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Siyanda Chrome Smelter

Surface Water Study

SLR Project No.: 710.19057.00008

Report No.: FINAL

September 2016

Siyanda Chrome Smelting Company (Pty) Ltd

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Project Manager	Paul Klimczak
Project Manager e-mail	pklimczak@slrconsulting.com
Author	Paul Klimczak
Reviewer	Steven Van Niekerk
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SURFACE WATER STUDY

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ACRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	**Definition**
ASTER GDEM	Advanced Spaceborne Thermal Emmission and Reflection Radiometer Global Digital Elevation Model
BPG	Best Practice Guidelines
DEM	Digital Elevation Model
DWAF	Department of Water Affairs and Forestry
EIA	Environmental Impact Assessment
FAO	Food and Agriculture Organisation
GN 704	Government Notice 704
HEC-RAS	Hydrologic Engineering Centres – River Analysis System
IDF	Intensity Depth Frequency
MAE	Mean Annual Evaporation
MAMSL	Meters Above Mean Sea Level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mcm	Million Cubic Meters
PrSciNat	Professional Natural Scientist
PCD	Pollution Control Dam
PWD	Process Water Dam
RWD	Return Water Dam
SACNASP	South African Council for Natural Scientific Professions
SANRAL	South African National Road Agency
SAWS	South African Weather Service
SCSC	Siyanda Chrome Smelting Company (Pty) Ltd
Tc	Time of Concentration
WMA	Water Management Area
WR2005	Water Resources of South Africa 2005 Study
WULA	Water Use License Application

SURFACE WATER STUDY

1 INTRODUCTION

1.1 BACKGROUND

SLR Consulting (Africa) (Pty) Ltd (SLR), an independent firm of environmental consultants, has been appointed by Siyanda Chrome Smelting Company (Pty) Limited (SCSC) to undertake a Technical Specialist Surface Water Study to support an Environmental Impact Assessment (EIA) for the construction and operation of a proposed ferrochrome smelter in the Limpopo Province of South Africa.

The preferred site is located on the farm Grootkuil 409 KQ, approximately eight kilometres north-west of Northam.

SCSC is proposing to process UG2 chrome concentrate from surrounding platinum mines and in broad terms, the project will comprise a railway siding, a raw materials offloading area, two 70 MW DC ferrochrome furnaces, crushing and screening plant, mineralised waste facility and related facilities such as material stockpiles, workshops, stores and various support infrastructure and services including powerlines, access and internal roads and pipelines.

The surface water study to follow includes a baseline hydrological assessment, flood study, conceptual stormwater management plan and water balance for the proposed infrastructure to ensure compliance with best practice and relevant legislation.

This surface water study was undertaken by a suitably qualified and experienced Hydrologist registered with the South Africa Council for Natural Scientific Professions (SACNASP) as a Professional Natural Scientist (PrSciNat) in the field of Water Resources Science. A copy of the Hydrologist's CV is presented in Appendix B.

1.2 ENVIRONMENTAL LEGISLATION - DWAF GOVERNMENT NOTICE 704

Government Notice 704 (Government Gazette 20118 of June 1999) (hereafter referred to as GN 704), was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. Whilst the proposed ferrochrome smelter is not a mine, it is a related activity, more specifically it is a mineral processing facility, as listed under GN 704. Therefore the proposed infrastructure is designed in accordance with GN 704, and the following design principles are applicable:

- *Condition 4* which defines the area in which, mine workings or associated structures may be located, with reference to a watercourse and associated flooding. Any residue deposit, dam, reservoir together with any associated structure or any other facility should be situated outside the 1:100 year flood-line. Any underground or opencast mining, prospecting or any other operation or activity should be situated or undertaken outside of the 1:50 year flood-line. Where the flood-line is less than 100 metres away from the watercourse, then a minimum watercourse buffer distance of 100 metres is required for infrastructure and activities.

- *Condition 5* which indicates that no residue or substance which causes or is likely to cause pollution of a water resource may be used in the construction of any dams, impoundments or embankments or any other infrastructure which may cause pollution of a water resource.

- *Condition 6* which describes the capacity requirements of clean and dirty water systems. Clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated to ensure conveyance of flows of a 1:50 year recurrence event. Clean and dirty water systems should not spill into each other more frequently than once in 50 years. Any dirty water dams should have a minimum freeboard of 0.8m above full supply level.

- *Condition 7* which describes the measures which must be taken to protect water resources. All dirty water or substances which may cause pollution should be prevented from entering a water resource (by spillage, seepage, erosion etc) and ensure that water used in any process is recycled as far as practicable.

- *Condition 10* which describes the requirements for operations involving extraction of material from the channel of a watercourse. Measures should be taken to prevent impacts on the stability of the watercourse, prevent scour and erosion resulting from operations, prevent damage to in-stream habitat through erosion, sedimentation, alteration of vegetation and flow characteristics, construct treatment facilities to treat water before returning it to the watercourse, and implement control measures to prevent pollution by oil, grease, fuel and chemicals.

1.3 SCOPE OF WORK AND REPORT STRUCTURE

This Surface Water Study includes the following:

- Baseline Hydrology – Section 2 presents the baseline hydrology of the site and surroundings including climate, storm intensities, regional and local topography, watercourse network, soils, vegetation, groundwater setting, records of flow and mean annual runoff.

- Flood Hydrology – Section 3 presents estimates of the flood hydrology of an unnamed tributary of the Brakspruit River which flows through the project area. The section will also include peak flow estimation results which will inform the flood-line modelling.

- Hydraulic Flood Modelling – Section 4 presents hydraulic flood modelling undertaken for the Brakspruit tributary, including methodology, software, results and the 1:50 year and 1:100 year flood-lines within the vicinity of the site.

- Conceptual Stormwater Management – Section 5 presents the recommended stormwater management measures to manage flood risks to the operation and minimise risks of polluting any water resources, including clean and dirty water catchment delineation, estimation of peak flows, channel routing and sizing, and sizing of pollution control dams.

- Site Wide Water Balance – Section 6 presents the water balance for the operation during average wet and dry seasons in order to inform estimates on re-use rates, makeup water requirement and requirements for discharge.

- Conclusions and Impact Assessment – Section 7 presents the key conclusions and recommendations of the study and qualitatively assesses the impacts of the project on the surface water environment.

- References – Section 8 presents a list of the reference documents used for preparation of this report.

2 BASELINE HYDROLOGY

2.1 INTRODUCTION

In order to inform the flood studies, design of stormwater management measures, and the site wide water balance, an understanding of the baseline hydrology is required. This section presents a comprehensive review of various information sources to define the baseline climatic and hydrological conditions of the site and surroundings.

2.2 CLIMATE

2.2.1 RAINFALL

No records of rainfall recorded at the site are available and as such rainfall data from the following sources was reviewed to characterise rainfall patterns at the site:

- The Daily Rainfall Extraction Utility programme.
- Water Resources of South Africa 2005 Study (WR2005).

The Daily Rainfall Extraction Utility programme database consists of more than 300 million rainfall values derived from 11,269 daily rainfall stations. The data in the database originated from many different organisations and individuals, each having their own structure and level of quality control. The rainfall data extracted using the Daily Rainfall Extraction Utility programme includes the Middlekop station (0587139 W) and the Northam station (0587477 W), which is presented in Table 2-1 alongside monthly average rainfall data obtained from the Water Resources of South Africa manual, (WR2005, 2009).

TABLE 2-1: MONTHLY AVERAGE RAINFALL

Month	Rainfall (mm)		
	Middlekop (0587139 W)	**Northam (0587477 W)**	**WR2005**
January	119	117	106.4
February	96	82	92.9
March	83	81	79.6
April	48	35	40.7
May	20	8	13.8
June	8	2	6.3
July	6	1	3.6
August	4	2	4.9
September	15	16	13.7
October	48	51	46.2
November	84	81	79.6
December	106	95	104.1
Annual	**639**	**571**	**592**

Details of the daily rainfall records used are presented in Table 2-2 below.

TABLE 2-2: DAILY RAINFALL RECORD DETAILS

Station Name	Period	No of years	Reliability (%)	Patched (%)	Missing (%)
MIDDELKOP - 0587139 W	1924 - 1972	48	96.49	3.51	0.0
NORTHAM - 0587477 W	1968 - 2000	32	99.60	0.40	0.0

The percentage reliability of a station is related to the amount of actual observed data within the rainfall record. If Northam station is taken as an example, a reliability of 99.6 percent indicates that of the 32 years of rainfall data recorded for the Northam station, 99.6 percent of the mentioned years make up the actual observed data. The patched data represents rainfall data that has been statistically generated from the observed data, to extend the available rainfall record.

The adopted MAP for the project area was obtained from the Northam station which totals 571 mm. It is located fairly close to the project area (8 km), and falls within the quaternary boundary of A24E and is a more complete rainfall record than Middlekop.

A review of the daily rainfall records from Northam rain gauge illustrates that the maximum rainfall depth within 1 day between 1968 and 2000 was 163.0mm, several other high rainfall depths are presented in Table 2-3.

TABLE 2-3: FIVE GREATEST DEPTHS OF RAINFALL RECORDED IN 1 DAY

Date	Rainfall (mm)
17/12/1995	163.0
11/03/1969	130.5
05/11/1994	104.0
16/02/1978	99.0
09/03/1997	95.0

A review of the wettest multi-day periods recorded are presented in Table 2-4, which shows the maximum depth of rain falling over consecutive days ranging from 1 to 30 days. As can be seen, the greatest depth of rain falling within a 30 day period was 512 mm which is almost 90 percent of the adopted MAP, whilst the greatest depth within a 180 day period was 892.0 mm which is over one and a half times the MAP. It is concluded that whilst MAP in this area is fairly low there has been significant rainfall on occasions.

TABLE 2-4: WETTEST PERIODS RECORDED ON CONSECUTIVE DAYS

Number of Consecutive Days	Total Depth of Rainfall (mm)
1	163.0
2	163.2
3	173.2
4	202.0
5	241.0
6	241.0
7	241.0
15	271.0
30	512.0
60	679.5
120	823.0
180	892.0

2.2.2 EVAPORATION

Monthly evaporation data was obtained from the Water Resources of South Africa manual, (WR2005, 2009). The project area lies within evaporation zone 3A, which has a total MAE of 1801 mm. The evaporation obtained is based on Symons pan evaporation measurements and needs to be converted to Lake evaporation. This is due to the Symons pan being located below the ground surface, and painted black which results in the temperature in the water being higher than of a natural open water body. The Symons pan is then multiplied by a lake evaporation factor[1] to obtain the adopted Lake evaporation. Below in Table 2-5 is a summary of the adopted evaporation for the project site.

TABLE 2-5: MONTHLY AVERAGE EVAPORATION

Months	Symons Pan Evaporation (mm)	Lake Evaporation Factor	Lake Evaporation (mm)
January	201.7	0.84	169.4
February	165.7	0.88	145.8
March	153.1	0.88	134.7
April	114.9	0.88	101.1
May	91.3	0.87	79.4
June	71.9	0.85	61.1
July	83.2	0.83	69.1
August	122.1	0.81	98.9
September	168.2	0.81	136.3
October	207.5	0.81	168.1
November	207.8	0.82	170.4
December	213.6	0.83	177.3
Total	**1801**	**N/A**	**1512**

[1] Evaporation factor obtained from WR2005

2.3 STORM INTENSITY DURATION FREQUENCY (IDF) ESTIMATES

The design storm rainfall depths were obtained from the design rainfall software (Smithers and Schulze, 2002). The programme is able to extract the storm rainfall depths for various recurrence intervals for the six closest rainfall stations as shown below in Table 2-6.

TABLE 2-6: SUMMARY OF SIX CLOSEST SAWS STATIONS

Station Name	SAWS Number	Distance (km)	Record Length (Years)	Mean Annual Precipitation (mm)	Altitude (mamsl)
NORTHAM (POL)	0587477 W	5.0	31	587	1007
JERSEY FARM	0587475 W	6.5	28	565	998
VLAKNEK	0587350 W	11.3	38	636	1050
MIDDELKOP	0587139 W	16.3	49	650	1113
DRIELAAGTE	0548483 W	15.0	39	572	1050
SAULSPOORT	0548280 W	26.1	38	611	1095

Differences in the MAP for the Middelkop and Northam stations are noted between the datasets of Smither Schulze (Table 2-6) and Daily Rainfall Extraction Utility program (Table 2-1), which is due to the different records lengths between these datasets. The differences in MAP are small and insignificant to the design of water management measures presented within this report.

The adopted storm rainfall depth to be used in the peak flow calculations is based on the gridded rainfall depths for the above six stations. The summary of the rainfall depths for the 5 minute duration up to the 1 day storm duration for various recurrence intervals are shown below in Table 2-7.

TABLE 2-7: ADOPTED STORM RAINFALL DEPTHS FOR THE PROJECT SITE

Duration	Rainfall Depth (mm)						
(m/h/d)	1:2 year	1:5 year	1:10 year	1:20 year	1:50 year	1:100 year	1:200 year
5 m	9.8	13.5	16.1	18.6	21.9	24.5	27.1
10 m	14.6	20.1	23.9	27.6	32.6	36.4	40.2
15 m	18.4	25.4	30.1	34.8	41.1	45.9	50.7
30 m	23.3	32.1	38.1	44.1	52.0	58.1	64.2
45 m	26.7	36.9	43.8	50.6	59.7	66.7	73.8
1 h	29.5	40.7	48.3	55.8	65.8	73.5	81.3
1.5 h	33.9	46.7	55.4	64.1	75.6	84.4	93.4
2 h	37.3	51.5	61.1	70.7	83.3	93.1	103.0
4 h	44.0	60.7	72.1	83.3	98.2	109.7	121.4
6 h	48.5	66.8	79.4	91.7	108.2	120.8	133.7
8 h	51.9	71.5	85.0	98.2	115.8	129.4	143.1
10 h	54.7	75.4	89.6	103.5	122.1	136.4	150.9
12 h	57.1	78.8	93.6	108.1	127.5	142.4	157.6
16 h	61.2	84.3	100.2	115.7	136.5	152.5	168.7
20 h	64.5	88.9	105.6	122.0	144.0	160.8	177.9
24 h	67.4	92.9	110.3	127.4	150.3	167.9	185.8
1 d	56.0	77.2	91.7	106.0	125.0	139.6	154.5

2.4 Hydrological Setting

2.4.1 Introduction

South Africa is divided into 19 water management areas (National Water Resource Strategy, 2004), managed by its separate water board. Each of the water management areas (WMA) is made up of several quaternary catchments which relate to the drainage regions of South Africa.

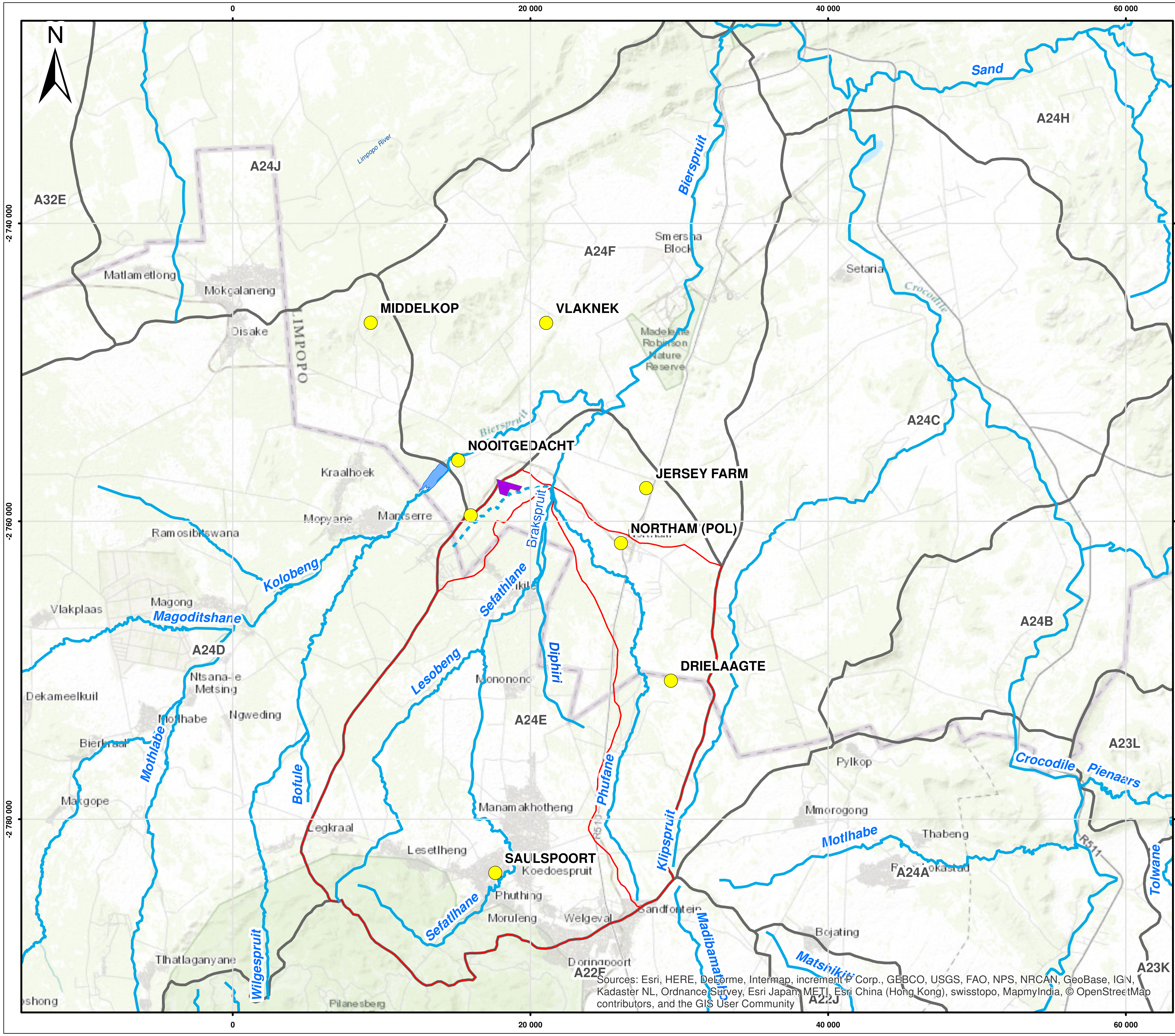
The project area falls within the Crocodile West and Marico WMA with the major rivers falling within the mentioned WMA being the Crocodile River, and the Marico River. All runoff from the project area is eventually drained north into the Limpopo River.

2.4.2 Regional Hydrology

The regional hydrological setting of the project site is indicated in Figure 2-1.

The WR2005 study[2], presents hydrological parameters for each quaternary catchment including area, mean annual precipitation (MAP) and mean annual runoff (MAR). Based on the WR2005 study, the project area falls within the quaternary catchment A24E, which comprises the Brakspruit and its tributaries. The total catchment area of A24E is 688 km^2 and it has a net MAR of 9.86 million cubic meters (mcm). There are no quaternary catchments upstream of A24E.

[2] WR2005: Water Resources of South Africa, 2005 Study (WRC, 2009).



Legend:

- Site Area
- Rainfall Stations
- Brakspruit Tributary
- Dams
- Rivers
- Quaternary Catchments
- Local Catchments

0 2.5 5 10 15
Kilometers

Scale as shown above

Projection: Transverse Mercator
Datum: Hartebeeshoek 1994

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Figure 2.1

Regional Hydrological Setting

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

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The main river within quaternary catchments A24E is the Brakspruit, which flows to the north, firstly to a confluence with the Bierspruit (7.5km north-east of the project area), which then flows onwards to a confluence with the Crocodile River approximately 33km north of the project area. The A24E quaternary catchment is bounded to the south by the Pilanesberg, which comprises an area of elevated topography and hills.

Based on the 1:50 000 topographical maps of the area, the tributaries of the Brakspruit are all non-perennial and include:

- The Sefatlhane (also known as the Moruleng in upstream reaches) flows north from the Pilanesberg to a confluence with the Lesobeng. Closer to the project area, and downstream of a confluence with the Diphiri, the Sefatlhane becomes the Brakspruit.
- The Lesobeng (also known as the Lesele in upstream reaches) flows north from the Pilanesberg to a confluence with the Sefathlane, approximately 23km south of the project area;
- The Phufane flows north and north-west from Sandfontein / Welgeval to a confluence with the Brakspruit, 2km east of the project area; and
- An unnamed tributary (referred to from here onwards as the Brakspruit tributary) flows past the southern site boundary to a confluence with the Brakspruit 2km east of the project area.

It should be noted that certain details of the above described watercourse network varies with different databases, and the above is based on the 1:50 000 topographical maps.

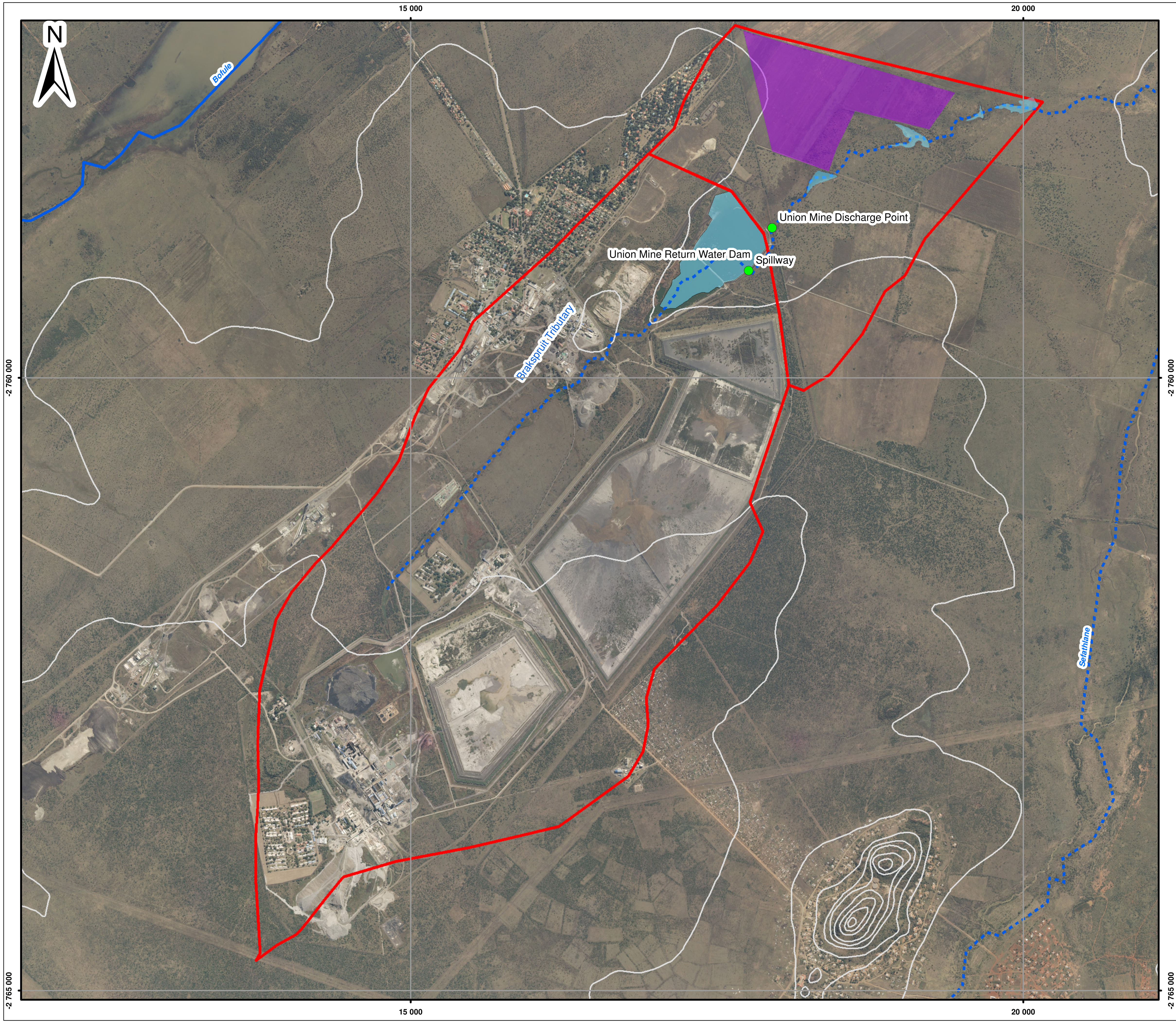
2.4.3 TOPOGRAPHY AND LOCAL HYDROLOGY

The local hydrological setting of the project site is indicated in Figure 2-2.

Topographical data for the site and surrounding is taken from the following sources:

- LiDAR Survey – an aerial survey of the site and immediate surroundings (220ha) was undertaken on 20 March 2016 by Southern Mapping. Survey data included 0.5m contours, survey points XYZ file (approximate resolution: 4 points per m^2), and ortho-rectified aerial imagery with a 10cm resolution.
- ASTER GDEM – the Advanced Spaceborne Thermal Emmission and Reflection Radiometer Global Digital Elevation Model features an elevation level taken on a 30m grid.
- 1:50 000 Topographical Maps – 20m contours for the region were obtained from Map 2427CC, 2526BB and 2527AA.

The catchment areas of the project area were delineated manually using the ASTER GDEM and 20 m contour set and are presented in Table 2-8.



Legend:

- Dams
- Catchments
- Siyanda Site Area
- Non-Perennial Rivers
- Perennial Rivers
- 20 m Contours

0 0.25 0.5 1 1.5 2
Kilometers

Scale as shown above

Projection: Transverse Mercator
Datum: Hartebeeshoek 1994

SIYANDA CHROME SMELTING COMPANY (Pty) Ltd

Figure 2-2

Local Hydrology

SLR

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

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TABLE 2-8: CATCHMENT AREAS OF LOCAL WATERCOURSES

Catchment Name	Area (km^2)
Phufane Catchment	156.7
Sefathlane Catchment	451.0
Brakspruit Tributary	23.4

The Brakspruit tributary flows through the Union Mine (located south-west of the Siyanda project), which features various tailings facilities, waste rock dumps and other surface infrastructure. At the eastern boundary of the Union Mine site, an earth dam wall was constructed, effectively forming a large return water dam (RWD) which is divided into two compartments and collects all runoff from the Union Mine site which is used as makeup water within the processing plant. The smaller compartment has a footprint of approximately 11ha, it always contains water and discharges into the larger (downstream) compartment during extended wet periods. The larger compartment has a footprint of approximately 39ha, it rarely contains a significant volume of water but is equipped with a concrete spillway which discharges to the Brakspruit tributary which flows through the Siyanda site. Discharge from the Union Mine site is via a V-notch weir upstream of a row of 3 box culverts, at the eastern Union Mine boundary, as shown in Figure 2-3, which was taken following a dry spell.

FIGURE 2-3: UNION MINE DISCHARGE POINT (25 FEBRUARY 2016)

It is assumed that stormwater from operational areas of the Union Mine (estimated to be at least 4.5km^2), will be collected and re-used in accordance with typical best practice.

Downstream of the Union Mine, the Brakspruit tributary features several small scale agricultural dams, which typically impound any flow within the watercourse, which will occur following significant rainfall.

2.4.4 SURFACE WATER QUALITY AND WATER USERS

Baseline monitoring of groundwater and surface water was undertaken and is presented in the Groundwater Impact Assessment report (SLR, 2016).

2.4.5 MEAN ANNUAL RUNOFF

The Brakspruit and its tributaries including Phufane, Sefathlane and the Brakspruit tributary, all fall within the A24E quaternary catchment, and estimates of the MAR for these catchments are presented in Table 2-9, assuming that MAR is proportional to catchment area.

TABLE 2-9: ESTIMATED MEAN ANNUAL RUNOFF (MAR) FOR LOCAL WATERCOURSES

Catchment Name	Area (km^2)	Total MAR (mcm)
Phufane Catchment	156.7	2.20
Sefathlane Catchment	451.0	6.35
Brakspruit Tributary Catchment	23.4	0.33
A24E Quaternary Catchment	688	9.86

Estimates for the Phufane and the Sefathlane catchments, indicate an MAR of 2.20 mcm and 6.35 mcm respectively, which correspond to a steady year round flow of 70 l/s and 201 l/s. Since these rivers are non-perennial, it can be assumed that little or no flows occur during the dry period, whilst significant flows occur during the wet season to makeup the steady flows mentioned.

2.4.6 VEGETATION

The vegetation types occurring in quaternary catchment A24E are tropical bush and savannah types (WR2005). More detailed information on the vegetation coverage at the site is presented in the Biodiversity Study (SAS, August 2016).

2.4.7 SOILS

Dominant soil types within quaternary catchment A24E are made up of moderate to deep clayey loam and sandy loam (WR2005) and will generate moderate to high volumes of runoff during intense storms events. More detailed information on the soil types encountered at the site is presented in the Soils, Land-Use and Land Capability Study (Terra Africa, March 2016).

3 FLOOD HYDROLOGY

3.1 INTRODUCTION

In order to map flood-lines for the Brakspruit tributary, an understanding of the flood hydrology is required.

The Brakspruit tributary flows through the Union Mine site, and the catchment includes several tailings dams, and mining infrastructure. Any flow within the watercourse is collected within a return water dam within the Union Mine site, which features a spillway along the southern wall. In the vicinity of the site, the watercourse features several small agricultural dams.

3.2 HISTORIC DATA

There are no flow gauging stations on the Brakspruit. The two nearest gauging stations are:

- A2H103: on the Bierspruit, at the outfall from Bierspruit Dam, upstream of the confluence with the Brakspruit 4km west of the project site, which was operational from 1961 - 1973.
- A2H108: on the Crocodile River, 35km north of the site, which has been operational since 1965 and has a catchment area of approximately 2 500km^2 upstream of the gauging station.

Neither of the above gauging stations are considered useful for estimating peak flows for the Brakspruit tributary because Bierspruit Dam will significantly attenuate peak flows, and the catchment area of the Crocodile River is 125 times larger than the Brakspruit tributary.

3.3 METHODOLOGY

The flood hydrology for the study area was modelled within HydroCAD version 10 stormwater modelling package. Rainfall runoff hydrographs were estimated using the Rational Method, which is considered suitable for small catchments (<15km^2). The Rational Method was first proposed in 1851 and has since become one of the most widely used methods of peak flow estimation.

The Rational Method allows for the estimation of a runoff coefficient based on the slope, soil permeability and vegetation to be considered. The runoff coefficient was estimated using the SANRAL Drainage Manual (SANRAL, 2013) method based on observations during a site visit on 25 March 2016, in addition to topographical data presented in Section 2.4.3, soils information presented in section 2.4.7 and vegetation coverage information presented in Section 2.4.6.

The Time of Concentration (Tc), which represents the rate at which runoff moves through a catchment, was calculated for both overland flow using the Kerby formula and channel flow using SCS method, as detailed within SANRAL Drainage Manual.

3.3.1 CATCHMENT CONCEPTUALISATION

Flow within the Brakspruit tributary (estimated at the downstream site boundary) is generated within two catchments:

- Union Mine catchment which will flow through the return water dam (RWD); and
- Siyanda site catchment which will flow into the watercourse downstream of the RWD.

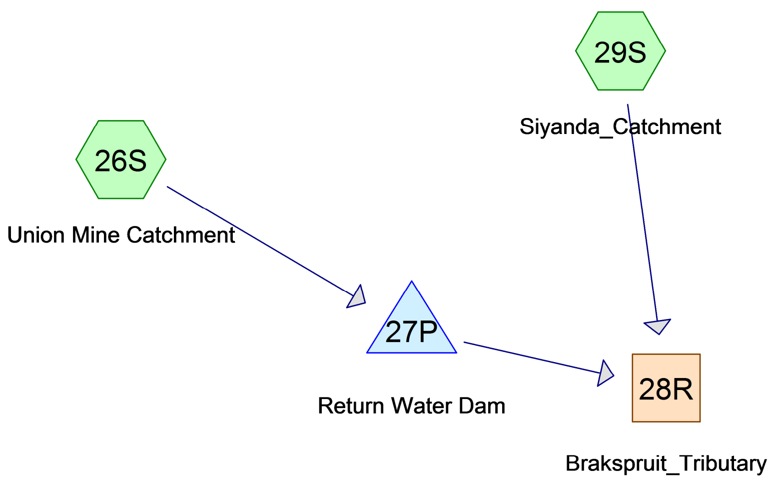


FIGURE 3-1: CONCEPTUALISATION OF CATCHMENT

The Union Mine RWD is modelled as an attenuation dam, the outflow from which is via the emergency spillway. It is assumed that the water level within the return water dam is at the crest of the spillway at the start of the event i.e. none of the inflow hydrograph is lost to storage within the dam. Attenuation of flow within the small agricultural dams is assumed to be insignificant given their small size, and these features were not modelled as attenuation dams.

FIGURE 3-2: EMERGENCY SPILLWAY FROM UNION MINE RETURN WATER DAM (25 FEBRUARY 2016)

3.3.2 INPUT PARAMETERS

The characteristics of each sub-catchment including the time of concentration or lag time, and the in-channel travel time between sub-catchments is presented in Table 3-1. The input parameters for the Union Mine RWD (modelled as an attenuation dam) are presented in **Error! Reference source not found.**.

TABLE 3-1: RATIONAL METHOD INPUT PARAMETERS

Catchment	Area (km^2)	Runoff Coefficient	Time of Concentration (mins)
Union Mine	15.75	1:50yr = 0.34 1:100yr = 0.38	124
Siyanda Catchment	4.42	1:50yr = 0.34 1:100yr = 0.38	93

TABLE 3-2: UNION MINE RWD DETAILS

Catchment	Footprint Area (m^2)	Spillway Width (m)	Spillway Length (m)
Union Mine Return Water Dam	390 000 (assumed vertical sides)	3	20

The travel time within the watercourse between the Union Mine return water dam, and the downstream end of the catchment was estimated to be 79 minutes, giving a total time of concentration of 203 minutes. The rainfall intensities used for flow estimation were 29.8mm/hr and 33.3mm/hr for the 1:50 year and 1:100 year rainfall events respectively.

3.4 RESULTS

The flood hydrographs for the Rational Method and SCS Method are presented in Figure 3-3 and Figure 3-4. These hydrographs are for the Brakspruit tributary at the downstream site boundary, where the total catchment area is 20.17km^2.

The peak flows for each of the watercourses estimated at the site boundary are presented in Table 3-3.

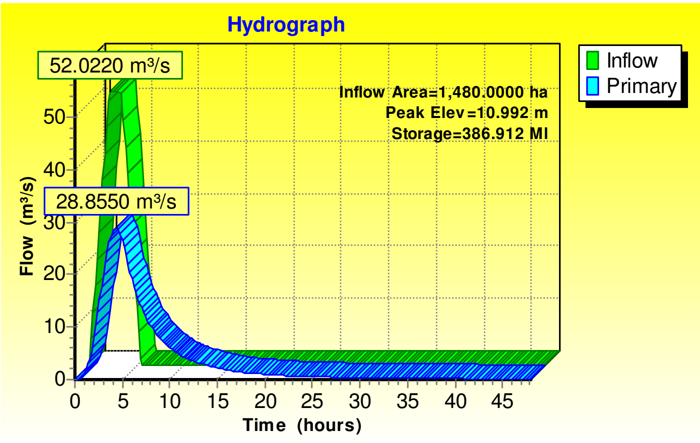


FIGURE 3-3: ATTENUATION OF THE 1:100 YEAR FLOOD WITHIN THE UNION MINE RWD

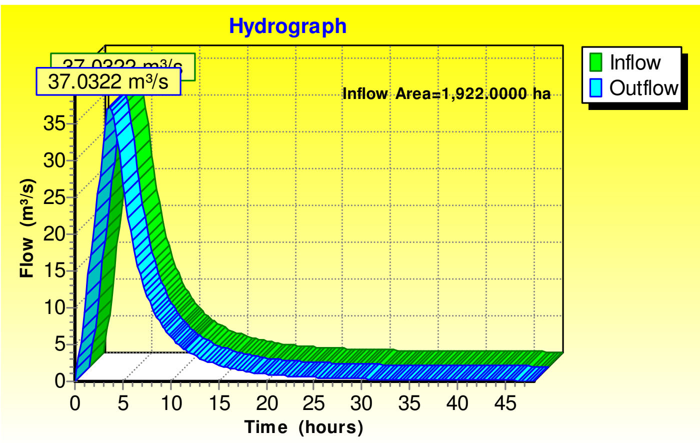


FIGURE 3-4: 1:100 YEAR FLOOD HYDROGRAPH AT DOWNSTREAM SITE BOUNDARY

TABLE 3-3: PEAK FLOW ESTMATES – RATIONAL METHOD AND SCS METHOD

Sub-Catchment	Rational Method	
	1:50 year flow(m^3/s)	1:100 year Flow (m^3/s)
Brakspruit Tributary	32	37

3.5 CONCLUSIONS AND RECOMMENDATIONS

The estimated peak flows presented above ignore any storage within the Union Mine RWD and assume that the water level in the dam has already reached the spillway at the start of the event. Given thatsite staff at Union Mine advise that there is rarely any water within the second compartment of the RWD, this is considered to be a conservative approach. Although it should be noted that the peak flow estimates are conservative, they are still considered realistic and are appropriate for informing the hydraulic flood modelling.

3.6 LIMITATIONS AND FURTHER WORK

Discounting any storage in the RWD below the spillway is considered to be a conservative approach but little can be done to improve upon this assumption without a much more detailed water balance model being undertaken on the Union Mine itself and it is not considered necessary to undertake any further work to improve upon the peak flow estimates presented above.

4 HYDRAULIC FLOOD MODELLING

4.1 INTRODUCTION

In order to inform the infrastructure layout for the proposed chrome smelter, understand and manage the risks of flooding to the operation and assess compliance with Condition 4 of GN704, modelling of the 1:50 year and the 1:100 year flood-lines is required for the section of the Brakspruit tributary which flows to the south east of the proposed smelter complex and associated infrastructure).

The following section details the approach and the methods used in the development of a hydraulic model for the purpose of defining the flood-lines.

4.2 METHODOLOGY

4.2.1 CHOICE OF SOFTWARE

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

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

4.2.2 TOPOGRAPHICAL DATA

As discussed in Section 2, a detailed LiDAR survey of the site and surrounding was available and was used to generate a DEM of the site and modelled section of the Brakspruit tributary.

The topographical data forms the foundation for the HEC-RAS model and is used to extract elevation data for the river profile together with the river cross-sections. The topographical data is also used to determine placement positions for the cross-sections along the river profile, such that the watercourse can be accurately modelled.

4.2.3 MODEL EXTENTS

The extent of the flood model is informed by the relevant hydraulic features which may impact flood levels in the vicinity of the proposed infrastructure and as such the model extends from the culvert at the Union Mine discharge point located approximately 600m upstream of the site, to just downstream of an agricultural dam located approximately 850m downstream of the site. A total length of approximately 3 080m of the Brakspruit tributary was modelled.

4.2.4 HYDRAULIC STRUCTURES

The notable hydraulic structures which were input into the model were:

- Culvert – the culvert at the Union Mine discharge point (Figure 2-2) was input as 3 x 1.8m wide, 0.4m high box culverts, with a road deck at 1m above the top of the culverts.
- Agricultural Dams – in total 4 small agricultural dams were identified along the modelled section of Brakspruit tributary, these were input by generating cross-section along the length of the dam wall including the outfall channel / spillway which were typically 1-1.5m lower than the dam wall.

4.2.5 ROUGHNESS COEFFICIENTS

The Manning's roughness factor n is used to describe the flow resistant characteristics of a specific surface. Based on the site visit undertaken, it was observed that the Brakspruit channel could be described as: *winding, some pools and shoals, with some ineffective slopes, some weeds and stones* and an n value of 0.05 was assigned to the channel. The floodplain could be described as: *light brush and trees* and an n value of 0.04 was assigned to the floodplain.

4.2.6 BOUNDARY CONDITIONS

The peak flows presented in Section 3 (1:50 year = 32m^3/s and 1:100 year = 37 m^3/s) were used as the upstream boundary along with a normal depth based on a gradient of 0.0038, and the downstream boundary was set as normal depth based on a gradient of 0.0038.

4.2.7 MODEL DEVELOPMENT

Development of the hydraulic model includes the following steps:

- Creation of a DEM from the topographical survey data;
- Generating cross-sections through the watercourses;
- Importing cross-sections, adding hydraulic structures and hydraulic modelling within HEC-RAS to generate flood levels at modelled cross-sections; and

- Importing flood levels and projecting levels onto the DEM to determine the flood inundation areas.

4.3 KEY ASSUMPTIONS

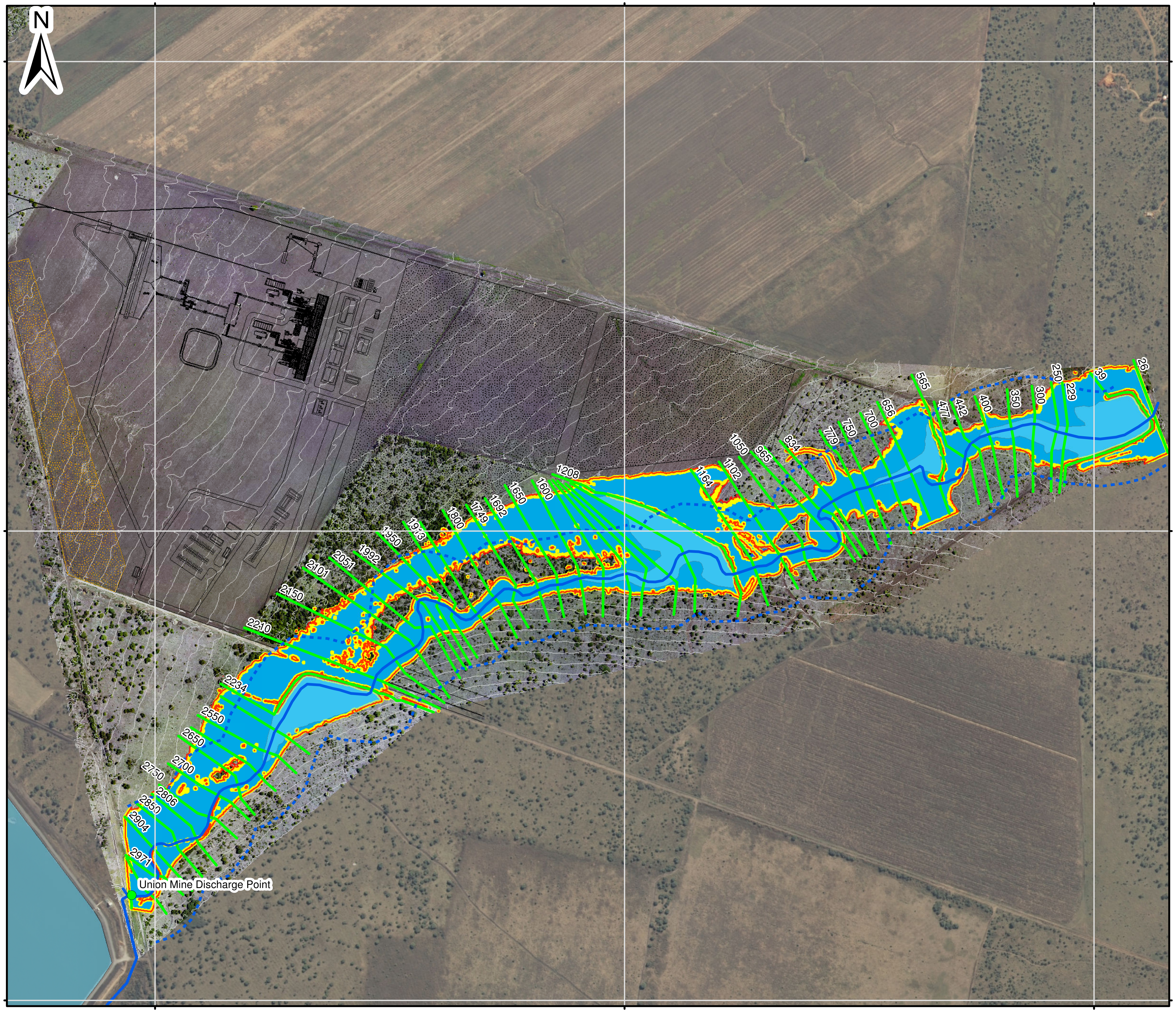
The following assumptions are made:

- That the topographic data provided was of a sufficient accuracy to enable hydraulic modelling at a suitable level of detail;
- There would be no significant attenuation or storage of floodwater within the farms dams in the vicinity of the project;
- The peak flow estimates adopted from Section 3 for the modelled events are realistic;
- The Manning's 'n' values used are considered suitable for both the 1:50 year and 1:100 events modelled;
- Steady state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate;
- A mixed flow regime which is tailored to both subcritical and supercritical flows was selected for running of the steady state model;
- No flood protection infrastructure was modelled;
- The modelling of the adopted flow through the respective hydraulic structures was undertaken, whilst assuming no blockages were present; and
- No abstractions from the river section or discharges into the river section were taken into account during the modelling.

4.4 RESULTS

Figure 4-1 presents the 1:50 and 1:100 year flood-lines and 100m buffers for the Brakspruit tributary. The 1:50 and 1:100 year flood-lines are very similar because the difference in flood levels between these two events is typically less than 100mm, often closer to 20-30mm.

The flood-lines are generally wide and extend past 100m from the centreline of the channel. This is a function of the numerous dams along the length of the watercourse, which cause water levels to rise until spilling over the dam wall.



Legend:

- 100m Buffer
- Brakspruit Tributary
- Cross Sections
- Dams
- 100yr Flood-Lines
- 50yr Flood-Lines
- Topsoil Stockpile
- Waste Facilities
- Site Layout
- 0.5m Contours

0 50 100 200 300 400 500
Meters

Scale as shown above

Projection: Transverse Mercator
Datum: Hartebeeshoek 1994

SIYANDA CHROME SMELTING COMPANY (Pty) Ltd

Figure 4-1

Flood-Lines

SLR

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

710.19057.00008	August 2016

4.5 CONCLUSIONS AND RECOMMENDATIONS

As presented in Figure 4-1, all vulnerable operational surface infrastructure is located outside of the 1:100 year flood-lines and 100m offset from the Brakspruit tributaries, thereby ensuring that there is no risk of fluvial flooding to this infrastructure.

The powerlines will cross the flood-lines and any watercourse crossings can be designed such that they do not impact upon conveyance within the floodplain and can withstand flow velocities during flood events, thereby ensuring that linear infrastructure not at risk of flooding, and does not increase risk of flooding to other vulnerable nearby receptors.

The proposed project powerline (which requires the crossing of the Phufane, Brakspruit and associated 2 tributaries) will require a service road for maintenance purposes. It should be noted that the existing dirt road (which follows the southern boundary of Portion 3 of Grootkuil) will be used and therefore no additional designated service road will be developed. The existing river crossings associated with this dirt road will remain unchanged and the impacts associated therewith are therefore expected to remain the same. A second existing dirt road traverses the farm and may be used as a backup access road to the project area (during the construction phase) if required. This road is also associated with existing river crossings and it is expected that these too will remain unchanged.

4.6 LIMITATIONS AND FURTHER WORK

The limitations on peak flow estimates are discussed in Section 3.

Steady state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate. This is a conservative approach as is ignores the effect of storage within the system and therefore produces higher flood levels than would be expected to occur in reality. In addition to pure conveyance, in-channel and floodplain flood storage exhibit a large influence on flood levels and floodplain extents within the low gradient watercourses such as the study catchment. As such, the steady state modelling will result in worse case (conservative) estimates of flooding, and resultant flood levels and floodplain extents would decrease if unsteady state modelling were undertaken using an inflow hydrograph as opposed to continuous peak flow;

The high resolution topographical data available has allowed an accurate hydraulic model to be developed, and the flood-lines whilst conservative, are considered to be robust and fit for purpose. No further work is considered necessary.

The design of linear infrastructure at watercourse crossings should take into account flood conditions to minimise flood risks to infrastructure or other vulnerable receptors nearby.

5 CONCEPTUAL STORMWATER MANAGEMENT PLAN

5.1 INTRODUCTION

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

- Bulk earthworks during construction will strip vegetation and expose top soils and subsoils to erosion by stormwater thereby increasing levels of suspended solids within local watercourses and water features;
- Stockpiles or waste material dumps will expose various chemical elements to stormwater, mobilising elements into local watercourses and water features;
- Storage and usage of process specific chemicals and vehicular related pollutants which, if not properly managed properly, may be washed by stormwater into local watercourses and water features; and
- Discharge of polluted or improperly treated stormwater, process water and sewage water into local watercourses or water features.

An impact upon the baseline water quality caused by mineral processing operations may impact upon the local aquatic ecosystems, and/or local human populations who use the water for drinking, washing, irrigating or livestock watering.

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

The aim of this conceptual stormwater management plan is to mitigate the above impacts by fulfilling the requirements of the National Water Act (Act 36 of 1998) and more particularly GN 704 (as discussed in Section 1).

The following definitions from GN 704 are appropriate to the classification of catchments and design of stormwater management measures at the Siyanda project:

- **Clean water system:** includes any dam, other forms of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of unpolluted (clean) water;

- **Dam:** includes any settling dam, slurry dam, evaporation dam, catchment or barrier dam and any other form of impoundment used for the storage of unpolluted water or water containing waste (i.e. dirty water);

- **Dirty area:** means any area at a mine or ***activity*** which causes, has caused or is likely to cause pollution of a water resource;

- **Dirty water system:** this includes any dirty water diversion bunds, channels, pipelines, dirty water dams or other forms of impoundment, and any other structure or facility constructed for the retention or conveyance of water containing waste (i.e. dirty water); and

- **Activity:** means any mining related process on the mine including the operation of washing plants, mineral processing facilities, mineral refineries and extraction plants; the operation and the use of mineral loading and off-loading zones, transport facilities and mineral storage yards, whether situated at the mine or not; in which any substance is stockpiled, stored, accumulated, dumped, disposed of or transported.

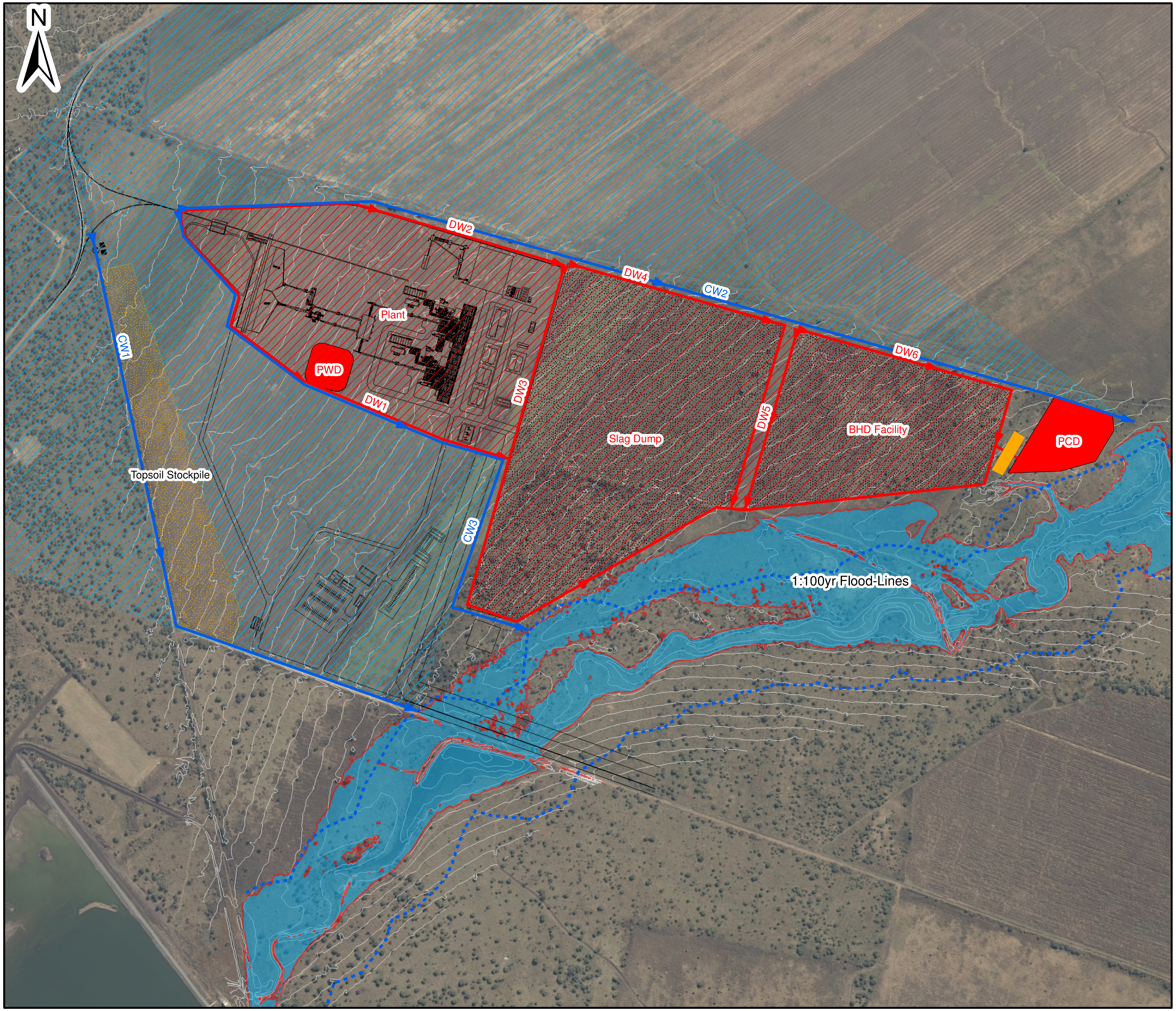
5.2 Design Principles For Stormwater Management

Informed by the baseline hydrology of the site and surroundings (presented in Section 2), a review of the proposed surface infrastructure has been undertaken, and a series of design principles for stormwater management have been developed to ensure compliance with the requirements of GN 704.

The proposed conceptual stormwater management plan is presented on Figure 5-1, the key features include:

- Clean stormwater will be diverted around dirty catchments and allowed to flow towards the watercourse located south-east of the site.
- The topsoil stockpile will be revegetated and any runoff will be collected in toe paddocks and allowed to evaporate or infiltrate.
- Dirty stormwater from the plant area (material transfer/storage/processing areas, furnace, service yard, and workshops) and waste facilities (slag dump and bag house dust facility) will be collected by perimeter drains and passed through a silt trap before being conveyed into the pollution control dam (PCD).
- Stormwater collecting in the PCD will be pumped to the Process Water Dam (PWD) during and after rainfall events to supply the plant's water requirements.

In order to meet the design principles detailed above, conceptual design details for the proposed stormwater management measures are presented below, along with the specific hydraulic design standards, methodologies, assumptions and input parameters for each measure proposed.



Legend:

- Clean Water Channels
- Dirty Water Channels
- Dirty Catchments
- Clean Catchments
- Dams
- Silt Trap
- Waste Facilities
- Topsoil Stockpile
- Site Layout
- 100m Buffer
- 100yr Flood-Lines
- 0.5m Contours

0 50 100 200 300 400
Meters
Scale as shown above

Projection: Transverse Mercator
Datum: Hartebeeshoek 1994

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Figure 5-1

Conceptual Stormwater Management Plan

SLR
SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

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5.3 SILT TRAP AND POLLUTION CONTROL DAM (PCD)

A single PCD is proposed in the east of the site, which is the lowest point thereby ensuring gravity drainage of runoff from all dirty water catchments identified. The PCD will be lined to prevent seepage of dirty water, which otherwise might pollute local surface and ground water resources. The PCD will feature an engineered spillway to convey design exceedance events through the PCD to the environment without causing erosion of the dam walls, which may compromise the structural integrity of the PCD.

It is recommended that operation of the PCD ensures that water levels are maintained at a sufficient level to accommodate the 1:50 year 24 hour runoff volumes plus a 0.8m freeboard i.e. stormwater should be pumped out of the PCD during and after rainfall events, to ensure that sufficient capacity is maintained within the PCD.

5.3.1 HYDRAULIC DESIGN STANDARDS

GN 704 requires that dirty water containment facilities are designed, constructed, maintained and operated so that they are not likely to spill into a clean water environment more than once in 50 years.

The following design standards are applied:

- The silt trap associated with the PCD is sized to accommodate runoff generated by the plant, slag dump and bag house dust facilities during a 1:2 year 24 hour duration event.
- The PCD is sized to accommodate runoff generated from a 1:50 year design rainfall (24 hour) event **and** the highest monthly rainfall (January) **less** the corresponding monthly evaporation (January) taking place over the surface area of the dam.

A critical component in sizing of PCDs in accordance with GN 704 is the rate at which water will be pumped from the pond for re-use at the plant. As part of the detailed design, which will be undertaken in support of the Water Use License Application (WULA), the PCD volume and pump-out rate will be checked using a daily timestep water balance model.

5.3.2 DESIGN METHODOLOGY

The catchments are presented on Figure 5-1, the average monthly rainfall depths are presented in Table 2-1, and the design rainfall depths are presented in Table 2-7. Runoff coefficients for the different catchment areas were estimated using Tables 3.7 and 3.8 of the SANRAL Drainage Manual. Different runoff coefficients were used to estimate runoff generated during different intensity storm events, or during a typical wet month.

5.3.3 DESIGN INPUT PARAMETERS

The design parameters used for sizing the silt trap and PCD are presented in Table 5-1 below.

TABLE 5-1: PWD, SILT TRAP AND PCD - DESIGN INPUT PARAMETERS

Catchment	Area (km^2)	1:2 year 24 hour Event		1:50 year 24 hour Event		Average Wet Month		
		Runoff Coef.	Rainfall (mm)	Runoff Coef.	Rainfall (mm)	Runoff Coef.	Rainfall (mm)	Evaporation (mm)
Plant	0.207	0.49	67.4	0.59	150.3	0.49	117	169
Slag Dump	0.223	0.26	67.4	0.43	150.3	0.22	117	169
Bag House Dust Dump	0.119	0.26	67.4	0.65	150.3	0.35	117	169

5.3.4 RECOMMENDATIONS

The recommended capacity requirements for the silt trap and PCD are presented in Table 5-2.

TABLE 5-2: SILT TRAP AND PCD CAPACITY

Facility	1:2yr Storm Runoff (m^3)	1:50yr Storm Runoff (m^3)	Wet Month Runoff (m^3)	Wet Month Evaporation (m^3)	Design Capacity (m^3)	PCD Footprint (m^2)
Silt Trap	13 547	N/A	N/A	N/A	13 547	2 000
PCD	N/A	46 098	23 000	2 880	66 219	17 000

5.4 DRAINAGE CHANNELS

The clean and dirty stormwater catchments and route of drainage channels are presented in Figure 5-1. The estimated design flows and recommended channel sizes are presented below.

5.4.1 DESIGN METHODOLOGY

A spreadsheet calculation using the Rational Method (as presented in the SANRAL Drainage Manual) was used to estimate design flows for the proposed channels.

The Rational Method equation is:

$$Q_T = \frac{C\,I\,A}{3.6}$$

Where:

Q_T = Peak Flow (m^3/s for specific return period);

C = Runoff Coefficient (%);

I = Rainfall Intensity (mm/hr); and

A = Area (km^2).

The runoff coefficients for each catchment were estimated using Tables 3.7 and 3.8 of the SANRAL Drainage Manual and the time of concentration was estimated for both overland flow and channel flow using equations 3.11 and 3.13 of the SANRAL Drainage Manual.

The worst case rainfall event for each catchment (i.e. duration = time of concentration) was taken from the Storm IDF estimates presented in Table 2-7.

Following estimation of the design flows for each diversion channel, the channels have been sized using the Manning's Equation to ensure that the flow capacity of the channel is sufficient to convey the 1:50 year flow.

The Mannings equation is:

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

Where:

A = Area of Channel

R = Hydraulic Radius (area / wetted perimeter);

S = Longitudinal Slope of Channel; and

n = Mannings Roughness Coefficient

5.4.2 Peak Flow Estimates

The rainfall intensities and peak flow estimates for each of the stormwater diversion channels are presented in Table 5-3.

TABLE 5-3: DESIGN FLOW ESTIMATES

Catchment	Area (km^2)	Runoff Coefficient	Time of Concentration (hours)	Rainfall Intensity (mm/hr)	Flow (m^3/s)
Cleanwater Catchment	1.305	0.278	1.234	58.61	7.41
Plant	0.207	0.589	0.313	149.18	5.06
Slag Dump	0.223	0.432	0.454	115.09	3.08
Bag House Dust Facility	0.119	0.694	0.410	125.63	2.87

5.4.3 RECOMMENDED CHANNEL SIZING

In order to accommodate the design flows, the recommended channel sizes are presented in Table 5-4. Figure 5-2 presents a typical cross-section through the channel.

The following assumptions were made during the design of the flow diversion channels:

- The channels are sized to take the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing will be uniform along their entire length.
- The longitudinal gradients are based on 0.5m contours from the LiDAR Survey undertaken on 20 March 2016 by Southern Mapping.
- Some cut and fill maybe required along the length of the channels to achieve the required gradient to ensure that water flows freely within the channels.
- Clean water will be kept out of the dirty water channels by constructing a linear bund with the material excavated from the channel (as shown on Figure 5-2).

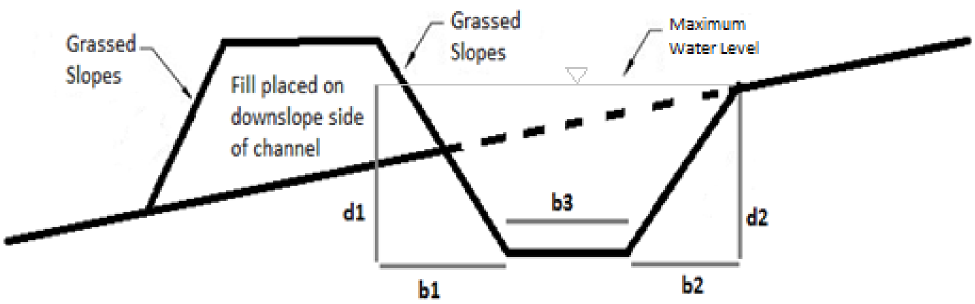

FIGURE 5-2: STORMWATER DIVERSION CHANNEL SIZING

TABLE 5-4: STORMWATER DIVERSION CHANNEL SIZING

Catchment	Total Flow	Drainage Channel	Design Flow		Channel dimension (refer to Fig 5-2)					S	n	A	P	R	V	Q
					b1	d1	b2	d2	b3							
	m^3/s		%	m^3/s	m	m	m	m	m	m/m		m^2	m	m	m/s	m^3/s
Cleanwater Catchment	5.91	CW1	50%	3.0	1.2	0.8	1.2	0.8	1.0	0.008	0.025	1.8	3.9	0.5	2.1	3.8
		CW2	27%	1.6	0.9	0.6	0.9	0.6	1.0	0.008	0.025	1.1	3.2	0.4	1.9	2.1
		CW3	23%	1.4	0.8	0.5	0.8	0.5	1.0	0.009	0.025	0.9	2.8	0.3	1.7	1.5
Plant	5.06	DW1	50%	2.5	1.1	0.7	1.1	0.7	1.0	0.009	0.025	1.4	3.5	0.4	2.1	3.0
		DW2	50%	2.5	1.1	0.7	1.1	0.7	1.0	0.007	0.025	1.4	3.5	0.4	1.9	2.7
All	8.04	DW3*	N/A	8.0	2.0	1.3	2.0	1.3	1.0	0.005	0.025	3.8	5.7	0.7	2.2	8.6
Slag Dump	3.08	DW4	50%	1.4	0.8	0.5	0.8	0.5	1.0	0.009	0.025	0.9	2.8	0.3	1.8	1.5
Bag House Dust Facility	2.87	DW5	50%	1.4	0.8	0.5	0.8	0.5	1.0	0.009	0.025	0.9	2.8	0.3	1.7	1.5
		DW6	50%	1.4	0.8	0.5	0.8	0.5	1.0	0.009	0.025	0.9	2.8	0.3	1.7	1.5

**DW3 channel sized to convey 100% of the flow from Plant, 50% from the Slag Dump and 50% from the Bag House Dust Facility*

The dirty water channels should be lined with a low permeability liner to prevent dirty water from infiltrating through the base of the channels which otherwise might impact upon the quality of the underlying groundwater.

5.5 IMPACT ON MEAN ANNUAL RUNOFF

The mean annual runoff (MAR) of quaternary catchment A24E (described in Section 2.4.2) equates to 14 331m^3/km^2. It is proposed that stormwater from a total area of 0.549km^2 is diverted away from the watercourses and into dirty water containment facilities to be re-used by the operation. The impact of this diversion on the MAR for the affected catchment was estimated and is presented in Table 5-5.

TABLE 5-5: IMPACTS ON MEAN ANNUAL RUNOFF

Catchment Name	Catchment Area (km^2)	MAR (mcm)	MAR (m^3/km^2)	Contained Area (km^2)	MAR Reduction (mcm)	MAR Reduction (%)
A24E	688	9.86	14 331	0.549	0.0079	0.0008%

The data presented in Table 5-5 suggest that the proposed stormwater management measures will have a negligible impact upon the MAR of the quaternary catchment.

5.6 LIMITATIONS AND FURTHER WORK

It is recommended that the capacity of the PCD is reviewed during detailed design of the stormwater measures by a daily timestep water balance model to ensure compliance with GN 704 and BPG A4 (DWAF, 2007), considering the predicted inflows to and outflows from each containment facilities taken from the site wide water balance.

It is recommended that the hydraulic gradients and channel sizes are checked during the detailed design of channels. The requirement for, and design of, in-channel velocity control measures should be confirmed during the detailed design of the channels.

The specification for lining of the channels and dams should also be confirmed during detailed design of these features.

6 SITE WIDE WATER BALANCE

6.1 INTRODUCTION

A site wide water balance model has been prepared to understand flows within the Siyanda Project operational water circuit during average dry season and average wet season conditions. The water balance has been developed by collating relevant design work supplied by the wider project team, and allows estimates of the typical flows, and volumetric requirements of make-up water or discharge of surplus water.

The modelled water balance circuit includes water inflows, losses and transfers for the following aspects of the operation:

- Smelter plant;
- Offices and workshops;
- Slag dump; and
- Bag house dust facility.

This water balance aims to ensure that dirty water is recycled and re-used within the operation in preference to abstracting and dirtying clean water resources. As such recycled water will be collected and transferred to the Process Water Dam (PWD) and re-used to supply process water to various activities at the site. Where needed, makeup water will be abstracted, from Municipal water supply, and backup supply will be from borehole(s) if Municipal water is temporarily unavailable.

6.2 METHODOLOGY

A spreadsheet model was used to represent the flows within the operational water circuit using information from the wider project team including:

- Design engineers for the waste management facilities – SLR; and
- Design engineers for the Furnace smelting complex - Tenova Pyromet and GLPS.

Water sources (inflows) were taken as:

- Stormwater collected from dirty catchments and conveyed to the PWD and/or PCD;
- Direct rainfall into the dams;
- Makeup water from Municipal water supply; and
- Backup supply (where Municipal water is unavailable) will be from borehole(s).

Water sinks (losses) were taken as:

- Evaporation from the dams;

- Losses of process water during activities on site;
- Losses of potable water; and
- Losses from the bag house dust facility (evaporation, seepage and interstitial lockup).

6.3 ASSUMPTIONS AND INPUT PARAMETERS

The water balance assumes the following:

- The water balance is steady state and no consideration is given to changes in flows associated with varying rainfall, production rates, or storage (e.g. start up water).
- Infrastructure is fully developed and operational, no consideration is given to changes in flows resulting from progressive development of infrastructure or changes in production rate.
- Rainfall related inflows and evaporation related losses for the wet and dry season scenarios were estimated based on: i) average values during the three driest months of the year; and ii) average values during the three wettest months of the year;
- Runoff and evaporation coefficients for each surface were fixed and not influenced by antecedent climatic conditions;
- All catchment areas are constant;
- Evaporation from the PWD and PCD would only occur if there was water in the dam;
- This water balance model is run for only steady state average wet season and average dry season conditions and no consideration is given to transient climate or storage of water between seasons i.e. flow in = flow out.

The input parameters used for the water balance are presented in Table 6-1.

TABLE 6-1: WATER BALANCE INPUT PARAMETERS

Parameter	Description	Source
Climate Data	• Average wet month rainfall = 98mm/month • Average wet month evaporation = 164mm/month • Average dry month rainfall = 2mm/month • Average dry month evaporation = 76mm/month	• Baseline Hydrology – Section 2
Furnace Facility and Associated Infrastructure	• Furnace and off gas plant losses = 26m^3/day • Irrigation = 12m^3/day • Potable Water = 96m^3/day, of which: o 20% is assumed to be lost o 80% is assumed to be collected and treated by sewage treatment plant	• Email from GLPS, 19 August 2016 • Assumed
Dams	• Process Water Dam footprint = 6000m^2 • Pollution Control Dam footprint = 17 000m^2 • Assume wetted area of PCD is only 10% of the footprint during the dry season.	• Site layout from GLPS, 24 August 2016 • Assumed

Parameter	Description	Source
Stormwater Catchments	• Plant: ○ Area = 207 170m^2 ○ Wet season runoff coefficient = 0.4 ○ Dry season runoff coefficient = 0.2 • Slag dump facility: ○ Area = 223 290m^2 ○ Wet season runoff coefficient = 0.3 ○ Dry season runoff coefficient = 0.2 • Bag house dust facility: ○ Area = 118 570m^2 ○ Wet season runoff coefficient = 0.4 ○ Dry season runoff coefficient = 0.2	• Stormwater Management Plan – Section 5
Baghouse Dust Disposal Facility	• Baghouse dust disposal rate: 4 000 tonnes/month • Water in slurry: 9 200m^3/month • Interstitial lockup: 0.472 * dust disposal rate • Seepage: assume 10^{-9} m/s seepage across liner. • Evaporation: assume 4 bags are wet at any time. • Bags surface area: 14m x 65m long	• Waste management design engineers - SLR

6.4 RESULTS

The water balances for the wet and dry seasons are presented in Figure 6-1 and Figure 6-2.

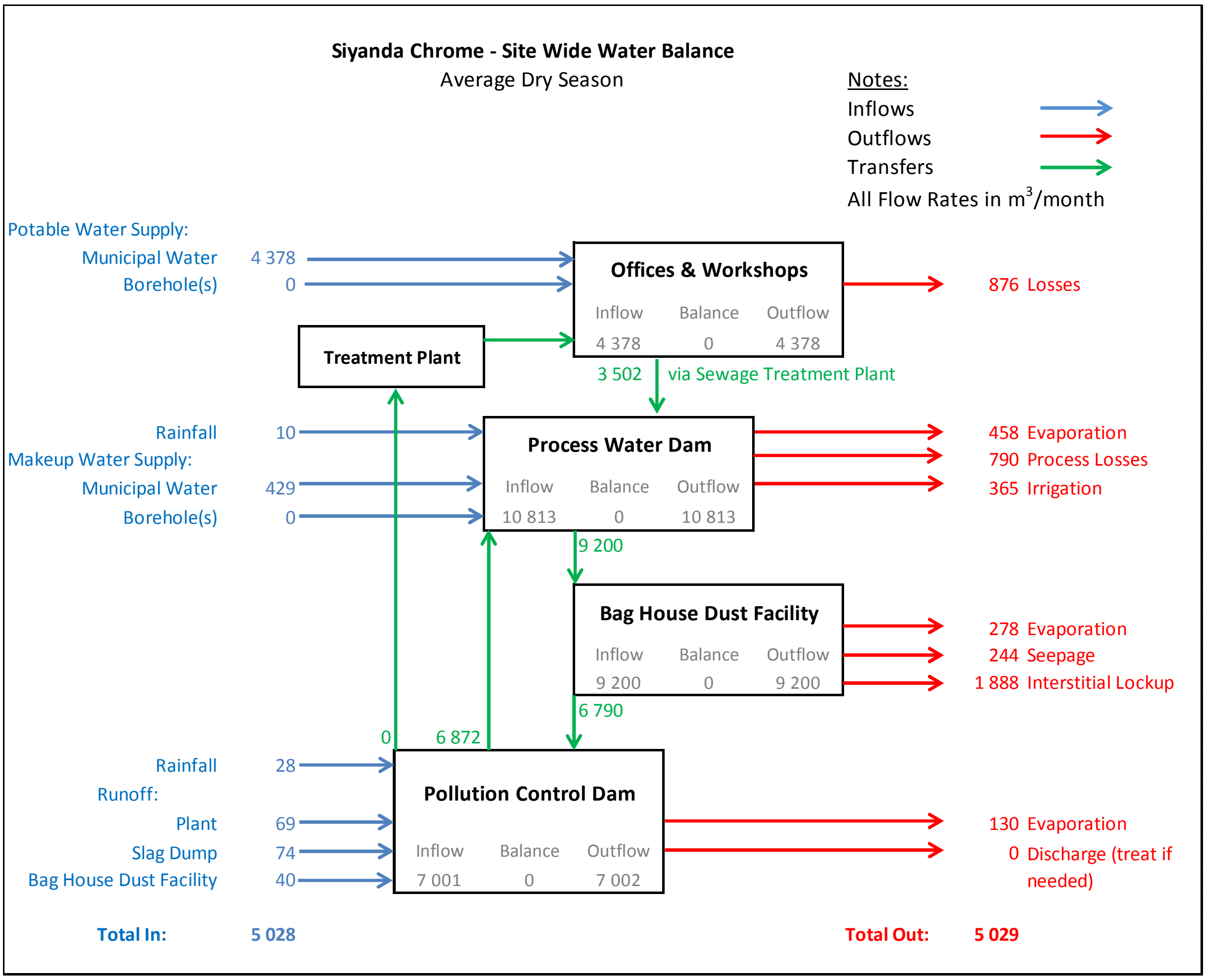

FIGURE 6-1: WATER BALANCE - DRY SEASON

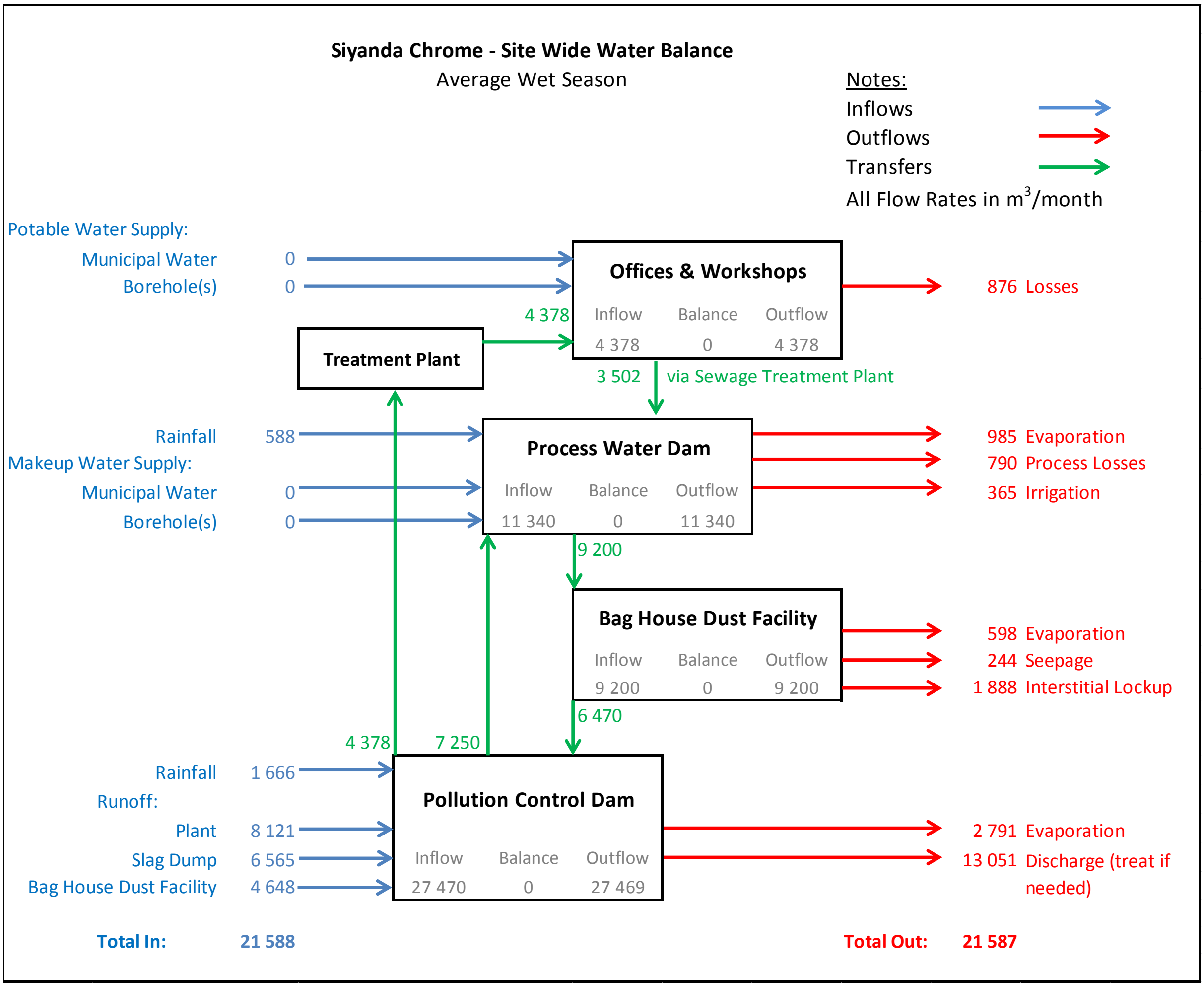

FIGURE 6-2: WATER BALANCE - WET SEASON

During the dry season, the operation will import potable water from the Municipality to supply offices and workshops and there will be no excess water to discharge. During the wet season, process and stormwater will be abstracted from the PCD to satisfy potable water demands and will be treated by a suitable specification plant prior to use. Despite re-using this water, during the wet season there will be a requirement to discharge excess water to the environment.

Any discharge would be subject to water quality and it is expected that process water will need to be passed through a treatment plant prior to discharge.

The rate of discharge during average wet season conditions is 13 051m^3/month, which equates to approximately 0.005m^3/s and is very low compared to the estimated flood flow in the Brakspruit tributary, estimated to be up to 37m^3/s during a 1:100 year event.

6.5 LIMITATIONS AND FURTHER WORK

This study makes use of various assumed and estimated parameters, and should be updated when more detailed information becomes available.

Whilst the likely discharge rates are low compared to flood flows within the Brakspruit tributary, it is recommended that the outfall pipe design considers erosion control measures to mitigate impacts on the channel.

Routine water quality monitoring of any discharge from the site, and any treated water used for supplying potable requirements, will be required to demonstrate compliance with the relevant water quality standards. Where exceedances of guidelines are identified, contingency plans should be implemented including a review of the site management practices and treatment plant performance.

7 CONCLUSIONS AND IMPACT ASSESSMENT

This surface water study report presents a description of the baseline hydrology of the site and surroundings which may be impacted by the proposed project. The site layout and project infrastructure has been reviewed in the context of the baseline hydrology and a series of mitigation measures developed for the project to minimise impacts and ensure compliance with GN 704.

Several different options for surface infrastructure were considered. The preferred option as presented herewith locates infrastructure sufficiently far from surface water features to minimise direct impacts on the surface water environment.

This study demonstrates that the project infrastructure is located outside of the flood-lines. Stormwater management measures are proposed to ensure that dirty stormwater is collected and re-used. The project will rely on potable water supplied by the Municipality, however during the wet season there will be a requirement to discharge excess water to the environment.

The proposed mining project includes various mitigation by design measures, theoretically without these measures the impacts on the environment would be much higher, although the project would almost certainly not be allowed to proceed as it would not comply with current best practice and relevant guidelines.

The potential unmitigated impacts (unrealistic worse-case scenario) are qualitatively assessed and presented in **Error! Reference source not found.**.

Various mitigation measures are recommended throughout this report, and the residual impacts of the project after considering the mitigation measures are qualitatively assessed and presented in Table 7-2.

In addition to the measures presented within this report, various recommendations for further work are presented to be undertaken during the next design phase of the project or during the operational life of the project.

Subject to implementing the mitigation measures and recommendations proposed herewith, it is concluded that the activities should be authorised.

TABLE 7-1: QUALITATIVE IMPACT ASSESSMENT – UNMITIGATED SCENARIO

	Impact	Severity	Duration	Extent	Consequence	Probability	Significance
Unmitigated Impacts	Without mitigation, the project may have the following impacts on/from natural drainage patterns:	The severity of the unmitigated impacts are as follows:	The duration of unmitigated impacts are as follows:	The extent of unmitigated impacts are as follows:	The consequence of unmitigated impacts are as follows:	The consequence of unmitigated impacts are as follows:	The consequence of unmitigated impacts are as follows:
	• Collection of stormwater, may reduce baseline flows downstream of the project.	• The project area is minor compared to the catchment of the Brakspruit tributary, the severity of reduction in baseline flows is low.	• Impacts on reduction in flows could be long term.	• Impacts would diminish in significance with distance from the site.	• Low	• Reduction in baseline flows could occur frequently, whenever it rains.	• Low
	• Without considering the drainage patterns, project infrastructure maybe located within flood-lines of local watercourses.	• Poorly located and designed infrastructure could have a high severity impact on the natural drainage patterns, by reducing channel conveyance during flood events.	• Impacts could be on a short term basis during/following a flood event.	• Impacts could stretch far downstream.	• Medium	• Any infrastructure within the flood-lines would be vulnerable to flooding frequently and for the lifetime of the project.	• High
	• Discharge of water at an uncontrolled rate into the Brakspruit tributary may cause erosion and channel scour.	• Uncontrolled discharges of water may cause moderate severity impacts on the local watercourses.	• Impacts could be on a short term basis during/following a flood event.	• Impacts could stretch far downstream.	• Medium	• Any uncontrolled discharge may occur frequently, whenever heavy rainfall occurs.	• Low
	Without mitigation, the project may have the following impacts on quality of surface water resources:	The severity of the unmitigated impacts are as follows:	The duration of unmitigated impacts are as follows:	The extent of unmitigated impacts are as follows:	The consequence of unmitigated impacts are as follows:	The consequence of unmitigated impacts are as follows:	The consequence of unmitigated impacts are as follows:
	• Discharge of dirty stormwater or process water may cause pollution of local watercourses.	• Discharge of dirty stormwater or process water could have a severe impact on the quality of local surface water resources.	• Long term for the lifetime of the project.	• Widespread, impacts could stretch far downstream.	• High	• Without mitigation there could be a high probability of impacting the quality of surface water resources.	• High.

TABLE 7-2: QUALITATIVE IMPACT ASSESSMENT – MITIGATED SCENARIO

	Impact	Severity	Duration	Extent	Consequence	Probability	Significance
Unmitigated Impacts	Considering mitigation measures, the residual impacts on/from natural drainage patterns are as follows:	The residual severity of the mitigated impacts are as follows:	The residual duration of mitigated impacts are as follows:	The residual extent of mitigated impacts are as follows:	The residual consequence of mitigated impacts are as follows:	The residual consequence of mitigated impacts are as follows:	The residual consequence of mitigated impacts are as follows:
	• Collection of stormwater, may reduce baseline flows downstream of the project.	• The project area is minor compared to the catchment of the Brakspruit tributary, the severity of reduction in baseline flows is low.	• Impacts on reduction in flows will be long term.	• Impacts will diminish in significance with distance from the site.	• Low	• Reduction in baseline flows could occur frequently, whenever it rains.	• Low
	• Project infrastructure is situated outside of the flood-lines.	• Infrastructure will have a low severity impact on the natural drainage patterns.	• Impacts will be short term during/following a flood event.	• Impacts will be local only.	• Low	• Infrastructure is outside of the flood-lines but may remain vulnerable to flooding from design exceedance events.	• Low
	• Discharge of water into the Brakspruit will be at a controlled rate and will not cause erosion and scour.	• Controlled discharge of water will have a low severity impacts on the local watercourses.	• Impacts will be short term during/following a flood event.	• Impacts will be local only.	• Low	• Controlled discharge may occur frequently, whenever heavy rainfall occurs.	• Low
	Considering mitigation measures, the project may have the following impacts on quality of surface water resources:	The residual severity of the mitigated impacts are as follows:	The residual duration of mitigated impacts are as follows:	The residual extent of mitigated impacts are as follows:	The residual consequence of mitigated impacts are as follows:	The residual consequence of mitigated impacts are as follows:	The residual consequence of mitigated impacts are as follows:
	• Dirty stormwater or process water will not be discharged and will not cause pollution of local watercourses.	• Discharge of dirty stormwater or process water will not impact on the quality of local surface water resources.	• Long term for the lifetime of the project.	• Impacts will be local only.	• Low	• With mitigation there is a low probability of impact on the quality of surface water resources.	• High.

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Paul Klimczak PrSciNat	**Steven Van Niekerk PrEng**	**Paul Klimczak PrSciNat**
(Project Manager)	**(Project Reviewer)**	**(Author)**

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APPENDIX A: NEMA REGULATION (2014) APPENDIX 6 SUMMARY

NEMA Regs (2014) - Appendix 6	Relevant section in report
Details of the specialist who prepared the report	Section 1.1.
The expertise of that person to compile a specialist report including a curriculum vitae	Appendix B.
A declaration that the person is independent in a form as may be specified by the competent authority	Appendix C.
An indication of the scope of, and the purpose for which, the report was prepared	Section 1.3.
The date and season of the site investigation and the relevance of the season to the outcome of the assessment	February 2016.
A description of the methodology adopted in preparing the report or carrying out the specialised process	Numerous methodologies discussed throughout the report to document baseline conditions and management measures.
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Baseline hydrological conditions are discussed in Section 2.
An identification of any areas to be avoided, including buffers	Flood-lines presented in Figure 4-1.
A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Figure 4-1.
A description of any assumptions made and any uncertainties or gaps in knowledge;	Assumptions discussed in Sections 3.3.2, 3.5, 4.3, 5.3, and 5.4.
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Discussed within the Section 7 and within the EIA.
Any mitigation measures for inclusion in the EMPr	Stormwater management plan presented in Section 5..
Any conditions for inclusion in the environmental authorisation	N/A
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	N/A
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	See Section 7.
If the opinion is that the proposed activity or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan	Water management measures are presented in Section 5 and 6.
A description of any consultation process that was undertaken during the course of carrying out the study	N/A. Consultation was undertaken as part of the EIA and has been detailed therein.
A summary and copies if any comments that were received during any consultation process	Appendix D
Any other information requested by the competent authority.	N/A

APPENDIX B: TECHNICAL SPECIALIST'S CV

Position: Senior Hydrologist

Name: Paul Klimczak

SLR global environmental solutions

Curriculum Vitae

Qualifications and Education

2000	Batchelor of Science (BSc) with Honours (Hons): Geology
2002	Master of Science (MSc): Hydrology for Environmental Management
2002	Diploma Imperial College (DIC)

Employment Record

2011 - Present	SLR Consulting Ltd, Johannesburg, South Africa
2008 - 2011	SLR Consulting Ltd, Bristol, United Kingdom
2005 - 2007	RPS Bowman Bishaw Gorham, Perth, Western Australia
2002 - 2005	RPS Group Ltd, Chepstow, United Kingdom

Professional Affiliations and Registrations

C.WEM – Chartered Water and Environmental Manager and Member of the Chartered Institution of Water and Environmental Management (CIWEM)

Cenv – Chartered Environmentalist

PrSciNat – Professional Natural Scientist in the field of Water Resource Science

Summary of Experience and Capability

Paul is a Senior Hydrologist based in Johannesburg, and has thirteen years of consultancy experience on variety of mining, energy, infrastructure, waste and urban development projects across the UK, Australia and Africa.

With a broad understanding of environmental issues in Africa, Australia and the UK, Paul works closely with clients, regulators and other technical specialists (e.g. hydrogeologists, engineers, ecologists, town planners and architects) to seek cost effective and sustainable strategies for minimising a projects impacts on the water environment.

Paul is professionally registered / chartered through CIWEM, SocEnv, and SACNASP. He is an approved technical reviewer under SLR's ISO9001 Quality Management Systems and responsible for undertaking and reviewing specialist various studies climate characterisation, flood hydrology, water balances and stormwater management plans.

Paul's input is provided across various stages of a project from initial constraints appraisal and risk identification at scoping stages, to layout / design optimisation during pre-feasibility studies, through environmental impact assessment and management plans, to working with engineers during detailed feasibility studies and construction phases, ultimately to compliance monitoring in operational stages.

African Project Experience

Date	Location	Client	Deliverable	Services Provided
2015	Panda Hill Project, SW Tanzania	Cradle Resources Ltd	Site Water Management for Pre-Feasibility Study and Feasibility Study	• Climate Characterisation • Flood-Line Mapping • River Diversion • Stormwater Management Plan • Water Balance • Flood-Lines Mapping
2015	Jeanette Project, Free State, RSA	Taung Gold	Surface Water Study for EIA	• Climate Characterisation • Baseline Hydrology • Flood-Line Mapping • Stormwater Management Plan • Water Balance
2015	Lake Albert Infrastructure Project, Uganda	EleQtra	Water Resources Specialist Study for EIS	• Baseline Hydrology • Hydrocensus • Water Quality Monitoring • Impact Assessment
2014	Kudumane Project, Northern Cape, RSA	Kudumane Manganese Resources	Surface Water Study for EIA	• Climate Characterisation • Baseline Hydrology • Flood-Line Mapping • River Diversion • Stormwater Management Plan • Water Balance
2014	Letlhakane Project, Botswana	A-Cap Resources	Surface Water Study for EIA	• Climate Characterisation • Baseline Hydrology • Flood-Line Mapping • River Diversion • Stormwater Management Plan • Water Balance
2013	Hinda Phosphate Project, Congo-Brazzaville	Cominco Resources	Site Water Management for Pre-feasibility Study	• Climate Characterisation • Baseline Hydrology • Flow Monitoring • Water Quality Monitoring • Flood-Line Mapping • River Diversion • Stormwater Management Plan • Water Balance
2013	Magazynskraal, North-West Province, RSA	Pilanesburg Platinum Mines	Surface Water Study for EIA	• Climate Characterisation • Baseline Hydrology • Flood-Line Mapping • Stormwater Management Plan • Water Balance
2013	Leeuwkop Project, North-West Province, RSA	Impala Platinum	Surface Water Study for EIA	• Climate Characterisation • Stormwater Management Plan • Water Balance • North-West Province, RSA
2012	Sedibelo West, North-West Province, RSA	Pilanesburg Platinum Mines	Surface Water Study for EIA	• Baseline Hydrology • Stormwater Management Plan • Water Balance

APPENDIX C: DECLARATION OF INDEPENDENCE

DECLARATION OF INDEPENDENCE

The independent Environment Assessment Practitioner I, ***Paul Klimczak***, declare that I:
• Act as an independent Environmental Practitioner for the Siyanda Chrome Smelter Project. • Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2014. • Have no and will not have any vested interest in the proposed activity proceeding. • Have no and will not engage in conflicting interests in the undertaking of the activity. • Undertake to disclose, to the competent authority, any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the Environmental Impact Assessment Regulations, 2014. • Will ensure that information containing all relevant facts in respect of the application are distributed or made available to interested and affected parties and the public.
Signature of Specialist:
Date: 20 September 2016

APPENDIX D: COMMENTS FROM CONSULTATION PROCESS

Issues Raised	Comment raised by	Response
The Brakspruit river runs through the site and when it rains, this river flows heavily, therefore it is important that water contamination is investigated for pollution spread downstream.	Comments raised by Adri Young at scoping meeting, Northam Town Hall, 23 July 2015.	With the exception of the proposed powerline, all infrastructure is located outside of the 1:100 year flood-lines. Water quality monitoring during the operational phase is discussed in the Groundwater Impact Assessment (SLR, 2016).
The Crocodile river is currently flowing with sewage water only. My concern is the impact that projects such as this will have in worsening issues like this in watercourses.		Any discharge from the site would be subject to water quality monitoring and it is expected that water will need to be passed through a treatment plant prior to discharge.
When you refer to keeping "dirty water" separate, what do you mean?		As per the Stormwater Management Plan, any runoff from areas classified as "dirty" will be contained and re-used where possible. Any discharge would be subject to water quality.
What will happen if groundwater and surface water is contaminated by the proposed smelter plant?	Comment raised by Sello Mogale at scoping meeting, Mmansterre, 21 July 2015	Any pollution of local water resources may adversely impact the health of water users and water based ecosystems. However, measures are proposed to prevent this from occurring. Should SCSC related surface and groundwater contamination take place, SCSC will ensure that compensation is provided in the form of water which is of equal of better quality and quantity.
Are you saying that there will not be any pollution in the rivers?	Comment raised by Sandy McGill, Mr and Mrs Schoeman at the scoping meeting, Swartklip Rec Centre, 21 July 2015	In accordance with Condition 7 of GN 704, Condition 7 describes the measures which must be taken to protect water resources. All dirty water or substances which may cause pollution should be prevented from entering a water resource (by spillage, seepage, erosion etc) and ensure that water used in any process is recycled as far as practicable. Section 5 and 6 presents measures to contain and re-use water. Any discharge would be subject to water quality.

RECORD OF REPORT DISTRIBUTION

SLR Reference:	710.19057.00008
Title:	Surface Water Study
Report Number:	FINAL
Proponent:	Siyanda Chrome Smelting Company (Pty) Ltd

Name	Entity	Copy No.	Date issued	Issuer