Tharisa Minerals:
Open Pit Backfilling, On Ground WRD Numerical Modelling and Hydrogeological Impact Assessment

Technical report

Project no: 720.20002.00065

Prepared for: SLR Consulting (South Africa) (Pty) Ltd

13 October 2022

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REPORT DISTRIBUTION LIST

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DOCUMENT HISTORY

Report no	Date	Version	Status
720.20002.00065	13 October 2022	5	Draft

List of abbreviations

Abbreviation	Description
ACS	Artesium Consulting Services
a	Annum
BDL	Below detection limit
CCP	Critical Control Parameters
DWAF	Department Water Affairs & Forestry
EIA	Environmental Impact Assessment
GW	Groundwater
HIA	Hydrogeological Impact Assessment
ha	hectare
I&AP	Interested and Affected Parties
LCT	Leachable Concentration Threshold
LoM	Life of Mine
mamsl	metres above mean sea level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mbgl	metres below ground level
Mil	Million
Mon	Month/s
OG	On-ground
P5	5^{th} Percentile (Lower range)
P50	50^{th} Percentile (Median)
P95	95^{th} Percentile (Upper range)
PC	Post Closure
PCD	Pollution Control Dam
PPCD	Plant Pollution Control Dam
PW	Process Water
RoM	Run of Mine
SANS	South African National Standards
SPRA	Source-Pathway-Receptor Analysis
SW	Surface Water
TCT	Total Concentration Threshold
TDS	Total Dissolved Solids
TSF	Tailings Storage Facility
WRD	Waste Rock Dump
ZOI	Zone of Influence

Executive Summary

The objective of the hydrogeological and hydrogeochemical study risk assessment for the proposed complete backfilling of two open pits and On Ground (OG) WRD mine residue facilities is to evaluate the risk to receptors. The risk assessment is for the surface water- and groundwater pathways, which is used to plan and design potential management and mitigation measures. A detailed review and analysis of the existing hydrogeological and hydrogeochemical data and reports and waste assessments was conducted. The main findings and conclusions are summarised below.

Main Findings

1. **Waste assessment** – Based on the geochemical analysis, all waste types (WRD and tailings), classify as Type 3 based on TCT0 exceedances. The TCT0 exceedances are irrelevant for the surface and groundwater pathways. The 2020 Vulcan Tailings sample classifies as Type 3 due to Cr exceedances. For the 2022 Vulcan tailings and all WRD samples, there are no LCT0 exceedances, and the waste can be classified as equivalent to Type 4. Although geochemical analysis of the solids and leaching components are important, it can differ from the actual field conditions.
2. **Monitoring Data –** The long-term water quality monitoring data from 2013 to 2021 of 232 process water samples were analysed statistically. From the analysis none of the samples exceeded the chromium SANS 241 Drinking Water Limit. Chromium is therefore not a parameter of concern at the site. The monitoring results confirmed that only Nitrate is a potential contaminant parameter.
3. **Dewatering** – The calibrated model showed combined East Pit and Samancor Underground simulated inflows in the order of ± 5 600 m^3/d. The average inflow rate simulated for the west and far west pits over the transient state calibration simulation period are ± 460 m^3/d and ± 600 m^3/d respectively. The water level data analysis shows that the dewatering cone from the respective open pits are of local extent (< 500 m) and do not currently point to major dewatering effects on neighbouring I & APs north and south of the west open pit.
4. At the deepest point of mining, the East Pit would dewater at a rate of ± 2 600 m^3/d, with the Samancor Underground dewatering being ± 3 900 m^3/d. The West Pit will dewater at a rate of ± 1 600 m^3/d (these abstraction volumes do not include additional water due to rainfall-runoff within the pit). The modelling results show that the West Pit cone extends ± 700 m to the south and would potentially affect 4 I & APs near the mine (1 – 10 m drawdown). These include borehole AMG11, The Retief Primary School borehole, as well as the Wolvaart and van der Hoven residences. Potential groundwater users within the Marikana informal settlement are also situated within the modelled ZOI (1 -10 m drawdown). The source of their water needs to be verified as it is inferred that they receive Magalies water. All the hydrocensus boreholes downstream of the site will be affected to an extent (1 – 10 m drawdown). It must be noted that most of the land uses are industrial and mining related. Due to the East Pit and West Pit's proximity to the Sterkstroom, the stream section directly adjacent to the open pits will most likely experience a drawdown effect (10 – 25 m).

5. **Residue Facilities** - From the unmitigated maximum impact nitrate mass migration results, the nitrate plumes do not travel < 500 m from the current and proposed new facilities for both East Pit and West Pit, with the main receptors being the Sterkstroom, Marikana settlement directly downstream of the mine, I & APs directly next to Far W WRD 1 (The Wolvaart and van der Hoven residences) and west of W WRD 1 (Retief Primary School borehole). The ZOI would also minimise nitrate mass migration off site and therefore migration impacts are low for the proposed new facilities. Nitrate is only an operational concern as it would decay to below SANS 241 Drinking Water Standard Limits after 5 - 10 years post operations.
6. **Impacts** – The simulated maximum cone of depression is < 700 m from the open pit boundaries (localised in extent) and potentially impact 4 I & APs as well as potential groundwater users at the Marikana Informal Settlement. Groundwater level and chemistry monitoring based on the updated monitoring protocol and if impacts are measured, mitigate by supply of alternative water to any impacted users. If specific fractures are intersected during mining these could be grouted/sealed to manage the impact. If verified based on monitoring data, the impact can be managed and reversed from a High to a Low impact.
7. Nitrate plume migration from current and proposed new residue facilities does not migrate more than < 500 m, with the open pits acting as a groundwater sink limiting migration (medium impact rating). The recommended Multiple-Capturing-Barrier-System mitigation and sustainable groundwater management plan should be included in the mine planning. The management plan should be activated based on monitoring, early warning, and verification of simulated potential impacts. Nitrate is only an operational concern as it would decay to below SANS 241 Drinking Water Standard Limits after 5 - 10 years post operations. The mitigation proposed would ensure management of the impact to a low-risk rating.
8. **Post Closure** - The backfilled open pits were simulated take 90 - 110 years to reach the decant level and would decant at estimated 200 m^3/d to 600 m^3/d. The water quality would be usable. Post closure re-watering and mass migration is not a significant impact. The flooded backfilled pits would form excellent artificial aquifers with usable water quality during the post-operational phase. Options to use these as water resources and enhance recharge yield by diverting surface water into these during flood conditions should be considered and evaluated via further modelling and studies. Nitrate degradation due to denitrification also causes the plumes to dissipate within a maximum of 5 - 10 years.

1. Source

1.1. A total of 17 solid phase (TCT) and geochemical leach tests (LCT) were done from 2019 to 2022. The TCT results indicated that the mine residue material (Tailings and Waste Rock) classifies as a Type 3 waste. The TCT component is irrelevant for the surface water and groundwater pathways. The LCT results (important for the aqueous pathway) for only one sample (2020 Tailings) classified as a Type 3 waste and was due to a chromium (Cr-3) exceedance. All the other samples did not exceed the LCT0 threshold for any parameter.

1.2. When chromium is excluded in the 2020 samples, the tailings material's leach test results conform to the SANS 241 Drinking Water Standard.

1.3. The 2020 tailings sample indicated a LCT chromium concentration of 0.4 mg/L which is a 400% exceedance of the LCT0 limit of 0.1 mg/L. However, chromium (Cr-3) is not present in the process water monitoring data and is an artefact of the laboratory scale leach tests. The 2022 Vulcan tailings samples (the process removes more chrome) have no LCT0 exceedances and could be equivalent to a Type 4 waste.

1.4. From the July 2022 hydrocensus conducted, only one downstream sample (OC BH 02) showed an exceedance of the manganese SANS 241 Drinking Water Limit. Apart from borehole OC BH 02, minimal exceedances of the P95 2013 upstream baseline were observed for sodium, sulphate, nitrate, and copper. These exceedances were still well below the SANS 241 Drinking Water Limits for the respective constituents.

1.5. From the surface water samples taken during the hydrocensus (Upstream TM SW01 and downstream TM SW04), the results show that only Cu concentrations exceed the P95 2013 upstream baseline, with no SANS 241 Drinking Water Limit exceedances.

1.6. The long-term water quality monitoring data from 2013 to 2021 of 232 process water samples were analysed statistically. From the analysis none of the samples exceeded the chromium SANS 241 Drinking Water Limit. Chromium is therefore not a parameter of concern at the site. The long-term water quality monitoring data gives a much more accurate representation of site conditions compared to laboratory scale leach test data.

1.7. Nitrate originates from the current arisings through explosives and does not originate from the geochemistry of the tailings. Based on historical data It can potentially build up to concentrations of ±160 mg/L in the process water and adjacent to waste facilities.

1.8. Nitrate degrades due to natural denitrification processes and a decay half-life of ± 110 - 160 days has been determined for this site. It is therefore only an operational concern and would decay to drinking water standards within 5 - 10 years after operations end. When nitrate is excluded, the water quality is good and close to SANS Drinking Water Standards.

2. Pathways

2.1. From the 813 groundwater and surface water monitoring samples taken over 9 years 2013 to 2022 no SANS 241 nitrate exceedance (> 11 mg/L) was observed > 500 m from the mine residue facilities. The existing tailings facilities shows that the groundwater flow velocities are sufficiently low which allows significant decay of nitrate with distance.

2.2. From statistical and spatial analysis of the water level data show that the dewatering cone from the open pits are of local (onsite) extent and do not currently point to major dewatering effects on neighbouring I & APs north and south of the west open pit.

3. Receptors

3.1. The local and regional groundwater flow is towards the north. The strike direction of the faults and dykes are also in a north/northwest to south/southeast direction. The majority of the downstream receiving environment is industrial, agricultural and/or mining, for which the minor nitrate contributions would not be a significant impact. Some localised small holding properties and informal settlements do exist.

3.2. Seven potential neighbouring receptors were identified:

3.2.1. Informal settlement (Marikana) to the north of West Pit

3.2.2. Lapologang Settlement to the south of Far W WRD 1.

3.2.3. The Sterkstroom from the W WRD 1 downstream to the edge of the Marikana Informal Settlement.

3.2.4. The Retief Primary School borehole.

3.2.5. The Wolvaart and van der Hoven residences directly south of Far W WRD 1.

3.2.6. The du Preez and Pretorius residences west of W WRD 1

3.2.7. The graveyard west of W WRD 1.

4. Results

4.1. The modelling results show that the West Pit cone extends ± 700 m to the south and would potentially affect 4 I & APs near the mine (1 – 10 m drawdown). These include borehole AMG11, The Retief Primary School borehole, as well as the Wolvaart and van der Hoven residences.

4.2. Potential groundwater users within the Marikana informal settlement are also situated within the modelled ZOI (1 -10 m drawdown). The source of their water needs to be verified as it is inferred that they receive Magalies water. All the hydrocensus boreholes downstream of the site will be affected to an extent (1 – 10 m drawdown). It must be noted that most of the land uses are industrial and mining related.

4.3. Due to the East Pit and West Pit's proximity to the Sterkstroom, the river section directly adjacent to the open pits will most likely experience a drawdown effect (10 – 25 m).

4.4. The simulations show that based on the lower range (P5) monthly catchment runoff flows, a 6 - 10 % impact would be observed from April – Oct. During these months, piping, or discharge from dewatered flow volumes in the Sterkstroom from an upstream point before the mine to a downstream point after mining activities can be employed to minimize the impact on the Sterkstroom groundwater baseflow. These impacts, especially on aquatic ecology, hydrology, and geohydrology, must be quantified in more detail by dedicated specialist studies to provide significance to the potential impacts.

4.5. From the unmitigated maximum impact nitrate mass migration results, the nitrate plume does not travel < 500 m from the proposed new facilities for both East Pit and West Pit, with the main receptors being the Sterkstroom, Marikana settlement directly downstream of the mine, I & APs directly next to Far W WRD 1 (The Wolvaart and van der Hoven residences) and west of W WRD 1 (Retief Primary School borehole). The ZOI would also minimise nitrate mass migration off site and therefore migration impacts are low for the proposed new facilities.

4.6. From the monitoring data and modelling results, nitrate mass migration within the Sterkstroom is limited and of local extent, as TM SW04 (located ± 1 km downstream) showed no nitrate exceedances during the July 2022 hydrocensus. Build-up of nitrate concentration directly downstream of the mining operations can be observed through LoM, but as seen with the long-term monitoring data concentrations would seldomly exceed the SANS 241 nitrate concentration limit (pulse events).

4.7. Impacts on receptors within the mine lease area (Marikana Settlement) and directly adjacent to Far West and West WRD 1 could be mitigated by supplying drinking water or would need to be relocated should any nitrate concentration build-up be observed by monitoring.

4.8. Nitrate is only an operational concern and is estimated to decay to below SANS 241 Drinking Water Standards along the migratory flow path within 5 – 10 years post facility closure.

5. Sustainable multiple barrier mitigation and management plan

5.1. Seepage from the waste rock facilities is governed by rainfall-recharge. Multiple mitigation measures can be employed to limit rainfall infiltration, and seepage. Resulting runoff can also be effectively managed.

5.2. A multiple barrier and sustainable management plan approach should be followed to ensure any potential seepage is mitigated:

i. The main nitrate seepage vector due to dewatering, is captured to the open pits during the operational phase. During the post-operational phase, the nitrate source would stop, and it would decay within 5 - 10 years. The resultant water quality would be close to drinking water standards.

ii. A shallow Perimeter Solution Trench (± 2.5 m deep) should be included at selected zones of WRD toe to capture shallow toe and diffuse seepage.

iii. Several monitoring boreholes (± 8) to be drilled 35 - 40 m deep to fully penetrate the discrete shallow weathered fracture zones (based on high resolution geophysical survey results) and subjected to aquifer tests. Pending regular monitoring results, boreholes could be equipped with submersible pumps to keep the groundwater head ± 15 m below the initial water levels.

iv. A green band of trees (Searsia lancea or equivalent) should be concurrently planted at selected areas as a biological nitrate sink which also controls shallow fugitive seepage if it emanates at the toe.

v. Post Closure rehabilitation and revegetation of the WRDs to limit rainfall recharge and therefore seepage.

vi. Shaping of the backfilled open pits in a concave shape to limit infiltration and direct runoff towards seepage capture canals/trenches.

vii. Time - Nitrate degrades due to natural denitrification processes and was proven to decay with a half-life of ± 110 - 160 days. It is therefore only an operational concern and would decay to drinking water standards within 5 - 10 years after operations end.

viii. Monitoring with feedback, active intervention, and control is important for the operational phase impact verification.

ix. After 5 - 10 years post operation the water from the mitigation boreholes and open pit decant volumes can be converted to sustainable drinking water to the community.

Table of contents

List of Figures

List of tables

1 Introduction

Artesium Consulting Services (Pty) Ltd (ACS) was appointed by SLR Consulting (South Africa) (Pty) Ltd (SLR) to conduct numerical groundwater flow and mass transport modelling to inform an EIA impact and hydrogeological risk assessment (HIA). The assessment is for the proposed full backfilling of both the West and East Open Pits, as well as construction of both the OG West and East Pit Waste Rock Dumps (WRD).

2 Objectives

The hydrogeological impact and risk assessment was done to:

1. Quantify the impacts to groundwater resources and groundwater users that the proposed open pit backfilling and above ground waste rock dump (WRD) extensions would have.
2. Inform on potential management and mitigation measures required for the respective mine residue facilities with specific reference to containment requirements.

3 Scope of Work

The scope of work consisted of:

1. Review and analysis of existing hydrogeological and hydrochemical data and reports.
2. Hydrocensus, sampling and hydrochemical monitoring data analysis and interpretation.
3. Groundwater modelling data review - Hydrochemical source term and material properties.
4. Groundwater numerical flow and mass transport modelling.
5. Hydrogeological Impact Assessment (HIA).
6. Recommendations on the management and mitigation measures required.
7. Compilation of a report.

4 Study Area

The Tharisa mine is located approximately 23 km southeast of Rustenburg in the Northwest Province of South Africa (Figure 5-1). The informal settlement, Lapologang, is located directly northwest of the proposed West WRD 2 facility and ATKV Buffelspoort approximately 1.4 km to the southeast. The Marikana informal settlement is also located directly north of the west pit. The proposed mine residue facilities fall within the Crocodile River (West) quaternary catchment A21K.

5 Hydrogeology

The site geological and hydrogeological setting (Figure 5-2) consists mainly of a shallow weathered bedrock aquifer system with intergranular porosity and permeability. The shallow semi-confined aquifer formed because of weathering of the norites, anorthosites, dolerite dykes and pyroxenites (i.e., regolith). It includes the differentially weathered and fractured bedrock underlying the regolith and is treated as a single weathered aquifer unit (SLR – Dewatering strategy, 2021).

The deeper solid/fractured bedrock aquifer comprises of the fractured and faulted norites, anorthosites and pyroxenites (Figure 6-12). The intact bedrock matrix itself is assumed to have very low matrix permeability, while its effective bulk permeability is enhanced by faults and mine openings (SLR – Dewatering strategy, 2021).

There are also several hydrogeological significant structures underlying the proposed WRD facilities, which also cut through the respective open pits (Figure 5-2). Most of the faults strike NW to SE, with a prominent dyke structure striking W to E and N to S. The dyke contacts are inferred to be more permeable, and therefore could act as preferential flow zones for potential mass migration.

From geotechnical assessments conducted at Tharisa, Clayey and nodular ferricrete soil horizons exist which are important as they could act as a seepage and hydrogeochemical barrier for mass migration (Inroads Consulting, 2021).

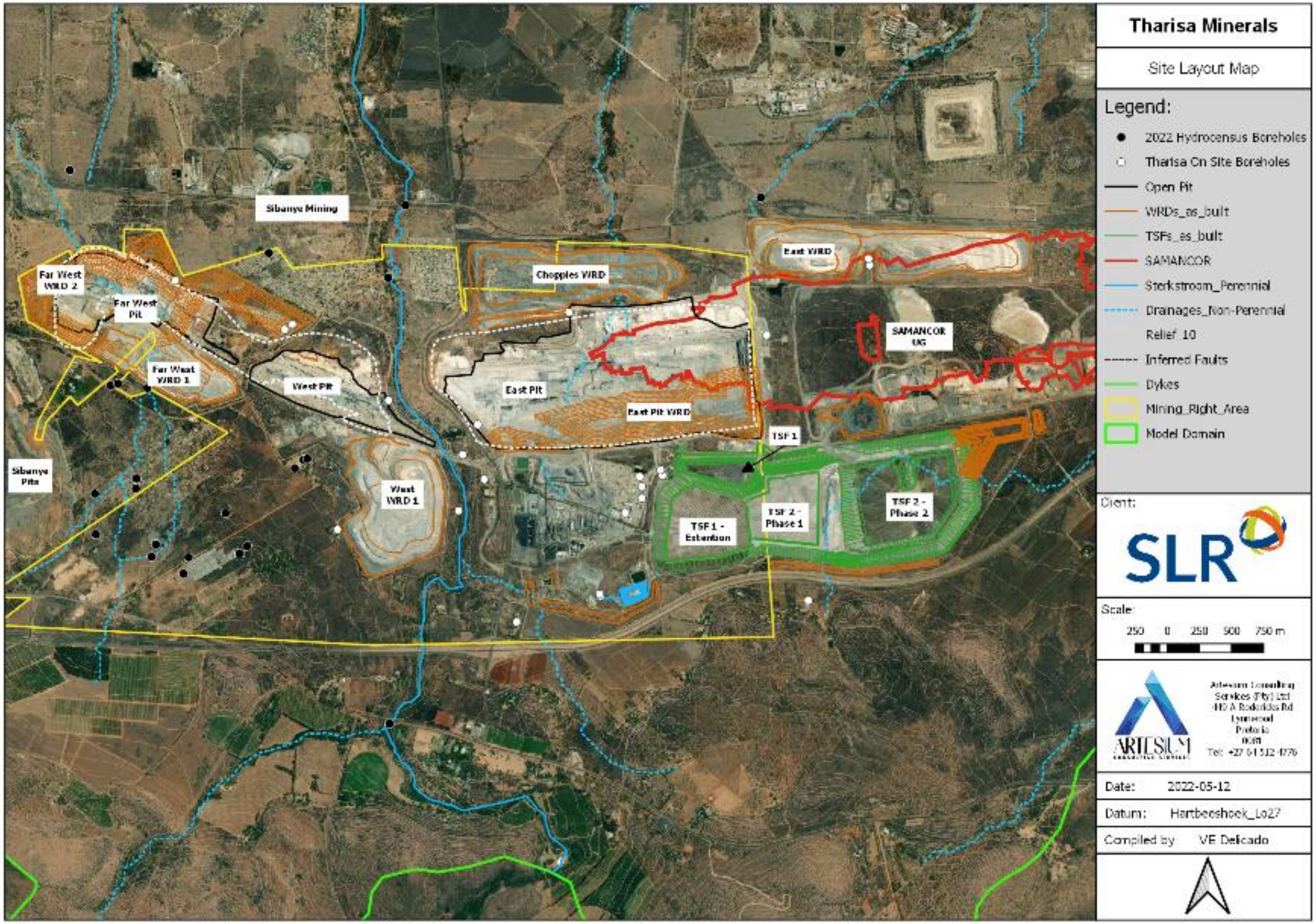

Figure 5-1: Tharisa mine locality map of the existing and planned infrastructure

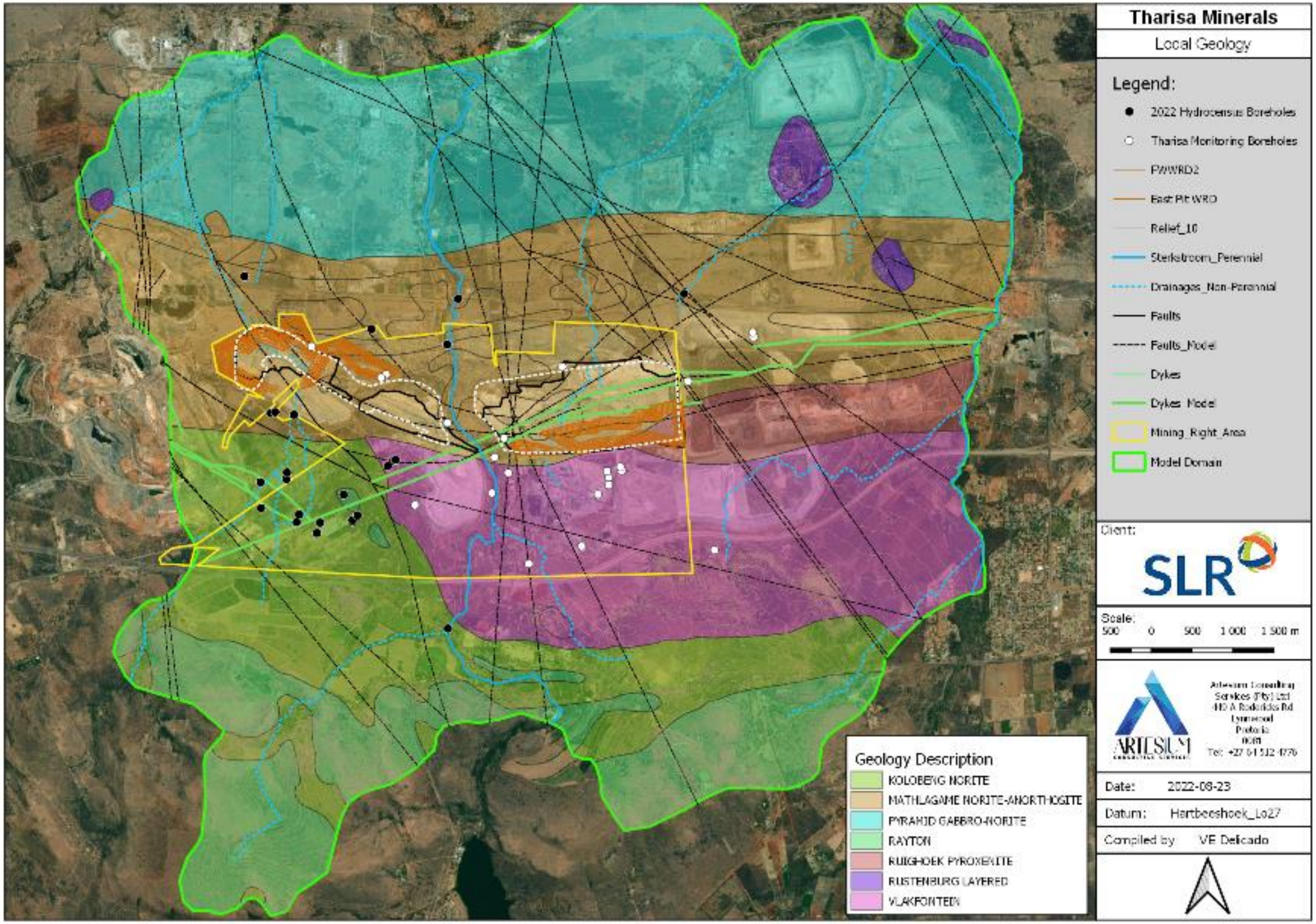

Figure 5-2: Geological and hydrogeological setting of the study area

6 Hydrogeological risk-based approach

The Risk Based Approach is used as part of the Hydrogeological Impact Assessment. As indicated in ACS (2022), the risk assessment framework consists of several inter-dependent steps (Figure 6-1).

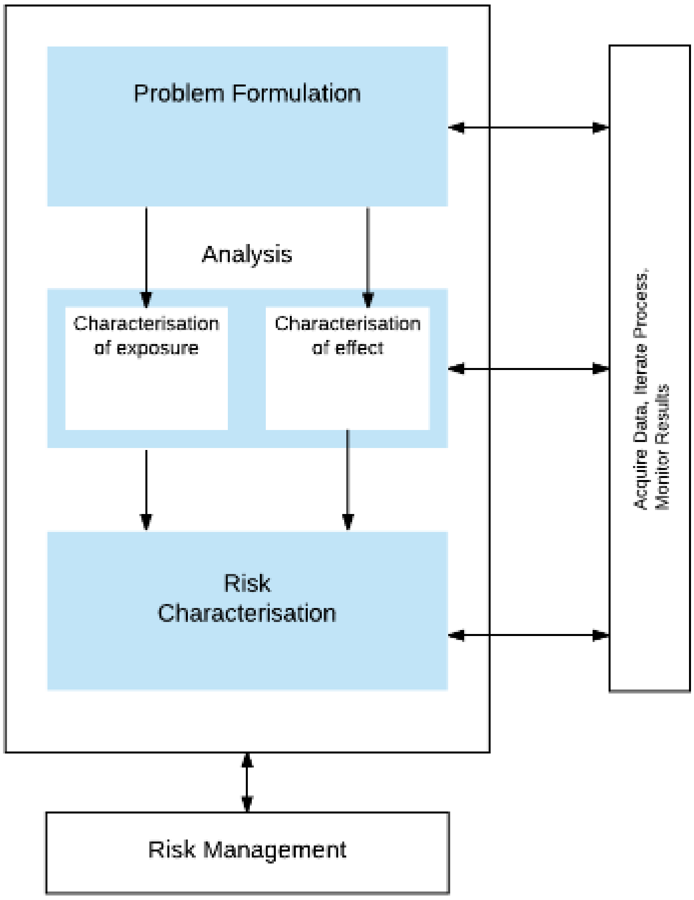

Figure 6-1 Risk assessment framework (adapted from Claassen et al, 2001)

The approach will assist in quantifying potential environmental impacts through the source-pathway-receptor analysis (Figure 6-2) and groundwater risk assessment framework (ACS, 2022).

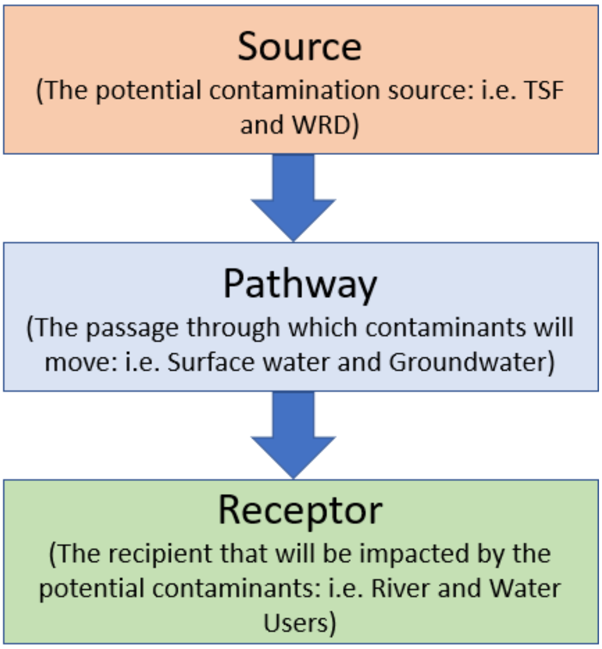

Figure 6-2: Source-pathway-receptor analysis (Chang, 1999; Gyozo & Andrea, 2011)

6.1 Source Characterization

Hydrogeochemical leach tests were done on the solid and liquid (dissolved) potential at UIS accredited laboratory in Pretoria (ACS, 2022). Geochemical samples (sampled in 2019, 2020 and 2022) representative of the proposed WRD and tailings material were analysed and interpreted. Together with the geochemical samples, the long-term water quality monitoring data (2013 - 2021) was analysed with the following findings (Table 6-2):

6.1.1 2020 Vulcan Tailings Waste Assessment – Representative of tailings material (SLR, 2020):

1. The solid phase (TCT) for Barium, Cobalt, Manganese, Nickle, and Vanadium exceeded the limits for the TCT0 threshold only and therefore classify the tailings as a Type 3 waste.
2. The leachable phase (LCT) for chromium exceeded the limits for the LCT0 threshold only and therefore classify as a Type 3 waste.

6.1.2 2022 Vulcan Tailings Waste Assessment – Representative of tailings material (SLR, 2022):

1. The solid phase (TCT) for Cobalt, Copper, Manganese, Nickle, and Vanadium exceeded the limits for the TCT0 threshold only and therefore classify the tailings as a Type 3 waste.
2. None of the parameters exceeded the limits for the liquid phase (LCT0) thresholds and samples classify as a Type 4 waste. In addition, it conforms to the SANS (241) Drinking Water Standards.

6.1.3 2019 and 2022 Mine Waste Rock Waste Assessment – Representative of Tharisa WRDs (SLR, 2019 & 2022):

1. 2019 - The solid phase (TCT) for Barium, Cobalt, Copper, Nickle, Fluorine, Manganese and Mercury exceeds the limits for the TCT0 threshold only and therefore classify the Waste Rock as a Type 3 waste.
2. 2022 - The solid phase (TCT) for Cobalt, Copper, Nickle, and Chromium (VI) exceeds the limits for the TCT0 threshold only and therefore classify the Waste Rock as a Type 3 waste.
3. 2019 & 2022 - None of the parameters exceeded the limits for the liquid phase (LCT0) thresholds and samples classify as a Type 4 waste. In addition, it conforms to the SANS (241) Drinking Water Standards.

Based on the geochemical analysis, all waste types (WRD and tailings), classify as Type 3 based on TCT0 exceedances. *The TCT0 exceedances are irrelevant for the surface and groundwater pathways*. The 2020 Vulcan Tailings sample classifies as Type 3 due to Cr exceedances. For the 2022 Vulcan tailings and all WRD samples, there are no LCT0 exceedances, and the waste can be classified as equivalent to Type 4. Although geochemical analysis of the solids and leaching components are important, it can differ from the actual field conditions (Section 6.1.4).

6.1.4 Hydrocensus with Hydrochemical long-term monitoring data analysis

The current water quality monitoring network consists of 3 surface water, 14 groundwater and 6 process water monitoring localities (Figure 6-3; ACS, 2022). A detailed data analysis study was conducted on the ambient, 2013 baseline, off-site and on-site surface and groundwater quality.

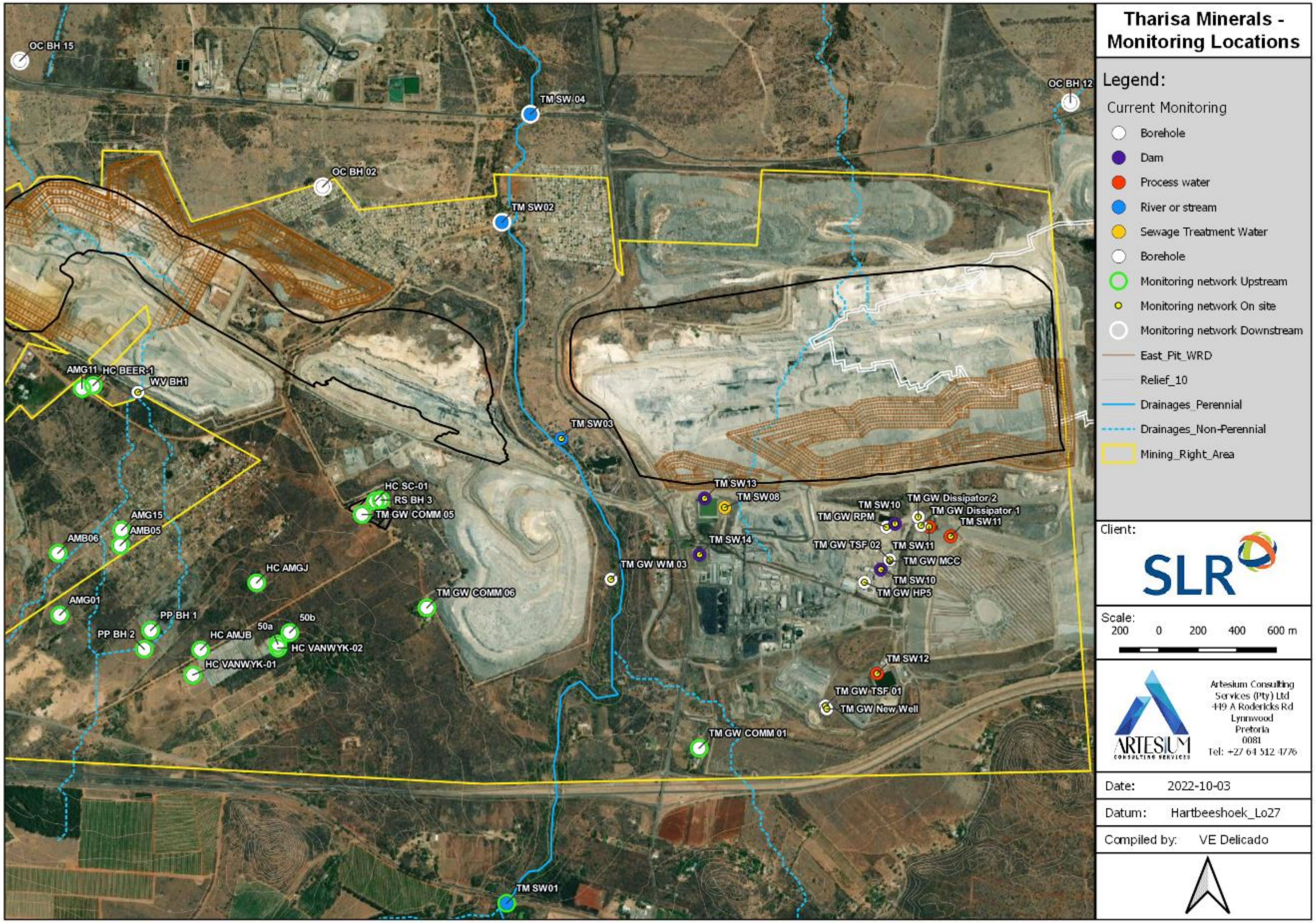

Figure 6-3: Hydrocensus and existing water monitoring localities

Table 6-1: Summary of long-term monitoring data reviewed (excluding July 2022 hydrocensus boreholes)

Monitoring Data Received	Groundwater (On site)	Groundwater (Off site)	Process Water	Surface water (Rivers and Streams)	Total Monitoring
Number of sample locations	10	4	6	3	23
Number of samples taken	178	131	457	253	1019
Max number of constituents	38	38	38	38	38
Number of water levels taken	56	76	[-]	[-]	132
Data from-to	Sep 2013 to Sep 2021 (8 years)				

The hydrogeological and water monitoring data analysis results shows that insufficient hydrogeological data (water use, water level and hydrochemistry) was available for the western and downstream areas of the Tharisa Mine. There are a number of Interested and Affected Parties (I&AP) located to the south of the west and far west open pits (Figure 6-10).

A hydrocensus was conducted on the 22nd of July 2022, where 21 groundwater, and 3 surface water locations were visited and sampled for hydrochemical analysis (Figure 6-3). This survey covered areas where there were previously insufficient data. The historical water monitoring results are more accurate than once off geochemical lab scale tests. It informs the source-pathway-receptor analysis as it is long-term and field scale data. A summary of the monitoring data analysed is indicated in Table 6-1 (ACS, 2022).

From the detailed analysis of the long-term water quality monitoring data spanning 8 years ACS (2022), as well as results from the sampling during the July 2022 hydrocensus, it was confirmed that nitrate is the only parameter of concern. Nitrate indicated minor SANS 241 Drinking Water Standard exceedances for the process water[1], surface water and on-site groundwater (Table 6-2). Nitrate breaks down along the flow path with a proven half-life of 110 - 160 days on this site (ACS, 2022 and Appendix B).

To be able to calculate concentration build-up with time for both the TSFs and WRDs on-site (nitrate source terms for numerical modelling), long-term monitoring data from boreholes directly downstream of facilities were utilised. From the 2013 groundwater and surface water baseline analysis the P50 (baseline) groundwater nitrate concentration was calculated at 3.4 mg/l (ACS, 2022).

The maximum nitrate concentration found at the process water monitoring locations TM SW11 and TM SW14 (which reflects nitrate build-up over time within the TSF circuit) in 8 years of monitoring data was ±100 mg/l. In line with the precautionary principle, a conservative maximum nitrate concentration build-up to 160 mg/l was estimated and was used for LoM. This reflects a nitrate concentration build-up of 0.57 mg/l/mon.

For the WRD nitrate source term determination, the monitoring data from borehole TM GW WM03 was utilised as an indication of nitrate build-up from waste rock sources. This borehole was selected as it is currently the only borehole downstream of a WRD with long term monitoring data available. The maximum nitrate concentration observed for the 8 years monitoring period was ±50 mg/l. In line with the precautionary principle, a conservative maximum nitrate concentration build-up of 160 mg/l was estimated and was used for LoM. Data showed that the WRD build-up was calculated to be ± 1 mg/l/mon.

1 Note that process water is not expected to conform to drinking water quality standards. The process water quality can be considered good quality water.

Table 6-2: Geochemical leach test and long-term water quality monitoring data & analysis– Source (ACS, 2022)

Parameter	Variable interval	2020 Tailings LCT Test (1 sample)	Vulcan Tailings LCT Tests (2 samples)	WRD LCT Tests (14 samples)	Variable interval	Process Water (232 samples)	Groundwater (on Site - 178 samples)	GW_Downstream TSF (77 samples)	GW_Downstream WRD (14 samples)	Groundwater (Off Site - 113 samples)	Sterkstroom (Upstream - 107 samples)	Sterkstroom (Downstream - 146 samples)	SANS 241 Limit	LCT0	Randwater - Rustenburg Municipality
pH	Min	9.04	7.7	9.29	P50	8.21	8.02	8.02	7.85	7.61	7.55	7.93	5 ≤ 9.7		7.86
	Max		9.2	9.65	P95	8.66	8.68	8.69	8.71	8.63	8.21	8.47			
TDS	Min	48	52.00	59.00	P50	739.11	676.72	692.00	503.10	376.93	73.28	114.33	≤1200	1000	301.91
	Max		412.00	66.00	P95	1095.83	942.81	851.44	673.98	496.11	121.06	274.70			
Ca	Min	7.16			P50	51.92	50.79	60.29	50.36	39.16	10.00	11.65			25.04
	Max				P95	75.96	79.98	83.58	62.24	73.69	17.06	27.65			
Mg	Min	2.21			P50	48.39	90.70	106.71	69.74	53.16	7.88	12.82			14.17
	Max				P95	81.85	148.37	127.25	78.50	70.72	13.29	30.53			
Na	Min	7.1			P50	112.44	18.21	21.20	15.09	13.76	4.19	6.21	≤200		30.14
	Max				P95	195.16	117.68	61.94	27.10	20.47	7.56	21.33			
F	Min	<0.1	0.2	0.2	P50	0.23	0.26	0.29	0.21	0.20	0.17	0.16	≤1.5	1.5	0.48
	Max		0.2	0.2	P95	0.47	0.50	0.50	0.72	0.33	0.27	0.25			
Ni	Min	0.006	<0.01	0.005	P50	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	≤0.07	0.07	0.004
	Max		<0.025	0.007	P95	0.002	0.009	<0.001	0.04	0.05	<0.001	<0.001			
Cl	Min	1.27	<2	<2	P50	86.95	37.10	37.33	36.89	17.04	8.02	8.04	≤250	300	55.62
	Max		4	<2	P95	152.86	136.19	84.14	44.80	46.04	15.30	18.42			
SO_4	Min	8	<2	3.33	P50	130.58	97.55	107.00	77.83	53.65	4.92	11.39	≤500	250	43.75
	Max		5	4.36	P95	265.98	199.10	167.20	92.19	73.63	10.42	41.62			
Al	Min (SPLP)	1.31	0.17		P50	<0.001	<0.002	0.003	<0.001	<0.002	<0.002	<0.003	≤0.2		0.05
	Max (SPLP)		0.51		P95	0.05	0.006	0.006	0.005	0.007	0.035	0.09			
As	Min	0.003	<0.001	0.003	P50	<0.001	<0.001	<0.001	<0.001	0.007	<0.001	<0.001	≤0.01	0.01	0.005
	Max		<0.01	0.005	P95	0.007	**0.01**	**0.01**	<0.001	**0.01**	0.007	0.007			
Cr	Min	**0.4**	<0.01	0.02	P50	<0.001	<0.003	0.004	<0.001	<0.001	<0.001	<0.001	≤0.05	0.1	0.003
	Max		<0.025	0.04	P95	0.02	0.03	0.03	0.005	<0.003	<0.003	<0.003			
Fe	Min	1.1			P50	<0.001	0.004	0.004	<0.001	<0.001	0.03	0.003	≤2		0.05
	Max				P95	0.004	0.009	0.009	<0.001	0.004	0.5	0.1			
Mn	Min	0.015	<0.025	0.015	P50	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	≤0.1	0.5	0.0097
	Max			0.043	P95	0.09	0.01	0.003	<0.001	**0.13**	**0.17**	0.04			
N_Ammonia	Min				P50	0.23	0.04	0.03	0.04	0.03	0.07	0.05	≤1.5		0.16
	Max				P95	1.25	0.16	0.12	0.11	0.15	0.26	0.13			
NO_2-N	Min				P50	0.73	0.10	0.10	0.07	0.08	0.07	0.08	≤0.9		0.13
	Max				P95	**12.85**	0.45	0.60	0.12	0.12	0.16	0.24			
NO_3-N	Min	0.45	<0.1	0.21	P50	**40.29**	**18.02**	**18.80**	**19.94**	2.24	0.37	0.9	≤11	11	0.63
	Max		0.3	0.28	P95	**80.20**	**49.42**	**37.11**	**46.13**	9.40	1.06	**13.82**			
B	Min	0.05	<0.025	<0.025	P50	<0.001					<0.001	<0.001	≤2.4	0.5	0.02
	Max		<0.025	<0.025	P95	0.032					<0.001	<0.001			
Ba	Min	0.15	<0.025	<0.025	P50	0.04					0.04	0.03	≤1.3	0.7	0.05
	Max		<0.025	<0.025	P95	0.06					0.05	0.04			
Cd	Min	<0.0001	<0.001	<0.001	P50	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	≤0.003	0.003	0.001
	Max		<0.001	<0.001	P95	0.002	0.005	0.005	<0.001	0.002	0.002	0.002			
Co	Min	0.001	<0.025	<0.025	P50	<0.001					<0.001	<0.001		0.5	
	Max		<0.025	<0.025	P95	<0.001					<0.001	<0.001			
Cu	Min	0.007	<0.01	<0.01	P50	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	≤2	2	0.008
	Max		<0.01	<0.01	P95	0.004	0.005	0.005	0.009	0.002	0.002	0.002			
Hg	Min	<0.0001	<0.001	<0.001	P50	<0.001	<0.001	0.014	<0.001	0.004	<0.001	<0.001	≤0.006	0.006	0.001
	Max		0.003	<0.001	P95	0.004	0.015	0.015	<0.001	0.007	0.007	0.007			
K	Min	2.3			P50	12.81	0.63	0.29	0.84	0.45	1.48	1.60			6.25
	Max				P95	22.40	4.53	1.10	2.56	1.15	2.86	3.28			
Li	Min	0.001			P50	<0.001					<0.001	<0.001			
	Max				P95	0.005					<0.001	<0.001			
Mo	Min	0.0006	<0.025	<0.025	P50	0.020					<0.001	<0.001	≤0.07	0.07	
	Max		<0.025	<0.025	P95	0.039					<0.001	<0.001			
Pb	Min	<0.001	<0.001	<0.001	P50	<0.001	0.004	0.004	<0.001	<0.001	<0.001	<0.001	≤0.01	0.01	0.006
	Max		<0.001	<0.001	P95	0.004	0.01	0.01	0.002	0.004	0.004	0.004			
Se	Min	0.0006	<0.001	<0.001	P50	<0.001	<0.001	0.008	<0.001	0.005	<0.001	<0.001	≤0.04	0.01	0.006
	Max		0.001	0.002	P95	0.005	0.03	0.025	<0.001	0.007	0.007	0.007			
V	Min	0.008	<0.025	<0.025	P50	0.003					<0.001	<0.001	≤0.2	0.2	
	Max		<0.025	<0.025	P95	0.013					<0.001	<0.001			
Zn	Min	0.002	<0.025	<0.025	P50	0.002	0.002	0.003	<0.001	0.002	0.002	<0.001	≤3	5	0.03
	Max		<0.025	<0.025	P95	0.04	0.04	0.04	0.007	0.02	0.008	0.007			

* Stats influenced by detection Limits

6.2 Source-Pathway Analysis

6.2.1 July 2022 Hydrocensus

During the July 20022 hydrocensus 21 groundwater and 3 surface water locations were visited and sampled for hydrochemical analysis (Figure 6-3, Appendix A).

The results (Table 11-1), showed that only one downstream sample (OC BH 02) showed an exceedance of the Manganese SANS 241 Drinking Water Limit (could occur naturally due to the local geological setting). The concentrations for most of the parameters of borehole OC BH 02 are also elevated above that of the P95 2013 upstream baseline values. This borehole is located directly downstream of an informal settlement (Figure 6-3), which could be the source for the elevated concentrations of TDS and ammonium (NH_4-N). Apart from borehole OC BH 02, minimal upstream baseline (2013) exceedances are observed for sodium, sulphate, nitrate, and copper. These baseline exceedances are not significant and well below the SANS 241 Drinking Water Limits for the respective constituents.

From the surface water samples taken (Upstream TM SW01 and downstream TM SW04), the results show that only Cu concentrations exceed the P95 2013 upstream baseline, with no SANS 241 Drinking Water Limit exceedances.

6.2.2 Parameters with significant exceedance of SANS 241 at the sources and pathway (ACS, 2022)

From the long-term monitoring data analysis (Table 6-3), it is evident that nitrate is the only parameter of concern in the process water and on-site groundwater. More than 86% of the samples exceed the SANS 241 Drinking Water Standard limit for the process water, and > 79% of samples exceed the SANS 241 Drinking Water Standard limit for the on-site groundwater.

Considering the downstream groundwater and surface water monitoring localities, no significant nitrate exceedance was observed in the groundwater. The downstream surface water results indicated that < 7% of samples exceeded the SANS 241 limit. Only the P95 (13.82 mg/L) and maximum downstream surface water concentration marginally exceeded the SANS 241, indicating that the impact is insignificant and rather due to short pulse surface water driven events (Figure 12-7).

A notable observation is that nickel and manganese were not found to significantly exceed SANS 241 in the process water[1]. The on-site groundwater indicated that < 6% of samples had a SANS 241 nickel exceedance, no significant manganese exceedance was observed (ACS, 2022).

The upstream groundwater indicated ± 5 % samples exceeded the nickel SANS 241 Drinking Water Limit. Manganese was found to exceed SANS 241 in ± 6% of upstream off-site samples with only the upper range (P95) concentration exceeding the manganese SANS 241 Drinking Water Limit. Upstream surface water also exceeds the Manganese SANS 241 Drinking Water Limit in ± 14% of samples (ACS, 2022).

This confirms that that both nickel and manganese are likely naturally occurring (geological setting) or due to upstream/off-site anthropogenic processes.

Table 6-3: Parameters with significant exceedance of SANS 241 at the sources and pathway locations

	Source		Source/pathway		Pathway		Pathway	
	Process water		On-site groundwater		Off-site groundwater		Surface water Upstream	Surface water Downstream
	NO3-N mg/l	NO2-N mg/l	NO3-N mg/l	Ni mg/l	Mn mg/l	Ni mg/l	Mn mg/l	NO3-N mg/l
Sample count	232	202	178	79	111	71	107	146
Total Sample Count	232	232	215	215	112	112	107	146
SANS 241 Limit	11	0.9	11	0.07	0.1	0.07	0.1	11
Exceedance Count	201	96	142	4	7	4	15	9
Exceedance %	86.64%	47.52%	79.78%	5.06%	6.31%	5.63%	14.02%	6.16%
Mean	40.55	2.86	21.69	0.007	0.02	0.008	0.04	3.26
P5	0.61	0.05	0.60	0.001	0.001	0.001	0.001	0.26
P50	40.29	0.73	18.02	0.001	0.001	0.001	0.001	0.95
P95	80.20	12.85	49.42	0.009	0.13	0.05	0.17	13.82

The spatial (bubble) plots with the latest available as well as maximum nitrate concentrations observed during monitoring are presented in Figure 6-4 and Figure 6-5 below. From Figure 6-4 it is evident that all the latest process water samples taken exceed the SANS 241 limit for nitrate. This is to be expected as nitrate build-up within the mining circuit is standard and well known as mining progresses.

It also shows that nitrate exceeds the SANS 241 limit for both TM SW02 and TM SW03 (directly downstream) in terms of the maximum nitrate concentration, but that all the latest measured nitrate concentrations for all 4 surface water sample locations within the Sterkstroom are below the SANS 241 limit. This emphasizes the observed effect of fluctuations / spikes in concentration which is due to seasonal wet and dry cycles and the contribution of changes in production of current arisings (ore) and waste rock rate over time (ACS, 2022). This also points to the fact that mass migration is limited and of local extent, as TM SW04 (located ± 1 km downstream) showed no nitrate exceedances during the July 2022 hydrocensus.

From the groundwater spatial plots in Figure 6-4, nitrate exceedances are evident for boreholes near (< 250 m) surface water dams and WRD / TSF facilities. This shows that nitrate exceedances are limited to the mining lease areas, and of local extent.

Spatial bubble plots with the latest available as well as maximum sulphate concentrations are presented in Figure 6-6 and Figure 6-7. Sulphate is normally a tracer for mining operations, but the bubble plot and leach tests show that no SANS 241 exceedances for sulphate have been observed on site from 2013 – 2022.

From the results, it is evident that no notable mass migration influences are observed to I & APs to the south and north of the west open pit (Figure 6-5 and Figure 6-7).

Figure 6-4: Spatial distribution of nitrate concentrations observed at surface water and process water monitoring localities

Figure 6-5: Spatial distribution of nitrate concentrations observed at groundwater monitoring localities

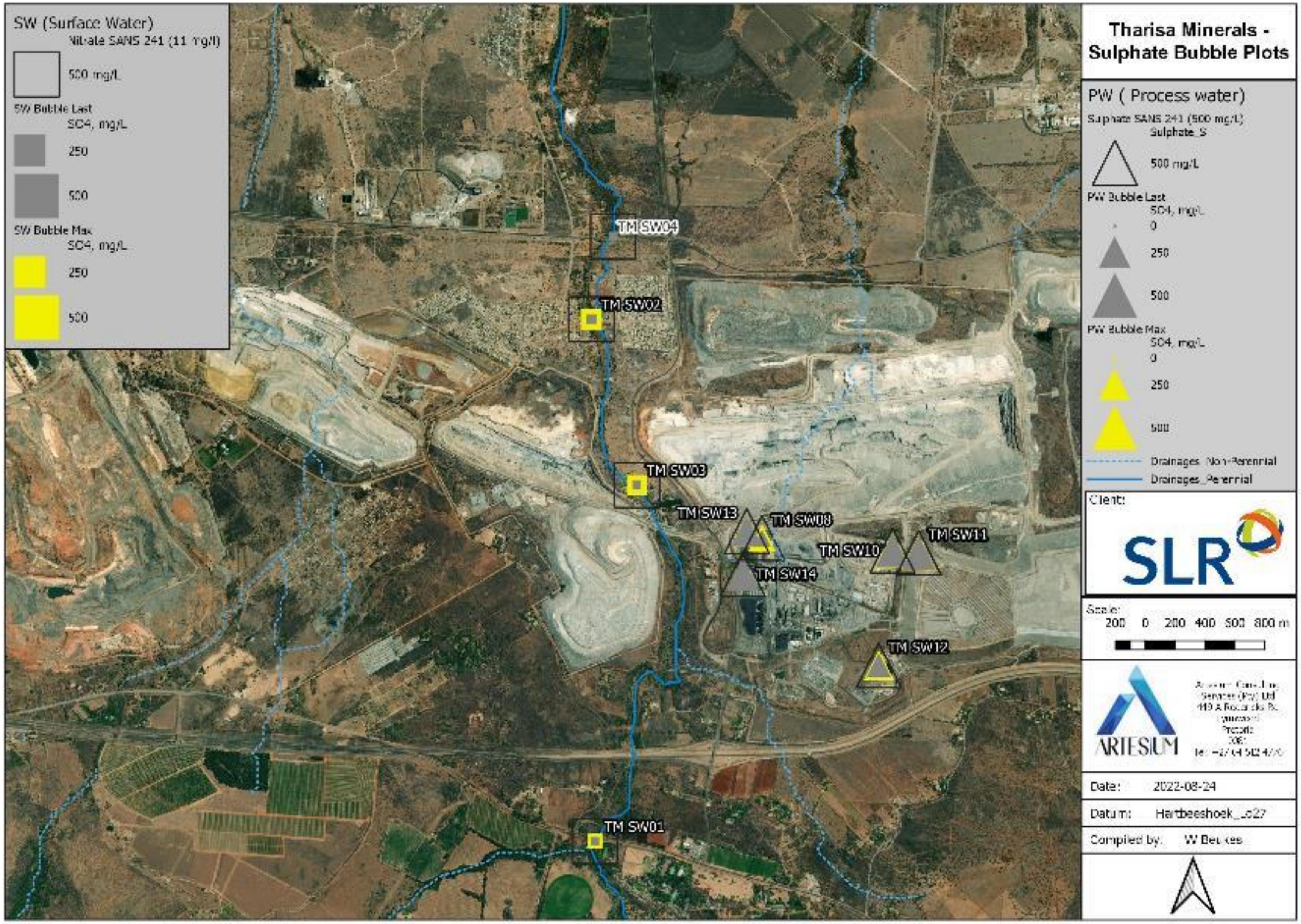

Figure 6-6: Spatial distribution of sulphate concentrations observed at surface water and process water monitoring localities

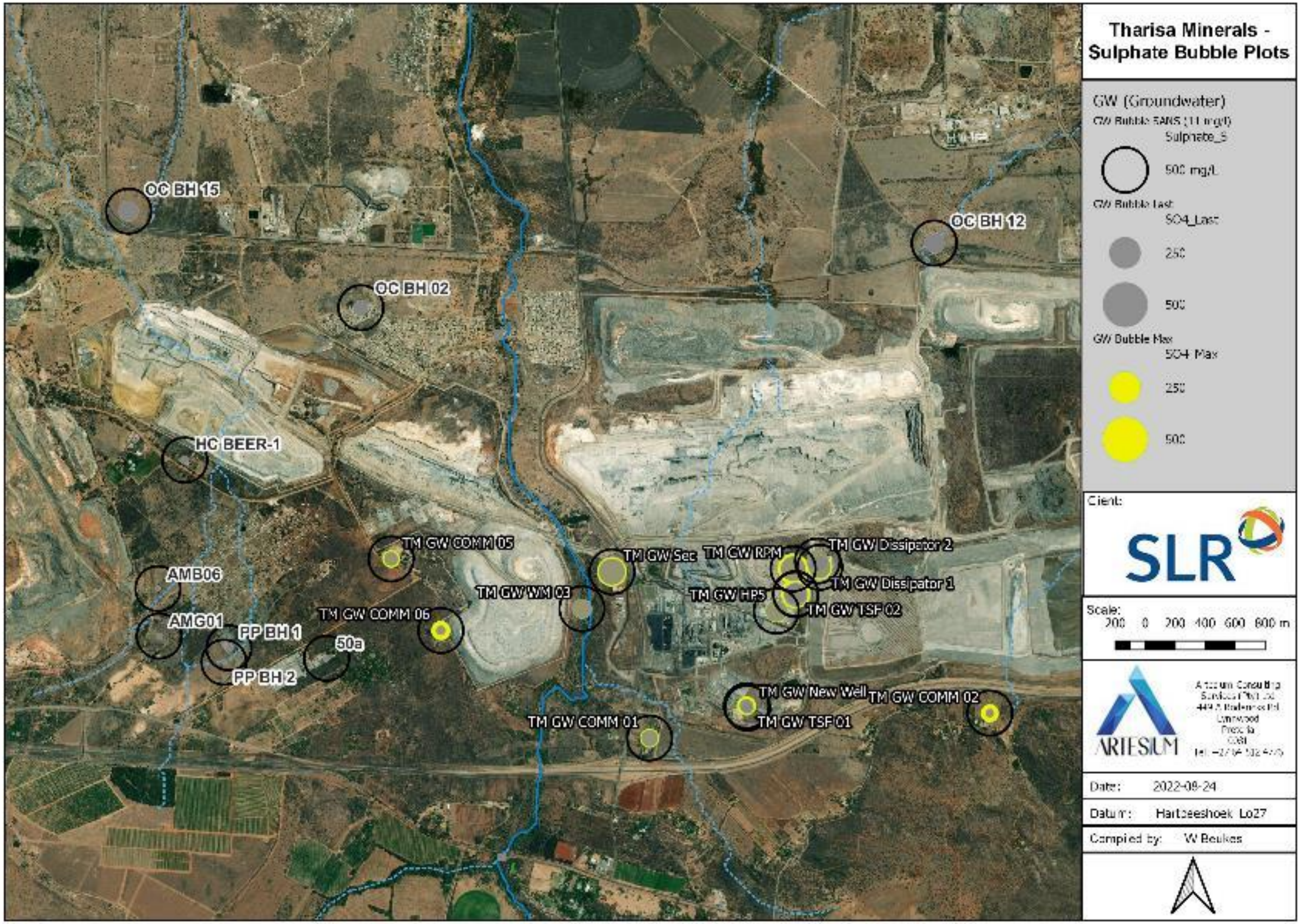

Figure 6-7: Spatial distribution of sulphate concentrations observed at groundwater monitoring localities

6.2.3 Hydrochemical water signature and isotope analysis

Analysis of the hydrochemical signature of each monitoring locality using a Piper diagram, three trends were identified (ACS, 2022):

- Trend 1 - The off-site groundwater and stream water are Magnesium and Bicarbonate dominant.
- Trend 2 - The on-site groundwater displays as Magnesium dominant, and Bicarbonate dominant to no dominant anion groups.
- Trend 3 - The process water shows that the cations are within the no dominant type group, and the anions also within the no dominant type group (GW RPM also plots in this zone, close to process water dams).

According to ACS (2022), the Process Water displays a greater chloride and sulphate signature than the stream water and groundwater.

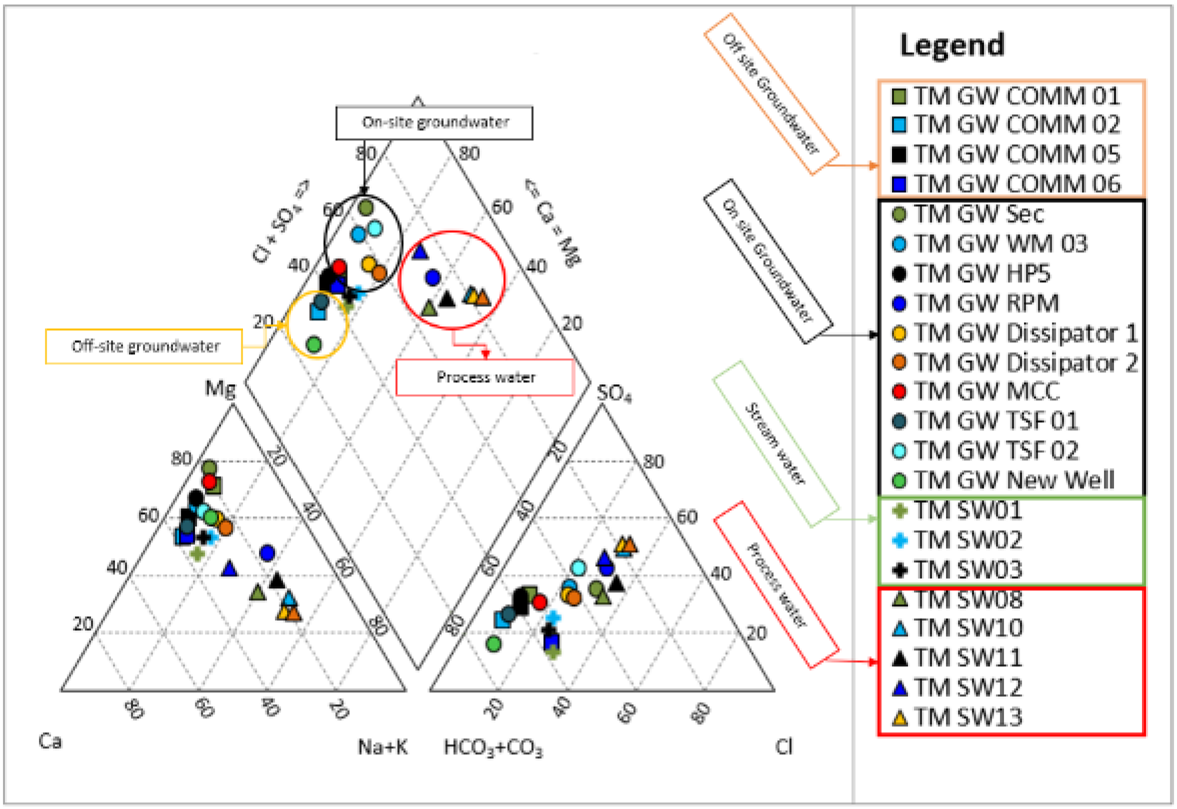

Figure 6-8: Piper diagram indicating the different hydrochemical signatures

As part of the pathway analysis (ACS, 2022), isotope data collected by Wits University (2021) were evaluated which revealed three distinct groups:

- Group 1 - Consists of T20 a pit sample collected from the far west pit, T23 is a groundwater sample collected from a borehole, both these samples are inferred to represent the groundwater isotopic signatures (Light water).
- Group 2 – Mixing zone of groundwater from pits, boreholes and the Sterkstroom stream (T3). Group is a mixture of the isotope rich and depleted sources.
- Group 3 – Heavy water from evaporation sources, made up of process waters dams, or boreholes near unlined dams.

According to the isotope data it is inferred that there is interaction between the pit water, borehole water and the Sterkstroom - surface water (ACS, 2022).

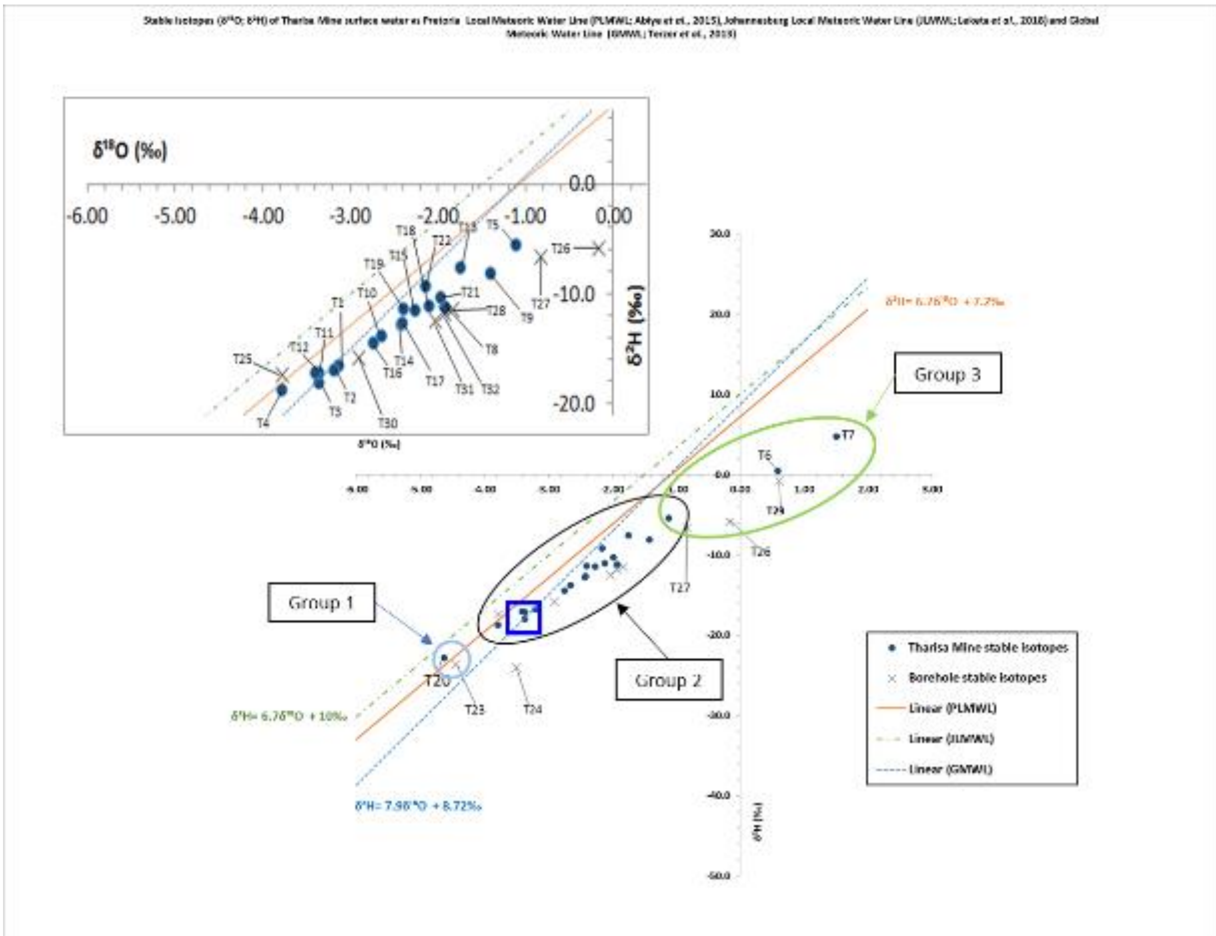

Figure 6-9: Stable isotope data and analysis from Tharisa Mine (Wits University, 2021)

6.3 Potential Receptors Analysis

From the hydrogeological data review and analysis (ACS, 2022), the bulk of the potential mass migration plume from the proposed surface WRD facilities would move downstream, in a north to northwest direction. As the open pits are a groundwater sink, mass migration from surface infrastructure would be drawn towards the open pit during mining operations and post closure rewatering, which would limit offsite migration. The following were determined as potential receptors (Figure 6-10):

1. Informal settlement (Marikana) to the north of West Pit.
2. Lapologang Settlement to the south of Far W WRD 1.
3. The Sterkstroom from the W WRD 1 downstream to the edge of the Marikana Informal Settlement.
4. The Retief Primary School borehole.
5. The Wolvaart and van der Hoven residences directly south of Far W WRD 1.
6. The du Preez and Pretorius residences west of W WRD 1.
7. The graveyard west of W WRD 1.

It must be noted that all land uses directly west (Sibanye) and north (Lonmin) of the Tharisa Mine Right Area is either industrial and/or Mining.

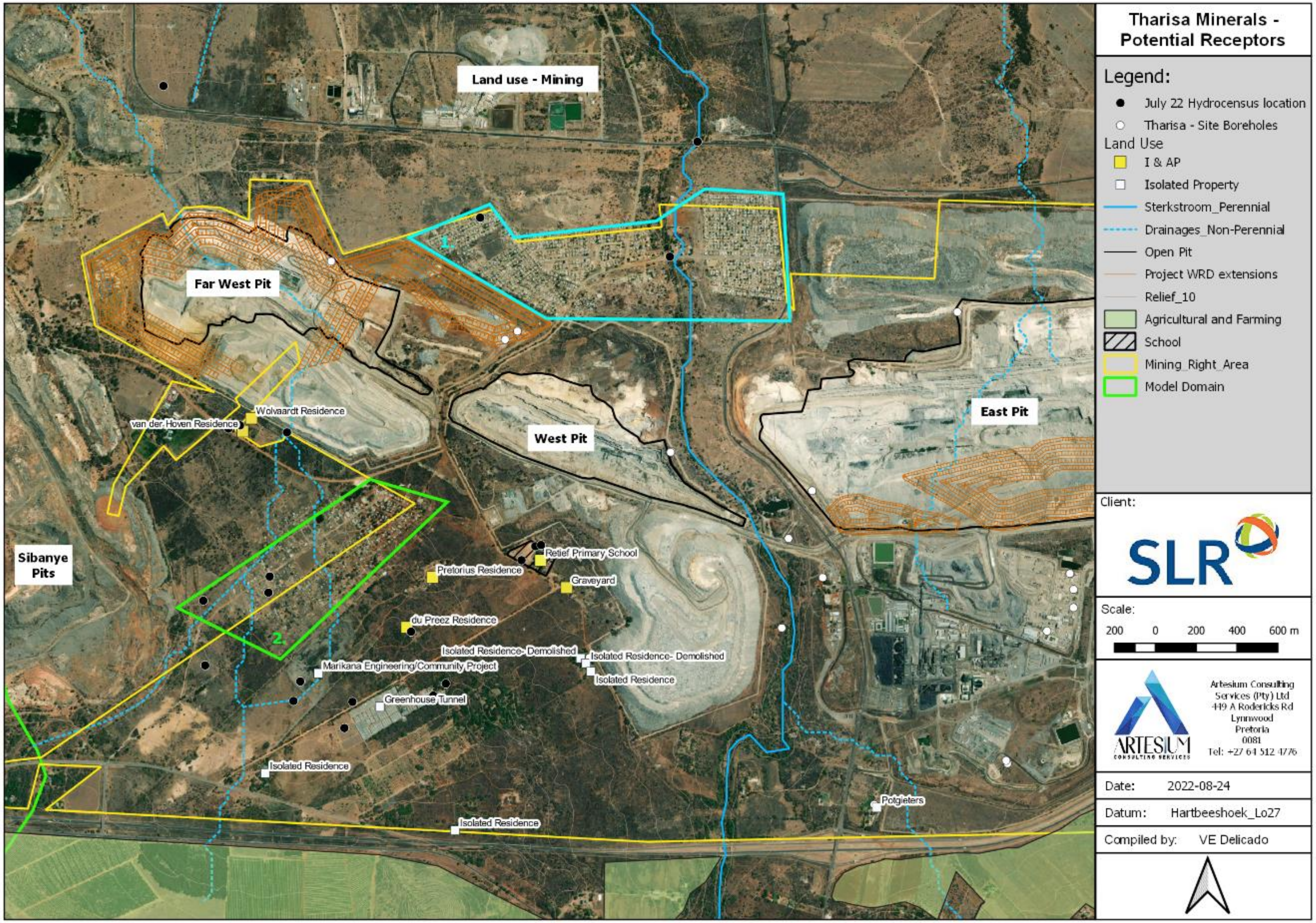

Figure 6-10: Spatial locations of potential receptors

6.4 Pathway-Receptor Analysis and Numerical Modelling

A three-dimensional numerical flow and mass transport model was developed and calibrated in Feflow (www.feflow.info) (Figure 6-19).

The purpose of the model is to simulate the regional and local groundwater system based on existing hydrogeological information and then include the newly planned mine residue facilities. This is to quantify the groundwater flow balance, flow directions, velocities, and the potential impacts of the planned new facilities on the groundwater system (Appendix B).

The initial step was to develop conceptual models to illustrate the current mass migration and to envisage the potential environmental mass migration from the development of the proposed mine residue facilities. The selected cross section locations are shown on Figure 6-11 below.

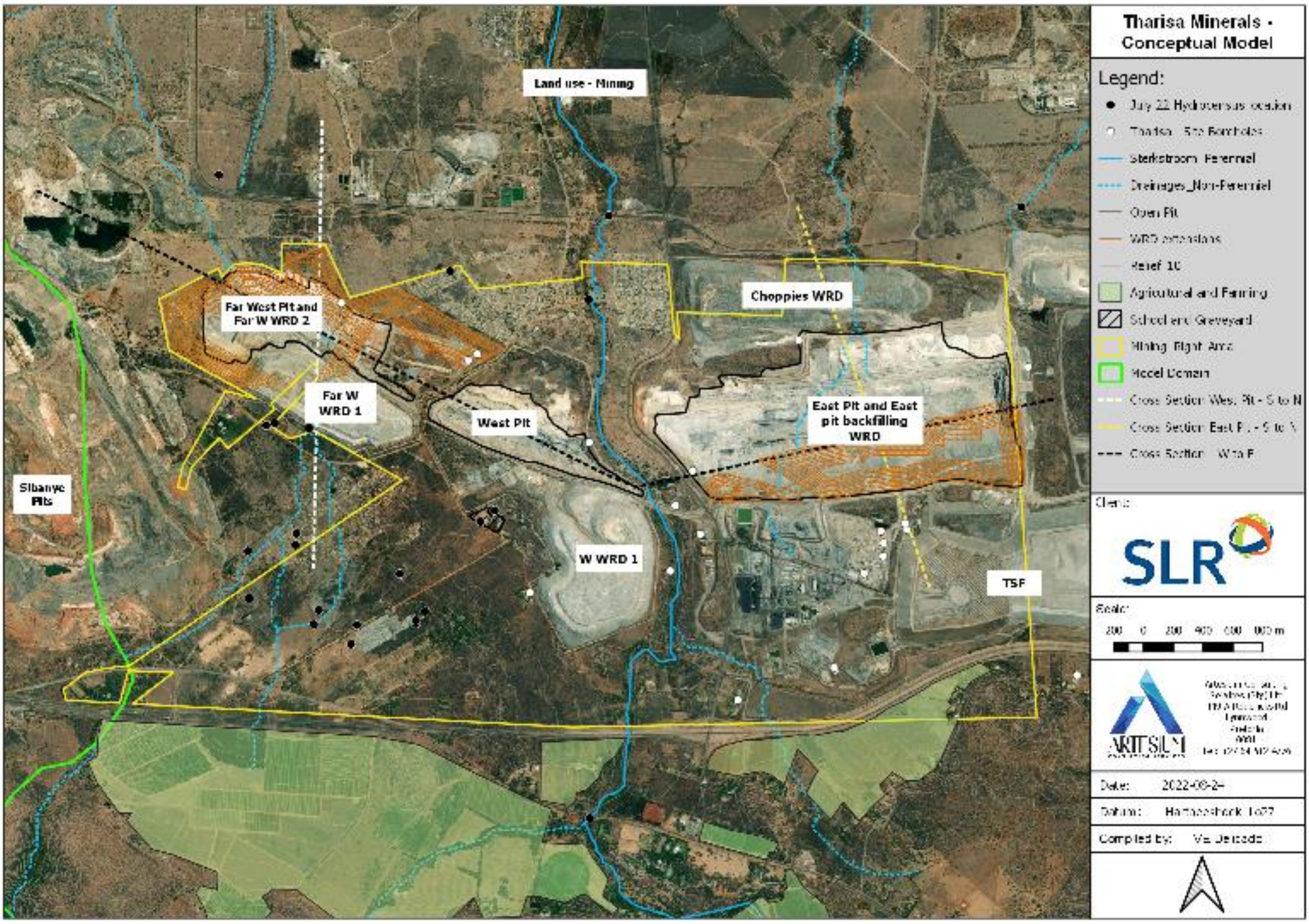

Figure 6-11: Cross Section Locations

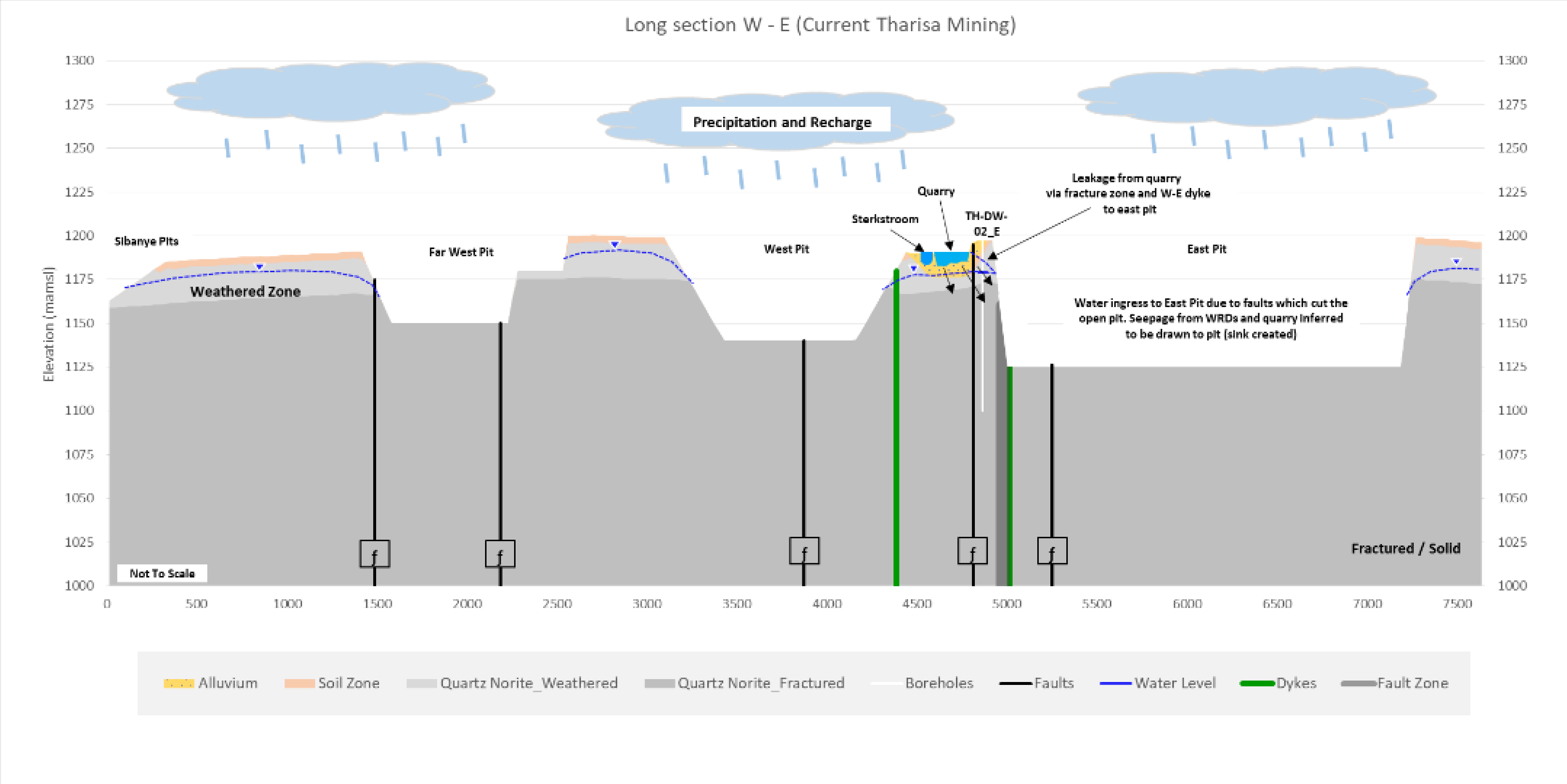

Figure 6-12: Conceptual model illustrating the current mining setup (W – E)

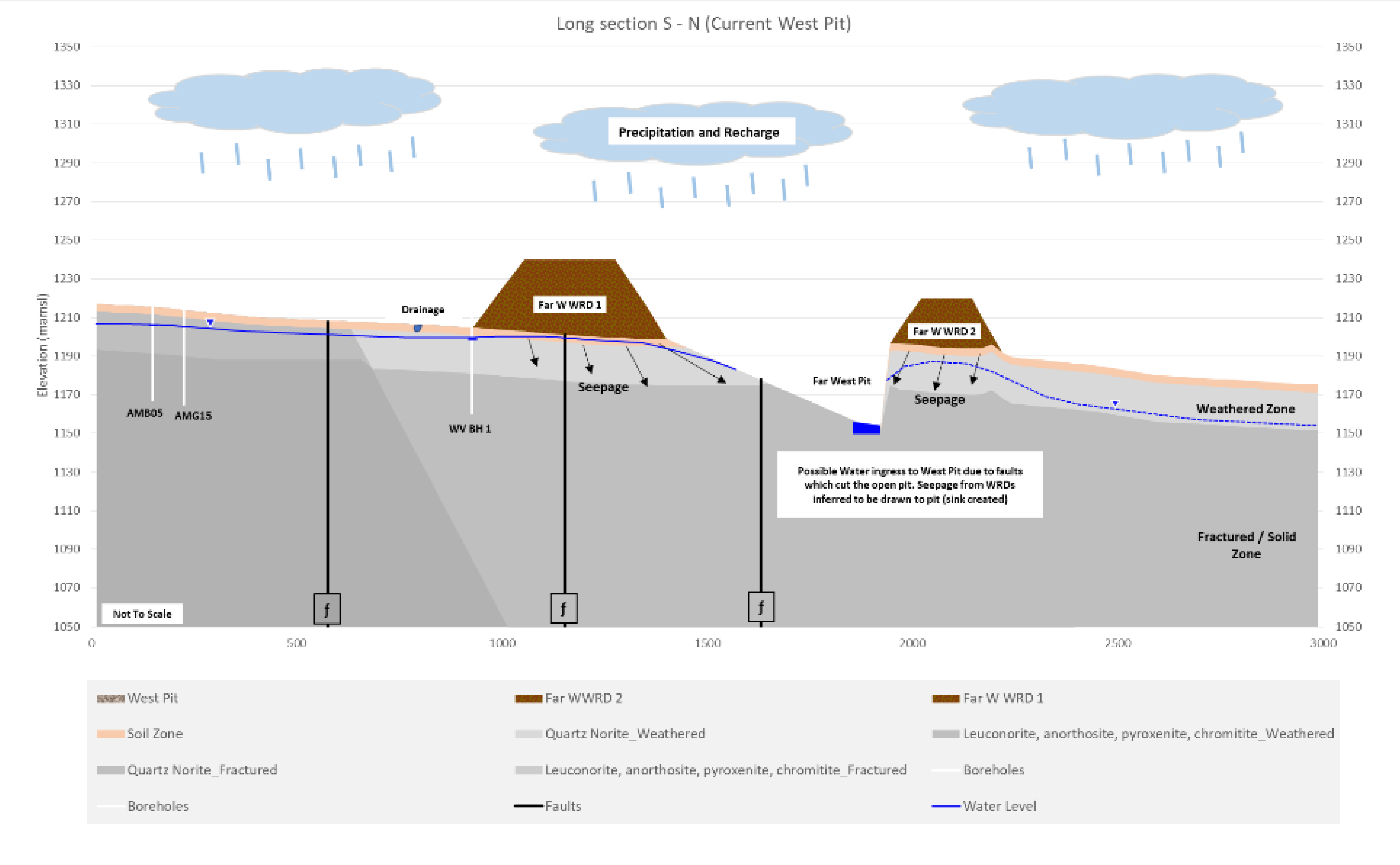

Figure 6-13: Conceptual model illustrating the current West Pit

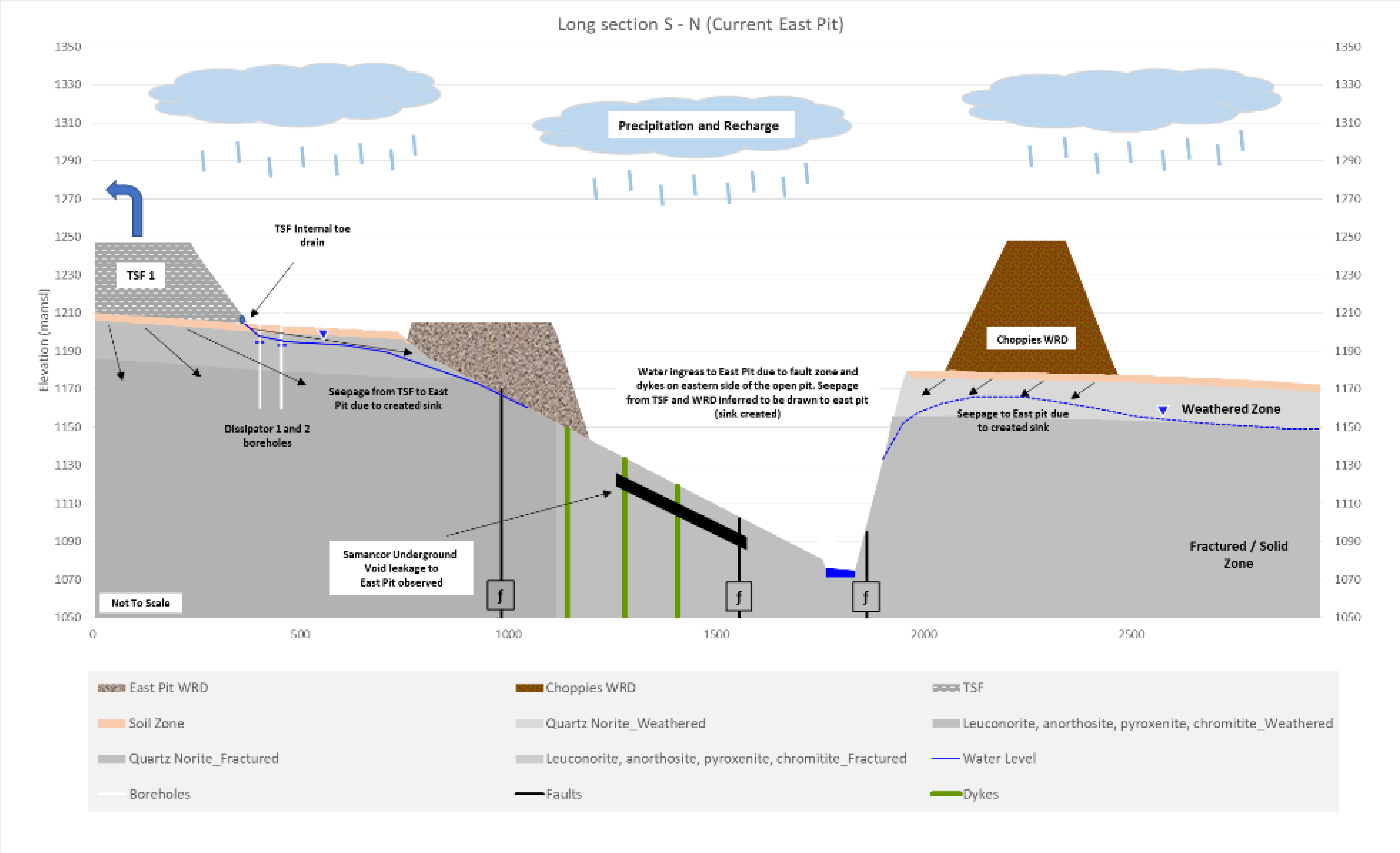

Figure 6-14: Conceptual model illustrating the current East Pit

Rainfall analysis was conducted (South African Water Research Commission, 2022) for inclusion in the numerical modelling (recharge). The data used covers a duration of ± 80 years (1938 to 2020). From the data, the mean annual precipitation (MAP) of the study area was calculated at 645 mm. From statistical analysis the P5 annual rainfall is 284 mm, with the P95 annual rainfall calculated at 967 mm (Figure 6-15).

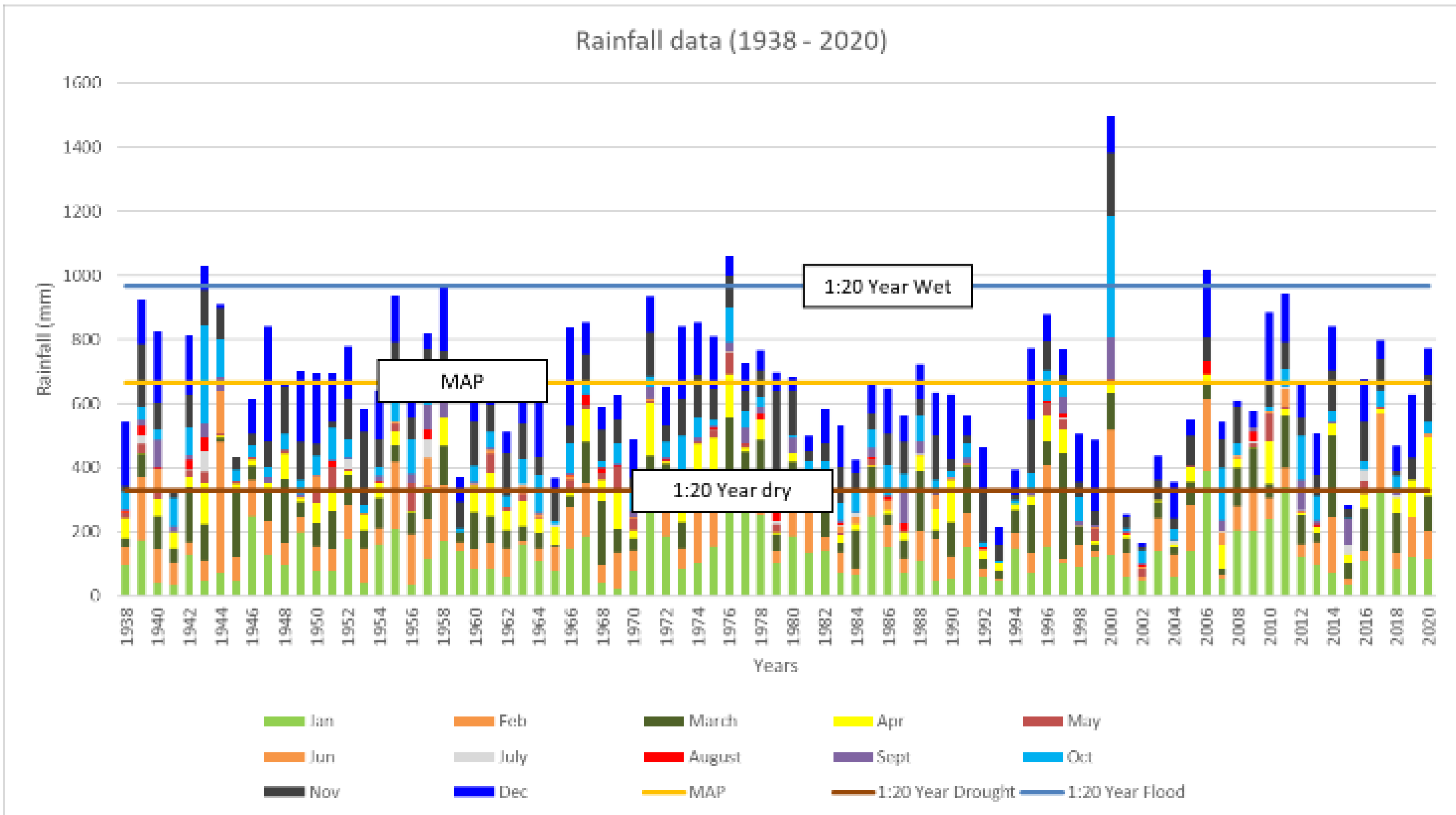

Figure 6-15: Rainfall analysis to be used for numerical modelling.

The peak rainfall months are December and January, with the months with the lowest rainfall being July and August (Table 6-4).

Table 6-4: Average Monthly Rainfall

Month	Jan	Feb	March	Apr	May	Jun	July	August	Sept	Oct	Nov	Dec
Average Rainfall (mm)	122.2	90.5	84.6	45.3	14.4	8.4	4.8	5.6	16.9	57.3	83.3	111.9

From the WGC (2008) report, a baseline P50 groundwater level of 14.7 mbgl could be determined from 16 water levels taken between Sep 2007 and May 2009 before the ramp up in mining commenced.

From the water level monitoring data (2013 to 2021, ACS, 2022), it is evident that the groundwater levels remained stable with some seasonal fluctuations observed (Figure 6-16). Dewatering impacts from the Far West, West and East open pits are localised (ACS, 2022). The mean onsite groundwater level is 10.9 mbgl, with the P50 groundwater level skewed deeper at 16.1 mbgl. The mean off-site groundwater level is 14.9 mbgl, with the P50 level at 11 mbgl. Water levels at borehole TM GW WM 03 (monitored up to 2017, now decommissioned) were significantly deeper than at other boreholes, water levels near 40 mbch were most likely due to agricultural abstraction.

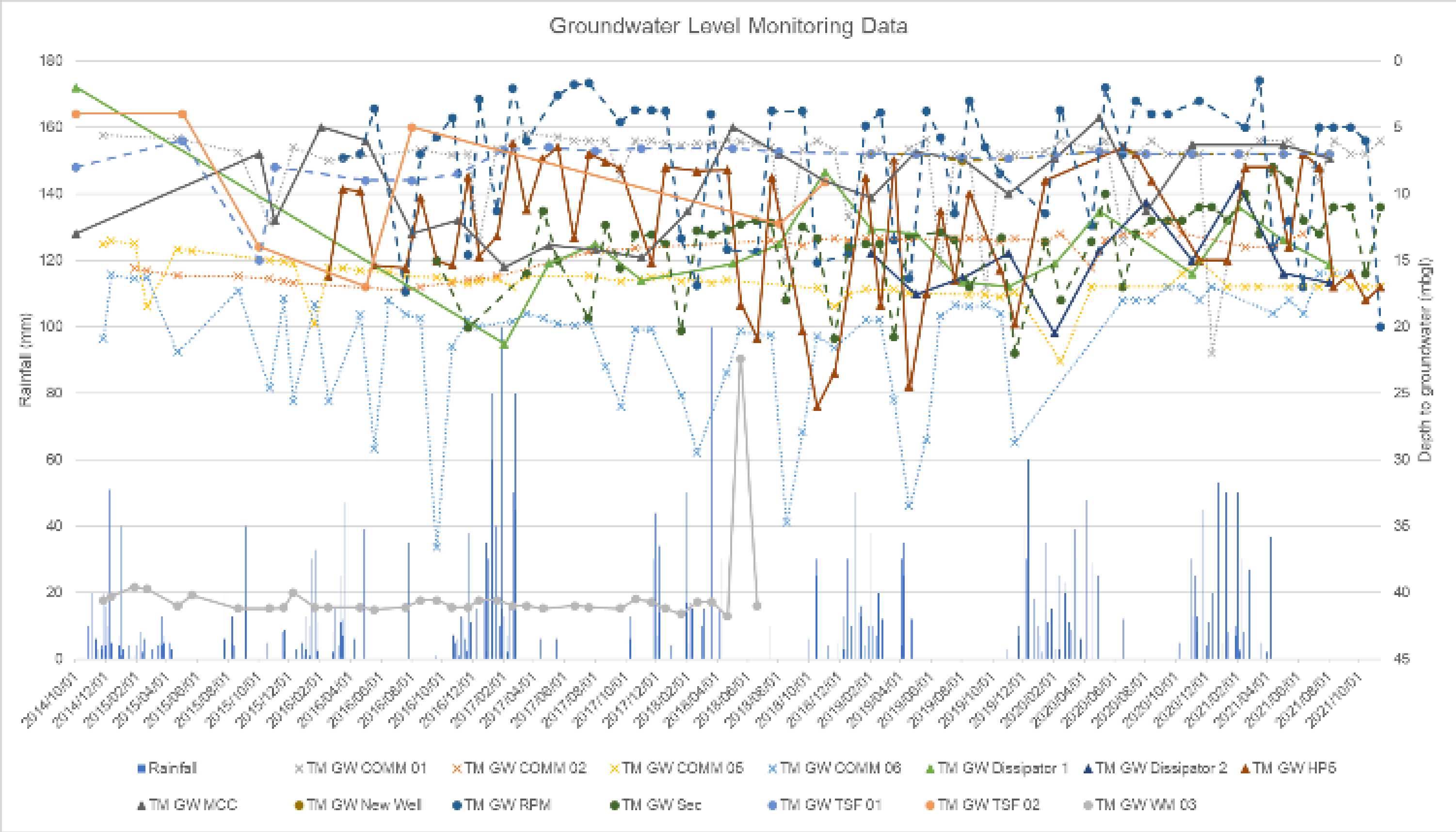

Figure 6-16: Groundwater level monitoring data from 2013 to 2021 (ACS, 2022)

During the July 2022 hydrocensus a total of 13 water levels were obtained and together with the long-term monitoring data provided (ACS, 2022) could be compared to the 2007 – 2009 study area baseline P50 water level.

From the 26 water levels shown in Figure 6-17, only two of the water levels are deeper than the baseline P50 calculated between 2007 – 2009. These boreholes (Dissipator 1 and Dissipator 2) are directly south of the east open pit, which shows the localised extent of the dewatering cone. The boreholes close to the Retief Primary school have water levels that are on or slightly deeper (15 - 17 mbch) than the 2007 – 2009 baseline P50 value. The school borehole is actively being abstracted, which would contribute towards deeper water levels.

Water levels measured at both the Wolvaart and van der Hoven residences directly south of Far W WRD 1 are also shallower than the P50 baseline. Some leakage is observed from TSF 1 in downstream boreholes, as water levels from these boreholes are shallow (above the average on-site groundwater level).

The water level data analysis shows that the dewatering cone from the respective open pits are of local extent (< 500 m) and do not currently point to major dewatering effects on neighbouring I & APs north and south of the west open pit.

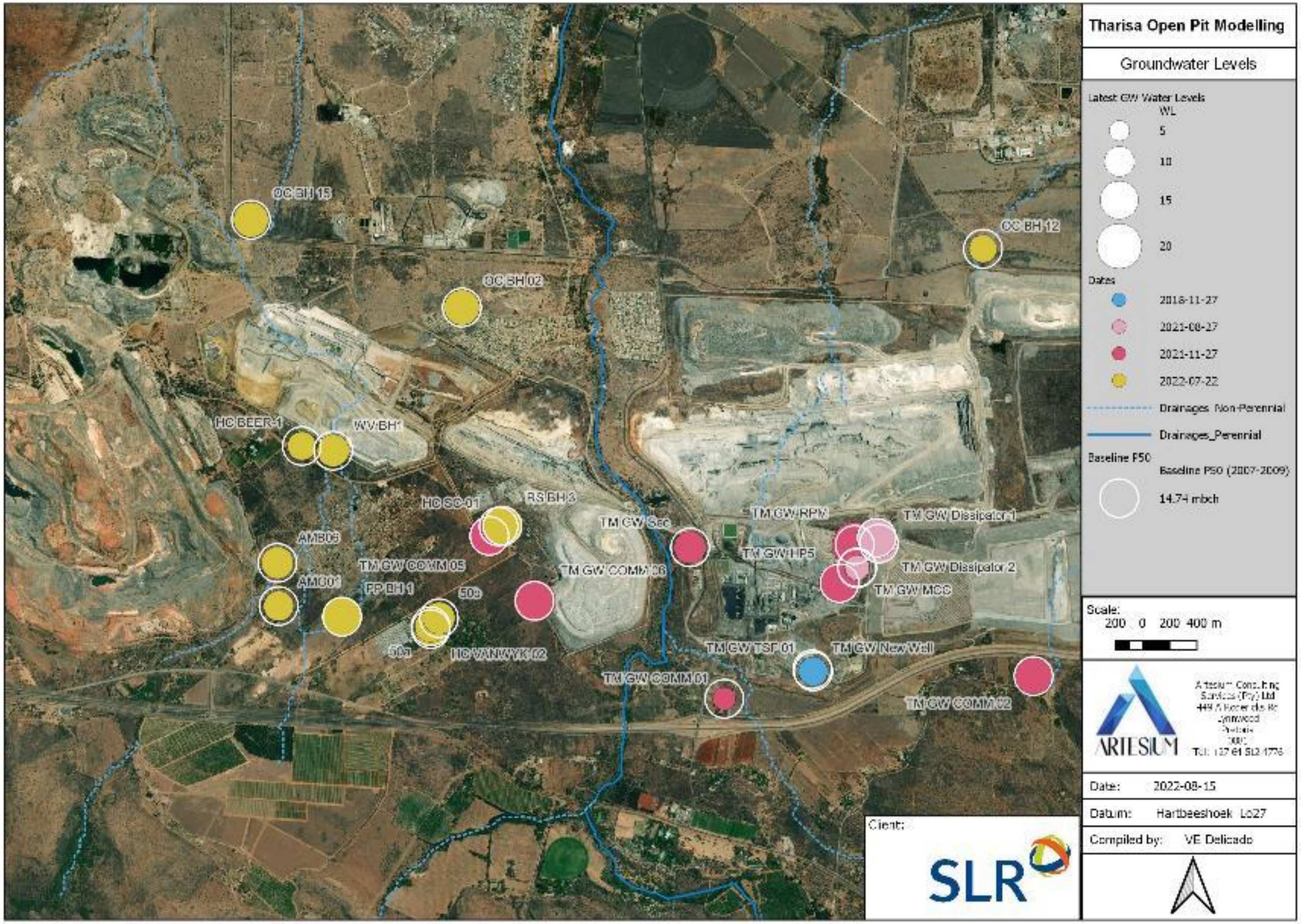

Figure 6-17: Bubble plots of measured groundwater levels and their spatial distribution

6.5 Groundwater Numerical Modelling

6.5.1 Calibration

The Steady State model had an acceptable calibration with an average groundwater level error (m) of 1.20 m, with 14 of the 16 boreholes calibrating to within ± 5 m from the actual groundwater level values (Figure 6-19).

The transient groundwater levels and pit inflows in the model also had an acceptable transient calibration as the simulated versus actual borehole hydraulic heads compare well for most of the boreholes with transient data provided. Overall, most simulated heads calibrate above the actual measured heads. For additional steady state calibration details refer to Section 12.

The calibrated model showed combined East Pit and Samancor Underground simulated inflows in the order of ± 5 600 m^3/d (as inflows from the SAMANCOR underground towards East pit is included – Figure 6-14 and Figure 6-18), which is comparable to the calculated groundwater inflow from onsite water volume in pit data received for Q4-2021. The average inflow rate simulated for the west and far west pits over the transient state calibration simulation period are ± 460 m^3/d and ± 600 m^3/d respectively (Figure 6-18).

The current simulated radius of influence is presented in Figure 6-20. From the hydrocensus and modelling data the dewatering cone from the respective open pits are of local extent and do not currently point to major dewatering effects on neighbouring I & APs north and south of the West Pit.

The current nitrate migration model was calibrated with nitrate concentrations from water monitoring localities between December 2021 and July 2022 (Section 12).

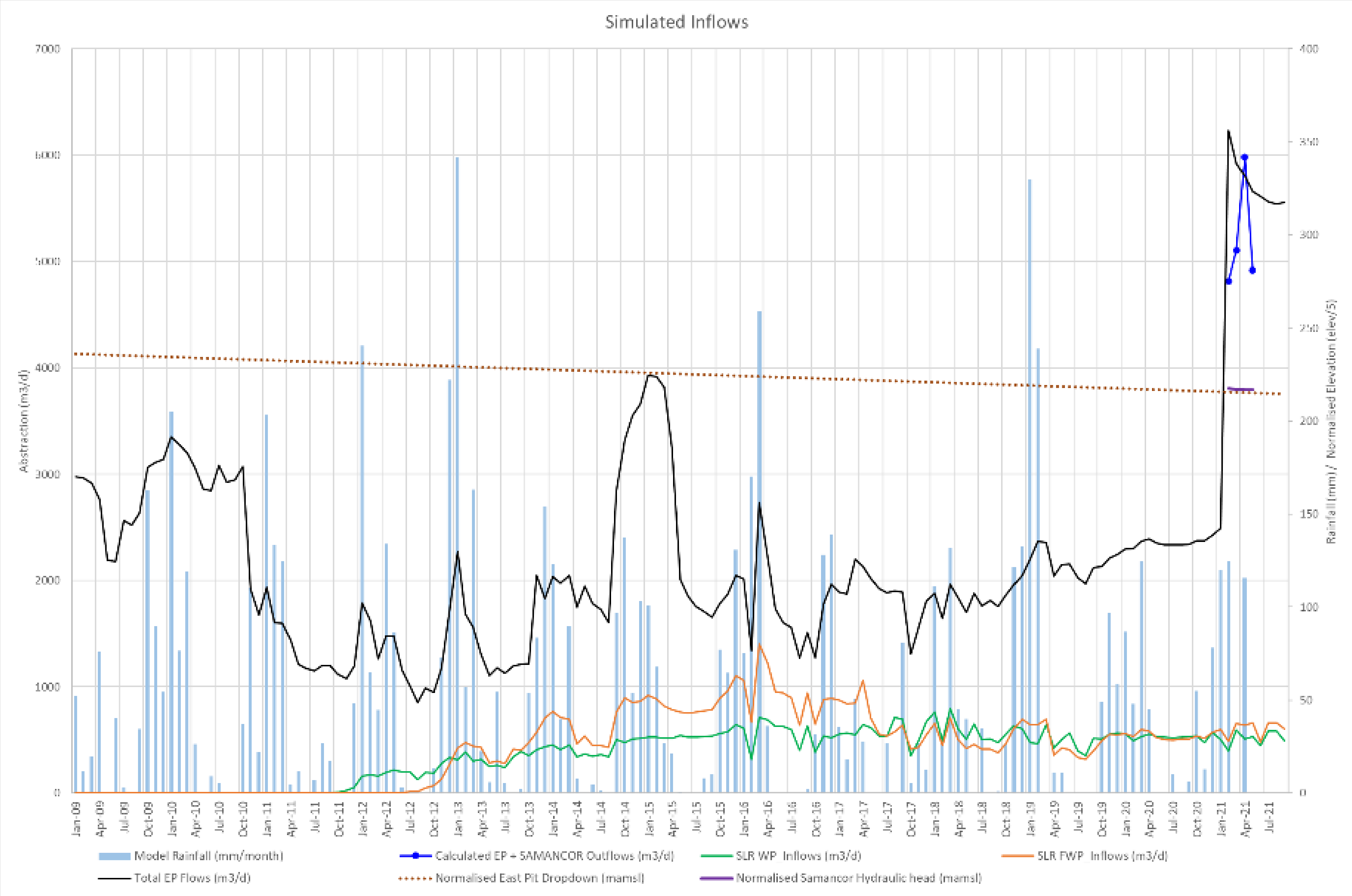

Figure 6-18: Simulated and measured pit inflows

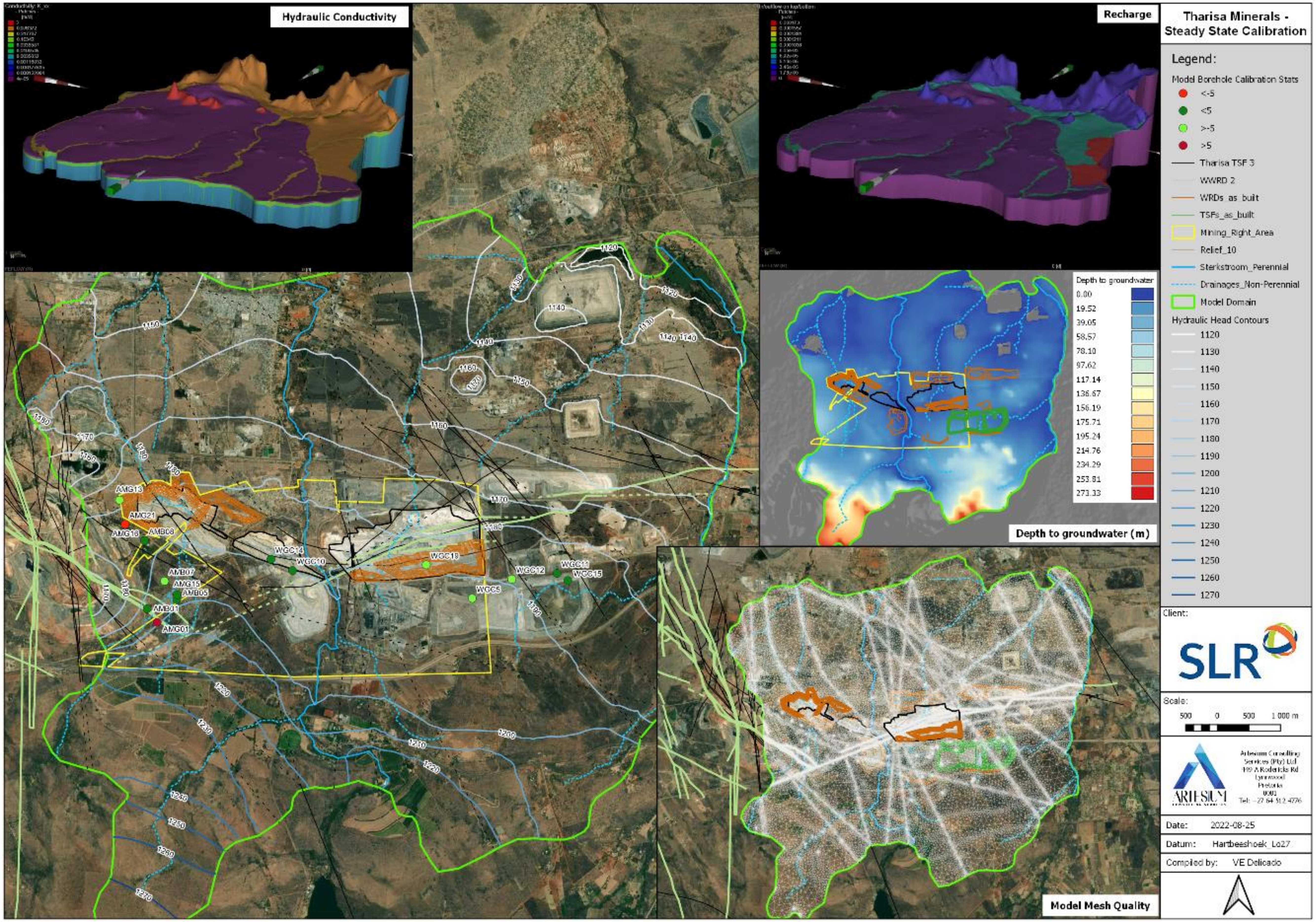

Figure 6-19: 3D Tharisa numerical model construction and steady state calibration

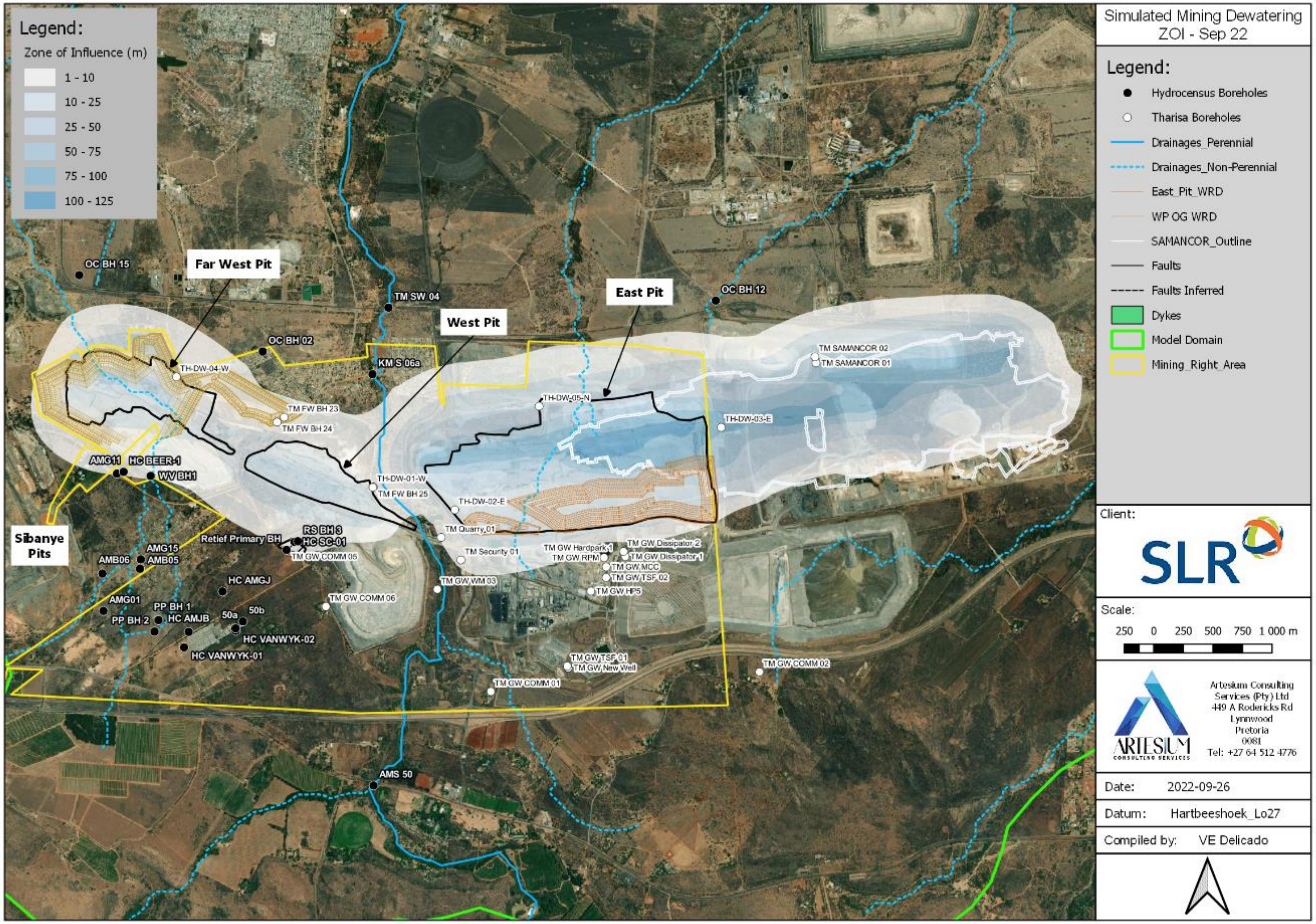

Figure 6-20: Simulated Open Pit Mining Radius of Influence (Sep 22)

6.5.2 Maximum Zone of Influence (ZOI) – East Pit, West Pit and Samancor Underground Dewatering

Both the East and West Pits are to be completed by middle to end 2032. At that stage, there would be a maximum Zone of Influence (ZOI) as the open pits would be at their deepest point. Dewatering from the Samancor Underground will be higher to ensure that the East Pit remains dry for mining. From the groundwater balance presented in Table 6-5, the East Pit would dewater at a rate of ± 2 600 m^3/d, with the Samancor Underground dewatering being ± 3 900 m^3/d. The West Pit will dewater at a rate of ± 1 600 m^3/d (these abstraction volumes do not include additional water due to rainfall-runoff within the pit).

In Figure 6-22 the dewatering cones are observed to be steep due to the geology and hydrogeological parameters of the site (low hydraulic conductivity). The dewatering cone of the East Pit and Samancor Underground is modelled to reach ± 1 000 m to the north, with the cone extending ± 3 400 m east from the edge of the pit, due to the position and size of the Samancor Underground. The East Pit dewatering cone does not extend past the TSF's towards the south of the pit, most likely due to facility leakage and groundwater flow direction.

Table 6-5: Maximum Mine Dewatering groundwater balance (2032)

TS Groundwater Balance (Maximum Dewatering - 2032)				
	Component	**Inflow (m^3/d)**	**Outflow (m^3/d)**	**Balance (m^3/d)**
1	Recharge - Model Domain (excl Facilities)	3386		**3386**
2	Flux from TSFs (off site)	128		**128**
3	East WRD (Choppies)	66		**66**
4	East WRD 2	72		**72**
5	West WRD 1	57		**57**
6	Far West WRD 1	150		**150**
7	West OG WRD	46		**46**
8	EP BF + East OG WRD	773		**773**
9	WP BF	459		**459**
10	TSF 1	30		**30**
11	TSF 1 Extension	78		**78**
12	TSF 2 Phase 1	328		**328**
13	TSF 2 Phase 2	357		**357**
14	UG2 Pit dewatering		-202	**-202**
15	Sibanye Pit dewatering		-321	**-321**
16	West Pit Dewatering		-1600	**-1600**
17	East Pit Dewatering		-2600	**-2600**
18	SAMANCOR UG		-3900	**-3900**
19	Quarry	145		**145**
20	On Site Dams	302		**302**
21	Abstraction from boreholes - Unknown			**0**
22	Model Storage Capture/Release	4836	-1720	**3116**
23	Baseflow and losses to drainages	1059	-1825	**-766**
	Total	**12271**	**-12168**	**102.1**
			Balance Error (%)	**-0.8%**

From Figure 6-22, the West Pit ZOI extends ± 800 m towards the north and ± 400 m towards the Sibanye operations to the west. The modelling results show that the cone extends ± 700 m to the south and would most likely affect I & APs near the mine (1 – 10 m drawdown). These include borehole AMG11, The Retief Primary School borehole, as well as the Wolvaart and van der Hoven residences.

The north-eastern section of the Lapologang informal settle will also be affected, with the Marikana informal settlement situated within the modelled ZOI (1 -10 m drawdown). All the hydrocensus boreholes downstream of the site will be affected to an extent (1 – 10 m drawdown). It must be noted that most of the land uses are industrial and mining related (Figure 6-22).

Due to the East Pit and West Pit's proximity to the Sterkstroom, the river section directly adjacent to the open pits will most likely experience a drawdown effect (10 – 25 m).

To evaluate / determine the impact of open pit dewatering on the Sterkstroom groundwater baseflow, the catchment scale Mean Monthly Runoff was utilised and compared to the modelled Sterkstroom maximum water inflow rates within the modelled ZOI. The results are presented in Figure 6-21 below.

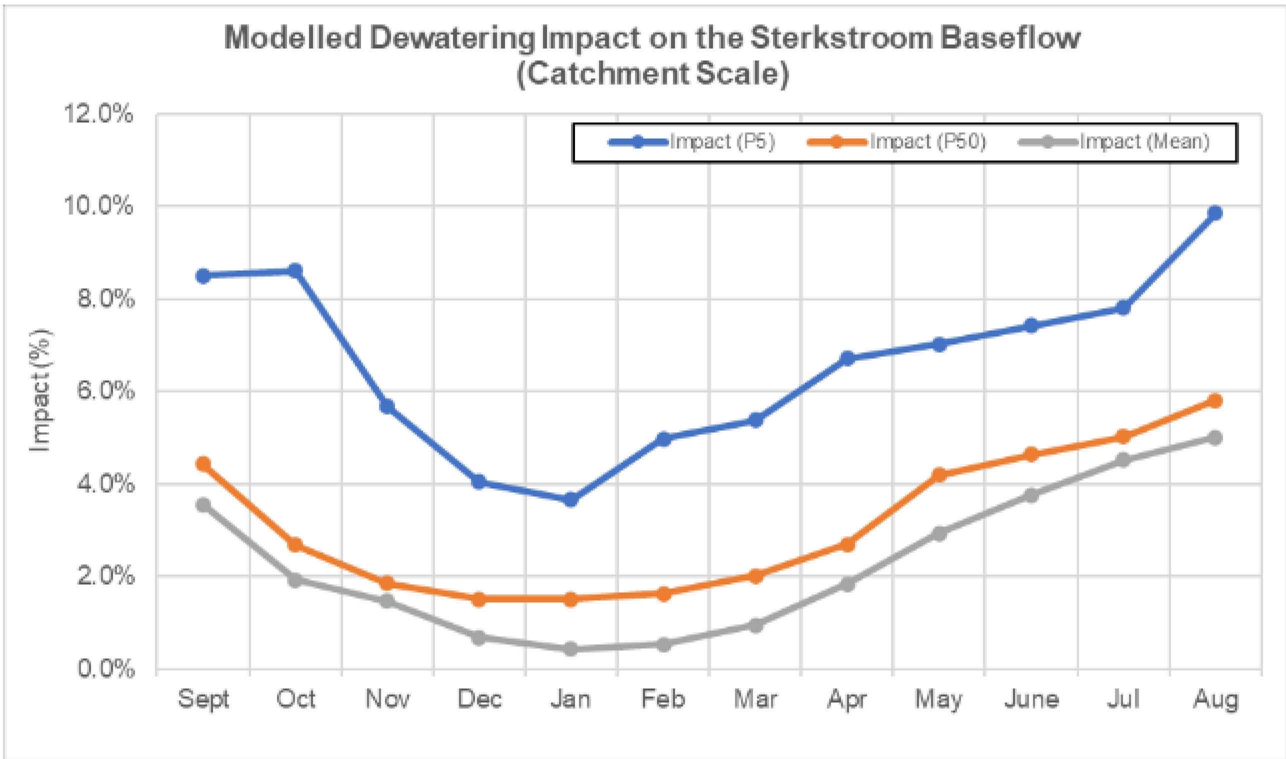

Figure 6-21 Simulated potential dewatering impacts on the Sterkstroom flow

The simulations show that based on the lower range (P5) monthly catchment runoff flows, a 6 - 10 % impact would be observed from April – Oct. During these months, piping, or discharge from dewatered flow volumes in the Sterkstroom from an upstream point before the mine to a downstream point after mining activities can be employed to minimize the impact on the Sterkstroom groundwater baseflow. These impacts, especially on aquatic ecology, hydrology, and geohydrology, must be quantified in more detail by dedicated specialist studies to provide significance to the potential impacts.

Based on the P50 and Mean catchment runoff statistics, the impact is < 6 % throughout the year. It is also evident that the size and shape of both pit dewatering cones would capture and minimise nitrate migration off site.

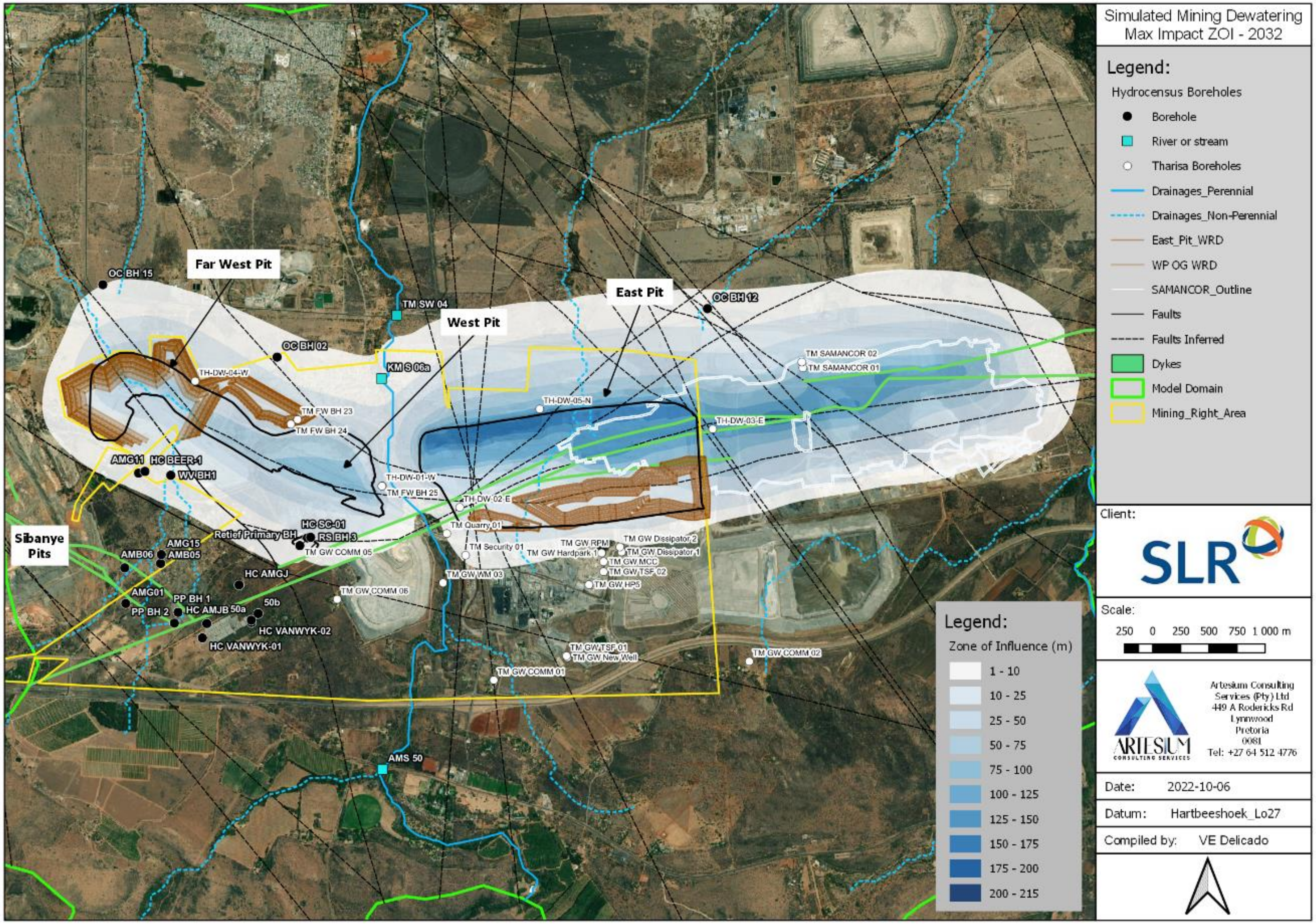

Figure 6-22: Maximum Dewatering Zone of Influence (2032)

6.5.3 Current (September 2022) simulated water balance and nitrate plumes

The mine surface infrastructure impacts were simulated with the calibrated steady state model to obtain the current flow and nitrate mass plume conditions. The scheduling information was provided by the client, and as seen in Section 6.5.1, the model calibrated well.

The current (September 2022) extent of the nitrate mass migration is presented in Figure 6-23, with the September 2022 model groundwater balance presented in Table 6-6.

The model flows are balanced within < 1 % error for this timestep, with majority of the water inflows owing to recharge (± 2 500 m^3/d), seepage from the constructed TSF's (± 890 m^3/d), and from storage (due to dewatering from the 4 open pits and Samancor underground contained within the model domain).

From Figure 6-23, it is evident that no nitrate impact is observed further than 500 m from mining infrastructure.

Table 6-6: September 2022 simulated groundwater balance

TS Groundwater Balance (September 22)				
	Component	**Inflow (m^3/d)**	**Outflow (m^3/d)**	**Balance (m^3/d)**
1	Recharge - Model Domain	2524		**2524**
2	Flux from Small TSFs (off site)	26		**26**
3	East WRD (Choppies)	83		**83**
4	East WRD 2	374		**374**
5	West WRD 1	294		**294**
6	Far West WRD 1	187		**187**
7	East OG WRD			**0**
8	West OG WRD			**0**
9	EP BF Z1	404		**404**
10	EP BF Z2	484		**484**
11	EP BF Z3	186		**186**
12	FWP BF	255		**255**
13	WP BF Z1	50		**50**
14	WP BF Z2	3		**3**
15	WP BF Z3	2		**2**
16	TSF 1	36		**36**
17	TSF 1 Extension	267		**267**
18	TSF 2 Phase 1	266		**266**
19	TSF 2 Phase 2	322		**322**
20	UG2 Pit dewatering		-203	**-203**
21	Sibanye Pit dewatering		-304	**-304**
22	West Pit Dewatering		-640	**-640**
23	Far West Pit Dewatering		-1092	**-1092**
24	East Pit Dewatering		-2139	**-2139**
25	SAMANCOR UG		-3554	**-3554**
26	Quarry	139		**139**
27	On Site Dams	274	-7	**268**
28	Abstraction from boreholes - Unknown			0
29	Boundary inflow to the north	490		**490**
30	Boundary outflow to the north		-520	**-520**
31	Model Storage Capture/Release	3731	-1919	**1812**
32	Baseflow and losses to drainages	504	-593	**-89**
	Total	**10900**	**-10972**	**-71.4**
			Balance Error (%)	**-0.7%**

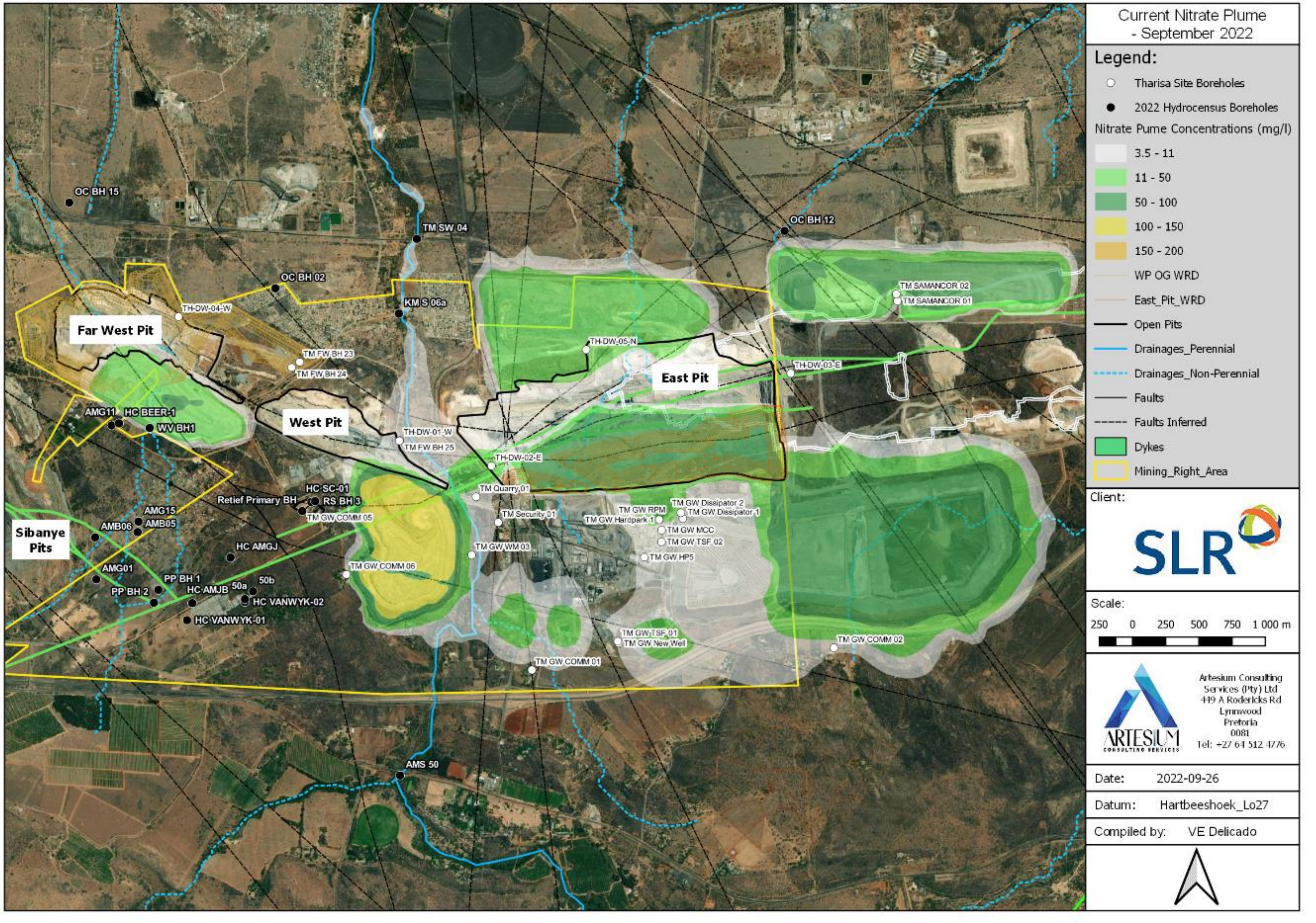

Figure 6-23: Simulated current (September 2022) nitrate mass plumes

6.5.4 Unmitigated nitrate mass migration - Max Impact East and West Pit Backfilling

Both the East Pit and West Pit backfilling is scheduled to be completed in January 2034, some 2 – 2.5 years after the completion of both the open pits (based on the schedules provided and approved). The East Pit backfilling was simulated to occur in three main stages, whilst the Far West Pit and West Pit is modelled in 4 main stages with the fourth being the merger of the two pit sections. These assumptions are based on open pit expansion utilising google maps, as well as the scheduling data provided.

At decommissioning / full backfilling (Figure 6-25), the nitrate plume from the West Pit is modelled to travel no more than 200 m north/northwest (due to the sink created from the Sibanye pit to the northwest). According to the model seepage towards the Sterkstroom (east) is observed, and travels ± 400 m downstream at elevated concentrations before it reaches the Marikana informal settlement to the north (contribution from the east pit and quarry also observed).

From the monitoring data and modelling results, nitrate mass migration within the Sterkstroom is limited and of local extent, as TM SW04 (located ± 1 km downstream) showed no nitrate exceedances during the July 2022 hydrocensus. Some build-up of nitrate directly downstream of the mining operations can be observed through LoM (Figure 6-24), but as seen with the long term monitoring data concentrations would seldomly exceed the SANS 241 nitrate concentration limit.

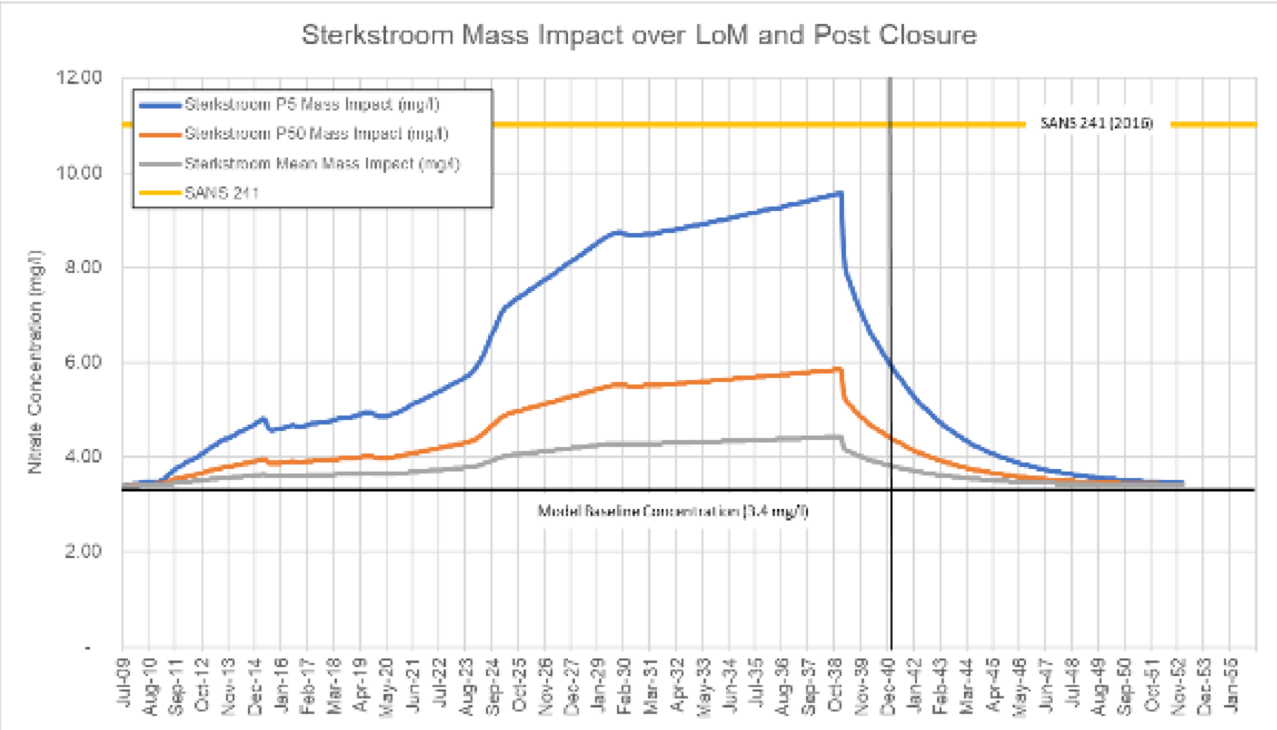

Figure 6-24 Sterkstroom Nitrate Mass impact over LoM and Post Closure

The modelling results show that at low flow (P5) Sterkstroom flows, the nitrate concentrations owing to mining can be elevated up to ± 9 mg/l at end of mine life (not considering monitoring data spikes (pulse events) in concentration which is due to seasonal wet and dry cycles and the contribution of changes in production of current arisings (ore) and waste rock rate over time). At median (P50) and mean Sterkstroom flows, nitrate build-up does not exceed ± 6 mg/l. It is proposed that additional Biomonitoring studies be conducted up and downstream of Tharisa to determine the cumulative impact of the nitrate build-up on the downstream ecosystem.

I & AP's directly south of Far W WRD 1 (The Wolvaart and van der Hoven residences) have simulated nitrate concentrations (± 50 – 100 mg/l) as localised seepage to the south is observed (± 100 m). Water would need to be provided to these residences should nitrate concentrations be observed from monitoring.

Considering the East mine section, nitrate migration above SANS 241 limits from the backfilled East Pit migrates < 100 m northeast towards the Marikana Informal settlement. Nitrate migration is also observed towards the east along the dyke contacts owing to SAMANCOR Underground rewatering (Figure 6-26).

Generally, nitrate migration is contained within the mine lease area and does not travel < 400 m from the mining infrastructure (localised Impacts). Seepage from the waste rock facilities is governed by rainfall (recharge is estimated at 12% - 15% of rainfall), and therefore multiple mitigation measures can be employed to limit rainfall infiltration and therefore seepage. Resulting runoff can also be effectively managed (see Section 6.5.6).

From the groundwater balance shown in Table 6-7, East OG WRD and pit backfilling recharge amounts to ± 1370 m^3/d, whilst the west pit backfilling recharge is modelled to be ± 740 m^3/d. Seepage from existing WRD's and TSF's reduce with time as and when these facilities are decommissioned based on the schedules provided..

Table 6-7: December 2033 simulated groundwater balance

TS Groundwater Balance (Max Impact Backfilling - December 33)				
	Component	**Inflow (m^3/d)**	**Outflow (m^3/d)**	**Balance (m^3/d)**
1	Recharge - Model Domain (excl Facilities)	1728		**1728**
2	Flux from TSFs (off site)	128		**128**
3	East WRD (Choppies)	118		**118**
4	East WRD 2	128		**128**
5	West WRD 1	101		**101**
6	Far West WRD 1	267		**267**
7	West OG WRD	82		**82**
8	EP BF + East OG WRD	1373		**1373**
9	WP BF	739		**739**
10	TSF 1	41		**41**
11	TSF 1 Extension	124		**124**
12	TSF 2 Phase 1	140		**140**
13	TSF 2 Phase 2	176		**176**
14	UG2 Pit dewatering		-205	**-205**
15	Sibanye Pit dewatering		-326	**-326**
16	West Pit Dewatering	2091	-2963	**-872**
17	East Pit Dewatering	3631	-4311	**-680**
18	SAMANCOR UG		-3376	**-3376**
19	Quarry	141		**141**
20	On Site Dams	302		**302**
21	Abstraction from boreholes - Unknown			**0**
22	Model Storage Capture/Release	3840	-3052	**788**
23	Baseflow and losses to drainages	1186	-1998	**-812**
	Total	**16333**	**-16229**	**104.1**
			Balance Error (%)	**-0.6%**

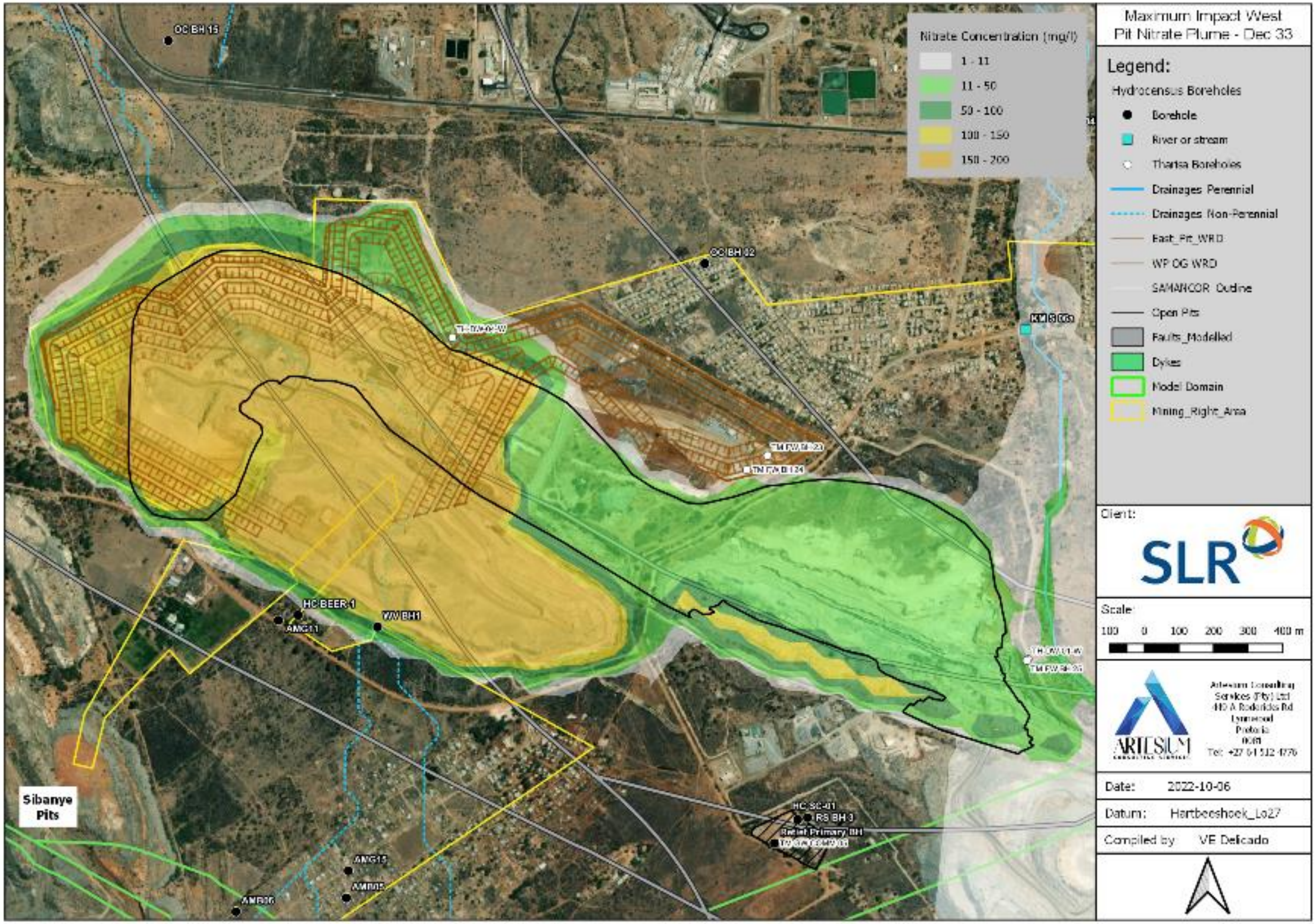

Figure 6-25: Maximum nitrate plume impact – West Pit Backfilling

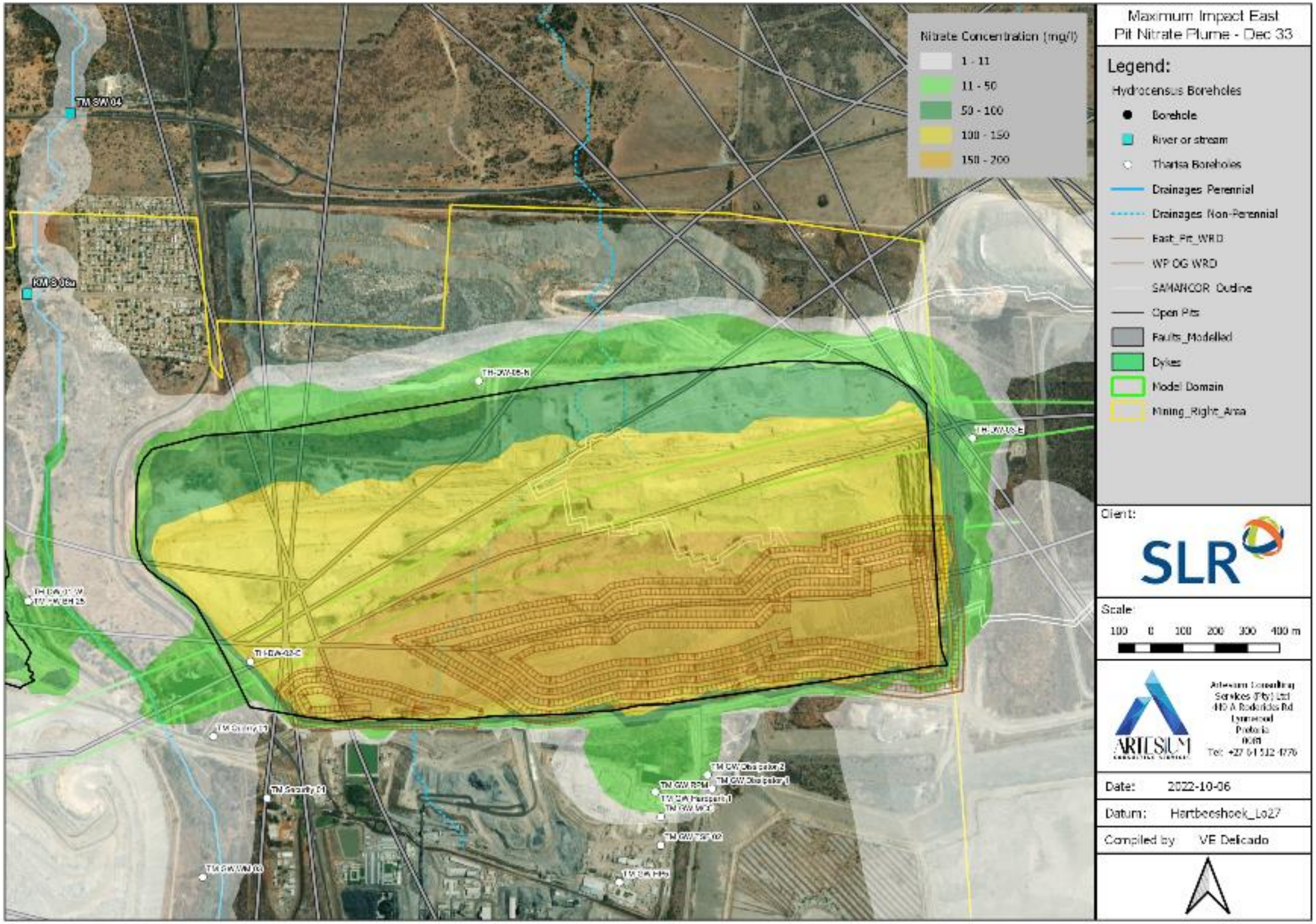

Figure 6-26: Maximum nitrate plume impact – East Pit Backfilling

6.5.5 Unmitigated nitrate mass migration - Maximum Impact East and West OG WRD's

Additional WRD facilities are planned above both the fully backfilled East Pit and Far west section of the West Pit (Figure 5-1). Both the East Pit and West Pit OG WRD's are planned to be commissioned March 2023, with the West Pit OG WRD constructed in 4 zones within the model domain. For the West Pit OG WRD, construction is estimated to start from a westerly to an easterly direction, to ensure ample time for liaison with authorities and I & APs from the Marikana settlement.

The simulated East Pit OG WRD maximum nitrate mass plume footprint is mostly confined to the East Pit footprint due to dewatering and rewatering of the fully backfilled pit (created sink). De-nitrification of the backfilled waste rock is also observed as the plume concentrations dissipate towards the north. Some nitrate mass migration is observed towards the east (most likely due to Samancor Underground rewatering), with the plume migrating no more than ± 400 m (Figure 6-27).

The groundwater balance at the East Pit OG WRD life of Facility (LoF) is presented in Table 6-8. Rewatering can be observed as less water is released from storage, with most of the mine infrastructure in the post-closure phase, i.e., less seepage due to facility capping as per the mine closure plan / commitments.

Table 6-8: East Pit OG WRD LoF groundwater balance

TS Groundwater Balance (EP OG WRD LoF - Dec 35)				
	Component	**Inflow (m^3/d)**	**Outflow (m^3/d)**	**Balance (m^3/d)**
1	Recharge - Model Domain (excl Facilities)	2629		**2629**
2	Flux from TSFs (off site)	128		**128**
3	East WRD (Choppies)	100		**100**
4	East WRD 2	108		**108**
5	West WRD 1	86		**86**
6	Far West WRD 1	226		**226**
7	West OG WRD	170		**170**
8	EP BF + East OG WRD	1030		**1030**
9	WP BF	554		**554**
10	TSF 1	35		**35**
11	TSF 1 Extension	105		**105**
12	TSF 2 Phase 1	130		**130**
13	TSF 2 Phase 2	209		**209**
14	UG2 Pit dewatering		-210	**-210**
15	Sibanye Pit dewatering		-333	**-333**
16	West Pit Dewatering	1994	-2900	**-906**
17	East Pit Dewatering	3442	-4379	**-937**
18	SAMANCOR UG		-2658	**-2658**
19	Quarry	141		**141**
20	On Site Dams	282		**282**
21	Abstraction from boreholes - Unknown			**0**
22	Model Storage Capture/Release	2326	-2368	**-42**
23	Baseflow and losses to drainages	1153	-1975	**-822**
	Total	**14846**	**-14822**	**23.5**
			Balance Error (%)	**-0.2%**

For the West Pit OG WRD, most of the nitrate migration occurs from the far west section of the pit, as the construction of the WRD occurs from a westerly to an easterly direction. The Far W WRD 1 also contributes to nitrate mass migration here.

Nitrate migration occurs in a north-westerly direction, with the plume modelled to travel no more than ± 200 m affecting no direct receptors. This movement can most likely be attributed to the Sibanye open pit sink created to the northwest of the facility. As mentioned, I & APs directly south of Far W WRD 1 could experience elevated nitrate concentrations (± 50 – 100 mg/l) as seepage to the south is observed (± 100 m). With the construction of the third and fourth sections of the West Pit OG WRD, I & APs would need to be moved (Marikana Settlement), with the nitrate concentrations lower than the first two sections due to less time for nitrate build-up to occur. Nevertheless, the nitrate mass plume migrates no more than ± 150 m from the proposed footprints.

Table 6-9 below illustrates the groundwater balance at maximum impact of the West Pit OG WRD.

Table 6-9: West Pit OG WRD LoF groundwater balance

TS Groundwater Balance (WP OG WRD LoF - Jan 41)				
	Component	**Inflow (m^3/d)**	**Outflow (m^3/d)**	**Balance (m^3/d)**
1	Recharge - Model Domain (excl Facilities)	2199		**2199**
2	Flux from TSFs (off site)	128		**128**
3	East WRD (Choppies)	92		**92**
4	East WRD 2	100		**100**
5	West WRD 1	79		**79**
6	Far West WRD 1	50		**50**
7	West OG WRD	155		**155**
8	EP BF + East OG WRD	856		**856**
9	WP BF	509		**509**
10	TSF 1	32		**32**
11	TSF 1 Extension	97		**97**
12	TSF 2 Phase 1	120		**120**
13	TSF 2 Phase 2	192		**192**
14	UG2 Pit dewatering		-203	**-203**
15	Sibanye Pit dewatering		-327	**-327**
16	West Pit Dewatering	1593	-2506	**-914**
17	East Pit Dewatering	2486	-3778	**-1292**
18	SAMANCOR UG	477	-2261	**-1784**
19	Quarry	110		**110**
20	On Site Dams	311		**311**
21	Abstraction from boreholes - Unknown			**0**
22	Model Storage Capture/Release	1805	-1525	**279**
23	Baseflow and losses to drainages	1138	-1908	**-770**
	Total	**12526**	**-12510**	**16.0**
			Balance Error (%)	**-0.1%**

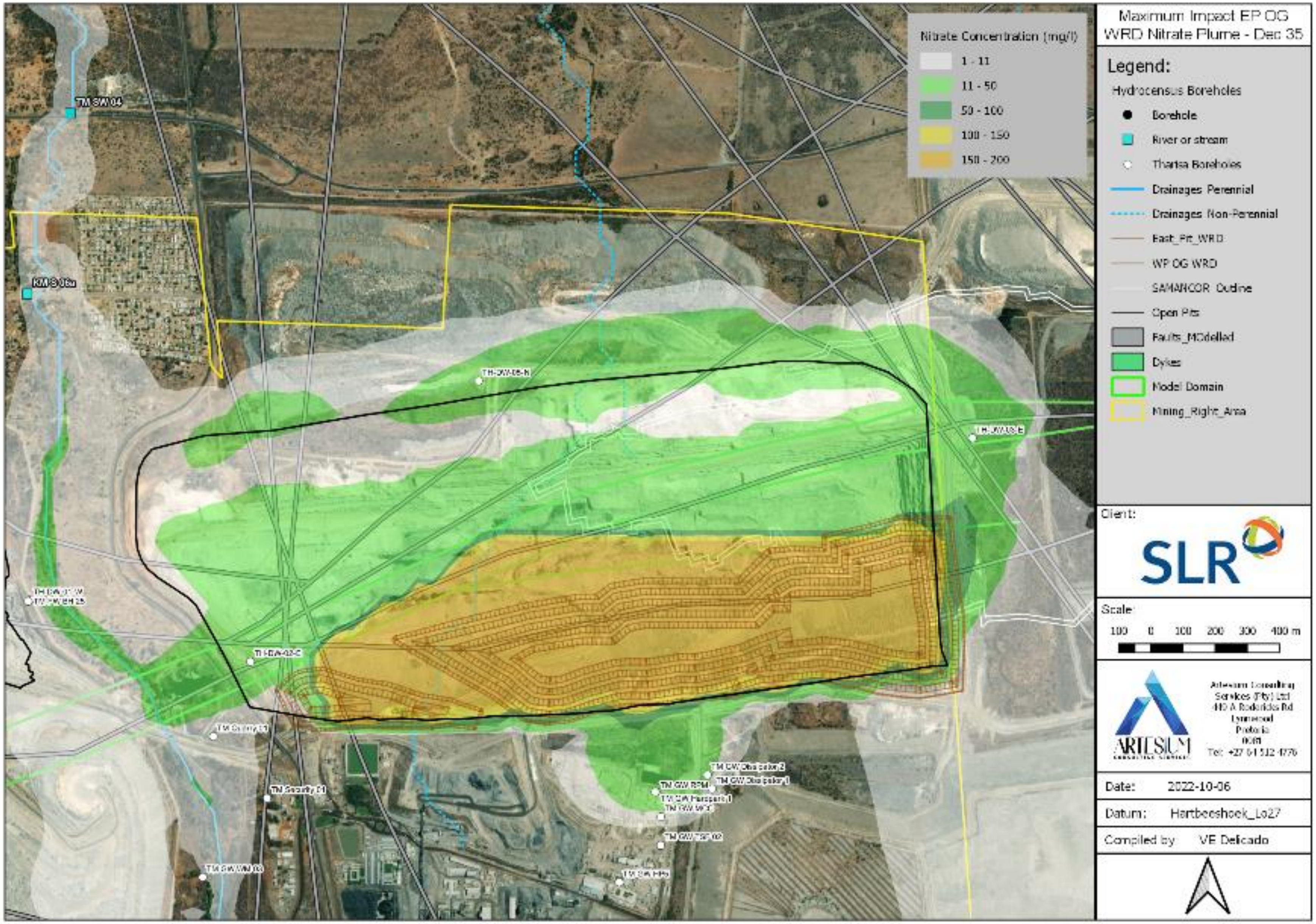

Figure 6-27: Maximum nitrate plume impact – East Pit OG WRD

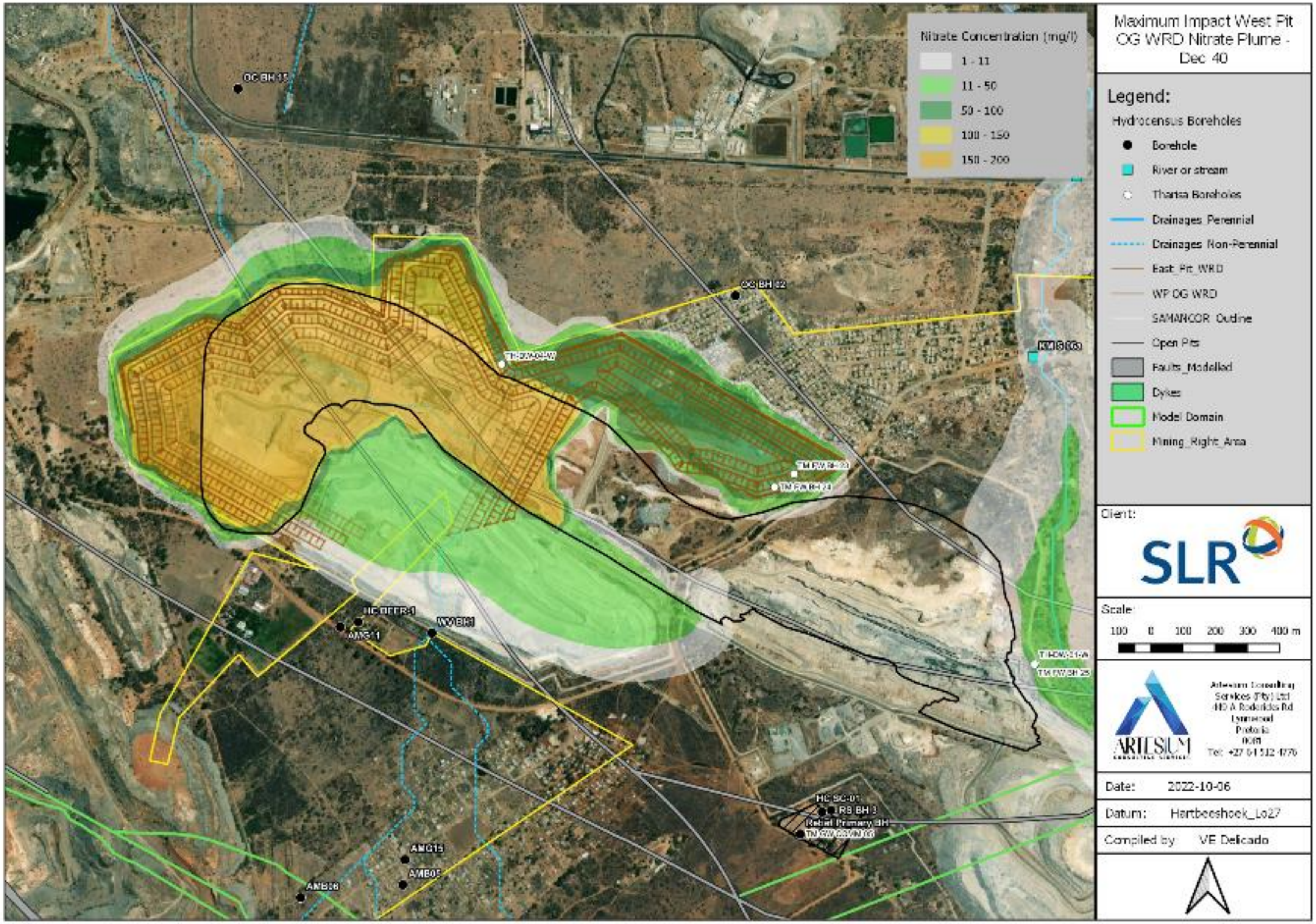

Figure 6-28: Maximum nitrate plume impact – West Pit OG WRD

6.5.6 Potential Nitrate Mass transport mitigation measures - Pathway

From the unmitigated maximum impact nitrate mass migration results, the nitrate plume does not travel < 500 m from the proposed new facilities for both East Pit and West Pit, with the main receptors being the Sterkstroom, Marikana settlement directly downstream of the mine, I & APs directly next to Far W WRD 1 (The Wolvaart and van der Hoven residences) and west of W WRD 1 (Retief Primary School borehole). The ZOI would also minimise nitrate mass migration off site and therefore migration impacts are low for the proposed new facilities.

From the geological information provided it was conservatively inferred that the faults/fractures and dyke contact zones are permeable and could act as potential seepage pathways for mass migration.

The East Pit seepage zones are presented in Figure 6-29. The East Pit has two main Fault and Dykes zones stretching from west to east through the open pit. During the operational and post closure rewatering phases of mining, these zones would act as pathways for water towards the pit, as the pit is seen as a sink for groundwater movement, which would also limit mass migration. Additionally, nitrate migration could potentially move towards the north via the two north-south trending fault zones. From the unmitigated modelling of the backfilled material as well as the OG WRD, nitrate plume movement is mostly limited to the open pit footprint.

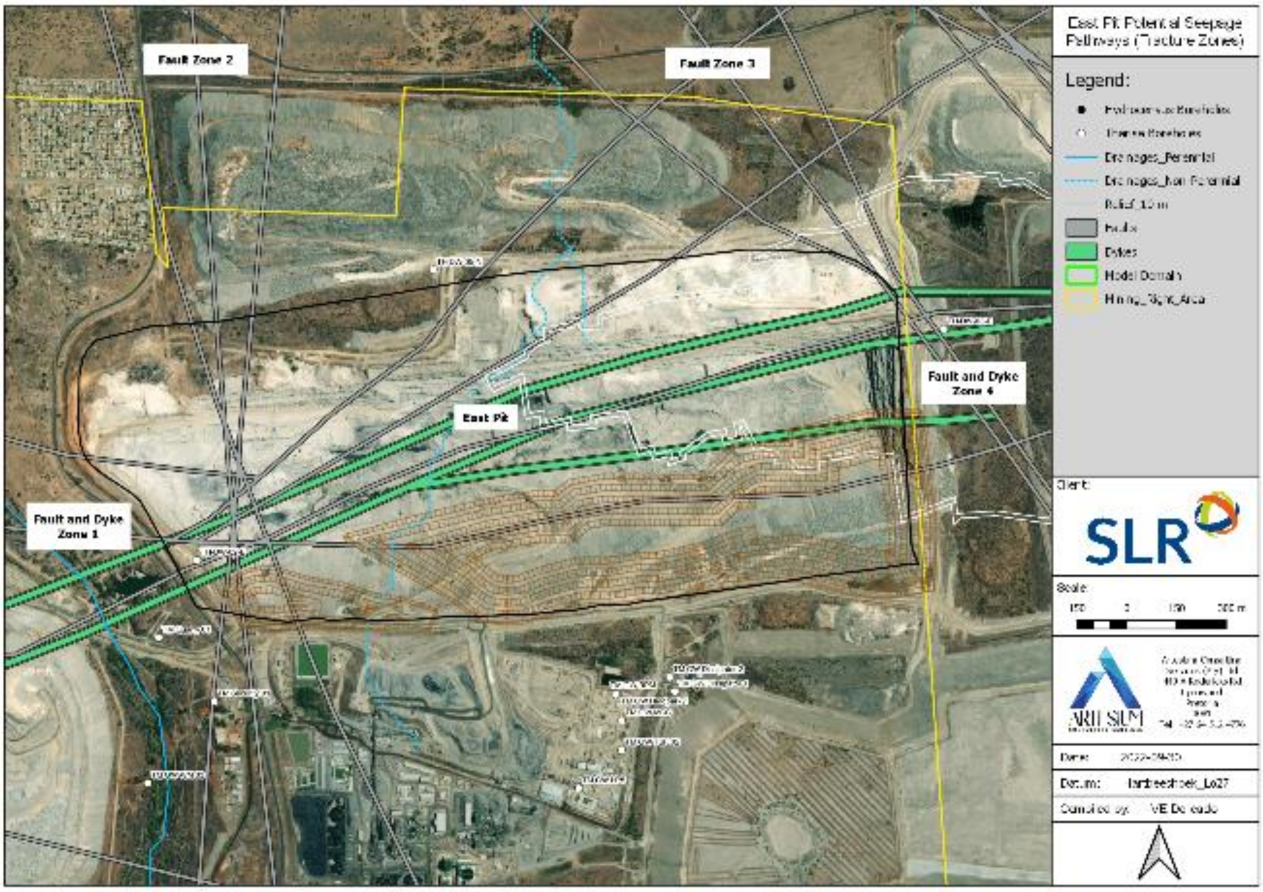

Figure 6-29: East Pit geological structures

The West Pit seepage zones are presented in Figure 6-30. In comparison to the East Pit structural information provided, the pit is characterised by a lot less faults (6 main faults). These could potentially allow for movement towards the northwest, as well as east towards the Sterkstroom. Please note that the West Pit would act as a groundwater sink, and most likely draw water towards the pit during operations and post closure rewatering. The Sibanye pit towards the northwest of the Tharisa West Pit also encourages some mass migration as seen in the unmitigated modelling results depending on where the water level is kept within the Sibanye pit.

Figure 6-30: West Pit geological structures

Though the nitrate migration impacts are considered low, to monitor and mitigate any potential mass movement along these fracture / dyke contact zones, the WRD nitrate plume migration mitigation plan would be to introduce the following mitigation approaches as a Multiple Barrier design and sustainable management plan, without the requirement of any basal physical barrier / liner system, as nitrate mass migration is limited (Figure 6-31):

- Monitoring boreholes downstream of facilities sited on the key fracture / dyke contact zones. These boreholes should be included within the mine monitoring protocol (to be updated) to aid in early detection of any potential nitrate migration and can if required be converted to seepage capturing boreholes based on the risk-based approach[2].
- A seepage capturing trench (2.5 m deep) for any shallow diffuse seepage close to the facility toe (selected areas), as well as management of surface water runoff from the facilities.
- Concurrent phytoremediation could be employed (e.g., Searsia Lancea Trees) to capture shallow fugitive seepage and enhance the biological nitrate barrier downstream of the facilities (selected areas).

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2 The borehole locations are conceptual pending geophysical studies to point out potential preferential flow zones

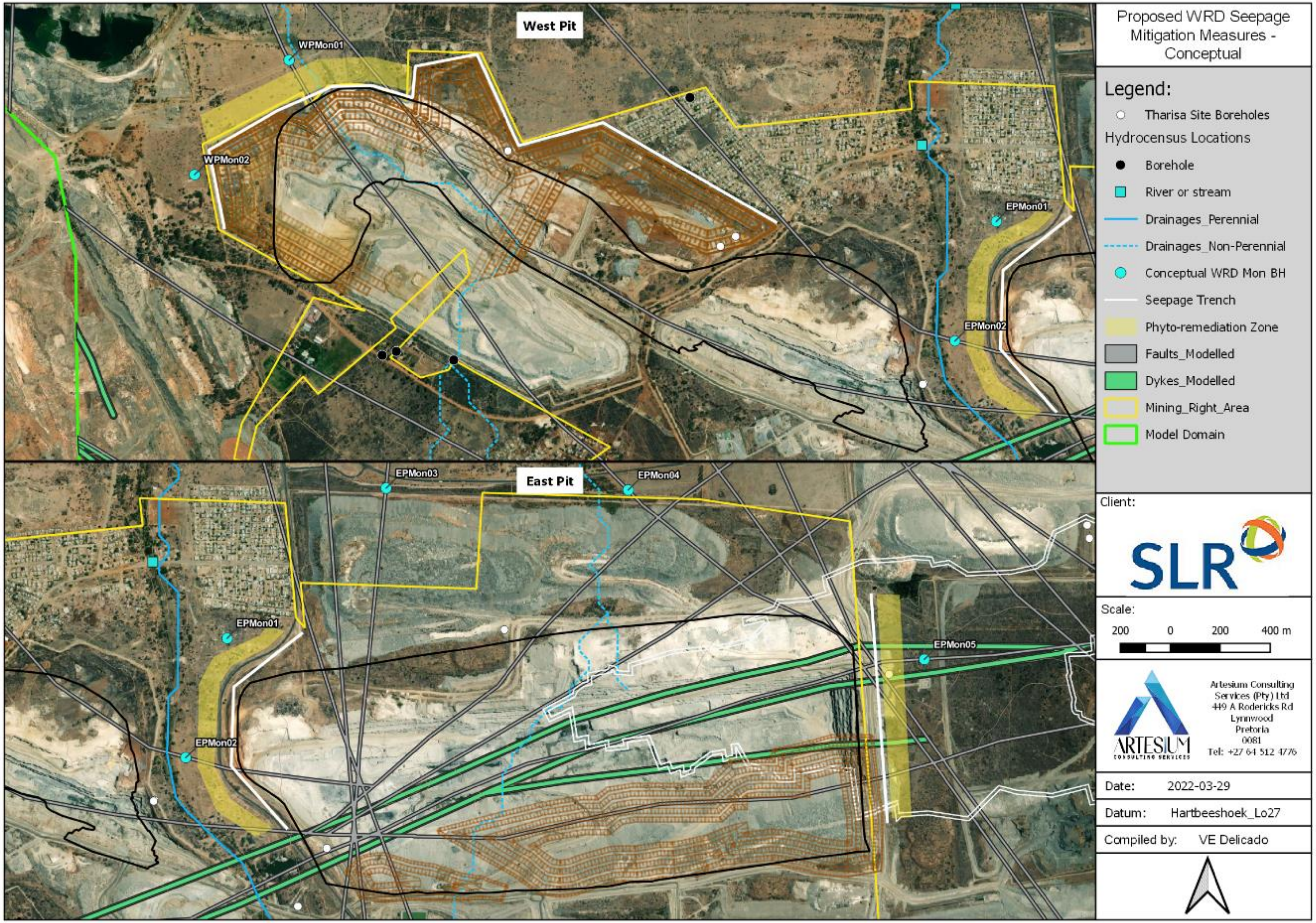

Figure 6-31: Proposed / Conceptual WRD nitrate mass mitigation measures.

6.5.6.1 The Sustainable Multiple-Barrier Mitigation Design and Management Plan – Pathway/receptor

Based on the simulated unmitigated WRD nitrate mass plumes, a sustainable multiple-barrier mitigation and management design is proposed. The multiple barriers include:

1. **Barrier 1:** Existing main seepage vector is drawn to the open pits - Anthropogenic Post Closure Permanent Sink
2. **Barrier 2:** Several Monitoring Boreholes (± 8) focused on fracture pathway zones which could be converted to seepage capturing boreholes to capture deep discrete seepage
3. **Barrier 3:** Shallow Perimeter Solution Trench (± 2.5 m deep) in selected areas to manage surface water runoff – Capture shallow Diffuse Seepage and Rainfall-Runoff.
4. **Barrier 4:** Concurrent Phytoremediation (Searsia Lancea Trees or equivalent) in selected areas – Capture surface and sheet flow and enhanced biological nitrate barrier + visual, dust and erosion mitigation
5. **Barrier 5:** Post Closure rehabilitation and revegetation of the WRDs to limit rainfall recharge and therefore seepage
6. **Barrier 6:** Shaping of the backfilled open pits in a concave shape to limit infiltration and direct runoff towards seepage capture canals/trenches.
7. **Barrier 7:** Time - Nitrate degrades due to natural denitrification processes and was proven with decay a half-life of ±110 - 160 days. It is therefore only an operational concern and would decay to drinking water standards within 5 - 10 years after operations end.
8. Monitoring feedback, active intervention, and control

The proposed Multiple-Barrier approach is presented in more detail in Figure 6-32 below and would ensure adequate management of the potential nitrate mass migration following a stringent risk-based approach.

It is important to note that the technical process is linked to a formal engineering solution and sustainable management plan. The final Decision-Making Process should be validated via a Feedback QAQC loop, to ensure and guarantee mitigation success without the requirement for a physical liner-barrier system (Figure 6-32).

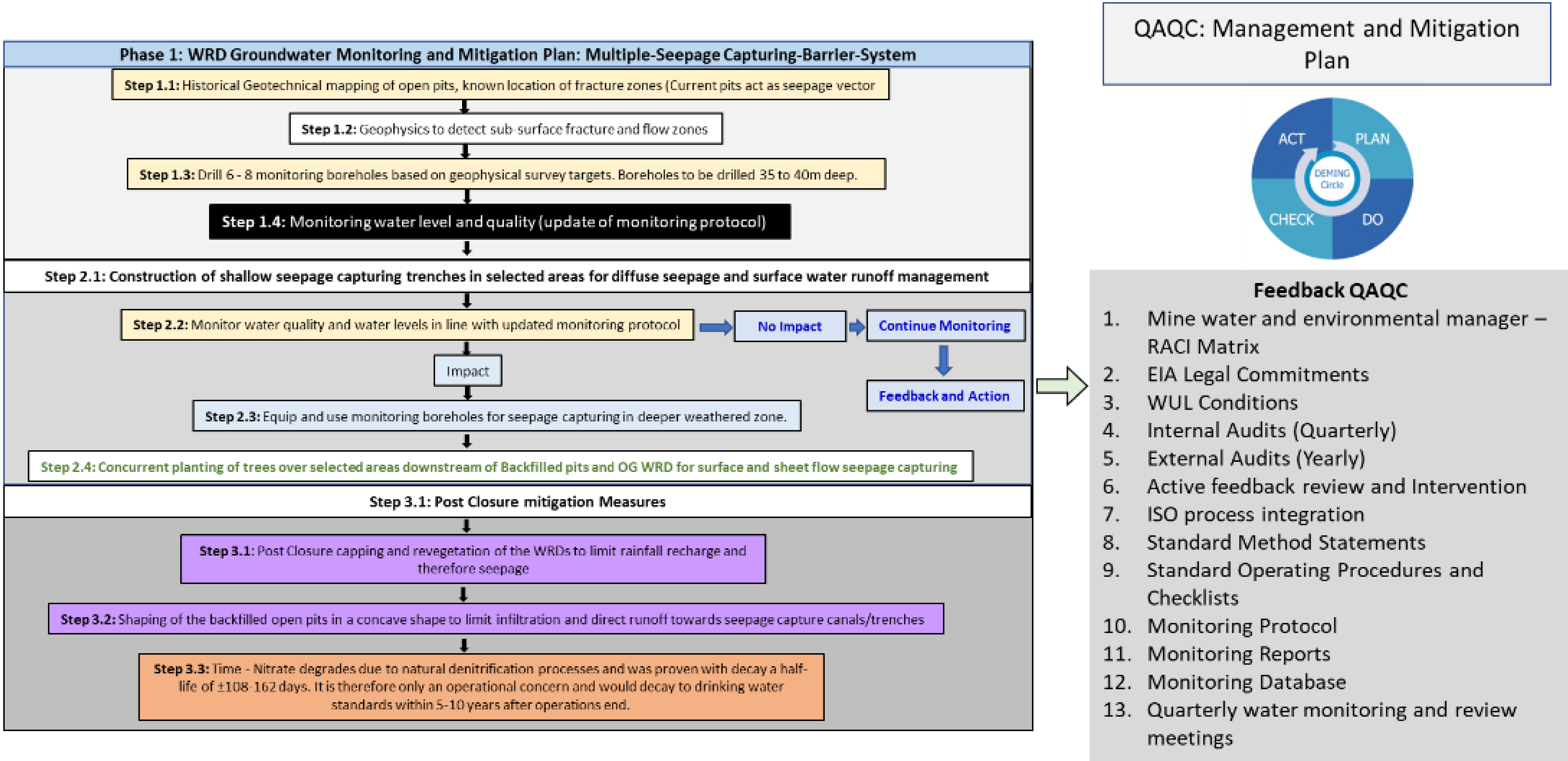

Figure 6-32: Sustainable Multiple-Barrier Risk Management Plan and Decision-Making Process

6.5.7 Post Closure Flow and Mass - Samancor Underground and Open Pit Rewatering modelling

Post-operational rewatering and decanting models were developed for the West Pit and East Pit. The closure plan for the pits is to backfill the pits with surplus waste rock in a concave shape. The backfilled pits water balance would be controlled by recharge estimated at ± 13 % of precipitation and storage in the backfilled pore space estimated at 20 % porosity.

The simulations showed that the East Pit would take around ±110 years to flood 40 mil m^3[3], assuming no upstream surface water ingress and includes the old Samancor Underground (Figure 6-33). The steady-state decanting rate would be ± 400 - 600 m^3/d (decanting within the weathered zone).

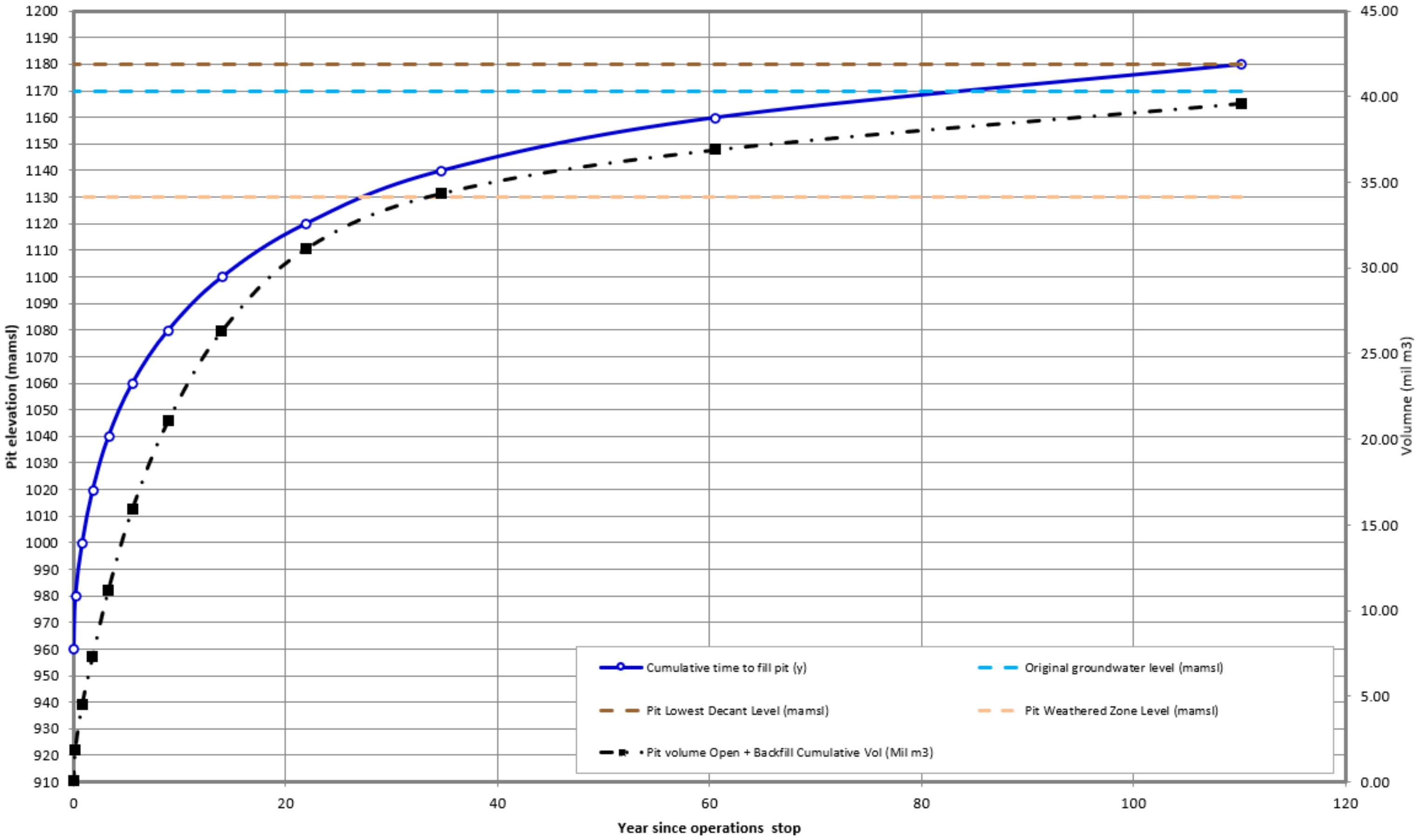

Figure 6-33: Tharisa East Pit – Post-Operational Pit Flooding and decanting (backfilled)

The West Pit would take around ± 90 years to flood with a total volume of 5 mil m^3, assuming no upstream surface water ingress (Figure 6-34). The steady-state decanting rate would be 200 - 300 m^3/d.

The water quality from both open pits is expected to be close to drinking water standards as nitrate, which is the only parameter of concern, would have been degraded within ± 5 - 10 years post-closure from the post closure modelling conducted (Figure 6-35).

[3] This is 20% the volume of the Hartebeespoort Dam.

The flooded or partially flooded open pits would form excellent artificial aquifers with usable water quality during the post-operational phase. Options to use the fully backfilled open pits as water resources and enhance recharge yield by diverting surface water into them during flood conditions should be considered and evaluated via further modelling and studies.

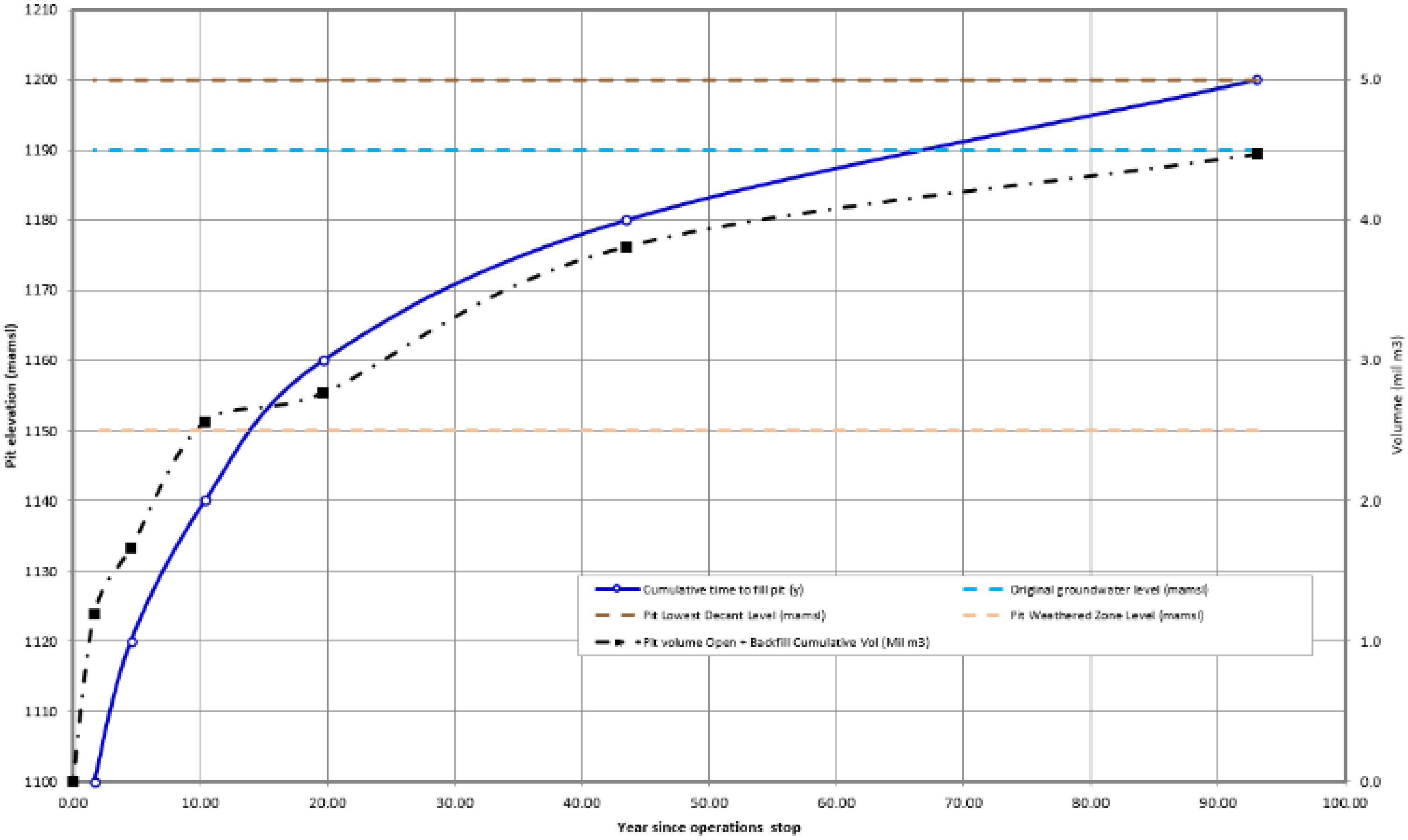

Figure 6-34: Tharisa West Pit – Post-Operational Pit Flooding and decanting (backfilled)

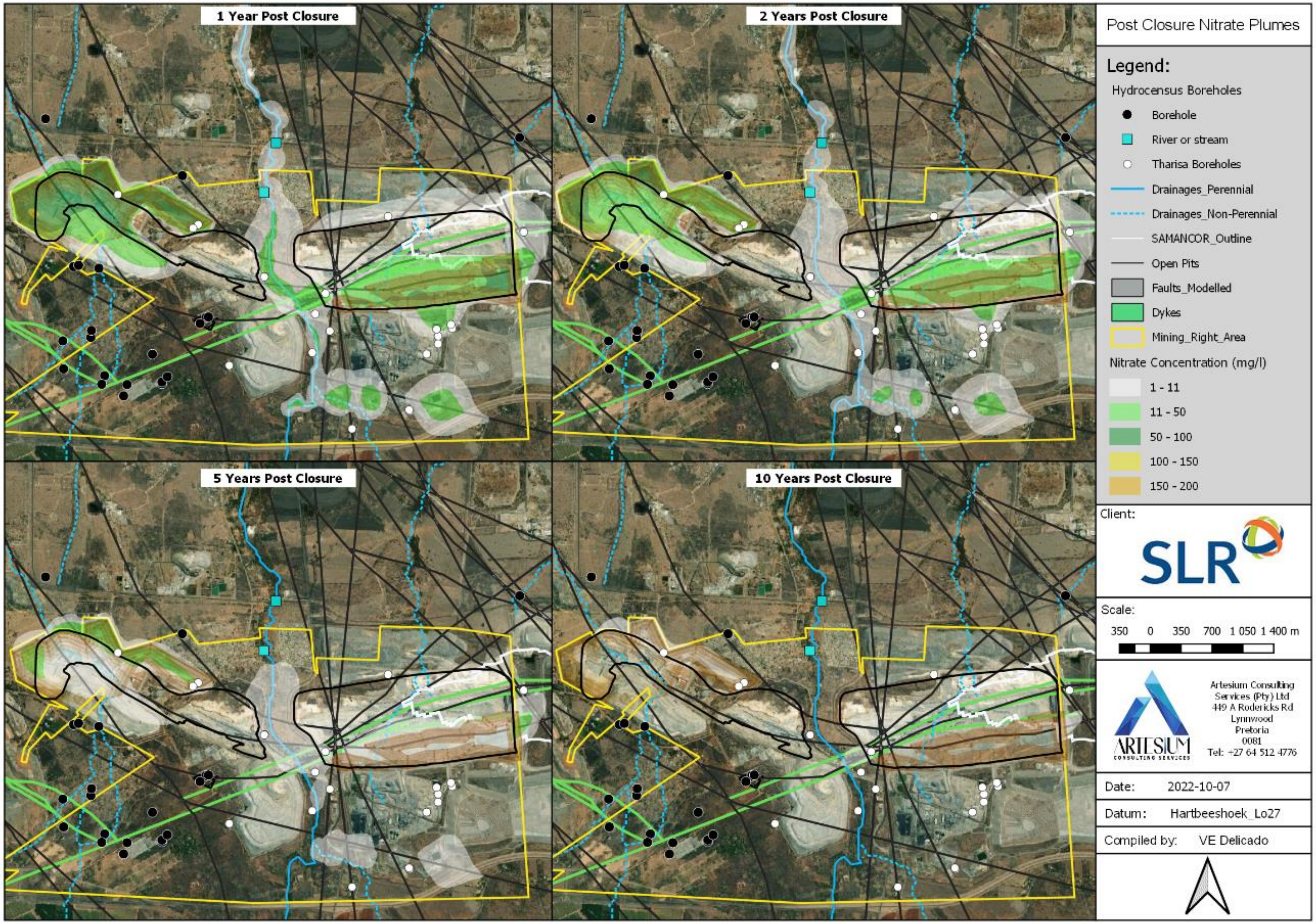

Figure 6-35: Tharisa Post Closure Plumes

7 Hydrogeological Impact Assessment (HIA)

From the numerical modelling and Source-Pathway-Receptor analysis, a hydrogeological impact & risk assessment (HIA) was conducted for the proposed new facilities. The summary and results of this analysis is presented in Table 7-1 below, with the Assessment Matrix presented in Appendix C.

One area of concern would be the dewatering effects and potential loss of groundwater yield to adjacent I & APs and informal settlements which are within the cone of depression. The modelling results show that the West Pit cone extends ± 700 m to the south and would potentially affect 4 I & APs near the mine (1 – 10 m drawdown). These include borehole AMG11, The Retief Primary School borehole, as well as the Wolvaart and van der Hoven residences.

Potential groundwater users within the Marikana informal settlement are also situated within the modelled ZOI (1 -10 m drawdown). The source of their water needs to be verified as it is inferred that they receive Magalies water. All the hydrocensus boreholes downstream of the site will be affected to an extent (1 – 10 m drawdown). It must be noted that most of the land uses are industrial and mining related (Figure 6-22).

Due to the East Pit and West Pit's proximity to the Sterkstroom, the stream section directly adjacent to the open pits will most likely experience a drawdown effect (10 – 25 m). The modelling shows that based on the low flow (P5) monthly catchment runoff flows, a 6 - 10 % impact would be observed from April – Oct. During these months, piping, or discharge from dewatered flow volumes in the Sterkstroom from an upstream point before the mine to a downstream point after mining activities can be employed to minimize the impact on the Sterkstroom groundwater baseflow. These dewatering effects can be managed and mitigated to a large extent.

Considering that the impacts from WRD facilities are governed by rainfall and therefore recharge, as well as the influence of the pit dewatering and rewatering creating a sink, the nitrate does not travel > 500 m from the mine residue facilities with localised impacts.

Based on the Source-Pathway-Receptor risk analysis, taking into consideration the sustainable adaptive multiple barrier approach proposed, nitrate migration from the proposed new facilities has insignificant and localised impacts, and no physical liner or semi-impermeable barrier system is required. Nitrate plumes from the proposed WRD facilities do migrate beyond the mine lease area (< 500m).

Post closure re-watering and mass migration is not a significant impact. The flooded backfilled pits would form excellent artificial aquifers with usable water quality during the post-operational phase. Options to use these as water resources and enhance recharge yield by diverting surface water into these during flood conditions should be considered and evaluated via further modelling and studies. Nitrate degradation due to denitrification also causes the plumes to dissipate within a maximum of 5 - 10 years after closure.

Table 7-1: Hydrogeological Impact Assessment Matrix

Nr	Activity	Impact	Without or With Mitigation	INTENSITY	DURATION	EXTENT	CONSEQUENCE	PROBABILITY	SIGNIFICANCE	Mitigation Measures	Mitigation Effect
						Construction Phase					
1	Contamination to ground- and surface water systems from oil, grease and diesel spillages from construction vehicles.	Contamination to groundwater systems	WOM	L	M	L	Low	M	Very Low	Road compaction and service facilities for mine vehicles with spillage sumps	Can be avoided, managed or mitigated
			WM	VL	M	L	Low	L	Very Low		Can be avoided, managed or mitigated
2	On-site sanitation.	Contamination to groundwater systems	WOM	L	H	VL	Low	M	Very Low	Monitoring systems to detect leaking and as well as visual observations of facilities conditions	Can be avoided, managed or mitigated
			WM	VL	H	VL	Low	VL	Insignificant		Can be avoided, managed or mitigated
3	Storage of chemicals and building materials during construction of waste facilities.	Contamination to groundwater systems	WOM	L	L	VL	Low	H	Low	Best practise storage facilities and spill kits	Can be avoided, managed or mitigated
			WM	VL	L	VL	Very low	VL	Insignificant		Can be avoided, managed or mitigated
						Operational Phase					
4	Dewatering and loss of yield from I & AP boreholes in close proximity to mining developments (South of West Pit) due to maximum impact ZOI	Groundwater resources	WOM	H	H	M	High	H	High	The simulated maximum cone of depression is < 700 m from the pits boundaries and potentially impact 4 I & APs. Groundwater level and chemistry monitoring based on the updated monitoring protocol and if impacts are measured, mitigate by supply of alternative water to any impacted users. If specific fractures are intersected during mining these could be grouted/sealed to manage the impact.	Can be reversed
			WM	L	M	L	Low	H	Low		Can be reversed
5	Dewatering and loss of yield from boreholes downstream of mining developments (Marikana Informal settlement) due to maximum impact ZOI	Groundwater resources	WOM	H	H	M	High	H	High	The simulated maximum cone of depression is < 700 m from the pits boundaries and potentially impact the Marikana Informal Settlement. Groundwater level and chemistry monitoring based on the updated monitoring protocol and if impacts are measured, mitigate by supply of alternative water to any impacted users. If specific fractures are intersected during mining these could be grouted/sealed to manage the impact.	Can be reversed
			WM	L	M	L	Low	H	Low		Can be reversed
6	Drawdown effect on the Sterkstroom due to open pit dewatering from East and West Pit	Surface water resources and baseflow	WOM	H	H	L	High	H	High	Monitor upstream and downstream Strekstroom flows, and specific boreholes located adjacent to the stream for early detection; Diversion of non-contact runoff to the Sterkstroom. Verification of mine dewatering impacts on the Sterkstroom based on specialist surface water studies and monitoring. If impacts are significant piping or discharge of dewatered volumes in the Sterkstroom to a downstream point after mining activities during low flow months.	Can be reversed
			WM	L	M	L	Low	H	Low		Can be reversed
7	Pit flooding during large rainfall events	Excess water; potential siltation of sump; mining delays	WOM	M	VL	L	Low	H	Low	Develop and implement a dewatering strategy and design that includes sumps, pumps and associated infra-structure	Can be avoided, managed or mitigated
			WM	L	VL	VL	Very low	M	Very Low		Can be avoided, managed or mitigated
8	Contamination of water in flooded pit during large rainfall events	Contamination to groundwater systems	WOM	M	VL	L	Low	H	Low	Design sufficient sump capacity to contain volumes from extreme wet events in the pit and the mine water balance buffer storage capacity.	Can be avoided, managed or mitigated
			WM	L	VL	VL	Very low	M	Very Low		Can be avoided, managed or mitigated
9	Existence of hydraulic connections between the East Pit and Samancor Underground and groundwater leakage into East Pit;	Increased inflows to open pit mining area	WOM	M	M	VL	Medium	H	Medium	The mine dewatering modelling accounted for the Samancor flooded underground. The transient dewatered volumes should be included in an updated transient mine water balance to ensure reuse and sufficient storage capacity during extreme wet events.	Can be avoided, managed or mitigated
			WM	L	M	VL	Low	L	Very Low		Can be avoided, managed or mitigated

Nr	Activity	Impact	Without or With Mitigation	INTENSITY	DURATION	EXTENT	CONSEQUENCE	PROBABILITY	SIGNIFICANCE	Mitigation Measures	Mitigation Effect
10	Excess water generated from dewatering without appropriate discharge options;	Discharge of water into the environment or provide water to the community for water supply	WOM	M	M	M	Medium	H	Medium	Develop and integrated, transient mine water and chemical mass load balance and align with the Integrated water and waste management plan & EIA; If excess water is clean (below SANS 241 standards), it could potentially be discharged into Sterkstroom downstream.	Can be avoided, managed or mitigated
			WM	L	L	L	Low	M	Very Low		Can be avoided, managed or mitigated
11	Existence of hydraulic connections between the East Pit, Quarry an Sterkstroom which allows mass migration towards Sterkstroom;	Contamination to groundwater and surface water systems	WOM	H	L	M	Medium	H	Medium	The groundwater sink created by East and West pit dewatering minimises mass migration.	Can be avoided, managed or mitigated
			WM	M	L	M	Medium	M	Low		Can be avoided, managed or mitigated
12	Nitrate migration from current mine residue facilities (TSF and WRDs) downstream: • North from Choppies WRD and East WRD, • West from East Pit and the quarry towards the Sterkstroom; and • East from west pit towards the Sterkstroom.	Contamination to groundwater and surface water systems	WOM	M	H	M	Medium	H	Medium	The recommended Multiple-Capturing-Barrier-System mitigation and sustainable groundwater management plan should be included in the mine planning. The management plan should be activated based on monitoring, early warning and verification of simulated potential impacts.	Can be avoided, managed or mitigated
			WM	M	H	M	Medium	M	Low		Can be avoided, managed or mitigated
13	Nitrate migration from current Far West WRD 1 and West WRD 1 towards I & APs directly adjacent to these facilities: • The Wolvaart and van der Hoven residences; and • Retief Primary School borehole.	Contamination to groundwater and surface water systems	WOM	M	H	M	Medium	H	Medium	The recommended Multiple-Capturing-Barrier-System mitigation and sustainable groundwater management plan should be included in the mine planning. The management plan should be activated based on monitoring, early warning and verification of simulated potential impacts.	Can be avoided, managed or mitigated
			WM	M	H	M	Medium	M	Low		Can be avoided, managed or mitigated
14	Nitrate migration from planned new facilities (open pit backfilling and OG WRDs) downstream: • East Pit backfilling northeast towards the Marikana Informal settlement; • East Pit backfilling east along the dyke contacts owing to SAMANCOR Underground rewatering; • West Pit backfilling northwest towards Sibanye pits; and • West Pit backfilling east towards Sterkstrroom.	Contamination to groundwater and surface water systems	WOM	M	H	M	Medium	H	Medium	The recommended Multiple-Capturing-Barrier-System mitigation and sustainable groundwater management plan should be included in the mine planning. The management plan should be activated based on monitoring, early warning and verification of simulated potential impacts.	Can be avoided, managed or mitigated
			WM	M	H	M	Medium	M	Low		Can be avoided, managed or mitigated
Closure, Decommissioning and Post Operational Phase											
15	Re-Watering and decanting of backfilled open pits into weathered zone	Contamination to groundwater and surface water systems	WOM	VL	VH	M	Medium	VH	Medium	The backfilled open pits was simulated take 90 - 110 years to reach the decant level and would decant at estimated 200 m³/d to 600 m³/d . The water quality would be usable. The flooded backfilled open pits would form excellent artificial aquifers with usable water quality during the post-operational phase. Options to use these as water resources and enhance recharge yield by diverting surface water into these during flood conditions should be considered and evaluated via further modelling and studies. The water quality from both open pits is expected to be close to drinking water standards as nitrate, which is the only parameter of concern, would have been degraded within ± 5 - 10 years post-closure from the post closure modelling conducted	Can be avoided, managed or mitigated
			WM	VL	H	M	Low	M	Very Low		Can be avoided, managed or mitigated
16	Nitrate mass transport and seepage from Mine Residue (TSFs and WRDs) downstream.	Contamination to groundwater and surface water systems	WOM	L	M	M	Medium	H	Medium	Phytoremediation (e.g., Planting of Searsia Lancea trees), rehabilitation of facilities, shaping and rehab of the waste rock facilities. Natural decay of nitrates due to de-nitrification. Modelling shows that nitrates decrease to below SANS 241 Drinking Water Standards within < 10 years post closure	Can be avoided, managed or mitigated
			WM	L	L	M	Low	M	Very Low		Can be avoided, managed or mitigated

8 Conclusions

9. **Waste assessment** – Based on the geochemical analysis, all waste types (WRD and tailings), classify as Type 3 based on TCT0 exceedances. The TCT0 exceedances are irrelevant for the surface and groundwater pathways. The 2020 Vulcan Tailings sample classifies as Type 3 due to Cr exceedances. For the 2022 Vulcan tailings and all WRD samples, there are no LCT0 exceedances, and the waste can be classified as equivalent to Type 4. Although geochemical analysis of the solids and leaching components are important, it can differ from the actual field conditions.
10. **Monitoring Data –** The long-term water quality monitoring data from 2013 to 2021 of 232 process water samples were analysed statistically. From the analysis none of the samples exceeded the chromium SANS 241 Drinking Water Limit. Chromium is therefore not a parameter of concern at the site. The monitoring results confirmed that only Nitrate is a potential contaminant parameter.
11. **Dewatering** – The calibrated model showed combined East Pit and Samancor Underground simulated inflows in the order of ± 5 600 m^3/d. The average inflow rate simulated for the west and far west pits over the transient state calibration simulation period are ± 460 m^3/d and ± 600 m^3/d respectively. The water level data analysis shows that the dewatering cone from the respective open pits are of local extent (< 500 m) and do not currently point to major dewatering effects on neighbouring I & APs north and south of the west open pit.
12. At the deepest point of mining, the East Pit would dewater at a rate of ± 2 600 m^3/d, with the Samancor Underground dewatering being ± 3 900 m^3/d. The West Pit will dewater at a rate of ± 1 600 m^3/d (these abstraction volumes do not include additional water due to rainfall-runoff within the pit). The modelling results show that the West Pit cone extends ± 700 m to the south and would potentially affect 4 I & APs near the mine (1 – 10 m drawdown). These include borehole AMG11, The Retief Primary School borehole, as well as the Wolvaart and van der Hoven residences. Potential groundwater users within the Marikana informal settlement are also situated within the modelled ZOI (1 -10 m drawdown). The source of their water needs to be verified as it is inferred that they receive Magalies water. All the hydrocensus boreholes downstream of the site will be affected to an extent (1 – 10 m drawdown). It must be noted that most of the land uses are industrial and mining related. Due to the East Pit and West Pit's proximity to the Sterkstroom, the stream section directly adjacent to the open pits will most likely experience a drawdown effect (10 – 25 m).
13. **Residue Facilities** - From the unmitigated maximum impact nitrate mass migration results, the nitrate plumes do not travel < 500 m from the current and proposed new facilities for both East Pit and West Pit, with the main receptors being the Sterkstroom, Marikana settlement directly downstream of the mine, I & APs directly next to Far W WRD 1 (The Wolvaart and van der Hoven residences) and west of W WRD 1 (Retief Primary School borehole). The ZOI would also minimise nitrate mass migration off site and therefore migration impacts are low for the proposed new facilities. Nitrate is only an operational concern as it would decay to below SANS 241 Drinking Water Standard Limits after 5 - 10 years post operations.
14. **Impacts** – The simulated maximum cone of depression is < 700 m from the open pit boundaries (localised in extent) and potentially impact 4 I & APs as well as potential groundwater users at the

Marikana Informal Settlement. Groundwater level and chemistry monitoring based on the updated monitoring protocol and if impacts are measured, mitigate by supply of alternative water to any impacted users. If specific fractures are intersected during mining these could be grouted/sealed to manage the impact. If verified based on monitoring data, the impact can be managed and reversed from a High to a Low impact.

15. Nitrate plume migration from current and proposed new residue facilities does not migrate more than < 500 m, with the open pits acting as a groundwater sink limiting migration (medium impact rating). The recommended Multiple-Capturing-Barrier-System mitigation and sustainable groundwater management plan should be included in the mine planning. The management plan should be activated based on monitoring, early warning, and verification of simulated potential impacts. Nitrate is only an operational concern as it would decay to below SANS 241 Drinking Water Standard Limits after 5 - 10 years post operations. The mitigation proposed would ensure management of the impact to a low-risk rating.
16. **Post Closure** - The backfilled open pits were simulated take 90 - 110 years to reach the decant level and would decant at estimated 200 m^3/d to 600 m^3/d. The water quality would be usable. Post closure re-watering and mass migration is not a significant impact. The flooded backfilled pits would form excellent artificial aquifers with usable water quality during the post-operational phase. Options to use these as water resources and enhance recharge yield by diverting surface water into these during flood conditions should be considered and evaluated via further modelling and studies. Nitrate degradation due to denitrification also causes the plumes to dissipate within a maximum of 5 - 10 years.

9 Recommendations

1. The monitoring network needs to be reviewed and a formal monitoring protocol developed. A parameter optimisation study should be conducted to only analyse for the critical control parameters (CCP) as there are only ± 5 important chemical parameters. This would save on lab analysis costs. Additional downstream monitoring locations for both surface water and groundwater are required. Monitoring data should be archived on a digital data base that should serve as a future reference. Monitoring reports should be issued on a quarterly (summary) and annual (detailed) basis. Management and mitigation measures should be adapted based on the monitoring results to effectively mitigate the impacts.
2. A hydrocensus should be conducted on an annual basis to evaluate the status of the potential surface water and groundwater receptors surrounding the site and proposed facilities.
3. The recommended Sustainable Multiple-Capturing-Barrier-System and sustainable groundwater management and mitigation plan should be included in the EMPR and IWWMP.
4. More detailed site characterization and modelling for implementation level accuracy to verify subsurface flow zones and hydraulic parameters with specific reference to:
   a. Clay layer thickness and continuity.
   b. Geophysical surveys to verify existence of dyke, dyke-contacts and fault/fracture zones and the thickness of the weathered zone.
   c. Drilling of site characterization holes (4 - 6 holes, 45 m to 70 m deep, 0.165 m diameter) and subject to aquifer tests to verify hydraulic parameters.
   d. Downhole geophysical surveys and lugeon tests on selected holes to verify depth permeability relationships.
   e. Sampling for chemical and isotope analysis.
   f. Update and recalibration of flow and mass transport model for implementation level accuracy.
   g. Sterkstroom wet and dry season flow data and based on hydrological, aquatic ecological and water use impact modelling.
5. The additional monitoring boreholes should be optimized during the pre- and operational phase site characterization (geophysics, drilling and aquifer testing) phases.
6. Options to use the fully backfilled open pits as water resources and enhance recharge yield by diverting surface water into them during flood conditions should be considered and evaluated via further modelling and studies.
7. The mine dewatering and mass transport model should be reviewed and updated every two years and/or once the KMLCS pit dewatering modelling are completed as the open pits form important sinks in the mass transport model (for dewatering planning purposes).
8. Biomonitoring should be included in the water monitoring protocol, up and downstream of Tharisa to determine the cumulative impact of the nitrate build-up on the downstream ecosystem.

10 References

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11 APPENDIX A - 22 JULY 2022 HYDROCENSUS INFORMATION AND LABORATORY RESULTS

Site Name	Latitude	Longitude	Site Status	Water Application	Water Level (mbgl)	Water Level (mbcl)	Collar (m)	Samples Taken (y/n)	Sample_ID	ACS Sample Number	Sampling Point	Borehole Condition	Casing Material	Responsible Person/ Entity	Contact Number	Comments
HC VANWYK-01	-25.74661	27.46722	Open	-	-	-	-	N	-		-	Not Found	Steel	-	-	Destroyed by construction works
HC AMGJ	-25.74234	27.47046	Closed	-	-	-	-	N	-		-	Not Found	Steel	GJC du Preez	0723893172	-
AMG11	-25.73338	27.46151	-	-	-	-	-	N	-		-	Not found	Steel	-	-	-
AMB05	-25.74063	27.46349	Open	-	-	-	-	N	-		-	Blocked	Steel	-	-	-
AMG15	-25.73992	27.46355	Open	-	-	-	-	N	-		-	Blocked	Steel	-	-	-
HC AMJB	-25.74545	27.46761	Open	-	-	-	-	N	-		-	Blocked	Steel	-	-	-
Retief Primary BH (TM GW COMM 05)	-25.73916	27.47584	Pumping /Closed	School water	-	-	0.75	Y	Retief Primary BH	AC0197	Water Tap	Closed	Steel	-	-	-
PP BH 2	-25.74542	27.46473	Closed	-	-	-	0	Y	PP BH 2	AC0200	HDPE	Closed	Steel	Pretorius GJC/SC	0828688322	
HC VANWYK-02	-25.74535	27.47156	Open	Monitoring	11.00	11	0	N	-		-	-	Steel	-	-	-
50a	-25.74517	27.47156	Open	Monitoring	11.00	11	0	Y	50a	AC0199	BH	-	Steel	-	-	-
50b	-25.74463	27.47216	Open	Monitoring	11.00	11	0	N			-		Steel	-	-	-
PP BH 1	-25.74456	27.46506	Closed	Industrial	15.00	15	0	Y	PP BH 1	AC0193	Tap	-	Steel	Pretorius GJC/SC	0828688322	Water goes to Pretorius and du Preez residences
AMG01	-25.74386	27.46041	Open	Monitoring	9.55	9.8	0.25	Y	AMG01	AC0202	BH	-	Steel	Ibrahim Mogodiri	0827945299	-
AMB06	-25.74100	27.46031	Open	Monitoring	10.80	11	0.2	Y	AMB06	AC0203	BH	-	Steel	Ibrahim Mogodiri	0827945299	-
HC SC-01	-25.73854	27.47651	Closed	Monitoring	8.85	9	0.15	N	-		-	-	Steel	-	-	-
RS BH 3	-25.73849	27.47679	Closed	Monitoring	15.00	15	0	N	-		-	-	Steel	-	-	-
WV BH1	-25.73354	27.46437	Closed	Domestic (no pump)	10.50	11	0.5	N	-		-	-	Steel	Woolvaardt PHC	0843974131	-
HC BEER-1	-25.73324	27.46207	Closed	Domestic	8.70	9	0.3	Y	HC BEER-1	AC0201	Water tap	-	Steel	N van der Hoven	07829212019	-
OC BH 02	-25.72401	27.47376	Open	Monitoring	12.60	13	0.4	Y	OC BH 02	AC0204	BH	-	Steel	-	-	Sewage smell
OC BH 12	-25.71999	27.51194	Open	Monitoring	7.75	8.5	0.75	Y	OC BH 12	AC0196	BH	-	Steel	-	-	-
OC BH 15	-25.71824	27.45828	Open	Monitoring	11.80	12.8	1	Y	OC BH 15	AC0194	BH	-	Steel	-	-	-
KM S 06a (TM SW02)	-25.72571	27.48303	Open	SW	-	-	-	Y	KM S 06a	AC0198	SW	-	-	-	-	-
TM SW 04	-25.72062	27.48436	Open	SW	-	-	-	Y	Add SW	AC0195	SW	-	-	-	-	-
AMS 50 (TM SW01)	-25.75711	27.48325	Open	SW	-	-	-	Y	AMS 50	AC0192	SW	-	-	-	-	-

Table 11-1 July 2022 Hydrocensus Laboratory Results

	pH	EC mS/m	TDS mg/l	Alkalinity mg CaCO3/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO4 mg/l	NO_3-N mg/l	NO_2-N mg/l	NH_4-N mg/l	o-PO_4 as P mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l	As mg/l	Cd mg/l	Cr mg/l	Cu mg/l
SANS 241 Limit			**1200**				**200**		**300**	**500**	**11**	**0.9**			**1.5**	**0.3**	**2**	**0.4**	**0.01**	**0.003**	**0.05**	**2**
2013 US Baseline_P95	7.9	85.7	566.7		59.5	65.3	17.6	1.7	22.8	67.3	6.5	0.1	0.09	0.05	0.2	0.003	0.003	0.001	0.007	0.001	0.001	0.001
AMS 50 (TM SW01)	7.3	5.4	42	18	3.9	3.2	2.3	1.2	3.3	4.8	0.3	BDL	0.08	BDL	BDL	BDL	0.1	BDL	BDL	BDL	BDL	BDL
PP BH 1	7.4	27.3	268	126	28.8	18.2	6.5	1.2	2.4	7.1	7.3	BDL	0.07	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.008
OC BH 15	7.3	69.3	504	324	62.5	58.7	17.6	1.0	8.9	91.2	7.1	BDL	0.18	BDL	BDL	BDL	BDL	0.02	BDL	BDL	BDL	0.018
TM SW04	7.8	8.0	60	28	5.8	5.5	3.6	1.1	3.1	9.1	0.5	BDL	0.09	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.002
OC BH 12	7.8	90.7	602	457	76.1	70.9	52.2	0.6	21.3	100.0	1.7	BDL	0.09	BDL	BDL	BDL	BDL	0.29	BDL	BDL	BDL	0.018
Retief Primary BH (TM GW COMM05)	7.4	57.3	474	287	47.4	53.7	11.8	0.6	16.1	47.9	5.3	BDL	0.11	BDL	BDL	BDL	BDL	0.001	BDL	BDL	BDL	0.017
KM S 06a	7.8	7.5	62	31	5.4	5.1	3.1	1.2	3.5	7.2	0.5	BDL	0.07	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.002
50a	6.9	24.2	240	134	24.4	17.0	8.2	0.5	4.6	3.3	0.9	BDL	0.09	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.007
PP BH 2	7.6	21.2	152	125	22.1	14.8	6.1	1.3	2.0	1.3	1.2	BDL	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.006
HC BEER-1	7.6	53.0	372	332	47.7	48.6	8.6	0.7	7.6	9.5	1.5	BDL	0.06	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.017
AMG01	7.4	13.5	128	45	12.4	7.2	4.4	2.7	1.4	2.9	6.1	BDL	0.14	BDL	BDL	BDL	BDL	0.07	BDL	BDL	BDL	0.003
AMB06	7.2	20.5	182	124	19.0	15.7	4.6	1.5	3.6	1.0	0.4	BDL	0.63	BDL	BDL	BDL	BDL	0.16	BDL	BDL	BDL	0.007
OC BH 02	8.0	192.0	1166	981	179.0	48.4	42.9	16.4	36.3	51.7	2.9	BDL	87.40	9.4	BDL	0.01	0.1	**1.04**	BDL	BDL	0.006	0.018

	Co mg/l	Hg mg/l	Ni mg/l	Pb mg/l	Se mg/l	Zn mg/l	CN (free) mg/l	Si mg/l	B mg/l	Ba mg/l	Mo mg/l	Sr mg/l	U mg/l	V mg/l	Sb mg/l	Th mg/l	Total Hard mg CaCO3/l	HCO_3 mg $CaCO_3$/l	CO_3 mg CaCO3/l	TON mg/l	Bal-cing %	
SANS 241 Limit		**0.006**	**0.07**	**0.01**	**0.04**	**5**	**0.2**		**2.4**	**0.7**			**0.03**		**0.02**							
2013 US Baseline_P95		0.007	0.07	0.004	0.007	0.002	BDL															
AMS 50 (TM SW01)	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4.9	BDL	0.02	BDL	0.01	BDL	BDL	BDL	0.0008	23	18	0.03	0.4	99.0	
PP BH 1	BDL	BDL	BDL	BDL	BDL	BDL	BDL	29.4	BDL	0.01	0.03	0.13	BDL	0.01	BDL	0.0007	147	126	0.3	7.3	99.8	
OC BH 15	BDL	BDL	0.01	BDL	BDL	BDL	BDL	30.6	BDL	0.01	0.05	0.21	BDL	0.01	BDL	0.0007	398	323	0.5	7.2	97.7	
TM SW04	BDL	BDL	BDL	BDL	BDL	BDL	BDL	5.9	BDL	0.02	0.01	0.02	BDL	BDL	BDL	0.0003	37	28	0.2	0.6	96.9	
OC BH 12	BDL	BDL	BDL	BDL	BDL	BDL	BDL	8.8	BDL	0.01	0.06	0.51	BDL	BDL	BDL	0.0003	482	454	2.6	1.8	100.0	
Retief Primary BH (TM GW COMM05)	BDL	BDL	BDL	BDL	BDL	0.5	BDL	37.9	BDL	0.03	0.05	0.19	BDL	0.01	BDL	0.0001	339	286	0.7	5.3	98.5	
KM S 06a	BDL	BDL	BDL	BDL	BDL	BDL	BDL	5.7	BDL	0.02	0.01	0.02	BDL	BDL	BDL	0.0001	35	30	0.2	0.5	98.4	
50a	BDL	BDL	BDL	BDL	BDL	BDL	BDL	33.6	BDL	0.01	0.03	0.10	BDL	0.01	BDL	2.00-05	131	134	0.1	0.9	99.3	
PP BH 2	BDL	BDL	BDL	BDL	BDL	BDL	BDL	26.1	BDL	0.00	0.02	0.10	BDL	0.01	BDL	1.00E-05	116	124	0.5	1.2	99.0	
HC BEER-1	BDL	BDL	BDL	BDL	BDL	0.014	BDL	29.4	BDL	0.01	0.05	0.18	BDL	0.01	BDL	3.00E-05	319	331	1.2	1.5	97.2	
AMG01	BDL	BDL	BDL	BDL	BDL	BDL	BDL	15.1	BDL	0.01	0.01	0.04	BDL	BDL	BDL	0	61	45	0.1	6.2	98.7	
AMB06	BDL	BDL	BDL	BDL	BDL	BDL	BDL	23.6	BDL	0.02	0.02	0.08	BDL	BDL	BDL	0	112	123	0.2	0.5	98.1	
OC BH 02	BDL	BDL	0.03	BDL	BDL	0.061	BDL	26.5	0.02	0.08	0.08	0.23	BDL	0.01	BDL	2.00E-05	647	972	8.5	2.9	97.0	

12 Appendix B - Numerical Modelling Assumptions, Material Properties and Calibration (ACS, 2022)

The following assumptions were made with listed limitations:

1. Prior to development, the system is in equilibrium and therefore in steady state.
2. The accuracy and scale of the assessment will result in acceptable deviations at specific points e.g., individual boreholes.
3. Site specific structural geological data was extrapolated to model boundaries, in line with precautionary principle.
4. Dykes inferred to be ± 20 - 30 m thick, with a permeable dyke contact zone of ± 5 m thick.
5. Fault zones inferred to be ± 10 m thick.
6. Seepages from surrounding facilities were included and modelled / calibrated to adequate level of accuracy (± 10%) as detailed modelling did not form part of the current study objectives (to give an overall hydrogeological impact before proposed facility impacts were added).
7. The potential current and future impact of surrounding mine dewatering and mass migration and its influence on the current site conditions were not included in this model.
8. Nitrate source terms were evaluated and estimated off existing site data and reports.

When assumptions were made or reference values used, a conservative approach was followed aligned with the precautionary principle (NEMA, 1998). A groundwater model is a representation of the real system. It is therefore an approximation, and the level of accuracy depends on the quality of the data that is available. The purpose of the model was not to simulate the actual field conditions (i.e., every dyke and fracture), but to simulate the proposed WRD activities and impact risk on the receiving environment. Based on the precautionary principle, the actual impacts would be smaller than the simulated impacts. The model input parameters are presented in Table 12-1.

Table 12-1: Numerical Model Input Parameters

Input parameter	Source, parameter, or assumption description	Data uncertainty
Topography (DEM)	The topographic elevations were interpolated from the 1:50 000 scale 20 m contour intervals, in combination with site specific topographical elevation data (1m intervals) provided by the client.	Low - Moderate
Rivers, streams, drainages	Digitised from topographical maps and aerial imagery (1:50 000 scale).	Low
Lithology	Geological map 2526 (1:250 000 scale).	Moderate - High
Geological structures	Data provided by Tharisa Geology Team in the form of dxf and datamine files. While the positions and extent are known the hydraulic characteristics are associated with uncertainty.	Moderate
Mine Layout	All mine layouts were supplied by the client (SLR and Tharisa).	Low
Boreholes and pumping rates	Aquatico surface and groundwater monitoring reports (client data). 2008, Water Geoscience Consulting, Groundwater Investigation for Tharisa Mine. 2021, SLR Consulting, Tharisa Mine Dewatering Strategy.	Moderate
Rainfall	Supplied by the client and measured at the TSF from 2014 to 2022. Data gaps filled by data from the South African Water Research Commission	Low - Moderate
Steady State Modelling Parameters – Flow Model		
Boundary conditions	Eastern model boundary – Fixed hydraulic head boundary with a max flow constraint = 0 m^3/d. This boundary represents an unknown stream to the east.	Low - Moderate
	Northern, Southern and Western boundary - Use of no flow boundary correlating with surface water divides/ Open pit mining operations (West).	Low - Moderate
	Rivers and drainages within the model domain are described by fixed head boundary conditions and maximum flow constraints of 0 m^3/d.	Low - Moderate

Input parameter	Source, parameter, or assumption description	Data uncertainty
Recharge	Use of the chloride method as an indication and previous groundwater studies conducted (calibration process)	Moderate - High
Hydraulic Conductivity	The hydraulic conductivity was estimated from geotechnical laboratory tests, pumping tests, previous studies, and literature.	Low
Aquifer thickness	The aquifer thickness is represented by a ± 5 - 8 m soil profile (Geotechnical investigations), ± 25 m weathered profile and ± 360 m sub-basement fractured/solid geological unit.	Moderate
Transient State Modelling Parameters & Mass transport model		
Initial Hydraulic Heads	Simulated heads obtained from simulated steady state conditions as calibrated. Initial hydraulic heads taken for 2009.	Moderate
Initial mass transport plumes	Historic and current hydrochemistry data from monitoring data were used to calibrate the initial mass plumes accordingly. A Kd of 0 was used within the modelling. 2019 - 2022, SLR Waste assessment reports and results to determine source terms.	Moderate
Specific Storage	The volume of water that a unit volume of aquifer releases from or takes into storage per unit change in head. $S = S_s \times D$. S_s, Storage was developed according to each layer thickness as indicated in Table 12-1	High
Effective Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock of earth material. Assumed conservative porosity of 1-5% was used in the transient simulations for the soil, weathered and rock matrix (Table 12-1).	High
Nitrate Decay Rate	In line with the precautionary principle, there exists a decay component for Nitrates and this decay rate was applied during modelling (400 to 1000-day de-nitrification process as indicated by literature).	Medium
Longitudinal dispersion coefficient	No field work has been conducted to determine the dispersivity. An approximation of 5 m was used.	High
Transverse dispersion coefficient	Transverse dispersivity was assumed to be 10 x smaller than the longitudinal dispersivity (0.5 m)	High

From analysis of various field work test results, analogue data sets and using the model calibration process, the following model input parameters were used (Table 12-2). The hydraulic conductivity values for Layer 1 to 3 selection was based on the onsite geotechnical test pits dug on site and permeability lab analyses conducted (Inroads Consulting, 2021). From the soil maps available online, the western section of the mine is covered by red hillwash soils, with the eastern section covered with clayey soils which have a low hydraulic conductivity (4×10^{-05} m/d). The thicknesses of these layers were extrapolated over the model domain based on the geotechnical data provided. To be conservative, no credit was taken for the natural clay barrier (clayey soils) over the facility footprints (precautionary principle).

The river alluvium was given a maximum depth of ± 5 m to represent the deeper weathering expected. The weathered zone (Layer 4) was given a thickness of 25 m, depending on the elevation (deeper weathering expected in valleys, minor/no weathering expected on hills).

Seepage is expected to move directly to the weathered zone. Deeper sections of the model have lower hydraulic conductivities (1 to 2 orders lower), and flow is governed by faults/fractures and the weathered dyke contacts (which are permeable in the conservative model approach). A Material Parameter Comparison between the modelled values from historical numerical models is presented in Figure 12-1 below.

Table 12-2: Numerical modelling parameters

Layer	Hydrostratigraphic Unit	Layer	Layer Thickness	Avg Elevation - 1192.4 (mamsl)	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)		Recharge			Porosity	Storativity	Specific Storage
						Kxy	Kz	% of MAP	Recharge (m/d)	Recharge (mm/a)			
Soil Layers	Quartzite	1 - 3	0.1		0.1	1.00E+00	1.00E+00	1.3%	2.37E-05	8.6	1.5%	8.26E-03	8.26E-02
	Norite	1 - 3	0.1		0.3	3.00E+00	3.00E+00	1.5%	2.73E-05	10.0	1.5%	8.26E-03	8.26E-02
	River Alluvium	1 - 3	5		2.25	4.50E-01	4.50E-01	4.5%	8.20E-05	29.9	5.0%	1.00E-02	2.00E-03
	Black Clays	1	1.4	1191.0	5.60E-05	4.00E-05	4.00E-05	0.3%	5.47E-06	2.0	3.5%	1.00E-03	7.14E-04
	Red soils_Hillwash	1	1.4	1191.0	1.21	8.64E-01	8.64E-01	4.0%	7.29E-05	26.6	2.5%	1.00E-02	7.14E-03
	Clayey Sand	2	1.1	1189.9	9.50E-03	8.64E-03	8.64E-03				2.5%	1.00E-02	9.09E-03
	Residual Silty Sand	3	0.6	1189.3	0.05	8.64E-02	8.64E-02				2.5%	1.00E-02	1.67E-02
Shallow weathered and fractured Aquifer	Quartzite, Shale	4	0.1		0.1	1.00	1.00				1.5%	8.26E-03	8.26E-02
	Quartz Norite	4	25	1164.3	2.1	0.08	0.08				1.5%	8.26E-03	3.30E-04
	Norite	4	25	1164.3	2.6	0.104	0.104				1.5%	8.26E-03	3.30E-04
	Norite-Anorthosite	4	25	1164.3	2.6	0.104	0.104				1.5%	8.26E-03	3.30E-04
	Feldspatic Pyroxenite	4	25	1164.3	2.6	0.10	0.10				1.5%	8.26E-03	3.30E-04
	Leuconorite, chromitite	4	25	1164.3	1.9	0.08	0.08				1.5%	8.26E-03	3.30E-04
	Anorthosite	4	25	1164.3	2.6	0.104	0.104				1.5%	8.26E-03	3.30E-04
	Gabbro-Norite	4	25	1164.3	1.5	0.06	0.06				1.5%	8.26E-03	3.30E-04
	Major Faults weathered	4	25	1164.3	23	0.92	0.92				1.5%	1.14E-03	4.56E-05
	Dykes contact weathered	4	25	1164.3	14	0.56	0.56				1.5%	1.14E-03	4.56E-05
	Dykes weathered	4	25	1164.3	0.1	0.004	0.004				1.5%	2.00E-04	8.00E-06
Fractured rock Aquifer	Quartzite, Shale	5	25	1139.3	0.07	2.75E-03	2.75E-03				0.8%	8.26E-04	3.30E-05
	Quartz Norite	5	25	1139.3	0.058	2.31E-03	2.31E-03				0.8%	8.26E-04	3.30E-05
	Norite	5	25	1139.3	0.072	2.87E-03	2.87E-03				0.8%	8.26E-04	3.30E-05
	Norite-Anorthosite	5	25	1139.3	0.072	2.87E-03	2.87E-03				0.8%	8.26E-04	3.30E-05
	Feldspatic Pyroxenite	5	25	1139.3	0.072	2.87E-03	2.87E-03				0.8%	8.26E-04	3.30E-05
	Leuconorite, chromitite	5	25	1139.3	0.052	2.09E-03	2.09E-03				0.8%	8.26E-04	3.30E-05
	Anorthosite	5	25	1139.3	0.072	2.87E-03	2.87E-03				0.8%	8.26E-04	3.30E-05
	Gabbro-Norite	5	25	1139.3	0.041	1.65E-03	1.65E-03				0.8%	8.26E-04	3.30E-05
	Major Faults	5	25	1139.3	0.634	2.53E-02	2.53E-02				0.8%	1.14E-04	4.56E-06
	Dykes contact	5	25	1139.3	0.386	1.54E-02	1.54E-02				0.8%	1.14E-04	4.56E-06
	Dykes	5	25	1139.3	0.003	1.10E-04	1.10E-04				0.8%	2.00E-05	8.00E-07
Solid rock Aquifer	Quartzite, Shale	6	100	1039.3	0.207	2.07E-03	2.07E-03				0.5%	8.26E-05	8.26E-07
	Quartz Norite	6	100	1039.3	0.174	1.74E-03	1.74E-03				0.5%	8.26E-05	8.26E-07
	Norite	6	100	1039.3	0.215	2.15E-03	2.15E-03				0.5%	8.26E-05	8.26E-07
	Norite-Anorthosite	6	100	1039.3	0.215	2.15E-03	2.15E-03				0.5%	8.26E-05	8.26E-07
	Feldspatic Pyroxenite	6	100	1039.3	0.215	2.15E-03	2.15E-03				0.5%	8.26E-05	8.26E-07
	Leuconorite, chromitite	6	100	1039.3	0.157	1.57E-03	1.57E-03				0.5%	8.26E-05	8.26E-07
	Anorthosite	6	100	1039.3	0.215	2.15E-03	2.15E-03				0.5%	8.26E-05	8.26E-07
	Gabbro-Norite	6	100	1039.3	0.124	1.24E-03	1.24E-03				0.5%	8.26E-05	8.26E-07
	Major Faults	6	100	1039.3	1.901	1.90E-02	1.90E-02				0.5%	1.14E-05	1.14E-07
	Dykes contact	6	100	1039.3	1.157	1.16E-02	1.16E-02				0.5%	1.14E-05	1.14E-07
	Dykes	6	100	1039.3	0.008	8.26E-05	8.26E-05				0.5%	2.00E-06	2.00E-08
Solid rock Aquifer	Quartzite, Shale	7	80	959.3	0.165	2.07E-03	2.07E-03				0.5%	8.26E-05	1.03E-06
	Quartz Norite	7	80	959.3	0.139	1.74E-03	1.74E-03				0.5%	8.26E-05	1.03E-06
	Norite	7	80	959.3	0.172	2.15E-03	2.15E-03				0.5%	8.26E-05	1.03E-06
	Norite-Anorthosite	7	80	959.3	0.172	2.15E-03	2.15E-03				0.5%	8.26E-05	1.03E-06
	Feldspatic Pyroxenite	7	80	959.3	0.172	2.15E-03	2.15E-03				0.5%	8.26E-05	1.03E-06
	Leuconorite, chromitite	7	80	959.3	0.126	1.57E-03	1.57E-03				0.5%	8.26E-05	1.03E-06
	Anorthosite	7	80	959.3	0.172	2.15E-03	2.15E-03				0.5%	8.26E-05	1.03E-06
	Gabbro-Norite	7	80	959.3	0.099	1.24E-03	1.24E-03				0.5%	8.26E-05	1.03E-06
	Major Faults	7	80	959.3	1.521	1.90E-02	1.90E-02				0.5%	1.14E-05	1.43E-07
	Dykes contact	7	80	959.3	0.926	1.16E-02	1.16E-02				0.5%	1.14E-05	1.43E-07
	Dykes	7	80	959.3	0.007	8.26E-05	8.26E-05				0.5%	2.00E-06	2.50E-08
Solid rock Aquifer	Quartzite, Shale	8	20	939.3	0.041	2.07E-03	2.07E-03				0.5%	8.26E-05	4.13E-06
	Quartz Norite	8	20	939.3	0.035	1.74E-03	1.74E-03				0.5%	8.26E-05	4.13E-06
	Norite	8	20	939.3	0.043	2.15E-03	2.15E-03				0.5%	8.26E-05	4.13E-06
	Norite-Anorthosite	8	20	939.3	0.043	2.15E-03	2.15E-03				0.5%	8.26E-05	4.13E-06
	Feldspatic Pyroxenite	8	20	939.3	0.043	2.15E-03	2.15E-03				0.5%	8.26E-05	4.13E-06
	Leuconorite, chromitite	8	20	939.3	0.031	1.57E-03	1.57E-03				0.5%	8.26E-05	4.13E-06
	Anorthosite	8	20	939.3	0.043	2.15E-03	2.15E-03				0.5%	8.26E-05	4.13E-06
	Gabbro-Norite	8	20	939.3	0.025	1.24E-03	1.24E-03				0.5%	8.26E-05	4.13E-06
	Major Faults	8	20	939.3	0.380	1.90E-02	1.90E-02				0.5%	1.14E-05	5.70E-07
	Dykes contact	8	20	939.3	0.231	1.16E-02	1.16E-02				0.5%	1.14E-05	5.70E-07
	Dykes	8	20	939.3	0.002	8.26E-05	8.26E-05				0.5%	2.00E-06	1.00E-07

Layer	Hydrostratigraphic Unit	Layer	Layer Thickness	Avg Elevation - 1192.4 (mamsl)	Transmissivity (m^2/d)	Hydraulic Conductivity (m/d)		Recharge			Porosity	Storativity	Specific Storage
						Kxy	Kz	% of MAP	Recharge (m/d)	Recharge (mm/a)			
Solid rock Aquifer	Quartzite, Shale	9	11	928.3	0.023	2.07E-03	2.07E-03				0.5%	1.03E-05	9.39E-07
	Quartz Norite	9	11	928.3	0.019	1.74E-03	1.74E-03				0.5%	1.03E-05	9.39E-07
	Norite	9	11	928.3	0.024	2.15E-03	2.15E-03				0.5%	1.03E-05	9.39E-07
	Norite-Anorthosite	9	11	928.3	0.024	2.15E-03	2.15E-03				0.5%	1.03E-05	9.39E-07
	Feldspatic Pyroxenite	9	11	928.3	0.024	2.15E-03	2.15E-03				0.5%	1.03E-05	9.39E-07
	Leuconorite, chromitite	9	11	928.3	0.017	1.57E-03	1.57E-03				0.5%	1.03E-05	9.39E-07
	Anorthosite	9	11	928.3	0.024	2.15E-03	2.15E-03				0.5%	1.03E-05	9.39E-07
	Gabbro-Norite	9	11	928.3	0.014	1.24E-03	1.24E-03				0.5%	1.03E-05	9.39E-07
	Major Faults	9	11	928.3	0.209	1.90E-02	1.90E-02				0.5%	1.14E-05	1.04E-06
	Dykes contact	9	11	928.3	0.127	1.16E-02	1.16E-02				0.5%	1.14E-05	1.04E-06
	Dykes	9	11	928.3	0.001	8.26E-05	8.26E-05				0.5%	2.00E-06	1.82E-07
Solid rock Aquifer	Quartzite, Shale	10	2	926.3	0.004	2.07E-03	2.07E-03				0.5%	1.03E-05	5.16E-06
	Quartz Norite	10	2	926.3	0.003	1.74E-03	1.74E-03				0.5%	1.03E-05	5.16E-06
	Norite	10	2	926.3	0.004	2.15E-03	2.15E-03				0.5%	1.03E-05	5.16E-06
	Norite-Anorthosite	10	2	926.3	0.004	2.15E-03	2.15E-03				0.5%	1.03E-05	5.16E-06
	Feldspatic Pyroxenite	10	2	926.3	0.004	2.15E-03	2.15E-03				0.5%	1.03E-05	5.16E-06
	Leuconorite, chromitite	10	2	926.3	0.003	1.57E-03	1.57E-03				0.5%	1.03E-05	5.16E-06
	Anorthosite	10	2	926.3	0.004	2.15E-03	2.15E-03				0.5%	1.03E-05	5.16E-06
	Gabbro-Norite	10	2	926.3	0.002	1.24E-03	1.24E-03				0.5%	1.03E-05	5.16E-06
	Major Faults	10	2	926.3	0.038	1.90E-02	1.90E-02				0.5%	1.14E-05	5.70E-06
	Dykes contact	10	2	926.3	0.023	1.16E-02	1.16E-02				0.5%	1.14E-05	5.70E-06
	Dykes	10	2	926.3	0.000	8.26E-05	8.26E-05				0.5%	2.00E-06	1.00E-06
Solid rock Aquifer	Quartzite, Shale	11	125	801.3	0.258	2.07E-03	2.07E-03				0.5%	1.03E-05	8.26E-08
	Quartz Norite	11	125	801.3	0.217	1.74E-03	1.74E-03				0.5%	1.03E-05	8.26E-08
	Norite	11	125	801.3	0.269	2.15E-03	2.15E-03				0.5%	1.03E-05	8.26E-08
	Norite-Anorthosite	11	125	801.3	0.269	2.15E-03	2.15E-03				0.5%	1.03E-05	8.26E-08
	Feldspatic Pyroxenite	11	125	801.3	0.269	2.15E-03	2.15E-03				0.5%	1.03E-05	8.26E-08
	Leuconorite, chromitite	11	125	801.3	0.196	1.57E-03	1.57E-03				0.5%	1.03E-05	8.26E-08
	Anorthosite	11	125	801.3	0.269	2.15E-03	2.15E-03				0.5%	1.03E-05	8.26E-08
	Gabbro-Norite	11	125	801.3	0.155	1.24E-03	1.24E-03				0.5%	1.03E-05	8.26E-08
	Major Faults	11	125	801.3	2.376	1.90E-02	1.90E-02				0.5%	1.14E-05	9.12E-08
	Dykes contact	11	125	801.3	1.446	1.16E-02	1.16E-02				0.5%	1.14E-05	9.12E-08
	Dykes	11	125	801.3	0.010	8.26E-05	8.26E-05				0.5%	2.00E-06	1.60E-08

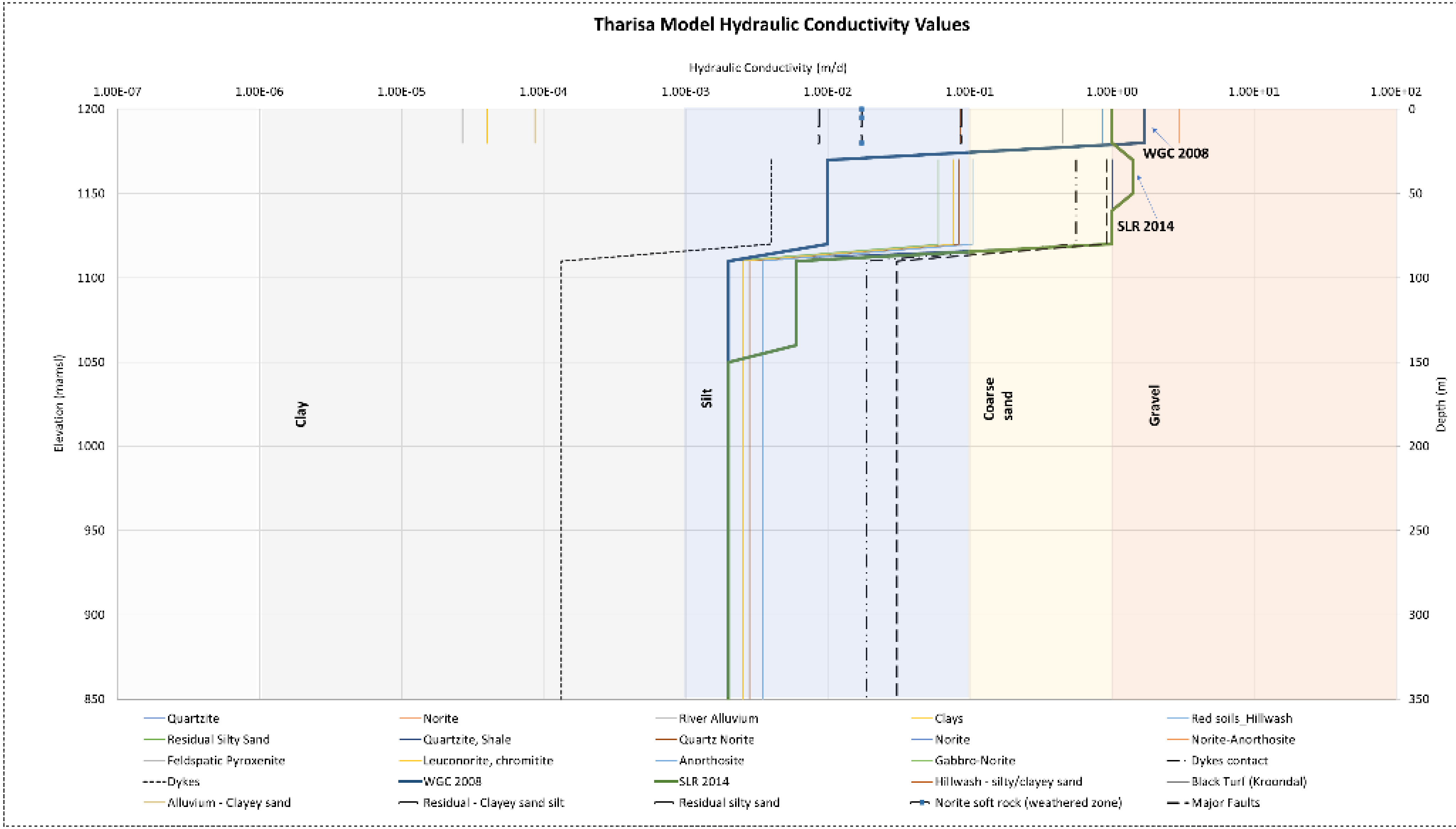

Figure 12-1: Model Material Parameters Comparison (ACS; 2022)

The Steady State model calibration showed to have an average groundwater level error (m) of 1.20 m, with 14 of the 16 boreholes calibrating to within ± 5 m from the actual groundwater level values (Table 12-3; Figure 12-2; Figure 12-3). A Root square Error (m) of 3.35 m and a steady state groundwater balance of 1.5% error was found (Table 12-4).

Table 12-3: Boreholes calibration table and statistical details

Obs no	Site name	X	Y	Z (mamsl) RL	Water Level (mbgl)	Measured Head (mamsl)	Simulated Head (mamsl)	Error - Above or below actual (m)	Absolute Error (m) AE	Root Square Error (m) RSE
2	WGC5	51180.24	-2848159.06	1207.85	12.15	1195.70	1192.32	-3.38	3.38	11.43
3	WGC10	48337.20	-2847717.41	1195.82	6.42	1189.40	1190.05	0.65	0.65	0.42
4	WGC19	50452.79	-2847627.81	1197.77	8.60	1189.17	1188.51	-0.66	0.66	0.44
5	WGC11	52523.37	-2847763.27	1198.49	16.33	1182.16	1185.40	3.23	3.23	10.44
6	WGC12	51806.56	-2847854.62	1204.28	14.85	1189.43	1188.94	-0.49	0.49	0.24
8	WGC14	47994.67	-2847540.01	1198.01	12.98	1185.03	1189.52	4.49	4.49	20.20
9	WGC15	52692.50	-2847876.95	1196.24	14.63	1181.61	1185.77	4.17	4.17	17.38
10	AMB05	46505.30	-2848181.33	1215.51	22.80	1192.71	1197.15	4.44	4.44	19.69
11	AMG13	45598.82	-2846603.33	1195.53	14.93	1180.60	1177.59	-3.01	3.01	9.07
12	AMG15	46511.26	-2848103.24	1214.11	21.50	1192.61	1196.34	3.73	3.73	13.89
13	AMG16	45995.49	-2847243.02	1206.37	19.25	1187.12	1187.37	0.25	0.25	0.06
14	AMG21	45687.47	-2846986.96	1203.10	14.21	1188.89	1183.70	-5.20	5.20	27.02
15	AMB01	46035.39	-2848323.34	1225.32	36.20	1189.12	1192.96	3.84	3.84	14.75
16	AMG01	46195.18	-2848538.46	1225.46	32.40	1193.06	1198.53	5.48	5.48	29.98
17	AMB08	45992.98	-2847244.12	1206.49	21.30	1185.19	1187.36	2.17	2.17	4.72
18	AMB07	46311.51	-2847886.69	1215.06	20.91	1194.15	1193.70	-0.45	0.45	0.20
Average				1206.59	18.09	1188.50	1189.70	1.20	2.85	11.25
Minimum				1195.53	6.42	1180.60	1177.59	-5.20	0.25	0.06
Maximum				1225.46	36.20	1195.70	1198.53	5.48	5.48	29.98
Correlation (R)							0.80		Σ = 45.64	Σ = 179.93
									1/n = 2.85	1/n = 11.25
										SQRT = 3.35
										RMS% of water level range = 22.21%

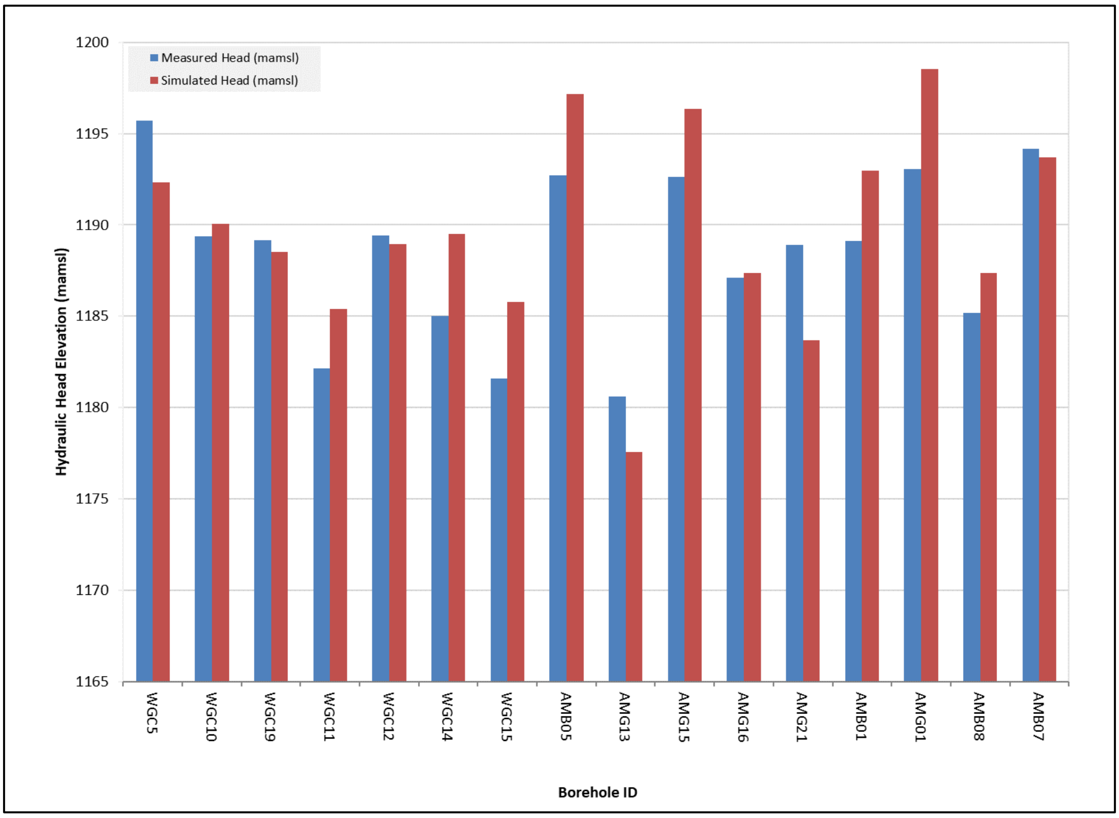

Figure 12-2: Measure vs Simulated hydraulic head comparison

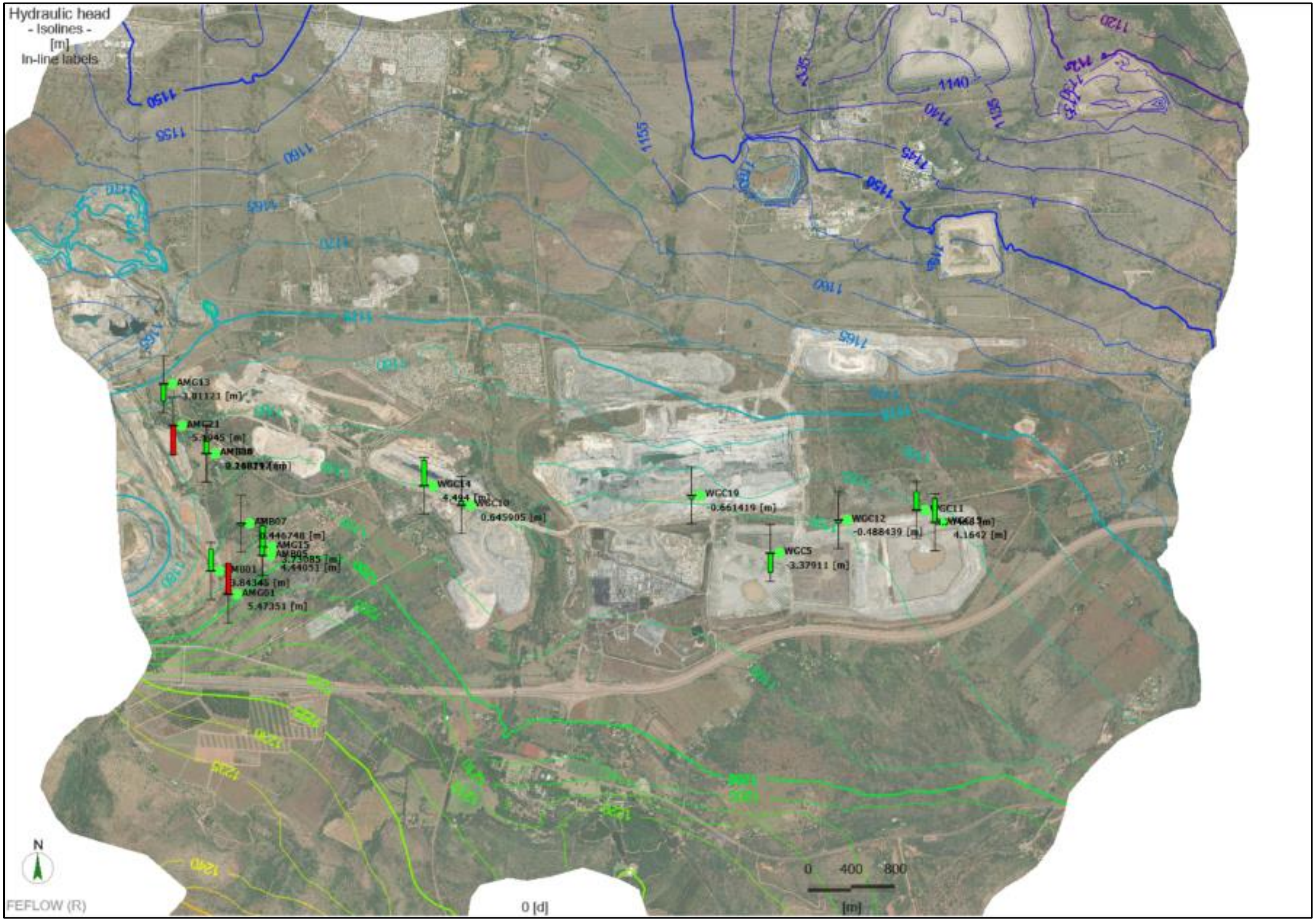

Figure 12-3: Pre-Mining Steady State Calibration Spatial Context

Table 12-4: Steady state groundwater balance

Model_3D Steady State Pre Mining Water Balance (2009)						
	Component	**Area (m^2)**	**Hydraulic Conductivity (m/d)**	**Inflow (m^3/d)**	**Outflow (m^3/d)**	**Balance (m^3/d)**
1	Recharge - Model Domain	92 631 200		2322		**2322**
2	Flux from Large TSF	1 314 527		48		**48**
3	Flux from Med TSF	477 308		30		**30**
4	Flux from Small TSF East			26		**26**
5	Flux from Small TSF West	-		24		**24**
6	UG2 Pit dewatering	119 870			-343	**-343**
7	Sibanye Pit dewatering	208 052			-483	**-483**
8	Far West Pit Evap/Dewatering	13 258			-16	**-16**
9	East Pit Evap/Dewatering	44 369			-65	**-65**
10	Abstraction from boreholes - Unknown					0
11	Quarry Leakage	7 870	4.23E-03	28		**28**
12	Large dam impact	315 000	4.23E-03	25	-121	**-96**
13	Large TSF Seepage dam				-26	**-26**
14	Base flow and losses to drainages			870	-2269	**-1400**
	Total			**3372**	**-3323**	**49.3**
					Balance Error (%)	**1.5%**

The Tharisa Mine Facility timelines / schedules are presented in Table 12-5 below (data provided by the client). Key aspects to note are the estimated pit Life of Mine schedules, which are linked to the approved smaller pit geometries as provided by SLR and verified by Tharisa. General assumptions for facility start and end date were made where data was not provided. West WRD 2 and TSF 3 were not included within this assessment. The estimated/calculated recharge and seepage volumes (from analogue data and model calibration) are also presented in the table below.

Table 12-5: Provided Mine scheduling timeframes

Facility	Material Type	Deposition/Excavation			Height (m) / Depth (m)	Recharge/Leakage
		Start Date	End Date	Duration (Years)		
TSF 1	Tailings	2011/07/01	2013/03/31	1.0	15	1E-03 m/d
TSF 1 Expansion	Tailings	2012/10/01	2016/10/01	3.9	36	1E-03 m/d
TSF 2 Phase 1 (1st bench to 1223 m.a.m.s.l.)	Tailings	2016/10/01	2017/11/30	1.2	17	1E-03 m/d
TSF 2 Phase 1 (2nd bench to 1239 m.a.m.s.l.)	Tailings	2018/12/01	2020/11/30	2.0	33	1E-03 m/d
TSF 2 Phase 1 (3rd bench to 1242 m.a.m.s.l.)	Tailings	2024/08/31	2025/04/01	0.6	36	1E-03 m/d
TSF 2 Phase 2 (1st bench to 1208 m.a.m.s.l.)	Tailings	2017/10/01	2019/01/31	1.3	16	1E-03 m/d
TSF 2 Phase 2 (2nd bench to 1231 m.a.m.s.l.)	Tailings	2020/11/01	2024/08/31	3.8	39	1E-03 m/d
TSF 2 Phase 2 (3rd bench to 1236 m.a.m.s.l.)	Tailings	2025/04/01	2025/09/04	0.4	44	1E-03 m/d
TSF 3 (Not Include/Not part of scope)	#N/A	#N/A	#N/A	#N/A	#N/A	-
East WRD (Choppies)	Waste Rock	2013/06/01	2019/09/01	6.3	65	12.5% of rainfall > 15 mm/mon
Choppies Extention (no plans yet)	Waste Rock	-	-	-	-	-
EWRD2	Waste Rock	2017/10/01	2024/02/01	6.3	67	12.5% of rainfall > 15 mm/mon
West WRD 1	Waste Rock	2013/03/01	2023/01/01	10.0	75	12.5% of rainfall > 15 mm/mon
West WRD 2 (Not include/Not part of scope)	#N/A	2022/06/01	#N/A	#N/A	#N/A	-
Far West WRD 1	Waste Rock	2018/09/01	2036/08/29	18.0	67	12.5% of rainfall > 15 mm/mon
TSF 1	Waste Rock	2009/06/01	2011/08/31	2.2	16	see TSF leakage
TSF 1 Expantion	Waste Rock	2011/07/01	2012/07/01	1.0	37	see TSF leakage
TSF 2 Phase 1 (1st bench to 1223 m.a.m.s.l.)	Waste Rock	2014/07/01	2016/07/30	2.1	18	see TSF leakage
TSF 2 Phase 1 (2nd bench to 1239 m.a.m.s.l.)	Waste Rock	2017/11/01	2018/11/30	1.1	34	see TSF leakage
TSF 2 Phase 1 (3rd bench to 1242 m.a.m.s.l.)	Waste Rock	2021/08/01	2022/02/01	0.5	37	see TSF leakage
TSF 2 Phase 2 (1st bench to 1208 m.a.m.s.l.)	Waste Rock	2016/11/01	2020/10/01	3.9	17	see TSF leakage
TSF 2 Phase 2 (2nd bench to 1231 m.a.m.s.l.)	Waste Rock	2015/07/01	2018/06/30	3.0	40	see TSF leakage
TSF 2 Phase 2 (3rd bench to 1236 m.a.m.s.l.)	Waste Rock	TBC	TBC	0.0	45	see TSF leakage
TSF3 (Not include/Not part of scope)	#N/A	2022/06/01	#N/A	#N/A	#N/A	-
East Pit BF	**Waste Rock**	**2016/05/01**	**2034/01/01**	**17.9**	**220**	**12.5% of rainfall > 15 mm/mon**
West Pit BF	**Waste Rock**	**2023/01/01**	**2034/01/01**	**11.2**	**110**	**12.5% of rainfall > 15 mm/mon**
East OG WRD	Waste Rock	2023/03/01	2035/12/31	13.0	-	12.5% of rainfall > 15 mm/mon
West OG WRD (Far West WRD 2)	Waste Rock	2023/03/01	2040/12/31	18.1	-	12.5% of rainfall > 15 mm/mon
East Pit	Excavation	2004/07/01	2032/05/31	27.9	-220.00	15% of rainfall > 15 mm/mon
West Pit	Excavation	2009/07/01	2032/12/31	23.5	-110.00	15% of rainfall > 15 mm/mon
Far West Pit	Excavation	2004/07/01	2023/06/30	19.0	-110.00	15% of rainfall > 15 mm/mon

Data sourced from shapefiles provided by Tharisa and Google Earth images - LoM Jan 2041

Simulated versus actual borehole hydraulic heads compare well for most of the boreholes with data available. Overall, most simulated heads calibrate higher than the actual measured heads (Figure 12-4 to Figure 12-6).

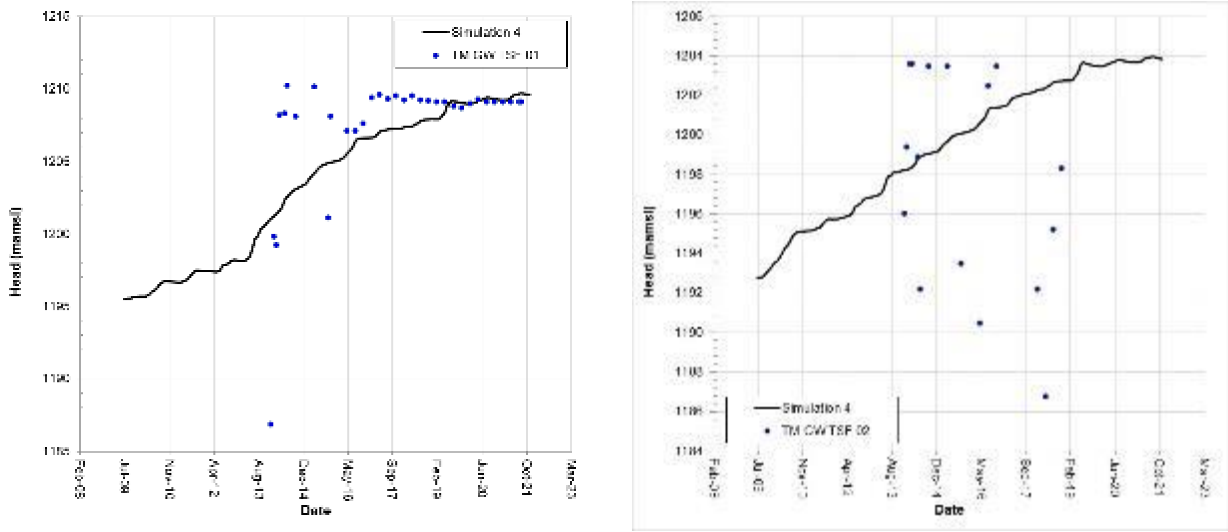

Figure 12-4: Measured vs simulated hydraulic head for TM GW TSF01 and TM GW TSF02

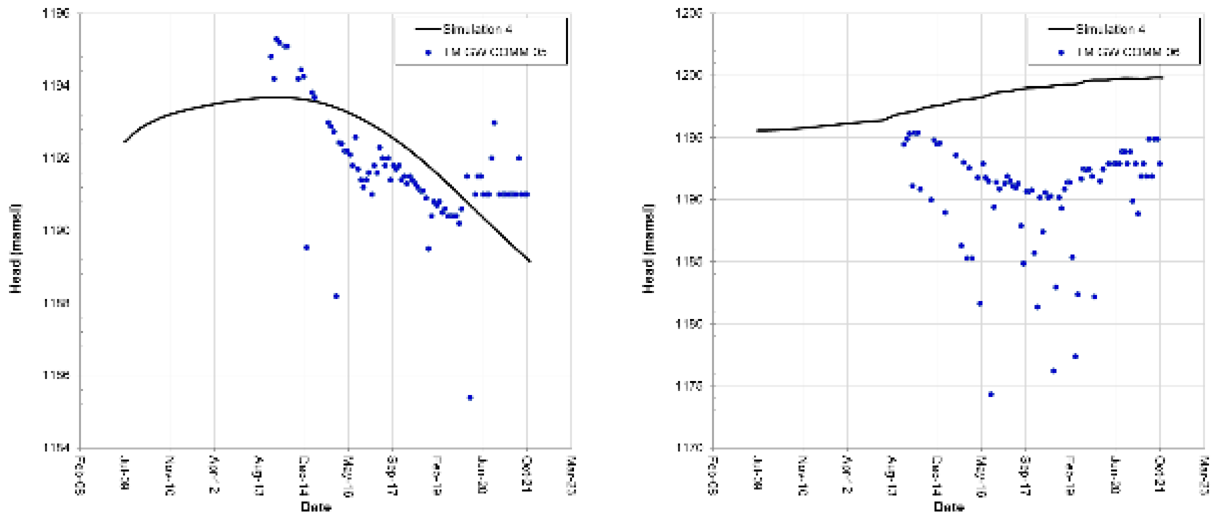

Figure 12-5: Measured vs simulated hydraulic head for TM GW Comm 05 and TM GW Comm 06

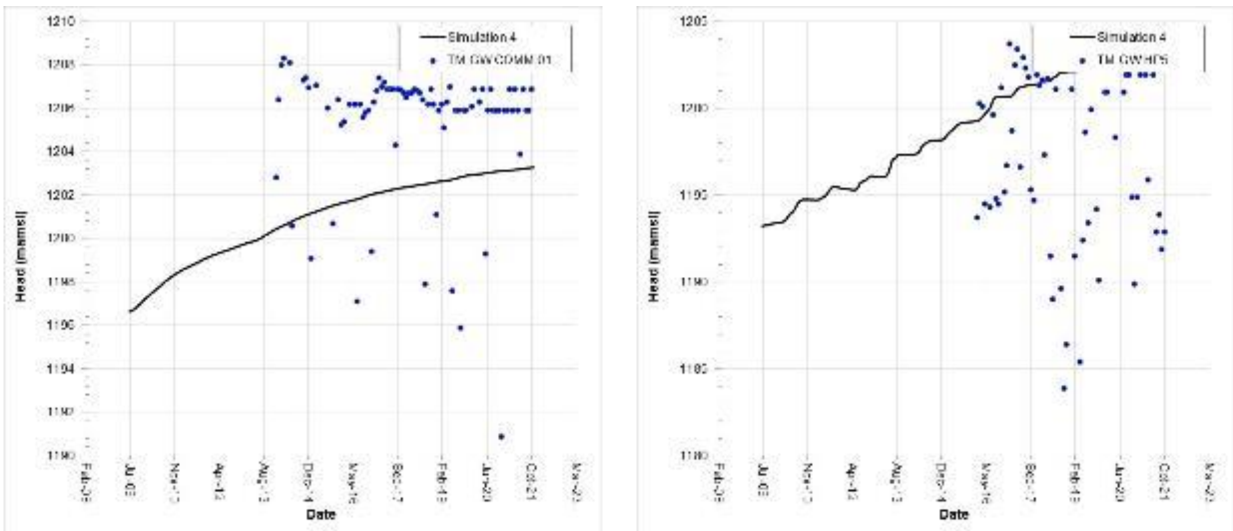

Figure 12-6: Measured vs simulated hydraulic head for TM GW HP5 and TM GW Comm 01

As mentioned in ACS (2022), nitrate is subject to natural decay with a calculated half-life of ± 110 days for this site. This was proven through the analysis of the TSF Dissipator's long-term water quality monitoring data where the concentration decayed from 74 mg/L to below SANS limits of 11 mg/L in 0.9 years (Figure 12-7). Analogue data from similar sites for nitrate decay is ± 160 days. From literature the nitrate half-life values of ± 400 days are given (Spitz & Moreno, 1996). For modelling purposes, a very conservative nitrate decay of 1000 days were used.

The observed fluctuations/spikes in concentration over time is because of wet and dry cycles (rainfall) and the contribution of changes in production of current arisings (ore) and waste rock rate over time (not shown on graph).

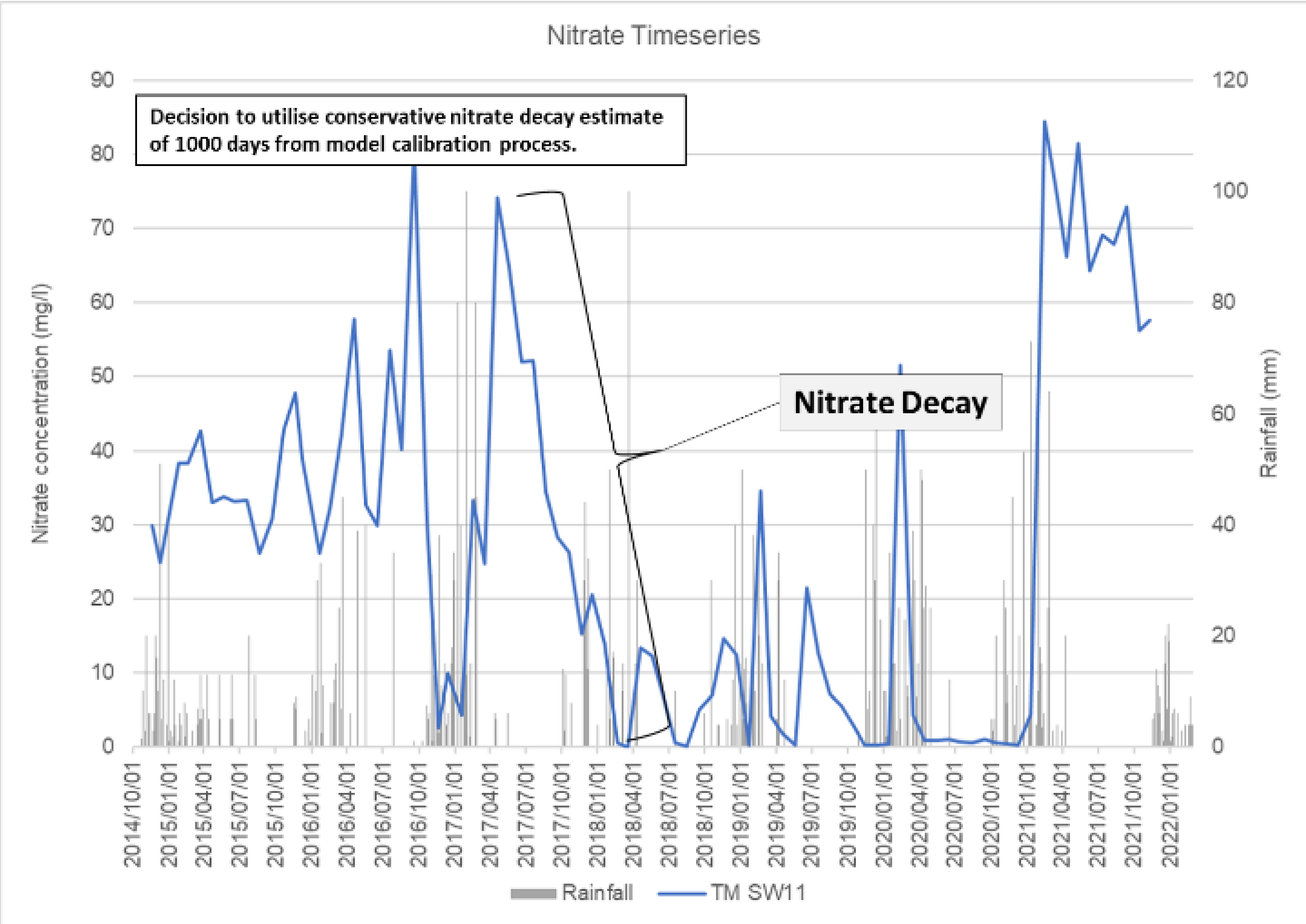

Figure 12-7: Time series data of TM SW11 proving the decay of nitrate

Figure 12-8 to Figure 12-10 show the accuracy of the nitrate mass concentration (measured versus Simulated) over time. The model shows to be calibrated for mass concentrations.

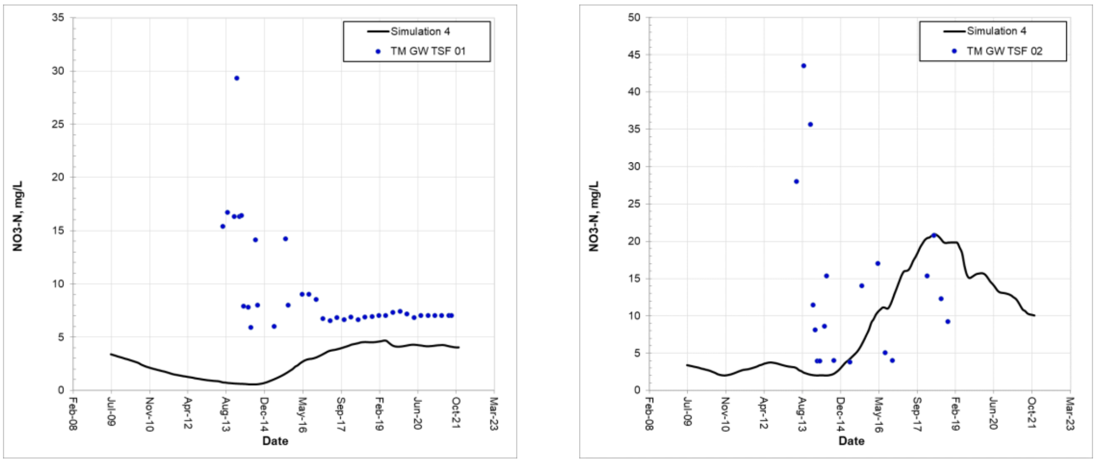

Figure 12-8: Measured vs simulated nitrate mass concentration for TM GW TSF01 and TM GW TSF02

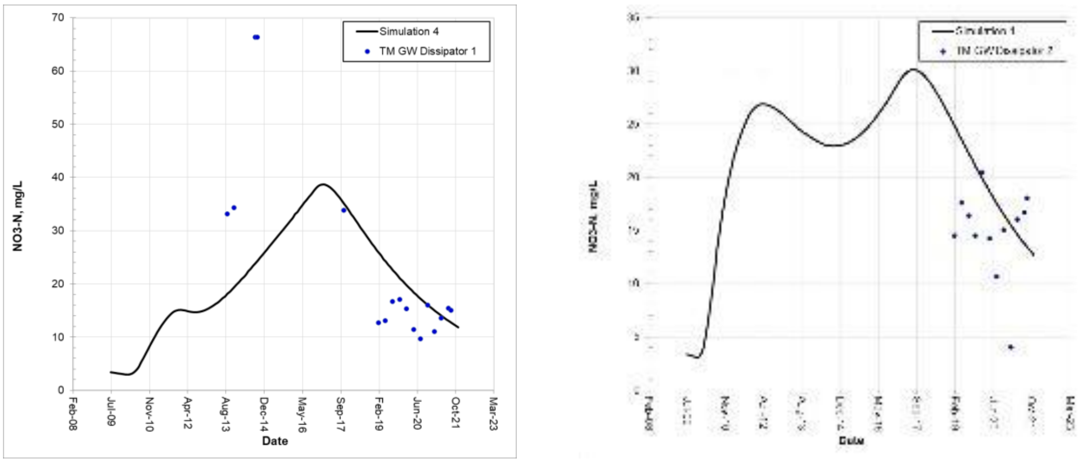

Figure 12-9: Measured vs simulated nitrate mass concentration for TM GW Dissipator 1 and TM GW Dissipator 2

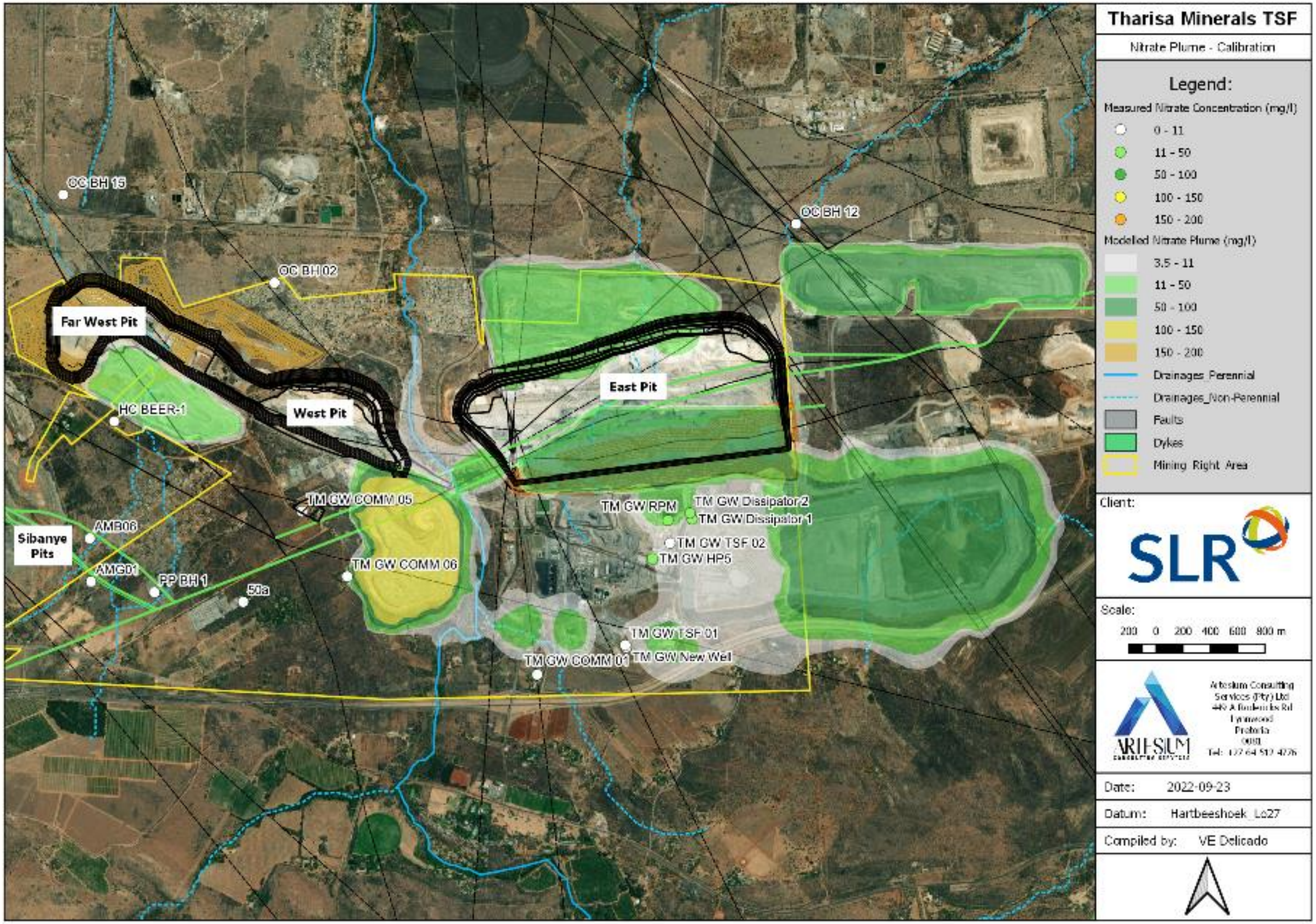

Figure 12-10: Calibrated nitrate mass plume

13 Appendix C – Impact Assessment Matrix

PART A: DEFINITIONS AND CRITERIA*		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of intensity, spatial extent, and duration**
Criteria for ranking of the INTENSITY of environmental impacts	**VH**	Severe change, disturbance, or degradation. Associated with severe consequences. May result in severe illness, injury, or death. Targets, limits, and thresholds of concern continually exceeded. Substantial intervention will be required. Vigorous/widespread community mobilization against project can be expected. May result in legal action if impact occurs.
	H	Prominent change, disturbance or degradation. Associated with real and substantial consequences. May result in illness or injury. Targets, limits and thresholds of concern regularly exceeded. Will definitely require intervention. Threats of community action. Regular complaints can be expected when the impact takes place.
	M	Moderate change, disturbance or discomfort. Associated with real but not substantial consequences. Targets, limits and thresholds of concern may occasionally be exceeded. Likely to require some intervention. Occasional complaints can be expected.
	L	Minor (Slight) change, disturbance or nuisance. Associated with minor consequences or deterioration. Targets, limits and thresholds of concern rarely exceeded. Require only minor interventions or clean-up actions. Sporadic complaints could be expected.
	VL	Negligible change, disturbance or nuisance. Associated with very minor consequences or deterioration. Targets, limits and thresholds of concern never exceeded. No interventions or clean-up actions required. No complaints anticipated.
	VL+	Negligible change or improvement. Almost no benefits. Change not measurable/will remain in the current range.
	L+	Minor change or improvement. Minor benefits. Change not measurable/will remain in the current range. Few people will experience benefits.
	M+	Moderate change or improvement. Real but not substantial benefits. Will be within or marginally better than the current conditions. Small number of people will experience benefits.
	H+	Prominent change or improvement. Real and substantial benefits. Will be better than current conditions. Many people will experience benefits. General community support.
	VH+	Substantial, large-scale change or improvement. Considerable and widespread benefit. Will be much better than the current conditions. Favourable publicity and/or widespread support expected.
Criteria for ranking the DURATION of impacts	**VL**	Very short, always less than a year. Quickly reversible
	L	Short-term, occurs for more than 1 but less than 5 years. Reversible over time.
	M	Medium-term, 5 to 10 years.
	H	Long term, between 10 and 20 years. (Likely to cease at the end of the operational life of the activity)
	VH	Very long, permanent, +20 years (Irreversible. Beyond closure)
Criteria for ranking the EXTENT of impacts	**VL**	A part of the site/property.
	L	Whole site.
	M	Beyond the site boundary, affecting immediate neighbours
	H	Local area, extending far beyond site boundary.
	VH	Regional/National

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	**Decision guideline**
Very High	Potential fatal flaw unless mitigated to lower significance.
High	It must have an influence on the decision. Substantial mitigation will be required.
Medium	It should have an influence on the decision. Mitigation will be required.
Low	Unlikely that it will have a real influence on the decision. Limited mitigation is likely required.
Very Low	It will not have an influence on the decision. Does not require any mitigation
Insignificant	Inconsequential, not requiring any consideration.

***VH = very high, H = high, M= medium, L= low and VL= very low and + denotes a positive impact.**

PART B: DETERMINING CONSEQUENCE							
INTENSITY = VL							
DURATION	Very long	VH	Low	Low	Medium	Medium	High
	Long term	H	Low	Low	Low	Medium	Medium
	Medium term	M	Very Low	Low	Low	Low	Medium
	Short term	L	Very low	Very Low	Low	Low	Low
	Very short	VL	Very low	Very Low	Very Low	Low	Low
INTENSITY = L							
DURATION	Very long	VH	Medium	Medium	Medium	High	High
	Long term	H	Low	Medium	Medium	Medium	High
	Medium term	M	Low	Low	Medium	Medium	Medium
	Short term	L	Low	Low	Low	Medium	Medium
	Very short	VL	Very low	Low	Low	Low	Medium
INTENSITY = M							
DURATION	Very long	VH	Medium	High	High	High	Very High
	Long term	H	Medium	Medium	Medium	High	High
	Medium term	M	Medium	Medium	Medium	High	High
	Short term	L	Low	Medium	Medium	Medium	High
	Very short	VL	Low	Low	Low	Medium	Medium
INTENSITY = H							
DURATION	Very long	VH	High	High	High	Very High	Very High
	Long term	H	Medium	High	High	High	Very High
	Medium term	M	Medium	Medium	High	High	High
	Short term	L	Medium	Medium	Medium	High	High
	Very short	VL	Low	Medium	Medium	Medium	High
INTENSITY = VH							
DURATION	Very long	VH	High	High	Very High	Very High	Very High
	Long term	H	High	High	High	Very High	Very High
	Medium term	M	Medium	High	High	High	Very High
	Short term	L	Medium	Medium	High	High	High
	Very short	VL	Low	Medium	Medium	High	High
			VL	**L**	**M**	**H**	**VH**
			A part of the site/ property	Whole site	Beyond the site, affecting neighbours	Extending far beyond site but localised	Regional/ National
			EXTENT				

PART C: DETERMINING SIGNIFICANCE							
PROBABILITY (of exposure to impacts)	Definite/ Continuous	**VH**	Very Low	Low	Medium	High	Very High
	Probable	**H**	Very Low	Low	Medium	High	Very High
	Possible/ frequent	**M**	Very Low	Very Low	Low	Medium	High
	Conceivable	**L**	Insignificant	Very Low	Low	Medium	High
	Unlikely/ improbable	**VL**	Insignificant	Insignificant	Very Low	Low	Medium
			VL	**L**	**M**	**H**	**VVH**
			CONSEQUENCE				