HUMBA ENVIRONMENTAL CONSULTANCY

HYDROLOGICAL IMPACT ASSESSMENT FOR THE PROPOSED GRAMMATIKOS MINING PROJECT IN THE MSUKALIGWA LOCAL MUNICIPALITY

Degree of Confidentiality	Client Confidentiality
Title	Hydrological Impact Assessment for the Proposed Grammatikos Mining Project in the Msukaligwa Local Municipality.
Date of Issue	May 2021
No. of Pages	42
Consultant details: **HUMBA ENVIRONMENTAL CONSULTANCY** 43 Montrose Street, Birchwood Court Vorna Valley, Midrand, 1685 Tel: 011 655 7301 Cell: 072 309 0502 Fax: 011 655 701 Email: tinashe@humba.org	Client details: **NSOVO ENVIRONMENTAL CONSULTANCY (PTY) LTD** 349 Spur Road Beaulieu, Witpoort (Beaulieu) Midrand, 1684 Tel: 011 041 3689 Fax: 086 602 8821 Email: rejoice@nsovo.co.za
Compiled by	Ms Celia Siebani
Report Number	NSO-01-HYR/04/21
Issue Number	Ver.03
Copy Number	1.1

SUGGESTED CITATION

Siebani P.C and Maramba T.R, 2021. Hydrological Impact Assessment Report for the proposed Grammatikos Mining Project in the Msukaligwa Local Municipality.

DISCLAIMER AND APPROACH

This report provides a description and assessment of identified local hydrological regimes and the larger study area. It also provides a concise description of the proposed development and identifies potential project-related impacts and mitigation measures.

This study does not provide detailed descriptions of the geology, soils, climate of the area, hydrology of the aquatic environments, assessments of surface water quality (sampling), detailed descriptions of aquatic and terrestrial flora and fauna, or provide a detailed review of the legal constraints associated with potential project-related impacts on the environment. It has been assumed for the purposes of this report that these aspects will be the subject of separate specialist studies during the EIA/WUL application processes.

DECLARATION

I, Celia Siebani declare that I –

- act as an independent specialist consultant in the fields of hydrological science;
- 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;
- do not 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 have or may have the potential to influence the decision of the competent authority or the objectivity of any report; and
- will provide the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not.

Celia Siebani (*BESc Hydrology and Water Resources*) (**SACNASP)**

EXECUTIVE SUMMARY

Introduction

Nsovo Environmental Consulting (Pty) Ltd commissioned Humba Environmental Consultancy (Pty) Ltd to undertake a hydrological impact assessment study for the proposed Grammatikos Mining Project in the Msukaligwa Local Municipality within the Gert Sibande District Municipality within the Mpumalanga Province

Grammatikos is planning to mine coal at Vogelfontein Colliery by means of underground mining methods over a period of between 8 and 12 years and an incline shaft will be located on Portion 5 of the Farm Vogelfontein245 IS. The preliminary production schedule indicates approximately 120 000 to 150 000 tonnes/month. Current geological information indicates that approximately 35 Million tons of coal can be mined at Vogelfontein.

The Receiving Environment

The proposed project falls between quaternary catchments (QC) X11A, B12A and C11F. In this study QC C11F was considered because the majority of the Mining Right Area (MRA) is located within it. QC C11F is drained by the perennial Renosterloop, Xspruit, Klein Xspruit and many non-perennial streams flowing southwards.

The catchment Mean Annual Precipitation (MAP), and Mean Annual Evaporation (MAE), are in the order of 700 mm and 1 450 mm, respectively. The evaporation in the area is relatively higher than the amount of rainfall this catchment receives.

Flood line Determination

Sub-catchments were delineated for the determination of flood lines on the nearby unnamed streams that could be potentially influenced by the proposed project.

The topographical data formed the foundation for the HEC-RAS model and was used to extract elevation data for the river profiles together with the river cross-sections. The topographical data was also used to determine the positions at which the cross-sections were taken along the river profile, so that the watercourse could be accurately modelled.

Floodlines for the 1:50-year and 1:100-year recurrence intervals were determined for the streams passing through the project site. The proposed project and mine and surface infrastructure were found to be located outside the 1:50- and 1:100-year floodlines.

Conceptual Stormwater Management Plan

A review of the proposed surface infrastructure was undertaken, and a series of design principles for stormwater management were developed to ensure compliance with the requirements of Government Notice (GN) Regulation 704.

In order to meet the design principles detailed above, conceptual design details for the proposed stormwater management measures were recommended for each of the layout infrastructure, along with the specific hydraulic design standards, methodologies, assumptions, and input parameters for each management measure proposed.

The channels were sized to accommodate the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing was uniform along the entire length. Some cutting and filling may be required along the length of the channels to achieve the required gradient to ensure that water flows freely within these channels. The clean water will be kept out of the dirty water channels by construction of a linear bund upstream of the channel with material excavated from the channel.

Surface Water Impact Assessment

Informed by the site layout, baseline hydrology, floodlines results and conceptual stormwater management plan, the potential impacts of the proposed activities on surface water receptors and the sensitivity of the surface water resources were discussed in section 5 of this report and presented along with a summary of mitigation measures and monitoring requirements.

The impacts of the proposed activities and the infrastructure were identified and then assessed based on the impact's magnitude, duration, probability, extent, severity and consequences and the receptor's sensitivity. This analysis then culminated in the determination of the impact significance which indicated the most important impacts and those that required stringent management. The local surface water resources were considered to be of low sensitivity.

Mitigation and monitoring measures were specified throughout the report. All measures implemented for the mitigation of impacts, should be regularly reviewed as best practice and as compliance with various licences issued on site by authorities. The purpose of the mitigation measures was to ensure that the pre-mining / current water resource status is not deteriorated by the mining activities.

Recommendations

- Stormwater management:
    - Separation of clean and dirty water through the development of stormwater structures as detailed in Section 4 of this report. It must be ensured that diverted runoff from disturbed areas is collected in dirty areas and clean water freely discharges to the surrounding clean catchment.
    - It is proposed that stormwater from dirty catchments is contained and reused at the processing plant and as dust suppression. Alternatively, it must be treated and discharged, effectively reducing the catchment area draining to the local watercourses.
    - Management of silt by ensuring that the disturbance of topsoil is minimised, sediment source and erosion control, phasing of earthworks activities, diversion of upslope

runoff from entering the earthworks areas and downstream treatment of any collected sediment runoff i.e., use of silt traps;

- Regularly schedule inspection and maintenance of water management facilities, to include inspection of drainage structures and liners for any in channel erosion or cracks; de-silting of silt traps/sumps and PCDs; and any pumps and pipelines should be maintained according to manufacturer's specifications;
- Infrastructure design: the design of all onsite access roads, plant areas, stockpiles, pump station etc. must include stormwater management and erosion control during both the construction and operational phases;

- Water Balance: the project requires a site wide water balance that will quantify the amount of water that might potentially be discharged into the environment.
  - A water conservation and water demand management (WC/WDM) plan to ensure that as much water as is possible, is collected and reused, is recommended.
- Mine Subsidence
  - It is imperative that, from the inception and planning of the project, proposed mining techniques and methodologies, post-mine stabilization and structural designs are clearly defined and designed to reduce the possibility of subsidence.
  - It is recommended that a mine subsidence study be undertaken to understand the possibility and magnitude of the impacts of subsidence, this then will inform the nature and magnitude of subsidence on surface water and all other environmental aspects.

Table of Contents

List of Figures

List of Photographs

List of Appendices

List of Tables

Acronyms and Abbreviations Used

Acronym / Abbreviation	Definition
Alt.	Alternative
DEM	Digital Elevation Model
DHSWS	Department of Human Settlement, Water and Sanitation
GN 704	Government Notice 704
ha	Hectare
HEC-RAS	Hydrologic Engineering Centre's River Analysis System
km	Kilometre
LC	Length to Centroid
M^3/s	Cubic Metres
MAE	Mean Annual Evaporation
mamsl	Metres above Mean Sea Level
MAP	Mean Annual Precipitation
MIPI	Midgley and Pitman
Mm	Millimetre
MR	Water Research Commission
MRA	Mining Right Area
n	Gauckler (manning Coefficient)
NWA	National Water Act (Act No. 36 of 1998)
NASADEM	National Aeronautics and Space Administration Digital Elevation Model
NEMA	National Environmental Management Act (Act No.107 of 1998)
PCSWWM	Personal Computer Storm Water Management Mode
RM2	Rational Method 2
Sanral	South African National Road Agency
SC	Sub-catchment
SDF	Standard Design Flood
SRTM	Shuttle Radar Topography Mission
WMA	Water Management Area
WR	Water Resource
WRC	Water Research Commission
WUL	Water Use Licence

1. Introduction

Nsovo Environmental Consulting (Pty) Ltd (hereafter referred to as the Client) commissioned Humba Environmental Consultancy (Pty) Ltd (hereafter referred to as Humba) to undertake a hydrological impact assessment study for the proposed Grammatikos Mining Project (hereafter referred to as the 'Project') in the Msukaligwa Local Municipality within the Gert Sibande District Municipality of Mpumalanga Province (Figure 1-1).

1.1. Project Background

The proposed project has an approved mining right (MP 30/5/1/1/2/10214MR) that was issued by the Department Mineral Resources and Energy (DMRE) on the 12th of October 2018. The application stretches over an area of 1027.38 ha.

Grammatikos is planning to mine coal at what would be called Vogelfontein Colliery by means of underground mining methods over a period of between 8 and 12 years and an incline shaft will be located on Portion 5 of the Farm Vogelfontein245 IS. The preliminary production schedule indicates approximately 120 000 to 150 000 tonnes/month. Current geological information indicates that approximately 35 Million tons of coal can be mined at Vogelfontein.

1.2. List of Mining Activities and Infrastructure

The following mining activities and surface infrastructures are proposed for the Project.

Activity	Areas
Development of the access shaft	0.28 ha
Underground Mining	349.9 ha
Construction of water management facilities such a Pollution Control Dam (PCD), berms and drains.	PCD – 0.4 ha Berms and Drains
Overburden and ROM Stockpiles	ROM Product Stock 0.18 ha Overburden 0.293 ha Topsoil – 0.11ha
Storage facilities for dangerous goods such as diesel	0.02 ha
Fans and electricity	0.9 ha
Waste Management Facilities	0.010 ha
Rehabilitation of the surface	81ha

1.3. Study Objectives

This study contributes to a suite of specialist studies as required for water use and environmental authorisations processes in terms of the requirements of the National Water Act (Act No. 36 of 1998) (NWA) and National Environmental Management Act (Act No.107 of 1998) (NEMA).

1.4. Scope of work and Report Structure

The scope of work and structure of the report is as follow:

- The Receiving Environment – Chapter 2 presents a review and analysis of various sources of rainfall and evaporation data. The section also presents the characterisation of the site's baseline hydrology and surroundings, including topography, watercourse network, and catchment delineation.
- Floodlines – Chapter 3 presents the 1:50-year and 1:100-year floodlines for the streams located near the proposed project. Floodlines were plotted with the proposed mine infrastructure to identify any potential encroachment.
- Conceptual Stormwater Management – Section 4 presents the recommended stormwater management measures including a review of the layout, peak flow estimation, hydraulic sizing of the drainage catchments, channels and the already sized PCD.
- Impact Assessment – Section 5 presents a quantitative impact assessment of the significance of the project's impact on the baseline surface water environment, a range of mitigation measures to minimise the impacts, and recommendations on the monitoring required.
- Conclusions and Recommendations – Section 0 summarises this report's main conclusions and a summary of the recommendations made based on this study.

1.4.1. Information Sourcing and Literature Review

A review of various information sources was undertaken to define the baseline climatic and hydrological conditions of the site and surroundings. A hydro-meteorological analysis and floodline assessments were carried out using the data obtained from the following sources:

- The South African Water Resources Commission Database (WR2012) (WRC, 2021) database to characterise the regional climate.
- The South African Atlas of Climatology and Agro-hydrology (WRC, 2008) was used to classify general land cover.
- NASADEM for understanding the regional topography and drainage pattern.
- Aerial Imagery on the world map (Google Earth).

1.5. Legislation and Policy Context

The following legislation was taken into account during this assessment:

1.5.1. The National Water Act (Act 36 of 1998)

Water resources management in South Africa is governed by the NWA. The Department of Human Settlements, Water and Sanitation (DHSWS) must, as custodians of water, ensure that resources are used, conserved, protected, developed, managed and controlled sustainably for the benefit of all persons and the environment. The NWA repealed many of the powers and functions of the Water Act of 1956. Key provision applying to the current study include:

- Catchment Areas - Any disturbance to a watercourse, such as the construction and operation of surface mining infrastructure, may require authorisation from DWS.

1.5.2. Regulations on the use of Water for Mining and Related Activities

Government Notice 704 (Government Gazette 20119 of June 1999) (hereafter referred to as GN704) was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. The four main regulations of GN704 applicable to this project are:

- Condition 4 – indicates that no person in control of a mine or activity may locate or place any residue deposit, dam, reservoir, together with any structure of another facility within the 1:100-year flood line or within a horizontal distance of 100-metres from any watercourse.
- Regulation 5 - 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.
- Regulation 6 - 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 the 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.
- Regulation 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.

1.5.3. Implications for the proposed project:

- Any proposed water uses that meet legislated thresholds must be specified and registered, and licensed.
- Any modifications to natural drainage lines on site must be investigated in terms of water use requirements.

- The developer is responsible for taking reasonable measures to prevent the pollution of water resources on land that the developer owns, controls, occupies or uses.
- The developers must remedy a situation where pollution of a water resource occurs following an emergency incident and where it is responsible for the incident or owns or is in control of the polluting substance involved.
- The applicant must take all reasonable measures to minimise the incident's impacts, undertake clean-up procedures, remedy the effects of the incident, and implement measures as directed by an auditor/specialist or the competent authority.
- Dirty water must be separated from clean water through a designed stormwater management plan.

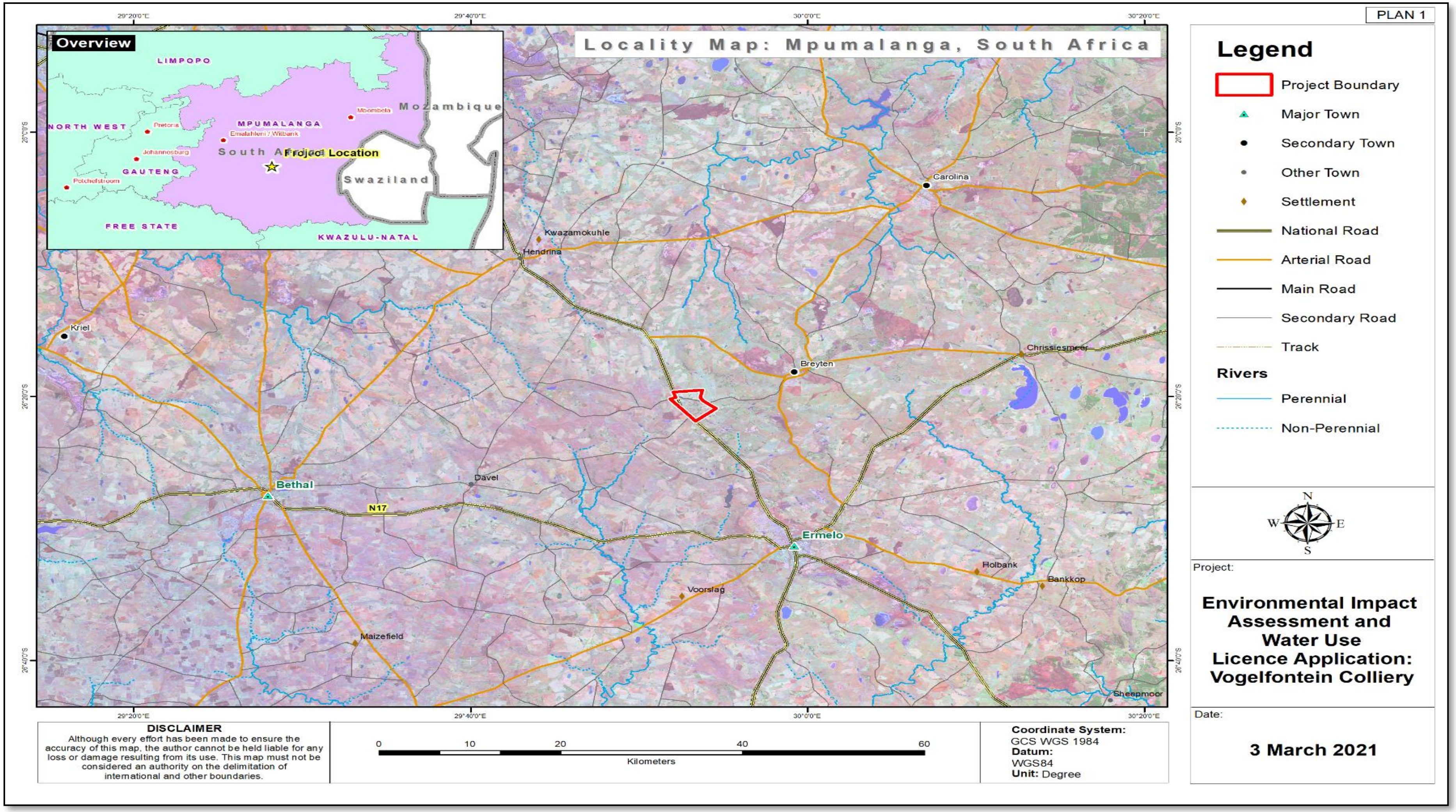


Figure 1-1: Location of the Proposed Project

2. The Receiving Environment

This section describes the baseline description of the proposed project's environment, which provided a fundamental understanding of the hydrological impact assessment.

2.1. Locality

The project is located on the Msukaligwa local municipality within the Gert Sibande district municipality within the Mpumalanga Province. The project site is approximately 16 kilometres (km) west of Bethal and 22 km north of Ermelo. The total application area is 1019. 89 ha.

2.2. Site Walkover

Humba's specialists undertook a site walkover on the 23rd of February 2021 to understand the natural drainage around the area and observe catchment characteristics. The study area's overall hydrological regime was studied and understood. Pictorial evidence was also gathered are presented between Photograph 2-1 and Photograph 2-2.

Photograph 2-1: Evidence of Blocked Culverts due to erosion and sedimentation

Photograph 2-2: Densely Vegetated Watercourse Around the site

Photograph 2-3: The Surface Water Bodies around the site

2.3. Topography

The area around the project site is generally flat, with elevation ranging between 1796 to 1820 mamsl. The elevation difference in the streams nearby ranges from 43 to 50 mamsl.

2.3.1. Meteorological Characteristics

This project site climate data was obtained from the Water Resources study (WR2012) study (WRC, 2021), which comprises the climatic and catchment information of each quaternary catchment (QC) in South Africa. The average hydro-meteorological parameters were calculated for QC C11F. The hydro-meteorological parameters are summarised in Table 2-1.

The catchment Mean Annual Precipitation (MAP), and Mean Annual Evaporation (MAE), respectively, are said to be 700 mm and 1 450 mm. The evaporation in the area is relatively higher than the amount of rainfall this catchment receives. The monthly distribution of the rainfall and evaporation are presented in Figure 2-1.

Table 2-1: Summary of Hydro-climatic Parameters around the Project Site (WRC, 2021) (mm)

Mon	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Mean
MAP	150	148	160	158	136	130	100	85	70	77	105	133	1450
MAE	81	115	117	119	84	75	39	15	9	8	10	27	700

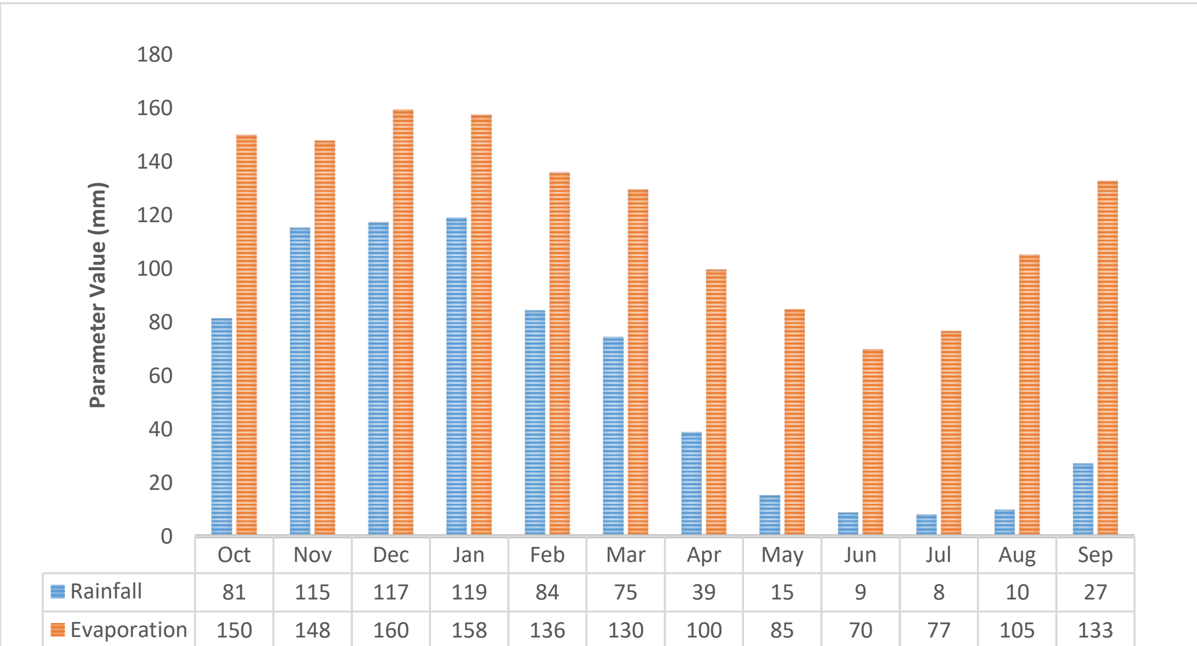


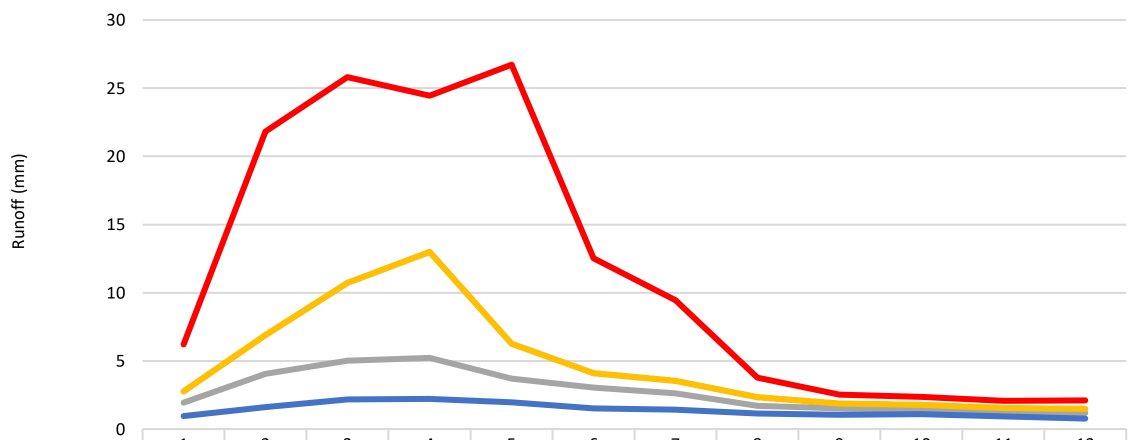
Figure 2-1: Rainfall and Evaporation distribution around the Project Site

2.4. Local and Regional Hydrology

The proposed project falls between QC X11A, B12A and C11F. QC B12A falls within the Olifants Water management Area (WMA), QC X11A falls within the Nkomati WMA and QC C11F falls within the Upper Vaal WMA. In this study QC C11F was considered because the majority of the Mining Right Area (MRA) is located within it. QC C11F is drained by the perennial Renosterloop, Xspruit, Klein Xspruit and many non-perennial streams flowing southwards. The hydrology around the site is presented in Figure 2-3.

2.4.1. Catchment Runoff

The WRSM2000/Pitman Software is a WRSM/Pitman is a mathematical model that simulate the movement of water through an interlinked system of catchments, river reaches, reservoirs, irrigation areas and mines (WRC, 2012). WRSM2000 simulates naturalised runoff around the project site at a unit runoff of 60.1 mm per annum. The runoff, when expressed as a percentage of rainfall, equates to 1.5%. The monthly runoff is distributed as presented in Table 2-1.



	1	2	3	4	5	6	7	8	9	10	11	12
E10	6	22	26	24	27	13	9	4	3	2	2	2
E30	3	7	11	13	6	4	4	2	2	2	2	1
E50	2	4	5	5	4	3	3	2	2	1	1	1
E70	3	7	11	13	6	4	4	2	2	2	2	1
E90	1	2	2	2	2	2	1	1	1	1	1	1

Figure 2-2: Runoff Distribution Around the Site

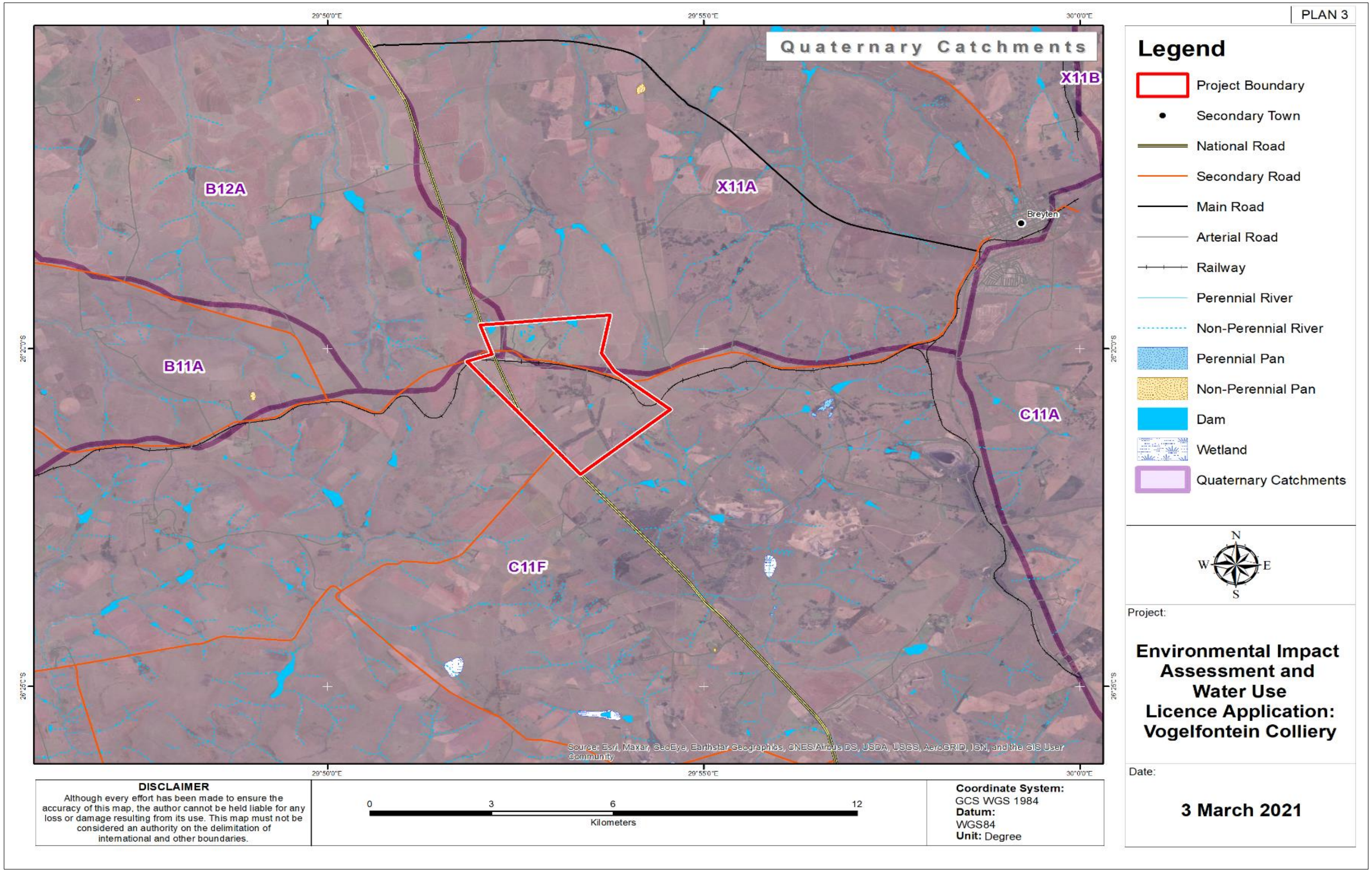


Figure 2-3: Local and Regional Hydrology around the Project Site

3. Floodlines Determination

3.1. Methodology

The floodlines determination and assessment methodology followed is discussed in the subsections below.

3.1.1. Topographical Data

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 with the river profile so that the watercourse can be accurately modelled.

A digital elevation model (DEM) was obtained for the greater catchment from the NASADEM data products at 1 arc second resolution. NASADEM extends the legacy of the Shuttle Radar Topography Mission (SRTM) by improving the DEM height accuracy and data coverage and providing additional SRTM radar-related data products. The improvements were achieved by reprocessing the original SRTM radar signal data and telemetry data with updated algorithms and auxiliary data not available at the time of the original SRTM processing. The NASADEM was used for catchment delineation and to develop a floodlines model.

3.1.2. Design Flood Peaks Calculations

Five (5) methods were used to determine design flood peaks for the delineated catchment including upstream contributing catchments (**Error! Reference source not found.**) at the site. The underlying assumption is that the largest possible peak flow will be observed when the storm rainfall event has a duration equal to the time of concentration of the catchment, i.e., the time required for the entire catchment to contribute runoff at the outlet (SANRAL, 2013). The seven methods that were used to evaluate the relevant design flood peaks for the site are as follows:

- Rational Method (RM2), as implemented by the DHSWS.
- Rational Method Alternative 3.
- Empirical Method (Midgley and Pitman) (also referred to as MIPI).
- Standard Design Flood (SDF) method as developed at the University of Pretoria.
- The Unit Hydrograph method.

3.1.3. Floodlines Hydraulic modelling

Floodlines for the watercourses nearby were determined for the 1:50-year and 1:100-year recurrence interval storm events.

3.1.4. Choice of Software

HEC-RAS 5.0.7 (US Army Corps of Engineers, 1995) was used to model the flood elevation profile for the 1:50-year and 1:100-year flood event. HEC-RAS is a hydraulic programme designed to perform one- or two-dimensional hydraulic calculations for a range of applications, from a single watercourse to an entire network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

The summary of the floodlines methodology is provided in Figure 3-1.

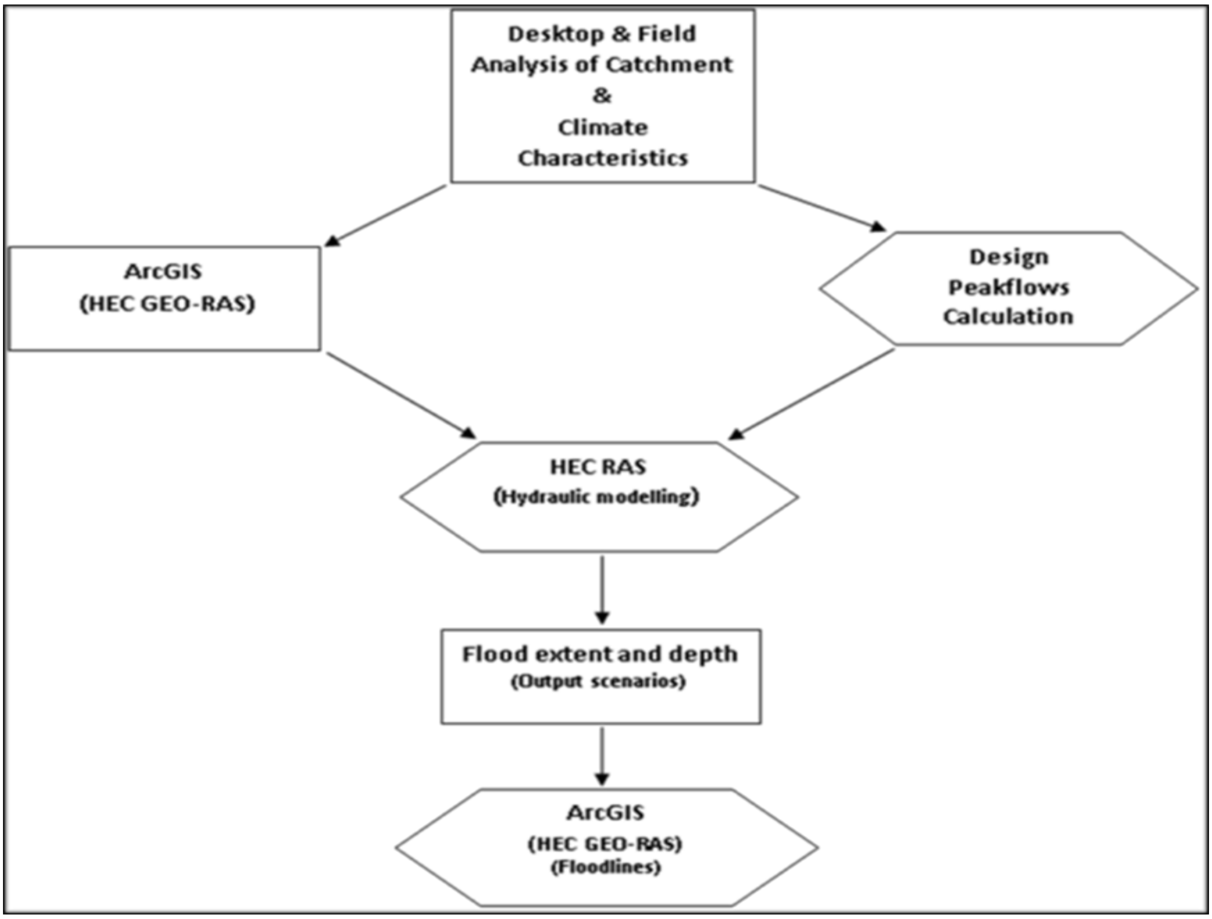


Figure 3-1: Summary of the Floodlines Assessment Methodology

3.1.5. Assumptions in the hydraulic model

In line with the development of the floodlines, the following assumptions were made:

- The topographic data used is of sufficient accuracy and coverage to enable hydraulic modelling at a suitable level of detail;
- The Manning's 'n' value used is considered suitable for use in all the modelled storm events (1:50 and 1:100-year events), as well as in representing both the channel and floodplain;

- Levees have been added to confine the modelling to the observed channels;
- Steady-state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate: and,
- The latest layout of the proposed mine was used.

3.1.6. Limitations

There was no detailed quality surveyed data at during this assessment as such, the NASADEM was used for modelling purposes. The floodlines are therefore indicative floodlines and are deemed sufficient for planning purposes. For detailed mine infrastructure design, these should be updated using site wide surveyed data.

3.2. Flood hydrology

3.2.1. Catchment delineation

Two sub-catchments were delineated for the purposes of modelling. The sub-catchments characteristics are shown in Table 3-1 and Figure 3-2.

Table 3-1: Sub-Catchment Characteristics

Parameter	**Parameter Value**	
Sub-catchments Name (SC)	SC1	SC2
Area (km^2)	1.5	0.45
Length of the longest watercourse (km)	1.3	0.69
LC - Distance to catchment centroid (km)	0.6	0.67
Equal area height difference (m)	50	47
Slope	0.0545	0.0973

*LC – is the distance from the catchment centroid to the catchment outlet along the longest river.

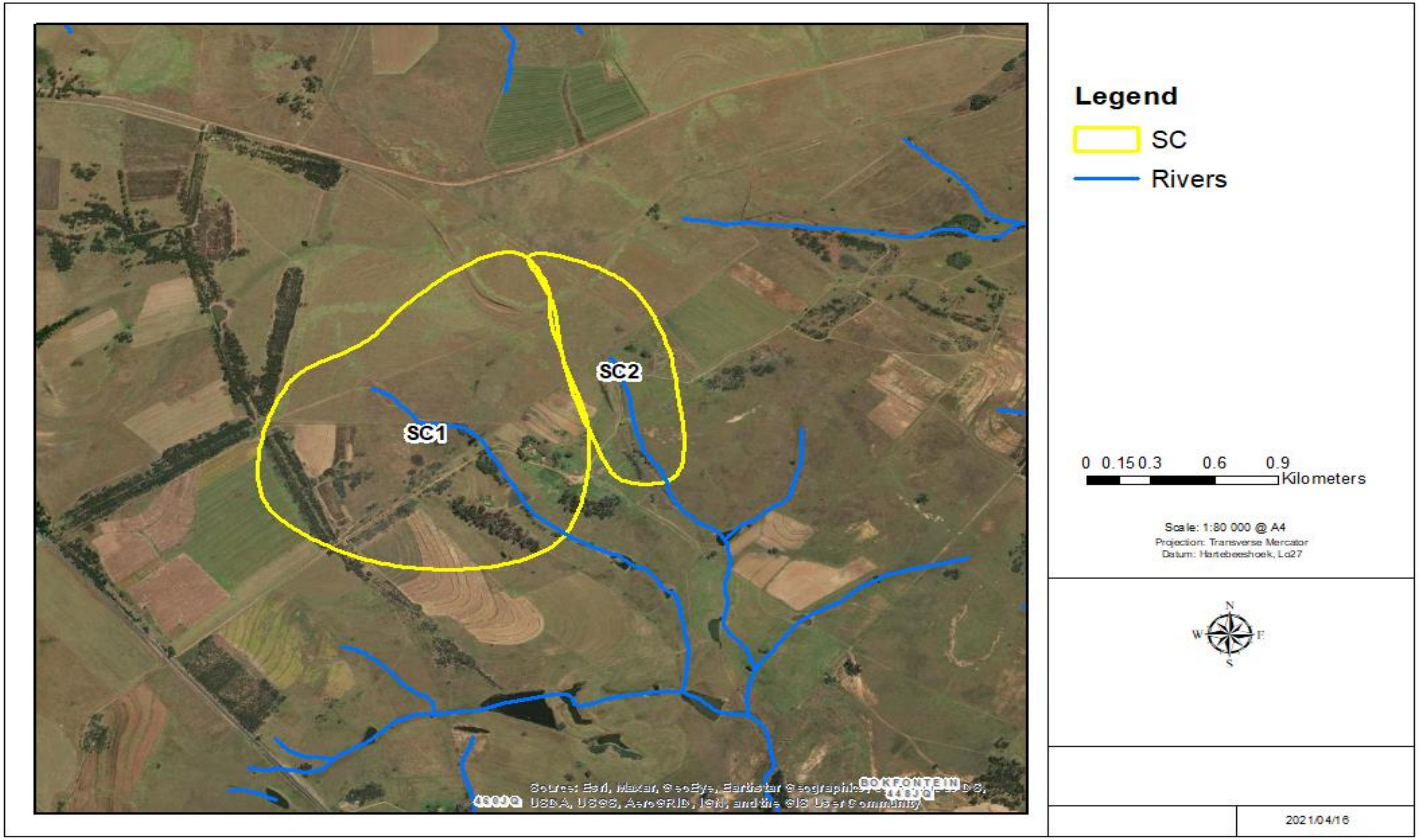


Figure 3-2: Quaternary Catchments Contributing to Peakflows

3.2.2. Flood Peak Estimates and boundary conditions

Design peak flows for the 1:50- and 1:100-year recurrence intervals were computed for the study site's watercourse using the methodologies listed in Section 3.1.2. This was undertaken to compare the results obtained by these methods. The comparison of the different flood peaks using different methods can be seen in Table 3-2.

Table 3-2: Results of the Deterministic Flood Peak Calculations in m^3/s

Method	Recurrence Interval	Sub-Catchment (SC)	
		SC1	SC2
Rational Method 2 (RM2)	1:50-year	34.46	12.63
	1:100-year	44.56	16.35
Unit Hydrograph	1:50-year	36.48	14.35
	1:100-year	44.25	17.4
Empirical Method (MIPI)	1:50-year	29.32	5.9
	1:100-year	40.7	8.2
Alternative Rational Method (RM3)	1:50-year	**48.73**	**19.24**
	1:100-year	**61.71**	**24.36**
Standard Design Flood Method	1:50-year	27.06	11.75
	1:100-year	34.18	18.84

The RM3, SDF, and Unit Hydrograph methods resulted in flood peaks of similar magnitude while MIPI resulted in flood lowest peaks. Flood Peaks calculated using the RM3 were adopted because they were higher and are deemed the most conservative.

3.3. Roughness coefficients

The Manning's roughness factor "n" is used to describe a specific surface's flow resistant characteristics. Based on the site visit undertaken, it was observed that streams were clean, straight, full stage and were no rifts or deep pools type of channels. Based on the Manning's n for Channels (Chow, 1959), an "n" value of 0.03 was assigned to the channel and 0.4 to the banks (floodplains).

3.4. Floodlines Delineation

Floodlines for the 1:50-year and 1:100-year recurrence intervals were determined for the river passing through the project site. The proposed project and mine surface infrastructure are located outside the 1:50- and 1:100-year floodline. The delineated floodlines are presented in Figure 3-3.

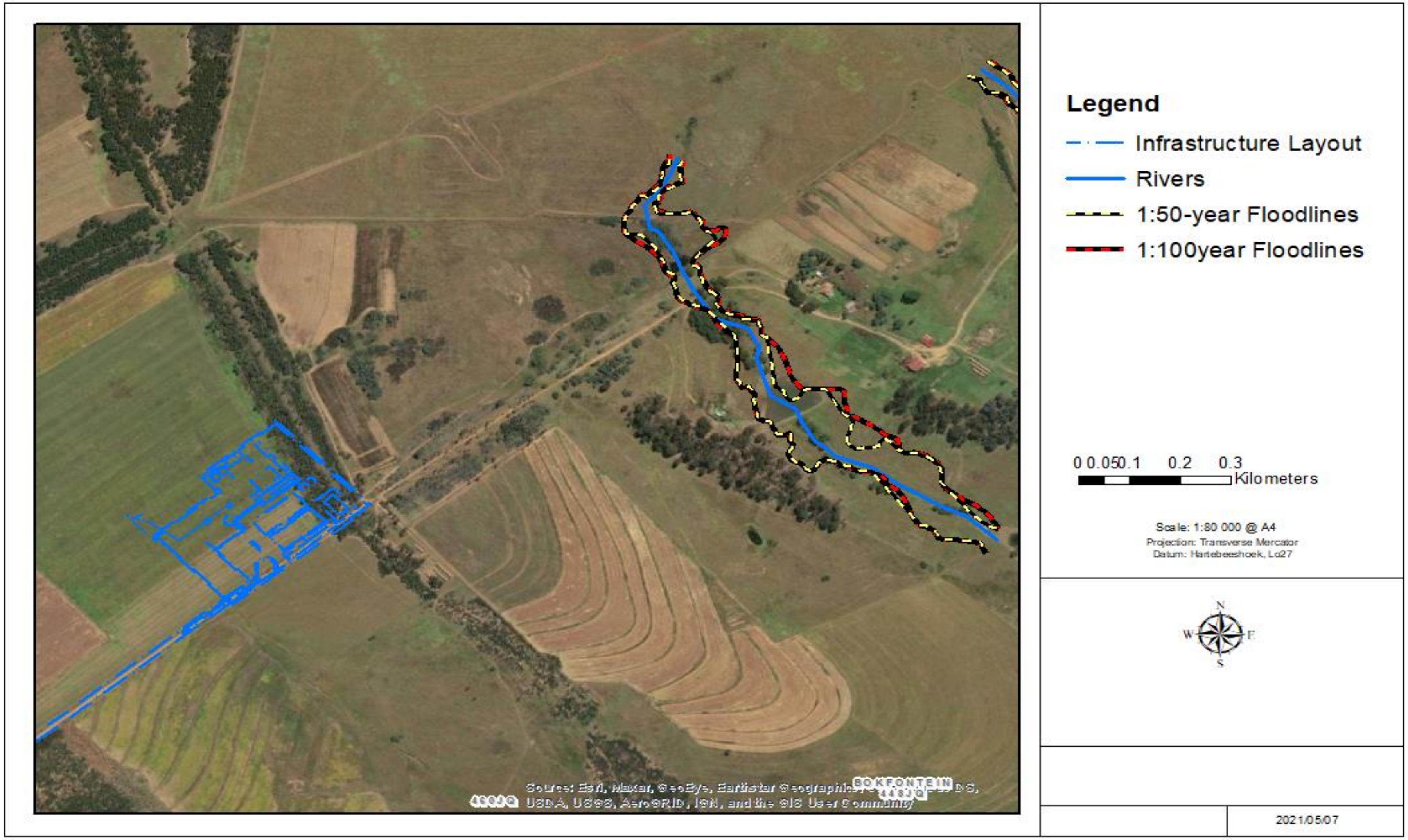


Figure 3-3: 1:50-year and 1:100-year Floodlines for the Unnamed Streams near the Project Site

4. Conceptual Stormwater Management Plan

4.1. Introduction

Mining 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 topsoils 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, may be washed out 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.
- Any impact upon the baseline water quality caused by primary 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 developments downstream.

The aim of this conceptual stormwater management plan is to mitigate the above impacts by fulfilling the requirements of the NWA and more particularly GN 704.

The following definitions from GN 704 are appropriate to the classification of catchments and design of stormwater management measures at the proposed Grammatikos 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 may include 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

The following terms were used to describe the elements of the Personal Computer Storm Water Management Mode (PCSWWM) software used for the development of the stormwater management plan:

Table 4-1: Definition of the stormwater management plan (SWMP) terms

SWMP Element	Description
Catchment (S)	That area determined by topographic features within which falling rain will contribute to runoff to a particular point under consideration.
Conduit (C)	Any artificial or natural duct, either open or closed, intended for the conveyance of fluids.
Channel	A natural or artificial waterway which periodically or continuously contains moving water, or which forms a connecting link between two bodies of water. It has a definite bed and banks which confine the water.
Discharge Points	The point, location or structure where water or drainage discharges from a stream, river, lake, tidal basin or drainage area; or pipe, channel, sewer, drain, or other conduits.

4.2. Design Principles for Stormwater Management Plan

Informed by the baseline hydrology of the site and surroundings, 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 SWMP is presented in Figure 4-1, the key features include:

- Clean stormwater will be diverted around dirty catchments and allowed to flow towards the river.
- Dirty stormwater from the primary mine sites (run of mine (ROM) stockpile, waste storage areas will be conveyed to suitably sized Pollution control Dams (PCDs) and re-used for dust suppression subject to water quality.

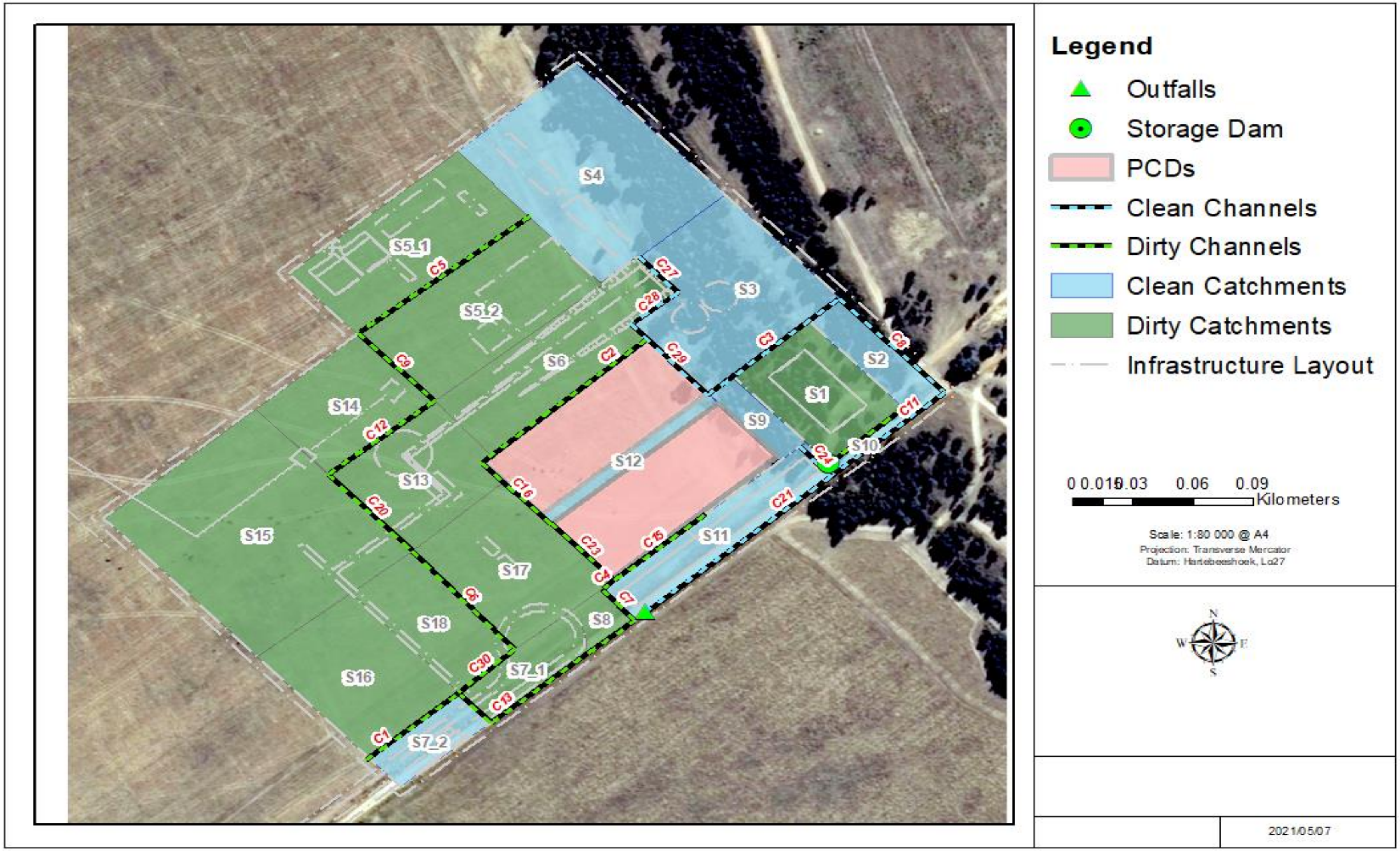


Figure 4-1: Conceptual SWMP

4.3. Pollution Control Dam

The 1:50-year flood event was routed through the sump and the proposed storage dam including the already specified PCDs in the mine layout. The two PCDs were modelled as one. PCD to determine the volume requirements to contain the 1:50-year flood event. The locations of the storage containment areas are depicted in Figure 4-1.

Table 4-2: Pollution Control Dams

Name	Max. Total Inflow (m^3/s)	Total inflow (ML)
PCD (Existing PCDs)	1.322	1.49
Storage Dam	0.2	0.417

4.3.1. 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 frequently than once in 50 years. A critical component in sizing the containment pond is the rate at which water is pumped from the pond for re-use at the site, which forms part of the site wide water balance. GN 704 also requires that as a minimum, the 1:50-year storm design volume and a 0.8 m freeboard allowance should always be available.

4.4. Drainage channels

4.4.1. Introduction

The clean and dirty stormwater catchments and route of drainage channels are presented in

4.4.2. Hydraulic Design Standards

As discussed in Section 1.5, GN 704 requires the following:

Capacity: dirty water systems are to be designed, constructed, maintained, and operated so that they are not likely to spill into a clean water system or the environment more frequently than once in 50 years.

Conveyance: all water systems are to be designed, constructed, maintained, and operated so that they convey a 1:50 year flood event.

Freeboard: as a minimum, any dirty water dams are to be designed, constructed, maintained, and operated to have 0.8 m freeboard above full supply level.

Collect and Re-Use: ensure that dirty water is collected and re-used as far as practicable.

Based on the infrastructure layouts, clean and dirty water catchment areas were delineated based on the expected quality of stormwater generated from the different catchments, where:

- Clean water catchment areas include the administration buildings, security buildings, parking areas and the areas upstream of infrastructure; and
- Dirty water catchment areas include the proposed infrastructure footprint including the ROM pads, shaft, topsoil stockpiles, loading areas and the proposed mine roads.
- Clean stormwater will be prevented from entering dirty water catchments by creating perimeter berms around the infrastructure footprint (channels and berms);
- Stormwater generated from the offices and parking areas will be considered clean and managed by clean water diversion berms or unlined clean water channels and diverted around dirty areas.
- Dirty water generating areas within the infrastructure layout areas and plants will generate runoff into the dirty water collection channels.
- Dirty stormwater will be collected by concrete lined open channels and circular culverts and conveyed to the PCD. Open channels are preferred for ease of maintenance and they minimise how deep the stormwater infrastructure needs to be excavated below ground level to accommodate design capacity, whilst maintaining suitable drainage gradients.
- Collected stormwater in the channels should pass through silt traps before being conveyed into the PCD. The sediment in the stormwater (likely to include ore) can then be recovered from the silt traps. and
- The PCDs will need to be a lined facility and equipped with a return water system.

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.

4.4.3. Design Methodology

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 rainfall event.

The Manning's 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 = Manning's Roughness Coefficient

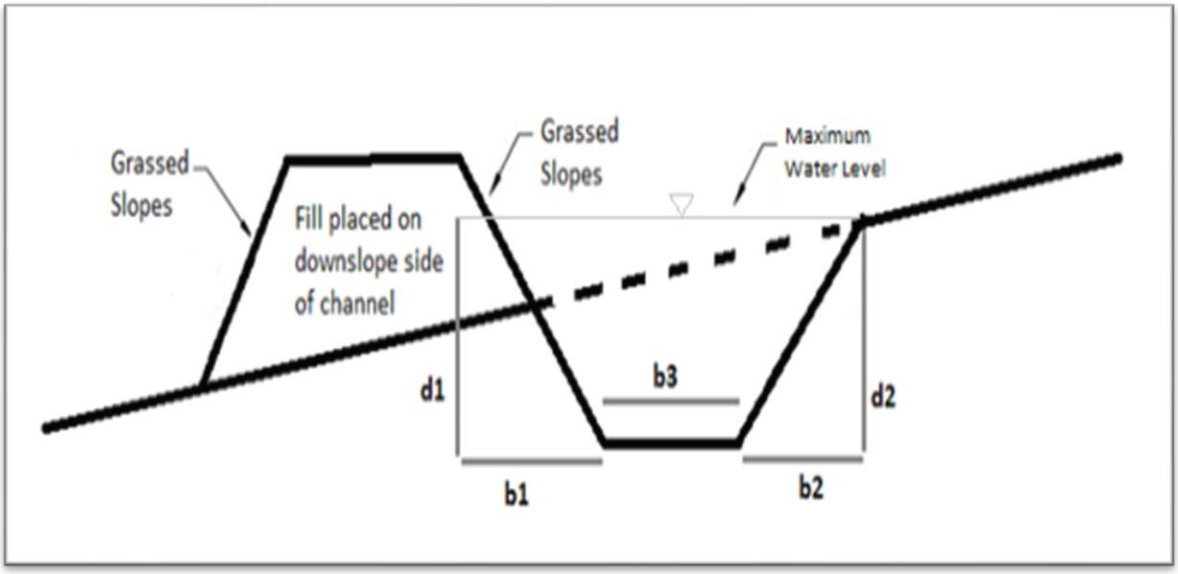


Figure 4-2: Schematic of a cross-sectional view of the channel design

4.4.4. Design Rainfall

A Type III storm profile was applied to the 1:50-year 24-hour rainfall depth (156 mm) to estimate peak flows from each catchment.

The channels were sized to take the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing will be uniform along the entire length. Some cut and fill may be required along the length of the channels to achieve the required gradient to ensure that water flows freely within these channels.

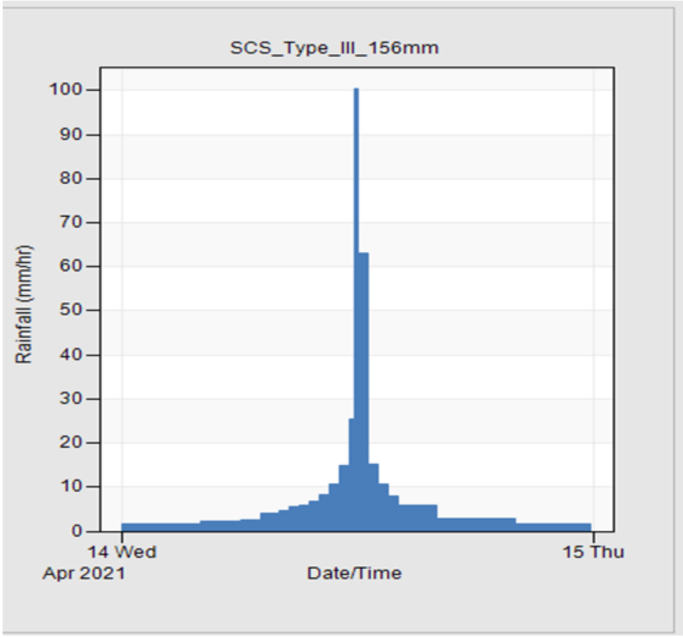


Figure 4-3: Rainfall Depth around the Project Site

Table 4-3: Stormwater Channel Sizing

Name	Description	Cross-Section	Side Slope (m)	Depth (m)	Width (m)	Barrels	Max. |Flow| (m^3/s)	Max. |Velocity| (m/s)	Max/Full Depth
C3	Clean	TRAPEZOIDAL	1.5	1	1	1	0.449	0.53	0.31
C8	Clean	TRAPEZOIDAL	1.5	1	1	1	0.644	0.77	0.29
C10	Dirty	TRAPEZOIDAL	1.5	1	1	1	0.200	0.68	0.27
C11	Clean	TRAPEZOIDAL	1.5	1	1	1	0.702	0.91	0.27
C13	Dirty	TRAPEZOIDAL	1.5	1	1	1	1.549	0.60	0.72
C14	Dirty	TRAPEZOIDAL	1.5	1	1	1	1.478	0.58	0.72
C6	Dirty	TRAPEZOIDAL	1.5	1	1	1	1.177	0.46	0.74
C18	Dirty	TRAPEZOIDAL	1.5	1	1	1	1.612	0.63	0.73
C20	Dirty	TRAPEZOIDAL	1.5	1	1	1	0.562	0.22	0.74
C21	Clean	TRAPEZOIDAL	1.5	1	1	1	0.734	1.21	0.22
C23	Dirty	TRAPEZOIDAL	1.5	1	1	1	0.923	0.34	0.71
C4	Dirty	TRAPEZOIDAL	1.5	1	1	1	1.353	0.53	0.72
C15	Dirty	TRAPEZOIDAL	1.5	1	1	1	1.322	0.52	0.71
C24	Clean	TRAPEZOIDAL	1.5	1	1	1	0.068	0.11	0.26
C27	Clean	TRAPEZOIDAL	1.5	1	1	1	0.436	0.51	0.34
C28	Clean	TRAPEZOIDAL	1.5	1	1	1	0.469	0.49	0.33
C29	Clean	TRAPEZOIDAL	1.5	1	1	1	0.433	0.48	0.32
C7	Dirty	TRAPEZOIDAL	1.5	1	1	1	1.413	0.55	0.72
C30	Dirty	TRAPEZOIDAL	1.5	1	1	1	1.310	0.51	0.73
C1	Dirty	CIRCULAR	1.0	0	0	1	0.962	1.23	1.00
C5	Dirty	CIRCULAR	1.0	0	0	1	0.032	0.04	1.00
C9	Dirty	CIRCULAR	1.0	0	0	1	0.200	0.25	1.00
C12	Dirty	CIRCULAR	1.0	0	0	1	0.798	1.02	1.00
C2	Dirty	CIRCULAR	1.0	0	0	1	0.031	0.05	1.00
C16	Dirty	CIRCULAR	1.0	0	0	1	0.950	1.21	1.00

4.5. Sub-Catchments

The sub-catchments contributing flow into the clean water diversion channels and the dirty water collection channels have been modelled within the PCSWMM software. The salient details of the sub-catchment characteristics are given in Table 4-4 below.

Table 4-4: Sub-Catchment Characteristics Used in The PCSWMM Model

Name	Description	Area (ha)	Width (m)	Impervious (%)	Infiltration (mm)	Runoff Volume (ML)	Peak Runoff (m^3/s)	Runoff Coefficient
S1	Dirty	0.296	29.63	40.0	7.42	0.430	0.200	0.950
S2	Clean	0.136	13.61	25.0	9.27	0.200	0.080	0.937
S3	Clean	0.534	53.43	25.0	9.27	0.770	0.320	0.937
S4	Clean	0.713	71.29	25.0	9.27	1.030	0.430	0.937
S6	Dirty	0.430	43.01	40.0	7.42	0.630	0.290	0.950
S8	Dirty	0.051	5.12	40.0	7.42	0.070	0.030	0.950
S9	Clean	0.070	7.03	25.0	9.27	0.100	0.040	0.937
S10	Clean	0.035	3.45	25.0	9.27	0.050	0.020	0.937
S11	Clean	0.263	26.28	25.0	9.27	0.380	0.160	0.937
S12	Clean	0.058	5.80	25.0	9.27	0.080	0.030	0.937
S13	Dirty	0.331	33.06	40.0	7.42	0.480	0.230	0.950
S14	Dirty	0.303	30.33	40.0	7.42	0.440	0.210	0.950
S15	Dirty	0.934	93.40	40.0	7.42	1.370	0.640	0.950
S16	Dirty	0.404	40.40	40.0	7.42	0.590	0.280	0.950
S17	Dirty	0.412	41.20	40.0	7.42	0.600	0.280	0.950
S18	Dirty	0.254	25.42	40.0	7.42	0.370	0.170	0.950
S7_1	Dirty	0.143	14.28	40.0	7.42	0.210	0.100	0.950
S7_2	Clean	0.114	11.40	25.0	9.27	0.160	0.070	0.937
S5_1	Dirty	0.476	47.60	25.0	9.27	0.690	0.280	0.937
S5_2	Dirty	0.487	48.73	25.0	9.27	0.700	0.290	0.937

4.6. Limitations and further work

- The conceptual stormwater management plant was undertaken using free available data from the NASA database of which the accuracy cannot be confirmed. Even though this SWMP cannot be used for design purposes, correct hydrological methodologies were followed. The conceptual SWMP must be improved when the site survey data is available.
- The specification for lining of the channels and the PCDs should also be confirmed during the detailed design of these features.

5. Surface Water Impact Assessment

Informed by the site layout, baseline hydrology, floodlines results, the stormwater management plan and the potential impacts of the proposed activities on surface water receptors and the sensitivity of the surface water resources are discussed in this section and presented along with a summary of mitigation measures and monitoring requirements.

5.1. Surface Water Sensitivity

The local surface water resources are of low sensitivity; the rationale for this sensitivity assessment is as follows:

- The project site is situated win QC C11F. The catchment is mostly taken up by rural areas where natural flows are through preferential flow and natural drainage as such, the probability of the catchment self-rehabilitating is high.
- Based on a review of the project description and listed activities in the previous section, a total of about 433.ha (4.3 km^2) is proposed for mining and supporting infrastructure. This area is 0.4% of the total extent of QC C11F, thereby implying a small, disturbed area of impacts.
- The peakflows were computed and has resulted in floodlines which are not encroaching the proposed project. Therefore, no flooding impact is foreseen with respect to the current project.
- The stormwater management plan has been developed to ensure that dirty water is contained, and clean water is returned to the environment.

5.2. Impact Assessment methodology

Identification of the possible impacts posed by the conducting of significant activities on the surface water resources has been undertaken for the three main stages of the project life cycle, namely the construction, operation and decommissioning and closure phases.

Impacts are assessed cumulatively where possible, in that the assessment considers the currently impacted environment. The impact rating methodology is presented in Appendix A.

5.3. Impact Description

Identification of the impact of the major activities on the surface water resources have been carried out for the three main stages of the project namely the construction, operation and closure phases and are discussed in subsections below.

Table 5-1: Summary of Identified Impact

Project Activities	Impact	Impact description
		Construction
Initial earthworks associated with site clearing, stripping and stockpiling of soil resources, preparations and construction of new surface infrastructure.	Water Quality Deterioration	• Deterioration of water quality as a result of the following • Clearing the surface and site preparations, for the mine infrastructure will result in exposure of soil surfaces to erosion factors. When a large area of vegetation is cleared and topsoil disturbed, exposing a large area of loose material, susceptible to erosion. During rainfall events, runoff from the exposed site will transport the eroded soil material in to the nearby water resources. • Uncontrolled spills of contaminants such as fuel and oils, and subsequent washing away of these into the surface water resources.
	Alteration of Flow and Drainage Patterns	• A reduction of runoff water quantity to the surface water resources system. When the initial stormwater management measures are constructed on site, the catchment area for runoff is reduced by 0.04%.
	Soil erosion and sedimentation	• Site clearing, digging of trenches, and topsoil removal will be undertaken during the construction of various mine infrastructure such as mine plant, beneficiating plant, which might lead to erosion and consequently siltation of watercourses. • The project could cause water resources pollution through sediment transport and other chemical parameters from runoff from the surface operations. • The risk of sedimentation is directly linked to the risk of erosion, as eroded soil particles will end up in nearby watercourses as sedimentation.

Operation		
Mining activities, stockpiling, and operation of surface infrastructure (diversion channels, pollution control dams, stockpiles, workshops & offices).	Water Quality Deterioration	• Deterioration of water quality because of the following: • Contaminated stormwater runoff from operational areas containing potential pollutants such as oils, solvents, paints, fuels and waste materials and discharge of dirty water into the catchment when extreme events do occur. Some of the structures may have the potential for seepage such as the waste rock dump, RoM pad, PCD dams and plant infrastructure areas. • The project could cause pollution of water resources through sediment transport and other chemical parameters from runoff from the waste and plant areas. • Discharge of excess water from the PCDs would also present risks to water quality
	Water quantity	• The excess water discharge from PCDs could result in alteration of flow regime of the streams. However, these impacts may be moderate, considering some reduction in flow from dirty stormwater sub-catchments and implementation of mitigation measures (storage and flow control measures).
Moving vehicles during operation phase could result in compacted surfaces.	Water Quality Deterioration	• Potential pollutants such as oils, solvents, paints, fuels and waste materials and discharge of dirty water into the catchment when extreme events do occur. Some of the structures may have the potential for seepage, such as the stockpile area
Potential abstraction of water from the River.	Alteration of drainage and flow	• Impacts on hydrological regime due to operational activities such as: o Increased runoff emerging from compacted paved surfaces.

	Erosion and Sedimentation	• Increased soil erosion emerging from uncompacted soils around the hardened area and stockpiles.
Subsidence of the mine.	Alteration of natural drainage and	• Mine failure could result in lateral or vertical ground movement thereby changing the land morphology, topography and interrupting the hydrologic environment. The nature of these impacts on the hydrologic environment may be massive. The subsidence affects the water table which consequence will affect the surface water resources with which it interacts through baseflow and recharge.
Closure		
Cessation of the mining and the removal and demolition of surface infrastructure and rehabilitation. Removal of surface infrastructure and rehabilitation.	Water Quality Deterioration	• Removal and handling of hazardous waste offsite and waste storage facilities, damage to waste handling facilities resulting in water quality deterioration
	Water quantity	• With adequate rehabilitation and closure some of the catchment is returned to a self-sustaining system. Return of natural drainage patterns as a result of freely draining topography
	Soil Erosion and Sedimentation	• Increased soil erosion emerging from uncompacted soils around the demolished mine. • Increase uncompacted areas due to moving maintenance vehicles could lead to increased soil erosion and sedimentation

5.4. Impact Rating

This section assesses the significance of potential unmitigated impacts (unrealistic worst-case scenario), and residual impacts of the project after considering the design mitigation measures proposed within this report using the quantitative assessment presented in Appendix A. Impact ratings are provided from Table 5-2 to Table 5-4

Table 5-2: Impacting Rating for Construction Phase

Issue	Activities	Corrective measures	Impact rating criteria					
			Nature	Extent	Duration	Magnitude	Probability	Significance
Construction Phase								
Water Quality Deterioration	Initial earthworks associated with site clearing, stripping and stockpiling of soil resources, preparations and construction of new surface infrastructure.	No	Negative	3	1	6	5	50
		Yes	Negative	2	1	6	3	27
	Leakage of fuel and hazardous material from moving vehicles and heavy machinery	No	Negative	3	1	8	5	60
		Yes	Negative	2	1	6	4	36
Alteration of Drainage and Flow	Increased runoff emerging from compacted surfaces	No	Negative	3	1	4	4	32
		Yes	Negative	3	1	2	3	18
	A reduction of runoff water quantity to the surface water resources system when initial stormwater management measures are constructed on site	No	Negative	3	1	6	5	50
		Yes	Negative	2	1	4	4	28
Sedimentation	Site clearing, digging of trenches and topsoil removal	No	Negative	4	1	8	5	65
		Yes	Negative	3	1	6	4	40
	Erosion from uncompacted surfaces	No	Negative	3	1	8	5	60
		Yes	Negative	2	1	6	4	36

Table 5-3: Impact Rating for Operational Phase

Issue	Activities	Corrective measures	Impact rating criteria					
			Nature	Extent	Duration	Magnitude	Probability	Significance
Operation Phase								
Water Quality Deterioration	Separation of clean and dirty water area: Clean water runoff from areas outside the dirty water footprint could flow into this area and potentially become polluted	No	Negative	5	4	8	4	68
		Yes	Negative	4	4	6	3	42
	Discharge of excess water from PCDs	No	Negative	3	4	6	4	52
		Yes	Negative	2	4	4	3	30
	Runoff and drainage from stockpiles resulting in acidic water	No	Negative	3	4	4	3	33
		Yes	Negative	2	4	2	2	16
	Spills such as fuel and diesels from vehicles and heavy machinery	No	Negative	4	4	8	4	64
		Yes	Negative	3	4	6	3	39
Alteration of Drainage and Flow	Increase runoff from compacted surfaces	No	Negative	3	4	8	4	60
		Yes	Negative	2	4	6	3	36
	Discharge of excess water from PCDs could increase downstream flow	No	Negative	4	4	4	3	36
		Yes	Negative	2	4	3	3	27
	Subsidence of mine leading to interruptions of the hydrologic environment.	No	Negative	3	4	8	5	75
		Yes	Negative	2	2	6	3	30
Sedimentation	Increased soil erosion emerging from uncompacted surfaces which could also result in sedimentation and blockage of culvert downstream.	No	Negative	5	4	8	5	85
		Yes	Negative	4	4	6	4	56

Table 5-4: Impact Rating for Closure and Decommissioning Phase

Issue	Activities	Corrective measures	Impact rating criteria					
			Nature	Extent	Duration	Magnitude	Probability	Significance
Closure and Decommissioning Phase								
Water Quality Deterioration	Removal and demolition of hazardous waste storage facilities such as stockpiles and diesel areas.	No	Negative	4	2	6	5	60
		Yes	Negative	3	2	4	4	36
Alteration of Drainage and Flow	Mine closure and decommissioning might permit the catchment to self-rehabilitate	Not required	Positive	3	4	8	5	75
			Positive	3	3	6	5	60
Sedimentation	Cessation and removal of mine surface infrastructure could lead to increased soil erosion in uncompacted surface	No	Negative	4	2	8	4	56
		Yes	Negative	3	2	6	3	33

5.5. Mitigation Measures

A summary of the measures developed to ensure compliance to legislative and design standards are presented below with additional mitigation measures that are also recommended to further reduce residual impacts on the surface water quality and quantity.

The following mitigation measures are recommended as per identified impact:

5.5.1. Water Quality

- In case of an occurrence of a discharge incident that could result in the pollution of surface water resources, the emergency response procedure should be implemented.
- Phasing / scheduling of earthworks should be implemented in order to minimise the footprint that is at risk of erosion at any given time, or schedule works according to the season i.e., earthworks during the dry winter season pose less impact.
- In the case of linear earthworks, phasing of working areas and progressive rehabilitation will be necessary to minimise the footprint of the extent of the disturbance at any given time.
- Water quality monitoring will be undertaken as per the monitoring programme outlined below.
- A post rehabilitation audit should be undertaken during the end of life of mine to ascertain whether the remediation has been successful is recommended and if not, further measures should be recommended and implemented; and
- Pollutant storage – any substances which may potentially pollute surface water must be stored within a suitably sized bunded area and where practicable covered by a roof to prevent contact with rainfall and/or runoff.

5.5.2. Sedimentation and Erosion

Monitoring and inspection of channels, silt traps, culverts, pipelines, dam walls and dams for signs of erosion, cracking, silting and blockages of inflows, to ensure the performance of the storm water infrastructure is recommended should a flood protection berm be developed as a mitigation measure. Monitoring should be undertaken monthly during wet season and after storm events or as per the site management schedule.

5.5.3. Alteration of Flow and Drainage

In order to minimise the alteration of flow, clean water around the mine must be diverted around the infrastructure then allowed to get to preferential flow into the environment.

The impacts of subsidence on surface water resources are inevitable and cannot be minimized. However, the probability of subsidence can be assessed in a separate study to curb its magnitude should it occur.

A substantial natural environment must be maintained in order to allow the catchment to rehabilitate faster and more frequently.

5.5.4. Designed mitigation measures

- Stormwater management:
  - Separation of clean and dirty water through the development of stormwater structures as detailed in Section 4 of this report. It must be ensured that diverted runoff from disturbed area is collected in dirty areas and clean water freely discharges to the surrounding clean catchment.
  - As discussed in section 4 above, it is proposed that stormwater from dirty catchments is contained and reused at the processing plant and as dust suppression. Alternatively, it must be treated and discharged, effectively reducing the catchment area draining to the local watercourses.
  - Management of silt by ensuring that the disturbance of topsoil is minimised, sediment source and erosion control, phasing of earthworks activities, diversion of upslope runoff from entering the earthworks areas and downstream treatment of any collected sediment runoff i.e., use of silt traps;
  - Regularly schedule inspection and maintenance of water management facilities, to include inspection of drainage structures and liners for any in channel erosion or cracks; de-silting of silt traps/sumps and PCDs; and any pumps and pipelines should be maintained according to manufacturer's specifications;
  - Infrastructure design: the design of all onsite access roads, plant areas, stockpiles, pump station etc. must include stormwater management and erosion control during both the construction and operational phases;

- Water Balance: the project requires a site wide water balance that will quantify the amount of water that might potentially be discharged into the environment.
  - Water conservation and water demand management (WC/WDM) measures to ensure that as much water as is possible, is collected and reused.

- Mine Subsidence:
  - It is imperative that from the inception and planning of the project that mining techniques and methodologies, post-mine stabilization and structural design are clearly defined and designed to reduce the possibility of subsidence.
  - It is recommended that a mine subsidence study be undertaken to understand the possibility and magnitude of the impacts of subsidence, this then will inform the

nature and magnitude of subsidence on surface water and all other environmental aspects.

5.5.5. Additional Mitigation Measures

In addition to the measures presented and discussed throughout this report, the following management measures should be implemented:

- Good housekeeping practices must be implemented and maintained by clean-up of accidental spillages, as well as ensuring all dislodged material like run-of-mine stockpile are kept within the confined storage footprints. In addition, clean-up material and materials safety data sheets for chemical and hazardous substances should be kept on site for immediate clean-up of accidental spillages of pollutants;
- Vehicles and plant equipment servicing must be undertaken within suitably equipped facilities, either within workshops, or within bunded areas, from which any stormwater is conveyed to a pollution control dam, after passing through an oil and silt interceptor.

All measures implemented for the mitigation of impacts, should be regularly reviewed as best practice and as compliance with various licences issued on site by authorities. The purpose of the mitigation measures is to ensure that the pre-mining / current water resource status is not deteriorated by the mining activities.

5.6. Monitoring and Reporting Recommendations

A monitoring programme is an essential tool to identify any risks of potential impacts as they arise and to assist in impact management plans. Monitoring should be implemented throughout the life of the project. Recommendations on surface water monitoring are presented in Table 5-5 below.

Table 5-5: Surface Water Monitoring Programme

Description	Monitoring Location	Frequency of sampling	Frequency of Reporting
Soil Erosion			
Soil erosion and sedimentation monitoring in all soil erosion potential sources	Cleared and compacted areas where the infrastructure will be built. The downstream areas of dams and road crossings.	Monitoring of erosion should occur during construction after every rainstorm or flood event. During operational phase, monthly monitoring should be undertaken.	After every major rainstorm / flood. Monthly monitoring report compiled by the appointed ECO during the construction phase.
Surface Water Quality			

Description	Monitoring Location	Frequency of sampling	Frequency of Reporting
Ensure that water quality monitoring is implemented up and downstream at the periphery of the 200 m working area	GPS co-ordinates of the monitoring locality can be established during the first monitoring.	Monitoring should be undertaken quarterly.	Reporting should be undertaken after each sampling activity.
Ensure that monitoring is implemented up and downstream at the periphery of the 100 m working area	Monitoring must be undertaken at precisely the same locality as the pre-construction, operation and closure phases monitoring.	Once a month for six months after completion of construction.	Monthly report should be compiled.
Leakage events			
A leak and spill management plan must be formulated to monitor and detect as soon as possible. **Site walkovers to determine the condition of facilities and identify any leaks or overflows, blockages, overflows, and system malfunctions for immediate remedial action**	Roads and areas where vehicles commute and areas where chemical storage containers are located. Areas where leakage is visible/detected.	Identification of any leakage events should occur monthly during the rehabilitation and construction phase, or directly after a leakage has been detected and for the operational phase, during maintenance activities	Monthly monitoring report compiled by the appointed ECO during the construction, operational and closure phases; and Report should be compiled for all the three phases of the project.
Infrastructure Monitoring			
Inspection of the temporary channels, and bridges for signs of erosion, cracking and silting to ensure the performance of these remains acceptable.	All proposed infrastructure	Daily during maintenance	Daily. Should erosion occur, measures should be reinstated.

The monitoring plan should be reviewed periodically to ensure the appropriateness of sites and sampling frequency during operation.

Table 5-6: Surface Water Quality Parameters of Concern

Parameters	
pH	Nitrate as N
Electrical conductivity	Ammonia
Total dissolved solids	Potassium
Total suspended solids	Nickel
Aluminium	Manganese
Calcium	Magnesium
Fluoride as F	Iron
Total alkalinity as $CaCO_3$	Copper
Chloride as Cl	Lead
Sulphate as SO_4	Sodium
Uranium	*E.coli*

6. Recommendations and Conclusion

6.1. Recommendations

The following surface water studies are recommendations once the mine has been established:

6.1.1. Site-Wide Balance

A site-wide water balance that considers extremes of climate, unsteady processing/production rates and storage within any aspect of the operation (such as would be required to fill process water dams prior to initial start-up or drawdown stored water through the dry season) is recommended for the mine.

Additionally, it is recommended that a site-wide water balance model must accommodate the new and future expansion.

6.1.2. Water Quality Assessment

A surface water quality monitoring program starting with an establishment of a baseline water quality must be undertaken. The water quality must be compared against the permissible guidelines provided by the DHSWS.

6.2. Conclusions

Floodlines for the 1:50-year and 1:100-year recurrence intervals were determined for the current river network passing through the project site. The proposed mine infrastructure. The local surface water resources are considered to be of low sensitivity because of their shallow nature and intermittent flow.

A conceptual SWMP has been developed to ensure compliance with the requirements of GN 704. As part of the detailed design process, detailed and high integrity/ resolution topography survey, a geotechnical investigation is necessary to assess the structural integrity of the existing embankment as well as to determine the dam footprint for the lining, compaction, flood protection berm and storage estimates.

Impacts have been identified, and recommendations of mitigation measures outlined in the report. All measures implemented for the mitigation of impacts should be regularly reviewed against best practice guidelines and to achieve compliance with the various licences issued on-site by the authorities. The project can continue if all mitigation and monitoring measures are implemented as recommended.

A monitoring programme is an essential tool to identify any risks of potential impacts as they arise and to assist in impact management plans by assessing if mitigation measures are operating effectively. Monitoring should be implemented throughout the life of the mine.

7. References

DWAF. (2006c). Best Practice Guideline G2: Water and Salt Balances. Pretoria, South Africa: Department of Water Affairs and Forestry.

NASADEM, 2020. https://earthexplorer.usgs.gov/

SANRAL. (2013). *Drainage Manual.* Pretoria.

South Africa. (1998). General Notice 704 of the National Water Act (36 of 1998). Pretoria: Department of Water and Forestry.

Water Resources of South Africa, 2012 Study (WR2012). http://waterresourceswr2012.co.za/

Water Resources of South Africa 1990 - Volume 1 Appendices. WRC Report 298/1.1/94

Appendix A: Impact Assessment Methodology

Status of Impact

The impacts are assessed as either having a:

- Negative effect (i.e. at a `cost' to the environment),
- Positive effect (i.e. a `benefit' to the environment), or
- Neutral effect on the environment.

Extent of the Impact

- (1) Site (site only),
- (2) Local (site boundary and immediate surrounds),
- (3) Regional,
- (4) National, or
- (5) International.

Duration of the Impact; The length that the impact will last for is described as either:

- (1) Immediate (<1 year)
- (2) Short term (1-5 years),
- (3) Medium term (5-15 years),
- (4) Long term (ceases after the operational life span of the project),
- (5) Permanent.

Magnitude of the Impact; The intensity or severity of the impacts is indicated as either:

- (0) none,
- (2) Minor,
- (4) Low,
- (6) Moderate (environmental functions altered but continue),
- (8) High (environmental functions temporarily cease), or
- (10) Very high / unsure (environmental functions permanently cease).

Probability of Occurrence; The likelihood of the impact actually occurring is indicated as either:

- (0) None (the impact will not occur),
- (1) Improbable (probability very low due to design or experience)
- (2) Low probability (unlikely to occur),
- (3) Medium probability (distinct probability that the impact will occur),
- (4) High probability (most likely to occur), or

- (5) Definite.

Significance of the Impact

Based on the information contained in the points above, the potential impacts are assigned a significance rating (S). This rating is formulated by adding the sum of the numbers assigned to extent (E), duration (D) and magnitude (M) and multiplying this sum by the probability (P) of the impact.

S= (E+D+M) P

The significance ratings are given below;

- **(<30) low** (i.e. where this impact would not have a direct influence on the decision to develop in the area),
- **(30-60) medium** (i.e. where the impact could influence the decision to develop in the area unless it is effectively mitigated),
- **(>60) high** (i.e. where the impact must have an influence on the decision process to develop in the area).