GEOHYDROLOGICAL ASSESSMENT FOR TSWANA LIME, LICHTENBURG, NORTH WEST PROVINCE

September 2022
Ref: 005803R01

For:

LAFARGE

Prepared by:

JG AFRIKA (PTY) LTD

DURBAN BRANCH
PO Box 2762
Westway Office Park, Durban
3635
Telephone: (031) 275 5500
Email: schapersr@jgafrika.co.za
Project Lead: Robert Schapers

VERIFICATION PAGE

Form 4.3.1

Rev 13

TITLE:

GEOHYDROLOGICAL ASSESSMENT FOR TSWANA LIME, LICHTENBURG, NORTH WEST PROVINCE

JG AFRIKA REF. NO.	DATE:	REPORT STATUS
005803R02	09/09/2022	First Issue

CARRIED OUT BY:

JG AFRIKA (PTY) LTD - DURBAN

Block C 1st Floor
1 The Boulevard
Westway Office Park
3629

Tel.: 031 275 5500
Email: schapersr@jgafrika.com

COMMISSIONED BY:

LAFARGE INDUSTRIES SOUTH AFRICA (PTY) LTD

1 Manana Road
Industrial Site
Lichtenburg
2740

Tel: 065 913 1666
Email: uneysa.taljard@lafarge.com

AUTHOR

Robert Schapers / Rainier Dennis

CLIENT CONTACT PERSON

Uneysa Taljard

SYNOPSIS

Specialist geohydrological assessment in support of water use authorisation for Tswana Lime near Lichtenburg, North West Province

KEY WORDS:

Geology, geohydrology, hydrocensus, groundwater use, boreholes, groundwater abstraction, groundwater model, risk and impact, monitoring

QUALITY VERIFICATION

This report has been prepared under the controls established by a quality management system that meets the requirements of ISO9001: 2015 which has been independently certified by DEKRA Certification

Verification	Capacity	Name	Signature	Date
Reviewed by	Executive Associate	Robert Schapers		07 Sep 2022
Authorised by	Technical Director	Mark Schapers		09 Sep 2022

Filename:	https://jgafrika.sharepoint.com/sites/Job5803-team-102-WIP-Internal-ES/Shared Documents/102-WIP-Internal-ES/105-Reports/tswana lime/005803R01 Tswana Lime Geohydro Report.docx

GEOHYDROLOGICAL ASSESSMENT FOR TSWANA LIME, LICHTENBURG, NORTH WEST PROVINCE

TABLE OF CONTENTS

TABLES

FIGURES

ANNEXURES

GEOHYDROLOGICAL ASSESSMENT FOR TSWANA LIME, LICHTENBURG, NORTH WEST PROVINCE

1 INTRODUCTION

This report presents the results of a detailed geohydrological assessment carried out for Tswana Lime Quarry site located 36 km north west of Lichtenburg in the North West Province. The geohydrological report has been prepared as a specialist study in support of the water use authorisation for the following water uses as per Section 21 of the National Water Act (Act No. 36 of 1998).

Section 21 (a) - taking water from a water resource
Section 21 (g) - disposing of waste in a manner which may detrimentally impact on a water resource
Section 21 (j) - removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people.

The scope of services is to prepare a geohydrological report to include the following:

- Geology and geohydrology of the area
- Hydrocensus, groundwater flow and recharge
- All water resources in the plant and surrounding areas must be indicated
- A groundwater model for the pit and area, which must show contaminant transport and impact prediction
- A groundwater monitoring programme indicating monitoring points upstream and downstream of all the waste facilities and the pit
- An impact assessment
- Yield testing of production boreholes to be used in the application and the test data must be shown in the report
- An assessment of ingress water from underground if it fills the pit at any point in time.

We refer to our proposal reference 005752 2117004, titled "Proposal for Detailed Geohydrological Assessments For Tswana Lime and Lichtenburg Cement Factory Plant Sites, North West Province", dated 10 November 2021. JG Afrika were appointed to proceed with the assessment under purchase order 4501873093, dated 26 April 2022.

2 INFORMATION SUPPLIED

The following information has been used in the preparation of this report:

<u>Reports, Documents and Guidelines</u>

- Letter reference 27/2/2/C131/8/1 of the Department Water and Sanitation, titled "Water Use Licence Application in Terms of Section 40 of the National Water Act, 1998 (Act 36 of 1998): Lafarge Industries South Africa (Pty) Ltd: For an old Cement Plant Situated on Portions 1, 27, 30, 32, 61, 71 of the Farm Lichtenburg 27 IP and Erf 1024 of the Farm Lichtenburg Extension 1 IP, in Lichtenburg Town, within the Ditsobotla Local Municipality, North West Province", dated 21 February 2022
- Report reference 5707 of JG Afrika (Pty) Ltd, titled "Tswana Lime Quarry Water Balance Study", draft, dated April 2022
- Report reference LI/MR9/2021/DS of Aquatico Scientific (Pty) Ltd, titled "Lafarge Industries Monthly Water Quality Assessment Report, October 2021", dated October 2021

- Report reference LI/AR1/2021/DS of Aquatico Scientific (Pty) Ltd, titled "Lafarge Industries Annual Water Quality Assessment Report, February 2021 – January 2022", dated 9 May 2022
- Report reference GW-16-09-CV414B of Tucana Solutions, titled "Lafarge Lichtenburg Cement Plant and Tswana Quarry – Geohydrological Report", version 1.4, dated February 2017
- Government Notice R267 of March 2017. National Water Act, 1998 (Act No. 36 of 1998). Regulations Regarding the Procedural Requirements for Water Use Licence Applications and Appeals
- The Department of Water Affairs, First Edition, February 2010. Operational Guideline: Integrated Water and Waste Management Plan
- Water Research Commission and Institute for Groundwater Studies, University of the Free State, January 2001. Manual on Pumping Test Analysis in Fractured-Rock Aquifers
- South African National Standard SANS10299-4:2003 – Part 4: Test Pumping of Water Boreholes
- South African National Standard, SANS241: 2015, Edition 2. Drinking Water.
- Aller L, Bennett T, Lehr JH, Petty, RJ and Hackett G (1987). *DRASTIC: A Standardized System for Evaluating Groundwater Pollution Potential using Hydrogeologic Settings*. NWWA/EPA Series, EPA-600/2-87-035
- Bredenkamp D, Botha LJ, van Tonder G and Janse van Rensberg H (1995). *Manual on Qualitative Estimation of Groundwater Recharge and Aquifer Storativity, Based on Practical Hydro-Logical Methods*. Water Research Commission, TT 73/95
- Parsons RP (1995). *A South African Aquifer System Management Classification*. WRC Report No. 77/95, Water Research Commission, Pretoria
- Taylor CJ (1983). *A Geohydrological Investigation of the Lichtenburg Area, Bo- Molopo Subterranean Water Control Area*. Division of Geohydrology, Department of Environment Affairs, Pretoria
- Vegter, J.R. (1995). *An Explanation of a Set of National Groundwater Maps*. WRC Report No. TT 74/95, Water Research Commission, Pretoria, South Africa
- JMC Weaver et al, 2007. Groundwater sampling, A Comprehensive Guide for Sampling Methods. Water Research Commission (TT303/07).

<u>Maps and Drawings</u>

- Map Sheet titled "2624 Vryburg", at a scale of 1:250000, dated 1991, of the Geological Map Series, supplied by the Geological Survey, Pretoria
- Map sheet titled, "2522 Vryburg", at a scale of 1:500 000, first edition, dated 2000, of the Hydrogeological Map Series of the Republic of South Africa, supplied by the Directorate: Geohydrology, of the Department of Water Affairs and Forestry
- Map Sheet titled "2625BB Itsoseng", at a scale of 1:50 000, dated 2001, digital version, of the Topocadastral Map Series, supplied by the Surveyor General

<u>Data</u>

- National Groundwater Archive (NGA) digital information, as supplied by The Department of Water and Sanitation (DWS) as at August 2022
- DWAF (2003a). Groundwater Resources Assessment Phase II Database. Website: www.dwaf.gov.za/Groundwater/GRAII.aspx
- DWAF (2003b). Groundwater Resources Assessment Phase II Database. Website: www.dwaf.gov.za/Groundwater/GRAII.aspx
- World Aerial Imagery obtained via Global Mapper as at August 2022
- SRTM30 Digital Elevation Model

- DRASTIC Aquifer Vulnerability dataset of South Africa
- Aerial magnetometer data (1km x 1km resolution) for South Africa
- SANBI Wetlands Coverage for South Africa (2010)
- Geohydrological yield map of South Africa (2009)
- Google Earth Pro version 7.3.3 of July 2020.

3 SITE DESCRIPTION

The Tswana Lime site is located on farms Driefontein 46 IO, Rondefontein 47 IO and Rietschraal 58 IO in the Ditsobotla Local Municipality of the North West Province. The site is approximately 35 km west north west of the town of Lichtenburg and can be accessed from Lichtenburg via the R503 followed by the D40. The location of the site is presented in Figure 1.

Figure 1: Site Locality

4 APPLICABLE WATER USE APPLICATIONS

The water use applications specific to the geohydrological assessment for the Tswana Lime Quarry site are summarised in Table 1 and presented in Figure 2.

Table 1: Summary Water Uses

Water Use	Description	Latitude	Longitude
TSWANA LIME SITE			
21 (a)	Tswana Borehole 1	-26.07618	25.78032
21 (b)	Dam for Dust Suppression	-26.07462	25.80234
21 (j)	Sump 1	-26.07237	25.80476
21 (j)	Sump 2	-26.08062	25.80250
21 (j)	Sump 3	-26.08325	25.80337
21 (j)	Sump 4	-26.08619	25.79825
21 (f)	Polfonteinspruit Discharge	-26.05332	25.80364
21 (g)	Limestone Stockpile	-26.08012	25.83195

Figure 2: Site Plan showing Water Uses Considered for the Application

5 BOREHOLE YIELD ASSESSMENT

5.1 Test Methodology

The water use application borehole was designated LQBH4 as per previous records, and is located at approximate coordinates S 26.076095° E 25.780376°. The depth of the borehole was measured as 52.9 mbgl and the static water level as 7.5 mbgl. The borehole was equipped with a submersible pump operating on a telemetry system with level sensors located in the storage tanks at the Tswana Lime plant. The abstraction rate of the borehole was measured at 3.26 l/s using the inline flow meter at the borehole. During peak plant demand times, the borehole typically operated on an cycle of 40 seconds on / 90 seconds off, subject to the tank levels.

The yield testing of the borehole was carried out by JG Afrika (Pty) Ltd over the period 02 to 03 August 2022. The yield test was carried out in accordance with the guidelines of the South African National Standard SANS10299-4:2003 – Part 4: Test Pumping of Water Boreholes, and the recommended guidelines for test pumping of fractured rock aquifers.

The yield testing methodology typically comprises a stepped phase followed by a constant discharge pumping phase. Due to potential supply interruptions at the Tswana Lime Quarry site, the general methodology had to be adapted around the operations of the site. The existing pump could not be removed to test the borehole due to the anticipated delays associated with the borehole being off line. The test was thus conducted using the existing pump at the existing rate and the constant discharge phase was only carried out since adjusting pumping rates was not achievable. Constant discharge testing was scheduled for 24 hours, however, the continuous supply of water to the Tswana Lime plant and the limited storage of 20 m^3, resulted in the storage overflow and potential flooding at the plant. On this basis the site foreman shut the pump off after just over 12 hours of constant discharge testing. This shut down was not adequately communicated to the yield testing crew therefore the initial recovery monitoring readings were not taken. Recovery was however carried out for a period equivalent to pumping or at least 95% of the original static water level as per the guidelines.

Constant discharge testing was carried out at a rate of 3.24 l/s for a period of 12 hours. The test resulted in a maximum drawdown of 7.33 m. No boundary effects were observed in the constant discharge phase. After the 12 hour constant discharge phase, the water level recovered to 95% of the pre-test static in under 360 minutes, indicating good fracture flow and no dewatering taking place. The yield test data and analysis is presented in Annexure B.

From the log-log graph, bi linear flow was evident from 2 minutes for the duration of pumping, and from the semi log graph, radial flow was evident from 15 minutes for the duration of pumping. No boundary conditions were observed. A transmissivity of 26.1 m^2/d was determined from the recovery plot. A minimum critical drawdown of 7.3 m (14.8 mbgl) was assessed from the constant discharge data. It is likely that the main fracture is considerably deeper and the minimum critical drawdown was considered conservative. A summary of sustainable yield analysis using the various methods of the FC program are as follows:

LQBH4								
Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
Basic FC	0.91	0.43	#NUM!		25.7		2.20E-03	7.3
Advanced FC			#NUM!		25.7		1.00E-03	7.3
FC inflection point	1.06	0.53						7.3
Cooper-Jacob	0.97	0.63			30.1		7.40E-03	7.3
FC Non-Linear								7.3
Barker	1.16	0.70	K_f =	4		S_s =	1.60E-04	7.3
Average Q_sust (l/s)	1.03	0.11	b =	8.48	Fractal dimension n =		2.08	

Recommended abstraction rate (L/s)	1.06	for 24 hours per day				
Hours per day of pumping: 24	1.06	L/s	for	24	hours per day	
Daily volume on recommended cycle	91.60	m3/d		Persons Served (Basic Human Needs)	3664	

The maximum daily volume that can be abstracted from the borehole using the conservative critical drawdown is 91.6 kl/d. Given the pump cycle observed on site, the borehole likely operates at less than 7.5 hours per 24 hour cycle. It is inferred that this could be as low as 3.25 hours per day shift cycle (12 hours). By increasing the critical drawdown to match the abstraction rate to 3.25 l/s, an available drawdown of 14 m was determined. This is inferred to be a reasonable representation of the main strike depth and the borehole is considered to be operating within the design of its sustainable yield.

LQBH4								
Method	Sustainable yield (l/s)	Std. Dev	Early T (m^2/d)		Late T (m^2/d)		S	AD used
Basic FC	1.75	0.82	#NUM!		25.7		2.20E-03	14.0
Advanced FC			#NUM!		25.7		1.00E-03	14.0
FC inflection point	1.54	0.57						14.0
Cooper-Jacob	1.86	1.21			30.1		7.40E-03	14.0
FC Non-Linear								14.0
Barker	2.23	1.34	K_f =	4		S_s =	1.60E-04	14.0
Average Q_sust (l/s)	1.84	0.29	b =	8.48	Fractal dimension n =		2.08	

Recommended abstraction rate (L/s)	1.86	for 24 hours per day				
Hours per day of pumping: 7.5	3.33	L/s	for	7.5	hours per day	
Daily volume on recommended cycle	89.85	m3/d		Persons Served (Basic Human Needs)	3594	

5.2 Water Quality

A groundwater sample was collected from the borehole for chemical analysis by JG Afrika (Pty) Ltd during the site assessment. The borehole sample was collected on 27 August 2022 and submitted to Talbot Laboratory for analysis of selected determinants of the Domestic Consumption SANS241 (2015) raw water suite. The results of analysis are summarized in Table 2, and the laboratory certificate of analysis is presented in Annexure C. The results of analysis were compared to screening guidelines to assess the potability and suitability for use. The SANS241 (2015) Drinking Water Standards were used for comparative purposes. The screening guideline values are included in the summary of results table. The results of analysis indicate that all the determinants analysed were within the screening limits. The groundwater is therefore potable and suitable for domestic use without treatment.

Table 2: Summary Results of Water Quality Analysis by Talbot Laboratory

Sample Position		**LQBH4**	**SANS 241 : 2015 Drinking Water**		
Sample Date		28-Aug-22			
Sampled by		MN			
Sample Method		submersible	**Upper Limits**		
Laboratory Certificate Number		023364/22			
Laboratory Sample Reference			Acute health	Aesthetic	Operational
Determinand	Unit	LICH 0114	Chronic health		
Micro biological determinands					
E. coli or faecal coliforms	Count per 100 mL	<1	Not detected		
Total coliforms	Count per 100 mL	<1			≤10
Heterotrophic plate count	Count per mL	300			1 000
Physical and aesthetic determinands					
Colour	mg/L Pt-Co	<10		15	
Conductivity at 25 °C	mS/m	61.8		170	
Total dissolved solids	mg/L	382		1200	
Turbidity	NTU	0.44		5	1
pH at 25 C	pH units	7.1			5 to 9.7
Chemical determinands — macro-determinands					
Nitrate as N	mg/L	1.51	11		
Nitrite as N	mg/L	<0.05	0.9		
Combined nitrate-nitrite	-	0.19	1		
Sulphate as SO42–	mg/L	12.6	500	250	
Fluoride as F–	mg/L	0.32	1.5		
Ammonia as N	mg/L	<1.5		1.5	
Chloride as Cl–	mg/L	13.4		300	
Sodium as Na	mg/L	17		200	
Zinc as Zn	mg/L	0.025		5	
Chemical determinands — micro-determinands					
Aluminium as Al	µg/L	1.4	300		
Antimony as Sb	µg/L	<1	20		
Arsenic as As	µg/L	<1	10		
Barium as Ba	µg/L	66	700		
Boron as B	µg/L	40	2400		
Cadmium as Cd	µg/L	<1	3		
Total chromium as Cr	µg/L	7.4	50		
Copper as Cu	µg/L	5.1	2000		
Cyanide (recoverable) as CN–	µg/L	<20	200		
Iron as Fe	µg/L	1.1	2000	300	
Lead as Pb	µg/L	<1	10		
Manganese as Mn	µg/L	<1	400	100	
Mercury as Hg	µg/L	<10	6		
Nickel as Ni	µg/L	<1	70		
Selenium as Se	µg/L	<1	40		
Uranium as U	µg/L	<1	30		
Chemical determinands —					
Total organic carbon as C	mg/L	3.9	10		
Phenols	µg/L	<2		10	

5.3 Borehole Management Plan

Based on analysis of the yield test data and water quality, a summary of the borehole management plan is presented in Table 3.

Table 3: Borehole Management Plan

Borehole ID	LQBH4
Water Quality	All within SANS241 limits
Compounds of Concern	none
Risk	none
Treatment / Action	Biannual monitoring
Sustainable Yield (l/s)	1.86
Recommended Duty	7.5
Abstraction Rate for Duty Period (8 hrs)	3.33
Volume on Specified Duty (m^3/d)	89.85
Critical Drawdown (mbgl)	21.5
Anticipated Maximum Head (m)	22
Recommended Pump Installation Depth (mbgl)	Per current installation

The water use application abstraction rate should be 1.86 l/s on a 24 hour duty to accommodate the maximum sustainable yield of the borehole. This equates to approximately 58657 m^3/a.

6 HYDROCENSUS

6.1 Introduction

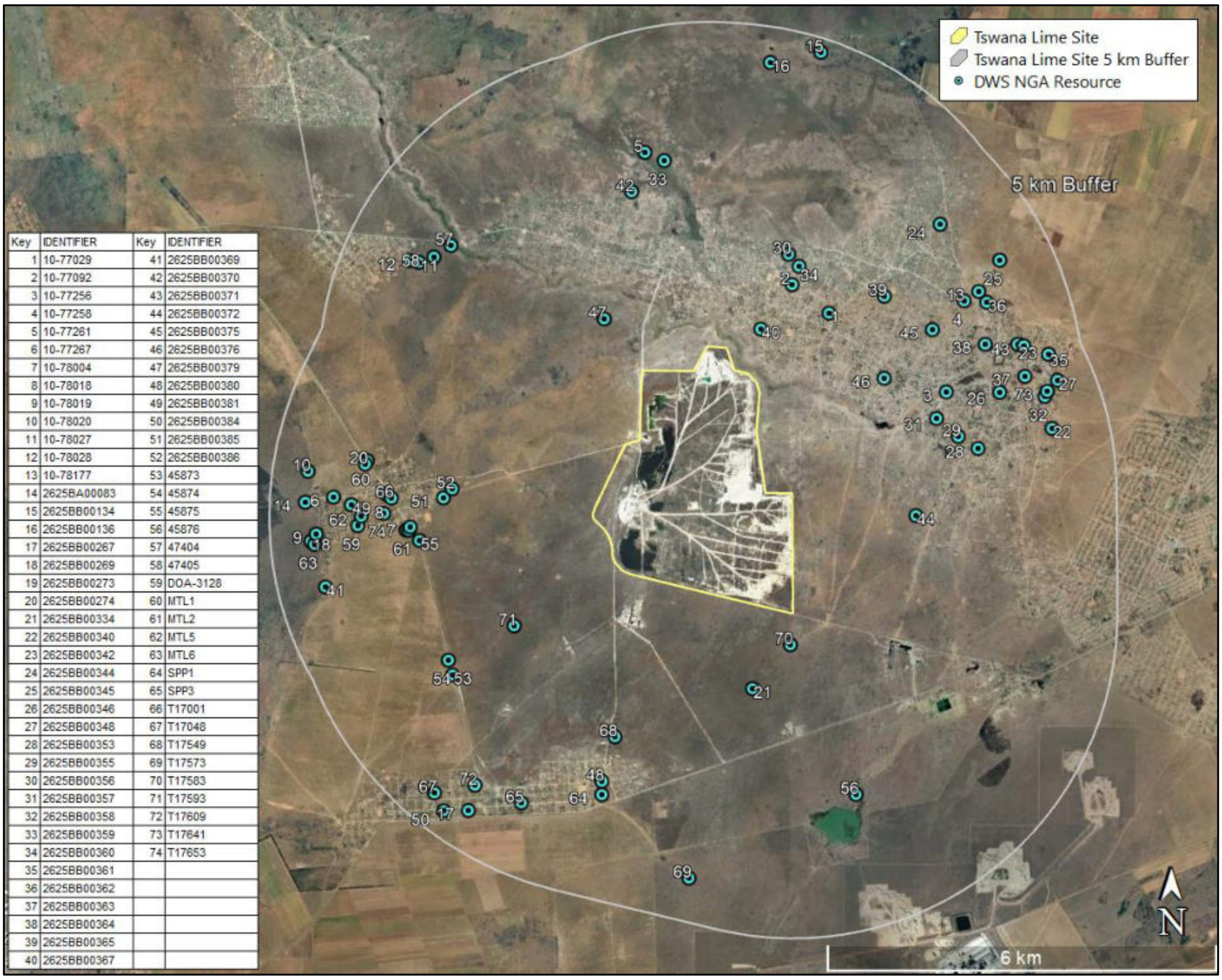
A hydrocensus was required to determine existing groundwater use in the project area and to establish possible impacts on existing resources from the Tswana Lime Quarry site activities. The hydrocensus further served to collect current water levels from known resources for the development of the groundwater model.

6.2 National Groundwater Archive (NGA)

The National Groundwater Archive (NGA) of the Department of Water and Sanitation was interrogated to establish the existence of any groundwater resources and groundwater use in proximity to the site. The NGA reported 74 (No.) resources within 5 km of the site. The NGA database of resource information is presented in Annexure D. The locations of resources as presented in the DWS database are presented in Figure 3. A summary of the information presented in the NGA for the listed resources is presented Table 4.

Table 4: Summary NGA Resource Information

Field Description	No of Resources.	Field Description	No of Resources.
Purpose		Status	
Production	41	Unknown	8
Exploration	5	Not Selected	33
Exploration / Production	1	Inaccessible	3
Not Specified	27	Abandoned	11
Equipment		Destroyed	12
Positive Displacement Pump	11	Monitoring	3
Not Specified	63	Standby	3
Yield		Obstructed	1
0	44		
>0	11		
Not Specified	19		
Statistical Information (Only Specified Boreholes)	**Minimum**	**Maximum**	**Average**
Water Level	0.8	60	9.47
Yield	0.5	32.1	6.74
Depth	14.95	150	72
Strike Depth	7	66	35



Key	IDENTIFIER	Key	IDENTIFIER
1	10-77029	41	2625BB00369
2	10-77092	42	2625BB00370
3	10-77256	43	2625BB00371
4	10-77258	44	2625BB00372
5	10-77261	45	2625BB00375
6	10-77267	46	2625BB00376
7	10-78004	47	2625BB00379
8	10-78018	48	2625BB00380
9	10-78019	49	2625BB00381
10	10-78020	50	2625BB00384
11	10-78027	51	2625BB00385
12	10-78028	52	2625BB00386
13	10-78177	53	45873
14	2625BA00083	54	45874
15	2625BB00134	55	45875
16	2625BB00136	56	45876
17	2625BB00267	57	47404
18	2625BB00269	58	47405
19	2625BB00273	59	DOA-3128
20	2625BB00274	60	MTL1
21	2625BB00334	61	MTL2
22	2625BB00340	62	MTL5
23	2625BB00342	63	MTL6
24	2625BB00344	64	SPP1
25	2625BB00345	65	SPP3
26	2625BB00346	66	T17001
27	2625BB00348	67	T17048
28	2625BB00353	68	T17549
29	2625BB00355	69	T17573
30	2625BB00356	70	T17583
31	2625BB00357	71	T17593
32	2625BB00358	72	T17609
33	2625BB00359	73	T17641
34	2625BB00360	74	T17653
35	2625BB00361		
36	2625BB00362		
37	2625BB00363		
38	2625BB00364		
39	2625BB00365		
40	2625BB00367		

Figure 3: Locations of Resources as Presented in the NGA

6.3 Field Verification

A field verification hydrocensus survey was carried out using the hydrocensus information collected during previous studies[1]. The survey was augmented with additional resources and current field information. A total of nine (9 No.) resources were identified during the previous and current survey. A summary of the resource information is presented in Table 5 and the approximate distribution of the boreholes is presented in Figure 4. The hydrocensus resource photos are presented in Annexure D. One (1 No.) water supply borehole, four (4 No.) monitoring boreholes and three (3 No.) unused boreholes were identified. One (1 No.) borehole could not be located although the borehole marker was identified in the field.

[1] Report reference GW-16-09-CV414B of Tucana Solutions, titled "Lafarge Lichtenburg Cement Plant and Tswana Quarry – Geohydrological Report", version 1.4, dated February 2017

Table 5: Summary Hydrocensus Borehole Information

KEY	SITE	Borehole ID	verified	Latitude	Longitude	Elevation (mamsl)	Water level (mbgl) July 22	Water level (mbgl) Feb 17	Borehole depth (m)	Pump depth (m)	Pump rate (l/s)	Pumping duration (hr/d)	Pump type	Water use	Owner	Telephone number
1	Tswana	LQBH4	yes	-26.07609	25.78037	1434	7.51		52.96		3.25	7.5	Sub	Domestic/Industrial	Lafarge	018-6333000
2	Tswana	LQBH5	no	-26.07964	25.80192	1446				Dry	dry			Monitoring	Lafarge	018-6333000
3	Tswana	LQBH6	yes	-26.07697	25.80051	1445								Not found	Lafarge	018-6333000
4	Tswana	LQBH7	yes	-26.07585	25.78095	1435	4.51						None	Monitoring	Lafarge	018-6333000
5	Tswana	LQBH8	yes	-26.07663	25.78403	1439	6.1	9.7						Monitoring	Lafarge	018-6333000
6	Tswana	LQBH9	yes	-26.07436	25.79851	1443	2.18	6.9			low			Monitoring	Lafarge	018-6333000
7	Tswana	LQBH28	yes	-26.05656	25.79878	1440					blocked			Not used	unknown	
8	Tswana	LQBH29	yes	-26.11219	25.79703	1435					damaged		Wind mill	Not used	unknown	
9	Tswana	LQBH30	yes	-26.10465	25.84330	1462					pump removed		Mono	Not used	unknown	

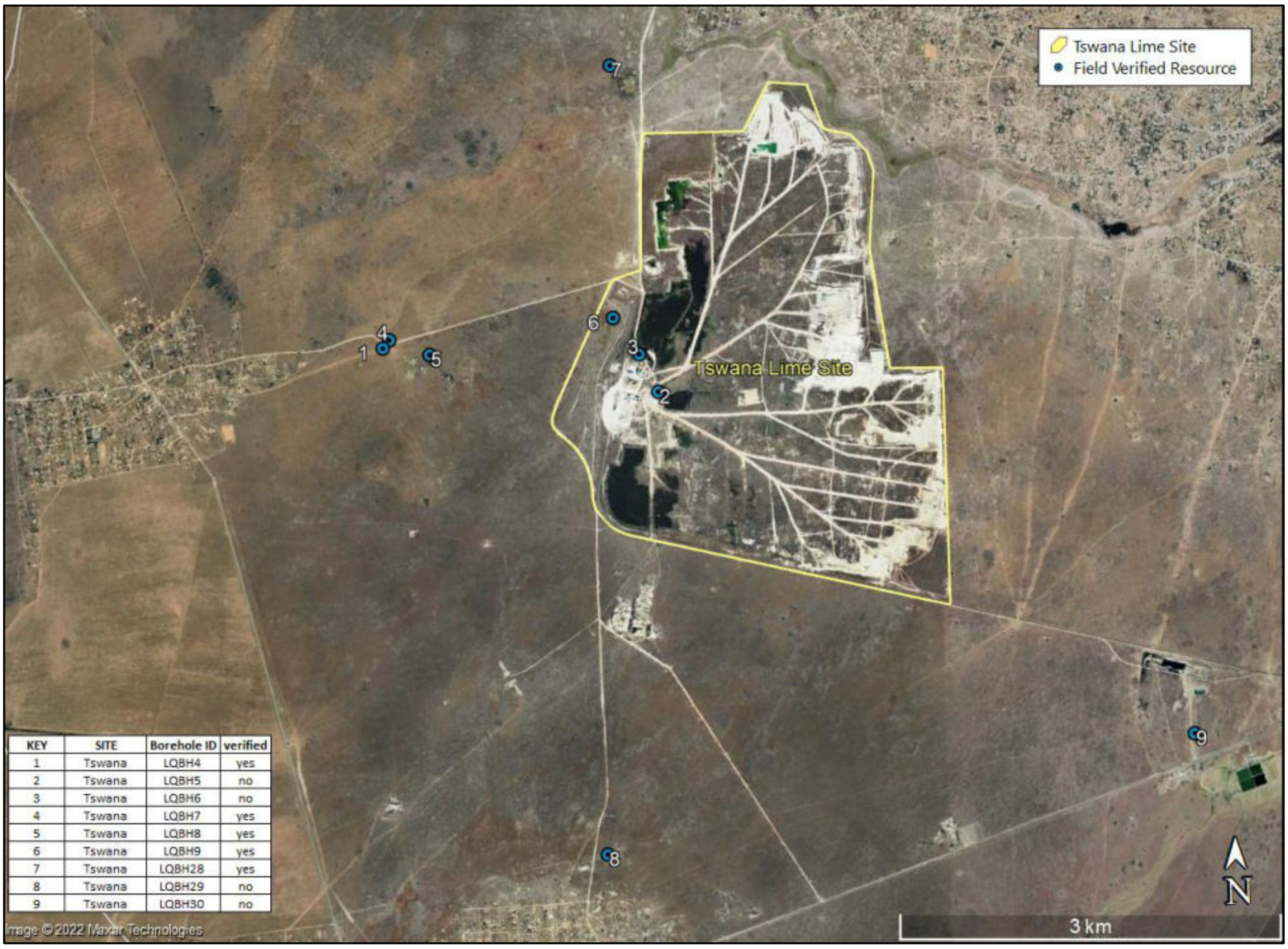


Figure 4: Field Verified Resources (After Tucana Solutions 2017)

7 NUMERICAL GROUNDWATER MODEL

7.1 Desktop Assessment

7.1.1 Study Area Selection

Since the focus of the study was to model the groundwater impacts of the Lafarge operations on the surrounding environment, it is important to delineate the study area based on physical properties that will be translated into boundary conditions for the groundwater model. When selecting the delineation criteria, the model extent must be large enough to accommodate considered receptors. The geohydrological map indicating the groundwater occurrence was used as the main delineation criteria with the structural lineaments traversing the area. The resulting model boundary where the south-eastern boundary is representative of a structural lineament is presented in Figure 5.

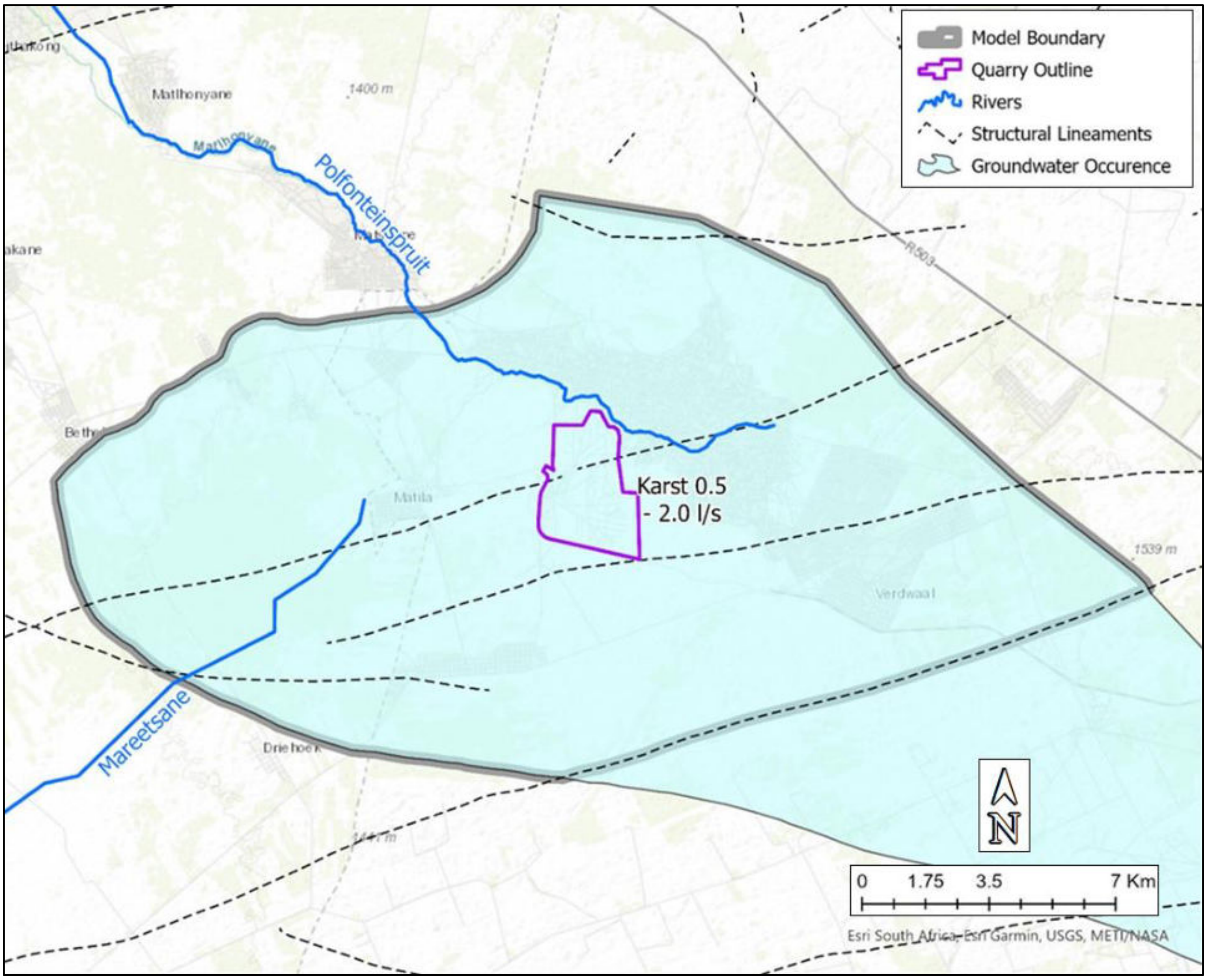


Figure 5: Tswana Lime Quarry Numerical Model Extent Boundary

7.1.2 Topography and Drainage

The study area has a relatively flat topography which ranges from 1377 maMSL to 1513 maMSL over a distance of 30 km. The study area boundary intersects four quaternary catchments (D41A, D41B, C31D and C31B) of which D41A and D41B make up the most of surface area of the selected study area. D41A and D41B are also representative of the head waters of the Polfonteinspruit and the Matreetsane Rivers respectively. A summary of the hydrological parameters for each of the quaternary catchments is presented in Table 6.

Table 6: Summary of Quaternary Catchment Hydrological Parameters

Quaternary Name	Area (km^2)	MAP (mm/a)	MAE (mm/a)	MAR (mm/a)	Baseflow (mm/a)	No Flow (%)
D41A	4298	509	1950	6	0	44
D41B	6164	443	1950	2	0	57
C31D	1493	530	1925	6	0	40
C31B	1742	553	1900	8	0	38

The topography and drainage of the model area is presented in Figure 6.

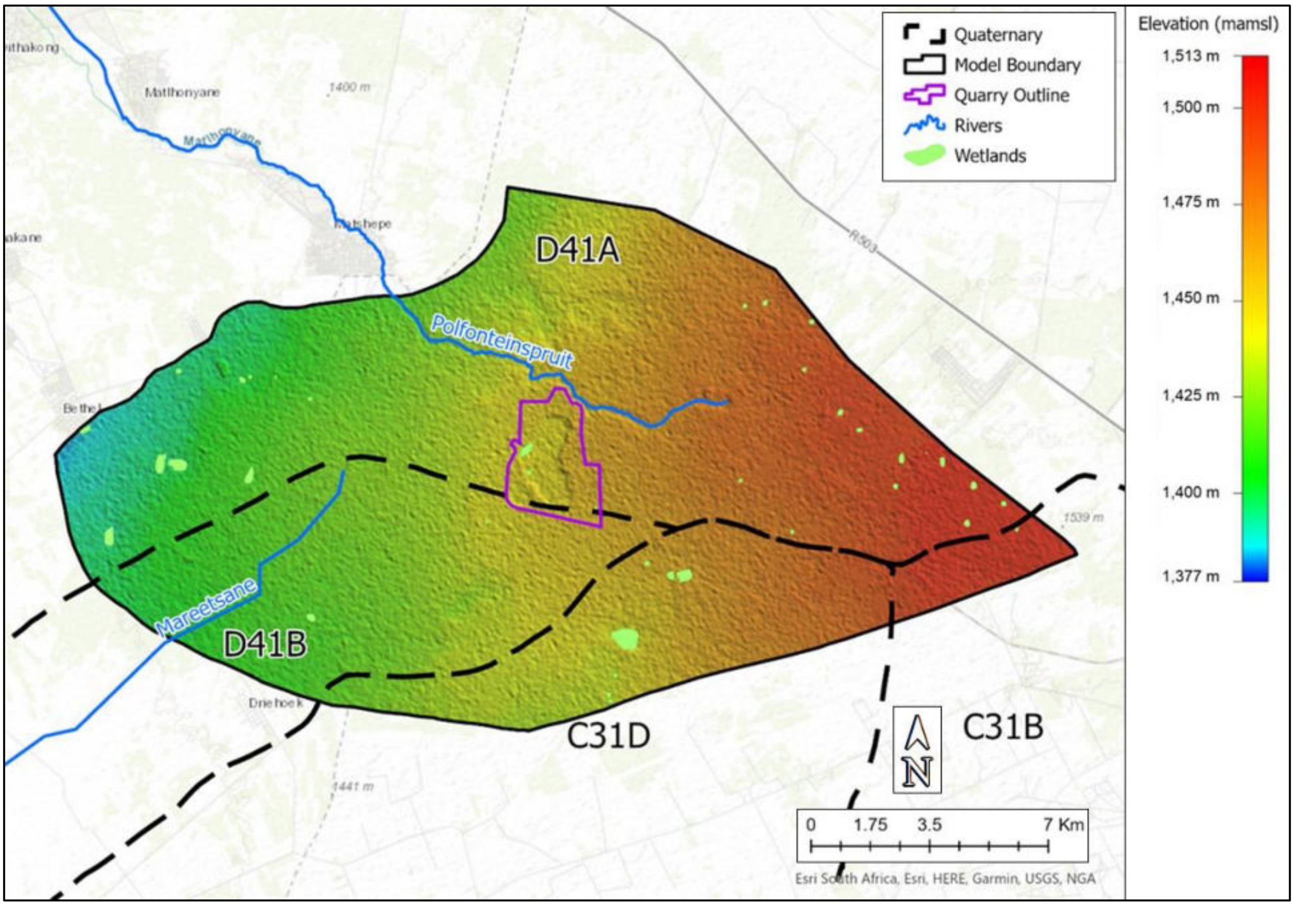


Figure 6: Topography and Drainage of the Model Extent

7.1.3 Regional Geology

The regional geology of the Lichtenburg area comprises quaternary and tertiary aged sands and rock which are underlain by Karoo Sequence Dwyka Formation, which in turn is underlain by Monte Christo, Oaktree and Black Reef Formations of the Transvaal Sequence, and finally by the Ritgat, Klipriviers and Alberton Formations of the Ventersdorp Supergroup. The various rock lithologies of geology in the project area are summarised in Table 7. The regional geology is presented in Figure 7.

Table 7: Geological Lithologies

Age	Supergroup / Sequence	Group / Subgroup	Formation	Lithology	Symbol
Quaternary				soil cover, quaternary sands	Qs
Tertiary				calcrete	T-Qc
Carboniferous	Karoo Sequence		Dwyka	tillite	C-Pd
Vaalian	Transvaal Sequence	Chuniespoort	Monte Christo	chert rich dolomite	Vmm
			Oaktree	dark chert poor dolomite	Vo
			Black Reef	quartzite, conglomerate, shale	Vbr
	Ventersdorp Supergroup	Platberg	Rietgat	breccia, conglomerate; greywacke, shale, limestone, tuff	R-Vk
Randian		Klipriviersberg		basaltic lava, agglomerate	Rk
			Alberton	Feldspar porphyry	Ra

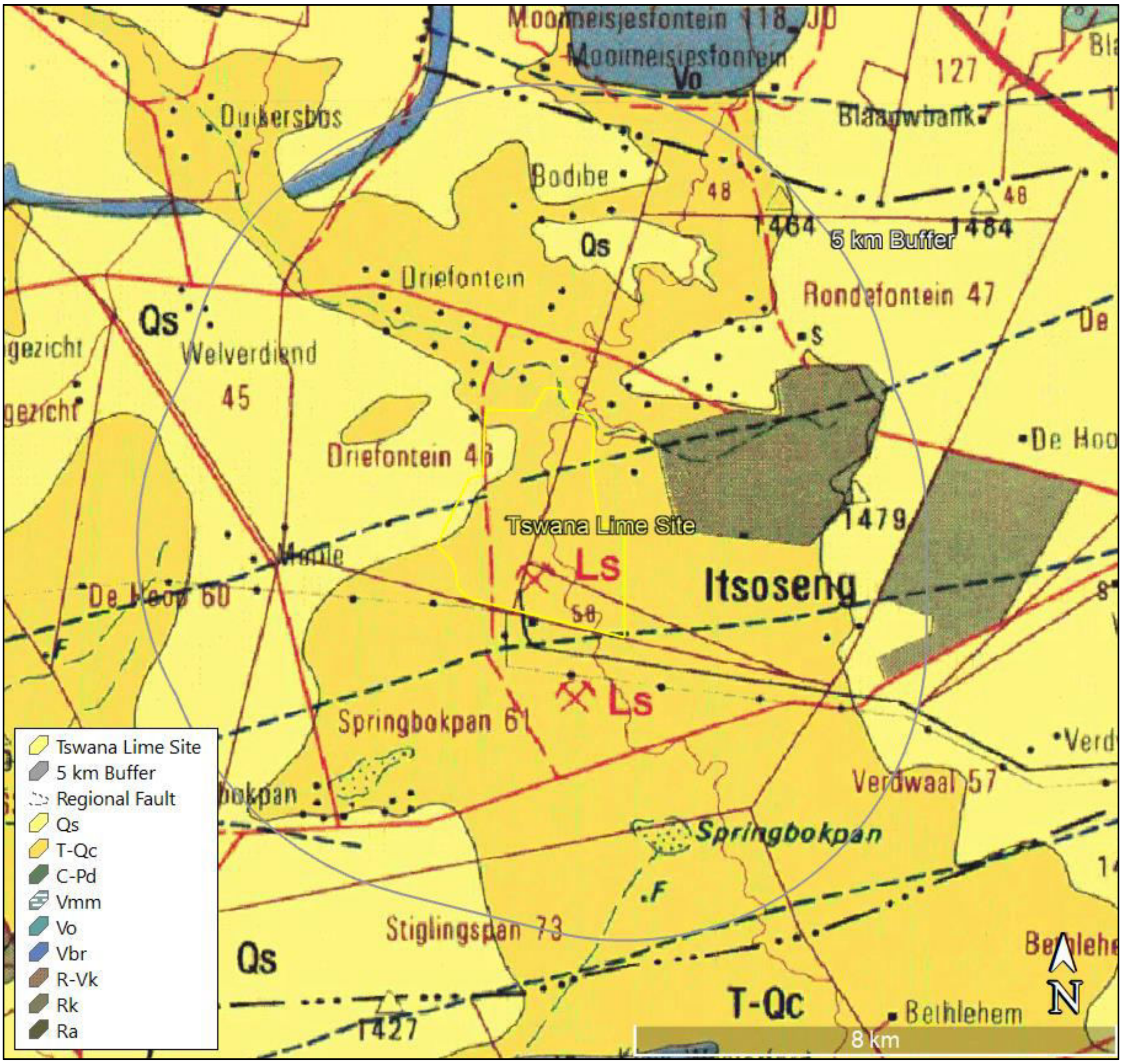


Figure 7: Regional Geology and Structures

7.1.4 Regional Structures

Dykes

The dolomite formations are subdivided by diabase dykes trending WSW to ENE and N to S which result in compartmentalisation in the dolomites.

Quartz Veins

Quartz veins trending NNE to SSW are evident with the disappearance of veins to the south.

Fractures

Major dyke and quartz veining correlates closely with joint directions within the Malmani Subgroup and present regional stress fields within the area. Regional faults are evident trending WSW to ENE. One regional fault is located on the southern side of the site, and one regional fault bisects the site.

7.1.5 Site Geology and Structures

The regional geology is of a karst nature and the specific surface deposits and structures traversing the area in a west to east direction are presented in Figure 8. Selected borehole logs indicate the presence of karst or dolomites underlying the area. The borehole logs are presented in Annexure E.

Boreholes presented in the DWS NGA database containing dolomite were used to delineate the top of the dolomite layer. The resulting contour of the top of the dolomites in the project area is presented in Figure 9.

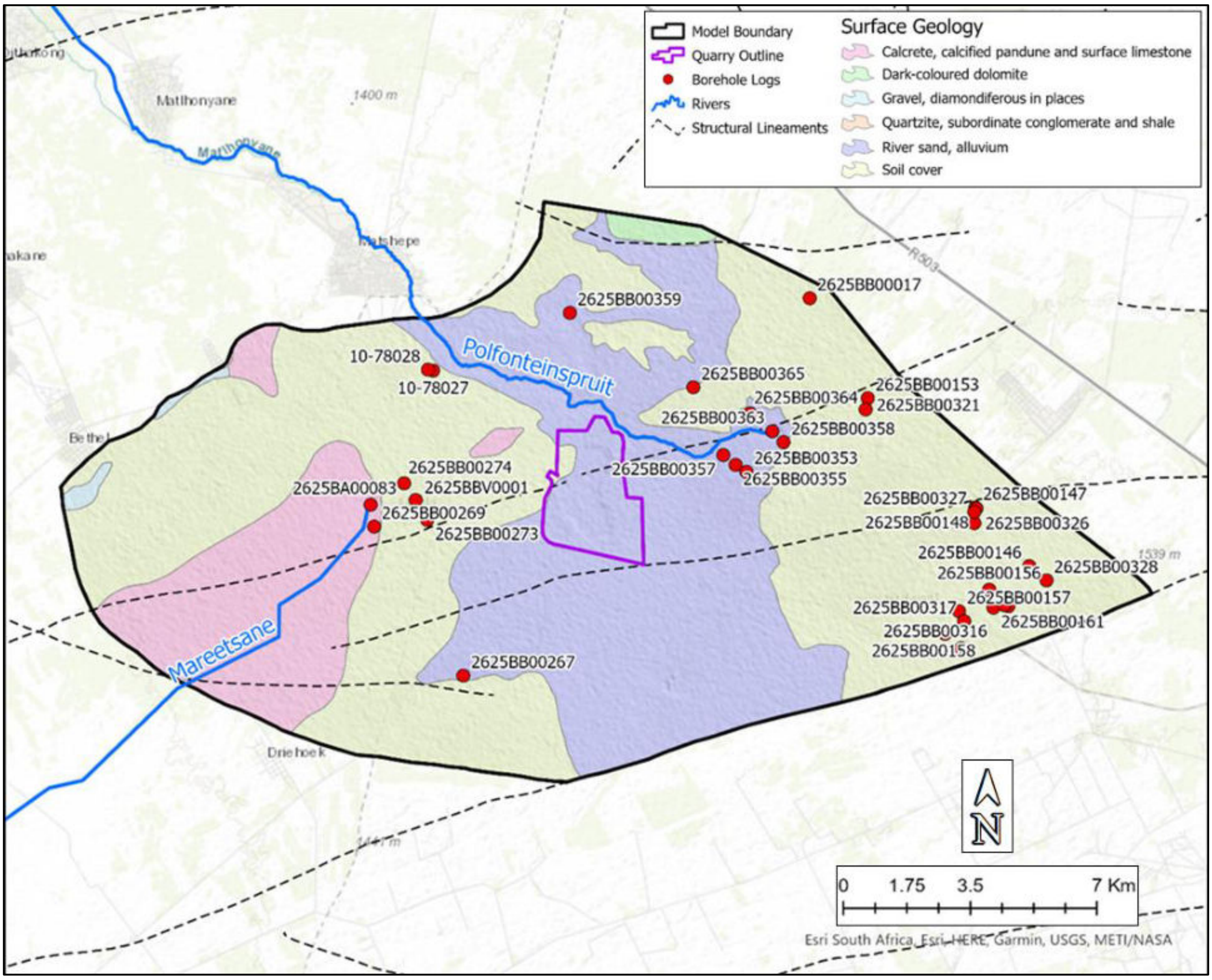


Figure 8: Surface Geology and Structures in the Model Extent

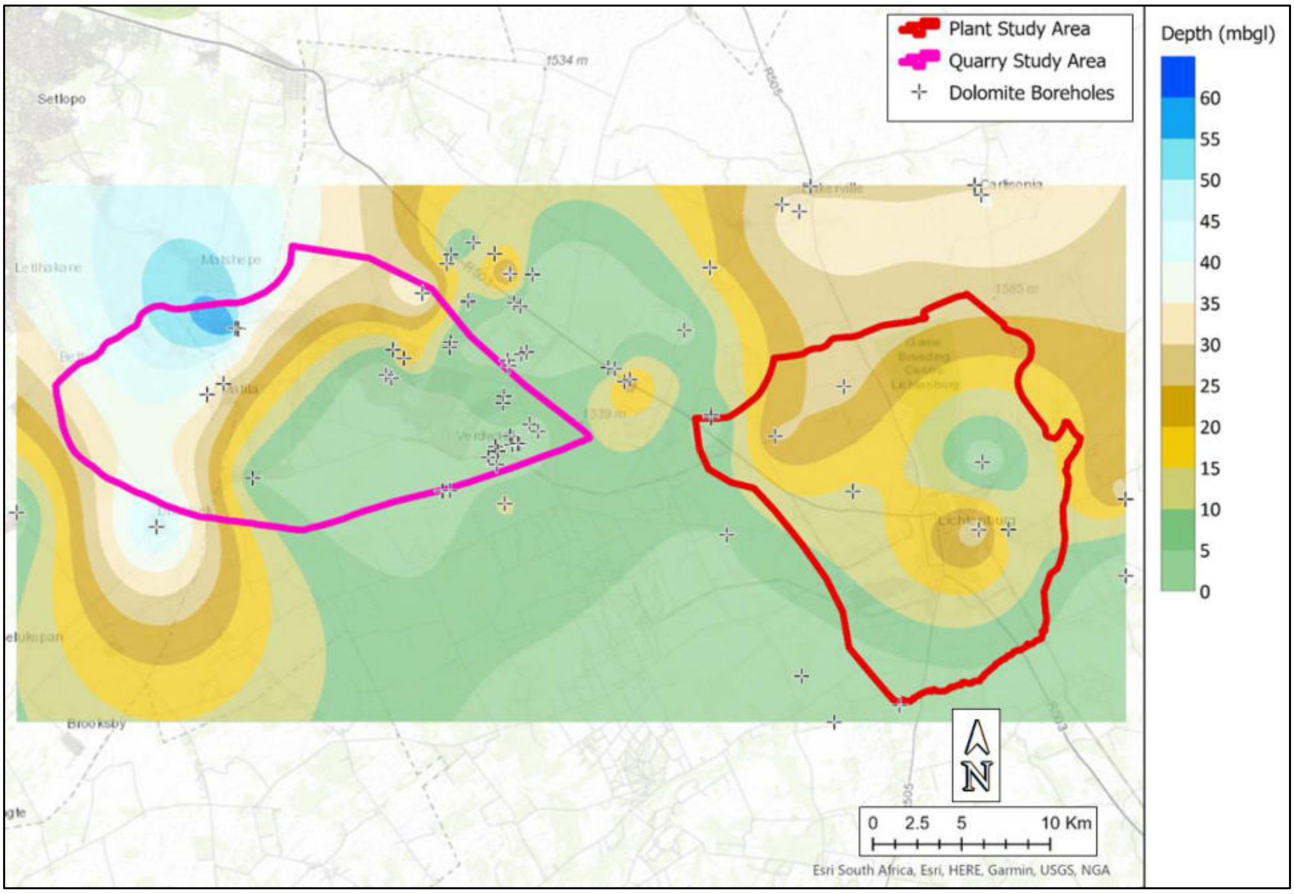


Figure 9: Interpolated Top of Dolomite Layer

7.1.6 Regional Magnetic Mapping

The regional magnetic mapping with a contour interval of 100 nT is presented in Figure 10. The mapping indicates that magnetic flux for the site has a range of 31100 nT to 33400 nT. Notable magnetic anomalies are evident within proximity of the project footprint and confirm the presence of the structural lineaments.

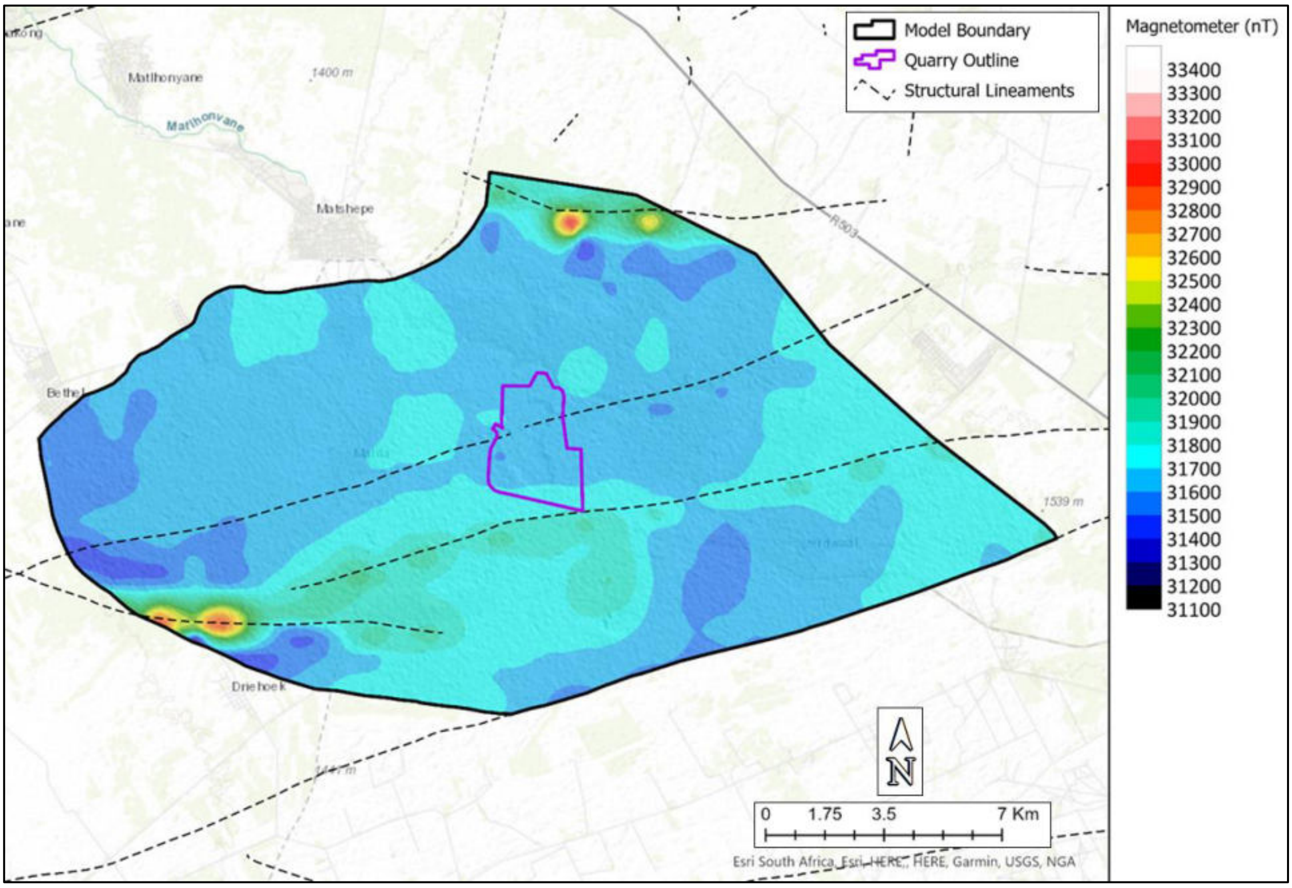


Figure 10: Regional Magnetic Mapping

7.1.7 Regional Geohydrology

The regional geohydrology of the project area can be broadly described as predominantly carbonate rocks comprising dolomite. The principal groundwater occurrence is from a karst aquifer type with median borehole yields in the range 0.5 to 2.0 l/s.

The project area comprises one aquifer class unit which in terms of the South African Aquifer Classification System is characterised as *Major*. The regional geohydrology of the project area is presented in Figure 11.

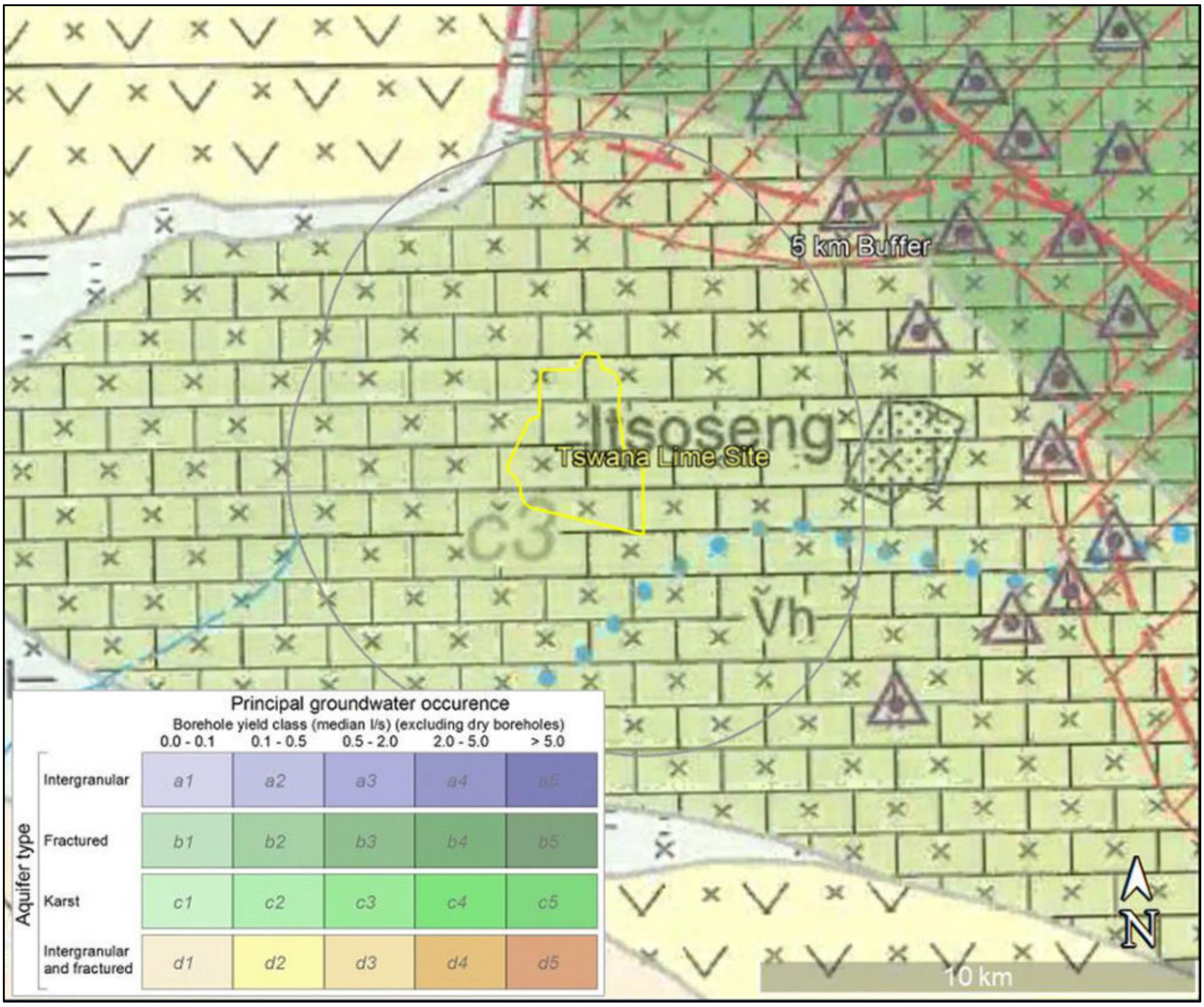


Figure 11: Regional Geohydrology

<u>Groundwater Occurrence</u>

Structurally controlled preferential solution of the dolomitic rock has occurred adjacent to dykes and within some linear depressions. This has developed a highly transmissive formation with strong borehole yields. Yields from dolomitic rock and brecciated chert zones can exceed 70 l/s, with average yields being approximately 20 l/s. Most boreholes penetrating the dolomite are generally shallow (less than 50 m) and the major water strikes are at depths of between 20 – 35 m. Boreholes drilled into the lower part of the dolomite formation at lower elevations generally have poor yields, irrespective of depths drilled. Yields of 1.0 l/s are then considered to be good. Boreholes within the lavas are generally low yielding, but dykes can also provide reasonable groundwater targets.

<u>Aquifer Classification</u>

It is inferred that one underlying aquifer is present beneath the site, but shallow or perched aquifers may also exist in the study area within the tertiary or recent deposits. The Parsons aquifer classification scheme allows the grouping of aquifer areas into types according to their associated supply potential, water quality, and local importance as a resource. The revised South African aquifer classification system is presented in Table 8.

Table 8: Aquifer Classification Scheme

Aquifer System	Defined by Parsons (1995)	Defined by DWAF Min Requirements (1998)
Sole Source Aquifer	An aquifer which is used to supply 50 % or more of domestic water for a given area, and for which there are no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.	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 or depleted.
Major Aquifer	High permeable formations usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (<150 mS/m).	High yielding aquifer (5-20 L/s) of acceptable water quality.
Minor Aquifer	These can be fractured or potentially fractured rocks, which do not have a high primary permeability or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying baseflow for rivers.	Moderately yielding aquifer (1-5 L/s) of acceptable quality or high yielding aquifer (5-20 L/s) of poor quality water.
Non-Aquifer	These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer as unusable. However, groundwater flow through such rocks, although imperceptible, does take place, and need to be considered when assessing the risk associated with persistent pollutants.	Insignificantly yielding aquifer (< 1 L/s) of good quality water or moderately yielding aquifer (1-5 L/s) of poor quality or aquifer which will never be utilised for water supply and which will not contaminate other aquifers.
Special Aquifer	An aquifer designated as such by the Minister of Water Affairs, after due process.	An aquifer designated as such by the Minister of Water Affairs, after due process.

Aquifer Vulnerability

Aquifer vulnerability can be classified according to the DRASTIC method. The DRASTIC aquifer vulnerability method makes use of seven (7) factors to calculate the vulnerability index value (Aller et al. 1987):

- Depth to groundwater (D) – determines the maximum distance contaminants travel before reaching the aquifer
- Net recharge (R) – the amount of water that is able to travel from ground surface to the water table
- Aquifer (A) – the composition of the aquifer material
- Soil media (S) – the uppermost portion of the unsaturated zone
- Topography (T) – the slope of the ground surface
- Impact of vadose zone (I) – the type of material present between the bottom of the soil zone and water table
- Hydraulic conductivity of the aquifer (C) – indicates the aquifer's ability to allow for the flow of water to occur.

This vulnerability index is used to determine the aquifer's vulnerability to pollution and the index ranges from 1 to 200, where 200 represents the theoretical maximum aquifer vulnerability. The DRASTIC index ranges between 85 and 160 over the study area, and is 135 in the immediate vicinity of the quarry operations as presented in Figure 12.

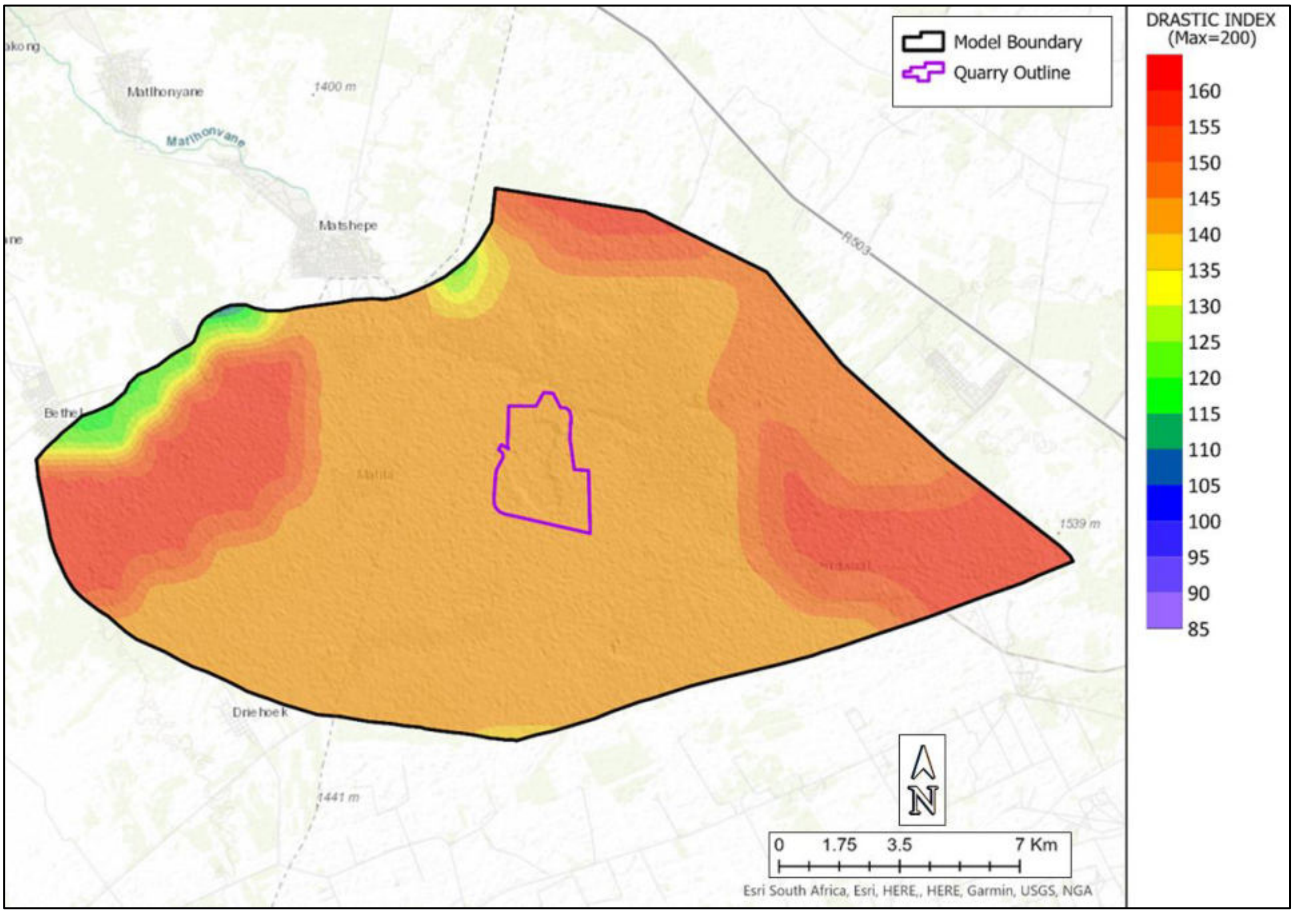


Figure 12: Aquifer Vulnerability Map of the Study Area

When considering the first variable (aquifer system) as a *Major* aquifer and the second variable (vulnerability) as *Medium to High*, the underlying aquifer requires a high level of protection.

TABLE A and B: Ratings for the Groundwater Quality Management classification system.			
AQUIFER SYSTEM MANAGEMENT CLASSIFICATION		SECOND VARIABLE CLASSIFICATION AQUIFER VULNERABILITY CLASSIFICATION	
Class	Points	Class	Points
Sole Source Aquifer System	6	High	3
Major Aquifer System	4	Medium	2
Minor Aquifer System	2	Low	1
Non-aquifer System	0		
Special Aquifer System	0 -6		

TABLE C: Appropriate level of groundwater protection required, based on the Groundwater Quality Management classification	
GQM INDEX	LEVEL OF PROTECTION
< 1	Limited protection
01-03	Low level protection
03-06	Medium level protection
06-10	High level protection
> 10	Strictly non-degradation

Variable 1	Variable 2
Aquifer System	Second Variable Description
Major Aquifer System	Vulnerability
	Medium High
4	2.5
GQM Index	Level of Protection
10.0	High level protection

7.1.8 Rainfall and Recharge

A summary of the quaternary rainfall and recharge figures are presented in Table 9 and Figure 13. The GRAII data set results in an average recharge of 4% of MAP (not considering D41B) and the Vegter estimate translates to a recharge of 8.5% of MAP.

Table 9: Summary of Quaternary Rainfall and Recharge

Quaternary Name	MAP (mm/a)	Recharge (GRAII) (mm/a)	Recharge (Vegter) (mm/a)
D41A	509	21.04	45
D41B	443	9.90	45
C31D	530	21.91	45
C31B	553	22.11	45

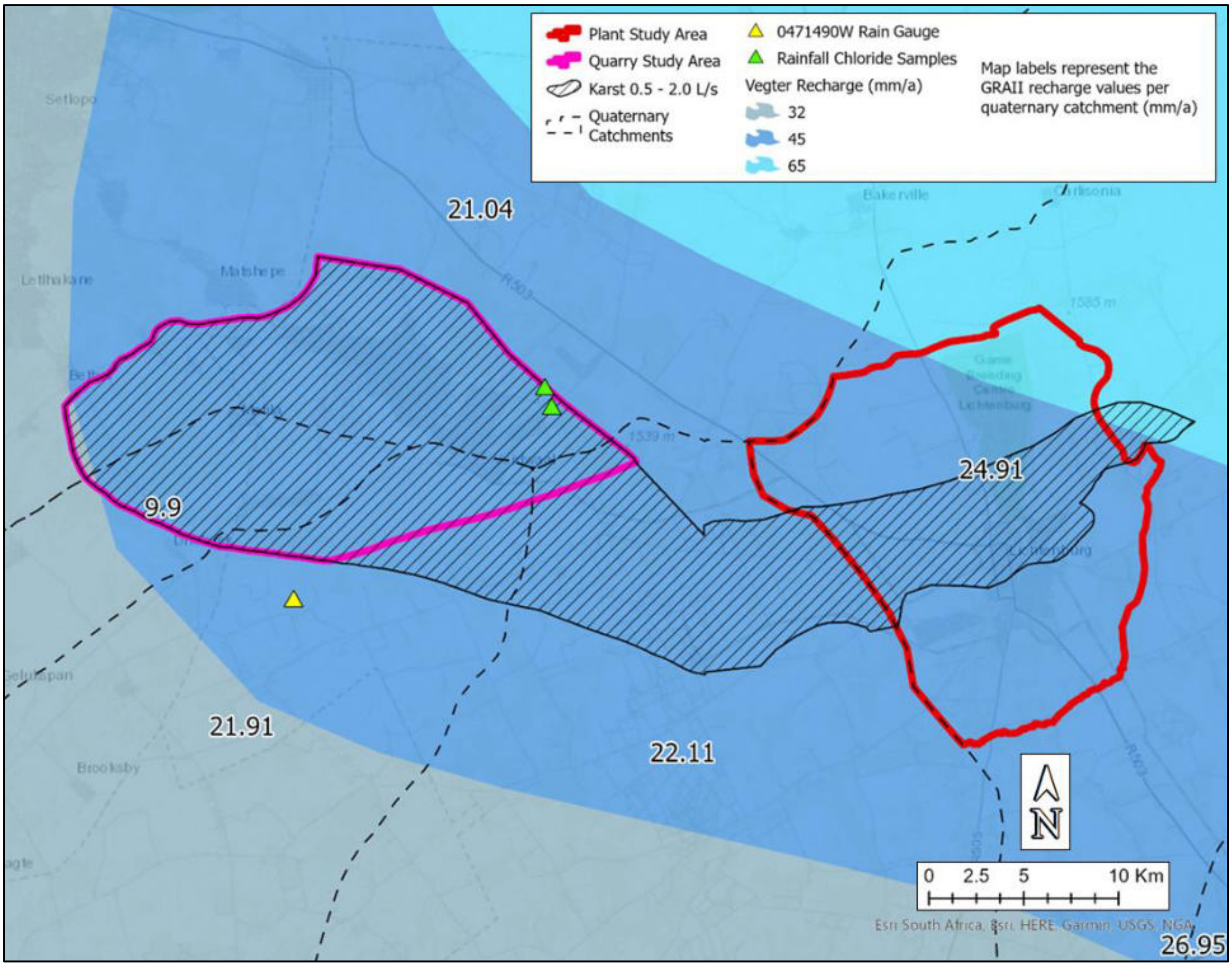


Figure 13: Study Area Recharge Values

Rainfall data for the project area was obtained from the SAWS rainfall station 0471490 W which is located approximately 14.8 km southwest of the site. The station was selected based on its record period and the reliability of historical rainfall data. The details of this rainfall station are presented in Table 10.

Table 10: Rainfall Station Details

Station Number	Station Name	MAP (mm)	Years Assessed	Reliability (%)	Longitude	Latitude
0471490 W	Lusthof	601	1950 - 1999	99.7	25.782460	26.168145

Most of the rainfall falls over the summer period (September to March), with a total rainfall depth over these seven months equating to 509 mm. It is also noted that low rainfall values are recorded over the winter months (April to August), with a total rainfall depth equating to 92 mm.

7.2 Model Assumptions and Limitations

The following needs to be described in a groundwater model:

- Geological and hydrogeological features
- Boundary conditions of the study area (based on the geology and hydrogeology)
- Initial water levels of the study area
- The processes governing groundwater flow
- Assumptions for the selection of the most appropriate numerical code.

Field data is essential in solving the conditions listed above and developing the numerical model into a site-specific groundwater model. Specific assumptions related to the available field data include:

- The top of the aquifer is represented by the generated groundwater heads
- The available geological/hydrogeological information was used to describe the different aquifers
- The available information on the geology and field tests are considered as correct
- All data provided by the Client is correct and have been correctly analysed
- Many aquifer parameters have not been determined in the field and therefore must be estimated.

To develop a numerical model of an aquifer system, specific assumptions must be made and include:

- The system is initially in equilibrium and therefore in steady state[2], even though natural conditions have been disturbed
- No abstraction boreholes were included in the initial model; however, they are included for the scenario outputs
- The boundary conditions assigned to the model are considered correct
- The impacts of other activities (e.g. agriculture) have not been considered.

A numerical groundwater model is a representation of the real system. It is therefore at most an approximation, and the level of accuracy depends on the quality of the data that is available. This implies that there are always errors associated with groundwater models due to uncertainty in the data and the capability of numerical methods to describe natural physical processes.

7.3 Generation of a Finite Difference Network

To investigate the behaviour of aquifer systems in time and space, it is necessary to employ a mathematical model. MODFLOW, a modular three-dimensional finite difference groundwater flow model was the software used during this investigation. It is an internationally accepted modelling package, which calculates the solution of the groundwater flow equation using the finite difference approach.

The simulation model used in this modelling study is based on three-dimensional groundwater flow as described by the following equation:

[2] In steady state systems, inputs and outputs are in equilibrium so that there is no net change in the system with time. In transient simulations, the inputs and outputs are not in equilibrium so there is a net change in the system with time. Steady state models provide average, long-term results. Transient models should be used when the groundwater regime varies over time.

$$\frac{\partial}{\partial x}(K_x\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_y\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_z\frac{\partial h}{\partial z})\pm W=S\frac{\partial h}{\partial t}$$

where,

h	=	Hydraulic head
Kx, Ky, Kz	=	Hydraulic conductivity in different directions
S	=	Storage coefficient
t	=	Time
W	=	Source (recharge) or sink (pumping) per unit area
x, y, z	=	Coordinate into model.

For steady state conditions the groundwater flow equation reduces to the following:

$$\frac{\partial}{\partial x}(K_x\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_y\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_z\frac{\partial h}{\partial z})\pm W=0$$

The model network was constructed using a cell size of 50m x 50m over two layers resulting in a total of 237534 active cells.

7.4 Boundary Conditions

A model boundary is the interface between the model area and the surrounding environment. Conditions on the boundaries must be specified. Boundaries occur at the edges of the model area and at locations in the model area where external influences are represented, such as rivers, wells, and leaky impoundments.

Criteria for selecting hydraulic boundary conditions are primarily topography, hydrology and geology. The topography and/or geology may yield boundaries such as impermeable strata or potentiometric surfaces controlled by surface water, or recharge/discharge areas such as inflow boundaries along mountain ranges. The flow system allows the specification of boundaries in situations where natural boundaries are a great distance away.

Boundary conditions are specified for the entire boundary and may vary with time. At a given boundary section, just one type of boundary condition can be assigned. As an example, it is not possible to specify groundwater flux and groundwater head at an identical boundary section. Boundaries in groundwater models can be specified as (but not limited to):

- Dirichlet (also known as fixed head or constant concentration) boundary conditions
- Neuman (or specified flux) boundary conditions
- General Head Boundary (GHB) (also known as a head dependant flux boundary).

The model area delineation is presented in Figure 5 and the boundaries were selected as no-flow boundaries, with the rivers selected as a constant head. The pit areas were modelled with the GHB condition.

7.5 Model Parameters

Every model consists of sources and sinks to add and remove water from the model domain to maintain the overall model water balance. In addition to the sources and sinks, this section describes the purpose and model parameters assigned to each layer of the model.

7.5.1 Layer Parameters

There is a distinct dolomitic unit underlying the surface geology and for this reason a two layer model was constructed. The top of layer 1 is the surface elevation of the model area and the bottom of layer 1 represents the top of the dolomitic unit. Layer 2 represents the dolomitic unit. A section through the model grid that illustrates the dip of the dolomitic unit is presented in Figure 14.

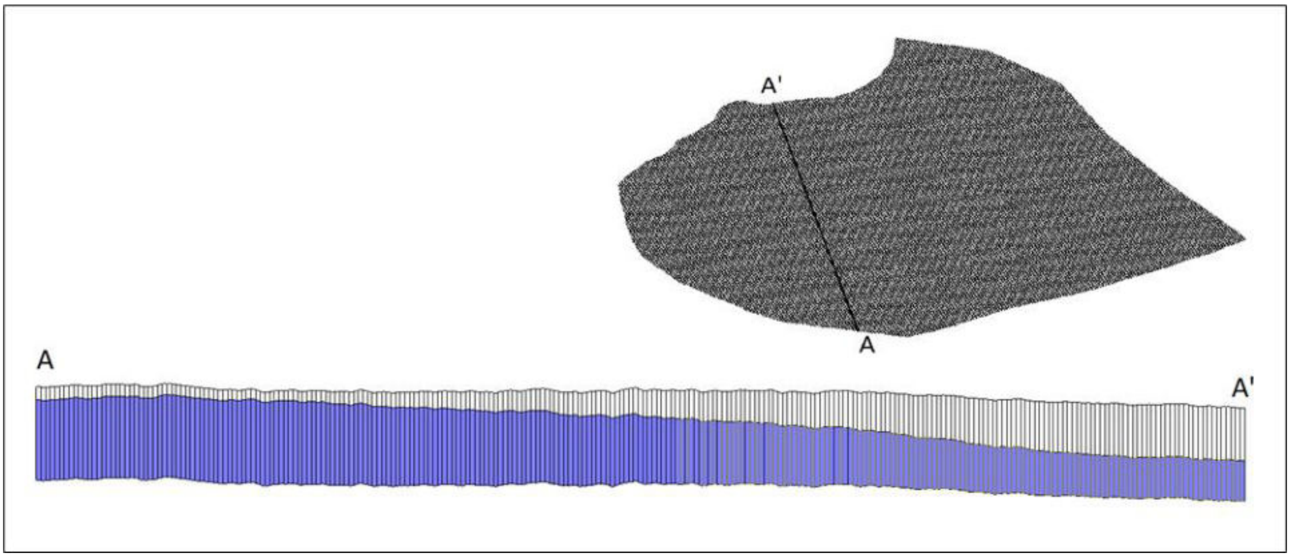


Figure 14: Two Layer Model Cross Section

A summary of the initial layer parameters estimated from available data is presented in Table 11.

Table 11: Summary of Layer Parameters

Layer No	Horizontal K (m/d)	Vertical Anisotropy	Porosity	Longitudinal Dispersivity
1	0.13	10	0.3	50
2	0.32	10	0.1	50

7.5.2 Structural Lineaments

No information was available of the physical properties of the structural lineaments, thus they were modelled as features having a horizontal and vertical hydraulic conductivity. The respective hydraulic conductivities were obtained through the model calibration process. The distribution of horizontal hydraulic conductivities present in both layers of the model is presented in Figure 15.

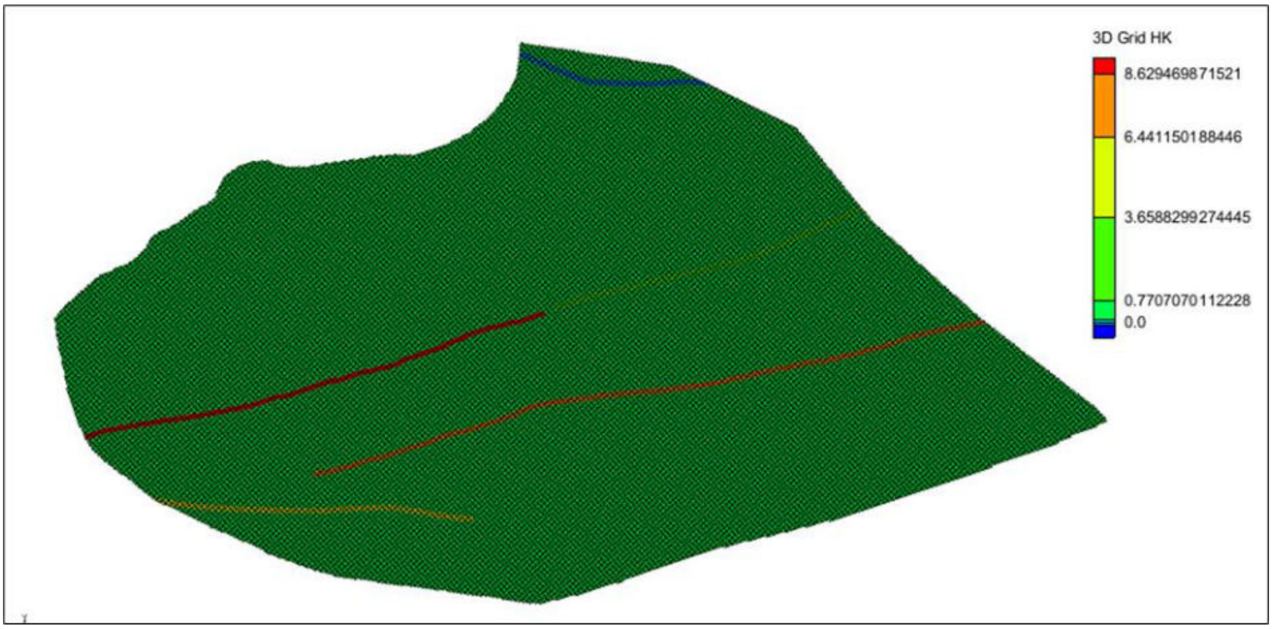


Figure 15: Structures Modelled as Variable Hydraulic Conductive Features

7.5.3 Recharge

Groundwater recharge is generally determined using the water balance method that relates a change in head to a change in volume through the storage coefficient considering rainfall, or through the chloride mass balance method, where the chloride in the groundwater is assumed to be a conservative tracer originating from rainfall. The latter method was used to estimate the initial recharge values since chloride monitoring data was available. The chloride mass balance method is expressed mathematically in the equation below.

$$R(mm/a) = \frac{PCl_p + D}{Cl_{gw}}$$

where,

P = Precipitation
D = Cl dry deposition (mg/m2/a)
Clp = Cl in precipitation
Clgw = Cl in groundwater

The chloride dry deposition is generally not available and common practice is to assume a dry deposition value of zero. The chloride mass balance method is further dependent on the chloride concentration in rainfall. The chemistry of rainfall seldom forms part of a monitoring program and therefore an estimation of the rainfall chloride concentration is required. Rainfall chloride values for different locations are presented in Figure 16. A distinction is made between locations close to the coast and those inland, as coastal areas typically have higher concentrations of chloride than inland areas with an equivalent MAP.

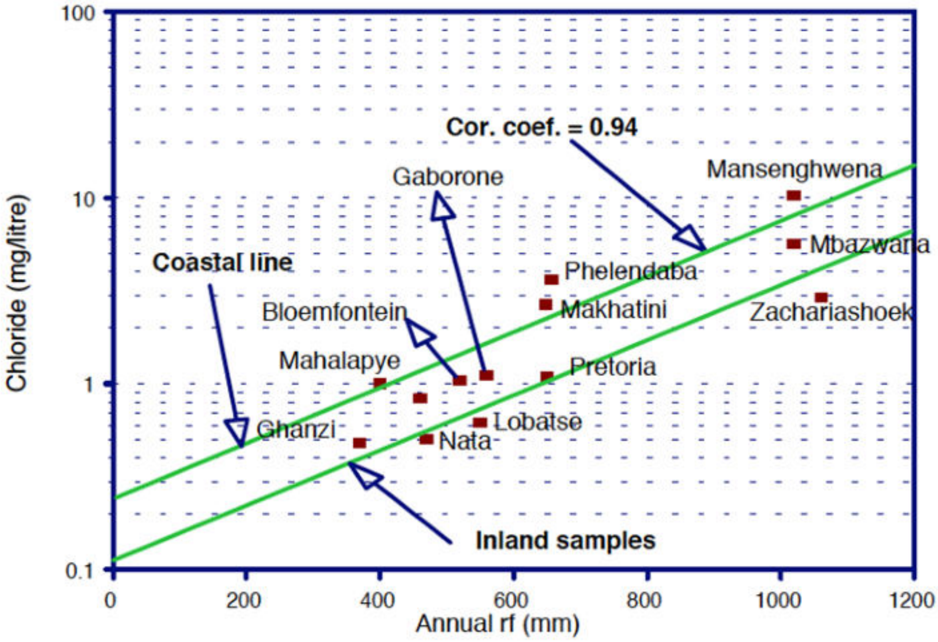


Figure 16:Typical Chloride Values Related to MAP

It is a general practice to calculate the representative groundwater chloride concentration using the harmonic mean as expressed in the equation below.

$$Cl_{gw} = N\left(\sum_{i=1}^{N}\frac{1}{Cl_{igw}}\right)^{-1}$$

The contributions of the borehole chloride concentrations are inversely proportional to the concentration itself in the harmonic mean formulation. This has the advantage that high concentration values, which are generally not related to the rainfall recharge tracer mechanism are suppressed. The calculated harmonic mean for the available borehole chemistry (LQBH8 and LQBH9) is 36.43 mg/l. From the DWS NGA, two historic rainfall chloride values in the project area were available. The average of the rainfall chloride values was calculated and the calculated recharge is then expressed as:

$$Recharge(mm/a) = \frac{PCl_p + D}{Cl_{gw}} = \frac{601(2.25)}{36.43} = 37.12\ mm/a$$

The calculated recharge corresponds well to the average of the GRAII and Vegter recharge values presented earlier.

7.6 Initial Conditions

The model was initialized with parameter values presented earlier, and with initial water levels, to solve the steady-state equation. Making use of historic borehole water levels that are considered static water levels, there exists a high correlation between surface topography and water levels across the study area. The correlation is presented in Figure 17.

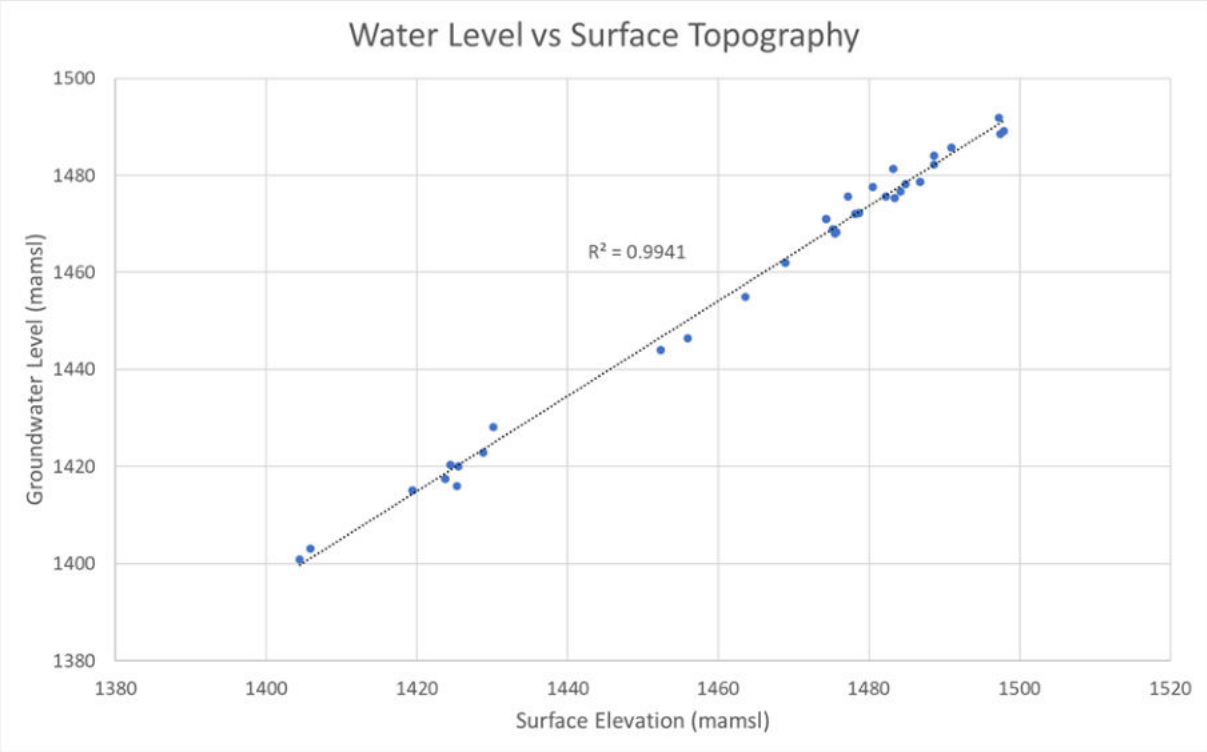


Figure 17: Water Level Correlation with Surface Topography

The Bayesian interpolation method to generate water levels is well suited when there exists a high correlation between surface topography and water level elevation. The Bayesian method employs Bayes' probability theorem that describes the probability of an observation, based on prior knowledge of conditions that might be related to the observation. The main advantage of using the Bayesian interpolation is that water levels can also be extrapolated to areas where no water level information exists, but where elevation data is available that will be used in the probability calculation of the estimated water level. The resultant initial model water levels is presented in Figure 18.

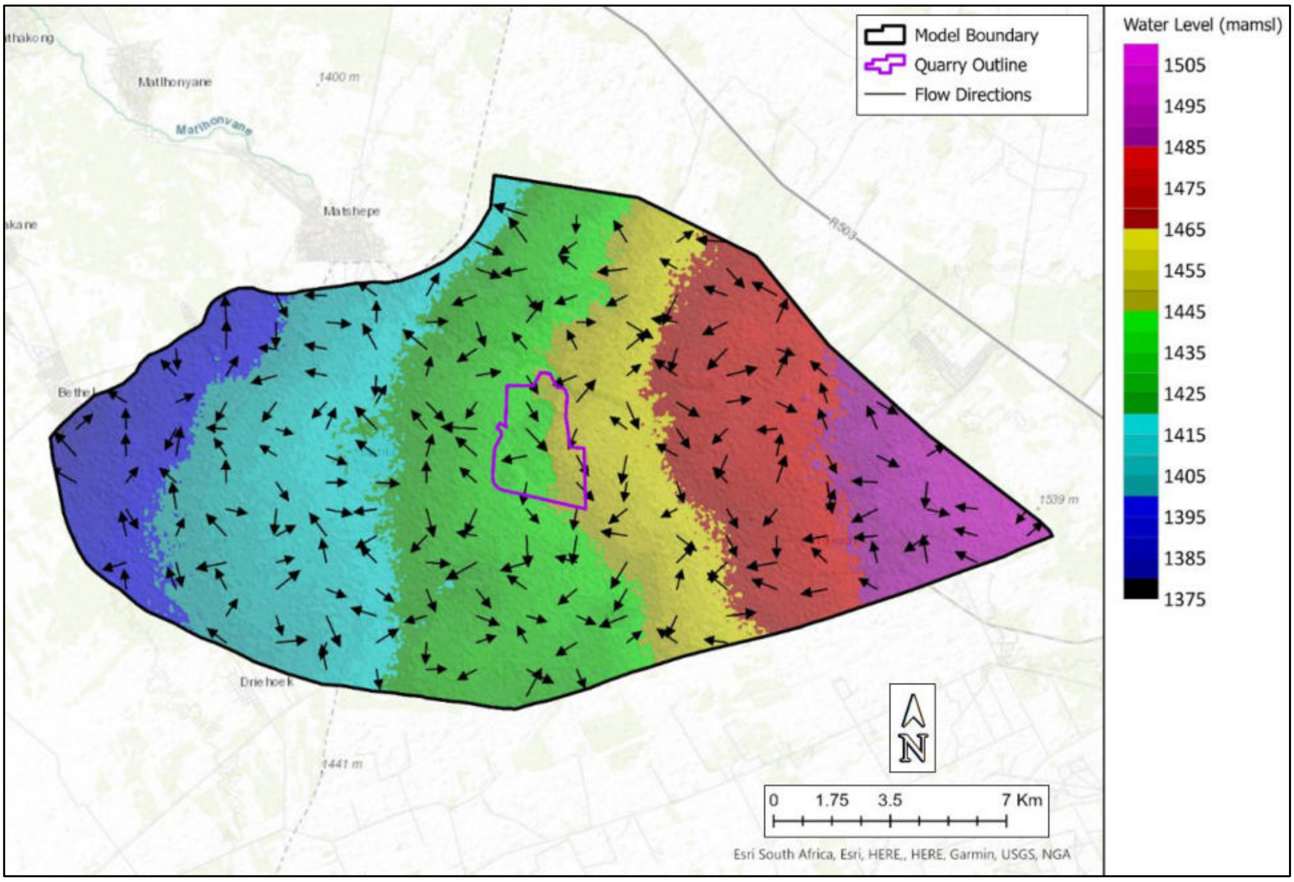


Figure 18: Static Water Level Map for Model Area

7.7 Model Calibration

The steady state head distribution is dependent upon the recharge, hydraulic conductivity, sources, sinks, and boundary conditions specified. For a given recharge component and set of boundary conditions, the head distribution across the aquifer under steady-state conditions can be obtained for a specific hydraulic conductivity value. The simulated head distribution can then be compared to the measured head distribution and the hydraulic conductivity or recharge values can be altered until an acceptable correspondence between measured and simulated heads is obtained. The advantage of a steady state model is that the parameter for specific storage is not required to solve the groundwater flow equation, therefore there are fewer unknown parameters to determine.

The calibration process was done by changing the model parameters for hydraulic conductivity and recharge. Borehole water levels were used to calibrate the steady state groundwater flow model. The calibration objective was reached when an acceptable correlation was obtained between the observed and simulated piezometric heads.

The observed versus simulated water levels for each calibration borehole are presented in Figure 19 and the spatial distribution of the boreholes used is presented in Figure 20. Not all NGA and hydrocensus boreholes were used in the calibration process due to the following:

- Boreholes subject to other abstraction points are not representative of static water levels. Both the NGA and hydrocensus datasets contain this case
- Water levels measured at different periods in time are subject to different rainfall and different site conditions resulting in variable outputs

- Dramatic differences between adjacent boreholes in close proximity, either due to monitoring at different times or intersection of different aquifer systems or geological features. To account for these types of borehole responses, substantial monitoring data is required to understand the behaviour with time, as well as a detailed understanding of the borehole construction.

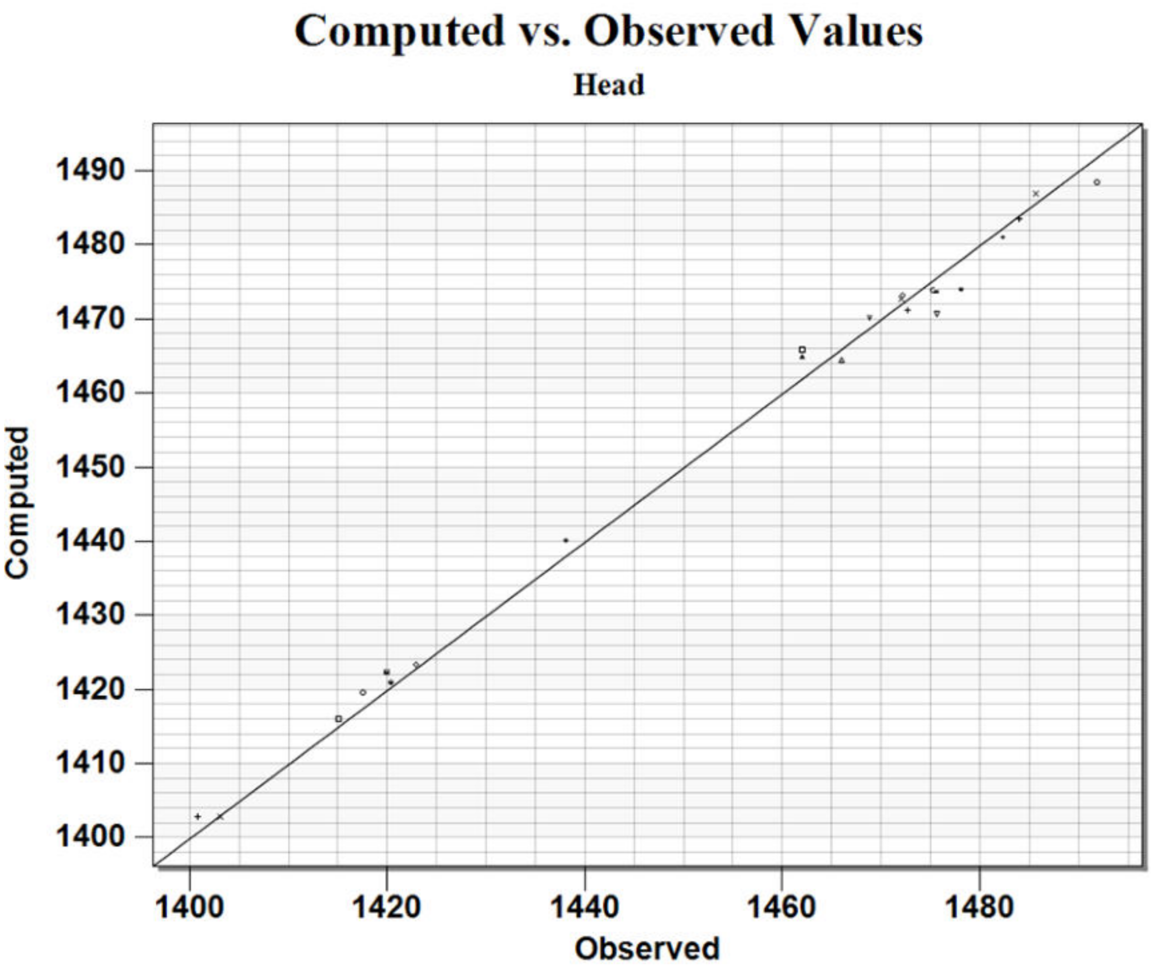


Figure 19: Correlation between Observed and Simulated Water Levels

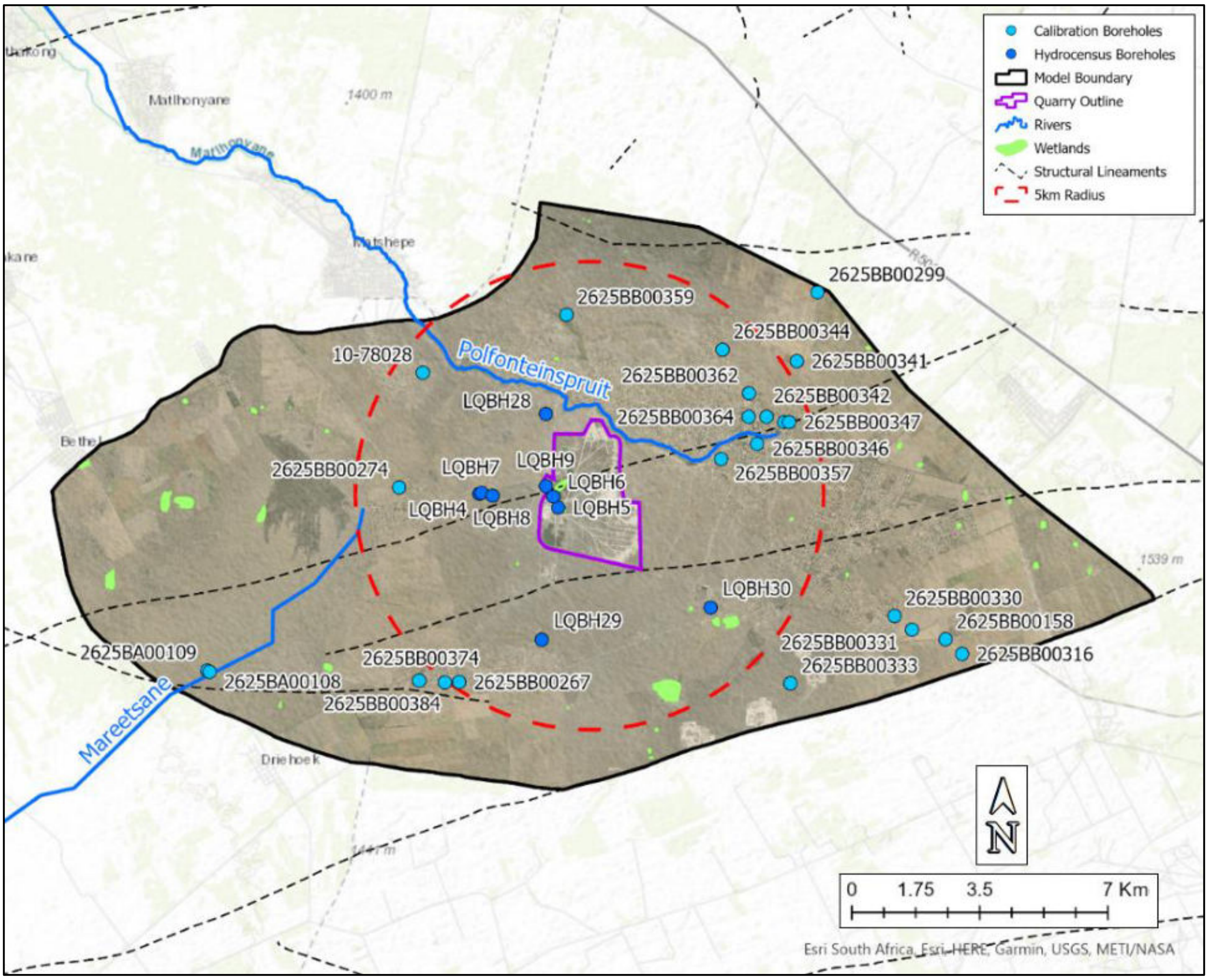


Figure 20: Spatial Distribution of Calibration Boreholes

7.8 Model Scenarios and Outputs

7.8.1 Methodology

To determine the impact on the receiving environment, the groundwater flux into the mine pits was modelled through the numerical groundwater flow model, and the potential sources of pollution were modelled through the use of mass transport.

Since insufficient source concentration data was available to model individual constituents of the source concentrations, it is assumed that a source concentration is 100 %, and the pollution plume is expressed in terms of the percentage decay. Conservative mass transport was assumed and it should be highlighted that since a steady state model was used, it must be considered as the worst case scenario, as it can take a long time to reach steady state. Dynamic changes in the geohydrological system are not considered in steady state.

Four time steps at 25, 50, 75 and 100 years for mass transport were considered. Pit areas were simulated with and without evaporation to illustrate the concentrating effect of evaporation on the source concentrations over prolonged periods of time. This report presents the simulations with evapotranspiration. Scenarios without evapotranspiration are included in Annexure F for reference.

7.8.2 Modelled Pit Inflows

The water level in the pits were inferred from site observations and from elevations acquired from the SRTM30 Digital Elevation Model. The pit flows are based on the regional model perspective, and has some limitations on accuracy. Survey of the pits is required to get better confidence and accuracy in the flows presented, since the flows diminish as the pit level drops. Further refinement can be obtained through additional monitoring boreholes in the vicinity of the pits. Additional parameters and factors that influence the flow calculation include, recharge, constant heads, interactions between pits, and the accurate dimensions of the top to bottom of the model layers.

The model results indicate that the net inflow from groundwater is in continual balance with the evaporation component resulting in a near zero net flow. The modelled inflows assume there is only a rainfall and groundwater inflow component, and no external input needed to be considered. The variability of the contribution from rainfall is offset by continuous evaporation, resulting in a general water balance in the pits, and as a result, the pit levels fluctuate periodically. The modelled zones are presented in Figure 21 and the total pit inflows are summarised in Table 12.

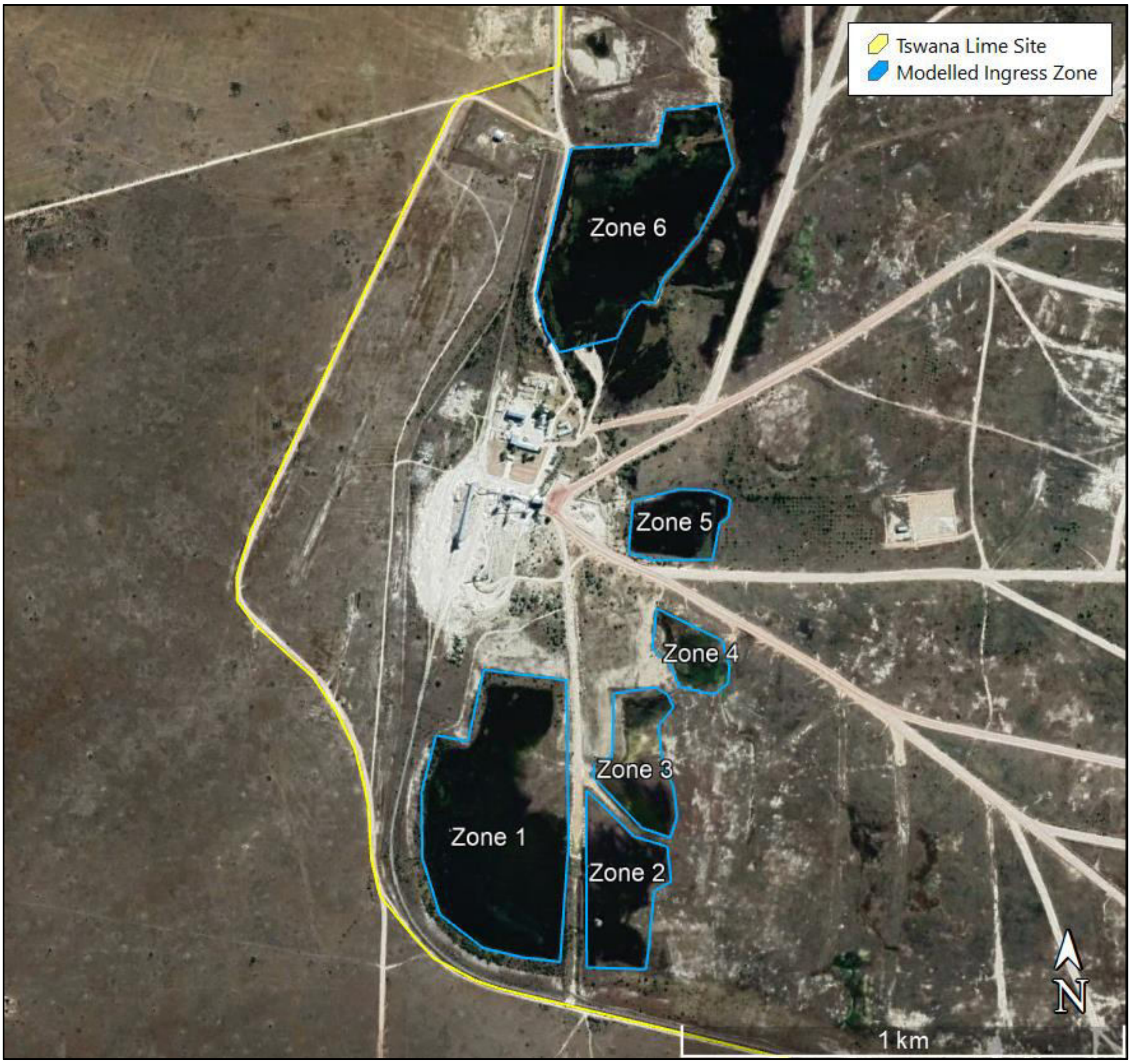


Figure 21: Modelled Pit Inflow Zones

Table 12: Summary Modelled Pit Inflows

Zone	Water Level in Pit (mamsl)	Total Pit Inflow (m^3/d)	Total Pit Outflow (m^3/d)	Evapotranspiration Component (m^3/d)	Nett Flow (Balance) (m^3/d)
1	1434	573.13	573.84	571.87	-0.718
2	1435	195.47	195.91	190.37	-0.437
3	1438	138.64	138.97	116.56	-0.328
4	1437	101.23	101.45	100.19	-0.222
5	1437	110.31	110.59	105.28	-0.278
6	1437	666.31	666.30	404.46	0.004

7.8.3 Mass Transport Model Results

The potential pollution sources that were considered are presented in Table 1 and Figure 2, with borehole LQBH4 pumping at 70 m^3/d as presented in the water balance report. This is in line with site observations and the sustainable yield determination presented earlier in this report, where the volume was calculated as 89 m^3/d. The potential pollution sources are presented in Figure 22 for reference.

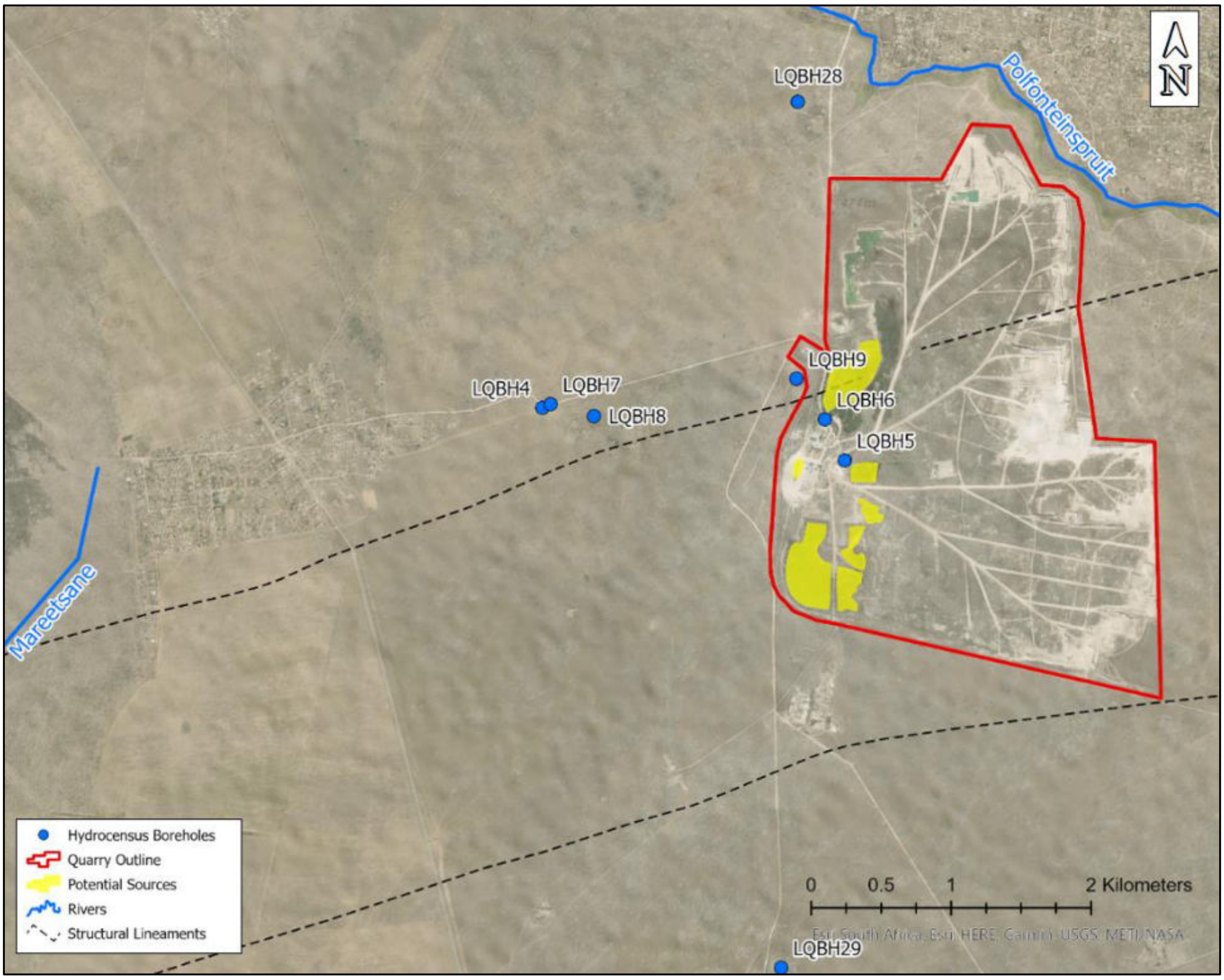


Figure 22: Spatial Distribution of Potential Pollution Sources

The conservative mass transport model results for the identified sources in steady state for Layer 1 and Layer 2 are presented in Figure 23 though Figure 30. The summary results of the 10 % and 100 % concentration contour travel distances along the structural lineament are presented in Table 13 to show the modelled plume migration with time. The selection of the higher conductivity structural lineament was chosen to show the worst case scenario of travel distances. At late time, it is evident that the plume movement is affected by the pumping taking place at LQBH4 as the plume moves in that direction. The travel distances were measured from a common reference point being the edge of Zone 6.

Table 13: Summary Mass Transport Model Results - Travel Distances

Layer	Period (Years)	100 % Travel Distance (m)	10 % Travel Distance (m)
1	25	306	942
	50	782	2277
	75	1273	3303
	100	1872	4369
2	25	351	1661
	50	1258	3120
	75	2098	4432
	100	2804	5696

For comparison, the 10 % concentration contour from Zone 6 and the quarry stockpile only reaches 121 and 128 m respectively in Layer 2 for the 100 year time step. This contained migration is due to the evaporation component.

With the evaporation switched on, the pits acts as a “pump” which contains the plume migration. Since the evaporation rate is more than three times that of rainfall, and recharge is about 6% of MAP, and as long as the pits are not shielded from evaporation through backfill, evaporation will create a gradient between the pit level and that of the immediate groundwater level surrounding the pits. The result of this is that the plume movement around these features stay contained. It is also evident that the source concentrations increase over time as the evaporation process does not allow for mass transport out of the system. This leads to a concentration of salts over time.

The scenario results without the effect of evaporation turned off are presented in Annexure F for reference. The source concentration remains constant.

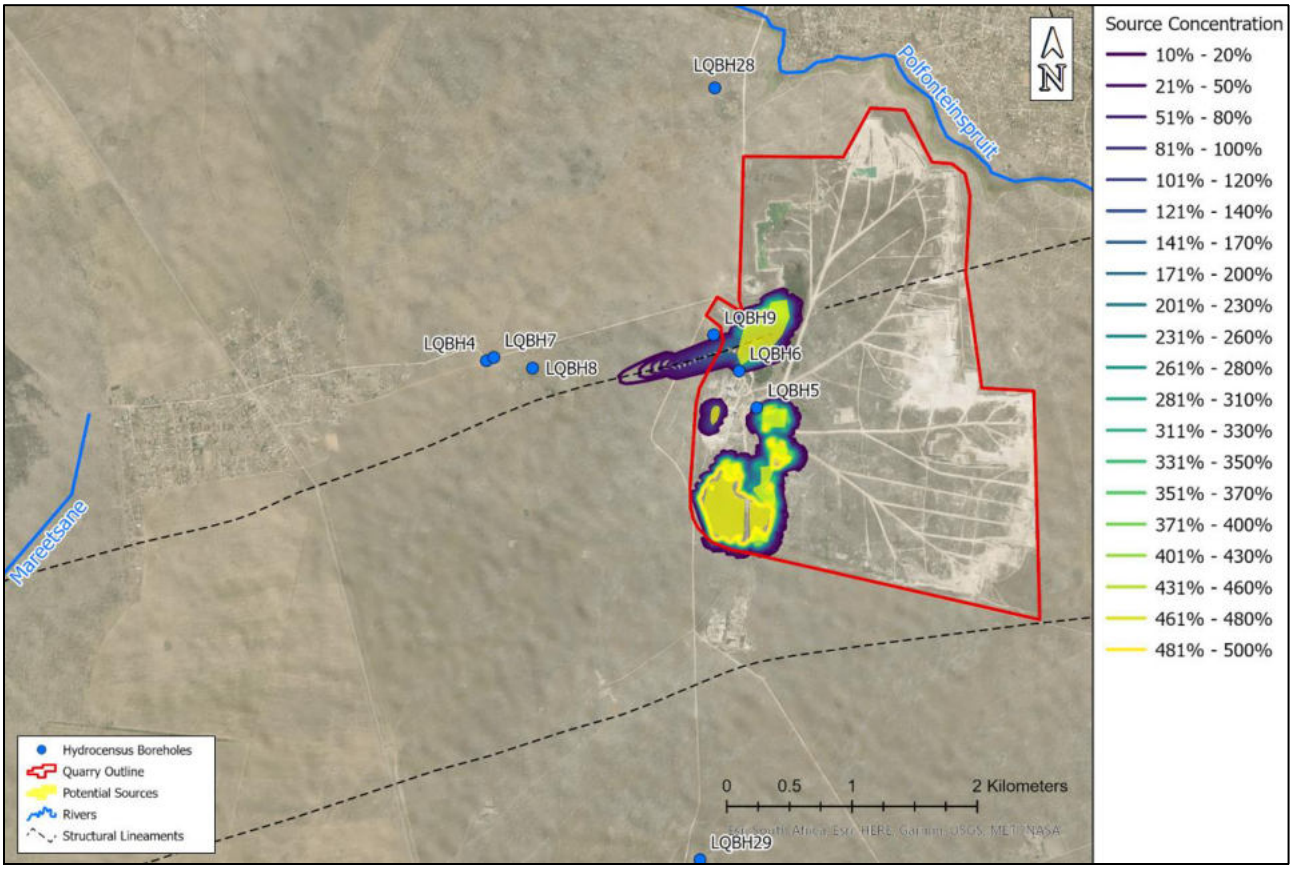


Figure 23: Mass Transport for Layer 1 - 25 Years

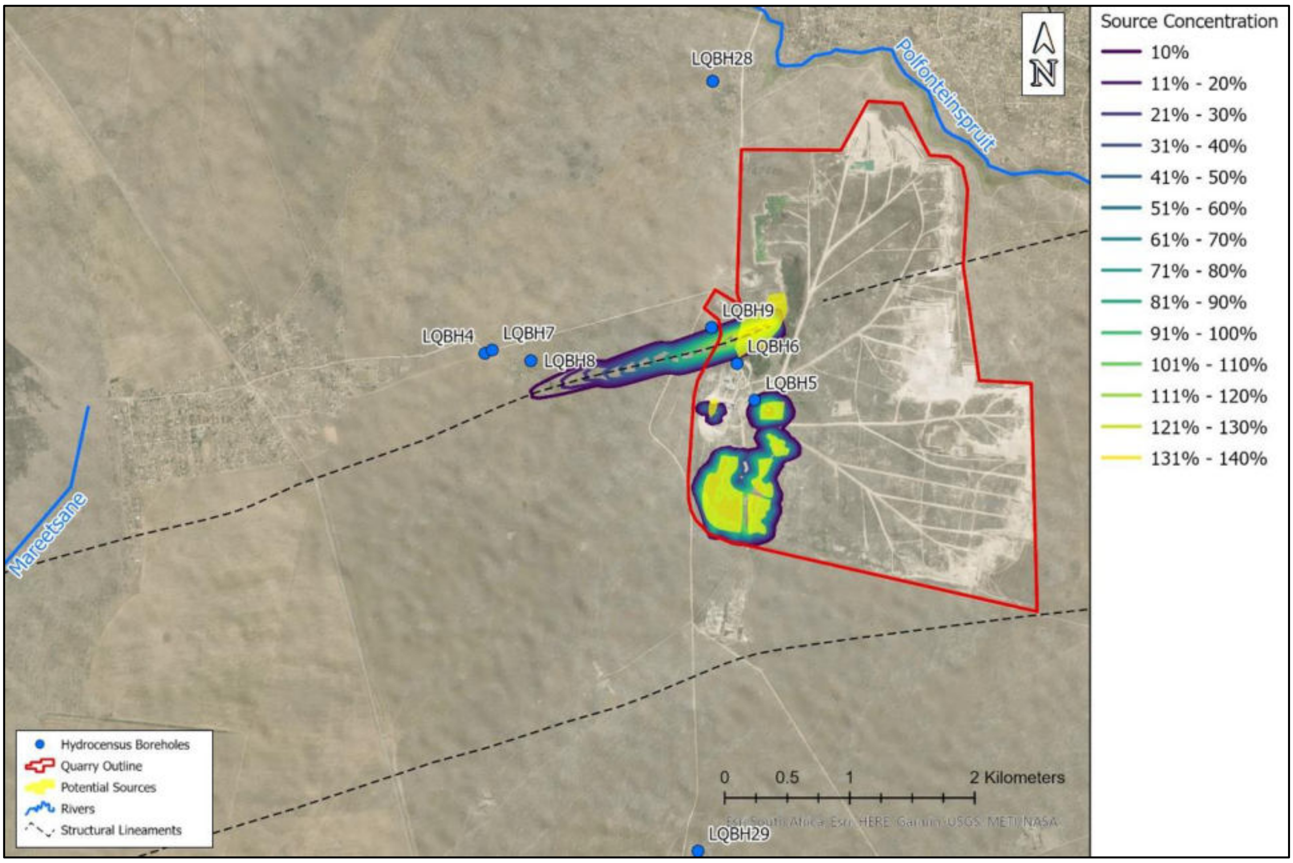


Figure 24: Mass Transport for Layer 2 - 25 years

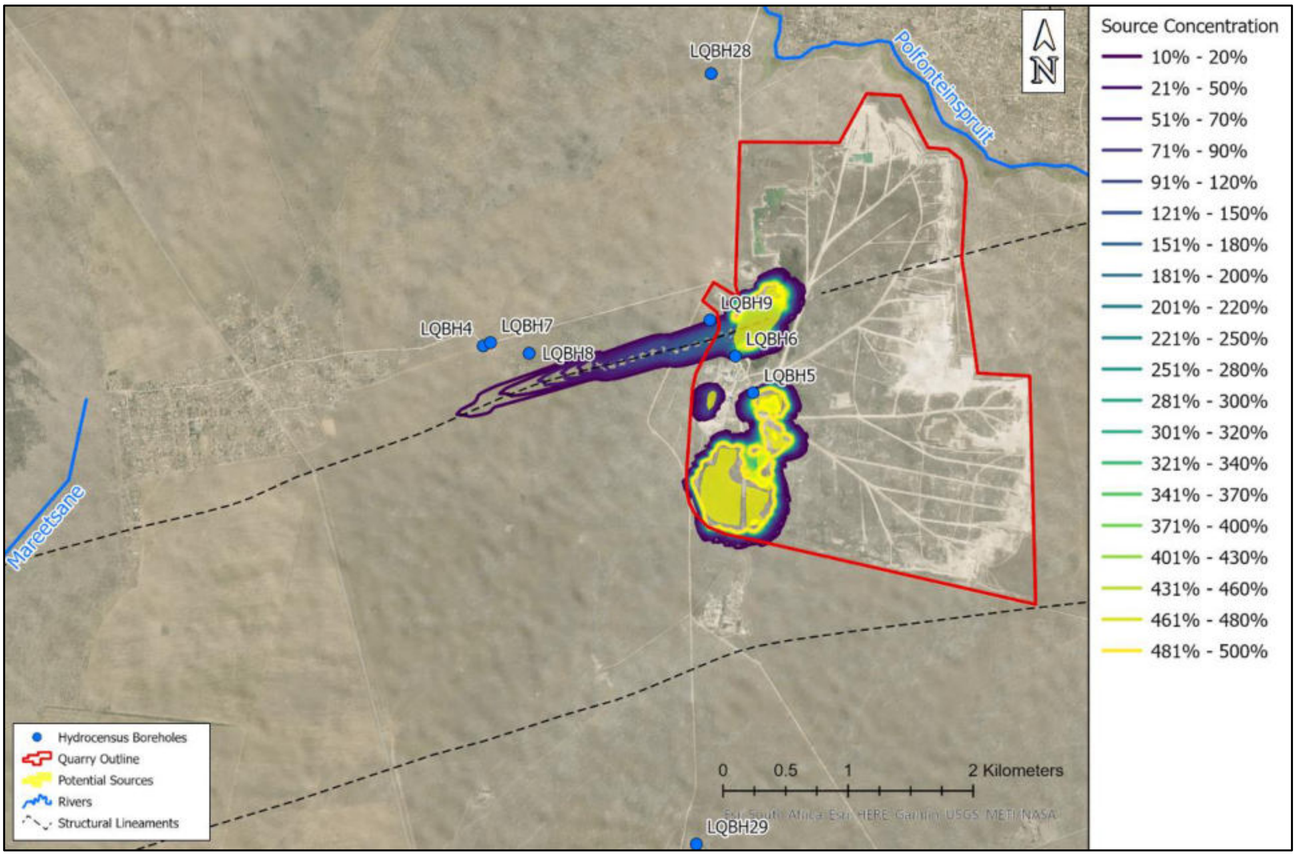


Figure 25: Mass Transport for Layer 1 - 50 Years

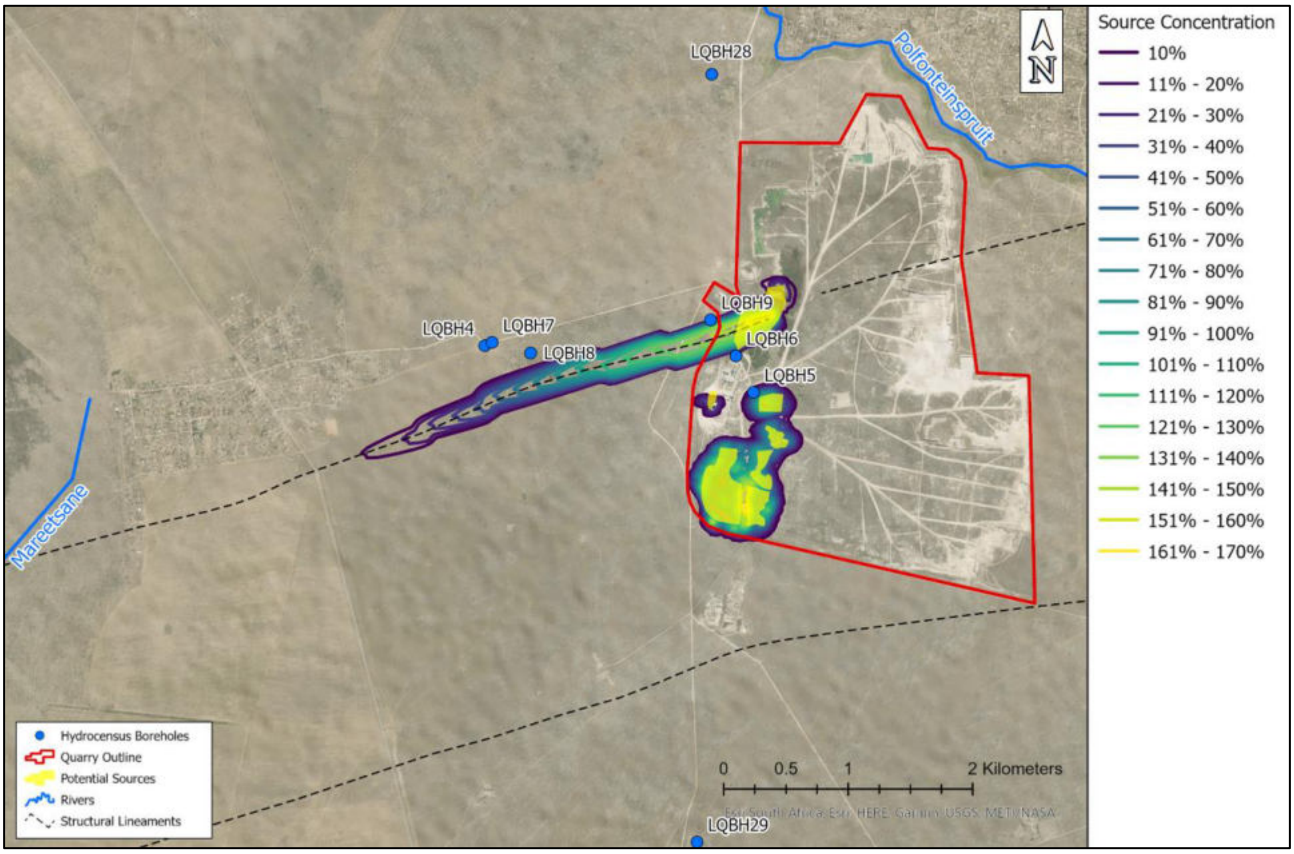


Figure 26: Mass Transport for Layer 2 - 50 Years

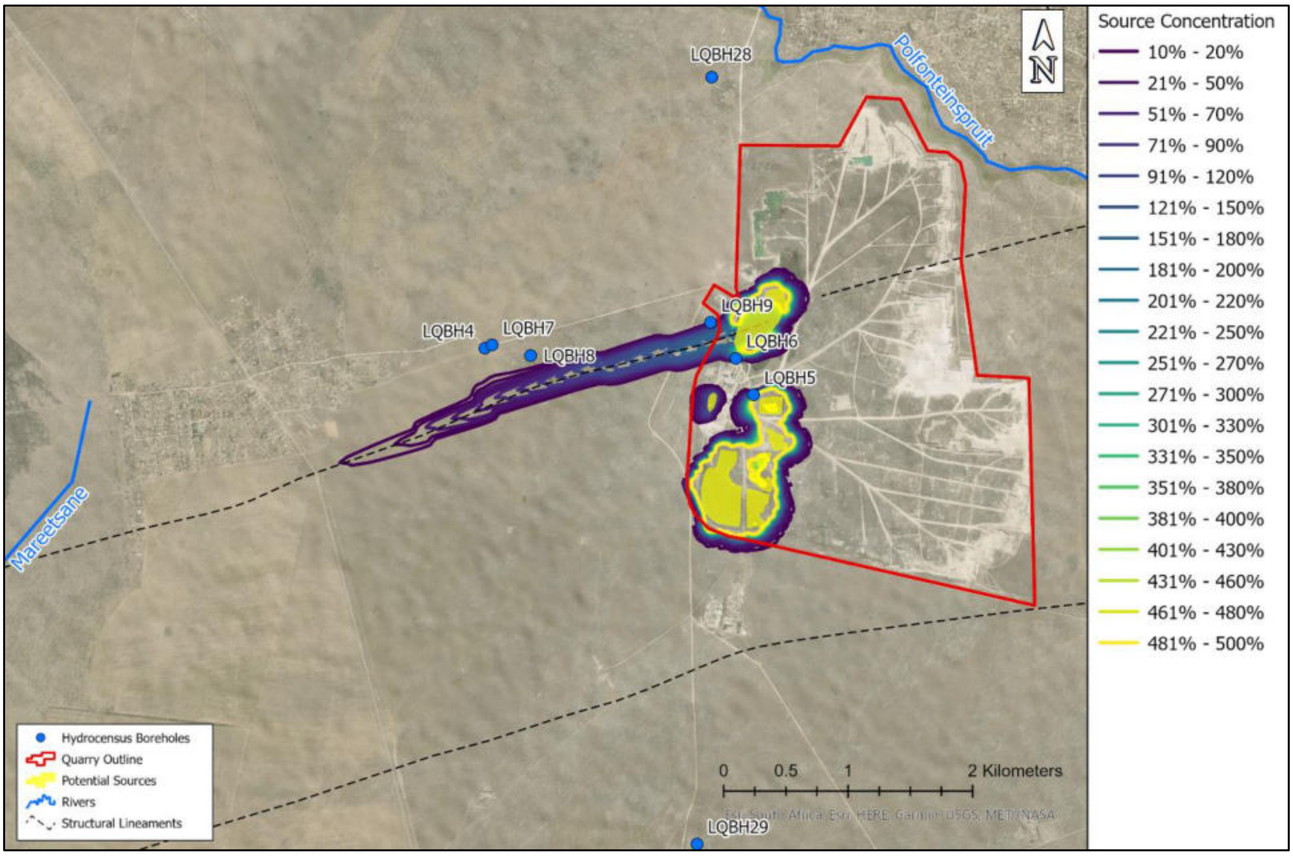


Figure 27: Mass Transport for Layer 1 - 75 Years

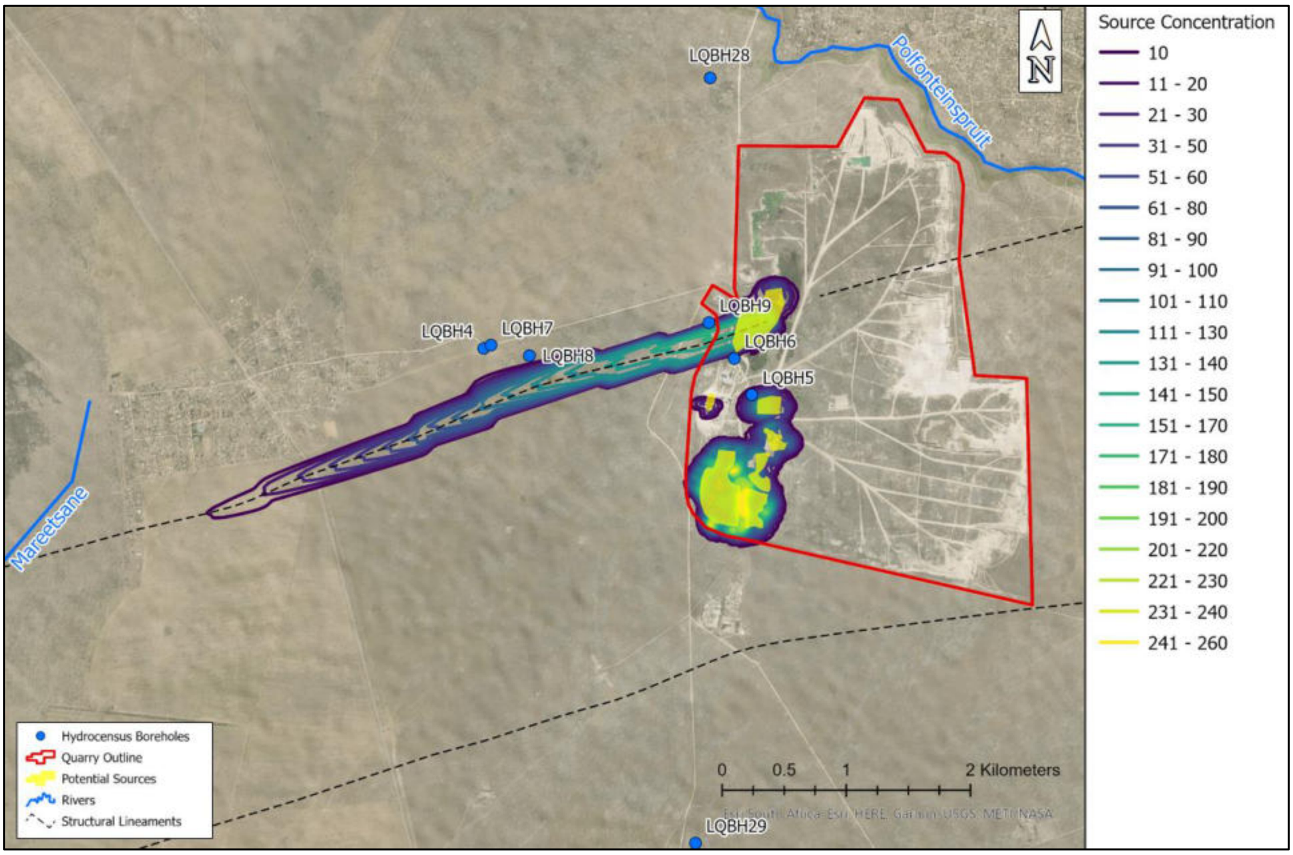


Figure 28: Mass Transport for Layer 2 - 75 Years

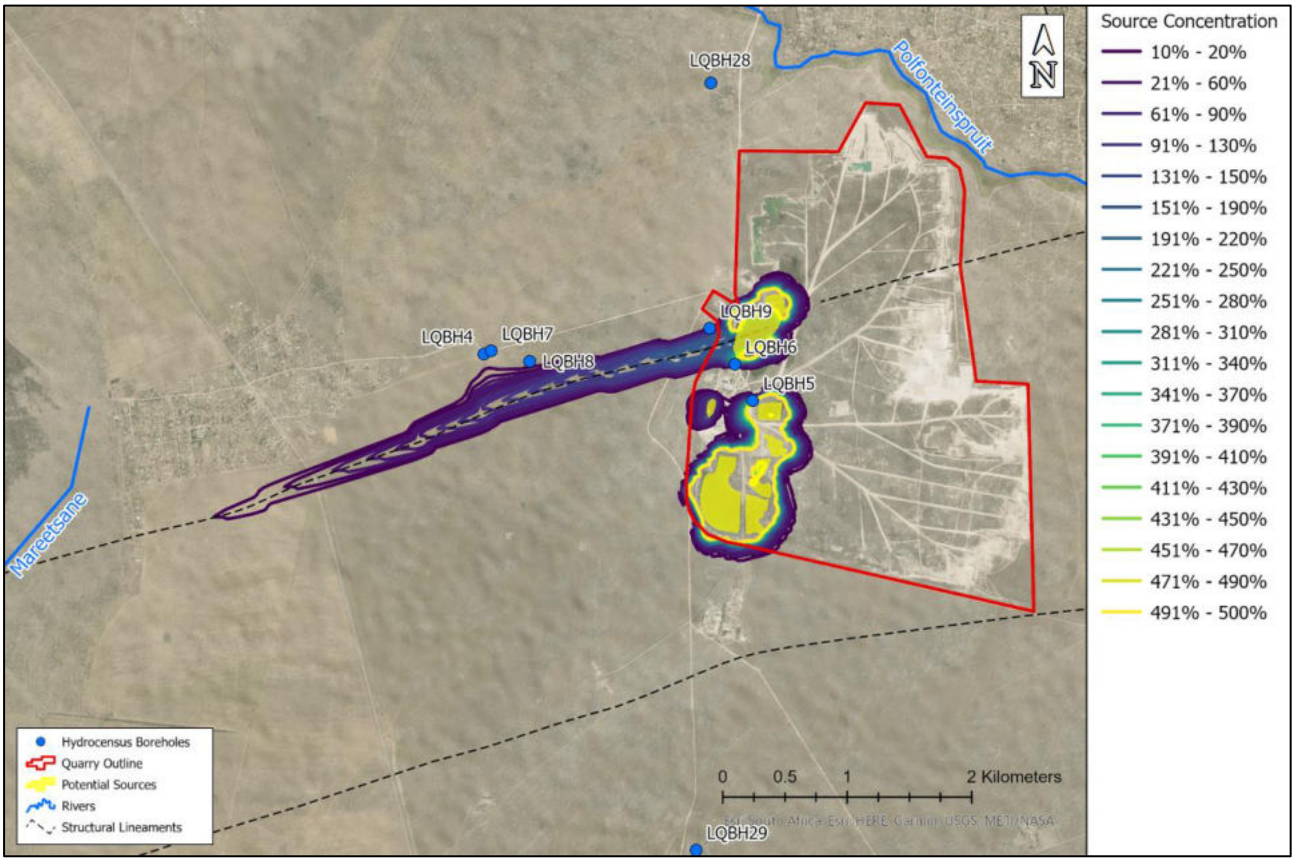


Figure 29: Mass Transport for Layer 1 - 100 Years

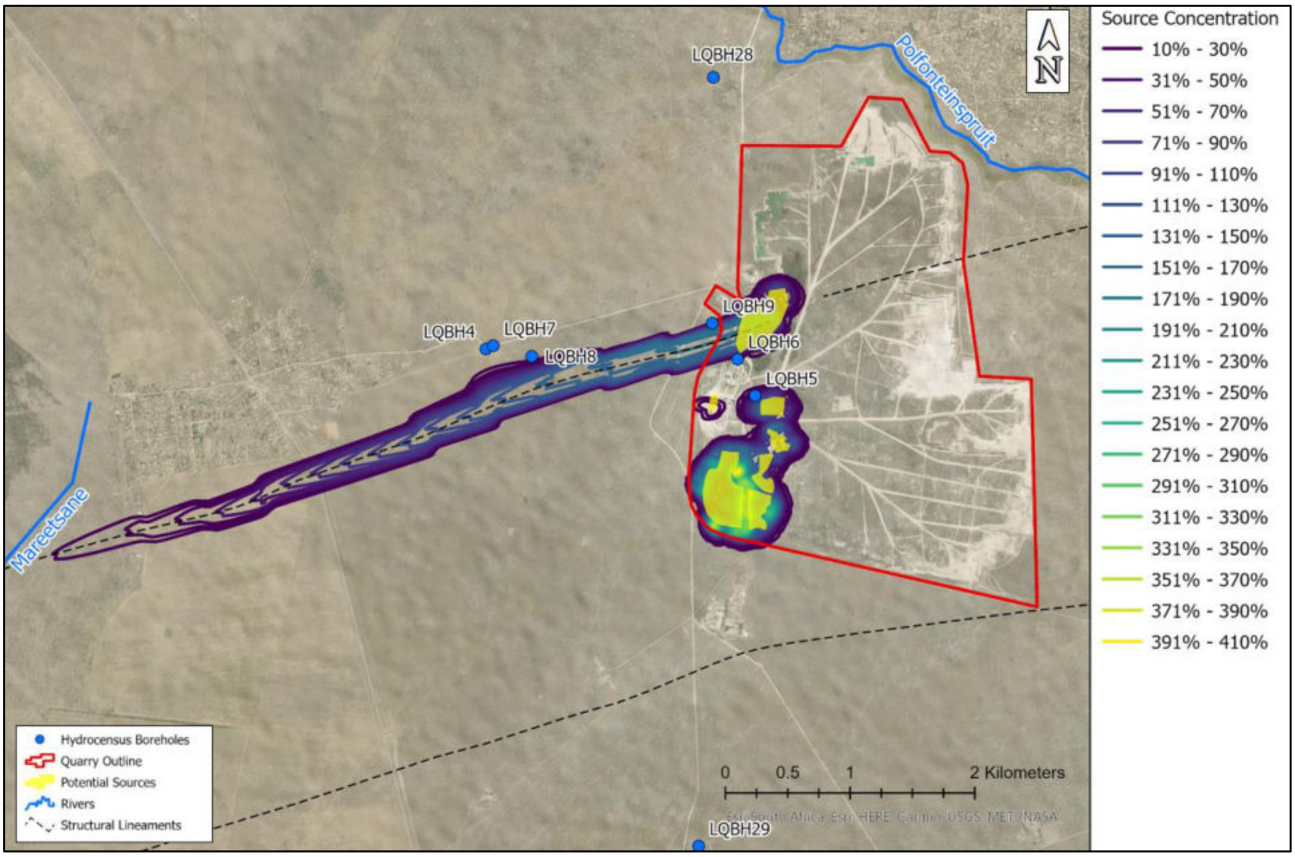


Figure 30: Mass Transport for Layer 2 - 100 Years

8 QUANTITATIVE ENVIRONMENTAL RISK ASSESSMENT AND MITIGATION

The quantitative environmental risk assessment (ERA) identifies operational phase activities that may impact on the groundwater receiving environments. The Significance Points (SP) score is calculated from the following equation using ranking scales:

$$SP = \text{probability} \times (\text{duration} + \text{scale} + \text{magnitude})$$

The ERA methodology is presented in Annexure G. The ERA for the operational phase for the groundwater receiving environment is summarised in Table 14. Most activities identified scored LOW or MODERATE for the pre mitigation ratings. Stockpiles scored HIGH. Most scores can be reduced with the introduction of mitigation measures include in Table 14.

Table 14: Summary Risk Assessment Scoring

Significance / Consequence	Activity	Probability	Duration	Scale	Magnitude	Significance	PRE MITIGATION SP SCORE and RATING	>60 indicates high environmental significance <30 indicates low environmental significance	Mitigation	POST MITIGATION SP SCORE and RATING	>60 indicates high environmental significance <30 indicates low environmental significance	Variation
Section 21 (a) - taking water from a water resource												
Quantity	Aquifer dewatering	medium to high	permanent	site to local	moderate	medium negative	3.5(5+1.5+6) = 44	MODERATE	operate borehole within the design yield monitoring	2(5+1+4) = 20	LOW	24
Quality	Deterioration of groundwater quality through abstraction	improbable to low	permanent	site	minor to low	low negative	1.5(5+1+3) = 14	LOW	none	1.5(5+1+3) = 14	LOW	0
Section 21 (b) - storing water												
Quantity	recharge of the groundwater system	high	permanent	site	minor	positive	4(5+1+2) = 32	MODERATE	none	4(5+1+2) = 32	MODERATE	0
Quality	Deterioration of groundwater quality through recharge	high	long	site to local	moderate	medium negative	4(4+1.5+6) = 46	MODERATE	monitor and manage control inflow water quality	2.5(4+1.5+5) = 26	LOW	20
	Use of dam water for dust suppression and impacts on groundwater quality in surrounding areas	high	long	site to local	low to moderate	medium negative	4(4+1.5+5) = 42	MODERATE	Improved water quality / treatment Controlled use	3(4+1.5+4) = 29	LOW	14
Section 21 (g) - disposing of waste in a manner which may detrimentally impact on a water resource												
Quantity	recharge of the groundwater system (see 21 (b))	high	permanent	site	minor	positive	4(5+1+2) = 32	MODERATE	none	4(5+1+2) = 32	MODERATE	0
Quality	Deterioration of groundwater quality through recharge (see 21 (b))	high	long	site to local	moderate	medium negative	4(4+1.5+6) = 46	MODERATE	monitor and manage control inflow water quality	2.5(4+1.5+5) = 26	LOW	20
	Impacts on downstream groundwater users	high	long	site to local	moderate	medium negative	4(4+1.5+6) = 46	MODERATE	monitor and manage groundwater model for mass transport - 50 years model refinement with additional monitoring points	2.5(4+1.5+5) = 26	LOW	20
	Future pit decant	improbable to low	permanent	site to local	minor to low	low negative	1.5(5+1.5+3) = 14	LOW	none	1.5(5+1.5+3) = 14	LOW	0
	Salt loading through evaporation process	high	long	site to local	moderate to high	medium high negative	4(4+1.5+7) = 50	MODERATE	monitor and manage control inflow water quality	3.5(4+1+7) = 42	MODERATE	8
	Prolonged leaks / leachate from stockpile and impacts on groundwater quality	high	permanent	local	high	high negative	4(5+2+8) = 60	HIGH	lining of PCD and water reuse / treatment Minimise stockpiles with water collection systems	3(5+1.5+6) = 38	MODERATE	23
	Mobilisation of existing elevated compounds in the soils matrix and impacts on groundwater quality	medium	short	site to local	moderate	medium negative	3(2+1.5+6) = 29	LOW	Controlled earthworks and spoil management	2.5(2+1+5) = 20	LOW	9
	Increased turbidity loading from construction areas and impacts on groundwater quality	high	short to medium	site to local	moderate	medium negative	4(2.5+1.5+6) = 40	MODERATE	Controlled earthworks and spoil management	2.5(2+1+5) = 20	LOW	20
	Contamination of soils from equipment and storage areas (hydrocarbons) and impacts on groundwater quality	high	short to medium	site to local	high	high negative	4(2.5+1.5+8) = 48	MODERATE	Rapid clean up response Equipment maintenance plan	3.5(2+1+7) = 35	MODERATE	13
	Major loss of containment, dam overflows and impacts on groundwater quality	low	short to medium	local	high	high negative	2(2.5+2+8) = 25	LOW	Management of facilities Improved water quality through reuse / treatment Rapid clean up response	2(2+2+6) = 20	LOW	5
Section 21 (j) - removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people												
Quantity	Aquifer dewatering	medium to high	permanent	site to local	moderate	medium negative	3.5(5+1.5+6) = 44	MODERATE	operate dewatering on localised scale isolate and minimise areas of dewatering discharge to adjacent dams to maitain water balance	2(5+1+4) = 20	LOW	24
	Impacts on downstream groundwater users	medium to high	permanent	site to local	moderate	medium negative	3.5(5+1.5+6) = 44	MODERATE	operate dewatering on localised scale isolate and minimise areas of dewatering discharge to adjacent dams to maitain water balance	2(5+1+4) = 20	LOW	24

9 MONITORING PLAN

9.1 Introduction

This section serves to provide the Client with a methodology to conduct groundwater monitoring to ensure reproducible and reliable results through consistent and appropriate sampling techniques. Monitoring information needs to be gathered in a confident manner to interpret groundwater chemistry over time, and to determine impacts associated with site infrastructure, such that meaningful management measures can be implemented for the site.

Two aspects in the monitoring plan need to be considered. These include;

- Groundwater levels
- Groundwater quality.

The procedures form the essence of the sampling plan. A borehole monitoring plan has already been established for the Tswana Lime Quarry site.

Groundwater chemistry should be monitored bi-annually and should be based on the investigation and detection monitoring developed by the Department of Water and Sanitation, and the General Limits of the of the General Authorisations[3].

9.2 Methodology

It is recommended that groundwater sampling be carried out in accordance with the Water Research Commission's Comprehensive Guide for Groundwater Sampling, as presented by Weaver and Cavé of Groundwater Sciences, CSIR (WRC Report No TT 303/07), and JG Afrika's standard operating procedures for environmental monitoring and field work.

For boreholes that are already in operation, samples can be collected from the existing borehole pump outlets (preferably at a reservoir or tap outlet at the wellhead). No purging will be required due to ongoing operation of the borehole, however, sample taps need to be sanitized and flushed prior to sample collection.

Un equipped boreholes will be purged using a submersible pump where appropriate. Purging of at least three well volumes is required. Groundwater samples will be collected from the discharge of the portable submersible pump and placed directly in sample bottles supplied by the laboratory. At the time of sampling, field measurements of pH, EC and temperature should be recorded on the sampling log. Sample bottles will be labelled and cooled in an insulated cool box on site. All samples will be dispatched to the laboratory within the laboratory's required sample holding times for the designated analysis. All sampling and monitoring equipment will be rinsed and decontaminated between each sampling point.

Water samples will be analysed by an SANAS accredited laboratory. The results of water level monitoring, purging details, and sampling and analysis are to be presented in a factual report. The results of analysis are to be compared to appropriate screening guideline values to give a comparative indication of chemistry trends and possible contamination. Any negative findings will be highlighted and recommendations made for future sampling and possible remedial measures.

[3] The Department of Water and Environmental Affairs, 6 September 2013. Government Notice No. 665. Revision of the General Authorisations in Terms of Section 39 of the National Water Act, 1998 (Act No. 36 of 1998)

9.3 Analysis Suite

The current groundwater analysis suite being applied at the Tswana Lime Quarry Site is summarised in Table 15, with the inclusion of additional recommended analysis.

Table 15: Analysis Suites

Frequency	Analytical List	Objective
Bi-annually	pH, EC, Ca, Mg, Na, K, Total Alkalinity, F, Cl, NH4(N), NO3(N), PO4, SO4, Al, Fe, Mn	Water quality and impacts
	SANS214:2015 – Raw Water	Domestic consumption
Annually	Ba, As, Co, Cr, Ni, Pb, Se, Sr, V, Zn, Mn, Cu, Ga, Ge, Rb, Y, Zr, Sn, W, Bi, Th, U, Hg	Water quality and impacts

9.4 Sample Locations

The existing and proposed groundwater monitoring locations are presented in Figure 31. It is noted that LQBH5 and LQBH6 need to be reinstated, and additional monitoring boreholes may include NBH1 to NBH3 to augment the data set.

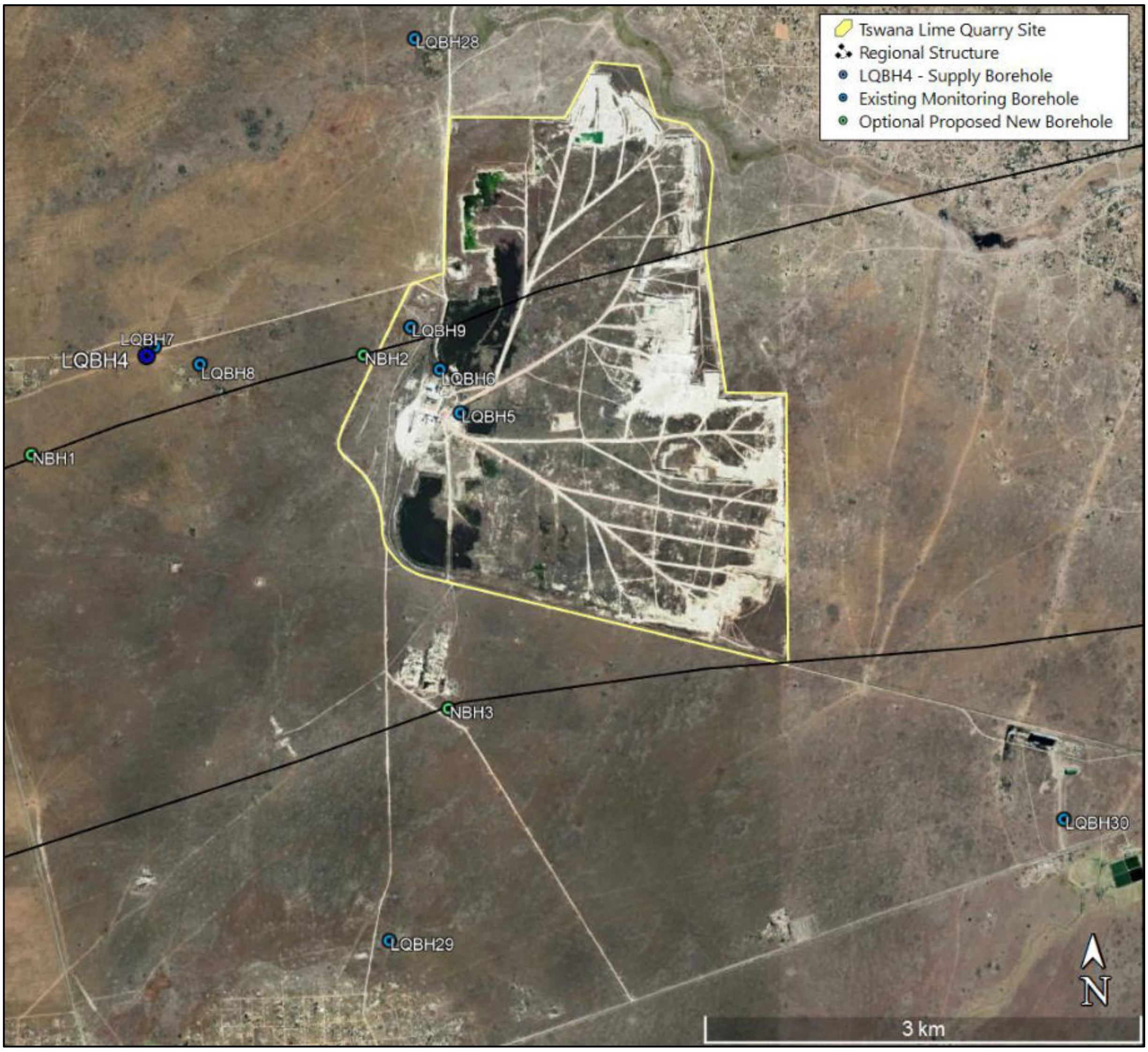


Figure 31: Tswana Lime Quarry Groundwater Monitoring Network

9.5 Revised Sampling Plan

The revised sampling plan is summarised in Table 16.

Table 16: Revised Sampling Plan

Frequency	Sample Locations	Analytical List	Comments
Bi-annually	LBH5	pH, EC, Ca, Mg, Na, K, Total Alkalinity, F, Cl, NH4(N), NO3(N), PO4, SO4, Al, Fe, Mn	Reinstate borehole
	LBH6		Reinstate borehole
	LBH7		Ongoing
	LBH9		Ongoing
	LBH28		Reinstate borehole
	NBH1		Proposed
	NBH3		Proposed
	LQBH4	SANS241 Raw Water	Ongoing, include monthly water levels and meter readings
	NBH1		Proposed, include monthly water levels
	NBH2		Proposed, include monthly water levels
Annually	LBH5	Ba, As, Co, Cr, Ni, Pb, Se, Sr, V, Zn, Mn, Cu, Ga, Ge, Rb, Y, Zr, Sn, W, Bi, Th, U, Hg	Reinstate borehole
	LBH6		Reinstate
	LBH7		Ongoing
	LBH9		Ongoing
	LBH28		Reinstate borehole
	NBH3		Proposed

10 CONCLUSIONS AND RECOMMENDATIONS

This report presents the results of a detailed geohydrological assessment carried out for Tswana Lime Quarry site located near Lichtenburg in the North West Province. The geohydrological report has been prepared as a specialist study in support of the water use authorisation for the following water uses as per Section 21 of the National Water Act (Act No. 36 of 1998).

- Section 21 (a) - taking water from a water resource
- Section 21 (g) - disposing of waste in a manner which may detrimentally impact on a water resource
- Section 21 (j) - removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people.

The aim of the assessment was to determine the sustainable yield of the current supply borehole designated LQBH4, conduct a hydrocensus to establish potential receptors, and to develop a numerical groundwater flow and mass transport model, to determine risk and impact.

The project area is underlain by a karst aquifer type and the aquifer class unit in terms of the South African Aquifer Classification System is characterised as *Major*. A groundwater model was developed for the study area and calibrated making use of data obtained from the NGA as well as from local hydrocensus information. The model was calibrated making use of water levels considered to be representative of static water levels, which represents the natural steady state of the system.

Potential pollution sources identified according to sections 21 (a), (g) and (j) of the National Water Act (Act No. 36 of 1998) were introduced into the model for the purpose of mass transport modelling over time steps of 25, 50, 75 and 100 years. The model outputs were to simulate groundwater influx associated with the quarry pits, and determine mass transport travel distances for the individual model layers over the model time steps in 25 year increments.

The sustainable yield of the supply borehole was determined as 58656 m^3/a through yield testing of the borehole. The model results indicate the groundwater flux in the pits to be in a state of equilibrium with inflows being offset by evaporation. The resulting simulations indicate the evaporation component acts as a “pump” from the individual pits, thus reducing the zone of impact for mass transport. The structural features evident through the project area do however act as a conduit for plume migration in a westerly direction.

The risk and impact of the water uses was reviewed by means of a quantitative environmental risk assessment (ERA) as developed for by the Operational Guideline: Integrated Water and Waste Management Plan. The aquifer vulnerability is considered medium to high, and the Parsons Groundwater Quality Management System gives the site a High Level of Protection index for the second variable vulnerability. The quantitative environmental risk assessment identified most listed activities to score LOW to MODERATE with the stockpile scoring HIGH. All activity scores can be significantly reduced with the application of appropriate mitigation measures, by focusing on the probability and Magnitude factor.

The mass transport results show a strong dependence on the characteristics of a structural lineament through the project area. More field data is required to confirm the effect of this feature, as the hydraulic conductivity of the structure was determined through the calibration process. Model calibration is also non-unique due to the many degrees of freedom that exist in the unknown parameters and/or uncertainty in measured results. To improve the model confidence, more data would be required to refine the current model. In particular, monitoring points around the pits would enhance the model output for determining groundwater flux into the pits. Additional monitoring boreholes were proposed around the pits and along the structural feature.

Annexure A: Declaration of Specialist

DECLARATION OF THE SPECIALIST

I ROBERT SCHAPERS, as the appointed Specialist hereby declare/affirm the correctness of the information provided or to be provided as part of the application, and that:

- In terms of the general requirement to be independent:
  - other than fair remuneration for work performed in terms of this application, have no business, financial, personal or other interest in the development proposal or application and that there are no circumstances that may compromise my objectivity; or
  - ~~am not independent, but another specialist (the "Review Specialist") that meets the general requirements set out in Regulation 13 of the NEMA EIA Regulations has been appointed to review my work (Note: a declaration by the review specialist must be submitted);~~
- I have disclosed to ~~the applicant~~, the EAP, ~~the Review EAP (if applicable), the Department and I&APs~~ all material information that has or may have the potential to influence the decision of the Department or the objectivity of any Report, plan or document prepared or to be prepared as part of the application; and
- I am aware that a false declaration is an offence in terms of Regulation 48 of the EIA Regulations.

09 Sep 2022

Signature of the Specialist: Date:

JG AFRIKA (PTY) LTD

Name of company (if applicable):

Annexure B: Yield Test Results and Analysis

Pumping Test Data

Project Name		**Lafarge Lichtenburg Geohydrological Assessment**			JG AFRIKA / LAFARGE	
BOREHOLE NUMBER		**LQBH4**			**Project Reference**	5803
					Contractor	JG Afrika
Co-Ordinates	**South**	-26.076095°	**Final Depth**	52.96	**Operator**	MN
	East	25.780376°	**Borehole Diameter**	160	**Supervision**	MN
Start Date		02-Aug-22	**Static Water Level**	7.51	**Test Pump Type**	existing submersible
End Date		03-Aug-22	**Available DD**	21.05	**Test Pump Depth**	28.56

Step Testing						**Constant Discharge Testing**								
Date			**Start Time**			**Date**	**02-Aug**	**Start Time**	**19:30**	**Water Level at Start**		**7.51**	**Observation Borehole**	
Steps			**Step Recovery**			**Contstant Discharge**				**Constant Recovery**			**ID**	
Step Number	Minutes	Draw down (S)	hh:mm:ss	Minutes	Draw down (S')	hh:mm:ss	Minutes	Draw down (S)	Rate	hh:mm:ss	Minutes	Draw down (S')	Draw down (S)	Draw down (S')
Step 1	1		0:01:00	1		0:00:30	0.5	2.02		0:00:30	0.5			
	2		0:02:00	2		0:01:00	1	2.78		0:01:00	1			
	3		0:03:00	3		0:02:00	2	3.49	3.250	0:02:00	2			
	5		0:04:00	4		0:03:00	3	3.79		0:03:00	3			
	7		0:05:00	5		0:05:00	5	4.15		0:05:00	5			
Average	10		0:07:00	7		0:07:00	7	4.35		0:07:00	7			
Rate	15		0:10:00	10		0:10:00	10	4.52	3.250	0:10:00	10			
0.860	20		0:15:00	15		0:15:00	15	4.72		0:15:00	15	2.36		
	30		0:40:00	40		0:20:00	20	5.85		0:20:00	20	1.66		
	40		0:50:00	50		0:25:00	25	5.94	3.250	0:25:00	25	1.60		
	50		1:00:00	60		0:30:00	30	4.84		0:30:00	30	1.54		
	60		1:10:00	70		0:40:00	40	5.26		0:40:00	40	1.45		
Step 2	1		1:20:00	80		0:50:00	50	5.37	3.250	0:50:00	50	1.38		
	2		1:30:00	90		1:00:00	60	5.34		1:00:00	60	1.28		
	3		1:40:00	100		1:10:00	70	5.57		1:10:00	70	1.20		
	5		1:50:00	110		1:20:00	80	5.65	3.250	1:20:00	80	1.16		
	7		2:00:00	120		1:30:00	90	5.75		1:30:00	90	1.13		
Average	10		2:30:00	150		1:40:00	100	5.87	3.250	1:40:00	100	1.08		
Rate	15		3:00:00	180		2:00:00	120	5.94		2:00:00	120	1.01		
2.080	20		3:30:00	210		2:30:00	150	6.08	3.250	2:30:00	150	0.89		
	30		4:00:00	240		3:00:00	180	6.27		3:00:00	180	0.80		
	40		4:30:00	270		3:30:00	210	6.43	3.250	3:30:00	210	0.70		
	50		5:00:00	300		4:00:00	240	6.50		4:00:00	240	0.59		
	60		5:30:00	330		4:30:00	270	6.65		4:30:00	270	0.53		
Step 3	1		6:00:00	360		5:00:00	300	6.71		5:00:00	300	0.48		
	2					5:30:00	330	6.80	3.250	5:30:00	330	0.41		
	3					6:00:00	360	6.91		6:00:00	360	0.35		
	5					7:00:00	420	6.64						
	7		**95% recovery level**		**0.00**	8:00:00	480	6.96						
Average	10					9:00:00	540	7.14	3.250					
Rate	15					10:00:00	600	7.25						
3.520	20					11:00:00	660	7.33						
	30					12:00:00	720	7.33						
	40													
	50													
	60													
Step 4	1													
	2													
	3													
	5													
	7													
Average	10													
Rate	15													
5.510	20		**Main Strike (mbgl)**		**>21.51**									
	30		**Critical Depth (mbgl)**		**7.3**									
	40		FC CD Rate	Graph CD Rate	Specified CD Rate									
	50						**Average Rate**		**3.250**	**95% recovery level**		**0.37**		**0.00**
	60		-	-	3.25									

YIELD ANALYSIS

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

LQBH4 — Main | Deriv | Inflection point method

Extrapolation time in years = (enter)	2	1051200	Extrapol.time in minutes	
Effective borehole radius (r_e) = (enter)	0.50	#NUM!	Est. r_e	From r(e) sheet
Q (l/s) from pumping test =	3.25	3.35E-03	S-late	Change r_e
s_a (available draw dow n), sigma_s = (enter)	14.0		Sigma_s from risk	Down
Annual effective recharge (mm) =	0	14.00	s_available w orking draw dow n(m)	
t(end) and s(end) of pumping test =	720	7.33	End time and draw dow n of test	
Average maximum derivative = (enter)	2.0	2.6	Estimate of average of max deriv	
Average second derivative = (enter)	0.4	0.0	Estimate of average second deriv	
Derivative at radial flow period = (enter)	#NUM!	#NUM!	Read from derivative graph	
	T-early[m²/d] =	#NUM!	Aqui. thick (m)	20
T and S estimates from derivatives	T-late [m²/d] =	25.69	Est. S-late =	1.10E-03
(To obtain correct S-value, use program RPTSOLV)	S-late =	2.20E-03	S-estimate could be w rong	

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) =	15.66	21.99	28.32	47.30
Q_sust (l/s) =	2.91	2.07	1.61	0.96
	Best case	→	→	**Worst case**

Average Q_sust (l/s) = 1.75

with standard deviation= 0.82

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

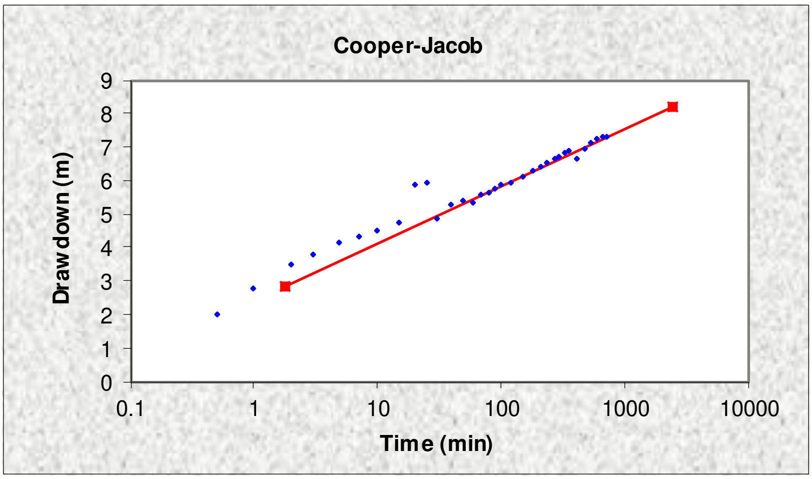
Cooper-Jacob method

Main | Theis | Cooper-Jacob 2

LQBH4

T(m²/d) =	**30.1**	r_e (m)=	0.50
S =	**7.40E-03**	Q (l/s) =	3.25

	No boundaries	1 no-flow	2 no-flow	Closed	
Q_sust	3.58	1.79	1.18	0.90	including influence of bh's
Avg. Q_sust =	**1.86**	std. dev =	1.21		



FC Inflection Point method for sustainable yield estimation

back to Sust_Q sheet | LQBH4 | Main

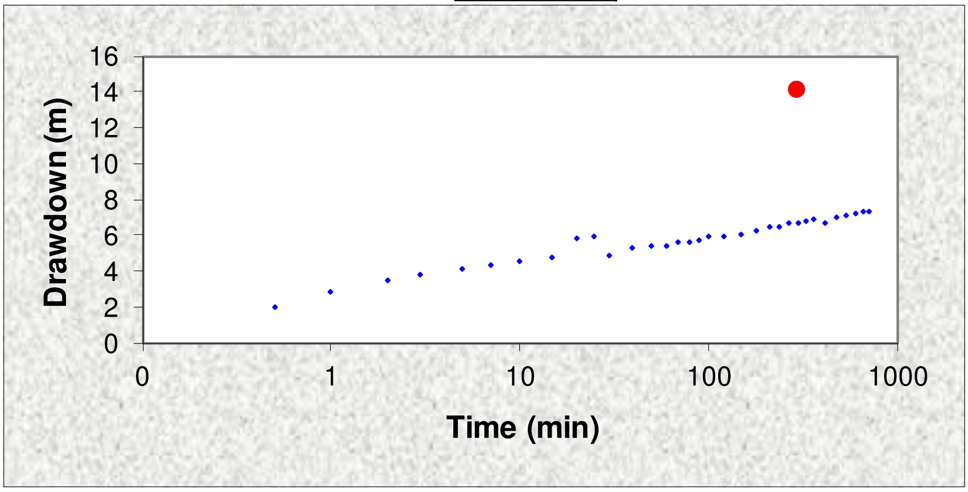
extrapolaltion time in years =	2	1051200
t(min) and s(m) at inflection point =	301.0	14
enter derivative value at inflection point time =		1.62

	No boundaries	1 no-flow	2 no-flow	Closed
sWell(Extrapol.time)	19.73	25.46	31.18	48.37
Q_sust	2.31	1.79	1.46	0.94
	Best case			Worst case

(including influence of bh's from sust_Q sheet)

Average Q-sust (l/s)= 1.54 std. dev = 0.57

301.00



Barker- Method

Main | LQBH4

r =	0.50	Extpol. t (y)	2	avail. draw	14.00

Manual Fit NO

K_f [m/d]	S_f [1/m]	b	n
100	1.60E-04	0.2	2

Automatic Fit with SOLVER YES

	Min	Value	Max
K_f [m/d] =	1	3.5889245	100000
S_f [1/m] =	1.00E-07	6.48E-04	0.005
b =	0.1	8.4820408	100
n =	1	2.0780902	3

Min, Max time to fit (min)

min	max
0	10000

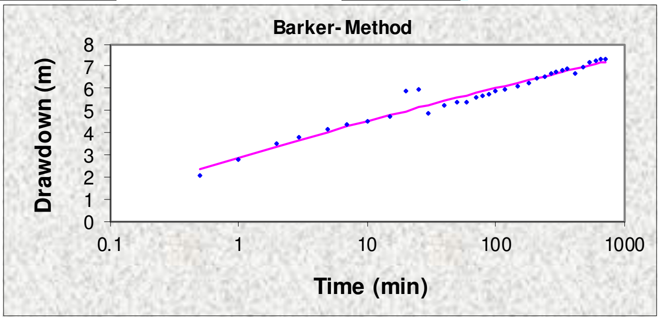
	K_f [m/d]	S_f [1/m]	b	n	N
Fit Parameters	3.59	6.48E-04	8.48	2.08	-0.0390

RMSE = 2.353702

	No boundaries	1 no-flow	2 no-flow	Closed
sWell(Extrapol.time)	10.85	23.51	29.83	36.16
Q_sust	4.19	1.94	1.53	1.26

(including influence of bh's from sust_Q sheet)

Fractal n = 2.08 **Average Q-sust (l/s)=** 2.23 std. dev = 1.34



LQBH4								
Method	**Sustainable yield (l/s)**	**Std. Dev**	**Early T (m^2/d)**		**Late T (m^2/d)**		**S**	**AD used**
Basic FC	1.75	0.82	#NUM!		25.7		2.20E-03	14.0
Advanced FC			#NUM!		25.7		1.00E-03	14.0
FC inflection point	1.54	0.57						14.0
Cooper-Jacob	1.86	1.21			30.1		7.40E-03	14.0
FC Non-Linear								14.0
Barker	2.23	1.34	K_f =	4		S_s =	1.60E-04	14.0
Average Q_sust (l/s)	**1.84**	**0.29**	b =	8.48	Fractal dimension n =		2.08	

Recommended abstraction rate (L/s)	**1.86**	for 24 hours per day				
Hours per day of pumping	7.5	3.33	L/s	for	7.5	hours per day
Daily volume on recommended cycle	89.85	m3/d	Persons Served (Basic Human Needs)	3594		

Annexure C: Laboratory Certificate of Analysis

TALBOT
A Level 1 B-BBEE company

sanas

[007553/22], [2022/09/16]

Certificate of Analysis

Project details

Customer Details

Customer reference:	LAFARGE LICHTENBURG (5803)
Quotation number:	Q2112-066
Order number:	5803
Company name:	JG AFRIKA
Contact address:	P O BOX 2762, WESTWAY OFFICE PARK, 3635
Contact person:	MFUNDO NTUZELA

Sampling Details

Sampled by:	CUSTOMER
Sampled date:	2022/08/27
Additional customer information:	023361/22- SAMPLED BY: M NTUZELA, 023362/22- SAMPLED BY: M NTUZELA, 023363/22- SAMPLED BY: M NTUZELA, 023364/22- SAMPLED BY: M NTUZELA

Sample Details

Sample type(s):	RAW WATER SAMPLES
Date received:	2022/09/02
Delivered by:	CUSTOMER - GILLITTS DEPOT
Temperature at sample receipt (°C):	14.9

Report Details

Testing commenced:	2022/09/02
Testing completed:	2022/09/16
Report date:	2022/09/16
Our reference:	007553/22

Analytical Results

Methods	Determinands	Units	023361/22	023362/22
			LICH 0111 27.08.2022	LICH 0112 27.08.2022
Chemical				
93	Sodium	mg Na/ℓ	5.1	4.9
83A	Aluminium	µg Al/ℓ	<1	2.4
83A	Arsenic	µg As/ℓ	<1	<1
83A	Boron	µg B/ℓ	24	33
83A	Barium	µg Ba/ℓ	7.4	7.3
83A	Cadmium	µg Cd/ℓ	<1	<1
83A	Copper	µg Cu/ℓ	3.6	2.4
83A	Iron	µg Fe/ℓ	<1	<1
92	Mercury	µg Hg/ℓ	<10	<10
83A	Manganese	µg Mn/ℓ	<1	<1
83A	Nickel	µg Ni/ℓ	<1	<1
83A	Lead	µg Pb/ℓ	<1	<1
83A	Antimony	µg Sb/ℓ	<1	<1
83A	Selenium	µg Se/ℓ	<1	<1
83A	Uranium	µg U/ℓ	<1	<1
83A	Zinc	µg Zn/ℓ	5.3	2.3
83A	Total Chromium	µg Cr/ℓ	9.7	15.6
16G	Chloride	mg Cl/ℓ	7.75	7.91
135	Cyanide*	µg CN/ℓ	<20	<20
40A	Colour (True)	mg Pt-Co/ℓ	<10	<10
2A	Electrical Conductivity at 25°C	mS/m	69.8	65.2
18G	Fluoride	mg F/ℓ	0.12	0.12
64G	Total Ammonia	mg N/ℓ	<1.5	<1.5
65Gc	Nitrate	mg N/ℓ	4.14	4.1
65Gb	Nitrite	mg N/ℓ	<0.05	<0.05
Calc.	Combined Nitrate + Nitrite (sum of Ratios)*	-	0.43	0.43
4	Turbidity	NTU	0.45	0.11
1	pH at 25°C	pH units	7.3	7.1
133	Total Phenols*	µg/ℓ	2	<2
67G	Sulphate	mg SO_4/ℓ	33.6	33.6
41	Total Dissolved Solids at 180°C	mg/ℓ	360	390
Microbiological				
32	*E.coli*	MPN/100mℓ	<1 (Not detected)	<1 (Not detected)
32	Total Coliforms	MPN/100mℓ	<1 (Not detected)	<1 (Not detected)
31	Standard Plate Count	colonies/mℓ	**>1000**	109

Methods	Determinands	Units	023361/22	023362/22
			LICH 0111 27.08.2022	LICH 0112 27.08.2022
Organics				
104	Total Organic Carbon	mg C/ℓ	3.0	4.8

Methods	Determinands	Units	023363/22	023364/22
			LICH 0113 27.08.2022	LICH 0114 27.08.2022
Chemical				
93	Sodium	mg Na/ℓ	5.2	17
83A	Aluminium	µg Al/ℓ	18.9	1.4
83A	Arsenic	µg As/ℓ	<1	<1
83A	Boron	µg B/ℓ	31	40
83A	Barium	µg Ba/ℓ	11.1	66
83A	Cadmium	µg Cd/ℓ	<1	<1
83A	Copper	µg Cu/ℓ	<1	5.1
83A	Iron	µg Fe/ℓ	11.6	1.1
92	Mercury	µg Hg/ℓ	<10	<10
83A	Manganese	µg Mn/ℓ	2.9	<1
83A	Nickel	µg Ni/ℓ	1.0	<1
83A	Lead	µg Pb/ℓ	<1	<1
83A	Antimony	µg Sb/ℓ	<1	<1
83A	Selenium	µg Se/ℓ	<1	<1
83A	Uranium	µg U/ℓ	<1	<1
83A	Zinc	µg Zn/ℓ	13.4	25
83A	Total Chromium	µg Cr/ℓ	13.8	7.4
16G	Chloride	mg Cl/ℓ	8.28	13.4
135	Cyanide*	µg CN/ℓ	<20	<20
40A	Colour (True)	mg Pt-Co/ℓ	<10	<10
2A	Electrical Conductivity at 25°C	mS/m	72.4	61.8
18G	Fluoride	mg F/ℓ	0.12	0.32
64G	Total Ammonia	mg N/ℓ	<1.5	<1.5
65Gc	Nitrate	mg N/ℓ	4.62	1.51
65Gb	Nitrite	mg N/ℓ	<0.05	<0.05
Calc.	Combined Nitrate + Nitrite (sum of Ratios)*	-	0.48	0.19
4	Turbidity	NTU	0.80	0.44
1	pH at 25°C	pH units	7.1	7.1
133	Total Phenols*	µg/ℓ	7	<2
67G	Sulphate	mg SO_4/ℓ	36.9	12.6
41	Total Dissolved Solids at 180°C	mg/ℓ	468	382
Microbiological				
32	*E.coli*	MPN/100mℓ	<1 (Not detected)	<1 (Not detected)

Methods	Determinands	Units	023363/22	023364/22
			LICH 0113 27.08.2022	LICH 0114 27.08.2022
32	Total Coliforms	MPN/100mℓ	**613**	<1 (Not detected)
31	Standard Plate Count	colonies/mℓ	**>1000**	300
Organics				
104	Total Organic Carbon	mg C/ℓ	0.82	3.9

Refer to the "Notes" section at the end of this report for further explanations.

Where the laboratory reporting limit for a test is higher than the required specification limit, the raw data is reviewed and the detection limit highlighted in bold font if outside of specification.

Specific Observations

1. The parameters tested on the samples submitted (lab numbers 023362/22 & 023364/22) conform to the SANS 241:2015 requirements for drinking water.

2. The parameters tested on the sample submitted (lab number 023361/22) conform to the SANS 241:2015 requirements for drinking water, with the exception of standard plate count.

- A standard plate count exceeding 1000 counts per ml indicates failure in the system and if any form of disinfection is currently being undertaken this should be investigated.

3. The parameters tested on the sample submitted (lab number 023363/22) conform to the SANS 241:2015 requirements for drinking water, with the exception of total coliforms & standard plate count.

- The presence of coliforms shows contamination from soil or vegetation which may become more serious after rain. The water is of doubtful quality and cannot be recommended for drinking unless properly disinfected.

Quality Assurance

Technical signatories

Inorganic Chemistry: Sipho Ngabhi | Microbiology: Olivia Magaya | Organic Chemistry: Lungani Ziqubu

Notes to this report

Limitations

This report shall not be reproduced except in full without prior written approval of the laboratory.
Results in this report relate only to the samples as taken, and the condition received by the laboratory.
Any opinions and interpretations expressed herein are outside the scope of SANAS accreditation.
The decision rule applicable to this laboratory is available on request.
Sample preparation may require filtration, dilution, digestion or similar. Final results are reported accordingly.
Where the laboratory has undertaken the sampling, the location of sampling and sampling plan are available on request. Talbot Laboratories is guided by the National Standards SANS 5667-3:2006 Part 3 Guidance on the Preservation and Handling of Water Samples; SANS 5667-1:2008 Part 1 Guidance on the Design of Sampling Programmes and Sampling Techniques and SANS 5667-2:1991 Part 2: Guidance on Sampling Techniques.
Customers to contact Talbot Laboratories for further information.

Uncertainty of measurement

Talbot Laboratories' Uncertainty of Measurement (UoM) values are:

- Identified for relevant tests.
- Calculated as a percentage of the respective results.
- Applicable to total, dissolved and acid soluble metals for ICP element analyses.
- Available upon request.

Analysis explanatory notes

Tests may be marked as follows:

^	Tests conducted at our Port Elizabeth satellite laboratory.
*	Tests not included in our Schedule of Accreditation and therefore that are not SANAS accredited.
#	Tests that have been sub-contracted to a peer laboratory.
NR	Not required -shown, for example, where the schedule of analysis varied between samples.
σ	Field sampling point on-site results.
a	Testing has deviated from Method.

Appendix 1: Specifications - SANS 241-1:2015 RECOMMENDED LIMITS

Reported Determinands	Limits	Reported Determinands	Limits
E.coli	0 Count/100mℓ (0 MPN/100mℓ)	Zinc	≤5000 µg/l (≤5 mg/ℓ)
Faecal Coliforms	0 Count/100mℓ (0 MPN/100mℓ)	Antimony	≤20 µg/ℓ (≤0.02 mg/ℓ)
Cryptosporidium species	Not Detected	Arsenic	≤10 µg/ℓ (≤0.01 mg/ℓ)
Giardia species	Not Detected	Barium	≤700 µg/ℓ (≤0.7 mg/ℓ)
Total Coliforms	≤10 Count/100mℓ (10 MPN/100mℓ)	Boron	≤2400 µg/ℓ (≤2.4 mg/ℓ)
Standard Plate Count	≤1000 Count/1mℓ	Cadmium	≤3 µg/ℓ (≤0.003 mg/ℓ)
Somatic Coliphages	Not Detected	Total Chromium	≤50 µg/ℓ (≤0.05 mg/ℓ)
Cytopathogenic viruses	Not detected	Copper	≤2000 µg/ℓ (≤2 mg/ℓ)
Enteric Virus (Sub#)	Not Detected	Cyanide	≤200 µg/ℓ (≤0.2 mg/ℓ)
Colour	≤15 mg/ℓ Pt-Co	Iron	Chronic: ≤ 2000 µg/ℓ (≤2 mg/ℓ)
Electrical Conductivity	≤170 mS/m	Iron	Aesthetic: ≤ 300 µg/ℓ (≤0.3 mg/ℓ)
Total Dissolved Solids at 180°C	≤1200 mg/ℓ	Lead	≤10 µg/ℓ (≤0.01 mg/ℓ)
Turbidity	Operational ≤1 NTU	Manganese	Chronic: ≤ 400 µg/ℓ (≤0.4 mg/ℓ)
Turbidity	Aesthetic ≤5 NTU	Manganese	Aesthetic: ≤100 µg/ℓ (≤0.1 mg/ℓ)
pH	≥ 5 to ≤ 9.7	Mercury	≤6 µg/ℓ (≤0.006 mg/ℓ)
Odour	Inoffensive	Nickel	≤70 µg/ℓ (≤0.07 mg/ℓ)
Free Chlorine	≤5 mg/ℓ	Selenium	≤40 µg/ℓ (≤0.04 mg/ℓ)
Monochloramine	≤3000 µg/ℓ (≤3 mg/ℓ)	Uranium	≤30 µg/ℓ (≤0.03 mg/ℓ)
Nitrate	≤11 mg/ℓ	Aluminium	≤300 µg/ℓ (≤0.3 mg/ℓ)
Nitrite	≤0.9 mg/ℓ	Total Organic Carbon	≤10 mg/ℓ
Combined Nitrate plus Nitrite (sum of Ratios)	≤1	Chloroform	≤300 µg/ℓ (≤0.3 mg/ℓ)
Sulphate	Acute: ≤ 500 mg/ℓ	Bromoform	≤100 µg/ℓ (≤0.1 mg/ℓ)
Sulphate	Aesthetic: ≤ 250 mg/ℓ	Dibromochloromethane	≤100 µg/ℓ (≤0.1 mg/ℓ)
Fluoride	≤1500 µg/ℓ (≤1.5 mg/ℓ)	Bromodichloromethane	≤60 µg/ℓ (≤0.06 mg/ℓ)
Ammonia	≤1.5 mg/ℓ	Trihalomethanes Ratio	≤1
Chloride	≤ 300 mg/ℓ	Microcystins	≤1 µg/ℓ
Sodium	≤200 mg/ℓ	Phenols	≤10 µg/ℓ (≤0.01 mg/ℓ)

End of Report

Talbot Laboratories (Pty) Ltd Reference: [007553/22] Page 6 of 6

Annexure D: Summary Hydrocensus and Resource Photographs

National Groundwater Archive Resources

SORT	Key	SITE	IDENTIFIER	COUNT	LAT	LONG	COORDMETHOD	ACCURACY	STATUS1	STATUS2	PURPOSE	EQUIPMENT	WLMIN	WLMAX	ABSTRACTION	YIELD	DEPTH	STRIKEDEPTH
2	1	Tswana	10-77029	1	-26.05340	25.83001	GPS	100	Unused: Abandoned		Production							
5	2	Tswana	10-77092	1	-26.04944	25.82432	GPS	100	Unused: Irreparably Destroyed		Production							
7	3	Tswana	10-77256	1	-26.06433	25.84808	GPS	100	Unused: Irreparably Destroyed		Production							
8	4	Tswana	10-77258	1	-26.05170	25.85083	GPS	100	Unused: Irreparably Destroyed		Production							
9	5	Tswana	10-77261	1	-26.03102	25.80165	GPS	100	In Use: Unknown									
12	6	Tswana	10-77267	1	-26.07890	25.75354	GPS	100	Unused: Abandoned		Production							
13	7	Tswana	10-78004	1	-26.08306	25.76539	GPS	100	Unused: Irreparably Destroyed									
14	8	Tswana	10-78018	2	-26.07847	25.76164	GPS	100	In Use: Unknown	Unknown: Inaccessible Geosite	Production							
15	9	Tswana	10-78019	1	-26.08404	25.75086	GPS	100	Unused: Abandoned									
16	10	Tswana	10-78020	1	-26.07531	25.74961	GPS	100	Unused: Standby		Production							
17	11	Tswana	10-78027	2	-26.04629	25.76675	GPS	100	In Use: Unknown	Unused: Irreparably Destroyed	Production			60		0.51	72	
18	12	Tswana	10-78028	2	-26.04605	25.76532	GPS	100	In Use: Unknown	Unused: Irreparably Destroyed	Production			4.26			80	
21	13	Tswana	10-78177	1	-26.05040	25.85307	GPS	100	Unused: Abandoned		Production							
57	14	Tswana	2625BA00083	6	-26.07961	25.74918	Map Estimated	100	Unused: Abandoned	Unused: Irreparably Destroyed	Production			12.35			90	66
66	15	Tswana	2625BB00134	1	-26.01716	25.82879	Map Estimated	100	In Use: Unknown		Production	Positive Displacemen		14.35		0	28.3	
68	16	Tswana	2625BB00136	1	-26.01855	25.82101	Map Estimated	100	In Use: Unknown		Production	Positive Displacemen		10.15		0	20.15	
79	17	Tswana	2625BB00267	10	-26.12244	25.77435	Map Estimated	100	Status Not Selected		Production					2.41	91	39
80	18	Tswana	2625BB00269	6	-26.08503	25.75007	Map Estimated	100	Unused: Abandoned		Production			15.07		0.9	78	
84	19	Tswana	2625BB00273	3	-26.08350	25.76476	Map Estimated	100	Unused: Abandoned		Production					0	96	
85	20	Tswana	2625BB00274	3	-26.07433	25.75846	Map Estimated	100	Unused: Abandoned		Production			6.19			72	47
93	21	Tswana	2625BB00334	4	-26.10550	25.81824	Map Estimated	100	Status Not Selected				6	18.6		0	-999	
94	22	Tswana	2625BB00340	1	-26.06939	25.86435	Map Estimated	100	Status Not Selected					8.07		0	-999	
96	23	Tswana	2625BB00342	2	-26.05772	25.85907	Map Estimated	100	Status Not Selected				5	7.23		0	-999	
98	24	Tswana	2625BB00344	2	-26.04106	25.84713	Map Estimated	100	Status Not Selected				6.7	7.19		0	-999	
99	25	Tswana	2625BB00345	4	-26.04606	25.85630	Map Estimated	100	Status Not Selected			Positive Displacemen	5	10.3		0	-999	
100	26	Tswana	2625BB00346	4	-26.06439	25.85630	Map Estimated	100	Status Not Selected			Positive Displacemen	2.35	3.4		0	-999	
102	27	Tswana	2625BB00348	2	-26.06272	25.86519	Map Estimated	100	Status Not Selected			Positive Displacemen	5.95	9		0	-999	
103	28	Tswana	2625BB00353	1	-26.07217	25.85296	Map Estimated	1000	Status Not Selected							0	81	
104	29	Tswana	2625BB00355	2	-26.07050	25.84991	Map Estimated	100	In Use: Unknown					11		0.5	63	
105	30	Tswana	2625BB00356	12	-26.04522	25.82380	Map Estimated	100	Status Not Selected			Positive Displacemen	8.27	9.77		1.5	25.7	
106	31	Tswana	2625BB00357	12	-26.06800	25.84657	Map Estimated	100	Status Not Selected			Positive Displacemen	3.35	5.05		1.7	14.95	
107	32	Tswana	2625BB00358	1	-26.06494	25.86324	Map Estimated	100	Status Not Selected			Positive Displacemen				0	76.8	
108	33	Tswana	2625BB00359	30	-26.03217	25.80463	Map Estimated	100	Status Not Selected				1.97	33.97		32	34.9	
109	34	Tswana	2625BB00360	6	-26.04689	25.82541	Map Estimated	100	Status Not Selected			Positive Displacemen	9.45	10.55		1.1	25.5	
110	35	Tswana	2625BB00361	20	-26.05911	25.86380	Map Estimated	100	Status Not Selected				1.89	33.99		32.1	38.7	
111	36	Tswana	2625BB00362	6	-26.05189	25.85430	Map Estimated	100	Status Not Selected			Positive Displacemen	6.32	7.32		1	31	
112	37	Tswana	2625BB00363	3	-26.06217	25.86019	Map Estimated	100	Status Not Selected							0	71	
113	38	Tswana	2625BB00364	4	-26.05772	25.85407	Map Estimated	100	Status Not Selected				1.55	2.15		0	79.7	
114	39	Tswana	2625BB00365	2	-26.05106	25.83852	Map Estimated	100	Status Not Selected			Positive Displacemen	8.62	9.12		0.5	25	
115	40	Tswana	2625BB00367	1	-26.05560	25.81951	GPS	100	Status Not Selected		Production					0		
116	41	Tswana	2625BB00369	1	-26.09139	25.75229	GPS	100	Status Not Selected		Production					0		
117	42	Tswana	2625BB00370	1	-26.03650	25.79960	GPS	100	Status Not Selected							0		
118	43	Tswana	2625BB00371	1	-26.05795	25.86000	GPS	100	Status Not Selected							0		
119	44	Tswana	2625BB00372	1	-26.08148	25.84340	GPS	100	Status Not Selected							0		
121	45	Tswana	2625BB00375	1	-26.05569	25.84594	GPS	100	Status Not Selected							0		
122	46	Tswana	2625BB00376	1	-26.06243	25.83850	GPS	100	Status Not Selected							0		
125	47	Tswana	2625BB00379	1	-26.05417	25.79535	GPS	100	Status Not Selected		Production					0		
126	48	Tswana	2625BB00380	1	-26.11839	25.79497	GPS	100	Status Not Selected		Production					0	16	
127	49	Tswana	2625BB00381	1	-26.07997	25.75630	GPS	100	Status Not Selected		Production					0		
128	50	Tswana	2625BB00384	1	-26.12248	25.77053	GPS	100	Status Not Selected		Production					0		

SORT	Key	SITE	IDENTIFIER	COUNT	LAT	LONG	COORDMETHOD	ACCURACY	STATUS1	STATUS2	PURPOSE	EQUIPMENT	WLMIN	WLMAX	ABSTRACTION	YIELD	DEPTH	STRIKEDEPTH
129	51	Tswana	2625BB00385	1	-26.07901	25.77053	GPS	100	Status Not Selected		Production					0		
130	52	Tswana	2625BB00386	1	-26.07776	25.77188	GPS	100	Status Not Selected		Production					0	27.43	
259	53	Tswana	45873	112	-26.10361	25.77192	GPS	100	In Use: Unknown	Unused: Monitoring (Irreparably Destroy	Exploration		5.35	11.98			150	
260	54	Tswana	45874	162	-26.10156	25.77128	GPS	100	In Use: Unknown	Unused: Obstructed - Collapsed	Exploration		5.23	12.24			150	
261	55	Tswana	45875	99	-26.08494	25.76683	GPS	100	In Use: Unknown	Unused: Monitoring (Obstructed - Dry)	Exploration		6.21	11.75			126	
262	56	Tswana	45876	29	-26.12021	25.83423	Map Estimated	100	Unused: Monitoring		Exploration		0.8	2.56		0	150	
264	57	Tswana	47404	3	-26.04394	25.77169	GPS	100	Status Not Selected		Exploration			1.71			145	7
265	58	Tswana	47405	3	-26.04555	25.76907	GPS	100	Unused: Abandoned	Unused: Standby	Exploration / Productio			5.71			145	17
268	59	Tswana	DOA-3128	1	-26.08287	25.75730	GPS	15	Unused: Abandoned		Production					0		
269	60	Tswana	MTL1	1	-26.07386	25.75878	GPS	15	Unused: Irreparably Destroyed		Production					0		
270	61	Tswana	MTL2	1	-26.08351	25.76520	GPS	15	Unused: Irreparably Destroyed		Production					0		
271	62	Tswana	MTL5	1	-26.08156	25.75783	GPS	15	Unused: Standby		Production					0		
272	63	Tswana	MTL6	1	-26.08548	25.75062	GPS	15	Unused: Irreparably Destroyed		Production					0		
273	64	Tswana	SPP1	1	-26.12023	25.79497	GPS	15	In Use: Unknown		Production					0		
274	65	Tswana	SPP3	1	-26.12137	25.78253	GPS	15	Unused: Abandoned		Production					0		
276	66	Tswana	T17001	1	-26.07904	25.76247	GPS	15	Unused: Abandoned		Production					0		
278	67	Tswana	T17048	1	-26.12000	25.76912	GPS	15	In Use: Unknown		Production					0		
279	68	Tswana	T17549	1	-26.11221	25.79700	GPS	15	In Use: Unknown		Production					0		
280	69	Tswana	T17573	1	-26.13183	25.80843	GPS	100	Unused: Irreparably Destroyed		Production					0		
281	70	Tswana	T17583	1	-26.09940	25.82406	GPS	15	Unknown: Inaccessible		Production					0		
283	71	Tswana	T17593	1	-26.09679	25.78144	GPS	15	Unknown: Inaccessible		Production					0		
285	72	Tswana	T17609	1	-26.11894	25.77537	GPS	1000	In Use: Unknown		Production					0		
286	73	Tswana	T17641	1	-26.06424	25.86359	GPS	15	Unused: Abandoned		Production					0		
287	74	Tswana	T17653	1	-26.08117	25.76129	GPS	15	Unused: Irreparably Destroyed		Production					0		

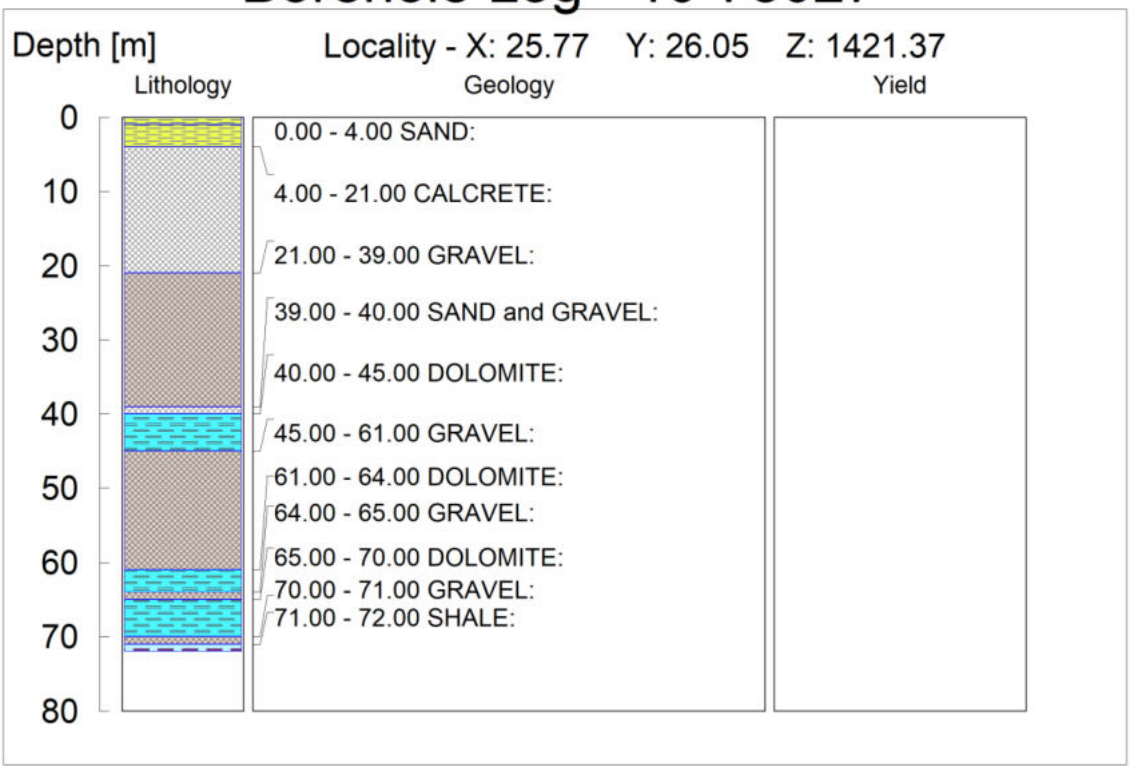
Field Verified Resource Photos

 (1) LQBH4	 (2) LQBH5
No photo – resource not found (3) LQBH6	 (4) LQBH7
 (5) LQBH8	 (6) LQBH9

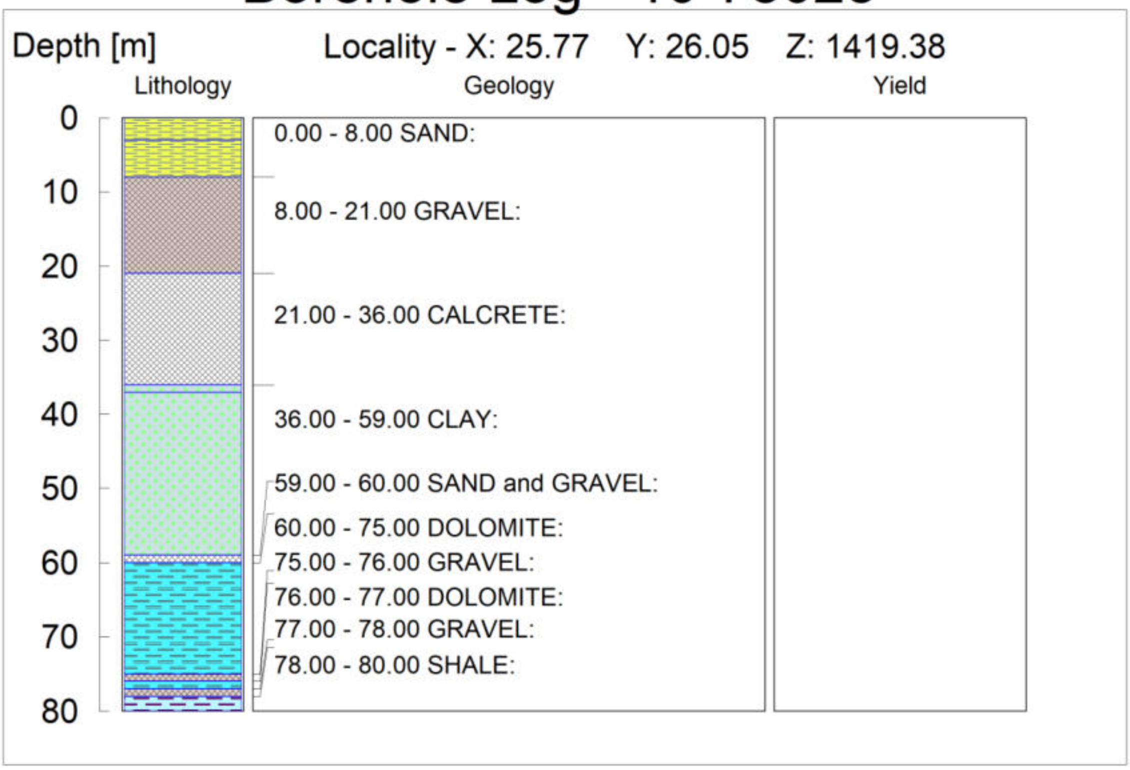
 (7) LQBH28	 (8) LQBH29
 (9) LQBH30	

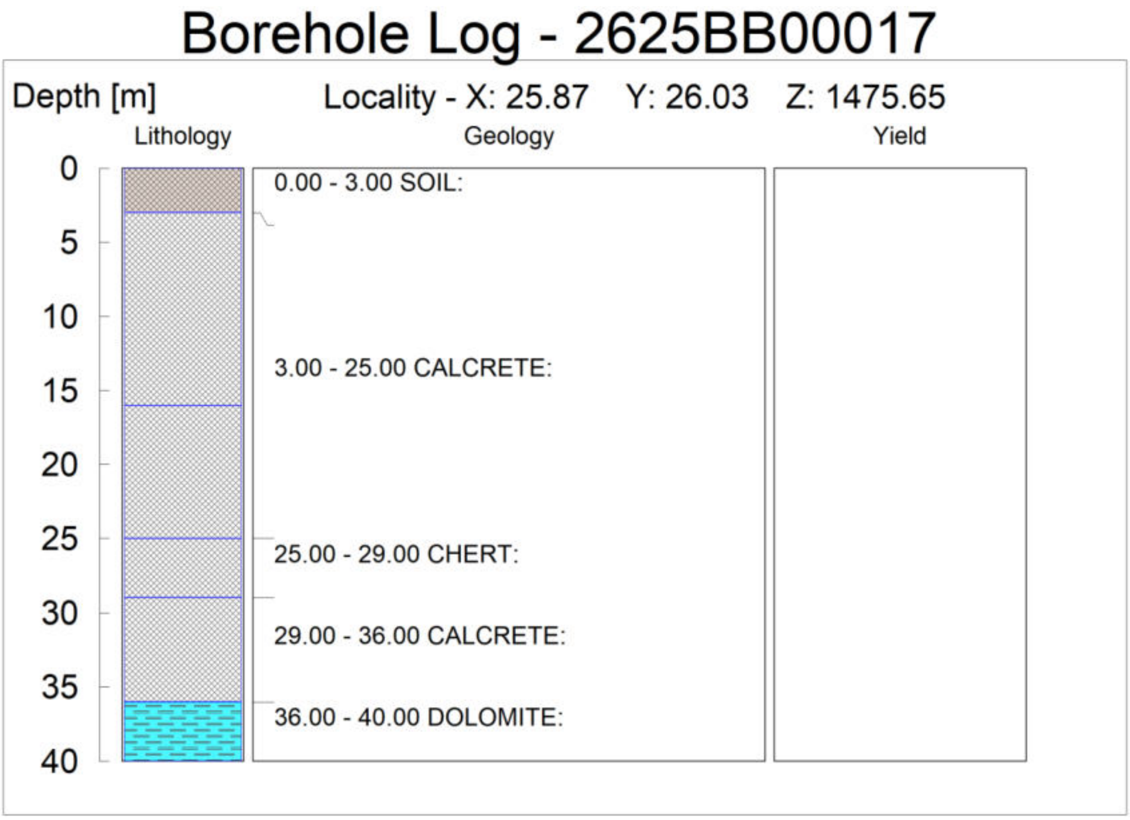
Annexure E: Borehole Logs for Model Layer Interpolation

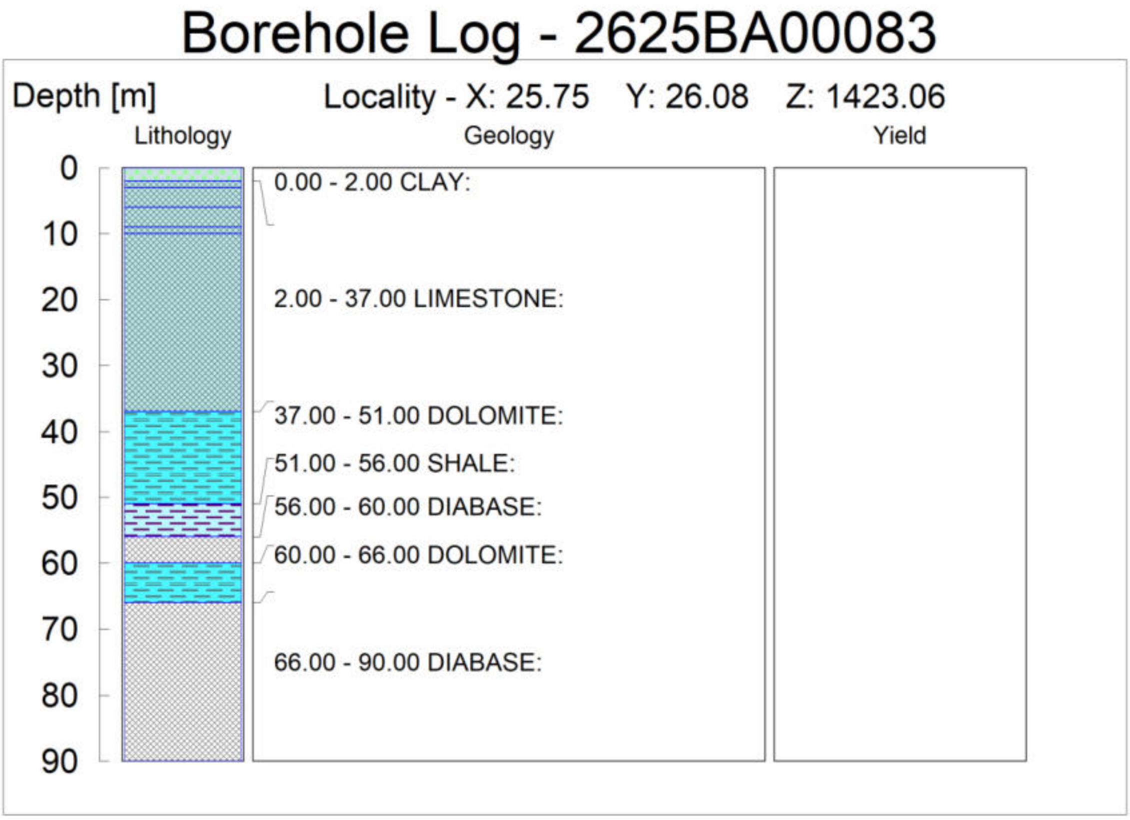
Borehole Log - 10-78027



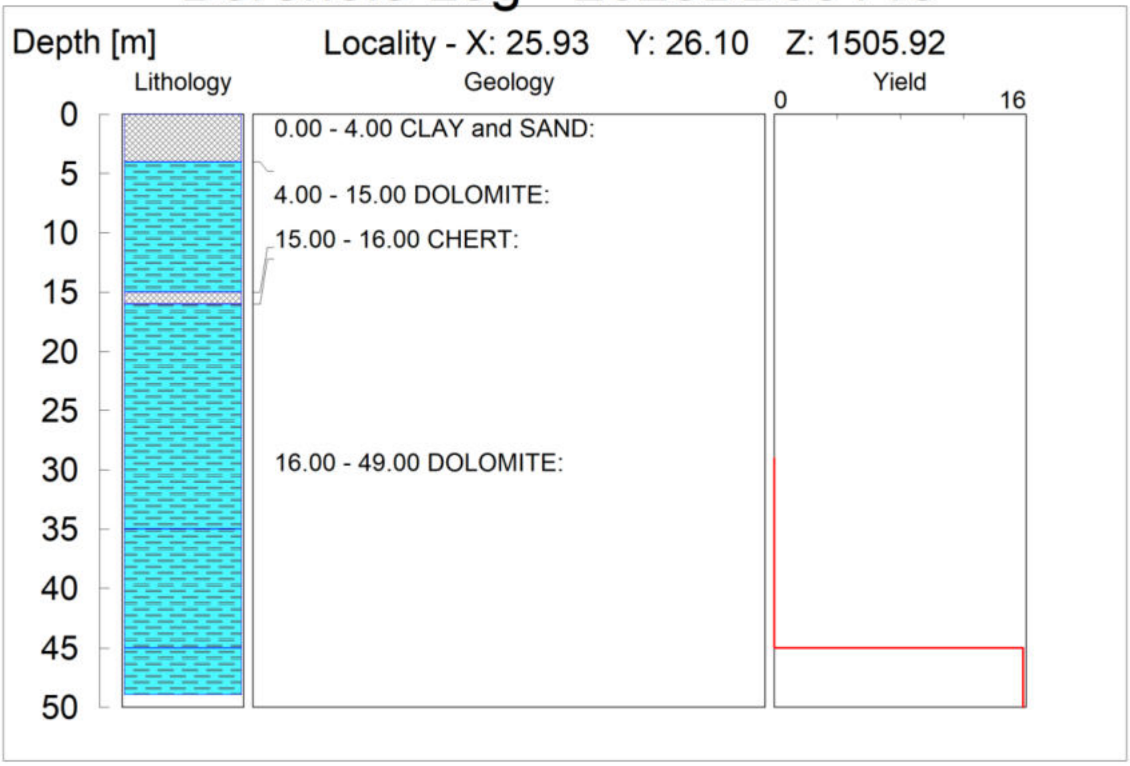
Borehole Log - 10-78028



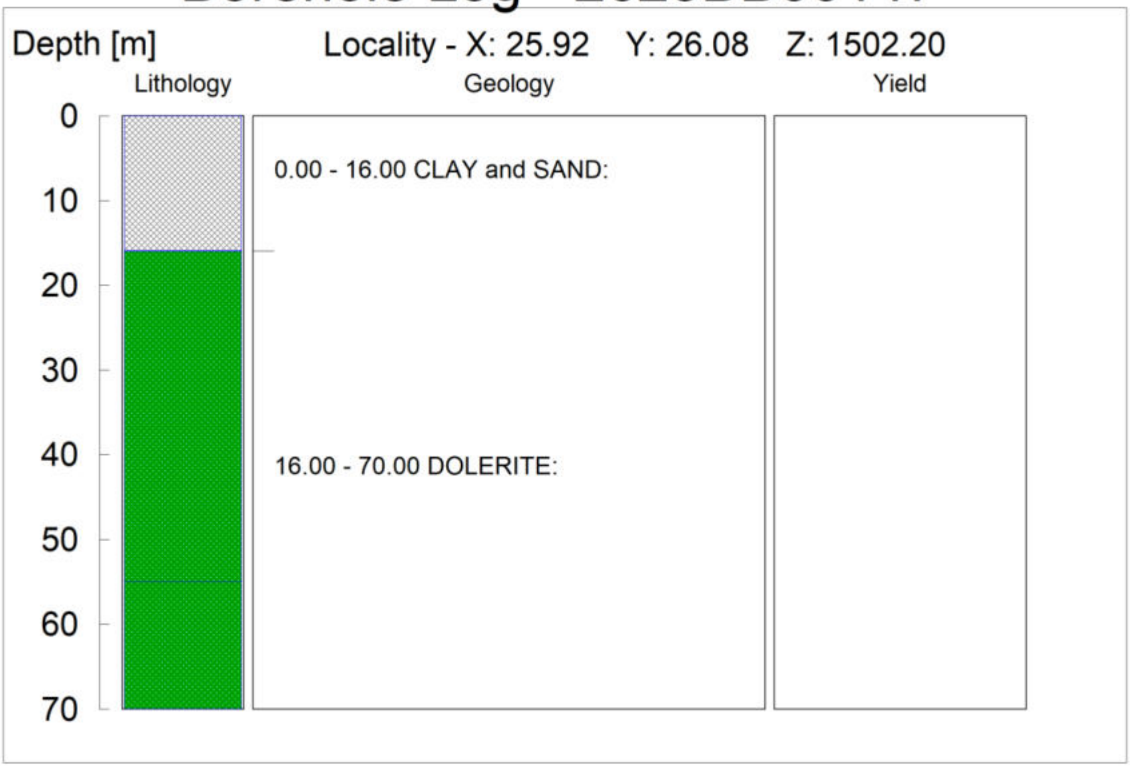

Borehole Log - 2625BB00017
Depth [m]
Locality - X: 25.87 Y: 26.03 Z: 1475.65
Lithology
Geology
Yield
0
5
10
15
20
25
30
35
40
0.00 - 3.00 SOIL:
3.00 - 25.00 CALCRETE:
25.00 - 29.00 CHERT:
29.00 - 36.00 CALCRETE:
36.00 - 40.00 DOLOMITE:

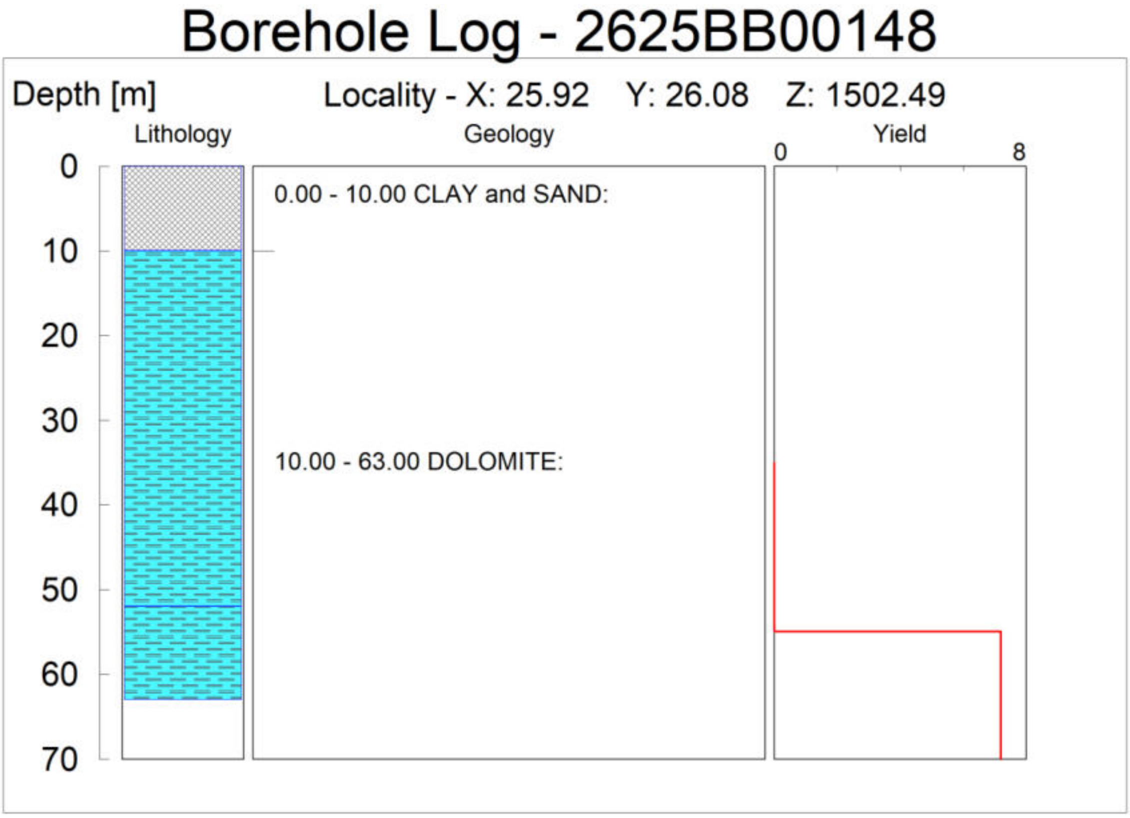

Borehole Log - 2625BA00083
Depth [m]
Locality - X: 25.75 Y: 26.08 Z: 1423.06
Lithology
Geology
Yield
0
10
20
30
40
50
60
70
80
90
0.00 - 2.00 CLAY:
2.00 - 37.00 LIMESTONE:
37.00 - 51.00 DOLOMITE:
51.00 - 56.00 SHALE:
56.00 - 60.00 DIABASE:
60.00 - 66.00 DOLOMITE:
66.00 - 90.00 DIABASE:

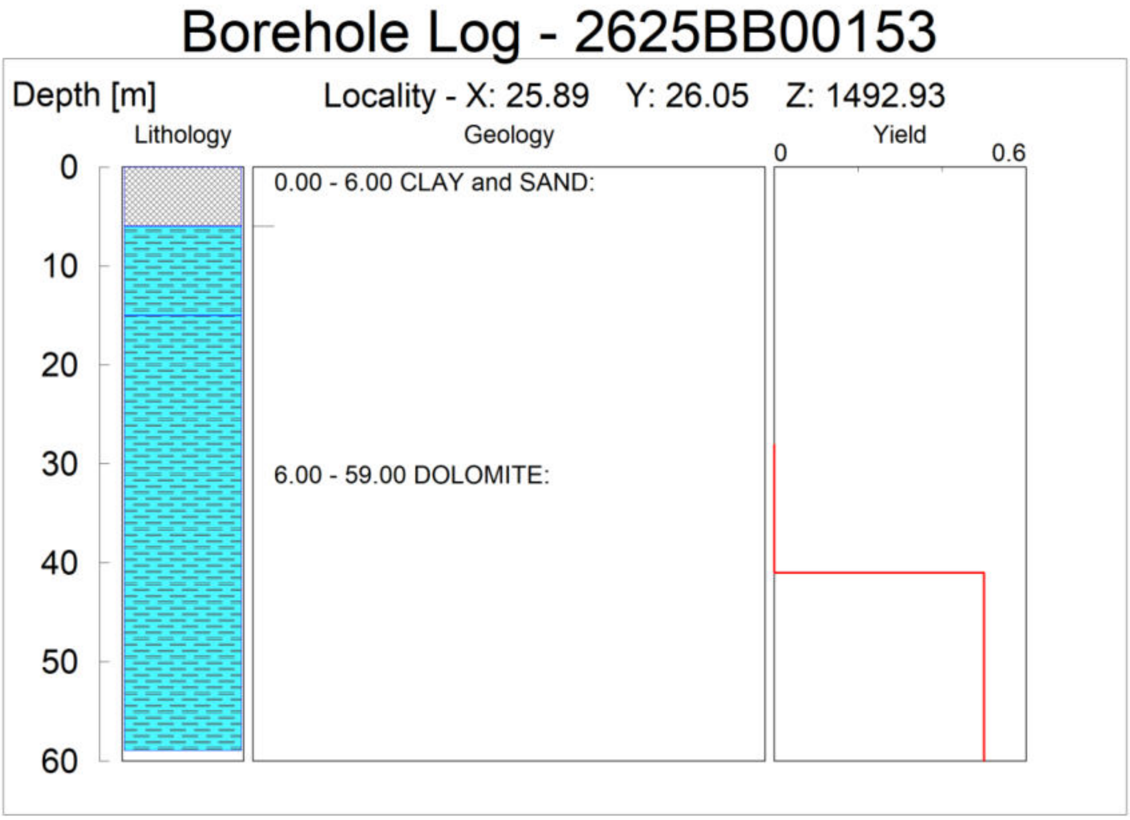
Borehole Log - 2625BB00146



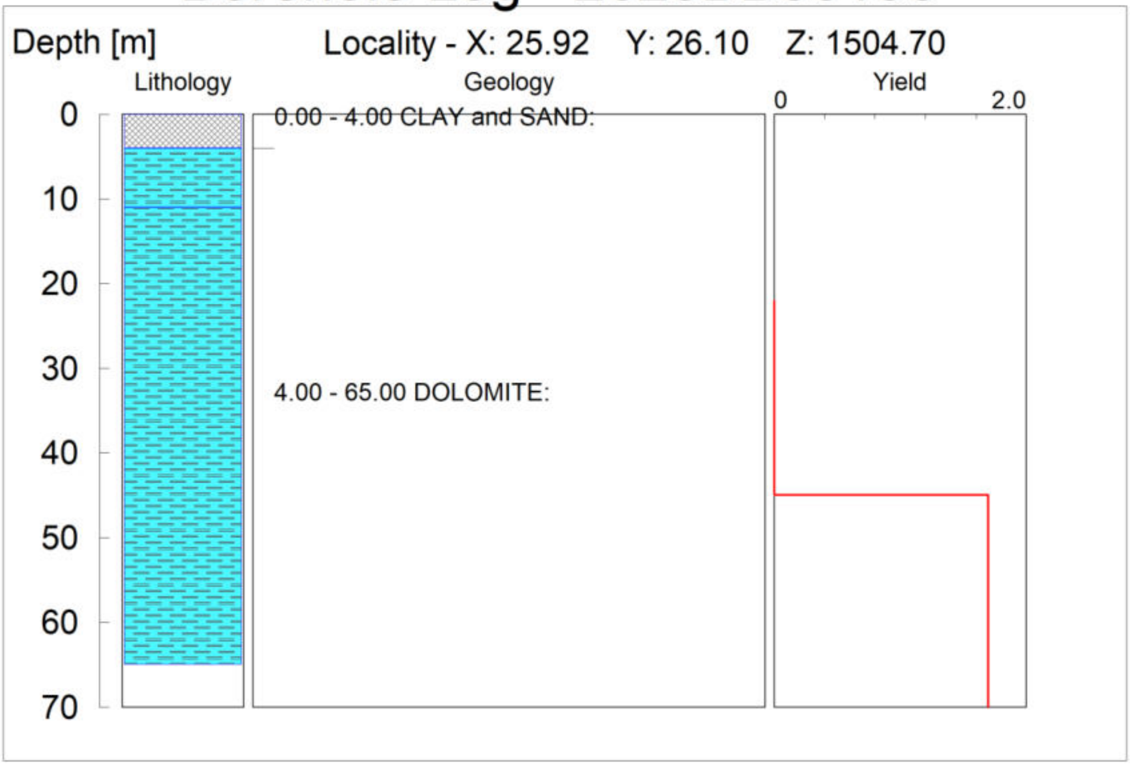
Borehole Log - 2625BB00147



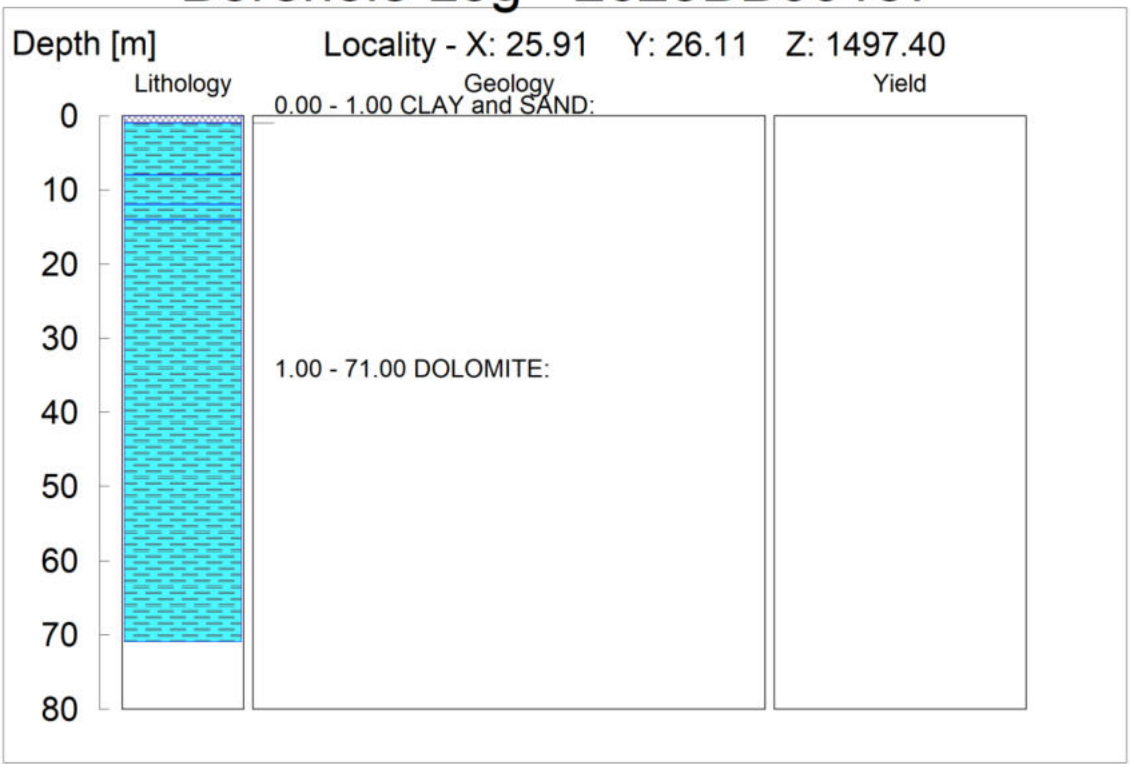

Borehole Log - 2625BB00148
Depth [m]
Locality - X: 25.92 Y: 26.08 Z: 1502.49
Lithology
Geology
Yield
0
8
0
10
20
30
40
50
60
70
0.00 - 10.00 CLAY and SAND:
10.00 - 63.00 DOLOMITE:


Borehole Log - 2625BB00153
Depth [m]
Locality - X: 25.89 Y: 26.05 Z: 1492.93
Lithology
Geology
Yield
0
0.6
0
10
20
30
40
50
60
0.00 - 6.00 CLAY and SAND:
6.00 - 59.00 DOLOMITE:

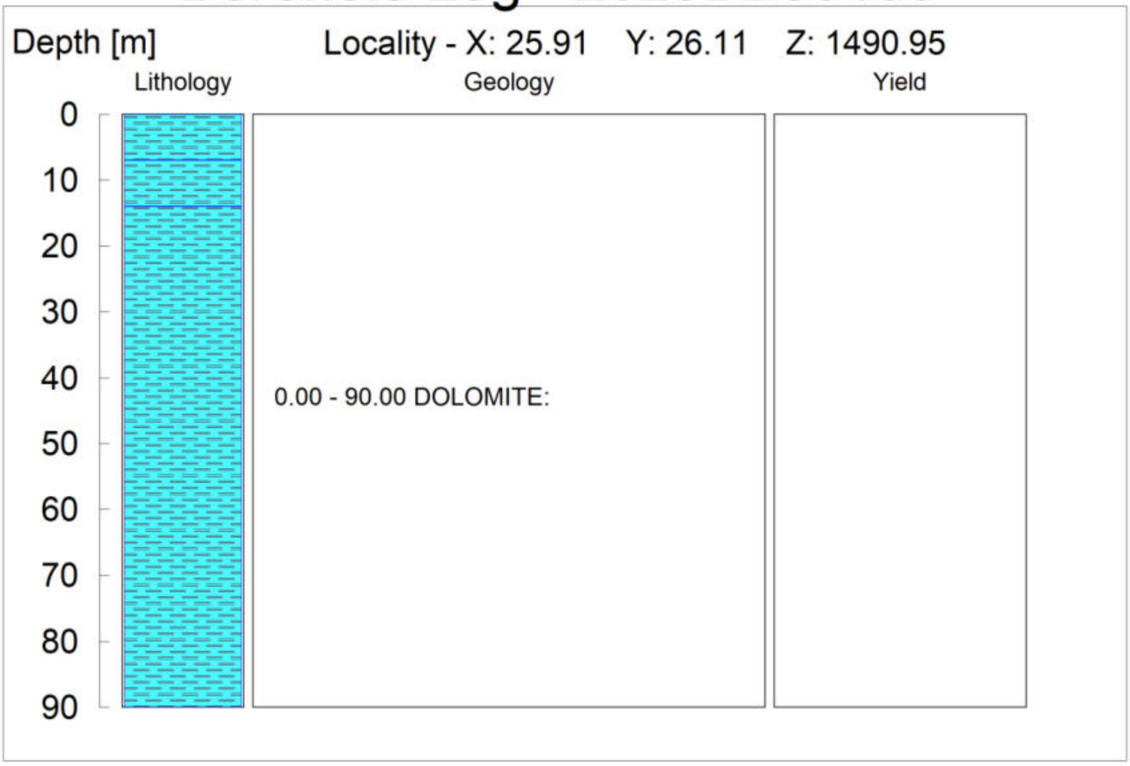
Borehole Log - 2625BB00156



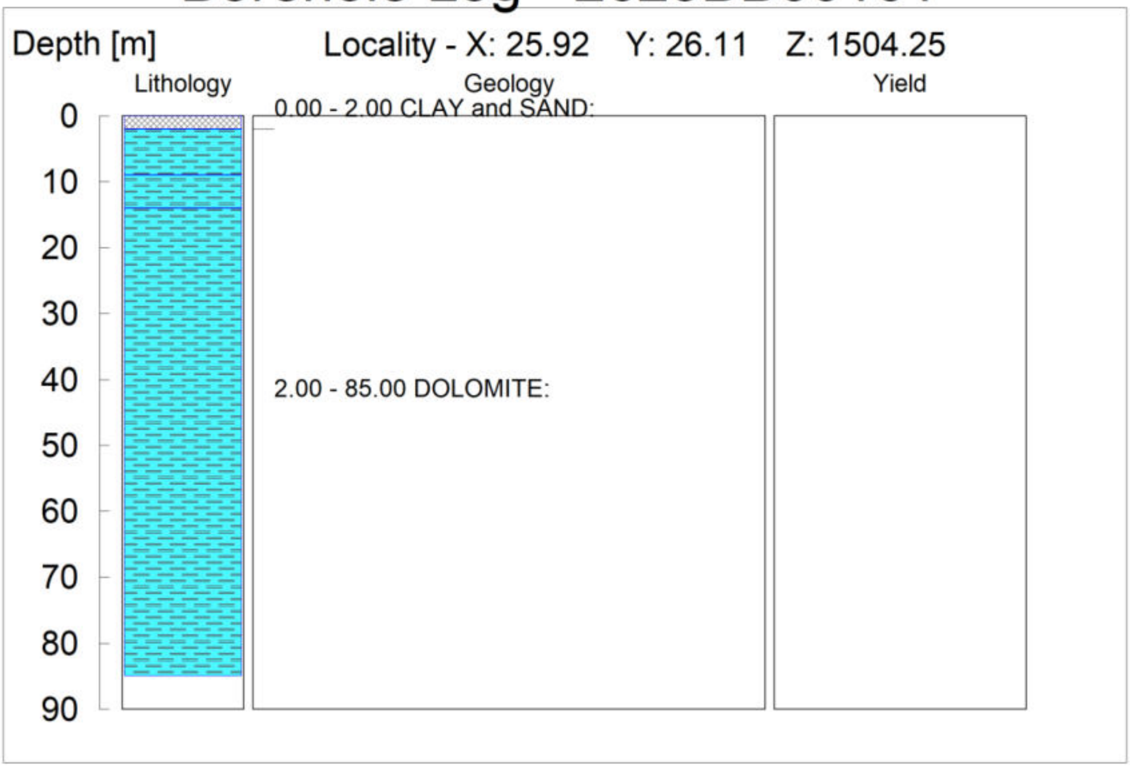
Borehole Log - 2625BB00157

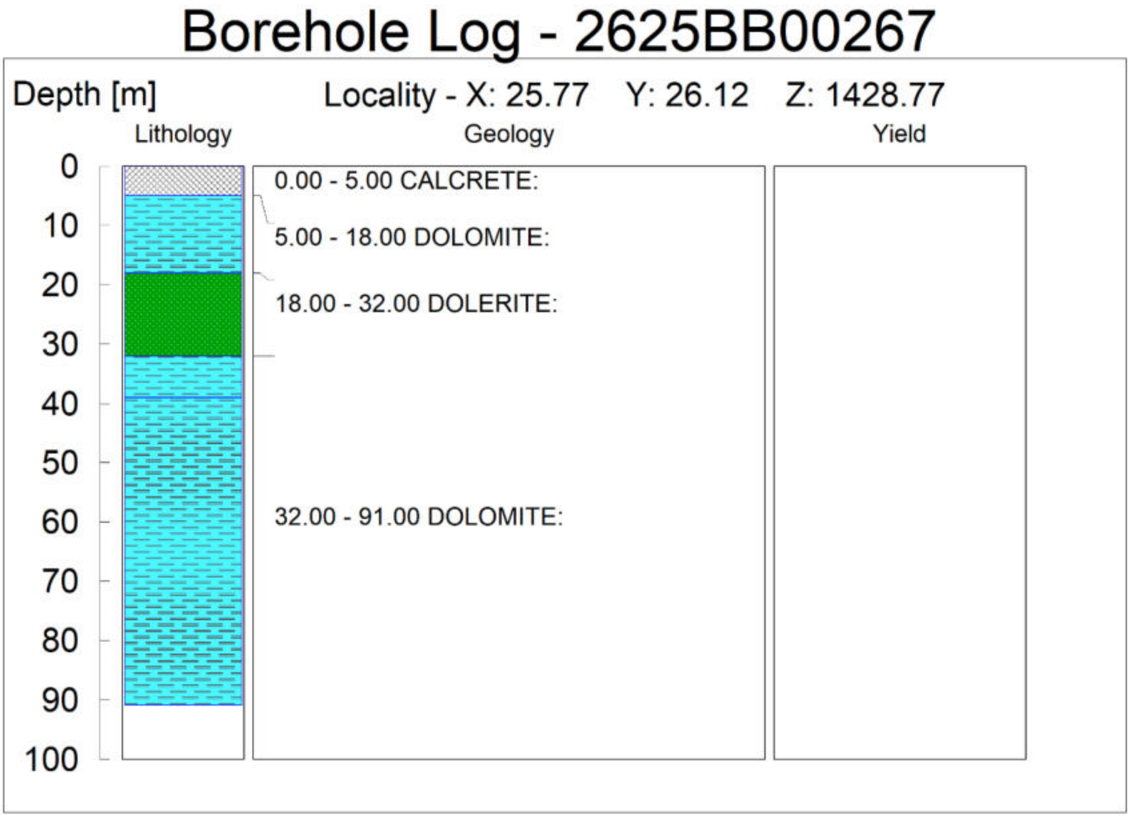


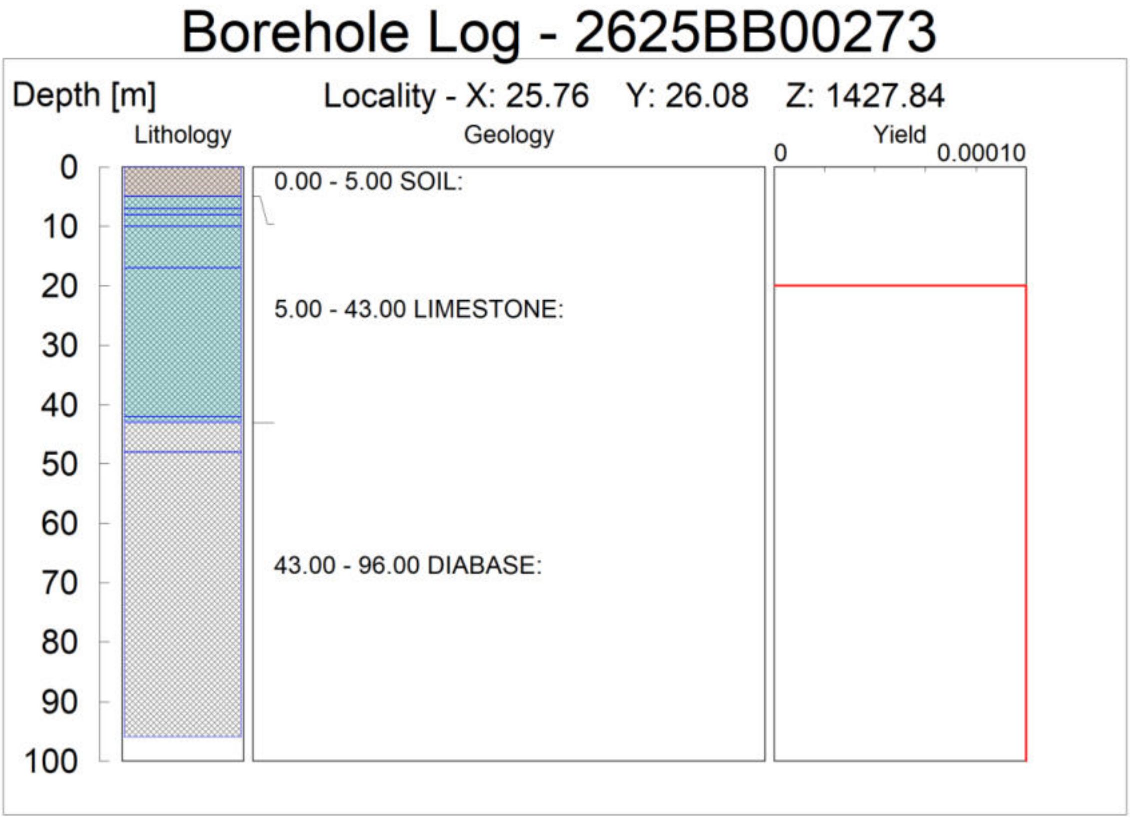
Borehole Log - 2625BB00158



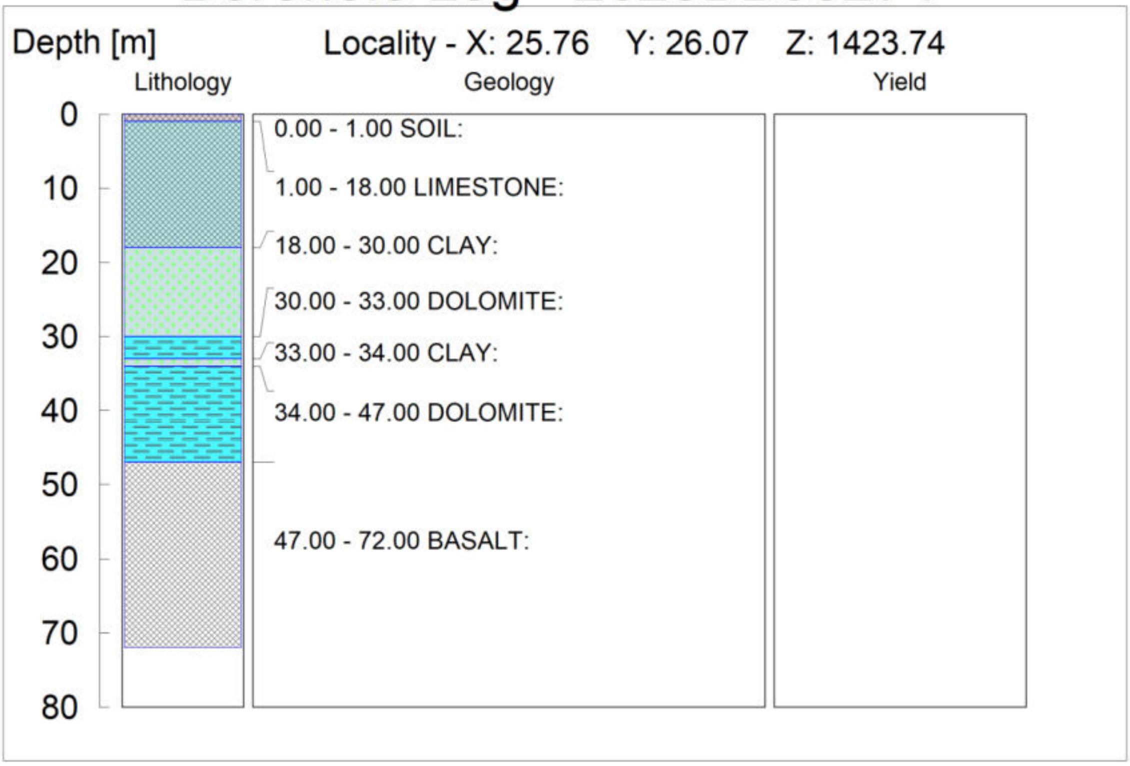
Borehole Log - 2625BB00161



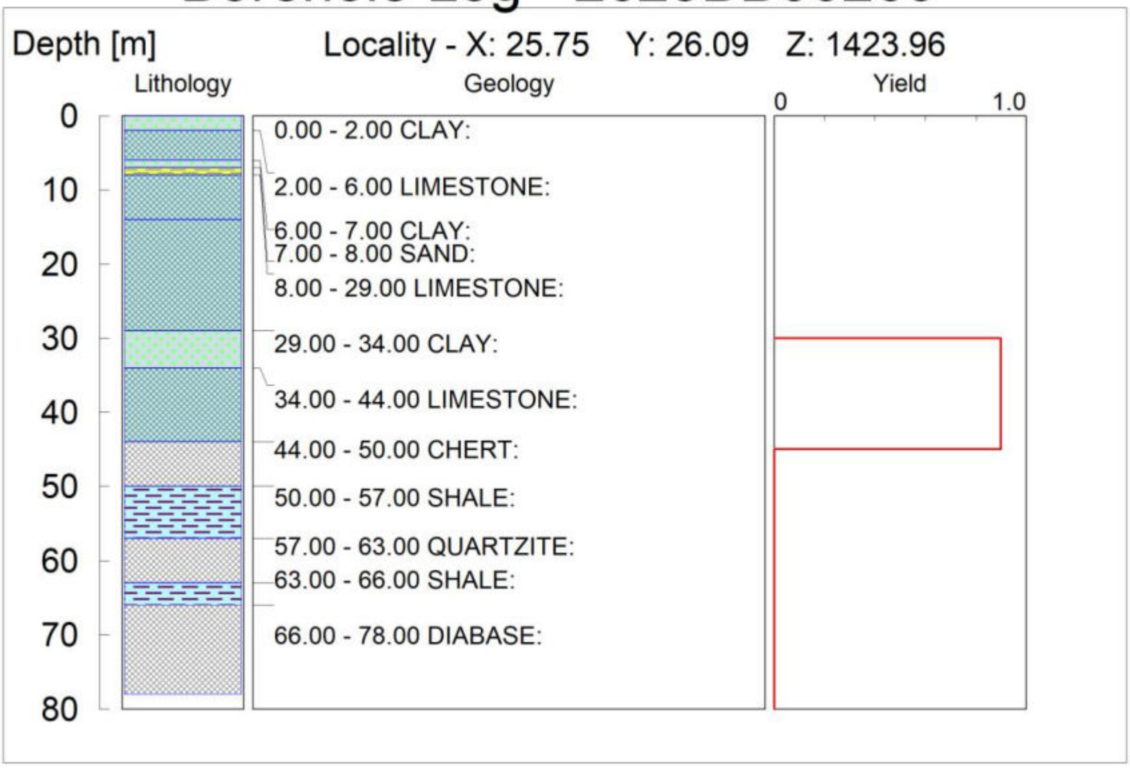

Borehole Log - 2625BB00267
Depth [m]
Locality - X: 25.77 Y: 26.12 Z: 1428.77
Lithology
Geology
Yield
0
10
20
30
40
50
60
70
80
90
100
0.00 - 5.00 CALCRETE:
5.00 - 18.00 DOLOMITE:
18.00 - 32.00 DOLERITE:
32.00 - 91.00 DOLOMITE:


Borehole Log - 2625BB00273
Depth [m]
Locality - X: 25.76 Y: 26.08 Z: 1427.84
Lithology
Geology
Yield
0
0.00010
0
10
20
30
40
50
60
70
80
90
100
0.00 - 5.00 SOIL:
5.00 - 43.00 LIMESTONE:
43.00 - 96.00 DIABASE:

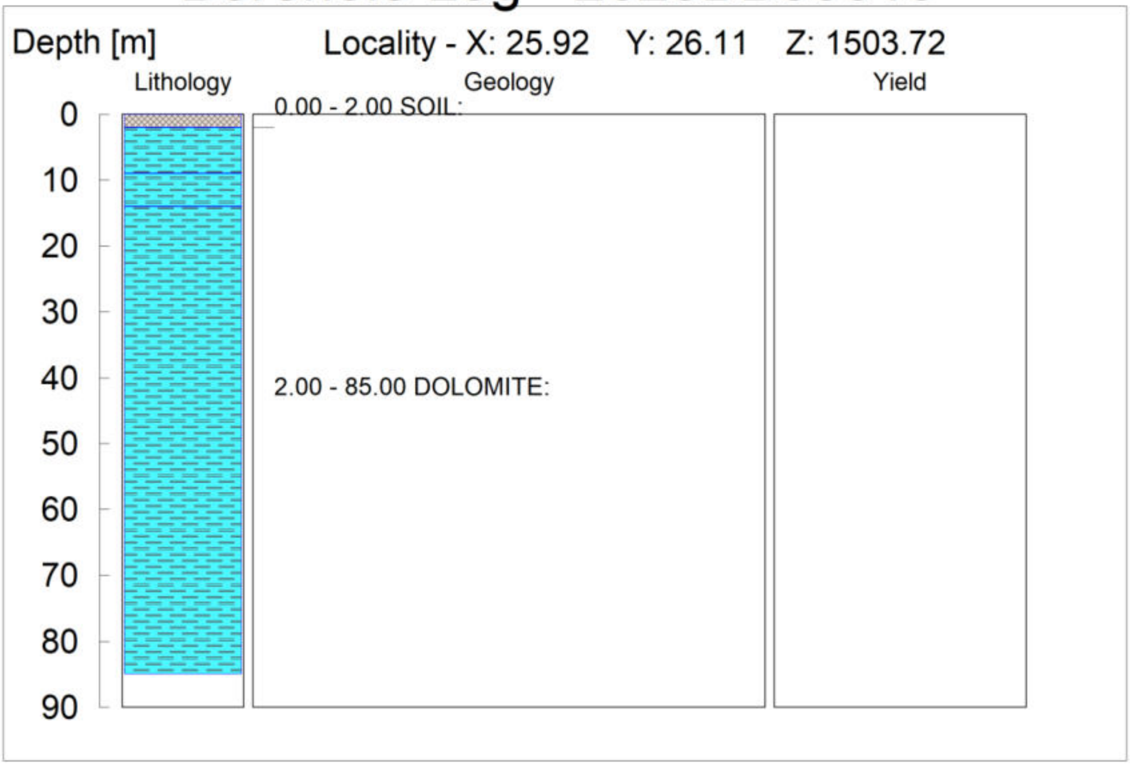
Borehole Log - 2625BB00274



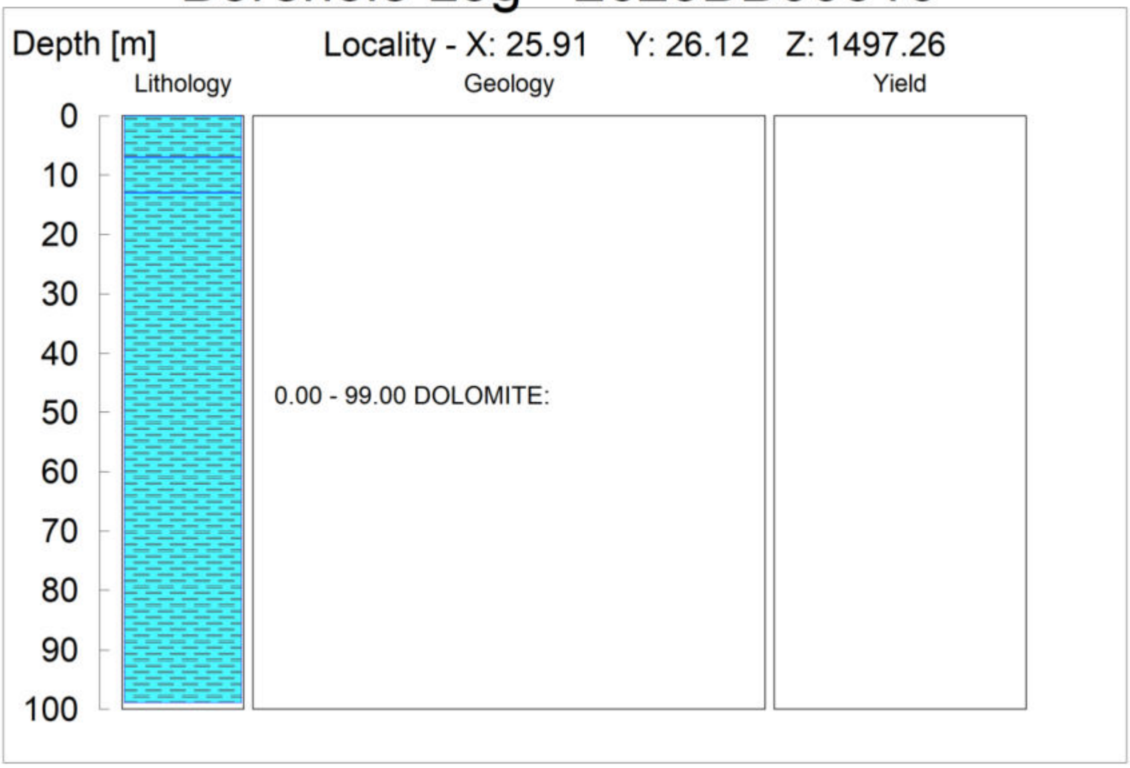
Borehole Log - 2625BB00269

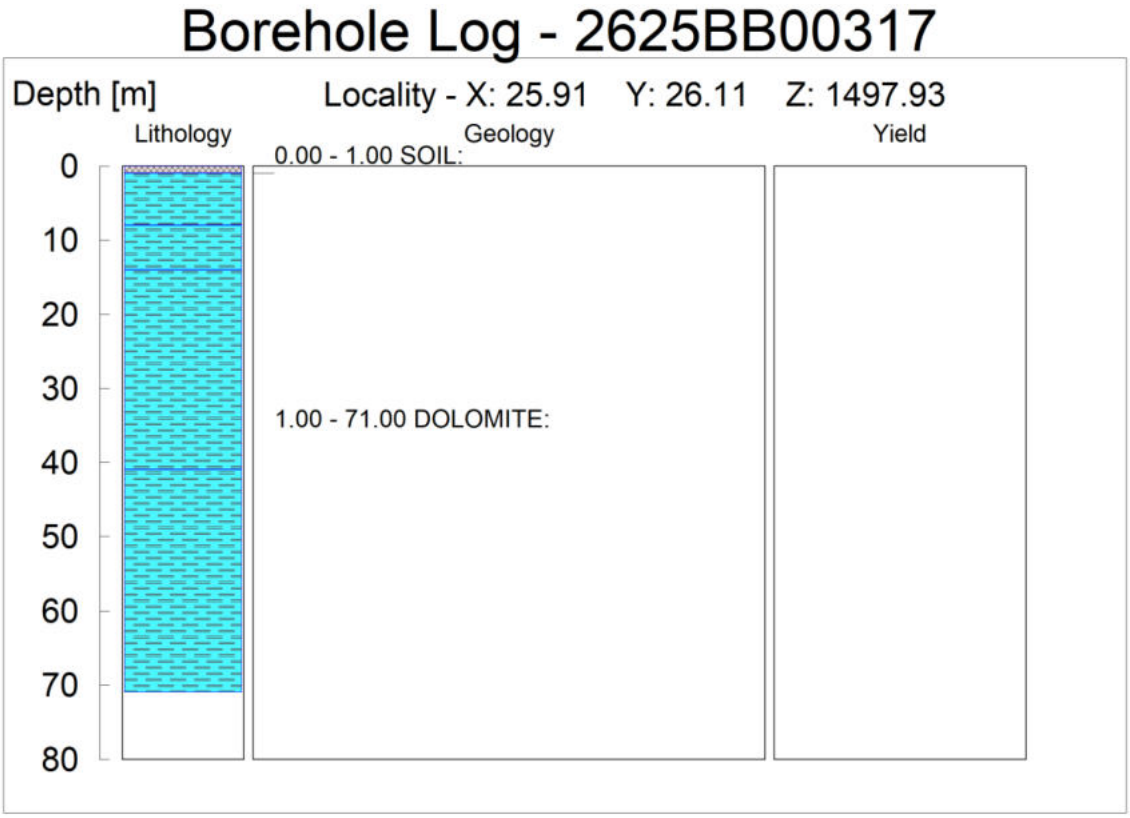


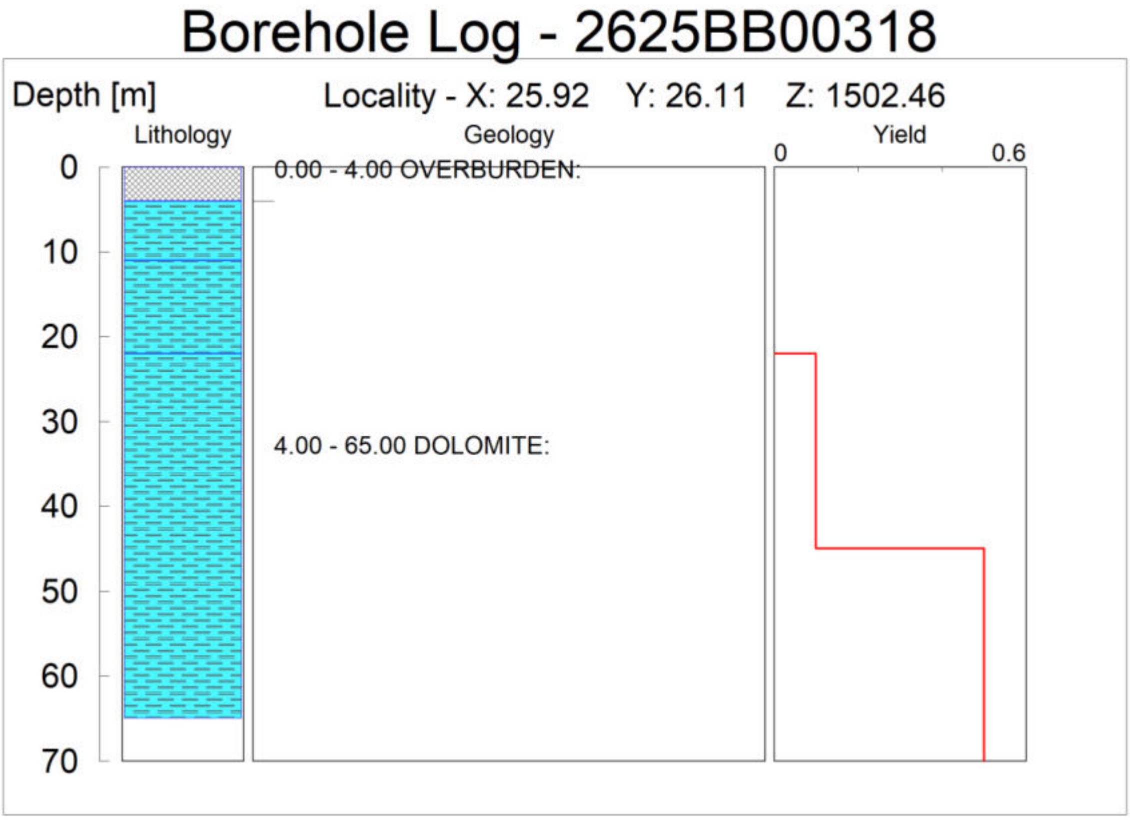
Borehole Log - 2625BB00313

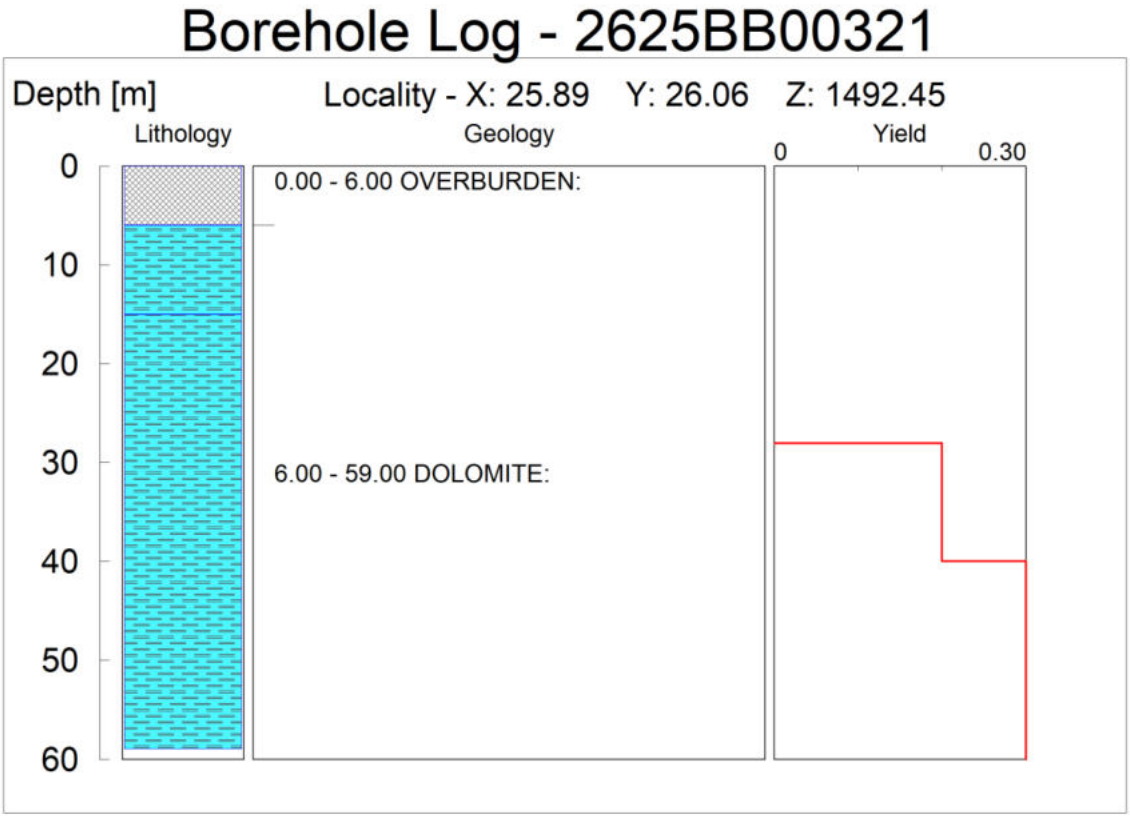


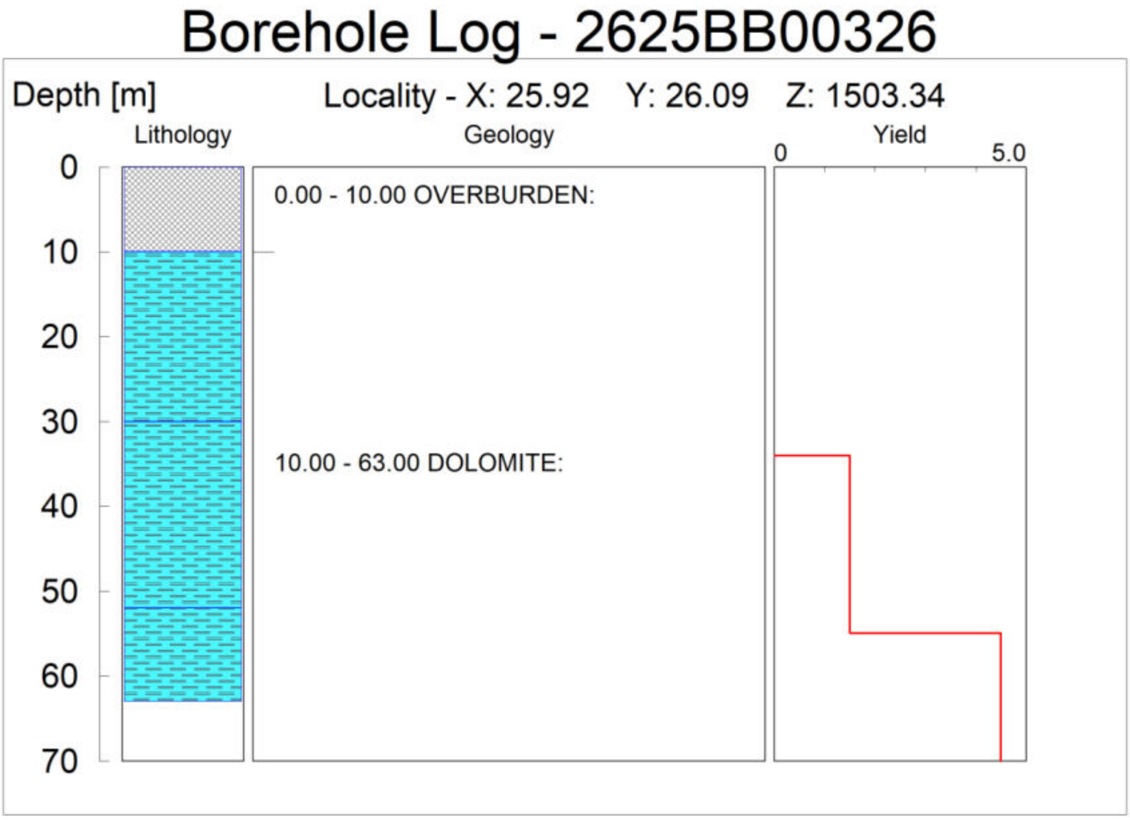
Borehole Log - 2625BB00316



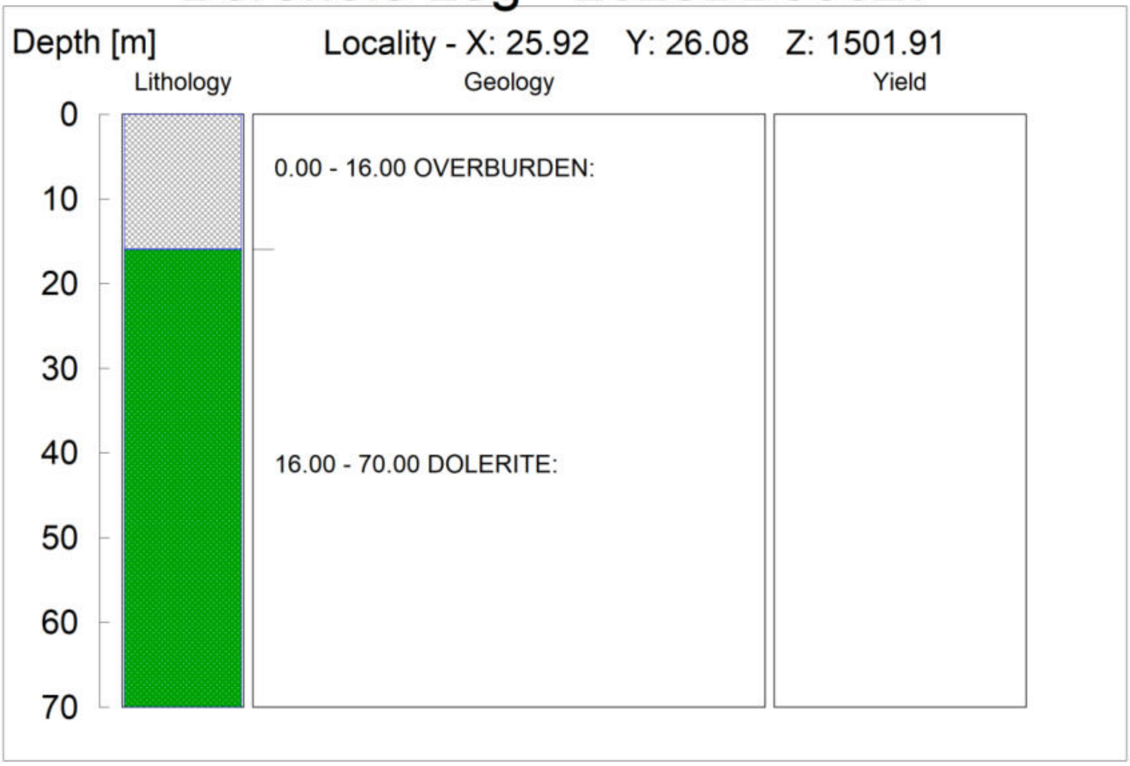

Borehole Log - 2625BB00317
Depth [m]
Locality - X: 25.91 Y: 26.11 Z: 1497.93
Lithology
Geology
Yield
0.00 - 1.00 SOIL:
1.00 - 71.00 DOLOMITE:
0
10
20
30
40
50
60
70
80


Borehole Log - 2625BB00318
Depth [m]
Locality - X: 25.92 Y: 26.11 Z: 1502.46
Lithology
Geology
Yield
0
0.6
0.00 - 4.00 OVERBURDEN:
4.00 - 65.00 DOLOMITE:
0
10
20
30
40
50
60
70

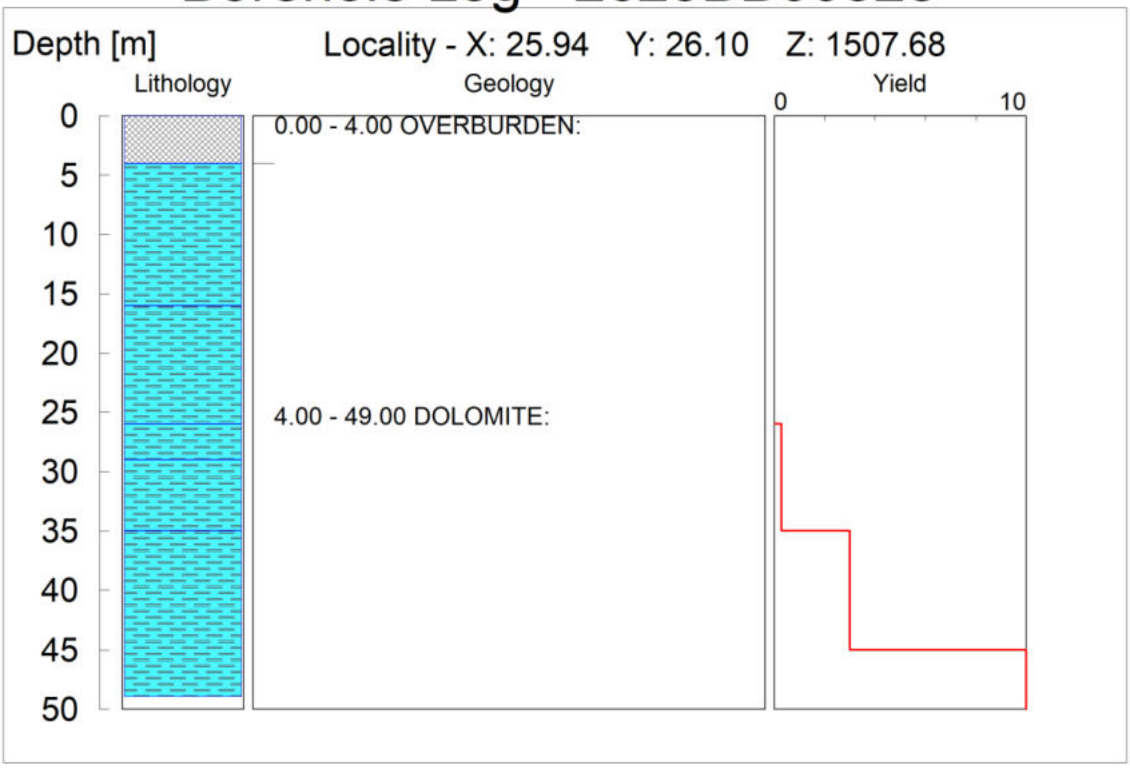

Borehole Log - 2625BB00321
Depth [m]
Locality - X: 25.89 Y: 26.06 Z: 1492.45
Lithology
Geology
Yield
0
0.30
0
10
20
30
40
50
60
0.00 - 6.00 OVERBURDEN:
6.00 - 59.00 DOLOMITE:


Borehole Log - 2625BB00326
Depth [m]
Locality - X: 25.92 Y: 26.09 Z: 1503.34
Lithology
Geology
Yield
0
5.0
0
10
20
30
40
50
60
70
0.00 - 10.00 OVERBURDEN:
10.00 - 63.00 DOLOMITE:

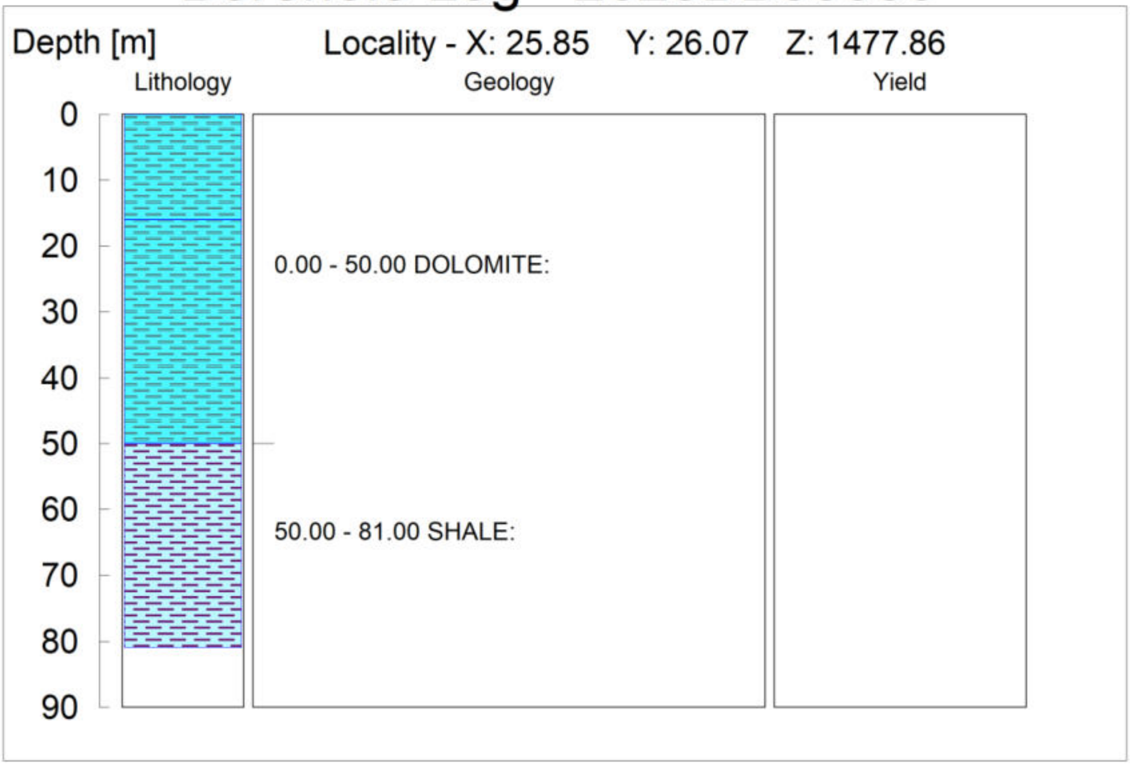
Borehole Log - 2625BB00327



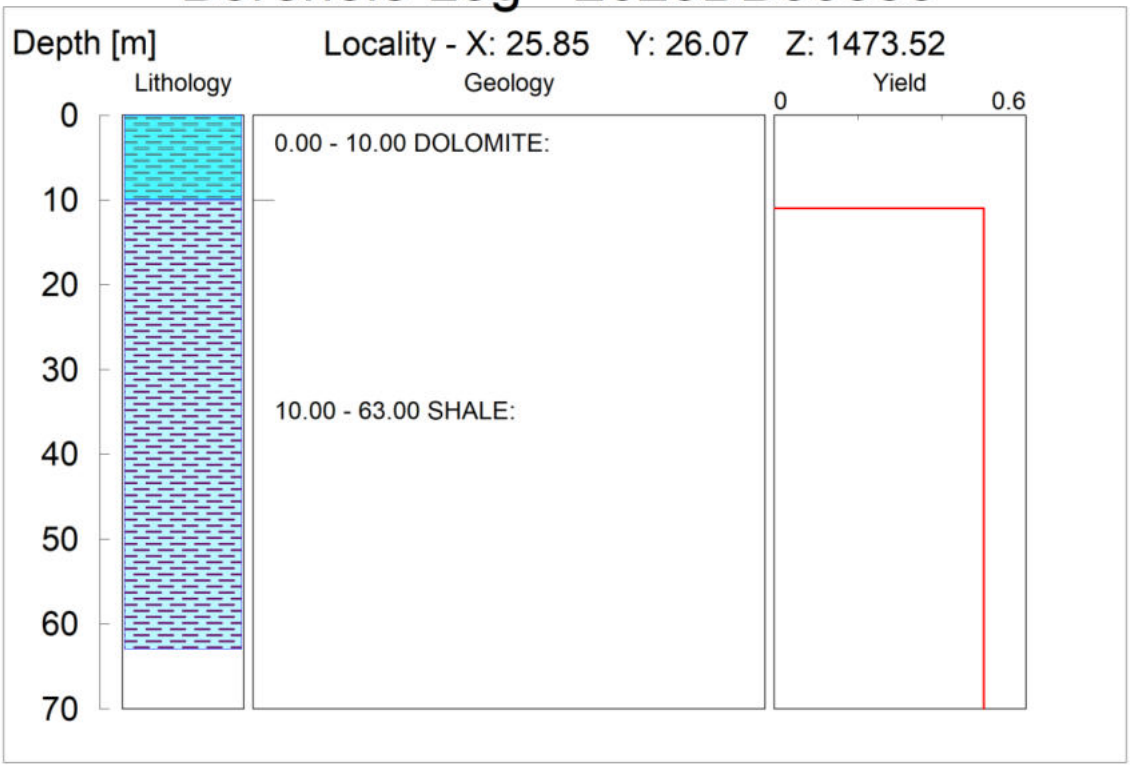
Borehole Log - 2625BB00328

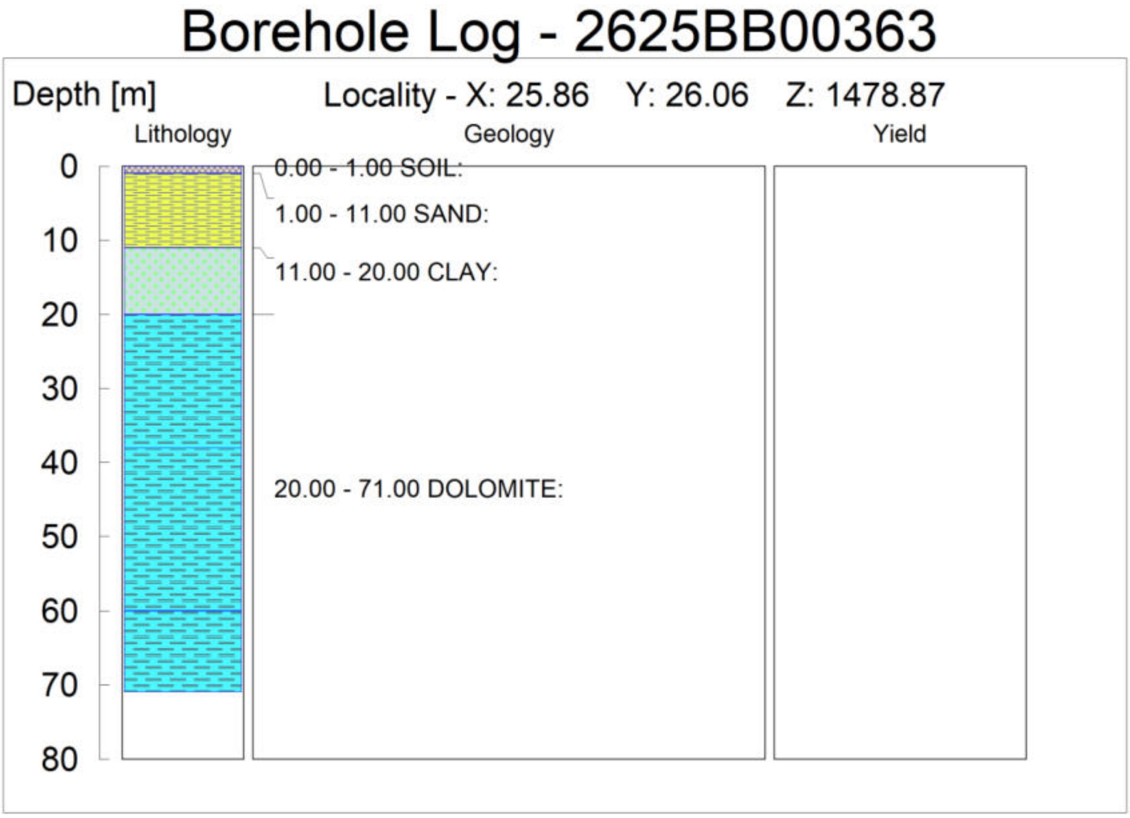


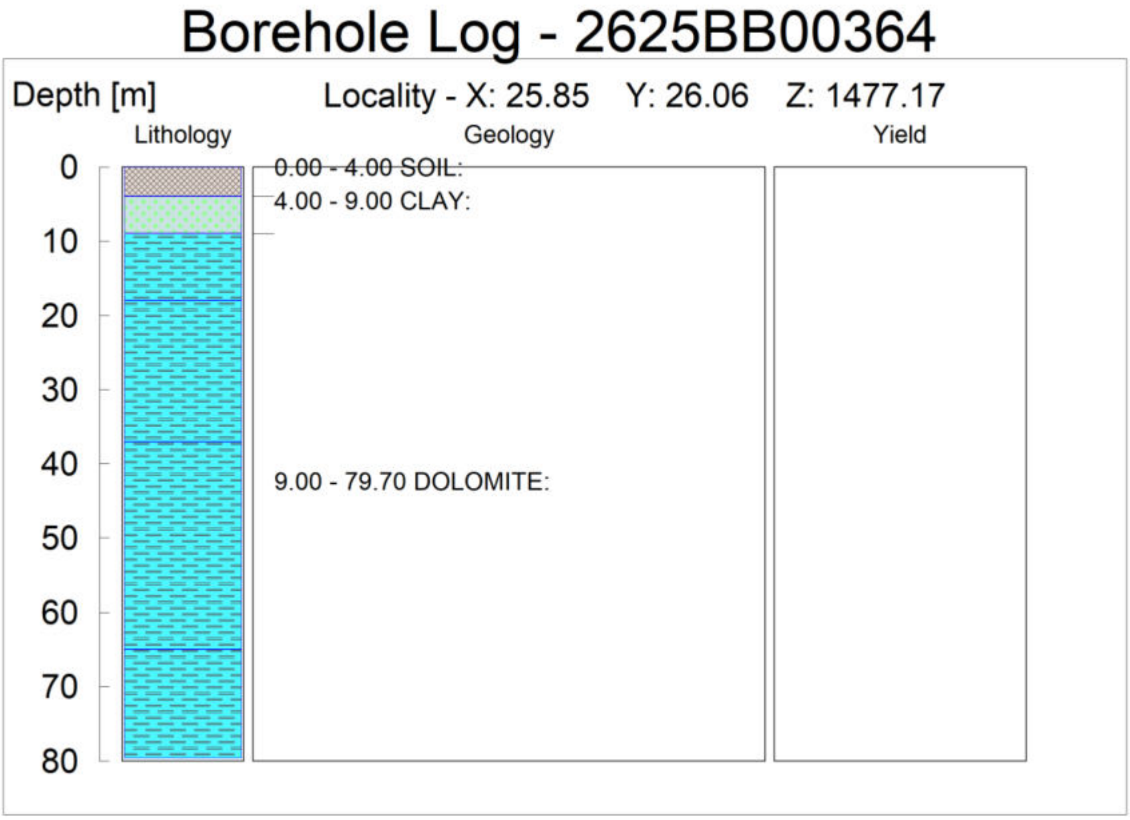
Borehole Log - 2625BB00353



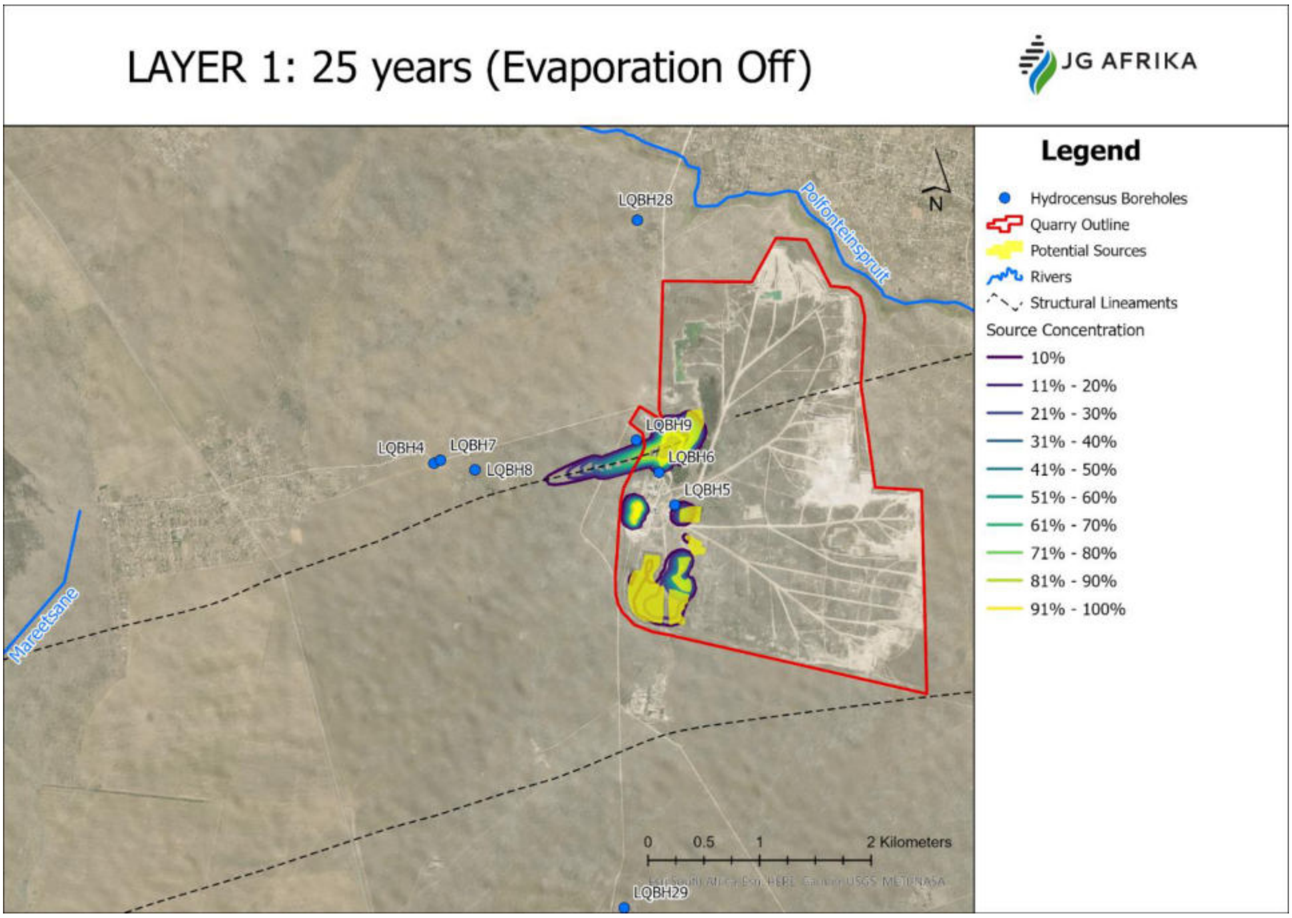
Borehole Log - 2625BB00355

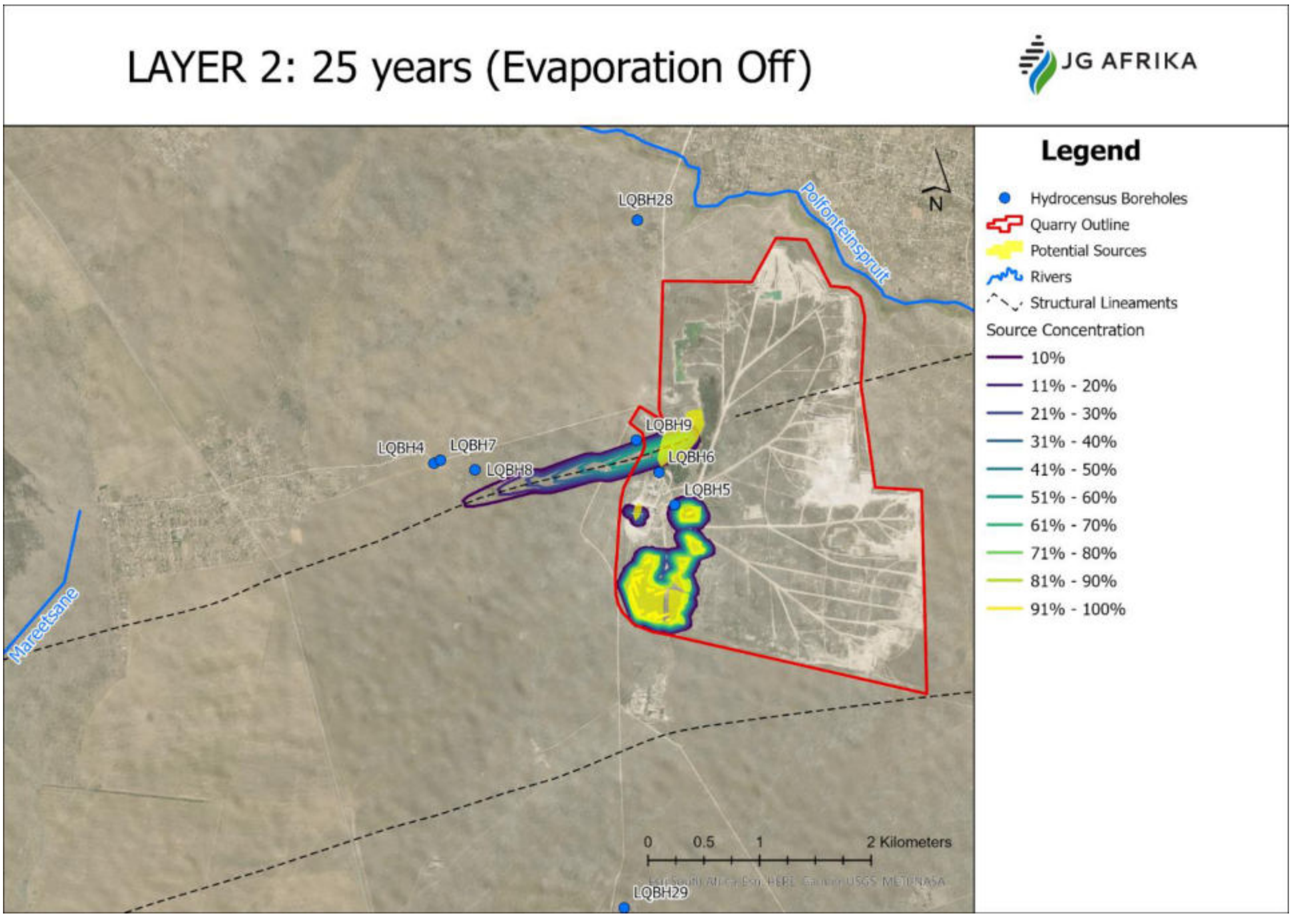


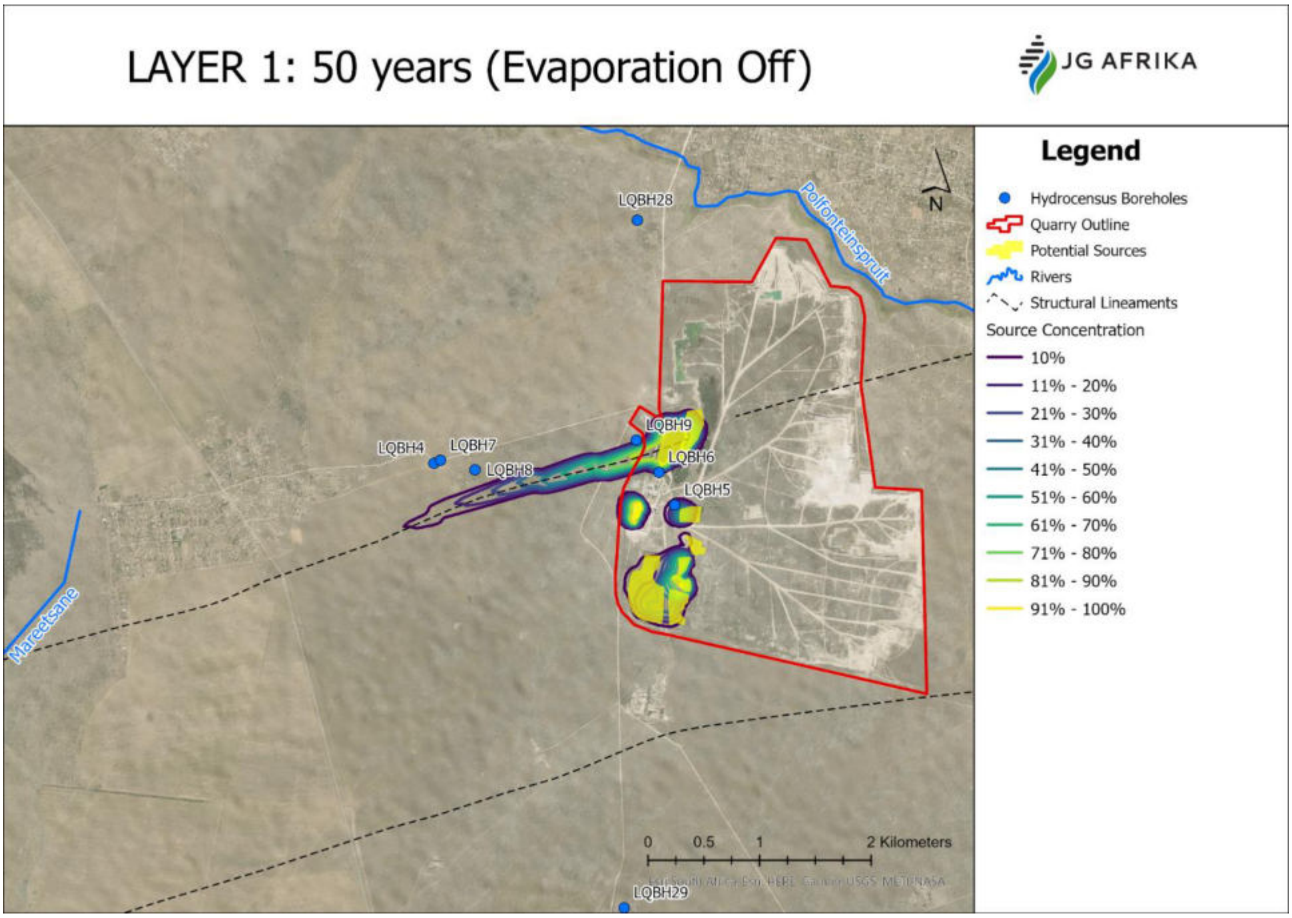

Borehole Log - 2625BB00363
Depth [m]
Locality - X: 25.86 Y: 26.06 Z: 1478.87
Lithology
Geology
Yield
0
10
20
30
40
50
60
70
80
0.00 - 1.00 SOIL:
1.00 - 11.00 SAND:
11.00 - 20.00 CLAY:
20.00 - 71.00 DOLOMITE:

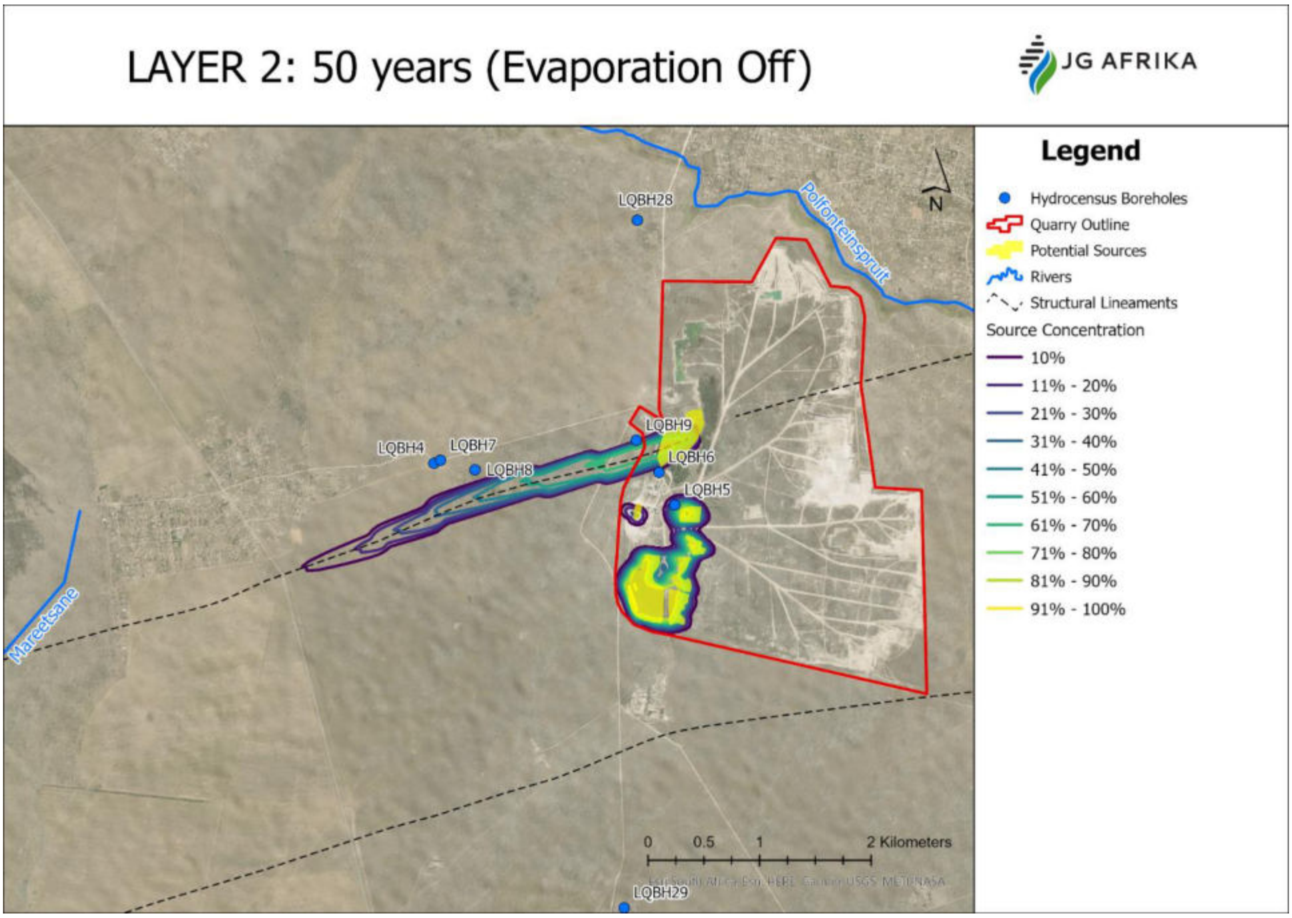

Borehole Log - 2625BB00364
Depth [m]
Locality - X: 25.85 Y: 26.06 Z: 1477.17
Lithology
Geology
Yield
0
10
20
30
40
50
60
70
80
0.00 - 4.00 SOIL:
4.00 - 9.00 CLAY:
9.00 - 79.70 DOLOMITE:

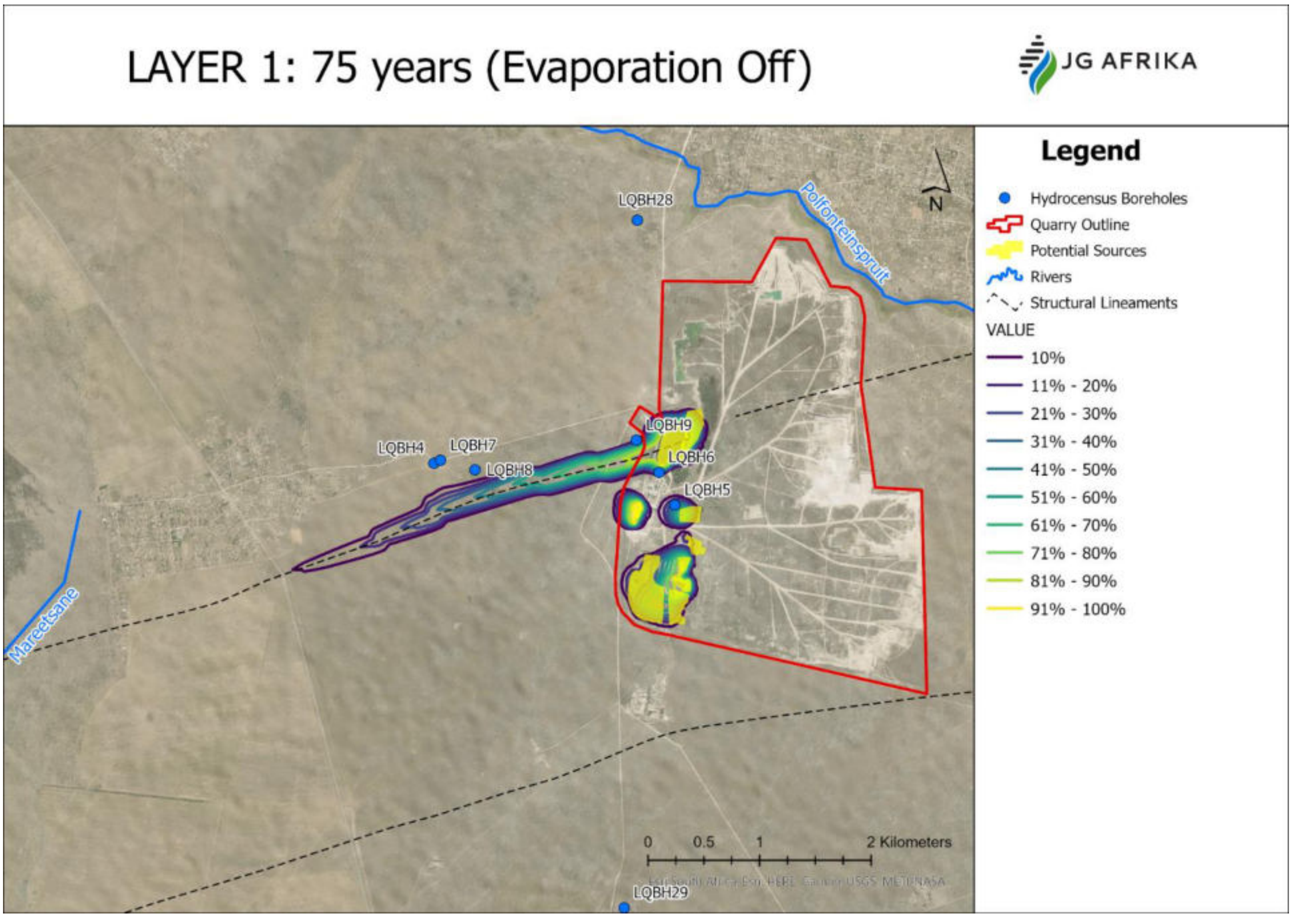
Annexure F: Mass Transport Model Results – Evaporation Off

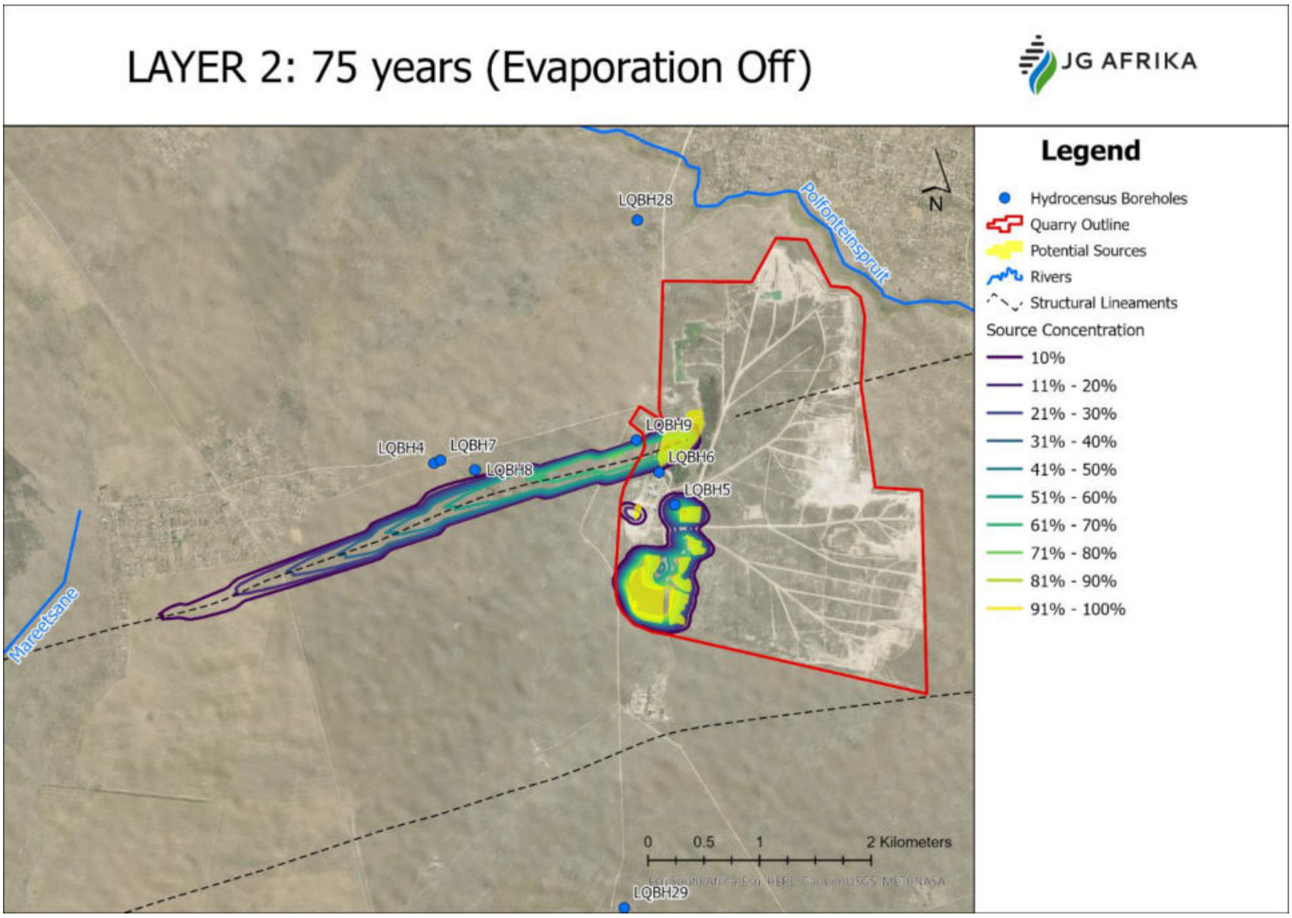

LAYER 1: 25 years (Evaporation Off)
JG AFRIKA
Legend
Hydrocensus Boreholes
Quarry Outline
Potential Sources
Rivers
Structural Lineaments
Source Concentration
10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
51% - 60%
61% - 70%
71% - 80%
81% - 90%
91% - 100%
N
LQBH28
Polfonteinspruit
LQBH9
LQBH4
LQBH7
LQBH8
LQBH6
LQBH5
Mareetsane
0
0.5
1
2 Kilometers
LQBH29

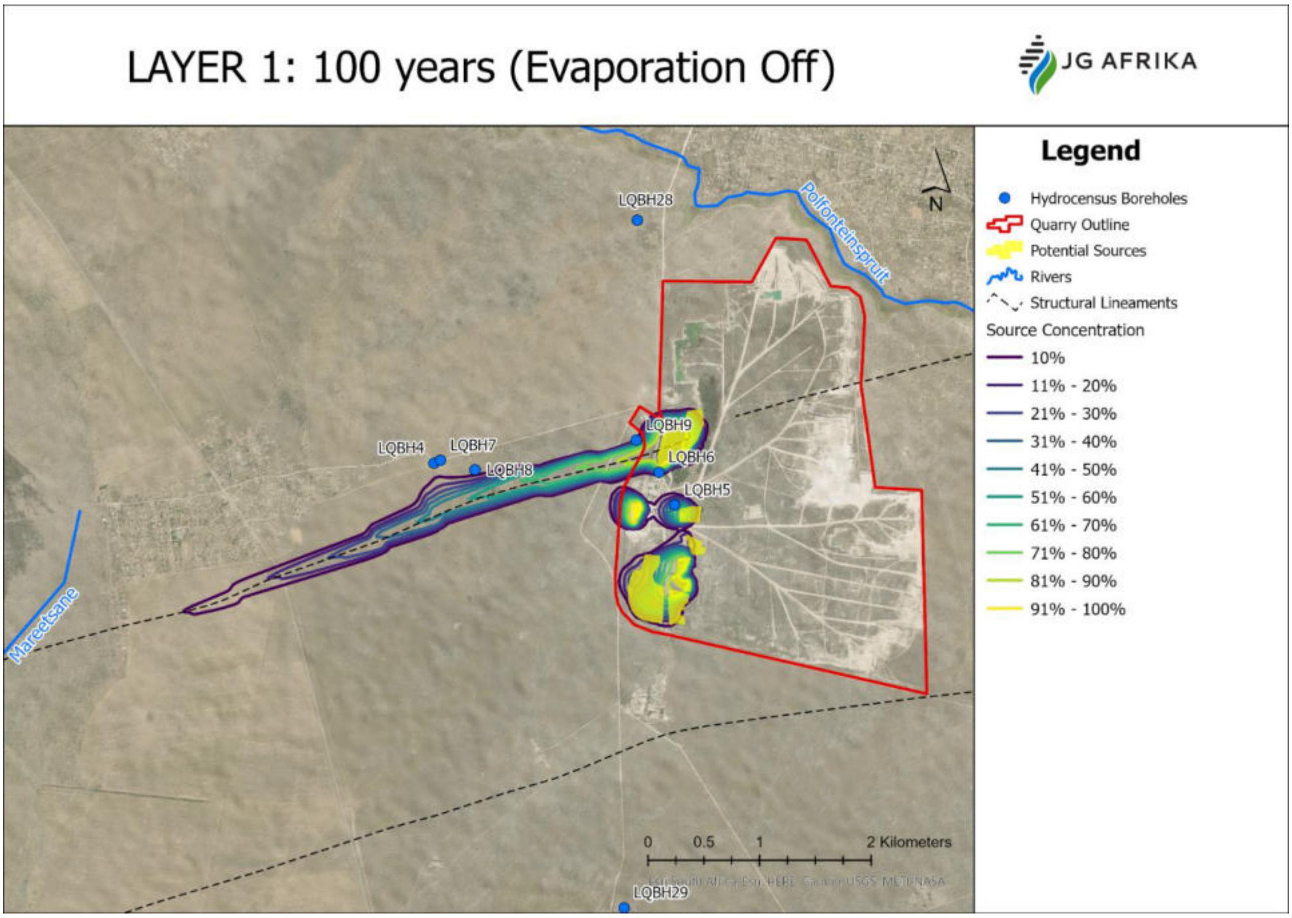

LAYER 2: 25 years (Evaporation Off)
JG AFRIKA
Legend
Hydrocensus Boreholes
Quarry Outline
Potential Sources
Rivers
Structural Lineaments
Source Concentration
10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
51% - 60%
61% - 70%
71% - 80%
81% - 90%
91% - 100%
N
LQBH28
Polfonteinspruit
LQBH9
LQBH4
LQBH7
LQBH8
LQBH6
LQBH5
Mareetsane
0
0.5
1
2 Kilometers
LQBH29

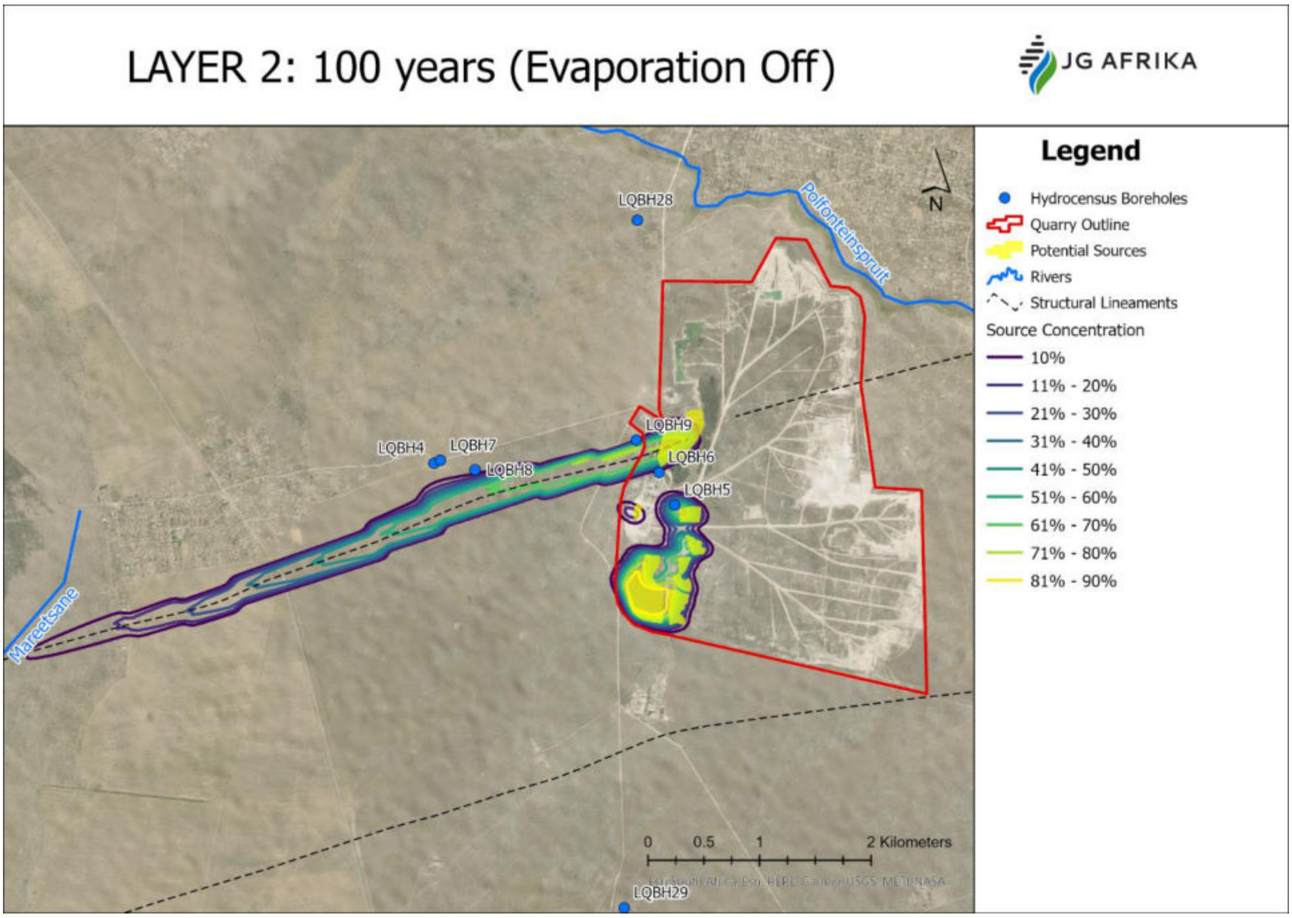

LAYER 1: 50 years (Evaporation Off)
JG AFRIKA
Legend
Hydrocensus Boreholes
Quarry Outline
Potential Sources
Rivers
Structural Lineaments
Source Concentration
10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
51% - 60%
61% - 70%
71% - 80%
81% - 90%
91% - 100%
LQBH28
LQBH9
LQBH4
LQBH7
LQBH8
LQBH6
LQBH5
LQBH29
Polfonteinspruit
Mareetsane
N
0 0.5 1 2 Kilometers


LAYER 2: 50 years (Evaporation Off)
JG AFRIKA
Legend
Hydrocensus Boreholes
Quarry Outline
Potential Sources
Rivers
Structural Lineaments
Source Concentration
10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
51% - 60%
61% - 70%
71% - 80%
81% - 90%
91% - 100%
LQBH28
LQBH9
LQBH4
LQBH7
LQBH8
LQBH6
LQBH5
LQBH29
Polfonteinspruit
Mareetsane
N
0 0.5 1 2 Kilometers


LAYER 1: 75 years (Evaporation Off)
JG AFRIKA
Legend
Hydrocensus Boreholes
Quarry Outline
Potential Sources
Rivers
Structural Lineaments
VALUE
10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
51% - 60%
61% - 70%
71% - 80%
81% - 90%
91% - 100%
LQBH28
LQBH9
LQBH4
LQBH7
LQBH8
LQBH6
LQBH5
LQBH29
Polfonteinspruit
Mareetsane
N
0 0.5 1 2 Kilometers


LAYER 2: 75 years (Evaporation Off)
JG AFRIKA
Legend
Hydrocensus Boreholes
Quarry Outline
Potential Sources
Rivers
Structural Lineaments
Source Concentration
10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
51% - 60%
61% - 70%
71% - 80%
81% - 90%
91% - 100%
LQBH28
LQBH9
LQBH4
LQBH7
LQBH8
LQBH6
LQBH5
LQBH29
Polfonteinspruit
Mareetsane
N
0 0.5 1 2 Kilometers


LAYER 1: 100 years (Evaporation Off)
JG AFRIKA
Legend
Hydrocensus Boreholes
Quarry Outline
Potential Sources
Rivers
Structural Lineaments
Source Concentration
10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
51% - 60%
61% - 70%
71% - 80%
81% - 90%
91% - 100%
LQBH28
Polfonteinspruit
LQBH9
LQBH4
LQBH7
LQBH8
LQBH6
LQBH5
Mareetsane
N
0 0.5 1 2 Kilometers
LQBH29


LAYER 2: 100 years (Evaporation Off)
JG AFRIKA
Legend
Hydrocensus Boreholes
Quarry Outline
Potential Sources
Rivers
Structural Lineaments
Source Concentration
10%
11% - 20%
21% - 30%
31% - 40%
41% - 50%
51% - 60%
61% - 70%
71% - 80%
81% - 90%
LQBH28
Polfonteinspruit
LQBH9
LQBH4
LQBH7
LQBH8
LQBH6
LQBH5
Mareetsane
N
0 0.5 1 2 Kilometers
LQBH29

Annexure G: Quantitative Environmental Risk Assessment (ERA) Guideline

Ref: Department of Water Affairs ***February 2010***
Operational Guideline: Integrated Water and Waste Management Plan

In terms of a quantitative environmental risk assessment (ERA), the assessment will be based on:

- Probability of occurrence which describes the likelihood of the impact actually occurring and is indicated as:-
  - Improbable, where the likelihood of the impact is very low;
  - Probable, where there is a distinct possibility of the impact to occur;
  - Highly probable, where it very likely that the impact will occur;
  - Definite, where the impact will occur regardless any management measure.
- Consequence of occurrence in terms of:
  - Nature of the impact;
  - Extent of the impact, either local, regional, national or across international borders;
  - Duration of the impact, either short term (0-5 years), medium term (6-15 years) or long-term (the impact will cease after the operational life of the activity) or permanent, where mitigation measures by natural processes or human intervention will not occur;
  - Intensity of the impact, either being low, medium or high effect on the natural, cultural and social functions and processes.
- Significance level of the risk posed by the water use, which is determined through a synthesis of the probability of occurrence and consequence of occurrence.

The applicant will have to rank the risks based on the quantitative assessment as described above into high, medium, or low risks. Management measures need to be identified to mitigate, prevent and /or reduce the risk. These measures will primarily be focussed on the risks identified as high in the ranking matrix, but will also include measures for medium and low risks. The management measures will be taken forward in the IWMP as part of the water use authorisation process.

In order to assess each of the factors for each impact the ranking scales as contained in Table 7-1 could be used. Once the factors had been ranked for each impact, the environmental significance of each impact could be assessed by applying the following formula:

SP = (magnitude + duration + scale) x probability

where SP is defined as significance points.

Table 7-1: Ranking Scales for ERA

PROBABILITY = P 5 – Definite / don't know 4 – High probable 3 – Medium probability 2 – low [probability 1 – Improbable 0 - None	**DURATION** = D 5 – Permanent 4 – Long-term ceases with operational life) 3 – Medium-term (5 – 15 years) 2 – Short-term (0-5 years) 1 - Immediate
SCALE = S 5 – International 4 – National 3 – Regional 2 – Local 1 – Site 0 – None	**MAGNITUDE** = M 10 – Very high / Don't know 8 – High 6 – Moderate 4 – Low 2 – Minor

The maximum value of significance points (SP) is 100. Environmental effects could therefore be rated as either high (H), moderate (M), or low (L) significance on the following basis:

- More than 60 points indicates high (H) environmental significance
- Between 30 – 60 points indicate moderate (M) environmental significance
- Less than 30 points indicates low (L) environmental significance.