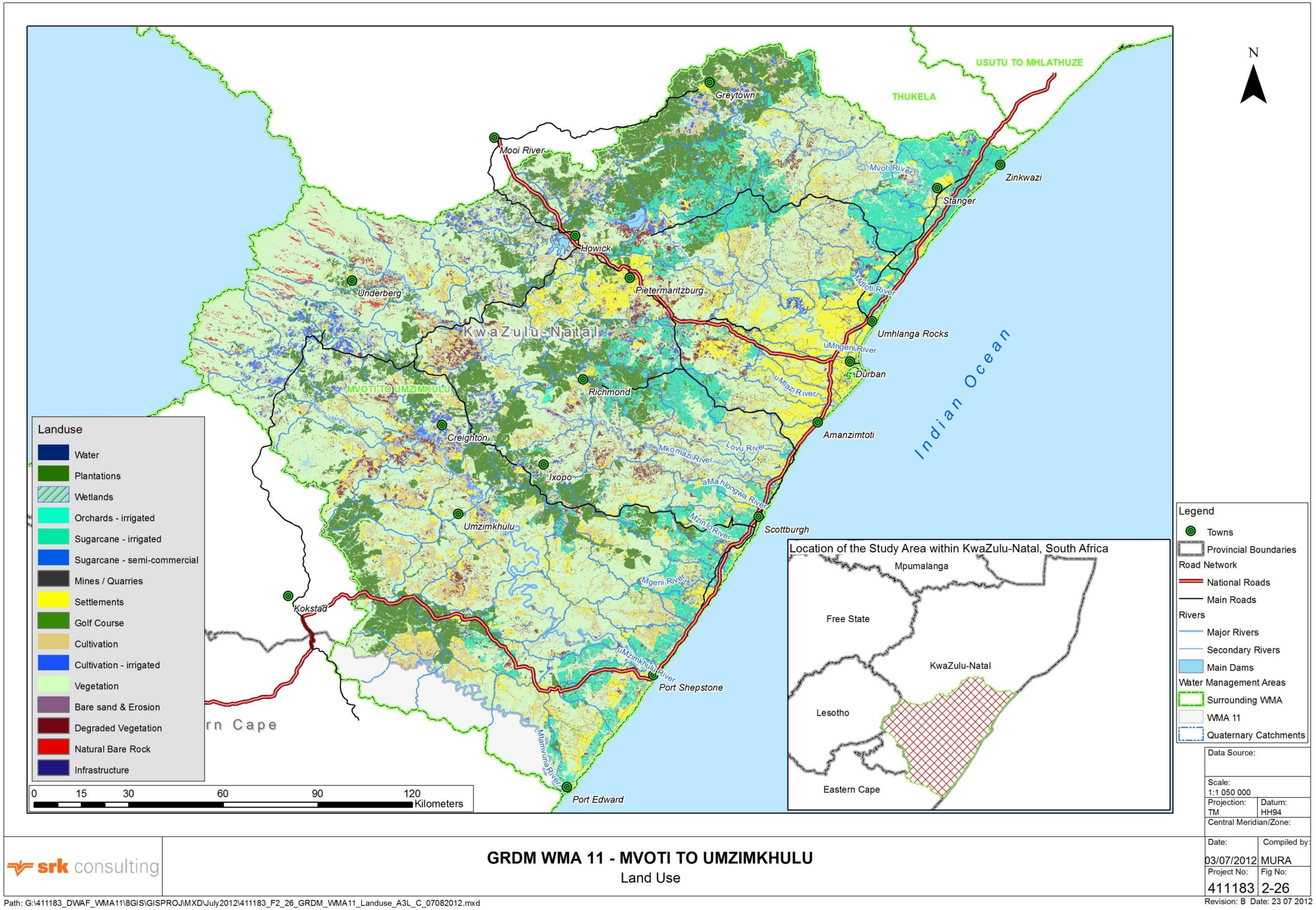

Figure 2-26: Land Use.

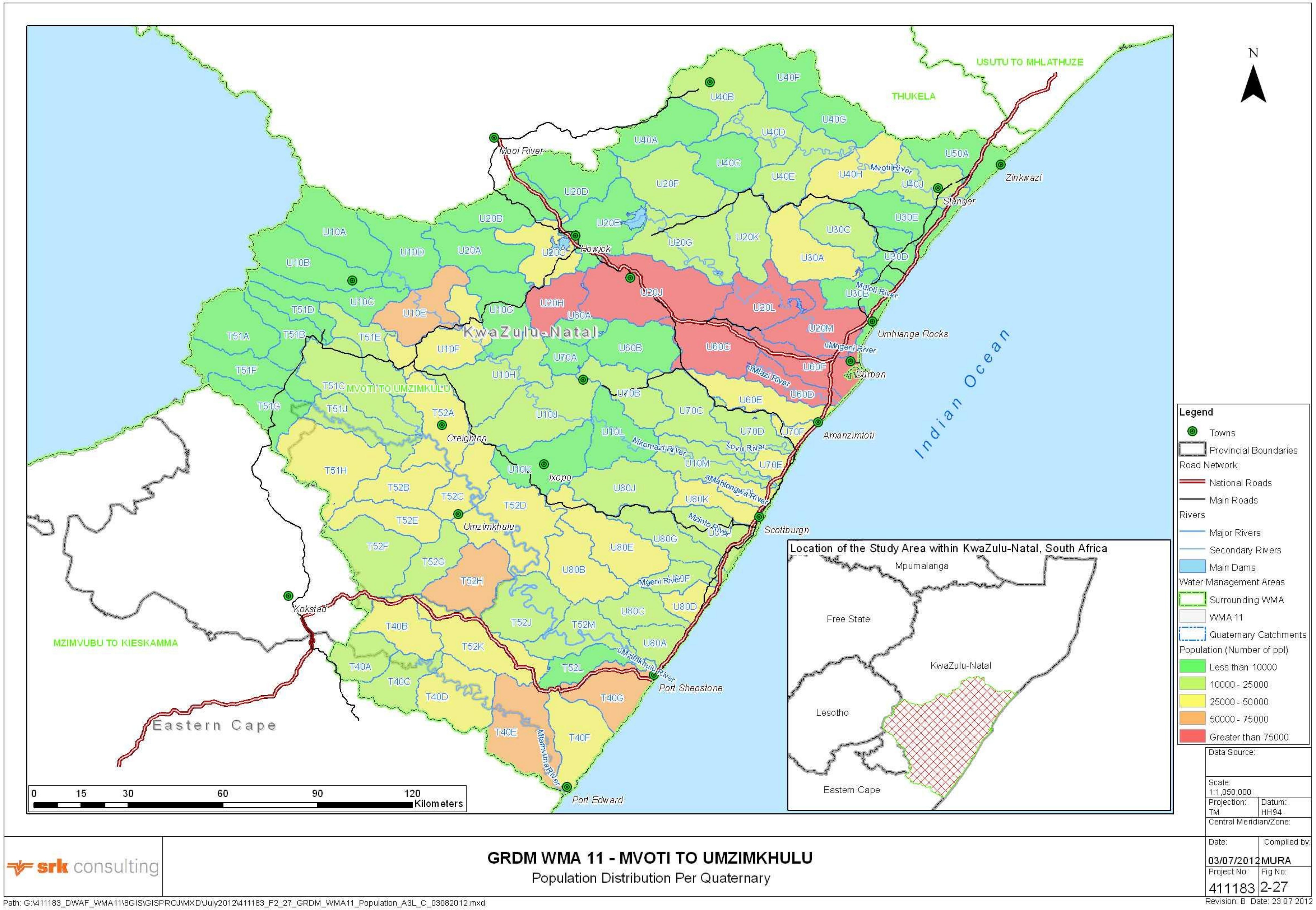

Figure 2-27: Population Distribution per Quaternary

3 Delineation of Groundwater Resource Units

According to the DWA (2011), the groundwater resource can be defined according to:

- The possible geographical extent of the study area and a brief description thereof;
- The role of groundwater in terms of sustaining other components of the hydrological system (baseflow to rivers, wetlands and estuaries);
- The degree of groundwater dependence (both social and environmental), including volumes of groundwater abstracted;
- Any identified aquifer stresses (quantity and quality); and
- Hydrogeological data and information available.

In consultation with the DWA, a tiered approach comprising consideration of primary, secondary and tertiary criteria has been used for the delineation of Groundwater Resource Units (GRUs) for the WMA and is detailed in the subsections below.

3.1 Primary Level of Delineation

3.1.1 Quaternary Catchments

- Ninety (90) quaternaries are present in WMA 11;
- Each quaternary unit constitutes the basic building block of the Groundwater Resource Unit (GRU[2]);
- Information and data are to be represented on a quaternary level to preserve completeness of datasets;
- Division of quaternaries creates inherent difficulties in the representation of datasets and results in the averaging of trends especially in areas where data is sparse; and
- Management of GRU's by Catchment Management Agencies (CMAs)/ Water User Associations (WUAs), etc. which include divided quaternary units with irregular boundaries, is both impractical and challenging.

3.2 Secondary Level of Delineation

3.2.1 Geological

- The geology of the Mvoti to Mzimkhulu WMA consists of a diverse assemblage of rock types. These lithological units consist of the structurally deformed and highly metamorphosed basement rocks of the Namaqua-Natal Province which is overlain by the sedimentary formations of the Natal Group which lie in a roughly parallel distribution pattern with the coastline. Cenozoic age deposits of marine, fluvial and aeolian derivation are also common along the coast of the WMA;
- The Karoo Supergroup dominates in one broad band; and
- The interior of the WMA is characterised by Jurassic age dolerite dykes and sills intruding into the preceding sedimentary deposits.

3.2.2 Hydrogeological

- The WMA is dominated by two aquifer types, namely, integranular & fractured and fractured;

[2] Groundwater Resource Units are areas within which geological, aquifer and groundwater characteristics are broadly similar

- Integranular and fractured aquifers are prevalent in the sedimentary formations of the Karoo Supergroup and the metamorphic rocks of the Namaqua-Natal Province;
- Fractured aquifers are prevalent in the Natal Group;
- A single occurrence of a karst aquifer is located near Port Shepstone. This is known as the Marble Delta and spans roughly 20 km^2. It has been reported that dewatering of groundwater does occur in order to enable mining and groundwater is also used for dust suppression, although exact quantities are not known; and
- There is good correlation between the topography and groundwater elevations (Bayesian relationship) and the groundwater surface mimics topography, indicating broadly unconfined conditions in the aquifers.

3.2.3 Hydrological

- The WMA contains four major rivers, namely, Mvoti (U40), Mgeni (U20), Mkomazi (U10) and Mzimkhulu (T52 & T51);
- Smaller rivers include Nonoti (U50), Mdloti (U30), Mlazi (U60), Lovu (U70),Mtamvuna (T40);
- Tertiary catchment U80 is drained by the Mzumbe, Mtwalume and Mpambanyoni rivers;
- The Tertiary catchments listed above have been described as water use sectors in previous studies and assessments which are listed below:
  - Water Resources Situation Assessment (DWAF, 2003) was conducted to collate all information pertaining to water requirements, availability and usage and subsequently develop a National Water Resource Strategy to protect, use, manage and control water resources in the WMA. Twelve Key Areas associated with secondary catchment boundaries were detailed although the Mzimkhulu, Mkomazi and the Mgeni were further subdivided into upper and lower catchment areas;
  - Mvoti to Mzimkhulu Water Management Area: Overview of Water Resources Availability and Utilisation (DWAF, 2003). In order to improve the representation of the water resources situation in the WMA, five sub-areas where identified. These included: Mvoti sub-area (between Tugela and Umgeni Rivers), Mgeni sub-area (between Mgeni and Mkomazi Rivers); Mkomazi sub–area; Mzimkulu sub-area, Coastal sub-area (between Mkomazi and Mtamvuna River, including the Mtamvuna River); and
  - Mvoti to Mzimkhulu WMA-Internal Strategic Perspective (DWAF, 2004) served as a guide to water management and water use licensing in the WMA. Eight Key Areas were identified which included: Mvoti (catchments U40 and U50); Mdloti (Tertiary catchment U30); Mgeni (Tertiary catchment U20); Mlazi and Lovu (Tertiary catchments U60 and U70); Mkomazi (Tertiary catchment U30); South Coast (Tertiary catchment U80); Mtamvuna (Tertiary catchment T40) and Mzimkhulu (Tertiary catchments T51 and T52).
- Within the WMA, secondary drainage region boundaries create eleven (11) distinct areas which include: Nonoti River (U50); Mvoti River (U40); Mdloti River (U30); Mgeni River (U20); Mlazi River (U60); Lovu River (U70); Mkomazi River (U10); Mzumbe, Mtwalume and Mpambanyoni rivers (U80); Mzimkhulu River (T52 and T51) and Mtamvuna (T40).

3.2.4 Groundwater abstraction

Abstraction has been quantified for the WMA on a quaternary level based on available and new data and have been discussed earlier in the report (Section 2.7.5 and represented in Figure 2-13). Accordingly, abstraction on a quaternary level ranges largely <0.06 to 2 Mm^3/a. Increased abstraction in the range from 2.01 to 4 Mm^3/a, occurs in quaternaries U10F, U10J, U70B, U40B (includes the town of Greytown) and U40J (includes the town of Stanger). The highest groundwater abstraction occurs in quaternary U50A (includes the town of Zinkwazi).

3.2.5 Groundwater component of baseflow

An assessment of surface water/groundwater interaction and groundwater component of baseflow has been made in section 2.7.8. Due to the enormity of the study area, average baseflow figures per quaternary have been considered and include GRAII, GRDM, Hughes, Pitman, Schultz and Van Tonder estimates. The EWR and Herold's baseflow estimate were inconsistent and were often in orders of magnitude of the total recharge available for the quaternary. The average baseflow were represented on a quaternary scale for the entire WMA, in order to quickly assess the dependence of surface water systems on groundwater. The baseflow (Mm^3/a) per quaternary ranges from 2.68 Mm^3/a (U70F) to 34.57 Mm^3/a (U10A).The higher baseflow values can be observed in the middle to upper reaches of the Mkomazi, Mzimkhulu, Mngeni and Mvoti Rivers and quaternaries T40G and T40F located between Port Shepstone and Port Edward along the coastline. Representation of the baseflow estimates can be observed in Figure 2-24.

3.3 Tertiary Level of Delineation

3.3.1 District Municipality Boundaries; Local Municipal Boundaries, Water User Association Areas/ Irrigation Boards

- The WMA contains six (6) District Municipalities, namely, iLembe, Umzinyathi, Umgungundlovu, eThekwini, Ugu and Sisonke;
- The WMA contains twenty three (23) Local Municipalities;
- Both District and Local Municipal Boundaries are irregular and largely do not conform to natural boundaries such as quaternaries and rivers;
- Only three Water User Association (WUA) areas, namely, Nkonza (near Creighton), Upper Mlaas and Lower Lovu (positioned to the north and east of Richmond) are gazetted; and
- The Irrigation Boards are undergoing transformation into WUAs and these boundaries are likely to be further refined to encompass whole quaternaries.

3.4 Proposed Groundwater Resource Units

- Using geological and hydrogeological characteristics, the WMA can be divided into two sectors (an eastern and a western sector) by a line passing in an approximately northeast to southwest orientation. The eastern sector comprises fractured aquifers associated with the Namaqua-Natal Province and Natal Group geological units, whilst the western sector comprises geological units of the Karoo Supergroup that have been intruded by dolerite dykes and sills;
- Where fractured type aquifers intercept a quaternary, the entire quaternary has been included for delineation;
- This line does not dissect WUAs or Irrigation Board areas;
- Hydrological characteristics are then considered:
  - Historical assessments of the WMA i.e. Water Resources Situation Assessment (DWAF 2003), Overview of Water Resources Availability and Utilisation (DWAF 2003) and the Internal Strategic Perspective (DWAF, 2004), made use of secondary catchment boundaries to create water use sectors/key areas, in order to facilitate further discussion and develop strategies;
  - These secondary catchment boundaries were superimposed; and
  - The Upper Mlaas and Lower Lovu WUAs are separated by a secondary drainage region boundary.

A total of fifteen (15) GRUs have thus been proposed. WUAs form a part of the GRU and have not been considered as separate GRUs. Table 3-1 provides greater detail on the proposed GRUs and the affected quaternaries. Figure 3-1 shows the location of the GRUs.

Table 3-1: Groundwater Resource Units (GRUs)

Groundwater Resource Unit	Affected Quaternary
GRU1	T40A to C
GRU2	T40D to G
GRU3	T51A to J
GRU4	T52A to C, E to G
GRU5	T52D, H to M
GRU6	U10A to H
GRU7	U10J to M
GRU8	U20A to H
GRU9	U20F to M
GRU10	U30A to E
GRU11	U40A to J
GRU12	U50A
GRU13	U60A to F
GRU14	U70A to F
GRU15	U80A to L

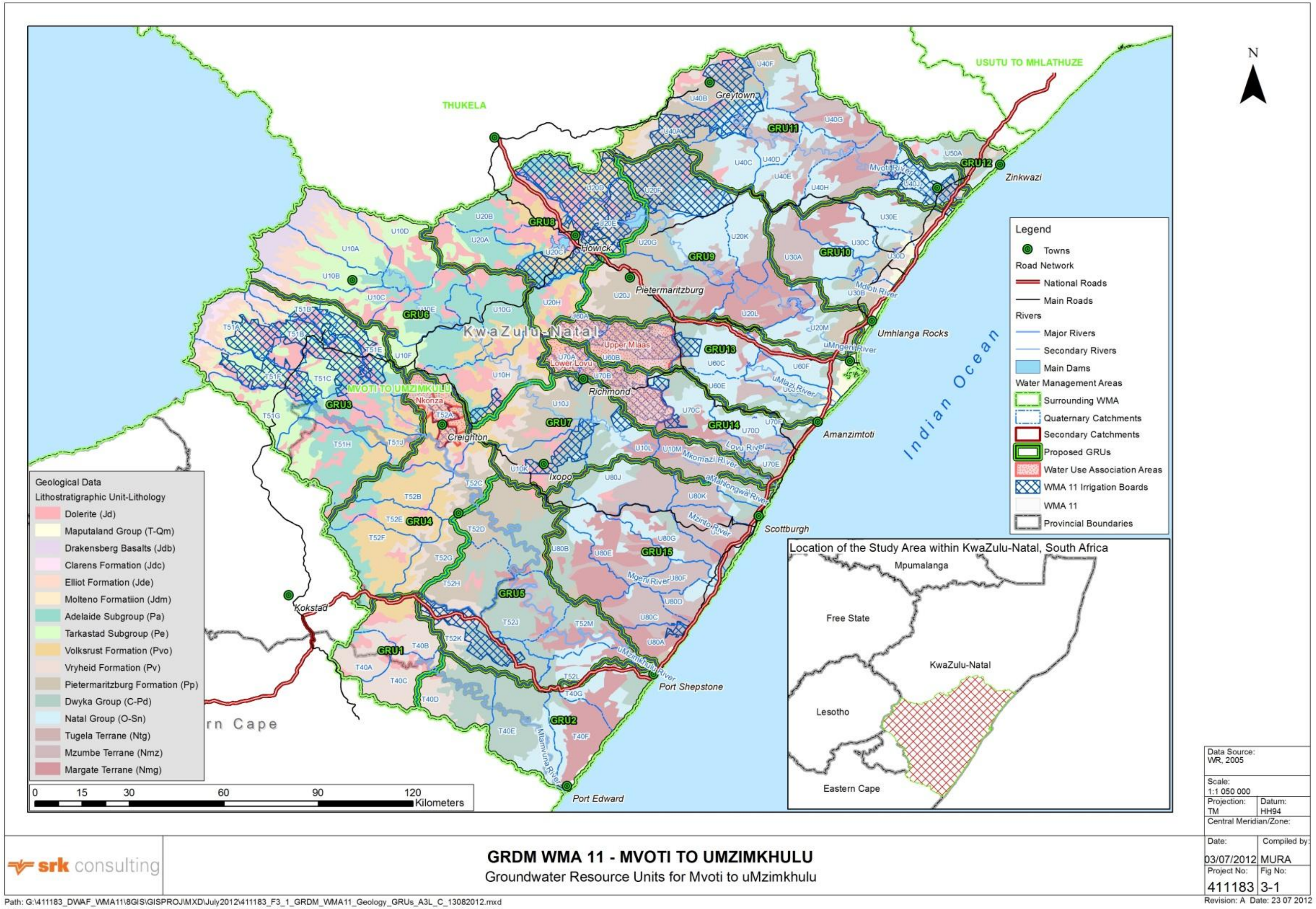

Figure 3-1: Groundwater Resource Units for Mvoti to uMzimkhulu

4 Classification of Groundwater Resource Units

4.1 Background to Classification of Groundwater Resource Units (GRDM, 2011)

4.1.1 Introduction

The Water Resource Classification System and other measures laid down by the Act are together intended to ensure the ecological sustainability of all the significant water resources by taking into consideration the social and economic needs of competing interests by all who rely on the water resources.

4.1.2 Objectives

The classification process is used to define the present state of the water resource and define the state towards which the resource has to be managed sustainably.

4.1.3 Procedure for determining different classes of water resources

The procedure to determine the different classes of water resources must comprise of the following seven steps:

Step 1: Delineate the units of analysis and describe the status quo of the water resource or water resources.

Step 2: Link the socio-economic and ecological value and condition of the water resource or water resources.

Step 3: Quantify the ecological water requirements and changes in non-water quality ecosystem goods, services and attributes.

Step 4: Determine an ecologically sustainable base configuration scenario.

Step 5: Evaluate scenarios within the integrated water resource management process.

Step 6: Evaluate the scenarios with stakeholders.

Step 7: Gazette and implement the class configuration.

4.1.4 Guide for classification of groundwater resource

Water resources must be classified into one of the following classes –

Class I water resource: This is one which is minimally used; and in which the configuration of the ecological categories of the water resources within a catchment results in an overall condition of that water resource that is minimally altered from its pre-development condition.

Class II water resource: This is one which is moderately used and in which the configuration of ecological categories of the water resources within a catchment results in an overall condition of that water resource that is moderately altered from its pre-development condition.

Class III water resource: This is one which is heavily used; and in which the configuration of ecological categories of the water resources within a catchment results in an overall condition of that water resource that is significantly altered from its pre-development condition.

Table 4-1: Guide for setting the present class of a groundwater unit based on observed environmental impact indicators

Present class	Generic description	Affected enviroment
Minimally used (I)	The water resource is minimally altered from its pre-development condition	No sign of significant impacts observed
Moderately used (II)	Localised low level impacts, but no negative effects apparent	Temporal, but not long-term significant impact to: – spring flow – river flow – vegetation – land subsidence – sinkhole formation – groundwater quality
Heavily used (III)	The water resource is significantly altered from its pre-development condition	Moderate to significant impacts to: – spring flow – river flow – vegetation – land subsidence – sinkhole formation – groundwater quality

Defining stress

The concept of stressed water resources is addressed by the NWA, but is not defined. Part 8 of the Act gives some guidance by providing the following qualitative examples of 'water stress':

- Where demands for water are approaching or exceed the available supply.
- Where water quality problems are imminent or already exist.
- Where water resource quality is under threat.

The groundwater stress index reflects water availability versus water used. Groundwater use should include water utilised by current water users, water required to sustain the Reserve as well as for BHN.

The Stress Index for an assessment area is defined as follows:

$$SI(\%) = \frac{gwUse}{Recharge} \times 100$$

Where; *gwUse* = Current groundwater use; *Recharge* = Recharge (as a volume)

In calculating the Stress Index, the variability of annual recharge is taken into account in the sense that not more than 65% of average annual recharge can be allocated on a catchment scale (Table 4-2).

Table 4-2: Guide for determining the level of stress of a groundwater unit

Present class	Description	Compliance (Spatial/Temporal)
I	Minimally used	≤20%
II	Moderately used	20% – 65%
III	Heavily used	> 65%

The NWA states that the system for classifying water resources may consider water quality requirements of water users without significantly altering the natural water quality characteristics of the resource. It gives a clear mandate to consider the fitness for the proposed beneficial use under consideration of the natural or geogenic background, which may actually render it unsuitable for the proposed use (e.g. natural fluoride concentrations exceeding drinking water limits).

It is therefore recommended to use the South African Water Quality Guidelines Vol. 1 – Domestic use (DWAF, 1996), or the national drinking water standard (SANS 241: 2006) for the present status category assessment of a water resource (Table 4-3).

Table 4-3: Present Status Category based on DWA water quality guidelines for domestic use

Present class	Description	Compliance (Spatial/Temporal)
I	DWA class 0 or 1 or natural background	95 %
II	DWA class 2 (95 % compliance) or natural background (75 % compliance)	75 %
III	DWA class 3 or 4 or natural background (<75 % compliance)	<75 %

4.2 Classification of Groundwater Resource Units for Mvoti to Mzimkhulu WMA

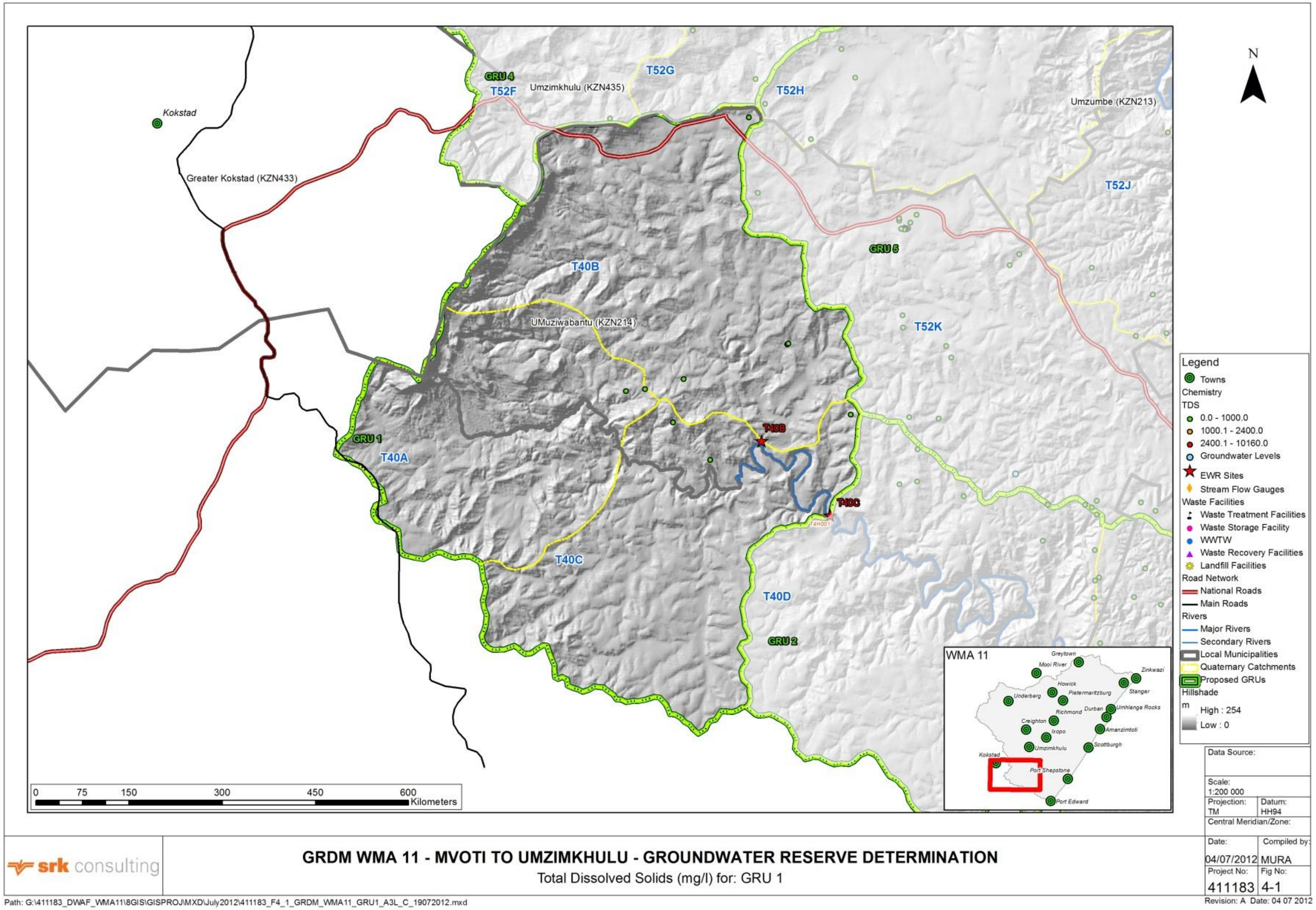

Figure 4-1: Total Dissolved Solids (mg/L) for GRU1

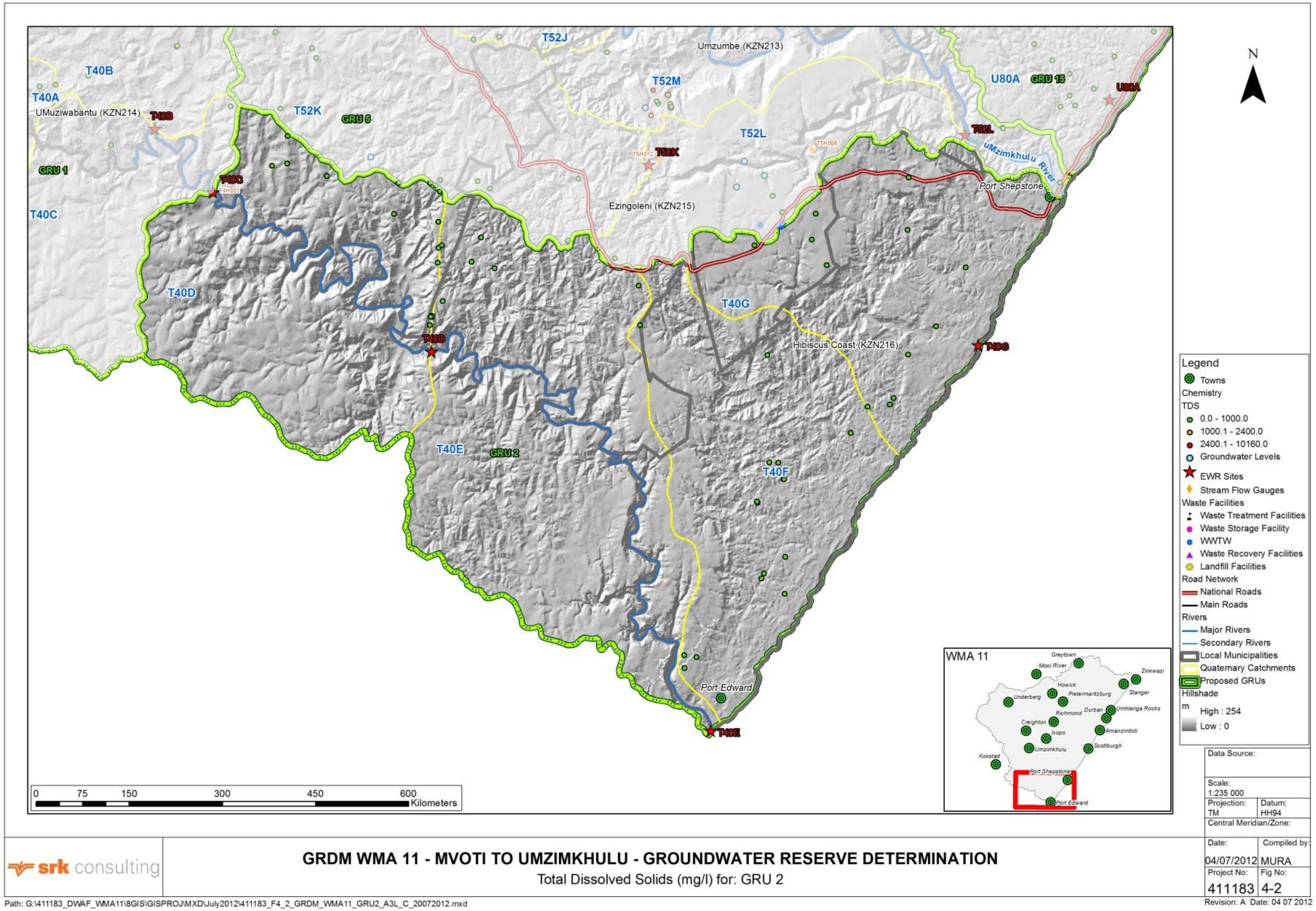

Figure 4-2: Total Dissolved Solids (mg/L) for GRU2

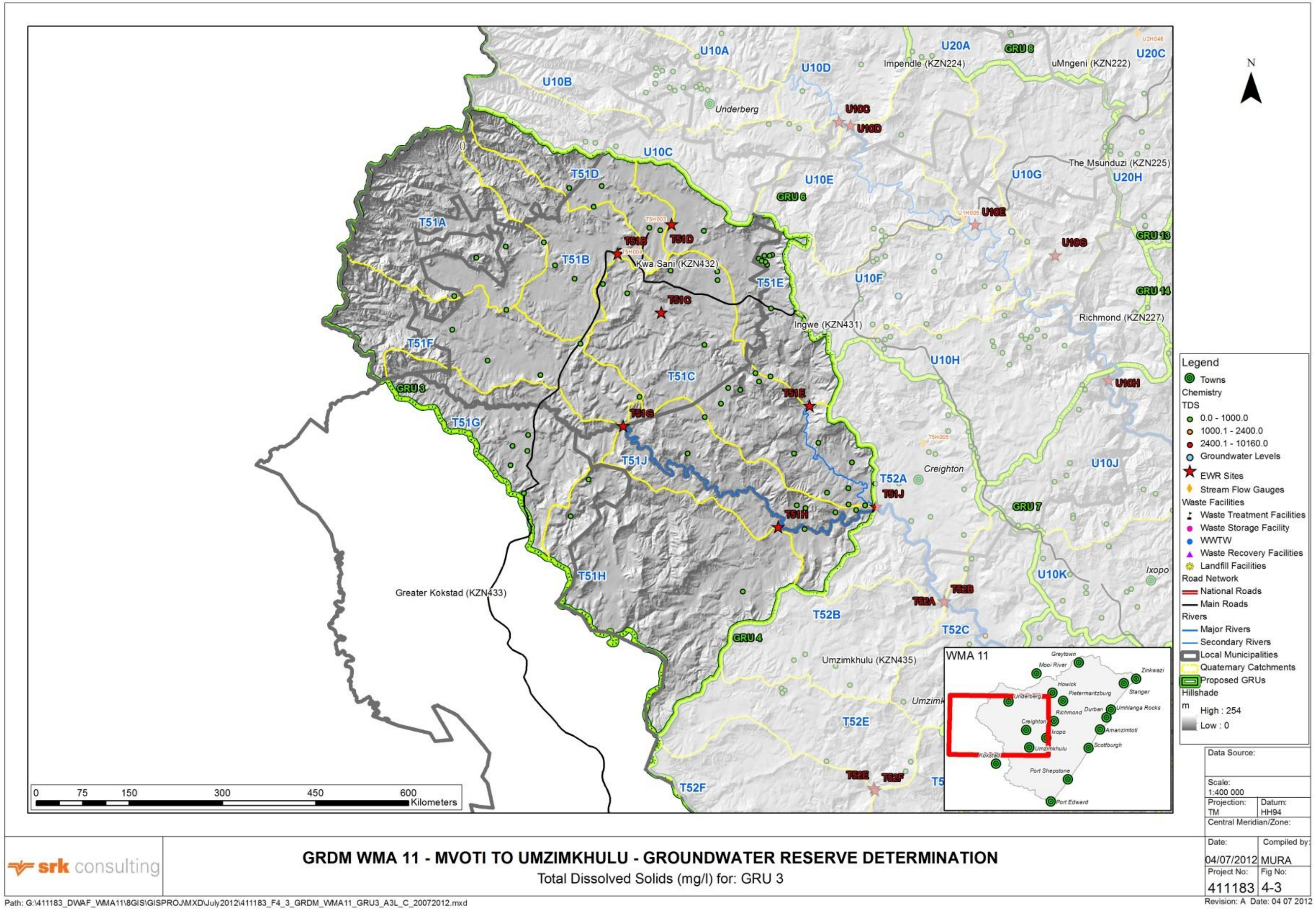

Figure 4-3: Total Dissolved Solids (mg/L) for GRU3

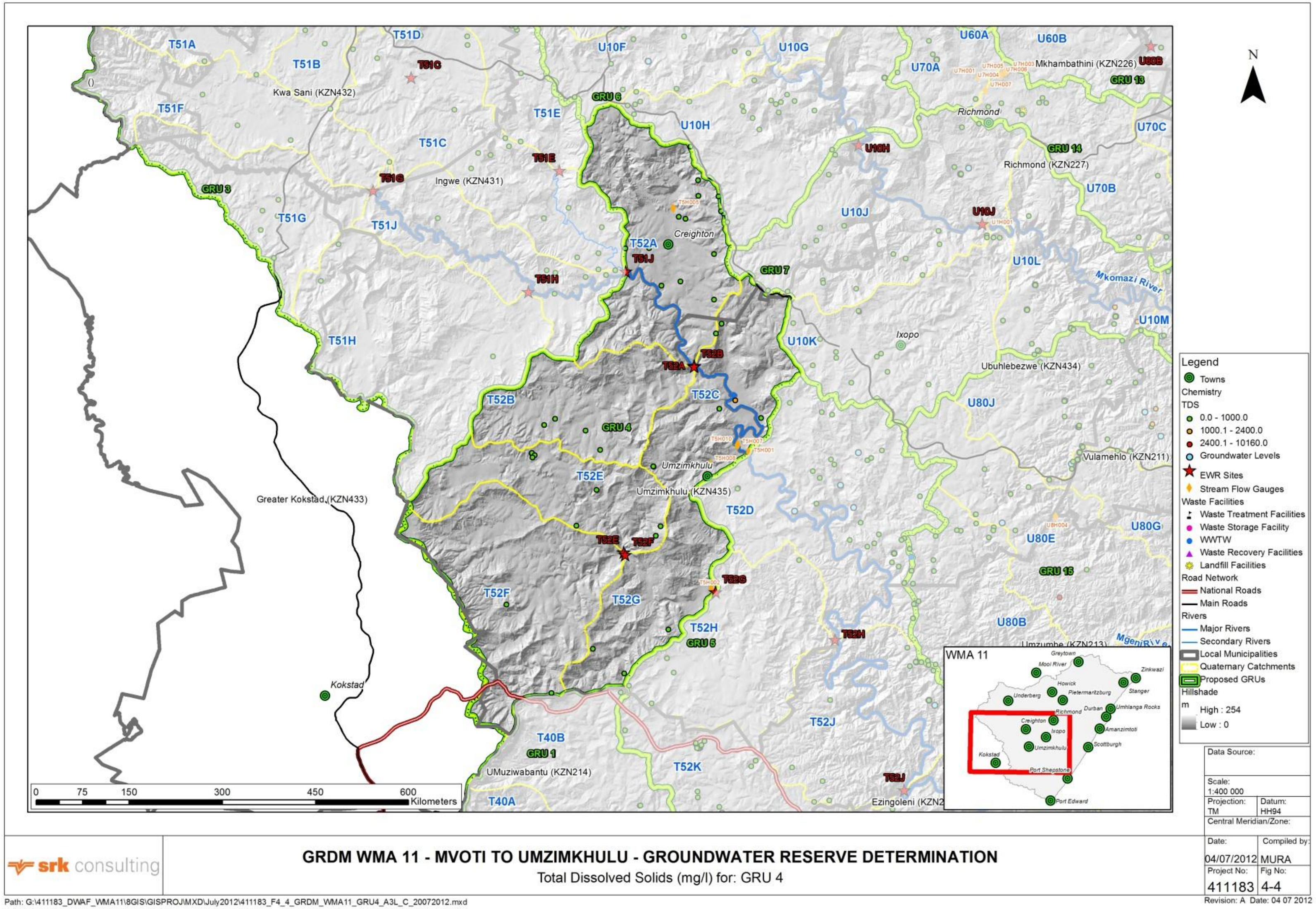

Figure 4-4: Total Dissolved Solids (mg/L) for GRU4

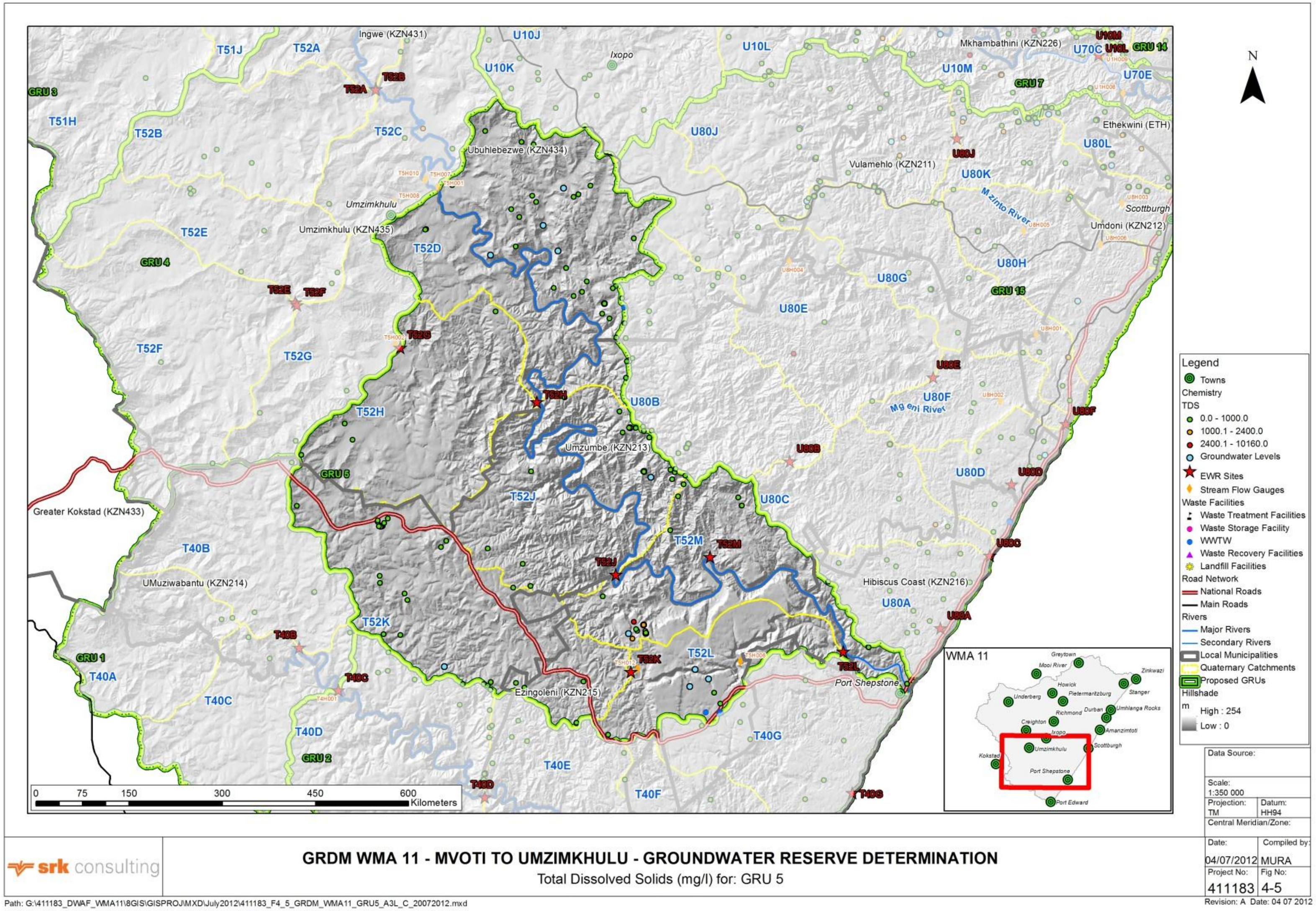

Figure 4-5: Total Dissolved Solids (mg/L) for GRU5

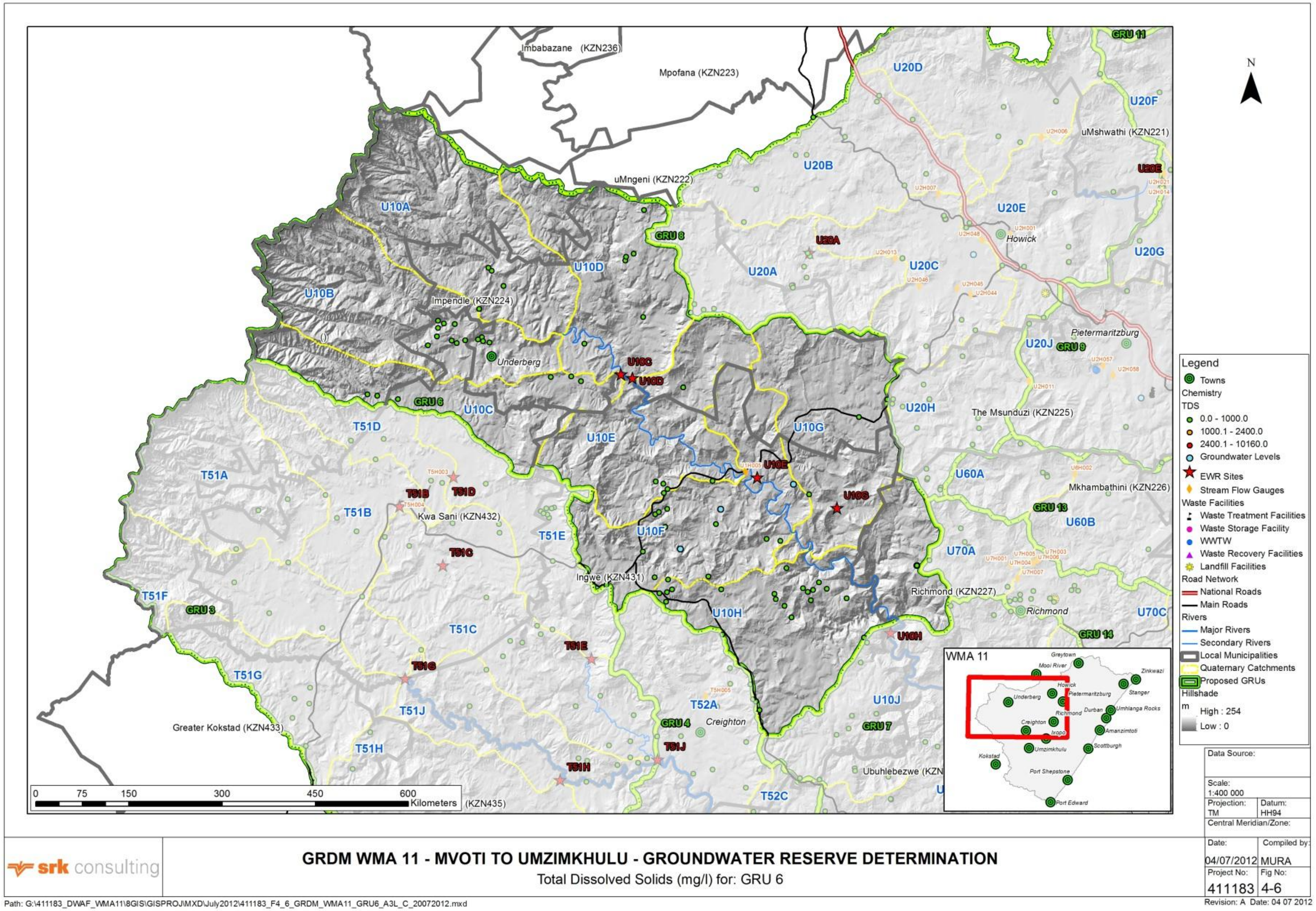

Figure 4-6: Total Dissolved Solids (mg/L) for GRU6

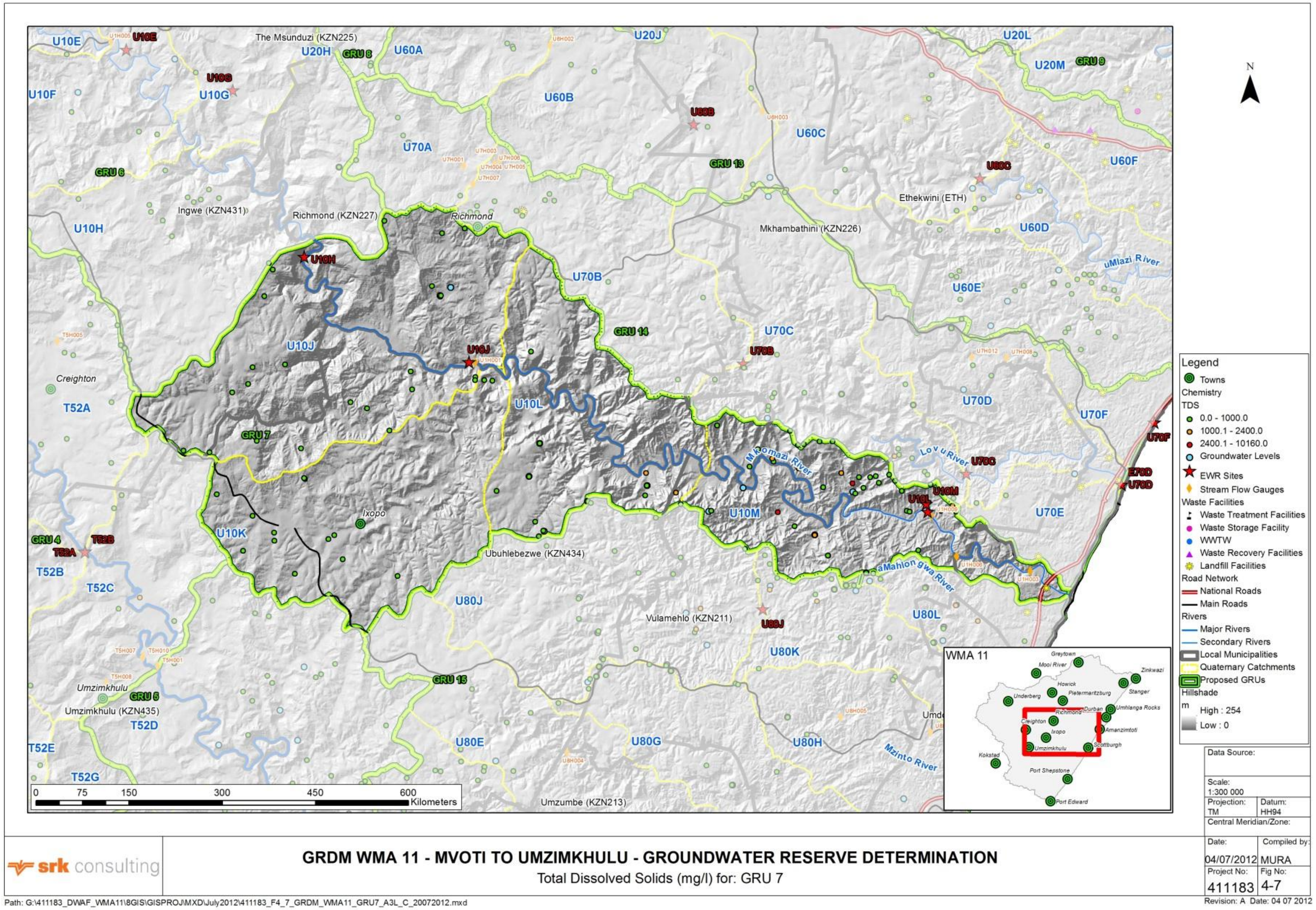

Figure 4-7: Total Dissolved Solids (mg/L) for GRU7

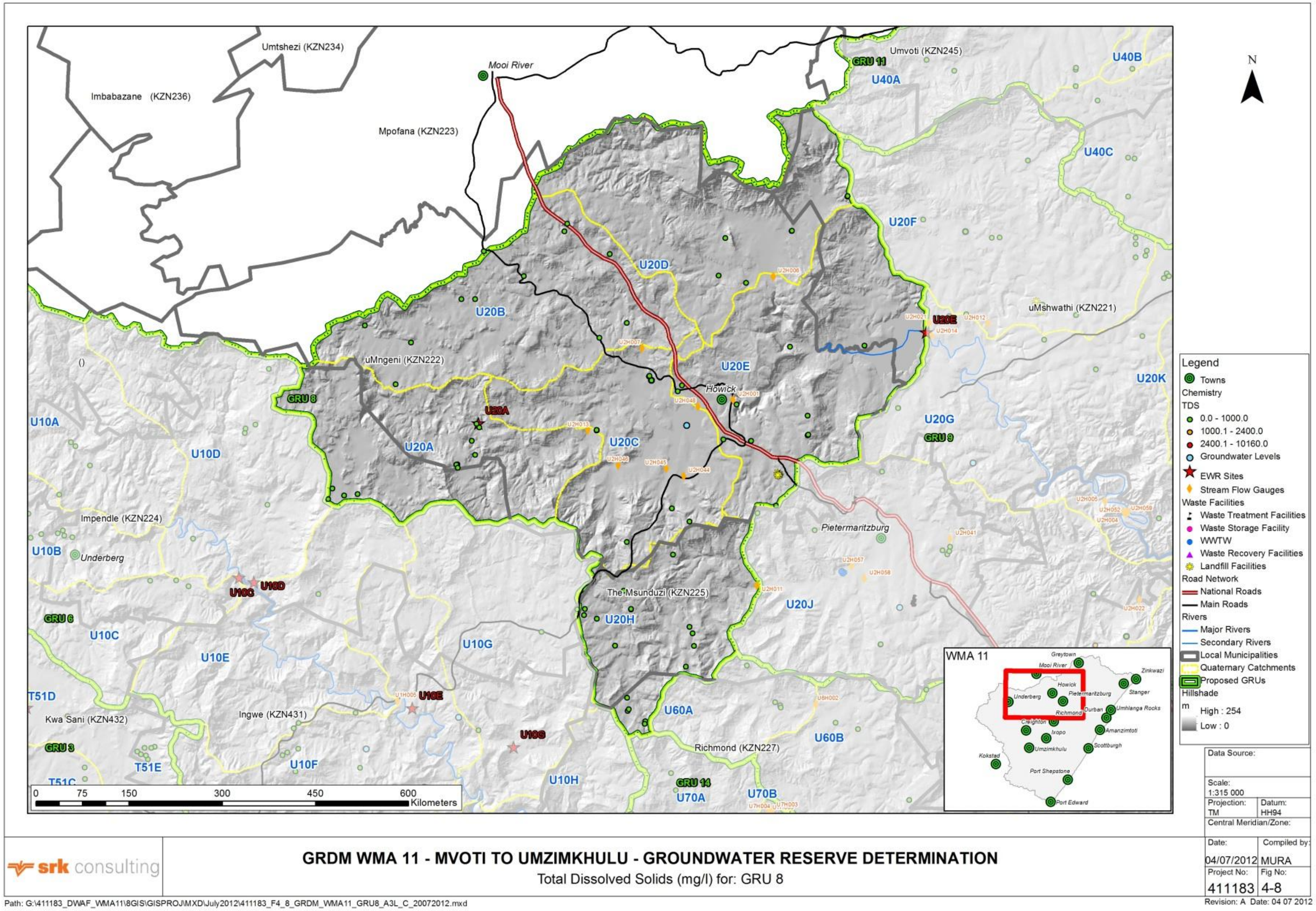

Figure 4-8: Total Dissolved Solids (mg/L) for GRU8

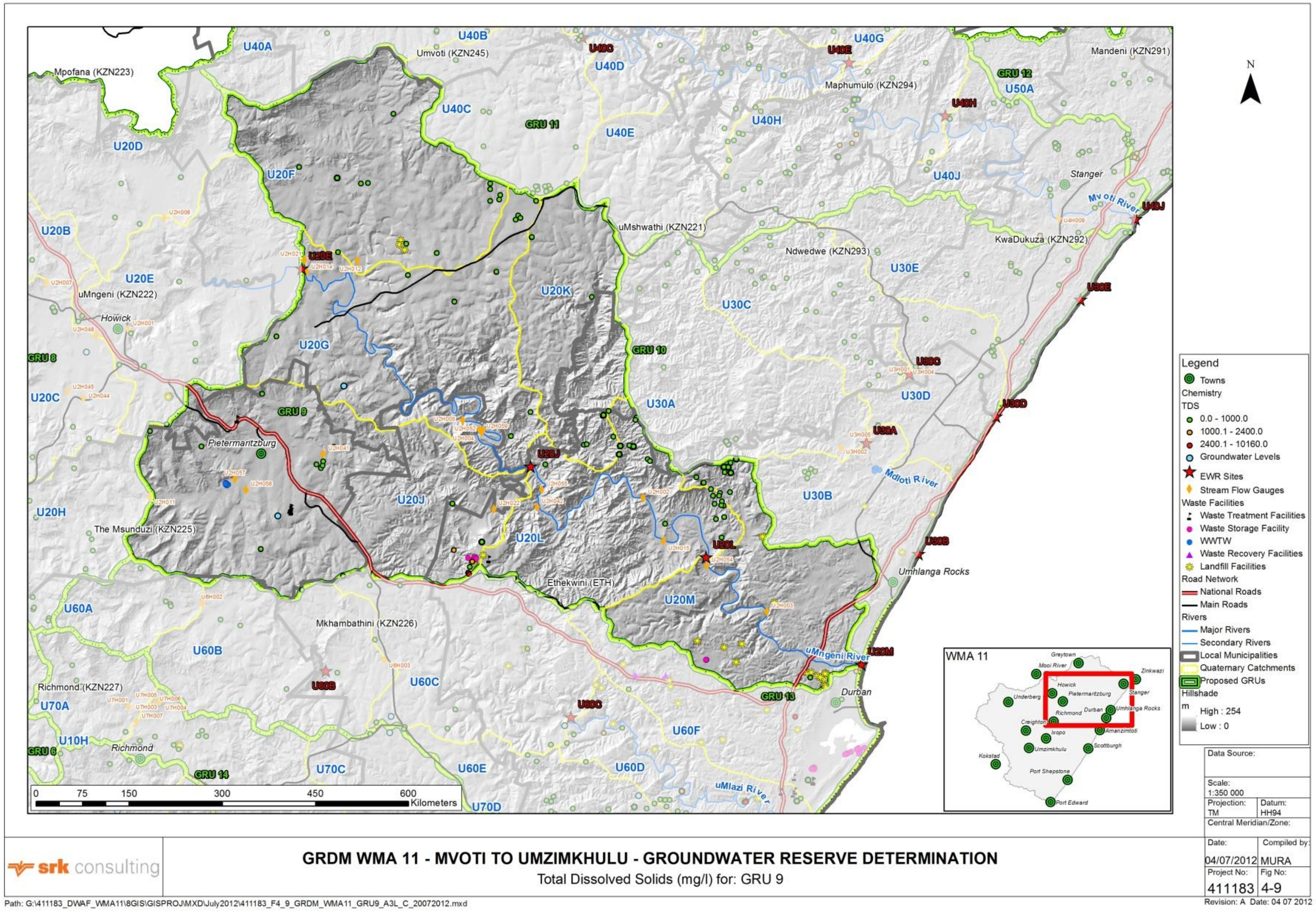

Figure 4-9: Total Dissolved Solids (mg/L) for GRU9

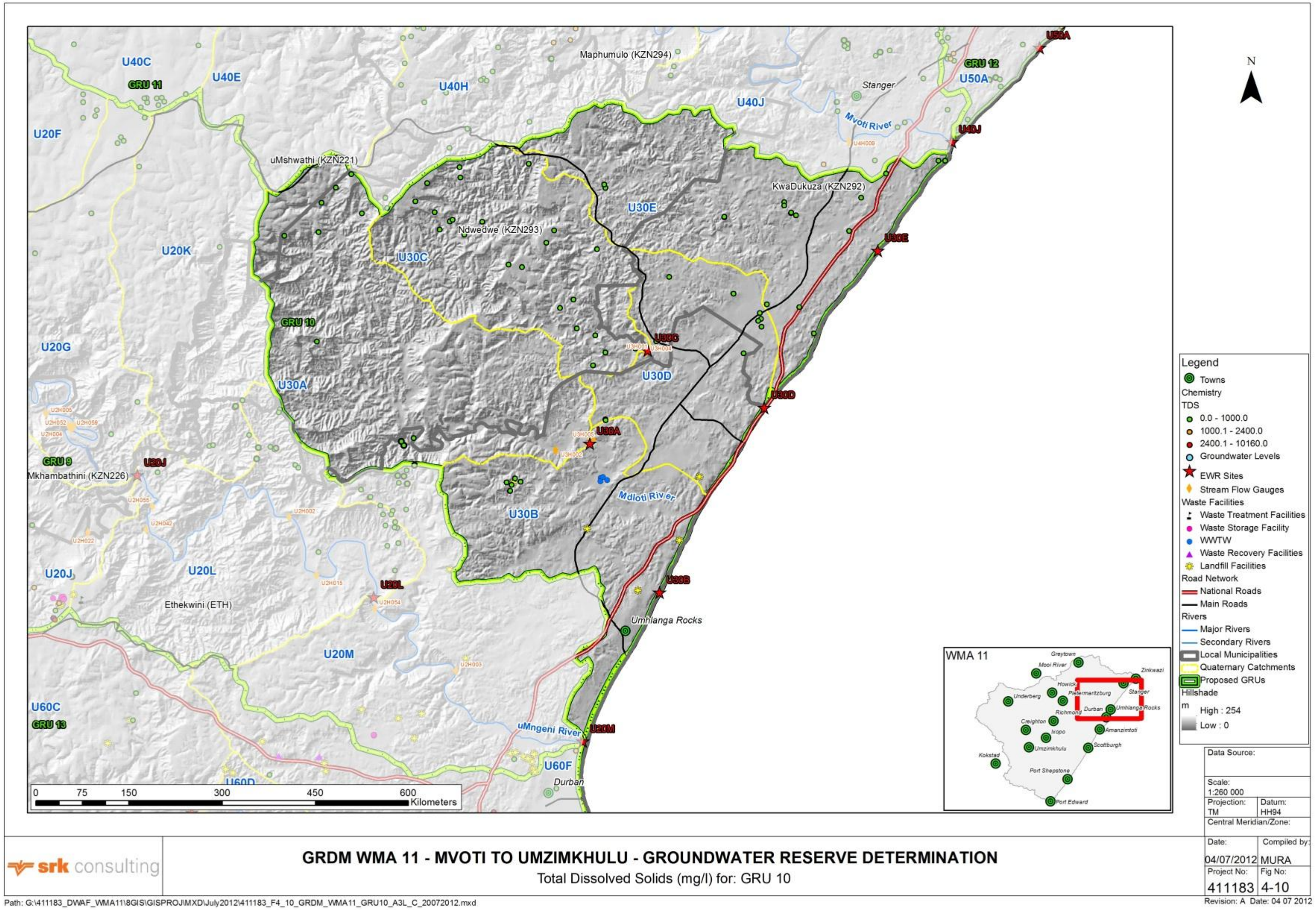

Figure 4-10: Total Dissolved Solids (mg/L) for GRU10

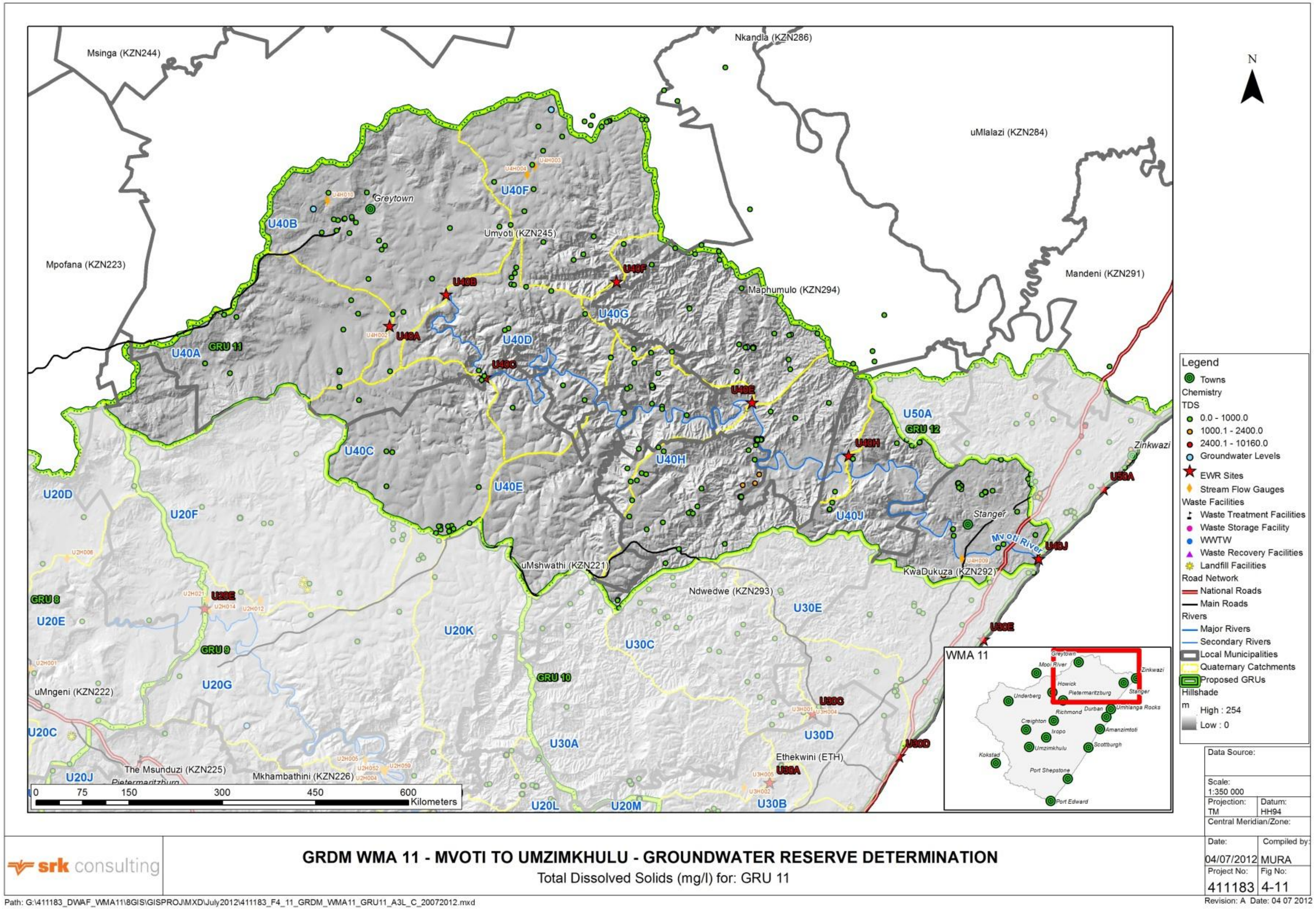

Figure 4-11: Total Dissolved Solids (mg/L) for GRU11

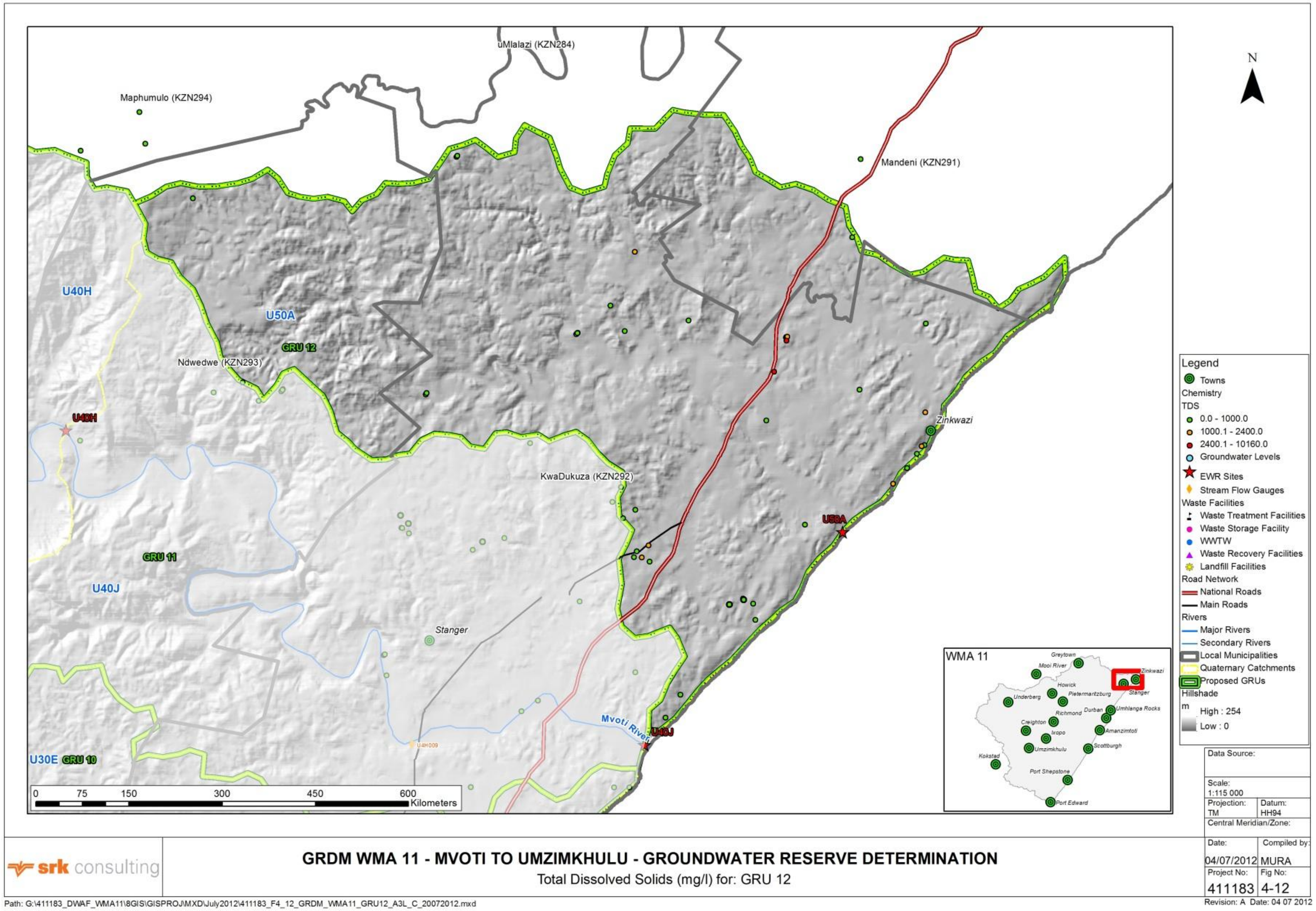

Figure 4-12: Total Dissolved Solids (mg/L) for GRU12

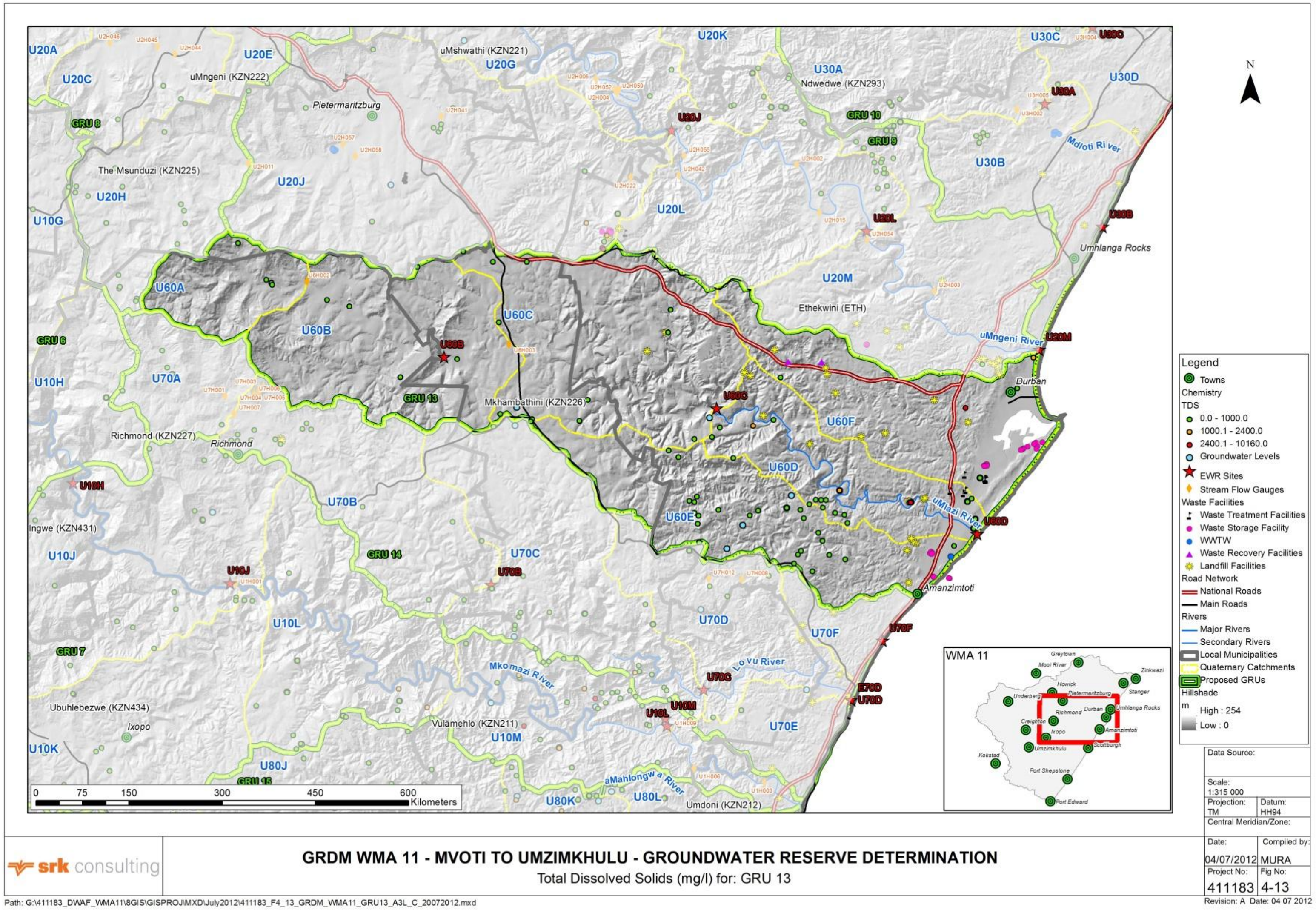

Figure 4-13: Total Dissolved Solids (mg/L) for GRU13

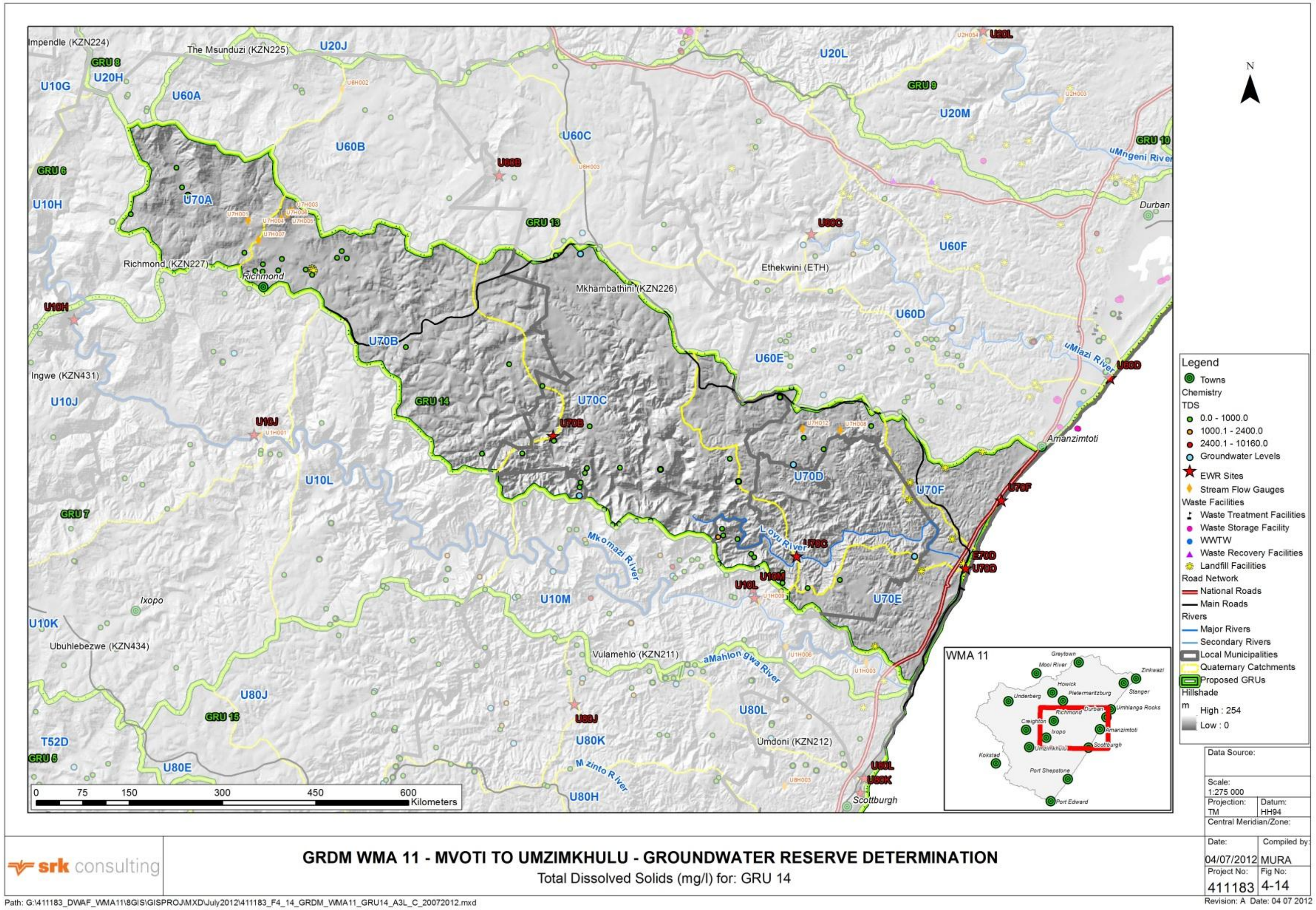

Figure 4-14: Total Dissolved Solids (mg/L) for GRU14

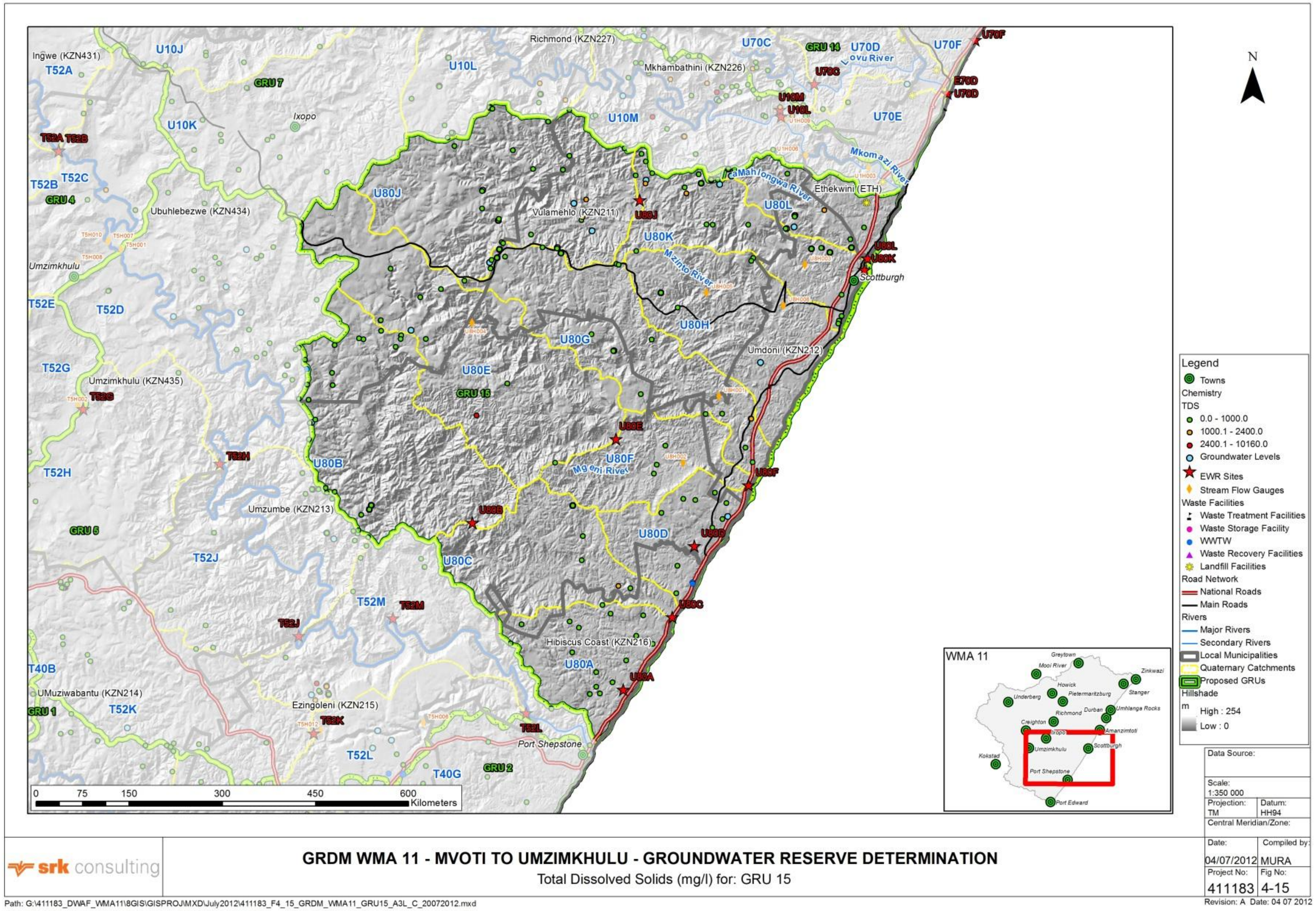

Figure 4-15: Total Dissolved Solids (mg/L) for GRU15

5 The Reserve

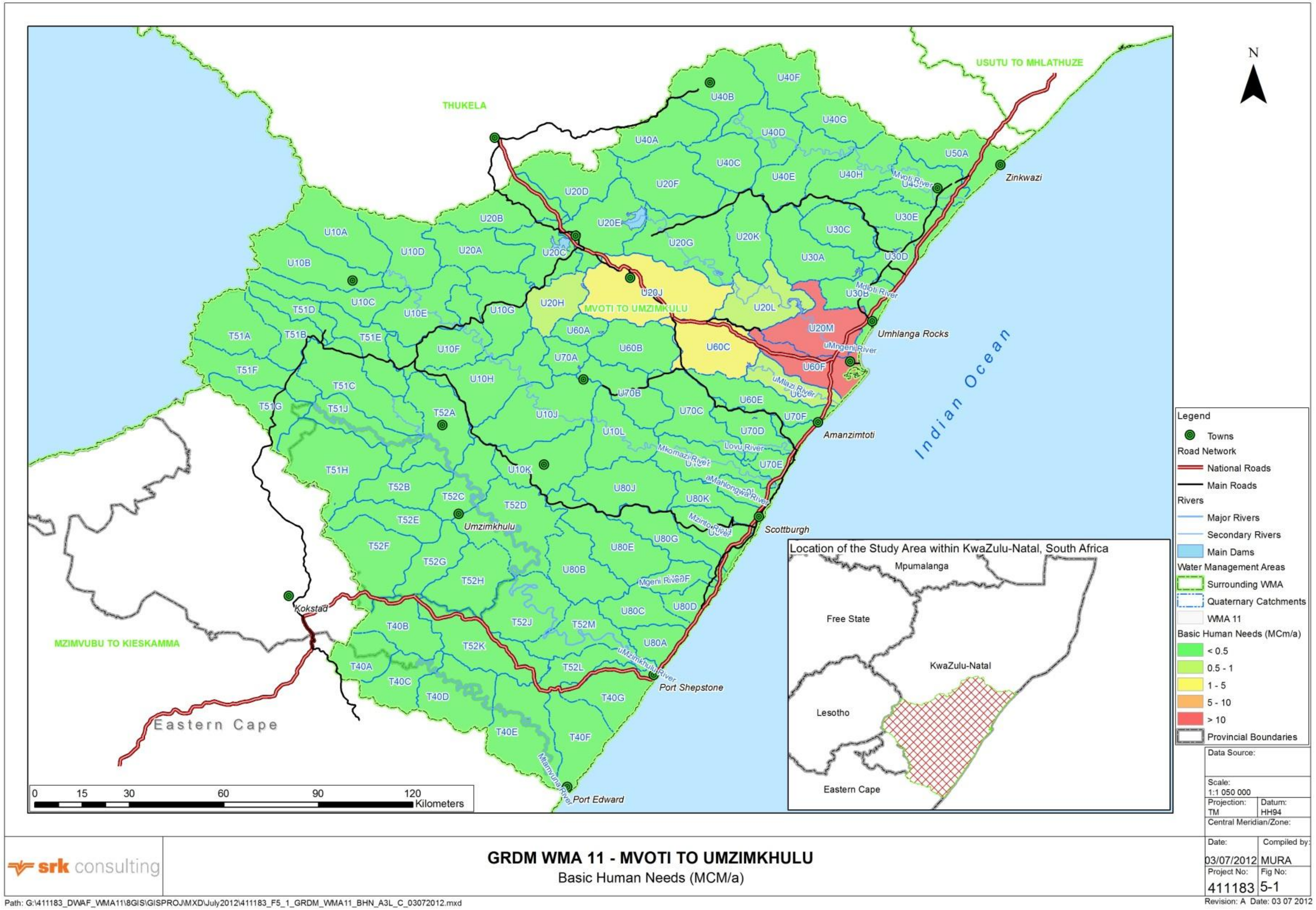

Figure 5-1: Basic Human Needs (MCM/a)

6 Resource Quality Objectives

7 Groundwater Monitoring

Monitoring requirements for each resource unit will be determined to ensure that resource quality objectives are met. The program will include locations, sampling frequency, list of determinants and reporting requirements.

Monitoring data will be utilised to determine resource management and compliance.

8 Conclusions and Recommendations

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All data used as source material plus the text, tables, figures, and attachments of this document have been reviewed and prepared in accordance with generally accepted professional engineering and environmental practices.

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Appendices

Appendix A: Data Sources

Appendix B: Hydrocensus

Appendix C: Potential Sources of Contamination to Groundwater

Appendix D: Aquifer Testing Data

Appendix E: Laboratory Analytical Certificates

Appendix F: Aquifer Vulnerability DRASTIC Indices

Appendix G: Images of River Systems in WMA 11

Appendix H: Surface Water Reserves (DWA)

Appendix I: Streamflow Hydrographs

Appendix J: Capacity Building

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