GEOHYDROLOGICAL INVESTIGATION FOR THE PROPOSED WASTE WATER TREATMENT WORKS DEVELOPMENT WEST OF LINDLEY, FREE STATE

MAY 2023

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GEOHYDROLOGICAL INVESTIGATION FOR THE PROPOSED WASTE WATER TREATMENT WORKS DEVELOPMENT WEST OF LINDLEY, FREE STATE

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 NSVT CONSULTANTS.

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: 19 MAY 2023

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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 than the storativity 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 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 ***NSVT Consultants*** to perform a geohydrological investigation for the proposed development of a waste water treatment work (WWTW) facility west of the town Lindey, located in the Free State province, South Africa.

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 a 1 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.

I should be noted that no background surface or groundwater chemistry monitoring data was made available to SGHS during this investigation. In addition, the hydrological and geohydrological screening reports relating to existing WWTW development was also not available for baseline analysis. This is expected to limit conclusions and recommendations made within this report.

3 BACKGROUND INFORMATION

3.1 Proposed Development

The proposed project is aimed at providing sewer and water reticulation for Bucket Eradication including the refurbishment of the sewer pumpstations, serving the Township area of Lindley/ Ntha. The main objectives of the overall project are to design and construct sewer infrastructure to eradicate buckets in the Township of Ntha, by developing the following:

a) Design and construction of a new WWTW with access road, security fence and operational buildings;

- 6Ml/day WWTW, including mechanical and electrical works.
- Access road – 1950m paved.
- New 2000m security fence.
- Operational buildings – offices, laboratory, stores, security, and administration

The proposed infrastructure layout for the WWTW development is presented in Figure 1 below.

Figure 1: Proposed WWTW infrastructure layout.

b) Bulk outfall sewer including sewer reticulation to 150 households.

- Pipeline – New 4000m x 300mm Ø sewer outfall pipeline from pumpstation 3 to
- Pumpstation 2 as well as Pumpstation 2 to new WWTW
- New pumpstation (Pump station 1) and raising main
- Top structures – 150 households
- Sewer reticulation – 150 households

c) Bulk water supply pipeline and water reticulation to 150 households.

- Pipeline – 4000m x 200mm Ø water supply pipeline
- Water reticulation - 150 households

3.2 Location and Scope of Work

The study area is situated west of the Lindley town and NTHA suburb and falls within the Nketoana Local Municipality within the Free State province of South Africa. The coordinates to the center of the study area are -27.870751° latitude and 27.888361° longitude. Local farming activities within the area include livestock and game farming. The location of the investigated site relative to Lindley is shown in Figure 2.

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.
- Geological investigation to map the presence (if any) of specific 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.

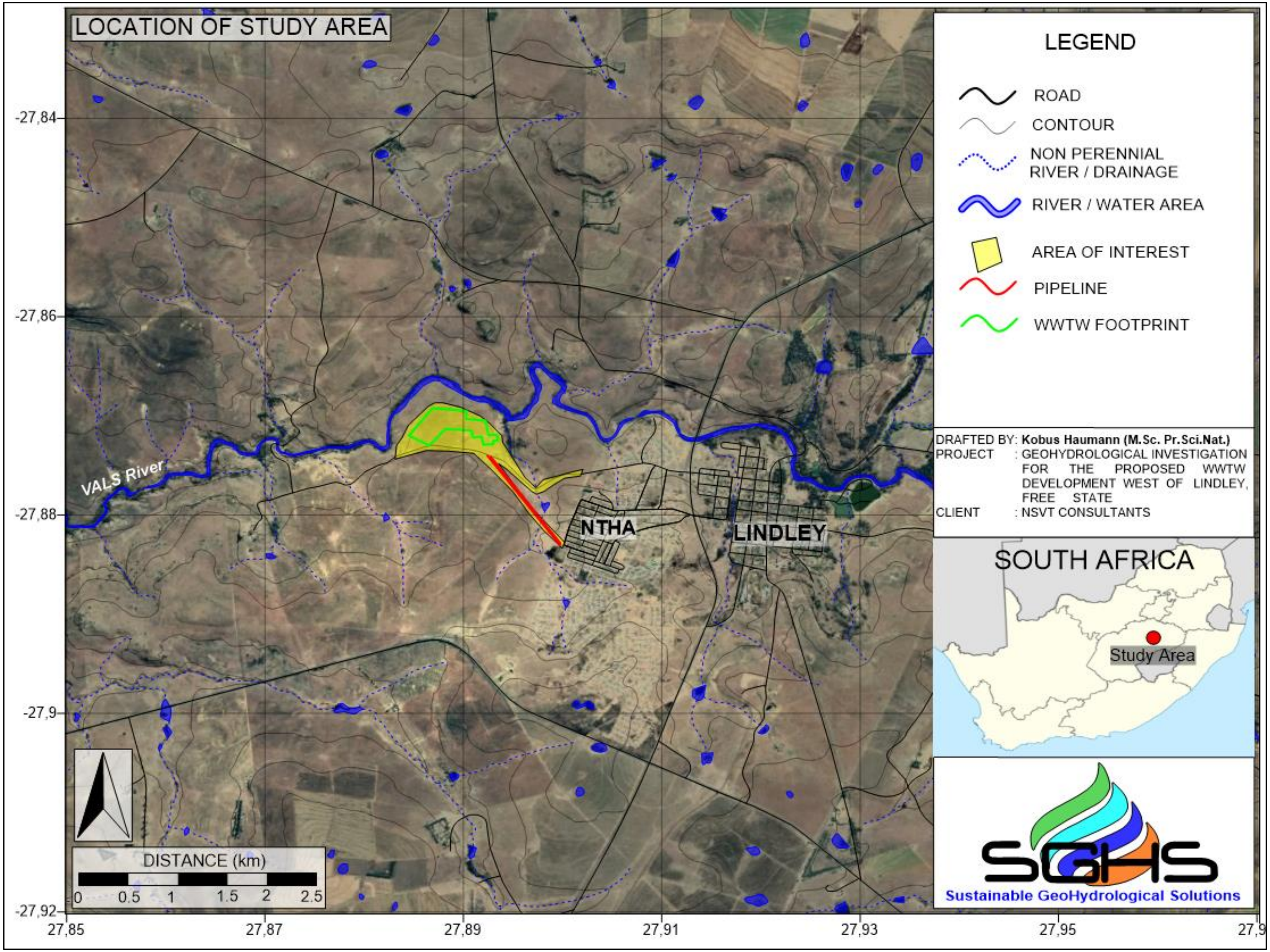


Figure 2: Study area relative to the Lindley and NTHA area.

3.3 Water Management Area (WMA)

The study area is located within the quaternary catchment C60B, falling within the Rhenoster/Vals Sub Catchment of the Middle Vaal Water Management Area (WMA). The Middle Vaal WMA, subdivided in to it's three sub water management area namely Middle Vaal, Sand/Vet and Rhenoster/Vals sub-WMA in relation to the study area is seen in Figure 3.

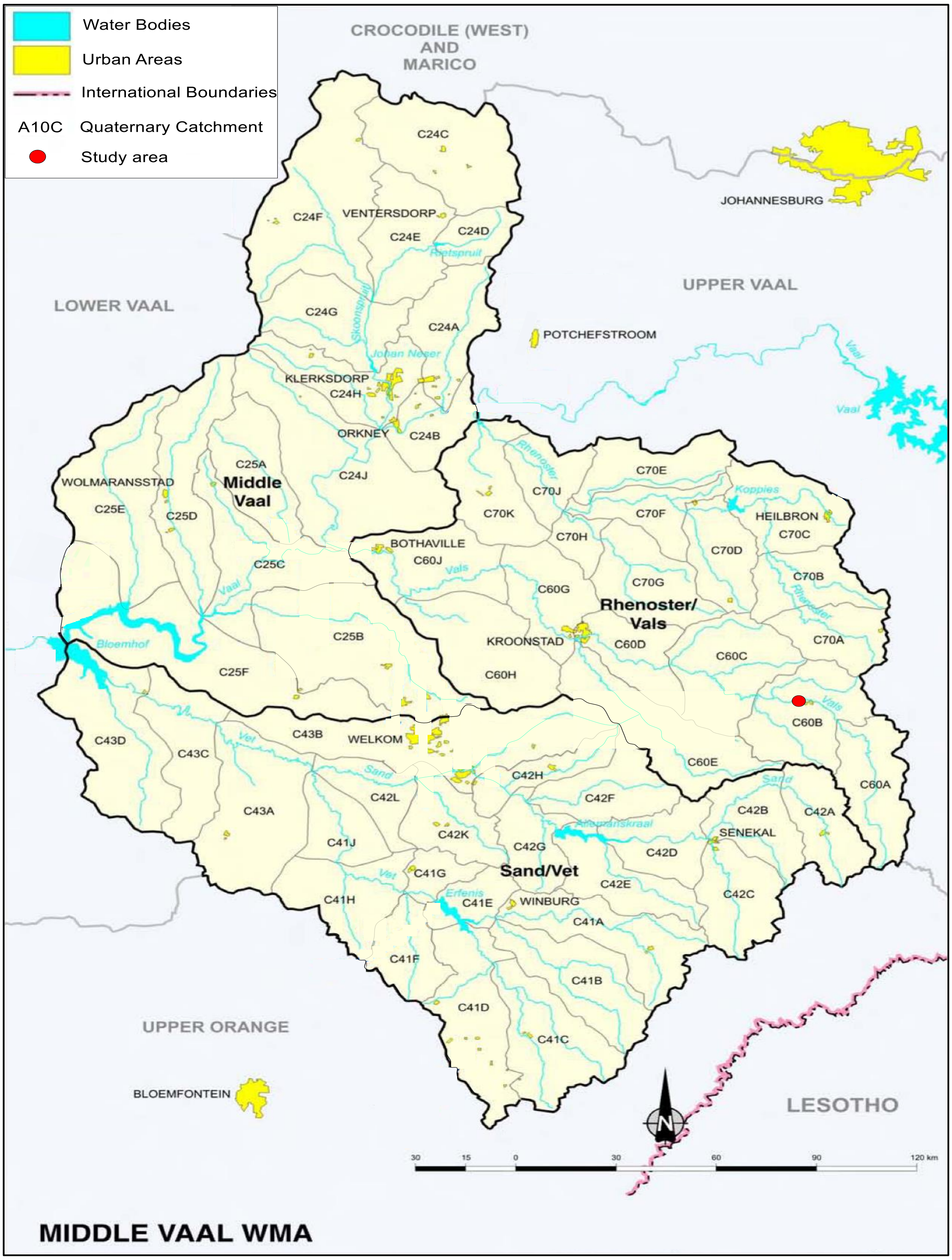


Figure 3: Middle Vaal WMA with its three sub-areas

The geohydrological properties of the quaternary catchment is provided in Table 1. This WMA is situated in the central part of South Africa, in the Free State and North West Province. It is located between the Upper Vaal and Lower Vaal water management areas and also borders on the Crocodile (West) and Marico as well as the Upper Orange WMAs. The Vaal River is the only main river in this WMA. It flows in a westerly direction from the Upper Vaal WMA, to be joined by the Skoonspruit, Rhenoster, Vals and Vet Rivers as main tributaries from the Middle Vaal WMA, before flowing into the Lower Vaal WMA and then into the Orange River.

Table 1: Geohydrolic properties of quaternary catchment C60B

Quaternary Catchment	Area (km^2)	Population	MAP (mm)	Recharge		Groundwater Use (Mm^3/a)	Groundwater Component of Baseflow (Mm^3/a)	Basic Human Needs (Mm^3/a)	Allocable Groundwater	
				(Mm^3/a)	% MAP				Total (Mm^3/a)	50% of Total
C60B	1021,6	10 790	617,8	10,11	1,6	0,5	8,26	0,1	1,25	0,63

Climate associated with the Middle Vaal WMA is temperate with frost occurring in winter months and is generally considered semi-arid. Mean annual rainfall ranges from 700 mm in the south-east to 400 mm in the west, and mainly occurs as summer thunderstorms. Vegetation is mainly grassland, with sparse bushveld in patches. The topography is relatively flat with no distinct features. Hilly terrain occurs to the south-east.

Average gross potential mean annual evaporation (as measured by Class A-Pan) ranges from 1 800 mm in the east to a high of 2 600 mm in the dry western parts. The highest A-pan evaporation is in January (range 200 mm to 300 mm) and the lowest evaporation is in June (100 to 120 mm). The annual S-pan evaporation for the quaternary catchment C60B is in the order of 1480 mm/a, which greatly exceeds mean annual precipitation rates (617,8 mm/a). Groundwater chemistries of the catchment is expected to represent a general dominance of a NaMg-HCO3 type groundwater chemistry.

3.3.1 Groundwater Unit (GRU 4b)

The proposed development site falls within a groundwater unit (GRU) 4 and is further subdivided herein as belonging to a GRU 4b. The GRU 4 is underlain by younger strata of the Karoo Supergroup represented by arenaceous rocks (sandstone) of the Beaufort Group. A further geologic characteristic of this GRU is the extensive occurrence of dolerite intrusions. These take the form of sub-horizontal sills that have invaded the comparatively flat-lying (horizontally bedded) sandstone along pre-existing planes of weakness. A mean chemical variable value in mg/L for these geological units are presented in Table 2 below.

Table 2: Mean concentrations of chemical and physical parameters per geological unit or formation in the Groundwater Unit 4b.

GeologicalUnit	No. of stations	No. of samples	Mean chemical variable value										
			pH	EC (mS/m)	Ca (mg/L)	Na (mg/L)	K (mg/L)	Mg (mg/L)	Cl (mg/L)	SO4 (mg/L)	CaCO3 (mg/L)	F (mg/L)	NO3 (mg/L)
Karoo Dolerite	13	23	8	117,1	97,4	73,3	8	54,4	130,5	113,4	296,9	0,384	7,2
Adelaide Subgroup	11	12	8,2	74,3	54,7	86	3,5	19	35,1	29,6	297,1	0,55	5,4
Tarkastad Subgroup	15	25	8,1	67,6	52	63,6	2,6	23,9	18,2	30,7	299,8	0,54	2,4
Alluvium	60	131	7,8	70,5	66,4	30,1	3,4	40,4	23,1	168,2	177,7	0,178	5,1

The GRU 4b encompasses the north-eastern portion of GRU 4 that receives a MAP of >550 mm, and which occupies a landscape that is generally located above a surface elevation of ~2000 mamsl. The more rural nature of the environment in this GRU is reflected in the ~69% of surface area that supports natural unimproved grassland as the principal land use type, followed by commercial dryland agriculture representing ~26% of the land use type in the area. Groundwater occurs in intergranular-and-fractured (type d) aquifers supporting borehole yields in the 2 (0.5-2 L/s) and 3 (2-5 L/s) yield class ranges. The GRU 4b encompasses the seven quaternary catchments listed in Table 3. The data presented in this table indicate median depths to groundwater level in the range 5-20 mbgl. It is notable, however, that the greatest water level depths (refer the 95%ile and maximum values in Table 3) occur in quaternary catchments C60D (our area of investigations) and C60F.

Table 3: Summary statistics for groundwater level data associated with GRU 4b per quaternary catchment.

Quaternary	N	Min	25%ile	Median	Mean	75%ile	95%ile	Max	Range
C60B	114	0.1	4.5	7.3	9.6	12.1	25	45.7	45.6
C60C	13	4	10	12.5	15.7	22	27.8	32	28
C60D	36	2.6	11.3	15.2	17.7	18.7	36.5	67.1	64.5
C60E	86	0.1	2.2	3.1	6	7.8	17.4	30.5	30.4
C60F	12	4.9	8.3	20.1	20.1	24.6	43.1	60	55.1
C70A	25	1.5	2.4	6	7.4	10.4	18.5	30	28.5
C70C	1	15	N/A	N/A	15	N/A	N/A	15	0

The hydrogeological environment of GRU 4b is assessed as being slightly modified from its natural status, and is therefore assigned a present ecological state (PES) of category of (B) slightly modified. The perennial river (Vals River), draining at the northern border of the proposed development presents a PES of (C) moderate. Both situations are unlikely to change in the foreseeable future.

3.4 Topography and Drainage

The Quaternary catchment of the study area (C60B) extends over an approximate area of 1 023 km^2. The Study area is illustrated Figure 4 in relation to surrounding rivers and surface drainage directions. The perennial Vals River is seen draining north of the proposed development site in an east to west direction. An overall local topographical decline can be seen in Figure 4, dipping from the east to west along the Vals river drainage.

The topography of the proposed development is divided into three independent watersheds, draining east, north and west, respectively. The study area therefore does not have an overall drainage direction but three. Surface water drainage will ultimately flow into the northern Vals River and hereafter continue draining in a western direction. Simulated drainage lines were added to Figure 4 to aid conceptualization of flow accumulation. The eastern watershed intersecting the study area is expected to receive the highest of all flow accumulation. The proposed pipeline extension intersects this watershed's simulated drainage line and mapped non-perennial river line.

Surface water runoff is expected to follow simulated drainage directions while groundwater is expected to mimic overall surface and river drainage where homogeneous horizontally extending geology is present. Groundwater is expected to flow parallel to intersecting dolerite intrusion contact zones where igneous geology and sedimentary structure contact boundaries exist. In this case an overall groundwater flow could be expected as temporary shallow baseflow towards the east, north and west (within simulated watersheds) while being channeled towards the west once confluenced with the Vals River.

The regional topography varies from 1 511 mamsl in the most south eastern section of the proposed development where the proposed pipeline starts, 1466 mamsl in the west. From these elevations the study area exhibits an estimated slope of 2 - 4 %.

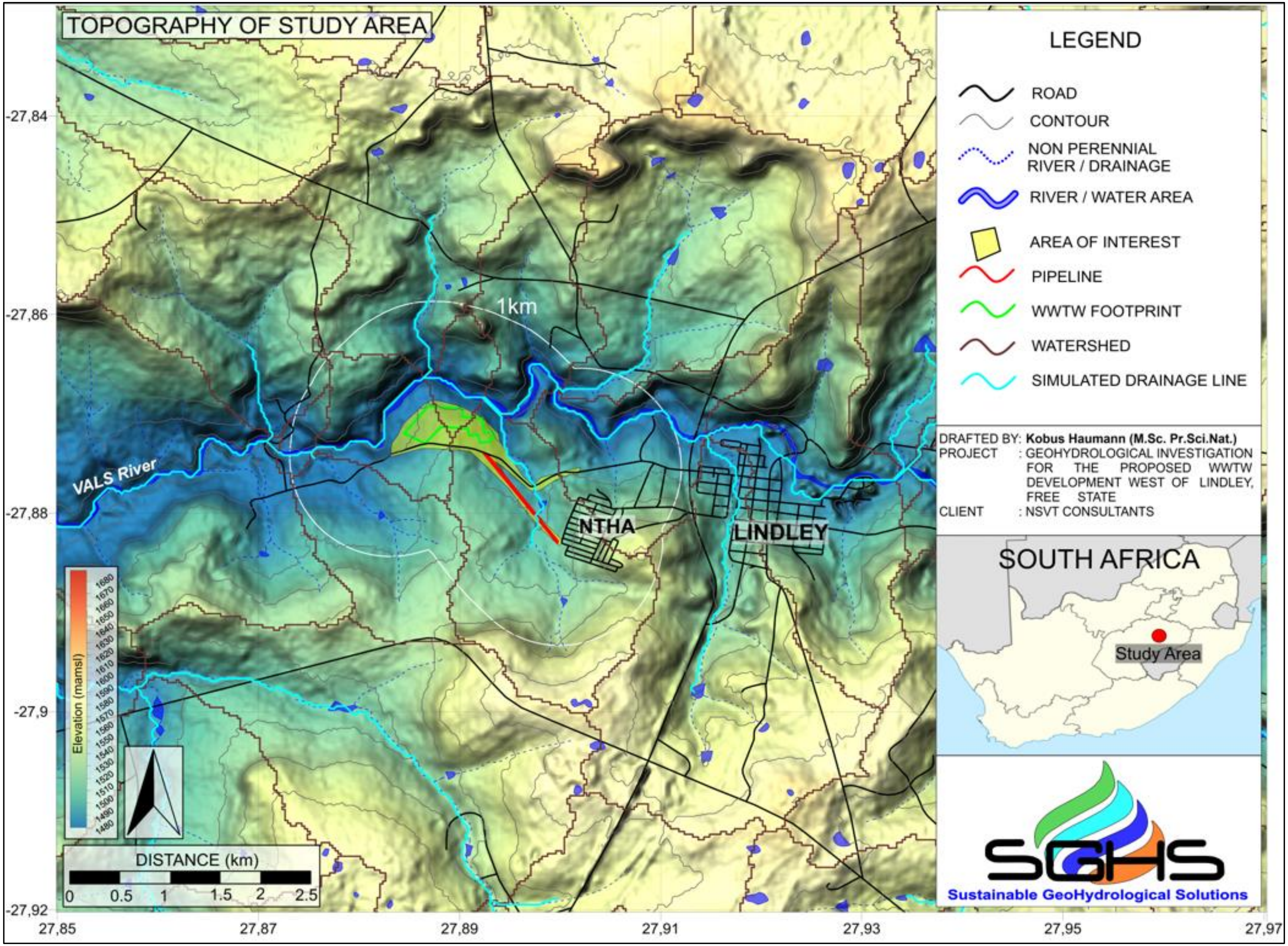


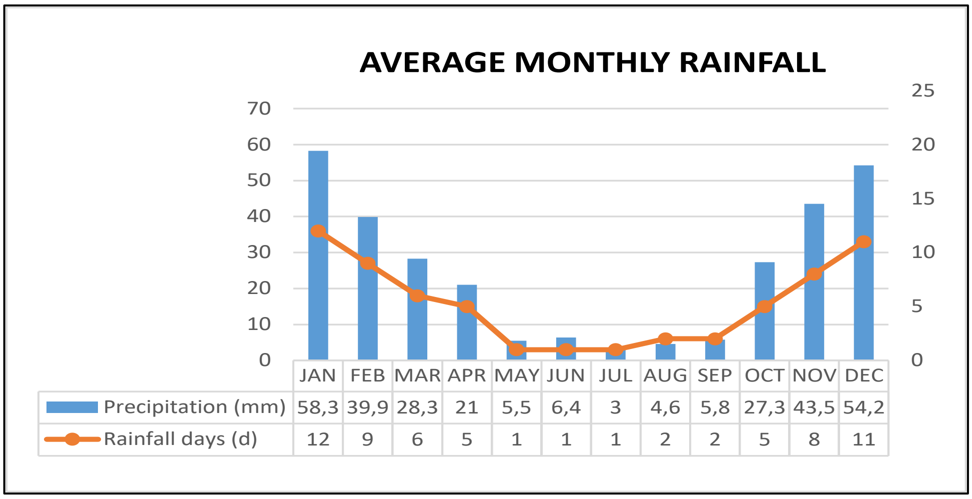
Figure 4: Topographical variation and drainage.

3.5 Climate

The investigated site is located in an semi-arid climatic region and is characterized by relatively low rainfall. In addition, rainfall in the area is highly unpredictable, both temporally and spatially. However, precipitation is seasonal with the majority of rain falling between December and January, as summer rainfall at an average of 297,8 mm/y (millimeters per year). Figure 5 shows the average rainfall values for the investigated area per month. This area receives its lowest rainfall during July and the most rainfall during January.

Temperature conditions can be extreme with temperature ranges between summer and winter. Although thunderstorms occur regularly in summer and hail incidents are infrequent, drought occurs at regular intervals. High winds occur during early and late summer during the change in season. Frost generally occurs during the winter months.

The monthly distribution of average daily maximum temperatures (Figure 6) shows that the average midday temperatures range from 26 °C in January to 15°C in June and July. The region is the coldest during July when the mercury drops to 2°C on average during the night.



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Precipitation (mm)	58,3	39,9	28,3	21	5,5	6,4	3	4,6	5,8	27,3	43,5	54,2
Rainfall days (d)	12	9	6	5	1	1	1	2	2	5	8	11

Figure 5: Average Monthly Rainfall.

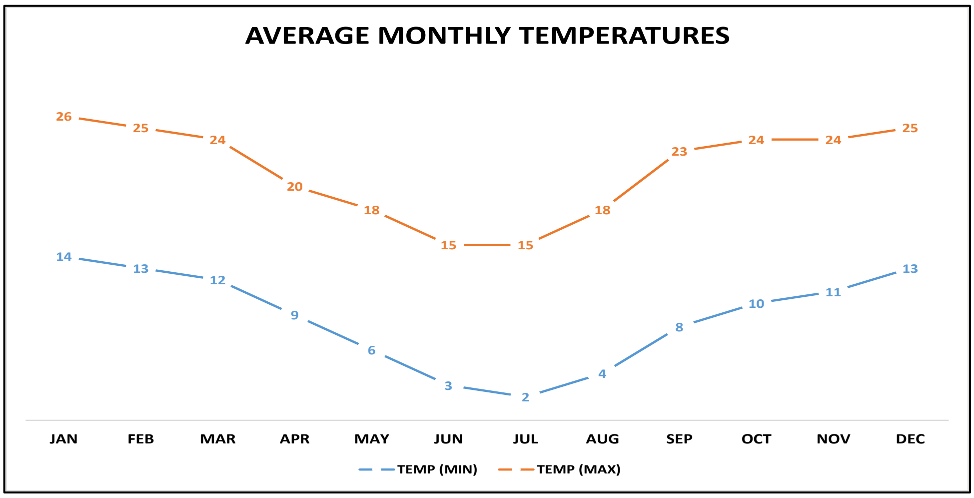


Figure 6: Average Monthly Minimum and Maximum Temperatures.

3.6 Regional Magnetic Setting

To accurately interpret regional aeromagnetic structures in proximity to the study area, a high-quality airborne aeromagnetic map was created and is displayed in Figure 7. From this image, defined prominent aeromagnetic structures are seen beneath and surrounding the study area.

From the refined aeromagnetic map, high-positive (red) magnetic field strengths are seen extending north, west and southeast of the study area.

Elevated magnetic field strengths are expected to be associated with the presence of sub-horizontal magnetic dolerite sill structures while lower magnetic strengths (light blue) are associated with non-magnetic sedimentary structures such as the Tarkastad and Adelaide Sub-Group sediments of the Beaufort Group. A southeast to northwest striking magnetic anomaly is seen intersecting the western section of the study area as well as the proposed pipeline. This anomaly in all likelihood represents a magnetic associable sub-horizontal dolerite sill structure.

While prominent aeromagnetic structures underlie most of the general area toward the northwest and southeast, their extents do not correlate with overall topographical variations within a 1km radius of the proposed development site. This is due to an expected effect of aeolian soil cover, potentially deeper soil profiles and the shallow subsurface presence of sedimentary structures of the Beaufort Group in the general area. It is however still expected that magnetic associable intrusive structures, such as dolerite, intrude/outcrop the surface of the investigated site. These structures may generally underly the surface at relatively shallow depths >500m northwest and 1km southwest of the proposed development footprint.

The location and extent of these magnetic associable geological structures are important in determining preferential groundwater flow paths and potential monitoring borehole placement. Surface to groundwater infiltration/recharge rates are also expected to be increased at the magnetic associable geological structure's contact zones with sedimentary geology.

Preferential groundwater flow is expected to occur in a downgradient topographical direction along these structures. Therefore, most of the groundwater flow is expected to drain in an east to west direction while the highest estimated groundwater flow should occur through the northern section of the proposed study area.

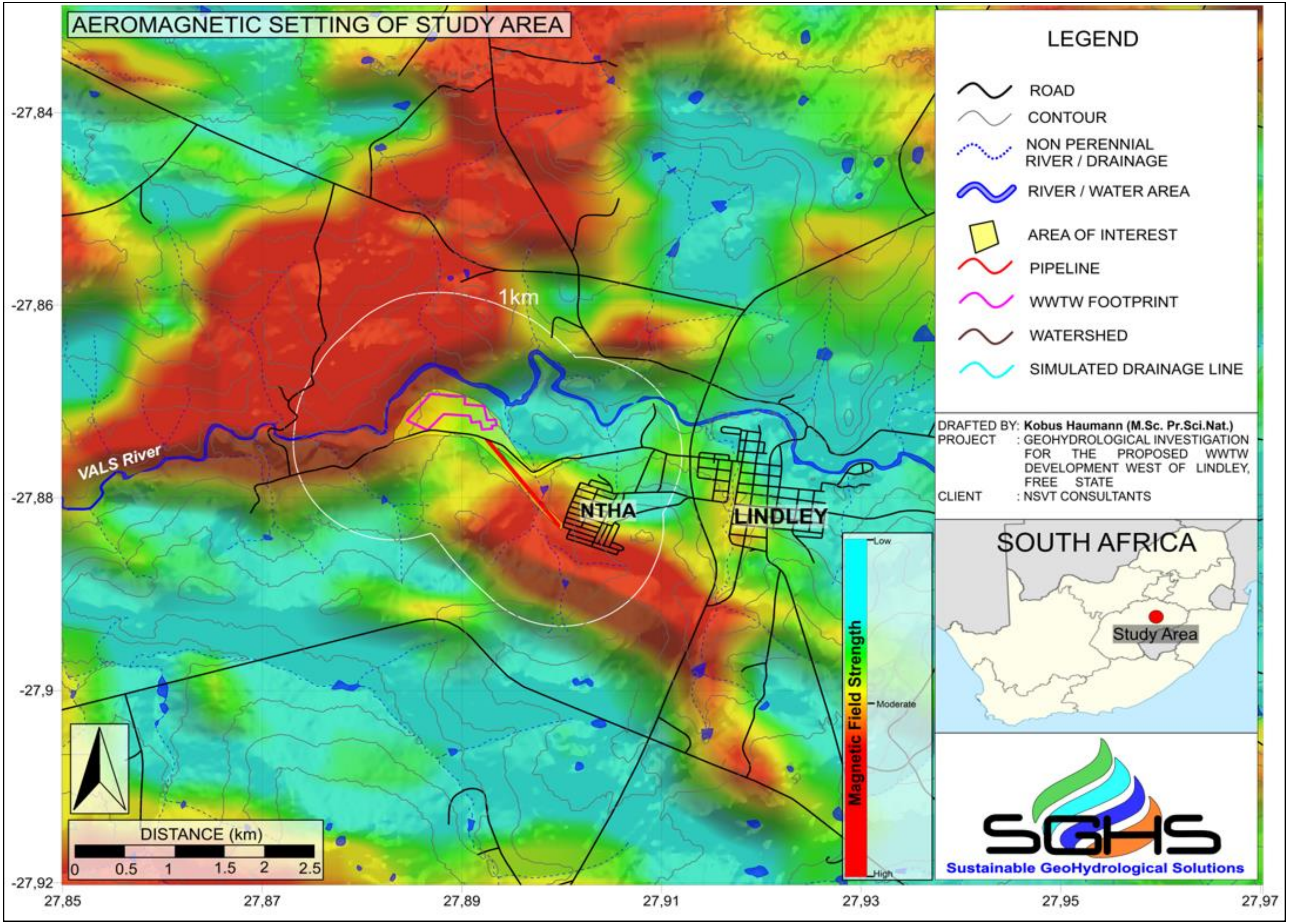


Figure 7: Regional Aeromagnetic Setting

3.7 Geological Setting

3.7.1 Stratigraphy

The study area is 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 range 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 8 with the study area located in the main Karoo 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 located within the Beaufort Group which is subdivided into the Tarkastad and Adelaide Subgroup. These two Subgroups are explained below.

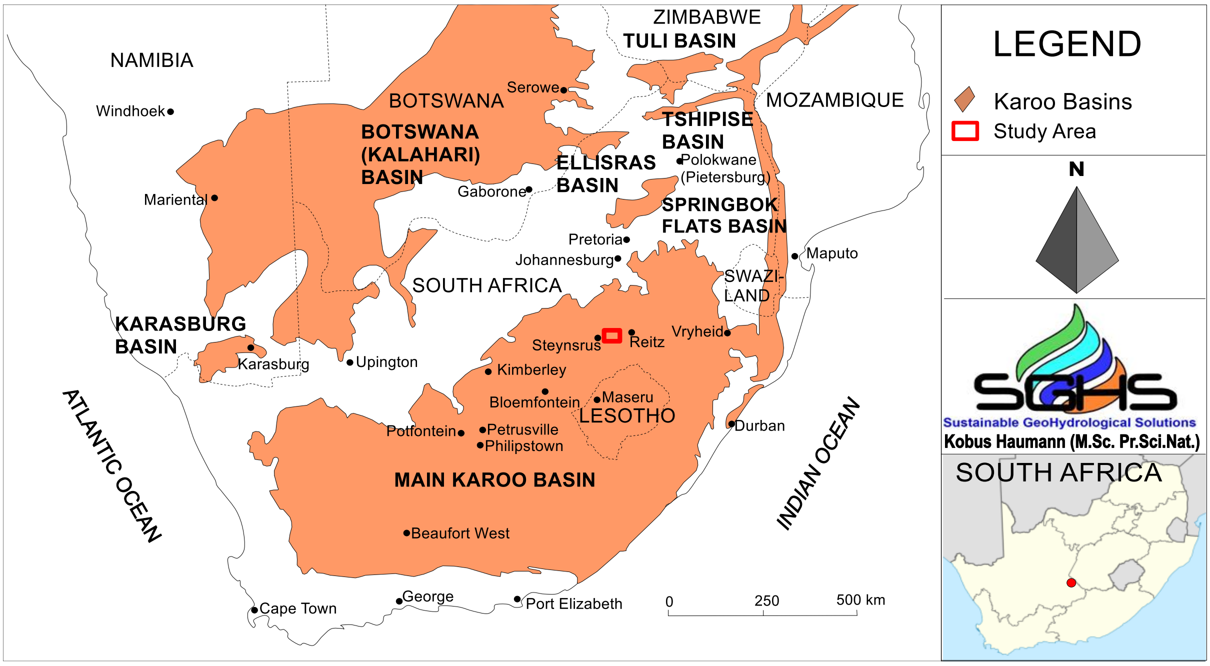


Figure 8: Location of Karoo Boundaries in South Africa and adjacent territories (modified after Johnson et al.,1996).

3.7.1.1 Beaufort Group

The Beaufort Group covers an area of approximately 200 000 km^3. It attains a maximum cumulative thickness of approximately 7 000 m in the foredeep of the Karoo Basin, thinning rapidly northwards consisting of fluvial deposited Permo-Triassic rocks (Catuneanu, *et al.*, 2005). The Beaufort Group is subdivided into two subgroups, namely:

- Tarkastad Subgroup
- Adelaide Subgroup

3.7.1.1.1 Adelaide Subgroup

The Adelaide Subgroup is divided into four formations (Figure 9) of which the Koonap, Middleton, and Balfour Formations form part of the proximal facies and the Normandien Formation that of the distal facies (north-eastern area of the Karoo Basin) (Catuneanu, *et al.*, 1998). The Subgroup attains a maximum thickness of approximately 5 000 m in the south-eastern area of the Karoo Basin and rapidly decreases towards the north to approximately 800 m (Johnson, *et al.*, 2006). The Koonap and Middleton Formations form a single fining-upward unit (Catuneanu *et al.*, 1998) consisting of mudstone and sandstones, where the red mudstones of the Middleton Formation distinguish it from the lower- and upper lying formations (Koonap & Balfour Formations) (Bordy *et al.*, 2011). The mudstones of the rest of the Adelaide Subgroup are generally greenish grey in colour (Catuneanu *et al.*, 1998).

In the northern part of the Basin, coarse to very coarse sandstone, or even granulestone, is common in the Normandien Formation. Sandstone constitutes 20% to 30% of the total thickness, but in certain areas may be as little as 10%, while some sandstone-rich intervals may in places contain up to 60% sandstone.

Individual sandstone units are thickest in the south (averaging 6m; maximum 60m) and become thinner northwards, except for the extreme northeast where thick, laterally extensive units are also present in the Normandien Formation. The mudrocks of the Adelaide Subgroup are generally massive and shows blocky weathering except in parts of the Normandien Formation where horizontal lamination is common (Johnson, *et al.*, 2006).

3.7.1.1.2 Tarkastad Subgroup

The Tarkastad Subgroup is divided into four formations (Figure 9). In the south, it comprises of a lower Katberg Formation and an upper Burgersdorp Formation and in the extreme north of a lower Verkykerskop Formation and an upper Driekoppen Formation. The subgroup attains a maximum thickness of nearly 2000 m in the south, decreasing to approximately 800 m towards the middle of its outcrop area and 150 m or less in the far north (Johnson, *et al.*, 2006).

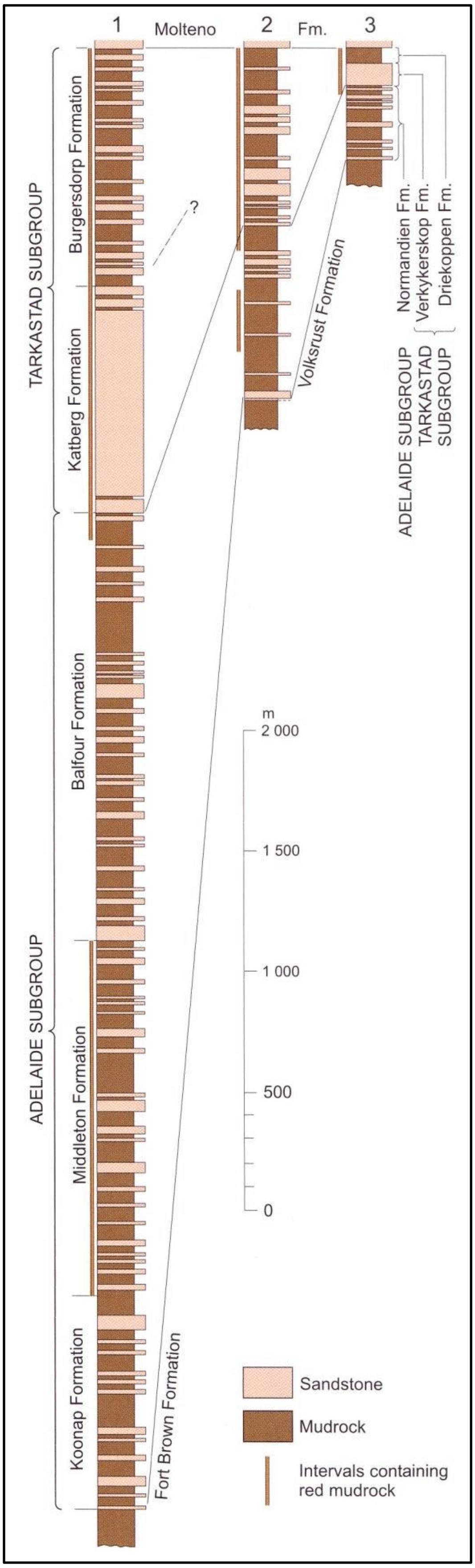


Figure 9: Stratigraphy of Subgroup Adeleide and Tarkastad of the Beaufort Group. Units thinner than about 7 m, are not shown (Johnson, et al., 2006).

3.7.1.2 Intrusive Karoo Dolerite

Towards the end of the Cape Orogeny, thermal dome uplift developed beneath almost the entire South African continent. Dolerite represents the roots of the volcanic system and is presumed to be of the same age as the extrusive lavas (Fitch and Miller, 1984). Extensive magnetic activity led to dolerite dykes, inclined sheets and sills to intrude the sedimentary rocks of the Karoo Super group during the Jurassic period to the north of the compressional sphere of the Cape Fold Belt.

The level of erosion that affected the Main Karoo basin has revealed the deep portions of the intrusive system, which displays a high degree of tectonic complexity. The Karoo intrusive can either occur as dykes, sills, or ring-complexes. The Karoo dolerite, which includes a wide range of petrological facies, consists of an interconnected network of dykes and sills and it is nearly impossible to single out any particular intrusive or tectonic event. It would appear that a very large number of fractures were intruded simultaneously by magma and that the dolerite intrusive network acted as a shallow stockwork-like reservoir.

Early mapping of the dolerite intrusive was done by Rogers and Du Toit (1903) in the Western Cape and Du Toit (1905) in the Eastern Cape. More recently the Geological Survey has published most of the 1:250 000 maps of the entire Karoo Basin. Detailed mapping of dolerite occurrences at specific localities in the southern Free State and Western Karoo was done hereafter. Figure 10 represents interconnected dykes and sills of the Main Karoo Basin, including a schematic cross-section through the basin as created by Prof. Gerrit van Tonder.

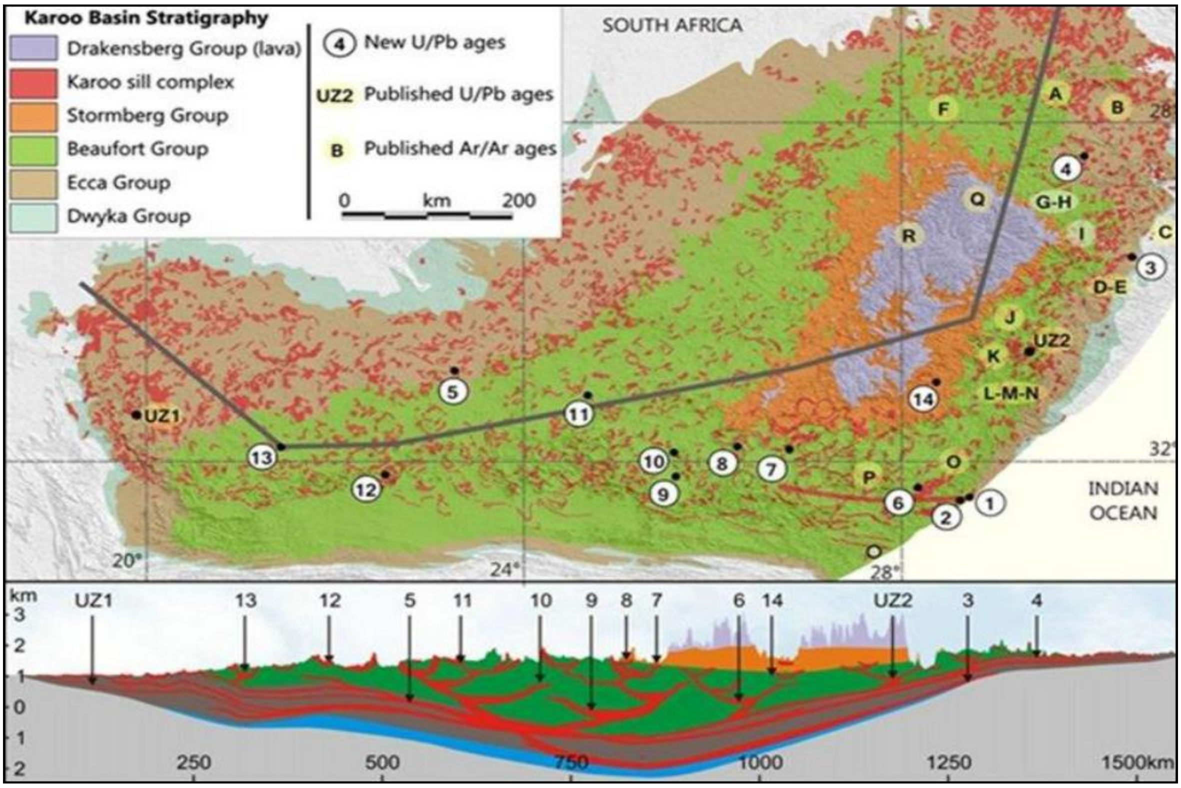


Figure 10: Interconnected dykes and sills of the Main Karoo Basin, including a schematic cross-section through the basin (Courtesy of Prof. Gerrit van Tonder).

3.7.1.2.1 Geometry, Structure & Mechanism of Dolerite Dyke Emplacement

Dolerite dykes are the primary targets for groundwater exploration and it is therefore important to understand the geometry, structure and mechanisms of emplacement.

Emplacement Mode: Dolerite dykes, like many other magmatic intrusions, develop by rapid hydraulic fracturing via the propagation of a fluid-filled open fissure, resulting in a massive magmatic intrusion with a neat and transgressive contact with country-rock. This fracturing mechanism is in contrast to the slow mode of hydraulic fracturing responsible for breccias-intrusions such as kimberlite. For the intrusion to develop, the magma pressure at the tip of the fissure must overcome the tensile strength of the surrounding rock. Dykes can develop vertically upwards or lateral along-strike over very long distances, as long as the magma pressure at the tip of the fissure is maintained. The intrusion of dolerite and basaltic dykes are therefore never accompanied by brecciation, deformation or shearing of the host-rock, at least during their propagation.

Dyke Attitude: All the dykes are sub-vertical with a dip seldom below 70 degrees. The attitude of dykes often changes with depth, as observed from many detailed borehole logs. This phenomenon can be attributed to vertical offsetting as a result of vertical en-échelon segmentation or due to interconnecting of dykes between sediment layers.

Dyke Width: The average thickness of Karoo dolerite dykes ranges between 2 and 10 meters. In general, the width of a dyke is a function of its length. No relationship has been found between trend and thickness (Woodford and Chevallier, 2002).

En-échelon Pattern: Dolerite dykes often exhibit an en-échelon pattern along strike, which are clearly detected by mapping. This is the case with the E-W shear dykes and their associated riedel-shears. Displacements in the vertical section also occur, often associated with horizontal, transgressive fracturing. These offsets are often observed.

Dyke Related Fracturing: The country rock is often fractured during and after dyke emplacement. These fractures form a set of master joints parallel to its strike over a distance that does not vary greatly with the thickness of the dyke (between 5m and 15m). The dolerite dykes are also affected by thermal- or columnar- jointing perpendicular to their margins. These thermal joints also extend into the host rock over a distance not exceeding 0.3m to 0.5m from the contact. Van Wyk (1963) observed two types of jointing associated with dyke intrusions in a number of coal mines in the Vryheid Dundee are, namely:

1. Three sets of pervasive-thermal, columnar joints that are approximately 120 degrees apart; and
2. Joints parallel to the contact, confined mainly to the host rock alongside the dyke.

Many cases of tectonic reactivation of the dolerite have been observed in the Loxton-Victoria West area (Woodford and Chevallier, 2001), especially on the N-S dykes that have been reactivated by cretaceous kimberlite activity or by more recent master jointing. Reactivation often results in sub-vertical fissures within the country rock and/or dyke itself, which are commonly highly weathered and filled with secondary calcite/calcrete (width of up to 150mm) uplifting or brecciation of the sediment along the dyke contact. Deformation and Contact Metamorphism of Host Rock: Localised up - warping of the country-rock is often observed adjacent to dipping dykes. Hydraulic fissure propagation, as mentioned above, cannot be responsible for this phenomenon, as the magma would have to be cool and become viscous in order to cause such deformation. This up - warping of the country-rock is commonly a near-surface phenomenon related to the supergene formation of clays with a high expansion coefficient in the "swelling" rock mass. The dolerite magma shows marked chilling against the sediments into which it has been injected. The chill zone generally exhibits the effects of contact metamorphism, where argillites are altered to hornfels or lydianite and arenaceous units are crystallized to quartzite. Van Wyk (1963) state that the jointed contact zone is less than 30cm wide, irrespectively of dyke thickness.

Petrography and dyke weathering: The effect of variable cooling of dykes following intrusion is also apparent in the way which dykes weather in the Western Karoo such as:

Thick dykes greater than 8m exhibit a prominent chill-margin containing a fine grained, porphyritic, melanocratic dolerite that weathers to produce well-rounded, small, white-speckled boulders. This zone is normally only 0.5 m to 1.5 m wide and exhibits well-developed thermal-shrinkage joints. The central portion of such dykes consists of medium to coarse grained, mesocratic and occasionally leucocratic dolerite that decomposes to a uniform 'gravely' material, which exhibits an exfoliation type of pattern. Sporadic fractures or meta-sedimentary veins are encountered in this zone and they often do not extend into the country rock. Magnetic traverses across these features normally produce two distinctive peaks. Thin dykes less than 3m commonly consist of fine-grained, porphyritic, melanocratic dolerite. These tend to be more resistant to weathering than the thicker dykes and in outcrop exhibit a uniform pattern of shrinkage-joints. The dyke weathers to produce small rounded, white-speckled boulders set in finer angular groundmass.

3.7.2 Local Geology

The mapped surface geology of the general study area is presented in Figure 11 as derived from a 1:250 000 Geological Series map. The proposed development site is mapped to be predominantly underlain by sandstone, mudstone and siltstone sediments of the Adelaide Sub-Groub (*Pa*) of the Beaufort Group which belongs to the overall Karoo Super-Group. Dune sand (*Qd*) of the Quaternary Era is mapped at the southern and northern border of the study area. A dolerite structure (*Jd*), correlating with mapped aeromagnetic structures in Figure 7 also underlies the northern border of the investigated site, while mapped to occasionally be overlain by dune sand (*Qd*).

Alluvium soils upstream and downstream of the investigated site are expected to be spread in general broad valleys along local streams and rivers. There is a low correlation between topographical variations, mapped surface geology and the high magnetic field strength structures. This suggests that intrusive dolerite structure most likely, do not intrude the regional surface area as defining features but could be present at deeper extents or general flat topographical features. It is expected that a sub-horizontal dolerite sill structure of varying extents underlies Alluvium soils and Beaufort Group sediments beneath the proposed development site more prominently toward the north and west than to the east of the proposed development site.

Increased heat and subsurface disturbance caused by the dolerite intrusions are expected to increase the transmissivity rates of the sedimentary deposits at contact boundaries. Increased surface to groundwater infiltration and groundwater flow rates are expected at these boundaries.

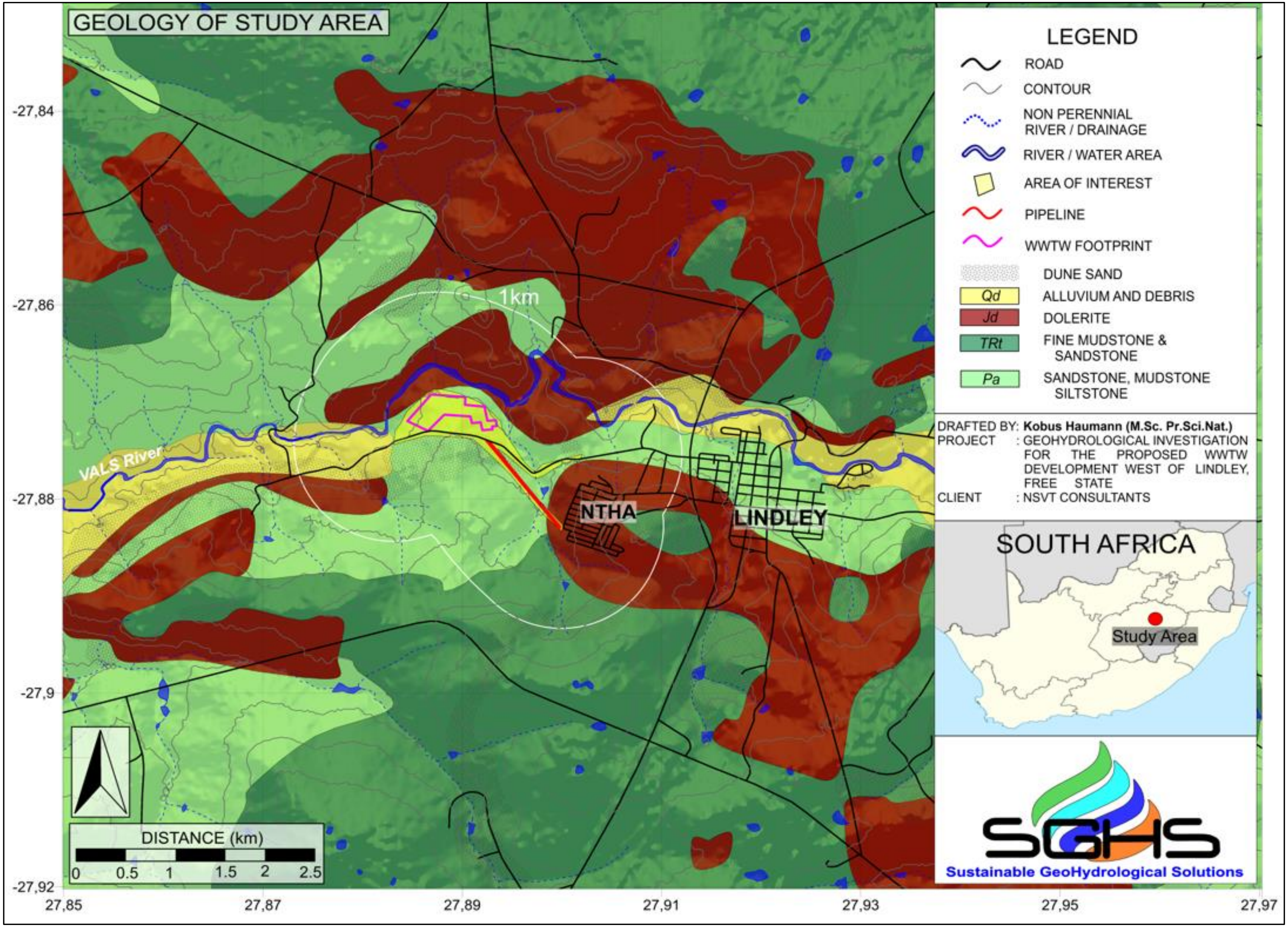


Figure 11: Local surface geology of the study area.

3.8 Geohydrology

3.8.1 Beaufort Group

It is expected that the aquifers in the Beaufort Group will be anisotropic but the geometry of the aquifers are further complicated by the migration of braided and meandering streams (Vivier, 1996). Thus the sandstones and mudstones of the Beaufort Group are also characterized by significantly low (virtually absent) primary porosity and permeability.

According to Woodford and Chevallier (2002) the main reason for these low permeabilities are due to the sandstones being generally poorly sorted, and that their primary porosities have been lowered considerably by diagenesis.

Secondary properties of these rocks, such as the degree, density, continuity and interconnection of fracturing, control the occurrence, storage and movement of groundwater (Van Wyk & Witthueser, 2011). The fact that many of the coarser sediments are lens shaped further complicates these aquifers, as the life-span of a borehole drilled into such structures may thus be limited, if not frequently recharged (Vivier, 1996).

The groundwater of the Beaufort Group are generally potable, but there are areas where this is not the case. The EC values vary between 70 and 1 200 mS/m with the majority below 300 mS/m. Sodium, chloride, fluoride and sulphate may exceed the maximum recommended limits.

3.8.1.1 Borehole Yields

According to Baran (2003), the lithology of the sedimentary deposits of the Beaufort Group appears to have little effect on the borehole yields. The majority of yields are generally between 0.1 and 2 l/s. Higher yields can occasionally be obtained by targeting occasional folds, faults and joint structures, where favourable recharge conditions exist.

The average water level depth varies between 10 and 20 mbgl but localities with shallower water levels are also common (mostly wide river valleys) (Baran, 2003).

3.8.2 Karoo Dolerite Suite

Extensive weathered zones often develop in dolerite sills that are situated in low lying and well drained areas - 'similar to weathered basins' described in other crystalline basement rocks (*Enslin, 1943; Wright and Burgess, 1992*). These localized, shallow intergranular aquifers are capable of storing large volumes of groundwater. Abstraction from these dense-massive structures is only possible where extensive weathering has occurred at depth below the water table.

Dolerite ring-dykes and inclined sheets seldom form negative features of the landscape, as they are more resistant to weathering. The hydrological properties of weathered dolerite ring structures and inclined sheets seem variable. Vegter (1995) mentioned that the upper or lower contact sills located within the weathered zone, for example 20 to 50 meters below ground level, are favorable zones for striking groundwater. Recent extensive exploration drilling along dolerite inclined sheets and ring dykes in the Victoria West area (*Chevallier et al, 2001*), indicated that contact between the sediment and the dolerite within the first 50m below surface did not yield significant volumes of groundwater. The contact between dolerite dykes and the host rock, within the weathered zone, remains the most important target for groundwater exploration (*Vegter, 1995 & Smart, 1998*).

Sedimentary rocks usually have low permeability and storativity values. Boreholes drilled into sedimentary rock formations are usually low yielding with the exception where bedding plane fractures are encountered within the sedimentary rocks or fractured baked contact zones between the sedimentary rocks and magnetic dolerite intrusions such as dykes and sills.

3.8.3 Quality

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

The groundwater electrical conductivity values are expected to vary from 150-370 mS/m. The aquifer has a *moderate* groundwater vulnerability rating that is only vulnerable to continuously discharged or leached pollutants in the long term when continuously discharged or leached.

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

A groundwater susceptibility matrix is given in Table 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 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 19 April 2023. All selected surface and groundwater observation and sampling locations are represented in Figure 12. Basic site properties for each investigated site is added to Table 5.

The aim of this census was to;

- Map geological structures.
- 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 groundwater to determine current local groundwater quality.

Table 5: Hydrocensus sample site background.

Site ID	Latitude	Longitude	Elevation (mamsl)	Comments
LR1	-27.868134°	27.871405°	1479	Residence with expected groundwater dependency.
LR2	-27.857072°	27.889425°	1508	Residence with expected groundwater dependency.
LR3	-27.863119°	27.898923°	1487	Residence with expected groundwater dependency.
LR4	-27.881481°	27.868836°	1500	Residence with expected groundwater dependency.
LBH1	-27.846972°	27.876416°	1555	Borehole fitted with windmill. Not actively in use. Borehole sealed.
LBH2	-27.859839°	27.915514°	1515	Borehole fitted with windmill. Not actively in use. Borehole sealed.
LS1	-27.872591°	27.869947°	1455	Vlas River Screening downstream location.
LS2	-27.868321°	27.891547°	1462	Vlas River Screening location at proposed outflow.
LS3	-27.874053°	27.923289°	1477	Vlas River Screening upstream location.
LS4	-27.874859°	27.894999°	1487	Eroded river channel recorded draining 100m east of the proposed development footprint. Polluted.
LS5	-27.868794°	27.890075°	1475	Surface water baseflow drainage recorded at the northern boundary of the proposed development site.
LS6	-27.880544°	27.900459°	1508	Additional sewage drainage leak 200m north of proposed pipeline.
LG1	-27.873856°	27.892889°	1493	Highly weathered and fractured mudstone outcrop recorded 100m southwest of the proposed development site.
LG2	-27.874093°	27.891587°	1500	Dolerite sill outcrop recorded 140m south of the proposed development area.
LG3	-27.873102°	27.888477°	1500	Dolerite sill outcrop recorded 300m south of the proposed development area.
LG4	-27.873001°	27.887784°	1497	Prominent sandstone outcrop recorded within the access road south of the proposed development footprint.
LG5	-27.876906°	27.878487°	1470	Extreme erosion was recorded 820m west of the proposed development site.
LG6	-27.870974°	27.893261°	1483	Eroded dune sand was recorded at the eastern boundary of the proposed development footprint.
LG7	-27.871566°	27.884041°	1472	Erosion at western boundary of the proposed development site.;
LG8	-27.867723°	27.888496°	1474	Dolerite sill structure was recorded to outcrop north of the study area.
LG9	-27.868302°	27.891480°	1462	Dolerite structure is seen outcropping the Vlas River riverbed.
LG10	-27.869310°	27.890430°	1480	Sandstone ridge outcrop at the northern border of the proposed development footprint.

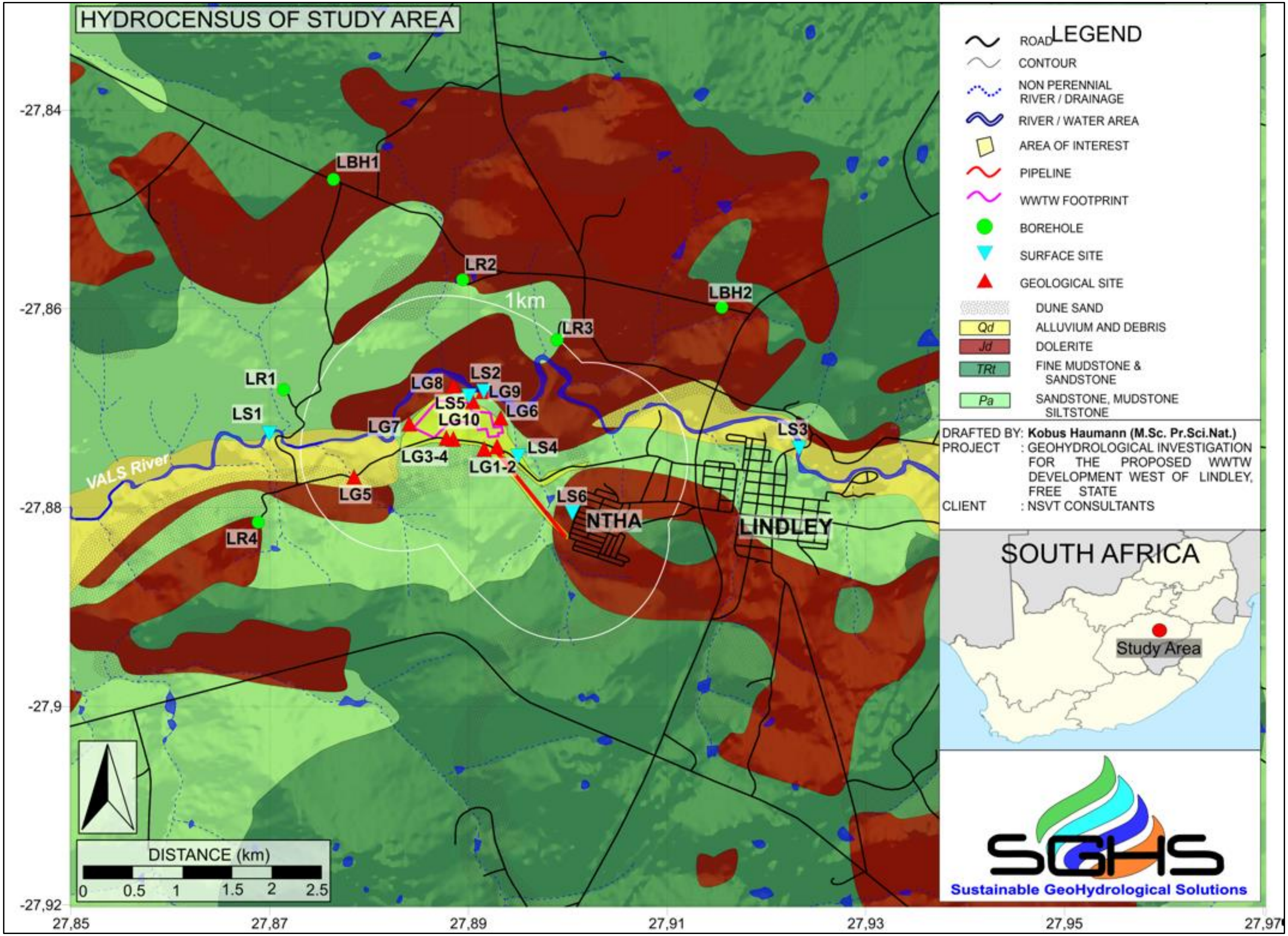


Figure 12: Visual observation and hydrocensus sample points identified in relation to the study area.

4.1 Surface Area

The surface area of the investigated site is indicated in Figure 13 in a northwest to southeast direction. From this image, the surface area of the investigated site is seen as relatively flat while dipping toward the general east. The local area appears to be in a visually good natural condition while being covered by grassland and shrub vegetation.

Figure 13: On site surface conditions.

4.2 Geological Mapping

4.2.1 Geology Site LG1

A highly weathered and fractured mudstone outcrop was recorded 100m southwest of the proposed development site. The outcrop (Figure 14) weathering varies as seen in Figure 14 from low to high. This site is expected to represent red mudstone of the Tarkastad Subgroup and Beaufort Group sedimentary structure, mapped to be present a further 2km south of the site.

Figure 14: Mudstone outcrop southeast of the investigated area (pen for scale).

4.3 Geology Site LG2 & LG3

A dolerite sill outcrop was recorded 140m south of the proposed development area as seen in Figure 15. The intrusive structure is expected to form part of a larger intrusive sub-horizontal sill structure. At this observation point the structure prominently intrudes the surface area with low weathering visible.

Figure 15: Dolerite outcrop 140m south of study area.

This dolerite sill structure becomes much more weathered 300m toward the west as seen in Figure 16.

Figure 16: Dolerite sill structure LG3

4.3.1 Geology Site LG4

A prominent sandstone outcrop (Figure 17) was recorded within the access road south of the proposed development footprint. This sedimentary structure does not appear highly weathered which may indicate that the absence of the dolerite sill structure in the immediate vicinity. The dolerite sill structure is expected to be a few meters deeper beneath the sandstone in this location.

Figure 17: Sandstone outcrop at the access road south of the proposed development site (pen for scale).

4.3.2 Geology Site LG5 to LG7

Extreme erosion was recorded 820m west of the proposed development site. Erosion channels are presented in Figure 18 below. This site represents eroded mapped dune and aeolian sand that has been flushed away by stormwater runoff from the south. Erosion at this site is expected to increase over time and contribute to high levels of sedimentation into the Vals River to the north.

Figure 18: Soil erosion 820m west of the proposed development.

Similar to Site LG5, eroded dune sand was recorded at the eastern boundary of the proposed development footprint, represented as site LG6 and shown in Figure 19 while additional erosion (LG7 - Figure 20) site was also recorded at the western boundary of the proposed development footprint. Due to the high erodibility associated with the sediments in the area, it is highly recommended that the already eroded sites be stabilized and appropriate stormwater management plan be drafted that specifically limits erosion.

Figure 19: Soil erosion east of the proposed development.

Figure 20: Soil erosion west of the proposed development.

4.3.3 Geology Site LG8 &LG9

A dolerite sill structure was recorded to outcrop north of the study area as seen in Figure 21. At this site the sill structure outcrops prominently while being flat and widely extending. This structure is expected to underly the proposed development at varying densities but a uniform extent.

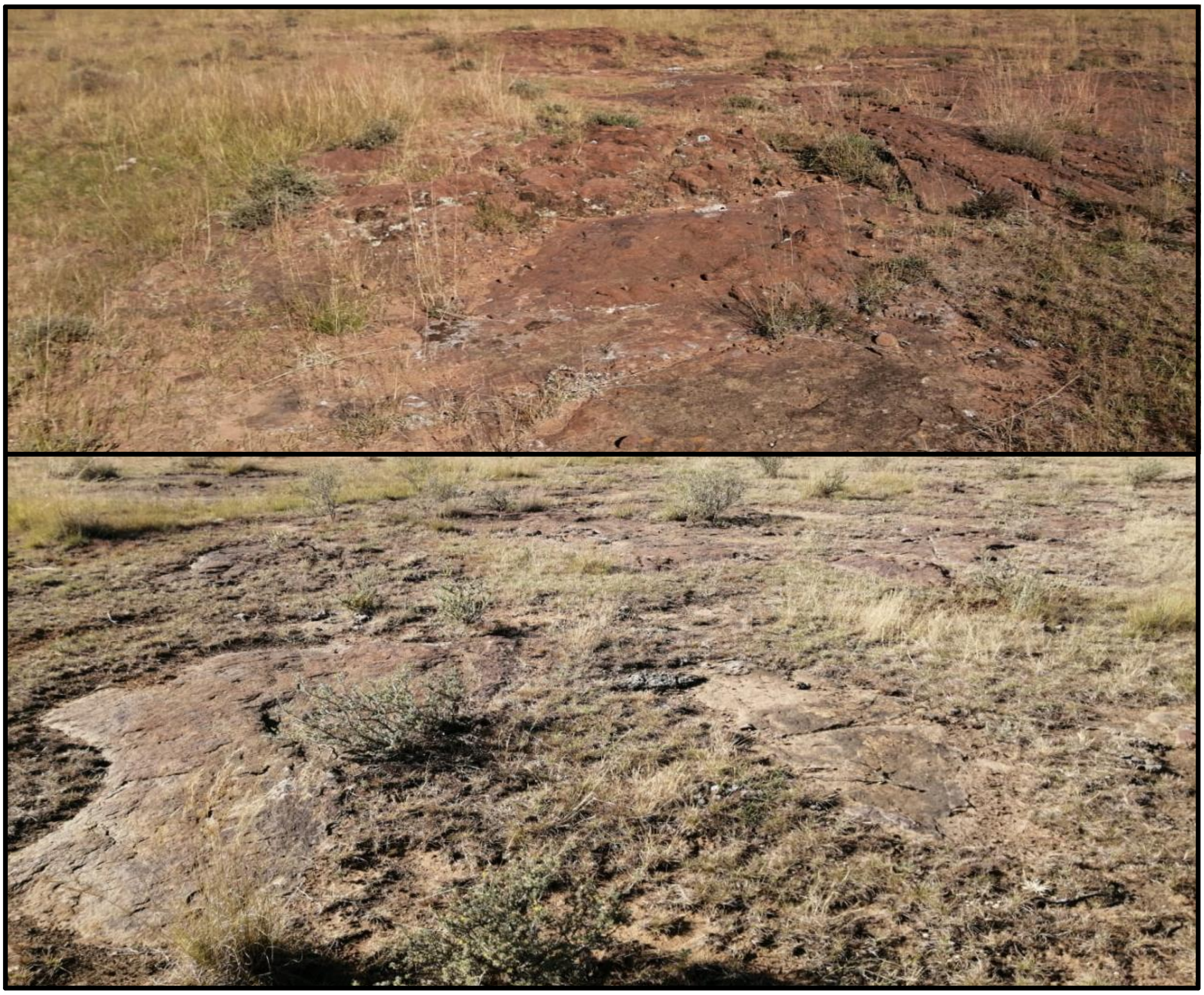


Figure 21: Dolerite sill bank 170m north of proposed development.

The same dolerite structure is seen at site LG9 outcropping the Vlas River riverbed Figure 22 north of the proposed development. The dolerite sill structure appears prominent and fractured with low weathering. This structure is expected to occur prominently below the proposed development site.

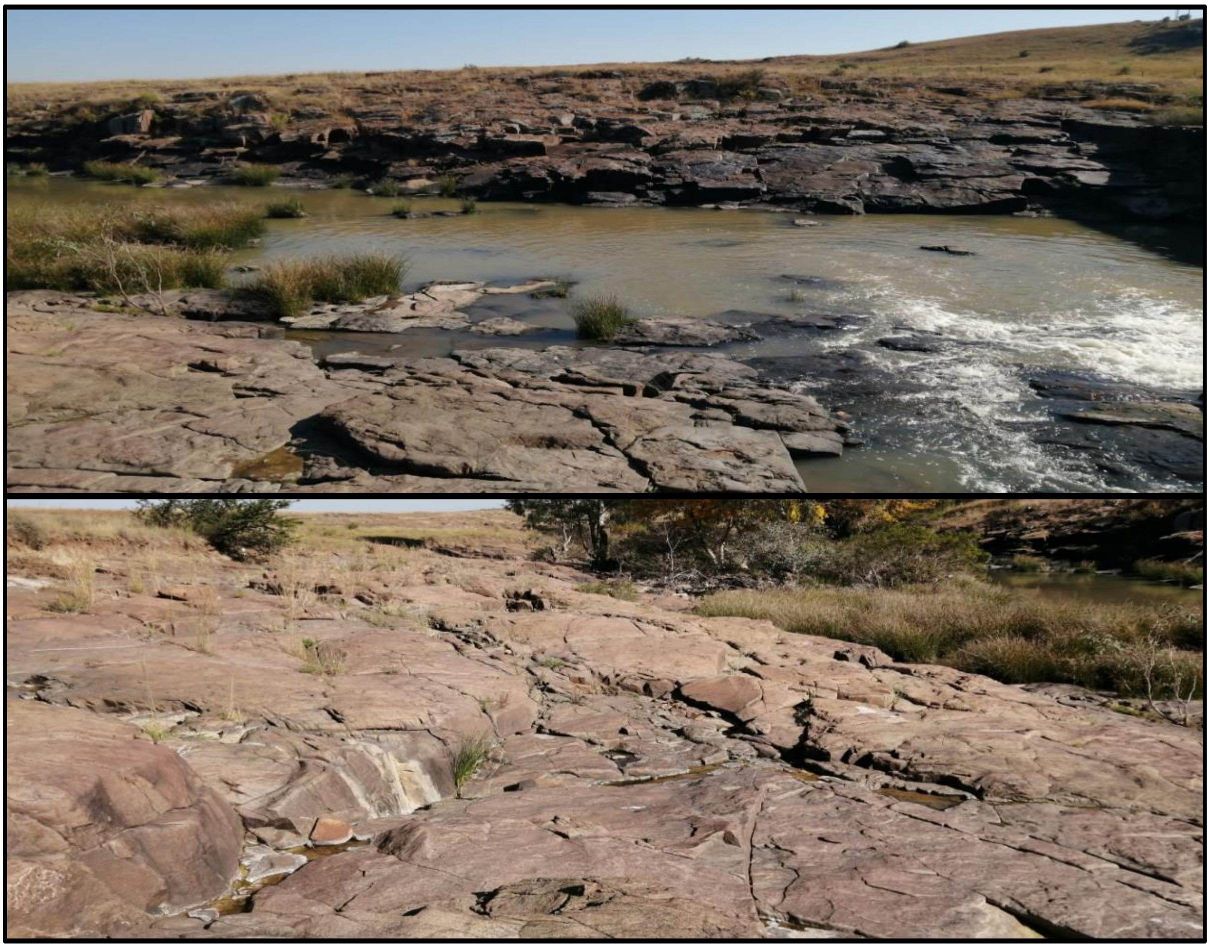


Figure 22: Dolerite outcrop north of the proposed development site.

4.3.4 Geology Site LG10

Site LG10 represents a sandstone ridge outcrop at the northern border of the proposed development footprint. The outcrop is represented in Figure 23 and is expected to extend a few meters deep beneath the center and eastern section of the proposed development footprint. The bottom of this sedimentary structure is expected to be highly weathered at dolerite sill contact boundaries. Baseflow drainage at sandstone and dolerite contact can be expected in a general eastern direction or along the dipping angle of the dolerite sill structure.

Figure 23: Site LG10 representing sandstone outcrop at the northern and central section of the study area.

4.4 Surface water sites

The investigated area experienced an above-average summer rainfall season prior to the site visit (19 April 2023). Surface water observation sites are therefore expected to represent areas that received high surface water accumulation. However, no stagnant surface water was recorded in the area, suggesting a relatively good drainage environment. The following sub-section will aim to address and discuss specific surface- and surface-water sites of importance.

4.4.1 Surface Site LS1, LS2 & LS3

The perennial Vals River (Figure 24) was recorded to drain 300m north of the proposed development in a general east to west direction. The site appears in a generally good flowing state. The site was screened at three different locations with screening concentrations represented in Table 6. The most downhill screening location represented the lowest pH values while also having the most elevated Electrical Conductivity (EC) and Total Dissolved Solids (TDS) concentrations. Site LS1 was sampled for bacteriological and inorganic chemistry testing, represented in Appendix A.

Figure 24: Vals River draining north of the proposed development,

Table 6: Vals River Screening.

VALS RIVER					
Site	Relevant To Site	pH	EC (mS/cm)	TDS (ppm)	Temp (˚C)
LS1	Downstream	6,82	0,5	310	16,1
LS2	At proposed outflow	6,85	0,4	280	16
LS3	Upstream (at existing WWTW outflow)	6,86	0,35	240	16

4.4.2 Surface Site LS4

An eroded river channel (Figure 25) was recorded draining 100m east of the proposed development footprint. This channel extends >2km to the south where water flow is expected to emanate from a leaking sewar system. Water flow is expected to exceed 7200 L/h and has a prominent sewage smell with prominent bacterial growth within the channel. Due to the sedimentary and aeolian nature of the local area's subsurface, the majority of water flow could be expected to occur within the subsurface, along the river channel. Based on Google Earth imaging this flow has been occurring for more than 23 years, but at unknown quality and quantity. It is expected that this water flow has greatly deteriorated the local groundwater and downstream river water quality. The site was sampled for bacteriological and inorganic chemistry testing, represented in Appendix A. It is highly recommended that quality of water flow be managed from the source of flow.

Figure 25: Eroded river channel

4.4.3 Surface Site LS5

Surface water drainage was recorded at the northern boundary of the proposed development site as seen in Figure 26. It is expected that this site represent surface to groundwater baseflow from an upstream source, draining downstream on top of the dolerite bedrock. While the source of the flow is unknown, the site provides a good example of baseflow to be expected in the general area. Surface water flow and accumulation at this and similar dolerite bedrock locations are expected to increase during elevated rainfall periods. Figure 26 also shows mineral precipitation at site LS5, suggesting poor local drainage in this location.

Figure 26: Surface water/baseflow drainage

4.4.4 Surface Site LS6

An additional drainage leak was recorded at site LS6 and represented in Figure 27. While surface water could not be recorded at the site during the site investigation, lush vegetation compared to surrounding dry vegetation can be used as an indicator of how the sewage distribution has occurred. Should subsurface infiltration rates exceed flow rates, the sewage leak is expected to flow within the subsurface to confluence with the eroded river channel of site LS4, contributing to its quality, quantity and associated effects on the regional groundwater system, also affecting the Vals River.

Figure 27: Drainage leak represented by green vegetation.

4.4.5 Recorded Boreholes

During the site investigation, the amount of boreholes that could be recorded within the 1km buffer was limited. No borehole use was recorded within this buffer, south of the Vals river. Three rural residences were recorded north and one south of the Vals River with expected groundwater use. These residences could however not be surveyed due to restricted access. Two boreholes were recorded >2km north of the proposed development site. These are boreholes LBH1 and LBH2. Both boreholes are fitted with windmill structures and could not be sampled due to being closed off. It is not expected that the residencies and their groundwater use north of the Vlas river would be impacted by the proposed development due to the hydraulic buffer created by the Vals river in-between. Should the river run dry during low rainfall periods however, water chemistries for water dependency at LR1 and LR4 should be monitored. The local area surrounding the investigated site is expected to partake in groundwater-dependent practices such as livestock watering and domestic use.

Figure 28: Boreholes LBH1 and LBH2 >2km north of the proposed development.

4.5 Water Chemistry

The water chemistry data for samples LS1 and LS4, represented in Appendix A present several degradation concerns.

Elevated colour and turbidity levels are noted in both samples, which suggests the presence of significant amounts of suspended materials, potentially from organic matter, clay, silt, or microbial contamination. This is also indicative of high particulates in the water and can affect the aesthetic quality.

Sample LS4 has a pH below the optimal range for drinking water, which might be due to dissolved carbon dioxide, organic matter, or specific minerals. The acidic nature should be addressed.

Both samples exhibit high Total Dissolved Solids (TDS) and Electrical Conductivity levels, with LS4 being exceptionally high. This could signify anthropogenic pollution or natural mineral content in the water source. This might also impact the water's taste and cause hardness and scale formation, with the Sodium, Alkalinity, and Chloride levels particularly elevated in LS4.

For the macro and micro determinants, the high concentrations of elements such as Aluminium, Antimony, Arsenic, Barium, Chromium, and Manganese, particularly in LS4, could pose health risks. These metals might be due to industrial contamination. Levels of toxic elements such as Arsenic, Cadmium, Lead, and Uranium, though relatively low, still need to be carefully considered.

The chemical analysis also reveals notably high Total Organic Carbon (TOC) and Phenols in sample LS4, indicative of potential organic contamination. This high organic content could foster the growth of microorganisms, pose health risks, and potentially impact the taste and odour of the water.

The ammonia level in LS4 is significantly high, suggesting possible pollution from wastewater. This, coupled with Nitrite and Nitrate levels within generally acceptable ranges, still warrants attention due to their potential health risks if the levels increase.

The bacterial report reveals a significant presence of faecal coliforms in both samples, a clear indicator of faecal contamination and potential presence of harmful pathogens, making the water unsafe for consumption without proper disinfection.

Given these findings, both samples indicate various issues that could impact the safety and suitability of the water for drinking purposes, necessitating appropriate treatment and possibly further investigation into the source of contamination.

4.6 Conclusion

The surface area of the proposed development footprint appears to be in a visually good natural condition while being covered by grassland and shrub vegetation. Groundwater dependent practices are domestic and livestock use with the inclusion of game farming in the broader area. The surface area drains in a general east to west direction and shows high risks of soil erosion that should be stabilized maintained and prevented from further erosion causing river sedimentation. The study area is expected to be holistically underlain by a prominent sub-horizontal dolerite sill structure at relatively shallow depths, of varying densities and of uniform extent. This structure slopes toward the Vals river and is covered by sedimentary structures of the Beaufort Group, especially in the central and eastern sections of the development footprint. The general area does not show evidence of ponding which suggests a relatively good drainage environment and/or elevated surface to groundwater infiltration rates. Evidence of baseflow was recorded at the northern boundary of the proposed development footprint, draining toward the Vals River and will seasonally fluctuate in it's flow intensity. The proposed development foundations are expected to intersect this baseflow and should be monitored.

A polluted eroded river channel was recorded at the eastern border of the development, also intersected by the proposed pipeline installment. The channel has a strong flowing stream of deteriorated quality that is expected to have been feeding the regional groundwater system for some years (>23 years based on Google Earth imaging). Based on these observations upstream of the proposed development and lack of borehole distributions in the general area, the local groundwater system is expected to be degraded with a water level depth draining into the Vals river and being locally elevated by the eroded river channel water flow. Electrical Conductivity (EC) and Total Dissolved Solids (TDS) concentrations increase from upstream to downstream within the river. It is recommended that sites LS1 and LS3 be incorporated into a water monitoring program.

5 GEOHYDROLOGICAL RISK AND VULNERABILITY

A list of expected impacts associated with groundwater contamination and degradation, related to the proposed development, is listed below. This list is derived from impact management outcomes and actions for the development and expansion of infrastructure.

- Environmental Awareness Training
- Site Establishment Development
- Water Supply Management
- Storm and Wastewater Management
- Solid and Hazardous Waste Management
- Protection of Watercourses and Estuaries
- Vegetation Clearing
- Sanitation
- Hazardous Substances
- Workshop, Equipment Maintenance and Storage
- Batching Plants
- Blasting
- Stockpiling and Stockpile Areas
- Steelwork Assembly and Erection
- Cabling and Stringing
- Temporary Closure of Site
- Dismantling of Old Equipment
- Landscaping and Rehabilitation

These potential impact categories were incorporated into an impact assessment methodology. For each potential impact, the DURATION (time scale), EXTENT (spatial scale), IRREPLACEABLE loss of resources, REVERSIBILITY of the potential impacts, the MAGNITUDE of negative or positive impacts, and the PROBABILITY of occurrence of potential impacts were assessed. These criteria are used to determine the significance of each impact, with and without proposed mitigation measures. The scales used to assess these variables and define the rating categories are tabulated in Table 7 and Table 8 below.

The geohydrological impact assessment produces the following outcomes:

- Assess the impacts (direct, indirect and cumulative) in terms of their significance (using suitable evaluation criteria, i.e. Impact Rating Methodology below).
- Provide suitable mitigation measures. In accordance with the mitigation hierarchy, negative impacts should be avoided, minimised, rehabilitated (or reinstated) or compensated for (i.e. offsets), whereas positive impacts should be enhanced.
- Consider time boundaries, including short to long-term implications of impacts for

project life-cycle (i.e. pre-construction, construction, operation and decommissioning).

- Consider spatial boundaries, including: Broad context of the proposed project (i.e. beyond the boundaries of the specific site).
- The provision of a statement of impact significance for each issue, which specifies whether or not a predetermined threshold of significance (i.e. changes in effects to the environment, which would change a significance rating) has been exceeded, and whether or not the impact presents a potential fatal flaw or not. This statement of significance should be provided for anticipated project impacts both before and after application of impact management actions.

Table 7: Evaluation components, ranking scales and descriptions (criteria).

Evaluation Component	Ranking Scale and Description (Criteria)
DURATION	**5 - Permanent** **4 - Long term**: Impact ceases after operational phase/life of the activity (> 20 years). **3 - Medium term**: Impact might occur during the operational phase/life of the activity (5 to 20 years). **2 - Short term**: Impact might occur during the construction phase (< 5 years). **1 - Immediate**
EXTENT or spatial scale/influence of impact	**5 - International**: Beyond National boundaries. **4 - National**: Beyond Provincial boundaries and within National boundaries. **3 - Regional**: Beyond 5 km of the proposed development and within Provincial boundaries. **2 - Local**: Within 5 km of the proposed development. **1 - Site-specific**: On site or within 100 m of the site boundary. **0 - None**
IRREPLACEABLE loss of resources	**5 – Definite** loss of irreplaceable resources. **4 – High** potential for loss of irreplaceable resources. **3 – Moderate** potential for loss of irreplaceable resources. **2 – Low** potential for loss of irreplaceable resources. **1 – Very low** potential for loss of irreplaceable resources. **0 - None**
REVERSIBILITY of impact	**5 –** Impact **cannot** be reversed. **4 – Low** potential that impact might be reversed. **3 – Moderate** potential that impact might be reversed. **2 – High** potential that impact might be reversed. 1 – Impact **will be** reversible. **0 – No** impact.
MAGNITUDE of NEGATIVE IMPACT (at the indicated spatial scale)	**10 - Very high:** Groundwater system availability / dependency / quality / quantity might be severely altered. **8 - High:** Groundwater system availability / dependency / quality / quantity might be considerably altered. **6 - Medium:** Groundwater system availability / dependency / quality / quantity might be notably altered. **4 - Low :** Groundwater system availability / dependency / quality / quantity might be slightly altered. **2 - Very Low:** Groundwater system availability / dependency / quality / quantity might be negligibly altered. **0 - Zero:** Groundwater system availability / dependency / quality / quantity will remain unaltered.
MAGNITUDE of POSITIVE IMPACT (at the indicated spatial scale)	**10 - Very high (positive):** Groundwater system availability / dependency / quality / quantity might be substantially enhanced. **8 - High (positive):** Groundwater system availability / dependency / quality / quantity might be considerably enhanced. **6 - Medium (positive):** Groundwater system availability / dependency / quality / quantity might be notably enhanced. **4 - Low (positive):** Groundwater system availability / dependency / quality / quantity might be slightly enhanced. **2 - Very Low (positive):** Groundwater system availability / dependency / quality / quantity might be negligibly enhanced. **0 - Zero (positive):** Groundwater system availability / dependency / quality / quantity will remain unaltered
PROBABILITY of occurrence	**5 - Definite**: >95% chance of the potential impact occurring. **4 - High probability**: 75% - 95% chance of the potential impact occurring. **3 - Medium probability**: 25% - 75% chance of the potential impact occurring **2 - Low probability**: 5% - 25% chance of the potential impact occurring. **1 - Improbable**: <5% chance of the potential impact occurring.
CUMULATIVE impacts	**High**: The activity is one of several similar past, present or future activities in the same geographical area, and might contribute to a very significant combined impact on the natural, cultural, and/or socio-economic resources of local, regional or national concern. **Medium**: The activity is one of a few similar past, present or future activities in the same geographical area, and might have a combined impact of moderate significance on the natural, cultural, and/or socio-economic resources of local, regional or national concern. **Low**: The activity is localised and might have a negligible cumulative impact. **None**: No cumulative impact on the environment.

Once the evaluation components have been ranked for each potential impact, the significance of each potential impact will be assessed (or calculated) using the following formula:

SP (significance points) = (duration + extent + irreplaceable + reversibility + magnitude) x probability

Table 8: Definition of impact significance ratings (positive and negative).

Significance Points	Environmental Significance	Description
125 – 150	Very High (VH)	An impact of very high significance will mean that the project cannot proceed, and that impacts are irreversible, regardless of available mitigation options.
100-124	High (H)	An impact of high significance which could influence a decision about whether or not to proceed with the proposed project, regardless of available mitigation options.
75-99	Medium-High (MH)	If left unmanaged, an impact of medium-high significance could influence a decision about whether or not to proceed with a proposed project. Mitigation options should be revisited.
40-74	Medium (M)	If left unmanaged, an impact of moderate significance could influence a decision about whether or not to proceed with a proposed project.
<40	Low (L)	An impact of low is likely to contribute to positive decisions about whether or not to proceed with a project. It will have little real effect and is unlikely to have an influence on project design or alternative motivation.
+	Positive impact (+)	A positive impact is likely to result in a positive consequence/effect, and is likely to contribute to positive decisions about whether or not to proceed with the project.

5.1 Conclusion

The expected impacts of the proposed development on the local groundwater regime, based on the groundwater impact matrix is summarized in Table 9. The full matrix describing the criteria used to determine the significance of each impact is added to **APPENDIX B**.

From the impact matrix, the total estimated groundwater impact from the proposed development will be of **MODERATE** significance (53,8 significance points) should no mitigation measures be followed. An impact of **LOW** significance (4 significance points) is expected should the suggested mitigation measures be adhered to.

Table 9: Summation of the groundwater impact matrix.

PROJECT ACTIVITY / CATEGORY	BEFORE MITIGATION			AFTER MITIGATION		
	TOTAL (SP)	SIGNIFICANCE	CUMULATIVE	TOTAL (SP)	SIGNIFICANCE	CUMULATIVE
Environmental awareness training	105	H	M	8	L	L
Site establishment development	63	M	M	4	L	L
Water Supply Management	72	M	M	8	L	L
Storm and waste water management	76	MH	L	6	L	L
Solid and hazardous waste management	57	M	M	4	L	L
Protection of watercourses and estuaries	60	M	M	2	L	L
Vegetation clearing	42	M	M	5	L	N
Sanitation	72	M	M	1	L	L
Hazardous substances	60	M	M	5	L	L
Workshop, equipment maintenance and storage	45	M	L	4	L	L
Batching plants	45	M	L	5	L	L
Blasting	68	M	L	5	L	N
Stockpiling and stockpile areas	26	L	L	4	L	L
Steelwork Assembly and Erection	14	L	M	1	L	N
Temporary closure of site	54	M	M	3	L	L
Dismantling of old equipment	22	L	L	2	L	L
Landscaping and rehabilitation	33	L	L	1	L	L
TOTAL ESTIMATED GROUNDWATER IMPACT	53,8	M	L	4,0	L	L

6 OVERALL CONCLUSION

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

The study area is located within a groundwater unit (GRU) 4b with a present ecological state (PES) of (B) slightly modified while the Vals river has a PES of (C) moderately modified. The study area is predominantly situated on a ***minor*** aquifer region and has a ***moderate*** groundwater vulnerability rating that is only vulnerable to continuously discharged or leached pollutants in the long term. A susceptibility matrix of the study area's local groundwater regime, therefore, suggests the aquifer system to have a ***medium*** susceptibility for contamination by anthropogenic activities which includes both aquifer vulnerability and the relative importance of the aquifer in terms of its classification.

The groundwater impact matrix of the study area suggests that the proposed development will pose an impact significance rating of **MODERATE** significance (53,8 significance points) should no mitigation measures be followed while an impact of **LOW** significance (4 significance points) is expected should the suggested mitigation measures be adhered to.

This conclusion is based on cumulative significance points of all evaluation components in the impact assessment matrix, incorporated with a groundwater susceptibility matrix, on-site and background geohydrological conditions and groundwater dependency. The proposed significance rating incorporates all present groundwater conditions discussed in this report.

It is highly recommended that all mitigation strategies listed in **APPENDIX B** be strictly followed.

6.1 RECOMMENDATIONS

Based on hydrogeological findings, the proposed development 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 are 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 ultimately be included in a groundwater table and quality monitoring program.
- It is highly recommended that a community awareness programme be conducted to inform the local community about the health and pollution risks associated with current surface and groundwater qualities as well as the qualities associated with WWTW sites. This should include all surface and groundwater dependent residents for health

reasons.

- It is highly recommended that water quality and quantity of flow at all leaking sewer infrastructure be determined and regulated and restricted from further flow..
- Any un-monitored increased abstraction of groundwater by the future drilling of boreholes within a 1km radius of the Vals River abstraction position should be reported and discouraged should it be considered by the municipality or land users.
- Specific footprints, layout and extensions of infrastructure should aim to avoid environmentally sensitive areas. The layout of the following infrastructure should be known where applicable. Offices, overnight vehicle parking areas, stores, workshop, stockpile and lay down areas, hazardous materials storage areas (including fuels), batching plant (if one is located at a construction camp), designated access routes, equipment cleaning areas, cooking and ablution facilities, waste and wastewater management. This will help determine and ensure that the development does not impact on sensitive areas identified. Construction sites must be located and managed not to impact on nearby watercourses.
- All spillage of oil or sewage onto concrete surfaces must be controlled by the use of an approved absorbent material and the used absorbent material must be disposed of at an appropriate waste disposal facility.
- Natural stormwater runoff not contaminated during the development and clean water can be discharged directly to watercourses and water bodies, subject to the Project Manager's approval and support by the ECO.
- Hazardous waste must be disposed of at a registered waste disposal site. Certificates of safe disposal for general, hazardous and recycled waste must be maintained.
- All watercourses must be protected from direct or indirect spills of pollutants such as solid waste, sewage, cement, oils, fuels, chemicals, aggregate tailings, wash and contaminated water or organic material resulting from the contractor's activities.
- Where possible, no development equipment must traverse any seasonal or permanent wetland.
- When working in or near any watercourse or estuary no altering of the bed, banks, course or characteristics of a watercourse are allowed.
- The use of ablution facilities and or mobile toilets must be used at all times and no indiscriminate use of the veld for the purposes of ablutions must be permitted under any circumstances.
- Mobile chemical toilets are not to be located closer than 100 m to any watercourse or water body. Toilets are to be emptied before long weekends and workers holidays, and must be locked after working hours.
- Any mitigation measure listed in the impact matrix provided in **APPENDIX B** and is not listed in this section should also be strictly adhered to

7 APPENDIX A

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Test report | **Case no: 2023 - 368** | Page 2 of 2

Determinand	Units	Methods used	Client sample name $$: LS1 Lab number: 368-1 value	Client sample name $$: LS4 Lab number: 368-2 Value
Physical & aesthetic determinands				
Colour	units Pt-Co	Chem-TM03	187	223
Turbidity	NTU	Chem-TM07	45.8	88.1
Total dissolved solids	mg/L	Chem-TM20	329.64	1067.86
pH	pH units	Chem-TM01	7.41	6.95
Electrical conductivity	mS/m	Chem-TM02	43.71	161.66
Chemical - Macro determinands				
Calcium as Ca	mg/L	Chem-TM19	38.51	59.75
Magnesium as Mg	mg/L	Chem-TM19	15.64	28.76
Sodium as Na	mg/L	Chem-TM19	29.69	117.83
Potassium as K	mg/L	Chem-TM19	5.74	25.87
Alkalinity	mg/L $CaCO_3$	Chem-TM05	188.98	513.00
Fluoride as F	mg/L	Chem-TM13	0.29	0.33
Chloride as Cl	mg/L	Chem-TM06	17.16	153.80
Nitrite as N	mg/L	Chem-TM11	<0.006	0.008
Nitrate as N	mg/L	Chem-TM09	0.90	0.72
Nitrate & Nitrite as N combined #	mg/L	Chem-TM20	0.900	0.728
Sulphate as SO_4	mg/L	Chem-TM19	21.81	54.42
Calcium Hardness	mg/L	Chem-TM20	96.15	149.18
Magnesium Hardness	mg/L	Chem-TM20	64.41	118.44
Total Hardness as $CaCO_3$	mg/L	Chem-TM20	160.56	267.62
Orthophosphate as P	mg/L	Chem-TM10	0.058	5.640
Ammonia (NH_3) as N	mg/L	Chem-TM08	<0.101	66.410
Chemical - Micro determinands - dissolved				
Aluminium as Al	ug/L	Chem-TM21	100.246	235.797
Antimony as Sb #	ug/L	Chem-TM21	1.637	2.143
Arsenic as As	ug/L	Chem-TM21	0.658	2.176
Barium as Ba	mg/L	Chem-TM19	109.500	107.820
Boron as B	mg/L	Chem-TM19	0.052	0.089
Cadmium as Cd #	ug/L	Chem-TM21	1.597	1.610
Chromium as Cr	ug/L	Chem-TM21	2.632	4.011
Copper as Cu	mg/L	Chem-TM19	<0.010	<0.010
Cyanide (total) as CN	ug/L	Chem-TM12	0.28	0.39
Iron as Fe	mg/L	Chem-TM19	0.105	0.093
Lead as Pb	ug/L	Chem-TM21	0.938	1.069
Manganese as Mn	ug/L	Chem-TM21	17.231	475.888
Nickel as Ni	ug/L	Chem-TM21	2.925	4.080
Selenium as Se	ug/L	Chem-TM21	1.098	1.037
Uranium as U	ug/L	Chem-TM21	3.599	3.138
Zinc as Zn	mg/L	Chem-TM19	<0.005	0.007
Chemical - Organic determinands				
Total organic carbon as C	mg/L	Chem-TM17	7.74	87.75
Phenols (total) *#	mg/L	*	<0.010	0.016
Bacterial report:				
Faecal Coliforms	MPN/100ml	BAC-TM 02	>2420	>2420
E. coli#	MPN/100ml	BAC-TM02	>2420	>2420

Comments:

Results marked with (#) in this report, are not included in the SANAS Schedule of Accreditation for this laboratory.

(1) Bacteriological results obtained from samples within 24 hours holding time, but exceeding the prescribed temperature of 10°C, may deviate.

Data marked with blue dollar signs ($$) is provided by the customer.

MPN = cfu

(BAC-TM02) - no growth reported as <1

Amendment reason: N/A

Signature: ____________

Dr L Deysel (Technical signatory / Technical manager)

All methods, excl CHEM-TM21

Signature: ____________

Dr T Chiweshe (Technical signatory, CHEM-TM21)

END OF REPORT

8 APPENDIX B

PROJECT ACTIVITY / CATEGORY	POTENTIAL GROUNDWATER IMPACT / NATURE OF IMPACT	OVERAAL SIGNIFICANCE																		MITIGATION
		BEFORE MITIGATION									AFTER MITIGATION									
		Magnitude	Duration	Extent	Irreplaceable	Reversibility	Probability	TOTAL (SP)	Significance	CUMULATIVE	Magnitude	Duration	Extent	Irreplaceable	Reversibility	Probability	TOTAL (SP)	Significance	CUMULATIVE	
LINDLEY WWTW																				
Environmental awareness training	All onsite staff are aware and understand their individual responsibilities.	8	4	3	3	3	5	105	H	M	2	2	2	1	1	1	8	L	L	Lack of environmental awareness training prior to commencement of the activities may lead to Environmental degradation during project development and operational phase. All staff should be aware of the conditions and controls linked to the EA and within the EMPr and made aware of their individual roles and responsibilities in achieving compliance with the EA and EMPr.Conduct environmental awareness training prior to commencement of the activities. All staff should be aware of the conditions and controls linked to the EA and within the EMPr and made aware of their individual roles and responsibilities in achieving compliance with the EA and EMPr. Environmental awareness training must include as a minimum of the following: a) Description of significant environmental impacts, actual or potential, related to their work activities. b) Mitigation measures to be implemented when carrying out specific activities. c) Emergency preparedness and response procedures. d) Emergency procedures. e) Procedures to be followed when working near or within sensitive areas. f) Wastewater management procedures. g) Water usage and conservation. h) Solid waste management procedures. i) Sanitation procedures.
Site establishment development	Keep site establishment and the development footprint to demarcated development area.	8	4	3	3	3	3	63	M	M	1	1	1	0	1	1	4	L	L	Impacts on the environment during site establishment and the development footprint to be demarcated within the evelopment area. A method statement must be provided by the contractor prior to any onsite activity that includes the layout of the construction camp in the form of a plan showing the location of key infrastructure and services where applicable. Specific footprints, layout and and extentions of infrastructure should aim to avoid environmentaly sensitive areas. The layout of the following infrastructure should be known where applicable. Offices, overnight vehicle parking areas, stores, the workshop, stockpile and lay down areas, hazardous materials storage areas (including fuels), the batching plant (if one is located at the construction camp), designated access routes, equipment cleaning areas , cooking and ablution facilities, waste and wastewater management. This will help determine and ensure that the site does not impact on sensitive areas identified in the environmental assessment or site walk through. Sites must be located where possible on previously disturbed areas and/or elevated areas, away from watercourses and avoiding exposed hard rock or weathered rock areas that may be associated with increased surface to groundwater infiltration rates. The use of existing accommodation for contractor staff, where possible, is encouraged.

Water Supply Management	Undertake responsible water usage	6	4	2	3	3	4	72	M	M	2	4	1	0	1	1	8	L	L	All abstraction points or boreholes must be registered with the DWS and suitable water meters installed to ensure that the abstracted volumes are measured on a daily basis. The Contractor must ensure the following: a. The vehicle abstracting water from a river does not enter or cross it and does not operate from within the river. b. No damage occurs to the river bed or banks and that the abstraction of water does not entail stream diversion activities. c. All reasonable measures to limit pollution or sedimentation of the downstream watercourse are implemented. Ensure water conservation is being practiced by: a. Minimising water use during cleaning of equipment; b. Undertaking regular audits of water systems; c. Including a discussion on water usage and conservation during environmental awareness training, and d. The use of grey water is encouraged. **MONITORING**:Registration of boreholes to be used is required prior to commencement of construction. Monitoring of abstraction volumes on a monthly basis during construction and during operational phases is required, accompanied by photographic evidence of flow meter units and condition of equipment. Proof of registration of boreholes from DWS and proof of monthly records are to be attached to yearly audit reports.
Storm and waste water management	Impacts to the environment caused by storm water and wastewater discharges during construction.	7	4	2	3	3	4	76	MH	L	1	2	1	0	2	1	6	L	L	Runoff from cement/ concrete batching areas must be strictly controlled, and contaminated water must be collected, stored and either treated or disposed of off-site, at a location approved by the project manager. All spillage of oil onto concrete surfaces must be controlled by the use of an approved absorbent material and the used absorbent material disposed of at an appropriate waste disposal facility. Natural storm water runoff not contaminated during the development and clean water can be discharged directly to watercourses and water bodies, subject to the Project Manager's approval and support by the ECO. Stormwater flow released from site should include stream flow reduction frameworks to reduce risk of soil erosion. Water that has been contaminated with suspended solids, such as soils and silt, may be released into watercourses or water bodies only once all suspended solids have been removed from the water by settling out these solids in settlement ponds. The release of settled water back into the environment must be subject to the Project Manager's approval and support by the ECO.
Solid and hazardous waste management	If wastes are inappropriately stored, handled and unsafely disposed of at unrecognised waste facilities.	7	4	2	3	3	3	57	M	M	1	1	0	1	1	1	4	L	L	All measures regarding waste management must be undertaken using an integrated waste management approach. Sufficient, covered waste collection bins (scavenger and weatherproof) must be provided. A suitably positioned and clearly demarcated waste collection site must be identified and provided. The waste collection site must be maintained in a clean and orderly manner. Waste must be segregated into separate bins and clearly marked for each waste type for recycling and safe disposal. Staff must be trained in waste segregation. Bins must be emptied regularly. General waste produced onsite must be disposed of at a registered waste disposal sites/ recycling company. Hazardous waste must be disposed of at a registered waste disposal site. Certificates of safe disposal for general, hazardous and recycled waste must be maintained.

Protection of watercourses and estuaries	Pollution and contamination of the watercourse environment and or estuary erosion.	8	4	3	2	3	3	60	**M**	**M**	1	1	0	0	0	1	2	**L**	**L**	All watercourses must be protected from direct or indirect spills of pollutants such as solid waste, sewage, cement, oils, fuels, chemicals, aggregate tailings, wash and contaminated water or organic material resulting from the contractor's activities. In the event of a spill, prompt action must be taken to clear the polluted or affected areas. Where possible, no development equipment must traverse any seasonal or permanent wetland. No return flow into the estuaries must be allowed and no disturbance of the estuarine functional zone should occur. Boreholes within the development footprint should be secured from objects or contamination entering at ground level and from tampering by employees. Development of permanent watercourse or estuary crossing must only be undertaken where no alternative access to tower position is available. There must not be any impact on the long term morphological dynamics of watercourses or estuaries. Existing crossing points must be favored over the creation of new crossings (including temporary access). When working in or near any watercourse or estuary, the following environmental controls and consideration must be taken: a) Water levels during the period of construction; No altering of the bed, banks, course or characteristics of a watercourse. b) During the execution of the works, appropriate measures to prevent pollution and contamination of the riparian environment must be implemented e.g. including ensuring that construction equipment is well maintained. c) Where earthwork is being undertaken in close proximity to any watercourse, slopes must be stabilised using suitable materials, i.e. sandbags or geotextile fabric, to prevent sand and rock from entering the channel. d) Appropriate rehabilitation and re-vegetation measures for the watercourse banks must be implemented timeously. In this regard, the banks should be appropriately and incrementally stabilised as soon as development allows.
Vegetation clearing	Vegetation clearing should be restricted to the authorised development footprint of the proposed infrastructure in order to buffer soil erosion.	4	4	2	2	2	3	42	**M**	**M**	1	2	1	0	1	1	5	**L**	**N**	Indigenous vegetation which does not interfere with the development must be left undisturbed. Rivers and watercourses must be kept clear of felled trees,vegetation cuttings and debris. Only a registered pest control operator may apply herbicides on a commercial basis and commercial application must be carried out under the supervision of a registered pest control operator, supervision of a registered pest control operator or is appropriately trained. No herbicides must be used in estuaries.
Sanitation	Unclean and poorly maintained toilet facilities available to staff may pose risk of disease and impact to the environment.	8	4	2	2	2	4	72	**M**	**M**	0	1	0	0	0	1	1	**L**	**L**	Mobile chemical toilets are installed onsite if no other ablution facilities are available. The use of ablution facilities and or mobile toilets must be used at all times and no indiscriminate use of the veld for the purposes of ablutions must be permitted under any circumstances. Where mobile chemical toilets are required, the following must be ensured: a) Toilets are located no closer than 100 m to any watercourse, borehole or water body. b) Toilets are secured to the ground to prevent them from toppling due to wind or any other cause. c) No spillage occurs when the toilets are cleaned or emptied and the contents are managed in accordance with the EMPr. d) Toilets are emptied before long weekends and workers holidays, and must be locked after working hours. e) Toilets are serviced regularly and the ECO must inspect toilets to ensure compliance to health standards. A copy of the waste disposal certificates must be maintained.

Hazardous substances	Unsafe storage, handling, use and disposal of hazardous substances causing environmental impact.	8	4	2	3	3	3	60	M	M	1	1	1	1	1	1	5	L	L	The use and storage of hazardous substances are to be minimised and non-hazardous and non-toxic alternatives substituted where possible. All hazardous substances must be stored in suitable containers. Containers must be clearly marked to indicate contents, quantities and safety requirements. All storage areas must be bunded. The bunded area must be of sufficient capacity to contain a spill / leak from the stored containers. Bunded areas are to be suitably lined with a SABS approved liner. An Alphabetical Hazardous Chemical Substance (HCS) control sheet must be drawn up and kept up to date on a continuous basis. All hazardous chemicals that will be used on site must have Material Safety Data Sheets (MSDS). Employees handling hazardous substances / materials must be aware of the potential impacts and follow appropriate safety measures. The Contractor must ensure that diesel and other liquid fuel, oil and hydraulic fluid is stored in appropriate storage tanks or in bowsers. The tanks/ bowsers must be situated on a smooth impermeable surface (concrete) with a permanent bund. The floor of the bund must be sloped, draining to an oil separator. Provision must be made for refueling at the storage area by protecting the soil with an impermeable groundcover. Where dispensing equipment is used, a drip tray must be used to ensure small spills are contained. All empty externally dirty drums must be stored on a drip tray or within a bunded area. No unauthorised access into the hazardous substances storage areas must be permitted. An appropriately sized and appropriate number of spill kits kept onsite relevant to the scale of the activity/s involving the use of hazardous substance must be available at all times. The responsible operator must have the required training to make use of the spill kit in emergency situations.
Workshop, equipment maintenance and storage	Potential for soil, surface water and groundwater contamination if improperly managed.	5	4	2	2	2	3	45	M	L	1	1	1	1	0	1	4	L	L	Where possible and practical all maintenance of vehicles and equipment must take place in the workshop area. During servicing of vehicles or equipment, especially where emergency repairs are effected outside the workshop area, a suitable drip tray must be used to prevent spills onto the soil. Leaking equipment must be repaired immediately or be removed from site to facilitate repair. Workshop areas must be monitored for oil and fuel spills. Appropriately sized spill kit kept onsite relevant to the scale of the activity taking place must be available. The workshop area must have a bunded concrete slab that is sloped to facilitate runoff into a collection sump or suitable oil/ water separator where maintenance work on vehicles and equipment can be performed. Water drainage from the workshop must be contained and managed in accordance with storm and waste water management.
Batching plants	Spillages and contamination of soil, surface water and groundwater.	5	3	3	2	2	3	45	M	L	1	1	1	1	1	1	5	L	L	Concrete mixing must be carried out on an impermeable surface. Batching plants areas must be fitted with a containment facility for the collection of cement laden water. Dirty water from the batching plant must be contained to prevent soil and groundwater contamination. Bagged cement must be stored in an appropriate facility and at least 10 m away from any water courses, gullies and drains. A washout facility must be provided for washing of concrete associated equipment. Water used for washing must be restricted. Hardened concrete from the washout facility or concrete mixer can either be reused or disposed of at an appropriate licenced disposal facility. Empty cement bags must be secured with adequate binding material if these will be temporarily stored on site. Sand and aggregates containing cement must be kept damp to prevent the generation of dust. Any excess sand, stone and cement must be removed or reused from site on completion of construction period and disposed at a registered disposal facility.

Blasting	Impact to the environment and existing boreholes through unsafe blasting practice.	5	4	1	3	4	4	68	M	L	2	1	1	1	0	1	5	L	N	Any blasting activity must be conducted by a suitably licensed blasting contractor. Notification of surrounding landowners, emergency services site personnel of blasting activity 24 hours prior to such activity should taking place on Site. Blasting should not occur within a 50m buffer or effective blast range (based on variable geotechnical conditions) from existing boreholes to preserve borehole structure stability.
Stockpiling and stockpile areas	Erosion and sedimentation as a result of stockpiling.	5	3	2	2	1	2	26	L	L	1	1	1	0	1	1	4	L	L	All material that is excavated during the project development phase (either during piling (if required) or earthworks) must be stored appropriately on site in order to minimise impacts to watercourses, and water bodies. All stockpiled material must be maintained and kept clear of weeds and alien vegetation growth by undertaking regular weeding and control methods. Topsoil stockpiles must not exceed 2m in height. During periods of strong winds and heavy rain, the stockpiles must be covered with appropriate material (e.g. cloth, tarpaulin etc.). Where possible, sandbags (or similar) must be placed at the bases of the stockpiled material in order to prevent erosion of the material.
Steelwork Assembly and Erection	Degradation as a result of steelwork assembly and erection.	2	4	1	0	0	2	14	L	M	0	1	0	0	0	1	1	L	N	During assembly, care must be taken to ensure that no wasted/unused materials are left on site e.g. cables, welding rods, cutting tools, bolts and nuts. Emergency repairs due to breakages of equipment must be managed in accordance with workshop, equipment maintenance and storage.
Temporary closure of site	Risk of environmental impact during periods of site closure greater than five days.	7	3	3	2	3	3	54	M	M	0	1	0	1	1	1	3	L	L	Bunds must be emptied (where applicable) and need to be undertaken in accordance with the impact management actions included in hazardous substances and workshop, equipment maintenance and storage. Hazardous storage areas must be well ventilated. Security personnel must be briefed and have the facilities to contact or be contacted by relevant management and emergency personnel. Cement and materials stores must have been secured. Toilets must have been emptied and secured. Refuse bins must have been emptied and secured. Drip trays must have been emptied and secured.

Dismantling of old equipment	Impact to the environment to be minimised during the dismantling, storage and disposal of old equipment commissioning.	3	2	2	2	2	2	22	L	L	0	1	1	0	0	1	2	L	L	All old equipment removed during the project must be stored in such a way as to prevent pollution of the environment. Oil containing equipment must be stored to prevent leaking or be stored on drip trays. All scrap steel must be stacked neatly and any disused and broken insulators must be stored in containers. Once material has been scrapped and the contract has been placed for removal, the disposal contractor must ensure that any equipment containing pollution causing substances is dismantled and transported in such a way as to prevent spillage and pollution of the environment. The Contractor must also be equipped to contain and clean up any pollution causing spills. Disposal of unusable material must be done at a licensed waste disposal site.
Landscaping and rehabilitation	Areas disturbed during the development phase are not returned to a state that approximates the original condition.	3	3	1	2	2	3	33	L	L	0	1	0	0	0	1	1	L	L	All spoil and waste must be disposed of to a registered waste site. Stockpiled topsoil must be used for rehabilitation (refer to Stockpiling and stockpiled areas). Stockpiled topsoil must be evenly spread so as to facilitate seeding and minimise loss of soil due to erosion. The rehabilitation must be timed so that rehabilitation can take place at the optimal time for vegetation establishment. Where impacted through construction related activity, all sloped areas must be stabilised to ensure proper habilitation is effected and erosion is controlled. Sloped areas stabilised using design structures or vegetation as specified in the design to prevent erosion of embankments. The contract design specifications must be adhered to and implemented strictly.