HYDROLOGICAL ASSESSMENT: PROPOSED MAKGANYANE IRON ORE MINE

Tsantsabane Municipality, Northern Cape, South Africa

07/08/2025

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Report Name	**HYDROLOGICAL ASSESSMENT: PROPOSED MAKGANYANE IRON ORE MINE**	
Specialist Theme	Surface Water Hydrology	
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Declaration	The Biodiversity Company and its associates operate as independent consultants under the auspice of the South African Council for Natural Scientific Professions. We declare that we have no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, 2017. We have no conflicting interests in the undertaking of this activity and have no interests in secondary developments resulting from the authorisation of this project. We have no vested interest in the project, other than to provide a professional service within the constraints of the project (timing, time and budget) based on the principals of science.	

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1 Introduction

1.1 Background

The Biodiversity Company was commissioned to conduct a Stormwater Management Plan (SWMP) for the proposed Makganyane Iron Ore Mine. The project comprises of 1549 ha and is located on Portion 2 (A Portion of Portion 1), Remainder Portion, Remainder Portion of Portion 1 and Portion 3 of the Farm Makganyene No 667, approximately 24 km north-west of Postmasburg in the Tsantsabane Municipality, Northern Cape (Figure 1-1).

The objective of the hydrological assessment is to limit any potential impacts of the proposed development on the surface water resources. The National Water Act (Act No. 36 of 1998) was used as the guidance document to meet this objective.

The preamble to the NWA recognises that the ultimate aim of water resource management is to achieve sustainable use of water for the benefit of all users and that the protection of the quality water resources is necessary to ensure sustainability of the nation’s water resources in the interests of all water users. The purpose of the Act is stated, in Section 2 as, inter alia:

- Promoting the efficient, sustainable and beneficial use of water in the public interest;
- Facilitating social and economic development;
- Protecting aquatic and associated ecosystems and their biological diversity;
- Reducing and preventing pollution and degradation of water resources; and
- Meeting international obligations.

The NWA presents strategies to facilitate sound management of water resources, provides for the protection of water resources, and regulates use of water by means of Catchment Management Agencies, Water User Associations, Advisory Committees and International Water Management.

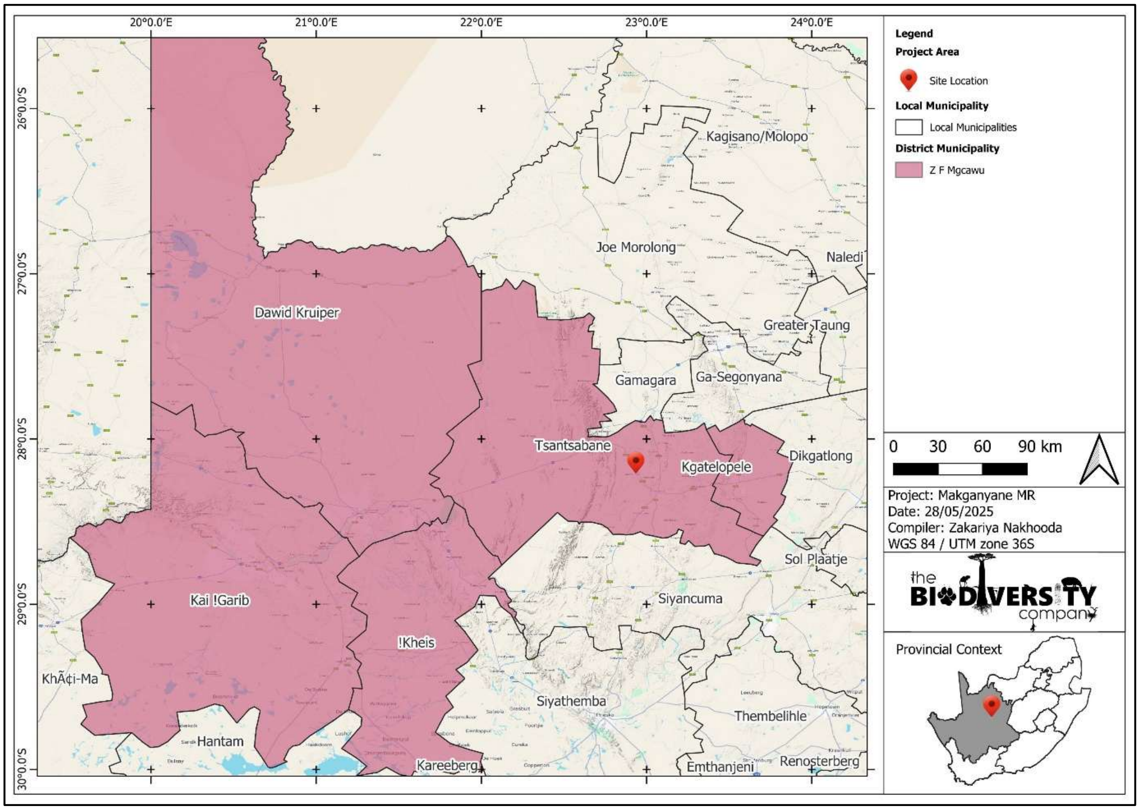

Figure 1-1 Locality Setting

1.2 Scope of Work

The aim of this study is to undertake a hydrological assessment for the Proposed Mine. The scope of works broadly comprises of the following:

- Overview of the site description and climatic assessment;
- Site Assessment;
- Catchment Delineation;
- Design Flood Peak Calculations: Calculations were performed to determine the anticipated flood peak magnitudes for the chosen flood return periods;
- Hydraulic Modelling: Hydraulic models were constructed to simulate the flow behaviour of the identified watercourses during the designated flood events;
- Determination of the 1:100-year floodline extents;
- Graphical Representation: The outcomes of the hydraulic models were translated into visual representations that depict the extents of the 1:100-year floodline; and
- Hydrological Impact Assessment.

1.3 Assumptions and Limitations

The following assumptions and limitations are applicable:

- It is assumed that all information received from the client is relevant and correct;
- The project description was based on information provided by the client, and any alterations to the area and/or missing data pertaining to the development would have affected the area surveyed and hence the results of this assessment;
- At the time of writing this report no detailed layouts were provided just the project boundary;
- Topographical data was attained from the client and the extent of this study is limited to the extent of the topographical data. It should be noted that the topographical data was deemed to adequately cover the watercourses within the proposed site footprint;
- The results of this study were largely based on the outcomes of a standardised hydrological assessment and historic information of the catchment;
- The floodline presented should only be used for indicative and environmental planning purposes, and not for detailed engineering designs, unless signed off by a suitably qualified and registered engineer;
- The floodline areas modelled in this assessment should be interpreted with caution; given the overall low resolution elevation data utilised; and
- Data presented in the hydrological model attempts to represent current catchment conditions, for which Google Earth satellite imagery was utilised.

2 Project Description

The project description was taken from the Final Scoping report compiled by Greenmined Environmental (Pty) Ltd (2025).

The Applicant, Assmang (Pty) Ltd, applied for a mining right (MR), environmental authorisation (EA), and waste licence (WL) to mine Hematite, Magnetite, Goethite, Limonite, Siderite, Pyrolusite, Psilomelane, Rhodochrosite, Manganite, Braunite, Hausmannite, Manganese ore, Iron ore, and Diamonds (general) from 1 549.61 ha that extends over Portion 2 (portion of Portion 1), Remainder Portion, Remainder Portion of Portion 1 and Portion 3 of the farm Makganyene No 667 in the Tsantsabane Local Municipality of the Northern Cape (Figure 2-1).

Should the relevant authorisations be granted, and the project proceeds the principal mining activities will entail the following:

- Site establishment and infrastructure development;
- Strip and stockpile of topsoil and overburden to access the ore (excavation);
- Opencast mining (including drilling and blasting);
- Transport, stockpile and crushing of run of mine ore (RoM);
- Transport of crushed ore to Beeshoek Mine; and
- Slope, landscape and rehabilitate the affected areas upon closure of the mine.

The preliminary layout of the mining area (Figure 6) is expected to include at least the following:

- Internal roads;
- Office complex (±1 ha):

- Ablution facilities,
- Diesel depot,
- Equipment workshop,
- Office containers,
- Parking area,
- Planning / meeting site rooms,
- Security access control,
- Water reservoir,
- Wash bays.

- Stockpile Area (±15 ha):
  - Crushing plant,
  - Weigh bridge and Operations Hut,
- Excavations (±36 ha):
  - Pit 1
  - Pit 2
- Waste rock dump (±64 ha);
- Water storage dam/s (for dewatering of the pits).

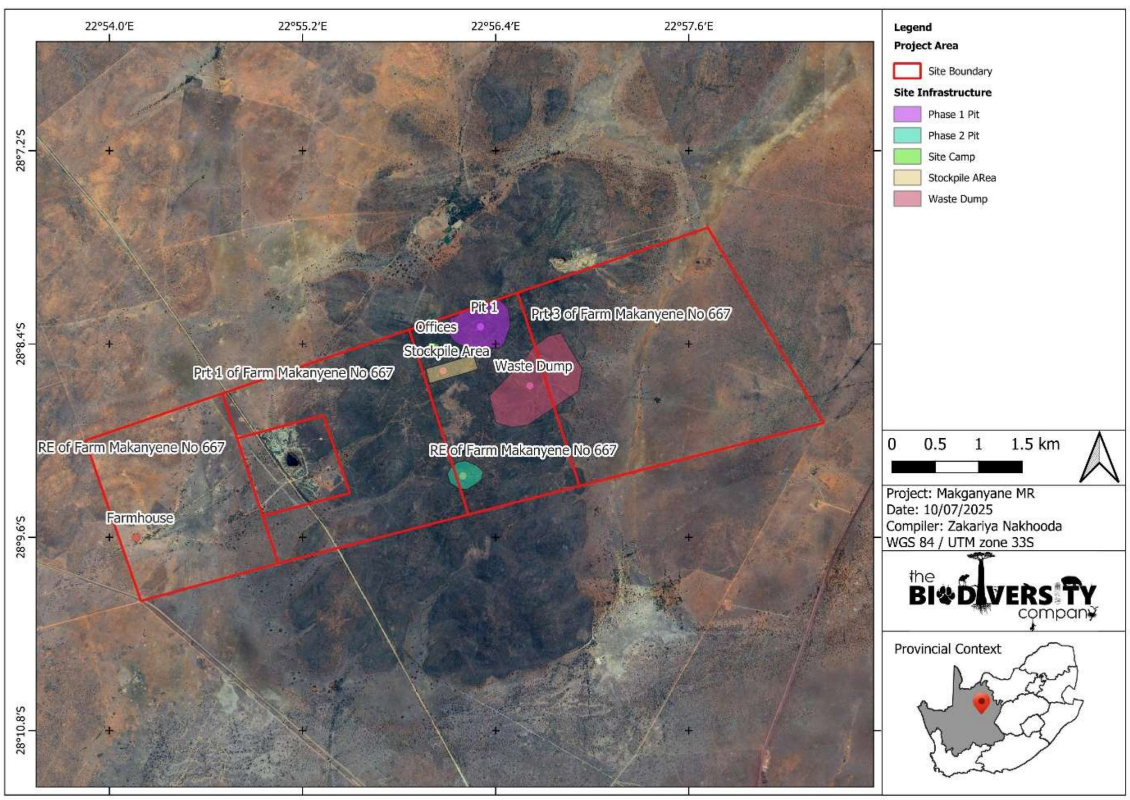

Figure 2-1 Site Setting

3 Catchment Hydrological Characteristics

3.1 Quaternary Catchment

The site falls within the Quaternary Catchment D73A within the Vaal-Orange Water Management Area (WMA 4) (Figure 3-1) and the Molopo sub-WMA. The typical climatic conditions associated with rainfall and runoff volumes for the quaternary catchment are presented in Table 3-1.

Table 3-1 Quaternary Catchment Information (WRC, 2012)

Quaternary Catchment	QC Area (km²)	MAP (mm)	MAE (mm)	MAR (mcm1)
D73A	3 238	323	2 450	-

Quaternary Catchment D73A has a Mean Annual Precipitation (MAP) of 323 mm. The monthly rainfall averages for D73A are presented in Table 3-2. The site falls within the D7C Rainfall Zone and the 7A evaporation zone with a Mean Annual Evaporation (MAE) of 2 450 mm. Monthly evaporation averages for D73A are presented in Table 3-3.

Table 3-2 Monthly Rainfall Averages (WRC, 2012)

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
48	56	61	34	16	6	4	6	7	19	27	37

Table 3-3 Monthly Evaporation Averages (WRC, 2012)

Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
364	427	460	260	120	43	27	49	53	147	206	281

A comparison between the mean monthly rainfall and evaporation is presented in Figure 3-2. The overall trends indicate greater evaporation than rainfall for all months of the year.

[1] Million Cubic Metres

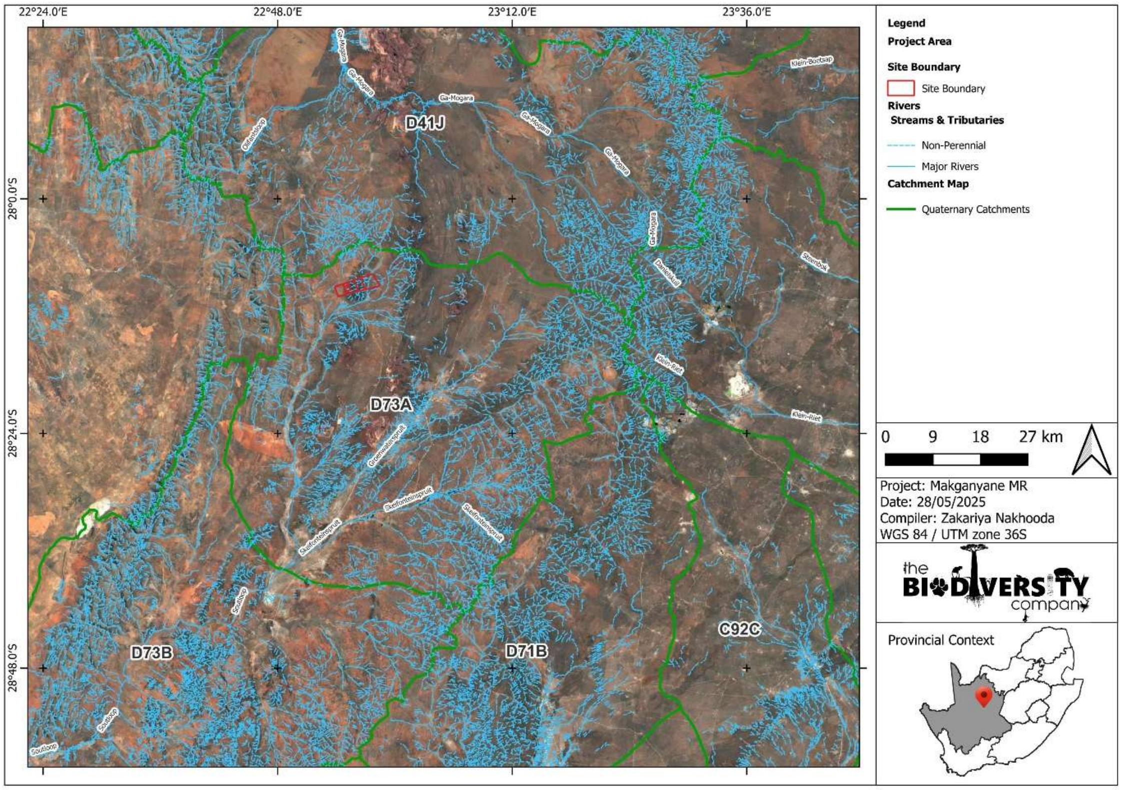

Figure 3-1 Hydrological Setting

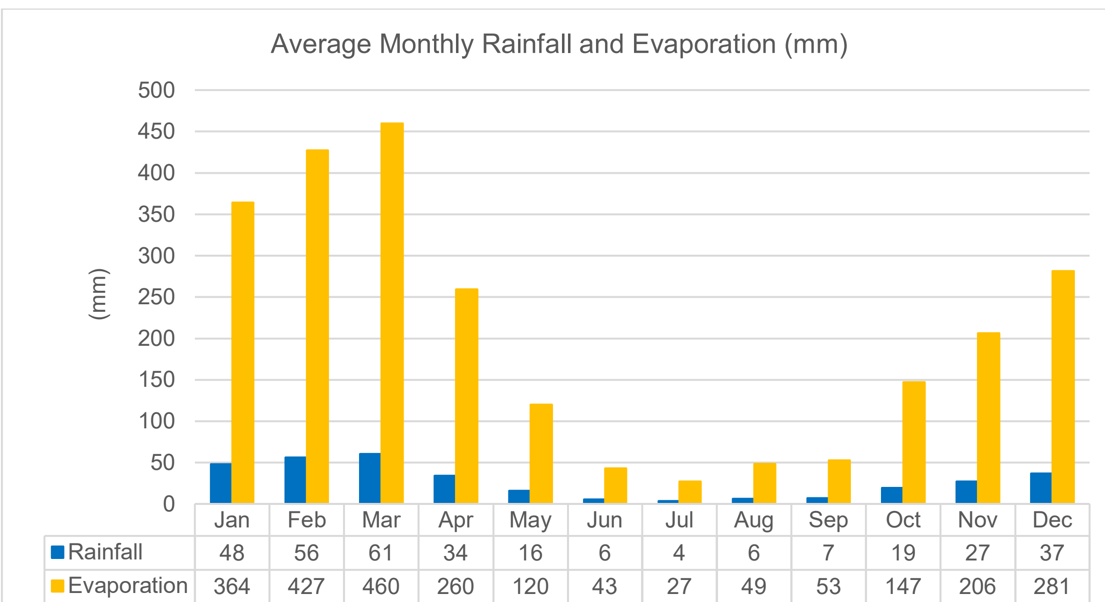

Figure 3-2 Average Monthly Rainfall and Evaporation for QC D73A

3.2 Site Specific Design Rainfall

Design rainfall is a probabilistic representation of rainfall intensity (depth of rainfall over a time period) at a certain location for a given duration and average recurrence interval. The design rainfall depths for the centroid of the site were extracted using the Design Rainfall Estimation software for South Africa (Smithers and Schulze, 2002). The rainfall data utilised to determine the design rainfall depths was extracted from the Rainfall Utility Tool (Table 3-4).

Table 3-4 Rainfall Station Utilised to Determine Design Rainfall Depths

Name	ID	Distance to Site (km)	Record (years)	Altitude (mamsl)	MAP (mm)
Aucampus	0320828_W	12.7	57	1 289	304
Lohatla	0321032_W	16.6	36	1 365	368
Mangore	0321159_W	18.0	34	1 438	377
Postmasburg	0321110_W	23.1	75	1 325	323
Wolhaarkop	0320654_W	28.5	68	1 222	285
Smythe	0356712_W	30.8	86	1 210	337

The output rainfall at each site includes a ninety percent upper, standard and lower bounds for all design rainfall values. For this assessment, the ninety percent upper value (bold value in Table 3-5) was used in the modelling to determine the indicative floodline. The rationale for the use of the upper bound is as follows:

- To consider any potential increases in the rainfall that may occur due to effects of climate change; and
- The type of infrastructure located at the proposed Mine.

The 24-hr design rainfall depths for the different return periods are illustrated in Table 3-5 and the value used is highlighted in **bold**.

Table 3-5 Design Rainfall Depths

Recurrence Interval (years)	1:2-year	1:5-year	1:10-year	1:20-year	1:50-year	1:100-year
Rainfall depth (mm)	55.8	79.0	95.3	111.9	**134.9**	153.2

3.3 Topography and Drainage

3.3.1 Topography

A Digital Elevation Model (DEM) has been created to identify lower lying regions as well as potential convex topographical features which could point towards preferential flow paths. The proposed Mine site ranges from 1 244 in the south-western region to 1 376 MASL within the vicinity of Pit 1, which can be considered the highest point at the site. The lower lying areas (generally represented in dark blue) represent the area that will have the highest potential to be characterised as watercourses (Figure 3-3).

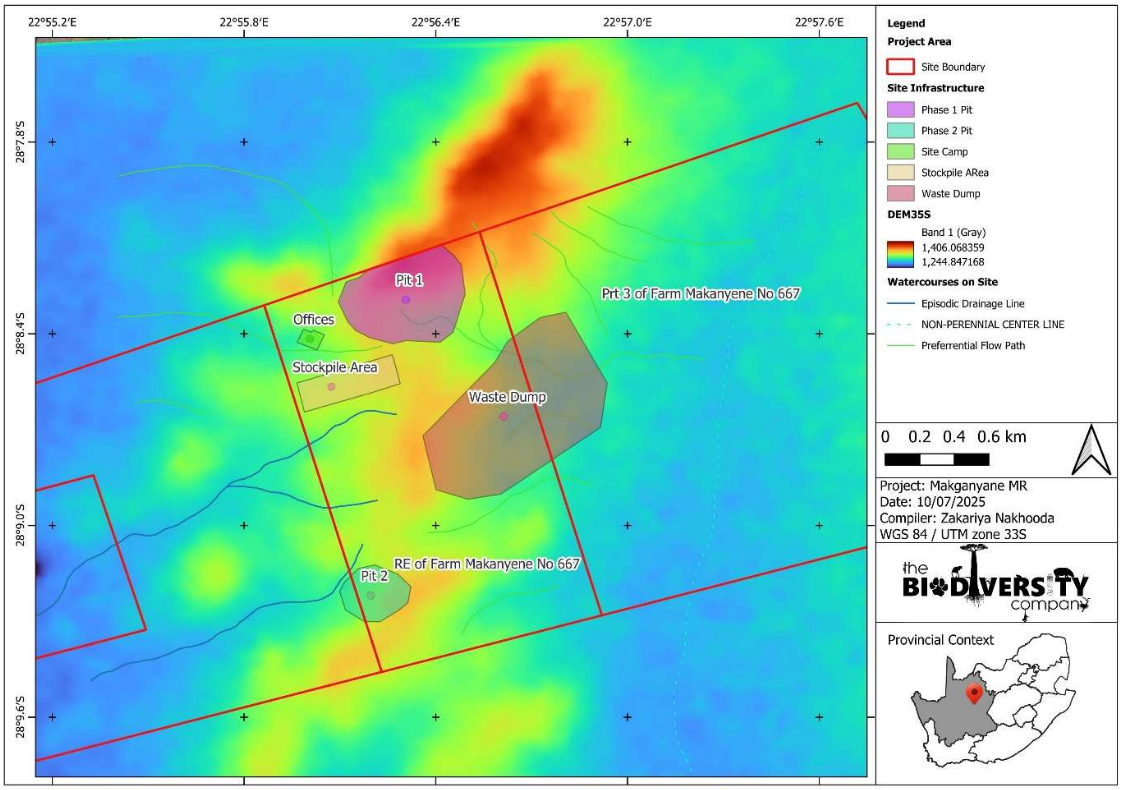

Figure 3-3 Digital Elevation Model

3.3.2 Drainage

The proposed Mine site is drained by a non-perennial tributary located towards the east of the mining area as well as smaller non-perennial drainage lines and preferential flow paths (Figure 3-4). The non-perennial tributary passes through the project area (away from proposed mine workings) in a southerly direction before eventually joining the Soutloop River some 57km downstream. These watercourses are predominantly dry, apart from runoff generated during and immediately after significant rainfall events.

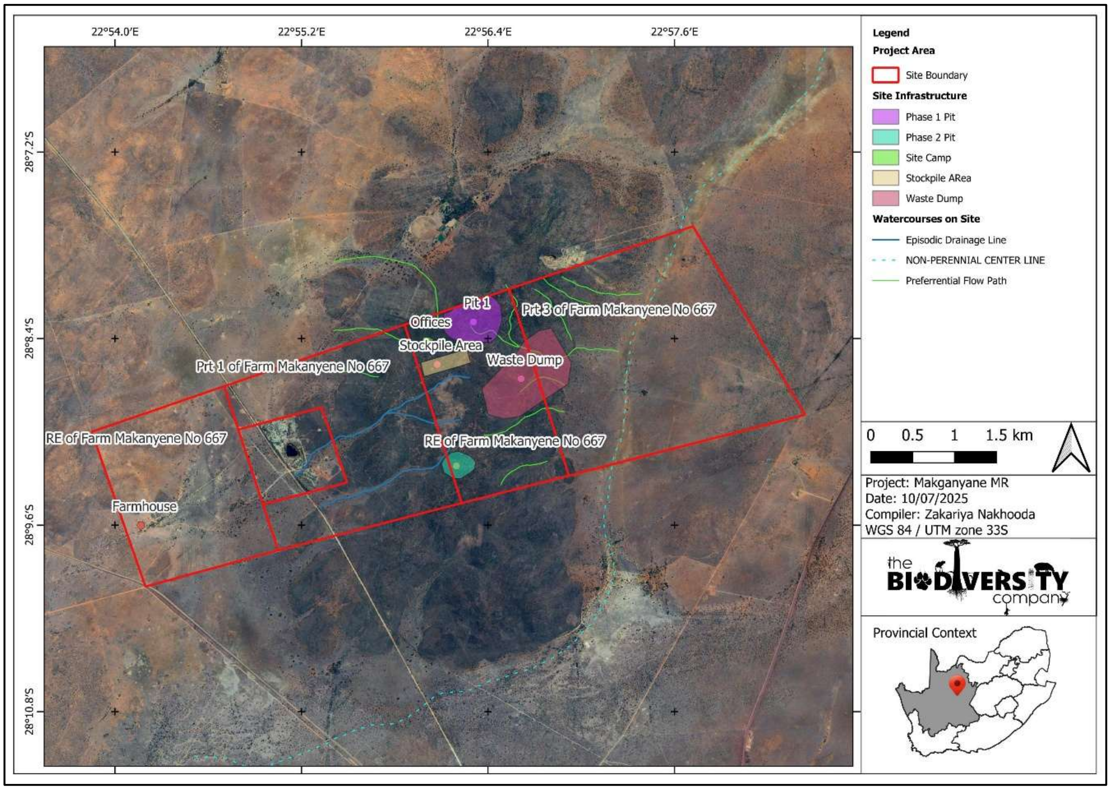

Figure 3-4 Drainage Setting of the Proposed Mine Site

3.4 Water Quality Assessment

Surface water quality samples were collected from the historic Kimberlite shaft. The results were compared to the Department of Water Affairs and Forestry (DWAF) now Department Water and Sanitation (1996). The results together with the relevant guidelines are presented in Table 3-6.

Table 3-6 Water Quality Analytical Results – Kimberlite Shaft

Analyte	Units	Guideline	Kimberlite shaft Shallow	Kimberlite shaft Deep
pH	pH	-	8.55	8.54
Electrical Conductivity	mS/m	-	85.6	85.8
Total Dissolved Solids	mg/l	-	575	569
Alkalinity	mg $CaCO_3$/l		286	287
Chlorine	mg/l	0.0002	**131**	**135**
Sulphate	mg/l	-	26.2	16.5
Nitrate	mg/l	-	0.439	0.399
Ammonium	mg/l	0.007	**0.096**	**0.082**
Phosphate	mg/l	-	-0.009	-0.009
Fluorine	mg/l	-	-0.263	-0.263
Calcium	mg/l	-	28.7	29.4
Magnesium	mg/l	-	72.5	70
Sodium	mg/l	-	76.2	73.4

Analyte	Units	Guideline	Kimberlite shaft Shallow	Kimberlite shaft Deep
Potassium	mg/l	-	11.5	11.2
Aluminum	mg/l	≤0.005	-0.002	-0.002
Iron	mg/l	-	-0.004	-0.004
Manganese	mg/l	0.18	0.067	0.056
Chromium	mg/l	0.007	-0.003	-0.003
Copper	mg/l	0.0003	0.026	0.029
Nickle	mg/l	-	-0.002	-0.002
Zinc	mg/l	0.002	-0.002	-0.002
Cobalt	mg/l	-	-0.003	-0.003
Cadmium	mg/l	0.00025	-0.002	-0.002
Lead	mg/l	0.0002	-0.004	-0.004
Thard - cal	mg $CaCO_3$/l	-	370	362

The water quality results indicated elevated levels of Chlorine and ammonium within the Kimberlite shaft.

It should be noted that apart from the shaft, no other surface water resources within the project site contained any water, as such extensive sampling could not be undertaken.

4 Site Assessment

A site visit was undertaken by TBC in April 2025 to assess the current stormwater infrastructure at the site as well as any potential impacts to the surrounding watercourses, and identify potential risks that may result from the proposed Mine. Images of the assessed sites together with a description is provide in Table 4-1.

Table 4-1 Photos of the Sites Assessed (April 2025)

Plate 1: Stockpile Area – The area lies on relatively flat terrain with the surface water draining towards the preferential flow path located along the northern boundary as show on Figure 4-4.


Plate 2: Pit 1- The Pit 1 site is located on the slope of a hill as can be seen above. The Pit 1 area naturally drains towards the preferential flow path as show on Figure 4-4.


Plate 3: Waste Dump - The area lies on relatively flat terrain with elevation increasing towards the east. The surface water draining towards the preferential flow paths located along the northern boundary and within the area as show on Figure 4-4.


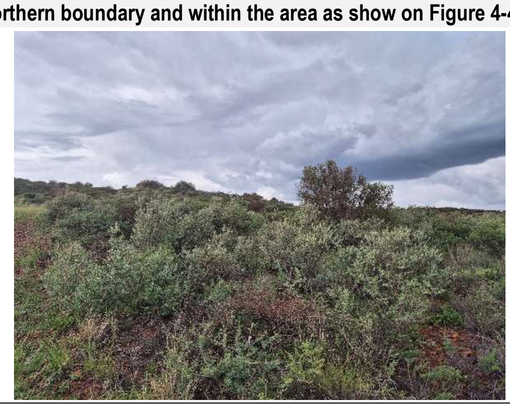

Plate 4: Pit 2 - The Pit 2 site is located on the slope of a hill as can be seen above. The Pit 2 area naturally drains towards the Episodic Drainage Line as show on Figure 4-4.

Plate 5: Image of the Episodic Drainage Line located within the site

5 Design Flood Peaks Calculations

5.1 Catchment Delineation

The contributing catchments to the non-perennial reach under consideration were delineated utilising the topographic data extracted from Google earth. The topographical data was then input to PCSWMM, where the watershed (catchment) delineation function was utilised. To provide a more accurate delineation, aerial imagery was utilised so that current land use and land transformation practices could be incorporated. The delineated catchment is represented in Figure 5-1. Catchment information that was used in generating the design flood estimates for the contributing catchment is summarised in Table 5-1.

Table 5-1 Catchment Parameters

Catchment Parameters	C1
Catchment Area (km^2)	39.38
Length of Longest watercourse (km)	8.2
Mean Annual Precipitation	323
Slope (m/m)	0.015
% of catchment underlain by dolomite	0
Curve Number (HEC-HMS Method)	83
Rainfall Distribution (HEC- HMS Method)	Type 3
SDF Basin Used	13
Kovacs Region Used	K1

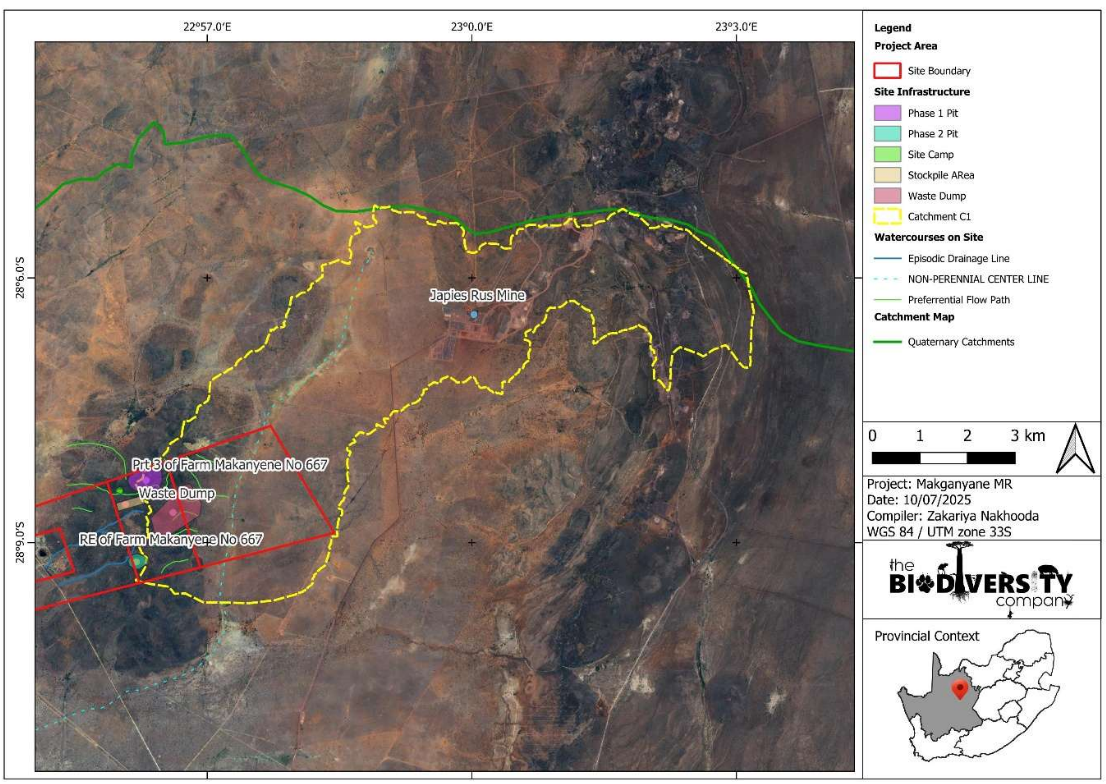

Figure 5-1 Delineated Catchments

5.2 Design Flood Peak Calculation Methods

To evaluate design flood peaks for a watercourse or reach, multiple methods can be utilised. These methods are presented in Table 5-2, together with a description elaborating the rationale behind their use or omission.

Table 5-2 Design Flood Peak Methodologies' Applicability

Method	Used	Comments
Rational Method Alternative 1	No	Applicable catchment <15km^2 but old database
Rational Method Alternative 2	No	Applicable catchment <15km^2 but old database
Rational Method Alternative 3	No	Applicable catchment <15km^2 with new database
Standard Design Flood (SDF) Method	**Yes**	Applicable catchment 10km^2 to 40 000km^2
SCS-SA Method	**Yes^**	Applicable catchment <30km^2
HEC-HMS	**Yes**	Applicable to catchments of all sizes
Empirical Methods		
Midgely and Pitman (M&P)	No	May be applicable to smaller catchments, with preference given to catchment > 100km^2

*The Rational Methods 1 and 2 are based on short, old rainfall databases published in 1978 and 1981 respectively and as a result were excluded as part of the assessment.
^Utilised with caution

The following methods were used to evaluate the relevant design flood peaks for the non-perennial watercourse under consideration owing to the catchment size (39.38 km^2):

- SDF;
- HEC-HMS model; and
- SCS- SA method;

These methods and associated limitations are elaborated upon in the underlying subsections.

5.2.1 Rational Method

The Rational Method uses storm rainfall and catchment characteristics to generate flood peaks. The Rational Method formula indicates that Q = CiA, where the product of rainfall intensity (i) and catchment area (A) is equal to the inflow rate of the system (iA) and C is the runoff co-efficient. The Rational Method yields a design peak only and the flood response is a function of the catchment slope, landuse, land cover, MAP (i.e. point precipitation) and return interval (RI). The time of concentration (Tc) of the flood peak is a function of the catchment dimensions; specifically the watercourse length and slope.

The Rational Method does not factor in a rainfall areal reduction factor (ARF) in its calculations. As a result, the Rational Method has generally been attributed to catchments with an area less than 15 km^2.

Design rainfall intensity is based on the Tc for the catchment. There have been a number of ways in which rainfall intensity could be determined. The methods are explained below:

- Alternative 1 – Using a Depth-Duration-Frequency Diagram
- Alternative 2 – The TR102 representative rainfall data (Adamson, 1981) and the modified Hershfield equation (SANRAL, 2013) is used; and
- Alternative 3 – This alternative stems from a Water Research Commission research project (Smithers & Schulze, 2012) where a rainfall database up to the year 2000 was used in determining the design rainfall. Data from 1 806 rainfall stations in South Africa which have at least 40 years of quality controlled daily records were utilised to estimate design rainfalls. Design rainfall for

durations ranging from 5 minutes to 7 days and for 2- to 200-year return periods at any 1’ latitude x 1’ longitude point in South Africa were determined.

5.2.2 SDF

The SDF Method specifically addresses the uncertainty in flood prediction under South African conditions. The runoff coefficient (C) used in the Rational Method is replaced by a calibrated value based on the sub division of the country into 29 regions or water management areas (WMAs) by using the 2-year mean of the annual daily maximum rainfall and average number of days per year on which thunder was heard. The method is generally a more conservative estimate than the Rational or UH Methods. The SDF Method can be applied to catchments from $10km^2$ to $40\ 000km^2$ in area.

5.2.3 HEC-HMS

The HEC-HMS programme was developed at the Hydrologic Engineering Center (HEC) of the US Army Corps of Engineers. HEC-HMS provides various methods to calculate the loss rate in a basin such as Deficit and constant, exponential loss, Green-Ampt, SCS Curve Number (CN), initial and Constant. Among the methods, the SCS-CN method is widely used. The Soil Conservation Service (SCS) proposed a parametric Unit Hydrograph model; this model is included in the programme.

5.2.4 SCS-SA Method

The SCS-SA Method is a design event-based approach to design flood estimation which has been adapted for use in southern Africa for small catchments (<30km) (Schmidt and Schulze, 1987). The adaptation to the original SCS method for southern Africa includes the following:

- Refinements to the soils classification to cater for soils in southern Africa and the linking of these to the local soil classification systems;
- The development of methods to account for regional differences in median antecedent soil moisture conditions prior to large rainfall events and for the joint association between rainfall and runoff;
- The estimation of design rainfall and typical storm distributions for southern Africa; and
- The development of an empirical equation to estimate catchment lag from small catchments in southern Africa.

5.2.5 Empirical Methods

The Empirical methods are based on the statistical correlation of observed peak flows in the region in question and the catchment properties to generate regional constants. The accuracy of the predictions is dependent on the similarity of the catchment characteristics to the generalised Kovacs K region constant. The Empirical Methods should be applied to catchments larger than $100km^2$ but could be applied with caution to catchments larger than $10\ km^2$ (SANRAL, 2013)

5.3 Design Flood Peak Results

Design flood peaks were calculated using the Rational, HEC-HMS model, SCS-SA and Empirical methods (RMF and M&P). The relevant flood peaks for the 1:100-year return interval for the catchment area is shown in Table 5-3.

Table 5-3 Design Flood Values

Catchment	Return Interval	HEC-HMS (m^3/s)	SCS-SA (m^3/s)	SDF (m^3/s)
C1	1:100-year	49.64	75.48	**81.87**

For the purposes of the hydraulic modelling undertaken as part of this assessment, and in keeping with a conservative approach, the highest peaks were utilised.

6 Hydraulic Modelling

6.1 Methodology

The US Army Corp of Engineers (USACE) Hydrologic Engineering Centre River Analysis System (HEC-RAS) model was used to calculate the relevant flood levels. HEC-RAS undertakes hydraulic calculations between user defined, consecutive river cross-sections along the defined length of the river channel. The HEC-RAS model simulates total energy of water by applying basic principles of mass, continuity and momentum as well as roughness factors between all cross sections (US Army Corps of Engineers, 1995). A depth of flow is calculated at each cross-section, which represents the level to which water will rise at that section, given the potential peak flows.

This was calculated for the 1:100-year recurrence interval for each of the non-perennial watercourses in question. Note that the extent of the topographical data was utilised as a boundary for the floodline delineations.

6.2 Model Inputs and Assumptions

The following model inputs and assumptions were made:

- The accuracy of the floodline delineation and flood hydrographs is reliant on the resolution of the topographical data. The greater the resolution, the higher the accuracy of the delineated flood lines. Readily available topography data attained from the client was utilised; and
- The relevant Manning's roughness coefficients (n) (Chow, 1959 and Arcement and Schneider, 1989) were estimated for channel characteristics, riparian and bank areas based on observations made during the site visit. Relevant values were obtained via data published in, 'HEC-RAS River Analysis System – Hydraulic Reference Manual Version 4.1' (January 2010). The Manning's roughness coefficients (n) for the tributaries was chosen to be 0.045 and the Manning's roughness coefficients (n) for the banks was chosen to be 0.05.

6.3 Results

The modelled 1:100-year floodline for the tributaries is presented in Figure 6-1.

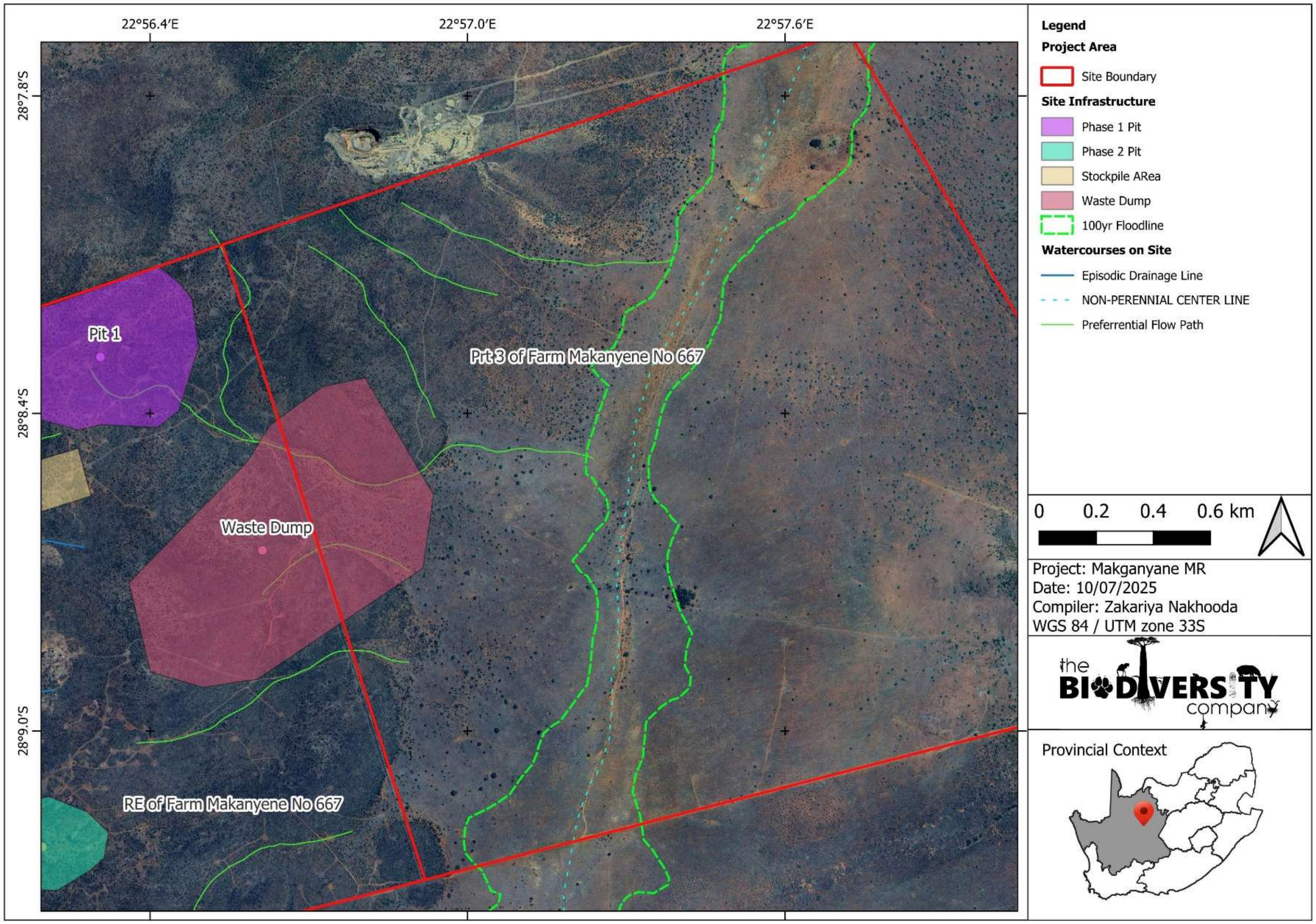

Figure 6-1 1:100-year Floodline

7 Impact Assessment Methodology

he assessment of impacts and mitigation evaluates the likely extent and significance of the potential impacts on identified receptors and resources against defined assessment criteria, to develop and describe measures that will be taken to avoid, minimise or compensate for any adverse environmental impacts, to enhance positive impacts, and to report the significance of residual impacts that occur following mitigation.

The key objectives of the risk assessment methodology are to identify any additional potential environmental issues and associated impacts likely to arise from the proposed project, and to propose a significance ranking. Issues/aspects will be reviewed and ranked against a series of significance criteria to identify and record interactions between activities and aspects, and resources and receptors to provide a detailed discussion of impacts. The assessment considers direct[2], indirect[3], secondary[4] as well as cumulative[5] impacts.

7.1 Definitions and Concepts

Environmental Significance

The concept of significance is at the core of impact identification, evaluation and decision-making. The concept remains largely undefined and there is no international consensus on a single definition. The following common elements are recognized from the various interpretations:

- Environmental significance is a value judgment
- The degree of environmental significance depends on the nature of the impact
- The importance is rated in terms of both biophysical and socio-economic values
- Determining significance involves the amount of change to the environment perceived to be acceptable to affected communities.

Significance can be differentiated into impact magnitude and impact significance. Impact magnitude is the measurable change (i.e. intensity, duration and likelihood). Impact significance is the value placed on the change by different affected parties (i.e. level of acceptability) (DEAT (2002) Impact Significance, Integrated Environmental Management, Information Series 5).

The concept of risk has two dimensions, namely the consequence of an event or set of circumstances, and the likelihood of particular consequences being realised (Environment Australia (1999) Environmental Risk Management).

Impact

The positive or negative effects on human well-being and / or the environment.

Consequence

The intermediate or final outcome of an event or situation OR it is the result, on the environment, of an event.

Likelihood

A qualitative term covering both probability and frequency.

[2] Impacts that arise directly from activities that form an integral part of the Project.
[3] Impacts that arise indirectly from activities not explicitly forming part of the Project.
[4] Secondary or induced impacts caused by a change in the Project environment.
[5] Impacts are those impacts arising from the combination of multiple impacts from existing projects, the Project and/or future projects.

Frequency

The number of occurrences of a defined event in a given time or rate.

Probability

The likelihood of a specific outcome measured by the ratio of a specific outcome to the total number of possible outcomes.

Environment

Surroundings in which an organisation operates, including air, water, land, natural resources, flora, fauna, humans and their interrelation (ISO 14004, 1996).

7.2 Methodology

The environmental significance assessment methodology is based on the following determination:

Environmental Significance = Overall Consequence x Overall Likelihood

Determination of Overall Consequence

Consequence analysis is a mixture of quantitative and qualitative information, and the outcome can be positive or negative. Several factors can be used to determine consequence. For the purpose of determining the environmental significance in terms of consequence, the following factors were chosen: Severity/Intensity, Duration and Extent/Spatial Scale. Each factor is assigned a rating of 1 to 5, as described in the tables below.

Determination of Severity / Intensity

Severity relates to the nature of the event, aspect or impact to the environment and describes how severe the aspects impact on the biophysical and socio-economic environment.

Table 7-1 Table to be used to obtain an overall rating of severity, taking into consideration the various criteria.

TYPE OF CRITERIA	RATING				
	1	2	3	4	5
Quantitative	**0-20%**	**21-40%**	**41-60%**	**61-80%**	**81-100%**
Qualitative	Insignificant / Non-harmful	Small / Potentially harmful	Significant/ Harmful	Great/ Very harmful	Disastrous Extremely harmful
Social/ Community response	Acceptable / I&AP satisfied	Slightly tolerable / Possible objections	Intolerable/ Sporadic complaints	Unacceptable / Widespread complaints	Totally unacceptable / Possible legal action
Irreversibility	Very low cost to mitigate/ High potential to mitigate impacts to level of insignificance/ Easily reversible	Low cost to mitigate	Substantial cost to mitigate/ Potential to mitigate impacts/ Potential to reverse impact	High cost to mitigate	Prohibitive cost to mitigate/ Little or no mechanism to mitigate impact Irreversible
Biophysical (Air quality, water quantity and quality, waste	Insignificant change / deterioration or disturbance	Moderate change / deterioration or disturbance	Significant change / deterioration or disturbance	Very significant change / deterioration or disturbance	Disastrous change / deterioration or disturbance

production, fauna and flora)	

Determination of Duration

Duration refers to the amount of time that the environment will be affected by the event, risk or impact, if no intervention e.g. remedial action takes place.

Table 7-2 Criteria for the rating of duration.

RATING	DESCRIPTION
1	Up to ONE MONTH
2	ONE MONTH to THREE MONTHS (QUARTER)
3	THREE MONTHS to ONE YEAR
4	ONE to TEN YEARS
5	Beyond TEN YEARS

Determination of Extent/Spatial Scale

Extent or **spatial scale** is the area affected by the event, aspect or impact.

Table 7-3 Criteria for the rating of extent / spatial scale.

RATING	DESCRIPTION
1	Immediate, fully contained area
2	Surrounding area
3	Within Business Unit area of responsibility
4	Within the farm/neighbouring farm area
5	Regional, National, International

Determination of Overall Consequence

Overall consequence is determined by adding the factors determined above and summarized below, and then dividing the sum by 3.

Table 7-4 Example of calculating overall consequence.

CONSEQUENCE	RATING
Severity	4
Duration	2
Extent	4
SUBTOTAL	**10**
TOTAL CONSEQUENCE: (Subtotal divided by 3)	**3.3**

Determination of Likelihood

The determination of likelihood is a combination of Frequency and Probability. Each factor is assigned a rating of 1 to 5, as described below.

Determination of Frequency

Frequency refers to how often the specific activity, related to the event, aspect or impact, is undertaken.

Table 7-5 Criteria for the rating of frequency.

RATING	DESCRIPTION
1	Once a year or once/more during operation
2	Once/more in 6 Months
3	Once/more a Month
4	Once/more a Week
5	Daily

Determination of Probability

Probability refers to how often the activity or aspect has an impact on the environment.

Table 7-6 Criteria for the rating of probability.

RATING	DESCRIPTION
1	Almost never / almost impossible
2	Very seldom / highly unlikely
3	Infrequent / unlikely / seldom
4	Often / regularly / likely / possible
5	Daily / highly likely / definitely

Overall Likelihood

Overall likelihood is calculated by adding the factors determined above and summarized below, and then dividing the sum by 2.

Table 7-7 Example of calculating overall likelihood.

CONSEQUENCE	RATING
Frequency	4
Probability	2
SUBTOTAL	**6**
TOTAL LIKELIHOOD (Subtotal divided by 2)	**3**

Determination of Overall Environmental Significance

The multiplication of overall consequence with overall likelihood will provide the environmental significance, which is a number that will then fall into a range of **LOW, LOW-MEDIUM, MEDIUM, MEDIUM-HIGH** or **HIGH**, as shown in the table below.

Table 7-8 Determination of overall environmental significance.

SIGNIFICANCE OR RISK	LOW	LOW-MEDIUM	MEDIUM	MEDIUM-HIGH	HIGH
Overall Consequence X Overall Likelihood	1 - 4.9	5 - 9.9	10 - 14.9	15 – 19.9	20 - 25

Qualitative description or magnitude of Environmental Significance

This description is qualitative and is an indication of the nature or magnitude of the Environmental Significance. It also guides the prioritizations and decision making process associated with this event, aspect or impact.

Table 7-9 Description of environmental significance and related action required.

SIGNIFICANCE	LOW	LOW-MEDIUM	MEDIUM	MEDIUM-HIGH	HIGH
Impact Magnitude	Impact is of very low order and therefore likely to have very little real effect. Acceptable.	Impact is of low order and therefore likely to have little real effect. Acceptable.	Impact is real, and potentially substantial in relation to other impacts. Can pose a risk to company	Impact is real and substantial in relation to other impacts. Pose a risk to the company. Unacceptable	Impact is of the highest order possible. Unacceptable. Fatal flaw.
Action Required	Maintain current management measures. Where possible improve.	Maintain current management measures. Implement monitoring and evaluate to determine potential increase in risk. Where possible improve	Implement monitoring. Investigate mitigation measures and improve management measures to reduce risk, where possible.	Improve management measures to reduce risk.	Implement significant mitigation measures or implement alternatives.

Based on the above, the significance rating scale has been determined as follows:

- **HIGH** - Of the highest order possible within the bounds of impacts which could occur. In the case of negative impacts, there would be no possible mitigation and / or remedial activity to offset the impact at the spatial or time scale for which it was predicted. In the case of positive impacts, there is no real alternative to achieving the benefit.
- **MEDIUM-HIGH -** Impacts of a substantial order. In the case of negative impacts, mitigation and / or remedial activity would be feasible but difficult, expensive, time-consuming or some combination of these. In the case of positive impacts, other means of achieving this benefit would be feasible, but these would be more difficult, expensive, time-consuming or some combination of these.
- **MEDIUM** - Impact would be real but not substantial within the bounds of those, which could occur. In the case of negative impacts, mitigation and / or remedial activity would be both feasible and fairly easily possible, In case of positive impacts; other means of achieving these benefits would be about equal in time, cost and effort.
- **LOW-MEDIUM** - Impact would be of a low order and with little real effect. In the case of negative impacts, mitigation and / or remedial activity would be either easily achieved of little would be required, or both. In case of positive impacts alternative means for achieving this benefit would likely be easier, cheaper, more effective, less time-consuming, or some combination of these.
- **LOW** - Impact would be negligible. In the case of negative impacts, almost no mitigation and or remedial activity would be needed, and any minor steps, which might be needed, would be easy, cheap, and simple. In the case of positive impacts, alternative means would almost all likely be better, in one or a number of ways, than this means of achieving the benefit.
- **INSIGNIFICANT** - There would be a no impact at all – not even a very low impact on the system or any of its parts.

7.3 Impact Mitigation

The impact significance without mitigation measures will be assessed with the design controls in place. Impacts without mitigation measures in place are not representative of the proposed development's actual extent of impact and are included to facilitate understanding of how and why mitigation measures were identified. The residual impact is what remains following the application of mitigation and management measures and is thus the final level of impact associated with the development. Residual impacts also serve as the focus of management and monitoring activities during project implementation to verify that actual impacts are the same as those predicted in this report.

The mitigation measures chosen are based on the mitigation sequence/hierarchy which allows for consideration of five (5) different levels, which include avoid/prevent, minimise, rehabilitate/restore, offset and no-go in that order.

The idea is that when project impacts are considered, the first option should be to avoid or prevent the impacts from occurring in the first place if possible, however, this is not always feasible. If this is not attainable, the impacts can be allowed, however they must be minimised as far as possible by considering reducing the footprint of the development for example so that little damage is encountered. If impacts are unavoidable, the next goal is to rehabilitate or restore the areas impacted back to their original form after project completion. Offsets are then considered if all the other measures described above fail to remedy high/significant residual negative impacts. If no offsets can be achieved on a potential impact, which results in full destruction of any ecosystem for example, the no-go option is considered so that another activity or location is considered in place of the original plan.

The mitigation sequence/hierarchy is shown in Figure 7-1 below.

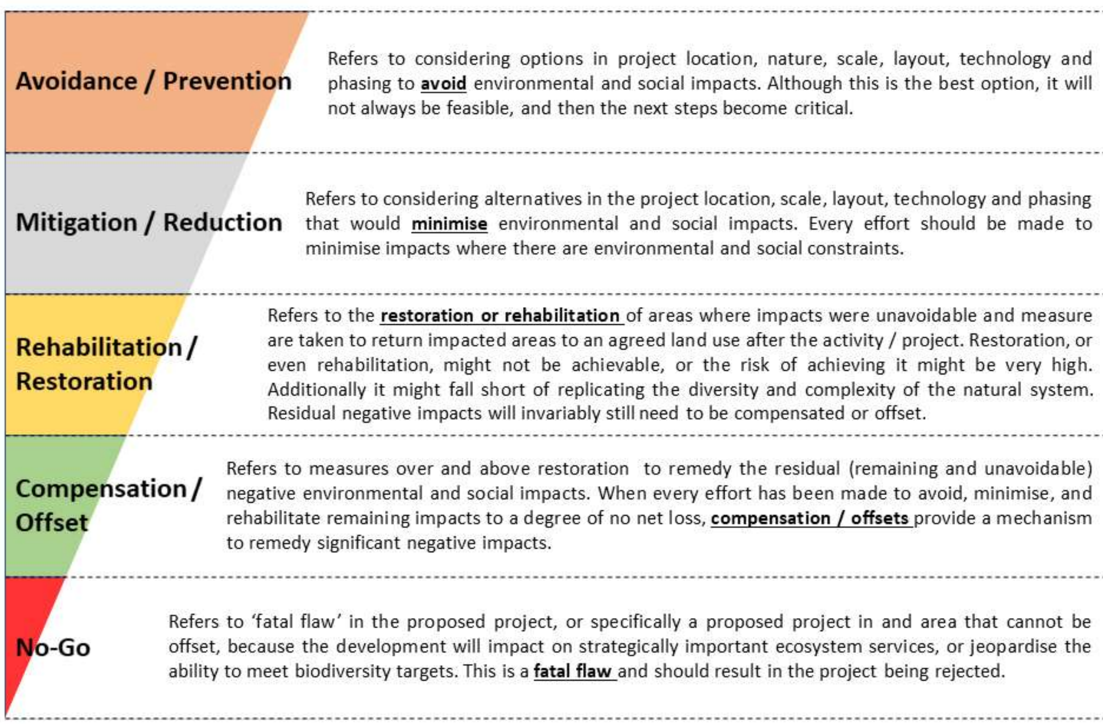

Figure 7-1 Mitigation Sequence/Hierarchy

8 Hydrological Impact Assessment

8.1 Construction Phase Impacts

The surface water impacts associated with the operations of the Proposed Mining Operation are likely to impact on the surrounding surface water resources by affecting the surface water quality and quantity. Identified impacts resulting from the activities include the following:

- Clearing of vegetation for mining operations;
- Water Quality:
  - Sedimentation;
  - Domestic waste and sewage;
  - Hydrocarbons and hazardous materials.
- Destruction of riverine habitat; and
- Alterations to the natural hydrological flow regime.

The impact assessment is presented in Table 8-1.

Table 8-1 Construction Phase Impact Assessment

Potential Impact: Vegetation Clearing	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	4	5	4	5	4	**19.5**	**Medium-High**	(-)
With Mitigation	2	5	3	5	3	**13.33**	**Medium**	(-)
Impact Description	The impacts associated with the removal of vegetation are as follows: • Increased risk of erosion resulting in increased sediments entering the watercourses resulting in changes to water quality; and • Increase in hard standing areas, resulting in potentially higher surface flow entering the nearby watercourses.							
Mitigation and Management Measures	• Areas where works are envisaged should be (where practical) limited to the extent of the footprint, and activities outside of the footprint should be kept to a minimum. • Vegetation should only be removed where absolutely necessary and the areas which can be rehabilitated, should be rehabilitated in a timely manner. • Vehicle movement should be kept to a minimum to reduce soil compaction and limited to existing or proposed roadways where practical. • Any soil excavated during the works, should be appropriately stored in stockpiles which are protected from erosion. • For the duration of the project, stormwater runoff should be directed away from active earthworks. • Signs of erosion must be addressed immediately to prevent further erosion; Temporary and permanent erosion control methods may include silt fences, flotation silt curtains, retention basins, detention ponds, interceptor ditches, seeding and sodding, riprap of exposed embankments, erosion mats, and mulching • The use of sediment traps and/or silt fences is encouraged. • Concentrated surface run-off from the project area flowing down the embankments can scour the surface. This should be catered for by means of the stormwater management plan through the aid channels with energy dissipaters that channel these flows in a controlled manner.							

Potential Impact: Water Quality - Sedimentation	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	3	4	4	4	5	16.5	Medium-High	(-)
With Mitigation	2	2	2	2	3	5	Low-Medium	(-)
Impact Description	As a result vegetation clearing, removal of topsoil for opencast mining activities and the development of road, it is anticipated that soils would be agitated and disperse.							
Mitigation and Management Measures	• Areas where works are envisaged should be (where practical) limited to the extent of the footprint, and activities outside of the footprint should be kept to a minimum. • Any soil excavated during the excavation, should be appropriately stored in stockpiles which are protected from erosion and bermed. • For the duration of the project, stormwater runoff should be directed away from active earthworks. • Signs of erosion must be addressed immediately to prevent further erosion; Temporary and permanent erosion control methods may include silt fences, flotation silt curtains, retention basins, detention ponds, interceptor ditches, seeding and sodding, riprap of exposed embankments, erosion mats, and mulching • Dust suppression at the site is encouraged. • The use of sediment traps and/or silt fences is encouraged. • Concentrated surface run-off from the project area flowing down the embankments can scour the surface. This should be catered for by means of the stormwater management plan through the aid channels with energy dissipaters that channel these flows in a controlled manner.							

Potential Impact: Water Quality - Domestic Waste and Sewerage	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	3	4	2	4	4	12	Medium	(-)
With Mitigation	1	2	1	2	2	2.67	Low	(-)
Impact Description	During the construction period it is anticipated that domestic waste will be generated by staff and contractors. As the project site is located within the vicinity of watercourses, there exists the potential of domestic waste entering them, resulting in impacts on water quality.							
Mitigation and Management Measures	• All contractors and employees should undergo induction which is to include a component of environmental awareness. The induction is to include aspects such as the need to avoid littering, the reporting and cleaning of spills and leaks and general good "housekeeping" • No dumping of any waste or material on-site may take place • All domestic waste must be placed in predefined storage areas and removed from the workings area. These areas should lie outside the 100-year floodline. • Staff should use ablution facilities, which should be located away from the flood plain. • Staff should actively inspect the area for any domestic waste.							

Potential Impact: Water Quality - Hydrocarbons and Hazardous materials	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	3	4	2	4	4	12	Medium	(-)
With Mitigation	2	2	1	2	2	3.33	Low	(-)
Impact Description	During the construction period it is anticipated that hazardous chemicals and/or materials may be stored and utilized on site. These could pose a risk to the surface water resources. The identified areas of concern are: • Waste Dump and stockpile areas; and • Access routes within the mining operations.							
Mitigation and Management Measures	• All contractors and employees should undergo induction which is to include a component of environmental awareness. The induction is to include aspects such as the need to avoid littering, the reporting and cleaning of spills and leaks and general good "housekeeping" • All dangerous goods must be stored in bunded areas located outside the 100-year floodline. • Material Safety Data Sheets should be easily accessible on site. • All hazardous materials should be clearly marked, and appropriate PPE utilized. • Vehicles and equipment should be stored in designated area outside the 100yr floodline. • Develop spill prevention and response plans to address potential leaks or spills of fuels, oils, or other hazardous substances. • The stormwater management plan must factor in the stockpile and waste dump areas and any associated runoff must be captured and re-used. • Trucks utilized for the transport of product should be covered to prevent fines from entering the surrounding environment..							

Potential Impact: Destruction of Riverine habitats	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	5	5	2	5	4	18	Medium-High	(-)
With Mitigation	3	5	2	5	2	11.67	Medium	(-)
Impact Description	The current project footprint is located within the vicinity of existing drainage lines. As such, stream diversions may be required. As such, construction related activities would impact on the riverine habitats. These impacts are listed below: • Increased risk of erosion resulting in increased sediments entering the watercourses resulting in changes to water quality; • Changes to the downstream water quality; • Habitat degradation; and • Alterations to the existing flow regime.							
Mitigation and Management Measures	• The delineated water resources should be marked as no-go areas. In the event that this is unavoidable, all means necessary should be taken to limit impacts to these and restrict the impacts to the smallest footprint. • Future mining activities should be located away from the water resources and associated floodlines. • Instream activities should be considered as least favorable options. • Should any instream activities be required such as the diversion of streams or channel modifications should occur in the dry period to prevent any unforeseen risks of erosion or inundation of the site. • Measures to prevent erosion of the area immediately downstream of the activity should be implemented. These could be the installation of gabions to prevent scour of the immediate downstream regions							

Potential Impact: Alterations to the Natural Flow Regime	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	4	4	3	4	5	**16.5**	**Medium-High**	(-)
With Mitigation	2	4	2	4	2	**8**	**Low-Medium**	(-)
Impact Description	As part of the mining operations, changes to the surface vegetation are anticipated, as such, the natural hydrological flow regime would be impacted upon. It is anticipated that additional hard standing areas will be developed, resulting in increased flows to the watercourses.							
Mitigation and Management Measures	• It is recommended that construction activities be undertaken in a phased approach. • Temporary stormwater management interventions should be included as part of the construction phase. The aim of this should be to control runoff volumes from the newly developed hard standing areas. • Vegetation should be re-established as soon as possible post any construction related activities.							

8.1.1 Operational Phase Impacts

The surface water impacts associated with the operations of the Proposed Mine are likely to impact on the surrounding surface water resources by affecting the surface water quality and quantity. Identified impacts resulting from the activities include the following:

- Water Quality:
    - Sedimentation;
    - Discharge from Operations;
    - Domestic waste and sewage;
    - Hydrocarbons and hazardous materials.
- Alterations to the natural hydrological flow regime:
    - Increased runoff;

The impact assessment is presented in Table 8-2.

Table 8-2 Operational Phase Impact Assessment

Potential Impact: Water Quality - Sedimentation	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	3	5	3	4	5	**16.5**	**Medium-High**	(-)
With Mitigation	2	2	2	2	3	**2.5**	**Low-Medium**	(-)
Impact Description	As a result of opencast mining activities there will be increased earthworks. As a result, sediment mobility is anticipated. This would result in increased sediments entering the watercourses resulting in changes to water quality.							
Mitigation and Management Measures	• Areas where works are envisaged should be (where practical) limited to the extent of the footprint, and activities outside of the footprint should be kept to a minimum. • Any soil excavated during the excavation, should be appropriately stored in stockpiles which are protected from erosion. • For the duration of the project, stormwater runoff should be directed away from active earthworks. • Signs of erosion must be addressed immediately to prevent further erosion; Temporary and permanent erosion control methods may include silt fences, flotation silt curtains, retention basins, detention ponds, interceptor ditches, seeding and sodding, riprap of exposed embankments, erosion mats, and mulching • Dust suppression at the site is encouraged. • The use of sediment traps and/or silt fences is encouraged. • Concentrated surface run-off from the project area flowing down the embankments can scour the surface. This should be catered for by means of the stormwater management plan through the aid channels with energy dissipaters that channel these flows in a controlled manner.							

Potential Impact: Water Quality – Discharge from operations	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	4	5	3	5	4	**18**	**Medium-High**	(-)
With Mitigation	2	3	1	2	2	**4**	**Low**	(-)
Impact Description	There exists the potential for dirty water to enter the surrounding watercourses as a result of operations. Dirty water sources are: • Overflow from PCDs; • Dirty water runoff; • Decant from mining Pits. This water has the potential to contaminate downstream surface water resources.							
Mitigation and Management Measures	• A stormwater management plan must be implemented. • Mining methods should aim to minimise discharge and promote the re-use of water within the operations. • Dirty water catchment areas should be bunded. • Dirty water should be contained in storage facilities, such as PCDs. • This water should either be treated and discharged or re-used within the operations. • Surface water quality sampling should be undertaken on a regular basis to ascertain whether impacts are detected and to what extent.							

Potential Impact: Water Quality - Domestic Waste and Sewerage	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	3	5	2	4	4	**13.33**	**Medium**	(-)
With Mitigation	1	2	1	2	2	**2.67**	**Low**	(-)
Impact Description	During the operations it is anticipated that domestic waste will be generated by staff and contractors. As the project site is located within the vicinity of watercourses, there exists the potential of domestic waste entering them, resulting in impacts on water quality.							
Mitigation and Management Measures	• All contractors and employees should undergo induction which is to include a component of environmental awareness. The induction is to include aspects such as the need to avoid littering, the reporting and cleaning of spills and leaks and general good "housekeeping" • No dumping of any waste or material on-site may take place • All domestic waste must be placed in predefined storage areas and removed from the workings area. These areas should lie outside the 100-year floodline. • Staff should use ablution facilities, which should be located away from the flood plain. • Staff should actively inspect the area for any domestic waste.							

Potential Impact: Water Quality - Hydrocarbons and Hazardous materials	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	3	5	2	4	4	**13.33**	**Medium**	(-)
With Mitigation	1	2	1	2	2	**2.67**	**Low**	(-)
Impact Description	During the operations it is anticipated that hazardous chemicals and/or materials may be stored and utilized on site. These could pose a risk to the surface water resources. The identified areas of concern are: • Waste Dump and stockpile areas; and • Access routes within the mining operations.							
Mitigation and Management Measures	• All contractors and employees should undergo induction which is to include a component of environmental awareness. The induction is to include aspects such as the need to avoid littering, the reporting and cleaning of spills and leaks and general good "housekeeping" • All dangerous goods must be stored in bunded areas located outside the 100-year floodline. • Material Safety Data Sheets should be easily accessible on site. • All hazardous materials should be clearly marked, and appropriate PPE utilized. • Vehicles and equipment should be stored in designated area outside the 100yr floodline. • Develop spill prevention and response plans to address potential leaks or spills of fuels, oils, or other hazardous substances. • The stormwater management plan must factor in the stockpile and waste dump areas and any associated runoff must be captured and re-used. • Trucks utilized for the transport of product should be covered to prevent fines from entering the surrounding environment..							

Potential Impact: Increased Surface water runoff	Severity	Duration	Extent	Frequency	Probability	Significance		Character
Without Mitigation	3	5	3	4	5	**16.5**	**Medium-High**	(-)
With Mitigation	2	5	2	3	3	**9.0**	**Low-Medium**	(-)
Impact Description	As part of the mining operations, changes to the surface vegetation are anticipated, as such, the natural hydrological flow regime would be impacted upon. It is anticipated that additional hard standing areas will be developed, resulting in increased flows to the watercourses.							
Mitigation and Management Measures	• A stormwater management plan must be implemented for the proposed site. The aim of this should be to control runoff volumes from the newly developed hard standing areas. • Vegetation should be re-established as soon as possible post any related activities.							

9 Recommendations

The following recommendations have been made to ensure the conservation of the aquatic resources;

- A competent Environmental Control Officer (ECO) must oversee the construction, operation and rehabilitation phases of the project, with watercourse areas as a priority;
- It is recommended that an Erosion Risk Assessment and Management Plan is completed and implemented to derive the areas at highest risk for erosion. These high-risk areas should then be key points for erosion management throughout the entirety of the project lifecycle.
- The Proposed Mine should have and implement a Rehabilitation Plan that will be active during the life of mine, as well as post-decommissioning. This is to ensure that ecological integrity and ecosystem services can be restored in the event of degraded wetlands and aquatic habitats.
- The Proposed Mine must have and implement a Remediation Plan that encompasses all types of pollution events associated with a Mine.

10 Discussion and Conclusions

The 1:100-year floodline was delineated for the watercourses identified across the site, utilising topographical data supplied by the client. It is recommended that no activities be undertaken within the 1:100-year floodline extents and that these be clearly marked. Based on the current site layout, no activities are envisaged within the 1:100yr floodline extent.

10.1 Risk and Impact Statement

The Proposed Mine is expected to pose "Low" to "Medium" post-mitigation risks to the identified watercourses. Achieving "Low" ratings depends on effective mitigation measures addressing stormwater management, erosion and sedimentation prevention, proper chemical use and storage, rehabilitation of disturbed areas, prevention of runoff into water resources and their buffers, and restricting heavy vehicle operations within specified zones.

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