GEOHYDROLOGICAL ASSESSMENT FOR A PROSPECTING RIGHT AT FARM AREACHAP426, NORTH WEST OF UPINGTON, NORTHERN CAPE

MAY 2019

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GEOHYDROLOGICAL ASSESSMENT FOR A PROSPECTING RIGHT AT FARM AREACHAP426, NORTH WEST OF UPINGTON, NORTHERN CAPE

It is our pleasure to include one electronic copy of the report.
We trust that the report will meet your expectations.

Please feel free to contact me should you have any queries or suggestions.

Yours sincerely.

J.W. HAUMANN
(M.Sc. Pr.Sci.Nat.)

Copies: One (1) electronic copy to WADALA MINING AND CONSULTING (PTY) LTD.

SPECIALIST STATEMENT DETAIL

This statement has been prepared with the requirements of the Environmental Impact Assessment Regulations and the National Environmental Management Act (Act 107 of 1998), any subsequent amendments and any other relevant National and / or Provincial Policies in mind.

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I, Mr. Kobus Haumann declare that this report has been prepared independently of any influence or prejudice as may be specified by the National Department of Environmental Affairs

PREPARED

Signed: Date: 20 MAY 2019

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GLOSSARY GEOHYDROLOGICAL TERMS AND ACRONYMS	
GEOHYDROLOGICAL TERMS	DEFINITIONS
Aquiclude	An aquiclude is an impermeable geological unit that does not transmit water at all. Dense unfractured igneous or metamorphic rocks are typical aquiclude.
Aquitards	An aquitard is a geological unit that is permeable enough to transmit water in significant quantities when viewed over large and long periods, but its permeability is not sufficient to justify production boreholes being placed in it. Clays, loams and shales are typical aquitards.
Borehole census	A field survey by which all relevant information regarding groundwater is gathered. This typically includes yields, borehole equipment, groundwater levels, casing height/diameter, co-ordinates, potential pollution risks, photos etc.
Confined Aquifer	A confined aquifer is bounded above and below by an aquiclude. In a confined aquifer, the pressure of the water is usually higher than that of the atmosphere, so that if a borehole taps the aquifer, the water in it stands above the top of the aquifer, or even above the ground surface. We then often speak of a free-flowing or artesian borehole.
Diffusivity (KD/S)	The hydraulic diffusitivity is the ratio of the transmissivity and the storativity of a saturated aquifer. It governs the propagation of chances a hydraulic head in the aquifer. Diffusivity has the dimension of Lenght^2/Time
Hydraulic Conductivity (K)	The hydraulic conductivity is the constant of proportionality in Darcy's Law. It is defined as the volume of water that will move through a porous medium in a unit time under a unit hydraulic gradient

	through a unit area measured at right angles to the direction of flow.
Leaky Aquifer	A leaky aquifer or semi-confined aquifer, is an aquifer whose upper and lower boundaries is aquitards, or one boundary is an aquitard and the other is an aquiclude. Water is free to move through the aquitards, either upwards or downwards. If a leaky aquifer is in hydrological equilibrium, the water level in a borehole tapping it may coincide with the water table.
Porosity	The porosity of a rock is its property of containing pores or voids. With consolidated rocks and hard rocks, a distinction is made between primary porosity, which is present when the rock is formed and secondary porosity, which develops later as a result of solution or fracturing.
Specific Yield (S_y)	The specific yield is the volume of water that an unconfined aquifer releases from storage per unit surface area or aquifer per unit decline of the water table. The values of the specific yield range from 0.01 to 0.3 and are much higher that the storativities of confined aquifers.
Storativity (S)	The storativity of a saturated confined aquifer of thickness D is the volume of water released from storage per unit surface area of the aquifer per unit decline in the component of hydraulic head normal to that surface.
Storativity Ratio	The storativity ratio is a parameter that controls the flow from the aquifer matrix blocks into the fractures of a confined fractured aquifer of the double-porosity type.
Susceptibility	A qualitative measure of the relative ease with which a groundwater body can be potentially be contaminated by anthropogenic activities.
Sustainable Yield	The yield calculated from aquifer test pumping by a professional geohydrologist. The yield refers to the

	recommended abstraction rate and pumping schedule for continues use.
Transmissivity (KD or T)	Transmissivity is the product of the average hydraulic conductivity K and the saturated thickness of the aquifer D. Consequently, transmissivity is the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the whole saturated thickness of the aquifer.
Unconfined Aquifer	An unconfined aquifer, also known as a water table aquifer, is bounded below by an aquiclude, but is not restricted by any confining layer above it. Its upper boundary is the water table and is free to rise and fall.
Recharge	Groundwater recharge or deep drainage or deep percolation is a hydrologic process where water moves downward from surface water to groundwater. This process usually occurs in the vadose zone below plant roots and is often expressed as a flux to the water table surface. Recharge occurs both naturally and anthropologically, where rainwater and or reclaimed water is routed to the subsurface.
Vulnerability	The likelihood for contamination to reach a specified position in a groundwater system after introduction at some location above the uppermost aquifer.
GEOLOGICAL TERMS	
Argillaceous rock	A type of sedimentary rock that contains a substantial amount of clay or clay-like compounds
Fault (Brittle Shear)	A planar fracture or discontinuity in a volume of rock, across which there has been significant displacement along the fractures as a result of earth movement
Intrusive rock	Rock that formed due to the cooling of magma that forced its way into fractures and cavities of other rock types without reaching the surface.(usually large crystal sizes)

Metasedimentary Rock	A sedimentary rock that appears to have been altered by metamorphism.
Sedimentary rock	A type of rock that formed by sedimentation material on the earth surface or in water bodies
Shear Zone	A shear zone is a structural discontinuity surface in the Earth's crust and upper mantle which forms as a response to inhomogeneous deformation partitioning strain into planar or curviplanar high-strain zones.

1 INTRODUCTION

Sustainable GeoHydrological Solutions (PTY) LTD was appointed by ***Wadala Mining and Consulting (PTY) LTD*** to perform a geohydrological specialist investigation as part as a definitive prospecting feasibility report and water use license application. The Farm Areachap 426 has already been prospected for zinc, copper, silver, sulphur, and iron since 2011. With the existing prospecting right approaching expiration, an additional exploration assessment was requested prior to expiration. In addition, a Section 102 bulk sampling application was listed. This report will form the first geohydrological assessment to be conducted on the farm due to updated legislation.

The objectives of the study are as follows:

- Desk study and site visit to establish a conceptual model of the area.
- Census of boreholes and surface water accumulation sites within at least a 2 km or greater radius of the study area to determine the potential utilization of existing boreholes, local groundwater levels and qualities as well as the current groundwater use in the area.
- Aerial photograph, topography, geology, geohydrology and aeromagnetic interpretation to improve the conceptual model of the area.
- Compile Geohydrological Report

2 LIMITATIONS

The statements, opinions, and conclusions contained in this report are based solely upon the services rendered by Sustainable GeoHydrological Solutions (PTY) LTD as described in this report, the scope of work as established for the report, and in accordance with our proposal. In performing these services and preparing the report, Sustainable GeoHydrological Solutions (PTY) LTD relied upon the information provided by others, including public agencies, whose information is not guaranteed by Sustainable GeoHydrological Solutions (PTY) LTD. No indications were found during our investigations that information contained in this report as provided to Sustainable GeoHydrological Solutions (PTY) LTD, was false.

This report is based on conditions encountered and the information reviewed at the time of the site investigations. Sustainable GeoHydrological Solutions (PTY) LTD disclaims responsibility for any changes that may have occurred after this time or any error in the analytical results received from the laboratory. This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties.

This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

3 BACKGROUND INFORMATION

3.1 Proposed Activity

The proposed prospecting activity is situated on copper-zinc volcanic hosted massive sulphide (VHMS) deposits. The primary objective will be to extract Cu-Zn-S-Ag-Fe ore from an opencast trench as well as from an existing underground shaft. Furthermore, exploration boreholes to a depth of 350 m are planned to be installed. An estimated total volume of 102 000 m^3 will be produced over four years.

Prospecting activities will primarily make use of existing roads and infrastructure while some additional roads will be created in order to access working and exploration areas. The full extent of all planned infrastructure and activities are not currently known, but existing features include an office and workshop complex, a series of shafts, mine dumps, excavations, ablutions, water storage, concrete surfaces and fence lines. Existing infrastructure of the investigated site is represented in Figure 3-1.

In **Appendix A** the layout of proposed trenching for bulk sampling as well as proposed RC drilling is illustrated. A table (Table 7-1) is also added to this appendix indicating intended prospecting activities, methods, mineral resources and time frames in terms of regulations 7(1)(f), 7(1)(h) and 7(1)(i). Activities are subdivided in three phases such as (1) trenching, (2) underground sampling through existing shaft and (3) infill drilling.

3.2 Location and Scope of Work

The prospecting right area is located within the Gordonia District Municipality of the Northern Cape Province and lies 30 km north-west of the town Upington on the R360. The prospecting area forms part of the farm Areachap 426 which has a total extent of 1 9653 0822 ha.

The coordinates to the center of the study area is -28.296529° latitude and 21.044424° longitude. Local farming activities within the area expected to include sheep and cattle farming. Boundary coordinates for the site plan is given in Table 3-1. The location of the site plan area (study area) relative to the greater Areachap 426 is shown in Figure 3-2.

Table 3-1: Site plan coordinates

CORNER	LATITUDE	LONGITUDE
A	-28.295051°	21.042291°
B	-28.293472°	21.047192°
C	-28.294701°	21.047661°
D	-28.296300°	21.043496°
E	-28.295437°	21.045413°
F	-28.297951°	21.047501°
G	-28.298939°	21.045122°
H	-28.296262°	21.043523°

The geohydrological investigation entails:

- A desk study to collect background information regarding climate, rainfall, geology, geohydrology, and aeromagnetic structures within the proposed development area. This information will aid in conforming calculated decisions regarding the development of the proposed project with respect to possible associated impacts on the local groundwater regime.
- Site visit to correlate the information that was collected during the desk study.
- Borehole census to determine local groundwater depth, use and quality.
- Geophysical investigation to map the presence (if any) of associable intrusive geological structures within the study area.
- Photo recording of current on site conditions as well as outcropping geological structures.
- Compilation of a geohydrological report.

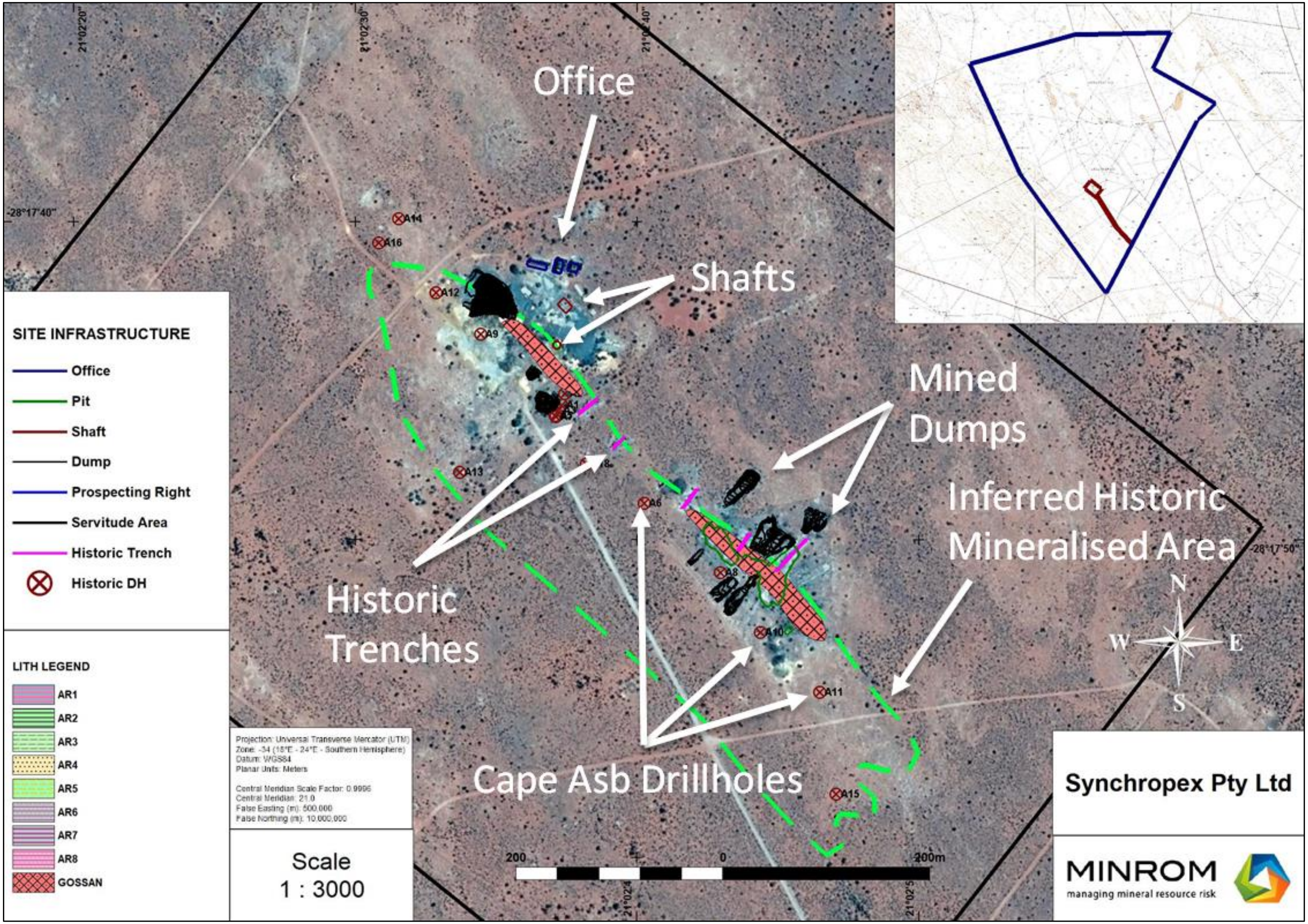

Figure 3-1: Present project infrastructure and geology

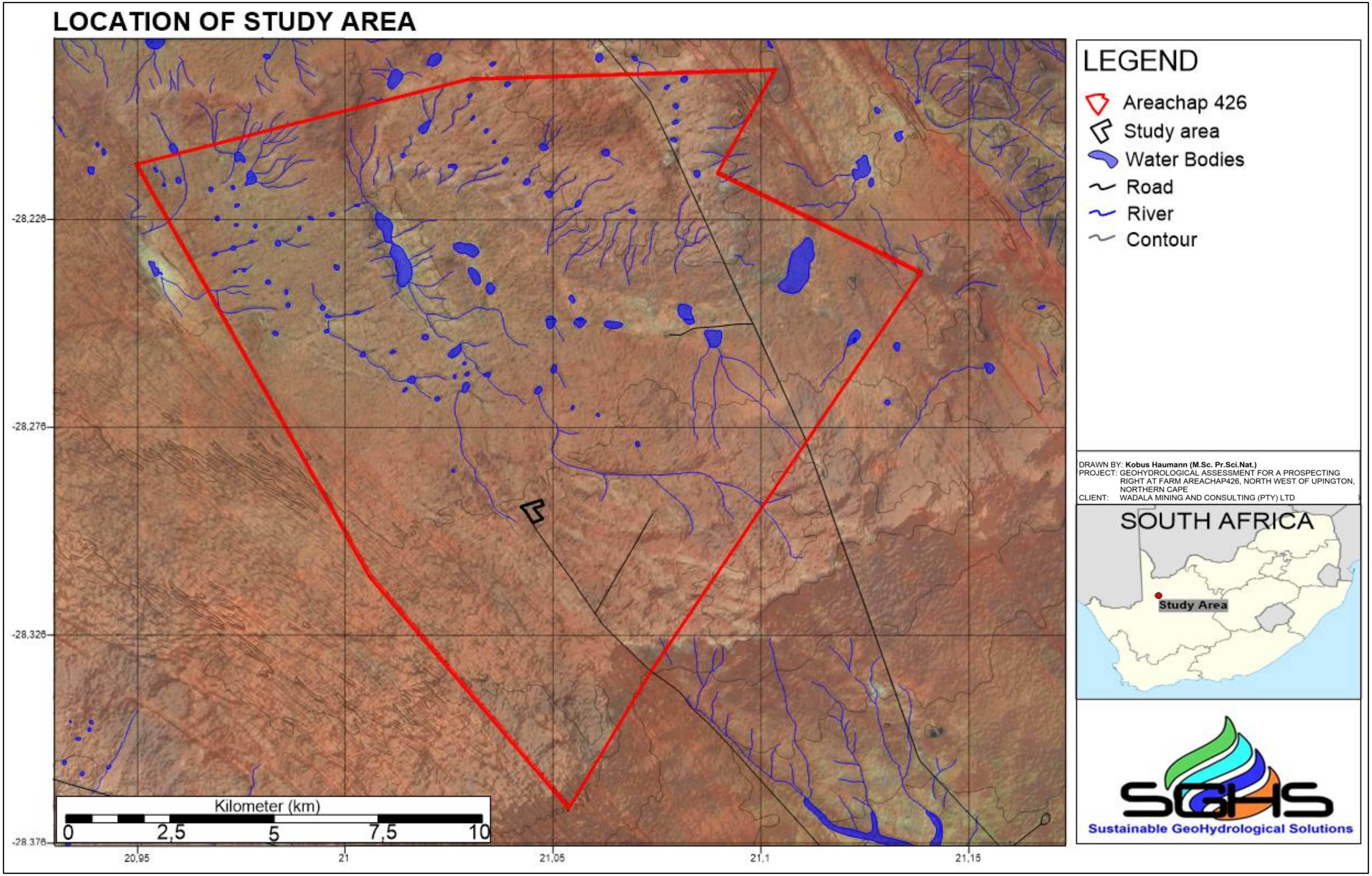

Figure 3-2: Study area relative to the farm Areachap.

3.3 Water Management Area (WMA)

The study area is situated across the D42E, D73F and D73E quaternary catchment area which forms part of the Lower Orange Water Management Areas (LOWMA), presented in Figure 3-3. The study area is also located across both the Boegoeberg Dam to Kanoneiland [Area 2] and the Kanoneiland to Pella [Area3] sub-areas.

The Lower Orange WMA is dominated by the Orange River, with few perennial tributaries and several episodic tributaries. It forms the lower reaches of the larger Orange River Basin but excludes the Vaal River Basin. The Lower Orange River is unique in that it is over 1000 km long, from the confluence of the Orange with the Vaal to a point where it becomes and estuary at Alexandra Bay and eventually meets the South Atlantic Ocean. For about half this distance if forms the main border with Namibia which necessitates a careful look at international obligations.

The topography of the Lower Orange WMA is such that it is largely flat, with large pans or endoreic areas that do not contribute significant runoff to the Orange River system. For this reason, communities and activities that exist out of logistical reach of the main stem of the river rely heavily on groundwater supplies.

Most of the activities dependent on the river are concentrated within close proximity of the main stem of the river. Hence, as a point of departure, the LOWMA was divided in to four sub-areas for the purposes of this report

These four sub-areas are listed below and illustrated in Figure 3-3 with reference to the investigated farm Areachap and the LOWMA while Table 3-2 presents specific land uses of the sub-areas.

- **Area 1**, Just upstream of the confluence of the Orange River with the Vaal River to Boegoeberg Weir (including just upstream of both the Orange and Vaal Rivers),
- **Area 2**, Boegoeberg Weir to Kanoneiland,
- **Area 3**, Kanoneiland to Pella, and
- **Area 4**, Pella to Alexander Bay.

3.3.1 WMA Climate

The area comprising the LOWMA is largely arid and experiences a harsh climate. It has the lowest mean annual rainfall in the country, varying from 400mm in the east to 50mm per annum on the west coast. Area 1 receives between 200 and 300mm of rainfall per annum, whereas, moving westwards, Sub-Areas 2, 3 and 4 largely receive between 0 and 100m per annum. Potential evaporation can reach 3 000mm per year.

Table 3-2: Land uses identified in the four geographic areas

[Area 1] Douglas to Boegoeberg	[Area 2] Boegoeberg to Kanon Islands	[Area 3] Keimoes to Pella	[Area 4] Pella to Alexander Bay
Sheep and goat farming.	Sheep and goat farming, including feedlots.	Sheep and goat farming.	Stock farming and ostrich farming.
Irrigation Farming (banks of Orange, Vaal and Riet Rivers): table grapes, vineyards, mielies, wheat, potatoes, Lucerne.	Irrigation Farming (banks of Orange): Table grapes, vineyards, dried fruit.	Irrigation Farming (banks of Orange): vineyards for wine and table grapes, watermelons, spanspek. Also dried fruit production.	Irrigation Farming (banks of Orange): vineyards, Hoodia, dates, paprika, tomatoes.
Diamond mining and prospecting.	Diamond mining and prospecting.	Diamond prospecting and base metal mining.	Alluvial diamond prospecting and larger-scale alluvial diamond mining at Kleinsee, Alexander Bay and Hondeklipbaai. Also semi-precious gems and quartzite mining.
Douglas conservancy	Conservation areas (Spitskop)	Conservation areas (Augrabies Falls National Park) and eco-tourism.	Conservation areas (/Ai-/Ais-Richtersveld Transfrontier Park) and eco-tourism. Including RAMSAR site at Alexander Bay Estuary.
Interest groups – Farming, Fishing.	Interest groups – Farming, Fishing.	Interest groups – Farming, Fishing.	Interest groups – Farming, Fishing, Recreation/ Canoeing.
	Urban infrastructure: airport, fuel depot, golf course, casino, salt works.	Industries: Game farming and salt works.	Recreation

3.3.2 WMA Groundwater

Groundwater utilization is of major importance across wide areas in the LOWMA and often constitutes the only source of water. It is mainly used for rural domestic supplies, stock watering and water supplies to towns off the main stem of the Orange. These resources must be properly managed and developed. As a result of the low rainfall, recharge of groundwater is limited and only small quantities can be abstracted on a sustainable basis. Aquifer characteristics (borehole yields and storage of groundwater) are also typically unfavorable because of the hard geological formation underlying most of the water management area.

In the Orange Tributaries sub-area 60% to 70% of the available water is supplied from groundwater sources. Groundwater also constitutes an important source of water for rural water supplies in the Orange River, although only a small proportion of the total available water. Much of the groundwater abstracted near the river (Orange sub-area), is recharged from the river and could also be accounted for as surface water.

The interaction between the mining activity and groundwater is managed through the EMPR and the water use licensing process. Some impacts do exist with regard to localized dewatering of aquifers. These impacts are however localized and very little data exist in this regard. The information from the compliance monitoring systems at the mines needs to be integrated into the DWAF monitoring systems and regularly reviewed. Mines utilize the groundwater available but are still largely dependent on surface water, which is in most cases supplied from the Orange River.

Boreholes and abstraction from boreholes are seldom managed properly and therefore the failure of boreholes is experienced. Borehole siting needs to be based on proper geo-technical work to limit the drilling of unsuccessful boreholes. As result of this some towns have drilled many boreholes without much success.

There is a need to provide groundwater information and to create an improved understanding of groundwater at a local level. Groundwater monitoring and data on the availability of groundwater in general is insufficient. Water quality is a limiting factor to groundwater use and varies from good to unacceptable in terms of potable standards. The groundwater quality is one of the main factors affecting the development of available groundwater resources. Although there are numerous problems associated with water quality, some of which are easily corrected, total dissolved solids (TDS), nitrates (NO_3 as N) and fluorides (F) represent the majority of serious water quality problems that occur.

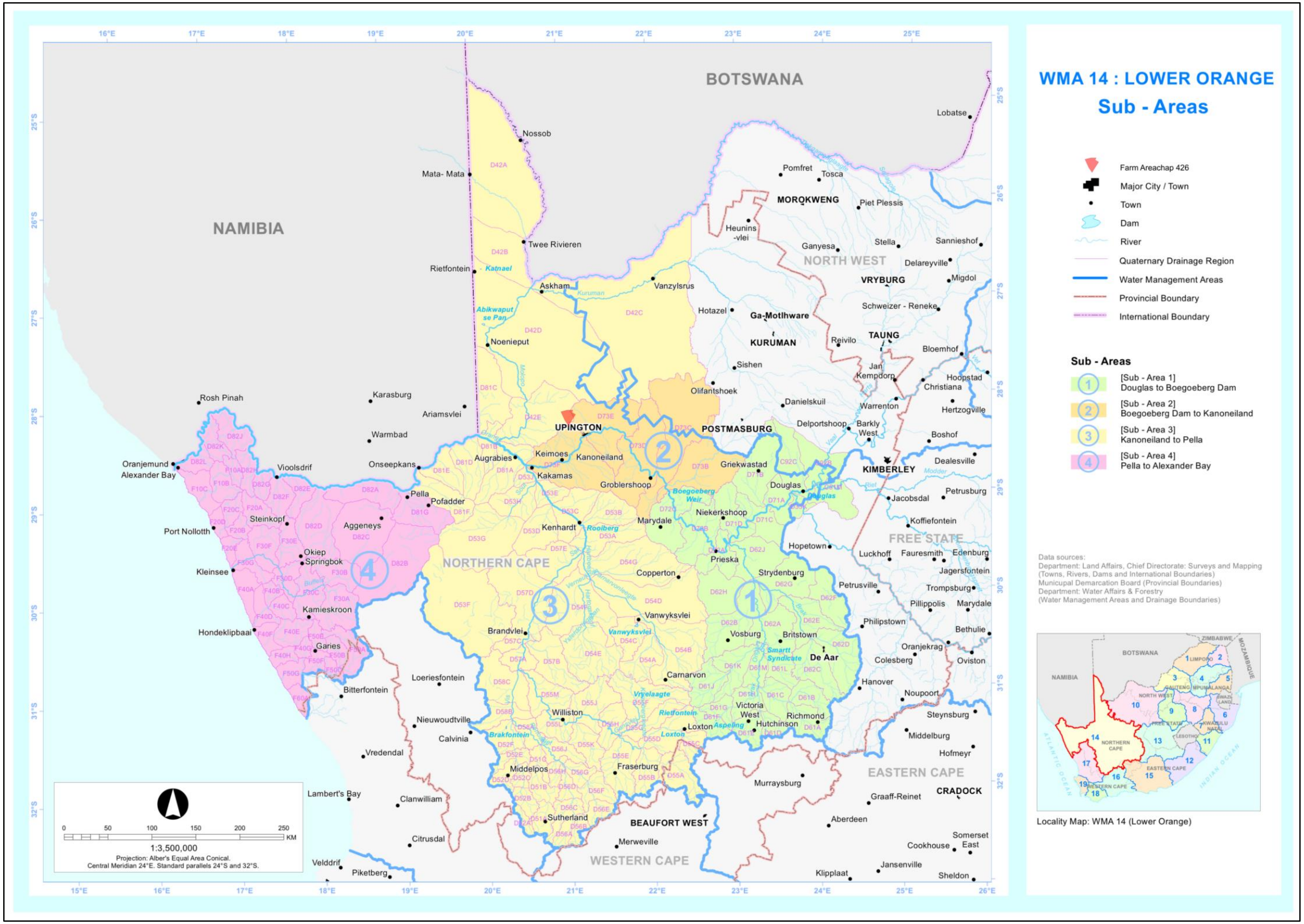

Figure 3-3: Lower Orange Water Management Area (WMA) with reference to sub-area placements and the study area (Farm Areachap426).

Adjusted from Water Affaris and Forestry (Ref: GM08_020).

3.4 Topography and Drainage

The study area is represented in Figure 3-4, relative to surface water drainage directions, local watersheds with associated drainage as well as quaternary catchment boundary divides between D42E, D73E and D73F also presented in Figure 3-3. South east of the catchment divide (D42E), surface water drainage is prominent in an overall south to south east direction while local surface water drainage within the quaternary catchment D42E is in an overall north west direction.

No perennial rivers are located within the borders of the study area. Due to the largely flat local topography, with large pans and endoreic areas that do not contribute significant runoff to the Orange River system, surface runoff is expected to be minimal. Table 3-3 is provided to summarize the key tributaries, per quaternary catchment, draining into the main stem of the Lower Orange River. The closest downstream perennial river connected to the study area's drainage is 37 km to the Molopo River to the west and north west. This river is reported to flow infrequently, if ever, due to the low rainfall generated in this LOWMA and therefore, little surface runoff exists.

Table 3-3: Summary of Tributaries per quaternary catchment draining into the main stem of the Orange River

Sub-Area	River	Order of river	Cumulative at Quaternary Catchment:	Cumulative/ Incremental Area (km2)	Unit MAR1 (mm)	Cumulative/ Incremental MAR	Mean Annual Runoff (MCM)	% of MAR for Total Orange R Basin	Standard Deviation*	Annual CV3
3	Molopo	5	D42E	4207,49	0-2.5	Cumltv.	143,42	1,21	292,62	2,04
2	Matjies	2	D73E	3866,68	2.5-5	Increm.	13,29	0,11	27,68	2,08
2	Kareeboom	2	D73F	4629,92	0-2.5	Increm.	9,62	0,08	20,65	2,15

The farm Areachap has an approximate elevation varying from 939 mamsl to 895 mamsl. The study area exhibits an overall estimated slope of 0 - 2 %. Overall groundwater flow is expected to mimic surface elevation variations where homogeneous horizontally extending geology is present. Groundwater is also expected to flow parallel to intersecting geological contact zones and dolerite intrusions.

3.5 Climate

The Areachap 426 area receives approximate 94mm of rain per year, with most rainfall only occurring during autumn months. Figure 3-5 shows the average rainfall values for the general area per month. This area receives its lowest rainfall during June (0mm) and the most rainfall during March (29mm). The monthly distribution of average daily maximum temperatures (Figure 3-6) shows that the average midday temperatures range from 19.8°C in June to 33°C in January to September. The region is the coldest during July when the mercury drops to 2.8°C on average during the night.

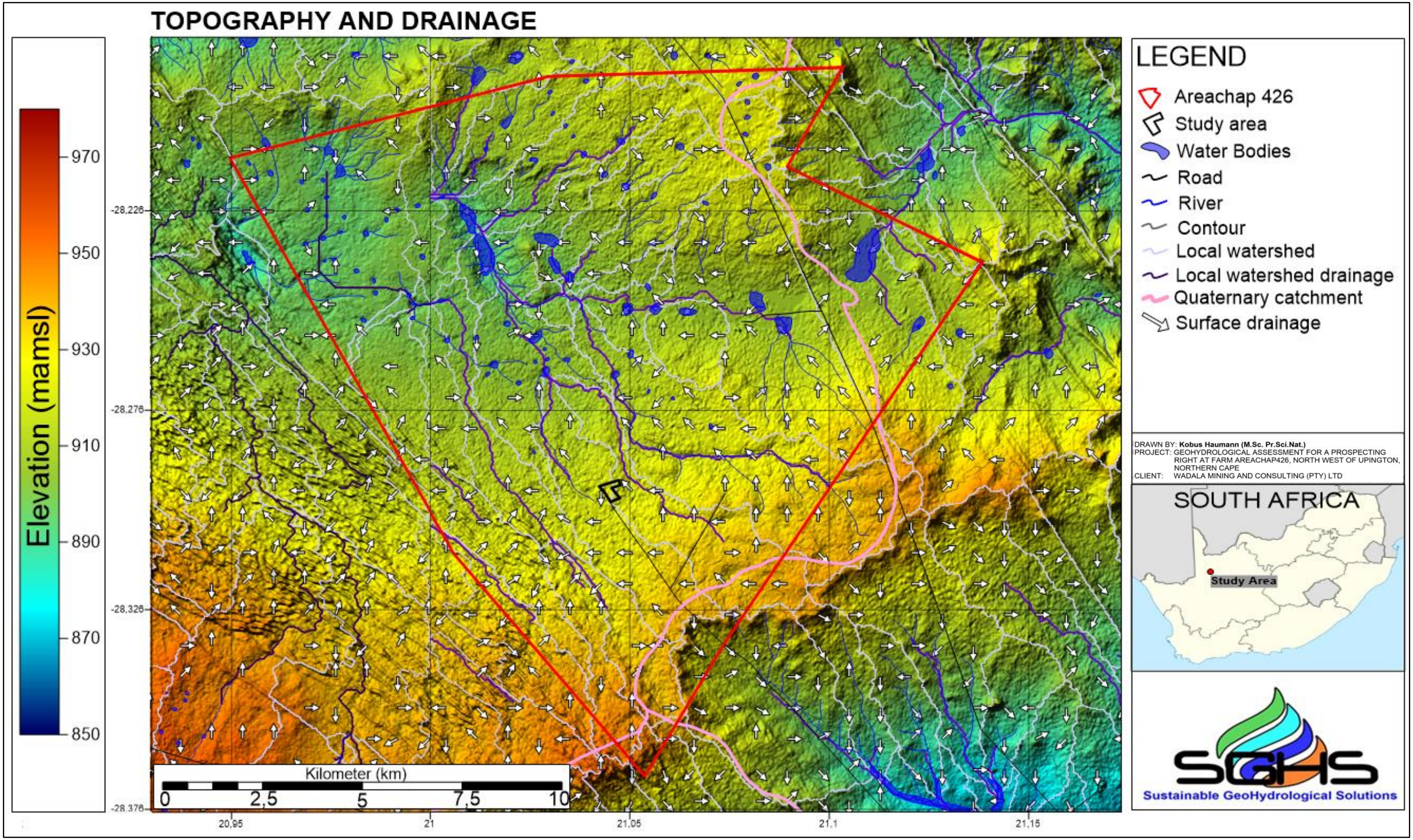

Figure 3-4: Topographical variation and drainage of Areachap426

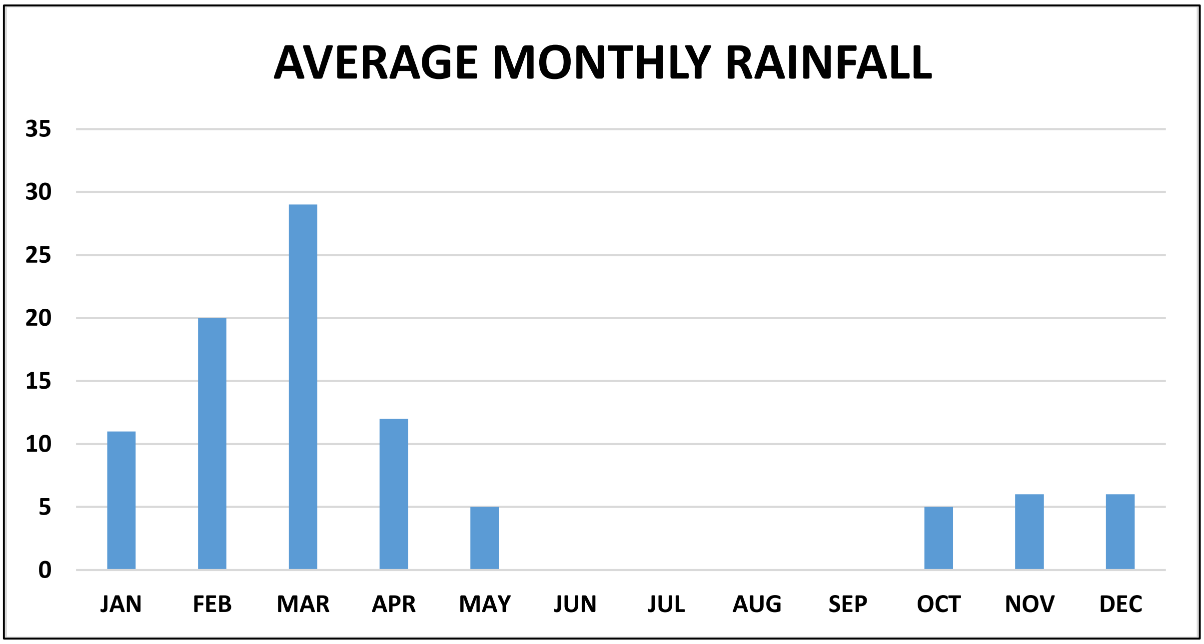

Figure 3-5: Average Monthly Rainfall.

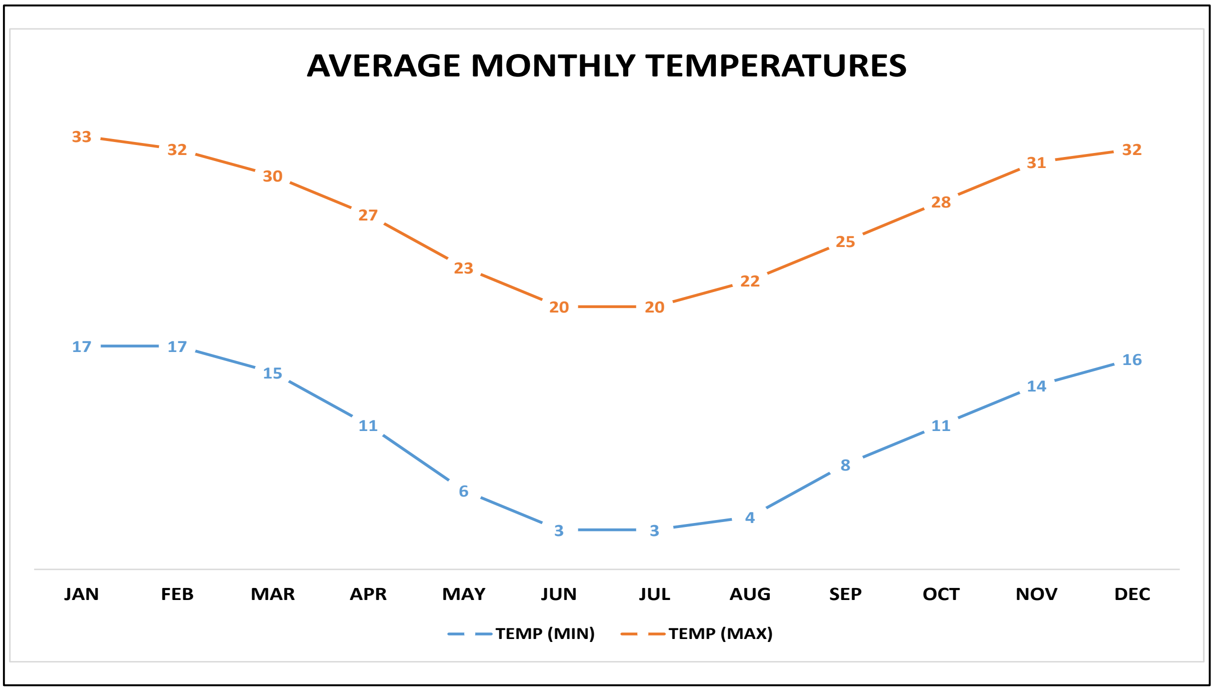

Figure 3-6: Average Monthly Minimum and Maximum Temperatures.

3.6 Regional Magnetic Setting

In order to accurately interpret regional aeromagnetic structures in proximity to the study area, a high quality airborne magnetic TIFF map from 1: 2 000 000 scale was incorporated into a high definition topo-aeromagnetic presentation represented in Figure 3-7 compared to the original Aeromagnetic map. From this image, higher defined prominent aeromagnetic structures are seen to intercept the study area.

A prominent aeromagnetic lineament is visible throughout the investigated site, extending in a south east to north west direction. This lineament also crosses right beneath the prospecting area. A mapped magnetic discontinuity, exported from a 1: 250 000 geological map, is seen west of the study area and correlates with a prominent magnetic lineament.

These lineaments of magnetic intensities are in all likelihood due to the presence of metasedimentary successions and intrusive rocks with increased magnetic susceptibility intersecting the regional area.

These lineaments may be caused by magnetic associable geological formations which are known to occur in the area. The location and extent of these structures are important in determining preferential groundwater flow paths through which pollution distribution may occur. These areas are also associated with an increased surface to groundwater infiltration/recharge rate.

An on-site magnetic investigation will be required to determine the uniformity/presence and extent of the mapped magnetic anomalies and lineaments beneath the study area. This in turn may help predetermine preferential subsurface groundwater flow conduits. Groundwater monitoring borehole placement will be determined by the orientation and extent of mapped magnetic structures.

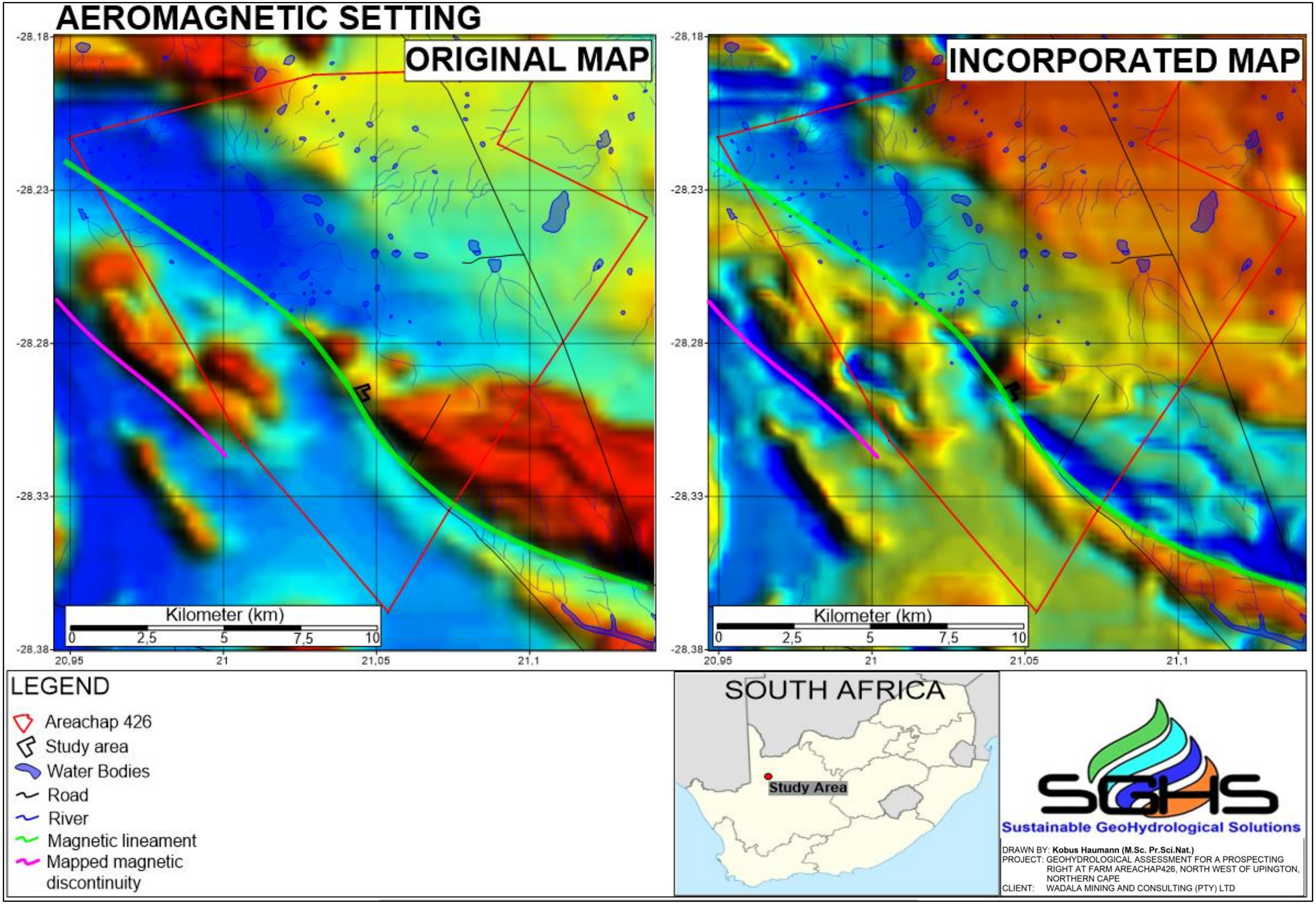

Figure 3-7: Regional aeromagnetic setting of Areachap426

3.7 Geological Setting

The area of investigation is situated at the boundary of two major geological sequences such as that of the Namaqua-Natal Metamorphic Province and the Karoo Sequence. This section aims to provide background to both sequences applicable.

3.7.1 The Namaqua-Natal Metamorphic Province

3.7.1.1 Location and Extend

The Namaqua-Natal Metamorphic Province (NNMP) occurs along the southern and south western margin of the Kaapvaal Craton and is bounded in the west and south by the Gariep and Saldania Belts respectively (Figure 3-8). The NNMP outcrops in the Northern Cape (Namaqua Sector or Namaqua Mobile Belt) and Kwazulu-Natal (Natal Sector or Natal Metamorphic Belt) Provinces. The igneous and metamorphic rocks of the NNMP formed during the Namaqua Orogeny that occurred approximately 1200 to 1000 Ma ago.

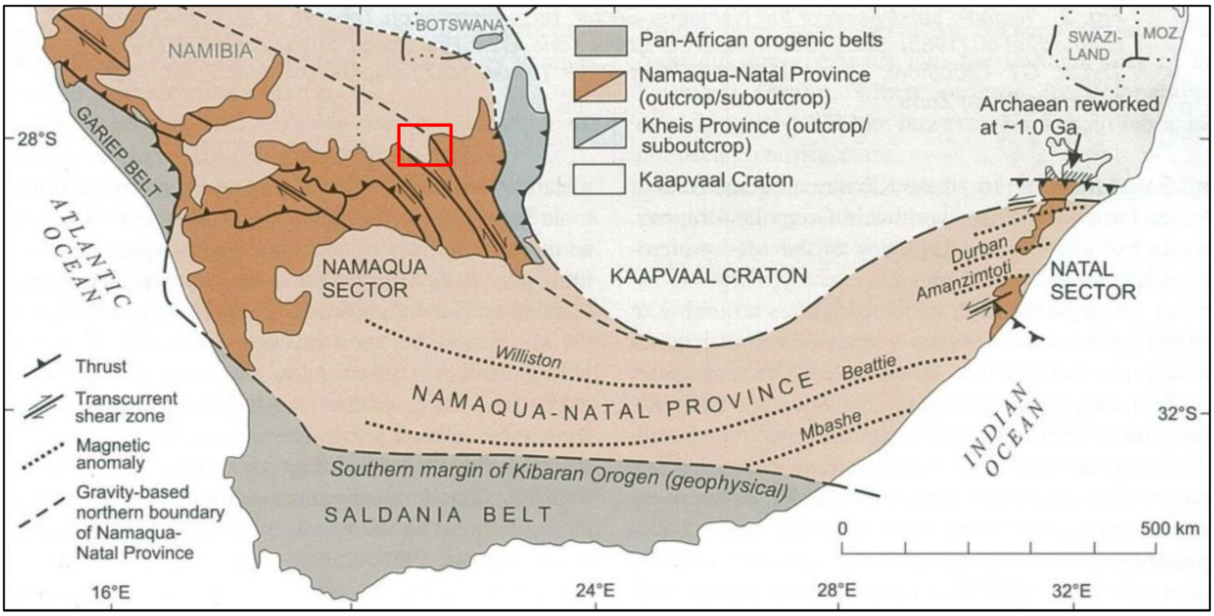

Figure 3-8: Geological setting of the Namaqua-Natal Metamorphic Province (Cornell et al., 2006). Study area indicated by red square.

3.7.1.2 Geology

The NNMP is subdivided into different tectonostratigraphic sub-provinces and terranes, based on marked changes in lithostratigraphy across structural discontinuities (Cornell *et al.,* 2006). The area of investigation is located within the Areachap Terrane.

3.7.1.2.1 Areachap Terrane

The Areachap Terrane is a north northwest trending belt bounded by the Trooilapspan and Brackbosch Shear zones in the east and the Boven Rugzeer Shear Zone in the west (Figure 3-9). The Areachap Terrane consists of metavolcanic rocks and immature sediments which are occasionally migmatized (Pettersson, 2008). The rocks of the Areachap Terrane are collectively known as the Areachap Group. The Areachap Group is subdivided into four formations and illustrated Figure 3-10.

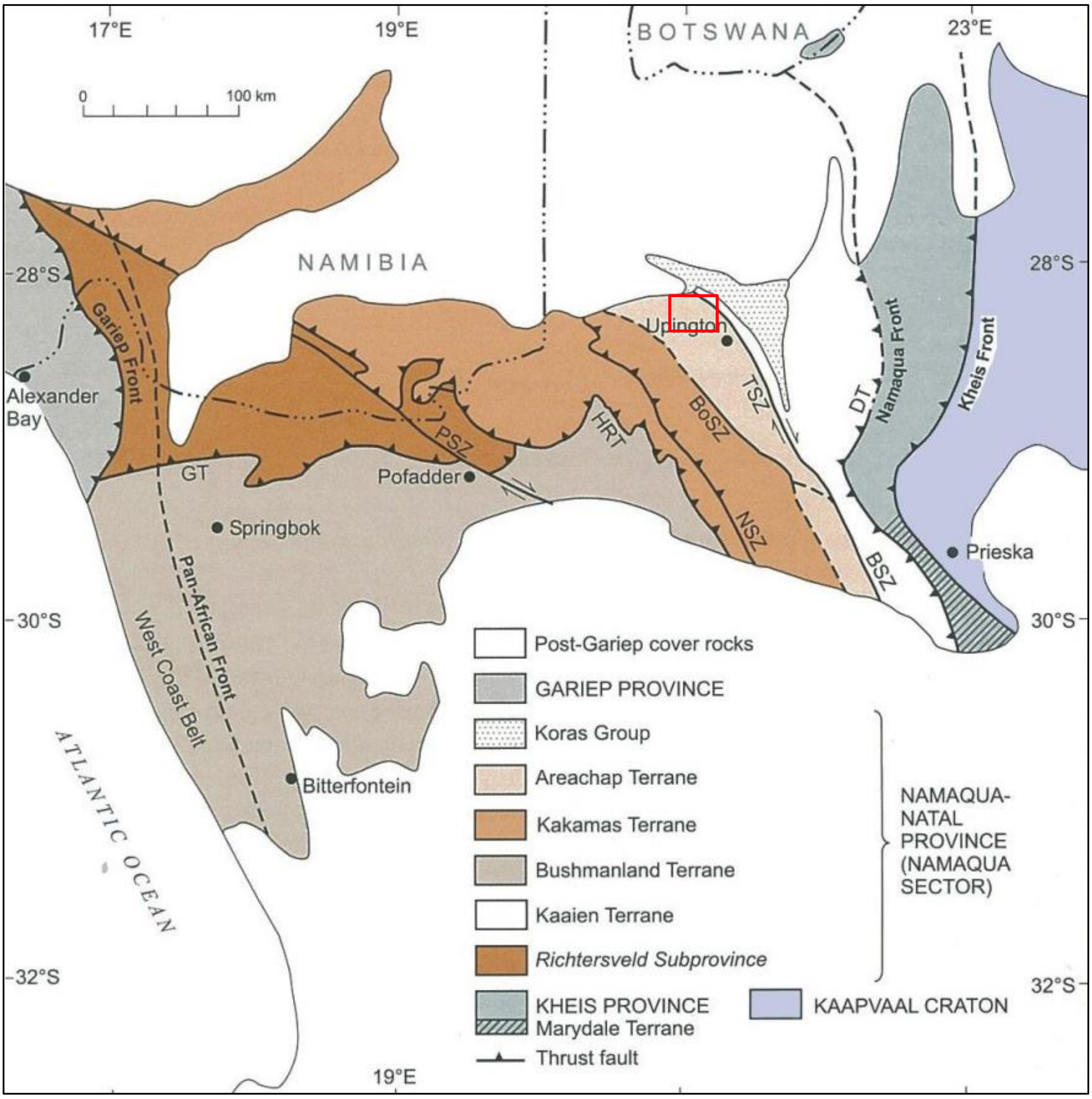

Figure 3-9: Tectonic subdivision of the Namaqua Sector of the NNMP (Cornell et al., 2006). BoSZ: Boven Rugzeer Shear Zone, BSZ: Brakbosch Shear Zone, DT: Dabep Thrust, GT: Groothoek Thrust, HRT: Hartbees River Thrust, NSZ: Neusberg Shear Zone, PSZ: Pofadder Shear Zone. Study area indicated by red square.

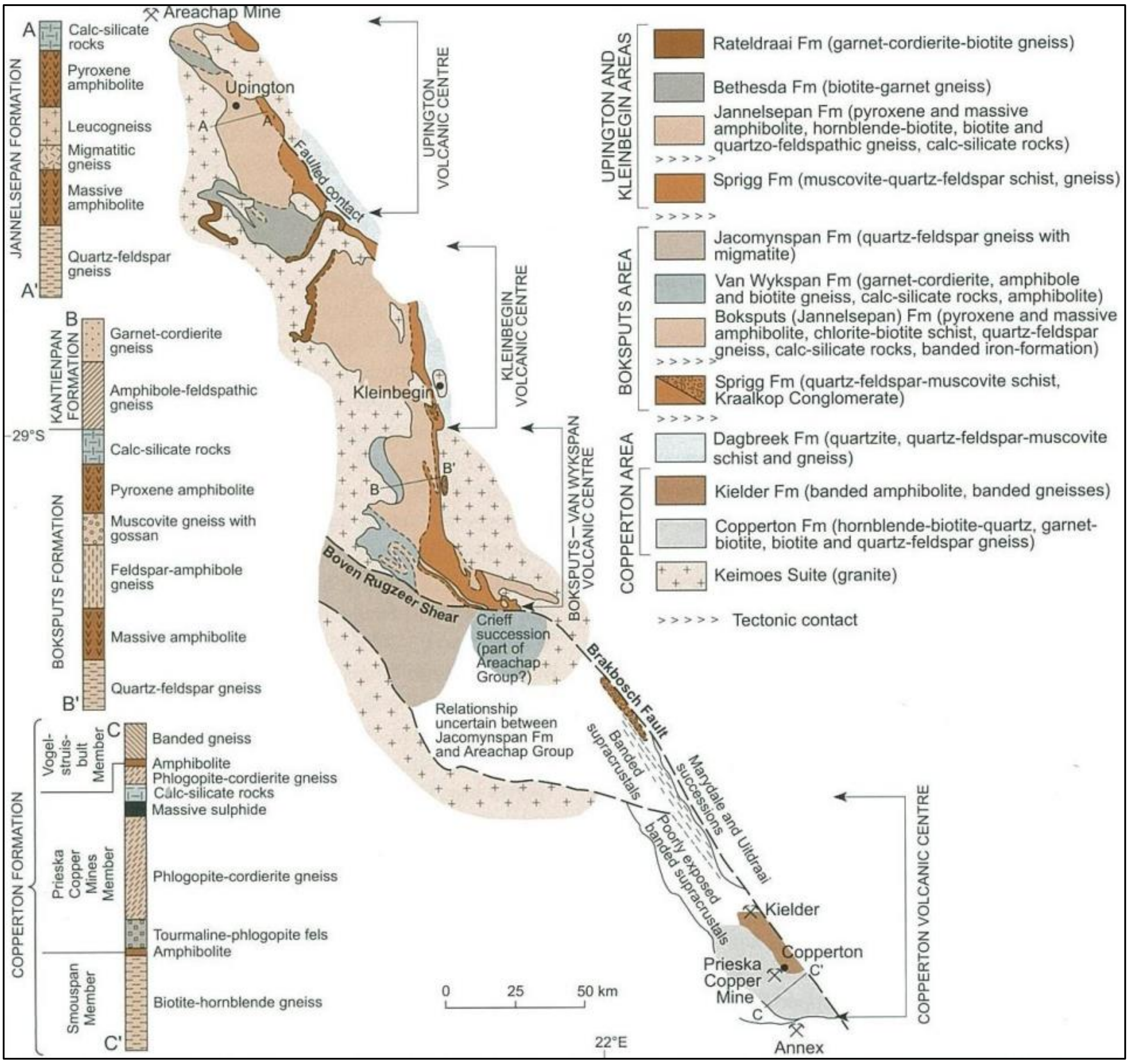

Figure 3-10: Lithstratigraphy and distribution of the Areachap Group (Cornell et al., 2006)

3.7.2 Karoo Sequence

The study area is partly located within the Karoo Supergroup which covers approximately two thirds of the current land surface of South Africa. Sedimentary and volcanic rocks of the Karoo Supergroup ranges in age from Late Carboniferous to the Early Jurassic.

In South Africa, rocks of the Karoo Supergroup are preserved in four different basins and a narrow strip along the Mozambique-South Africa border known as the Lebombo Mountain Range. These basins are given in Figure 3-11 with the study area located on the boundary of the Botswana (Kalahari) Basin.

The Karoo Supergroup is made up of the 1) Drakensberg and Lebombo Groups, 2) Molteno, Eliot and Clarens Formations, 3) the Dwyka and Ecca Groups as well as 4) the Beaufort Group. Our area of investigation is partly located within the Dwyka Group.

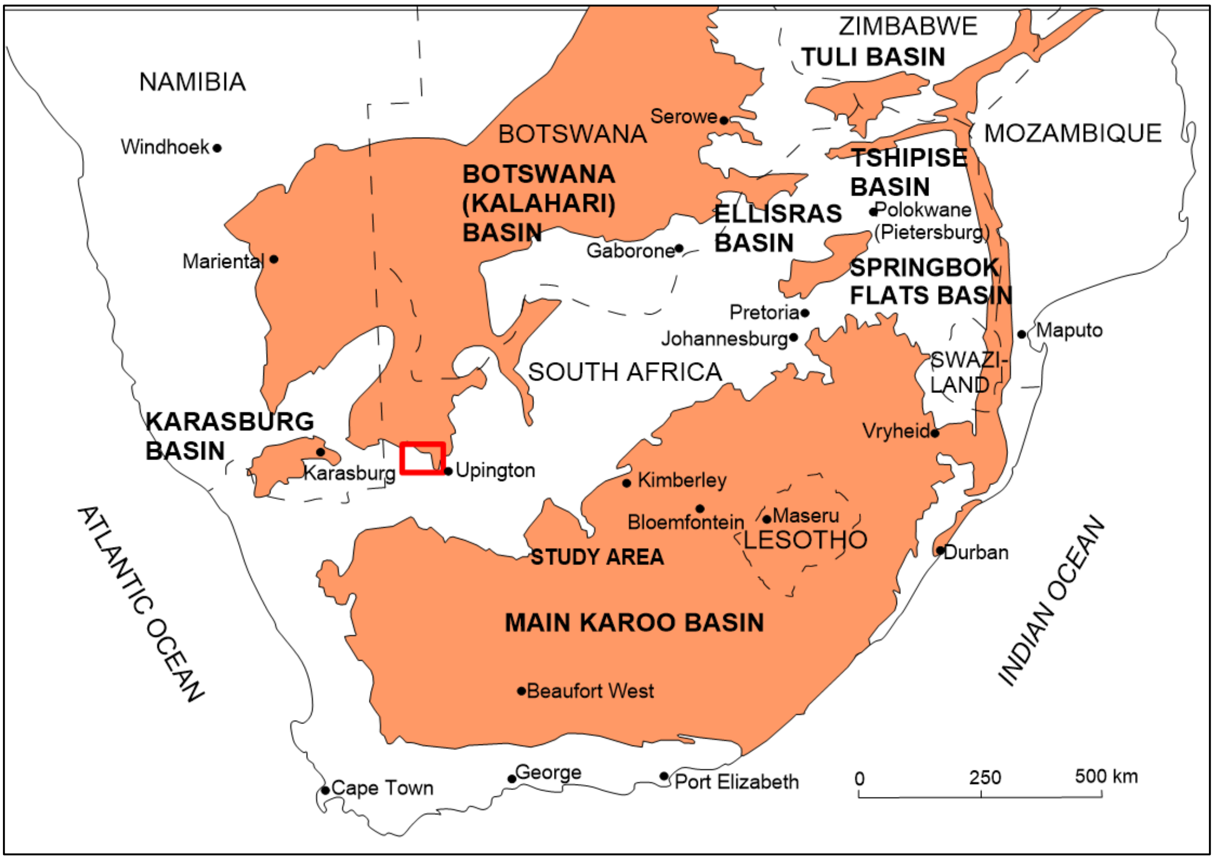

Figure 3-11: Location of Karoo Boundaries in South Africa and adjacent territories (modified after Johnson et al.,1996). Study area indicated by red square.

3.7.2.1 Dwyka Group

The Dwyka Group consists predominantly of diamictite and to a lesser extent of conglomerate, pebbly sandstone, and mudrock with dispersed stones (Visser, Von Brunn, & Johnson, 1990). Along the northern basin margin the Dwyka Group overlies glaciated Precambrian bedrock surfaces and in the south it overlies the Cape Supergroup unconformably/paraconformably, while in the east it unconformably overlies the Natal Group and Msikaba Formation (Johnson *et al.*, 2006).

The Dwyka Group shows distinct lithological differences over the Basin, which led to the recognition of a northern valley/inlet facies and a southern platform facies (Johnson, *et al.*, 2006; Woodford & Chevallier, 2002). The northern facies has a highly variable lithology, low massive diamictite (±20 %) and high mudrock/sandstone (±40 %) content, where the southern facies has a fairly uniform lithology, high massive diamictite (±70 %) and low mudrock/sandstone (±8 %) content (Visser *et al.*, 1990).

The thickness of the Dwyka Group generally increases southwards (Du Toit, 1954) with a thickness of 500-800 m in the south and 100-200 m at the northern margin of the southern facies from where it is highly variably further northwards (0-600 m) (Visser *et al.*, 1990).

The diamictite facies is generally massive, but may be stratified in places (Woodford & Chevallier, 2002). The diamictite is highly compacted, generally clast-rich, with rounded to angular, frequently striated pebbles and boulders up to 2 m across derived from pre-Karoo rocks (Johnson, *et al.*, 2006). The diamictite is blue-greenish in colour (Figure 3-12) (Du Toit, 1954).

The conglomerate facies ranges from single layer boulder beds to poorly sorted pebble and granule conglomerates (Johnson, *et al.*, 2006). The sandstone facies consists of either very fine- to medium grained, massive to ripplelaminated, or medium- to coarse grained, trough cross-bedded, immature sandstones (Johnson, *et al.*, 2006). The mudrock facies consists of dark-coloured, commonly carbonaceous mudstone, shale or silty rhythmites (Johnson, *et al.*, 2006).

Figure 3-12: Generalised lithostratigraphy of the Karoo Supergroup in the Main Karoo Basin (Johnson et al., 2006).

3.7.3 Local Geology

The rocks outcropping the local area are both metamorphic and sedimentary. The investigated site is illustrated in Figure 3-13 in relation to 1:250 000 mapped geological structures.

The prospecting area is seen to be predominantly underlain by rocks of the Dwyka Group (C- Pd) which consists predominantly of diamictite and to a lesser extent of conglomerate, pebbly sandstone, and mudrock with dispersed stones. The study area is also seen to be underlain by the Gordonia Formation (Qg) of the Kalahari Group which consists of windblown sands and dunes of red-brown coloration. The tillite of the Dwyka Group is expected to be partially covered by gravel and sand of the Gordonia Formation.

A massive south east to north west magnetic lineament is seen to intersect the study area. This anomaly does however not correspond with mapped surface geology. The magnetic lineament is expected to be caused by metavolcanic rocks and occasionally migmatized immature sediments of the Areachap Terrane. Groundwater flow and surface to groundwater infiltration rates are expected to be increased at the weathered contact boundaries of geological structures associated with the magnetic lineament.

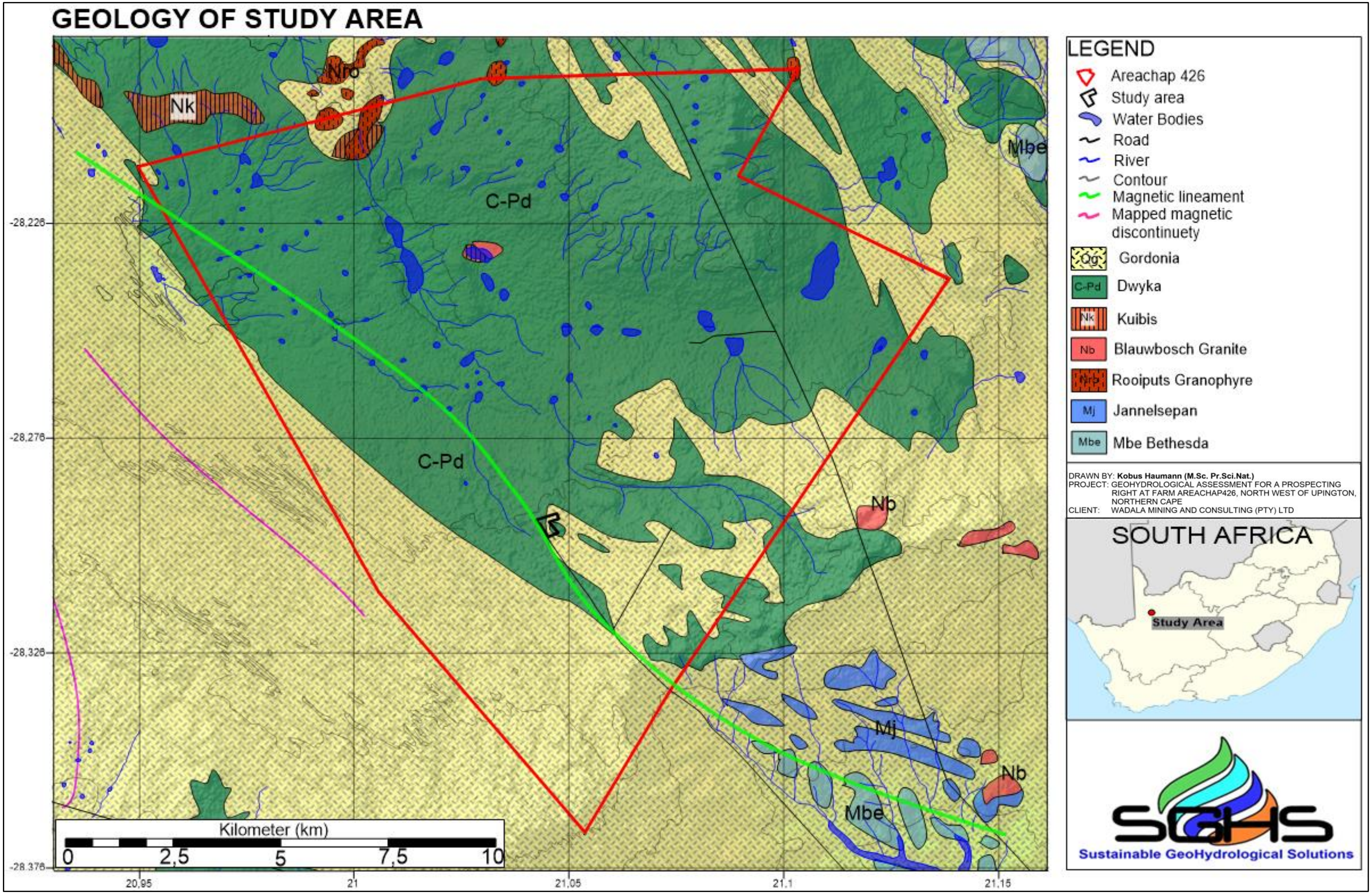

Figure 3-13: Geological map of study area

3.8 Geohydrology

3.8.1 Namaqua Sector

Groundwater within the Namaqua Sector of the NNMP occurs within three different aquifer systems (Friese *et al.,* 2006; Pietersen *et al.*, 2009):

- Fractured bedrock
- Weathered zone (regolith)
- Sandy or alluvial aquifers

The geometry of these aquifer systems are controlled and influenced by the underlying geology of igneous and metamorphic rocks and its deformation history of metamorphic evolution, and the geomorphic development of the Namaqua Belt, including weathering (Pietersen *et al.*, 2009). Despite the great variety of these metamorphic and igneous rocks, they are homogenous in two respects (Vegter, 2006):

I. Virtually no primary porosity (except alluvial aquifers).
II. Secondary porosity due to fracturing and weathering.

According the Pietersen *et al.* (2009) the fractured bedrock and regolith systems are generally linear systems associated with the structurally controlled valleys (Figure 3-14) and may be laterally extensive depending on the nature of the faults systems. Weathering processes; mechanical disintegration, chemical solution and deposition modifies the porosity/permeability of the fractures systems, implying either an increase or decrease in porosity and or permeability (Vegter, 2006). As a result of these structurally controlled valleys (Figure 3-14 & Figure 3-15), localized, shallow circulation groundwater flow systems are dominant in the near surface environment (Friese *et al.*, 2006).

Groundwater flow within the Namaqua sector is complex as it is a function of complex topographic and hydrogeological environments with multiple flow systems (Friese *et al.*, 2006). The natural groundwater flow can be subdivided into local, intermediate and regional flow regimes:

- *Local flow* paths are characteristic short
- *Intermediate flow* paths are longer and deeper than local flow and can underlie several local flow regimes.
- *Regional flow regimes* theoretically extend from regional recharge areas to distant discharge areas, such as rivers or may be presented by higher salinity structurally controlled artesian springs.

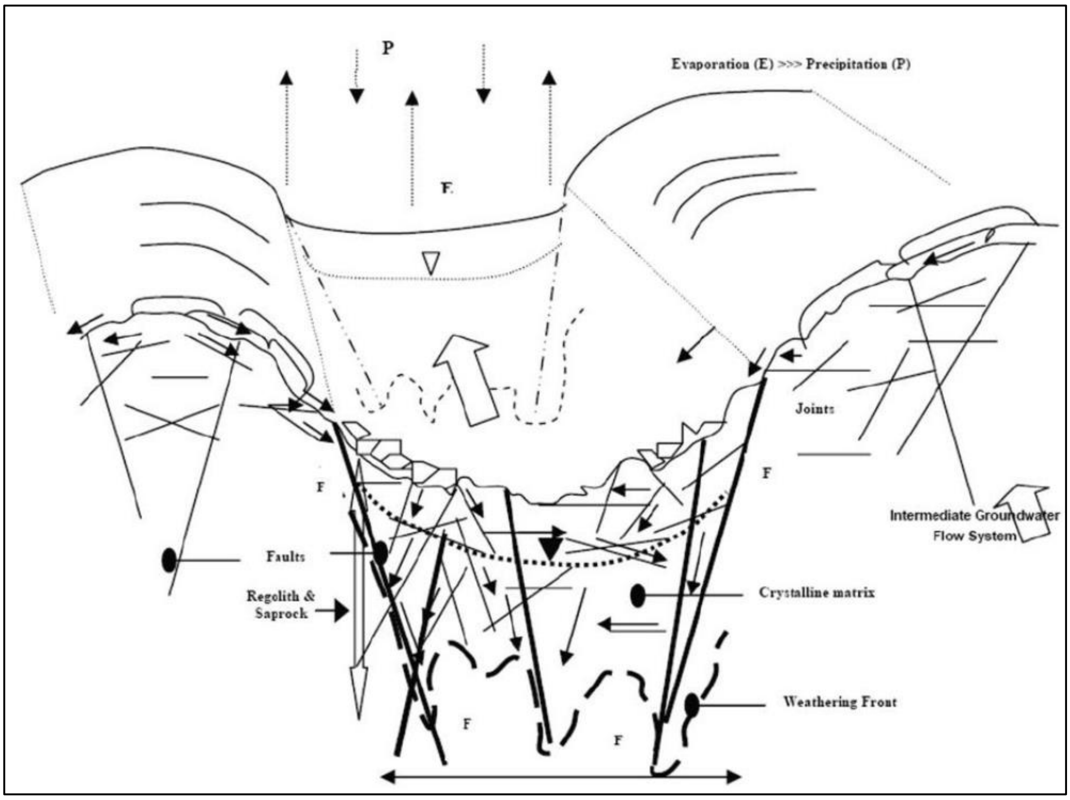

Figure 3-14: Proposed aquifer geometry and local to intermediate flow regimes for a typical structurally controlled valley (Friese *et al.*, 2006).

Figure 3-15: Structurally controlled valley in the rocks of the Namaqua sector of the NNMP. Windpump indicates that the valley have been targeted for groundwater.

According to Vegter (2006), in contrast to areas with thick sandy cover, recharge is favored by shallow sandy soil, calcrete and exposures of fractured rocks. The reasons are twofold;

I. A thick sand-cover retains and prevents rain water from entering the underlying formations and thus allows its complete dissipation through evapotranspiration. On the other hand, once rain water has passed through a shallow cover and has entered the underlying fractured rocks, evapotranspiration loss is minimized.
II. Runoff is promoted by shallow sandy soil, calcrete and rock exposure and accumulates in low lying areas and rivers. Here the concentrated volume favors recharge provided infiltration is not inhibited by the presence of clayey soil.

3.8.2 Dwyka Group

3.8.2.1 Geohydrological Characteristics

The Dwyka Group are generally considered to be an aquitard rather than an aquifer, as the diamictite and shales have very low hydraulic conductivities and virtually no primary voids (Vivier, 1996). Even though the Dwyka Group is considered to be an aquitard, there are a few localities where there are exploitable aquifers and this is where sand and gravel were deposited on beaches or where the Dwyka Group was fractured significantly (Woodford & Chevallier, 2002). These features are only exploitable if the recharge in these areas is significant. Thus the Dwyka Group is not ideal for the development of large-scale development for groundwater supply.

The groundwater of the Dwyka Group is generally brackish, especially along the coastal zones, (saline) with EC values often exceeding 300 mS/m. EC values tend to decrease inland. The quality of the groundwater improves in fractures or jointed zones of the Dwyka Group, where significant groundwater movement and turnovers take place, with EC values ranging between 25 and 200 mS/m (Meyer, 2001). Sodium, calcium, magnesium, chloride and sulphate may often exceed maximum allowable limits (Meyer, 2001).

3.8.2.2 Borehole Yields

According to various authors the Dwyka Group is a low yielding aquifer, as it is generally considered an aquitard rather than an aquifer. Yields are generally lower than 0.5 l/s. Areas where the Dwyka Group have been fractured significantly can have yields of up to 10 l/s (King, 2002), but it is rather rare. According to Schafer (2011), fractures or joints that are present within the Dwyka Group have the tendency to be mineralised (kaolinised), and this mineralisation can actually be followed on surface. The mineralisation of this fractures or joints decreases the potential yield that can be encountered. According to King (2002) the success rate of drilling a successful borehole in the Dwyka Group is 30 to 40 %. If one is successful in locating groundwater within the Dwyka Group, the sustainable yield is normally not that favourable, as the aquifer normally has a complete linear response (Schapers, 2011).

3.8.3 Quality

The study area is situated on a *poor* aquifer system which is a low to negligible yielding aquifer system of moderate to poor water quality.

The electrical conductivity values are expected to vary between 150 mS/m and 520 mS/m. The aquifer has a *least* groundwater vulnerability rating that is only vulnerable to continuously discharged or leached pollutants in the long term.

Due to the study area's aquifer system having a ***poor*** aquifer classification and ***least*** aquifer vulnerability rating, it can be assumed that the aquifer has a ***low*** susceptibility for contamination.

A groundwater susceptibility matrix is given in Table 3-4, representing a qualitative measure of the relative ease with which a groundwater body can be potentially contaminated by anthropogenic activities and includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification.

Table 3-4: Groundwater Susceptibility Matrix

		AQUIFER CLASSIFICATION		
VULNERABILITY		Poor	Minor	Major
	Least	Low 1	Low 2	Medium 3
	Moderate	Low 2	Medium 4	High 6
		Medium 3	High 6	High 9

4 HYDROCENSUS

A site investigation (hydrocensus) was conducted on 15 April 2019. During this site visit all relevant data collection and conceptualization took place.

- A hydrocensus was conducted in a respective >6 km radius surrounding the proposed development site. The aim of this census was to;
- Map geological structures via visual analysis.
- Determine local urban and rural groundwater dependencies and related influences to local groundwater quality and quantity.
- Record groundwater levels to estimate groundwater flow directions in order to establish possible subsurface contamination flow paths.
- Chemical sampling of surface water (if applicable) and groundwater to determine current local groundwater quality.

4.1 Surface Site Observations

All selected surface and groundwater observation and sampling locations are represented in Figure 4-1. These locations were plotted in relation to regional aeromagnetics and surface geology maps to help conceptualize the distribution of possible preferential groundwater flow paths that may be associated with contaminant transport. Basic site properties for each investigated site is added to Table 4-1.

Table 4-1: Background to hydrocensus sample sites

Site name	Latitude	Longitude	Elevation (mamsl)	Static Water Level (mbgl)	Water Level (mbgl)	Groundwater Elevation (mamsl)	EC (mS/m)	pH	T (°C)	Equipment	Use	Comments
GBH1	-28.295646	21.043255	925	50,83	-	874,17	>600	1,56	20,3	-	Ventilation	-
GBH1B	-28.295321	21.043499	925	-	-	-	-	-	-	-	Ventilation	Damaged casing
GBH2	-28.299227	21.039204	918	-	-	-	-	-	-	-	None	Dry
GBH3	-28.273696	21.045090	907	-	48,42	858,58	283	8,3	19,1	Windpump	Livestock	-
GBH4	-28.265417	21.015642	897	-	39,23	857,77	265	6,21	26,1	Windpump	Livestock	-
GBH5	-28.266416	21.015378	899	-	-	-	-	-	-	Windpump	Livestock	Not working
GBH6	-28.287553	21.009533	909	46,42	-	862,58	-	-	-	Solar power	Livestock	-
GBH7	-28.288152	21.067918	919	-	-	-	-	-	-	Windpump	Livestock	-
GBH8	-28.287952	21.067757	921	-	87,35	833,65	322	6,51	26,9	Solar power	Livestock	-
GBH9	-28.296367	21.074411	933	-	-	-	-	-	-	Windpump	Livestock	-
GBH10	-28.295170	21.073815	927	-	-	-	-	-	-	Diesel pump	Livestock	-
GBH11	-28.277770	21.061791	915	-	29,5	885,5	-	-	-	Windpump	Livestock	-
GBH12	-28.253288	21.083131	903	28,43	-	874,57	-	-	-	Windpump	None	Deteriorated
GBH13	-28.248413	21.084700	903	-	-	-	-	-	-	Windpump	Livestock	-

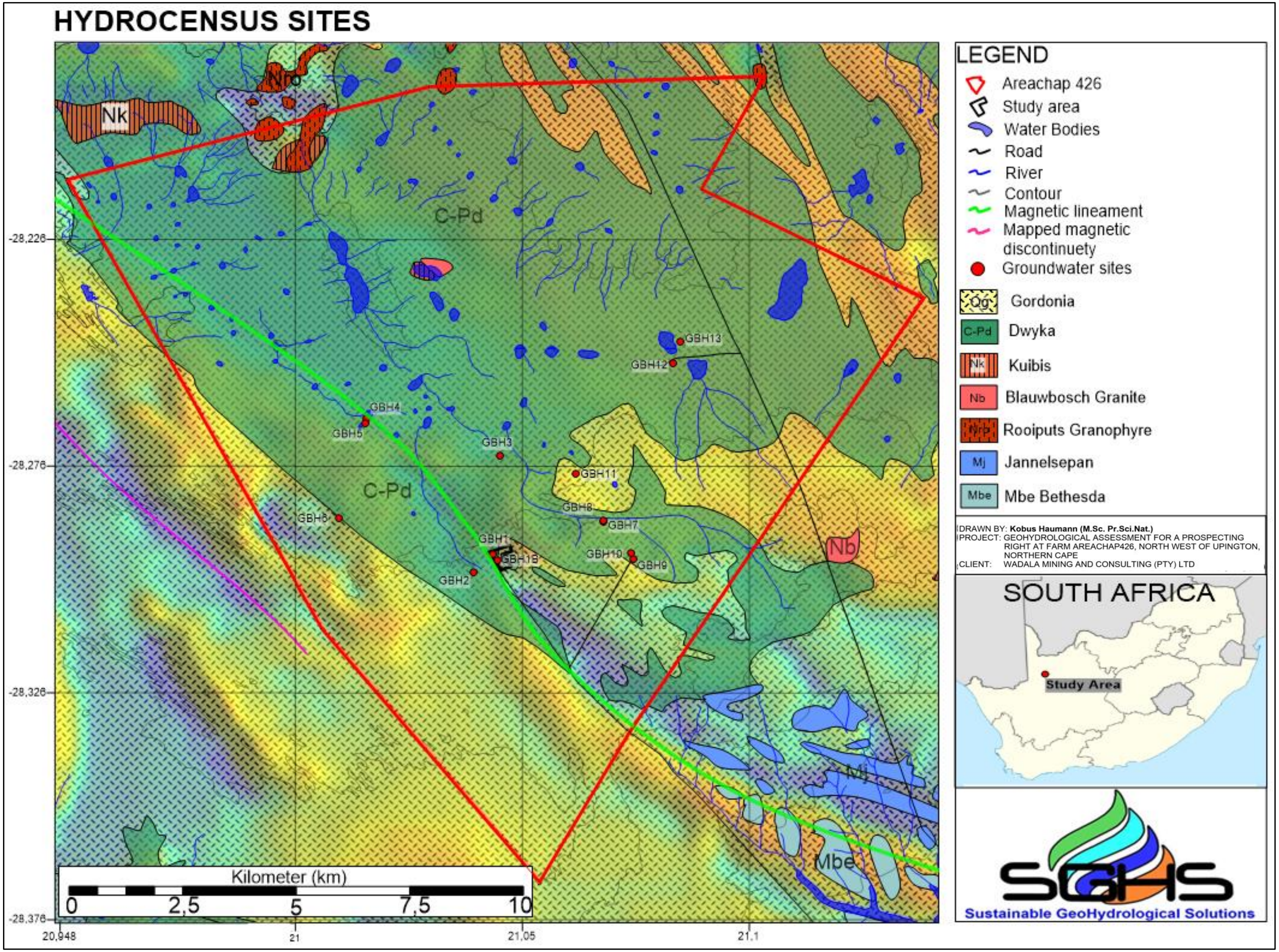

Figure 4-1: Hydrocensus sample sites identified in relation to the study area, regional aeromagnetics and surface geology

4.1.1 Surface Area

The surface area of the investigated site is indicated in Figure 4-2 in a south east direction. From this image, the characteristically flat surface topography is evident. The investigated area is clear to have been previously mined with ore aggregate distributed across the area. The local area beyond the existing copper mine borders appears to be in visual good natural quality. Although the area was reported to receive heavy rainfall prior to the site visit, no surface water accumulation sites were recorded within the Areachap426 farm during the investigation.

Figure 4-2: On site surface conditions.

4.1.2 Geological Mapping

During the site investigation, it was confirmed that the study area is underlain by Jannelspan Formation consisting of gossan, various pyroxene and massive amphibolite, hornblende-biotite, biotite and quartzo-feldspathic gneiss, and calc-silicate rocks. The investigated site appears parsley intruded by dolerite dykes and is shallow underlain by excessive calcrete. Calcrete is commonly found as a discontinuous layer of very dense, nodular calcrete just below the thin topsoil; visible as discrete outcrops. Trenching indicated that the calcrete layer has a hard nature, which extends into the weathered bedrock, to depths of more than 20m in places.

Already existing trenches were used to indicate underground geological structures within the subsurface. Images representing these observed trenches are added to **Appendix B** while the distribution of these trenches are presented in Figure 7-1 and Figure 7-2

Historic Trench 1 (HT1) is located closest to the existing dumping site. This trench has an estimated depth of 4m. This site represents highly weathered calc-silicate that is intruded by a dolerite dyke. This dyke is expected to have a general north west to south east orientation.

Geological contact boundaries connected to this dyke may be associated increased transmissivity rates. These areas are expected to have increased surface to groundwater infiltration rates as well as preferential groundwater flow paths, along which pollution migration may occur.

Historic Trench 2 (HT2) is located further towards the south east of HT1. This site has an reported depth of 40m. The site predominantly represents weathered calcrete. No visible indication of and extending dolerite dyke.

Historic Trench 3 (HT3) is a long and shallow extending trench. The site predominantly represents weathered calc-silicate rock.

Remaining Historical Trenches (RHT) are represented by overall non defined fell in trenches. Observed geology suggest that the study area is underlain by the Jannelspan Formation. The area appears to be highly weathered.

4.2 Recorded Boreholes and Groundwater Observations

During the site investigation, 12 boreholes and 2 shafts were recorded within a >6 km radius of the study area. These boreholes are expected to reveal local groundwater chemical qualities as well as associable groundwater levels and flow directions. The local area surrounding the investigated site was recorded to partake in groundwater dependent practices such as livestock activities.

4.2.1 Ventilation Shaft 1 (GBH1)

Ventilation shaft GBH1 (Figure 4-3) was recorded on site in close proximity to existing dumps. The site was accessed for in field chemistry testing. A static groundwater level of 50.83 mbgl was recorded which is expected to represent the regional static groundwater level.

The shaft revealed an on site TDS of >3999 ppm and an EC of >600 mS/m at 20.3°C. an extremely acidic groundwater pH level of 1,56 was recorded. This indicates a deteriorated groundwater quality compared to what is expected in the area. Groundwater samples were collected from the shaft to undergo inorganic and hydrocarbon analysis which is discussed in Section 4,3.

Recorded groundwater temperatures appear relatively elevated and could be as a result of increased humidity within the shaft itself. Prolonged shaft wall exposure to elevated humidity and temperatures may cause pH levels to decrease (become more acidic) considering acidic minerals expected to be present within the shaft such as phyrite (FeS_2). It is highly recommended that the shaft be properly sealed and cased to restrict additional acidification.

Figure 4-3: Ventilation shaft 1 (GHB1)

4.2.2 Ventilation Shaft 1B (GBH1B)

A ventilation shaft was recorded on site, in close proximity to the existing dumps and site office. This shaft appears to be damaged (bottom left corner of Figure 4-4) with casing failure and could not be sampled for chemical analysis or groundwater levels. This shaft is reported to be up to 200m deep. Underground sampling will be conducted from this site at 70mbgl to 90mbgl.

4.2.3 Borehole GBH2

A borehole, expected to have been installed as an exploration or monitoring borehole is recorded 500m south west of the investigated site. This borehole however, was filled with sand and debris to a depth of 4,31mbgl during the site investigation. No groundwater observations could be collected. Borehole GBH2 is represented in Figure 4-5.

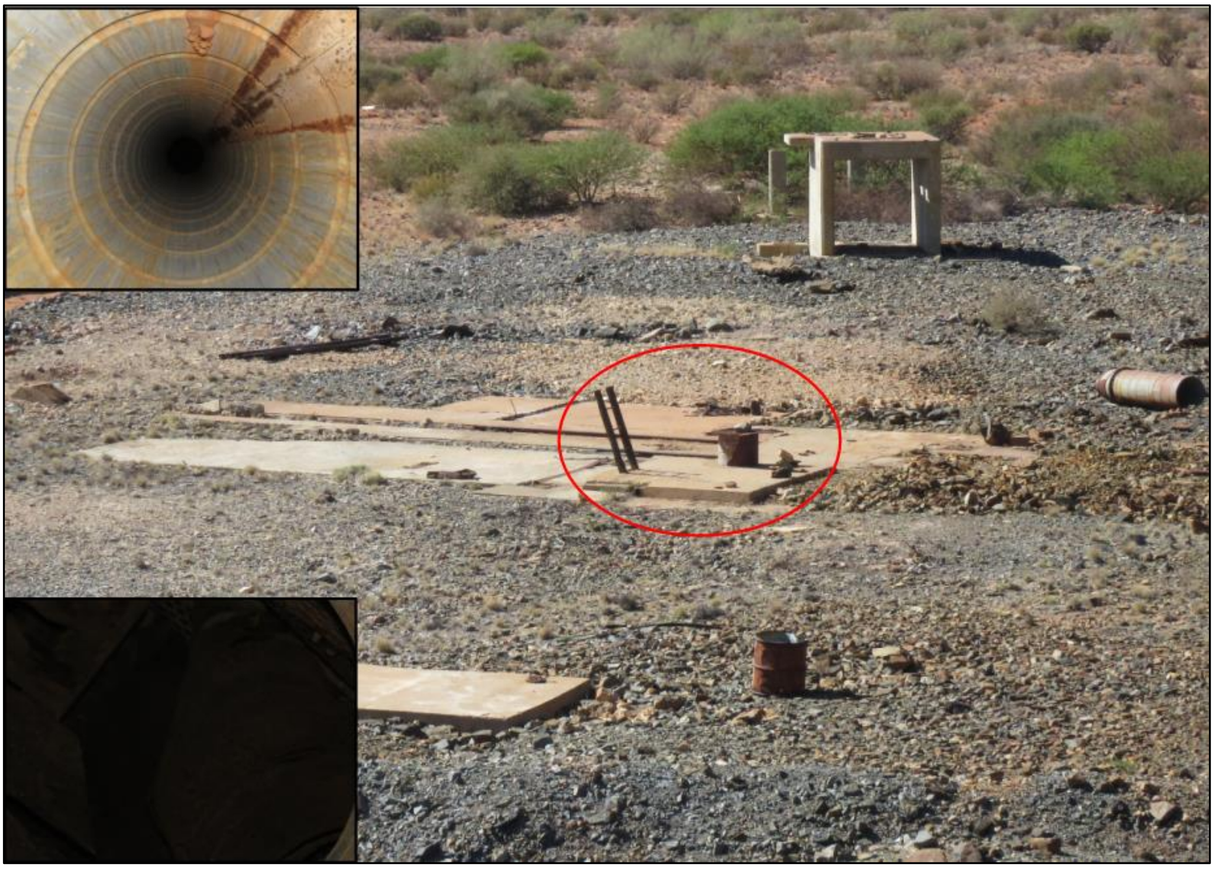

Figure 4-4: Ventilstion shaft 1B (GHB1B) represented by red circle.

Figure 4-5: Borehole GBH2

4.2.4 Borehole GBH3

Borehole GBH3 is located 2,2km north of the investigated site and is represented in Figure 4-6. This bore was being pumped for livestock use during the investigation and had a groundwater level of 48,42mbgl. In field chemistry analysis revealed an EC of 283mS/m and a pH of 8,1 at 19,1 °C. These chemistries correlate to expected groundwater quality.

Figure 4-6: Borehole GBH3

4.2.5 Borehole GBH4

This borehole is located 4,2 km north west of the investigated site and is fitted with a windmill (Figure 4-7). A groundwater level of 39,23mbgl was recorded at this site. In field chemistry analyses revealed an EC of 265 mS/m and a pH of 6,21 at 26,1 °C. The site represents groundwater of moderate quality and is in line with what is to be expected in the area. The site was sampled for groundwater inorganic analysis due to it's location on the aeromagnetic lineament downstream of the study area. Water analyses will be discussed in Section 4,3.

Figure 4-7: Borehole GBH4

4.2.6 Borehole GBH5

Borehole GBH5 is located 4,2km north west of the investigated site and 100m south of borehole GBH4. The bore does not appear to be in use and was inaccessible for water level recording or chemistry analysis. This site is represented in Figure 4-8.

Figure 4-8: Borehole GBH5

4.2.7 Borehole GBH6

Borehole GBH6 (Figure 4-9) was recorded 3,4km west of the investigated site. This borehole is equipped with an electrical pump, driven by solar power. A water level of 46,42mbgl was recorded at this site. Water sampling could not be conducted at this site. Borehole water is reported to be used for livestock activities.

Figure 4-9: Borehole GBH6

4.2.8 Borehole GBH7 & GBH8

Borehole GBH7 (Figure 4-10) and GBH8 (Figure 4-11) are located 2,2km east of the investigated site. Both boreholes are fitted with windmills while only GBH7 is windmill driven and GBH is solar driven. Borehole GBH7 proved to be inaccessible while BGH8 was sampled for analysis.

Borehole GBH8 had a deep groundwater table of 87,35mbgl. This table depth may be exaggerated by water pumping for an unknown time prior to the water level recording. A water sample was collected from a water pipe filling the nearby dam from GBH8. On site chemistries revealed an EC of 322 mS/m and a pH of 6,51 at 26,9 °C. The water appears to be of moderate quality as expected of the area. Borehole GHB8 was sampled for inorganic groundwater analyses. Chemistry results are discussed in Section 4,3.

Figure 4-10: Borehole GBH7

Figure 4-11: Borehole GBH8

4.2.9 Borehole GBH9 & GBH10

Borehole GBH9 (Figure 4-12) and GBH10 (Figure 4-13) are located 2,7km east of the investigated site. Both boreholes were inaccessible for groundwater observation. While BGH9 is windmill driven, GBH10 appears to be driven by a diesel pump.

Figure 4-12: Borehole GBH9

Figure 4-13: Borehole GBH10

4.2.10 Borehole GBH11

Borehole GBH11 (Figure 4-14) was recorded 2,2km east of the investigated site. This borehole was being pumped during the time of investigation and had a recorded groundwater level of 29,5mbgl. Although the groundwater table depth is expected to be exaggerated by pumping, the recorded water level is much more elevated than other boreholes recorded in the area. Water is expected to be used for livestock activities.

Figure 4-14: Borehole GBH11

4.2.11 Borehole GBH12

Borehole GHB12 (Figure 4-15) is located 5,6km north east of the investigated site. This borehole was not in use during the site investigation. The bore appears to be in a deteriorated (poor) condition, a static groundwater table of 28,43mbgl was recorded at this site. This suggests a local perched or elevated groundwater table. No water sampling was collected at this site.

Figure 4-15: Borehole GBH12

4.2.12 Borehole GBH13

Borehole GHB13 (Figure 4-16) was recorded 6,2 km north east of the investigated site. The bore is equipped with a windmill and is in good working condition. The site is expected to supply water for livestock activities. No groundwater levels or chemistry sampling was collected at this site.

Figure 4-16: Borehole GBH13

4.3 Sampled Chemistry

During the hydrocensus, multiple borehole sites were identified in the study area. Three bores were identified for inorganic chemistry sampling and one hydrocarbon analyses. These boreholes included GBH1, GBH4 and GBH8 as they were expected to contain the most site representative groundwater chemistry. Analyzed inorganic chemistry results are represented in **APPENDIX C.**

A piper (Figure 4-17) and Stiff (Figure 4-18) diagram was added to illustrate specific water types sampled. From both these figures, Bore GBH1 is seen to be of strong calcium chloride type, GBBH4 of medium sodium chloride type while GBH8 has a mixed to calcium chloride type

Water analyses revealed GBH1 to be highly degraded by elevated sulphate, electrical conductivity, magnesium, calcium, sodium, phosphate, aluminium, copper, iron and severely acidic pH. GBH4 also show sign of elevated electrical conductivity, magnesium, sodium, potassium, chloride, bromide and sulphate. GBH8 shows to be in better quality with elevated electrical conductivity, sodium, potassium, fluoride and chloride.

The Stiff and Piper diagram does not show the three bores to be of the same water type. This suggest a deteriorated water quality along the geological contact boundary represented by the magnetic lineament compared to surrounding groundwater quality. The deterioration in water quality is expected to be due to the increased dissolution of salts at these contact boundaries, exposed to oxidation.

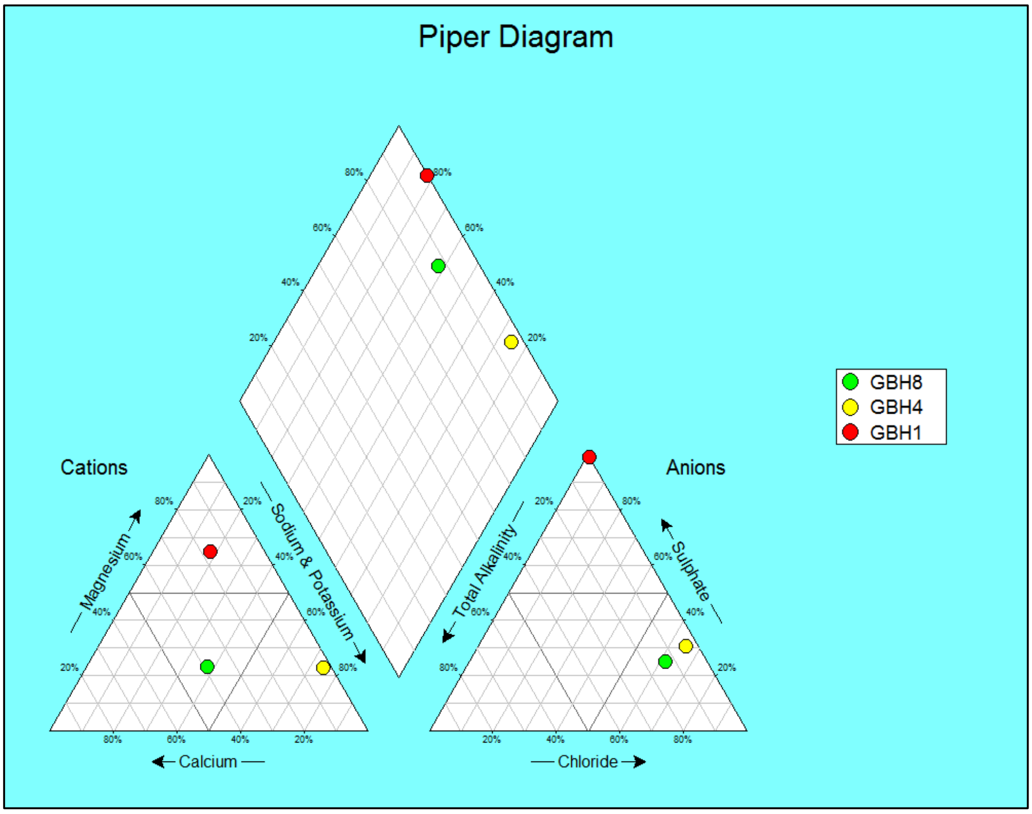

Figure 4-17: Piper diagram of bores GBH1, GBH4 and GBH8

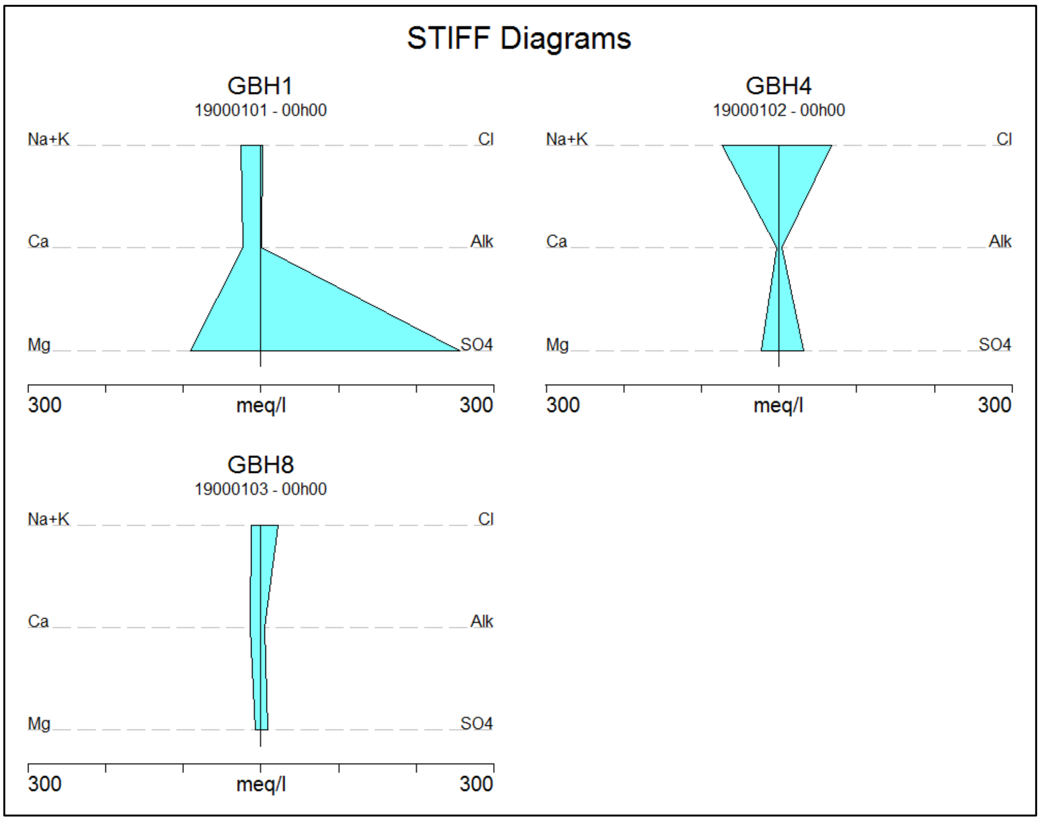

Figure 4-18: Stiff diagram of bores GBH1, GBH4 and GBH8

A ventilation shaft (GBH1) was selected to undergo hydrocarbon analysis. This site is selected due to its preferential location in close proximity to existing infrastructure, dumps and previous mining activities. Analyzed results are represented in Figure 4-19. This site did not reveal any detectable concentrations of GRO's, PAH's, DRO's or diagnostic ratios.

Gasoline Range Organics (GRO's)

PARAMETER	RESULT
MTBE	<5 µg/liter
TAME	<5 µg/liter
Benzene	<1 µg/liter
Toluene	<10 µg/liter
Ethylbenzene	<2 µg/liter
m+p-Xylene	<4 µg/liter
o-Xylene	<2 µg/liter
1,3,5-Trimethylbenzene	<2 µg/liter
1,2,4-Trimethylbenzene	<2 µg/liter
Naphthalene	<2 µg/liter

Polycyclic Aromatic Hydrocarbons (PAH's)

PARAMETER	RESULT
Acenaphthene *	<1 µg/liter
Acenaphthylene *	<1 µg/liter
Flourene *	<1 µg/liter
Phenanthrene *	<1 µg/liter
Anthracene *	<1 µg/liter
Fluoranthene *	<1 µg/liter
Pyrene *	<1 µg/liter

Diesel Range Organics (DRO's)

PARAMETER	RESULT
C10 *	<1 µg/liter
C11 *	<1 µg/liter
C12 *	<1 µg/liter
C13 *	<1 µg/liter
C14 *	<1 µg/liter
C15 *	<1 µg/liter
C16 *	<1 µg/liter
C17 *	<1 µg/liter
C18 *	<1 µg/liter
C19 *	<1 µg/liter
C20 *	<1 µg/liter

Diagnostic Ratios

PARAMETER	RESULT
1,3,5TMB : 1,2,4TMB *	#Num!
(B+T)/(E+X) *	#Num!
Total VPHs Identified *	<10 µg/liter
Estimated VPHs Unidentified *	<10 µg/liter
Estimated TOTAL VPHs *	<10 µg/liter

Figure 4-19: Borehole GBH1 hydrocarbon analysis

4.4 Conclusion and Recommendations

- The surface topography is characteristically flat with a minimal topographical decline towards the north west. The local area appears to be in visual good natural quality.
- No specific water accumulation of watercourses was observed during the site visit.
- During the site investigation, twelve (12) boreholes and two (2) ventilation shafts were recorded within the study area.
- The local area surrounding the investigated site was recorded to partake in groundwater dependent practices such as livestock activities.
- No large scale abstraction boreholes were recorded in the area.
- The total volume of local groundwater abstraction is unknown.
- During the site investigation, it was confirmed that the study area is underlain by Jannelspan Formation consisting of gossan, various pyroxene and massive amphibolite, hornblende-biotite, biotite and quartzo-feldspathic gneiss, and calc-silicate rocks. The investigated site appears parsley intruded by dolerite dykes with evidence of calc mineralization within dolerite fractures which may restrict preferential groundwater flow.
- Borehole GBH4 is mapped to be linked to the study area via a north west trending magnetic lineament. Preferential groundwater flow is expected to occur along this lineament. Borehole GBH4 as with shaft GBH1 appears to be of deteriorated groundwater quality. Water type classification diagrams (Stiff and Piper) does not suggest that the two sites share the same water type. This discourages the idea that GBH4 is degraded due to prospecting at GBH1. Both GBH1 and GBH4 may however be deteriorated due to their geological distribution or exposure to oxygen and humidity on exposed geological surfaces within the bore and shaft, enhancing mineral oxidation.
- An overall static groundwater table was recorded across the study area at GBH1 (50.83 mbgl / 874.17 mamsl), GBH6 (46,42 mbgl / 862,58 mamsl) and GBH12 (28,43 mbgl / 874,57 mamsl). These were the only three sites where groundwater tables were not expected to be influenced by pumping activity. Although depth to groundwater tables vary significantly, the groundwater elevations vary less than 13m across a recorded radius of 6m.
- An overall groundwater flow is expected towards the north west.
- Bore GBH1 is seen to be of strong calcium chloride type, GBBH4 of medium sodium chloride type while GBH8 has a mixed to calcium chloride type.
- Hydrocarbon sampling did not reveal any detectable concentrations of GRO's, PAH's, DRO's or diagnostic ratios.
- Recorded groundwater temperatures appear relatively elevated at shaft GBH1 and

could be as a result of increased humidity within the shaft itself. Prolonged shaft wall exposure to elevated humidity and temperatures may cause pH levels to decrease (become more acidic) considering acidic minerals expected to be present within the shaft such as phyrite (FeS2). It is highly recommended that the shaft be properly sealed and cased to restrict additional acidification.

Due to a lack of monitoring borehole sites, restricted accessibility to existing boreholes, distributed groundwater abstraction and limited geophysical data, an accurate groundwater flow map indicating static groundwater levels could not be compiled. Should such a map be constructed based on the three static groundwater levels from boreholes GBH1, GBH6 and GBH12, a straight forward south east to north west groundwater flow direction will be evident.

Local groundwater abstraction is not expected to greatly affect overall groundwater flow directions, especially connected to regional groundwater flow beneath the investigated site.

It is highly recommended that all boreholes in use within and closely surrounding the study area be restricted from water abstraction for at least a day prior to the mine licensing application phase's geohydrology investigation. This will allow for true groundwater levels to be recorded.

Installation of monitoring boreholes are **highly** recommended to be drilled in close proximity, north west (downstream) and south east (upstream), along the mapped magnetic lineament, of the investigated site to monitor local groundwater level and quality fluctuations. Drilling logs collected during this phase may also be used to determine basement rock depth. Installed boreholes may also be used for local groundwater dewatering to allow sampling at GBH1B.

By conducting an in depth geophysical investigation (to map all dykes and lineaments), and measuring true groundwater levels, accurate monitoring borehole placement can be specified prior to and fduring the mining license application phase. These monitoring boreholes will be used to monitor groundwater qualities and levles during the EMP.

5 PRELIMINARY GEOHYDROLOGICAL RISK AND VULNERABILITY OF STUDY AREA TO PROPOSED DEVELOPMENT

In order to determine the estimated risk of a proposed development on the local groundwater regime, a number of varying factors will need to be considered. There are various methods for assessing groundwater vulnerability and the main ones include SINTACS, GOD, SEEPAGE, the AVI rating system, ISIS, EPIK and DRASTIC. For the purpose of this risk assessment, the "DRASTIC' method of analysis will be used in this study.

The DRASTIC Index (DI) is a model for evaluating pollution potential of a specific area and its name is an acronym derived from seven parameters required for its use. These are:

- Depth to water table
- Recharge (net)
- Aquifer media
- Soil media
- Topography
- Impact of the vadose zone
- Conductivity (Hydraulic)

The classification ratings for these groundwater vulnerability parameters are illustrated in Table 5-2.

Conductivity classification ratings are given in Table 5-1.

Table 5-1: Ratings for Hydraulic conductivity of different aquifer types

Slope	Hydraulic Conductivity	Rate
Dolomite	1x10^4 – 1x10^2	10
Integranular	1x10^2 – 1x10^1	6
Fractured	1x10^1 – 1x10^-5	3
Fractured and weathered	1x10^1 – 1x10^-1	1

Table 5-2: Ratings assigned to groundwater vulnerability parameters (Lynch et al., 1994)

Depth to groundwater (D_R)

Range (m)	Rating
0 – 5	10
5 – 15	7
15 – 30	3
> 30	1

Net Recharge (R_R)

Range (mm)	Rating
0 – 5	1
5 – 10	3
10 – 50	6
50 – 100	8
> 100	9

Aquifer Media (A_R)

Range	Rating
Dolomite	10
Intergranular	8
Fractured	6
Fractured and weathered	3

Soil Media (S_R)

Range	Rating
Sand	8 – 10
Shrinking and/or aggregated clay	7 - 8
Loamy sand	6 - 7
Sandy loam	5 - 6
Sandy clay loam and loam	4 - 5
Silty clay loam, sandy clay and silty loam	3 - 4
Clay loam and silty clay	2 – 3

Topography (T_R)

Range (% slope)	Rating
0 – 2	10
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, Soutspansberg, Karoo (northern), Bushveld, Olifantshoek	4
Karoo (southern)	5
Table Mountain, Witteberg, Granite, Natal, Witwatersrand, Rooiberg, Greenstone, Dominion, Jozini	6
Dolomite	9
Beach sands and Kalahari	10

An equation will be used for the pollution potential (DRASTIC Index) as is given below:

DRASTIC Index (DI) = DrDw + RrRW + ArAw + SrSw + TrTw + IrIw + CrCw

Where, r is the rating for the area evaluated and

w is the importance weight of the parameter (normally from 1 to 5) - refer to

Table 5-3: Description of parameter weights used when assessing groundwater vulnerability

Weight	Significance	Description
1	Least	Negligible contribution in factors that have an impact on an aquifer
2	Less	Little effect in enhancement or reduction of vulnerability
3	Moderate	Medium effect
4	More	Consideration in the assessment process AND is crucial due to its properties in relation to aquifer vulnerability>
5	Most	Has the most important properties that could affect aquifer vulnerability.

The corresponding weights to these parameters were as follows:

Parameter	*Weights*
Depth to groundwater (D_w)	5
Recharge (R_w)	4
Aquifer media (A_w)	3
Soil Media (S_w)	2
Topography (T_w)	1
Impact of Vadose zone (I_w)	5
Hydraulic Conductivity (C_w)	3

Total DI groundwater vulnerability values will be classified according to the prescribed values below.

- Insignificant (3-5)
- Very low (15-20)
- Low (20-25)
- Moderate (25-30)
- High (30-45)
- Very High (45-60)
- Extreme (60-110)

5.1 Site Analysis

5.1.1 Depth to Groundwater

Overall ground water tables recorded within the investigated site ranged from 39,23mbgl (GBH4) to 87,35mbgl (GBH8). Two examples of shallower groundwater tables were recorded 2,6km north east (GBH11 / 29,50mbgl) and >6km north east (GBH12 / 28,43mbgl) of the investigated site.

Based on information gathered during the site investigation, the depth to groundwater in proximity to the investigated site is estimated to be >30mbgl with a vulnerability significance rating estimated at **0.02** and a weight of **5**.

1.1.1 Net Recharge

The study area is situated in the quaternary catchment D42E, D73F and D73E of the LOWMA. These areas are associated with an estimated groundwater recharge rate of 0 - 5 mm/a. Therefore the net recharge vulnerability significance rating is estimated at **0.03** with a weight of **4.**

5.1.2 Aquifer Media

According to geological and airborne magnetic mapping as well as on site geological, the study area is expected to be underlain by weathered, fractured and intergrannular geology caused by an intrusive dolerite dyke and presence of Jannelspan Formation. Therefore an aquifer media vulnerability significance rating is estimated at **2** with a weight of **3.**

5.1.3 Soil Media

The study area was recorded to be underlain by a sand - loamy sand soil profile. Therefore a soil media vulnerability significance rating is estimated at **4.56** with a weight of **2.**

5.1.4 Topography

The study area forms part of a characteristically flat topography with a decline of estimated 0 - 2 %. Therefore a soil media vulnerability significance rating is estimated at **0.36** with a weight of **9.**

5.1.5 Impact of the Vadose Zone

The study area has been mapped to form part of the Karoo Supergroup as wel as the Namaqua metamorphic rocks. It therefore has an impact on vadose zone vulnerability significance rating estimated at **0.21** with a weight of **5.**

5.1.6 Hydraulic Conductivity

The hydraulic conductivity of the study area is estimated to be directly related to the weathered, fractured and intergrannular geology. This aquifer type is expected to have a vulnerability significance rating estimated at **1** with a weight of **3.**

1.2 Conclusion

The following DRASTIC Index (DI) pollution potential equation can be compiled.

DRASTIC Index (DI) = DrDw + RrRW + ArAw + SrSw + TrTw + IrIw + CrCw

DRASTIC Index (DI)=(0.02)(5) + (0.03)(4) + (2)(3) + (4.56)(2) + (0.36)(9) + (0.21)(5) + (1)(3)

DRASTIC Index (DI) = 22.63

The calculated DRASTIC Index (DI) suggests that the study area exhibit a susceptibility and vulnerability rating of **VERY LOW** to **LOW**.

It is highly recommended that a groundwater monitoring program be developed in conjunction with additional borehole drilling to identify and mitigate pollution sources as well as to monitor local water qualities and levels.

6 OVERALL CONCLUSION AND RECOMMENDATIONS

The risk of groundwater pollution is directly related to the nature of the activity. Through an in depth desktop and site investigation the following results could be drafted:

6.1 Conclusions

- The investigated site was identified to be situated north west of the town Upington while predominantly surrounded by groundwater dependent practices such as livestock activities.
- Prospecting activities will primarily make use of existing roads and infrastructure while some additional roads will be created in order to access working and exploration areas. The full extent of all planned infrastructure and activities are not currently known, but existing features include an office and workshop complex, a series of shafts, mine dumps, excavations, ablutions, water storage, concrete surfaces and fence lines.
- The surface topography is characteristically flat with a minimal topographical decline towards the north west. The local area appears to be in visual good natural quality.
- The study area is situated across the D42E, D73F and D73E quaternary catchment areas which forms part of the Lower Orange Water Management Areas (LOWMA). The study area is also located across both the Boegoeberg Dam to Kanoneiland and the Kanoneiland to Pella sub-areas.
- The investigated site is found within a summer rainfall district and experiences a harsh climate with one of the lowest mean annual rainfall in the country. Potential evaporation can reach 3 000 mm per year.
- An analyzed aeromagnetic map indicates a massive magnetic lineament to intersect the study area in a south east to north west direction. This lineaments is in all likelihood due to the presence of metasedimentary successions and intrusive rocks with increased magnetic susceptibility intersecting the regional area. The extent of this lineament is associated with an increased surface to groundwater infiltration/recharge rate and preferential groundwater flow paths through which pollution distribution may occur.
- The prospecting area is mapped to have surface geology consisting Dwyka Group (C- Pd) which consists predominantly of diamictite and to a lesser extent of conglomerate, pebbly sandstone, and mudrock with dispersed stones. The study area is also seen to be underlain by the Gordonia Formation (Qg) of the Kalahari Group which consists of wind blown sands and dunes of red-brown coloration.
- During the site investigation, it was confirmed that the study area is underlain by Jannelspan Formation consisting of gossan, various pyroxene and massive amphibolite, hornblende-biotite, biotite and quartzo-feldspathic gneiss, and calc-silicate rocks. The investigated site appears parsley intruded by dolerite dykes with

evidence of calc mineralization within dolerite fractures which may restrict preferential groundwater flow.

- The local groundwater flow direction is expected to follow a south east to north west direction.
- The local groundwater regime is believed to form part of an unconfined to semi-confined aquifer system. The regional aquifer is expected to have secondary porosity due to fracturing and weathering and virtually no primary porosity (except alluvial aquifers). Localized shallow circulation of groundwater flow systems can be expected in the near surface environment.
- A total of 2 shafts and 12 borehole sites were recorded during a hydrocensus investigation.
- Overall ground water tables recorded within the investigated site ranged from 39,23mbgl (GBH4) to 87,35mbgl (GBH8). Two examples of shallower groundwater tables were recorded 2,6km north east (GBH11 / 29,50mbgl) and >6km north east (GBH12 / 28,43mbgl) of the investigated site.
- A static groundwater level of 50.83 mbgl was recorded at GBH1 beneath the prospecting are which is expected to represent the regional static groundwater level.
- Water analyses revealed GBH1 to be highly degraded by elevated sulphate, electrical conductivity, magnesium, calcium, sodium, phosphate, aluminium, copper, iron and severely acidic pH. GBH4 also show sign of elevated electrical conductivity, magnesium, sodium, potassium, chloride, bromide and sulphate. GBH8 shows to be in better quality with elevated electrical conductivity, sodium, potassium, fluoride and chloride.
- In the Lower Orange Water Management Areas (LOWMA) some impacts do exist with regard to localized dewatering of aquifers. These impacts are however regarded as localized with very little existing data.
- GBH1 did not reveal any detectable concentrations of GRO’s, PAH’s, DRO’s or diagnostic ratios.
- Borehole GBH4 is mapped to be linked to the study area via a north west trending magnetic lineament. Preferential groundwater flow is expected to occur along this lineament. Borehole GBH4 as with shaft GBH1 appears to be of deteriorated groundwater quality. Water type classification diagrams (Stiff and Piper) does not suggest that the two sites share the same water type. This discourages the idea that GBH4 is degraded due to prospecting at GBH1. Both GBH1 and GBH4 may however be deteriorated due to their geological distribution or exposure to oxygen and humidity on exposed geological surfaces within the bore and shaft, enhancing mineral oxidation.

- The study area is situated on a *poor* aquifer system which is a low to negligible yielding aquifer system of moderate to poor water quality.
- The local aquifer has a *least* groundwater vulnerability rating that is only vulnerable to continuously discharged or leached pollutants in the long term.
- Due to the study area's local aquifer system having a ***poor*** aquifer classification and ***least*** aquifer vulnerability rating, the local aquifer has a ***low*** susceptibility for contamination.

Considering the local aquifer's classification, vulnerability rating, susceptibility for contamination and calculated DRASTIC Index (DI) for the regional aquifer, it is suggested that the prospecting area exhibit a susceptibility and vulnerability rating of **VERY LOW** to **LOW**.

Activity (2) of the proposed prospecting plan (Table 7-1) requires underground sampling of 70mbgl to 90mbgl at GBH1B. If groundwater dewatering is required, abstraction borehole drilling will be needed in close proximity to GBH1B to dewater the local aquifer to a depth of at least 100mbgl. This may be required permanently during the prospecting phase or periodically prior to sampling.

If periodic groundwater abstraction is required for shaft sampling the estimated vulnerability rating will be **LOW** to **MODERATE.** This vulnerability rating may be influenced by hydrolic results acquired from aquifer pump testing to be conducted at newly drilled boreholes in close proximity to GBH1B.

It is highly recommended that a groundwater monitoring program be developed in conjunction with additional borehole drilling to identify and mitigate possible pollution sources as well as to monitor local water levels and qualities.

Should all recommendations be adhered to, considering aquifer dewatering and restricting cross contamination to the local groundwater system, the associated risk regarding the proposed development can be regarded as **LOW.**

6.2 Recommendations

Based on hydrogeological findings, the further development of the prospecting area can only be considered if the following recommendations are strictly adhered to:

- Due to limited site specific groundwater monitoring sites, the drilling of additional monitoring boreholes is **HIGHLY** recommended:
  - To function as site characterization boreholes, estimate basement rock depths as well as estimating site specific groundwater table depths,
  - To undergo hydraulic testing and profiling to determine site specific groundwater flow parameters,
  - To be used as groundwater abstraction sites to lower the regional groundwater table to at least 100mbgl prior to shaft sampling.
  - To ultimately be included in a groundwater table and quality monitoring program.
- Recommended monitoring boreholes are to include additional up- and downstream monitoring boreholes that should be drilled as part of the implementation of the future monitoring programme. Monitoring borehole placements are to be in close proximity of GBH1B, existing and suggested fuel cell storage sites, any other areas that may be associated with the storage of liquid chemicals and the actual excavation sites, to monitor seepage, spillages and groundwater levels.
- Appropriate lining is recommended to be installed at all water work bodies and dumping sites to restrict contamination to groundwater.
- Should abstracted groundwater be stored in evaporation dams, precipitated minerals should be disposed as toxic substances.
- Special attention should be directed at storm water diversion structures to restrict pollutants such as hydrocarbons, cleaning chemicals and other waste water chemicals from seeping into the subsurface and underlying groundwater table.
- It is highly recommended that a community awareness programme be conducted to inform the local community about the health and pollution risks associated with the prospecting and dewatering activity.
- Boreholes and shafts within the regional area (Areachap426) should be investigated and properly cased to restrict cross contamination to groundwater via possible exposed mineral oxidation.
- Any un-monitored increased abstraction of groundwater by the possible future drilling of boreholes within a 1km radius of the waste site can increase flow gradients and velocities and will have to be discouraged or monitored should it be considered by the municipality or land users.

It is highly recommended that all boreholes in use within and closely surrounding the study area be restricted from water abstraction for at least a day during the mine licensing application phase. This will allow for true groundwater levels to be recorded. By conducting an in depth geophysical investigation (to map all dykes and lineaments), and accurately measuring true groundwater levels, accurate monitoring borehole placement can be suggested. These monitoring boreholes will be used to monitor groundwater qualities during the EMP and be used for additional groundwater abstraction if deemed necessary to lower the groundwater table for the proposed mining activity.

7 APPENDIX A

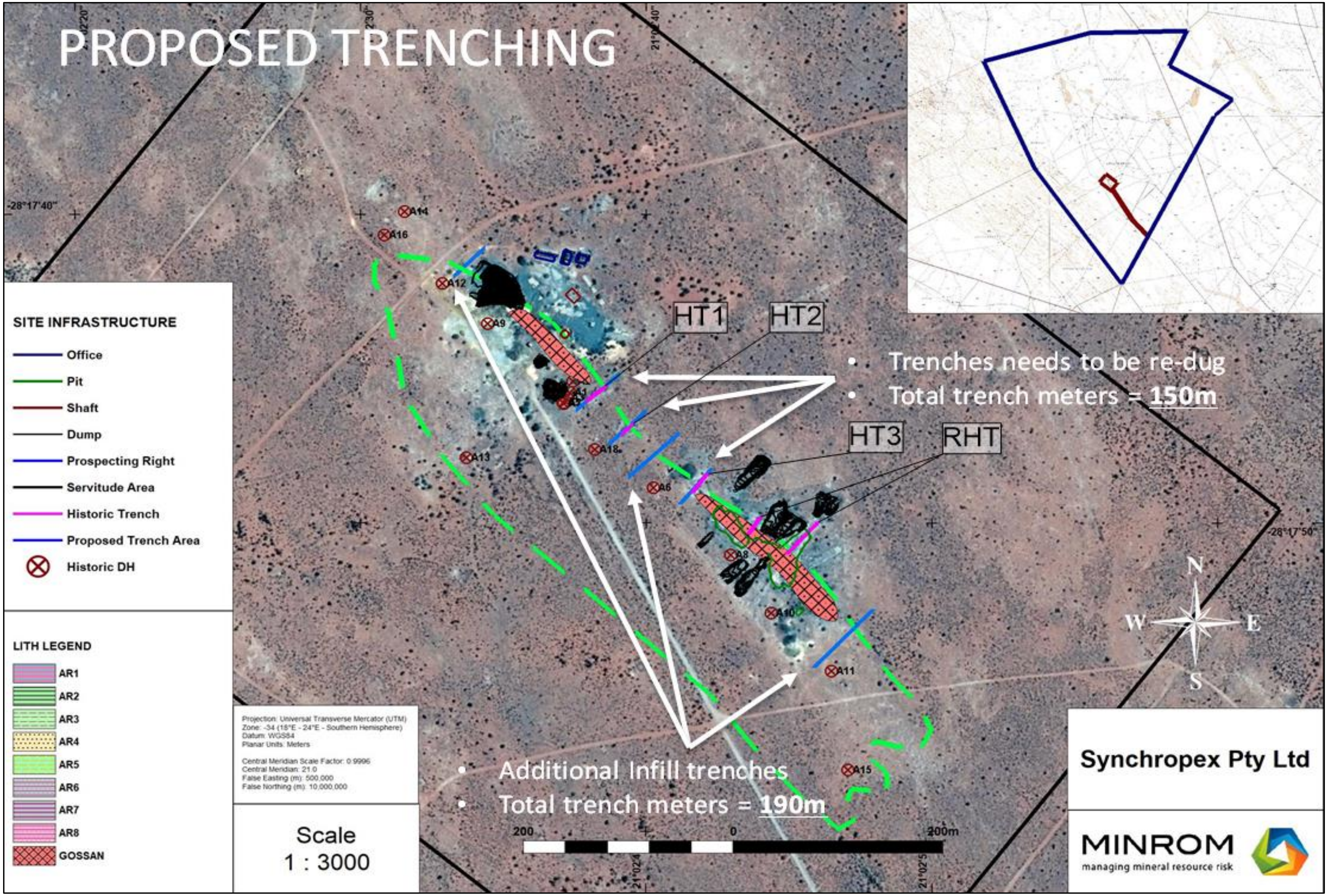

Figure 7-1: Proposed trenching at the study area

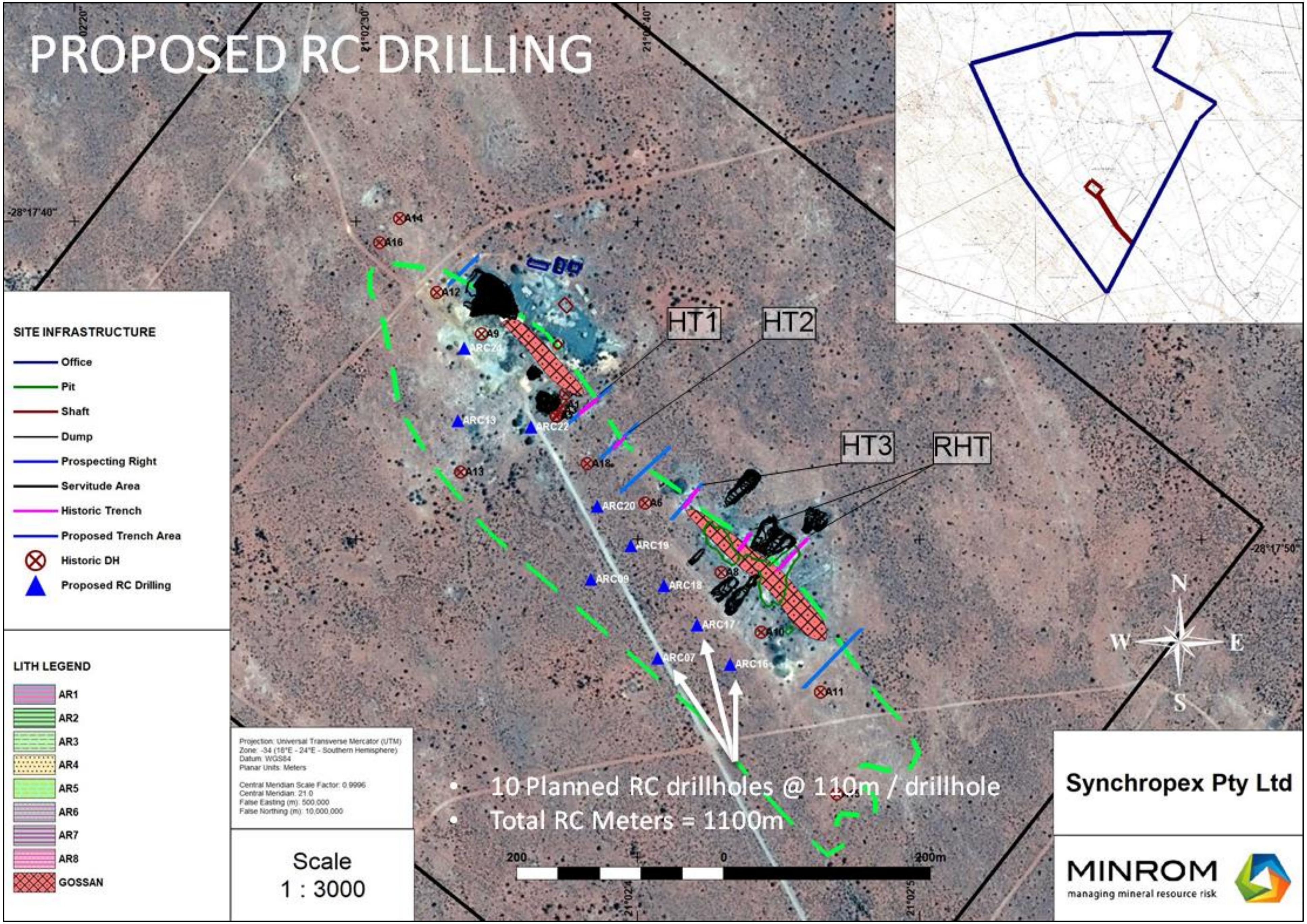

Figure 7-2: Proposed RC drilling at the study area

Table 7-1: Intended prospecting activities and methods, mineral resources and time frames in terms of Regulations 7(1)(f), 7(1)(h) and 7(1)(i).

Phase	Activity (what are the activities that are planned to achieve optimal prospecting)	Skill(s) required (refers to the competent personnel that will be employed to achieve the required results)	Timeframe (in months) for the activity)	Outcome (What is the expected deliverable, e.g. Geological report, analytical results, feasibility study, etc.)	Timeframe for outcome (deadline for the expected outcome to be delivered)	What technical expert will sign off on the outcome? (e.g. geologist, mining engineer, surveyor, economist, etc)
1	Trench of 150 meter by 20 meters width maximum depth 20 meters as per AAPS drilling campaign 60 000 cubic meter	Geologist and metallurgist to do R&D to develop an economic viable metal extraction process	16 months	Geological CPR and financial model on Cu-Zn-Ag-S	2019	Geologist and economist and mining plan by AB Global Mining Consultants
2	Underground sampling 70 to 90 meter by 10.5 meters width with 200 meter strike through existing exploration shaft	Geologist and metallurgist to do R&D to develop an economic viable metal extraction process	June 2019 for 18 months	Geological CPR and financial model on Cu-Zn-Ag-S	2020	Geologist and economist to provide mine plan and life of mine +- 20 years
3	Infill drilling by challenger drilling as per geologist request 10 drill holes to 350 meters	Geologist and metallurgist to do R&D to develop an economic viable metal extraction process	February 2018 for 12 months	Geological CPR and financial model on Cu-Zn-Ag-S	February 2019	Geologist and economist to provide mine plan and life of mine +- 20 years

8 APPENDIX B

Figure 8-1: HT1 with dolerite dyke intrusion and weathered calc-silicate

Figure 8-2: HT1 with dolerite dyke intrusion and calc mineralization

Figure 8-3: HT2 with weathered calc-silicate with no visible sign of an extended dolerite intrusion

Figure 8-4: HT3 predominantly presenting weathered calc-silicate rocks

Figure 8-5: RHT representing Jannelspan Formation and calc-silicate rocks

Figure 8-6: RHT representing Jannelspan Formation and weathered calc-silicate rocks

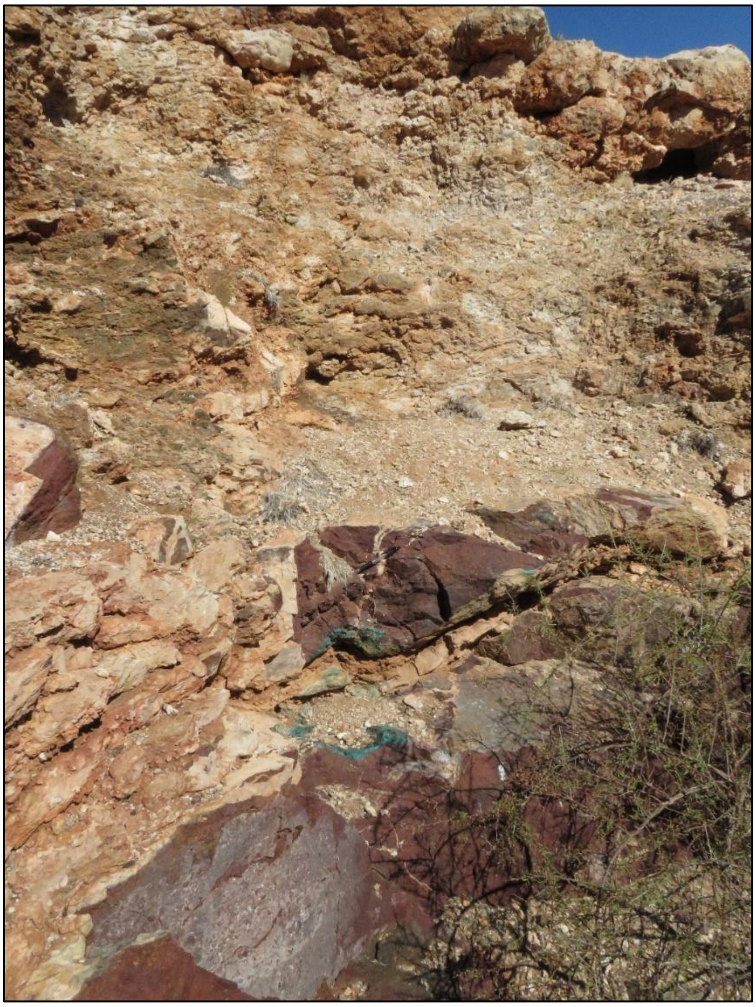

Figure 8-7: RHT representing Jannelspan Formation and highly weathered calc-silicate rocks

Figure 8-8: RHT representing Jannelspan Formation and highly weathered calc-silicate rocks

Figure 8-9: RHT representing Jannelspan Formation and highly weathered calc-silicate rocks

9 APPENDIX C

Determinand	Units	Methods used	South African National Standard (SANS) 241:2006&2015 for drinking water (partial)	Client sample name:		
				GBH1	GBH4	GBH8
			Class 1 (Recommended levels) Class 2 (Maximum allowable for limited time) ** EU standard	Lab number:		
				324-1	324-2	324-3
			Value	Value	Value	Value
Chemical report						
pH #	pH units	Chem-TM06	5.5 tot 9.7	2.30	8.18	7.65
Electrical conductivity #	mS/m	Chem-TM06	≤ 170	1469	833	334
Calcium as Ca #	mg/L	Chem-TM02	≤150 - 300	478	50	268
Magnesium as Mg #	mg/L	Chem-TM02	≤70 - 100	1104	274	97
Sodium as Na #	mg/L	Chem-TM02	≤ 200	587	1639	295
Potassium as K #	mg/L	Chem-TM02	≤50 - 100	3.17	102.9	13.2
P-Alkalinity #	mg/L	Chem-TM06		0	0	0
M-Alkalinity #	mg/L	Chem-TM06		0	195	235
Fluoride as F #	mg/L	Chem-TM01	≤ 1.5	nd	3.69	1.90
Chloride as Cl #	mg/L	Chem-TM01	≤ 300	89	2390	795
Nitrite as N #	mg/L	Chem-TM01		<0.2	<0.2	<0.2
Bromide as Br #	mg/L	Chem-TM01	**≤3	nd	14.3	0.58
Nitrate as N #	mg/L	Chem-TM01	≤ 11	<0.1	1.3	10.0
Phosphate as PO_4 #	mg/L	Chem-TM01	*≤15.33	nd	<2	<2
Sulphate as SO_4 #	mg/L	Chem-TM01	≤ 500	12296	1496	433
Calcium Hardness #	mg/L	calculated	≤375 - 750	1195	126	670
Magnesium Hardness #	mg/L	calculated	≤287 - 410	4525	1123	398
Total Hardness as $CaCO_3$ #	mg/L	calculated	≤662 - 1160	5720	1248	1068
Total Dissolved Solids #	mg/L	calculated	≤ 1200	15482	6168	2180
Aluminium as Al #	mg/L	Chem-TM02	≤ 0.300	677.2	0.045	<0.020
Arsenic as As #	mg/L	Chem-TM02	≤ 0.010	<0.020	<0.020	<0.020
Barium as Ba #	mg/L	Chem-TM02	≤ 0.700	0.018	0.047	0.071
Boron as B #	mg/L	Chem-TM02	≤ 2.400	1.060	3.360	0.831
Cadmium as Cd #	mg/L	Chem-TM02	≤ 0.003	0.806	<0.020	<0.020
Cobalt as Co #	mg/L	Chem-TM02	≤ 0.500	3.260	<0.020	<0.020
Chromium as Cr #	mg/L	Chem-TM02	≤ 0.050	0.038	<0.020	<0.020
Copper as Cu #	mg/L	Chem-TM02	≤ 2.000	240.9	0.120	0.048
Iron as Fe #	mg/L	Chem-TM02	≤ 2.000 (chronic health)	303.6	0.119	0.024
	mg/L	Chem-TM02	≤ 0.300 (aesthetic)			
Manganese as Mn #	mg/L	Chem-TM02	≤ 0.400 (Chronic health)	33.7	<0.020	<0.020
	mg/L	Chem-TM02	≤ 0.100 (Aesthetic)			
Nickel as Ni #	mg/L	Chem-TM02	≤ 0.070	0.167	<0.020	<0.020
Molybdenum as Mo #	mg/L	Chem-TM02		<0.020	<0.020	<0.020
Lead as Pb #	mg/L	Chem-TM02	≤ 0.010	0.151	0.003	0.016
Selenium as Se #	mg/L	Chem-TM02	≤ 0.040	0.028	<0.020	<0.020
Vanadium as V #	mg/L	Chem-TM02	≤ 0.200	<0.010	<0.010	<0.010
Zinc as Zn #	mg/L	Chem-TM02	≤ 5.000	537.8	0.037	<0.020