ZANDBERG SAND MINE

FLOODLINE DETERMINATION REPORT

December 2021

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Report Title: Floodlines Determination Report

December 2021

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EXECUTIVE SUMMARY

Sustainable Drop Projects (Pty) Ltd was appointed to undertake floodline determination as part of the requirements towards completing applications for environmental authorizations for the planned expansion of mining activities by Zandberg Sand Mining. There are a number of alternatives being considered for this planned expansion. Hydrologically, all alternatives under consideration are located within quaternary catchment H40J which falls within the Breede-Overberg Water Management Area (WMA).

The study was conducted through the assessment of Google Earth Satellite imagery, QGIS and site visit as a form of ground truthing as well as desktop-based assessment of data using a variety of tools including Excel spreadsheets, the WRSM2000/WR2012 study and the HEC-RAS application. Catchment characterisation was done using information from satellite images and analysis of Digital Elevation Model (DEM) created using Google Earth Imagery. Climate data used was obtained from 2012 Water Resource study database of the Water Research Commission (WRC, 2012).

The activities undertaken as part of the study included a desk-top based investigation of the sites ‘as well as the regional hydrology, determination of the design rainfall depth for the site corresponding to a 1-day duration with a recurrence interval of 100-years, the use of the rational formula to estimate the corresponding 100-year flood peak flow and finally the routing of this flood peak flow through a 1-dimensional hydraulic model to determine the extent of this flow.

Site-based investigations conducted on 27 November 2021, however, revealed that there was no evidence of flow at the time of the visit. This suggests the drainage line at best experiences ephemeral flow. Moreover, closer on-site investigation suggests that the drainage line is not a defined watercourse in the area that risks being altered by the proposed mining activities.

From the hydraulic model simulation, the Breede River’s 100-year flood inundation areas were determined. All 3 site alternatives under consideration are clear of the inundation area. It is, therefore, the conclusion of this assessment that any of the site alternatives can be pursued since they do not lie within the 100-year flood inundation area provided they are in compliance with other environmental requirements.

D ocument control

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Paulo Kagoda

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1. INTRODUCTION

1.1. Background

Sustainable Drop Projects (Pty) Ltd was appointed to undertake floodline determination as part of the requirements towards completing applications for environmental authorizations for the planned expansion of mining activities by Zandberg Sand Mining. The planned mining development currently has 3 site alternatives on Portion 4 of the Farm Zandberg Fontein 97, Western Cape that are under consideration. The farm is situated approximately 8 km southwest of the Town of Robertson within the Langeberg Local Municipality, which falls under the jurisdiction of the Robertson District Municipality, Western Cape Province.

1.2. Legislative Requirements and Guidelines

The following key legislative requirements and guidelines are relevant to this study:

- National Water Act, 1998 (Act No. 36 of 1998) (NWA)
- Government Notice No. 704 (GN704) of the NWA – Regulations on the Use of Water for Mining and Related Activities Aimed at the Protection of Water Resources - In accordance with this Government Notice, no person in control of a mine or activity may locate or place any residue deposit, dam, reservoir, together with any associated structure or any other facility within the 1:100 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, borehole or well, excluding boreholes or wells drilled specifically to monitor the pollution of groundwater, or on water-logged ground, or on ground likely to become water-logged, undermined, unstable or cracked. Exceptions exist, details of which can be found within the GN704.
- National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA) and associated Environmental Impact Assessment (EIA) 2014 Regulations.

2. SCOPE OF WORK

The following was defined as the scope of work for the study:

- Description of the baseline (current) surface water hydrology;
- Determine the 24-hr or 1-day duration rainfall depths corresponding to the 100-year recurrence intervals.
- Derive the flood peaks for the 100-year recurrence intervals
- Set-up a 1-dimensional hydraulic model on the study catchment
- Apply the hydraulic model to determine the 1:100 year floodlines;

3. SITE LOCATION AND DESCRIPTION

All 3 site alternatives under consideration are located within the Langeberg local municipality as reflected in Figure 3-1. The sites lie to the south of the Breede River and would form an expansion to the on-going sand mining activities already being undertaken by Zandberg Sand Mines.

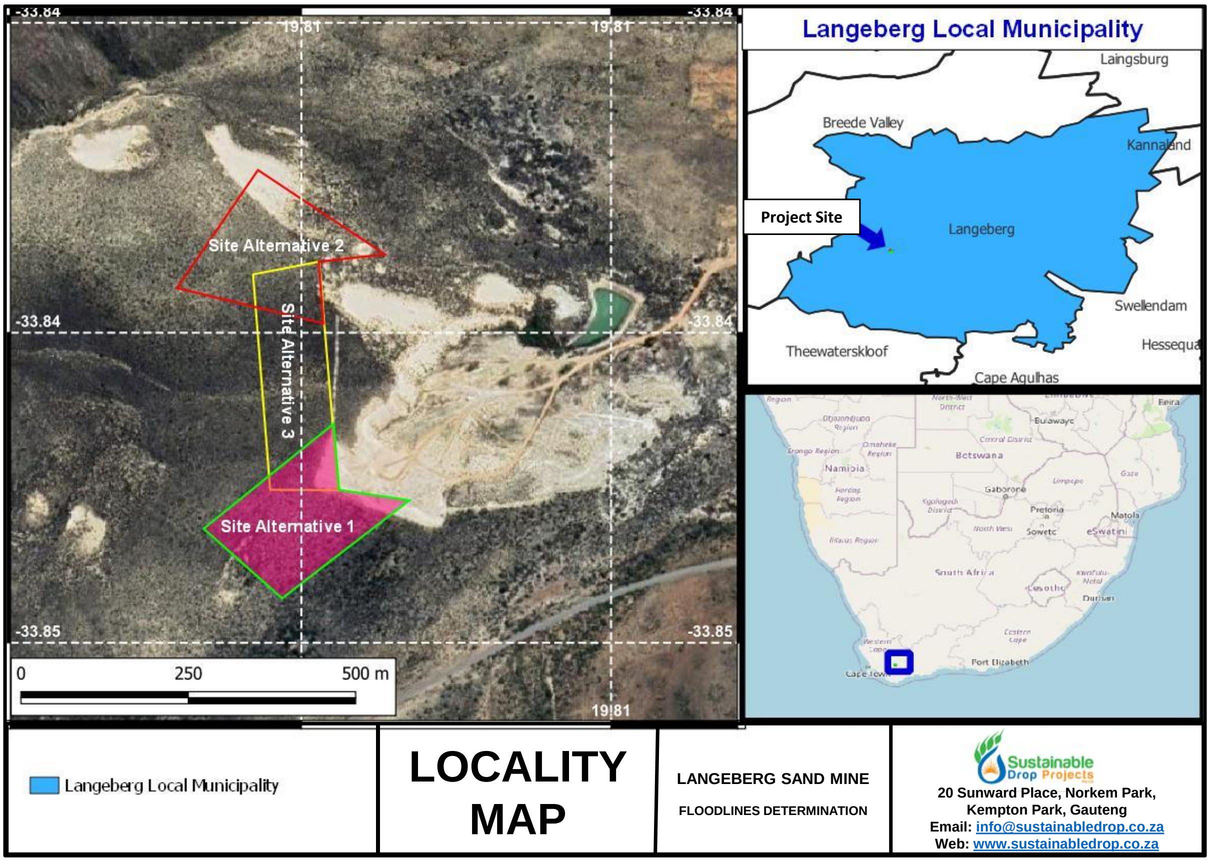

Figure 3-1: Location of the Mining Site alternatives for the Zandberg Sand Mine

a) On-going activities adjacent to site alternatives

b) Approximate location of site alternative 3

Figure 3-2: Select Images of the Site

It was immediately apparent while conducting the site-based investigations that the terrain for all 3 alternatives can characterised as steep with a rising gradient in the westward to north-western direction.

From the desktop assessment, aerial imagery suggests that there is a drainage line that cuts across in a west to east direction across site alternative 3. Site-based investigations conducted on 27 November 2021, however, revealed that there was no evidence of flow at the time of the visit. This suggests the drainage line at best experiences ephemeral flow. Moreover, closer on-site investigation suggests that the drainage line is not a defined watercourse in the area that risks being altered by the proposed mining activities.

4. METHODOLOGY

The study was conducted through the assessment of Google Earth Satellite imagery, QGIS and site visit to confirm ground truth as well as desktop-based assessment of data using a variety of tools including spreadsheets and the HEC-RAS application. Catchment characterisation was done using information from satellite images and analysis of Digital Elevation Model (DEM) created using Google Earth Imagery. Climate data used was obtained from 2012 Water Resource study database of the Water Research Commission (WRC, 2012).

4.1. Materials and Resources used

The following materials and resources were used to conduct this study:

- QGIS Software Application
- Design Rainfall software of South Africa (Schulze,2002)
- Google Earth Pro
- HEC-RAS (US Army Corps of Engineers, 2010)
- WR2012 database (WRC, 2012)
- Microsoft Excel spreadsheets

4.2. Determination of Surface Water Resources Baseline

A hydrological baseline assessment was undertaken to determine the pre-development conditions against which impacts of proposed development and operations would be evaluated. This involved consideration of regional and site hydrology.

4.3. Site-Based Investigations

To validate findings from the desktop-based study and to obtain additional relevant information, a site visit was conducted on 27 November 2021.

4.4. Flood Lines Determination

To achieve the objectives of the hydrological investigations, the following approach was implemented,

- A preliminary desktop-based study was undertaken to obtain as much understanding about the proposed project and the hydrological setting of the location.
- A site examination was conducted and this provided the opportunity for the team to verify information obtained from the desk-based study and also additional information to fill gaps identified during the preliminary desktop-based study.
- A 30m STRM Digital Elevation Model (DEM) was obtained and used to delineate the catchment within which the project site lies. Delineation of the catchments was undertaken using SAGA routines within processing toolbox of QGIS.
- SAGA routines within processing toolbox of QGIS were also used to derive flow paths (streams/rivers) from the DEM.
- The Design Rainfall Utility Software was used to derive the 1-day duration rainfall for the study catchment corresponding to recurrence interval of 100-years.
- Estimation of the design flood at recurrence interval of 100-years was undertaken using the Rational Method,
- HEC-RAS - a 1-demensional hydraulic model – was then used to simulate river flow in the catchments and to indicate the inundation levels corresponding to the 100-year design floods.
- Based on the floodlines generated, a brief discussion of findings was made and compiled into a draft report which subsequently has been finalized (this document) following a review and feedback from the client.

5. BASELINE SURFACE HYDROLOGY

The site for the proposed development and activities is located within quaternary catchment H40J (Figure 5-1) within the Breede-Overberg Water Management Area (WMA) with the quaternary catchment's characteristics presented in Table 5-1. In order to inform the flood analysis, an understanding of baseline hydrology is required. This section presents a comprehensive review of relevant hydrological information and defines the baseline climatic and hydrological conditions of the site and surroundings.

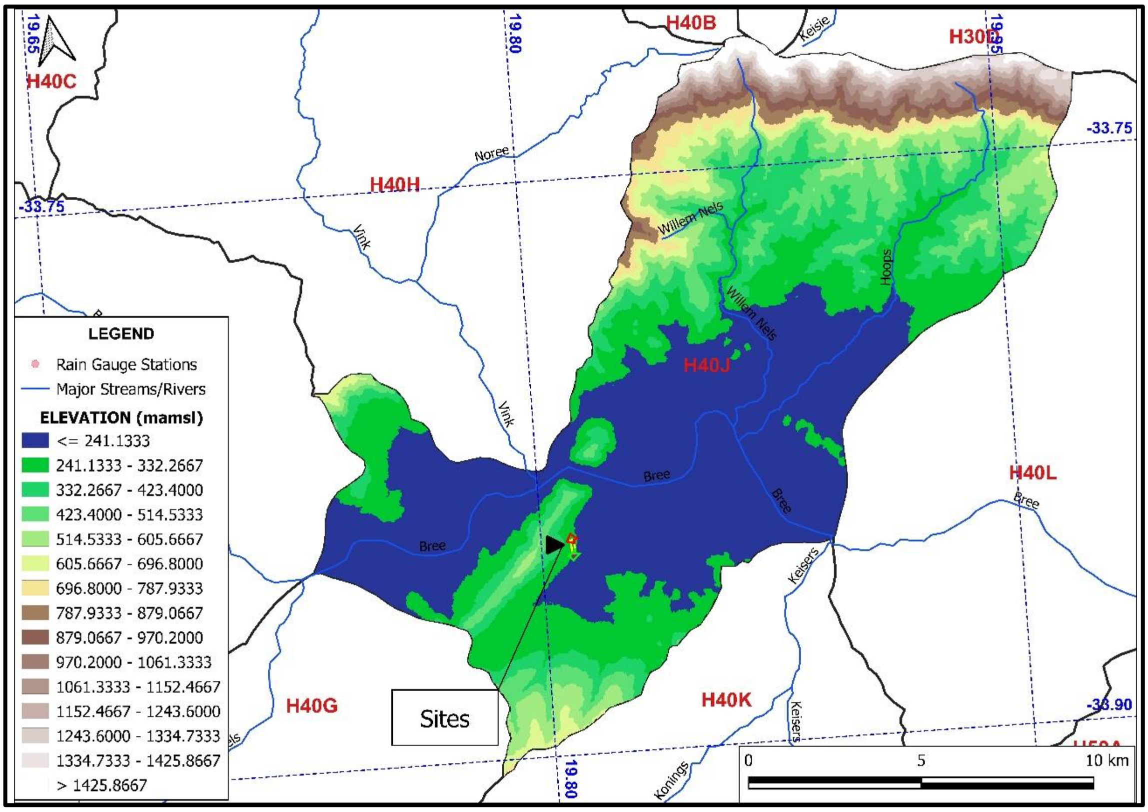

Figure 5-1: Regional and Site Hydrological Setting

As shown in Figure 5-1, the site alternatives under consideration are located to the south of the Breede Rivers which flows through the quaternary catchment in a westerly direction.

Table 5-1: H40J Catchment Characteristics

Catchment Area	204 km²
Mean Annual Runoff	10.85 Mm^3
Mean Annual Precipitation	424 mm
Mean Annual Evaporation (S pan)	1560 mm

5.1. Trends of long-term average monthly rainfall and evaporation

To understand the precipitation pattern for the project area, the statistics of the surrounding stations were extracted and these are presented in Table 5-2. Table 5-3 shows the monthly rainfall and evaporation situation for the quaternary catchment in which the project site is located. The relevant data was derived from the WR2012 database. The rainfall data presented in the table below is for SAWS Station No. 0023629 W, the closest rainfall station to the site, whose mean annual precipitation is 270 mm/year. Also presented in the table below are the monthly evaporation values for the quaternary catchments across which the project site lies.

Table 5-2: Summary of Rainfall input stations

SAWS Number	Distance from Site (km)	Location		Mean Annual Precipitation (mm)
		Latitude	Longitude	
0023611 W	17.22	-33.70	19.87	481
0023629 W	15.21	-33.98	19.85	270
0024110 W	24.12	-33.83	20.07	283
0024197 W	30.65	-33.78	20.13	320
0007183 W	28.68	-34.05	19.62	538

Table 5-3: Mean monthly rainfall and evaporation distribution for H40J Quaternary Catchment

Month	Rainfall (mm/month)	Evaporation (mm/month)
Jan	16.44	234.00
Feb	20.81	185.00
Mar	24.08	153.00
Apr	45.31	99.00
May	45.37	61.00
Jun	46.01	42.00
Jul	48.88	46.00
Aug	49.44	64.00
Sep	29.39	99.00
Oct	34.40	151.00
Nov	32.00	193.00
Dec	22.29	234.00

(Source: WRSM2000)

It is apparent from Table 5-3 that the catchment lies within a winter rainfall part of the country since the months of April to August are when most rainfall is received.

5.2. Regional average Monthly Temperatures

The regional temperature data (Table 5-4)) was obtained from Climate-Data.Org. For this study, the temperature data for Robertson was used.

Table 5-4: Project Site Monthly Temperatures (Source: https://en.climate-data.org/africa/south-africa/western-cape/robertson-13552/)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avg. Temperature °C	22.1	22.2	20.6	18	15.1	11.8	11.1	12.1	14.1	17	18.7	21
Min. Temperature °C	16	16.3	15.1	12.5	9.7	6.3	5.5	6.4	8.2	11	12.6	14.9
Max. Temperature °C	29.9	29.8	27.8	24.5	21.2	17.7	17.2	18.1	20.6	24	26.1	28.7

5.3. Climate

A plot of the regional monthly temperatures, evaporation and rainfall data was prepared and is shown in Figure 5-2. It is clear from the plot that on average evaporation exceeds rainfall throughout the year.

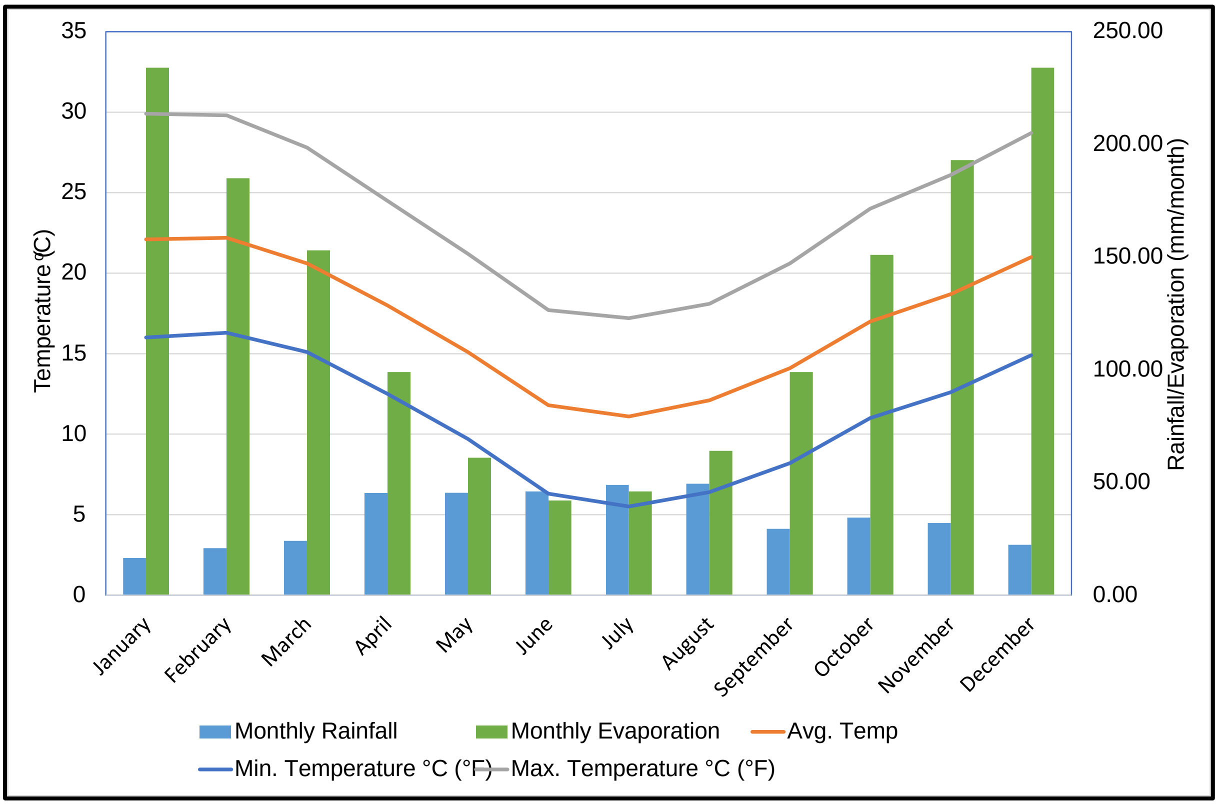

Figure 5-2: Plot of Catchment Evaporation vs Rainfall for Project Site

The plot clearly indicates that the seasonal pattern of evaporation and temperatures is nearly identical while both of these patterns differ from the seasonal rainfall pattern. This is characteristic of a winter rainfall region. It is also apparent that the Mean Annual Evaporation (MAE) exceeds the Mean Annual Rainfall (MAP) on account of the mean monthly values of evaporation for all months except June and July being greater than the corresponding monthly rainfall values.

5.4. Design Rainfall Depths

Design storm estimates for various return periods and storm durations were sourced from the Design Rainfall Estimation Software for South Africa, developed by the University of Natal in 2002 as part of a WRC project K5/1060 (Smithers and Schulze, 2002). This method uses a Regional L-Moment Algorithm in conjunction with a Scale Invariance approach to provide site specific estimates of Design Rainfall depths for specified durations at various recurrence intervals. Table 5-5 presents the design rainfall depths that were derived from the Smithers and Schulze method based for Station No. 0023629 W.

Table 5-5: 1-day Design Rainfall Depths (mm)

Station Name	SAWS No.	Altitude (m)	Duration	Recurrence Interval (Years)	
				50	100
RHEBOKSKRAAL	0023629_W	290	1 day	94.9 mm	111.2 mm

6. FLOOD ANALYSIS

The focus of the flood analysis was the Bree River's catchment up to the point it exits the quaternary catchment H40J (Figure 6-1). This then necessitated the consideration of all the quaternary catchments upstream that contribute to flow within Breede River and its various tributaries. The aim of the flood analysis undertaken as part of this study was to fulfil the requirements of the National Water Act (Act 36 of 1998).

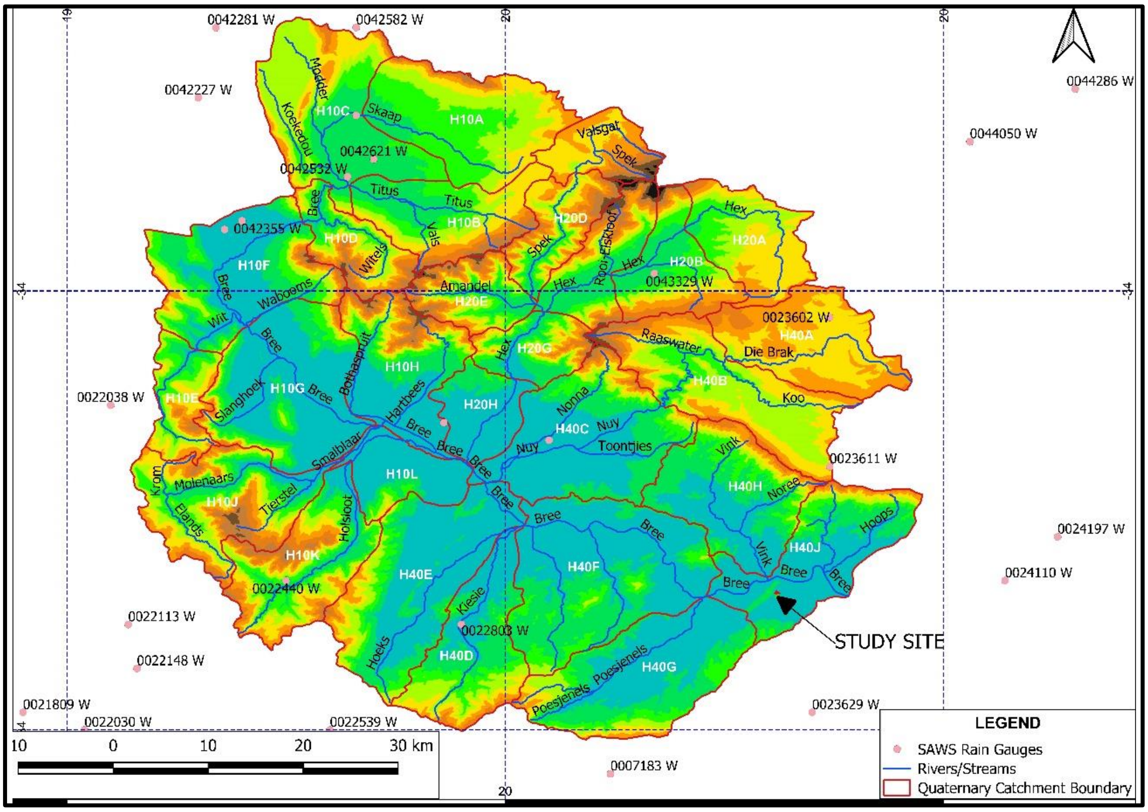

Figure 6-1: Flood Study Catchment

For this study, the rational formula (Equation 6.1) was applied to determining the flood peaks for the study catchment. The basis of the relationship was the law of conservation of mass and the hypothesis was that the flow rate was directly proportional to the size of the contributing area and the rainfall intensity.

$$Q = \frac{C I A}{3.6} \qquad \text{Equation 6.1}$$

Where:

	Q	is the peak flow (m^3/s)
	C	is the run-off coefficient
	I	is the average rainfall intensity over the catchment (mm/hour)
	A	is the effective area of the catchment (km^2)
	3.6	is the conversion factor

The rational formula's application was based on the following assumptions: -

I. The rainfall has a uniform areal distribution across the total contributing catchment
II. The rainfall has a uniform temporal distribution for at least duration equal to the time of concentration (T_c).
III. The peak discharge occurs when the total catchment contributes to the flow at the exit, which occurs at the end of the critical storm duration, or the time of concentration (T_c).
IV. The run-off coefficient remains constant throughout the duration of the storm
V. The return period of the peak flow, T, is the same as that of the rainfall intensity.

Run-off Coefficients

There is no objective theoretical method for determining the run-off coefficient of a catchment (SANRAL, 2013) and as a result the subjective elements of experience and engineering judgement play a very important role in the determination of the run-off coefficient. For this study, SANRAL Drainage manual was referenced on how Table 6-1 can be applied in the determination of the run-off coefficient.

Table 6-1: Recommended values of run-off factor C for use in the Rational method (Source: SANRAL Drainage Manual)

Rural (C_1)				
Component	Classification	Mean annual rainfall (mm)		
		< 600	600 - 900	> 900
Surface Slope (Cs)	Vleis and Pans (<3%)	0.01	0.03	0.05
	Flat areas (3 to 10%)	0.06	0.08	0.11
	Hilly (10 to 30%)	0.12	0.16	0.20
	Steep areas >30%)	0.22	0.26	0.30
Permeability (Cp)	Very Permeable	0.03	0.04	0.05
	Permeable	0.06	0.08	0.10
	Semi Permeable	0.12	0.16	0.20
	Impermeable	0.21	0.26	0.30
Vegetation (Cv)	Thick bush and Plantation	0.03	0.04	0.05
	Light Bush and farm lands	0.07	0.11	0.15
	Grasslands	0.17	0.21	0.25
	No vegetation	0.26	0.28	0.30

Urban (C_2)	
Use	Factor
Lawns	
Å Sandy, Flat (<2%)	0.05 – 0.10
Å Sandy, steep (>7%)	0.15 – 0.20
Å Heavy soil, flat (<2%)	0.13 – 0.17
Å Heavy soil, steep (<7%)	0.25 – 0.35
Residential Area	
Å Houses	0.30 – 0.50
Å Flats	0.50 – 0.70
Industry	
Å Light Industry	0.50 – 0.80
Å Heavy Industry	0.60 – 0.90
Business	
Å City Centre	0.70 – 0.95
Å Suburban	0.50 – 0.70
Å Streets	0.70 – 0.95
Å Maximum Flood	1.00

6.1.1. Landcover

In order to determine the runoff coefficient, (C), for application in Equation 6.1, the 2013-14 SA National Land-Cover dataset was referenced (GEOTERRAIMAGE, 2015). The 2013-14 SA National Land-Cover dataset has been generated from digital, multi-seasonal Landsat 8 multispectral imagery, acquired between April 2013 and March 2014. The land-cover dataset, which covers the whole of South Africa, is presented in a map-corrected, raster format, based on 30x30m cells equivalent to the image resolution of the source Landsat 8 multi-spectral imagery. The dataset contains 72 land-cover/use information classes, covering a wide range of natural and man-made landscape characteristics. It is from this national dataset that the study sub-catchments' landcover was derived and is presented in Figure 6-2.

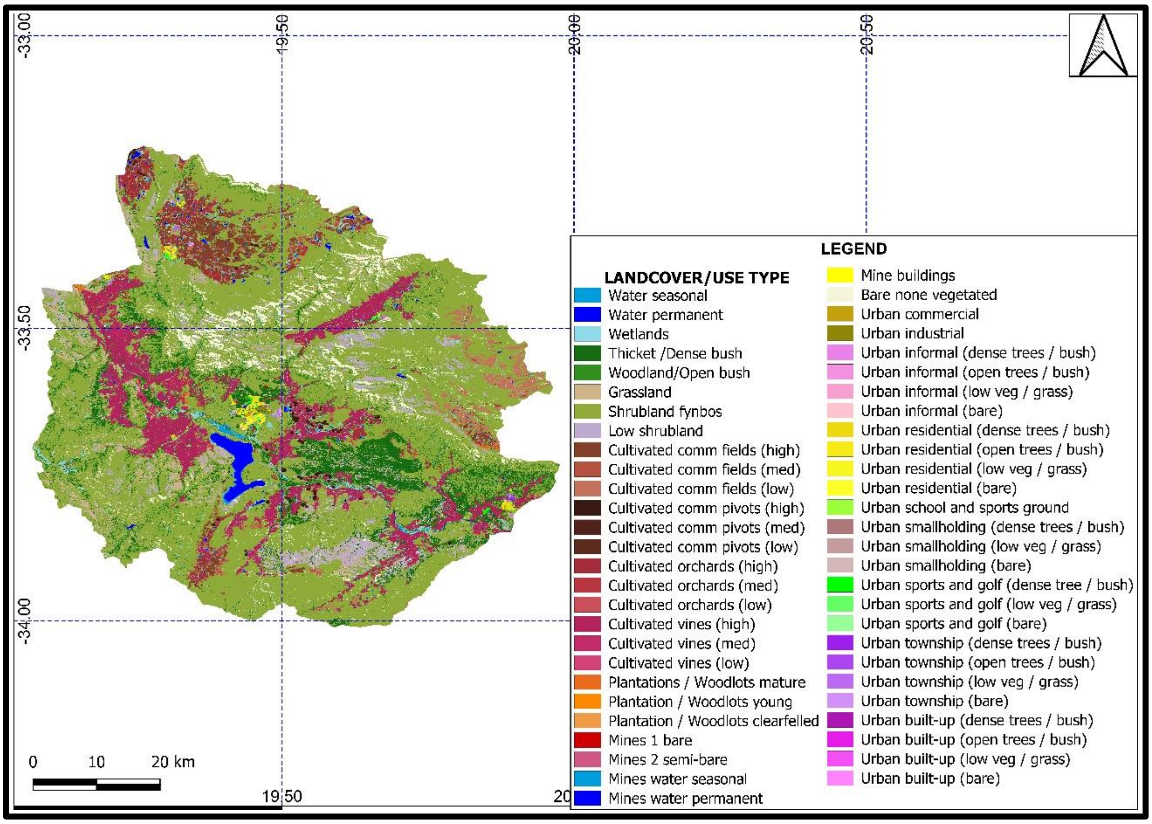

Figure 6-2: Catchment Land Cover/Use Types

Table 6-2: Catchment Land Cover/Use Type by Area

Land Cover/Use Type	Area	
	m^2	as %age of Total Catchment Area
Water seasonal	22 619 936.03	0.39%
Water permanent	57 119 028.48	0.99%
Wetlands	87 641 777.67	1.52%
Thicket /Dense bush	466 951 596.91	8.11%
Woodlan/Open bush	105 749 162.38	1.84%
Grassland	249 291 048.89	4.33%
Shrubland fynbos	3 443 972 168.16	59.79%
Low shrubland	203 788 269.67	3.54%
Cultivated comm fields (high)	117 991 326.26	2.05%
Cultivated comm fields (med)	62 029 429.21	1.08%
Cultivated comm fields (low)	94 990 746.34	1.65%
Cultivated comm pivots (high)	15 536 062.58	0.27%
Cultivated comm pivots (med)	3 299 572.24	0.06%
Cultivated comm pivots (low)	794 203.21	0.01%
Cultivated orchards (high)	79 550 442.47	1.38%
Cultivated orchards (med)	21 696 459.95	0.38%
Cultivated orchards (low)	2 655 101.00	0.05%
Cultivated vines (high)	378 103 900.89	6.56%
Cultivated vines (med)	91 023 378.61	1.58%

Land Cover/Use Type	Area	
	m^2	as %age of Total Catchment Area
Cultivated vines (low)	9 607 956.99	0.17%
Plantations / Woodlots mature	10 771 631.03	0.19%
Plantation / Woodlots young	786 628.88	0.01%
Plantation / Woodlots clearfelled	569 214.02	0.01%
Mines 1 bare	1 160 589.95	0.02%
Mines 2 semi-bare	487 503.82	0.01%
Mines water seasonal	60 145.29	0.00%
Mines water permanent	71 497.31	0.00%
Mine buildings	17 224.19	0.00%
Bare none vegetated	192 029 478.81	3.33%
Urban commercial	1 791 609.99	0.03%
Urban industrial	3 085 141.31	0.05%
Urban informal (dense trees / bush)	43 920.58	0.00%
Urban informal (open trees / bush)	15 267.88	0.00%
Urban informal (low veg / grass)	773 444.97	0.01%
Urban informal (bare)	503 626.35	0.01%
Urban residential (dense trees / bush)	11 012 488.81	0.19%
Urban residential (open trees / bush)	123 097.20	0.00%
Urban residential (low veg / grass)	5 543 557.29	0.10%
Urban residential (bare)	1 319 944.69	0.02%
Urban school and sports ground	3 326 679.75	0.06%
Urban smallholding (dense trees / bush)	83 124.87	0.00%
Urban smallholding (low veg / grass)	351 396.06	0.01%
Urban smallholding (bare)	38 183.79	0.00%
Urban sports and golf (dense tree / bush)	2 605 040.06	0.05%
Urban sports and golf (open tree / bush)	4 781.50	0.00%
Urban sports and golf (low veg / grass)	1 294 600.66	0.02%
Urban sports and golf (bare)	21 972.05	0.00%
Urban township (dense trees / bush)	1 095 566.01	0.02%
Urban township (open trees / bush)	18 150.00	0.00%
Urban township (low veg / grass)	3 572 178.87	0.06%
Urban township (bare)	889 391.14	0.02%
Urban built-up (dense trees / bush)	251 945.29	0.00%
Urban built-up (open trees / bush)	14 316.90	0.00%
Urban built-up (low veg / grass)	325 827.74	0.01%
Urban built-up (bare)	1 386 115.38	0.02%

On the basis of the guideline recommendations for runoff coefficient determination in Table 6-1 and the landcover types for catchment (Figure 6-1 and Table 6-2), a representative run-off coefficient value of 0.33 was obtained on an area-weighted basis.

6.2. Peak Flow Rates

The rational formula (Equation 6-1) was applied to obtain and determine the flood peaks for study basin. The detailed output is presented in Appendix 1 with a summary presented in Table 6-3.

Table 6-3: Catchment Flood Peak Estimates

Recurrence Interval (years)	Flood Peak (m^3/s)
50	1 409.33
100	1 651.39

7. HYDRAULIC MODELLING

The main motivation for this floodline determination study was to determine area that would be inundated by a flood with a recurrence interval of 100-years. To determine this, a 1-dimensional hydraulic model was set up for the Breede River up to its confluence with its tributary using the HEC RAS 5.0.6 application.

HEC-RAS is designed to perform one-dimensional hydraulic calculations. This was further used to define the channel and banks within the model.

7.1. Modelling Assumptions

The key assumptions include:

- The Manning's *n* value used is considered suitable for use in the 100-year return periods modelled, as well as in representing both the channel and banks.
- A steady state model has been used to define flooding. The use of a steady state model assumes that the area of interest is sensitive to peak flows rather than flood volume. Due to the topography of the site, peak flows are expected to be suitable for defining flood extents.

7.2. Model Set-Up

A default Manning's n value of 0.035 was used in defining the roughness for the channel and banks (Chow, 1959). The peak flows used in the hydraulic model were calculated and presented in Table 6-3. Peak flows and inflow boundaries have been calculated based upon an understanding and the delineation of the respective catchment.

The *Ras Mapper* application that comes embedded within the HEC-RAS was used to generate the river cross-section cutlines. Starting with a cross-sectional spacing of 100 m, alterations (deletion and additions of cross-sections) were manually made within the Ras Mapper environment based on the morphology of stream. Following this, elevations along each cross-section were computed by Ras Mapper from the STRM Digital Elevation Model (DEM).

7.3. Results

Following the successful set-up of the model, it was applied in Steady State configuration to route a flood peak flow with the recurrence interval of 100 years through the Breede River. The 100-year floodline results of the hydraulic modelling are presented in Figure 7-1 where the floodline extent for the 1:100 year event is mapped.

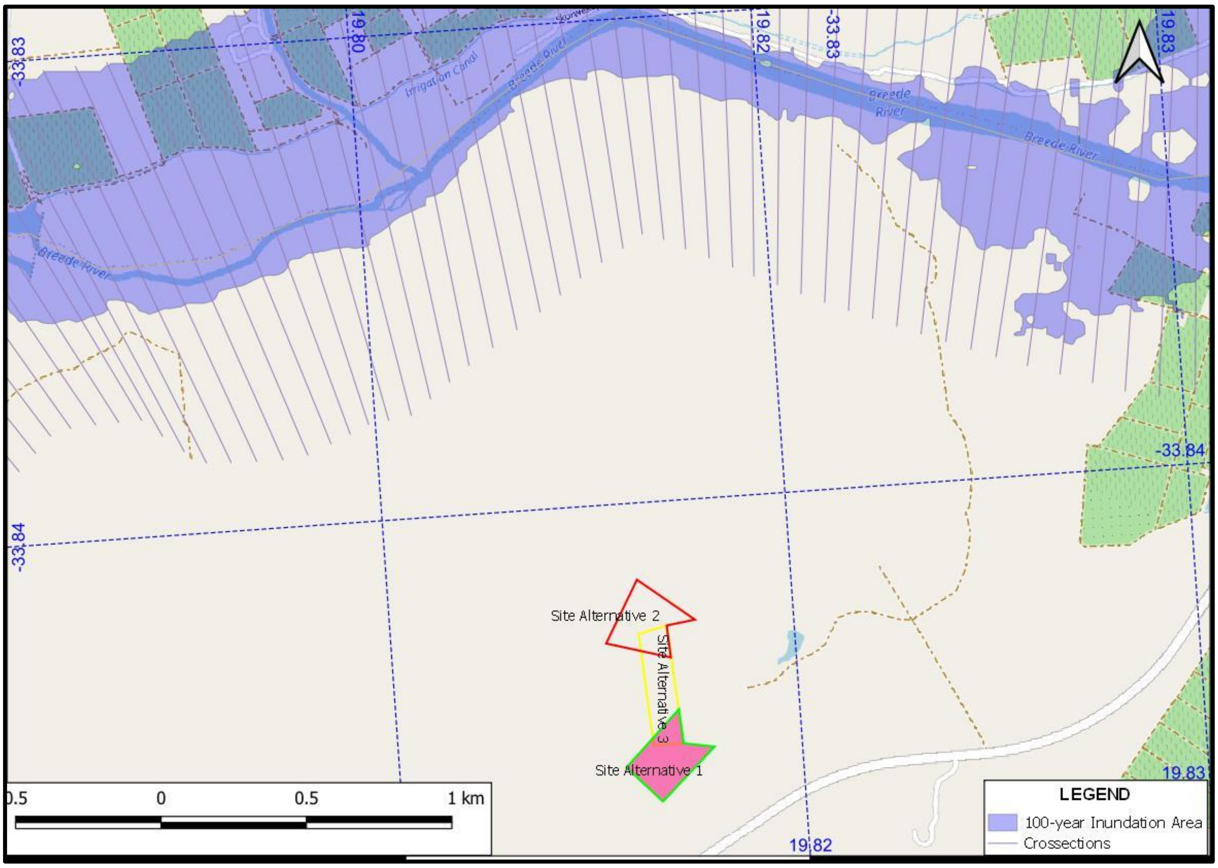

Figure 7-1: 100-year Inundation Area

It is apparent that all 3 site alternatives do not lie within the inundation area.

8. CONCLUSIONS AND RECOMMENDATIONS

This floodline determination study was conducted in support of the applications for environmental authorizations/Water Use License Application (WULA) for the Zanberg Sand Mine. The activities undertaken as part of the study included a desk-top based investigation of the site alternatives as well as the regional hydrology, determination of the design rainfall depth for the site corresponding to a 1-day duration with a recurrence interval of 100-years, the use of the rational formula to estimate the corresponding 100-year flood peak flow and finally the routing of this flood peak flow through a 1-dimensional hydraulic model to determine the extent of this flow.

From the hydraulic model simulation, the Breede River's 100-year flood inundation areas were determined. All site alternatives under consideration are not within the inundation area and as such can all remain under consideration PROVIDED they are in compliance with the findings of other specialist studies required to support the application.

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APPENDICES

Appendix 1: Rational Formula Calculations and Output

MAP	424		
			Catchment
			-
Area	km^2		5 057.10
	m^2		5 057 100 719.39
Longest Path	km		156.72
	m		156 723.92
Elevation at 10% of the length of the water course (m)			167.00
Elevation at 85% of the length of the water course (m)			497.00
Average slope of the longest water course			0.0028
Time of Concentration (hrs)			31.22
Point Intensity (mm/hour)			
50 year			3.04
100 year			3.56
Runoff Coefficient, C			0.33
Peak Flow (m^3/s)			
50 year			1 409.33
100 year			1 651.39

	50 year	100 year
Point Design Rainfal	94.90	111.20