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ANNUAL GROUNDWATER MONITORING REPORT FOR GROOTEGELUK MINE (Q2 and Q4 2022)

Document Production / Approval Record

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LIMITATION

- Some boreholes are not accessible with a vehicle and thus were not purged as per prescribed Exxaro's procedure.
- Not all boreholes are available for sampling, as such some are sampled once a year instead of twice due to either accessibility issues such as vegetation and or pump not functioning on the day of sampling.
- There are a few boreholes that have not been found despite the available co-ordinates and thus need to be re-drilled while one borehole has been destroyed by the expansion of the mine pit and thus will need to be replaced.
- While purging needs to be done until the parameter movement stabilizes on the multimeter probe, some boreholes have low recovery volumes and thus it becomes difficult to wait for the analytes to stabilize, in which case the borehole is pumped dry and the recovery is sampled with no further delay.

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EXECUTIVE SUMMARY

Groundwater is an integral component of the environment and as such the Department of Water and Sanitation's mandate is to look after all of the country's water resource. The custodianship vested on DWS extends to grating of Water Use Licenses (IWUL), which is accompanied by a set of conditions that seek to protect the water resource of the country be it surface or groundwater.
The Grootegeluk IWUL **(07/A42J/GB/6418)** issued in July 2018 requires the bi-annual monitoring of the ground water resource. The monitoring program followed in 2022 was approved by the Department as part of the IWUL.
Groundwater monitoring within the Grootegeluk area has been on-going for more than 20 years and the historical records are currently preserved on the EQuIS database which Exxaro procured from Earth Soft PTY, a software company for this sole purpose.

The results for 2022 monitoring was compared with the historical data and the following deductions were made:

- Generally the condition of boreholes is deteriorating due to lack of planned maintenance.
- The groundwater level in and around the mine has stabilized and no visible draw-down can be interpreted for the reporting period 2022.
- The last major fluctuation in groundwater level was recorded over 10 years ago, and thus this has not been an issue of concern in recent years.
- The groundwater levels in the plant area, where abstraction boreholes are used to abstract water from the basalt aquifer and contain any historical pollution, has stabilized. In contrast to previous years when clear fluctuations were recorded which could be linked the either an increase in the pumping or natural recharge from a high rainfall event.
- The ground water chemistry for the 2022 reporting period is stable, compared to previous years where salt load acclamation in the abstraction boreholes in the plant was clearly evident.
- Outside the plant area to the north and east we can see the evolution of water from freshly recharged Calcium and Sodium rich water to a more chlorine and sulphate rich water indicating long residence, which promotes ion exchange and other secondary chemical reaction.
- Overall the groundwater in the areas surrounding the mine activity area is of relatively good background quality with no signs of mining induced quality deterioration.

1. INTRODUCTION

1.1 PROJECT SLA BASIS & PERSONNEL INVOLVED

The groundwater monitoring and reporting for Grootegeluk mine is done in-house by the hydrogeology department based in head office Pretoria. Physical monitoring and report compilation is conducted by Mr Mashudu Ngobeli in his capacity as Exxaro's Senior Hydrogeologist. The report is then reviewed and approved by Mr Reynie Reyneke, the Principal Hydrogeologist, and subsequently handed to the Senior Environmental Specialist Exxaro for review and acceptance.

1.2 BACKGROUND INFORMATION

LOCATION AND BACKGROUND

Exxaro's Grootegeluk Coal Mine is located approximately 20 km west of Lephalale in the Limpopo Province. Grootegeluk is an opencast coal mine where mining activities started in 1980. The mining area, consisting of six adjoining farms, consists of a total of 6528.54 hectares (ha). The current mining pit cover a surface area of approximately 1223,98 ha and the current depth of mining in the open pit is approximately 132 m. Appelvlakte 448LQ and Goedehoop 457 LQ was included into the Grootegeluk Mining Right in 2018, bringing the total area to 8703.35 hectares (ha), however this portion of the right still needs to be executed. The mine produced a total of 29.8 mtpa of product in 2022. The coal is sold to Mittal Steel, the export market and to Eskom's Power Stations.

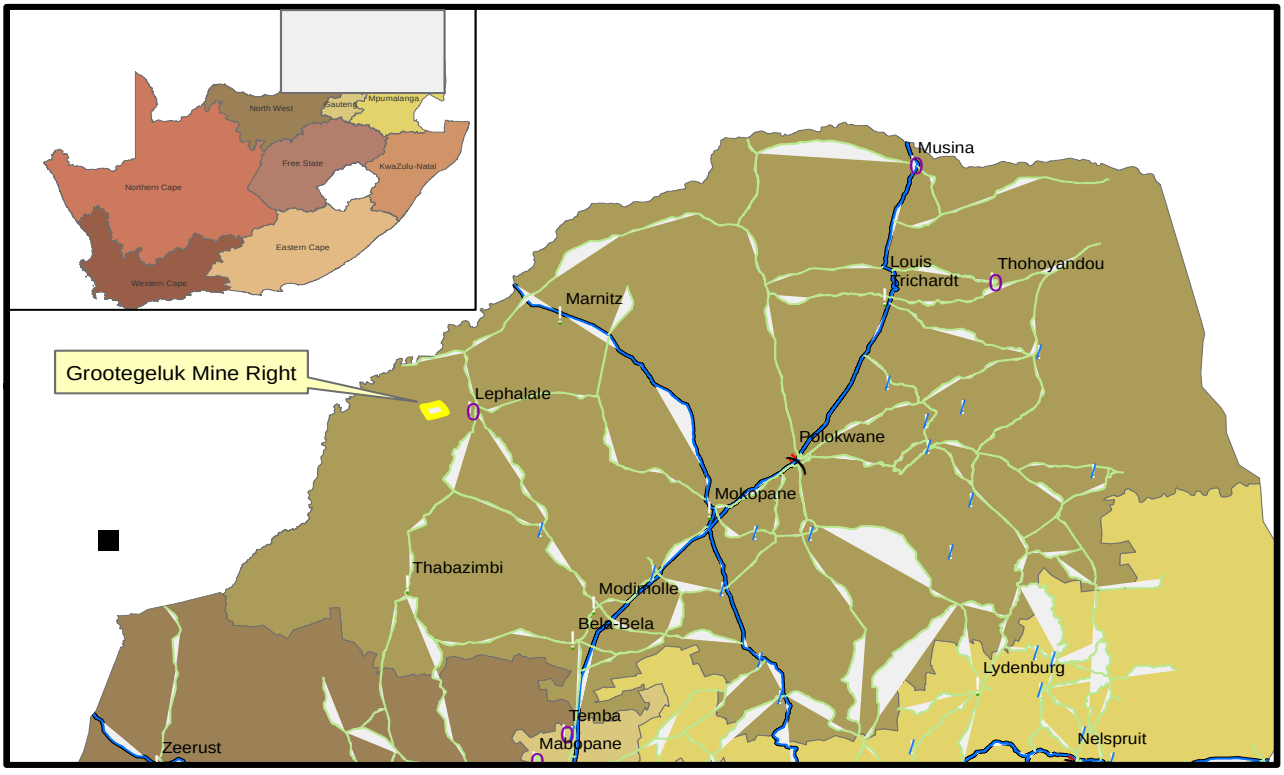

Figure 1: Grootegeluk locality map

GEOLOGY

Grootegeluk mine is situated in the Waterberg coal field which has an east-west striking length of approximately 88km, complemented by a north-south width of ± 40km within the Republic of South Africa. The Waterberg coal field also extends westward into Botswana.

The coal seams occur in the Ecca Group (Volksrust and Vryheid formations) of the Karoo sequence. The upper part of the coal deposit, the Volksrust formation (±60m thick), comprises intercalated mudstone or carbonaceous shale and bright coal layers. It displays such a well-developed repetition of coal-shale assemblages that it can be divided into seven discreet sedimentary cycles or zones (Zone 11 – Zone 5). The terms "zone" and "sample" are used at Grootegeluk coal mine and on the Thabametsi project instead of "seam" and "ply" due to the site-specific intercalated nature of the coal and shale.

The Volksrust formation is classified as a Thick Interbedded Seam Deposit Type according to the South African guide to the systematic evaluation of coal resources and coal reserves (SANS 10320, 2004).

The Vryheid formation (± 55m thick) forms the lower part of the coal deposit and comprises carbonaceous shale and sandstone with interbedded dull coal seams varying in thickness from 1.5m to 9m. Due to its nature it is classified as a Multiple Seam Deposit Type according to the South African guide to the systematic evaluation of coal resources and coal reserves (SANS 10320, 2004). There are five coal zones in the Vryheid formation, predominantly dull coal, with some bright coal developed at the base of Zones 2, 3 and 4.

HYDROGEOLOGY

Grootegeluk mine is underlain by sedimentary rocks of the Karoo Supergroup. The Karoo sequence, in the area, is situated in a graben structure which is defined by the Zoetfontein fault to the north and the Eenzaamheid fault to the south. The more recent Daarby fault cuts across the whole coalfield and intercepts the mining area between the open pit and plant area.

The aquifers of the Karoo Supergroup (mainly Ecca Group in the mining area) display characteristics of the intergranular and fractured regime. The Ecca Group is not known for the development of major aquifers, but occasional high-yielding boreholes may be present. The aquifers that occur in the area can in general be classified as minor aquifers (low yielding), but of high importance, as they are sometimes the only source of water for farming and rural communities.

The Eenzaamheid and the Daarby faults are impermeable as is evident by the difference in water levels on either side of the faults. Boreholes on the western side of the Daarby fault have deeper water levels than boreholes drilled on the eastern side of the fault. Two principal aquifers have been identified in the project area:

- A shallow aquifer formed in the weathered zone;
- A deeper aquifer formed by fracturing of the Karoo sediments (Ecca Group).

Average transmissivities calculated from packer tests conducted on three exploration boreholes in the Thabametsi area ranged between 0.05 and 2.3 m^2/day. As a general observation the hydraulic conductivity decreases with depth.

Pumping tests were conducted on selected boreholes by ERM in 2010 and Aurecon in 2014. The boreholes tested by Aurecon were high yielding and possibly intersected major fault/fracture zones. The transmissivities of the tested boreholes ranged from 0.2 to 182 m^2/day. The estimated average early-time transmissivity of all the tested boreholes was 1.9 m^2/day; while the average late-time transmissivity was 2.7 m^2/day. It was found that, although the Daarby fault has low permabilities, boreholes which are drilled into faults, associated with the Daarby fault, can be highly transmissive.

1.3 PROJECT OBJECTIVES

The primary objective of this annual report is the interpretation of the annual ground water results, so as to indicate the impact of the mining activities on the resource and to show the effectiveness of the mitigation measures that have been put in place to mitigate these impacts. This report considers the approved "Grootegeluk water monitoring program'' ref: OPI GG/H03.103 (Anexture3) as well as the water quality limits as set out in the conditions of the IWUL. .

The format of this report will address groundwater related inserts from the Grootegeluk water monitoring program document in effort to cover only the necessary related compliance requirements.

2. METHODOLOGY

The recommended methodology is addresses as item 7.1 in the Grootegeluk water monitoring procedure as can be seen in Annexure 3 attached of this report. Exxaro has developed an internal groundwater sampling procedure as guideline that is aimed at standardizing how groundwater samples are collected and handled, during a sampling campaign.

2.1 PURGING

Water standing in a borehole prior to sampling may not represent in-situ ground-water quality; stagnant water should therefore be purged from the borehole and filter pack prior to sampling.

The purging procedure should ensure that samples collected from the borehole are representative of the ground water to be monitored. The following purging and sampling procedure is based on a low flow purging concept as prescribed by the United States' Environmental Protection Agency (US EPA) in the document: RCRA Ground-Water Monitoring, Draft Technical Guidance, November 1992.

Purging is accomplished by removing ground water from the borehole at low flow rates using a pump. The use of bailers to purge monitoring boreholes generally is avoided, and only used as a backup plan where our vehicle mounted pumping rig cannot access specific boreholes. Research has shown that the "plunger" effect created by continually raising and lowering the bailer into the borehole can result in continual development or overdevelopment of the borehole.
Boreholes should be purged at or below their recovery rate. This is achieved by ensuring that the water level in the borehole does not drop significantly during purging. A low purge rate also will reduce the possibility of stripping VOCs from the water and will reduce the likelihood of mobilizing colloids in the subsurface that are immobile under natural flow conditions.

Purging continues until measurements of redox potential (ORP), pH, Electrical Conductivity (EC) and dissolved oxygen have stabilized within approximately 10% over at least two measurements – for example, over two successive measurements made, approximately three minutes apart.

2.2 DECONTAMINATION OF SAMPLING EQUIPMENT

The recommended cleaning procedure for sampling equipment, used for the sampling of inorganic constituents are:

- Before commencement of a sampling campaign all monitoring equipment is washed with a non-phosphate detergent.
- Rinse the equipment with tap water.

2.3 SAMPLING

Groundwater samples are taken directly after the required field parameters have stabilised. Depending on the analytical requirements, sample preparation and preservation (i.e. filtering and acidification) is done immediately after the sample is collected (in the field). The following minimum requirements is adhered to:

- Measurement and recording Static Water Level (SWL) in the borehole before a pump or any other equipment is inserted in the hole.
- Sample bottles are filled to the brim
- Samples for major ions are kept cool (~ 4 °C) by means of a cooler box filled with ice.
- Samples are filtered and acidified for metal analyses
- Samples for petroleum hydrocarbon and other organic analyses should be preserved according to the laboratory's requirements, where necessary.
- Sample bottles are clearly marked with the sample name and sample date.

3. GROUNDWATER SAMPLING

The groundwater monitoring network design for Grootegeluk is based on the risk-based source-pathway-receptor principle. A groundwater monitoring network contains monitoring positions assesses the groundwater status at certain areas. Both the impact on water quality and water quantity should be addressed in the monitoring system. The boreholes in the network also covers the following:

- Source monitoring – monitoring close to possible contaminant sources;
- Plume (pathway) monitoring – monitoring along identified contamination plumes;
- Impact (receptor) monitoring – monitoring at expected sensitive receptors; and
- Monitoring of the background water quality and levels.

The Ground Water Sampling boreholes identified are then broken up into the following groups.

GROUP	BOREHOLE TOTAL	MONITORING OBJECTIVE
Site monitoring Boreholes	24	Quality
Compliance monitoring boreholes	28	Quality
Abstraction boreholes	20	Quality
Cyclic ponds monitoring	4	Quality

Table 1: Groundwater network groups

It is important to note that the last group of boreholes in the table above namely the cyclic ponds monitoring category is accounted for in the site and compliance categories. The 4 boreholes are WBR03, WBR04 and WBR24 which are part of the Site monitoring group and WBR49 which is part of the Compliance monitoring group, and thus will not be discussed separately.

3.1 COMPLIANCE MONITORING BOREHOLES

We have a total of 28 boreholes in this category and these includes 1 borehole WB41 which is similarly part of the 20 abstraction boreholes. Below is a table of all the compliance boreholes showing the ground water levels for both quarter 2 and quarter 4 monitoring events 2022.

COMPLIANCE	2022 Q2	2021 Q4
GW01S	Dry	Dry
JY25	35,5	35.3
LT23	64,5	Vegetation cover thick
LT39	Dense vegetation cover	Dense vegetation cover
MY19	Dense vegetation cover	Dense vegetation cover
MY50	No access road	No access road
TE88	17,5	17
TE90	46	Dry
TE96	13,3	12.6
VP03	67,5	73,5
WB41	Dry	Tap
WBR01	Tap	Tap
WBR02	8,5	9,3
WBR07	Dry	Dry
WBR09A	39	37.6
WBR10	30.8	28
WBR18	No access road	No access road
WBR32	6.5	7
WBR33	Dry	68
WBR38	Dry/Blocked	Dry/Blocked
WBR41	77	Dry
WBR42	78	Dry
WBR43	Thorn tree cover/inaccessible	Thorn tree cover/inaccessible
WBR45	Awaiting re-drill	Awaiting re-drill
WBR46	39.4	39.5
WBR48	Lost under excavation material	Lost under excavation material
WBR49	11.6	10.8
WBR50	31.5	Dry

Table 2: Compliance boreholes network with water levels in mbgl

For the 2022 sample run 16 boreholes were samples in Q2, and these dropped to 13 in Q4 where WBR41 and WBR42 were dry and could not be sampled with LT23 lost in the thick vegetation.

Figure 2: Compliance boreholes

3.2 ABSTRACTION BOREHOLES

A total of 20 abstraction boreholes are recommended for monitoring purposes, where the objective is to consider both the water level and quality of the groundwater.

ABSTRACTION	Q2 2022 (WL)	Q4 2022 (WL)
WB 33	Tap	Tap
WB 35	Awaiting re-drill	Awaiting re-drill
WB 36A	17.5	16
WB 38	Remove from network	Remove from network
WB 39A	Tap	Tap
WB41	Dry	Tap
WB 42	No electricity	No electricity
WB 43	Tap	Tap
WB 45	18	18
WB 46	Tap	Tap
WB 49	No electricity	No electricity
WB 50	Blocked	Blocked
WB 51	Awaiting re-drill	Awaiting re-drill
WB 52	Tap	Tap
WB 53	Tap	Tap
WB 54	Tap	Tap
WB 55	3.2	3.3
WB 56	Tap	Tap
WB 57	12.6	12,7
WB 59	Electricity disconnected	Electricity disconnected

Table 3: Abstraction boreholes network with water levels in mbgl

From a total of 20 boreholes 8 were not sampled, where WB42, WB49, WB56 and WB59 all have pumps fitted but the electricity is disconnected rendering them inaccessible for sampling. Boreholes, WB35, WB38 and WB51 cannot be located in the field and thus assumed destroyed and are scheduled to be drilled in 2023. In Q4 borehole WB41 which was dry in Q2 was now filled with water and now the number of sampled boreholes went up to 13.

Figure 3: Abstraction boreholes

3.3 SITE MONITORING BOREHOLES

In addition to the recommended compliance and abstraction monitoring boreholes, Grootegeluk went a step further and made provision for an additional site monitoring network comprising of 24 boreholes of which 7 are from the abstraction boreholes network. This is in effort to gather additional data that will increase the understanding of the groundwater resource within and around the mining area. Table 4 lists all the site groundwater monitoring boreholes and indicates the levels for 2022.

SITE MONITORING	Q2 2021 (WL)	Q4 2022 (WL)
AV01	5	5.1
WB25	5	5
WB34	13.5	10.5
WB36A	17.5	16
WB39A	Tap	Tap
WB45	18	18
WB46	Tap	Tap

WB50	Blocked	Blocked
WB53	Tap	Tap
WB55	3.2	3.3
WB56	Tap	Tap
WB60	Construction, access	Construction, access
WB62	8.6	8.1
WBR03	6,2	6
WBR04	8	8,2
WBR05	6	Thorn Tree
WBR15	11.8	No access
WBR17	Awaiting re-drill	Awaiting re-drill
WBR24	11.5	11
WBR29	7	6.8
WBR31	7,6	8,5
WBR35	Access issue	Access issue
WBR39	Dry	Dry
WBR40	7,2	8,6

Table 4: Site monitoring boreholes network with WL in mbgl

Figure 4: Site monitoring boreholes

From Table 4 we see that a total of 24 boreholes only 19 were sampled in Q2 while the number dropped to 17 in the Q4, this is generally due to the continued deterioration of the condition of boreholes and access roads, while some boreholes are not marked hence during the rainy season these boreholes are covered in vegetation and thus become inaccessible.

3.4 MONITORING POINTS COMPLIANCE SUMMARY

MONITORING CARTEGORY	TOTAL BH	SAMPLED Q1	%COMPLIANCE Q1	SAMPLED Q4	%COMPLIANCE Q4
Compliance	28	16	57%	13	46%
Abstraction	20	12	60%	13	65%
Site Monitoring	24	19	79%	17	70%
Cyclic Ponds	4	4	100%	4	100%

Table 5: Monitoring network group compliance

From Table 5 it is evident that there was a decrease in the boreholes sampled between Q2 and Q4. The reasons for not sampling the specific boreholes are explained in sections 3.1, 3.2 and 3.3. It should be noted that the overall sampled boreholes still give a good representation of the ground water systems at the mine.
A slight concern can be raised around the relatively lower percentage monitoring compliance of 75% and 65% for the Abstraction boreholes in Q2 and Q4 respectively. Important to note is that these boreholes are situated in and around the plant area on the basalt aquifer and are mostly equipped with pumps for abstraction as per the license and are pumped as is required. When these boreholes are not in use or if there is construction work taking place around the vicinity of the boreholes, the power source are normally isolated or removed. Thus, when the boreholes are not actively pumped it is impossible to retrieve a sample, as the infrastructure is in the way. It is recommended that this be addressed.

Overall with a large number of boreholes in a monitoring network, it is it is unlikely that they will all be available for sampling at all times, since the are also impacted by rainy conditions, moving machinery that caucuses damage to the casing, borehole collapse and in some cases the boreholes dry up.

4. QUALITY ASSURANCE QUALITY CONTROL (QA/QC)

4.1 DUPLICATES

Laboratories have fixed methodologies for analyzing each specific analyte, and these needs to be adhered to very strictly to ensure the accuracy of analysis. This can be tested in many ways and one of them is by submitting a duplicate sample under a different sample name to see if the lab will be able to reproduce corresponding analysis data for each analyte from the two samples, as these should be similar. This is one way of determining the level of confidence that can be assigned to the laboratory and consequently the data in question.

Duplicate samples are taken to test if the laboratory is consistent and adhere to their own standards when analysing water chemistry one such method is calculating RDP, short for relative percent difference, which is a measure of the change in a value relative to the average of that value.

	pH	EC	Ca	Mg	Na	SO4	F
	7,4	101	110	38	40	48	1,2
	7,4	99,76	111	37,5	42	48,6	1,1
RPD	0	1,2	0,9	1,3	4,8	1,2	8,6

Table 6: Comparison between Normal and Field duplicate samples

From the 2022 data one sample with a duplicate was sampled in Q2. This is sample AV01, which was submitted to the laboratory with a location code GG22_Q2_006 and the duplicate code was GG22_Q2_066. These codes are used to make sure that the laboratory cannot know which samples they are working on at any point.

In the two samples above a good plausibility of analyte values is evident on Ec, Mg, Na and SO_4 with pH an Ca being spot on at 100%, where F owes its inconsistency its low inherent value, however when considering the bigger picture of the sample chemistry signature is plausible. Looking at these figures in totality we can conclude that the laboratory subscribes to a reasonable and accurate code of practise.

- water from agricultural/mining activities.

To understand the chemistry of water the use of a piper plot is one of multiple methods that can be used to simplify the understanding of the water regime.

5. EXCEEDANCE REPORT

The exceedance report (ref. annexure 2) is a extraction pulled out of the EQuIS database, where the saved analytical results from the laboratory are matched against the set limit from the IWUL document as prescribed by DWS and where an individual analyte in the water quality exceeds the IWUL limit, such analyte is highlighted in red or marked with a cross for easy visualization. Below is a table of the exceedance report for analytical data of the 2 and 4th quarter water quality results 2022. Only 9 analytes are specified in the approved IWUL document and as such only those with set limits can be used for the purpose of this report.

Substance / Parameter	Water quality limit
pH	5-9.5
Electrical Conductivity (mS/m)	370
Calcium (Ca) in mg/l	300
Magnesium (Mg) in mg/l	200
Sodium (Na) in mg/l	400
Chloride (Cl) in mg/l	600
Sulphate (SO4) in mg/l	600
Nitrate (NOxN) in mg/l	20
Fluoride (F) in mg/l	1.9

Table 7: Groundwater Quality Limit

The table above is an extract from the Grootegeluk Operating Instruction document dated 10 October 2018, which was submitted to DWS and ultimately approved as a working document for GROOTEGELUK WATER MONITORING PROGRAM (Annexure 1) ref: License Number: 07/A42J/GB/6418.

With reference to the WQO the selected analytes were compared to the IWUL limits and where the groundwater analysis result exceeded the prescribed maximum, that value is highlighted in red for easy reference. The discussion below will focus on these exceedances.

BH_ID	Period	pH	EC in mS/m	Calcium as Ca	Magnesium as Mg	Sodium as Na	Chloride as Cl	Sulphate as SO?	Nitrate as N	Fluoride as F
IWULLIMIT		5 - 9,5	370	300	200	400	600	600	20	1,9
AV01	05 March 2022	9	31.2	10	4	42	24	5	0.2	0.5
AV01	13 Dec 2022			12	3	43	28	8	0.9	0.3
JY25	6 March 2022	6.5	40.3	24	11	46	35	12	0.2	0.8
JY25	13 Dec 2022			22	8	42	38	13	<0.1	0.7
LT23	7 March 2022	7.2	100	130	49	20	21	202	0.7	1.2
TE88	8 March 2022	7.7	629	129	372	713	1502	1079	0.3	0.5
TE88	13 Dec 2022			16	450	643	1311	657	0.9	0.2
TE96	9 March 2022	7.3	349	166	157	365	653	585	0.2	0.5
TE96	13 Dec 2022			77	206	310	618	376	0.9	<0.2
VP03	10 March 2022	7.4	101	110	38	40	103	48	1.0	1.2
VP03	13 Dec 2022			102	31	32	75	52	0.4	1.4
WB25	11 March 2022	8.3	203	42	160	53	67	455	0.1	0.6
WB25	13 Dec 2022			26	79	51	62	240	2.5	<0.2
WB33	12 March 2022	7.9	77.0	85	24	36	44	177	2.8	0.4
WB33	13 Dec 2022			85	22	35	42	131	2.2	<0.2
WB34	13 March 2022	6.7	205	234	122	74	75	940	28	0.3
WB34	13 Dec 2022			222	83	66	52	666	23	<0.2
WB36A	14 March 2022	8.1	177	70	104	167	152	703	0.2	0.5
WB36A	13 Dec 2022			33	60	120	175	280	0.1	0.5
WB39A	15 March 2022	7.4	321	481	260	73	39	2103	4.7	1.0
WB39A	13 Dec 2022			329	180	46	37	1219	1.7	1.4
WB41	16 March 2022	7.8	278	386	231	62	31	1653	9.0	1.3
WB41	13 Dec 2022			417	167	45	38	1270	2.1	1.5
WB43	17 March 2022	7.6	12.2	12	1	5	12	3	0.2	0.3
WB43	13 Dec 2022			11	1	4	18	4	0.1	<0.2
WB45	18 March 2022	7.6	260	311	210	66	31	1420	11	0.6
WB45	13 Dec 2022			329	158	50	32	1132	3.1	0.5
WB46	19 March 2022	7.8	214	229	187	41	30	1034	10	1.5
WB52	20 March 2022	7.3	275	328	183	121	63	1396	14	0.9
WB52	13 Dec 2022			399	138	101	60	1091	3.4	0.6
WB53	21 March 2022	7.5	276	373	213	73	35	1610	11	0.6
WB53	13 Dec 2022			465	187	49	39	1717	1.1	0.6
WB54	22 March 2022	7.7	281	392	241	58	33	1749	3.6	1.6
WB54	13 Dec 2022			361	150	42	35	1225	1.0	1.8
WB55	23 March 2022	7.4	246	226	237	57	44	1529	0.1	0.2
WB55	13 Dec 2022			265	164	40	47	1213	<0.1	<0.2
WB56	24 March 2022	7.4	113	117	52	43	34	308	10	0.3
WB56	13 Dec 2022			105	39	43	36	188	7.6	<0.2
WB57	25 March 2022	7.6	109	57	75	64	41	454	0.1	0.3
WB57	13 Dec 2022			60	82	68	36	415	<0.1	<0.2
WB62	26 March 2022	7.4	186	184	141	64	38	1022	0.2	0.2
WB62	13 Dec 2022			94	62	53	38	536	<0.1	<0.2
WBR01	27 March 2022	7.4	45.5	33	18	39	25	<2	2.2	0.5
WBR01	13 Dec 2022			33	11	33	26	2	1.9	0.2
WBR02	28 March 2022	7.2	47.4	33	17	37	39	3	0.1	0.4
WBR02	13 Dec 2022			26	10	32	39	<2	<0.1	<0.2
WBR03	29 March 2022	7.6	65.4	46	22	32	53	46	0.9	0.5
WBR04	30 March 2022	7.7	259	291	230	69	64	1508	0.1	0.2
WBR04	13 Dec 2022			250	135	56	77	1087	<0.1	<0.2
WBR05	31 March 2022	7.9	329	42	348	332	207	1574	0.3	0.3
WBR09A	32 March 2022	6.6	78.4	46	26	39	218	2	6.4	0.3
WBR09A	13 Dec 2022			51	27	40	210	2	4.6	<0.2
WBR10	33 March 2022	7.4	90.6	91	44	34	55	166	20	0.3
WBR10	13 Dec 2022			96	47	38	57	139	22	<0.2
WBR15	34 March 2022	8.2	84.5	33	29	32	76	8	1.1	0.5
WBR24	35 March 2022	8.8	87.9	24	22	113	143	99	0.4	0.4
WBR24	13 Dec 2022			17	19	105	130	78	<0.1	<0.2
WBR29	36 March 2022	8.2	146	12	197	82	30	479	0.4	0.4
WBR29	13 Dec 2022			34	213	68	32	433	<0.1	<0.2
WBR31	37 March 2022	7.6	102	24	105	57	24	248	1.4	0.6
WBR31	13 Dec 2022			25	74	55	26	141	<0.1	<0.2
WBR32	38 March 2022	7.4	69.0	49	26	51	90	<2	0.3	0.5
WBR32	13 Dec 2022			51	27	54	89	2	0.3	0.3
WBR33	13 Dec 2022			57	20	42	51	272	<0.1	1.2
WBR40	39 March 2022	8.5	55.2	7	26	62	68	13	0.4	0.5
WBR40	13 Dec 2022			6	33	66	60	27	0.3	<0.2
WBR41	40 March 2022	7.2	84.0	93	36	40	48	68	0.4	2.3
WBR42	41 March 2022	7.1	103	84	38	58	130	60	0.4	2.7
WBR46	42 March 2022	7.5	548	195	170	603	829	<2	5.1	3.0
WBR46	13 Dec 2022			33	17	34	26	2	1.9	0.2
WBR49	43 March 2022	6.3	78.9	25	15	116	222	2	3.7	<0.2
WBR49	13 Dec 2022			15	8	99	204	3	3.0	<0.2
WBR50	44 March 2022	7.1	329	135	94	460	583	299	0.3	2.3
WBR50	13 Dec 2022			151	99	464	741	223	<0.1	3.9

Table 8: Groundwater analysis with exceedance report

pH

The pH is scale that measures the acidity of alkalinity of a solution. The lower range figures in a pH scale symbolizes more acidic solutions while a pH of 7 represent a neutral solution and the upper scale is representative of an alkaline environment.
In the previous sample run WBR35 was in exceedance, but unfortunatly the borehole is not accessible due to recent excavations diverting the mining road.

Electrical Conductivity (Ec)

Electrical conductivity is the measure of the amount of electrical current a material can carry or its ability to carry a current. Electrical conductivity is also known as specific conductance. Conductivity is an intrinsic property of a material, measured in micro-**Siemens** per metre or µS/m.

Figure 5: Spatial distribution of boreholes with EC exceedance

The approved limit for EC in groundwater is 370 µS/cm. The data shows that 2 of the boreholes sampled in 2022 exceeded this limit either once or twice in the 2 sample runs conducted. Increase in EC measures the water's ability to conduct electricity. Common ions in water that conduct electrical current include sodium, chloride, calcium, and magnesium. Because dissolved salts and other inorganic chemicals conduct electrical current, conductivity increases as salinity increases.
Boreholes TE88 and WBR50 seem to be structurally controlled and they lie along the Eenzaamheid fault or at the least its secondary fissures.

Calcium

Calcium is a mineral that is necessary for life. In addition to building bones and keeping them healthy, calcium enables our blood to clot, our muscles to contract, and our heart to beat. About 99% of the calcium in our bodies is in our bones and teeth. However, symptoms of nausea, poor appetite, vomiting and constipation may be present with mild increases in blood calcium levels. Moderate high levels of hypercalcemia may produce fatigue or excessive tiredness. Heart rhythm abnormalities increased urinary frequency, and kidney stones may also be present.

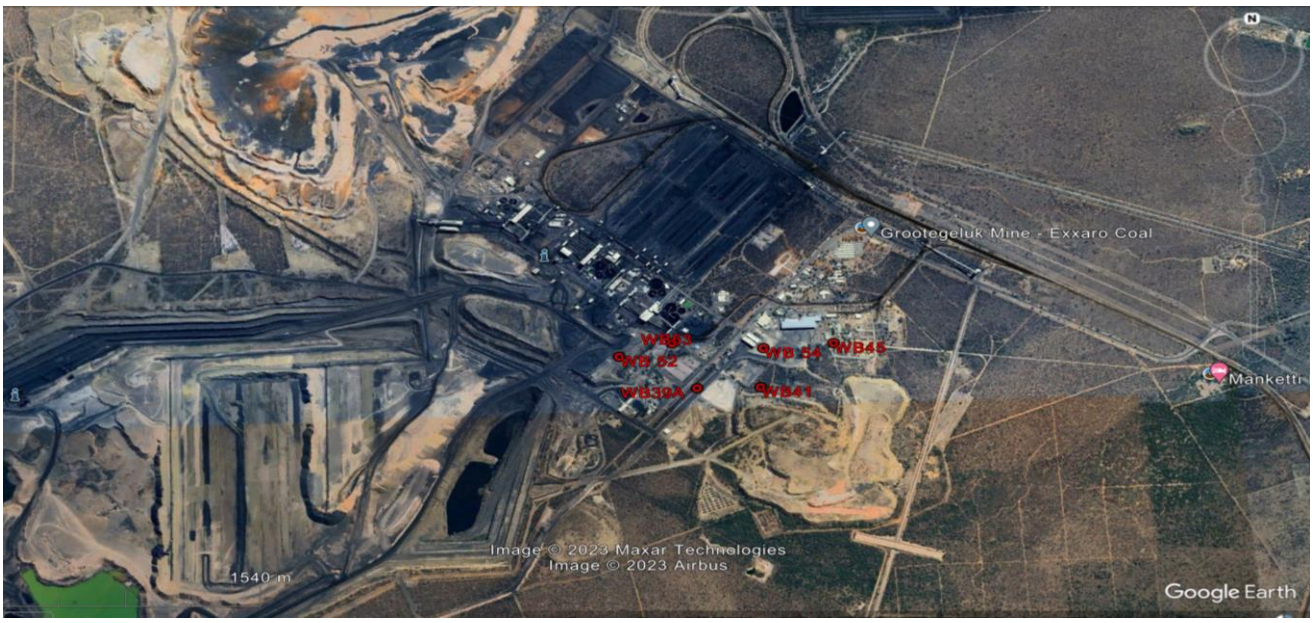

Figure 6: Spatial distribution of boreholes with Ca exceedance

There are 6 boreholes with elevated calcium concentration, and all these are located around the plant and workshop area. These boreholes are linked in the subsurface geology and they all fall within the basalt block which is recharged artificially by water from the plant process that passively infiltrate the ground. This wastewater is able to gain ions from the washing process and this builds up overtime with repeated pumping and infiltration.

Magnesium

Magnesium is the eleventh most abundant element by mass in the human body and is essential to all cells and some 300 enzymes. Magnesium is also known to cure severe forms of psychiatric dysfunctions including panic attacks, stress, anxiety, and undue agitations.

Figure 7: Spatial distribution of boreholes with Mg exceedance

From the 11 boreholes with magnesium exceedance a total of 9 boreholes are located on the basalt, and hance the assumption will be that this has the plant wastewater infiltration contribution linked to it as in the case with calcium.

Sodium

Sodium is an essential element for all animals and some plants. Sodium ions are the major cation in the extracellular fluid (ECF) and as such are the major contributor to the ECF osmotic pressure and ECF compartment volume. Loss of water from the ECF compartment increases the sodium concentration, a condition called hypernatremia.

Figure 8: Spatial distribution of boreholes with Na exceedance

The three boreholes consistently exceed the Na concentration as prescribed in the IWUL. This seems to be structurally controlled as the exceeding boreholes appear to be along the Enzamheid fault.

Chloride

Elevated levels of chloride are typically associated with having high or elevated total dissolved solids. Not only can chloride cause the water to have a taste problem, it can induce corrosion of metal piping and fixtures, appliances, and heat-exchange units.

Figure 9: Spatial distribution of boreholes with Cl exceedance

Na and Cl are common salts that normally go hand in hand in nature, and a such in this case as well there seem

to be a strong correlation in terms of the exceedance spatial distribution, which like in the case of Na seem to be structurally controlled by the fault in the vicinity.

Sulphate

The sulphate or sulphate (see spelling differences) ion is a polyatomic anion with the empirical formula SO_4^{2-}. Sulphate is the spelling recommended by IUPAC. A high concentration of Sulphate in water can potentially result in acidic conditions, in appropriate volumes and potentially lower the pH of liquids and consequently aid in dissolving metals.

Figure 10: Spatial distribution of boreholes with SO_4 exceedance

The SO_4 limit was exceeded in 14 boreholes in the 2022 sampling run, which is a drop from the 22 boreholes in the preceding year. While the abstraction boreholes have high sulphate concentration this is mainly from the physical breakdown of pyrites which are inherent in coal, and once freed from mechanical breakdown by virtue of density will sink to the bottom of the floatation slag to be released with the water that will ultimately percolate into the ground.

Nitrate (N)

Nitrate is a chemical found in fertilizers, manure, agricultural runoff, dairy lagoons, and liquid waste discharged from septic tanks. Nitrate also naturally occurs at safe levels in vegetables. Rain or irrigation can carry nitrate down through soil into groundwater. Your drinking water may contain nitrate if your well draws from this groundwater.

Figure 11: Spatial distribution of boreholes with N exceedance

Fluoride (F)

Fluoride is an inorganic, monatomic anion with the chemical formula F−, whose salts are typically white or colourless. Side effect of excess fluoride includes but not limited to dental fluorosis and skeletal fluorosis. When in high concentration, fluoride can be a lethal poison. Random occurrence of Fluoride concentration in excess of the prescribed limit could possibly be from 2 sources, either there are Fluoride bearing rocks in the drilled borehole such as Apatite, or alternatively be introduced by fertilizers into pastures.

Legume-based pastures, contain several contaminants, of which F and Cd are considered to be of most concern because they have potentially harmful effects on soil quality, livestock health, and food safety. Incidences of fluorosis in grazing livestock, and accumulation of Cd in the edible offal products of livestock, above the maximum permissible concentration set by food authorities have been reported in many countries.

Figure 12: Spatial distribution of boreholes with F exceedance

During the 2021 sampling period Fluoride was exceeded in boreholes WBR46 and WBR50, along the fault-line, and the assumption has always been that of a structurally controlled occurrence along a major fault line. In 2022 for the first time there is a new register of F exceedance in WBR41 and WBR42, how these 2 new samples are connected is still unknown at this stage and warrants further investigation.

6. SUMMARY AND CONCLUSIONS

The water level in and around the mine has stabilized and in the last 5-year period from 2017 to 2022 there has seen very little change or fluctuation.

The chemistry of the groundwater away from the mining area is predominantly recently recharged water and mostly shows no signs of quality deterioration. This natural groundwater has chemistry varying from Ca/Mg Bicarbonate (Ca/Mg (HCO3)2) type to Ca/Mg SO4 or Ca/Mg Cl (Ca/MgSO4 / Ca/MgCl2) type, the shift mainly owed to ion exchange with residency.

More boreholes are becoming inaccessible due to access roads and vegetation that is not being controlled or maintained. This impacts the percentage of borehole that can be sampled during each sample run. It is recommended that the mine focus on improving the accessibility to boreholes by maintaining the roads and removing the vegetation around the boreholes. The overall exceedance report seems to have improved, which could be owed possibly to the immense rainfall in the area within the reporting period.