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RI301-00183/40

MIDDELBURG FERROCHROME (MFC)
CLOSURE OF CDR SLIMES FACILITY DESIGN REPORT

Rev	Description	Date
08	Issued in Draft	10 June 2021

Knight Piésold
CONSULTING

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Middelburg Ferrochrome (MFC) is a production facility plant owned by Samancor located in Middelburg, Mpumalanga and is one of the largest chrome producers in the world. The process plant produces alloys that are transported to the ports of Durban and Richard's Bay for export to producers of speciality steel and stainless steel.

MFC was established in 1964 and during its operation a process known as Chrome Direct Reduction (CDR) was undertaken at MFC. This process involved a production of waste dust that was mixed with water that resulted in slimes material (slurry) that was required to be disposed. During the period of 1990 – 2000, the waste was deposited into a facility constructed by MFC known as CDR slimes facility which is licensed in terms of water use 21 (g) of the National Water Act, and the facility has been out of commission since the year 2000.

The CDR slimes facility has been dormant since 2000 and MFC have no intention to utilise the facility for any future works. MFC intends to apply for the decommissioning of the facility to the Department of Environment, Forestry and Fisheries (DEFF).

The purpose of this report is to provide a detail design of the safe removal and disposing of the CDR's waste to a suitable facility.

1.2 SCOPE OF WORKS

Knight Piésold (Pty) Ltd were appointed by Samancor Chrome to provide the closure design for the decommissioning of the facility. The scope of work for the design includes:

- Site investigation on the CDR facility
- Design of storm water interception system and passive water treatment.
- A review of the geochemical and geohydrological studies to assist with the design of interception infrastructure.
- The cover design post removal of the waste.
- Design drawings and Bill of Quantities study

This design report forms an Appendix to the Basic Assessment Report (BAR) submitted to the DEFF.

2.0 SITE CHARACTERISTICS

2.1 SITE LOCATION

The CDR facility is located on the farm Middelburg town and Townlands no 287 JS near Middelburg, Mpumalanga, on west of the Vaalbankspruit. **Table 2-1** below presents a summary of the pertinent location details for the site. **Figure 2-1** and **Figure 2-2** and presents the regional and local setting.

Table 2-1: Summary of Project Location Details

Province	Mpumalanga
District Municipality	Nkangala District Municipality
Local Municipality	Steve Tshwete Local Municipality
Nearest Town	Middelburg
Property Name and Number	Portion 280 of Portion 155 Middelburg town and Townlands no 287 JS
SG Number:	TOJS00000000028700280
GPS Co-ordinates (Relative centre point of CDR)	25° 48' 32.50" S
	29° 29' 7.35" E
Pre-Closure Land Use	Decommissioned waste facility on active industrial site
Final Land Use	Rehabilitated area on active industrial site

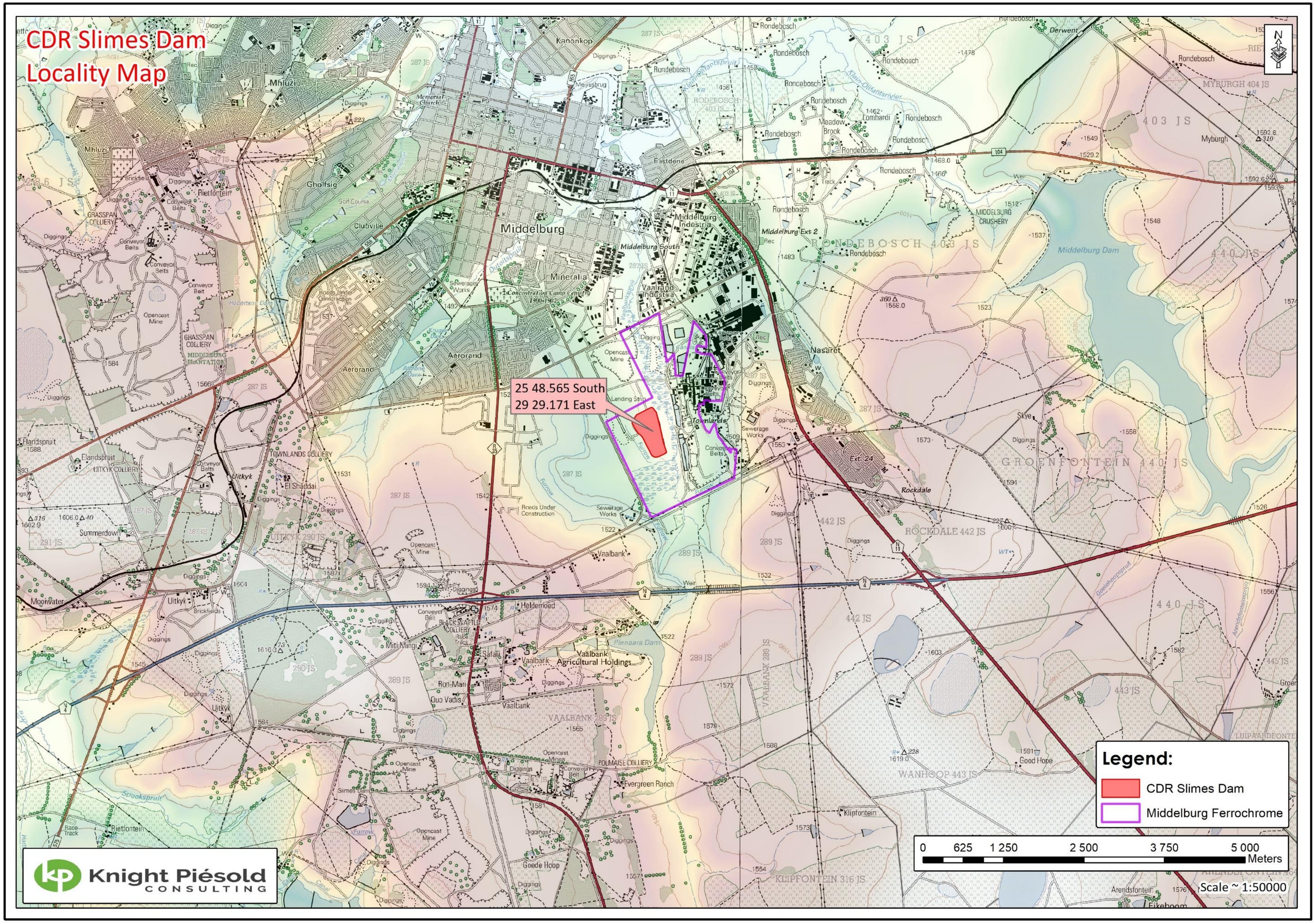

Figure 2-1: MFC Regional Locality

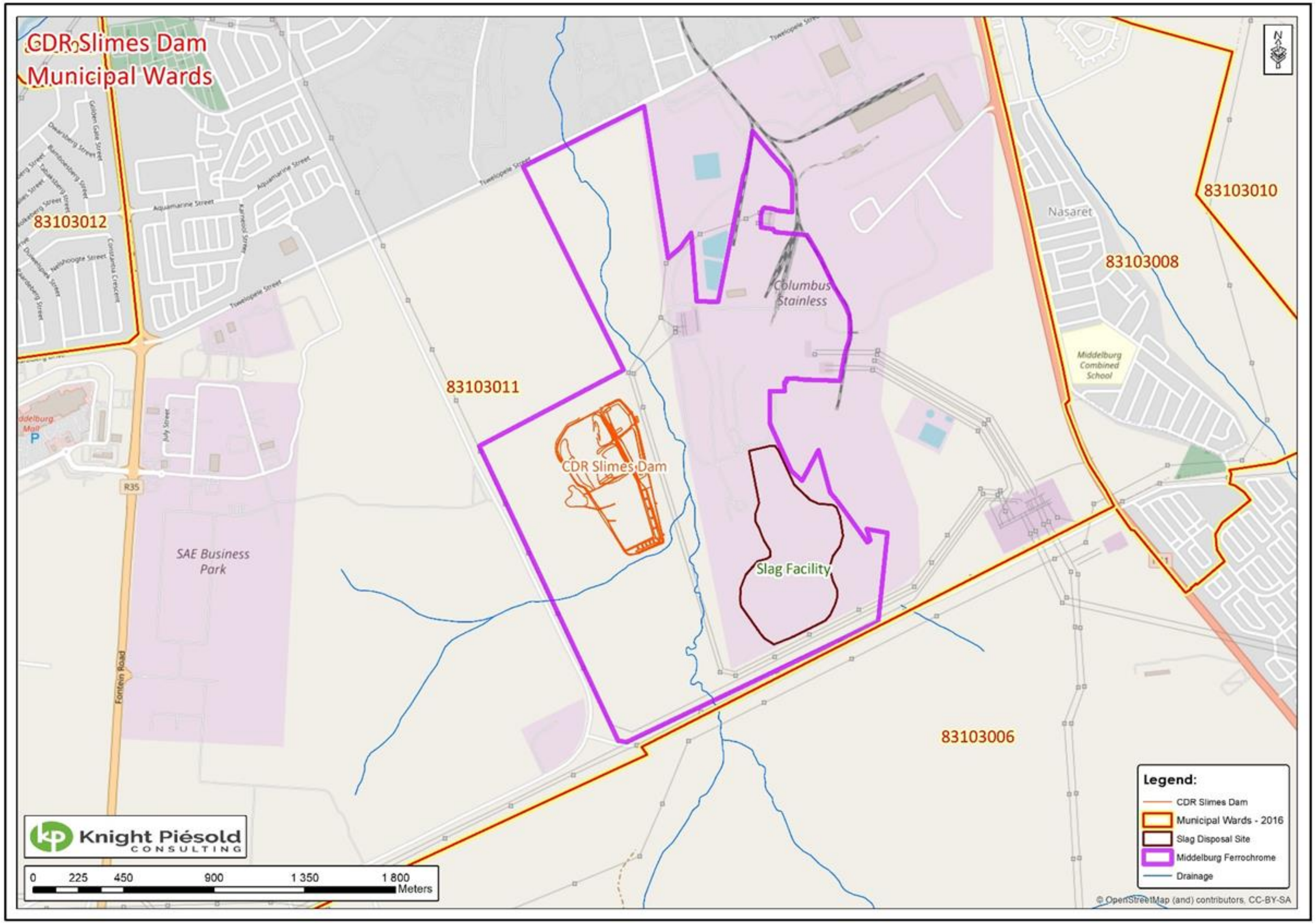

Figure 2-2: Local Setting in relation to Steve Tshwete Municipal Wards

2.2 SITE LAYOUT

The CDR Slimes Facility consists of following components, as shown in **Figure 2-3**:

- Two Paddocks:
  - Southern Paddock (slimes dam utilised until the year 2000)
  - Northern Paddock (unused slimes dam)
- Two Pollution Control Dams (PCD) located on the eastern side of Northern Paddock:
  - Return Water Dam
  - Storm Water Dam
- Toe paddocks to contain runoff from the outer slopes of the facility:
  - Toe paddocks are constructed around the east and south of the southern paddock dam.

Only the south paddock was used during the operational phase of the facility. It was calculated that there is 120 000 m^3 of CDR Slimes in the southern paddock. At an estimated density of 1,8 t/m^3 this equates to 216 000 tonnes.

The impoundment walls of the two paddocks are engineered earth walls with a maximum height of 5 m, crest width of approximately 4 m and side slope 1 in 2.5.

Shortly after cessation of deposition into the south paddock, a 150 mm thick capping layer of soil was placed over the CDR Slimes. This capping layer is now sparsely vegetated with grass. This can be found in drawing 301-00183-40-101.

A storm water cut-off channel was excavated around the western side of the CDR Slimes Facility to divert runoff from the catchment lying to the west around the north and south sides of the Facility.

The intention of MFC is to remove all the material that was deposited in the slime's facility, transfer the waste including any contaminated soil, to appropriately licenced facilities and , flatten the paddock walls to original site slopes. The aim is to remove the waste and restore the area.

The PCD's are intended to remain in-situ and they will be converted into clean water dams.

The complete site layout can be found in drawing 301-00183-40-100 in **Appendix A**.

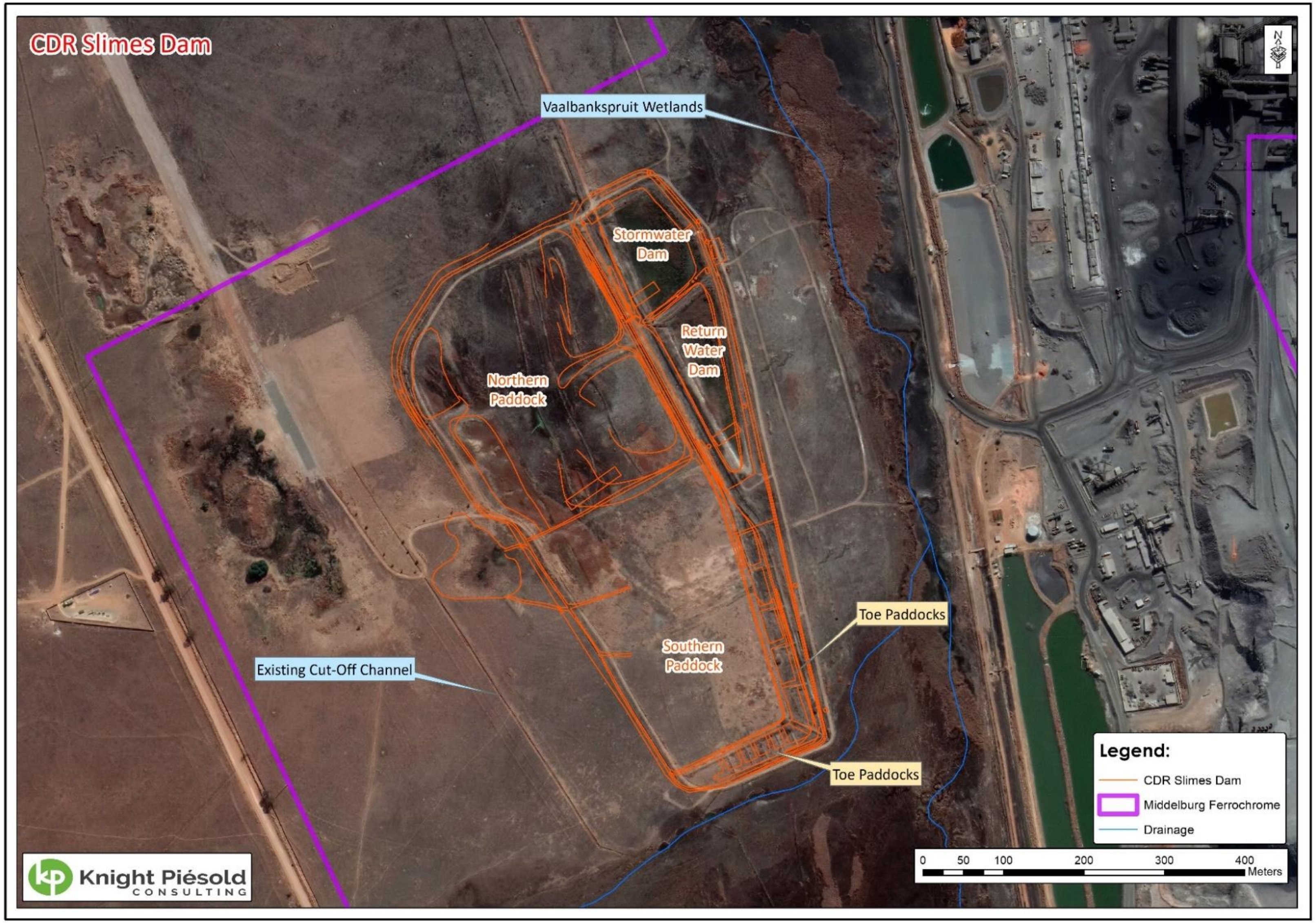

Figure 2-3: Aerial View of CDR Dump

2.3 CLIMATE

Middelburg is at the heart of the highveld and experiences summer rain (October to March) and cold winters (May to August). The maximum average temperatures are between 10℃ - 20℃. The cold winters (May to August) with very little rainfall. (Climate-Data.Org, 2021).

Table 2-2 shows the average climate temperatures received in Middelburg.

Table 2-2: Climate Conditions in Middelburg

Climate Details	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature (°C)	20.1	20	18.8	16.3	13.5	10.7	10.4	13.6	17.1	18.7	19	19.9
Min. Temperature (°C)	15.2	15.1	13.8	11	7.2	4.1	3.4	6.4	9.6	12	13.4	14.9
Max. Temperature (°C)	25.3	25.5	24.4	21.9	20	17.8	17.8	21.1	24.6	25.6	24.8	25.2
Precipitation/Rainfall (mm)	126	96	92	43	16	6	6	9	20	72	106	122
Humidity (%)	68	65	64	62	53	51	46	40	39	50	61	66
Rainy Days (d)	12	10	9	5	2	1	1	1	3	8	11	12

There is very high rainfall received in Middelburg during October to March and very little rainfall days between April to September. It is recommended that removal operation should be in the dry season because of the following reasons:

- High rainfall and possible storms events of 1 in 2 – 200 year could result in:
  - Run-off from the exposed waste,
  - Leachate/seepage due to ponding water or saturated waste,
  - Waste exposed for extended period due to the delays caused by the rainfall.
- Certain areas on site may become highly saturated which could result in plant and equipment getting stuck in the works.
- When waste (Type1 and Type 3) is deposited to licenced landfill could be delayed due to heavy rainfall because of the risks of spillage.

3.0 SITE INVESTIGATIONS & RECOMMENDATIONS

This section outlines extracts from different studies completed by other parties and Knight Piésold's evaluation.

3.1 GEOCHEMICAL ANALYSIS AND WASTE CLASSIFICATION

The geochemical analysis undertaken by Delta H Water Systems Modelling was carried out in 2020. Refer to Appendix H of the BAR for the full report. Delta H reports that five (5) borehole testing pits was drilled (MF1 to MF5) as shown in **Figure 3-1**, whereby nine (9) samples were taken at varying depths (0.0 – 5.0 m). The profiles confirmed both vertical and horizontal heterogeneity of the material (Delta H, 2020).

The boreholes were drilled with a push rig and retrieved with Shelby tubes which was done sent for geochemical analysis. The layering was found to be inconsistent between the different profiles as shown in **Table 3-1**. The variation in soil profiles and chemical compositions is due to the different furnace type and heat, steel grade, composition of raw material used as well as operational parameters.

Table 3-1: Core Logs for Borehole Samples (Delta H, 2020)

MF01			MF02		
Depth top (mbgl)	Depth bottom (mbgl)	Description	Depth top (mbgl)	Depth bottom (mbgl)	Description
0.00	0.15	brown top soil	0.00	0.10	brown top soil
0.15	0.20	dry, powdery black FC	0.10	0.80	interlayered dark-grey/black FC
0.20	1.00	dark grey, moist, clayey FC	0.80	1.00	moist black, powdery FC
1.00	1.20	grey/black fine interlayered FC, moist	1.00	1.20	dark grey, clayey FC
1.20	1.40	black FC	1.20	1.80	dark grey to black FC
1.40	1.80	grey and black interlayered FC	1.80	2.00	Grey, clayey FC
1.80	2.20	black FC, less moist	2.00	2.90	moist grey FC with black layers
2.20	2.80	weathered, clayey red-brown shale	2.90	3.00	moist, black FC
2.80	3.00	brown-orange weathered bedrock	3.00	5.00	interlayered weathered shale/mudst/sst
MF03			**MF04**		
Depth top (mbgl)	Depth bottom (mbgl)	Description	Depth top (mbgl)	Depth bottom (mbgl)	Description
0.00	0.15	reddish brown top soil	0.00	0.10	red-brown top soil
0.15	0.90	interlayered grey and dark grey, clayey FC	0.10	0.80	interlayered grey/dark grey, clayey FC
0.90	1.00	black FC	0.80	1.00	black FC
1.00	1.15	grey FC with thin, light-grey layers	1.00	1.40	interlayered dark-grey/grey/black FC
1.15	1.50	black FC	1.40	1.60	weathered bedrock grey-brown with nodules (rhyolite?)
1.50	2.30	weathered sst/mudst/shale	1.60	1.80	weathered orange-brown shale/sst
MF03					
Depth top (mbgl)	Depth bottom (mbgl)	Description			
0.00	0.20	reddish brown top soil			
0.20	0.40	interlayered grey and black FC			
0.40	0.70	black, powdery FC			
0.70	0.90	grey FC			
0.90	1.00	black FC			
1.00	1.80	grey, clayey FC			
1.80	2.00	light grey FC			
2.00	3.00	weathered, clayey bedrock (interlayered sst/ mudst/shale)			

Figure 3-1: Testing Locations on CDR Dam (Delta H, 2020)

According to Delta H (2020), and as shown in Tables 4-3 of their report, all samples exceeded the total concentrations (TCT0) (aqua regia) thresholds for Barium (Ba) and Lead (Pb). Samples that exceeded other TCTO limits are provided in **Table 3-2**.

Table 3-2: Samples that Exceeded TCTO Limits (Delta H, 2020)

Element	Samples that Exceeded the TCTO Limits
Barium (Ba)	All samples exceeded
Lead (Pb)	All samples exceeded
Cobalt (Co)	MF1 1-2m, MF2 0.5-1m, MF2 3-4m, MF3 0.5-1.5m, MF4 0.5-1.5m, and MF5 0.2-0.8m
Vanadium (V)	MF1 1-2m, MF2 0.5-1m, MF2 3-4m, MF3 0.5-1.5m, MF4 0.5-1.5m, and MF5 0.2-0.8m
Copper (Cu)	MF2 0.5-1m, MF2 3-4m, MF3 0.5-1.5m, MF4 0.5-1.5m, and MF5 0.2-0.8m
Manganese (Mn)	MF2 0.5-1m, MF2 3-4m, MF3 0.5-1.5m, MF4 0.5-1.5m, and MF5 0.2-0.8m
Chrome Total (Cr)	MF2 0.5-1m, MF3 0.5-1.5m, and MF4 0.5-1.5

Element	Samples that Exceeded the TCTO Limits
Nickel (Ni)	MF1 0-1m, MF1 1-2m, MF2 0.5-1m, MF3 0.5-1.5m, MF4 0.5-1.5m, MF5 0.2-0.8m and MF5 1-2m
Zinc (Zn)	MF2 3-4m
Cr(VI)	MF1 1-2m, MF2 2-2.5m, MF3 0.5-1.5m, MF4 0.5-1.5 and MF5 1-2m
Fluoride (F)	MF1 1-2m, MF2 2-2.5m, MF5 0.2-0.8m and MF5 1-2m

The following exceedances are noted for the distilled water leachable concentrations (1:20 ratio) as shown in **Table 3-3**.

Table 3-3: Exceedances for Distilled Water Leachable Concentrations (Delta H, 2020)

Element	Exceedances for Distilled Water Leachable Concentrations (1:20 ratio)	
	LCTO	LCT2
Chrome Total (Cr)	MF1 0-1m, MF1 1-2m, MF3 0.5-1.5m, MF4 0.5-1.5m, MF5 0.2-0.8m and MF5 1-2m	-
Cr(VI)	MF1 0-1m, MF1 1-2m, MF2 2-2.5m, MF5 0.2-0.8m and MF5 1-2m	MF3 0.5-1.5m
Total Dissolved Solids (TDS)	MF2 2-2.5m	-
Sulphate (SO4)	MF1 1-2m, MF2 0.5-1m, and MF2 2-2.5m	-
Fluoride (F)	MF2 3-4m, MF4 0.5-1.5m and MF5 0.2-0.8m	-

Based on the prescribed analysis of total concentrations and the distilled water leachate (1:20 solid to liquid ratio only) concentrations, the following classification was given:

The general exceedance of the total concentration thresholds TCT0 for Barium and Lead in all samples (i.e., TCT0 < TC<TCT1, as well as the other exceedances) along with all leachable concentrations below their LCT1 thresholds (i.e., LC <LCT1) for Cr total, Cr(VI), TDS, SO4 and F classifies all samples, except for sample MF3 0.5-1.5m, formally as Type 3 Waste. This waste type theoretically requires a Class C landfill design unless a risk assessment by a qualified person suggests otherwise. Only sample MF3 0.5-1.5m exceeded the LCT2 threshold for Cr(VI), classifying the sample as Type 1 Waste, requiring a Class A landfill design. The Cr(VI) concentration in the waste sample (MF3 0.5-1.5m) was found to be 5.1 which exceed the LCT2 level of 5.0 as shown in Table 3-3.

The chemical analysis on the samples taken and corresponding waste classification is shown in **Table 3-4**.

Table 3-4: Summary of Waste Classification for Nine (9) Samples Taken from CDR Dam (Delta H, 2020)

BH No.	Depth (m)	TCT	LCT	Waste Type	Disposal Landfill site
MF1	0 - 1	<TCT1	<LTC1	Type 3	Class C
MF1	1 - 2	<TCT1	<LTC1	Type 3	Class C
MF2	0.5 - 1	<TCT1	<LTC1	Type 3	Class C
MF2	2 - 2.5	<TCT1	<LTC1	Type 3	Class C
MF2	3 - 4	<TCT1	<LTC1	Type 3	Class C
MF3	0.5 - 1.5	<TCT1	<LCT3	Type 1	Class A
MF4	0.5 - 1.5	<TCT1	<LTC1	Type 3	Class C
MF5	0.2 - 0.8	<TCT1	<LTC1	Type 3	Class C
MF5	1 - 2	<TCT1	<LTC1	Type 3	Class C

The geochemical assessment of the five (5) CDR Slimes samples confirmed both the vertical and horizontal heterogeneity of the material observed in previous studies. This leads to variations in the classification of the waste type. Although the majority of the samples was classified as Type 3 Waste, some sections of the CDR Slimes disposal area exceeded the LCT2 threshold for Cr(VI). These could not be referenced to a particular horizon throughout the dump. It is recommended that a continuous sampling and testing be done during construction to identify different waste for the purpose of adequately handling and disposing the waste to relevant site.

3.1.1 PROPOSED ACTIONS

The presence of Cr(VI) in the material as proven to be the key concentration that influences the classification of the waste Type. The (Delta H, 2020) report recommends that the CDR Slimes should be classified spatially into areas of Type 3 and Type 1 waste, based on a sampling grid using total Cr(VI) as the criterion to identify areas of concern. Any material that is positively identified as:

- Type 1 waste must be removed to an appropriately licenced facility.
- Type 3 waste is proposed to be relocated to MFC's slag dump which is licenced to receive Type 3 waste (Licence number 12/9/11/L834/6)

The CDR Slimes facility pre-dates the current regulations, so no liner was installed in the basin of the facility. The facility is currently reliant on the 150 mm thick capping layer of soil to prevent ingress of rainwater and subsequent seepage into the underlying soil.

The procedure advised by (Delta H, 2020) for final closure of the CDR Slimes facility is to remove the waste from site and rehabilitate the disturbed ground. Delta H recommended a soil sampling after removal of the waste material to assess potential secondary sources. The soil sampling results will be used to inform if further classification of the in-situ material is required, and it will be used for determining the depth of excavation of in-situ material that came in contact with the waste.

3.2 GEOHYDROLOGY STUDY

3.2.1 GEOHYDROLOGY STUDY BY GOLDER ASSOCIATES

Geohydrology study was untaken by Golder in 2018 to define and confirm the potential impacts of the onsite contamination sources on groundwater as well as the potential impacts to the receptors (Golder Associates Africa, 2018). The full report is available in **Appendix C**. Golder ranked the CDR slimes facility out of other potential pollution sources:

- Northern paddock of CDR slimes facility as the 7th most likely source of groundwater contamination
- Southern paddock of CDR slimes facility as the 8th most likely source of groundwater contamination
- Historical return and storm water dams as the 9th most likely source of groundwater contamination

Borehole WD9, 15A and 17A are downstream of the CDR slimes facility and they did not indicate high concentration of Cr(VI) around the CDR facility. The borehole layout is shown in **Figure 3-2**.

Golder concluded that the CDR slimes facility was not considered to be the main source of groundwater contamination around the Middelburg plant.

Figure 3-2: Testing Locations for Groundwater Contamination (Golder Associates Africa, 2018)

3.2.2 GROUNDWATER ANALYSIS BY KNIGHT PIESOLD

This section contains a summary of the groundwater quality around the CDR slimes facility. The groundwater points are shown on **Figure 3-3**. Refer to Appendix H of the BAR for the table of groundwater quality results.

There are 38 groundwater testing points on site and the results from these points were compared against the SANS 241:2015 guidelines and the Department of Water Affairs and Forestry (DWAF) South African Water Quality Guidelines for Domestic Use (1996) (DWAF, 1996). The dataset used covers results from 2018: Quarter 1 to 4 (Q1 – Q4), 2019 Quarter 1 to 4 (Q1 – Q4), and 2020 Quarter 1 to 3 (Q1 – Q3).

The parameters that were analysed are: Electrical Conductivity (EC), pH, Calcium (Ca), Chloride (Cl), Nitrate and Nitrite (NO3 + NO2), Sulphate (SO4), Aluminium (Al), Hexavalent Chromium (Cr VI), Fluoride (F), Manganese (Mn) and Sodium (Na). There were no guidelines from these two standards for: Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Ammonia and Ammonium, therefore, they were could not analysed for exceedances.

The electrical conductivity (EC) was exceeded for both the SANS 241 guidelines and the DWAF guidelines. The SANS Aesthetic guideline limit of 170 mS/m was exceeded in more than half of the points. About 40 sites exceeded the EC DWAF guideline. The highest recorded electrical conductivity reading on the analysed data is 411 mS/m, obtained from point WD 8 in 2020 Q2.

The pH reading at seven sites exceeded the SANS 241 Operational guideline limit, and 3 of these sites also exceeded the DWAF guideline. The highest recorded pH is 9.92, obtained at WD 5 C in 2018 Q3. The SANS 241 standards do not have guidelines for calcium, therefore only the DWAF guidelines were used to analyse the results for calcium. The concentration of calcium exceeded the DWAF guidelines in more than 35 points, of which more than 14 had exceedances recorded for all their quarterly results.

The concentration of chlorine did not exceed the SANS 241 Aesthetic guideline limit of ≤300 mg/l at any of the sites. However, 11 of the sites exceeded the DWAF's 100 mg/l guideline, and two of these sites exceeded for all their quarterly readings (for the received data). The highest chlorine concentration (235 mg/l) was recorded at WD 7 from 2018 Q1. The concentrations of nitrate also did not exceed the SANS 241 guideline (200 mg/l). However, the DWAF guideline was exceeded at 8 sites, and the highest concentration was measured at WD 19 as 37.5 mg/l in 2018 Q2.

The SANS 241 Acute and Aesthetic guidelines for sulphate were both exceeded at more than 20 sites, with the highest concentration recorded as 2 132 mg/l at WD 8 in 2020 Q2. The DWAF guidelines were exceeded in more than 25 sites. There no exceedances recorded for aluminium and hexavalent chromium (Cr VI).

The DWAF guidelines were exceeded in more than 15 sites for fluoride; the SANS 241 guidelines were exceeded in more than 10 sites. In terms of manganese, no exceedance was recorded for the SANS 241 guidelines, however exceedances from 21 sites were recorded for the DWAF guidelines. The concentration of sodium exceeded the SANS 241 operational limit of ≤ 200 mg/l at 22 sites and exceeded the DWAF guidelines at more than 30 sites.

Figure 3-3: Groundwater Testing Points (Knight Piesold Consulting , 2021)

3.3 CONCLUSION OF SITE INVESTIGATION

The analysis and summary of the geochemical and geohydrology reports provided information about CDR facility and the impacts on the surrounding area of the plant boundary.

Delta H concluded that there is presence of Type 1 and Type 3 waste in the facility, most volume being Type 3 waste.. The main chemical compound found in the geochemical analysis that influenced the classification of the waste is hexavalent Chromium (Cr VI). Type 3 waste must be deposited into existing process plant operations (MFC slag disposal facility) located on the plant that is licensed to receive Type 3 waste and Type 1 waste must be removed and disposed to appropriately licensed Class 1 facility.

The geohydrology study conducted by (Golder Associates Africa, 2018) did not indicate ground water contamination caused by the CDR facility.

The groundwater analysis conducted by (Knight Piesold Consulting , 2021) considered results from a total of 38 groundwater points around the CDR facility were compared against SANS 241:2015 and DWAF (1996). The following were concluded:

- About 40 points exceeded the electrical conductivity required by DWAF guideline.
- The pH reading at seven points exceeded the SANS 241 Operational guideline limit, and 3 of these points also exceeded the DWAF guideline requirements.
- The SANS 241 Acute and Aesthetic guidelines for sulphate were both exceeded at more than 20 points.
- The DWAF and SANS 241 guidelines were exceeded in more than 15 and 10 sites for fluoride respectively
- The concentration of calcium exceeded the DWAF guidelines in more than 35 points, of which more than 14 had exceedances recorded for all their quarterly results
- In terms of manganese exceedances from 21 sites were recorded for the DWAF guidelines
- The concentration of sodium exceeded the SANS 241 operational limit of ≤ 200 mg/l at 22 sites and exceeded the DWAF guidelines at more than 30 sites
- There no exceedances recorded for aluminium and hexavalent chromium (Cr VI)

The analysis conducted by (Knight Piesold Consulting , 2021) does indicate that there is ground water contamination due to exceedances of DWAF and SANS 241 guidelines.

3.4 RECOMMENDATION

3.4.1 CLOSURE AND DECOMMISSIONING PLAN

The following recommendations are made:

i. Sample grid analysis should be done during construction to determine the type of waste found in the southern paddock taking Cr (VI) as the main constraint for classification.
ii. Type 1 waste should be removed from the plant to licensed landfill.
iii. Type 3 waste should be removed and deposited into MFC slag disposal licensed facility.

iv. Sampling of the soil is conducted and excavation of 500 mm deep of soil is classified and removed either to the corresponding Type 1 or Type 3 facility.

v. Further testing of the soil is conducted to check if additional excavations is required.

vi. Excavate, dose, and spread impounding paddock walls and toe paddock walls from the northern and southern dam compartments over the slime dams.

vii. Rehabilitate and revegetate the site.

viii. The RWD and SWD should be left in-situ and converted to clean water dams.

3.4.2 RISKS TO CONSIDER DURING EXECUTION OF THE CLOSURE AND DECOMMISSIONING:

- Rain delays and construction timeline must be considered, working during the rainy season imposes more risks on hydrology and stormwater management.

4.0 LEGISLATIVE REVIEW

4.1 WASTE MANAGEMENT LICENCE

The CDR slime dams is licenced with National Water Act, 1998 (Act No. 36 of 1998) (NWA) under the licence number 04/B12D/G/1193. The facility has not been in use from year 2000 and decommissioning of the facility is required. A large percentage of the waste currently existent in the southern compartment of the CDR dam is Type 3 which can be disposed on MFC slag disposal facility (licence number 12/9/11/L834/6), located on the plant few kilometers away from the CDR slime dams.

The Type 1 waste will have to be transported and disposed to a licence landfill facility. The testing and analysis done on the facility did not pick up a high volume of Type 1 waste but due to the waste heterogenous in nature (both vertically and horizontally), the material must be screened on grid analysis to ensure Type 1 waste is not disposed to the Type 3 waste disposal facility.

4.2 COMPLIANCE TO REGULATION 636

The National Environmental Management: Waste Act, 2008 dictates the National Norms and Standards for Disposal of Waste to Landfill.

The Knight Piésold design, specifications and relevant documents were set out to ensure compliance to these standards are obliged. **Table 4-1** provides a summary of the compliance with clauses of the Regulation for this closure design. Further discussion of some of the clauses are listed in the indicated Sections.

The complete checklist for Department of Water and Sanitation (DWS) compliance to National Environmental Management Waste Act Regulations can be found in **Appendix B**.

Table 4-1 summarises all the DWS requirements required for receiving approval for this project. This design does not require a capping design or barrier system because the waste is removed from the facility. Any contaminated soil will be removed to ensure there is no risks of any contamination. **Table 4-1** below will indicate that there some activities that are Not Applicable (N/A) to this project and supporting information is indicated in the comment section.

Table 4-1: Compliance to Regulation 636

Description for Compliance	Comment / Reference Documents	Refer to Section
1.0 Technical report signed by Professional Engineer	The design report is signed and reviewed by professional engineer registered with Engineering Council of South Africa (ECSA)	This report
2.0 Technical drawings signed by Professional Engineer	The technical drawings is signed and reviewed by professional engineer registered with Engineering Council of South Africa (ECSA)	Appendix A
3.0 Site Investigation: Surface topography and drainage	Site investigations have been carried out by: (Delta H, 2020) (Golder Associates Africa, 2018) (Knight Piesold Consulting , 2021) Knight Piésold Site Investigation Surface topography and drainage conditions on site (earth channel, wetland, RWD/SWD) have been assessed and considered in the design it can be found in drawings in Appendix A. It is unclear at this stage whether there are any underdrains incorporated in the impounding walls of the Slimes Dam. If any are encountered during the rehabilitation work, then any unsuitable material or pipework will have to be removed from the site and disposed of in a licensed landfill.	Appendix A & Section 5.0
4.0 Site Investigation: Sub-surface features:		
Soil classification	When the waste is removed the soil will be excavated 0.5 m deep to ensure no contaminated soil remains in the facility. The soil will also be tested and checked if further excavations is required. The classification of the soil is not applicable to this project because there is no barrier system required to be installed. Permeability, density, Atterberg limits, etc is not required for analysis.	Section 5.0
Geology	Intensive investigation on the geology of the sites is not required because the main objective is to remove the waste and rehabilitate the dams. Geology of the surrounding areas like the Vaalbankspruit wetland have been assessed.	Section 3.0
Geohydrology	Groundwater contamination assessment was untaken by Golder and Knight Piésold which is discussed in Section 3. The slimes dam (southern compartment) was classified as the 8th most likely source of groundwater contamination. The analysis conducted by (Knight Piésold Consulting , 2021) does indicate that there is ground water contamination due to exceedances	Section 3.0

Description for Compliance	Comment / Reference Documents	Refer to Section
	of DWAF and SANS 241 guidelines. Decommissioning of the facility with closure plan is advisable to avoid any possible future contaminations.	
5.0 Site Classification:		
Waste type	Five (5) borehole testing pits was drilled with nine (9) samples taken at different depths. Type of waste is classified as Type 3 and Type 1 as per GNR 635. Sample grid analysis must be used during construction for determining the type of waste found in the southern paddock taking Cr(VI) concentrations as the main constraint for classification.	Section 3.1 & 5.1
Site life	The site is closed and rehabilitated to be similar to the surroundings. The rehabilitation and vegetation layer placed on top needs to be monitored as per the post closure monitoring schedule provided in the Basic Assessment Report.	6.0
Depth of excavation below NGL (m)	The depth of excavation below NGL will be 0.5 m deep. This is to remove potential contaminated soil and rehabilitate the area. This is not applicable.	5.0
Maximum height above NGL (m)	N/A	5.0
6.0 Site Layout:		
Access	The site is within MFC main boundary fence and access is controlled.	5.0
Separation of clean and dirty water	The stormwater plan have been discussed in Section 5 for separation of clean and dirty water and can be found in drawings 301-00183-40-100/101/102.	5.0
Monitoring system positions (for surface and ground water)	Discussed in Section 5.0	5.0
Monitoring for gas generation and migration (250 m)	This is not applicable. The site is rehabilitated.	N/A
Capping and closure plan	There is no capping design required for this project. The waste will not remain in the dam and no contaminated soils present after construction. The closure plan involves the removal of waste to licenced facilities and once the waste has been removed, the site will be rehabilitated and revegetated	5.0
7.0 Testing of Soils, construction materials and waste:		

Description for Compliance	Comment / Reference Documents	Refer to Section
Soil permeability	Soil permeability is not required, there is no barrier design required for this works that requires low permeable soils.	N/A
Effect of leachate on permeability	Effects of leachate on permeability is not applicable to this project. The waste will be removed, and contaminated soil will be excavated. The effect of leachate on permeability of the soil or GCL is not required.	N/A
Compaction properties using Standard Proctor	No compaction is required for this works. Soil will be placed for vegetation but not compacted. There is no building of slopes, earthworks or barrier systems installed that will require compaction properties to be assessed. If there is any compaction to be required soil will be tested and compacted to 95% Proctor Density at +-2% OMC.	N/A
Shear strength tests for natural materials and interface shear strength for all geosynthetic materials	Not applicable to this project, closure design does not require geosynthetic material to evaluate shear strength and interface testing.	N/A
Geosynthetic materials	Not applicable to this project, closure design does not require geosynthetic material	N/A
Geomembranes in capping compliant with SANS 1525 Type lll GM	Not applicable to this project, closure design does not require geomembrane material	N/A
Waste (physical) tests, compressibility, compatibility, compacted density, and stoichiometry	Testing of waste have been conducted to obtain geochemical results and classified as Type 1 and Type 3. Testing of waste against compaction and interaction with materials is not required for this design. There is no barrier system required for this closure design.	N/A
8.0 Technical Design:		
Separation of clean and dirty water	Refer to Section 5.0	5.0
Minimum permissible unsaturated zone	The is no ground water table located in the dams or surrounding areas. There is no unsaturated zones to be assessed for possible risks against a barrier system (not required).	N/A
Design of the lining system	Not applicable to this project, closure design does not require barrier design with lining system	N/A
Design of leachate collection system atmospheric pressure, service life, strength and creep collapse, ballast, protection layer compatibility	Not applicable to this project, closure design does not require geosynthetic material for analysing the required.	N/A

Description for Compliance	Comment / Reference Documents	Refer to Section
Factor of Safety quantified	Not applicable to this project, closure design does not require barrier system or any risks that require factor of safety calculation	N/A
Gas Management Systems	This is no capping design required for this project that requires a gas capillary layer. The waste does not have any aesthetic gas that could have potential risks to life.	N/A

5.0 TEHNICAL DESIGN

5.1 METHODOLOGY OF DESIGN

From the analysis and review of the site investigations the methodology of the design required for this CDR facility could be determined. It was concluded that the Type 1 waste and contaminated soil immediately below should be removed to a suitably licensed landfill or dumping site. Most material in the CDR slimes dam is Type 3 waste which will be loaded and hauled to MFC's slag dump on the eastern side of the Vaalbankspruit. A stormwater management plan for separating clean and dirty water is also important to avoid contamination of the surrounding area and flooding during design storm. The impounding walls of the CDR slimes facility and the toe paddock bund walls should be dozed down over the area previously covered by CDR Slimes. The pollution control dams (RWD/SWD) should be left in situ with proper stormwater management plan in place.

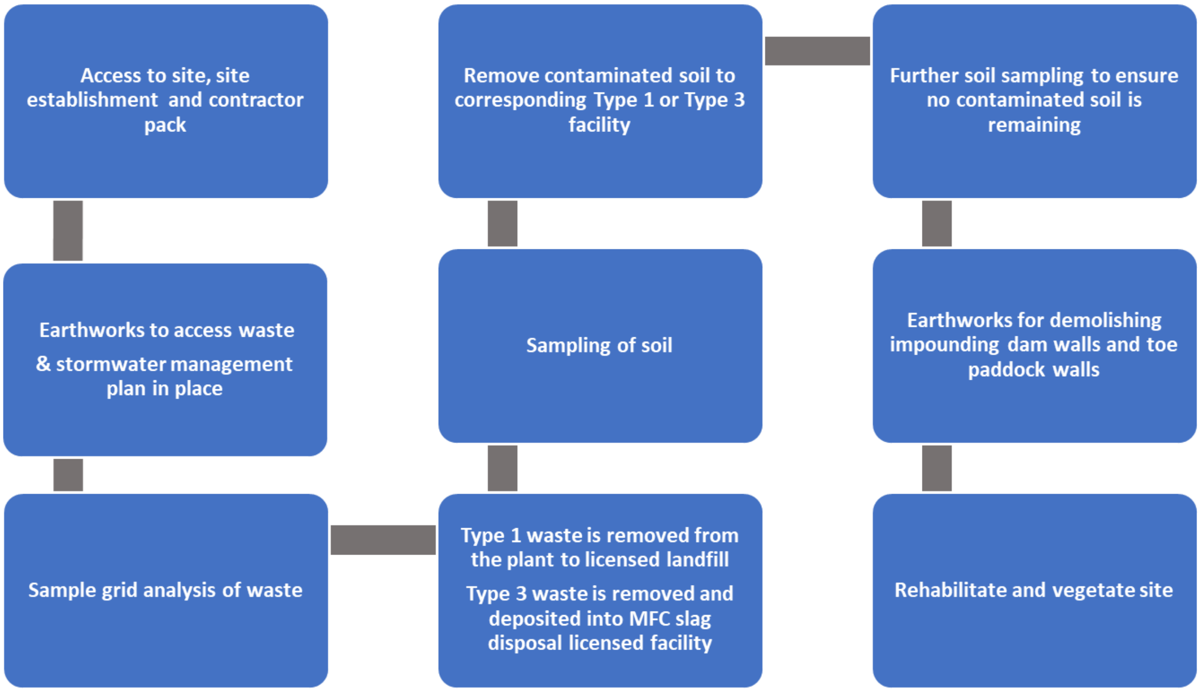

Figure 5-1: Methodology Flowchart for Design

The methodology can be summarized as follows:

I. Contractor will be given access to site, site establishment will be implemented, access roads will be shown to the contractor for established route that does not disturb or affect the wetland surrounding the CDR facility.

II. Excavate, load and haul CDR Slimes classified as Type 1 waste to a designated site (for purposes of this report estimated to be 20% of the total volume of CDR Slimes – 24 000 m³ or approximately 43 000 tonnes). Existing topsoil cover which may be in contact with Type 1 waste should be removed and transported to a designated site along with the Type 1 waste.

III. Excavate, load and haul CDR Slimes classified as Type 3 waste including existing topsoil cover in contact with it to MFC's slag dump (for purposes of this report estimated to be 80% of the total volume of CDR Slimes –96 000 m³ or 173 000 tonnes).

IV. Excavate, load and haul 0.5 m of contaminated soil classified as Type 1 waste from under the CDR Slimes to a designated area (estimated 6 500 m³ or approximately 12 000 tonnes).

V. Excavate, load and haul 0.5 m of contaminated soil classified as Type 3 waste from under the CDR Slimes to MFC's slag dump (estimated 25 500 m³).

VI. Excavate or doze down the impounding walls around the two paddocks and spread the material over the area in the south paddock previously covered by CDR Slimes (estimated 25 000 m³).

VII. Excavate or doze down the toe paddock bund walls and spread the material over the area in the south paddock previously covered by CDR Slimes (estimated 1 500 m³).

VIII. Excavate to expose the penstocks and outfall pipes in both paddocks, demolish all concrete work and cart away to designated landfill.

IX. Implement stormwater management plan for clean and dirty water.

X. Spread topsoil previously removed and stockpiled for re-use from capping layer over the affected area. Topsoil may be procured from commercial source if shortage of material.

XI. Placing seeding for vegetation of facility.

Figure 5-2 shows the CDR facility in relation to the slag dump where the Type 3 waste is proposed to be disposed. The Vaalbankspruit and associated wetlands occur between the CDR facility and the slag dump. To avoid any impacts to the Vaalbankspruit, the trucks should make use of the existing roads as shown in green and red in Figure 5-2. The truck transporting the Type 3 waste should make use of the existing crossing of the Vaalbankspruit (circled) and the trucks transporting the Type 1 waste should use the existing gate to get onto the public road.

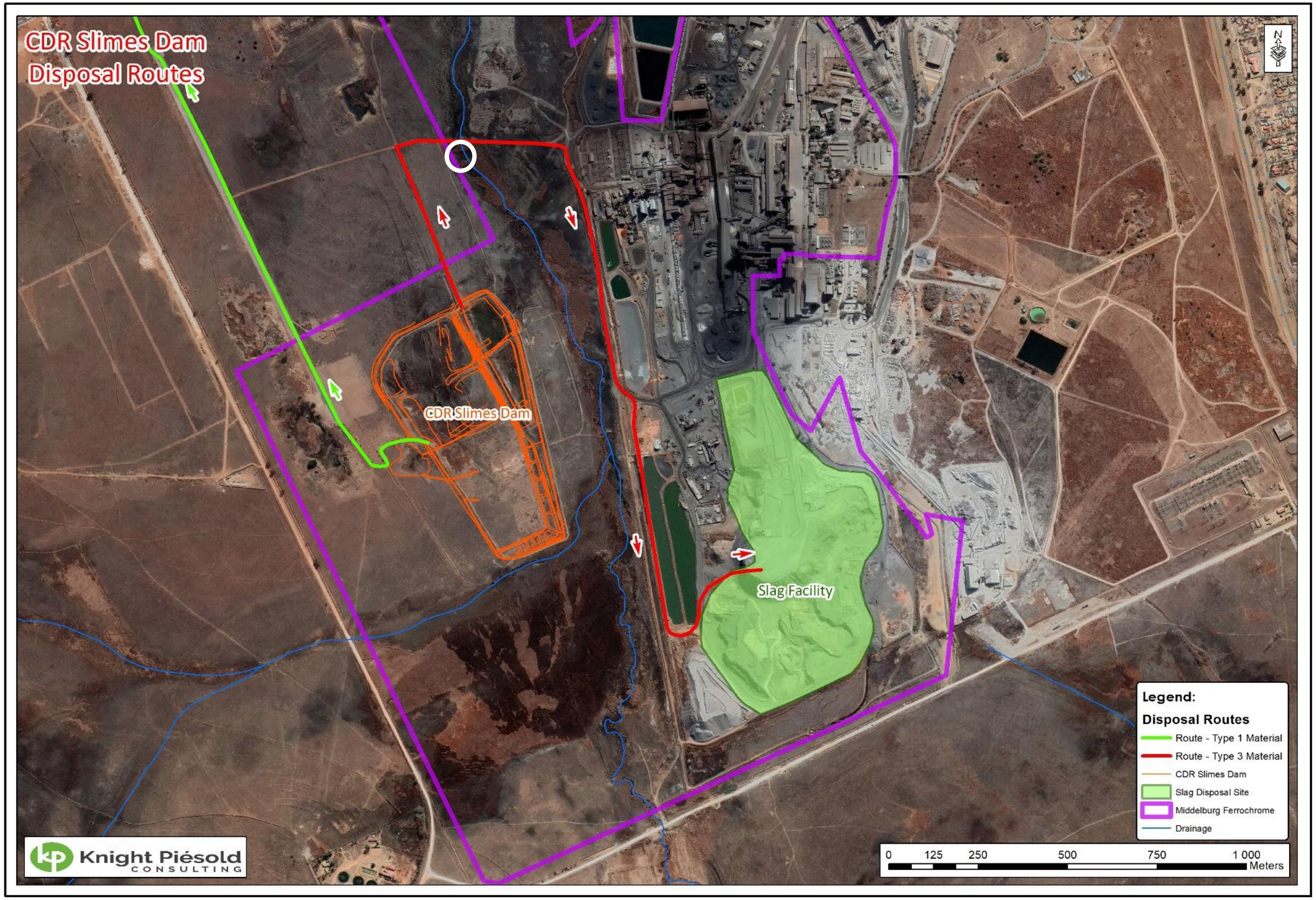

Figure 5-2: Routes to dispose waste types

5.2 HYDROLOGY AND WATER MANAGEMENT

The return water and storm water dams are situated on the eastern side of the northern paddock of the CDR Slimes facility and were intended to store supernatant water and rainfall decanted off the CDR Slimes facility. The water collected in the PCD was intended to be recycled back to the plant during operation. The inter-connected dams are fed by runoff from the two paddocks of the slimes dam, as well as by seepage from the slope upgradient of the slimes dam. The dams are monitored during the year to check for spillage. The historic monitoring data shows that PCD does not passed more than 60 percent of its capacity even in the rainy season.

The estimated capacities of the two dams are 20 750 m^3 (RWD) and 19 000 m^3 (SWD) with a combined capacity of 39 750m^3. The accumulated water was left to evaporate.

A storm water cut-off trench was excavated around the western side of the CDR Slimes Dam to divert clean runoff from the upstream catchment around the Slimes Dam. Consequently, the catchment area contributing runoff to the dams was reduced to the 31.6 ha (Ha) which is area between the cut-off trench and the dams. After removal of the CDR slimes and rehabilitation of this area, the runoff reporting to the dams will be clean water. The inflow into the PCD were calculated for various design storms ranging from 1 in 2yr to 1 in 200-year. The hydrological assessment provides the various volumes expected in the PCD post closure. A rational method was used to determine the volumes.

5.2.1 RATIONAL METHOD

The Rational Method has been used to calculate inflows to the dams as follows. The parameters used for the calculation can be found in **Table 5-1**.

Table 5-1: Parameters for Calculation

Description	Value
Catchment area	36.1 Ha
Coefficient of runoff	Varies (0 – 1.0)
Surface area RWD (North)	10 360 m^2
Surface area SWD (South)	9 412 m^2
Average depth	2 m
Capacity RWD	20 720 m^3
Capacity SWD	18 824 m^3
Length of slope-watercourse (L)	624 m
Average length of slope (S_{av})	18 m/m

The equation to calculate the time of concentration (Tc) can be found below (The South African Roads Agency , 2019):

$$T_c = \frac{0.87L^2}{(1000)(S_{av})} \text{ (Equation 1)}$$

Where:

T_c = Time of concentration (hrs)

L = Length of slope (m)

S_{av} = Average slope (m/m)

The equation to calculate the peak flow for the T-year return period (m^3/s) is

$$Q = \frac{(C)(I)(A)}{3.6} \text{ (Equation 2)}$$

Q = Peak flow rate (m^3/s)

C = Run-off co-efficient

I = Average rainfall intensity over catchment (mm/hr)

A = Effective area of catchment (km^2)

5.2.2 RESULTS OF CALCULATIONS

The results for the calculation of the time of concentration T_c peak discharge into the pollution control dams can be found in **Table 5-2** and the flow rates and storm volumes can be found in **Table 5-3**. For the storm volumes the calculation was based on assumption of an inflow hydrograph with a peak rate (Q) and triangular distribution of base width $3T_c$. The return periods was calculated from 2 up to 200 years to get an understanding of what is expected for critical conditions.

Table 5-2: Calculation for Time of Concentration

Description	Calculated Value
Catchment Area (km^2)	0,316
Time of concentration (hrs)	3,1

Table 5-3: Summary of Calculation for Peak Flow Rates & Storm Volumes

Calculation	Design Storm						
Return period (years), T	**2**	**5**	**10**	**20**	**50**	**100**	**200**
Runoff coefficient	0,31	0,32	0,33	0,34	0,38	0,42	0,42
Avg. Precipitation (mm)	44,50	60,80	70,80	81,70	98,00	109,80	122,50
Intensity (mm/hr)	14,40	19,60	22,90	26,40	31,70	35,50	39,60
Peak flow rates (m^3/s)	0,40	0,60	0,70	0,80	1,10	1,30	1,50
Storm Volumes (m^3)	6 447	9 194	11 145	12 986	17 841	21 903	24 437

5.2.3 CONCLUSION OF RESULTS

The peak flow rates range from 0.4 – 1.5 m^3/s. The cut-off trench upstream reduced the catchment area. The combined volumes of the RWD and SWD is 39 544 m^3. The calculated storm volumes will be contained in the PCD complex. The combined capacity of PCD is and expected storm volume is 24 437 m^3. The storm volumes results in maximum of 60% of the capacity of the PCD.

5.2.4 CONTAMINATED (DIRTY) WATER MANAGEMENT DURING CONSTRUCTION

During construction, the waste will be opened for testing, excavating and removal. There is risk of stormwater could flood the works. The run-off water from the waste will be collected and temporarily stored in the PCD. The expected maximum water level in the PCD is 60% of its capacity. The water level should be monitored during construction and if the level exceed 60% mark, the following should be implemented:

a) The removal should be done in a manner that run-off water is contained within the removal area, e.g., paddock / cells sequence. This will reduce run-off water from the waste into the PCD. Illustration of the paddocks be found in drawing 301-00183-40-101, the idea is to remove waste from south to north as indicated by the arrows in the drawings.

b) If there is still more water, a pumps and pipeline must be available (max capacity of 1.5 m^3/s) to pump contaminated water from the pollution control dams back to the plant for re-use..

c) Contractor must manage ground/surface water that may seep/leachate from the waste during rainy season, they may create temporary trenches and sump collection points to pump this water into the pollution control dams,

d) No contaminated water must be allowed to enter the wetland and any trenches or areas that have been contaminated by dirty water must be excavated out of the facility before construction concludes,

e) When the decommissioning of the facility is complete the contaminated water retained in the SWD/RWD must be removed and emptied out and the PCD rehabilitated to receive clean water.

f) These areas will be tested and confirmed that there is no soil contamination.

5.2.5 POST CLOSURE STORM WATER MANAGEMENT CLEAN WATER MANAGEMENT

When construction completed and the CDR facility is decommissioned, rehabilitated, the impounding walls and paddocks that would have helped with stormwater management will be dosed over and spread across for rehabilitation. This leaves the area exposed and requires stormwater management. The dam capacities have shown in calculations that it can handle the design storm during rainy season. It is assumed that the water retained in the dams or from that which is originating upstream of the facilities is clean. The following stormwater management plan must be followed:

a) The water retained in the dam must be tested to check if is not contaminated.

b) The RWD and SWD must maintain 800 mm freeboard limits as per DWS regulations

c) There is an emergency spillway installed in this facility which may be used for unforeseen circumstances, but spillages must be avoided to maintain freeboard limits.

5.3 CLOSURE & REHABILITATION

When the waste is removed from the dams together with contaminated soil, testing will be done on all areas to ensure no contaminated soil as remained. Once this is confirmed closure and rehabilitation can commence which consists of the following:

I. Excavate and dose dam walls and toe paddock walls, spread material over surface of CDR northern and southern compartments.

II. Excavations along existing penstock outfall pipes to expose pipes.

III. Demolish existing reinforcement concrete foundation blacks and concrete outfall pipes.

IV. Place and spread topsoil from borrow pit or commercial sources in 200 mm layer.

V. Supply and install seeding of rehabilitation areas.

5.4 CONSTRUCTION DRAWINGS

Construction drawings signed by Professional Engineer showing site layout, sections, and necessary details to execute this works can be found in **Appendix A**.

5.5 CAPACITY OF RECEPTOR TYPE 3 SLAG DUMP

5.5.1 CAPACITY CHECK FOR ANNUAL VOLUME

MFC annual deposition of slag from plant operations is 150 000 m^3/annum and the estimated volume to be removed from CDR and disposed to the licenced facility is 156 732 m^3 which leaves 245 268 m^3 remaining if you consider the maximum allowed volume of 522 000 m^3 that can be deposited per Annum.

Table 5-4 shows the volume remaining as per the annual maximum that can be allowed after CDR slimes waste is deposited.

Table 5-4: MFC Allowed Capacity Per Annum as per WULa

DESCRIPTION	VALUE	UNIT
Total Allowed Capacity Per Annum (WULa)	552 000,00	m^3
Total MFC Deposition Per Annum from Plant Operations	150 000,00	m^3
Total Estimated Volume Deposited from CDR	156 732,00	m^3
Available Volume after MFC CDR Deposition (As per Max Annual Volume from WULa)	**245 268.00**	**m^3**

Table 5-4 shows that there is 245 268 m^3 of volume remaining after deposition of CDR waste which does not exceed the maximum annual amount specified in WULa, which indicates that there is no risks or amendments required to the slag disposal dump.

5.5.2 CAPACITY CHECK FOR TOTAL VOLUME

The estimated volume of the waste to be removed and disposed to a licensed facility is 156 732 m^3. The waste will be deposited at the existing MFC slag dump which is licenced to receive type 3 waste. The MFC slug dump has the capacity of 8.7 million cubes. The calculated stored volume in 2021 is 3.65 million cubes.

Table 5-5 show the available capacity of the MFC slug dump after the disposal of the CDR slimes waste.

Table 5-5: Capacity of Slag Dump

DESCRIPTION	VALUE	UNIT
Total Capacity of Type 3 Slag Dump	8 700 000,00	m^3
Total Volume Stored to Date (End of 2021)	3 650 000,00	m^3
Total Volume remaining after 2021	5 050 000,00	m^3
Total Volume of CDR (Considering All Type 3 Waste)	156 732,00	m^3
Available Volume at the MFC slag dump post deposition of CDR waste	**4 893 268,00**	**m^3**

Table 5-5 above shows a total capacity of the slag dump is 4 893 268 m^3 remaining which indicates that there is no risks or amendments required to the slag disposal dump.

5.6 SCHEDULE AND CONSTRUCTION TIMELINE

It is estimated that the project to remove all contaminated material from site and rehabilitate the exposed area can be completed by specialist experienced contractor in 14 months and 24 months for medium sized contractor.

At an estimated in-situ density of 1.8 t/m^3 this will entail removal of 216 000 tons of CDR Slimes and 37 500 tons of contaminated soil. Assuming a 24-day working month, 40-ton trucks utilised by experienced contractor and 20-ton trucks utilised by medium sized contractor.

This estimate of the rate at which material should be removed is clearly dependent on the plant fleet available, the percentage of material that can be disposed of locally, and the destination of material that must be sent to a licenced landfill.

Table 5-6 shows that the estimated time for an experienced contractor with high percentage of ownership for large dump trucks (40 tons) is 366 days (14 months), this works out to around 750 tons of waste removed per day. This calculation have been checked with large waste removal companies and some clarified that if the working days is extended the project can be completed in less than 14 months.

Table 5-6: Estimation Time for Specialist Experienced Large Contractor

Description	Value
Waste	216 000,00 tons
Soil	35 700,00 tons
Total	251 700,00 tons
Day of site (14 months)	366,00 days
40-Ton truck capacity for one load	35,00 tons
No. of truck loads required in total	7 192.00 loads
No. of truck loads required per day	22.00 loads

Volume of waste to be removed per day	750.00 tons

Table 5-7 shows the estimated time for a medium sized contractor with high percentage of medium sized dump trucks (20 tons) can be completed in 576 days (24 months). This may pose a problem as it would extend into rainy season and time related cost might be higher because of the extended required time to complete the works.

Table 5-7: Estimated Time for Medium Sized Contractor

Description	Value
Waste	216 000,00 tons
Soil	35 700,00 tons
Total	251 700,00 tons
Day of site (24 months)	576,00 days
20-Ton truck capacity for one load	15,00 tons
No. of truck loads required in total	16 780.00 loads
No. of truck loads required per day	30.00 loads
Volume of waste to be removed per day	440.00 tons

It is recommended by Knight Piésold that the project be awarded to a large waste removal company with the relevant fleet available to complete this work that avoids working through the rainy season.

6.0 POST CLOSURE MANAGEMENT AND MONITORING

Once the waste has been removed, the site will be rehabilitated and revegetated with a seed mixture of *Hyparrhenia hirta, Themeda triandra and Imperata cylindrica*, which has been identified as the dominant species occurring on the site (Yggdrasil Scientific Services, 2012). Monitoring of the vegetation is required during the life of the plant.

MFC should continue with their existing environmental monitoring programme. It is further recommended that an assessment of the vegetation cover establishment and site inspections by independent external consultants be undertaken for an estimated period of 5 years.

The 5-year period is made up of decommissioning and rehabilitation of the site (1 year), active maintenance and aftercare (2 years) and passive maintenance and aftercare (2 years).

Further roles and responsibilities are outlined in the Environmental Management Programme (EMPr) and Closure Plan (Part B of BAR).

7.0 CONSTRUCTION QUALITY ASSURANCE (CQA) PLAN

The construction activities for this project does not entail the installation of geosynthetics nor materials that require stringent CQA. The waste is going to be removed and monitored by the Engineer and Employer. CQA plan was provided for the waste removal and earthworks activities.

Please refer to **Appendix D** for Construction Quality Assurance Plan.

8.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared:

Denzil Govender, BSc Eng.
Engineer

Prepared:

Duncan Grant Stuart, PR.Eng.
Technical Consultant

Reviewed:

Thabang Mokoma , PR.Eng.
Principal Engineer

Approval that this document adheres to the Knight Piésold Quality System: X

9.0 REFERENCES

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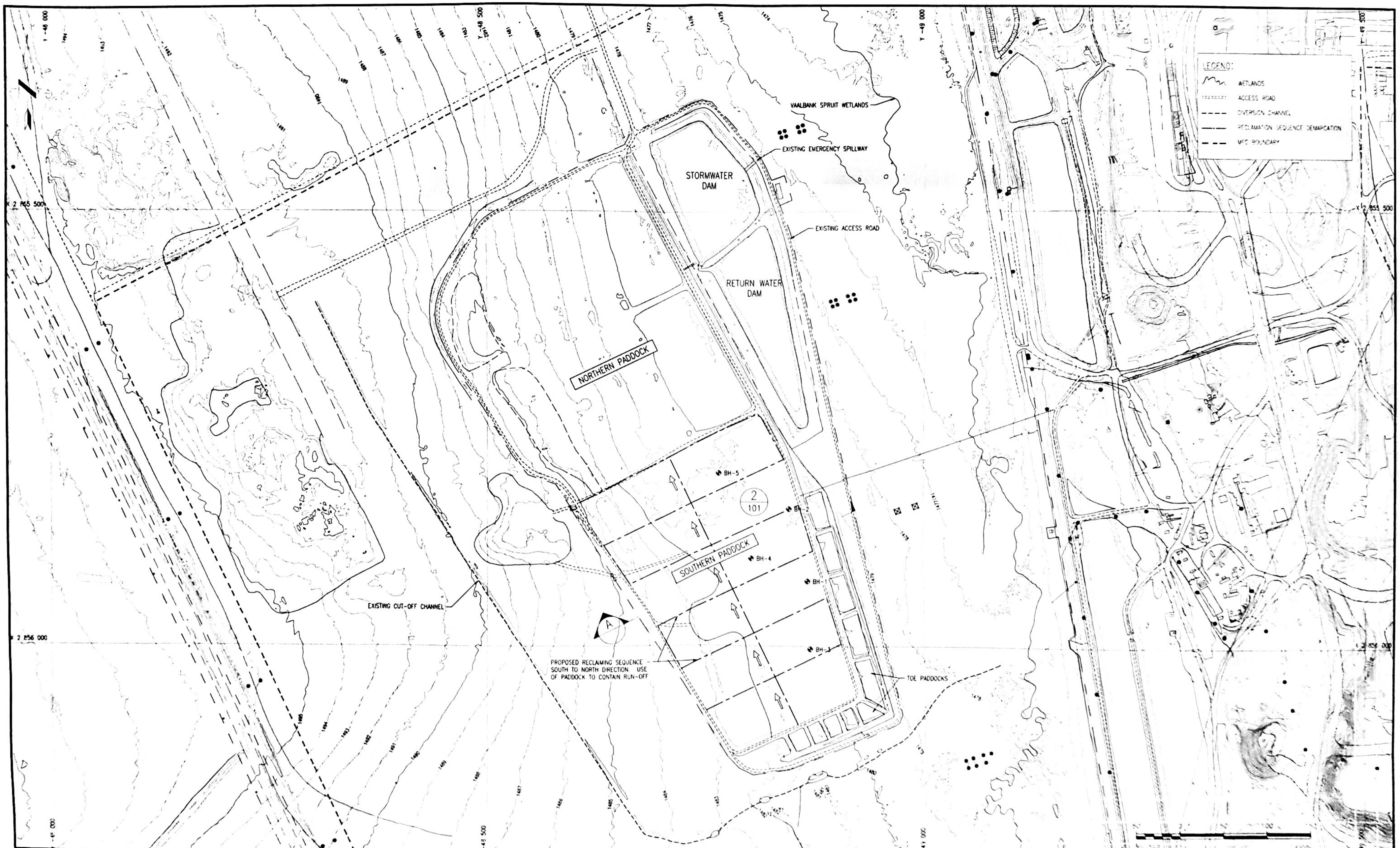
APPENDIX A

DRAWINGS



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PRIMARY DISCIPLINE	CIVIL	
DRAWN	BOP	15/03/2021
DRAWING CHECK	DG	18/03/2021
DESIGN	DG	15/03/2021
DESIGN CHECK	TM	15/03/2021
PROJECT ENGINEER	-	-

-

REVISION

REV No	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	15/03/21	ISSUED FOR REVIEW	BOP	DG	TM
B	17/03/21	ISSUED FOR PROPOSAL	BOP	DG	TM
-	-	-	-	-	-
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20140489
24/03/21

DISCLAIMER

These drawings have been prepared by Knight Piésold Consulting (Pty) Ltd based on information available at the time of preparation. Where site conditions necessitate an [illegible] any party without the prior written consent of Knight Piésold Consulting (Pty). Knight [illegible] suffered by any party resulting from these drawings where and adoption or amendment to the drawings has taken place without obtaining the prior written consent of Knight Piésold Consulting (Pty) Ltd.

REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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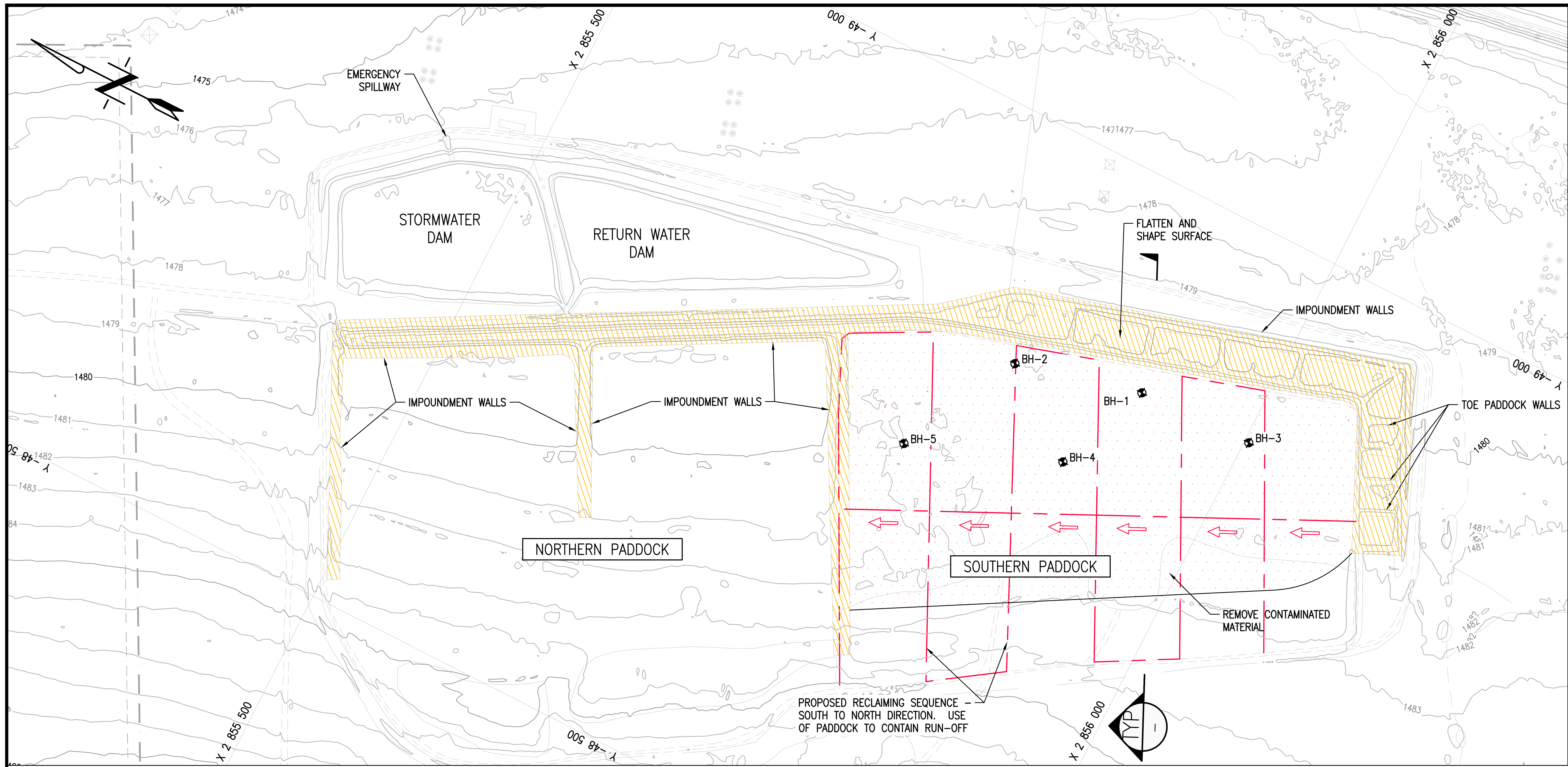
-	-	-
-	-	-
-	-	-

BURG FERROCHROME
DAM - CDR
GENERAL LAYOUT

DRAWING NUMBER	SCALE	REV
301-00183-40-100	1:2000	B



SLIMES DAM LAYOUT
SCALE 1:2000

KEY:

- CONTAMINATED MATERIAL (CDR SLIMES) TO BE REMOVED
- EXCAVATE AND SPREAD MATERIAL OVER SOUTH PADDOCK PREVIOUSLY COVERED BY CDR SLIMES

WASTE REMOVAL LAYERWORKS NOTES:

1. WASTE TO BE CLASSIFIED AS PER SAMPLING GRID PROFILE. TYPE 1 WASTE TO BE REMOVED TO LICENSED FACILITY OFF PLANT SITE. TYPE 3 WASTE TO BE REMOVED AND DEPOSITED IN MFC SLAG DISPOSAL FACILITY. WASTE CANNOT BE REMOVED IF SAMPLING HAS NOT BEEN CONDUCTED UNLESS APPROVAL HAS BEEN GIVEN BY CLIENT OR ENGINEER/ENVIRONMENTALIST.
2. RECLAIM AS PER PROPOSED SEQUENCE – SOUTH TO NORTH. USE PADDOCKS TO CONTAIN RUN-OFF.
3. ONCE WASTE HAS BEEN REMOVED, SOIL SAMPLING MUST BE INITIATED TO CHECK FOR CONTAMINATION. EXCAVATE 500mm DEEP TO REMOVE POTENTIAL CONTAMINATED SOIL. SOIL CLASSIFIED AS TYPE 1 WASTE MUST BE REMOVED AND DEPOSITED TO LICENSED FACILITY OFF PLANT SITE. SOIL CLASSIFIED AS TYPE 3 WASTE MUST BE DEPOSITED IN MFC SLAG DISPOSAL FACILITY.
4. SAMPLE IN-SITU MATERIAL TO CHECK IF FURTHER CLASSIFICATION AND ADDITIONAL EXCAVATION IS REQUIRED.

BOREHOLE SETTING OUT DATA

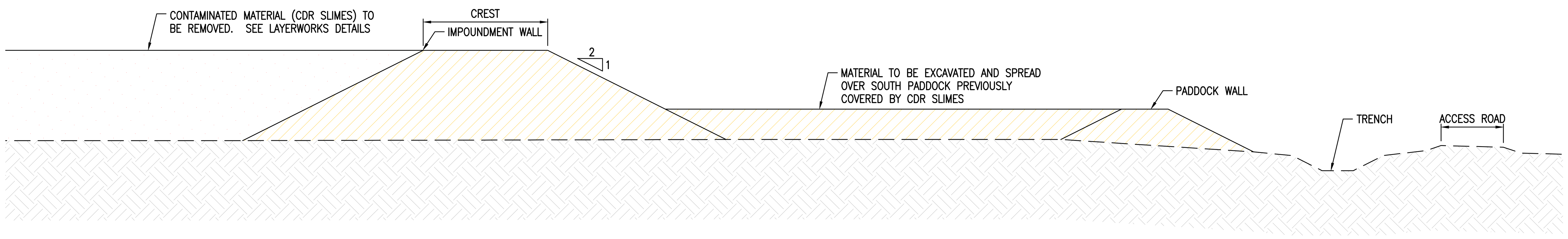
POINT	Y	X	CDR SLIMES WASTE TYPE
BH-1	-48866.76	2855925.46	3
BH-2	-48846.01	2855842.30	3
BH-3	-48869.48	2856003.03	1
BH-4	-48802.68	2855899.75	3
BH-5	-48765.94	2855801.01	3

REHABILITATION AND CLOSURE NOTES:

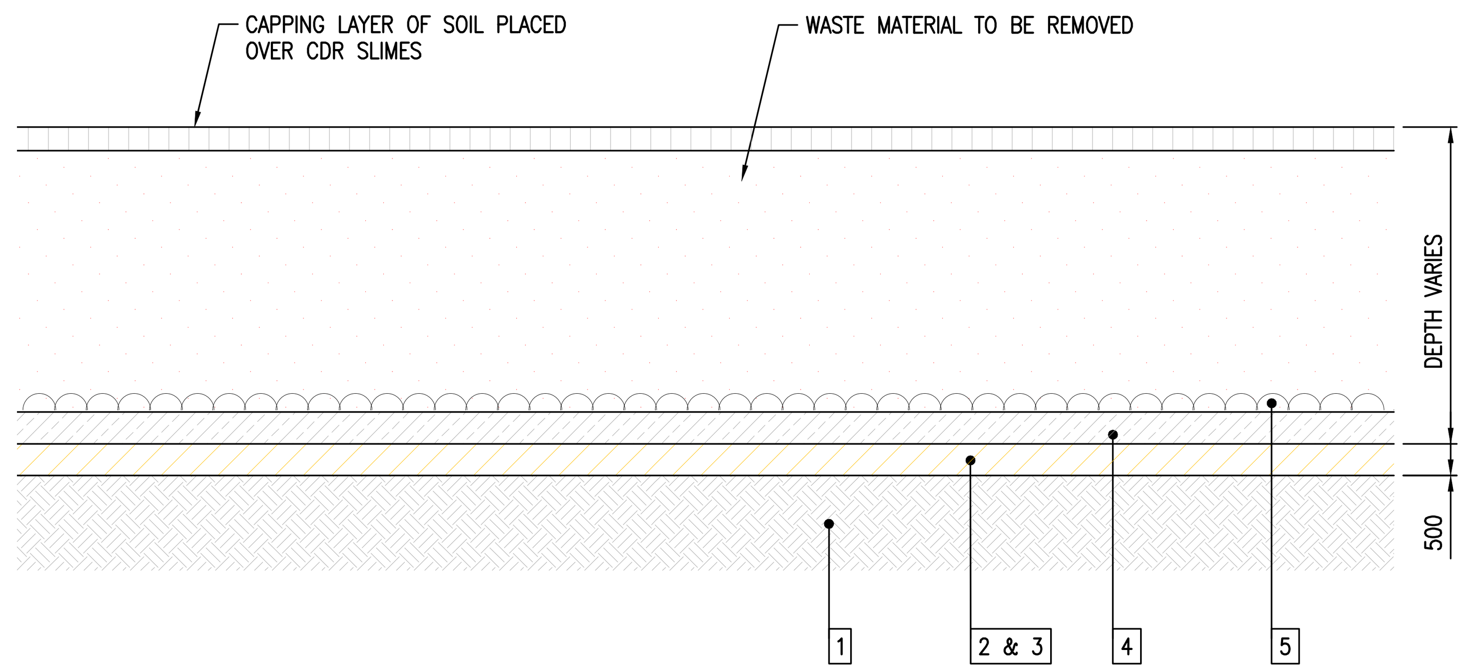
1. ALL WORK CARRIED OUT IN CONFORMANCE TO RELEVANT SANS 1200 STANDARD SPECIFICATION AND PROJECT BASIC ASSESSMENT REPORT.
2. DRAWINGS BASED ON SURVEY PROVIDED BY PREMIER MAPPING CC – DATED 17 OCTOBER 2019.
3. EXCAVATE OR DOZE DOWN THE IMPOUNDING WALLS AROUND THE TWO PADDOCKS AND SPREAD THE MATERIAL OVER THE AREA IN THE SOUTH PADDOCK PREVIOUSLY COVERED BY CDR SLIMES.
4. EXCAVATE TO EXPOSE THE PENSTOCKS AND OUTFALL PIPES IN BOTH PADDOCKS, DEMOLISH ALL CONCRETE WORK AND CART AWAY TO DESIGNATED LANDFILL.
5. SPREAD TOPSOIL PREVIOUSLY REMOVED AND STOCKPILED FOR RE-USE FROM CAPPING LAYER OVER THE AFFECTED AREA. SITE WILL BE REHABILITATED AND REVEGETATED WITH A SEED MIXTURE OF HYPARRHENIA HIRTA, THEMEDA TRIANDRA AND IMPERATA CYLINDRICA.

LAYERWORKS:

1. ORIGINAL GROUND LEVEL
2. REMOVE 500mm SOIL LAYER AFTER REMOVAL OF WASTE MATERIAL AND SPREAD WITH MATERIAL FROM DOZED IMPOUNDMENT AND PADDOCK WALLS
3. TEST SOIL TO CONFIRM IF ALL WASTE HAS BEEN REMOVED IN CASE FURTHER EXCAVATION IS REQUIRED
4. CAP WITH TOPSOIL LAYER FROM DESIGNATED TOPSOIL STOCKPILE
5. RE-VEGETATE WITH SEED MIXTURE AS PER REHABILITATION AND CLOSURE NOTES.



1 – TYPICAL SECTION THROUGH SOUTH PADDOCK
SCALE 1:100



1 – TYPICAL WASTE REMOVAL LAYERWORKS
SCALE 1:100

2500 0 2500 5000 7500
MILLIMETRES 1:100

50 0 50 100 150
METRES 1:2000

Knight Piésold CONSULTING

Pr.Eng#:20140489
25 March 2021

PRIMARY DISCIPLINE	CIVIL	
DRAWN	BDP	15/03/2021
DRAWING CHECK	DG	16/03/2021
DESIGN	DG	15/03/2021
DESIGN CHECK	TM	15/03/2021
PROJECT ENGINEER	–	–
–		

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	15/03/21	ISSUED FOR REVIEW	BDP	DG	TM
B	17/03/21	ISSUED FOR PROPOSAL	BDP	DG	TM
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
–	–	–	–	–	–
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REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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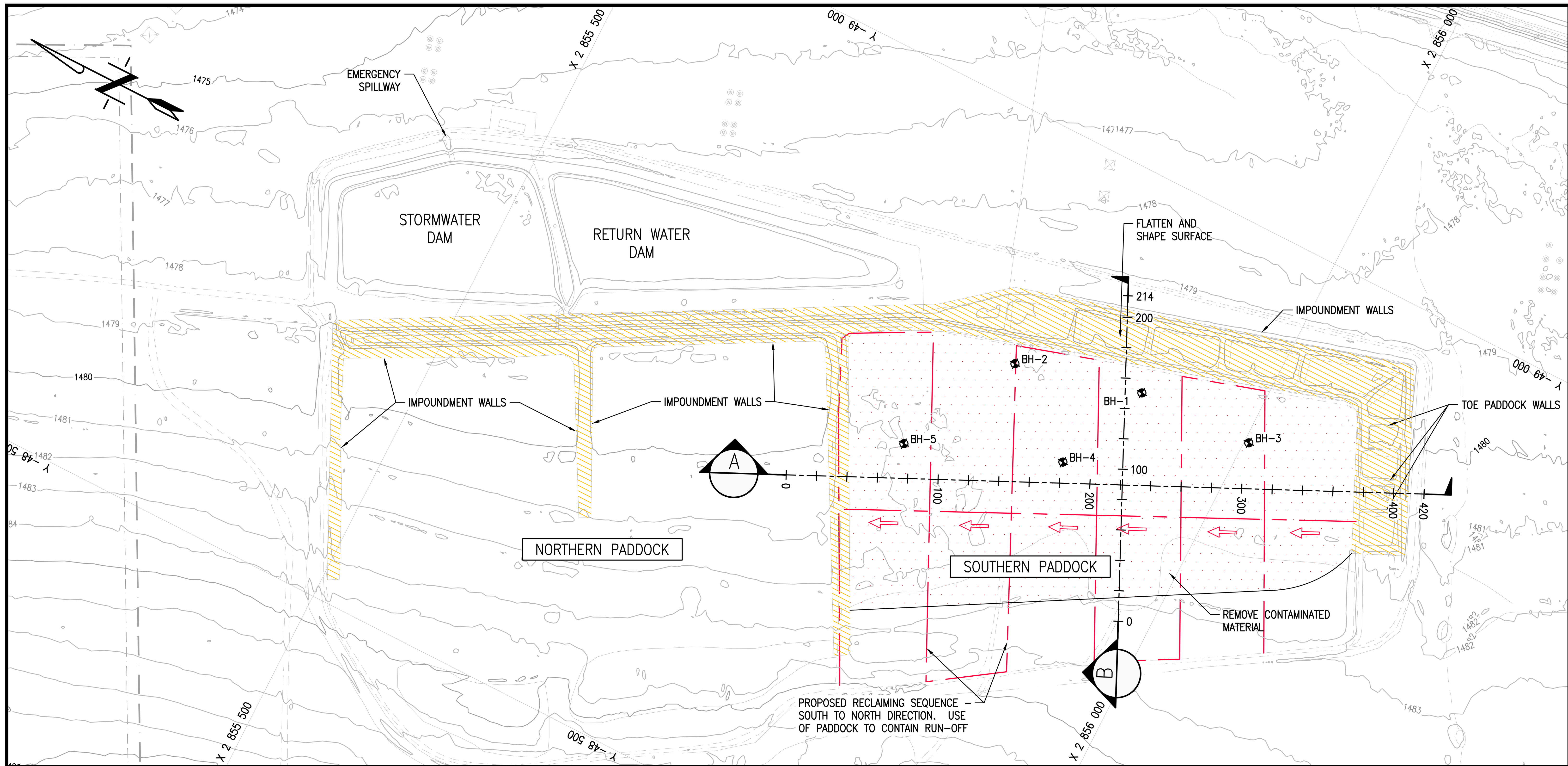
MIDDELBURG FERROCHROME
SLIMES DAM – CDR
WASTE REMOVAL LONGSECTION AND DETAILS

DRAWING NUMBER	SCALE	REV.
301-00183-40-101	AS SHOWN	B

P:\301-00183\40\A\DRAWINGS\KP\For Proposal\301-00183-40-101.dwg



KEY:

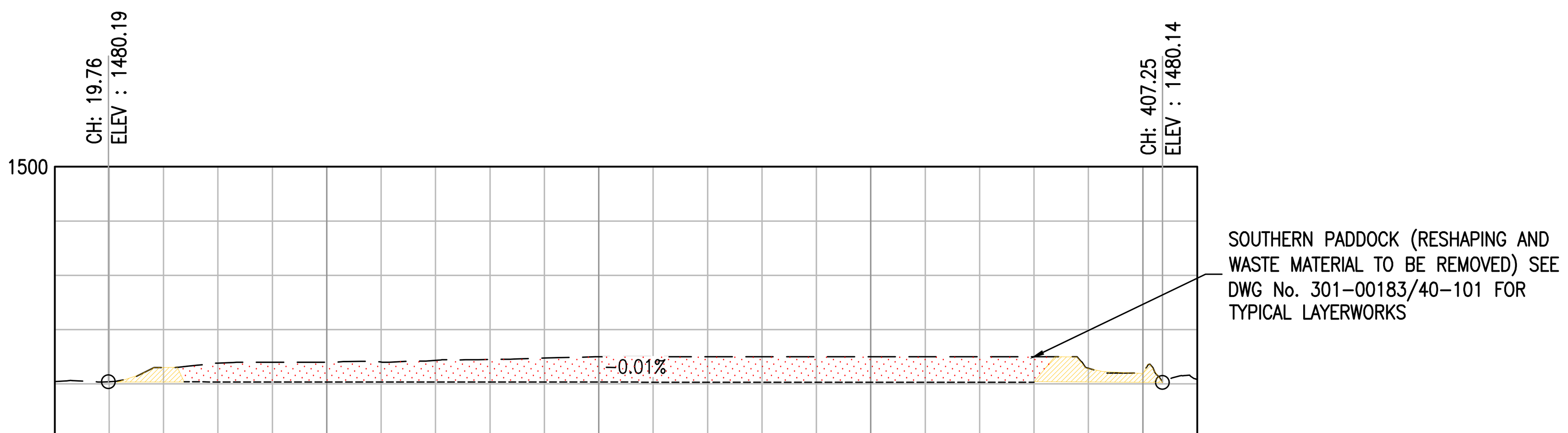
CONTAMINATED MATERIAL (CDR SLIMES) TO BE REMOVED

EXCAVATE AND SPREAD MATERIAL OVER SOUTH PADDOCK PREVIOUSLY COVERED BY CDR SLIMES

SLIMES DAM LAYOUT
SCALE 1:2000

SCALES:
Horizontal 1:2000
Vertical 1:500

DATUM 1475.00

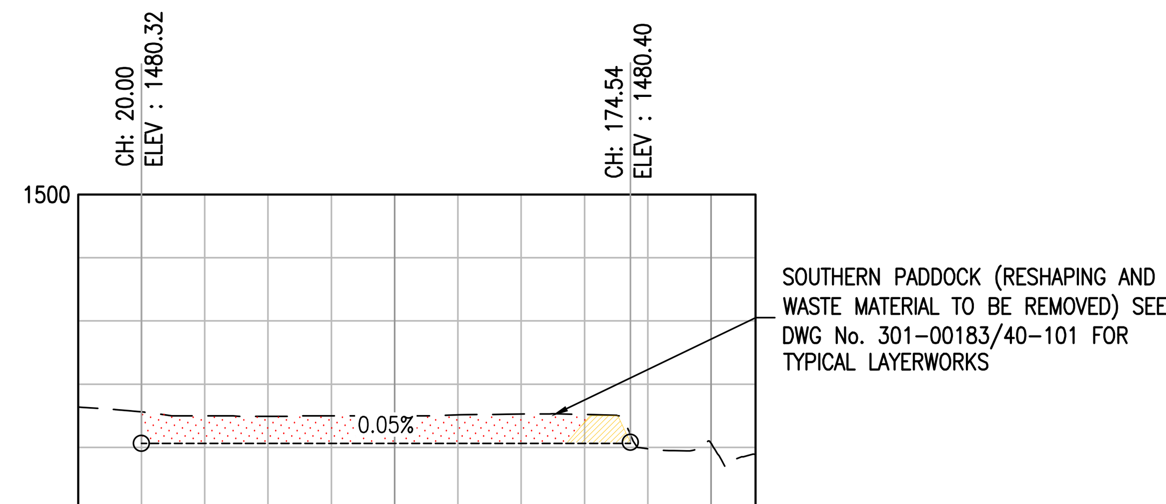


CHAINAGE (m)	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00	220.00	240.00	260.00	280.00	300.00	320.00	340.00	360.00	380.00	400.00		420.00
EXISTING GROUND LEVELS (m)	1480.20	1481.50	1481.91	1482.00	1482.00	1482.02	1482.17	1482.25	1482.38	1482.50	1482.50	1482.50	1482.50	1482.50	1482.50	1482.50	1482.50	1482.50	1481.43	1481.20		1480.43
DESIGN LEVELS (m)	1480.19	1480.19	1480.19	1480.18	1480.18	1480.18	1480.17	1480.17	1480.17	1480.17	1480.16	1480.16	1480.16	1480.16	1480.15	1480.15	1480.15	1480.15	1480.14	1480.14	1480.14	
CUT / FILL	0.00	–1.31	–1.72	–1.82	–1.82	–1.84	–2.00	–2.08	–2.21	–2.33	–2.33	–2.34	–2.34	–2.34	–2.35	–2.35	–2.35	–2.35	–1.29	–1.06	0.00	

LONGSECTION – SLIMES DAM A
CHAINAGE 0.00m TO 420.00m

SCALES:
Horizontal 1:2000
Vertical 1:500

DATUM 1475.00



CHAINAGE (m)	20.00	40.00	60.00	80.00	100.00	120.00	140.00	160.00	180.00	200.00	214.07
EXISTING GROUND LEVELS (m)	1482.81	1482.50	1482.45	1482.50	1482.50	1482.58	1482.63	1482.61	1479.89	1480.33	1479.45
DESIGN LEVELS (m)	1480.32	1480.33	1480.34	1480.35	1480.36	1480.37	1480.39	1480.40	1480.40		
CUT / FILL	–2.48	–2.16	–2.10	–2.14	–2.13	–2.20	–2.25	–2.22	–0.55		

LONGSECTION – SLIMES DAM B
CHAINAGE 0.00m TO 214.07m

10 0 20 40
METRES 1:500

50 0 50 100 150
METRES 1:2000

Knight Piésold CONSULTING

Pr.Eng#:20140489
25 March 2021

PRIMARY DISCIPLINE	CIVIL	
DRAWN	BDP	15/03/2021
DRAWING CHECK	DG	16/03/2021
DESIGN	DG	15/03/2021
DESIGN CHECK	TM	15/03/2021
PROJECT ENGINEER	–	–
–		

REVISION

REV.No.	DATE	DESCRIPTION	DRAWN	CHKD.	APPD.
A	15/03/21	ISSUED FOR REVIEW	BDP	DG	TM
B	17/03/21	ISSUED FOR PROPOSAL	BDP	DG	TM
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DISCLAIMER

REFERENCE DRAWINGS

DRAWING No.	MAKERS No.	TITLE
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MIDDELBURG FERROCHROME
SLIMES DAM – CDR
WASTE REMOVAL
LONGITUDINAL SECTIONS A & B

DRAWING NUMBER	SCALE	REV.
301–00183–40–102	AS SHOWN	B

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APPENDIX B

DWS CHECKLIST FOR WASTE LICENSE APPLICATION TECHNICAL DESIGN

water & sanitation
Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

APPLICATION FOR ORAL PRESENTATION OF WASTE LICENCE APPLICATION TECHNICAL DESIGN

(As per Minimum Requirements 2nd Edition 1998 Clause 5.2.4)

REVIEW OF LICENCE APPLICATIONS: PRELIMINARY CHECKLIST

Project Name: Closure of CDR Slimes Facility Design Report

1. Technical Report and Drawings

1.1 Signed by applicant (MR2 clause 5.2.4)

Name:____________________ Email:______________________ Phone:_________________

1.2 Signed by Professional Engineer (Civil)(MR2 clause 8.1 and R636 clause 3(2))

Name/ECSA Registration No.: **Thabang Mokoma (20140489)**

Email: **tmokoma@knightpiesold.com**

Phone: **073 449 5055**

Please refer to design report for RI301-00183/40 for detailed responses to the sections below. The drawings and relevant documents can also be found in the report.

2. Site Investigation: Surface Topography and Drainage

Site investigations have been carried out by:

- (Delta H, 2020)
- (Golder Associates Africa, 2018)
- (Knight Piesold Consulting , 2021)
- Knight Piésold Site Investigation

Surface topography and drainage conditions on site (earth channel, wetland, RWD/SWD) have been assessed and considered in the design it can be found in drawings in Appendix A. It is unclear at this stage whether there are any underdrains incorporated in the impounding walls of the Slimes Dam. If any are encountered during the rehabilitation work, then any unsuitable material or pipework will have to be removed from the site and disposed of in a licensed landfill.

3. Site Investigation: Sub-surface features (MR2 clause 6.3)

a) Soil Classification

When the waste is removed the soil will be excavated 0.5 m deep to ensure no contaminated soil remains in the facility. The soil will also be tested and checked if further excavations is required. The classification of the soil is not applicable to this project because there is no barrier system required to be installed. Permeability, density, Atterberg limits, etc is not required for analysis.

b) Geology

Intensive investigation on the geology of the sites is not required because the main objective is to remove the waste and rehabilitate the dams. Geology of the surrounding areas like the Vaalbankspruit wetland have been assessed.

c) Geohydrology

Groundwater contamination assessment was untaken by Golder and Knight Piésold which is discussed in Section 3. The slimes dam (southern compartment) was classified as the 8th most likely source of groundwater contamination. The analysis conducted by (Knight Piésold Consulting , 2021) does indicate that there is ground water contamination due to exceedances of DWAF and SANS 241 guidelines. Decommissioning of the facility with closure plan is advisable to avoid any possible future contaminations

d) Miscellaneous (presence of undermined/earth tremors/open-cast mine/mining potential/surface subsidence potential and dolomites)

Not applicable to this project.

4. Site Investigation Landfill Gas and Air Quality (MR2 clause 6.5)

Not applicable to this project. The waste does not have any aesthetic gas that could have potential risks to life.

5. Confirmation of Site Classification (MR2 clause 8.2.1 and R634, 635 and 636)

a) Waste type

Five (5) borehole testing pits was drilled with nine (9) samples taken at different depths. Type of waste is classified as Type 3 and Type 1 as per GNR 635. Sample grid analysis must be used during construction for determining the type of waste found in the southern paddock taking Cr(VI) concentrations as the main constraint for classification.

b) Site life (years)

The site is closed and rehabilitated to be similar to the surroundings. The rehabilitation and vegetation layer placed on top needs to be monitored as per the post closure monitoring schedule provided in the Basic Assessment Report.

c) Depth of excavation below NGL (m)

The depth of excavation below NGL will be 0.5 m deep. This is to remove potential contaminated soil and rehabilitate the area. This is not applicable.

d) Maximum height above NGL (m)

Not applicable to this project.

6. Site Layout (MR2 clause 8.2.3) (scale 1: 1 000 and 1m contours)

a) Access

The site is within MFC main boundary fence and access is controlled.

b) Separation of clean and Dirty water

The stormwater plan have been discussed in Section 5 for separation of clean and dirty water and can be found in drawings 301-00183-40-100/101/102.

c) Monitoring system positions (for surface and ground water)

Discussed in Section 5.0 of the design report.

d) Monitoring for gas generation and migration (250m)

This is not applicable. The site is rehabilitated.

e) Capping and closure plan

There is no capping design required for this project. The waste will not remain in the dam and no contaminated soils present after construction. The closure plan involves the removal of waste to licenced facilities and once the waste has been removed, the site will be rehabilitated and revegetated

7. Testing of Soils, construction materials and waste (MR2 clause 8.3)

a) Soil permeability (MR2 8.3.1)

Soil permeability is not required, there is no barrier design required for this works that requires low permeable soils.

b) Effect of leachate on permeability (MR2 clause 8.3.1 and R636 (3) (2)(d) and (i))

Effects of leachate on permeability is not applicable to this project. The waste will be removed, and contaminated soil will be excavated. The effect of leachate on permeability of the soil or GCL is not required.

c) Compaction properties using Standard Proctor (MR2 clause 8.3.2)

No compaction is required for this works. Soil will be placed for vegetation but not compacted. There is no building of slopes, earthworks or barrier systems installed that will require compaction properties to be assessed. If there is any compaction to be required soil will be tested and compacted to 95% Proctor Density at +-2% OMC.

d) Shear strength tests for natural materials and interface shear strength for all geosynthetic materials (residual and saturated conditions), factor of safety determined (recognising pore pressures) (MR2 8.3.3)

Not applicable to this project, closure design does not require geosynthetic material to evaluate shear strength and interface testing.

e) Geosynthetic materials (MR2 clause 8.3.4 and R636 (3) (2)(d) and (e) strength, interface friction, durability and compatibility, and quality assurance are minimum requirement.

Not applicable to this project, closure design does not require geosynthetic material

f) Geomembranes in capping compliant with SANS 1525 Type lll GM.

Not applicable to this project, closure design does not require geomembrane material.

g) Waste (physical) tests (clause 8.3.5) compressibility, compatibility, compacted density, and stochiometry

Testing of waste have been conducted to obtain geochemical results and classified as Type 1 and Type 3. Testing of waste against compaction and interaction with materials is not required for this design. There is no barrier system required for this closure design.

8. Technical Design (MR2 clause 8.4) Quantifies parameters and predicts future performance

a) Separation of clean and dirty water (drains and 0,5m freeboard in PCD) (MR2 clause 8.4.1) **Refer to Section 5.0**

b) Minimum permissible unsaturated zone (2m) (MR2 clause 8.4.2)

The is no ground water table located in the dams or surrounding areas. There is no unsaturated zones to be assessed for possible risks against a barrier system (not required).

c) Design of the lining system (MR2 clause 8.4.3 and R636 3(2) (b to i)

Not applicable to this project, closure design does not require barrier design with lining system

d) Design of leachate collection system (MR2 clause 8.4.4 and R636 3(2) (b to i) atmospheric pressure, service life, strength and creep collapse, ballast, protection layer compatibility.

Not applicable to this project, closure design does not require geosynthetic material for analysing the required.

e) Factor of Safety quantified (MR2 clause 8.4.5; 8.4.8 and Board Notice 256 of 2013 3(5))

Not applicable to this project, closure design does not require barrier system or any risks that require factor of safety calculation

f) Gas Management Systems (MR2 clause 8.4.6)

This is no capping design required for this project that requires a gas capillary layer. The waste does not have any aesthetic gas that could have potential risks to life.

g) Design of Capping Systems (MR2 clause 8.4.7 and 8.5) base liner performance monitoring results, erosion

Not applicable to this project.

9. Declaration: I the undersigned, certify that for the above named facility the technical report and drawings are ready for presentation in accordance with the above checklist compliance.

Signed by Design Engineer: 

Name: Thabang Mokoma
Email: tmokoma@knightpiesold.com
Phone: 073 449 5055

APPENDIX C

GEOHYDROLOGY STUDY REPORT BY GOLDER ASSOCIATES

February 2018

SAMANCOR CHROME - MIDDELBURG FERROCHROME

Integrated Geohydrology Study: Technical Report

Submitted to:
Samancor Chrome - Middelburg Ferrochrome
Hendrina/Middelburg Road - N11
Middelburg
1050

REPORT

Report Number: 1418954-303586-1

Distribution:

1 x Electronic Copy - SAMANCOR CHROME
1 x Electronic Copy - ProjectReports@golder.co.za

Golder Associates

Table of Contents

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FIGURES

APPENDICES

1.0 INTRODUCTION

Samancor Chrome – Middelburg Ferrochrome (MFC) appointed Golder Associates Africa (Golder) to update the existing geohydrological understanding at their Ferrochrome operation in Middelburg, Mpumalanga.

This groundwater study is required to provide an updated understanding of the groundwater regime at Middelburg Ferrochrome after the additional groundwater monitoring boreholes as well as the extension of the infiltration gallery was implemented. Furthermore, the study has to define and confirm the potential impacts of the onsite contamination sources on groundwater as well as the potential impacts to the receptors.

The project approach is based on an integrated Source – Pathway – Receptor (SPR) model for the MFC facility.

2.0 PROJECT AIM & OBJECTIVES

2.1 Aim

This study is required to:

- Provide an updated understanding of the groundwater regime at Middelburg Ferrochrome; and
- Define and confirm the potential impacts the onsite activities may have on the groundwater as well as the potential impacts to the receptors.

2.2 Objective

The main objective of the study is to **comprehensively assess the geohydrological understanding and develop plans to improve infrastructure if required**.

The study will provide:

- An **integrated understanding** of the source-pathway-receptor chain at Middelburg Ferrochrome.
- This understanding extends to the **cause and effect relationships** between changes at source and receptor impacts. Including an understanding of the contribution of potential adjacent industrial sources.
- The study will indicate source and pathway aspects that can be addressed in further site management.

2.3 Requirements

- Source term characterisation: This has the objective of quantifying the mass load of contaminants entering the groundwater pathway;
- Pathway assessment: this has the objective of determining how potential source contributions are distributed /attenuated within the groundwater system;
- Receptor toxicity assessment: This has the objective of identifying the potential contribution to receptors of any potential contaminates identified from the groundwater pathway study;
- Updateable salt load balance.

2.4 Scope of work

The project flow diagram showing the scope of work is shown in Figure 1.

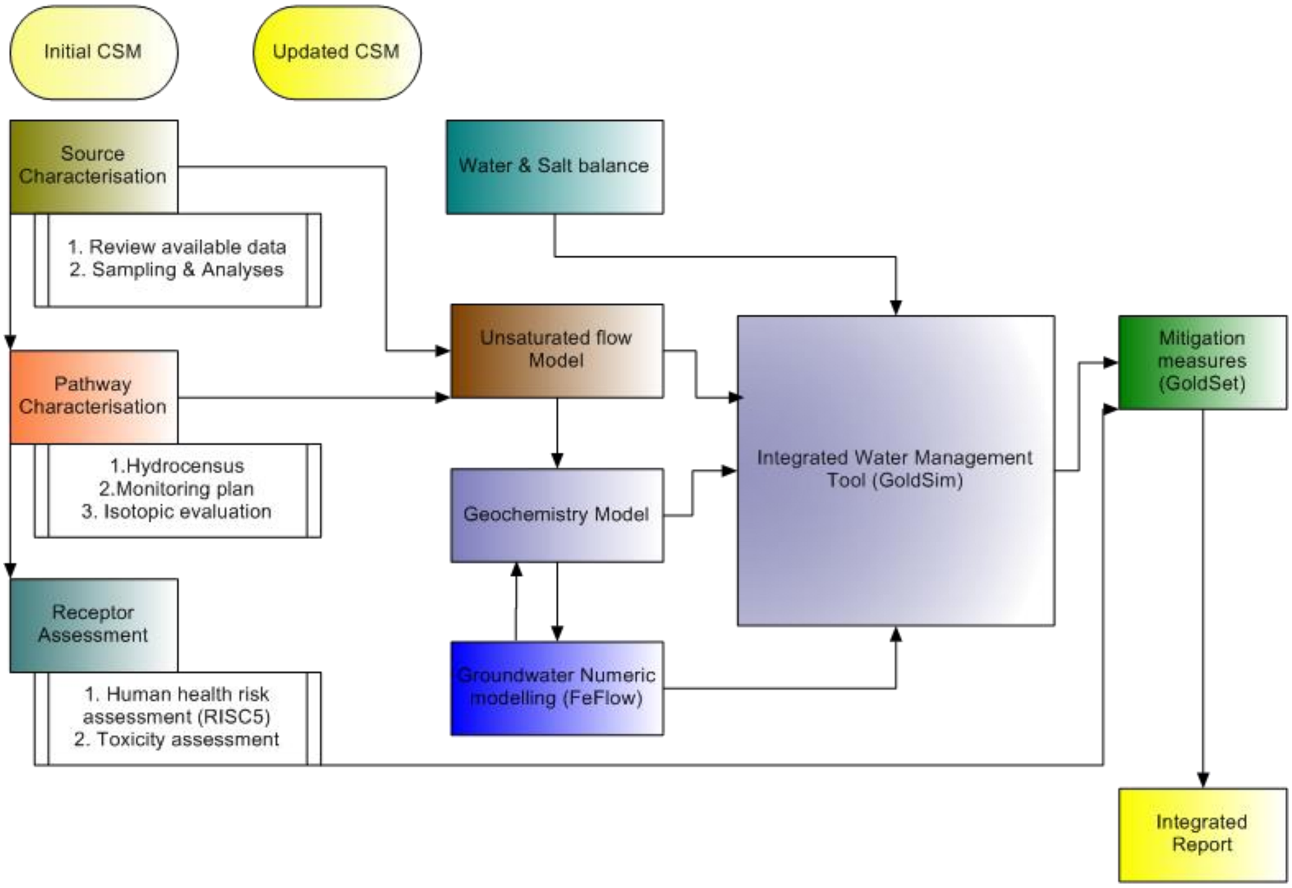


Figure 1: Project Flow Diagram

3.0 BACKGROUND INFORMATION

Various studies and investigations have been conducted at the site. Background information has been received from MFC which are listed in the sections that follow.

3.1 Reports

Consultants	Date	Description/Comments
Knight Piesold Consultants	June 2011	Clean and Dirty Water Separation.
	November 2013	Environmental Liability Assessment for Waste Facilities
	July 2014	Risk Assessment And Options Analysis For South Western Slag Dump.
	May 2010	Report on Piezometer readings and performance of seepage interception gallery
Knight Piesold / Terra Soil	April 2012	**An assessment of the pollution status of soils that are encountered in the vicinity of Samancor's Ferrochrome Plant**.
Knight Piesold / Peter Wade	April 2012	Options Analysis and Risk Assessment Report
Nepid Consultants	January 2013	Interpretation of historic and 2012 data for Biomonitoring of Vaalbank Spruit
	March 2014	Annual biomonitoring report

Consultants	Date	Description/Comments
Golder Associates	2014	MFC copy of Golder IWWMP
	Jan 2010	Interim Integrated Water and Waste Management Plan
	July 2011	Delineation of Groundwater Pollution Plumes and Predictions of Plume Migration
	July 2009	EIA for Ferrochrome Plant

3.2 Drawings

Consultant	Date	Drawing ID	Description
Knight Piesold Consulting	13/04/2011	30100183-05-01 REV P1	Stormwater Management System, Northern Section
		30100183-05-02 REV P1	Proposed Stormwater Management System Layout and Details, South Section
		30100183-05-03 REV P1	Stormwater interception trench adjacent to MTC, Sheet 1 of 2
		30100183-05-04 REV P1	Stormwater Management System, Manholes details
		30100183-05-05 REV P1	Stormwater Management System, Norhtern Section Outfall pipe, Long sections
		30100183-05-06 REV P1	Stormwater Management System, Central Section Outfall Pipe, Long sections
Columbus Stainless Drawing Office	09/04/1997	Infiltration gallery sump	Infiltration Gallery Weir Wall Layout and Details
WLPU Consulting Engineers	06/09/1994	Infiltration gallery	Pollution Control Infiltration Gallery Layout and Sections
MFC	2012	MFC - COLUMBUS STAINLESS BORDERS	Google image with site border
MFC	2009	SITE MAP DRAWING (2009 Rev 06):	Boreholes and Site Layout
MFC	Aug 2014	Arial photo 2014	Arial image with waste facilities

3.3 Data

Laboratory	File Name	Date	Description
Yanka Laboratories	MFC Soil Samples	01 August 2014	This was analysis that was done on all the soil textures and colours found at the historical dump. No report that was compiled. Study conducted for possible capping. The methodology was TCLP and total analysis
	Water monitoring data		Water monitoring data (analyses by Yanka Laboratories)
	Water Balance requirements		Water balance data and schematics

Laboratory	File Name	Date	Description
	for MES updates 1		
	Various	2011	Data used for 2011 Geochemical modelling
Supplied by MFC as excel file	*Complete Consolidated Water Results.xlsx*".	2008 to 2015	An excel file that contains data in tabs labelled Borehole, Dam, Spurit and Pond for each year. The date was cleaned as described in Golder Data Report April 2016 (Appendix B). The files from a specific data group, i.e. Borehole, Dam, Pond, Spruit for the different years were combined. The combined files were written to excel files labelled: PondAll2008to2015.xlsx BoreholeAll2008to2015.xlsx SpruitAll2008to2015.xlsx DamAll2008to2015.xlsx The following variables were explored in the data tidying process: "ID", "Date", "Conductivity", "pH", "Calcium", "Chloride", "Magnesium", "Potassium", "Nitrate", "Ammonia", "Sodium", "Sulphate", "Chromium", "Hexavalent.Chromium", "Fluoride", "Iron", "Manganese". Other Variables were not considered and should be evaluated before using. This data was used for this assessment.

4.0 FACILITY DELINEATION

The delineation of the facilities at MFC is shown in Figure 2 and listed in **Table 1** .

Table 1: Potential source areas at the MFC (Golder 2011 report)

Source No	Potential source	Source No	Potential source
1	Historical Kloof Slag Disposal Site	9	Historical Return Water Dams
2	Coal Stockpile	10	Dam 4B
3	Raw Materials Stockpile	11	Dam 4A
4	M3 and M4 Raw Materials Stockpile	12	Dam 3B
5	Low Carbon Stockpile	13	Dam 3A
6	Historical Ash Disposal Site	14	Pond 6B
7	Unused Slimes Dam	15	Main Slag Disposal Site
8	Old Slimes Dam	16	Infiltration Gallery

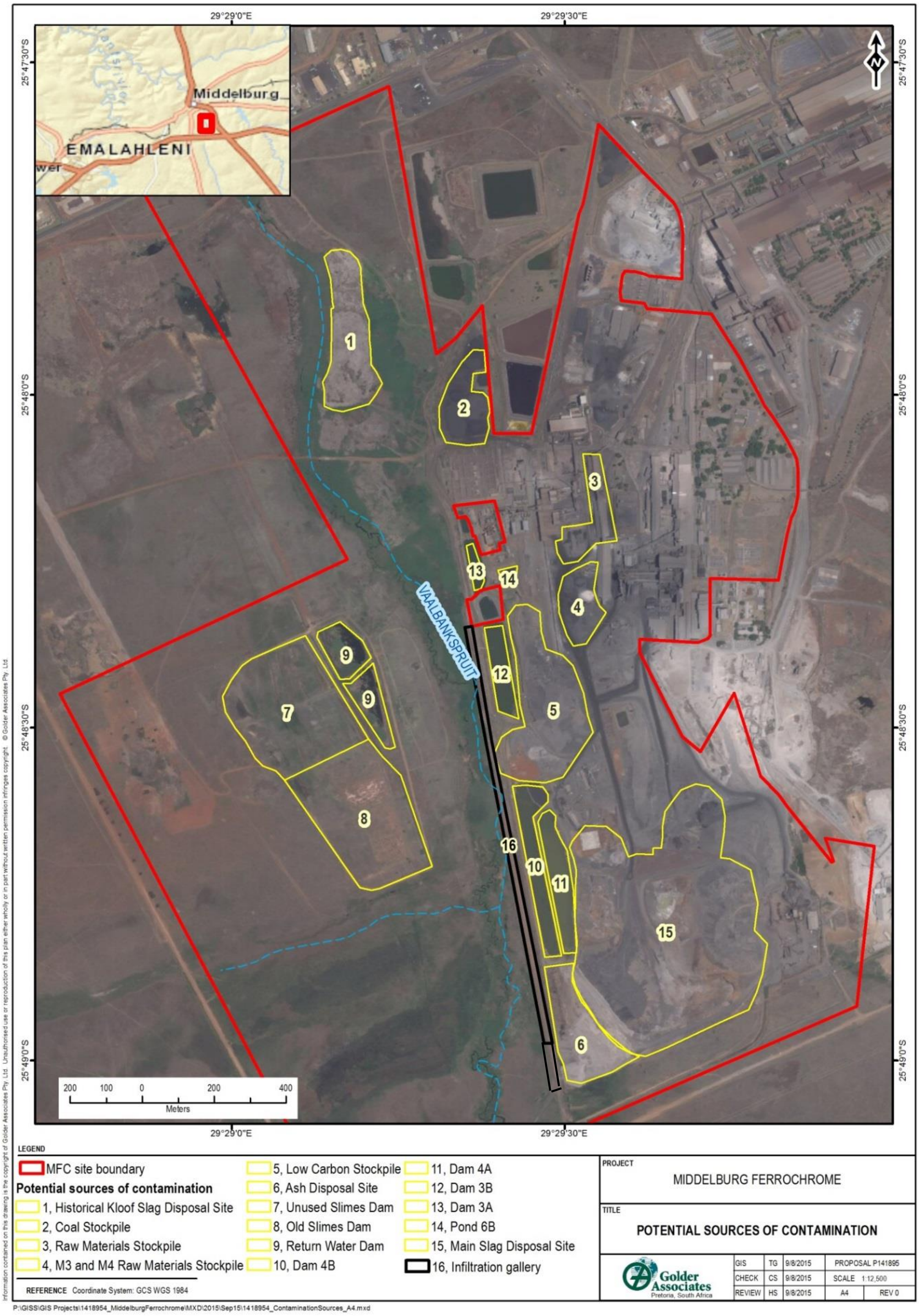


Figure 2: Potential contamination sources

5.0 SOURCE CHARACTERISATION

5.1 Sampling and Fieldwork

During the site visit conducted from 25 – 27 May 2015, the Golder representative was accompanied to the various facilities by a MFC representative. Samples were collected by means of a small spade or shovel and transferred to plastic sample bags and stored in storage container. Samples which were collected specifically for analysis of organic constituents were immediately transferred to 60 ml amber glass jars and stored in a cold storage container. Composite samples were collected from the waste facilities, but ten samples were collected from the Main Slag Disposal Facility (Facility 15) due to the significant variance in the waste streams disposed in the facility. Sediment samples were collected from the Infiltration Gallery (SD3, SD9 and SD11) and from the trench between MFC and Harsco. Table 2 and Figure 3 indicate the sample numbers and the various sampling positions.

Table 2: Waste and sediment samples collected

Waste		Sediment	
Facility 1 (FA1)	Facility 5 (FA5)	Facility 9 - RWD1 (FA9RWD1)	Harsco (Camisil) (Harsco4)
Facility 2 (FA2)	Facility 6 (FA6)	Facility 9 -RWD2 (FA9RWD2)	Harsco run-off
Facility 3 (FA3)	Facility 7 (FA7)	Facility 10 Dam 4B (FA10)	Harsco Trench A (HarscoA)
Facility 4 (FA4)	Facility 8 (FA8)	Facility 11 Dam 4A (FA11)	Harsco Trench B (HarscoB)
Facility 15 (FA15-1 – FA15-10)		Facility 12 Dam 3B (FA12)	SD3
		Facility 13 Dam 3A (FA13)	SD9
		Facility 14 Pond 6B (FA14)	SD11
		SP2	MB1

5.2 Sample analyses

The waste and sediment samples were analysed by Jones Environmental laboratory. Analyses included:

- Total digestion (*aqua regia*):
  - Semi-quantitative 33 element ICP scan;
- Total sVOC on selected samples;
- ASLP deionised water extract (1:20):
  - Semi-quantitative 33 element ICP scan;
  - Cr(VI);
  - SO_4, Cl_2, F_2, NH_4, NO_3; and
  - pH and TDS.

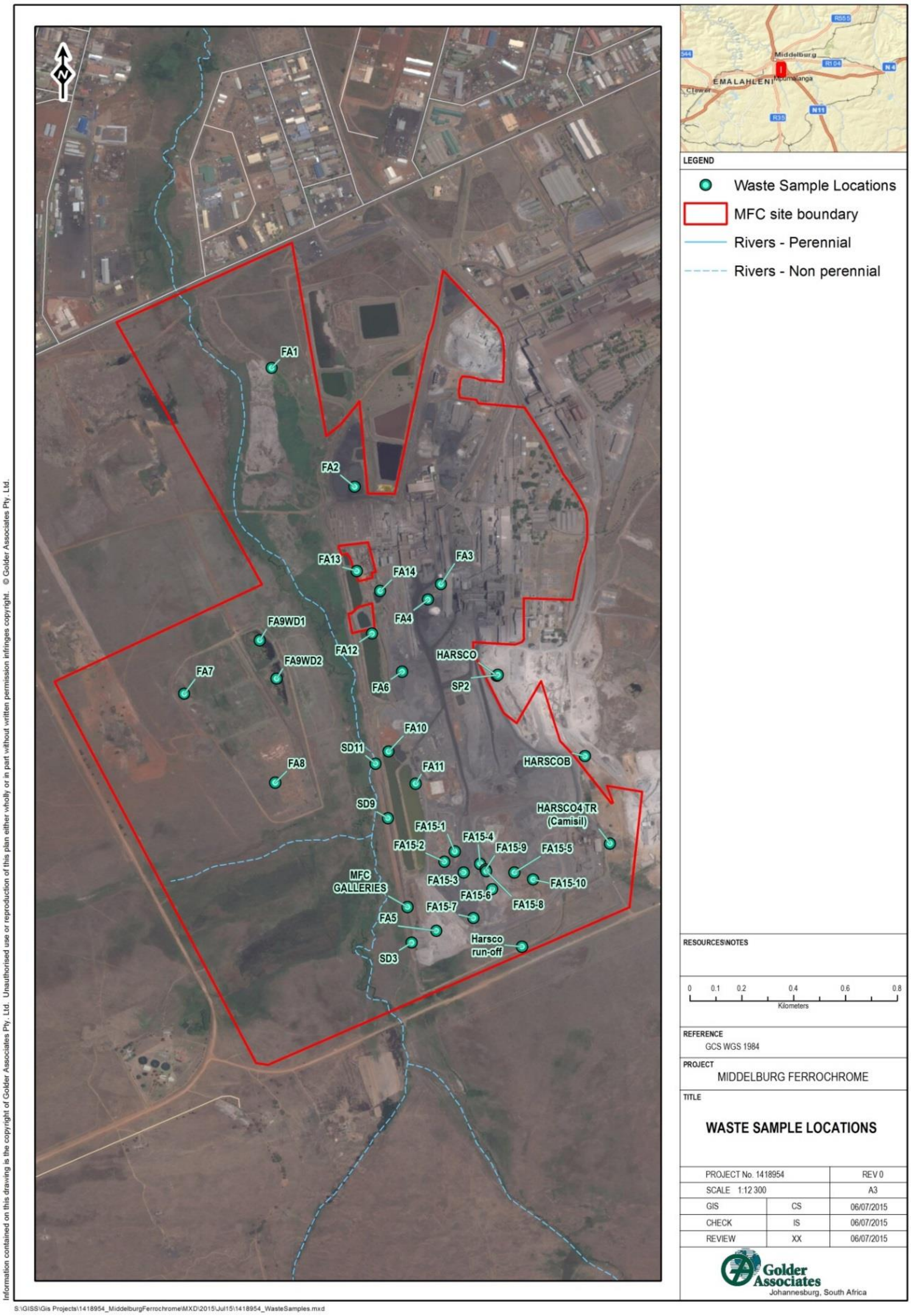


Figure 3: Waste and sediment sampling points

5.3 Analytical results

The analytical certificates of the waste and sediment samples are included in Appendix B. A summary of these results will be detailed and discussed in the sections that follow. As evaluation of the potential sources the data was compared with the National Norms and Standards for the assessment of waste for landfill disposal (GN R.635 of 2013).

5.3.1 Sediments from Containment facilities and Infiltration Gallery

The total concentrations of CoCs in sediment samples from the Containment Facilities and the Infiltration Gallery and trenches are shown in Table 3 and leachable concentrations of CoCs in Table 4.

Trench between Harsco and MFC

- Total Ba, Cu and Mn concentration, exceeding TCT0 levels, in all samples, but the leachable concentrations of these CoCs were < LCT0 levels;
- Total As in Harsco Run-off and Harsco 4 samples exceeding TCT0, but leachable concentrations < LCT0;
- Total Pb concentration of Harsco Run-off, Harsco B, Harsco 4 and SP2 were > TCT0 with leachable Pb concentrations > LCT0;
- Total Ni and Zn concentrations in Harsco A (Ni only), Harsco B and SP2 exceeded TCT0 while the leachable concentrations were < LCT0 levels;
- The leachable Cr(VI) and Mo concentrations in Harsco A and Harsco B exceeded the LCT0 levels;
- Harsco B had elevated NO_3 concentration, exceeding LCT0 level;
- The sediment samples had alkaline pH levels (8.05 – 11.56).

Containment facilities

- Facility 9 RWD: Total As, Ba, Co, Cu, Pb, Mn, V and Zn, exceeding TCT0 levels. However, the concentrations of these CoCs in the water samples were < LCT0 levels;
  - The F, SO_4 and TDS concentrations of the Water from Facility 9 exceeded LCT0 levels;
- Facility 10 Dam 4B: Total As, Ba, Cu, Pb and Mn concentrations, but concentrations of these CoCs in water were < LCT0 levels.
  - Concentrations of Cr, Cr(VI), Mo, Cl, F, NO_3, SO_4 and TDS were above LCT0;
- Facility 11 Dam 4A: Total Ba, Cu, Mn, Ni and Zn concentrations > TCT0, but concentrations of these CoCs in water was < LCT0;
  - Cr, Cr(VI), Mo, F, NO_3, SO_4 and TDS concentrations in water samples exceeded LCT0 levels;
- Facility 12 Dam 3B: Total Ba, Cu, Pb, Mn, Ni and Zn concentrations > TCT0, but concentrations of these CoCs in water was < LCT0;
  - Mo, F, NO_3, SO_4 and TDS concentrations in water samples exceeded LCT0 levels
- Facility 13 Dam 3A: Elevated total As, Ba, Cr(VI), Cu, Pb, Mn, Mo, Ni and Zn concentrations, but concentrations of these CoCs in water were < LCT0 levels;
  - The Mo, F, NO_3, SO_4 and TDS concentrations in water samples exceeded LCT0 levels:
- Facility 14 Pond 6B: Total Ba, Co, Cu, Pb, Mn, Ni and Zn concentrations exceeded TCT0 levels, but the concentrations of these CoCs in the water samples were < LCT0 levels; and
  - The Mo, F, NO_3, SO_4 and TDS concentrations in water samples exceeded LCT0 levels.

Table 3: Total concentrations of CoCs in Sediment samples

CoCs	TCT0	TCT1	TCT2	SD3	SD9	SD11	HARSCO RUN-OFF	HARSCO A	HARSCO B	HARSCO 4	SP2	MB01	FA9 - RWD1	FA9 - RWD2	FA 10 DAM 4B	FA11 DAM 4A	FA12 DAM 3B	FA13 DAM 3A	FA14 POND 6B
									mg/kg										
As	5.8	500	2000	2.6	6.6	12.1	14.1	<0.5	1.9	7.1	<0.5	2.5	20.9	19.2	83.3	<0.5	<0.5	32.7	<0.5
B	150	15000	60000	<0.25	<0.25	<0.25	<0.25	34.0	38.2	<0.25	41.6	9.7	<0.25	<0.25	<0.25	14.1	<0.25	<0.25	<0.25
Ba	62.5	6250	25000	180	188	420	693	231	264	235	189	270	432	195	323	73	106	308	100
Cd	7.5	260	1040	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.1
Cr	46000	800000	N/A	1075	1084	590.3	950.3	1708	1429	562.3	1335	671.4	678.9	268.4	282.5	4155	3509	2949	6568
Cr(VI)	6.5	500	2000	<0.3	1.6	0.8	0.9	3.1	1.6	<0.3	0.6	1.8	0.8	<0.3	1.2	<0.3	0.5	24.7	<0.3
Co	50	5000	20000	15.9	29.6	50.4	43.8	9.1	21.1	30.8	10.6	12.5	68.4	45.5	20.4	14.4	36.5	44	67.7
Cu	16	19500	78000	33	26	64	46	23	33	35	74	35	51	80	74	46	118	75	43
Fe	ng			36320	55130	86740	78590	16930	33000	56060	17950	30550	90390	88940	95180	20520	41740	56950	43090
Pb	20	1900	7600	18	24	40	35	18	24	38	36	19	32	15	34	10	25	64	35
Mn	1000	25000	100000	580	866	2090	3499	3547	1955	1568	2416	1512	2776	714	1126	1127	1161	2643	1911
Mo	40	1000	4000	28.3	45.8	73.5	27.4	21.5	18	7.5	32.6	8	5.5	4.7	34.8	7	7.8	579.2	6.6
Ni	91	10600	42400	54.1	45.6	50.2	72	190.1	169.4	80.4	211.7	86.7	67.3	73.3	81.7	177.2	102.2	1726	388.8
Se	10	50	200	1	1	2	2	2	2	2	2	2	2	<1	3	1	<1	2	1
V	150	2680	10720	98	97	130	110	128	93	103	121	80	189	304	113	133	82	127	74
Zn	240	160000	640000	154	69	95	188	229	392	120	384	221	521	169	121	561	590	422	3350

Grey: TC >TCT0 but < TCT1; Yellow: TC >TCT1 but < TCT2; Red: TC >TCT2

Table 4: Leachable concentrations of CoCs in Sediment samples

CoCs	LCT0	LCT1	LCT2	LCT3	SD3	SD9	SD11	HARSCO RUN-OFF	HARSCO A	HARSCO B	HARSCO 4	SP2	MB01	FA9 RWD1	FA9 RWD2	FA10 DAM 4B	FA11 DAM 4A	FA12 DAM 3B	FA13 DAM 3A	FA14 POND 6B
pH					7.85	8.49	8.62	8.36	10.88	11.56	8.05	10.44	9.3	7.9	8.91	9.66	9.64	8.37	8.7	9.85
mg/l																				
Al	ng				0.15	0.96	0.87	1.55	<0.02	2.27	0.34	<0.02	<0.02	<0.02	0.02	0.03	0.057	0.02	0.02	0.032
As	0.01	0.5	1	4	0.005	0.01	0.013	0.005	0.005	0.009	0.006	0.003	0.004	0.007	0.003	0.003	0.005	0.004	0.003	0.003
Ba	0.7	35	70	280	0.083	0.047	0.025	0.035	0.044	0.015	0.104	0.016	0.025	0.025	0.047	0.046	0.004	<0.003	0.061	<0.003
Ca	ng				12.72	2.41	1.37	2.32	9.19	14.92	4.68	4.8	1.11	49.82	339.1	8.6	15.6	61.3	26.1	8.4
Cr	0.1	5	10	40	0.004	0.012	0.02	0.034	0.084	0.43	0.003	0.036	0.013	0.0004	0.002	0.4333	1.913	0.015	0.014	0.029
Cr(VI)	0.05	2.5	5	20	<0.015	<0.015	<0.015	<0.015	0.054	0.05	<0.015	0.021	<0.015	<0.015	<0.015	0.333	1.351	<0.015	<0.015	<0.015
Co	0.5	25	50	200	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.047	0.029	0.029	0.028	0.042
Cu	2	100	200	800	0.018	0.018	0.016	<0.007	<0.007	0.011	0.008	<0.007	<0.007	0.01	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Fe					0.11	0.45	0.43	0.75	<0.02	<0.02	0.22	<0.02	<0.02	<0.02	<0.02	0.323	0.051	<0.02	0.051	0.251
Pb	0.01	0.5	1	4	0.005	<0.005	<0.005	0.008	0.051	<0.005	0.011	0.069	0.008	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Mg	ng				3.37	0.36	0.37	0.79	0.01	<0.1	1.54	0.27	1.06	20.01	150.3	64	44.1	44.1	40.3	39.5
Mn	0.5	25	50	200	0.05	0.003	0.002	0.001	<0.0002	<0.0002	0.002	<0.0002	<0.0002	0.005	0.002	0.059	0.006	0.002	0.002	0.013
Mo	0.07	3.5	7	28	0.08	0.39	0.58	0.04	0.08	0.21	0.01	0.04	0.02	0.01	0.06	0.76	1.02	0.85	0.81	0.35
Ni	0.07	3.5	7	28	0.024	0.013	0.018	0.005	<0.002	0.003	0.013	<0.002	0.004	0.007	0.003	0.098	0.031	0.036	0.025	0.075
K	ng				5.22	9.59	6.23	1.61	1.04	3.46	0.72	0.67	1.28	21.08	149.5	802.7	562.1	582.6	589.7	682.2
Se	0.01	0.5	1	4	<0.003	0.004	<0.003	<0.003	0.009	<0.003	0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Na	ng				17.8	32.4	25.7	3.9	8.4	3.7	1.8	6.1	4.2	59.5	611.7	892	723	742	764	715

CoCs	LCT0	LCT1	LCT2	LCT3	SD3	SD9	SD11	HARSCO RUN-OFF	HARSCO A	HARSCO B	HARSCO 4	SP2	MB01	FA9 RWD1	FA9 RWD2	FA10 DAM 4B	FA11 DAM 4A	FA12 DAM 3B	FA13 DAM 3A	FA14 POND 6B
V	0.2	10	20	80	0.0004	0.001	0.0005	0.0005	0.033	0.003	0.0003	0.087	0.002	<0.0002	0.005	0.017	0.028	0.002	0.002	0.027
Zn	5	250	500	2000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.028	0.077	0.031	0.021	0.018	0.054
Cl	300	15000	30000	120000	9.6	12.1	7.8	0.9	1.9	2.5	0.7	1.6	0.5	12.8	126.1	335	299	297	272	260
F	1.5	75	150	600	0.28	0.83	0.93	0.35	0.42	<0.015	0.2	1.03	0.89	0.57	5.6	9.6	9.7	9.8	9.7	12.6
NO_3	11	550	1100	4400	<0.125	3.06	<0.125	<0.125	1.01	13.7	0.66	1.91	0.95	1.30	0.2	300	297	509	60.6	201
SO_4	250	12500	25000	100000	56.4	41.3	27.5	4.0	16.8	10.4	8.06	6.11	3.6	280	2503	1095	936	1275	1031	750
TDS	1000	12500	25000	100000	131	111	80.4	21.2	83	107	36.6	51.7	21.5	514	3591	4510	3484	3904	3365	3491

Grey: TC >LCT0 but <LCT1; Yellow: TC >LCT1 but <LCT2; Orange: TC >LCT2 but <LCT3; Red: >LCT3

Infiltration Gallery

Samples collected from Infiltration Gallery (SD3, SD9 and SD11) showed the following:

- Total and leachable As concentrations, exceeding TCT0 and LCT0 respectively, in SD9 and SD11;
- Total Ba and Cu in all sediment samples (>TCT0) with low leachability (<LCT0);
- Total Pb and Mo in SD9 and SD11 (>TCT0) while the leachable Mo concentration in all sediment samples exceeded LCT0 levels;
- SD11 had total Co and Mn, exceeding TCT0;
- The leachable concentration of all CoCs (except As and Mo) were < LCT0 levels.

5.3.2 Waste samples

Table 5 presents the total concentrations of CoCs and Table 6 presents leachable concentrations of CoCs in waste samples. Results indicate the following:

- Facility 1: Total Mn and V concentrations > TCT0 and leachable Pb concentration > LCT0;
- Facility 2: Total Ba concentration exceeded TCT0 while the leachable concentrations of all CoCs were < LCT0 levels;
- Facility 3: Total Cu concentration > TCT0 and the leachable Pb concentration exceeded LCT0;
- Facility 4: None of the total concentrations of CoCs exceeded TCT0 levels, but the leachable Cr, and Mo concentrations exceeded LCT0 levels;
- Facility 5: The total Cr(VI), Mn, Ni and Zn concentrations exceeded TCT0 levels, while the leachable Cr, CR(VI) and Pb concentrations were > LCT0 levels;
- Facility 6: Cr(VI) concentration, exceeding TCT0 and leachable Cr and Cr(VI) concentrations were > LCT0 levels;
- Facility 7: Total concentrations of As, Ba, Cu, Pb and V exceeded TCT0, but the leachable concentrations of all CoCs were < LCT0 levels;
- Facility 8: Total As, Ba, Co, Cu, Pb and V concentration exceeded TCT0 levels and the leachable Cr(VI) concentration exceeded LCT0 the level;
- Facility 15: CoCs in these waste streams were variable and included total Ba, Cu, Cr(VI), Pb, Mn, Mo, Ni (all samples) and Zn, exceeding TCT0 levels. The Cr(VI) concentration in FA15-6 exceeded the TCT1 level;
    - Leachable concentrations exceeding LCT0 levels included As, Pb, Mo, Se, NO_3 and SO_4, while the main CoC were Cr and Cr(VI), exceeding LCT0 in the majority of samples. The leachable Cr in FA15-6 exceeded LCT3 while the Cr(VI) concentration in the same sample were > LCT2.

Table 5: Total concentrations of CoCs in Waste samples

CoCs	TCT0	TCT1	TCT2	FA1	FA2	FA3	FA4	FA5	FA6	FA7	FA8	FA15-1	FA15-3	FA15-4	FA15-5	FA15-6	FA15-7	FA15-8	FA15-9	FA15-10
	mg/kg																			
As	5.8	500	2000	<0.5	1	<0.5	<0.5	<0.5	<0.5	13.1	20.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	<0.5	<0.5	<0.5
B	150	15000	60000	7.63	18.83	2.1	<0.25	6.89	<0.25	<0.25	<0.25	<0.25	<0.25	7.71	<0.25	76.69	6.04	1.39	5.87	<0.25
Ba	62.5	6250	25000	40	68	43	28	29	21	129	99	79	58	36	52	69	92	42	52	60
Cd	7.5	260	1040	<0.1	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	1.9	0.3	<0.1	<0.1	0.4
Cr	46000	800000	N/A	7702	21.7	673.2	107.7	10280	2910	210.3	363.7	9135	3346	8170	3484	4320	7780	8015	6143	10020
Cr(VI)	6.5	500	2000	0.3	0.3	0.3	<0.3	22.6	18.3	<0.3	3.6	18.3	<0.3	2.9	5	861	3.8	48.9	27.7	1
Co	50	5000	20000	3.6	5.3	8.8	2.4	17.7	14.4	23.7	51.6	35.6	26.3	10.2	20.4	30.2	16.1	32.9	13.6	193.8
Cu	16	19500	78000	8	8	16	13	11	11	33	32	66	3	13	21	89	14	25	16	137
Fe	ng			3914	1702	6781	2961	13860	10740	77230	77630	48800	18760	11020	22690	36510	14550	28140	12410	77800
Pb	20	1900	7600	<5	<5	5	<5	12	<5	23	28	25	<5	11	17	142	22	12	<5	132
Mn	1000	25000	100000	1435	57	212	195	1639	638	502	645	1621	1277	1381	844	5160	1275	1348	1477	5929
Hg	0.93	160	640	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.3
Mo	40	1000	4000	2.1	1.7	2.8	1.6	18	3	3.5	3.7	69.9	17.2	12.1	22.4	293.7	17	31	12.4	3.4
Ni	91	10600	42400	37.8	7.4	67.5	19.3	117.4	87.1	31.4	34.6	3272	101.8	177.4	412.1	2510	155.6	2293	140	936.7
V	150	2680	10720	165	8	18	8	108	31	150	159	120	12	102	57	42	110	97	114	44
Zn	240	160000	640000	117	15	79	<5	306	108	56	109	354	13	148	187	2307	600	607	178	18520

Grey: TC >TCT0 but < TCT1; Yellow: TC >TCT1 but < TCT2; Red: TC >TCT2

Table 6: Leachable concentration of CoCs in Waste samples

CoCs	LCT0	LCT1	LCT2	LCT3	FA1	FA2	FA3	FA4	FA5	FA6	FA7	FA8
pH					10.2	8.07	10.48	12.01	10.39	12.79	7.77	7.84
						mg/l						
Al	ng				0.05	0.1	0.06	3.12	0.04	0.07	0.07	0.75
As	0.01	0.5	1	4	0.0025	<0.0025	<0.0025	0.0065	0.006	<0.0025	0.0034	0.0032
Ba	0.7	35	70	280	<0.003	0.095	0.052	0.025	<0.003	0.295	0.071	0.047
Ca	ng				3.5	9.66	11.9	16.39	6.77	96.26	2.27	2.93
Cr	0.1	5	10	40	0.048	0.0002	0.012	0.49	1.59	0.386	0.001	0.076
Cr(VI)	0.05	2.5	5	20	<0.015	<0.015	<0.015	<0.015	0.511	0.168	<0.015	0.142
Co	0.5	25	50	200	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Cu	2	100	200	800	<0.007	<0.007	<0.007	0.013	<0.007	<0.007	<0.007	0.008
Fe					<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.04	0.51
Pb	0.01	0.5	1	4	0.039	<0.005	0.017	<0.005	0.011	<0.005	<0.005	0.005
Mg	ng				0.21	3.11	0.06	<0.1	0.54	<0.1	1.06	0.83
Mn	0.5	25	50	200	<0.0002	0.0024	<0.0002	<0.0002	<0.0002	<0.0002	0.0056	0.0005
Hg	0.006	0.3	0.6	2.4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Mo	0.07	3.5	7	28	0.0014	0.0029	0.0039	0.0788	0.0114	0.0045	0.004	0.0066
Ni	0.07	3.5	7	28	<0.002	<0.002	<0.002	0.004	<0.002	<0.002	0.002	0.003
P					0.0027	0.002	0.0014	0.0017	0.0006	0.0008	0.0025	0.0198
K	ng				0.03	0.21	1.16	4.35	1.08	2.51	0.73	2.73
Se	0.01	0.5	1	4	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Na	ng				0.02	0.41	2.46	5.06	0.68	3.07	0.68	2.31
V	0.2	10	20	80	0.021	<0.0002	0.006	0.001	0.007	<0.0002	<0.0002	0.0002
Zn	5	250	500	2000	0.0005	0.0007	0.0005	0.0008	<0.0002	0.0018	0.0006	0.001

CoCs	LCT0	LCT1	LCT2	LCT3	FA1	FA2	FA3	FA4	FA5	FA6	FA7	FA8
Cl	300	15000	30000	120000	<0.1	0.5	0.8	1.7	1.2	1.4	0.2	0.4
F	1.5	75	150	600	0.04	0.065	0.245	0.11	0.02	<0.015	0.075	0.3
NO3	11	550	1100	4400	<0.125	<0.125	1.25	8.92	1.27	1.49	<0.125	1.17
SO4	250	12500	25000	100000	0.49	27.6	22.1	1.54	8.24	3.58	7.06	8.03
TDS	1000	12500	25000	100000	107	43	53.3	56	31.7	181	17.2	40.2

Grey: TC >LCT0 but <LCT1; Yellow: TC >LCT1 but <LCT2; Orange: TC >LCT2 but <LCT3; Red: >LCT3

CoCs	LCT0	LCT1	LCT2	LCT3	FA15-1	FA15-3	FA15-4	FA15-5	FA15-6	FA15-7	FA15-8	FA15-9	FA15-10
pH					8.94	10.13	10.48	10.23	9.58	10.76	11.41	11.08	8.97
mg/l													
Al	ng				<0.02	0.63	0.73	0.15	<0.02	1.34	6.61	12.41	<0.02
As	0.01	0.5	1	4	<0.0025	<0.0025	0.0045	0.0041	0.0755	0.0087	0.0081	0.0073	0.0057
Ba	0.7	35	70	280	<0.003	0.048	<0.003	0.003	0.033	0.015	<0.003	<0.003	0.055
Ca	ng				0.9	1.58	7.92	3.83	41.14	4.81	8.55	7.61	41.74
Cr	0.1	5	10	40	0.008	0.035	0.298	0.424	20.1	0.769	1.79	1.66	0.416
Cr(VI)	0.05	2.5	5	20	0.154	<0.015	0.082	0.098	27.752	0.358	0.369	0.663	0.236
Co	0.5	25	50	200	<0.002	<0.002	<0.002	<0.002	0.004	<0.002	<0.002	<0.002	0.047
Cu	2	100	200	800	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007
Fe					<0.02	<0.02	<0.02	<0.02	<0.02	0.02	<0.02	<0.02	0.63
Pb	0.01	0.5	1	4	0.007	0.007	0.008	0.013	0.033	0.008	0.005	<0.005	<0.005
Mg	ng				0.88	0.4	0.25	0.5	0.34	0.04	<0.1	0.01	14.88
Mn	0.5	25	50	200	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	0.0135
Hg	0.006	0.3	0.6	2.4	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

CoCs	LCT0	LCT1	LCT2	LCT3	FA15-1	FA15-3	FA15-4	FA15-5	FA15-6	FA15-7	FA15-8	FA15-9	FA15-10
Mo	0.07	3.5	7	28	0.0006	0.0005	0.0138	0.0181	0.2501	0.0273	0.0382	0.0495	0.0123
Ni	0.07	3.5	7	28	<0.002	<0.002	<0.002	<0.002	<0.002	0.003	<0.002	<0.002	0.004
P					<0.0005	<0.0005	0.0011	<0.0005	0.0014	<0.0005	<0.0005	<0.0005	0.0245
K	ng				0.19	0.12	2.08	1.4	32.71	3	3.15	2.8	<0.01
Se	0.01	0.5	1	4	<0.003	<0.003	<0.003	<0.003	0.063	<0.003	<0.003	<0.003	0.042
Na	ng				1.21	0.08	2.2	1.42	45.43	2.67	2.82	3.45	<0.01
V	0.2	10	20	80	0.006	0.001	0.007	0.005	0.005	0.005	0.002	0.003	<0.0002
Zn	5	250	500	2000	0.0005	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.002
Cl	300	15000	30000	120000	0.4	0.1	1.5	0.7	32.7	1.2	2.5	2.4	168.2
F	1.5	75	150	600	0.065	<0.015	<0.015	0.15	0.07	0.09	0.03	0.03	0.615
NO3	11	550	1100	4400	1.50	<0.125	1.23	1.14	26.4	2.07	2.73	2.60	0.992
SO4	250	12500	25000	100000	1.04	1.1	8.23	6.65	72.2	8.13	6.08	7.97	1056
TDS	1000	12500	25000	100000	8.3	66.8	55.4	30.8	332	27.9	38.5	38.8	600

Grey: TC >LCT0 but <LCT1; Yellow: TC >LCT1 but <LCT2; Orange: TC >LCT2 but <LCT3; Red: >LCT3

5.4 Discussion

The current and historical data indicate that the waste facilities contribute to the contaminant load, but the main contribution to surface and groundwater contamination are from:

- Main Slag Disposal facility (Facility 15);
- Containment facilities: RWD, Dam 3A, 3B, 4A, 4B and Pond 6A & 6B; and
- Infiltration Gallery.

A screening of the waste samples and Containment facility sediment and water quality indicate that the main CoCs include NO_3, SO_4, Cr(VI), F and Mo. The other CoCs (As, Ba, Cu, Co, Pb, Ni, Mn and Zn) are only present in the total concentrations and not leachable concentrations and are therefore not available to migrate to the surface and groundwater. This is verified by the absence of these CoCs in the Vaalbankspruit and groundwater samples (see sections 6.0 and 6.3).

5.4.1 Nitrate

The containment facilities (Dam 3A, 3B, 4A, 4B and Pond 6B) water contains some NO_3 but not in the sediment samples collected from these facilities. The sediment sample from the trench between MFC and Harsco indicated elevated NO_3 concentration. The historic time series data for the facilities are presented in Figure 4 to Figure 7. Currently the facilities have a concentrations between 100 and 200 mg/l Nitrate. With the Nitrate concentration in Dam4A&B and Pond6A strongly related to pH (Figure 8) with the Nitrate concentrations being limited to below 100mg/l when the pH is above 9.

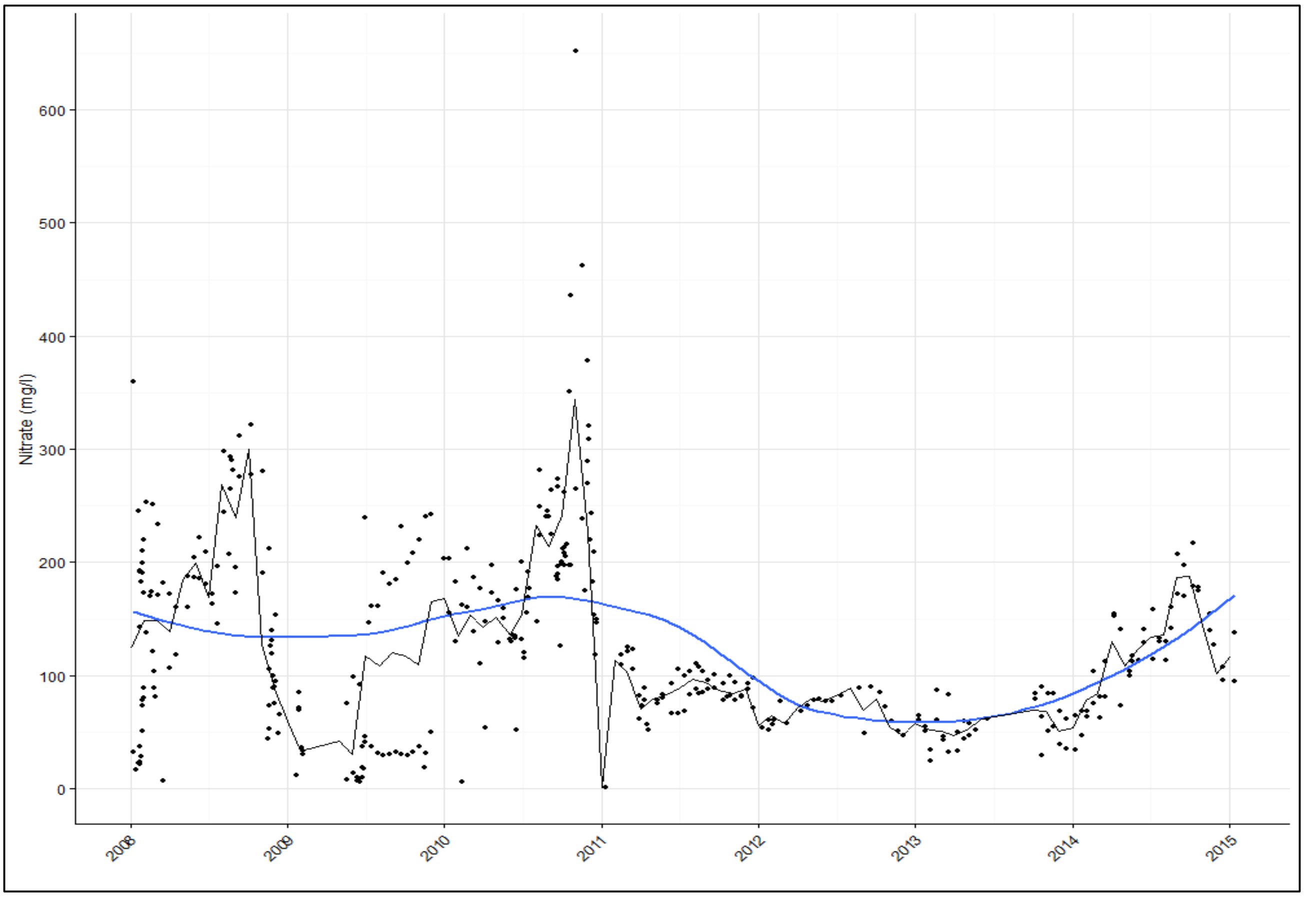


Figure 4: Dam3A&B time series plot of Nitrate concentrations (blue line indicate as smoothed mean and black line a monthly mean)

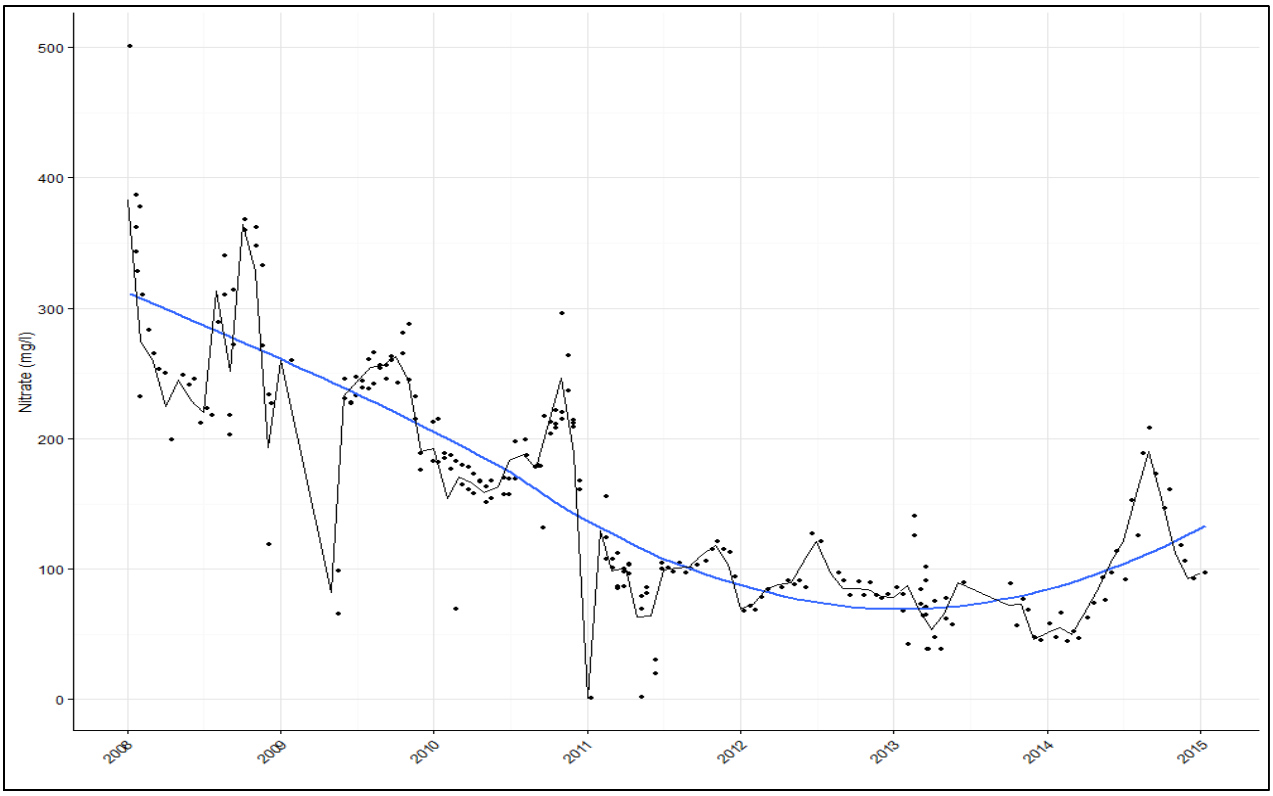


Figure 5: Dam4A,B&C time series plot of Nitrate concentrations (blue line indicate as smoothed mean and black line a monthly mean)

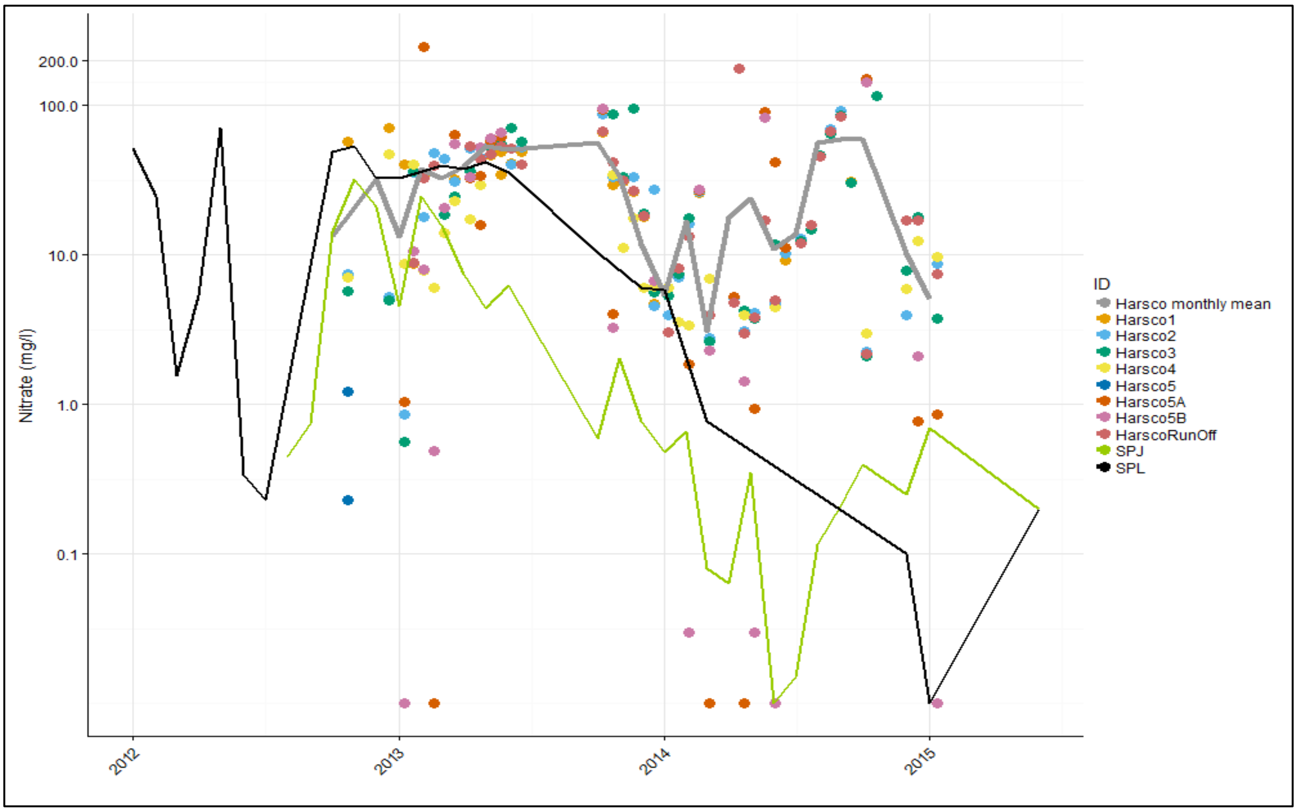


Figure 6: Harsco monitoring time series plot of Nitrate concentrations (grey line indicate as smoothed mean and monthly means of monitoring point at SPL and SPJ are also presented)

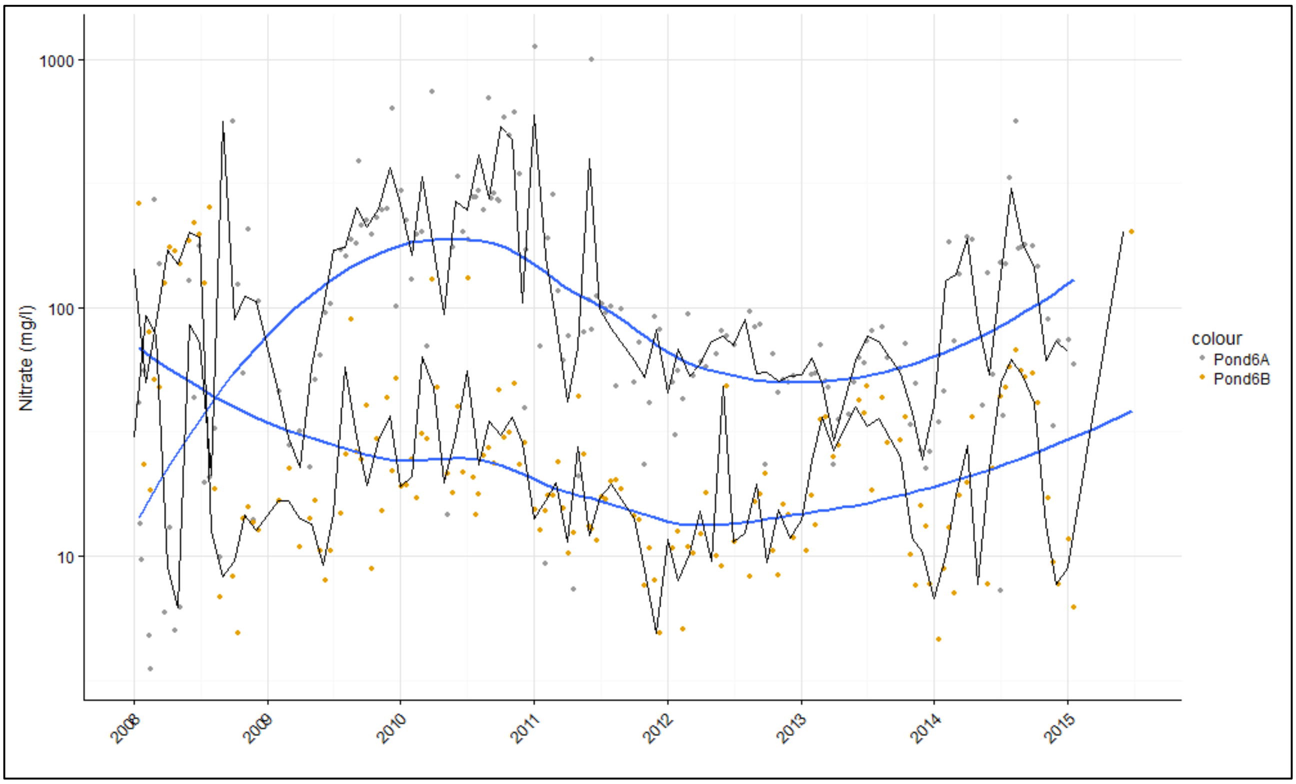


Figure 7: Pond6A & 6B time series plot of Nitrate concentrations (blue line indicate as smoothed mean and black line a monthly mean)

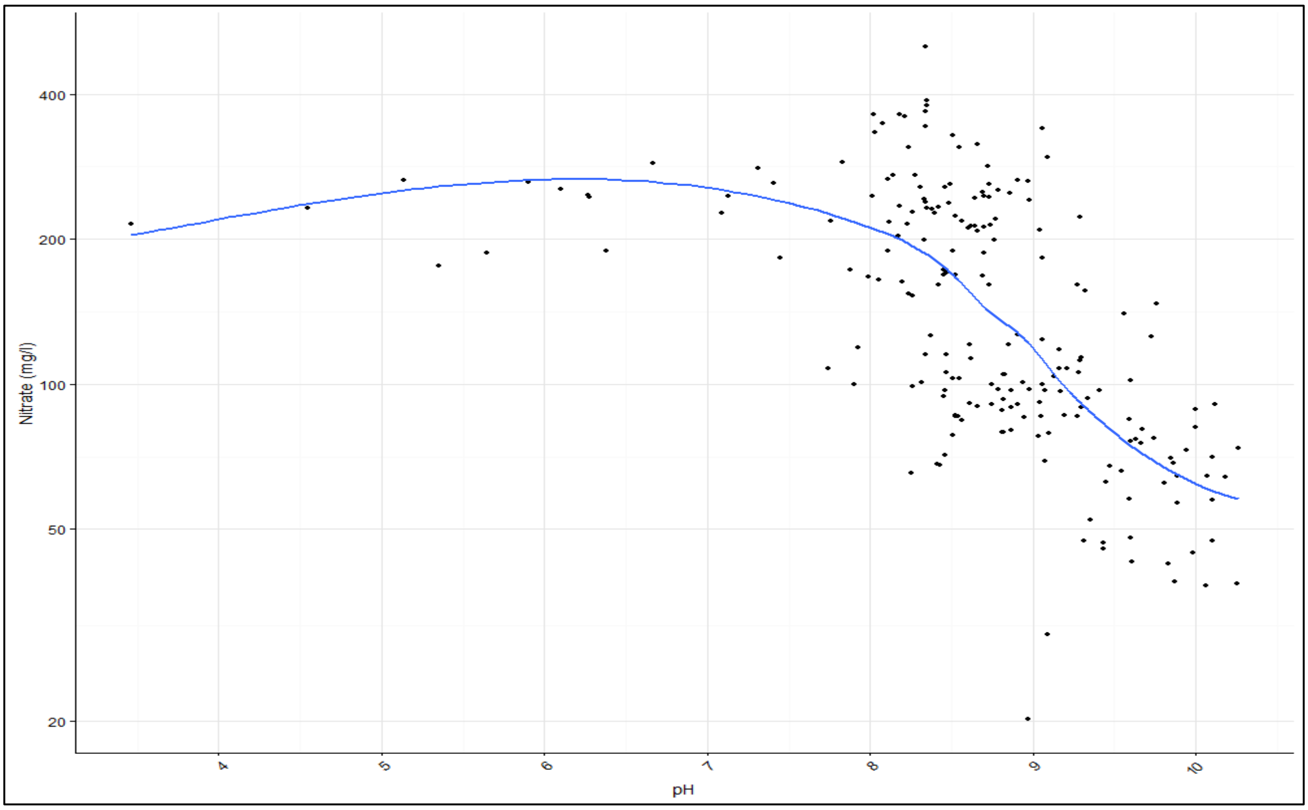


Figure 8: Dam4 Nitrate concentrations as correlated with pH (blue line indicate as smoothed mean)

In the current sampling, only one waste sample from the Main Slag Disposal Site had elevated NO_3 concentration. However, a number of samples recorded high NO_3 as part of the MFC sampling program of Slag Disposal Facility. The 2010 Golder sampling also indicated high NO_3 in this facility.

5.4.2 Sulphate and Sodium

The major cation and anion combination contributing to the salt load is Na and SO_4. Sources contributing to the load of Na and SO_4 are:

- One waste sample from Main Slag Disposal Facility (Facility 15);
- Sediment from the RWD (Facility 9); and
- Old Slimes Dam

The historic time series data of the sulphate concentration in water samples are presented in Figure 9 to Figure 12 of Dam3, Dam4, Harsco and Pond6A & 6B respectively. The sulphate from the Old Slimes Dam can be estimated form borehole data (Figure 13). The sulphate data varies between 500 and 1500 mg/l for these facilities. The sodium time series data are presented in Figure 14 to Figure 18 and varies between 100 and 1000mg/l.

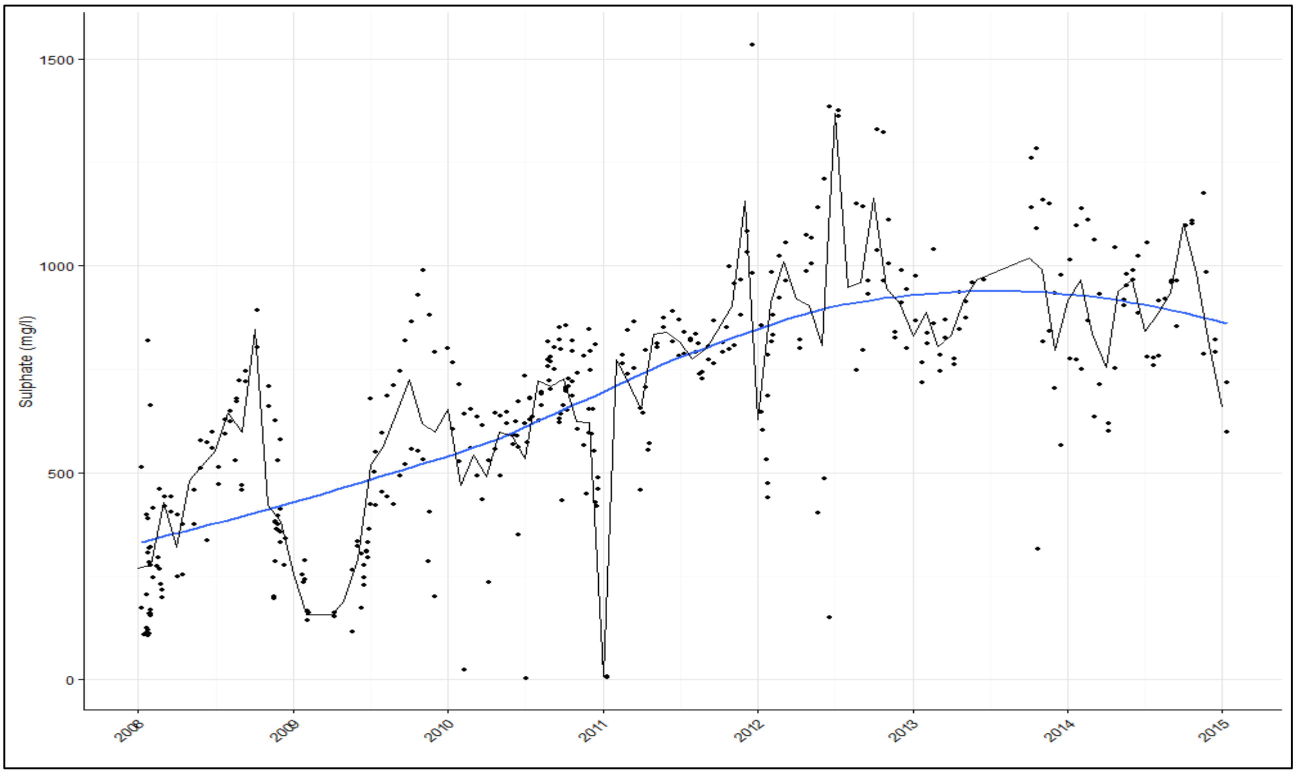


Figure 9: Dam3A&B time series plot of Sulphate concentrations (blue line indicate as smoothed mean and black line a monthly mean)

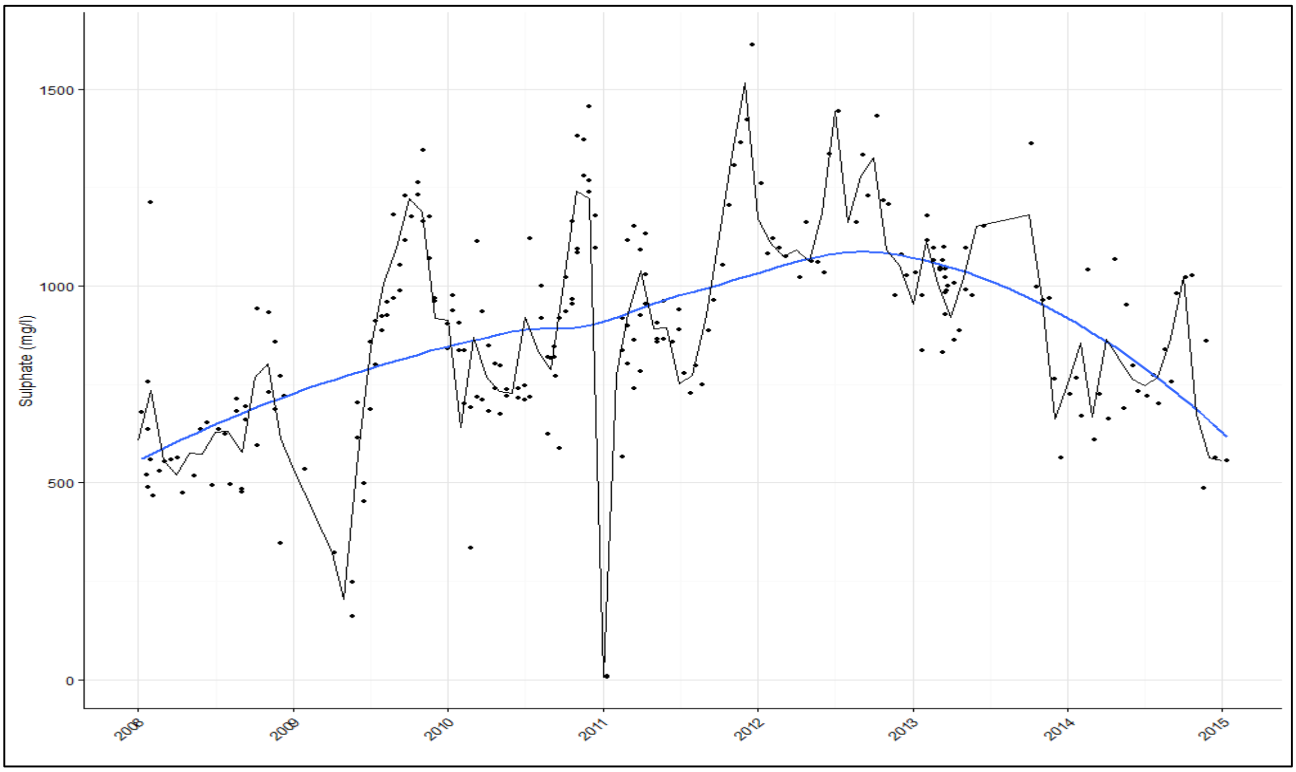


Figure 10: Dam4A,B&C time series plot of Sulphate concentrations (blue line indicate as smoothed mean and black line a monthly mean)

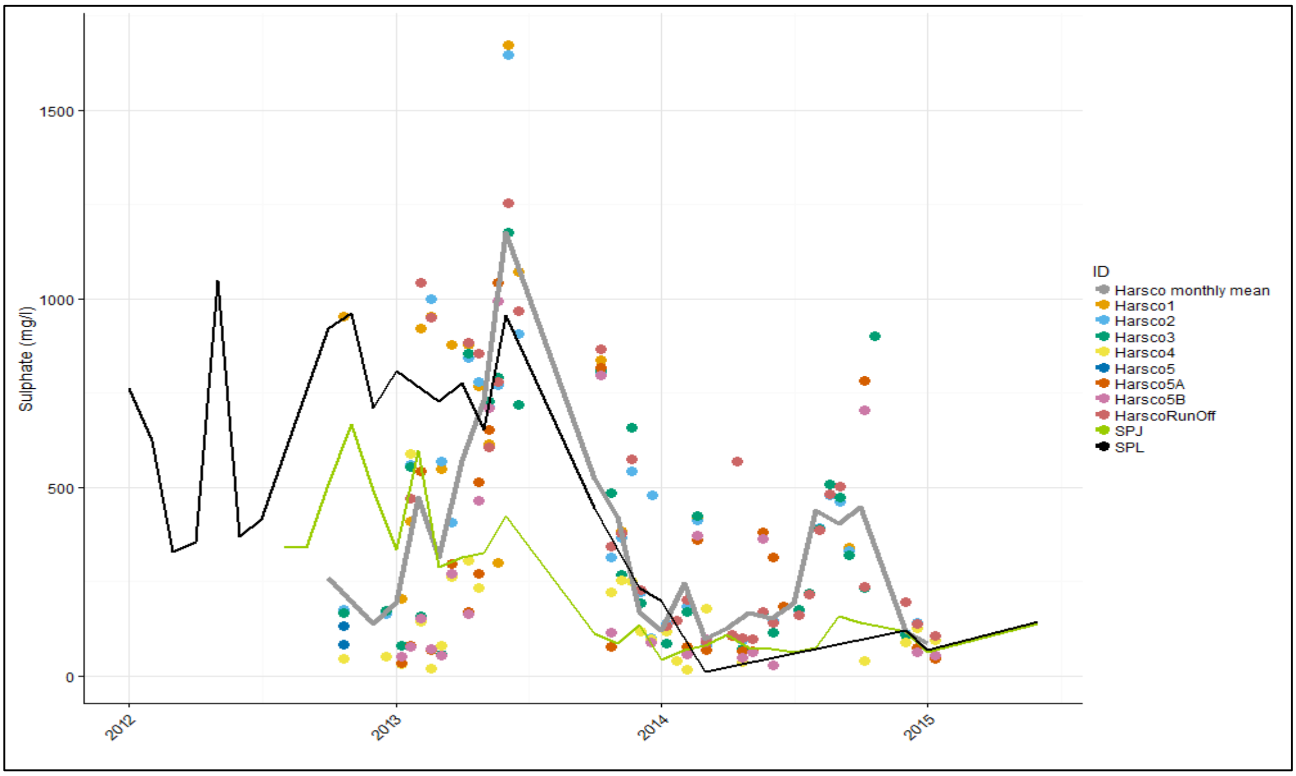


Figure 11: Harsco monitoring time series plot of Sulphate concentrations (grey line indicate as smoothed mean and monthly means of monitoring point at SPL and SPJ are also presented)

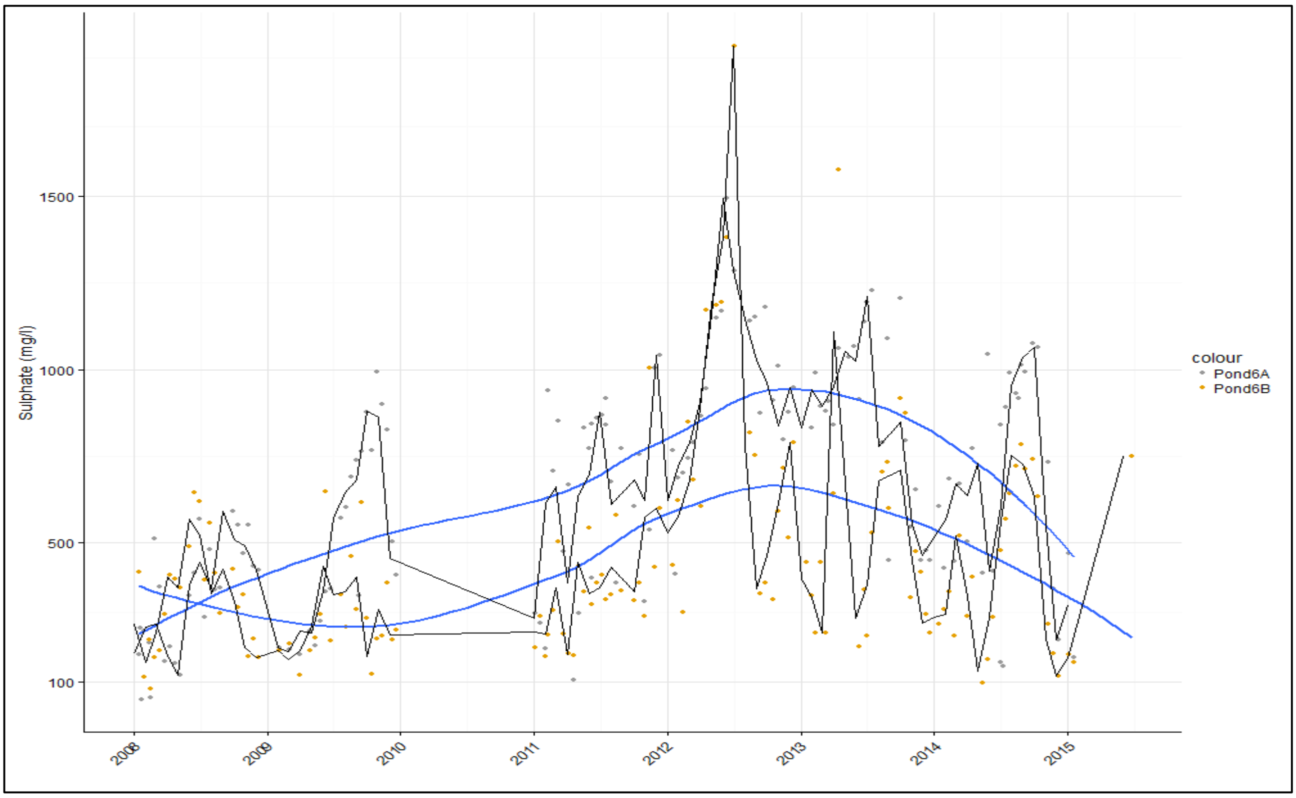


Figure 12: Pond6A & 6B time series plot of Sulphate concentrations (blue line indicate as smoothed mean and black line a monthly mean)

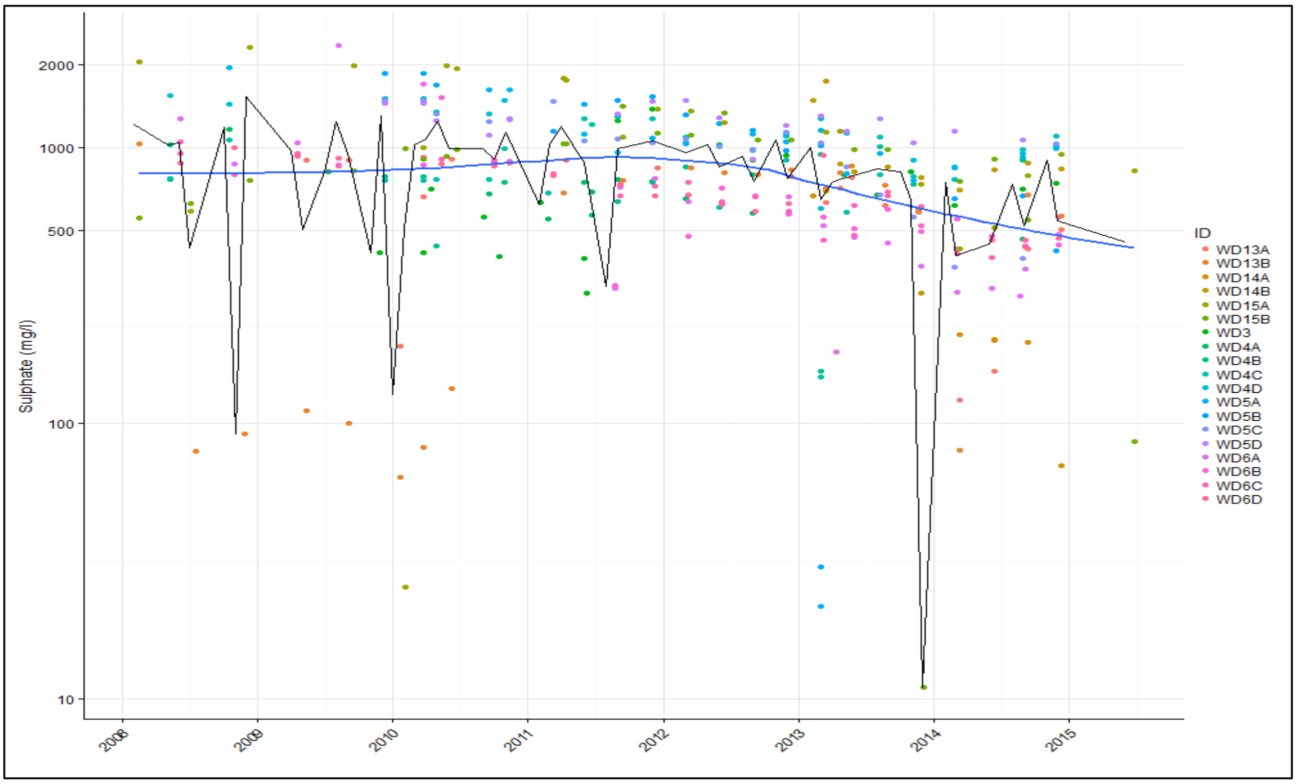


Figure 13: Boreholes around the Old Sludge Dams time series plot of Sulphate concentrations (blue line indicate as smoothed mean and black line a monthly mean)

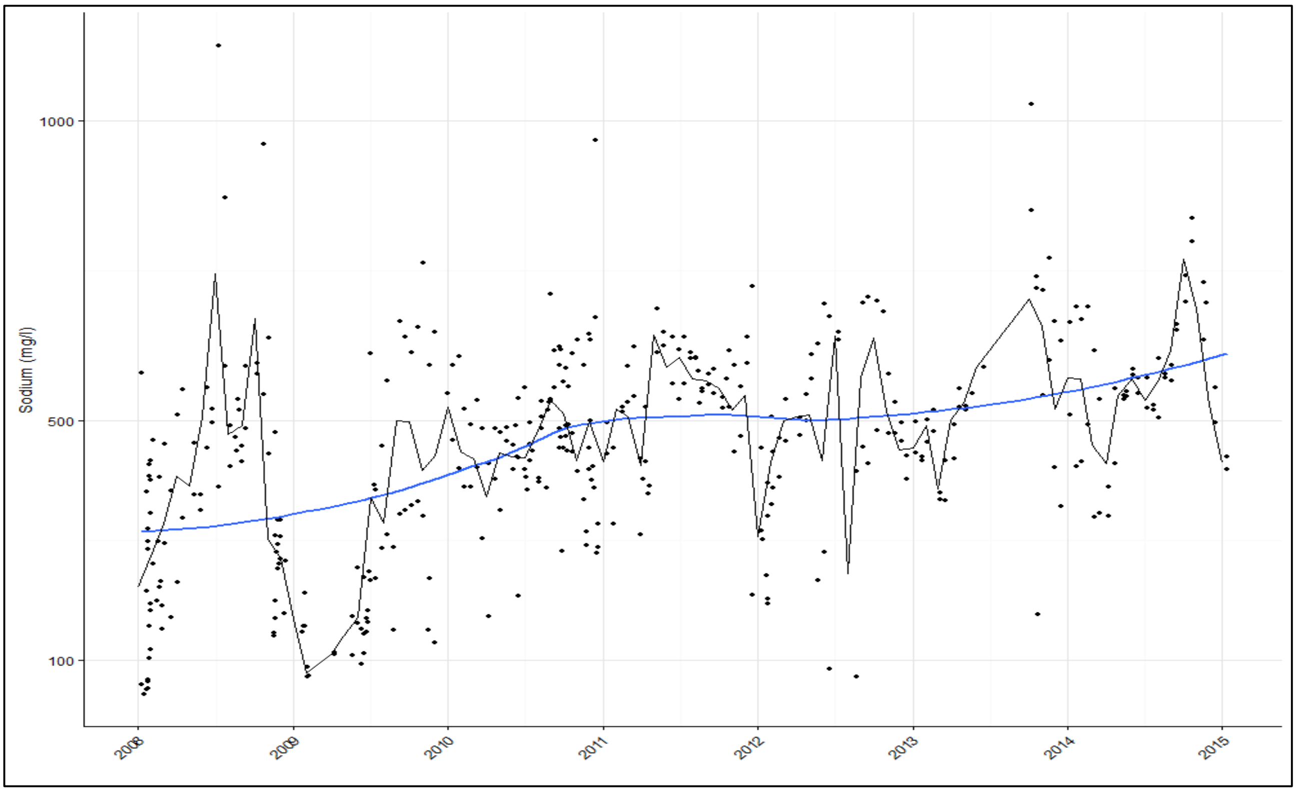


Figure 14: Dam3A&B time series plot of Sodium concentrations (blue line indicate as smoothed mean and black line a monthly mean)

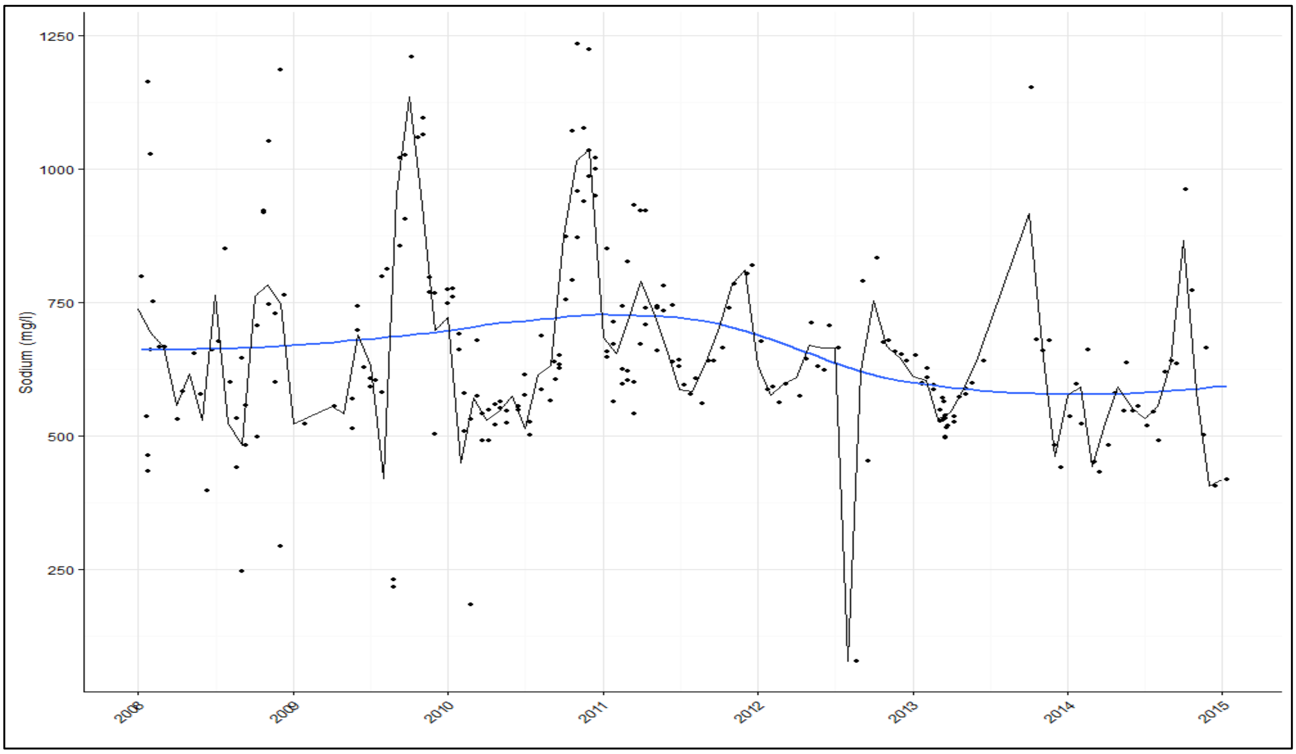


Figure 15: Dam4A,B&C time series plot of Sodium concentrations (blue line indicate as smoothed mean and black line a monthly mean)

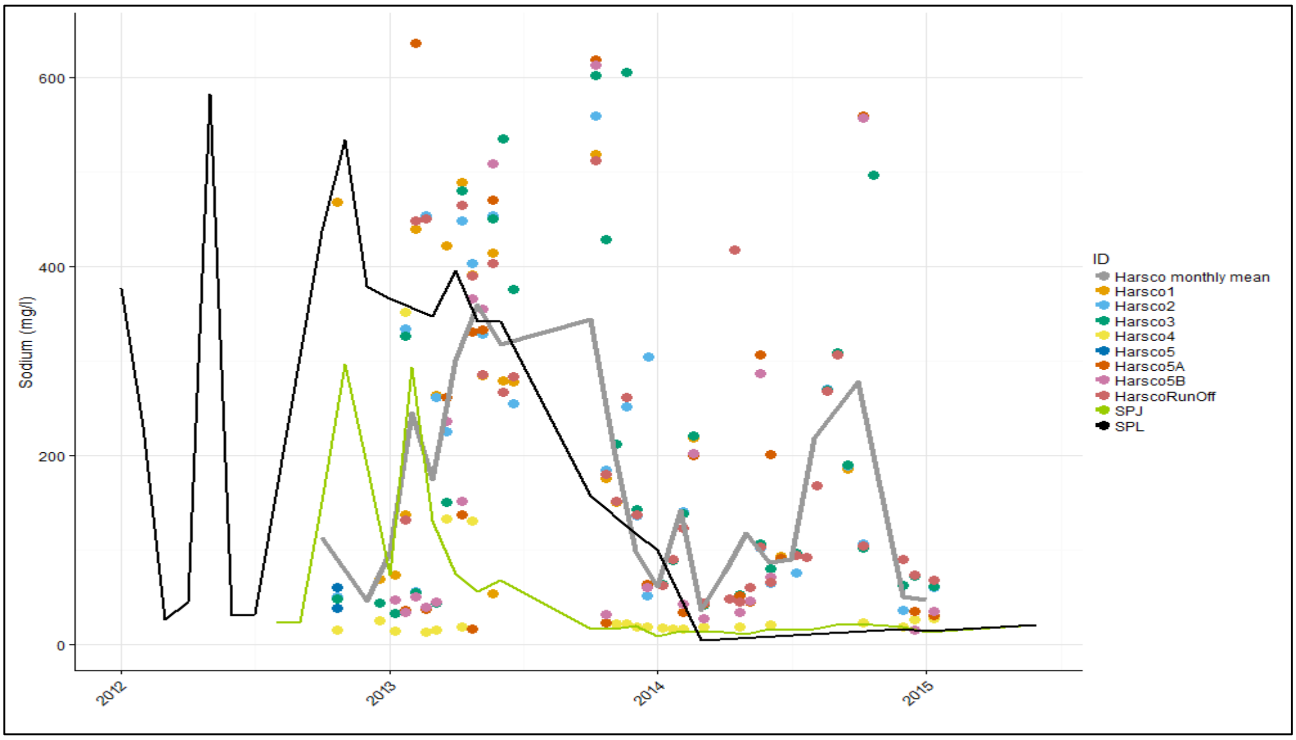


Figure 16: Harsco monitoring time series plot of Sodium concentrations (grey line indicate as smoothed mean and monthly means of monitoring point at SPL and SPJ are also presented)

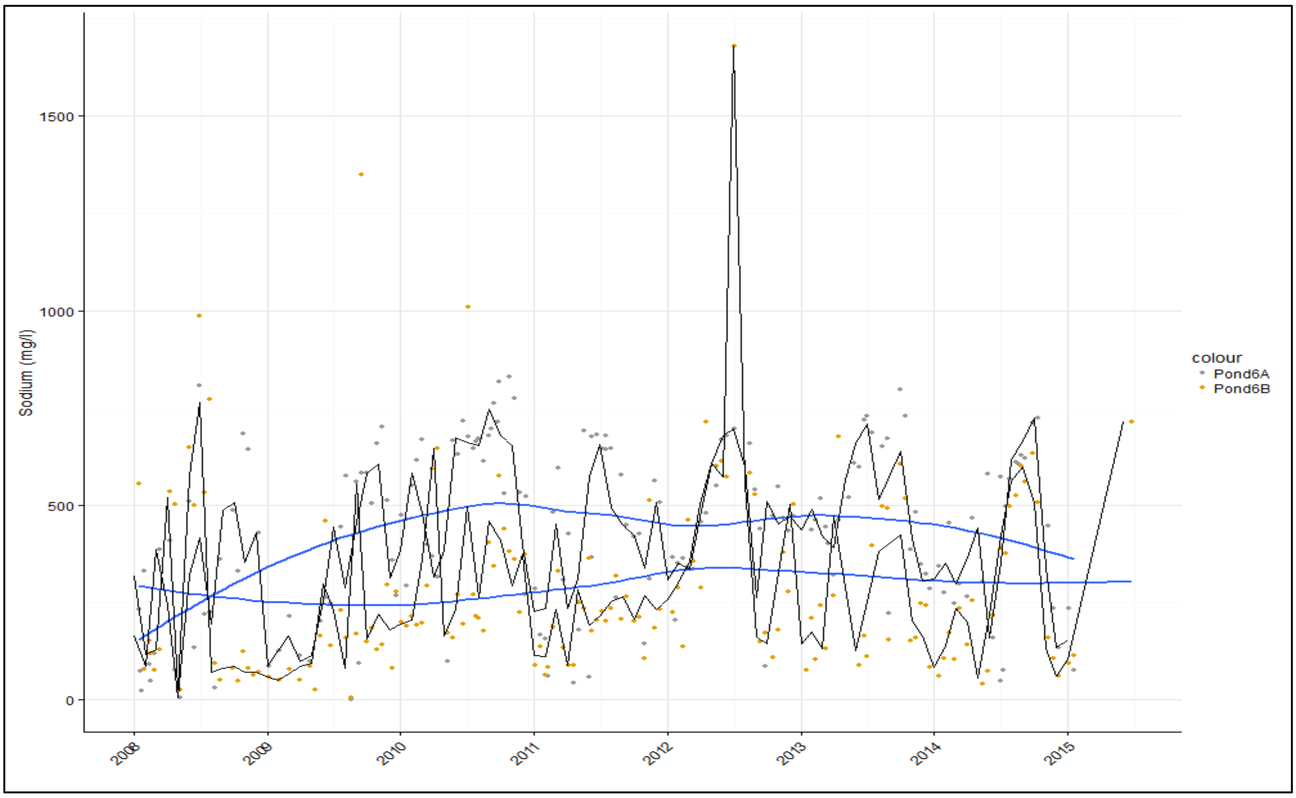


Figure 17: Pond6A & 6B time series plot of Sodium concentrations (blue line indicate as smoothed mean and black line a monthly mean)

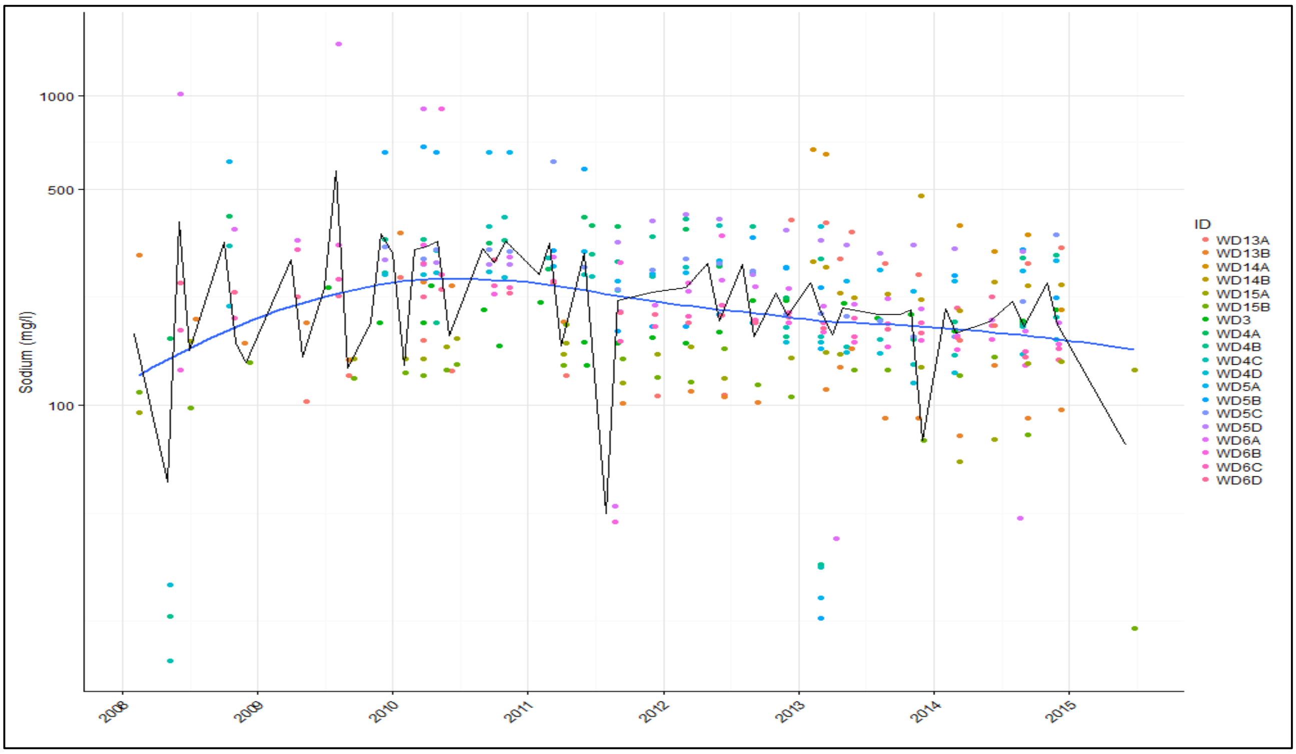


Figure 18: Boreholes around the Old Sludge Dams time series plot of Sodium concentrations (blue line indicate as smoothed mean and black line a monthly mean)

5.4.3 Chromium and chromium (VI)

Cr(VI) was only detected in water samples from Dam 4A and 4B. The waste samples collected from the Main Slag Disposal facility had elevated Cr(VI) concentrations, with one sample having a concentration of 27.8 mg/l in the 1:20 deionised water extract. Other waste samples containing some Cr(VI) concentration include:

- Low carbon stockpile (Facility 5);
- Ash Disposal site (Facility 6); and
- Old Slimes dam (Facility 8).

Sediments collected from the trench between Harsco and MFC had a Cr(VI) concentrations of around 0.05 mg/l as well as sediment from Dam 3A.

The oxidation of carbon sources in the solid waste facilities by Cr(VI) could be the reason for the attenuation of the Cr(VI) content and could be the cause of the high NO_3 concentrations in system.

The time series data (Figure 19 to Figure 22) indicate water qualities of Chromium below 1mg/l for the boreholes at the Old Slimes dam, Pond6A and Dam3A&B. Dam4A,B&C has values as high as 5mg/l and a number of samples collected for the Harsco area has values as high as 20mg/l.

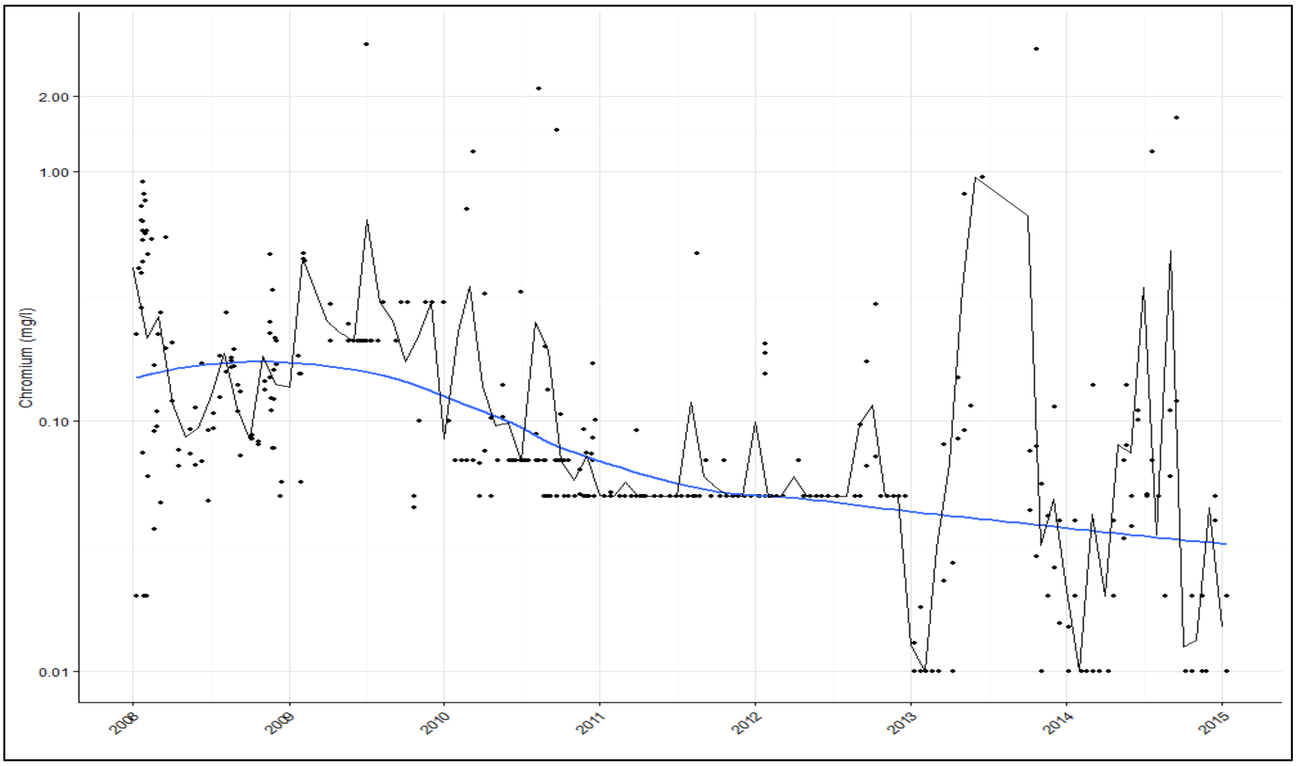


Figure 19: Dam3A&B time series plot of Chromium concentrations (blue line indicate as smoothed mean and black line a monthly mean)

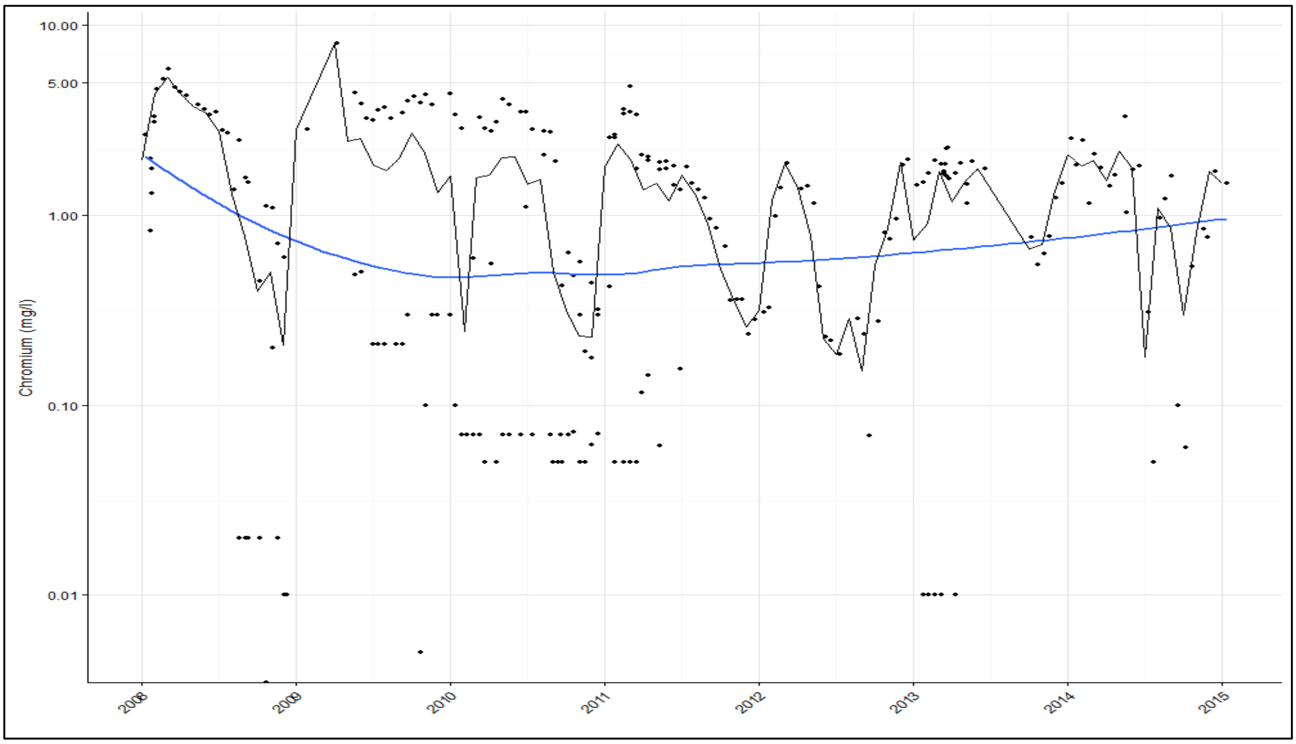


Figure 20: Dam4A,B&C time series plot of Chromium concentrations (blue line indicate as smoothed mean and black line a monthly mean)

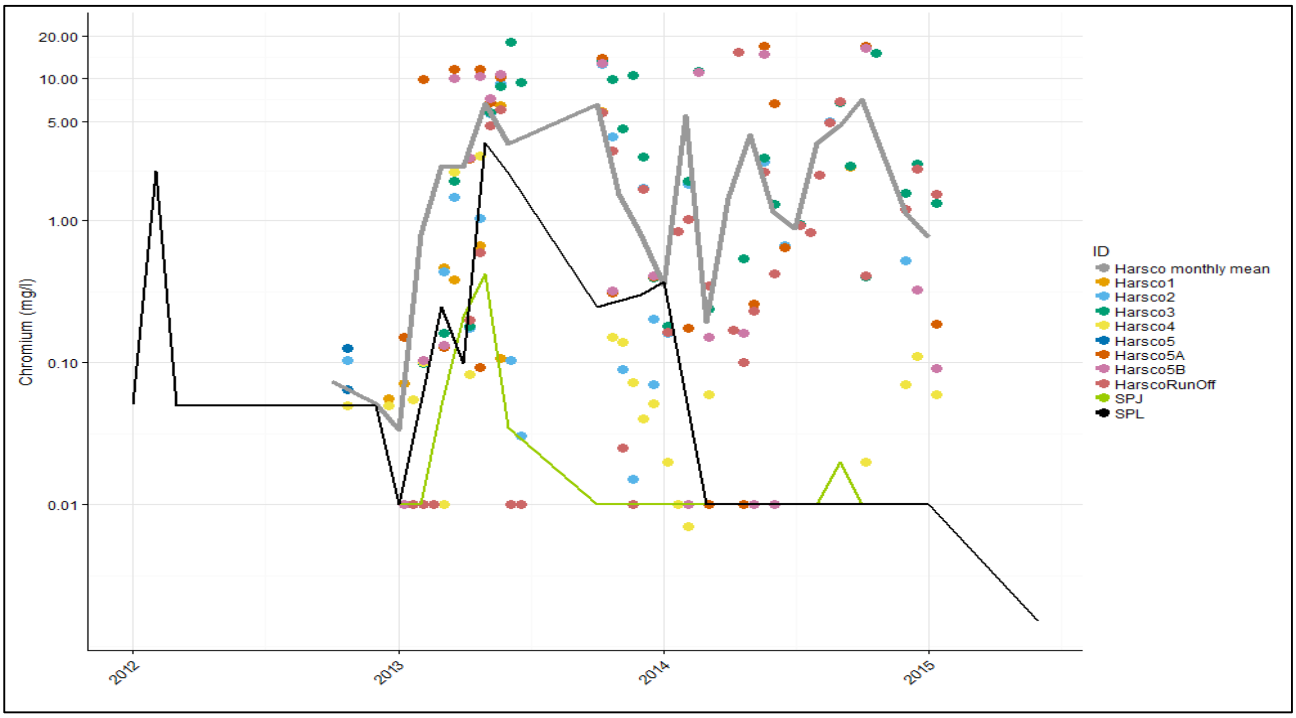


Figure 21: Harsco monitoring time series plot of Chromium concentrations (grey line indicate as smoothed mean and monthly means of monitoring point at SPL and SPJ are also presented)

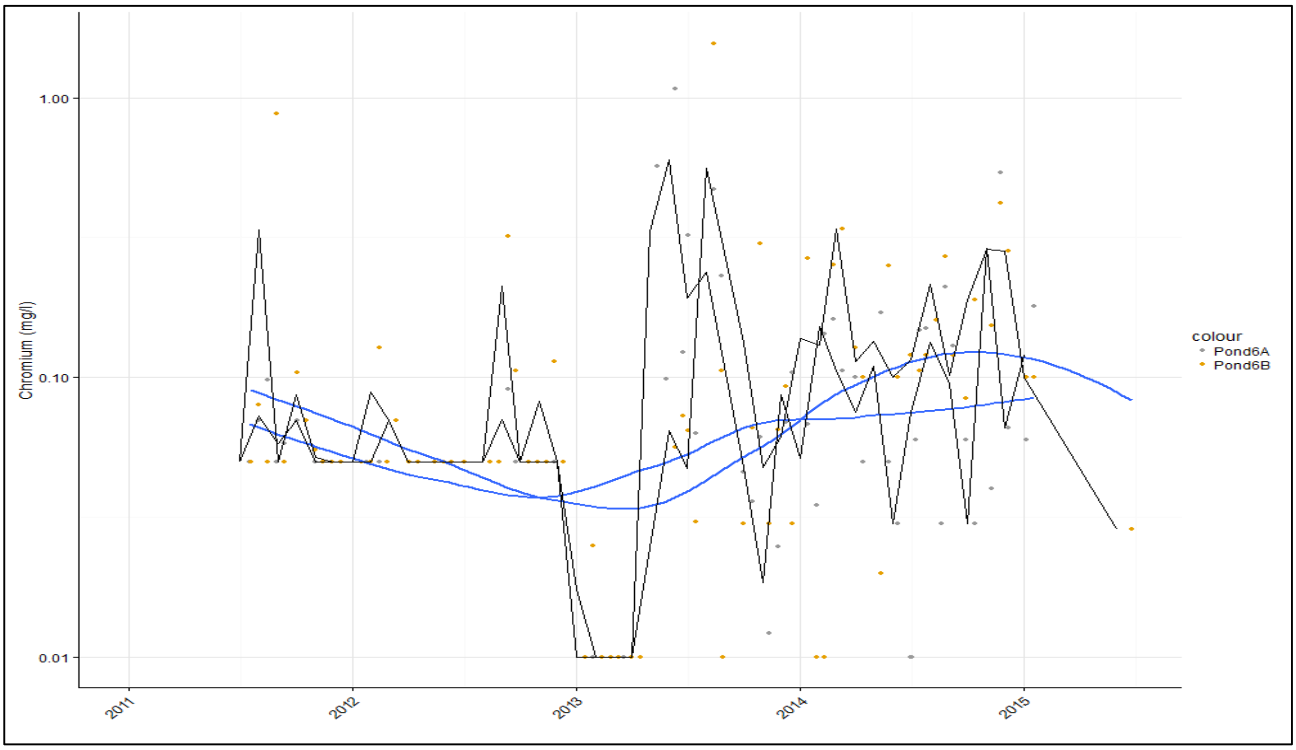


Figure 22: Pond6A & 6B time series plot of Chromium concentrations (blue line indicate as smoothed mean and black line a monthly mean)

5.4.4 Fluoride and Molybdenum

The water samples collected from the containment facilities (Dam 3A, 3B, 4A, 4B and Pond 6B) had F concentrations (Figure 23 and Figure 26) ranging from 1mg/l to 15mg/l F. None of the waste samples showed significant F concentrations, but the sediment from Dam 3A, Pond 6B and SP2 had slightly raised F concentrations.

Molybdenum (Mo) was present in the current analytical results in raised concentrations in selected samples, including:

- Waste samples: M3 and M4 Raw Materials Stockpile (Facility 4) and Main Slag Disposal Facility (Facility 15); and
- Sediment samples: Dam 3A, SD3, SD9, SD11 and Trench between Harsco and MFC.

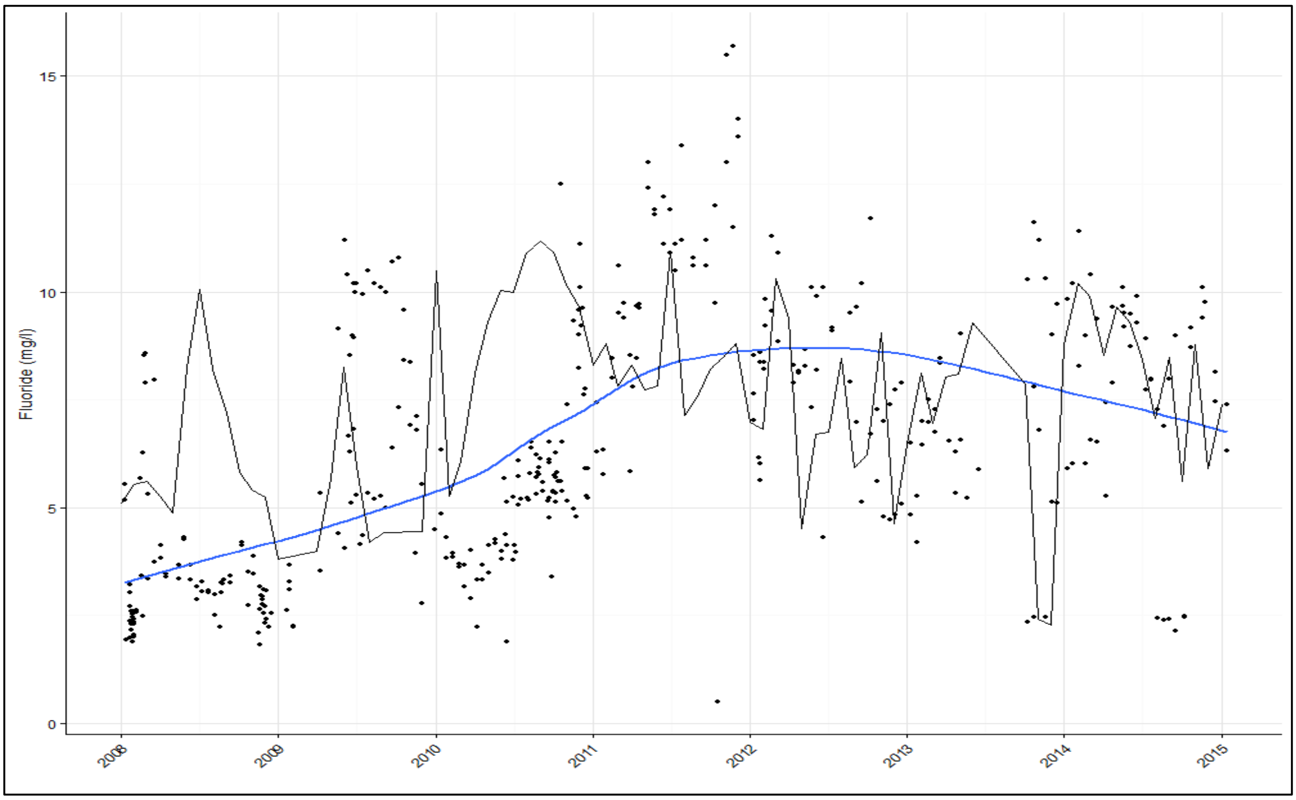


Figure 23: Dam3A&B time series plot of Fluoride concentrations (blue line indicate as smoothed mean and black line a monthly mean)

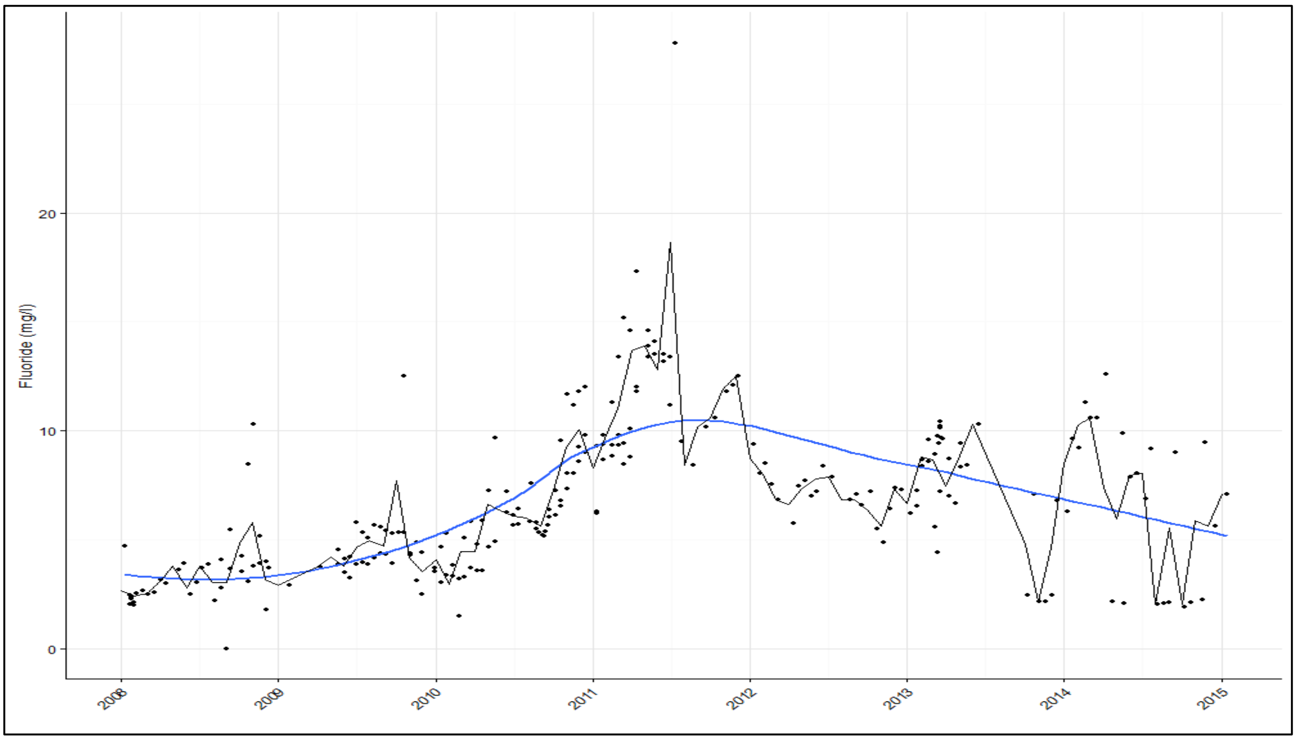


Figure 24: Dam4A,B&C time series plot of Fluoride concentrations (blue line indicate as smoothed mean and black line a monthly mean)

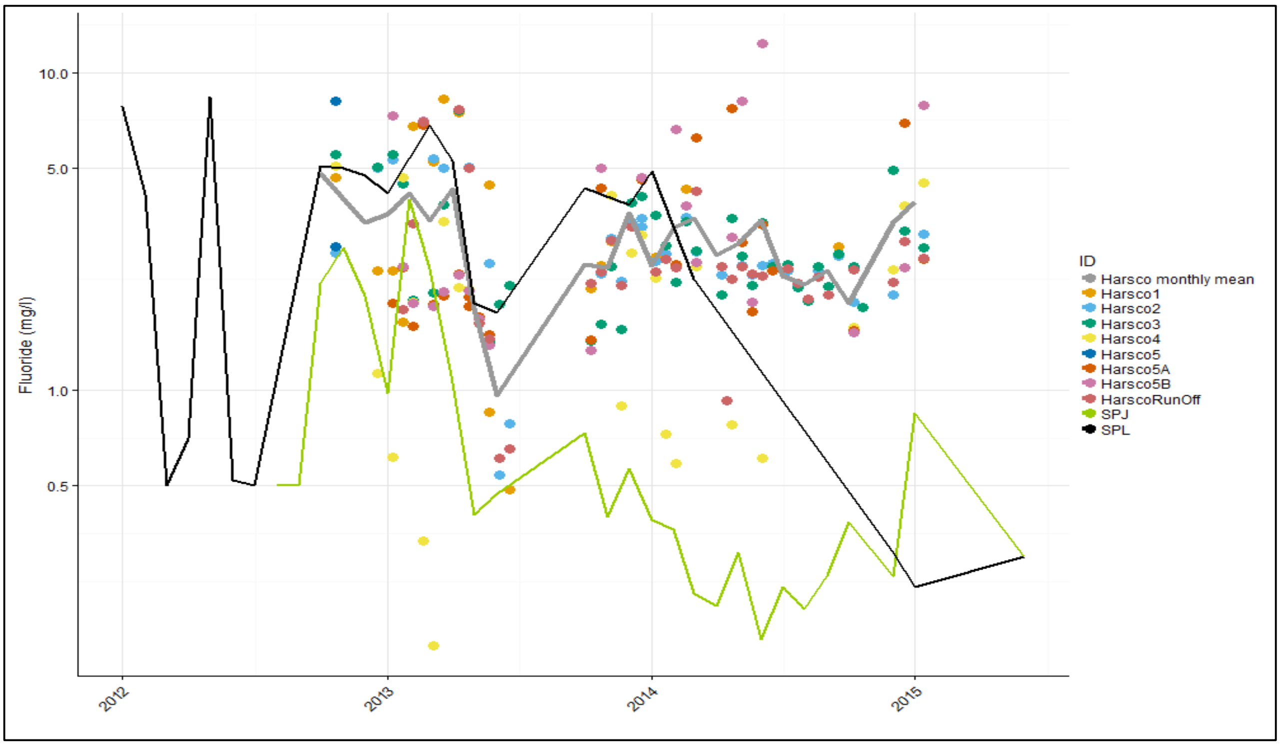


Figure 25: Harsco monitoring time series plot of Fluoride concentrations (grey line indicate as smoothed mean and monthly means of monitoring point at SPL and SPJ are also presented)

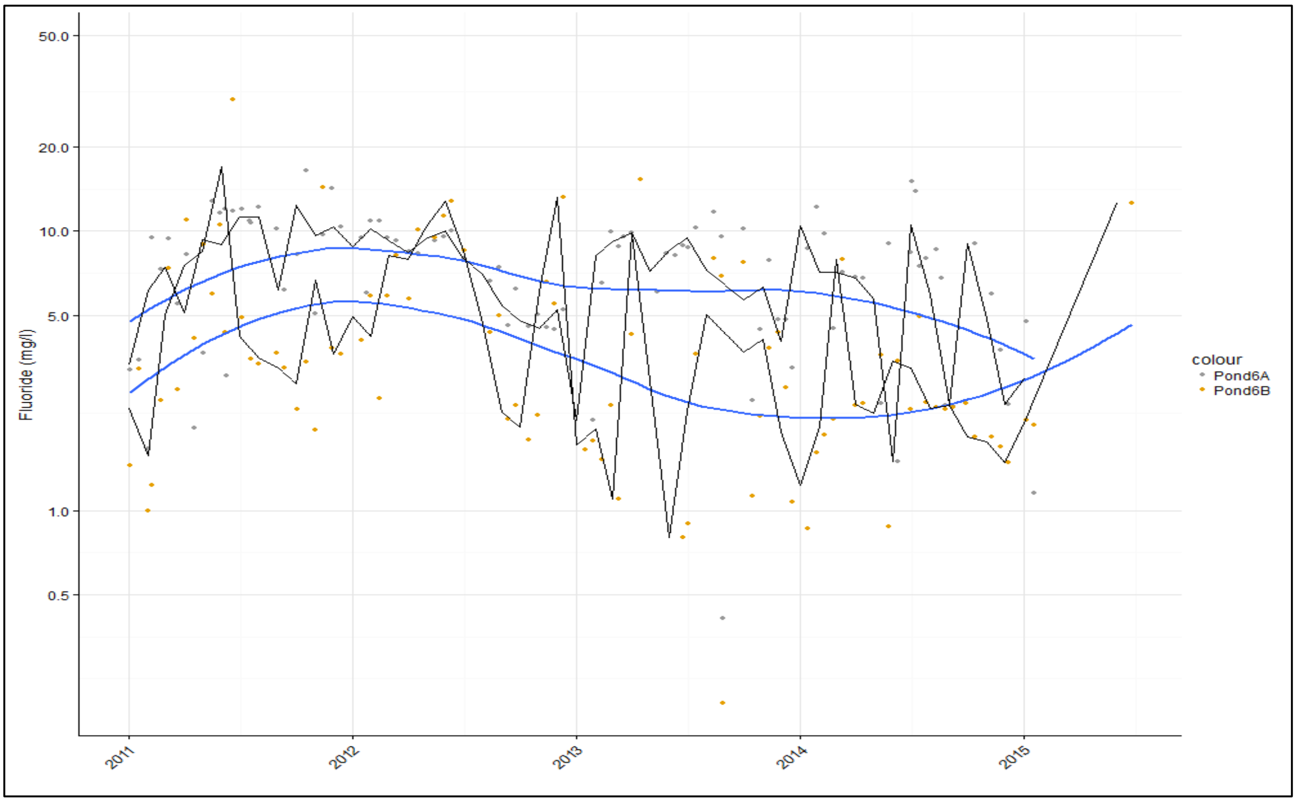


Figure 26: Pond6A & Pond6B time series plot of Fluoride concentrations (blue line indicate as smoothed mean and black line a monthly mean)

6.0 PATHWAY ASSESSMENT

The pathway assessment included evaluation of seepage and groundwater quality, Environmental Stable Isotope (ESI) assessment and evaluation of monitoring data.

6.1 Sampling and analyses

The following samples were collected and analysed for this assessment:

- Isotope testing:
  - Infiltration gallery monitoring holes: SD5, SD9 and SD11;
  - Containment facilities: RWD1, RWD2, Dam 4A and 4B, Dam 3A and 3B, and Pond 6B;
  - Groundwater samples: BH1, BH3 A & B, BH4 A & B, BH5 A & B, BH8 A & B and N3-880;
- Groundwater samples were collected from 23 boreholes for chemical analyses (Figure 27)

Samples were analysed as follows:

- Environmental stable isotopes of hydrogen (^{2}H or Deuterium) and oxygen (^{18}O);
- Major cations (Na, K, Ca, Mg);
- Major anions (F, Cl, SO_4, NO_3);
- Physico-chemical parameters (pH, EC, alkalinity, TDS); and
- Inorganic CoCs (including Al, Cr (VI), Mn, Mo, Fe, Ni, Cu, Zn, Pb, As etc).

6.2 Groundwater quality

The analytical results of the groundwater samples collected during this study are shown in Table 7. These results were compared to the DWS Drinking Water Standards Class II (Marginal) (2006). Since there are no guidelines for Co, Mo and Ni, the US EPA Tap water standards were used to evaluate these concentrations.

The screening of the groundwater samples indicated the following:

- CoCs include NO_3, SO_4, Cr (VI), Na, F and Mo;
- The highest NO_3 concentrations were recorded in the Infiltration Gallery (SD3, SD9 and SD11) and BH1, down gradient of Dam 3A. Borehole SP2 (between Harsco and MFC), BH2A and 2B (between Raw materials and Low carbon stockpile) and BH 5A and 5B (on boundary between Columbus and MFC Coal Stockpile) also had elevated NO_3 concentrations.
- SO_4 concentrations were elevated in BH2A, WD17A, WD15A (next to RWD) and SD11 (Infiltration Gallery).
- BH2A and BH11 are the only boreholes with elevated Cr and Cr(VI) concentrations;
- BH1, SD 5, BH11, BH3B and SD11 had elevated Mo concentrations;
- Elevated F concentrations were found in BH7 A & B, SD5 and WD9; and
- BH1, BH2 A, BH11, SD11 and WD17 A had elevated Na concentrations.

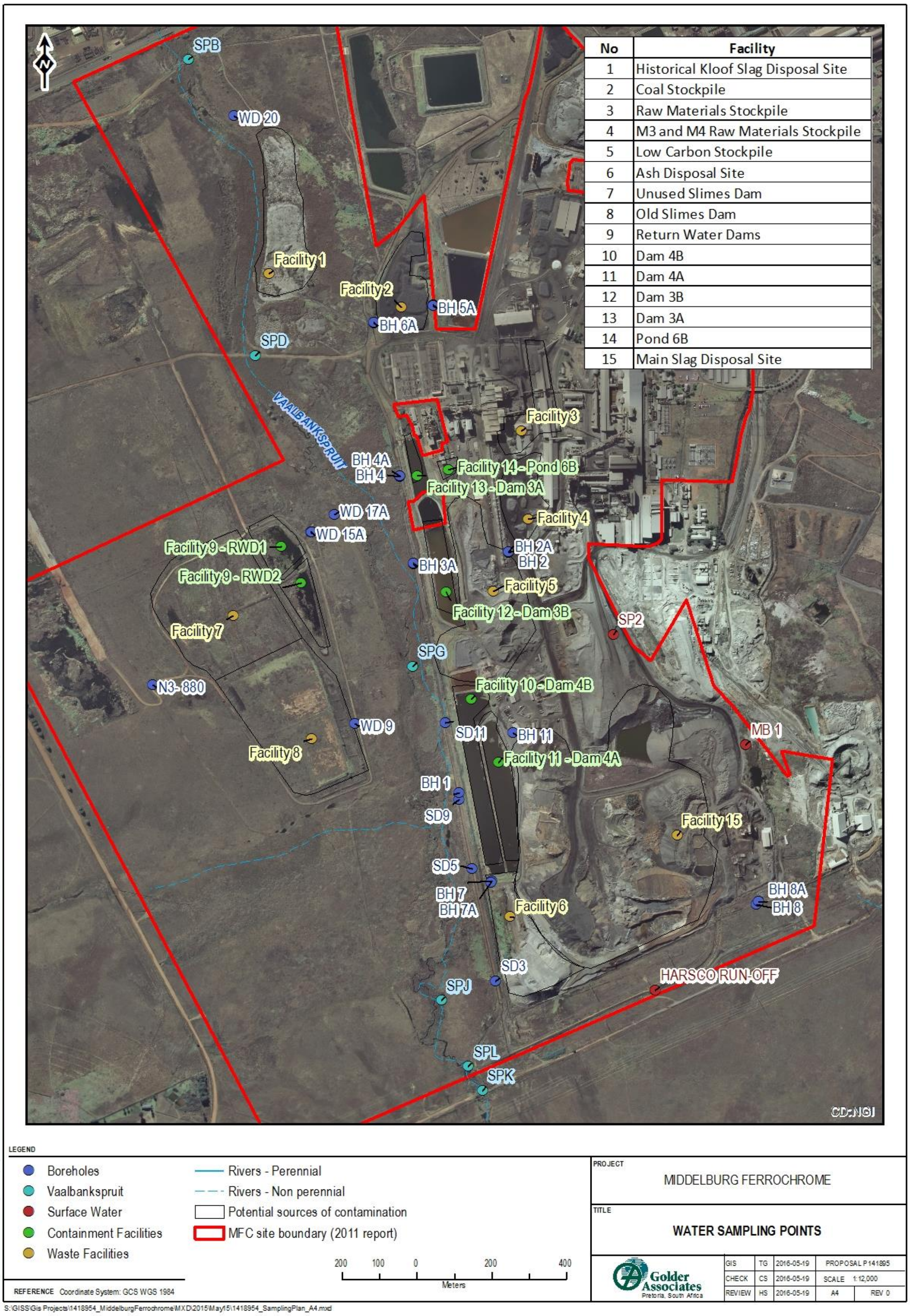


Figure 27: Surface and groundwater sampling points

Table 7: Water quality of monitoring boreholes compared to DWS Class II water quality guidelines

	DWS Class II	BH1	BH2A	BH2B	BH3A	BH3B	BH4A	BH4B	BH5A	BH5B	BH6A	BH6B	BH7	BH7A	BH8
EC uS/cm	3000	3394	2771	726	294	1744	739	773	689	911	1111	1149	428	371	191
pH	4-10.5	7.66	6.39	7.08	10.26	7.63	7.18	6.96	7.96	7.77	7.46	7.31	8.96	8.4	6.95
							mg/l								
Al	0.3	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
As	0.3	0.0025	0.0025	0.0025	0.0069	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0476	0.034	0.0025
Ba	400	0.077	0.02	0.143	0.005	0.068	0.147	0.123	0.025	0.023	0.033	0.058	0.007	0.025	0.078
Ca	150	386.7	143	58.2	3.7	96.2	62.1	64.2	50.5	77.9	105.9	106.8	1	4.2	8.5
Cd	0.02	0.0006	0.0007	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Cl	200	403.6	286.5	42.7	11.5	214.2	64.7	64.2	35.9	46.2	52.6	38.6	2.7	2.3	4.8
Co	0.006*	0.002	0.021	0.006	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Cr	0.05	0.0017	0.1384	0.0119	0.0015	0.0056	0.0029	0.0015	0.0015	0.0017	0.0019	0.0015	0.0015	0.0015	0.0015
Cr(VI)	0.02	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Cu	30	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
F	1.5	0.3	0.3	0.3	0.3	0.5	0.3	0.3	0.3	0.3	0.3	0.3	9.6	7.2	0.3
Fe	0.2	0.02	0.037	0.032	0.02	0.02	0.027	0.02	0.03	0.02	0.02	0.02	0.02	0.02	1.275
Hg	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
K	50	4.4	22.4	2.2	0.2	2.5	1.6	1.6	2.2	1.7	0.5	2.4	0.5	0.7	2.3
Mg	70	159.7	102.4	32.9	0.1	46.8	42.2	41.1	36.8	41.7	57	47.7	0.2	2	5
Mn	0.1	0.027	0.077	0.002	0.002	0.009	0.003	0.006	0.089	0.002	0.002	0.002	0.004	0.056	0.183
Mo	0.01*	0.013	0.006	0.002	0.003	0.01	0.002	0.002	0.002	0.002	0.002	0.002	0.004	0.004	0.002
Na	200	246.4	327.6	36.5	59.1	191.3	26.7	26.1	39.7	52.7	42.8	54.3	98.4	77.7	18.6
NH_4	1	0.03	0.03	0.03	0.93	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.12	0.35	0.05

	DWS Class II	BH1	BH2A	BH2B	BH3A	BH3B	BH4A	BH4B	BH5A	BH5B	BH6A	BH6B	BH7	BH7A	BH8
Ni	0.039*	0.008	0.016	0.003	0.002	0.004	0.002	0.002	0.002	0.002	0.004	0.002	0.002	0.002	0.002
NO_3	10	1289.6	422.5	63.4	0.2	202.8	68.7	74.1	6.2	46.2	89.7	227.4	0.8	1	0.3
Pb	0.05	0.006	0.007	0.028	0.038	0.009	0.019	0.021	0.01	0.019	0.016	0.028	0.005	0.005	0.005
Sb	0.2	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Se	0.05	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
SO_4	400	380.15	695.73	97.01	29.29	353.25	82.62	84.29	110.61	202.31	281.1	183.71	5.81	5.88	13.81
TDS	1000	3806	1299	570	256	970	495	522	428	759	947	915	273	230	112
V	1	0.0015	0.0017	0.0061	0.0015	0.0096	0.0058	0.0044	0.0015	0.0015	0.0015	0.0093	0.0015	0.0015	0.0015
Zn	10	0.017	0.025	0.025	0.025	0.024	0.012	0.011	0.012	0.011	0.016	0.016	0.015	0.018	0.04

* US EPA Tap water guideline

	DWS Class II	BH8A	BH11	MB1	N3-880	SD 5	SD11	SD3	SD9	SP2	WD9	WD15A	WD15B	WD17A	WD20
EC uS/cm	3000	190	1316	315	134	381	2658	537	2908	862	536	2196	483	2915	561
pH	4-10.5	7.45	7.95	8.01	6.76	8.58	7.66	7.66	7.69	8	7.9	7.18	7.54	7.2	7.22
							mg/l								
Al	0.3	0.02	0.02	0.02	0.02	0.055	0.028	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
As	0.3	0.0025	0.0027	0.0025	0.0025	0.0025	0.0027	0.0025	0.0025	0.0039	0.0043	0.0025	0.0025	0.0025	0.0025
Ba	400	0.085	0.02	0.007	0.067	0.052	0.022	0.258	0.094	0.037	0.016	0.018	0.031	0.018	0.028
Ca	150	9.2	39.5	23.2	6	6.8	82.6	43.3	313	78.1	8.2	230.9	40.2	287.8	32.6
Cd	0.02	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0008	0.0005	0.0005	0.0008	0.0005	0.0007	0.0005
Cl	200	5.6	81.1	1.7	2.8	27.5	259.5	33	293.5	55.6	6.8	81	31.4	241.7	29.3
Co	0.006*	0.002	0.007	0.002	0.002	0.002	0.009	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.004
Cr	0.05	0.0015	0.474	0.0015	0.0015	0.0015	0.0027	0.0015	0.0015	0.0028	0.0015	0.0015	0.0015	0.0015	0.0015

	DWS Class II	BH8A	BH11	MB1	N3-880	SD 5	SD11	SD3	SD9	SP2	WD9	WD15A	WD15B	WD17A	WD20
Cr(VI)	0.02	0.006	0.444	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006
Cu	30	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
F	1.5	0.3	0.4	0.3	0.3	1.7	0.3	0.3	0.3	0.3	4.7	0.3	0.5	0.3	0.3
Fe	0.2	0.02	0.02	0.02	8.752	0.02	0.195	0.02	0.02	0.02	0.145	9.758	0.02	7.208	0.02
Hg	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
K	50	2.1	27.8	4.2	1	1.2	2.1	1.6	3.8	3.2	1.3	0.7	13.7	0.6	0.9
Mg	70	4	10.9	12.1	5.9	4.7	58	15	125.6	44.9	4.7	157.1	16.1	207.4	29.7
Mn	0.1	0.002	0.012	0.006	0.346	0.002	0.124	0.002	0.307	0.007	0.099	0.177	0.033	1.515	0.004
Mo	0.01*	0.002	0.091	0.002	0.002	0.013	0.283	0.002	0.005	0.002	0.004	0.002	0.002	0.002	0.002
Na	200	22	200.3	21.3	8.8	65.1	478.5	34.6	171.4	32.2	93.3	129.9	19	235.7	36.9
NH_4	1	0.04	0.25	0.03	0.03	0.03	0.03	0.03	0.08	0.03	1.57	0.05	0.03	0.39	0.03
Ni	0.039*	0.002	0.019	0.002	0.002	0.002	0.042	0.002	0.011	0.002	0.002	0.003	0.002	0.003	0.002
NO_3	10	1.7	171.7	0.3	0.2	0.4	280.5	27.1	1019.8	29	0.8	0.8	3.7	0.4	36.8
Pb	0.05	0.005	0.025	0.005	0.005	0.007	0.013	0.006	0.008	0.025	0.007	0.02	0.005	0.018	0.013
Sb	0.2	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Se	0.05	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
SO_4	400	5.02	274.76	23.4	1.96	27.64	762.29	28.81	286.52	106.47	1.91	823.5	85.37	1188.2	65.81
TDS	1000	116	1020	215	79	239	1411	420	2769	753	320	2121	349	2287	336
V	1	0.0015	0.0436	0.0015	0.0015	0.0015	0.0083	0.0015	0.0015	0.0071	0.0015	0.0036	0.0015	0.0015	0.0015
Zn	10	0.023	0.039	0.008	0.009	0.041	0.028	0.012	0.025	0.019	0.013	0.023	0.031	0.01	0.007

* US EPA Tap water guideline

6.3 Macro Element Analyses

The macro element dataset were used for a Piper Diagram analysis and the results are illustrated in Figure 28. The Piper Plot indicates the following characteristics:

Three main clusters based on the macro element concentrations –

- Cluster (1) represents a Ca/Mg-SO_4 group which indicate a SO_4 source and is known to be representing the stagnant part of a groundwater flow system. This cluster includes borehole pairs BH5A/B and -6A/B which have a slightly elevated SO_4 concentration;
- The water from RWD 1 (Point (4) on the Piper) is closely related to Cluster (1) thus indicating a contribution from the RWD area to the local groundwater in that area;
- Cluster (2) represents the so-called dynamic part of the Piper Diagram and represents monitoring sites on the far west and east areas (N3-880, MB1 and BH8A/B) and the deeper aquifer water intercepted in BH3A and BH7A). The hydrochemistry signature is a typical Ca/Mg-HCO_3 falling on a cation Base Exchange line to become a Na-HCO_3 type;
- Cluster (3) represents the Containment Facilities east of the Vaalbankspruit and displays a prominent Na-K/HCO_3-SO_4 signature; and
- The external contribution of SO_4 from upstream areas in the south in the Vaalbankspruit should not be excluded, however, the drastic increase of SO_4 concentrations at monitoring sites SPG (277 mg/l SO_4), SPD (343 mg/l SO_4) and SPB (306 mg/l SO_4) indicate SO_4 feed into the drainage system either from the RWD and/or the Containment Facilities just east of the drainage.

The Piper Diagram clearly shows a dynamic water flow regime in the MFC site area – a pristine water type on the western, eastern and southern margins (Cluster (2)), getting impacted by the contributions from the Containment Facilities and the RWDs (Cluster (3) and Point (2)) and finally ends in the Vaalbankspruit and surrounding areas as Cluster (1) water types (consisting of a pool of elevated hydrochemical constituents).

6.4 Environmental Stable Isotope (ESI) assessment

The objective of the environmental stable isotope (ESI) assessment was to determine leakage from the water containment facilities. The application of the environmental stable isotopes of hydrogen (Deuterium) and oxygen (^{18}O) is widely applied where investigations of different origins/path ways in the groundwater flow cycle are conducted. These isotopes are part of the water molecule and occur naturally in waters and in biological and geological materials. Changes in the physical conditions of the water cycle, tends to alter the natural isotope signature and the resulting compositions can be used as a groundwater flow path tracer.

Both the hydrochemistry (macro and trace elements) analyses and the ESI assessment indicated a range of pollution possibilities of the local groundwater regime – which is probably not only contributed by the MFC activity on the site, but from external activities as well. Shallow and deep boreholes close to the containment facilities report the same impacted water quality signatures, thus the whole flow profile at these sites are impacted with the same source water.

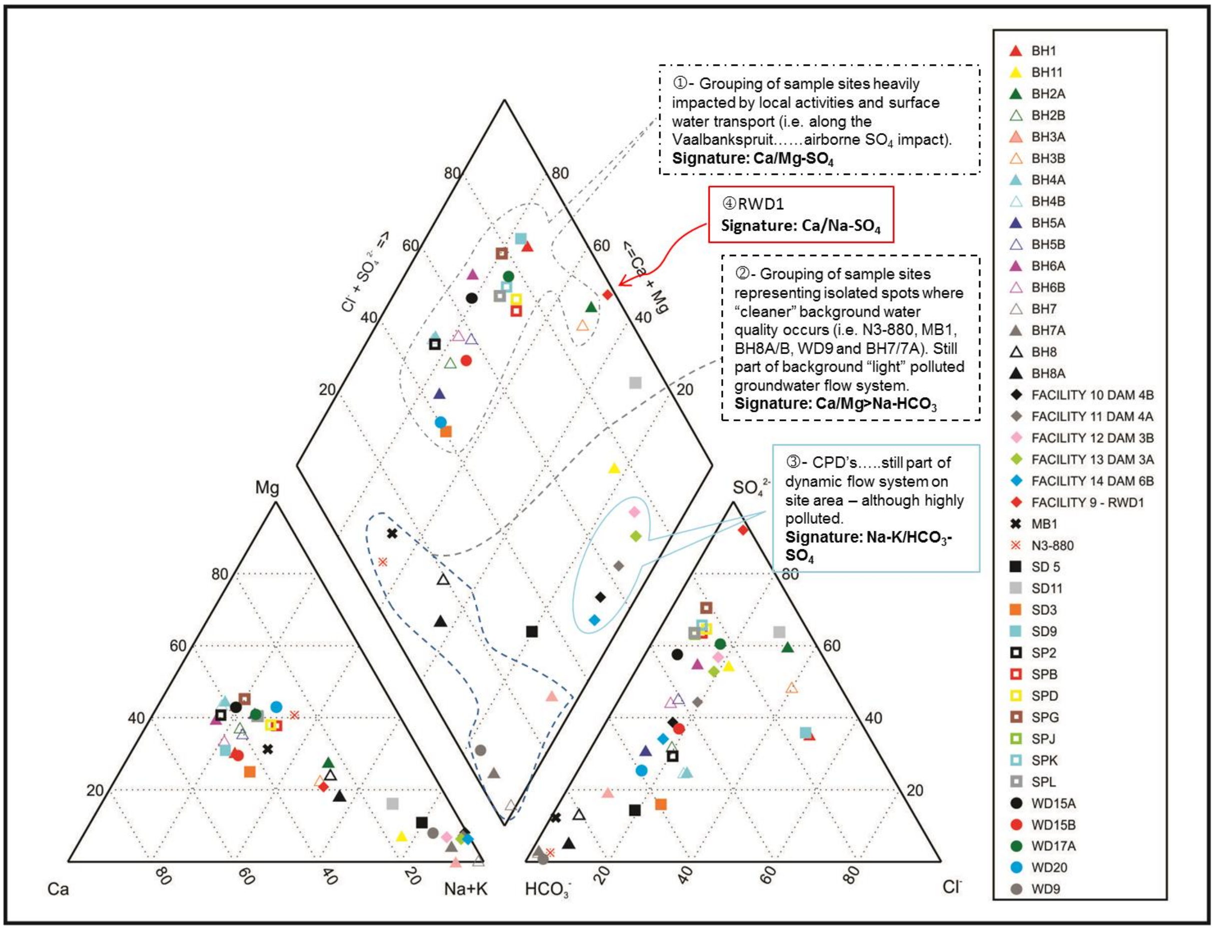


Figure 28: Piper Diagram presentation of various monitoring sites at the MFC site area.

The ESI dataset is illustrated in the Harmon Graig Diagram, Figure 29 below and reveals that four (4), basic groupings are relevant, i.e.

- All the sampled monitoring sites plot on a distinctive evaporation line (called the "MFC Evaporation" Line which links with the Global Meteoric Water Line. The latter intersection is represented by deep borehole BH3A and to some extent, seepage site SD5. The water sampled in borehole BH3A, probably represents the deeper and less impacted groundwater on the site;
- RWD (1) represents the most evaporated water body in the MFC site;
- The Containment Facilities (Dam 4B, Dam 4A, Dam 3B, Dam 3A and Pond 6B) falls in a specific grouping and characteristically on the MFC Evaporation Line. This indicates that the water bodies are significantly evaporated and enriched in the heavier ^{18}O Isotope which represents a good tracer for the area;
- The boreholes, excluding BH3A/B, falls in a specific grouping on the MFC Evaporation Line – between the Containment Facilities and the pristine water body (i.e. deeper groundwater and those in the upstream and boundaries on the east and west of the site area);
- Shallow borehole BH3B plots much closer to the Containment Facility grouping; thus indicating a significant link with the water in Dam 3B; and
- Seepage SD9 falls in the "less impacted" borehole grouping on the evaporation line, but specifically BH1 (red dot on top of BH1 triangle).

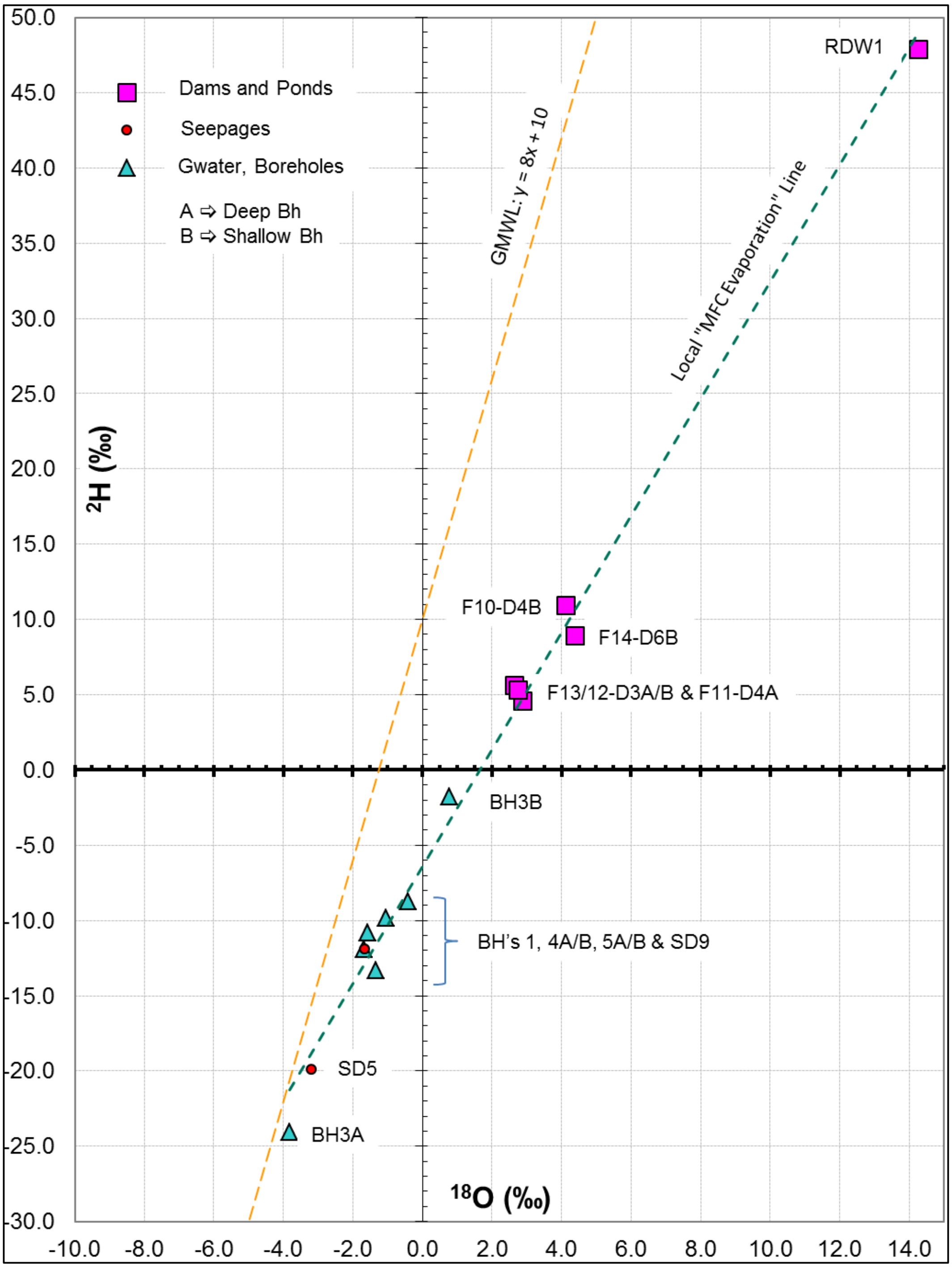


Figure 29: ESI plot of water sources on the Middleburg Ferro-Chrome Site.

The ESI signatures of the MFC site area indicates four significant groupings of which the RWD and Containment Facilities represents the heavy evaporated water component. Traces of this evaporated water are present in the seepages as well as in the shallow and deeper water bearing zones – especially along the natural flow gradient from southwest to northwest over the site area. This trend indicates that water carrying the "evaporation signature" introduced in the Containment Facility water body due to isotopic fractionation (i.e. enrichment of the heavier ^{18}O oxygen isotope can be traced downstream from the Containment Facilities in the seepages (SD9) and boreholes (BH1, BH4A/B, BH5A/B). The shallow groundwater at BH3B (close to

Dam 3B) shows the contribution (flow from source) quite clearly as it plots much closer to the Containment Facility grouping on the Harmon Graig ESI Plot than the rest.

The ESI analyses reports a highly evaporated source (i.e. water sources in the containment facilities) on the site area which falls on a “local MFC” Evaporation Line and this gives a significant signature to the water quality from these facilities. This signature can be traced to the remaining sample sites; thus confirming a local pollution scenario in virtually all water sources on the site. All the ESI sample analyses plots perfectly on the this line, as well as the “fresher”/slightly contaminated (indicated by a definitive isotopic lighter grouping) parts of the groundwater regime and almost intersects with the Global Meteoric Water Line – indicating recent recharged and unpolluted water in the far field areas. Down slope shallow boreholes of the containment facilities and solid waste facilities analysis indicates the contribution in seepage water is about 50% groundwater and 50% seepage from the containment facilities.

6.5 Groundwater model development and flow directions

A numerical groundwater flow model was required to assess and predict potential groundwater impacts associated with the smelter operations at Middelburg Ferrochrome. The model estimates the fluxes of the different impacted areas. The receiving groundwater environment and associated impacts was modelled using the steady state calibrated model.

In 2011 Golder developed a site-specific numerical groundwater flow and contaminant transport model using the finite element FEFLOW 6.0 software code. This model was updated using the latest FEFLOW 6.2 code using the latest groundwater levels and information as well the updated conceptual understanding.

The following scope of work was completed:

i) Update of the site-specific numerical groundwater flow and transport model for the MFC site with the latest information (groundwater levels).

ii) Re- calibrate the groundwater model with these water levels in steady state.

iii) Estimate expected groundwater flow directions and rates in the vicinity of the site.

6.5.1 Site information

6.5.1.1 Water levels and flow directions

A hydrocensus of boreholes and surface water bodies was carried out in May 2015 by Golder. During which 88 boreholes were visited. Water levels were measured at 88 boreholes, 84 of which were reported to be static water levels. Statistics of the water levels can be seen in Table 8. The groundwater levels are shallow with an average of 2.3 mbgl. The groundwater levels ranges from artesian – 9.82 mbgl. Four wells were found to be artesian (BH 3A, BH 4B, WD 16A en MB 3).

Table 8: Hydrocensus July 2015 - Water level statistics

Summary of Static Water Level Data	Value
Count	88
Min (mbgl	0
Max (mbgl)	9.82
Average (mbgl)	2.30
Standard Deviation	1.72
Correlation of Elevation and Piezometric head	0.99

The piezometric head and topographical elevation display a correlation in the order of 0.99 from which it is inferred that groundwater flow directions are expected to mimic surface topography (Figure 30).

Groundwater gradients mimics the topography and groundwater flows from the elevated areas towards the Vaalbankspruit, a tributary of the Klein Olifants River.

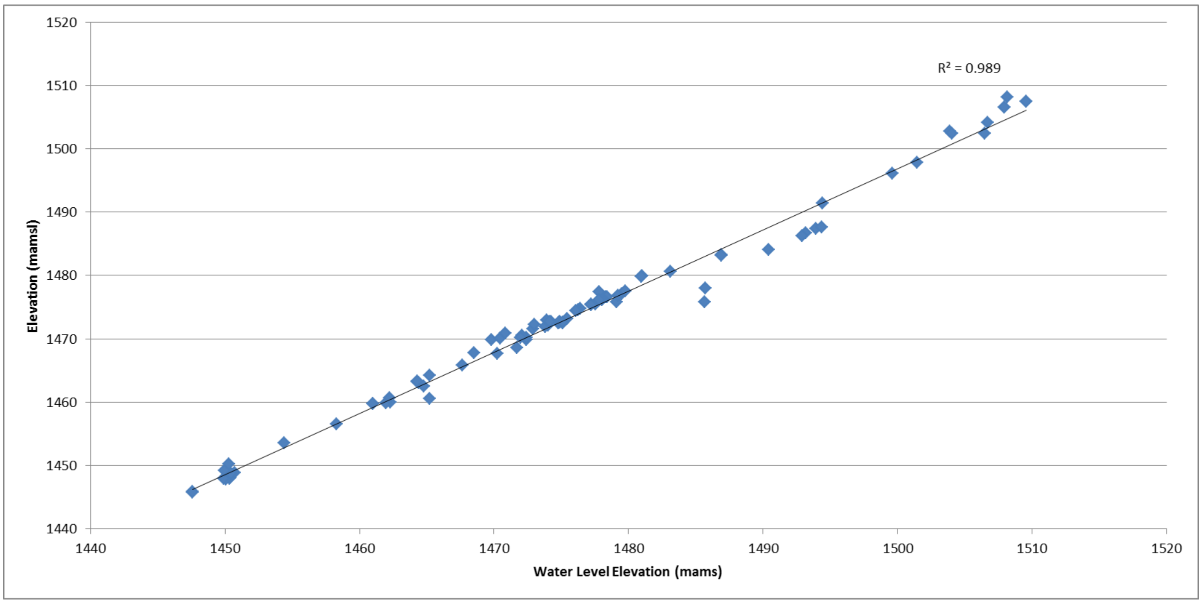


Figure 30: Correlation between Elevation and Water level Elevation

The Bar chart below indicates the mbgl measured on site (Figure 31). The water levels are shallow and average below 3mbgl. This is probably due to the close vicinity of the Vaalbank spruit or low hydraulic conductivity.

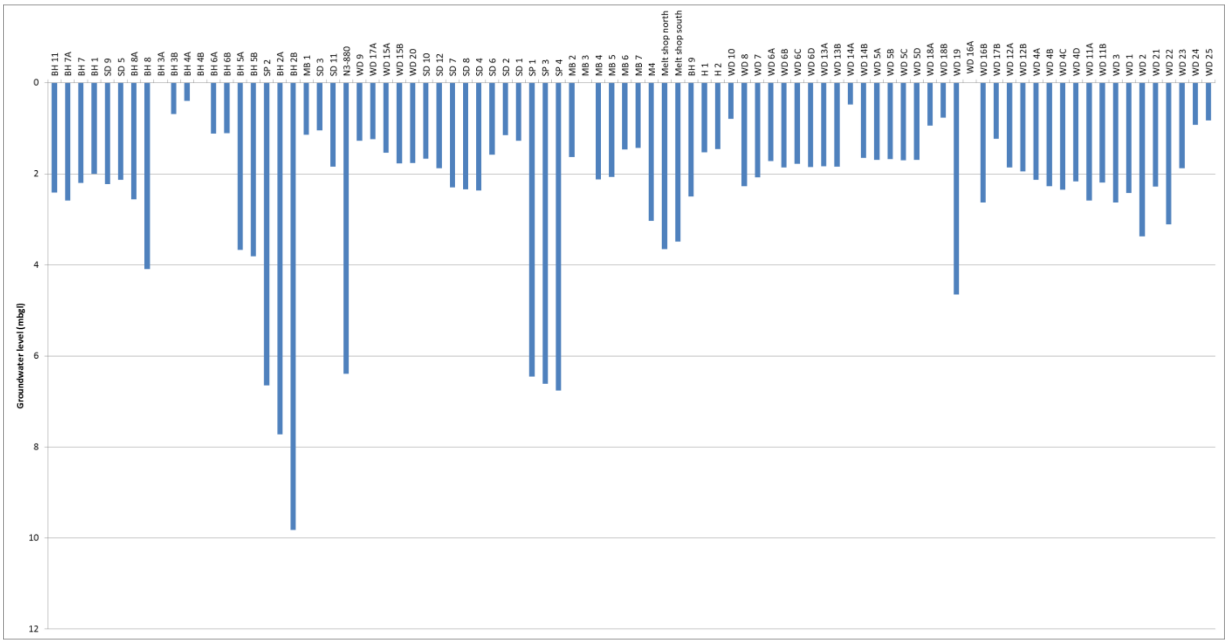


Figure 31: Bar-Chart of the groundwater levels (mbgl).

The groundwater distribution are presented in Figure 32, indicating the depth to groundwater (mbgl) in May 2015. The regional flow direction is from south to north along the river; thus following the surface runoff direction and topography as indicated. The more local groundwater flow on site is towards the Vaalbankspruit (Figure 33).

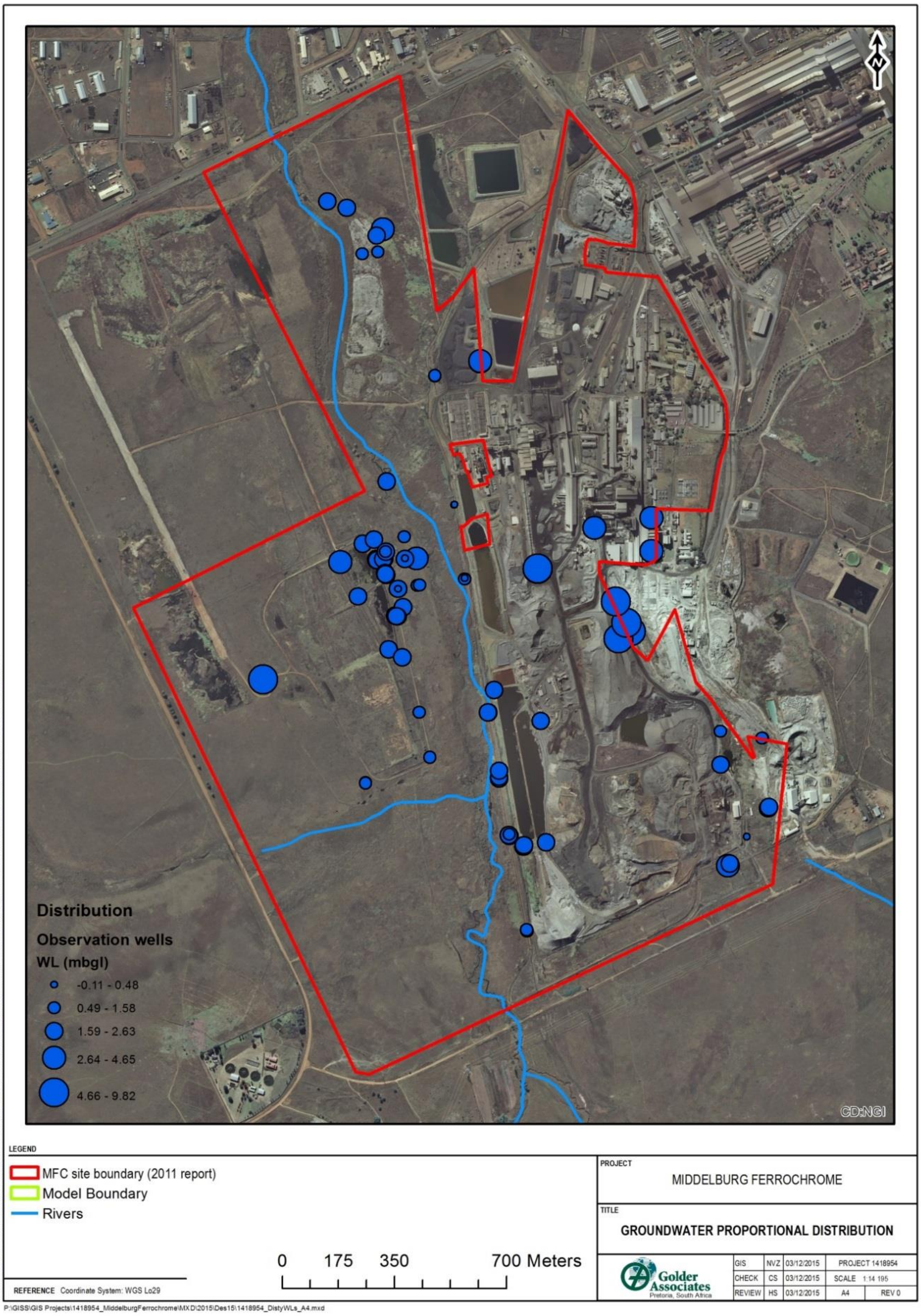


Figure 32: Groundwater level distribution (mbgl)

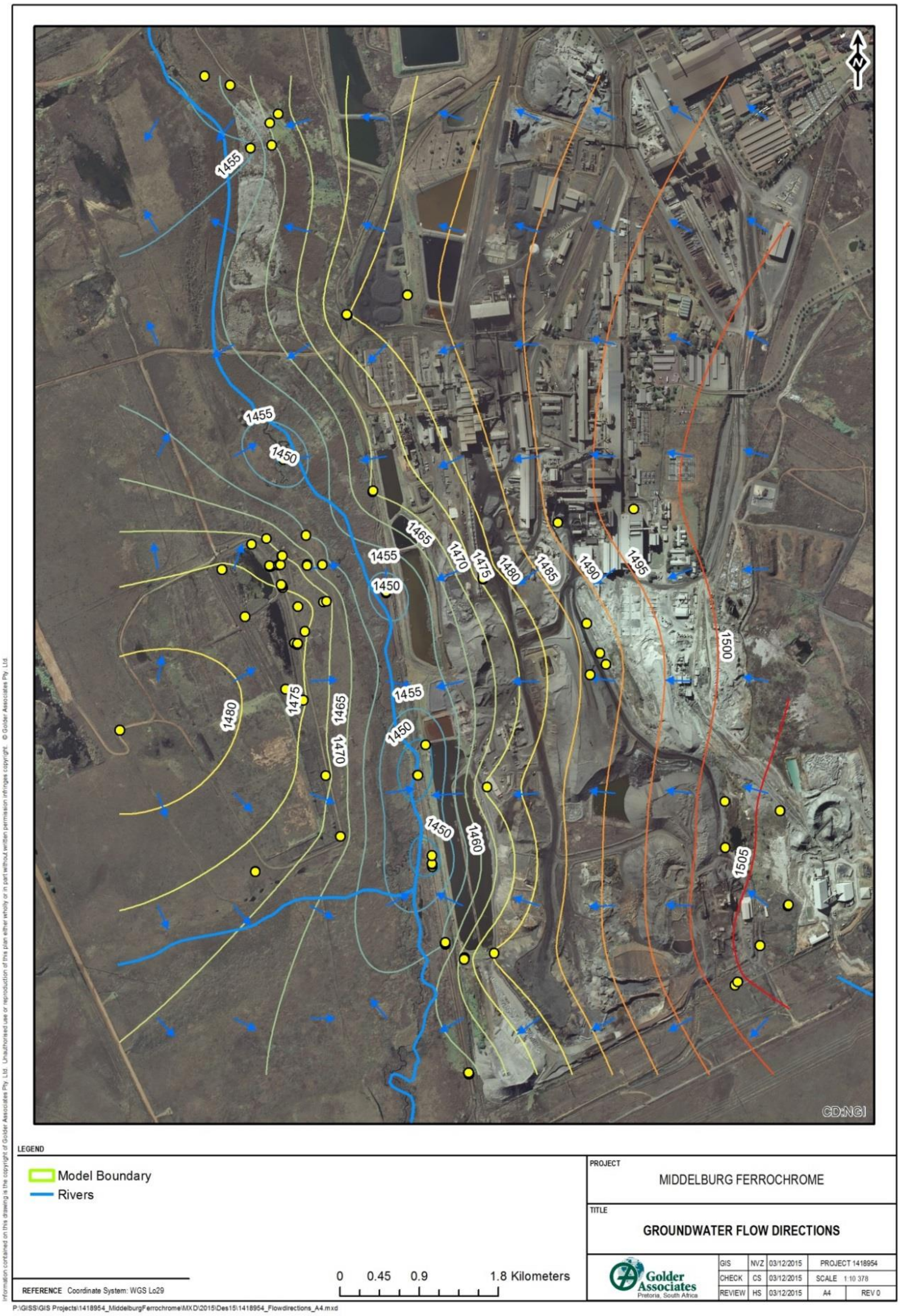


Figure 33: Groundwater Flow Directions

6.5.1.2 Aquifer types

The local surface geology in the vicinity of the MFC plant and waste facilities consists predominantly of the following:

- Loskop Formation, consisting of shale, siltstone, mudstone and quartzite. Most of the study area, including the plant and northern section of the waste areas, are underlain by these lithologies.
- Selons River Formation, consisting of rhyolite. The southern section of the waste area is underlain by this formation.
- Diabase intrusions cover the northern section of the study area, in particular the northern section of the plant and the Historical Kloof Slag Disposal Site.

Although the rock types described above are not known to contain economic aquifers, groundwater contributes to stream flow and in some instances high yielding boreholes have been recorded. The following aquifers underlie the site:

- **Weathered Aquifer:** A shallow, weathered aquifer in the weathered shale, rhyolite and diabase. All the formations have similar weathering characteristics and although the aquifer parameters may vary dependent on the rock type, the groundwater flow mechanisms are similar. The most consistent water strike is located at the fresh bedrock / weathering interface.
- **Fractured Aquifer:** A deeper, non-weathered aquifer where fracture flow dominates. Groundwater migration within the upper portion of this aquifer appears to be governed by jointing while major faults and intrusions form the significant conduits at depth

The surface geology was used as parameter zones and can be seen in Figure 34. The north of the site is underlain by shale, mudstone and siltstone. The centre of the site is predominantly diamictite. The Southern part of the site is Ryolite. These zones were used for the recharge and conductivities areas in the calibration.

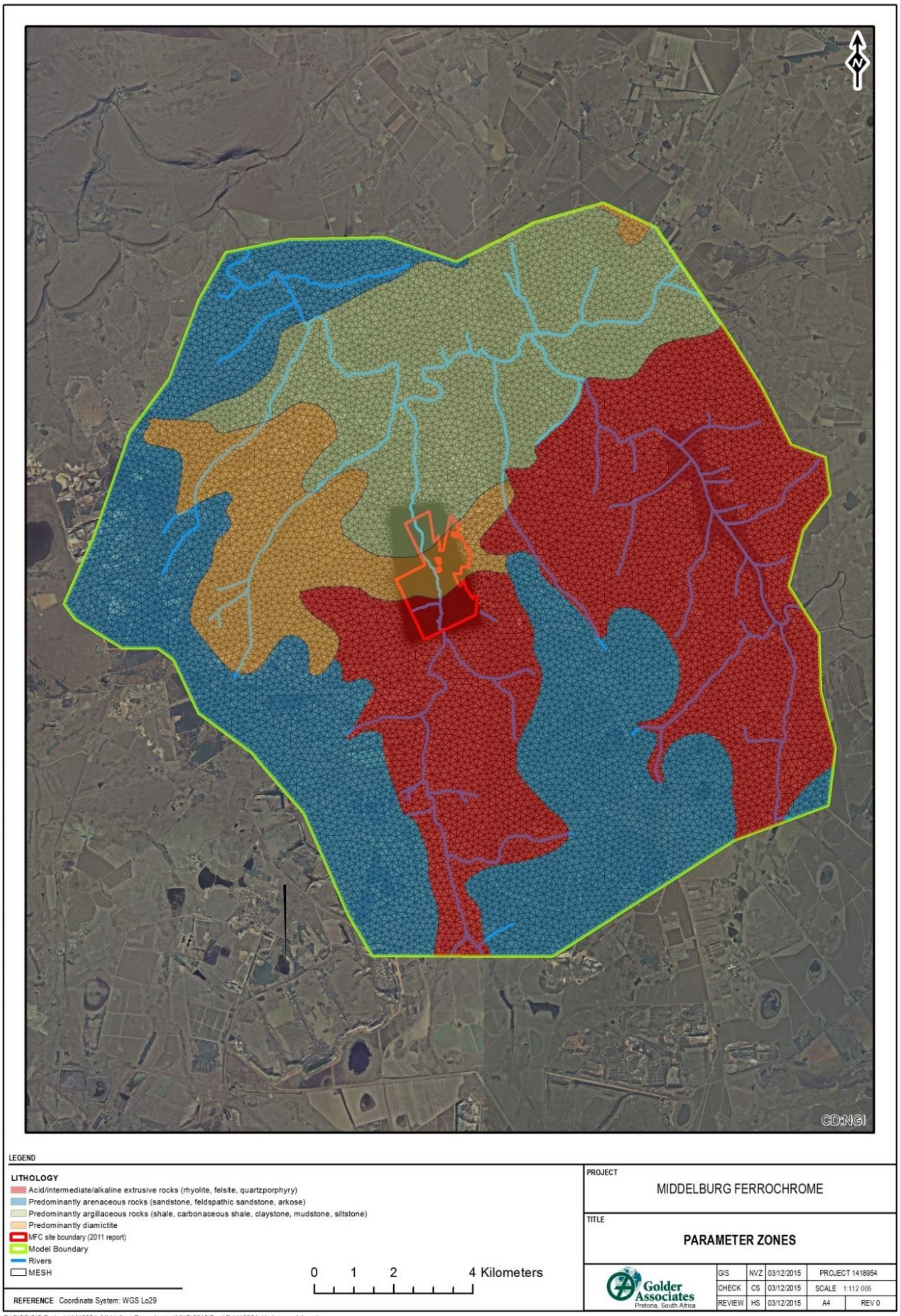


Figure 34: Aquifer Zones used in model

6.5.1.3 Conceptual understanding

The Conceptual understanding for the model was based on the 2011 Conceptual Model. The updated water levels for the site visit was incorporated into the understanding:

- The geology underlying the MFC site is not known to contain economic aquifers, but groundwater contributes to stream flow and in some instances relative higher yielding boreholes have been recorded on site. The following aquifers underlie the site:
  - Weathered Aquifer: A shallow, weathered aquifer in the weathered shale, rhyolite and diabase. All the formations have similar weathering characteristics and although the aquifer parameters may vary dependent on the rock type, the groundwater flow mechanisms are similar. The most consistent water strike is located at the fresh bedrock / weathering interface.
  - Fractured Aquifer: A deeper, non-weathered aquifer where fracture flow dominates. Groundwater migration within the upper portion of this aquifer appears to be governed by jointing while major faults and intrusions form the significant conduits at depth.
  - The two aquifers are hydraulically connected. The aquifers are classified as minor.
  - Aquifer hydraulic parameters are estimated to be between 1.14E-02 m/d to 9.9E-04 m/d for hydraulic conductivity and between 2 and 3 m^2/day for transmissivity.
- The regional groundwater flow direction is from south to north along the drainage, but locally the groundwater flow is east – west, towards the Vaalbankspruit
- Recharge values of approximately 1.2 mm/a, or 0.2% of the MAP 660 mm/a, were calibrated.
- The groundwater level range from artesian to 9.82 mbgl, with an average groundwater level of 2.3 mbgl.
- A correlation coefficient of 0.99 exists between groundwater levels and topography; this confirms that groundwater mimics topography.
- The most pronounced contamination is the southern section of the site where the Main Slag Disposal Facility and Dams 4A and 4B are located. Contamination from these sources, as with all the other sources, migrates towards the Vaalbankspruit.
- The infiltration gallery is effective in slowing down the migration to the Vaalbankspruit, but it is not 100% effective as it focuses primarily on the shallow weathered aquifer. This aquifer is more susceptible to contamination, but there is a possibility that contaminants can bypass the system through the underlying fractured aquifer.
- The current monitoring network (referring to Feb 2011) makes it difficult to distinguish between the groundwater qualities of the two aquifers.
- Conceptually, the largest part of the site is predominantly underlain by shale bedrock. The weathered zone above the bedrock is about 2 to 4m deep with a 1m thick ferricrete layer above the weathered shale material. Due to the low permeability of the underlying material shallow groundwater is found at depths between 0 and 2m deep.

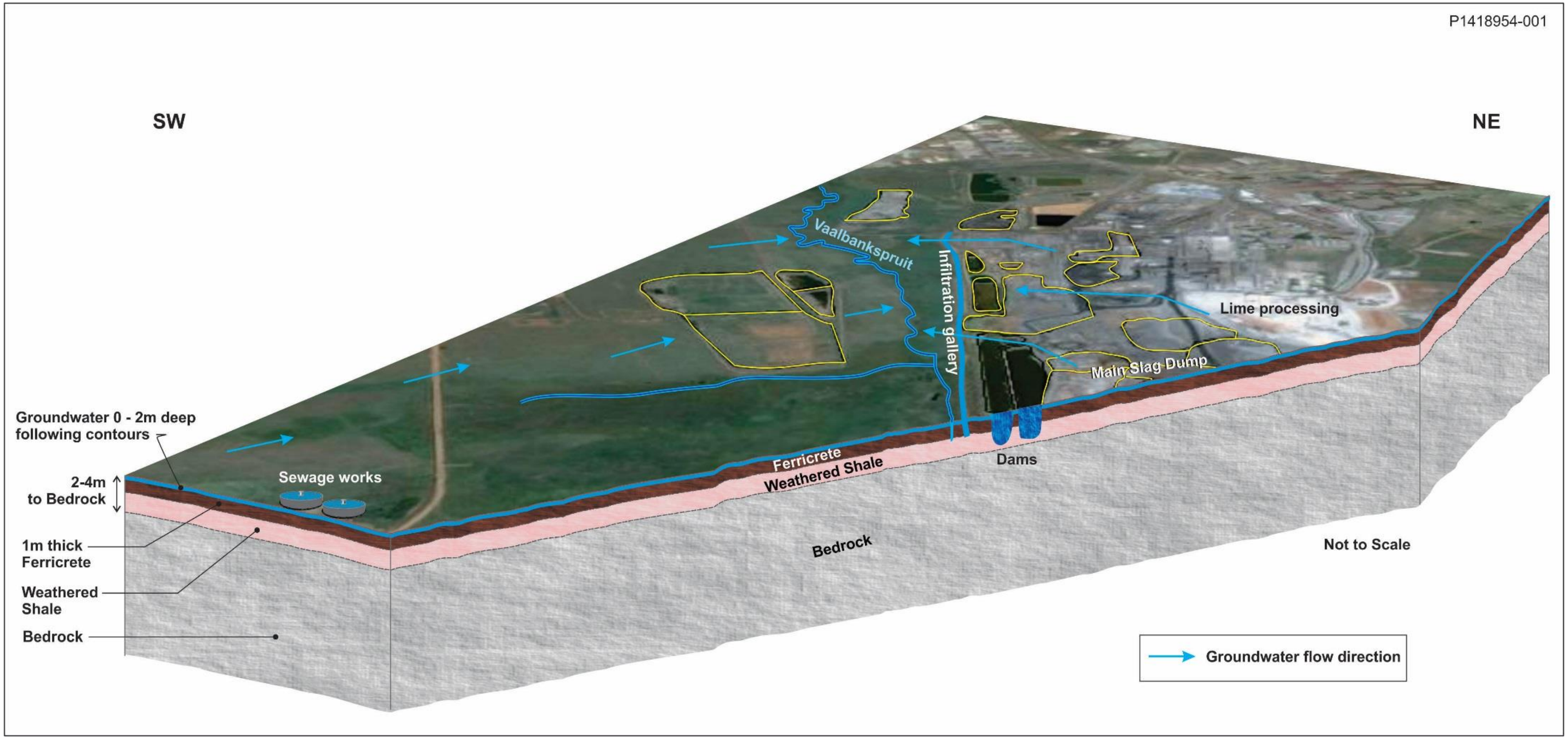


Figure 35: Conceptual Model

6.5.2 Numerical groundwater modelling

6.5.2.1 Software selection

The code selected for conducting the modelling of the MFC study area is FEFLOW 6.2. FEFLOW can be efficiently used to describe the spatial and temporal distribution of groundwater contaminants, to plan and design remediation strategies and to assist in designing alternatives and effective monitoring schemes. FEFLOW is used worldwide as a high-end groundwater numerical modelling tool.

6.5.2.2 Model area

The modelling area was selected based on topographical control. Boundaries of the numerical model were chosen to reflect the geometry of the groundwater system. Since there is a good correlation between surface topography and depth to groundwater; it is possible to select surface drainage catchment watersheds as shown in Figure 36. The modelled area is approximately 254 km^2.

6.5.2.3 Finite element mesh

Feflow ©, unlike many other modelling packages, takes a conceptual model approach to mesh development. In this way, the mesh is developed to explicitly include structures such as fault zones, dykes drainage lines, site layout, geological contacts and boreholes. The finite element mesh allows for variable size elements and thus for refinement around points of interest such as the mining tunnels or abstraction boreholes

A finite element network (grid) was designed to provide a high resolution of the numerical solution. The finite element grid was compiled by FEFLOW, which facilitated the construction of a triangular mesh consisting of 127,569 elements and 85,768 nodes. Figure 37 illustrates a three-dimensional view of the finite element numerical model area.

The Mesh quality:

- Obtuse angles 0% > 120, 3.6 % > 90;
- Delauney Violating Triangles: 0 %.

6.5.2.4 Model boundaries

Boundary conditions express the way the considered domain interacts with its environment. In other words, they express the conditions of known water flux, or known variables, such as piezometric head. Different boundary conditions result in different solutions hence the importance of stating the correct boundary conditions. Boundary conditions in a groundwater flow model can be specified either as:

- Dirichlet Type (or constant head) boundary conditions or:
- Neuman Type (or specified flux) boundary conditions; or
- A mixture of the above.

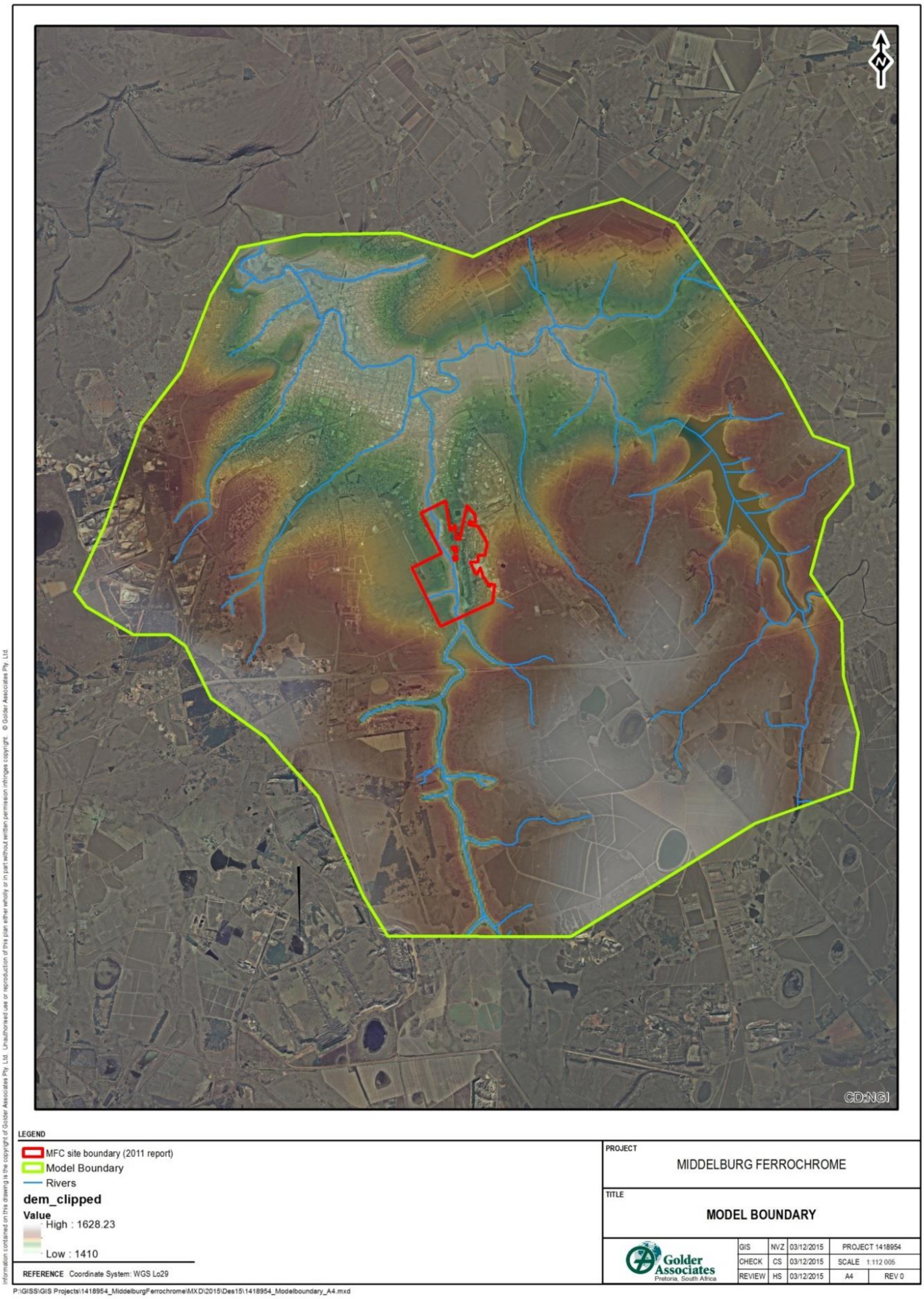


Figure 36: Model boundary

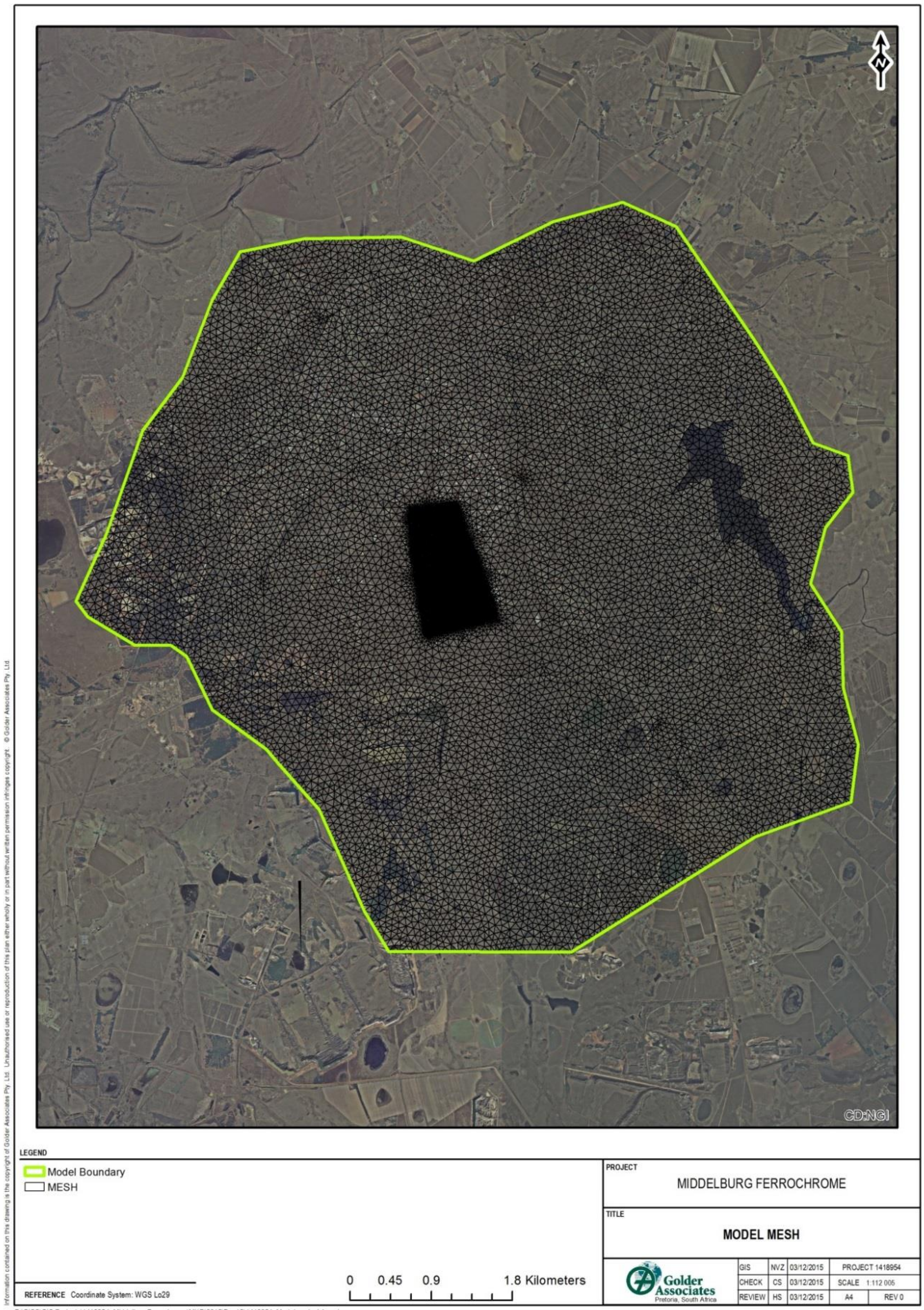


Figure 37: FEFLOW Mesh

The perimeter boundaries are represented numerically by what is referred to as a “no-flow” boundary condition (zero specified flux Neuman Type II boundary condition). Model boundaries were selected along natural watershed position with an approximate hexgon shape (Table 9). Total model perimeter boundary has a length of 62.3 km.

Table 9: Model boundary condition

Boundary	Topographical feature	Boundary condition
Northern Boundary	Local watershed	Neumann special Case (No flow boundary Condition)
Eastern Boundary	Local watershed	Neumann special Case (No flow boundary Condition)
Western Boundary	Local watershed	Neumann special Case (No flow boundary Condition)
Southern Boundary	Local watershed	Neumann special Case (No flow boundary Condition)

6.5.2.5 Model layers

The site is represented by a three-layered model based on field data and the 2011 data. The model layers were kept the same in the update of the groundwater model. The first layer is assigned a thickness of 10m below ground surface, layer 2 is assigned a thickness of 10m and layer 3 is assigned various thicknesses. The boundaries of the numerical model are shown on Figure 38

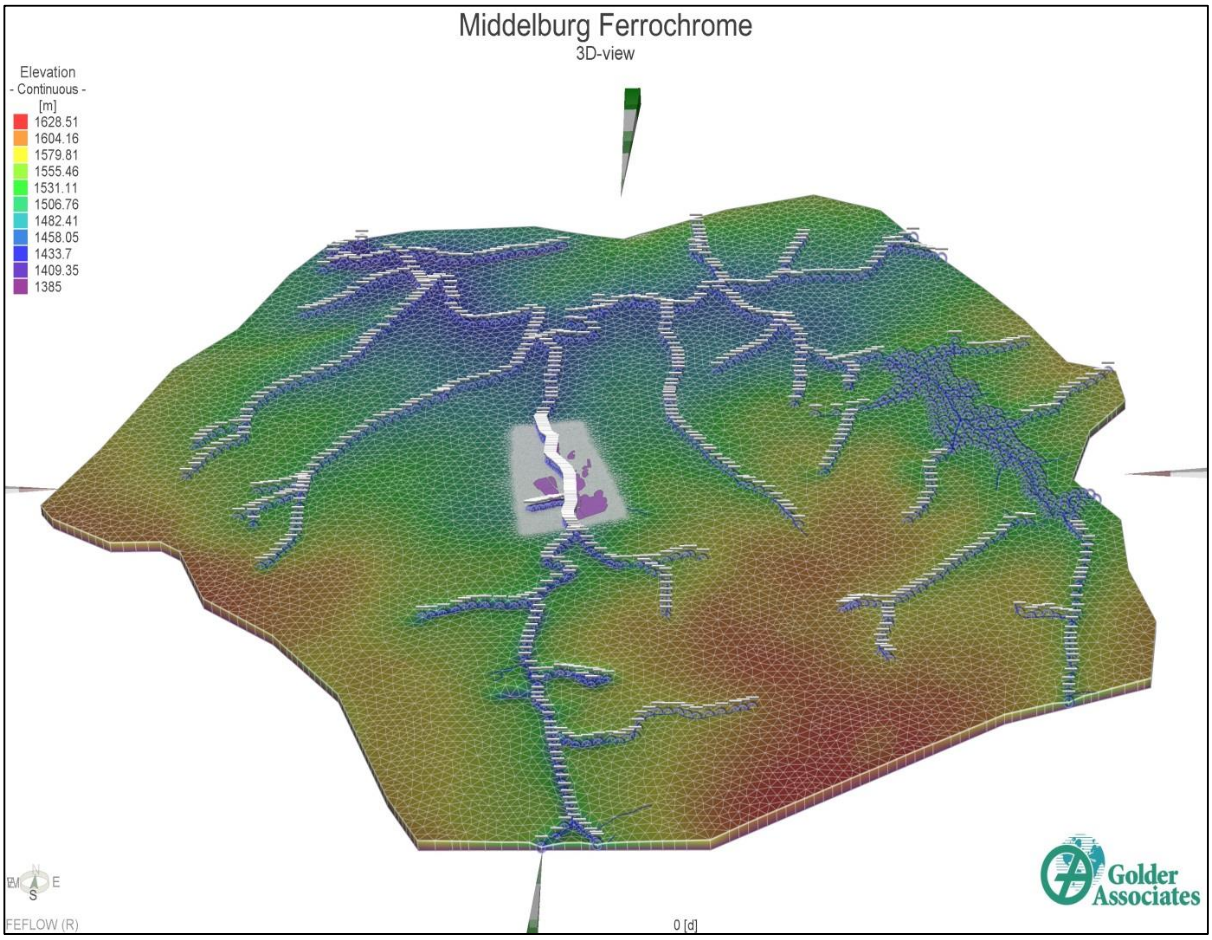


Figure 38: Model 3D with Boundary Conditions

6.5.2.6 Hydraulic conductivity and recharge

A standard trial and error process was followed to calibrate the model. Calibration of the numerical groundwater flow model has been achieved through a combination of assumptions based on field measurements and changing the hydraulic properties and boundary conditions used in the model to obtain a set of parameters that produces an acceptable correlation between observed and measured elements.

The recharge ranges from 0.5% on the Karoo sediments to 5% on the waste areas (Table 10 and Figure 39).

Table 10: Aquifer parameters and recharge

Hydraulic Zone	Layer	Average Thickness (m)	Hydraulic Conductivity (m/d)		
			Kx	Ky	Kz
Weathered zone	1	10	7.90E-04 to7.90E-02	7.90E-04 to7.90E-02	7.90E-04 to7.90E-02
Fractured zone	2	10	7.90E-04 to7.90E-02	7.90E-04 to7.90E-02	7.90E-04 to7.90E-02
Fresh Zone	3	9 - 222	1.00E-05	1.00E-05	1.00E-05

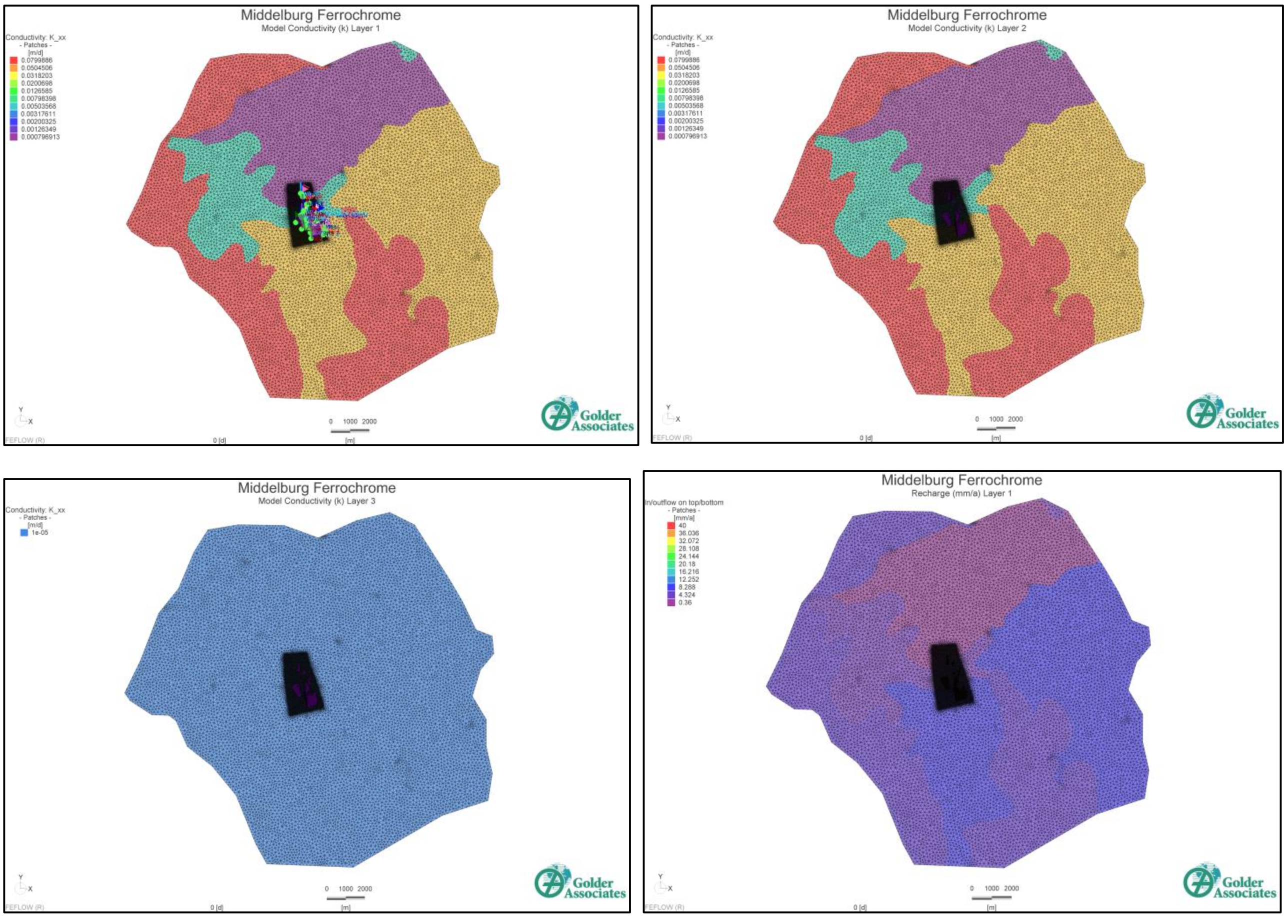


Figure 39: Hydraulic conductivities (Layer 1-3) and Recharge (layer 1) used on the different layers

6.5.2.7 Hydrogeological numerical modelling scenario

A three-dimensional numerical model was constructed to represent the conceptual groundwater system of the study area. The model has been developed as a tool to aid in evaluating the impacts of the proposed Scenario for a steady state model.

A three dimensional steady state groundwater flow model representing the study area was constructed to represent pre-mining groundwater flow conditions. These conditions serve as the initial conditions for the transient simulations of groundwater flow and mass transport associated with mine development.

The three dimensional groundwater flow equation on which Feflow modelling is based is expressed below;

$$\frac{\partial}{\partial x}\left(Kx\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(Ky\frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(Kz\frac{\partial h}{\partial z}\right)\pm W=S\frac{\partial h}{\partial t}$$

Where;

h: Hydraulic Head [L]

Kx, Ky, Kz = Hydraulic conductivity [L/T]

S = storage coefficient

T = Time [T[

W = Source and sinks [L/T]

Calibration is the process of identifying a suitable set of hydraulic parameters, boundary conditions and stresses that best describe the observed hydraulic heads or fluxes within a defined catchment (Anderson and Woesner, 1992). Under steady state conditions the groundwater flow equation is reduced to exclude storativity and only transmissivity (or hydraulic conductivity) and recharge are considered in the calibration process. The difference between the simulated and measured heads was calculated for each borehole (Table 11).

Three methods were used to express the error in the calibration:

- **Mean Error (ME):** Mean difference between the measured and simulated water levels.
- **Mean Absolute Error (MAE):** Mean of the absolute value of the differences between the measured and simulated heads.
- **Root Mean Square Error (RMS):** Average of the squared differences between the measured and simulated heads

The suitability of the calibrations was evaluated on five criteria;

- Residual error (m): < 10% of the model thickness
- Absolute residual (m): <10% of the model thickness
- Root mean square error (m): <10% of the model thickness
- Normalized root mean square error (m): <10%
- Correlation: >0.95

The observation boreholes is highly concentrated in and around the site. The regional calibrated flow is from South to North.

The head elevation data from 84 observation boreholes were used to calibrate the steady-state flow model (The difference between the simulated and measured heads was calculated for each Four methods were used to for the calibration process:

- Mean Error (ME), which indicates the mean difference between the measured and simulated water levels. The average ME is 1.82 m.

- Mean Absolute Error (MAE) is the absolute value of the differences between the measured and simulated heads. The MAE is 5.82 m.
- The Root Mean Square Error (RMSE) is the ratio of the total water level change across the model domain. When the ratio is small, the errors are small relative to the overall water level and model response. The RMSE is 7.67% of the range in water levels, which is acceptable.

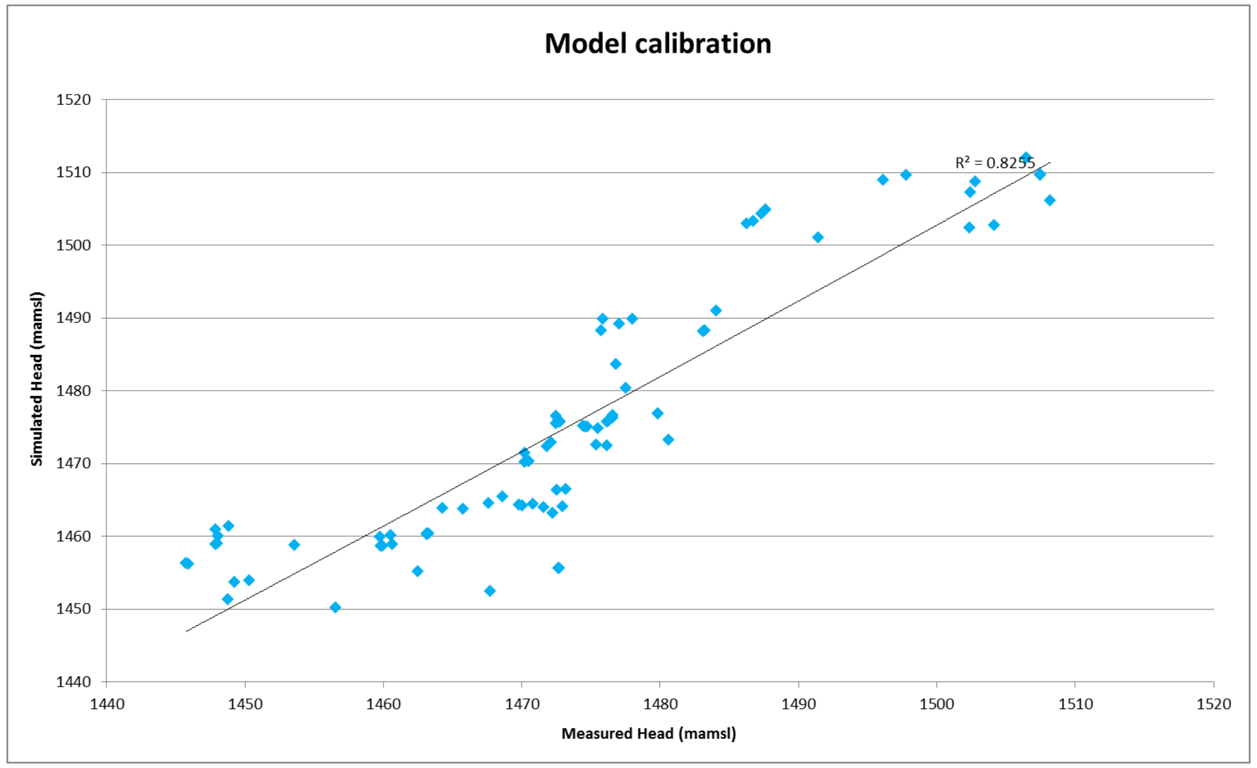
A scatterplot and bar chart of the calibration results can be seen in Figure 40.

Table 11: Simulated vs Observed Calibration summary

ID	X	Y	WL elevation (mamsl)	Elevation (mamsl)	Water level (mbgl)	LABEL	Measured head (mamsl)	Sim Head (mamsl)	Mean Absolute Error (m) MAE	Mean Error(m) ME	Root Mean Sqaure Error (m) RMS
1	49872	-2855985	1502.773544	1504	1.14	MB 1	1502.77	1508.706662	5.94	-5.94	35.24
2	49873	-2856091	1502.409245	1504	1.63	MB 2	1502.409245	1507.221184	4.81	-4.81	23.15
3	49955	-2856318	1508.180256	1508	0	MB 3	1508.180256	1506.117485	2.06	2.06	4.26
4	50021	-2856227	1507.471958	1510	2.12	MB 4	1507.471958	1509.667166	2.20	-2.20	4.82
5	50023	-2856224	1507.510267	1510	2.07	MB 5	1507.51	1509.765104	2.26	-2.26	5.09
6	50003	-2856006	1506.500167	1508	1.47	MB 6	1506.500167	1512.020157	5.52	-5.52	30.47
7	50002	-2856006	1506.505668	1508	1.43	MB 7	1506.505668	1511.9912	5.49	-5.49	30.09
8	49546	-2855573	1486.750991	1493	6.45	SP 1	1486.750991	1503.240701	16.49	-16.49	271.91
9	49554	-2855691	1486.271458	1493	6.65	SP2	1486.271458	1502.917869	16.65	-16.65	277.10
10	49578	-2855641	1487.335794	1494	6.61	SP 3	1487.335794	1504.339768	17.00	-17.00	289.14
11	49592	-2855668	1487.640588	1494	6.76	SP 4	1487.640588	1504.824496	17.18	-17.18	295.29
12	49268	-2856616	1463.140094	1464	1.27	SD1	1463.140094	1460.387935	2.75	2.75	7.57
13	49267	-2856614	1463.147592	1464	1.15	SD2	1463.147592	1460.306739	2.84	2.84	8.07
14	49267	-2856613	1463.276255	1464	1.05	SD3	1463.276255	1460.320933	2.96	2.96	8.73
15	49213	-2856315	1459.947036	1462	2.37	SD4	1459.947036	1458.716333	1.23	1.23	1.51
16	49212	-2856313	1459.848271	1462	2.13	SD5	1459.848271	1458.70679	1.14	1.14	1.30
17	49213	-2856311	1460.647060	1462	1.58	SD6	1460.64706	1458.900805	1.75	1.75	3.05
18	49182	-2856135	1448.087381	1450	2.3	SD7	1448.087381	1460.023447	11.94	-11.94	142.47
19	49182	-2856131	1448.003927	1450	2.34	SD8	1448.003927	1459.054896	11.05	-11.05	122.12
20	49181	-2856129	1447.860186	1450	2.23	SD9	1447.860186	1458.92504	11.06	-11.06	122.43
21	49147	-2855924	1445.895033	1448	1.67	SD10	1445.895033	1456.166922	10.27	-10.27	105.51
22	49148	-2855924	1445.735576	1448	1.84	SD11	1445.735576	1456.317351	10.58	-10.58	111.97
23	49166	-2855854	1448.819982	1451	1.88	SD12	1448.819982	1461.433377	12.61	-12.61	159.10
24	48740	-2855557	1477.071585	1479	2.42	WD 1	1477.071585	1489.224257	12.15	-12.15	147.69
25	48685	-2855448	1475.779176	1479	3.37	WD 2	1475.779176	1488.253275	12.47	-12.47	155.60
26	48756	-2855390	1472.509801	1475	2.63	WD 3	1472.509801	1476.566725	4.06	-4.06	16.46
27	48800	-2855442	1472.766144	1475	2.13	WD 4A	1472.766144	1475.751709	2.99	-2.99	8.91
28	48798	-2855441	1472.653261	1475	2.27	WD 4B	1472.653261	1475.957181	3.30	-3.30	10.92
29	48801	-2855441	1472.456788	1475	2.35	WD 4C	1472.456788	1475.539114	3.08	-3.08	9.50
30	48798	-2855439	1472.653866	1475	2.17	WD 4D	1472.653866	1475.779707	3.13	-3.13	9.77
31	48829	-2855490	1474.731474	1476	1.69	WD 5A	1474.731474	1475.054894	0.32	-0.32	0.10
32	48827	-2855486	1474.565340	1476	1.68	WD 5B	1474.56534	1475.089184	0.52	-0.52	0.27
33	48830	-2855193	1448.748274	1450	1.7	WD 5C	1448.748274	1451.292754	2.54	-2.54	6.47
34	48825	-2855483	1474.427986	1476	1.69	WD 5D	1474.427986	1475.178868	0.75	-0.75	0.56
35	48860	-2855620	1476.585035	1478	1.72	WD 6A	1476.585035	1476.286456	0.30	0.30	0.09
36	48857	-2855618	1476.569245	1478	1.86	WD 6B	1476.569245	1476.662739	0.09	-0.09	0.01
37	48863	-2855621	1476.308373	1478	1.78	WD 6C	1476.308373	1475.878927	0.43	0.43	0.18
38	48864	-2855619	1476.182597	1478	1.85	WD 6D	1476.182597	1475.670974	0.51	0.51	0.26
39	48878	-2855750	1475.500420	1478	2.08	WD 7	1475.50042	1474.793954	0.71	0.71	0.50
40	48836	-2855725	1477.510018	1480	2.27	WD 8	1477.510018	1480.332887	2.82	-2.82	7.97
41	48931	-2855925	1471.605066	1473	1.27	WD 9	1471.605066	1464.02865	7.58	7.58	57.40

ID	X	Y	WL elevation (mamsl)	Elevation (mamsl)	Water level (mbgl)	LABEL	Measured head (mamsl)	Sim Head (mamsl)	Mean Absolute Error (m) MAE	Mean Error(m) ME	Root Mean Sqaure Error (m) RMS
42	48965	-2856066	1467.745727	1469	0.79	WD 10	1467.745727	1452.440831	15.30	15.30	234.24
43	48791	-2855377	1469.827770	1472	2.59	WD 11A	1470.22777	1471.476624	1.25	-1.25	1.56
44	48791	-2855377	1470.227770	1472	2.19	WD 11B	1472.150513	1472.862529	0.71	-0.71	0.51
45	48819	-2855438	1472.150513	1474	1.86	WD 12A	1471.86	1472.323853	0.46	-0.46	0.22
46	48823	-2855437	1471.859971	1474	1.95	WD 12B	1475.408366	1472.568344	2.84	2.84	8.07
47	48881	-2855591	1475.418366	1477	1.83	WD 13A	1476.192209	1472.494028	3.70	3.70	13.68
48	48881	-2855591	1475.408366	1477	1.84	WD 13B	1470.528212	1470.325865	0.20	0.20	0.04
49	48865	-2855534	1477.362209	1478	0.48	WD 14A	1470.238687	1470.206771	0.03	0.03	0.00
50	48865	-2855534	1476.192209	1478	1.65	WD 14B	1469.827445	1464.34422	5.48	5.48	30.07
51	48827	-2855416	1470.528212	1472	1.54	WD 15A	1467.634308	1464.531253	3.10	3.10	9.63
52	48828	-2855416	1470.238687	1472	1.77	WD 15B	1459.75698	1459.907873	0.15	-0.15	0.02
53	48887	-2855436	1469.827445	1470	0	WD 16A	1472.98797	1464.143533	8.84	8.84	78.22
54	48887	-2855439	1467.634308	1470	2.63	WD 16B	1472.247	1463.178777	9.07	9.07	82.23
55	48884	-2855369	1459.746980	1461	1.24	WD 17A	1460.543951	1460.132421	0.41	0.41	0.17
56	48884	-2855369	1459.756980	1461	1.23	WD 17B	1456.544315	1450.227954	6.32	6.32	39.90
57	48925	-2855523	1472.987970	1474	0.94	WD 18A	1462.494535	1455.192461	7.30	7.30	53.32
58	48932	-2855522	1472.247000	1473	0.77	WD 18B	1468.607001	1465.424045	3.18	3.18	10.13
59	48923	-2855437	1460.543951	1465	4.65	WD 19	1465.796668	1463.737588	2.06	2.06	4.24
60	48645	-2854306	1456.544315	1458	1.76	WD 20	1464.277714	1463.873848	0.40	0.40	0.16
61	48705	-2854327	1462.494535	1465	2.28	WD 21	1453.585136	1458.782533	5.20	-5.20	27.01
62	48818	-2854394	1468.607001	1472	3.11	WD 22	1484.060405	1490.99083	6.93	-6.93	48.03
63	48799	-2854415	1465.796668	1468	1.88	WD 23	1491.423684	1500.997764	9.57	-9.57	91.66
64	48803	-2854466	1464.277714	1465	0.92	WD 24	1497.820973	1509.56224	11.74	-11.74	137.86
65	48753	-2854473	1453.585136	1454	0.83	WD 25	1496.147561	1508.908136	12.76	-12.76	162.83
66	48444	-2855820	1484.060405	1490	6.39	N3- 880	1447.892775	1460.951124	13.06	-13.06	170.52
67	49478	-2855340	1491.423684	1494	3.03	M4	1475.858439	1489.861962	14.00	-14.00	196.10
68	49657	-2855308	1497.820973	1501	3.65	MELT SHOP NORTH	1478.006867	1489.838657	11.83	-11.83	139.99
69	49657	-2855413	1496.147561	1500	3.49	MELT SHOP SOUTH	1449.255865	1453.72943	4.47	-4.47	20.01
70	49181	-2856110	1447.892775	1450	2	BH 1	1450.295605	1453.972675	3.68	-3.68	13.52
71	49302	-2855471	1475.858439	1486	9.82	BH 2	1470.044936	1464.214662	5.83	5.83	33.99
72	49302	-2855469	1478.006867	1486	7.72	BH 2A	1470.850136	1464.472334	6.38	6.38	40.68
73	49073	-2855502	1449.255865	1450	0.69	BH 3	1483.240213	1488.229846	4.99	-4.99	24.90
74	49073	-2855499	1450.295605	1450	0	BH 3A	1483.106587	1488.199208	5.09	-5.09	25.93
75	49041	-2855268	1470.044936	1470	0.4	BH 4	1479.882592	1476.843968	3.04	3.04	9.23
76	49042	-2855266	1470.850136	1471	0	BH 4A	1479.856871	1476.854508	3.00	3.00	9.01
77	49123	-2854812	1483.240213	1487	3.67	BH 5	1473.22124	1466.486699	6.73	6.73	45.35
78	49123	-2854813	1483.106587	1487	3.81	BH 5A	1472.549146	1466.328608	6.22	6.22	38.70
79	48981	-2854860	1479.882592	1481	1.12	BH 6A	1502.393443	1502.376	0.02	0.02	0.00
80	48980	-2854858	1479.856871	1481	1.11	BH 6B	1504.140662	1502.732074	1.41	1.41	1.98
81	49258	-2856346	1473.221240	1475	2.2	BH 7	1480.600704	1473.283562	7.32	7.32	53.54
82	49257	-2856350	1472.549146	1475	2.59	BH 7A	1476.846311	1483.621532	6.78	-6.78	45.90
83	49896	-2856410	1502.393443	1506	4.09	BH 8	1472.739448	1455.624165	17.12	17.12	292.93

ID	X	Y	WL elevation (mamsl)	Elevation (mamsl)	Water level (mbgl)	LABEL	Measured head (mamsl)	Sim Head (mamsl)	Mean Absolute Error (m) MAE	Mean Error(m) ME	Root Mean Sqaure Error (m) RMS
84	49902	-2856403	1504.140662	1507	2.56	BH 8A	1472.659013	1455.597867	17.06	17.06	291.08
Average			1473.61	1475.92	2.31		1473.86	1475.71	5.82	-1.85	59.29
Minimun			1445.74	1447.57	0.00		1445.74	1450.23	0.02	-17.18	0.00
Maximum			1508.18	1509.59	9.82		1508.18	1512.02	17.18	17.12	295.29
Correlation							90.85				
								SUM	488.60	-33.52	1925.18
								SUM/N	5.82	-0.40	22.92
										SQRT	4.79
										Water Level Change	62.44
										RMS%	**7.67%**



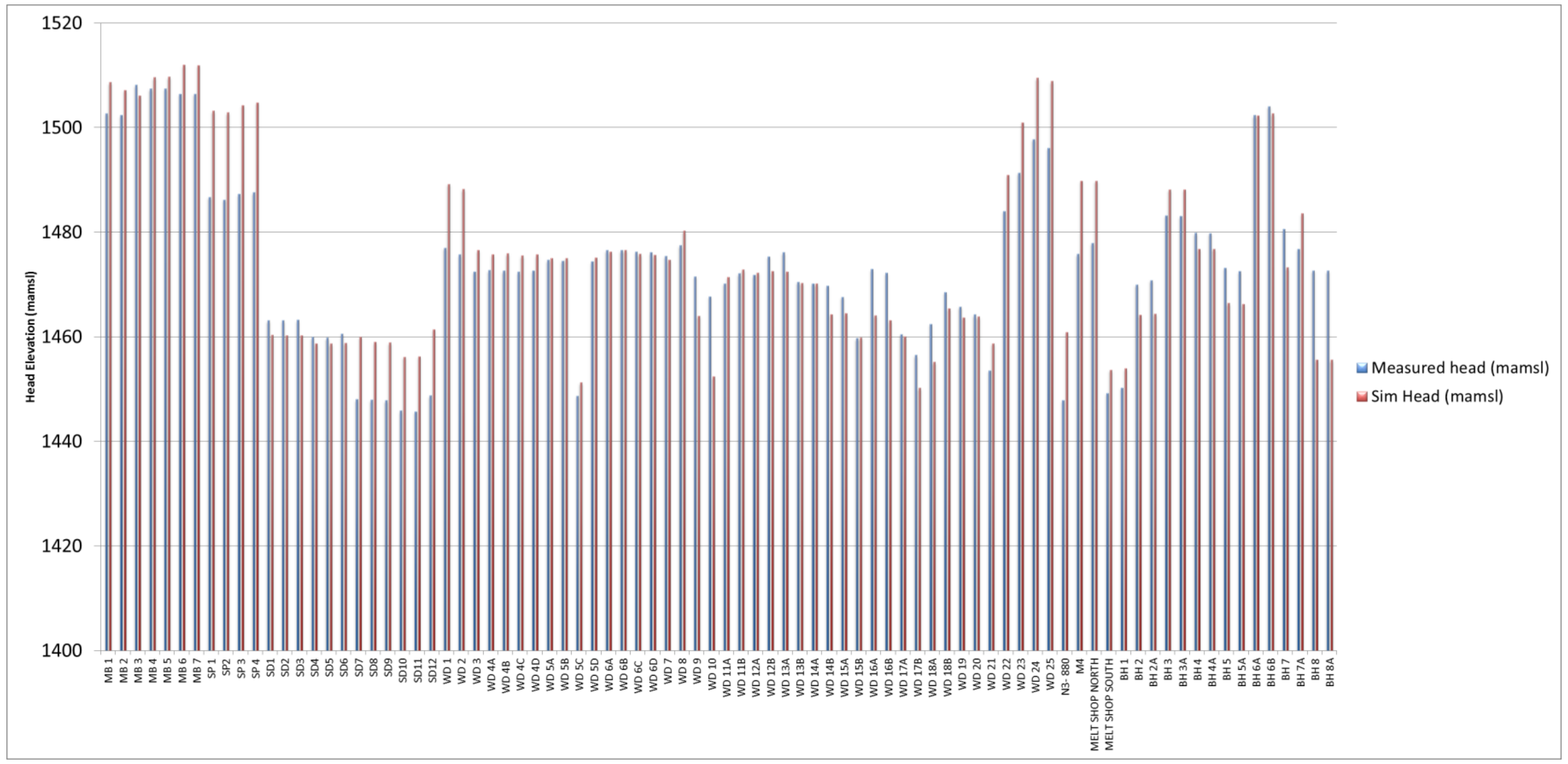


Figure 40: Bar-chart and Scatterplot of the simulated vs observed groundwater levels

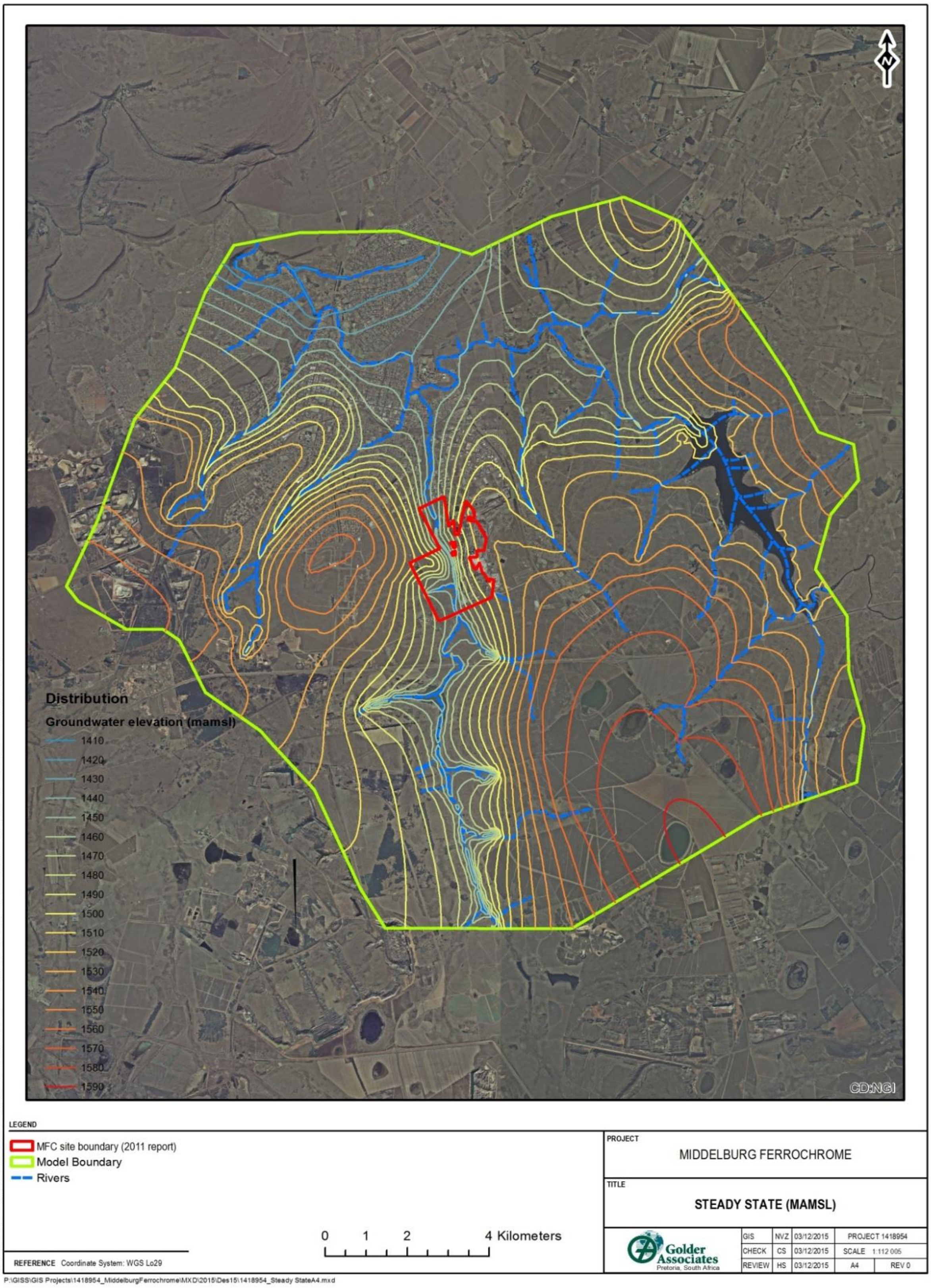


Figure 41: Steady State contours (mamsl)

7.0 RECEPTOR ASSESSMENT

The main receptor identified is the Vaalbankspruit. Samples were collected from 6 monitoring points in the Vaalbankspruit (Figure 27). These samples were analysed for:

- Major cations (Na, K, Ca, Mg);
- Major anions (F, Cl, SO_4, NO_3);
- Physico-chemical parameters (pH, EC, alkalinity, TDS); and
- Inorganic CoCs (including Al, Cr (VI), Mn, Fe, Ni, Cu, Zn, Pb, As).

Samples from the same sampling points were submitted to GARL for toxicity testing.

7.1 Water quality evaluation

Table 12 show the analytical results of Vaalbankspruit samples compared with DWS Drinking water Standards Class II. These results show that the water quality of the Vaalbankspruit is acceptable, except the Mo and NO_3 concentrations in SPB and SPD exceeding the standards.

Table 12: Water quality of Vaalbankspruit compared to DWS Class II water quality guidelines

	DWS Class II	SPK	SPL	SPJ	SPG	SPB	SPD
EC uS/cm	3000	461	467	462	725	1015	1112
pH	4-10.5	6.88	6.88	6.9	7.28	7.89	7.72
				mg/l			
Al	0.3	0.02	0.02	0.02	0.02	0.02	0.02
As	0.3	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025
Ba	400	0.074	0.076	0.079	0.088	0.063	0.09
Ca	150	30.1	29.9	29.8	54	63.1	71.7
Cd	0.02	0.0005	0.0005	0.0005	0.0005	0.0005	0.0007
Cl	200	15.2	14.8	14.9	23.9	38.2	44.3
Co	0.006*	0.002	0.002	0.002	0.002	0.002	0.002
Cr	0.05	0.0015	0.0015	0.0015	0.0015	0.0054	0.0045
Cr(VI)	0.02	0.006	0.006	0.006	0.006	0.006	0.006
Cu	30	0.007	0.007	0.007	0.007	0.007	0.007
F	1.5	0.3	0.3	0.3	0.3	0.7	0.6
Fe	0.2	0.106	0.107	0.058	0.02	0.02	0.02
Hg	0.005	0.001	0.001	0.001	0.001	0.001	0.001
K	50	7.5	7.3	7.3	7.5	23.8	21.3
Mg	70	21.5	21.3	21.2	42.1	46.5	51.2
Mn	0.1	0.048	0.089	0.056	0.064	0.008	0.009
Mo	0.01*	0.002	0.002	0.002	0.002	0.026	0.021
Na	200	21.5	21	20.8	30.7	59	63
NH_4	1	0.08	0.06	0.13	0.07	0.05	0.08
Ni	0.039*	0.002	0.002	0.002	0.002	0.002	0.002
NO_3	10	0.3	0.2	0.2	0.2	14	24.7
Pb	0.05	0.005	0.005	0.005	0.005	0.005	0.005

	DWS Class II	SPK	SPL	SPJ	SPG	SPB	SPD
Sb	0.2	0.002	0.002	0.002	0.002	0.002	0.002
Se	0.05	0.003	0.003	0.003	0.003	0.003	0.003
SO_4	400	141.51	144.8	139.1	277.38	306.05	342.64
TDS	1000	308	307	314	532	651	796
V	1	0.0015	0.0015	0.0015	0.0015	0.0015	0.0016
Zn	10	0.016	0.011	0.011	0.014	0.017	0.031

7.2 Vaalbankspruit Monitoring data

Historic monitoring data for the Vallbankspruit was evaluated to determine areas where potential contribution of the CoC from the site are evident.

7.2.1 Nitrate

The montly mean Nitrate concentations of the main sampling points in the Vaalbankspruit are shown in Figure 42. A box plot of the mean monthly nitrate concentrations at the main sampling points is presented in Figure 43. Although season fluctuation and some variability in the data is observed a mean increase of 10.6mg/l in the nitrate concentration is observed at SPD. Upstream data at SPK indicate some spikes in the data but the mean at SPD is significantly sifted as compared to SPK.The mean nitrate concentration at SPB is below the DWS drinking water standard although some results above the standard are recorded.

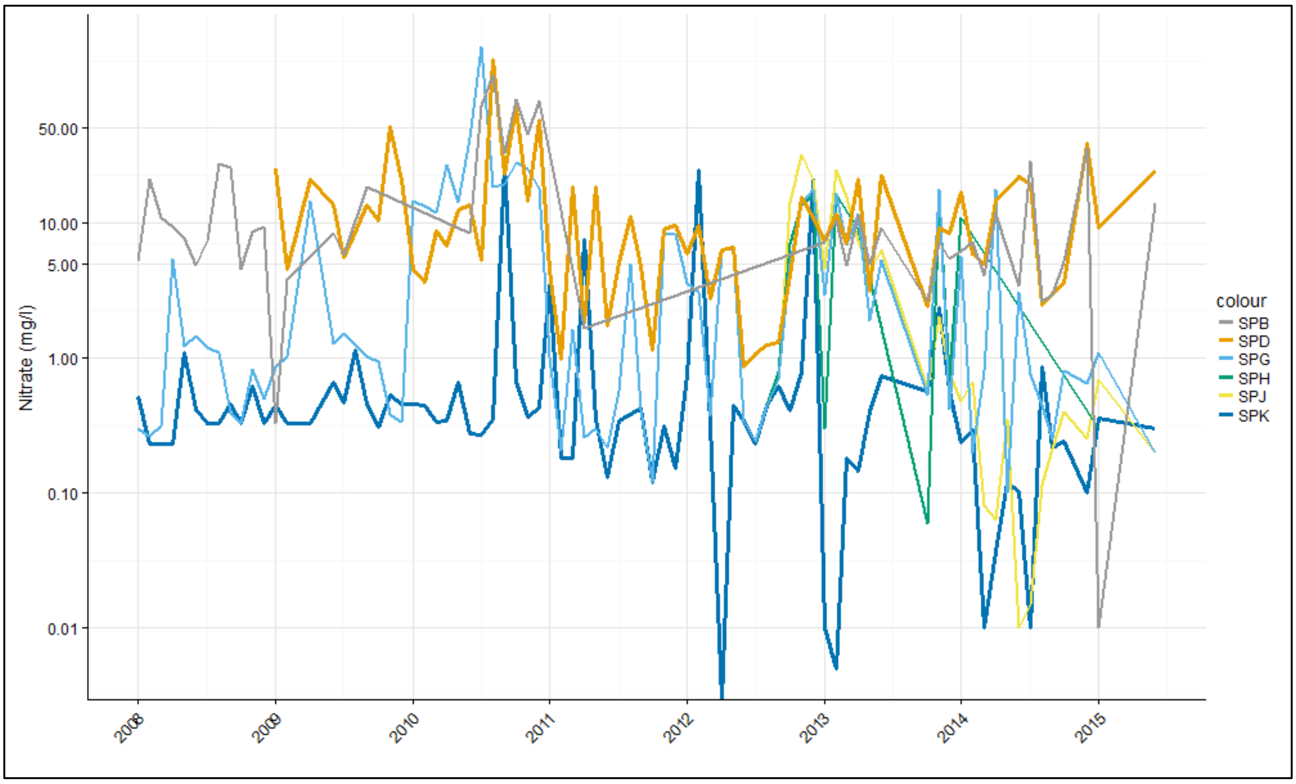


Figure 42: Vaalbankspruit monitoring data time series plot of Nitrate concentrations (sampling point SPK and SPD are presented as thicker lines)

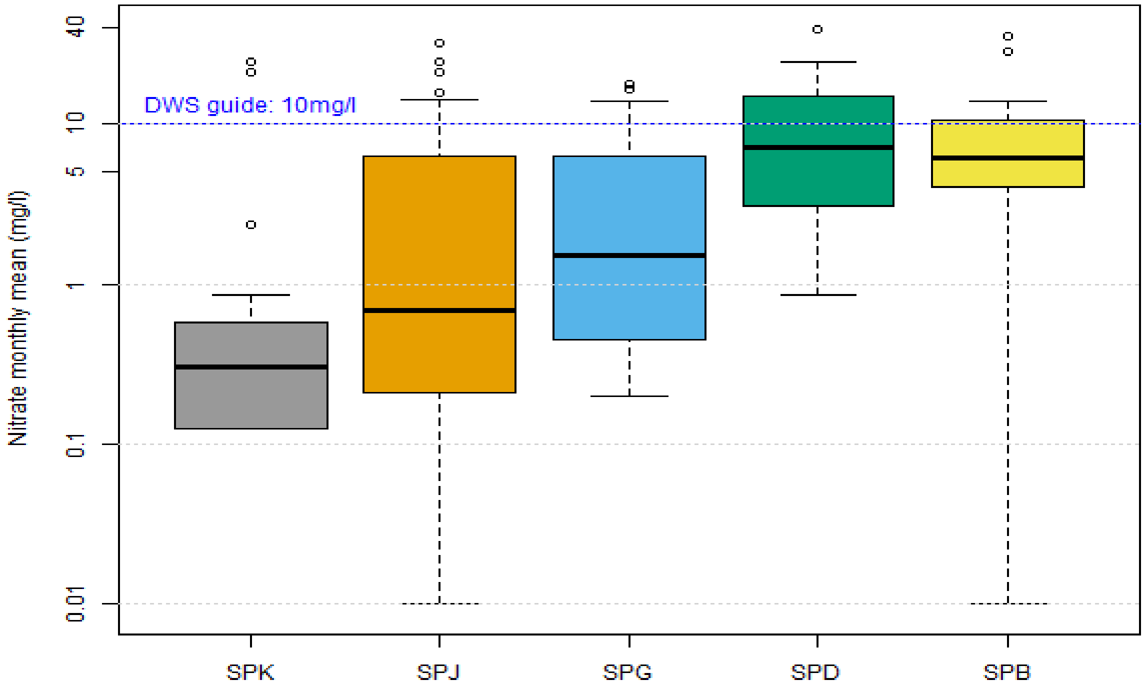


Figure 43: Vaalbankspruit monitoring data box plot of Nitrate concentration since 2012

7.2.2 Sulphate

The montly mean sulphate concentations of the main sampling points in the Vaalbankspruit are presented in Figure 44. A box plot of the mean monthly sulphate concentrations for the the sampling points in the Vaalbankspruit is presented in Figure 45. Although season fluctuation and some variability in the data is observed, a mean increase of 106mg/l sulphate is observed at SPD. Upstream data at SPK increase in certain periods to arround 500mg/l. At these times there was little difference between the upstream and down stream data. However, at times when the upstream data improves to arround 100mg/l, the largest difference between the two points are recorded. Sulphate concentrations is strongly correlated with calcium concentrations in the main Vaalbankspruit samples SPK, SPJ, SPG, SPD, SPB for data from 2012 (Figure 46).

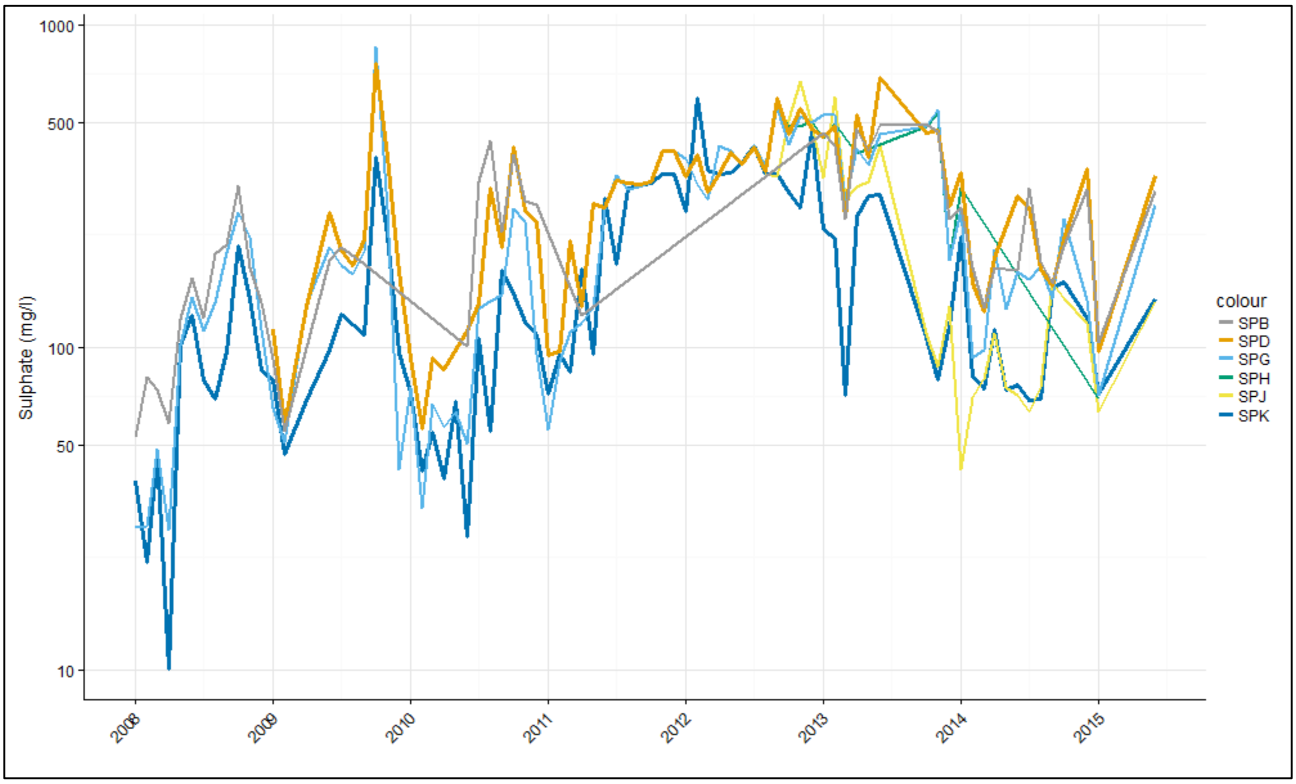


Figure 44: Vaalbankspruit monitoring data time series plot of Sulphate concentrations (sampling point SPK and SPD are presented as thicker lines)

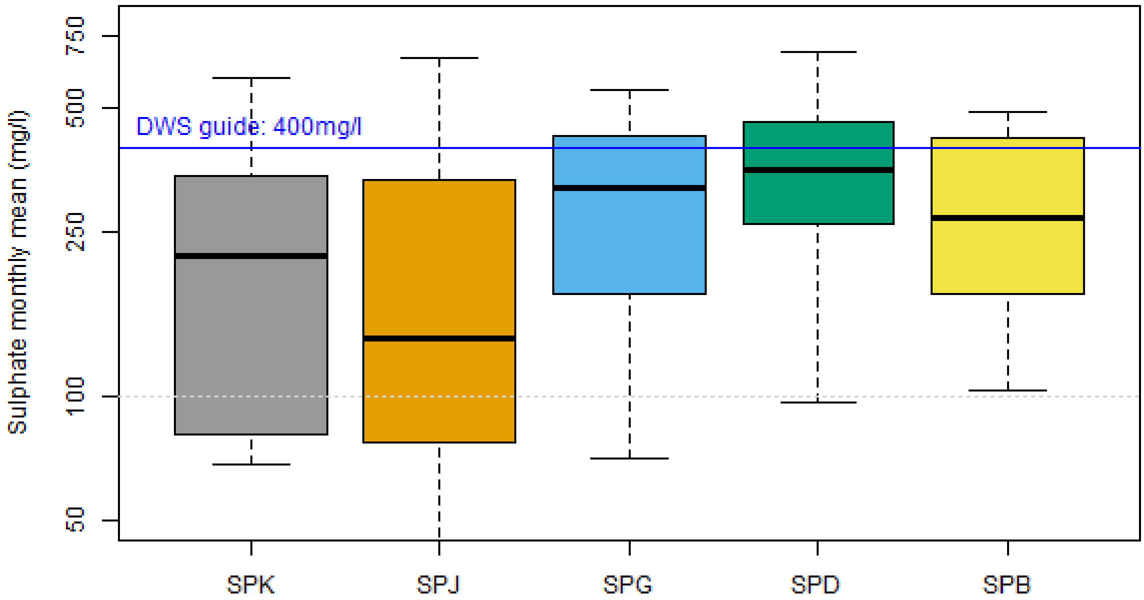


Figure 45: Vaalbankspruit monitoring data box plot of Sulphate concentration since 2012

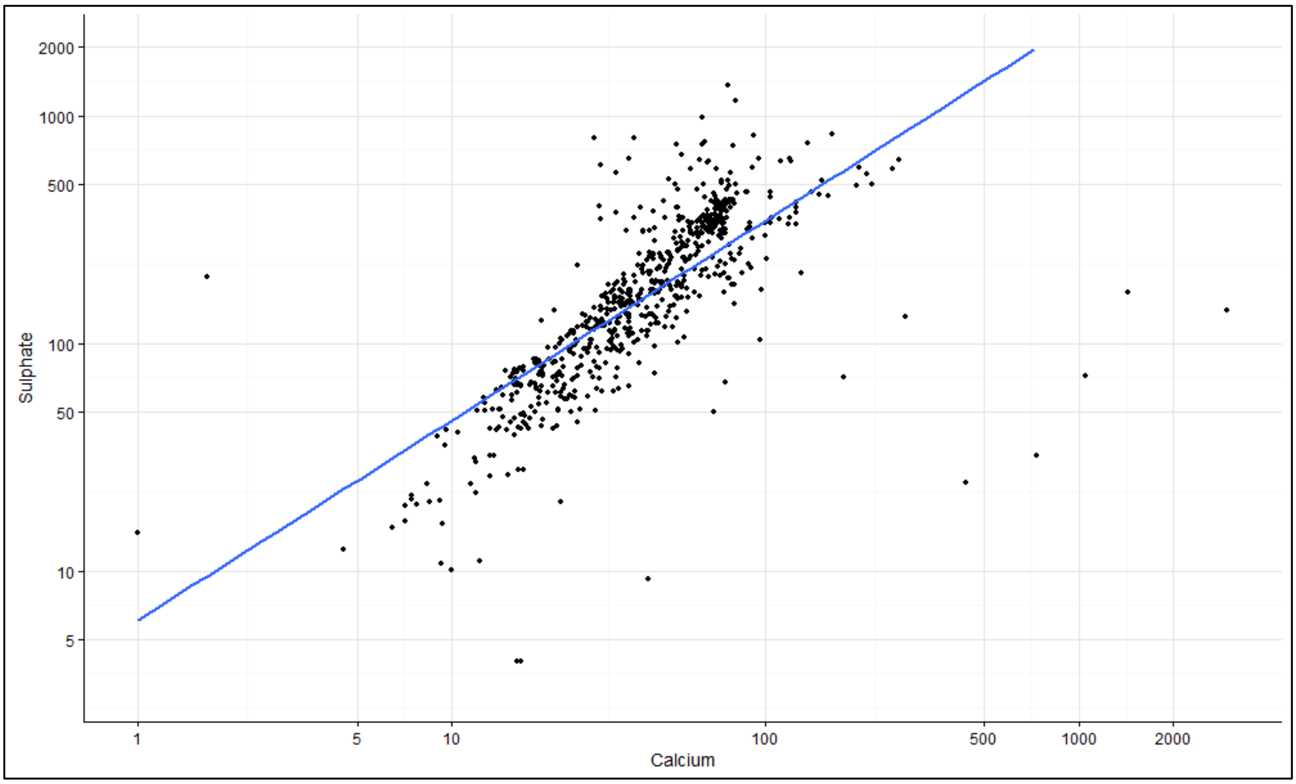


Figure 46: Sulphate concentrations correlation with Calcium concentration in the main Vaalbankspruit samples SPK, SPJ, SPG, SPD, SPB for data from 2012

7.2.3 Sodium

The monthly mean Sodium concentrations of the main sampling points in the Vaalbankspruit is graphed in Figure 47. A box plot of the difference between the sampling points and the upstream sampling point at SPK is presented in Figure 48. Although monthly fluctuation are observed, a mean increase of 55.9mg/l is observed at SPD as compared to SPK. All the results at sampling point SPB are below the DWS guide value.

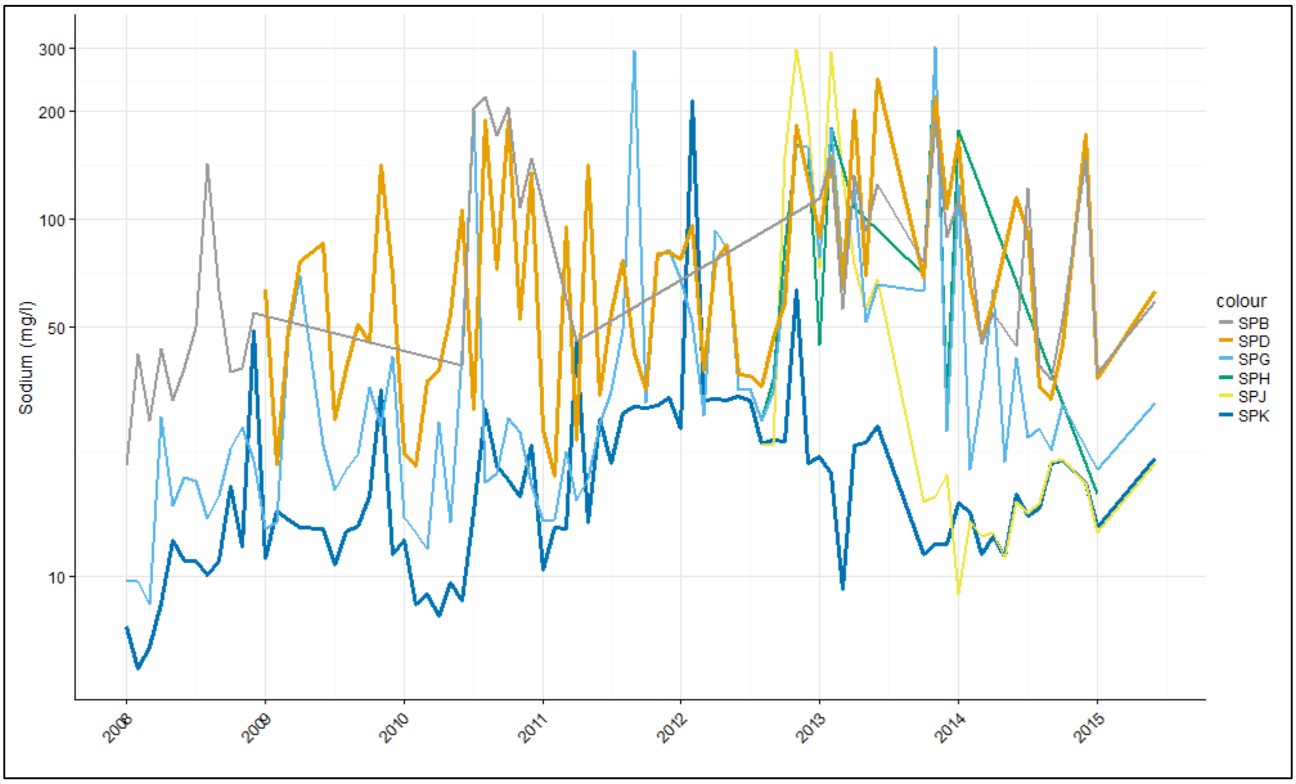


Figure 47: Vaalbankspruit monitoring data time series plot of Sodium concentrations (sampling point SPK and SPD are presented as thicker lines)

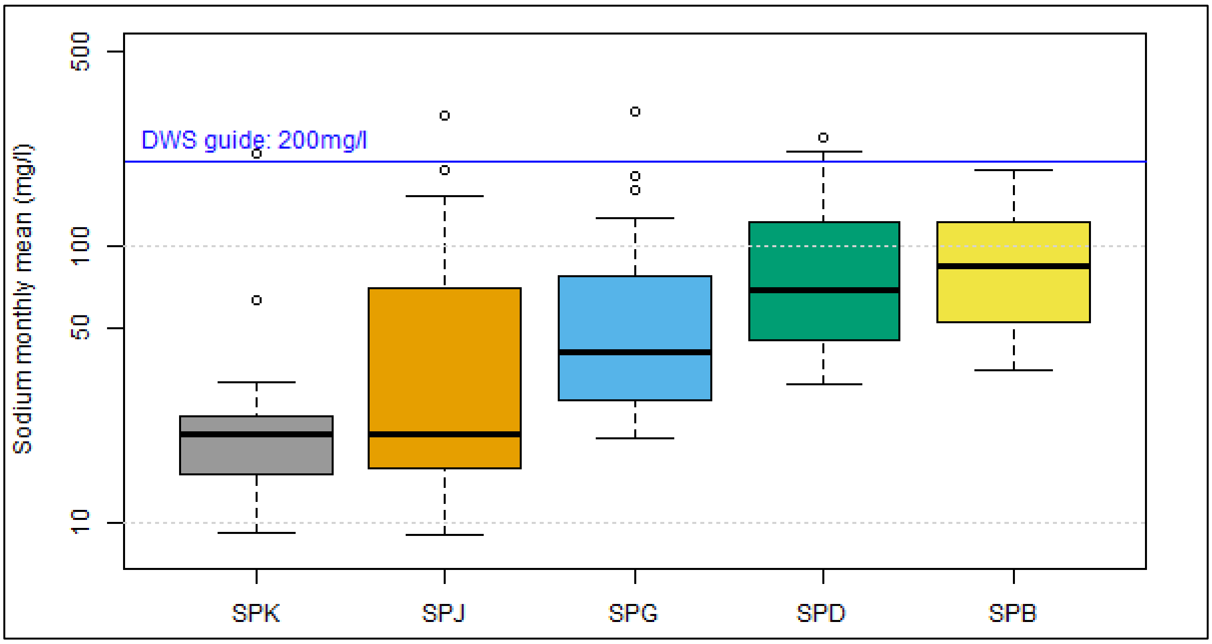


Figure 48: Vaalbankspruit monitoring data box plot of Sodium concentration since 2012

7.2.4 Chromium

The chromium analysis data for Vaalbankspruit are essentially recording the detection limit (Figure 49) of the laboratory at the time of analysis. Some small spikes above the detection limits can be seen as analytical noise and is also recorded in the upstream sampling point at SPK. An improvement in detection limits after 2013 is observed although some noise in the data is still seen.

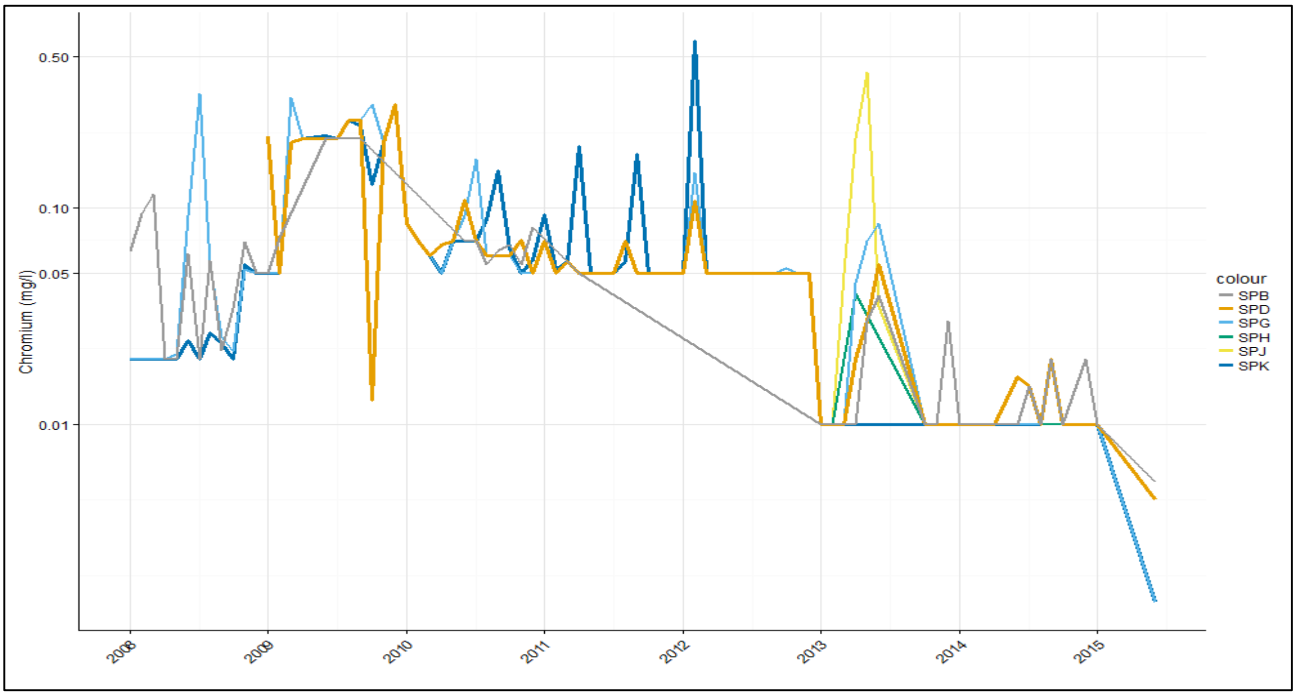


Figure 49: Vaalbankspruit monitoring data time series plot of Chromium concentrations (sampling point SPK and SPD are presented as thicker lines)

7.2.5 Molybdenum

Very little data is available and time series cannot be determined.

7.2.6 Fluoride

The monthly mean fluoride concentrations of the main sampling points in the Vaalbankspruit is graphed in Figure 50. The graph indicates that the detection limits before 2013 were 0.5mg/l which was too high to properly distinguish results form background analysis. After 2013 however the detection limits have improved and data can be used better to evaluate the Fluoride conditions. A box plot of the difference between the sampling points and the upstream sampling point at SPK after 2013 is presented in Figure 51. Although monthly fluctuation are observed a mean increase of 0.99mg/l fluoride is observed at SPD as compared to SPK. At SPB only a few samples were recorded above the DWS guide value.

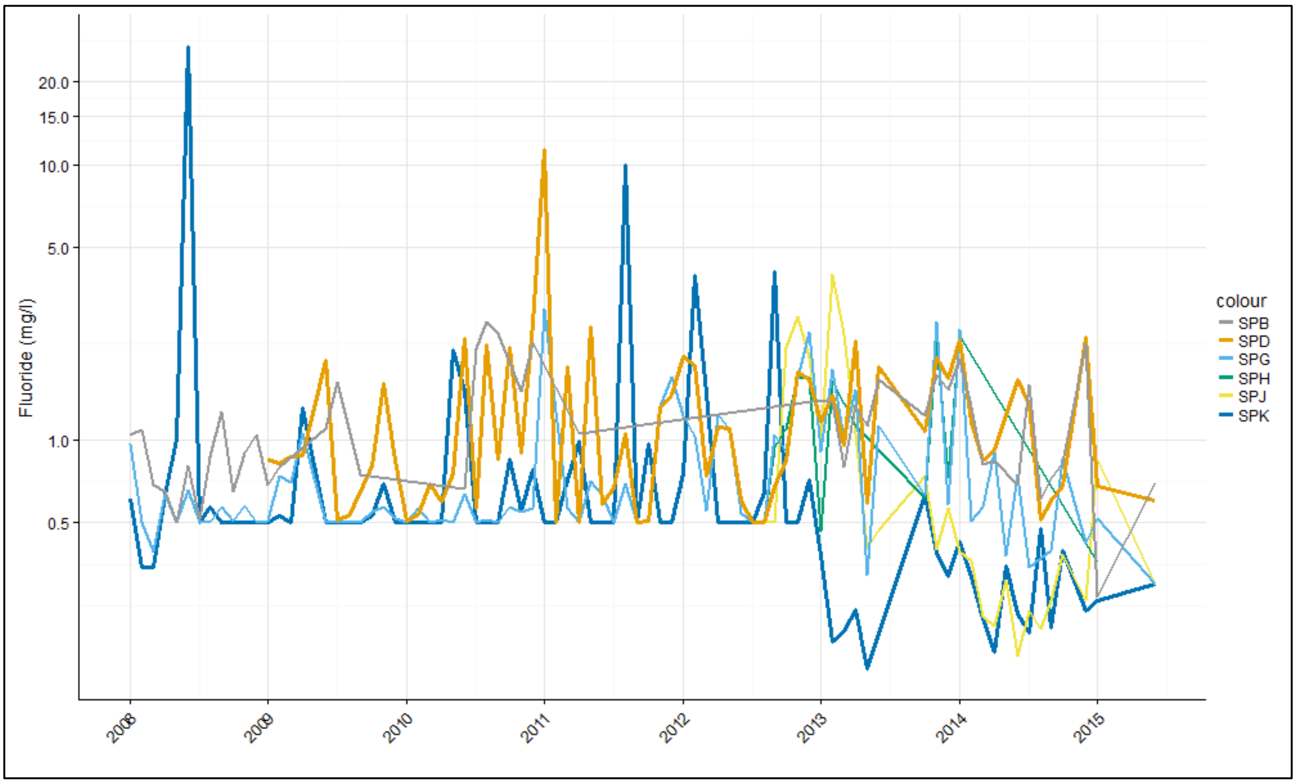


Figure 50: Vaalbankspruit monitoring data time series plot of Fluoride concentrations (sampling point SPK and SPD are presented as thicker lines)

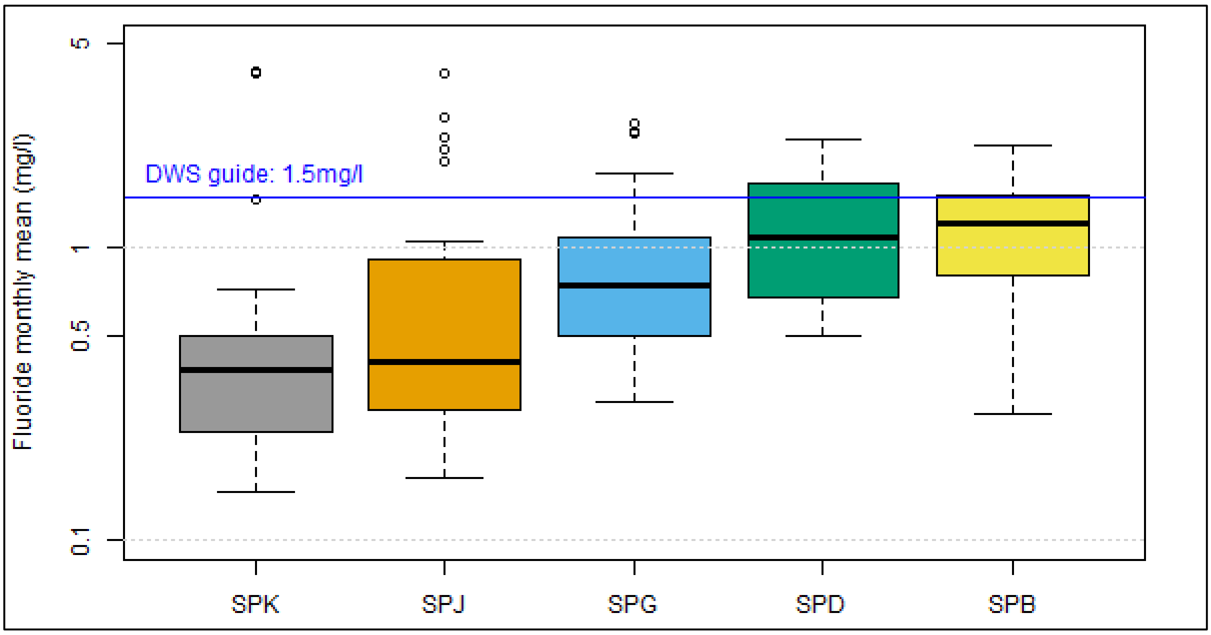


Figure 51: Vaalbankspruit monitoring data box plot of Fluoride concentration since 2012

7.3 Whole Effluent Toxicity Test

The focus of the Whole Effluent Toxicity Test (WET) was on the receiving environment that comprises the aquatic ecosystems in the Vaalbankspruit. The detailed analytical report of the WET test is included in Appendix B.

The test organisms included the following:

- *Vibrio fischeri* (bacteria) bioluminescent screening;
- *Selenastrum capricornutum* (algae) growth inhibition screening;
- *Daphnia pulex* (water flea) acute toxicity screening; and
- *Poecilia reticulata* (guppy) acute toxicity screening.

Various types of toxicity classification systems have been developed by scientists in different countries to be able to assign a hazard score to polluted environments (Persoone *et al.* 2003). Using a hazard classification system developed by Persoone *et al.* (2003) one can classify sites using the toxicity data of the non-diluted samples. The percentage effect of toxicity (PE) (Mortality or inhibition of growth, luminescence, reproduction or feeding) is used to rank the water sample into one of five classes (Table 13) based on the highest toxic response shown in at least one of the tests applied (Persoone *et al.* 2003).

Table 13: Acute Hazard Classification system for natural waters (Persoone et al. 2003)

	Class	Hazard	Percentage Effect
	I	No acute hazard	None of the tests show a toxic effect (i.e. an effect value that is significantly higher than that in the controls).
	II	Slight acute hazard.	A statistically significant PE is reached in at least one test, but the effect level is below 50%.
	III	Acute hazard.	The 50% Percentage Effect (PE50) is reached or exceeded in at least one test, but the effect level is below 100%.
	IV	High acute hazard, tolerant taxa present.	The PE100 is exceeded in at least one test.
	V	Very high acute hazard.	The PE100 is exceeded in all tests.

From the screening and undiluted definitive results, the samples were classified as follows:

- SPK, SPL, SPJ, SPG, SPB and SPD were classified as having a slight acute hazard due to at least one of the environmental bioassay results exceeding the statistically significant percentage effect (PE) with the indicator organisms (Table 14);
  - SPL, SPJ, SPG and SPB reached or exceeded the PE of 10% for *D. pulex;*
  - SPK exceeded the PE (10% mortality) for both *D. pulex* and *P. reticulate*;
  - SPD exceeded the PE of 20% inhibition for *V. fischeri* as well as the PE (10% mortality) for *D. pulex*;
- SD9 was classified as having an acute hazard (Table 14) due to the 50% percentage effect being reached in the *D. pulex* bioassay exposure;
  - SD9 expressed algal stimulation <20% and therefore not significantly different from the control;
- The Containment Facilities (Dam 4B, Dam 4A, Dam 3B, Dam 3A and Pond 6B) were all classed as having a high acute hazard (Table 14) due to the percentage effect of 100% being reached in at least one test;
  - All these samples reached 100% mortality in the *P. reticulata* bioassay;
  - The *D. pulex* bioassay additionally indicated 100% mortality in the Dam 4B, Dam 4A and Pond 6B;

- Pond 6B indicated 70% inhibition with the *S. capricornutum*;
- These samples reached or exceeded 20% stimulation with the *S. capricornutum* and therefore there is a potential for algal blooms to occur at these sites or at sites exposed to these samples.

From the bioassay results, the toxicity indicated that the samples collected from the SD9, Dam 4B, Dam 4A, Dam 3B, Dam 3A and Pond 6B have the potential to result in acute effects in the aquatic environment and therefore impact the ecological integrity. The pH of samples should fall within 6-9 in order to limit the effect of pH on the expressed toxicity; pH values outside of this range can drive the expressed toxicity from a physiological point of view as well as by the availability of dissolved ions. Three of the samples Dam 4B, Dam 4A and Pond 6B exceeded this range with pH's greater than 9.00 and this could have an effect on the results. To reduce the acute toxicity effects to below 50% mortality in all the test Dam4 requires a 5.3 times dilution of the water, Dam3 requires a 1.7 times dilution and Pond6A a 6.7 times dilution. Algal blooms could be a controlling factor in the chemistry of nitrates in these facilities which is indicated to be correlated to pH to some extent.

The samples collected from the SPK, SPL, SPJ, SPG, SPB and SPD sites do not currently pose an acute effect towards the aquatic environment, however, long term changes may be seen in the invertebrate composition at impacted sites exposed to these samples which includes the upstream sample at SPK. This effect on the invertebrates is potential from upstream pesticide sources.

Table 14: Hazard Classification of Samples collected from MFC in May 2015

	Hazard Class	Percentage Effect
SPK	II	10% mortality was exceeded in the *D. pulex* and *P. reticulata* bioassays
SPL	II	10% mortality was reached by the *D. pulex* bioassay
SPJ	II	10% mortality was reached by the *D. pulex* bioassay
SPG	II	10% mortality was reached by the *D. pulex* bioassay
SPB	II	10% mortality was reached by the *D. pulex* bioassay
SPD	II	20% inhibition of *S. capricornutum* and 10% mortality by the *D. pulex* bioassay
SD9	III	50% mortality was reached by the *D. pulex* bioassay
DAM 4B	IV	100% PE reached by *D. pulex* and *P. reticulate* bioassays
DAM 4A	IV	100% PE reached by *D. pulex* and *P. reticulate* bioassays
DAM 3B	IV	100% PE reached by *P. reticulate* bioassay
DAM 3A	IV	100% PE reached by *P. reticulate* bioassay
POND 6B	IV	100% PE reached by *D. pulex* and *P. reticulate* bioassays

8.0 UPDATED CONCEPTUAL SITE MODEL

An updated CSM was developed for MFC based on the current understanding of the site and the evaluation of new analytical data. Figure 52 show the updated understanding of the MFC facility, indicating the source areas, release mechanisms towards the pathways as well as the receptors.

The waste facilities were divided into East and West facilities, with the West facilities including Facilities 7, 8 and 9 which is located on the western side of the Vaalbankspruit. The rest of the facilities, including the Infiltration Gallery forms part of the East facilities (eastern side of Vaalbankspruit). This separation is based on the difference in the chemical fingerprint of the waste and sediments from the different facilities. Facilities 7 – 9 had significant higher SO_4 concentrations than the other facilities. From the ESI assessment it is also clear that Facility 9 (RWD) have a significant impact on groundwater quality.

Two cross sections of the Site were compiled to illustrate the current understanding of movement of contaminants. Data evaluation indicated different mechanisms of contaminant movement in the northern (north of the Infiltration Gallery; Figure 53) and southern (including Containment Facilities and Infiltration Gallery; Figure 54) parts of the Site. Both these cross sections are in a NW to SE direction.

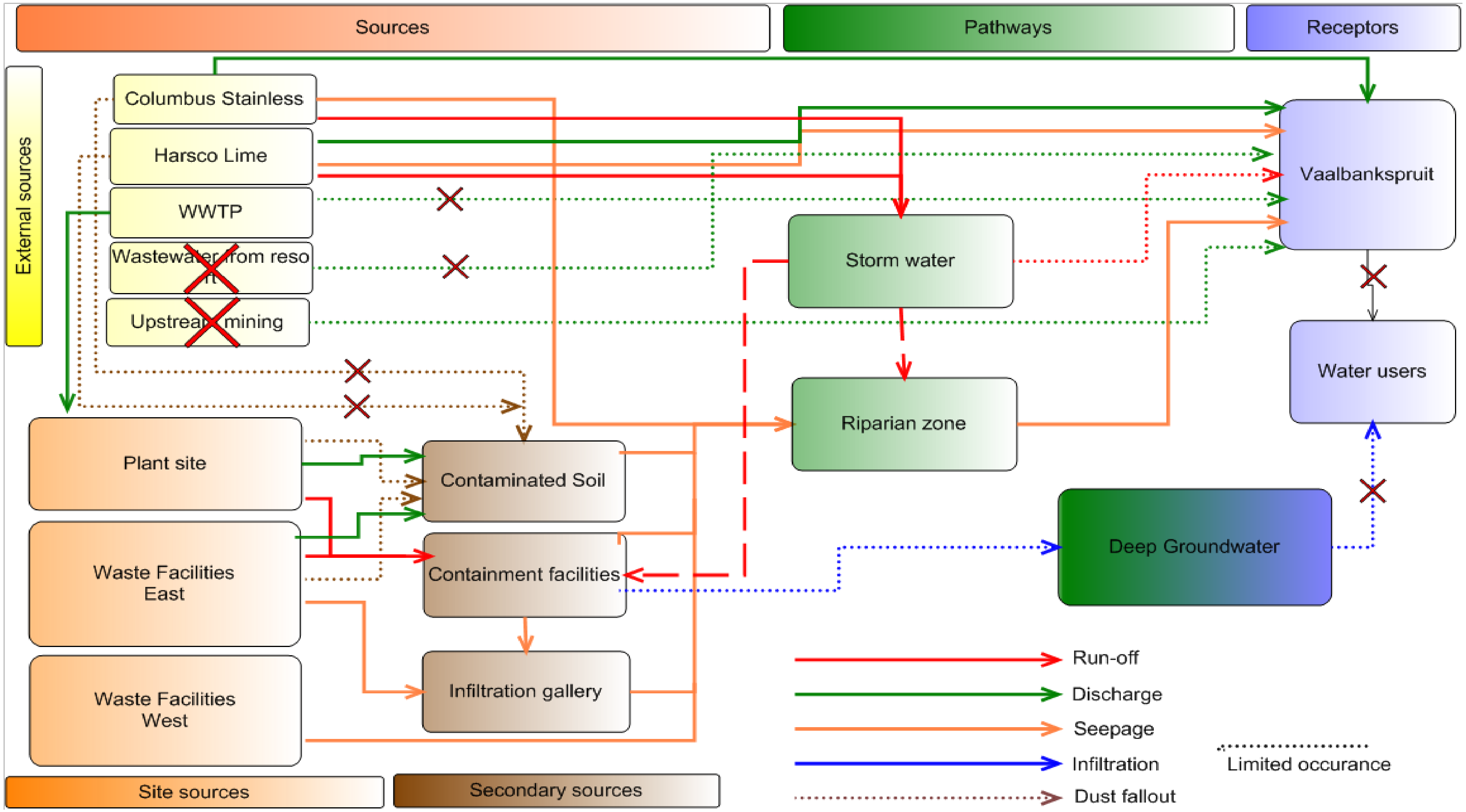


Figure 52: Updated CSM

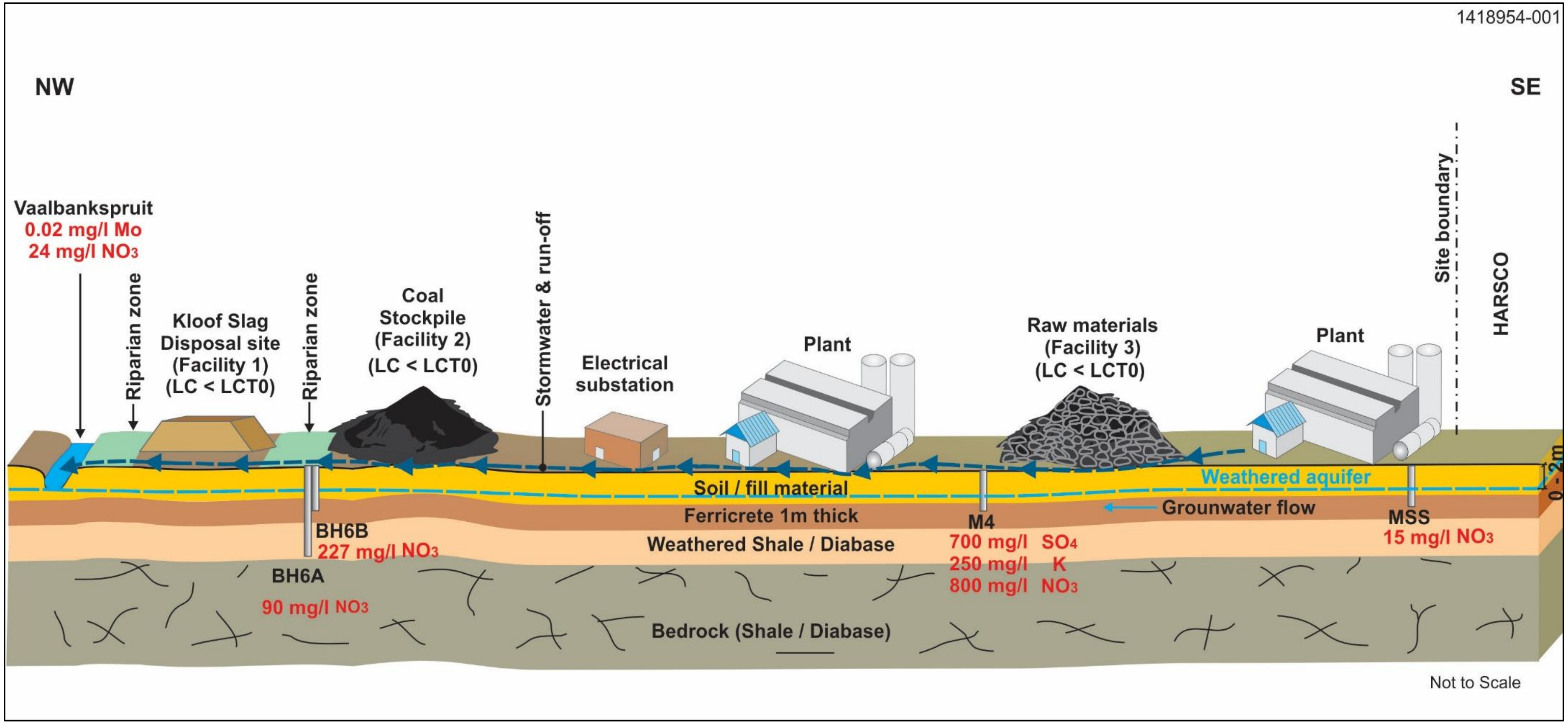


Figure 53: MFC Cross section: Northern portion

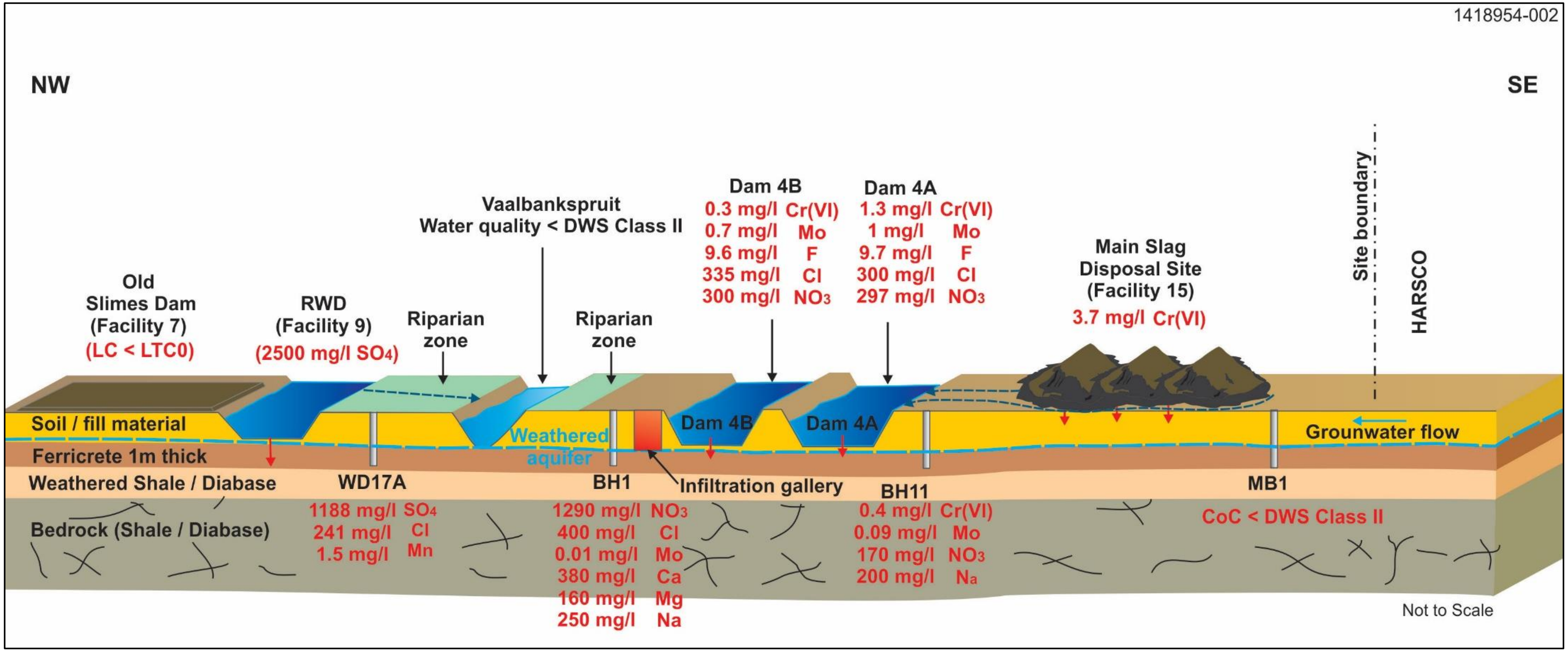


Figure 54: MFC Cross section: Southern portion

8.1 Northern cross section

The waste facilities in the northern part of the plant have low concentrations of all CoCs (< LCT0), indicating insignificant contribution of contaminants to groundwater (Figure 53). Box plots of the containment facilities, boreholes and sampling points in the Vaalbankspruit (Figure 55 to Figure 59) indicate borehole M4, Dam3 and Pond6 as the main potential sources of constituents of concern.

Melt Shop South (MSS) which is upstream of MFC operations, contain 15 mg/l NO_3. This concentration increases to 800 mg/l in M4 (next to Facility 3 and Facility 4) and decrease to 227 mg/l in BH6B (next to Facility 2). Borehole M4 also had elevated K and SO_4 concentrations, but these decreased to acceptable levels in BH6B.

Since the waste materials do not have sufficiently high concentrations to significantly raise groundwater concentrations, it is assumed that contaminated storm water and run-off from the Plant areas contribute to the contaminant load to groundwater. Furthermore, the SPD and SPB monitoring points in the Vaalbankspruit have higher concentrations than the upstream monitoring points (SPG), indicating contribution from the Site (See section 7.2).

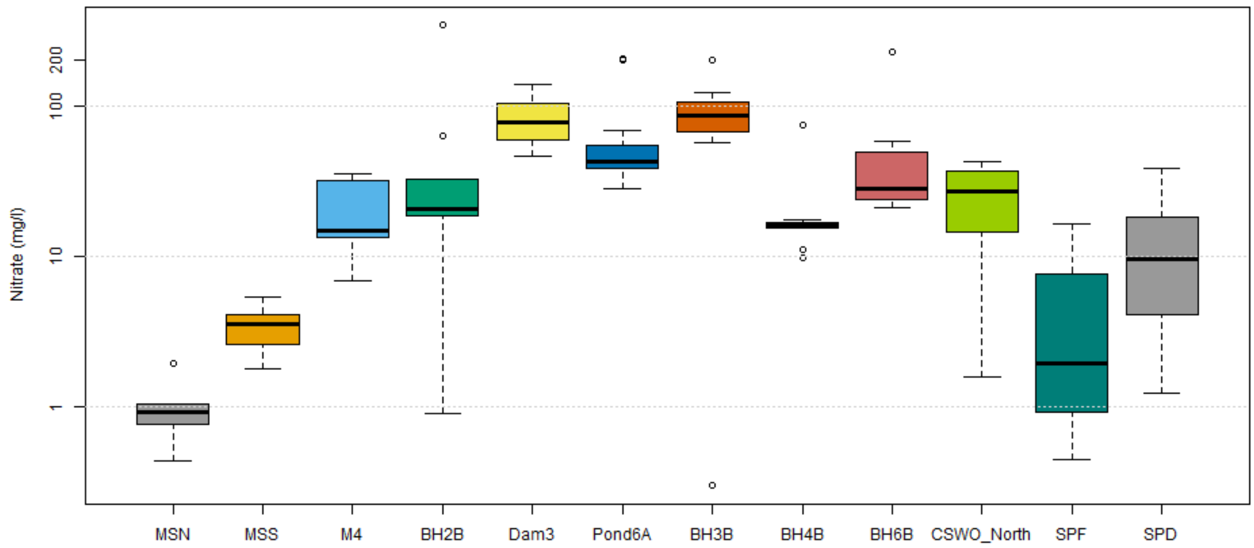


Figure 55: Boxplot of Nitrate concentration data from 2012 for sampling points along an east west transect towards the north of the site

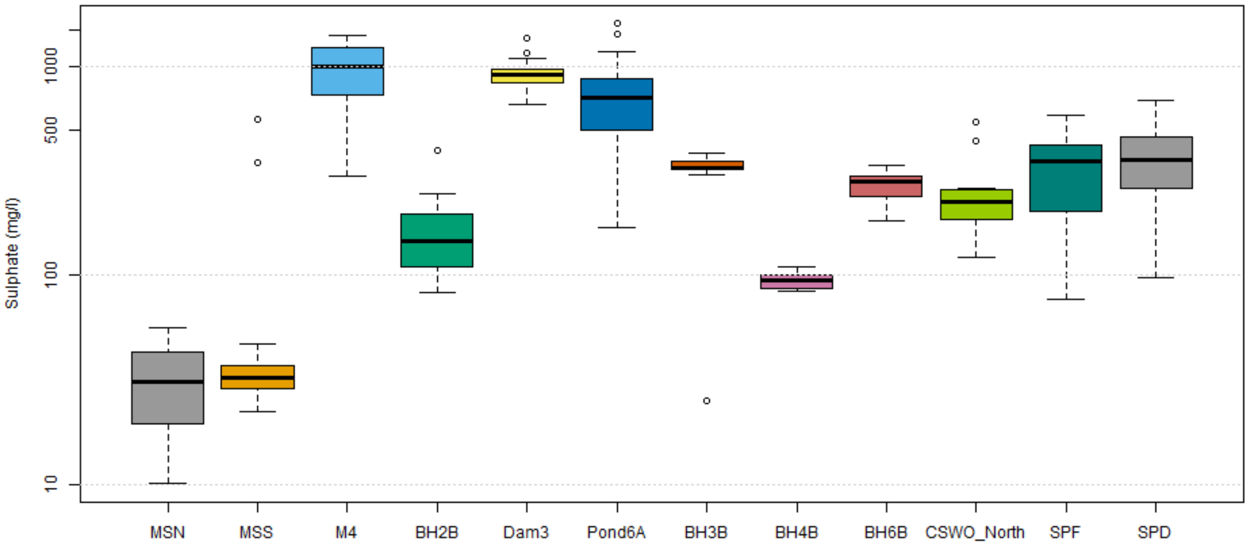


Figure 56: Boxplot of Sulphate concentration data from 2012 for sampling points along an east west transect towards the north of the site

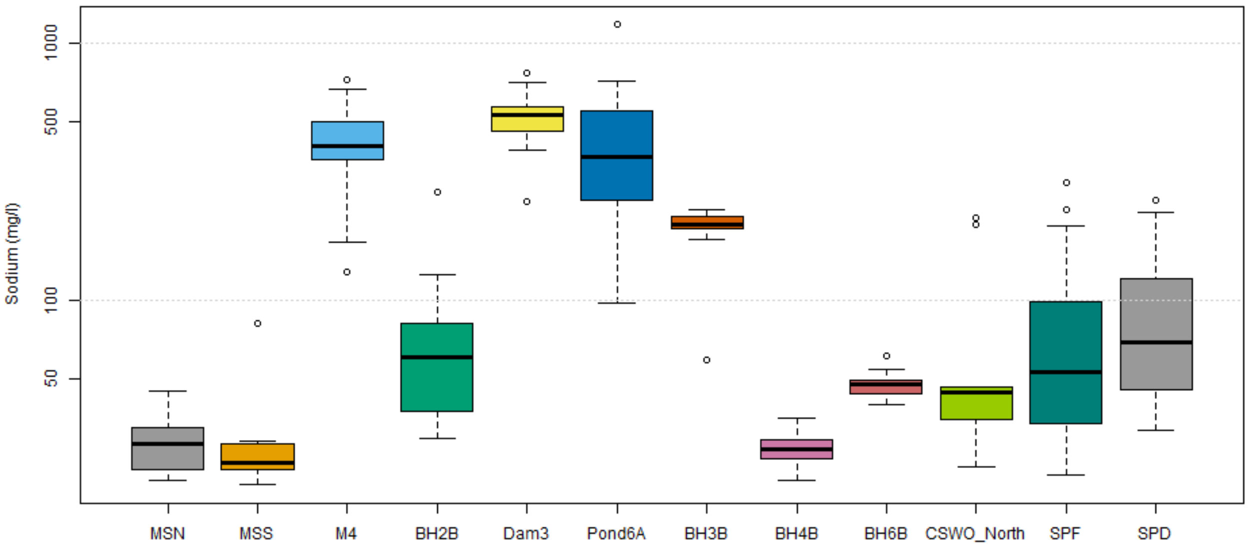


Figure 57: Boxplot of Sodium concentration data from 2012 for sampling points along an east west transect towards the north of the site

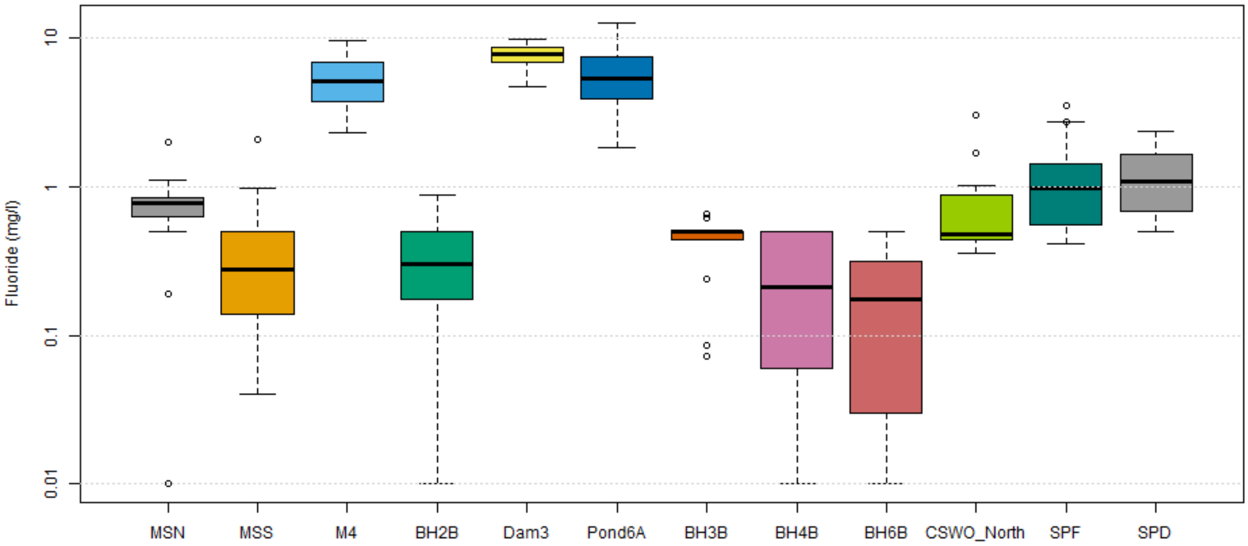


Figure 58: Boxplot of Fluoride concentration data from 2012 for sampling points along an east west transect towards the north of the site

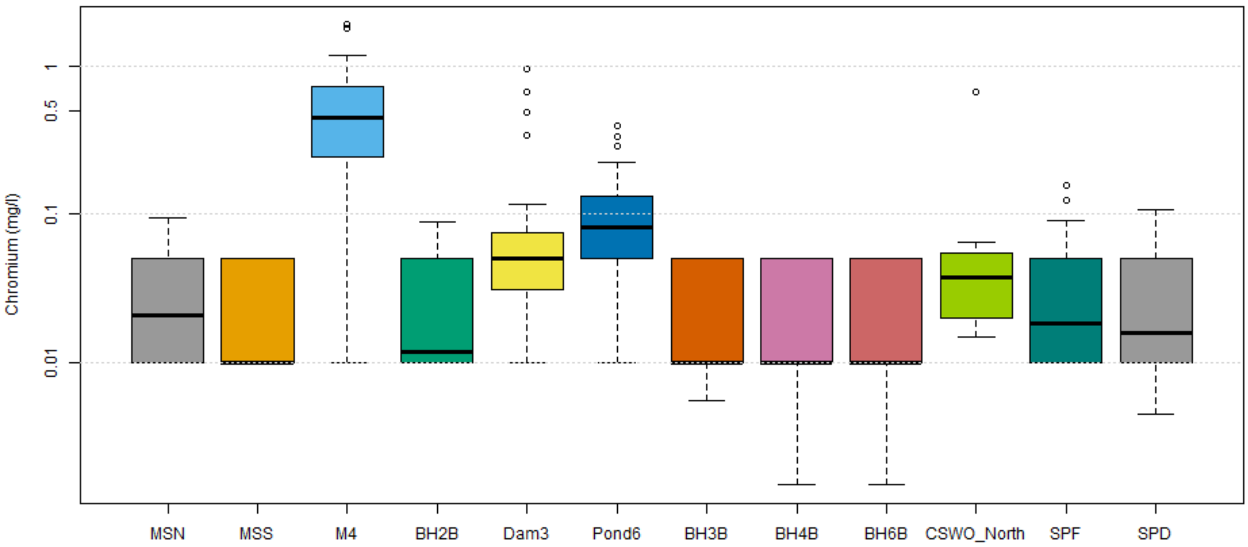


Figure 59: Boxplot of Chromium concentration data from 2012 for sampling points along an east west transect towards the north of the site

8.2 Southern cross section

The cross section of the southern section of the Site (Figure 54) and box plots of the containment facilities, boreholes and sampling points in the Vaalbankspruit point to the Containment Facilities (Dam 4A & 4B) being the highest potential source. Waste in Facility 15 and Facility 9 also could contribute to the Cr(VI) and SO_4 load respectively.

The quality of groundwater in borehole MB1 (between Harsco and MFC, upslope of Facility 15) are acceptable, with the concentrations of all CoCs < DWS drinking water standards. BH11 is impacted by site operations and the concentrations of Cr(VI), Mo, NO_3 and Na exceeds the DWS Class II standards.

The groundwater deteriorates towards BH1, with significant increases in NO_3, Cl, Ca and Mg concentrations. This indicates the contribution of Dam 4A, Dam 4B towards concentrations in the Infiltration Gallery.

The RWD (Facility 9) contribute to the SO_4 load of the groundwater on the western side of the Vaalbankspruit, as illustrated by the water quality in WD17A (Section 5.4.2).

The water quality in the Vaalbankspruit in the southern section of the Site is below DWS Class II and lower than concentrations at SPD (Section 7.2).

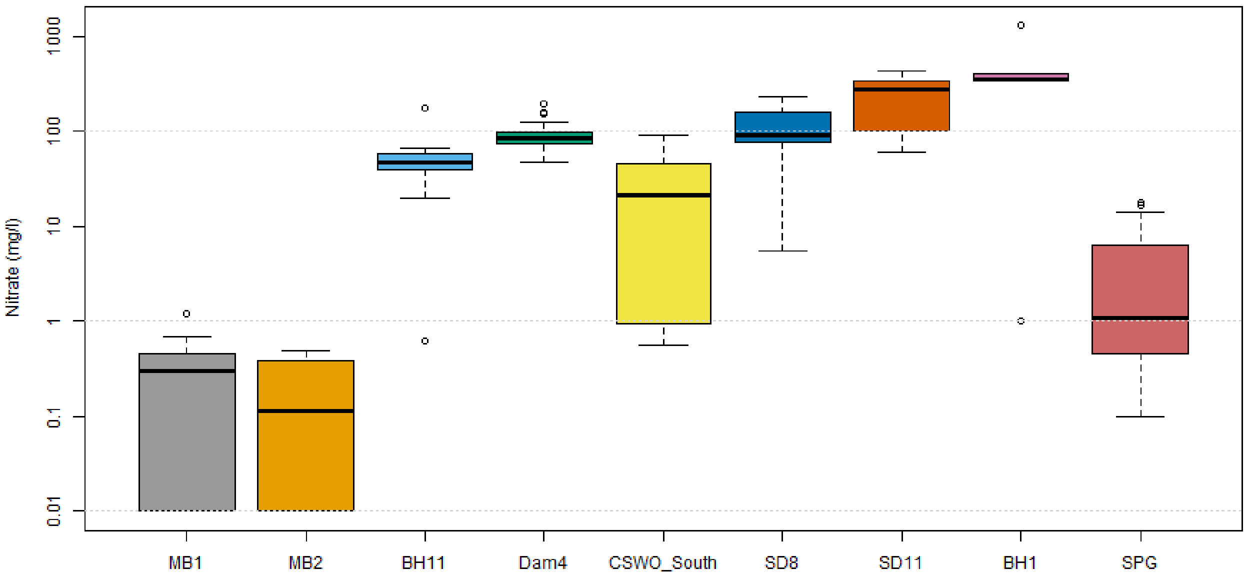


Figure 60: Boxplot of Nitrate concentration data from 2012 for sampling points along an east west transect towards the south of the site

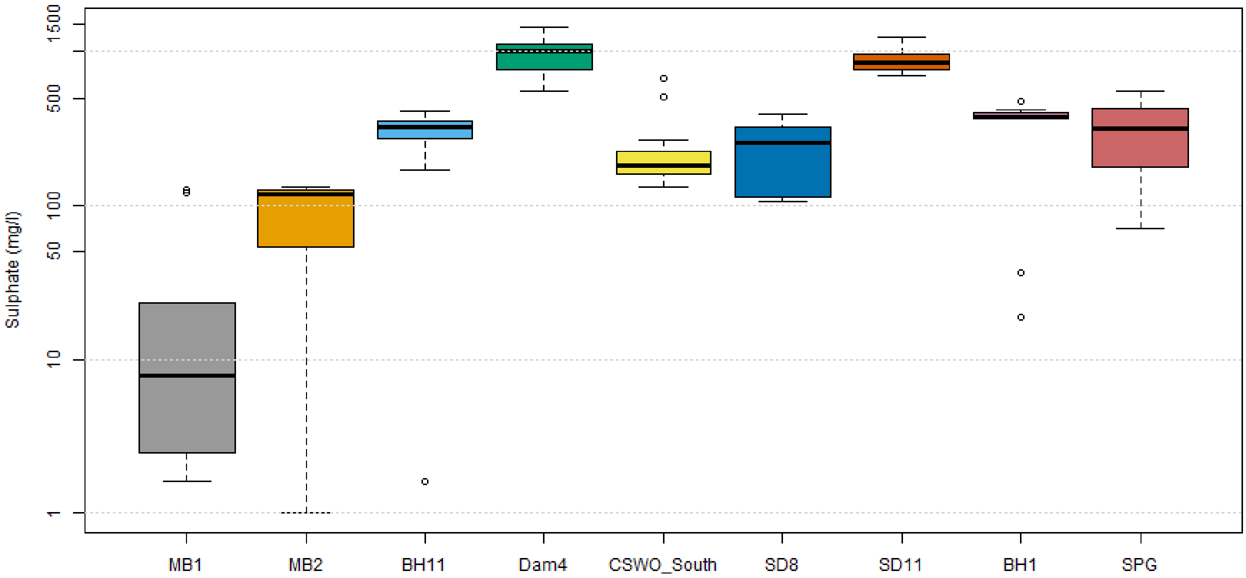


Figure 61: Boxplot of Sulphate concentration data from 2012 for sampling points along an east west transect towards the south of the site

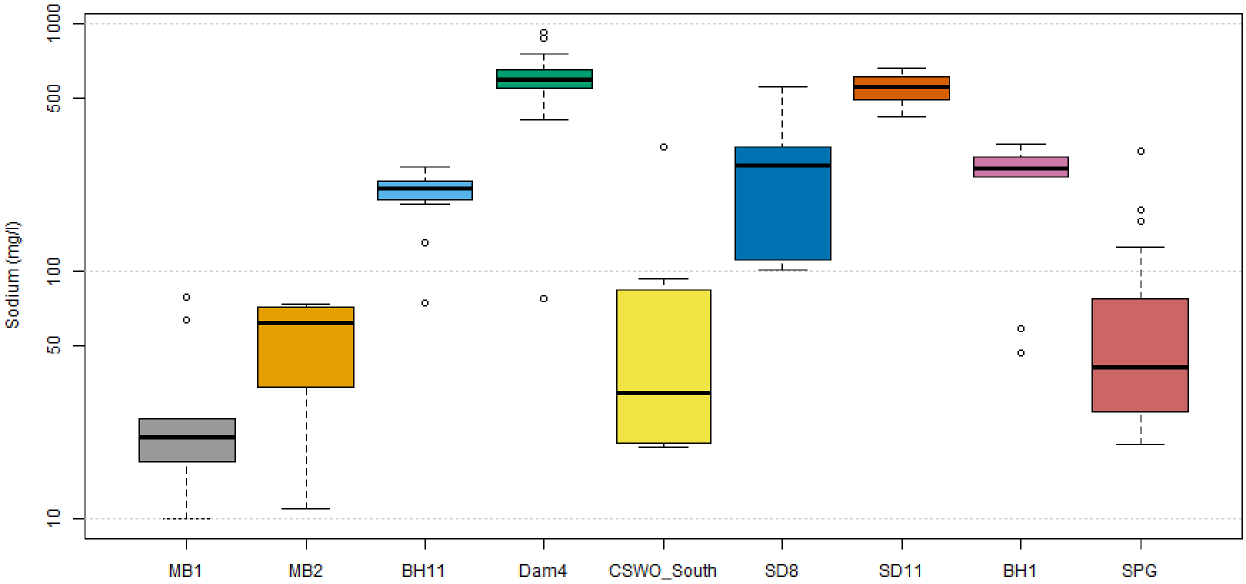


Figure 62: Boxplot of Sodium concentration data from 2012 for sampling points along an east west transect towards the south of the site

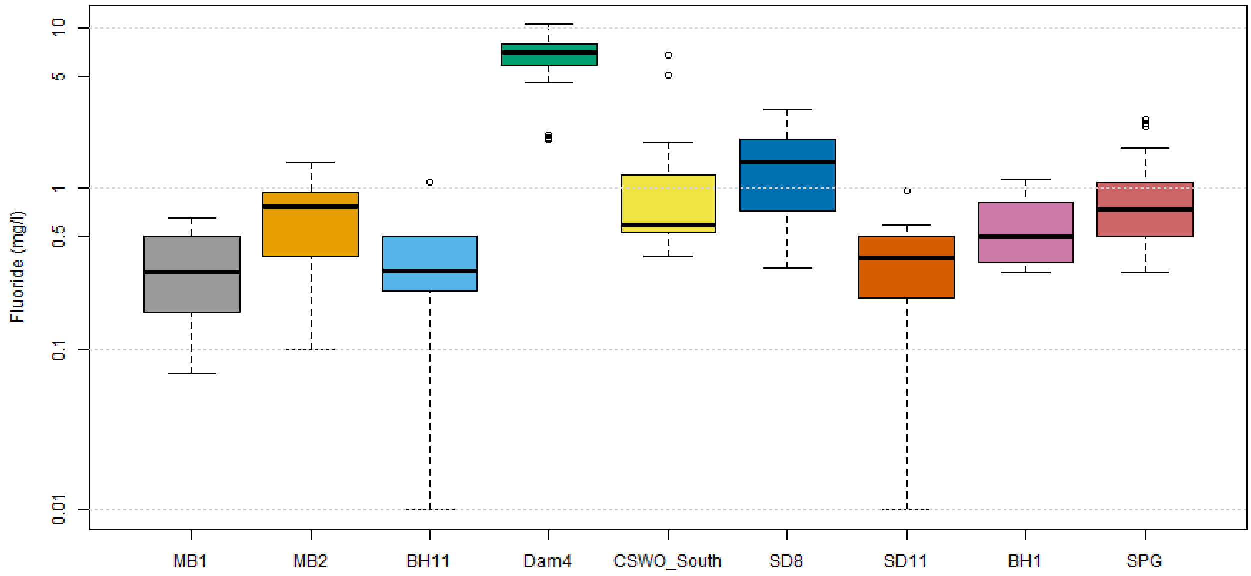


Figure 63: Boxplot of Fluoride concentration data from 2012 for sampling points along an east west transect towards the south of the site

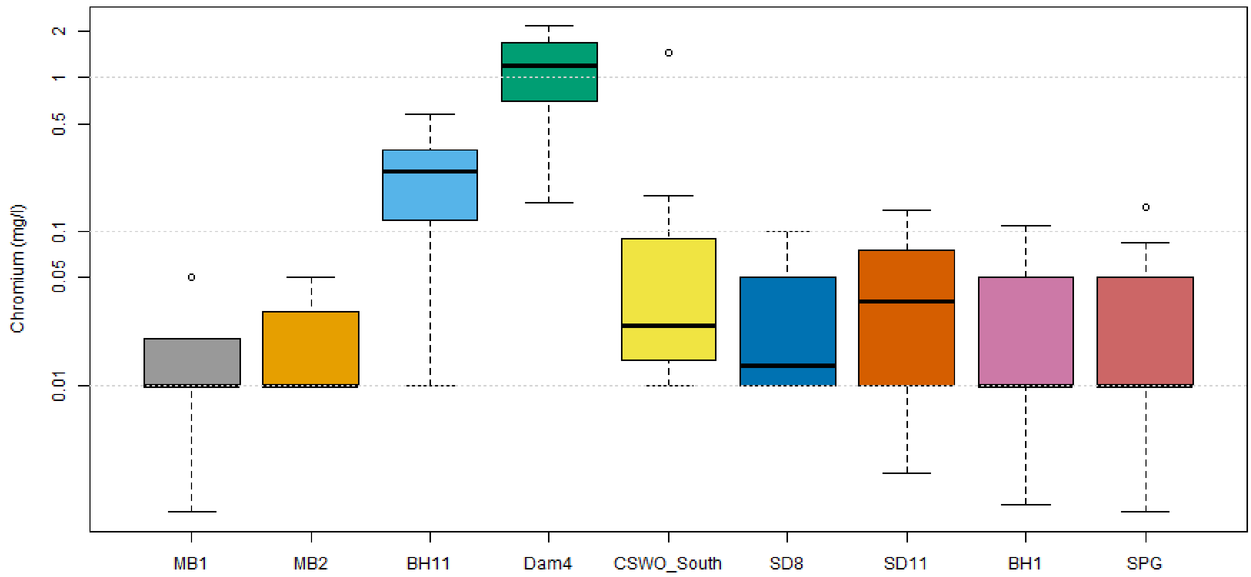


Figure 64: Boxplot of Chromium concentration data from 2012 for sampling points along an east west transect towards the south of the site

9.0 CONCLUSION

The main constituents identified in the study indicating potential increase in the Vaalbankspruit are NO_3, SO_4, Na, F and Mo. The NO_3 and Mo concentration at sampling points SPB and SPD in the Vaalbankspruit exceeded the DWS Drinking water standards for sampling conducted in this study. Monitoring data since 2012 indicate that the median concentration of all the constituents are below the DWS guide. However, approximately 30% of mean monthly data for NO_3, SO_4 and F are above the DWS guide values. Due to lack of monitoring data Mo could not be assessed.

The samples collected from the SPK, SPL, SPJ, SPG, SPB and SPD sites do not currently pose an acute effect towards the aquatic environment. However, long term changes may be seen in the invertebrate composition but this includes the upstream sample at SPK. This effect on the invertebrates is potential due to upstream pesticide sources and not related to the site activities.

The highest on site concentrations of the constituents indicated occur in the Ponds and Dams. Waste Facility 15 also has high concentrations and potential could contribute as source. The infiltration gallery would limit the impact from the facilities but some further consideration of the contribution of Pond 6A which is not contained by the gallery is required.

Groundwater flow is indicated to be directly towards the Vaalbankspruit across the site. Monitoring boreholes downslope of the infiltration gallery indicate a similar constituent composition to the water in the containment facilities. The isotope study indicates that approximately 50% of the water in these downslope monitoring boreholes potentially originate from the containment facilities.

Limited upstream groundwater impacts are indicated from the data. However, a highly variable surface water contribution is indicated from other industrial areas.

As compared to the concentrations of the onsite water quality approximately a 10 fold dilution is observed in the Vaalbankspruit water quality. Toxicity assessment indicates that the highest dilution required to limit toxicity effects would be around 6 times dilution. This is also confirmed by the toxicity test in the Vaalbankspruit indicating no acute toxicity.

GOLDER ASSOCIATES AFRICA (PTY) LTD.

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CS/EH/ck

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APPENDIX A

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GOLDER ASSOCIATES AFRICA (PTY) LTD

APPENDIX B

Data Report

TECHNICAL MEMORANDUM

DATE 18 April 2016 **PROJECT No.** 1418954_Mem001_MFC Data Report

TO L Ehlers / V Mposi
Middelburg Ferrochrome

CC

FROM C Steyn **EMAIL** csteyn@golder.co.za

MFC GEOHYDROLOGICAL STUDY: DATA REPORT

1.0 INTRODUCTION

Samancor Chrome – Middelburg Ferrochrome (MFC) appointed Golder Associates Africa (Golder) to update the existing geohydrological understanding at their Ferrochrome operation in Middelburg, Mpumalanga. As part of this study data was provided by MFC. The objective of this memo is to describe how the raw data was manipulated to obtain a tidy data set that can easily be shared, computed on, and analysed. A secondary objective is to provide a code book describing the variables and their values in the tidy data set.

2.0 PRINCIPLES OF A TIDY DATA SET

The four general principles of a tidy data set are:

- Each variable you measure should be in one column;
- Each different observation of that variable should be in a different row;
- There should be one table for each “kind” of variable;
- If you have multiple tables, they should include a column in the table that allows them to be linked.

A few other things that make a data set much easier to handle:

- Include a row at the top of each data table/spreadsheet that contains full row names;
- If sharing in Excel, the tidy data should be in one Excel file per table:
  - No multiple worksheets;
  - No macros applied to the data; and
  - No columns/cells should be highlighted.
- Have a code book that contains:
  - Information about the variables (including units) in the data set not contained in the tidy data;
  - Information about the summary choices made;

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- Information about the study or monitoring design; and
- Sampling location numbers for consistency.

- The steps of data cleaning conducted should be very clear.

Exploring the data to ensure consistency and realistic values is important before data evaluation commences. In this study histograms, time series plot and box plots were used to consider the data. In the report only the box plots are presented but the other plots will be provided. The box-and-whisker plot (box plot, for short) is an exploratory graphic used to show the distribution of a dataset.

The box shows the interquartile range that contains values between 25th and 75th percentile. The line inside the box show the median. The two "whiskers" show adjacent values. The upper adjacent value (upper mark) is the value of the largest observation that is less than or equal to the upper quartile plus 1.5 the length of the interquartile range. Analogously the lower adjacent value (lower mark) is the value of the smallest observation that is greater than or equal to the lower quartile less 1.5 times the length of interquartile range. Outliers are observations outside lower-upper mark range.

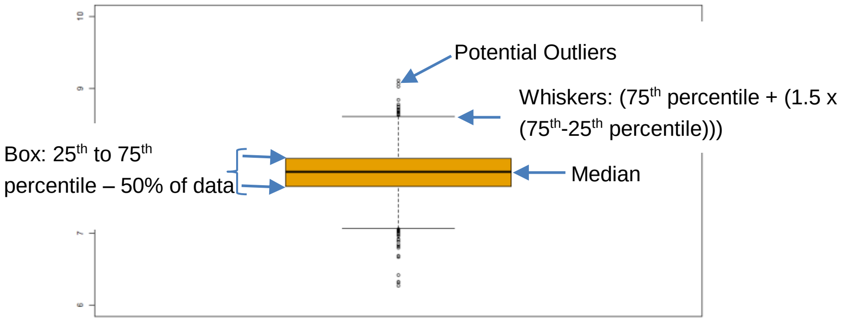

Figure 1: Graphic of values in a box plot.

3.0 DATA RECEIVED

In January 2016 the water monitoring results were obtained in the following excel file: "*Complete Consolidated Water Results.xlsx*". This file contained data from 2008 to 2015 in tabs labelled Borehole 20xx, Dam 20xx, Spruit 20xx and Pond 20xx. A screen clip of a section of the tabs are is presented in Figure 2.

Figure 2: Data tabs in excel file "Complete Consolidated Water Results.xlsx"

4.0 EXCEL MANIPULATION OF DATA

Each tab in the excel file was saved under a separate file as a CSV file. The CSV files were labelled according to the original tab data type and date, as indicated above. The following manipulation of the data was conducted in excel:

- All blank columns were deleted.
- Merged cells were unmerged and the column title copied to all the newly created cells.
- In most files observation were in columns and variables in rows. In the tabs Borehole 2009 to Borehole 2012 files observations for each location and date was presented in the rows and the variables in columns. Separate titles for each location was supplied. This data was transposed into a new excel sheet, average calculations deleted and variables aligned as these were not consistent.
- Looking at the data it was observed by looking at the conductivity and pH data, as well as the date cell that some complete record sets were shifted one cell down. The entire records were shifted down.

- In manipulating the data and exploring the data individual records were also observed to be shifted and not aligned with the rest of the data record set. These individual records were shifted to align to the rest of the record set.
- Some unlabelled columns and rows were deleted.

5.0 FURTHER DATA TIDYING USING R

All further data manipulation and analysis was conducted in “R”. “R” is an open source programming language and software environment for statistical computing and graphics. The following data manipulation was conducted:

- The data was transposed so that columns are variables and rows are observations.
- The column names (variable names) were made consistent across all the files.
- The sample location names were made consistent across all the files.
- The denotation of below detection limits of the “<” sign was removed leaving the detection limit as a numerical value to include into analysis. Therefore, below detection values are recorded as the detection value and not zero.
- Any columns without data was removed.
- Some histograms, box plots and time series data was plotted to explore the data to see if in general the data follow expectation.
- The following variables were explored in the data tidying process: "ID", "Date", "Conductivity", "pH", "Calcium", "Chloride", "Magnesium", "Potassium", "Nitrate", "Ammonia", "Sodium", "Sulphate", "Chromium", "Hexavalent.Chromium", "Fluoride", "Iron", "Manganese". Other Variables were not considered and should be evaluated before using.
- The files from a specific data group, i.e. Borehole, Dam, Pond, Spruit for the different years were combined. The combined files were written to an excel files labelled:
  - PondAll2008to2015.xlsx
  - BoreholeAll2008to2015.xlsx
  - SpruitAll2008to2015.xlsx
  - DamAll2008to2015.xlsx

6.0 CODE BOOK

The following section describes the structure of the four excel sheets and presents some of the exploration of the data.

6.1 PondAll2008to2015.xlsx

After creating consistency between the data related to ponds the data was stored in the file PondAll2008to2015.xlsx. The location IDs and the number of observations of each are presented in Table 1. The variables and their number of observations are presented in Table 2. The following adjustments were made to data in combining the files:

- All IDs labelled with only P4, P5, P6A or P6B was changed to read Pond4, Pond5, Pond6A, Pond6B.
- In the data collected by Golder in the current study. Two samples were collected and labelled as Pond4A and Pond4B. These were both changed to just read Pond4.
- The conductivity from the current study was adjusted to present it as mS/m as for the other data sets.
- Some adjustments of the variable names were made to be consistent between the files.

The box plots of some of the variables explored are presented in Figure 3 to Figure 5.

Table 1: Number of observations of location IDs in the PondAll2008to2015.xlsx file.

ID	Number of observations
CSWONorth	23
CSWOSouth	25
Pond4	125
Pond5	155
Pond6A	173
Pond6ASputterBox	2
Pond6B	161

Table 2: Number of observations of variables in the PondAll2008to2015.xlsx file.

Variable	Number of observations	Comments / Units
ID	664	ID of sampling locations
Date	664	Date of sampling
Total.Alkalinity	190	mg $CaCO_3$/ℓ
Bicarbonate.Alkalinity	187	mg $CaCO_3$/ℓ
Carbonate.Alkalinity	187	mg $CaCO_3$/ℓ
M.Alkalinity	187	mg $CaCO_3$/ℓ
P.Alkalinity	187	mg $CaCO_3$/ℓ
Conductivity	394	mS/m
pH	644	Unit less
Total.Hardness	187	mg $CaCO_3$/ℓ
Calcium.Hardness	187	mg $CaCO_3$/ℓ
Magnesium.Hardness	187	mg $CaCO_3$/ℓ
Total.Dissolved.Solids	407	mg/ℓ
Suspended.Solids	312	mg/ℓ
Temperature	187	ºC
Chemical.Oxygen.Demand	312	mg O_2/ℓ
Ammonia	190	mg N/ℓ
Calcium	664	mg Ca/ℓ
Chloride	190	mg Cl/ℓ
Magnesium	664	mg Mg/ℓ
Nitrate	648	mg N/ℓ
Ortho.Phosphate	190	mg P/ℓ
Potassium	298	mg K/ℓ
Sodium	655	mg Na/ℓ
Silicon	157	mg Si/ℓ
Sulphate	545	mg SO_4/ℓ

Variable	Number of observations	Comments / Units
Aluminium	248	mg Al/ℓ
Arsenic	190	mg As/ℓ
Barium	190	mg Ba/ℓ
Boron	187	mg B/ℓ
Cadmium	190	mg Cd/ℓ
Chromium	315	mg Cr/ℓ
Hexavalent.Chromium	659	mg Cr(VI)/ℓ
Cobalt	190	mg Co/ℓ
Copper	190	mg Cu/ℓ
Fluoride	651	mg F/ℓ
Iron	661	mg Fe/ℓ
Lead	190	mg Pb/ℓ
Manganese	315	mg Mn/ℓ
Mercury	190	mg Hg/ℓ
Nickel	190	mg Ni/ℓ
Phenol	187	mg Phenol/ℓ
Cyanide	163	mg CN/ℓ
Total.Kjeldahl.Nitrogen	179	mg N/ℓ
Total.Phosphorous	184	mg P/ℓ
Antimony	9	mg Sb/ℓ
Beryllium	8	mg Be/ℓ
Lithium	10	mg Li/ℓ
Molybdenum	9	mg Mo/ℓ
Selenium	13	mg Se/ℓ
Strontium	5	mg Sr/ℓ
Tin	5	mg Sn/ℓ
Vanadium	8	mg V/ℓ
Zinc	8	mg Zn/ℓ
Total.Organic.Carbon	33	mg C/ℓ
TOX	28	µg/ℓ
Langelier.Index	103	
pHs	99	
Sodium.Absorption.Ratio	104	
TDS.to.EC.Ratio	104	
Corrosion.Ratio	104	
Ryznar.Index	104	
Oxygen.Absorbed	25	mg O_2/ℓ

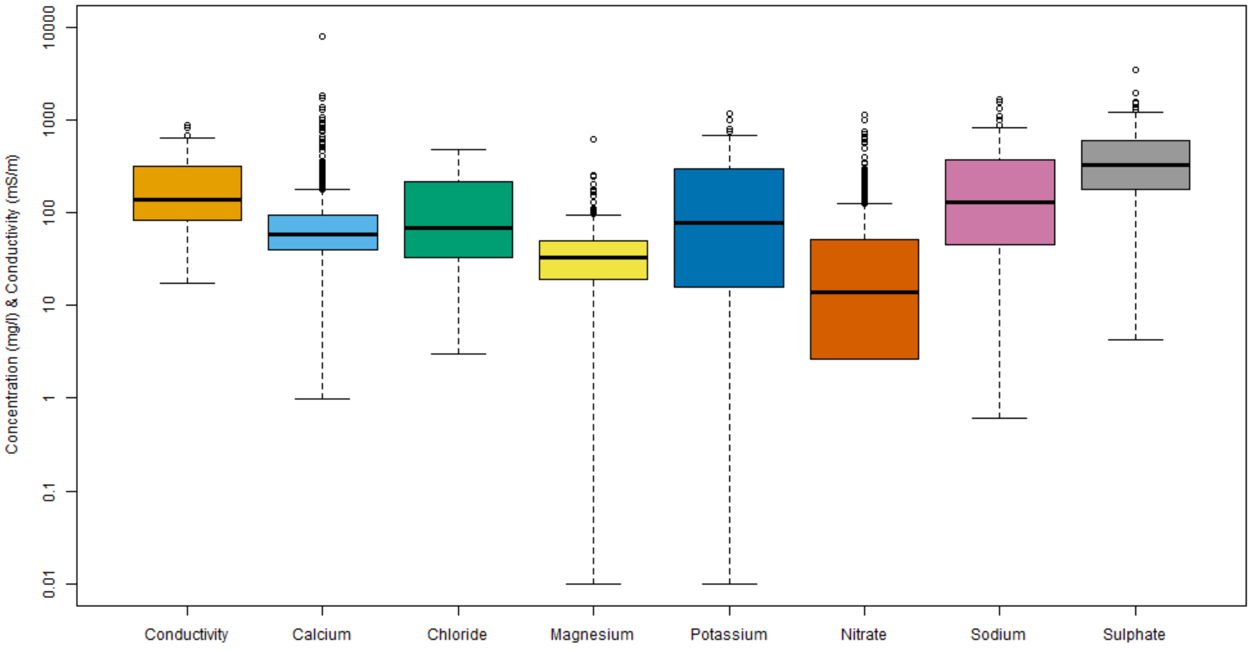

Figure 3: Box plots of Pond data for higher median constituents

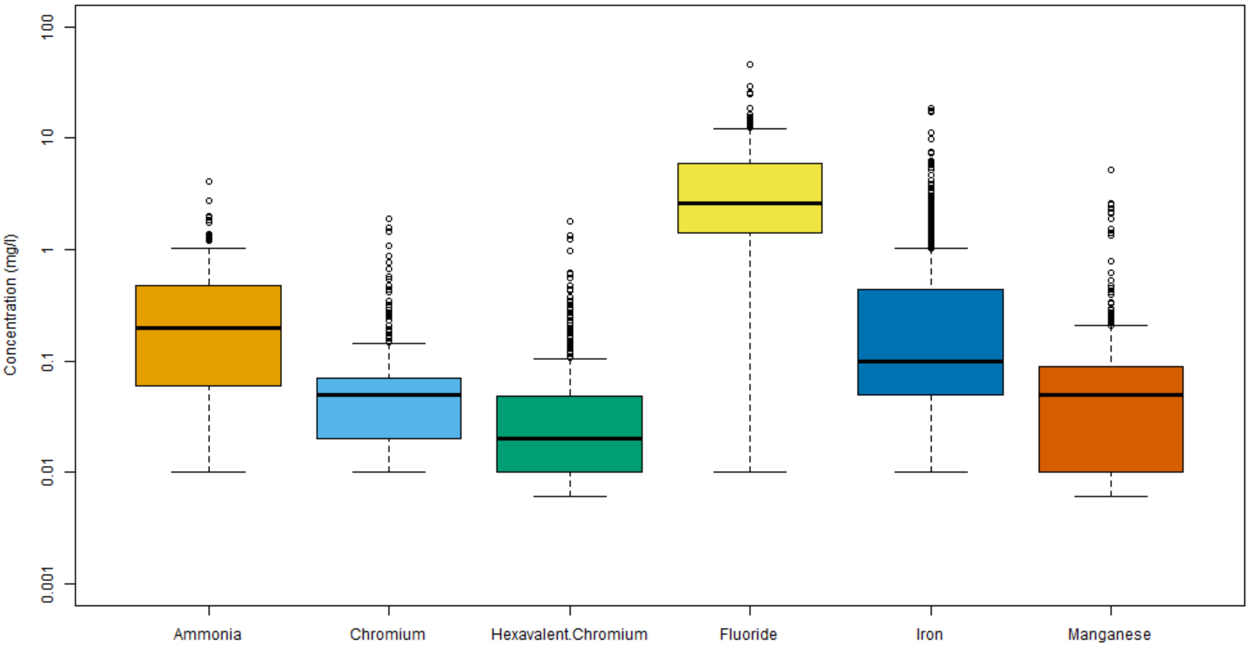

Figure 4: Box plots of Pond data for lower median constituents

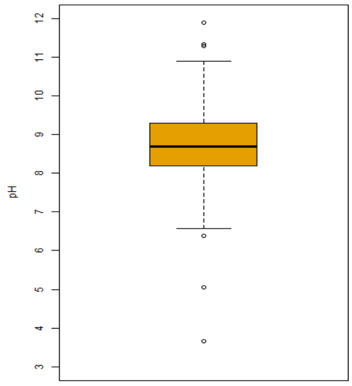

Figure 5: Box plots of Pond data for pH

6.2 BoreholeAll2008to2015.xlsx

After creating consistency between the data related to boreholes the data was stored in the file BoreholeAll2008to2015.xlsx. The location IDs and the number of observations of each are presented in Table 3. The variables and their number of observations are presented in Table 4. The following adjustments were made to data in combining the files:

- The IDs were adjusted by:
  - Removing prefixes: MFCBH_ and MFC_;
  - Adjusting Meltshop IDs: MeltshopNorth to MSN, MeltshopSouth to MSS;
  - Removing “-“;
  - After removing prefixes some IDs only had numbers. The prefix BH was added to number 1A, 2A, 2B, 3A, 3B, 4A, 4B, 5A, 5B, 6A, 6B, 7A, 7B, 8A, 8B, 9, 11;
  - IDs for M4, H1 and H2 were inconsistent and changed;
  - Adding B to IDs: Some boreholes with B suffix was omitted and a B was added to BH8, BH7 and BH2 that did not have any reference;
  - Adding A to references with WD11;
  - Removing extra zeros in SD / WD numbers: Some of the SD and WD numbers had were referenced as SD0x. This 0 was removed to be consistent between all IDs.
- The conductivity from the current study was adjusted to present it as mS/m as for the other data sets.
- Some adjustments of the variable names were made to be consistent between the files.
- Two Manganese values were presented in some records. The record considered to be the main value was labelled as Manganese and the second record as Total.Manganese.

The box plots of some of the variables explored are presented in Figure 6 to Figure 8.

Table 3: Number of observations of location IDs in the BoreholeAll2008to2015.xlsx file.

ID	Number of observations
BH1	10
BH11	22
BH2A	13
BH2B	20
BH3A	16

ID	Number of observations
BH3B	16
BH4A	16
BH4B	16
BH5A	15
BH5B	15
BH6A	18
BH6B	17
BH7A	21
BH7B	16
BH8A	21
BH8B	17
BH9	20
H1	45
H2	49
M4	21
MB1	9
MB2	8
MB3	8
MSN	44
MSS	53
MTC2	5
MTC3	5
MTC4	5
N3880	23
SD1	22
SD10	8
SD11	32
SD12	24
SD2	26
SD3	19
SD4	13
SD5	24
SD6	18
SD7	10
SD8	15
SD9	5
SP1	17
SP2	18
SP3	17
SP4	17

ID	Number of observations
WD1	23
WD10	23
WD11A	23
WD11B	13
WD12A	26
WD12B	17
WD13A	23
WD13B	25
WD14A	7
WD14B	11
WD15A	25
WD15B	23
WD16A	22
WD16B	22
WD17A	21
WD17B	20
WD18A	20
WD18B	20
WD19	35
WD2	23
WD20	31
WD21	30
WD22	10
WD23	47
WD24	50
WD25	48
WD3	23
WD4A	15
WD4B	21
WD4C	28
WD4D	21
WD5A	25
WD5B	19
WD5C	24
WD5D	21
WD6A	26
WD6B	20
WD6C	26
WD6D	24
WD7	25

ID	Number of observations
WD8	25
WD9	23

Table 4: Number of observations of variables in the BoreholeAll2008to2015.xlsx file.

Variable	Number of observations	Comments / Units
ID	1853	ID of sampling locations
Date	1852	Date of sampling
Total.Alkalinity	953	mg $CaCO_3$/ℓ
Bicarbonate.Alkalinity	925	mg $CaCO_3$/ℓ
Carbonate.Alkalinity	925	mg $CaCO_3$/ℓ
M.Alkalinity	925	mg $CaCO_3$/ℓ
P.Alkalinity	925	mg $CaCO_3$/ℓ
Conductivity	1522	mS/m
pH	1675	Unit less
Total.Hardness	986	mg $CaCO_3$/ℓ
Calcium.Hardness	986	mg $CaCO_3$/ℓ
Magnesium.Hardness	986	mg $CaCO_3$/ℓ
Total.Dissolved.Solids	1850	mg/ℓ
Suspended.Solids	1780	mg/ℓ
Temperature	1695	ºC
Chemical.Oxygen.Demand	1811	mg O_2/ℓ
Ammonia	1185	mg N/ℓ
Calcium	1838	mg Ca/ℓ
Chloride	1813	mg Cl/ℓ
Magnesium	1838	mg Mg/ℓ
Nitrate	1804	mg N/ℓ
Ortho.Phosphate	1014	mg P/ℓ
Potassium	1687	mg K/ℓ
Sodium	1837	mg Na/ℓ
Silicon	1116	mg Si/ℓ
Sulphate	1803	mg SO_4/ℓ
Aluminium	1225	mg Al/ℓ
Arsenic	1014	mg As/ℓ
Barium	1014	mg Ba/ℓ
Boron	986	mg B/ℓ
Cadmium	1014	mg Cd/ℓ
Chromium	1837	mg Cr/ℓ
Hexavalent.Chromium	1824	mg Cr(VI)/ℓ
Cobalt	1670	mg Co/ℓ

Variable	Number of observations	Comments / Units
Copper	1014	mg Cu/ℓ
Fluoride	1803	mg F/ℓ
Iron	1809	mg Fe/ℓ
Lead	1014	mg Pb/ℓ
Manganese	1838	mg Mn/ℓ
Mercury	1010	mg Hg/ℓ
Nickel	1670	mg Ni/ℓ
Phenol	986	mg Phenol/ℓ
Total.Organic.Carbon	164	mg C/ℓ
Cyanide	873	mg CN/ℓ
Total.Kjeldahl.Nitrogen	986	mg N/ℓ
Total.Phosphorous	958	mg P/ℓ
Oxygen.Absorbed	978	mg O_2/ℓ
Lithium	36	mg Li/ℓ
Total.Manganese	16	mg Mn/ℓ
TOX	67	µg/ℓ
Langelier.Index	669	
pHs	664	
Sodium.Absorption.Ratio	666	
TDS.to.EC.Ratio	664	
Corrosion.Ratio	663	
Ryznar.Index	657	
Anion.Sum	704	
Cation.Sum	709	
Difference	706	
X..Difference	224	
Molybdenum	28	mg Mo/ℓ
Selenium	28	mg Se/ℓ
Vanadium	28	mg V/ℓ
Zinc	28	mg Zn/ℓ
Antimony	28	mg Sn/ℓ
Beryllium	28	mg Be/ℓ

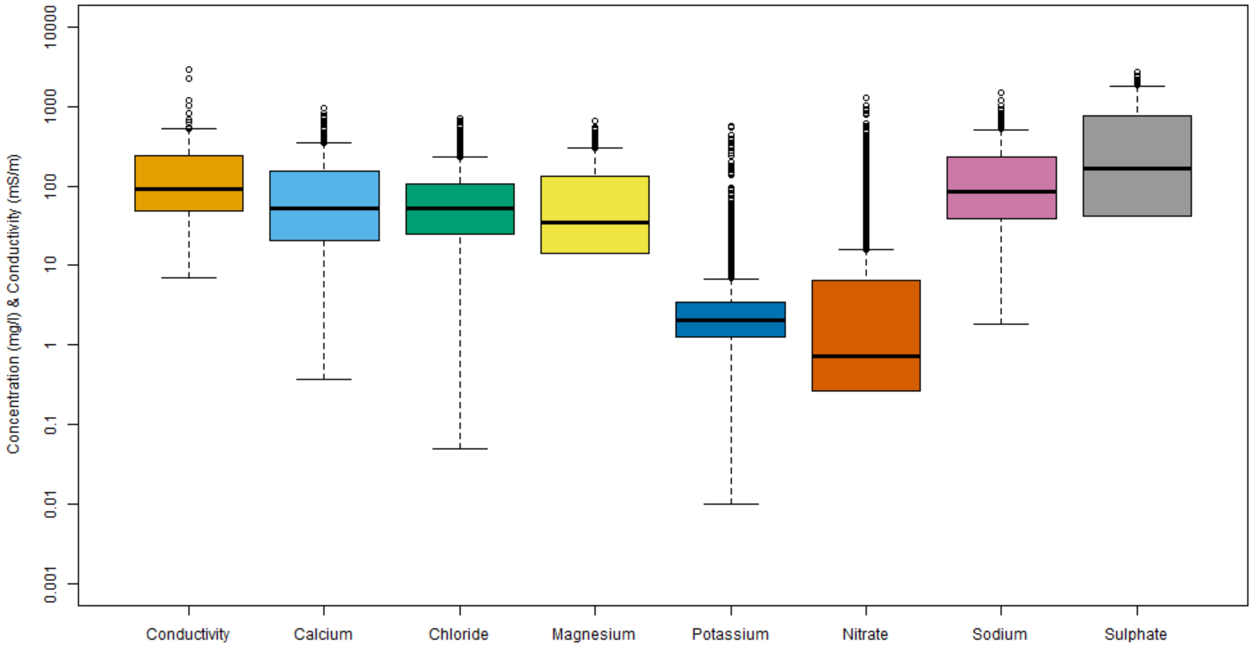

Figure 6: Box plots of Borehole data for higher median constituents

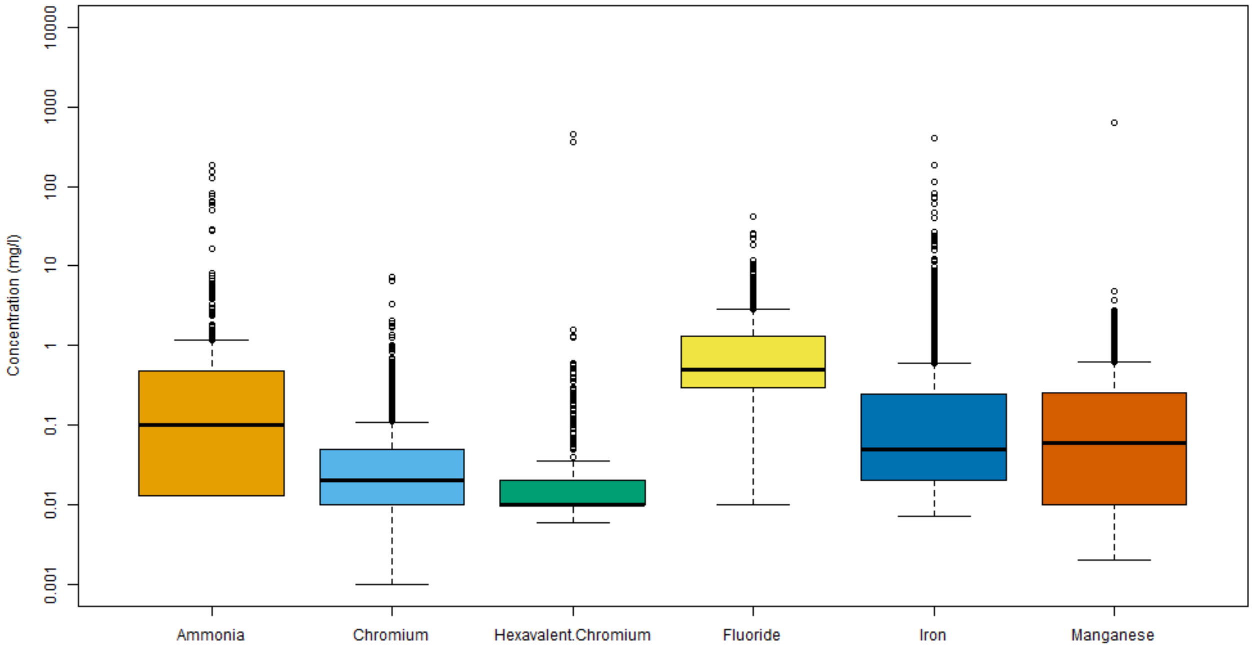

Figure 7: Box plots of Borehole data for lower median constituents

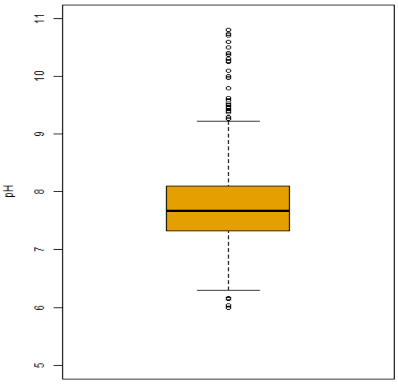

Figure 8: Box plots of Borehole data for pH

6.3 SpruitAll2008to2015.xlsx

After creating consistency between the data related to the Spruit it was stored in the file SpruitAll2008to2015.xlsx. The location IDs and the number of observations of each are presented in Table 5. The variables and their number of observations are presented in Table 6. The following adjustments were made to data in combining the files:

- The IDs were adjusted by:
  - Removing prefixes: MFC_;
  - Changing all references of the Klein Olifants River to KleinOlifants;
  - Removing the Suffex _VA.
- The conductivity from the current study was adjusted to present it as mS/m as for the other data sets.
- Some adjustments of the variable names were made to be consistent between the files.

The box plots of some of the variables explored are presented in Figure 9 to Figure 11.

Table 5: Number of observations of location IDs in the SpruitAll2008to2015.xlsx file.

ID	Number of observations
KILOSTREET	135
KleinOlifants	159
SPB	147
SPC	1
SPD	132
SPF	155
SPG	158
SPH	24
SPJ	53
SPK	240
SPL	74

Table 6: Number of observations of variables in the SpruitAll2008to2015.xlsx file.

Variable	Number of observations	Comments / Units
ID	1278	ID of sampling locations
Date	1275	Date of sampling
Total.Alkalinity	1273	mg $CaCO_3$/ℓ
Bicarbonate.Alkalinity	335	mg $CaCO_3$/ℓ
Carbonate.Alkalinity	335	mg $CaCO_3$/ℓ
M.Alkalinity	335	mg $CaCO_3$/ℓ
P.Alkalinity	335	mg $CaCO_3$/ℓ
Conductivity	786	mS/m
pH	1030	Unit less
Total.Hardness	339	mg $CaCO_3$/ℓ
Calcium.Hardness	380	mg $CaCO_3$/ℓ
Magnesium.Hardness	359	mg $CaCO_3$/ℓ
Total.Dissolved.Solids	758	mg/ℓ
Suspended.Solids	1241	mg/ℓ
Temperature	335	ºC
Chemical.Oxygen.Demand	1242	mg O_2/ℓ
Ammonia	341	mg N/ℓ
Calcium	1227	mg Ca/ℓ
Chloride	1263	mg Cl/ℓ
Magnesium	1271	mg Mg/ℓ
Nitrate	1245	mg N/ℓ
Ortho.Phosphate	341	mg P/ℓ
Potassium	365	mg K/ℓ
Sodium	1249	mg Na/ℓ
Silicon	252	mg Si/ℓ
Sulphate	1252	mg SO_4/ℓ
Aluminium	542	mg Al/ℓ
Antimony	27	mg Sb/ℓ
Arsenic	341	mg As/ℓ
Barium	341	mg Ba/ℓ
Beryllium	22	mg Be/ℓ
Boron	335	mg B/ℓ
Cadmium	341	mg Cd/ℓ
Chromium	1271	mg Cr/ℓ
Hexavalent.Chromium	1255	mg Cr(VI)/ℓ
Cobalt	341	mg Co/ℓ
Copper	341	mg Cu/ℓ
Fluoride	1248	mg F/ℓ
Iron	1272	mg Fe/ℓ

Variable	Number of observations	Comments / Units
Lead	341	mg Pb/ℓ
Lithium	16	mg Li/ℓ
Manganese	1271	mg Mn/ℓ
Mercury	341	mg Hg/ℓ
Molybdenum	22	mg Mo/ℓ
Nickel	1080	mg Ni/ℓ
Phenol	165	mg Phenol/ℓ
Cyanide	165	mg CN/ℓ
Total.Kjeldahl.Nitrogen	165	mg N/ℓ
Total.Phosphorous	147	mg P/ℓ
Oxygen.Absorbed	116	mg O_2/ℓ
Selenium	13	mg Se/ℓ
Strontium	7	mg Sr/ℓ
Tin	7	mg Sn/ℓ
Vanadium	13	mg V/ℓ
Total.Organic.Carbon	18	mg C/ℓ
TOX	18	µg/ℓ
Langelier.Index	156	
pHs	156	
Sodium.Absorption.Ratio	156	
TDS.to.EC.Ratio	156	
Corrosion.Ratio	156	
Ryznar.Index	149	
Anion.Sum	155	
Cation.Sum	155	
Difference	154	
X..Difference	18	
Zinc	6	mg Zn/ℓ

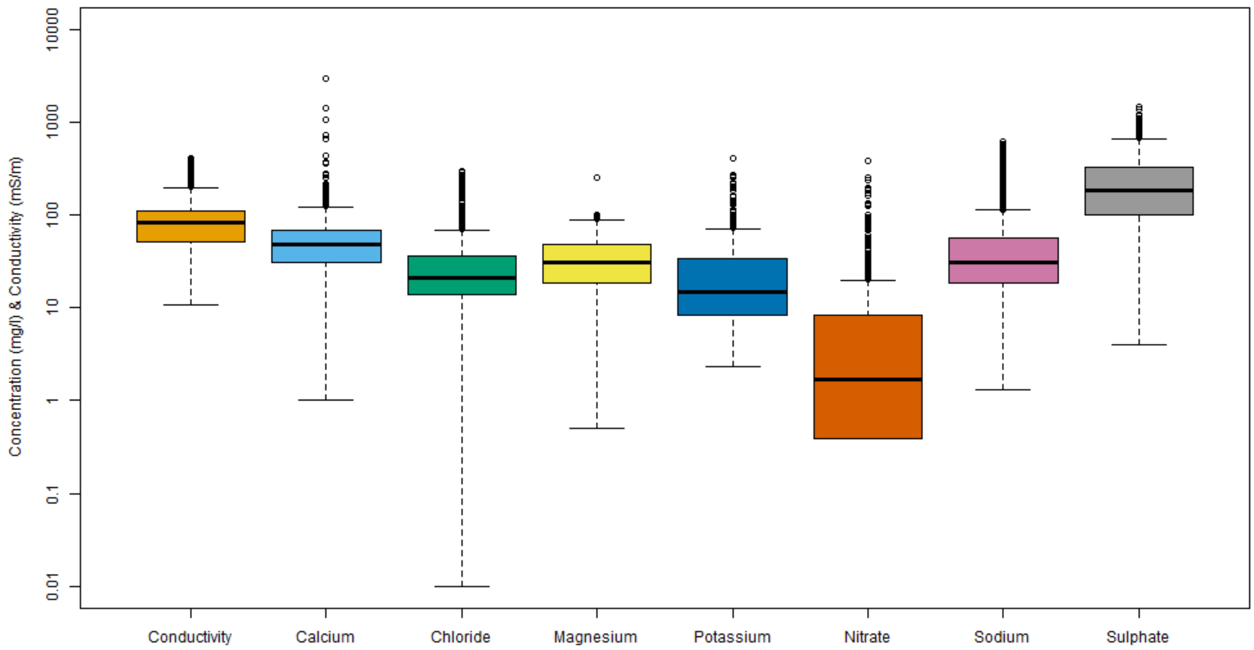

Figure 9: Box plots of Spruit data for higher median constituents

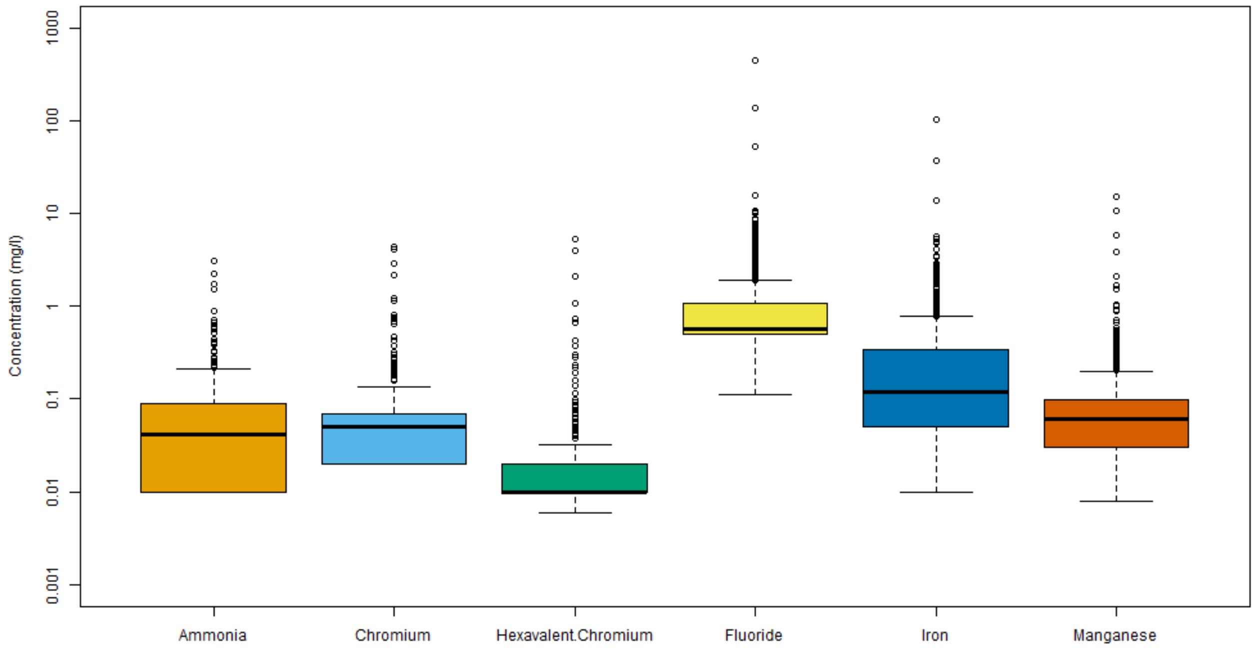

Figure 10: Box plots of Spruit data for lower median constituents

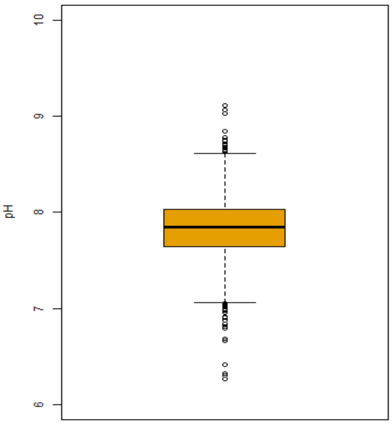

Figure 11: Box plots of Spruit data for pH

6.4 DamAll2008to2015.xlsx

After creating consistency between the data related to the Dams it was stored in the file DamAll2008to2015.xlsx. The location IDs and the number of observations of each are presented in Table 7. The variables and their number of observations are presented in
Table 8. The following adjustments were made to data in combining the files:

- The IDs were adjusted by:
  - Removing prefixes: MFC_;
  - Changing references with only D as prefix to Dam;
  - Removing the /4B in a sample labelled with as Dam4A/4B to only read Dam4A;
  - Changing “MarsPlantWater” to “Mars”;
  - Changing capitalised HARSCOx references to Harsocox;
  - Changing “MARSRUNOFF” to MarsRunoff to be consistent.
- The conductivity from the current study was adjusted to present it as mS/m as for the other data sets.
- Some adjustments of the variable names were made to be consistent between the files.

The box plots of some of the variables explored are presented in Figure 12 to Figure 14.

Table 7: Number of observations of location IDs in the DamAll2008to2015.xlsx file.

ID	Number
CDRReturnNorth	1
CDRReturnSouth	1
CSWONorth	39
CSWOSouth	43
Dam3A	242
Dam3B	164
Dam4A	91
Dam4B	81
DAM4B	8

ID	Number
Dam4C	65
DM	50
DTD	20
ETPintoPond	1
Gallery1	7
Gallery2	7
GalleryA	1
GalleryC	1
GallerySouth	1
GallerySumpSouth	4
Harco6A	2
Harsco1	26
Harsco2	44
Harsco3	41
Harsco4	26
Harsco5	2
Harsco5A	27
Harsco5B	24
HarscoRunOff	33
M4RunOff1	2
M4RunOff2	2
M4RunOff3	2
M4RunOff4	2
MARS	61
MarsReturnWater	1
MarsRunOff	97
SiltTrap	31
SouthSump	1

Table 8: Number of observations of variables in the DamAll2008to2015.xlsx file.

Variable	Number of observations	Comments / Units
ID	1251	ID of sampling locations
Date	1250	Date of sampling
Total.Alkalinity	1161	mg $CaCO_3$/ℓ
Bicarbonate.Alkalinity	560	mg $CaCO_3$/ℓ
Carbonate.Alkalinity	560	mg $CaCO_3$/ℓ
M.Alkalinity	560	mg $CaCO_3$/ℓ
P.Alkalinity	560	mg $CaCO_3$/ℓ
Conductivity	827	mS/m
pH	1115	Unit less

Variable	Number of observations	Comments / Units
Total.Hardness	1127	mg $CaCO_3$/ℓ
Calcium.Hardness	1131	mg $CaCO_3$/ℓ
Magnesium.Hardness	1064	mg $CaCO_3$/ℓ
Total.Dissolved.Solids	839	mg/ℓ
Suspended.Solids	1191	mg/ℓ
Temperature	562	ºC
Chemical.Oxygen.Demand	1217	mg O_2/ℓ
Ammonia	561	mg N/ℓ
Calcium	894	mg Ca/ℓ
Chloride	1232	mg Cl/ℓ
Magnesium	936	mg Mg/ℓ
Nitrate	1192	mg N/ℓ
Ortho.Phosphate	561	mg P/ℓ
Potassium	1127	mg K/ℓ
Sodium	1231	mg Na/ℓ
Silicon	366	mg Si/ℓ
Sulphate	1211	mg SO_4/ℓ
Aluminium	638	mg Al/ℓ
Antimony	30	mg Sb/ℓ
Arsenic	561	mg As/ℓ
Barium	561	mg Ba/ℓ
Beryllium	17	mg Be/ℓ
Boron	561	mg B/ℓ
Cadmium	578	mg Cd/ℓ
Chromium	1236	mg Cr/ℓ
Hexavalent.Chromium	1171	mg Cr(VI)/ℓ
Cobalt	561	mg Co/ℓ
Copper	585	mg Cu/ℓ
Fluoride	1225	mg F/ℓ
Iron	1236	mg Fe/ℓ
Lead	561	mg Pb/ℓ
Lithium	13	mg Li/ℓ
Manganese	1201	mg Mn/ℓ
Mercury	551	mg Hg/ℓ
Molybdenum	17	mg Mo/ℓ
Nickel	733	mg Ni/ℓ
Phenol	856	mg Phenol/ℓ
Cyanide	519	mg CN/ℓ
Total.Kjeldahl.Nitrogen	549	mg N/ℓ
Total.Phosphorous	537	mg P/ℓ

Variable	Number of observations	Comments / Units
Oxygen.Absorbed	228	mg O_2/ℓ
Selenium	10	mg Se/ℓ
Strontium	6	mg Sr/ℓ
Tin	7	mg Sn/ℓ
Vanadium	31	mg V/ℓ
Zinc	31	mg Zn/ℓ
Total.Organic.Carbon	64	mg C/ℓ
TOX	38	µg/ℓ
Langelier.Index	404	
pHs	399	
Sodium.Absorption.Ratio	400	
TDS.to.EC.Ratio	400	
Corrosion.Ratio	400	
Ryznar.Index	389	
Anion.Sum	418	
Cation.Sum	414	
Difference	410	
X..Difference	221	
Nitrite	2	

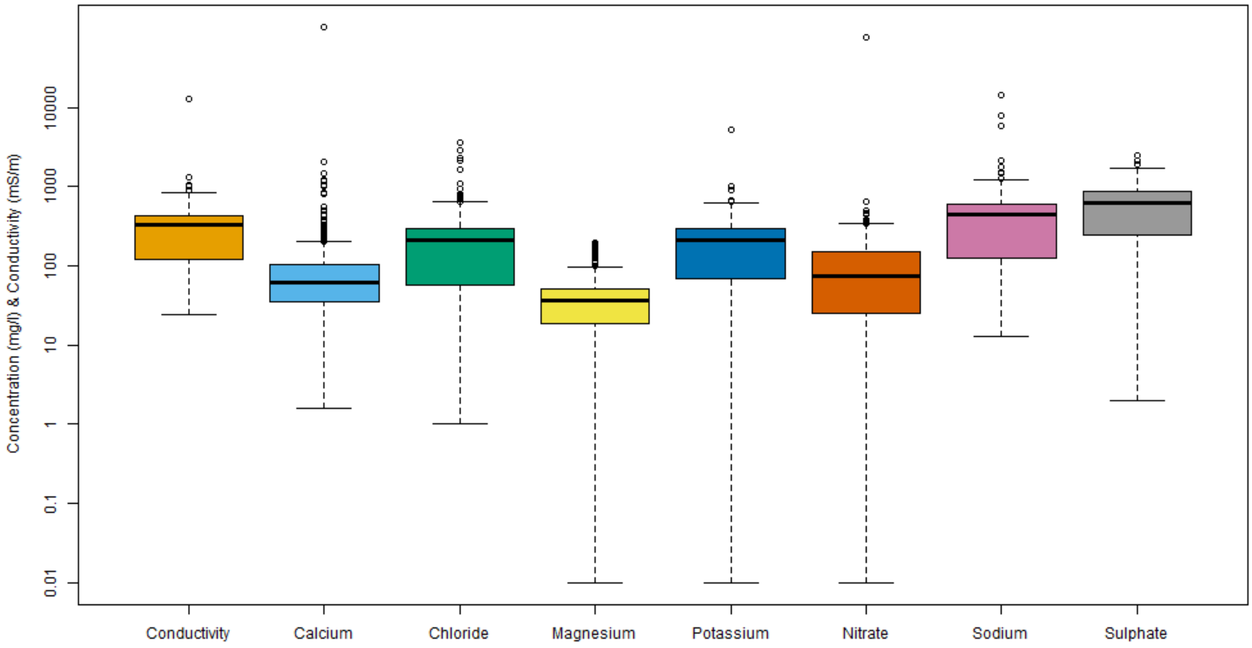

Figure 12: Box plots of Dam data for higher median constituents

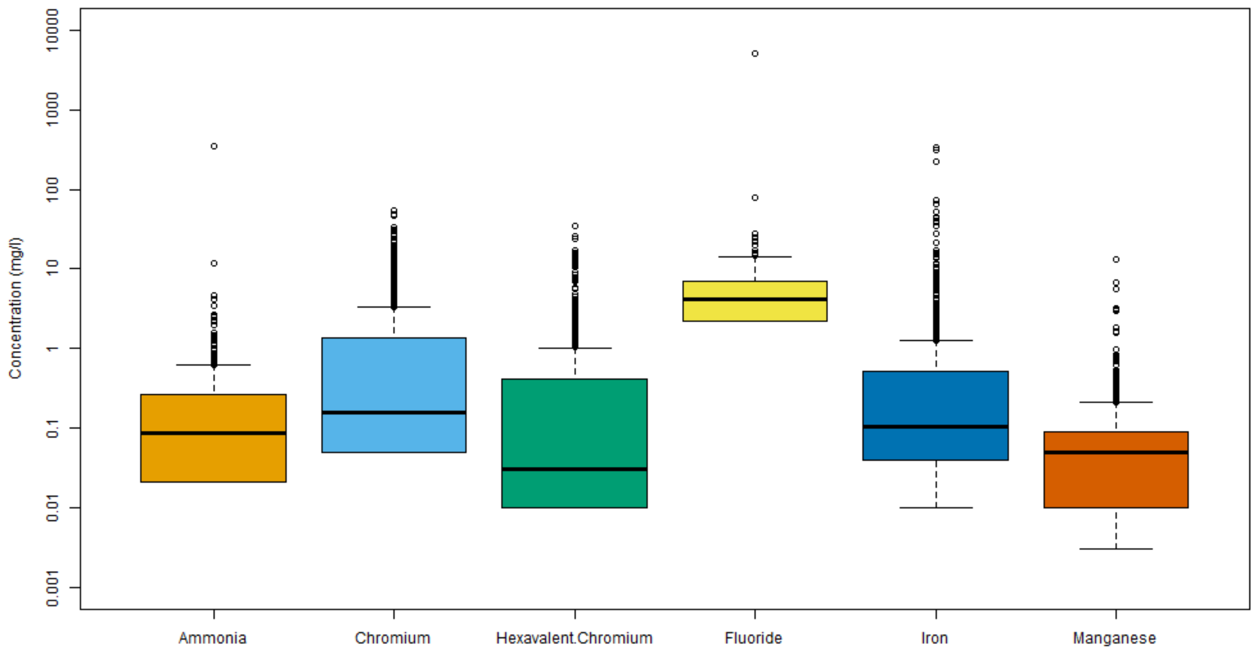

Figure 13: Box plots of Dam data for lower median constituents

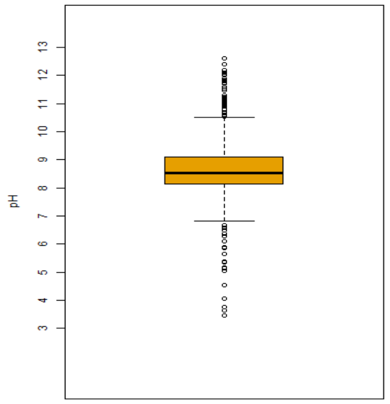

Figure 14: Box plots of Dam data for pH

7.0 CONCLUSION

The objective of this memo is to describe how the raw data was manipulated to obtain a tidy data set that can easily be shared, computed on, and analysed. In January 2016 the water monitoring results were obtained in the following excel file: "*Complete Consolidated Water Results.xlsx*". This file contained data from 2008 to 2015 in separate worksheets.

The files from a specific data group, i.e. Borehole, Dam, Pond, Spruit for the different years were combined. The combined files were written to excel files labelled:

- PondAll2008to2015.xlsx
- BoreholeAll2008to2015.xlsx
- SpruitAll2008to2015.xlsx
- DamAll2008to2015.xlsx

The following variables were explored in the data tidying process: "ID", "Date", "Conductivity", "pH", "Calcium", "Chloride", "Magnesium", "Potassium", "Nitrate", "Ammonia", "Sodium", "Sulphate", "Chromium", "Hexavalent.Chromium", "Fluoride", "Iron", "Manganese". Other Variables were not considered and should be evaluated before using.

Yours sincerely,

GOLDER ASSOCIATES AFRICA (PTY) LTD.

C Steyn
Senior Soil Scientist

E Herselman
Senior Soil Scientist

CS/EH/cs

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APPENDIX C

Analytical Certificates

National Research Foundation | iThemba LABS
Laboratory for Accelerator Based Sciences

Environmental Isotope Laboratory

Postal address: Private Bag 11, Wits, 2050, South Africa.
Physical Address: Empire Road (between Jan Smuts Avenue and Yale Road)
Tel ++27 11 351 7000/1 (switchboard/secretary), Fax ++27 11 351 7053

Report

Reference: GOLD002

Date: 24th July 2015

Stable isotope analysis on fifteen (15) water samples

submitted by Dr Eddie van Wyk
Golder Associates

Project No. 1418954 Phase 200

— —

M.J. Butler, O.H.T. Malinga, M. Mabitsela

confidential

1. General

Fifteen water samples were submitted by Dr E. van Wyk of Golder Associates for D/H ($^{2}H/^{1}H$) and $^{18}O/^{16}O$ analysis. The samples were received on the 5th of June 2015.

2. Stable Isotope Analysis

Water D/H ($^{2}H/^{1}H$) and $^{18}O/^{16}O$ ratios were analysed in the laboratory of the Environmental Isotope Group (EIG) of iThemba Laboratories, Gauteng.

The equipment used for stable isotope analysis consists of a Thermo Delta V mass spectrometer connected to a Gasbench. Equilibration time for the water sample with hydrogen is about 40 minutes and CO2 is equilibrated with a water sample in about twenty hours. Laboratory standards, calibrated against international reference materials, are analysed with each batch of samples. The analytical precision is estimated at 0.2‰ for O and 0.8‰ for H.

Analytical results are presented in the common delta-notation:

$$\delta^{18}O(‰) = \left[\frac{(^{18}O/^{16}O)_{sample}}{(^{18}O/^{16}O)_{standard}} - 1 \right] \times 1000$$

which applies to D/H ($^{2}H/^{1}H$), accordingly. These delta values are expressed as per mil deviation relative to a known standard, in this case standard mean ocean water (SMOW) for $\delta^{18}O$ and δD.

3. Results

The analytical results are presented in Tables 1 and 2 and partially illustrated in Figure 1.

The stable isotope analyses for all samples data could be well reproduced within the expected analytical error limits. Figure 1 shows these data in a $\delta^{18}O$ vs. δD space relative to the Global Meteoric Water Line (GMWL, Craig, 1961).

4. References

Craig, H. (1961). Isotopic variations in meteoric waters. *Science*, **133**, 1702–1703.

Table 1: Analytical Results

			Deuterium	Oxygen-18
Lab No	Field Name	Description	δD‰ SMOW	δ^{18}O‰ SMOW
GOLD 023	Dam 3A	2015/05/25	+4.6	+2.90
GOLD 024	Dam 3B	2015/05/25	+5.6	+2.66
GOLD 025	Pond 6B	2015/05/25	+8.9	+4.38
GOLD 026	F-9-RWD1	2015/05/25	+47.9	+14.27
GOLD 027	Dam 4A	2015/05/26	+5.3	+2.77
GOLD 028	Dam 4B	2015/05/26	+10.9	+4.14
GOLD 029	BH 1	2015/05/26	-13.3	-1.35
GOLD 030	BH 3A	2015/05/26	-24.1	-3.83
GOLD 031	BH 3B	2015/05/26	-1.8	+0.78
GOLD 032	BH 4A	2015/05/26	-9.8	-1.04
GOLD 033	BH 4B	2015/05/26	-8.7	-0.40
GOLD 034	BH 5A	2015/05/26	-11.9	-1.67
GOLD 035	BH 5B	2015/05/26	-10.8	-1.58
GOLD 036	S05	2015/05/26	-19.9	-3.18
GOLD 037	S09	2015/05/26	-11.9	-1.65

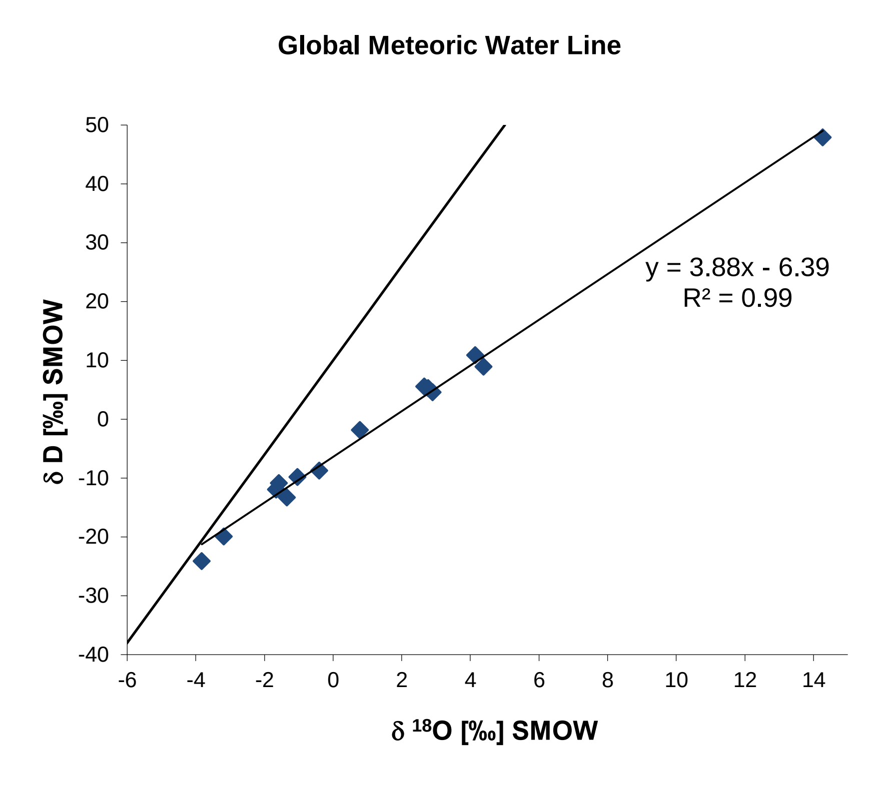

Figure 1: Stable isotope data relative to Global Meteoric Water Line (Craig, 1961).

Table 2: Stable isotope aliquot determinations

Lab No.	Field Name:	Description	Deuterium analysis	Deuterium Batch	δD‰ SMOW	Oxygen-18 analysis	Oxygen-18 Batch	δ18O‰ SMOW
GOLD 023	Dam 3A	2015/05/25	a	2015/07/21	4.1	a	2015/07/23	2.84
			b		5.1	b		2.95
				avg.:	**4.6**		**avg.:**	**2.90**
				diff.:	*1.0*		*diff.:*	*0.11*
GOLD 024	Dam 3B	2015/05/25	a	2015/07/21	5.5	a	2015/07/23	2.71
			b		5.6	b		2.61
				avg.:	**5.6**		**avg.:**	**2.66**
				diff.:	*0.1*		*diff.:*	*0.10*
GOLD 025	Pond 6B	2015/05/25	a	2015/07/21	8.8	a	2015/07/17	4.33
			b		9.0	b		4.43
				avg.:	**8.9**		**avg.:**	**4.38**
				diff.:	*0.3*		*diff.:*	*0.10*
GOLD 026	F-9-RWD1	2015/05/25	a	2015/07/21	47.5	a	2015/07/17	14.30
			b		48.3	b		14.25
				avg.:	**47.9**		**avg.:**	**14.27**
				diff.:	*0.7*		*diff.:*	*0.05*
GOLD 027	Dam 4A	2015/05/26	a	2015/07/21	5.7	a	2015/07/17	2.78
			b		4.9	b		2.76
				avg.:	**5.3**		**avg.:**	**2.77**
				diff.:	*0.8*		*diff.:*	*0.02*
GOLD 028	Dam 4B	2015/05/26	a	2015/07/21	11.0	a	2015/07/17	4.15
			b		10.8	b		4.14
				avg.:	**10.9**		**avg.:**	**4.14**
				diff.:	*0.2*		*diff.:*	*0.01*

GOLD 029	BH 1	2015/05/26	a	2015/07/21	-13.2	a	2015/07/17	-1.36
			b		-13.4	b		-1.34
				avg.:	**-13.3**		**avg.:**	**-1.35**
				diff.:	*0.2*		*diff.:*	*0.03*
GOLD 030	BH 3A	2015/05/26	a	2015/07/21	-23.7	a	2015/07/17	-3.79
			b		-24.4	b		-3.87
				avg.:	**-24.1**		**avg.:**	**-3.83**
				diff.:	*0.7*		*diff.:*	*0.08*
GOLD 031	BH 3B	2015/05/26	a	2015/07/21	-2.0	a	2015/07/17	0.73
			b		-1.6	b		0.83
				avg.:	**-1.8**		**avg.:**	**0.78**
				diff.:	*0.4*		*diff.:*	*0.10*
GOLD 032	BH 4A	2015/05/26	a	2015/07/21	-9.7	a	2015/07/23	-0.98
			b		-10.0	b		-1.10
				avg.:	**-9.8**		**avg.:**	**-1.04**
				diff.:	*0.3*		*diff.:*	*0.12*
GOLD 033	BH 4B	2015/05/26	a	2015/07/21	-9.1	a	2015/07/17	-0.38
			b		-8.3	b		-0.43
				avg.:	**-8.7**		**avg.:**	**-0.40**
				diff.:	*0.8*		*diff.:*	*0.05*
GOLD 034	BH 5A	2015/05/26	a	2015/07/21	-12.2	a	2015/07/23	-1.69
			b		-11.7	b		-1.65
				avg.:	**-11.9**		**avg.:**	**-1.67**
				diff.:	*0.4*		*diff.:*	*0.04*
GOLD 035	BH 5B	2015/05/26	a	2015/07/21	-10.6	a	2015/07/17	-1.62
			b		-11.0	b	2015/07/23	-1.54
				avg.:	**-10.8**		**avg.:**	**-1.58**
				diff.:	*0.4*		*diff.:*	*0.08*
GOLD 036	S05	2015/05/26	a	2015/07/21	-19.8	a	2015/07/17	-3.14
			b		-20.0	b		-3.23
				avg.:	**-19.9**		**avg.:**	**-3.18**
				diff.:	*0.2*		*diff.:*	*0.09*
GOLD 037	S09	2015/05/26	a	2015/07/21	-12.0	a	2015/07/17	-1.67
			b		-11.8	b		-1.64
				avg.:	**-11.9**		**avg.:**	**-1.65**
				diff.:	*0.2*		*diff.:*	*0.03*

01 July 2015

T0384

WHOLE EFFLUENT TOXICITY TEST REPORT

G2015/50

Submitted to:
Elize Herselman
Golder Associates Africa (Pty) Ltd
P O Box 6001
Halfway House
1685

Client Number. GAL2093

Distribution:

1 Copy - Golder Associates Africa (Pty) Ltd
1 Copy - GARL

REPORT

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TABLES

1.0 CUSTOMER DETAILS

Requested by:	Elize Herselman
Company name:	Golder Associates Africa (Pty) Ltd
Address:	P O Box 6001
	Halfway House
	1685
Telephone number:	011 254 4800/ 083 782 2225
Fax number:	011 315 0317
E-mail:	eherselman@golder.co.za

2.0 LABORATORY DETAILS

Company name:	Golder Associates Research Laboratory
Division:	Toxicity Division
Physical Address:	25 Main Avenue
	Florida
	1709
Telephone number:	011 672 0666
Fax number:	011 672 0008
Registration Number	2006/020508/07

Enclosed please find Test report number G2015/50. The results only relate to the sample(s) tested. GARL does not accept responsibility for any matters arising from the further use of the results. Tests marked “Not SANAS Accredited” in this report are not included in the SANAS Schedule of Accreditation for this laboratory.

No part of the report may be quoted in isolation of the rest of the text without the written permission of GARL. Tests marked “Not SANAS Accredited” fall outside the scope of SANAS accreditation. Opinions and Interpretations expressed herein are outside the scope of SANAS accreditation.

This report supersedes results reported by telephone or fax.

Please contact the laboratory if further information is required. We look forward to being of assistance to you.

Yours faithfully

____

Mahadi Motsumi

(Quality Manager)

3.0 REQUESTED ANALYSES

Analyses performed:	**Sample reference numbers**
15 and 30 minute *Vibrio fischeri* bioluminescent screening test	15/334- 15/340
15 and 30 minute Vibrio fischeri bioluminescent definitive test	15/341- 15/345
72h *Selenastrum capricornutum* growth inhibition screening test	15/334- 15/340
72h *Selenastrum capricornutum* growth inhibition definitive test	15/341- 15/345
24 and 48h *Daphnia pulex* acute toxicity screening test	15/334- 15/340
24 and 48h Daphnia pulex acute toxicity definitive test	15/341- 15/345
96h *Poecilia reticulata* acute toxicity screening test	15/334- 15/340
96h Poecilia reticulata acute toxicity definitive test	15/341- 15/345

4.0 INTRODUCTION TO TESTS REQUESTED

License number:	Not applicable
License toxicity testing requirements:	Not applicable
Plant name and / or location:	Not available
Name of receiving water body (s) up and downstream of discharge:	Not available

5.0 SAMPLE INFORMATION

5.1 WATER SAMPLES

Sample reference name(s):	**Collection date and time**	**Sample reference number(s):**
SPK	25.05.2015 Time Unknown	15/334
SPL	25.05.2015 Time Unknown	15/335
SPJ	25.05.2015 Time Unknown	15/336
SPG	25.05.2015 Time Unknown	15/337
SPB	25.05.2015 Time Unknown	15/338
SPD	25.05.2015 Time Unknown	15/339
SD9	25.05.2015 Time Unknown	15/340
F-10 DAM 4B	25.05.2015 Time Unknown	15/341
F-11 DAM 4A	25.05.2015 Time Unknown	15/342
F-12 DAM 3B	25.05.2015 Time Unknown	15/343
F-13 DAM 3A	25.05.2015 Time Unknown	15/344
F-14 POND 6B	25.05.2015 Time Unknown	15/345

Sampling technique:	Grab
Name of sampler (s):	N Erasmus
Description of sample container (s) :	2L Plastic
Date and time of sample receipt at testing laboratory:	29.05.2015 Time 09:45
Comments:	None

6.0 METHODOLOGY

Test Conditions

All toxicity tests were conducted in environmentally controlled rooms using standard techniques.

Quality assurance

The GARL Aquatic toxicology laboratory's Policy and Quality Manual, intended to support and maintain all aspects of the Quality System, is based on the application of ISO/IEC 17025. The following Quality Assurance information would be made available on request: in-house reference toxicant test data and control charts, Proficiency Testing Scheme test data, additional lot and batch numbers and raw toxicity test data.

Toxicity units

The toxicity unit (TUa) for each test performed is calculated as 100% (full strength effluent expressed as percentage) divided by the effective concentration or LC50 expressed as percentage sample dilution (e.g. *Daphnia pulex* and *Poecilia reticulata* acute toxicity tests) and EC50 (e.g. *Vibrio fischeri* bioluminescent test and *Selenastrum capricornutum* growth inhibition test) (Tonkes & Baltus, 1997). If there is not sufficient toxicity in a sample to enable the determination of an EC50/LC50 value, then an acute toxicity unit of <1 will be assigned to the sample.

Table 1: Toxicity Units (Tonkes and Baltus, 1997)

Toxicity Unit	Conclusion
< 1	Limited to Not Acutely Toxic
1 - 2	Negligibly Acute Toxic
2 - 10	Mildly Acutely Toxic
10 - 100	Acutely Toxic
> 100	Highly Acutely Toxic

T 01: *Vibrio fischeri* bioluminescent test, EN ISO 11348-3 (2007)

Test endpoint:	% growth inhibition relative to control and/or EC20 and EC50 values
Exposure period:	15 and 30 minutes
Deviation from reference method:	None
Test chamber type:	Polystyrene cuvettes for luminometer
Test sample volume:	500 ul
Number of replicates per sample:	2
Test temperature:	15°C ±2°C
Test organism species name and source:	Lyophilized *Vibrio fischeri* luminescent bacteria (NRRL B-11177)
Luminescent measurement:	Luminoskan TL, Hygiene Monitoring System
Reagent batch number:	VF 1014
Statistical methods used:	Bio Orbit software
Test endpoint:	% growth inhibition relative to control and/or EC20 and EC50 values

T 02: *Selenastrum capricornutum* growth inhibition test, OECD Guideline 201 (2006)

Test endpoint:	% growth inhibition relative to control and/or EC20 and EC50 values
Exposure period:	72h
Deviation from reference method:	None
Test chamber type:	10 cm path length long cells
Test sample volume:	25 ml
Number of replicates per sample:	2
Test temperature:	21°C-25°C
Test organism species name and source:	*Selenastrum capricornutum*, Printz algae beads (CCAP 278/4 Cambridge, UK)
OD measurement:	Jenway 6300 Spectrophotometer
Test organism source:	CCAP 278/4 Cambridge, UK
Algal beads batch number:	SC050315
Statistical methods used:	Regression analyses

T 03: *Daphnia pulex* acute toxicity test, US EPA (2002)

Test endpoint:	% mortality and/or LC10 and LC50 values
Exposure period:	24 and 48h
Deviation from reference method:	None
Test chamber type:	50 ml disposable polystyrene cups
Test sample volume:	25 ml
Number of test organisms per chamber:	5
Number of replicates per sample:	4
Feeding frequency:	None
Test temperature:	21°C±2°C
Test organism species name, age and source:	*Daphnia pulex,* less than 24h old obtained from in-house cultures
Statistical methods used:	Probit software\TSK

T 04: *Poecilia reticulata* acute toxicity test, US EPA (1996)

Test endpoint:	% mortality and/or LC10 and LC50 values
Exposure period:	96h
Deviation from reference method:	None
Test chamber type:	250 ml disposable polystyrene cups
Test sample volume:	200 ml
Number of test organisms per sample:	10
Number of replicates per sample:	2
Feeding frequency:	None
Test temperature:	23°C±2°C
Test organism species name, age and source:	*Poecilia reticulata,* 7-21 days old. Obtained from Internal stock.
Statistical methods used:	Probit software\TSK

7.0 RESULTS

Table 2: 15/334 and 15/335 Toxicity Results

Physical and chemical data	**Method number**	**Sample reference number(s) and description**	
		15/334 SPK	15/335 SPL
pH	M 09	7.70	7.64
Conductivity (µS/cm)	M 05	486	479
Dissolved oxygen concentration (mg/l)	"Not SANAS Accredited"	7.79	7.65
Total residual chlorine (present✓/not present ×)		×	×
Temperature (˚C)		20	20

Tebogo Gwamanda
Analytical Chemist

Toxicity test results			
15 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))	T 01	-3.5	-1.2
30 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))		-6.7	+0.11
30 minute *Vibrio fischeri* bioluminescent test toxicity unit (TUa)		<1	<1
72h *Selenastrum capricornutum* growth inhibition screening test (% growth inhibition (-) or growth stimulation (+))	T 02	+59	+23
72h *Selenastrum capricornutum* growth inhibition test toxicity unit (TUa)		<1	<1
24h *Daphnia pulex* acute toxicity screening test (% mortality)	T 03	25	0
48h *Daphnia pulex* acute toxicity screening test (% mortality)		30	10
48h *Daphnia pulex* acute toxicity test toxicity unit (TUa)		<1	<1
96h *Poecilia reticulata* acute toxicity screening test (% mortality)	T 04	20	0
96h *Poecilia reticulata* acute toxicity test toxicity unit (TUa)		<1	<1

Mahadi Motsumi
(Quality Manager)

Table 3: 15/336 and 15/337 Toxicity Results

Physical and chemical data	Method number	Sample reference number(s) and description	
		15/336 SPJ	15/337 SPG
pH	M 09	7.59	7.79
Conductivity (µS/cm)	M 05	479	800
Dissolved oxygen concentration (mg/l)	"Not SANAS Accredited"	7.72	7.66
Total residual chlorine (present✓/not present ×)		Trace	✓
Temperature (˚C)		20	20

Tebogo Gwamanda
Analytical Chemist

Toxicity test results			
15 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))	T 01	-4.4	+0.11
30 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))		-4.1	-2.2
30 minute *Vibrio fischeri* bioluminescent test toxicity unit (TUa)		<1	<1
72h *Selenastrum capricornutum* growth inhibition screening test (% growth inhibition (-) or growth stimulation (+))	T 02	+20	+54
72h *Selenastrum capricornutum* growth inhibition test toxicity unit (TUa)		<1	<1
24h *Daphnia pulex* acute toxicity screening test (% mortality)	T 03	0	10
48h *Daphnia pulex* acute toxicity screening test (% mortality)		20	30
48h *Daphnia pulex* acute toxicity test toxicity unit (TUa)		<1	<1
96h *Poecilia reticulata* acute toxicity screening test (% mortality)	T 04	0	0
96h *Poecilia reticulata* acute toxicity test toxicity unit (TUa)		<1	<1

Mahadi Motsumi
(Quality Manager)

Table 4: 15/338 and 15/339 Toxicity Results

Physical and chemical data	**Method number**	**Sample reference number(s) and description**	
		15/338 SPB	15/339 SPD
pH	M 09	7.96	7.93
Conductivity (µS/cm)	M 05	1036	1124
Dissolved oxygen concentration (mg/l)	"Not SANAS Accredited"	7.76	7.98
Total residual chlorine (present✓/not present ×)		×	×
Temperature (˚C)		20	20

Tebogo Gwamanda
Analytical Chemist

Toxicity test results			
15 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))	T 01	+8.4	-24
30 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))		+3.8	-35
30 minute *Vibrio fischeri* bioluminescent test toxicity unit (TUa)		<1	<1
72h *Selenastrum capricornutum* growth inhibition screening test (% growth inhibition (-) or growth stimulation (+))	T 02	+54	+50
72h *Selenastrum capricornutum* growth inhibition test toxicity unit (TUa)		<1	<1
24h *Daphnia pulex* acute toxicity screening test (% mortality)	T 03	25	0
48h *Daphnia pulex* acute toxicity screening test (% mortality)		25	20
48h *Daphnia pulex* acute toxicity test toxicity unit (TUa)		<1	<1
96h *Poecilia reticulata* acute toxicity screening test (% mortality)	T 04	0	0
96h *Poecilia reticulata* acute toxicity test toxicity unit (TUa)		<1	<1

Mahadi Motsumi
(Quality Manager)

Table 5: 15/340 Toxicity Results

Physical and chemical data	Method number	Sample reference number(s) and description 15/340 SD9
pH	M 09	7.95
Conductivity (µS/cm)	M 05	3 520
Dissolved oxygen concentration (mg/l)	"Not SANAS Accredited"	6.66
Total residual chlorine (present✓/not present ×)		×
Temperature (˚C)		20

Tebogo Gwamanda
Analytical Chemist

Toxicity test results		
15 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))	T 01	-13
30 minute *Vibrio fischeri* bioluminescent screening test (average % inhibition (-) or stimulation (+))		-18
30 minute *Vibrio fischeri* bioluminescent test toxicity unit (TUa)		<1
72h *Selenastrum capricornutum* growth inhibition screening test (% growth inhibition (-) or growth stimulation (+))	T 02	+16
72h *Selenastrum capricornutum* growth inhibition test toxicity unit (TUa)		<1
24h *Daphnia pulex* acute toxicity screening test (% mortality)	T 03	15
48h *Daphnia pulex* acute toxicity screening test (% mortality)		50
48h *Daphnia pulex* acute toxicity test toxicity unit (TUa)		UR
96h *Poecilia reticulata* acute toxicity screening test (% mortality)	T 04	0
96h *Poecilia reticulata* acute toxicity test toxicity unit (TUa)		<1

UR *Insufficient toxicity data available from screening results to determine TUa with certainty.*

Mahadi Motsumi
(Quality Manager)

Table 6: 15/341 and 15/342 Toxicity Results

Physical and chemical data	Method number	Sample reference number(s) and description	
		15/341 F-10 DAM 4B	15/342 F-11 DAM 4A
pH	M 09	9.79	9.83
Conductivity (µS/cm)	M 05	6 740	5 420
Dissolved oxygen concentration (mg/l)	"Not SANAS Accredited"	10.73	7.73
Total residual chlorine (present✓/not present ×)		Trace	Trace
Temperature (˚C)		20	20

Tebogo Gwamanda
Analytical Chemist

Toxicity test results

15 minute *Vibrio fischeri* bioluminescent toxicity definitive test sample concentrations (%)		T 01	**Average % inhibition (-) or stimulation (+)**	
6.25			+5.7	+17
12.5			+1.7	+13
25			-30	-12
50			-61	-49
100			-84	-83
15 minute *Vibrio fischeri* bioluminescent definitive test (% sample concentration)	EC20 value EC50 value		9.2 20	16 26
30 minute *Vibrio fischeri* bioluminescent toxicity definitive test sample concentrations (%)			**Average % inhibition (-) or stimulation (+)**	
6.25			+2.6	+16
12.5			-7.3	+13
25			-31	-11
50			-62	-52
100			-89	-87
30 minute *Vibrio fischeri* bioluminescent definitive test (% sample concentration)	EC20 value EC50 value		10 19	15 25
30 minute *Vibrio fischeri* bioluminescent test toxicity unit (TUa)			5.3	4

Mahadi Motsumi
(Quality Manager)

Table 7: 15/341 and 15/342 Toxicity Results

Toxicity test results		Method number	Sample reference number(s) and description	
			15/341 F-10 DAM 4B	15/342 F-11 DAM 4A
72h *Selenastrum capricornutum* growth inhibition toxicity definitive test sample concentrations (%)		T 02	**% Growth inhibition (-) or growth stimulation (+)**	
6.25			-52	+67
12.5			-10	+80
25			+15	+124
50			-12	+179
100			+135	+190
72h *Selenastrum capricornutum* growth inhibition definitive test (% sample concentration)	EC20 value EC50 value		*	*
72h *Selenastrum capricornutum* growth inhibition test toxicity unit (TUa)			<1	<1

* *EC20 and EC50 could not be determined due to limited or no toxicity.*

Mahadi Motsumi
(Quality Manager)

Table 8: 15/341 and 15/342 Toxicity Results

Toxicity tests results		**Method number**	**Sample reference number(s) and description**	
			15/341 F-10 DAM 4B	15/342 F-11 DAM 4A
24h *Daphnia pulex* acute toxicity definitive test sample concentrations (%)		T 03	**Mortality (%)**	
6.25			0	0
12.5			0	0
25			0	0
50			95	15
100			100	100
24h *Daphnia pulex* acute toxicity definitive test (% sample concentration)	LC10 value LC50 value		* 37	* 64
48h *Daphnia pulex* acute toxicity definitive test sample concentrations (%)			**Mortality (%)**	
6.25			0	0
12.5			0	5
25			0	25
50			100	30
100			100	100
48h *Daphnia pulex* acute toxicity definitive test (% sample concentration)	LC10 value LC50 value		* 35	20 46
48h *Daphnia pulex* acute toxicity test toxicity unit (TUa)			2.9	2.2

* *LC10 could not be determined by the statistical programme.*

Mahadi Motsumi
(Quality Manager)

Table 9: 15/341 and 15/342 Toxicity Results

Toxicity test results		**Method number**	**Sample reference number(s) and description**	
			15/341 F-10 DAM 4B	15/342 F-11 DAM 4A
96h *Poecilia reticulata* acute toxicity definitive test sample concentrations (%)		T04	**Mortality (%)**	
1.5625			0	-
3.125			0	10
6.25			10	0
12.5			0	0
25			30	0
50			100	90
100			100	100
96h *Poecilia reticulata* acute toxicity definitive test (% sample concentration)	LC10 value LC50 value		12 25	* 38
96h *Poecilia reticulata* acute toxicity test toxicity unit (TUa)			4	2.6

* *LC10 could not be determined by the statistical programme*

Mahadi Motsumi
(Quality Manager)

Table 10: 15/343 and 15/344 Toxicity Results

Physical and chemical data	**Method number**	**Sample reference number(s) and description**	
		15/343 F-12 DAM 3B	15/344 F-13 DAM 3A
pH	M 09	8.59	8.94
Conductivity (µS/cm)	M 05	5 750	5 080
Dissolved oxygen concentration (mg/l)	"Not SANAS Accredited"	7.24	8.30
Total residual chlorine (present✓/not present ×)		✓	×
Temperature (˚C)		20	20

Tebogo Gwamanda
Analytical Chemist

Toxicity test results				
15 minute *Vibrio fischeri* bioluminescent toxicity definitive test sample concentrations (%)		T 01	**Average % inhibition (-) or stimulation (+)**	
6.25			+23	+26
12.5			+27	+29
25			+20	+27
50			+8.6	+19
100			-17	-27
15 minute *Vibrio fischeri* bioluminescent definitive test (% sample concentration)	EC20 value EC50 value		*	*
30 minute *Vibrio fischeri* bioluminescent toxicity definitive test sample concentrations (%)			**Average % inhibition (-) or stimulation (+)**	
6.25			+24	+24
12.5			+30	+34
25			+23	+30
50			+12	+11
100			-19	-30
30 minute *Vibrio fischeri* bioluminescent definitive test (% sample concentration)	EC20 value EC50 value		*	*
30 minute *Vibrio fischeri* bioluminescent test toxicity unit (TUa)			<1	<1

* *EC20 and EC50 could not be determined due to limited or no toxicity.*

Mahadi Motsumi
(Quality Manager)

Table 11: 15/343 and 15/344 Toxicity Results

<table>
<tr><th colspan="2" rowspan="2">Toxicity test results</th><th rowspan="2">Method number</th><th colspan="2">Sample reference number(s) and description</th></tr>
<tr><th>15/343
F-12 DAM 3B</th><th>15/344
F-13 DAM 3A</th></tr>
<tr><td colspan="2">72h Selenastrum capricornutum growth inhibition toxicity definitive test sample concentrations (%)</td><td rowspan="8">T 02</td><td colspan="2">% Growth inhibition (-) or growth stimulation (+)</td></tr>
<tr><td colspan="2">6.25</td><td>-20</td><td>+10</td></tr>
<tr><td colspan="2">12.5</td><td>+27</td><td>+46</td></tr>
<tr><td colspan="2">25</td><td>+75</td><td>+53</td></tr>
<tr><td colspan="2">50</td><td>+102</td><td>+93</td></tr>
<tr><td colspan="2">100</td><td>+104</td><td>+102</td></tr>
<tr><td>72h Selenastrum capricornutum growth inhibition definitive test
(% sample concentration)</td><td>EC20 value
EC50 value</td><td>*</td><td>*</td></tr>
<tr><td colspan="2">72h Selenastrum capricornutum growth inhibition test toxicity unit
(TUa)</td><td><1</td><td><1</td></tr>
</table>

* *EC20 and EC50 could not be determined due to limited or no toxicity.*

Mahadi Motsumi
(Quality Manager)

Table 12: 15/343 and 15/344 Toxicity Results

Toxicity tests results		**Method number**	**Sample reference number(s) and description**	
			15/343 F-12 DAM 3B	15/344 F-13 DAM 3A
24h *Daphnia pulex* acute toxicity definitive test sample concentrations (%)			**Mortality (%)**	
6.25			10	15
12.5			10	20
25			5	30
50			5	5
100			15	10
24h *Daphnia pulex* acute toxicity definitive test (% sample concentration)	LC10 value LC50 value		*	*
48h *Daphnia pulex* acute toxicity definitive test sample concentrations (%)		T 03	**Mortality (%)**	
6.25			15	20
12.5			20	20
25			10	45
50			5	15
100			25	15
48h *Daphnia pulex* acute toxicity definitive test (% sample concentration)	LC10 value LC50 value		*	*
48h *Daphnia pulex* acute toxicity test toxicity unit (TUa)			<1	<1

* *LC10 and LC50 could not be determined due to low toxicity.*

Mahadi Motsumi
(Quality Manager)

Table 13: 15/343 and 15/344 Toxicity Results

Toxicity test results		**Method number**	**Sample reference number(s) and description**	
			15/343 F-12 DAM 3B	15/344 F-13 DAM 3A
96h *Poecilia reticulata* acute toxicity definitive test sample concentrations (%)		T04	**Mortality (%)**	
6.25			10	40
12.5			10	10
25			0	0
50			10	20
100			100	100
96h *Poecilia reticulata* acute toxicity definitive test (% sample concentration)	LC10 value LC50 value		17 62	4.9 59
96h *Poecilia reticulata* acute toxicity test toxicity unit (TUa)			1.6	1.7

Mahadi Motsumi
(Quality Manager)

Table 14: 15/345 Toxicity Results

Physical and chemical data	**Method number**	**Sample reference number(s) and description** 15/345 F-14 POND 6B
pH	M 09	9.99
Conductivity (µS/cm)	M 05	5 410
Dissolved oxygen concentration (mg/l)	"Not SANAS Accredited"	11.01
Total residual chlorine (present✓/not present ×)		×
Temperature (˚C)		20

Tebogo Gwamanda
Analytical Chemist

Toxicity test results			
15 minute *Vibrio fischeri* bioluminescent toxicity definitive test sample concentrations (%)		T 01	**Average % inhibition (-) or stimulation (+)**
6.25			+1.1
12.5			-21
25			-45
50			-71
100			-88
15 minute *Vibrio fischeri* bioluminescent definitive test (% sample concentration)	EC20 value EC50 value		5.9 14
30 minute *Vibrio fischeri* bioluminescent toxicity definitive test sample concentrations (%)			**Average % inhibition (-) or stimulation (+)**
6.25			-4.3
12.5			-28
25			-49
50			-71
100			-86
30 minute *Vibrio fischeri* bioluminescent definitive test (% sample concentration)	EC20 value EC50 value		6.4 15
30 minute *Vibrio fischeri* bioluminescent test toxicity unit (TUa)			6.7

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Table 15: 15/345 Toxicity Results

Toxicity test results		**Method number**	**Sample reference number(s) and description** 15/345 F-14 POND 6B
72h *Selenastrum capricornutum* growth inhibition toxicity definitive test sample concentrations (%)		T 02	**% Growth inhibition (-) or growth stimulation (+)**
6.25			-32
12.5			-9
25			-21
50			-84
100			-70
72h *Selenastrum capricornutum* growth inhibition definitive test (% sample concentration)	EC20 value EC50 value		1.7 49
72h *Selenastrum capricornutum* growth inhibition test toxicity unit (TUa)			2.0

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Table 16: 15/345 Toxicity Results

Toxicity tests results		Method number	Sample reference number(s) and description 15/345 F-14 POND 6B
24h *Daphnia pulex* acute toxicity definitive test sample concentrations (%)		T 03	**Mortality (%)**
6.25			10
12.5			10
25			35
50			45
100			100
24h *Daphnia pulex* acute toxicity definitive test (% sample concentration)	LC10 value LC50 value		10 35
48h *Daphnia pulex* acute toxicity definitive test sample concentrations (%)			**Mortality (%)**
6.25			15
12.5			15
25			45
50			45
100			100
48h *Daphnia pulex* acute toxicity definitive test (% sample concentration)	LC10 value LC50 value		16 40
48h *Daphnia pulex* acute toxicity test toxicity unit (TUa)			2.5

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Mahadi Motsumi
(Quality Manager)

Table 17: 15/345 Toxicity Results

Toxicity test results		**Method number**	**Sample reference number(s) and description** 15/345 F-14 POND 6B
96h *Poecilia reticulata* acute toxicity definitive test sample concentrations (%)		T04	**Mortality (%)**
1.5625			30
3.125			40
6.25			10
12.5			20
25			40
50			100
100			100
96h *Poecilia reticulata* acute toxicity definitive test (% sample concentration)	LC10 value LC50 value		* 26
96h *Poecilia reticulata* acute toxicity test toxicity unit (TUa)			3.8

* *LC10 and LC50 could not be determined by the statistical programme.*

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(Quality Manager)

8.0 ADDITIONAL REQUIREMENTS OR COMMENTS:

The results obtained for the 12 samples collected in the vicinity of Middleburg Ferrochrome (MFC) are presented below followed by the hazard classifications of the sites. Individual bioassay results are discussed as well as the physico-chemical parameters for each site. Individual bioassay toxicity units were determined according to the method of Tonkes & Baltus (1997) (Table 1), whilst the overall Site Hazard Classifications were based on the criteria (Table 18) of Persoone *et al.* (2003). All tests were conducted according to accredited methodologies (Section 6) and adhered to the respective control criteria.

9.0 RESULTS

The Physico-chemical parameters of the samples collected in the vicinity of MFC were within the acceptable Dissolved Oxygen (DO) guidelines of >4 mg/l. The pH of samples should fall within 6-9 in order to limit the effect of pH on the expressed toxicity; pH values outside of this range can drive the expressed toxicity from a physiological point of view as well as by the availability of dissolved ions. Three of the samples collected in the vicinity of MFC (F-10 Dam 4B, F-11 Dam 4A and F-14 Pond 6B) exceeded this range with pH's greater than 9.00.

9.1 15/334 SPK

The physico-chemical parameters for the sample collected from the SPK site measured a pH of 7.7, Electrical Conductivity (EC) of 486 µS/cm and Dissolved Oxygen (DO) concentration of 7.79 mg/l. Total residual Chlorine was not present in this sample. The SPK sample did not indicate toxicity towards the bacterial bioassay *V. fischeri* as the expressed result (6.7% inhibition) did not vary significantly from the control after 30min. The *S. capricornutum* exposure indicated 59% stimulation. Whilst this result does not indicate toxicity towards green algae species, as the stimulation result is ≥20% different from the control, there is an increased probability of algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, Nitrite, Orthophosphate). Both the *D. pulex* and *P. reticulata* toxicity results were statistically different from the controls with 30% mortality and 20% mortality respectively. An effect value which is statistically different from the controls indicates the possibility of long term chronic effects as opposed to short term acute effects. All four bioassays indicated toxicity results below 50% (and therefore no acute effects), these tests could be allocated a toxicity unit of <1 TUa (Limited to Not Acutely toxic).

The Acute Hazard Classification (Table 24) of the water collected at the SPK site indicated a classification of Class II, and therefore a Slight Acute Hazard (A statistically significant Percentage Effect is reached in at least one test, but the effect level is below 50%). The statistically significant Percentage Effect (10% mortality) was exceeded in the *D. pulex* and *P. reticulata* bioassays.

9.2 15/335 SPL

The physico-chemical parameters for the sample collected from the SPL site measured a pH of 7.64, EC of 479 µS/cm and DO concentration of 7.65 mg/l. Total residual Chlorine was not present in this sample. The SPL sample only expressed 0.11% stimulation with *V. fischeri* and 23% stimulation with *S. capricornutum*. Neither of these two bioassays therefore indicated toxicity as a result of the SPL sample. The stimulation indicated by the green algae bioassay was ≥20% when compared to the control growth, there is therefore an increased probability to result in algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, Nitrite, Orthophosphate). The *D. pulex* mortality result was statistically different from the controls with 10% mortality whilst the *P. reticulata* bioassay did not express any toxic results (0% mortality). An effect value which is statistically different from the controls indicates the possibility of long term chronic effects as opposed to short term acute effects. All four bioassays indicated toxicity results below 50% (and therefore no acute effects), these tests could be allocated a toxicity unit of <1 TUa (Limited to Not Acutely toxic).

The Acute Hazard Classification (Table 24) of the water collected at the SPL site indicated a classification of Class II, and therefore a Slight Acute Hazard (A statistically significant Percentage Effect is reached in at least one test, but the effect level is below 50%). The statistically significant Percentage Effect (10% mortality) was reached by the *D. pulex* bioassay.

9.3 15/336 SPJ

The physico-chemical parameters for the sample collected from the SPJ site measured a pH of 7.59, EC of 479 µS/cm and DO concentration of 7.72 mg/l. Total residual Chlorine was present in trace amounts in this sample. The SPJ sample only expressed 4.1% inhibition with *V. fischeri* and 20% stimulation with *S. capricornutum*. Neither of these two bioassays therefore indicated toxicity as a result of exposure to the SPJ sample. The stimulation indicated by the green algae bioassay was ≥20% when compared to the control growth, there is therefore an increased probability to result in algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, Nitrite, Orthophosphate). The *D. pulex* mortality result was statistically different from the controls with 20% mortality whilst the *P. reticulata* bioassay expressed 0% mortality and therefore no toxicity. An effect value which is statistically different from the controls indicates the possibility of long term chronic effects as opposed to short term acute effects. All four bioassays indicated toxicity results below 50% (and therefore no acute effects), these tests could be allocated a toxicity unit of <1 TUa (Limited to Not Acutely toxic).

The Acute Hazard Classification (Table 24) of the water collected at the SPJ site indicated a classification of Class II, and therefore a Slight Acute Hazard (A statistically significant Percentage Effect is reached in at least one test, but the effect level is below 50%). The statistically significant Percentage Effect (10% mortality) was reached by the *D. pulex* bioassay.

9.4 15/337 SPG

The physico-chemical parameters for the sample collected from the SPG site measured a pH of 7.79, EC of 800 µS/cm and DO concentration of 7.66 mg/l. Total residual Chlorine was present in this sample. The SPG sample expressed 2.2% inhibition with *V. fischeri* and 54% stimulation with *S. capricornutum*. Neither of these two bioassays therefore indicated toxicity as a result of exposure to the SPG sample. The stimulation indicated by the green algae bioassay was ≥20% when compared to the control growth, there is therefore an increased probability to result in algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, Nitrite, Orthophosphate). The *D. pulex* mortality result was statistically different from the controls with 30% mortality. The *P. reticulata* bioassay expressed 0% mortality and therefore no toxicity. An effect value which is statistically different from the controls indicates the possibility of long term chronic effects as opposed to short term acute effects. All four bioassays indicated toxicity results below 50% (and therefore no acute effects), these tests could be allocated a toxicity unit of <1 TUa (Limited to Not Acutely toxic).

The Acute Hazard Classification (Table 24) of the water collected at the SPG site indicated a classification of Class II, and therefore a Slight Acute Hazard (A statistically significant Percentage Effect is reached in at least one test, but the effect level is below 50%). The statistically significant Percentage Effect (10% mortality) was exceeded by the *D. pulex* bioassay

9.5 15/338 SPB

The physico-chemical parameters for the sample collected from the SPB site measured a pH of 7.96, EC of 1 036 µS/cm and DO concentration of 7.76 mg/l. Total residual Chlorine was not present in this sample. The SPB sample expressed 3.8% stimulation with *V. fischeri* and 54% stimulation with *S. capricornutum*. Neither of these two bioassays therefore indicated toxicity as a result of exposure to the SPB sample. The stimulation indicated by the green algae bioassay was ≥20% when compared to the control growth, there is therefore an increased probability to result in algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, nitrite, Orthophosphate). The *D. pulex* mortality result was statistically different from the controls with 25% mortality. The *P. reticulata* bioassay expressed 0% mortality and therefore no toxicity. An effect value which is statistically different from the controls indicates the possibility of long term chronic effects as opposed to short term acute effects. All four bioassays indicated toxicity results below 50% (and therefore no acute effects), these tests could be allocated a toxicity unit of <1 TUa (Limited to Not Acutely toxic).

The Acute Hazard Classification (Table 24) of the water collected at the SPB site indicated a classification of Class II, and therefore a Slight Acute Hazard (A statistically significant Percentage Effect is reached in at least one test, but the effect level is below 50%). The statistically significant Percentage Effect (10% mortality) was exceeded by the *D. pulex* bioassay

9.6 15/339 SPD

The physico-chemical parameters for the sample collected from the SPD site measured a pH of 7.93, EC of 1 124 µS/cm and DO concentration of 7.98 mg/l. Total residual Chlorine was not present in this sample. The SPD sample resulted in 35% inhibition with the *V. fischeri* and therefore did vary significantly from the control after 30min. The *S. capricornutum* exposure indicated 50% stimulation. Whilst this result does not indicate toxicity towards green algae species, as the stimulation result is ≥20% different from the control, there is an increased probability of algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, Nitrite, Orthophosphate). The *D. pulex* mortality result was statistically different from the controls with 20% mortality, whilst the *P. reticulata* toxicity results did not indicate toxicity (0% mortality). An effect value which is statistically different from the controls indicates the possibility of long term chronic effects as opposed to short term acute effects. All four bioassays indicated toxicity results below 50% (and therefore no acute effects), these tests could be allocated a toxicity unit of <1 TUa (Limited to Not Acutely toxic).

The Acute Hazard Classification (Table 24) of the water collected at the SPD site indicated a classification of Class II, and therefore a Slight Acute Hazard (A statistically significant Percentage Effect is reached in at least one test, but the effect level is below 50%). The statistically significant Percentage Effect for *S. capricornutum* (20% inhibition) and the statistically significant Percentage Effect for *D. pulex* (10% mortality) was exceeded by this sample.

9.7 15/340 SD9

The physico-chemical parameters for the sample collected from the SD9 site measured a pH of 7.95, EC of 3 520 µS/cm and DO concentration of 6.66 mg/l. Total residual Chlorine was not present in this sample. The SD9 sample resulted in 18% inhibition with the *V. fischeri* and 16% stimulation with *S. capricornutum* and therefore did vary significantly from the controls after the respective exposure periods. The *D. pulex* mortality result expressed 50% mortality and therefore indicates acute toxicity and the potential for sensitive invertebrate species to be affected when exposed to this site water. The *P. reticulata* toxicity results did not indicate toxicity (0% mortality). An effect value which is statistically different from the controls indicates the possibility of long term chronic effects as opposed to short term acute effects. Due to limited toxicity information, it was not possible to assign a toxicity unit to the *P. reticulata* results. However the three remaining bioassays indicated toxicity results below 50% (and therefore no acute effects) and these tests could be allocated a toxicity unit of <1 TUa (Limited to Not Acutely toxic).

The Acute Hazard Classification (Table 24) of the water collected at the SD9 site indicated a classification of Class III (Acute Hazard: The 50% Percentage Effect is reached or exceeded in at least one test, but the effect level is below 100%).The Percentage Effect of 50% was reached in the *D. pulex* bioassay when exposed to the sample collected from SD9.

9.8 15/341 F-10 DAM 4B

The physico-chemical parameters for the sample collected from the F-10 DAM 4B site measured a pH of 9.79, EC of 6 740 µS/cm and DO concentration of 10.73 mg/l. Total residual Chlorine was present in trace amounts in this sample. The pH of this sample was outside the pH range (6-9) in which pH is not a contributor to expressed toxic effects. pH values outside of this range can drive the expressed toxicity from a physiological point of view as well as by the availability of dissolved ions. Due to the elevated EC of this sample, there is an increased likelihood that the pH could be affecting the availability of contaminants to the exposed test organisms. The pH remained >9 even when this samples was diluted to 1.5625% (Table 18).

The water collected from the F-10 DAM 4B site indicated elevated toxicity towards three of the bioassays (*V. fischeri, D. pulex* and *P. reticulata*). The *V. fischeri* indicated 89% inhibition, whilst the *D. pulex* and *P. reticulata* expressed 100% mortality. The *S. capricornutum* expressed 135% stimulation when compared to the control growth. This stimulation result was ≥20% from the control and therefore there is an increased probability of algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, Nitrite, Orthophosphate).

Sufficient statistical data was available from the *V. fischeri, D. pulex* and *P. reticulata* definitive exposures to determine LC/EC50 concentrations as well as the associated toxicity units (TUa). The EC50 for the *V. fischeri* was calculated at a dilution of 19%, and resulted in a toxicity unit of 5.3 TUa. This sample was therefore acutely toxic to bacteria. The LC50 for the *D. pulex* was determined at a dilution of 35% and the *P. reticulata* would need to be diluted to 25%. The toxicity unit for these two bioassays was calculated at 2.9 TUa and 4.0 TUa respectively. Therefore the samples collected from the F-10 DAM 4B site were classified as being Mildly acutely toxic towards sensitive invertebrate and fish species.

Due to the percentage effect of 100% being reached in at least one of the bioassays conducted (*D. pulex* and *P. reticulata*), the Acute Hazard Classification (Table 24) of the water collected from the F-10 DAM 4B site indicated a classification of Class IV, a High Acute Hazard. This site therefore indicates a high potential for only very tolerant taxa to be found.

Table 18: Physical parameters of dilution series after 96hr fish exposure: Sample 15/341 (F-10 DAM 4B site)

Before	pH	EC	DO	After	pH	EC	DO
100%	9.78	6671	9.59	**100%**	9.52	6560	5.94
50%	9.80	3610	7.93	**50%**	9.38	3540	6.08
25%	9.76	2025	7.43	**25%**	9.06	1992	6.27
12.5%	9.67	1223	7.26	**12.5%**	8.78	1208	6.67
6.25%	9.49	773	7.20	**6.25%**	8.48	779	6.64
3.125%	9.23	539	7.16	**3.125%**	8.38	546	6.73
1.5625%	9.23	528	7.33	**1.5625%**	8.64	559	6.41

9.9 15/342 F-11 DAM 4A

The physic-chemical parameters for the sample collected from the F-11 DAM 4A site measured a pH of 9.83, EC of 5 420 µS/cm and DO concentration of 7.73 mg/l. Total residual Chlorine was present in trace amounts in this sample. The pH of this sample was outside the pH range (6-9) in which pH is not a contributor to expressed toxic effects. pH values outside of this range can drive the expressed toxicity from a physiological point of view as well as by the availability of dissolved ions. Due to the elevated EC of this sample, there is an increased likelihood that the pH could be affecting the availability of contaminants to the exposed test organisms. The pH remained >9 even when this samples was diluted to 1.5625% (Table 19).

The water collected from the F-11 DAM 4A site indicated elevated toxicity towards three of the bioassays (*V. fischeri, D. pulex* and *P. reticulata*). The *V. fischeri* indicated 87% inhibition, whilst the *D. pulex* and *P. reticulata* expressed 100% mortality. The *S. capricornutum* expressed 190% stimulation when compared to the control growth. This stimulation result was ≥20% from the control and therefore there is an increased probability of algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, Nitrite, Orthophosphate).

Sufficient statistical data was available from the *V. fischeri, D. pulex* and *P. reticulata* definitive exposures to determine LC/EC50 concentrations as well as the associated toxicity units (TUa). The EC50 for the *V. fischeri* was calculated at a dilution of 25%. The LC50 for the *D. pulex* was determined at a dilution of 46% and the *P. reticulata* would need to be diluted to 38%. The toxicity unit for these three bioassays was calculated at 4.0 TUa, 2.2 TUa and 2.6 TUa respectively. Therefore the samples collected from the F-10 DAM 4B site were classified as being Mildly acutely toxic towards sensitive bacteria, invertebrate and fish species.

Due to the percentage effect of 100% being reached in at least one of the bioassays conducted (*D. pulex* and *P. reticulata*); the Acute Hazard Classification (Table 24) of the water collected from the F-11 DAM 4A site indicated a classification of Class IV, a High Acute Hazard. This site therefore indicates a high potential for only very tolerant taxa to be found.

Table 19: Physical parameters of dilution series after 96hr fish exposure: Sample 15/342 (F-11 DAM 4A)

Before	pH	EC	DO	After	pH	EC	DO
100%	9.84	5380	7.40	**100%**	9.36	5270	6.14
50%	9.83	2940	7.18	**50%**	9.00	2890	6.00
25%	9.73	1707	7.15	**25%**	8.80	1678	6.77
12.5%	9.60	1013	7.13	**12.5%**	8.53	1005	6.89
6.25%	9.35	657	7.14	**6.25%**	8.34	657	6.79
3.125%	9.06	486	7.24	**3.125%**	8.46	499	6.80

9.10 15/343 F-12 DAM 3B

The physic-chemical parameters for the sample collected from the F-12 DAM 3B site measured a pH of 8.59, EC of 5 750 µS/cm and DO concentration of 7.24 mg/l. Total residual Chlorine was present in this sample. The pH of this sample was within the pH range (6-9) in which pH is not a contributor to expressed toxic effects.

The water collected from the F-12 DAM 3B site indicated elevated toxicity towards the *P. reticulata* bioassay with 100% mortality. Sufficient statistical data was available from *P. reticulata* definitive exposure to determine the LC50 concentration at 62% and a toxicity unit of 1.6 TUa. This sample therefore expressed Negligible Acute Toxicity towards fish. The *V. fischeri* results did not vary significantly from the control (19% inhibition), whilst the *D. pulex* bioassay exceeded the statistically significant percentage effect with 25% mortality. An effect value which is statistically different from the controls indicates the possibility of long term chronic effects as opposed to short term acute effects. The *S. capricornutum* expressed 135% stimulation when compared to the control growth. This stimulation result was ≥20% from the control and therefore there is an increased probability of algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, Nitrite, Orthophosphate). The results from these three bioassays did not exceed 50% and therefore a toxicity unit of <1 TUa (Limited to Not Acutely Toxic) could be assigned for bacteria, algae and invertebrates.

Due to the percentage effect of 100% being reached in at least one of the bioassays conducted (*P. reticulata*), the Acute Hazard Classification (Table 24) of the water collected from the F-12 DAM 3B site indicated a classification of Class IV, a High Acute Hazard. This site therefore indicates a high potential for only very tolerant taxa to be found.

Table 20: Physical parameters of dilution series after 96hr fish exposure: Sample 15/343 (F-12 DAM 3B)

Before	pH	EC	DO	After	pH	EC	DO
100%	8.52	5710	7.05	**100%**	8.82	5520	5.65
50%	8.56	3140	7.07	**50%**	8.80	3090	6.59
25%	8.54	1814	7.08	**25%**	8.60	1780	6.63
12.5%	8.49	1089	7.09	**12.5%**	8.40	1074	6.61
6.25%	8.46	709	7.08	**6.25%**	8.28	717	6.32

9.11 15/344 F-13 DAM 3A

The physic-chemical parameters for the sample collected from the F-13 DAM 3A site measured a pH of 8.94, EC of 5 080 µS/cm and DO concentration of 8.30 mg/l. Total residual Chlorine was not present in this sample. The pH of this sample was within the pH range (6-9) in which pH is not a contributor to expressed toxic effects.

The water collected from the F-13 DAM 3A site indicated elevated toxicity towards the *P. reticulata* bioassay with 100% mortality. Sufficient statistical data was available from *P. reticulata* definitive exposure to determine the LC50 concentration at 59% and a toxicity unit of 1.7 TUa. This sample therefore expressed Negligible Acute Toxicity towards fish. The *V. fischeri* and the *D. pulex* bioassay results exceeded the statistically significant percentage effect with results indicating 30% inhibition and 15% mortality respectively. An effect value which is statistically different from the controls, but less than 50%, indicates the possibility of long term chronic effects as opposed to short term acute effects. The *S. capricornutum* expressed 102% stimulation when compared to the control growth. This stimulation result was ≥20% from the control and therefore there is an increased probability of algal blooms should this water be released into an aquatic resource. This algae stimulation could be as a result of increased nutrient availability in the sample (e.g. Nitrate, Nitrite, Orthophosphate). The results from these three bioassays did not exceed 50% and therefore a toxicity unit of <1 TUa (Limited to Not Acutely Toxic) could be assigned for bacteria, algae and invertebrates.

Due to the percentage effect of 100% being reached in at least one of the bioassays conducted (*P. reticulata*), the Acute Hazard Classification (Table 24) of the water collected from the F-13 DAM 3A site indicated a classification of Class IV, a High Acute Hazard. This site therefore indicates a high potential for only very tolerant taxa to be found.

Table 21: Physical parameters of dilution series after 96hr fish exposure: Sample 15/344 (F-13 DAM 3A)

Before	pH	EC	DO	After	pH	EC	DO
100%	8.93	4990	7.75	**100%**	8.81	4600	6.01
50%	8.93	2730	7.36	**50%**	8.43	1790	6.77
25%	8.85	1571	7.21	**25%**	8.60	1562	6.71
12.5%	8.70	960	7.15	**12.5%**	8.39	629	6.70
6.25%	8.60	638	7.09	**6.25%**	8.27	320	6.33

9.12 15/345 F-14 POND 6B

The physic-chemical parameters for the sample collected from the F-14 POND 6B site measured a pH of 9.99, EC of 5 410 µS/cm and DO concentration of 11.01 mg/l. Total residual Chlorine was not present in this sample. The pH of this sample was outside the pH range (6-9) in which pH is not a contributor to expressed toxic effects. pH values outside of this range can drive the expressed toxicity from a physiological point of view as well as by the availability of dissolved ions. Due to the elevated EC of this sample, there is an increased likelihood that the pH could be affecting the availability of contaminants to the exposed test organisms. The pH remained >9 even when this samples was diluted to 1.5625% (Table 24).

The water collected from the F-14 POND 6B site indicated elevated toxicity towards all four of the bioassays (*V. fischeri, S. capricornutum, D. pulex* and *P. reticulata*). The *V. fischeri* indicated 86% inhibition, whilst the *D. pulex* and *P. reticulata* expressed 100% mortality. The *S. capricornutum* expressed 70% inhibition when compared to the control growth. Sufficient statistical data was available from the definitive exposures to determine LC/EC50 concentrations as well as the associated toxicity units (TUa). The EC50 value for the *V. fischeri* was calculated at a dilution of 15%, and resulted in a toxicity unit of 6.7 TUa. The EC50 for the *S. capricornutum* was determined at a dilution of 49% and a toxicity unit of 2.0 TUa. The *D. pulex* would need to be diluted to 40% and the *P. reticulata* would need to be diluted to 26% in order to reach their LC50. The toxicity unit for these two bioassays was calculated at 2.5 TUa and 3.8 TUa respectively. Therefore based on the toxicity unit results, the sample collected from the F-14 POND 6B site was classified as being Mildly acutely toxic towards sensitive invertebrate, algae, invertebrate and fish species.

Due to the percentage effect of 100% being reached in at least one of the bioassays conducted (*D. pulex* and *P. reticulata*), the Acute Hazard Classification (Table 24) of the water collected from the F-14 POND 6B site indicated a classification of Class IV, a High Acute Hazard. This site therefore indicates a high potential for only very tolerant taxa to be found.

Table 22: Physical parameters of dilution series after 96hr fish exposure: Sample 15/345 (F-14 POND 6B)

Before	pH	EC	DO	After	pH	EC	DO
100%	10.00	5350	10.55	**100%**	9.54	5000	6.25
50%	9.97	2840	8.02	**50%**	9.29	1930	6.35
25%	9.91	1535	7.44	**25%**	8.92	1510	6.59
12.5%	9.77	933	7.23	**12.5%**	8.53	936	6.60
6.25%	9.55	616	7.15	**6.25%**	8.39	596	6.84
3.125%	9.30	465	7.14	**3.125%**	8.23	469	6.77
1.5625%	9.09	384	7.14	**1.5625%**	8.27	391	6.71

9.13 Hazard Classification and Discussion

Various types of toxicity classification systems have been developed by scientists in different countries to be able to assign a hazard score to polluted environments (Persoone *et al.* 2003). Using a hazard classification system developed by Persoone *et al.* (2003) one can classify sites using the toxicity data of the non-diluted samples. The percentage effect of toxicity (PE) (Mortality or inhibition of growth, luminescence, reproduction or feeding) is used to rank the water sample into one of five classes (Table 18) based on the highest toxic response shown in at least one of the tests applied (Persoone *et al.* 2003).

Table 23: Acute Hazard Classification system for natural waters (Persoone et al. 2003)

	Class	Hazard	Percentage Effect
	I	No acute hazard	None of the tests show a toxic effect (i.e. an effect value that is significantly higher than that in the controls).
	II	Slight acute hazard.	A statistically significant PE is reached in at least one test, but the effect level is below 50%.
	III	Acute hazard.	The 50% Percentage Effect (PE50) is reached or exceeded in at least one test, but the effect level is below 100%.
	IV	High acute hazard, tolerant taxa present.	The PE100 is exceeded in at least one test.
	V	Very high acute hazard.	The PE100 is exceeded in all tests.

Table 24: Hazard Classification of Samples collected from MFC in May 2015

		Hazard Class	Percentage Effect
15/334	SPK	II	A statistically significant PE is reached in at least one test, but the effect level is below 50%.
15/335	SPL	II	A statistically significant PE is reached in at least one test, but the effect level is below 50%.
15/336	SPJ	II	A statistically significant PE is reached in at least one test, but the effect level is below 50%.
15/337	SPG	II	A statistically significant PE is reached in at least one test, but the effect level is below 50%.
15/338	SPB	II	A statistically significant PE is reached in at least one test, but the effect level is below 50%.
15/339	SPD	II	A statistically significant PE is reached in at least one test, but the effect level is below 50%.
15/340	SD9	III	The 50% Percentage Effect is reached or exceeded in at least one test, but the effect level is below 100%.
15/341	F-10 DAM 4B	IV	The PE100 is exceeded in at least one test.
15/342	F-11 DAM 4A	IV	The PE100 is exceeded in at least one test.
15/343	F-12 DAM 3B	IV	The PE100 is exceeded in at least one test.
15/344	F-13 DAM 3A	IV	The PE100 is exceeded in at least one test.
15/345	F-14 POND 6B	IV	The PE100 is exceeded in at least one test.

From the screening and undiluted definitive results, the samples collected from SPK, SPL, SPJ, SPG, SPB and SPD were classified as having a slight acute hazard due to at least one of the environmental bioassay results exceeding the statistically significant percentage effect (PE) with the indicator organisms. The samples collected from SPL, SPJ, SPG and SPB reached or exceeded the PE of 10% for *D. pulex*, whilst the sample collected from SPK exceeded the PE (10% mortality) for both *D. pulex* and *P. reticulata*. The sample collected from the SPO site exceeded the PE of 20% inhibition for *V. fischeri* as well as the PE (10% mortality) for *D. pulex*. The sample collected from the SD9 site was classified as having an acute hazard due to the 50% percentage effect being reached in the *D. pulex* bioassay exposure. The samples collected from F-10 Dam 4B, F-11 Dam 4A, F-12 Dam 3B, F-13 Dam 3A and F-14 Pond 6B were all classed as having a high acute hazard due to the percentage effect of 100% being reached in at least one test. This classification was due to all five of these samples reaching 100% mortality in the *P. reticulata* bioassay. The *D. pulex* bioassay additionally indicated 100% mortality in the F-10 Dam 4B, F-11 Dam 4A and F-14 Pond 6B samples. The sample collected from the F-14 Pond 6B site indicated 70% inhibition with the *S. capricornutum*, whilst the sample collected SD9 expressed algal stimulation <20% and therefore not significantly different from the control. The remaining 10 samples reached or exceeded 20% stimulation with the *S. capricornutum* and therefore there is a potential for algal blooms to occur at these sites or at sites exposed to these samples. Causes for this increased algae stimulation should be identified and addressed.

From the bioassay results, the toxicity indicated that the samples collected from the SD9, F-10 Dam 4B, F-11 Dam 4A, F-12 Dam 3B, F-13 Dam 3A and F-14 Pond 6B sites have the potential to result in acute effects in the aquatic environment and therefore impact the ecological integrity. The samples collected from the SPK, SPL, SPJ, SPG, SPB and SPD sites do not currently pose an acute effect towards the aquatic environment, however, long term changes may be seen in the invertebrate composition at impacted sites exposed to these samples.

Please note:
Opinions and Interpretations expressed herein are outside the scope of SANAS accreditation.

Any queries regarding the results should be lodged with Mahadi Motsumi within 14 days from the date of report receipt. The samples cannot be retained from the date of this report. If any queries relating to the results associated with these samples are received, then re-sampling will have to take place.

10.0 REFERENCES

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GOLDER ASSOCIATES RESEARCH LABORATORY (PTY) LTD.

Mahadi Motsumi
Quality Manager

MM

Reg. No. 2006/020508/07
Director: RGM Heath

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Attention :	Ilse Snyman
Date :	17th June, 2015
Your reference :	1418954
Our reference :	Test Report 15/8219 Batch 1
Location :	Middelburg Ferrochrome (MFC)
Date samples received :	3rd June, 2015
Status :	Final report
Issue :	1

Thirty five samples were received for analysis on 3rd June, 2015 of which thirty four were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

NOTE: Under International Laboratory Accreditation Cooperation (ILAC), ISO 17025 (UKAS) accreditation is recognised as equivalent to SANAS (South Africa) accreditation.

Compiled By:

Simon Gomery BSc
Project Manager

Bob Millward BSc FRSC
Principal Chemist

Client Name:	Golder Associates Africa Ltd	**Report :**	**Solid**
Reference:	1418954		
Location:	Middelburg Ferrochrome (MFC)	**Solids:** V=60g VOC jar, J=250g glass jar, T=plastic tub	
Contact:	Ilse Snyman		
JE Job No.:	15/8219		

Please see attached notes for all abbreviations and acronyms

J E Sample No.	1-4	5-8	9-10	11	12	13	14	15	16	17-18			
Sample ID	SD3	SD9	SD11	HARSCO RUN-OFF	HARSCO TRENCH A	HARSCO TRENCH B	HARSCO (CAMISIL)	SP2	MB01	FACILITY 9 - RWD1			
Depth													
COC No / misc													
Containers	V B	V B	B	B	B	B	B	B	B	B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	27/05/2015	27/05/2015	26/05/2015	26/05/2015	26/05/2015			
Sample Type	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Aluminium	26890	19710	21700	26670	9967	17510	25940	10360	16380	28420	<50	mg/kg	TM30/PM15
Antimony	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	mg/kg	TM30/PM15
Arsenic	2.6	6.6	12.1	14.1	<0.5	1.9	7.1	<0.5	2.5	20.9	<0.5	mg/kg	TM30/PM15
Arsenic #	-	-	-	-	-	-	-	-	-	-	<0.5	mg/kg	TM30/PM15
Barium	180	188	420	693	231	264	235	189	270	432	<1	mg/kg	TM30/PM15
Barium #	-	-	-	-	-	-	-	-	-	-	<1	mg/kg	TM30/PM15
Beryllium	1.8	1.3	1.9	2.4	<0.5	0.8	1.7	<0.5	0.7	2.2	<0.5	mg/kg	TM30/PM15
Cadmium	<0.1	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	0.3	<0.1	<0.1	<0.1	mg/kg	TM30/PM15
Cadmium #	-	-	-	-	-	-	-	-	-	-	<0.1	mg/kg	TM30/PM15
Calcium	5534	12170	5636	8811	249400	168800	4439	215500	194400	10130	<500	mg/kg	TM30/PM15
Chromium	1075.0_{AB}	1084.0_{AB}	590.3_{AB}	950.3_{AB}	1708.0_{AC}	1429.0_{AC}	562.3_{AB}	1335.0_{AC}	671.4_{AB}	678.9_{AB}	<0.5	mg/kg	TM30/PM15
Chromium #	-	-	-	-	-	-	-	-	-	-	<0.5	mg/kg	TM30/PM15
Cobalt	15.9	29.6	50.4	43.8	9.1	21.1	30.8	10.6	12.5	68.4	<0.5	mg/kg	TM30/PM15
Cobalt #	-	-	-	-	-	-	-	-	-	-	<0.5	mg/kg	TM30/PM15
Copper	33	26	64	46	23	33	35	74	35	51	<1	mg/kg	TM30/PM15
Copper #	-	-	-	-	-	-	-	-	-	-	<1	mg/kg	TM30/PM15
Iron	36320	55130_{AB}	86740_{AB}	78590_{AB}	16930	33000	56060_{AB}	17950	30550	90390_{AB}	<20	mg/kg	TM30/PM15
Lead	18	24	40	35	18	24	38	36	19	32	<5	mg/kg	TM30/PM15
Lead #	-	-	-	-	-	-	-	-	-	-	<5	mg/kg	TM30/PM15
Magnesium	1937	3371	1445	2126	55910	33030	2944	52220	32120	3749	<25	mg/kg	TM30/PM15
Manganese	580	866	2090	3499_{AB}	3547_{AB}	1955	1568	2416	1512	2776_{AB}	<1	mg/kg	TM30/PM15
Manganese #	-	-	-	-	-	-	-	-	-	-	<1	mg/kg	TM30/PM15
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	mg/kg	TM30/PM15
Mercury #	-	-	-	-	-	-	-	-	-	-	<0.1	mg/kg	TM30/PM15
Molybdenum	28.3_{AB}	45.8_{AB}	73.5_{AB}	27.4_{AB}	21.5	18.0	7.5	32.6_{AB}	8.0	5.5	<0.1	mg/kg	TM30/PM15
Molybdenum #	-	-	-	-	-	-	-	-	-	-	<0.1	mg/kg	TM30/PM15
Nickel	54.1	45.6	50.2	72.0	190.1	169.4	80.4	211.7	86.7	67.3	<0.7	mg/kg	TM30/PM15
Nickel #	-	-	-	-	-	-	-	-	-	-	<0.7	mg/kg	TM30/PM15
Phosphorus	318	154	196	645	51	323	175	89	154	304	<10	mg/kg	TM30/PM15
Potassium	2182	2091	2091	2322	484	1964	1411	977	1019	2683	<5	mg/kg	TM30/PM15
Selenium	1	1	2	2	2	2	2	2	2	2	<1	mg/kg	TM30/PM15
Selenium #	-	-	-	-	-	-	-	-	-	-	<1	mg/kg	TM30/PM15
Sodium	772	1348	863	282	540	1433	201	920	443	1688	<5	mg/kg	TM30/PM15
Vanadium	98	97	130	110	128	93	103	121	80	189	<1	mg/kg	TM30/PM15
Boron (Aqua Regia Soluble)	<0.25	<0.25	<0.25	<0.25	33.97	38.24	<0.25	41.62	9.72	<0.25	<0.25	mg/kg	TM30/PM15
Zinc	154	69	95	188	229	392	120	384	221	521	<5	mg/kg	TM30/PM15
Zinc #	-	-	-	-	-	-	-	-	-	-	<5	mg/kg	TM30/PM15
Aluminium (2:1 Ext)	0.15	0.96	0.87	1.55	<0.02	2.27	0.34	<0.02	<0.02	<0.02	<0.02	mg/l	TM30/PM20
Antimony (2:1 Ext)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	mg/l	TM30/PM20
Arsenic (2:1 Ext)	0.0047	0.0104	0.0129	0.0047	0.0050	0.0089	0.0057	0.0025	0.0041	0.0066	<0.0025	mg/l	TM30/PM20
Barium (2:1 Ext)	0.083	0.047	0.025	0.035	0.044	0.015	0.104	0.016	0.025	0.025	<0.003	mg/l	TM30/PM20
Beryllium (2:1 Ext)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	mg/l	TM30/PM20
Cadmium (2:1 Ext)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	0.0008	<0.0005	mg/l	TM30/PM20
Calcium (2:1 Ext)	127.2	24.1	13.7	23.2	91.9	149.2	46.8	48.0	11.1	498.2_{AB}	<0.2	mg/l	TM30/PM20

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Jones Environmental Laboratory

Client Name:	Golder Associates Africa Ltd	**Report :**	**Solid**
Reference:	1418954		
Location:	Middelburg Ferrochrome (MFC)	**Solids:** V=60g VOC jar, J=250g glass jar, T=plastic tub	
Contact:	Ilse Snyman		
JE Job No.:	15/8219		

Please see attached notes for all abbreviations and acronyms

J E Sample No.	1-4	5-8	9-10	11	12	13	14	15	16	17-18			
Sample ID	SD3	SD9	SD11	HARSCO RUN-OFF	HARSCO TRENCH A	HARSCO TRENCH B	HARSCO (CAMISIL)	SP2	MB01	FACILITY 9 - RWD1			
Depth													
COC No / misc													
Containers	V B	V B	B	B	B	B	B	B	B	B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	27/05/2015	27/05/2015	26/05/2015	26/05/2015	26/05/2015			
Sample Type	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Chromium (2:1 Ext)	0.0345	0.1190	0.1975	0.3405	0.8393	4.2680_{AB}	0.0343	0.3573	0.1329	0.0040	<0.0015	mg/l	TM30/PM20
Cobalt (2:1 Ext)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	mg/l	TM30/PM20
Copper (2:1 Ext)	0.018	0.018	0.016	<0.007	<0.007	0.011	0.008	<0.007	<0.007	0.010	<0.007	mg/l	TM30/PM20
Iron (2:1 Ext)	0.11	0.45	0.43	0.75	<0.02	<0.02	0.22	<0.02	<0.02	<0.02	<0.02	mg/l	TM30/PM20
Lead (2:1 Ext)	0.005	<0.005	<0.005	0.008	0.051	<0.005	0.011	0.069	0.008	<0.005	<0.005	mg/l	TM30/PM20
Magnesium (2:1 Ext)	33.7	3.6	3.7	7.9	0.1	<0.1	15.4	2.7	10.6	200.1_{AB}	<0.1	mg/l	TM30/PM20
Manganese (2:1 Ext)	0.506	0.028	0.018	0.007	<0.002	<0.002	0.019	<0.002	<0.002	0.051	<0.002	mg/l	TM30/PM20
Mercury (2:1 Ext)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	mg/l	TM30/PM20
Molybdenum (2:1 Ext)	0.832	3.948_{AB}	5.821_{AB}	0.442	0.752	2.130	0.076	0.429	0.249	0.085	<0.002	mg/l	TM30/PM20
Nickel (2:1 Ext)	0.024	0.013	0.018	0.005	<0.002	0.003	0.013	<0.002	0.004	0.007	<0.002	mg/l	TM30/PM20
Phosphorus (2:1 Ext)	0.196	0.061	0.037	0.100	0.007	0.008	0.053	0.014	0.022	0.057	<0.005	mg/l	TM30/PM20
Potassium (2:1 Ext)	52.2	95.9	62.3	16.1	10.4	34.6	7.2	6.7	12.8	210.8_{AB}	<0.1	mg/l	TM30/PM20
Selenium (2:1 Ext)	<0.003	0.004	<0.003	<0.003	0.009	<0.003	0.003	<0.003	<0.003	<0.003	<0.003	mg/l	TM30/PM20
Sodium (2:1 Ext)	177.7	323.5_{AB}	256.6_{AB}	39.0	83.9	37.4	18.4	60.8	41.9	594.5_{AB}	<0.1	mg/l	TM30/PM20
Vanadium (2:1 Ext)	0.0035	0.0070	0.0047	0.0049	0.3265	0.0274	0.0033	0.8650	0.0151	<0.0015	<0.0015	mg/l	TM30/PM20
Zinc (2:1 Ext)	0.011	0.007	0.008	0.009	0.005	0.005	0.007	0.006	0.007	0.013	<0.003	mg/l	TM30/PM20
Aluminium (Water Soluble)	0.30	1.92	1.74	3.10	<0.04	4.54	0.68	<0.04	<0.04	<0.04	<0.04	mg/kg	TM30/PM20
Antimony (Water Soluble)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM20
Arsenic (Water Soluble)	0.009	0.021	0.026	0.009	0.010	0.018	0.011	0.005	0.008	0.013	<0.005	mg/kg	TM30/PM20
Barium (Water Soluble)	0.166	0.094	0.050	0.070	0.088	0.030	0.208	0.032	0.050	0.050	<0.006	mg/kg	TM30/PM20
Beryllium (Water Soluble)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	mg/kg	TM30/PM20
Cadmium (Water Soluble)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	mg/kg	TM30/PM20
Calcium (Water Soluble)	254.4	48.2	27.4	46.4	183.8	298.4	93.6	96.0	22.2	996.4_{AB}	<0.4	mg/kg	TM30/PM20
Chromium (Water Soluble)	0.069	0.238	0.395	0.681	1.679	8.536_{AB}	0.069	0.715	0.266	0.008	<0.003	mg/kg	TM30/PM20
Cobalt (Water Soluble)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM20
Copper (Water Soluble)	0.036	0.036	0.032	<0.014	<0.014	0.022	0.016	<0.014	<0.014	0.020	<0.014	mg/kg	TM30/PM20
Iron (Water Soluble)	0.22	0.90	0.86	1.50	<0.04	<0.04	0.44	<0.04	<0.04	<0.04	<0.04	mg/kg	TM30/PM20
Lead (Water Soluble)	0.01	<0.01	<0.01	0.02	0.10	<0.01	0.02	0.14	0.02	<0.01	<0.01	mg/kg	TM30/PM20
Magnesium (Water Soluble)	67.4	7.2	7.4	15.8	0.2	<0.2	30.8	5.4	21.2	400.2_{AB}	<0.2	mg/kg	TM30/PM20
Manganese (Water Soluble)	1.012	0.056	0.036	0.014	<0.004	<0.004	0.038	<0.004	<0.004	0.102	<0.004	mg/kg	TM30/PM20
Mercury (Water Soluble)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	mg/kg	TM30/PM20
Molybdenum (Water Soluble)	1.664	7.896_{AB}	11.642_{AB}	0.884	1.504	4.260	0.152	0.858	0.498	0.170	<0.004	mg/kg	TM30/PM20
Nickel (Water Soluble)	0.048	0.026	0.036	0.010	<0.004	0.006	0.026	<0.004	0.008	0.014	<0.004	mg/kg	TM30/PM20
Phosphorus (Water Soluble)	0.39	0.12	0.07	0.20	0.01	0.02	0.11	0.03	0.04	0.11	<0.01	mg/kg	TM30/PM20
Potassium (Water Soluble)	104.4	191.8	124.6	32.2	20.8	69.2	14.4	13.4	25.6	421.6_{AB}	<0.2	mg/kg	TM30/PM20
Selenium (Water Soluble)	<0.006	0.008	<0.006	<0.006	0.018	<0.006	0.006	<0.006	<0.006	<0.006	<0.006	mg/kg	TM30/PM20
Sodium (Water Soluble)	355.4	647.0_{AB}	513.2_{AB}	78.0	167.8	74.8	36.8	121.6	83.8	1189.0_{AB}	<0.2	mg/kg	TM30/PM20
Vanadium (Water Soluble)	0.007	0.014	0.009	0.010	0.653	0.055	0.007	1.730	0.030	<0.003	<0.003	mg/kg	TM30/PM20
Zinc (Water Soluble)	0.022	0.014	0.016	0.018	0.010	0.010	0.014	0.012	0.014	0.026	<0.006	mg/kg	TM30/PM20
Natural Moisture Content	120.8	42.9	31.3	34.4	54.5	1.3	67.3	0.3	5.8	10.3	<0.1	%	PM4/PM0
Ammoniacal Nitrogen as NH4 (water soluble)	<0.6	<0.6	<0.6	<0.6	<0.6	1.2	<0.6	<0.6	<0.6	3.0	<0.6	mg/kg	TM38/PM20
Hexavalent Chromium	<0.3	1.6	0.8	0.9	3.1	1.6	<0.3	0.6	1.8	0.8	<0.3	mg/kg	TM38/PM20

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	1-4	5-8	9-10	11	12	13	14	15	16	17-18			
Sample ID	SD3	SD9	SD11	HARSCO RUN-OFF	HARSCO TRENCH A	HARSCO TRENCH B	HARSCO (CAMISIL)	SP2	MB01	FACILITY 9 - RWD1			
Depth													
COC No / misc													
Containers	V B	V B	B	B	B	B	B	B	B	B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	27/05/2015	27/05/2015	26/05/2015	26/05/2015	26/05/2015			
Sample Type	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Hexavalent Chromium #	-	-	-	-	-	-	-	-	-	-	<0.3	mg/kg	TM38/PM20
Chloride (2:1 Ext)	96	121	78	9	19	25	7	16	5	128	<1	mg/l	TM38/PM20
Chloride (2:1 Ext) #	-	-	-	-	-	-	-	-	-	-	<1	mg/l	TM38/PM20
Fluoride (2:1 Ext)	2.75	8.30	9.25	3.50	4.15	<0.15	2.00	10.25AA	8.90	5.65	<0.15	mg/l	TM27/PM20
Hexavalent Chromium (2:1 Ext)	<0.15	<0.15	<0.15	<0.15	0.54	0.50	<0.15	0.21	<0.15	<0.15	<0.15	mg/l	TM38/PM20
Nitrate as NO3 (2:1 Ext)	<1.25	30.60	<1.25	<1.25	10.10	136.59	6.55	19.09	9.48	13.02	<1.25	mg/l	TM38/PM20
Nitrate as NO3 (2:1 Ext) #	-	-	-	-	-	-	-	-	-	-	<1.25	mg/l	TM38/PM20
Sulphate as SO4 (2:1 Ext)	564.2	412.5	275.1	40.0	167.5	103.6	80.6	61.1	35.6	2803.5	<1.5	mg/l	TM38/PM20
Sulphate as SO4 (2:1 Ext) #	-	-	-	-	-	-	-	-	-	-	<1.5	mg/l	TM38/PM20
Chloride (Water Soluble)	192	242	156	18	38	50	14	32	10	256	<2	mg/kg	TM38/PM20
Chloride (Water Soluble) #	-	-	-	-	-	-	-	-	-	-	<2	mg/kg	TM38/PM20
Fluoride (Water Soluble)	5.5	16.6	18.5	7.0	8.3	<0.3	4.0	20.5AA	17.8	11.3	<0.3	mg/kg	TM27/PM20
Nitrate as NO3 (Water Soluble)	<2.5	61.2	<2.5	<2.5	20.2	273.2	13.1	38.2	19.0	26.0	<2.5	mg/kg	TM38/PM20
Nitrate as NO3 (Water Soluble) #	-	-	-	-	-	-	-	-	-	-	<2.5	mg/kg	TM38/PM20
Sulphate as SO4 (Water Soluble)	1128	825	550	80	335	207	161	122	71	5607	<3	mg/kg	TM38/PM20
Sulphate as SO4 (Water Soluble) #	-	-	-	-	-	-	-	-	-	-	<3	mg/kg	TM38/PM20
Electrical Conductivity @25C (2:1 Ext)	1555	1604	1182	347	746	1444	393	492	346	3673	<2	uS/cm	TM76/PM20
pH (2:1 Ext)	7.85	8.49	8.62	8.36	10.88	11.56	8.05	10.44	9.30	7.90	<0.01	pH units	TM73/PM20
Total Dissolved Solids (2:1 Ext)	1312	1110	804	212	830	1072	366	517	215	5142	<10	mg/l	TM20/PM20
Total Dissolved Solids (Water Soluble)	2624	2220	1608	424	1660	2144	732	1034	430	10284	<20	mg/kg	TM20/PM20
Ammoniacal Nitrogen as NH4 (2:1 Ext)	<0.3	<0.3	<0.3	<0.3	<0.3	0.6	<0.3	<0.3	<0.3	1.3	<0.3	mg/l	TM38/PM20
Hexavalent Chromium (water soluble)	<0.3	<0.3	<0.3	<0.3	1.7	1.0	<0.3	0.4	<0.3	<0.3	<0.3	mg/kg	TM38/PM20

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : **Solid**

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	19-20	21-24	25-28	29	30	31-32	33	34-35	36	37			
Sample ID	FACILITY 9 - RWD2	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	FACILITY 12 DAM 3B	FACILITY 13 DAM 3A	FACILITY 14 POND 6B	FACILITY 7 (3)	FACILITY 8 (3)	FACILITY 1 (2)	FACILITY 2 (2)			
Depth													
COC No / misc													
Containers	B	V B	V B	B	B	B	B	B	B	B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	25/05/2015	26/05/2015	26/05/2015	25/05/2015	25/05/2015			
Sample Type	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Soil	Soil	Soil	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Aluminium	28910	20870	32140	14950	24690	11690	18970	16210	48490	5529	<50	mg/kg	TM30/PM15
Antimony	<1	<1	<1	<1	<1	<1	<1	<1	<5$_{AB}$	<1	<1	mg/kg	TM30/PM15
Arsenic	19.2	83.3	<0.5	<0.5	32.7	<0.5	-	-	-	1.0	<0.5	mg/kg	TM30/PM15
Arsenic$^{\#}$	-	-	-	-	-	-	13.1	20.5	<0.5	-	<0.5	mg/kg	TM30/PM15
Barium	195	323	73	106	308	100	-	-	-	68	<1	mg/kg	TM30/PM15
Barium$^{\#}$	-	-	-	-	-	-	129	99	40	-	<1	mg/kg	TM30/PM15
Beryllium	1.9	3.0	0.8	0.7	1.1	0.7	2.0	2.0	0.6	<0.5	<0.5	mg/kg	TM30/PM15
Cadmium	<0.1	<0.1	0.1	<0.1	<0.1	0.1	-	-	-	<0.1	<0.1	mg/kg	TM30/PM15
Cadmium$^{\#}$	-	-	-	-	-	-	<0.1	<0.1	<0.1	-	<0.1	mg/kg	TM30/PM15
Calcium	5411	934	201800	49820	82830	71430	1078	1539	255100	11040	<500	mg/kg	TM30/PM15
Chromium	268.4$_{AB}$	282.5$_{AB}$	4155.0$_{AD}$	3509.0$_{AD}$	2949.0$_{AE}$	6568.0$_{AE}$	-	-	-	21.7	<0.5	mg/kg	TM30/PM15
Chromium$^{\#}$	-	-	-	-	-	-	210.3	363.7$_{AB}$	7702.0$_{AE}$	-	<0.5	mg/kg	TM30/PM15
Cobalt	45.5	20.4	14.4	36.5	44.0	67.7	-	-	-	5.3	<0.5	mg/kg	TM30/PM15
Cobalt$^{\#}$	-	-	-	-	-	-	23.7	51.6	3.6	-	<0.5	mg/kg	TM30/PM15
Copper	80	74	46	118	75	43	-	-	-	8	<1	mg/kg	TM30/PM15
Copper$^{\#}$	-	-	-	-	-	-	33	32	8	-	<1	mg/kg	TM30/PM15
Iron	88940$_{AB}$	95180$_{AB}$	20520	41740	56950$_{AB}$	43090	77230$_{AB}$	77630$_{AB}$	3914	1702	<20	mg/kg	TM30/PM15
Lead	15	34	10	25	64	35	-	-	-	<5	<5	mg/kg	TM30/PM15
Lead$^{\#}$	-	-	-	-	-	-	23	28	<5	-	<5	mg/kg	TM30/PM15
Magnesium	4060	2484	42060	15780	36650	24130	944	804	43040	3047	<25	mg/kg	TM30/PM15
Manganese	714	1126	1127	1161	2643$_{AB}$	1911	-	-	-	57	<1	mg/kg	TM30/PM15
Manganese$^{\#}$	-	-	-	-	-	-	502	645	1435	-	<1	mg/kg	TM30/PM15
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	-	<0.1	<0.1	mg/kg	TM30/PM15
Mercury$^{\#}$	-	-	-	-	-	-	0.1	0.1	<0.1	-	<0.1	mg/kg	TM30/PM15
Molybdenum	4.7	34.8$_{AB}$	7.0	7.8	579.2$_{AE}$	6.6	-	-	-	1.7	<0.1	mg/kg	TM30/PM15
Molybdenum$^{\#}$	-	-	-	-	-	-	3.5	3.7	2.1	-	<0.1	mg/kg	TM30/PM15
Nickel	73.3	81.7	177.2	102.2	1726.0$_{AC}$	388.8$_{AB}$	-	-	-	7.4	<0.7	mg/kg	TM30/PM15
Nickel$^{\#}$	-	-	-	-	-	-	31.4	34.6	37.8	-	<0.7	mg/kg	TM30/PM15
Phosphorus	287	395	160	135	163	346	191	324	61	237	<10	mg/kg	TM30/PM15
Potassium	2111	4606	2665	1646	979	3709	1137	1134	236	147	<5	mg/kg	TM30/PM15
Selenium	<1	3	1	<1	2	1	-	-	-	<1	<1	mg/kg	TM30/PM15
Selenium$^{\#}$	-	-	-	-	-	-	1	1	1	-	<1	mg/kg	TM30/PM15
Sodium	876	970	1560	674	411	2475	108	174	294	125	<5	mg/kg	TM30/PM15
Vanadium	304$_{AB}$	113	133	82	127	74	150	159	165	8	<1	mg/kg	TM30/PM15
Boron (Aqua Regia Soluble)	<0.25	<0.25	14.11	<0.25	<0.25	<0.25	<0.25	<0.25	7.63	18.83	<0.25	mg/kg	TM30/PM15
Zinc	169	121	561	590	422	3350$_{AB}$	-	-	-	15	<5	mg/kg	TM30/PM15
Zinc$^{\#}$	-	-	-	-	-	-	56	109	117	-	<5	mg/kg	TM30/PM15
Aluminium (2:1 Ext)	0.10	1.52	0.39	0.48	0.16	0.04	0.07	0.75	0.05	0.10	<0.02	mg/l	TM30/PM20
Antimony (2:1 Ext)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	mg/l	TM30/PM20
Arsenic (2:1 Ext)	0.0043	0.0246	0.0089	0.0054	0.0133	0.0231	0.0034	0.0032	0.0025	<0.0025	<0.0025	mg/l	TM30/PM20
Barium (2:1 Ext)	0.047	0.046	0.004	<0.003	0.061	<0.003	0.071	0.047	<0.003	0.095	<0.003	mg/l	TM30/PM20
Beryllium (2:1 Ext)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	mg/l	TM30/PM20
Cadmium (2:1 Ext)	<0.0005	<0.0005	<0.0005	<0.0005	0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	mg/l	TM30/PM20
Calcium (2:1 Ext)	102.4	1.8	16.8	6.2	85.9	5.1	22.7	29.3	35.0	96.6	<0.2	mg/l	TM30/PM20

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	19-20	21-24	25-28	29	30	31-32	33	34-35	36	37			
Sample ID	FACILITY 9 - RWD2	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	FACILITY 12 DAM 3B	FACILITY 13 DAM 3A	FACILITY 14 POND 6B	FACILITY 7 (3)	FACILITY 8 (3)	FACILITY 1 (2)	FACILITY 2 (2)			
Depth													
COC No / misc													
Containers	B	V B	V B	B	B	B	B	B	B	B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	25/05/2015	26/05/2015	26/05/2015	25/05/2015	25/05/2015			
Sample Type	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Soil	Soil	Soil	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Chromium (2:1 Ext)	0.0104	0.1769	0.3096	0.9353	0.9273	0.0280	0.0085	0.7593$_{AB}$	0.4759	0.0019	<0.0015	mg/l	TM30/PM20
Cobalt (2:1 Ext)	<0.002	0.004	0.004	<0.002	<0.002	0.008	<0.002	<0.002	<0.002	<0.002	<0.002	mg/l	TM30/PM20
Copper (2:1 Ext)	<0.007	<0.007	0.019	<0.007	0.025	0.009	<0.007	0.008	<0.007	<0.007	<0.007	mg/l	TM30/PM20
Iron (2:1 Ext)	0.06	0.40	0.49	0.56	0.25	0.15	0.04	0.51	<0.02	<0.02	<0.02	mg/l	TM30/PM20
Lead (2:1 Ext)	0.006	0.009	0.024	0.015	0.016	<0.005	<0.005	0.005	0.039	<0.005	<0.005	mg/l	TM30/PM20
Magnesium (2:1 Ext)	51.2	2.1	3.7	1.6	19.3	23.1	10.6	8.3	2.1	31.1	<0.1	mg/l	TM30/PM20
Manganese (2:1 Ext)	0.162	0.016	0.017	0.006	0.023	0.011	0.056	0.005	<0.002	0.024	<0.002	mg/l	TM30/PM20
Mercury (2:1 Ext)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	mg/l	TM30/PM20
Molybdenum (2:1 Ext)	0.130	0.147	0.496	0.144	1.877	0.590	0.040	0.066	0.014	0.029	<0.002	mg/l	TM30/PM20
Nickel (2:1 Ext)	0.007	0.017	0.085	0.005	0.018	0.162	0.002	0.003	<0.002	<0.002	<0.002	mg/l	TM30/PM20
Phosphorus (2:1 Ext)	0.053	0.206	0.236	0.045	0.129	0.533	0.025	0.198	0.027	0.020	<0.005	mg/l	TM30/PM20
Potassium (2:1 Ext)	55.3	88.8	197.8$_{AB}$	74.0	69.2	441.1$_{AB}$	7.3	27.3	0.3	2.1	<0.1	mg/l	TM30/PM20
Selenium (2:1 Ext)	<0.003	0.020	0.011	<0.003	0.045	0.020	<0.003	<0.003	<0.003	<0.003	<0.003	mg/l	TM30/PM20
Sodium (2:1 Ext)	192.3	104.1	265.0$_{AB}$	80.6	321.4$_{AB}$	581.2$_{AB}$	6.8	23.1	0.2	4.1	<0.1	mg/l	TM30/PM20
Vanadium (2:1 Ext)	0.0066	0.0465	0.2332	0.0715	0.1200	0.0268	<0.0015	0.0021	0.2111	<0.0015	<0.0015	mg/l	TM30/PM20
Zinc (2:1 Ext)	0.006	0.012	0.051	0.023	0.032	0.025	0.006	0.010	0.005	0.007	<0.003	mg/l	TM30/PM20
Aluminium (Water Soluble)	0.20	3.04	0.78	0.96	0.32	0.08	0.14	1.50	0.10	0.20	<0.04	mg/kg	TM30/PM20
Antimony (Water Soluble)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM20
Arsenic (Water Soluble)	0.009	0.049	0.018	0.011	0.027	0.046	0.007	0.006	0.005	<0.005	<0.005	mg/kg	TM30/PM20
Barium (Water Soluble)	0.094	0.092	0.008	<0.006	0.122	<0.006	0.142	0.094	<0.006	0.190	<0.006	mg/kg	TM30/PM20
Beryllium (Water Soluble)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	mg/kg	TM30/PM20
Cadmium (Water Soluble)	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	mg/kg	TM30/PM20
Calcium (Water Soluble)	204.8	3.6	33.6	12.4	171.8	10.2	45.4	58.6	70.0	193.2	<0.4	mg/kg	TM30/PM20
Chromium (Water Soluble)	0.021	0.354	0.619	1.871	1.855	0.056	0.017	1.519$_{AB}$	0.952	0.004	<0.003	mg/kg	TM30/PM20
Cobalt (Water Soluble)	<0.004	0.008	0.008	<0.004	<0.004	0.016	<0.004	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM20
Copper (Water Soluble)	<0.014	<0.014	0.038	<0.014	0.050	0.018	<0.014	0.016	<0.014	<0.014	<0.014	mg/kg	TM30/PM20
Iron (Water Soluble)	0.12	0.80	0.98	1.12	0.50	0.30	0.08	1.02	<0.04	<0.04	<0.04	mg/kg	TM30/PM20
Lead (Water Soluble)	0.01	0.02	0.05	0.03	0.03	<0.01	<0.01	0.01	0.08	<0.01	<0.01	mg/kg	TM30/PM20
Magnesium (Water Soluble)	102.4	4.2	7.4	3.2	38.6	46.2	21.2	16.6	4.2	62.2	<0.2	mg/kg	TM30/PM20
Manganese (Water Soluble)	0.324	0.032	0.034	0.012	0.046	0.022	0.112	0.010	<0.004	0.048	<0.004	mg/kg	TM30/PM20
Mercury (Water Soluble)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	mg/kg	TM30/PM20
Molybdenum (Water Soluble)	0.260	0.294	0.992	0.288	3.754	1.180	0.080	0.132	0.028	0.058	<0.004	mg/kg	TM30/PM20
Nickel (Water Soluble)	0.014	0.034	0.170	0.010	0.036	0.324	0.004	0.006	<0.004	<0.004	<0.004	mg/kg	TM30/PM20
Phosphorus (Water Soluble)	0.11	0.41	0.47	0.09	0.26	1.07	0.05	0.40	0.05	0.04	<0.01	mg/kg	TM30/PM20
Potassium (Water Soluble)	110.6	177.6	395.6$_{AB}$	148.0	138.4	882.2$_{AB}$	14.6	54.6	0.6	4.2	<0.2	mg/kg	TM30/PM20
Selenium (Water Soluble)	<0.006	0.040	0.022	<0.006	0.090	0.040	<0.006	<0.006	<0.006	<0.006	<0.006	mg/kg	TM30/PM20
Sodium (Water Soluble)	384.6	208.2	530.0$_{AB}$	161.2	642.8$_{AB}$	1162.4$_{AB}$	13.6	46.2	0.4	8.2	<0.2	mg/kg	TM30/PM20
Vanadium (Water Soluble)	0.013	0.093	0.466	0.143	0.240	0.054	<0.003	0.004	0.422	<0.003	<0.003	mg/kg	TM30/PM20
Zinc (Water Soluble)	0.012	0.024	0.102	0.046	0.064	0.050	0.012	0.020	0.010	0.014	<0.006	mg/kg	TM30/PM20
Natural Moisture Content	32.7	32.1	59.5	20.8	6.0	77.9	14.5	3.1	0.3	1.5	<0.1	%	PM4/PM0
Ammoniacal Nitrogen as NH4 (water soluble)	<0.6	<0.6	2.1	<0.6	<0.6	37.7	1.0	<0.6	<0.6	<0.6	<0.6	mg/kg	TM38/PM20
Hexavalent Chromium	<0.3	1.2	<0.3	0.5	24.7	<0.3	-	-	-	0.3	<0.3	mg/kg	TM38/PM20

Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : **Solid**

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	19-20	21-24	25-28	29	30	31-32	33	34-35	36	37			
Sample ID	FACILITY 9 - RWD2	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	FACILITY 12 DAM 3B	FACILITY 13 DAM 3A	FACILITY 14 POND 6B	FACILITY 7 (3)	FACILITY 8 (3)	FACILITY 1 (2)	FACILITY 2 (2)			
Depth													
COC No / misc													
Containers	B	V B	V B	B	B	B	B	B	B	B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	25/05/2015	26/05/2015	26/05/2015	25/05/2015	25/05/2015			
Sample Type	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Soil	Soil	Soil	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Hexavalent Chromium #	-	-	-	-	-	-	<0.3	3.6	0.3	-	<0.3	mg/kg	TM38/PM20
Chloride (2:1 Ext)	37	23	98	18	84	294	-	-	-	5	<1	mg/l	TM38/PM20
Chloride (2:1 Ext) #	-	-	-	-	-	-	2	4	<1	-	<1	mg/l	TM38/PM20
Fluoride (2:1 Ext)	4.90	5.70	5.75	5.80_{AB}	17.00_{AA}	14.40_{AA}	0.75	3.00	0.40	0.65	<0.15	mg/l	TM27/PM20
Hexavalent Chromium (2:1 Ext)	<0.15	0.19	<0.15	<0.15	2.24	<0.15	-	-	-	<0.15	<0.15	mg/l	TM38/PM20
Hexavalent Chromium (2:1 Ext)#	-	-	-	-	-	-	<0.15	1.42	<0.15	-	<0.15	mg/l	TM38/PM20
Nitrate as NO3 (2:1 Ext)	<1.25	20.46	20.20	25.33	9.66	7.75	-	-	-	<1.25	<1.25	mg/l	TM38/PM20
Nitrate as NO3 (2:1 Ext) #	-	-	-	-	-	-	<1.25	11.65	<1.25	-	<1.25	mg/l	TM38/PM20
Sulphate as SO4 (2:1 Ext)	665.3	88.6	453.4	108.2	658.9	689.6	-	-	-	275.7	<1.5	mg/l	TM38/PM20
Sulphate as SO4 (2:1 Ext) #	-	-	-	-	-	-	70.6	80.3	4.9	-	<1.5	mg/l	TM38/PM20
Chloride (Water Soluble)	74	46	196	36	168	588	-	-	-	10	<2	mg/kg	TM38/PM20
Chloride (Water Soluble) #	-	-	-	-	-	-	4	8	<2	-	<2	mg/kg	TM38/PM20
Fluoride (Water Soluble)	9.8	11.4	11.5	11.6_{AB}	34.0_{AA}	28.8_{AA}	1.5	6.0	0.8	1.3	<0.3	mg/kg	TM27/PM20
Nitrate as NO3 (Water Soluble)	<2.5	40.9	40.4	50.7	19.3	15.5	-	-	-	<2.5	<2.5	mg/kg	TM38/PM20
Nitrate as NO3 (Water Soluble) #	-	-	-	-	-	-	<2.5	23.3	<2.5	-	<2.5	mg/kg	TM38/PM20
Sulphate as SO4 (Water Soluble)	1331	177	907	216	1318	1379	-	-	-	551	<3	mg/kg	TM38/PM20
Sulphate as SO4 (Water Soluble) #	-	-	-	-	-	-	141	161	10	-	<3	mg/kg	TM38/PM20
Electrical Conductivity @25C (2:1 Ext)	1590	700	1626	626	1793	3314	249	372	165	634	<2	uS/cm	TM76/PM20
pH (2:1 Ext)	8.10	9.81	10.16	10.15	9.54	9.58	7.77	7.84	10.20	8.07	<0.01	pH units	TM73/PM20
Total Dissolved Solids (2:1 Ext)	1205	523	1225	383	1992	2628	172	402	1072	430	<10	mg/l	TM20/PM20
Total Dissolved Solids (Water Soluble)	2410	1046	2450	766	3984	5256	344	804	2144	860	<20	mg/kg	TM20/PM20
Ammoniacal Nitrogen as NH4 (2:1 Ext)	<0.3	<0.3	0.7	<0.3	<0.3	10.7	0.4	<0.3	<0.3	<0.3	<0.3	mg/l	TM38/PM20
Hexavalent Chromium (water soluble)	<0.3	0.5	<0.3	<0.3	4.8	<0.3	-	-	-	<0.3	<0.3	mg/kg	TM38/PM20
Hexavalent Chromium (water soluble)#	-	-	-	-	-	-	<0.3	2.9	<0.3	-	<0.3	mg/kg	TM38/PM20

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	38	39	40-41	42-44	45-46	47	48	49-51	52	53			
Sample ID	FACILITY 3 A	FACILITY 3 B	FACILITY 4 (2)	FACILITY 5 (2)	FACILITY 6 (3)	FACILITY 15-1	FACILITY 15-3	FACILITY 15-4	FACILITY 15-5	FACILITY 15-6			
Depth													
COC No / misc													
Containers	B	B	B	B	B	B	B	V B	B	B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	25/05/2015	26/05/2015	27/05/2015	27/05/2015	27/05/2015	27/05/2015	27/05/2015			
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Aluminium	219	6841	4615	23750	4173	27260	15390	36460	15920	9400	<50	mg/kg	TM30/PM15
Antimony	<1	<1	<1	<5$_{AB}$	<1	<5$_{AB}$	<1	<5$_{AB}$	<1	<1	<1	mg/kg	TM30/PM15
Arsenic	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.6	<0.5	mg/kg	TM30/PM15
Arsenic #	-	-	-	-	-	-	-	-	-	-	<0.5	mg/kg	TM30/PM15
Barium	4	43	28	29	21	79	58	36	52	69	<1	mg/kg	TM30/PM15
Barium #	-	-	-	-	-	-	-	-	-	-	<1	mg/kg	TM30/PM15
Beryllium	<0.5	0.5	<0.5	<0.5	<0.5	1.1	0.8	0.7	0.7	<0.5	<0.5	mg/kg	TM30/PM15
Cadmium	<0.1	<0.1	<0.1	0.2	<0.1	<0.1	<0.1	0.1	<0.1	1.9	<0.1	mg/kg	TM30/PM15
Cadmium #	-	-	-	-	-	-	-	-	-	-	<0.1	mg/kg	TM30/PM15
Calcium	<500	10700	67170	178600	39510	106300	27850	130500	64270	110700	<500	mg/kg	TM30/PM15
Chromium	116.6	673.2$_{AB}$	107.7	10280.0$_{AE}$	2910.0$_{AD}$	9135.0$_{AE}$	3346.0$_{AD}$	8170.0$_{AE}$	3484.0$_{AD}$	4320.0$_{AE}$	<0.5	mg/kg	TM30/PM15
Chromium #	-	-	-	-	-	-	-	-	-	-	<0.5	mg/kg	TM30/PM15
Cobalt	0.6	8.8	2.4	17.7	14.4	35.6	26.3	10.2	20.4	30.2	<0.5	mg/kg	TM30/PM15
Cobalt #	-	-	-	-	-	-	-	-	-	-	<0.5	mg/kg	TM30/PM15
Copper	2	16	13	11	11	66	3	13	21	89	<1	mg/kg	TM30/PM15
Copper #	-	-	-	-	-	-	-	-	-	-	<1	mg/kg	TM30/PM15
Iron	1234	6781	2961	13860	10740	48800$_{AB}$	18760	11020	22690	36510	<20	mg/kg	TM30/PM15
Lead	<5	5	<5	12	<5	25	<5	11	17	142	<5	mg/kg	TM30/PM15
Lead #	-	-	-	-	-	-	-	-	-	-	<5	mg/kg	TM30/PM15
Magnesium	<25	3890	4502	65260	2725	39130	21360	47030	20070	41410	<25	mg/kg	TM30/PM15
Manganese	9	212	195	1639	638	1621	1277	1381	844	5160$_{AB}$	<1	mg/kg	TM30/PM15
Manganese #	-	-	-	-	-	-	-	-	-	-	<1	mg/kg	TM30/PM15
Mercury	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	mg/kg	TM30/PM15
Mercury #	-	-	-	-	-	-	-	-	-	-	<0.1	mg/kg	TM30/PM15
Molybdenum	10.1	2.8	1.6	18.0	3.0	69.9$_{AB}$	17.2	12.1	22.4	293.7$_{AE}$	<0.1	mg/kg	TM30/PM15
Molybdenum #	-	-	-	-	-	-	-	-	-	-	<0.1	mg/kg	TM30/PM15
Nickel	2.8	67.5	19.3	117.4	87.1	3272.0$_{AE}$	101.8	177.4	412.1$_{AB}$	2510.0$_{AE}$	<0.7	mg/kg	TM30/PM15
Nickel #	-	-	-	-	-	-	-	-	-	-	<0.7	mg/kg	TM30/PM15
Phosphorus	<10	63	25	45	72	74	<10	41	27	83	<10	mg/kg	TM30/PM15
Potassium	111	469	206	351	408	709	418	591	389	2502	<5	mg/kg	TM30/PM15
Selenium	<1	<1	<1	1	<1	1	1	1	1	4	<1	mg/kg	TM30/PM15
Selenium #	-	-	-	-	-	-	-	-	-	-	<1	mg/kg	TM30/PM15
Sodium	61	663	443	299	383	487	389	454	334	2095	<5	mg/kg	TM30/PM15
Vanadium	5	18	8	108	31	120	12	102	57	42	<1	mg/kg	TM30/PM15
Boron (Aqua Regia Soluble)	<0.25	2.10	<0.25	6.89	<0.25	<0.25	<0.25	7.71	<0.25	76.69	<0.25	mg/kg	TM30/PM15
Zinc	<5	79	<5	306	108	354	13	148	187	2307	<5	mg/kg	TM30/PM15
Zinc #	-	-	-	-	-	-	-	-	-	-	<5	mg/kg	TM30/PM15
Aluminium (2:1 Ext)	0.14	0.06	3.12	0.04	0.07	<0.02	0.63	0.73	0.15	<0.02	<0.02	mg/l	TM30/PM20
Antimony (2:1 Ext)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	mg/l	TM30/PM20
Arsenic (2:1 Ext)	0.0049	<0.0025	0.0065	0.0060	<0.0025	<0.0025	<0.0025	0.0045	0.0041	0.0755	<0.0025	mg/l	TM30/PM20
Barium (2:1 Ext)	0.007	0.052	0.025	<0.003	0.295	<0.003	0.048	<0.003	0.003	0.033	<0.003	mg/l	TM30/PM20
Beryllium (2:1 Ext)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	mg/l	TM30/PM20
Cadmium (2:1 Ext)	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	mg/l	TM30/PM20
Calcium (2:1 Ext)	11.5	119.0	163.9	67.7	962.6$_{AC}$	9.0	15.8	79.2	38.3	411.4$_{AB}$	<0.2	mg/l	TM30/PM20

Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	38	39	40-41	42-44	45-46	47	48	49-51	52	53			
Sample ID	FACILITY 3 A	FACILITY 3 B	FACILITY 4 (2)	FACILITY 5 (2)	FACILITY 6 (3)	FACILITY 15-1	FACILITY 15-3	FACILITY 15-4	FACILITY 15-5	FACILITY 15-6			
Depth													
COC No / misc													
Containers	B	B	B	B	B	B	B	V B	B	B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	25/05/2015	26/05/2015	27/05/2015	27/05/2015	27/05/2015	27/05/2015	27/05/2015			
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Chromium (2:1 Ext)	0.0103	0.1189	4.9010$_{AC}$	15.9400$_{AC}$	3.8600$_{AB}$	0.0835	0.3526	2.9770$_{AB}$	4.2420$_{AC}$	201.0000$_{AF}$	<0.0015	mg/l	TM30/PM20
Cobalt (2:1 Ext)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.004	<0.002	mg/l	TM30/PM20
Copper (2:1 Ext)	<0.007	<0.007	0.013	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	<0.007	mg/l	TM30/PM20
Iron (2:1 Ext)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	mg/l	TM30/PM20
Lead (2:1 Ext)	0.008	0.017	<0.005	0.011	<0.005	0.007	0.007	0.008	0.013	0.033	<0.005	mg/l	TM30/PM20
Magnesium (2:1 Ext)	1.1	0.6	<0.1	5.4	<0.1	8.8	4.0	2.5	5.0	3.4	<0.1	mg/l	TM30/PM20
Manganese (2:1 Ext)	0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	mg/l	TM30/PM20
Mercury (2:1 Ext)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	mg/l	TM30/PM20
Molybdenum (2:1 Ext)	0.018	0.039	0.788	0.114	0.045	0.006	0.005	0.138	0.181	2.501	<0.002	mg/l	TM30/PM20
Nickel (2:1 Ext)	<0.002	<0.002	0.004	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	mg/l	TM30/PM20
Phosphorus (2:1 Ext)	0.040	0.014	0.017	0.006	0.008	<0.005	<0.005	0.011	<0.005	0.014	<0.005	mg/l	TM30/PM20
Potassium (2:1 Ext)	6.8	11.6	43.5	10.8	25.1	1.9	1.2	20.8	14.0	327.1$_{AB}$	<0.1	mg/l	TM30/PM20
Selenium (2:1 Ext)	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003	0.063	<0.003	mg/l	TM30/PM20
Sodium (2:1 Ext)	8.1	24.6	50.6	6.8	30.7	12.1	0.8	22.0	14.2	454.3$_{AB}$	<0.1	mg/l	TM30/PM20
Vanadium (2:1 Ext)	0.0054	0.0639	0.0147	0.0688	<0.0015	0.0582	0.0080	0.0746	0.0544	0.0503	<0.0015	mg/l	TM30/PM20
Zinc (2:1 Ext)	0.005	0.005	0.008	<0.003	0.018	0.005	0.003	0.004	0.004	0.004	<0.003	mg/l	TM30/PM20
Aluminium (Water Soluble)	0.28	0.12	6.24	0.08	0.14	<0.04	1.26	1.46	0.30	<0.04	<0.04	mg/kg	TM30/PM20
Antimony (Water Soluble)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM20
Arsenic (Water Soluble)	0.010	<0.005	0.013	0.012	<0.005	<0.005	<0.005	0.009	0.008	0.151	<0.005	mg/kg	TM30/PM20
Barium (Water Soluble)	0.014	0.104	0.050	<0.006	0.590	<0.006	0.096	<0.006	0.006	0.066	<0.006	mg/kg	TM30/PM20
Beryllium (Water Soluble)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	mg/kg	TM30/PM20
Cadmium (Water Soluble)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	mg/kg	TM30/PM20
Calcium (Water Soluble)	23.0	238.0	327.8	135.4	1925.2$_{AC}$	18.0	31.6	158.4	76.6	822.8$_{AB}$	<0.4	mg/kg	TM30/PM20
Chromium (Water Soluble)	0.021	0.238	9.802$_{AC}$	31.880$_{AC}$	7.720$_{AB}$	0.167	0.705	5.954$_{AB}$	8.484$_{AC}$	402.000$_{AF}$	<0.003	mg/kg	TM30/PM20
Cobalt (Water Soluble)	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	0.008	<0.004	mg/kg	TM30/PM20
Copper (Water Soluble)	<0.014	<0.014	0.026	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	<0.014	mg/kg	TM30/PM20
Iron (Water Soluble)	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	<0.04	mg/kg	TM30/PM20
Lead (Water Soluble)	0.02	0.03	<0.01	0.02	<0.01	0.01	0.01	0.02	0.03	0.07	<0.01	mg/kg	TM30/PM20
Magnesium (Water Soluble)	2.2	1.2	<0.2	10.8	<0.2	17.6	8.0	5.0	10.0	6.8	<0.2	mg/kg	TM30/PM20
Manganese (Water Soluble)	0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM20
Mercury (Water Soluble)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	mg/kg	TM30/PM20
Molybdenum (Water Soluble)	0.036	0.078	1.576	0.228	0.090	0.012	0.010	0.276	0.362	5.002	<0.004	mg/kg	TM30/PM20
Nickel (Water Soluble)	<0.004	<0.004	0.008	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	mg/kg	TM30/PM20
Phosphorus (Water Soluble)	0.08	0.03	0.03	0.01	0.02	<0.01	<0.01	0.02	<0.01	0.03	<0.01	mg/kg	TM30/PM20
Potassium (Water Soluble)	13.6	23.2	87.0	21.6	50.2	3.8	2.4	41.6	28.0	654.2$_{AB}$	<0.2	mg/kg	TM30/PM20
Selenium (Water Soluble)	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.126	<0.006	mg/kg	TM30/PM20
Sodium (Water Soluble)	16.2	49.2	101.2	13.6	61.4	24.2	1.6	44.0	28.4	908.6$_{AB}$	<0.2	mg/kg	TM30/PM20
Vanadium (Water Soluble)	0.011	0.128	0.029	0.138	<0.003	0.116	0.016	0.149	0.109	0.101	<0.003	mg/kg	TM30/PM20
Zinc (Water Soluble)	0.010	0.010	0.016	<0.006	0.036	0.010	0.006	0.008	0.008	0.008	<0.006	mg/kg	TM30/PM20
Natural Moisture Content	0.6	<0.1	3.3	0.6	1.8	5.6	<0.1	0.3	0.8	10.9	<0.1	%	PM4/PM0
Ammoniacal Nitrogen as NH4 (water soluble)	<0.6	3.3	<0.6	<0.6	<0.6	<0.6	<0.6	1.0	1.1	3.7	<0.6	mg/kg	TM38/PM20
Hexavalent Chromium	<0.3	0.3	<0.3	22.6	18.3	18.3	<0.3	2.9	5.0	861.0	<0.3	mg/kg	TM38/PM20

Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	38	39	40-41	42-44	45-46	47	48	49-51	52	53			
Sample ID	FACILITY 3 A	FACILITY 3 B	FACILITY 4 (2)	FACILITY 5 (2)	FACILITY 6 (3)	FACILITY 15-1	FACILITY 15-3	FACILITY 15-4	FACILITY 15-5	FACILITY 15-6			
Depth													
COC No / misc													
Containers	B	B	B	B	B	B	B	V B	B	B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	25/05/2015	26/05/2015	27/05/2015	27/05/2015	27/05/2015	27/05/2015	27/05/2015			
Sample Type	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid	Solid			
Batch Number	1	1	1	1	1	1	1	1	1	1	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Hexavalent Chromium #	-	-	-	-	-	-	-	-	-	-	<0.3	mg/kg	TM38/PM20
Chloride (2:1 Ext)	8	8	17	12	14	4	1	15	7	327	<1	mg/l	TM38/PM20
Chloride (2:1 Ext) #	-	-	-	-	-	-	-	-	-	-	<1	mg/l	TM38/PM20
Fluoride (2:1 Ext)	0.20	2.45	1.10	0.20	<0.15	0.65	<0.15	<0.15	1.50	0.70	<0.15	mg/l	TM27/PM20
Hexavalent Chromium (2:1 Ext)	<0.15	<0.15	<0.15	5.11	1.68	1.54	<0.15	0.82	0.98	277.52	<0.15	mg/l	TM38/PM20
Nitrate as NO3 (2:1 Ext)	<1.25	12.53	89.24	12.71	14.93	15.01	<1.25	12.31	11.43	263.61	<1.25	mg/l	TM38/PM20
Nitrate as NO3 (2:1 Ext) #	-	-	-	-	-	-	-	-	-	-	<1.25	mg/l	TM38/PM20
Sulphate as SO4 (2:1 Ext)	6.9	220.9	15.4	82.4	35.8	10.4	11.0	82.3	66.5	722.0	<1.5	mg/l	TM38/PM20
Sulphate as SO4 (2:1 Ext) #	-	-	-	-	-	-	-	-	-	-	<1.5	mg/l	TM38/PM20
Chloride (Water Soluble)	16	16	34	24	28	8	2	30	14	654	<2	mg/kg	TM38/PM20
Chloride (Water Soluble) #	-	-	-	-	-	-	-	-	-	-	<2	mg/kg	TM38/PM20
Fluoride (Water Soluble)	0.4	4.9	2.2	0.4	<0.3	1.3	<0.3	<0.3	3.0	1.4	<0.3	mg/kg	TM27/PM20
Nitrate as NO3 (Water Soluble)	<2.5	25.1	178.5	25.4	29.9	30.0	<2.5	24.6	22.9	527.2	<2.5	mg/kg	TM38/PM20
Nitrate as NO3 (Water Soluble) #	-	-	-	-	-	-	-	-	-	-	<2.5	mg/kg	TM38/PM20
Sulphate as SO4 (Water Soluble)	14	442	31	165	72	21	22	165	133	1444	<3	mg/kg	TM38/PM20
Sulphate as SO4 (Water Soluble) #	-	-	-	-	-	-	-	-	-	-	<3	mg/kg	TM38/PM20
Electrical Conductivity @25C (2:1 Ext)	131	640	1636	433	7855	172	119	475	314	3975	<2	uS/cm	TM76/PM20
pH (2:1 Ext)	8.54	10.48	12.01	10.39	12.79	8.94	10.13	10.48	10.23	9.58	<0.01	pH units	TM73/PM20
Total Dissolved Solids (2:1 Ext)	116	533	560	317	1812	83	668	554	308	3315	<10	mg/l	TM20/PM20
Total Dissolved Solids (Water Soluble)	232	1066	1120	634	3624	166	1336	1108	616	6630	<20	mg/kg	TM20/PM20
Ammoniacal Nitrogen as NH4 (2:1 Ext)	<0.3	1.7	<0.3	<0.3	<0.3	<0.3	0.3	0.5	0.6	1.6	<0.3	mg/l	TM38/PM20
Hexavalent Chromium (water soluble)	<0.3	0.3	<0.3	10.3	3.4	3.2	<0.3	1.6	2.0	615.5	<0.3	mg/kg	TM38/PM20

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : **Solid**

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	54	55	56	57							LOD/LOR	Units	Method No.
Sample ID	FACILITY 15-7	FACILITY 15-8	FACILITY 15-9	FACILITY 15-10									
Depth													
COC No / misc													
Containers	B	B	B	B									
Sample Date	27/05/2015	27/05/2015	27/05/2015	27/05/2015									
Sample Type	Solid	Solid	Solid	Solid									
Batch Number	1	1	1	1									
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015									
Aluminium	30990	35730	32580	13820							<50	mg/kg	TM30/PM15
Antimony	<5 AB	<5 AB	<5 AB	<5 AB							<1	mg/kg	TM30/PM15
Arsenic	<0.5	<0.5	<0.5	<0.5							<0.5	mg/kg	TM30/PM15
Arsenic #	-	-	-	-							<0.5	mg/kg	TM30/PM15
Barium	92	42	52	60							<1	mg/kg	TM30/PM15
Barium #	-	-	-	-							<1	mg/kg	TM30/PM15
Beryllium	0.8	0.8	0.8	1.4							<0.5	mg/kg	TM30/PM15
Cadmium	0.3	<0.1	<0.1	0.4							<0.1	mg/kg	TM30/PM15
Cadmium #	-	-	-	-							<0.1	mg/kg	TM30/PM15
Calcium	137800	131700	145700	29550							<500	mg/kg	TM30/PM15
Chromium	7780.0 AE	8015.0 AE	6143.0 AE	10020.0 AE							<0.5	mg/kg	TM30/PM15
Chromium #	-	-	-	-							<0.5	mg/kg	TM30/PM15
Cobalt	16.1	32.9	13.6	193.8							<0.5	mg/kg	TM30/PM15
Cobalt #	-	-	-	-							<0.5	mg/kg	TM30/PM15
Copper	14	25	16	137							<1	mg/kg	TM30/PM15
Copper #	-	-	-	-							<1	mg/kg	TM30/PM15
Iron	14550	28140	12410	77800 AB							<20	mg/kg	TM30/PM15
Lead	22	12	<5	132							<5	mg/kg	TM30/PM15
Lead #	-	-	-	-							<5	mg/kg	TM30/PM15
Magnesium	37350	44910	38100	60820							<25	mg/kg	TM30/PM15
Manganese	1275	1348	1477	5929 AB							<1	mg/kg	TM30/PM15
Manganese #	-	-	-	-							<1	mg/kg	TM30/PM15
Mercury	<0.1	<0.1	<0.1	0.3							<0.1	mg/kg	TM30/PM15
Mercury #	-	-	-	-							<0.1	mg/kg	TM30/PM15
Molybdenum	17.0	31.0 AB	12.4	3.4							<0.1	mg/kg	TM30/PM15
Molybdenum #	-	-	-	-							<0.1	mg/kg	TM30/PM15
Nickel	155.6	2293.0 AD	140.0	936.7 AB							<0.7	mg/kg	TM30/PM15
Nickel #	-	-	-	-							<0.7	mg/kg	TM30/PM15
Phosphorus	29	31	21	192							<10	mg/kg	TM30/PM15
Potassium	729	499	649	13130							<5	mg/kg	TM30/PM15
Selenium	1	1	1	4							<1	mg/kg	TM30/PM15
Selenium #	-	-	-	-							<1	mg/kg	TM30/PM15
Sodium	534	392	521	13620							<5	mg/kg	TM30/PM15
Vanadium	110	97	114	44							<1	mg/kg	TM30/PM15
Boron (Aqua Regia Soluble)	6.04	1.39	5.87	<0.25							<0.25	mg/kg	TM30/PM15
Zinc	600	607	178	18520 AC							<5	mg/kg	TM30/PM15
Zinc #	-	-	-	-							<5	mg/kg	TM30/PM15
Aluminium (2:1 Ext)	1.34	6.61 AC	12.41 AC	<0.02							<0.02	mg/l	TM30/PM20
Antimony (2:1 Ext)	<0.002	<0.002	<0.002	<0.002							<0.002	mg/l	TM30/PM20
Arsenic (2:1 Ext)	0.0087	0.0081	0.0073	0.0057							<0.0025	mg/l	TM30/PM20
Barium (2:1 Ext)	0.015	<0.003	<0.003	0.055							<0.003	mg/l	TM30/PM20
Beryllium (2:1 Ext)	<0.0005	<0.0005	<0.0005	<0.0005							<0.0005	mg/l	TM30/PM20
Cadmium (2:1 Ext)	<0.0005	<0.0005	<0.0005	<0.0005							<0.0005	mg/l	TM30/PM20
Calcium (2:1 Ext)	48.1	85.5	76.1	417.4 AB							<0.2	mg/l	TM30/PM20

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : Solid

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	54	55	56	57									
Sample ID	FACILITY 15-7	FACILITY 15-8	FACILITY 15-9	FACILITY 15-10									
Depth													
COC No / misc													
Containers	B	B	B	B									
Sample Date	27/05/2015	27/05/2015	27/05/2015	27/05/2015									
Sample Type	Solid	Solid	Solid	Solid									
Batch Number	1	1	1	1									
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015							LOD/LOR	Units	Method No.
Chromium (2:1 Ext)	7.6900$_{AB}$	17.8500$_{AC}$	16.6300$_{AC}$	4.1630$_{AB}$							<0.0015	mg/l	TM30/PM20
Cobalt (2:1 Ext)	<0.002	<0.002	<0.002	0.047							<0.002	mg/l	TM30/PM20
Copper (2:1 Ext)	<0.007	<0.007	<0.007	<0.007							<0.007	mg/l	TM30/PM20
Iron (2:1 Ext)	0.02	<0.02	<0.02	0.63							<0.02	mg/l	TM30/PM20
Lead (2:1 Ext)	0.008	0.005	<0.005	<0.005							<0.005	mg/l	TM30/PM20
Magnesium (2:1 Ext)	0.4	<0.1	0.1	148.8$_{AB}$							<0.1	mg/l	TM30/PM20
Manganese (2:1 Ext)	<0.002	<0.002	<0.002	0.135							<0.002	mg/l	TM30/PM20
Mercury (2:1 Ext)	<0.001	<0.001	<0.001	<0.001							<0.001	mg/l	TM30/PM20
Molybdenum (2:1 Ext)	0.273	0.382	0.495	0.123							<0.002	mg/l	TM30/PM20
Nickel (2:1 Ext)	0.003	<0.002	<0.002	0.004							<0.002	mg/l	TM30/PM20
Phosphorus (2:1 Ext)	<0.005	<0.005	<0.005	0.245							<0.005	mg/l	TM30/PM20
Potassium (2:1 Ext)	30.0	31.5	28.0	2462.0$_{AF}$							<0.1	mg/l	TM30/PM20
Selenium (2:1 Ext)	<0.003	<0.003	<0.003	0.042							<0.003	mg/l	TM30/PM20
Sodium (2:1 Ext)	26.7	28.2	34.5	4011.0$_{AF}$							<0.1	mg/l	TM30/PM20
Vanadium (2:1 Ext)	0.0530	0.0233	0.0255	<0.0015							<0.0015	mg/l	TM30/PM20
Zinc (2:1 Ext)	0.004	0.004	0.003	0.023							<0.003	mg/l	TM30/PM20
Aluminium (Water Soluble)	2.68	13.22$_{AC}$	24.82$_{AC}$	<0.04							<0.04	mg/kg	TM30/PM20
Antimony (Water Soluble)	<0.004	<0.004	<0.004	<0.004							<0.004	mg/kg	TM30/PM20
Arsenic (Water Soluble)	0.017	0.016	0.015	0.011							<0.005	mg/kg	TM30/PM20
Barium (Water Soluble)	0.030	<0.006	<0.006	0.110							<0.006	mg/kg	TM30/PM20
Beryllium (Water Soluble)	<0.001	<0.001	<0.001	<0.001							<0.001	mg/kg	TM30/PM20
Cadmium (Water Soluble)	<0.001	<0.001	<0.001	<0.001							<0.001	mg/kg	TM30/PM20
Calcium (Water Soluble)	96.2	171.0	152.2	834.8$_{AB}$							<0.4	mg/kg	TM30/PM20
Chromium (Water Soluble)	15.380$_{AB}$	35.700$_{AC}$	33.260$_{AC}$	8.326$_{AB}$							<0.003	mg/kg	TM30/PM20
Cobalt (Water Soluble)	<0.004	<0.004	<0.004	0.094							<0.004	mg/kg	TM30/PM20
Copper (Water Soluble)	<0.014	<0.014	<0.014	<0.014							<0.014	mg/kg	TM30/PM20
Iron (Water Soluble)	0.04	<0.04	<0.04	1.26							<0.04	mg/kg	TM30/PM20
Lead (Water Soluble)	0.02	0.01	<0.01	<0.01							<0.01	mg/kg	TM30/PM20
Magnesium (Water Soluble)	0.8	<0.2	0.2	297.6$_{AB}$							<0.2	mg/kg	TM30/PM20
Manganese (Water Soluble)	<0.004	<0.004	<0.004	0.270							<0.004	mg/kg	TM30/PM20
Mercury (Water Soluble)	<0.002	<0.002	<0.002	<0.002							<0.002	mg/kg	TM30/PM20
Molybdenum (Water Soluble)	0.546	0.764	0.990	0.246							<0.004	mg/kg	TM30/PM20
Nickel (Water Soluble)	0.006	<0.004	<0.004	0.008							<0.004	mg/kg	TM30/PM20
Phosphorus (Water Soluble)	<0.01	<0.01	<0.01	0.49							<0.01	mg/kg	TM30/PM20
Potassium (Water Soluble)	60.0	63.0	56.0	4924.0$_{AF}$							<0.2	mg/kg	TM30/PM20
Selenium (Water Soluble)	<0.006	<0.006	<0.006	0.084							<0.006	mg/kg	TM30/PM20
Sodium (Water Soluble)	53.4	56.4	69.0	8022.0$_{AF}$							<0.2	mg/kg	TM30/PM20
Vanadium (Water Soluble)	0.106	0.047	0.051	<0.003							<0.003	mg/kg	TM30/PM20
Zinc (Water Soluble)	0.008	0.008	0.006	0.046							<0.006	mg/kg	TM30/PM20
Natural Moisture Content	2.2	6.8	1.5	1.9							<0.1	%	PM4/PM0
Ammoniacal Nitrogen as NH4 (water soluble)	1.0	<0.6	<0.6	<0.6							<0.6	mg/kg	TM38/PM20
Hexavalent Chromium	3.8	48.9	27.7	1.0							<0.3	mg/kg	TM38/PM20

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : **Solid**

Solids: V=60g VOC jar, J=250g glass jar, T=plastic tub

Please see attached notes for all abbreviations and acronyms

J E Sample No.	54	55	56	57							LOD/LOR	Units	Method No.
Sample ID	FACILITY 15-7	FACILITY 15-8	FACILITY 15-9	FACILITY 15-10									
Depth													
COC No / misc													
Containers	B	B	B	B									
Sample Date	27/05/2015	27/05/2015	27/05/2015	27/05/2015									
Sample Type	Solid	Solid	Solid	Solid									
Batch Number	1	1	1	1									
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015									
Hexavalent Chromium #	-	-	-	-							<0.3	mg/kg	TM38/PM20
Chloride (2:1 Ext)	12	25	24	1682							<1	mg/l	TM38/PM20
Chloride (2:1 Ext) #	-	-	-	-							<1	mg/l	TM38/PM20
Fluoride (2:1 Ext)	0.90	0.30	0.30	6.15							<0.15	mg/l	TM27/PM20
Hexavalent Chromium (2:1 Ext)	3.58	3.69	6.63	2.36							<0.15	mg/l	TM38/PM20
Nitrate as NO3 (2:1 Ext)	20.73	27.28	26.00	9.92							<1.25	mg/l	TM38/PM20
Nitrate as NO3 (2:1 Ext) #	-	-	-	-							<1.25	mg/l	TM38/PM20
Sulphate as SO4 (2:1 Ext)	81.3	60.8	79.7	10563.0							<1.5	mg/l	TM38/PM20
Sulphate as SO4 (2:1 Ext) #	-	-	-	-							<1.5	mg/l	TM38/PM20
Chloride (Water Soluble)	24	50	48	3364							<2	mg/kg	TM38/PM20
Chloride (Water Soluble) #	-	-	-	-							<2	mg/kg	TM38/PM20
Fluoride (Water Soluble)	1.8	0.6	0.6	12.3							<0.3	mg/kg	TM27/PM20
Nitrate as NO3 (Water Soluble)	41.5	54.6	52.0	19.8							<2.5	mg/kg	TM38/PM20
Nitrate as NO3 (Water Soluble) #	-	-	-	-							<2.5	mg/kg	TM38/PM20
Sulphate as SO4 (Water Soluble)	163	122	159	21126							<3	mg/kg	TM38/PM20
Sulphate as SO4 (Water Soluble) #	-	-	-	-							<3	mg/kg	TM38/PM20
Electrical Conductivity @25C (2:1 Ext)	467	760	646	17932							<2	uS/cm	TM76/PM20
pH (2:1 Ext)	10.76	11.41	11.08	8.97							<0.01	pH units	TM73/PM20
Total Dissolved Solids (2:1 Ext)	279	385	388	6002							<10	mg/l	TM20/PM20
Total Dissolved Solids (Water Soluble)	558	770	776	12004							<20	mg/kg	TM20/PM20
Ammoniacal Nitrogen as NH4 (2:1 Ext)	0.5	<0.3	<0.3	<0.3							<0.3	mg/l	TM38/PM20
Hexavalent Chromium (water soluble)	7.3	7.9	13.5	4.8							<0.3	mg/kg	TM38/PM20

Client Name:	Golder Associates Africa Ltd	**SVOC Report :**	**Solid**
Reference:	1418954		
Location:	Middelburg Ferrochrome (MFC)		
Contact:	Ilse Snyman		
JE Job No.:	15/8219		

Please see attached notes for all abbreviations and acronyms

J E Sample No.	1-4	5-8	21-24	25-28	45-46	49-51			
Sample ID	SD3	SD9	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	FACILITY 6 (3)	FACILITY 15-4			
Depth									
COC No / misc									
Containers	V B	V B	V B	V B	B	V B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015			
Sample Type	Sediment	Sediment	Sediment	Sediment	Solid	Solid			
Batch Number	1	1	1	1	1	1			
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	LOD/LOR	Units	Method No.
SVOC MS									
Phenols									
2-Chlorophenol	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
2-Methylphenol	<10	<10	<10	<200$_{AD}$	<10	7875$_{AD}$	<10	ug/kg	TM16/PM8
2-Nitrophenol	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
2,4-Dichlorophenol	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
2,4-Dimethylphenol	<10	<10	<10	<200$_{AD}$	<10	28421$_{AD}$	<10	ug/kg	TM16/PM8
2,4,5-Trichlorophenol	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
2,4,6-Trichlorophenol	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
4-Chloro-3-methylphenol	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
4-Methylphenol	<10	<10	<10	<200$_{AD}$	<10	16860$_{AD}$	<10	ug/kg	TM16/PM8
4-Nitrophenol	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
Pentachlorophenol	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
Phenol	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
PAHs									
2-Chloronaphthalene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
2-Methylnaphthalene	<10	<10	<10	<200$_{AD}$	355	37052$_{AD}$	<10	ug/kg	TM16/PM8
Naphthalene	<10	<10	<10	<200$_{AD}$	264	9180$_{AD}$	<10	ug/kg	TM16/PM8
Acenaphthylene	<10	<10	<10	<200$_{AD}$	23	<200$_{AD}$	<10	ug/kg	TM16/PM8
Acenaphthene	<10	<10	<10	<200$_{AD}$	214	<200$_{AD}$	<10	ug/kg	TM16/PM8
Fluorene	<10	<10	<10	<200$_{AD}$	110	15356$_{AD}$	<10	ug/kg	TM16/PM8
Phenanthrene	<10	<10	<10	<200$_{AD}$	800	41242$_{AD}$	<10	ug/kg	TM16/PM8
Anthracene	<10	<10	<10	<200$_{AD}$	99	19776$_{AD}$	<10	ug/kg	TM16/PM8
Fluoranthene	<10	<10	<10	<200$_{AD}$	567	14181$_{AD}$	<10	ug/kg	TM16/PM8
Pyrene	<10	<10	<10	<200$_{AD}$	560	18716$_{AD}$	<10	ug/kg	TM16/PM8
Benzo(a)anthracene	<10	<10	<10	1475$_{AD}$	237	17806$_{AD}$	<10	ug/kg	TM16/PM8
Chrysene	<10	<10	<10	608$_{AD}$	446	10781$_{AD}$	<10	ug/kg	TM16/PM8
Benzo(bk)fluoranthene	<10	<10	<10	1778$_{AD}$	691	21106$_{AD}$	<10	ug/kg	TM16/PM8
Benzo(a)pyrene	<10	<10	<10	635$_{AD}$	215	9161$_{AD}$	<10	ug/kg	TM16/PM8
Indeno(123cd)pyrene	<10	<10	<10	<200$_{AD}$	212	4895$_{AD}$	<10	ug/kg	TM16/PM8
Dibenzo(ah)anthracene	<10	<10	<10	<200$_{AD}$	82	2650$_{AD}$	<10	ug/kg	TM16/PM8
Benzo(ghi)perylene	<10	<10	<10	474$_{AD}$	457	8440$_{AD}$	<10	ug/kg	TM16/PM8
Phthalates									
Bis(2-ethylhexyl) phthalate	<10	<10	<10	1933$_{AD}$	492	<200$_{AD}$	<10	ug/kg	TM16/PM8
Butylbenzyl phthalate	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
Di-n-butyl phthalate	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
Di-n-Octyl phthalate	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
Diethyl phthalate	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8
Dimethyl phthalate	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$	<10	ug/kg	TM16/PM8

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All solid results are expressed on a dry weight basis unless stated otherwise.

Client Name:	Golder Associates Africa Ltd	**SVOC Report :**	**Solid**
Reference:	1418954		
Location:	Middelburg Ferrochrome (MFC)		
Contact:	Ilse Snyman		
JE Job No.:	15/8219		

Please see attached notes for all abbreviations and acronyms

J E Sample No.	1-4	5-8	21-24	25-28	45-46	49-51							
Sample ID	SD3	SD9	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	FACILITY 6 (3)	FACILITY 15-4							
Depth													
COC No / misc													
Containers	V B	V B	V B	V B	B	V B							
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015							
Sample Type	Sediment	Sediment	Sediment	Sediment	Solid	Solid							
Batch Number	1	1	1	1	1	1					LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015							
SVOC MS													
Other SVOCs													
1,2-Dichlorobenzene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
1,2,4-Trichlorobenzene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
1,3-Dichlorobenzene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
1,4-Dichlorobenzene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
2-Nitroaniline	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
2,4-Dinitrotoluene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
2,6-Dinitrotoluene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
3-Nitroaniline	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
4-Bromophenylphenylether	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
4-Chloroaniline	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
4-Chlorophenylphenylether	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
4-Nitroaniline	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
Azobenzene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
Bis(2-chloroethoxy)methane	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
Bis(2-chloroethyl)ether	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
Carbazole	<10	<10	<10	<200$_{AD}$	72	11610$_{AD}$					<10	ug/kg	TM16/PM8
Dibenzofuran	<10	<10	<10	<200$_{AD}$	321	16069$_{AD}$					<10	ug/kg	TM16/PM8
Hexachlorobenzene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
Hexachlorobutadiene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
Hexachlorocyclopentadiene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
Hexachloroethane	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
Isophorone	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
N-nitrosodi-n-propylamine	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8
Nitrobenzene	<10	<10	<10	<200$_{AD}$	<10	<200$_{AD}$					<10	ug/kg	TM16/PM8

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Client Name: Golder Associates Africa Ltd | **VOC Report :** **Solid**
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Please see attached notes for all abbreviations and acronyms

J E Sample No.	1-4	5-8	21-24	25-28	45-46	49-51	LOD/LOR	Units	Method No.
Sample ID	SD3	SD9	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	FACILITY 6 (3)	FACILITY 15-4			
Depth									
COC No / misc									
Containers	V B	V B	V B	V B	B	V B			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015			
Sample Type	Sediment	Sediment	Sediment	Sediment	Solid	Solid			
Batch Number	1	1	1	1	1	1			
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
VOC MS									
Dichlorodifluoromethane	<2	<2	<2	<2	<2	<2	<2	ug/kg	TM15/PM10
Methyl Tertiary Butyl Ether	<2	<2	<2	<2	<2	<2	<2	ug/kg	TM15/PM10
Chloromethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Vinyl Chloride	<2	<2	<2	<2	<2	<2	<2	ug/kg	TM15/PM10
Bromomethane	<1	<1	<1	<1	<1	<1	<1	ug/kg	TM15/PM10
Chloroethane	<2	<2	<2	<2	<2	<2	<2	ug/kg	TM15/PM10
Trichlorofluoromethane	<2	<2	<2	<2	<2	<2	<2	ug/kg	TM15/PM10
1,1-Dichloroethene (1,1 DCE)	<6	<6	<6	<6	<6	<6	<6	ug/kg	TM15/PM10
Dichloromethane (DCM)	<7	<7	<7	<7	<7	<7	<7	ug/kg	TM15/PM10
trans-1-2-Dichloroethene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,1-Dichloroethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
cis-1-2-Dichloroethene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
2,2-Dichloropropane	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
Bromochloromethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Chloroform	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,1,1-Trichloroethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,1-Dichloropropene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Carbon tetrachloride	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
1,2-Dichloroethane	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
Benzene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Trichloroethene (TCE)	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,2-Dichloropropane	<6	<6	<6	<6	<6	<6	<6	ug/kg	TM15/PM10
Dibromomethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Bromodichloromethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
cis-1-3-Dichloropropene	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
Toluene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
trans-1-3-Dichloropropene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,1,2-Trichloroethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Tetrachloroethene (PCE)	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,3-Dichloropropane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Dibromochloromethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,2-Dibromoethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Chlorobenzene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,1,1,2-Tetrachloroethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Ethylbenzene	<3	<3	<3	<3	<3	17	<3	ug/kg	TM15/PM10
p/m-Xylene	<5	<5	<5	<5	<5	47	<5	ug/kg	TM15/PM10
o-Xylene	<3	<3	<3	<3	<3	26	<3	ug/kg	TM15/PM10
Styrene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Bromoform	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Isopropylbenzene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,1,2,2-Tetrachloroethane	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
Bromobenzene	<2	<2	<2	<2	<2	<2	<2	ug/kg	TM15/PM10
1,2,3-Trichloropropane	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
Propylbenzene	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
2-Chlorotoluene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
1,3,5-Trimethylbenzene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
4-Chlorotoluene	<3	<3	<3	<3	<3	<3	<3	ug/kg	TM15/PM10
tert-Butylbenzene	<5	<5	<5	<5	<5	6	<5	ug/kg	TM15/PM10
1,2,4-Trimethylbenzene	<6	<6	<6	<6	<6	119	<6	ug/kg	TM15/PM10
sec-Butylbenzene	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
4-Isopropyltoluene	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
1,3-Dichlorobenzene	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
1,4-Dichlorobenzene	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
n-Butylbenzene	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
1,2-Dichlorobenzene	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
1,2-Dibromo-3-chloropropane	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
1,2,4-Trichlorobenzene	<7	<7	<7	<7	<7	<7	<7	ug/kg	TM15/PM10
Hexachlorobutadiene	<4	<4	<4	<4	<4	<4	<4	ug/kg	TM15/PM10
Naphthalene	<27	<27	<27	<27	<27	15541_{AC}	<27	ug/kg	TM15/PM10
1,2,3-Trichlorobenzene	<7	<7	<7	<7	<7	<7	<7	ug/kg	TM15/PM10
Surrogate Recovery Toluene D8	106	106	110	92	75	64	<0	%	TM15/PM10
Surrogate Recovery 4-Bromofluorobenzene	117	123	125	70	53	61	<0	%	TM15/PM10

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Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman

J E Job No.	Batch	Sample ID	Depth	J E Sample No.	Analysis	Reason
No deviating sample report results for job 15/8219						

Please note that only samples that are deviating are mentioned in this report. If no samples are listed it is because none were deviating.
Only analyses which are accredited are recorded as deviating if set criteria are not met.

NOTES TO ACCOMPANY ALL SCHEDULES AND REPORTS

JE Job No.: 15/8219

SOILS

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 (UKAS) accreditation applies to surface water and groundwater and one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

Samples must be received in a condition appropriate to the requested analyses. All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. If this is not the case you will be informed and any test results that may be compromised highlighted on your deviating samples report.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS) accredited - UK.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
++	Result outside calibration range, results should be considered as indicative only and are not accredited.
*	Analysis subcontracted to a Jones Environmental approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x2 Dilution
AB	x5 Dilution
AC	x10 Dilution
AD	x20 Dilution
AE	x50 Dilution
AF	x100 Dilution

JE Job No: 15/8219

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
PM4	Gravimetric measurement of Natural Moisture Content and % Moisture Content at either 35°C or 105°C. Calculation based on ISO 11465 and BS1377.	PM0	No preparation is required.				
TM15	Modified USEPA 8260. Quantitative Determination of Volatile Organic Compounds (VOCs) by Headspace GC-MS.	PM10	Modified US EPA method 5021. Preparation of solid and liquid samples for GC headspace analysis.			AR	Yes
TM16	Modified USEPA 8270. Quantitative determination of Semi-Volatile Organic compounds (SVOCs) by GC-MS.	PM8	End over end extraction of solid samples for organic analysis. The solvent mix varies depending on analysis required.			AR	Yes
TM20	Modified USEPA 8163. Gravimetric determination of Total Dissolved Solids/Total Solids	PM20	Extraction of dried and ground samples with deionised water in a 2:1 water to solid ratio for anions. Extraction of as received samples with deionised water in a 2:1 water to solid ratio for ammoniacal nitrogen. Samples are extracted using an orbital shaker.			AD	Yes
TM27	Modified US EPA method 9056.Determination of water soluble anions using Dionex (Ion-Chromatography).	PM20	Extraction of dried and ground samples with deionised water in a 2:1 water to solid ratio for anions. Extraction of as received samples with deionised water in a 2:1 water to solid ratio for ammoniacal nitrogen. Samples are extracted using an orbital shaker.			AD	Yes
TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7	PM15	Acid digestion of dried and ground solid samples using Aqua Regia refluxed at 112.5 °C. Samples containing asbestos are not dried and ground.			AD	Yes
TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7	PM15	Acid digestion of dried and ground solid samples using Aqua Regia refluxed at 112.5 °C. Samples containing asbestos are not dried and ground.	Yes		AD	Yes
TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7	PM20	Extraction of dried and ground samples with deionised water in a 2:1 water to solid ratio for anions. Extraction of as received samples with deionised water in a 2:1 water to solid ratio for ammoniacal nitrogen. Samples are extracted using an orbital shaker.			AD	Yes
TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	PM20	Extraction of dried and ground samples with deionised water in a 2:1 water to solid ratio for anions. Extraction of as received samples with deionised water in a 2:1 water to solid ratio for ammoniacal nitrogen. Samples are extracted using an orbital shaker.			AD	Yes
TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	PM20	Extraction of dried and ground samples with deionised water in a 2:1 water to solid ratio for anions. Extraction of as received samples with deionised water in a 2:1 water to solid ratio for ammoniacal nitrogen. Samples are extracted using an orbital shaker.	Yes		AD	Yes

JE Job No: 15/8219

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	PM20	Extraction of dried and ground samples with deionised water in a 2:1 water to solid ratio for anions. Extraction of as received samples with deionised water in a 2:1 water to solid ratio for ammoniacal nitrogen. Samples are extracted using an orbital shaker.			AR	Yes
TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	PM20	Extraction of dried and ground samples with deionised water in a 2:1 water to solid ratio for anions. Extraction of as received samples with deionised water in a 2:1 water to solid ratio for ammoniacal nitrogen. Samples are extracted using an orbital shaker.	Yes		AR	Yes
TM73	Modified US EPA methods 150.1 and 9045D. Determination of pH by Metrohm automated probe analyser.	PM20	Extraction of dried and ground samples with deionised water in a 2:1 water to solid ratio for anions. Extraction of as received samples with deionised water in a 2:1 water to solid ratio for ammoniacal nitrogen. Samples are extracted using an orbital shaker.			AD	Yes
TM76	Modified US EPA method 120.1. Determination of Specific Conductance by Metrohm automated probe analyser.	PM20	Extraction of dried and ground samples with deionised water in a 2:1 water to solid ratio for anions. Extraction of as received samples with deionised water in a 2:1 water to solid ratio for ammoniacal nitrogen. Samples are extracted using an orbital shaker.			AD	Yes

Jones Environmental Laboratory

Registered Address : Unit 3 Deeside Point, Zone 3, Deeside Industrial Park, Deeside, CH5 2UA. UK

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Golder Associates Africa Ltd
Ditsela Place
1204 Park Street
Hatfield
Pretoria
Gauteng
South Africa

Attention :	Ilse Snyman
Date :	17th June, 2015
Your reference :	1418954
Our reference :	Test Report 15/8219 Batch 2
Location :	Middelburg Ferrochrome (MFC)
Date samples received :	3rd June, 2015
Status :	Final report
Issue :	1

Forty samples were received for analysis on 3rd June, 2015 of which forty were scheduled for analysis. Please find attached our Test Report which should be read with notes at the end of the report and should include all sections if reproduced. Interpretations and opinions are outside the scope of any accreditation, and all results relate only to samples supplied.
All analysis is carried out on as received samples and reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected.

NOTE: Under International Laboratory Accreditation Cooperation (ILAC), ISO 17025 (UKAS) accreditation is recognised as equivalent to SANAS (South Africa) accreditation.

Compiled By:

Paul Lee-Boden BSc
Project Manager

Bob Millward BSc FRSC
Principal Chemist

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : **Liquid**

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=HNO_3

Please see attached notes for all abbreviations and acronyms

J E Sample No.	62-63	64-65	66-67	68-69	70-71	72-73	74-77	78-79	80-81	82-83			
Sample ID	SPK	SPL	SPJ	SPG	SPB	SPD	SD3	SD11	SP2	MB1			
Depth													
COC No / misc													
Containers	HN P	HN P	HN P	HN P	HN P	HN P	V HN P G	HN P	HN P	HN P			
Sample Date	25/05/2015	25/05/2015	25/05/2015	25/05/2015	25/05/2015	25/05/2015	27/05/2015	27/05/2015	26/05/2015	27/05/2015			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	2	2	2	2	2	2	2	2	2	2	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Dissolved Aluminium #	<20	<20	<20	<20	<20	<20	<20	28	<20	<20	<20	ug/l	TM30/PM14
Dissolved Antimony #	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Arsenic #	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	2.7	3.9	<2.5	<2.5	ug/l	TM30/PM14
Dissolved Barium #	74	76	79	88	63	90	258	22	37	7	<3	ug/l	TM30/PM14
Dissolved Beryllium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Cadmium #	<0.5	<0.5	<0.5	<0.5	<0.5	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Calcium #	30.1	29.9	29.8	54.0	63.1	71.7	43.3	82.6	78.1	23.2	<0.2	mg/l	TM30/PM14
Total Dissolved Chromium #	<1.5	<1.5	<1.5	<1.5	5.4	4.5	<1.5	2.7	2.8	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Cobalt #	<2	<2	<2	<2	<2	<2	<2	9	<2	<2	<2	ug/l	TM30/PM14
Dissolved Copper #	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	ug/l	TM30/PM14
Total Dissolved Iron #	106	107	58	<20	<20	<20	<20	195	<20	<20	<20	ug/l	TM30/PM14
Dissolved Lead #	<5	<5	<5	<5	<5	5	6	13	25	<5	<5	ug/l	TM30/PM14
Dissolved Magnesium #	21.5	21.3	21.2	42.1	46.5	51.2	15.0	58.0	44.9	12.1	<0.1	mg/l	TM30/PM14
Dissolved Manganese #	48	89	56	64	8	9	<2	124	7	6	<2	ug/l	TM30/PM14
Dissolved Mercury #	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	ug/l	TM30/PM14
Dissolved Molybdenum #	<2	<2	<2	<2	26	21	<2	283	<2	<2	<2	ug/l	TM30/PM14
Dissolved Nickel #	<2	<2	<2	<2	<2	<2	<2	42	<2	<2	<2	ug/l	TM30/PM14
Dissolved Phosphorus #	<5	<5	<5	<5	10	5	54	28	20	<5	<5	ug/l	TM30/PM14
Dissolved Potassium #	7.5	7.3	7.3	7.5	23.8	21.3	1.6	2.1	3.2	4.2	<0.1	mg/l	TM30/PM14
Dissolved Selenium #	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	ug/l	TM30/PM14
Dissolved Sodium #	21.5	21.0	20.8	30.7	59.0	63.0	34.6	478.5AB	32.2	21.3	<0.1	mg/l	TM30/PM14
Dissolved Vanadium #	<1.5	<1.5	<1.5	<1.5	<1.5	1.6	<1.5	8.3	7.1	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Zinc #	16	11	11	14	17	31	12	28	19	8	<3	ug/l	TM30/PM14

Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : **Liquid**

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=HNO_3

Please see attached notes for all abbreviations and acronyms

J E Sample No.	62-63	64-65	66-67	68-69	70-71	72-73	74-77	78-79	80-81	82-83	LOD/LOR	Units	Method No.
Sample ID	SPK	SPL	SPJ	SPG	SPB	SPD	SD3	SD11	SP2	MB1			
Depth													
COC No / misc													
Containers	HN P	HN P	HN P	HN P	HN P	HN P	V HN P G	HN P	HN P	HN P			
Sample Date	25/05/2015	25/05/2015	25/05/2015	25/05/2015	25/05/2015	25/05/2015	27/05/2015	27/05/2015	26/05/2015	27/05/2015			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	2	2	2	2	2	2	2	2	2	2			
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
PAH MS													
Naphthalene #	-	-	-	-	-	-	<0.014	-	-	-	<0.014	ug/l	TM4/PM30
Acenaphthylene #	-	-	-	-	-	-	<0.013	-	-	-	<0.013	ug/l	TM4/PM30
Acenaphthene #	-	-	-	-	-	-	<0.013	-	-	-	<0.013	ug/l	TM4/PM30
Fluorene #	-	-	-	-	-	-	<0.014	-	-	-	<0.014	ug/l	TM4/PM30
Phenanthrene #	-	-	-	-	-	-	<0.011	-	-	-	<0.011	ug/l	TM4/PM30
Anthracene #	-	-	-	-	-	-	<0.013	-	-	-	<0.013	ug/l	TM4/PM30
Fluoranthene #	-	-	-	-	-	-	<0.012	-	-	-	<0.012	ug/l	TM4/PM30
Pyrene #	-	-	-	-	-	-	<0.013	-	-	-	<0.013	ug/l	TM4/PM30
Benzo(a)anthracene #	-	-	-	-	-	-	<0.015	-	-	-	<0.015	ug/l	TM4/PM30
Chrysene #	-	-	-	-	-	-	<0.011	-	-	-	<0.011	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	-	-	-	-	-	-	<0.018	-	-	-	<0.018	ug/l	TM4/PM30
Benzo(a)pyrene #	-	-	-	-	-	-	<0.016	-	-	-	<0.016	ug/l	TM4/PM30
Indeno(123cd)pyrene #	-	-	-	-	-	-	<0.011	-	-	-	<0.011	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	-	-	-	-	-	-	<0.01	-	-	-	<0.01	ug/l	TM4/PM30
Benzo(ghi)perylene #	-	-	-	-	-	-	<0.011	-	-	-	<0.011	ug/l	TM4/PM30
PAH 16 Total #	-	-	-	-	-	-	<0.195	-	-	-	<0.195	ug/l	TM4/PM30
Benzo(b)fluoranthene	-	-	-	-	-	-	<0.01	-	-	-	<0.01	ug/l	TM4/PM30
Benzo(k)fluoranthene	-	-	-	-	-	-	<0.01	-	-	-	<0.01	ug/l	TM4/PM30
PAH Surrogate % Recovery	-	-	-	-	-	-	85	-	-	-	<0	%	TM4/PM30
Fluoride	<0.3	<0.3	<0.3	0.3	0.7	0.6	<0.3	<0.3	<0.3	<0.3	<0.3	mg/l	TM27/PM0
Sulphate #	141.51	144.80	139.10	277.38	306.05	342.64	28.81	762.29	106.47	23.40	<0.05	mg/l	TM38/PM0
Chloride #	15.2	14.8	14.9	23.9	38.2	44.3	33.0	259.5	55.6	1.7	<0.3	mg/l	TM38/PM0
Nitrate as NO3 #	0.3	0.2	<0.2	<0.2	14.0	24.7	27.1	280.5	29.0	0.3	<0.2	mg/l	TM38/PM0
Ammoniacal Nitrogen as NH4 #	0.08	0.06	0.13	0.07	0.05	0.08	<0.03	<0.03	<0.03	0.03	<0.03	mg/l	TM38/PM0
Hexavalent Chromium #	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Total Alkalinity as CaCO3 #	56	66	64	88	130	134	112	88	190	172	<1	mg/l	TM75/PM0
Electrical Conductivity @25C #	461	467	462	725	1015	1112	537	2658	862	315	<2	uS/cm	TM76/PM0
pH #	6.88	6.88	6.90	7.28	7.89	7.72	7.66	7.66	8.00	8.01	<0.01	pH units	TM73/PM0
Total Dissolved Solids #	308	307	314	532	651	796	420	1411	753	215	<10	mg/l	TM20/PM0
Total Cations	4.40	4.34	4.32	7.69	10.15	11.08	4.94	29.76	9.07	3.19	<0.00	mmolc/l	TM0/PM0
Total Anions	4.50	4.75	4.60	8.21	10.28	11.46	4.21	29.47	8.05	3.98	<0.00	mmolc/l	TM0/PM0
% Cation Excess	-1.12	-4.51	-3.14	-3.27	-0.64	-1.69	7.98	0.49	5.96	-11.02		%	TM0/PM0

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

Please see attached notes for all abbreviations and acronyms

J E Sample No.	84-85	86-89	90-93	94-95	96-97	98-99	100-101	102-103	104-107	108-111			
Sample ID	FACILITY 9 - RWD1	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	FACILITY 12 DAM 3B	FACILITY 13 DAM 3A	FACILITY 14 DAM 6B	BH8	BH8A	BH7	BH7A			
Depth													
COC No / misc													
Containers	HN P	V HN P G	V HN P G	HN P	HN P	HN P	HN P	HN P	V HN P G	V HN P G			
Sample Date	25/05/2015	26/05/2015	26/05/2015	25/05/2015	25/05/2015	25/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	2	2	2	2	2	2	2	2	2	2	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Dissolved Aluminium #	<20	30	57	<20	<20	32	<20	<20	<20	<20	<20	ug/l	TM30/PM14
Dissolved Antimony #	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Arsenic #	<2.5	<2.5	4.6	4.0	2.9	<2.5	<2.5	<2.5	47.6	34.0	<2.5	ug/l	TM30/PM14
Dissolved Barium #	57	9	11	4	4	7	78	85	7	25	<3	ug/l	TM30/PM14
Dissolved Beryllium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Cadmium #	0.8	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Calcium #	339.1_{AB}	8.6	15.6	61.3	26.1	8.4	8.5	9.2	1.0	4.2	<0.2	mg/l	TM30/PM14
Total Dissolved Chromium #	<1.5	433.3	1913.0	15.0	13.7	28.7	<1.5	<1.5	<1.5	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Cobalt #	<2	47	29	29	28	42	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Copper #	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	ug/l	TM30/PM14
Total Dissolved Iron #	<20	323	51	<20	51	251	1275	<20	<20	<20	<20	ug/l	TM30/PM14
Dissolved Lead #	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	ug/l	TM30/PM14
Dissolved Magnesium #	150.3_{AB}	64.0	44.1	44.1	40.3	39.5	5.0	4.0	0.2	2.0	<0.1	mg/l	TM30/PM14
Dissolved Manganese #	<2	59	6	<2	2	13	183	<2	4	56	<2	ug/l	TM30/PM14
Dissolved Mercury #	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	ug/l	TM30/PM14
Dissolved Molybdenum #	64	756	1023	853	808	348	<2	<2	4	4	<2	ug/l	TM30/PM14
Dissolved Nickel #	3	98	31	36	25	75	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Phosphorus #	13	714	338	105	76	673	<5	6	58	83	<5	ug/l	TM30/PM14
Dissolved Potassium #	149.5_{AB}	802.7_{AB}	562.1_{AB}	582.6_{AB}	589.7_{AB}	682.2_{AB}	2.3	2.1	0.5	0.7	<0.1	mg/l	TM30/PM14
Dissolved Selenium #	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	ug/l	TM30/PM14
Dissolved Sodium #	611.7_{AB}	892.0_{AB}	722.8_{AB}	742.0_{AB}	764.1_{AB}	714.8_{AB}	18.6	22.0	98.4	77.7	<0.1	mg/l	TM30/PM14
Dissolved Vanadium #	5.2	16.6	27.5	<1.5	<1.5	26.7	<1.5	<1.5	<1.5	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Zinc #	28	77	31	21	18	54	40	23	15	18	<3	ug/l	TM30/PM14

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All solid results are expressed on a dry weight basis unless stated otherwise.

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

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J E Sample No.	84-85	86-89	90-93	94-95	96-97	98-99	100-101	102-103	104-107	108-111			
Sample ID	FACILITY 9 - RWD1	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	FACILITY 12 DAM 3B	FACILITY 13 DAM 3A	FACILITY 14 DAM 6B	BH8	BH8A	BH7	BH7A			
Depth													
COC No / misc													
Containers	HN P	V HN P G	V HN P G	HN P	HN P	HN P	HN P	HN P	V HN P G	V HN P G			
Sample Date	25/05/2015	26/05/2015	26/05/2015	25/05/2015	25/05/2015	25/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	2	2	2	2	2	2	2	2	2	2	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
PAH MS													
Naphthalene #	-	<0.014	<0.014	-	-	-	-	-	0.090	0.030	<0.014	ug/l	TM4/PM30
Acenaphthylene #	-	<0.013	<0.013	-	-	-	-	-	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Acenaphthene #	-	<0.013	<0.013	-	-	-	-	-	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Fluorene #	-	<0.014	<0.014	-	-	-	-	-	<0.014	<0.014	<0.014	ug/l	TM4/PM30
Phenanthrene #	-	<0.011	<0.011	-	-	-	-	-	<0.011	<0.011	<0.011	ug/l	TM4/PM30
Anthracene #	-	<0.013	<0.013	-	-	-	-	-	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Fluoranthene #	-	<0.012	<0.012	-	-	-	-	-	<0.012	<0.012	<0.012	ug/l	TM4/PM30
Pyrene #	-	<0.013	<0.013	-	-	-	-	-	<0.013	<0.013	<0.013	ug/l	TM4/PM30
Benzo(a)anthracene #	-	<0.015	<0.015	-	-	-	-	-	<0.015	<0.015	<0.015	ug/l	TM4/PM30
Chrysene #	-	<0.011	<0.011	-	-	-	-	-	<0.011	<0.011	<0.011	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	-	<0.018	<0.018	-	-	-	-	-	<0.018	<0.018	<0.018	ug/l	TM4/PM30
Benzo(a)pyrene #	-	<0.016	<0.016	-	-	-	-	-	<0.016	<0.016	<0.016	ug/l	TM4/PM30
Indeno(123cd)pyrene #	-	<0.011	<0.011	-	-	-	-	-	<0.011	<0.011	<0.011	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	-	<0.01	<0.01	-	-	-	-	-	<0.01	<0.01	<0.01	ug/l	TM4/PM30
Benzo(ghi)perylene #	-	<0.011	<0.011	-	-	-	-	-	<0.011	<0.011	<0.011	ug/l	TM4/PM30
PAH 16 Total #	-	<0.195	<0.195	-	-	-	-	-	<0.195	<0.195	<0.195	ug/l	TM4/PM30
Benzo(b)fluoranthene	-	<0.01	<0.01	-	-	-	-	-	<0.01	<0.01	<0.01	ug/l	TM4/PM30
Benzo(k)fluoranthene	-	<0.01	<0.01	-	-	-	-	-	<0.01	<0.01	<0.01	ug/l	TM4/PM30
PAH Surrogate % Recovery	-	74	72	-	-	-	-	-	94	70	<0	%	TM4/PM30
Fluoride	5.6	9.6$_{AB}$	9.7	9.8	9.7	12.6	<0.3	0.3	9.6	7.2	<0.3	mg/l	TM27/PM0
Sulphate #	2503.11	1095.16	936.48	1275.00	1031.21	749.92	13.81	5.02	5.81	5.88	<0.05	mg/l	TM38/PM0
Chloride #	126.1	335.0	299.4	296.5	271.9	259.7	4.8	5.6	2.7	2.3	<0.3	mg/l	TM38/PM0
Nitrate as NO3 #	<0.2	300.3	296.5	508.8	60.6	201.1	0.3	1.7	0.8	1.0	<0.2	mg/l	TM38/PM0
Ammoniacal Nitrogen as NH4 #	0.43	0.92	0.31	0.52	0.25	1.20	0.05	0.04	0.12	0.35	<0.03	mg/l	TM38/PM0
Hexavalent Chromium #	<0.006	0.333	1.351	0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Total Alkalinity as CaCO3 #	48	1338	808	596	580	1150	88	88	218	186	<1	mg/l	TM75/PM0
Electrical Conductivity @25C #	4667	5954	4757	4956	4656	4917	191	190	428	371	<2	uS/cm	TM76/PM0
pH #	8.91	9.66	9.64	8.37	8.70	9.85	6.95	7.45	8.96	8.40	<0.01	pH units	TM73/PM0
Total Dissolved Solids #	3591	4510	3484	3904	3365	3491	112	116	273	230	<10	mg/l	TM20/PM0
Total Cations	59.72$_{AB}$	65.02	50.22	53.86	52.94	52.21	1.70	1.80	4.36	3.77	<0.00	mmolc/l	TM0/PM0
Total Anions	56.63	63.85	48.88	55.03	41.71	49.18	2.19	2.05	4.57	3.92	<0.00	mmolc/l	TM0/PM0
% Cation Excess	2.66	0.91	1.35	-1.07	11.86	2.99	-12.60	-6.49	-2.35	-1.95		%	TM0/PM0

Please include all sections of this report if it is reproduced
All solid results are expressed on a dry weight basis unless stated otherwise.

Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : **Liquid**

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=$HN0_3$

Please see attached notes for all abbreviations and acronyms

J E Sample No.	112-115	116-119	120-123	124-127	128-129	130-131	132-133	134-135	136-137	138-139			
Sample ID	BH1	SD 5	SD9	BH11	BH2B	BH2A	BH3B	BH3A	N3-880	WD9			
Depth													
COC No / misc													
Containers	V HN P G	V HN P G	V HN P G	V HN P G	HN P	HN P	HN P	HN P	HN P	HN P			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	27/05/2015	26/05/2015	26/05/2015	27/05/2015	27/05/2015			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	2	2	2	2	2	2	2	2	2	2	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Dissolved Aluminium #	<20	55	<20	<20	<20	<20	<20	<20	<20	<20	<20	ug/l	TM30/PM14
Dissolved Antimony #	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Arsenic #	<2.5	<2.5	<2.5	2.7	<2.5	<2.5	<2.5	6.9	<2.5	4.3	<2.5	ug/l	TM30/PM14
Dissolved Barium #	77	52	94	20	143	20	68	5	67	16	<3	ug/l	TM30/PM14
Dissolved Beryllium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Cadmium #	0.6	<0.5	0.8	<0.5	<0.5	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Calcium #	386.7 AA	6.8	313.0 AA	39.5	58.2	143.0	96.2	3.7	6.0	8.2	<0.2	mg/l	TM30/PM14
Total Dissolved Chromium #	1.7	<1.5	<1.5	474.0	11.9	138.4	5.6	<1.5	<1.5	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Cobalt #	<2	<2	<2	7	6	21	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Copper #	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	ug/l	TM30/PM14
Total Dissolved Iron #	<20	<20	<20	<20	32	37	<20	<20	8752	145	<20	ug/l	TM30/PM14
Dissolved Lead #	6	7	8	25	28	7	9	38	5	7	<5	ug/l	TM30/PM14
Dissolved Magnesium #	159.7 AA	4.7	125.6 AA	10.9	32.9	102.4	46.8	<0.1	5.9	4.7	<0.1	mg/l	TM30/PM14
Dissolved Manganese #	27	<2	307	12	<2	77	9	<2	346	99	<2	ug/l	TM30/PM14
Dissolved Mercury #	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	ug/l	TM30/PM14
Dissolved Molybdenum #	13	13	5	91	<2	6	10	3	<2	4	<2	ug/l	TM30/PM14
Dissolved Nickel #	8	<2	11	19	3	16	4	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Phosphorus #	139	17	97	19	11	<5	28	<5	<5	285	<5	ug/l	TM30/PM14
Dissolved Potassium #	4.4	1.2	3.8	27.8	2.2	22.4	2.5	0.2	1.0	1.3	<0.1	mg/l	TM30/PM14
Dissolved Selenium #	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	ug/l	TM30/PM14
Dissolved Sodium #	246.4 AA	65.1	171.4	200.3	36.5	327.6 AA	191.3	59.1	8.8	93.3	<0.1	mg/l	TM30/PM14
Dissolved Vanadium #	<1.5	<1.5	<1.5	43.6	6.1	1.7	9.6	<1.5	<1.5	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Zinc #	17	41	25	39	25	25	24	25	9	13	<3	ug/l	TM30/PM14

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Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : **Liquid**

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
H=H_2SO_4, Z=ZnAc, N=NaOH, HN=HNO_3

Please see attached notes for all abbreviations and acronyms

J E Sample No.	112-115	116-119	120-123	124-127	128-129	130-131	132-133	134-135	136-137	138-139	LOD/LOR	Units	Method No.
Sample ID	BH1	SD 5	SD9	BH11	BH2B	BH2A	BH3B	BH3A	N3-880	WD9			
Depth													
COC No / misc													
Containers	V HN P G	V HN P G	V HN P G	V HN P G	HN P	HN P	HN P	HN P	HN P	HN P			
Sample Date	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	27/05/2015	26/05/2015	26/05/2015	27/05/2015	27/05/2015			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	2	2	2	2	2	2	2	2	2	2			
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
PAH MS													
Naphthalene #	<0.014	0.020	-	<0.014	-	-	-	-	-	-	<0.014	ug/l	TM4/PM30
Acenaphthylene #	<0.013	<0.013	-	<0.013	-	-	-	-	-	-	<0.013	ug/l	TM4/PM30
Acenaphthene #	<0.013	<0.013	-	<0.013	-	-	-	-	-	-	<0.013	ug/l	TM4/PM30
Fluorene #	<0.014	<0.014	-	<0.014	-	-	-	-	-	-	<0.014	ug/l	TM4/PM30
Phenanthrene #	<0.011	<0.011	-	<0.011	-	-	-	-	-	-	<0.011	ug/l	TM4/PM30
Anthracene #	<0.013	<0.013	-	<0.013	-	-	-	-	-	-	<0.013	ug/l	TM4/PM30
Fluoranthene #	<0.012	<0.012	-	<0.012	-	-	-	-	-	-	<0.012	ug/l	TM4/PM30
Pyrene #	<0.013	<0.013	-	<0.013	-	-	-	-	-	-	<0.013	ug/l	TM4/PM30
Benzo(a)anthracene #	<0.015	<0.015	-	<0.015	-	-	-	-	-	-	<0.015	ug/l	TM4/PM30
Chrysene #	<0.011	<0.011	-	<0.011	-	-	-	-	-	-	<0.011	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	<0.018	<0.018	-	<0.018	-	-	-	-	-	-	<0.018	ug/l	TM4/PM30
Benzo(a)pyrene #	<0.016	<0.016	-	<0.016	-	-	-	-	-	-	<0.016	ug/l	TM4/PM30
Indeno(123cd)pyrene #	<0.011	<0.011	-	<0.011	-	-	-	-	-	-	<0.011	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	<0.01	<0.01	-	<0.01	-	-	-	-	-	-	<0.01	ug/l	TM4/PM30
Benzo(ghi)perylene #	<0.011	<0.011	-	<0.011	-	-	-	-	-	-	<0.011	ug/l	TM4/PM30
PAH 16 Total #	<0.195	<0.195	-	<0.195	-	-	-	-	-	-	<0.195	ug/l	TM4/PM30
Benzo(b)fluoranthene	<0.01	<0.01	-	<0.01	-	-	-	-	-	-	<0.01	ug/l	TM4/PM30
Benzo(k)fluoranthene	<0.01	<0.01	-	<0.01	-	-	-	-	-	-	<0.01	ug/l	TM4/PM30
PAH Surrogate % Recovery	70	72	-	81	-	-	-	-	-	-	<0	%	TM4/PM30
Fluoride	<0.3	1.7	<0.3	0.4	<0.3	<0.3	0.5	<0.3	<0.3	4.7	<0.3	mg/l	TM27/PM0
Sulphate #	380.15	27.64	286.52	274.76	97.01	695.73	353.25	29.29	1.96	1.91	<0.05	mg/l	TM38/PM0
Chloride #	403.6	27.5	293.5	81.1	42.7	286.5	214.2	11.5	2.8	6.8	<0.3	mg/l	TM38/PM0
Nitrate as NO3 #	1289.6	0.4	1019.8	171.7	63.4	422.5	202.8	<0.2	<0.2	0.8	<0.2	mg/l	TM38/PM0
Ammoniacal Nitrogen as NH4 #	<0.03	<0.03	0.08	0.25	<0.03	<0.03	<0.03	0.93	<0.03	1.57	<0.03	mg/l	TM38/PM0
Hexavalent Chromium #	<0.006	<0.006	<0.006	0.444	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Total Alkalinity as CaCO3 #	158	134	122	126	154	86	90	112	76	244	<1	mg/l	TM75/PM0
Electrical Conductivity @25C #	3394	381	2908	1316	726	2771	1744	294	134	536	<2	uS/cm	TM76/PM0
pH #	7.66	8.58	7.69	7.95	7.08	6.39	7.63	10.26	6.76	7.90	<0.01	pH units	TM73/PM0
Total Dissolved Solids #	3806	239	2769	1020	570	1299	970	256	79	320	<10	mg/l	TM20/PM0
Total Cations	43.27	3.59	33.50	12.29	7.26	30.38	17.04	2.76	1.19	4.89	<0.00	mmolc/l	TM0/PM0
Total Anions	43.26	4.04	33.13	13.30	7.33	31.10	18.47	3.17	1.64	5.12	<0.00	mmolc/l	TM0/PM0
% Cation Excess	0.01	-5.90	0.56	-3.95	-0.48	-1.17	-4.03	-6.91	-15.90	-2.30		%	TM0/PM0

Jones Environmental Laboratory

Client Name:	Golder Associates Africa Ltd	**Report :**	**Liquid**
Reference:	1418954		
Location:	Middelburg Ferrochrome (MFC)		
Contact:	Ilse Snyman	**Liquids/products:**	V=40ml vial, G=glass bottle, P=plastic bottle
JE Job No.:	15/8219		$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HNO_3$

Please see attached notes for all abbreviations and acronyms

J E Sample No.	140-141	142-143	144-145	146-147	148-149	150-151	152-153	154-155	156-157	158-159			
Sample ID	WD17A	BH5B	BH5A	BH6B	BH6A	WD20	BH4B	BH4A	WD15A	WD15B			
Depth													
COC No / misc													
Containers	HN P	HN P	HN P	HN P	HN P	HN P	HN P	HN P	HN P	HN P			
Sample Date	27/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	26/05/2015	26/05/2015	27/05/2015	27/05/2015			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	2	2	2	2	2	2	2	2	2	2	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
Dissolved Aluminium #	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	ug/l	TM30/PM14
Dissolved Antimony #	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Arsenic #	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	ug/l	TM30/PM14
Dissolved Barium #	18	23	25	58	33	28	123	147	18	31	<3	ug/l	TM30/PM14
Dissolved Beryllium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Cadmium #	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.8	<0.5	<0.5	ug/l	TM30/PM14
Dissolved Calcium #	287.8 AA	77.9	50.5	106.8	105.9	32.6	64.2	62.1	230.9 AA	40.2	<0.2	mg/l	TM30/PM14
Total Dissolved Chromium #	<1.5	1.7	<1.5	<1.5	1.9	<1.5	<1.5	2.9	<1.5	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Cobalt #	<2	<2	<2	<2	<2	4	2	2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Copper #	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	ug/l	TM30/PM14
Total Dissolved Iron #	7208	<20	30	<20	<20	<20	<20	27	9758	<20	<20	ug/l	TM30/PM14
Dissolved Lead #	18	19	10	28	16	13	21	19	20	<5	<5	ug/l	TM30/PM14
Dissolved Magnesium #	207.4 AA	41.7	36.8	47.7	57.0	29.7	41.1	42.2	157.1 AA	16.1	<0.1	mg/l	TM30/PM14
Dissolved Manganese #	1515	<2	89	<2	<2	4	6	3	177	33	<2	ug/l	TM30/PM14
Dissolved Mercury #	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	ug/l	TM30/PM14
Dissolved Molybdenum #	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	ug/l	TM30/PM14
Dissolved Nickel #	3	<2	<2	<2	4	<2	<2	<2	3	<2	<2	ug/l	TM30/PM14
Dissolved Phosphorus #	18	7	6	11	12	58	68	128	8	16	<5	ug/l	TM30/PM14
Dissolved Potassium #	0.6	1.7	2.2	2.4	0.5	0.9	1.6	1.6	0.7	13.7	<0.1	mg/l	TM30/PM14
Dissolved Selenium #	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	ug/l	TM30/PM14
Dissolved Sodium #	235.7 AA	52.7	39.7	54.3	42.8	36.9	26.1	26.7	129.9	19.0	<0.1	mg/l	TM30/PM14
Dissolved Vanadium #	<1.5	<1.5	<1.5	9.3	<1.5	<1.5	4.4	5.8	3.6	<1.5	<1.5	ug/l	TM30/PM14
Dissolved Zinc #	10	11	12	16	16	7	11	12	23	31	<3	ug/l	TM30/PM14

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All solid results are expressed on a dry weight basis unless stated otherwise.

Jones Environmental Laboratory

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Report : Liquid

Liquids/products: V=40ml vial, G=glass bottle, P=plastic bottle
$H=H_2SO_4$, Z=ZnAc, N=NaOH, $HN=HN0_3$

Please see attached notes for all abbreviations and acronyms

J E Sample No.	140-141	142-143	144-145	146-147	148-149	150-151	152-153	154-155	156-157	158-159			
Sample ID	WD17A	BH5B	BH5A	BH6B	BH6A	WD20	BH4B	BH4A	WD15A	WD15B			
Depth													
COC No / misc													
Containers	HN P	HN P	HN P	HN P	HN P	HN P	HN P	HN P	HN P	HN P			
Sample Date	27/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	27/05/2015	26/05/2015	26/05/2015	27/05/2015	27/05/2015			
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water			
Batch Number	2	2	2	2	2	2	2	2	2	2	LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015			
PAH MS													
Naphthalene #	-	-	-	-	-	-	-	-	-	-	<0.014	ug/l	TM4/PM30
Acenaphthylene #	-	-	-	-	-	-	-	-	-	-	<0.013	ug/l	TM4/PM30
Acenaphthene #	-	-	-	-	-	-	-	-	-	-	<0.013	ug/l	TM4/PM30
Fluorene #	-	-	-	-	-	-	-	-	-	-	<0.014	ug/l	TM4/PM30
Phenanthrene #	-	-	-	-	-	-	-	-	-	-	<0.011	ug/l	TM4/PM30
Anthracene #	-	-	-	-	-	-	-	-	-	-	<0.013	ug/l	TM4/PM30
Fluoranthene #	-	-	-	-	-	-	-	-	-	-	<0.012	ug/l	TM4/PM30
Pyrene #	-	-	-	-	-	-	-	-	-	-	<0.013	ug/l	TM4/PM30
Benzo(a)anthracene #	-	-	-	-	-	-	-	-	-	-	<0.015	ug/l	TM4/PM30
Chrysene #	-	-	-	-	-	-	-	-	-	-	<0.011	ug/l	TM4/PM30
Benzo(bk)fluoranthene #	-	-	-	-	-	-	-	-	-	-	<0.018	ug/l	TM4/PM30
Benzo(a)pyrene #	-	-	-	-	-	-	-	-	-	-	<0.016	ug/l	TM4/PM30
Indeno(123cd)pyrene #	-	-	-	-	-	-	-	-	-	-	<0.011	ug/l	TM4/PM30
Dibenzo(ah)anthracene #	-	-	-	-	-	-	-	-	-	-	<0.01	ug/l	TM4/PM30
Benzo(ghi)perylene #	-	-	-	-	-	-	-	-	-	-	<0.011	ug/l	TM4/PM30
PAH 16 Total #	-	-	-	-	-	-	-	-	-	-	<0.195	ug/l	TM4/PM30
Benzo(b)fluoranthene	-	-	-	-	-	-	-	-	-	-	<0.01	ug/l	TM4/PM30
Benzo(k)fluoranthene	-	-	-	-	-	-	-	-	-	-	<0.01	ug/l	TM4/PM30
PAH Surrogate % Recovery	-	-	-	-	-	-	-	-	-	-	<0	%	TM4/PM30
Fluoride	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.5	<0.3	mg/l	TM27/PM0
Sulphate #	1188.20	202.31	110.61	183.71	281.10	65.81	84.29	82.62	823.50	85.37	<0.05	mg/l	TM38/PM0
Chloride #	241.7	46.2	35.9	38.6	52.6	29.3	64.2	64.7	81.0	31.4	<0.3	mg/l	TM38/PM0
Nitrate as NO3 #	0.4	46.2	6.2	227.4	89.7	36.8	74.1	68.7	0.8	3.7	<0.2	mg/l	TM38/PM0
Ammoniacal Nitrogen as NH4 #	0.39	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.05	<0.03	<0.03	mg/l	TM38/PM0
Hexavalent Chromium #	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	mg/l	TM38/PM0
Total Alkalinity as CaCO3 #	472	188	208	186	166	162	176	168	520	108	<1	mg/l	TM75/PM0
Electrical Conductivity @25C #	2915	911	689	1149	1111	561	773	739	2196	483	<2	uS/cm	TM76/PM0
pH #	7.20	7.77	7.96	7.31	7.46	7.22	6.96	7.18	7.18	7.54	<0.01	pH units	TM73/PM0
Total Dissolved Solids #	2287	759	428	915	947	336	522	495	2121	349	<10	mg/l	TM20/PM0
Total Cations	41.69	9.65	7.33	11.68	11.85	5.70	7.76	7.77	30.12	4.51	<0.00	mmolc/l	TM0/PM0
Total Anions	41.00	10.02	7.58	12.30	12.10	6.03	8.28	8.01	29.84	4.88	<0.00	mmolc/l	TM0/PM0
% Cation Excess	0.83	-1.88	-1.68	-2.59	-1.04	-2.81	-3.24	-1.52	0.47	-3.94		%	TM0/PM0

Client Name: Golder Associates Africa Ltd **SVOC Report :** **Liquid**
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

Please see attached notes for all abbreviations and acronyms

J E Sample No.	74-77	86-89	90-93	104-107	108-111	112-115	116-119	124-127					
Sample ID	SD3	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	BH7	BH7A	BH1	SD 5	BH11					
Depth													
COC No / misc													
Containers	V HN P G	V HN P G	V HN P G	V HN P G	V HN P G	V HN P G	V HN P G	V HN P G					
Sample Date	27/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015					
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water					
Batch Number	2	2	2	2	2	2	2	2			LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015					
SVOC MS													
Phenols													
2-Chlorophenol#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
2-Methylphenol#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
2-Nitrophenol	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
2,4-Dichlorophenol#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
2,4-Dimethylphenol	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
2,4,5-Trichlorophenol#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
2,4,6-Trichlorophenol	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
4-Chloro-3-methylphenol#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
4-Methylphenol	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
4-Nitrophenol	<10	$<100_{AB}$	$<200_{AC}$	<10	<10	<10	<10	<10			<10	ug/l	TM16/PM30
Pentachlorophenol	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Phenol	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
PAHs													
2-Chloronaphthalene#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
2-Methylnaphthalene#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Phthalates													
Bis(2-ethylhexyl) phthalate	<5	$<50_{AB}$	$<100_{AC}$	<5	<5	<5	<5	<5			<5	ug/l	TM16/PM30
Butylbenzyl phthalate	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Di-n-butyl phthalate#	<1.5	$<15.0_{AB}$	$<30.0_{AC}$	<1.5	<1.5	<1.5	<1.5	<1.5			<1.5	ug/l	TM16/PM30
Di-n-Octyl phthalate	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Diethyl phthalate#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Dimethyl phthalate	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Other SVOCs													
1,2-Dichlorobenzene#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
1,2,4-Trichlorobenzene#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
1,3-Dichlorobenzene#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
1,4-Dichlorobenzene#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
2-Nitroaniline	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
2,4-Dinitrotoluene#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
2,6-Dinitrotoluene	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
3-Nitroaniline	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
4-Bromophenylphenylether#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
4-Chloroaniline	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
4-Chlorophenylphenylether#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
4-Nitroaniline	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
Azobenzene#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
Bis(2-chloroethoxy)methane#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
Bis(2-chloroethyl)ether#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Carbazole#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
Dibenzofuran#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
Hexachlorobenzene#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Hexachlorobutadiene#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Hexachlorocyclopentadiene	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Hexachloroethane#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30
Isophorone#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
N-nitrosodi-n-propylamine#	<0.5	$<5.0_{AB}$	$<10.0_{AC}$	<0.5	<0.5	<0.5	<0.5	<0.5			<0.5	ug/l	TM16/PM30
Nitrobenzene#	<1	$<10_{AB}$	$<20_{AC}$	<1	<1	<1	<1	<1			<1	ug/l	TM16/PM30

Client Name: Golder Associates Africa Ltd
Reference: 1418954
Location: Middelburg Ferrochrome (MFC)
Contact: Ilse Snyman
JE Job No.: 15/8219

VOC Report : **Liquid**

Please see attached notes for all abbreviations and acronyms

J E Sample No.	74-77	86-89	90-93	104-107	108-111	112-115	116-119	120-123	124-127				
Sample ID	SD3	FACILITY 10 DAM 4B	FACILITY 11 DAM 4A	BH7	BH7A	BH1	SD 5	SD9	BH11				
Depth													
COC No / misc													
Containers	V HN P G	V HN P G	V HN P G	V HN P G	V HN P G	V HN P G	V HN P G	V HN P G	V HN P G				
Sample Date	27/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015	26/05/2015				
Sample Type	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water	Ground Water				
Batch Number	2	2	2	2	2	2	2	2	2		LOD/LOR	Units	Method No.
Date of Receipt	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015	03/06/2015				
VOC MS													
Dichlorodifluoromethane	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Methyl Tertiary Butyl Ether #	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	ug/l	TM15/PM10
Chloromethane #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
Vinyl Chloride #	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	ug/l	TM15/PM10
Bromomethane	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	ug/l	TM15/PM10
Chloroethane #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
Trichlorofluoromethane #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,1-Dichloroethene (1,1 DCE) #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
Dichloromethane (DCM) #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
trans-1-2-Dichloroethene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,1-Dichloroethane #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
cis-1-2-Dichloroethene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
2,2-Dichloropropane	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	ug/l	TM15/PM10
Bromochloromethane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Chloroform #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
1,1,1-Trichloroethane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
1,1-Dichloropropene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
Carbon tetrachloride #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
1,2-Dichloroethane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Benzene #	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	ug/l	TM15/PM10
Trichloroethene (TCE) #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,2-Dichloropropane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Dibromomethane #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
Bromodichloromethane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
cis-1-3-Dichloropropene	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Toluene #	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	ug/l	TM15/PM10
trans-1-3-Dichloropropene	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
1,1,2-Trichloroethane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Tetrachloroethene (PCE) #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,3-Dichloropropane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Dibromochloromethane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
1,2-Dibromoethane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Chlorobenzene #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
1,1,1,2-Tetrachloroethane #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Ethylbenzene #	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	ug/l	TM15/PM10
p/m-Xylene #	<1	<1	<1	<1	<1	<1	<1	<1	<1		<1	ug/l	TM15/PM10
o-Xylene #	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	ug/l	TM15/PM10
Styrene	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Bromoform #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
Isopropylbenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,1,2,2-Tetrachloroethane	<4	<4	<4	<4	<4	<4	<4	<4	<4		<4	ug/l	TM15/PM10
Bromobenzene #	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
1,2,3-Trichloropropane #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
Propylbenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
2-Chlorotoluene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,3,5-Trimethylbenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
4-Chlorotoluene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
tert-Butylbenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,2,4-Trimethylbenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
sec-Butylbenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
4-Isopropyltoluene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,3-Dichlorobenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,4-Dichlorobenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
n-Butylbenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,2-Dichlorobenzene #	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
1,2-Dibromo-3-chloropropane	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
1,2,4-Trichlorobenzene	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
Hexachlorobutadiene	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
Naphthalene	<2	<2	<2	<2	<2	<2	<2	<2	<2		<2	ug/l	TM15/PM10
1,2,3-Trichlorobenzene	<3	<3	<3	<3	<3	<3	<3	<3	<3		<3	ug/l	TM15/PM10
Surrogate Recovery Toluene D8	98	97	96	95	96	105	105	96	96		<0	%	TM15/PM10
Surrogate Recovery 4-Bromofluorobenzene	97	98	99	98	98	104	105	98	97		<0	%	TM15/PM10

JE Job No.: 15/8219

SOILS

Please note we are only MCERTS accredited (UK soils only) for sand, loam and clay and any other matrix is outside our scope of accreditation.

Where an MCERTS report has been requested, you will be notified within 48 hours of any samples that have been identified as being outside our MCERTS scope. As validation has been performed on clay, sand and loam, only samples that are predominantly these matrices, or combinations of them will be within our MCERTS scope. If samples are not one of a combination of the above matrices they will not be marked as MCERTS accredited.

It is assumed that you have taken representative samples on site and require analysis on a representative subsample. Stones will generally be included unless we are requested to remove them.

All samples will be discarded one month after the date of reporting, unless we are instructed to the contrary.

If you have not already done so, please send us a purchase order if this is required by your company.

Where appropriate please make sure that our detection limits are suitable for your needs, if they are not, please notify us immediately.

All analysis is reported on a dry weight basis unless stated otherwise. Results are not surrogate corrected. Samples are dried at 35°C ±5°C unless otherwise stated. Moisture content for CEN Leachate tests are dried at 105°C ±5°C.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

Where a CEN 10:1 ZERO Headspace VOC test has been carried out, a 10:1 ratio of water to wet (as received) soil has been used.

% Asbestos in Asbestos Containing Materials (ACMs) is determined by reference to HSG 264 The Survey Guide - Appendix 2 : ACMs in buildings listed in order of ease of fibre release.

WATERS

Please note we are not a UK Drinking Water Inspectorate (DWI) Approved Laboratory .

ISO17025 (UKAS) accreditation applies to surface water and groundwater and one other matrix which is analysis specific, any other liquids are outside our scope of accreditation.

As surface waters require different sample preparation to groundwaters the laboratory must be informed of the water type when submitting samples.

Where Mineral Oil or Fats, Oils and Grease is quoted, this refers to Total Aliphatics C10-C40.

DEVIATING SAMPLES

Samples must be received in a condition appropriate to the requested analyses. All samples should be submitted to the laboratory in suitable containers with sufficient ice packs to sustain an appropriate temperature for the requested analysis. If this is not the case you will be informed and any test results that may be compromised highlighted on your deviating samples report.

SURROGATES

Surrogate compounds are added during the preparation process to monitor recovery of analytes. However low recovery in soils is often due to peat, clay or other organic rich matrices. For waters this can be due to oxidants, surfactants, organic rich sediments or remediation fluids. Acceptable limits for most organic methods are 70 - 130% and for VOCs are 50 - 150%. When surrogate recoveries are outside the performance criteria but the associated AQC passes this is assumed to be due to matrix effect. Results are not surrogate corrected.

DILUTIONS

A dilution suffix indicates a dilution has been performed and the reported result takes this into account. No further calculation is required.

NOTE

Data is only reported if the laboratory is confident that the data is a true reflection of the samples analysed. Data is only reported as accredited when all the requirements of our Quality System have been met. In certain circumstances where all the requirements of the Quality System have not been met, for instance if the associated AQC has failed, the reason is fully investigated and documented. The sample data is then evaluated alongside the other quality control checks performed during analysis to determine its suitability. Following this evaluation, provided the sample results have not been effected, the data is reported but accreditation is removed. It is a UKAS requirement for data not reported as accredited to be considered indicative only, but this does not mean the data is not valid.
Where possible, and if requested, samples will be re-extracted and a revised report issued with accredited results. Please do not hesitate to contact the laboratory if further details are required of the circumstances which have led to the removal of accreditation.

ABBREVIATIONS and ACRONYMS USED

#	ISO17025 (UKAS) accredited - UK.
B	Indicates analyte found in associated method blank.
DR	Dilution required.
M	MCERTS accredited.
NA	Not applicable
NAD	No Asbestos Detected.
ND	None Detected (usually refers to VOC and/SVOC TICs).
NDP	No Determination Possible
SS	Calibrated against a single substance
SV	Surrogate recovery outside performance criteria. This may be due to a matrix effect.
W	Results expressed on as received basis.
+	AQC failure, accreditation has been removed from this result, if appropriate, see 'Note' on previous page.
++	Result outside calibration range, results should be considered as indicative only and are not accredited.
*	Analysis subcontracted to a Jones Environmental approved laboratory.
AD	Samples are dried at 35°C ±5°C
CO	Suspected carry over
LOD/LOR	Limit of Detection (Limit of Reporting) in line with ISO 17025 and MCERTS
ME	Matrix Effect
NFD	No Fibres Detected
BS	AQC Sample
LB	Blank Sample
N	Client Sample
TB	Trip Blank Sample
OC	Outside Calibration Range
AA	x5 Dilution
AB	x10 Dilution
AC	x20 Dilution

JE Job No: 15/8219

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM0	Not available	PM0	No preparation is required.				
TM4	Modified USEPA 8270 method for the solvent extraction and determination of 16 PAHs by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.				
TM4	Modified USEPA 8270 method for the solvent extraction and determination of 16 PAHs by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.	Yes			
TM15	Modified USEPA 8260. Quantitative Determination of Volatile Organic Compounds (VOCs) by Headspace GC-MS.	PM10	Modified US EPA method 5021. Preparation of solid and liquid samples for GC headspace analysis.				
TM15	Modified USEPA 8260. Quantitative Determination of Volatile Organic Compounds (VOCs) by Headspace GC-MS.	PM10	Modified US EPA method 5021. Preparation of solid and liquid samples for GC headspace analysis.	Yes			
TM16	Modified USEPA 8270. Quantitative determination of Semi-Volatile Organic compounds (SVOCs) by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.				
TM16	Modified USEPA 8270. Quantitative determination of Semi-Volatile Organic compounds (SVOCs) by GC-MS.	PM30	Water samples are extracted with solvent using a magnetic stirrer to create a vortex.	Yes			
TM20	Modified USEPA 8163. Gravimetric determination of Total Dissolved Solids/Total Solids	PM0	No preparation is required.	Yes			
TM27	Modified US EPA method 9056.Determination of water soluble anions using Dionex (Ion-Chromatography).	PM0	No preparation is required.				
TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7	PM14	Analysis of waters and leachates for metals by ICP OES. Samples are filtered for dissolved metals and acidified if required.				

JE Job No: 15/8219

Test Method No.	Description	Prep Method No. (if appropriate)	Description	ISO 17025 (UKAS)	MCERTS (UK soils only)	Analysis done on As Received (AR) or Dried (AD)	Reported on dry weight basis
TM30	Determination of Trace Metal elements by ICP-OES (Inductively Coupled Plasma - Optical Emission Spectrometry). Modified US EPA Method 200.7	PM14	Analysis of waters and leachates for metals by ICP OES. Samples are filtered for dissolved metals and acidified if required.	Yes			
TM38	Soluble Ion analysis using the Thermo Aquakem Photometric Automatic Analyser. Modified US EPA methods 325.2, 375.4, 365.2, 353.1, 354.1	PM0	No preparation is required.	Yes			
TM73	Modified US EPA methods 150.1 and 9045D. Determination of pH by Metrohm automated probe analyser.	PM0	No preparation is required.	Yes			
TM75	Modified US EPA method 310.1. Determination of Alkalinity by Metrohm automated titration analyser.	PM0	No preparation is required.	Yes			
TM76	Modified US EPA method 120.1. Determination of Specific Conductance by Metrohm automated probe analyser.	PM0	No preparation is required.	Yes			

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APPENDIX D

CONSTRUCTION QUALITY ASSURANCE PLAN

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301-00183/40

MIDDELBURG FERROCHROME (MFC)
CONSTRUCTION QUALITY ASSURANCE PLAN

Rev	Description	Date
0	Issued in Final	June 10, 2021

Knight Piésold CONSULTING

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FIGURES

ABBREVIATIONS

BoQ	Bill of Quantities
CDR	Chrome Direct Dust
DEFF	Department of Environment Forestry and Fisheries
EAP	Environmental Assessment Practitioner
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme
EMS	Environmental Management Systems
MFC	Middelburg Ferrochrome
WML	Waste Management Licence
WMLO	Waste Management Licence Officer

1.0 GENERAL NOTE

1.1 TERMS OF REFERENCE

Knight Piésold (Pty) Ltd (KP) has prepared this Construction Quality Assurance (CQA) Plan for the removal of CDR slimes and rehabilitation of the site/area.

1.2 PURPOSE AND SCOPE OF THE CONSTRUCTION QUALITY ASSURANCE PLAN

The purpose of the CQA Plan is to provide the CQA procedures and monitoring requirements for removal and rehabilitation of the CDR slimes site. The CQA Plan is intended to:

1) Define the responsibilities of parties involved with the construction/removal and rehabilitation of the waste,
2) Provide guidelines, process and procedures for the removal and rehabilitation/construction of the of the components of the cover/capping system.
3) Establish testing protocols.
4) Establish guidelines for construction documentation (process and procedures); and
5) Provide the means for assuring that the project is constructed in conformance to the *Technical Specifications*, permit conditions, applicable regulatory requirements, and *Construction Drawings*.

This CQA Plan addresses the removal of waste, constructing a capping layer and vegetation required for the rehabilitating the site. It should be emphasized that appropriate earthworks procedures be followed for the layer works, stormwater management and installation of seeding for vegetation installed during construction. This CQA Plan delineates procedures to be followed for monitoring construction during these activities.

The CQA monitoring activities associated with the selection, evaluation, and placement of layer works are included in the scope of this plan.

This document forms an Appendix to the CDR Slimes Design Report which is an Appendix to the Basic Assessment Report (BAR) submitted to the Department of Environment Forestry and Fisheries (DEFF).

1.3 REFERENCES

The CQA Plan includes references to test procedures in the latest editions of South African National Standard Specifications and the American Society for Testing and Materials (ASTM).

The standard specification for this project is SANS 1200 (1986) ‘Standardised Specification for Civil Engineering Construction’ as are applicable in their entirety. This document contains variations and additions to the standard specifications and therefore takes precedence where applicable.

Variations and Additions contained in this document pertain to the following specifications:

1. PSA: GENERAL: SANS 1200A
2. PSC: SITE CLEARANCE: SANS 1200C
3. PSD: EARTHWORKS: SANS 1200D
4. PSDB: EARTHWORKS: SANS 1200 DB
5. PSDE: SMALL EARTH DAMS: SANS 1200DE

The standard specifications are written in terms of three parties, namely:

i. The Owner
ii. The Engineer
iii. The Contractor

The Employer has appointed the Engineer to ensure that the Contractor is adhering to technical and quality issues (quality assurance).

I. Regulation No. R636 National Norms and Standards for Disposal of Waste to Landfill. Government Gazette No. 36784, Dept. of Environmental Affairs. (August 2013)

II. Water Use 21 (g) of the National Water Act (NWA, 36 of 1998), Department of Water and Sanitation

2.0 DEFINITIONS RELATING TO CQA

This CQA Plan is devoted to Construction Quality Assurance. In the context of this document, Construction Quality Assurance and Construction Quality Control are defined as follows:

Construction Quality Assurance (CQA) *- A planned and systematic pattern of means and actions designed to assure adequate confidence that materials and/or services meet contractual and regulatory requirements and will perform satisfactorily in service. CQA refers to means and actions employed by the CQA Consultant to assure conformity of the project "Work" with this CQA Plan, the Drawings, and the Technical Specifications.*

Construction Quality Control (CQC) - *Actions which provide a means to measure and regulate the characteristics of an item or service in relation to contractual and regulatory requirements. Construction Quality Control refers to those actions taken by the Contractor, Manufacturer, or Rehabilitation Installer to verify that the materials and the workmanship meet the requirements of this CQA Plan, the Drawings, and the Technical Specifications.*

2.1 LINES OF COMMUNICATION

The organization chart in **Figure 2-1** indicates the lines of communication and authority related to this project.

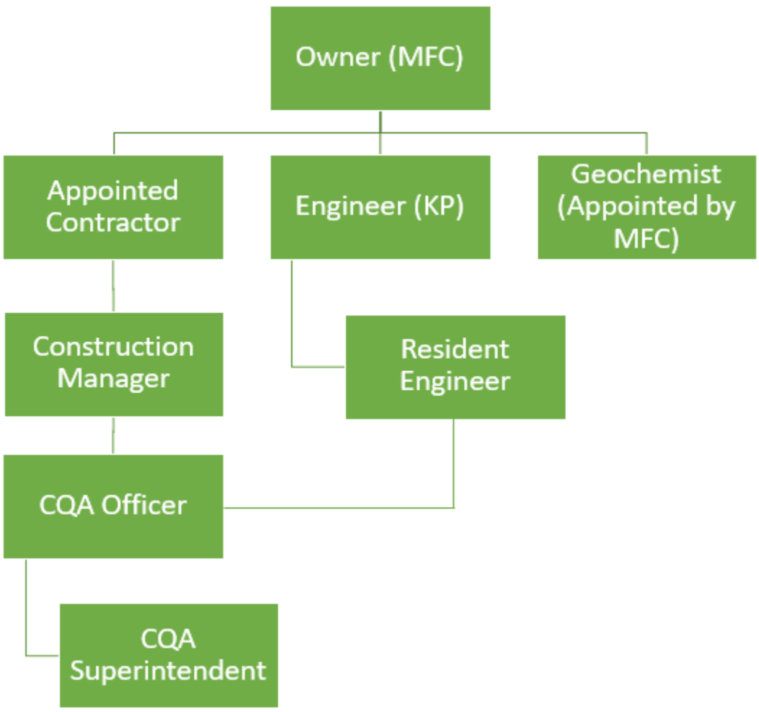

Figure 2-1: Lines of Communication - Organization Chart

2.2 OWNER

The Owner of this project is Samancor – Middelburg Ferrochrome (MFC). The "Owner" refers to MFC employees responsible for the execution of this project.

2.3 ENGINEER

2.3.1 RESPONSIBILITIES

The Engineer is responsible for the *Design*, *Drawings*, and *Technical Specifications* for the project work. In collaboration with the Contractor, the Engineer will be responsible for the Quality Assurance. In this CQA Plan, the term "Engineer" refers to Knight Piésold (KP). The "Engineer" is represented by the Resident Engineer (RE) and /or the Assistant Resident Engineer (ARE).

The Engineer, or his representatives will be observing and documenting activities related to the CQC and CQA of the earthwork's components used in the construction of the Project as required by this CQA Plan and the *Technical Specifications*.

2.3.2 QUALIFICATIONS

The Engineer shall be a Professional Engineer, registered with ECSA. The Engineer should have expertise, which demonstrates significant familiarity with capping/cover earthworks as appropriate, including design and construction experience related to cover and rehabilitation systems.

2.3.3 PERSONNEL

2.3.3.1 RESIDENT ENGINEER (RE)

The RE is the Engineer's representative on site (if required OR required full-time on site) and will ensure:

1. Attend site and other meetings as required on behalf of the Engineer, should he not be able to do so in person.
2. The RE will be responsible for the overall CQA for the project and will guide the ARE on the CQA for the barrier systems.
3. Will provide engineering review of CQA related activities.
4. Acts as the on-site representative of the Engineer.
5. Attends CQA-related meetings (e.g., pre-construction, daily, weekly or designates a representative to attend the meetings)
6. Oversees the ongoing preparation of the Record Drawings
7. Reviews test results provided by Contractor
8. Assigns locations for testing and sampling
9. Oversees the collection and shipping of laboratory test samples
10. Reviews results of laboratory testing and makes appropriate recommendations

11. Reviews the calibration and condition of on-site CQA equipment
12. Reviews the Material Quality Control (MQC) documentation
13. Reports unresolved deviations from the CQA Plan, Drawings, and Technical Specifications to the Engineer and the Construction Manager
14. With the Engineer, prepares the CQA report documenting that the project was constructed in general accordance with the Construction Documents

2.4 APPOINTED CONTRACTOR

2.4.1 RESPONSIBILITIES

In this CQA Plan, Contractor refers to an independent party or parties, contracted by the Owner, performing the work in general accordance with this CQA Plan, the *Drawings*, and the *Technical Specifications*. The Contractor will be responsible for the removal of waste, installation of the soils, stormwater management and vegetation components of the capping systems. This work will include removing waste to allocated disposal facility, stormwater management (separating dirty and clean water), demolishing existing works, site clearance, subgrade preparation, excavation and backfill, and rehabilitation and seeding of the capping area.

The Contractor will be responsible for constructing the capping system and appurtenant components in general accordance with the *Drawings* and complying with the quality control requirements specified in the *Technical Specifications*.

2.4.2 QUALIFICATIONS

Qualifications of the Contractor are specific to the construction contract. The Contractor should have a demonstrated history of successful environmental projects related to earthworks, waste removal, stormwater management and vegetation of capping system construction and shall maintain current state and federal licenses as appropriate.

2.4.3 PERSONNEL

2.4.3.1 CONSTRUCTION MANAGER

The Construction Manager is responsible for managing the construction and implementation of the Drawings, and Technical Specifications for the project work. The Construction Manager is selected/appointed by the Owner.

2.4.3.2 CONSTRUCTION QUALITY CONTROL AND ASSURANCE OFFICER

The Contractor will further be responsible for Quality Control and Assurance in collaboration with the Engineer and the Owner. The Contractor will appoint a Construction Quality Control and Assurance (CQCA) Officer, who will be responsible to do quality control and assurance and gather and store the necessary Quality Test Results for inclusion into the CQA Report.

The CQCA Officer shall supervise and be responsible for executing and Construction Quality Control and Assurance activities relating to removal of waste and the construction of the earthworks and installation of the seeding for vegetation of the Project. Specifically, the CQCA Officer:

Attends Pre-Construction and other meetings as needed:

1) Reviews the project Design, this CQA Plan, Drawings, and Technical Specifications
2) Compiles Quality Control Plans, Method Statements and Inspection and Test Plans for the required work
3) Administers the CQA program (i.e., provides supervision of and manages on-site CQA personnel and reviews field reports)
4) Is responsible for the collection and shipping of laboratory test samples
5) Notes on-site activities in daily field reports and reports to the Engineer and Construction Manager
6) Prepares a daily summary report for the project
7) Reviews the Record Drawings
8) With the CQA Site Manager, prepares the CQA report documenting that the project was constructed in general accordance with the Construction Documents.

2.5 GEOCHEMIST

2.5.1 RESPONSIBILITIES

A geochemist will be available to the project team to advise on sampling protocols and areas of concern for additional sampling.

2.6 REQUIREMENTS FOR PROJECT

2.6.1 CLASS A LANDFILL DISPOSAL

The Class A Landfill disposal site is responsible for disposal of Type 1 waste and ensuring sufficient capacity is made available to receive waste. The Waste facility site must be licenced as Class A Landfill facility to receive Type 1 waste.

2.6.2 CLASS C LANDFILL DISPOSAL

The Class C Landfill disposal site (MFC slag dump disposal) is responsible for disposal of Type 3 waste and ensuring sufficient capacity is made available to receive waste. The Waste facility site must be licenced as Class C Landfill facility to receive Type 3 waste.

2.6.3 CQA LABORATORY

The CQA Laboratory is a party, independent from the Contractor, Manufacturer and Owner, that is responsible for conducting tests in general accordance with ASTM, SANS, and other applicable test standards on samples of soil, and in the field and in either an on-site or off-site laboratory.

The CQA Laboratory will have experience in testing soils and materials and will be familiar with ASTM, SANS, and other applicable test standards. The CQA Laboratory will be capable of providing test results within a maximum of seven days of receipt of samples and will maintain that capability throughout the duration of earthworks construction and rehabilitation.

2.7 DEFICIENCY IDENTIFICATION AND RECTIFICATION

If a defect is discovered in the work, the RE will evaluate the extent and nature of the defect. If the defect is indicated by an unsatisfactory test result, the RE will determine the extent of the deficient area by additional tests, observations, a review of records, or other means that the Engineer deems appropriate.

After evaluating the extent and nature of a defect, the RE will notify the Contractor and Construction Manager and schedule appropriate re-tests when the work deficiency is corrected by the Contractor.

The Contractor will correct the deficiency to the satisfaction of the Engineer. If a project specification criterion cannot be met, or unusual weather conditions hinder work, then the Contractor will develop and present to the Engineer suggested solutions for approval.

Defect corrections will be monitored and documented by CQA personnel prior to subsequent work by the Contractor in the area of the deficiency.

3.0 SITE AND PROJECT CONTROL

3.1 PROJECT COORDINATION MEETINGS

Meetings of key project personnel are necessary to assure a high degree of quality during installation and to promote clear, open channels of communication. Therefore, Project Coordination Meetings are an essential element in the success of the project. Several types of Project Coordination Meetings are described below, including:

1) Pre-construction meetings
2) Progress meetings
3) Problem or work deficiency meetings.

3.1.1 PRE-CONSTRUCTION MEETING

Pre-Construction Meeting will be held at the site prior to construction of the Project. At a minimum, the Pre-Construction Meeting will be attended by the Construction Manager, Engineer and Contractor.

Specific items for discussion at the Pre-Construction Meeting include the following:

1) Appropriate modifications or clarifications to the CQA Plan
2) The Drawings and Technical Specifications
3) The responsibilities of each party
4) Lines of authority and communication
5) Methods for documenting and reporting, and for distributing documents and reports
6) Acceptance and rejection criteria
7) Protocols for testing
8) Protocols for handling deficiencies, repairs, and re-testing od earthworks
9) The time schedule for all operations
10) Procedures for packaging and storing archive samples
11) Repair procedures
12) Soil stockpiling locations

The Construction Manager will conduct a site tour to observe the current site conditions and to review construction material and equipment storage locations. A person in attendance at the meeting will be appointed by the Construction Manager to record the discussions and decisions of the meeting in the form of meeting minutes. Copies of the meeting minutes will be distributed to all attendees.

3.1.2 PROGRESS MEETINGS

Progress meetings will be held between the Construction Manager, Contractor, Engineer, ARE and other concerned parties participating in the construction of the project. The non-site-based parties can attend the meetings via video conference (MS Teams or similar) if required. This meeting will include discussions on the current progress of the project, planned activities for the next week, and revisions to the work plan and/or schedule.

The WMLO shall meet (or otherwise connect) with the Engineer and Contractor on a monthly basis, or more frequently as may be required during the initial stages of the project.

The meeting will be documented in meeting minutes prepared by a person designated by the Construction Manager at the beginning of the meeting. Within 2 working days of the meeting, draft minutes will be transmitted to representatives of parties in attendance for review and comment. Corrections and/or comments to the draft minutes shall be made within 2 working days of receipt of the draft minutes to be incorporated in the final meeting minutes.

3.1.3 PROBLEM OR WORK DEFICIENCY MEETING

A special meeting will be held when and if a problem or deficiency is present or likely to occur. The meeting will be attended by the Contractor, the Construction Manager and the ARE (Engineer's representative), and other parties as appropriate. If the problem requires a design modification, the Engineer should either be present at, consulted prior to, or notified immediately upon conclusion of this meeting. The purpose of the work deficiency meeting is to define and resolve the problem or work deficiency as follows:

1) Define and discuss the problem or deficiency
2) Review alternative solutions
3) Select a suitable solution agreeable to all parties
4) Implement an action plan to resolve the problem or deficiency

The Construction Manager will appoint one attendee to record the discussions and decisions of the meeting. The meeting record will be documented in the form of meeting minutes and copies will be distributed to all affected parties. A copy of the minutes will be retained in facility records.

3.1.4 ENVIRONMENTAL AWARENESS TRAINING

Before the commencement of any work on-site, the Contractor's site management staff shall attend an environmental awareness training course, presented by the WMLO. No induction or course should be given until the Engineer has been afforded the opportunity to appraise it and provide comment.

The presentation shall be conducted in English. As a minimum, training shall include:

- Explanation of the importance of complying with the WML and EMPr
- Discussion of the potential environmental impacts of construction activities
- Explanation of the management structure of individuals responsible for matters pertaining to the EMPr.
- Employees' roles and responsibilities, including emergency preparedness
- Explanation of the mitigation measures that must be implemented when carrying out their activities
- Explanation of the requirements of the WML and EMPr.

The Contractor shall keep records of all environmental training sessions, including names of attendees, dates of their attendance and the information presented to them. Records of environmental training sessions shall be submitted to the Engineer and WMLO.

3.1.5 INSPECTION PROCEDURES

The day-to-day monitoring and verification that the EMPr is being adhered to shall be undertaken by the Engineer and WMLO.

An audit by an independent auditor will be undertaken on an annual basis for a period of 5 years.

The Engineer shall undertake daily photographic monitoring of the site.

3.1.6 FINES

A system of fines/ contractual penalties shall be implemented to ensure compliance with the EMPr. Where the Contractor inflict damage on the environment or fail to comply with any of the environmental specifications of the WML or EMPr, they may be liable to pay a fine / incur penalties in terms of the contract. The Contractor is deemed to not have complied with the EMPr if:

- There is evidence of contravention of the EMPr specifications, including any non-compliance with an approved MS
- Construction activities take place outside the defined boundaries of the site
- Environmental damage ensues due to negligence
- The Contractor fails to comply with corrective or other instructions issued by the Engineer or WML within a specific time period
- The Contractor fails to respond adequately to complaints.

4.0 DOCUMENTATION

4.1 OVERVIEW

An effective CQA Plan depends largely on recognition of all construction activities that should be monitored and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The Engineer will document that quality assurance requirements have been addressed and satisfied.

The CQCA Officer will provide the Construction Manager with signed descriptive remarks, data sheets, and logs to verify that monitoring activities have been carried out. The CQCA Officer will also maintain, at the job site, a complete file of Drawings and Technical Specifications, a CQA Plan, checklists, test procedures, daily logs, and other pertinent documents.

4.2 DAILY RECORDKEEPING

Preparation of daily CQA documentation will consist of daily field reports prepared by the CQCA Officer which may include CQA monitoring logs and testing data sheets. This information may be regularly submitted to and reviewed by the Construction Manager and Engineer. Daily field reports will include documentation of the observed activities during each day of activity. The daily field reports may include monitoring logs and testing data sheets. At a minimum, these logs and data sheets will include the following information:

1) The date, project name, location, and other identification
2) A summary of the weather conditions
3) A summary of locations where construction is occurring
4) Equipment and personnel on the project
5) A summary of meetings held and attendees
6) A description of materials used and references of results of testing and documentation
7) Identification of deficient work and materials
8) Results of re-testing corrected “deficient work”
9) An identifying sheet number for cross referencing and document control
10) Descriptions and locations of construction monitored
11) Type of construction and monitoring performed
12) Description of construction procedures and procedures used to evaluate construction
13) A summary of test data and results
14) Calibrations or re-calibrations of test equipment and actions taken as a result of re-calibration
15) Decisions made regarding acceptance of units of work and/or corrective actions to be taken in instances of substandard testing results

16) A discussion of agreements made between the interested parties which may affect the work
17) Signature of the respective CQCA Officer.

4.3 CONSTRUCTION PROBLEMS AND RESOLUTION DATA SHEETS

Construction Problems and Resolution Data Sheets, to be submitted with the daily field reports prepared by the CQCA Officer, describing special construction situations, will be cross-referenced with daily field reports, specific observation logs, and testing data sheets and will include the following information, where available:

1) A detailed description of the situation or deficiency
2) The location and probable cause of the situation or deficiency; how and when the situation or deficiency was found or located
3) Documentation of the response to the situation or deficiency
4) Final results of responses
5) Measures taken to prevent a similar situation from occurring in the future
6) Signature of the CQCA Officer and a signature indicating concurrence by the Construction Manager.

The Construction Manager will be made aware of significant recurring non-conformance with the *Drawings*, *Technical Specifications*, or CQA Plan. The cause of the nonconformance will be determined and appropriate changes in procedures or specifications will be recommended. These changes will be submitted to the Construction Manager for approval. When this type of evaluation is made, the results will be documented and any revision to procedures or specifications will be approved by the Contractor, Construction Manager and Engineer.

A summary of supporting data sheets, along with final testing results and the Engineer's approval of the work, will be required upon completion of construction.

4.4 PHOTOGRAPHIC DOCUMENTATION

Photographs will be taken and documented in order to serve as a pictorial record of work progress, problems, and mitigation activities. These records will be stored on the agreed electronic storage platform. These records will be presented to the Engineer on regular basis and to the Construction Manager upon completion of the project. Photographic reporting data sheets, where used, will be cross-referenced with observation and testing data sheet(s), and/or construction problem and solution data sheet(s).

4.5 DESIGN AND/OR SPECIFICATION CHANGES

Design and/or specifications changes may be required during construction. In such cases, the CQCA Officer and ARE will notify the Engineer. Design and/or specification changes will be made with the written agreement of the Engineer and will take the form of an addendum to the *Drawings* and *Technical Specifications*.

4.6 CQA REPORT

At the completion of the Project, the Engineer will submit to the Owner a CQA report signed and sealed by a Professional Engineer. The CQA report will acknowledge:

1) That the work has been performed in compliance with the *Drawings* and *Technical Specifications*
2) Physical sampling and testing have been conducted at the appropriate frequencies
3) That the summary document provides the necessary supporting information.

At a minimum, this report will include:

1) MQC documentation
2) A summary report describing the CQA activities and indicating compliance with the *Drawings* and *Technical Specifications* which is signed and sealed by the CQCA Officer
3) A summary of CQA / CQC testing, including failures, corrective measures, and retest results
4) Contractor and Installer personnel resumes and qualifications as necessary
5) Records of sample locations, the name of the individual conducting the tests, and the results of tests
6) *Record Drawings* as provided by the Surveyor
7) Daily field reports.

The Record Drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., plan dimensions and appropriate elevations). Record Drawings and required base maps will be prepared by a qualified Professional Land Surveyor. These documents will be reviewed by the Engineer and included as part of the CQA Report.

5.0 GENERAL: SANS 1200A

5.1 PSA: DRAWINGS

The Contractor shall be given free of charge 3 (three) A0 paper prints of all Drawings. If for any reason the Contractor requires additional prints, the cost of these prints will be charged to him. At the completion of the Works the Contractor shall return one complete set of drawings marked-up to show all as-constructed "**As-built**" details and levels and positions.

The Engineer may, if he considers it necessary, instruct the Contractor to prepare working drawings showing his proposed method of construction. All Contractor's drawings, whether ordered by the Engineer or not shall be made at the Contractor's expense and one paper print of each shall be supplied to the Engineer for approval. The approval of the Engineer must be obtained before any Works involving them is commenced.

The approval by the Engineer of the Contractor's working drawings does not relieve the Contractor of any responsibility for the accuracy of dimensions or details, and for agreement and conformity with the Specifications and Drawings attached to the Contract. At the completion of the Works the Contractor shall supply to the Employer free of charge electronic copies of his drawings in dxf or dwg format.

At the completion of the Works the Engineer's representative must develop one set of complete "as-built" plans of all constructed works including levels and final positions. One hard and an electronic copy will be submitted to the Employer. Data for the as-built drawings will be provided by the Contractor.

It is requested that the Employer and Engineer review the proposed method of construction (if any) and review the design considerations as proposed on the construction drawings. Any deviations that are presented by the Contractor or the Engineer must include options and measures with its implications.

5.2 PSA: MATERIALS

5.2.1 MATERIAL QUALITY FOR BACKFILLING

Samples of materials to be used upon the Works shall, when required, be submitted at the Contractor's expense to the Engineer for approval before use, and any material brought on to the Works which, in the opinion of the Engineer, does not meet the standard of the sample so submitted or is considered by him in any way unsuitable for its designed purpose, shall be removed immediately once instructions to that effect have been given.

5.2.2 SAMPLING OF WASTE

A geochemist either provided by the contractor or employer shall sample the waste before disposing to required landfill disposal site. If the classification of the waste is undetermined it shall not be disposed until the geochemist has tested and provided results of the classification.

5.3 PSA: CONTRACTOR'S PLANT AND TOOLS

The Contractor's Plant and tools shall be of modern design and construction, suitable for the duties required of them. They shall be in sound working condition and shall be sufficiently ample in capacity or number to enable the Works to be carried out efficiently and expeditiously.

If during the course of the Contract, the Engineer or the Engineer's Representative considers that any item or items of constructional plant are in any way inefficient or inadequate to complete the Works within the Contract period, or do not meet the required safety standards, the Engineer shall have the right to call on the Contractor to either:

i. Put the constructional plant in order, or
ii. Remove such constructional Plant and replace it with other efficient and /or safe Plant, or, and
iii. Provide additional similar Plant or plant of greater capacity.

The Employer shall have the right to stop all or part of the Works where constructional Plant not complying with required safety standards is being used until such time as the Plant has been made safe or replaced with approved Plant.

No additional payment will be made to the Contractor for expenses incurred in complying with any or all of the above".

In addition, he shall have available on the Site or readily available adequate standby Plant to ensure that operations designed to be executed continuously are not unduly disrupted because of breakdown of any Plant provided for such operations.

5.4 PSA: CONSTRUCTION

5.4.1 SURVEY AND SETTING OUT (IF APPLICABLE)

i. Prior to any construction taking place the Employer Mine Surveyor will supply Contractor with a Digital terrain model (DTM) of the total area where the construction will take place and supply the relevant bench mark information to be used for the setting out of the works. This DTM will form the basis for all original ground levels to be used for all cut and fill volume controls. The Contractor may carry his own checks with regard to the DTM and the bench marks and report any discrepancies to the Engineer. Once agreement has been reached the DTM and relevant bench mark information must be signed off as accepted by the Contractor.
ii. Should the Contractor require additional bench marks for the setting out of his works this must be discussed with the Engineer and the Employer Mine Surveyor. The Contractor must construct such benchmarks to industry standards which will be surveyed by the Employer mine surveyor and the relevant spatial data handed over to the Contractor for agreement and signoff.
iii. The Contractor's Surveyor will be responsible for the setting out of all works from the bench marks supplied by the Employer Mine Surveyor.
iv. All earthwork volumes will be checked and approved by the Employer Mine Surveyor before payments are made.
v. The Engineer will carry out random checks to ensure works are set out correctly
vi. The following survey tasks will be required from the Contractor mine surveyor for agreement with the Engineer.

a. Ground levels must be recorded at 5m or 10m intervals on the centre line, upstream and downstream toe positions of all structures, embankments and fills after site clearance and again after:

- removal of unsuitable material
- completion of excavations

The grids and lines for each survey operation must be co-incident in plan.

i. Ground levels must be recorded at 10m intervals on the centre line left and right bank positions of all trenches, canals and drains after site clearance and prior to excavation and again on completion of the excavation to the required depths and grades.

ii. Ground levels must be recorded on a 15m grid over borrow areas immediately after site clearance. After removal of unsuitable materials and/or topsoil and/or fill material as required, a re-survey will be required on the ground and records levels as described above. The grids and lines before and after soil removal must be co-incident in plan. Where borrow areas are within the dam basin, the borrow areas must be re-surveyed on the same co-incident grid to form part of the as-built records.

iii. Upon completion of the works an as-built survey and with marked-up drawings are required showing as-constructed details and levels and positions of all embankments and structures. The survey must be in electronic format suitable for import to "AutoCAD" software.

The Employer must inform the Engineer on the completion of impoundment walls and trenches to design elevations and cross-sections. Thereafter, a check may be carried out by the Engineer's Representative to verify these elevations and cross-sections.

5.4.2 WATCHING, BARRICADING, LIGHTING AND TRAFFIC CROSSINGS

The Contractor must programme his Works in such a way that the area is secure at all times. The Employer reserves the right to suspend Works if, in his opinion, this requirement is not being complied with and, further, to make secure the area and recover any costs involved in labour and materials from monies due to the Contractor.

The Contractor shall make provision for any temporary Works as may be required for the purpose of ensuring the safety of adjoining Works and property and for the protection of all persons or animals. He shall be responsible for all damage, injuries and accidents that may occur through his omission of any necessary provision in this respect.

The Contractor shall make full provision for all watching and lighting necessary for the protection of all persons, animals, vehicles, etc., from injury by reason of the Works. He shall provide ample warning signs; guard rails, etc., around open trenches, stacks of material, excavated materials, debris or the like, and shall provide walkways over trenches wherever required for the convenience of the public.

The Contractor shall provide and maintain all necessary temporary protection of finished and/or existing Works liable to be damaged during the progress of the Works by properly covering up, isolating, etc., as required. The Contractor shall be responsible for any damage which may occur and shall make good at his own expense.

Every excavation which is accessible to the public, including the Employer's personnel, or which is adjacent to public roads or thoroughfares, or whereby the safety of persons may be endangered shall be:

i. In accordance with SHE Rules for Contractors

ii. Provided with red warning lights, or other boundary indicators, which are clearly visible at night, or when visibility is poor.

The Employer reserves the right to stop any Works in progress which he deems to be unsafe and to expedite all necessary and appropriate action. All costs in this regard will be to the Contractor’s account.

The Contractor shall so arrange his Works that flow of the Employer's vehicular and pedestrian traffic can be maintained at all times. In this respect, it may be necessary that culverts and pipes be constructed in sections.

All work must be arranged so that onsite operations and pedestrian traffic can be maintained at all times.

5.4.3 SITE SENSITIVITY AND NO-GO AREAS

Figure 5-1 provides a map that the superimposes the proposed activity and its associated structures and infrastructure on the environmental sensitivities of the site indicating any areas that should be avoided, including buffers.

Figure 5-2 provides a map of no-go areas with two levels. Complete no-go areas (indicated in red) and areas in which no development should take place (indicated in green hatch).

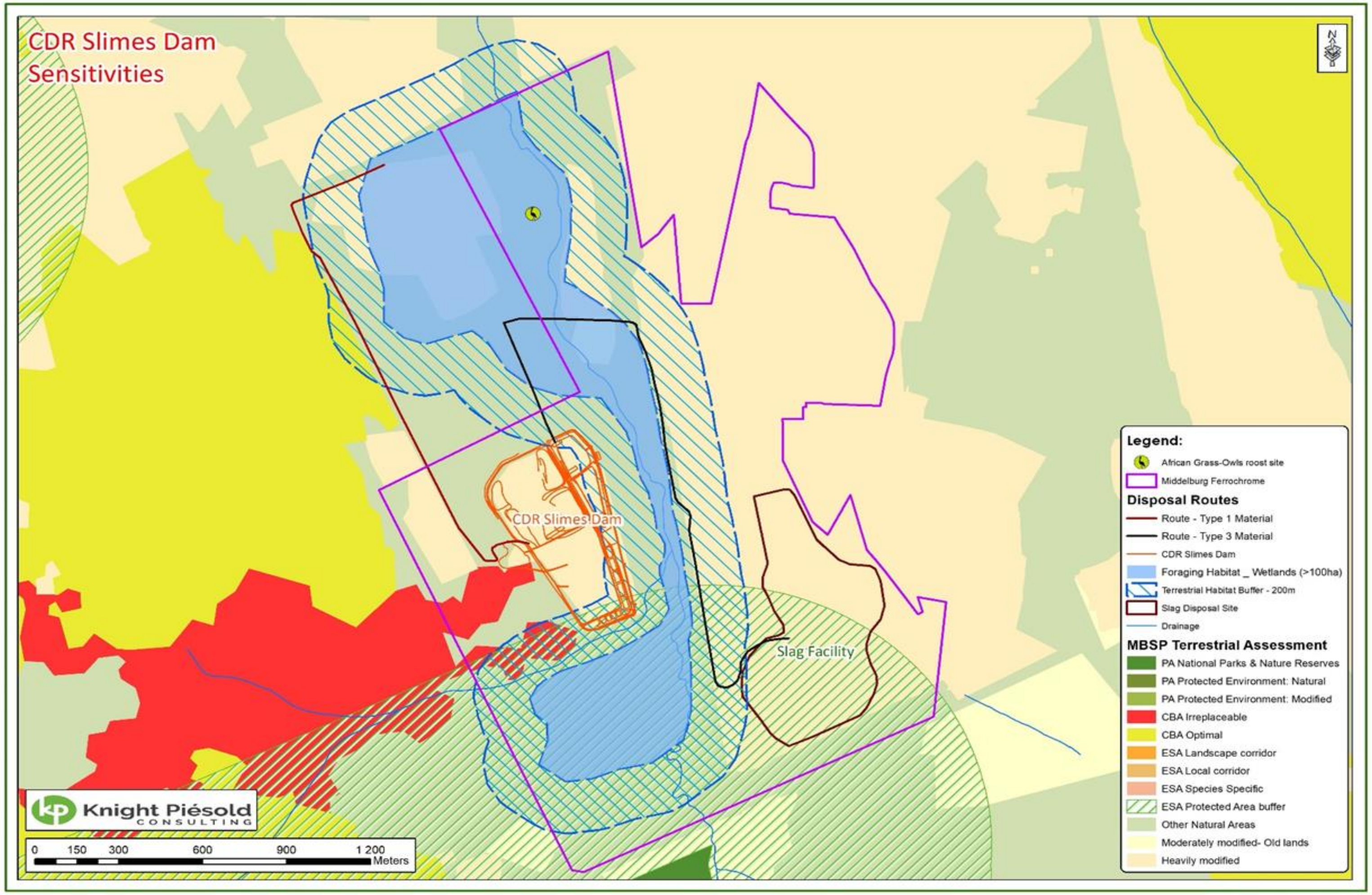

Figure 5-1: Site Sensitivities

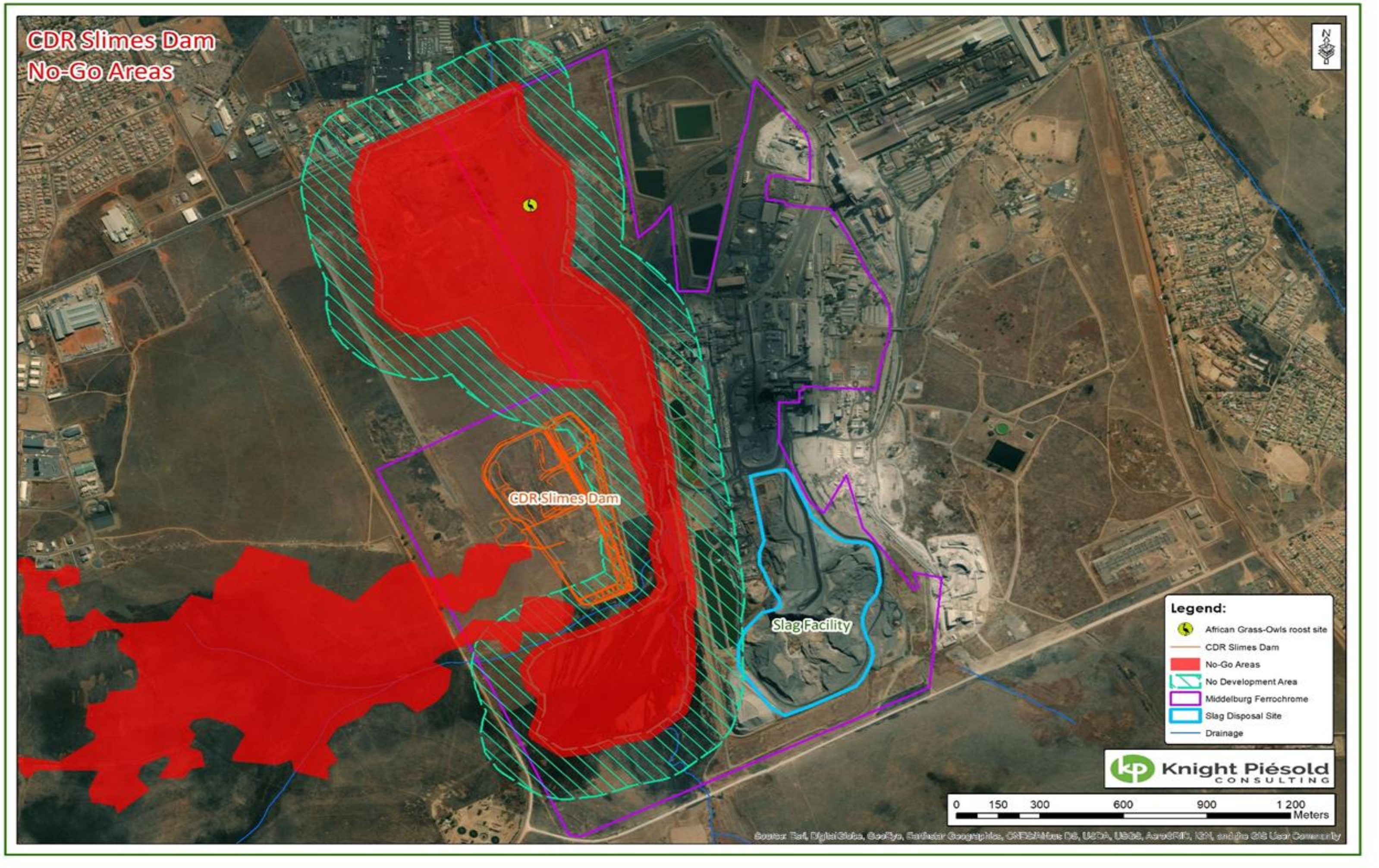

Figure 5-2: No-Go Areas

5.4.4 PROTECTION OF OVERHEAD AND UNDERGROUND SERVICES

Further to the provisions of this sub-clause, the Contractor shall arrange with the Engineer or the Employer to point out any underground or overhead services which may be affected by construction activities prior commencing with the Works. Where necessary the Contractor shall excavate trenches by hand under direction of the Engineer or Employer to establish the exact location of services.

The Contractor shall be solely responsible throughout the contract period for the safety and protection of services. Repair of known services damaged by the Contractor shall be to his account.

Any deviation of services affected by construction, whether carried out by the Contractor or other authority will be paid for by the Employer.

5.4.5 POLLUTION

The Contractor shall provide adequate containers with lids for the disposal of refuse. Containers shall be provided at the Site for employees and if applicable at the Site office. The Contractor shall ensure that his employees do not pollute any Works areas with refuse.

All domestic and general waste generated by the Contractor during the execution of the Works shall be neatly maintained, in accordance with the requirements of the EMP and SHE Rules. All waste shall be disposed of on a regular basis in the same way as the Mine disposes of its waste. The Contractor is to familiarise himself with the preferred disposal Site and associated procedures for all his waste disposal requirements during construction.

In general, no on-Site disposal of domestic and general waste will be permitted.

Inert construction waste shall be collected and dumped by the Contractor at locations approved by the Engineer and/or Employer. The dumps shall be covered by soil.

Waste spillage must be cleaned daily, if the contractor spills waste, he shall remove it and clean the area before end of construction day.

5.4.6 SAFETY

The Works in connection with the Contract are to be done on property subject to the Mines Health and Safety Act No 29 of 1996 as amended. The Contractor will therefore nominate a competent person (within the meaning of the regulations under the Mines Health and Safety Act) who will be appointed in writing by the Employer as subordinate manager to assist in the control, management and direction of the Works in terms of the provisions of the MHS Act. This appointment shall remain in force until practical completion of the Works has been affected.

All Contractor’s Equipment, constructional plant, Temporary Works and Materials used by the Contractor and the Works carried out by the Contractor's personnel are subject to the safety regulations of the Employer (SHE Rules) and thereby also subject to the inspection and acceptance by their officials at all times.

First aid rooms, attendants and equipment as required by the Minerals and Petroleum Resources Development Act 28 of 2002 are to be provided at the Site by the Employer. Cost for transport to and treatment at a hospital will be to the Contractor's account.

The Contractor shall prominently display a copy of this Act.

5.4.7 METHOD OF CONSTRUCTION

Acceptance of the Works does not signify acceptance of methods of construction and does not in any way relieve the Contractor of any of his responsibilities for the Works, and it shall not be used as a basis for claiming compensation where the proposed methods of construction do not comply with the requirements of construction.

The Engineer reserves the right to instruct the Contractor to supply, for approval prior to the start of the activity, a detailed method statement for any construction activity.

5.4.8 SITE INSTRUCTION BOOK

A communication and site instruction book/diary must be made available onsite to record all requests and decisions made.

6.0 SITE CLEARANCE: SANS 1200C

6.1 PSC: DISPOSAL OF MATERIAL (NON-CONTAMINATED)

All material from the clear and grub (type 4 waste) exercise is to be placed in a neat stockpile(s), as directed by the Engineer. The disposal area shall be within a one-way distance of 5 000 m of the area from which it was excavated.

Vegetation and wood from the clearing operations shall be disposed of either by stockpiling as firewood at designated locations, or by stockpiling and burning within the basin area if authorized in writing by the Engineer. Any ash and large stumps or other unburned pieces shall be buried within the basin in a manner so as to ensure that debris cannot interfere with the operation of dam outlets or drainage systems or detract from the appearance of the area.

Any burning shall take place within a cleared area, under strict supervision, after obtaining all necessary burning permits and the Engineer's approval, so as to ensure that no fires can spread to the surrounding areas.

Adequate fire fighting equipment shall be available during and for sufficient time after all burning operations to eliminate all fire hazards. The Contractor shall be liable for any damage which occurs due to fires running out of control.

Where applicable, fencing wire shall be neatly wound into rolls or coils and all such wire, together with all fence posts, gates and other material from structures shall be stacked at designated Sites within the contract area or as directed by the Engineer.

6.2 PSC: CONSERVATION OF TOPSOIL

Where overburden or material resulting from clearance of the Site is acceptable for use as topsoil and capping material, it shall be stockpiled adjacent to the Site from which it is stripped for later use on embankment slopes and elsewhere where topsoil is specified or required. Topsoil not required for the Works shall be stockpiled in a designated topsoil stockpile for later use by others.

7.0 EARTHWORKS: SANS 1200D

7.1 PSD: EXCAVATION OF TRENCHES, CANALS AND FOUNDATION

The Contractor shall excavate whatever materials are encountered to the depths, cross-sections and grades shown on the drawings. Excavated material not required or unsuitable for backfill and / or for embankment construction shall be transported to and disposed of at a suitable Site away from the Site of Works as directed by the Engineer. The disposal area shall be within a one-way distance of 5 000 m of the area from which it was excavated.

The unit of measurement for all excavation (other than for the purposes of borrowing to fill) shall be the cubic metre of in-situ material excavated (measured Nett). It should be noted that when excavations are cut through embankments for the placing of drains, pipes, pipe encasements, puddle flanges etc., the payment for these excavations shall be based on Nett dimensions with the measurable depth of excavation limited to that of the maximum vertical dimension of the drain, pipe or encasement structure at each particular cross-section. Similarly, the measurable width shall be the design width of each particular cross-section. All costs associated with the excavation greater than these dimensions i.e., battering back (but excluding backfilling with concrete or soil in over break as stipulated), shall not be considered for payment.

Working space for formworks insertion and removal inclusive of additional excavation and backfill compacted to specification will only be paid for were instructed in writing by the Engineer. The measurement shall be the square metre of shuttered face.

The rates tendered must allow for the operation as described and haulage to within a one-way distance of 5 000 m of the Site. The disposal area is to be left as described in Clause PSD13.

The bases of all excavations are to be inspected and approved by the Engineer before backfilling commences or blinding is cast as the case may be. (Refer Clause PSD12).

Where applicable, the standard specification for preparation of rock surfaces shall apply to hard, non-erodible rock surfaces. “Slush” grouting with 1:3 cement / sand grout (refer specification PSDK4) may be required on hard, highly fractured rock and shall be measured per square metre of specified thickness under the relevant billed item were instructed by the Engineer.

Soft, erodible rock surfaces shall be prepared by removal of all loose particles and moistened immediately before being covered with fill material, or grout as instructed by the Engineer.

NB: Excavations for pipe plinths and anchor blocks shall be so carried out and so trimmed to the outline of the concrete Works shown on the drawings that the excavated surfaces will act as forms for the concrete Works. No shuttering will be considered or paid for below ground level.

7.2 EXCAVATION OF UNSUITABLE MATERIAL BELOW WASTE

Unsuitable material (sludge and contaminated soils) must be removed to such depths, widths and lengths as the Engineer may determine once the CDR dump have been dewatered. The material removed must be transported to and disposed of at a suitable site in accordance with the ESIA/EMP guidelines (Class A and Class C Landfill facilities). If the material is tested and found to be type 4 waste it can be directed by Employer away from the Site of Works or stockpiled for re-use as directed by the Engineer.

The unit of measurement for unsuitable material removal shall be the cubic metre of in-situ material removal (measured Nett). The rates must allow for the operation as described and haulage to within the waste disposal landfill site (Class A and Class C Landfill facilities).

7.3 PREPARATION OF APPROVED NATURAL SOIL BENEATH WASTE (IF APPLICABLE)

Prior to commencement of construction of layer works and capping, the approved natural soil beneath the base areas shall be prepared by ripping or other means to a depth of 300mm, water added, if necessary, mixed and then compacted to the approval of the Engineer by not less than eight passes of an approved six metric tonne roller (method) or to 95% Standard Proctor dry density as directed by the Engineer. The soils must be tested before backfilling and preparation can commence.

It is imperative that this layer is compacted to such a degree to ensure that the indicated densities and moisture contents or such lesser densities and corresponding moisture contents as may be specified by the Engineer can be achieved on subsequent layers.

The unit of measurement for ripping, watering, rotivating and compacting the approved founding layer is the design square metre.

7.4 CONSTRUCTION OF FINAL CAPPING LAYERS

The final capping layer works must be constructed or shaped by obtaining selected soil from excavations, approved borrow pits or stockpiles or commercial sources and prepared the same into a homogeneous mix in a manner and location approved by the Engineer and then forming it to the dimensions and elevations given on the drawings.

Material forming the layer works shall be compacted in layers as detailed in **Clause 4.6** and of regular appearance with all cross-sections having the minimum sizes detailed on drawings and having side slopes not steeper than specified. The sides of the embankments must be compacted to hard durable faces. Any spoil resulting from this operation is to be removed and disposed of at no extra cost.

The unit of measurement for layer works shall be the design cubic metre of placed material after compaction, trimming and forming to the specified dimensions. The Contractor will not be paid for layer works constructed in excess of the dimensions specified. The Engineer will decide on acceptance or rejection of layer works which are oversized.

The Contractor is to allow in his rate for re-shaping the slopes and layer works and compacting to the correct size final shape and size.

Material suitable for layer works shaping construction should fit within the bounds defining G7 or G9 material as a minimum. The material must be verified from onsite investigations against these criteria before use.

Test of suitable material must form a smooth curve within the bounds of the grading envelope. The Contractor shall carry out sufficient test to satisfy himself about the consistency of material placed in the embankments. Check test will be carried out by the Engineer and the results made available to the contractor. Material not conforming to the specifications should be blended to achieve requirements, or, failing this, the material must be spoiled. Any material containing organic material is unsuitable and must be spoiled.

7.5 BORROW PITS (IF APPLICABLE)

7.5.1 GENERAL

Borrow pit areas shall be kept to a minimum. Opening of borrow pit areas shall be limited to the areas required to provide material for construction. Areas not authorized by the Engineer and surplus to requirements will not be considered for payment.

The Contractor shall be responsible for ensuring that materials obtained from borrow pits conform to the material requirements specified by the Engineer. These criteria include in brief terms, the material particle size distribution ((i.e., grading envelope) minimum density and moisture content requirements.

To this end the Contractor will be required to excavate a reasonable number of trial pits at his own cost to prove suitability of each borrow area location.

The Contractor, unless otherwise directed, shall obtain the required material by borrowing in these areas to such widths, lengths and depths as the Engineer may direct, no payment for removal of borrow material to fill will be made. (Payment will only be made for the formation of layer works or as selected fill where applicable – refer Clause 4.4 above).

Furthermore, in all instances (unless otherwise waived by the Engineer), the Contractor will be required to bring to the optimum moisture content range, material in the borrow pits designated for construction use. Such material must have a uniform moisture content before leaving the borrow area(s).

No polluted water is to be used in any moisture conditioning requirement for materials used in the Works.

Payment for the opening of borrow areas not allocated by the Engineer, will not be considered.

Borrow from borrow pits will normally be limited to material which can be loosened by the use of mechanical rippers having a minimum fly wheel power of 130 kW and operating weight of 23 000 kg (e.g., a Caterpillar D7, Komatsu D85) in good condition and driven by a competent operator.

All borrow areas are to be left in a safe and neat state as directed by the Engineer at no extra cost.

Should stripping of unsuitable material overlying suitable material in a borrow pit be required, it shall be to such depths as determined by the Engineer. These unsuitable materials shall be disposed of at a suitable Site near the borrow area or as directed by the Engineer. The disposal area shall be within a one-way distance of 5 000 m of the area from which it was removed.

The unit of measurement for unsuitable material removed shall be the volume of in-situ material removed measured in cubic metres. The rates tendered must allow for the operation as described, including haulage to within 5 000 m of the borrow area, and, stockpiling or spreading and sloping as required by the Engineer. If material is from commercial source (borrow pit off site), it shall be stockpiled within 5000 m from the site and haulage must be allowed in the tendered rates. The disposal area is to be left as described in **Clause 4.10.**

7.5.2 BORROW PITS – RESTRICTIONS

Fill material for all compacted layer works must be free of all surface vegetation and approved by the Engineer. This material will generally be obtained from the following sources:

- borrow pit(s) within the confines of the Employers property,
- suitable spoil from trenches and excavations,
- borrow areas outside of the Employers boundaries and
- from commercial sources.

Under no circumstances must fill for compacted layer works be obtained from the following areas:

- 2.0 m either side of the area of the toe drains,
- 2.0 m either side of the centre line of the drainage outlet trenches and
- 2.0 m downstream of the any pond or dams
- Within a distance of 30 m from the inside toe of the inner perimeter wall.

Should these restrictions not be adhered to, the Contractor shall, at his own expense, restore the original ground level in the affected areas by compacting selected material to the specifications provided by the Engineer.

Borrow pit areas shall be neatly and safely finished off and unused material shall be levelled off and compacted within the pits. Final sides of borrow pits shall not be steeper than 1 vertical in 3 horizontals. The costs of these Works are deemed to be included in the rates for excavation of unsuitable to waste and / or placing fill from borrow.

7.6 COMPACTION TO A SPECIFIED DENSITY (IF APPLICABLE)

7.6.1 GENERAL

The standards of compaction required are shown on the drawings and densities obtained must be not less than the minimum specified Proctor density. The Proctor density described herein is the Standard Proctor – unless otherwise stated.

All compacted fill material is to be placed in horizontal layers and compacted in loose layers, with a depth not greater than 300mm, to a density not less than the minimum specified density. It should be further noted that a uniform moisture content (as per specification) is to be achieved throughout the loose layer prior to compaction. (Refer to materials preparation in **Clause 4.4** above).

All compaction must be carried out in a direction parallel to the centre line of the earthworks, working on a predetermined pattern that must ensure that the whole area of the layer receives uniform compaction.

The moisture content must, unless otherwise specified, be in the range between two per cent (2%) below and two per cent (2%) above Standard Proctor Density optimum moisture content, (or any other range specified on the drawings or by the Engineer from time to time) whichever is applicable. Compacted layers with non-uniform moisture contents or moisture contents outside the specified range are deemed to have failed regardless of the densities achieved. The required moisture content must be distributed uniformly throughout each layer of material.

Suitable compaction equipment must be utilized to ensure efficiency of operations.

Layer thicknesses are to be maintained to specification at all times. Preparation of each newly laid layer prior to placement of each additional layer should specifically involve:

- Scarification of the approved layer (newly laid compacted layer).
- Watering of the approved in-situ layer prior to bringing in the next loose layer.

7.6.2 COMPACTION CONTROL

The Contractor shall provide an adequate Site laboratory, equipment, facilities and experienced and competent personnel for carrying out the required compaction tests. Should the Engineer at any time consider any of the above to be inadequate for this purpose, he shall instruct the Contractor to cease further Works on compaction or other laboratory related Works until such time as the Contractor has remedied the deficiency.

The onus shall be on the Contractor to ensure the following:

i. That the state of the material when placed is such that the compaction as specified in **Clause 4.6.1** will be obtained.

ii. That material selected for use in compacted embankments shall be approved by the Engineer on the basis of the maximum dry density (Proctor or Mod AASHTO, whichever is applicable) being equal to or greater than a minimum density to be specified by the Engineer as well as being at the required moisture content, and, on the basis of the particle size distribution of the material falling within a specified envelope (refer **Clause 4.4**).

Hence with the object of controlling the selection and compaction of all materials used in the various layers of fill, grading analyses, Standard Proctor density tests must be performed whichever is applicable and corresponding moisture content evaluations on each type of material which are to be used, including mixed or blended materials.

No polluted water is to be used in any moisture conditioning requirement for materials in the Works.

In addition to the tests required for his own control the Contractor shall allow for at least two density checks per 1000 square metre block of material compacted per layer, or, in the case of narrow widths (as determined by the Engineer) at least 2 tests per 100m of narrow strip. The recognised method of determining the density is the sand replacement test. However, the Radio Isotope or other approved method may be used (if approved by the Engineer) for density and moisture checks, provided suitable agreement is obtained between this method and the sand replacement method and provided the necessary calibration and specified tests to these instruments are undertaken at intervals to be specified by the Engineer.

If an alternative method of density determination is accepted, the sand replacement method shall be used as a control check on a frequency determined by the Engineer on site. The moisture content of the sample shall be determined by oven drying as specified for the Standard Proctor compaction methods.

To account for material variability, approved density tests are to be accepted based on the following:

i. Layer works compacted to 95% Standard Proctor Density: If any one of the two density tests per 1000m² block (or narrow strip) is below 95% then the entire block will be re-ripped, re-watered and re-compacted.

ii. The compaction control tests must be carried out as laid down in “Standard Methods of Road Construction Materials, TMH 1” published by the National Institute of Transport and Road Research of the CSIR. Standard Proctor density tests shall be carried out in accordance with procedures set out in ASTM D 698.

iii. Field density and moisture content tests are to be carried out within 6 hours after the completion of each section of the layer, unless otherwise agreed by the Engineer.

The Engineer reserves the right to order additional in-situ density tests at any location on any strip.

When the compaction of any section of any layer, for which a density and moisture content is specified, is completed, test results must be made available to the Engineer.

No subsequent layer is to be placed until such time as the previous layer has been approved by the Engineer in writing.

Accurate records of all compaction control tests must be maintained throughout the construction process, i.e., test data, chainage and layer elevation.

These records must be available on Site for inspection by the Engineer at all times.

Where tests reveal that the density or moisture content of any layer, at any depth, is not to specification, the layer must be re-ripped, re-compact and re-water. If the specified density cannot be obtained by further compaction of the material such material must be removed and replaced by material capable of yielding the specified density.

7.6.3 TESTING ADJACENT TO ADJOINT STRUCTURES (IF APPLICABLE)

Where compacted material abuts up against adjoining structures, at least two density tests shall be taken per layer of contact material adjacent to the structure.

Such testing may be increased to confirm the density of the material in close proximity to such structures to ensure water-tightness of the join. The Engineer reserves the right to order additional testing or independent confirmatory testing as the situation warrants.

7.7 STRIPPING AND STOCKPILING OF TOPSOIL

Topsoil from excavations and borrow pits must be stripped to such depths and extent as indicated on the drawings or as directed by the Engineer and stockpiled for later re-use in rehabilitating the embankment side slopes or as otherwise required by the Engineer in accordance with the ESIA/EMP requirements.

7.8 SAFETY PRECAUTIONS IN EXCAVATIONS AND CONTRACTOR’S LIABILITY

7.8.1 SAFETY PRECAUTION

It is the Contractor’s responsibility to ensure safety of all excavations and must ensure that all reasonable measures are considered to ensure that shoring or by side sloping of the ground takes place. The Engineer reserves the right to instruct the Contractor to strut banks and sides of excavations, etc and / or side slope of such banks and sides of excavations etc. over any surface where the excavations are dangerous and / or to conform with any safety precaution in terms of relevant regulations.

Such instructions must be considered final and binding.

All strutting must be of sufficient strength to ensure the safety of all persons in the excavations and must be suitably arranged to permit the construction of whatever is necessary, and the Engineer's decision as to this shall be binding upon the works. The works must be immediately rectified if any strut is deemed by the Engineer to be unsafe or of such character as will impede or impair the construction of the Works. No under-cutting of excavations will be allowed.

7.8.2 CONTRACTOR'S LIABILITY

The Contractor shall be responsible for making good, or having made good, at his own expense any slips, falls, caving in of ground, damage to walls, structures or Works caused by reason of his acts or Works, or by causes within his control and shall indemnify the Engineer against any claims made in respect of loss of life, or injury or damage to persons, animals or things, caused by reason of his Works or through causes in his control. The Contractor's rates will be held to cover all such liabilities and the Engineer shall have the right, if they shall have suffered loss by reason of the above, to deduct the value of such loss from any monies due or that may become due to the Contractor.

7.9 DE-WATERING

Suitable pumps, pumping equipment, well points must be operated and maintained and all other water devices necessary to properly de-water and maintain free from water all excavations and all groundwater until completion of the Works.

No work shall be executed in water without the written permission of the Engineer.

The whole of the Works must be thoroughly drained and clear of water as long as may be required.

Channels or sumps excavated outside the works for dewatering purposes, must be refilled and made good to a standard equivalent to the original conditions (and as directed by the Engineer) when they are no longer required.

The Engineer may order additional permanent works to be constructed to deal with springs or seepage liable to endanger the Works after completion of the Works.

7.10 SPOIL DISPOSAL (NON – CONTAMINATED)

Dumping areas (which may include used borrow pits) shall be allocated for the disposal of all surplus material from clear Site operations, excavations, removal of unsuitable material, and for topsoil stripped from the Site etc. Such areas shall be within a one-way distance of 5 000 m of the Sites of excavation. These areas shall be maintained in a neat condition and when completed, levelled off by grading to within 150 mm from level or a given surface as directed. The rates tendered must allow for all such levelling and trimming and for haulage within a one-way distance of 5 000 m from the Sites of removal. Dumping area shall be approved by the Engineer.

7.11 SURFACES

7.11.1 BACKFILLING

Backfilling to foundations and trenches must be carried out by replacing selected excavated material in loose 150mm or 200mm layers or as specified on the drawings, each layer being thoroughly compacted, rammed and / or consolidated before the succeeding layer is placed or such other ways as may be directed by the Engineer. In areas where specified compaction densities and moisture contents are required for backfill, then the identical testing and approval procedures as outlined in Clause PSD 6 will be enforced.

Heavy compaction equipment may not approach so close as to cause damage or permanent displacement of structures.

Any defects caused due to subsidence of the backfilling, must be repaired at the ground surface, by filling by banking to a height of about 100mm above the level of the adjacent ground surface to allow for any settlements and before completion of the Works.

Care must be taken to ensure that any structures being buried are not damaged by the compaction effort. Repairs for and damage arising from this shall be for the Contractor's account, and items for repair or replacement shall be indicated and accepted by the Engineer at his sole discretion.

7.11.2 OVER EXCAVATION

Backfilling to over-excavation below the required levels or depths necessary to obtain a suitable bottom is to be carried out to the instructions and satisfaction of the Engineer and entirely at the Contractor's expense as follows:

i. **Material not for structural Support** - Where the material excavated is not required for structural support, the over-excavation must be filled with selected material, free from stones in 150mm or 200mm layers or as specified on the drawings and compacted to a density not less than that of the surrounding undisturbed material at the designated moisture content.

ii. **Material for Structural Support -** Where the material excavated was required for structural support, the over-excavation shall be backfilled with 15 MPa/19mm concrete (or concrete of other strength and or aggregate sizing to be specified by the Engineer) including all necessary work etc to prevent its inclusion with the structural concrete.

7.12 MEASUREMENTS AND EXCAVATION CLASSIFICATION

7.12.1 GENEAL

All excavation quantities throughout, in all classes of material, will be measured nett. Such excavation quantities do not include for cut to fill operations from borrow areas where material removed will be measured in placed and or compacted fill. Refer **Clause 4.1** and **Clause 4.4.**

Excavations shall be measured per cubic metre, divided into the following classes:

i. **Material Class "A" -** This classification shall include all kinds of ground encountered except those defined in Class "B" hereinafter and shall include made-up ground, paving's, rubbish, gravel, sand, silt, hard ouklip and calcareous material, clay, soft rock, ground interspersed with small boulders of rock not exceeding 0.5 m3 (one half of a cubic metre), dumped waste rock, material in compacted embankments and all other materials which can, in the opinion of the Engineer, be excavated by hand or by machine without drilling and blasting, or without the use of power breaking tools such as an hydraulic hammer,

ii. **Material Class “B” -** In the case of canal, trench and small excavation, this classification shall mean granite, quartz, dolomite etc, or rock of similar hardness which in the opinion of the Engineer or his representative, can only be removed by drilling and blasting. Solid boulders in excess of 0.5 m^3 (one half of a cubic metre) will be classified in this category. This classification shall apply whether or not blasting is authorised.

In the case of bulk excavation this classification shall mean granite, quartz, dolomite etc or rock of similar hardness found in its original position which cannot be loosened by a bulldozer having a minimum fly wheel power of 130 kW and operating weight of 23 000 kg (e.g., a Caterpillar D7, Komatsu D85 or equivalent in good condition, fitted with an approved single tine ripper and driven by a competent operator). This classification shall apply whether or not blasting is authorised.

One rate has been allowed in the Schedule of Rates for Class "B" material to cover all types and depths of excavation work. Spoiling of Class "B" material shall be as for Class "A" material. The excavation rate for Class "B" shall therefore include any extra required for spoiling the rock.

Note: If the Contractor considers that any material to be excavated is classified as Class "B" above, he shall submit a written request to the Engineer or his representative for his ruling. Failing such a request, the excavations shall be deemed to be in Class "A". The decision of the Engineer as to the classification of the material shall be final and binding.

7.12.2 OVER BREAK

The backfill to an over-break zone will either be a specified class of concrete or selected and compacted earth filling. In the case of compacted earth filling, this will be done in 150mm loose layers compacted at OMC to the specified density.

For the purpose of these Works, concrete backfill will be 15MPa/19mm and earth backfill will be selected and approved material compacted to 95% Proctor density at OMC. The type of filling to be used will be determined by the Engineer. All backfilling will be to the Engineer’s approval.

The same shall apply to sloping surfaces. All over-break zones must be kept to a minimum.

7.13 UNAUTHORISED EXCAVATION

An unauthorised excavation must be avoided where possible unless authorised by the Engineer.

7.14 HAULAGE

The Contractor shall at his own cost construct and maintain temporary haul roads as required along the routes designated by the Engineer.

If the Contractor chooses, for reasons of his own, to transport material by a different route, the measurement of distance for transport will be along the routes designated by the Engineer.

In the case of borrow pits, the Contractor shall be restricted to the routes designated by the Engineer.

Free haulage of material excavated from a borrow pit, stockpile, excavation etc or cutting shall be limited to a distance of five kilometres (5 000 m) measured from the edge of the borrow pit, stockpile area or cutting along the designated route. Haulage from designated sources or to designated stockpiles shall also be included as free haul.

Overhaul is that portion of the total haulage beyond the free haul limit and is measured separately. For the purposes of this Contract, the free haul distance has been set at a one-way distance of five kilometres (5 000 m).

The unit of measurement for overhaul in the case of compacted fill or placed material shall be the cubic metre. kilometre being the product of distance measured in kilometres to the nearest tenth of a kilometre and the cubic metres of compacted or placed (whichever is applicable) material transported. However, in the case of cut to spoil, or stockpile the unit of measurement for overhaul shall be the cubic metre. kilometre being the product of the distance measured in kilometres to the nearest tenth of a kilometre and the cubic metre of undisturbed in-situ material prior to being transported.

7.15 WASTE DISPOSAL

The Contractor shall not spoil, stockpile waste of any material without approval. He shall dispose waste which includes surplus and unsuitable material in areas designated:

- Type 1 waste to Class A Landfill Licensed Disposal Site
- Type 3 Waste to Class C (MFC Slag Dump) Licensed Disposal Site
- Type 4 Waste to designated areas specified by Engineer or Employer

The contractor shall obtain confirmation from the Engineer or Employer of the type of waste before disposal and transporting to required facility.

7.16 SEEDING AND VEGETATION

Where and as scheduled, grass, seeding or other vegetation shall be planted after topsoiling has been completed. On completion of planting, the planted area shall be neatly trimmed and well watered. The Contractor shall ensure that the planted areas are not permitted to dry out. Any grass or other vegetation that fails to grow shall be replaced by the Contractor, at his expense, with fresh grass or other vegetation or seed, as appropriate, until satisfactory cover is obtained.

8.0 SMALL EARTHWORKS: SANS 1200DE

8.1 DEFINITIONS

i. **Defects:** Any aspect of materials and workmanship forming part of the Works that, in the opinion of the Engineer, is due to the failure of the Contractor to comply with his obligations in terms of the agreement.

8.2 CLASS OF EXCAVATIONS

The classes of material for excavation shall be as defined in Project Specification **Clause 4.11**. The Contractor shall excavate whatever materials are encountered to the depths, cross-sections and grades shown on the drawings. Excavated material not required or unsuitable for backfill and / or for embankment construction shall be transported to and disposed of at a suitable Site away from the Site of Works as directed by the Engineer. The disposal area shall be within a one-way distance of 5 000 m of the area from which it was excavated. The unit of measurement for all excavation shall be the cubic metre of in-situ material excavated (measured nett). It should be noted that when excavations are cut through embankments for the placing of drains, pipes, pipe encasements, puddle flanges etc., the payment for these excavations shall be based on nett dimensions with the measurable depth of excavation limited to that of the maximum vertical dimension of the drain, pipe or encasement structure at each particular cross-section. Similarly, the measurable width shall be the design width of each particular cross-section. All costs associated with excavations greater than these dimensions (i.e., including backfilling with concrete or soil as required) shall not be considered for payment.

The rates tendered must allow for the operation as described and haulage to within a one-way distance of 5 000 m of the Site (Refer **Clause 4.13**). The disposal area is to be left as described in **Clause 4.10.**

9.0 MONITORING

As a general approach, MFC will ensure that the monitoring programmes comprise the following:

- A formal procedure
- Appropriately calibrated equipment
- Where samples require analysis, they would be preserved according to laboratory specifications
- An accredited, independent, commercial laboratory would undertake the sample analyses
- Parameters to be monitored should be agreed with the relevant authority
- If necessary, following the initial monitoring results, certain parameters may be removed from the monitoring programme in consultation with a specialist and/or the relevant authority
- Monitoring data would be stored in a structured database
- Data would be interpreted and reports on trends in the data would be compiled by an appropriately qualified person
- Both the data and the reports would be kept on record for the life of the operation

10.0 CERTIFICATION

This report was prepared and reviewed by the undersigned.

Prepared:

Denzil Govender, BSc. Eng
Civil Engineer

Reviewed & Approved:

Thabang Mokoma, Pr. Eng.
Principal Engineer

Approval that this document adheres to Knight Piésold Quality Systems: x