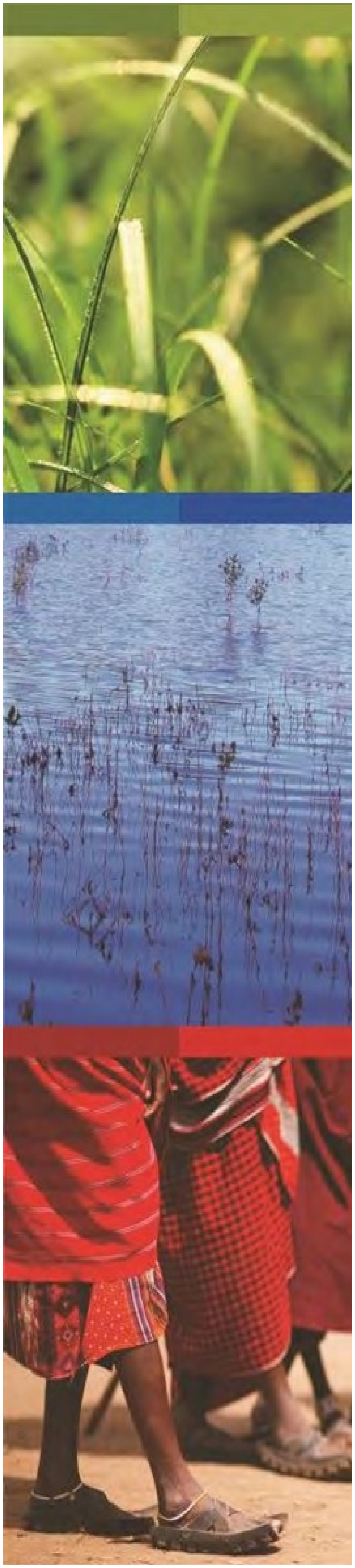

# Proposed Open Pit Magnetite Mine and Concentrator Plant, Mokopane, Limpopo Province

## Surface Water Report

**Project Number:**

VMC3049

**Prepared for:**

Pamish Investments No. 39 (Pty) Ltd

July 2015

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This document has been prepared by Digby Wells Environmental.

| | |
|---|---|
| **Report Type:** | **Surface Water Report** |
| **Project Name:** | **Proposed Open Pit Magnetite Mine and Concentrator Plant, Mokopane, Limpopo Province** |
| **Project Code:** | **VMC3049** |

| Name | Responsibility | Signature | Date |
|---|---|---|---|
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| Andrew Pirie (MSc Water Resource Management) | Floodline Determination | | July 2015 |
| Sivan Dhaver (BSc Hons Hydrology) | Storm Water Management Plan, Technical Reviewer and Specialist Report Compiler | | July 2015 |

# EXECUTIVE SUMMARY

This report details the surface water assessment for a proposed open pit magnetite mine located in Mokopane, within the Limpopo Province of South Africa. The scope of work undertaken for this project included the following:

- Baseline hydrology, detailing the regional and local hydrology for the project area. This includes investigating the rivers / drainage lines, topography and mean annual runoff (MAR) within the project area;
- Climate, detailing site temperature, humidity, design rainfall depths, mean annual precipitation (MAP) and mean annual evaporation (MAE) within the project area;
- Surface water quality, including the historic water quality and current water quality status of the rivers covering the project area;
- Flood hydrology, involving delineation of floodlines for rivers within close proximity to project surface infrastructure;
- Storm Water Management Plan, involving the separation of clean and dirty water as per GN704 of the National Water Act, 1998 (Act No. 36 of 1998);
- Surface water impact assessment, identifying surface water impacts, and providing necessary mitigation measures if required; and
- Compilation of the above into a surface water assessment report.

From the assessment of baseline hydrology, the following observations were made:

- The project infrastructure falls within two quaternary catchment (A61G and A62B), with all runoff from these quaternary catchments eventually draining into the Mogalakwena River;
- All runoff from the project area drains into the Mogalakwena River, via the Borobela River and two unnamed tributary of the Mogalakwena River located on the north-western and south-western boundary of the proposed tailings dam.
- The project area has steep topography in the upper reaches of the aforementioned river catchments where slopes can exceed 12%, however for the majority of the project area, slopes are flat to gentle and fall between 0 and 3%. The Arcadia soil form covers most of the project area (Soils, Land Capability, Land Use and Soil Stripping Plan - Digby Wells, 2015). This specific soil has a high clay content (greater than 55%), and a high infiltration capacity when dry due to the presence of large cracks, but once wet they begin to swell reducing permeability. The combination of flat topography and clay soils will likely result in ponding of surface water during extreme storm events.

- The adopted MAP (mm) and the MAE (mm) for the project area based on the data obtained from quaternary catchment A61G is 585 mm and 1512 mm respectively;

Temperature and relative humidity is based on modelled data (2011 – 2013) (Lakes Environmental 2015). Average monthly maximum temperature was 19.7 °C, with minimum of 18.6°C and the monthly mean temperature of 19.2°C. The relative humidity annual values for maximum, minimum and mean relative humidity are given as 63.9%, 60.4% and 64.2%, respectively.

The assessment of the current water quality status of the project area was undertaken on the 15th and the 16th January 2015. A total of five samples (SW01 – SW05) were taken. SW01 was taken on the Sterk River while SW02 to SW05 were taken on the Mogalakwena River. The Borobela River and an unnamed tributary of the Mogalakwena River were not flowing during the site visit, and therefore no sampling was undertaken there.

The water quality results were benchmarked against the Department of Water and Sanitation (DWS) River Water Quality Objectives and are summarised as follows:

- When compared with the SANS 241-1:2011, the overall surface water quality of the collected samples falls within the recommended water quality concentration limits (Class I and II – SANS 241-1:2011);
- When compared with the SAWQGs for Irrigation, SW04 and SW05 samples show a high TDS concentration which exceeds the ideal standard, whilst it was still below the maximum acceptable standard of 540 mg/L. The TDS are a measure of the quantity of various inorganic salts dissolved in water which is normally used as an indicator of the salinity of the water;
- The pH values for SW04 and SW05 samples also exceed the maximum acceptable standards for irrigation;
- When compared with the SAWQGs (General), samples at SW02, SW03 and SW05 show elevated levels of ammonia concentrations which are above the SAWQG concentration limits;
- TDS, Chlorides and Calcium levels at SW04 and SW05 also exceed the ideal standards whilst still within the acceptable standards; and
- SW04 and SW05 show higher pH levels which are above the SAWQG's limits.

Water quality was benchmarked against the SANS 241-1:-2011 drinking water standards, as well as the South African Water Quality Guidelines for Agricultural Use: Irrigation (DWAF, 1996), and the General Resource Water Quality Objectives (DWS, 2011).

A floodline determination was undertaken for the Borobela River, and the unnamed tributaries of the Mogalakwena River. From the modelling results, it is observed that flooding occurs on the south-western portion of Pit 1, the north-western and south eastern-boundary of the proposed tailings dam and the north western boundary of the proposed return water dam. Flooding is primarily due to the flat topography around the vicinity of the project area, together with poorly defined drainage paths. The D4380 road which bisects the project area causes backing up of flood waters due to the flat topography, the poorly defined drainage paths and insufficient capacity of the culverts/bridges in some areas.

A detailed Storm Water Management Plan is proposed, as per GN704 requirements of the National Water Act, 1998 (Act No. 36 of 1998). In order to meet the requirements of GN704, the following storm water management measures are proposed:

- Clean water diversion channels to divert clean water to the downstream environment or nearby watercourse;
- Dirty water channels around all proposed stockpile areas, waste rock dump areas, contractors camp areas and plant areas, such that all dirty water is channelled and contained to respective Pollution Control Dams (PCD's);
- PCD's which capture dirty water runoff from the mentioned areas above; and
- River diversions.

Regarding the containment of dirty water runoff, two options are proposed:

- Option 1 requires additional PCDs over and above what was originally proposed with the dirty water runoff being gravity fed to the proposed PCDs; and
- Option 2 requires fewer but larger volume PCDs to be located centrally within the project area. The dirty water runoff may however have to be pumped to these PCDs, and not necessarily gravity fed as in option 1.

It should be noted that the sizing of the PCDs were only undertaken for option 1.

Peak flows for the conveyance channels which include clean and dirty water channels together with the proposed river diversions, range from 1.73 $m^3$/s to 17.96 $m^3$/s.

PCD sizes range from 3 163 $m^3$ to 42 300 $m^3$, with pumping rates required to remove the volume from the PCD's over a period of 10 days ranging from 4 l/s to 49 l/s.

For the surface water impact assessment, the main impacts are flooding to infrastructure.

Proposed mitigation measures include:

- A river diversion located alongside the north western boundary of the existing tailings dam (see Plan 7, Appendix B);
- Increasing the capacity of the culvert (C01) located along Tributary E,(see Plan 6, Appendix B);
- Repositioning of the lower grade stockpile south west of the Borobela River (see Plan 6); and
- A river diversion located upstream of Pit 1, to capture and convey runoff around the north-eastern boundary of pit 1 into the Borobela River (see Plan 7).

Measures to mitigate the risk of flooding include, construction of river diversions, increasing culvert capacities on the D4380 road, and repositioning of proposed infrastructures. The details of the proposed mitigation measures mentioned are described below:

- The river diversion shown as “River diversion 15 – 16” and “River diversion 16 – 19” (see Plan 7), should be designed to cater for the 1:100 year peak discharge of 23.23 $m^3/s$ and 31.98 $m^3/s$ at section 15 – 16 and 16 – 29. The river diversion needs to extend from the upstream culvert located at node 15 to the downstream culvert on the D4380 road at node 29. During final design, energy dissipation structures should be constructed at the outlet of the channel, so as to cater for high velocities due to the proposed river diversion.
- At culvert C01, the capacity needs to be increased, as overbank flow occurs on the right bank, flooding the southern portion of the tailings dam area, while extending further north-west along the D4380 road. Culvert C01 therefore needs to be sized to safely handle the 1:100 year peak flow of 129.03 $m^3/s$.
- Repositioning of the lower grade stockpile south-east of the Borobela River is required, as flood inundation is anticipated (see Plan 6). It is therefore recommended that the mentioned infrastructure falls outside of the demarcated 1:100 year floodline or 100 m buffer, whichever is greater.
- A river diversion is required to be constructed along the north-eastern boundary of Pit 1, prevent flooding into the pit. This diversion is to be sized to contain the 1:100 year flood event which has a peak flow of 16.85 $m^3/s$. The aforementioned river diversion is shown as “river diversion 9 – 10” (see Plan 7).

It should be noted that only major culverts located directly on the river/drainage path were modelled.

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# LIST OF ABBREVIATIONS AND ACRONYMS

| Abbreviation | Description |
|---|---|
| AMD | Acid mine drainage |
| C01 | Culvert Number 1 |
| DWAF | Department of Water Affairs and Forestry |
| DWS | Department of Water and Sanitation |
| DEM | Digital Elevation Model |
| D4380 | District Road Number 4380 |
| EIA | Environmental Impact Assessment |
| EMP | Environmental Management Programme |
| GN704 | Government Notice 704 in Government Gazette 20119 |
| GPS | Global Positioning System |
| ha | hectares |
| km | Kilometre |
| LIDAR | Light Detection And Ranging |
| m | Metre |
| MAE | Mean Annual Evaporation |
| mamsl | Metres above mean sea level |
| MAP | Mean Annual Precipitation |
| Mg/l | Milligrams per litre |
| MRA | Mining Right Application |
| mg/L | milligrams per litre |
| mm | Millimetre |
| mS/m | Milli Siemens per metre |
| $m^3$ | Cubic metre |
| PCD | Pollution Control Dam |
| RoM | Run of Mine |
| SANAS | South African National Accreditation System |
| STP | Sewage Treatment Plant |
| SAWQG | South African Water Quality Guidelines |
| TDS | Total Dissolved Solids |
| WISH | Windows Interpretation System for Hydrogeologists |
| WRC | Water Research Commission |
| WRD | Waste Rock Dump |
| WMA | Water Management Area |
| WULA | Water Use Licence Application |

# 1 Introduction

Digby Wells Environmental (hereafter Digby Wells) has been appointed by Pamish Investments No 39 (Pty) Ltd to undertake an Environmental Impact Assessment (EIA) for a proposed magnetite open pit project near Mokopane, in the Limpopo Province.

This report presents the findings of the surface water assessment in support of the EIA, and should be read in collaboration with the other specialist studies undertaken for the EIA.

## 1.1 Terms of Reference

The scope of works required for the surface water assessment is indicated below:

- Define the regional and local hydrology for the project area. This includes investigating the rivers and drainage, topography and Mean Annual Runoff (MAR), within the project area;
- Define the climate characteristics, which details site specific rainfall, temperature, humidity, storm rainfall depths, Mean Annual Precipitation (MAP) and Mean Annual Evaporation (MAE) for the project area;
- Assess the surface water quality which includes detailing the historic water quality and current water quality status of the rivers covering the project area, and involves the setting up of a surface water quality monitoring network;
- Undertake floodline modelling, which involves delineation of floodlines for rivers within close proximity of project infrastructure;
- Develop a Storm Water Management Plan (SWMP) which includes the separation of clean and dirty water as per GN704 of the National Water Act (No 36 of 1998);
- Undertake a surface water impact assessment which details all identified surface water impacts, while also providing the necessary mitigation measures, if any; and
- Compile a surface water assessment report detailing the above.

## 1.2 Project Description and Location

The proposed project area is located on the farms Vogelstruisfontein 765 LR, Vriesland 781 LR, Vleigekraal 783 LR, Schoonoord 786 LR and portions Re/1, Re/2, 3, 4, 5 and 6 of the farm Bellevue 808 LR.

The proposed project is situated approximately 45 kilometres (km) north-west of Mokopane and 65 km west of Polokwane. The villages of Ditlotswana, Malokong, Mosate and Sepharane fall within the Project area. The villages within 5 km of the project area include, but are not limited to: Eckstein, Eseldrift, Ga-Mabuela, Ga-Masipa, Ga-Masoge, Ga-Modipana, Ga-Mokwena, Ga-Ramurulane, Goede Hoop, Haakdoring, Kaditshwene, Kwakwalata Mesopotamia, Lyden, Mabuladihlare, Mmahlogo, Phafola, and Rooivaal.

The N11 national route is situated 5 km east and the R518 regional road is situated 2.5 km south of the proposed Project area respectively. Numerous secondary roads run through the project area, with the main secondary road bisecting the project area being the D4380 Road.

A summary of the regional and local settings, which indicates the infrastructure layout in relation to the proposed project area, is shown in Plan 1 and Plan 2 respectively (Appendix B).

# 2 Baseline Hydrology

## 2.1 Regional Hydrology

South Africa is divided into 19 Water Management Areas (WMA) (National Water Resource Strategy, 2004), managed by separate Catchment Management Agencies (CMAs). Each of the WMA is made up of quaternary catchments which relate to the drainage regions of South Africa, ranging from A to X (excluding O). These drainage regions are subdivided into four known divisions based on size. For example, the letter A represents the primary drainage catchment, A2 for example will represent the secondary catchment, A21 represents the tertiary catchment and A21D would represent the quaternary catchment which is the lowest subdivision in the Water Resources of South Africa 2005 (WR2005) manual (WRC,2009). Each of the quaternary catchments have associated hydrological parameters including area, Mean Annual Precipitation (MAP) and Mean Annual Runoff (MAR) to name a few.

The Project area is located within the boundaries of quaternary catchments A61G and A62B found in the Limpopo River catchment which is WMA number one (WMA 01); this is illustrated in Plan 3 (Appendix B).

### 2.1.1 Rainfall and Evaporation

The regional MAP and MAE for both quaternary catchments are listed in Table 2-1.

**Table 2-1 Summary of Regional MAP and MAE Estimates**

| Quaternary Catchment | MAP (mm) | MAE (mm) |
|---|---|---|
| A61G | 585 | 1800 |
| A62B | 529 | 1850 |

This data was obtained from the WR2005 manual and provides a general overview of the rainfall and evaporation for the quaternary catchments. A more site specific climate analysis is provided in Section 2.4 of this report.

### 2.1.2 Mean Annual Runoff

The MAR as obtained from the WR2005 study is an estimation of the surface runoff reporting to the outlets of the mentioned quaternary catchments A61G and A62B. Placement of infrastructure may potentially impact the MAR of quaternary catchments A61G and A62B; this is due to runoff being contained within these mentioned areas, as per GN 704 requirements (see Section 5).

Area weighting of infrastructure (stockpiles, pits, tailings dam, etc.) against the quaternary catchment areas is used to assess and quantify the percentage MAR lost within quaternary catchments A61G and A62B as a result of the project infrastructure. This is summarised in Table 2-2.

**Table 2-2: Summary of Loss of MAR million cubic meters (mcm) due to Project Infrastructures**

| Quaternary Catchment | Total Area ($km^2$) | MAR (mcm) | Infrastructure Area ($km^2$) | Percentage decrease in MAR (%) | Loss in MAR (mcm) |
|---|---|---|---|---|---|
| A61G | 927 | 15.31 | 2.50 | 0.27 | 0.04 |
| A62B | 710 | 14.97 | 3.25 | 0.46 | 0.07 |

From Table 2-2 it is concluded that the loss in MAR due to the project is 0.04 million cubic meters per annum and 0.07 mcm per annum for quaternary catchments A61G and A62B respectively. This accounts for a decrease in MAR for quaternary catchments A61G and A62B of approximately 0.27% and 0.46% respectively. This is considered negligible.

The following should be noted:

- Table 2-2 provides a total loss of runoff on an annual basis due to the project infrastructure, within quaternary catchments A61G and A62B, and does not consider the variations in runoff losses during the wet and dry season flows. This was not undertaken as a result of the lack of measured flow data within quaternary catchments A61G and A62B; and
- The total loss of the MAR with respect to groundwater draw down is zero (Groundwater Report, Digby Wells, 2015), therefore loss in MAR is only likely to be from surface infrastructure placement.

## 2.2 Local Hydrology

### 2.2.1 Site Characterisation

A field assessment of the current state of the project area was conducted on the 15th and 16th of January 2015, with a floodline determination site visit conducted on the 10th and 11th of June 2015. Surface water resources (rivers and drainages) within the project area and the surrounding areas were assessed (see Plan 4).

This section summarises the findings of the site visit as follows:

- The project area is mainly characterised by flat terrain with isolated parts showing hilly terrain with drainage lines traversing the project area. Average slope along drainage lines in the infrastructure area is 2 %;
- The site mainly consists of farms and the villages that surround the proposed mining site. The communities use the water from the rivers for domestic purposes, livestock watering and irrigation for subsistence farming;
- There are two are major rivers (Mogalakwena River and Sterk River) located south of the Project area. The Sterk River is a tributary of the Mogalakwena River. The Mogalakwena River flows in a northerly direction and forms a tributary to the Limpopo River;
- Other non-perennial rivers (Borobela and other unnamed tributaries) located within the Project area were dry at the time of the site visit. Figure 2-1 to Figure 2-3 present some of the photos of the project area and local rivers (perennial and non-perennial); and
- Of the three mentioned rivers only the Mogalakwena River is characterised as perennial, which means that flow occurs all year round, while flow in the Borobela and the Sterk River is usually limited to the wet season (between October to January).

**Figure 2-1: Photos showing combination of flat terrain (looking south west from the D4380 road) and hills (looking north east from proposed pit 1 area) within the project area**

**Figure 2-2: Photo of the Sterk River (left) taken on the bridge of R518 road looking north, and Mogalakwena River (right) taken on an unnamed road looking north-west**

**Figure 2-3: Photos indicating the dry drainages within the project area**

### 2.2.2 Site Specific Rivers and Drainage

All runoff emanating from the infrastructure area eventually drains into the Mogalakwena River via the Borobela River and two unnamed tributaries (see Plan 4). The unnamed tributaries flow along the north-western and south-eastern boundaries of the tailings storage facility (TSF).

The D4380 road bisects the infrastructure area and follows a north-westerly direction to the settlement of Moshate. This road is made up of more than 20 identified culverts (see floodline site visit, Section 4). Runoff emanating upstream (north-east) of this road is conveyed through these culverts and eventually flows into the Mogalakwena River.

The majority of the Project area falls within the Arcadia soil form (Soils, Land Capability, Land Use and Soil Stripping Plan - Digby Wells, 2015). This specific soil has high clay content (greater than 55%). The soil has a high infiltration capacity when dry due to the presence of large cracks, but once wet they begin to swell thus reducing permeability.

Due to the flat topography (average slope of 2 %), soil characteristics and generally undefined drainage pathways which characterise most parts of the project area, ponding of surface water will occur during extreme storm events. Majority of ponding is anticipated to occur along the D4380 road.

Three major catchments (project catchments) which drain the project area were identified, namely catchment 1, 2 and 3 (see Plan 4). These catchments capture and convey runoff emanating from upstream and within the project area, and eventually contribute to (and impact) the downstream runoff of the Mogalakwena River.

Catchment 1 drains the runoff emanating from the western side of the project area into the Borobela River. Within this catchment a runoff trench was identified along the downstream side of the D4380 road (see plan 4). This runoff trench serves to capture and convey runoff in a north-westerly direction into the Borobela River.

Catchment 2 drains the mid-section of the project area with all runoff emanating from this catchment flowing into the unnamed tributary of the Mogalakwena River located along the north-western boundary of the TSF.

Catchment 3 drains the south-eastern side of the Project area, with all runoff emanating within this catchment flowing into the unnamed tributary of the Mogalakwena River located along the south-eastern boundary of the TSF.

A summary of the rivers and drainage, showing the project catchment are indicated in Plan 4 (Appendix B).

### 2.2.3 Topography of Project Area

The topography of majority of the project area is characterised as flat, with majority of the project area slopes ranging from 0 – 3 %, while steeper sections such as the Malokong Hill located east of Pit 1 exceed slopes of 12%.

Elevations at the upstream boundary for the identified project catchments (catchment 1, 2 and 3) range from 1160 mamsl – 1200 mamsl, and drop to just below 1000 mamsl at their respective catchment outlets (see Plan 4).

## 2.3 Climate

### 2.3.1 Rainfall

Table 2-3 indicates the maximum average monthly rainfall over a three year period (2011 – 2013) obtained from the Lakes Environmental modelled data (Lakes Environmental 2015). The highest monthly maximum rainfall was for January 2013 with a value of 224.8 mm, and the annual maximum total is 798.3 mm.

**Table 2-3: Average Monthly Rainfall for the Project Area for the Period 2011-2013 (Lakes Environmental 2015)**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Monthly Rainfall (Max over the 3 year period) | 224.8 | 67.3 | 39.6 | 33.0 | 6.4 | 0.3 | 3.0 | 45.2 | 40.4 | 68.6 | 121.9 | 147.8 | 798.3 |

Due to the limited amount of rainfall data (2011 – 2013) available above, the WR2005 data was used to represent the rainfall for the project area. According to the WR2005 study, rainfall stations with a record of more than 15 years were used over a period from 1920 to 2004 to calculate the MAP for quaternary catchments in South Africa. Monthly rainfall percentages provided in the WR2005 study for rainfall zone A6C was used to convert the MAP of 585 mm for quaternary catchment A61G to average monthly rainfall. Although the infrastructure area falls over quaternary catchments A61G and A62B, quaternary catchment A61G was selected as it had a higher MAP. Average monthly data adopted for the project area is indicated in Table 2-4.

**Table 2-4: Average Monthly Rainfall for the Project Area Obtained from the WR2005 Study**

| Month | Average Monthly Rainfall (mm) |
|---|---|
| January | 112.7 |
| February | 91.9 |
| March | 66.6 |
| April | 37.6 |
| May | 11.9 |
| June | 5.3 |
| July | 3.6 |
| August | 3.9 |
| September | 13.3 |
| October | 42.6 |
| November | 89.7 |
| December | 105.7 |
| **MAP** | **585** |

### 2.3.2 Evaporation

MAE was obtained from the WR2005 study for quaternary catchment A61G and was selected to represent the project area. The evaporation obtained from the WR2005 study is based on Symons pan evaporation measurements and needs to be converted to Lake Evaporation. This is due to the Symons pan being located below the ground surface, and painted black which results in the temperature of the water being higher than that of a natural open water body. The Symons pan is then multiplied by a lake evaporation factor to obtain lake evaporation. Table 2-5 is a summary of the adopted average monthly evaporation for the project area.

**Table 2-5: Average Monthly Evaporation for the Project Area Obtained from the WR2005 Study**

| Months | Symons Pan Evaporation (mm) | Lake Evaporation Factor | Lake Evaporation (mm) |
|---|---|---|---|
| January | 198.0 | 0.84 | 161.5 |
| February | 164.7 | 0.88 | 151.9 |
| March | 160.0 | 0.88 | 163.7 |
| April | 124.0 | 0.88 | 166.3 |
| May | 103.0 | 0.87 | 144.9 |
| June | 83.7 | 0.85 | 140.8 |
| July | 90.7 | 0.83 | 109.1 |
| August | 126.4 | 0.81 | 89.6 |

| Months | Symons Pan Evaporation (mm) | Lake Evaporation Factor | Lake Evaporation (mm) |
|---|---|---|---|
| September | 167.6 | 0.81 | 71.1 |
| October | 199.4 | 0.81 | 75.3 |
| November | 185.2 | 0.82 | 102.4 |
| December | 197.3 | 0.83 | 135.7 |
| **Total** | **1800** | **N/A** | **1512** |

### 2.3.3 Temperature

Three-year average maximum, minimum and mean temperatures for the project area are shown in Figure 2-4 and Table 2-6. Temperature and relative humidity is based on modelled data (2011 – 2013) (Lakes Environmental 2015). Average monthly maximum temperature was 19.7 °C, with minimum of 18.6°C and the monthly mean temperature of 19.2°C. The relative humidity annual values for maximum, minimum and mean relative humidity are given as 63.9%, 60.4% and 64.2%, respectively. This pattern followed the seasonal variations, with highest temperatures during summer months and lowest during winter.

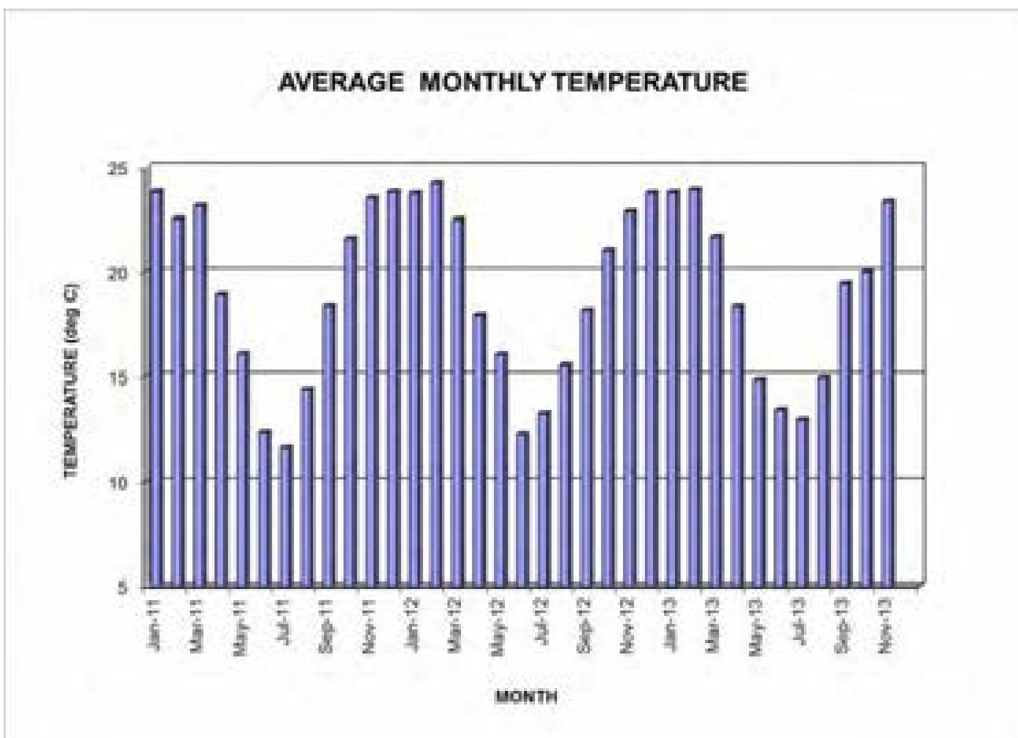


**Figure 2-4: Average Monthly Temperature derived from the Project Area Modelled Data 2011-2013 (Lakes Environmental 2015)**

**Table 2-6: Average Monthly Temperature derived from the Project Area Modelled Data 2011-2013 (Lakes Environmental 2015)**

| Temperature (deg °C) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Monthly Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Monthly Max** | 23.8 | 24.2 | 23.2 | 18.9 | 16.1 | 13.4 | 13.2 | 15.6 | 19.4 | 21.6 | 23.5 | 23.8 | 19.7 |
| **Monthly Min** | 23.8 | 22.5 | 21.7 | 17.9 | 14.8 | 12.3 | 11.6 | 14.4 | 18.2 | 20.0 | 22.9 | 23.4 | 18.6 |
| **Monthly Mean** | 23.8 | 23.6 | 22.4 | 18.4 | 15.7 | 12.7 | 12.6 | 15.0 | 18.7 | 20.9 | 23.2 | 23.6 | 19.2 |

### 2.3.4 Relative Humidity

Figure 2-5 and Table 2-7 depict the relative humidity for the Project area. The annual values for maximum, minimum and mean relative humidity are given as 63.9%, 60.4% and 64.2%, respectively. For the entire three years, maximum relative humidity of 69.3% in July and the lowest of 57.6% were calculated for November. The highest minimum (65.4%) was observed in June and the lowest (56.5%) in November.

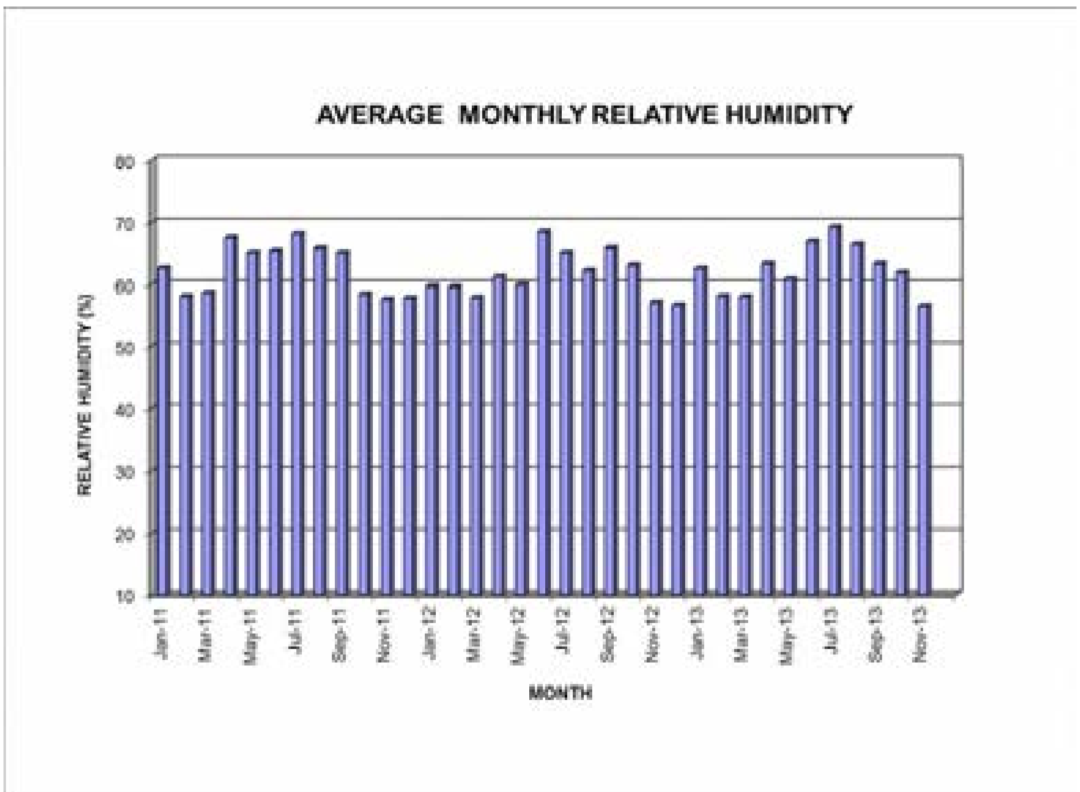


**Figure 2-5: Average Monthly Relative Humidity derived from the Project Area Modelled Data 2011-2013 (Lakes Environmental 2015)**

**Table 2-7: Average Monthly Relative Humidity derived from the Project Area Modelled Data 2011-2013 (Lakes Environmental 2015)**

| Relative Humidity (%) | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Monthly Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly Max | 62.7 | 59.6 | 58.7 | 67.6 | 65.2 | 68.5 | 69.3 | 66.4 | 65.9 | 63.1 | 57.6 | 62.2 | 63.9 |
| Monthly Min | 59.7 | 58.1 | 57.9 | 61.2 | 60.0 | 65.4 | 65.2 | 62.2 | 63.4 | 58.4 | 56.5 | 56.7 | 60.4 |
| Monthly Mean | 61.7 | 58.6 | 58.2 | 64.1 | 62.0 | 67.0 | 67.5 | 64.8 | 64.8 | 61.2 | 57.1 | 58.9 | 62.2 |

### 2.3.5 Storm Rainfall Depths

The closest weather stations to the Project area are presented in Table 2-7. The data was used to estimate the 24 hour design rainfall depth (Table 2-9) using the Design Rainfall Estimation (DRE) in South Africa (Smithers and Schulze, 2003).

**Table 2-8: Summary of the Closest Rainfall Stations**

| Station Name | SAWS Number | Distance from Project Centre (km) | Record Length (years) | Lat (°) (') | Long (°) (') | MAP (mm) | Altitude (m) |
|---|---|---|---|---|---|---|---|
| VERDOORNSDRAAI | 0676237_W | 13.7 | 57 | 23° 57' | 28° 38' | 519 | 970 |
| GROENFONTEIN | 0633482_W | 14.8 | 46 | 24° 2' | 28° 38' | 638 | 1200 |
| ZAAIPLAATS | 0633393_W | 17.1 | 79 | 24° 3' | 28° 42' | 629 | 1058 |
| VAALPENSKRAAL | 0676523_W | 22.3 | 43 | 23° 42' | 28° 48' | 506 | 1104 |
| SWERWERSKRAAL | 0676705_W | 24.2 | 52 | 23° 44' | 28° 54' | 474 | 1066 |
| BACCHUS | 0633185_W | 24.5 | 39 | 24° 5' | 28° 37' | 625 | 1175 |

Table 2-9 presents the estimated rainfall depth for a 24 hour rainfall event for various return periods using the Design Rainfall Estimation (DRE) in South Africa (Smithers and Schulze, 2003) for the stations mentioned in Table 2-8 above.

**Table 2-9: Estimated 24 Hour Design Rainfall Depth**

| Design rainfall return period (yrs) | 1:2 | 1:5 | 1:10 | 1:20 | 1:50 | 1:100 | 1:200 |
|---|---|---|---|---|---|---|---|
| 24 Hr design peak rainfall (mm) | 67.3 | 91.7 | 109.2 | 127.1 | 152.1 | 172.1 | 193.4 |

## 2.4 Surface Water Quality

Surface water quality samples have been collected from the Mogalakwena and Sterk River on the 15th and 16th of January 2015. Amongst the identified sampling points within and around the project area, most drainages/rivers on the eastern side of the project area were found to be dry. Photos of the dry drainages/rivers are presented in Figure 2-3.

Water samples were submitted to Aquatico Laboratory (Pty) Ltd, a SANAS accredited laboratory in Pretoria for analysis of their physical and chemical quality status. Plan 5 (Appendix B) indicates the surface water sampling locations.

Water quality results have been benchmarked against the South African National Standards (SANS) 241-1: 2011 drinking water standards. This part of SANS 241 specifies the quality of acceptable drinking water, defined in terms of microbiological, physical, aesthetic and chemical determinants, at the point of delivery. Water that complies with this part of SANS 241 is deemed to present an acceptable health risk for lifetime consumption (this implies an average consumption of 2 L of water per day for 70 years by a person that weighs 60 kg).

The results were also benchmarked with the General Resource Water Quality Objectives (DWS, 2011) and the South African Water Quality Guidelines for Agricultural Use: Irrigation (DWAF, 1996) as indicated in Table 2-12 and Table 2-13 below.

The Resource Water Quality Objectives (RWQOs) are defined by the Department of Water and Sanitation, based on the National Water Act as “clear goals relating to the quality of the relevant water resources” (DWAF, 2006a). In South Africa, the South African Water Quality Guidelines (SAWQG) has been developed as discrete values that depict the change from one category of fitness for use to another (DWAF, 1996).

The water quality guidelines describe the “fitness for use” of a water resource, while the Water Quality Objectives defines “what management action is required” for a water resource. The fitness for use of water defines how suitable the quality of water is for its intended use. The following fitness for use categories are linked to the SAWQGs:

- **Ideal** – the use of water is not affected in any way; 100% fit for use by all users at all times; desirable water quality (TWQR);
- **Acceptable** – slight to moderate problems encountered on a few occasions or for short periods of time;
- **Tolerable** – moderate to severe problems are encountered; usually for a limited period only; and
- **Unacceptable** – water cannot be used for its intended use under normal circumstances at any time (DWAF, 2006c).

The generic RWQOs were developed as part of the national water quality assessment study (DWS, 2011). For the purpose of this study, the ideal and acceptable standards will be used for the assessment of the water quality on the Sterk River and Mogalakwena River. Table 2-11 present the water quality result benchmarked against the Department of Water and Sanitation's Resource Water Quality Objectives.

The water quality results are attached on Appendix C of this report. Table 2-10 below presents the coordinates of the sampling points and Table 2-11, Table 2-12 and Table 2-13 present the water quality results benchmarked with (SANS) 241: 2011 and the RWQOs respectively.

**Table 2-10: Surface Water Monitoring Locations**

| Site Name | Latitude | Longitude |
|---|---|---|
| SW1 | -23.97113100 | 28.69598600 |
| SW2 | -23.90947000 | 28.7265100 |
| SW3 | -23.87934000 | 28.68970900 |
| SW4 | -23.95324400 | 28.78766200 |
| SW5 | -23.92715000 | 28.75387500 |

*All coordinates are in decimal degrees using the Geographic (latitude and longitude) WGS 1984 coordinate system

SW1 is on the Sterk River outside the project area. The sample was taken under the bridge on the R518 road. The river is flowing is a north-easterly direction where it joins the Mogalakwena River inside the Project area (Plan 5, Appendix B).

SW2 is a monitoring point on the Mogalakwena River after the Sterk River confluence. This monitoring point is still within the boundaries of the Project area.

SW3 is an upstream point in relation to the Project area, in the Mogalakwena River. This point is outside of the Project area. Water quality at this point will be used for comparison against the downstream point to establish if there are any changes or impacts of selected water quality parameters resulting from proposed mining activities.

SW4 is a downstream point on the Mogalakwena River which is outside the Project area. Water quality results from this point will represent the upstream water quality before it passes through the project area.

SW5 is a point on the Mogalakwena River within the project area. This is a point within the Project area (located below Sepharane village) before the Sterk River joins the Mogalakwena River.

Watercourses or drainage lines that were identified within the infrastructure area were dry at the time of site visit and sampling was not possible, the dry drainages/rivers can be seen on Figure 2-3.

## Table 2-11: Water Quality Results benchmarked against the SANS 241-1:2011 Drinking Water Quality Standards

| Date | Sample ID | | Total Dissolved Solids* | Nitrate $NO_3$ as N* | Chlorides as Cl* | Total Alkalinity as $CaCO_3$* | Sulphate as $SO_4$ * | Calcium as Ca * | Magnesium as Mg* | Sodium as Na* | Potassium as K* | Iron as Fe* | Manganese as Mn* | Conductivity at 25° C in mS/m | pH-Value at 25° C | Aluminium as Al* | Free and Saline Ammonia as N* | Fluoride as F* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Class I | (Recommended) | <1000 | <10 | <200 | N/S | <400 | <150 | <70 | <200 | <50 | <0.2 | <0.1 | <150 | 5-9.5 | <0.3 | <1 | <1 |
| | Class II | (Max. Allowable) | 1000-2400 | 10-20 | 200-600 | N/S | 400-600 | 150-300 | 70-100 | 200-400 | 50-100 | 0.2-2 | 0.1-1 | 150-370 | 4-5 or 9.5-10 | 0.3-0.5 | 1-2 | 1-1.5 |
| | | Duration | 70 years | 70 years | 70 years | N/S | 70 years | 70 years | 70 years | 70 years | 70 years | 70 years | 70 years | 70 years | No Limit | 1 year | None | 1 year |
| 2015/01/15 | SW01 | | 78.00 | 0.55 | 11.30 | 30.30 | 3.41 | 7.38 | 2.94 | 7.82 | 3.33 | 0.00 | 0.00 | 9.80 | 7.77 | 0.00 | 0.15 | 0.13 |
| 2015/01/15 | SW02 | | 86.00 | 0.33 | 11.90 | 39.10 | 3.70 | 8.33 | 3.80 | 9.93 | 2.45 | 0.00 | 0.00 | 11.70 | 7.79 | 0.00 | 0.09 | 0.09 |
| 2015/01/15 | SW03 | | 84.00 | 0.35 | 11.00 | 35.20 | 3.61 | 8.29 | 3.25 | 10.60 | 2.43 | 0.00 | 0.00 | 12.40 | 7.95 | 0.00 | 0.05 | 0.13 |
| 2015/01/15 | SW04 | | 371.00 | 0.30 | 53.70 | 197.00 | 43.20 | 33.80 | 28.80 | 57.40 | 4.31 | 0.00 | 0.00 | 57.30 | 8.43 | 0.00 | 0.04 | 0.52 |
| 2015/01/15 | SW05 | | 339.00 | 0.31 | 51.00 | 210.00 | 19.00 | 31.80 | 24.50 | 51.60 | 3.85 | 0.00 | 0.00 | 51.30 | 8.41 | 0.00 | 0.09 | 0.67 |

*Unit for parameters = mg/L

### 2.4.1 Water Quality Analysis Results compared against the SANS 241-1: 2011 Drinking Water Standards

The overall surface water quality of the sampled points falls within the recommended water quality concentration limits (Class I and II – SANS 241-1:2011).

In general, water quality at the sampled sites did not indicate any elevated element concentrations. High flows that were observed during sampling may have also contributed to dilution of concentration levels of analysed parameters.

## Table 2-12: Water Quality Results benchmarked against the South Africa Water Quality Guidelines: Agriculture Irrigation

| Date | Sample ID | Total Dissolved Solids* | Chromium Cr* | Copper Cu* | Lead Pb* | Zinc Zn* | Sodium as Na* | Potassium as K* | Iron as Fe* | Manganese as Mn* | pH-Value at 25° C | Aluminium as Al* | Free and Saline Ammonia as N* | Fluoride as F* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ideal | 90 | 0.1 | 0.2 | 0.2 | 1 | 115 | NS | 5 | 0.02 | <6.5 | 5 | NS | 2 |
| | Not Acceptable | >540 | >1.0 | >5.0 | >2.0 | >5.0 | >460 | NS | >20 | >10.0 | >8.4 | >20 | NS | >15.0 |
| 2015/01/15 | SW01 | 78.00 | -0.001 | -0.001 | -0.004 | -0.002 | 7.82 | 3.33 | 0.00 | 0.00 | 7.77 | 0.00 | 0.15 | 0.13 |
| 2015/01/15 | SW02 | 86.00 | -0.001 | -0.001 | -0.004 | -0.002 | 9.93 | 2.45 | 0.00 | 0.00 | 7.79 | 0.00 | 0.09 | 0.09 |
| 2015/01/15 | SW03 | 84.00 | -0.001 | -0.001 | -0.004 | -0.002 | 10.60 | 2.43 | 0.00 | 0.00 | 7.95 | 0.00 | 0.05 | 0.13 |
| 2015/01/15 | SW04 | 371.00 | -0.001 | -0.001 | -0.004 | -0.002 | 57.40 | 4.31 | 0.00 | 0.00 | 8.43 | 0.00 | 0.04 | 0.52 |
| 2015/01/15 | SW05 | 339.00 | -0.001 | -0.001 | -0.004 | -0.002 | 51.60 | 3.85 | 0.00 | 0.00 | 8.41 | 0.00 | 0.09 | 0.67 |

*Unit for parameters = mg/l

Where NS: is Not Specified (There are no specified Guidelines value)

### 2.4.2 Water Quality Analysis Results compared against the South Africa Water Quality Guidelines for Irrigation

SW04 and SW05 samples show a high TDS concentration which exceeds the ideal standard for irrigation, whilst it was still below the maximum acceptable standard of 540 mg/L. The TDS are a measure of the quantity of various inorganic salts dissolved in water which is normally used as an indicator of the salinity of the water.

The pH values for SW04 and SW05 also exceeded the maximum acceptable standards for irrigation.

## Table 2-13: Water Quality Results Benchmarked against the Resource Water Quality Objectives Developed for National Water Quality Assessment Study (DWS, 2011)

| Date | Sample ID | Total Dissolved Solids* | Nitrate $NO_3$ as N* | Chlorides as Cl * | Total Alkalinity as $CaCO_3$* | Sulphate as $SO_4$ * | Calcium as Ca | Magnesium as Mg* | Sodium as Na* | Potassium as K* | Iron as Fe* | Manganese as Mn* | Conductivity at 25° C in mS/m | pH-Value at 25° C | Aluminium as Al* | Free and Saline Ammonia as N* | Fluoride as F* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Acceptable | 350 | 10 | 120 | N/A | 165 | 80 | 100 | 92.5 | 50 | N/A | N/A | <150 | >8.0 | N/A | 0.044 | 1 |
| | Ideal | 200 | 6 | 40 | N/A | 80 | 10 | 70 | 70 | 25 | N/A | N/A | 150-370 | ≥6.5 - ≤8 | N/A | 0.015 | 0.7 |
| | | | | | | | | | | | | | | | | | |
| 2015/01/15 | SW01 | 78.00 | 0.55 | 11.30 | 30.30 | 3.41 | 7.38 | 2.94 | 7.82 | 3.33 | 0.00 | 0.00 | 9.80 | 7.77 | 0.00 | 0.15 | 0.13 |
| 2015/01/15 | SW02 | 86.00 | 0.33 | 11.90 | 39.10 | 3.70 | 8.33 | 3.80 | 9.93 | 2.45 | 0.00 | 0.00 | 11.70 | 7.79 | 0.00 | 0.09 | 0.09 |
| 2015/01/15 | SW03 | 84.00 | 0.35 | 11.00 | 35.20 | 3.61 | 8.29 | 3.25 | 10.60 | 2.43 | 0.00 | 0.00 | 12.40 | 7.95 | 0.00 | 0.05 | 0.13 |
| 2015/01/15 | SW04 | 371.00 | 0.30 | 53.70 | 197.00 | 43.20 | 33.80 | 28.80 | 57.40 | 4.31 | 0.00 | 0.00 | 57.30 | 8.43 | 0.00 | 0.038 | 0.52 |
| 2015/01/15 | SW05 | 339.00 | 0.31 | 51.00 | 210.00 | 19.00 | 31.80 | 24.50 | 51.60 | 3.85 | 0.00 | 0.00 | 51.30 | 8.41 | 0.00 | 0.09 | 0.67 |

*Unit for parameters = mg/L

### 2.4.3 Water Quality Analysis Results compared against the Resource Water Quality Objectives (RWQO)

The following can be concluded from the water quality results:

- Sites SW02, SW03 and SW05 show elevated levels of ammonia concentrations which were above the SAWQG concentration limits;
- TDS, Chlorides and Calcium levels at SW04 and SW05 also exceed the ideal standards although they still fall within the acceptable standards; and
- SW04 and SW05 show higher pH levels which are above the SAWQG's limits.

High ammonia levels in the above mentioned points are likely as a result of organic pollution such as fertilizer runoff from the cultivated areas. Municipal wastes from built up areas such as Mokopane, Sekgagapeng, Maroteng and Ga-Pila and their surrounding industrial areas are also likely to contribute to the high ammonia levels.

Possible source of chlorides and calcium are agricultural runoff (fertilizers), wastewater from industries and municipalities or from calcium-containing host rocks and minerals through which the river would naturally flow.

# 3 Peak Flow and Containment Volume Methodologies

## 3.1 Introduction

Peak flow estimates are used for input into the hydraulic model (which is discussed in section 4) and in the conceptual sizing of required storm water infrastructure (discussed in Section 5).

### 3.1.1 Rational Methodology

Peak flow calculations were obtained using the Rational Method. The Rational Method is a hydrological method used to predict peak runoff. It is based on the equation shown below:

$Q_T = CIA$

where:

$Q_T$ = *Estimate of the peak rate of runoff for some recurrence interval (e.g. a 1 in 50 year flood)*

C = *Runoff coefficient*

I = *Average rainfall intensity for the recurrence interval T*

A = *Catchment contributing to the peak*

The runoff coefficient C is based on a number of different physical characteristics of the site. These include the vegetation type, slope and drainage properties of the soil and land use characteristics. The Rational Method is suitable for small catchments (less than 15 $km^2$), however, it may be applied to larger catchments (up to 100 $km^2$) based on experience, and is used extensively around the world.

It should be noted that the Utilities Programme for Drainage (UPD), which is a software program that has the Rational Method built in, was used to calculate the peak flows for the Project area.

### 3.1.2 SCS Methodology

All conceptual sizing of containment facilities are based on the SCS methodology. The SCS Method, described fully in Schmidt and Schulze (1987), is particularly suited to small catchments (less than 30 $km^2$) and takes into account the quantity, time distribution and duration of rainfall, land use, soil type and size and characteristics of the generating catchment. It is based on the principle that runoff is caused by the rainfall that exceeds the cumulative infiltration of the soil. Soil types are divided into four hydrological groups, ranging from soils with low runoff potential (well-drained with high infiltration ability and permeability such as sand and gravel), to soils with high runoff potential (very low infiltration rates and permeability such as shallow soils with clay, peat or rock).

The method used a curve number (CN) which can be determined from observation of the characteristics of the catchment. The curve number expresses a catchments storm flow response to a rainfall event (Schulze et al. 1992). This response is dependent on the catchment characteristics such as hydrological soil properties, catchment slope and land use. The SCS storm flow depth equation is given below:

$$Q = \frac{(P - I_a)^2}{P - I_a + S} \quad \text{for } \boldsymbol{P > I_a}$$

where

| | | |
|---|---|---|
| $Q$ | = | stormflow depth (mm), |
| $P$ | = | daily rainfall depth (mm), usually input as a one-day design rainfall for a given return period, |
| $S$ | = | potential maximum soil water retention (mm), |
| | = | index of the wetness of the catchment's soil prior to a rainfall event, |
| $I_a$ | = | initial losses (abstractions) prior to the commencement of stormflow, comprising of depression storage, interception and initial infiltration (mm) |
| | = | 0.1 $S$ |

# 4 Flood Hydrology

## 4.1 Introduction

In order to understand and manage the risk of flooding to the proposed infrastructure layout, and to ensure compliance with Condition 4 of GN704, it is necessary to determine the 1:50 year and the 1:100 year floodlines for a section of the Borobela River, together with minor tributaries of the Mogalakwena River which pass near the proposed infrastructure. Condition 4 of GN704 states that no infrastructure should be placed within the 1:100 year floodline, or within a horizontal distance of 100 metres (whichever is greatest) from any watercourse.

This section details how rivers were defined, the methods used in the development of the hydraulic model, key assumptions and limitations, flood modelling results and recommendations.

## 4.2 Site Visit and Drainage Line Definition

A site visit was conducted on the 10th and 11th of June 2015 with the aim of assessing the non-perennial rivers passing through the proposed infrastructure area, and to measure the dimensions of hydraulic structures such as bridges and culverts. The site visit revealed that the Project area was flat, and that in certain instances drainage lines were difficult to distinguish from the surrounding vegetation and topography. Furthermore, none of these rivers were found to be flowing during the above mentioned site visit, as well as during an earlier site visit conducted on the 15th and 16th of January 2015. In order to define drainage lines near the proposed infrastructure for floodline modelling, the following process was followed:

- The existing 1:50 000 topographical river dataset was compared to a 0.5m spatial resolution Digital Elevation Model (DEM) created from 0.5m LIDAR contour survey data;
- High resolution aerial imagery with a spatial resolution of 10cm was assessed for the appearance of any drainage lines; and
- A stream definition process was run in Arc Hydro, an extension of ArcGIS 10.2, using the above mentioned DEM.

A combination of the above processes resulted in four (4) non-perennial systems draining the area associated with the location of proposed surface infrastructure on site. Plan 4 indicates the resulting non-perennial drainage lines (Tributary A to E) on which floodline modelling was conducted, as well as the 1:50 000 topographical rivers.

## 4.3 Methodology

### 4.3.1 Choice of Software

HEC-RAS 4.1 (Brunner, 2010) was used for the purposes of modelling the flooding associated with a 1:50 year and 1:100 year flood event. HEC-RAS is a hydraulic programme used to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

HEC-GeoRAS is an extension of HEC-RAS which utilises the ArcGIS environment. The HEC-GeoRAS extension is used to extract the cross-sections and river profiles from a Digital Elevation Model (DEM) for export into HEC-RAS for modelling and is used again to project the modelled flood levels back onto the DEM to generate flood-lines associated with the modelled events.

### 4.3.2 Topographical Data

Detailed 0.5m LIDAR contour survey data was provided by the client, this data was utilised for the HEC-RAS model. The topographical data forms the foundation for the HEC-RAS model and is used to extract elevation data for the river profile together with the river cross-sections. The topographical data is also used to determine placement positions for the cross-sections along the river profile, such that the watercourse can be accurately modelled.

### 4.3.3 Peak Flows Used

The Rational Method was used to calculate the 1:50 and 1:100 year peak flows. The Rational Method is described in section 3.1.1 of this report. A summary of the catchment characteristics and peak flows used for each of the rivers are listed below in Table 4-1.

**Table 4-1 Summary of Peak Flows used in the Flood Study**

| Modelled Rivers / Drainages | Tributary A and B | Tributary C | Tributary D | Tributary E |
|---|---|---|---|---|
| Area ($km^2$) | 57.15 | 2.30 | 15.22 | 48.01 |
| Length of Longest Watercourse (km) | 11.07 | 3 | 6.2 | 12.4 |
| Height Difference along 10-85 (m) | 61.5 | 58.77 | 37.16 | 69.07 |
| Distance to Catchment Centroid (km) | 5.6 | 1.6 | 3.6 | 5.6 |
| Peak Flow Method | Rational | Rational | Rational | Rational |
| 1:50 Year Peak Flow ($m^3/s$) | 128.05 | 17.96 | 51.2 | 100.74 |
| 1:100 Year Peak Flow ($m^3/s$) | 163.66 | 23.23 | 65.89 | 129.03 |

10:85 Height difference (m): difference in elevation height at 10% and 85% of the length of the longest water course to determine average slope

Distance to Catchment Centroid: the distance measured from the catchment outlet along the watercourse and then perpendicular to the centroid (km)

### 4.3.4 Hydraulic Structures

One of the key objectives of the site visit was to determine the existence of any hydraulic structures within the modelled section of the Borobela River, together with the unnamed tributaries of the Mogalakwena River flowing through the infrastructure area.

Hydraulic structures were identified and were included in the hydraulic models. Hydraulic structures are indicated on Plan 4 and a summary of the dimensions of the hydraulic structures is presented in Table 4-2 below. Illustrations are provided below in Figure 4-1, Figure 4-2 and Figure 4-3.

**Table 4-2: Summary of Dimensions of Hydraulic Structures**

| Name | Number of Openings | Opening Width (m) | Opening Height (m) | Deck Thickness (m) | Number of Piers | Pier Width (m) |
|---|---|---|---|---|---|---|
| C01 | 1 | 6.00 | 1.50 | 0.57 | 0 | 0.00 |
| C02 | 2 | 1.75 | 0.90 | 0.77 | 1 | 0.77 |
| C03 | 2 | 5.20 | 3.72 | 1.08 | 1 | 0.60 |
| Other minor Culverts | 1 | 1.50 | 0.50 | 0.20 | 0 | 0.00 |

**Figure 4-1: A photograph of culvert C01 taken on the north-eastern side of the D4380 road looking south-west**

**Figure 4-2: A photograph of culvert C02 taken on the north-eastern side of the D4380 road looking south-west**

**Figure 4-3: A photograph of bridge C03 taken on the north-eastern side of the D4380 road looking south-west**

### 4.3.5 Roughness Coefficients

The Manning's roughness factor 'n' is used to describe the flow resistant characteristics of a specific surface. A Manning's 'n' value of 0.040 was assigned to both the floodplain and the channel because of vegetation growth within the channel. In most cases it was difficult to distinguish between the channel and floodplain.

## 4.4 Model Development

Development of the hydraulic model includes the following steps:

- Creation of a DEM from the topographical survey data;
- Digitising the stream centre lines and flow paths using HEC-GeoRAS;
- Generating cross-sections approximately every 100 m through the watercourses using HEC-GeoRAS;
- Importing geometric data, adding hydraulic structures, entering the Manning's 'n' values, entering peak flows and normal depth upstream and downstream boundary conditions, and performing steady mixed flow regime hydraulic modelling within HEC-RAS to generate flood levels at modelled cross-sections; and
- Importing flood levels and projecting levels onto the DEM using HEC-GeoRAS to determine the flood inundation areas.

## 4.5 Assumptions and Limitations

The following assumptions are made:

- The topographic data provided was of a sufficient accuracy to enable hydraulic modelling at a suitable level of detail;
- Based on site observations of the channel and floodplain characteristics, a Manning's 'n' value of 0.040 was assigned to both the floodplain and the channel. This is because in most cases it was difficult to distinguish between the channel and floodplain;
- A steady state hydraulic model was run which assumes flow is continuous at the determined peak flow rates. This is a conservative approach which results in higher flood levels than if unsteady state modelling was performed;
- A mixed flow regime which is tailored to both subcritical and supercritical flows was selected for running of the steady state model;
- No flood protection infrastructure was modelled;
- The modelling of the adopted flow through the respective hydraulic structures was undertaken, and assumed no blockages were present;
- No abstractions from the river section or discharges into the river section were taken into account during the modelling; and

- Floodlines are for environmental purposes only and not for mine planning or any form of construction.

### 4.6 Flood Modelling Results

The 1:50 and 1:100 year floodlines are illustrated on plan 6. From the flood modelling the following results are obtained:

- Tributary A and B: The 1:100 year flooding will impact on the proposed fences, storm water trench, dirty water trench and lower grade stockpile along the Borobela River (Tributary A) and an unnamed tributary (Tributary B) of the Borobela.
- Tributary C: Flooding occurs on the southern end of Pit 1, the northern side of the tailings dam, and the north-western boundary of the return water dam. Flooding is primarily due to the flat topography around the vicinity of the Project area, together with poorly defined drainage paths.
- Tributary D: The 1:100 year flooding impacts the proposed fences, low grade stockpile, lower grade stockpile, PCD, dirty water trench, site road, pipeline and storm water trench.
- Tributary E: The backing up of the flood water along the D4380 road will move in a north-westerly direction flooding the tailings dam, fence, site road and storm water dam.
- Overbank flow occurs over most of the modelled rivers specifically tributary E and tributary C (see Plan 6, Appendix B). This is due to the topography of the area being flat, resulting in flows not being contained within the rivers/drainage paths. The D4380 road which bisects the project area, causes backing up of flood waters due to the flat topography, the poorly defined drainage paths and insufficient capacity of the culverts/bridges in some areas, to cater for the 1:50 year and 1:100 year peak discharges.

## 5 Storm Water Management Plan

### 5.1 Introduction

Mining operations have the potential to impact upon the natural water quality of an area in the following ways:

- Bulk earthworks which will strip vegetation and expose top soils and sub-soils. Storm water flows will contribute to erosion thereby increasing levels of suspended solids within local watercourses and water features;
- Earthwork and mineral processing operations may expose elements naturally occurring within soils and geology to storm water, mobilising them into local watercourses and water features;

- Storage and usage of process specific chemicals and vehicular related pollutants which, if not properly managed properly, may be washed by storm water into local watercourses and water features; and
- Discharge of polluted or improperly treated storm water, process water and sewage water into local watercourses or water features may occur.

A negative impact on the baseline water quality by mining operations will likely affect local aquatic ecosystems, and/or local population who use the water for drinking, washing, irrigating or livestock watering.

In addition to the above, stormwater may pose a risk of flooding to a proposed development, if not managed correctly.

The aim of this conceptual Storm Water Management Plan is to mitigate the above impacts by fulfilling the requirements of the National Water Act, 1998 (Act No.36 of 1998) and more particularly GN 704 (as discussed in Section 1).

The following definitions from GN 704 are appropriate to the classification of catchments and design of storm water management measures for the Magnetite Project:

- **Clean water system:** includes any dam, other forms of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of unpolluted (clean) water;
- **Dam:** includes any settling dam, slurry dam, evaporation dam, catchment or barrier dam and any other form of impoundment used for the storage of unpolluted water or water containing waste (i.e. dirty water);
- **Dirty area:** means any area at a mine or ***activity*** which causes, has caused or is likely to cause pollution of a water resource;
- **Dirty water system:** This includes any dirty water diversions bunds, channels, pipelines, dirty water dams or other forms of impoundment, and any other structure or facility constructed for the retention or conveyance of water containing waste (i.e. dirty water); and
- **Activity:** means any mining related process on the mine including the operation of washing plants, mineral processing facilities, mineral refineries and extraction plants; the operation and the use of mineral loading and off-loading zones, transport facilities and mineral storage yards, whether situated at the mine or not; in which any substance is stockpiled, stored, accumulated, dumped, disposed of or transported.

## 5.2 Principles for Storm Water Management Plan

The Storm Water Management Plan outlined in this section will only detail the proposed placement of respective storm water controls, and the anticipated peak discharges and volumes within the drainage channels and containment facilities. No detailed design is provided in this report.

The conceptual Storm Water Management Plan is presented on Plan 7 (Appendix B); the key features include:

- Clean water diversions will allow for runoff upstream of the infrastructure footprints which includes the TSF, open pit areas, and plant area;
- Dirty water channels will ensure that dirty water emanating from the dirty mine areas are captured and conveyed to respective PCDs; and
- River diversions at specific points of interest will ensure that flow within any watercourse that traverses or is within close proximity to proposed infrastructures are conveyed to their respective downstream reach. The proposed river diversions serve not only to divert runoff from the upstream section of the specified river/drainage path, but also to ensure that the 1:100 year peak discharge is safely contained within the river diversion.

## 5.3 General Exclusions/ Limitations

The following exclusions should be noted:

- **Sizing of dirty sumps within the open pits**. Runoff generated within the pits and any groundwater seepage into the pits will collect within the lowest point of the pit and will be pumped out for re-use at the mine. To manage risks of flooding to vulnerable infrastructure within the pit, it is recommended that a drainage sump is incorporated into the base of the pit to accommodate runoff from a 1:10 year 24 hour duration rainfall event and that pumps are sized to empty the sump within 5 days. In the case of larger storm events or extended wet periods, the amount of water collected will be considerably more, inundating a substantially larger area than just the drainage sump, and it is recommended that, if the mining operation is affected by such a scenario, then the design standards and design methodology are revisited to deliver a more robust in-pit drainage scheme.
- **Sizing of the RWD**. The RWD dam must be sized using a daily time step water balance, which takes into consideration the maximum storage volumes anticipated within the RWD, together with the 1: 50 year storm event.

## 5.4 Proposed Storm Water Management Measures

In order to meet the design principles detailed above, the following storm water management measures are proposed:

- Clean water diversion channels to divert clean water to the downstream environment or nearby watercourse;
- Dirty water channels around all stockpile areas, waste rock dump areas, contractors camp areas and plant areas, such that all dirty water is captured and contained in respective PCD’s;

- PCD’s which capture and contain dirty water runoff from the aforementioned dirty areas; and
- River diversions.

Regarding the containment of dirty water runoff, two options are proposed:

- Option 1 requires additional PCDs over and above what was originally proposed with the dirty water runoff being gravity fed to the proposed PCDs; and
- Option 2 requires fewer but larger volume PCDs to be located centrally within the project area. The dirty water runoff may however have to be pumped to these PCDs, and not necessarily gravity fed as in option 1.

It should be noted that the sizing of the PCDs were only undertaken for option 1.

A layout showing the proposed storm water controls mentioned above is presented in Plan 7.

## 5.5 Drainage Channels and River Diversions

### 5.5.1 Catchment Characteristics and Peak Flow Estimates

A summary of the catchment characteristics together with the estimated peak flows required to size the proposed clean water diversion channels, the dirty water channels and the river diversions are presented in Table 5-1 and Table 5-2.

**Table 5-1 Summary of Catchment Characteristics**

| Catchment | Area ($km^2$) | Length of Longest watercourse (km) | [1]10:85 Height difference (m) | Time of Concentration (hours) | C - Factor |
|---|---|---|---|---|---|
| Clean water 3 - 4 | 0.24 | 1.26 | 4.33 | 0.63 | 0.252 |
| Clean water 3 - 5 | 1.13 | 2.48 | 156.60 | 0.35 | 0.276 |
| Clean water 6 - 7 | 0.49 | 1.10 | 151.90 | 0.14 | 0.276 |
| Clean water 6 - 8 | 0.51 | 1.23 | 160.46 | 0.15 | 0.276 |
| Clean water 11 - 12 | 0.41 | 1.38 | 6.14 | 0.62 | 0.252 |
| Clean water 11 - 28 | 0.11 | 0.65 | 4.89 | 0.28 | 0.252 |
| Clean water 13 - 14 | 0.79 | 1.98 | 15.39 | 0.65 | 0.252 |
| Clean water 17 - 18 | 0.70 | 1.36 | 5.64 | 0.62 | 0.252 |
| Clean water 19 - 20 | 2.08 | 3.46 | 32.51 | 0.93 | 0.252 |

[1] 10:85 Height difference (m): difference in elevation height at 10% and 85% of the length of the longest water course to determine average slope

| Catchment | Area ($km^2$) | Length of Longest watercourse (km) | [1]10:85 Height difference (m) | Time of Concentration (hours) | C - Factor |
|---|---|---|---|---|---|
| Clean water 19 - 21 | 1.69 | 3.43 | 16.65 | 1.19 | 0.252 |
| Clean water 24 - 25 | 0.76 | 1.51 | 227.69 | 0.17 | 0.276 |
| Clean water 24 - 26 | 0.21 | 1.39 | 36.72 | 0.31 | 0.276 |
| Clean water 27 - 22 | 0.29 | 0.83 | 3.60 | 0.42 | 0.252 |
| Clean water 27 - 23 | 0.22 | 1.01 | 3.10 | 0.56 | 0.252 |
| Clean water 28 - 2 | 0.84 | 3.19 | 14.37 | 1.16 | 0.252 |
| River diversion 9 - 10 | 1.10 | 2.14 | 138.81 | 0.31 | 0.276 |
| **River diversion 15 - 16 | 2.30 | 2.98 | 58.77 | 0.63 | 0.276 |
| **River diversion 16 - 29 | 3.60 | 3.52 | 58.80 | 0.75 | 0.276 |
| *Dirty water channels | 0.71 | 1.63 | 7.32 | 0.69 | 0.510 |

**Table 5-2 Summary of Peak Flows**

| Catchment | **Channel Nodes | Q50 year flow ($m^3/s$) | Q100 year flow ($m^3/s$) |
|---|---|---|---|
| Clean water 3 - 4 | 3 - 4 | 1.73 | 2.34 |
| Clean water 3 - 5 | 3 - 5 | 12.48 | 16.15 |
| Clean water 6 - 7 | 6 - 7 | 4.22 | 5.46 |
| Clean water 6 - 8 | 6 - 8 | 4.94 | 6.39 |
| Clean water 11 - 12 | 11 - 12 | 2.99 | 3.88 |
| Clean water 11 - 28 | 11 - 28 | 1.23 | 1.59 |
| Clean water 13 - 14 | 13 - 14 | 5.49 | 7.11 |
| Clean water 17 - 18 | 17 - 18 | 5.04 | 6.52 |
| Clean water 19 - 20 | 19 - 20 | 11.36 | 14.71 |
| Clean water 19 - 21 | 19 - 21 | 7.75 | 10.03 |
| Clean water 24 - 25 | 24 - 25 | 7.73 | 10.01 |
| Clean water 24 - 26 | 24 - 26 | 2.45 | 3.17 |
| Clean water 27 - 22 | 27 - 22 | 2.64 | 3.42 |
| Clean water 27 - 23 | 27 - 23 | 1.75 | 2.27 |
| Clean water 28 - 2 | 28 - 2 | 3.94 | 5.10 |
| River diversion 9 - 10 | 9 - 10 | 13.02 | 16.85 |
| ***River diversion 15 - 16 | 15 - 16 | 17.96 | 23.23 |
| ***River diversion 16 - 29 | 16 - 29 | 24.74 | 31.98 |
| *Dirty water channels | N/A | 10.08 | 12.40 |

* All dirty water channels should be sized based on the 1 in 50 year peak flow as indicated in the above table.

** Nodes indicated in Plan 7 are representative of the channel/river diversion section required, e.g. nodes 3 – 4, represent a clean water channel that should be sized for the 1 in 50 year storm event which amounts to a discharge of 1.73 $m^3/s$.

*** River diversion 15 – 16 and River diversion 16 – 29, is a single river diversion divided into two respective sections.

## 5.6 Pollution Control Dams

### 5.6.1 Applicable GN704 Points

- GN 704 requires that dirty water containment facilities are designed, constructed, maintained and operated so that they are not likely to spill into a clean water environment more than once in 50 years. A critical component in sizing the containment pond is the rate at which water is pumped from the pond for re-use at the mine. GN 704 also requires that as a minimum, the 1: 50 year design volume and a 0.8m freeboard allowance should always be available. As part of the detailed design of the containment facilities the containment volumes will need to be assessed by daily time step water balance model to ensure compliance with GN 704. Modelling must be undertaken using daily rainfall and evaporation data from nearby weather stations in addition to the predicted inflows to and outflows from each containment facilities.
- The PCD's should be operated such that they are empty; this is to ensure that a 1: 50 year storm event for which they are sized can be adequately contained if it occurs. It is therefore recommended that the 1: 50 year volume be pumped out from the PCD after a storm to ensure the PCD always has capacity, in case another storm event occurs.

A summary of the required volumes for the proposed PCDs are shown in Table 5-3. Locations are indicated on Plan 7.

**Table 5-3 Summary of PCD Volumes ($m^3$) and Pump Rates (L/s)**

| Name | Area ($km^2$) | CN | Required Volume ($m^3$) | Pumping rates (L/s) | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | 1 day | 2 day | 3 day | 4 days | 10 days |
| PCD 1 | 0.595 | 60 | 35700 | 413 | 207 | 138 | 103 | 41 |
| PCD 2 | 0.705 | 60 | 42300 | 490 | 245 | 163 | 122 | 49 |
| PCD 3 | 0.040 | 50 | 1687 | 20 | 10 | 7 | 5 | 2 |
| PCD 4 | 0.199 | 70 | 15869 | 184 | 92 | 61 | 46 | 18 |
| PCD 5 | 0.600 | 60 | 36000 | 417 | 208 | 139 | 104 | 42 |
| PCD 6 | 0.435 | 60 | 26100 | 302 | 151 | 101 | 76 | 30 |
| PCD 7 | 0.075 | 50 | 3163 | 37 | 18 | 12 | 9 | 4 |

As indicated, a second option (option 2) can be considered so as to manage the containment of dirty water within the project area. It is proposed that fewer PCDs be constructed, and allocated centrally. These PCDs will have a larger volume, and dirty water runoff may have to be primarily pumped to the respective PCDs, instead of it being gravity fed as in option 1.

# 6 Potential Surface Water Impacts Assessment

The section details the surface water (quality and quantity) impacts that have been identified as a result of the proposed mine and its associated activities. The section will also provide the significance of those impacts on the water resources as derived from the impact assessment methodology described below.

## 6.1 Impact Methodology

Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

The significance rating process follows the established impact/risk assessment formula:

| |
|---|
| Significance = CONSEQUENCE X PROBABILITY X NATURE |

Where

| |
|---|
| Consequence = intensity + extent + duration |

And

| |
|---|
| Probability = likelihood of an impact occurring |

And

| |
|---|
| Nature = positive (+1) or negative (-1) impact |

The matrix calculates the rating out of 147, whereby intensity, extent, duration and probability are each rated out of seven as indicated in Table 6-1. The weight assigned to the various parameters is then multiplied by +1 for positive and -1 for negative impacts.

Impacts are rated prior to mitigation and again after consideration of the mitigation has been applied; post-mitigation is referred to as the residual impact. The significance of an impact is determined and categorised into one of seven categories (The descriptions of the significance ratings are presented in Table 6-3.

It is important to note that the pre-mitigation rating takes into consideration the activity as proposed, (i.e., there may already be some mitigation included in the engineering design). If the specialist determines the potential impact is still too high, additional mitigation measures are proposed.

### Table 6-1: Impact Assessment Parameter Ratings

| RATING | INTENSITY/REPLACABILITY | | EXTENT | DURATION/REVERSIBILITY | PROBABILITY |
|---|---|---|---|---|---|
| | Negative impacts | Positive impacts | | | |
| 7 | Irreplaceable loss or damage to biological or physical resources or **highly** sensitive environments. Irreplaceable damage to **highly sensitive** cultural/social resources. | Noticeable, on-going natural and / or social benefits which have improved the overall conditions of the baseline. | International The effect will occur across international borders. | Permanent: The impact is irreversible, even with management, and will remain after the life of the project. | Definite: There are sound scientific reasons to expect that the impact will definitely occur. >80% probability. |
| 6 | Irreplaceable loss or damage to biological or physical resources or **moderate to highly** sensitive environments. Irreplaceable damage to cultural/social resources of **moderate to highly** sensitivity. | Great improvement to the overall conditions of a large percentage of the baseline. | National Will affect the entire country. | Beyond project life: The impact will remain for some time after the life of the project and is potentially irreversible even with management. | Almost certain / Highly probable: It is most likely that the impact will occur. <80% probability. |

| | INTENSITY/REPLACABILITY | | | | |
|---|---|---|---|---|---|
| | **Negative impacts** | **Positive impacts** | | | |
| 5 | Serious loss and/or damage to physical or biological resources or **highly** sensitive environments, limiting ecosystem function.<br>Very serious widespread social impacts. Irreparable damage to highly valued items. | On-going and widespread benefits to local communities and natural features of the landscape. | Province/ Region<br>Will affect the entire province or region. | Project Life (>15 years): The impact will cease after the operational life span of the project and can be reversed with sufficient management. | Likely: The impact may occur. <65% probability. |
| 4 | Serious loss and/or damage to physical or biological resources or **moderately** sensitive environments, limiting ecosystem function.<br>On-going serious social issues. Significant damage to structures / items of cultural significance. | Average to intense natural and / or social benefits to some elements of the baseline. | Municipal Area<br>Will affect the whole municipal area. | Long term: 6-15 years and impact can be reversed with management. | Probable: Has occurred here or elsewhere and could therefore occur. <50% probability. |

| | INTENSITY/REPLACABILITY | | | | |
|---|---|---|---|---|---|
| | **Negative impacts** | **Positive impacts** | | | |
| 3 | Moderate loss and/or damage to biological or physical resources of **low to moderately** sensitive environments and, limiting ecosystem function.<br>On-going social issues. Damage to items of cultural significance. | Average, on-going positive benefits, not widespread but felt by some elements of the baseline. | Local<br>Local extending only as far as the development site area. | Medium term: 1-5 years and impact can be reversed with minimal management. | Unlikely: Has not happened yet but could happen once in the lifetime of the project, therefore there is a possibility that the impact will occur. <25% probability. |
| 2 | **Minor loss and/or effects** to biological or physical resources or low sensitive environments, not affecting ecosystem functioning.<br>Minor medium-term social impacts on local population. Mostly repairable. Cultural functions and processes not affected. | Low positive impacts experience by a small percentage of the baseline. | Limited<br>Limited to the site and its immediate surroundings. | Short term: Less than 1 year and is reversible. | Rare / improbable: Conceivable, but only in extreme circumstances. The possibility of the impact materialising is very low as a result of design, historic experience or implementation of adequate mitigation measures. <10% probability. |

| | INTENSITY/REPLACABILITY | | | | |
|---|---|---|---|---|---|
| | **Negative impacts** | **Positive impacts** | | | |
| 1 | **Minimal to no loss** and/or effect to biological or physical resources, not affecting ecosystem functioning. Minimal social impacts, low-level repairable damage to commonplace structures. | Some low-level natural and / or social benefits felt by a very small percentage of the baseline. | Very limited/Isolated Limited to specific isolated parts of the site. | Immediate: Less than 1 month and is completely reversible without management. | Highly unlikely / None: Expected never to happen. <1% probability. |

## Table 6-2: Probability/Consequence Matrix

Significance

| Probability \ Consequence | -21 | -20 | -19 | -18 | -17 | -16 | -15 | -14 | -13 | -12 | -11 | -10 | -9 | -8 | -7 | -6 | -5 | -4 | -3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | -147 | -140 | -133 | -126 | -119 | -112 | -105 | -98 | -91 | -84 | -77 | -70 | -63 | -56 | -49 | -42 | -35 | -28 | -21 | 21 | 28 | 35 | 42 | 49 | 56 | 63 | 70 | 77 | 84 | 91 | 98 | 105 | 112 | 119 | 126 | 133 | 140 | 147 |
| 6 | -126 | -120 | -114 | -108 | -102 | -96 | -90 | -84 | -78 | -72 | -66 | -60 | -54 | -48 | -42 | -36 | -30 | -24 | -18 | 18 | 24 | 30 | 36 | 42 | 48 | 54 | 60 | 66 | 72 | 78 | 84 | 90 | 96 | 102 | 108 | 114 | 120 | 126 |
| 5 | -105 | -100 | -95 | -90 | -85 | -80 | -75 | -70 | -65 | -60 | -55 | -50 | -45 | -40 | -35 | -30 | -25 | -20 | -15 | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | 105 |
| 4 | -84 | -80 | -76 | -72 | -68 | -64 | -60 | -56 | -52 | -48 | -44 | -40 | -36 | -32 | -28 | -24 | -20 | -16 | -12 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 | 64 | 68 | 72 | 76 | 80 | 84 |
| 3 | -63 | -60 | -57 | -54 | -51 | -48 | -45 | -42 | -39 | -36 | -33 | -30 | -27 | -24 | -21 | -18 | -15 | -12 | -9 | 9 | 12 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 36 | 39 | 42 | 45 | 48 | 51 | 54 | 57 | 60 | 63 |
| 2 | -42 | -40 | -38 | -36 | -34 | -32 | -30 | -28 | -26 | -24 | -22 | -20 | -18 | -16 | -14 | -12 | -10 | -8 | -6 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 |
| 1 | -21 | -20 | -19 | -18 | -17 | -16 | -15 | -14 | -13 | -12 | -11 | -10 | -9 | -8 | -7 | -6 | -5 | -4 | -3 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 |

## Table 6-3: Significance Rating Description[2]

| Score | Description | Rating |
|---|---|---|
| 109 to 147 | A very beneficial impact that may be sufficient by itself to justify implementation of the project. The impact may result in permanent positive change | Major (positive) (+) |
| 73 to 108 | A beneficial impact which may help to justify the implementation of the project. These impacts would be considered by society as constituting a major and usually a long-term positive change to the (natural and / or social) environment | Moderate (positive) (+) |
| 36 to 72 | An positive impact. These impacts will usually result in positive medium to long-term effect on the natural and / or social environment | Minor (positive) (+) |
| 3 to 35 | A small positive impact. The impact will result in medium to short term effects on the natural and / or social environment | Negligible (positive) (+) |
| -3 to -35 | An acceptable negative impact for which mitigation is desirable. The impact by itself is insufficient even in combination with other low impacts to prevent the development being approved. These impacts will result in negative medium to short term effects on the natural and / or social environment | Negligible (negative) (-) |
| -36 to -72 | A minor negative impact requires mitigation. The impact is insufficient by itself to prevent the implementation of the project but which in conjunction with other impacts may prevent its implementation. These impacts will usually result in negative medium to long-term effect on the natural and / or social environment | Minor (negative) (-) |
| -73 to -108 | A moderate negative impact may prevent the implementation of the project. These impacts would be considered as constituting a major and usually a long-term change to the (natural and / or social) environment and result in severe changes. | Moderate (negative) (-) |
| -109 to -147 | A major negative impact may be sufficient by itself to prevent implementation of the project. The impact may result in permanent change. Very often these impacts are immitigable and usually result in very severe effects. The impacts are likely to be irreversible and/or irreplaceable. | Major (negative) (-) |

[2] It is generally sufficient only to monitor impacts that are rated as negligible or minor

## 6.2 Construction Phase

### 6.2.1 Activity Summary

Activities under the construction phase include site clearance by removing vegetation, topsoil and softs removal and stockpiling, surface infrastructure development such as storm water channels, bridges, dams, offices, workshops and development of access and haul roads. These activities may cause impact on the surface water resources as discussed in the sections below.

**Table 6-4: Interactions and Impacts of Activity**

| Interaction | Impact |
|---|---|
| Exposure of soils due to loss of vegetation | Siltation of surface water resources leading to deteriorated water quality. |

#### 6.2.1.1 *Surface Water Quality Impacts*

Clearing and stripping of vegetation leaves the soils prone to erosion during rainfall events, and as a result runoff from these areas which will be high in suspended solids will cause an increase in turbidity to the downstream receiving rivers. This impact will therefore deteriorate the water quality and hence impact the downstream water users, as well as the aquatic life. However, this impact can greatly be prevented and/or reduced if the recommended measures listed below are implemented.

#### 6.2.1.2 *Management/ Mitigation Measures*

The following mitigation measures are recommended:

- Clearing of vegetation must be limited to the project site, and the use of existing access roads must be prioritized so as to minimise construction of new access roads in these areas;
- The construction phase must be prioritised to the dry months of the year (May-October) to limit mobilisation of sediments or hazardous substances from construction vehicles used during site clearing and grubbing;
- All runoff emanating from the dirty water areas which include, low grade stockpiles, high grade stockpiles, plant area and waste rock dump will need to be conveyed first to a silt trap before entering the containment facility e.g. PCD, or storm water dam;
- The removed topsoil must be covered or vegetated as soon as possible to prevent sediment erosion;
- Within the cleared area along the downstream boundary, temporary trenches must be constructed along with a temporary excavated storage area. All dirty water runoff will then be captured and contained within the temporary storage facility;
- Haul roads must be well compacted to avoid erosion of the soil into the streams; and

- Dust suppression on the haul roads and cleared areas must be regularly undertaken.

#### 6.2.1.3 *Impact Ratings*

**Table 6-5: Siltation of Surface Water Resources**

| **IMPACT DESCRIPTION: Siltation of surface water resources leading to deteriorated water quality** | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| ***PRE-MITIGATION*** | | | |
| Duration | Medium term (3) | Equal to the duration of the construction phase | Significance: Minor - negative (-70) |
| Extent | Local (3) | The impacts will be localised to the nearby water resources from where the silt is being generated and the immediate downstream | |
| Intensity x type of impact | Moderately high - negative (-4) | This will have moderate impacts resulting in a, limited ecosystem functionality for downstream users | |
| Probability | Certain (7) | Without appropriate mitigation, there will definitely be dust generated and this will be in large amounts | |
| ***Mitigation/ Management actions*** | | | |
| - -Clearing of vegetation must be limited to the project site<br>- The construction phase must be prioritised to the dry months of the year (May-October)<br>- Within the cleared area along the downstream boundary, temporary trenches must be constructed along with a temporary excavated storage area<br>- Haul roads must be well compacted to avoid erosion of the soil into the streams<br>- -Use dust suppressants | | | |
| ***POST-MITIGATION*** | | | |
| Duration | Medium term (3) | As for pre-mitigation | Significance: Minor - negative (-36) |
| Extent | Local (3) | As for pre-mitigation | |
| Intensity x type of impact | Moderate - negative (-3) | Mitigation will reduce the impacts | |
| Probability | Probable (4) | Mitigation will reduce the erosion and thus siltation sources probability significantly | |

## 6.3 Operational Phase

### 6.3.1 Operational Mining Activities

Activities that may have surface water impacts during the operational phase include development of two open pits by drilling and blasting, truck and shovel methods, development of one waste rock dump, concentrator plant including crushing, grinding and screening, hauling of waste rock and including construction of a Tailings Storage Facility.

**Table 6-6: Interactions and Impacts of Activity**

| Interaction | Impact |
|---|---|
| Runoff from the dirty water areas (dumps, plant area, etc.) | Runoff reporting into the rivers resulting in water contamination. |
| Development of Surface Infrastructure (Stockpiles, Workshops, Office, Dams etc.) | Reduction of Catchment Yield |

#### 6.3.1.1 *Surface Water Quality Impacts*

Blasting during the operational phase releases ammonium nitrate from the explosive residue. This chemical contaminates the water in the pit and can potentially contaminate the streams if water is discharged into the natural environment. Nitrate and ammonia from blasting residues can lead to eutrophication (nutrient enrichment) of water bodies. They may also be converted into toxic nitrite. Ammonia ($NH_3$ as opposed to $NH_4^+$) is highly toxic to fish and many aquatic organisms at even low (µg/L) concentrations.

Dirty water runoff from the contaminated surfaces and the infrastructure within the 1:100 year floodline in the mine (dumps, plant area, etc.) has the potential to contaminate and silt up the natural water resources (Borobela and the Mogalakwena Rivers and various unnamed tributaries). Infrastructure within the 1:100 year floodline include dirty water trench, lower grade stockpile, southern end of Pit 1, tailings dam, site road and storm water dam (see section 4.6), this impact will therefore deteriorate the water quality and hence impact the downstream water users.

#### 6.3.1.2 *Management/ Mitigation Measures*

These impacts can be prevented and/or reduced by implementing the following measures:

- All the dirty water emanating from the dirty water areas must be stored in the PCD's for re-use within the mine so as to prevent unnecessary discharge into the environment;
- Should the contained water be more than the water use requirement, the Best Practice Guidelines (BPGs) advise that the water be recycled or as the last resort be treated to acceptable levels and discharged either to the natural environment or be supplied to other industries as a lower grade of water;

- Based on GN704 requirements regarding storm water management for mining activities it is noted that all clean and dirty water must be separated. Therefore, clean water emanating from upstream of the mine will be diverted away and discharged to the nearby watercourse or environment, while dirty water emanating from the mine area needs to be captured and contained. The clean water and dirty water controls must be sized to accommodate the 1:50 year storm event (GN 704, 1999);
- All runoff emanating from the dirty water areas which include, low grade stockpiles, high grade stockpiles, plant area, waste rock dump will need to be conveyed first to a silt trap before entering the containment facility e.g. PCD and the storm water dam, see Plan 7;
- The removed topsoil must be covered or vegetated as soon as possible to prevent sediment erosion;
- Two diversions were identified, one located upstream of Pit 1, while the other located along the north western boundary of the tailings dam. The diversions need to be sized to accommodate the 1:100 year storm event, this will prevent flooding of infrastructure during a 1:100 year storm event (please see Plan 7, Appendix B for the Storm Water Management Plan layout);
- Proposed mitigation measures for flooding include a river diversion located alongside the north-western boundary of the existing TSF (see Plan 7, Appendix B), increasing the culvert capacity of the culvert (C01) located along Tributary E, repositioning of the lower grade stockpile southwest of the Borobela River, and a river diversion located upstream of Pit 1, to capture and convey runoff around the eastern boundary of pit 1 into the Borobela River (Plan 7);
- The river diversion shown as “river diversion 15 – 16” (Plan 7) should be designed to cater for the 1:100 year peak discharge of 23 $m^3$/s. The river diversion needs to extend from the upstream culvert located at node 15 to the downstream culvert on the D4387 road, at node 16. During final design, energy dissipation structures should be constructed at the outlet of the channel, so as to cater for high velocities due to the river diversion;
- At culvert C01 the capacity needs to be increased. This is due to cross sectional drainage profile of Tributary E being insufficient to contain the 1:100 year discharge. As a result overbank flow occurs on the right bank, flooding the south eastern portion of the tailings dam area, while extending further southwest. The culvert C01 therefore needs to be sized to safely handle the 1:100 year peak flow (129.03 $m^3$/s);
- Repositioning of the lower grade stockpile southwest of the Borobela River is required, as flood inundation is anticipated (Plan 6, Appendix B). It is therefore recommended that the mentioned infrastructure falls outside of the demarcated 1:100 year floodline or 100 m buffer, whichever is greater; and
- A river diversion is required to be constructed along the eastern boundary of Pit 1, so as to prevent flooding of the pit. This diversion is to be sized to contain the 1:100

year flood event which amounts to 16.85 $m^3$/s. The mentioned river diversion is shown as “river diversion 9 – 10” (Plan 7).

#### 6.3.1.3 Surface Water Quantity Impacts

Containment of dirty water runoff from the construction site and the construction of pits will reduce the amount of runoff reporting to the surrounding rivers (Borobela River and the two unnamed tributaries of the Mogalakwena River). A decrease in the catchment yield may have an impact on the downstream water users as they may not have sufficient water for their needs, while also decreasing the flows required for the ecological reserve.

The infrastructure footprint area (2.50 $km^2$ and 3.25 $km^2$) makes up less than 1 percent of total catchment of 585 $km^2$ and 529 $km^2$.respectively. The percentage decrease in MAR amounts to 0.27% and 0.46% for quaternary catchments A61G and A62B respectively. This accounts for a loss of between 1.3 L/s and 2.2 L/s for quaternary catchments A61G and A62B respectively.

Therefore, the loss in MAR for both quaternary catchments (A61G and A62B) is considered to be insignificant.

#### 6.3.1.4 Impact Ratings

**Table 6-7: Water Contamination**

| **IMPACT DESCRIPTION:** Runoff reporting into the rivers resulting in water contamination. | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| ***PRE-MITIGATION*** | | | |
| Duration | Medium term (3) | Impact can be minimised with management | Significance: Minor - negative (-70) |
| Extent | Local (3) | Impact from erosion could be felt at local streams not ignoring the fact that sediments can settle | |
| Intensity x type of impact | Moderately high - negative (-4) | The impact has moderate intensity as it can be corrected over shorter period of time | |
| Probability | Certain (7) | Erosion will take place as long as it rains on a bare ground | |
| ***Mitigation/ Management actions*** | | | |
| ▪ All the dirty water emanating from the dirty water areas must be stored in the PCD’s for re-use<br>▪ All runoff emanating from the dirty water areas should be conveyed first to a silt trap before entering the containment facility | | | |
| ***POST-MITIGATION*** | | | |
| Duration | Medium term (3) | As mitigation is implemented, the erosion will be limited to the times of operation of each small site | Significance: Minor - negative (-36) |

| | | | |
|---|---|---|---|
| Extent | Local (3) | Impact limited to the smaller areas cleared and not yet rehabilitated each time | |
| Intensity x type of impact | Moderate - negative (-3) | Mitigation will reduce the intensities of the occurring erosion | |
| Probability | Probable (4) | Mitigation will not completely stop erosion but will significantly reduce | |

**Table 6-8: Reduction of Catchment Yield**

| **IMPACT DESCRIPTION:** Reduction of Catchment Yield | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| ***PRE-MITIGATION*** | | | |
| Duration | Medium term (3) | Impact can be minimised with management | Significance: Minor - negative (-42) |
| Extent | Limited (2) | Water resources and users affected will be within the rivers within the sub catchments | |
| Intensity x type of impact | Very low - negative (-1) | The impacts can be very small as the levels of runoff are expected to be very small based on the MAP and area covered by infrastructure | |
| Probability | Certain (7) | Catchment yield reduction is inevitable, however the small the scale is. | |
| ***Mitigation/ Management actions*** | | | |
| ▪ River Diversion should be implemented to reduce the clean water lost by diverting it away from operations. | | | |
| ***POST-MITIGATION*** | | | |
| Duration | Medium term (3) | Impacts will occur occasionally hence will most likely not last as long as the life of mine | Significance: Minor - negative (-42) |
| Extent | Limited (2) | This will be limited to the project area infrastructure area | |
| Intensity x type of impact | Very low - negative (-1) | Same with pre mitigation | |
| Probability | Certain (7) | The impact will occur in any case. | |

### 6.3.2 Closure and Rehabilitation

Activities during this phase include dismantling and removal of major equipment and infrastructure, rehabilitation of disturbed areas including stockpile dumps and pits, partial backfilling of the open pits using 80% of the waste rock produced and post-closure monitoring.

**Table 6-9: Interactions and Impacts of Activity**

| Interaction | Impact |
|---|---|
| Exposure of soils after with the removal of infrastructure | Siltation of surface water resources leading to deteriorated water quality. |
| Runoff from the formerly dirty areas improving after rehabilitation dirty water areas (closure phase, etc.) and thus reduced sources of erosion | Reduction of contamination of watercourses by dirty water runoff. |

#### 6.3.2.1 *Surface Water Quality Impacts*

Removal of infrastructure exposes the surface and leaves it prone to erosion, that may result in siltation of the natural water resources (Borabela and the Mogalakwena Rivers and various unnamed tributaries) when runoff reports to these rivers. Dirty water runoff from the contaminated surfaces in the mine can lead to contamination of river water. Overflow from the partially backfilled voids may also contaminate the surrounding rivers. This will deteriorate the water quality and hence impact the downstream water users as well as the aquatic life.

These impacts can be prevented and/or reduced by implementing the following measures:

- Use of accredited contractors for removal or demolition of infrastructures must be ensured;
- Surface inspection on the fully rehabilitated areas must be undertaken to ensure a surface profile that allows good drainage. This will ensure improvement or increased catchment yield on to the surrounding streams;
- Where rehabilitation (grass seeding of topsoil cover) is not effective, sedimentation should be mitigated by installing silt traps at areas where the surface runoff enters the surface water resources; and
- The river diversions done during construction (as indicated in section 5) will have to remain until post closure. This will ensure that rivers do not flow through the contaminated areas as this will have an impact on the water quality.

#### 6.3.2.2 *Impact Ratings*

**Table 6-10: Water Contamination**

| **IMPACT DESCRIPTION:** Siltation of surface water resources leading to deteriorated water quality. | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| ***PRE-MITIGATION*** | | | |
| Duration | Long term (4) | Equal to the duration of the construction phase | Significance: Minor - negative (-70) |
| Extent | Municipal Area (4) | The impacts will be localised to the nearby water resources from where the silt is being generated and the immediate downstream | |
| Intensity x type of impact | Very high - negative (-6) | This will have moderate impacts resulting in a, limited ecosystem functionality for downstream users | |
| Probability | Likely (5) | Without appropriate mitigation, there will definitely be dust generated and this will be in large amounts | |
| ***Mitigation/ Management actions*** | | | |
| ▪ Use of accredited contractors for removal or demolition of infrastructures must be ensured<br>▪ Surface inspection on the fully rehabilitated areas must be undertaken to ensure a surface profile that allows good drainage<br>▪ Where rehabilitation (grass seeding of topsoil cover) is not effective, sedimentation should be mitigated by installing silt traps<br>▪ The river diversions done during construction (as indicated in section 5) will have to remain until post closure | | | |
| ***POST-MITIGATION*** | | | |
| Duration | Medium term (3) | As for pre-mitigation | Significance: Negligible - negative (-27) |
| Extent | Local (3) | As for pre-mitigation | |
| Intensity x type of impact | Moderate - negative (-3) | Mitigation will reduce the impacts | |
| Probability | Unlikely (3) | Mitigation will reduce the erosion and thus siltation sources probability significantly | |

**Table 6-11: Siltation of Surface Water Resources**

| **IMPACT DESCRIPTION:** Reduction of contamination of watercourses by dirty water runoff. | | | |
|---|---|---|---|
| **Dimension** | **Rating** | **Motivation** | **Significance** |
| ***PRE-MITIGATION*** | | | |
| Duration | Medium term (3) | Positive benefits as the contamination source is removed | Significance: Minor - positive (36) |
| Extent | Local (3) | Benefits are limited to the local catchment | |
| Intensity x type of impact | Moderate - positive (3) | An ongoing positive benefit that is immediately felt on the nearby catchments of project where impacts was considerable | |
| Probability | Probable (4) | The realization of the benefit of decomissioning ill be felt if the decommissioning activities are implemented well | |
| ***Mitigation/ Management actions*** | | | |
| ▪ Use of accredited contractors for removal or demolition of infrastructures must be ensured | | | |
| ***POST-MITIGATION*** | | | |
| Duration | Medium term (3) | As for pre-mitigation | Significance: Minor - positive (45) |
| Extent | Local (3) | As for pre-mitigation | |
| Intensity x type of impact | Moderate - positive (3) | As for pre-mitigation | |
| Probability | Likely (5) | Use of accredited and experienced contractors will ensure that benefits are fully achieved | |

### 6.3.3 Unplanned Events and Low Risks

Accidental spillages of hazardous substances (e.g. hydrocarbons) from vehicles and other machineries during construction, operation and closure phase may cause an impact on water quality in the surrounding rivers (Borobela and Mogalakwena), should it enter.

There is a risk of flooding and subsequent damage to the mine infrastructure if placed within the 1:100 year floodline or 100 m buffer, whichever is greater. Infrastructure within the 1 in 100 year floodline include dirty water trench, lower grade stockpile, southern end of Pit 1, tailings dam, site road and storm water dam. This may lead to mobilisation of hazardous substances from the mine area and impact on the river water quality.

#### 6.3.3.1 *Measures to Limit the Chances of Unplanned Risks to Occur*

Management measures regarding the maintenance of all mine vehicles must be undertaken. This will ensure that any spillages or leakages of fuel and oil are reduced.

The fuel, lubricant and explosives storage facilities must be located on a hard standing area (paved or concrete surface that is impermeable), roofed and bunded in accordance with SANS1200 specifications. This will prevent mobilization of leaked hazardous substances. An emergency spillage response plan should be in place and accessible to the responsible monitoring team. The Material Safety Data Sheets (MSDS) should be kept on site for the Life of Mine for reference to anytime in terms of handling, storage and disposal of materials.

The river diversions shown as "river diversion 9 – 10" (Plan 7) has to be implemented to prevent flooding of the pit. Repositioning of the lower grade stockpile southwest of the Borobela River is also required, as flood inundation is anticipated (Plan 6, Appendix B).

## 6.4 Cumulative Impacts

Negative water quality impacts can result in deterioration of the surface water systems. The project infrastructure falls within quaternary catchments A61G and A62B. All runoff draining from the project area will eventually report to the downstream Mogalakwena River.

It is important to note that within and around the project area a number of surface water uses exist namely, livestock watering, domestic uses, irrigation and mining. These existing activities/ land uses already pose a risk to the surface water resource quality.

A surface water monitoring plan was developed which looked at the current baseline conditions of the Mogalakwena River at specific points where runoff emanating from the project area drains into the Borobela River and other unnamed tributaries. The monitoring plan is indicated in (Plan 7, Appendix B).

The baseline water quality results indicated that the overall surface water quality of the upstream, within and downstream of the project area falls within the recommended water quality guideline limits (Class I – SANS 241-1:2011). However, when comparing the water quality sampling results against the SAWQGs for SW01, SW02, SW03 and SW05, ammonia limits were exceeded, while in SW04 the pH limit was exceeded.

There are several sources of ammonia which can either result from natural activities such as decaying organic matter, the natural geology or anthropogenic activities such as from human and animal excretion, which could be occurring in the area. Furthermore, runoff from livestock and crop farming, and from built up areas such as Mokopane, Sekgagapeng, Maroteng and Ga-Pila and their surrounding industrial areas are also likely to contribute to the high ammonia levels. The negative impacts identified in this assessment will not necessarily result in non-existent impacts in terms of ammonia, as cumulative impacts can arise if the pit water exposed to nitrate rich water is released to the surface water system and possibly increase the nitrate concentration in the Mogalakwena River.

Mining activities upstream were identified; however, the baseline water quality does not show evidence of significant impacts from these upstream mining activities such as elevated sulfates, heavy metals, trace elements or pH. For that reason, in terms of other elements, the activities could potentially introduce new impacts to the catchment. The proposed Magnetite Mine will therefore need to strictly abide to the mitigation measures presented in this report and ensure that there is zero discharge of dirty water. This will prevent water quality within the Mogalakwena River from deteriorating and adding to subsequent cumulative impacts.

The water use needs will add to the water demand of the catchment, thus water demand and supply management will be important. In addition to the potential impacts from the mining on water quality, the dewatering of the pit could alter the surface water quantity in the stream hence any identified mitigation measures prescribed through groundwater models should be adhered to, so as to prevent cumulative impacts.

# 7 Surface Water Monitoring Programme

A monitoring programme is essential as a management tool to detect negative impacts as they arise and to ensure that the necessary mitigation measures are implemented. It also ensures that storm water management structures are in working order. Monitoring should be implemented throughout the life of the mine. The impacts on water quality will be determined by comparing the monitoring data against the SANS 241-1:2011 drinking water quality standards, as well as the South African Water Quality Guidelines for Agricultural Use: Irrigation (DWAF, 1996), and the General Resource Water Quality Objectives (DWS, 2011).

Water quality monitoring is recommended at the locations provided in Table 2-10 and indicated in Plan 5, Appendix B.

The surface water monitoring plan is detailed in Table 7-1.

## Table 7-1 : Surface Water Monitoring Programme

| Monitoring Element | Comment | Frequency | Responsibility |
|---|---|---|---|
| Water quality | Ensure that monitoring is implemented to cover all mining activity areas. Recommended monitoring sites are shown in Plan 5.<br>Water quality parameters that need to be analysed are shown in Table 2-11. | -Monthly during construction.<br>- Reduce to quarterly on rehabilitated areas.<br>- This can further be reduced to biannually (wet and dry season) when most of the project area is rehabilitated.<br>-Monitoring needs to carry on three years after the project has ceased, as is standard practice to detect residual impacts. | Environmental Officer |
| Water quantity | Flow monitoring should be carried out in channels and pipelines and at facilities on site just before the water enters the storage ponds and PCDs from the channels at nodes<br>Monitoring water levels in dams and channels by visual assessments along the channels<br>Records of Pit dewatering volumes to inform the water balance | -Instantaneous where automatic flow meters are in place for real time measurements.<br>-Where there are no automatic flowmeters weekly monitoring needs to be done.<br>-In operational areas, daily records need to be kept. | Environmental Officer |
| Physical structures and SWMP performance | Personnel should have a walk around facilities to determine the facilities conditions and pick out any anomalies such as leaks or overflows and system malfunctions. | As often as is possible, most preferable daily | Environmental Officer |
| | Dams are inspected for silting and blockages of inflows, pipelines for hydraulic integrity; monitor the overall SWMP performance. | Quarterly or monthly with the general maintenance schedule at the mine | |

| Monitoring Element | Comment | Frequency | Responsibility |
|---|---|---|---|
| Meteorological data | Measure rainfall | Real time automatic weather system if in place, otherwise collect rainfall readings after every rainfall event | Environmental Technician Sampler |
| Rehabilitation | Observe and monitor through visual assessments the vegetation growth in the rehabilitated sites | Depends on growth cycle of planted vegetation, if monitoring for effectiveness of erosion control, monitor after rain events | Environmental Officer |

# 8 Consultation Undertaken

During the surface water site visit for sample collection, Digby Wells communicated with the Tribal Council and community people to gain access to their land. No stakeholder engagement took place during the study.

# 9 Comments and Responses

| | | | | | |
|---|---|---|---|---|---|
| The project may result in water pollution. | Abel Kotzé & Stephanus Kotzé | Trekdrift Boerdery BK (Bellevue Pt. 5) | 26 March 2015 | Registration & Comment Form | Surface and groundwater impact assessments have been undertaken, with the findings presented as part of the EIA Report. The studies assessed potential impacts on water quality and quantity, with respect to surrounding receptors. These studies developed and recommended mitigation and management plans to manage potential impacts to surface and groundwater resources.<br>A Stormwater management plan was compiled for the project (Section 5) based on GN 704 of the National Water Act no 36 of 1998 and DWS best practice guidelines. GN 704 ensures that all dirty water generated from the proposed mining activities is contained, whilst all clean water is diverted away to the downstream environment. Conceptual designs such as PCD sizes and anticipated peak discharges on channel sections are calculated; such that all dirty water (polluted water) emanating from the mine is contained and does not enter the downstream clean water environment.<br>The final drawdown cone extends approximately 1 km from the pit areas in the northern, southern |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | and eastern directions, limited by the hills located east and west of the pit areas. The dewatered extent at LOM extends approximately 1.5 km northwest of Pit 1, but does not impact on any groundwater users. |

| | | | | | |
|---|---|---|---|---|---|
| What will the radius of possible water impacts be? | H van Vuuren | Bellevue farmer / owner | 26 March 2015 | Village Meeting | Since the storm water management plan is designed for the 1:50 year storm event, spillages from the PCDs may be possible during the life of mine if a large storm event occurs. All PCDs however are to be managed such that they always have sufficient capacity to store the 1:50 year storm event, by ensuring water levels within each PCD are maintained at acceptable levels. Therefore with the implementation of the stormwater management plan, the radius of possible water impacts will be maintained to within the mine area.<br>The final drawdown cone extends approximately 1 km from the pit areas in the northern, southern and eastern directions, limited by the hills located east and west of the pit areas. The dewatered extent at LOM extends approximately 1.5 km northwest of Pit 1, but does not impact on any groundwater users. |

# 10 Conclusions

The project infrastructure falls within two quaternary catchment (A61G and A62B), with all runoff from these quaternary catchments eventually draining into the Mogalakwena River. The Project area has a MAP of 585 mm and a MAE of 1512 mm. It is concluded that all runoff from the project area drains into the Mogalakwena River, via the Borobela River and two unnamed tributary of the Mogalakwena River located on the north-western and south-western boundary of the proposed tailings dam.

The project area has steep topography in the upper reaches of the aforementioned river catchments where slopes can exceed 12%, however for the majority of the project area, slopes are flat to gentle and fall between 0 and 3%. The Arcadia soil form covers most of the project area (Soils, Land Capability, Land Use and Soil Stripping Plan - Digby Wells, 2015). This specific soil has a high clay content (greater than 55%), and a high infiltration capacity when dry due to the presence of large cracks, but once wet they begin to swell reducing permeability. The combination of flat topography and clay soils will likely result in ponding of surface water during extreme storm events.

Water quality was benchmarked against the SANS 241-1:-2011 drinking water standards, as well as the South African Water Quality Guidelines for Agricultural Use: Irrigation (DWAF, 1996), and the General Resource Water Quality Objectives (DWS, 2011):

Five water quality samples were taken on the 15th and the 16th January 2015., namely SW01, SW02, SW03, SW04 and SW05. The water quality samples were taken on the Sterk River and the Mogalakwena River. Sampling at the downstream Borobela River was not possible at the time of site visit due to it being dry.SW01 was taken on the Sterk River while SW02 to SW05 was taken on the Mogalakwena River. The Borobela River and the unnamed tributary of the Mogalakwena River were not flowing during the site visit, therefore no sampling was undertaken. The water quality results were benchmarked against the Water quality results have been benchmarked against the South African National Standards (SANS) 241-1: 2011 drinking water standards and the Department of Water and Sanitation's Resource Water Quality Objectives (General and Agricultural Use: Irrigation) and the results show the following:

When compared with the SANS 241-1:2011, the overall surface water quality of the collected samples falls within the recommended water quality concentration limits (Class I and II – SANS 241-1:2011).

When compared with the SAWQGs for Irrigation, SW04 and SW05 sample has shown high TDS concentration which exceeds the ideal standard for, whilst it was still below the maximum acceptable standard of 540 mg/L. The TDS are a measure of the quantity of various inorganic salts dissolved in water which is normally used as an indicator of the salinity of the water. The pH values for SW04 and SW05 sample also exceeded the maximum acceptable standards for irrigation. When compared with the SAWQGs (General), samples at SW02, SW03 and SW05 have shown elevated levels of ammonia concentrations which were above the SAWQG concentration limits. TDS, Chlorides and Calcium levels at SW04 and SW05 also exceeded the ideal standards whilst still within the acceptable standards.SW04 and SW05 have shown higher pH levels which are above the SAWQG's limits.

It is recommended to continue with the water quality monitoring, during construction, operational and post closure stages of the proposed mine. The proposed monitoring plan is indicated in Section 6.

A stormwater management plan was undertaken based on GN 704 of the National Water Act (NWA) no 36 of 1998, which relates specifically to the separation of clean and dirty water within a mining environment. The Storm Water Management Plan is based on GN 704 requirements and includes various proposed infrastructure. The infrastructure includes clean water diversion channels, dirty water channels, river diversions and PCDs.

Regarding the containment of dirty water runoff, two options are proposed:

- Option 1 requires additional PCDs over and above what was originally proposed with the dirty water runoff being gravity fed to the proposed PCDs; and

- Option 2 requires fewer but larger volume PCDs to be located centrally within the project area. The dirty water runoff may however have to be pumped to these PCDs, and not necessarily gravity fed as in option 1.

It should be noted that the sizing of the PCDs were only undertaken for option 1.

It was observed that flooding occurs on the south-western portion of Pit 1, the north-western and south-eastern boundary of the TSF and the north- western boundary of the return water dam. Flooding is primarily due to the flat topography associated with the project area, together with poorly defined drainage paths. It should be noted that only major culverts located directly on the modelled river/drainage path were modelled. Overbank flow occurs over most of the modelled rivers, specifically tributary E and tributary C (see Plan 6, Appendix B). This is due to the topography of the area being flat, resulting in flows not being contained within the rivers/drainage paths. The D4380 road which bisects the project area, causes backing up of flood waters due to the flat topography, the poorly defined drainage paths and insufficient capacity of the culverts/bridges in some areas, to cater for the 1 in 50 year and 1:100 year peak discharges.

The drainages on site were investigated during the site visit and indicated that the National Geo-Spatial CD:NGI, 2013 delineated rivers did not represent the on-site conditions accurately. A detailed DEM was used as input to the ArcHydro tool within ArcGIS to refine the drainage paths which was used in the flood model.

For the surface water impact assessment, the main impact is the potential flooding of the proposed infrastructure. As outlined earlier in the report flooding could potentially occur in the south-western portion of Pit 1, the north-western and south-eastern boundary of the TSF and the north-western boundary of the return water dam.

Proposed mitigation measures to address flood risk to the site include:

- A river diversion located alongside the north-western boundary of the existing TSF (see Plan 7);
- Increasing the culvert capacity of the culvert (C01) located along Tributary E (see Plan 6);
- Repositioning of the lower grade stockpile southwest of the Borobela River due to flood inundation (see Plan 6); and
- A river diversion located upstream of Pit 1 to capture and convey runoff around the eastern boundary of Pit 1 into the Borobela River (see Plan 7).

At culvert C01, the capacity needs to be increased. This is due to cross sectional drainage profile of Tributary E being insufficient to contain the 1:100 year discharge as per comment in executive summary. As a result overbank flow occurs on the right bank, flooding the south-eastern portion of the tailings dam area, while extending further southwest. The culvert C01 therefore needs to be sized to safely handle the 1:100 year peak flow (129.03 $m^3/s$).

Repositioning of the lower grade stockpile southwest of the Borobela River is required, as flood inundation is anticipated (see Plan 6). It is therefore recommended that the mentioned infrastructure falls outside of the demarcated 1:100 year floodline or 100 m buffer, whichever is greater.

A river diversion is required to be constructed along the eastern boundary of Pit 1 to prevent flooding into the mentioned pit. This diversion should be sized to contain the 1:100 year flood event which amounts to 16.85 $m^3/s$. The mentioned river diversion is shown as "river diversion 9 – 10" (see Plan 7).

The river diversion shown as "River diversion 15 – 16" and "River diversion 16 – 19" (see Plan 7), should be designed to cater for the 1:100 year peak discharge of 23.23 $m^3/s$ and 31.98 $m^3/s$ at section 15 – 16 and 16 – 29 respectively. The river diversion needs to extend from the upstream culvert located at node 15 to the downstream culvert on the D4380 road at node 29. During final design, energy dissipation structures should be constructed at the outlet of the channel, so as to cater for high velocities due to the proposed river diversion.

The finding of the surface water assessments, indicate that the project can go ahead with the relevant control measures being implemented in the form of monitoring, implementation of mitigation measures and rehabilitation. .

# 11 References

Brunner G.W. (2010): HEC-RAS – River Analysis System Hydraulic Reference Manual, US Army Corps of Engineers Hydrologic Engineering Centre (HEC)

Department of Water and Sanitation. Business Case for the Limpopo Catchment Management Agency.

DWAF. 2004. Crocodile (West) and Marico Water Management Area: Internal Strategic Perspective of the Marico-Upper Molopo & Upper Ngotwane catchments. Prepared by Goba

Department of Water and Sanitation (DWS), 2006. Best Practice Guideline series.

Department of Water Affairs and Forestry, (2006). Resource Directed Management of Water Quality: Management Instruments. Volume 4.2.1: Users' Guide: Resource Water Quality Objectives (RWQOs) Model (Version 4.0). Edition 2. Water Resource Planning Systems Series, Sub-Series No. WQP 1.7.2.1. ISBN No. 0-621-3675-8. Pretoria, South Africa.

Department of Water Affairs and Forestry (2007a). The Development of the Water Resource Classification System (WRCS). First Edition. Volume 1. Overview and 7–step classification procedure. Chief Directorate: Resource Directed Measures.

Department of Water Affairs and Forestry (2007b). The Development of the Water Resource Classification System (WRCS). First Edition. Volume 2. Ecological, hydrological and water quality guidelines for the 7-step classification procedure. Chief Directorate: Resource Directed Measures.

Government Notice 704 (GN704). Regulations on the Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources. Published in Government Gazette 20119.

Joint Limpopo River Basin Study scoping phase, January 2010. Final Report On behalf of the Limpopo Basin Permanent Technical Committee – LBPTC.

Joint Water Quality Baseline Report for Limpopo Basin between Botswana and South Africa 2011/12 Department of Water Affairs: Botswana Department of Water Affairs: South Africa

Lakes Environmental Software, 2015. AERMET_MET156291_Mokopane. (Accessed 12 June 2015). www.weblakes.com

Moahloli Keeve Steyn in association with Golder and Associates and Tlou and Matji (Pty) Ltd. DWAF Report No. PWMA 03/000/00/0404.

National Water Act (No 36 of 1998),

South African Bureau of Standards (SABS). 2011. South African National Standard: SANS 241-1:2011: Drinking Water.

Utility Programs for Drainage (UPD). 2007. Version 1.1.0. Developed by Sinotech cc. Available online: www.sinotechcc.co.za/software

Water Research Commission (WRC), 2005. Water Resources of South Africa.

# Appendix A: Declaration of Independence

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I, Sivan Dhaver as duly authorised representative of Digby Wells and Associates (South Africa) (Pty) Ltd., hereby confirm my independence (as well as that of Digby Wells and Associates (South Africa) (Pty) Ltd.) and declare that neither I nor Digby Wells and Associates (South Africa) (Pty) Ltd. have any interest, be it business, financial, personal or other, in any proposed activity, application or appeal in respect of Pamish Investments No. 39 (Pty) Ltd, other than fair remuneration for work performed, specifically in connection with the proposed Magnetite Mine Project, Limpopo Province.

**Full name:** Sivan Dhaver

**Title/ Position:** Hydrologist

**Qualification(s):** B.Sc. (Hons) Hydrology

**Experience (years):** 9 years

**Registration(s):** Pr Sci Nat

# Appendix B: Plans

Plan 1: Regional Setting

Plan 2: Infrastructure Layout

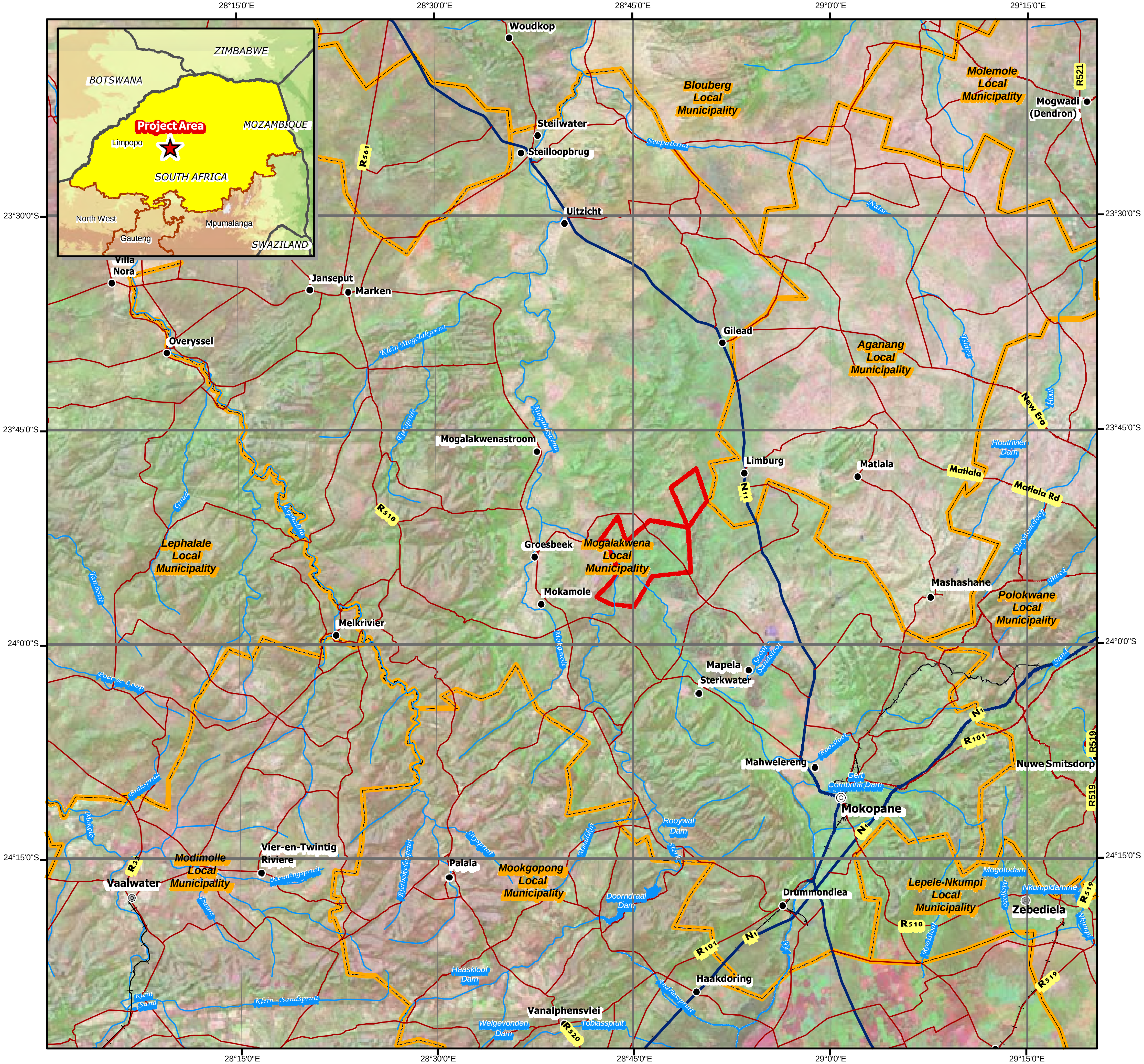
Plan 3: Quaternary Catchment

Plan 4: Site Drainage

Plan 5: Surface Water sampling points

Plan 6: Floodlines

Plan 7: Storm Water Management Plan




Plan 1

# Pamish Investments Magnetite Mine EIA

## Regional Setting

### Legend

- Project Area
- Secondary Town
- Other Town
- Settlement
- Main Road
- National Road
- Railway Line
- River
- Dam
- Local Municipal Boundary

DIGBY WELLS ENVIRONMENTAL

•Sustainability •Service •Positive Change •Professionalism •Future Focused •Integrity

Projection: Transverse Mercator
Datum: WGS 1984
Central Meridian: 29°E

Ref #: scm.VMC3049.201408.102
Revision Number: 1
Date: 20/08/2014

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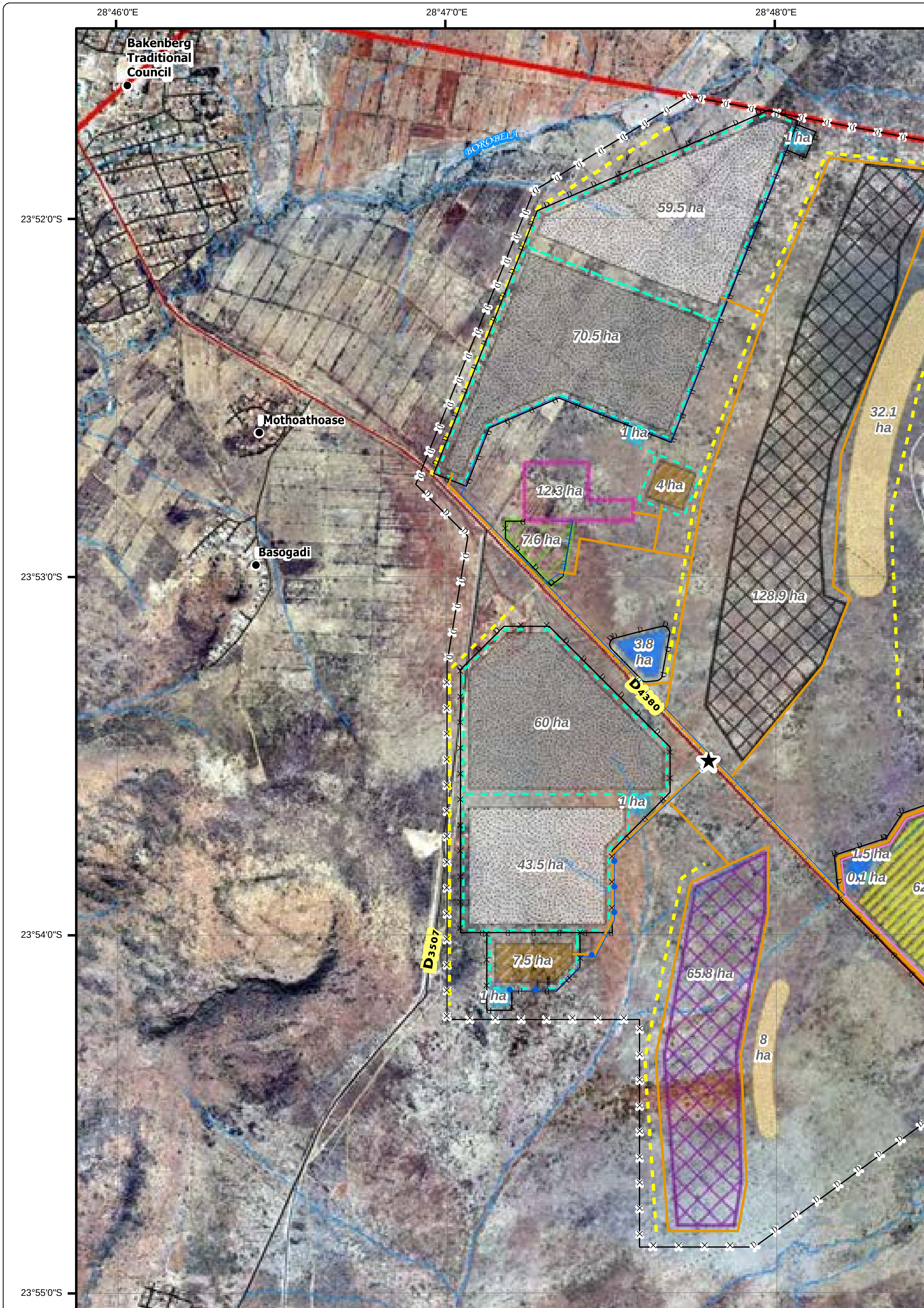
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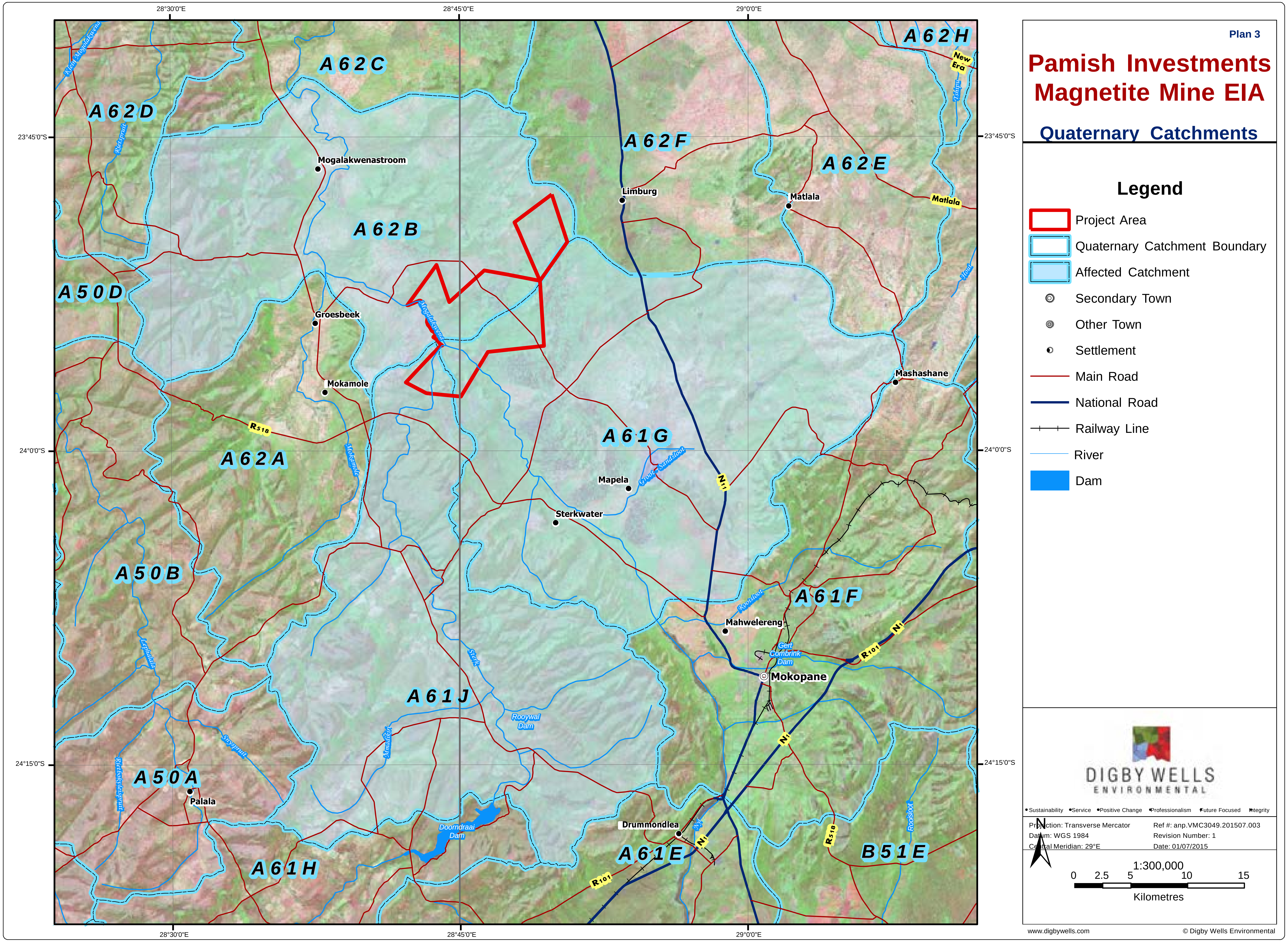
Plan 3
Pamish Investments Magnetite Mine EIA
Quaternary Catchments
Legend
Project Area
Quaternary Catchment Boundary
Affected Catchment
Secondary Town
Other Town
Settlement
Main Road
National Road
Railway Line
River
Dam
DIGBY WELLS
ENVIRONMENTAL
Sustainability Service Positive Change Professionalism Future Focused Integrity
Projection: Transverse Mercator
Datum: WGS 1984
Central Meridian: 29°E
Ref #: anp.VMC3049.201507.003
Revision Number: 1
Date: 01/07/2015
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A61J
A50A
A61H
A61E
B51E
Mogalakwenastroom
Limburg
Matlala
Matlala
New Era
Groesbeek
Mokamole
Mashashane
R518
Mapela
Sterkwater
Mahwelereng
Gert Combrink Dam
Mokopane
Rooywal Dam
Palala
Doorndraai Dam
Drummondlea
N11
N1
R101
R518
Groot Sandsloot
Mogalakwena
Mokamole
Rooisloot
Sterk
Mmadikiri
Sterkspruit
Lephalala
Rietspruit
Nyl


Plan 4

# Pamish Investments Magnetite Mine EIA

## Surface Water Sampling Points

### Legend

- Project Area
- Surface Water Sampling Points
- Settlement
- National / Arterial Route
- Main Road
- Minor Road
- Track
- Non-Perennial Stream (1:50 000 Topo Data)
- Perennial Stream (1:50 000 Topo Data)
- Dam Wall
- Dam / Lake
- Non-Perennial Pan / Stream

DIGBY WELLS ENVIRONMENTAL

•Sustainability •Service •Positive Change •Professionalism •Future Focused •Integrity

Projection: Transverse Mercator
Datum: WGS 1984
Central Meridian: 29°E

Ref #: anp.VMC3049.201507.004
Revision Number: 1
Date: 01/07/2015

N

Kilometres
1:80,000

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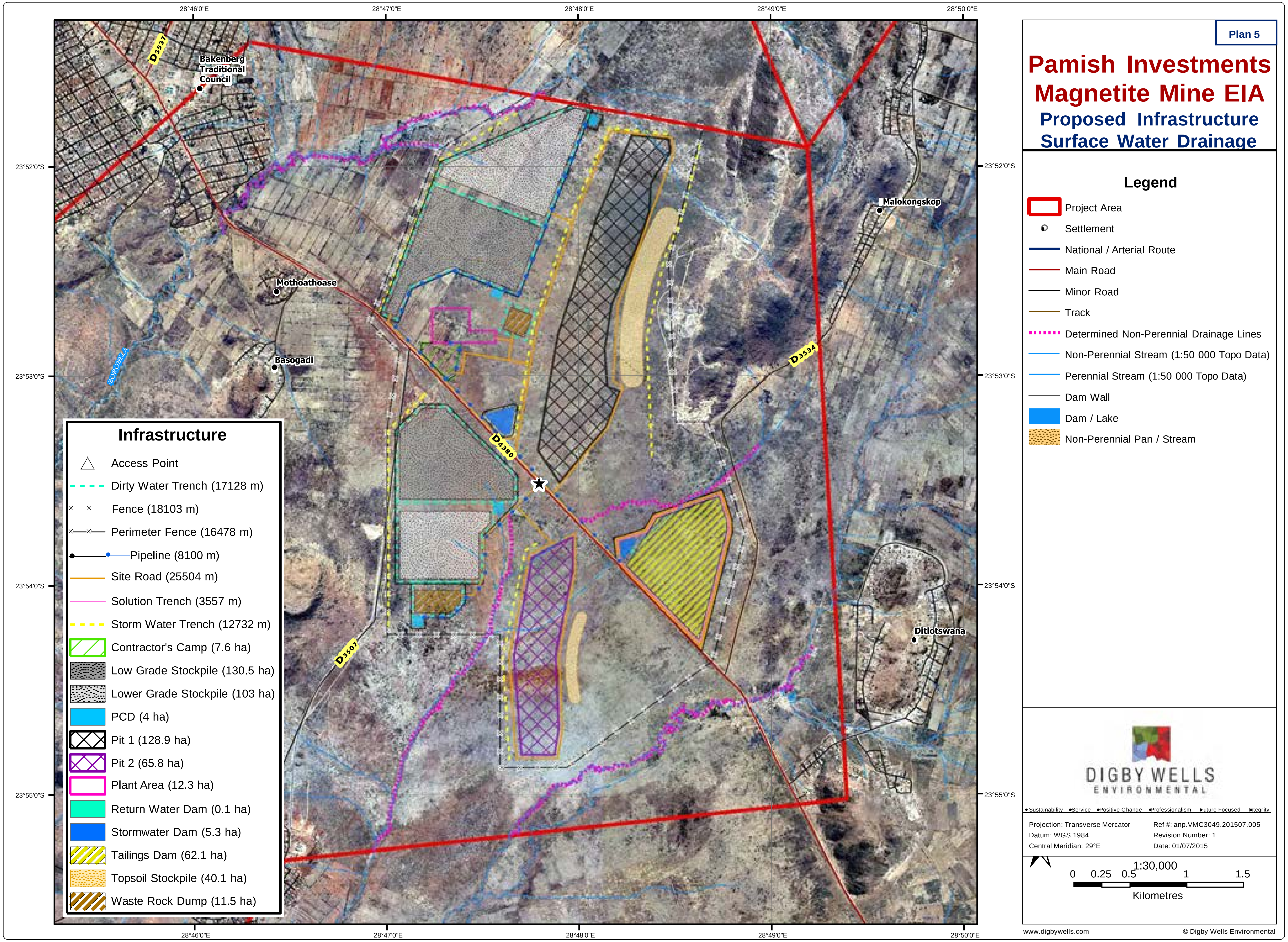

Plan 5
Pamish Investments Magnetite Mine EIA
Proposed Infrastructure
Surface Water Drainage
Legend
Project Area
Settlement
National / Arterial Route
Main Road
Minor Road
Track
Determined Non-Perennial Drainage Lines
Non-Perennial Stream (1:50 000 Topo Data)
Perennial Stream (1:50 000 Topo Data)
Dam Wall
Dam / Lake
Non-Perennial Pan / Stream
Infrastructure
Access Point
Dirty Water Trench (17128 m)
Fence (18103 m)
Perimeter Fence (16478 m)
Pipeline (8100 m)
Site Road (25504 m)
Solution Trench (3557 m)
Storm Water Trench (12732 m)
Contractor's Camp (7.6 ha)
Low Grade Stockpile (130.5 ha)
Lower Grade Stockpile (103 ha)
PCD (4 ha)
Pit 1 (128.9 ha)
Pit 2 (65.8 ha)
Plant Area (12.3 ha)
Return Water Dam (0.1 ha)
Stormwater Dam (5.3 ha)
Tailings Dam (62.1 ha)
Topsoil Stockpile (40.1 ha)
Waste Rock Dump (11.5 ha)
Bakenberg Traditional Council
Mothoathoase
Basogadi
Malokongskop
Ditlotswana
D3537
D4380
D3534
D3507
28°46'0"E
28°47'0"E
28°48'0"E
28°49'0"E
28°50'0"E
23°52'0"S
23°53'0"S
23°54'0"S
23°55'0"S
DIGBY WELLS ENVIRONMENTAL
Sustainability Service Positive Change Professionalism Future Focused Integrity
Projection: Transverse Mercator
Datum: WGS 1984
Central Meridian: 29°E
Ref #: anp.VMC3049.201507.005
Revision Number: 1
Date: 01/07/2015
1:30,000
0 0.25 0.5 1 1.5
Kilometres
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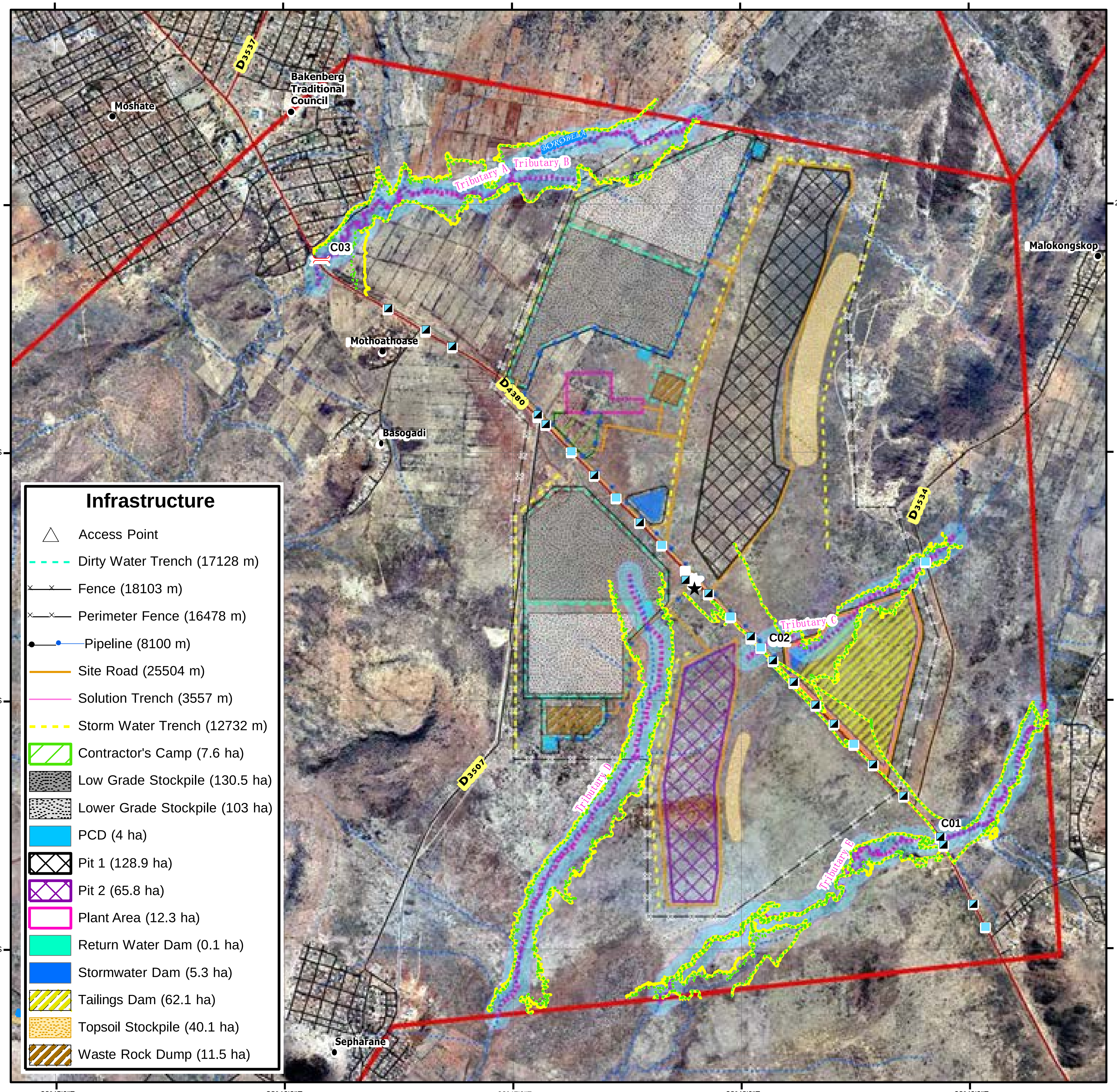
Plan 6

# Pamish Investments Magnetite Mine EIA

## Floodlines




### Legend

- Project Area
- Bridge
- Culvert
- Settlement
- Main Road
- Minor Road
- Track
- Determined Non-Perennial Drainage Lines
- Non-Perennial Stream (1:50 000 Topo Data)
- 100m Buffer of Watercourses

### Floodlines

- 1:50 Year Floodline
- 1:100 Year Floodline

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Projection: Transverse Mercator
Datum: WGS 1984
Central Meridian: 29°E

Ref #: anp.VMC3049.201507.006
Revision Number: 1
Date: 01/07/2015

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Kilometres

1:30 000

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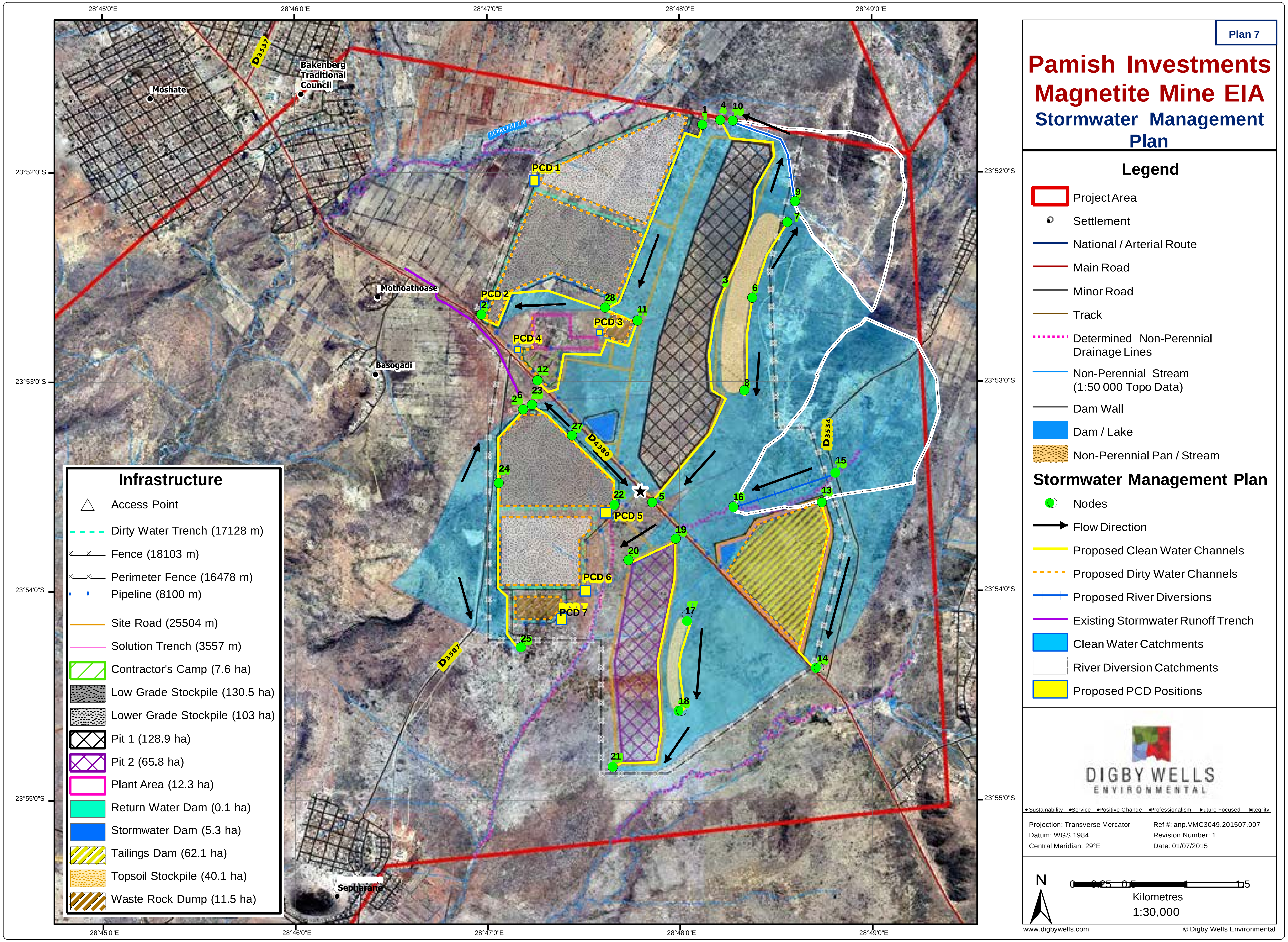
Plan 7
Pamish Investments Magnetite Mine EIA
Stormwater Management Plan
Legend
Project Area
Settlement
National / Arterial Route
Main Road
Minor Road
Track
Determined Non-Perennial Drainage Lines
Non-Perennial Stream (1:50 000 Topo Data)
Dam Wall
Dam / Lake
Non-Perennial Pan / Stream
Stormwater Management Plan
Nodes
Flow Direction
Proposed Clean Water Channels
Proposed Dirty Water Channels
Proposed River Diversions
Existing Stormwater Runoff Trench
Clean Water Catchments
River Diversion Catchments
Proposed PCD Positions
Infrastructure
Access Point
Dirty Water Trench (17128 m)
Fence (18103 m)
Perimeter Fence (16478 m)
Pipeline (8100 m)
Site Road (25504 m)
Solution Trench (3557 m)
Contractor's Camp (7.6 ha)
Low Grade Stockpile (130.5 ha)
Lower Grade Stockpile (103 ha)
Pit 1 (128.9 ha)
Pit 2 (65.8 ha)
Plant Area (12.3 ha)
Return Water Dam (0.1 ha)
Stormwater Dam (5.3 ha)
Tailings Dam (62.1 ha)
Topsoil Stockpile (40.1 ha)
Waste Rock Dump (11.5 ha)
Moshate
Bakenberg Traditional Council
Mothoathose
Basogadi
Sepharane
D3537
D4380
D3534
D3507
PCD 1
PCD 2
PCD 3
PCD 4
PCD 5
PCD 6
PCD 7
28°45'0"E
28°46'0"E
28°47'0"E
28°48'0"E
28°49'0"E
23°52'0"S
23°53'0"S
23°54'0"S
23°55'0"S
DIGBY WELLS ENVIRONMENTAL
Sustainability Service Positive Change Professionalism Future Focused Integrity
Projection: Transverse Mercator
Datum: WGS 1984
Central Meridian: 29°E
Ref #: anp.VMC3049.201507.007
Revision Number: 1
Date: 01/07/2015
N
0 0.25 0.5 1 1.5
Kilometres
1:30,000
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# Appendix C: Water Quality Results

aquatico Laboratories (Pty). Ltd.

## Test Report



**Client:** Digby Wells & Associates
**Address:** 359 Pretoria Ave, Fern Isle, Section 5, Ferndale, Randburg
**Report no:** 22424
**Project:** Digby Wells & Associates

**Date of certificate:** 23 January 2015
**Date accepted:** 19 January 2015
**Date completed:** 23 January 2015
**Revision:** 0

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Lab no:** | | | 199390 | 199391 | 199392 | 199393 | 199394 |
| **Date sampled:** | | | 15-Jan-15 | 15-Jan-15 | 15-Jan-15 | 15-Jan-15 | 15-Jan-15 |
| **Sample type:** | | | Water | Water | Water | Water | Water |
| **Locality description:** | | | SW01 | SW02 | SW03 | SW04 | SW05 |
| **Analyses** | **Unit** | **Method** | | | | | |
| A pH | pH | ALM 20 | 7.77 | 7.79 | 7.95 | 8.43 | 8.41 |
| A Electrical conductivity (EC) | mS/m | ALM 20 | 9.80 | 11.7 | 12.4 | 57.3 | 51.3 |
| A Total dissolved solids (TDS) | mg/l | ALM 26 | 78 | 86 | 84 | 371 | 339 |
| A Total alkalinity | mg $CaCO_3$/l | ALM 01 | 30.3 | 39.1 | 35.2 | 197 | 210 |
| A Chloride (Cl) | mg/l | ALM 02 | 11.3 | 11.9 | 11.0 | 53.7 | 51.0 |
| A Sulphate ($SO_4$) | mg/l | ALM 03 | 3.41 | 3.70 | 3.61 | 43.2 | 19.0 |
| A Nitrate ($NO_3$) as N | mg/l | ALM 06 | 0.549 | 0.325 | 0.351 | 0.295 | 0.308 |
| A Ammonium ($NH_4$) as N | mg/l | ALM 05 | 0.146 | 0.089 | 0.048 | 0.038 | 0.087 |
| A Orthophosphate ($PO_4$) as P | mg/l | ALM 04 | 0.148 | 0.033 | 0.032 | 0.042 | 0.032 |
| A Fluoride (F) | mg/l | ALM 08 | 0.134 | 0.091 | 0.133 | 0.522 | 0.672 |
| A Calcium (Ca) | mg/l | ALM 30 | 7.38 | 8.33 | 8.29 | 33.8 | 31.8 |
| A Magnesium (Mg) | mg/l | ALM 30 | 2.94 | 3.80 | 3.25 | 28.8 | 24.5 |
| A Sodium (Na) | mg/l | ALM 30 | 7.82 | 9.93 | 10.6 | 57.4 | 51.6 |
| A Potassium (K) | mg/l | ALM 30 | 3.33 | 2.45 | 2.43 | 4.31 | 3.85 |
| A Aluminium (Al) | mg/l | ALM 31 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 |
| A Iron (Fe) | mg/l | ALM 31 | <0.003 | <0.003 | <0.003 | <0.003 | <0.003 |
| A Manganese (Mn) | mg/l | ALM 31 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A Total chromium (Cr) | mg/l | ALM 31 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A Copper (Cu) | mg/l | ALM 31 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A Nickel (Ni) | mg/l | ALM 31 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A Zinc (Zn) | mg/l | ALM 31 | <0.002 | <0.002 | <0.002 | <0.002 | <0.002 |
| A Cobalt (Co) | mg/l | ALM 31 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A Cadmium (Cd) | mg/l | ALM 31 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| A Lead (Pb) | mg/l | ALM 31 | <0.004 | <0.004 | <0.004 | <0.004 | <0.004 |
| A Turbidity | NTU | ALM 21 | 21.0 | 23.9 | 39.2 | 22.8 | 22.7 |
| A Total hardness | mg $CaCO_3$/l | ALM 26 | 31 | 36 | 34 | 203 | 180 |
| N Suspended solids (SS) | mg/l | ALM 25 | 18 | 22 | 61 | 35 | 30 |
| N Vanadium (V) | mg/l | ALM 32 | <0.001 | <0.001 | <0.001 | 0.006 | 0.008 |

A = Accredited N = Non accredited O = Outsourced S = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine
The results relates only to the test item tested.
Results reported against the limit of detection.
Results marked 'Not SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory.
Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation.