Aquila rapax	Tawny Eagle	VU	moderate-high
Polemaetus bellicosus	Martial Eagle	VU	moderate
Falco naumanni	Lesser Kestrel	VU	moderate-high
Falco biarmicus	Lanner Falcon	NT	moderate-high
Ardeotis kori	Kori Bustard	VU	high
Neotis ludwigii	Ludwig's Bustard	VU	moderate
Charadrius pallidus	Chestnut-banded Plover	NT	moderate-low
Glareola nordmanni	Black-winged Pratincole	NT	moderate-low
MAMMALS			
Acinonyx jubatus	Cheetah	VU	low
Atelerix frontalis	South African Hedgehog	NT	low
Bathyergus janetta	Namaqua Dune Mole-rat	NT	low
Bunolagus monticularis	Riverine Rabbit	CR	low
Chrysochloris asiatica	Cape Golden Mole	DD	low
Chrysochloris visagiei	Visagie's Golden Mole	CR	low
Cistugo lesueuri	Leseur's Wing-gland Bat	NT	low
Cistugo seabrai	Angolan Wing-gland Bat	VU	low
Crocidura cyanea	Reddish-grey Musk Shrew	DD	moderate-high
Crocidura fuscomurina	Tiny Musk Shrew	DD	low
Crocidura hirta	Lesser Red Musk Shrew	DD	moderate
Crocidura silacea	Lesser Grey-brown Musk Shrew	DD	low
Crocuta crocuta	Spotted Hyaena	NT	low
Cryptochloris wintoni	De Winton's Golden Mole	CR	low
Damaliscus lunatus	Western Tsessebe	EN	low
Diceros bicornis bicornis	Black Rhinoceros - arid ecotype	CR	low
Elephantulus intufi	Bushveld Elephant-shrew	DD	low
Equus zebra hartmannae	Hartmann's Mountain Zebra	EN	low
Erimitalpa granti	Grant's Golden Mole	VU	low
Graphiurus platyops	Rock Dormouse	DD	low
Hippotragus equinus	Roan Antelope	VU	low
Parahyaena brunnea	Brown Hyaena	NT	moderate
Lycaon pictus	African Wild Dog	EN	low
Manis temminckii	Ground Pangolin	VU	low
Mellivora capensis	Honey Badger	NT	moderate
Miniopterus schreibersii	Schreiber's Long-fingered Bat	NT	moderate
Mirounga leonina	Southern Elephant Seal	EN	low
Myosorex varius	Forest Shrew	DD	low
Mystromys albicaudatus	White-tailed Rat	EN	low
Otomys slogetti	Sloggett's Rat	DD	low
Panthera leo	Lion	VU	low
Paratomys littledalei	Littledale's Whistling Rat	NT	low
Petromys typicus	Dassie Rat	NT	low
Poecilogale albinucha	African Striped Weasel	DD	low
Rhinolophus capensis	Cape Horseshoe Bat	NT	low
Rhinolophus clivosus	Geoffroy's Horseshoe Bat	NT	moderate
Rhinolophus darlingi	Darling's Horseshoe Bat	NT	moderate-low
Rhinolophus denti	Dent's Horseshoe Bat	NT	moderate-low
Rhinolophus fumigatus	Ruppel's Horseshoe Bat	NT	low
Suncus varilla	Lesser Dwarf Shrew	DD	low
Tatera leucogaster	Bushveld Gerbil	DD	moderate
Xerus princeps	Mountain Ground Squirrel	NT	low

Ninety-two red data species from five categories (IUCN) are known to occur in the Northern Cape (Invertebrates, Reptiles, Frogs and Mammals) and the Q-grid 2722BD (birds). Of these, 18 are listed as Data Deficient (DD), 28 as Near Threatened (NT), 35 as Vulnerable (VU), 6 as Endangered (EN) and 5 as Critically Endangered (CR). It is estimated that 63 of the 92 species have a low probability of occurring in the study area; 8 have an estimated moderate-low probability of occurring, 15 a moderate and 4 a moderate-high probability (Table 3). Additionally, two red data are estimated to have a high probability of occurring in the study area:

The Secretarybird, *Sagittarius serpentarius* (Falconiformes: Sagittariidae), is a Near Threatened (NT) bird found throughout sub-Saharan Africa. The Secretarybird prefers open grassland with scattered trees, shrubland and open woodland savanna. The species is currently not threatened but local populations in South Africa are decreasing.

The Kori Bustard, *Ardeotis kori* (Gruiformes: Otididae), is listed as Vulnerable – the species is found singly or in loose groups in the non-breeding season. The Kori Bustard is found in fairly dry, open savanna (rainfall between 100 and 600 mm per annum); also in Nama-Karoo dwarf shrubland and occasionally in western grasslands and dry grassy pan edges. Threats to the species include habitat loss, poisoning, deliberate snaring and dogs. The species is also vulnerable to overhead collisions with power lines.

4.4.3 Protected Faunal Species

The Northern Cape includes ten provincially listed protected species (www.speciesstatus.sanbi.org – NEMBA status).

Table 26: Protected species of the Northern Cape.

Biological Name	English Name	NEMBA status	Probability
Aonyx capensis	African Clawless Otter	protected	low
Atelerix frontalis	South African Hedgehog	protected	low
Ceratotherium simum	White Rhinoceros	protected	low
Circus ranivorus	African Marsh Harrier	protected	low
Crocuta crocuta	Spotted Hyaena	protected	low
Diceros bicornis	Black Rhinoceros	protected	low
Felis nigripes	Black-footed Cat	protected	moderate
Parahyaena brunnea	Brown Hyaena	protected	moderate
Spheniscus demersus	African Penguin	protected	low
Vulpes chama	Cape Fox	protected	moderate

It is estimated that seven of the ten species listed in Table 26 are unlikely to occur in the study area (low estimated probability of occurrence); three species are considered to have a moderate probability of occurrence.

4.4.4 Concerns

The study area is located in the relatively untransformed Northern Cape Province of South Africa. On a regional scale, the Kathu Bushveld regional vegetation community (part of the Eastern Kalahari Bushveld Bioregion) is listed as Least Threatened and 98.8% remains untransformed (VegMap 2006). That being said, significant developments have been proposed for the Northern Cape in general as well as the region in which the study area is located since 2006 (pers. obs.) Proposed developments include Photovoltaic Plants (solar energy), transmission power lines and mining developments. On an EIA level, these projects are usually treated singly and consequently the impact assessments seldom consider the cumulative effects of all of these proposed land transformations.

In addition, the study area is untransformed and well connected; the effects of habitat transformation and fragmentation (loss of connectivity, edge effects etc.) are likely insignificant in the region of the study area (except for the developed areas such as the town of Hotazel). It is therefore considered highly likely that at least two red data animals will be present in the study area (Secretarybird and Kori Bustard) and at least moderately likely, that at least another nineteen species will occur (cf. Table 25). Species such as the Black-footed Cat are poorly known and the potential impacts of the proposed project on these species are difficult to predict.

5 RECOMMENDATIONS

5.1 Flora

Based on the information available and the nature of the project, the following recommendations are made:

1. Due to the untransformed nature of the landscape, new infrastructure should be kept close to existing infrastructure as practically possible to prevent additional habitat fragmentation
2. The area along the western boundry is associated with a riparian wetland, its should be managed in accordance with the National Water Management Act.
3. Due to the critical function of vegetation to stabilise the soils within an arid landscape, unnecessary destruction of vegetation should be avoided at all cost.
    a. Should the proposed activity have a detrimental impact on the vegetation cover in the area, steps should be taken immediately to address and stabilise it because it posses the following risks:
        i. Failure to address the loss of vegetation would enhance/ accelerate deflation, which could result in a deflation hollow/ blowout (Strahler & Strahler 1987)
        ii. The absence of vegetation would also increase the abrasion potential of the wind (Strahler & Strahler 1987).
    b. It should be noted, that because this is an arid environment, it is far more difficult to address vegetation loss and to facilitate rehabilitation than in more humid environments. THUS PREVENTION IS BETTER THAN CURE!
4. To ensure environmental legal compliance in terms of
    a. the national Forests Act
    b. the provincial Nature and Environmental Conservation Ordinance
    c. the national Conservation of Agricultural Resources Act
    d. the National Environmental Management Biodiversity Act
        i. it is strongly recommended that a detail vegetation survey be completed by a regional vegetation specialist during the optimal flowering period (April/ May, August/ September), prior to construction to:
            - identify all those species for which permits are required to allow their removal or destruction
            - identify plant specimens, which would qualify for plant rescue or for which seed should be obtained to assist with their re-establishment
            - document qualitative and quantitative, the species present, their composition and ecological drivers, to facilitate future rehabilitation of the area, should the activity be stopped and closure required, without this information no baseline information would be available to facilitate and monitor/ measure the success of the rehabilitation process.
5. Effective storm water management should form a critical component of the design of the areas, as the increased runoff from the infrastructure will enhance the effect of localised rainfall events on the drainage areas present in the area, this include the runoff to be generated from buildings, parking areas and roads. The emphasis should be on water retention and flow reduction to prevent the displacement of vegetation and subsequent excessive erosion.
6. To facilitate baseline data collection and future monitoring, it is strongly recommended that high resolution aerial photographs be taken prior to construction, repeated once during construction and on completion of construction and thereafter at least once a year for the duration of the activity; without this information it would not be possible to identify areas of:
    a. vegetation loss
    b. ponding
    c. erosion
    d. encroachment/ disturbance
    e. rehabilitation/ restoration and/ or their progress/ success
7. Should ornamental gardens be established for what so ever reason, then only regionally indigenous species should be used!

5. Conceptual groundwater impact assessment

5.1. Construction phase

During the construction phase the historic mine area will be dewatered. It is expected that the mine area will be completely dewatered. Depth to groundwater level in the area as measured in the hydrocensus and the newly drilled monitoring boreholes range around 27 to 32 mbgl. The water level in the opencast pit is thus expected to be lowered below the surrounding regional groundwater level leading to groundwater inflows into the pit area from the surrounding aquifers.

The groundwater that seeps into the open pit from the surrounding aquifers will have to be pumped from the mining area in order to ensure a dry working environment. This will lead to localised dewatering of the aquifers surrounding the historic mining area. Groundwater inflow rates are not expected to exceed 10 m^3/day. The zone of influence of the drawdown cone is calculated using Sichardt's equation:

$$R_i = 3000 D_0 \sqrt{k}$$

Where:

R_i = radius of the zone of influence;
D_0 = maximum drawdown in groundwater level of 72 m (assume 100 m deep historic mining that have to be dewatered and a regional groundwater level of 28 mbgl); and
k = aquifer hydraulic conductivity (using a minimum hydraulic conductivity of 0.001 m/day for the non-fractured host rock and a maximum hydraulic conductivity of 0.021 m/day for individual fractures it is calculated to be between 1.16E-8 and 2.43E-7 m/sec for the fractured rock aquifer).

Thus, it can be calculated that the maximum zone of influence in the general competent rock using a hydraulic conductivity of 2.43E-7 m/sec is around 110 m. Based on this it can be said that none of the privately owned boreholes will be impacted by the mine dewatering.

Surface construction of the discard and tailings dumps, settling and evaporation ponds, pollution control dams, haul roads and offices will not breach the groundwater level and is therefore not expected to have any notable impact on the groundwater levels.

In general it can be said that the impacts during the construction phase will be small.

5.2. Operational phase

5.2.1. Groundwater level drawdown and the zone of influence

The mine floor elevations are below the general groundwater level thus causing groundwater inflows into the mining areas from the surrounding aquifers during operations. The mining areas will have to be actively dewatered to ensure a safe working environment. Pumping groundwater that seeps into the mine area to surface will cause dewatering of the surrounding aquifers and an associated decrease in groundwater level within the zone of influence of the dewatering cones.

The zone of influence of the dewatering cone depends on several factors including the depth of mining below the regional groundwater level, recharge from rainfall to the aquifers, vertical infiltration of the recharging water, the size of the mining area, the aquifer transmissivity, and aquifer storativity amongst others. An analytical calculation of the theoretical zone of influence is again done using Sichardt's equation:

$$R_i = 3000 D_0 \sqrt{k}$$

Where:

R_i = radius of the zone of influence;

D_0 = maximum drawdown in groundwater level (assume 100 m deep excavations to the deepest point of the LMO seam and average groundwater levels of 28 mbgl – thus 72 m available drawdown); and

k = aquifer hydraulic conductivity (using a minimum hydraulic conductivity of 0.001 m/day for the non-fractured host rock and a maximum hydraulic conductivity of 0.021 m/day for individual fractures it is calculated to be between 1.16E-8 and 2.43E-7 m/sec for the fractured rock aquifer).

Thus, it can be calculated that the maximum zone of influence in the general competent rock using a hydraulic conductivity of 1.16E-8 m/sec is around 25 m. The calculated zone of influence in the individual groundwater bearing fractures with hydraulic conductivities of up to 2.43 m/sec range up to 110 m from the mining area.

Sichardt's equation is widely acknowledged to under estimate the zone of influence somewhat. Therefore, a value of 200 m is assumed to be conservative. The zone of influence is indicated on Figure 5.1. Based on this calculation, and as shown in Figure 5.1, it can be said that none of the privately owned boreholes will be impacted by the mine dewatering.

Please note that the Witleegte stream has non-perennial flows. Therefore, even though the channel represents a topographical low, it is considered that the drawdown cone can develop to the opposite side of the topographical depression due to a combination of:

- The depth of the mining and groundwater level in the area;
- The apparent poor hydraulic connection between the stream and the underlying aquifer due to the very low hydraulic conductivity of the rock material; and
- The non-perennial nature of the stream.

5.2.2. Water inflows into the mining area

Three components of inflow need to be considered for dewatering of the open pit area:

- Direct rainfall onto the open pit;
- Recharge into the rehabilitated areas (shown by Hodgson & Krantz to be around 8 % of MAR); and
- Inflow of groundwater from adjacent aquifers.

5.2.2.1. Direct rainfall onto the pit

In order to calculate the theoretical rainfall recharge volumes that have to be dewatered to ensure effective dewatering of the mining area it is necessary to quantify:

- The surface area where recharge can take place:
  - Open pit - the full extent of the annual open pit is taken into account;
- Average annual rainfall – 350 mm; and
- Percentage recharge from rainfall into the open pit: - 100 %.

The average daily dewatering capacity required to remove direct recharge from rainfall onto the pit is summarised in Table 5.1. The calculated direct rainfall onto the pit area range between 7 and 63 m^3/day depending on the size of the open pit. Do note that these listed values are only annual average values. In reality the rainy season occurs between October and April with little rainfall occurring during the dry season. Therefore, direct rainfall into the pit during the rainy season will be higher than the values shown in Table 5.1. The direct rainfall into the pit could possibly as high as 150 m^3/day during January 2018 when the open pit area is at its largest with a total combined area of 65 760 m^2 for the pits opened during 2016, 2017, and 2018 (keep in mind that rehabilitation only begins three years after mining started). January is also the month with the highest average rainfall at 70 mm.

The average direct rainfall will be balanced by evaporation that will also influence the required dewatering volumes and the numbers calculated here could be seen as a worst-case scenario.

5.2.2.2. Recharge onto the rehabilitated areas

As discussed in Section 4.7 recharge onto rehabilitated areas have been characterised to be around 8 % of mean annual rainfall by Hodgson & Krantz (1998). The mine works plan indicates that continuous rehabilitation of the opencast areas will take place during the life of mine. However, the mine works plan also state that rehabilitation will only start 3 years after the ore mining operation started. Thus, it can be assumed that rehabilitation will start around 2018.

For the purpose of this study it is assumed that each year from 2018 onwards one year's worth of mining area will be rehabilitated. Thus, during 2018 the total area mined during 2015 will be rehabilitated and so forth.

The calculated recharge volumes into the rehabilitated areas are summarised in Table 5.1. It should be noted that these calculated values represent the worst-case scenario as a notable portion of the recharging rainwater will be retained within the rehabilitated material (possibly up to 20 %) thus decreasing the dewatering requirement. The water retained within the rehabilitated material will lead to a rising water level in the rehabilitated material.

An important point to note is that although a portion of the recharging water will be retained in the rehabilitated material the depth to mine pit floor will increase over time as the mining continues towards the west. This will allow for the rainwater that recharge into the rehabilitated material to run under gravity along the pit floor towards the topographically lowest point in the excavations, which would be represented by the latest active mining area. The recharged water will converge and accumulate at the lowest excavated point from where it can be dewatered.

Thus, it can be said that the final volume of water that enters the mining area through recharge onto the rehabilitated material, and that will have to be dewatered, will be somewhat lower than the theoretical maximum values calculated here and summarised in Table 5.1.

5.2.2.3. Groundwater inflow volumes

In order to conceptually quantify the groundwater inflows into the pit area the "equivalent well approach" is used. This approach is commonly used to estimate the inflows into opencast mine workings. The approach assumes that dewatering of the excavation is approximated by the use of an imaginary borehole, fully penetrating the entire saturated thickness of the aquifer. Water is abstracted at a uniform rate to maintain the groundwater level in the aquifer below the level of the excavation. The excavation itself is assumed to represent a large diameter well.

Theoretical groundwater inflow volumes are calculated using the "modified Dupuit equation":

$$Q = \frac{\pi k(H^2 - h^2)}{\ln\frac{R}{r}}$$

Where:

Q = the inflow volume;
k = the hydraulic conductivity (calculated to be between 1.16E-8 and 2.43E-7 m/sec for the fractured rock aquifer – refer to Section 5.2.1);
H = the hydraulic head above the final pit floor at distance R (taking into consideration the pit depth for each year, and an average depth to the regional groundwater level of 28 m);
h = hydraulic head above the final pit floor at distance r (equal to 0 m under the assumption that the water level will be drawn down the final pit floor level);
r = the radius of the imaginary borehole required to simulate the areal extent of the mining area (calculated based on the total proposed Perth mining area of 236 300 m^2 to be approximately 275 m); and

R = the radial extent of drawdown (m) or distance to negligible drawdown based on Sichardt's equation – (calculated to be 200 m from the edge of the mine area – refer to Section 5.2.1).

The Dupuit equation represents the steady state volume of water leaking into the workings as a result of the change in hydraulic gradient within the infinitely extending aquifer. It does not include the effect of recharge or boundary barriers.

The effect of recharge is calculated using the equation:

$$Q_{Recharge} = \pi R^2 \rho$$

Where:

Q = Pit inflow due to recharge (m/sec);
R = radial extent of the drawdown cone based on the Sichardt equation (calculated at 200 m from the edge of the mine area in Section 5.2.1); and
ρ = recharge rate to the aquifer (at 2 % of 350 mm MAR calculated to be 2.22E-10 m/sec).

The theoretical groundwater inflow volumes at different average hydraulic conductivities for the surrounding rock material are summarised in Table 5.1. The hydraulic conductivities are calculated from the aquifer transmissivities obtained from pump testing using the equation:

T = k x d

Where:

T = transmissivity as calculated from aquifer test data (m^2/day)
k = hydraulic conductivity; and
d = the saturated thickness of the rock material that is drained. This varies depending on the depth of the pit floor beneath the regional groundwater level

As discussed previously the transmissivity of the rock material range between an expected minimum of 0.1 m^2/day for the competent, non-fractured host rock, and a maximum of 0.58 m^2/day for individual fractures. The absolute distribution of this range of transmissivities around and within the mine area is not known. Therefore a range of inflows are calculated using minimum, average, and maximum theoretical average transmissivities to obtain a better understanding of the potential inflow volumes. It has to be noted that the calculated values are in effect steady state calculated values and does not take into consideration transient state conditions as a 3D numerical flow model would.

From Table 5.1 it can be seen that using average hydraulic conductivities the groundwater inflow volumes into the pit area range between 10 and 120 m^3/day over the life of mine. As expected, the inflow volumes are initially relatively low and then increase over time due to:

- The increasing size of the mined-out area which increase the wall space through which seepage from the surrounding aquifers into the mine area increase;
- The increasing depth of the pit floor elevation below the regional groundwater level. Following the Darcy Equation this increases the groundwater flow gradient which leads to increased inflows; and
- Increased recharge into the rehabilitated material (approximately 8 % of MAR) compared to that of the natural, pre-mined area (effectively approximately 1 to 3 % of MAR)

At the end of the life of mine, when the mined out area is the largest, the rehabilitated area is the largest, and the pit floor is the deepest below the regional groundwater levels, groundwater inflows are expected to be 120 m^3/day when using the average hydraulic conductivity values.

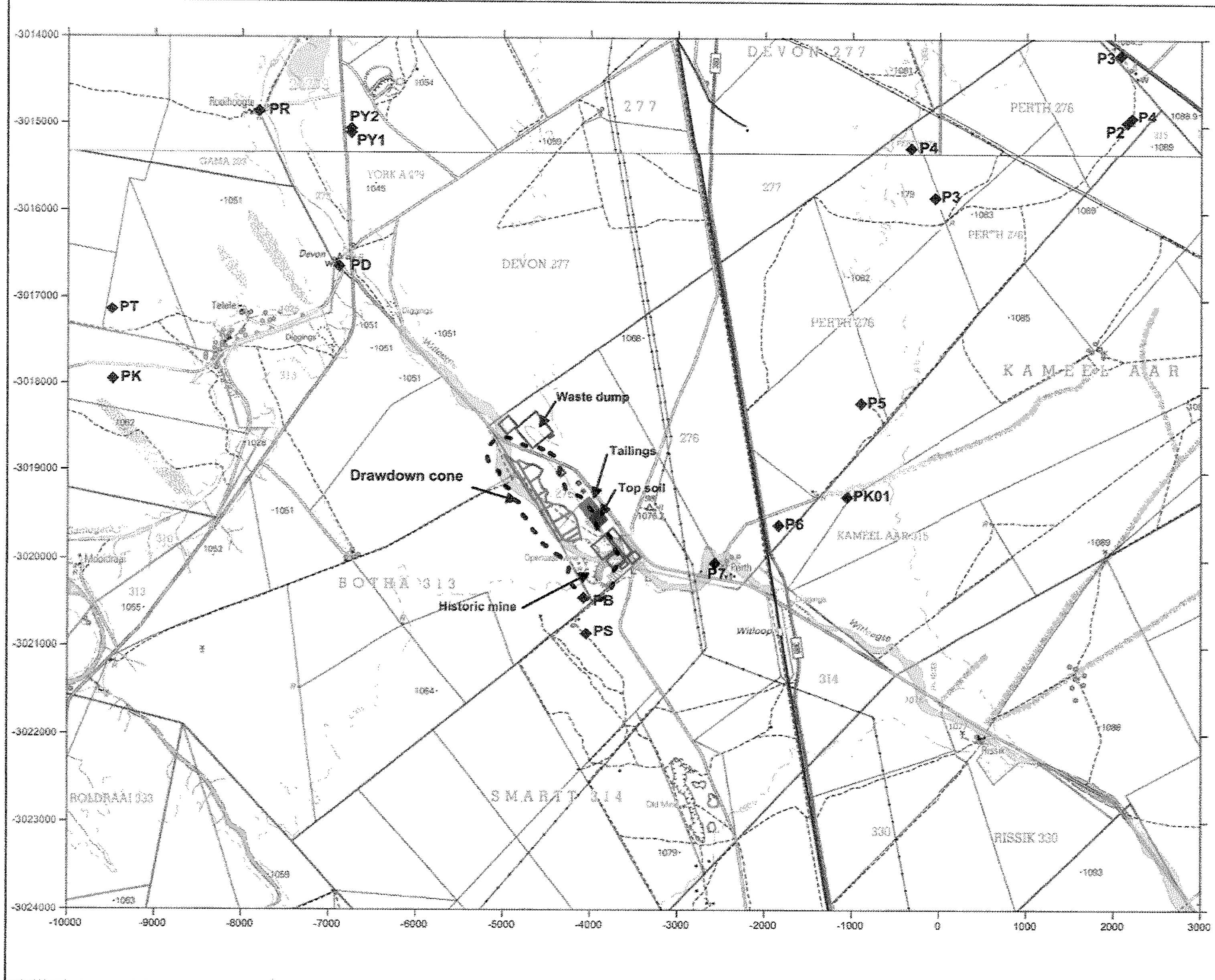
It has to be pointed out that recharge from rainfall (directly into the pit and into the rehabilitated material) will not be a constant value as shown in Table 5.1 where annual rainfall is averaged for daily values. In reality the rainy season occurs between October and April with little rainfall occurring during the dry season. Therefore, direct rainfall into the pit during the rainy season will be higher than the values shown in Table 5.1. As discussed in Section 5.2.2.1 the direct rainfall into the pit could possibly as high as 150 m^3/day during January 2018 when the open pit is at its largest with a total combined area of 65 760 m^2 for the pits opened during 2016, 2017, and 2018 (keep in mind that rehabilitation only begins three years after mining started). January is also the month with the highest average rainfall at 70 mm.

5.2.3. Groundwater contamination

Groundwater flows around the mining area, within the zone of influence of the mine dewatering cone, will be directed towards the mine area. Water will be pumped from the pit to surface water management structures and therefore very little to no contamination is expected to reach the surrounding aquifers from the opencast pit area.

The waste, topsoil, and tailings storage facilities are located mostly outside the zone of influence of the drawdown cone around the mining area. Therefore, it can be said that any contamination from these sources will not necessarily be drawn towards the mining area and could leave the mine area.

The detail designs of the waste, tailings, and top soil storage facilities are not currently known. The sandy gravel that overlies the area around the proposed mine inherently has a relatively high hydraulic conductivity compared to the competent rock and can have a conductivity in the order of 1 to 5 m/day. This could lead to significant contaminant migration away from surface infrastructure should there be vertical seepage from these infrastructure towards the underlying sandy gravel. It is assumed that the sandy gravel will be excavated (average thickness of 5.6 m), or sealed off using a synthetic liner and leakage detection system, especially at the tailings and waste facilities, which will prevent contamination of the underlying aquifers.



PT◆ Hydrocensus position

Proposed Development

- Proposed top soil area
- Proposed tailings area
- Proposed office areas
- Proposed waste area
- Proposed mine area

Reference Maps

Topographical: 2722BB; 2722BD 2723AA; 2723AC
Geological: 2722
Satellite image: Google Earth
Mine development: As supplied
WGS84 Datum LO23

Client: Sebilo

Project: Perth Manganese Mine

Figure Number: 5.1

Figure Name: Groundwater level drawdown zone of influence - Operational phase

Scale: As shown

Date: April 2012
Revision: 1

Designed: MP
Approved:

Future Flow

Unit 111, Mont Blanc, View St, Roodeplaat 0181
P.O. Box 161, Menlyn, 0063
Pretoria, South Africa

Table 5.1: Theoretical steady state pit inflows

Year	Pit area (m^2)	Underground area (m^2)	Pit depth (m)	Underground depth (m)	Groundwater inflows (m^3/day)			Recharge inflows (m^3/day)	Total groundwater inflows (m^3/day)			Direct rainfall (m^3/day)	Recharge onto rehab areas (m^3/day)	Total mine inflows (m^3/day)		
					Min	Ave	Max		Min	Ave	Max			Min	Ave	Max
2015	Construction	No underground mining	35	No underground mining	4	10	23	0.03	4	10	23	Construction	No rehab yet	4	10	23
2016	7 640		40		7	17	40	0.03	7	17	40	7	No rehab yet	14	24	47
2017	13 610		40		7	17	40	0.03	7	17	40	20	No rehab yet	27	37	60
2018	44 510		40		7	17	40	0.03	7	17	40	63	1	71	80	104
2019	32 800		67		22	54	130	0.03	22	54	130	31	2	56	87	163
2020	14 830		67		22	54	130	0.03	22	54	130	14	5	42	73	149
2021	18 790		82.47		31	75	182	0.03	31	75	182	18	8	57	101	207
2022	28 270		84.38		32	78	188	0.03	32	78	188	27	9	68	114	224
2023	7 150	8690	No open pit mining	90	36	86	207	0.03	36	86	207	7	10	53	103	224
2024	No open pit mining	13790		90	36	86	207	0.03	36	86	207	7	12	55	105	226
2025		18550		90	36	86	207	0.03	36	86	207	7	13	55	105	227
2026		28090		100	41	99	240	0.03	41	99	240	7	13	61	119	260

m = metres
m/sec = metres per second
m^3/day = cubic metres per day

5.3. Decommissioning phase

5.3.1. Groundwater level recovery

Mine dewatering will stop during the decommissioning phase and the groundwater level in the aquifers surrounding the mine will start to recover as the water level in the mined-out area rises. However, it is considered that during the time span of the decommissioning phase (assumed to be less than 6 months) there will be little measurable rise in the water levels due to the fact that the underground area will require a large volume to be flooded.

5.3.2. Contamination of the surrounding aquifers

Groundwater flows around the mining area, within the zone of influence of the mine dewatering cone, will remain directed towards the mine area even though mine dewatering has stopped. This is due to the fact that the decommissioning phase is not expected to last more than 6 months which is not sufficient time for the water level in the pit area to recover significantly.

As discussed in Section 5.2.3 the waste, topsoil, and tailings storage facilities are located mostly outside the zone of influence of the drawdown cone around the mining area. Therefore, it can be said that any contamination from these sources will not necessarily be drawn towards the mining area and could leave the mine area.

5.4. Long term post-operational phase

5.4.1. Recovery of groundwater levels

The water level in the pit area is expected to rise once mine dewatering stop. The rate of rise of the groundwater will be dependent on:

- Recharge into the rehabilitated material can be assumed to be around 8 to 10 % of mean annual rainfall (Hodgson & Krantz 1998);
- There will be inflows into the pit from the surrounding aquifers. The inflow rate will depend to a large extend on the groundwater flow gradient between the surrounding aquifers and the water level in the rehabilitated material;
- There will be little to no impact from evaporation on the rising water level other than removal of recharging water before it reaches the saturated zone; and
- The volume of space to be filled:
    - Pore volume in the rehabilitated opencast area (shown to be in the order of 20 % of the total volume of rehabilitated material); and
    - Open void space in the underground mine

As described above the water inflows into the rehabilitated pit will depend on groundwater inflows from the surrounding aquifers as well as rainfall recharge. Rainfall recharge can be assumed to be 8 % of the mean annual rainfall (Hodgson & Krantz, 1998). The total opencast pit area is measured to be approximately 167 000 m^2. Using the average annual rainfall of 350 mm, it can be calculated that 4 676 m^3 of water will enter the rehabilitated material on an annual basis. This equates to a daily average of approximately 13 m^3/day.

Average inflows from the surrounding aquifers were calculated to be around 10 to 120 m^3/day in Section 5.2.2. The inflows are partly controlled by the groundwater flow gradient with increasing flow associated with higher flow gradients. The inflows will reduce over time as the water level in the pit area rise and the flow gradient decreases due to the reduced vertical difference between the surrounding regional groundwater levels and the water level in the pit. For the purpose of this discussion an average of 100 m^3/day is used.

These inflows from the surrounding aquifers can of course vary depending on the actual average hydraulic conductivity as listed in Table 5.1. Using the minimum aquifer hydraulic conductivity inflows range between 5 and 65 m^3/day (average 45 m^3/day) and using the maximum hydraulic conductivity yields inflows ranging between 25 and 260 m^3/day (average 165 m^3/day).

Based on the above it can be calculated that average daily groundwater inflows of approximately 115 m^3/day can be expected into the rehabilitated material. Incorporating the range of average minimum and maximum hydraulic conductivities it is estimated that inflow could have a minimum of around 60 m^3/day and a maximum of 180 m^3/day.

Using an average porosity of 20 % of the rehabilitated material, the pit area of 167 000 m^3, an average mining depth of 69 m, and an average depth to groundwater regional groundwater level of 28 m as calculated from the exploration drilling database it can be calculated that 1.42 Mm^3 of void space has to be filled in the rehabilitated opencast area before the regional groundwater level is reached.

The underground mine area measures 68 800 m^2. The seam thickness in the underground area is calculated to be average 12 m. This is calculated based on the apparent thickness, and does not take into consideration the dip of the ore body. The Mine Works Program indicates a mineable resource of 6 m. Using the total underground area of 68 800 m^2, the mining height (6 m), and a void ratio of 70 %, it is calculated that the underground area will require approximately 289 000 m^3 of water to be submerged.

Thus, it can be calculated that the combined underground void and rehabilitated material void space require approximately 1.7 Mm^3 of water to become submerged.

Using the groundwater inflow rates and void space it is calculated that recovery of the groundwater levels to the level of the regional groundwater level (28 mbgl) will take approximately 40 years using average inflows from surrounding aquifers. Applying the maximum and minimum groundwater inflows (based on minimum and maximum aquifer hydraulic conductivities) it is shown that this time line for groundwater level recovery has a range of a maximum of 75 years, and a minimum of 25 years.

Taking into the consideration the current water level in the historic mine it is considered that the maximum timeline of 75 years are unrealistic and a timeline somewhere between the average of 40 years, and the minimum of 25 years, for the mine to become submerged is possibly a good reflection of site specific conditions.

5.4.2. Contamination of the surrounding aquifers

As seen in Section 5.4.1 the groundwater level in the rehabilitated material of the opencast pit will recover to near pre-development levels around 30 to 40 years after closure. The rising water level will allow near natural groundwater flow directions to be re-established. This will allow contamination to migrate away from the mine area in a down gradient direction.

The waste, topsoil, and tailings storage facilities are located mostly outside the zone of influence of the drawdown cone around the mining area. Therefore, it can be said that any contamination from these sources will not necessarily be drawn towards the mining area and could leave the mine area. As the groundwater flow patterns are re-established through rising water levels in the rehabilitated area the plume will migrate from the mine in a down gradient direction, towards the west where the Witleegte stream channel forms a topographical low. Once the contamination accumulates here, the migration direction will change towards the northwest, along the stream channel.

Contaminant migration from the mining area through the fractured rock aquifer will be limited. It is not expected that the plume will extend more than 700 to 1 000 m from the mining areas.

The detail design and closure management plans of the waste, tailings, and top soil storage facilities are not currently known. The sandy gravel that overlies the area around the proposed mine inherently has a relatively high hydraulic conductivity compared to the competent rock and can have a conductivity in the order of 1 to 5 m/day. This could lead to significant contaminant migration away from surface infrastructure should there be vertical seepage from these infrastructure towards the underlying sandy gravel. It is assumed that the sandy gravel will be excavated (average thickness of 5.6 m), or sealed off using a synthetic liner and leakage detection system, especially at the tailings and waste facilities, which will prevent contamination of the underlying aquifers.

It is assumed that the tailings and waste facilities will be sloped, capped, and vegetated in order to reduce oxygenation and rainfall recharge into the facilities. In the long term this will reduce the vertical seepage from the facilities towards the underlying sandy gravel and fractured rock aquifers.

5.4.3. Decant potential

As calculated in Section 5.4.1 the groundwater level in the rehabilitated material will recover within around 30 to 40 years after closure. The natural groundwater levels in the mining area are relatively deep below surface at 28 mbgl on average (ranging between 14.60 and 36.70 mbgl).

At no point is the floor elevation of the underground mine above the topographical levels around the perimeter of the opencast area. Therefore, no decant directly from the underground mine is expected.

Decant from the rehabilitated opencast area is more difficult to evaluate. The natural groundwater level in the vicinity of the area is on average around 28 mbgl as discussed previously in this report. Because of the elevated recharge into the rehabilitated material, and the increased transmissivities and storage capacities compared to the surrounding natural, un-mined areas it is possible that the groundwater level can continue to rise in the rehabilitated area after the elevation of the surrounding regional groundwater level has been reached.

It is calculated that under ideal conditions the water level in the rehabilitated material can reach surface around 10 to 15 years after the regional groundwater level was reached, thus around 40 to 55 years after mine closure. Once the water reaches surface elevation, decant onto surface could occur. However, the rate of rise of the water level, as well as the decant potential will be reduced by:

- Once the water level in the rehabilitated area rise above the regional groundwater level (saturated zone), the water pressure in the rehabilitated area will start to force the water out of the rehabilitated pit area, and into the surrounding un-mined, unsaturated rock material. The portion of the water in the rehabilitated material that will be lost in this way, and thus the extent to which the rate of rise of the water level in the rehabilitated material is reduced depends on the transmissivity and storage capacity of the un-mined rock material;

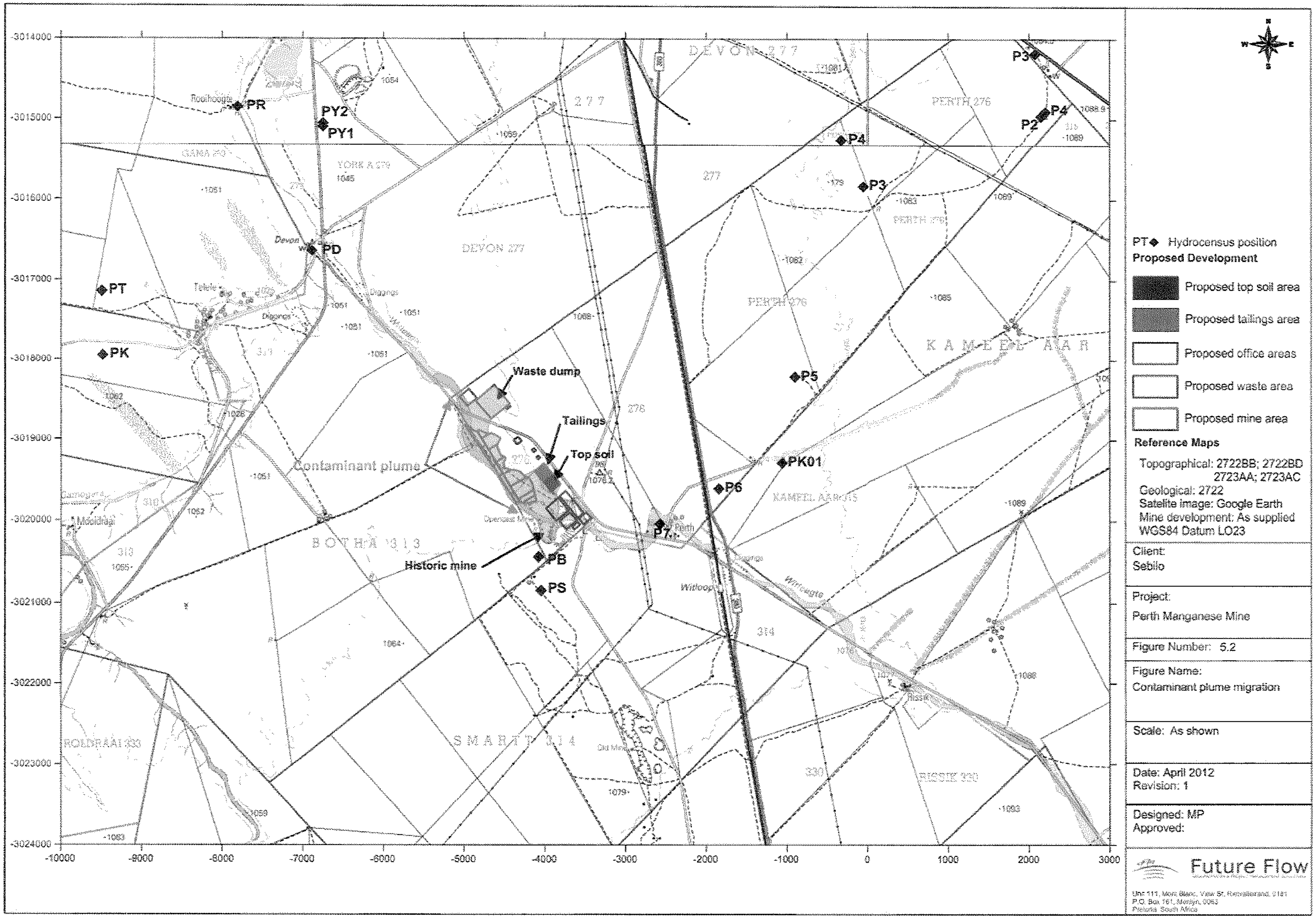
- Once near surface elevations are reached (from 10 mbgl and shallower) water will seep into the surrounding sandy gravels. These gravels have a higher transmissivity and storage capacity than the competent, fractured rock aquifer. Therefor the reduction in the rate of rise of the water level will be reduced further; and
- The relatively high evaporation that characterise the climate in the area will further reduce the rate of rise.

Overall, there is a possibility that surface decant will occur. However, the probability of decant occurring it is currently unsure and it is recommended that on completion of the mine operations a monitoring borehole be installed at the north-western corner of the rehabilitated opencast area at coordinates:

4 980 E; -3 018 700 S.

This borehole will serve to monitor the rate of rise, and quality, of the water in the rehabilitated material. The borehole will serve as an early warning system for potential decant. The water quality data can also be used to determine the decant water quality and the impacts on the surrounding environment.

It should be noted that in the event that the water level in the rehabilitated material rise to the reach the elevation of the sandy gravel it is possible that a dispersed seepage front will develop somewhere down gradient from the mine, in the area between the Witleegte stream and the mine area. It is recommended that should the water level in the proposed monitoring borehole reach the sandy gravel lithologies active monitoring of the area between the mine and the stream be implemented to monitor for any shallow, poor quality seepage daylighting from the sandy gravel.


PR
PY2
PY1
PD
PT
PK
P3
P4
P2
P3
P4
P5
PK01
P6
P7
PB
PS
Waste dump
Tailings
Top soil
Historic mine
Contaminant plume
DEVON 277
PERTH 276
KAMEEL AAR
BOTHA 313
SMARTT 314
RISSIK 330
ROLDRAAI 333
YORK A 279
GAMA 310
Devon
Telele
Rooihoogte
Mooidraai
Perth
Witloop
Rissik
-3014000
-3015000
-3016000
-3017000
-3018000
-3019000
-3020000
-3021000
-3022000
-3023000
-3024000
-10000
-9000
-8000
-7000
-6000
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
PT◆ Hydrocensus position
Proposed Development
Proposed top soil area
Proposed tailings area
Proposed office areas
Proposed waste area
Proposed mine area
Reference Maps
Topographical: 2722BB; 2722BD
2723AA; 2723AC
Geological: 2722
Satelite image: Google Earth
Mine development: As supplied
WGS84 Datum LO23
Client:
Sebilo
Project:
Perth Manganese Mine
Figure Number: 5.2
Figure Name:
Contaminant plume migration
Scale: As shown
Date: April 2012
Revision: 1
Designed: MP
Approved:
Future Flow
Unit 111, Mont Blanc, View St, Rietvalleirand, 0181
P.O. Box 161, Menlyn, 0063
Pretoria, South Africa

6. Impact management plan

6.1. Dewatering of the aquifers due to mine dewatering

The surrounding aquifers will be dewatered due to mine dewatering. This process cannot be stopped. It is also impractical to attempt to reduce the inflows.

The groundwater seeping into the mined-out area will have to be pumped to surface to ensure safe working conditions. The water pumped from the underground area will be classified as "dirty" water and as such will have to be managed by the mine. The water will be pumped to a pollution control dam from where it can be re-used in the plant.

6.2. Control surface water inflows into the mine area

Installation of surface berms and diversion trenches will reduce the surface inflows into the mine area during rainfall events, and therefore the volume of "dirty" water that will have to be managed.

6.3. Monitoring of contamination of the surrounding aquifers

As discussed previously in this document chemical reactions through oxidation of the ore body material could lead to elevated manganese concentrations. The chemical reactions will continue to take place until the ore body in the underground and opencast areas is submerged and oxygen displaced. Once the oxidising conditions are removed the element concentrations will stop increasing.

Little can be done to manage the contamination spread and it is recommended that the groundwater monitoring program be continued after mine closure to monitor for any contamination migrating away from site. Monitoring boreholes should include not only dedicated mine monitoring boreholes, but also privately owned boreholes that could potentially be impacted.

These privately owned boreholes should include:
- Owner – Mr Eben Anthonissen: P7, P6, P5;
- Owner – Mr Henk Venter: PK01;
- Owner – Mrs Koba Albagten: PD;

Boreholes PB and PS, which are located close to the Perth mine are monitoring boreholes owned by UMK Mine and it is assumed that they perform regular monitoring on those boreholes.

The monitoring program should allow for:

- Monthly monitoring:
  - Depth to groundwater level in all boreholes;
  - Field pH, EC, TDS measurements in all boreholes;
- Quarterly monitoring:

- Depth to groundwater level in all boreholes;
- Sampling of all boreholes and submitting the samples to an accredited laboratory for chemical analysis. The elements that should be analysed for are shown in Table 4.2.

6.4. Contamination of the underlying aquifers due to seepage from surface infrastructure

Seepage from the tailings and waste facilities can contaminate the underlying aquifers as discussed in Section 5.4.2. It is recommended that:

- The high transmissivity sandy gravel that underlies the target areas for the facilities should be excavated. This will reduce the risk to the surrounding environment due to potential widespread, and relatively rapid, migration of poor quality seepage from the surface infrastructure;
- If possible, a liner system or under drain system (herringbone drain system) should be installed underneath the tailings and waste facilities together with a leak detection system in order to reduce and manage vertical seepage into the underlying aquifers;
- The tailings and waste facilities be sloped, capped, and vegetated as part of the rehabilitation plan in order to reduce oxygenation and rainfall recharge into the facilities. In the long term this will reduce the vertical seepage from the facilitates towards the underlying sandy gravel and fractured rock aquifers;
- The newly installed mine specific monitoring boreholes should be monitored on a regular basis for changes in groundwater levels and quality that could indicate seepage from the surface infrastructure and contamination of the aquifers; and
- Additional monitoring boreholes should be installed at the tailings and top soil storage areas.

6.5. Installation of a monitoring borehole within the rehabilitated area after closure to monitor the decant potential

It is recommended that on completion of the mine operations a monitoring borehole be installed at the north-western corner of the rehabilitated opencast area at coordinates:
Easting: 4 980 ; Northing: -3 018 700 (WGS84, LO23).

This borehole will serve to monitor the rate of rise, and quality, of the water in the rehabilitated material. The borehole will serve as an early warning system for potential decant. The water quality data can also be used to determine the decant water quality and the impacts on the surrounding environment. It should be noted that in the event that the water level in the rehabilitated material rise to the reach the elevation of the sandy gravel it is possible that a dispersed seepage front will develop somewhere down gradient from the mine, in the area between the Witleegte stream and the mine area. It is recommended that should the water level in the proposed monitoring borehole reach the sandy gravel lithologies active monitoring of the area between the mine and the stream be implemented to monitor for any shallow, poor quality seepage daylighting from the sandy gravel.

7. Conclusions and recommendations

7.1. General conclusions

- The site topography is best described as being relatively flat with little topographical features. Locally, the natural topography dips slightly towards the stream beds of the non-perennial Witleegte and Ga-Mogara streams. The natural topographical gradient on site is calculated to be around 1:60 to 1:70;
- The project is situated in the Ga-Mogara River catchment which drains into the Kuruman River. The Ga-Mogara River is non-perennial that flows immediately west of the project boundary. the non-perennial Witleegte stream runs along the western boundary of Perth with the Farm Botha 313. The stream drains towards the north. Approximately 4 km northwest of the proposed mining area the two streams join, and is then known as the Ga-Mogara stream;
- The average annual precipitation is 349 mm/a. Annual average evaporation rates are in the order of 2 026 mm/a; and
- Large portions of the region are covered by a sandy gravel which mask any geological structures from surface mapping. The hydrogeological maps of the area show the presence of north-south trending regional fault lines that divide the Makganyene and Danielskuil Formations into blocks with north / south displacement noted along these faults. The presence of such faults is also confirmed from the results of the ground geophysical investigation.

7.2. Baseline hydrogeology

7.2.1. Aquifer description

- Three aquifers occur in the area. These three aquifers are associated with a) the primary sandy gravel material, b) the fractured rock and leached banded iron formation aquifer, and c) the dolomitic aquifers of the Griqualand West Sequence;
- The upper aquifer forms due to the vertical infiltration of recharging rainfall through the primary sandy gravel material being retarded by the lower permeability of the underlying competent rock. Exploration borehole log data shows that this aquifer ranges between 3 and 10 m in thickness and is on average 5.6 m thick. Drilling results show this aquifer to be dry in large portions of the study area. This aquifer is seasonal and mostly carries water only during and shortly after rainfall events when rainfall recharges into the material. The material is dry for large portions of the year;
- Groundwater flows in the fractured rock aquifer are associated with the secondary fracturing in the competent rock that was formed by the major north / south striking faulting seen from the hydrogeological maps and confirmed by the ground geophysical survey. The general transmissivity of the competent rock material is considered to be around 0.1 m^2/day or less. Aquifer testing results show that the transmissivity of individual fractures range between 0.25 and 0.7 m^2/day. Drilling results show that aquifer strikes can occur down to 80 m in this area; and

- Dolomitic aquifers are recognised to potentially be of concern to mining activities due to the potential large inflow volumes in areas where karstic dolomite is intersected. The dolomitic karst aquifer in the region is well known for its high potential. Inspection of exploration drilling core on neighbouring farms show that the dolomite in the area appears to be competent with no indication of weathering or karstification. Karstic dolomite is highly variable in competence and transmissivity over short distances and this is no guarantee that karstic dolomite won't be found on site, however, based on the general constant high competence and total absence of indications of karstic dolomite it can be concluded that the likelihood of intercepting karstic dolomite is very low.

7.2.2. Depth to groundwater level

- The depth to groundwater level generally ranges between 14.60 and 36.70 mbgl. The average depth to groundwater is calculated to be 28 mbgl, with the groundwater level around the pit specifically (boreholes SB01, SB03 and SB04) calculated at 27.3 mbgl;
- Plotting groundwater level elevation versus topographical elevation for this area (and omitting the anomalous depth to groundwater in borehole PK) yields a 94.6 % correlation for the fractured rock aquifer. From these correlation figures it can be concluded that there are no large scale impacts on the groundwater levels in the area;
- Considering the average depths to groundwater level, Figure 4.1 and Figure 4.2 it is concluded that the water level in the historic Perth Pit is equivalent to the surrounding, and regional, groundwater levels and the system is in equilibrium. Based on this, and the high net evaporation from the area, it can be concluded that there is a net inflow into the pit, and the pit does not recharge into the surrounding aquifers; and
- The groundwater level contours and flow patterns for the weathered rock aquifer are shown in Figure 4.3. Groundwater flows are directed from the east towards the topographical lows representing the Witleegte stream bed. Flow gradients are calculated at 1:100 to 1:350.

7.2.3 Groundwater use and classification

- Groundwater forms the sole source of water supply to the local landowners for both domestic use and agricultural (stock watering) purposes. No measured water use volumes are available. Using standard minimum use volumes of 25 l per person per day for domestic use it is calculated that less than 10 m^3 of water is used per day for domestic use;
- Agricultural water use from the 12 agricultural use boreholes is estimated at 120 m^3/day (10 m^3/day from each borehole); and
- Following the Parsons Classification system the aquifers in the area is classified as a **minor** aquifer based on the low yields from the aquifer. However, the aquifers are of **high importance** to the local landowners due to the fact that it forms the sole source of water supply.

7.2.4. Groundwater quality

- The regional groundwater quality in general is relatively poor with almost all samples having elements within the SANS241 domestic use guideline Class II and exceeding Class II. The main elements that show elevated concentrations include chloride, nitrate, calcium, magnesium and sodium;
- Comparing 1976 DWA NGDB and 2012 Future Flow chemical analysis results show:
  - Chloride concentration: The general chloride concentration during 1976 ranged between 200 and 450 mg/L, with an individual sample showing a concentration of 845 mg/L. During 2012 the general trend remained at 200 to 450 mg/L. Some individual samples show elevations of 650 to 1 350 mg/L;
  - Nitrate concentration: During 1976 there were two distinct ranges in nitrate concentration with around half of the samples showing concentrations between 1 and 7 mg/L, and the rest having an average concentration ranging between 60 to 150 mg/L. During 2012 the concentrations ranged between 30 and 90 mg/L, with individual samples reaching 283 mg/L. None of the sample points show concentrations less than 30 mg/L;
  - Calcium concentration: During 1976 more than half of the samples indicated concentrations between 20 and 70 mg/L, with some samples ranging up to 130 mg/L. Individual samples reached 160 to 470 mg/L. During 2012 concentrations in general range between 150 and 500 mg/L, with the lowest concentration being 90 mg/L;
  - Magnesium concentration: During 1976 more than half the samples ranged between 20 to 70 mg/L. Individual samples ranged between 120 and 160 mg/L, or even up to 390 mg/L. During 2012 the general concentration ranges between 80 and 300 mg/L, with the lowest concentration measured at 61 mg/L;
- Plotting the chemical analysis results on a Piper diagram show that all the samples plot within the upper portion of the diamond indicating static water;
- The water generally has a magnesium / chloride or calcium / chloride dominant character;
- Comparison to Perth pit water quality show that the pit was character is magnesium chloride dominant, which is comparable to a number of groundwater samples, including samples PD, PS1, UMK14, sB02, SB03, and SB04;
- Water quality from all the new boreholes drilled around the historic mine area and into the ore body show elevated manganese concentrations; and
- Sample SB02, which is drilled into the historic underground mine, is considered to provide an indication of the expected long term groundwater quality after mine closure. The sample show highly elevated concentrations of chloride, sulphate, nitrate, fluoride, calcium, magnesium, sodium, manganese, and zinc.

7.2.5. Aquifer transmissivity and storativity

- The aquifer transmissivity of the fractured rock material ranges between 0.25 and 0.7 m^2/day. The newly drilled monitoring boreholes targeted geological structures that could act as potential groundwater flow pathways, and the transmissivity of these boreholes are considered to be higher than the average transmissivity of the general competent, fractured, host rock. The general aquifer transmissivity of the un-fractured host rock is considered to be less than 0.1 m^2/day. This is confirmed by the very low transmissivity seen in borehole P5 which yielded extremely little water. At 72 hours after completion of the drilling only 2 to 3 m of water had accumulated in the borehole; and

- The hydraulic conductivities of the fractured rock aquifer are calculated to range around 0.012 and 0.021 m/day. This means that groundwater migrate at a rate of between 0.012 and 0.021 m/day through the aquifers. These are very low numbers and not conducive to large flow volumes through the area.

7.2.6. Acid base accounting and static leach testing

- ABA tests have been performed by *i*LEH on two samples as detailed in Table 4.5. Samples were collected from waste and ore material. Results indicate that:
    - NNP: The NNP of samples "Waste" and "*i*LEH" exceed 20 kg $CaCO_3$/tonne and can be considered safe;
    - NPR: The NPR of the samples far exceeds the neutralising guideline of 3 and ranges between 450 and 510. Based on this the material can be classified as acid neutralising;
    - Sulphide S and NAG pH: The Sulphide-S ratio for both samples is less than 0.01, while the final NAG pH is measured at between 7.7 and 8.0. Based on Price's guidelines no further ARD testing is required provided there are no metal leaching concerns.
- The sulphide percentages in all the samples fall below 0.3 %;
- Final NAG pH values for the roof material range around 8 to 9. This corresponds to the NPR ratios of between 23 and 83 which are much greater than the guideline value of 3, indicating that the rock material is acid neutralising;
- It is concluded that it is unlikely that the material will be acid forming. Should some acid conditions form it will be buffered and neutralised by the high neutralising capacity of the rock material. In addition, any such acid conditions that form will only be sustainable in the short term due to the very low Sulphur-S percentages;
- Static leach testing done on the two samples shows that in general there is no concern around the element leach concentrations. Cadmium, Mercury, and Manganese do indicate some elevated concentrations. However, cadmium and mercury is reported at the limit of the detection capability of the analysis method. Therefore, there is uncertainty around the actual concentration values for these two elements and whether they do in fact exceed the Class II guideline values; and
- Based on the leach test results manganese is the only element where it can be said with certainty that the leach concentrations are expected to exceed domestic use guidelines. This is expected due to the natural elevated manganese concentrations in the area associated with the ore body.

7.3. Conceptual impact assessment

7.3.1. Construction phase

- The historic mine area will be dewatered causing a drawdown in the surrounding groundwater levels. It is expected that the historic mine will be completely dewatered, thus to a level of approximately 100 m below surface. The groundwater level will therefore be drawn down by approximately 72 m. The maximum zone of influence of the drawdown cone in the general competent rock is around 110 m;
- Surface construction of the discard and tailings dumps, settling and evaporation ponds, pollution control dams, haul roads and offices will not breach the groundwater level and is therefore not expected to have any notable impact on the groundwater levels; and
- In general it can be said that the impacts during the construction phase will be small.

7.3.2. Operational phase

7.3.2.1. Groundwater level drawdown and zone of influence

- The mine floor elevations are below the general groundwater level thus causing groundwater inflows into the mining areas from the surrounding aquifers during operations. The mining areas will have to be actively dewatered to ensure a safe working environment. Pumping groundwater that seeps into the mine area to surface will cause dewatering of the surrounding aquifers and an associated decrease in groundwater level within the zone of influence of the dewatering cones;
- The maximum zone of influence in the general competent rock is expected to be around 25m. The calculated zone of influence in the individual groundwater bearing range up to 110 m from the mining area. A value of 200 m is assumed to be conservative;
- The Witleegte stream has non-perennial flows. Therefore, even though the channel represents a topographical low, it is considered that the drawdown cone can develop to the opposite side of the topographical depression due to a combination of:
  - The depth of the mining and groundwater level in the area;
  - The apparent poor hydraulic connection between the stream and the underlying aquifer due to the very low hydraulic conductivity of the rock material; and
  - The non-perennial nature of the stream.

7.3.2.2. Water inflows into the mine area

- Direct recharge from rainfall: The calculated direct rainfall onto the pit area range between 7 and 63 m^3/day depending on the size of the open pit. These listed values are only annual average values and in reality the rainy season occurs between October and April with little rainfall occurring during the dry season. Therefore, direct rainfall into the pit during the rainy season will be higher than the values shown in Table 5.1. The direct rainfall into the pit could possibly as high as 150 m^3/day during January 2018 when the open pit area is at its largest with a total combined area of 65 760 m^2 for the pits opened during 2016, 2017, and

2018 (keep in mind that rehabilitation only begins three years after mining started). January is also the month with the highest average rainfall at 70 mm;

- Recharge onto the rehabilitated area: The calculated recharge volumes into the rehabilitated areas are summarised in Table 5.1. These calculated values represent the worst-case scenario as a notable portion of the recharging rainwater will be retained within the rehabilitated material (possibly up to 20 %) thus decreasing the dewatering requirement. The water retained within the rehabilitated material will lead to a rising water level in the rehabilitated material; and
- Groundwater inflow volumes: Using average hydraulic conductivities the groundwater inflow volumes into the pit area range between 10 and 120 m^3/day over the life of mine. As expected, the inflow volumes are initially relatively low and then increase over time. At the end of the life of mine groundwater inflows are expected to be 120 m^3/day when using the average hydraulic conductivity values.

7.3.2.3. Groundwater contamination

- Groundwater flows around the mining area, within the zone of influence of the mine dewatering cone, will be directed towards the mine area. Water will be pumped from the pit to surface water management structures and therefore very little to no contamination is expected to reach the surrounding aquifers from the opencast pit area;
- The waste, topsoil, and tailings storage facilities are located mostly outside the zone of influence of the drawdown cone around the mining area. Therefore, it can be said that any contamination from these sources will not necessarily be drawn towards the mining area and could leave the mine area; and
- The sandy gravel that overlies the area around the proposed mine inherently has a relatively high hydraulic conductivity compared to the competent rock and can have a conductivity in the order of 1 to 5 m/day. This could lead to significant contaminant migration away from surface infrastructure should there be vertical seepage from these infrastructure towards the underlying sandy gravel.

7.3.3. Decommissioning phase

- Mine dewatering will stop during the decommissioning phase and the groundwater level in the aquifers surrounding the mine will start to recover as the water level in the mined-out area rises. However, it is considered that during the time span of the decommissioning phase (assumed to be less than 6 months) there will be little measurable rise in the water levels due to the fact that the underground area will require a large volume to be flooded. This will contain any contamination within the zone of influence of the cone of depression within the mining area;
- The waste, topsoil, and tailings storage facilities are located mostly outside the zone of influence of the drawdown cone around the mining area. Therefore, it can be said that any contamination from these sources will not necessarily be drawn towards the mining area and could leave the mine area.

7.3.4. Long term post-operational phase

7.3.4.1. Recovery of groundwater level

- The water level in the pit area is expected to rise once mine dewatering stop;
- Using the calculated groundwater inflow rates and void space in the rehabilitated material and underground mine it is calculated that recovery of the groundwater levels to the level of the regional groundwater level (28 mbgl) will take approximately 40 years using average inflows from the surrounding aquifers. Applying the maximum and minimum groundwater inflows (based on minimum and maximum aquifer hydraulic conductivities) it is shown that this time line for groundwater level recovery has a range of a maximum of 75 years, and a minimum of 25 years.

7.3.4.2. Contamination of the surrounding aquifers

- The groundwater level in the rehabilitated material of the opencast pit will recover to near pre-development levels around 30 to 40 years after closure. As the groundwater flow patterns are re-established through rising water levels in the rehabilitated area the plume will migrate from the mine in a down gradient direction, towards the west where the Witleegte stream channel forms a topographical low. Once the contamination accumulates here, the migration direction will change towards the northwest, along the stream channel;
- The waste, topsoil, and tailings storage facilities are located mostly outside the zone of influence of the drawdown cone around the mining area. Therefore, any contamination from these sources will not necessarily be drawn towards the mining area and could leave the mine area;
- Contaminant migration from the mining area through the fractured rock aquifer will be limited. It is not expected that the plume will extend more than 700 to 1 000 m from the mining areas;
- The sandy gravel that overlies the area around the proposed mine inherently has a relatively high hydraulic conductivity compared to the competent rock and can have a conductivity in the order of 1 to 5 m/day. This could lead to significant contaminant migration away from surface infrastructure should there be vertical seepage from these infrastructure towards the underlying sandy gravel. It is assumed that the sandy gravel will be excavated (average thickness of 5.6 m), or sealed off using a synthetic liner and leakage detection system, especially at the tailings and waste facilities, which will prevent contamination of the underlying aquifers; and
- It is assumed that the tailings and waste facilities will be sloped, capped, and vegetated in order to reduce oxygenation and rainfall recharge into the facilities. In the long term this will reduce the vertical seepage from the facilities towards the underlying sandy gravel and fractured rock aquifers.

7.3.4.3. Decant potential

- At no point is the floor elevation of the underground mine above the topographical levels around the perimeter of the opencast area. Therefore, no decant directly from the underground mine is expected;
- Decant from the rehabilitated opencast area is more difficult to evaluate. The natural groundwater level in the vicinity of the area is on average around 28 mbgl. It is possible that the groundwater level can continue to rise in the rehabilitated area after the elevation of the surrounding regional groundwater level has been reached. Under ideal conditions the water level in the rehabilitated material can reach surface around 10 to 15 years after the regional groundwater level was reached, thus around 40 to 55 years after mine closure. Once the water reaches surface elevation, decant onto surface could occur;
- The probability of decant occurring it is currently unsure and it is recommended that on completion of the mine operations a monitoring borehole be installed at the north-western corner of the rehabilitated opencast area at coordinates: 4 980 E; -3 018 700 S. This borehole will serve to monitor the rate of rise, and quality, of the water in the rehabilitated material. The borehole will serve as an early warning system for potential decant. The water quality data can also be used to determine the decant water quality and the impacts on the surrounding environment; and
- In the event that the water level in the rehabilitated material rise to the reach the elevation of the sandy gravel it is possible that a dispersed seepage front will develop somewhere down gradient from the mine, in the area between the Witleegte stream and the mine area.

7.4. Impact management recommendations

7.4.1. Dewatering of the aquifers

- The surrounding aquifers will be dewatered due to mine dewatering. This process cannot be stopped. It is also impractical to attempt to reduce the inflows; and
- The groundwater seeping into the mined-out area will have to be pumped to surface to ensure safe working conditions. The water pumped from the underground area will be classified as "dirty" water and as such will have to be managed by the mine. The water will be pumped to a pollution control dam from where it can be re-used in the plant.

7.4.2. Control surface water inflows

- Installation of surface berms and diversion trenches will reduce the surface inflows into the mine area during rainfall events, and therefore the volume of "dirty" water that will have to be managed.

7.4.3. Monitoring of contamination of the surrounding aquifers

Little can be done to manage the contamination spread and it is recommended that the groundwater monitoring program be continued after mine closure to monitor for any contamination migrating away from site. Monitoring boreholes should include not only dedicated mine monitoring boreholes, but also privately owned boreholes that could potentially be impacted, including:

- Owner – Mr Eben Anthonissen: P7, P6, P5;
- Owner – Mr Henk Venter: PK01;
- Owner – Mrs Koba Albagten: PD.

The monitoring program should allow for:

- Monthly monitoring:
  - Depth to groundwater level in all boreholes;
  - Field pH, EC, TDS measurements in all boreholes;
- Quarterly monitoring:
  - Depth to groundwater level in all boreholes; and
  - Sampling of all boreholes and submitting the samples to an accredited laboratory for chemical analysis. The elements that should be analysed for are shown in Table 4.2.

7.4.4. Contamination of the aquifers underlying surface infrastructure

Seepage from the tailings and waste facilities can contaminate the underlying aquifers as discussed in Section 5.4.2. It is recommended that:

- The high transmissivity sandy gravel that underlies the target areas for the facilities should be excavated. This will reduce the risk to the surrounding environment due to potential widespread, and relatively rapid, migration of poor quality seepage from the surface infrastructure;
- If possible, a liner system or under drain system (herringbone drain system) should be installed underneath the tailings and waste facilities together with a leak detection system in order to reduce and manage vertical seepage into the underlying aquifers;
- The tailings and waste facilities be sloped, capped, and vegetated as part of the rehabilitation plan in order to reduce oxygenation and rainfall recharge into the facilities. In the long term this will reduce the vertical seepage from the facilitates towards the underlying sandy gravel and fractured rock aquifers;
- The newly installed mine specific monitoring boreholes should be monitored on a regular basis for changes in groundwater levels and quality that could indicate seepage from the surface infrastructure and contamination of the aquifers; and
- Additional monitoring boreholes should be installed at the tailings and top soil storage areas.

7.4.5. Installation of an additional monitoring borehole

It is recommended that on completion of the mine operations a monitoring borehole be installed at the north-western corner of the rehabilitated opencast area at coordinates:

Easting: 4 980 ; Northing: -3 018 700 (WGS84, LO23).

This borehole will serve to monitor the rate of rise, and quality, of the water in the rehabilitated material. The borehole will serve as an early warning system for potential decant. The water quality data can also be used to determine the decant water quality and the impacts on the surrounding environment. It is recommended that should the water level in the proposed monitoring borehole reach the sandy gravel lithologies active monitoring of the area between the mine and the stream be implemented to monitor for any shallow, poor quality seepage daylighting from the sandy gravel.

8. References

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APPENDIX A:

GROUND GEOPHYSICAL SURVEY RESULTS

A1: Introduction

A ground geophysical survey was conducted in March 2012. A ground geophysical survey is a method used to characterise the subsurface physical conditions without the use of extensive intrusive drilling programmes. Due to the lithology present at the project area, the magnetic method was employed to delineate possible weathered zones, dykes sills or contacts for background monitoring boreholes and characterisation. Areas of interest such as the pit area, the tailings area, and border with the Witleegte stream were targeted in the initial survey.

A2: Methodology

The Magnetic method was employed for the survey. Four lines were surveyed around the opencast mining area. Positions were surveyed using a hand held Global Positioning System (GPS) unit (Cartesian coordinates, WGS 84 datum). The effective station spacing chosen to delineate possible features were set at 10 m. Borehole target were identified in the field from the obtained field data. The following is a description of the geophysical method employed:

A2.1: Magnetic method

A one-man portable Geotron G5 magnetometer was employed to conduct the survey. The G5 instrument is a resonance, proton magnetometer and monitors the precession of atomic particles in an ambient magnetic field to provide an absolute measure of the earth's total magnetic field intensity in nanoTeslas (nT).

The proton magnetometer has a sensor, which consists of a bottle (casing) containing a proton rich fluid, usually water or kerosene, around which a coil is wound that is connected to the measuring apparatus. Each proton has a magnetic moment M and because it is always in motion, it also possesses an angular momentum G, rather like a spinning top. In an ambient magnetic field like that of the earth's magnetic field (F), the majority of the protons align themselves parallel with this field with the remainder anti-parallel to the field (Figure A1, B). Consequently, the volume of proton-rich liquid acquires a net magnetic moment in the direction of the surrounding ambient field (F).

A current is applied to the coil surrounding the liquid and generates a magnetic field roughly 50 to 100 times that of the ambient magnetic field but perpendicular to F. The protons align themselves to the magnetic direction (Figure A1, B). When the applied current is switched of the protons process around the pre-existing ambient field F (Figure A1, C), at the Larmor precession frequency (fp) which is proportional to the magnetic field strength F.

$F = 2\pi f_p / \phi_p$

where:

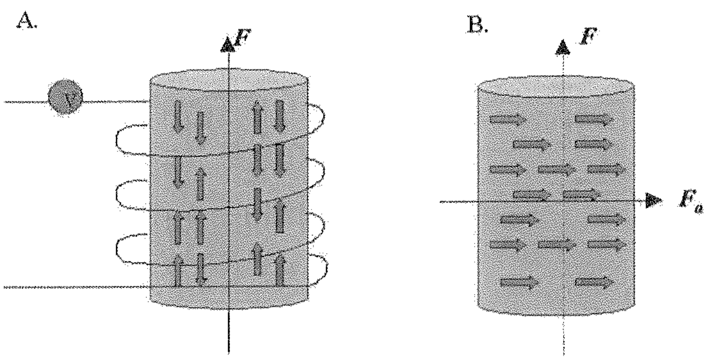
ϕ_p is the gyromagnetic ratio of the proton (ratio between magnetic moment and spin angular momentum, see Figure A1, D)

and $\phi_p = 0.26753$ **Hz/nT and** $2\pi/\phi_p = 23.4859$ **nT/Hz**

Thus: $F = 23.4859 f_p$

For example, for F = 50 000 nT, f_p = 2128.94 Hz.

Because protons are charged particles they will induce an alternating voltage during precession at the same frequency as f_p into the surrounding coil. Interaction between adjacent protons causes the precession to decay within 2-3 seconds, which is ample time for measuring the precession frequency. The G5 magnetometer gives a direct readout of the field strength in nanoTeslas and can be output into a solid state memory for downloading onto a computer (Reynolds, 1997).



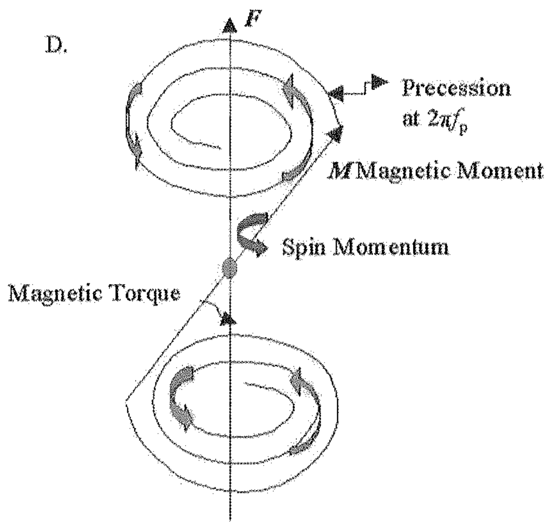


Figure A1: Basic operating principles of a proton magnetometer. After Kearey and Brooks (1991)

A3: Geophysical survey results

A3.1: Traverse 1

Line 1 was traverses from south to north, on the eastern side of the existing pit area, and up to where it met with the dirt road. A distinct change in geology can be seen from Station 590 onwards. Borehole SB01 was drilled at Station 740.

A3.2: Traverse 2

Traverse 2 was laid out from east to west, from the end of Traverse 1, to the farm boundary with the farm Botha which runs along the Witleegte stream channel. A geological anomaly can be seen between Stations 0 and 330. It is difficult to determine whether it is a fault structure that was crossed at a shallow angle, or possibly a zone of deeper weathering.

Borehole SB05 is drilled at Station 180.

A3.3: Traverse 3

The traverse was performed in a north / south direction, from the end of Traverse 2. The traverse was run parallel to the fence with the farm Botha, and as such also followed the Witleegte stream channel.

A distinct geological anomaly can be seen between Stations 330 and 440. Borehole SB03 was drilled at Station 430. A further geological anomaly can be seen between Stations 520 and 640, as well as a general change in geology from Station 820 onwards.

The influence of the ore body can be seen from Station 980 to 1 370. From 1 370 to 1 600 two more distinct anomalies can be seen. It was decided to drill borehole SB02 at station 1 470. The borehole drilled into the old underground mine, which then explains the two large anomalies from Station 1 370 onwards.

A3.4: Traverse 4

The traverse was performed in an east west direction. The traverse aimed to identify any geological structures south of the proposed waste dump area. As with Traverse 2, which was also run from east to west, the traverse show a general decrease in magnetic intensity from Station 0 to Station 240. Again, it is difficult to interpret this anomaly as it could represent a zone of deeper weathering, or possibly as geological structure that was crossed at a shallow angle.

Borehole SB04 was drilled at Station 240.

A4: Drilling targets

Four drilling targets were identified:

Table A1: Drilling targets

Borehole	Geophysical survey point	Easting	Northing
SB01	Traverse 1, Station 740	-4 073	-3 019 568
SB02	Traverse 3, Station 1 470	-4 147	-3 020 048
SB03	Traverse 3, Station 430	-4 683	-3 019 248
SB04	Traverse 4, Station 240	-4 620	-3 019 162
SB05	Traverse 2, Station 180	-4 747	-3 018 894

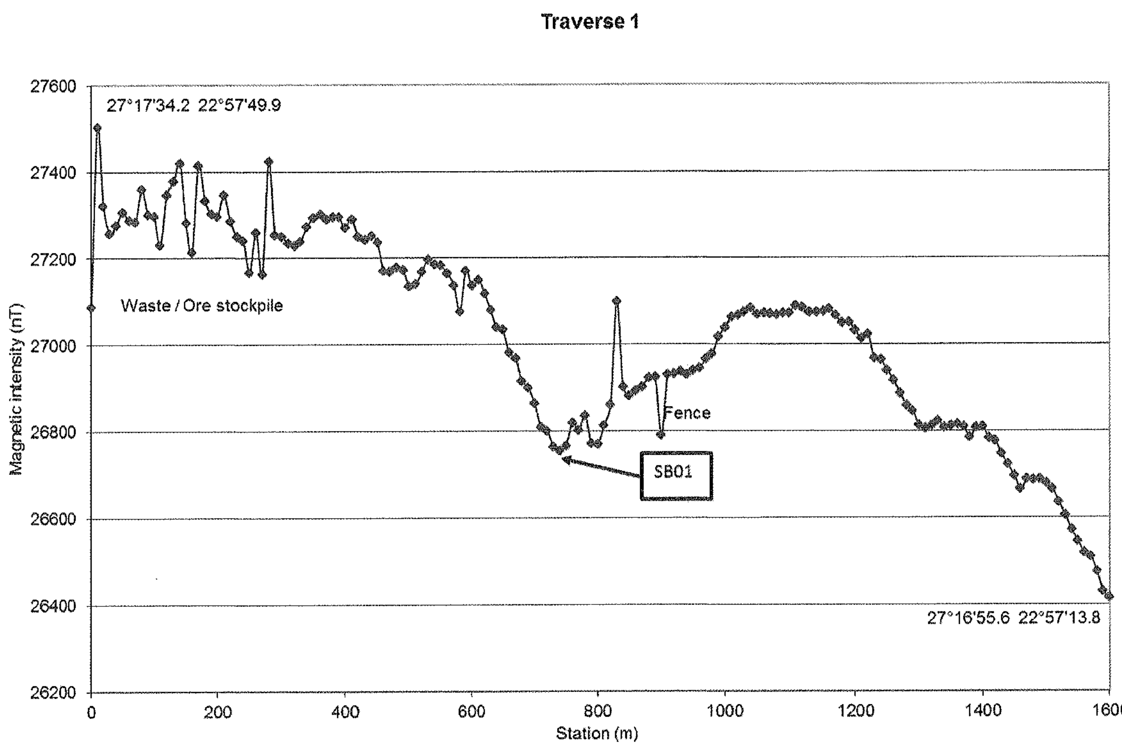


Figure A2: Traverse 1 geophysical survey graph

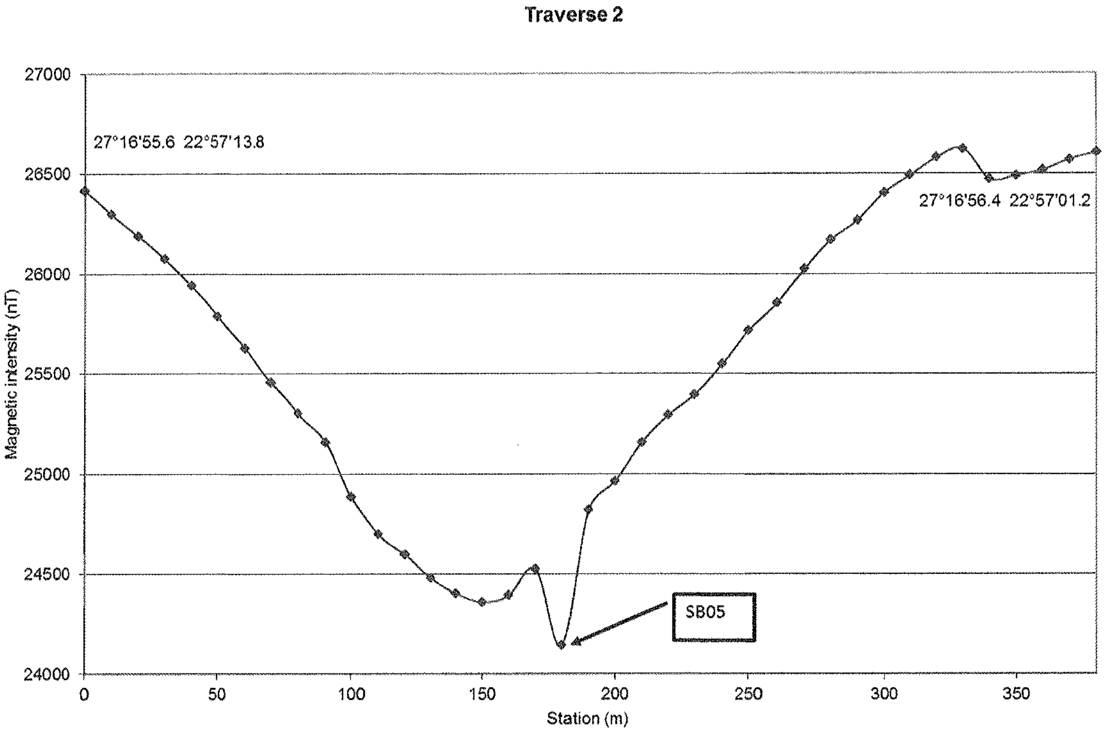


Figure A3: Traverse 2 geophysical survey graph

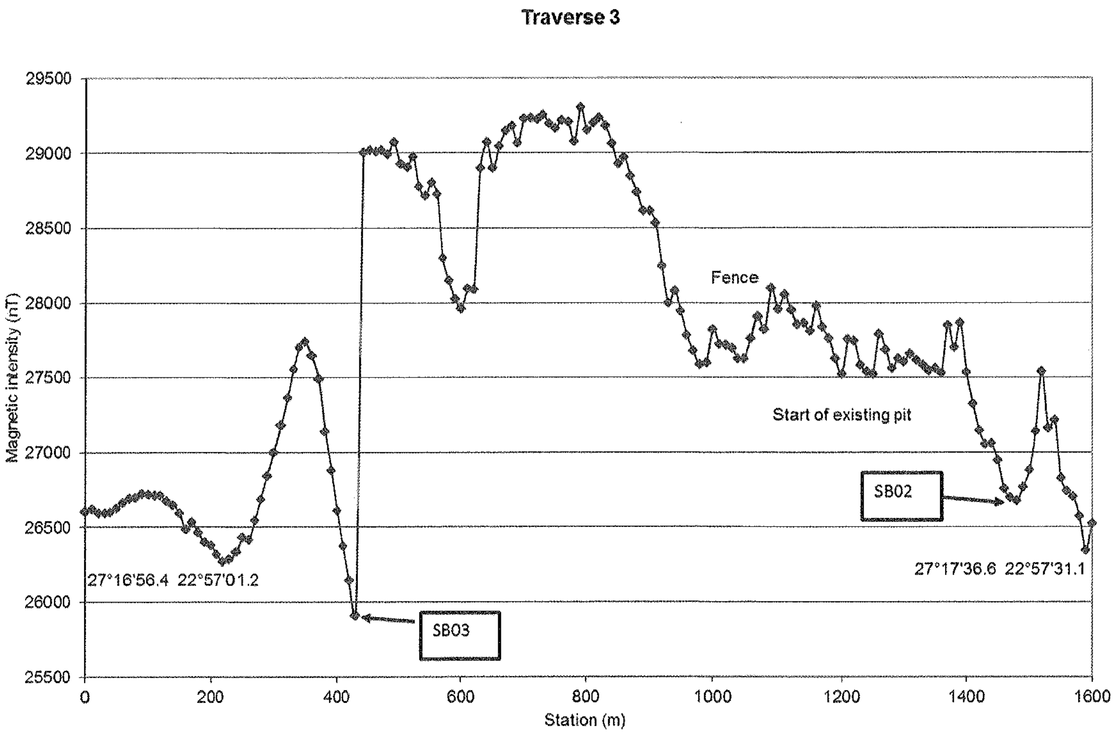


Figure A4: Traverse 3 geophysical survey graph

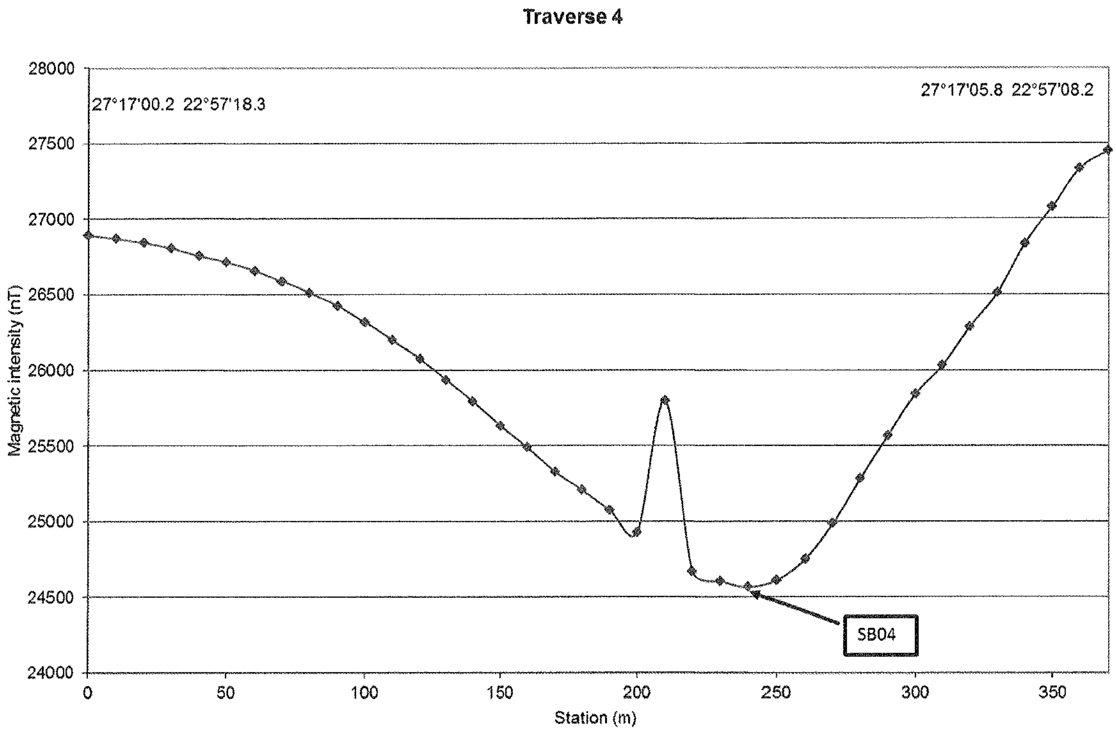


Figure A5: Traverse 4 geophysical survey graph

A5: Geophysical survey field data

Station	Traverse 1	Traverse 2	Traverse 3	Traverse 4
0	27087	26414	26605	26892
10	27504	26297	26620	26871
20	27322	26189	26593	26844
30	27258	26075	26595	26808
40	27277	25940	26600	26757
50	27306	25789	26627	26716
60	27288	25626	26662	26659
70	27284	25455	26689	26588
80	27359	25300	26698	26513
90	27302	25158	26724	26425
100	27298	24883	26719	26316
110	27232	24698	26713	26199
120	27347	24598	26712	26074
130	27378	24481	26674	25935
140	27420	24402	26650	25793
150	27282	24358	26596	25632
160	27215	24393	26488	25489
170	27414	24525	26534	25330
180	27334	24142	26462	25207
190	27303	24818	26400	25072
200	27298	24961	26379	24930
210	27346	25155	26318	25797
220	27286	25294	26270	24672
230	27250	25396	26285	24604
240	27241	25549	26332	24565
250	27167	25714	26430	24609
260	27260	25852	26418	24750
270	27163	26021	26545	24986
280	27424	26168	26686	25285
290	27253	26266	26840	25567
300	27250	26403	26998	25840
310	27235	26491	27183	26029
320	27230	26580	27367	26285
330	27239	26624	27557	26509
340	27272	26472	27701	26836
350	27293	26490	27736	27079
360	27302	26517	27646	27330
370	27290	26571	27490	27450
380	27295	26605	27139	
390	27295		26882	
400	27271		26609	
410	27290		26373	
420	27250		26146	
430	27243		25910	
440	27252		29002	
450	27237		29020	
460	27170		29006	
470	27169		29018	
480	27178		28991	
490	27172		29072	
500	27134		28927	
510	27140		28902	
520	27169		28976	

530	27197		28776	
540	27185		28713	
550	27183		28801	
560	27165		28725	
570	27137		28302	
580	27076		28149	
590	27170		28026	
600	27136		27961	
610	27150		28094	
620	27118		28087	
630	27080		28901	
640	27040		29071	
650	27034		28899	
660	26981		29046	
670	26969		29146	
680	26916		29182	
690	26901		29066	
700	26864		29227	
710	26810		29233	
720	26801		29221	
730	26765		29256	
740	26755		29194	
750	26767		29163	
760	26819		29219	
770	26802		29209	
780	26837		29078	
790	26772		29305	
800	26770		29152	
810	26814		29202	
820	26860		29233	
830	27098		29182	
840	26902		29061	
850	26882		28924	
860	26892		28970	
870	26903		28844	
880	26923		28739	
890	26925		28615	
900	26791		28611	
910	26930		28532	
920	26932		28248	
930	26939		27998	
940	26931		28080	
950	26941		27944	
960	26945		27784	
970	26966		27679	
980	26978		27585	
990	27018		27598	
1000	27038		27819	
1010	27063		27724	
1020	27067		27715	
1030	27075		27694	
1040	27084		27624	
1050	27068		27625	
1060	27073		27762	
1070	27070		27907	

1080	27068		27819	
1090	27073		28092	
1100	27073		27954	
1110	27090		28054	
1120	27085		27948	
1130	27075		27851	
1140	27074		27864	
1150	27077		27808	
1160	27082		27974	
1170	27066		27833	
1180	27050		27762	
1190	27051		27624	
1200	27032		27521	
1210	27013		27754	
1220	27024		27746	
1230	26969		27584	
1240	26965		27538	
1250	26940		27525	
1260	26917		27786	
1270	26888		27686	
1280	26858		27559	
1290	26846		27627	
1300	26813		27605	
1310	26805		27658	
1320	26813		27614	
1330	26822		27580	
1340	26808		27544	
1350	26812		27559	
1360	26816		27530	
1370	26809		27849	
1380	26786		27698	
1390	26807		27865	
1400	26810		27534	
1410	26784		27325	
1420	26777		27147	
1430	26747		27052	
1440	26722		27057	
1450	26697		26945	
1460	26667		26754	
1470	26688		26694	
1480	26687		26672	
1490	26689		26768	
1500	26679		26882	
1510	26667		27139	
1520	26636		27537	
1530	26606		27161	
1540	26571		27214	
1550	26545		26825	
1560	26518		26738	
1570	26510		26702	
1580	26476		26574	
1590	26430		26347	
1600	26414		26522	

APPENDIX B:

HYDROGEOLOGICAL BOREHOLE DRILLING RESULTS

B1: Introduction

The drilling phase was a follow on from the geophysical survey and five targets derived from the geophysics were drilled. The drilling was conducted using a Rotary Air Percussion drilling machine, with air delivered from a high volume compressor. The field technician on site record data on water strike depths and blow yields while also sampling drilling chips in one meter intervals.

The drilling positions in relation to the mining area can be seen in Figure 4.3 in the main body of the report. The boreholes SB01, SB04, and SB05 were all completed to a depth of 50 m. Borehole SB03 which aim to monitor the impacts on the groundwater environment on the western side of the proposed mine workings, where it will be at its deepest (around 100 m) was completed to a depth of 100 m. Borehole SB02, which is also drilled on the western side of the existing mine workings was intended to also reach 100 m depth. However, the borehole drilled into the old underground workings and had to be abandoned at 42 m depth. The boreholes were mainly drilled to characterise the aquifers in the project area and subsequently to serve as monitoring points for the groundwater monitoring required by DWA.

B2: Drilling results

Table B1 summarises the data for the five boreholes drilled including the finalised borehole construction data.

The lithologies intercepted during drilling in general consisted of weathered shale, sandstone as well as weathered diabase. The rock was fairly competent material with weathered and fractured zones not exceeding 20 m.

Table B1: Summary of the new characterisation / monitoring boreholes

	Borehole ID	**SB01**	**SB02**	**SB03**	**SB04**	**SB05**
Borehole Location	**Easting (LO 23)**	-4 073	-4 147	-4 683	-4 620	-4 747
	Northing (LO 23)	-3 019 568	-3 020 048	-3 019 248	-3 019 162	-3 018 894
	Elevation (mamsl)	1 062	1 066	1 055	1 055	1 062
Borehole Data	**Borehole Depth (m)**	50	42	101	50	50
	Blow Yield (L/s)	Damp	Drilled into flooded mine	Damp	Damp	None
	Water Strike depth (m)	47-50 (damp)	42 (mine)	82	47-50 (damp)	None
	Static Water Level (mbgl)	26.28	27	24.35	31.27	Dry
Borehole Construction Data	**Solid Casing PVC (Diameter - ID mm)**	114	None	114	114	114
	Depth from, to (m)	0-50	None	0-100	0-50	0-50
	Perforated Casing (Diameter - ID mm)	114	None	114	114	114
	Depth from, to (m)	0-50	None	0-100	0-50	0-50

Borehole Construction

From	To
0	1
1	2
2	3
3	4
4	5
5	6
6	7
7	8
8	9
9	10
10	11
11	12
12	13
13	14
14	15
15	16
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35	36
36	37
37	38
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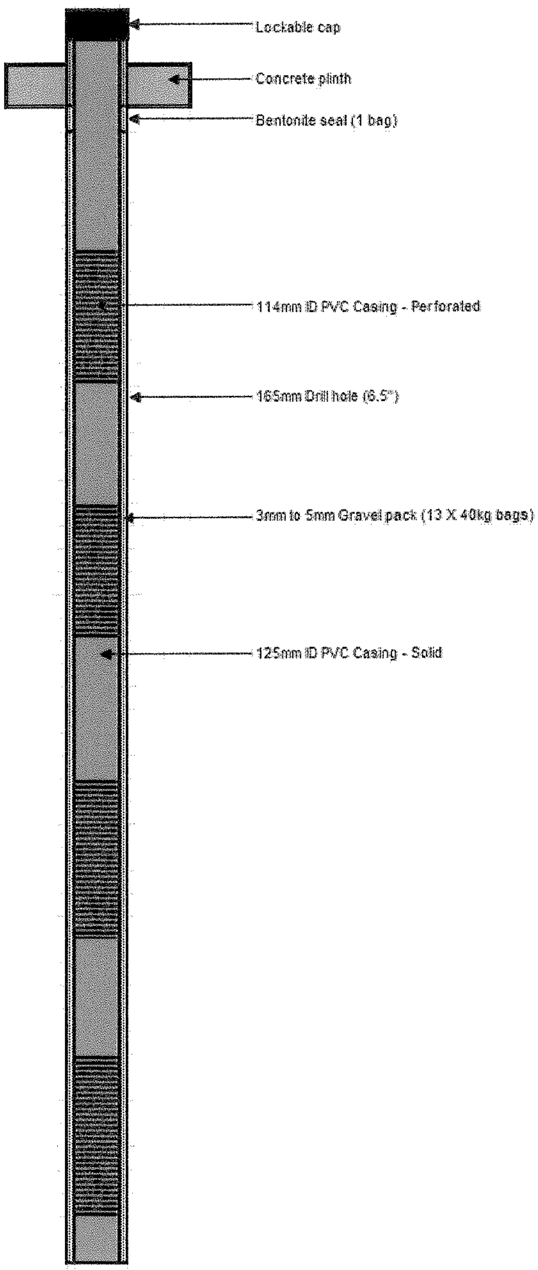
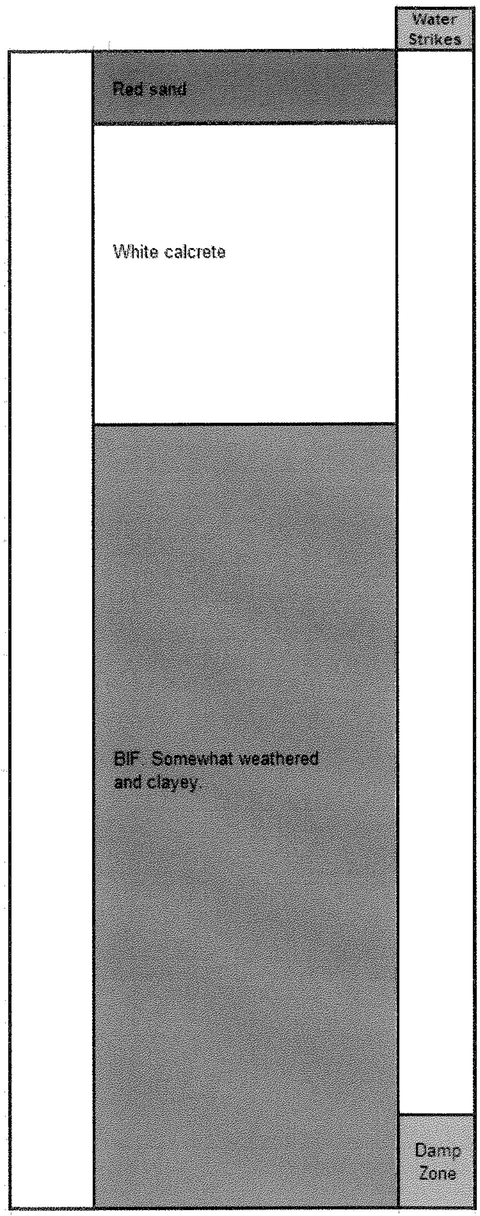
46	47
47	48
48	49
49	50



Geological Log
SB01



Borehole Construction

From	To
0	1
1	2
2	3
3	4
4	5
5	6
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7	8
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9	10
10	11
11	12
12	13
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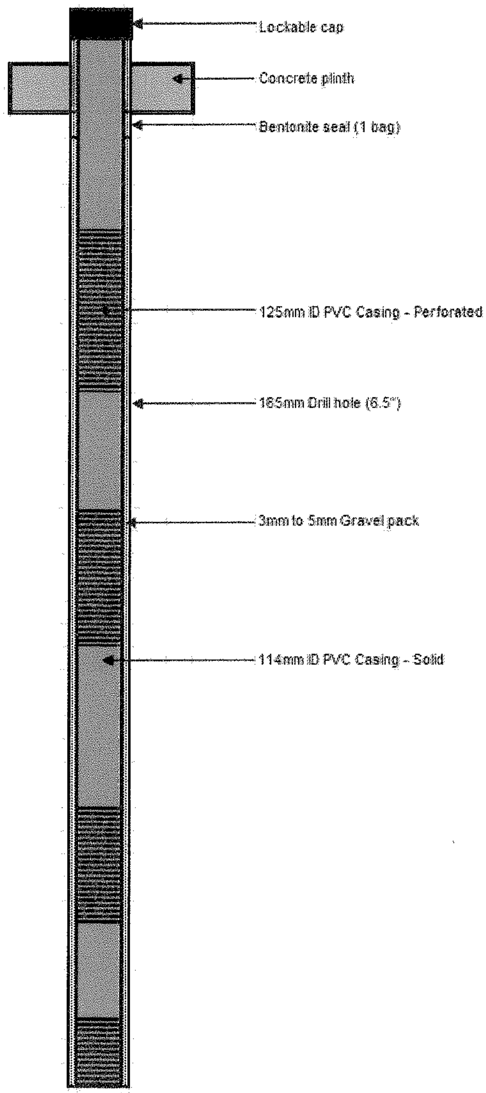
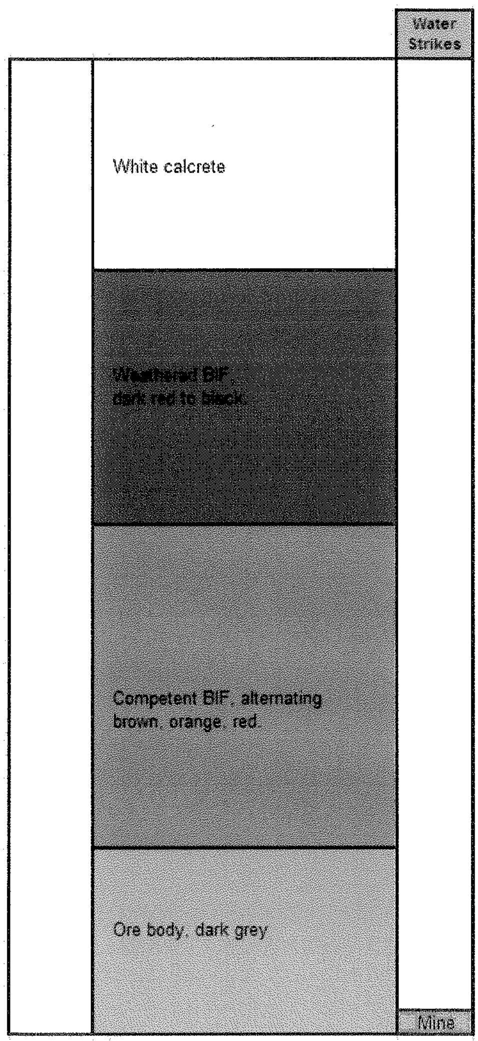
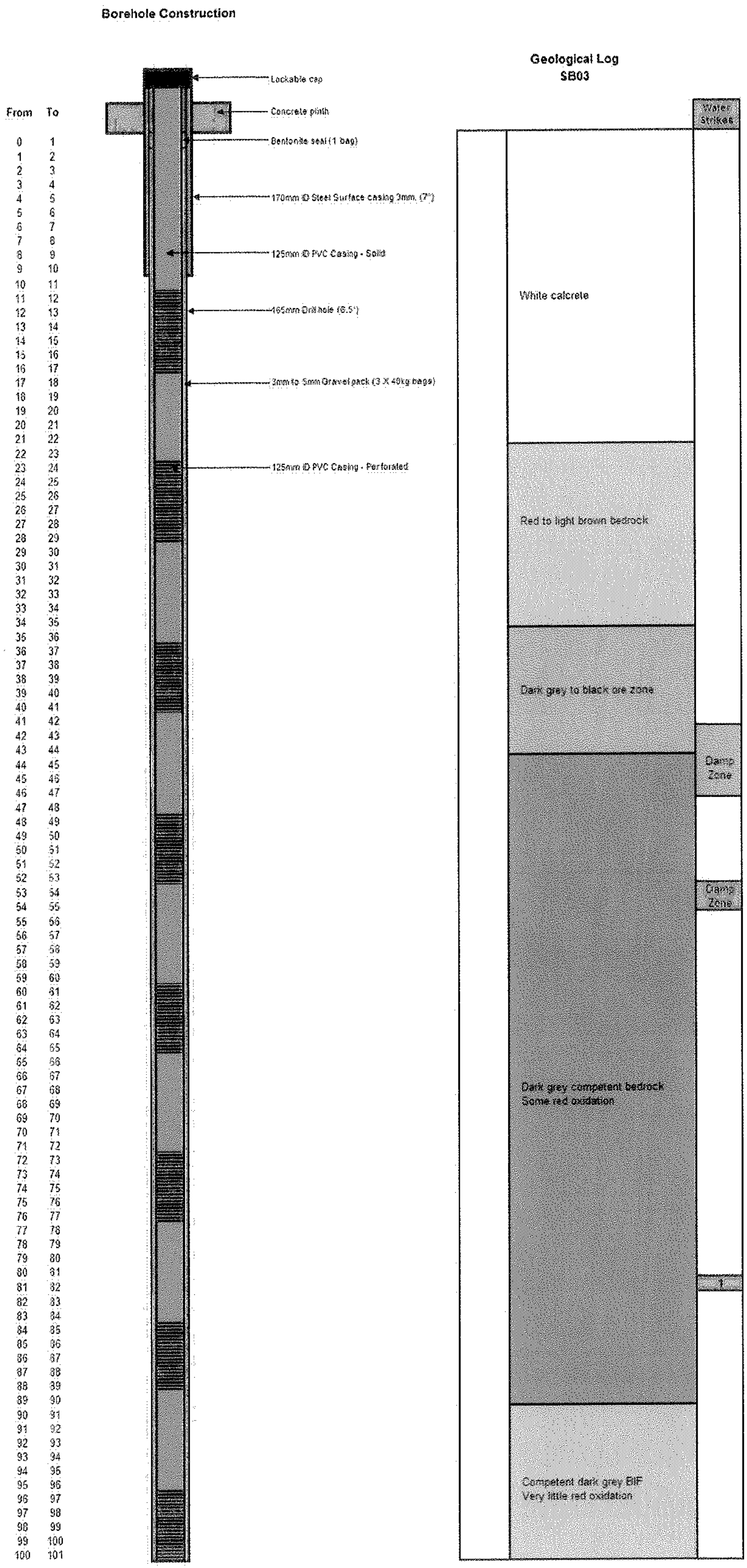
41	42



Geological Log
SB02




Borehole Construction
Geological Log
SB03
From To
0 1
1 2
2 3
3 4
4 5
5 6
6 7
7 8
8 9
9 10
10 11
11 12
12 13
13 14
14 15
15 16
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92 93
93 94
94 95
95 96
96 97
97 98
98 99
99 100
100 101
Lockable cap
Concrete plinth
Bentonite seal (1 bag)
170mm ID Steel Surface casing 3mm. (7")
125mm ID PVC Casing - Solid
165mm Drill hole (6.5")
3mm to 5mm Gravel pack (3 X 40kg bags)
125mm ID PVC Casing - Perforated
Water Strikes
White calcrete
Red to light brown bedrock
Dark grey to black ore zone
Damp Zone
Damp Zone
Dark grey competent bedrock
Some red oxidation
1
Competent dark grey BIF
Very little red oxidation

Borehole Construction

From	To
0	1
1	2
2	3
3	4
4	5
5	6
6	7
7	8
8	9
9	10
10	11
11	12
12	13
13	14
14	15
15	16
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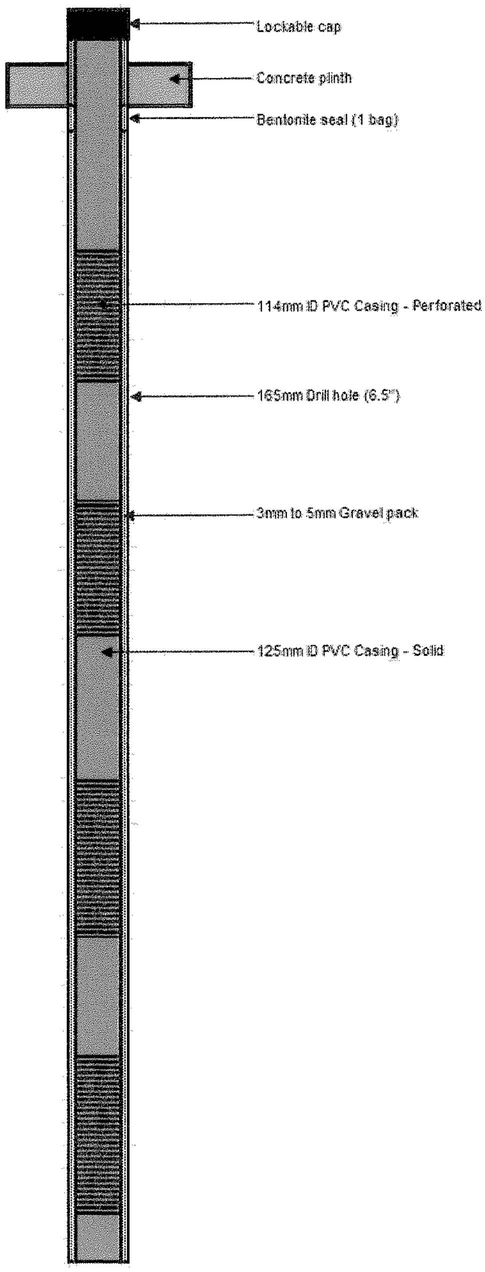
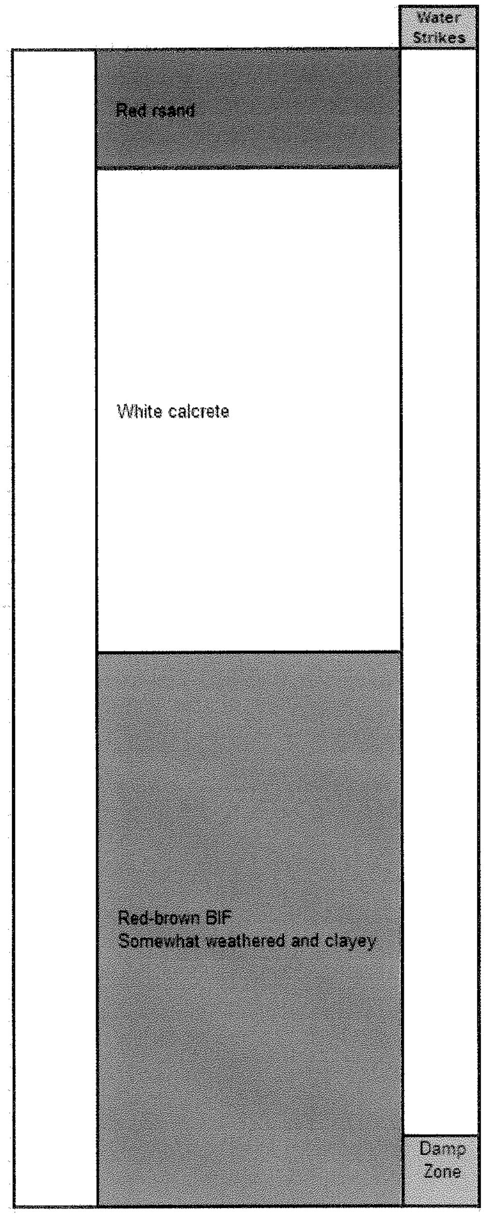


Geological Log
SB04



Borehole Construction

From	To
0	1
1	2
2	3
3	4
4	5
5	6
6	7
7	8
8	9
9	10
10	11
11	12
12	13
13	14
14	15
15	16
16	17
17	18
18	19
19	20
20	21
21	22
22	23
23	24
24	25
25	26
26	27
27	28
28	29
29	30
30	31
31	32
32	33
33	34
34	35
35	36
36	37
37	38
38	39
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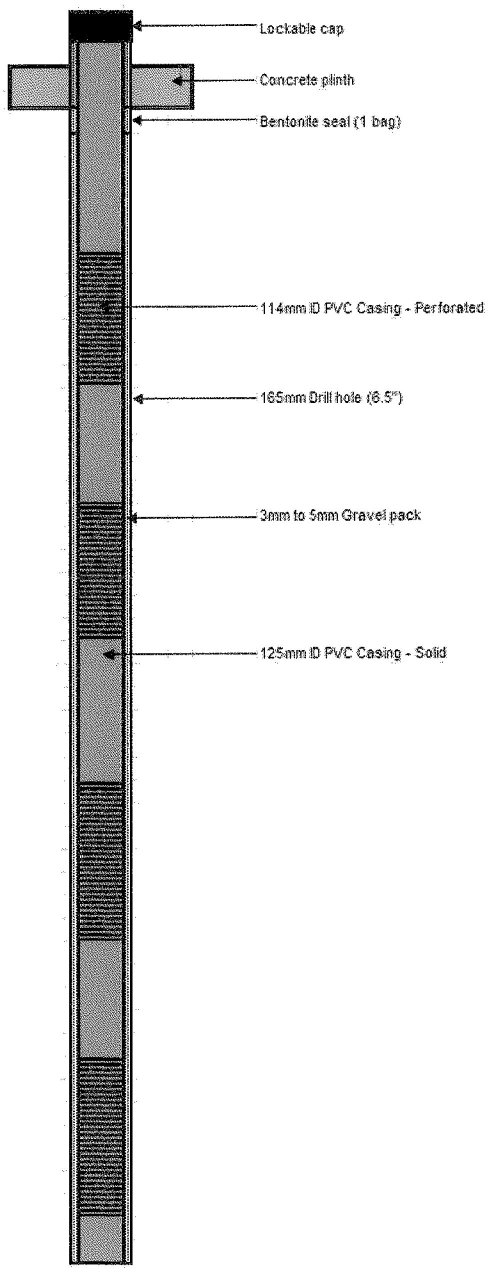
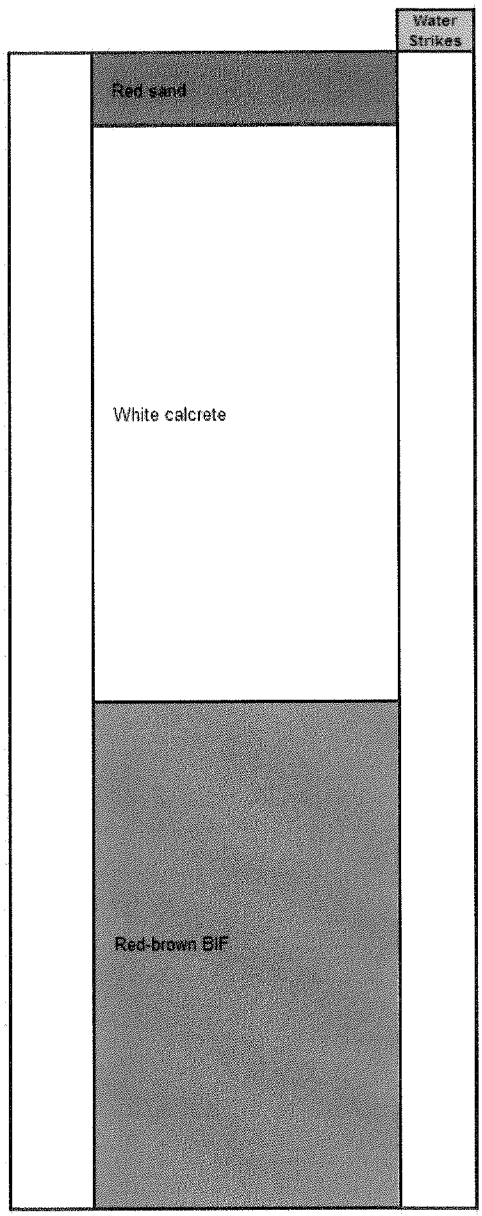
40	41
41	42
42	43
43	44
44	45
45	46
46	47
47	48
48	49
49	50



Geological Log
SB05



APPENDIX C:

AQUIFER TEST RESULTS

C1: Introduction

Aquifer testing of the three boreholes was conducted from the 26th to the 29th of August 2011. Only Constant-discharge and recovery tests were performed during this study.

C2: Methodology – constant discharge tests

For the constant-rate tests, the boreholes were pumped between eight and 14 minutes until pump in-take was reached. Upon completion of each constant-discharge test, recovering groundwater levels were measured. A summary of the derived aquifer parameters and drawdown data obtained during testing are presented in Table C1.

C2.1: Analysis

The constant-discharge test results enable the hydraulic characteristics of the aquifers intersected by each test production bore to be determined. The following methods were used to analyse the constant discharge data acquired:

- Theis straight line and recovery method for the pumping boreholes (Kruseman and De Ridder, 2000);
- The Cooper-Jacob ("straight-line") method (Kruseman and De Ridder, 2000) of analysis is a modification of the Theis equation and the data must meet certain requirements in order to be applicable; and
- Theis Recovery method.

The aquifer transmissivity of the fractured rock material ranges between 0.25 and 0.7 m^2/day. It has to be noted that these boreholes targeted geological structures that could act as potential groundwater flow pathways, and the transmissivity of these boreholes are considered to be higher than the average transmissivity of the general competent, fractured, host rock. The general aquifer transmissivity of the un-fractured host rock is considered to be less than 0.1 m^2/day. This is confirmed by the very low transmissivity seen in borehole P5 which yielded extremely little water. At 72 hours after completion of the drilling only 2 to 3 m of water had accumulated in the borehole.

The aquifer hydraulic conductivities can be calculated from the obtained data using the equation:

$$T = k \times d$$

Where:

T = aquifer transmissivity (as calculated from the aquifer test results);
k = aquifer hydraulic conductivity; and
d = saturated thickness of the aquifer (which of the purpose of this calculation is assumed to be the depth of the borehole minus the depth to groundwater level in that borehole).

As seen from Table C1 the hydraulic conductivities of the fractured rock aquifer are calculated to range around 0.012 and 0.021 m/day. This means that groundwater migrate at a rate of between 0.012 and 0.021 m/day through the aquifers. These are very low numbers and not conducive to large flow volumes through the area.

Aquifer storativity of the rock material is estimated from the aquifer test results. It should be noted that the obtained values are likely to be inaccurate due to the fact that they were calculated from single borehole tests. Ideally storativity of an aquifer is calculated from the groundwater level response to pumping measured in a borehole some distance away from the borehole being pumped. Calculating the storativity from the data collected in the borehole being pumped leads to uncertainty in the obtained results. Unfortunately, there were no boreholes close to each other that could be used as monitoring boreholes during the aquifer tests. The calculated aquifer storativity values range between 1.18E-10 and 2.18E-9, which are very low numbers.

Table C1: Aquifer test results

Parameter	Unit	P1	P2	P3	P4	P5
Borehole depth	m	50	42	101	50	50
Water strike	mbgl	None	42 (U/G mine)	82	50	Dry
Static water level	mbgl	26.28	27.00	24.35	31.27	-
Pumping rate	L/s	0.2	No test – Borehole drilled into underground mine	0.5	0.2	No test – borehole is dry
Transmissivity	m^2/day					
Theis		0.25		0.60	0.28	
Cooper-Jacob		0.31		0.67	0.33	
Recovery		0.02		0.33	0.12	
Average transmissivity		0.28		0.53	0.24	
Aquifer hydraulic conductivity	m/day	0.012		0.021	0.013	
Storage capacity (estimate)	-	1.74E-10		2.18E-9	1.18E-10	

Borehole pump test data sheet

Site:	Perth				
Borehole ID:	SB01			Date drilled	2012/04/03
Easting (WGS84, LO23)	-4 073			BH Depth (m)	50
Northing (WGS84, LO23)	-3 019 568			Final SWL (mbgl)	26.7
Elevation (mamsl)	1 062			Stand pipe (magl)	0.42
SWL (mbgl)	22.00				
Pumping Phase				Recovery Phase	
Time(min)	WL	Q(L/s)		Time (min)	WL
0.5	23			0.5	42.95
1.5	25.46			1.5	42.95
2.5	29.59			2.5	42.75
3.5	32.61			3.5	42.75
4.5	33.74			4.5	42.32
5	35.55			5	42.1
7	38.18			7	42.07
10	42.04	0.52		10	42.06
15	42.55	0.25		15	41.82
20	43.17	0.18		20	41.76
25	43.87	0.18		25	41.76
30	45.02	0.13		30	41.51
40	45.02	0.12		40	41.47
50	Pump intake			50	41.47
60				60	40.84
70				70	39.57
80				80	38.67
90				90	38.01
100				100	37.74
120				120	37.52
140				140	37.04
160				160	36.72
180				180	36.24
200				200	35.49
220				220	34.62
240				240	34.02

Borehole pump test data sheet

Site:	Perth				
Borehole ID:	SB03			Date drilled	2012/04/04
Easting (WGS84, LO23)	4147			BH Depth (m)	100
Northing (WGS84, LO23)	-3020048			Final SWL (mbgl)	24.65
Elevation (mamsl)	1066			Stand pipe (magl)	0.3
SWL (mbgl)	22.37				
Pumping Phase				Recovery Phase	
Time(min)	WL	Q(L/s)		Time (min)	WL
0.5	26.99			0.5	43.07
1.5	27.75			1.5	43
2.5	28.4			2.5	43.82
3.5	28.73			3.5	42.81
4.5	28.96			4.5	42.72
5	29.01			5	42.7
7	29.1			7	41.5
10	29.74	0.7		10	41.03
15	31.23	0.68		15	40.74
20	32.63	0.68		20	39.03
25	34.73	0.62		25	38.64
30	36.01	0.55		30	38.01
40	40.13	0.5		40	37.91
50	41.72	0.5		50	37.53
60	42.29	0.5		60	37.38
70	42.37	0.48		70	37.13
80	43.04	0.48		80	37.02
90	45.72	0.46		90	36.87
100	45.72	0.46		100	36.74
120	45.92	0.45		120	36.52
140	46.57	0.42		140	36.29
160	47.09	0.41		160	36.14
180	47.73	0.26		180	35.72
200	48.53	0.26		200	35.43
220	48.74	0.2		220	35.17
240	49.32	0.17		240	34.98

Borehole pump test data sheet

Site:	Perth				
Borehole ID:	SB04			Date drilled	2012/04/06
Easting (WGS84, LO23)	-4620			BH Depth (m)	50
Northing (WGS84, LO23)	-3019162			Final SWL (mbgl)	30
Elevation (mamsl)	1055			Stand pipe (magl)	0.35
SWL (mbgl)	31.02				
	Pumping Phase			Recovery Phase	
Time(min)	WL	Q(L/s)		Time (min)	WL
0.5	33.24			0.5	40.96
1.5	33.47			1.5	40.9
2.5	33.86			2.5	40.9
3.5	33.98			3.5	40.9
4.5	34.08			4.5	40.9
5	35.36			5	40.74
7	36.55			7	40.72
10	37.95	0.2		10	40.56
15	40.26	0.14		15	40.42
20	41.21	0.09		20	40.42
25	41.73			25	40.23
30	Pump intake			30	40.07
40				40	39.98
50				50	39.72
60				60	39.72
70				70	39.72
80				80	39.63
90				90	39.59
100				100	39.42
120				120	39.3
140				140	38.74
160				160	38.74
180				180	38.7
200				200	38.65
220				220	38.24
240				240	38.17

APPENDIX D:

LABORATORY ANALYSIS CERTIFICATES

CLEAN STREAM
Scientific Services (Pty.) Ltd.

489 Jacqueline Drive, Garsfontein, Pretoria, 0042
P.O. Box 905008, Garsfontein, 0042
Tel (012) 348 2813/4, Fax 012 348 8575

Specialists in environmental monitoring

Test Report

Client: Future Flow Cc
Address: Unit 111,Monf Blanc, 489 View Street, Rietvalleirand, 0181
Report No: 7888 **Project:** Future Flow

Date of certificate: 16 Apr 2012
Date accepted: 10 Apr 2012
Date completed: 13 Apr 2012

	Lab no:		84839	84840	84841	84842	84843	84844	84845
	Date sampled:		24 Mar 2012	24 Mar 2012	24 Mar 2012	24 Mar 2012	24 Mar 2012	24 Mar 2012	21 Mar 2012
	Sample type:		Water	Water	Water	Water	Water	Water	Water
	Locality description		P1-2	P3-4	P5	P6	P7	PD	PS1
	Analyses:	Method							
A	pH	CSM 20	8.10	7.46	7.30	7.60	7.92	8.00	7.40
A	Electrical conductivity (EC) mS/m	CSM 20	97.20	191.40	328.80	142.10	244.10	202.80	339.10
A	Total dissolved solids (TDS) mg/l	CSM 06	466	1100	2533	767	1520	1172	2215
A	Total alkalinity mg/l	CSM 01	267.7	235.5	192.1	284.7	75.8	256.9	201.8
A	Chloride (Cl) mg/l	CSM 02	67.5	436.2	1330.7	230.6	646.5	388.4	833.9
A	Sulphate (SO4) mg/l	CSM 03	19.20	45.67	152.19	24.90	174.75	91.13	79.15
A	Nitrate (NO3) mg/l as N	CSM 06	33.099	64.587	82.573	41.665	72.947	84.756	283.538
A	Ammonium(NH4) mg/l as N	CSM 05	0.265	0.172	0.469	<0.015	<0.015	<0.015	0.102
A	Orthophosphate (PO4) mg/l as P	CSM 04	<0.025	<0.025	0.029	<0.025	<0.025	<0.025	<0.025
A	Fluoride (F) mg/l	CSM 11	0.511	0.278	0.255	0.211	<0.183	0.337	0.364
A	Calcium (Ca) mg/l	CSM 30	67.789	197.817	459.961	144.669	206.114	163.270	480.010
A	Magnesium (Mg) mg/l	CSM 30	61.110	109.161	251.036	77.150	93.921	137.668	299.712
A	Sodium (Na) mg/l	CSM 30	34.51	102.15	136.27	74.99	276.61	144.13	108.02
A	Potassium (K) mg/l	CSM 30	2.322	3.282	5.017	2.544	3.688	8.752	9.577
A	Aluminium (Al) mg/l	CSM 31	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
A	Iron (Fe) mg/l	CSM 31	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
A	Manganese (Mn) mg/l	CSM 31	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
A	Total chromium (Cr) mg/l	CSM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Copper (Cu) mg/l	CSM 31	<0.001	<0.001	0.005	<0.001	<0.001	<0.001	0.008
A	Nickel (Ni) mg/l	CSM 31	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
A	Zinc (Zn) mg/l	CSM 31	0.024	0.074	1.038	0.034	0.211	0.027	<0.004
A	Cobalt (Co) mg/l	CSM 31	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
A	Cadmium (Cd) mg/l	CSM 31	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Silver (Ag) mg/l	CSM 32	<0.002	0.002	0.005	<0.002	0.002	<0.002	0.006
N	Gallium (Ga) mg/l	CSM 32	0.006	0.006	0.012	0.007	0.007	0.007	0.015
N	Boron (B) mg/l	CSM 32	0.173	0.378	0.443	0.248	1.871	0.579	0.337
N	Barium (Ba) mg/l	CSM 32	0.121	0.228	0.140	0.165	0.067	0.100	0.228
N	Beryllium (Be) mg/l	CSM 32	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
N	Bismuth (Bi) mg/l	CSM 32	0.02	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
N	Tellurium (Te) mg/l	CSM 32	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023	<0.023
N	Lithium (Li) mg/l	CSM 32	0.003	0.010	0.011	0.006	0.017	0.016	0.014
N	Molybdenum (Mo) mg/l	CSM 32	0.039	0.039	0.073	0.038	0.052	0.039	0.074
A	Lead (Pb) mg/l	CSM 31	<0.001	0.002	0.041	<0.001	<0.001	<0.001	0.037
N	Rubidium (Rb) mgl	CSM 31	0.092	0.085	0.184	0.091	0.088	0.084	0.205

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NATD = Not able to determine

sanas testing laboratory T0374

Report checked by: H. Holtzhausen (Laboratory Manager)

CLEAN STREAM
Scientific Services (Pty.) Ltd.

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P.O. Box 905008, Garsfontein, 0042
Tel (012) 348 2813/4, Fax 012 348 8575

Specialists in environmental monitoring

Test Report

Client: Future Flow Cc
Address: Unit 111,Monf Blanc, 489 View Street, Rietvalleirand, 0181
Report No: 7888 **Project:** Future Flow

Date of certificate: 16 Apr 2012
Date accepted: 10 Apr 2012
Date completed: 13 Apr 2012

	Analyses:	Method							
	Lab no:		84839	84840	84841	84842	84843	84844	84845
	Date sampled:		24 Mar 2012	24 Mar 2012	24 Mar 2012	24 Mar 2012	24 Mar 2012	24 Mar 2012	21 Mar 2012
	Sample type:		Water	Water	Water	Water	Water	Water	Water
	Locality description		P1-2	P3-4	P5	P6	P7	PD	PS1
N	Silicon (Si) mg/l	CSM 33	33.544	25.662	23.371	25.853	15.633	17.155	26.502
N	Strontium (Sr) mg/l	CSM 31	0.600	1.120	2.064	0.715	1.248	1.457	2.971
N	Vanadium (V) mg/l	CSM 32	0.023	0.004	<0.003	0.006	0.003	0.015	0.004
N	Thallium mg/l	CSM 32	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087	<0.087
A	Total hardness mg/l	CSM 26	471	943	2182	679	901	975	2433
A	Bicarbonate alkalinity mg CaCO3/l	CSM 26	264.5	234.8	191.8	283.7	75.2	254.4	201.3

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Report checked by: H. Holtzhausen (Laboratory Manager)

sanas testing laboratory T0374

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Address: Unit 111,Monf Blanc, 489 View Street, Rietvalleirand, 0181
Report No: 7888 **Project:** Future Flow

Date of certificate: 16 Apr 2012
Date accepted: 10 Apr 2012
Date completed: 13 Apr 2012

Lab no:			84846
Date sampled:			26 Mar 2012
Sample type:			Water
Locality description			UMK14
Analyses:		**Method**	
A	pH	CSM 20	7.78
A	Electrical conductivity (EC) mS/m	CSM 20	149.20
A	Total dissolved solids (TDS) mg/l	CSM 06	727
A	Total alkalinity mg/l	CSM 01	237.7
A	Chloride (Cl) mg/l	CSM 02	204.2
A	Sulphate (SO4) mg/l	CSM 03	22.51
A	Nitrate (NO3) mg/l as N	CSM 06	67.556
A	Ammonium(NH4) mg/l as N	CSM 05	<0.015
A	Orthophosphate (PO4) mg/l as P	CSM 04	0.046
A	Fluoride (F) mg/l	CSM 11	0.360
A	Calcium (Ca) mg/l	CSM 30	113.495
A	Magnesium (Mg) mg/l	CSM 30	93.406
A	Sodium (Na) mg/l	CSM 30	76.77
A	Potassium (K) mg/l	CSM 30	6.155
A	Aluminium (Al) mg/l	CSM 31	<0.006
A	Iron (Fe) mg/l	CSM 31	<0.006
A	Manganese (Mn) mg/l	CSM 31	<0.001
A	Total chromium (Cr) mg/l	CSM 31	<0.002
A	Copper (Cu) mg/l	CSM 31	<0.001
A	Nickel (Ni) mg/l	CSM 31	<0.003
A	Zinc (Zn) mg/l	CSM 31	0.040
A	Cobalt (Co) mg/l	CSM 31	<0.002
A	Cadmium (Cd) mg/l	CSM 31	<0.001
N	Silver (Ag) mg/l	CSM 32	<0.002
N	Gallium (Ga) mg/l	CSM 32	0.006
N	Boron (B) mg/l	CSM 32	0.766
N	Barium (Ba) mg/l	CSM 32	0.032
N	Beryllium (Be) mg/l	CSM 32	<0.001
N	Bismuth (Bi) mg/l	CSM 32	<0.01
N	Tellurium (Te) mg/l	CSM 32	<0.023
N	Lithium (Li) mg/l	CSM 32	0.011
N	Molybdenum (Mo) mg/l	CSM 32	0.036
A	Lead (Pb) mg/l	CSM 31	<0.001
N	Rubidium (Rb) mgl	CSM 31	0.050

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sanas Testing Laboratory T0374

Report checked by: H. Holtzhausen (Laboratory Manager)

Directors: Ryno Erdmann (Managing), Fritz Bekker, Jaco de Klerk. Company registration number: 2006/028605/07. Vat no: 4360195723

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Scientific Services (Pty.) Ltd.

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Specialists in environmental monitoring

Test Report

Client: Future Flow Cc
Address: Unit 111,Monf Blanc, 489 View Street, Rietvalleirand, 0181
Report No: 7888 **Project:** Future Flow

Date of certificate: 16 Apr 2012
Date accepted: 10 Apr 2012
Date completed: 13 Apr 2012

Lab no:			84846
Date sampled:			26 Mar 2012
Sample type:			Water
Locality description			UMK14
Analyses:		**Method**	
N	Silicon (Si) mg/l	CSM 33	14.448
N	Strontium (Sr) mg/l	CSM 31	0.785
N	Vanadium (V) mg/l	CSM 32	0.008
N	Thallium mg/l	CSM 32	<0.087
A	Total hardness mg/l	CSM 26	668
A	Bicarbonate alkalinity mg CaCO3/l	CSM 26	236.3

A = Accredited (Included in the SANAS Schedule of Accreditation); N = Not accredited (Excluded from the SANAS Schedule of Accreditation)
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Report checked by: H. Holtzhausen (Laboratory Manager)

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Environmental Noise Impact Assessment

Sebilo Perth Mining

Proposed Open Cast Mine and Underground Mine
RE Farm Perth 276, Kuruman

Northern Cape

Project No: 026/2012
Compiled by: B v/d Merwe
Date: 16 April 2012

Executive Summary

Purpose of the study

- The noise survey was carried out in order to determine the prevailing ambient noise levels in and in the vicinity of the proposed Sebilo mine;
- To project the noise impact of the proposed mining activities on the abutting residential areas;
- To recommend engineering control measures to minimise the noise impact on the abutting residential areas.

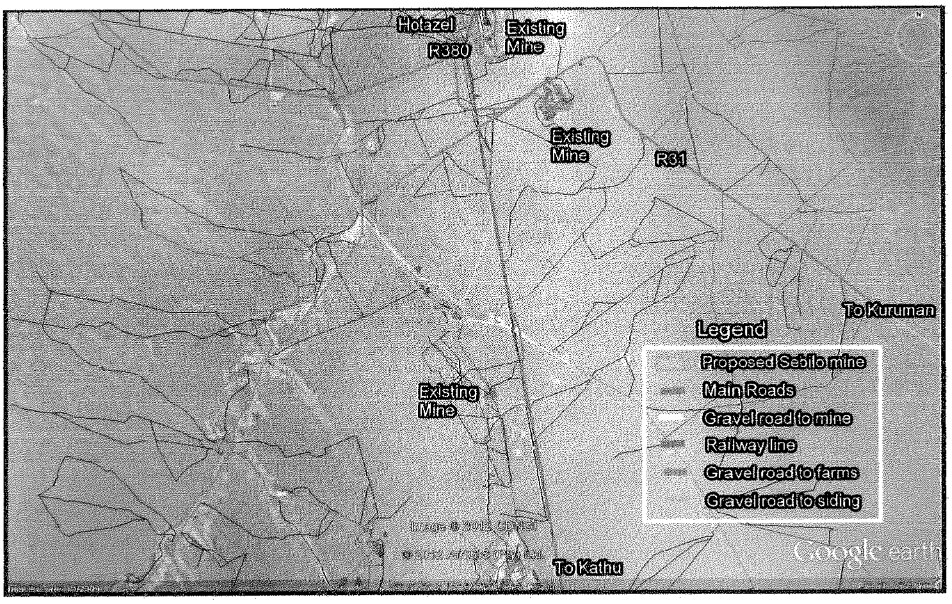
Introduction

The open cast and underground mine will be situated within a disturbed area west of old mining activities and along an existing gravel road. The UMK open cast mine is abutting the proposed Sebilo mine to the south and the entrance to the UMK mine is along the southern boundary of the proposed mine.

The proposed entrance route to the new open cast mine will be off the existing gravel road that is used by vehicles going to the UMK mine. Limited conveying of the manganese ore will take place by road and most of the ore will be conveyed on a daily basis to the railway siding from where it will be loaded onto a train. The main railway line and R380 road is to the east and used by trains and traffic respectively during the day and night time periods. There are three existing mines in a radius of 7 500m from the proposed Sebilo mine.

People living in the vicinity of these existing mines are already exposed to higher noise levels due to the existing mining activities, traffic and rail road noise. The noise survey was carried out on 19 and 20 April 2012.

The study area in the vicinity of the proposed mine is illustrated in the following aerial imagery.



Location of the proposed Sebilo mine

The alleged noise impact on the environment and the residents living in the vicinity of the proposed mining area will be investigated.

The distances between the proposed mine and noise sensitive areas are as follows:

- Sebilo mine and Hotazel – 9 750m
- Sebilo mine and the farm Devon (Measuring point 13) – 4 210m
- Sebilo mine and the Farm Mooidraai (Measuring point 14) – 5 310m
- Sebilo and staff accommodation (Measuring point 7) – 1 750m

Site Characteristics

The following observations were made in the vicinity of the proposed Sebilo mine:

- The traffic noise is the main contributor to the prevailing ambient noise level along the main feeder roads and a finite type noise is created along the gravel roads and railway line;
- The distant mine activities from the abutting open cast mines were audible along the southern side of the mine and at some of the other measuring points;
- Heavy duty vehicles are using the gravel road to UMK mine and the R380 and R31 roads for hauling ore from other mines;
- There are natural and manmade topographical barriers, which can deflect and absorb the open cast mine activity noise;
- Train noise is audible at times at the measuring points which are situated between the proposed mine and the R380 road;
- The study area cannot be classified as a rural district according to Table 2 of SANS 10103 of 2008, due to the existing mine activities, main feeder roads and railway infra-structure in the vicinity of the proposed Sebilo mine.

Current noise sources

The following are noise sources in the vicinity of and the boundaries of the study area:

- Heavy duty vehicles travelling along the R31 and R380 roads;
- Railway noise;
- Rattling sounds from vehicles traveling on the gravel road;
- Existing traffic noise along the gravel road that lead to the proposed mine;
- Existing blasting noise and vibration at the UMK open cast mine;
- Farming type noise;
- Birds and insects;
- Wind noise.

Results

The prevailing ambient noise levels for the study area are typical of the noise levels expected in a district with mining activities at a distance and feeder roads with intermittent increased noise levels. The noise survey indicates that there is already increased noise levels because of existing mining activities within the vicinity of the proposed mine.

The prevailing ambient noise levels within the study area during daytime and night time are given in Table 6.

Location	Ambient noise level during daytime - dBA	Ambient noise level during night time - dBA
R31 Road	64.1	55.1
R380 Road	57.4	56.4
Gravel roads	33.0	31.2
Boundary of the mine - northern	33.7	33.9
Boundary of the mine - southern	56.3	46.0
Gravel road to siding	37.4	39.5
Gravel road to mine	49.9	45.1

There will be an increase during the construction phase of the project in earthmoving activities and traffic to and from the proposed open-cast and shaft area. This will however be temporarily and the existing gravel road to the abutting UMK-mine will be used. During the operational phase of the mine, noise will be more permanent but to the same extend as what is experienced currently with the abutting mining activities. There is however no residential areas within 1 750m (staff accommodation to the east) and 4 210m (farm house to the north east).

Conclusion and summary

The mining at the proposed open cast mine and the shaft will take place in the vicinity of existing mines and vacant land which is covered with natural vegetation.

This area where the proposed mine will be situated cannot be classified as a rural type district according to the definition of Table 2 of the SANS 10103 of 2008 because of the existing mining activities.

The residents in the vicinity of the proposed mine are already exposed to the different and higher noise levels that is created by the existing mining activities, traffic and rail way noise.

The proposed mining activities will create a shift in the near field prevailing ambient noise levels and at times this will create a temporary shift in the far field noise levels.

The noise intrusion can however be controlled by means of approved acoustic screening measures, state of the art equipment, proper noise management principles and compliance to the International Finance Corporation's Environmental Health and Safety Guidelines.

Barend van der Merwe
Acoustic Consultant

Contents:

1. **Purpose of the study**

- The noise survey was carried out in order to determine the prevailing ambient noise levels in and in the vicinity of the proposed Sebilo mine;
- To project the noise impact of the proposed mining activities on the abutting residential areas;
- To recommend engineering control measures to minimise the noise impact on the abutting residential areas.

2. **Introduction**

The open cast and underground mine will be situated within a disturbed area west of old mining activities and along an existing gravel road. The UMK open cast mine is abutting the proposed Sebilo mine to the south and the entrance to the UMK mine is along the southern boundary of the proposed mine.

The proposed entrance route to the new open cast mine will be off the existing gravel road that is used by vehicles going to the UMK mine. Limited conveying of the manganese ore will take place by road and most of the ore will be conveyed on a daily basis to the railway siding from where it will be loaded onto a train. The main railway line and R380 road is to the east and used by trains and traffic respectively during the day and night time periods. There are three existing mines in a radius of 7 500m from the proposed Sebilo mine.

People living in the vicinity of these existing mines are already exposed to higher noise levels due to the existing mining activities, traffic and rail road noise.

The noise survey was carried out on 19 and 20 April 2012.

The study area in the vicinity of the proposed mine is illustrated in Figure 1.

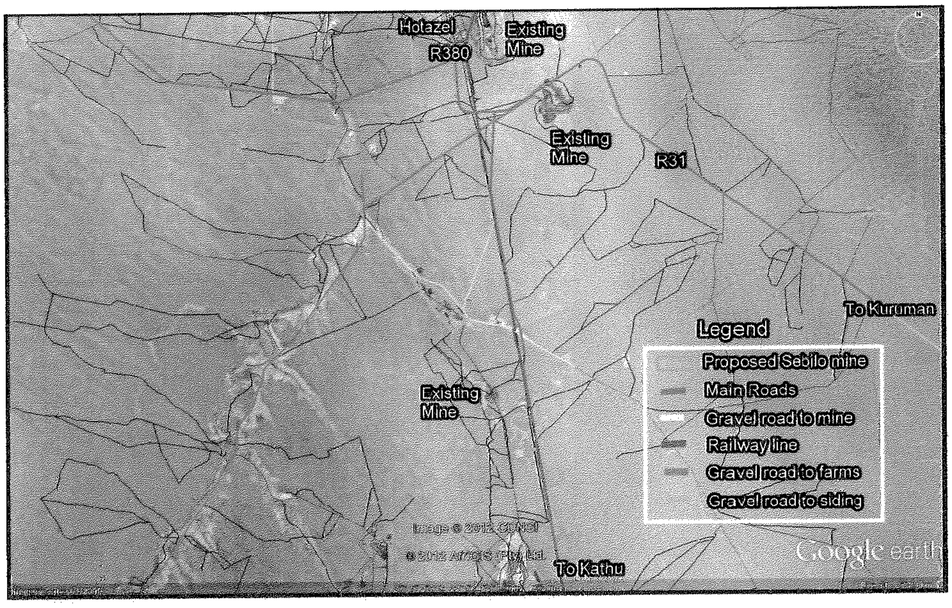


Figure 1: Location of the proposed Sebilo mine

The alleged noise impact on the environment and the residents living in the vicinity of the proposed mining area will be investigated.

3. Background to noise and ground vibration

Noise

Sound is a wave motion, which occurs when a sound source sets the nearest particles of air in motion. The movement gradually spreads to air particles further away from the source. Sound propagates in air with a speed of approximately 340 m/s.

The sound pressure level in free field conditions is inversely proportional to the square of the distance from the sound source – Inverse Square Law. Expressed logarithmically as decibels, this means the sound level decrease 6 dB with the doubling of distance. This applies to a point source only. If the sound is uniform and linear then the decrease is only 3 dB per doubling of distance.

The decibel scale is logarithmic therefore decibel levels cannot be added together in the normal arithmetic way, for example, two sound sources of 50 dB each do not produce 100 dB but 53 dB, nor does 50 dB and 30 dB equal 80 dB, but remains 50 dB.

Air absorption is important over large distances at high frequencies and it depends on the humidity but is typically about 40 dB/km @ 4000 Hz. Traffic noise frequencies are mainly mid/low and will be unaffected below 200m.

When measuring the intensity of a sound, an instrument, which duplicates the ear variable sensitivity to sound of different frequency, is usually used. This is achieved by building a filter into the instrument with a similar frequency response to that of the ear. This is called an A-weighting filter because it conforms to the internationally standardized A-weighting curves. Measurements of sound level made with this filter are called A-weighted sound level measurements, and the unit is dB.

Sound propagation is affected by wind gradient rather than the wind itself. The profile of the ground causes such a gradient. The sound may be propagated during upwind conditions upwards to create a sound shadow. A downwind refracts the sound towards the ground producing a slight increase in sound level over calm isothermal conditions.

The velocity of sound is inversely proportional to the temperature therefore a temperature gradient produces a velocity gradient and a refraction of the sound. Temperature decreases with height and the sound is refracted upwards.

For a source and receiver close to the ground quite large attenuation can be obtained at certain frequencies over absorbing surfaces, noticeably grassland. This attenuation is caused by a change in phase when the reflected wave strikes the absorbing ground and the destructive interference of that wave with the direct wave. The reduction in sound tends to be concentrated between 250 Hz and 600 Hz.

Noise screening can be effective when there is a barrier between the receiver and the source i.e. walls, earth mounds, cuttings and buildings. The performance of barriers is frequency dependent. To avoid sound transmission through a barrier the superficial mass should be greater than 10 Kg/m^2.

There is a complex relation between subjective loudness and the sound pressure level and again between annoyance due to noise and the sound pressure level. In general the ear is less sensitive at low frequencies and the ear will only detect a difference in the sound pressure level when the ambient noise level is exceeded by 3-5 dBA.

There are certain effects produced by sound which, if it is not controlled by approved acoustic mitigatory measures, seem to be construed as undesirable by most people and they are:

- Long exposure to high levels of sound, which may damage the hearing or create a temporary threshold shift – in industry or at areas where music is played louder than 95 dBA. This will seldom happen in far-field conditions;
- Interference with speech where important information by the receiver cannot be analyzed due to loud noises;
- Excessive loudness;
- Annoyance.

A number of factors, for example clarity of speech, age of listener and the presence of noise induced threshold displacement, will influence the comprehensibility of speech communication.

The effect of noise (with the exception of long duration, high level noise) on humans is limited to disturbance and/or annoyance and the accompanying emotional reaction. This reaction is very difficult to predict and is influenced by the emotional state of the complainant, his attitude towards the noisemaker, the time of day or night and the day of the week.

Types of noise exposure:

Continuous exposure to noise – The level is constant and does not vary with time e.g. traffic on freeway and an extractor fan;
Intermittent exposure to noise – The noise level is not constant and occurs at times e.g. car alarms and sirens;
Exposure to impact noise – A sharp burst of sound at intermittent intervals e.g. explosions and low frequency sound.

Depending upon the intensity of the sound, the length of time of exposure and how often over time the ear is exposed to it, noise affects humans differently. Urban dwellers are besieged by noise, not only in the city streets but also in the busy workplaces and household noises.

Table 1: Recommended sound pressure levels for certain areas.

Descriptor	Limit	Situation or effect
LAeq, 24	70 dBA	Negligible risk of hearing impairment
LAeq, 8	75 dBA	Negligible
LAeq	30 dBA	Excellent speech intelligibility
LAeq	55 dBA	Fairly good speech intelligibility
LAeq	30 dBA	No sleep disturbance in a bedroom
LAmax	45 dBA	No sleep disturbance – peak inside bedroom
LAeq	55 dBA	Residential areas, outdoors, daytime
LAeq	45 dBA	Residential areas, outdoors, night time

This time-varying characteristics of environmental noise are described using statistical noise descriptors:

Leq: The Leq is the constant sound level that would contain the same acoustic energy as the varying sound level, during the same period of time.

L_{Max}: The instantaneous maximum noise level for a specified period of time.

L_{Min}: The instantaneous minimum noise level for a specified period of time.

The following relationships occur for increases in A-weighted noise levels:

- The trained healthy human ear is able to discern changes in sound levels of 1 dBA under controlled conditions in an acoustic laboratory;
- It is widely accepted that the average healthy ear can barely perceive noise level changes of 3 dBA;
- A change in sound level of 5 dBA is a readily perceptible increase in noise level;
- A 10-dBA change in the sound level is perceived as twice as loud as the original source.

The World Bank in the Environmental Health and Safety Regulations has laid down the following noise level guidelines:

- Residential area – 55 dBA for the daytime and 45 dBA for the nighttime period;
- Industrial area – 70 dBA for the day- and nighttime periods.

The difference between the actual noise and the ambient noise level and the time of the day and the duration of the activity, will determine how people will respond to sound and what the noise impact will be. In order to evaluate such, there must be uniform guidelines to evaluate each scenario. The SANS 10103 of 2008 has laid down sound pressure levels for specific districts and has provided the following continuous noise levels per district which is illustrated in Table 2.

Table 2: Recommended noise levels for different districts.

1	2	3	4	5	6	7
	Equivalent continuous rating level $L_{Req,T}$ for ambient noise dBA					
	Outdoors			Indoors, with open windows		
Type of district	Day-night L_{Rdn} 2)	Daytime L_{Rd} 1)	Night-time L_{Rn} 1)	Day-night L_{Rdn} 2)	Daytime L_{Rn} 1)	Night-time L_{Rn} 1)
a) Rural districts	45	45	35	35	35	25
b) Suburban districts with little road traffic	50	50	40	40	40	30
c) Urban districts	55	55	45	45	45	35
d) Urban districts with some workshops, with business premises and with main roads	60	60	50	50	50	40
e) Central business district	65	65	55	55	55	45
f) Industrial districts	70	70	60	60	60	50

The reference time intervals can be specified to cover typical human activities and variations in the operation of noise sources and are for daytime between 6h00 to 22h00 and for nighttime between 22h00 and 6h00.

The response to noise can be classified as follows:

- An increase of 1dBA to 3dBA above ambient noise level will cause no response from the affected community. For a person with normal hearing an increase of 0dBA to 3 dBA will not be noticeable
- An increase between 1dBA – 10dBA will elicit little to sporadic response. When the difference is more than 5 dBA above the ambient noise level a person with normal hearing will start to hear the difference.
- An increase between 5dBA and 15 dBA will elicit medium response from the affected community.
- An increase between 10dBA and 20 dBA will elicit strong community reaction.

Because there is no clear-cut transition from one community response to another as well as several variables, categories of responses can overlap. This should be taken into consideration during the evaluation of a potential noise problem.

There is therefore a mixture of activities and higher noise levels as per the above recommended continuous rating levels within i.e. residential, industrial and feeder roads in close proximity of each other.

The ambient noise level will therefore differ throughout the study area, depending on the region and the measuring position in relation to areas with existing mining activities.

People exposed to an increase in the prevailing ambient noise level will react differently to the noise levels and the response is given in Table 3.

Table 3: Estimated community/group response when the ambient noise level is exceeded

1	2	3
Excess)$L_{Req,T}$ 1)	**Estimated community/group response**	
dB	**Category**	**Description**
0	None	No observed reaction
0-10	Little	Sporadic complaints
5-15	Medium	Widespread complaints
10-20	Strong	Threats of community/group action
>15	Very strong	Vigorous community/group action

1) Calculate)$L_{Req,T}$ from the appropriate of the following:

a))$L_{Req,T}$ = $L_{Req,T}$ of ambient noise under investigation MINUS $L_{Req,T}$ of the residual noise (determined in the absence o the specific noise under investigation).

b))$L_{Req,T}$ = $L_{req,T}$ of ambient noise under investigation MINUS the maximum rating level for the ambient noise given in table 1.

c))$L_{Req,T}$ = $L_{Req,T}$ of ambient noise under investigation MINUS the typical rating level for the applicable district as determined from table 2.

The difference between the actual noise and the ambient noise level will determine how people will respond to sound.

<u>Ground vibration</u>

Human reaction to vibration will be in response to the resulting effects of both ground and airborne vibration and in particular the combined effects of such vibration. The blasting process is the biggest contributor to vibration.

Routine blasting operations regularly generate air over pressure levels at 15m from the blast of about 120 dB. A constant wind velocity of $5m/s^{-1}$ will generate the pressure equivalent of 120 dB at 15m from the blasting area. At 140 dB the wind velocity will increase to $8m/s^{-1}$.

Wavelength differences associated with this frequency range mean that any effects of topography are likely to be pronounced for the audible component of air over pressure levels rather than the concussive component. A topographic barrier i.e. an earthberm or rock face will play an important role in reducing the audible effect rather than the concussive effect. A series of quarry faces between the receptor and the source will be more effective to reduce the air over pressure levels.

The shock waves have a relatively high dominant frequency and the energy contained in the shock wave will reduce rapidly as the resultant energy will be subjected to geometric and natural attenuation. Rock formations absorb the vibrations and/or the distance from the source which will result in the shock wave to be attenuated by 6dB in the doubling of distance from the source.

The blast design chart suggested in Rock Slope Engineering by Wyllie and Mah, 2004 will be used to quantify damage potential to residential properties. It is generally accepted that residential buildings of sound construction can safely withstand peak particle velocity (PPV) in m/s of 50mm/s. Poorly constructed buildings should however not be subjected to PPV's of more than 10mm/s. Figure 2 depicts the typical vibration control diagram where the charge per delay is combined with the distance from the blast to indicate the safe and damage zones and when damage to structures can be expected.

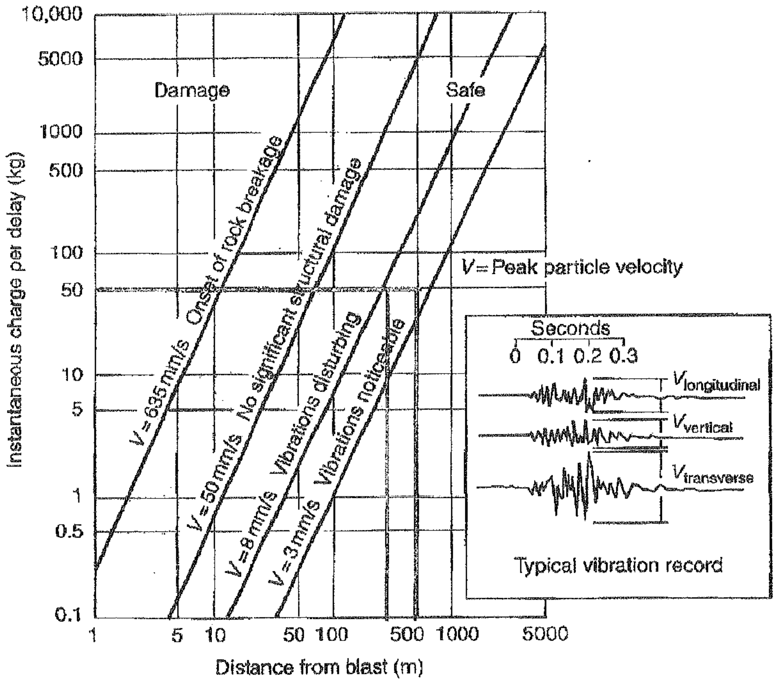


Figure 2 – Blast design chart

Meteorological conditions such as wind speed, direction, temperature, cloud cover and humidity will affect the intensity of the air over pressure levels perceived at a distance from the blasting area. A blast in a motionless atmosphere will reduce the air over pressure level by 6.0 dB as the distance from the source doubles.

The air over pressure levels at the source should be minimized in order for the energy to be within acceptable criteria at a distance. This could be achieved by proper blast design. In general, individual blasts should not exceed 50mm/s in the vicinity of properly constructed buildings and the average level should not exceed 10mms in the vicinity of poorly constructed buildings. These levels conform to the British Standards 6472 and the USA Bureau of Mine Standards, RU 8507.

4. Study Methodology

4.1 Instrumentation

Noise survey

The noise survey was conducted in terms of the provisions of SANS 10103 of 2008 (The measurement and rating of environmental noise with respect to annoyance and to speech communication).

The following instruments were used in the noise survey:

Instrument 1

Larsen Davis Integrated Sound Level meter Type 1 – Serial no. S/N 0001072;
Larsen Davis Pre-amplifier – Serial no. PRM831 0206;
Larsen Davis ½" free field microphone – Serial no. 377 B02 SN 102184;
Larsen Davis Calibrator 200 – Serial no.3073.

The instrument was calibrated before and after the noise readings were done and coincided within 1.0 dBA.

Batteries were fully charged and a windshield was in use at all times.

The calibration certificates are attached as Appendix A.

The measured ambient noise level during the daytime and night time periods will be the baseline ambient noise criteria for the study area and will be evaluated in terms of SANS 10103 of 2008.

4.2 Measuring points

The measuring points as illustrated in Figure 3 were selected in and around the proposed mining area to determine the prevailing ambient noise levels of the study area.

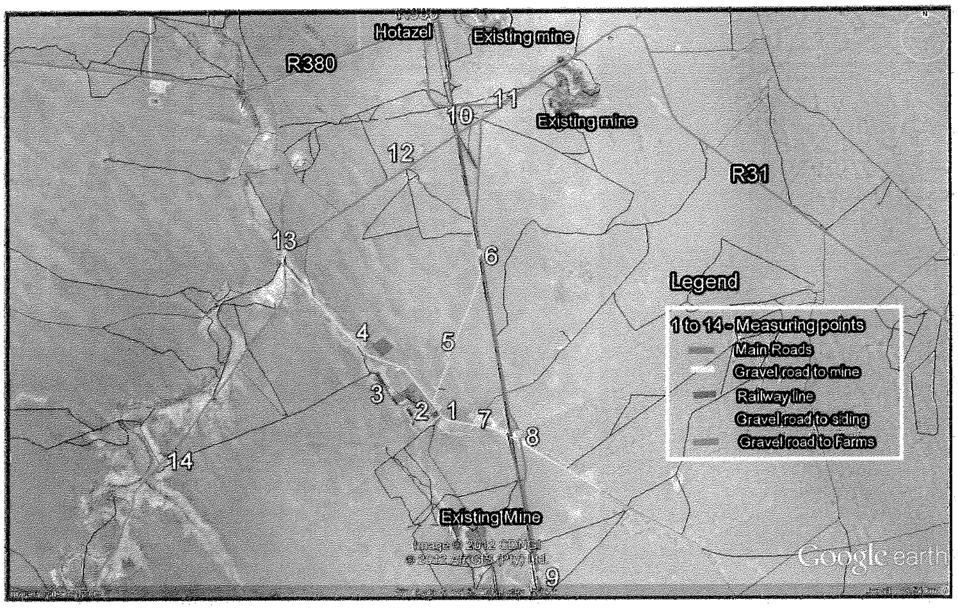


Figure 3: Measuring points in the vicinity of the proposed mine

The distances between the proposed mine and noise sensitive areas are as follows:

- Sebilo mine and Hotazel – 9 750m
- Sebilo mine and the farm Devon (Measuring point 13) – 4 210m
- Sebilo mine and the Farm Mooidraai (Measuring point 14) – 5 310m
- Sebilo and staff accommodation (Measuring point 7) – 1 750m

The spatial information of the measuring points is given in Table 4.

Table 4: Measuring points and co-ordinates for the proposed Sebilo mine

Position	X WGSDD	Y WGSDD	Remarks
1	27^0 17,522 S	022^0 57,924 E	On the south-eastern boundary of the proposed mine next to the entrance road to UMK mine.
2	27^0 17,589 S	022^0 57,668 E	Southern corner of the proposed mine. Distant mine activity noise.
3	27^0 17,329 S	022^0 57,302 E	Western side of the proposed mine. Distant mine activity noise.
4	27^0 16,790 S	022^0 56,931 E	North-western side of the mine. Insect and wind noise.
5	27^0 16,906 S	022^0 56,046 E	Along the gravel road to the railway siding. Distant traffic, mine and railway noise.
6	27^0 16,906 S	022^0 56,046 E	Along the railway line. Finite type noise when train pass measuring point. Traffic noise.
7	27^0 17,623 S	022^0 58,336 E	Along the gravel road leading to the UMK and Sebilo mine. Traffic and distant mine noise.
8	27^0 17,825 S	022^0 58,943 E	Along the R380 road. Traffic and railway noise.
9	27^0 13,920 S	022^0 58,526 E	Opposite the crushers, silos of Mamothane mine along the R380. Mine and traffic noise.
10	27^0 17,461 S	022^0 59,199 E	Along the R380 road. Traffic noise.
11	27^0 14,110 S	022^0 58,458 E	Along the R31 road. Traffic noise.
12	27^0 14,545 S	022^0 57,694 E	Along the gravel feeder road. Farm activity noise, birds, insects and wind noise.
13	27^0 15,717 S	022^0 55,914 E	Along the gravel feeder road. Farm activity noise, birds, insects and wind noise. Devon.
14	27^0 18,098 S	022^0 54,295 E	Along the gravel feeder road. Farm activity noise, birds, insects and wind noise. Mooidraai.

The following is of relevance to the ambient noise measurements:

- The L_{Aeq} was measured over a representative sampling period exceeding 10 minutes at each measuring point;
- The noise survey was carried out during the day and nighttime period being 6h00 to 22h00 for the day time and 22h00 to 6h00 for the night time period.

4.3 Site Characteristics

The following observations were made in the vicinity of the proposed Sebilo mine:

- The traffic noise is the main contributor to the prevailing ambient noise level along the main feeder roads and a finite type noise is created along the gravel roads and railway line;
- The distant mine activities from the abutting open cast mines were audible along the southern side of the mine and at some of the other measuring points;
- Heavy duty vehicles are using the gravel road to UMK mine and the R380 and R31 roads for hauling ore from other mines;
- There are natural and manmade topographical barriers, which can deflect and absorb the open cast mine activity noise;
- Train noise is audible at times at the measuring points which are situated between the proposed mine and the R380 road;
- The study area cannot be classified as a rural district according to Table 2 of SANS 10103 of 2008, due to the existing mine activities, main feeder roads and railway infra-structure in the vicinity of the proposed Sebilo mine.

4.4 Current noise sources

The following are noise sources in the vicinity of and the boundaries of the study area:

- Heavy duty vehicles travelling along the R31 and R380 roads;
- Railway noise;
- Rattling sounds from vehicles traveling on the gravel road;
- Existing traffic noise along the gravel road that lead to the proposed mine;
- Existing blasting noise and vibration at the UMK open cast mine;
- Farming type noise;
- Birds and insects;
- Wind noise.

4.5 Atmospheric conditions during noise survey

The noise readings were carried out at the different measuring points and the prevailing atmospheric conditions i.e. wind speed, wind direction and temperature were taken into consideration. The readings were done away from any large vertical structures, which may influence the outcome of the readings.

The following meteorological conditions were recorded:

19 April 2012 - Daytime

- Wind speed – less than 2.5m/s;
- Temperature – 31.5°C – No strong temperature gradient occurred near the ground;
- Cloud cover – No clouds;
- Wind direction – The wind was blowing from a south-westerly direction;
- Humidity – 20% humidity.

19 April 2012 – Night time

- Wind speed – less than 0.8m/s;
- Temperature – 20.5°C ;
- Cloud cover – No clouds;
- Wind direction – The wind was blowing from a south-westerly direction;
- Humidity – 20 % humidity.

20 April 2012 - Daytime

- Wind speed – less than 1.5m/s;
- Temperature – 30.5°C ;
- Cloud cover – Scattered;
- Wind direction – The wind was blowing from a south-westerly direction;
- Humidity – 20% humidity.

5. Results of the noise survey

Table 5 indicates the prevailing ambient noise levels for the specific areas, which include all the noise sources currently in the study area. Some of the noise readings include existing mine activities, existing plant noise and traffic noise along haul roads and/or gravel roads.

Table 5: Noise levels for the day and night time periods for the Sebilo mine study area.

Position	Day time			Night time		
	Leq -dBA	Lmax (Fast) - dBA	Lmin (Fast) - dBA	Leq - dBA	Lmax (Fast) - dBA	Lmin (Fast) - dBA
1	**56.3**	79.7	25.7	**46.0**	52.4	44.8
2	**36.5**	62.8	18.4	**32.2**	47.5	27.0
3	**30.8**	63.1	20.1	**35.5**	57.2	26.3
4	**31.1**	61.8	18.9	**31.2**	56.2	25.7
5	**33.8**	62.5	20.2	**30.8**	47.4	22.6
6	**40.9**	64.8	20.9	**48.1**	60.9	33.7
7	**49.9**	75.6	26.7	**45.1**	79.6	28.0
8	**57.4**	73.3	22.7	**56.4**	77.6	27.0
9	**57.4**	73.3	22.7	**55,5**	66.7	52.5
10	**58.8**	77.4	30.1	**48.3**	73.6	25.4
11	**64.1**	82.1	30.0	**55.1**	78.6	27.0
12	**36.1**	60.6	26.2	**31.2**	56.2	25.7
13	**33.4**	58.3	25.0	**31.2**	56.2	25.7
14	**34.6**	60.4	21.1	**31.2**	56.2	25.7

The prevailing ambient noise levels for the study area are typical of the noise levels expected in a district with mining activities at a distance and feeder roads with intermittent increased noise levels. The noise survey indicates that there is already increased noise levels because of existing mining activities within the vicinity of the proposed mine.

The prevailing ambient noise levels within the study area during daytime and night time are given in Table 6.

Table 6: Prevailing ambient noise levels

Location	Ambient noise level during daytime - dBA	Ambient noise level during night time - dBA
R31 Road	64.1	55.1
R380 Road	57.4	56.4
Gravel roads	33.0	31.2
Boundary of the mine - northern	33.7	33.9
Boundary of the mine - southern	56.3	46.0
Gravel road to siding	37.4	39.5
Gravel road to mine	49.9	45.1

A noise and vibration survey was carried out during an overburden blast at an existing open cast mine whereby 30.3 tons of explosives were used to uplift 40.187m^3 of soil at a depth of 13.6m. The increase in the Leq(1sec) at a distance of 900m from the blasting site is illustrated in Figure 4.

The wind was blowing at 2.2m/s towards the measuring point and the peak noise level was 110.0dB(linear and not indicated in this graph) was for a second only. The prevailing ambient noise level increased during the blast after which the prevailing ambient noise level of 33.0dBA was maintained.

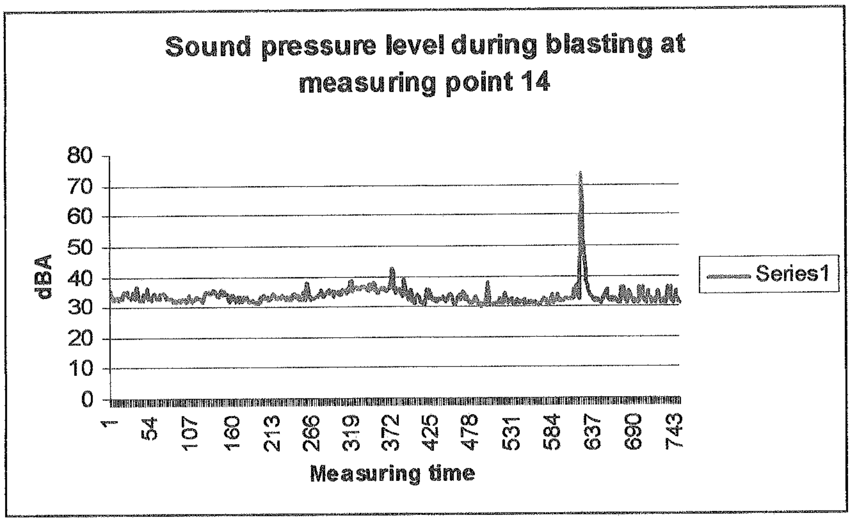


Figure 4: Increase in the sound pressure level during a blast at 440m

The increase in the ground vibration level at 440m from the blast is illustrated in Table 7. Structural damage to buildings with historical value (clay huts) may occur at 10mm/s and properly constructed modern type buildings at 25mm/s.

Table 7: Vibration level during a blast

Position	**Magnitude**			**Peak Vector**
	Transverse – mm/s	Vertical – mm/s	Longitudinal - mm/s	Peak Vector Sum
During overburden blast at 440m from the blasting area	1.650 (15Hz)	2.670 (21Hz)	5.210 (24Hz)	**5.28mm/s**

The vibration level of 5.28mm/s at 440m from the blast is well below the limit where structural damage can occur.

In an open cast mine there are different mine machinery that is used for drilling, excavation of soil and the removal of ore etc. and the noise levels at 15m from the different sources are given in Table 8. These are machinery that is most of the times used in an open cast mine.

Table 8: Sound pressure levels of mine machinery at 15m

	Description	**Leq dBA**
1	Excavator 1200	78.3
2	Excavator 870	81.4
3	Excavator 650	81.6
4	Dozer D11R	89.4
5	Dozer D10T	88.4
6	Dozer D9T	96.1
7	Dozer D155	83.3
8	Dozer D6R	90.2

	Description	Leq dBA
9	Grader 140H	97.4
10	Terex TR60	99.9
11	Volvo A40	85.6
12	HD 325	91.3
13	Diesel Browser Hino WHM 503GP	103.4
14	TLB	94.4
15	Lighting plant	85.8
16	Hitachi 670	102.9
17	Bell B40	86.1
18	Crawler Drill & Ingersol Rand compressor	96.5
19	Tornado – Tyre drill	102.0
20	Drill rig	99.3

6. Discussion

The prevailing noise level at the existing plant east of the mine along the R380 road is 56.6dBA. The noise level at 900m from such a plant, should a similar plant be erected at the Sebilo Perth site, will be 44.5dBA. This calculation is based on the noise reduction of 6.0dB per doubling of the distance from the plant.

The mining activities at the abutting opencast mine was hardly audible because of the distance, topography and vegetation which are important factors in noise propagation.

Noise or sound is part of our daily exposure to different sources which is part of daily living and some of the sounds which may be intrusive such as traffic noise forms part of the ambient noise which people get accustomed to without noticing the higher sound levels.

Any person in the workplace and at home is exposed to the following noise levels on a daily basis as illustrated in Table 9.

Table 9: Different noise levels in and around the house that a person is exposed to on a daily basis

	Activity	dBA
Communication	Whisper	30
Communication	Normal Conversation	55-65
Communication	Shouted Conversation	90
Communication	Baby Crying	110
Communication	Computer	37-45
Home/Office	Refrigerator	40-43
Home/Office	Radio Playing in Background	45-50
Home/Office	Background Music	50
Home/Office	Washing Machine	50-75
Home/Office	Microwave	55-59

	Activity	dBA
Home/Office	Clothes Dryer	56-58
Home/Office	Alarm Clock	60-80
Home/Office	Vacuum Cleaner	70
Home/Office	TV Audio	70
Home/Office	Flush Toilet	75-85
Home/Office	Ringing Telephone	80
Home/Office	Hairdryer	80-95
Home/Office	Maximum Output of Stereo	100-110

Two aspects are important when considering potential noise impacts of a project and it is:

- The increase in the noise level, and;
- The overall noise level produced

There will be an upwards shift in the immediate prevailing noise level and to a lesser degree some distance from the mine.

The traffic noise (traffic on the gravel roads), farming activity noise, railway noise, ventilation fan noise, conveyor noise makes up the prevailing ambient noise in the vicinity of the study area. The prevailing noise level may change according to the season of the year when farming activities such as ploughing and harvesting becomes the pre-dominant contributor to the higher noise levels.

In terms of noise increases, people exposed to an increase of 2 dBA or less would not notice the difference. Some people exposed to increases of 3-4 dBA will notice the increase in noise level, although the increase would not be considered serious. Noise increases of 5dBA and above are very noticeable, and, if these are frequent incidents, or continuous in nature, could represent a significant disturbance.

The prevailing winds and the temperature will play an important role on how the noise from the existing mine operations such as traffic, conveyor, mine ventilation fan, other existing mine activities and power generation will be experienced by the people in the vicinity of the mine activities. The prevailing wind in the vicinity of the proposed mine during the time of the noise survey is north-north east during daytime and northeast during night time.

There will be an increase during the construction phase of the project in earthmoving activities and traffic to and from the proposed open-cast and shaft area. This will however be temporarily and the existing gravel road to the abutting UMK-mine will be used. During the operational phase of the mine, noise will be more permanent but to the same extend as what is experienced currently with the abutting mining activities. There is however no residential areas within 1 750m (staff accommodation to the east) and 4 210m (farm house to the north east).

In Table 10 is the calculated noise levels of the machinery and equipment used in an open cast mine.

Table 10: Typical noise attenuation of equipment during the open cast mining activities

Equipment	Line-of-Sight Estimated Noise Level Attenuation - dBA						
	5m	10m	20m	40m	80m	160m	320m
Cumulative distance from source	5m	15m	35m	75m	155m	315m	635m
Excavator 1200	78.3	68.3	58.3	52.3	46.3	40.3	34.3
Excavator 870	81.4	71.4	61.4	55.4	49.4	43.4	37.4
Excavator 650	81.6	71.6	61.6	55.6	49.6	43.6	37.6
Dozer D11R	89.4	79.4	73.4	76.4	70.4	64.4	58.4
Dozer D10T	88.4	78.4	72.4	66.4	60.4	54.4	49.4
Dozer D9T	96.1	86.1	76.1	70.1	64.1	58.1	52.1
Dozer D155	83.3	73.3	63.3	57.3	51.3	45.3	39.3
Dozer D6R	90.2	80.2	70.2	64.2	58.2	52.2	48.2
Grader 140H	97.4	87.4	77.4	71.4	65.4	59.4	53.4
Terex TR60	99.9	89.9	79.9	73.7	67.7	61.7	55.7
Volvo A40	85.6	75.6	65.6	59.6	53.6	47.6	41.6
HD 325	91.3	81.3	71.3	65.3	59.3	53.3	47.3
Diesel Browser Hino WHM 503GP	103.4	93.4	83.3	77.3	71.3	65.3	59.3
TLB	94.4	84.4	74.4	68.4	62.4	56.4	50.4
Lighting plant	85.8	75.8	65.8	59.8	53.8	47.3	41.3
Hitachi 670	102.9	92.9	82.9	76.9	70.9	64.9	58.9
Bell B40	86.1	76.1	66.1	60.1	54.1	58.1	52.1
Crawler Drill & Ingersol Rand compressor	96.5	86.5	76.5	70.5	64.5	58.5	52.5
Tornado – Tyre drill	102.0	92.0	82.0	75.0	69.0	63.0	57.0
Drill rig	99.3	89.3	79.3	73.3	67.3	61.6	56.6

The noise levels calculated in Table 13 is for direct line of sight and medium soft ground conditions. There will be a further noise reduction of up to 7.0dBA should the activities take place lower than ground level as the rock face will create a noise barrier.

The projected noise contours during mine activities is illustrated in Figure 5. The projected noise level at 800m from the open cast pit activities will be 56.0dBA when all the equipment is working at one time in one area. There will however be a further reduction of 7.0dBA when the activities take place below ground level. The yellow contour represents the 43,0dBA and the green contour represents the 35.0dBA noise levels.

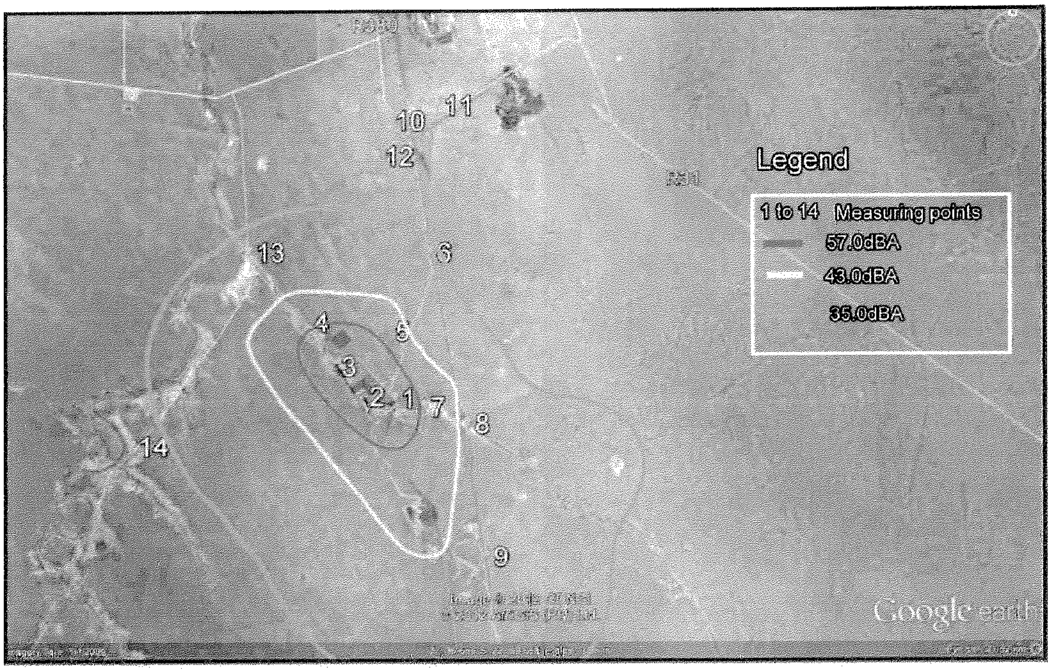


Figure 5: Noise contours during open cast activities at the proposed open cast mine.

The noise contour at the proposed shaft is given in Figure 6. This will be a point noise source and the noise level at the shaft will be 85.0dBA and at the red contour the calculated noise level will be between 56.0dBA, yellow contour 43.0dBA and green contour 35.0dBA.

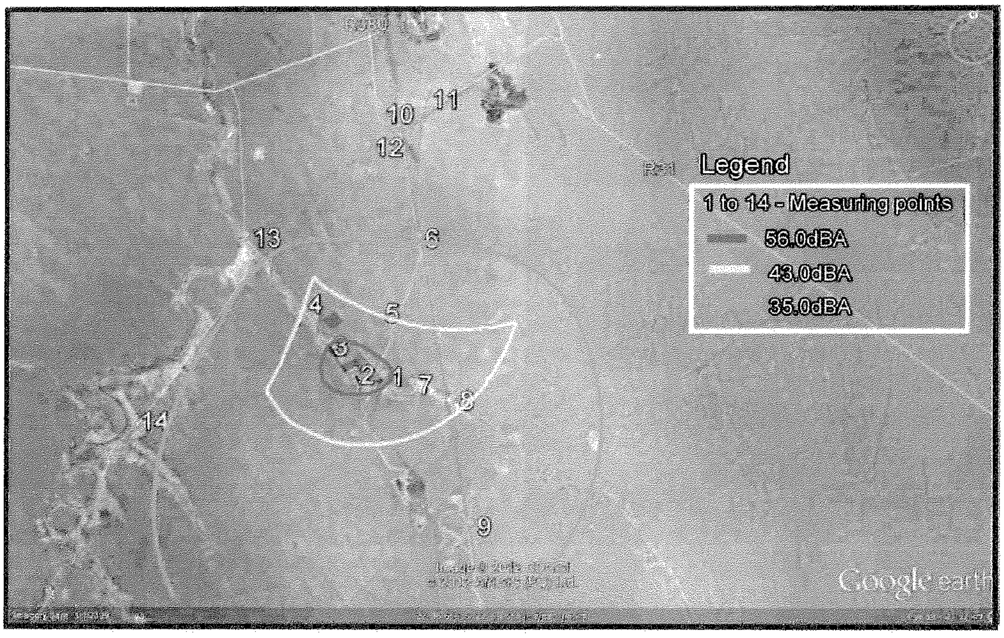


Figure 6: Noise contours for the proposed shaft area.

Air blast noise levels

The air blast contour is given in Figure 7. The red contour is 85dB, the yellow contour 77.0dB and the green contour 61.0dB.

Figure 7: Air blast noise contour at the open cast pit.

The prevailing ambient noise levels in the vicinity of the proposed opencast mine will be exceeded for the duration of the blast only after which the prevailing ambient noise level will be maintained.

7. Environmental impact assessment

The development of the open cast mine and the shaft will take place in stages and it is envisaged that the following processes and/or activities will form part of the establishment of the mine:

Construction phase

- Grading and building of new internal roads and haul roads;
- Preparation of the footprint area, earthworks & construction;
- Construction of conveyor between the mine and the plant.

Operational phase

- Drilling;
- Overburden blasting;
- Removal of ore by free digging;
- Conveying of ore by means of conveyor and/or hauling.

Decommissioning phase

- Rehabilitation of mined area.

7.1 Construction

The noise assessment of the different activities and the Environmental Management Plan (EMP) during the construction phase is given in Table 10 and the assessment methodology is attached as Appendix A.

Table 10: Noise impact assessment and EMP during the construction phase

Aspect	Impact	Significance Rating	Mitigation	Result after mitigation measures	Responsible person	Monitoring
Grading and building of new internal roads and haul roads;	Noise	Medium	All construction equipment to comply with the standards as for construction vehicles as explained in the IFC's Environmental Health & Safety Regulations.	Low to Medium	Mine manager	Environmental audits during the construction phase
Preparation of the footprint area, earthworks & construction;	Noise	Medium	All construction equipment to comply with the standards as for construction vehicles as explained in the IFC's Environmental Health & Safety Regulations. The work to be undertaken during normal working hours only.	Low to Medium	Mine manager	Environmental audits during the construction phase
Construction of conveyor between the mine and the plant	Noise and vibration	Medium	Any construction work to take place during normal working hours;	Low to Medium	Mine manager	Environmental audits during the construction phase

7.2 Operational

The noise and vibration assessment of the different activities during the operational phase and the EMP is given in Table 11 and the assessment methodology is attached as Appendix A.

Table 11: Noise and vibration impact assessment during the operational phase

Aspect	Impact	Significance rating	Mitigation	Result after mitigation measures	Responsible person	Monitoring
Drilling	Noise	Medium	Acoustic screening measures as recommended by the IFC.	Low to medium	Mine manager	Noise monitoring to be done
Overburden blasting	Noise	Medium	Acoustic screening measures as recommended by the IFC. An earthberm of 15m to be erected along the northern boundary of the property opposite the residential property along the open cast mine.	Low to medium	Mine manager and contractor	Noise and vibration monitoring at specific locations
Removal of ore by means of free digging.	Noise and vibration	Medium	Acoustic screening measures as recommended by the IFC.	Medium	Mine manager	Noise monitoring
Conveying of ore by means of conveyor or hauling	Noise	Medium	Conveyor to be serviced and noisy rollers replaced immediately.	Low to medium	Mine manager	Noise monitoring

7.3 Decommissioning phase

The assessment of the different activities during the decommissioning phase is given in Table 12 and the assessment methodology is attached as Appendix A.

Table 12: Impact assessment during the decommissioning phase

Aspect	Impact	Significance rating	Mitigation	Result after mitigation measures	Responsible person	Monitoring
Rehabilitation of mined area	Noise	Medium	All relevant Environmental Health and Safety Guidelines of the IFC to be complied with during this phase.	Low to medium	Mine manager	Noise monitoring

The noise impact on the environment and the people residing in the vicinity of the proposed mine will have to be pro actively managed during the construction and operational phases. The shift in the prevailing ambient noise levels will be temporary during the construction phase and more permanent during the operational phase.

Ground vibration will not be an issue because there are no sensitive habitable areas within the vicinity of the opencast mine. Air blast noise will however be audible at times.

8. Recommendations

The following three primary variables should be considered when designing acoustic screening measures for the control of sound and/or noise:

- The source - Reduction of noise at the source;
- The transmission path - Reduction of noise between the source and the receiver;
- The receiver - Reduction of the noise at the receiver.

The following measures must be considered prior to the acquisition of earthmoving equipment:

- Enclosure of engine bays;
- Modification of radiator fan design and materials;
- Installation of louvers on radiator and hydraulic cooling fans;
- Re-engineering of exhaust systems.

The following are the Environmental, Health and Safety Guidelines of the IFC of the World Bank, which should be taken into consideration during the construction and operational phases of the project:

- Selecting equipment with lower sound power levels;
- Installing silencers for fans;
- Installing suitable mufflers on engine exhausts and compressor components;
- Installing acoustic enclosures for equipment causing radiating noise;
- Installing vibration isolation for mechanical equipment;
- Re-locate noise sources to areas which are less noise sensitive, to take advantage of distance and natural shielding;
- Taking advantage during the design stage of natural topography as a noise buffer;

- Develop a mechanism to record and respond to complaints.

The following vibration screening measures for the control of vibration must be provided:

The air blast levels and vibration levels to be monitored and controlled during each blasting operation. The standards implemented by the USA Bureau of Mine Standards, RU 8507, must be used as a guideline to monitor and control blasting operations.

- The limit for ground vibration should not exceed 20mm/s at the nearest residential property;
- An over pressure limit of 134 dB should not be exceeded. Near schools and churches not to exceed 128 dB;
- No blasting to take place when there are windy conditions.

The Regulations under the Mines Health and Safety Act require the owner of the operation to ensure that the health and safety of employees and people will not be affected during blasting.

Blasts must be designed so that ground vibration and air over pressure levels are adhered to. In order to comply with the above, the following measures should be implemented:

- A scheme of vibration and air over pressure monitoring to be implemented;
- A scheme by which air over pressure is controlled;
- Days and times of blasting operations to be established;
- Ensure that the correct design relationship exists between burden, spacing and hole diameter;
- Ensure the maximum amount of explosive on any one day delay interval, the maximum instantaneous charge, is optimized by considering:
  - Reduce the number of holes per detonator delay interval;
  - Reduce the instantaneous charge by in-hole delay techniques;
  - Reduce the bench height or hole depth;
  - Reduce the borehole diameter.
- Always attempt to minimize the resulting environmental effects of blasting operations and to recognize the fact that the perception of blasting events occurs at levels of vibration well below those necessary for the possible onset of the structural damage, but nevertheless at levels that can concern occupants abutting the mining area;
- Be aware that relatively small changes in blast design can produce noticeable differences in environmental emissions. It is very often in response to changes in these emissions rather than their absolute value that complaints are made.

Scheme of vibration monitoring must include the following:

- The location and number of monitoring points;
- The type of equipment to be used and the parameters to be measured;
- The frequency of monitoring;
- The method by which such data are made available to management;
- The method by which such data are used in order to ensure that the site vibration limit is not exceeded and to mitigate any environmental effects of blasting.

9. Conclusion and summary

The mining at the proposed open cast mine and the shaft will take place in the vicinity of existing mines and vacant land which is covered with natural vegetation.

This area where the proposed mine will be situated cannot be classified as a rural type district according to the definition of Table 2 of the SANS 10103 of 2008 because of the existing mining activities.

The residents in the vicinity of the proposed mine are already exposed to the different and higher noise levels that is created by the existing mining activities, traffic and rail way noise.

The proposed mining activities will create a shift in the near field prevailing ambient noise levels and at times this will create a temporary shift in the far field noise levels.

The noise intrusion can however be controlled by means of approved acoustic screening measures, state of the art equipment, proper noise management principles and compliance to the International Finance Corporation's Environmental Health and Safety Guidelines.

Barend van der Merwe
Acoustic Consultant

10. References:

Environmental, Health and Safety Guidelines for Community Noise and Mining, World Health Organisation, Geneva, 1999;

Environmental, Health and Safety (EHS) Guidelines, World Health Organisation, Geneva, 1999;

Google Earth – Aerial photos;

Noise Control Regulations;

Rock Slope Engineering, Wyllie and Mah, 2004;

SANS 10103 of 2008 – The measurement and rating of environmental noise with respect to land use, health, annoyance and to speech communication;

The Scottish Government – Controlling the Environmental Effects of Surface Mineral Workings;

USA Bureau of Mine Standards, RU 8507;

Woods Practical Guide to Noise Control, Sharland Ian, 1972

11. Definitions/Noise:

Ambient noise
The totally encompassing sound in a given situation at a given time and usually composed of sound from many sources, both near and far

A-weighted sound pressure level (sound level) (L_{pA}), in decibels
The A-weighted sound pressure level is given by the equation:

$L_{pA} = 10 \log (p_A/p_o)^2$

where

p_A is the root-mean-square sound pressure, using the frequency weighting network A in pascals; and

p_o is the reference sound pressure (p_o = 20 μPa).

NOTE The internationally accepted symbol for sound level is dBA.

Distant source
A sound source that is situated more than 500 m from the point of observation

Equivalent continuous A-weighted sound pressure level ($L_{Aeq,T}$), in decibels
The value of the A-weighted sound pressure level of a continuous, steady sound that, within a specified time interval T, has the same mean-square sound pressure as a sound under consideration whose level varies with time. It is given by the equation

$$L_{Aeq,T} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A^2(t)}{p_o^2} dt \right]$$

Where
$L_{Aeq,T}$ is the equivalent continuous A-weighted sound pressure level, in decibels, determined over a time interval T that starts at t_1 and ends at t_2;

p_o is the reference sound pressure (p_o = 20 μPa); and

$p_A(t)$ is the instantaneous A-weighted sound pressure of the sound signal, in pascals.

Impulsive sound
Sound characterised by brief excursions of sound pressure (acoustic impulses) that significantly exceed the residual noise

Initial noise
The component of the ambient noise present in an initial situation before any change to the existing situation occurs

Intelligible speech
Speech that can be understood without undue effort

Low frequency noise
Sound, which predominantly contains frequencies below 100 Hz

Nearby source
A sound source that is situated at a distance of 500 m or less from the point of observation

Residual noise
The ambient noise that remains at a given position in a given situation when one or more specific noises are suppressed

Specific noise
A component of the ambient noise which can be specifically identified by acoustical means and which may be associated with a specific source
NOTE Complaints about noise usually arise as a result of one or more specific noises.

Ambient sound level
Means the reading on an integrating impulse sound level meter taken at a measuring point in the absence of any alleged disturbing noise at the end of a total period of at least 10 minutes after such meter was put into operation.

Disturbing noise
Means a noise that cause the ambient noise level to rise above the designated zone level by 7.0dBA or if no zone level has been designated, the typical rating levels for ambient noise in districts, indicated in table 2 of SANS 10103.

Noise nuisance
Means any sound which disturbs or impairs the convenience or peace of any person

Appendix A

Description of Impact	Before Mitigation: Magnitude	Duration	Scale	Probability	Score	Significance rating	Reversibility	Frequency	Mitigation Measures	After Mitigation: Magnitude	Duration	Scale	Probability	Score	Significance rating	Reversibility	Frequency
Construction Phase																	
Grading and construction of new internal feeder road and haul roads																	
Grading and build of new feeder roads and haul roads	6	2	2	4	40	M			Use machinery that complies with the International Finance Corporations (IFC) Environmental Health and Safety Regulations	6	2	2	3	30	L/M		
Preparation of footprint area, earthworks and construction																	
Earthworks, civil construction of infra-structure	6	2	2	4	40	M			Use machinery and equipment that complies with the IFC's Environmental Health and Safety Regulations	6	2	2	3	30	L/M		
Construction of the conveyor																	
Construction of the conveyor	6	2	3	4	44	M			By using the natural topography to screen off the noise. Use a system that does not exceed 60dBA at 7m from the conveyor.	6	2	2	3	30	L/M		
Operational phase																	
Drilling																	
Drilling of holes for blasting	6	2	2	4	40	M			Use machinery that complies with the IFC's Environmental Health and Safety Regulations	6	2	2	3	30	L/M		
Overburden blasting																	
Blasting of overburden soil and/or rock	8	3	3	5	70	M			Safe blasting operations schedule and comply with the Blast design chart	8	3	3	4	56	M		

Removal of coal by free digging																	
Removal of ore by heavy-duty machinery and equipment	6	3	2	3	33	M			Use machinery that complies with the IFC's Environmental Health and Safety Regulations	6	5	3	3	33	L/M		
Conveying of coal by means of conveyor																	
Conveyor system	6	5	3	4	54	M			Conveyor to be services and noisy rollers replaced immediately	6	5	3	3	33	L/M		
Decommissioning phase																	
Rehabilitation of mined area																	
Back-fill of mined areas with overburden material and top soil	6	2	2	4	40	M			Use machinery that complies with the IFC's Environmental Health and Safety Regulations	6	2	2	3	30	L/M		

Appendix B

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CERTIFICATE OF CALIBRATION

CERTIFICATE NUMBER	*2012-0382*
ORGANISATION	*dB ACOUSTICS*
ORGANISATION ADDRESS	*P.O. BOX 1291, ALLENSNEK, 1737*
CALIBRATION OF	*INTEGRATING SOUND LEVEL METER with built-in ⅓-OCTAVE/OCTAVE FILTER and ½" MICROPHONE*
CALIBRATED BY	*M. NAUDÉ*
MANUFACTURERS	*LARSON.DAVIS and PCB*
MODEL NUMBERS	*831 and 377 B02*
SERIAL NUMBERS	*0001072 and 102184*
DATE OF CALIBRATION	*27 FEBRUARY 2012*
RECOMMENDED DUE DATE	*FEBRUARY 2013*
PAGE NUMBER	*PAGE 1 OF 4*

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28 February 2012
DATE OF ISSUE

Only Member : Marianka Naudé

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CERTIFICATE OF CALIBRATION

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ORGANISATION ADDRESS	P.O. BOX 1291, ALLENSNEK, 1737
CALIBRATION OF	ACOUSTIC CALIBRATOR
CALIBRATED BY	M. NAUDÉ
MANUFACTURER	LARSON.DAVIS
MODEL NUMBER	CAL 200
SERIAL NUMBER	3073
DATE OF CALIBRATION	27 FEBRUARY 2012
RECOMMENDED DUE DATE	FEBRUARY 2013
PAGE NUMBER	PAGE 1 OF 3

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