GOEDGEVONDEN COAL MINE

2021
Groundwater Model Update for Underground

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COMPILED FOR:	Goedgevonden Coal Mine (GGV) Glencore Coal, South Africa P/Bag X7265 Emalahleni, Mpumalanga
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Executive Summary

This report updates the 2021 *Groundwater Square* numerical groundwater impact assessment (Ref: GW2_444GGVg, July 2021) of the Goedgevonden Coal Mine (GGV) to include the underground mining areas for which authorisation is sought. The most important consideration is the undermining of the two streams in the area:

- Central UG undermining the Zaaiwaterspruit river diversion between the North-pit and South-pit.
- Eastern UG undermining a small tributary/wetland system to the Zaaiwaterspruit, east of East-pit.

The base-case numerical model (Model-1) for the post-mining groundwater flow and decant situation assumed that none of the underground adits will be sealed water-tight, i.e., resulting in the entire GGV mining area having similar water level elevations. One modelling variation (second scenario, Model-2) assumed that adits would be sealed water-tight (note that mine water would flow unhindered in all areas where underground mining would intersect any of the three Pits). The third scenario assumed that the Zaaiwaterspruit would not be undermined, thus separating the southern and northern mining areas in terms of free-flow of mine water.

Operational phase

For average rainfall conditions, 1600m^3/d of the current water balance could be attributed to groundwater inflow into the opencast workings of the three pits. Towards the end of mining, this may reduce to 1300m^3/d because of the expanding mines around the North-pit and South-pit. However, during wet rainfall cycles, these volumes may increase to 3400m^3/d and 3000m^3/d, respectively, even higher during extreme wet rainfall cycles.

Although the water engineers were tasked with calculating the water balance, a high-level estimate was calculated for the total water balance, which accounts for groundwater inflow and rainfall recharge (to active areas and rehabilitated areas) and evaporation potential. See Table 6.2.

The total groundwater inflow into the underground workings is expected to be 3130m^3/d at the end of mining but can reduce by almost 75% (total water balance of 830m^3/d) if the Zaaiwaterspruit is not undermined due to the shallow 4Seam. If the advice of *Bare Rock Consulting* (Ref: BR_16_2021s March 2022) is followed to not mine <20m deep, the 4Seam beneath the Zaaiwaterspruit will not be mined as well as the southern portion of the eastern stream tributary of the Zaaiwaterspruit, then the underground water balance will be even lower (85% reduction, total water balance of 480m^3/d).

Post-closure phase

According to the long-term post-mining decant assessment, the mine water quality of the three pits will reach 4000mg/L due to the co-disposal of coal discard.

According to the mine plan (i.e. base-case, Model-1 scenario), all opencast pits and underground areas will be interlinked, resulting in the biggest decant occurring at the lowest point. The North-pit is not expected to decant, while the largest decant volume is expected from the South-pit after 15years to 20years (depending on the dewatering effect of neighbouring mines and the rate of flooding in the shallowest 4Seam underground mining areas beneath the two spruits). Table 6.6 from below serves as a comparison of the anticipated decant for all three modelling scenarios.

Table 6.6 Comparison of long-term post-mining groundwater base-flow/decant volumes (m^3/d) of the three modelling scenarios

Base-flow/decant zone		**Model-1: Do not seal any adits/shafts to the underground**		**Model-2: Seal adits/shafts to the underground**		**Model-3: No undermining of the Zaaiwaterspruit between the North-pit and South-pit.**	
		Volume (m^3/d)	**Total (m^3/d)**	**Volume (m^3/d)**	**Total (m^3/d)**	**Volume (m^3/d)**	**Total (m^3/d)**
Decant at pit perimeter	North-pit-	0	8930	0	7500	970	8570
	South-pit	6720		4940		4940	
	East-pit	2210		2560		2660	
Decant seeping from underground into river	Zaaiwaterspruit tributary at East-pit	130 *	390 *	130 *	350 *	130 *	370 *
	Zaaiwaterspruit between North-pit and South-pit	260 *		220 *		240 *	

* If subsidence occurs where the 4Seam mining is too shallow, then all decant might occur in the streams.

For the base-case, the main decant areas would be the North-pit (=0m^3/d), South-pit (=6720m^3/d), East-pit (=2210m^3/d), Zaaiwaterspruit tributary at East-pit (130m^3/d) and Zaaiwaterspruit between North-pit and South-pit (=260m^3/d). These volumes can double during wet rainfall cycles or much lower during dry rainfall cycles. Decant will vary seasonally.

Due to having the lowest decant elevation, the South-pit may decant the highest volume, irrespective of the modelling scenario, but in the vicinity of the North-pit and Zaaiwaterspruit decant points. If the adits are sealed, less water will flow into the South-pit, compared to when the adits are not sealed, i.e. lower projected decant volume. Some decant might occur from the North-pit if the Zaaiwaterspruit is not undermined.

If subsidence occurs where the 4Seam mining is too shallow, then all decant might occur in the streams.

If no shallow underground mining is undertaken beneath the streams, no instream decant is expected, except relatively minor seepages near the Pit decant points.

Assuming that the pits will be relatively dry for the LOM to enable mining, it will take 15years to 20years for the first decant to occur. This can be delayed by 5years to 10years if no shallow underground mining is undertaken beneath the streams.

The biggest inter-mine flow interaction will be with Khutala from the west (557m^3/d in the Pit A area). It is also likely that significant inter-mine flow will occur from the neighbouring eastern/south-eastern/southern underground areas once these flood.

Recommendations to reduce the mine water balance during both the operational phase and post-closure phase:

- Only mine the underground sections beneath the streams, which are >20m deep (recommended during geotechnical engineering stability assessment by *Bare Rock Consulting*, Ref: BR_16_2021s March 2022). This applies to 4Seam coal beneath the Zaaiwaterspruit (between the North-pit and South-pit) and the eastern wetland stream tributary of the Zaaiwaterspruit (east of East-pit).
- Grout underground sections where large groundwater inflows are observed.
- Ensure that barrier pillars with neighbouring mines are as wide as possible.
- Effectively reduce the infiltration potential of opencast pits through good rehabilitation, shaping, vegetation and run-off designs.

Recommendations to improve the mine water balance during both the operational phase and post-closure phase:

- Where possible, coal discard and carbonaceous rocks should be placed in the deepest part of the pit (at least 20m deep) and covered as soon as possible.

Table of Contents

1. INTRODUCTION

1.1. Background

Groundwater Square updated the Goedgevonden (GGV) groundwater impact assessment, inclusive of numerical groundwater modelling in 2021 (Ref: GW2_444GGVg, July 2021). This model did not provide for the envisaged underground mining areas for which authorisation is now sought in both the GGV and Oogiesfontein Sections.

Glencore appointed *Jacana Environmentals* to assist with an EMP amendment for the GGV Complex and requested *Jacana Environmentals* to approach *Groundwater Square* to revise the recent report based on the proposed new mine layout. The most important consideration of the proposed underground mining is that the plan is to undermine two streams in the area:

- Central UG undermining the Zaaiwaterspruit river diversion.
- Eastern UG undermining a small tributary/wetland system to the Zaaiwaterspruit.

1.2. Study Approach

The latest *Groundwater Square* groundwater report (Ref: GW2_444GGVg, July 2021) was updated with the revised numerical modelling results for the entire GGV area, inclusive of opencast and underground mining according to the Sep'2021 life-of-mine (LOM) plan. Several sections and paragraphs have been duplicated for completeness. Geochemical predictions for the underground were determined from the 2019 geochemical laboratory and geochemical modelling work.

Where relevant, report sections were reproduced from the existing 2021 report.

It is believed that the current model, which was originally compiled in 2018, and then refined for the updated LOM plans in 2019 and 2021, and again for the 2021-underground, is probably sufficiently calibrated.

Groundwater level and groundwater quality trends were researched in the mentioned 2021 report, through data analysis and in terms of numerical groundwater modelling predictions. Groundwater levels & quality, mine water quality and mine water balance information were evaluated in terms of contamination status, groundwater level trends and groundwater quality trends.

Geochemical conditions were assessed in terms of the placement of coal discard material into the mined voids and considering the geochemical findings of nearby GOSA mines iMpunzi and Tweefontein.

In addition to the post-mining decant assessment (i.e. location, volume, quality over time), groundwater inter-flow between opencast/underground mining units were investigated and relevant groundwater information for the mine water balance were determined on an annual basis.

The groundwater impacts of the mine Residue Facility (MRF), Old Ogies Dump and Discard Dumps in and around GGV were described conceptually.

Recommendations were made on updating the existing groundwater monitoring system.

1.3. Description of Activities

The current total area to be mined is approximately 3200ha of which 800ha will be underground mining. Based on the mine plan, the opencast areas were determined as North-pit (610ha), South-pit (1260ha) and East-pit (530ha) for a total of (2400ha).

According to the opencast life of mine (LOM) plan, indicated in Figure 1.2, mining will continue until 2043. Opencast mining is undertaken through both dragline and truck and shovel methodologies. The LOM includes mining of the pillars of the Old Ogies workings. Underground developments, in the deeper reserves to the north and underneath the Zaaiwaterspruit (between the North Pit and South Pit) and small tributary/wetland system to the Zaaiwaterspruit (east of the East Pit), over a 6year period for both the 4Seam and 2Seam, are being applied for (see Figures 1.3).

The following description of the mining environment serves as background to the groundwater impact assessments (see Figures 1.1-1.3 and 2.1-2.2):

- Existing Goedgevonden Colliery (GGV), mining:

  - Zaaiwater Pit (expansion project – old Ogies Colliery pillar extraction).
  - North-pit 1 and North-pit 2 (including the expansion project old – Ogies Colliery pillar extraction).
  - South-pit opencast.
- Neighbouring mining:
  - *South32/Seriti* Khutala Mine Block A (±280ha) opencast pit on Zondagsvlei 9-IS to the west. The expected decant elevation for the neighbouring *South32/Seriti* Block A opencast pit is ±1570mamsl.
  - Zondagsvlei Project Z opencast and underground directly north of Khutala Mine Block A and west of Goedgevonden North-pit.
  - Khutala and Zibulo underground mining - 4Seam and 2Seam to the south and west.
  - Klipspruit and Zibulo opencast mines to the north, north of the Ogies dyke.
  - According to Google Earth aerial photographs, the Kleinzuikersboschplaat area of the Klipspruit underground is mined opencast.
  - The northern portion of the Goedgevonden reserve, north of the Zaaiwater river diversion, was historically mined underground (Old Ogies Colliery underground workings, 1920's).
  - Historical and current mining at Witcons and Tavistock are located further to the east and southeast.
- Planned mining
  - Underground mining is being planned (and applied for) around the current opencast areas in both the GGV area and the Ogiesfontein area in the northeast.

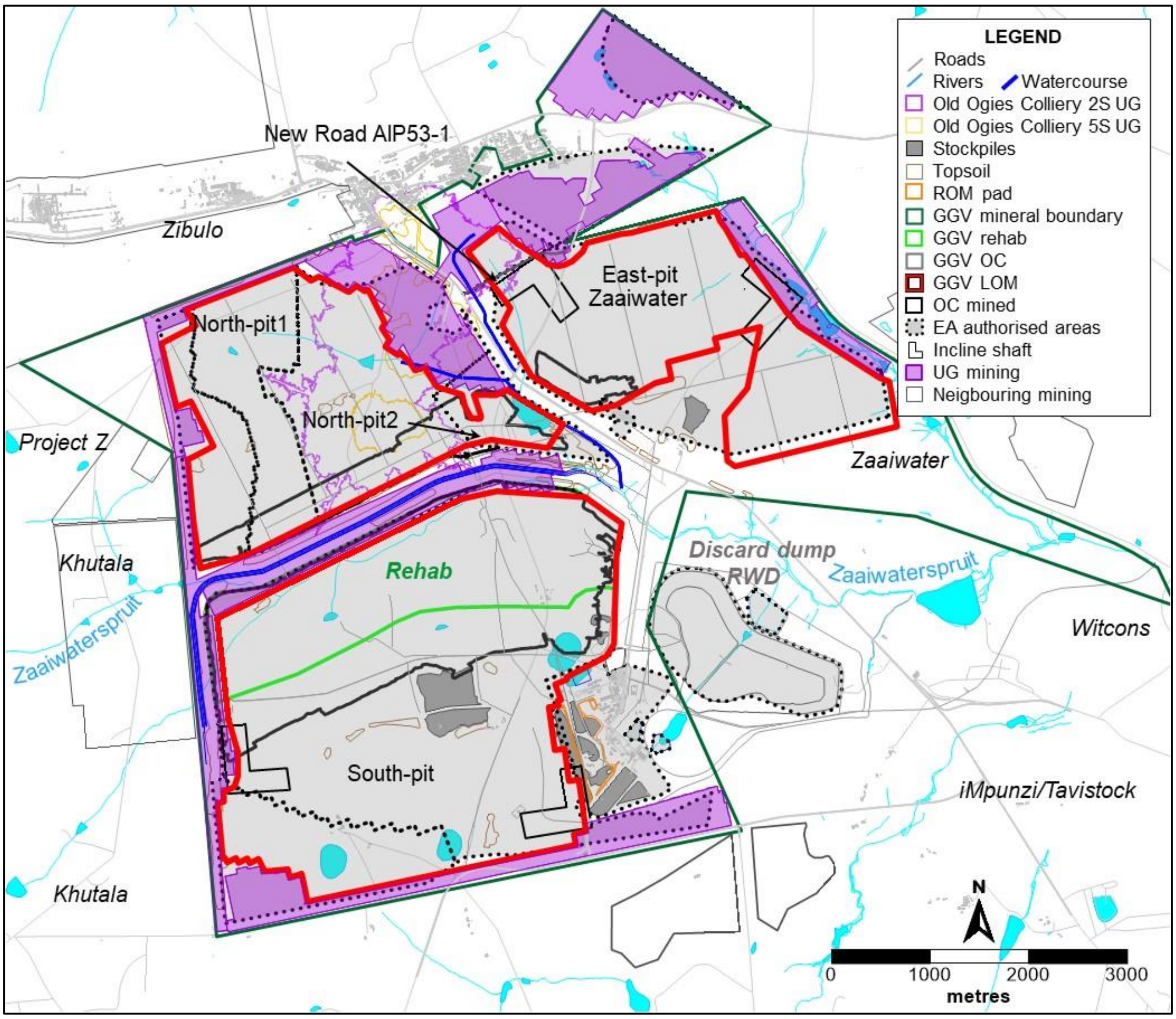


Figure 1.1 **Goedgevonden Mine layout and infrastructure indicating neighbouring mining**

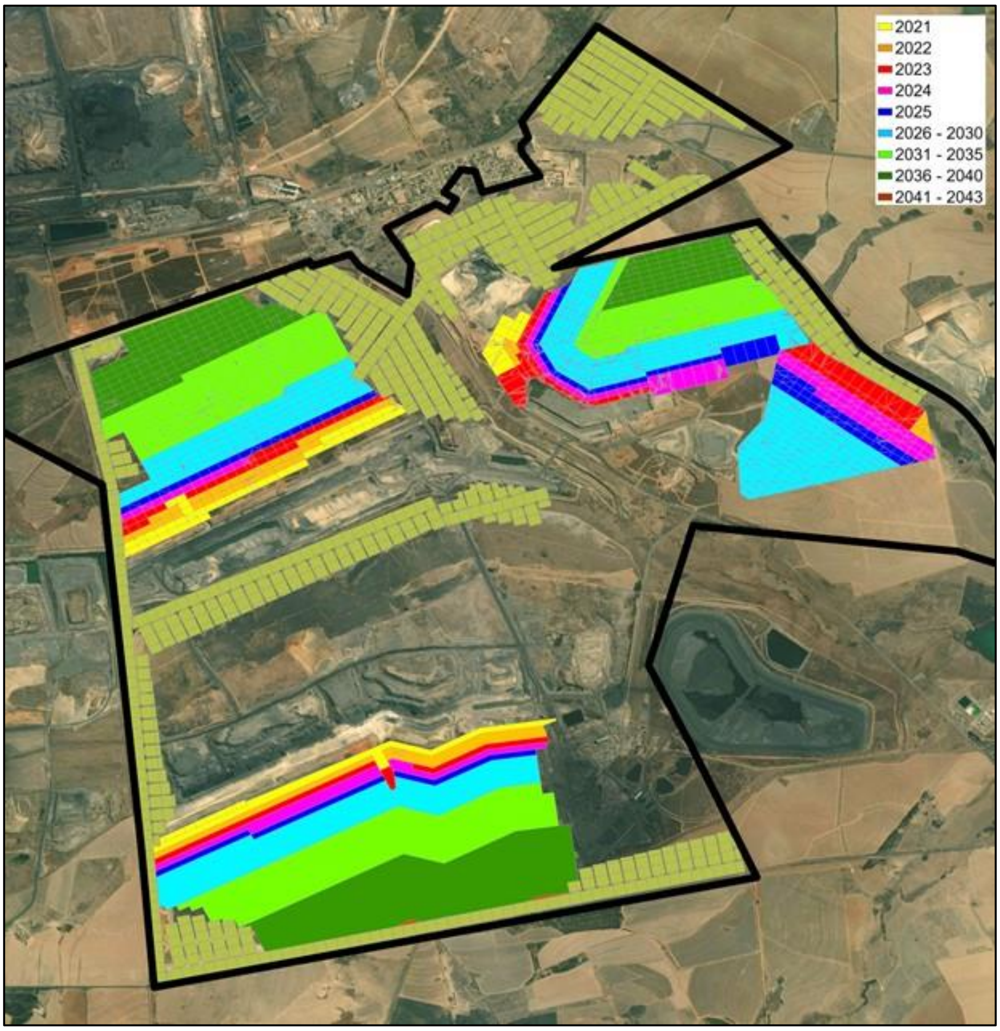
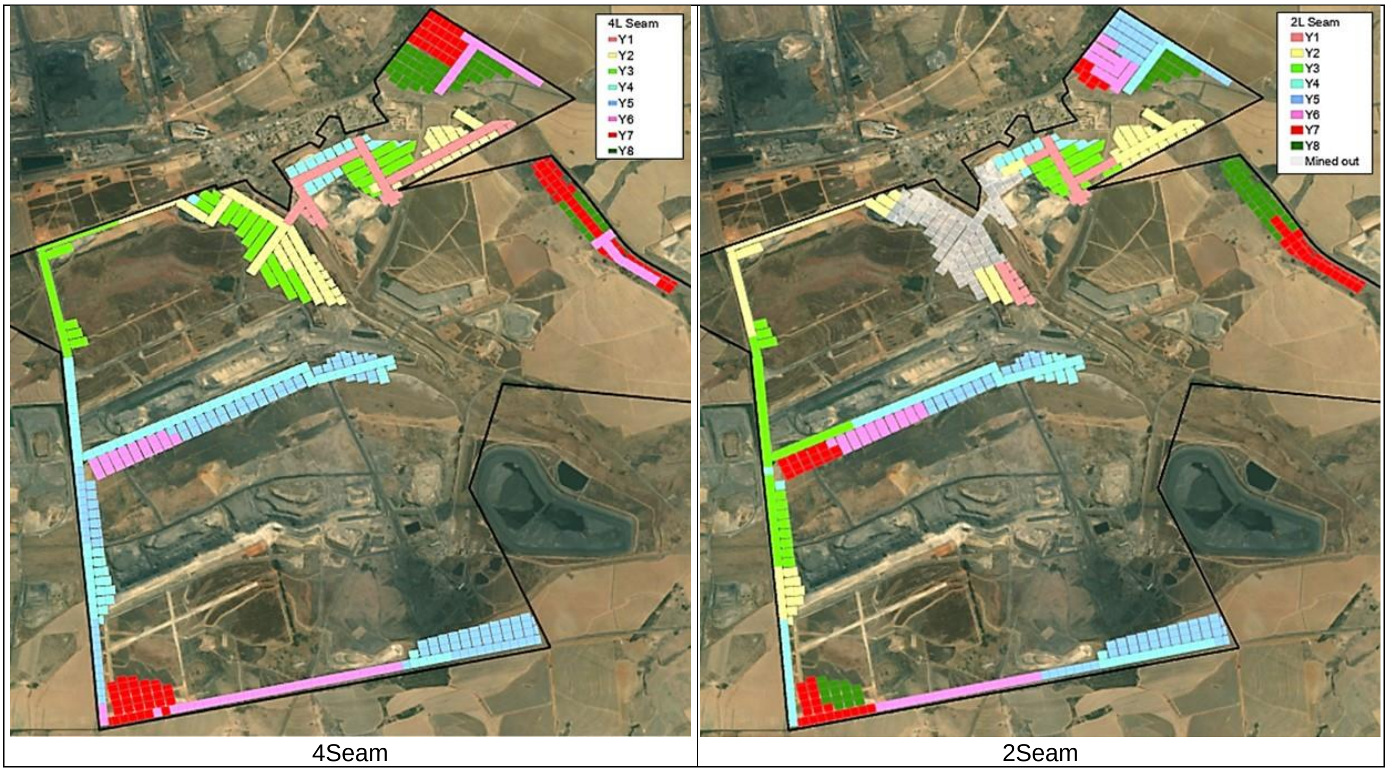


Figure 1.2 GGV opencast life-of-mine plan



4Seam

2Seam

Figure 1.3 GGV 4Seam and 2Seam underground life-of-mine plan

The following comments relate to the processing of coal:

- The plant has been operational since 2009 and is designed to process more than 12Mtpa ROM. The expansion project initiated in 2013 will eventually allow for an additional 12Mtpa and includes a pillared ROM tip and overland conveyor, as well as a raw coal sized stockpile providing for surge and storage capacity between the existing ROM, the ROM tip and the plant. The second phase has another 1000tph module planned, similar to the existing two modules, and a 5Seam Coal Handling Processing Plant or a blending facility within the plant dirty water footprint.
- The coal discard (moisture content 13% by mass – peak feed current and future 280kt/month to 420kt/month) generated during the beneficiation process is placed on the Mine Residue Facility (MRF). The ROM values for the period between August 2018 and August 2019 ranged between ±550kt/month and <1,1Mt/month, while the coal discard produced for the same period ranged between ±81kt/month and ± 152kt/month.
- Approximately 70% of the coal discard from the coal beneficiation plant are placed back into the pits as part of the rehabilitation process.
- Slurry tonnage ranging between ±37kt/month and ±113kt/month thickened to range between ±86kt/month and ±262kt/month, (between August 2019 and August 2020) produced during the coal beneficiation process is pumped to the MRF for dewatering and disposal.
- The MRF (165ha – 3.3Mm^3) liner incorporates 2 x 150mm compacted clay layers, overlain by a 150mm desiccation, protection and drainage layer (2020 IWWMP) [3 x 150mm compacted clay layers, totalling 450mm in thickness, covered by a desiccation layer – 2007 IWUL).
- The downstream flanks of the facility are contained by a seepage cut-off trench excavated down to impermeable strata. The lateral seepage intercepted by the trench is returned via a sump into the return water system.

A recent environmental audit determined that the Old Ogies Dump and Discard Dumps in and around GGV are not described in terms of their impacts on the groundwater system. These aspects are addressed conceptually in this report.

1.4. Terms of Reference / Scope of Study

The following terms of reference are proposed:

- Update the life-of-mine information and maps.
- Perform a geochemical assessment of underground mining areas.
- Adapt the numerical model grid and update numerical groundwater model.
- Perform numerical modelling.
- Update report with impact assessment findings.
- Discuss findings with *Jacana Environmentals*.

Disclaimer – The state of hydrogeological knowledge will be presented as accurately as possible using available information. Groundwater Square will exercise due care and diligence in gathering and evaluating relevant information, and performing calculations. Groundwater Square will not accept any liability in the event of encountering unexpected aquifer conditions during mining and further investigations.

2. SETTING

GGV is situated in the Mpumalanga Province, 7km south of the town of Ogies. Summarising from the previous *Groundwater Square* groundwater impact assessment report (Ref:44d, 2019):

- A mean annual precipitation (MAP) of 700mm/a and a mean annual evaporation (MAE) of 1650mm/a is applicable to all relevant calculations in this report (WRC study by Midgley, 1994).
- The mean annual S-class pan evaporation in the vicinity of *GGV* is 1345mm (DWS Station B1E001 Witbank at Witbank Dam, Golder 2020 IWWMP).
- Natural drainage is primarily to the northeast and east, with the Zaaiwaterspruit and Klippoortjiespruit being the major drainage lines (Figures 2.1, 2.2 and 3.1). The mining area is roughly divided in half by the wide floodplain of the Zaaiwaterspruit with stream diversion (J&W, 2013).
- Surface elevations within the regional model boundary (Figure 2.1) range between 1530mamsl (northeast) and 1630mamsl (south).
- The GGV area comprises gently sloping ground with slopes generally ranging 1% to 5%. As can be seen in Figures 2.1 and 2.2, the original location of the Zaaiwaterspruit along the northern border the South-pit has been diverted between the North-pit and the South-pit.

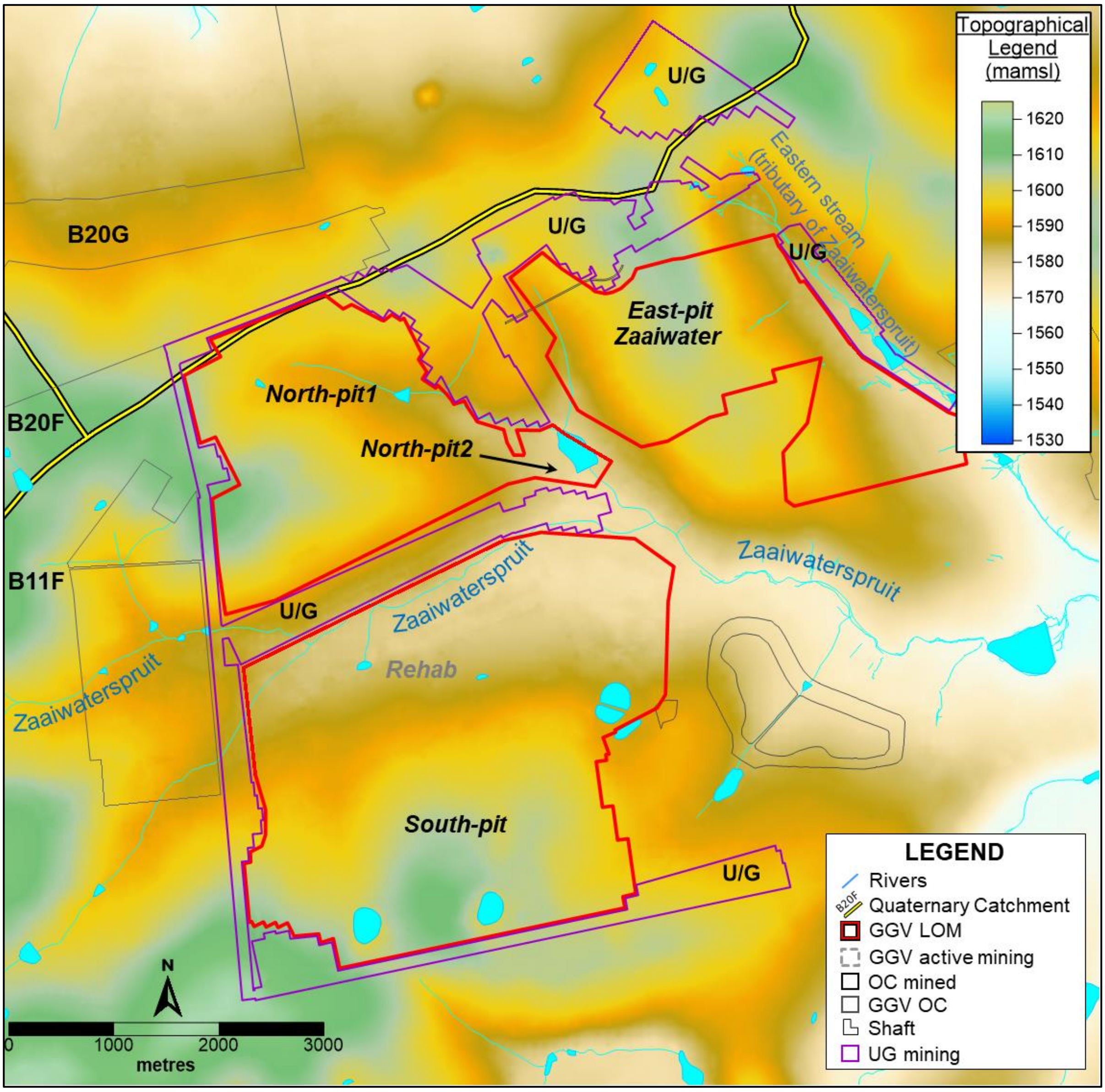


Figure 2.1 *Mine layout portrayed against the thematic depiction of pre-mining surface topography include*

- Locally, the coal-bearing unit of the Ecca Group, namely the Vryheid Formation, contains the mineable coal seams of the 5Seam, 4SeamU, 4SeamL and 2Seam, as well as strata comprised of sandstone/mudstone/siltstone/shale. The coal seams occur in a succession ranging in depth between 3.6m and 103.1m below surface.
- Based on the coal qualities summarised in the 2006 Mine Works Plan in Table 2.2, large areas of high Sulphur (S) content are present, which are irregularly distributed. The average S contents are for 5Seam (1.4%), Select and Top 4Seams (1.3%), 2Seam Select (1.3%) and 2Seam Top (1.1%).
- The west east striking Ogies dyke transects the Ogies Combined School grounds on Ptn.35 of the farm Grootpan 7 IS between the old Ogies Colliery and the old Ogies Navigation Colliery to the north. The northern-most portion of the former is also located north of the dyke. The Ogies dyke is ±15m thick and dips between 73 and 79 degrees to the south.
  - A major southwest-northeast orientated structural geological feature (graben) is known to transect the neighbouring Khutala underground area to the south, also observed in Glencore Tweefontein Colliery to the southeast.

Figure 2.2 Mine layout portrayed against Google Earth aerial photo backdrop

An analysis of the natural rainfall cycles indicated the wettest periods in 2000-2001, 2009-2011 and 2019-2022. A very dry rainfall cycle was experienced 2012-2015.

3. DATA

Mine water volume records and hydrogeological information from previous GGV groundwater studies, the integrated water use license, the 2020 IWWMP (*Golder*, Ref: 1791205-333857-5, July 2020) and data sets from ongoing environmental monitoring system (sourced from the contracted service provider, *Aquatico Scientific (Pty) Ltd*) were evaluated.

Limited field verification of monitoring points, focusing on the flooding status of the old Ogies Colliery 2Seam underground workings was performed within GGV in 2019 and 2021.

3.1. Mine Water Management

The 2017 Expansion WUL provides for the abstraction and reuse of 1.60Mm^3/a, 2.84Mm^3/a and 1.42Mm^3/a, respectively from the Zaaiwater Pit, South-pit and the North-pit (total 5.86Mm^3/a). The following comments relate to the mine water circuit (see Figure 3.1):

- Water accumulation in the pits is channelled to a temporary in-pit collection dam from where the water is pumped to the Zaaiwater Container, North Pit 1 Container and Ramp 1 Container. Mainly clear water is pumped from the north (North Pit Expit) to the Spaghetti Junction. Water from the Spaghetti Junction is distributed to the Raw Water Dam, Waterpan and MRF. Water is sent to the MRF only when Raw Water Dam and Waterpan volumes are at full capacity.
- The lined Raw Water Dam (RWD) receives water from the Western Stormwater Dam (PCD), Spaghetti Junction, Waterpan, and the Return Water Dam. The dam supplies to the Raw Water Tank, process water to the plant (average plant raw water feed 9,600m^3/d - Golder 2020), flow to the Return Water Dam and overflow to the Eastern Stormwater Dam (PCD). The RWD has an estimated storage capacity of 78 000m^3. The 2013 study indicated the plant raw water feed to be approximately 8,282m^3/d from 2015 onwards.
- During times of water deficit, make-up water is pumped into the Raw Water Dam from the Waterpan pipeline. Similarly, during times of water surplus, water is pumped from the Raw Water Dam via the Waterpan pipeline to underground storage at Waterpan or Boschmans South.
- The *J&W* 2013 mine water balance indicated the average volume of water that needed to be brought in over the winter period for the next 3years amounted to ±2,200m^3/d, over the LOM ±820m^3/d, and over the last 5 years of mining ±850m^3/d for average rainfall.
- *J&W* also stated that, for average rainfall conditions, 4,220m^3/d would need to be pumped to the Tweefontein Water Treatment Facility or available underground storage over the LOM. Over the last 5years of mining the volume would increase to 6,120m^3/d.

The post-closure water make was indicated to amount to approximately 8,500m^3/d. The 2019 *GW2* Groundwater Impact Assessment indicated an average post-closure water make of approximately 8,700m^3/d, which may double during extremely wet rainfall seasons, but much lower during extremely dry seasons.

The *Golder* IWWMP (2020) indicated average water make of 4,926m^3/d for the opencast section over the total LOM. Their water balance simulated for the period 2020/01/01 to 2020/03/31, which showed an overall deficit of 482m^3/day, indicated average water make of 5,903m^3/d for the opencast sections and 10,879m^3/d (average based on historical data) dewatering from the old Ogies underground workings, thus 16,782m^3/d in total.

Further comment on the Old Ogies underground workings is provided in Section 3.2.

Meter readings made available for this study indicate approximate averages of 4,125m^3/d for North Pit Expit and 3,871m^3/d for South Pit Expit being pumped for the 2019/20 hydrogeological year, which respectively increased to 6,249m^3/d and 4,565m^3/d (total 10,814m^3/d) for the first quarter of the 2020/21 year.

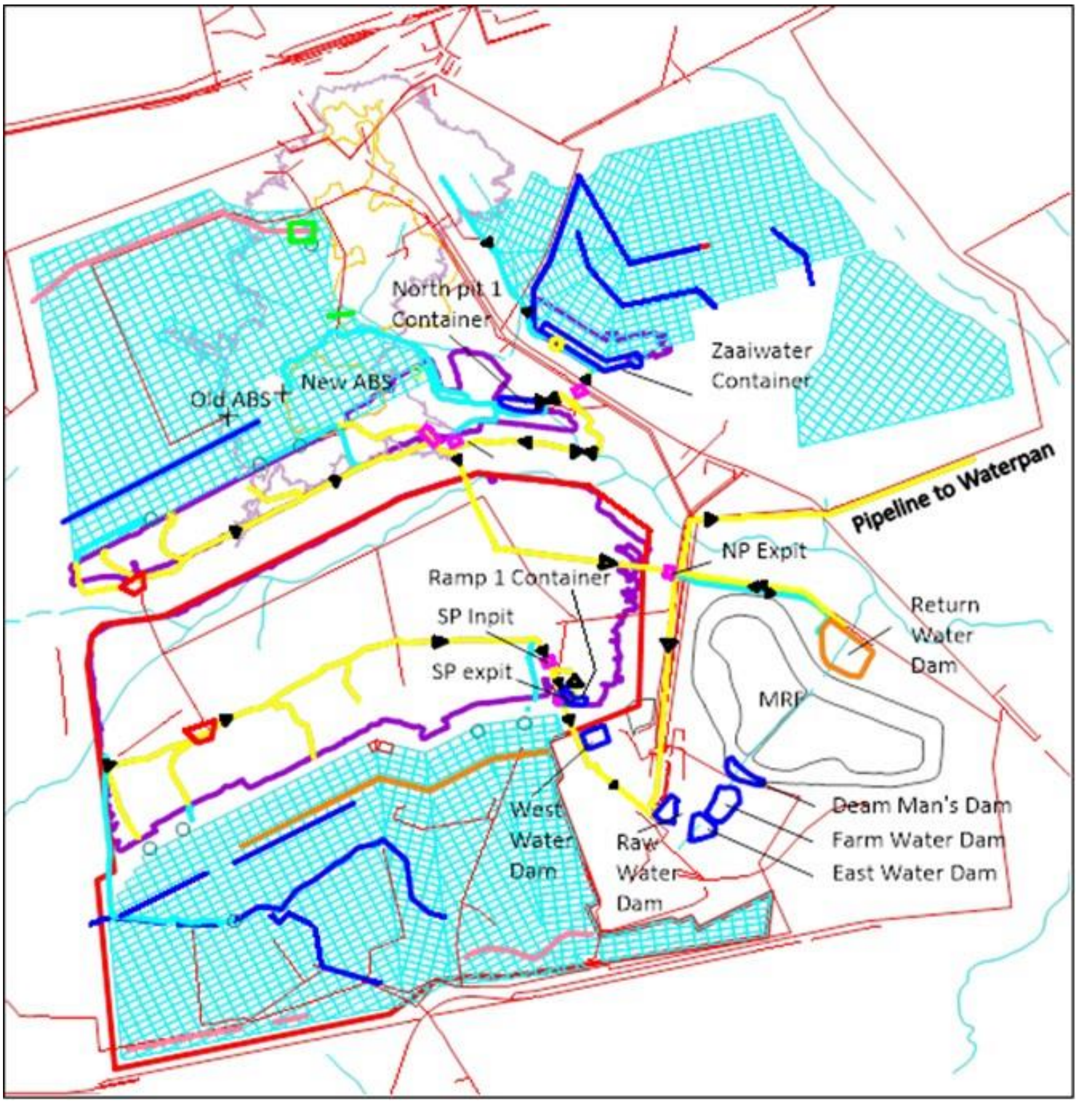


Figure 3.1 GGV current mine water management plan (ref: GW2_444GGVg, 2021)

The following additional comments are important:

- The lined "Eastern Pollution Control Dam" (PCD) or Eastern Stormwater Dam (ESWD) has a capacity of ±60,000m^3 (2020 IWWMP). Dirty runoff from the plant area, product stockpiles and overflow water from the Raw Water Dam is directed to the Eastern PCD. Excess water spills to the unlined "Farm Dam", which in turn overflows into the Railway Dam or Deadman Dam (±10 000m^3). Water from the Deadman Dam is pumped to the MRF Return Water Dam. The "Farm Dam", which has a significant clean catchment area within the rail loop, has a capacity of 27,000m^3 (2020 IWWMP).
- The lined "Western PCD" or Western Stormwater Dam (WSWD), which has a capacity of ±34,000m^3 (2020 IWWMP), contains dirty runoff from the workshops as well as treated water from the Sewage Treatment Plant. The stormwater is channelled to a silt trap before entering the dam. Outflows include Raw Water Tank demand and process water to the Raw Water Dam. The sewage treatment plant (capacity 50m^3/d) treats the sewage effluent from the offices and workshops.
- The Raw Water Storage Tank (10,000m^3) is supplied from the Raw Water Dam and Western Stormwater Dam. The main purpose of the storage tank is to supply water for dust suppression, fire water at stockpiles, wash bay and dust suppression on haul roads to the pits. The 2020 IWWMP indicates flow rates of 660m^3/d to both ROM stockpiles (34.8ha) and product stockpile (14.5ha), as well as 1,946m^3/d to dust suppression on the haul roads to the pits. The wash bay is used for the washing of mine trucks and other production equipment. The Raw water storage tank supplies the wash bay with approximately 660m^3/day of water.
- The lined MRF Return Water Dam has a capacity of ±239,000m^3 (2020 IWWMP). The Tailings Return Water Dam receives runoff, seepage and slurry return water from the MRF. Water is

pumped from the Tailings Return Water Dam to the Raw Water Dam for reuse in the coal processing plant.

- The water treatment plant is used to process the supernatant from the Mine Residue Facility. The treated water is used within the offices and workshops. The water treatment plant has an estimated total treatment capacity of 50m^3/day(?).
- The primary river diversions are the Zaaiwaterspruit and Southern Tributary diversions. The latter intercepts clean runoff approaching the plant area from the west and the south and conveys the water in an easterly direction around the plant, following the alignment of the rail loop for most of its length. Once it has passed the MRF, the canal passes under the railway line and discharges the water into the Zaaiwaterspruit, just upstream of Witcons Dam.
- Secondary water management measures exist in the form of the southern diversion canals. Two sacrificial clean water diversion canals have been constructed to the south of the advancing pit, directing clean runoff in a westerly direction into the upstream end of the Zaaiwaterspruit diversion. The area to the north of the lower canal has been stripped in preparation for mining and is therefore considered part of the dirty water system.

3.2. Old Ogies Colliery Flooding Status

The water volume pumped from the old Ogies Colliery to enable mining its remaining pillars is adding a significant volume to the GGV water balance.

During mid-2021 (Ref: GW2_444GGVg, 2021), it was estimated that the old Ogies Colliery 2Seam underground workings (Figure 3.2) potentially still featured a significant water volume above the 1526.65mamsl level north of the "New ABS" borehole.

Based on the in-pit mined-out floor elevations, the North Pit opencast advancement intersection of the old Ogies Colliery 2Seam underground workings ranged from ±1520mamsl to ±1540mamsl along the north-western intersection. The southern portion of the southernmost 5Seam underground workings (±318,068m^2) was also already been intersected between ±1556.5 and ±1562mamsl, basically leaving these workings dewatered. The northern 5Seam workings were still flooded ±2m above the floor at the beginning of January 2018.

For various reasons, it was not possible to determine the underground volumes during the 2021 study because of the uncertainties relating to the borehole collar elevations, mine water level depths and whether boreholes penetrated the underground workings. Assuming a water level of 1524mamsl in the 2Seam workings indicated water in isolated pools totalling ±1.6Mm^3. At a water level of 1522mamsl, only ±0.1Mm^3 would be contained in the workings. It is believed that the mine water level already reached 1554mamsl in 2019.

Assuming the northern 5Seam underground section to be flooded, this equates to ±0.889Mm^3.

Mine water quality data for a sample taken from "New ABS" borehole during the 29/4/2021 site visit is included in Table 3.1.

Table 3.1 Old Ogies Colliery 2Seam underground workings – Water Quality

Sample Id	pH	EC (mS/m)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)	Fe (mg/L)
New ABS	2.82	886	12 381	545	664	214	38.2	7.43	9 267	<0.35	1 381

Additional information is contained in the previous groundwater impact assessment (Ref: GW2_444GGVg, 2021)

3.3. Database

All current and inactive groundwater, mine water & surface water monitoring localities are indicated in Figure 3.2. Active monitoring boreholes are indicated in Figure 3.3. Pertinent hydrogeological information (e.g. location, starting and ending water levels, aquifer testing, as well as starting and ending water qualities) for existing monitoring boreholes are listed in Tables 3.2A-C.

Pertinent surface water information in terms of "mine water" qualities and "rivers and streams" water qualities (e.g. location, point description, selective, median monthly quality concentrations and statistical analyses for the period Dec' 2012 to Mar' 2021) are listed in Tables 3.3A-B and 3.5A-B.

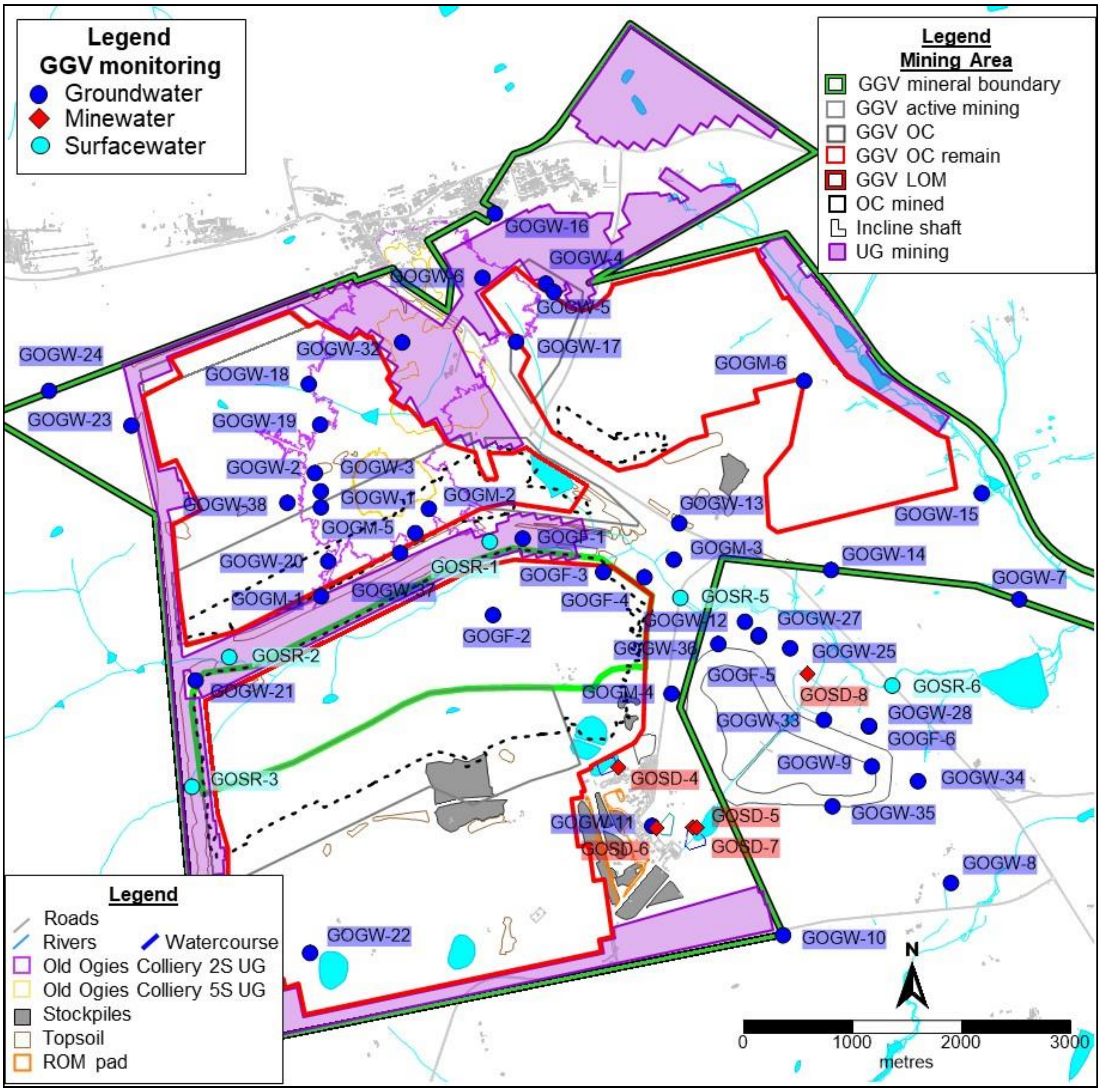


Figure 3.2 ***All active and inactive groundwater, mine water & surface water monitoring localities***

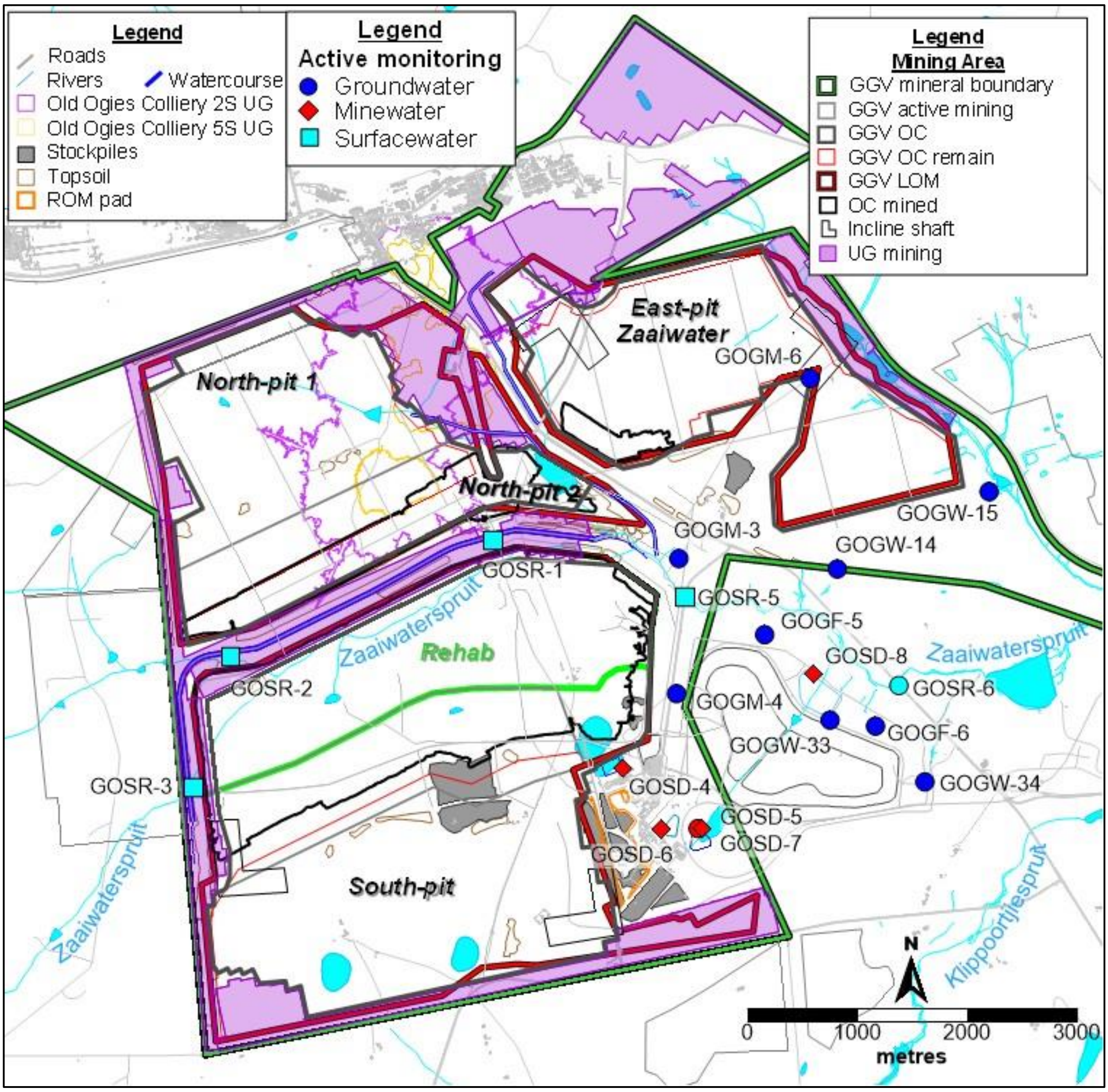


Figure 3.3 All current (active) groundwater monitoring localities

Table 3.2A Pertinent hydrogeological information – location and groundwater level ranges

Borehole number	Coordinate (WGS84)			Starting and ending water levels (m)			
	Latitude	Longitude	Z	Date	Water level	Date	Water level
GOGW-1#	-26.07585	29.04401	1610.40				
GOGW-2#	-26.07302	29.04345	1597.00	2013/06/10	18.21	2014/12/02	16.83
GOGW-3	-26.07453	29.04400					
GOGW-4	-26.05736	29.06464	1599.90	2013/03/12	5.07	2017/12/08	8.44
GOGW-5	-26.05805	29.06537	1599.50	2013/03/12	4.47	2017/12/08	4.64
GOGW-6*	-26.05688	29.05882	1593.90	2013/03/12	11.45	2017/09/13	9.63
GOGW-7	-26.08343	29.10807	1557.70	2013/03/12	3.04	2017/12/08	2.8
GOGW-8	-26.10687	29.10183	1565.80	2013/03/13	1.21	2017/12/08	4.34
GOGW-9#	-26.09724	29.09456					
GOGW-10*	-26.11120	29.08643					
GOGW-11#	-26.10217	29.07441					
GOGW-12	-26.08529	29.08291	1560.90	2013/03/13	2.22	2017/12/08	1.11
GOGW-13#	-26.07716	29.07688	1586.90	2013/03/13	6.08	2016/09/22	7.85
GOGW-14	-26.08101	29.09081	1583.20	2013/03/13	7.2	2021/03/15	7.11
GOGW-15	-26.07466	29.10463	1553.80	2013/03/13	2.77	2021/03/15	2.35
GOGW-16	-26.05158	29.05996					
GOGW-17	-26.06217	29.06190	1580.10	2013/03/13	5.08	2017/12/08	5.56
GOGW-18*	-26.06567	29.04289	1588.20	2013/03/12	3.07	2016/03/16	7.43
GOGW-19*	-26.06902	29.04394	1584.90	2014/06/23	5.64	2017/12/06	4.8
GOGW-20	-26.08032	29.04468					
GOGW-21	-26.09017	29.03252					
GOGW-22#	-26.11268	29.04303	1606.70	2013/03/13	1.33	2017/06/05	1.76
GOGW-23	-26.06910	29.02662	1608.80	2013/03/12	4.74	2019/06/12	4.18
GOGW-24	-26.06623	29.01907	1606.10	2013/03/12	10.59	2019/06/12	10.32
GOGW-25	-26.08748	29.08706	1556.80	2013/03/13	2.81	2017/12/08	0.98
GOGW-27	-26.08650	29.08416	1562.90	2013/03/13	3.42	2017/12/08	1.35
GOGW-28	-26.09394	29.09430	1553.00	2013/03/11	0.89	2017/12/06	0.32
GOGW-32#	-26.06222	29.05145	1593.60	2013/03/11	24.17	2017/03/22	18.21
GOGW-33	-26.09340	29.09016	1563.60	2013/03/11	7.25	2021/03/17	10.26
GOGW-34	-26.09846	29.09880	1563.80	2013/03/11	1.88	2021/03/17	2.20
GOGW-35#	-26.10054	29.09095	1573.10	2013/03/11	10.36	2015/09/25	6.49
GOGW-36*	-26.08713	29.08047	1564.00	2013/03/11	6.94	2020/03/11	5.81
GOGW-37#	-26.07963	29.05127	1584.80	2013/03/12	7.14	2013/09/02	7.84
GOGW-38#	-26.07548	29.04093	1602.50	2013/03/12	19.67	2015/09/25	19.33
GOGF-1	-26.07843	29.06252					
GOGF-2	-26.08475	29.05980					
GOGF-3	-26.08120	29.06990	1560.90	2013/06/12	3.58	2017/12/08	2.71
GOGF-4	-26.08162	29.07369					
GOGF-5	-26.08640	29.08420	1560.90	2013/06/12	3.71	2021/03/17	2.49
GOGF-6	-26.09389	29.09430	1553.00	2013/03/11	0.48	2021/03/17	0.70
GOGM-1#	-26.08320	29.04403	1587.00	2011/03/01	43.76	2013/12/02	48.11
GOGM-2#	-26.07597	29.05391		2011/03/01	45.28	2014/01/01	49.11
GOGM-3^	-26.08016	29.07638	1569.40	2012/02/20	4.31	2020/09/22	5.20
GOGM-4^	-26.09124	29.07618	1578.80	2012/02/20	7.24	2020/09/22	7.71
GOGM-5	-26.07798	29.05267		2011/06/01	45.13	2013/12/03	47.41
GOGM-6^	-26.06539	29.08833	1588.20	2012/02/20	2.58	2020/09/22	2.77

[#] = Destroyed, [*} = Blocked, damaged or no access, [^] = Not UG borehole

Table 3.2B Pertinent hydrogeological information – hydraulic information

Borehole number	Alternative number	Date	Collar (m)	Depth (m)	Water level (m)	Hydraulic conductivity through slug-testing (m/d)
GOGW-23		20180821	0.50	45.96	4.59	4.84E-03
GOGW-24		20180821	0.34	13.30	11.13	4.56E-02
GOGW-28	GVV-2S	20180813	0.30	4.54	0.28	6.71E+00
GOGW-33		20180813	0.59	37.18	11.77	1.79E-03
GOGW-34		20180813	0.33	45.55	1.45	2.47E-01
GOGF-6	GVV-2D	20180813	0.38	28.26	0.58	1.45E-02
GOGM-3	GZM-3	20180813	0.77	29.59	5.25	3.47E-02

Table 3.2C Pertinent hydrogeological information –groundwater quality ranges

Borehole number	Starting water quality					Ending water quality				
	Start date	EC (mS/m)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)	End date	EC (mS/m)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)
GOGW-1	2006/01/26	42.4	30	114	11.5	2013/06/10	68	24	102	0.4
GOGW-2	2006/01/26	46.7	14	86	0.9	2014/12/02	44	36	16	8.3
GOGW-3	2006/01/26	48	17	102	1.0	2009/12/15	88	77	74	4.0
GOGW-4	2006/12/07	37	37	34	1.0	2017/12/08	50	96	9	<0.46
GOGW-5	2006/06/28	28	40	16	1.0	2017/12/08	107	369	<0.45	<0.46
GOGW-6	2006/06/28	66	6	268	1.0	2017/09/13	86	10	429	1.9
GOGW-7	2006/06/28	8	4	15	1.0	2017/12/08	7	4	3	1.2
GOGW-8	2006/03/28	17	24	72	1.0	2017/12/08	17	25	<0.45	<0.46
GOGW-9	2006/03/28	20	<1	66	1.0	2008/03/17	12	3	6	1.0
GOGW-10	2006/03/28	29	4	4	1.0	2012/12/05	26	<1.408	2	<0.06
GOGW-11	2006/03/28	13	4	61	1.0	2012/12/05	236	7	2033	9.3
GOGW-12	2006/03/28	15	4	71	1.0	2017/12/08	19	5	47	6.3
GOGW-13	2006/03/28	30	14	62	4.0	2016/09/22	32	22	2	8.8
GOGW-14	2006/03/28	27	14	122	16.0	2021/03/15	22.73	10.23	1.80	21.41
GOGW-15	2006/06/28	11	4	<1	1.0	2021/03/15	11.26	5.27	1.71	<0.46
GOGW-17	2006/03/28	16	1	51	1.0	2017/12/08	16	4	<0.45	<0.46
GOGW-18	2006/03/28	29	1	102	1.0	2016/03/16	27	<2.303	1	0.8
GOGW-19	2006/03/28	14	4	43	1.0	2014/09/18	889	367	0	0.7
GOGW-20	2006/03/28	15		14	1.0	2009/12/15	32	<1.00	26	1.0
GOGW-21	2006/06/28	20	11	60	4.0	2009/09/16	46	<1.00	15	1.0
GOGW-22	2006/03/28	17	4	53	1.0	2017/06/05	14	4	4	0.9
GOGW-23	2006/03/28	13	1	24	1.0	2018/12/14	13	4	<0.452	6.7
GOGW-24	2006/03/28	18	1	<1.00	1.0	2018/09/05	19	3	5	<0.46
GOGW-25	2006/03/28	28	1	162	3.0	2017/12/08	13	3	1	<0.46
GOGW-26	2006/03/28	18	6	52	1.0	2007/10/24	15	11	1	1.0
GOGW-27	2008/03/17	7	4	<1.00	2.0	2017/12/08	63	5	306	<0.46
GOGW-28	2007/10/25	8	3	19	1.0	2017/12/06	156	10	1104	<0.46
GOGW-30	2007/10/25	8	6	<1.00	3.0	2008/06/13	8	4	1	6.7
GOGW-31	2007/10/24	17	18	12	3.0					
GOGW-32	2012/12/05	36.2	3	32	7.2	2017/03/22	17	16	5	9.9
GOGW-33	2012/12/05	23.1	7	44	11.0	2021/03/17	71.3	18.23	298	4.82
GOGW-34	2012/12/05	7.76	<1.4	3	3.1	2021/03/17	7.36	7.95	3.46	0.46
GOGW-35	2012/12/05	9.09	<1.4	0	6.3	2015/12/14	192	21	9	1.0
GOGW-36	2012/12/05	8.32	<1.4	3	5.3	2020/03/11	10.54	2.82	10.36	0.6
GOGW-37	2012/12/05	12.4	<1.4	2	6.7	2013/09/02	12	2	4	3.9
GOGW-38	2012/12/05	22.4	11	2	18.5	2015/09/25	27	<0.776	<0.957	2.1
GOGW-39	2012/12/05	28.9	2	4	2.8	2017/12/06	21	9	3	2.3
GOGF-1	2006/03/28	23	41	18	1.0	2018/12/12	11	3	3	4.9
GOGF-2	2006/03/28	18	7	70	1.0	2009/12/15	14	6	18	1.0
GOGF-3	2006/06/28	15	24	3	1.0	2017/12/08	13	23	1	<0.459
GOGF-4	2006/06/28	10	4	9	1.0	2008/03/17	16	4	1	1.0
GOGF-5	2007/10/24	9	4	4	1.0	2021/03/17	238.6	13.21	1375	<0.46
GOGF-6	2007/10/25	6	1	<1.00	1.0	2021/03/17	37.3	4.64	77.84	<0.46
GOGM-1	2012/01/16	15.2	9	12	7.7	2013/12/02	13	5	<0.132	4.8
GOGM-2	2012/01/16	25	10	13	5.8	2012/07/23		12	4	6.0
GOGM-3	2011/10/25	320	553	565	0.2	2021/03/17	207	404	290	<0.46
GOGM-4	2012/01/16	16	<1.4	10	<0.06	2021/03/17	14.98	3.20	9.78	<0.46
GOGM-5	2012/01/16	19	10	12	10.7	2021/03/15	14.81	5.37	6.84	<0.46
GOGM-6	2012/01/16	13	<1.4	<0.13	2.8	2020/09/22	17.9	7.22	13.4	<0.35

As far as the active monitoring site groundwater quality is concerned (Table 3.2C), regular monitoring boreholes GOGW-33 (south-eastern MRF Return Water Dam corner), and GOGM-3 (west of MRF) exceed the SANS 241-1:2015 aesthetic health limit for SO_4, whereas borehole GOGF-5 (north of MRF) exceeds the acute health (GOGF-5) limits.

An EC profile conducted on the water column in borehole GOGM-3 with a YSI 600XLM Multi-Parameter Probe during September 2020 indicated the EC to increased/ deteriorated from ±150mS/m to ±200mS/m between 13m and 16m below surface, from where the quality further deteriorated to 208mS/m to the end of the hole. Borehole GOGW-14 is indicative of a persistent non-mining related NO_3 concentration problem exceeding the SANS 241-1:2015 acute health limit.

The current groundwater monitoring system is not adequate to qualify inter-mine flow along both the western and southern boundaries, as well as the flooding status and available storage capacity of the old Ogies Colliery 2Seam underground workings. The monitoring system also cannot provide enough information to improve the numerical model calibration.

Recommendations in terms of commissioning addition monitoring points focusing on inter-mine groundwater flow were made in the previous groundwater model update and was addressed again in this report.

Table 3.3A Pertinent mine water monitoring information

Monitoring Point	Alternative number	Coordinate (WGS84)		Comment
		Latitude	Longitude	
GOSD-4	GOSWR10	-26.09734	29.07129	Western PCD dirty stormwater dam
GOSD-5	GOSWR11	-26.10229	29.07814	Eastern PCD dirty stormwater dam
GOSD-6	GOSWR12	-26.10234	29.07479	Raw water dam
GOSD-7	GOSWR13	-26.10230	29.07850	Existing farm dam
GOSD-8	GOSWR14	-26.08961	29.08864	Return water dam

Table 3.3B Pertinent mine water quality information

Monitoring point	Median Mine Water Qualities October 2011 to March 2021										
	pH	EC (mS/m)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)	T-Alk (mg/L)
GOSD-4	7.59	301	3062	438	274	62.4	16	25.9	2050	0.61	196
GOSD-5	7.94	321	3223	456	300	59.7	16.5	17	2223	5.42	107
GOSD-6	7.83	331	3399	467	323	60.6	16.5	15.7	2308	3.26	159
GOSD-7	7.53	278	2657	371	242	49.3	13	16.1	1822	2.75	88.5
GOSD-8	8.04	337	3363	462	332	61.7	17.1	15.6	2342	4.89	139

Table 3.4A Pertinent River & stream monitoring information

Monitoring point	Alternative number	Coordinate (WGS84)		Comment
		Latitude	Longitude	
GOSR-1		-26.07869	29.05950	Zaaiwaterspruit downstream GVV Ramp dam
GOSR-2		-26.08824	29.03560	Zaaiwaterspruit at bridge (licence condition)
GOSR-3		-26.09895	29.03218	Zaaiwaterspruit upstream at boundary with Zondagsvlei 9 IS
GOSR-5		-26.08332	29.07699	Zaaiwaterspruit @ the entrance road bridge
GOSR-6		-26.09056	29.09643	Spruit east of GVV, outside mine boundary @t R545 bridge

Table 3.4B Pertinent River & stream water quality information

Point		Zaaiwaterspruit water qualities – December 2012 to March 2021										
		pH	EC (mS/m)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)	T-Alk (mg/L)
GOSR-1	Min	4.53	23.74	198	16.60	10.10	1.58	0.60	1.41	79.93	0.06	6.00
	Max	8.30	365.90	3772	552.00	338.74	268.96	21.10	30.09	2578	14.10	229.88
	Med	7.16	105.00	781	93.90	68.50	33.53	10.90	11.84	507	0.46	44.00
GOSR-2	Min	4.10	16.00	132.00	10.40	6.92	1.11	0.55	1.41	35.85	0.06	7.26
	Max	7.93	425.00	4258.00	597.61	407.34	147.81	48.20	82.00	3099.91	2.25	254.00
	Med	7.22	84.75	659.00	72.75	54.15	29.80	9.66	13.94	374.50	0.46	66.25
GOSR-3	Min	3.18	15.8	124	9.32	6.78	5.3	0.041	1.41	8.55	0.057	6
	Max	8.18	435	4062	553	383	146	26.3	43.1	2856	2.47	320
	Med	7.33	105	712	95	64	46	8.6	10.4	499	0.459	160
GOSR-5	Min	3.31	12.72	94	9.81	6.37	2.69	1.95	1.41	34.7	0.06	8
	Max	8.19	327.6	3094	376	295	242	32.1	52.4	2261	1.19	143
	Med	7.18	77.95	601.5	71	42	29.7	12.3	22.1	324	0.46	47
GOSR-6	Min	3.01	33.9	175	21.1	12.8	4.52	1.17	1.62	91.3	0.057	6
	Max	9.17	385	3673	482	408	136	41.5	89.2	2647	5.6	165
	Med	4.68	140	1143	129	100	38.9	8.78	12.5	754	0.459	50

As shown in Table 3.4B, the river and stream water quality are poor. The median Zaaiwaterspruit instream SO_4 quality (152mg/L) for the corresponding period, immediately after the confluence with the Klippoortjiespruit, below the railway line bridge (WISR-7, Witcons Section of Tweefontein Colliery), is, however, below the SANS 241-1:2015 aesthetic limit. The instream quality of the Zaaiwaterspruit crossing the western boundary to enter GGV is of long-standing concern.

3.4. External Groundwater Users

The scope of work for this study did not include an updated hydrocensus. For the sake of completeness, pertinent external groundwater users' information relating to the 2019 *GW2* Groundwater Impact Assessment are summarised in Tables 3.5A-D. The relevant boreholes and wells are depicted in Figure 3.4.

Table 3.5A Hydrocensus - owner information

Nr on Map	Name of Owner	Address	Contact person	Telephone number	Name of Farm	Farm Nr
BH01	Boetie Gani	PO Box 187, Ogies, 2230	Boetie Gani		Grootpan	7 IS
BH02	Boetie Gani	PO Box 275, Ogies, 2230	Boetie Gani		Grootpan	7 IS
BH03	Boetie Gani	PO Box 275, Ogies, 2230	Boetie Gani		Grootpan	7 IS
BH04	Boetie Gani	PO Box 187, Ogies, 2230	Boetie Gani		Grootpan	7 IS
BH05	Boetie Gani	PO Box 187, Ogies, 2230	Boetie Gani		Grootpan	7 IS
OS-1	Ogies Combined	PO Box 165, Ogies, 2230	Mrs v.d. Merwe	013 643 1011	Grootpan	7 IS
OS-2	Ogies Combined	PO Box 165, Ogies, 2230	Mrs v.d. Merwe	013 643 1011	Grootpan	7 IS
OS-2 New	Ogies Combined	PO Box 165, Ogies, 2230	Mrs v.d. Merwe	013 643 1011	Grootpan	37 IS
WSW-20	Western Reserve	Project			Grootpan	7 IS
Mosque Well	Ogies Mosque	Main Ogies Bethal Rd Goedgevonden. No. 3		27-17-7851010	Goedgevonden	10 IS

Table 3.5B Hydrocensus – location information

Nr on Map	Drainage Region	Latitude	Longitude	Elevation (mamsl)	Site Type	Info Source	Site Status	Site Purpose	User Consumer	User Application	Equipment
BH01	B20G	26.05050	29.06774	1601.00	B	G	G	P	N	AD	S
BH02	B20G	26.05109	29.06805	1602.00	B	G	U	P	N		N
BH03	B20G	26.05124	29.06809	1602.00	B	G	U	P	N	AS	N
BH04	B20G	26.05010	29.06656	1598.00	B	G	U	P	N	AS	N
BH05	B20G	26.05050	29.06775	1597.00	B	G	U	P	N		N
OS-1	B20G	26.04811	29.07126	1602.00	B	G	G	P	N	DA	S
OS-2	B20G	26.04836	29.06874	1602.00	B	G	U	P	N		S
OS-2 New		26.04838	29.06883	1602.00	B	G	G	P	N	DA	S
WSW-20	B20G	26.04813	29.07135	1602.00	B	G	G	O	N	TM	N
Mosque Well	B11F	26.06503	29.05593	1581.00	D	G	U	P	N	DA	N

Codes: Site Type: B - Borehole, D - Dug well, Info Source: G - Geologist/technician/operator's record, Site Status: D - Destroyed, G - In use, U - Unused, Site Purpose: E – Exploration, O - Observation, P - Production(water supply), User Consumer: N - Non-urban, User Application: AD – Agricultural and domestic use, AS – Agricultural – stock watering only, DA – Domestic – all purposes, TM – Industrial – mining, Equipment: C – Centrifugal pump, H – Hand pump, M – Mono-type pump, N – No equipment, P – Piston pump, S – Submersible pump, W – Windpump,

Table 3.5C Hydrocensus – hydrogeological information

Borehole Number	Date	Collar (m)	Depth (m)	Water Level (m)	Sustainable Safe Yield 24hr/d (L/s)	Recommended Abstraction Schedule (hours/d)	Recommended Abstraction Rate (m^3/d)
BH01	20180208		150.00	66.35			
BH02	20180207		150.00	23.40	0.02		
BH03	20180205		150.00	44.39	0.01		
BH04	20180206		100.00	16.55	0.02		
BH05	20180205		100.00	Dry			
OS-1	20181130	0.19	85.40	38.10	0.15	8	7.484
OS-2	20181202	0.17	136.41	72.46			
OS-2 New	20181130				0.04	8	1.996
WSW-20	20181130	0.41	30.00	7.43			
Mosque Well	20180910		6.53	3.51	0.16		

Table 3.5D Hydrocensus – groundwater quality information

BH Nr	Date	pH	EC (mS/m)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO3 (as N) (mg/L)	Mn (mg/L)
BH01	2017/12/18	8.22	48.8	340.0	39.9	24.1	28.8	6.1	17.8	174	0.78	<0.01
	2020/09/23	6.76	312	3043.9	456.4	251.8	55.6	11.1	15.2	2116	<0.35	4.28
BH02	2017/12/18	8.13	29.9	208.0	21.1	10.5	36.1	6.1	3.92	11.3	<0.459	<0.01
	2020/09/18	7.04	42.5	225.8	29.8	15.2	36.4	1.9	5.01	38.2	0.36	0.02
BH03	2017/12/18	7.66	15	89.0	9.3	4.0	18.9	2.6	2.67	<0.45	<0.459	<0.01
	2020/09/18	6.98	24.9	116.9	15.3	9.2	9.6	2.4	4.96	10.2	<0.35	<0.01
BH04	2017/12/18	6.97	37.4	264.0	20.9	18.5	29.3	6.3	29	68.7	4.43	<0.01
	2020/09/18	7.38	41.1	249.2	42.4	16.5	19.3	4.2	4.03	83.5	0.97	<0.01
Mosque Well	2018/09/10	7.63	83.3	538.9	81.8	27.3	33.1	34.8	29.23	227.45	4.80	<0.01
	2021/03/19	7.36	19.42	144.0	17.4	8.5	9.4	5.1	6.98	22.94	<0.45	0.05
OS-1	2018/11/30	8	27.10	140.46	36.81	4.62	9.67	2.65	6.42	15.70	1.01	<0.01
	2021/05/13	7.68	59.3	430	88.64	25.05	18.62	5.61	7.04	149.50	<0.46	2.12
OS-2	2018/12/02	7.24	30.60	155.00	32.93	9.11	11.50	2.77	8.35	18.20	<0.35	0.08

Based on a geophysical survey commissioned during November 2018, a water supply borehole [S26.06883 E29.06168] was drilled within the GGV area, 750m southeast of the Mosque. The borehole was drilled to a depth of 140m with a reported blow yield of 1,800 to 2,000L/hour.

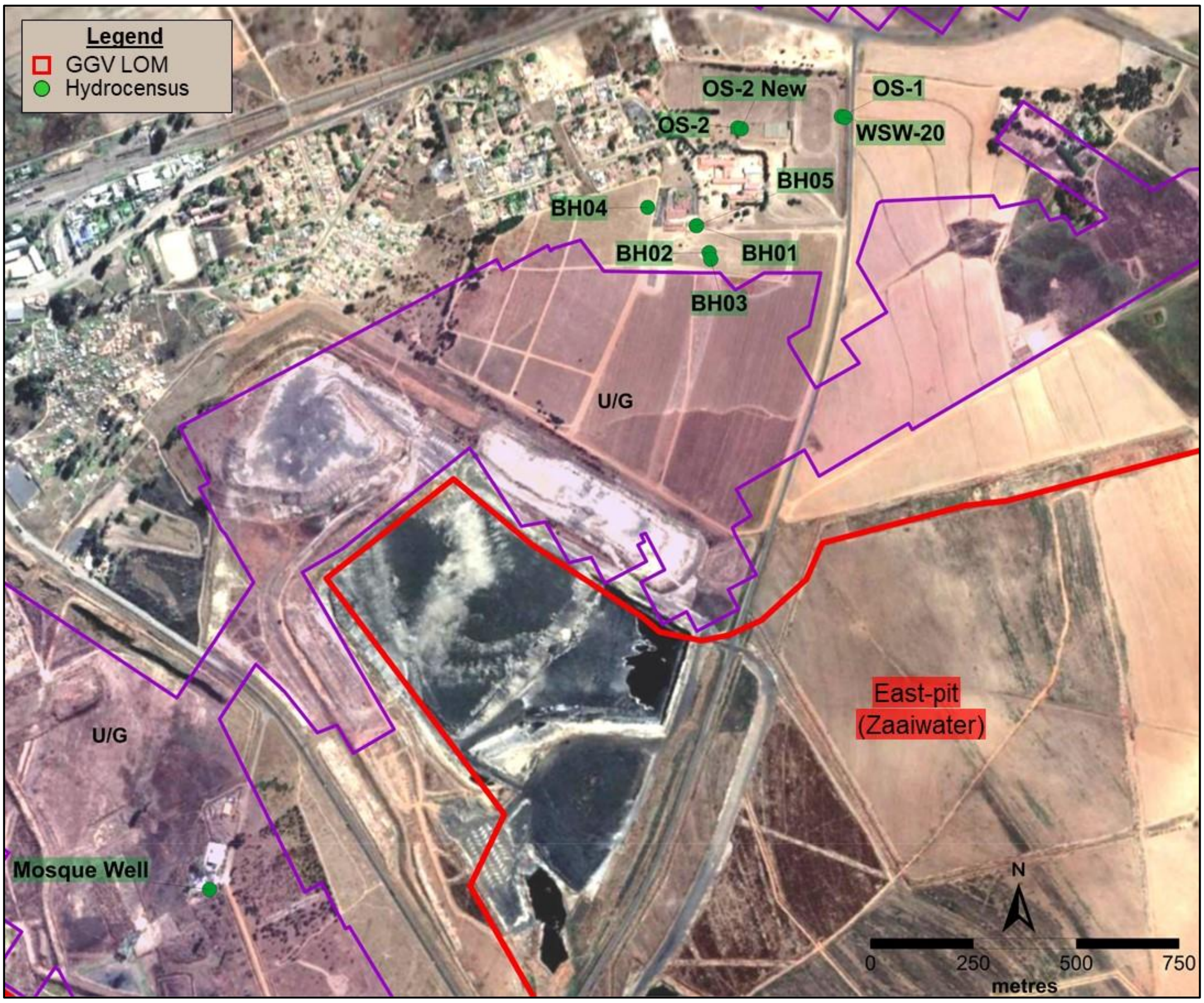


Figure 3.4 External users monitoring localities

4. CONCEPTUAL MODEL

With the exception of new groundwater monitoring data gathered over the past two years, the bulk of the information in this text was based on the 2019 *Groundwater Square* impact assessment (Ref: 444GGVd, 2019).

4.1. Aquifer Parameters

The major groundwater flow units/aquifers (as described in Table 4.1) were identified/based on the interpretation of geological and hydrogeological information, experience in neighbouring coal fields and the compilation of numerical groundwater flow and transport models. Hydraulic characteristics of these aquifer layers are presented in Tables 4.2 and 4.3. The following additional comments are important:

- Representative aquifer hydraulic conductivities are believed to be relatively constant/similar in the surrounding region/setting. The main alterations in terms of the aquifer parameters occur where:
    - Opencast backfill materials have a much higher hydraulic conductivity (see Table 4.3).
    - Underground mining may essentially present a zone of free flow.
- Although the vertical hydraulic conductivity may be lower than the horizontal hydraulic conductivity in the deep fractured aquifer by a factor of 2, and possibly a factor of 10 for the deep non-fractured aquifers, the numerical model did not provide for this.
- No major continuous zones of preferential flow were identified in the GGV reserve.
- The west-east Ogies Dyke north of GGV, which traverse the Klipspruit Plant area was not provided for in the numerical model, as groundwater at shallow depths may "overtop" the dyke, and groundwater flow rates across the dyke were presumed low (this viewpoint may be altered in future evaluations).
- Specific/additional comments from other groundwater reports (to which *Groundwater Square* agrees):
    - The average regional piezometric surface is topographically controlled.
    - Seasonal perched aquifer conditions do occur.
    - Pre-2005 drilling indicated:
        - Fracturing associated with the structural features is poorly developed.
        - No significant water strikes were encountered, and low blow-yields are evidence of low hydraulic conductivity associated with the structures and a general low permeable environment.
        - Shale/dolerite, shale/granite and shale/lava contact zones (often forming exploitable aquifers) are not water-bearing.
        - Groundwater occurrence is accordingly marginal and restricted to minor fracturing and possibly bedding planes.

Table 4.1 Aquifer layers

Aquifer	Average depth	Description	Comment
Aquifer-1	0m to 30m (30m thick)	Shallow weathered zone aquifer, which includes the overburden material	Unconfined to semi-confined conditions. Deepest water strikes and depth of hydrogeological weathering used as indicator of zone bottom.
Aquifer-2	30m to 70m (45m thick)	Deep fractured aquifer	Beyond boundaries of proposed mining. Observations have shown that the potential for the Karoo aquifer to transmit water is largely restricted at depths exceeding 60m to 80m below surface.
Aquifer-3	>70m	Deep non-fractured aquifer	Almost all fractures are believed closed.

Table 4.2 Aquifer layer parameters

Aquifer Layer	Thickness (m)	Hydraulic conductivity (m/d) [m/s]	Storativity	Porosity	Rainfall Recharge (m/d) {mm/a} [%of MAP]
Aquifer-1	30m	(0.04) [4.6×10^{-7}]	0.04	0.07	(3.8×10^{-5}) {14} [2]
Aquifer-2	40m	(0.01) [1.2×10^{-7}]	0.02	0.07	
Aquifer -3		(1×10^{-4}) [1.2×10^{-9}]	0.01	0.03	

Table 4.3 Additional aquifer hydraulic conductivity and recharge values used in the Regional-Model post-mining scenarios

Ecca-Aquifer-1	Hydraulic conductivity (m/d) [m/s]	Rainfall Recharge (m/d) {mm/a} [%of MAP]
Pre-mining	Tables 4.1 to 4.2	($3.8x10^{-5}$) {14} [2]
Opencast Backfill	(100) [$10x10^{-4}$]	($2.3x10^{-4}$) {84} [12]
Underground Mining	Free-flow	Shallow = ($3.8x10^{-5}$) {14} [2] Deep = ($1.9x10^{-5}$) {7} [1]

The following comments relate to the calibrated recharge value of 2% of MAP (=14mm/a =$3.8x10^{-5}$m/d):

- Recharge values are based on previous hydrogeological assessments in the surrounding coal fields, several independent calculations and numerical groundwater model calibrations.
- Hodgson (2005/2007/2010) used ranges of recharge depending on depth of mining, mining methodology, etc. Values as low as 1.5% of MAP applied to the water balance of deep coal seams.
- Natural chloride concentrations in uncontaminated groundwater (10mg/L to 25mg/L) indicated that natural rainfall recharge might be as high as 2%-7% of MAP, possibly relating to shallow groundwater movement, i.e. a short residence time in the shallow weathered zone aquifer.

4.2. Aquifer Boundaries

The model boundary/domain are indicated in Figures 1.1 and 4.1. Boundary conditions as employed in the numerical groundwater flow and transport models are summarised in Table 4.4.

Table 4.4 Numerical model boundaries – Regional-Model

Boundary	Boundary type	Comment
Internal rivers/spruits/pans. i.e. inside the model domain	Seepage face	Seepage to surface if groundwater should rise above the stream/riverbed elevation/surface
North, west and south	Constant head	Based on previous groundwater models in these areas.
East – where rivers/streams/pans are absent and no direct connection to neighbouring mining	No-flow	Along topographical high

4.3. Aquifer Geometry

Figure 4.1 depicts the location of 5 cross-sections through the LOM opencast mining areas. The cross-sections are attached as Figures 4.2. The original surface topography is indicated in unmined areas and the rehabilitated area in the South-pit is also shown.

The following important comments relate to the geometry of the topography and coal seams:

- Coal seam elevations in relation to surface topography and streams are very important (i.e. aquifer geometry) in determining:
    - Groundwater flow directions.
    - Numerical model boundaries.
    - Identifying long-term post-mining decant areas.
- As can be seen the shallowest mining in the pits are near the decant areas, due to the general topographical slope (see cross-sections WE1, NWSE, SWNE1 and SWNE2). The 2Seam underground is also shallow beneath the Zaaiwaterspruit (between the North-pit and South-pit) and east of the East-pit. The 4Seam underground, which overlay the 2Seam, is even shallower (not indicated on the cross-sections)
- Coal seam elevations do not vary to the same degree as the topographical elevations, resulting in the mining depth ranging from <30m to >100m.
- The highest topographical elevation (1620mamsl) occurs along the south-western corner of the South-pit, with the highest elevations of the other two pits along their northern boundaries (1590mamsl and 1605mamsl). According to the latest LOM plan, the deepest regions will be targeted as underground projects.
- The lowest topographical elevations, where decant can be expected after mine closure, are very similar for all three pits:

  - North-pit south-eastern boundary (1554.1mamsl).
  - East-pit Zaaiwater eastern boundary (1551.7mamsl).
  - South-pit north-eastern boundary (1551.2mamsl).
- The Zaaiwaterspruit drains southeast, and its tributary from Khutala drains east through the mining area, constituting low points on the cross-sections. According to the geological model, mining of the 4Seam underneath the Zaaiwaterspruit will range 10m to 30m deep. A portion of 4Seam underneath the Zaaiwaterspruit tributary (east of the East-pit), will range 20m to 30m deep.
- All coal seams are lower than the decant elevations (see 2Seam coal floor in Figure 4.3).

The geotechnical engineering stability assessment by *Bare Rock Consulting* (Ref: BR_16_2021s March 2022) indicated that the 4Seam varies between 10m and 25m deep (average 15m) below the diverted Zaaiwaterspruit. In the eastern area wetland, east of the East-pit in the Zaaiwaterspruit tributary, the 4Seam varies between 15m and 30m deep (average 20m). The roof of the 2Seam under the river diversion varies between 40m deep in the west and 20m deep in the east. In the eastern area under the wetland the seam varies in depth from north to south from 60m to 40m. The geometry of the pillar designs are the same on both coal seams (3.5m mining height, 11.5m pillar width and 18m centre-to-centre distance).

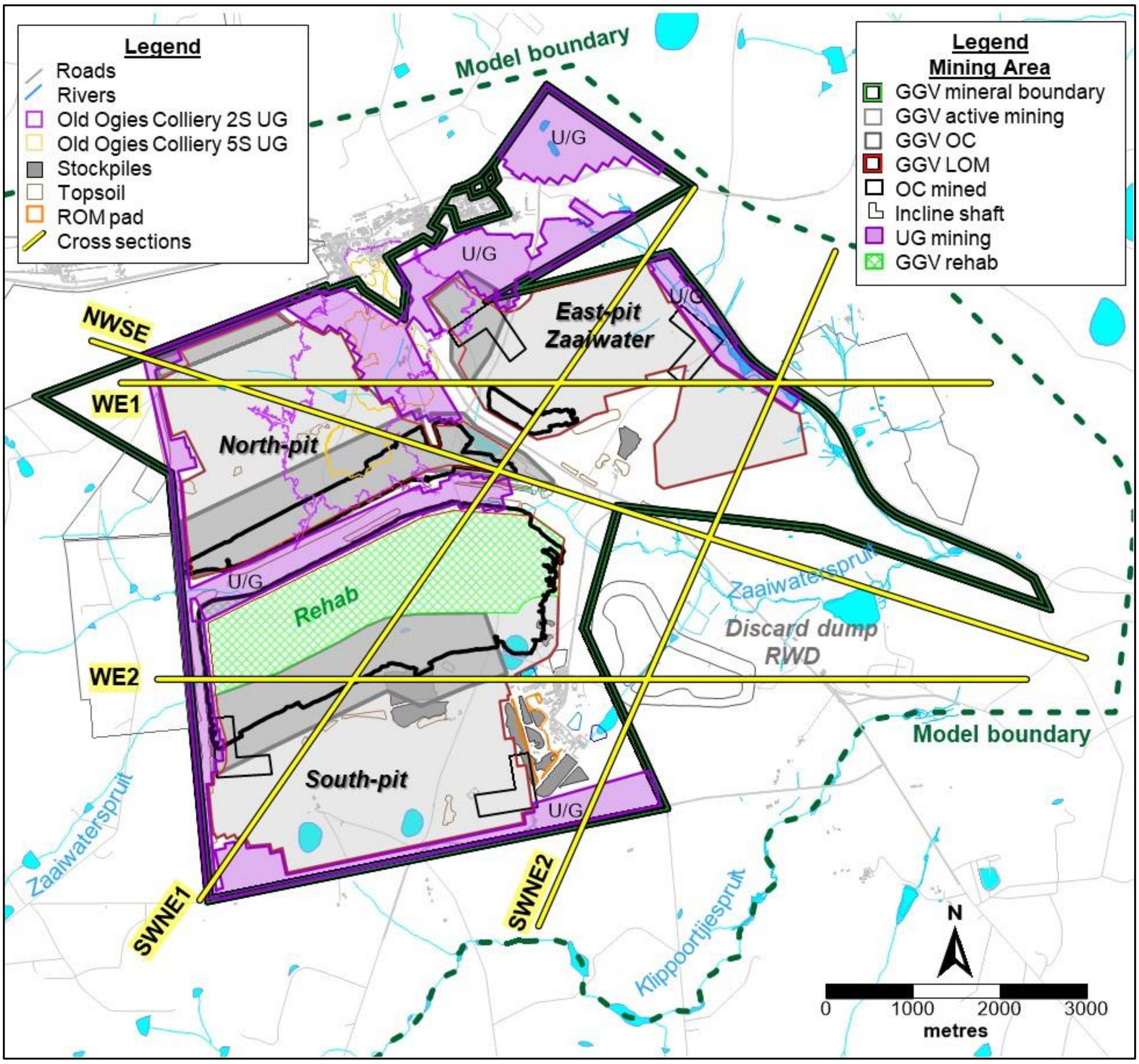
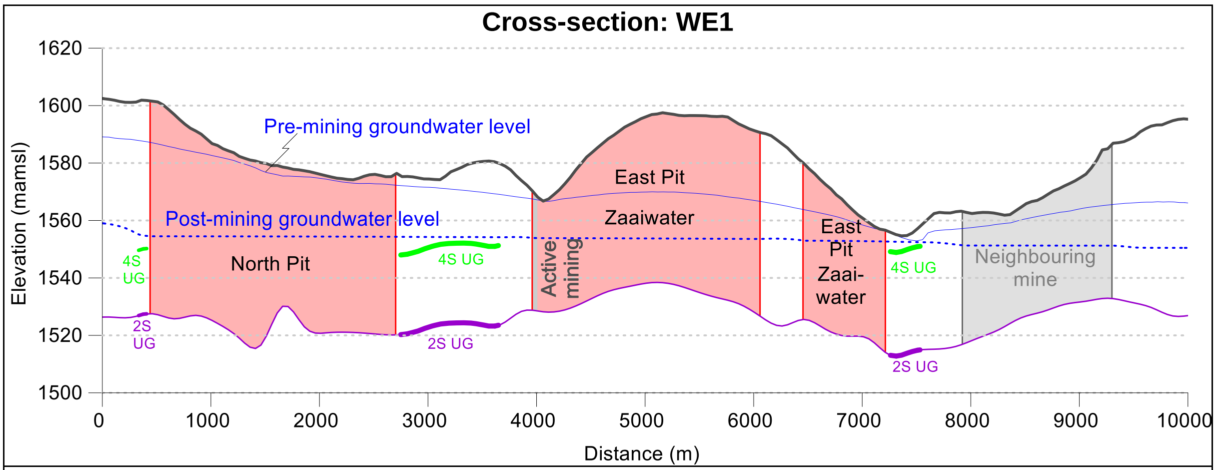
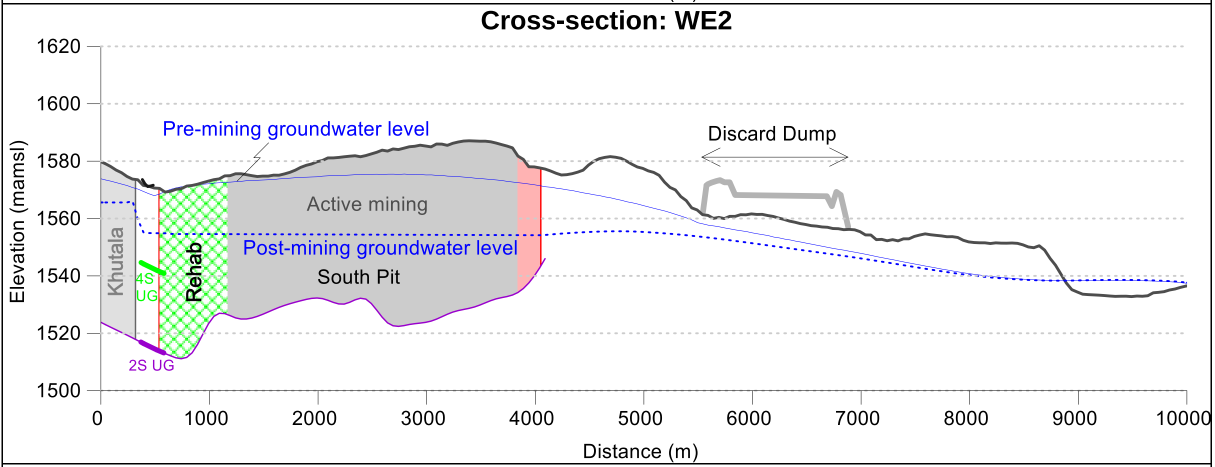
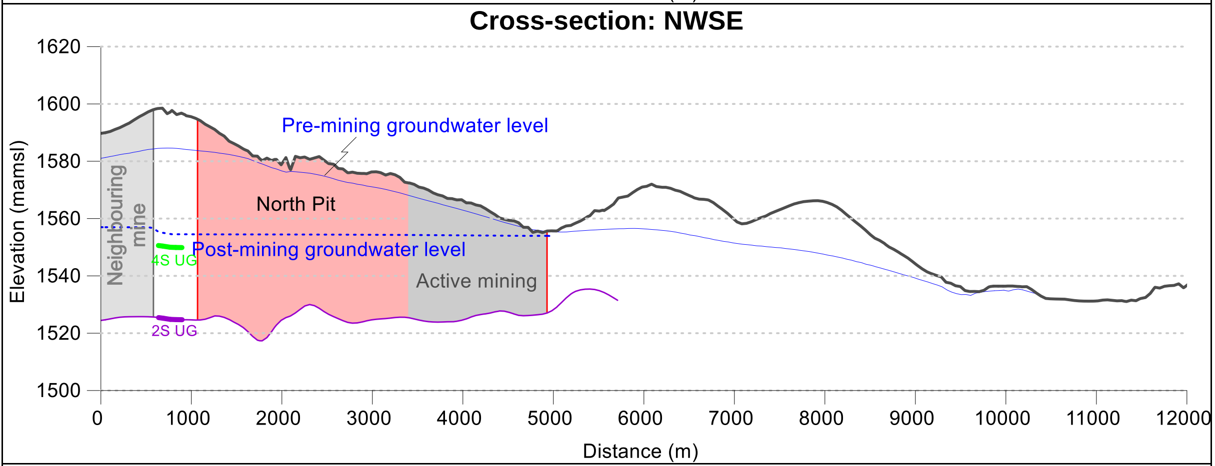
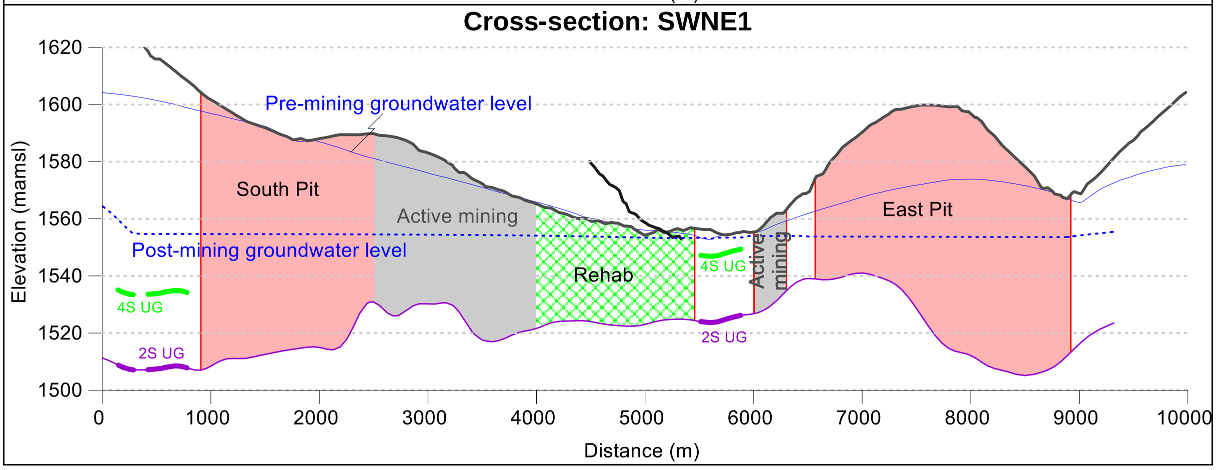


Figure 4.1 Location of cross-section lines


Cross-section: WE1
Elevation (mamsl)
1620
1600
1580
1560
1540
1520
1500
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (m)
Pre-mining groundwater level
Post-mining groundwater level
North Pit
4S UG
2S UG
Active mining
East Pit
Zaaiwater
East Pit Zaai-water
Neighbouring mine


Cross-section: WE2
Elevation (mamsl)
1620
1600
1580
1560
1540
1520
1500
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (m)
Pre-mining groundwater level
Post-mining groundwater level
Discard Dump
Khutala
4S UG
2S UG
Rehab
Active mining
South Pit


Cross-section: NWSE
Elevation (mamsl)
1620
1600
1580
1560
1540
1520
1500
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
Distance (m)
Pre-mining groundwater level
Post-mining groundwater level
Neighbouring mine
4S UG
2S UG
North Pit
Active mining


Cross-section: SWNE1
Elevation (mamsl)
1620
1600
1580
1560
1540
1520
1500
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Distance (m)
Pre-mining groundwater level
Post-mining groundwater level
South Pit
Active mining
Rehab
4S UG
2S UG
Active mining
East Pit

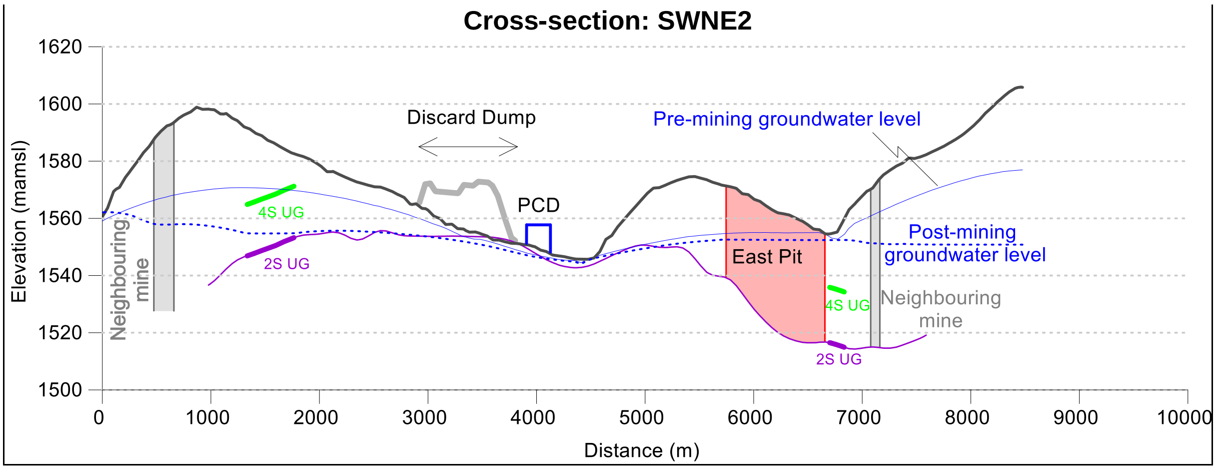


Figure 4.2 *Cross-sections (see locations of cross-sections in Figure 4.1)*

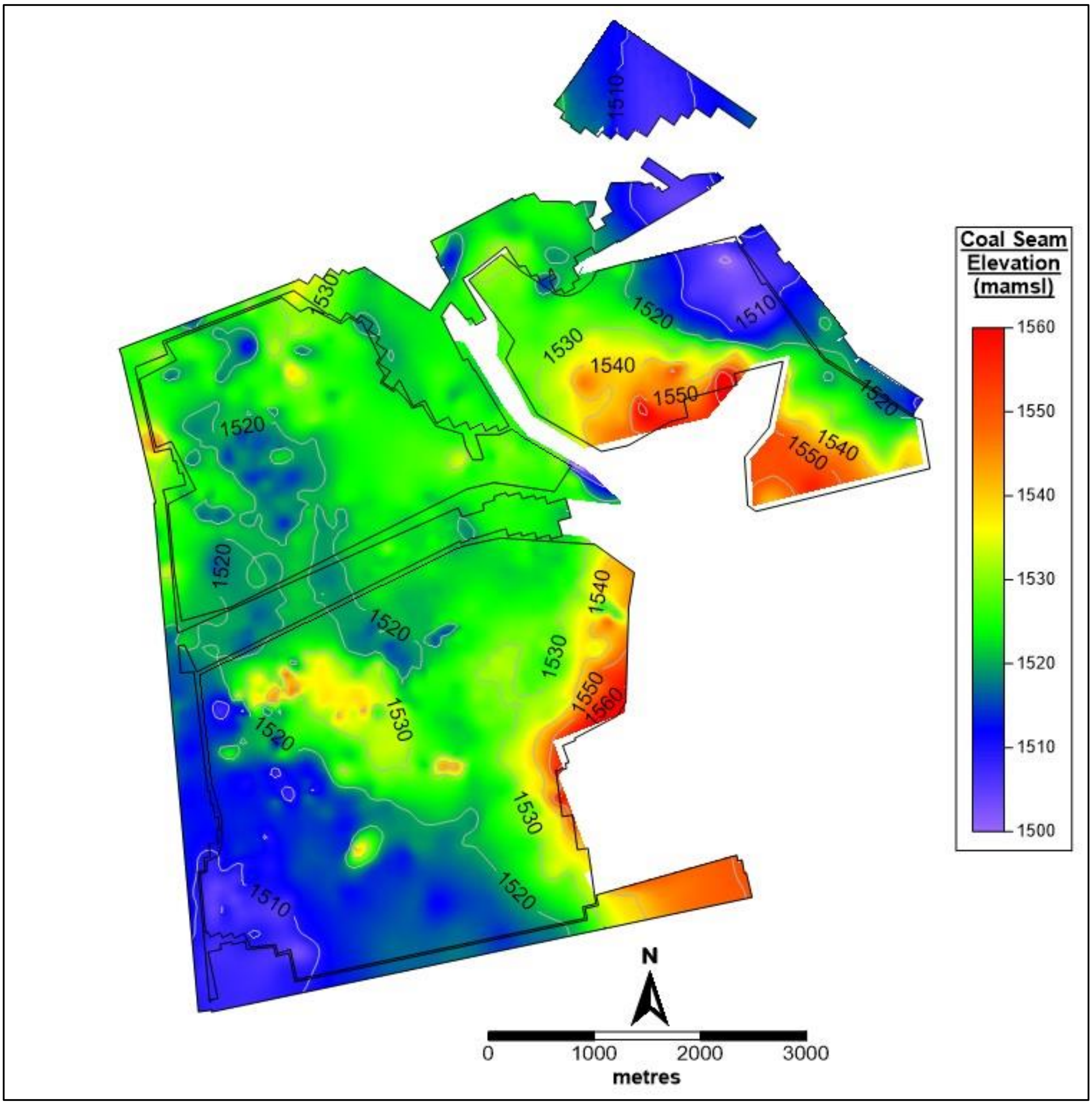


Figure 4.3 *2Seam floor contours*

4.4. Groundwater Levels and Groundwater Flow

Groundwater level data in active monitoring boreholes are depicted in Figure 3.4. Pre-mining groundwater levels and groundwater flow directions, as determined through numerical modelling (see model discussion in Section 6), are depicted in Figure 4.4. Natural regional pre-mining groundwater level elevations probably emulated the surface topography. Figure 4.5 depicts groundwater levels in the GGV groundwater monitoring system.

Groundwater levels typically vary 1m to 3m deep in low-lying areas such as rivers and streams. In the high-lying areas, groundwater levels may be 10m deep and even 20m deep in extreme cases. It is believed that significant evaporation and evapotranspiration occurs from the shallow groundwater table in/around streams and wetland areas.

Except for monitoring boreholes into the underground, no other borehole indicated a definite mining impact.

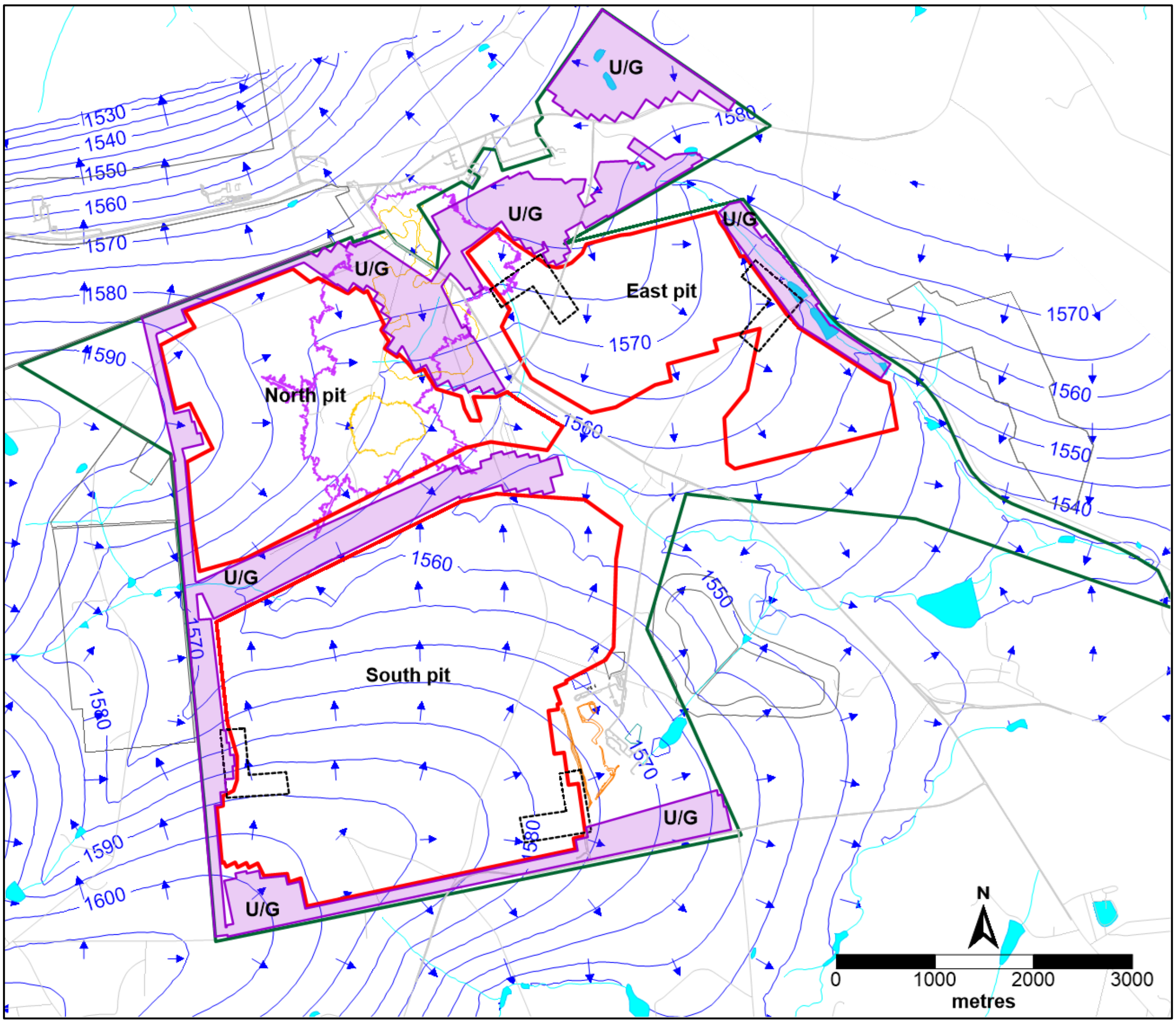


Figure 4.4 Numerically simulated steady-state pre-mining groundwater level elevations (mamsl)

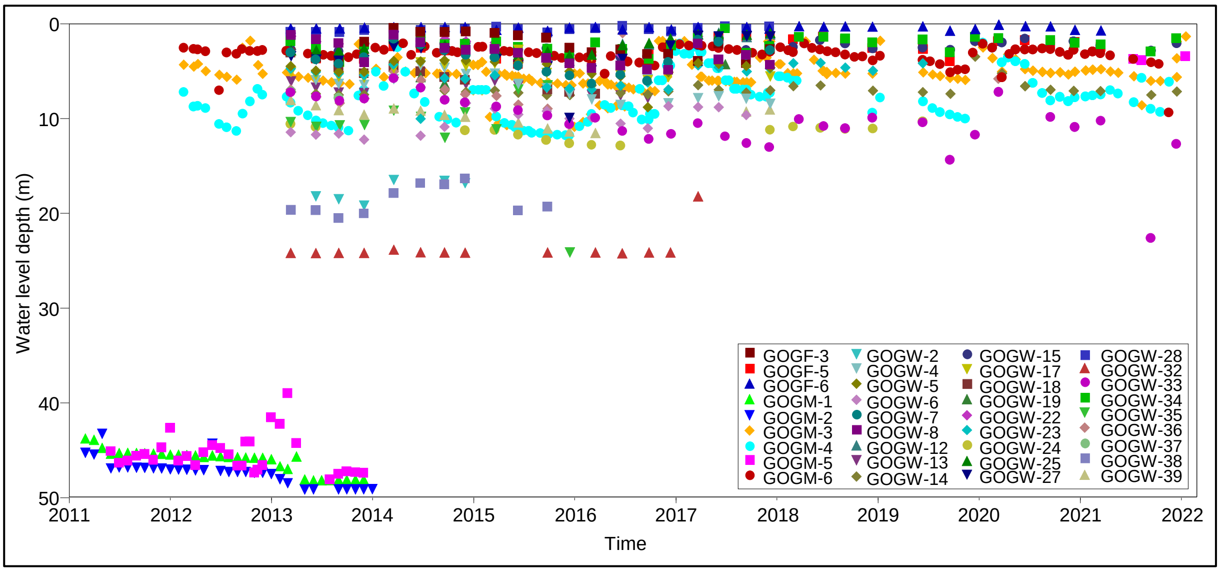


Figure 4.5 ***Groundwater level depth (m) trend graph of inactive and active monitoring boreholes***

4.5. Groundwater Quality

Groundwater quality data are attached as Appendix 2. Graphs of pH, EC and SO_4 trends are indicated in Figures 4.6A-C, for the active monitoring boreholes depicted in Figure 3.4, mine water monitoring localities and surface water monitoring localities. Monitoring data of inactive monitoring boreholes are not included because these do not reflect any of the current impacts. Selective starting and ending water qualities for existing GGV monitoring boreholes are listed in Table 3.2C.

The background groundwater quality as determined from unimpacted boreholes in the area is listed in Table 4.5. Additional comments and graphs on the groundwater monitoring system are contained in the 2021 impact assessment report (Ref:444GGVg, 2021).

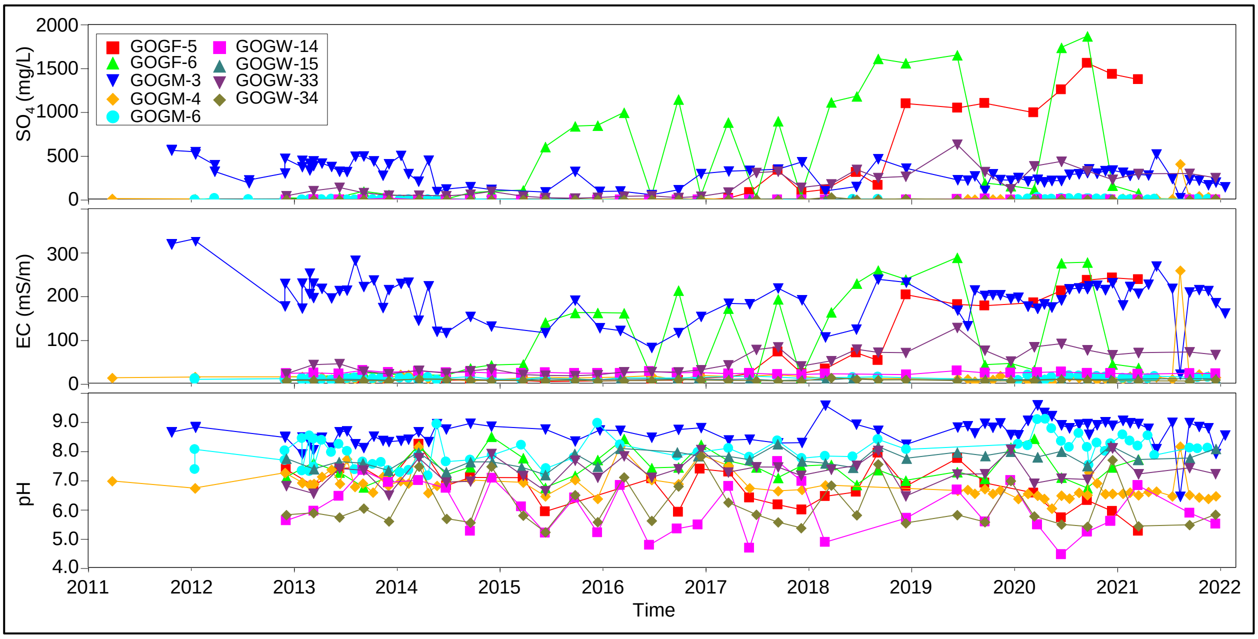


Figure 4.6A ***pH, EC, SO_4 groundwater quality trend graph of active monitoring boreholes***

Figure 4.6B pH, EC, SO_4 groundwater quality trend graph of active mine water monitoring

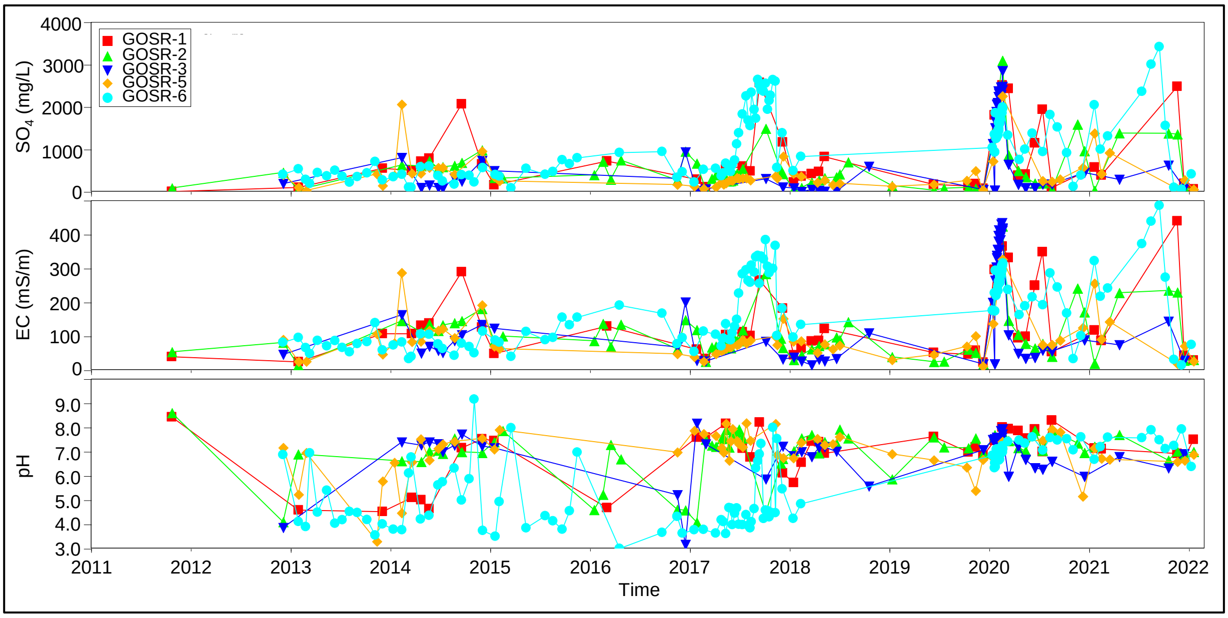


Figure 4.6C pH, EC, SO_4 groundwater quality trend graph of active surface water monitoring

Table 4.5 Background inorganic groundwater quality and SAWQG-DU

	Background water quality	SANS 241 - 2006 Domestic Water		SANS 241 - 2015 Domestic Water
		Class 1 *	Class II **	Limit
pH	6.2-8.6	5 - 9.5	4 - 10	5 – 9.7
EC (mS/m)	<40	<150	150 - 370	170 (Aesthetic)
TDS (mg/L)	<130	<1000	1000 - 2400	120 (Aesthetic)
Ca (mg/L)	<25	<150	150 - 300	
Mg (mg/L)	<15	<70	70 - 100	
Na (mg/L)	<25	<200	200 - 400	200 (Aesthetic)
K (mg/L)	<10	<50	50 - 100	
Cl (mg/L)	<25	<200	200 - 600	300 (Aesthetic)
T.Alk. (mg/L)	<150			
SO_4 (mg/L)	<30	<400	400 - 600	250 (Aesthetic), 500 (Acute health)
NO_3 - N (mg/L)	<10	<10	10 - 20	<11 (Acute health)
F (mg/L)	<1	<1.0	1.0 - 1.5	1.5 (Chronic health)
Fe (mg/L)	<1	< 0.2	0.2 - 2.0	<0.3 (Aesthetic), 2 (Chronic health)
Mn (mg/L)	<1	< 0.1	0.1 - 1.0	0.1 (Aesthetic), 0.4 (Chronic health)
Al (mg/L)	<0.3	<0.3	0.3-0.5	<0.3 (Operational)

* Recommended operational limit ** Maximum allowance for limited duration

4.6. Mine Water Volumes and Quality

The water pumped from the temporary in-pit collection dams to the Zaaiwater Container, North Pit 1 Container and Ramp 1 Container are not currently monitored for quality as per the database. The following monitoring data is relevant (see water quality statistics in Table 4.6 for the period October 2011 to January 2019):

- Raw Water Dam (RWD):
    - The RWD receives water from the Western Stormwater Dam (PCD), Spaghetti Junction, Waterpan, and the Return Water Dam. The dam supplies to the Raw Water Tank, process water to the plant (average plant raw water feed 9600m^3/d - Golder 2020), flow to the Return Water Dam and overflow to the Eastern Stormwater Dam (PCD). The RWD has an estimated storage capacity of 78 000m^3. The 2013 study indicated the plant raw water feed to be around 8282m^3/d from 2015 onwards.
    - RWD - GOSD-6 Median Mine Water Qualities October 2011 to March 2021: pH=7.8 SO4=2308mg/L.
- "Eastern Pollution Control Dam" (PCD) or Eastern Stormwater Dam (ESWD):
    - The PCD/ESWD has a capacity of ±60,000m^3 (2020 IWWMP). Dirty runoff from the plant area, product stockpiles and overflow water from the Raw Water Dam is directed to the Eastern PCD. Excess water spills to the unlined "Farm Dam", which in turn overflows into the Railway Dam or Deadman Dam (±10 000m^3). Water from the Deadman Dam is pumped to the MRF Return Water Dam. The "Farm Dam", which has a significant clean catchment area within the rail loop, has a capacity of 27,000m^3 (2020 IWWMP);
    - ESWD - GOSD-5 Median Mine Water Qualities October 2011 to March 2021: pH=7.9 SO4=2223mg/L.
    - "Farm Dam" - GOSD-7 Median Mine Water Qualities October 2011 to March 2021: pH=7.5 SO4=1822mg/L.
- "Western PCD" or Western Stormwater Dam (WSWD):
    - The Western PCD / WSWD has a capacity of ±34,000m^3 (2020 IWWMP), contains dirty runoff from the workshops as well as treated water from the Sewage Treatment Plant. The stormwater is channelled to a silt trap before entering the dam. Outflows include Raw Water Tank demand and process water to the Raw Water Dam. The sewage treatment plant (capacity 50m^3/d) treats the sewage effluent from the offices and workshops.
    - WSWD - GOSD-4 Median Mine Water Qualities October 2011 to March 2021: pH=7.6 SO4=2050mg/L.
- Raw Water Storage Tank:
    - The Raw Water Storage Tank (10,000m^3) is supplied from the Raw Water Dam and Western Stormwater Dam. The main purpose of the storage tank is to supply water for dust suppression, fire water at stockpiles, wash bay and dust suppression on haul roads to the pits. The 2020 IWWMP indicates flow rates of 660m^3/d to both ROM stockpiles (34.8ha) and product stockpile (14.5ha), as well as 1,946m^3/d to dust suppression on the haul roads to the pits. The wash bay is used for the washing of mine trucks and other production equipment. The Raw water storage tank supplies the wash bay with approximately 660m^3/day of water.
- Mine Residue Facility (MRF) Return Water Dam:
    - The lined MRF Return Water Dam has a capacity of ±239,000m^3 (2020 IWWMP). The Tailings Return Water Dam receives runoff, seepage and slurry return water from the MRF. Water is pumped from the Tailings Return Water Dam to the Raw Water Dam for reuse in the coal processing plant;
    - MRF Return Water Dam – GOSD-8 Median Mine Water Qualities October 2011 to January 2019: pH=8.0 SO4=2342mg/L.

Table 4.6 Average of monthly water qualities between October 2011 and January 2019

Monitoring point		pH	EC (mS/m)	TDS (mg/L)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	SO4 (mg/L)	NO3 (mg/L)	T-Alk (mg/L)
GOSD-4	Western PCD dirty stormwater dam	7.5	292	2926	423	257	57	15.0	30	1982	1.9	179
GOSD-5	Eastern PCD dirty stormwater dam	7.6	312	3115	458	278	55	15.6	17	2179	5.9	89
GOSD-6	Raw water dam	7.7	324	3302	479	303	57	15.7	16	2301	3.9	137
GOSD-7	Existing farm dam	7.5	246	2287	335	211	45	12.4	16	1573	3.3	82
GOSD-8	Return water dam	8.0	332	3401	479	327	58	17.4	15	2375	5.5	124
GOSD-10	Water transfer point for ramp 1a in GGV up to December 2017	5.1	437	4327	510	446	96	28.3	13	3181	0.7	39
GOSD-11	Water transfer point for ramp 1b in pit up to May 2015		276	2755	414	226	39	19.5	7	2047	2.4	9
GOSD-12	Water transfer point for ramp 6 Ramp 6-Sump 1a, to 05/2015	6.1	26	146	12	11	9	3.0	17	68	3.0	9

5. GEOCHEMISTRY

Geostratum performed an environmental geochemical assessment for the 2019 *Groundwater Square* groundwater impact assessment, specifically to determine the potential for Acid Mine Drainage (AMD) and to estimate major element concentrations in mine water (Ref: GW2_444GGVd, 2019). Numerical geochemical modelling was undertaken to simulate the long-term post-mining mine water quality trends of the three pits and the MRF.

Based on numerical geochemical modelling at neighbouring *Glencore* iMpunzi and Tweefontein Collieries, the geochemical trends for coal discard backfill into the pits and underground mining, which took account of interflow between opencast and underground sections, could be determined.

The entire geochemical assessment is not included in this report. However, the following was concluded from the original models (note that both waste rock and coal discard will be backfilled into the pits – the following comments address the individual characteristics of each – this is important for the geochemical model to calculate the contributions and interaction so each):

- Changes in major ions:
    - Alkalinity is the dominant anion in the infiltrating groundwater into the backfilled opencast and in the rainwater in the coal discard dump but is quickly replaced by sulphate as the dominant anion due to sulphide oxidation. Sulphate is a conservative (mobile) chemical in the surface and groundwater environment and the first indicator of sulphide oxidation in mine drainage.
    - *Waste rock:* The waste rock backfill contains some pyrite and will generate sulphate concentrations above 500mg/L over the short term, which will increase to 2500mg/L within about 15years to 25years, remaining at 2500mg/L to 3200mg/L over the long term.
    - *Coal Discard:* The coal discard contains a significant pyrite content and will generate sulphate concentrations of 500mg/L to 4000mg/L over the short term, remaining at 2500mg/L to 5000mg/L between 15years to 75years. Over the long term, the sulphate is expected to range between 4000mg/L to 5000mg/L in the anoxic zone, while the concentration will further increase in the oxic zone above 5000mg/L to 8000mg/L.
    - Calcium and magnesium will be the dominant cations in the interstitial water due to the initial neutralization reactions of carbonate minerals. In hotspots in the oxic zone where carbonate minerals become depleted, aluminium, iron and manganese will become major cations in acidic seepage from the material as not enough calcium and magnesium are present.
- Changes in pH conditions:
    - *Waste rock:* The average backfill composition in the pits will have a pH of 6.5-7.5. The carbonate minerals will become depleted at the top of the unsaturated zone but not in the average backfill and the pH will remain at these levels over the long term if only waste rock (and no coal discard) is backfilled above the long-term decant elevation.
    - *Coal Discard:* Discard in the oxic zone (e.g. outer layer of dump) will have a pH of 3-5, while coal discard at the centre of the dump in the anoxic zone will be circum-neutral.
- Metals in seepage/mine water:
    - In neutral pit water, aluminium, iron and manganese will mostly be present at concentrations of below 5mg/L. Where slight to moderate acidification occurs, seepage will have aluminium, iron and manganese concentrations above 10mg/L. In acidic drainage, the concentration of trace metals cobalt and nickel will also become elevated (0.1mg/L to 2mg/L).
    - However, metal concentrations under highly acidic conditions can be very erratic and will change significantly between each monitoring run.
- AMD evolution:
    - The geochemistry of AMD will change over time as summarized in Table 5.2 and 5.3. During the first stage of AMD, pyrite oxidation takes place, but enough calcite and dolomite minerals are available to neutralise the acid generated. If enough calcium (from calcite) is present to remove sulphates from solution (as gypsum precipitation), SO_4 will remain at approximately 2000mg/L. If magnesium becomes a dominant cation (due to more dolomite present) sulphate might increase to approximately 3000mg/L.
    - During the second AMD stage pyrite oxidation will take place, but carbonate minerals will be depleted. Gypsum will not precipitate anymore as no calcium is generated (from carbonates anymore), and gypsum will rather begin to dissolve, contributing to the sulphate in solution.

  Acidic conditions will be reached, with sulphate concentrations rising well above 2500mg/L. Aluminium and iron will become major cations, and Al-Fe-sulphates will then start to precipitate.
  - Pyrite will be depleted in the upper oxidation zone during the third AMD stage but may still be present deeper in the rock pile. Gypsum will also be depleted, and sulphate concentrations will decrease. Metal concentrations will also start to decrease, resulting in a change in the secondary Al-Fe-sulphates. Conditions will remain acidic as silicate minerals are usually not able to neutralise the long-term acidity.
  - It is important to note that all three stages may eventually be present as different parts of mine waste are subjected to unique oxidation degrees. The upper oxic zone of a dump will reach Stage 3 quicker, while deeper saturated parts will remain as Stage 1.
  - Only AMD Stage 1 will be reached in the average backfill. However, carbonaceous material in the unsaturated oxic zone may reach Stage 2. The neutral coal discard at the centre of the dump will remain at Stage 1, while discard in the outer oxic rim will reach stage 2 and 3.

The following were concluded if 70% of the Plant coal discard is placed back into the pits:

- Pyrite as %S for the average waste rock in the original 2019 models was 0.13%. However, if 70% of the Plant coal discard is mixed into the waste rock backfill at each pit, the average pyrite could increase to 0.4% if mixed evenly throughout the 30m unsaturated profile. In a worst-case scenario, based on slurry pyrite, the pyrite content could increase to 0.85%.
- Note that the SO_4 concentrations would be approximately 1.3x higher (4000mg/L) compared to only waste rock. In hot-spot areas, the concentrations can exceed 5000mg/L.
- The pH levels may drop as low as 4, compared to portions of the pit where pH of 6.5-7.5 is possible in the absence of coal discard. The carbonate minerals will become depleted at the top of the unsaturated zone.
- In neutral pit water Al, Fe and Mn will mostly be present at concentrations of below 5mg/L. Where slight acidification occurs, seepage will have Al, Fe and Mn concentrations above 10mg/L. In acidic drainage the concentration of trace metals Co and Ni will also become elevated (0.1mg/L to 2mg/L).

A major assumption is that an effort will be made to place the Plant coal discard below the decant elevation as much as possible.

Discard in the oxic zone of the MRF (e.g. outer layer of dump) will have a pH of 3-5, while coal discard at the centre of the dump in the anoxic zone will be circum-neutral. Discard contains a significant pyrite content and will generate a sulphate concentration of between 500mg/L to 4000mg/L over the short term. Over the long-term the sulphate will remain at 4000mg/L to 5000mg/L in the anoxic zone, while the concentration will further increase in the oxic zone above 5000mg/L to 8000mg/L.

It was assumed that the samples were representative of the material. The geochemical properties from neighbouring GOSA Tweefontein and iMpunzi Mines provided guidance on the validity of results. In the backfill of a single opencast mine the mine water quality can vary significantly due to the heterogeneity of the 1) backfilled rock and 2) variation in unsaturated zone depth. It is not possible to model this heterogeneity. The model only simulates mineralogical reactions based on the typical composition of the material.

Mine water qualities were not assessed to validate the geochemical model because of the mixing of mine water in the water circuit. The short-term geochemical modelling results were in good agreement with typical mine water measurements in the coalfield. However, validation of the model should take place through the dedicated sampling of water pumped from the Pits during both the dry and wet portions of the rainfall season.

It is likely that the opencast areas will freely interact with the underground. Because the underground groundwater ingress through the mine roof will be much smaller than the volume of water that flows into the underground through access from opencast areas, the underground mine water qualities will be similar to the opencast mine water qualities. Assuming that underground areas can be sealed off entirely, Stage 1 conditions will be present over the long-term and SO4 concentrations will reach 2500mg/L.

The geochemical trends used in the numerical model for the individual mining units for the post-mining situation are summarised in Figure 6.7.

Table 5.1 Estimated range for pH and SO_4 concentrations in seepage

Pit	**Average seepage from material over model time**			
	Term	**Short term**	**Medium term**	**Long term**
No coal discard	**AMD Stage**	**Stage 1**	**Stage 1 & 2**	**Stage 1 & 2**
North-pit	Time	0-25 years	25-100 years	100-200 years
South-pit	pH (range)	6.5-7.5	7.5-6.0	7.0-6.0
East-pit	SO_4 (range)	500-2 500	2 500-3 200	2 500-3 200
Coal discard	**AMD Stage**	**Stage 1**	**Stage 1 & 2**	**Stage 1 & 2**
North-pit	Time	0-25 years	25-100 years	100-200 years
South-pit	pH (range)	5.5-7.0	4.0-5.5	
East-pit	SO_4 (range) *	500-3500	3500-4000	4000-3500
Discard Dump	**AMD Stage**	**Stage 1 - 2**	**Stage 1 – 3**	**Stage 1 – 3**
	Time	0-15 years	15-75 years	75-100 years
	pH (range)	7.0-8.0 (anoxic) 7.0-5.0 (oxic)	7.0-8.0 (anoxic) 5.0-4.0 (oxic)	7.0-8.0 (anoxic) 4.0-3.0 (oxic)
	SO4 (range)	2 000-4 000	2 000-5 000	4 000-5 000 (anoxic) 5 000-8 000 (oxic)
Underground	SO4	2500		

6. IMPACT ASSESSMENT

This impact assessment is an update to the 2019 impact assessment (Ref: GW2_44GGVd, 2019) and was structured similarly. Three modelling scenarios were performed for the post-mining situation:

- Model-1: Do not seal any adits/shafts to the underground.
- Model-2: Seal adits/shafts to the underground.
- Model-3: No undermining of the Zaaiwaterspruit between the North-pit and South-pit.

(Model-3 is important because the geotechnical engineering stability assessment by *Bare Rock Consulting* (Ref: BR_16_2021s March 2022) recommended that no mining is conducted where the roof of the excavation is shallower than 20m below surface. Because the final decision on the mining under the streams will probably a combination of Model-1 and Model-3 because the *Bare Rock* study indicated that the 4Seam varies between 10m and 25m deep below the diverted Zaaiwaterspruit. In the eastern area wetland, east of the East-pit in the Zaaiwaterspruit tributary, the 4Seam varies between 15m and 30m deep. The roof of the 2Seam is minimum 20m and 40m deep respectively under the two streams).

Similar to the 2019 & 2021 impact assessments, the following approaches were used in the evaluation of the potential groundwater impacts:

- The FEFLOW finite element numerical groundwater flow and transport modelling software package was used to calculate the extent of dewatering, water balance, likely decant volumes, inter-mine flow volumes and contamination plumes:
  - The model domain in relation to mining is depicted in Figures 1.1 and 4.1.
  - The model grid consisted of 9 layers and 1.8million mesh elements to accommodate the geometry of the aquifers and coal seams.
  - The extent of the model grid and cell size (minimum 10m) are believed to be suitable for the purpose of the current impact assessment.
  - Seams-5, 4 & 2 constituted the bottom of model Layers-2, 4 & 6.
  - The cross-sections discussed in Section 4.3 provides an explanation of the aquifer geometry (e.g. depths/elevations of coal seams in relation to aquifers).
- Water volume stage curves are presented in Figure 6.1 and 6.2, respectively for the opencast and underground:
  - A 20% bulking factor was assumed for the backfill into opencast pits. The decant elevations and flooding volumes at the time of decant are also indicated in the Figure 6.1 and Table 6.1. A total of 124.2Mm^3 can be stored in pit areas after mining.
  - The underground volume stage curves were calculated per year of mining and not in terms of elevation. This was done because the complicated mine design and scheduling with underground areas around the edges of the opencast pits. Water volumes were determined by applying a weight factor of 1.5 to the LOM tonnage. A total of 21.6Mm^3 can be stored in mined underground areas after mining.
- Model parameters are listed in Tables 4.1 to 4.3. The model boundary conditions are discussed in Section 4.2 (note that constant head boundary conditions were employed to the west, south and north according to the post-mining groundwater level findings from previous groundwater studies for neighbouring mines).
- The most important neighbouring mines that were considered for the post-mining impact assessment/scenario were:
  - Khutala:
    - Existing Khutala opencast pit bordering GGV to the west.
    - Planned Khutala opencast pits bordering GGV to the southeast.
    - Existing Khutala underground bordering GGV to the south and west.
  - Klipspruit/Zibulo/Kleinzuikerboshplaat/Project Z:
    - Opencast areas to the north and west of the GGV North-pit.
  - Tweefontein:
    - Tweefontein underground bordering GGV to the east.
    - Zaaiwater opencast bordering GGV to the east.

- Neighbouring mines may all potentially contribute to the regional groundwater flow system:
  - This will become important in terms of regional inter-mine flow.
  - The long-term/post-mining impacts of these areas on the mine water balance and water quality of GGV were investigated.
- Pre- and post-mining groundwater flow were assessed through steady-state modelling.
- Transient flow modelling was performed to determine:
  - Groundwater base-flow volumes during mining/operation and post-mining.
  - Dewatering impact zone.
  - Time to decant.
  - Contamination movement.
- Water balance calculations took cognisance of groundwater base-flow/inflow and rainfall recharge.
- Several spreadsheet calculations were performed to expand on the numerical model calculations.

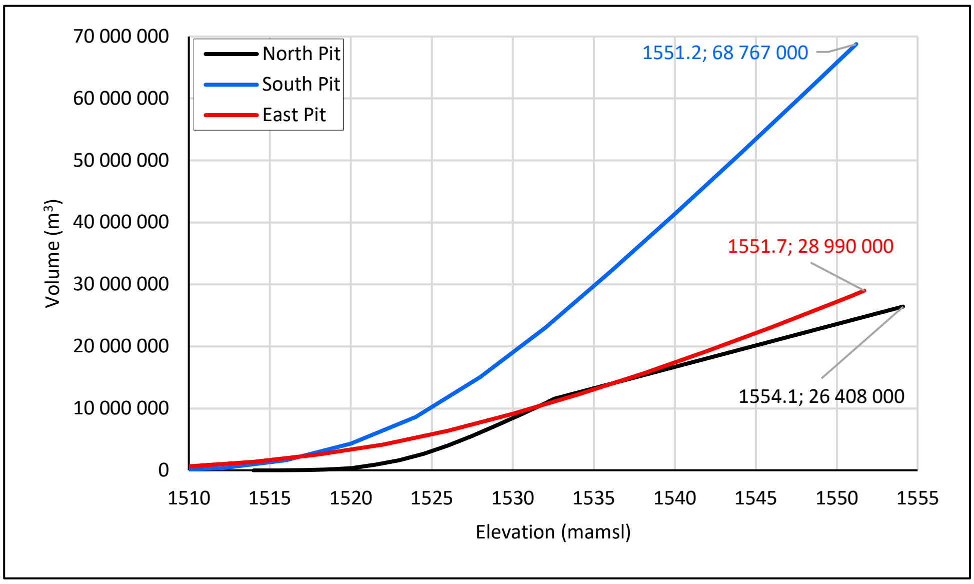


Figure 6.1 Opencast water volume stage curves – volume (m^3) vs mine floor elevation (mamsl)

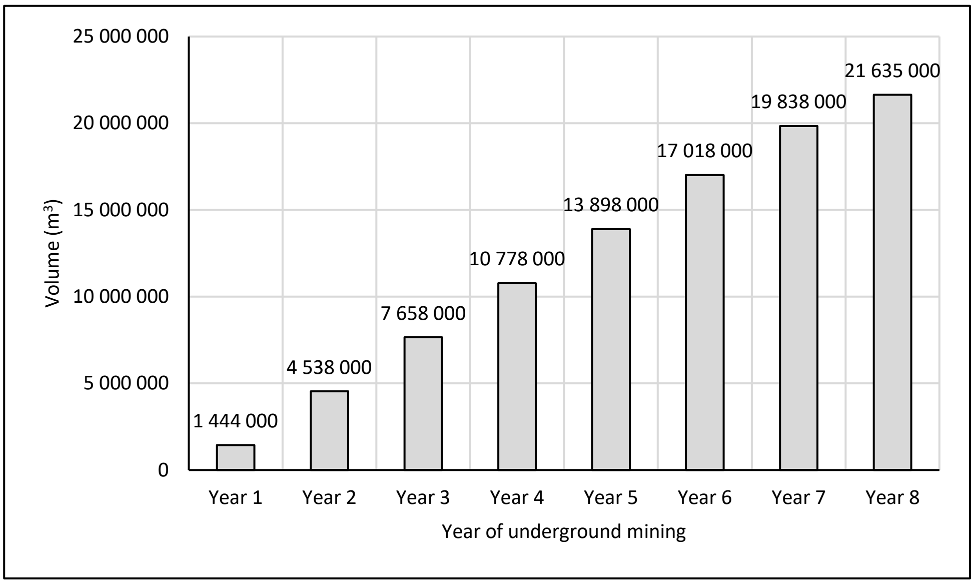


Figure 6.2 Underground water volume storage potential – volume (m^3) vs years of mining

6.1. Potential Impacts Associated with Opencast and Underground Mining

Results – Operational Phase

Pertinent information on the pit geometry is listed in Table 6.1. The geotechnical engineering stability assessment by *Bare Rock Consulting* (Ref: BR_16_2021s March 2022) recommended that no mining be conducted where the roof of the excavation is shallower than 20m below surface.

The 4Seam varies in depth of between 10 and 25m with the average being 15m below surface in the area under the diverted river. In the eastern area where the wetland is located, the roof thickness of the no 4 seam varies between 15 and 30m with the average thickness of 20m.

The roof of the 2Seam under the river diversion varies in thickness between 40m in the west and 20m in the east. In the eastern area under the wetland the seam varies in depth from north to south from 60m to 40m below surface. The geometry of the pillar designs is the same on both coal seams (3.5m mining height, 11.5m pillar width and 18m centre-to-centre distance).

The following conclusions were reached on the operational phase groundwater impacts:

- Mine water balance – opencast mining:
  - The main components of the opencast water balance are groundwater inflow and direct rainfall recharge on mined-out, rehabilitated and operational mining areas:
    - The volumes of water expected to flow into the opencast mining area are summarised in Table 6.2 and Figure 6.3 (seasonal variations will occur, but an average scenario is presented). Note that groundwater inflow will decrease in the North-pit and South-pit because of the expansion effect of the surrounding mines.
    - Higher inflow volumes can be expected for short periods (during excessively wet rainfall periods), and dryer conditions will typically prevail during the winter months.
  - The calculated volumes can serve as input to the detailed operational balance (to be performed by mining engineers), i.e. incorporating rainfall recharge, evaporation aspects and water use in the Operational Phase balance. Therefore, although the water engineers will calculate the water balance, a high-level estimate is provided of the total water balance, which accounts for groundwater inflow as well as rainfall recharge (to active areas and rehabilitated areas) and evaporation potential. See summary in Table 6.2, presented in Figure 6.3.
  - Average annual underground groundwater inflow volumes are presented in Table 6.3 and Figure 6.4. These volumes include the rainfall recharge component and may partially intercept some groundwater inflow that would have occurred into the opencast pits. Calculations also provided for the correct allocation of water ingress for mining periods where the 2Seam will be mined before the 4Seam is mined.
  - Because the two spruits will be undermined, the 3130m^3/d over almost 800ha equates to ±21% of the annual rainfall, which is considered relatively high.
    - Therefore Table 6.3 and Figure 6.4 also indicates the difference in the water balance if the Zaaiwaterspruit is not undermined, which can reduce the underground water balance by almost 75% (total water balance of 830m^3/d).
    - The mentioned geotechnical investigation by *Bare Rock Consulting* (Ref: BR_16_2021s March 2022) recommended that no mining be conducted in areas where the mine roof is <20m deep. This applies only to the 4Seam underneath the Zaaiwaterspruit and the southern portion of the eastern stream, tributary of Zaaiwaterspruit. The results for such a mining scenario is indicated in Table 6.3 and Figure 6.4 (85% reduction in underground water balance, total water balance of 480m^3/d).

      (The rates of groundwater inflow in shallow underground mining beneath the spruits may very hugely depending on whether subsidence occurs, rock hardness and fracturing.)
  - Although a rainfall deficit applies on an annual basis (MAP<MAE), summer rainfall will create a positive balance during certain months, especially during "wet" rainfall cycles.
- Decant and water storage:
  - None of the three pits is expected to decant to surface during mining because excess water in the Pits will be pumped out to keep the workings dry, and the mine floors are below the decant elevation for each Pit.

  - Given the slope of the coal floor and the LOM plan for which certain areas have to be kept dry, it may be possible that portions of the underground can be used to store water in depressions or underground dams. However, these portions will not be fully flooded unless underground seals are installed (which may be impractical).
  - Groundwater flow directions will be toward the opencasts and dewatered rock strata above underground mining areas (i.e. no sub-surface decant to the neighbouring aquifers).
- Impact on groundwater levels:
  - During mining, groundwater levels in the immediate vicinity of the open pits will be influenced (as numerically simulated and partially observed by GGV groundwater monitoring). This dewatering cone was probably limited to <200m from the Pit perimeter for the first few years (i.e. prior to the current situation), gradually expanding over time.
  - The maximum groundwater level impact zone around the opencast will be <400m, except near wetlands and low-laying surface water drainage areas (see Figure 6.5). However, due to the compounded effect of neighbouring mining, the maximum dewatering cone/zone of influence around the opencast will be further to the north, west and south (not indicated).
  - The drawdown beyond the indicated impact zones will not be distinguishable from seasonal groundwater trends. The biggest groundwater level drawdown effect will be observed at the Pit boundary, depending on the Pit floor depth below the groundwater table (≤50m).
- Impact on groundwater quality:
  - The aquifers surrounding un-flooded mining sections are not expected to be impacted in terms of groundwater quality due to groundwater flowing toward the dewatered mining area.
  - The initial groundwater flow into the opencast would have been of similar quality to the background groundwater quality listed in Table 4.5. At present, the groundwater inflow quality is a mixture of uncontaminated background quality and coal-related impacts by surface activities (e.g. coal crushing/processing and surface water dams). Khutala underground and Pit A opencast may contribute mine water to the North-pit (less likely) and South-pit if these areas flood before the completion of the GGV mining.
  - If water is pumped from the opencast pits and underground areas, the SO_4 concentrations should be <800mg/L. However, after being in contact with acid generating material for some time, especially in the pits, SO_4 concentrations will increase (concentrations in the surface dam water circuit exceed 2000mg/L because of the influence of highly contaminated water in areas, such as the Mine Residue Facility (MRF).
  - All water pumped from the opencast is expected to be of neutral pH.
- Where possible, coal discard from the Plant, and carbonaceous rocks should be placed in the deepest part of the pit (at least 20m deep) and covered as soon as possible.
- The geochemical model should be updated every 4years to 5years if deemed necessary by a hydro-geochemist.

Table 6.1 Pertinent opencast physical information relevant to the mine water balance

Pit #	Avg. depth to 2Seam floor (m)		Decant elevation (mamsl)	Mining area (ha)	Water volume storage potential (Mm^3)	Flooded opencast backfill situation below decant elevation	
	Below pre-mining surface	**Below decant elevation**				**Saturated**	**Unsaturated**
North-pit	61.5	31.0	1554.1	613	26.4	50%	50%
South-pit	56.4	27.3	1551.2	1260	68.8	48%	52%
East-pit	56.9	27.1	1551.7	534	29.0	48%	52%
TOTAL				2407	124.2		

Table 6.2 Pertinent opencast water balance information – water-make operational phase

Pit #	Groundwater inflow into pits (m^3/d)				High-level estimate of all water (groundwater inflow, rainfall recharge and evaporation) pits (m^3/d)			
	Current mining		**End of mining**		**Current mining**		**End of mining**	
	Average *	**Maximum**	**Average**	**Maximum**	**Average ***	**Maximum**	**Average**	**Maximum**
North-pit	600	1300	230	500	1900	4200	2200	2900
South-pit	700	1500	500	1150	3000	6800	3600	4000
East-pit	300	600	600	1350	700	1600	2500	2700
TOTAL	1600	3400	1300	3000	5600	12600	9300	9600

* Mine water can dry up significantly during dry rainfall cycles

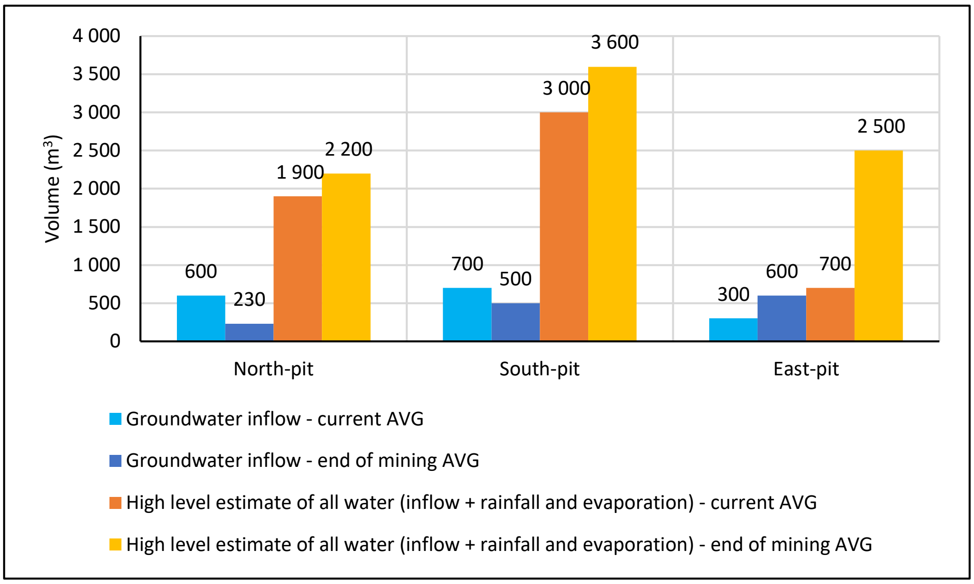


Figure 6.3 **Groundwater inflow volumes (m^3) and high-level estimates of total water balance (groundwater inflow, rainfall recharge and evaporation – m^3) during the operational phase**

Table 6.3 **Groundwater inflow into the underground (m^3/d) during the operational phase for the scenarios where the Zaaiwaterspruit is 1) undermined and if it 2) is not undermined, as well as 3) undermined except where the 4Seam is shallower than 20m**

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8 = Total
UG mine plan	20	70	140	1 000	2 070	2 710	3 040	3 130
UG mine plan, but not Zaaiwaterspruit	20	70	110	140	200	410	740	830
UG mine plan, but not <20m under any stream	20	70	140	140	200	210	390	480

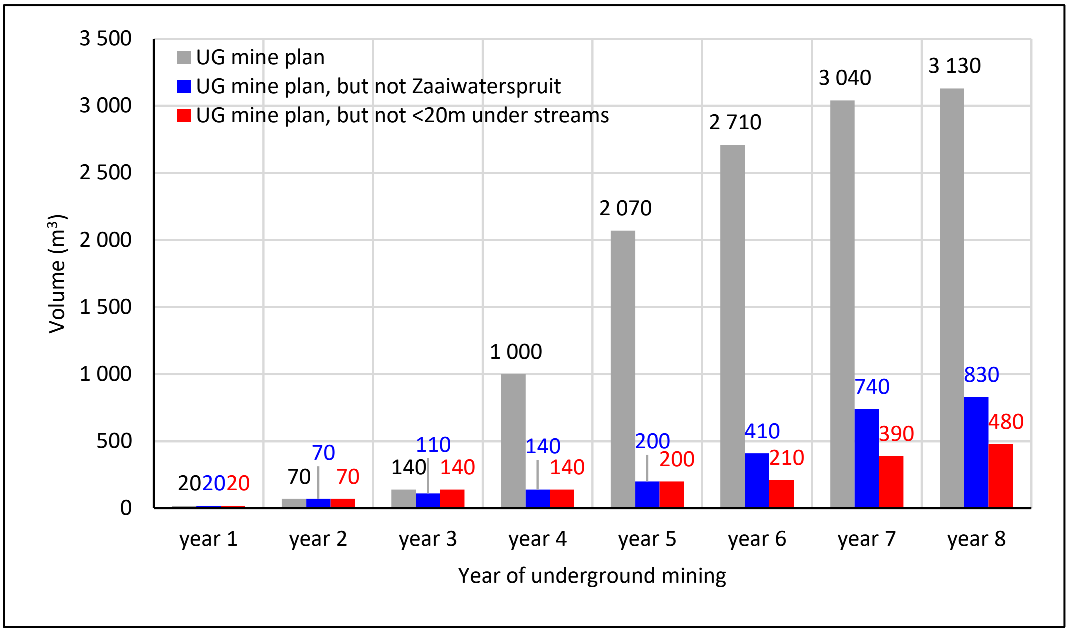


Figure 6.4 **Groundwater inflow into the underground (m^3/d) during the operational phase for the scenarios where the Zaaiwaterspruit is 1) undermined and if it 2) is not undermined, as well as 3) undermined except where the 4Seam is shallower than 20m**

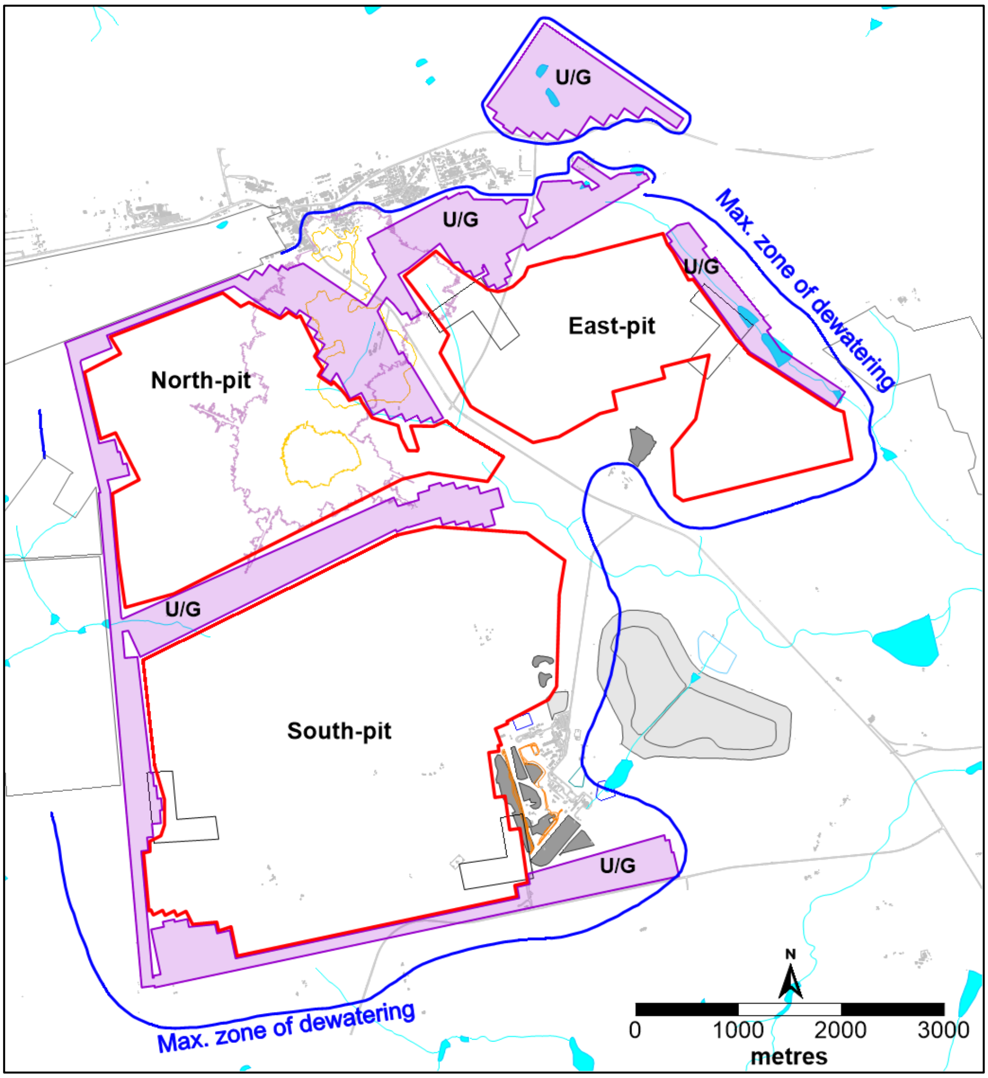


Figure 6.5 Groundwater level impact zones – maximum zone of dewatering

Results – Post-Mining Phase

The effect of the wet rainfall cycle since 2019 on the mine water balance was evident. It is possible that a large component of the water balance was due to surface water runoff. Both the wet periods each summer and the longer term cycles over multiple years, are important.

The revised mine design includes underground areas, which will influence the mine water balance. In addition, the LOM plans by neighbouring mining companies, especially to the west, south and north, also affect the mine water balance. These LOMs were deduced from original mine plans in possession of *Groundwater Square* (not shared with GGV due to confidentiality of the information) and interpretations of Google Earth images over recent years.

Considering that all three opencast pits will be directly connected to underground mining, the following conclusions were reached:

- Time to decant (assuming all underground target areas are mined):
  - Calculations took account of depth to pit floor, the presumption on the moisture content of backfill material, soil subsidence, in-pit water volume at the end of mining, and natural rainfall recharge at 12% of MAP to the opencast and 21% recharge to the underground and because of the undermining of the two spruits (ranging between 5% and >100% in areas underlying the two spruits and between 1% and 5% for the rest of the underground mining area, depending on the depth to the 2Seam and 4Seam). The indicated times to decant in Table 6.4 is 15years-20years after mining for the entire area due to being interconnected and having similar decant elevations.
    - If the Zaaiwaterspruit is not undermined, or shallow underground beneath both streams (<20m deep) are not mined, the first decant will be delayed by a 5years to 10years.
    - With ineffective drainage, surface water will pond on top of the backfill material, and flooding will occur much earlier.
  - Decant will occur directly to the surface at the areas indicated in Figures 6.8.
  - Sub-surface decant will occur as groundwater contamination plumes and base-flow/seepage migration in the groundwater flow direction.
- Flooding status at the time of decanting:
  - As indicated in Table 6.1, ±50% of the backfill material in all three pits will be flooded.
  - Volume stage curves for each pit and the underground areas are included as Figures 6.1-6.2.
- Impact on groundwater levels:
  - The anticipated zone of influence for the operational zone, as indicated in Figure 6.5, may shrink over a period of decades after mining. Due to the compounding effect of neighbouring mining (and their duration of mining), the maximum dewatering cone/zone of influence is difficult to indicate. Given the nearby opencast-mining by Khutala to the west and south (future), opencast-mining to the west and north of the North-pit, and Tweefontein to the east, the current operational phase dewatering zone will continue to expand until all mining have ceased.
  - The in-pit groundwater levels will establish at the decant elevations of 1554.1mamsl, 1551.2mamsl and 1551.7mamsl for North-pit, South-pit and East-pit, respectively.
  - Groundwater flow will essentially be toward the opencast or into active/new mining areas until groundwater levels reach the flooding elevation.
  - Private users at the edge of the dewatering zone, north of the East-pit underground, at Ogies Town, are discussed in Section 3.4 (Figure 3.5). As far as could be determined, no other privately-owned boreholes are located within the indicated groundwater level impact zone.
- Mine water balance and decant volumes/quality:
  - Table 5.1 and Figure 6.7 serves as a summary of the expected mine water quality.
  - Tables 6.5-6.6 and Figures 6.8-6.9 serve as a summary of the expected decant volumes for the three modelling scenarios (Note that if subsidence occurs where the 4Seam mining is too shallow (modelling scenarios-1&2), then all decant might occur in the streams):
    - Due to having the lowest decant elevation, the South-pit may decant the highest volume, irrespective of the modelling scenario, but in the vicinity of the North-pit and Zaaiwaterspruit decant points (see Figure 6.8).
    - Some decant might occur from the North-pit if the Zaaiwaterspruit is not undermined.

        - If the adits are sealed, less water will flow into the South-pit, which explains the lower projected decant volume from the pit, compared to when the adits are not sealed.
    - A distinction was made between decant to the surface and sub-surface decant. While most water might typically decant at the pit perimeter (within approximately 50m from the edge of mining along the downslope of the topography), a component of the pit water will also flow laterally away from the pit beneath the land surface. This contamination plume will eventually daylight a few hundred metres from the pit at lower surface topography, or in a local stream. This sub-surface decant will be less contaminated than the decant at the pit perimeter because the plume will mix with aquifer groundwater and there will also be rainfall recharge. Therefore, a distinction was made between the following decant components, all with different volumes for the three modelling scenarios:
        - Decant to surface at the Pit perimeters.
        - Decant to surface in low-lying areas, 50m and 200m from the Pit perimeter.
        - Groundwater flow can develop contamination plumes in the groundwater flow direction.
    - As can be seen in Table 6.4, the natural rainfall recharge to the three GGV pits will equate to 5540m^3/d, which is less than 60% of the expected decant volumes. A significant component can be contributed from rainfall recharge to the underground and mine water inflows from neighbouring mines (discussed below).
    - Evaporation and transpiration by plants in areas where the mine water is decanting and where the groundwater table will be shallow (i.e. adjacent to the decant areas) will reduce the volumes. Contaminated groundwater decanting to surface as base-flow can manifest as contaminated surface water run-off or salts precipitating on surface (which may, in turn, be transported further by rainfall run-off).
    - Decant will vary seasonally.
- Inter-mine flow volumes:
    - The anticipated rates at which mine water flow will occur to/from neighbouring mines are summarised in Figure 6.10 for the modelling scenario where the adits are not sealed. The results of all three modelling scenarios are summarised in Figure 6.11. The biggest inter-mine flow interaction will be with Khutala from the west with long-term average inflows of ±557m^3/d.
    - The total inflow from surrounding areas into the North-pit and South-pit over the long-term cannot be determined accurately because the inflow component from the Khutala 2Seam and 4Seam underground to the south, west and southeast could not be extracted accurately with a high degree of uncertainty, from the numerical model, due to the manner in which it is calculated in the numerical model.
    - Except for the contamination plumes into the Zaaiwaterspruit, downstream of the North-pit and South-pit, and the Zaaiwaterspruit tributary, downstream of the East-pit, the only outflow from GGV mining is expected east of the East-pit underground (44m^3/d).
- Impact on groundwater quality:
    - Model results in the shallow weathered zone aquifer after 20/50/200years, are included in Figure 6.12.
    - Until flooding occurs, the contamination plume will be restricted to the immediate vicinity of mining.

Table 6.4 Pertinent decant information for the scenario where adits are not sealed

Pit #	Decant elevation (mamsl)	Time to flood (years)		Post-mining decant volumes (m^3/d)	
		Min	Max	Expected rainfall recharge	Simulated decant
North-pit	1554.1	15 – 20 *		1 411	0
South-pit	1551.2			2 900	6 720
East-pit	1551.7			1 230	2 210
Zaaiwaterspruit tributary at East-pit				3 132	130
Zaaiwaterspruit between North-pit and South-pit					260
All other underground areas					
TOTAL				5 540 for pits 8 672 for all mining	9 320

* 5years to 10years longer if the 4Seam underground beneath the streams, which are <20m deep, are not mined.

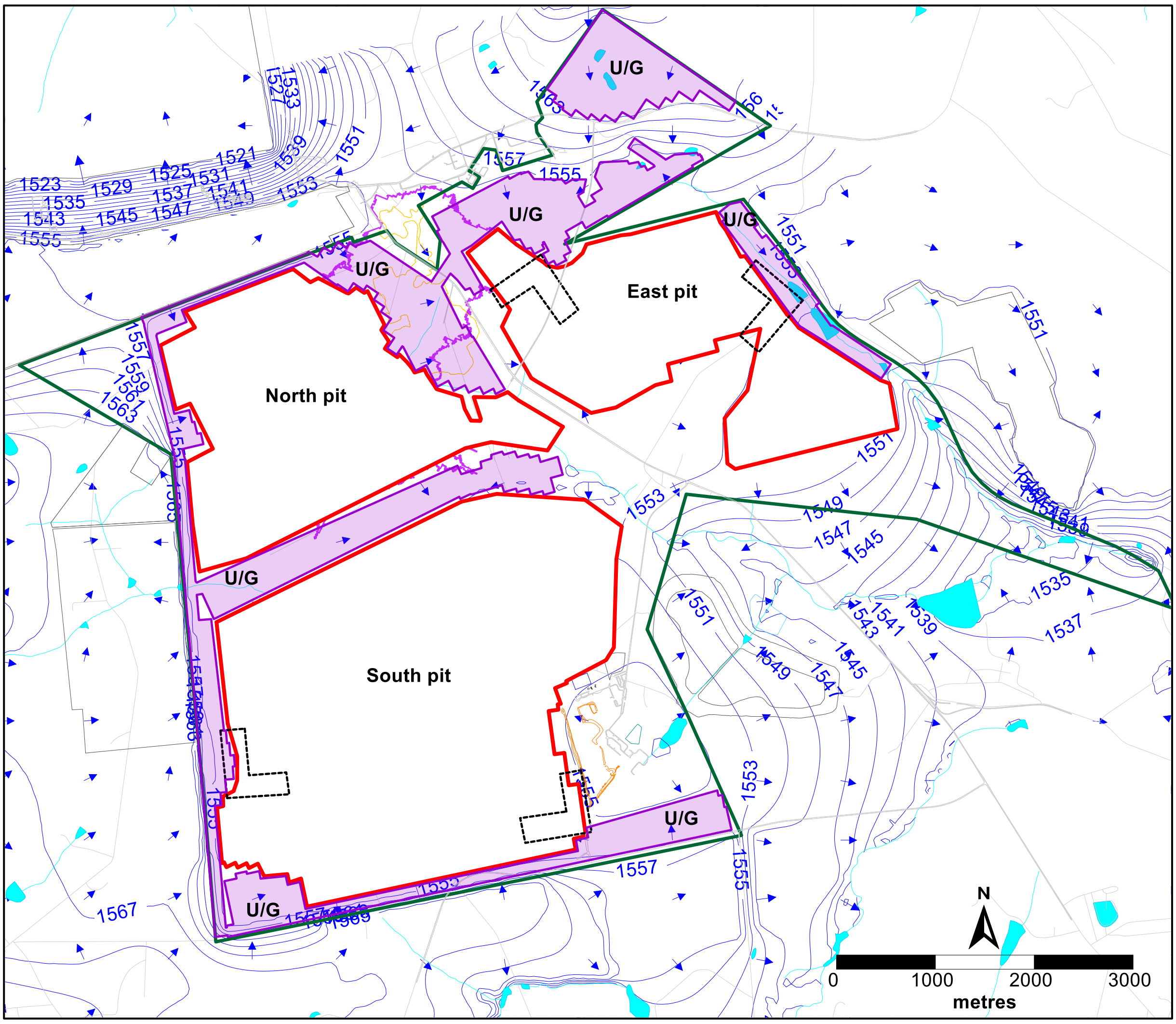


Figure 6.6 Groundwater level elevations – post-mining

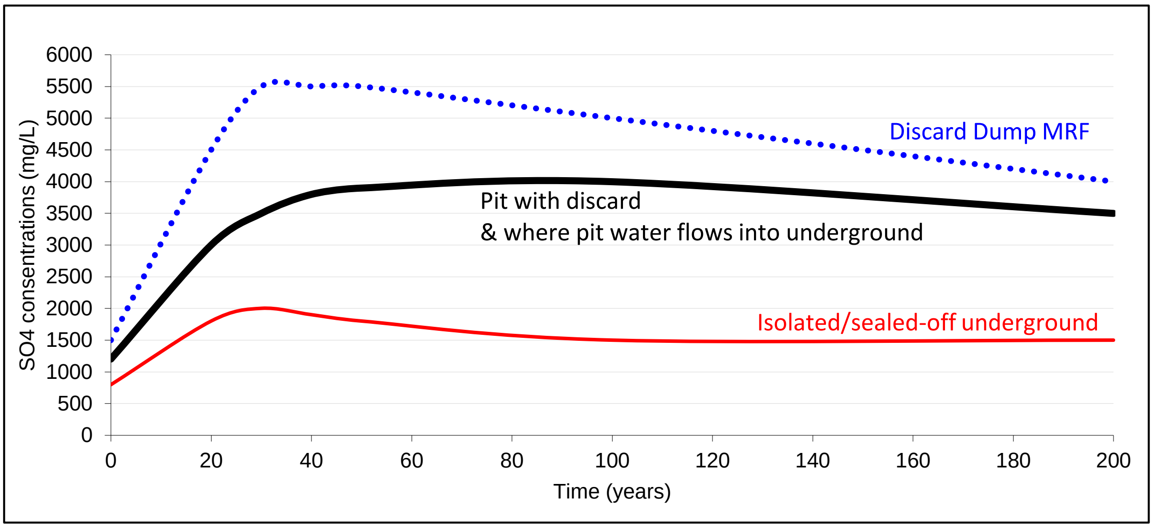


Figure 6.7 Mine water quality trend predictions – post-mining

Table 6.5 *Long-term post-mining groundwater base-flow/decant interaction with surface environment for the scenario where the adits are not sealed (also see Table 6.6)*

Base-flow/decant zone		Volume (m^3/d)		SO_4 conc. (mg/L)
Decant at pit perimeter	North-pit-	0	Mine water Total = 8930	4000
	South-pit	6 720		4000
	East-pit	2 210		4000
Decant seeping from underground into river	Zaaiwaterspruit tributary at East-pit	130 *	Underground mining seepages Total = 389 *	1500 - 4000
	Zaaiwaterspruit between North-pit and South-pit	260 *		
Sub-surface decant	Downstream from Nort-pit and South-pit	<100	Mixture of pit water base-flow and groundwater in local aquifers	250 - 1000
	Downstream from East-pit			

* If subsidence occurs where the 4Seam mining is too shallow, then all decant might occur in the streams.

Table 6.6 *Comparison of long-term post-mining groundwater base-flow/decant volumes (m^3/d) of the three modelling scenarios*

Base-flow/decant zone		Model-1: Do not seal any adits/shafts to the underground		Model-2: Seal adits/shafts to the underground		Model-3: No undermining of the Zaaiwaterspruit between the North-pit and South-pit.	
		Volume (m^3/d)	Total (m^3/d)	Volume (m^3/d)	Total (m^3/d)	Volume (m^3/d)	Total (m^3/d)
Decant at pit perimeter	North-pit-	0	8930	0	7500	970	8570
	South-pit	6720		4940		4940	
	East-pit	2210		2560		2660	
Decant seeping from underground into river	Zaaiwaterspruit tributary at East-pit	130 *	390 *	130 *	350 *	130 *	370 *
	Zaaiwaterspruit between North-pit and South-pit	260 *		220 *		240 *	

* If subsidence occurs where the 4Seam mining is too shallow, then all decant might occur in the streams.

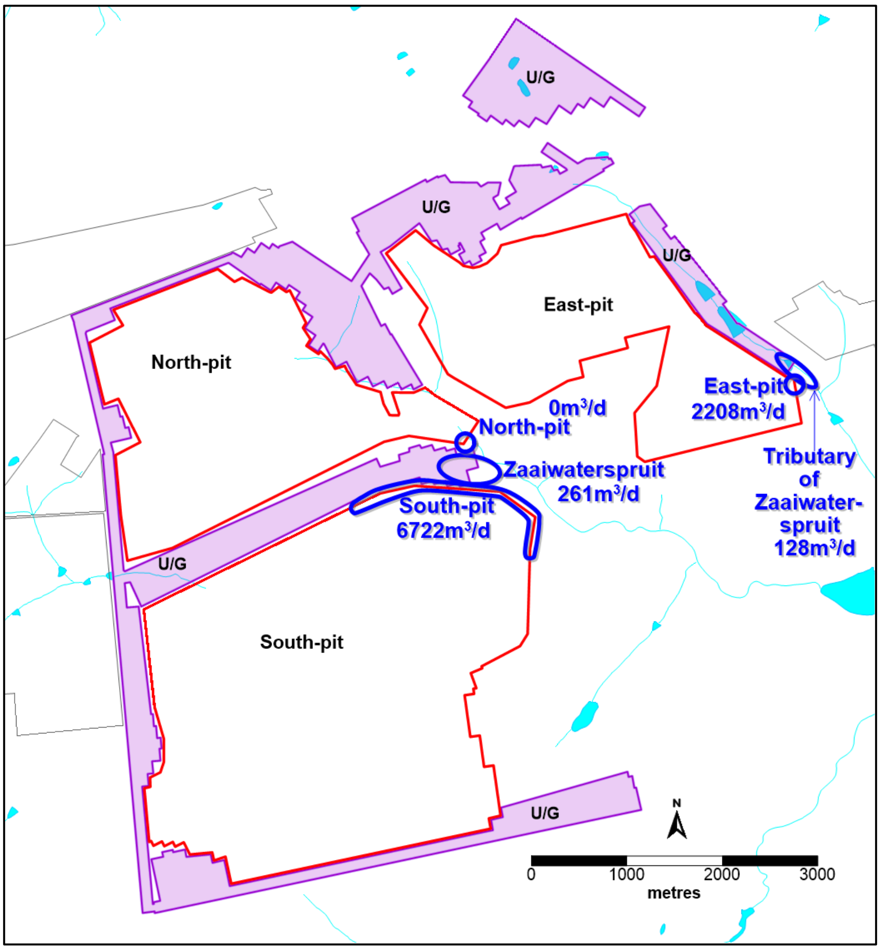


Figure 6.8 *Decant summary for the scenario where the adits are not sealed (see results for other two scenarios in Tables 6.5-6.6)*

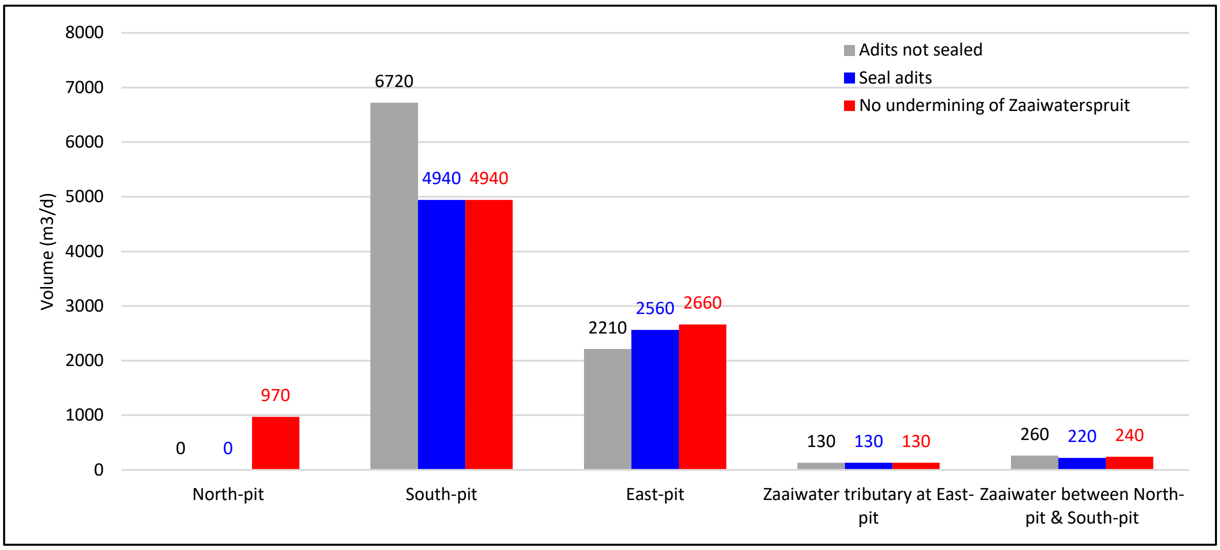


Figure 6.9 Decant volume (m^3/d) summary for the three modelling scenarios

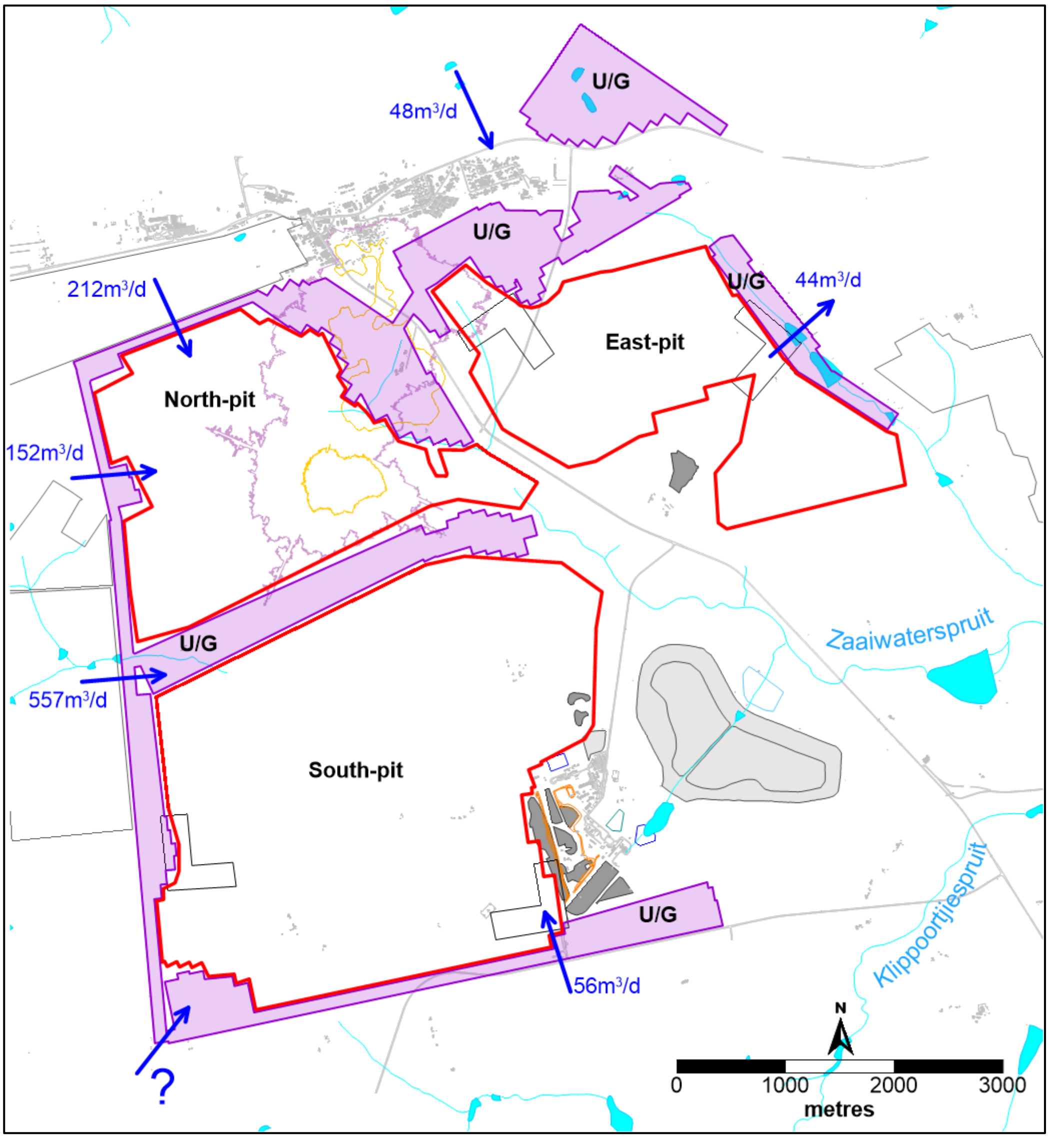


Figure 6.10 Inter-mine flow rates (m^3/d) for Model-1 scenario where no adits are sealed

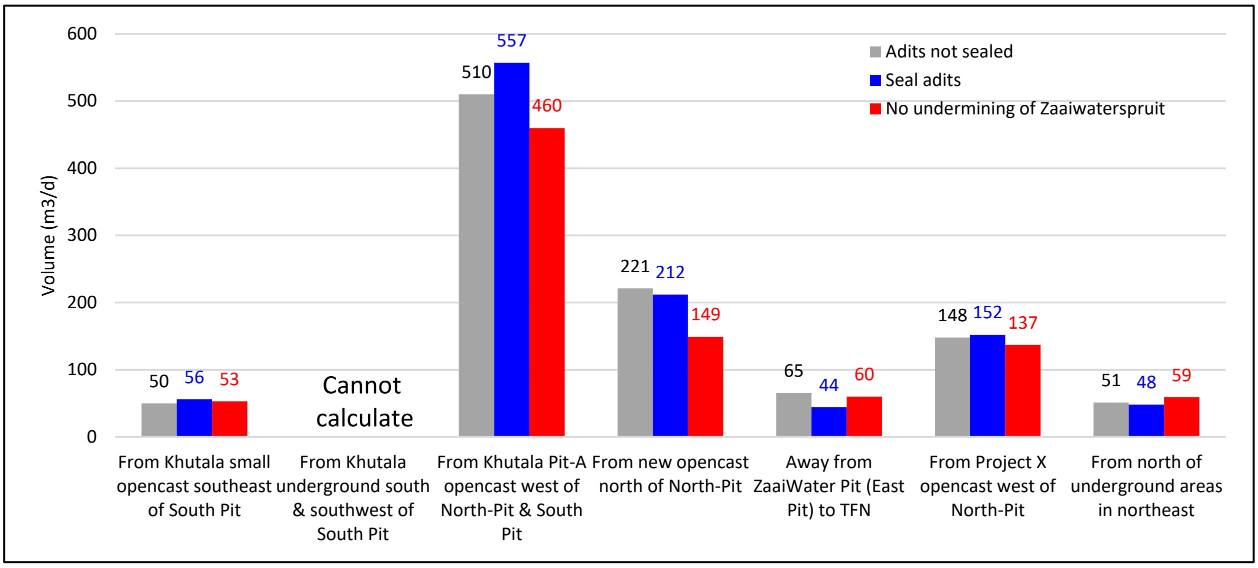


Figure 6.11 Inter-mine flow rates (m^3/d) for all three modelling scenarios

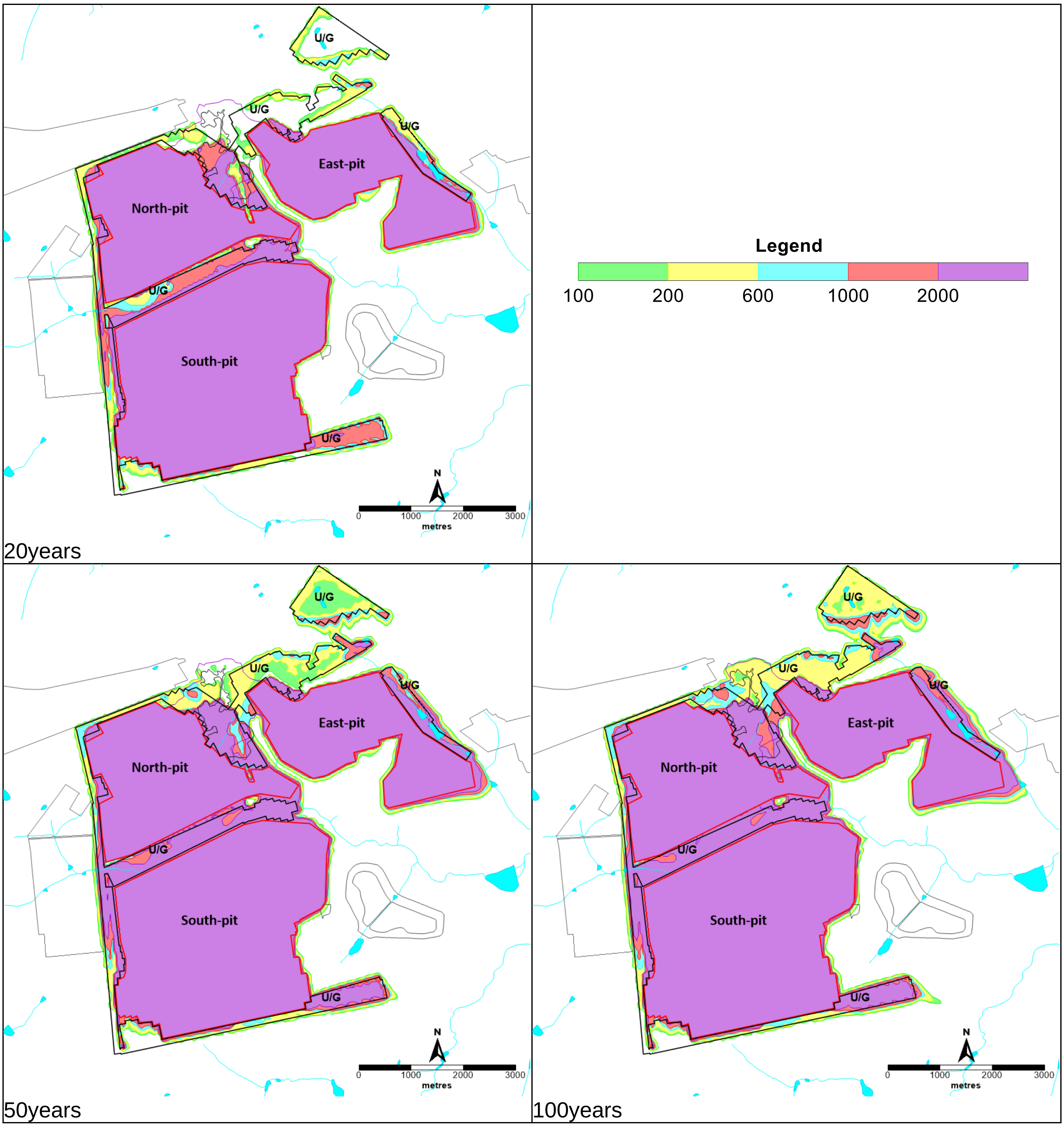


Figure 6.12 **Numerically simulated SO_4 contamination plume (mg/L), 20/50/100years after flooding for Model-1 scenario where no adits are sealed**

6.2. Assessment of Potential Impacts Associated with MRF

Given the observed impact that the Mine Residue Facility (MRF) is having on the receiving groundwater system and possibly the surface water environment, a discussion on the expected water qualities from this facility is important.

Results – Operational Phase

The current potential to contaminate the local aquifers will remain until the MRF is closed. The active mine water circuit is influencing the water qualities in the return water dam that is associated with the MRF.

Results – Post-Mining Phase

Table 5.1 and Figure 6.7 serve as a summary of the expected seepage water quality from the MRF.

Coal discard contains a significant pyrite content and will generate a sulphate concentration of between 500mg/L to 4000mg/L over the short term (<15years). However, all indications are that, over the long-term, the seepage water will remain at 4000mg/L to 5000mg/L in the anoxic zone, while the concentration will further increase in the oxic zone above 5000mg/L to 8000mg/L.

Therefore, the water balance of the MRF will be important during the post-closure phase.

6.3. Assessment of Potential Impacts Associated with Ogies Dump and Overburden Dumps

A recent environmental audit determined that the Old Ogies Dump and Overburden Dumps around GGV are not described in terms of their impacts on the groundwater system.

The Old Ogies Dump is located south of Ogies Town, North of the East-Pit (see Figure 6.13). It was used decades ago during the mining of the Old Ogies Underground, which targeted the 5Seam and 2Seam. The earliest Google Earth image indicates the dump as rehabilitated with a soil cover and vegetation in 2006. The Old Ogies Dump was not remined after 2006, but an Overburden Dump, consisting of white overburden material, was developed to the east of the Ogies Dump, which expanded and started covering the Ogies Dump towards the end of 2018. One year later, darker type rock material was placed on this Dump, which now covers almost 70% of the Ogies Dump.

Due to the expanding opencast and underground mining, the East-pit extends to 150m from the Ogies Dump and it will overlap with the planned underground delineation.

Fortunately, one groundwater monitoring borehole, GOGW-6, that was monitored until 2017 (when it was covered by mentioned overburden material – see Figure 6.13) could provide information on groundwater quality. Assuming that the borehole was sampled correctly between 2012 and 2016, the main indicator parameters reflected only marginal contamination (EC = 80 mS/m to 100mS/m, SO_4 = 270mg/L to 470mg/L at neutral pH).

Several Overburden Dumps, which contain very little acid-generating rock, have been placed around the opencast mining area.

Results – Operational Phase

The current potential to contaminate the local aquifers will be limited given the relatively uncontaminated groundwater system, assuming that non-carbon material will continue to be dumped on the Ogies Dump or the operation ceases.

Groundwater flow is expected from the Ogies Dump vertically down into the underground workings at a low rate of infiltration and should not impact groundwater in Ogies Town.

The Overburden Dumps should have limited potential to increase groundwater recharge on the footprint areas of these Dumps. Due to the dewatering of the aquifers around the pits and above underground areas, the Overburden Dumps should not result in rising groundwater levels. Given the low recharge potential, little or no acid-generating material, and the relatively short period before the Dumps are placed back into the pits, the potential to contaminate the groundwater system is very small.

Groundwater flow is expected from the Overburden Dumps vertically down into the underground workings or toward the pits at a low rate of infiltration and should not impact groundwater.

Results – Post-Mining Phase

After the Overburden Dumps areas are rehabilitated by placing this material back into the pits, the water balance of the Ogies Dump will continue as before the additional storage of overburden rock on the Dump.

Eventually, groundwater flow is expected from the Ogies Dump in the direction of the East Pit (i.e. south), and should not influence groundwater in Ogies Town. Groundwater in the aquifers beneath all footprint areas of the Discard Dumps will flow in the direction of the three pits.

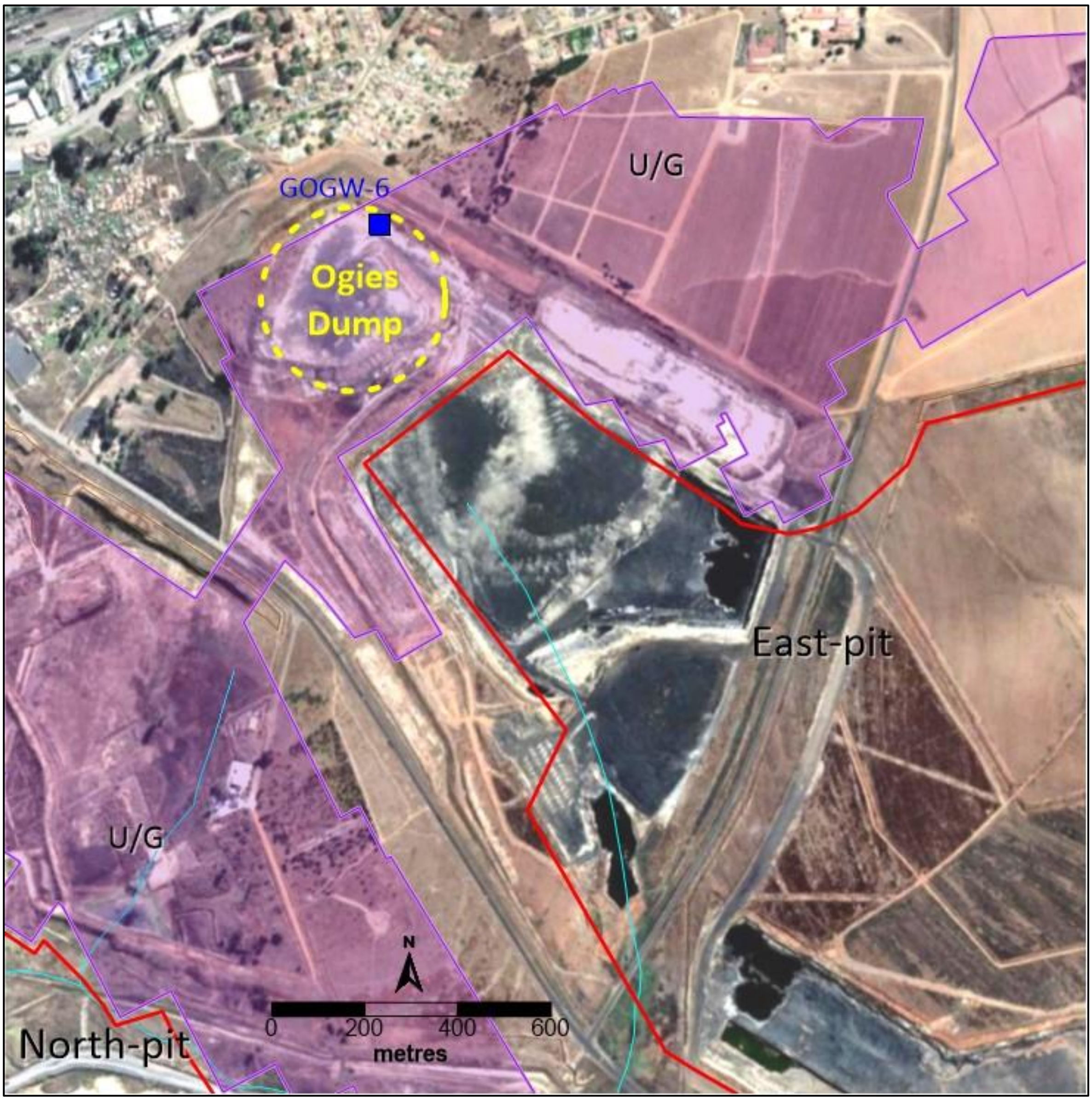


Figure 6.13 ***Google Earth images of Ogies Dump, also indicating the LOM and destroyed monitoring borehole GOGW-6***

7. RECOMMENDATIONS

7.1. Mine Water Balance and Quality

The four main ways in which the mine water balance can be reduced during both the operational phase and post-closure phase are:

- Only mine the underground sections beneath the streams, which are >20m deep (recommended during geotechnical engineering stability assessment by *Bare Rock Consulting*, Ref: BR_16_2021s March 2022). This applies to 4Seam coal beneath the Zaaiwaterspruit (between the North-pit and South-pit) and the eastern wetland stream tributary of the Zaaiwaterspruit (east of East-pit).
- Grout underground sections where large groundwater inflows are observed.
- Ensure that barrier pillars with neighbouring mines are as wide as possible.
- Effectively reduce the infiltration potential of opencast pits through good rehabilitation, shaping, vegetation and run-off designs.

Where possible, coal discard from the Plant, and carbonaceous rocks should be placed in the deepest part of the pit (at least 20m deep) and covered as soon as possible.

7.2. Groundwater Monitoring

A well-designed monitoring programme serves as a means of verifying numerical modelling predictions of the potential mining impacts. It is also an early warning system for taking corrective actions.

As part of the water management plan/strategy, it is necessary to comprehend the pollution mechanism and characteristics of the Mine and to monitor how pollution changes with time. The cumulative impacts from/on neighbouring mines and the receiving environment should be considered.

The existing and newly recommended monitoring boreholes listed in Table 7.1 (depicted in Figure 7.1) should be used to monitor/study inter-mine flow with neighbouring mines through shared berms, the dewatering impact, the in-pit mine water quality in rehabilitated areas and dewatering in the direction of mining. Drilling of new holes will be required to replace defunct holes (x2), establish berm boreholes (x6, of which one medium-depth and one deep borehole is needed on the shared boundary with the Khutala Pit A to the west), establish an in-pit mine borehole in the rehabilitated portion of the South-pit (x1). All holes will provide information on the dewatering of surrounding aquifers.

These boreholes have been numbered according to the *Glencore* numbering philosophy (GOGW = Shallow weathered zone monitoring borehole, GOGF = Deep fractured aquifer monitoring borehole, GOGM = Mine water monitoring borehole).

Additional boreholes will be required within two years.

GGV drilled a borehole, indicated as "GGV BH Oct'21" in Figure 7.1. Other than its coordinates, the detail of this hole is not known. It might prove valuable in terms of the underground dewatering and should be included in the monitoring system. The following additional comments are important:

- Dedicated monitoring boreholes should be drilled to replace any boreholes destroyed by mining activities (as advised by hydrogeological studies).
- During the latter stages of mining, the flooding status of the rehabilitated areas will become critical in predicting decant (volume and quality). In-pit boreholes will be important.
- Hydrocensus boreholes identified in 2019 falling outside the regular monitoring zones should also be monitored (though less frequently).
- Recommended groundwater sampling methodology:
    - Hydrochemical profiling of each borehole water column (i.e. measurements of pH, EC, temperature and other parameters) should be performed.
    - Boreholes should be grab-sampled at predetermined depths, as determined from the borehole water column geochemical profile, geology and occurrence of water intersections.
    - Boreholes containing pumps should be sampled under application conditions, i.e. collecting a pumped water sample.
- Recommended groundwater monitoring within the predicted impact zones of groundwater levels and groundwater quality:

Groundwater levels	Groundwater quality	
	Quarterly	**Six-monthly**
Monthly	As a minimum: pH, EC, TDS, Ca, Mg, Na, K, Cl, SO_4, NO_3, Tot.Alk., Si, Fe, Mn, Al	Additional recommendations by geochemist (PO_4, NO_3, NH_3. trace metals in acidic water [Co, Ni, Pb, Se]).

  - Once the impacts of potential contamination sources and dewatering have been established (sufficient information gathered), monitoring schedules and analyses can be adapted, as determined by a groundwater expert in consultation with *DWS*.
- Water quality criteria:
  - If groundwater qualities are found to exceed the specified limits of the SANS-241 (2015) Drinking Water Guidelines, <u>or site-specific water quality objectives</u>, action may be required to improve/mitigate the source of contamination.
  - Current catchment water quality objectives should be considered, which take cognisance of the background groundwater quality, neighbouring mining and feedback/discussions with upstream/downstream water users.
- Reporting:
  - Data should be collated in a well-structured formal database.
  - Six-monthly data reports should be submitted to management.
  - Monitoring data should be reviewed in detail on an annual basis, specifically to:
    - Addressing any actions that could reduce impacts.
    - Motivation for additional monitoring localities, change in schedules etc.

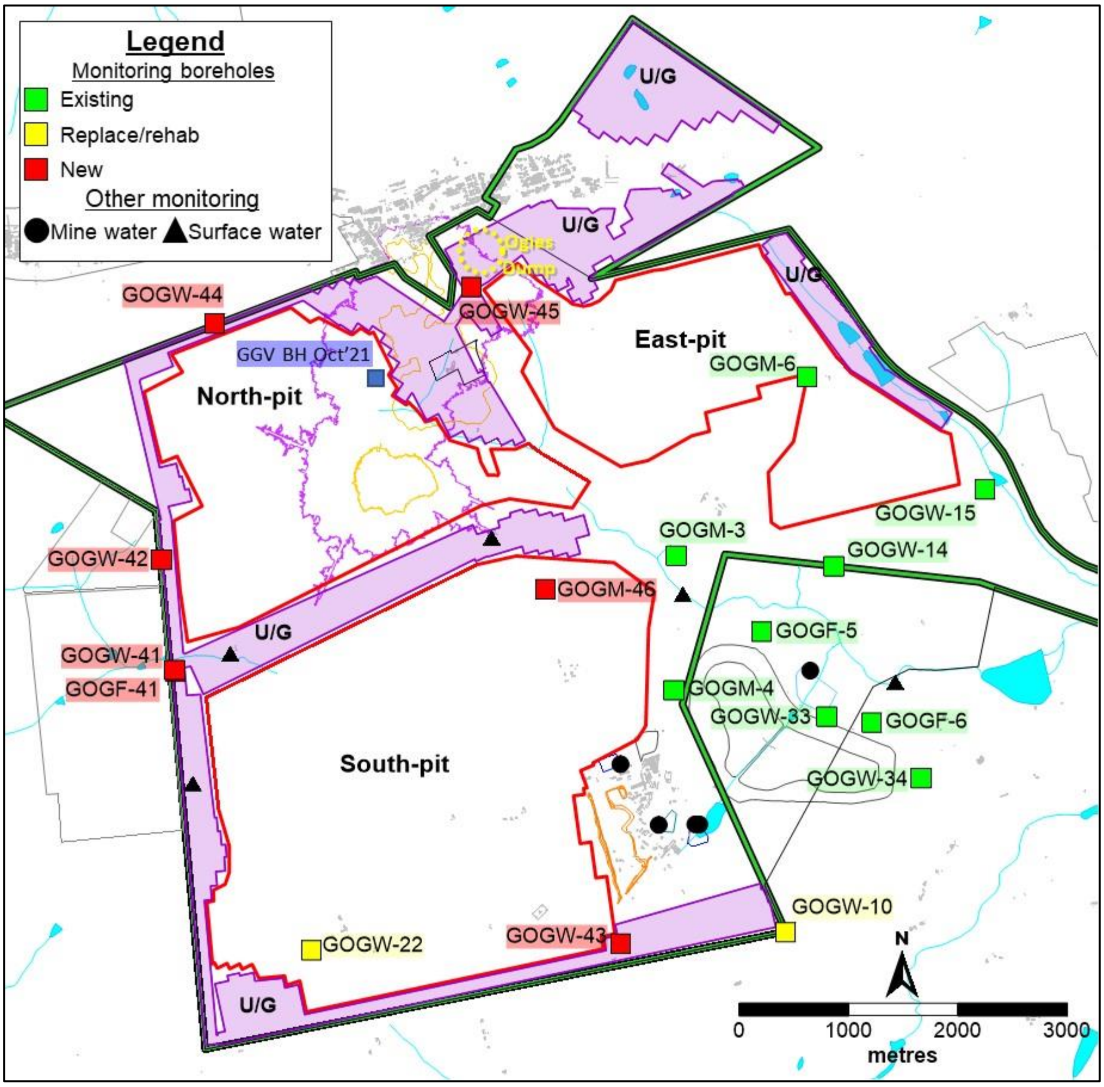


Figure 7.1 Recommended groundwater monitoring localities

Table 7.1 Recommended groundwater monitoring localities

Borehole Number	Coordinate (WGS84)			Comment
	Latitude	Longitude	Z	
GOGF-5	-26.08640	29.08420	1560.9	Monitoring around Mine Residue Facility.
GOGF-6	-26.09389	29.09430	1553	
GOGW-33	-26.09340	29.09016	1563.6	
GOGW-34	-26.09846	29.09880	1563.8	
GOGW-14	-26.08101	29.09081	1583.2	Mining impact and Mine Residue Facility monitoring.
GOGM-3	-26.08016	29.07638	1569.4	Mining impact monitoring.
GOGM-4	-26.09124	29.07618	1578.8	
GOGM-6	-26.06539	29.08833	1588.2	
GOGW-10*	-26.11118	29.08643	tbd	
GOGW-15	-26.07466	29.10463	1553.8	
GOGW-22*	-26.11268	29.04303	1606.7	
GOGW-41 ** GOGF-41 **	-26.08969	29.03055	tbd	Berm monitoring boreholes to assess inter-mine flow.
GOGW-42 **	-26.08049	29.02931	tbd	
GOGW-43 **	-26.11214	29.07133	tbd	
GOGW-44 **	-26.06232	29.03533	tbd	
GOGW-45 **	-26.06232	29.03533	tbd	
GOGM-46 **	-26.08424	29.05845	tbd	In-pit/ODEX borehole at lowest mine floor to monitor mine water quality and level
GGV BH Oct'21	-26.06480	29.04849	1 582,575 toc 1 582,072 boc	Borehole drilled by GGV. Incorporate if drilling specifications/construction relevant

* Replace or rehabilitate borehole
** New borehole

The recommendations for groundwater monitoring are not complete for the LOM, but the recommendations will be a significant upgrade to the groundwater monitoring system. "Upstream" and inter-mine flow monitoring will become more important. Dedicated monitoring will also be required once a mining license is received for the underground expansion. Therefore, it is further recommended that:

- Future monitoring should include the qualities of water pumped from the pits to better comprehend the ABA process.
- Additional in-pit monitoring boreholes should be drilled in rehabilitated areas, at least one borehole for each mining section where the floor is the deepest.

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