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Farm Kloof 143 Portion Diamantgat Groundwater Assessment, Siyathemba Local Municipality, Northern Cape Province.

Report Prepared for

Mr Pieter Smit

Report Number 1905

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Disclaimer

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

Glossary of Terms

Aquifer	A water-bearing geological formation capable of supplying economic quantities of groundwater to wells, boreholes and springs.
Anticline	A fold of rock layers that slope downward on both sides of a common crest
Contamination	The introduction of any substance into the environment by the action of man.
Fractured-rock Aquifer	Aquifers where groundwater occurs within fractures and fissures in hard-rock formations.
Graben	An elongated trough of land produced by subsidence of the earth's crust between two faults
Groundwater	Refers to the water filling the pores and voids in geological formations below the water table.
Groundwater Flow	The movement of water through openings and pore spaces in rocks below the water table i.e. in the saturated zone. Groundwater naturally drains from higher lying areas to low lying areas such as rivers, lakes and the oceans. The rate of flow depends on the slope of the water table and the transmissivity of the geological formations.
Groundwater Recharge	Refers to the portion of rainfall that actually infiltrates the soil, percolates under gravity through the unsaturated zone (also called the Vadose Zone) down to the saturated zone below the water table (also called the Phreatic Zone).
Groundwater Resource	All groundwater available for beneficial use, including by man, aquatic ecosystems and the greater environment.
Groundwater Resource Units	(GRU's) Represent provisional zones defined for the purposes of assessing and managing the groundwater resources of a region, in terms of large-scale abstraction from relatively shallow (depth < 300m) production boreholes. They represent areas where the broad geohydrological characteristics (i.e. water occurrence and quality, hydraulic properties, flow regime, aquifer boundary conditions etc.) are anticipated to be similar.
Permeability	The ease with which a fluid can pass through a porous medium and is defined as the volume of fluid discharged from a unit area of an aquifer under unit hydraulic gradient in unit time (expressed as $m^3/m^2 \cdot d$ or m/d). It is an intrinsic property of the porous medium and is independent of the properties of the saturating fluid; not to be confused with *hydraulic conductivity*, which relates specifically to the movement of water.
Pollution	The introduction into the environment of any substance by the action of man that is, or results in, significant harmful effects to man or the environment.
Recharge	The addition of water to the zone of saturation, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Storativity (S)	The volume of water released from storage per unit of aquifer storage area per unit change in head.
Syncline	A fold of rock layers that slope upward on both sides of a common low point
Synclinorium	A large syncline with superimposed smaller folds

Unconfined Aquifer	An aquifer with no confining layer between the water table and the ground surface where the water table is free to fluctuate.
Unsaturated Zone	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water; synonymous with *zone of aeration* or *vadose zone*.
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is at atmospheric pressure, the depth to which may fluctuate seasonally.

List of Abbreviations

DWS	Department of Water and Sanitation
EC	Electrical Conductivity (salinity of water)
GSU	Great Stock Unit
GA	General Authorisation
m	metres
mamsl	metres above mean sea level
mbgl	metres below ground level
mS/m	milli-Siemens per metre
m^3/a	cubic metres per annum
mm	millimetres
m^3/m	cubic metres per month
mg/ℓ	milligrams per litre
Ma	Million years
MAP	Mean annual precipitation or rainfall
NGA	National Groundwater Archive
WULA	Water Use License Application

1 Introduction

1.1 Appointment

The consultant was telephonically contacted by Mr Smit on 11 April 2019 to submit a cost proposal for the compilation of a hydrogeological report to be submitted for a Water Use License Application (WULA). A cost proposal was submitted on 15 April 2019 which was subsequently accepted by Mr Smit.

The site is located approximately 15 km northeast of Niekerkshoop in the Northern Cape Province. It falls within the jurisdiction area of the Siyathemba Local Municipality which in turn forms part of the Pixley Ka Seme District Municipality (see **Figure 1** and **Figure 2**).

1.2 Scope of Report

The Scope of Work supplied by Mr Smit was for a geohydrological study for a WULA.

The deliverables for the groundwater study report includes:

a. A preliminary assessment of the baseline groundwater conditions at the site;
b. Yield testing of the proposed production boreholes;
c. Potential impacts of the proposed prospecting activities on groundwater at the site and surrounds;
d. Mitigation measures to limit these groundwater impacts; and
e. A monitoring programme to monitor potential groundwater impacts (quantity and quality).

In order to carry out a preliminary assessment of hydrogeological conditions at the site and its surrounds, the following was proposed:

1. Collate available groundwater information such as those data at the Department of Water Affairs' (DWA) national groundwater archives (NGA), the DWA 1:500 000 hydrogeological map series, the DWA phase 2 national groundwater resource assessment data, satellite images and published geological maps and reports;
2. Conduct a hydrocensus of the site and the surrounding area (1 km radius).
3. Undertake satellite image lineament mapping for the area to ascertain if there are any significant faults or dykes near or beneath the site which may form a conduit for movement of contaminants into the aquifer;
4. Capture the data collected in a GIS database and produce maps for the report;
5. Assess impacts on groundwater and recommend mitigation measures to reduce the potential impacts; and
6. Compile and submit a final report in which the groundwater baseline conditions and impacts will be described and the results and recommendations summarized.

1.3 Purpose of Report

The purpose of this report is to provide an independent hydrogeological assessment of the groundwater conditions and resources at the site, and to carry out a preliminary assessment of the potential groundwater impacts that are likely to arise as a result of the proposed abstraction for irrigation purposes. In addition, it is a requirement to advise the client about necessary precautions to be taken to protect the groundwater resources of the area.

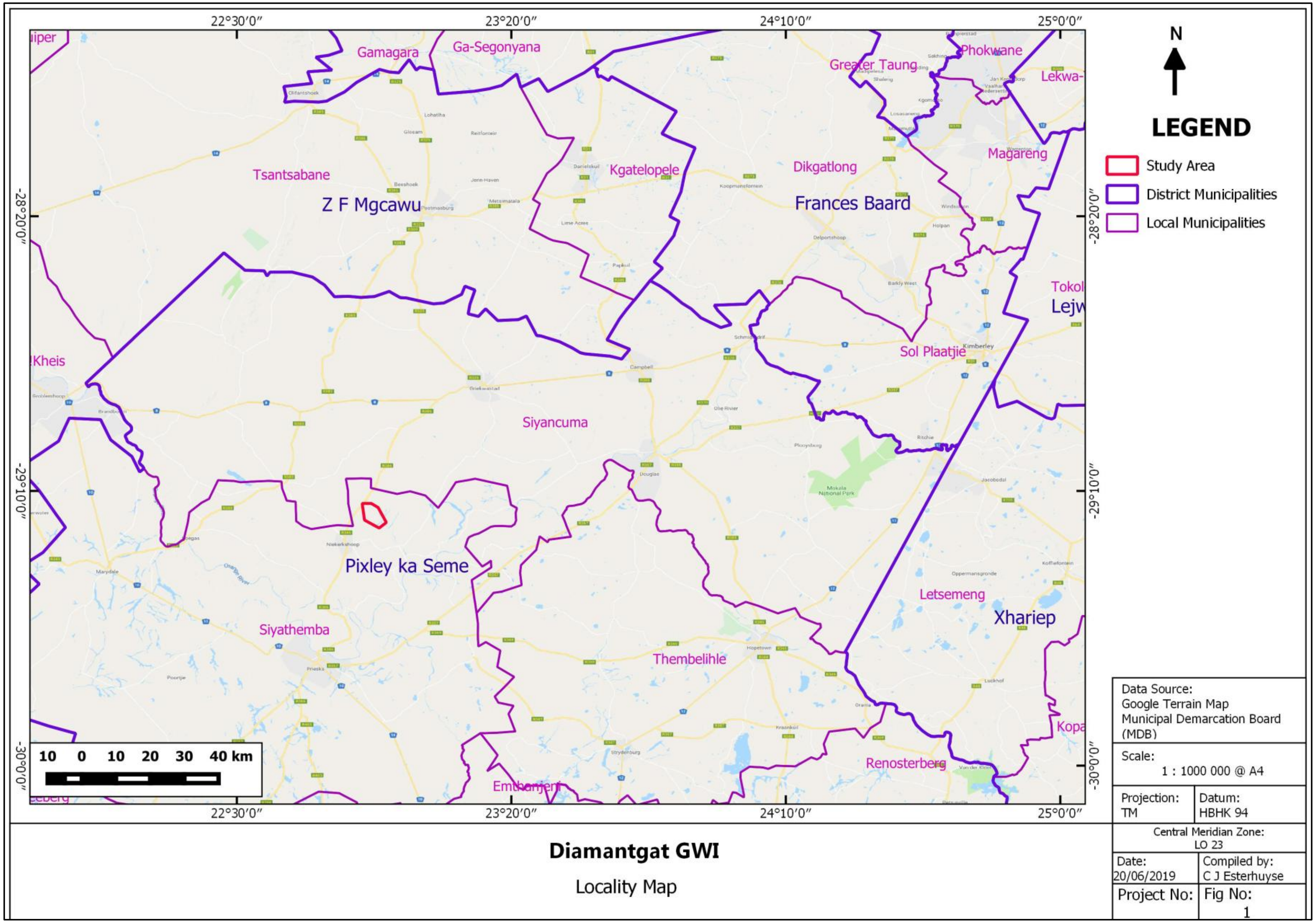


Figure 1: Locality Map

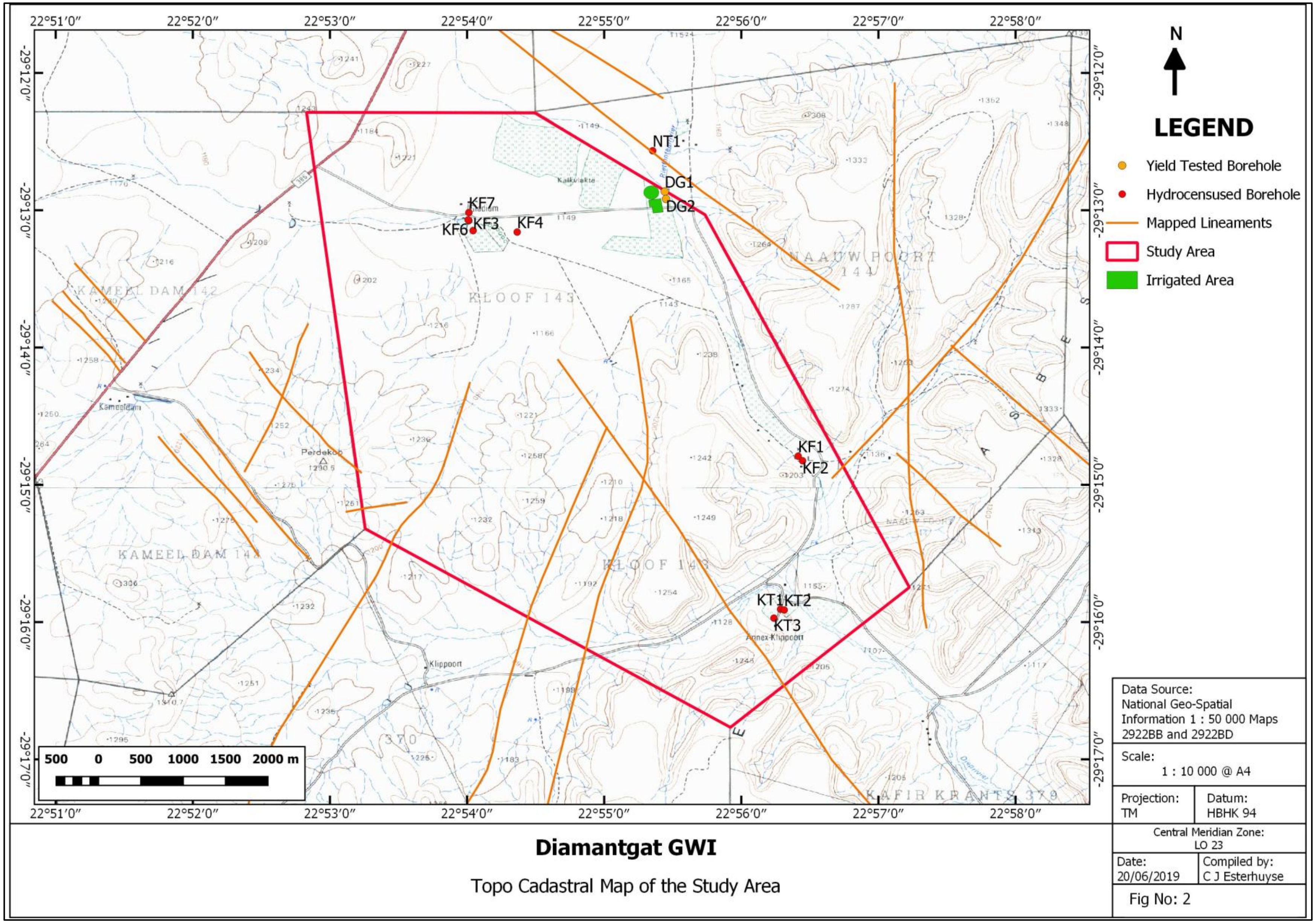


Figure 2: Topo Cadastral Map of Study Area

1.4 Project Description

Approximately 5 ha is currently under irrigation at Diamantgat. Irrigation water is obtained from two production boreholes at the site. However, a Water Use License has not been issued for this abstraction and DWS informed the client to either apply for a Water Use License or cease the irrigation activities. The client decided to opt for a Water Use License and is currently in the process of applying for a Water Use License to irrigate 5.2 ha. This specialist study is needed to support the WULA. Proposed production boreholes were yield tested by the client and yield test data were analysed to determine the long term sustainable yield of these boreholes. The calculated water demand for irrigating the proposed 5.2 ha is approximately 40 000 m^3/a (based on an irrigation water demand of 7 700 m^3/ha/a).

1.5 Background

The site is located approximately 15 km northeast of Niekerkshoop. The closest main road, the R386 gravel road, which links Niekerkshoop to the south with the N8 highway to the north, intersects the far northwestern part of the study area. Access to the site is via a 4 km long private road from the site to the R386 dirt road.

Farms and small communities in the area are totally dependent on groundwater. No surface water occurs in the immediate surrounding area and the closest perennial surface water occurs in the Orange River approximately 24 km southeast of the site.

2 Work Programme

A hydrocensus was conducted on Monday 6 May 2019 for the local site and surrounding areas. Simultaneously, hydrogeological information (borehole depth, yield, groundwater intersections, groundwater use and estimated abstraction, etc.) was collected for the area. Additional information obtained from the DWS National Groundwater Archive (NGA) was added to this database.

3 Physiography and Climate

The study area varies in altitude from a minimum of 1 110 meters above mean sea level (mamsl) in the far southeast, to a maximum of 1 254 mamsl in the far south. The site surface topography slopes gently to the east to the non-perennial Rietfontein River which drains southwards to the Orange River. Generally, the site topography is flat throughout except for elevated hills in the southern part. Here the Rietfontein River has cut a valley >120 m deep into the surrounding hilly area. Southeast of the site the Rietfontein River is renamed Dieprivier. The area east of the site is hilly and forms part of the Asbetos Hills. Elevations in access of 1300 mamsl are common in this area.

Surface water on the site is only present briefly during and after thunderstorms. Numerous drainage lines are mapped for the site. These mainly drain to the northeast and east except for a few small drainage lines in the southern part of the area that drain from the hills in the southern part southwards to join the Rietfontein River.

The site falls roughly within the centre part of Quaternary Drainage Region D71D, for which the 2016 General Authorisation (GA) allows an average of 45 m^3/d of groundwater to be abstracted over a year period per ha of property owned (General Notice 538 in Government Gazette 40243 of 2 September 2016).

The climate of the area is typically semi-desert, with very hot summers and cold winters. Temperature data for the site (as supplied by the World Bank) for the period 1901-2016 is summarized in Table 1 below. The data indicates that January is the hottest month, with an average daily temperature of 25.78°C, and July the coldest, with an average daily temperature of 9.97°C. In June and July, the minimum daily temperature frequently drops below freezing point. Therefore frost is common during the winter months.

Table 1: Climate Data for Diamantgat

World Bank Climate Data (1901 - 2016) for Station -29.06 22.90													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Ave Temp (°C)	25.78	25.00	22.36	18.12	13.48	9.93	9.97	12.06	15.97	19.43	22.27	24.64	
Ave Precipitation (mm)	36.99	49.33	53.28	27.62	12.47	6.52	4.83	8.54	5.57	15.94	22.39	23.25	266.7

The site falls within a summer rainfall area, with a mean annual precipitation (MAP) of 266 mm (World Bank, 1901 - 2016) which is slightly higher than than the MAP for Quaternary Catchment D71D (248 mm), which includes the site. The average monthly precipitation values for the site, as provided by the World Bank, are indicated in the above Table 1.

The table clearly indicates that the site is located in a summer rainfall area with >85% of the MAP occurring during the months of October to April. March is the wettest month, with an average precipitation of >50 mm, whilst July is the driest with <5 mm.

4 Geology

Figure 3 indicates the general geology of the site, which is located on the eastern flank of the northeast-southwest striking Ongeluk-Witwater synclinorium (Da Silva, 2011). Table 2 below indicates the lithological units underlying the site.

Table 2: Geological Description of Units (after Council for Geoscience, 1995)

<table>
<tr><th>Code</th><th>Geology</th><th>Formation</th><th>Sub-Group</th><th>Group</th><th>Sequence</th></tr>
<tr><td></td><td>Alluvium</td><td></td><td></td><td></td><td></td></tr>
<tr><td>k</td><td>Kimberlite (-- Fissure, ♦Pipe)</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Mdi</td><td>Diabase (latest classification dolerite)</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Vm</td><td>Diamicite, banded jasper, siltstone, mudstone, dolomite with chert, greywacke</td><td>Makganyene</td><td></td><td>Postmas-burg</td><td rowspan="5">Griqualand West</td></tr>
<tr><td>Vka</td><td>Riebeckitic jaspelite, brown jaspilite, chert, conglomerate at base</td><td>Kameel-fontein</td><td rowspan="2">Koegas</td><td rowspan="4">Ghaap-plato</td></tr>
<tr><td>Vp</td><td>Greenish mudstone</td><td>Pannetjie</td></tr>
<tr><td>Vd</td><td>Blue and brown jaspilite, chert</td><td>Daniëlskuil</td><td rowspan="2">Asbes-berge</td></tr>
<tr><td>Vk</td><td>Banded ironstone, haematite lenses, brown jaspilite, crocidolite, chert</td><td>Kuruman</td></tr>
</table>

The general strike of the Griqualand West Sequence is northeast-southwest in the area. The stratigraphy in the area was deformed by thrusting from the west. The thrusting produced a series of open, north-south plunging anticlines, synclines and grabens. The gentle open folding is manifested in the Dimoten Syncline and the Maremane Anticline to the north and the Ongeluk-Witwater

Synclinorium at the site. The folding resulted in upliftment and erosion preceding the deposition of the overlying Olifantshoek Group and an event of north-south block faulting occurred.

The geological map indicates that large areas of the central and northern parts of the study area are covered by recent deposits of alluvium. These deposits occur along the flat plains and drainage lines in the area and are normally thin, seldom exceeding 10 m in vertical thickness. However, at the site these deposits attain significant vertical thickness. Geological logs of boreholes drilled in the area indicate alluvium extending to below 30 mbgl at places. The general dip of the rocks in the study area is gently to the west in the eastern part, east in the central part and steeper west in the extreme western parts thereof. This indicates that a syncline runs through the central part of the study area and an anticline occurs on the extreme western part thereof.

Banded ironstone, jaspilite, crocidolite and chert of the Kuruman Formation (Griqualand West Sequence) outcrop in the eastern half of the study area. The western part of the site is mainly underlain by jaspilite and chert of the Daniëlskuil Formation. This Formation conformably overlies the older Kuruman Formation.

A small outcrop of the Makganyene Formation occurs in the far north-western part of the study area. This Formation consists mainly of diamicite with lesser banded jasper, siltstone, mudstone, dolomite with chert and greywacke. An erosion unconformity separates this Formation from the older rocks of the Ghaapplato Group below it. Diamictite of the Makganyene Formation generally hosts a well-defined aquifer. This Formation displays extreme thickness variations, from 3 m near the Orange River, to 70 m near Kuruman and up to 500 m in a borehole near Postmasburg (Visser, 1971). The upper part of this Formation has a 1–3 m thick tuffaceous unit that characteristically separates the diamictites of the Makganyene Formation from an overlying 900 m thick succession of basaltic andesites of the Ongeluk Formation.

A longitudinal outcrop of diabase, approximately parallel to the sedimentary strike, occurs in the southern part of the study area and approximately 3 km south of the site. After publication of this geological map, it was agreed to no longer distinguish between diabase and dolerite and to only use the term dolerite. The geochemical composition of both rock types is similar, however, the term diabase was previously used for pre-Karoo intrusions of this rock type.

Several lineaments in the area are indicated on the geological map. Lineaments were also mapped from Google Earth images and overlain on the geology map (see **Figure 3**). Often these lineaments are difficult to locate in the field due to weak outcrops (covered by recent deposits) and scattered large trees, which limit sight (to observe tree lines associated with lineaments). Normally these lineaments are faults and fracture systems that have been intruded by dolerite dykes or kimberlite fissures, but this could not be confirmed in the field due to lack of outcrops. It is also expected that the structures extend well beyond the mapped occurrences, but are obscured by the surface cover. A kimberlite pipe is mapped 7 km southwest of the site and immediately west of the R386 road. The pipe occurs on one of the mapped lineaments and therefore it is assumed that this lineament is a kimberlite fissure.

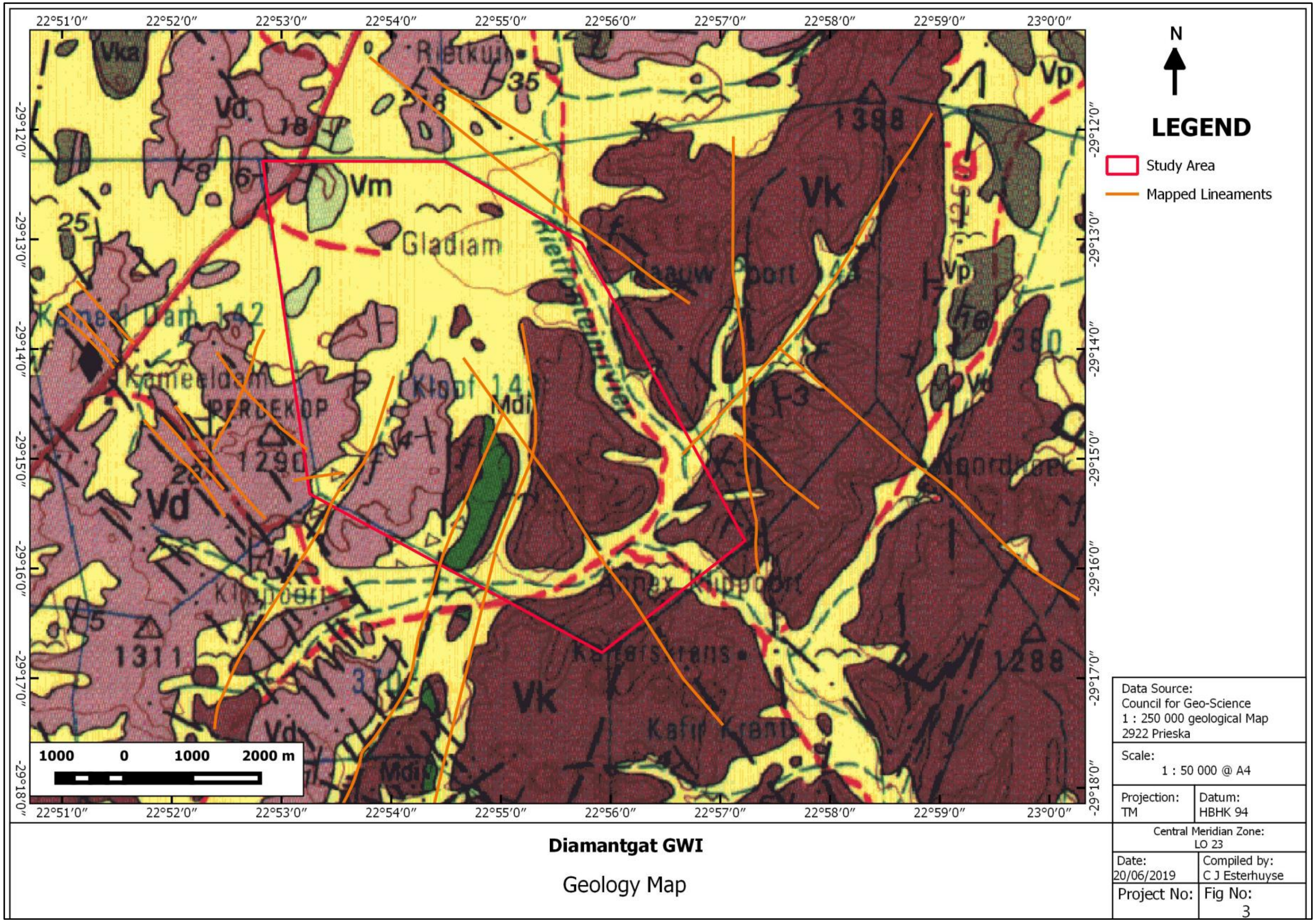


Figure 3: Geology with Mapped Lineaments (after the CGS, 1995)

5 Hydrogeology

5.1 Aquifer Characteristics

Groundwater in the study area occurs in two main aquifer systems, namely, an unconfined to semi-confined primary aquifer system, mainly consisting of some topsoil with underlying alluvium and weathered bedrock, and a secondary (or fractured-rock) aquifer system.

The primary aquifer is usually developed in localised pebble horizons within the alluvial deposits, as well as in the weathered zone directly beneath the surface cover. This aquifer has the potential to yield vast volumes of groundwater and is therefore an important and reliable source of water supply in the low lying areas where groundwater levels are shallow (normally <15 mbgl). Groundwater levels in surveyed boreholes at the site vary between 14 and 17 mbgl and are well within the alluvial zone (which extends to >30 m) at this locality.

The secondary aquifers are formed by jointing and fracturing of the otherwise solid bedrock. Joints and fractures are formed by faulting, cooling of magma outflows, intrusion of dolerite dykes, folding and other geological forces. Generally the harder rocks (BIF, quartzite, chert and dolerite) fracture more easily under stress (to form superior aquifers), compared to the softer sediments like shale, which deform rather than fracture under stress.

According to the 1:500 000 Hydrogeological map sheet of Prieska (DWS, 2002), the site is situated on fractured aquifer, with expected yields of successful boreholes ranging between 0.5 – 2.0 L/s, as illustrated in **Figure 4**. This area is underlain by the top of the Kuruman Formation. Nonetheless, these yields can be significantly improved by utilising scientific methods to determine optimum drill localities.

The hydrogeological map does not indicate any primary or intergranular aquifer at this locality. However, information collected from the owner, Mr Smit, and NGA data indicate that a relative thick alluvial deposit at the site forms a significant primary aquifer.

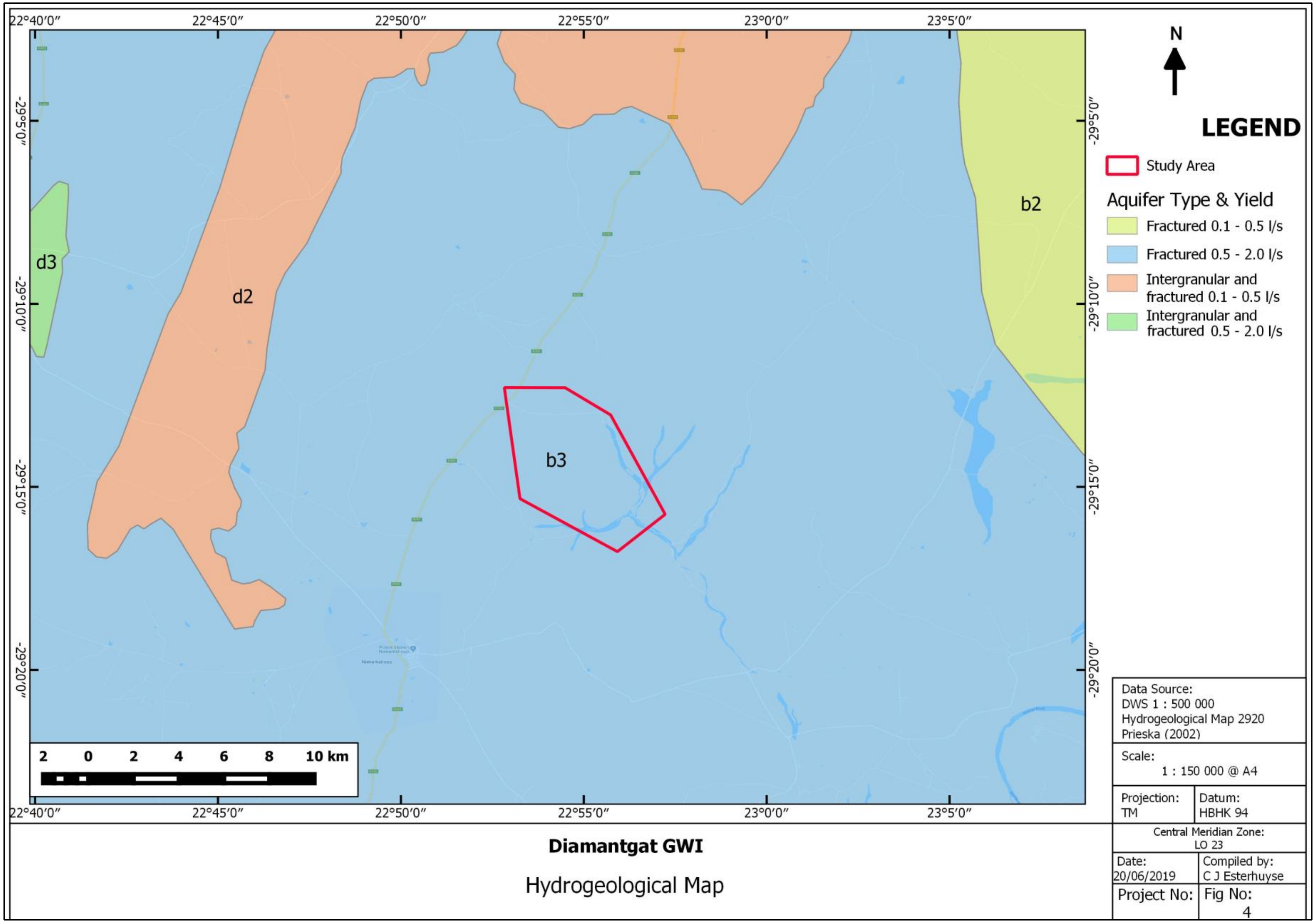


Figure 4: Hydrogeological Map

5.2 Hydrocensus

A hydrocensus of the site and surrounds was conducted on 6 May 2019. Mr. Smit accompanied the consultant, indicated the borehole localities and supply relative hydrogeological information of the boreholes. Thirteen boreholes, located on the site and immediate surrounds, were surveyed during the hydrocensus. Abstraction from each borehole was estimated based on pump yields and average pumping times reported by the owner. The hydrocensus results are summarised in Table 3 below. **Figure 5** indicates the localities of the hydrocensus and NGA boreholes.

Table 3: Summary of Hydrocensus Results for the Farm Kloof 143 Area

Bh No	Latitude	Longi-tude	Depth (mbgl)	Yield (L/s)	Water Level (mbgl)	EC (mS/m)	pH	Equipment	Pump Intake (mbgl)	Pump Yield (L/s)	Est Annual Abstr (m^3)	Comments
DG1	-29.21440	22.92404	32	30	17.15	69	7.50	Solar Pump	26	8.9	19 300	0-32m: Alluvium - large pebbles at bottom, cannot penetrate further
DG2	-29.21530	22.92419	33.80	30	17.30	70	7.49	Solar Pump	26	8.9	19 300	0-33.8m: Alluvium - large pebbles at bottom, cannot penetrate further
KF1	-29.24653	22.94025	28		15.17	75	7.55	Solar Pump	26	11.1	19 000	Very old borehole
KF2	-29.24709	22.94079	28		15.15			Solar Pump	26	11.1	19 000	Very old borehole near KF1
KF3	-29.21915	22.90074	40	8.3	14.85	130	7.40	Solar Pump	29	6.9	22 356	Stopped in dolerite
KF4	-29.21932	22.90609	25.56	30	14.63			Solar Pump	25	10.6	34 344	Owner reported 32 m, partially collapsed?
KF5	-29.21794	22.90022	42.28	20	14.86	118	7.50	Submersible	31	5.6	7 258	0-26m: Gravel, silt, clay; -32m Fractured BIF; -42m BIF
KF6	-29.21784	22.90012	28	30	14.85	120	7.50	Submersible	26	10.9	14 126	0-26m: Gravel, silt, clay; -28m Fractured BIF
KF7	-29.21695	22.90022	33.26	30	14.65			Submersible	26	0.6	648	
KT1	-29.26511	22.93811	25.14	30	14.43	120	7.55	Solar Pump	23	11.1	11 988	
KT2	-29.26521	22.93855	29.58	30	14.42			Solar Pump	23	11.1	11 988	
KT3	-29.26620	22.93731	40	3.6	14.62			Solar Pump	18	0.4	432	
NT1	-29.20945	22.92257	29	30		105	7.55	Solar Pump	25	0.5	540	Baseplate Closed
		Average	**31.89**	**24.7**	**15.17**	**100.88**	**7.51**			**Total Abstraction**	**180 280**	
		Median	**29.58**	**30**	**14.85**	**111.5**	**7.50**					

Groundwater levels at the site are generally shallow and vary between 14 and 17 m below ground level (mbgl). The average groundwater level for the surveyed boreholes is 15.17 mbgl and the median groundwater level is 14.85 mbgl. A relative small difference between these two values indicates that the average value is not skewed by a few abnormally shallow or deep groundwater levels. The shallowest recorded groundwater level is 14.42 mbgl at borehole KT2 located in the Rietfontein River valley at Annex Klippoort (which forms part of the cadastral farm Kloof 143). This locality falls in the far southern part of the study area. The deepest recorded groundwater level (17.30 mbgl) was measured in borehole DG2 on the north-eastern boundary of the study area. A dug trench exists in the alluvial deposits approximately 110 m east of borehole DG2 where there was mined for diamonds in the past. Therefore, this site is locally known as ”Diamantgat”. The dug trench intersected poorly sorted gravel with silt and clay beds. Groundwater seeps into the trench and the groundwater level in the trench is approximately 8 mbgl. This indicates that a perched groundwater level exists in the argillaceous alluvial material on top of the coarse gravel beds which supply groundwater to the adjacent boreholes.

Electrical Conductivity (EC) values measured during the hydrocensus vary between 69 and 130 mS/m. The highest EC was recorded at borehole KF3 and the lowest at borehole DG1. Borehole KF3 is located in an open field south of Gladiam homestead and the field measured EC is only marginally higher than those recorded at boreholes KF5 and KF6 approximately 150 m north of this borehole. Therefore this higher EC value does not really characterize an anomaly.

Most of the surveyed boreholes are linked to the primary aquifer at the site and therefore the reported maximum borehole yields are much higher than expected for this area. An average borehole yield of >24 L/s was calculated from the reported borehole yields.

The NGA data for this area (site and area 10 km surrounding the site) are summarized in Table 4. The data indicate that the average borehole yield for the successful boreholes drilled in this area is 3.24 L/s, whilst the median yield is 2.99 L/s. This suggests that the mean value is only marginally skewed by higher yielding boreholes. Normally the median yield is a more realistic indication of the expected yield of successful boreholes drilled in this area. Both the median and average borehole yields obtained from the NGA data for the site and immediate surrounds are higher than the yields indicated by the 1:500 000 Hydrogeological map sheet. This discrepancy is likely due to the limited number of boreholes with yield information in that area and the area intersecting adjacent higher yielding groundwater zones.

The average borehole depth is 57.5 mbgl with an average groundwater level of 14.62 mbgl. These values are also skewed by a few outliers as indicated by the median values of *c.*45 mbgl and *c.*10.00 mbgl, respectively. The average groundwater level of the surveyed boreholes is similar to the mean for the NGA boreholes.

Table 4: Summary of NGA data for Farm Kloof 143 and surrounds

ID No	Latitude	Longitude	Farm	WL (mbgl)	Yield (L/s)	Depth (mbgl)	Main Water Strike (mbgl)	Lithology
2922BD00165	-29.28922	22.95521	KAFFIR KRANTZ	31		48	38	0-30: Soil; -48: Diabase
2922BD00017	-29.28367	22.89938	KLIPPOORT			102		0-24: Clay; -84: Shale, -102: Dolerite
2922BD00013	-29.28367	22.96605	KAFIR KRANS			90		0-11: Boulders; -19: Dolerite; -90: No Sample
2922BD00015	-29.28366	22.89938	KLIPPOORT	24	0.37	45	26	0-13: Clay; -45: Granite (likely dolerite)
2922BD00016	-29.28366	22.89939	KLIPPOORT			93		0-3: Clay; -36: Shale; -93: Dolerite
2922BD00018	-29.28366	22.89940	KLIPPOORT			138		0-36: Alluvium; -138: Diabase
2922BD00012	-29.28366	22.96605	KAFIR KRANS	15.24	7.57	22.86	18.29	0-2.4: Gravel; -22.8: Dolerite
2922BD00014	-29.28366	22.96606	KAFIR KRANS	10	0.5	26	24	0-6: Sand; -26: Shale
2922BB00012	-29.23366	22.89938	KLOOF	6.1	0.01	25.91	22.86	0-8.5: Gravel; -25.9: Dolerite
2922BB00011	-29.15034	22.86605	KRUIS PAD	10	5.48	24	18	0-6: Clay; -24: Granite (likely dolerite)
2922BB00010	-29.15033	22.86605	KRUIS PAD	6	5.48	18	13	0-7: Clay; -18: Granite (likely dolerite)
			Mean	**14.62**	**3.24**	**57.52**	**22.88**	
			Median	**10.00**	**2.99**	**45.00**	**22.86**	

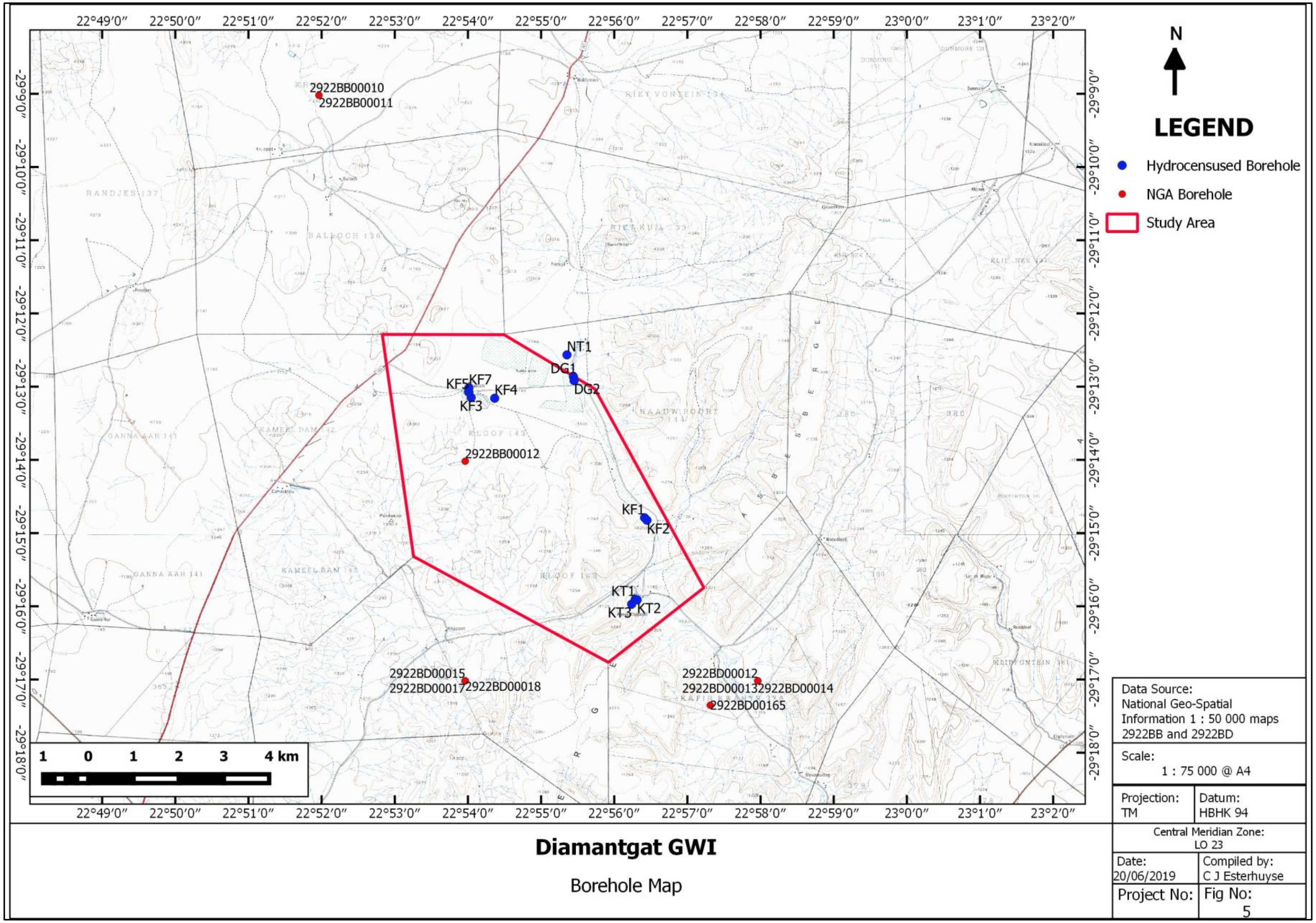


Figure 5: Borehole Map

Satellite image lineament mapping was carried out for the area to ascertain if there are any faults or dykes near or beneath the site, which may form conduits for movement of contaminants into the aquifer. These lineaments are shown on the cadastral map of the area in **Figure 2**. No lineaments which may be good yielding water structures could be identified for the site. However, it does not implicate that that no lineaments cross the site as lineaments may be obscured by the alluvial cover. Groundwater contamination, originating from irrigation and fertilizing practises, is a potential concern, and the proposed activity must employ proper mitigation measures (e.g. a groundwater monitoring programme, prevention of over irrigation) should a license be issued.

Table 5 below defines the different aquifer classes. Based on this table the aquifer underlying the site can be classified as a Major Aquifer Region.

Table 5: Aquifer Class

Aquifer Class	Description
Sole source aquifer	An aquifer which is used to supply 50% or more of urban domestic water for a given area, for which there are no reasonably available alternative sources should this aquifer be impacted upon on or depleted
Major Aquifer region	High-yielding aquifer of acceptable quality water
Minor Aquifer region	Moderately yielding aquifer of acceptable quality or high yielding aquifer of poor quality, or aquifer which will never be utilized for water supply and which will not contaminate other aquifers
Poor Aquifer region	Insignificantly yielding aquifer of good quality or moderately yielding aquifer of poor quality, or aquifer which will never be utilized for water supply and which will not contaminate other aquifers
Special Aquifer region	An aquifer designated as such by the Minister of Water Affairs, after due process

6 Groundwater Resource Units

The site falls within Quaternary Catchment D71D as indicated in **Figure 6**. A single groundwater resource unit (GRU) was determined for the site based on surface drainage. This GRU is also indicated in **Figure 6**. Table 6 indicates the GRA2 data for the Quaternary Catchment as well as for the Diamantgat GRU. The storativity value for Diamantgat GRU is based on recent yield tests conducted on six boreholes within the study area and is considerably higher (in the order of 3 magnitudes) than the average value for Quaternary Catchment D71D. This high storativity value is a direct result of the primary aquifer type underlying the site and immediate surrounds.

Recharge for the site was regarded as slightly more than that of the greater Quaternary Catchment due to a slightly higher MAP for the site and the primary aquifer type underlying the site (average recharge of 2.05% and 1.66% respectively). Current groundwater abstraction for Diamantgat GRU is based on a grazing capacity of 10ha/GSU and a water consumption of 75L/d/GSU and irrigation water demand of 7 700 m^3/ha/a. The table indicates that the average recharge based groundwater resource potential for Diamantgat is approximately 2 568 000 m^3/a. However, the recharge decreases to approximately 1 242 000 m^3/a during dry spells. The dry spell recharge is 31 times the calculated water demand of 40 000 m^3/a required for the proposed irrigation.

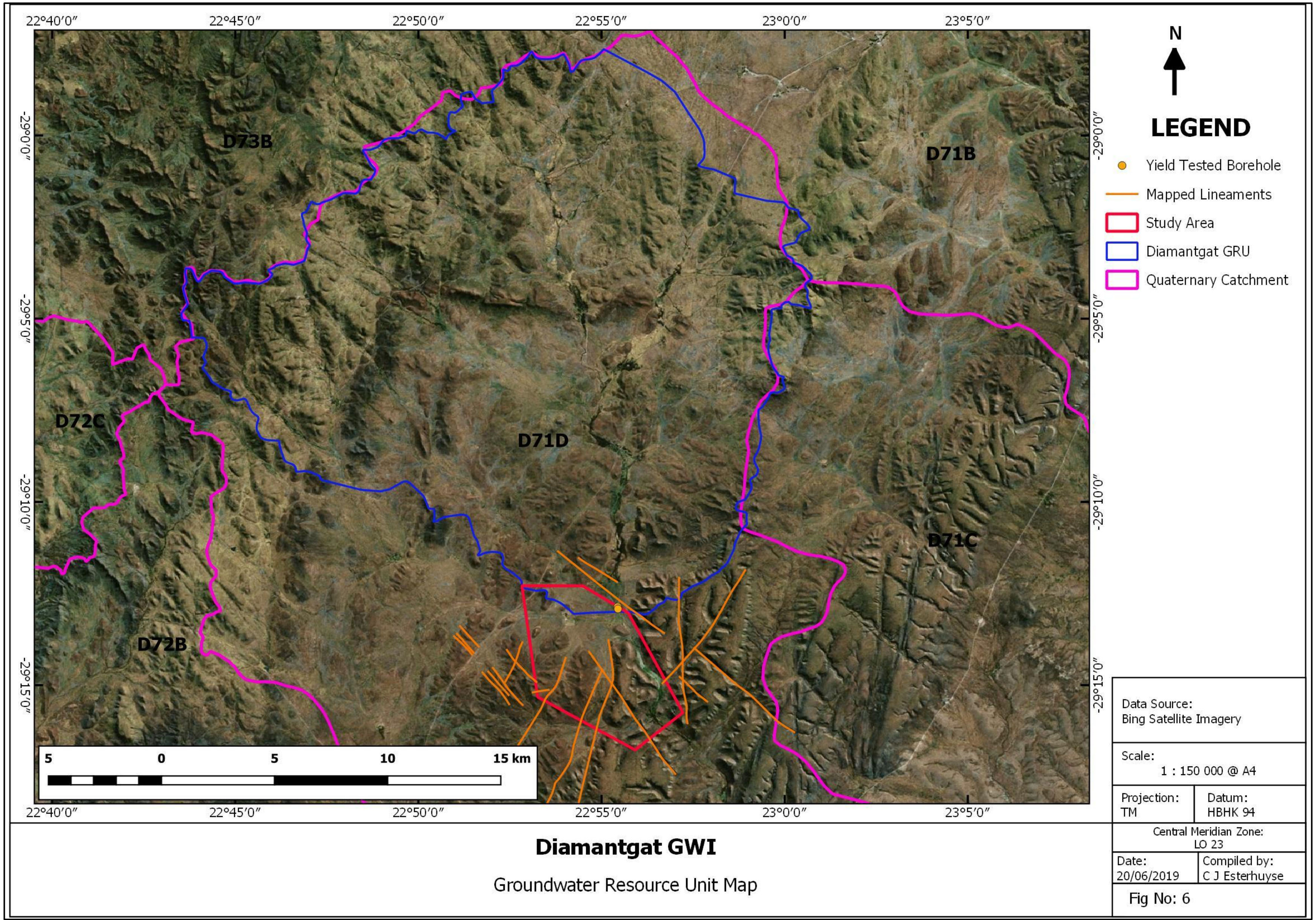


Figure 6: Groundwater Resource Unit Map

Table 6: GRA2 Data for Diamantgat

Quaternary Catchment	Area	Storativity	Drought Index	Mean Annual Contribution to River Baseflow	Annual Abstraction	Mean Annual Potential Recharge				Recharge Based Average Groundwater Resource Potential		Comments
	km^2		years	m^3/km^2/a	m^3/a	m^3/a				m^3/a		
						Normal (Mean)		Dry Season		Normal	Dry Season	
			Di	Bf	At	Re	% of MAP	Re (dry)	% of MAP	AGRP	AGRP (dry)	
D71D	1 712	6.98E-05	1.28	0	477 473	7 040 910	1.66%	4 490 110	1.06%	6 563 437	4 012 637	
Diamantgat	487	2.94E-03	1.25	0	96 616	2 664 867	2.05%	1 338 933	1.03%	2 568 252	1 242 318	Annual abstraction based on irrigation (7700 m^3/ha/a) and stock (75L/GSU/d) demand
GSU = Great Stock Unit, Grazing capacity = 10 ha/ GSU												

7 Yield Testing

In order to determine the long term sustainable yields of the proposed production boreholes at the site and to verify that these boreholes can meet the proposed demand, two production boreholes at Diamantgat were yield tested. The localities of these two boreholes (DG1 and DG2) as well as other nearby boreholes are indicated in **Figure 7**. Boreholes were first submitted to a step drawdown test (SDT) consisting of four one hour steps followed by a recovery test, then a 48 hour constant discharge test (CDT) and finally another recovery test. Table 7 summarizes the yield test results.

Table 7: Yield Test Summary

Bh No	Latitude (DD)	Longitude (DD)	Depth (mbgl)	RWL* (mbgl)	Discharge Rates (L/s)				Draw Down @ last Step (m)	48 Hr Constant Discharge Test	
					Step 1	Step 2	Step 3	Step 4		Pump Rate (L/s)	Max Draw-down (m)
DG1	-29.21440	22.92404	32.00	17.15	5.13	10.12	15.06	20.14	4.45	18.63	4.81
DG2	-29.21530	22.92419	33.80	17.30	5.27	10.37	15.38	20.34	5.80	18.15	5.56
*RWL = Rest Water Level											

The yield test results were analysed by means of the FC (which includes FC, Theis, Barker, Inflection Point and Cooper-Jacob) and Recovery methods. In order to be conservative an extrapolation time of two years without recharge was used for the FC-analyses. During the analysis of yield test data for borehole DG2 there was allowed for continuous abstraction at 7.0 L/s from borehole DG1 which is 105 m away from this borehole. The relevant yield test data and diagnostic plots are captured in **Appendix 1**. Groundwater level recovery after pump shutdown was extremely quick at both boreholes. This results in high sustainable yields calculated by the recovery method which were rather omitted in the final estimate of the long term sustainable yield of both boreholes.

Table 8 summarizes the results obtained from the yield test analyses. Maximum available draw downs were considered to be the average value of the maximum drawdown reached during the yield tests and distance from rest water level to reported main water strike.

Table 8 indicates that the the T values of the two yield tested boreholes at Diamantgat differ significantly. The boreholes are only 105 m apart and abstract groundwater from the alluvial aquifer. This discrepancy indicates the heterogeneity of the primary aquifer caused by clay and silt layers and lenses.

Table 8: Summary of Yield Test Analyses

Bh No	Coordinates		Depth (mbgl)	Rest Water Level (mbgl)	Available Draw Down (m)	Fractal Dimension	Log Derivative	FC-Method Sustainable Yield		FC-Analysis		Comments
	Latitude	Longitude						ℓ/s @ 24h/d	m³/d	Ave S	Ave T (m²/d)	
DG1	-29.21440	22.92404	32.00	17.15	6.9	1.81	0.07	7.0	605	1.82E-03	205.3	
DG2	-29.21530	22.92419	33.80	17.30	7.5	2.03	0.04	11.5	994	4.05E-03	551.4	Allowed for abstraction from DG1 at 7 L/s
							TOTAL	**18.5**	**1 598**			
							Average			**2.93E-03**	**378.4**	

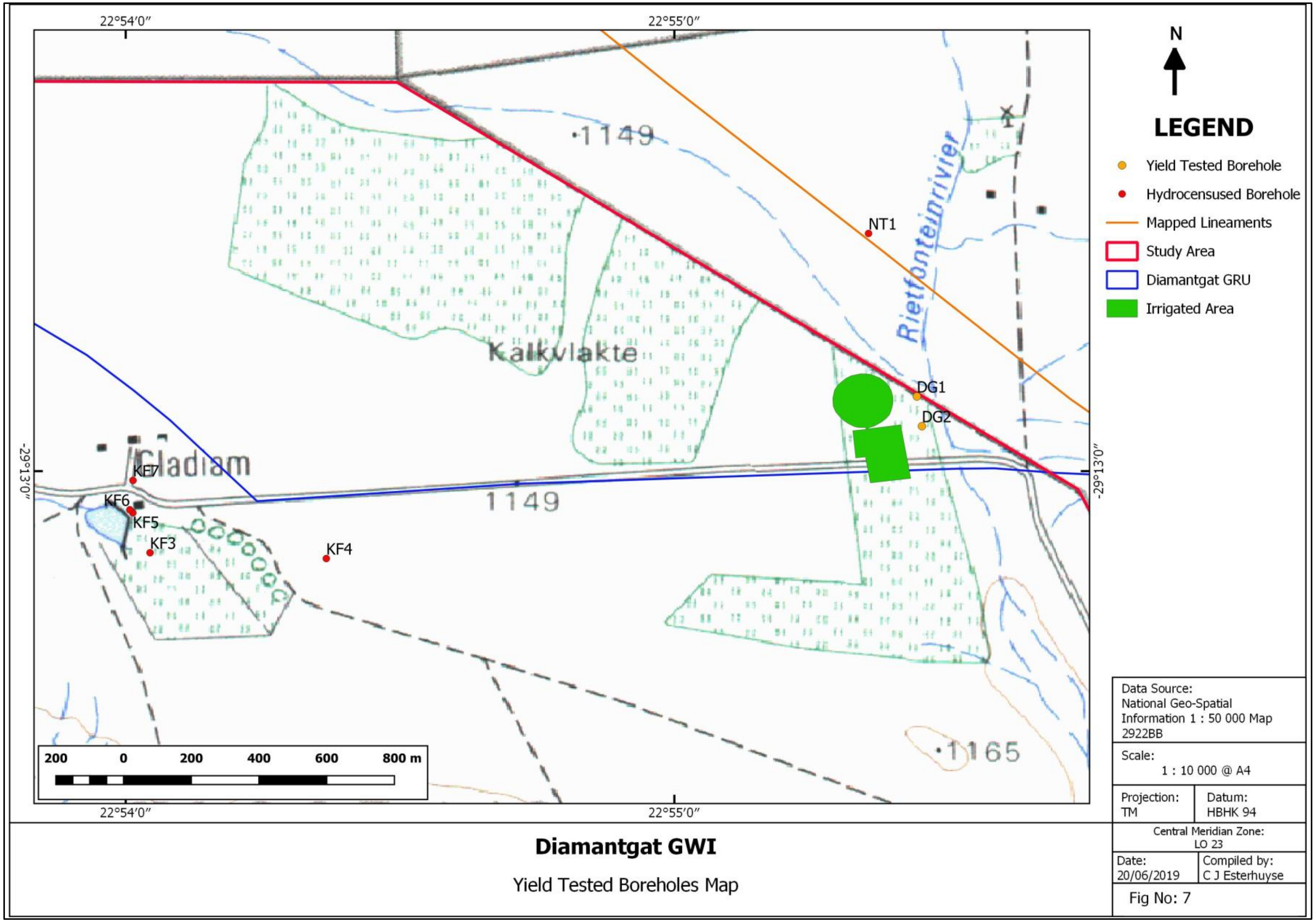


Figure 7: Yield Tested Boreholes Map

Table 8 further indicates that the two yield tested boreholes have a combined sustainable yield of 18.5 L/s continuously or approximately 583 000 m^3/a. This is >14 times the 40 000 m^3/a needed for irrigation purposes and approximately 47% of the Recharge Based Groundwater Resource Potential during dry periods for Diamantgat GRU. Therefore, the two yield tested boreholes should be able to easily supply the future irrigation water demand.

The log derivative value can be used to identify the fractures system at the yield tested borehole as follows:

>0.5	Limited, single fracture
0.25 - 0.5	Good fracture network
<0.25	Radial flow, homogeneous aquifer (like primary aquifer)

Similarly the fractional dimension value identifies groundwater flow towards the borehole as follows:

1	Linear flow
1.5	Bi-linear flow
2	Radial flow (primary aquifer type).

Thus it is clear that radial flow occurs at both boreholes DG1 and DG2. This means the aquifer behaves like a primary aquifer with no preferred direction of groundwater flow, which is to be expected from the alluvial aquifer underlying the site.

8 Possible Impacts and Mitigation Measures

The aim of this section is to make a preliminary assessment of any potential groundwater impacts that are likely to arise as a result of the proposed farming activities. **Figure 7** indicates the positions of boreholes and irrigated land at Diamantgat. No mapped structures intersect the irrigation area. Therefore this site seems to be favourable for irrigation from a groundwater point of view. Table 9 and Table 10 indicate possible groundwater impacts during the operation and closure phases with and without mitigation measures considered, respectively. These mitigation measures are also indicated in the tables.

Potential impacts include the following:

- Contamination of groundwater from oil spills from agricultural machines;
- Contamination of groundwater from fertilizers and pesticides used on crops;
- Groundwater contamination from surface runoff flowing into open abandoned boreholes;
- Increased salinity in aquifers due to over abstraction;
- Lowering of the water table by abstraction of groundwater during operation; and
- Decreased seasonal groundwater flow towards local drainage channels.

The tables clearly indicate that with proper mitigation measures implemented, the significance of the impacts can be considerably reduced should the water use licence be issued. From a hydrogeological point of view there is no reason to withhold this licence provided the above mitigation measures are implemented.

The impact rating methodology is indicated in **Appendix 2**.

Table 9: Possible Groundwater Impacts during Operational Phase

Operation Phase												
Impact description	Extent of Impacts		Intensity of Impacts		Duration of Impacts		Consequence		Probability of Impacts	Significance of impacts	Status of Impacts	Confidence
Without Mitigation	Rating	Quanti-tative Rating	Rating	Quanti-tative Rating	Rating	Quanti-tative Rating	Rating	Quanti-tative Rating	Rating	Rating	Rating	
Groundwater contamination by oil and fuel spills from agricultural machinery	Local	1	Low	1	Short	1	Very Low	3	Possible	Insignificant	Negative	High
Lowering of the water table by abstraction of groundwater during operation.	Regional	2	Medium	2	Long - Reversible	3	High	7	Probable	High	Negative	High
Decreased seasonal groundwater flow towards local drainage channels	Local	1	Low	1	Long - Reversible	3	Low	5	Possible	Very Low	Negative	High
Increased salinity in aquifers, due to the lower inflow rate from groundwater	Regional	2	Low	1	Long - Reversible	3	Medium	6	Improbable	Low	Negative	High
Groundwater contamination from fertilizers and pesticides used on crops	Local	1	Medium	2	Long - Reversible	3	Medium	6	Probable	Medium	Negative	High
Essential mitigation measures: • Implement and follow water saving procedures and methodologies and ensure that no over irrigation exists. • Spread wellfield over a large enough area to minimize drawdown effects. • Install a sufficient number of boreholes to keep abstraction from each to the minimum. • A monitoring system must be implemented to monitor groundwater and surface water quality, flow and water levels. • Ensure vehicles and equipment are in good working order and drivers and operators are properly trained. • Place oil traps under stationary machinery, only re-fuel machines at fuelling station, immediately clean oil and fuel spills. • Ensure that the minimum volumes of fertilizer and pesticides are used to prevent over-fertilizing and groundwater contamination												
Impact description	Extent of Impacts		Intensity of Impacts		Duration of Impacts		Consequence		Probability of Impacts	Significance of impacts	Status of Impacts	Confidence

With Mitigation	Rating	Quanti-tative Rating	Rating	Quanti-tative Rating	Rating	Quanti-tative Rating	Rating	Quanti-tative Rating	Rating	Rating	Rating	
Groundwater contamination by oil and fuel spills from agricultural machinery	Local	1	Low	1	Short	1	Very Low	3	Improbable	Insignificant	Negative	High
Lowering of the water table by abstraction of groundwater during operation.	Local	1	Medium	2	Medium	2	Low	5	Possible	Very Low	Negative	High
Decreased seasonal groundwater flow towards local drainage channels	Local	1	Low	1	Medium	2	Very Low	4	Possible	Insignificant	Negative	High
Increased salinity in aquifers, due to the lower inflow rate from groundwater	Local	1	Medium	2	Medium	2	Low	5	Improbable	Very Low	Negative	High
Groundwater contamination from fertilizers used on crops	Local	1	Medium	2	Medium	2	Low	5	Possible	Very Low	Negative	High

Table 10: Possible Groundwater Impacts during Closure Phase

Impact description	Extent of Impacts		Intensity of Impacts		Duration of Impacts		Consequence		Probability of Impacts	Significance of impacts	Status of Impacts	Confidence
Without Mitigation	**Rating**	**Quanti-tative Rating**	**Rating**	**Quanti-tative Rating**	**Rating**	**Quanti-tative Rating**	**Rating**	**Quanti-tative Rating**	**Rating**	**Rating**	**Rating**	
Groundwater contamination by oil and fuel spills	Local	1	Low	1	Short	1	Very Low	3	Probable	Insignificant	Negative	High
Groundwater contamination from surface runoff flowing into open, abandoned boreholes.	Regional	2	Medium	2	Long - Reversible	3	High	7	Probable	High	Negative	High

Essential mitigation measures:

- A groundwater monitoring system must be implemented to monitor groundwater quality and water levels.
- Ensure vehicles and equipment are in good working order and drivers and operators are properly trained.
- Ensure that good housekeeping rules are applied.
- Abandoned production boreholes and other open boreholes must be capped to prevent groundwater pollution from surface runoff.

Impact description	Extent of Impacts		Intensity of Impacts		Duration of Impacts		Consequence		Probability of Impacts	Significance of impacts	Status of Impacts	Confidence
With Mitigation	**Rating**	**Quanti-tative Rating**	**Rating**	**Quanti-tative Rating**	**Rating**	**Quanti-tative Rating**	**Rating**	**Quanti-tative Rating**	**Rating**	**Rating**	**Rating**	
Groundwater contamination by oil and fuel spills	Local	1	Low	1	Short	1	Very Low	3	Possible	Insignificant	Negative	High
Groundwater contamination from surface runoff flowing into open, abandoned boreholes	Regional	2	Low	1	Short	1	Very Low	4	Improbable	Insignificant	Negative	High

9 Groundwater Monitoring Programme

To monitor the potential impact of the proposed irrigation on the groundwater resources, several on-site pumping and non-pumping boreholes must be included in a monitoring programme. Monitoring should include the following:

- Boreholes where a pump is installed must be equipped with a conduit pipe (25 ID class 6 irrigation pipe) attached to the pump's rising pipes and installed to *c*.1 m above the pump inlet. This will prevent the dipmeter probe from becoming stuck around the rising pipes and electrical cables. A water level dipmeter with 1 cm calibration and 100 m cable will have to be obtained for this;
- The water level (and volumes abstracted at the production boreholes) must be recorded on at least a monthly, but preferably weekly, basis at the production pumping boreholes. Best results are obtained if automatic flow meters and water level recorders set to take hourly readings are installed;
- Water samples must also be collected at selected production boreholes on a six-monthly basis and submitted to SANAS accredited laboratories for analysis of the macro-chemistry;
- Production boreholes DG1 and DG2 as well as borehole NT1 must be utilized as monitoring boreholes where groundwater levels are recorded on at least a monthly, but preferably weekly, basis. This will give an early warning of large drawdowns;
- Rainfall should also be recorded on-site on a daily basis; and
- The monitoring data must be evaluated on an annual basis by a hydrogeologist and a monitoring report compiled.

10 Conclusions

Based on the information discussed in this report, the following can be concluded regarding the groundwater conditions at Diamantgat (the site):

- The site is located approximately 15 km north-east of Niekerkshoop in the Northern Cape province;
- An estimated 40 000 m^3/a of groundwater is needed to irrigate a proposed 5.2 ha of land;
- The site surface topography slopes gently to the south along the non-perennial Rietfontein River which drains southwards to the Orange River;
- Generally, the site topography is flat throughout except for elevated hills in the southern part where the Rietfontein River has cut a deep valley into the surrounding hilly area;
- Surface water on the site is only present briefly during and after thunderstorms;
- The MAP for the site is approximately 267 mm;
- Large parts of the study area are covered by alluvial deposits. Although these deposits are normally thin, it acquires significant vertical thickness in the study area;
- The eastern part of the study area, which includes the site, is mainly underlain by rocks of the Kuruman Formation of the Ghaapplato Group, which consist mainly of banded ironstone, jaspilite, crocidolite and chert;

- Younger rocks of the Daniëlskuil Formation, consisting of jaspilite and chert, underlie the western parts of the site;
- A small outcrop of the Makganyane Formation, consisting of diamicite with lesser banded jasper, siltstone, mudstone, dolomite with chert and greywacke, occurs in the far north-western part of the study area;
- Recharge for the site is approximately 2.05% of the MAP (or 5.5 mm/a);
- The groundwater map indicates that the site is underlain by a fractured aquifer with an average maximum immediate yield for successful boreholes drilled in this region of 0.5 – 2.0 L/s. However, these yields can be significantly improved by utilising scientific methods to determine optimum drill localities;
- Lineament mapping indicates several lineaments in the surrounding areas, but none at the site;
- Thirteen boreholes within the study area were surveyed during the hydrocensus;
- Hydrogeological information obtained during the hydrocensus indicate a significant primary aquifer exists in the relative thick alluvial deposits;
- A perched groundwater level exists on top of the upper clayey layers of this alluvial deposit;
- The site is located within Quaternary Catchment D71D for which the 2016 General Authorisation (GA) allows an average of 45 m^3/d of groundwater to be abstracted over a year period per ha of property owned;
- One GRU was identified for the site based on surface drainage. The recharge based groundwater resource potential of this GRU is approximately 2 568 000 m^3/a during normal years and 1 242 000 m3/a during dry spells;
- The average groundwater level for the study area is approximately 15.2 mbgl;
- Groundwater quality in the study area, based on field measured ECs, is generally good with measured ECs ranging from 69 to 130 mS/m;
- Two boreholes, DG1 and DG2, were yield tested and yield test analyses indicate a combined long term sustainable yield of approximately 583 000 m^3/a (18.5 L/s continuously) for the two boreholes. This is considerably more than the irrigation demand, but still <50% of the dry season groundwater resource potential of the GRU;
- Groundwater level recovery after pump shutdown was extremely quick at both boreholes, which results in anomalously high sustainable yields calculated by the Recovery Method. Therefore these values were omitted during calculations of the recommended sustainable yield for both boreholes;
- Storativity values calculated from the yield test data are significantly higher than that indicated in the GRA2 data for Quaternary Catchment D71D, which can directly be linked to the primary aquifer;
- Although the two yield tested boreholes are close together, the calculated T-values differ significantly which indicates the heterogeneity of the primary aquifer;
- From a groundwater perspective, the proposed irrigation site is favourable, as long as possible groundwater contamination sources are well controlled;

- The impact of the proposed prospecting on local groundwater sources can be significantly reduced by implementing mitigation measures during the irrigation and decommission phases;
- A monitoring programme is preferable to identify red flag situations, if any, timeously.

11 Recommendations

Based on the conclusions in this report, the following is recommended:

1. Groundwater levels must be measured monthly at production boreholes DG1 and DG2 as well as borehole NT1 to ensure that that groundwater levels do not decline excessively due to the irrigation activities. For this purpose a small hole has to be drilled in the base plate of borehole NT1;
2. Groundwater samples must be collected on a 6-monthly basis at borehole DG2 and submitted to a SANS accredited laboratory for macro chemical analysis to monitor possible groundwater pollution and take remedial steps if necessary;
3. The two yield tested boreholes can be equipped and managed as indicated in Table 11 below:

Table 11: Recommended Operation of Yield Tested Boreholes

Bh No	Coordinates		Bh Depth (mbgl)	Rest Water Level (mbgl)	Available Draw Down (m)	Recom pump intake (mbgl)	Max Pumping Water Level (mbgl)	Recom Sustainable Yield		Comments
	Latitude	Longitude						ℓ/s @ 24h/d	m^3/d	
DG1	-29.21440	22.92404	32.00	17.15	6.9	27	24.0	7.00	605	Allowed for abstraction from borehole DG1 at 7.0 L/s
DG2	-29.21530	22.92419	33.80	17.30	7.5	28	25.0	11.50	994	
							Total	18.5	1 598	

4. Should groundwater levels decline below the maximum allowable drawdown level, abstraction from borehole(s) must be ceased until groundwater levels have recovered above maximum allowable levels;
5. Rainfall must be recorded on a daily basis at the site;
6. Monitored data must be analysed by a qualified hydrogeologist at least on an annual basis in order to identify red flag situations timeously and take the necessary preventative measures;
7. The following mitigation measures should be implemented during the different phases in order to limit the impact on groundwater resources:
   - During the operational phase, the following mitigation measures are desirable:
     a) Implement and follow water saving procedures and methodologies and ensure that no over irrigation exists.
     b) Spread wellfield over a large enough area to minimise drawdown effects.
     c) Install a sufficient number of boreholes to keep abstraction from each to the minimum.
     d) A monitoring system must be implemented to monitor groundwater and surface water quality, flow and water levels.

e) Ensure vehicles and equipment are in good working order and drivers and operators are properly trained.

f) Place oil traps under stationary machinery, only re-fuel machines at fuelling station, immediately clean oil and fuel spills.

g) Ensure that only an adequate amount of fertilizer is used to prevent over-fertilizing.

h) Ensure that good housekeeping rules are applied, i.e prevent littering and ensure good ablution and sanitation facilities are available for personnel on site.

i) Implement and follow water saving procedures and methodologies.

j) Cap and seal all unused boreholes to prevent surface water from entering the borehole

- The following mitigation measures are required during the decommissioning phase:

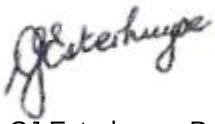
  a) A groundwater monitoring system must be implemented to monitor groundwater quality and water levels.

  b) Ensure vehicles and equipment are in good working order and drivers and operators are properly trained.

  c) Ensure that good housekeeping rules are applied.

  d) Abandoned production boreholes and other open boreholes must be capped to prevent groundwater pollution from surface runoff.

Prepared by



CJ Esterhuyse Pr Sci Nat
Consultant Hydrogeologist

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World Bank (20 June 2019): http://sdwebx.worldbank.org/climateportal/index.cfm?page=country historical_climate&ThisRegion=Africa&ThisCCode=ZAF

World Weather Online (20 June 2019): http://www.worldweatheronline.com/Postmasburg-weather-averages/Northern-Cape/ZA.aspx

Appendix 1: Yield Test Data, Diagnostic Plots and Analyses

Scenic route 565 t/a Welltek Services
Vat nr: 45902 54720
Email: welltekservices@gmail.com

wellTek services
Borehole testing and associated projects

CC Registration nr: 2005/137492/23
18 Highfield Road, EAST LONDON, 5205
Cell: +27 (0)71 031 5086
Fax: +27 (0)86 517 9242

BOREHOLE TEST RECORD

Borehole Number:	DG1	Province:	NORTHERN CAPE
Alternative Number:		District:	NIEKERKSHOOP
Coordinates: Latitude [°S]	29.214492	Town/Village/Farm:	
Longitude [°E]	22.924041	Rig Type & number:	TOYOTA 13
Date & Time Test Started:	2019/05/06 00:00	Operator:	THOMAS
Date & Time Test Ended:	2019/05/09 00:00	Supervisor:	STANLEY
Consultant:			
CONSULTANT - DATA PROVIDED / INSTRUCTIONS:			**EXISTING INSTALLATION:**
Borehole depth [mbgl]:		Diesel/Electric/Wind/Hand	SUBMERSIBLE
Blow Yield [l/s]:		Pump Make & Serial no:	7,5 KW
Water Strike Depth(s) [mbgl]:		Intallation Depth (m)	26 M
Installation depth [mbgl]:		Type & Condition - Pump:	WORKING
Estimated Steps [l/s] - Step 1:		- Column:	80 MM GALV STEEL
Step 2:		- Pump House	N/A
Step 3:			**FIELD MEASUREMENTS:**
Step 4:		Depth Before Test [mbcl]:	32.00
Step 5:		Depth after Test [mbcl]:	32.00
Step 6:		Water Level before Test [mbcl]:	17.15
Step Duration [min]:		Water Level after Test [mbcl]:	17.15
Step Recovery Duration [Hrs]:		Casing Depth [mbcl]:	
Constant Yield [l/s]:		Casing Height [magl]:	0.00
Constant Duration [Hrs]:		Casing Diameter [mm]:	170.00
Recovery Duration [Hrs] / Drawdown %:			**TEST PUMP INSTALLATION DETAILS:**
Lenghth of Layflat Required [m]:		Pump Used:	BP 65 M
Frequency of pH and EC Measurements:		Depth Installed [mbcl]:	27.00
SAMPLE INSTRUCTIONS:		Datum Level above Casing [m]:	0.32
		Length of Layflat [m]:	50.00

GENERAL ACTIONS:

Supplied new steel cover [Yes/No]:	NO	Slug Test [Yes/No]:	N/A
Welded existing steel cover back on [Y/N]:	NO	Re-install existing pump [Yes/No]:	YES LEFT IT WORKING
Borehole Marking [Yes/No]:	NO	If not, where was it stored?	N/A
Site Cleaning and Finishing [Yes/No]:	YES	Maintenance work [Hrs]:	N/A
Data Reporting and Recording [Yes/No]:	YES	Maintenance Travel [km]:	N/A
Digital Photo Taken? [Yes/No]	NO	List of parts replaced/repaired:	N/A
RETREAT FROM SITE		Date &Time Sampled:	NO SAMPLE TAKEN

RETREAT FROM SITE

It is hereby acknowledged that upon leaving the site, all existing equipment is in an acceptable condition.

NAME:	
DESIGNATION:	
SIGNATURE:	
DATE:	

COMMENTS BY ONSITE CREW

BOREHOLE NO:	DG1	WATER LEVEL [mbdl]:	17.47	WATER DEPTH [mbgl]:	17.15	AVAILABLE DRAWDOWN [m]:	9.85

STEPPED DISCHARGE TEST & RECOVERY

DISCHARGE RATE 1			RPM		DISCHARGE RATE 2			RPM		DISCHARGE RATE 3			RPM	
DATE & TIME		2019/05/07 07:00			DATE & TIME		2019/05/07 08:00			DATE & TIME		2019/05/07 09:00		
TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)
1	0.52		1		1	1.54		1		1	2.58		1	
2	0.60	5.44	2		2	1.82	9.50	2		2	2.62	14.51	2	
3	0.75		3		3	1.86	10.06	3		3	2.82	15.03	3	
5	0.77	5.11	5		5	1.96		5		5	2.90		5	
7	0.79		7		7	2.02		7		7	2.95		7	
10	0.80		10		10	2.03		10		10	2.97		10	
15	0.82		15		15	2.05		15		15	2.99	15.06	15	
20	0.83	5.13	20		20	2.07	10.12	20		20	3.02		20	
30	0.84		30		30	2.09		30		30	3.04		30	
40	0.85		40		40	2.11	10.15	40		40	3.06	15.10	40	
50	0.85	5.14	50		50	2.14		50		50	3.08		50	
60	0.86		60		60	2.17		60		60	3.10		60	
			70					70					70	
			80					80					80	
			90					90					90	
			100					100					100	
			110					110					110	
			120					120					120	
			150					150					150	
	Average Yield (l/s):	5.14	180			Average Yield (l/s):	10.12	180			Average Yield (l/s):	15.07	180	
	Drawdown (%):	8.73	210			Drawdown (%):	22.03	210			Drawdown (%):	31.47	210	

DISCHARGE RATE 4			RPM		DISCHARGE RATE 5			RPM		DISCHARGE RATE 6			RPM	
DATE & TIME		2019/05/07 10:00			DATE & TIME		2019/05/07 10:00			DATE & TIME		2019/05/07 10:00		
TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)
1	3.64		1		1			1		1			1	2.11
2	3.79	20.14	2		2			2		2			2	1.54
3	3.90		3		3			3		3			3	1.20
5	4.07		5		5			5		5			5	1.04
7	4.15	20.16	7		7			7		7			7	0.81
10	4.20		10		10			10		10			10	0.63
15	4.24	20.14	15		15			15		15			15	0.48
20	4.28		20		20			20		20			20	0.41
30	4.33		30		30			30		30			30	0.35
40	4.37	2.012	40		40			40		40			40	0.29
50	4.4		50		50			50		50			50	0.26
60	4.45		60		60			60		60			60	0.20
			70					70					70	0.09
			80					80					80	0.00
			90					90					90	
			100					100					100	
			110					110					110	
			120					120					120	
			150					150					150	
			180					180					180	
			210					210					210	
			240					240					240	
	Average Yield (l/s):	8.81	300			Average Yield (l/s):	0.00	300			Average Yield (l/s):	0.00	300	
	Drawdown (%):	45.18	360			Drawdown (%):		360			Drawdown (%):		360	

DATUM LEVEL ABOVE GROUND [m]:	0.32	WAS SAND PUMPED ?	NO
STATIC WATER LEVEL AFTER STEPPED DISCHARGE TEST [mbdl]:	17.47	WAS THE WATER CLEAN?	YES

STEPPED DRAWDOWN SUMMARY

STEP	DURATION [min]	DRAWDOWN [m]	DRAWDOWN [%]	AVERAGE YIELD [l/s]	RECOVERY [min]	RECOVERY [m]	RECOVERY [%]	STEP	DURATION [min]	DRAWDOWN [m]	DRAWDOWN [%]	AVERAGE YIELD [l/s]	RECOVERY [min]	RECOVERY [m]	RECOVERY [%]
1	60	0.86	8.73	5.14				5		0.00		0.00			
2	60	2.17	22.03	10.12				6		0.00		0.00			
3	60	3.10	31.47	15.07				7							
4	60	4.45	45.18	8.81				8							
DATE & TIME END:		2019/05/07 11:00						TOTAL:	240.00	4.45	45.18		0	0.00	0.00
COMMENTS:															

BOREHOLE NO:		DG1				WATER LEVEL [mbdl]:		17.47			WATER LEVEL [mbgl]:		17.15
CONSTANT DISCHARGE TEST & RECOVERY													
DISCHARGE BOREHOLE					**OBSERVATION HOLE 1**			**OBSERVATION HOLE 2**			**OBSERVATION HOLE 3**		
TEST STARTED					WATER LEVEL [mbcl]:		N/A	WATER LEVEL [mbcl]:		N/A	WATER LEVEL [mbcl]:		N/A
DATE & TIME:		2019/05/07 13:00			CASING HEIGHT [m]:		N/A	CASING HEIGHT [m]:		N/A	CASING HEIGHT [m]:		N/A
TEST COMPLETED					CASING DIAMETER [m]:		N/A	CASING DIAMETER [m]:		N/A	CASING DIAMETER [m]:		N/A
DATE & TIME:		2019/05/10 13:00			DISTANCE [m]:		N/A	DISTANCE [m]:		N/A	DISTANCE [m]:		N/A
TIME [min]	DRAWDOWN [m]	YIELD [l/s]	TIME [min]	RECOVERY [m]	TIME: [min]	DRAWDOWN [m]	RECOVERY [m]	TIME: [min]	DRAWDOWN [m]	RECOVERY [m]	TIME: [min]	DRAWDOWN [m]	RECOVERY [m]
1	2.18		1	2.10	1			1			1		
2	2.36		2	1.55	2			2			2		
3	3.24	18.60	3	1.21	3			3			3		
5	3.68		5	1.08	5			5			5		
7	3.74		7	0.83	7			7			7		
10	3.86		10	0.62	10			10			10		
15	3.92	18.62	15	0.48	15			15			15		
20	3.94		20	0.30	20			20			20		
30	3.97		30	0.18	30			30			30		
40	3.99	18.60	40	0.09	40			40			40		
60	4.00		60	0.00	60			60			60		
90	4.02		90		90			90			90		
120	4.04		120		120			120			120		
150	4.05	18.61	150		150			150			150		
180	4.06		180		180			180			180		
210	4.07		210		210			210			210		
240	4.08	18.62	240		240			240			240		
300	4.10		300		300			300			300		
360	4.12	18.64	360		360			360			360		
420	4.14		420		420			420			420		
480	4.16	18.61	480		480			480			480		
540	4.17		540		540			540			540		
600	4.18		600		600			600			600		
720	4.20		720		720			720			720		
840	4.22		840		840			840			840		
960	4.24		960		960			960			960		
1080	4.26	18.62	1080		1080			1080			1080		
1200	4.28		1200		1200			1200			1200		
1320	4.31		1320		1320			1320			1320		
1440	4.33		1440		1440			1440			1440		
1560	4.35	18.63			1560			1560			1560		
1680	4.36				1680			1680			1680		
1800	4.39				1800			1800			1800		
1920	4.43	18.64			1920			1920			1920		
2040	4.49				2040			2040			2040		
2160	4.52				2160			2160			2160		
2280	4.59				2280			2280			2280		
2400	4.63	18.65			2400			2400			2400		
2520	4.67				2520			2520			2520		
2640	4.73				2640			2640			2640		
2760	4.77	18.62			2760			2760			2760		
2880	4.81				2880			2880			2880		
					3000			3000			3000		
					3120			3120			3120		
					3240			3240			3240		
					3360			3360			3360		
					3480			3480			3480		
					3600			3600			3600		
					3720			3720			3720		
					3840			3840			3840		
					3960			3960			3960		
					4080			4080			4080		
					4200			4200			4200		
					4320			4320			4320		
DURATION TOTALS [min]			CDT:	2880	RECOVERY:		1440	OBS 1:	0	OBS 2:	0	OBS 3:	0
DRAWDOWN / RECOVERY [m]			CDT:	4.81	RECOVERY:		0.00	OBS 1:	0.00	OBS 2:	0.00	OBS 3:	0.00
DRAWDOWN / RECOVERY [%]			CDT:	48.83	RECOVERY:		100.00	OBS 1:	0.00	OBS 2:	0.00	OBS 3:	0.00
AVERAGE YIELD [l/s]			CDT:	18.63	COMMENTS:								

FC-METHOD : Estimation of the sustainable yield of a borehole

DG1 — Main | Deriv | Inflection point method

Extrapolation time in years = (enter)	2	1051200	Extrapol.time in minutes
Effective borehole radius (r_e) = (enter)	0.05 ←	0.05	← Est. r_e — From r(e) sheet
Q (l/s) from pumping test =	18.63	1.65E-03	← S-late ← Change r_e
s_a (available drawdown), sigma_s = (enter)	6.9		← Sigma_s from risk — Down
Annual effective recharge (mm) =	0	6.90	s_available working drawdown(m)
t(end) and s(end) of pumping test =	2880	4.81	End time and drawdown of test
Average maximum derivative = (enter)	2.3 ←	2.3	Estimate of average of max deriv
Average second derivative = (enter)	0.2 ←	0.2	Estimate of average second deriv
Derivative at radial flow period = (enter)	0.28 ←	0.28	Read from derivative graph

T and S estimates from derivatives	T-early[m²/d] =	1046.15	Aqui. thick (m)	15
	T-late [m²/d] =	129.34	Est. S-late =	8.25E-04
(To obtain correct S-value, use program RPTSOLV)	S-late =	1.65E-03	S-estimate could be wrong	

BASIC SOLUTION

(Using derivatives + subjective information about boundaries)

Maximum influence of boundaries at long time

(No values of T and S are necessary)

	No boundaries	1 no-flow	2 no-flow	Closed no-flow
sWell (Extrapol.time) =	11.20	17.04	22.88	40.38
Q_sust (l/s) =	11.47	7.54	5.62	3.18
	Best case	→	→	**Worst case**

Average Q_sust (l/s) = 6.27

with standard deviation= 3.50

(If no information exists about boundaries skip advanced solution and go to final recommendation)

ADVANCED SOLUTION

(Using derivatives+ knowledge on boundaries and other boreholes)

(Late T-and S-values a priori + distance to boundary)

T-late [m²/d] = (enter) → 129.34

S-late = (enter) → 1.65E-03

1. BOUNDARY INFORMATION (choose a or b) — (Code =9999 = dummy value if not applicable)

(a) Barrier (no-flow) boundaries →	Closed Square	Single Barrier	Intersect. 90°	2 Parallel Barriers
Bound. distance a[meter] : (enter)	9999	9999	9999	9999
Bound. distance b[meter] : (enter)			9999	9999
s_Bound(t = Extrapol.time) [m] =	0.31	0.07	0.15	0.14

(b) Fix head boundary + no-flow →	Closed Fix	Single Fix	90°Fix+no-flow	// Fix+no-flow
Bound. distance to fix head a[meter] : (enter)	9999	9999	9999	9999
Bound. distance to no-flow b[meter] : (enter)			9999	9999
s_Bound(t = Extrapol.time) [m] =	-0.25	-0.07	-0.01	0.00

2. INFLUENCE OF OTHER BOREHOLES →	Q (l/s)	r (m)	u_r	W(u,r)
			0.00E+00	#NUM!
			0.00E+00	#NUM!
s_(influence of BH1,BH2) =	0.00	0.00	1.09E-11	24.66

SOLUTION INCLUDING BOUNDS AND BH's

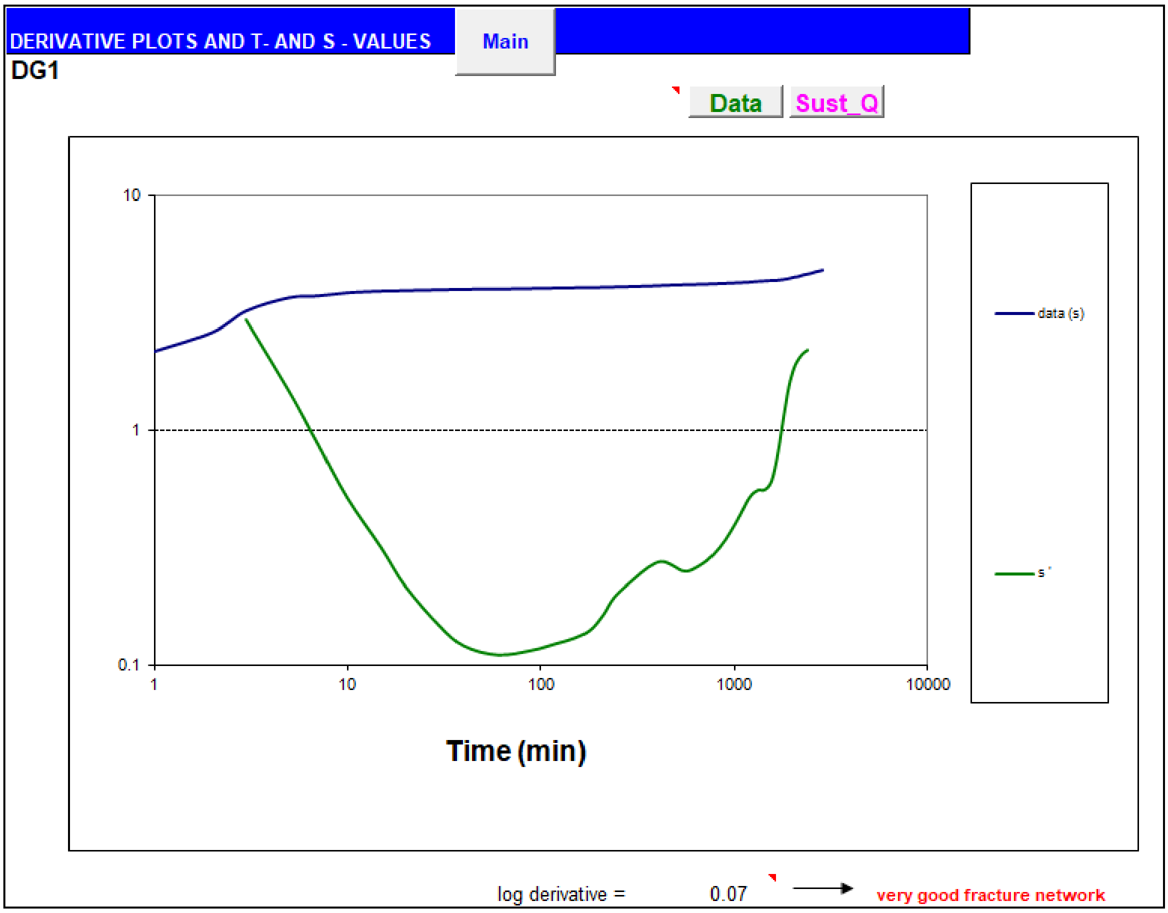
Fix head + No-flow : Q_sust (l/s) =	9999.00	9999.00	9999.00	9999.00
No-flow : Q_sust (l/s) =	9999.00	9999.00	9999.00	9999.00

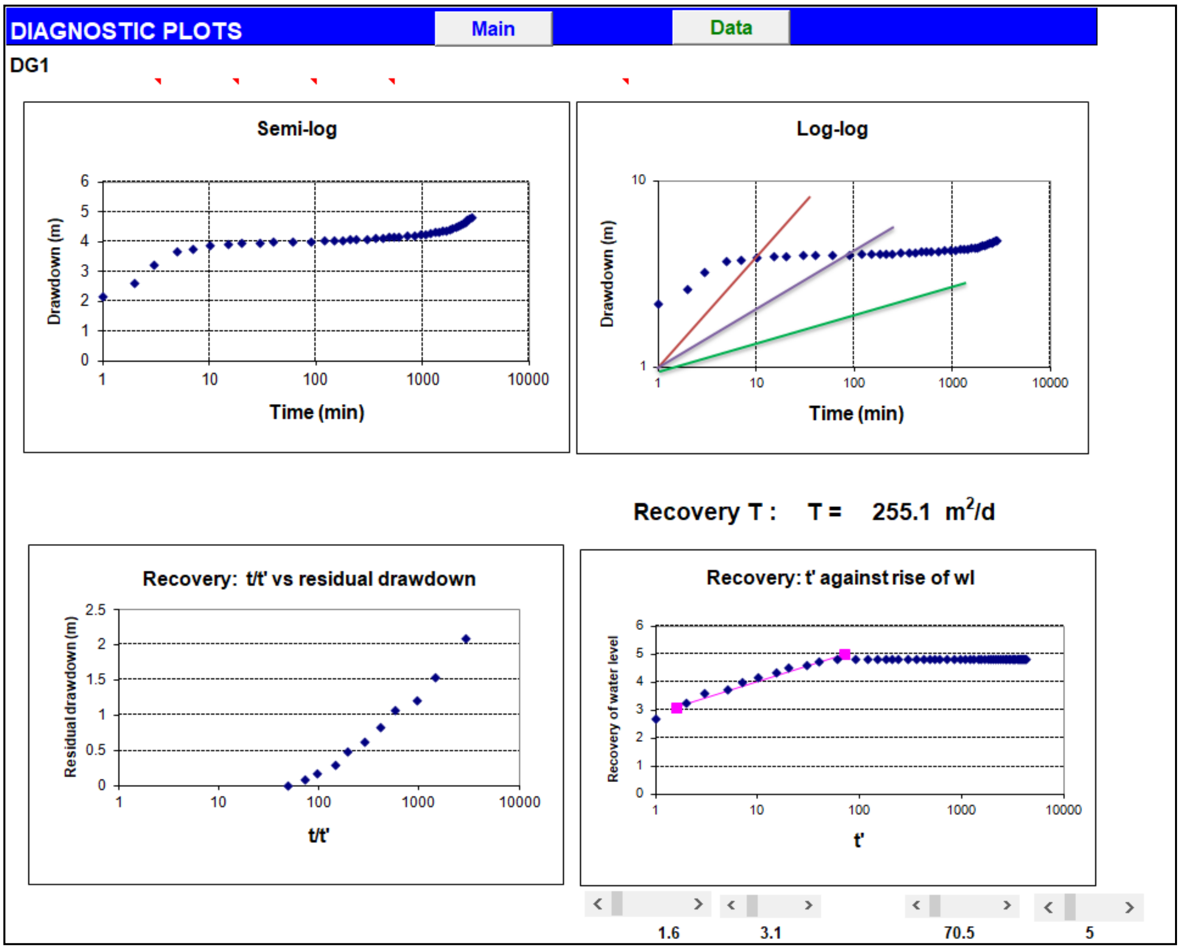
Enter selected Q for risk analysis = (enter) → | Sigma_s = 0.000 | Up | Risk

(Go to Risk sheet and perform risk analysis from which sigma_s will be estimated : only for barrier boundaries)

FINAL RECOMMENDED ABSTRACTION RATE

Abstraction rate (l/s) for 24 hr/d = (enter)	7.00
Total amount of water allowed to be abstracted per month (m³) =	18144


DERIVATIVE PLOTS AND T- AND S - VALUES
Main
DG1
Data
Sust_Q
data (s)
s'
Time (min)
log derivative = 0.07
very good fracture network


DIAGNOSTIC PLOTS
Main
Data
DG1
Semi-log
Drawdown (m)
Time (min)
Log-log
Drawdown (m)
Time (min)
Recovery T : T = 255.1 m²/d
Recovery: t/t' vs residual drawdown
Residual drawdown (m)
t/t'
Recovery: t' against rise of wl
Recovery of water level
t'
1.6
3.1
70.5
5

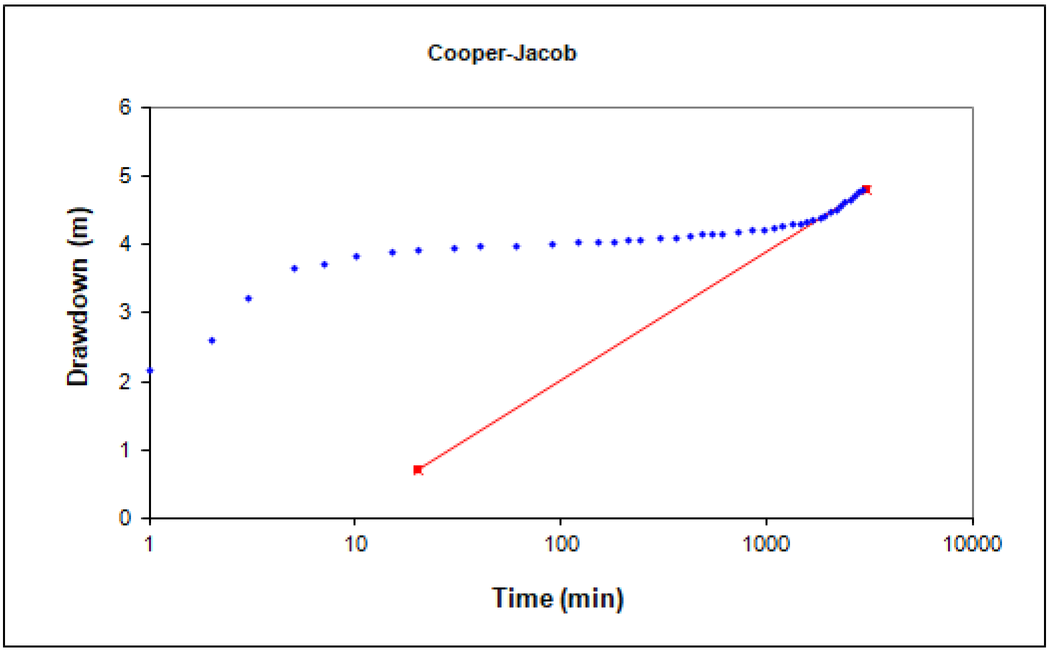
Cooper-Jacob method

Main | Theis | Cooper-Jacob 2

DG1

T(m^2/d) =	156.5	r_e (m)=	0.80	0.80
S =	3.26E+00	Q (l/s) =	18.63	

	No boundaries	1 no-flow	2 no-flow	Closed	
Q_sust	13.41	6.71	4.43	3.35	including influence of bh's
Avg. Q_sust =		6.97	std. dev =	4.51	



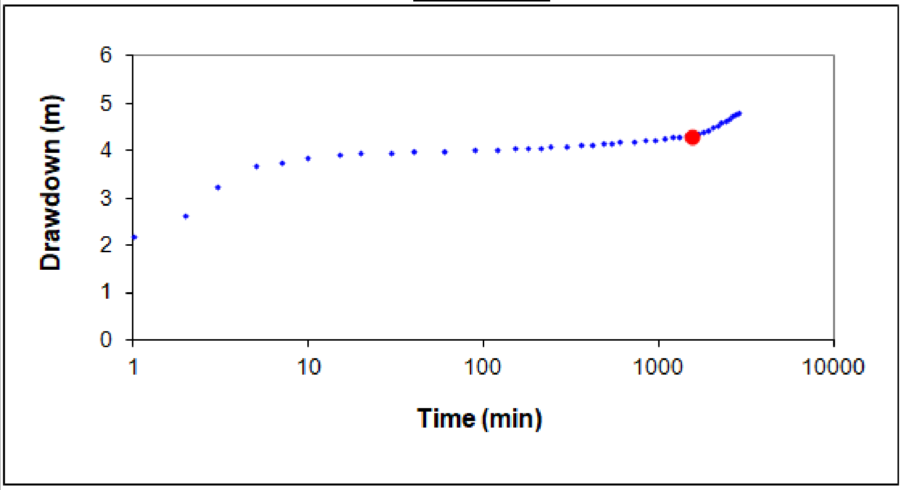
FC Inflection Point method for sustainable yield estimation

back to Sust_Q sheet | DG1 | Main

extrapolaltion time in years =	2	1051200
t(min) and s(m) at inflection point =	1539.0	4.3
enter derivative value at inflection point time =	0.56	0.56

	No boundaries	1 no-flow	2 no-flow	Closed	
sWell(Extrapol.time)	5.89	7.47	9.06	13.81	(including influence of bh's from sust_Q sheet)
Q_sust	13.61	10.72	8.85	5.80	
	Best case			Worst case	

Average Q-sust (l/s)= 9.30 std. dev = 3.28



time	drawdown
1539	4.3

FC - Non Linear Method to estimate Q_Sust

Top

$s(t)=AQ+BQ^{e}(\log(t))^{G}+CQ^{P}\log(t)$

Fit stepdrawdown data first: Manual - use buttons OR : Auto - solver

comment

Extrapolation	
Ext_pol time (min)	
1051200	
Q (L/s)	Drawdown (m)
14.1	6.92

Fit graph →

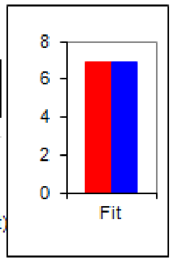
☑ Manual param ☐ Auto fit param

(Choose which parameter set to use for Q_sust)

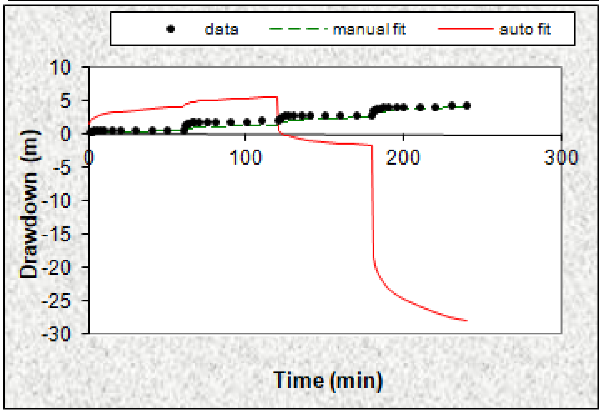
Available drawdown (m) = 6.9

No boundaries	1 no-flow	2 no-flow	Closed
14.1	7.1	4.7	2.4

Q_Sust (L/s)= 5.76 std.dev = 5.08



skin effect	Non-Darcian loss		Darcian loss			
A	C	p	B	n	e	
0.00E+00	0.00E+00	2	2.90E-05	2	1.49	manual fit
3.56E-03	-3.05E-11	3.66	3.56E-03	2.00	1.00	auto fit param



Barker- Method

Main

DG1

r =	0.10	Extpol. t (y)	2	avail. draw	6.90

Manual Fit — YES

Kf [m/d]	Sf [1/m]	b	n
15	2.00E-03	24.543	1.81

Automatic Fit with SOLVER — NO

	Min	Value	Max
Kf [m/d] =	1	2763.2191	100000
Sf [1/m] =	1.00E-07	1.00E-07	0.005
b =	0.1	17.138372	100
n =	1	1.2625087	3

Min, Max time to fit (min)

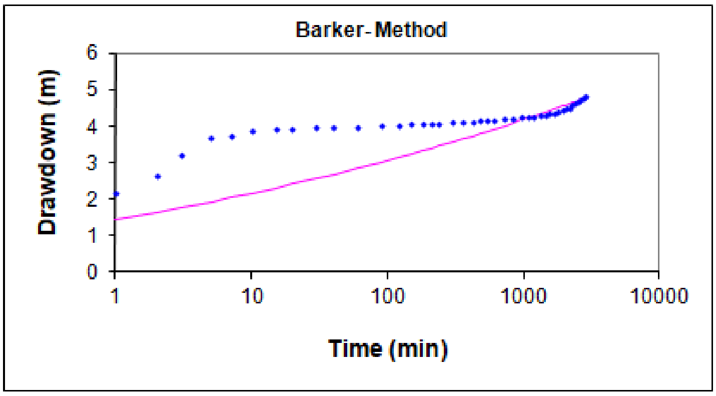
min	max
0	10000

	Kf [m/d]	Sf [1/m]	b	n	N
Fit Parameters	15.00	2.00E-03	24.54	1.81	0.0950

RMSE = 27.29695

	No boundaries	1 no-flow	2 no-flow	Closed
sWell(Extrapol.time)	9.55	21.22	27.06	32.89
Q_sust	13.46	6.06	4.75	3.91

Fractal n = 1.81 Average Q-sust (l/s)= 7.04 std. dev = 4.37



Recovery Method	DG1	
Safe yield =	Volume Pumped / (Days pumped + Days Full Recovery)	
Pump Rate	18.63	L/s
CDT Duration	48	h
Abstraction	3219	m^3
Pump duration	2	d
Full recovery	60	min
	0.04	d
Safe yield	1577	m^3/d
	18.25	L/s

Summary — Main — **DG1**

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)	Late T (m^2/d)	S	AD used
☑	Basic FC	6.27	3.50	1046	129.3	1.65E-03	6.9
☐	Advanced FC						
☑	FC inflection point	9.30	3.28				4.3
☑	Cooper-Jacob	6.97	4.51		156.5	3.26E+00	6.9
☑	FC Non-Linear	5.76	5.08	487.0		1.80E-03	6.9
☐	Recovery	18.25		244.1	330.1		
☑	Barker	7.04	4.37	K_f = 15		S_s = 2.00E-03	6.9
	Average Q_sust (l/s)	7.07	1.36	b = 24.54	Fractal dimension n =	1.81	
						Ave T	Ave S
						205.32	1.82E-03

Recommended abstraction rate (L/s)		7.00	for 24 hours per day
Hours per day of pumping	12	9.90	L/s for 12 hours per day
Hours per day of pumping	8	12.13	L/s for 8 hours per day
Amount of water allowed to be abstracted per month		18144	m^3
Amount of water allowed to be abstracted per day		597	m^3
Borehole could satisfy the basic human need of		24192	persons
Is the water suitable for domestic use (Yes/No)		Y	

Recommended pump depth below surface (m)	27
Total Casing length	
Blow yield (l/s)	
Critical depth that water level must not exceeded (mbgl)	24
Depth of borehole (m)	32
Rest water level (mbgl)	17.15

Scenic route 565 t/a Welltek Services
Vat nr: 45902 54720
Email: welltekservices@gmail.com

welltek services
Borehole testing and associated projects

CC Registration nr: 2005/137492/23
18 Highfield Road, EAST LONDON, 5205
Cell: +27 (0)71 031 5086
Fax: +27 (0)86 517 9242

BOREHOLE TEST RECORD

Borehole Number:	DG2	Province:	NORTHERN CAPE
Alternative Number:		District:	NIEKERKSHOOP
Coordinates: Latitude [°S]	29.215340	Town/Village/Farm:	
Longitude [°E]	22.924195	Rig Type & number:	TOYOTA 13
Date & Time Test Started:	2019/05/12 00:00	Operator:	THOMAS
Date & Time Test Ended:	2019/05/15 00:00	Supervisor:	STANLEY
Consultant:			

CONSULTANT - DATA PROVIDED / INSTRUCTIONS:			**EXISTING INSTALLATION:**
Borehole depth [mbgl]:		Diesel/Electric/Wind/Hand	SUBMERSIBLE
Blow Yield [l/s]:		Pump Make & Serial no:	AQUAPUMP
Water Strike Depth(s) [mbgl]:		Intallation Depth (m)	26 M
Installation depth [mbgl]:		Type & Condition - Pump:	AQUAPUMP 7,5 KW
Estimated Steps [l/s] - Step 1:		- Column:	80 MM GALV STEEL
Step 2:		- Pump House	N/A
Step 3:			**FIELD MEASUREMENTS:**
Step 4:		Depth Before Test [mbcl]:	33.80
Step 5:		Depth after Test [mbcl]:	33.80
Step 6:		Water Level before Test [mbcl]:	17.30
Step Duration [min]:		Water Level after Test [mbcl]:	17.30
Step Recovery Duration [Hrs]:		Casing Depth [mbcl]:	
Constant Yield [l/s]:		Casing Height [magl]:	0.38
Constant Duration [Hrs]:		Casing Diameter [mm]:	210.00
Recovery Duration [Hrs] / Drawdown %:			**TEST PUMP INSTALLATION DETAILS:**
Lenghth of Layflat Required [m]:		Pump Used:	BP 65 M
Frequency of pH and EC Measurements:		Depth Installed [mbcl]:	27.00
SAMPLE INSTRUCTIONS:		Datum Level above Casing [m]:	0.42
		Length of Layflat [m]:	50.00

GENERAL ACTIONS:

Supplied new steel cover [Yes/No]:	NO	Slug Test [Yes/No]:	N/A
Velded existing steel cover back on [Y/N]:	NO	Re-install existing pump [Yes/No]:	YES LEFT IT WORKING
Borehole Marking [Yes/No]:	NO	If not, where was it stored?	N/A
Site Cleaning and Finishing [Yes/No]:	YES	Maintenance work [Hrs]:	N/A
Data Reporting and Recording [Yes/No]:	YES	Maintenance Travel [km]:	N/A
Digital Photo Taken? [Yes/No]	NO	List of parts replaced/repaired:	N/A
RETREAT FROM SITE		Date &Time Sampled:	NO SAMPLE TAKEN

It is hereby acknowledged that upon leaving the site, all existing equipment is in an acceptable condition.

NAME:	
DESIGNATION:	
SIGNATURE:	
DATE:	

COMMENTS BY ONSITE CREW

BOREHOLE NO:	DG2	WATER LEVEL [mbdl]:	17.72	WATER DEPTH [mbgl]:	16.92	AVAILABLE DRAWDOWN [m]:	9.70

STEPPED DISCHARGE TEST & RECOVERY

DISCHARGE RATE 1	RPM				DISCHARGE RATE 2	RPM				DISCHARGE RATE 3	RPM			
DATE & TIME	2019/05/12 13:00				DATE & TIME	2019/05/12 14:00				DATE & TIME	2019/05/12 15:00			
TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)
1	1.20		1		1	2.12		1		1	4.02		1	
2	1.26	5.28	2		2	2.40	9.05	2		2	4.06	14.82	2	
3	1.30		3		3	2.51		3		3	4.22	15.32	3	
5	1.31	5.26	5		5	2.62	10.36	5		5	4.26		5	
7	1.32		7		7	2.66		7		7	4.30		7	
10	1.33		10		10	2.68		10		10	4.40	15.39	10	
15	1.34	5.27	15		15	2.70	10.38	15		15	4.48		15	
20	1.34		20		20	2.77		20		20	4.50		20	
30	1.35		30		30	2.79	10.37	30		30	4.52		30	
40	1.35	5.28	40		40	2.81		40		40	4.54	15.38	40	
50	1.36		50		50	2.83	10.39	50		50	4.56		50	
60	1.36		60		60	2.85		60		60	4.58		60	
			70					70					70	
			80					80					80	
			90					90					90	
			100					100					100	
			110					110					110	
			120					120					120	
			150					150					150	
Average Yield (l/s):		5.28	180		Average Yield (l/s):		10.35	180		Average Yield (l/s):		15.36	180	
Drawdown (%):		14.02	210		Drawdown (%):		29.38	210		Drawdown (%):		47.22	210	

DISCHARGE RATE 4	RPM				DISCHARGE RATE 5	RPM				DISCHARGE RATE 6	RPM			
DATE & TIME	2019/05/12 16:00				DATE & TIME	2019/05/12 16:00				DATE & TIME	2019/05/12 16:00			
TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)	TIME (min)	DRAWDOWN (m)	YIELD (l/s)	TIME (min)	RECOVERY (m)
1	5.92		1		1			1		1			1	0.37
2	5.70	21.19	2		2			2		2			2	0.17
3	5.56	20.32	3		3			3		3			3	0.10
5	5.58		5		5			5		5			5	0.05
7	5.61		7		7			7		7			7	0.00
10	5.64		10		10			10		10			10	
15	5.69	20.35	15		15			15		15			15	
20	5.7		20		20			20		20			20	
30	5.73		30		30			30		30			30	
40	5.76	20.34	40		40			40		40			40	
50	5.78		50		50			50		50			50	
60	5.8		60		60			60		60			60	
			70					70					70	
			80					80					80	
			90					90					90	
			100					100					100	
			110					110					110	
			120					120					120	
			150					150					150	
			180					180					180	
			210					210					210	
			240					240					240	
Average Yield (l/s):		20.37	300		Average Yield (l/s):		0.00	300		Average Yield (l/s):		0.00	300	
Drawdown (%):		61.03	360		Drawdown (%):			360		Drawdown (%):			360	

DATUM LEVEL ABOVE GROUND [m]:	0.80	WAS SAND PUMPED ?	NO
STATIC WATER LEVEL AFTER STEPPED DISCHARGE TEST [mbdl]:	17.72	WAS THE WATER CLEAN?	YES

STEPPED DRAWDOWN SUMMARY

STEP	DURATION [min]	DRAWDOWN [m]	DRAWDOWN [%]	AVERAGE YIELD [l/s]	RECOVERY [min]	RECOVERY [m]	RECOVERY [%]	STEP	DURATION [min]	DRAWDOWN [m]	DRAWDOWN [%]	AVERAGE YIELD [l/s]	RECOVERY [min]	RECOVERY [m]	RECOVERY [%]
1	60	1.36	14.02	5.28				5		0.00		0.00			
2	60	2.85	29.38	10.35				6		0.00		0.00			
3	60	4.58	47.22	15.36				7							
4	60	5.92	61.03	20.37				8							
DATE & TIME END:		2019/05/12 17:00						TOTAL:	240.00	5.92	61.03		0	0.00	0.00
COMMENTS:															

BOREHOLE NO:	DG2	WATER LEVEL [mbdl]:	17.72	WATER LEVEL [mbgl]:	16.92

CONSTANT DISCHARGE TEST & RECOVERY

DISCHARGE BOREHOLE		OBSERVATION HOLE 1		OBSERVATION HOLE 2		OBSERVATION HOLE 3	
TEST STARTED		WATER LEVEL [mbcl]:	N/A	WATER LEVEL [mbcl]:	N/A	WATER LEVEL [mbcl]:	N/A
DATE & TIME:	2019/05/13 08:20	CASING HEIGHT [m]:	N/A	CASING HEIGHT [m]:	N/A	CASING HEIGHT [m]:	N/A
TEST COMPLETED		CASING DIAMETER [m]:	N/A	CASING DIAMETER [m]:	N/A	CASING DIAMETER [m]:	N/A
DATE & TIME:	2019/05/17 08:20	DISTANCE [m]:	N/A	DISTANCE [m]:	N/A	DISTANCE [m]:	N/A

TIME [min]	DRAWDOWN [m]	YIELD [l/s]	TIME [min]	RECOVERY [m]	TIME: [min]	DRAWDOWN [m]	RECOVERY [m]	TIME: [min]	DRAWDOWN [m]	RECOVERY [m]	TIME: [min]	DRAWDOWN [m]	RECOVERY [m]
1	2.71		1	0.86	1			1			1		
2	2.96	15.71	2	0.31	2			2			2		
3	3.48		3	0.16	3			3			3		
5	4.28		5	0.09	5			5			5		
7	4.74	18.13	7	0.00	7			7			7		
10	5.22		10		10			10			10		
15	5.25		15		15			15			15		
20	5.28	18.14	20		20			20			20		
30	5.30		30		30			30			30		
40	5.31		40		40			40			40		
60	5.32	18.16	60		60			60			60		
90	5.32		90		90			90			90		
120	5.33		120		120			120			120		
150	5.33	18.15	150		150			150			150		
180	5.34		180		180			180			180		
210	5.34	18.16	210		210			210			210		
240	5.35		240		240			240			240		
300	5.36	18.14	300		300			300			300		
360	5.37		360		360			360			360		
420	5.38		420		420			420			420		
480	5.39	18.17	480		480			480			480		
540	5.40	18.16	540		540			540			540		
600	5.40		600		600			600			600		
720	5.41	18.16	720		720			720			720		
840	5.42		840		840			840			840		
960	5.42		960		960			960			960		
1080	5.43		1080		1080			1080			1080		
1200	5.43		1200		1200			1200			1200		
1320	5.44	18.14	1320		1320			1320			1320		
1440	5.44		1440		1440			1440			1440		
1560	5.44		1560		1560			1560			1560		
1680	5.45		1680		1680			1680			1680		
1800	5.46	18.14	1800		1800			1800			1800		
1920	5.48		1920		1920			1920			1920		
2040	5.49		2040		2040			2040			2040		
2160	5.50	18.16	2160		2160			2160			2160		
2280	5.51		2280		2280			2280			2280		
2400	5.52		2400		2400			2400			2400		
2520	5.53		2520		2520			2520			2520		
2640	5.54		2640		2640			2640			2640		
2760	5.55	18.15	2760		2760			2760			2760		
2880	5.56		2880		2880			2880			2880		
					3000			3000			3000		
					3120			3120			3120		
					3240			3240			3240		
					3360			3360			3360		
					3480			3480			3480		
					3600			3600			3600		
					3720			3720			3720		
					3840			3840			3840		
					3960			3960			3960		
					4080			4080			4080		
					4200			4200			4200		
					4320			4320			4320		

DURATION TOTALS [min]	CDT:	2880	RECOVERY:	2880	OBS 1:	0	OBS 2:	0	OBS 3:	0
DRAWDOWN / RECOVERY [m]	CDT:	5.56	RECOVERY:	0.00	OBS 1:	0.00	OBS 2:	0.00	OBS 3:	0.00
DRAWDOWN / RECOVERY [%]	CDT:	57.32	RECOVERY:	100.00	OBS 1:	0.00	OBS 2:	0.00	OBS 3:	0.00
AVERAGE YIELD [l/s]	CDT:	18.15	COMMENTS:							

FC-METHOD : Estimation of the sustainable yield of a borehole

Main | Deriv | Inflection point method

DG2

Extrapolation time in years = (enter)	2	1051200	Extrapol.time in minutes
Effective borehole radius (r_e) = (enter)	0.10	0.00	Est. r_e / From r(e) sheet
Q (l/s) from pumping test =	18.15	1.65E-03	S-late / Change r_e
s_a (available drawdown), sigma_s = (enter)	7.5		Sigma_s from risk / Down
Annual effective recharge (mm) =		7.50	s_available working drawdown(m)
t(end) and s(end) of pumping test =	2880	5.56	End time and drawdown of test
Average maximum derivative = (enter)	0.5	0.5	Estimate of average of max deriv
Average second derivative = (enter)	0.1	0.1	Estimate of average second deriv
Derivative at radial flow period = (enter)	0.25	0.25	Read from derivative graph
	T-early[m²/d] =	1163.02	Aqui. thick (m) 15
T and S estimates from derivatives	T-late [m²/d] =	594.95	Est. S-late = 8.25E-04
(To obtain correct S-value, use program RPTSOLV)	S-late =	1.65E-03	S-estimate could be wrong

BASIC SOLUTION

(Using derivatives + subjective information about boundaries)

(No values of T and S are necessary)

Maximum influence of boundaries at long time

	No boundaries	1 no-flow	2 no-flow	Closed no-flow
sWell (Extrapol.time) =	8.13	9.36	10.60	14.31
Q_sust (l/s) =	16.75	14.54	12.84	9.52
	Best case	→		**Worst case**
Average Q_sust (l/s) =	13.14			
with standard deviation=	3.05			

(If no information exists about boundaries skip advanced solution and go to final recommendation)

ADVANCED SOLUTION

(Using derivatives+ knowledge on boundaries and other boreholes)

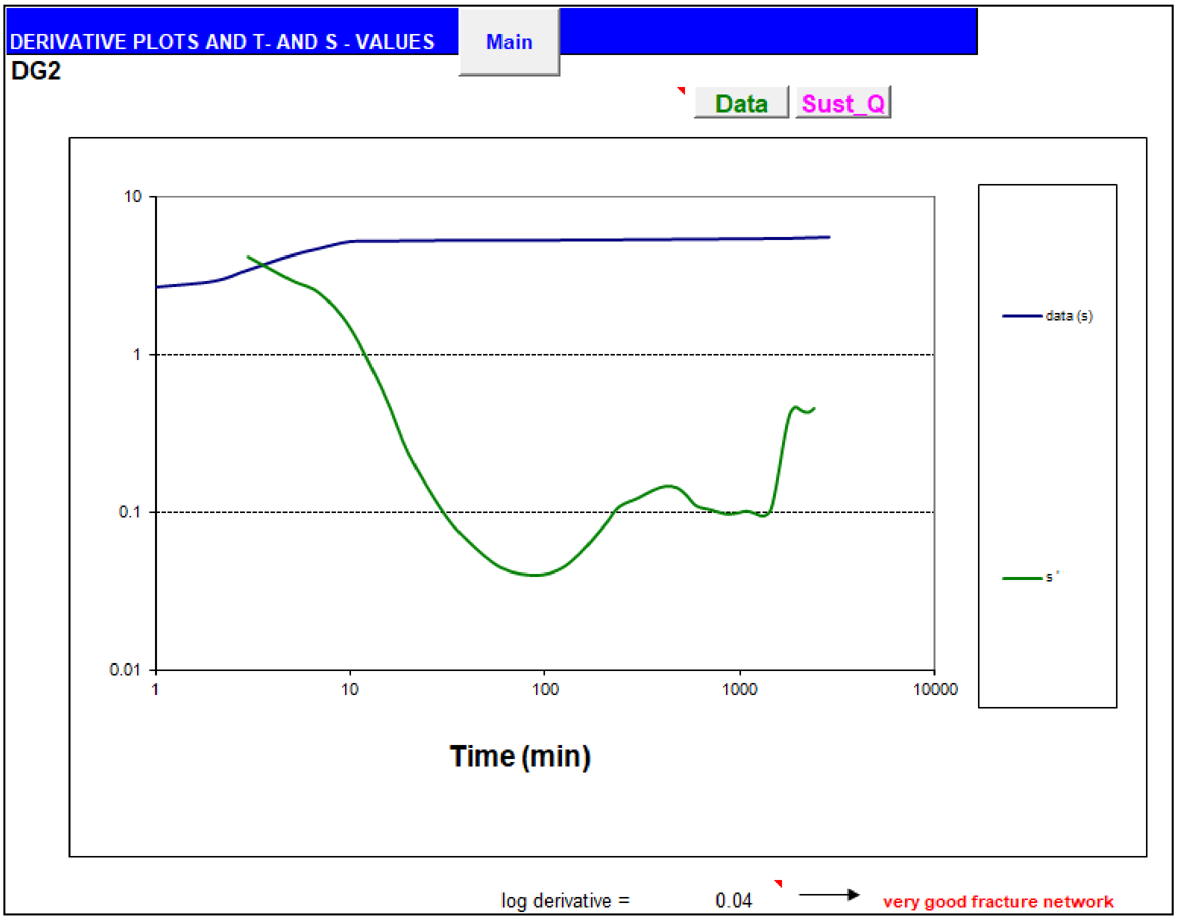
(Late T-and S-values a priori + distance to boundary)

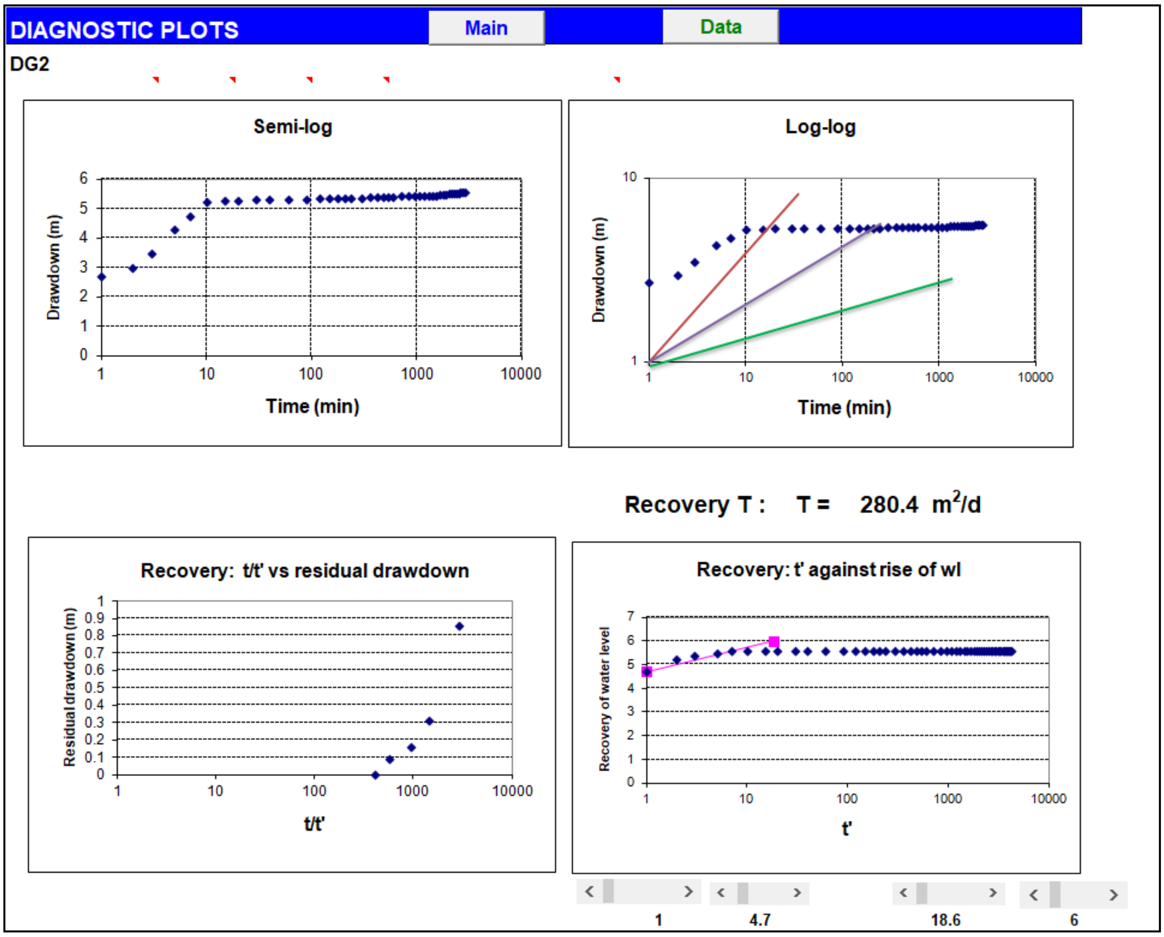
T-late [m²/d] = (enter) →	594.95			
S-late = (enter) →	1.65E-03			
1. BOUNDARY INFORMATION (choose a or b)	(Code =9999 = dummy value if not applicable)			
(a) Barrier (no-flow) boundaries →	Closed Square	Single Barrier	Intersect. 90°	2 Parallel Barriers
Bound. distance a[meter] : (enter)	9999	9999	9999	9999
Bound. distance b[meter] : (enter)			9999	9999
s_Bound(t = Extrapol.time) [m] =	1.11	0.15	0.38	0.35
(b) Fix head boundary + no-flow →	Closed Fix	Single Fix	90°Fix+no-flow	// Fix+no-flow
Bound. distance to fix head a[meter] : (enter)	9999	9999	9999	9999
Bound. distance to no-flow b[meter] : (enter)			9999	9999
s_Bound(t = Extrapol.time) [m] =	-0.39	-0.15	-0.14	-0.04
2. INFLUENCE OF OTHER BOREHOLES →	Q (l/s)	r (m)	u_r	W(u,r)
BH1	7	105	1.05E-05	10.89
			0.00E+00	#NUM!
s_(influence of BH1,BH2) =	0.88	0.00	9.50E-12	24.80
SOLUTION INCLUDING BOUNDS AND BH's				
Fix head + No-flow : Q_sust (l/s) =	9999.00	9999.00	9999.00	9999.00
No-flow : Q_sust (l/s) =	9999.00	9999.00	9999.00	9999.00
Enter selected Q for risk analysis = (enter) →		Sigma_s =	0.000 Up	Risk

(Go to Risk sheet and perform risk analysis from which sigma_s will be estimated : only for barrier boundaries)

FINAL RECOMMENDED ABSTRACTION RATE

Abstraction rate (l/s) for 24 hr/d = (enter)	11.50
Total amount of water allowed to be abstracted per month (m³) =	29808


DERIVATIVE PLOTS AND T- AND S - VALUES
Main
DG2
Data
Sust_Q
10
1
0.1
0.01
1
10
100
1000
10000
data (s)
s'
Time (min)
log derivative = 0.04
very good fracture network


DIAGNOSTIC PLOTS
Main
Data
DG2
Semi-log
Drawdown (m)
Time (min)
Log-log
Drawdown (m)
Time (min)
Recovery T : T = 280.4 m²/d
Recovery: t/t' vs residual drawdown
Residual drawdown (m)
t/t'
Recovery: t' against rise of wl
Recovery of water level
t'
1
4.7
18.6
6

Cooper-Jacob method

Main | Theis | Cooper-Jacob 2

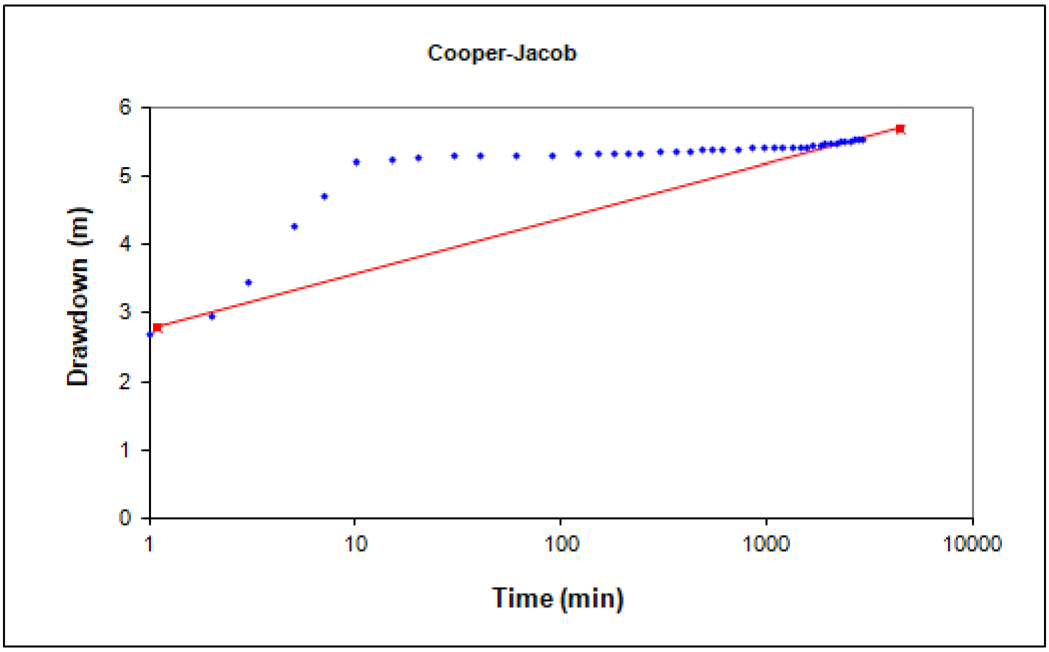
DG2

T(m²/d) =	357.1	r_e (m)=	0.80
S =	3.16E-04	Q (l/s) =	18.15

0.80

	No boundaries	1 no-flow	2 no-flow	Closed
Q_sust	15.79	7.89	5.21	3.95
Avg. Q_sust =		8.21	std. dev =	5.31

including influence of bh's



FC Inflection Point method for sustainable yield estimation

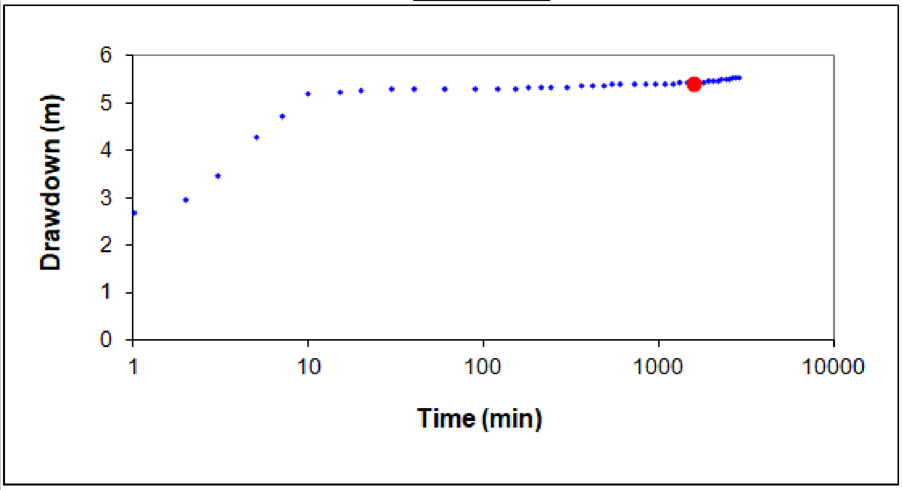
back to Sust_Q sheet | DG2 | Main

extrapolaltion time in years =	2	1051200
t(min) and s(m) at inflection point =	1589.0	5.4
enter derivative value at inflection point time =	0.17 ←	0.17

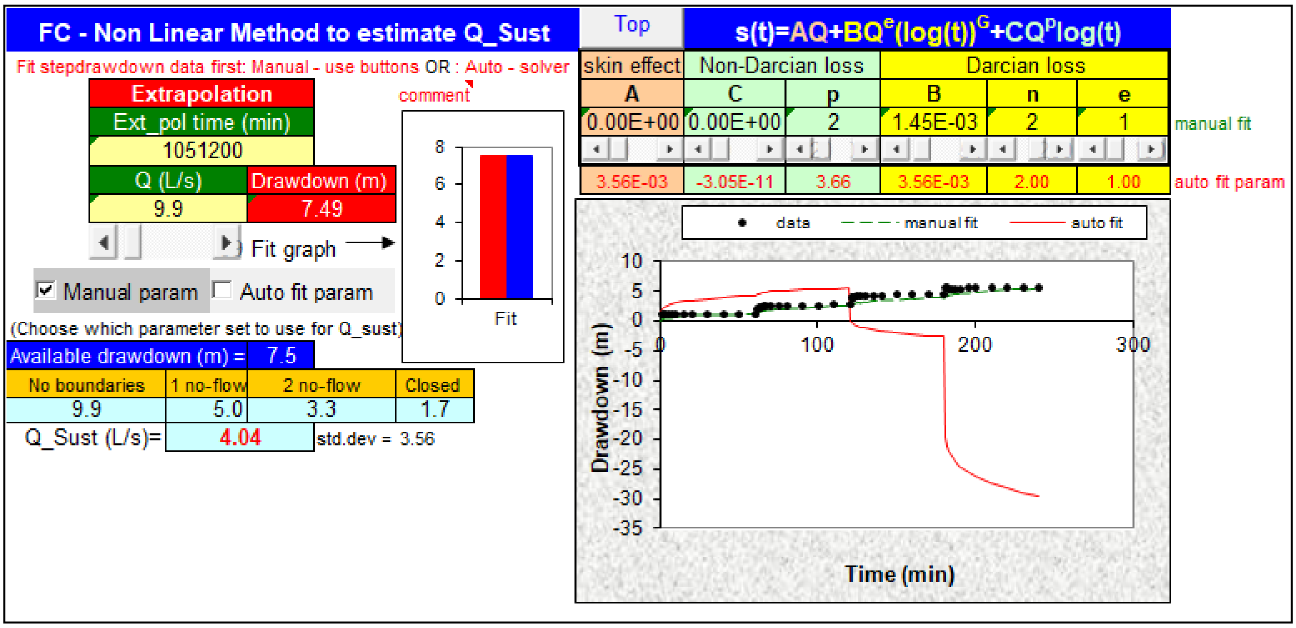
	No boundaries	1 no-flow	2 no-flow	Closed
sWell(Extrapol.time)	6.75	7.21	7.68	9.08
Q_sust	14.53	13.59	12.76	10.80
	Best case			Worst case

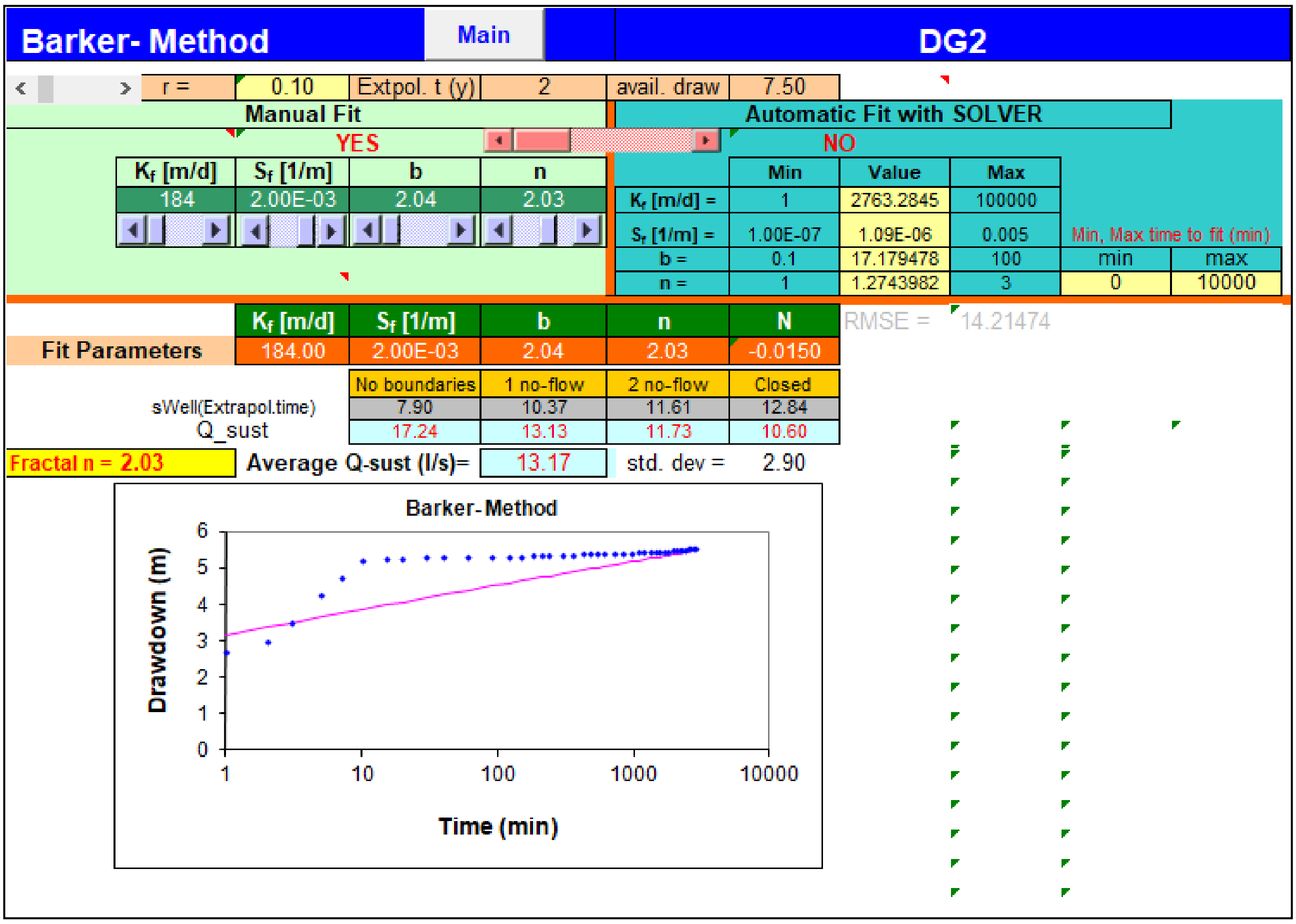
(including influence of bh's from sust_Q sheet)

Average Q-sust (l/s)= 12.84 std. dev = 1.59



time	drawdown
1589	5.4


FC - Non Linear Method to estimate Q_Sust
Top
s(t)=AQ+BQ^e(log(t))^G+CQ^Plog(t)
Fit stepdrawdown data first: Manual - use buttons OR : Auto - solver
comment
Extrapolation
Ext_pol time (min)
1051200
Q (L/s)
Drawdown (m)
9.9
7.49
Fit graph
Manual param
Auto fit param
(Choose which parameter set to use for Q_sust)
Available drawdown (m) = 7.5
No boundaries
1 no-flow
2 no-flow
Closed
9.9
5.0
3.3
1.7
Q_Sust (L/s)=
4.04
std.dev = 3.56
Fit
skin effect
Non-Darcian loss
Darcian loss
A
C
p
B
n
e
0.00E+00
0.00E+00
2
1.45E-03
2
1
manual fit
3.56E-03
-3.05E-11
3.66
3.56E-03
2.00
1.00
auto fit param
data
manual fit
auto fit
Drawdown (m)
Time (min)


Barker- Method
Main
DG2
r =
0.10
Extpol. t (y)
2
avail. draw
7.50
Manual Fit
Automatic Fit with SOLVER
YES
NO
Kf [m/d]
Sf [1/m]
b
n
184
2.00E-03
2.04
2.03
Min
Value
Max
Kf [m/d] =
1
2763.2845
100000
Sf [1/m] =
1.00E-07
1.09E-06
0.005
Min, Max time to fit (min)
b =
0.1
17.179478
100
min
max
n =
1
1.2743982
3
0
10000
Kf [m/d]
Sf [1/m]
b
n
N
RMSE =
14.21474
Fit Parameters
184.00
2.00E-03
2.04
2.03
-0.0150
No boundaries
1 no-flow
2 no-flow
Closed
sWell(Extrapol.time)
7.90
10.37
11.61
12.84
Q_sust
17.24
13.13
11.73
10.60
Fractal n = 2.03
Average Q-sust (l/s)=
13.17
std. dev =
2.90
Barker-Method
Drawdown (m)
Time (min)

Recovery Method	DG2	
Safe yield =	Volume Pumped / (Days pumped + Days Full Recovery)	
Pump Rate	18.15	L/s
CDT Duration	72	h
Abstraction	4704	m^3
Pump duration	3	d
Full recovery	7	min
	0.00	d
Safe yield	1566	m^3/d
	18.12	L/s

Summary — Main — **DG2**

Applicable	Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
☑	Basic FC	13.14	3.05	1163		594.9		1.65E-03	7.5
☐	Advanced FC								
☐	FC inflection point								
☑	Cooper-Jacob	8.21	5.31			357.1		3.16E-04	7.5
☐	FC Non-Linear	4.04	3.56			327.0		8.50E-03	7.5
☐	Recovery	18.12		702.1		702.1			
☑	Barker	13.17	2.90	K_f =	184		S_s =	2.00E-03	7.5
	Average Q_sust (l/s)	11.51	2.86	b =	2.04	Fractal dimension n =		2.03	
								Ave T	Ave S
								551.39	4.05E-03

Recommended abstraction rate (L/s)		11.50	for 24 hours per day
Hours per day of pumping	12	16.27	L/s for 12 hours per day
Hours per day of pumping	8	19.92	L/s for 8 hours per day
Amount of water allowed to be abstracted per month		29808	m^3
Amount of water allowed to be abstracted per day		980	m^3
Borehole could satisfy the basic human need of		39744	persons
Is the water suitable for domestic use (Yes/No)		Y	

Recommended pump depth below surface (m)	28
Total Casing length	
Blow yield (l/s)	
Critical depth that water level must not exceeded (mbgl)	25
Depth of borehole (m)	33.8
Rest water level (mbgl)	17.30

Appendix 2: Impact Assessment Methodology

The significance of all potential impacts that would result from the proposed Project is determined in order to assist decision-makers. The significance rating of impacts is considered by decision-makers, as shown below.

- **INSIGNIFICANT**: the potential impact is negligible and **will not** have an influence on the decision regarding the proposed activity.
- **VERY LOW**: the potential impact is very small and **should not** have any meaningful influence on the decision regarding the proposed activity.
- **LOW**: the potential impact **may not** have any meaningful influence on the decision regarding the proposed activity.
- **MEDIUM**: the potential impact **should** influence the decision regarding the proposed activity.
- **HIGH**: the potential impact **will** affect a decision regarding the proposed activity.
- **VERY HIGH**: The proposed activity should only be approved under special circumstances.

The **significance** of an impact is defined as a combination of the **consequence** of the impact occurring and the **probability** that the impact will occur. The significance of each identified impact[1] must be rated according to the methodology set out below:

Step 1 – Determine the **consequence** rating for the impact by determining the score for each of the three criteria (A-C) listed below and then **adding** them[2]. The rationale for assigning a specific rating, and comments on the degree to which the impact may cause irreplaceable loss of resources and be irreversible, must be included in the narrative accompanying the impact rating:

Rating	Definition of Rating	Score
A. *Extent* *– the area over which the impact will be experienced*		
Local	Confined to project or immediately adjacent areas	1
Regional	The region, e.g. City of Cape Town	2
(Inter) national	Nationally or beyond	3
B. ***Intensity*** *– the magnitude of the impact in relation to the sensitivity of the receiving environment, taking into account the degree to which the impact may cause irreplaceable loss of resources*		
Low	Site-specific and wider natural and/or social functions and processes are negligibly altered	1
Medium	Site-specific and wider natural and/or social functions and processes continue albeit in a modified way	2
High	Site-specific and wider natural and/or social functions or processes are severely altered	3
C. ***Duration*** *– the timeframe over which the impact will be experienced and its reversibility*		
Short-term	Up to 2 years (i.e. reversible impact)	1
Medium-term	2 to 15 years (i.e. reversible impact)	2
Long-term	More than 15 years (state whether impact is irreversible)	3

[1] This does not apply to minor impacts which can be logically grouped into a single assessment.
[2] Please note that specialists are welcome to discuss the rating definitions as they apply to their study with the EIA team.

The combined score of these three criteria corresponds to a **Consequence Rating**, as follows:

Combined Score (A+B+C)	3 – 4	5	6	7	8 – 9
Consequence Rating	Very low	Low	Medium	High	Very high

Example 1:

Extent	Intensity	Duration	**Consequence**
Regional 2	Medium 2	Long-term 3	**High** 7

Step 2 – Assess the **probability** of the impact occurring according to the following definitions:

Probability– the likelihood of the impact occurring	
Improbable	< 40% chance of occurring
Possible	40% - 70% chance of occurring
Probable	> 70% - 90% chance of occurring
Definite	> 90% chance of occurring

Example 2:

Extent	Intensity	Duration	**Consequence**	**Probability**
Regional 2	Medium 2	Long-term 3	**High** 7	Probable

Step 3 – Determine the overall **significance** of the impact as a combination of the **consequence** and **probability** ratings, as set out below:

		Probability			
		Improbable	Possible	Probable	Definite
Consequence	Very Low	**INSIGNIFICANT**	**INSIGNIFICANT**	**VERY LOW**	**VERY LOW**
	Low	**VERY LOW**	**VERY LOW**	**LOW**	**LOW**
	Medium	**LOW**	**LOW**	**MEDIUM**	**MEDIUM**
	High	**MEDIUM**	**MEDIUM**	**HIGH**	**HIGH**
	Very High	**HIGH**	**HIGH**	**VERY HIGH**	**VERY HIGH**

Example 3:

Extent	*Intensity*	*Duration*	***Consequence***	***Probability***	***Significance***
Regional 2	Medium 2	Long-term 3	**High** 7	Probable	**HIGH**

Step 4 – Note the **status** of the impact (i.e. will the effect of the impact be negative or positive?)

Example 4:

Extent	*Intensity*	*Duration*	***Consequence***	***Probability***	***Significance***	***Status***
Regional 2	Medium 2	Long-term 3	**High** 7	Probable	**HIGH**	**– ve**

Step 5 – State your level of **confidence** in the assessment of the impact (high, medium or low).

Depending on the data available, you may feel more confident in the assessment of some impact than others. For example, if you are basing your assessment on extrapolated data, you may reduce the confidence level to low, noting that further groundtruthing is required to improve this.

Example 5:

Extent	*Intensity*	*Duration*	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Regional 2	Medium 2	Long-term 3	**High** 7	Probable	**HIGH**	**– ve**	High

Step 6 – Identify and describe practical **mitigation** and **optimisation** measures that can be implemented effectively to reduce or enhance the significance of the impact. Mitigation and optimisation measures must be described as either:

- **Essential**: best practice measures which must be implemented and are non-negotiable; and.
- **Best Practice**: recommended to comply with best practice, with adoption dependent on the proponent's risk profile and commitment to adhere to best practice, and which must be shown to have been considered and sound reasons provided by the proponent if not implemented.

Essential mitigation and optimisation measures must be inserted into the completed impact assessment table. The impact should be re-assessed with mitigation, by following Steps 1-5 again to demonstrate how the extent, intensity, duration and/or probability change after implementation of the proposed mitigation measures.

Example 6: A completed impact assessment table

	Extent	***Intensity***	***Duration***	***Consequence***	***Probability***	***Significance***	***Status***	***Confidence***
Without mitigation	Regional 2	Medium 2	Long-term 3	**High** 7	Probable	**HIGH**	**– ve**	High
Essential mitigation measures: Xxx1 Xxx2 Xxx3								
With mitigation	Local 1	Low 1	Long-term 3	**Low 5**	Improbable	**VERY LOW**	**– ve**	High