APPENDIX T

Groundwater Assessment

REPORT

Turfvlakte Groundwater Baseline and Impact Assessment

Exxaro Coal (Pty) Ltd

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Executive Summary

Background

Exxaro Coal (Pty) Ltd (Exxaro) has appointed Golder Associates Africa (Pty) Ltd (Golder) to conduct a groundwater baseline investigation and Environmental Impact Assessment (EIA) at Turfvlakte adjacent to Grootegeluk Mine, Limpopo Province.

Golder understands that this investigation is for the proposed extension of Exxaro's mining activities onto the adjacent farm, Turfvlakte 463 LQ. The farm Turfvlakte 463 LQ lies on the south-eastern border of the Grootegeluk Mining Rights Area.

The opencast operations will consist of two pits, namely Pit 1 and Pit 2. Pit 1 will be 158 ha in size and will be 88 m deep, while Pit 2 will be 64 ha and 109 m deep. The interburden and coal mined from Pit 1 and Pit 2 will be transported to and handled at the existing Grootegeluk Coal Mine plants.

This document reports on both the Phase I (groundwater baseline) and Phase II (groundwater impact assessment) of the groundwater investigation and is to support the requirements of the Environmental Authorization Requirements, which include the EIA, Environmental Management Programme (EMP) and Integrated Water Use License Application (IWULA).

Objectives

The objective of the overall groundwater investigation is to compile a groundwater baseline of the in-situ hydrogeological conditions at the Turfvlakte investigation area. This includes the flow regime (drawdown and inflow), groundwater chemistry as well as the rock geochemistry (acid generating characteristics);

The phase I groundwater baseline study objective furthermore aims to:

- Characterise the prevailing groundwater situation;
- Define the water bearing strata in the area;
- Determine current groundwater level distribution and flow directions;
- Assess groundwater vulnerability;
- Determine baseline groundwater quality; and
- Develop an initial conceptual groundwater model.

Following the baseline assessment report an in-depth groundwater specialist report was compiled which include the following:

- Update of the numerical groundwater flow and transport and impact assessment;
- Impact assessment (IA) of the proposed project on the receiving groundwater environment; and
- Proposed mitigation measures for expected major impacts.

Scope of Work

Phase I - Field Work and Baseline Assessment

Parts of the field investigations (exploration drilling and slug testing) was conducted by Exxaro who also collected the data of these investigations.

Golder's scope of work for the baseline assessment is as follows:

- Desk study and field preparation; and
- Site visit and Hydrocensus;
  - Groundwater Chemical Analyses x 8 of existing groundwater users.
- Geophysical survey;
- Exxaro drilling programme (exploration drilling conducted by Exxaro);
- Aquifer testing of six identified boreholes; and
- Review and verify selected groundwater monitoring data.

Phase II -Impact Assessment

- Geochemistry:
  - Geochemical analyses (static as well as kinetic test work); and
  - Interpretation of the geochemical results and construct a geochemical model to assist the impact assessment.
- Develop impact scenarios based on the baseline assessment, life of mine (LOM) plan and geochemical assessment;
- GCS to include the Turfvlakte project into their existing Grootegeluk groundwater flow and transport model;
- Develop mitigation/management measures for all major impacts; and
- Groundwater Impact Assessment report.

Conclusions

The following conclusions are made from the baseline groundwater investigation (Phase I):

- The investigation area is characterised by the igneous and sedimentary rocks of the Karoo Supergroup. Turfvlakte Project Area is located on the Waterberg Coalfield and includes all the major units of the Karoo Supergroup, comprising from surface of the Stormberg Group, Beaufort Group, Ecca Group and the Dwyka Group forming the basement;
- Two aquifer systems are distinguished at Turfvlakte in the Karoo Supergroup namely:
  - Top weathered aquifer; and
  - Fractured secondary aquifer.
- The local groundwater flow direction is south-east towards the Mokolo River;
- The groundwater quality of the investigation area is mainly represented by poor (Class 3) to unacceptable drinking water quality (Class 4);
- The following constituents of the groundwater samples exceed the DWAF (1996), Agriculture use target water quality range limit EC, TDS, Na, Cl, F, Mn, Fe, Zn, N and SO_4 concentrations; and

- The baseline water quality at Turfvlakte is represented by boreholes TESPES 68 (Class 1) and TESPES 47 (Class 1) which are un-impacted by mining activities and are representative of calcium magnesium bicarbonate type of water (Ca, Mg)$(HCO_3)_2$.

The following conclusions are made from the Impact Assessment (Phase II):

- Numerical groundwater flow and contaminant transport modelling was used to quantify the likely construction, operational and post closure phase impacts of the proposed Turfvlakte project. The scenarios that were simulated include:
  - Groundwater inflows and the extent of potential dewatering;
  - Potential impact on surrounding groundwater users; and
  - Potential contaminant plumes that may originate from the mining areas.

Construction Phase

- During construction of the new activities at Turfvlakte minimal additional impacts on the groundwater system is expected. The main activities that could impact on groundwater in this phase include constructing and clearing of footprint areas for construction. The impacts are expected to have a low significance rating.

Operational Phase

- Groundwater Quantity:
  - The mine floor elevation is below the general groundwater level thus causing groundwater inflows into the two proposed open pit mining areas from the surrounding aquifers during operations. The mining areas will have to be actively dewatered to ensure a safe working environment. Pumping water that seeps into the mine areas will cause dewatering of the surrounding aquifers and an associated decrease in groundwater level within the zone of influence of the dewatering cone;
  - When assessing the 1.5 Mtpa preferred mining on Turfvlakte the extent of drawdown could reach ~1400 m to the east of the two open pits and ~1600 m to the west (so the Turfvlakte dewatering cone would merge with the Grootegeluk pit drawdown cone);
  - For the 3 Mtpa alterative mining schedule, the extent of drawdown could reach ~1100 m to the east of the two open pits and ~950 m to the west (so the Turfvlakte dewatering cone would merge with the Grootegeluk pit drawdown cone). The reduced impacted of the 3 Mtpa alterative mining schedule is due to the quicker mining progression and shorter mining period; and
  - The impact on groundwater levels do not extend across the Daarby Fault to the north or the Eenzaamheid Fault to the south. No privately-owned boreholes were located in proximity to the proposed project (2018 hydrocensus). Therefore, it is not expected that the dewatering activities associated with the Turfvlakte mining will impact negatively on existing privately-owned boreholes.
- Mine inflow volumes:
  - The 1.5 Mtpa preferred mining schedule entails the mining of Pit 1 from year 1 to year 11. The simulated groundwater inflow into open pit 1 fluctuate between ~580 m^3/d and ~290 m^3/d. The pit floor depths in Pit 1 range from 46 mbgl in the north part to 77 mbgl in the southern/central part. In Pit 2 located north east of Pit 1, mining also commences in year 12 and ceases in year 16. Mining depths range from ~39 mbgl in the south eastern part of the pit and deepens to 120 mbgl in the

north-western part of the proposed pit. The simulated groundwater inflows ranged between ~270 and 380 m^3/d;

- The 3 Mtpa alterative mining schedule entails the mining of both pits at the same time, i.e. from year 1 to year 7.

  The simulated groundwater inflow into open pit 1 fluctuate between ~590 m^3/d and ~300 m^3/d. In Pit 2, where mining occurs concurrently with Pit 1 but only from year 1 to year 4. The simulated groundwater inflows ranged between ~640 and 440 m^3/d; and

- It is also important to view these volumes for the water make of the mine in relation to natural evaporation. Evaporation will take place over the total area of the open pits and could reduce the actual seepage volume.

- Groundwater Quality:
  - Groundwater flow directions south of the Daarby fault will be directed towards the mining areas due to the mine dewatering. Therefore, contamination will be contained within the mining area, and little contamination will be able to migrate away from the mining area; and
  - Contamination from the mining areas is generally contained within the mining areas. The environmental impact significance is expected to be low.
- Post Closure Phase:
  - In the post closure phase, the open pit is deemed to be partly backfilled and vegetated, with final voids in Pit 1 and Pit 2. A flow gradient exists towards both pits after closure due to the rehabilitated pits and final voids acting as a sink. The environmental impact significance is expected to be low. Once the mining has ceased, ARD and leaching of trace elements is still likely to occur within the backfilled pits due to the contact of water and oxygen through natural process including rainfall and groundwater seepage. Once the ARD forming material is however saturated, the formation of ARD is reduced. The partially backfilled Pit 1 and Pit 2 are likely to act as a contaminant sink post closure (i.e. contaminants could migrate toward pit post closure) and therefore no significant migration of the contaminants from the 2 partially backfilled pits is expected. The contaminants are generally confined to the pits post closure. No privately-owned boreholes are likely to be impacted based on the impact simulations; and
  - Given the climatic and topographical environment at Turfvlakte as well as the future presence of final voids in Pit 1 and Pit 2; decant or surface discharge from the open pits are unlikely.

Recommendations

The following groundwater recommendations are made:

- The 9 boreholes sampled during 2018 to be monitored as initial monitoring boreholes to monitor baseline/background conditions at Turfvlakte as part of the Grootegeluk existing groundwater monitoring plan;
- The sampling and water level monitoring is to be done on a quarterly basis during the baseline period for one year when it should be re-evaluated;
- Monitoring boreholes to be drilled into the backfilled pit to determine the inflow rates as the pit water levels rebound. Drilling of monitoring boreholes to be aligned with mine health and safety regulations;

- A pit lake feasibility study should be conducted to determine the optimal size of the final void to ensure minimal post closure impacts. In addition, the geochemical assessment should be updated based on the likely final void/pit lake dimensions;
- Consideration should be given to separate handling of calcrete in the soft overburden so that this material, which is high in neutralisation potential as confirmed by kinetics of the soft overburden, can be used in covers for the backfilled pits, and the base of the final void of Pit 1;
- During trial mining or grade control drilling, samples of different lithologies in the hard overburden should be subjected to further acid-base accounting tests to confirm whether they should be precautionarily considered to be potentially acid-generating; and
- The numerical flow and contaminant transport model and the geochemical model should be updated every 2 years with the latest monitoring, analyses and structural data.

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1.0 BACKGROUND

Exxaro Coal (Pty) Ltd (Exxaro) has appointed Golder Associates Africa (Pty) Ltd (Golder) to conduct a groundwater baseline investigation and Environmental Impact Assessment (EIA) at Turfvlakte adjacent to Grootegeluk Mine, Limpopo Province.

Golder understands that this investigation is for the proposed extension of Exxaro's mining activities onto the adjacent farm, Turfvlakte 463 LQ. The farm Turfvlakte 463 LQ lies on the south-eastern border of the Grootegeluk Mining Rights Area (Figure 1).

Exxaro wishes to develop two new open pits at Turfvlakte (Figure 1), on the southern area, for the mining of Benches 9A, 9B and 11.

This document reports on both the Phase I (groundwater baseline) and Phase II (groundwater impact assessment) of the groundwater investigation and is to support the requirements of the Environmental Authorization Requirements, which include the EIA, Environmental Management Programme (EMP) and Integrated Water Use License Application (IWULA).

2.0 OBJECTIVES

The objective of the overall groundwater investigation was to compile a groundwater baseline of the in-situ hydrogeological conditions at the Turfvlakte investigation area. This includes the flow regime (drawdown and inflow), groundwater chemistry as well as the rock geochemistry (acid generating characteristics).

The groundwater baseline study objective furthermore aims to:

- Characterise the prevailing groundwater situation;
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Following the baseline assessment report an in-depth groundwater specialist report was compiled which include the following:

- Update of the numerical groundwater flow and transport and impact assessment;
- Impact assessment (IA) of the proposed project on the receiving groundwater environment; and
- Proposed mitigation measures for expected major impacts.

3.0 SCOPE OF WORK

The proposed hydrogeological scope of work is divided into two phases, as updated by Exxaro Project Manager's clarification dated 1 August 2017.

3.1 Phase I - Field Work and Baseline Assessment

Parts of the field investigations (exploration drilling and slug testing) was conducted by Exxaro who also collected the data of these investigations.

Golder's proposed scope of work for the baseline assessment is as follows:

- Desktop study and field preparation;
- Site visit and Hydrocensus:
  - Groundwater Chemical Analyses x 8 of existing groundwater users.
- Geophysical survey;
- *Exxaro drilling programme (exploration drilling conducted by Exxaro)*;
- Aquifer testing of six identified boreholes;
- Review and verify selected groundwater monitoring data; and
- Groundwater baseline report.

3.2 Phase II -Impact Assessment

- Geochemistry:
  - Geochemical analyses (static as well as kinetic test work); and
  - Interpretation of the geochemical results and construct a geochemical model to assist the impact assessment.
- Develop impact scenarios based on the baseline assessment, life of mine (LOM) plan and geochemical assessment;
- GCS to include the Turfvlakte project into their existing Turfvlakte groundwater flow and transport model;
- Develop mitigation/management measures for all major impacts; and
- Groundwater impact assessment (IA) report.

3.3 Geochemistry Study

A detailed geochemistry study was carried out, the results of which were incorporated into the contaminant transport model (section 10.1.8 below) and the impact assessment (section 10.2 below). The full geochemistry study is presented in APPENDIX D.

4.0 DESCRIPTION OF INVESTIGATION AREA

4.1 Locality

The farm, Turfvlakte 463 LQ is located within the boundaries of the Lephalale Local Municipality, on the south-eastern border of the Exxaro's Grootegeluk Mining Rights Area in the Limpopo Province. It is situated ~18 km west of the town of Lephalale (Figure 1).

Turfvlakte Project Area falls within the A42J Quaternary Catchment Area as seen in Figure 1.

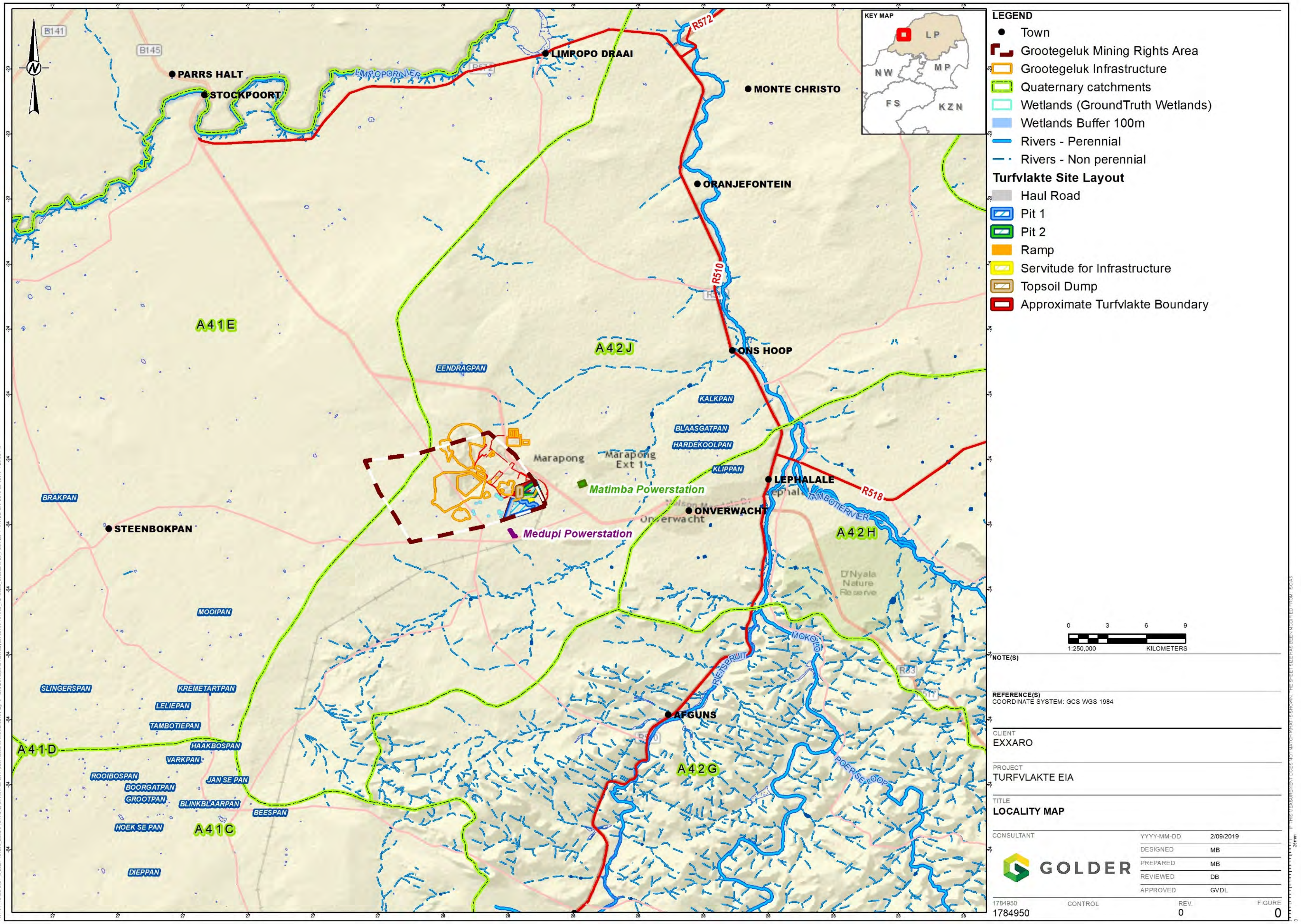


Figure 1: Locality Map

4.2 Climate and Temperature

The Turfvlakte Project Area is situated in the Waterberg Region of South Africa which falls within the subtropical high-pressure belt. (Golder 2017).

The highest temperatures are typically experienced during the summer months of December, January and February, and the lowest during the winter months of June, July and August. Average summer and winter minimum and maximum temperatures are indicated in Table 1 below (Golder 2017).

Table 1: Average Summer and Winter - Minimum and Maximum Temperatures

Season	Minimum	Maximum
Summer	11°C	40°C
Winter	0°C	28°C

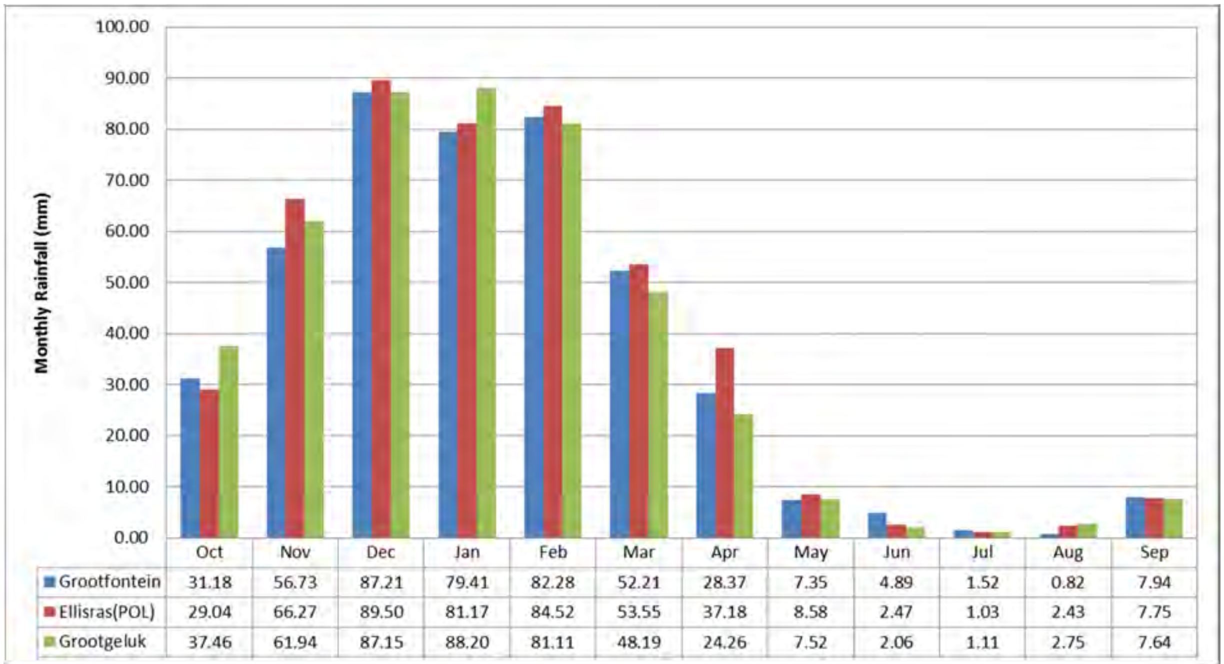
4.3 Rainfall

Data from three rainfall stations analysed are presented in Table 2. The selection of the three stations are based on the stations being the closest to the site with reasonably long and reliable records. The average Mean Average Perspiration (MAP) of the three stations are 450.6 mm per annum.

Table 2: Metadata for the Rain Gauges

Station Name	Station No.	Distance km	Latitude Degrees	Longitude Degrees	Record Years	Patched Data %	Reliability %	MAP mm	Altitude mamsl
Grootfontein	0674429 W	18.796	23.39	27.45	44	57.9	42.1	440	853
Ellisras (POL)	0674400 W	17.102	23.41	27.44	33	66.2	33.8	463	837
Grootegeluk	0674100 W	0.000	23.40	27.34	24	76.9	23.0	449	908

The three stations that were analysed follow the same trend in both wet and dry seasons, illustrated in Figure 2. The wet season is from October to March and the dry season from April to September, with December recording the maximum average rainfall record and July the minimum average rainfall record.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Grootfontein	31.18	56.73	87.21	79.41	82.28	52.21	28.37	7.35	4.89	1.52	0.82	7.94
Ellisras(POL)	29.04	66.27	89.50	81.17	84.52	53.55	37.18	8.58	2.47	1.03	2.43	7.75
Grootgeluk	37.46	61.94	87.15	88.20	81.11	48.19	24.26	7.52	2.06	1.11	2.75	7.64

Figure 2: Average monthly rainfall for the stations analysed

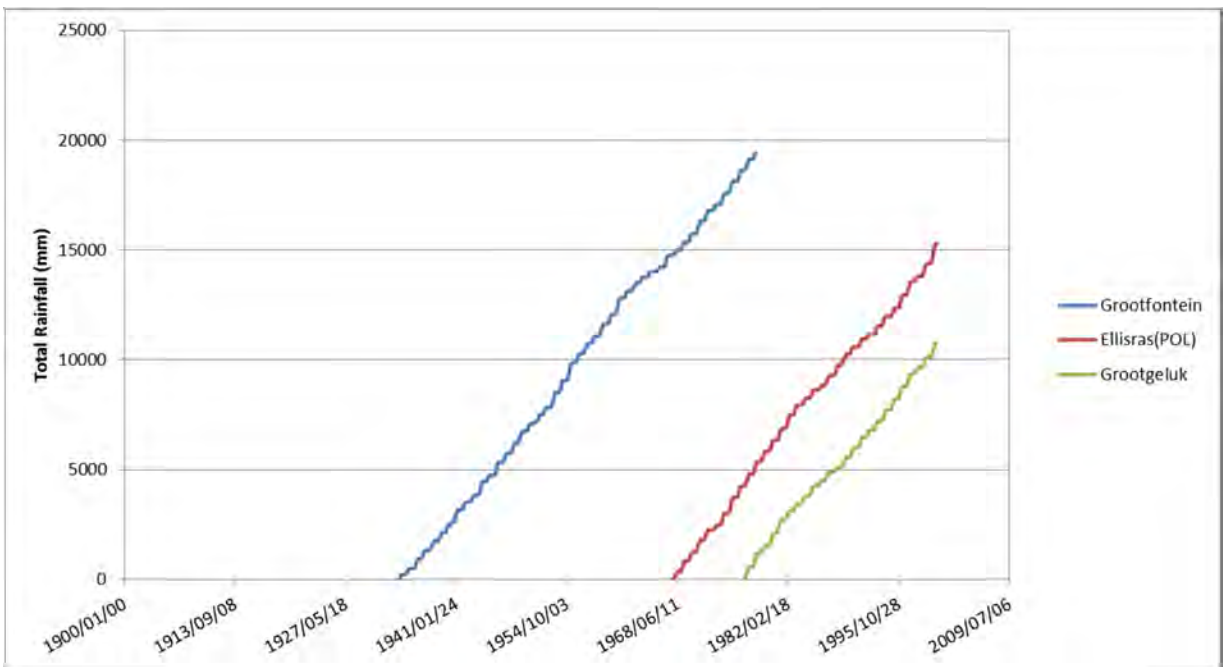


Figure 3: Cumulative Rainfall for the stations

Although Grootegeluk is the closest station to the site, Ellisras (POL) has the largest MAP and less patched data. Figure 3 shows the cumulative rainfall over time. All three rainfall stations follow the same trend. Both Ellisras (POL) and Grootfontein rainfall stations have higher reliabilities than Grootegeluk. Although Ellisras (POL) has 8.3% more patched data as compared to Grootfontein, it has the larger MAP which ensures that the water balance model will consider the conservative precipitation preventing the risk of flooding, and it was therefore selected for use in the study.

The monthly Ellisras (POL) statistics shows that January and February have the maximum rainfall record with 245 mm/month as presented in Figure 4.

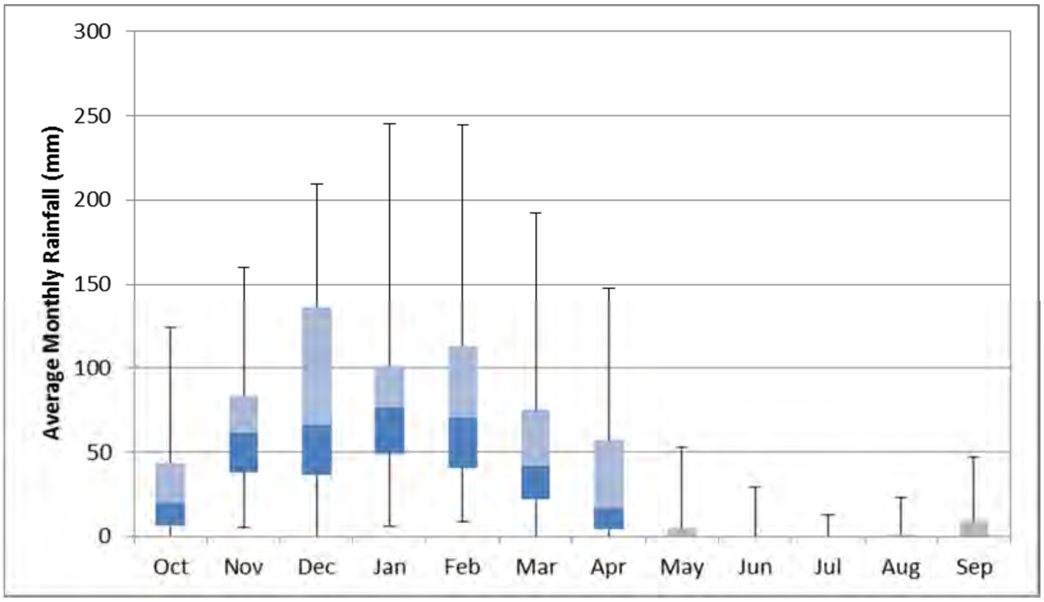


Figure 4: Ellisras (POL) Rainfall Station monthly statistics

The distribution curve in Figure 5 was drawn from the annual rainfall measures of the past 33 years. From Figure 5, over 50% of the annual rainfall data recorded falls below 650 mm.

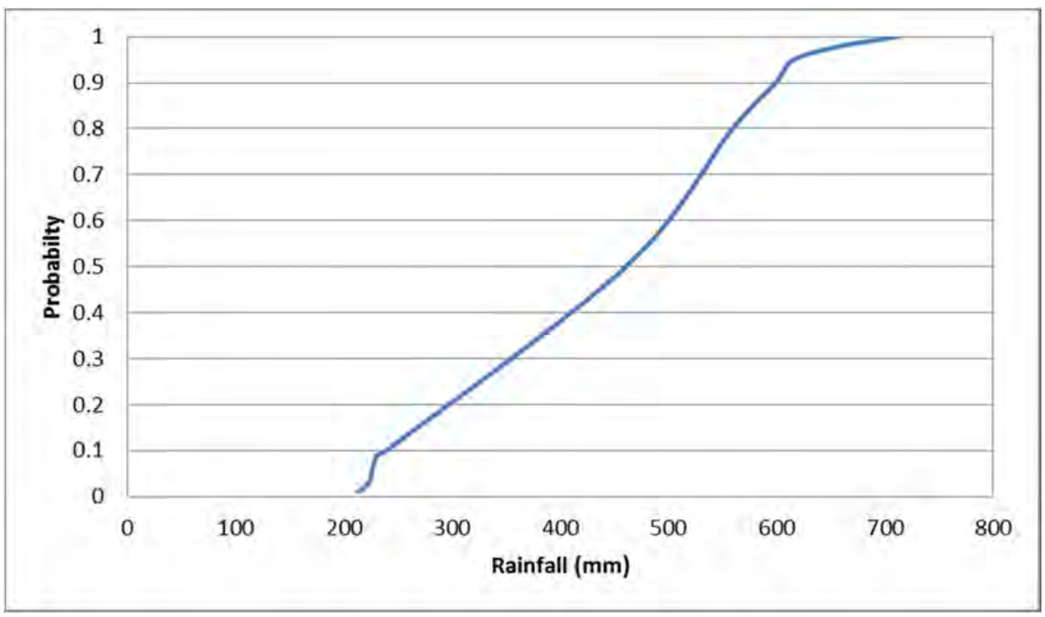


Figure 5: Distribution Curve of the Annual rainfall over the last 33 years

A number of probability distributions were fit to the 24-hour maximum annual storm events recorded. The Log Normal distribution resulted in the best fit. Storm depth for the various specified recurrence intervals, based on this fitted distribution are presented in Table 3.

Table 3: 24 Hour Storm Rainfall for various Annual Recurrence Intervals

Return period (years)	2	5	10	20	25	50	100	200	500	1000
Maximum 24-hr Rainfall (mm)	59	79	92	104	108	120	132	144	160	172

4.4 Mean Evaporation

The nearest Symons (S)-Pan evaporation station to the Turfvlakte farm (A4E007) has a Mean Annual Evaporation of 1 844 mm/year. Mean monthly evaporation values are presented in Figure 6. Take note that the mean annual evaporation is almost 4 times higher than the rainfall.

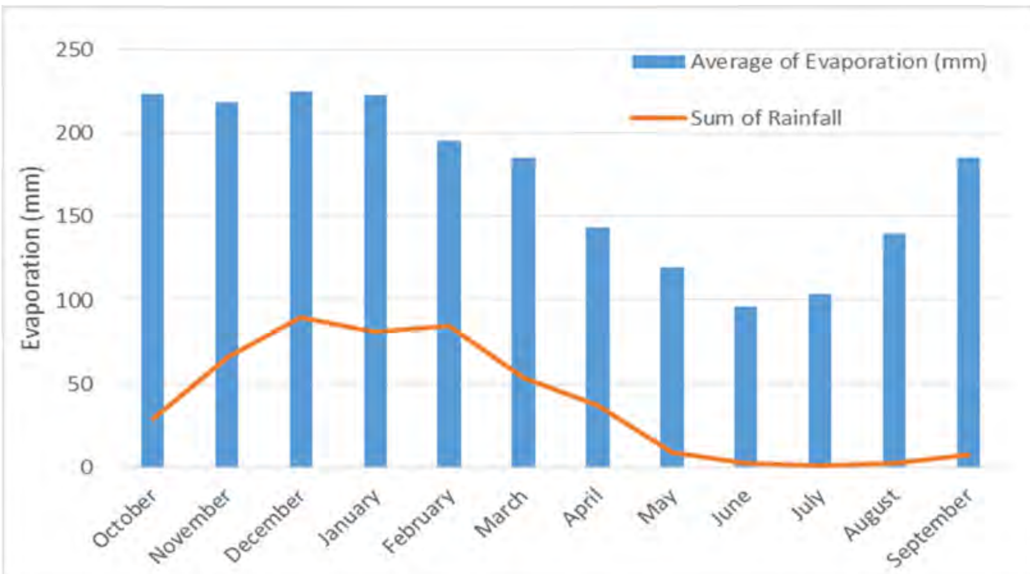


Figure 6: Average monthly evaporation measurements for the Lephalale area

4.5 Topography and Drainage

The Turfvlakte investigation and surrounding area general topography is described as plains, with slopes that vary between 0 and 3%. Altitudes around the Grootegeluk mine vary from 900 to 922 m above mean sea level (mamsl), whereas altitudes on Turfvlakte range from 877 to 890 mamsl (Figure 7). The area is generally featureless except for elevation differences caused by Nelsonkop (922 m) in the north and the Waterberg Mountain Range (1 500 m) in the south. Drainage appears to be in an east-north-easterly direction towards the Mokolo River and consists mainly of dry sandy gullies such as the Sandloopspruit (Golder 2017).

The Mokolo River is approximately 810 mamsl, while the Turfvlakte investigation area is approximately 877 mamsl. This results in an almost negligible gradient of 80:21000 m or 0.0038%. General topographical drainage appears to be in an east-north-easterly direction towards the Mokolo River. No natural drainage channels occur on the Turfvlakte investigation area. Due to the flat topography, highly permeable sands and the absence of any surface water drainage courses, the Grootegeluk mining area and Turfvlakte project area have limited impact on the surface hydrology of the Mokolo Catchment (Exxaro, 2010).

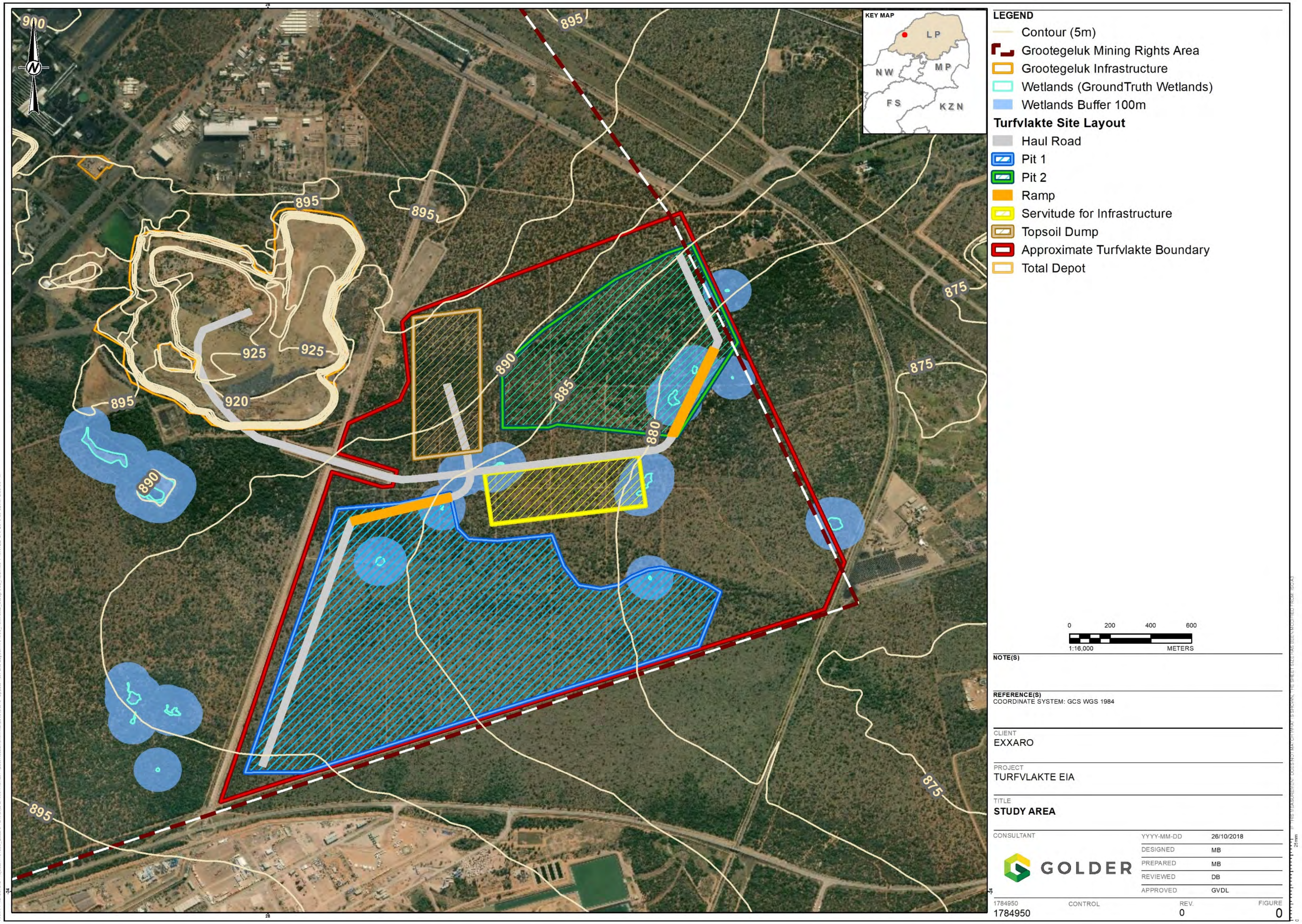


Figure 7: Site Layout and Topography

5.0 PHASE I - GROUNDWATER BASELINE

5.1 Desk Study

5.1.1 Existing Groundwater Information

5.1.1.1 Existing Groundwater Data Base Boreholes

The existing borehole information for Turfvlakte and surrounding investigation area as per Golder's groundwater database (Aquabase) and existing hydrogeological reports are indicated on Figure 8 and comprises of:

- Golder Zonderwater Hydrocensus (2014) - boreholes to the north-east of Turfvlakte mine;
- GCS Hydrocensus (2014) - boreholes west of Turfvlakte mine;
- Aquatico monitoring boreholes; and
- Grootegeluk mine monitoring and abstraction boreholes (101 boreholes).

5.1.2 Geology

5.1.2.1 Regional Geology

Based on the 1:250 000 Geological Map Series 2326 Ellisras, Council for Geoscience (Figure 9), the regional geology in the area is characterised by the igneous and sedimentary rocks of the Karoo Supergroup. The Turfvlakte Project is situated on the southern portion of the Limpopo Depression, a relatively small corridor between the Limpopo River in the west and the Palala-Pietersburg Plateau in the east (Golder 2017).

The Turfvlakte Project Area is located on the Waterberg Coal Field and includes all the major units of the Karoo Supergroup (Table 4), comprising from surface of the Stormberg Group, Beaufort Group, Ecca Group and the Dwyka group forming the basement (Figure 12).

The Waterberg Coal Field covers an area of approximately 88 km (east to west) and 40 km north south. The coalfield also extends westward into Botswana. The Waterberg Coal Field is part of the late Palaeozoic to early Mesozoic (100 - 200 Ma) Erathems of the Karoo Supper Group. The coalfield is fault-bounded and forms a graben structure. The Eenzaamheid Fault forms the southern boundary, with rocks of the Waterberg Group occurring to the south and the Karoo to the north. The northern boundary is delineated by the Zoetfontein Fault with Archaean granites outcropping north of the fault (Golder 2017).

The coal seams of the Waterberg Coal Field occur in the Volksrust and Vryheid Formations of the Karoo Super Group. These are also referred to as the Grootegeluk and Goedgedacht Formations, respectively.

The coalfield is further subdivided by the Daarby Fault that delineates a shallower western part of the coalfield, which is suitable for opencast mining and a deep north-eastern part, which is not suitable for opencast mining. The Zoetfontein Fault was tectonically active before and during Karoo deposition, while the Eenzaamheid and Daarby faults, as most of the other faults in the Waterberg Coalfield, are younger than the Karoo Sequence.

Sedimentation occurred in a shallow east-west striking trough and the general direction of transport was ENE-WSW. Karoo sediments are deposited on the Waterberg Group in the southern portion of the coalfield, while the basement rocks to the north of the Zoetfontein Fault are Archaean rocks. The paleo-floor in the eastern portion consists of granite and basic rocks of the Bushveld Igneous Complex. Relatively few dolerite dykes' outcrop in the south-eastern portion of the coalfield and no sills have been intersected in any of the exploration boreholes (Golder 2017).

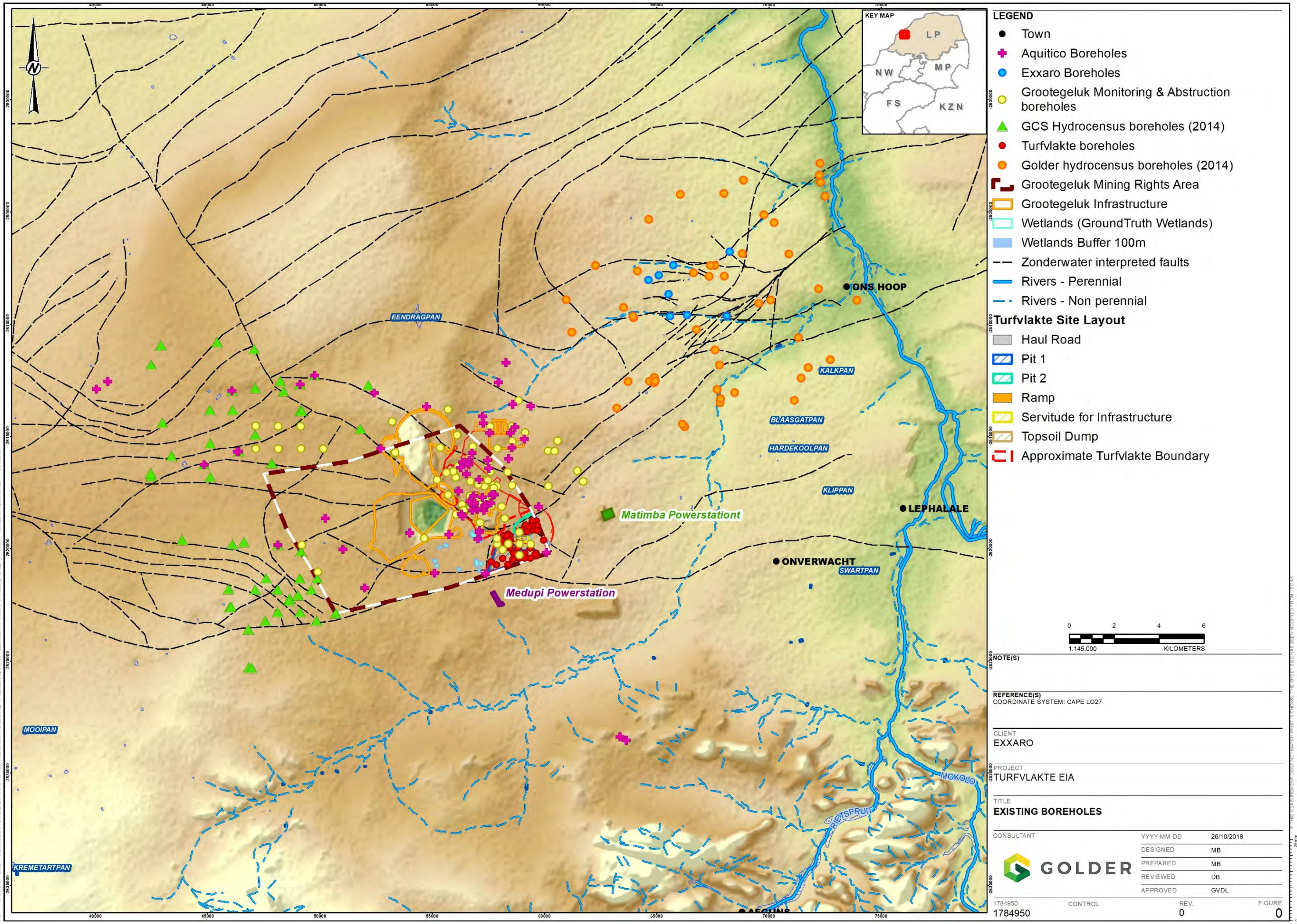


Figure 8: Existing Borehole Positions

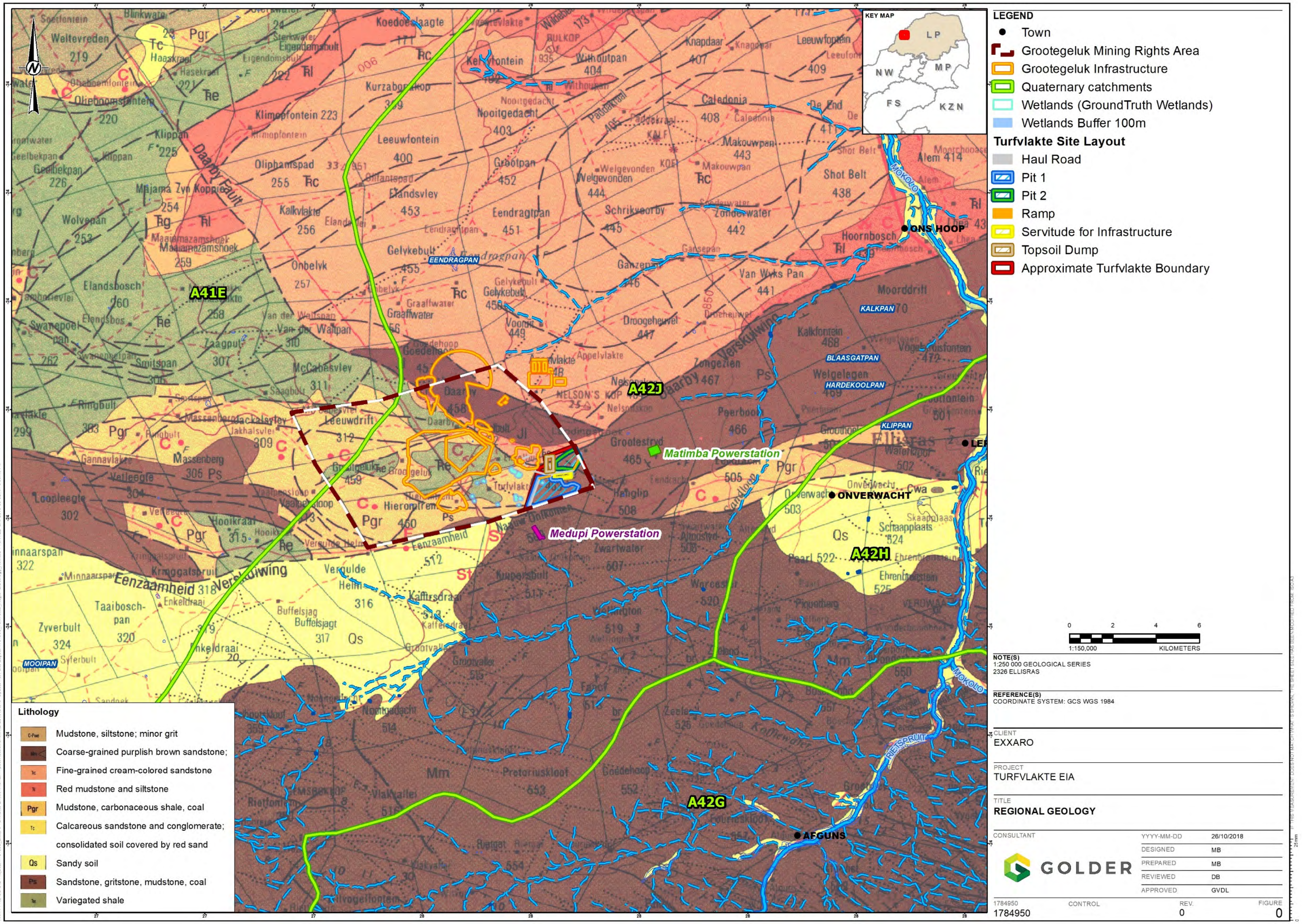


Figure 9: Regional Geology

Table 4: Stratigraphy of the Karoo Super Group

GROUP	FORMATION (SACS – 1980)	FORMATION (Cilliers 1951)	Representative Rock Type	Average Thickness
STORMBERG	Drakensberg Basalt	Drakensberg	Lava, purplish to red, amygdaloidal	95 m
	Clarens Sandstone	Cave Sandstone	Sandstone, fine grained, white to yellow brown to reddish	80 m
	Elliot	Red Beds	Mudstone, red to chocolate brown, clayey	90 m
	Molteno	Molteno	Sandstone, white, medium to coarse grained, scattered pebbles	15 m
BEAUFORT	Beaufort	Beaufort	Mudstone, purple and greenish grey, alternating at top, light grey at base	90 m
ECCA	Volksrust Shale	Upper Ecca	Intercalated shale and bright coal	60 m
	Vryheid	Middle Ecca	Sandstone and grit, inter-calated carbonaceous shale, siltstone, few thick coal seams, mainly dull	55 m
	Pietermaritzburg Shale	Lower Ecca	Shale and sandstone, grit in lower portions	150 m
DWYKA	Dwyka	Dwyka	Tillite	3 m

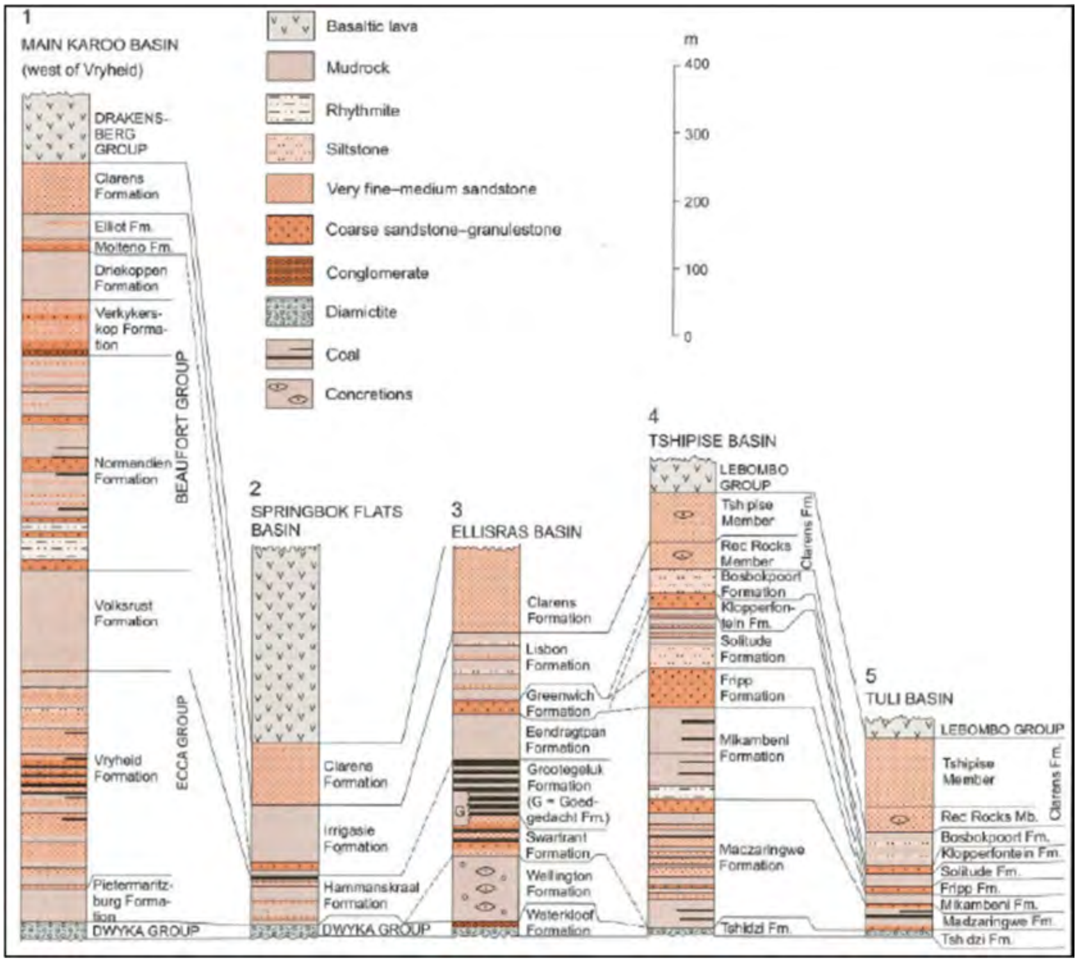


Figure 10: Stratigraphy of the Karoo Supergroup in the north-eastern part for the main Karoo Basin and the Springbok Flats, Ellisras, Tshipise and Tuli Basins (from Council for Geosciences, 2006)

5.1.2.2 Structural Geology

Three major geological fault zones intersect the greater study area, i.e. Zoetfontein Fault (to the north of Grootegeluk mine), Daarby Fault(north – east trending fault) and Eenzaamheid Fault to the south of Turfvlakte, as well as several minor faults and fractures which have been delineated by Exxaro as indicated on Figure 12.

5.1.2.3 Zoetfontein Fault

The Zoetfontein Fault is a high angled east northeast – west southwest striking major fault. Significant post-Karoo displacement is evident and is known to be still seismically active; this resulted in the extensive downthrow to the north and sinistral horizontal movement. The basement complex consists of Archaean granite and gneiss, outcropping to the north of the fault zone (GCS, 2005).

5.1.2.4 Daarby Fault

The Daarby Fault is a major north-east, then north-west trending fault, assumed to be part of one set of events because both “legs” of the fault exhibit the same throw and throw direction. Both faults have consequently been combined into the one name. The Daarby Fault is a normal fault with a downthrow of 360 m to the north and the fault dips at an angle of between 50º and 60º to the north, bringing up-thrown Beaufort and Ecca Group Formations to the south into contact with the down-thrown Letaba, Clarens, Elliott and Molteno Formations in the north.

5.1.2.5 Eenzaamheid Fault

The Eenzaamheid Fault, situated south of the Daarby fault, has a throw of 250 m to the north brining the up-thrown Waterberg Group on the southern side of the fault into contact with the down-thrown Beaufort and Ecca Groups on the northern side of the fault. The dip angle of the Eenzaamheid Fault is near vertical. Evidence of a possible link between the Eenzaamheid and Daarby Faults exists from exploration boreholes on the farm Turfvlakte.

5.1.2.6 Minor faulting

The associated step faults, associated with the Daarby and Eenzaamheid faults, are classed as minor faulting that have varying strikes, throws and throw directions. These faults have been interpreted from exploration boreholes, the geological model and mapping within the open pit excavation (Golder 2017).

5.1.2.7 Local Geology

The Turfvlakte Project Area is dominated by the geology of three major Karoo Super Group Formations, namely the Volksrust, the Vryheid and the Clarence Formations. The local geology of the Waterberg Coal Field as found in the vicinity of the project area is presented in Figure 12 (Exxaro).

The general stratigraphy of the Turfvlakte Project Area consists of weathered formation which is approximately 25 to 30m thick and is made up of topsoil, calcrete, minor ferricrete, a sandy alluvium, weathered shale, clay, and non-reactive carbonaceous material. A generalized stratigraphy for the Turfvlakte project areas is shown in Figure 11.

The overburden overlays minor occurrences of Volksrust Formation coals in the western portion of the project area that disappears to the east of the project area. These coal measures are predominately material from what is defined as Benches 4 and 5 at Grootegeluk mine. In the eastern portion of the farm, the Vryheid Formation lies directly under the overburden (Exxaro). The thickness distribution of the overburden is shown in Figure 13 (Exxaro).

Description		Thickness
Completely weathered, reddish brown to brown (where reworked with organic material), non-cohesive, aeolian sand with abundant quartz grains, upper most part of the profile.		29.35m
Hard to very hard, nodular, boulder or hardpan calcrete. Minor sporadic occurrences of ferricrete		
Highly weathered, cream to brown and reddish brown in places, coarse grained to gravelly, loose to moderately cemented (calcified), with abundant quartz grains and quartz pebbles throughout the horizon. Some rounded Karoo siltstone/shale fragments, alluvial sand.		
Highly weathered, yellowish brown and cream to brownish grey and light grey, fine grained, soft to slightly/moderately hard shale fragments and chips in a very fine powdery clay matrix, moulds in hand but has overall granular feel when moulded, weathered Karoo shales/siltstone		
Highly to completely weathered, light yellow brown and cream to brownish grey, fine grained and powdery, minor very soft to clayey shale fragments, easily moulded when compressed in hand and stains hands when wet, weathered Karoo shales/siltstones.		
Volkrust formation: Intercalated shale and bright coal layers. Only present in western portion of project area.		14.50m
Vryheid formation: Sandstone and grit, intercalated carbonaceous shale, siltstone, few thick coal seams, mainly dull		30.73m

Figure 11: Generalised Stratigraphy of Turfvlakte Project Area (Adapted from Exxaro)

The full Waterberg coal succession does not occur on the project area. A number of factors contribute to this. These include but are not limited to (Exxaro):

- Differential weathering of the coal measures of the Volksrust and Vryheid Formations; and
- The project area is situated in a narrow corridor that is bounded by two regional faults namely the Daarby and Eenzaamheid Faults. These faults appear to have a number of smaller, sympathetic faults associated with them. These fault zones make the project area more structurally complex and may contribute to the disappearance of portions of the coal measures in the area (Exxaro). These faults have been inferred by Exxaro from exploration boreholes and the geological model (Figure 12).

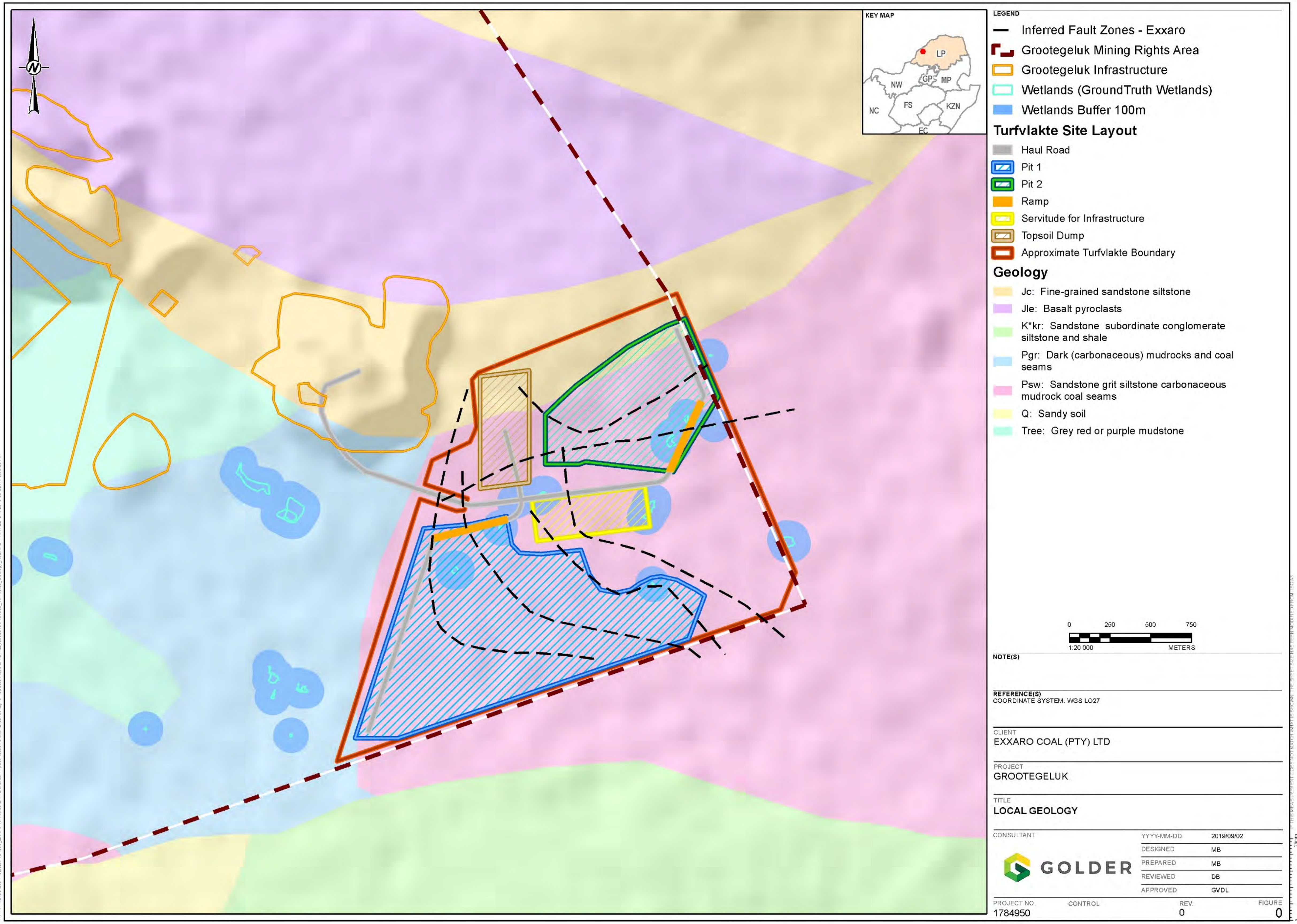


Figure 12: Turfvlakte Local Geology

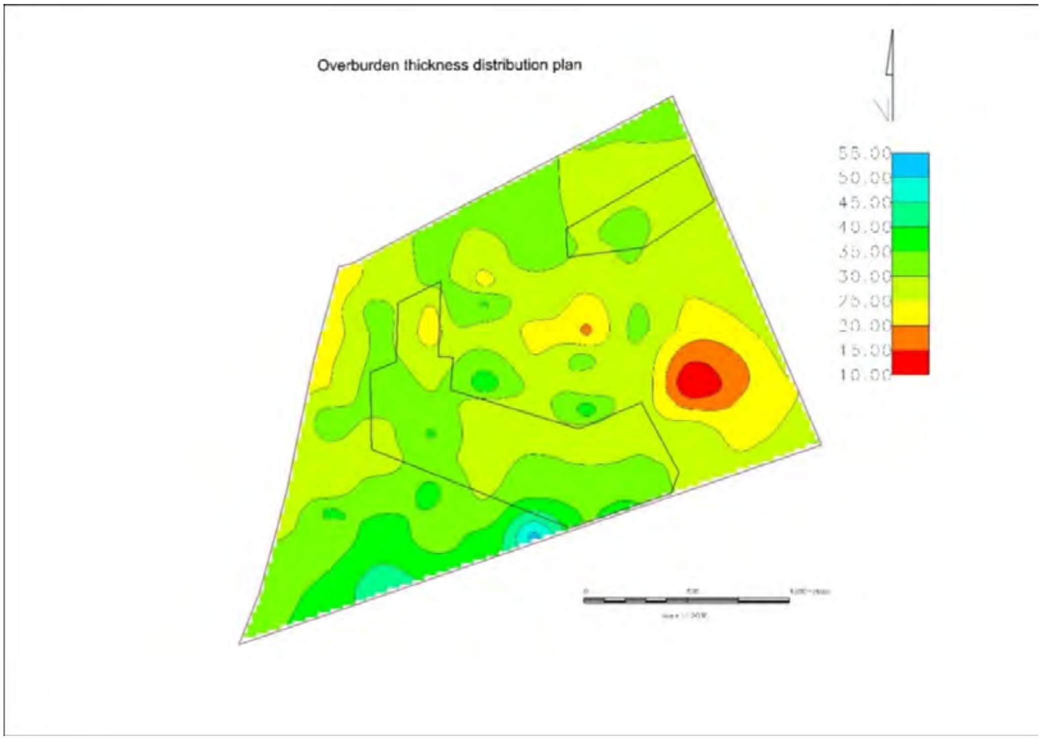


Figure 13: Overburden Thickness Distribution (Adapted from Exxaro)

5.1.3 Hydrogeology

5.1.3.1 Regional Aquifer Classification and Borehole Yield

The published Hydrogeological Map Series by DWAF (1996) was used to define the regional aquifer classification (Figure 14). The aquifer at the Turfvlakte Project Area is classified as minor aquifer system.

The small western part of the Turfvlakte project area aquifer is classified as a fractured aquifer zone whereas the greater part (locality of pit 1 and 2) is classified as intergranular and fractured. Both aquifer zones have an average borehole yield between 0.5 l/s and 2.0 l/s (Figure 15) which are typical yields of the Karoo Super Group.

5.1.3.2 Aquifer Classification

Based on the drilling results, two aquifer systems are distinguished at Turfvlakte in the Karoo Supergroup namely:

- Top weathered aquifer system; with an average thickness of ~ 28 m. The average water level is about 24 m below ground level (mbgl) which means that the bottom of the weathered zone is saturated and water-bearing; and
- Fractured secondary aquifer system; with an average thickness of ~ 15 m below the weathered aquifer system and is characterised by secondary fractures resulting in preferential flow paths for the groundwater flow and possible contaminant migration.

5.1.3.3 Top Weathered Aquifer

Borehole logs form Exxaro indicate that the top part of the rock formation is composed of a weathered aquifer system of variable thickness. The depth of weathering ranges from 14.25 to 36.05 (mbgl) with an average weathering depth of 28.3 mbgl (Table 8).

These weathered deposits comprise of topsoil, calcrete, minor ferricrete, a sandy alluvium, weathered shale, clay and non-reactive carbonaceous material (Exxaro 2018).

5.1.3.4 Fractured Secondary Aquifer

The major aquifer type in the greater Turfvlakte investigation area is characterised by secondary fractures and weathering zones that essentially control groundwater flow and mass transport. The most important characteristics of fractures are the relatively high transmissivity with relatively low storage properties. In contrast, the matrix blocks between the fractures or fracture zones have very low to zero transmissivity but may have significantly higher storativity. The combination of the fracture and matrix properties result in significant flow and mass transport velocities (>> 100 m/d) through the fractures while sorption by the aquifer and storage of water and contaminants occur in the matrix (Roux, 2009).

Water strikes depths encountered during by the Exxaro Drilling Programme (2017-2018) range from 20 to 39 mbgl with and average strike depth of 28.7 mbgl. Blow yield measured during the drilling programme ranges from 0.13 to 3.49 l/s with an average yield of 0.68 l/s.

The Daarby Fault represents one of the major structures controlling the regional hydrogeology as it has been identified to be a barrier to groundwater flow (Roux, 2003). Groundwater levels on either side of the fault differ considerably (up to 100 m).

Although the Daarby Fault is characterised as a no-flow boundary in a regional context, field investigations have indicated that small amounts of seepage could take place across the fault, from the northern to the southern compartment. Steenekamp (2001) predicted the transmissivity of the fault to be approximately 0.01 m^2/d.

Basalt is usually characterised by insignificant transmissivity and storativity values. However, field investigations indicate that the Letaba Basalt (north of the Daarby Fault) is fractured and weathering occurred between successive lava flows. Aquifer tests conducted on several boreholes located in the basalt indicated that the T-values range between 0.7 to 380 m^2/d, with an average of 62 m^2/d (ERM, 2012).

The lower contact between the Letaba Formation and the Clarens Formation is represented by an erosion surface with yield between 2 l/s and 12.7 l/s. ERM postulates that the highest mobility of contaminants will be associated with this layer (ERM, 2012).

5.1.3.5 Aquifer Thickness

The aquifer thickness depends strongly on the type of aquifer in the area, especially in the case of fractured bedrock aquifers. Because secondary, fractured rock aquifers occur in the Turfvlakte area, aquifer thickness depends strongly on the presence, depths and orientations of the fractures or fracture systems through which flow takes place. The depths at which water yielding fractures are intersected in the Turfvlakte area vary significantly from 20 to 39 mbgl (Exxaro 2017-2018).

In the Stormberg basalt aquifer to the north of the Daarby Fault, much of the formation is weathered and fracturing occurs throughout the rock thickness. To the south of the Daarby Fault in the Ecca and Beaufort Groups sandstones and shales, very limited fracturing has occurred in general and groundwater flow is restricted to post-depositional faulting and associated fracturing (Golder 2017).

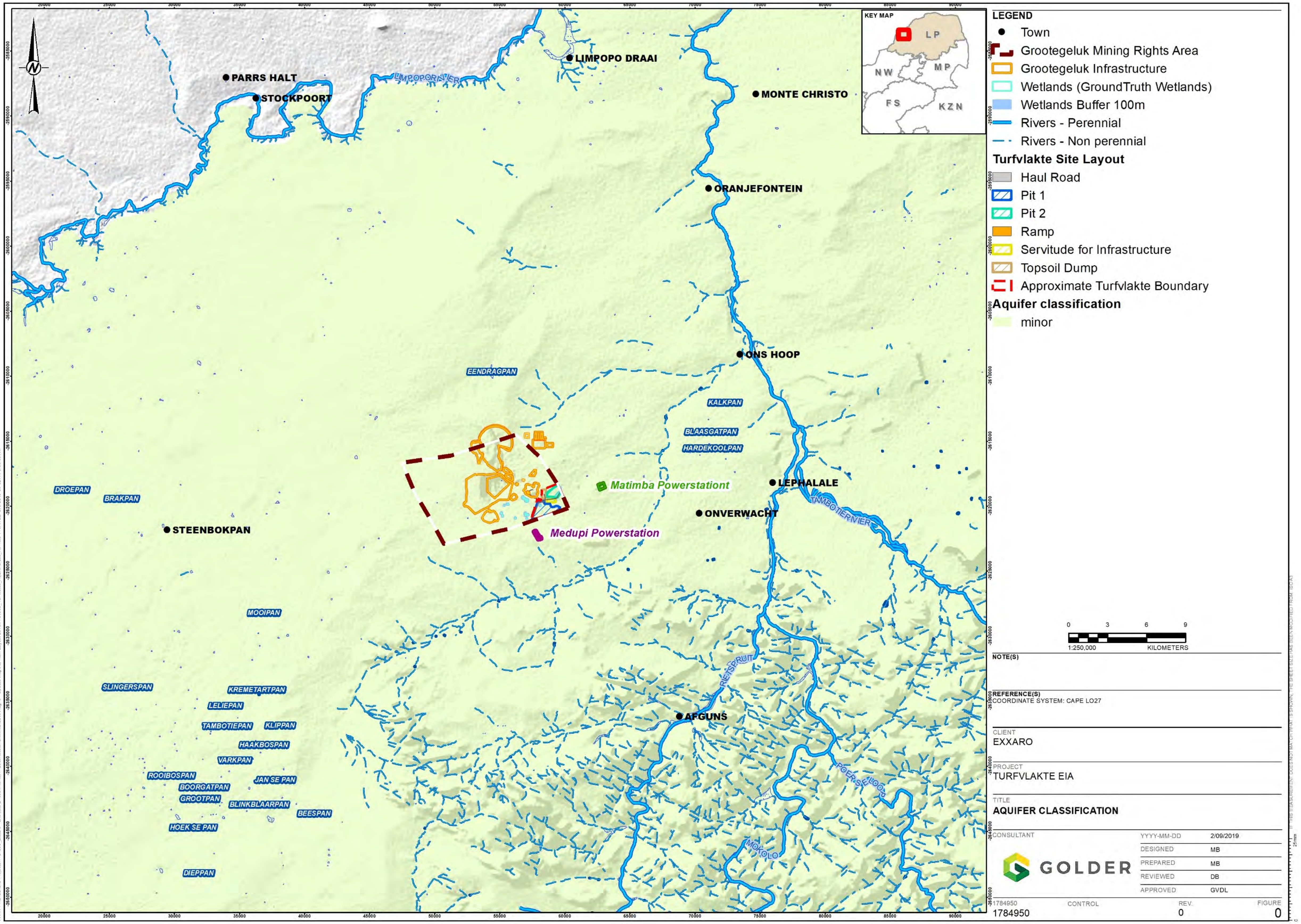


Figure 14: Regional Aquifer Classification

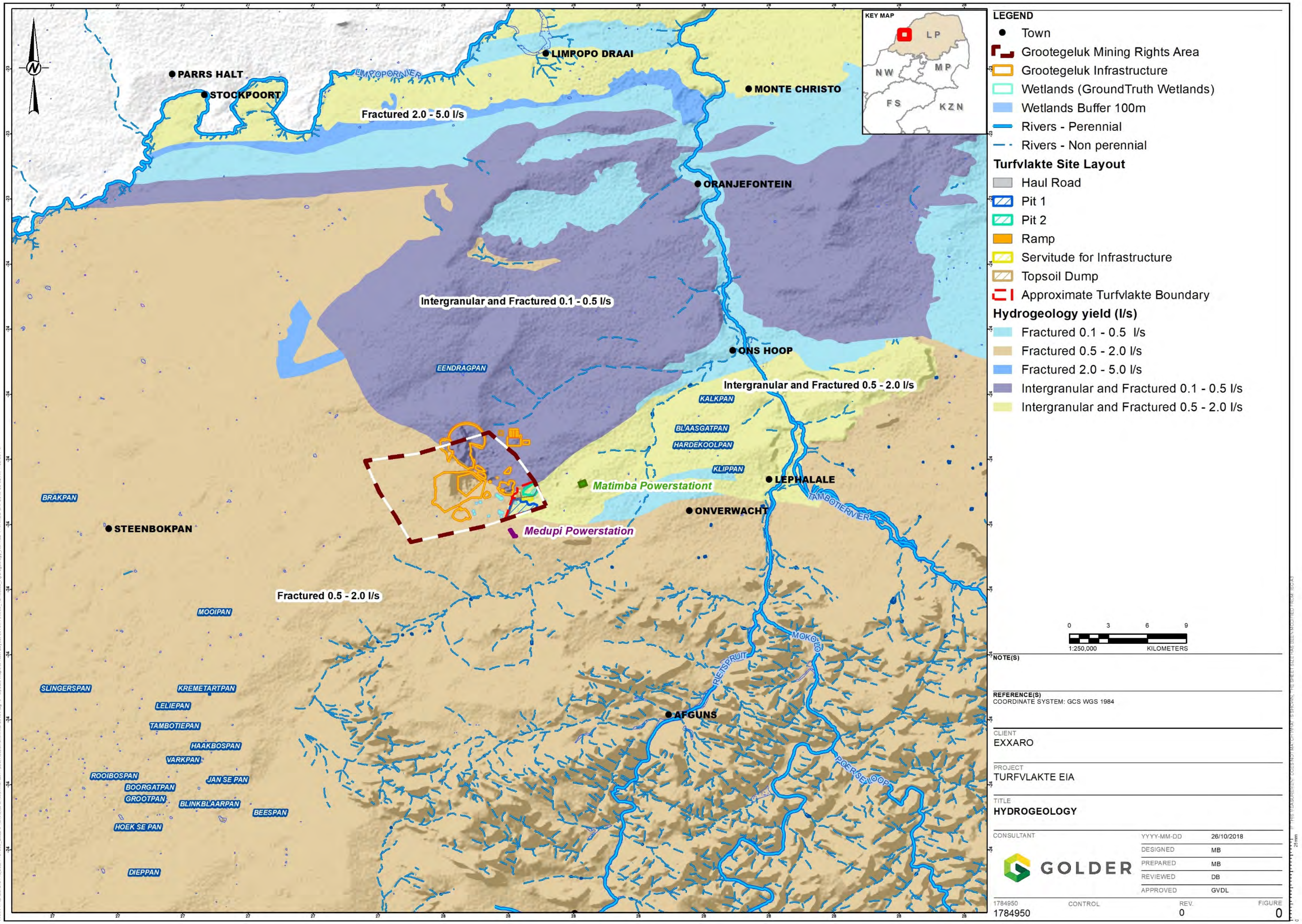


Figure 15: Hydrogeology

5.1.4 Groundwater Level and Flow Direction

The published Groundwater Resource Map Series – Sheet 2 (DWAF 1995), indicate the water level to range between 20 to 40 mbgl (Figure 17).

The groundwater water levels reported by Exxaro's Turfvlakte drilling programme (2017 - 2018), range between 9.79 (TESPES44) to 24.0 (TESPES46) (mbgl) with an average level of 18.24 mbgl.

The correlation between the altitudes and water levels of newly drilled boreholes are 32% as indicted in Figure 16. This poor correlation indicate that the onsite groundwater level is probable affected by existing surrounding mining activities and local geological conditions, possibly the regional Eenzaamheid and local fault zones (5.1.2.7. The piezometric contours and flow direction for Turfvlakte investigation area is indicated on Figure 17, and the flow direction is south-east towards the Mokolo River.

Regionally the groundwater flow directions are towards the Mokolo and Limpopo Rivers which are the primary receptors in the project area. The groundwater flow for the greater investigation area to include Grootegeluk mine and Turfvlakte is part of the Phase II groundwater modelling outcome.

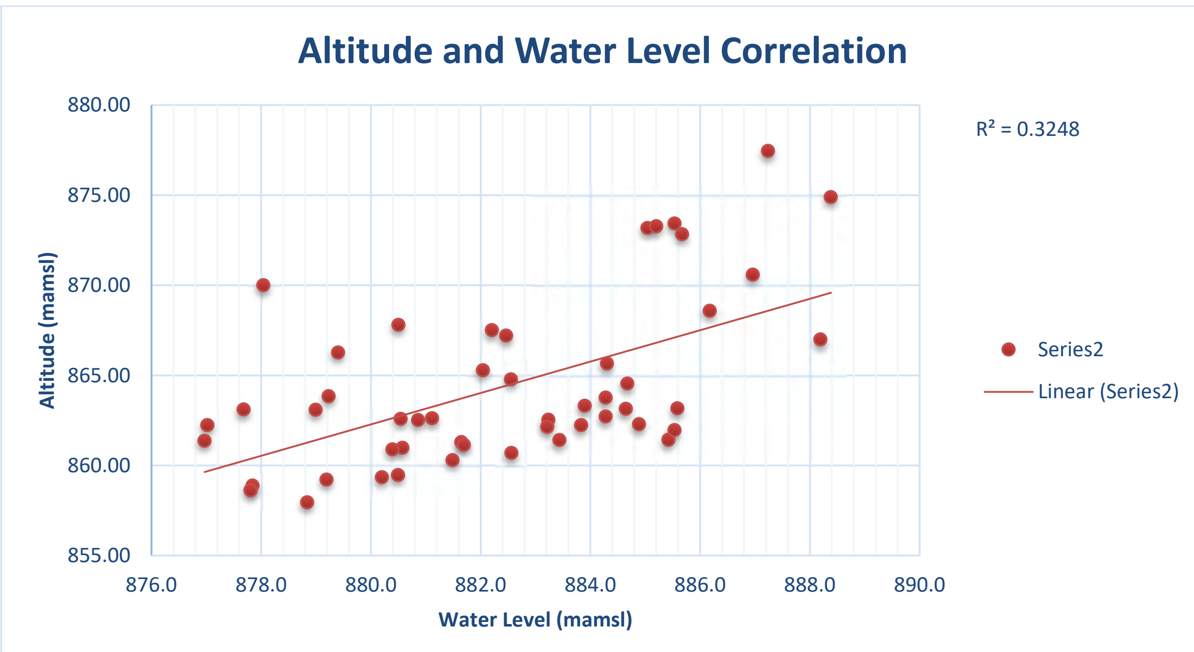


Figure 16: Altitude and Water Level Correlation

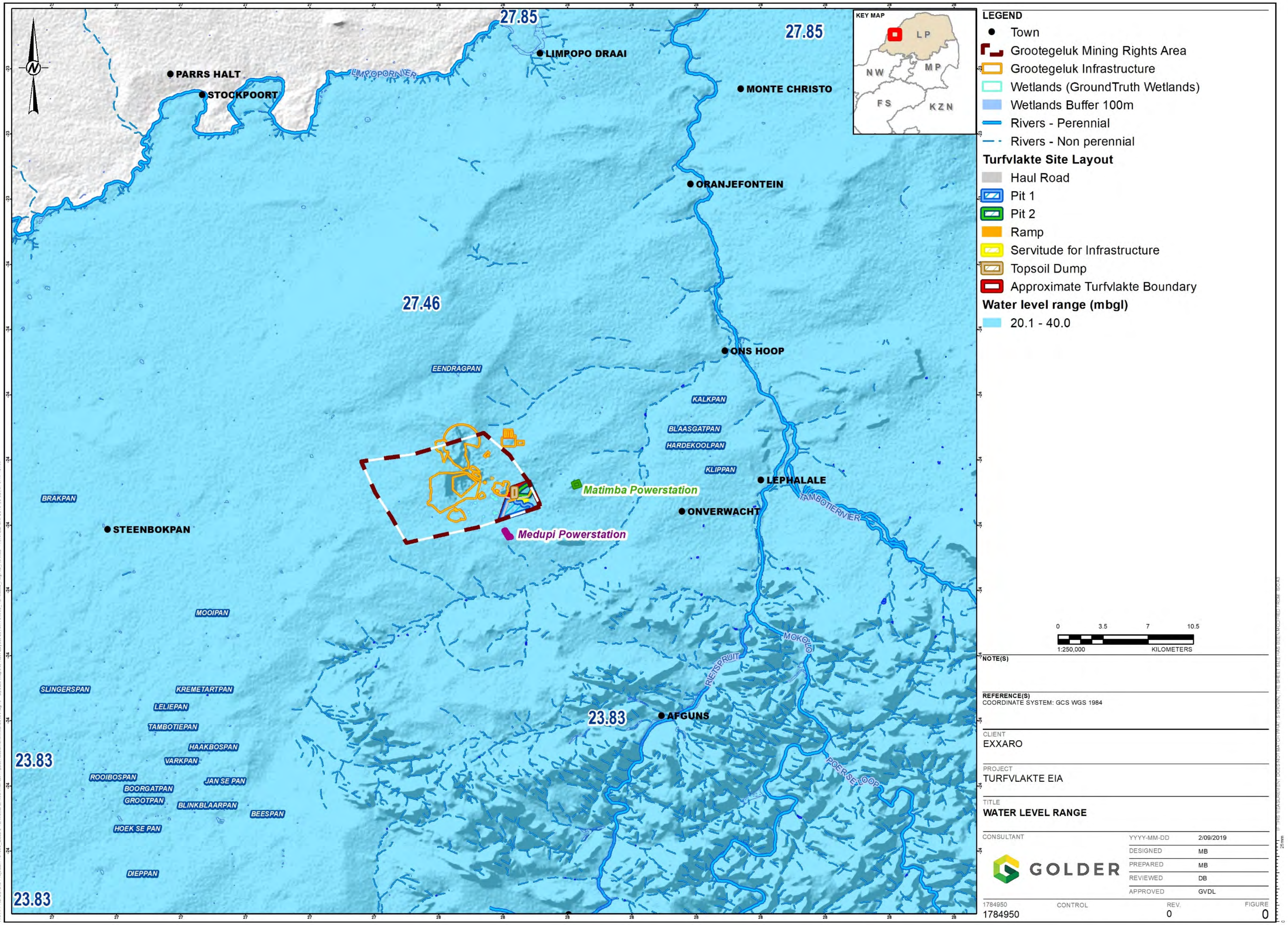


Figure 17: Groundwater Resource Map Series (DWAF 1995) - Regional Water Level

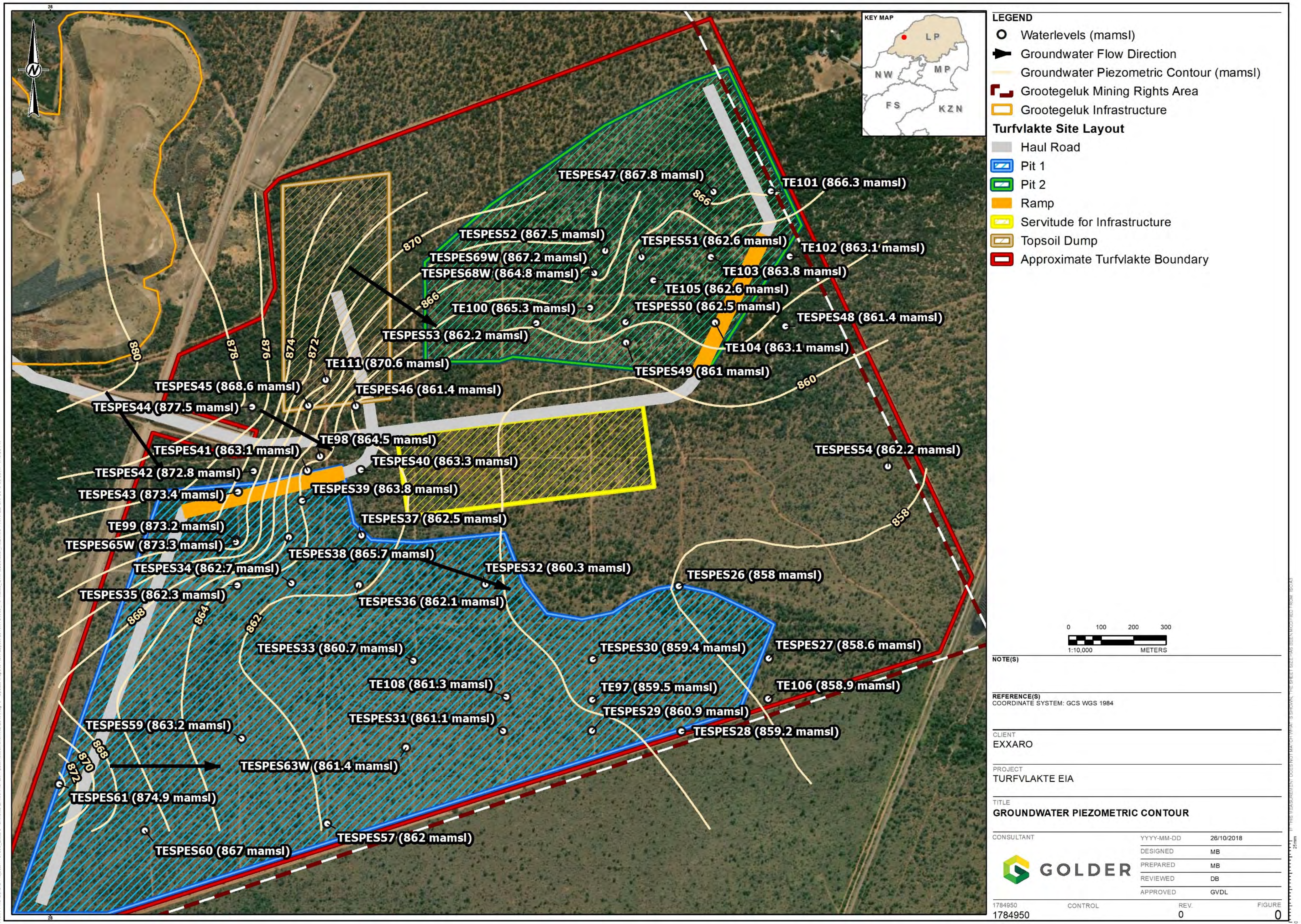


Figure 18: Turfvlakte Groundwater Piezometric Contours

5.1.5 Regional Aquifer Recharge

From the published hydrogeological maps (DWAF 1996) the average recharge of the greater northern part of Turfvlakte study area is shown as between 5 and 10 mm per annum, whereas the southern part is shown as between 10 and 15 mm per annum (Figure 19).

5.1.5.1 Chloride Ratio Method

The Chloride Ratio Method was used to estimate the aquifer recharge for the area. The Chloride method calculates the recharge using the ratio between the average chloride in rainfall and the average chloride in the groundwater.

The chloride concentration should only result from the natural, hydrological, and evaporative processes as expressed below:

$$\mathbf{RE}\ \% = \frac{\mathbf{Clr}}{\boldsymbol{Clgw}} \boldsymbol{X100}$$

Where: Cl_r is the concentration of chloride in rainfall (mg/l)

Cl_{gw} is the concentration of chloride in the groundwater (mg/l)

= 1.0 mg/l /150.6 mg/l (Harmonic Mean groundwater samples)

= 0.7%

The Harmonic mean of chloride was calculated from the 2018 hydrocensus samples (x 6) and samples collected during the aquifer testing programme (x 6). The current accepted concentration of chloride concentration in rainfall for the area is 1.0 mg/l.

Recharge = 0.7% of the MAP 450.6 mm = 3.2 mm per annum. This recharge value is however lower but more site specific, as the recharge value of 5 to 15 mm per annum as indicated on the published hydrogeological maps (Figure 19). Note that the chloride concentrations are elevated due to impacts from surrounding mining activities and not completely representative.

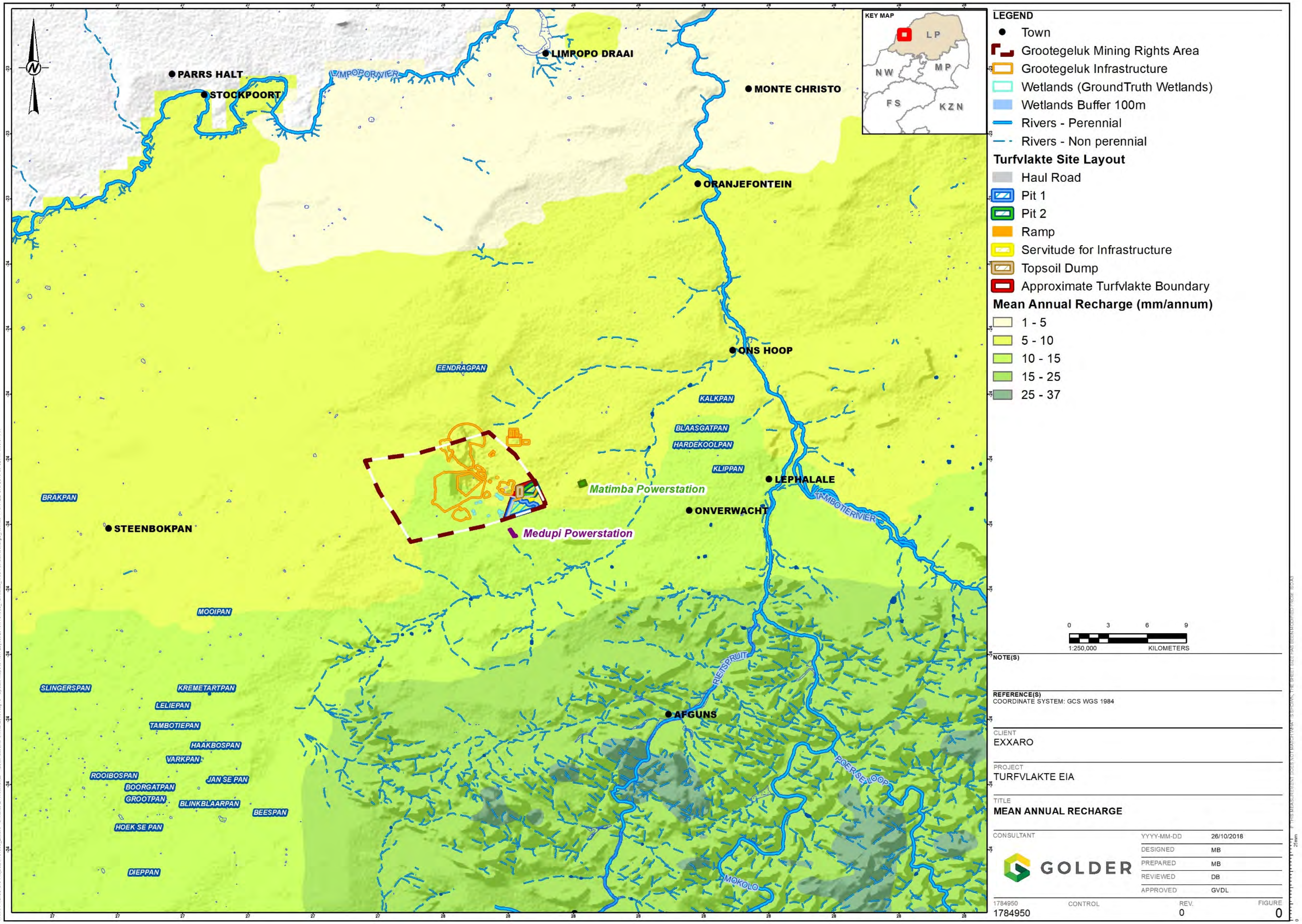


Figure 19: Groundwater Mean Annual Recharge (Vegter 1996)

6.0 FIELD INVESTIGATIONS

6.1 Hydrocensus

A hydrocensus was conducted during January 2018 at six selected boreholes at the Turfvlakte mining area and are listed in Table 5 and indicated on Figure 20. The objective of the hydrocensus was to determine existing groundwater quality status at these sample points and to serve as a quality reference of laboratories previously used for monitoring purposes. The results are discussed accordingly in section 7.0.

These samples were collected as per Golder's standard sampling procedures and submitted to UIS Analytical Services an accredited laboratory in Pretoria. The analytical result certificates are attached in Appendix B.

Table 5: 2015 Hydrocensus Boreholes

Borehole number	Water Level (mbgl)	Sampled Date	Comments
TESPES 59	19.56	18/01/2018	Turfvlakte
TESPES 28	18.91	19/01/2018	Turfvlakte
WBR 46	41.02	19/01/2018	West of Grootegeluk Pit
WBR 50	32.54	19/01/2018	South East of Renoster Dump
WBR 01	15.1	19/01/2018	North of Turfvlakte
TESPES 47	12.81	19/01/2018	Turfvlakte

6.1.1 Field Parameters

The following hydrochemical field parameters (pH and EC) were measured in the field during the hydrocensus sampling process and are summarised in Table 6.

Table 6: Field Parameters

Sampled boreholes	Water Level	pH	EC (mS/m)	Comments
TESPES 59	19.56	6.33	819	Open hole
TESPES 28	18.91	6.93	1312	Open hole
WBR 46	41.02	6.64	843	Open hole
WBR 50	32.54	7.07	376	Open hole
WBR01	15.15	7.38	49	Pumping well
TESPES 47	12.81	7.02	133	Open hole

The Electrical Conductivity (EC) ranges from 49 mS/m in monitoring borehole WBR01 to 1312 mS/m in monitoring borehole (TESPES28). Most of these measured values are above the SANS 241:2011 maximum allowable limit of 170 mS/m, indicating that these boreholes are probably impacted by surrounding mining activities. Borehole WBR01 (pumping well) located to the east of the site appears to be un-impacted.

The pH values are slightly acidic to neutral and ranges from 6.33 (TESPE59) to 7.38 (WBR01).

The groundwater quality assessment is described in section 7.0.

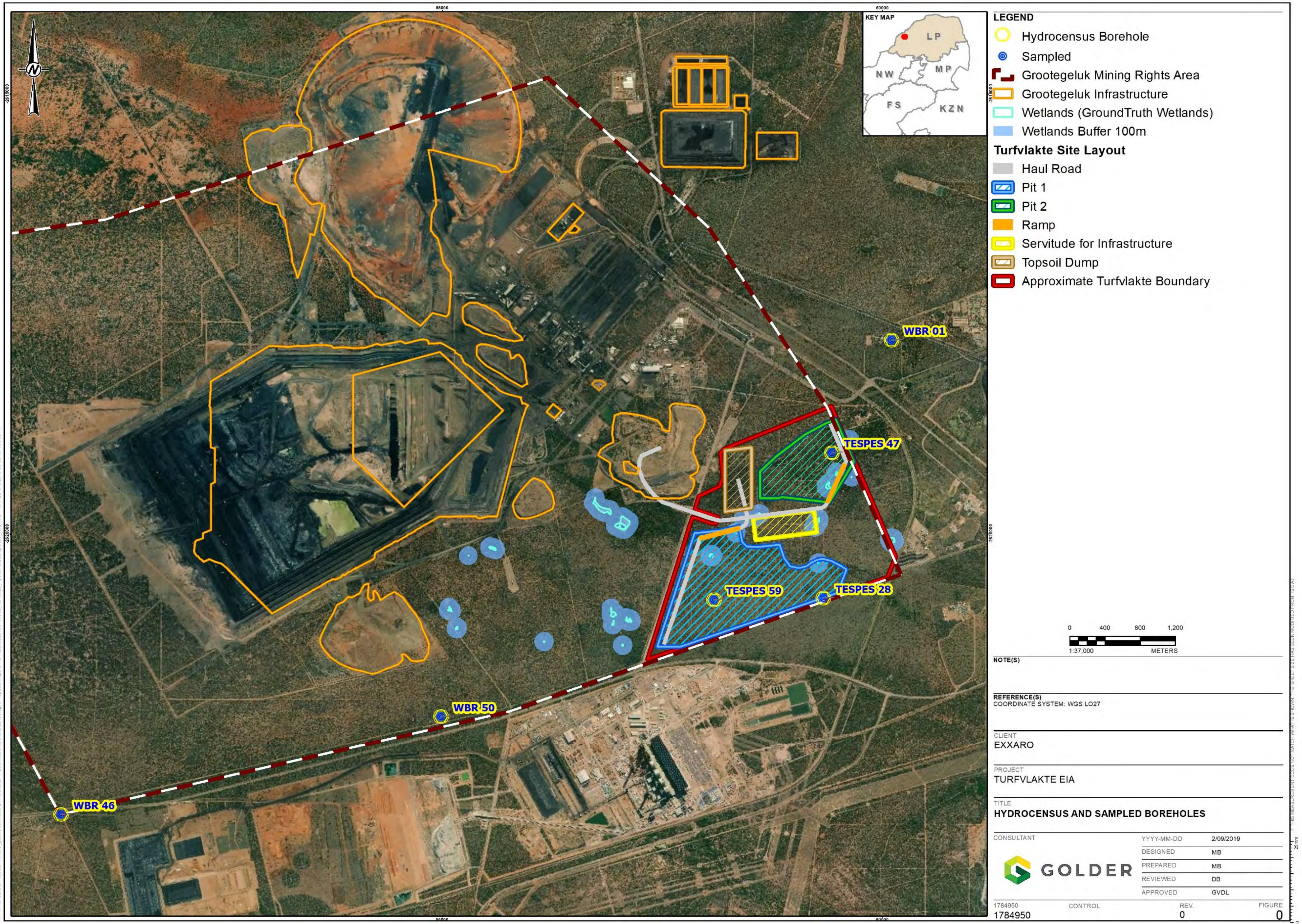


Figure 20: 2018 Hydrocensus and Sampled Boreholes

6.2 Geophysical Survey

An Earth Resistivity Imaging (ERI) survey was conducted at selected traverse positions at Turfvlakte. The objective of the ERI survey was to:

- Identify zones of deeper weathering and fracturing of the bedrock;
- Map potential geological structures/Exxaro delineated fault zones (Figure 21) which could act as preferential groundwater flow paths; and
- To gain a conceptual understanding of the sub-surface of the surveyed area.

The Geophysical survey comprised of Lund 2D Earth Resistivity Imaging (ERI) method with a proposed depth of investigation of approximately 50 m.

The geophysical survey comprising out of six traverses and was conducted during October 2017. The traverses start, and end points were supplied by the Exxaro geophysicist, who also supervised the ERI survey.

The geophysical traverses were surveyed at 10 m station intervals, with all station marked in the field. A handheld GPS was used to take coordinates at every 100 m interval in WGS-84 format. The traverse positions are indicated on Figure 21.

6.2.1 Earth Resistivity Imaging Method (ERI)

The ERI survey was conducted with the Abem Lund 2D resistivity system. The most common minerals forming soils and rocks have very high resistivity in a dry condition, and the resistivity of soils and rocks is therefore normally a function of variations in water content and the concentration of dissolved ions in the groundwater. Resistivity investigations are thus used to identify zones with different electrical properties, which can then be referred to different geological strata.

The electrode separation and survey protocol used, determine the depth of investigation. The measuring protocols used were Wenner array with an investigation depth of approximately 60 m, using 100 m cables with 10 m spacing intervals.

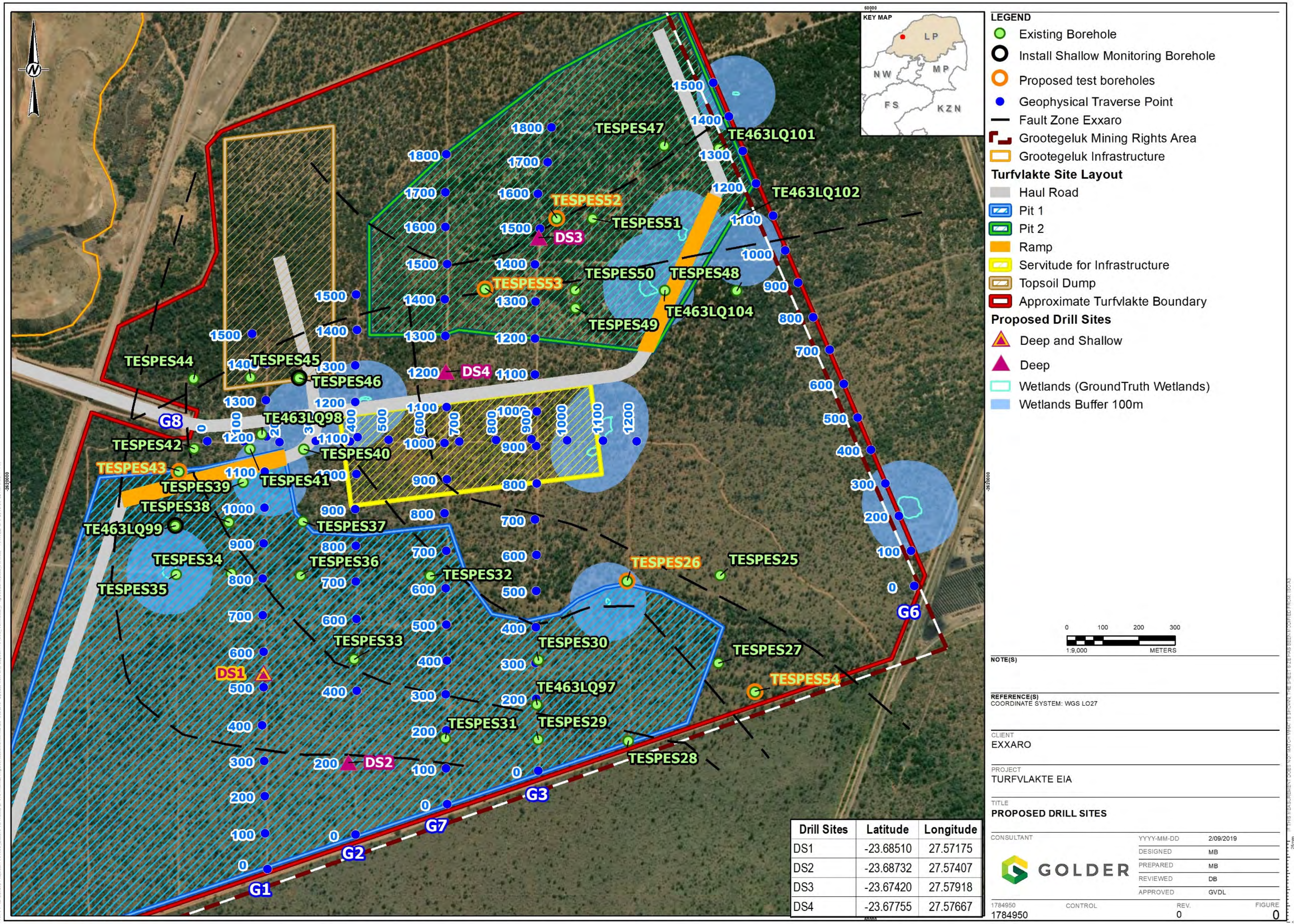
6.2.2 Field work

The ERI survey is basically an automated Wenner-type sounding. A large number of soundings with different AB (current electrodes) and MN (potential electrodes) are done along a line. Apparent resistivities are calculated, yielding resistivity-depth sections. The depth of exploration is a function of the electrode spacing used, with the maximum depth not exceeding twelve times the electrode spacing used. Depending on the data density, depths can be accurate to within 10%.

The survey at Turfvlakte was done using Abem Lund 2D resistivity system. The system automatically cycles through electrodes placed into the ground along a 400 m cable connection, varying the positions of the potential and current electrodes. By doing this an accurate subsurface picture of the resistivity distribution in the ground is built up. The setup achieved a 60 m depth of investigation.

The most common minerals forming soils and rocks have very high resistivity in dry conditions, and the resistivity of soils and rocks is therefore normally a function of variations in water content and the concentration of dissolved ions in the groundwater.

Resistivity investigations are thus used to identify zones with different electrical properties, which can then be referred to different geological strata.



Drill Sites	Latitude	Longitude
DS1	-23.68510	27.57175
DS2	-23.68732	27.57407
DS3	-23.67420	27.57918
DS4	-23.67755	27.57667

Figure 21: Geophysical Traverse Positions and Proposed Drill Sites

6.2.3 Geophysical Results

The geophysical data were evaluated by plotting the data as 2D profiles and are listed in Appendix A.

Four proposed drill sites were selected and are summarised in Table 7 and indicated on Figure 21. The provisional drilling sites target low resistivity zones associated with faulting and possible preferred groundwater flow paths. Additional shallow monitoring boreholes positions were selected hydrogeologically.

The average weathering depth of the formations as defined by the ERI method is ~25 mbgl (Exxaro drilling results confirm average depth of 28.7 mbgl - Table 8), and drilling targets are mainly deep weathering and fracture zones in the Karoo sediments.

Table 7: Proposed Drilling Targets

Drill Site	Latitude	Longitude	Traverse/station No.	Monitoring Borehole	Borehole Number Allocated
DS-1	-23.68510	27.57175	T1/540	Deep and Shallow	TESPES66W
DS-2	-23.68732	27.57407	T2/200	Deep	TESPES63W
DS-3	-23.67420	27.57918	T3/1475	Deep	TESPES68W
DS-4	-23.67755	27.57667	T7/1700	Deep	TESPES64W

6.3 Exxaro Drilling Programme (2017-2018)

An extensive exploration and groundwater drilling programme were conducted by Exxaro. A total of 54 boreholes were drilled comprising of 48 exploration and 6 groundwater monitoring boreholes, as indicated on Figure 22. The four provisional drilling targets were drilled (Table 7). The drilling results as provided by Exxaro are summarised in Table 8.

The recorded water strikes range from 20 to 39 mbgl with and average water strike depth of 28.7 mbgl. Blow yield measured during the drilling programme range from 0.13 to 3.49 l/s with an average yield of 0.68 l/s, which corresponds well with the average borehole yield of the published hydrogeological maps series by DWAF (1996) of between 0.5 l/s and 2.0 l/s (Figure 15).

Table 8: Exxaro Newly Drilled Boreholes

Borehole Number	Latitude	Longitude	Altitude (mamsl)	SWL (mbgl)	SWL (mamsl)	Water strike (mbgl)	Blow Yield (l/s)	Depth (m)	Depth of Weathering (mbgl)	Casing (mbgl)	Casing Construction
TE98	-23.67927	27.57168	884.7	20.13	864.55	-	N/A	55.94	26.9	26.94	Cemented
TESPES50	-23.67555	27.58012	880.9	18.34	862.52	24.00	N/A	85.02	27.0	26.97	Unperforated
TE104	-23.67556	27.58259	879.0	15.91	863.08	-	N/A	66.57	29.1	29.05	Cemented
TE97	-23.68599	27.57920	880.5	21.03	859.47	-	N/A	69.28	30.6	30.61	Cemented
TE101	-23.67193	27.58413	879.4	13.14	866.26	-	N/A	63.13	24.3	24.28	Cemented
TE108	-23.68591	27.57682	881.6	20.36	861.29	-	N/A	72.55	29.8	29.77	Cemented
TE99	-23.68158	27.56935	885.0	11.87	873.17	-	N/A	72.56	32.8	32.84	Cemented
TESPES46	-23.67788	27.57266	885.4	24.00	861.43	23.00	N/A	62.84	33.0	32.95	Cemented
TE100	-23.67515	27.57914	882.0	16.76	865.28	-	N/A	89.26	25.0	24.98	Cemented
TE102	-23.67373	27.58466	877.7	14.58	863.10	-	N/A	60.57	29.5	29.49	Cemented
TE103	-23.67375	27.58248	879.2	15.39	863.84	-	N/A	69.45	28.9	28.89	Cemented
TESPES28	-23.68687	27.58166	879.2	19.98	859.21	31.00	N/A	73.93	31.2	31.18	Unperforated
TESPES69W	-23.67420	27.57926	882.5	15.27	867.20	-	N/A	28.00	28.0	28.00	Perforated
TESPES49	-23.67612	27.58014	880.6	19.60	860.98	22.00	N/A	80.96	27.0	27.01	Unperforated
TESPES25	-23.68267	27.58408	878.0	-	-	-	-	-	-	-	-
TESPES66W	-23.68510	27.57186	883.842	-	-	-	-	74.96	-	-	-
TESPES64W	-23.67756	27.57675	883.5	-	-	-	-	71.81	-	-	-
TESPES56	-23.68695	27.57180	884.5	-	-	-	-	82.96	-	-	-
TESPES62	-23.68689	27.56447	887.8	-	-	-	-	110.08	-	-	-
TESPES59	-23.68707	27.56951	885.6	22.37	863.17	28.44	N/A	81.00	28.5	28.44	Unperforated
TE106	-23.68597	27.58406	877.8	18.96	858.88	-	N/A	76.28	26.2	26.17	Cemented
TESPES60	-23.68961	27.56683	888.2	21.20	867.00	33.94	N/A	88.94	33.9	33.94	Unperforated
TE111	-23.67715	27.57183	887.0	16.38	870.58	-	N/A	63.56		24.90	Cemented
TESPES57	-23.68942	27.57187	885.5	23.58	861.96	32.00	N/A	93.05	36.1	36.05	Unperforated
TESPES41	-23.67966	27.57133	884.6	21.50	863.15	-	N/A	63.04	24.0	24.01	Perforated
TESPES44	-23.67789	27.56980	887.2	9.79	877.45	25.59	N/A	72.91	25.6	25.59	Unperforated
TESPES27	-23.68486	27.58408	877.8	19.19	858.62	26.44	N/A	70.02	26.4	26.44	Unperforated
TESPES33	-23.68492	27.57425	882.6	21.87	860.69	29.17	N/A	74.98	29.2	29.17	Unperforated
TESPES39	-23.68049	27.57118	884.3	20.52	863.76	26.00	N/A	67.96	26.0	26.00	Unperforated

Borehole Number	Latitude	Longitude	Altitude (mamsl)	SWL (mbgl)	SWL (mamsl)	Water strike (mbgl)	Blow Yield (l/s)	Depth (m)	Depth of Weathering (mbgl)	Casing (mbgl)	Casing Construction
TESPES35	-23.68283	27.56939	884.9	22.60	862.29	39.00	N/A	80.07	31.2	31.15	Unperforated
TESPES30	-23.68487	27.57922	880.2	20.85	859.35	39.00	N/A	65.04	29.8	29.84	Unperforated
TESPES51	-23.67376	27.58056	881.1	18.50	862.62	25.00	N/A	84.75	25.3	25.28	Perforated
TESPES45	-23.67787	27.57135	886.2	17.60	868.58	27.00	N/A	64.90	27.0	27.04	Perforated
TESPES29	-23.68686	27.57919	880.4	19.50	860.89	33.00	0.13	80.22	32.2	32.24	Unperforated
TESPES40	-23.67964	27.57280	883.9	20.59	863.31	27.00	0.15	58.94	27.9	27.90	Unperforated
TESPES38	-23.68150	27.57081	884.3	18.65	865.66	31.00	0.17	74.91	30.4	30.41	Unperforated
TESPES68W	-23.67419	27.57919	882.6	17.78	864.78	26.00	0.17	96.88	29.2	29.21	Cemented
TESPES32	-23.68280	27.57625	881.5	21.20	860.29	25.05	0.16	63.83	25.1	25.05	Unperforated
TESPES48	-23.67567	27.58454	877.0	15.60	861.37	22.00	0.19	75.06	22.2	22.20	Unperforated
TESPES37	-23.68145	27.57282	883.2	20.70	862.54	30.00	0.24	74.99	29.0	28.98	Unperforated
TESPES42	-23.67967	27.56984	885.7	12.85	872.82	20.00	0.28	69.01	30.8	30.77	Perforated
TESPES52	-23.67358	27.57956	882.2	14.70	867.51	27.00	1.30	84.04	26.1	26.11	Perforated
TESPES47	-23.67194	27.58255	880.5	12.70	867.80	26.00	0.63	69.00	27.1	27.08	Perforated
TESPES31	-23.68686	27.57673	881.7	20.55	861.15	31.00	0.19	84.99	29.0	28.98	Unperforated
TESPES36	-23.68283	27.57275	883.2	21.07	862.15	33.00	0.25	72.10	25.3	25.30	Unperforated
TESPES61	-23.68834	27.56446	888.4	13.50	874.88	28.03	0.88	101.10	28.0	28.03	Unperforated
TESPES43	-23.68024	27.56941	885.5	12.11	873.42	30.00	0.75	72.90	32.2	32.17	Perforated
TESPES63W	-23.68732	27.57405	883.4	22.03	861.41	35.00	0.31	84.84	33.0	33.00	Cemented
TE105	-23.67439	27.58089	880.5	17.96	862.59	-	0.29	78.47	26.3	26.33	Unperforated
TESPES53	-23.67557	27.57766	883.8	21.60	862.23	34.00		98.99	26.5	26.45	Perforated
TESPES26	-23.68286	27.58159	878.8	20.89	857.95	39.00	3.00	75.02	34.0	34.00	Unperforated
TESPES34	-23.68277	27.57088	884.3	21.56	862.72	28.31	0.50	74.91	28.3	28.31	Unperforated
TESPES65W	-23.68164	27.56935	885.2	11.94	873.26	22.00	0.60	29.50	29.5	29.50	Perforated
TESPES54	-23.67955	27.58737	877.0	14.79	862.23	27.00	3.49	65.00	14.3	14.25	Unperforated
Minimum			877.0	9.79	857.95	20.00	0.13	28.00	14.25	14.25	
Maximum			888.4	24.00	877.45	39.00	3.49	110.08	36.05	36.05	
Average			882.6	18.24	864.29	28.74	0.68	73.98	28.30	28.23	

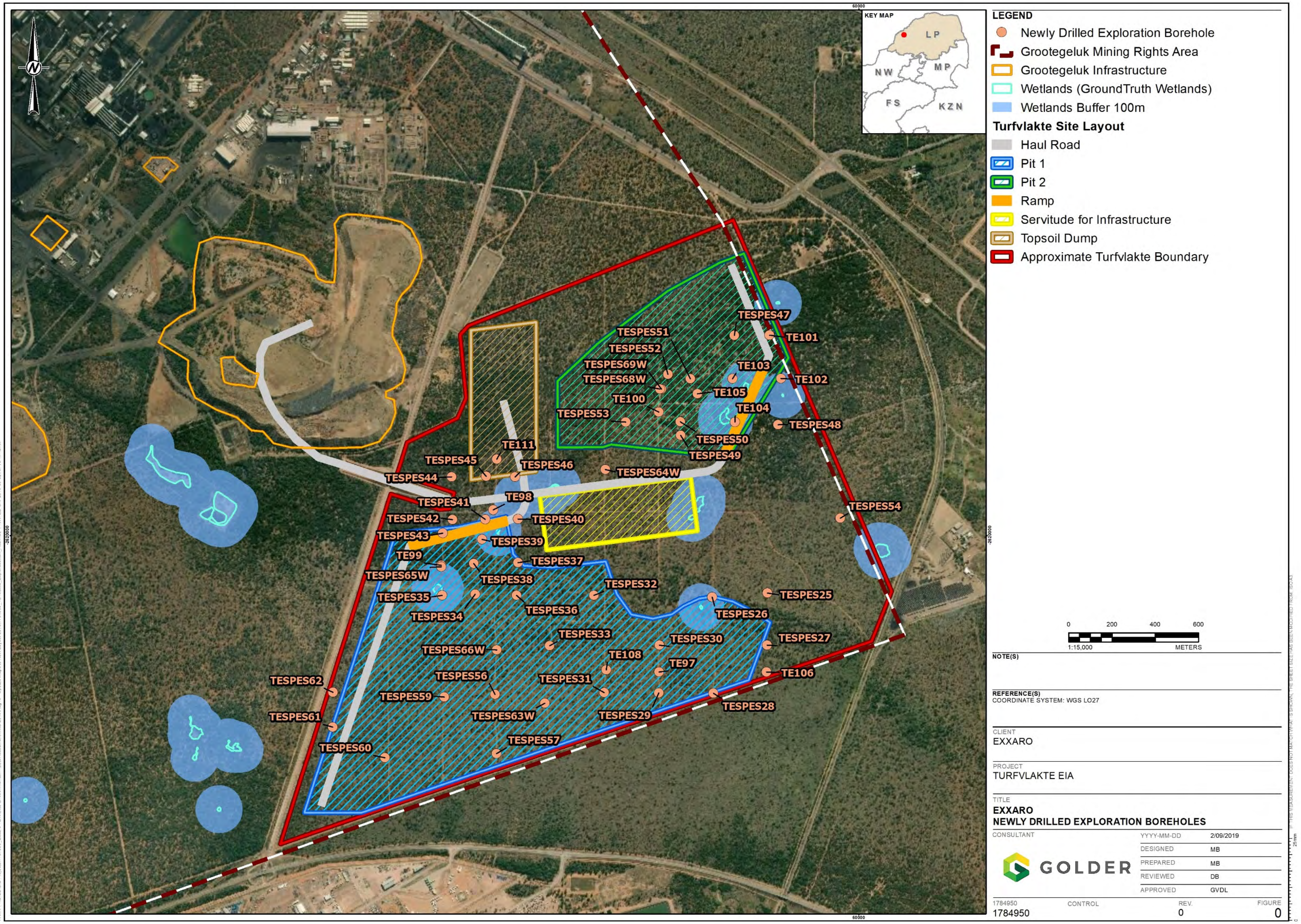


Figure 22: Newly Drilled Exploration Boreholes - Exxaro

6.4 Aquifer Testing

6.4.1 Short Term Aquifer Testing

Short term aquifer testing was conducted during January 2018 at six selected boreholes as indicated on Figure 23.

The aquifer testing programme was conducted by Meerkat Borehole Testing Contractor using a positive displacement pump under the controlled supervision of a Golder's hydrogeologist.

The objective of the aquifer testing was:

- To determine aquifer parameters; and
- To determine sustainable borehole yields.

The aquifer testing programme consists out of step drawdown test (SDT) followed by a constant discharge test (CDT), and a water level recovery test. Each SDT comprised four to five 15-minute steps at increasing pumping rates. The aim of the SDT is to assess the performance of the borehole under different pumping yields and determine the pumping rate for the CDT.

The CDT is conducted to determine the hydraulic parameters of the aquifer and identify possible aquifer boundaries. The CDT's were conducted for periods of 6 hours, after which the water level recovery was measured with electronic water level data loggers. The CDT pumping rates were set at yields determined from the SDT to be sustainable for the planned duration of the test. Water levels were monitored with electronic water level data loggers in adjacent boreholes during each CDT's to determine if there is connectivity between the boreholes (Figure 24). One representative borehole was monitored with an electronic water level data logger continuously during the testing programme (Figure 24).

Water-level recovery measurements were taken for the same period as pumping during the SDT and CDT or to 100% recovery of the original water level. The pumping yields were measured volumetrically during the testing programme.

Pumping rates varied from 0.4 /s (TESPES 68W) to 1.53 l/s (TESPES 61). The static water levels of the pump tested boreholes ranges from 11.96 (TESPES 43) to 21.96 mbgl (TESPES 63W) with an average water level of 17.42 mbgl.

A total of eight groundwater samples, including two duplicate samples (Table 14) were collected at the pump tested boreholes during the aquifer testing programme. These samples were collected as per Golder's standard sampling procedures submitted to UIS Analytical Services an accredited laboratory in Pretoria. The two duplicate samples were collected and analysed for quality control (Highlighted in blue - Table 4).

The aquifer testing programme are summarised in Table 9 and the aquifer testing pumping graphs are listed in the Appendix C of the report.

Table 9: Summarised Aquifer Testing Programme

Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	No. of Calibration Tests	Final Yield of Calibration (l/s)	Calibration Drawdown (m)	Pump Inlet Yield(l/s)	Duration of CDT (Min)	Yield of CDT (l/s)	Drawdown of CDT (m)
TESPES 26	75.02	20.2	5	2.88	39.98	1.8	150	1.43	39.98
TESPES 34	74.91	21.17	4	2.05	39.71	0.97	360	0.82	20.50
TESPES 61	101.1	12.93	4	3.51	47.47	1.64	210	1.53	47.47
TESPES 63W	84.84	21.96	5	1.9	38.90	1.28	360	1.04	17.66

Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	No. of Calibration Tests	Final Yield of Calibration (l/s)	Calibration Drawdown (m)	Pump Inlet Yield(l/s)	Duration of CDT (Min)	Yield of CDT (l/s)	Drawdown of CDT (m)
TESPES 43	72.9	11.96	5	2.9	48.56	1.44	360	0.8	23.81
TESPES 68W	96.88	16.35	2	0.8	-	-	360	0.4	14.44

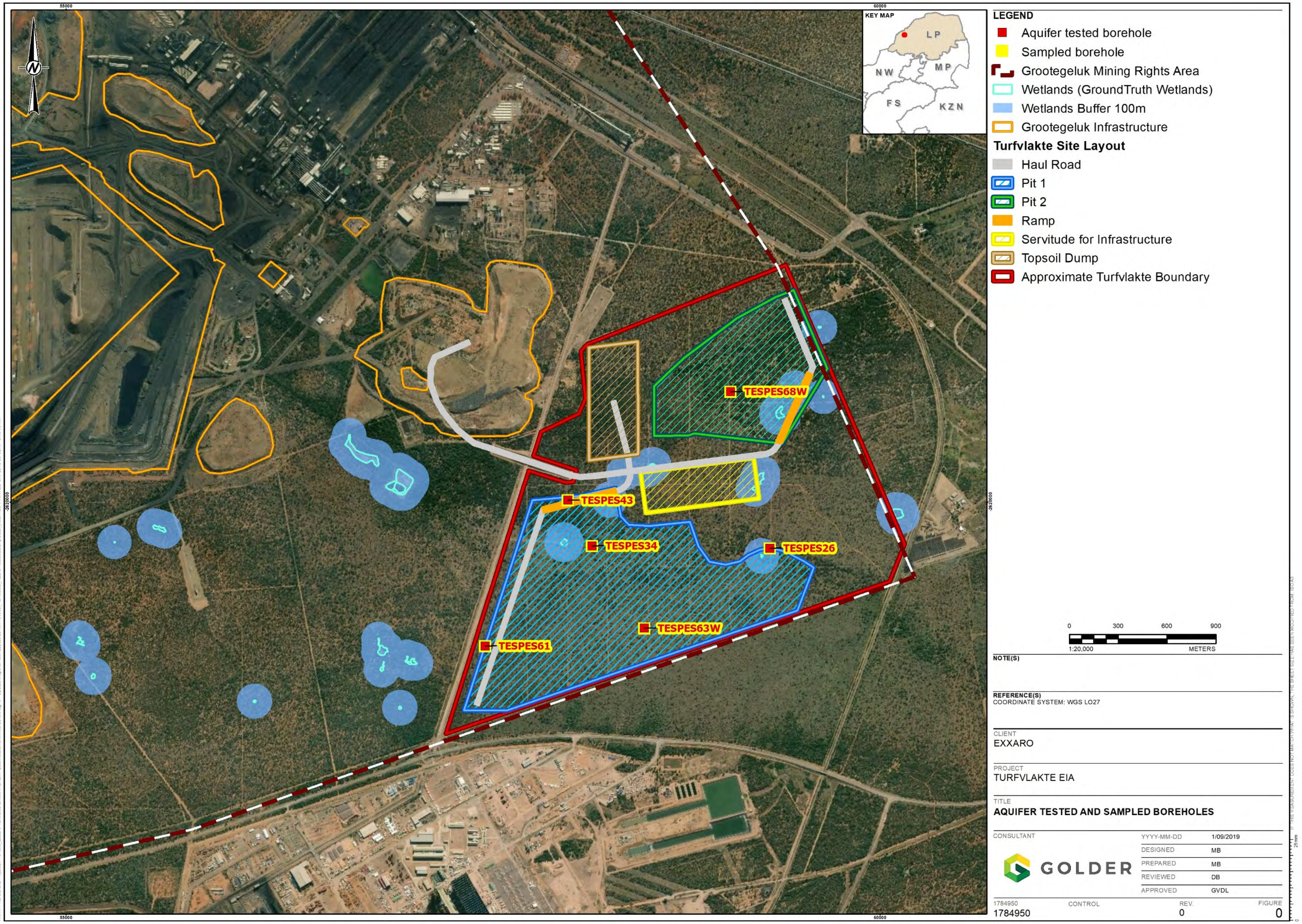


Figure 23: Aquifer Tested and Sampled Boreholes

6.4.1.1 Aquifer Testing Results

Test pumping results were interpreted by means of the FC Method developed by the Institute for Groundwater Studies at Free State University, Bloemfontein and the results are summarised in Table 11 and pump testing graphs are listed in the Appendix C.

The heterogeneous nature of the aquifer is evident from the variability in the calculated transmissivity values. This behaviour is typical for fractured and weathered sedimentary hard rock aquifers. The calculated transmissivity values of the weathered and fractured aquifer zones (combined aquifer zone) range from 2.1 – 6.3 m^2/d, whereas the fractured aquifer zone range from 1.1 – 9.2 m^2/d. These values are typical for Karoo aquifers systems.

Table 11 shows the Mean, Harmonic Mean and Geometric Mean for the drawdown and recovery aquifer test data for both the weathered and fractured aquifer zones. It is generally accepted that the Harmonic Mean is one of the better estimates to describe the aquifer characteristics from the aquifer parameter data set.

The Harmonic Mean (Cooper-Jacob Analyses) of the weathered and fractured aquifer zone (combined aquifer zone) is 3.27 m^2/d and for the fractured aquifer zone 1.97 m^2/d.

6.4.1.2 Observed Monitoring Boreholes

The water levels of adjacent boreholes were monitored with electronic level logger during the aquifer testing programme to determine if there is any interaction between the boreholes (Figure 24). One representative borehole (TESPES53) was monitored with an electronic water level data logger continuously during the testing programme. This data logger recorded a gradually raise of 0.16 m (recharge) over the testing programme period, indicating that there was no influence on the regional groundwater level due to aquifer testing programme.

During the CDT at the deep monitoring borehole (TESPES43W), no drawdown was recorded at the shallow monitoring borehole TE99, indicating that for this area the shallow and deep aquifer are not linked.

The observation results are summarised in Table 10. Monitoring boreholes highlighted in blue (Table 10) water levels were influenced during the CDT’s.

Table 10: Observed Monitoring Boreholes

Aquifer Tested Borehole	Monitoring Borehole	Influence on Water Levels of Monitoring Borehole
TESPES63	TESPES 56	Fluctuation of water level of 0.04 m
TESPES 34	TESPES 38	Drawdown of 0.75 m
TESPES 61	TESPES 62	Water level raised 0.17 m
TESPES 26	TESPES 27	No influence, fluctuating water level
	TESPES 28	No influence, fluctuating water level
TESPES 43 W	TE 99 (Shallow Monitoring)	Water level raised 0.1 m, aquifers not linked, TE 99 shallow borehole
	TESPES 42	Drawdown of 0.31 m (few bad data points, but certain drawdown trend)
TESPES 68 W	TESPES 52	No influence, fluctuating water level
	TESPES 69W	Drawdown of 1.02 m (few bad data points, but with a positive drawdown trend)

Aquifer Tested Borehole	Monitoring Borehole	Influence on Water Levels of Monitoring Borehole
Entire Testing Programme	TESPES 53 (Master Diver)	Water level raised gradually over course of testing programme from 19.74 to 19.58 m (Recharge of 0.16 m)

The site representative borehole TESPES 53 showed an increase in water level of 0.16 m over time, which relates to groundwater recharge for the testing period. There was an increase of 0.1 m in the water level of the shallow monitoring borehole TE99 during the CDT of the deep monitoring borehole TESPES 43 W. This indicated that the shallow and deep aquifers systems are not linked.

Water level drawdowns were observed in three monitoring boreholes during the CDT's, highlighted in blue in Table 10. These water level drawdowns were used to calculate representative storativity (s) values for Turfvlakte and are listed in Table 11. Aquifer test software was applied for calculations.

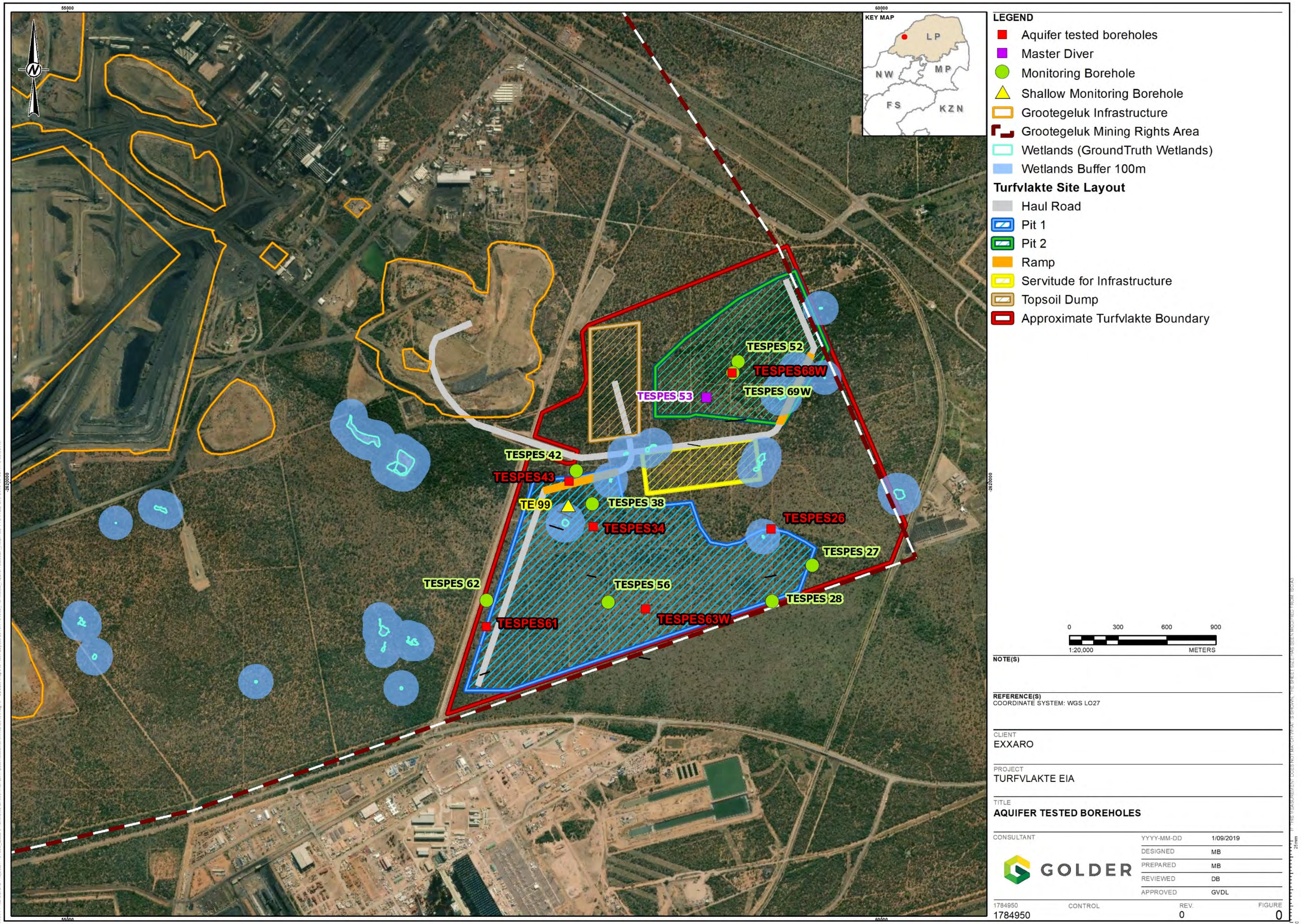


Figure 24: Aquifer tested and Observed Monitoring Boreholes

Table 11: Aquifer Parameters

Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	Duration of CDT (Min)	Yield of CDT (l/s)	Drawdown of CDT (m) % Recovery	Transmissivity values (Cooper-Jacob Analyses) (m^2d)	Transmissivity values (Theis Recovery Analyses) (m^2d)	Storativity
Weathered and Fractured Aquifer Zone								
TESPES 26	75.02	20.2	150	1.43	39.98	4.1	1.2	-
TESPES 34	74.91	21.17	360	0.82	20.5	2.9	1.2	4.84E-14
TESPES 61	101.1	12.93	210	1.53	47.47	6.3	2.4	-
TESPES 43	72.9	11.96	360	0.8	23.81	2.1	2.4	3.58E-04
Minimum	72.90	11.96	150.00	0.80	20.50	2.10	1.20	4.84E-14
Maximum	101.10	21.17	360.00	1.53	47.47	6.30	2.40	3.58E-04
Average	80.98	16.57	270.00	1.15	32.94	3.85	1.80	1.79E-04
Mean	74.97	16.57	285.00	1.13	31.90	3.50	1.80	1.79E-04
Harmonic Mean	79.54	15.52	235.51	1.05	29.23	3.27	1.60	9.68E-14
Geometric Mean	80.22	16.04	252.77	1.09	31.02	3.54	1.70	4.16E-09
Fractured Aquifer Zone								
TESPES 63W	84.84	21.96	360	1.04	17.66	9.2	10.7	-
TESPES 68W	96.88	16.35	360	0.4	14.44	1.1	1.1	8.46E-03
Minimum	84.84	16.35	360.00	0.40	14.44	1.10	1.10	8.46E-03
Maximum	96.88	21.96	360.00	1.04	17.66	9.20	10.70	8.46E-03
Average	90.86	19.16	360.00	0.72	16.05	5.15	5.90	8.46E-03
Mean	90.86	19.16	360.00	0.72	16.05	5.15	5.90	8.46E-03
Harmonic Mean	90.46	18.74	360.00	0.58	15.89	1.97	1.99	8.46E-03

Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	Duration of CDT (Min)	Yield of CDT (l/s)	Drawdown of CDT (m) % Recovery	Transmissivity values (Cooper-Jacob Analyses) (m^2d)	Transmissivity values (Theis Recovery Analyses) (m^2d)	Storativity
Geometric Mean	90.66	18.95	360.00	0.64	15.97	3.18	3.43	8.46E-03

6.4.2 Slug Testing

Exxaro conducted slug testing at various exploration and groundwater monitoring boreholes which are indicated on Figure 25 and summarised in Table 12.

Slug tests provide a rapid means of assessing the in-situ hydraulic conductivity in boreholes with insufficient yields (low yields) to undertake pumping tests. The test involves measuring the water-level response in a borehole to a rapid displacement of water. The displacement was induced through the introduction of a slug below the rest water level. The rate of recession of the water level displacement provides an indication of the hydraulic conductivity of the borehole. The water level responses were measured using an electronic water level data logger.

The slug testing results as interpreted by Exxaro; hydraulic parameters are summarised in Table 12. The Average, Mean, Harmonic Mean and Geometric Mean were calculated for the weathered and fractured aquifer zones, with the Harmonic Mean as one of the better estimates to describe the aquifer characteristics from the aquifer parameter data set.

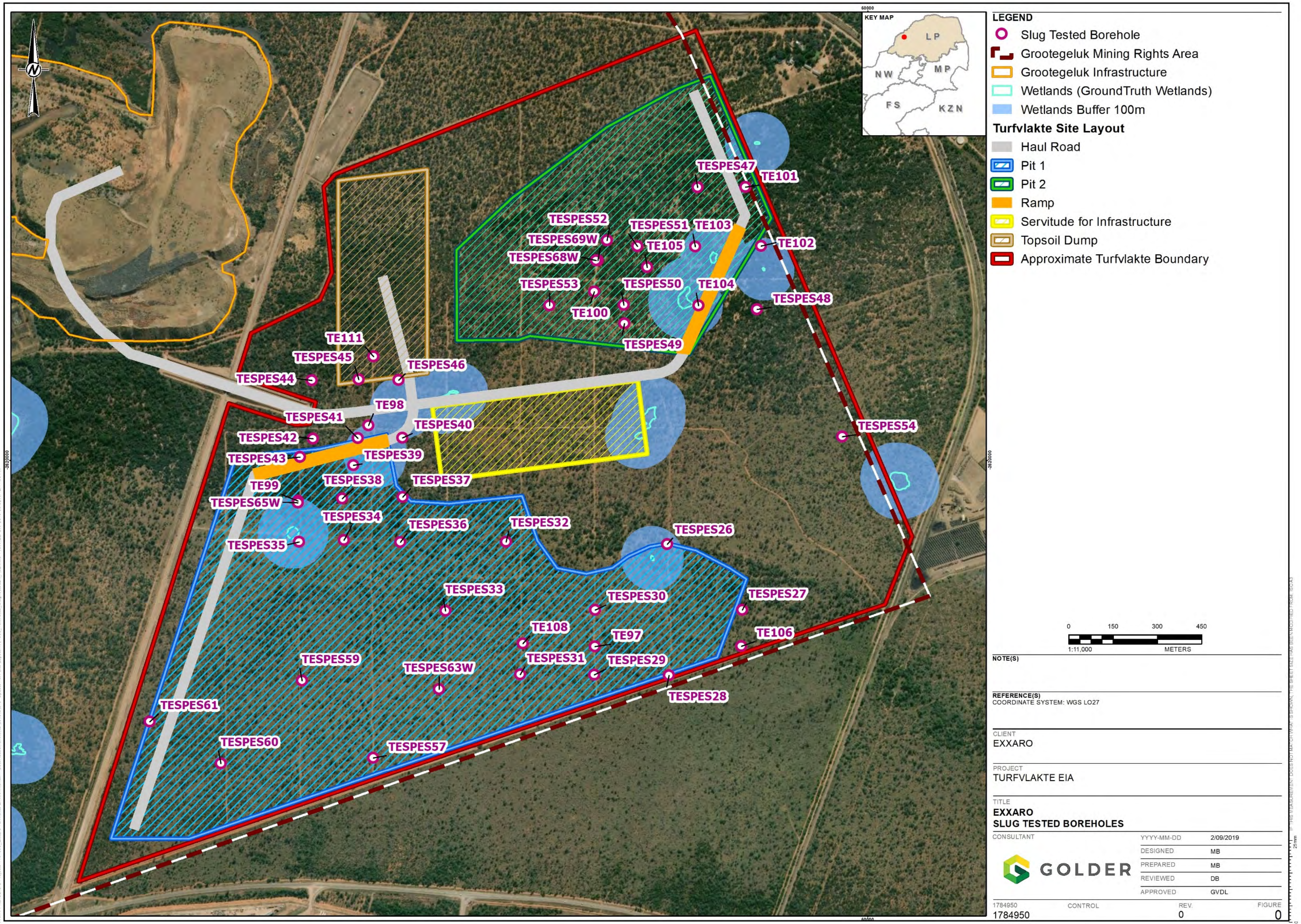


Figure 25: Exxaro Slug Tested boreholes

Table 12: Summarised Slug Testing Results

BH Number	K Formation Slug In (m/d)	K Formation Slug Out (m/d)	K Formation Average (m/d)	K Fracture Slug In (m/d)	K Fracture Slug Out (m/d)	K Fracture Average (m/d)
Fractured Aquifer						
TE98	0.1	N/A	0.1	N/A	N/A	N/A
TE111	0.08	N/A	0.08	N/A	N/A	N/A
TE104	0.09	N/A	0.09	N/A	N/A	N/A
TE97	0.08	N/A	0.08	N/A	N/A	N/A
TE101	0.05	N/A	0.05	N/A	N/A	N/A
TE108	0.08	N/A	0.08	N/A	N/A	N/A
TE99	0.06	N/A	0.06	N/A	N/A	N/A
TESPES46	0.13	N/A	0.13	N/A	N/A	N/A
TE100	0.06	N/A	0.06	N/A	N/A	N/A
TE102	0.1	N/A	0.1	N/A	N/A	N/A
TE103	0.09	N/A	0.09	N/A	N/A	N/A
TESPES68W	0.07	N/A	0.07	3.98	N/A	3.98
TESPES63W	0.14	0.08	0.18	11.98	N/A	11.98
Minimum	0.05	0.08	0.05	3.98	0.00	3.98
Maximum	0.14	0.08	0.18	11.98	0.00	11.98
Average	0.09	0.08	0.09	7.98	0.00	7.98
Mean	0.08	0.08	0.08	7.98	0.00	7.98
Harmonic Mean	0.08	0.08	0.08	5.97	0.00	5.97
Geometric Mean	0.08	0.08	0.09	6.91	0.00	6.91
Count	13	1	13	2	0	2

BH Number	K Formation Slug In (m/d)	K Formation Slug Out (m/d)	K Formation Average (m/d)	K Fracture Slug In (m/d)	K Fracture Slug Out (m/d)	K Fracture Average (m/d)
Weathered and Fractured Aquifer (Combined Aquifer zones)						
TESPES28	0.09	N/A	N/A	N/A	N/A	N/A
TESPES69W	0.25	N/A	N/A	N/A	N/A	N/A
TESPES49	0.08	N/A	N/A	N/A	N/A	N/A
TESPES59	0.08	N/A	N/A	N/A	N/A	N/A
TE106	0.06	N/A	N/A	N/A	N/A	N/A
TESPES60	0.07	N/A	N/A	N/A	N/A	N/A
TESPES50	0.07	N/A	N/A	N/A	N/A	N/A
TESPES57	0.06	N/A	N/A	N/A	N/A	N/A
TESPES41	0.1	N/A	N/A	N/A	N/A	N/A
TESPES44	0.08	N/A	N/A	N/A	N/A	N/A
TESPES27	0.07	N/A	N/A	N/A	N/A	N/A
TESPES33	0.09	N/A	N/A	N/A	N/A	N/A
TESPES39	0.1	N/A	N/A	N/A	N/A	N/A
TESPES35	0.08	N/A	N/A	N/A	N/A	N/A
TESPES30	0.11	N/A	N/A	N/A	N/A	N/A
TESPES51	0.07	N/A	N/A	N/A	N/A	N/A
TESPES45	0.1	N/A	N/A	N/A	N/A	N/A
TESPES29	0.09	N/A	N/A	2.48	N/A	N/A
TESPES40	91	N/A	N/A	3.07	N/A	N/A
TESPES38	0.09	N/A	N/A	3.93	N/A	N/A
TESPES32	0.11	N/A	N/A	3.42	N/A	N/A
TESPES48	0.08	N/A	N/A	4.8	N/A	N/A
TESPES37	0.1	N/A	N/A	7.57	N/A	N/A

BH Number	K Formation Slug In (m/d)	K Formation Slug Out (m/d)	K Formation Average (m/d)	K Fracture Slug In (m/d)	K Fracture Slug Out (m/d)	K Fracture Average (m/d)
TESPES42	0.15	0.16	0.23	10.12	25.18	22.71
TESPES52	0.25	0.22	0.36	175.51	1134.36	742.69
TESPES47	0.13	0.3	0.28	45.18	64.9	77.63
TESPES31	0.08	N/A	0.08	4.83	N/A	4.83
TESPES36	0.12	0.12	0.18	7.97	9.1	12.52
TESPES61	0.11	0.14	0.18	84.7	116.86	143.14
TESPES43	0.18	0.14	0.25	62.34	43.76	84.22
TE105	0.1	0.08	0.14	10.38	6.36	13.56
TESPES26	1.94	2.19	3.04	605.08	893.27	1051.71
TESPES34	0.22	0.17	0.31	28.93	14.94	36.4
TESPES65W	0.91	0.38	1.1	41.13	36.59	59.42
TESPES54	1.89	1.19	2.49	1134.36	387.4	1328.06
Minimum	0.06	0.08	0.08	2.48	6.36	4.83
Maximum	91.00	2.19	3.04	1134.36	1134.36	1328.06
Average	2.83	0.46	0.72	124.21	248.43	298.07
Mean	0.10	0.17	0.27	10.25	43.76	68.53
Harmonic Mean	0.11	0.19	0.24	7.96	24.31	24.80
Geometric Mean	0.15	0.26	0.36	20.76	66.02	76.33
Count	35	11	12	18	11	12

Note: N/A – Not Applicable

7.0 GROUNDWATER QUALITY – 2018

The groundwater baseline quality of the investigation area is represented by 12 samples:

- Six Hydrocensus samples; and
- Six CDT samples and two duplicates.

7.1.1 Water Quality Standards

The analytical results of the groundwater samples were compared to the following standards;

- DWAF, Agriculture use, livestock watering, volume 5 (1996); and
- DWAF, domestic water quality guidelines, volume 1(1996) and Water Research Commission (WRC), Water Quality Guidelines, 1998.

The DWAF Agriculture use for livestock watering target water quality range, with no adverse effects to live stock is used as reference, whereas the DWAF 1996 guidelines were used to classify and discuss the water quality classes (Table 13).

Table 13: WRC Water Quality Classes (1998)

Water quality class	Description	Drinking health effects
Class 0	Ideal water quality	No effects, suitable for many generations.
Class 1	Good water quality	Suitable for lifetime use. Rare instances of sub-clinical effects.
Class 2	Marginal water quality, water suitable for short-term use only	May be used without health effects by majority of users but may cause effects in some sensitive groups. Some effects possible after lifetime use.
Class 3	Poor water quality	Poses a risk of chronic health effects, especially in babies, children and the elderly. May be used for short-term emergency supply with no alternative supplies available.
Class 4	Unacceptable water quality	Severe acute health effects, even with short-term use.

7.1.2 Groundwater Analytical Results 2017

The analytical results of the 14 groundwater samples (including two duplicates highlighted as blue) are listed in Table 14 and indicated on Figure 26. A highlighted value in red exceeds the DWAF Agriculture use for livestock watering target water quality range, whereas the water quality classes are classified using the DWAF (199) Drinking Water Standards (black highlighted values exceed Class 0 values).

The groundwater quality of the investigation area is mainly represented by poor (Class 3) to unacceptable drinking water quality (Class 4).

The following constituents exceed the DWAF (1996), Agriculture use target water quality range limit; TDS, Cl, F, Fe, and SO_4 concentrations. These elevated hydrochemical concentrations are probably related to historical mining activities (mine water discharge) and in a smaller percentage to the local geology.

Table 14: Summarised Analytical Results

Borehole Number	PH	EC (mS/m)	TDS (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	Total Alkalinity $CaC0_3$ (mg/l)	Cl (mg/l)	SO_4 (mg/l)	NO_3 as N (mg/l)	F (mg/l)	Cu (mg/l)	Mn (mg/l)	Fe (mg/l)	Zn (mg/l)	Al (mg/l)	Cr (mg/l)	Water Quality Class
TESPES 34	6.8	**358**	**2890**	**323**	**148**	**391**	10.9	349	**607**	**867**	0.43	0.551	0.027	**0.679**	<0.01	**0.679**	<0.001	<0.001	3
TESPES 63	6.86	**766**	**5390**	**691**	**306**	**537**	**36.4**	372	**1100**	**1930**	0.59	0.551	0.039	**0.988**	<0.01	**0.988**	<0.001	<0.001	4
TESPES 61	5.81	**516**	**3620**	**536**	**158**	**345**	**61.5**	90.3	**302**	**1930**	<0.3	**0.768**	0.025	**2.06**	**0.128**	**2.06**	0.386	<0.001	3
TESPES 68	6.69	**89.9**	**618**	**100**	35.6	60.9	3.92	273	68.4	138	<0.13	0.21	0.007	**0.298**	<0.01	0.298	0.005	<0.001	1
TESPES 26	6.43	**454**	**3670**	**390**	**200**	**504**	20.4	350	**900**	**1070**	0.63	0.391	0.035	**1.13**	<0.01	**1.13**	<0.001	<0.001	4
TESPESE 841 (duplicate TESPES 34)	6.77	**358**	**2900**	**327**	147	**388**	10.8	352	**605**	**851**	0.44	0.522	0.03	**0.665**	<0.01	**0.665**	<0.001	<0.001	3
TESPESE 681 (duplicate TESPES 63)	6.84	**770**	**5180**	**695**	299	**512**	**34.1**	374	**1080**	**1900**	0.58	0.485	0.045	**0.991**	<0.01	**0.991**	<0.001	<0.001	4
TESPES 43	6.57	**163**	**1220**	**132**	**79.6**	**168**	4.43	374	**153**	**326**	2.21	0.602	0.017	**0.206**	<0.01	0.206	0.02	<0.001	2
TESPES 59	6.75	**1010**	**7060**	**761**	**497**	**731**	**87.6**	476	**1690**	**2450**	1.14	**1.12**	0.071	**1.2**	**77.6**	1.2	<0.001	<0.001	4
TESPES 28	6.68	**705**	**5580**	**574**	**419**	**438**	**43.7**	127	**2320**	**559**	1.73	0.65	0.045	**1.14**	**14**	1.14	<0.001	<0.001	4
WBR 46	6.82	**757**	**5630**	**325**	**285**	**1100**	**150**	644	**1910**	**800**	**20.4**	**3.65**	0.132	**0.316**	<0.01	0.316	0.009	<0.001	4
WBR 50	7.1	**309**	**2050**	**138**	**95.9**	**418**	**31.1**	351	**691**	**276**	0.54	**3.34**	0.14	**0.448**	<0.01	0.448	<0.001	<0.001	3
WBR 01	7.44	42.1	302	35	18.4	37.2	2.33	189	25.2	2.11	2.21	0.211	0.044	0.002	<0.01	0.002	<0.001	0.001	0
TESPES 47	7.09	**114**	**770**	**102**	55.1	**100**	3.24	361	**113**	137	<0.3	**0.714**	0.041	0.235	<0.01	0.235	<0.001	<0.001	1
DWAF Agriculture use, livestock watering. Target Water Quality Range – with no adverse effects	-	-	0-1000	0-1000	0-500	0-2000	-	-	0-1500	0-1000	0-100	0-2	0-0.5	0-10	0-10	0-20	0-5	0-1	
Class 0 Max. Allowable Limit	9.5	<70	<450	<80	<70	<100	<25	-	<100	<200	<6	<0.7	<0.1	<0.1	<0.01	-	-	-	
Class 1 Max. Allowable Limit	10	150	1000	150	100	200	50	-	200	400	10	0.7-1.0	1.0-1.3	0.1-0.4	0.01-0.2	-	-	-	
Class 2 Max. Allowable Limit	10.5	370	2400	300	200	400	100	-	600	600	20	1.0-1.5	1.3-2.0	1.0-4.0	0.2-2.0	-	-	-	
Class 3 Max. Allowable Limit	11	520	3400	>300	400	1000	500	-	1200	1000	40	1.5-3.5	2.0-15	4.0-10.0	2.0-10.0	-	-	-	
Class 4 Max. Allowable Limit	>11	>520	>3400	>300	>400	>1000	>500	-	>1200	>1000	>40	>3.5	>15	>10.0	>10.0	-	-	-	
Minimum	5.81	42.1	302	35	18.4	37.2	2.33	90.3	25.2	2.11	0.43	0.21	0.007	0.002	0.128	0.002	0.005	0.001	
Maximum	7.44	1010	7060	761	497	1100	150	644	2320	2450	20.4	3.65	0.14	2.06	77.6	2.06	0.386	0.001	
Average	6.76	458	3349	366	196.0	409.3	35.74	334.5	826	945	2.81	0.983	0.050	0.740	30.58	0.740	0.105	0.001	

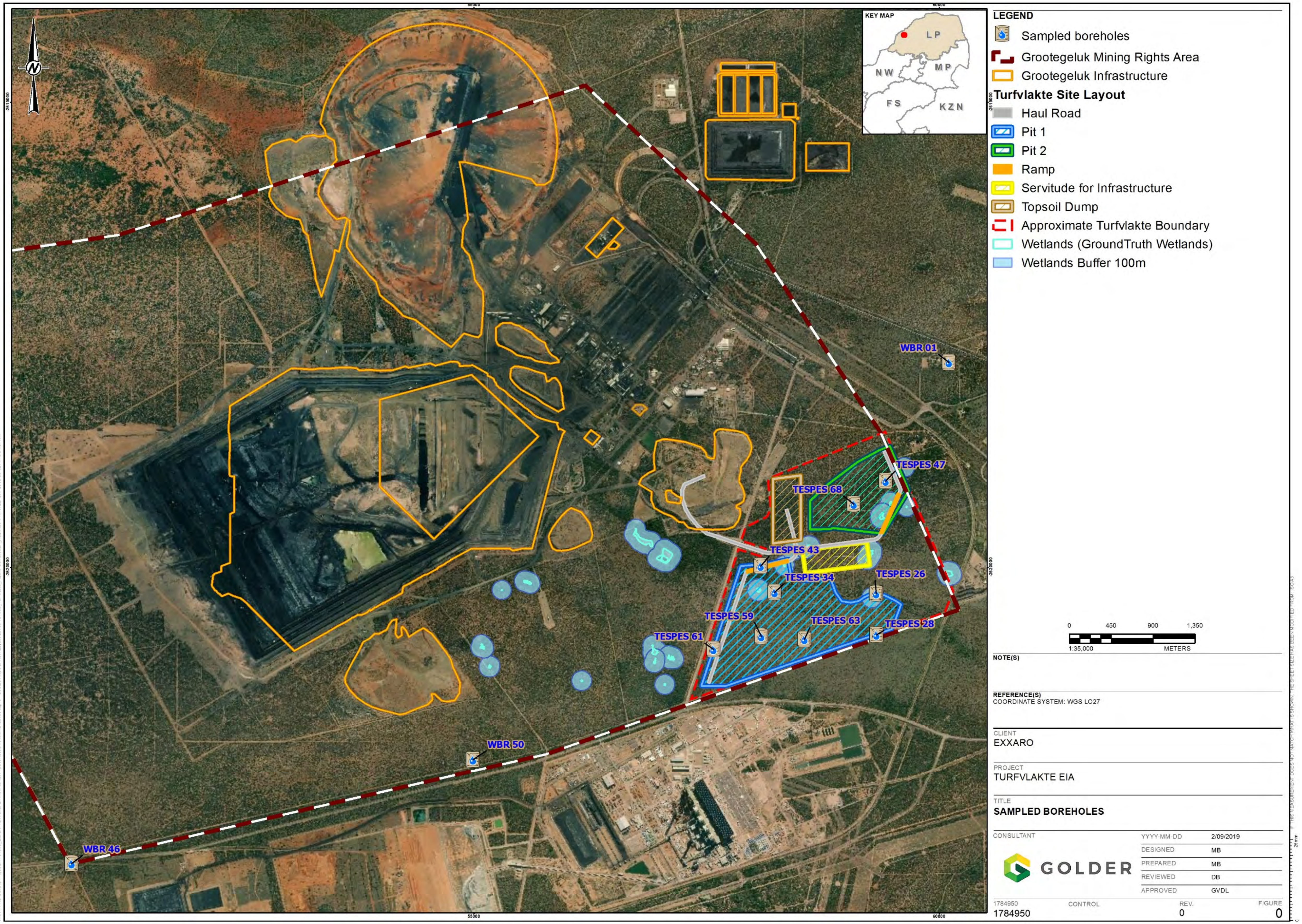


Figure 26: Sampled Boreholes

7.1.3 Groundwater Classification

The groundwater quality results of the representative sampled boreholes are visually represented on an expanded Durov and Piper diagrams to distinguish between the different water quality classes/types.

7.1.3.1 *Expanded Durov Diagram*

Expanded Durov diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted on the top part of the diagram and the anion percentages on the left part. A projection of these cation and anion percentages onto the central area presents the chemical signature of the major ion composition of the water. The chemical signature can be related to various hydrochemical environments and conditions.

On the Expanded Durov Diagram (Figure 27) three of the samples TESPES 68, TESPES 47 and WBR1 plot on blue sector of the diagram and represent background groundwater (calcium magnesium bicarbonate type of water ((Ca, Mg)$(HCO_3)_2$).

Whereas most of the boreholes plot on the red sector and is representative of magnesium sulphate type of water (Mg)SO_4. The plot position on the diagram indicates impacted water with magnesium and sulphate enrichment. These types of enrichment are typical of coal mining environments.

TESPES 28 plot on the purple sector (type of water is seldom found), and are representative of magnesium chloride type of water (Mg) Cl. The plot position on the diagram indicates water with minor magnesium and chloride enrichment.

WBR46 and WBR50 plot on the green sector representative of sodium, potassium chloride type of water (Na, K)Cl. The plot position on the diagram indicates water with minor sodium, potassium and chloride enrichment, associated with natural saline water and deep mine water.

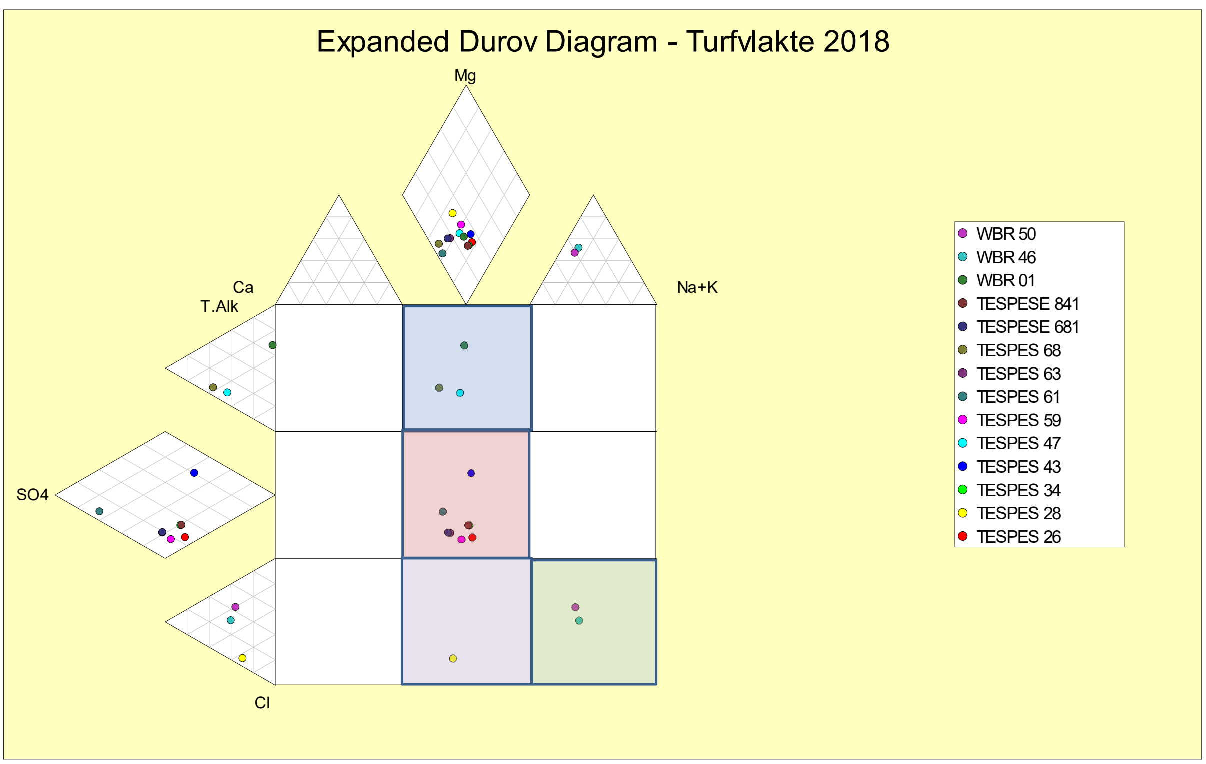


Figure 27: Expanded Durov Diagram - 2018

7.1.3.2 Piper Diagram

Piper diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted on the left triangle and the anion percentages on the right triangle. A projection of these cation and anion presentations onto the central diamond presents the chemical signature of the major ion composition of the water.

The sampled boreholes TESPES 68, TESPES 47 and WBR01, plot on blue sector of the Piper diagram and show a signature of calcium magnesium bicarbonate type of water $(Ca,Mg)(HCO_3)_2$. This type of water is associated with recent rainfall recharge and not impacted groundwater.

The majority of sampled boreholes groundwater quality on the Piper diagram (Figure 28) show a signature of calcium/magnesium sulphate type of water $(Ca,Mg)SO_4$ (red sector). Whereas sampled boreholes WBR46 and WBR50 show a signature of sodium potassium chloride type of water respectively ((Na,K)Cl).

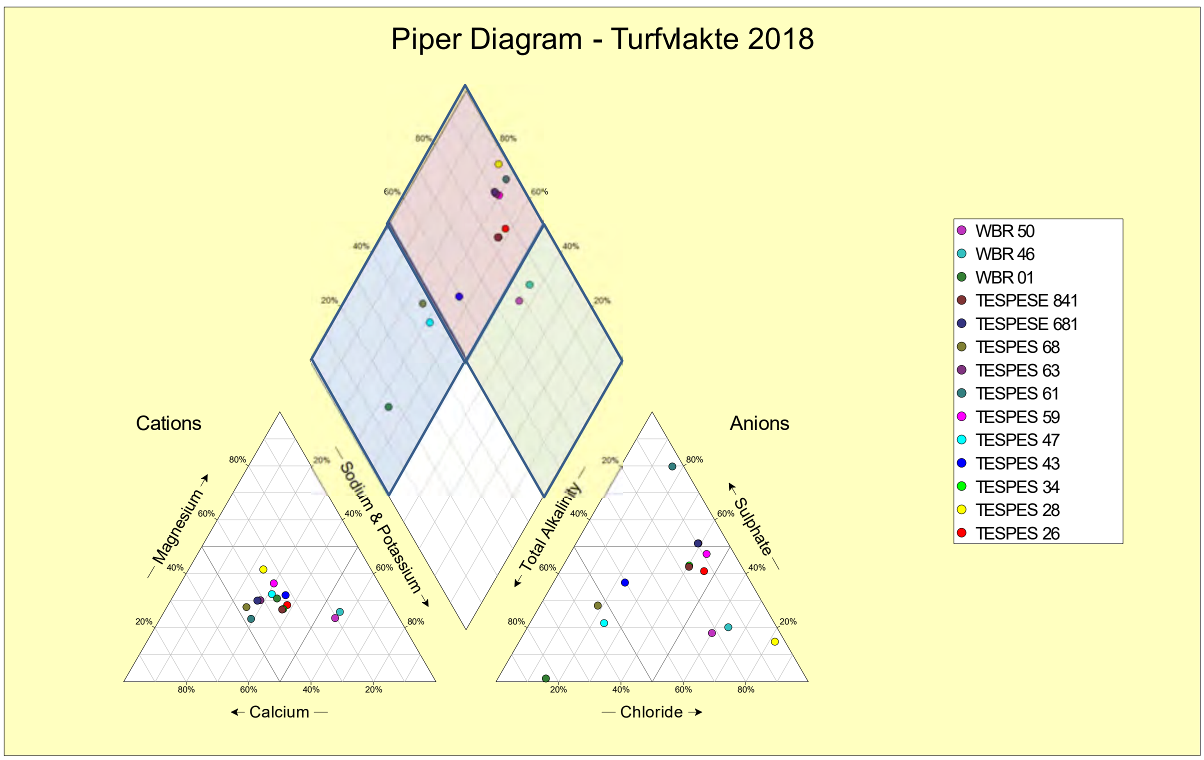


Figure 28: Piper Diagram - 2017

7.1.4 Baseline and Background Groundwater Quality 2018

The 2018 Turfvlakte baseline/background groundwater quality is based on macro chemistry analyses of the nine groundwater samples collected on Turfvlakte Project Area during the hydrocensus and aquifer testing programme.

The properties of groundwater are overwhelmingly determined by hydrogeochemical processes taking place as rain or surface water enter the ground and react with rock-forming minerals. This natural baseline quality will vary between geological formations (rock types), therefore, each area will be characterised by an almost unique groundwater quality type resulting from the influence of the local geology. The baseline may vary spatially within aquifers of the same type due to variations in the original sediments known as lithofacies. The chemistry also evolves with time as the water moves along flow lines.

A number of geochemical processes for example oxidation and reduction (controlling natural levels of Fe, Mn, As and Cr), mineral solubility (controlling F and Ba concentrations), and sorption and exchange with mineral surfaces (affecting the concentrations of many metals and ionic constituents) may help shape the unique natural characteristics of groundwater (Golder 2017).

Baseline concentrations of a substance in groundwater may be defined in several different ways. It is impossible to decide if groundwater is polluted/impacted unless the baseline is known. An ideal starting point is to locate waters where there are no traces of anthropological impacts, however at Turfvlakte (pre-mining period) the sampled boreholes are already impacted and will represent a background water quality or current groundwater conditions, which can be used as a benchmark against which the results of future groundwater quality can be monitored to evaluate any associated impacts from the proposed Turfvlakte mining project on the groundwater system.

The hydrochemical concentrations are compared to the DWAF (1996) Agriculture livestock water use, target water quality range limit and the baseline quality are represented by the Median of the concentrations. The background water quality representative of the sampled Turfvlakte boreholes are summarised in Table 15 below.

Table 15: Baseline Groundwater Quality

Item	Physical Parameters			Macro Determinants (Major Ions and Trace Metals)								Minor Determinant		
	pH	EC	TDS	Ca	Mg	Na	K	Cl	SO_4	NO3 as N	MALK	F	Fe	Mn
		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	Mg/l	mg/l	mg/l	mg/l
No. of Records	9	9	9	9	9	9	9	9	9	9	9	9	9	9
10% Percentile	5.81	89.9	618	100	35.6	60.9	3.24	68.4	137	0.13	90.3	68.4	0.01	0.206
Median Baseline Water Quality	6.69	454	3620	390	158	391	20.4	607	867	0.59	350	607	0.01	0.988
Average	6.63	464.0	3424	401	210.9	363.9	30.2	805.9	1045.22	0.829	308.03	805.93	10.20	0.882
90% Percentile	7.09	1010	7060	761	497	731	87.6	2320	2450	2.21	476	2320	77.6	2.06
DWAF Agriculture use, livestock watering. Target Water Quality Range – with no adverse effects	-	-	0-1000	0-1000	0-500	0-2000	-	0-1500	0-1000	0-100	-	0-2	0-10	0-10

7.1.5 Correlation of Duplicate Samples

Two duplicate groundwater samples were taken during the aquifer tested program at TESPES 34 and TESPES 63 to compare analytical results. The chemical elements as per Table 14 of the duplicate samples were compared as indicated in Figure 29 and Figure 30 and showed a 100% (TESPES 34) and 99.9% (TESPES 63) correlation respectively.

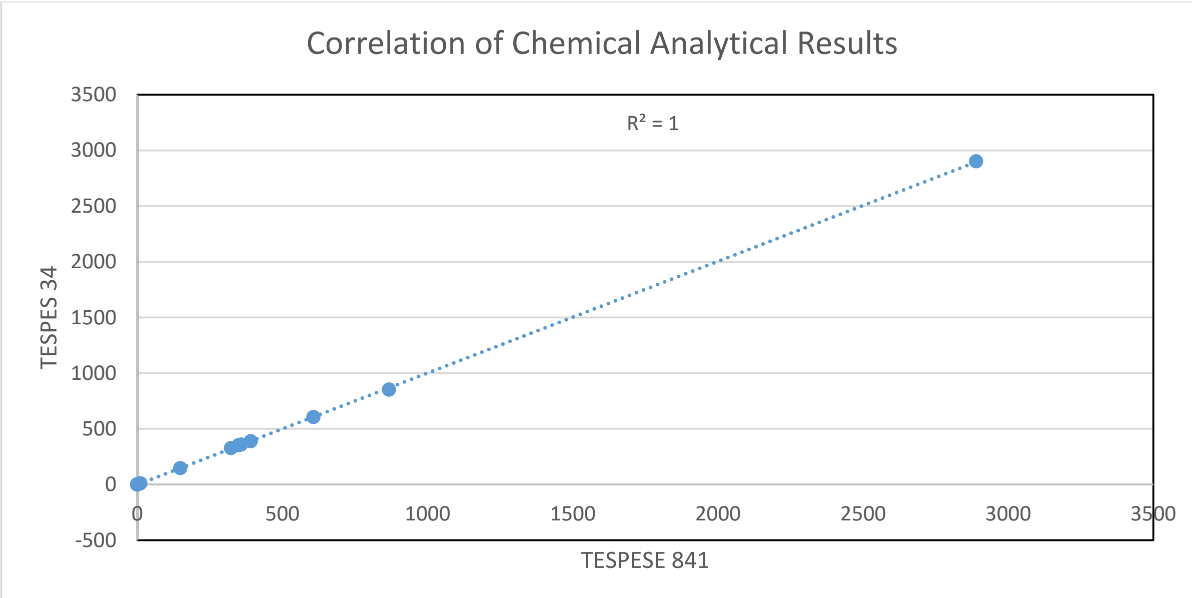


Figure 29: Correlation of Duplicate Samples TESPES 34

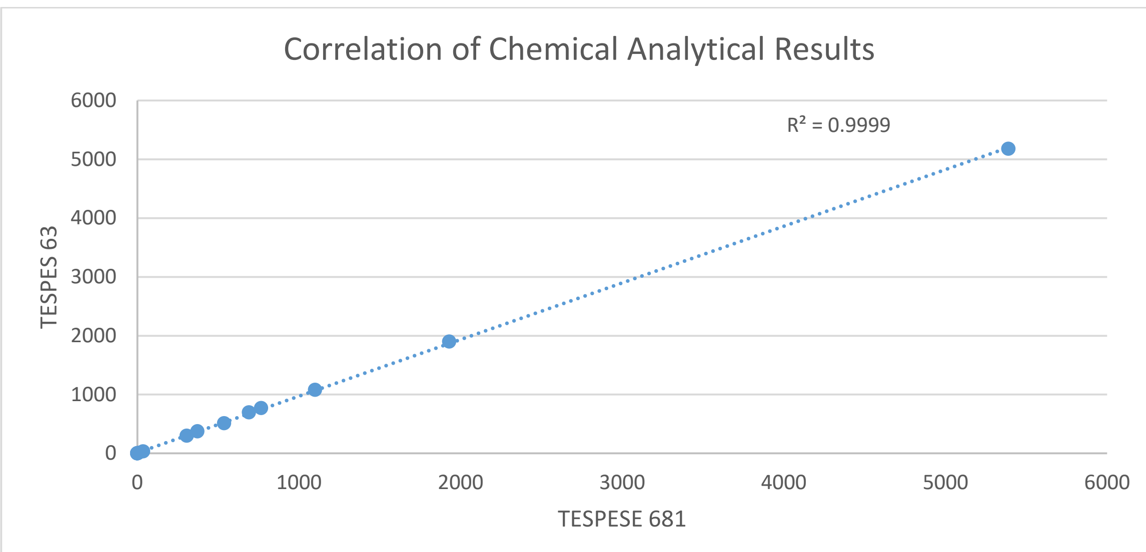


Figure 30: Correlation of Duplicate Samples TESPES 63

7.1.6 Verification of Groundwater Monitoring Data

Two existing monitoring boreholes (WBR01 and WBR50), were sampled during the hydrocensus (01/2018; Table 14) in order to verify the results with existing monitoring data from the Exxaro database (11/2017)(Table 16). The two sets of chemical results as indicated in Figure 31 to Figure 32 showed an exceptional 99.9% correlation respectively.

Table 16: Summarised Analytical Results - Exxaro Data Base

BH No.	WL (mbgl)	Date Sampled	pH	EC [mS/m]	TDS [mg/l]	M Alk. [mg/l CaCO3]	Ca [mg/l]	K [mg/l]	Mg [mg/l]	Na [mg/l]	F [mg/l]	Cl [mg/l]	NO3 as N [mg/l]	SO4 [mg/l]	Al [mg/l]	Cr [mg/l]	Cu [mg/l]	Fe [mg/l]	Mn [mg/l]	Zn [mg/l]
WBR01	-	15/11/2017	7.42	42.1	286	187	31.8	1.87	17.9	40.4	0.132	25.3	2.33	2.18	0.014	<0.001	<0.001	<0.01	<0.001	<0.001
WBR50	75.3	16/11/2017	7.26	318	2130	351	128	29.5	96	438	3.14	731	<0.13	280	<0.001	<0.001	0.003	<0.01	0.491	<0.001

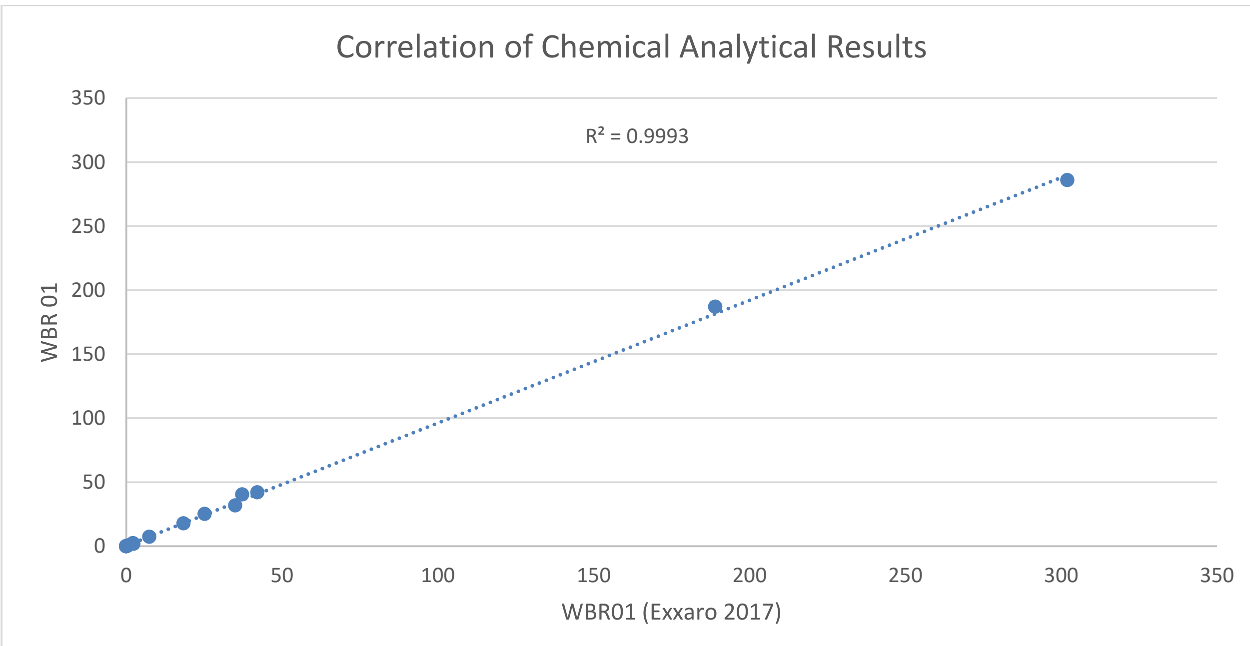


Figure 31: Correlation of WBR1 – Database and Hydrocensus Samples

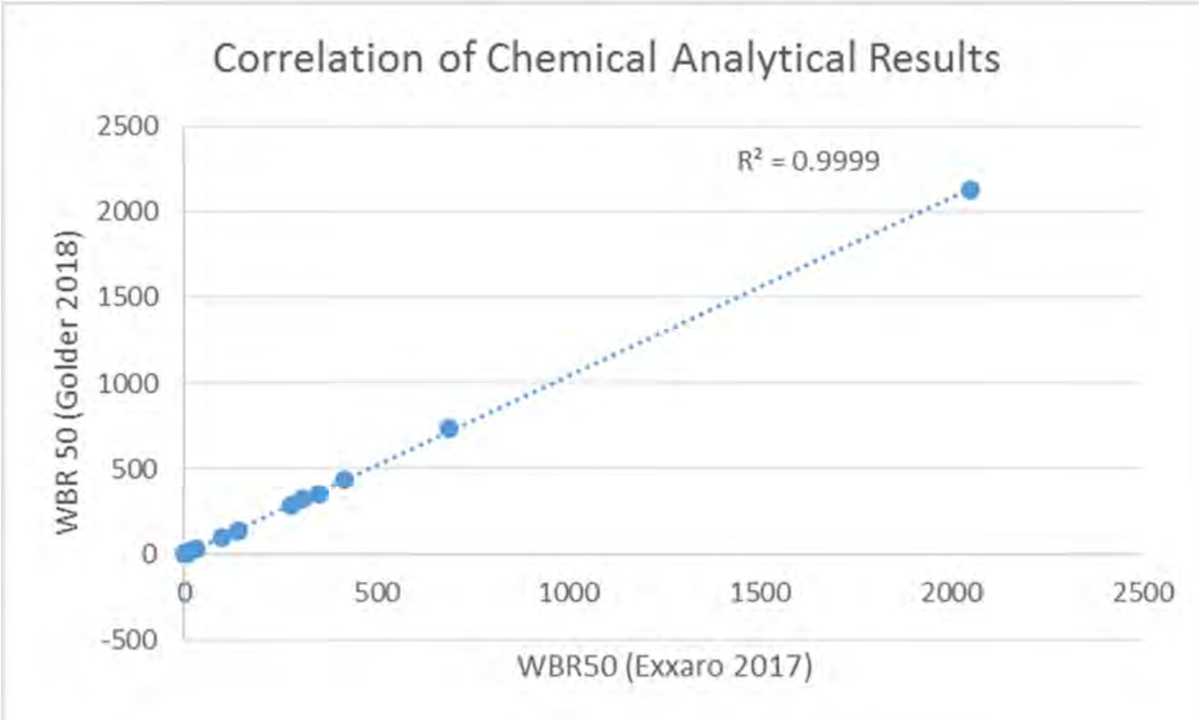


Figure 32: Correlation of WBR 50 – Database and Hydrocensus Samples

7.1.7 Possible Impacted Boreholes

The latest Sulphate and EC concentrations, of the sampled boreholes were classed based on the DWAF Water Quality Classification and are indicated on Figure 33 and Figure 34. The groundwater quality status of these boreholes was used to illustrate any potential deterioration of groundwater quality in the sampled boreholes of Turfvlakte.

From this classification, it is evident that the groundwater quality of the boreholes located in the middle of Turfvlakte and WBR46 are probably impacted from historical mining activities.

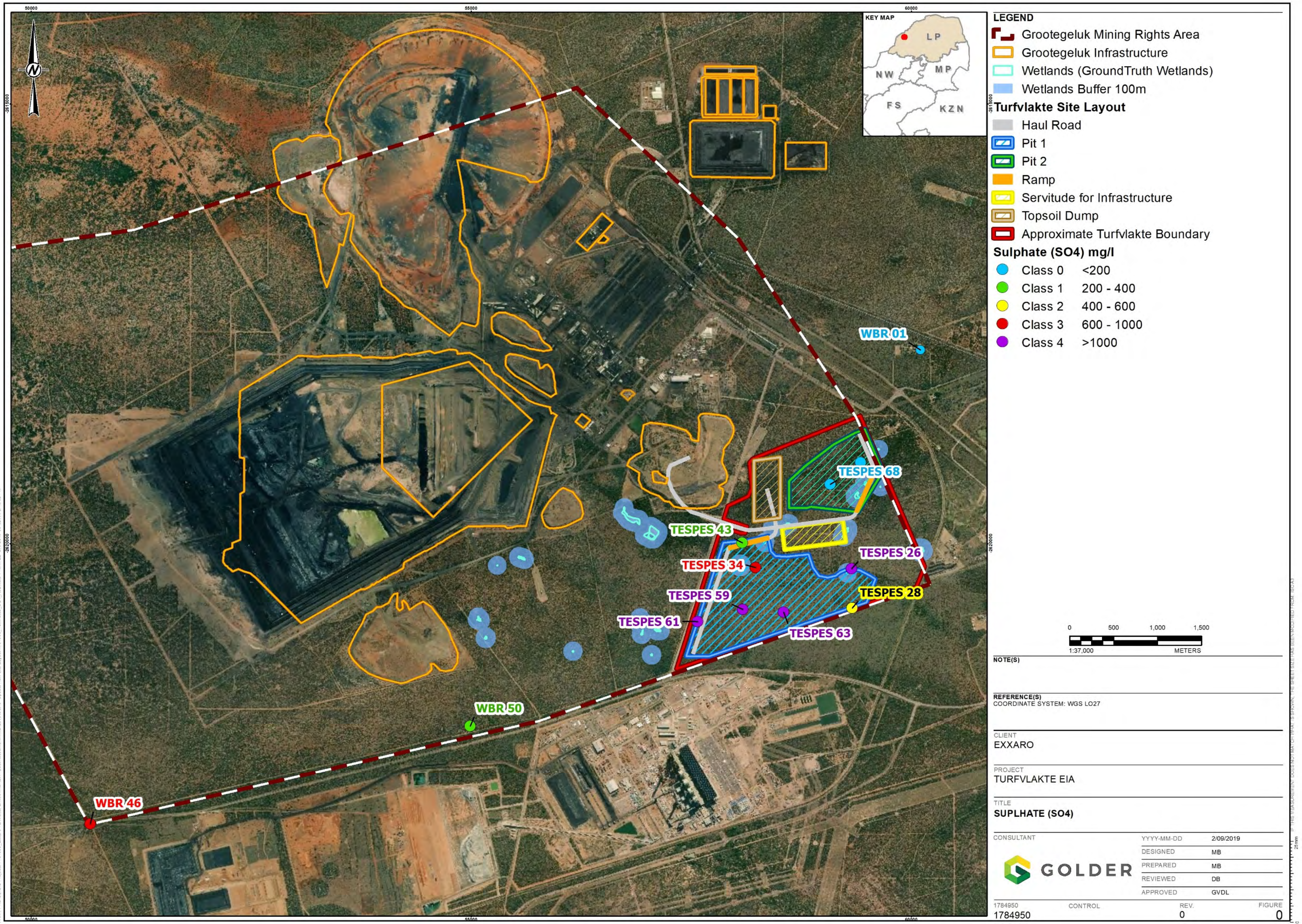


Figure 33: Sulphate Concentrations (mg/l)

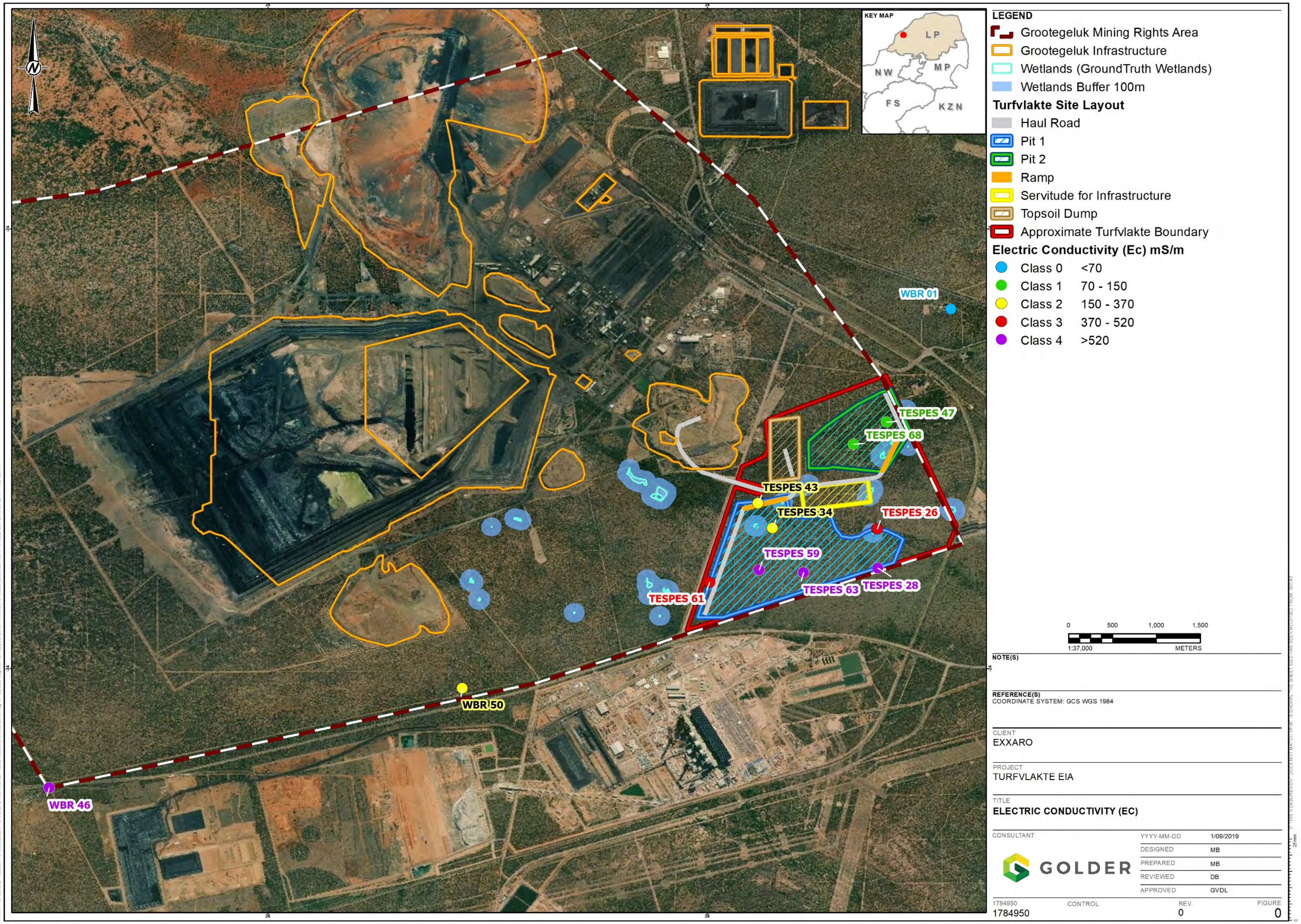


Figure 34: EC Concentrations (mS/m)