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Provisional Hydrogeological Assessment for EIA and EMP inclusion

Mashala Resources – Proposed DeWittekrans Section

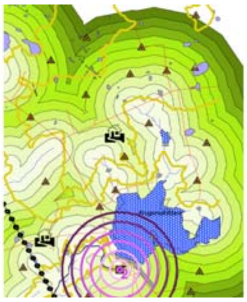
Version -1st DRAFT

26 June 2009

Client Name: Mashala Resources

Project Number: 08-111




GCS (Pty) ltd.
Johannesburg Durban Kimberley Windhoek
Directors: AC Johnstone (Managing) SE Scawthon (Financial) AH Barbour (Non-exec)* V Cresswell (Non-exec)*
Reg No: 2004/000765/07 Est. 1987

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GCS Environmental Unit

ATTENTION: Magdalene von Ronge

Please find attached the Hydrogeological report for the De Wittekrans Section.

Please do not hesitate to contact us should you require any additional information.

Best regards,

Pieter Labuschagne

GCS Project Hydrogeologist

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Hydrogeological Assessment

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** External Review*

CONTENTS PAGE

List of Tables

List of Figures

List of Appendixes:

1 Introduction and Overview

GCS was appointed by Mashala Resources (Pty) Ltd to compile the Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) for the proposed De Wittekrans open cast and underground coal mine. This report supplies the hydrogeological aspects for inclusion into the EIA/EMP.

The main hydrogeological concerns are the potential de-watering of the regional aquifer system and contamination transport from the underground mining area and the surface waste storage facilities towards the groundwater and surface water systems, mainly with a focus on contaminants such as sulphate, acidity and iron.

Mashala Resources wish to gain an understanding of the hydrogeological environment within the direct vicinity of the proposed mining activities to assist in determining the most effective way to mitigate against potential negative impacts on aquifer quality and quantity.

1.1 Scope of work

The aim of the groundwater investigation was to assess the current groundwater environment and to predict the impact of mining on this environment in terms of quantity and quality. This data will be used to compile the relevant environmental reports and sections of the EIA/EMP. In order to achieve the aim of the investigation the following objectives and tasks were set:

a) Determine the nature of the groundwater system in terms of flow patterns and gradients, aquifer parameters and geological conditions by installing and testing six observation/monitoring boreholes. This will be supported with other borehole data in the area and with literature studies.

b) Characterise the hydrochemistry of groundwater prior to mining.

c) Determine the acid and/or neutralising potential of the rock associated with the proposed mining activities by doing Acid Base Accounting (ABA) on selected coal, overburden and floor material samples.

d) Develop a numerical groundwater flow and solute transport model for the proposed mining activities.

e) Prepare the Groundwater Impact and Risk Assessment, based on the available information, for inclusion in the EIA/EMP.

Several borehole and stream samples were obtained during the field assessment (October to November 2008), and the sample analyses were included into the study. Several private boreholes were also visited on the Knapdaar farms since this was initially included as part of the investigation area.

1.2 Limitations

The following limitations applied throughout the assessment phase:

- Where reliable data was absent, consciously conservative/worse case assumptions were made when undertaking risk and impact assessments.
- Long term predictions on pollution, migration rates and loads to receiving water bodies were based on field monitoring/observation data and literature where applicable. Where

information gaps were identified they have been brought to the attention of the client and recommendations were made on measures proposed to bridge data gaps.

- The proposed mining progression plan in terms of the mine life cycle was obtained from the Mashala Resources. If this changes over time, the numerical model will need to be updated and calibrated accordingly.
- All prediction in terms of de-watering and future de-cant need to be revised when the final mine plans are available. It is also good practice to revise predictions one year after mining has started. Updated information in terms of detail elevation data and geology can be applied with one year of groundwater levels and quality data.

2 Physical Geography

The following section provides an overview of the physical characteristics of the surrounding environment. These are regarded as important aspects in terms of the hydrogeological environment.

2.1 Extent of Investigation

The proposed De Wittekrans mining section is situated on Portions 5, 7, 10, 11 and the remaining extents of Portions 1 and 2 of the farm De Wittekrans 218 IS, the remaining extent of Portion 1 of the farm Tweefontein 203 IS, the remaining extent of the farm Groblershoek 191 IS and all portions on the farm Groblershoop 192 IS and Israel 207 IS. The project area is situated between the towns of Ermelo and Hendrina in the Mpumalanga Province, on the western side of the N11.

The local potential zone of influence was delineated according to the boundaries of the local mini-sub catchment. This area is considered sensitive for possible impacts from the proposed mining activities (refer to Figure 2-1). This boundary was used for the purpose of the hydrogeological assessment. The application of groundwater flow boundaries is explained in more detail in Section 5.

2.2 Topography and Surface Drainage

Figure 2-1 shows the general topography of the mining site, which is mainly situated along the Klein Olifants River. The elevation ranges from 1 662 meters above mean sea level (mamsl) to 1 595 mamsl towards the river. The proposed mining area lies on both sides of the Klein Olifants River. Surface runoff from most of the area to be mined will discharge into the Klein Olifants River.

The significance of topographical setting for this assessment and in general in terms of Karoo Aquifer systems is that groundwater usually mimics the topography (more in following sections about groundwater flow patterns).

2.3 Rainfall

Mean annual rainfall is approximately 710mm and mean annual evaporation is >2000 mm per annum. The winter months contribute very little to the annual rainfall for this area.

The significance of rainfall figures for this assessment and in general in terms of Karoo Aquifer systems is that approximately 2 to 5% of annual rainfall will be recharged to the regional aquifer system (more in following sections about aquifer hydraulics).

2.4 General Geological Description

2.4.1 Regional geology

The De Wittekrans Coal Project is situated in the Ermelo Coalfield (Mpumalanga Coal field), some 22km north west of Breyten, and 10km south east of Hendrina. The project is accessible from the N11, which runs through the north east of the property.

The geology comprise sedimentary rocks of the Middle Ecca Stage of the Karoo System (refer to Figure 2-2). The area around Ermelo is underlain by arenaceous strata of the Vryheid Formation of the Karoo Supergroup. The lithological units common in this group are coal seams, quartzite, sandstones and mudstones. They are intercalated into lenticular bodies that vary in properties such as thickness and weathering therefore weak strata of limited extent and thickness can be expected below highly competent strata.

All of the coal seams occur within the Vryheid Formation of the Ecca Group (Karoo Supergroup). The Karoo Supergroup comprises the following Groups (in decreasing age):

- Dwyka;
- Ecca;
- Beaufort;
- Stormberg; and
- Drakensberg.

The Ecca Group is comprised of the following Formations (in decreasing age):

- Pietermaritzburg;
- Vryheid; and
- Volksrust.

The Karoo succession commences with Dwyka tillite at the base which outcrops along valley flanks and floors. The tillite was deposited on a very uneven surface and is therefore not laterally persistent. The tillite is overlain on average by about 90m of shales and sandstones before the coal zone starts.

The C seam of the Ermelo Coalfield equates to the number four seam of the Highveld Coalfield and the Gus Seam of the Utrecht and Newcastle Coalfields. The types of coal present in the area vary and depend very much on the proximity of the dolerite intrusions and the temperatures to which the coal was subjected by intruding sill and/or dykes. These types include bituminous, lean-bituminous, anthracitic, and burnt.

At this locality, all the major coal seams may be present to some degree, although it is the B Upper, B Lower, C Upper and the C Lower Seams that are of economic interest, which occur generally over the entire area under question. The A Seams (A Upper and A Lower) occur intermittently across the deposit, and will only be exploited where opencast mining occurs.

The B Seams and C Seams occur over the entire property, and will be exploited by both opencast and underground means. The B-Seam is preserved at higher elevations over the prospecting area. The seam is developed mostly as carbonaceous shale and shaly coal, with an average thickness of 2.7 metres. A prominent glauconitic sandstone marker is found just above the B Seam.

The C Seam is parted from the B-Seam by 7 to 15 meters thick coarse-grained, poorly sorted, arkosic sandstone and consists mostly of dull torbanitic coal. The seam thickness is constantly developed around 2.5 meters.

Structurally, the coal seams are relatively undeformed, although some faulting has been identified. Dolerite intrusions occur in the area, but these do not appear to have had any material impact on the structure of the coal.

Refer to **Appendix A** for a typical borehole log.

2.4.2 Coal Seam Dimensions

Exploration borehole data was obtained from Mr. Nico Denner, which is involved in the exploration and mine planning (Gemecs, 2009).

The coal floor elevation contour map for the C Lower coal seam can be viewed from Figure 2-3.

Figure 2-4 indicates the C Lower coal seam depth with geological structures.

Figure 2-5 shows the C Lower seam in cross sections – these were constructed through the numerical software Visual Modflow that will be applied for groundwater modelling purposes (refer to Section 5).

Figure 2-6 shows a north-south and east-west cross section through the area as per the SRK report (Development of the De Wittekrans Coal Project, near Hendrina, Mpumalanga Province, SRK Consulting, Report No 399526, April 2009, for Mashala Resources), the B and C Lower seams are indicated.

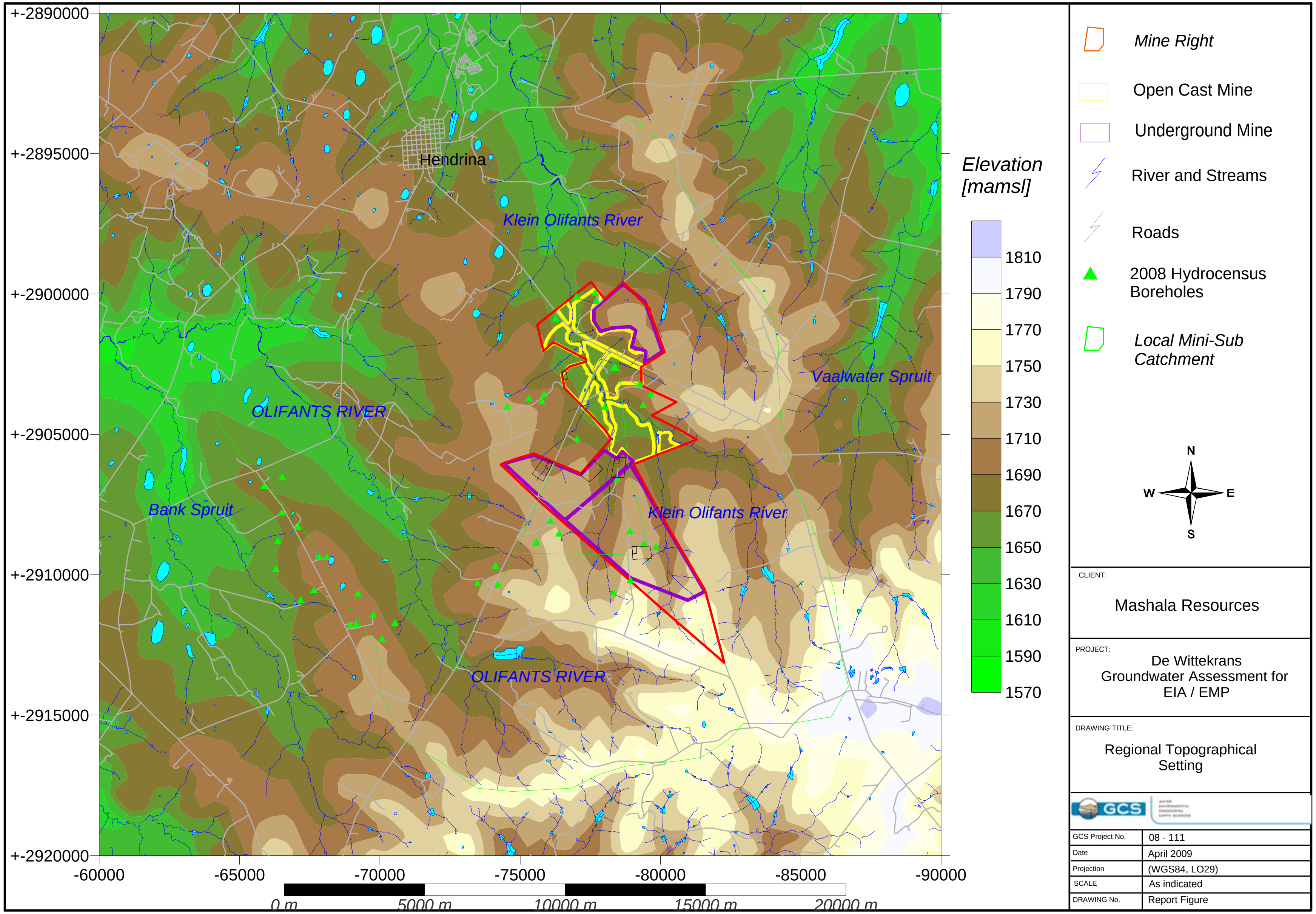


Figure 2-1: Topographical setting of the proposed De Wittekrans mini- sub-catchment area

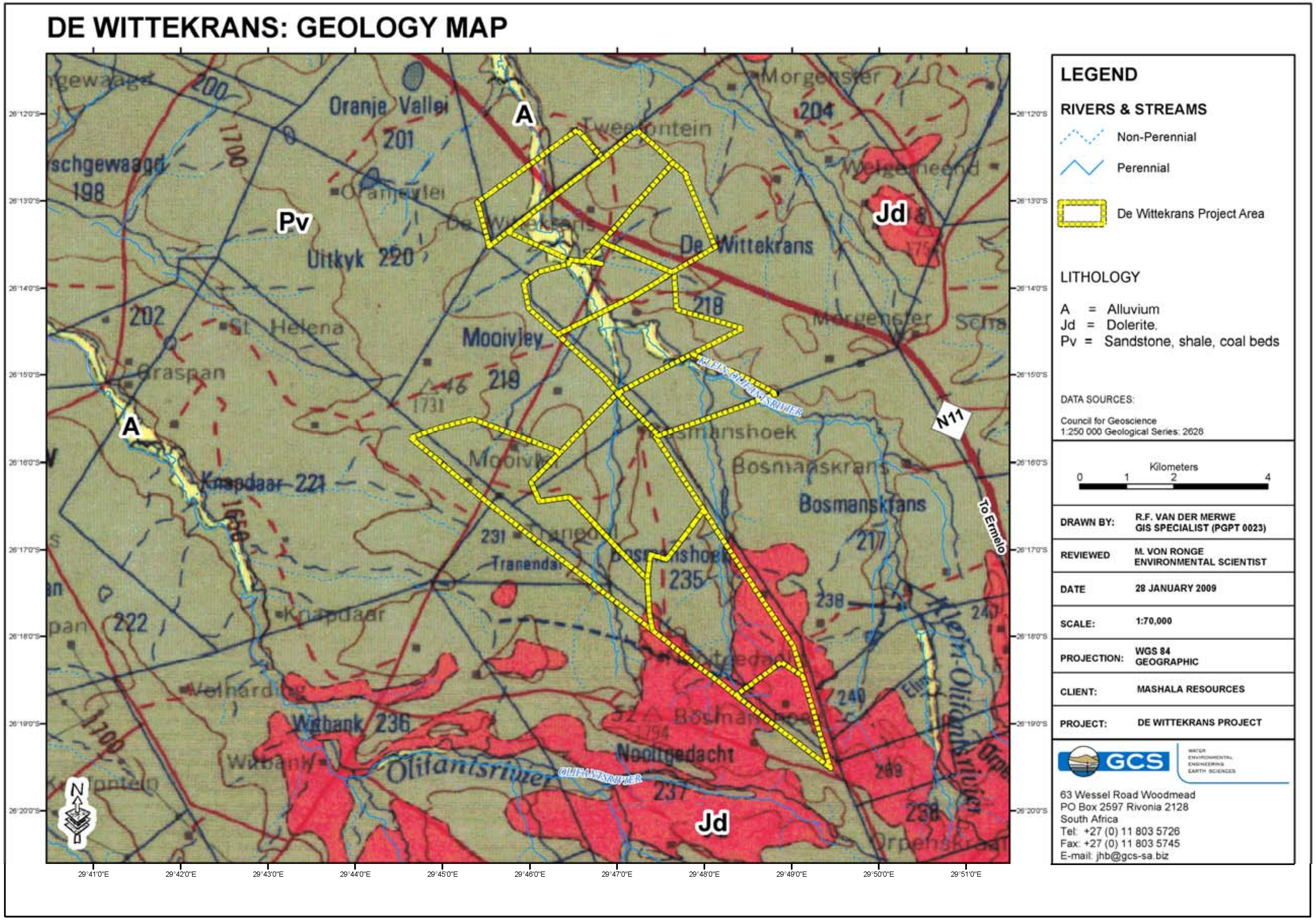


Figure 2-2: Surface geology and approximate De Wittekrans mining area

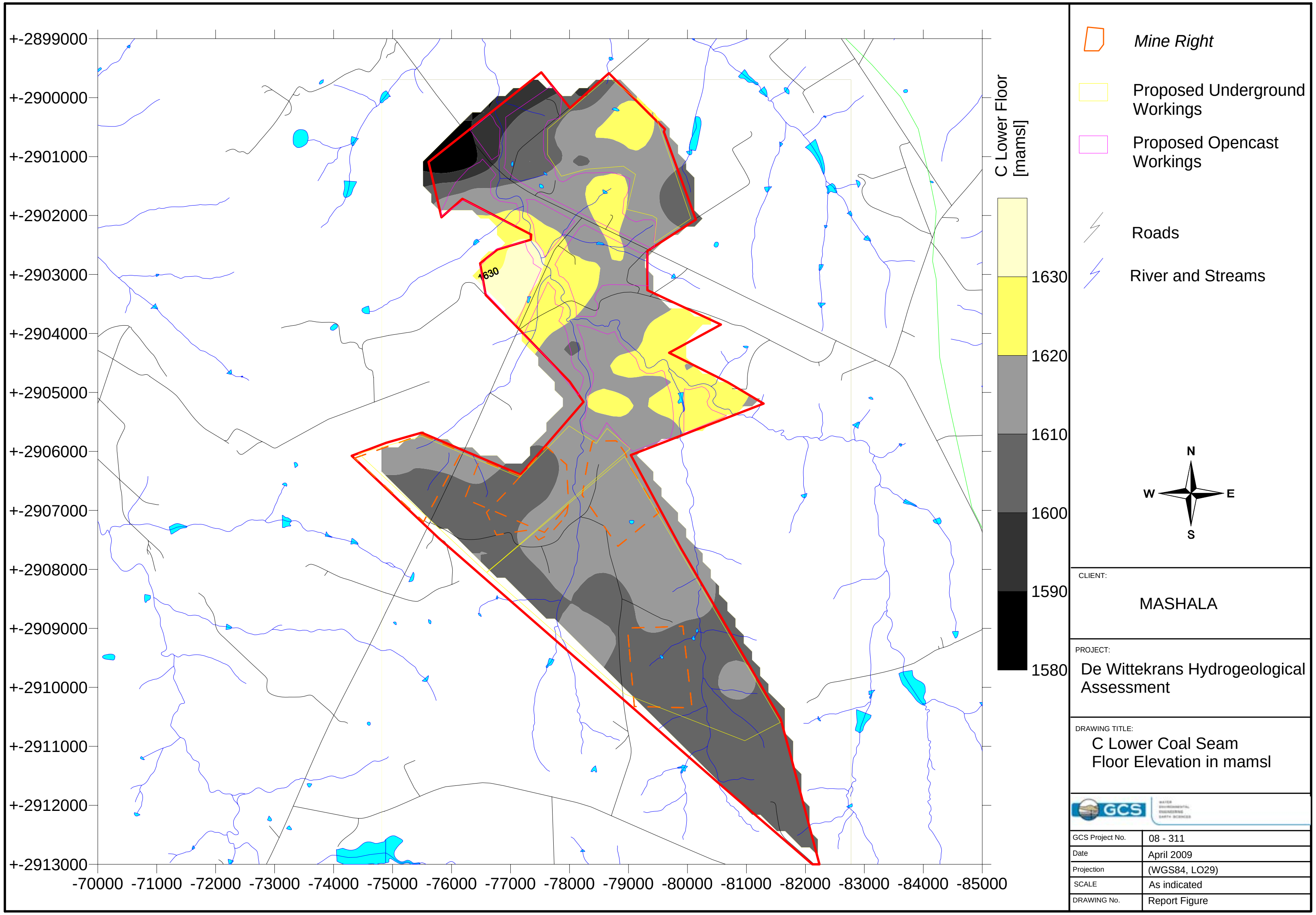


Figure 2-3: Coal floor elevation contour map for the maximum mining depth (C lower) of the DeWittekrans Section

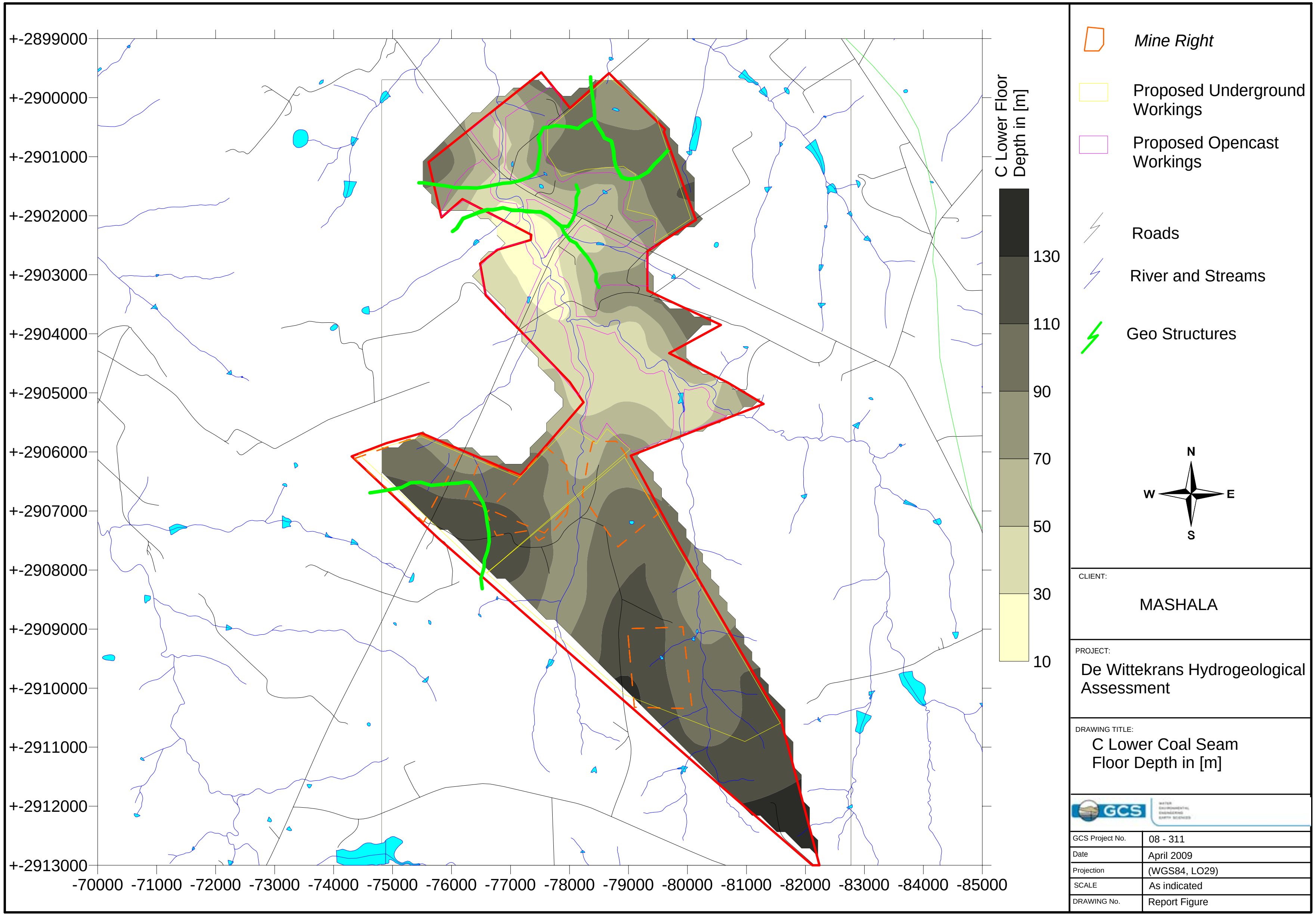
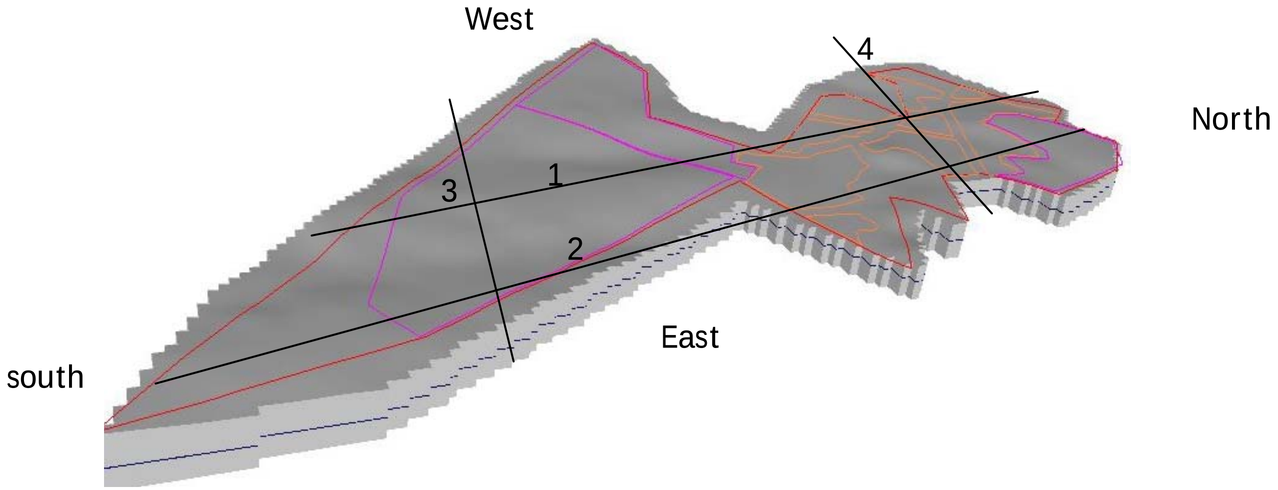
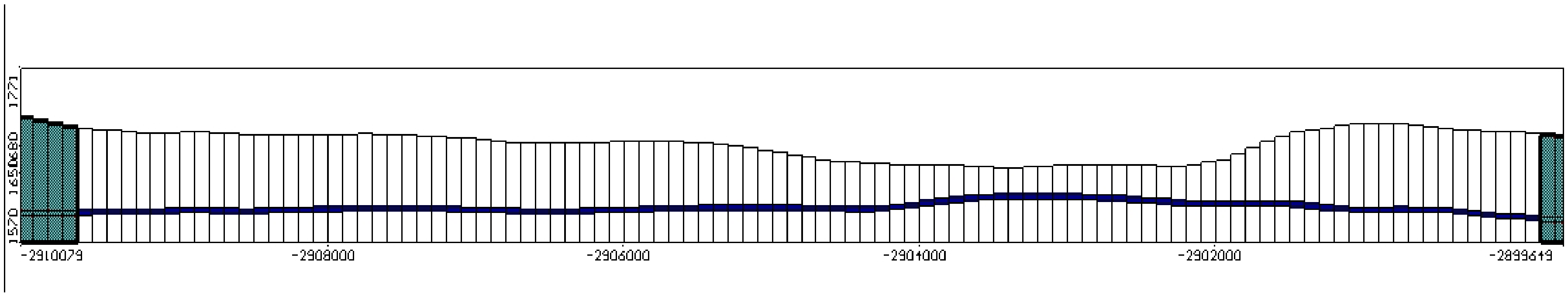


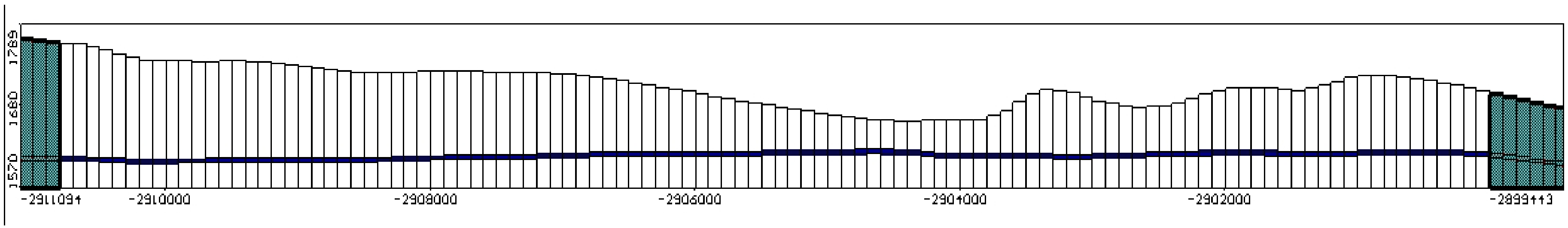
Figure 2-4: Coal floor depth contour map for the maximum mining depth (C lower) of the DeWittekrans Section



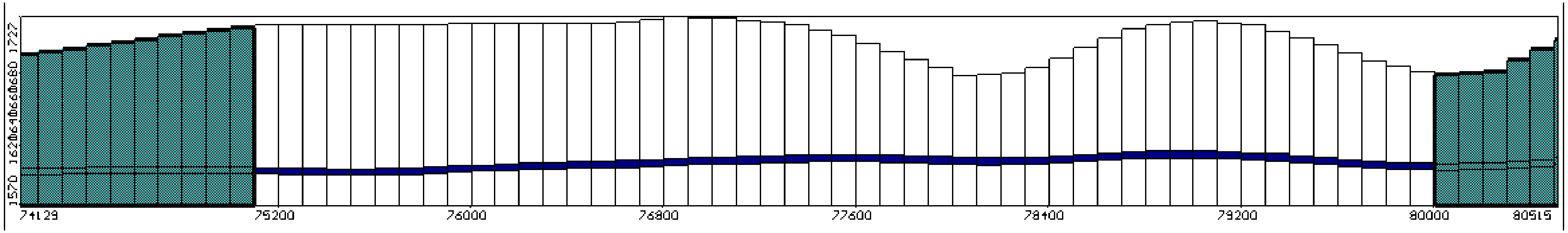
Line 1: North-South Cross-Section showing C Lower Coal Seam



Line 2: North-South Cross-Section showing C Lower Coal Seam



Line 3: West-East Cross-Section showing C Lower Coal Seam



Line 4: West-East Cross-Section showing C Lower Coal Seam

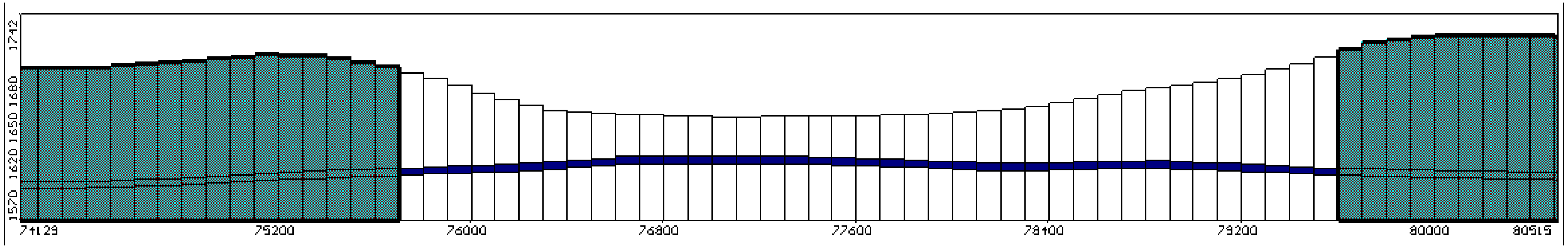


Figure 2-5: Cross-sections through the DeWittekrans area.

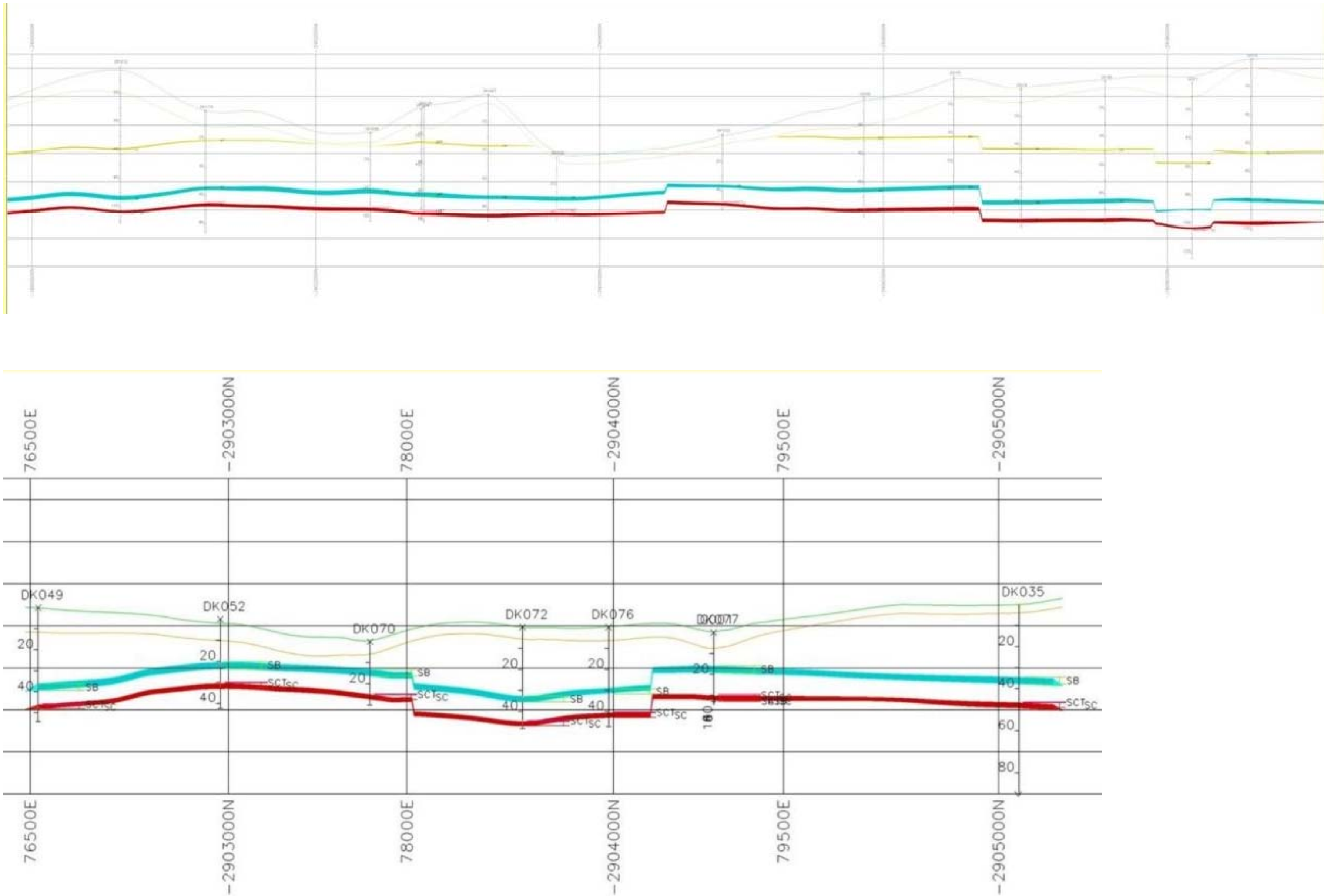


Figure 2-6: Cross sections obtained from the SRK report (north-south and east-west) showing the B and C coal seams

3 *Baseline Hydrogeological Assessment*

The baseline hydrogeological assessment is based on the following data sets:

- 2009 field assessment and drilling of six (6) additional monitoring boreholes by GCS.
- Literature for the regional aquifers and DWAF borehole database.
- Coal floor and geological data obtained from Mashala Resources for the De Wittekrans Area.
- Water Research Commission (WRC) reports:
  - Hodgson, F.D.I. Wagner, H. and Shipman, B.J. (1995) Guidelines for environmental protection - pollution problems and hydrological disturbances resulting from increased underground extraction of coal. Chamber of Mines of SA Guideline.
  - BREDENKAMP, D.B., BOTHA, L.J., VAN TONDER, G.J., AND VAN RENSBURG, H.J. 1995. Manual on the quantitative estimation of groundwater recharge and aquifer storativity. Water Research Commission, TT 73/95, Pretoria.
  - Hodgson, F.D.I and Krantz, R.M. (1998) Groundwater quality deterioration in the Olifants River Catchment above the Loskop Dam with specialised investigations in the Witbank Dam Sub-Catchment. WRC Report No 291/1/98.
  - Parsons, R. (1995). A South African Aquifer System Management Classification. Water Research Commission Report No. KV 77/95.
  - SABS (2001). South African Standard Specification Drinking Water. SABS 241 Edition 5.
  - The groundwater resources of the Republic of South Africa, sheets 1 and 2. (1996). Water Research Commission and Department of Water Affairs and Forestry.
  - The national groundwater database. Department of Water Affairs and Forestry, Pretoria, South Africa.
  - WEAVER, J.M.C. 1992. Groundwater sampling. Water Research Commission project No 339, TT 54/92, Pretoria.
  - Development of the De Wittekrans Coal Project, near Hendrina, Mpumalanga Province, SRK Consulting, Report No 399526, April 2009, for Mashala Resources

3.1 Borehole Localities

Six groundwater monitoring boreholes were drilled during the GCS field assessment in May/June 2009. The coordinates of these holes are shown in Table 3-1 and the localities in Figure 3-1. The geological borehole logs are attached in **Appendix B**.

As part of the October 2008 field assessment, a borehole census around the mining area was undertaken. Forty five (45) boreholes were visited and water samples and groundwater level data was obtained from some of these boreholes. The main purpose was to identify borehole (groundwater) users in the direct vicinity of the proposed mining operations as well as to obtain information on regional groundwater quality. The data obtained is provided in Table 3-2 and the borehole localities shown in Figure 3-1. It must be noted that the Knapdaar farms were also visited.

From the information obtained from the regional hydrocensus survey, it was found that groundwater is used mainly for domestic supply and for livestock watering. The borehole yields from the regional aquifers are relatively low and groundwater cannot be pumped in quantities sufficient for extensive crop irrigation purposes.

Table 3-1: Description of newly drilled monitoring boreholes at the proposed De Wittekrans mining site

BH ID	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Z (mamsl)	WL (mbch)	Wl Elev (mamsl)	BH Depth (mbgl)	Water Strike (mbgl)
NBH1	-77928.0	2906135.1	1685	9.2	1675.8	37	very low seepage
NBH2	-78281.0	2905748.3	1677	3.14	1673.86	30	13m
NBH3	-77010.1	2904080.9	1672	11.73	1660.27	37	23m
NBH4	-77560.3	2905976.6	1702	7.25	1694.75	30	11m
NBH5A	-77038.4	2900837.9	1665	6.68	1658.32	85	11m
NBH5B	-77033.4	2900833.9	1665	11.75	1653.25	12	only seepage
NBH6	-78600.7	2905752.5	1685	8.52	1676.48	30	only seepage

Water level not recovered after drilling (highlighted)

Mbch = meters below collar height

Table 3-2: Boreholes visited during the 2008 borehole census

BH ID	Farm Name	Farm Owner	Contact Details	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mamsl)	WL (mbgl)	Collar Height	Equipment	pH	EC (mS/m)	TDS	Use	Comments
BH1	Witbank 12	Gilbert	082 651 2845	-73480.46	2910329.48	1694	15.11	0.25	Windpump	7.08	0.81	0.40	Domestic and stock watering	Wind-pump that pumps into a concrete tank for farm dwellers and cattle.
BH2	Witbank 12	Gilbert	082 651 2845	-74128.23	2909700.5	1693			Windpump				Stock farming	Wind-pump that pumps into a concrete tank for cattle.
BH3	Graspan 6	Jaco de Klerk	083 268 0814	-65880.12	2906862.53	1674			Windpump	7.21	0.33	0.16	Domestic	Water used by farm dwellers.
BH4	Graspan 6	Jaco de Klerk	083 268 0814	-66525.02	2906556.71	1669			Windpump				Unused	Located in the cattle farm. Pump seems to be broken.
BH5	Graspan 6	Jaco de Klerk	083 268 0814	-66496.6	2907809.7	1676	6.81	0	Windpump				Unused	Located in the recently cultivated farm. Pump seems to be broken.
BH6	Graspan 3	Gilbert	082 651 2845	-67084.27	2908323.53	1685	3.98	0.27	None	6.92	0.14	0.07	Unused	Open borehole was drilled by the previous farm owner and left it un-equipped.
BH7	Graspan 11	Gilbert	082 651 2845	-66361.55	2908821.72	1672	3.21	0	Windpump				Unused	Pump broken. Empty concrete tanks next to the borehole.
BH8	Witbank 7	M. Kadish	082 469 4108	-69150.38	2911771.46	1716	20.16	0	Mono pump	7.37	0.62	0.31	Domestic	Pump connected to a tank. Water is used in the farm house, workshop and compound.

BH ID	Farm Name	Farm Owner	Contact Details	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mam sl)	WL (mbgl)	Collar Height	Equipment	pH	EC (mS/m)	TDS	Use	Comments
BH9	Witbank 7	M. Kadish	082 469 4108	-68944.45	2911814.67	1715			Windpump				Stock farming	Water is pumped into a concrete tank for cattle farming.
BH10	Witbank 7	M. Kadish	082 469 4108	-70538.6	2911736.86	1681			Windpump	8	0.18	0.18	Domestic and stock watering	Water is pumped into a concrete tank for cattle farming.
BH11	Witbank 7	M. Kadish	082 469 4108	-70076.15	2912308.3	1704	5.89	0.23	None				Unused	An open borehole, wind-pump was removed.
BH12	Graspan 4	Gilbert	082 651 2845	-68103.42	2909396.97	1694	14.25	0.44	Submersible pump	8.23	0.37	0.18	Domestic	Located about 100m from a dam in the farm. Water used only by farm dwellers.
BH13	Graspan 4	Gilbert	082 651 2845	-69216.07	2910694.82	1689	11.85	0.5	Windpump				Stock farming	Water is pumped into a concrete tank for cattle farming.
BH14	Graspan 4	Gilbert	082 651 2845	-69765.27	2911446.79	1702			Broken Mono Pump				Unused	Borehole was used to supply water to the compound before the pump was stolen.
BH15	Graspan 4	Gilbert	082 651 2845	-67832.82	2909384.47	1707	6.63	0	None				Unused	Pump was removed. It was used for domestic purpose and cattle farming before the removal of the pump.
BH16	Graspan 3	Gilbert	082 651 2845	-67649.85	2910565.75	1685	4.93	0	Submersible pump				Domestic	Borehole located next to the farm house and used for domestic purpose.
BH17	Graspan 3	Gilbert	082 651 2845	-67179.64	2910918.96	1667			Windpump	7.43	0.37	0.19	Domestic and stock watering	Borehole located on a wetland, pumping into 2 concrete tanks.
BH18	Graspan 3	Gilbert	082 651 2845	-66303.49	2909819.73	1668			Broken Windpump					Broken windpump with a concrete tank next to it. Located on a grassy wetland area.
BH19	Witbank 12	Gilbert	082 651 2845	-74213.21	2910380.2	1724	2.9	0	None					Open borehole. Blocked at about 3m. Located in an what used to be a cattle farm.
BH20	Trenedal 0002	Gilbert	082 651 2845	-76386.18	2908555.77	1730			Windpump	8.67	0.34	0.17	Domestic and stock watering	Water is pumped into a concrete tank for domestic use in the compound and cattle farming. Water level could not be measured.
BH21	Trenedal 0002	Gilbert	082 651 2845	-76074.16	2908112.94	1743	5.65	0	Broken Windpump				Unused	Located next to old, vandalized farm houses. Connected to 2 concrete tanks.

BH ID	Farm Name	Farm Owner	Contact Details	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mamsl)	WL (mbgl)	Collar Height	Equipment	pH	EC (mS/m)	TDS	Use	Comments
BH22	Trenedal 0002	Gilbert	082 651 2845	-75578.34	2908860.16	1722			Windpump	8.45	0.23	0.11	Cattle farming	Water is pumped into a concrete tank for drinking by cattle. Located on an open area just upgradient to a wetland.
BH23	Trenedal 0002	Gilbert	082 651 2845	-75557.14	2908898.81	1719	8.45	0	None				Unused	Open borehole located about 30m from a windpump. Pump was removed.
BH24	Tweefontein	John Schinkerling	084 581 3049	-77713.38	2900280.12	1689	8.17	0.36	Submersible pump	6.35	0.25	0.12	Domestic and stock watering	Borehole located next to a farm house.
BH25	Tweefontein	John Schinkerling	084 581 3049	-77672.22	2899976.28	1694	2.75	0.19	None				Unused	Old, open borehole next to a farm house. A wind-pump was removed from the borehole.
BH26	Tweefontein	John Schinkerling	084 581 3049	-76999.68	2900124.07	1652	4.75	0	Submersible pump				Used occasionally	Borehole located on a wetland, at the bottom of the mountain. Connected to the two tanks in the farm house.
BH27	Tweefontein	John Schinkerling	084 581 3049	-76268.47	2900900.89	1667			Hand pump	6.24	0.23	0.11	Domestic	Located about 150m from the Ermelo-Hendrina road, on a grassy land used for grazing. Water is used by farm dwellers.
BH28	De Wittekrans	Anel Shulze	083 628 8212	-78015.57	2904040.34	1653			Submersible pump				Stock farming	Two boreholes located on a valley, about 300m from the river. Used to pump water concrete tanks for cattle. Water has a strong smell of sulphur.
BH29	De Wittekrans	Anel Shulze	083 628 8212	-78016.54	2904044.77	1654	6.29	0.2	Submersible pump	7.32	0.42	0.21	Stock farming	
BH30	De Wittekrans	Anel Shulze	083 628 8212	-79387.83	2903981.09	1681			Windpump				Unused	Borehole not currently in use, located on the mountain side on a grazing land.
BH31	De Wittekrans	Anel Shulze	083 628 8212	-79653.98	2903597.13	1707			None				Unused	Unused borehole closed with concrete on top, had a windpump which was removed by the previous farm owner.
BH32	De Wittekrans	Anel Shulze	083 628 8212	-79255.61	2903219.07	1694			Windpump				Unused	Borehole with a broken windpump located at a farm used as grazing land.

BH ID	Farm Name	Farm Owner	Contact Details	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mamsl)	WL (mbgl)	Collar Height	Equipment	pH	EC (mS/m)	TDS	Use	Comments
BH33	De Wittekrans	Anel Shulze	083 628 8212	-75783.49	2903848.69	1704			Windpump	7.57	0.21	0.1	Domestic	Borehole located next to a village in the farm. Water is pumped into a concrete tank and used by farm workers.
BH34	De Wittekrans	Anel Shulze	083 628 8212	-75850.88	2903603.1	1688			Broken Windpump				Unused	Two boreholes located on a grazing land in the farm. Both windpumps are broken. They were connected to concrete tanks for stock watering.
BH35	De Wittekrans	Anel Shulze	083 628 8212	-75309.49	2903741.77	1698			Broken Windpump				Unused	
BH36	De Wittekrans	Anel Shulze	083 628 8212	-74540.42	2904033.15	1707			Windpump	7.41	0.41	0.2	Stock farming	Borehole equiped with a windpump and pumps into a concrete tank for stock watering.
BH37	De Wittekrans	Anel Shulze	083 628 8212	-77032.54	2905184.57	1684	8.09	0	Windpump	5.86	0.46	0.23	Domestic and stock watering	Borehole equipped with a windpump and pumps into a concrete tank for domestic use and stock watering.
BH38	Israel	C. J. De Vos	082 388 3008	-78316.23	2910652.63	1717			Submersible pump				Domestic	Borehole located on a wetland next to a dam. Connected to 3 tanks that supply to a farm house, workshop and to the farm worker's village.
BH39	Israel	C. J. De Vos	082 388 3008	-78930.06	2910220.92	1741	13.59	0.21	Submersible pump				Used occasionally	Water contains oil.
BH40	Israel	C. J. De Vos	082 388 3008	-79408.41	2908927.45	1733			Submersible pump	7.86	0.36	0.18	Domestic and stock watering	Borehole located next to the farm worker's village, used to supply water to the farm house, village and cattle.
BH41	Israel	C. J. De Vos	082 388 3008	-79842.24	2909035.39	1751	23.62	0	Submersible pump				Used occasionally	Located among the mielie fields, upgradient to a dam.
BH42	Israel	C. J. De Vos	082 388 3008	-78915.77	2908473.46	1726	2.37	0	Broken Windpump				Unused	Borehole was used for irrigation before the pump broke, located on the boundary between the mielie and the potato fields.
BH43	Israel	C. J. De Vos	082 388 3008	-78450.55	2906621.34	1691			Windpump	7.95	0.13	0.06	Unused	Borehole located next to an old, unoccupied village, on a grazing land.

BH ID	Farm Name	Farm Owner	Contact Details	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mam sl)	WL (mbgl)	Collar Height	Equipment	pH	EC (mS/m)	TDS	Use	Comments
BH44	De Wittekrans	B. De Lange	082 862 7515	-78394.65	2902656.49	1674	44.53	0	Submersible pump				Domestic	The only borehole in the farm used for domestic purpose in the farm house. No agricultural use of groundwater. Located on a grazing land.
BH45	De Wittekrans	B. De Lange	082 862 7515	-78347.74	2902647.34	1669			Spring	5.02	0.09	0.04	Domestic	Spring located about 40m from a borehole. Used by farm workers for domestic purpose.

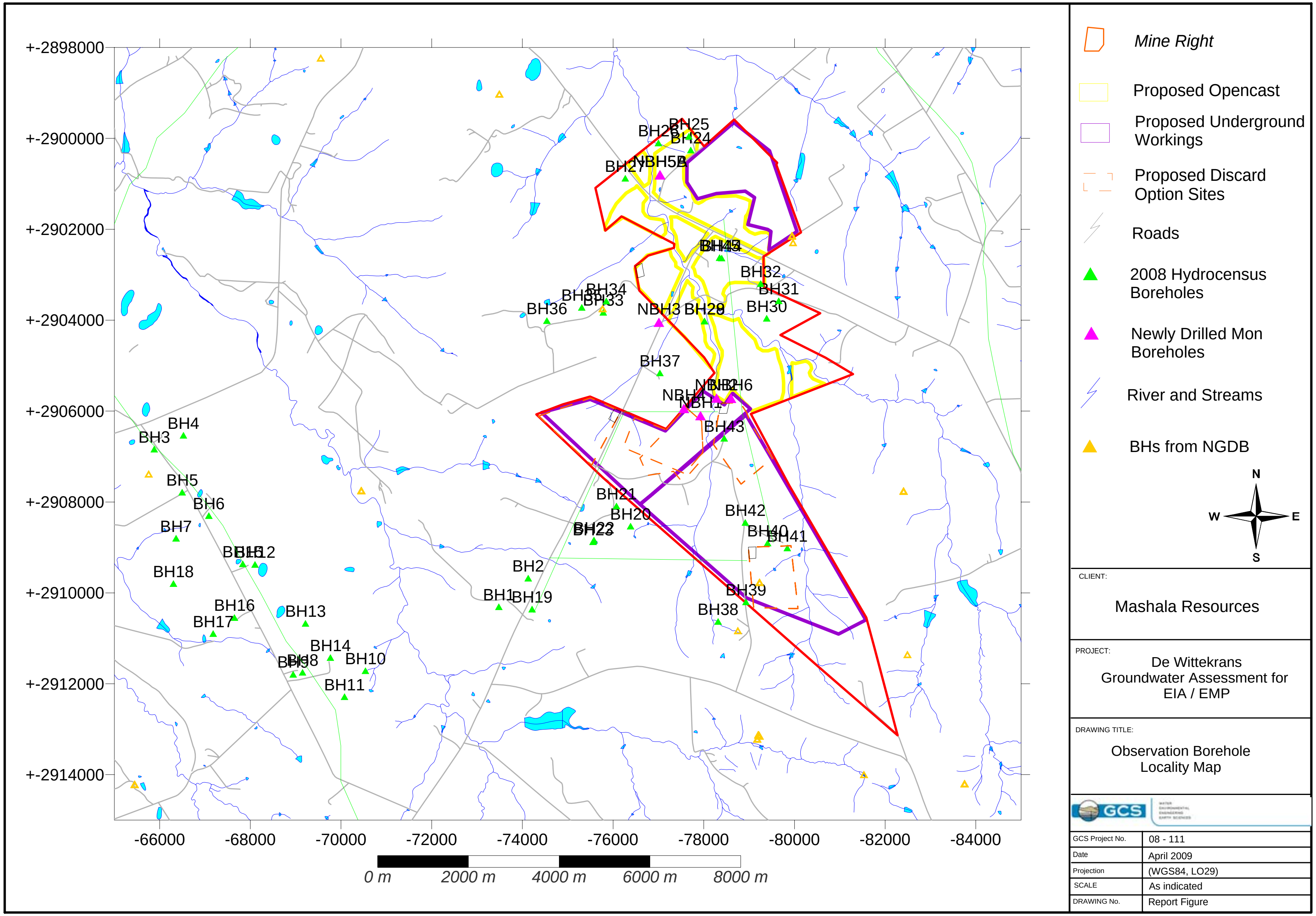


Figure 3-1: Borehole Locality Map in the vicinity of the proposed De Wittekrans mining section

3.2 Aquifer Description

Kirchner *et al.* (1991) has estimated 2-4% of annual effective rainfall recharge for the Karoo Basin. This recharge to the weathered aquifer drains towards regional surface water courses and less than 60% of the recharge emanates in streams. The remainder is withdrawn through evapotranspiration from the weathered aquifer or drained towards the deeper fractured aquifer system.

The conceptual hydrogeological model of the area is based on the generally accepted model for the Mpumalanga coal fields. Three principal aquifers[1] are identified; the weathered aquifer, the fractured Karoo aquifer and the fractured pre-Karoo aquifer (Hodgson & Krantz, 1998). The Karoo rocks are not known for the development of aquifers but occasional high yielding boreholes may be present. Generally these rock types can be divided into two distinct aquifers, namely a shallow weathered aquifer and a deeper fractured aquifer. The newly drilled boreholes as well as an assessment of the available exploration borehole logs revealed the following:

- In general weathering occurred from 2 to 15 meters, these sections were cased by means of steel casing to protect the borehole from collapsing. Seepage was observed in almost all the boreholes on shallow depths within this weathered zone. However, it must be noted that no significant groundwater yields were obtained, all low seepage and NBH1 was almost dry.
- Hard and fresh sandstone/shale were intersected on depths >15 m. This can be regarded as the fractured Karoo and regional aquifer. The C Lower Coal Seam is also located within this aquifer.
- Alluvial deposits were intersected along the Klein Olifants River and significant seepage occurs, which confirms discharge or the aquifers into local rivers and streams.

The geological logs for the newly drilled monitoring boreholes are attached in **Appendix B.**

3.2.1 Aquifer Hydraulics

Aquifer testing was conducted on the new boreholes by applying conventional slug testing. Due to the poor aquifer yield (0.1 l/sec to no seepage at all) it was decided to apply slug tests on the boreholes and measure the recovery time to reach the original piezometric heads[2]. The results of the tests are shown in Table 3-3 and the test graphs in **Appendix C**. It can be seen from Table 3-3 that the hydraulic conductivity (K in m/day) corresponds with normal Karoo Aquifer type hydraulic parameters. The values range from 0.01 to 0.0009 m/day.

Table 3-3: Aquifer Test Results for the newly drilled Ferreira boreholes

Borehole No	Depth (m)	Water Strike	SWL (m) (17/06/2009)	Rose to Wl (m)	Time of Recovery (min)	Recover to WL (m)	K (m/day) range from recovery data*	
NBH1	37		9.20	8.96	110	8.935	0.00096	
NBH2	30	13m	3.145	3.05	180	3.144	0.00305	0.010
NBH3	37	23m	11.70	11.60	120	11.70	0.00221	0.005
NBH4	30	11m	7.31	6.8	150	7.235	0.00238	0.004
NBH5	85	11m	6.675	6.45	55	6.641	0.00170	0.003
NBH6	30		8.52	8.2	120	8.545	0.00273	
AVG							**0.002**	**0.005**

WL = Water Level and K = Hydraulic conductivity (m/day)[3]

[1] *Aquifer – A body of rock, consolidated or unconsolidated, that is sufficiently permeable to conduct groundwater and to yield significant quantities of water to wells and springs.*

[2] *Piezometric head (ϕ) is the sum of the elevation and pressure head. An unconfined aquifer has a water table and a confined aquifer has a piezometric surface, which represents a pressure head. The piezometric head is also referred to as the hydraulic head.*

[3] *Hydraulic conductivity (K) is the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured perpendicular to the area [L/T]. Hydraulic conductivity is a function of the permeability and the fluid's density and viscosity.*

3.3 Groundwater Levels

The groundwater levels within the boreholes were measured as a first step to determine the groundwater flow directions for the area. It can be seen from the borehole description tables in the previous section (Table 3-1 and Table 3-2) and the following water level summary table (Table 3-4) that groundwater levels range from 2.3 to 23 mbgl (the pumped water level of BH44 is ignored). The monitoring boreholes on site indicate water levels from 3 to 11 mbgl with an average of 8.3 mbgl.

Figure 3-3 shows the groundwater depth contour map for the De Wittekrans area; these were obtained by using the available borehole information and by applying the Kriging interpolation method. It must therefore be noted that this only supplies an overview of the regional groundwater depths in graphical format and only for overview purposes.

Table 3-4: Groundwater level summary table for the De Wittekrans Area

	BH ID	Y (m in LO 29, WGS84)	X (m in LO 29, WGS84)	Alt (mamsl)	WL (mbgl)	Wl Elevation [mamsl]
Hydro Census Boreholes	BH42	-78915.77	2908473.46	1726	2.37	1723.63
	BH25	-77672.22	2899976.28	1694	2.75	1691.25
	BH19	-74213.21	2910380.2	1724	2.9	1721.1
	BH7	-66361.55	2908821.72	1672	3.21	1668.79
	BH6	-67084.27	2908323.53	1685	3.98	1681.02
	BH26	-76999.68	2900124.07	1652	4.75	1647.25
	BH16	-67649.85	2910565.75	1685	4.93	1680.07
	BH21	-76074.16	2908112.94	1743	5.65	1737.35
	BH11	-70076.15	2912308.3	1704	5.89	1698.11
	BH29	-78016.54	2904044.77	1654	6.29	1647.71
	BH15	-67832.82	2909384.47	1707	6.63	1700.37
	BH5	-66496.6	2907809.7	1676	6.81	1669.19
	BH37	-77032.54	2905184.57	1684	8.09	1675.91
	BH24	-77713.38	2900280.12	1689	8.17	1680.83
	BH23	-75557.14	2908898.81	1719	8.45	1710.55
	BH13	-69216.07	2910694.82	1689	11.85	1677.15
	BH39	-78930.06	2910220.92	1741	13.59	1727.41
	BH12	-68103.42	2909396.97	1694	14.25	1679.75
	BH1	-73480.46	2910329.48	1694	15.11	1678.89
	BH8	-69150.38	2911771.46	1716	20.16	1695.84
	BH41	-79842.24	2909035.39	1751	23.62	1727.38
	BH44	-78394.65	2902656.49	1674	44.53	1629.47
	AVG				**8.5452**	
	MIN				**2.37**	
	MAX				**23.62**	
New Boreholes	NBH1	-77928.0	2906135.1	1685	9.2	1675.8
	NBH2	-78281.0	2905748.3	1677	3.14	1673.86
	NBH3	-77010.1	2904080.9	1672	11.73	1660.27
	NBH4	-77560.3	2905976.6	1702	7.25	1694.75
	NBH5A	-77038.4	2900837.9	1665	6.68	1658.32
	NBH5B	-77033.4	2900833.9	1665	11.75	1653.25
	NBH6	-78600.7	2905752.5	1685	8.52	1676.48
	AVG				**8.3243**	
	MIN				**3.14**	
	MAX				**11.75**	

It is known that in similar geological terrains, a linear relationship exists between the groundwater table and the topography. This can, however, not just be accepted and had to be tested. This was done by plotting the borehole collar elevation against the measured groundwater elevation. If a linear correlation exists, it can be assumed that the groundwater table would mimic the topography.

Plotting groundwater level versus the topographical elevation at each observation point yields a 95 % correlation (Refer to Figure 3-2). This also indicates that there is currently no external influence such as large-scale abstraction on the groundwater resources in the area. However, it can be seen that BH44's water level (wl) plots of-line and it is assumed that the borehole was pumped shortly before the wl was measured. In general, most of the hydro-census boreholes indicates pumping water levels and not complete static water levels. Discresion will be applied during the model applications accordingly.

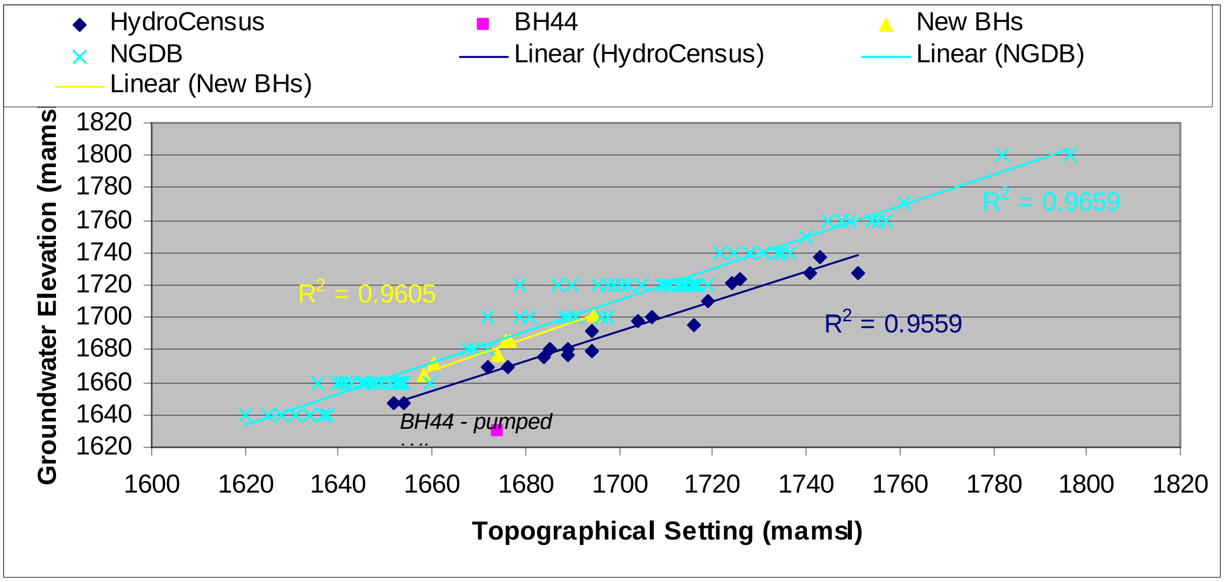


Figure 3-2: Correlation between surface elevation and groundwater elevation for the Ferreira Area

Once it has been established that a correlation between the groundwater table and the topography exists, a Bayesian Interpolation[4], that incorporates both the topography and the measured groundwater elevations, can be done. The interpolated groundwater table, based on the Bayesian Interpolation, is shown on Figure 3-4. The interpolated groundwater contour for the opencast mining area (refer to Figure 3-5) map indicates groundwater elevations to be from 1 640 to 1 690 m amsl at the mining area.

It can be seen that the C Lower seam occur a depth of 1630 m amsl to 1580 m amsl. This indicates that all mining will occur below the regional piezometric head.

The groundwater gradient[5] for the site was calculated by using random selected boreholes. The calculation is summarised in Table 3-5. It can be seen that moderately groundwater gradients occur across the proposed mining site; gradient factors ranging from 1:45 to 1:20.

[4] *Environmental phenomena (e.g. rainfall and the occurrence of groundwater) cover such vast areas, that it is not always possible to measure their associated variables at all relevant points in space and time. Interpolation is a method to obtain values for these variables at points where no measurements were taken.*

Groundwater levels often follow the surface topography of the aquifer. If the latter variable can be sampled more frequently than the first one, then one can use this information to improve estimates of the first variable. Bayesian Kriging is an interpolation method that uses this principle. In this approach, the classical statistical analysis of Ordinary Kriging is replaced by a Bayesian statistical analysis. The beauty of the Bayesian approach is that it allows one to express prior knowledge of the variable with a qualified guess that can be included in the estimation.

Bayesian interpolation is done with the estimator

$$Z^*(\mathbf{x}_o) = \sum_{i=1}^{n} \alpha_i \left[Z(\mathbf{x}_i) - \mu(\mathbf{x}_i) \right] + \mu_0(\mathbf{x}_0)$$

where $\mu(x_j)$ is the qualified guess for site x_j. The coefficients α_i , i=1,…,n can again be determined from a system of linear equations and is a function of the parameters σ(Sigma) , k and ρ(Rho).

[5] *Hydraulic gradient is the rate of change in the total head per unit distance of flow in a given direction.*

Table 3-5: Groundwater gradient calculation

Parameter	NBH1-NBH2	NH24-BH26	*AVG*
h1	1685	1689	
h2	1677	1652	
h1-h2	8.0	37.0	
L	353.0	713.7	
I	0.0227	0.052	***0.037***
Factor	**44.125**	**19.289**	***31.707***

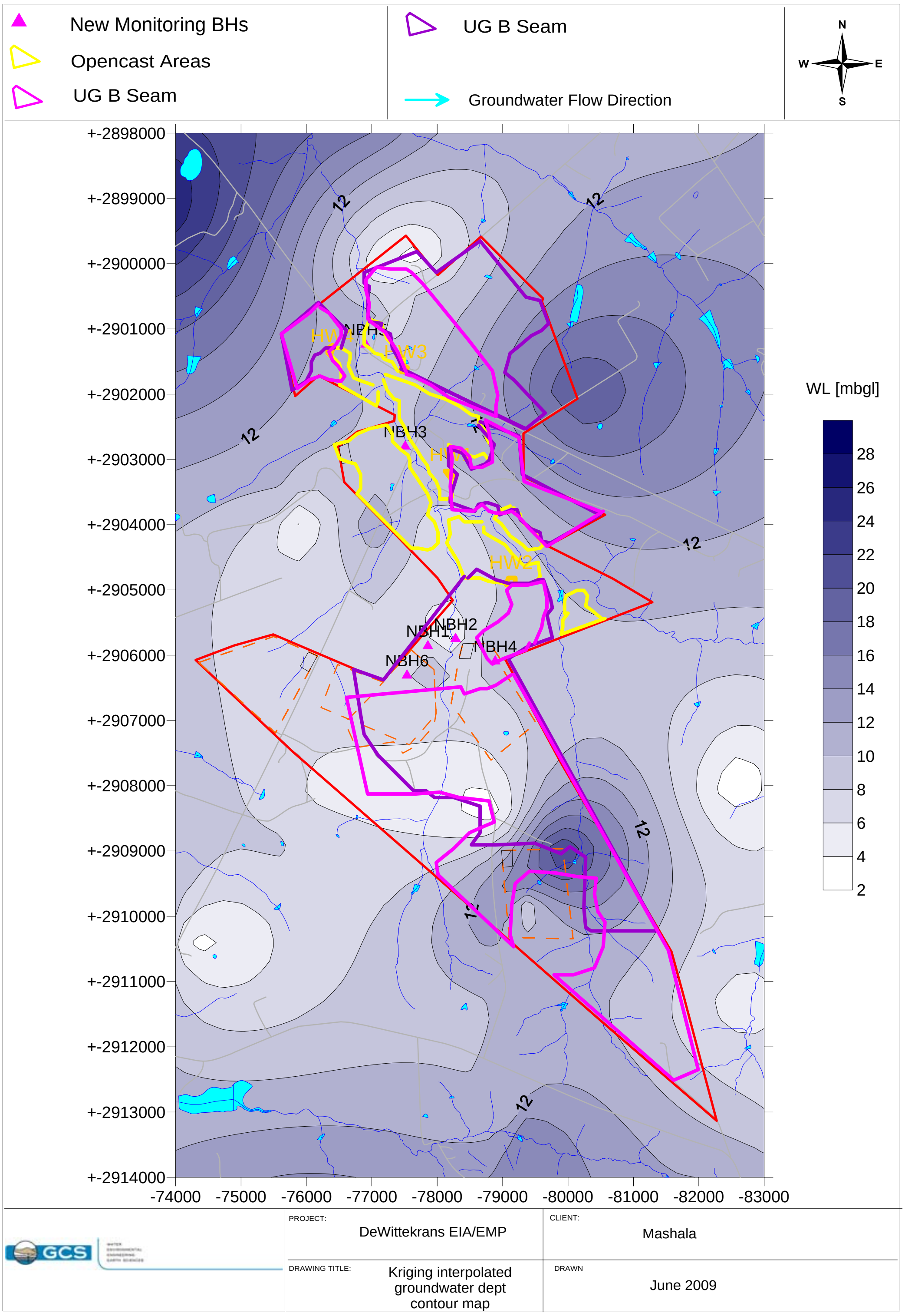


Figure 3-3: Kriging interpolated groundwater level depth for the DeWittekrans Area

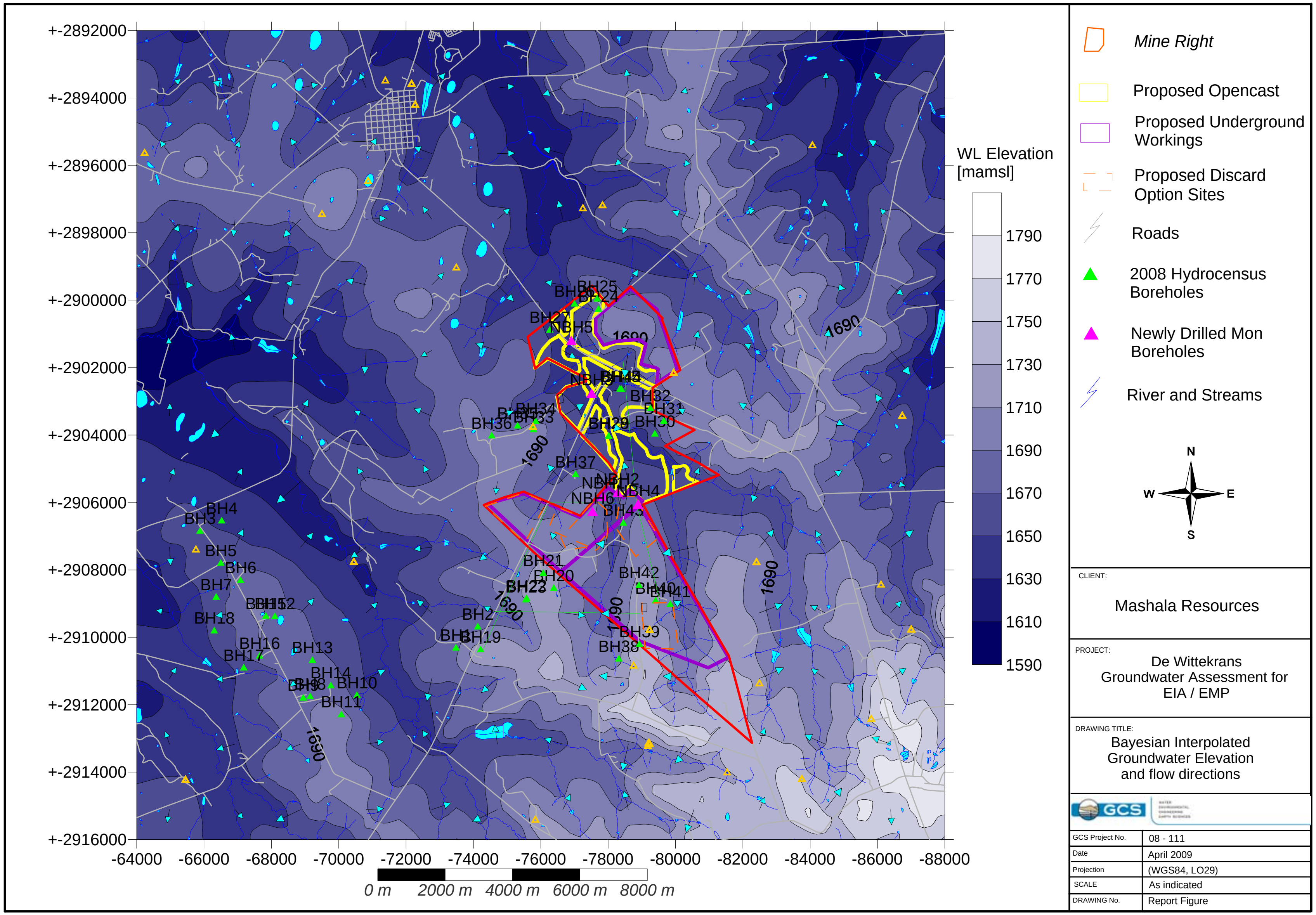


Figure 3-4: Bayesian interpolation of the groundwater level elevations of the area with flow directions.

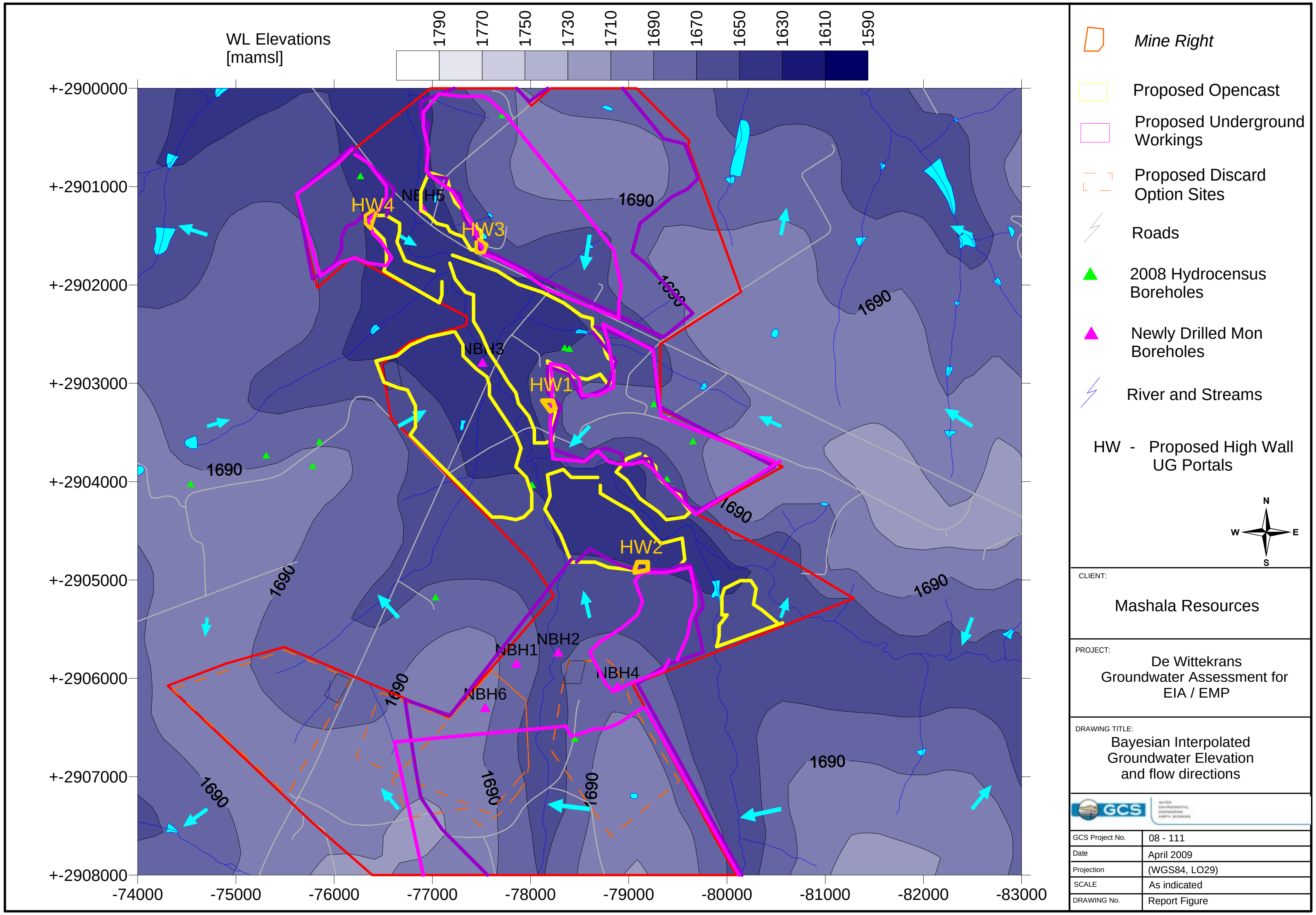


Figure 3-5: Bayesian interpretation of the groundwater level elevations of the area with flow directions for the Open Cast Area

3.3.1 Concluding Remarks

Available groundwater level data indicate piezometric heads of <1650 mamsl for the proposed opencast mining area and coal floor depths around 1640 to 1590 mamsl. This means that mining will mainly occur within the saturated zone (below the water table for the unconfined[6] aquifer zones and below the piezometric head for the confined[7] aquifer zones) of the proposed hydrogeological profile. The piezometric heads are mainly controlled by fractures, and cracks within the Karoo strata and seepages along the mining profile will occur accordingly.

The site is situated on low yielding aquifers. These aquifers have very low potential in terms of development due to the low yield. The aquifers are of minor regional importance in terms of community water supply and can therefore be classified as a **Minor Aquifer System** according to the Parsons Classification methods (WRC, 1995). However, for certain farms and smaller communities it is the sole source of water.

The aquifer tests results are applied in the calculation of preliminary flow velocities of the groundwater (which normally acts as the carrier of pollution in the hydrogeological environment). The calculations are performed as follows:

$$v = \frac{Ki}{\phi}$$

where: *v = flow velocity (m/day)*
K = hydraulic conductivity (m/day)
i = probable average hydraulic gradient
ϕ = probable average porosity

By applying the range of hydraulic conductivity values obtained from the aquifer testing, flow velocities between 0.001 and 0.003 m/day were calculated (0.6 m/year). These can be observed from Table 3-6. Any pollutants generated by the mining activities (SO_4 content usually) will therefore migrate according to these flow rates or a little slower depending on retardation through absorption of the flow paths.

> *It must be noted that de-watering activities during the operational phase will cause a cone of depression towards the mining areas and groundwater flow tends to flow back towards these areas. This will limit mass transport to the surrounding aquifers during operations. Mass transport away from the site can therefore increase after the rebound of water levels during the de-commissioning phase and after.*

However, groundwater movement along dykes and fault zones could flow at rates of approximately 75 m/year and more. These subsequently result in preferred groundwater flow paths and sensitive aquifer zones.

These values are compared to the numerical model results later on in this report.

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[6] *An unconfined, water table or phreatic aquifer are different terms used for the same aquifer type, which is bounded from below by an impermeable layer. The upper boundary is the watertable, which is in contact with the atmosphere so that the system is open.*

[7] *A confined aquifer is a formation in which the groundwater is isolated from the atmosphere at the point of discharge by impermeable geologic formations; confined groundwater is generally subject to pressure greater than atmospheric.*

Table 3-6: Flow velocity calculation for the area

	Flow velocity	Hydraulic conductivity	Gradient	Porosity
	(m/day)	(m/day)		
NBH1-NBH2	0.001	0.005	0.023	0.1
BH24-BH26	0.003	0.005	0.052	0.1
AVG	**0.002**			
HAR MEAN	**0.002**			
V (m/year)	**0.576**			

3.4 Water Quality

Groundwater quality was assessed in order to obtain an idea of the pre-mining and ambient groundwater quality and current status.

A total of six groundwater samples were collected during the hydrocensus investigation in November 2008. It can be seen from Table 3-7 that neutral pH values and fairly low TDS concentrations were obtained. The groundwater quality from borehole Tweefontein1 possibly indicate the impact of agricultural activities, as suggested by the elevated nitrate (No_3) concentration in the groundwater.

Table 3-7: Hydrocensus water quality data

Date Sampled	Station ID	pH	Cond	HCO3	TDS	Ca	Cl	Fe	Mg	Mn	NO3	Na	SO4	K	F
			mS/m	mg/l											
27-Nov-08	Spring	5.9	13.4	10	86	18.4	17	0.05	7.7	0.10	5.5	10	5.0	5.3	0.10
27-Nov-08	De Wit 2	7.8	54.8	250	351	36.8	24	0.30	9.1	0.10	0.5	73	5.0	5.0	0.10
27-Nov-08	De Wit 6	8.1	27.2	141	174	34.7	5	0.05	6.3	0.10	0.5	20	5.0	8.8	0.10
27-Nov-08	Tweefontein 1	6.6	32.9	38	211	31.1	45	0.05	6.4	0.10	10.8	26	10.0	5.0	0.10
27-Nov-08	Tweefontein 4	7.1	29.9	129	191	36.2	6	0.05	8.6	0.10	3.1	19	6.0	7.0	0.10
27-Nov-08	Israel 3	8.3	45.6	227	292	25.9	9	0.05	4.9	0.10	0.5	87	5.0	5.0	0.19

Water samples were obtained from the newly drilled boreholes in June 2009. The positions of the boreholes are shown in Figure 3-1. The results of the chemical analyses for the newly drilled boreholes are summarised in Table 3-8 and compared to the 1998 DWAF standards for domestic use. Again, it can be seen from the results that fairly good qualities were obtained from the newly drilled monitoring boreholes.

The groundwater quality character is shown graphically in the form of a Piper[8] and Durov diagram in Figure 3-6 and Figure 3-7. The groundwater generally has a good quality with sodium and bi-carbonate dominant character.

It is recommended that follow-up samples be obtained to confirm the pre-mining conditions and to develop a database for future reference purposes.

SampleID	Sample_Date	pH	Cond	Na	K	Mg	Ca	Fe	Cl	SO4	NO3	HCO3
Units		pH units	mS/m	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
NBH1	17/06/2009	8.16	34	35	7.4	12	37	0.07	7	<5	<0.5	180
NBH2	17/06/2009	8.3	45	98	7.2	7.9	17	0.19	18	<5	<0.5	223

[8] The Piper diagram represents the concentrations as percentages, this is achieved by working the percentage that each represents of the major cations (Ca, Mg and Na+K). Analyses are plotted on the basis of the percent of each cation (or anion). Each apex of a triangle represents a 100% concentration of one of the three constituents. As water flows through an aquifer it assumes a diagnostic chemical composition as a result of interaction with the lithological framework (Fetter, 1998).

NBH3	17/06/2009	8.31	25	24	6.1	9.1	24	0.09	7	<5	<0.5	135
NBH4	17/06/2009	8.19	47	73	12.6	14.5	36	0.18	8	<5	<0.5	250
NBH5	17/06/2009	8.31	28	48	<5.0	7.2	16	0.44	10	<5	<0.5	145
NBH6	17/06/2009	8.47	22	32	8.4	8.7	20	0.18	9	<5	<0.5	110
ID		**pH**	**EC**	**Na**	**K**	**Mg**	**Ca**	**Fe**	**Cl**	**SO4**	**NO3 as N**	
Class 0 Limits		5 - 9.5	70	100	25	70	80	0.5	100	200	6	
Class 1 Limits		4.5 - 10	150	200	50	100	150	1	200	400	10	
Class 2 Limits		4 - 10.5	370	400	100	200	300	5	600	600	20	
Class 3 Limits		3 -- 11	520	1000	500	400	>300	10	1200	1000	40	
Class 4 Limits		3 -- 11	>520	>1000	>500	>400		>10.0	>1200	>1000	>40	

Quality of Domestic Water Supplies, DWA&F, Second Edition 1998	
Class 0	- **Ideal water quality** - Suitable for lifetime use.
Class 1	- **Good water quality** - Suitable for use, rare instances of negative effects.
Class 2	- **Marginal water quality** - Conditionally acceptable. Negative effects may occur in some sensitive groups
Class 3	- **Poor water quality** - Unsuitable for use without treatment. Chronic effects may occur.
Class 4	- **Dangerous water quality** - Totally unsuitable for use. Acute effects may occur.

South Africa Water Quality Guidelines, Volume 1: Domestic Use, DWA&F, First Edition 1993 & Second Edition 1996	
NR	- **Target water quality range** - No risk.
IR	- **Good water quality** - Insignificant risk. Suitable for use, rare instances of negative effects.
LR	- **Marginal water quality** - Allowable low risk. Negative effects may occur in some sensitive groups
HR	- **Poor water quality** - Unsuitable for use without treatment. Chronic effects may occur.

Table 3-8: Results of the chemical analyses for the newly drilled boreholes

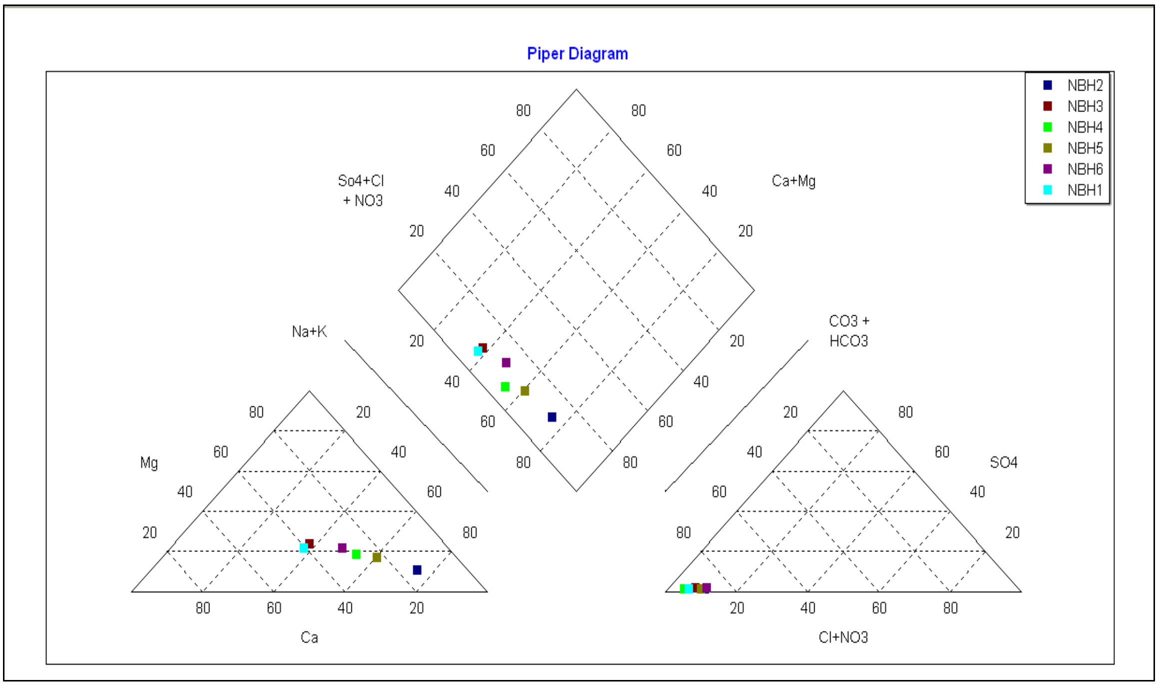


Figure 3-6: Piper diagram for the De Wittekrans boreholes

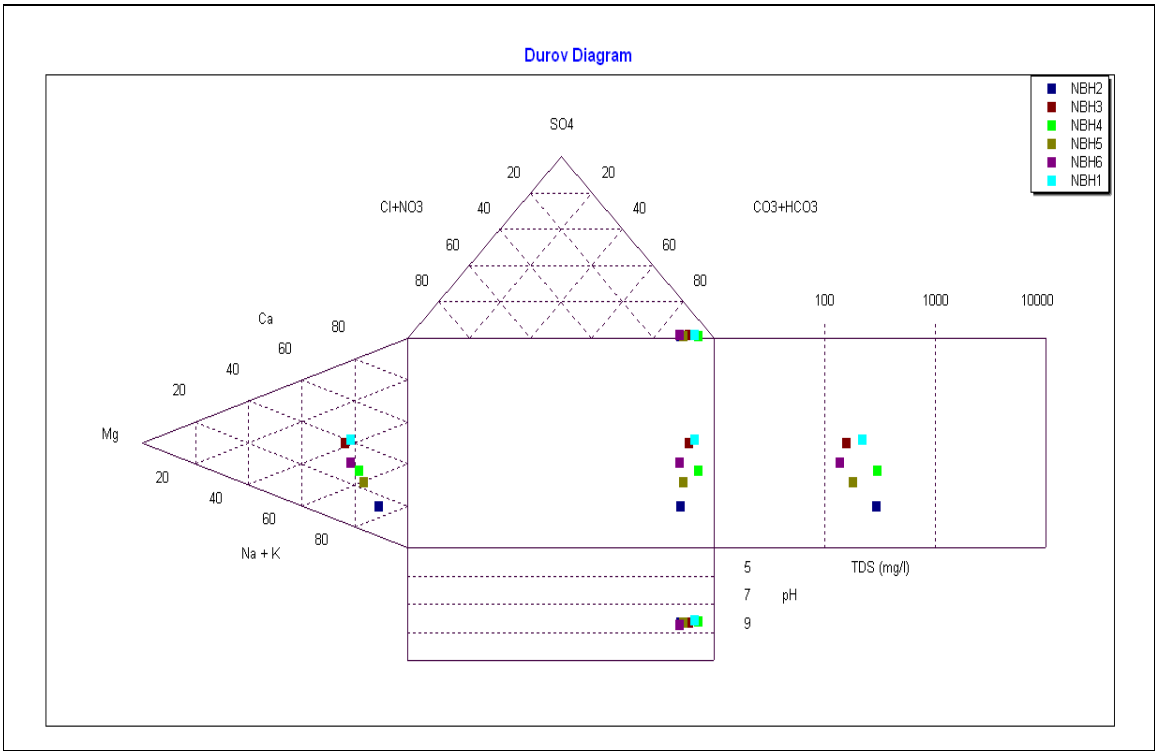


Figure 3-7: Durov Diagram for the DeWittekrans boreholes

4 Acid Base Accounting

Wait for results from lab – samples were submitted on 19 June 2009.

Acid Base Accounting (ABA) was undertaken in order to obtain a first order (preliminary) indication of the geochemical characteristics of the rock material associated with he coal seams. Static leach testing was conducted on material samples to determine the acid and neutralizing potential.

Samples were obtained from the roof, coal and floor material during the drilling phase in June 2009 and the samples were submitted to the Institute of Groundwater Studies (IGS) analytical laboratory at the University of the Free State for ABA analyses. The samples were collected from drilling chips obtained from the percussion drilling during the drilling of the monitoring boreholes. The samples were mainly collected from NBH3 and 5 and composite samples made up.

The ABA testing results are summarised in Table 4-1. The samples indicate a relatively ***high acid generation potential***. However, it must be noted that actual coal seam samples were also submitted for ABA; these will be removed during the opencast operations, only the overburden and footwall material will remain and exposed to oxidise. It can be seen that the shale layer above the coal seam in BH3 indicates a final pH of 1.18 and 3.88 kg/t of SO4. **This can be regarded as a high risk in terms of future and potential long-term acid mine drainage conditions. The test work done during this assessment must be regarded as preliminary and for indication purposes only. It is recommended that follow-up testing work be conducted and more detail be supplied accordingly.** A start value of 2000 mg/l SO4 will be applied in the numerical mass transport model based on the kg/ton averages obtained from the ABA.

Table 4-1: Results of the static ABA

5 Numerical Model

In order to investigate the behaviour of aquifer systems in time and space, it is necessary to employ a mathematical model. The model simulates steady and non-steady flow of groundwater in an heterogeneous flow system in which aquifer layers can be confined, unconfined, or a combination of confined and unconfined. Flow from external stresses, such as abstraction from boreholes, aerial recharge, evapotranspiration, flow to drains, and flow through riverbeds, can be simulated.

A groundwater flow and transport model was developed for the proposed De Wittekrans Mining Section in order to:

- Understand the pre-mining versus the anticipated operational and post-operational groundwater flow system.
- Simulate the effects of dewatering during the mining operations, particularly to simulate the drawdown cone that will be generated by the dewatering. This will assist in identifying the zone of influence as well as in planning for the mine water balance.
- Simulate the rise (rebound) in groundwater levels after mine closure.
- Predict the impacts that the mining operations will have on groundwater quality in the area (both during and after mining operations).
- Assist in identifying possible decant points.

The flow and contaminant transport model was constructed using version 4.3 of the Visual MODFLOW software developed by Waterloo Hydrogeologic Inc. (Waterloo, Ontario CANADA, 2008). The model is based on the conceptual model developed from the findings of the desktop and the baseline investigation.

The following aspects were identified that can negatively influence some of the modelling output data:

- Groundwater calibration data was only available in close proximity to the mining area and not distributed across the entire model grid area. Recommendations regarding monitoring requirements to bridge this data gap needs to be identified when the final mine plans are available.

5.1 Conceptualization and Model Grid Generation and Flow Modeling

Based on the available data, a conceptual model of the study area was formulated. The conceptual model characterises the aquifers that occur in the area, the spatial relation between the aquifers, aquifer thickness, general hydrogeology, and groundwater levels and flow directions.

The flow model was set up as a three layer, semi-confined / confined aquifer. The grid used for the model simulations is shown in Figure 5-1.

The borders of the numerical model were chosen at what were considered to be natural flow boundaries. These include the higher topographical areas to the east, west and south of the proposed mining area according to the natural surface drainage paths (streams).

The groundwater model domain covers an area of about 24 x 24 km, where approximately 40% was allocated as no-flow boundary cells. The model mesh size is 50 m x 50 m in the vicinity of the mining area. The rest of the model mesh was coarser to reduce model simulation time. This is standard practise and does not influence the accuracy of the results obtained.

River, general head boundaries and drain cells were applied within the model grid where applicable. No flow boundaries were applied to the sub-catchment boundaries. Drain nodes were also applied along certain stream sections to obtain realistic groundwater levels along the lower topographical areas.

Three percent recharge of the MAR was applied which is approximately 18 to 25 mm per annum.

Due to the complexity of the geological conditions, different parameter values were assigned to different lithologies and geological structures. For example, the dolerite has a low permeability while fractures or faults are expected to have a higher permeability. The initial parameters of the different lithologies were obtained from pumping test data, or cited from various existing literature. The initial parameter values were adjusted during the calibration process within realistic ranges in order to match the water level calculated by the numerical model to that measured in the field. The various parameters input into the model are shown in Table 5-1.

Table 5-1: Input parameters to the flow model

Parameter	Value used or range
Permeability	0.8 to 0.0001 m/day
Vertical permeability	0.08 to 0.00001 m/day
Specific storage coefficient	0.001 to 0.000061
Specific yield	0.15 to 0.01
Recharge	18 mm/yr
Porosity	0.05 to 0.18
Top elevation	Corresponded to surface topography

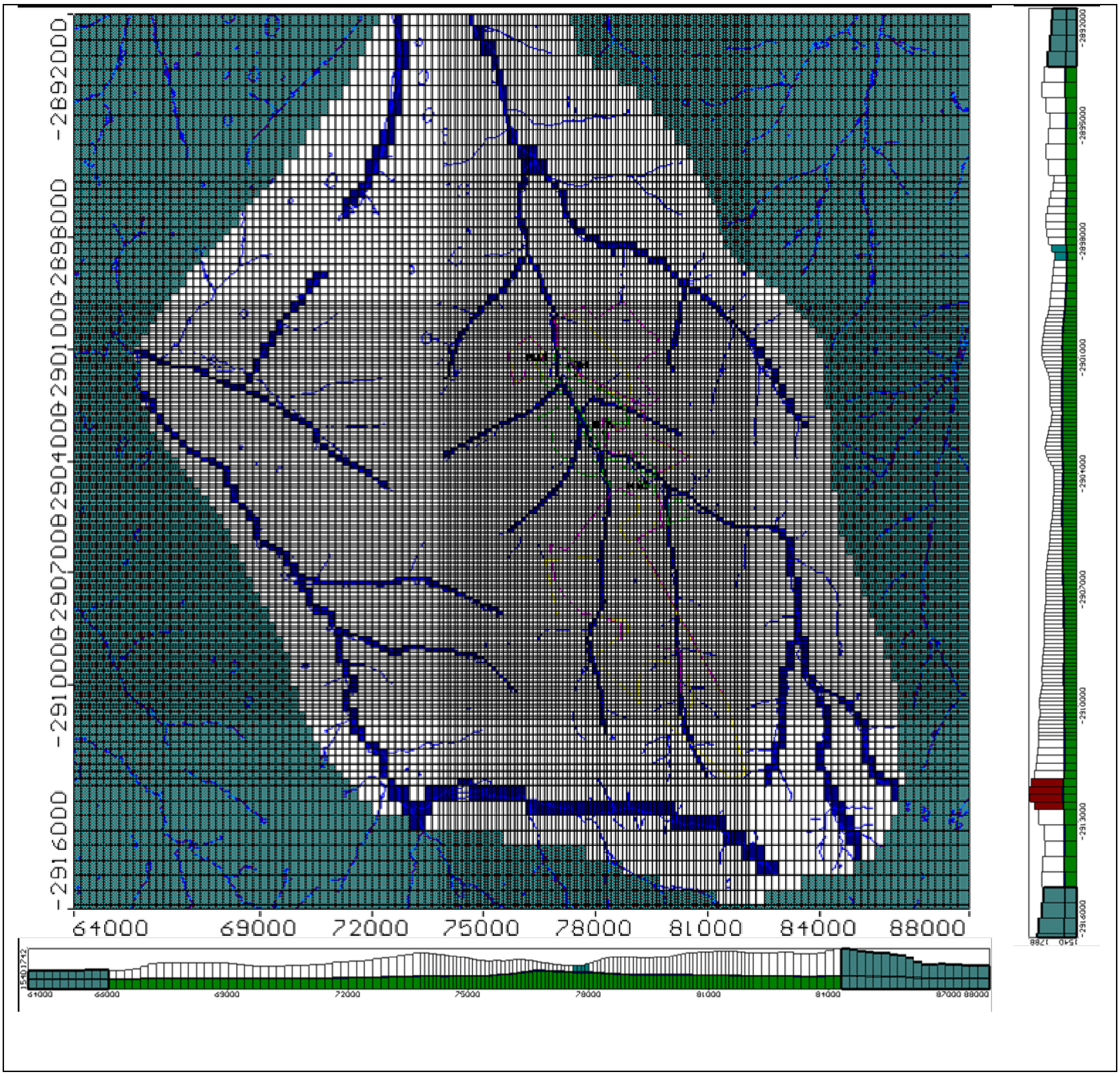


Figure 5-1: Model grid for the De Wittekrans assessment area

5.2 Flow Model and Calibration

The model was first calibrated for groundwater levels and flow in steady state, whereby the aquifer parameters are varied within realistic ranges as determined during the baseline study.

The groundwater levels calculated by the model were compared to those recorded during the historical and current investigations. Boreholes that were used as correlation points during the calibration process are listed in **Section 3.1**.

A sensitivity analysis indicates that the numerical model is most sensitive for changes in hydraulic conductivity; this implies that the accuracy of k values is very important and that these be confirmed when mining started by applying propoer pump testing to all boreholes.

The flow model was first run under steady state conditions to provide pre-mining groundwater levels and gradients. A plot of the correlation between calculated and observed groundwater levels is presented in Figure 5-2. It can be seen from the figure that a good correlation was obtained. It must be noted that certain NGDB data points were also applied to obtain a proper distribution of data points for the model grid.

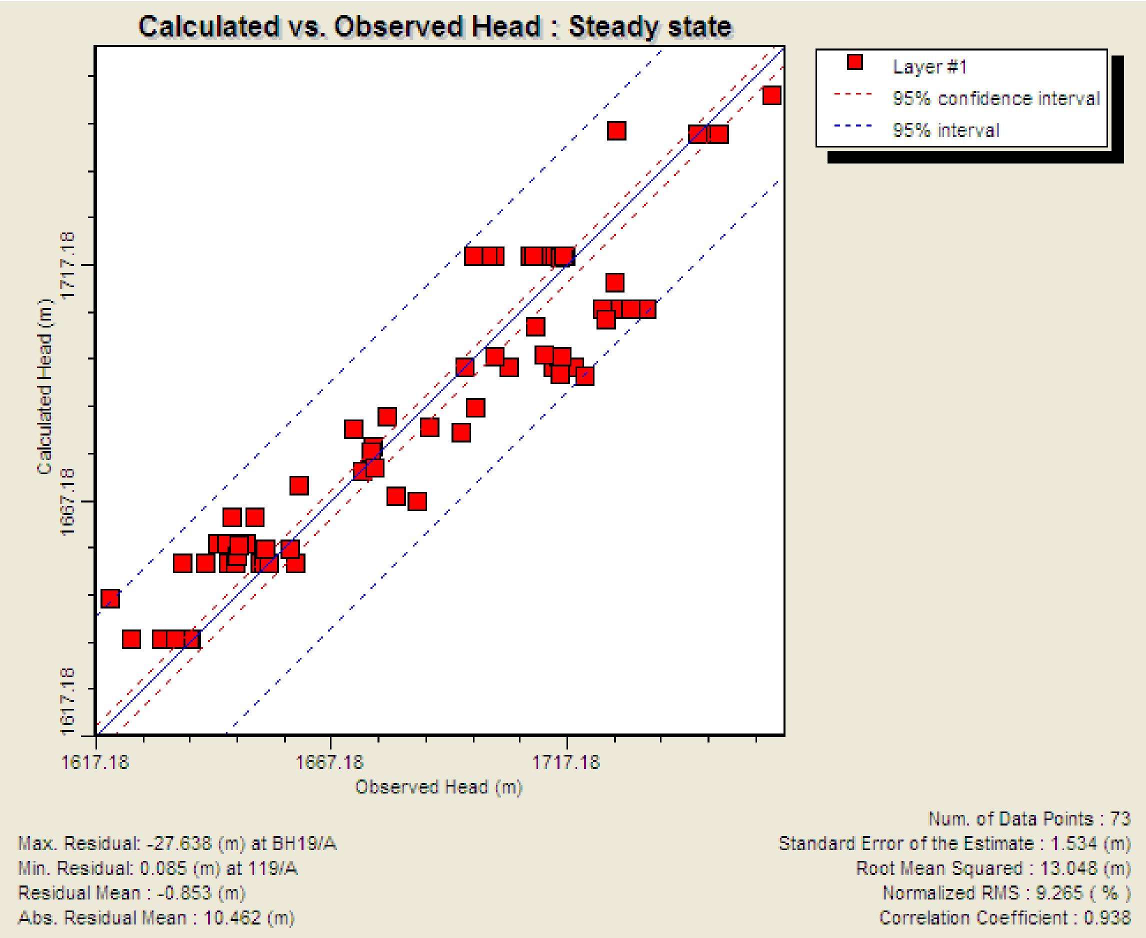


Figure 5-2: Calculated VS observation heads for the Ferreira numerical flow model

The simulated flow directions and calibrated flow model are presented in Figure 5-3.

It can be seen from the calibrated flow model that the streams and surface drainage paths control groundwater levels as well as ground water flow directions.

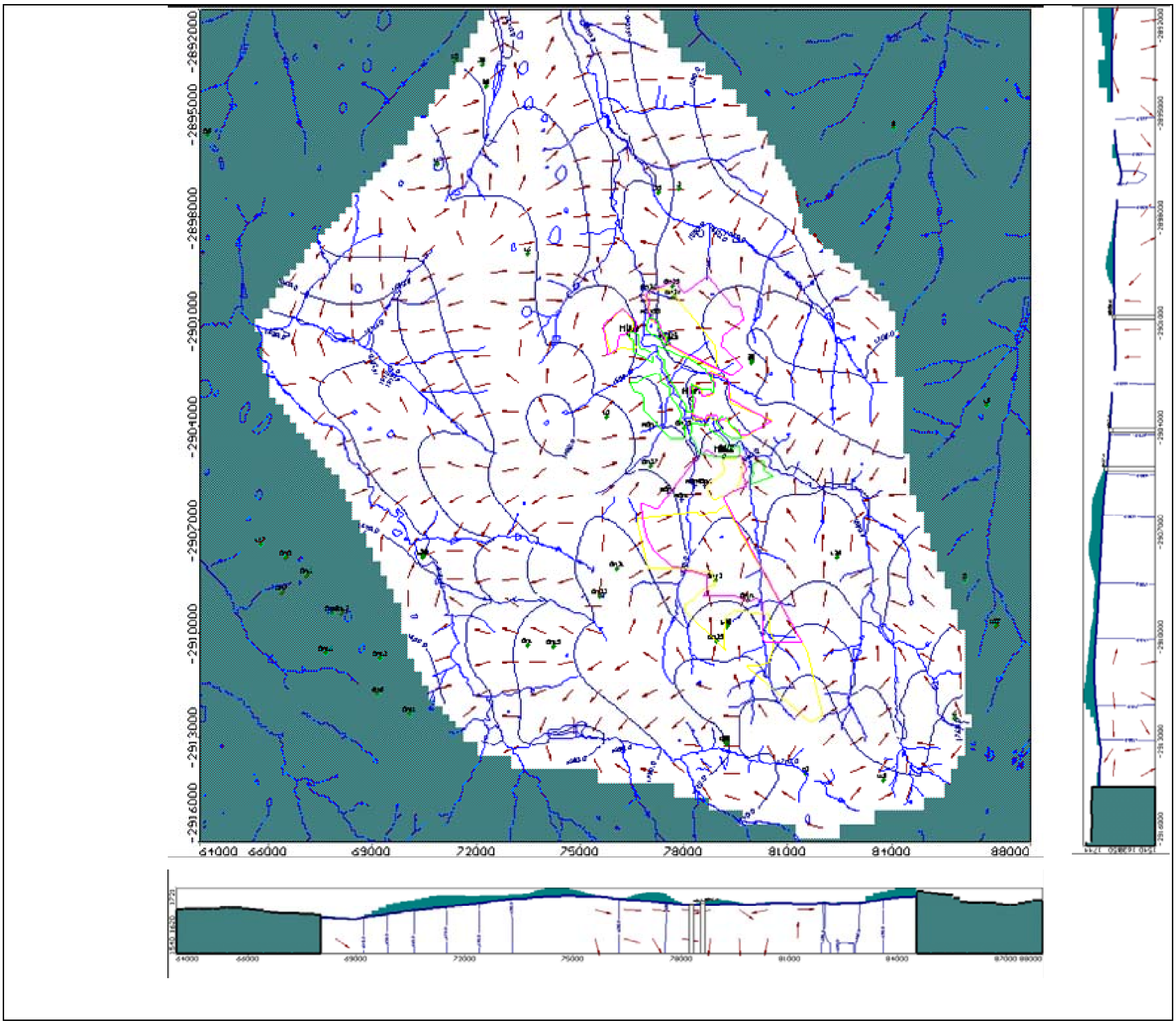


Figure 5-3: Calibrated flow and flow direction for the Ferreira numerical flow model.

5.3 Modelling of mining operations

5.3.1 Outline

The following information was obtained from the 1995 Hodgson Report:

Underground Mining:

Bord-and-pillar mining is usually done by continuous miners. A certain amount of blasting may be necessary. Hydraulic packer testing confirms that coal is generally permeable to water flow, except in deep mines. At levels deeper than 100 m, most fractures in the coal are filled with calcite. Calcite decreases permeability, while at the same time increasing the base potential of the coal to neutralise acid water.

Influx rates of water into underground bord-and-pillar areas are usually low. Water seeps are usually present in the coalface of new development. These dry up as mining progresses. The vertical hydraulic conductivity of the over- and underlying sediments is too low to convey significant amounts of water into underground mines. Sub-vertical fissures that yield water for a limited period (weeks rather than months) may be intersected on occasion. In exceptional cases, a sustained but low flow of groundwater may be intersected. Instances where coal mining had to stop for a length of time because of groundwater influx are almost non-existing.

The accurate quantification of groundwater influx into bord-and-pillar workings is difficult, if not impossible. A vast number of depressions in the coal floor exist where water accumulates before reporting to central facilities. Water on the coal seam is usually only notable when it interferes with mining. The data sited in this report on influx of water into bord-and-pillar areas are 28 years of observations in collieries (these values were first proposed by Hodgson in a 1995 report to the Water Research Commission).

In theory, influx into bord-and-pillar areas should depend on the area of a mine. This correlation is demonstrated in Figure 5-4.

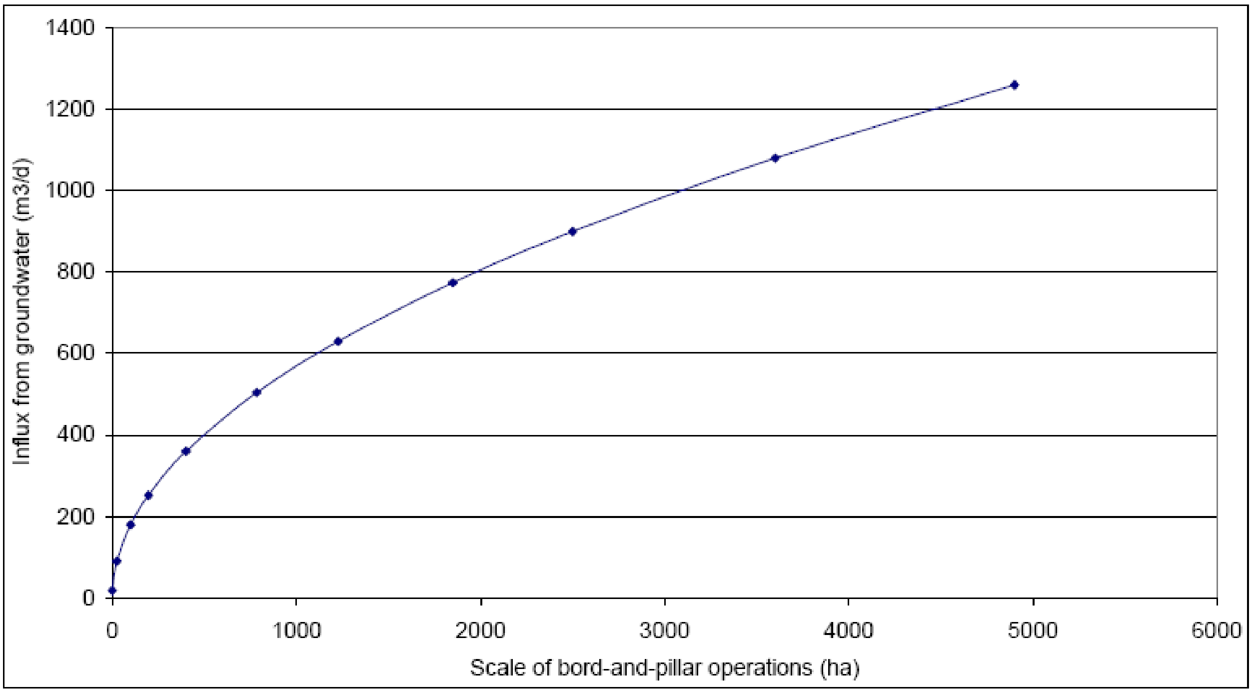


Figure 5-4: Empirical relationship between the area mined by bord-and-pillar methods and water influx for an average mining depth of 60 m (Hodgson, 1995).

In reality, influx is also dependent on mining depth. A sliding scale to incorporate the depth of mining is suggested in Table 5-2.

Table 5-2: Anticipated recharge to bord-and-pillar mining in the Mpumalanga Area (Hodgson, 1995)

Description	Recharge as a % of annual rainfall
Influx into bord-and-pillar mining > 100 m	1.0
Influx into bord-and-pillar mining 60 - 100 m	1.5
Influx into bord-and-pillar mining 30 - 60 m	2.0
Influx into bord-and-pillar mining 15 - 30 m	2.5
Influx into bord-and-pillar mining < 15 m	4 - 6
Recharge to undisturbed Karoo sediments	3.0

Opencast Mining:

The amount and intensity of rainfall add another set of variables to the recharge equation. Information has shown that recharge could vary by as much as 50 - 200% of the normal value at 10 percentile extremes (500 mm/a and 1 000 mm/a) for a typical rainfall time series in Mpumalanga.

Water in operating opencast pits is derived from various sources. Table 5-3 provides a breakdown of these sources.

Table 5-3: Water recharge characteristics for opencast mining (Hodgson, 1995)

Sources which contribute water	Water sources into opencast pits	Suggested average values
Rain onto ramps and voids	20 - 100% of rainfall	70% of rainfall
Rain onto unrehabilitated spoils (run-off and seepage)	30 - 80% of rainfall	60% of rainfall
Rain onto levelled spoils (run-off)	3 - 7% of rainfall	5% of rainfall
Rain onto levelled spoils (seepage)	15 - 30% of rainfall	20% of rainfall
Rain onto rehabilitated spoils (run-off)	5 - 15% of rainfall	10% of rainfall
Rain onto rehabilitated spoils (seepage)	5 - 10% of rainfall	8% of rainfall
Surface run-off from pit surroundings into pits	5 - 15% of total pit water	6% of total pit water
Groundwater seepage	2 - 15% of total pit water	10% of total pit water

Consultants generally accept the recharge and influx values suggested in this chapter. These values were first proposed by Hodgson in a 1995 report to the Water Research Commission, and have remained unchanged. Differences arise as a result of varying pit sizes, states for rehabilitation and final run-off coefficients. These factors are mining- and time-related. Mine plans are revised on a regular basis, and unless exactly the plans are used, different recharge values are obtained.

In this evaluation, such factors have become part of the dataset and geographic information system. All that is required is an update of the values when circumstances change.

5.3.2 De Wittekrans Dewatering

Mine dewatering will take place during the operational phase to ensure a safe working environment. This will cause dewatering of the surrounding aquifers, and a subsequent drawdown in groundwater levels. Aquifers will supply groundwater at varying fluxes according to relative hydraulic gradients and conductance. The resultant cone of depression[9] will expand over time due to the increasing area of the underground mining and continued dewatering of the mine workings.

Due to the relatively low hydraulic conductivity of the rock material, the extent of the drawdown cone will be limited in extent, displaying steep flow gradients.

The dewatering of the proposed opencast and underground mining development was simulated using drain nodes. These nodes allow the setting of a reference level to which the mining area will be dewatered over a specified time period. The level was determined by applying the coal floor elevation data for the C-Lower Seam.

Table 5-4 and Figure 5-5 shows the applied mining schedule for the model (the data was obtained from the SRK report[10]; it is however important to confirm if the correct interpretation of the data was applied):

According to the data from the SRK report both the B and C seam will be mined during the open-cast phase and approximately 160 000 tpm from each seam will be mined. This requires a mining advance rate

[9] Cone of Depression – A depression in the potentiometric surface of a body of groundwater that has the shape of an inverted cone and develops around a well/mine shaft/open pit mine from which water is being withdrawn.

[10] Development of the De Wittekrans Coal Project, near Hendrina, Mpumalanga Province, SRK Consulting, Report No 399526, April 2009, for Mashala Resources

per month on the opencast operations of some 800 to 1000 m. Six open-cast blocks will be mined, the locations and applied time frames can be seen from Figure 5-6.

Underground mining operations will require an average production of 270,000tpm (150,000tpm from the B Seam operations and 120,000tpm from the C Seam operations) to be achieved and maintained. It is expected that three mechanised continuous mining sections in the B Seam, each producing 55,000tpm, and that three mechanised continuous mining sections, using roadheaders, in the C Seam, each producing 40,000tpm (due to the assumed issues of the intra seam partings and "floating stone"), will be required. This requires a mining advance per month in each underground section of some 100-120m. For the groundwater model, the proposed four underground mining blocks (as per the SRK report) were scheduled according to the layout as per Figure 5-7.

Table 5-4: Applied life of mine schedule for the DeWittekrans numerical flow model

Description	**Year**	**Time in years**	**Time in days**	**Description**	**Year**	**Time in years**	**Time in days**
Start OC	2010	0	0	**Mine Closure**	**2031**	**21**	**7665**
OC only – section 1	2011	1	365	5	10155	26	9490
OC only – section 1	2012	2	730	10	20310	31	11315
OC only – section 1 and 2	2013	3	1095	20	40620	41	14965
OC only – section 2	2014	4	1460	30	60930	51	18615
OC only – section 2	2015	5	1825	50	101550	71	25915
Start UG	2016	6	2190	70	142170	91	33215
OC and UG	2017	7	2555	80	162480	101	36865
OC and UG	2018	8	2920	100	203100	121	44165
OC and UG	2019	9	3285				
OC and UG	2020	10	3650				
Open Cast stop	2021	11	4015				
UG only	2022	12	4380				
UG only	2023	13	4745				
UG only	2024	14	5110				
UG only	2025	15	5475				
UG only	2026	16	5840				
UG only	2027	17	6205				
UG only	2028	18	6570				
UG only	2029	19	6935				
UG only	2030	20	7300				

Note: When the final mine plan is available the groundwater model should be adjusted accordingly.

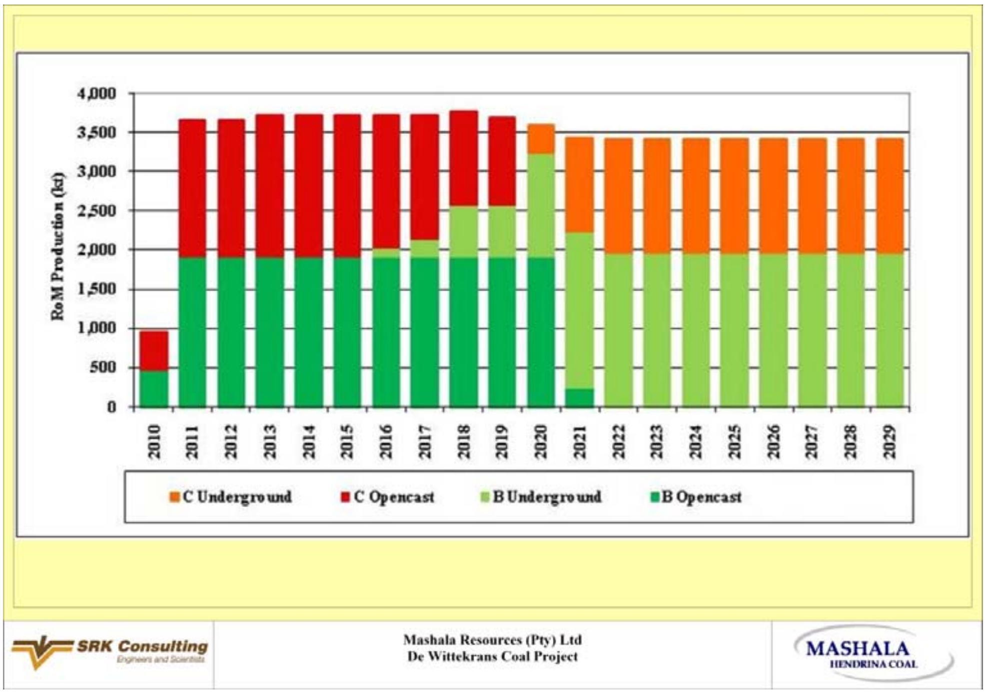


Figure 5-5: Planned production rates (SRK, 2009)

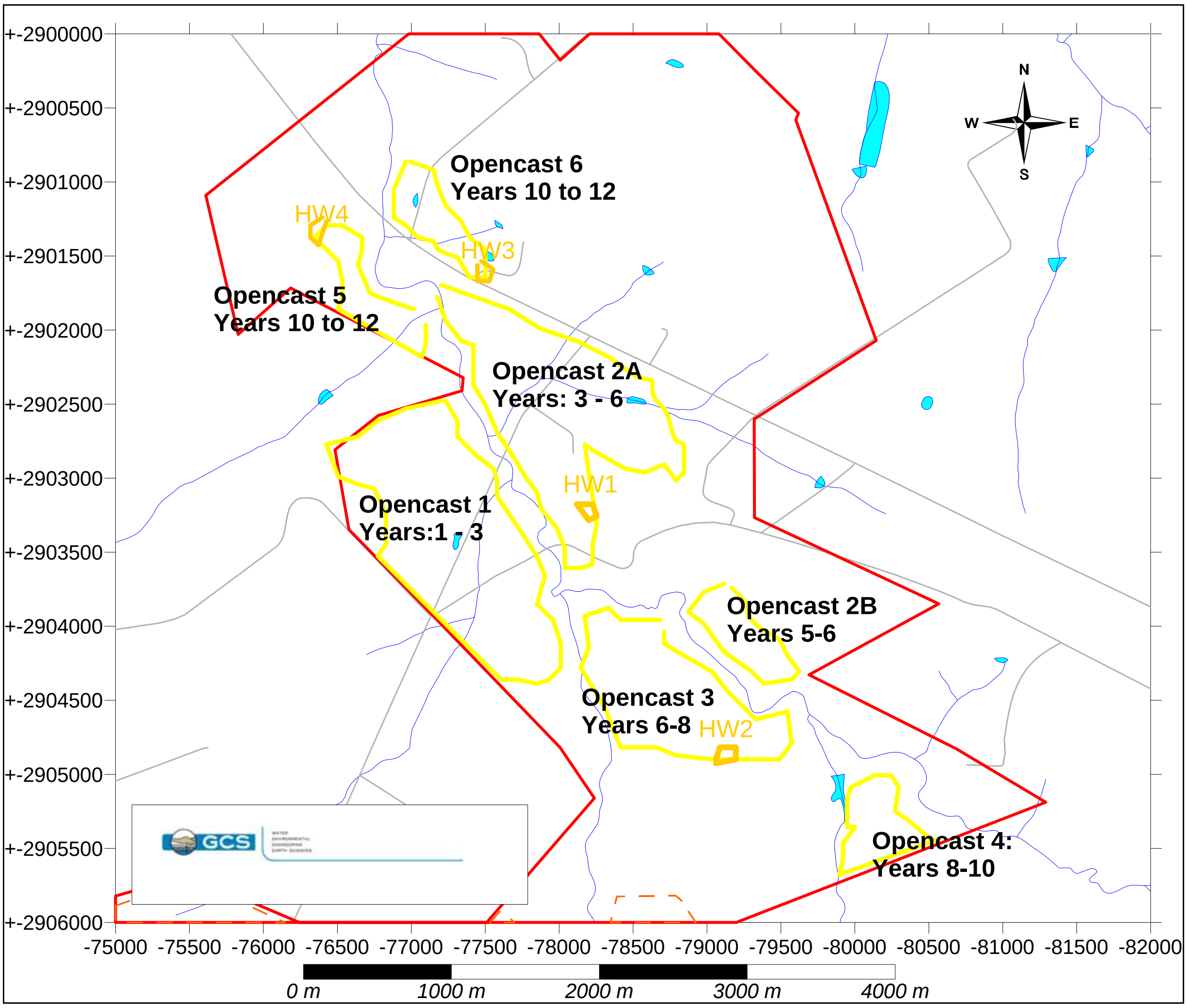


Figure 5-6: Proposed opencast mining blocks for the De Wittekrans coal mine

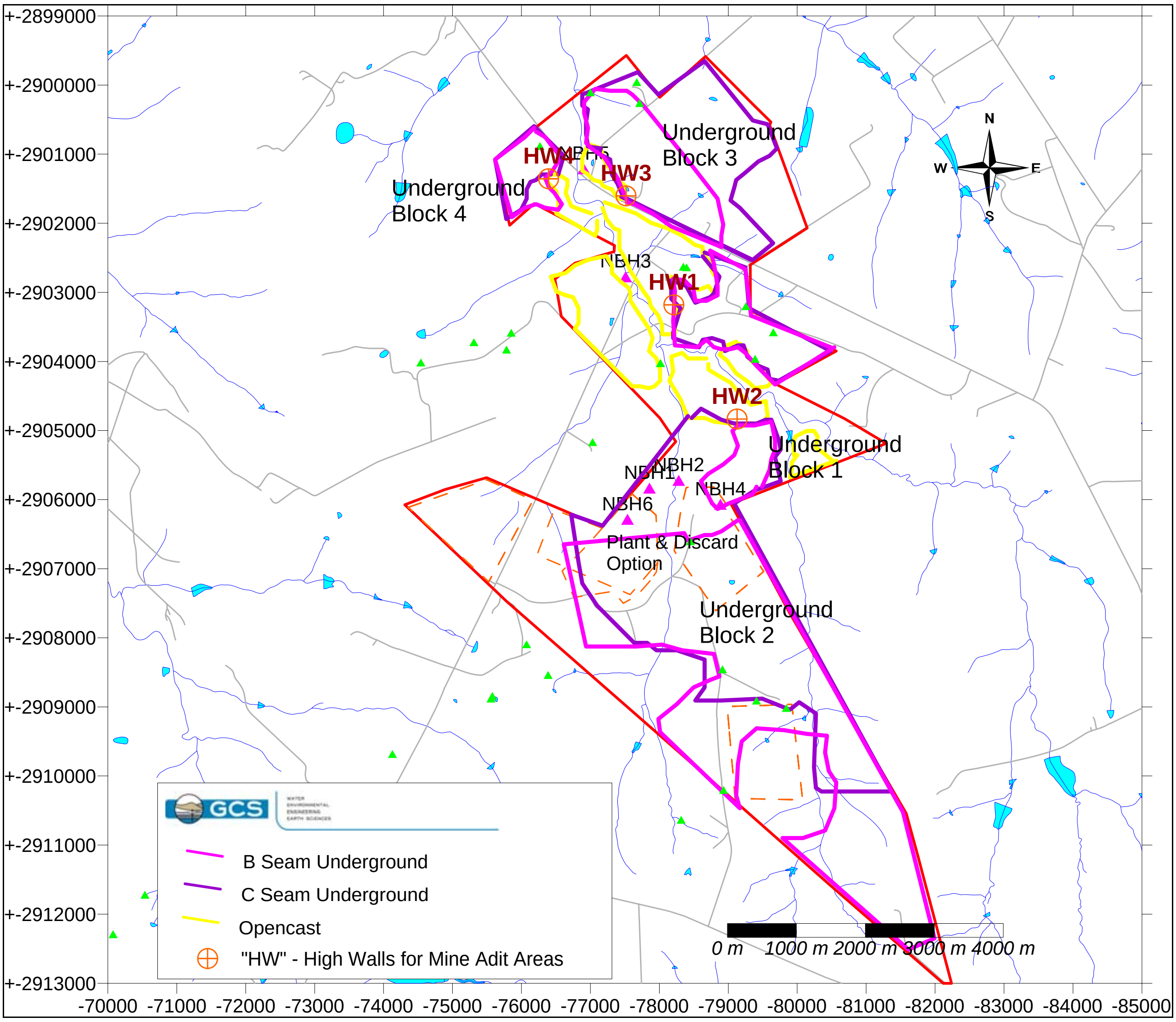


Figure 5-7: Proposed underground mining blocks for the De Wittekrans coal mine

The results of the flow model dewatering simulations can be viewed as follows:

Figure 5-8: 5 Years after mining has started; opencast mining is in progress at Block 2. Block 1 is completed and rehabilitated.

Figure 5-9: 10 Years after mining has started; Opencast Blocks 1 to 5 were mined and current mining is at opencast block 6 which is the last block to be mined. Underground mining started in year 6 and is now progressing in Underground Block 1.

Figure 5-10: 15 Years after mining has started; Underground mining is now at Block 2 and Block 1 is completed and in the process of recharging.

Figure 5-11: 21 Years after mining has started and the life of mine has been reached. Mine closure and final rehabilitation will commence. This can be regarded as the maximum zone of influence caused by the mine de-watering activities. The 1 m drawdown contour line indicates the zone of influence around the mining area. It can be seen that the zone of influence on groundwater levels ranges between 200 m and 800 m around the mining area.

It can be seen from the model predictions that the opencast mining activities will have a more direct impact on the weathered aquifer in terms of de-watering and recharge. Underground mining will occur at depths >30m; this implies mining below sandstone and shale layers that is less weathered and more impermeable. It is therefore suggested that the impact on surface water flow and shallow base-flow will be less.

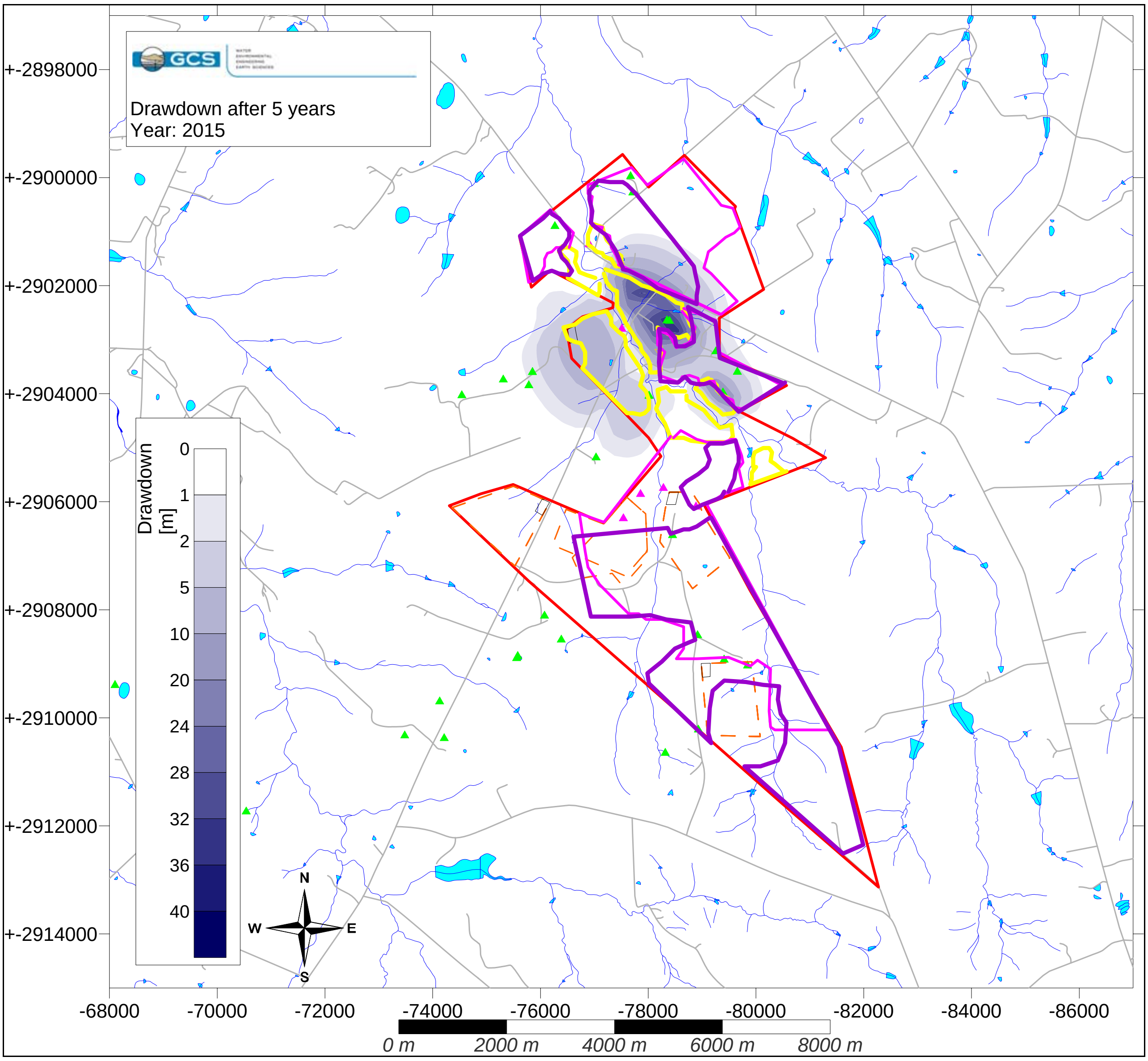


Figure 5-8: Dewatering simulation after 5 years for the De Wittekrans opencast mining area

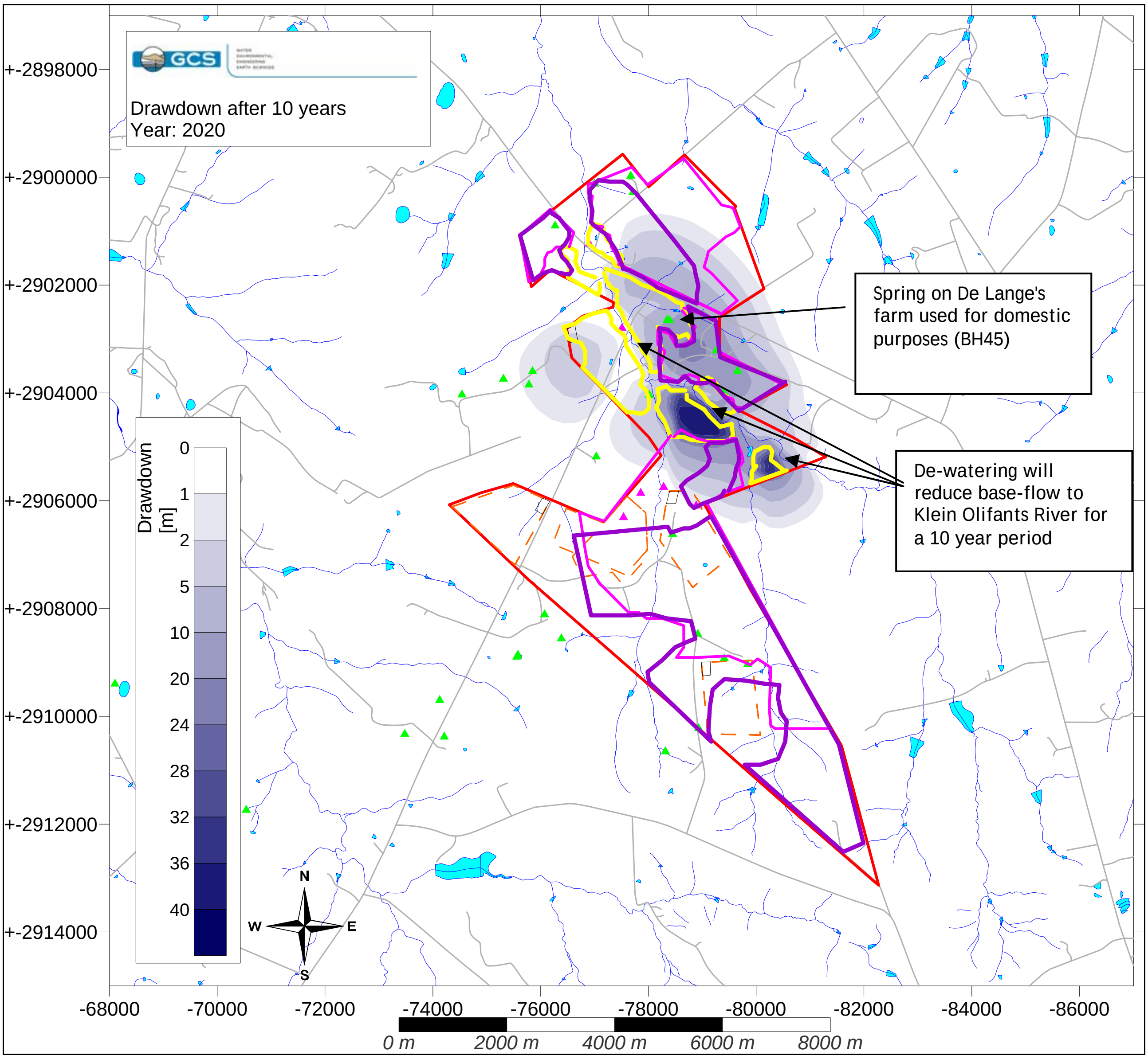


Figure 5-9: Dewatering simulation after 10 years –De Wittekrans opencast and underground mining area

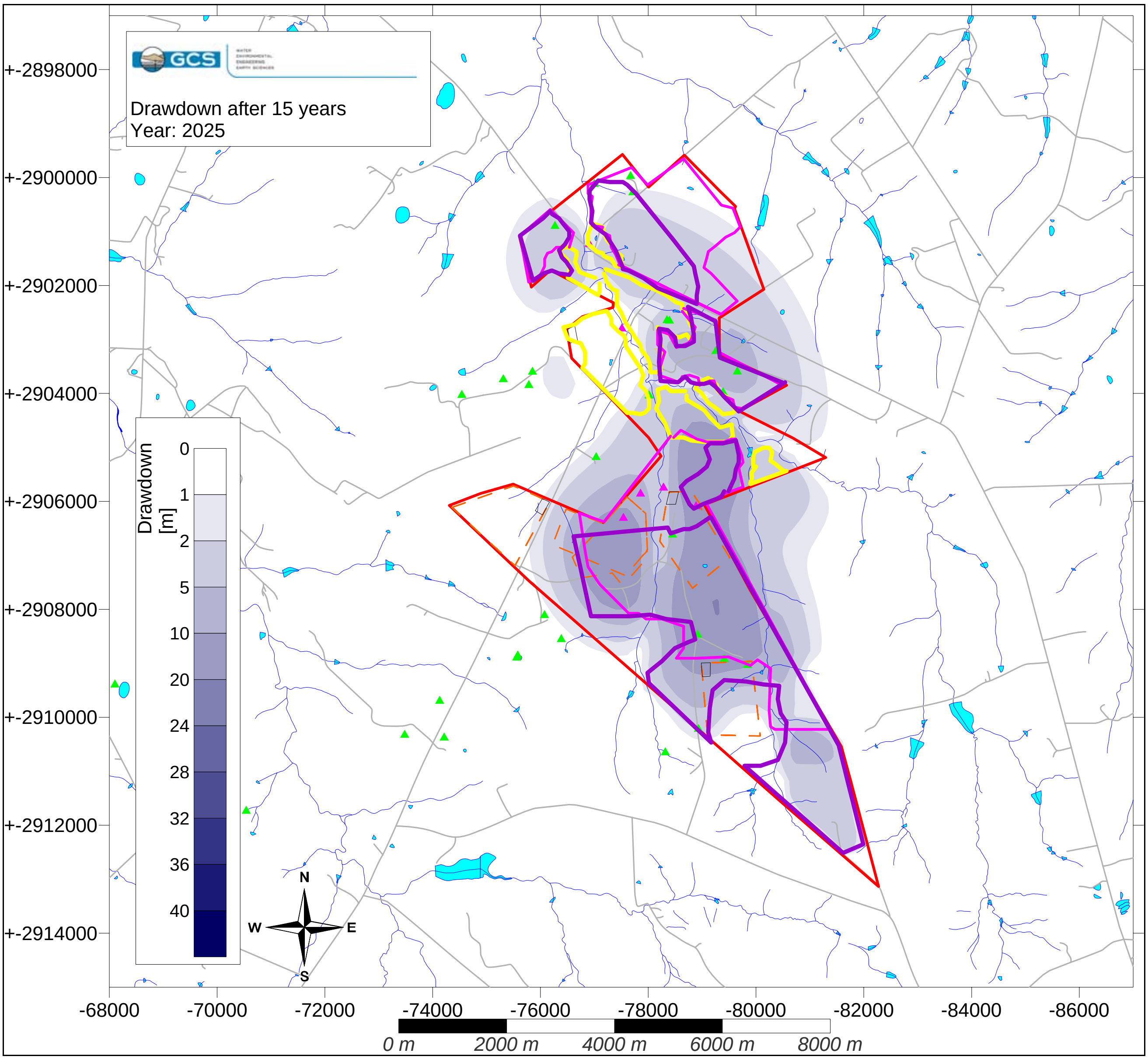


Figure 5-10: Dewatering simulation after 15 years –De Wittekrans opencast and underground mining area

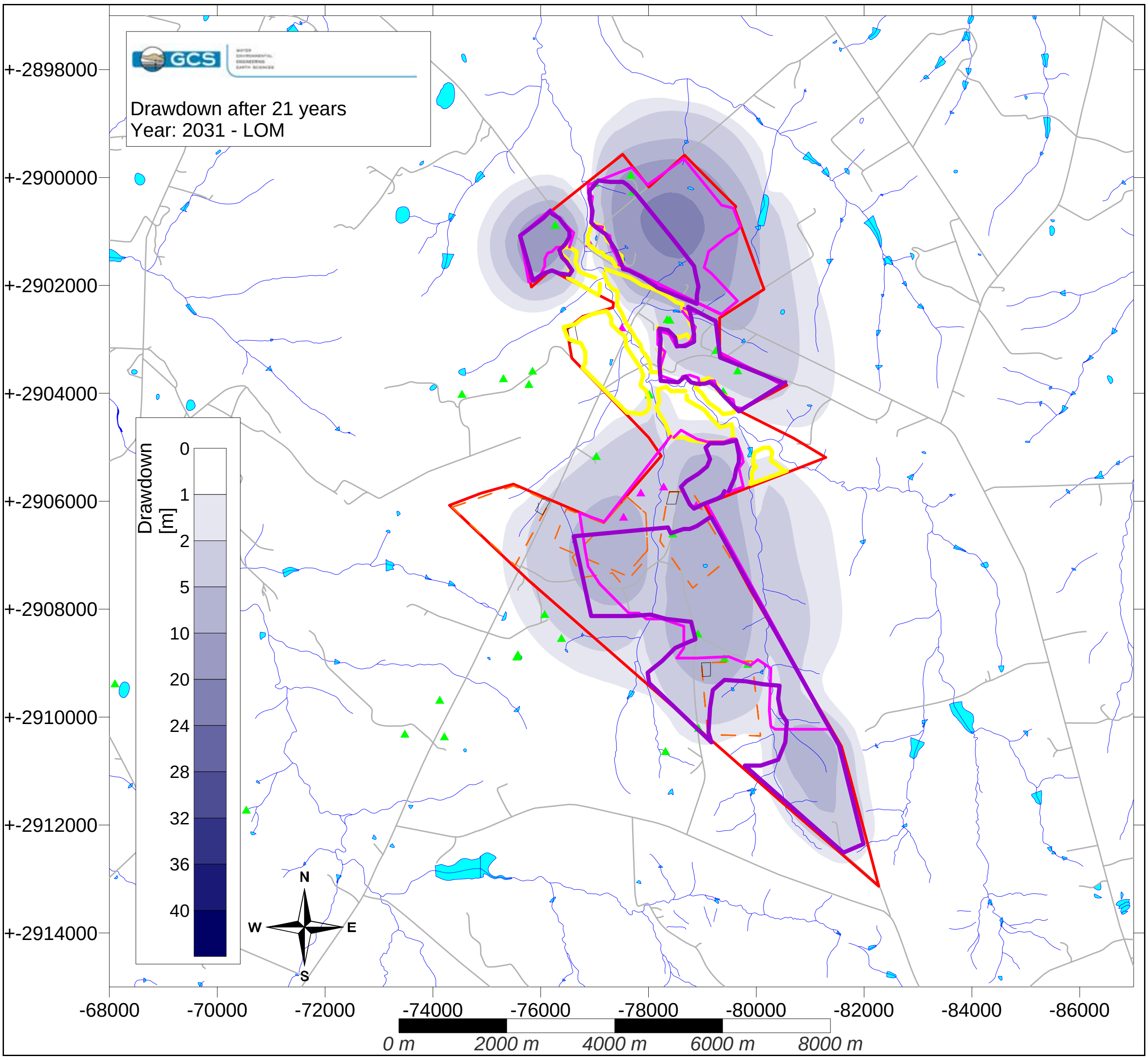


Figure 5-11: Dewatering simulation after 21 years –De Wittekrans opencast and underground mining area

Predicted Inflow Rates

Predicted inflow rates were obtained from the modelling simulations. The conceptual mining area was sub-divided into sub-sections. The 9 sub-sections represent mine development over time; e.g. section 1 is developed and mined during the first 6 months, section 2 over the next 6 months, section 3 over the next 1 year, etc. Different zones were allocated to each section within the groundwater model. Zone budgets for the drain nodes are then exported and the inflow rates can be captured accordingly.

Table 5-5 shows the predicted inflow rates for the opencast areas (these values must be treated as an indication and a 20% up/down be allowed to cover existing uncertianties). These values must be applied to design the mine-s water balance and associated containment dams.

Table 5-6 shows the predicted inflow rates for the underground areas.

Table 5-7 shows the combined inflow rates

Figure 5-12 indicates the predicted inflow rates over time for the opencast and underground workings separately. Figure 5-13 shows the combined inflow rates over time. The flow model simulation indicates an initial opencast mine inflow rate of approximately 100 m^3/day with an average of about 65 over the 12 year period. *It can be seen that available groundwater will significantly increase from year 8 and decrease again from year 15. it is recommended that the mine plan be adjusted to allow for smaller chnages in available groundwater. It is appreciated that rapid increases will result in difficult water balance management.*

As mining continues underground from years 6 to 21 and a bigger area is developed with increasing depth below the regional groundwater level, the inflow rate can increase again to an approximate average of 200 m^3/day (about 2.5 l/sec) water are released from storage. The inflow rate will gradually decrease and stabilise when the system moves into equilibrium during the underground mining phase.

Table 5-5: Calculated Inflow rates for the proposed opencast mine

Opencast						
Year	**Days**	Zone 2	Zone 3	Zone 4	Zone 5	**TOTAL m³/day**
1	**365**	108.4				**108.4**
2	**730**	91.1				**91.1**
3	**1095**	102.2				**102.2**
4	**1460**		151.1			**151.1**
5	**1825**		145.0			**145.0**
6	**2190**		140.7			**140.7**
7	**2555**			128.2		**128.2**
8	**2920**			120.2		**120.2**
9	**3285**			117.3		**117.3**
10	**3650**			114.5		**114.5**
11	**4015**				66.7	**66.7**
12	**4380**				63.1	**63.1**
13	**4745**					**0.0**
14	**5110**					**0.0**
15	**5475**					**0.0**
16	**5840**					**0.0**
17	**6205**					**0.0**
18	**6570**					**0.0**
19	**6935**					**0.0**
20	**7300**					**0.0**
21	**7665**					**0.0**
AVERAGE						**64.2**

Table 5-6: Calculated Inflow rates for the proposed underground mine

Underground											
Year	Days	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	TOTAL
		m³/day									
1	**365**										**0.0**
2	**730**										**0.0**
3	**1095**										**0.0**
4	**1460**										**0.0**
5	**1825**										**0.0**
6	**2190**	171.6									**171.6**
7	**2555**	160.0									**160.0**
8	**2920**	90.3	155.0								**245.3**
9	**3285**	74.9	150.2	50.0							**275.2**
10	**3650**	21.8	149.6	233.3							**404.7**
11	**4015**			470.3							**470.3**
12	**4380**			525.9	55.1						**581.0**
13	**4745**				397.9	100.0	39.3				**537.2**
14	**5110**				357.0	100.0	86.0				**543.0**
15	**5475**					159.9	425.1				**585.1**
16	**5840**						296.0				**296.0**
17	**6205**							357.6			**357.6**
18	**6570**							260.7			**260.7**
19	**6935**							48.7	219.7		**268.4**
20	**7300**								164.6		**164.6**
21	**7665**									48.6	**48.6**
AVERAGE											**255.7**

Table 5-7: Calculated Inflow rates for both the opencast and underground workings

Combined			
Year	Days	TOTAL	
		m³/day	l/sec
1	365	**108.4**	**1.3**
2	730	**91.1**	**1.1**
3	1095	**102.2**	**1.2**
4	1460	**151.1**	**1.7**
5	1825	**145.0**	**1.7**
6	2190	**312.3**	**3.6**
7	2555	**288.2**	**3.3**
8	2920	**365.4**	**4.2**
9	3285	**392.5**	**4.5**
10	3650	**519.1**	**6.0**
11	4015	**536.9**	**6.2**
12	4380	**644.2**	**7.5**
13	4745	**537.2**	**6.2**
14	5110	**543.0**	**6.3**
15	5475	**585.1**	**6.8**
16	5840	**296.0**	**3.4**
17	6205	**357.6**	**4.1**
18	6570	**260.7**	**3.0**
19	6935	**268.4**	**3.1**
20	7300	**164.6**	**1.9**
21	7665	**48.6**	**0.6**
AVERAGE		**319.9**	**3.7**

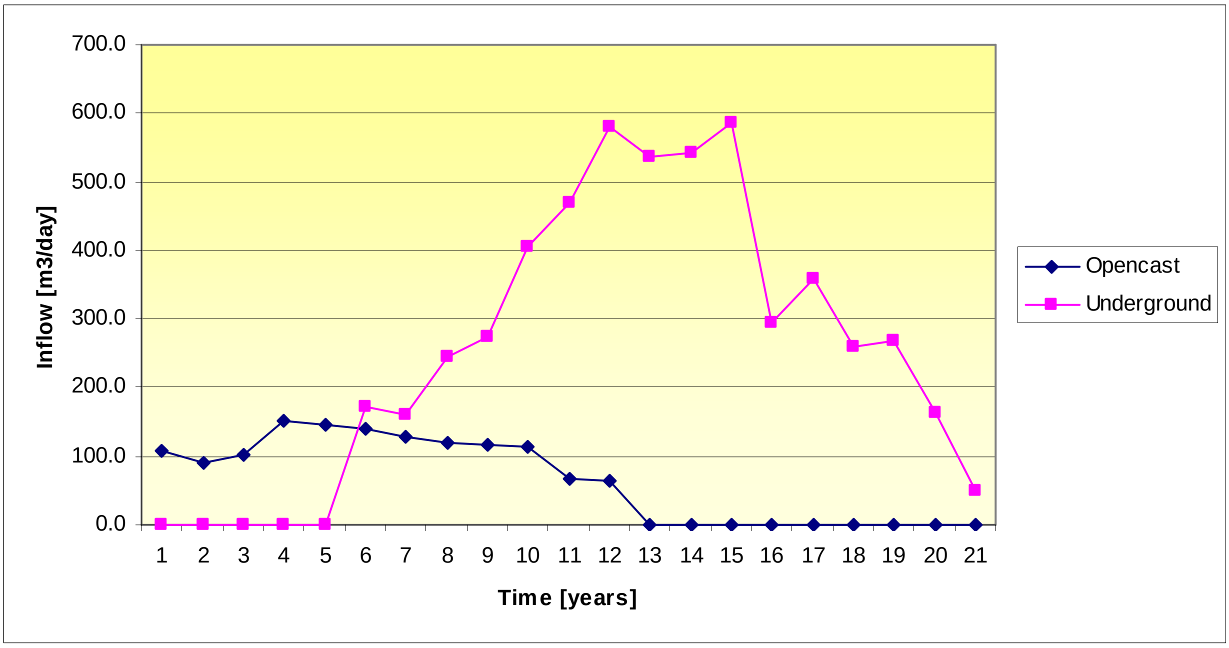


Figure 5-12: Predicted Inflow rates for the proposed De Wittekrans mining sections separately

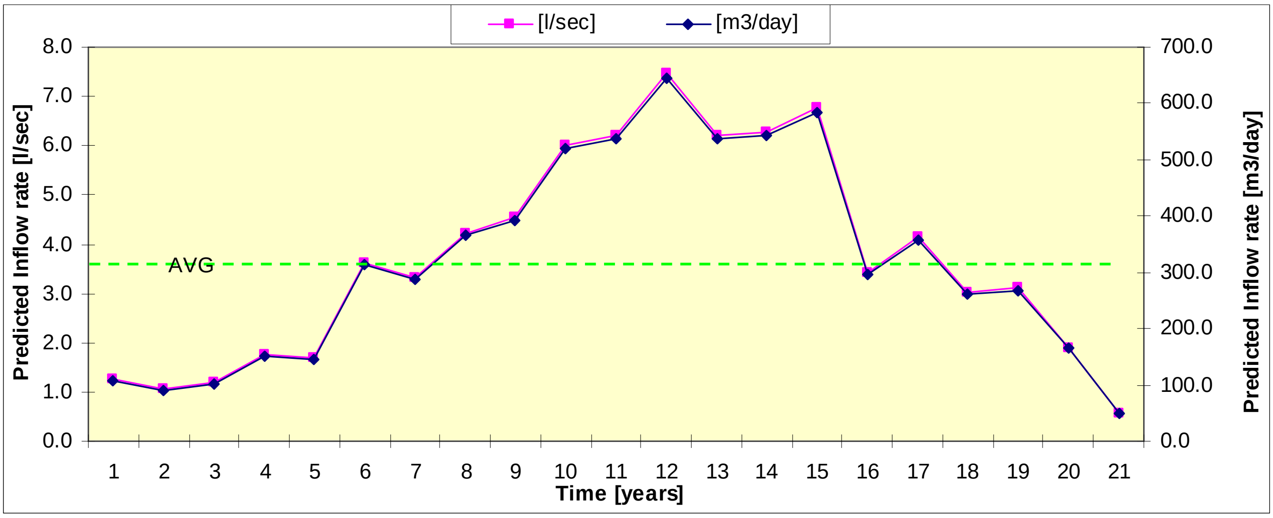


Figure 5-13: Predicted Inflow rates for the proposed De Wittekrans mining sections combined

<u>Impact on the perennial and non-perennial rivers, streams and fountains in the proposed zone of influence of the mine:</u>

Base-flow in the shallow perched aquifer usually occurs above impermeable dolerite sills, ferricrete, clay and sandstone layers. Where the streams cut through or onto these formations, water tends to seep from the rock contact zones into the streams. Although rainfall and run-off dominate regional stream flow, seepage from groundwater also contributes. It can be seen from Figure 5-9 that the maximum drawdown area only intersects the Klein Olifants River, which runs through the proposed opencast area. De-watering of the opencast sections will impact on the base flow towards the Klein Olifants River for the 1st 10 years of the mining project. The opencast areas will be recharged fairly rapidly initially (during and directly after closure) due to the nature of the backfilled material. This will increase the recovery rate of the regional groundwater levels significantly and will reduce the impact of mining on the Klein Olifants River accordingly.

The impact of the mining activities on the nearby streams can therefore be regarded as significant during operations but it should decrease with time. The spring located on Mr. De Lange's farm will also be impacted on since it is located within opencast block 2A (refer to Figure 5-9). The significance of this site as existing water supply source needs to be identified because of the possible long-term or permanent impact.

The zone budget function was again applied and zones were allocated to the Klein-Olifants system to obtain an indication of the impact on the system due to de-watering activities. The zones were applied to the entire 1st model layer and include the aquifer as well as the stream basins and can be viewed from Figure 5-14. The graphs for each zone are presented by Figure 5-15. The reduction in aquifer flow and the recovery thereof afterwards can be seen.

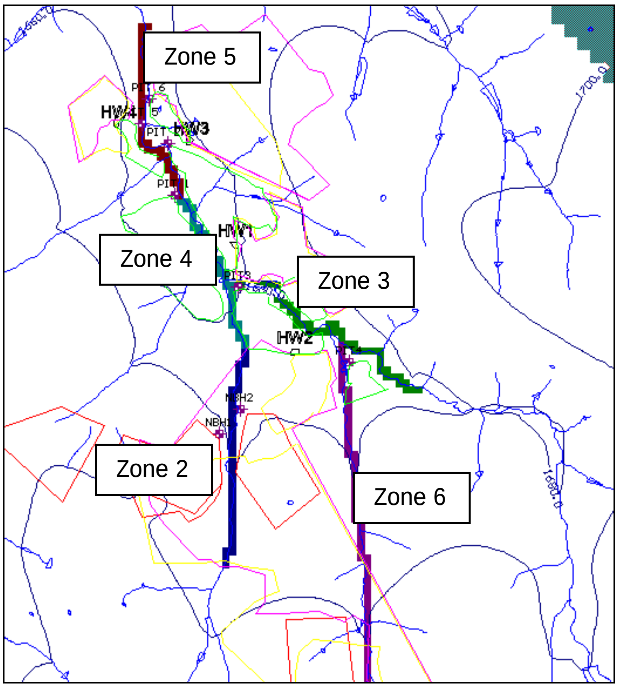
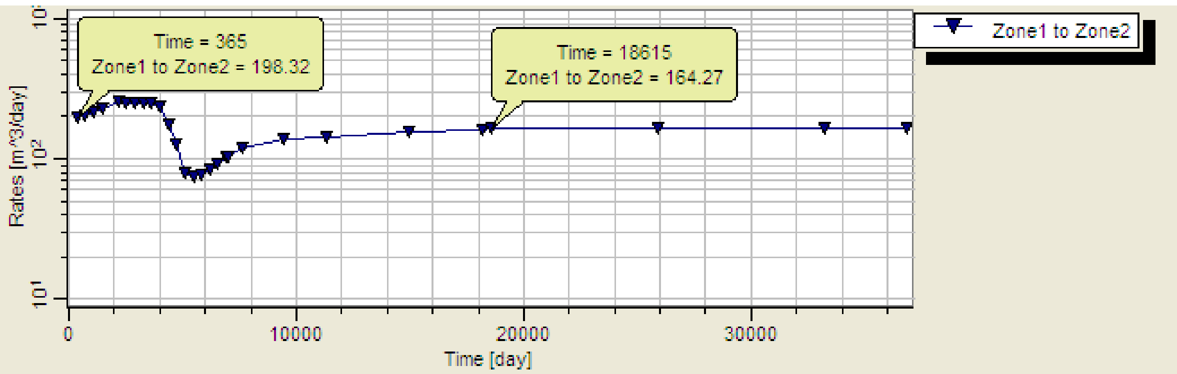


Figure 5-14: Stream zones for baseflow reduction calculation/prediction



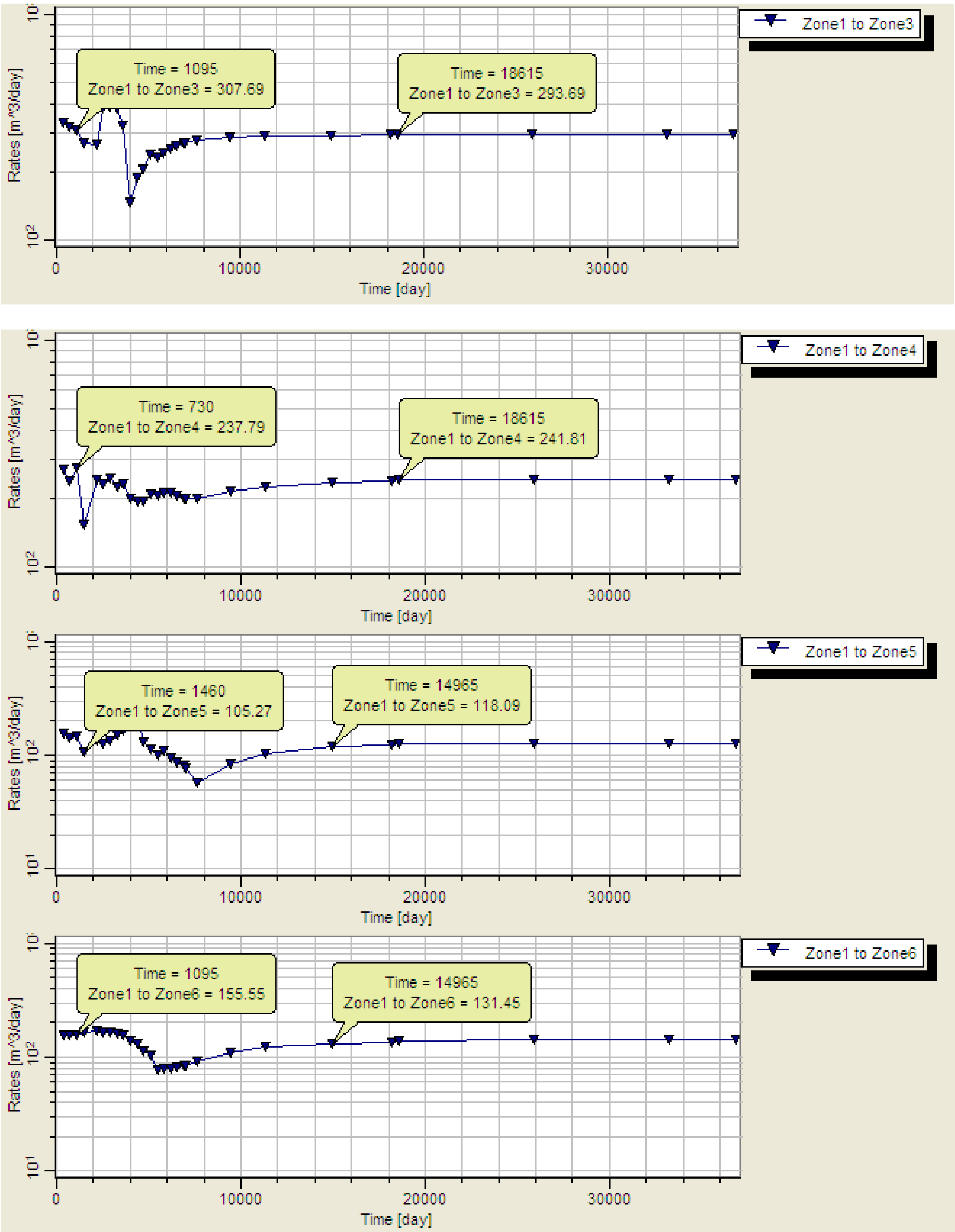


Figure 5-15: Zone inflows according to layer 1 along streams

<u>Groundwater level recovery:</u>

Groundwater levels will recover during the decommissioning and post closure phase, due to mine dewatering being stopped.

The simulated rebound and change in groundwater level in the area is shown in Figure 5-16. The figure shows that the groundwater levels will initially recover at a faster rate, due to higher flow gradients. Over time, as the groundwater level rises and the flow gradient decreases, the recovery rate will decrease. The groundwater levels in close proximity to the underground workings will stabilise after approximately 20 to 40 years. It must be noted that the underground voids will keep on de-water the surrounding aquifer as it is recharged with groundwater and gradually fill up to reach a level of approximately 1670 to 1680 mamasl. However, if the mine is backfilled with slurry material this process can be changed significantly (it is suggested that this aspects needs to be clarified and confirmed).

Figure 5-17 shows the predicted drawdown after 51 years or 30 years after closure in monitoring and hydrocensus boreholes situated in close proximity to each of the mining sections.

The following section looks into the possibility of associated poor quality decant/seepage.

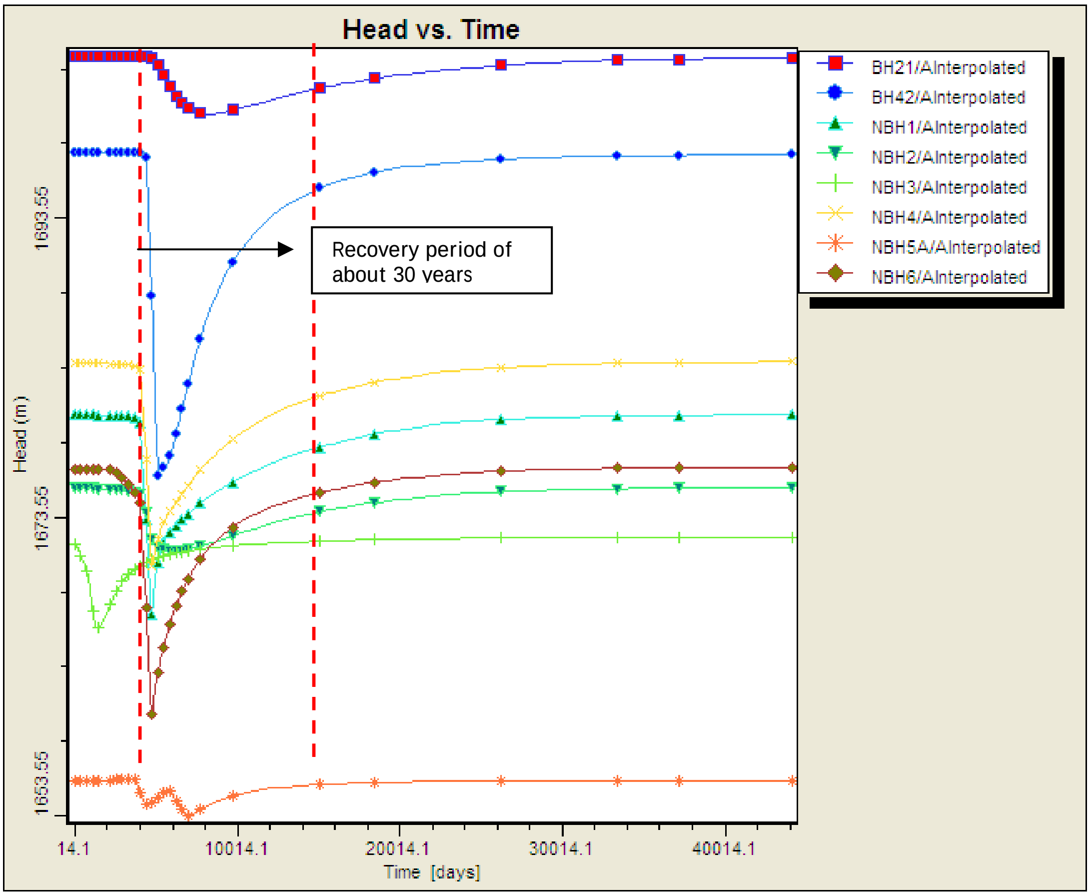


Figure 5-16: Simulated rebound period from observation boreholes within the Mining Area

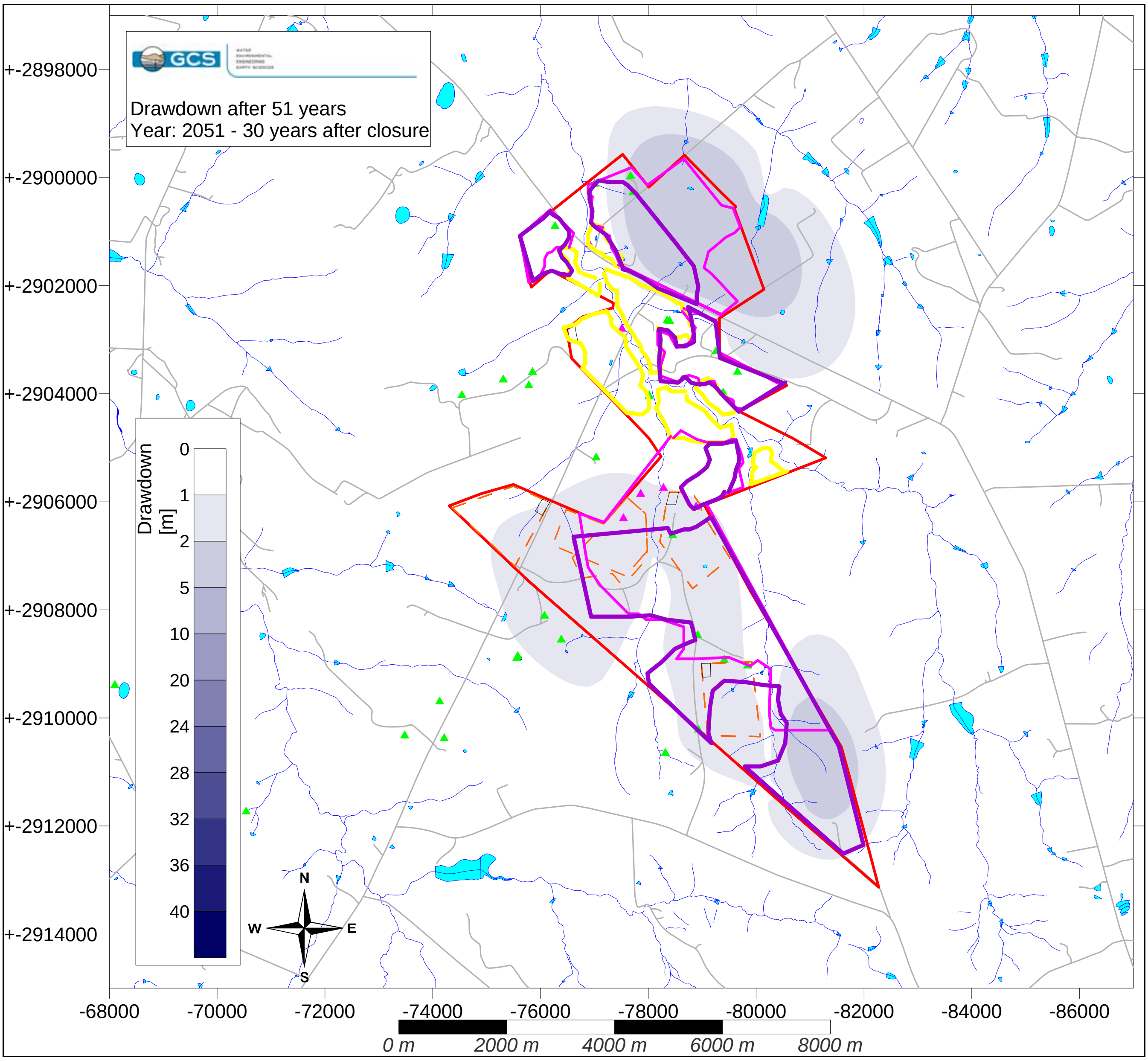


Figure 5-17: Residual dewatering simulation after 51 years –De Wittekrans opencast and underground mining area

Possible Decant/Diffuse Seepage:

When the mining activities stop, the groundwater levels will start to recover to the same level, or almost to the natural pre-mining groundwater level[11]. As the water level recovers, the natural groundwater gradients will be restored and groundwater will start to flow down gradient, away from the mining area, towards the local streams and rivers.

Figure 5-18 indicates the C Lower floor elevations and projected water flow directions within the mine voids. It can be seen that the coal floor dips away from the proposed mine adits (refer to "HW" on map) in general. This will prevent water flowing out of the adit systems.

[11] Post mining groundwater levels can differ from pre-mining levels if aquifer permeability is changed significantly. Usually opencast pits are backfilled with broken overburden rock and spoil material, which results in much higher permeability and recharge rates (at least initially until a certain degree of compaction is reached). Normal recharge is around 3-5% and can increase to 12% for old backfilled opencast pit.

Figure 5-19 shows the preliminary and predicted decant or diffuse seepage areas. These must be regarded as an indication/preliminary only at this stage. **It is recommended that the numerical groundwater model be updated within the 1st year of mining operations, once sufficient groundwater monitoring information is available. The following aspects need to be updated:**

- o More accurate elevation/topographical data for the mining area and mine blocks,
- o All observation boreholes need to be surveyed for accurate collar and water level elevation, this must be done before any mining started,
- o At least three sets of water level data from the monitoring boreholes, and
- o A final mine progression plan.

Figure 5-20 and Figure 5-21 show the predicted decant elevations. Again, these are preliminary and need to be confirmed at a later stage. The decant quantities will be approximately 30% of the predicted inflow rates for the opencast mining areas.

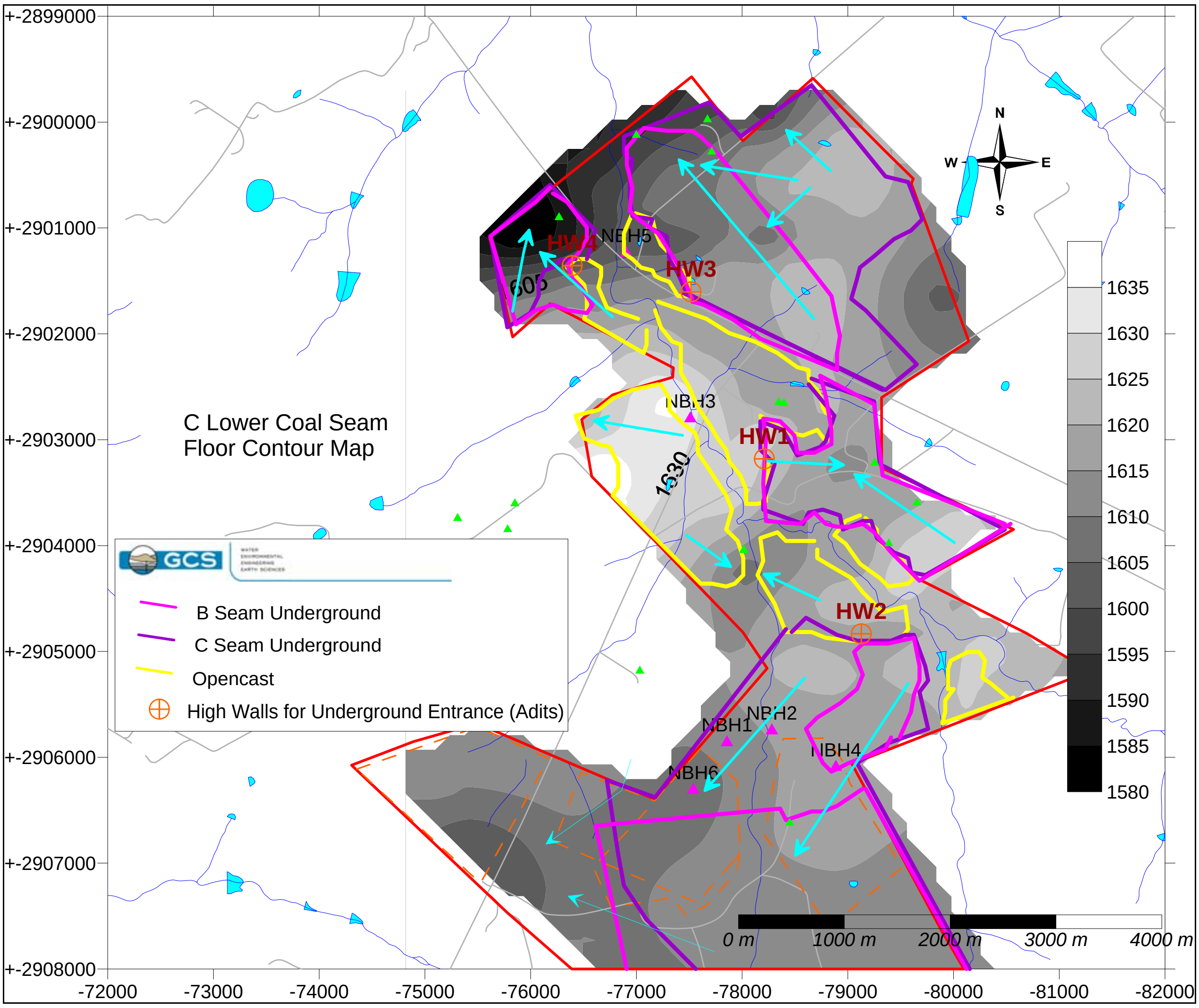


Figure 5-18: Graphical illustration of the C Lower Coal Seam –floor contour map and dip directions

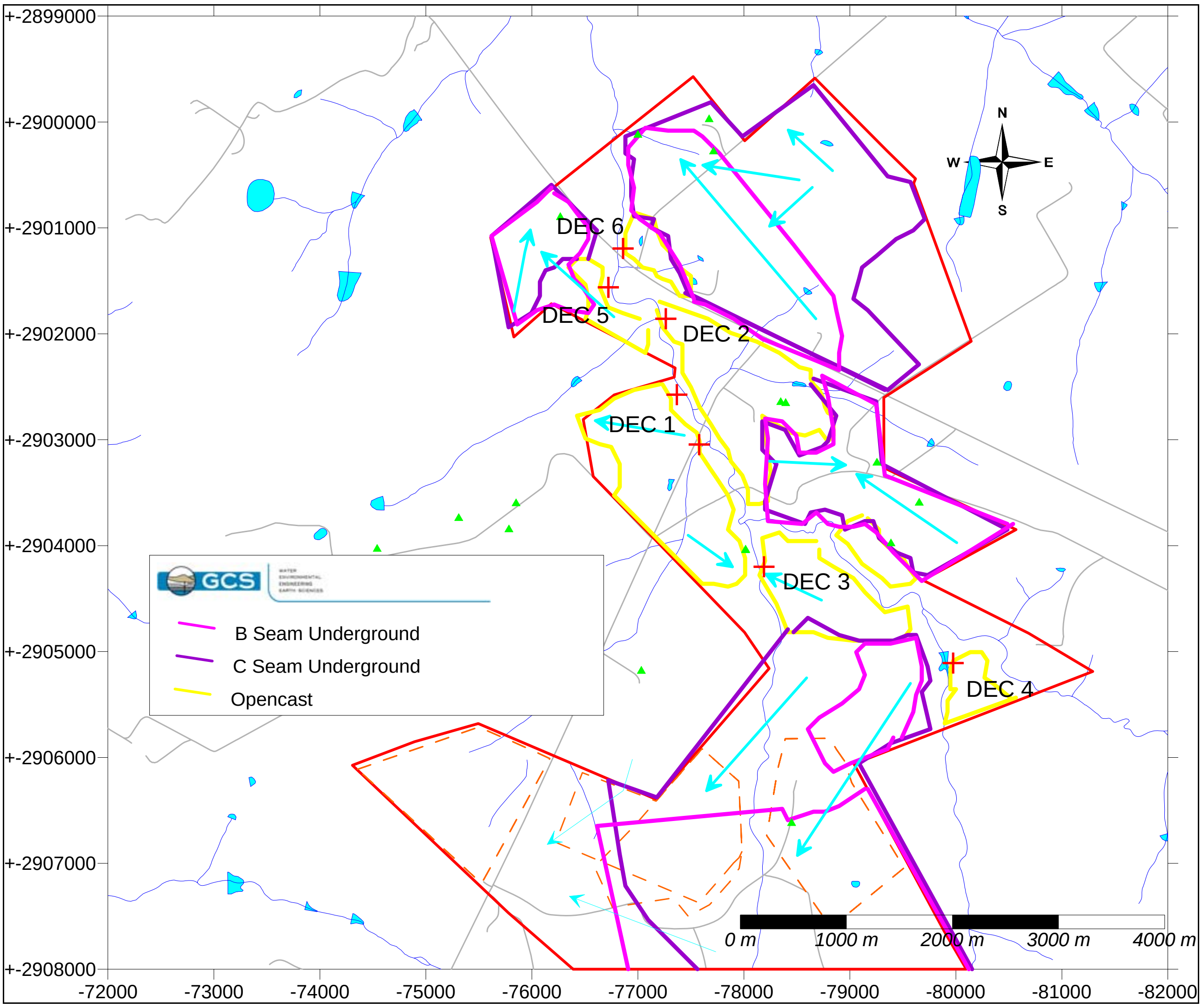


Figure 5-19: Predicted decant/seepage areas for the De Wittekrans mining area

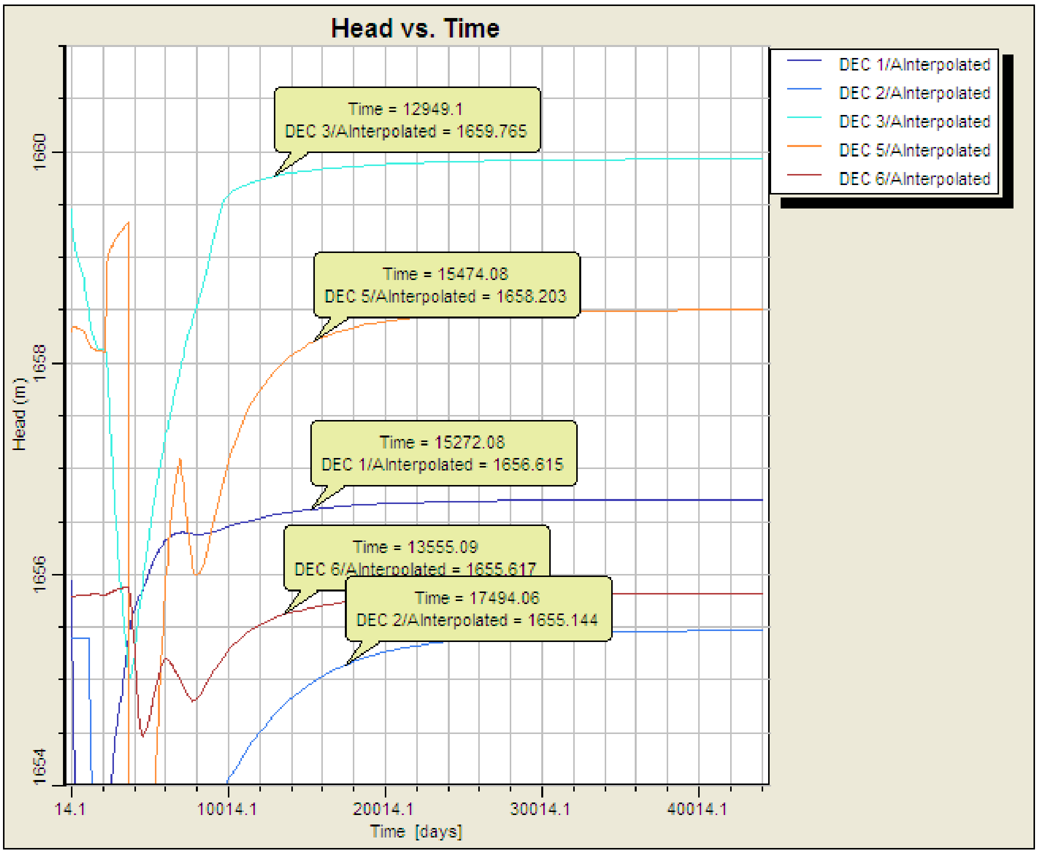


Figure 5-20: Predicted decant elevations for the different opencast pits 1, 2, 3, 5 and 6

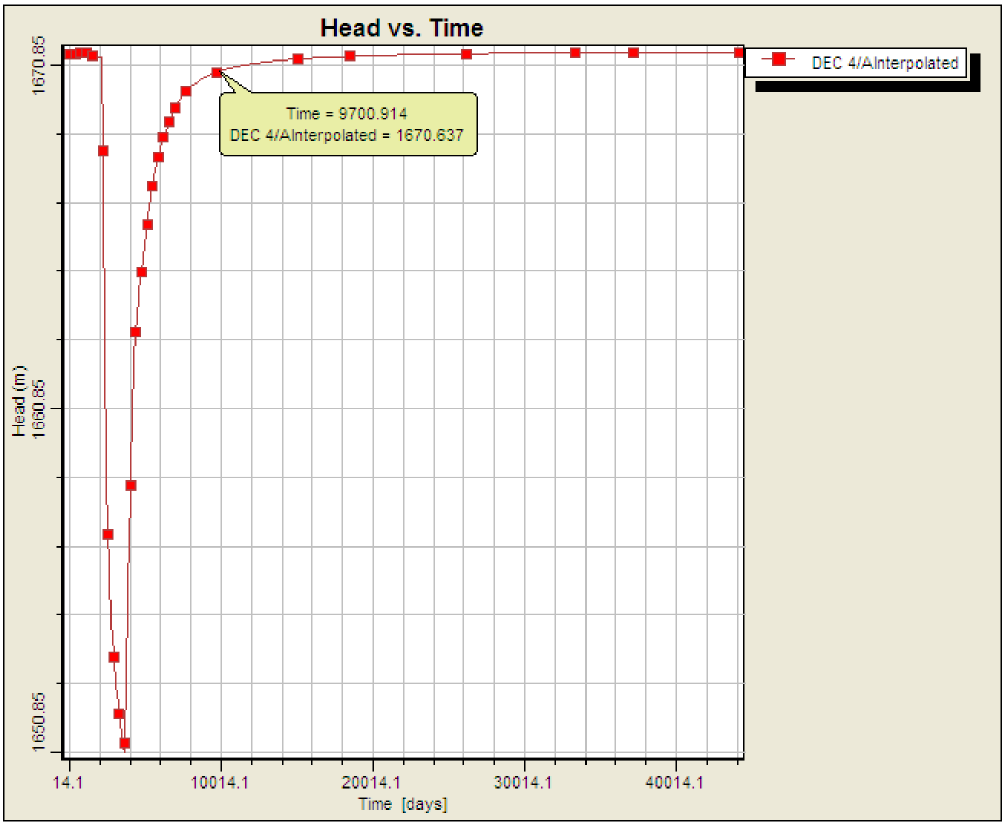


Figure 5-21: Predicted decant elevation for opencast pit 4

5.4 Contaminant Transport Modelling

Following the calibration of the flow model, a contaminant transport model was constructed for the mining area. In order to determine the long-term effect of the mining on groundwater quality, the post-operational migration of contamination was simulated. Sulphate (SO_4) was chosen as the parameter to be modelled, as sulphate is one of the typical end-products of acid rock drainage from the coal mining environment (which the ABA testing shows as a good possibility). It typically comprises about 50% of the Total Dissolved Solids (TDS) in groundwater contaminated by coal mining. To determine the specific input parameters for mass transport modelling, coal seam and overburden samples are usually obtained and certain laboratory testing conducted to determine the possible composition of leachate from the material under recharge conditions.

Due to the recovery of groundwater levels in the post-mining environment, contamination will be able to migrate away from the mining area. This can lead to the contamination of surrounding aquifers and streams. The numerical model was used to determine the extent of contamination from the mining areas, and which flow direction it will migrate down gradient of the mining area. A starting mass concentration of 2000mg/l was used in order to simulate the worse-case scenario.

Observation points were added to the model grid to determine the breakthrough period (time for SO4 plume to reach certain observation points) and order of magnitude. These points were located in sensitive areas down-gradient of the proposed mining areas and surface infrastructure areas. Sensitive areas include alluvial stream basins, private boreholes and topographical low points.

Surface infrastructure:

Figure 5-22 shows the predicted breakthrough curves for the two monitoring boreholes that were drilled down-gradient from the two discard facilities and other surface infrastructure which include the plant, workshops offices coal stockpiles, dirty water dams, etc. At this stage the exact area for the future discard-dump, plant and stockpile areas are not confirmed and both areas (refer to Figure 5-23 option 1 and 4) were included in the model. It is therefore good practice to assess impacts accordingly and assume that one of the areas will eventually be used. It is further recommended that the model be upgraded if any changes in the existing information occurs.

Figure 5-23 and Figure 5-24 indicate the predicted contamination plume directly after operations and 100 years after closure. The modelling shows that the contamination will migrate approximately 8 00 m in 100 years after mining activities have stopped.

The figures show that the non-perennial streams to the north and east of the mining area will be impacted by the contaminant migration. This impact is expected to increase the the salt loads of the streams.

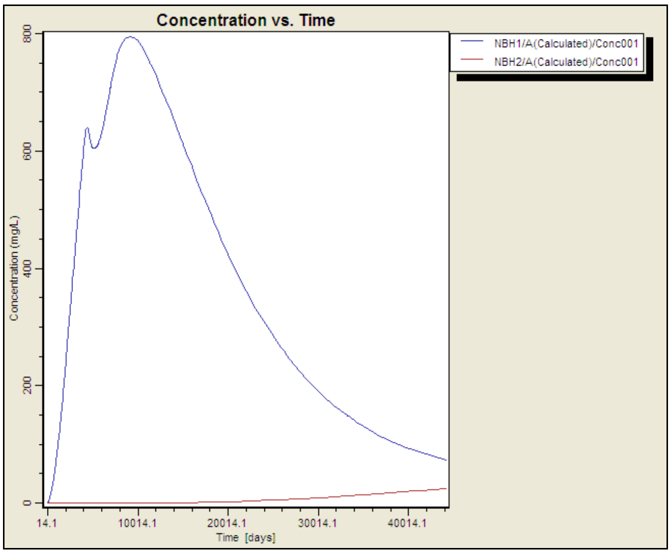


Figure 5-22: Breakthrough curves for the Discard observation points

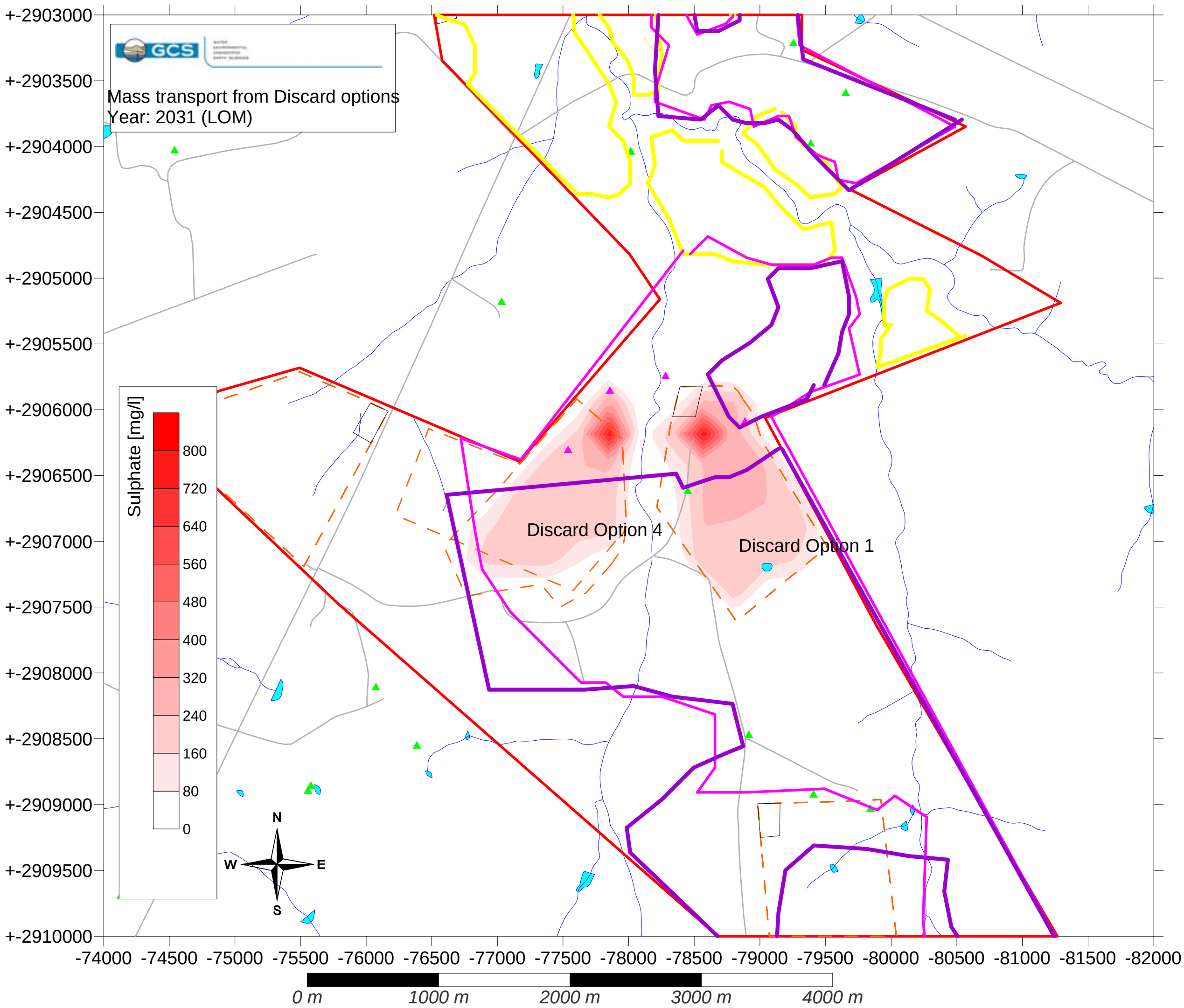


Figure 5-23: Predicted sulphate plume for the discard areas during the mine closure phase

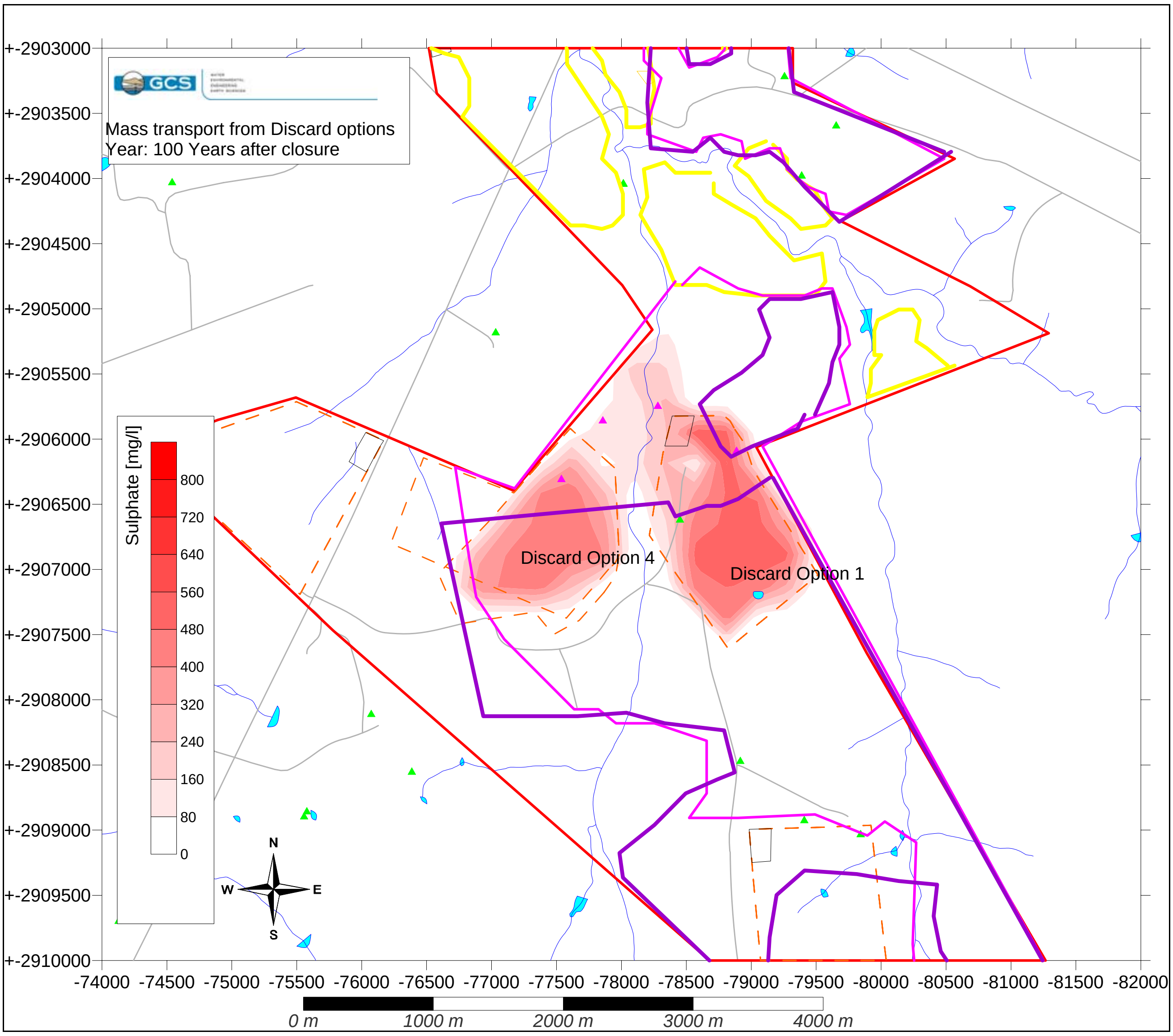


Figure 5-24: Predicted sulphate plume for the discard areas 100 years after closure

Mining Activities:

The proposed opencast and underground workings were added to the mass transport model grid accordingly. The following conclusions can be made:

- Figure 5-25 show the expected breakthrough curves for observation points down-gradient of the proposed open cast pits. These were located where decant and seepage is expected. It can be seen that low sulphate concentrations are expected and that the concentrations will decrease as the pits reach stability. The predicted sulphate plumes can be seen from Figure 5-26 and Figure 5-27. The mass transport model will be calibrated after the ABA (acid base accounting) results are received back from the laboratory.
- Figure 5-28 to Figure 5-31 indicates the predicted sulphate plumes for all mining activities, underground workings included. The model simulations for both the 1st and 2nd model layers are presented.
- It can be seen that sulphate concentrations of between 50 and 800 mg/l will reach the Klein Olifants River. The salt load to the system can be calculated after the model is calibrated within the 1st year of mining.

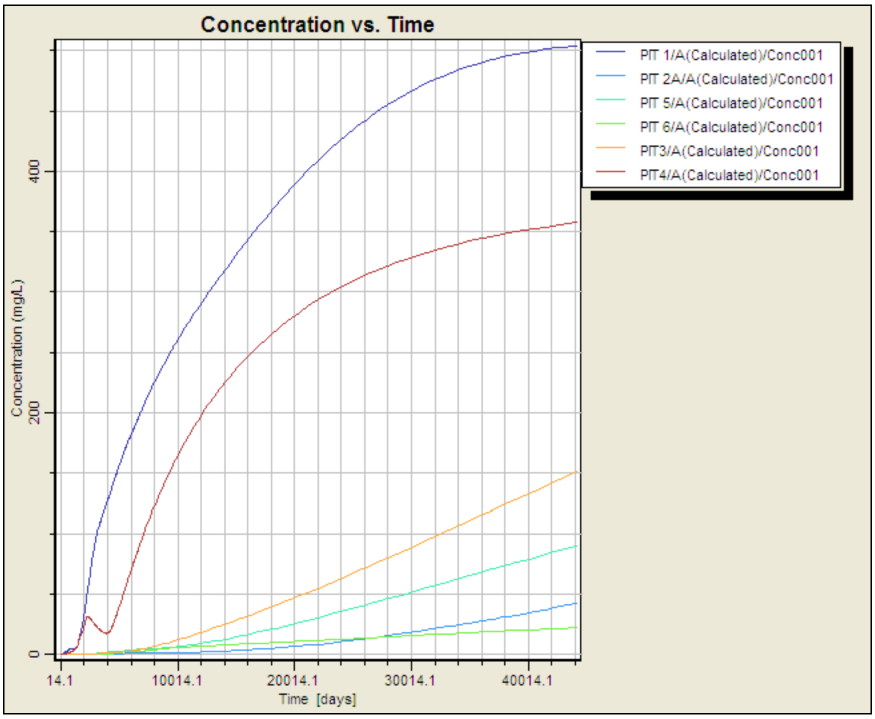


Figure 5-25: Breakthrough curves for the opencast observation points

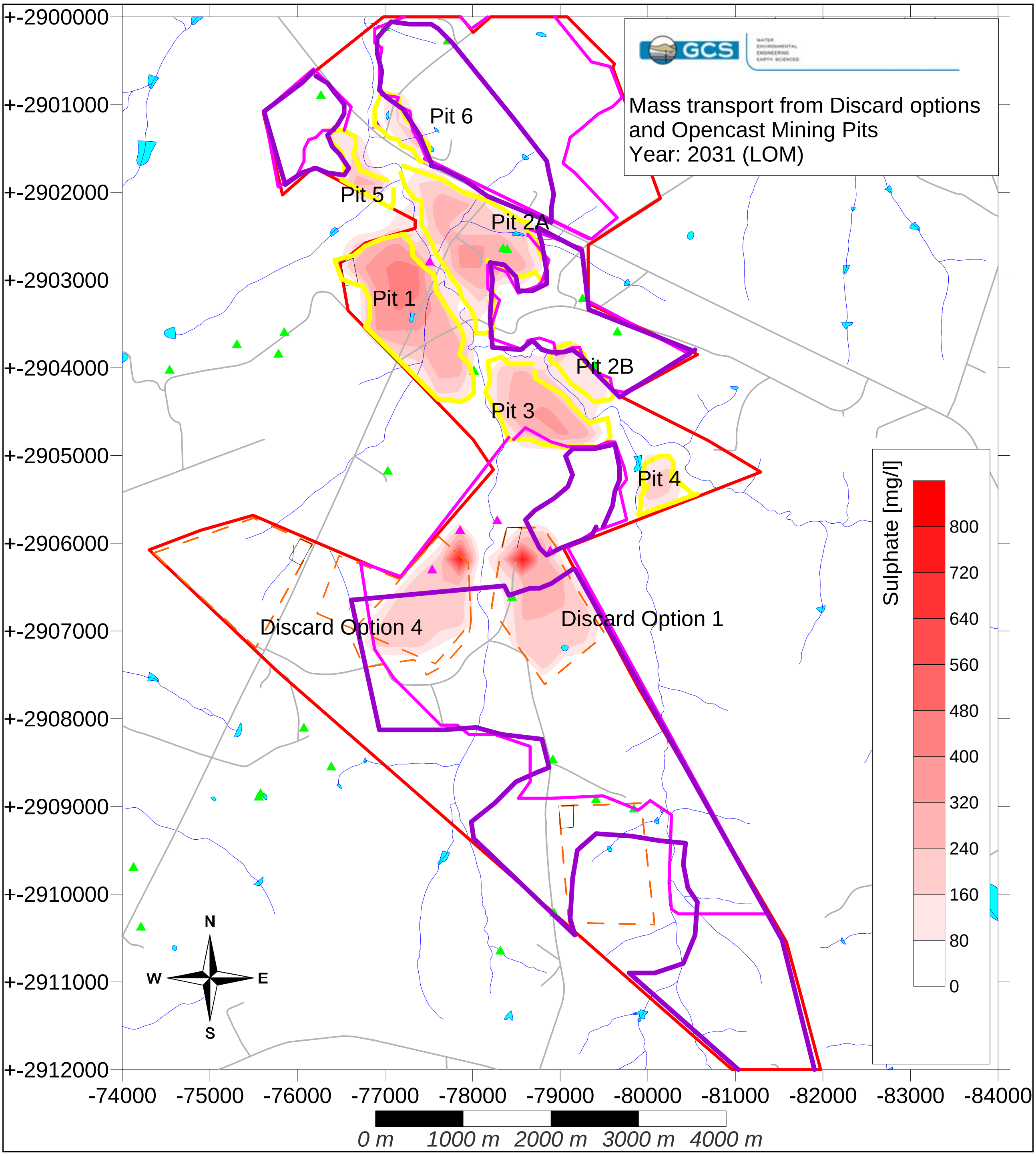


Figure 5-26: Predicted sulphate plume for the discard areas and opencast pits during the mine closure phase

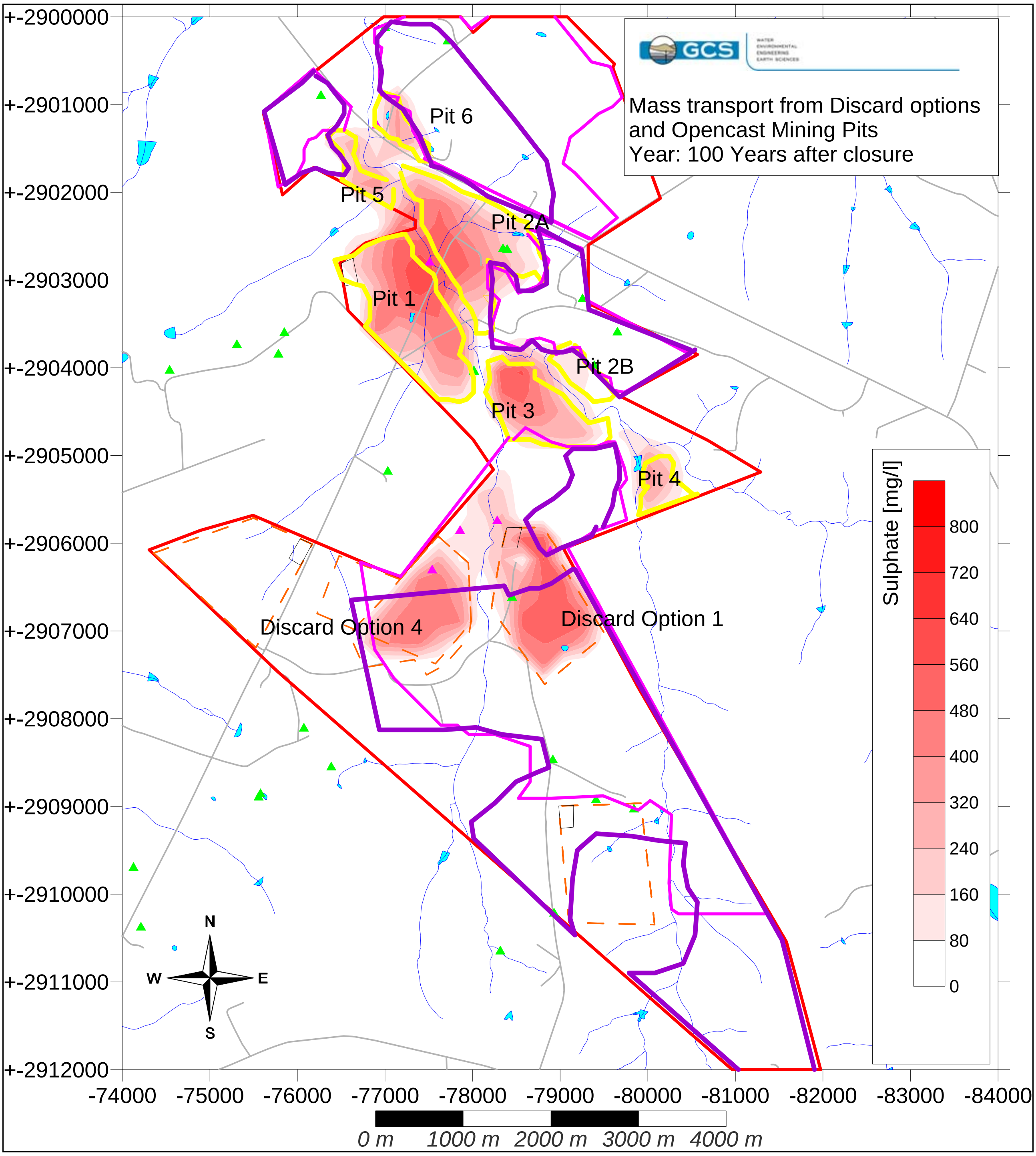


Figure 5-27: Predicted sulphate plume for the discard areas and opencast pits 100 years after closure

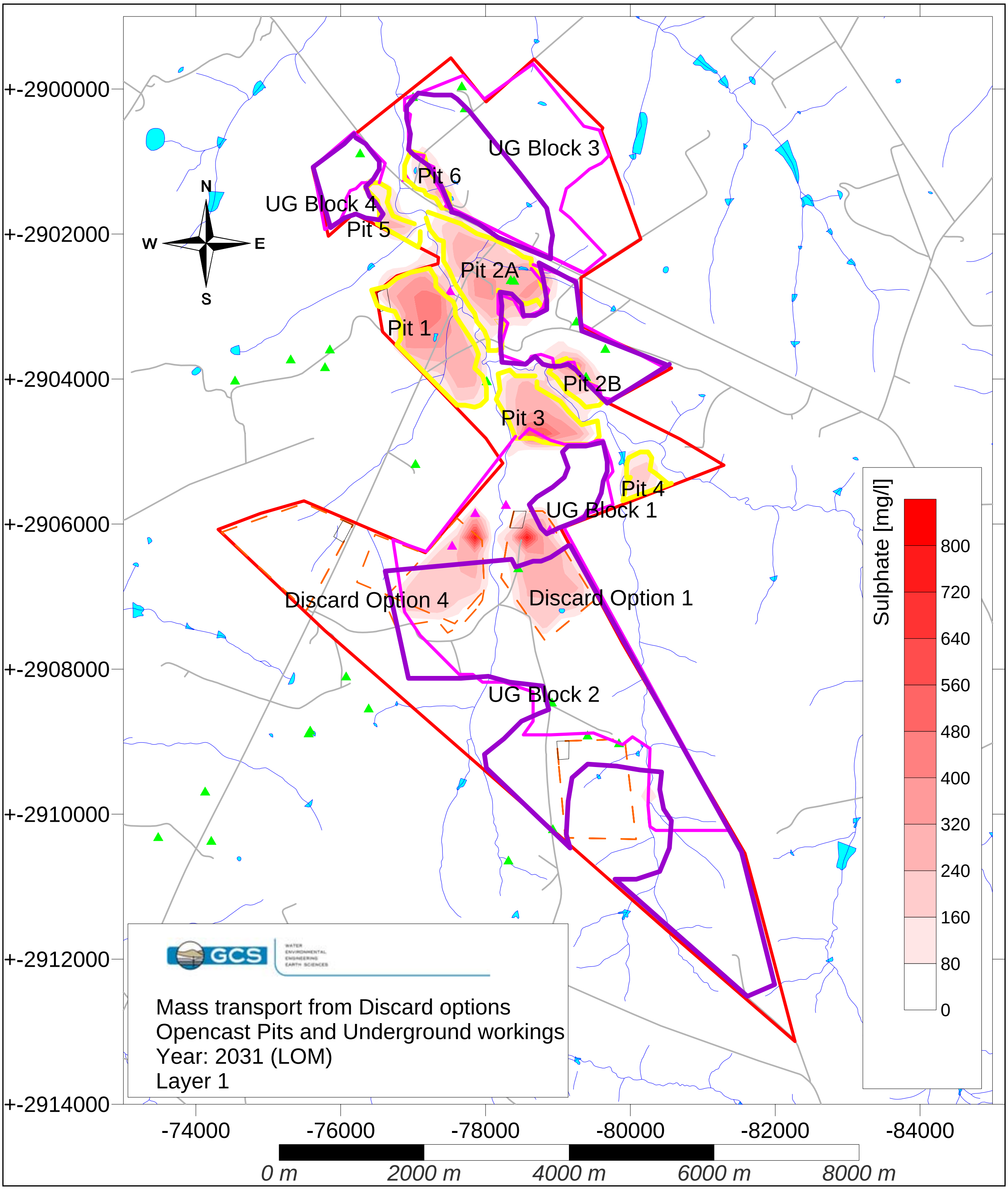


Figure 5-28: Predicted sulphate plume for all mining activities during the mine closure phase – layer 1

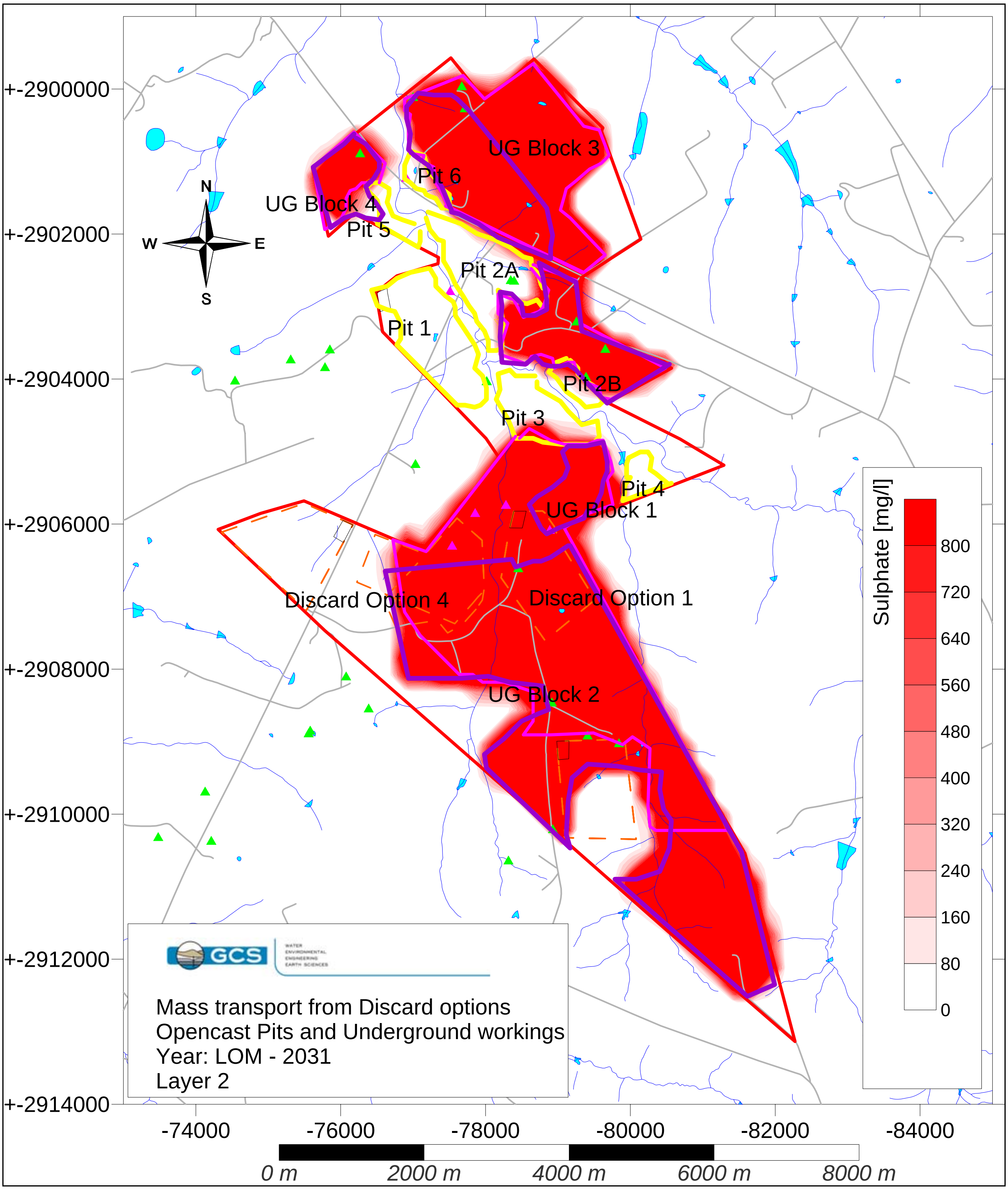


Figure 5-29: Predicted sulphate plume for all mining activities during the mine closure phase – layer 2

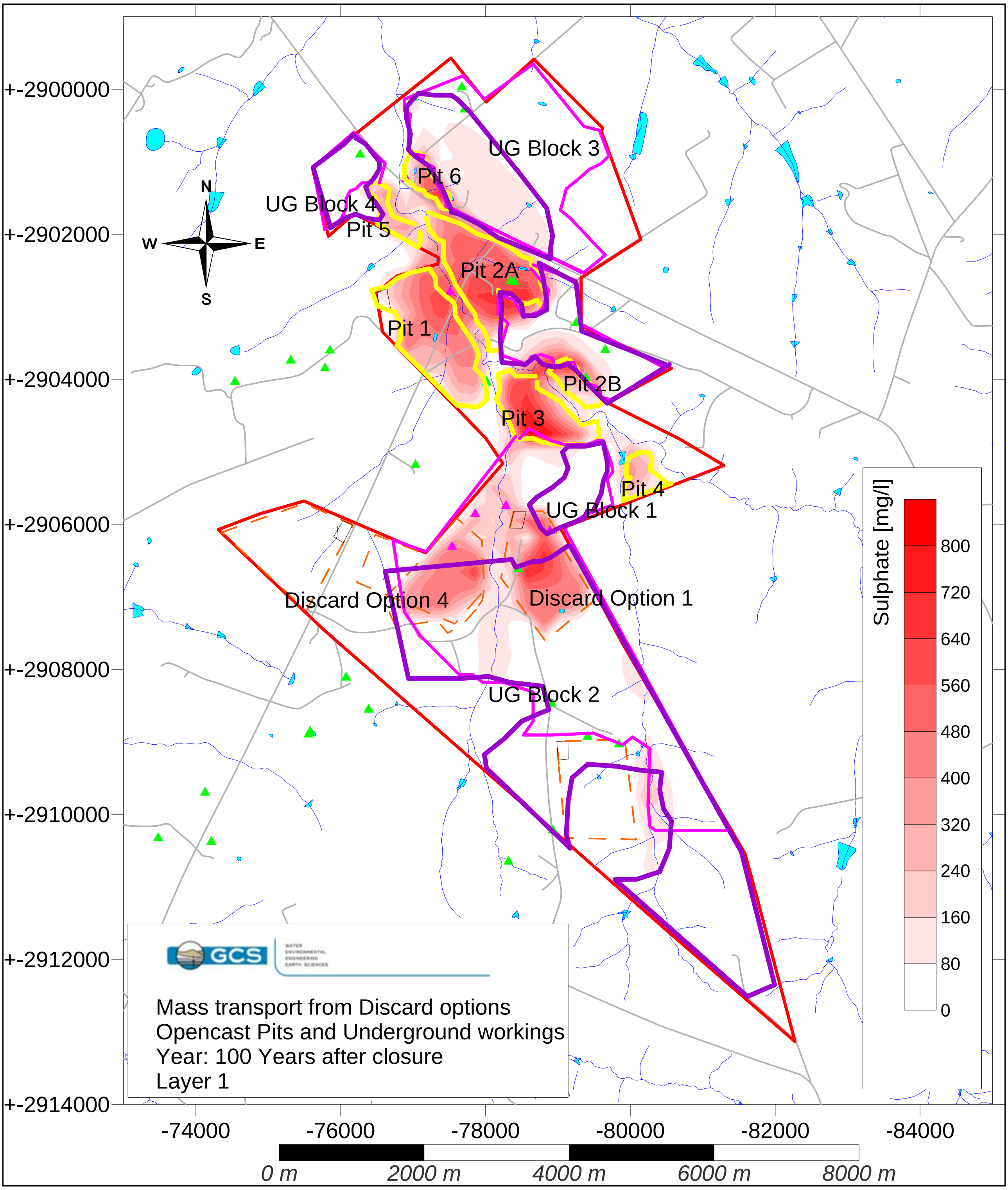


Figure 5-30: Predicted sulphate plume for all mining activities 100 years after closure – layer 1

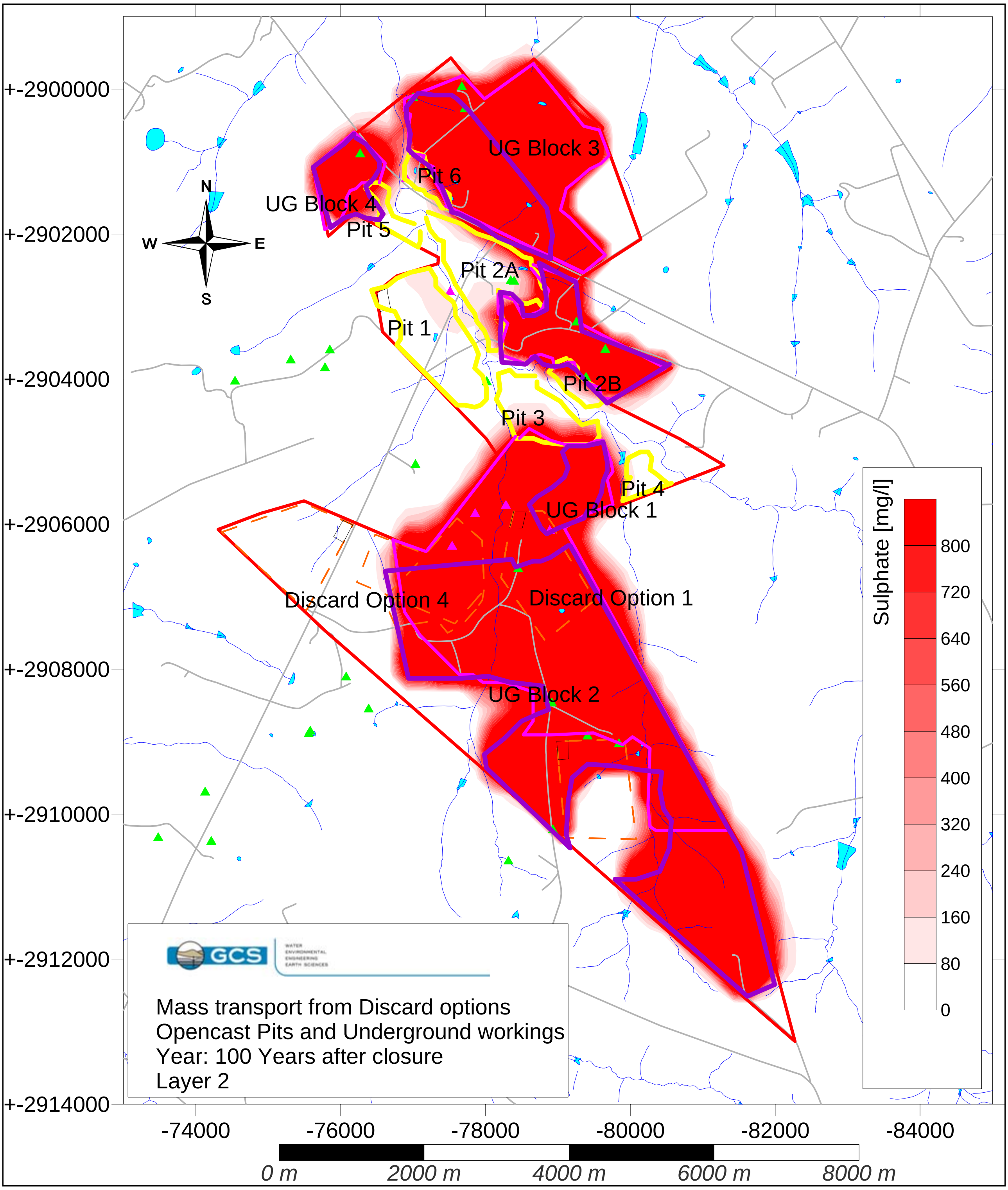


Figure 5-31: Predicted sulphate plume for all mining activities 100 years after closure – layer 2

6 Risk Assessment

The risk assessment is performed based on guidelines provided by the GCS Environmental Unit.

6.1 Risk identification and consequences

The risks identified through the numerical groundwater modelling were discussed during the previous sections. Table 6-1 supplies a summary of the expected risk aspects and their consequences.

Table 6-1: Identified risk aspects and consequence

	Risk Aspect	Consequence
Construction & Operational Phases	Dewatering of the aquifers. Refer to Section 5.3.2.	The flow model indicates: a). Lowering of the regional groundwater level; the 1m drawdown contour line will only reach a distance between 500 and 1000m during the last year of mining (21 years LOM). b). Impact on aquifer yield and storage capacity within this zone. Direct impact on production boreholes and springs currently used by farmers within the predicted zone. c). Impact on base-flow and stream flow reduction within this zone.
	Impact on operational water balance. Refer to Section 5.3.2.	The flow model indicates mine inflows to be on average 300 m^3/day. The mine must allow for this in their future water balance planning.
	Potential contamination from the proposed mining activities: ☞ Mining infrastructure: Plant, discard, slurry, pollution control dams, coal stockpile areas, etc. ☞ Opencast mining. ☞ Underground mining. Refer to Section 5.4.	Oxidation of underground material, overburden from the opencast section and coal being stockpiled on site, discard and slurry can generate poor quality leachate that could contaminate the aquifers.
	Contamination of the aquifers through other mining activities: ☞ Mine sewage, ☞ Oil, diesel and petrol storage areas, ☞ Workshop Areas	These activities have the potential to contaminate the underlying aquifers. The contamination is expected to be localised.
Decommiss & ioning	Rebound (recovery) of water levels	Groundwater levels will recover to near pre-mining levels a certain period after mine dewatering stopped This will restore groundwater flow patterns and gradients away from the mining area.

	Risk Aspect	Consequence
	Potential contamination of groundwater from poor quality leachate from discard and slurry.	The mass transport model indicates a plume towards the Klein Olifants River from the potential surface infrastructure on site to remain and increase after closure.
	Potential contamination of groundwater from poor quality leachate originating from mined-out areas	The mass transport model indicates a plume towards the Klein Olifants River.
	Decant from the mining areas	Possible long-term poor quality seepage/decant from the opencast mine workings and associated contamination of private boreholes, streams and aquifers. Underground workings will 1st decant into the opencast workings; no sub-surface seepages are expected from underground workings.

6.2 Risk estimation

6.2.1 Construction and Operational phases

Table 6-2: Dewatering of the aquifers

Nature: Groundwater levels in the aquifers surrounding the mining area will be lowered due to the mine dewatering. This will lead groundwater flow directions and gradients being reversed towards the mining area thereby containing pollution to the immediate vicinity of the mining activities. The groundwater levels will be lowered by a maximum of 50 m within the opencast mining areas and by 1 m up to 100 m away. The lowering of the groundwater levels will also impact on the base flow volumes to streams within the zone of influence.

The underground workings will not de-water the upper aquifer system completely and drawdown cones will not necessarily reach the workings where mining is deep enough. Water will be released from storage in the lower system due to the depth of the underground workings and the occurrence of impermeable sandstone layers above that separate the upper and lower aquifers from each other. However, connections between the two aquifers occur along discrete geological zones like intrusions, faults, bedding planes, etc.

	Without mitigation	With mitigation
Extent	Local (2)	Local (2)
Duration	Very Long term(5)	Very Long term(5)
Intensity	Low (2)	Low (2)
Probability	Definite (3)	Probable (2)
Significance	**Moderate to High (12)**	**Moderate to High (11)**
Status (positive or negative)	Negative – lowering of groundwater levels and	

	reducing spring flow and river flow. Positive – restricting contaminant migrations away from the mining site.	
Reversibility	Levels will recover when the mine dewatering stops after 10 to 30 years.	
Irreplaceable loss of resources?	Yes – possible (need to confirm significance of spring)	
Can impacts be mitigated?	Partly for opencast but none for underground.	
Mitigation: It is difficult to mitigate the lowering of the groundwater levels within the underground workings, which has to be done to ensure a save working (mining) environment. Mine planning can however be optimised to ensure that underground blocks be planned to allow for underground water storage and that other areas be allowed to recover. This will only be possible if the low elevation areas be mined 1st and that transport routes to other areas be away from these areas, where underground seepage will be contained. Mine planning must further focus on reducing the risk of subsidence to surface through sound rock mechanics and pillar size. However, the opencast sections can be kept small and rehabilitation is undertaken concurrent with mining through the roll-over method of mining . Under these circumstances no opencast section to be de-watered for more than 18 months or the time period of de-watering be kept as small as possible per opencast block.		
Cumulative impacts: Lowering of groundwater levels, mine inflows, handling of dewatered seepage, groundwater flow directions directed towards the mine area, reduction in base flow volumes to rivers and streams.		
Residual Impacts: Groundwater levels will recover once mine dewatering stops. Modelling simulations indicate that the groundwater levels will stabilise approximately 30 years after mining stops.		

Table 6-3: Impact on operational water balance

Nature: Groundwater will flow into the mining areas; the combined average rate is about 300 m^3/day. The water will have to be pumped from the mining areas and evaporated from ponds, used in the plant or used for dust suppression, depending on whether the mine operates in a water deficit or surplus environment. It is expected that there will be a water deficit and therefore the water pumped from the underground workings can be used in the plant area. Any additional or re-circulated water will be contained in evaporation ponds where it will evaporate. The impact on the local and regional aquifers was already discussed in the previous table.

Table 6-4: Contamination of the aquifer from the mining areas

Nature: ABA analyses show that acid mine drainage (AMD) formation is expected and some poor quality leachate can occur based on leach potential of the material. This can potentially influence the water quality in the surrounding aquifers. However, groundwater flow directions will be directed towards the mining area and contaminant migration away from the mining area will be limited initially.

However, once groundwater levels have rebound to pre-mining conditions, the flow direction will be towards the lower stream areas away from the mine; this will result in contaminant transport away from the mine towards the stream. Different opencast and underground sections will be mined at different times; some will be mined while others are allowed to recharge with groundwater and ongoing rehabilitation will continue on all opencast sections.

Poor quality seepage will be more significant from the opencast sections during the construction and operational phases. But in general, the impact on water quality will be more significant after closure. Underground workings will 1st decant into the opencast workings; no sub-surface seepages are expected from underground workings.

	Without mitigation	**With mitigation**
Extent	Local (2)	Site (1)
Duration	Permanent (6)	Very Long term (5)
Intensity	Medium (2)	Low (1)
Probability	Definite (3)	Probable (2)
Significance	**Moderate to High (13)**	**Moderate (9)**
Status (positive or negative)	Negative	
Reversibility	Partly	
Irreplaceable loss of resources?	Partly	
Can impacts be mitigated?	Partly	

Mitigation:

The extent to which acid mine drainage will be generated from the pits will be controlled by careful handling of the spoils, and specifically any pyritic material, like the shale, during the operational phase; and by flooding the exposed coal seam at the bottom section of the pits as quickly as possible. The shale/sandstone that will be stripped above the coal seam will be backfilled to the lowest possible elevation during the roll-over method of mining. This will ensure that the potential poor quality material is flooded as quickly as possible after mining is completed and so reduce the risk of oxidation and acidification.

On final rehabilitation the pits will be shaped and re-vegetated according to acceptable DME standards. This will ensure a free draining area and limit the risk of decant from the pits.

If the mitigation measures discussed above are implemented, it is expected that acid mine drainage from the pits can be minimised and possibly cease after closure. Furthermore, if water levels can be managed inside the pit and not rise into the perched weathered aquifer as described above, it is not anticipated that potential contamination generated inside the pits will have a significant impact on downstream groundwater users. The information presented here must be confirmed through the

results of the proposed on-going monitoring programme and re-calibration of the numerical transport model. There is not much that can be done to mitigate contamination from the underground areas. A Buffer zone can be left towards sensitive areas.
Cumulative impacts: Impact on groundwater quality.
Residual Impacts: Seepage away from the area will continue into the post-mining phase.

Table 6-5: Contamination of the aquifer from other activities associated with the mining operations

Nature: Spillage of oils and liquids and from the mine sewage works can lead to contamination of the aquifers.		
	Without mitigation	**With mitigation**
Extent	Immediate vicinity of mining area (1)	Immediate vicinity of mining area (1)
Duration	Medium (3)	Medium (3)
Intensity	Low (1)	Very Low (0)
Probability	Possible (1)	Improbable (0)
Significance	**(Low to moderate) 6**	**(Low)4**
Status (positive or negative)	Negative	
Reversibility	No	
Irreplaceable loss of resources?	No	
Can impacts be mitigated?	Yes	
Mitigation: Storage and maintenance features should be designed properly and good house keeping should be in place to prevent accidental spillage.		
Cumulative impacts: Contamination of the aquifers.		
Residual Impacts: Seepage away from the area will continue into the post-mining phase.		

6.2.2 Decommissioning and Post-mining phases

Table 6-6: Dewatering of aquifers

Nature: The groundwater levels in the mining area will start to recover when the mine dewatering stops. This will lead to the re-establishment of groundwater levels, flow directions and flow gradients to near pre-mining levels. This will re-establish the base flow rates within the zone of influence.

The effect of operational de-watering will remain for a period of approximately 30 years after mine closure.

The rebound of the groundwater levels will enable contamination to migrate away from the mining area, and could possibly lead to decant.

	Without mitigation	**With mitigation**
Extent	Site (1)	
Duration	Very Long term (5)	
Intensity	Low (1)	
Probability	Definite (3)	
Significance	**Moderate (10)**	
Status (positive or negative)	Positive – Re-establishing groundwater levels and flow directions. Springs seepage rates will be restored in the zone of influence. Negative – Enabling contamination to migrate away from the mining area and possibly decant.	
Reversibility	Partly.	
Irreplaceable loss of resources?	Partly.	
Can impacts be mitigated?	No.	

Mitigation: Opencast rehabilitation will occur during the operational phase as part of the roll-over menthod of mining and water will be allowed to recovery in the shortest possible time.

The impact from the underground workings will remain for a longer period of time.

Cumulative impacts: Recovery of groundwater levels, re-establishment of groundwater flow directions and gradients, migration of contamination away from the mining area, possible decant.

Residual Impacts: None**.**

Table 6-7: Contamination of the surrounding aquifers

Nature:

Contamination of the surrounding aquifer system will be caused by:

- Poor quality seepage from opencast pits due to oxidation of back-fill material and exposed coal seams,
- Poor quality seepage from underground workings due to exposed coal seams and oxidation,
- Poor quality seepage from surface infrastructure.

Numerical modelling show that the potential contamination will migrate up to 1 000 m from the mining area within a period of 100 years from the cessation of mining.

Modelling indicates that sulphate concentrations between 50 and 800 mg/l will reach the Klein Olifants River at certain stream sections. The salt load to the system needs to be calculated after the model is calibrated within the 1st year of mining. It is expected that the River system will handle most of the salt load. This aspect will be confirmed one year after mining and in accordance with communications with DWAF in terms of the reserve determination.

	Without mitigation	**With mitigation**
Extent	Local (2)	Site (1)
Duration	Very Long term (5)	Very Long term (5)
Intensity	Medium (2)	Medium (2)
Probability	Definite (3)	Probable (2)
Significance	**Moderate to High(12)**	**Moderate (10)**
Status (positive or negative)	Negative.	
Reversibility	Partly.	
Irreplaceable loss of resources?	Partly	
Can impacts be mitigated?	Yes	

Mitigation:

Opencast: The mitigation applied during the operational phase (the roll-over method of mining and concurrent rehabilitation, as per Table 6-4) will ensure that the impact from the opencast mining section be limited.

Surface infrastructure: Rehabilitation of all surface infrastructure, especially the discard dump and slurry ponds will occur directly after mining activities have stopped. Proper rehabilitation will prevent rain water infiltrating discard and other sensitive areas.

Cumulative impacts: Contamination of surrounding aquifers, impact on surface water quality in streams to the north and east.

Residual Impacts: Continuous contaminant migration away from the mining areas.

Table 6-8: Decant from the mining area

Nature: With rising groundwater levels when mine dewatering stops there is an increasing risk of decant from the mining area. Any seepage into the mining area will find its way towards the lowest point in the mine where it will accumulate and the mine void area will start to fill. Decant from the proposed mine portal is highly unlikely, as the coal seam dips away from the holings. However, an area of possible decant through subsurface seepage at the topographical low towards the non-perennial stream, was identified.

	Without mitigation	**With mitigation**
Extent	Local (2)	Site (1)
Duration	Very Long term (5)	Very Long term (5)
Intensity	High (3)	Moderate (2)
Probability	Probable (2)	Possible (1)
Significance	**Moderate to High (12)**	**Moderate (9)**
Status (positive or negative)	Negative.	
Reversibility	No.	
Irreplaceable loss of resources?	Partly.	
Can impacts be mitigated?	Yes	

Mitigation:

It is important to understand that the final elevations at which mine water will decant onto the surface can, to a certain extent, be manipulated through sound mine planning. Interconnections between underground workings and the surface may, for instance, be sealed. Opencast pits could be planned so that their perimeters follow the surface contours along the lowest side of the pit and not cut directly across streams, and the underground mine layout can be designed to avoid subsidence to surface.

The rate of flooding of the pit post-closure will be monitored with monitoring boreholes drilled into the spoils. The location of these borehole, to be drilled in the deepest part of the pits near the decant points *(these should be confirmed after one year of mining and when the final mine progression plans are available);* will be determined during the operational and decommissioning phases. These monitoring boreholes will be used to determine whether the water level in the pit has risen above the decant elevation, which is usually the lowest topographical elevation at closure (refer to the discussion section and associated figures), but also depends on the dip of the coal seam. Ideally the water level inside the pits must be kept 3 - 5 m below the decant level to prevent seepage into the perched aquifer in the subsoil.

The rate and level to which groundwater will rise in the pits is largely determined by the volume of rainwater recharged. The most effective way to control in-pit groundwater levels during post closure is to ensure that the roll-over method of mining is kept up throughout the operational phase. This will significantly reduce the rate of recharge to the pits during and post mining. It would be good practice to leave only one strip open at any one time during the operational phase. At decommissioning, the pits must be backfilled and re-vegetated as quickly as possible to ensure that the rate of recharge to the pits is minimised as soon as possible. The backfill must be shaped to ensure no ponding on the rehabilitated area. All clean surface runoff must be diverted away from

the pit through a series of cut-off trenches and berms. Clean runoff must be diverted back into the catchment. The quality of decant emanating from the pits will be controlled by backfilling the material that has a high acid generating potential (shale and pyritic rock from the overburden) to the lowest portions of the pit and flooding the these areas as quickly as possible, as discussed previously. If decant occur, evaporation dams can be constructed within the perimeter of the pit to contain all decant. This aspect needs to be planned during the operational phase in terms of dam locality, dam size and lining requirements. The extent, magnitude and location of decant can be determined with greater confidence once groundwater monitoring information becomes available. It is recommended that the impact of decant be evaluated one year after mining commence, once monitoring information is available.
Cumulative impacts: Decant, long term mitigation required.
Residual Impacts: Continuous decant from the mining area and possible impacts on surface water bodies.

7 GROUNDWATER MANAGEMENT PLAN

7.1 Groundwater Management Objectives

7.1.1 Construction Phase

To prevent contamination of surface water runoff from the box cuts and infrastructure development.

Actions: Construction Phase

- Separate clean and dirty runoff and contain dirty water in adequately sized pollution control dams. Ensure that pollution control dams are adequately sized according to the specifications in DWAF's GN704 or other applicable regulations.
- Prevent dirty water runoff from leaving the box cuts and adits in the general mining area.
- Keep dirty areas as small as possible.
- Compact the base of dirty areas, like the ROM coal stockpile, discard and slurry facilities, workshops and oil and diesel storage areas to minimise infiltration of poor quality water to the underlying aquifers.

7.1.2 Operational Phase

To restrict the impact of polluted groundwater to the mining area and mitigate the loss of groundwater from the catchment.

Actions: Operational Phase

- Reduce the recharge potential through spoils in the opencast mining area by ongoing rehabilitation through implementing and maintenance of the roll-over method of mining.
- Eliminate the development of subsidence to surface through sound underground mine planning and leaving sufficient pillars underground.
- Re-use groundwater seepage collected in the pits to adequately sized pollution control facilities in the mining process.
- Keep dirty areas like the pollution control dam and coal stockpiles, dischard and slurry facilities, workshops and oil and diesel storage areas as small as possible.
- Contain poor quality runoff from dirty areas and divert this water to pollution control dam for re-use.

7.1.3 Groundwater Closure Objectives

- To negotiate and get the groundwater closure objectives approved by Government during the Decommissioning Phase of the project, based on the results of the monitoring information obtained during the Construction and Operational Phases of the project, and through verification of the numerical model constructed for the project.
- To continue the groundwater quality and groundwater level monitoring for a period of two to four years after mining ceases in order to establish post-closure groundwater level and quality trends. The monitoring information must be used to update, verify and recalibrate

the predictive tools used during the study to increase the confidence in the closure objectives and management plans.

- To present the results of the monitoring programme to Government on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with Government.
- To negotiate mine closure with Government based on the results of the groundwater monitoring undertaken, after the two-four year post-closure monitoring period.

Actions: Closure

- Use the results of the monitoring programme to confirm/validate the predicted impacts on groundwater availability and quality after closure.
- Update existing predictive tools to verify long-term impacts on groundwater, if required.
- Present the results to Government on an annual basis to determine compliance with the closure objectives set during the Decommissioning Phase.

7.2 Groundwater Management Implementation plan

7.2.1 Management of groundwater availability (quantity)

- The groundwater that flows into the pits during the operational phase of mining will be re-used continually as part of the mine water balance. This will create a localised cone of depression around the mining area and will reverse groundwater flow towards the pit. This cone of depression is not anticipated to extend more than 1km from the pit, but cumulative impacts could be more extensive.
- Further management measures implemented during the roll-over method of mining will relate to continuous rehabilitation as mining progresses. The recharge potential for un-levelled spoils is higher than that for levelled spoils or re-vegetated areas. Optimisation of continuous rehabilitation will effectively minimise recharge to the areas disturbed by mining and thus reduce the impact of mining on the availability of groundwater, as well as on the amount of leachate that could be generated inside the pits.
- Groundwater seeping into the underground workings must be collected in dedicated underground sumps and re-used as part of the mining operations.
- Sufficient pillars must be left underground, as part of sound mine planning, to avoid subsidence of the roof to surface. This will ensure that the rate of recharge to the underground workings remain at natural rates and will minimise decant from the workings post-closure.
- Groundwater monitoring will be undertaken in the monitoring boreholes to generate a database. The information will be used to evaluate and confirm trends.
- Finalisation of the rehabilitation programme will be undertaken during the decommissioning phase. Groundwater monitoring boreholes will be drilled into the rehabilitated spoils to monitor groundwater levels and quality inside the pits. These boreholes must be drilled in the deepest part of the pits and must be screened and cased to ensure accurate monitoring.
- Rehabilitation of the underground workings

7.2.2 Management of groundwater quality

- The shale and pyritic rocks present in the overburden material of the opencast sections will be backfilled at the bottom of the pits to ensure that it is flooded as quickly as possible and so minimise acid mine drainage.
- In order to limit the generation of acid mine drainage inside the pits, it is recommended that the pits are flooded as quickly as possible. The rate of groundwater level rise in the pits will be monitored with the aid of the spoils boreholes to ensure that water levels in the pits do not exceed the decant elevation. The water level in the pits must be kept below the depth of weathering to ensure that contamination does not enter the perched aquifer and migrate towards streams. This level is approximately 5 - 15m below surface. Once the pits are flooded according to the description above, it will be shaped and re-vegetated according to DME acceptable standards. This will ensure a free draining area and limit the risk of decant from the pit. Surface runoff will be diverted from the rehabilitated area by constructing berms and cut off trenches around the mining areas and to divert clean runoff back into the catchment. This will also minimise erosion over the rehabilitated area.
- The extent to which acid mine drainage will be generated from the pits will be controlled by careful handling of the spoils, and specifically the shale and other pyritic overburden, during the operational phase; and by flooding the bottom section of the pits as quickly as possible, as discussed above.
- If the mitigation measures discussed above are implemented, it is expected that acid mine drainage from the pits can be minimised after closure. Furthermore, if water levels can be managed inside the pits and not rise into the perched weathered aquifer, it is not anticipated that potential contamination generated from the pits will significantly impact on private groundwater users downstream of the mine.
- If decant occur evaporation dams can be constructed within the perimeter of the pit to contain all decant. This aspect needs to be planned during the operational phase in terms of dam locality, dam size and lining requirements.
- The spread of contaminated leachate from the underground workings will be managed through containing seepage in dedicated underground holding facilities and re-using this water as part of the mining operations. A buffer zone will be left around the underground workings to contain potential contaminated leachate and limit its spread into the surrounding aquifers.

7.3 Monitoring: Groundwater

Groundwater monitoring will be undertaken to establish the following:

- <u>The impact of mine dewatering on the surrounding aquifers.</u> This will be achieved through monitoring of groundwater levels in the monitoring boreholes. If private boreholes are identified within the zone of impact on groundwater levels, these will be included in the monitoring programme.
- <u>Groundwater inflow into the mine workings.</u> This will be achieved through monitoring of groundwater levels in the monitoring boreholes.
- <u>Groundwater quality trends</u>. This will be achieved through sampling of the groundwater in the monitoring boreholes.

- The rate of groundwater recovery and the potential for decant after mining ceases and full rehabilitation. This will be achieved through drilling of additional boreholes into the rehabilitated spoils for monitoring purposes. These boreholes must be drilled in the deepest sections of the rehabilitated pits in the vicinity of the decant points.
- Groundwater monitoring will be undertaken according to SABS and DWAF requirements according to the schedule presented in Table 7-1 below.

Table 7-1: Groundwater monitoring programme

Monitoring position	Sampling interval	Analysis	Water Quality Standards
Construction, Operational and Decommissioning Phases			
All monitoring boreholes	Monthly: measuring the depth of groundwater levels	No analysis required	South African Water Quality Guidelines: Domestic Use
All monitoring boreholes	Quarterly: sampling for water quality analysis (April, July, Oct, Jan)	Full SABS analysis Groundwater level	South African Water Quality Guidelines: Domestic Use
All hydrocensus boreholes	Bi-Annually (April, Oct)	Full SABS analysis Groundwater level	South African Water Quality Guidelines: Domestic Use
Rainfall	Daily at the mine	No analysis required	Not Applicable
Post-closure phase for 2 to 4 years after mining ceases			
All monitoring boreholes	Quarterly (April, July, Oct, Jan)	Full SABS analysis Groundwater level	South African Water Quality Guidelines: Domestic Use
All hydrocensus boreholes	Bi-Annually (April, Oct)	Full SABS analysis Groundwater level	South African Water Quality Guidelines: Domestic Use
Spoils boreholes (After rehabilitation)	Monthly	Full SABS analysis Groundwater level	South African Water Quality Guidelines: Domestic Use
Rainfall	Daily at the mine	No analysis required	Not Applicable

It is recommended that additional monitoring boreholes be constructed when the final mine plans are confirmed. This will be done within the 1st 3 to 6 months of mine development. . It is also recommended that the monitoring programme be revised if any contamination or significant lowering in groundwater levels are detected. The extent of revision will be determined by the results obtained.

Laboratory analysis techniques will comply with SABS guidelines. The groundwater monitoring database will be updated on a monthly basis as information becomes available. The database will be used to analyse the information and evaluate trends noted. An annual compliance report will be compiled and submitted to the authorities for evaluation and comment. This report will be submitted by 15 December annually for the construction, operational and decommissioning phases as well as for two years after mining ceases. The mine will develop a monitoring response protocol after the completion of the Construction Phase of the project. This protocol will describe procedures in the event that groundwater monitoring information indicates that action is required.

7.4 Financial provision: Groundwater

The financial provision that must be provided to comply with the commitments made with respect to groundwater includes:

- Groundwater monitoring during mining operations, according to the schedule presented in Table 7-1 above.
- Drilling of monitoring boreholes according to the following guideline (seven boreholes were drilled to obtain an idea of the pre-mining conditions in June 2009; this network will be expaned to cater for full operational/closure monitoring purposes):
  - At least three down gradient of the discard facility and one up gradient,
  - The drilling of a borehole into the spoils of each opencast mining area after rehabilitation to monitor the rate of groundwater level rise in the pits as well as the potential for decant. This borehole will probably have to be drilled using ODEX methods.
  - Drilling of one borehole in each underground working according to scientific base selection practices to measure rebound,
  - Other areas where poor quality seepage are expected from mining activities. These will be identified as mining progresses, based on the implemented monitoring programme and observations on site.
  - Two boreholes down-gradient of dirty water dams and slurry ponds.
- Groundwater monitoring after mining ceases, for an initial period of two to 4 years. The length of this monitoring period must be negotiated with Government during the Decommissioning Phase of the project.

7.5 Environmental Awareness Plan: Groundwater

- Mine employees must be made aware, through the required training programmes, of the significance of the groundwater monitoring programme to ensure that the boreholes are maintained and the monitoring schedule adhered to.
- Mining sub-contractors and mine personnel must be instructed, through the required training programmes, to implement and maintain the roll-over method of mining to ensure that potential impacts on mining are minimised.

8 References

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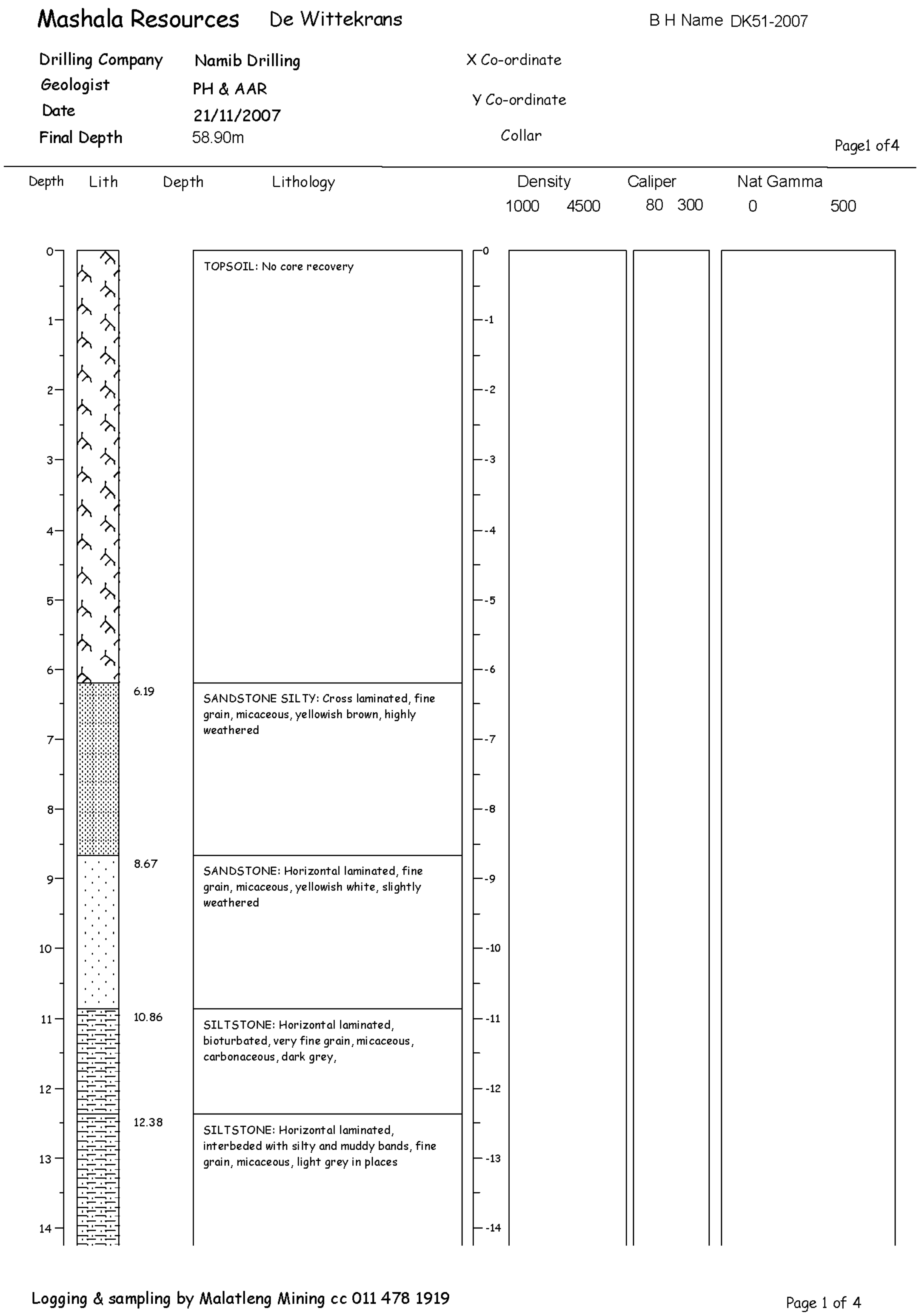
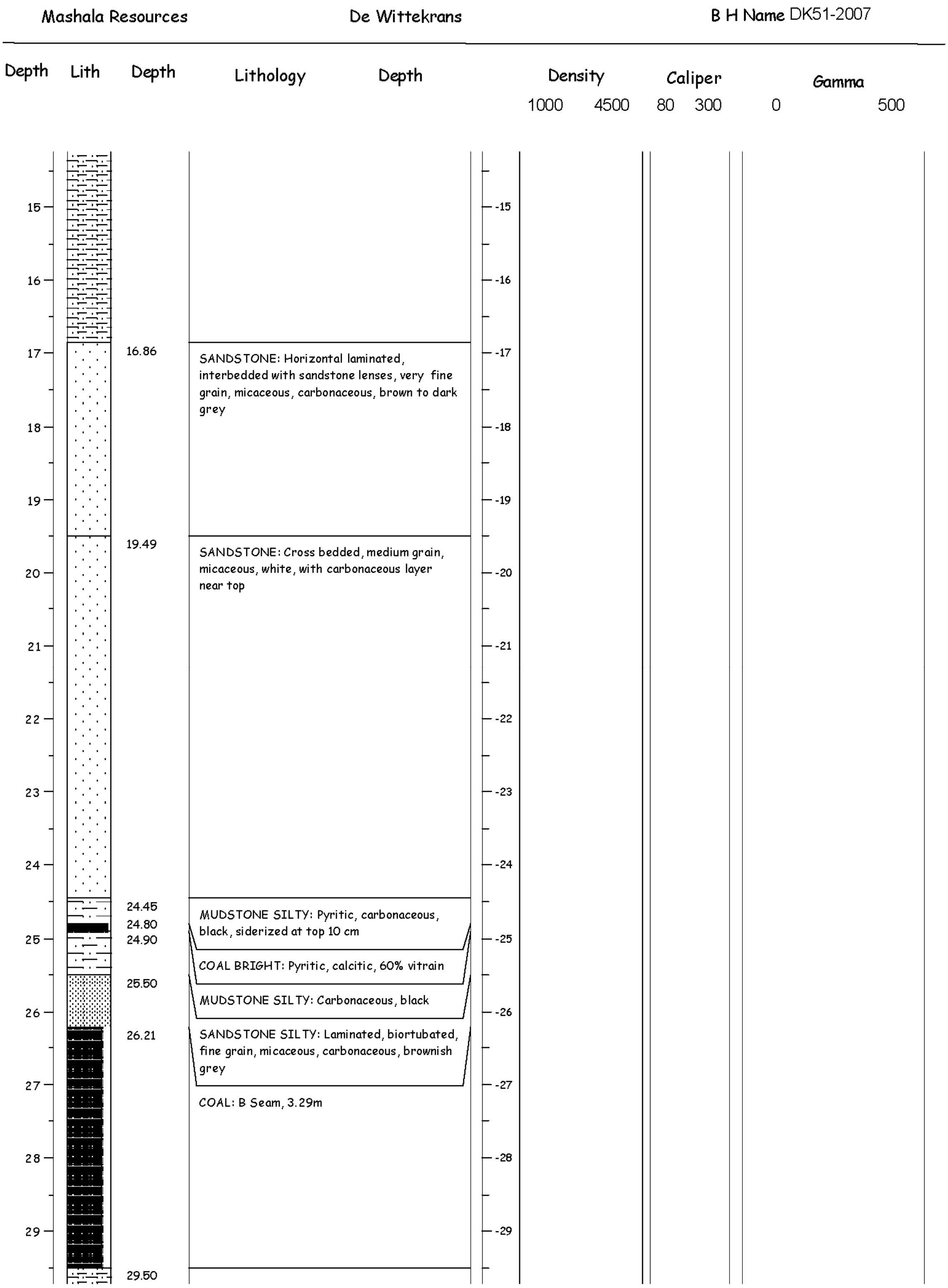
- WEAVER, J.M.C. 1992. Groundwater sampling. Water Research Commission project No 339, TT 54/92, Pretoria.
- Development of the De Wittekrans Coal Project, near Hendrina, Mpumalanga Province, SRK Consulting, Report No 399526, April 2009, for Mashala Resources
- Coal Floor Data from Mr. Nico Denner, Gemecs, May 2009.

Appendix A - Geological logs:

A1 - Typical log from exploration borehole





Logging & sampling by Malatleng Mining cc 011 478 1919

Page 2 of 4

Mashala Resources De Wittekrans B H Name DK51-2007

Depth Lith Depth Lithology Depth Density Caliper Gamma

Density 1000 4500 Caliper 80 300 Gamma 0 500

Depth	Lithology
29.83	SILTSTONE: Laminated, very fine grain. micaceous, carbonaceous, black to grey
	SANDSTONE: Cross bedded , interbedded with mudstone in places, coase grain, micaceous, off white, gritty
32.73	SANDSTONE: Horizontal laminated, fine grain, micaceous, carbonaceous, brown to light grey
33.37	SILTSTONE: Dark grey to black
33.97	MUDSTONE: Carbonaceous, black
34.40	SILTSTONE: Cross laminated, very fine grain, pyritic, carbonaceous, light brown to grey
35.30	SHALE: Coaly, torbanitic, Sampled
35.94	COAL: CU Seam, 0.51m
36.45	SILTSTONE: Laminated, brownish, Parting Sampled with the upper coal
36.49	COAL: CL Seam, 1.30m
37.79	SANDSTONE: Coarse grain, off white, gritty
38.39	MUDSTONE SILTY: Laminated, brownish black
38.90	SILTSTONE: Cross laminated, interbedded with gritty oof white sandstone bands, very fine grain, micaceous, carbonaceous, brownish grey, muddy towards base
41.54	MUDSTONE: Carbonaceous, brownish black
43.51	SANDSTONE: Bioturbated, medium grain, micaceous, light brownish grey, with worm burrows

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Page 3 of 4

Mashala Resources | De Wittekrans | B H Name DK51-2007

Depth (from)	Depth (to)	Lithology
45.09	46.79	MUDSTONE: Carbonaceous, brownish black
46.79	47.17	SANDSTONE: Cross laminated, medium grain, micaceous, light brownish grey, bioturbted with worm burrows at top 15cm, silty to base
47.17	50.00	MUDSTONE: Carbonaceous, black, flacky with sandstone bands
50.00	56.03	SANDSTONE SILTY: Cross laminated, fine grain, micaceous, carbonaceous, light grey
56.03	58.90	DOLERITE: Coarse crystalline, greenish grey

Density: 1000 – 4500 | Caliper: 80 – 300 | Gamma: 0 – 500

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Page 4 of 4

B2 - Logs for the new monitoring boreholes

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BOREHOLE LOG: HYDROGEOLOGY AND CONSTRUCTION

Borehole No.:NBH 1	Map Ref.: 2630CA (WGS84)	
Client: Mashala Resources	S coord.: 26.26235	
Project: Mashala Resources (Ferreira)	E coord.: 29.78009	
Project No: 08/111	Airlift yield (final):	(l/s)
Farm: Witbank	Water level: 9.20	(mbcl)
District: Ermelo, Mpumalanga	Collar Height:	(m)
Province: Mpumalanga	Altitude:	(mamsl)
Logged by: Fela Ditlhale	Borehole Depth: 37	(m)
Date Completed: 10/06/2009	Geophysical. Peg No.:	

Borehole diamter (mm)

Dia: 219		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12	12	37				

Water Strikes:	1	2	3	4	5	6	7
Depth:							
Strike yield (l/s							
Cum yield (l/s)							

Plain casing diameter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	6						

Perforated casing diamter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
6	12						

Sanitary Seal:	From	To	Gravel pack:	From	To	Bags:	

GEOLOGY: (Lithology: Colour; Grain Size; Clay Content; Weathering; Secondary features)

from	to	description	Penetration Rate (/m)
0	1	Soil, brown orange, fine, top soil	
1	3	Sand, brown orange, fine with orange round 8 - 10mm pebbles	
3	9	Sand, light yellow cream, micaceous (white), fine grained	
9	13	Shale & Sandstone, interbedded, laminated, slightly weathered	
		Shale: black, carbonaceous, micaceous (white), very fine grained	
		Sandstone: grey, micaceous, fine grained	
13	17	Shale, grey to black, carbonaceous, micaceous(white & brownish)	
		weathered, very fine grained	
17	19	Sandstone, light grey, fine grained, micaceous (white), fairly hard	
19	20	Sandstone, grey, fine grained, micaceous, mixed with black shiny	
		coal	
20	21	Shale, black, fine grained, micaceous (white), carbonaceous	
21	22	Sandstone, light grey, fine grained, micaceous (white) in places	
22	27	Shale, black, fine grained, laminated, micaceous	
27	29	Sandstone, light grey, fine grained, micaceous (white) in places	
29	31	Shale, black, coaly (looks like coal), very fine grained, micaceous	
		in places	
31	33	Sandstone & Shale, grey to dull grey, carbonaceous shale, micaceous	
33	36	Sandstone, light grey, fine grained, hard, micaceous (white)	
36	37	Sandstone, light grey, medium to gritty, sub-angular to rounded	
		grains, micaceous in places, hard	

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BOREHOLE LOG: HYDROGEOLOGY AND CONSTRUCTION

Borehole No.:NBH 2	Map Ref.: 2630CA (WGS84)	
Client: Mashala Resources	S coord.: 26.	
Project: Mashala Resources (Ferreira)	E coord.: 29.	
Project No: 08/111	Airlift yield (final):	(l/s)
Farm: Witbank	Water level: 3.145	(mbcl)
District: Ermelo, Mpumalanga	Collar Height:	(m)
Province: Mpumalanga	Altitude:	(mamsl)
Logged by: Fela Ditlhale	Borehole Depth: 37	(m)
Date Completed: 09/06/2009	Geophysical. Peg No.:	

Borehole diamter (mm)

Dia: 219		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12	12	30				

Water Strikes:	1	2	3	4	5	6	7
Depth:	13						
Strike yield (l/s	0.1						
Cum yield (l/s):							

Plain casing diameter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12						

Perforated casing diamter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to

Sanitary Seal:	From	To	Gravel pack:	From	To	Bags:

GEOLOGY: (Lithology: Colour; Grain Size; Clay Content; Weathering; Secondary features)

from	to	description	Penetration Rate (/m)
0	1	Soil, yellowish brown, very fine, top soil	
1	3	Sand, yellowish brown, fine, clayey, moist	
3	4	Sand, yellowish brown grey, coarse	
4	5	Sand, yellowish brown grey, fine	
5	6	Mudstone, black, dull, silty, laminated, interbedded black & brown layers	
6	7	Sandstone, highly weathered, light grey with light yellow sand, fine grained	
7	12	Sandstone & Shale, laminated, weathered, micaceous	
		Sandstone: dark grey, fine grained	
		Shale: Black, fine grained	
12	13	Sandstone,dark grey, laminated (lighter layers interbedding), micaceous (white), weathered	
13	14	Sandstone & Shale, Shale: dark grey, micaceous (white), fine grained	
		Sandstone: grey white, coarse grained, quartz in places	
14	25	Sandstone, grey white, coarse grained, quartz in places	
25	30	Sandstone & Shale, laminated, hard	
		Sandstone: light grey, fine grained, micaceous (white)	
		Shale: black, carbonaceous, fine grained	

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BOREHOLE LOG: HYDROGEOLOGY AND CONSTRUCTION

Borehole No.:NBH 3	Map Ref.: 2630CA (WGS84)	
Client: Mashala Resources	S coord.: 26.24386	
Project: Mashala Resources (Ferreira)	E coord.: 29.77078	
Project No: 08/111	Airlift yield (final):	(l/s)
Farm: Witbank	Water level:	(mbcl)
District: Ermelo, Mpumalanga	Collar Height:	(m)
Province: Mpumalanga	Altitude:	(mamsl)
Logged by: Fela Ditlhale	Borehole Depth: 37	(m)
Date Completed:16/06/2009	Geophysical. Peg No.:	

Borehole diamter (mm)

Dia: 219		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12	12	37				

Water Strikes:	1	2	3	4	5	6	7
Depth:	23						
Strike yield (l/s							
Cum yield (l/s)							

Plain casing diameter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12						

Perforated casing diamter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to

Sanitary Seal:	From	To	Gravel pack:	From	To	Bags:

GEOLOGY: (Lithology: Colour; Grain Size; Clay Content; Weathering; Secondary features)

from	to	description	Penetration Rate (/m)
0	1	Soil, orange brown, clayey, fine, top soil	
1	3	Sand, orange brown grey, clayey, fine to coarse	
3	6	Sandstone, highly weathered, yellowish grey, coarse grained, micaceous (white) in places	
6	7	Sandstone, weathered, orange yellow grey, coarse grained, micaceous (white) in places	
7	9	Sandstone, weathered, orange grey, fine to medium grained	
9	10	Sandstone, fairly hard, grey, fine grained	
10	14	Sandstone, fine grained, hard, micaceous (white), interbedded with black to brown carbonaceous shale, laminated	
14	22	Sandstone & Shale, grey to black, carbonaceous, relatively hard, fine grained	
22	23	Sandstone & Shale, grey to black, fine grained, thin pitch black layer interbedded	
23	30	Sandstone, grey, gritty, pyrite in places, thin carbonaceus layer interbedded	
30	32	Sandstone, grey, gritty, hard	
32	35	Coal, black, concoidal fracture	
35	37	Sandstone, fine to medium grained, hard	

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BOREHOLE LOG: HYDROGEOLOGY AND CONSTRUCTION

Borehole No.:NBH 4	Map Ref.: 2630CA (WGS84)	
Client: Mashala Resources	S coord.: 26.26094	
Project: Mashala Resources (Ferreira)	E coord.: 29.77640	
Project No: 08/111	Airlift yield (final):	(l/s)
Farm: Witbank	Water level: 6.675	(mbcl)
District: Ermelo, Mpumalanga	Collar Height:	(m)
Province: Mpumalanga	Altitude:	(mamsl)
Logged by: Fela Ditlhale	Borehole Depth: 30	(m)
Date Completed:10/06/2009	Geophysical. Peg No.:	

Borehole diamter (mm)

Dia: 219		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12	12	30				

Water Strikes:	1	2	3	4	5	6	7
Depth:	11						
Strike yield (l/s	0.1						
Cum yield (l/s)							

Plain casing diameter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12						

Perforated casing diamter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to

Sanitary Seal:	From	To	Gravel pack:	From	To
				Bags:	

GEOLOGY: (Lithology: Colour; Grain Size; Clay Content; Weathering; Secondary features)

from	to	description	Penetration Rate (/m)
0	1	Soil, yellowish brown, fine, top soil	
1	3	Sand, yellowish brown red, coarse grained, clayey	
3	5	Sand, yellowish (dull), coarse grained, clayey	
5	6	Sand, brownish yellow, medium grained	
6	7	Sand, light brown,fine to medium grained	
7	11	Sandstone, light yellowish (goldish when wet), weathered, quartz and micaceous (white) in places	
11	12	Shale, black, dull, laminated, carbonaceous, very fine grained, mixed with brown soil	
12	14	Sandstone, grey, weathered, fine grained	
14	19	Sandstone, light grey, weathered, very fine grained	
19	21	Sandstone, light grey, fine grained, micaceous (white) in places	
21	24	Sandstone, grey, fine to medium grained, micaceous (white), laminated	
24	30	Shale, grey to black, very fine grained, micaceous, laminated	

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BOREHOLE LOG: HYDROGEOLOGY AND CONSTRUCTION

Borehole No.:NBH 5a	Map Ref.: 2630CA (WGS84)	
Client: Mashala Resources	S coord.: 26.21459	
Project: Mashala Resources (Ferreira)	E coord.: 29.77087	
Project No: 08/111	Airlift yield (final):	(l/s)
Farm: Witbank	Water level: 6.675	(mbcl)
District: Ermelo, Mpumalanga	Collar Height:	(m)
Province: Mpumalanga	Altitude:	(mamsl)
Logged by: Fela Ditlhale	Borehole Depth: 30	(m)
Date Completed:16/06/2009	Geophysical. Peg No.:	

Borehole diamter (mm)

Dia: 219		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12	12	85				

Water Strikes:	1	2	3	4	5	6	7
Depth:	11						
Strike yield (l/s	0.1						
Cum yield (l/s)							

Plain casing diameter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	6						

Perforated casing diamter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
6	12						

Sanitary Seal:	From		To	Gravel pack:	From	To	Bags:

GEOLOGY: (Lithology: Colour; Grain Size; Clay Content; Weathering; Secondary features)

from	to	description	Penetration Rate (/m)
0	1	Soil, dark brown orange, fine, top soil	
1	2	Sand, orange brown, fine to medium, clayey	
2	5	Sand, yellowish grey orange, fine, clayey	
5	6	Sand, dark brown to black, fine, clayey	
6	7	Sand, grey orange, fine, clayey	
7	8	Shale, black, fine grained, weathered, micaceous (white) in places	
8	11	Sandstone, grey, fine grained, weathered, micaceous (white) in places	
11	12	Shale, black, fine grained, weathered, micaceous (white) in places	
		laminated	
12	13	Sandstone, grey, fine grained, micaceous (white) in places	
13	14	Shale, black, fine grained, carbonaceous, micaceous (white)	
14	28	Sandstone, grey, fine grained, micaceous (white)	
28	36	Shale, black, coaly, very fine grained, dull, laminated	
36	38	Shale, black, very fine, mixed with coal	
38	49	Shale & Sandstone, Shale: black, very fine grained, interbedded with	
		grey, fine grained, micaceous, hard sandstone	
49	50	Shale, black, very fine, mixed with coal	
50	62	Shale, black, fine grained, laminated, carbonaceous	
62	75	Shale & Sandstone, Shale: black, very fine grained, interbedded with	
		grey, fine grained sandstone	
75	80	Sandstone, light grey, fine grained	
80	81	Shale & Sandstone, Shale: black, very fine grained, interbedded with	
		grey, fine grained, sandstone	
81	85	Sandstone, grey, fine grained	

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BOREHOLE LOG: HYDROGEOLOGY AND CONSTRUCTION

Borehole No.:NBH 5b	Map Ref.: 2630CA (WGS84)	
Client: Mashala Resources	S coord.:	
Project: Mashala Resources (Ferreira)	E coord.:	
Project No: 08/111	Airlift yield (final):	(l/s)
Farm: Witbank	Water level: 11.75	(mbcl)
District: Ermelo, Mpumalanga	Collar Height:	(m)
Province: Mpumalanga	Altitude:	(mamsl)
Logged by: Fela Ditlhale	Borehole Depth: 12	(m)
Date Completed:17/06/2009	Geophysical. Peg No.:	

Borehole diamter (mm)							
Dia: 219		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12						

Water Strikes:	1	2	3	4	5	6	7
Depth:							
Strike yield (l/s							
Cum yield (l/s):							

Plain casing diameter (mm)							
Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	6						

Perforated casing diamter (mm)							
Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
6	12						

Sanitary Seal:	From	To	Gravel pack:	From	To	Bags:

GEOLOGY: (Lithology: Colour; Grain Size; Clay Content; Weathering; Secondary features)

from	to	description	Penetration Rate (/m)
0	1	Soil, brown orange, fine, top soil	
1	2	Sand, Light brown orange, fine, clayey	
2	6	Sand, yellow grey orange, fine	
6	7	Coal, black	
7	8	Sandstone, grey, weathered, fine, mixed with coal	
8	11	Sandstone, dark grey, fine grained	
11	12	Sandstone, grey, fine grained, hard	

GCS WATER ENVIRONMENTAL ENGINEERING EARTH SCIENCES

BOREHOLE LOG: HYDROGEOLOGY AND CONSTRUCTION

Borehole No.:NBH 6	Map Ref.: 2630CA (WGS84)
Client: Mashala Resources	S coord.: 26.25886
Project: Mashala Resources (Ferreira)	E coord.: 29.78680
Project No: 08/111	Airlift yield (final): (l/s)
Farm: Witbank	Water level: (mbcl)
District: Ermelo, Mpumalanga	Collar Height: (m)
Province: Mpumalanga	Altitude: (mamsl)
Logged by: Fela Ditlhale	Borehole Depth: 30 (m)
Date Completed:09/06/2009	Geophysical. Peg No.:

Borehole diamter (mm)

Dia: 219		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12	12	30				

Water Strikes:	1	2	3	4	5	6	7
Depth:							
Strike yield (l/s)							
Cum yield (l/s)							

Plain casing diameter (mm)

Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to
0	12						

Perforated casing diamter (mm)

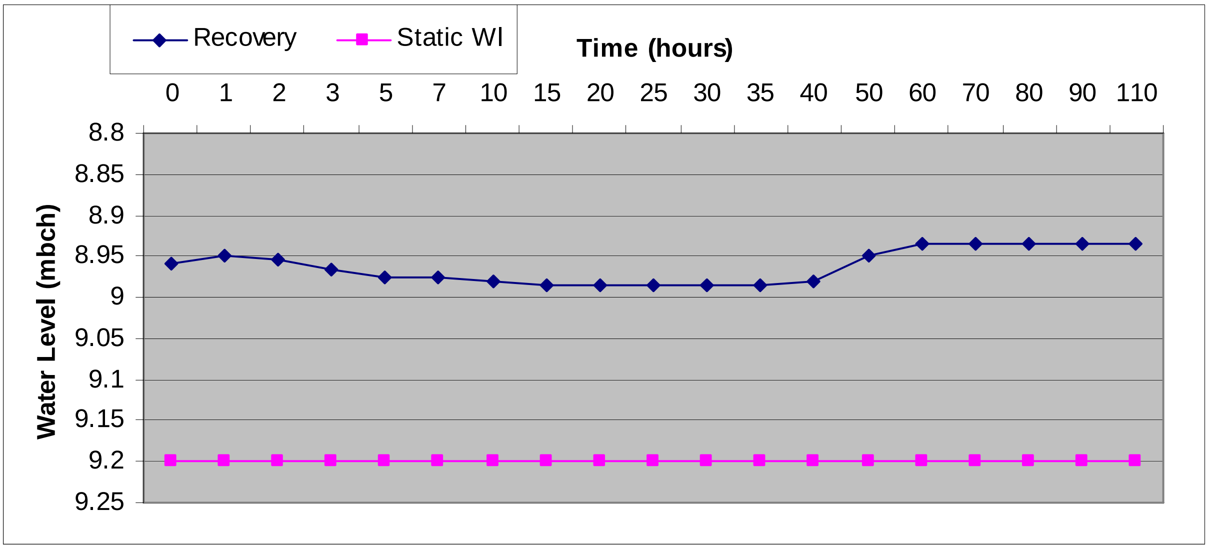
Dia: 165		Dia: 165		Dia:		Dia:	
from	to	from	to	from	to	from	to

Sanitary Seal:	From	To	Gravel pack:	From	To	Bags:

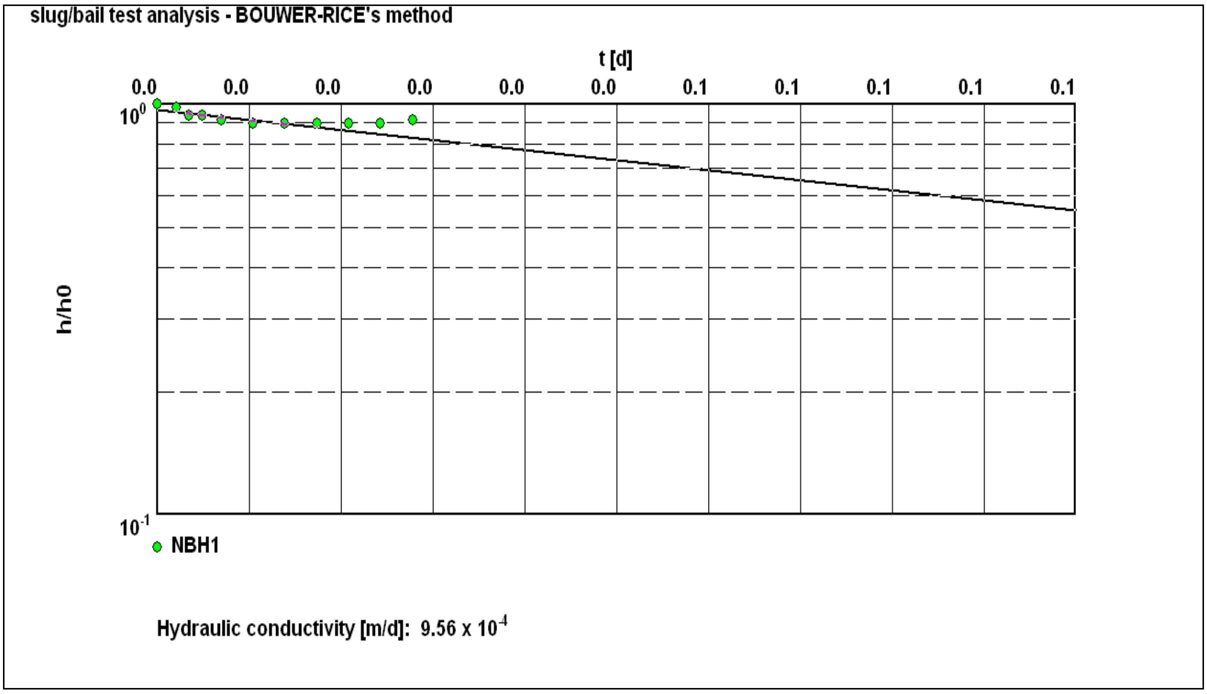
GEOLOGY: (Lithology: Colour; Grain Size; Clay Content; Weathering; Secondary features)

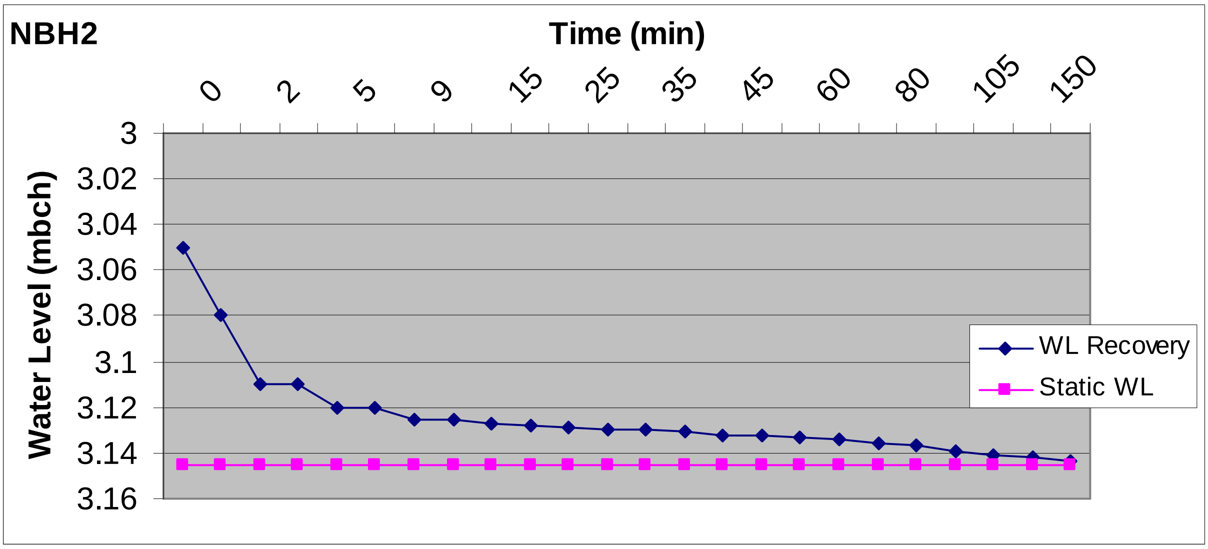
from	to	description	Penetration Rate (/m)
0	1	Soil, orangish brown, fine, top soil	
1	2	Sand, cream, medium grained	
2	5	Sand, greyish brown, medium grained	
5	7	Sand, dark grey brown, medium grained	
7	10	Sand, greyish brown, medium grained	
10	11	Sand, greyish cream, medium grained	
11	12	Sand, brownish orange, medium to coarse grained	
12	14	Shale, grey to black, fine grained, laminated	
14	15	Sandstone, grey fine grained, laminated (thin black layers)	
15	17	Shale, grey to black, fine grained, laminated, carbonaceous	
17	19	Sandstone, grey, very fine grained, micaceous (white)	
19	20	Shale, black, coaly, fine grained, micaceous (shiny), carbonaceous	
20	30	Sandstone & Shale. Sandstone: grey, weathered, medium rounded	
		grains. Shale: black, coaly, micaceous, carbonaceous	

Appendix B – Aquifer Test Data

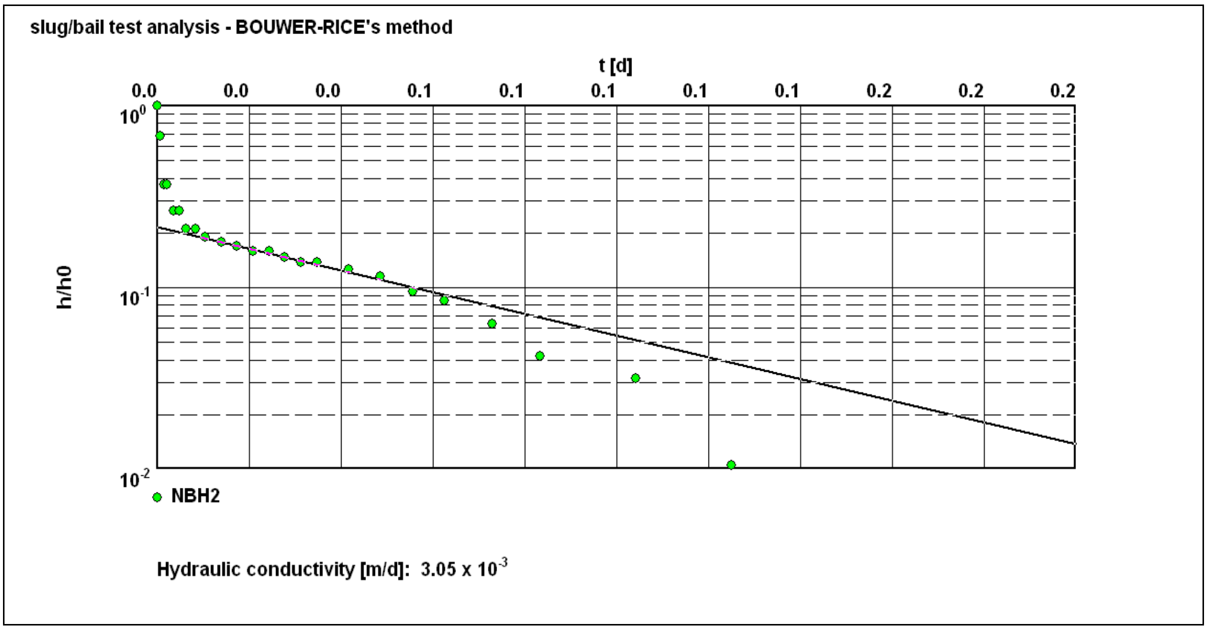


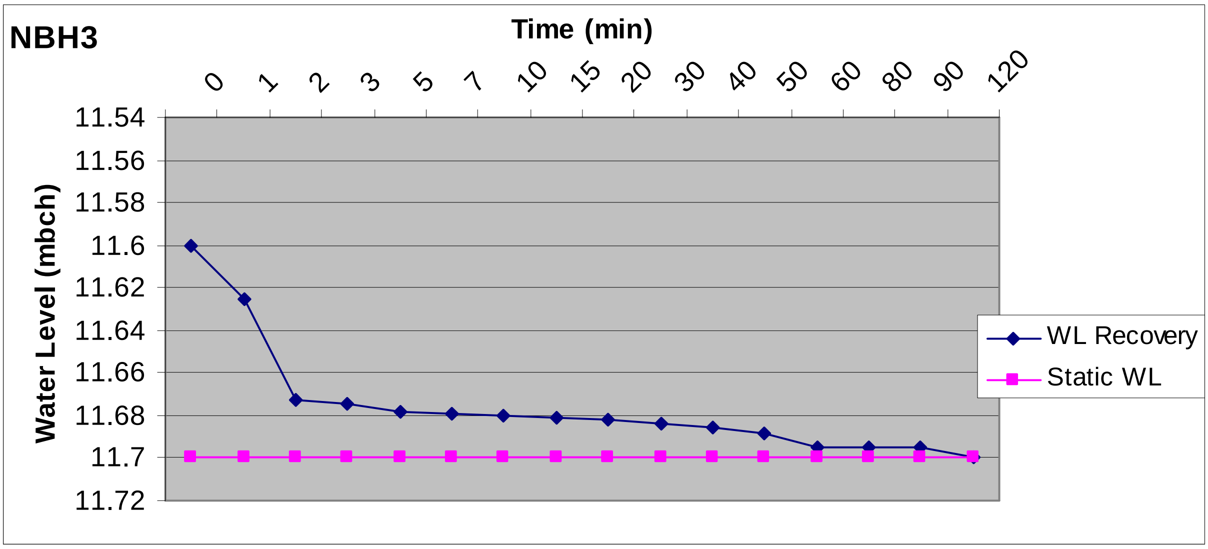
Borehole NBH1 raw data



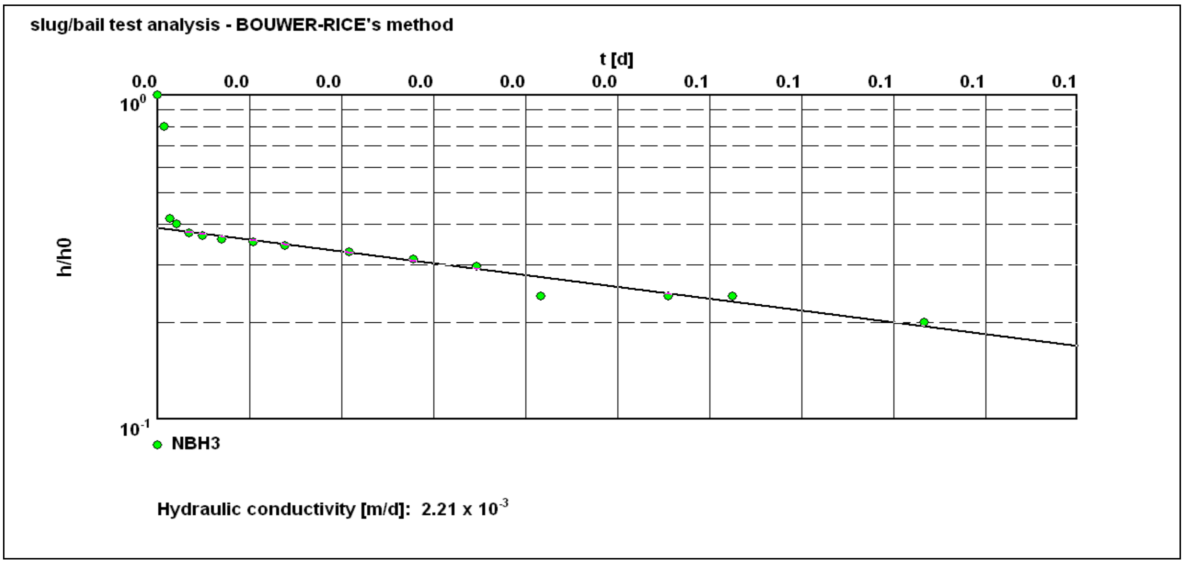


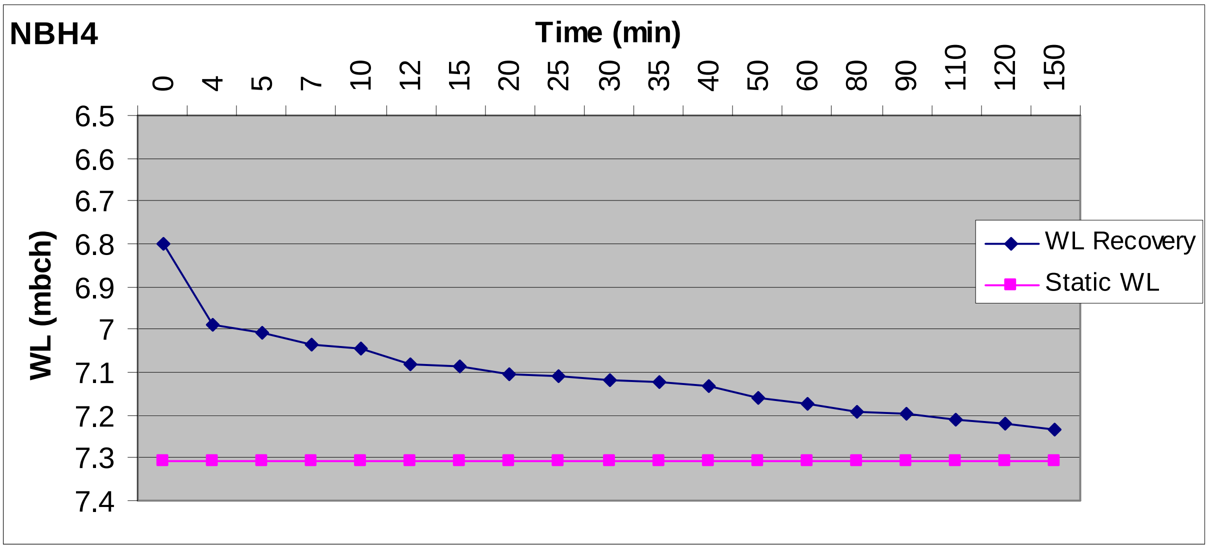
Borehole NBH2 raw data



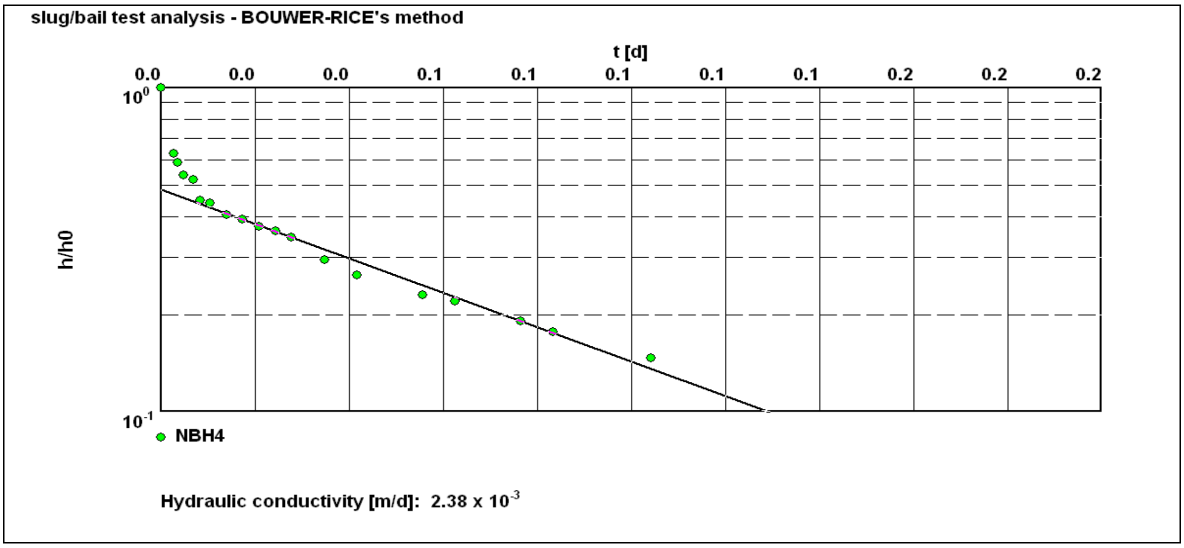


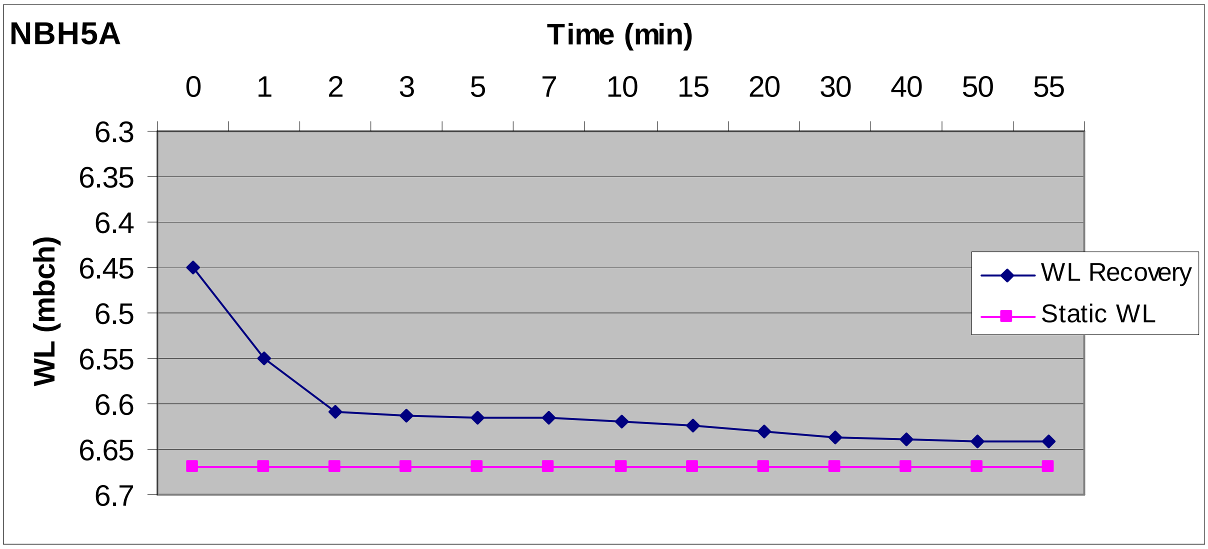
Borehole NBH3 raw data



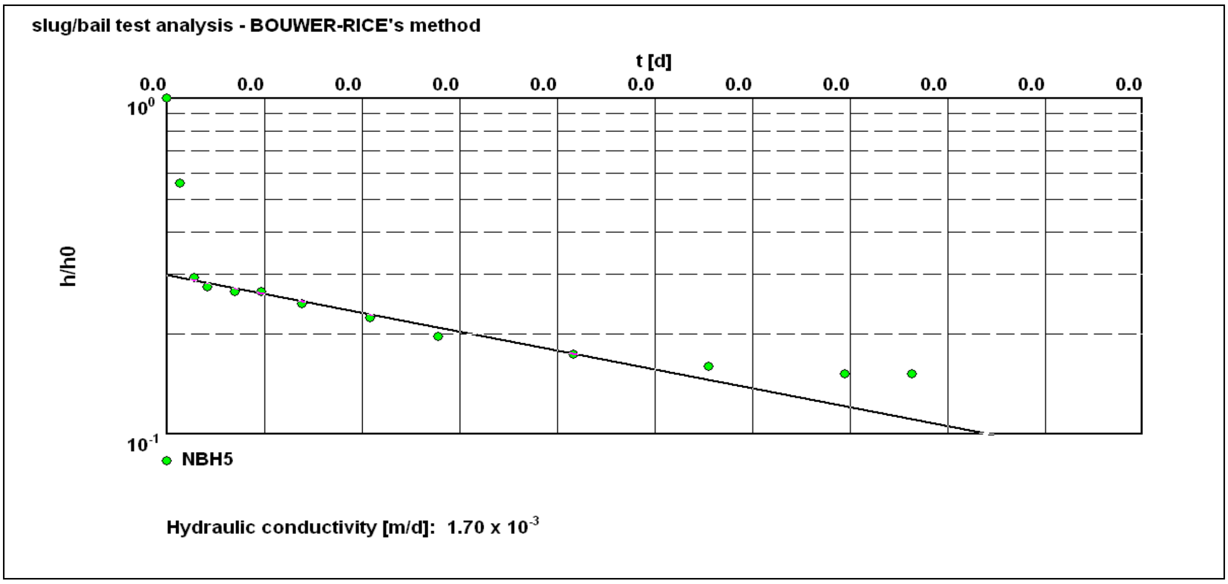


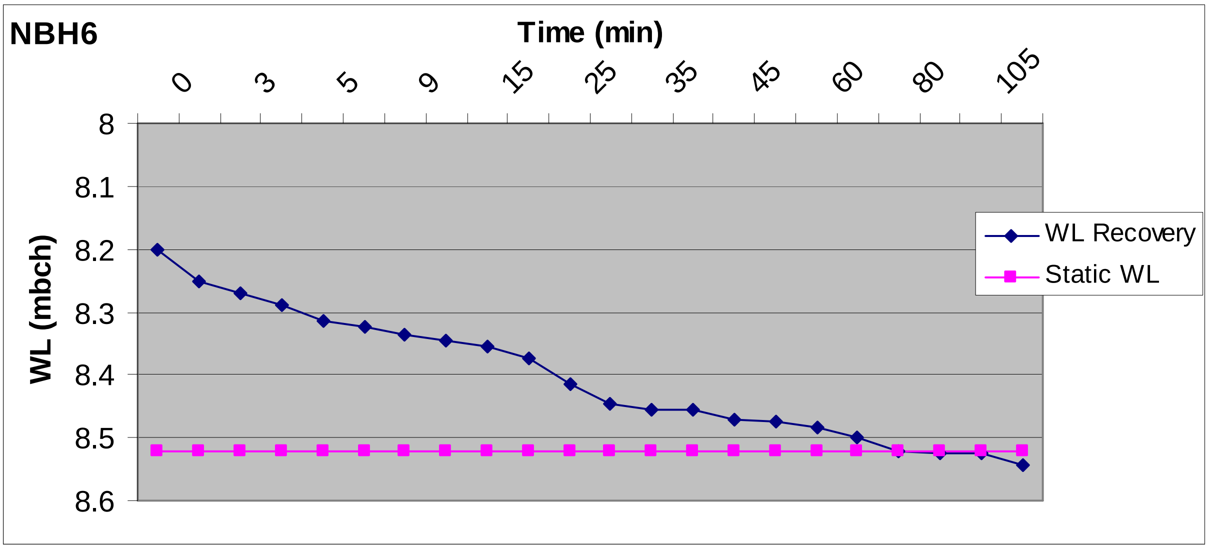
Borehole NBH4 raw data





Borehole NBH5A raw data





Borehole NBH6 raw data