Surface Water Hydrology Report for the Kanakies Mining Project

Report Prepared for

Cabanga Environmental cc

Report Number CAB001

Report Prepared by

SD Hydrological Services (Pty) Ltd

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Acronyms and Abbreviations

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

Acronyms / Abbreviations	Definition
DEM	Digital Elevation Model
DWAF	Department of Water Affairs and Forestry
MAE	Mean Annual Evaporation
MAMSL	Meters Above Mean Sea Level
MAP	Mean Annual Precipitation
WMA	Water Management Area

1 Introduction

SD Hydrological Services (Pty) Ltd has been appointed by Cabanga Environmental cc, to undertake a surface water specialist study for the proposed Kanakies Mining Project.

The section to follow briefly summarises the required scope of work.

2 Scope of Work

The scope of works includes the following:

- **Baseline hydrology -** Undertake a detailed desktop assessment which includes, review of all existing information for the project area including, mean annual runoff (MAR), mean annual precipitation (MAP), mean annual evaporation (MAE), catchment areas of interest, topography, identification of surface water resources (rivers, drainage paths etc.) and storm rainfall depths for various recurrence intervals.
- **Storm water management plan** – Undertake a stormwwater management plan based on the Department of Water Affairs and Forestry (DWAF) (Best Practice Guidelines – G1: Storm Water Management, August 2006).
- **Water balance** – Develop a water balance for the project based on the DWAF, (G2: Best Practice Guidelines, Water and Salt Balance, August 2006).
- **Floodline delineation**– Undertake floodline modelling for the section of the rivers/drainages which flows adjacent to the project area
- **Surface water impact assessment** – Undertake a surface water impact assessment for the proposed project activities.
- **Surface water report** – Compilation of surface water report.

A locality map indicating the project location is shown in Figure 2-1 below.

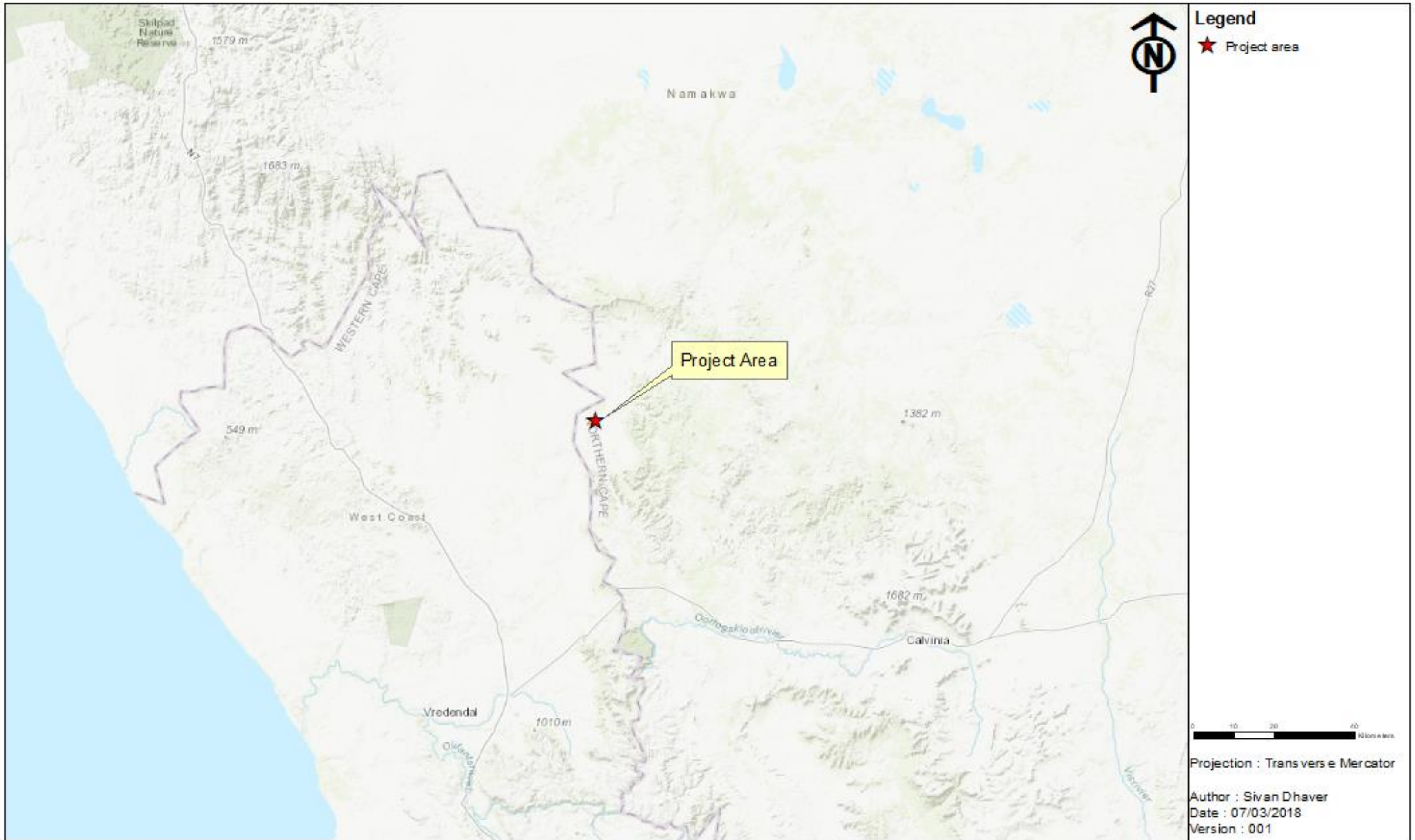

Figure 2.1

TITLE : Locality Map

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3 Baseline Hydrology

A baseline hydrological assessment was undertaken to inform sections relating to the water balance, storm water management plan, and the floodline assessment study. The section which follows provides a review of various information sources to define the baseline climatic and hydrological conditions of the project area and surroundings.

3.1 Hydrological Settings

3.1.1 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 quaternary catchments which relate to the drainage regions of South Africa, ranging from A – X (excluding O). These drainage regions are subdivided into four known divisions based on size. For example, the letter A represents the primary drainage catchment, A2 for example will represent the secondary catchment, A21 represents the tertiary catchment and A21D would represent the quaternary catchment which is the lowest subdivision in the Water Resources 2005 Study (WR2005) manual. Each of the quaternary catchments have associated hydrological parameters including area, mean annual precipitation (MAP) and mean annual runoff (MAR) to name a few.

The project area falls within the Olifants/Doorn WMA with the major river falling within the mentioned WMA being the Olifants, Doring, Krom, Sand and Sout.

3.1.2 Regional Hydrology and Topography

The project area falls within the south eastern boundary of the E33A quaternary catchments. The quaternary catchment E33A has a net mean annual runoff (MAR) of 0.9 million cubic meters (mcm), and is based on the WR2005 study.

Majority of the runoff from the project area is eventually drained south into the Krom River and Doring River, which run along the southern and eastern boundary of the project area.

Average elevations at the upstream northern boundary of quaternary catchment E33A range from 600 meters above mean sea level (mamsl) to 950 mamsl, and decreases to between 300 – 350 mamsl further south, closer towards the project location. Average slopes at the project area range between 1% and 3 % and is characterised as flat.

The hydrological setting of the project area is indicated in Figure 3-1. The digital elevation model (DEM) was sourced from the USGS website (http://hydrosheds.cr.usgs.gov/dataavail.php).

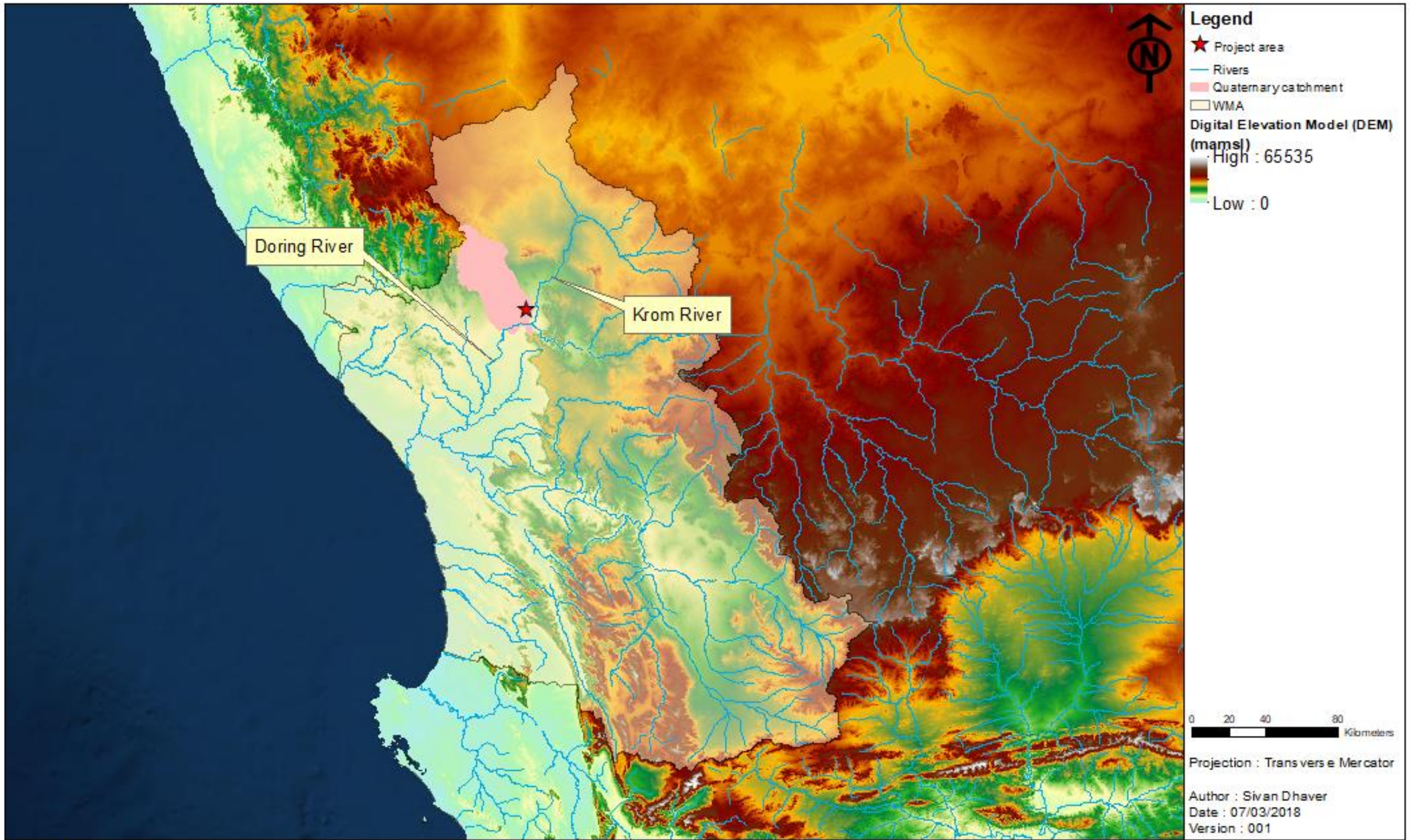

Figure 3.1

TITLE : Summary of Hydrological Setting

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3.2 Climate

The climate data presented below is used in the development of the water balance, which is presented in the sections to follow.

3.2.1 Rainfall

Rainfall data was extracted from two sources, these include:

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

The Daily Rainfall Utility is a programme that was developed by Richard Kunz, from the Institute for Commercial Forestry Research (ICFR, 2004), in conjunction with the School of Bioresources Engineering and Environmental Hydrology (BEEH) at the University of KwaZulu-Natal, Pietermaritzburg, South Africa. The utility assists the user in extracting observed and in-filled daily rainfall values from a database which was developed by Steven Lynch in the course of a Water Resources Commission (WRC) funded research project (K5/1156) awarded to BEEH. The project, titled “The development of a raster database of annual, monthly and daily rainfall for southern Africa”, was completed in March 2003. The daily rainfall 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 three main custodians of rainfall data in South Africa include, inter alia, the

- South African Weather Service (SAWS).
- Agricultural Research Council (ARC).
- South African Sugarcane Research Institute (SASRI).

Summary of the six nearest rainfall stations as per the output from the design rainfall program (described in section 4.1), together with the monthly rainfall obtained from WR2005 is shown below in Table 3-1.

Table 3-1 Summary of monthly rainfall

Months	CLOUDSKRAAL 0133050 W	NIEUWOUDVILLE (POL) 0133202 W	KAMABOES 0159104 W	LOERIESFONTEIN - POL 0160807 A	LOERIESFONTEIN - (POL) 0160807 W	NUWERUS (POL) 0131639 W	WR2005
January	7	5	4	6	6	**3**	4
February	12	8	7	11	11	**3**	5
March	17	14	10	15	15	**6**	8
April	34	26	18	21	21	**14**	13
May	61	48	26	25	24	**19**	16
June	81	61	35	32	32	**25**	21
July	72	51	30	24	24	**21**	18
August	65	52	31	23	22	**22**	18
September	39	29	16	13	14	**11**	10
October	29	20	13	11	11	**10**	8
November	20	15	10	13	13	**8**	7
December	12	10	6	8	8	**4**	4
MAP (mm)	**449**	**338**	**206**	**202**	**203**	**146**	**133**

Based on the above estimations it is observed that the MAP ranges between 133 mm to 449 mm, with the average MAP of the six nearest stations estimated to be 257 mm. The MAP obtained from the WR2005 study for quaternary catchment E33A is the lowest measured MAP estimated at 133 mm. The adopted MAP for the project area was selected based on reliability, amount of years patched data within the rainfall record, the altitude and relative location from the project area. From all the station data, it was noted that stations located at higher altitudes had higher MAP values.

The adopted MAP was therefore based on station 0131639 W (Nuwerus (POL)), due to the similar elevation when compared to the project area and a higher percentage reliability of measured data.

Based on the rainfall pattern shown in Table 3-1, it is observed that the wet season extends between the months of April to September, with the dry season ranging from October to March. Majority of the total MAP falls within the wet season and accounts for greater than 76 percent of the total MAP.

3.2.2 Evaporation

Monthly evaporation data was obtained from the Water Resources of South Africa Manual, (WR2005, 2009). The project area lies within evaporation zone 14A, which has a total MAE of 2088 mm. Evaporation was calculated using a Symons pan, which is a square shaped containment, filled with water and buried below the natural ground level as indicated in Figure 3-2. Change in water level as a result of evaporation losses is then measured daily and recorded.

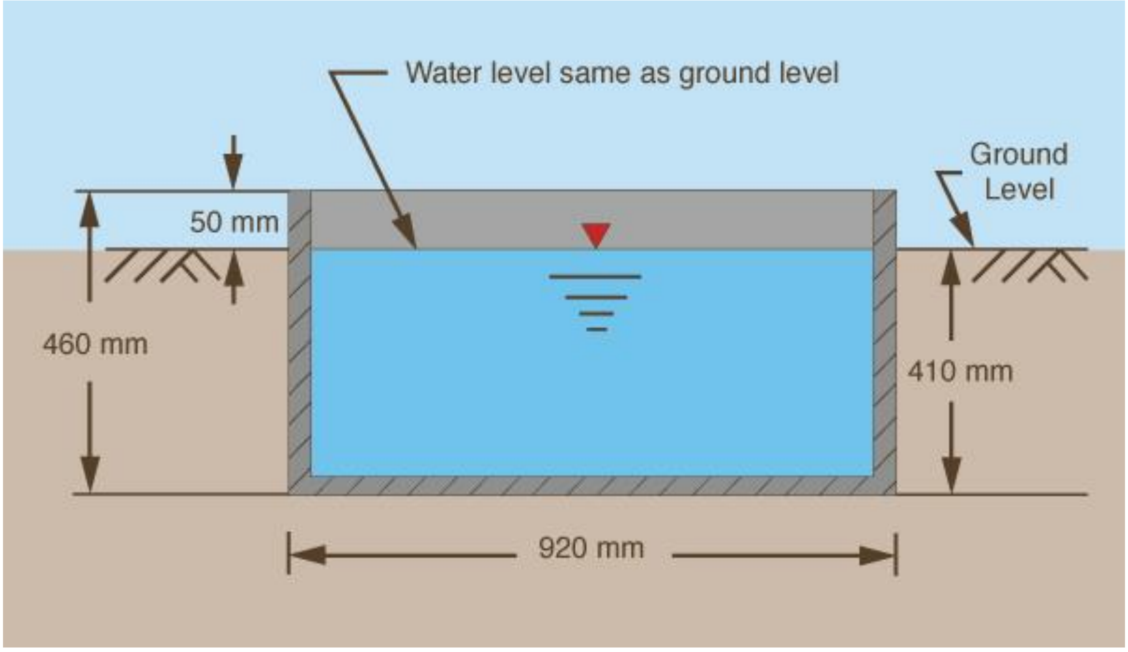

Figure 3-2 Symons Pan

The Symons pan evaporation obtained needs to be converted to lake evaporation, this this is due to the Symons pan being located below the ground surface, and painted black which results in the temperature of the water being higher than of a natural open water body. The Symons pan is then multiplied by a lake evaporation factor to obtain the adopted Lake evaporation to be used which is more representative of the evaporation rates from a natural body of water. Below in Table 3-2 is a summary of the adopted evaporation for the project site.

Table 3-2: Summary of evaporation data

Months	Symons Pan Evaporation (mm)	Lake Evaporation Factor	Lake Evaporation (mm)
January	275	0.84	231
February	231	0.88	203
March	215	0.88	189
April	153	0.88	135
May	103	0.87	90
June	77	0.85	65
July	76	0.83	63
August	106	0.81	86
September	150	0.81	122
October	198	0.81	160
November	235	0.82	193
December	269	0.83	223
Total	**2088**		**1760**

High evaporation rates are experienced between the months of September to April, with a peak monthly evaporation of 231 mm occurring in January. Lower evaporation occurs between the months of May to August and range from 63 mm to 90 mm. It is observed that throughout the year evaporation rates exceed the monthly rainfall, resulting in a negative climatic water balance.

4 Flood Hydrology

4.1 Storm Rainfall Depths

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 4-1.

Table 4-1 Summary of six closest SAWS stations as per the design rainfall software

Station Name	SAWS Number	Distance (Km)	Record length (Years)	Mean Annual Precipitation (mm)	Altitude (mamsl)
CLOUDSKRAAL	0133050 W	38.5	85	382	800
NIEUWOUDVILLE (POL)	0133202 W	45.1	91	343	720
KAMABOES	0159104 W	49.4	33	151	620
LOERIESFONTEIN - POL	0160807 A	54.1	82	202	885
LOURIESFONTEIN (POL)	0160807 W	54.1	91	202	885
NUWERUS (POL)	0131639 W	67.3	74	152	415

It should be noted that the MAP obtained for the six closest stations above, differ from the MAP of the same stations obtained using the Daily Rainfall Extraction Utility. The reason is, due to the extension of the existing record as a result of patched data being taken into account. The summary of the storm rainfall depths are shown below in Table 4-2, and will be used in the calculation of peak flows for all catchments required in the development of the storm water management plan.

Table 4-2 Summary of storm rainfall depths

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	4.7	6.5	7.7	8.9	10.4	11.6	12.9
10 m	6.7	9.2	11	12.6	14.9	16.6	18.3
15 m	8.2	11.4	13.5	15.6	18.3	20.4	22.6
30 m	10.5	14.5	17.2	19.9	23.4	26.1	28.8
45 m	12.1	16.7	19.8	22.9	27	30.1	33.2
1 h	13.3	18.5	21.9	25.3	29.8	33.3	36.8
1.5 h	15.4	21.3	25.3	29.2	34.4	38.3	42.4
2 h	17	23.6	28	32.3	38	42.4	46.9
4 h	19.9	27.6	32.7	37.8	44.5	49.6	54.8
6 h	21.8	30.2	35.9	41.4	48.8	54.4	60.1
8 h	23.3	32.2	38.3	44.2	52.1	58.1	64.2
10 h	24.5	33.9	40.3	46.5	54.8	61.1	67.5
12 h	25.5	35.3	42	48.5	57.1	63.6	70.3
16 h	27.3	37.7	44.8	51.7	60.9	67.9	75.1
20 h	28.7	39.7	47.1	54.4	64.1	71.4	79
24 h	29.9	41.3	49.1	56.7	66.8	74.5	82.3
1 d	23.7	32.8	39	45	53	59.1	65.3

4.2 Peak Flow Methodology

Due to the size of the project area and associated catchments delineated, the Rational method together with the Regional Maximum Flood (RMF) method was adopted. Below is a brief summary on the mentioned peak flow estimation methodologies.

4.2.1 Rational Method

The Rational Method is a hydrological method used to predict peak runoff with the equation being shown below.

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

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 coefficient C is based on a number of different physical characteristics of the site. These include the vegetation type and the slope drainage properties of the soil. The percentage of land used for residential or industrial development or under paved roads is also taken into account. The Rational Method is suitable for small catchments and is a method used extensively around the world.

A spreadsheet calculation using the Rational Method (as presented in the SANRAL Drainage Manual) was used to estimate peak flows to be used in undertaking the floodline delineation and storm water management plan. The runoff coefficients for each catchment were estimated using the SANRAL Drainage Manual, summarised in Table 4-3 and Table 4-4.

Table 4-3 Recommended value for runoff factor (SANRAL, 2006)

Rural (C_1)					Urban (C_2)	
Component	Classification	Mean annual rainfall (mm)			Use	Factor
		< 600	600 - 900	> 900		
Surface slope (C_s)	Vleis and pans (<3%)	0,01	0,03	0,05	*Lawns*	
	Flat areas (3 to 10%)	0,06	0,08	0,11	- Sandy, flat (<2%)	0,05 - 0,10
	Hilly (10 to 30%)	0,12	0,16	0,20	- Sandy, steep (>7%)	0,15 – 0,20
	Steep areas (>30%)	0,22	0,26	0,30	- Heavy soil, flat (<2%)	0,13 – 0,17
					- Heavy soil, steep (>7%)	0,25 – 0,35
Permeability (C_p)	Very permeable	0,03	0,04	0,05	*Residential areas*	
	Permeable	0,06	0,08	0,10	- Houses	0,30 – 0,50
	Semi-permeable	0,12	0,16	0,20	- Flats	0,50 – 0,70
	Impermeable	0,21	0,26	0,30	*Industry*	
Vegetation (C_v)					- Light industry	0,50 – 0,80
	Thick bush and plantation	0,03	0,04	0,05	- Heavy industry	0,60 – 0,90
	Light bush and farm lands	0,07	0,11	0,15	*Business*	
					- City centre	0,70 – 0,95
	Grasslands	0,17	0,21	0,25	- Suburban	0,50 – 0,70
	No vegetation	0,26	0,28	0,30	- Streets	0,70 – 0,95
					- Maximum flood	1,00

Table 4-4 Adjustment factor for C (SANRAL, 2006)

Return period (years)	2	5	10	20	50	100
Factor (Ft) for steep and impermeable catchments	0,75	0,80	0,85	0,90	0,95	1,00
Factor (Ft) for flat and permeable catchments	0,50	0,55	0,60	0,67	0,83	1,00

The time of concentration was estimated for channel flow using the equations below:

$$T_{c\ channel} = \left(\frac{0.87L^2}{1000\left(\frac{H_{0.85L} - H_{0.10L}}{(1000)(0.75L)}\right)} \right)^{0.385}$$

Where:

$T_{c\ channel}$ = time of concentration for channel flow (hours);

L = hydraulic length of catchment (km);

$H_{0.10L}$ = elevation height at 10% of the length of the watercourse (m);

$H_{0.85L}$ = elevation height at 85% of the length of the watercourse (m);

The worst case rainfall event for each catchment (i.e. duration = time of concentration) was taken from the storm rainfall depth estimates presented in Table 4-2.

To determine the anticipated peak flows at the respective catchment outlets using the Rational method, the catchment hydrology of the project area will have to be assessed, this involves:

- Delineation of catchment areas for identified outlets at the identified rivers/watercourses.
- Determining the appropriate runoff coefficient (C-Factor) which best represents the specific catchment, and is based on site visit observations and/or areal imagery and topography data.
- Determining the length of longest flow path, which is the identified flow path within the specific catchment from the upstream catchment boundary down to the outlet.
- Calculate the time of concentration (Tc). This is the time taken for a single drop of water to flow from the furthest point in a specific catchment to the outlet.

A summary of the catchment hydrology and peak flow calculations are presented in the sections to follow which include the proposed storm water management plan and the floodline modelling sections, namely sections 5 and 6 respectively.

4.2.2 RMF Method

The Francou-Rodier method involves estimation of peak flows based on effective catchment area and a dimensionless K-factor which is based on the hydrological characteristics of the respective catchment. Francou and Rodier distinguishes between three different zones based on observations of more than 1200 floods, and include, the flood zone (above 100 km^2 – floods dictated by area), the transition zone (between 1 km^2 and 100 km^2), and the storm zone (less than 1 km^2 – floods dictated by precipitation intensity).

During the 1980's after a series of flooding in Southern Africa the Francou-Roudier method was adopted for Southern African conditions. For each of the corresponding flood, a K-factor was calculated and was based on the maximum three day rainfall observed together with the soil characteristics. These K-factors where then used to categorise Southern Africa into nine regions.

The Regional Maximum Flood (RMF) can then be calculated using the Francou-Roudier formula for recurrence intervals from 50 years up to 200 years using the Qt/RMF ratios for Southern Africa, whilst for smaller recurrence intervals logarithmic interpolation can be undertaken. The RMF formula is indicated below:

$Q\ (RMF) = x * Ae^y$

Where	Q	– flood discharge (m^3/s)
	Ae	– effective drainage area (km^2)
	x	– regional coefficient
	y	– regional exponent

It should be noted that the regional coefficient and the regional exponent are based on the K-factor selected.

5 Storm water Management Plan

A storm water management plan is required so as to ensure there is adequate clean and dirty water separation such that, all water emanating from the mine area (dirty water) is captured, conveyed and safely contained, whilst the clean water emanating from the upstream environment is diverted away to the nearest watercourse or downstream environment.

The regulation which allows for the management of clean and dirty water within a mining environment is Government Notice 704, and is described in the section below.

5.1 Government Notice 704

GN 704 (Government Gazette 20118 of June 1999) was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. The five main principle conditions of GN 704 applicable to this project are:

- 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.

The proposed infrastructure layout plan is shown below in Figure 5-1.

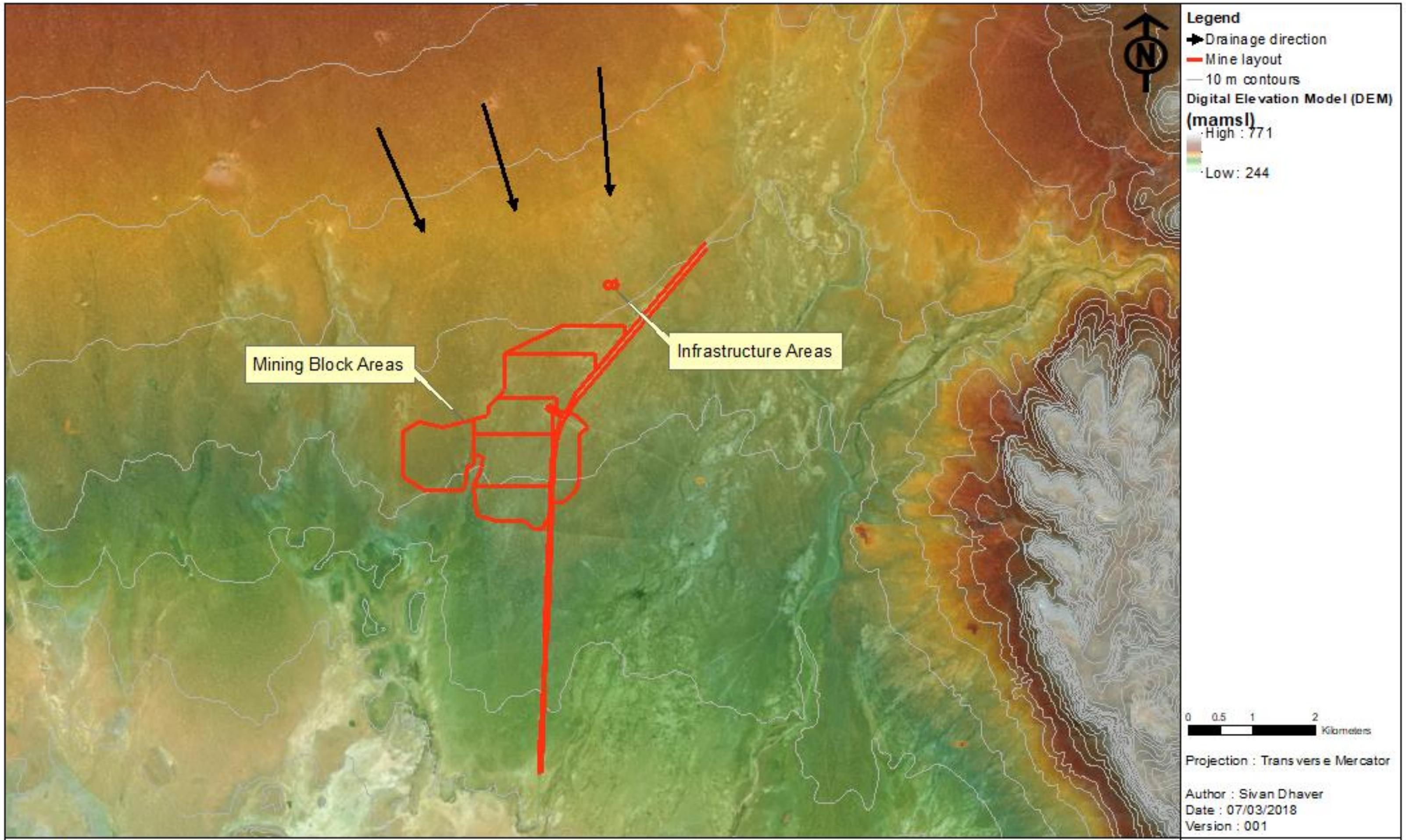

Figure 5.1

TITLE : Summary of Infrastructure Layout

5.2 Storm water Management Plan

5.2.1 Introduction

As mentioned a storm water management plan is required as per GN 704 of the National Water Act No 36 of 1998, with the main objective of the proposed storm water management plan being to ensure the separation of clean and dirty water during the proposed mining operation.

The section below details the proposed storm water management

5.2.2 Conceptual sizing of clean and dirty water channels

Based on the project layout placement, the drainage direction within close proximity of the primary infrastructure areas occurs in a north to south direction. Therefore, all clean water runoff emanating from the upstream catchment boundary is to be diverted around the proposed infrastructure areas and mining block areas to the nearest watercourse or clean water environment.

It is proposed that all clean water channels be unlined vegetated trapezoidal channels of which an example is shown below in Figure 5-2.

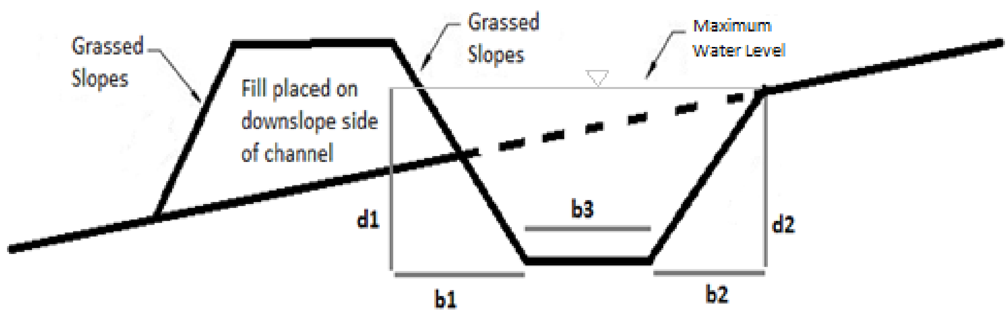

Figure 5-2 Clean water diversion channel conceptual design

All dirty water channels which collect runoff from the stockpile areas, waste rock dump areas, infrastructure areas are to be discharged into silt traps. Dirty water channels are to be vegetated and unlined, and based on trapezoidal designs.

Summary of the catchment hydrology, peak flow estimations and clean and dirty water conceptual sizing of the trapezoidal channels are shown below in Table 5-1 - Table 5-3 respectively.

Table 5-1 Summary of catchment hydrology

Name	Area (km^2)	Length of longest watercourse (m)	Height Difference (m)	Rainfall Intensity (Q_{50})	Tc (hours)	C-Factor
Cleanwater Diversion, Stockpile/Waste Rock Dump Catchments	2.00	3449	17	25.25	1.33	0.24
Infrastructure area Catchment	0.01	100	1	73.20	0.25	0.46

Table 5-2 Summary of peak flows

Name	Peak flows for various recurrence intervals (years)					
	2 year	5 year	10 year	20 year	50 year	100 year
Cleanwater Diversion, Stockpile/Waste Rock Dump Catchments	0.75	1.15	1.49	1.92	2.80	3.76
Infrastructure area Catchment	0.05	0.07	0.08	0.09	0.12	0.14

Table 5-3 Summary of channel sizing

Channel Section	Q (m^3/s)	Bottom width (m)	Calculated Top width (m)	Calculated depth (m)	Velocity (m/s)	Design depth (m)	Type
Cleanwater Diversions	2.80	1.0	7.00	0.65	1.47	1.0	Trapezoidal-Unlined
Stockpile/Waste Rock Dump channels	2.80	1.0	7.00	0.65	1.47	1.0	Trapezoidal-Unlined
Infrastructure Areas Channels	0.12	1.0	4.00	0.14	0.61	0.5	Trapezoidal-Unlined

Channels surrounding the waste rock dump and the stockpile areas are to be vegetated unlined trapezoidal channels with side slopes of 1:3 (1 Vertical: 3 Horizontal), bottom width of 1 m and design depth of 1 m.

Channels placed within the infrastructure areas are to be vegetated unlined trapezoidal channels with a width sideslopes of 1:3, bottom width of 1 m and design depth of 0.5 m.

Vegetated unlined channels are recommended for all areas where stormwater conveyance is required, with silt traps at the channel outlets. Vegetated channels encourage lower runoff velocities and trap sediments.

The stormwater maintenance plan described in the section below must be adhered to so that the functioning of the stormwater channels are maintained throughout the year.

5.3 Storm water Maintenance Plan and Monitoring

The primary purpose of the storm water maintenance plan is to ensure proper functioning of the storm water controls. The storm water maintenance plan is to be carried out during specific periods of the year, these periods include pre wet season, pre dry season and peak wet season months.

The rationale behind these key periods is listed below:

- Pre wet season - During the period leading up to the wet season various activities are required to ensure that all storm water controls are functioning effectively. These activities include undertaking a site inspection to assess blockages/debris within key locations including main channels (clean and dirty water). Levels of siltation within the silt traps should also be checked and the appropriate action taken to ensure sufficient storage is available for the wet period. The pre wet season site inspection should occur towards the end of April.
- Peak wet season – During this period site inspections should be undertaken as a follow up on the initial pre wet season site inspection. This is undertaken so as to determine if the preceding rains resulted in any damages to the storm water controls, and if any blockages had occurred at key locations mentioned. During the peak wet season month, site inspections should occur towards the end of June and July.
- Pre dry season – During this period, a site inspection should be undertaken to assess and rectify any damages as a result of the rainfall for the remainder of the wet season following January. Although during the dry season no major rainfall is anticipated, there may be short duration high intensity rainfall events that could produce high peak flows at the storm water control outlets. It is therefore necessary to undertake a site visit to ensure all storm water controls are functioning correctly. The pre dry season site inspection should be undertaken towards the end of September.

Summary of the storm water maintenance plan is indicated below:

Table 5-4 Summary of storm water maintenance plan

Months	Wet Season	Dry Season	SITE INSPECTION AND REMEDIATION		
			Pre Dry Season	Pre Wet Season	Peak Wet Season
January					
February					
March					
April					
May					
June					
July					
August					
September					
October					
November					
December					

A monitoring programme is essential as a management tool to detect negative impacts as they arise and to ensure that the necessary mitigation measures are implemented. It also ensures that storm water management structures are in working order. Monitoring should be implemented throughout the project life.

6 Floodline Modelling

6.1 Introduction

The floodline modelling was undertaken for river sections of the Krom and the Doring, which flow along the eastern and southern boundary of the project area. The main objective of the floodline model assessment is to delineate the 1:50 and 1:100 year floodline for the section of the mentioned rivers located within close proximity to the project area.

GN 704 (Government Gazette 20118 of June 1999) was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. The main principle condition of GN 704 applicable to this project is:

- **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 floodline is less than 100 metres away from the watercourse, then a minimum watercourse buffer distance of 100 metres is required for infrastructure and activities.

6.2 Model Development

6.2.1 Adopted Software

HEC-RAS 5.0 was used for the purposes of routing the peak flows resulting from the 1:50 year and 1:100 year storm event through the identified rivers. 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 the extent of flooding.

6.2.2 Roughness Coefficients

The Manning’s roughness factor “n” is used to describe the frictional characteristics of a specific surface. Selection of the Manning’s roughness factor is based on the surface characterisation of the river section being modelled. The surface characteristics investigated includes vegetation cover and also the degree of meandering of the river. According to (Chow, 1959), meandering rivers can increase the Manning’s roughness factor by as much as 30 percent.

Based on the vegetation cover identified from areal imagery and site visit photography, an average Manning’s “n” factor ranging of 0.05 was selected to best represent the frictional characteristics of the surface of the watercourse which includes the main channel and floodplain.

6.3 Peak Flow Estimation and Model Setup

To determine the anticipated peak flows at the respective catchment outlets using the RMF method, the catchment hydrology of the project area will have to be assessed, this involves:

- Estimating the catchment sizes.
- Determining the appropriate K factor representative of the delineated catchments.

The summary of the catchment hydrology and the peak flows is shown in Table 6-1 and Table 6-2 below.

Table 6-1 Summary of catchment hydrology

Name	Area (km^2)	K-Factor
Floodline Catchment	14188	4

It should be noted that a K-factor of 4 was selected which best represented the rainfall and soil characteristics of the Upper and Olifants/Doorn WMA.

Table 6-2 Summary of peak flows

Name	Peak flows (m^3/s) for various recurrence intervals (years)					
	2 year	5 year	10 year	20 year	50 year	100 year
Floodline Catchment	1067	1368	1652	1995	**2536**	**3145**

The summary of the model setup which includes amongst others, the digitised drainages and cross sections are shown in Figure 6-1 below.

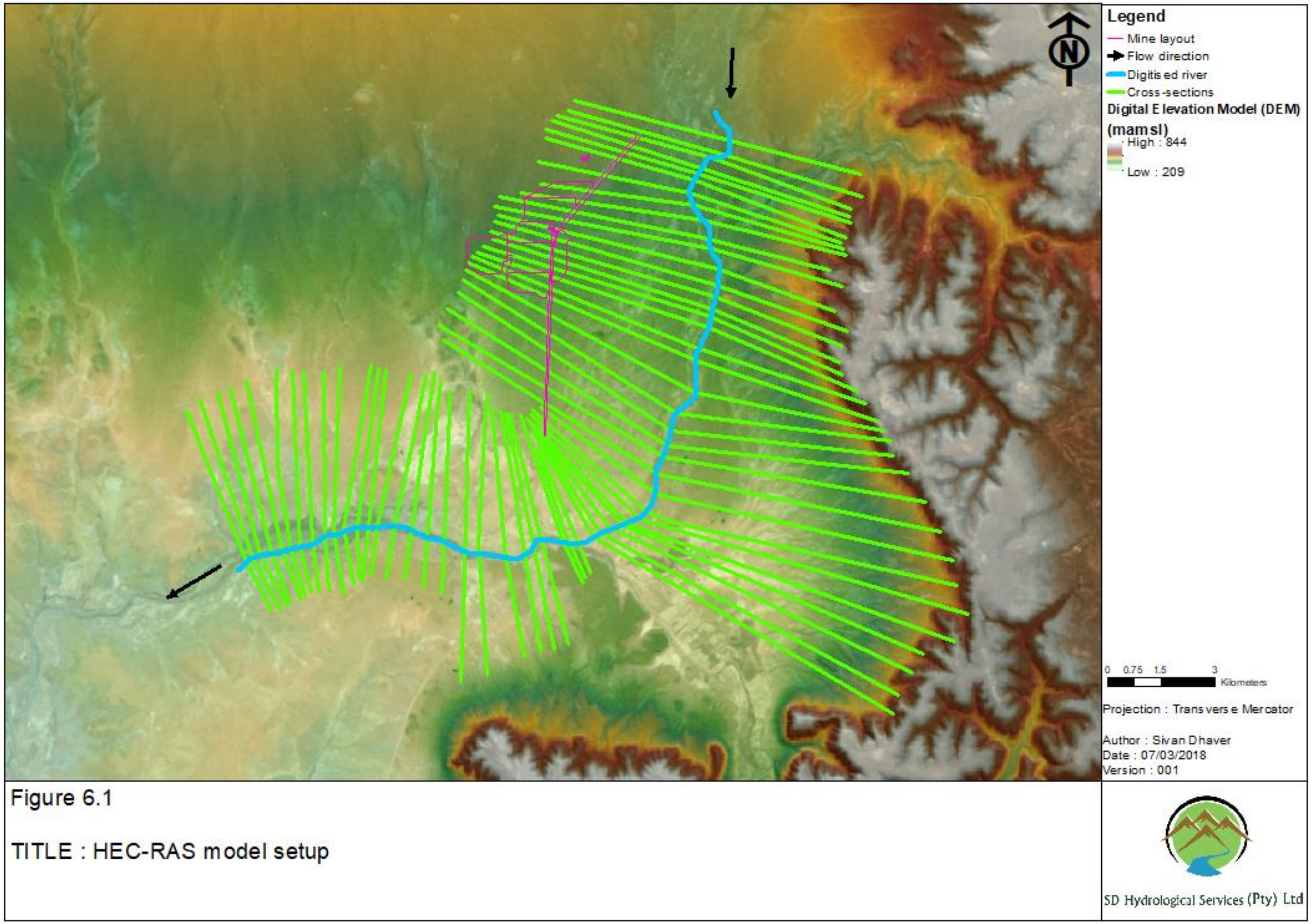

Figure 6.1

TITLE : HEC-RAS model setup

6.3.1 Assumptions and Limitations

The following assumptions are made:

- The topographic data provided was of a sufficient accuracy to enable hydraulic modelling at a suitable level of detail.
- The DEM used to model the section of the Krom and Doring River was obtained from the Japan Aerospace Exploration Agency Earth Observation Research Centre (/www.eorc.jaxa.jp), as the level of accuracy was observed to be much higher than the DEM derived from the 10 m contour dataset.
- A sub-critical flow regime, steady state hydraulic modelling was selected for the running of the model.
- No storage facilities where modelled.
- No flood protection infrastructure was modelled.
- The floodlines produced should only be used for indicative and environmental purposes, and not for detailed engineering design, unless signed off by a registered engineer

6.3.2 Results

Summary of the key results are listed below:

- All of the proposed mine layout falls outside of the 1:100 year floodline. Summary of the delineated 1:50 year and 1: 100 year floodline is indicated in Figure 6-2 below.
- Minor drainages/streams, which traverse the project area, were identified. Their corresponding catchment areas ranged between 1 km^2 and 5 km^2, and the proximity to the infrastructure area with the exception of one stream falls more than 1 km from the drainage/stream centreline. As a result, flooding beyond the 100 m drainage/stream centreline buffer is improbable. However all infrastructures should fall outside of the mentioned 100 m buffer.

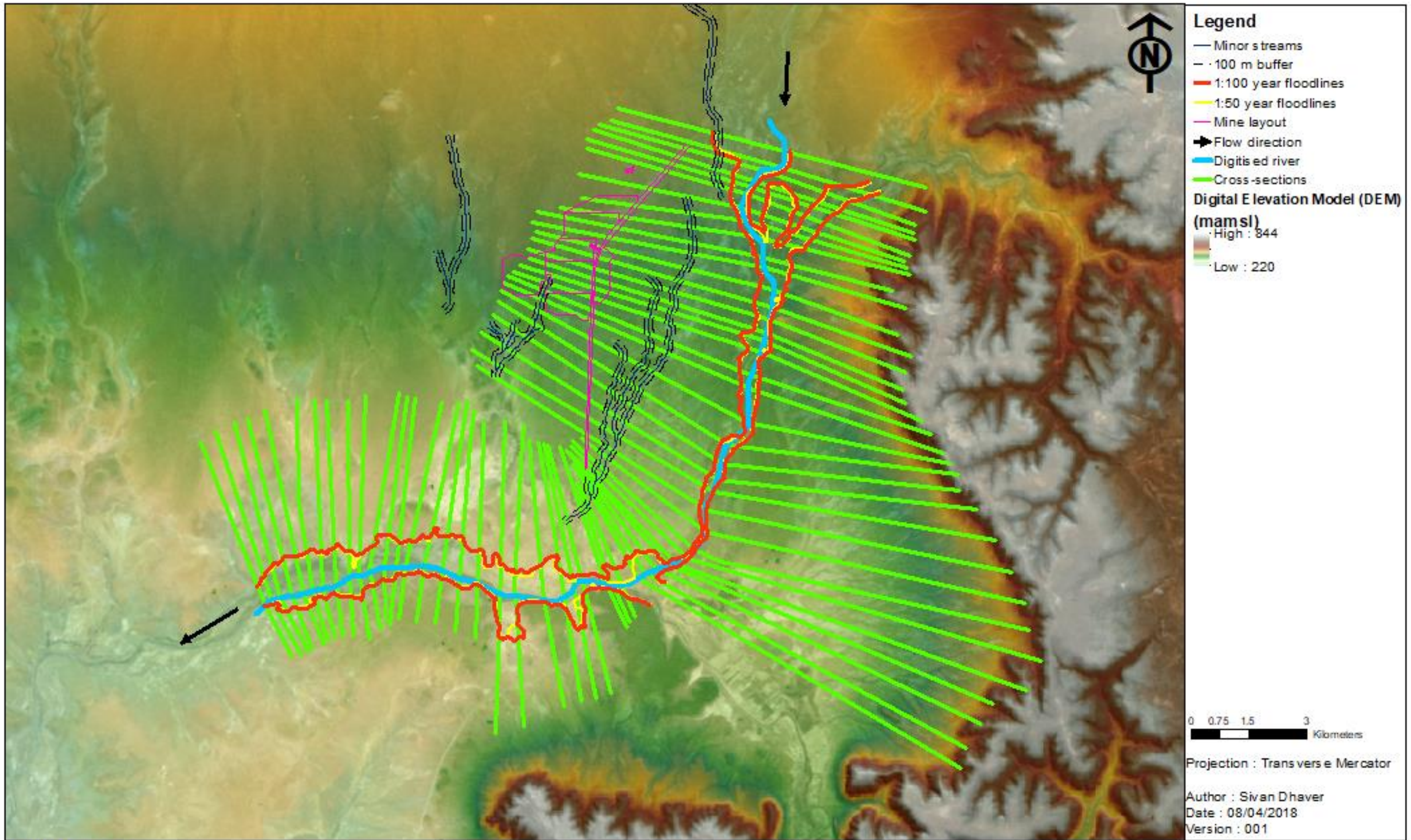

Figure 6.2

TITLE : Summary of the 1:50 year and 1:100 year delineated floodlines.

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7 Water balance

7.1 Introduction

A site wide water balance process flow diagram (pfd) has been prepared to understand flows within the proposed Kanakies mining project (see Figure 7-1).

The water balance was developed using an excel spreadsheet model, taking into consideration the annual monthly averages.

The water balance was developed in accordance with the Best Practice Guideline G2 – Water and Salt Balances (DWAF, 2010).

7.2 Assumptions and Input Parameters

The water balance assumes the following:

- Runoff coefficients for each surface were fixed and not influenced by antecedent moisture conditions.
- Catchment and surface areas for the average periods are constant.
- The summary of areas and runoff factors are listed below:
  - Mining block area - 40 000 m^2, runoff factor of 0.04.
  - Sump surface area – 2 000 m^2 (5 % of mining block area).
  - Stockpile surface area – 21 000 m^2 runoff factor of 0.03.
- The water balance assumes no groundwater ingress occurs within the mining blocks.

7.3 Summary of Results

Summary of results are presented below:

- No spillages are anticipated to occur from silt trap 1 and silt trap 2, which have a surface area of 60 m^2 and 80 m^2 respectively, and a depth less than 1 m. The respective silt traps are able to contain the runoff from their respective catchments due to the overall low anticipated monthly rainfall and the high evaporation rates at the project area.
- Average monthly runoff volumes reporting to silt trap 1 and silt trap 2 respectively are 6.10 m^3 and 8.07 m^3 respectively and exclude direct rainfall.
- All runoff collected within the mining block sumps are lost through evaporation.

Summary of results for the average monthly water balance at the proposed Kanakies Mine is shown below in Table 7-1

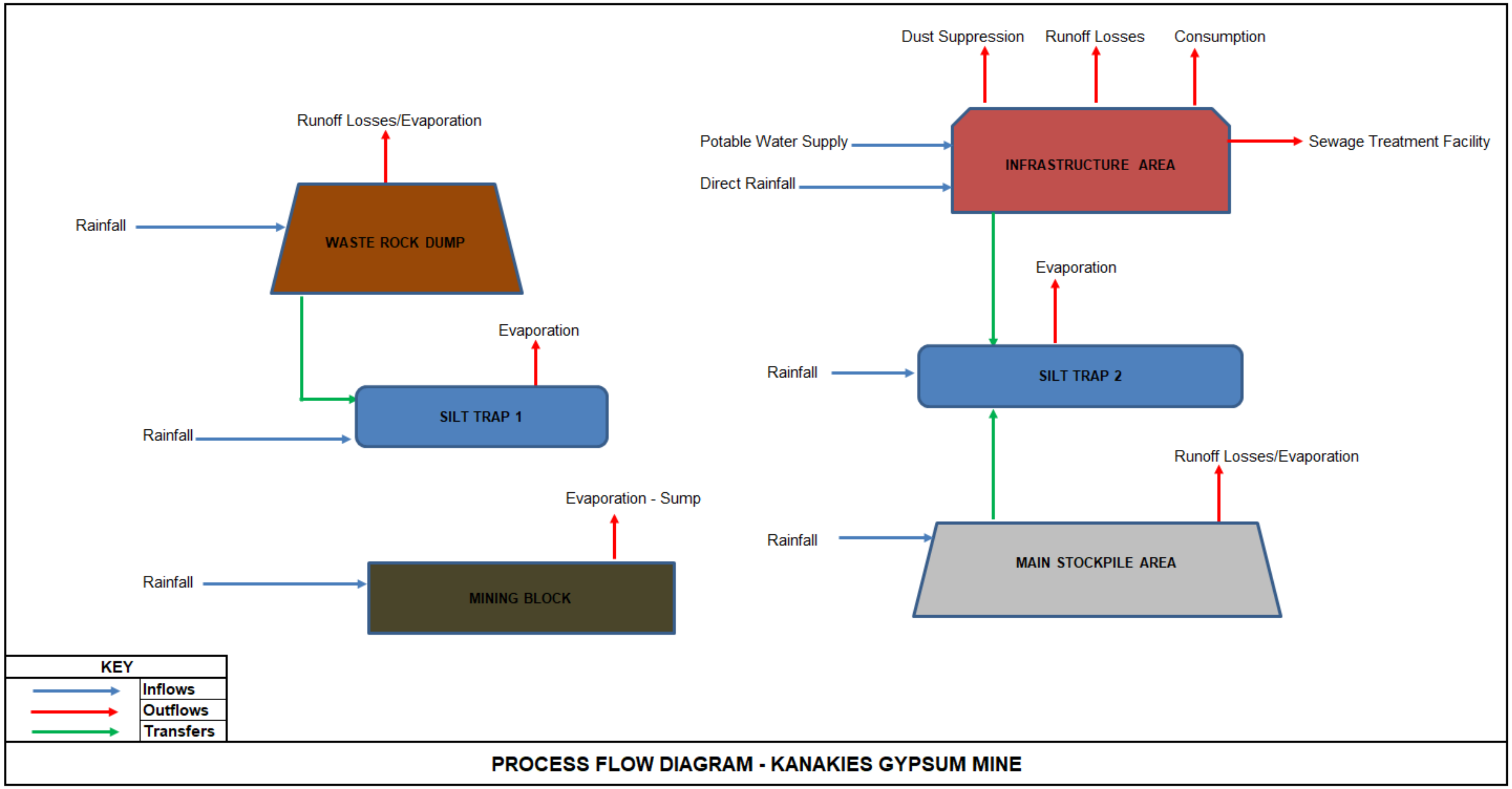

Figure 7-1 PFD for the Kanakies Gypsum Mine

Table 7-1 Summary of monthly average water balance results for the Kanakies Gypsum mine

Facility Name	Water In		Water Out		Balance
	Water Circuit/stream	Quantity (m^3/month)	Water Circuit/stream	Quantity (m^3/month)	
WASTE ROCK DUMP	Rainfall	243.91	Evaporation/Runoff Losses	237.81	
			Silt Trap 1	6.10	
	Total	**243.91**		**243.91**	
MINING BLOCK	Rainfall	487.81	Evaporation - Sump	143.04	
			Runoff Losses	344.77	
	Total	**487.81**		**487.81**	
INFRASTRUCTURE AREA	Rainfall	4.88	Dust Suppression	2 436.67	
	Potable Water Supply - Borehole	2 467.13	Consumption	4.57	
			Sewage Treatment Facility	25.89	
			Runoff Losses	4.49	
			Silt Trap 2	0.39	
	Total	**2 472.00**		**2 472.00**	
MAIN STOCKPILE AREA	Rainfall	256.10	Evaporation/Runoff Losses	248.42	
			Silt Trap 2	7.68	
	Total	**256.10**		**256.10**	
Total Water Balance		**3 204**		**3 204**	

8 Surface Water Impact Assessment

The aim of this section is to identify the potential surface water impacts that are likely to arise as a result of the proposed project.

8.1 Impact Assessment Methodology

To ensure uniformity, the assessment of potential impacts is addressed in a standard manner so that a wide range of impacts are comparable. For this reason a clearly defined rating methodology has been used to assess the impacts identified in each specialist study.

The significance (quantification) of potential environmental impacts have been determined using a ranking scale, based on the following (terminology has been taken from the Guideline Documentation on EIA Regulations, by the Department of Environmental Affairs and Tourism, April 1998):

Status of Impact	
+: Positive (A benefit to the receiving environment)	
N: Neutral (No cost or benefit to the receiving environment)	
-: Negative (A cost to the receiving environment)	
Magnitude:=M	***Duration:=D***
10: Very high/don't know	5: Permanent
8: High	4: Long-term (ceases with the operational life)
6: Moderate	3: Medium-term (5-15 years)
4: Low	2: Short-term (0-5 years)
2: Minor	1: Immediate
0: Not applicable/none/negligible	0: Not applicable/none/negligible
Scale:=S	***Probability:=P***
5: International	5: Definite/don't know
4: National	4: Highly probable
3: Regional	3: Medium probability
2: Local	2: Low probability
1: Site only	1: Improbable
0: Not applicable/none/negligible	0: Not applicable/none/negligible

The environmental significance of each potential impact is assessed using the following formula:

Significance Points (SP) = (Magnitude + Duration + Scale) x Probability

The maximum value is 100 significance points (SP). Potential environmental impacts were rated on the following basis:

Significance	***Environmental Significance Points***	***Colour Code***
High (positive)	>60	H
Medium (positive)	30 to 60	M
Low (positive)	<30	L
Neutral	0	N
Low (negative)	>-30	L
Medium (negative)	-30 to -60	M
High (negative)	<-60	H

Table 8-1 Summary of Impact Assessment (Construction Phase)

POTENTIAL ENVIRONMENTAL IMPACT	APPLICABLE AREA	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION							ACTION PLAN
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP	
CONSTRUCTION PHASE																		
SURFACE WATER HYDROLOGY IMPACT ASSESSMENT																		
Sedimentation of downstream drainage/watercourses	Proposed Infrastructure Areas, Mining Blocks	During the construction phase, loose or disturbed material as a result of construction activities such as soil and debris may be washed into the nearest downstream drainages/watercourses during normal to heavy infrequent rainfall events. This will result in sedimentation of the downstream affected drainage/watercourse. Although the monthly rainfall anticipated within the project area is relatively low, larger storm events having a higher recurrence interval may occur.	6	2	2	3	30	-	M	To reduce the risk of sedimentation to downstream drainages/watercourses from dirty water areas such as temporary topsoil/ material stockpile areas/waste rock dump areas and any additional dirty water areas, a temporary storm water management plan should be implemented. This will include construction of temporary ditches and runoff containment areas, such that all runoff emanating from the topsoil/material stockpile areas, waste rock dump, proposed infrastructure areas, together with any additional dirty water areas are conveyed and contained within the site area. Construction activities should be undertaken during the dry season if possible to limit the possibility of normal to heavy infrequent rainfall events.	4	2	2	2	16	-	L	Ensure the site storm water management plan is in place prior to the construction activities. The temporary storm water controls must be maintained such that no blockages are present in the channels and containment ditches to ensure effective functioning.

Hydrocarbon fuel spillage	Proposed Infrastructure Areas, Mining Blocks	During the construction phase a high volume of traffic by vehicles will occur due to the transport of equipment/material to site. Potential spillages of hydrocarbons on the site area is therefore envisaged. If no mitigation measures are present, hydrocarbon spillages can easily be washed downstream by heavy rains, and end up in the downstream drainages/watercourse.	6	2	2	3	30	-	M	All vehicles must be serviced timeously to ensure the potential for leakages of hydrocarbons are minimized.	4	2	2	2	16	-	L	Develop a detailed schedule of vehicles being used during the construction phase and their service history. Only vehicles which have been effectively serviced should be allowed onsite.
Reduction of catchment yield	Proposed Infrastructure Areas, Mining Blocks	Reduction of catchment yield as a result of the footprint areas of the associated infrastructure as the footprint areas will no longer form part of the natural downstream catchment thereby potentially resulting in a decrease of runoff downstream	2	4	2	2	16	-	L	The loss of catchment area as a result of the associated infrastructure cannot be mitigated. The only way to mitigate the above mentioned impacts is to not proceed with the mining option. Therefore the impact rating for pre and post mitigation measures will remain unchanged. It should also be noted that the project footprint area makes up less than 1% of the total quaternary catchment area of E33A (1355 km^2) and will therefore result in a negligible loss in runoff.	2	4	2	2	16	-	L	No action plan is required.
Flooding of proposed infrastructure area and mining blocks	Proposed Infrastructure Areas, Mining Blocks	Floodlines will be required on all major watercourses within close proximity to the proposed infrastructures. Based on GN 704 requirements, the mine infrastructure in question should fall outside of the 1:100 year floodline or the 100 m river buffer, whichever is greater. This is undertaken so as to minimise damage to infrastructures during periods of extreme flooding.	10	4	2	4	64	-	H	The floodline modelling was undertaken for sections of the Krom River and Doring River, which flow along the southern and eastern boundary of the project area. Based on the results of the assessment the infrastructure area falls outside of the 1:100 year floodline. All infrastructures should also be placed outside of the 100 m	4	4	2	2	20	-	L	All infrastructure is to be placed outside of the 1:100 year floodline or 100 m buffer, whichever is greater.

										stream centreline buffer of all minor streams.								

Table 8-2 Summary of Impact Assessment (Operational Phase)

POTENTIAL ENVIRONMENTAL IMPACT	APPLICABLE AREA	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION							ACTION PLAN
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP	
OPERATIONAL PHASE																		
SURFACE WATER HYDROLOGY IMPACT ASSESSMENT																		
Pollution of downstream watercourse	Proposed Infrastructure Areas, Mining Blocks	During the operational phase of the mine, a storm water management plan which adheres to GN 704 requirements in terms of separation of clean and dirty water is required so as to ensure no mixing of clean and dirty water occurs. Lack of proper storm water controls will result in dirty water contaminating the downstream clean water environment. The storm water management plan will ensure that all clean water is diverted away from the mine infrastructure area, whilst all dirty water is captured and conveyed to the applicable containment facility.	6	4	2	4	48	-	M	A conceptual storm water water management plan was developed. The storm water management plan was completed, which details the proposed placement of clean and dirty water channels. All clean and dirty water controls were sized based on the 1:50 year storm event as per GN 704 requirements. Runoff from the waste rock dumps, stockpile areas and infrastructure areas are to be collected in silt traps. All hydrocarbon areas are to be bunded and roofed.	4	4	2	2	20	-	L	Ensure that the storm water management plan is implemented which includes the storm water maintenance plan. The maintenance plan is required to ensure that all storm water controls function efficiently.

Table 8-3 Summary of Impact Assessment (Decommissioning and Closure Phase)

POTENTIAL ENVIRONMENTAL IMPACT	APPLICABLE AREA	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION							RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION							ACTION PLAN
			M	D	S	P	TOTAL	STATUS	SP		M	D	S	P	TOTAL	STATUS	SP	
DECOMMISIONING AND CLOSURE PHASE																		
SURFACE WATER HYDROLOGY IMPACT ASSESSMENT																		
Siltation of water resources	Proposed Infrastructure Areas, Mining Blocks	Activities during this phase include dismantling and removal of major equipment and infrastructure, rehabilitation of disturbed areas including the stockpile areas, waste rock dumps, mining blocks and infrastructure areas. The major impacts to consider in the decommissioning and closure phase will be siltation of surface water resources as a result of soil erosion influenced by removal of infrastructures.	6	4	2	4	48	-	M	Ensure that the surface profile is rehabilitated to promote natural runoff drainage and avoid ponding of water within the rehabilitated area. Surface inspection should be continuously undertaken to ensure runoff drains into the downstream drainage/rivers. All rehabilitated areas must be established with vegetation.	4	4	2	2	20	-	L	Ensure a proper surface water rehabilitation plan is developed.

9 Conclusions and Recommendations

The summary of conclusions are listed below:

- Summary of the primary impacts relating to the proposed project relate to flooding of infrastructure and the pollution of downstream watercourse as a result of mixing of clean and dirty water.
- The results of the water balance indicate that the current mine layout falls outside of the 1:100 year floodline of the Krom River and Doring River section. All infrastructures should also be placed outside of the 100 m stream centreline buffer of all minor streams.
- Clean water diversions located on the upstream boundary of the infrastructure areas and mining block areas are to be vegetated unlined trapezoidal channels with side slopes of 1:3 (1 Vertical: 3 Horizontal), bottom width of 1 m and design depth of 1 m.
- Channels surrounding the waste rock dump and the stockpile areas are to be vegetated unlined trapezoidal channels with side slopes of 1:3, bottom width of 1 m and design depth of 1 m.
- Channels placed within the infrastructure areas are to be vegetated unlined trapezoidal channels with side slopes of 1:3, bottom width of 1 m and design depth of 0.5 m.
- The storm water management plan should be followed so as to ensure clean and dirty water separation and thereby mitigating the impact of pollution of the downstream watercourses.
- All hydrocarbon storage areas be bunded and roofed.

The following is recommended

- The water balance should be updated during the operational phase once more data becomes available as the areas of the clean and dirty water infrastructure footprints may change.

Prepared by

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Hydrologist

10 References

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Appendices

Appendix A: HEC-RAS Results

Floodline Catchment

Cross Section	Profile	Peak Flow (m^3/s)	Water Stage Elevation (m)	Velocity (m/s)	Froude Number
24127	50 Year	2536	360.41	1.79	0.41
24127	100 Year	3145	360.65	1.98	0.43
23638	50 Year	2536	357.08	3.81	0.85
23638	100 Year	3145	357.26	3.95	0.85
23244	50 Year	2536	355.09	1.62	0.29
23244	100 Year	3145	355.38	1.78	0.31
22823	50 Year	2536	353.4	4.07	0.7
22823	100 Year	3145	353.62	4.3	0.72
22637	50 Year	2536	352.14	3.42	0.63
22637	100 Year	3145	352.37	3.28	0.6
22432	50 Year	2536	351.02	2.43	0.52
22432	100 Year	3145	351.23	2.55	0.54
22038	50 Year	2536	349.03	2.34	0.52
22038	100 Year	3145	349.23	2.44	0.51
21682	50 Year	2536	347.44	1.95	0.45
21682	100 Year	3145	347.68	1.95	0.45
21188	50 Year	2536	345.18	2.72	0.52
21188	100 Year	3145	345.42	2.87	0.52
20581	50 Year	2536	342.64	2.02	0.45
20581	100 Year	3145	342.9	2.17	0.46
20283	50 Year	2536	340.86	2.04	0.58
20283	100 Year	3145	341.23	2.2	0.57
19636	50 Year	2536	338.53	2.04	0.37
19636	100 Year	3145	338.86	2.24	0.38
19178	50 Year	2536	336.43	1.89	0.59
19178	100 Year	3145	336.81	2.12	0.58
18851	50 Year	2536	333.97	2.54	0.56
18851	100 Year	3145	334.43	2.8	0.58
18489	50 Year	2536	332.51	2.96	0.47
18489	100 Year	3145	332.85	3.3	0.5

18279	50 Year	2536	332.02	2.32	0.39
18279	100 Year	3145	332.37	2.47	0.39
17988	50 Year	2536	330.12	4.45	0.85
17988	100 Year	3145	330.36	4.78	0.87
17343	50 Year	2536	326.48	1.92	0.43
17343	100 Year	3145	326.91	2.11	0.43
16971	50 Year	2536	325.46	2.3	0.38
16971	100 Year	3145	325.93	2.46	0.39
16098	50 Year	2536	320.02	5.55	0.95
16098	100 Year	3145	320.47	5.92	0.96
15243	50 Year	2536	315.37	2.19	0.34
15243	100 Year	3145	315.89	2.36	0.35
14755	50 Year	2536	313.52	2.99	0.57
14755	100 Year	3145	313.95	3.38	0.6
14320	50 Year	2536	310.14	4.72	0.74
14320	100 Year	3145	310.64	4.9	0.72
13971	50 Year	2536	308.76	1.9	0.42
13971	100 Year	3145	309.18	2.13	0.45
13473	50 Year	2536	305.28	4.17	0.85
13473	100 Year	3145	305.78	4.15	0.8
12916	50 Year	2536	298.92	1.86	0.57
12916	100 Year	3145	299.45	2.34	0.61
12351	50 Year	2536	296.36	1.39	0.36
12351	100 Year	3145	296.59	1.52	0.38
12045	50 Year	2536	295.62	1.19	0.32
12045	100 Year	3145	295.82	1.26	0.32
11711	50 Year	2536	295.02	1.66	0.3
11711	100 Year	3145	295.24	1.69	0.3
11560	50 Year	2536	294.66	2.36	0.34
11560	100 Year	3145	294.89	2.45	0.34

11262	50 Year	2536	293.22	3.89	0.61
11262	100 Year	3145	293.76	3.59	0.52
10906	50 Year	2536	292.4	2.64	0.38
10906	100 Year	3145	292.21	3.78	0.56
10672	50 Year	2536	289.79	5.84	0.96
10672	100 Year	3145	291.17	3.77	0.53
10195	50 Year	2536	285.94	1.96	0.34
10195	100 Year	3145	286.52	2.06	0.36
9971	50 Year	2536	284.58	3.8	0.66
9971	100 Year	3145	285.16	3.6	0.66
9771	50 Year	2536	282.03	5.14	0.97
9771	100 Year	3145	282.48	5.48	0.96
9167	50 Year	2536	279.84	2.43	0.36
9167	100 Year	3145	280.33	2.61	0.37
8845	50 Year	2536	279.55	1.05	0.21
8845	100 Year	3145	280	1.15	0.23
8489	50 Year	2536	279.04	2.08	0.34
8489	100 Year	3145	279.44	2.22	0.35
7930	50 Year	2536	277.39	3.55	0.49
7930	100 Year	3145	277.49	4.13	0.56
7183	50 Year	2536	272.94	4.65	0.78
7183	100 Year	3145	273.55	4.17	0.65
6772	50 Year	2536	271.91	2.06	0.35
6772	100 Year	3145	272.19	2.21	0.36
6132	50 Year	2536	268.87	4.47	0.87
6132	100 Year	3145	269.08	4.59	0.87
5655	50 Year	2536	266.89	0.99	0.22
5655	100 Year	3145	267.21	1.12	0.24
5165	50 Year	2536	266.35	0.96	0.24
5165	100 Year	3145	266.65	1.07	0.25
4668	50 Year	2536	265.37	1.86	0.39

4668	100 Year	3145	265.65	2.02	0.4
4190	50 Year	2536	264.06	1.09	0.33
4190	100 Year	3145	264.31	1.28	0.35
3938	50 Year	2536	263.11	1.17	0.43
3938	100 Year	3145	263.33	1.38	0.45
3639	50 Year	2536	262.05	1.25	0.36
3639	100 Year	3145	262.27	1.4	0.37
3254	50 Year	2536	260.79	1.65	0.41
3254	100 Year	3145	261.04	1.77	0.41
2936	50 Year	2536	259.15	2.7	0.59
2936	100 Year	3145	259.41	2.96	0.61
2667	50 Year	2536	257.95	1.7	0.42
2667	100 Year	3145	258.18	1.88	0.44
2287	50 Year	2536	256.58	1.64	0.41
2287	100 Year	3145	256.79	1.78	0.42
1906	50 Year	2536	254.88	2.38	0.53
1906	100 Year	3145	255.1	2.53	0.53
1641	50 Year	2536	253.97	2.17	0.39
1641	100 Year	3145	254.21	2.27	0.39
1417	50 Year	2536	253.61	1.56	0.28
1417	100 Year	3145	253.84	1.68	0.29
1104	50 Year	2536	252.66	2.13	0.57
1104	100 Year	3145	252.92	2.16	0.53
809	50 Year	2536	252.01	1.67	0.28
809	100 Year	3145	252.31	1.75	0.28
565	50 Year	2536	251.1	3.36	0.61
565	100 Year	3145	251.38	3.53	0.61
342	50 Year	2536	249.28	1.75	0.62
342	100 Year	3145	249.53	1.97	0.64