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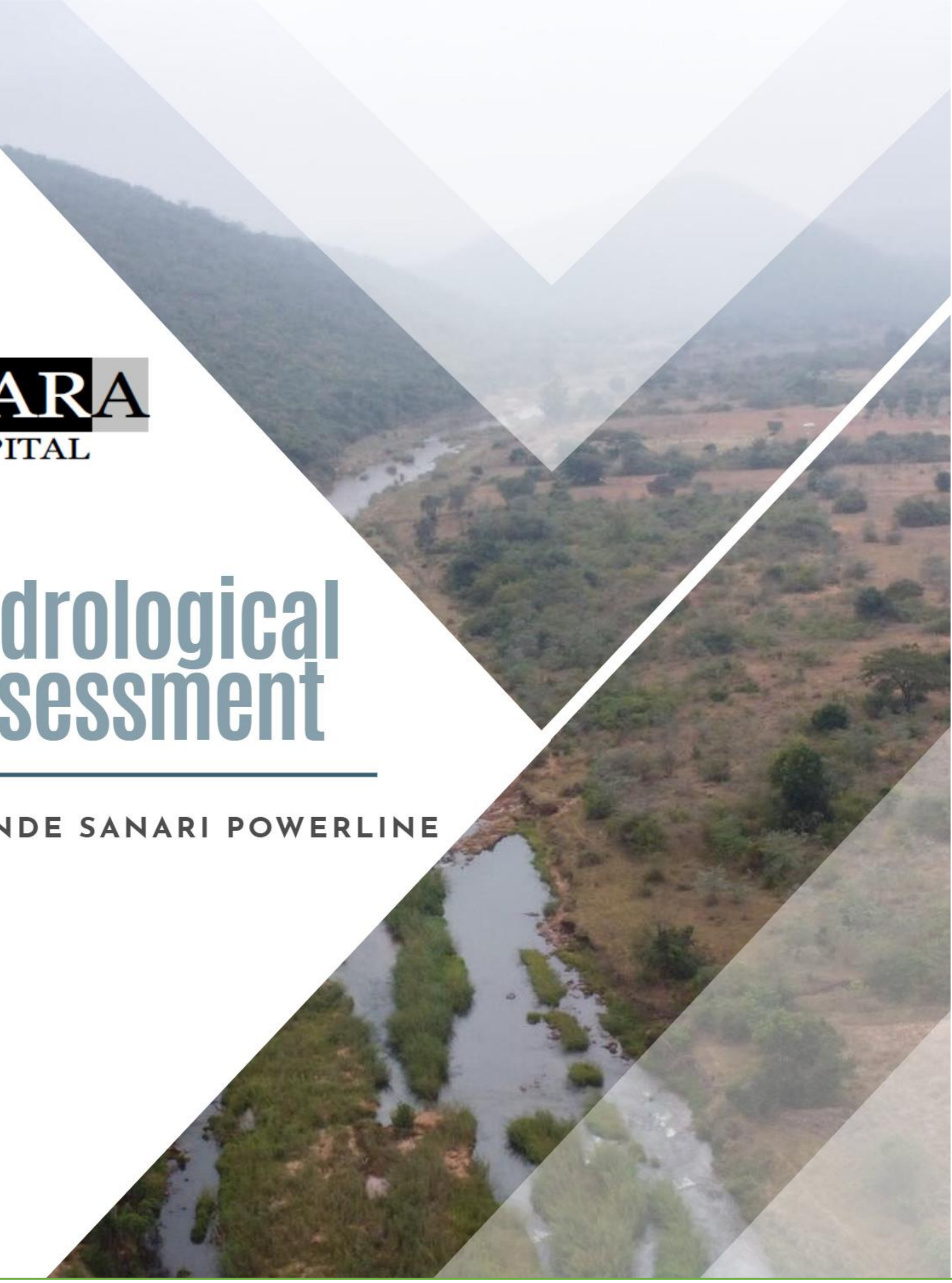

Hydrological Assessment

MAKONDE SANARI POWERLINE

PROPOSED CONSTRUCTION OF ±7KM 132KV POWER LINE FROM MAKONDE SANARI POWERLINE AT TSWERA TO NEW MUTSHIKILI SUBSTATION AT THENGWE WITHIN THULAMELA LOCAL MUNICIPALITY OF VHEMBE DISTRICT, LIMPOPO PROVINCE

June 2023

PROPOSED CONSTRUCTION OF ±7KM 132KV POWER LINE FROM MAKONDE SANARI POWERLINE AT TSWERA TO NEW MUTSHIKILI SUBSTATION AT THENGWE WITHIN THULAMELA LOCAL MUNICIPALITY OF VHEMBE DISTRICT, LIMPOPO PROVINCE

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GLOSSARY OF TERMS

This section provides a catalogue of terms and definitions, which may be used in this report and, or other documents appended to the report. Where more than one definition for a term exists in the literature, additional definitions have been provided for clarity.

Table 1: Glossary of terms

Term	Definition
Catchment	A catchment defines an area within which water will naturally drain to a defined point.
Catchment Management Agencies	Catchment Management Agencies were created in terms of the National Water Act, 1998 (Act 36 of 1998) to manage water resources within defined major catchments.
Development	Means the building, erection, construction or establishment of a facility, structure or infrastructure, including associated earthworks or borrow pits, that is necessary for the undertaking of a listed or specified activity but excludes any modification, alteration or expansion of such a facility, structure or infrastructure, including associated earthworks or borrow pits, and excluding the redevelopment of the same facility in the same location, with the same capacity and footprint.
E10 to E90	A range of exceedance probability of events – this is the likelihood of a storm event of a certain magnitude being exceeded.
Floodlines	mean lines on a map or drawing depicting water levels likely to be reached by a flood having a specified recurrence interval;
Floodplain	means the land adjoining a watercourse which is susceptible to inundation by floods up to the one-hundred-year recurrence interval;
HEC-RAS	Hydrologic Engineering Center's River Analysis System software that allows the user to perform one-dimensional steady flow calculations, one and two-dimensional unsteady flow calculations, sediment transport/mobile bed computations, and water temperature/water quality modelling.
HEC-GeoRAS	HEC-GeoRAS is a set of procedures, tools, and utilities for processing geospatial data in ArcGIS using a graphical user interface (GUI). The interface allows the preparation of geometric data for import into HEC-RAS and processes simulation results exported from HEC-RAS.
Hydrology	Hydrology describes a field of study that analyses the natural cycles of water as it passes through the environment. Aspects analysed include rainfall, evaporation, transpiration and runoff. Hydrology also refers to the results of analysis of certain aspects of hydrological cycles, such as river flow, or likely peak floods.
MAE	Mean Annual Evaporation refers to the yearly average amount of water that evaporates from open water bodies, land and vegetation surfaces into the atmosphere.

Term	Definition
MAP	Mean Annual Precipitation refers to the yearly average precipitation generally calculated from the last 30 years of data for a place or region.
MAR	Mean Annual Runoff refers to the average amount of water that flows down a particular river, per year, expressed either as a depth (in millimetres) of water spread evenly across the entire drainage basin, or as a volume (in cubic metres) of water flowing past a given point.
Return Period:	Also known as a recurrence interval is an estimate of the likelihood of an event. This is the average interval between rainfall or flood events equalling or exceeding a specified severity.
Runoff	Surface runoff is defined as the water that finds its way into a surface water channel without infiltration into the soil and may include overland flow, interflow and base flow.
SDF	Standard Design Flood method specifically addresses the uncertainty in flood prediction under South African conditions.
WMAs	Water Management Areas. These are catchments defined by the Department of Water and Sanitation for the South African Province, they provide the framework within which water will be managed at regional or catchment level.

LIST OF ABBREVIATIONS / ACRONYMS

ARM	Alternative Rational method
DDF	Depth Duration Frequency
DEM	Digital Elevation Model
DWS	Department of Water and Sanitation
SDF	Standard Design Flood
MAE	mean annual evaporation
MAP	mean annual precipitation
MAR	mean annual runoff
Q_T	Flood peak for return period T
RMDWA	Rational method DWA
RMAL	Rational method Alternative algorithm
SAWS	South African Weather Services
T	Return Period
TIN	Triangulated Irregular Network
SDF	SDF method
WMA	Water Management Area
WUL	Water Use Licences
UPD	Utility Programs for Drainage

1. INTRODUCTION

1.1 BACKGROUND

DIGES Group has appointed Zara Capital (PYT) LTD to undertake technical Hydrological assessment and flood determination for the proposed construction of the ±7-kilometer 132KV powerline from Makonde Sanari Powerline at Tswera, to the new Mutshikili substation at Thengwe within Thulamela Local Municipality of Vhembe District, Limpopo province.

The assessment includes two proposed powerline corridors and the respective powerline routes. The following sections detail the approach and the methods used in the development of a hydraulic model to define the flood extents (1:50 year, 1:100 year) for the proposed powerline.

1.2 STUDY AREA

The proposed ±7-kilometer 132KV powerline project aims to address voltage constraints, thermal limits, and reliability issues in the Mutshikili substation area. This substation is intended to strengthen the existing network supplied by the Makonde substation, specifically the Makonde-Thengwe 22kV feeder. The feeder currently faces challenges of overloading and non-compliance with the reliability guide due to its total length of 295 kilometers. Among all the feeders from the Makonde substation, the MTG feeder has the highest number of customers, with 15,233 and a total load of 7.5 MVA.

The two proposed powerline corridors, spanning approximately 7 kilometers, are in the Thulamela Local Municipality of the Vhembe District in Limpopo. The powerline routes pass through the rural settlements of Tswera, Maheni, Makwilidza, and Thengwe, between the coordinates 22°44'54.05"S 030°37'13.64"E and 22°42'38.42"S 030°34'25.62"E. These rural settlements are characterized by extensive subsistence farms, which are demarcated into paddocks to support livestock. The proposed site falls within the Soutpansberg mountain range, also known as the "Salt Pan Mountain range," which extends to the Matikwa Natural Reserve, approximately 30 kilometers away from the proposed powerline site.

The objective of the study is to determine the 1:100-year floodlines for various design storms and durations within the proposed construction area for the two powerline corridors. Additionally, the study assesses the potential impacts of the proposed construction activities on the receiving environment, including the catchment and the rural settlement. Mitigation measures are also considered to minimize any adverse effects resulting from the project.

The location of the study site is shown in **Figure 1-1**.

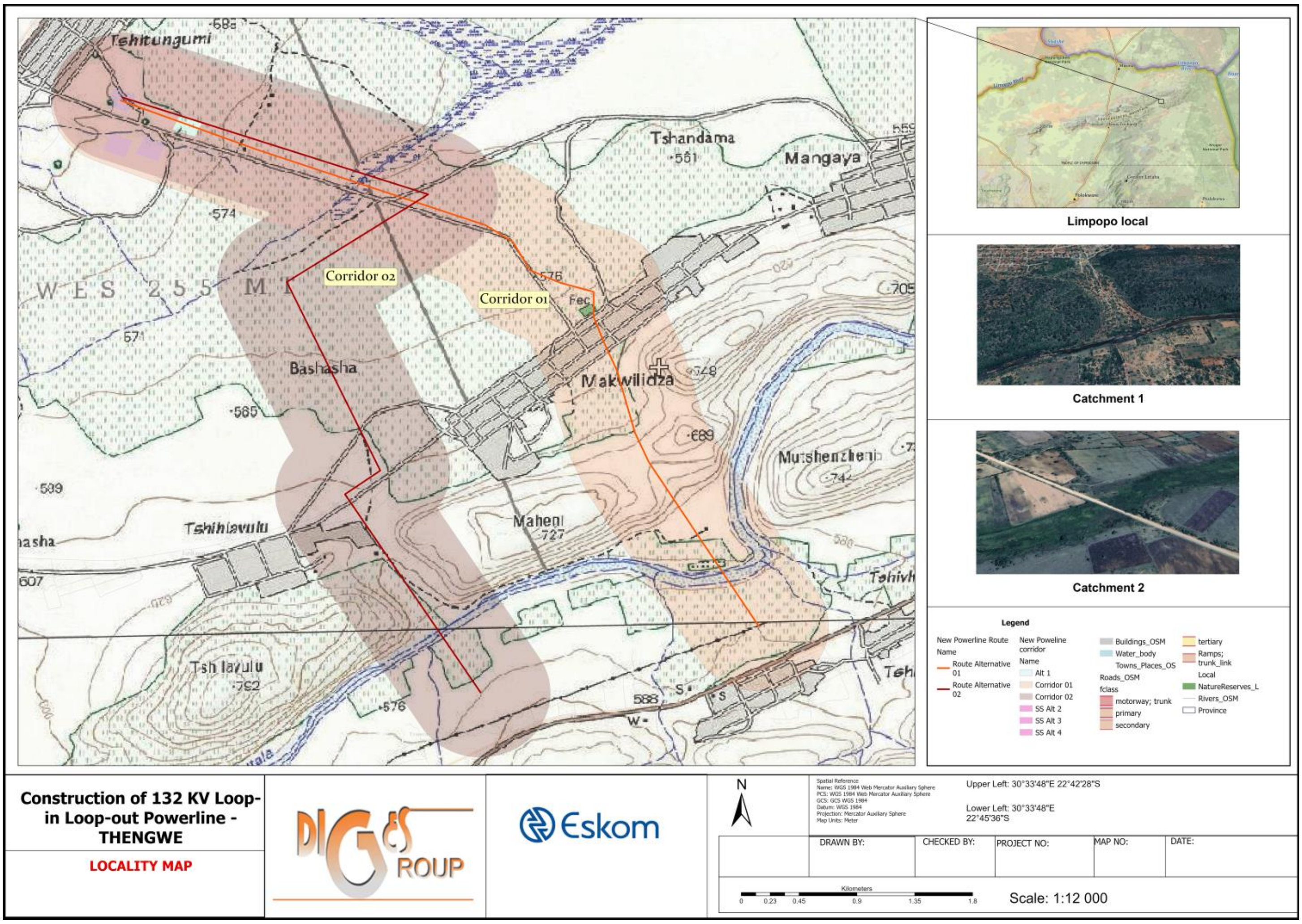

Figure 1-1. Locality map of the proposed 132KV powerline. Two proposed alternative routes to be assessed are indicated on the locality map.

2 SCOPE OF WORK

The study included the following:

- **Baseline hydrology:** - Undertake a detailed desktop assessment which includes, a review of all existing information for the project area including, mean annual runoff (MAR), mean annual precipitation (MAP), mean annual evaporation (MAE), catchment characteristics, topography, identification of surface water resources (rivers, drainage paths etc.) and storm rainfall depths for various recurrence intervals.
- **Flood line Determination:** – Model a succession of design storms at specific durations; Produce peak flows and determine flood lines indicating the areas that will be inundated during a 100-year flood event at the study area. Determination of flood risk and flood hazard throughout the study site.
- **Recommendation:** - Recommend mitigation options associated to hydraulic analysis.

3 HYDROLOGICAL ASSESSMENT

3.1 INTRODUCTION

To inform the impacts and risk assessments presented by the proposed study, an understanding of baseline hydrology is required. This section presents a comprehensive review of various information sources and defines the baseline climatic and hydrological conditions of the site and surroundings.

3.2 CLIMATIC CONDITIONS

3.2.1 Rainfall and Evaporation

Rainfall data was also extracted from the DWS online database which is available freely and can be accessed online via the DWS website. The final source of rainfall data was obtained from the Water Resources of South Africa 2005 Study, (WR2005, 2009). The mean annual temperature ranges from about 18 °C, in the mountainous areas, to more than 28 °C in the northern and eastern parts of the Limpopo Water Management Area (WMA). With an average of about 25,5 °C for the area around the site. Maximum temperatures are experienced in January and minimum temperatures occur on average in July.

Rainfall is strongly seasonal and occurs mainly during the summer months (i.e., October to March). The peak rainfall months are January and February, and rainfall occurs generally as convective thunderstorms and due to orographic cooling in the mountainous areas in the western part of the catchment. Cyclones, causing moderate to high intensity rainfall of long duration, occur occasionally in the far eastern parts of the proposed construction site. The mean annual precipitation varies from less than 450 mm in the plains zone to more than 1 800 mm in the mountainous areas.

The average potential mean annual gross evaporation (MAE) ranges between 1 800 mm, in the extreme western mountainous region, to 2 400 mm in the northern and eastern areas. The highest A-pan evaporation occurs in the period October to January and the lowest is in June.

Figure 4-1 presents the regional hydrology including the South African Weather Services (SAWS) and Department of Water and Sanitation (DWS) weather stations selected to characterize rainfall and evaporation at the site.

The rainfall station selected to represent the study site is SAWS station 0760324 (SILOAM), which is located approximately 21.1 kilometers Southwest of the site with a rainfall record length of 92 years. The rainfall records show a mean annual precipitation (MAP) of 470.0 mm, which will be adopted for the site.

Table 3-1 presents the average monthly rainfall and evaporation adopted for the site.

Table 3-1: Average monthly Rainfall and Evaporation

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Rainfall (mm)	130	116	90	51	20	11	11	14	35	74	116	128	470
Lake Evaporation	198	197	209	198	170	161	129	180	87	97	135	168	1780

3.2.2 Return Period Rainfall Depths

The data taken from the four nearest rain stations (to the central point on site) was used to estimate the 24-hour design rainfall depth using the Design Rainfall Estimation (DRE) in South Africa (Smithers and Schulze, 2003). A summary of the input stations is presented in **Table 3-2-2**.

Table 3-2-2: Summary of weather stations used for generating rainfall DDF for the site

Station Name	SAWS Number	Distance from the site (km)	Record length (years)	MAP (mm)	Altitude(m)
SILOAM	0760324_	21.0	92.0	470.0	574
SIBASA	0766837 W	26.6	87	928.0	705
GOOLDVILLE HOSPITAAL	0766863 A	21.0	37.0	1077.0	710
FOLONHODWE	0766842 W	21.6	44.0	279.0	710
BOLTMAN	0724361 W	35.0	49.0	574.0	590
RAMBUDA	0766827 W	21.1	45.0	1034.0	720
		24.4		**727.0**	**668**

The Smithers and Schulze method of DDF rainfall estimation is considered more robust than previous single site methods. WRC Report No. K5/1060 provides further detail on the verification and validation of the method. **Error! Reference source not found.** presents DDF rainfall estimates that were derived from the Smithers and Schulze method.

Table 3-2-3: Depth Duration Frequency Estimates for the site

Duration (m/h/d)	Rainfall Depth (mm)						
	1:2yr	1:5yr	1:10yr	1:20yr	1:50yr	1:100yr	1:200yr
5 m	8	11.3	13.6	15.9	19	21.4	23.9
10 m	13.9	19.6	23.6	27.6	33	37.2	41.6
15 m	19.2	27.1	32.6	38.1	45.6	51.4	57.5
30 m	28.2	39.8	48	56	67	75.6	84.5
45 m	35.3	49.9	60.1	70.2	83.9	94.7	105.9
1 h	41.4	58.6	70.5	82.4	98.5	111.2	124.3
1.5 h	51.9	73.4	88.3	103.2	123.4	139.3	155.7
2 h	60.9	86.1	103.6	121.1	144.8	163.4	182.7
4 h	72.6	102.6	123.5	144.4	172.6	194.8	217.7
6 h	80.5	113.7	136.9	160	191.2	215.8	241.2
8 h	86.5	122.3	147.2	172.1	205.7	232.1	259.4
10 h	91.6	129.4	155.8	182	217.6	245.6	274.5
12 h	95.9	135.5	163.1	190.6	227.9	257.2	287.5
16 h	103.1	145.7	175.4	205.1	245.1	276.7	309.2
20 h	109.1	154.2	185.6	217	259.4	292.7	327.2
24 h	114.3	161.5	194.4	227.2	271.6	306.6	342.6
1 d	94.8	133.9	161.3	188.5	225.4	254.3	284.2
2 d	120.8	170.6	205.4	240.1	287	323.9	362
3 d	139.1	196.5	236.6	276.6	330.6	373.1	417
4 d	153.1	216.3	260.5	304.4	364	410.8	459.1
5 d	165	233.1	280.6	328	392.1	442.6	494.6
6 d	175.4	247.7	298.3	348.6	416.7	470.3	525.7
7 d	184.6	260.8	314	367	438.8	495.2	553.4

3.3 Hydrological Setting

3.3.1 Introduction

South Africa is divided into 9 water management areas (WMA), managed by separate water boards. Each water management area (WMA) is made up of quaternary catchments which relate to the drainage regions of South Africa, ranging from A to X (excluding O). These drainage regions are subdivided into four known divisions based on size.

For example, the letter A denotes the primary drainage catchment, A2 will represent the secondary catchment, A21 represents the tertiary catchment and A21D would represent the quaternary catchment, which is the lowest subdivision in the WR2005 manual. Each of the quaternary catchments have associated hydrological parameters including area, mean annual precipitation (MAP) and mean annual runoff (MAR) to name a few.

The proposed construction site of the 132KV powerline falls in the Luvuvhu Catchment which is in the Limpopo province and together with the Letaba Catchment forms the Limpopo Water Management Area (WMA). The Luvuvhu Catchment forms part of the larger Limpopo system which drain into the sea in northern Mozambique.

3.3.2 Regional Hydrology

The two corridors proposed for the construction fall within the quaternary catchment A92B which has a gross total catchment area of 578.5 km^2, with a net MAR of 41.89 mm^3. The upstream contributing quaternary catchment to A92B is A92A.

The major river within quaternary catchments A92A and A92B is the Mutale River which flows through the proposed construction area. The Mutale River is an ephemeral river that forms a tributary to the Luvuvhu River which flows Northeast, joining the Limpopo River north of the Kruger National Park.

Average elevations at the eastern and western quaternary catchment boundary of A92B range from approximately 470 m.a.s.l. to about 1500 m.a.s.l. The elevation drops gradually to 576 m.a.s.l. along the Mutale River's intersection with the proposed construction site. The hydrological setting of the proposed construction site is indicated in Figure 3-1. The Digital Elevation Model (DEM) was sourced from the United States Geological Survey (USGS).

The surface water attributes of the A92B quaternary catchment are summarized in the table below. This includes the Mean Annual Precipitation (MAP), Mean Annual Runoff (MAR), and Mean Annual Evaporation (MAE) as obtained from the Water Resources of South Africa 2018 Study (WR2012).

Figure 4 1 presents the regional hydrology.

Quaternary Catchment	Catchment Area km^2	MAE (mm)	Evaporation Zone	Rainfall Zone	MAP (mm)	MAR (mm^3)
A92B	578.5	1763	5A	W	470	41.89

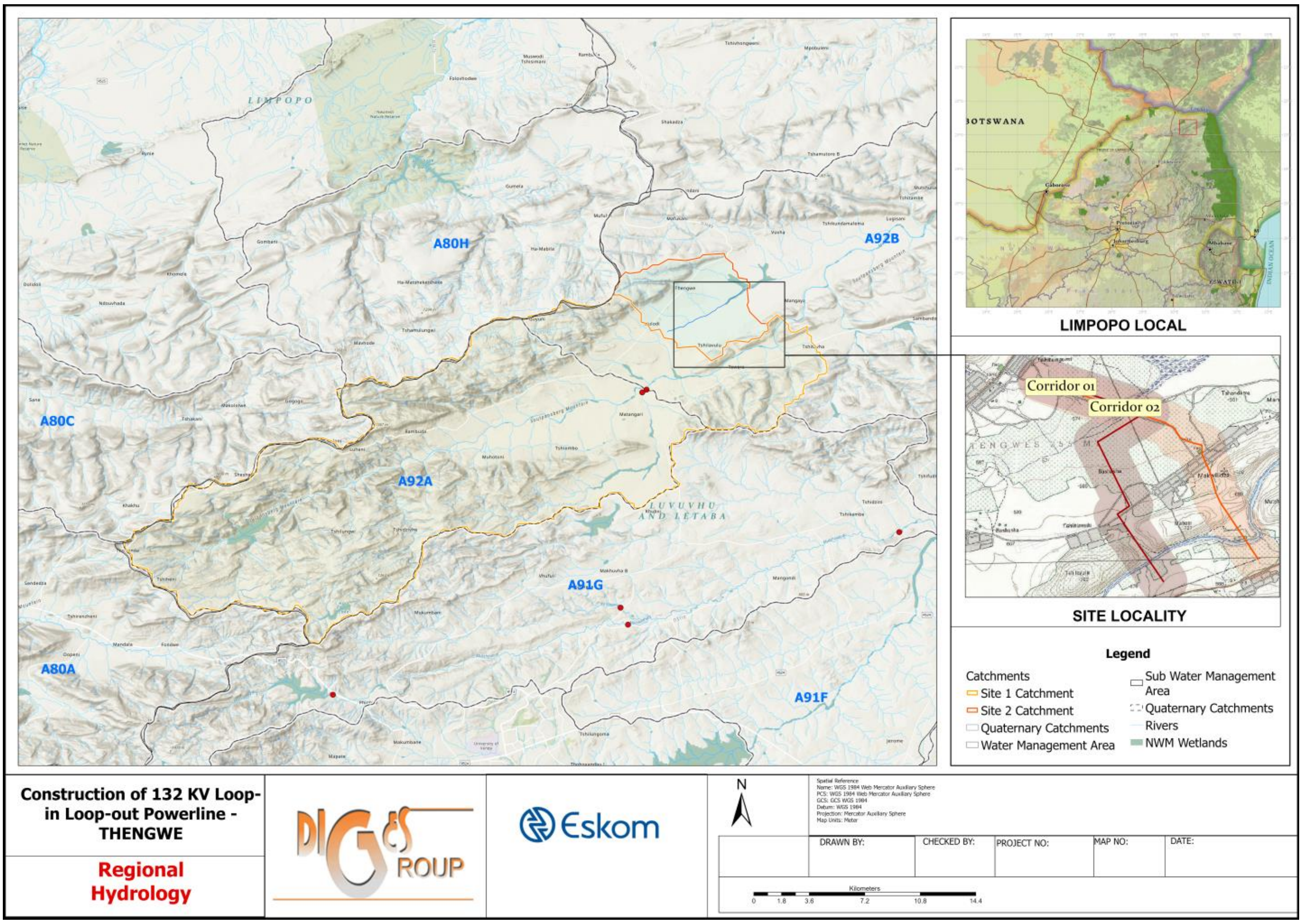

Figure 3-1: Regional Hydrology

3.3.3 Topography and Vegetation

The Proposed 132KV powerline is situated on the eastern part of the Soutpansberg Mountain range which rises to about 1500 m.a.s.l. The hydrogeomorphic setting is a channelled valley bottom formed by the Mutale River. The relief along the channelled valley bottom is gentle with a range of low mountains and plains near the northern banks of the Mutale River as shown in **figure 3.1.** It appears to display numerous floodplain characteristics with alluvial deposits and alternate flow paths within the system.

The east-west orientation of the mountain range creates a landscape that influences rainfall distribution and is responsible for the biotic distribution in within the proposed construction site. The two dominant types of vegetation for the area are the Soutpansberg Mountain Bushveld and the Makuleke Sandy Bushveld which is found along the valley of the Mutale River. Both types of vegetation form part of the Savannah Biome and are classified as vulnerable. They are dominated by tree species which form a mosaic of vegetation communities including subtropical thickets, Mistbel bush clumps and arid mountain bushveld.

From a site visit it was observed that most of the areas, especially the watercourses, are covered by grass (both long and short), as shown in Figure 3-2. The vegetation surrounding the project area is made up of a mixture of grassland, shrubland and trees, as shown in **Figure 3-2.**

Figure 3-2: Catchment 1; Typical Riverian Vegetation

Catchment 1: Vegetation around stream catchment		
		
		

Catchment 2: Vegetation around stream catchment		
		
		

4 FLOOD ASSESSMENT

4.1 INTRODUCTION

This section outlines the methodology and inputs employed to establish the 1:100-year floodlines and presents the results of the model. To effectively guide the channel realignment and flood protection measures at the two locations, it is imperative to comprehend the flood hydrology of the Mutale River and the adjoining tributary intersecting the powerline.

The Mutale River is a perennial river, and based on anecdotal evidence, it can be concluded that surface water flow events occur continuously across the catchment. Consequently, employing standard best practice methods for flood estimation in such catchments is deemed suitable for accurately representing the flood hydrology. Therefore, this study on floodlines and hydrology incorporates a comprehensive review of both regional and local hydrological data, along with anecdotal evidence from historical flood events. Additionally, regional methodologies for flood hydrology in ungauged catchments are utilized to estimate flow rates.

To assess the flood risks and define the flood peaks for the 1:100-year extreme event, two sub-catchments were identified. These sub-catchments encompass the watercourses in the vicinity of the proposed construction site and serve as the basis for determining the flood peaks.

4.2 INPUT DATA SOURCES

This section provides the methodology and inputs used to determine the 1:100-year floodlines and the model results.

Two sub-catchments were delineated to cover the watercourses within the vicinity of the two corridors and were utilised to determine the flood peaks for the 1: 100-year extreme event for the purposes of defining the flood risks.

4.2.1 Topography

The study area and its surroundings exhibit an undulating topography, with some relatively wide floodplains and wetlands. The available dataset contains contour lines at a 20-meter interval, which were used to generate a Digital Elevation Model (DEM). This DEM served as a crucial input for the floodline modelling process.

The predominant land use in the proposed construction area is primarily rural with urbanized residential areas. Additionally, there are patches of cultivated land and expanses of grazing land. The soil in this area demonstrates high to moderate infiltration and drainage characteristics, facilitating water movement through the ground. Moreover, the proposed construction area is characterized by a diverse array of fringing vegetation, along with extensive emergent and submerged vegetation. This vegetation includes rushes and grasses that grow within the floodplains.

4.2.2 Sub-catchment Delineation

Sub-catchments were delineated to cover the streams within the two proposed powerline corridors and were utilised to determine the flood peaks, for 1: 100-year extreme events. The delineated sub-catchments are highlighted in **figure 3-1**.

Based on the provided 20-meter elevation contour lines, the following catchments were delineated:

Catchment 1: This catchment is the larger of the two and encompasses a significant portion of Quaternary catchment A92B. It includes Zone 2, which refers to the transfer zone of the Mutale River. The catchment is characterized by its contribution to the overall flow of the Mutale River within the study area. For flood modelling purposes, a specific 1-kilometer section of the river within this catchment was selected. This section is crucial for understanding and predicting flood behaviour and assessing potential flood risks.

Catchment 2: This catchment represents a smaller area compared to Catchment 1. It is part of Quaternary catchment A92B and includes a tributary situated on a gentle slope. The tributary contributes to the overall water flow within the study area, eventually joining the main Mutale River. Although smaller in size, this catchment plays a significant role in the hydrological dynamics of the region and is an important component of the overall flood analysis.

These delineated catchments allow for a more focused examination of the specific areas of interest within the study area, enabling a detailed assessment of the flood risks and providing valuable information for floodline modelling and related decision-making processes.

The sub catchments are characterised for the peak flow calculations as detailed in the Drainage Manual (SANRAL, 2007). The values of each model parameter class were determined through a process of professional judgment and visual inspection based on the terrain characteristics and the fraction of the catchment.

Catchment characteristics were evaluated and used to estimate the flood peaks for the following catchments:

Table 4-1: Catchment Characteristics

Parameter	Catchment 1	Catchment 2
Catchment area - km^2	402.97	37.42
Mean annual precipitation – mm	470	470
Length of longest stream – km	53.61	5.6
Height difference along 10-85 slope -m	114	23
Average slope along the 10-85 - m/m	0.0119	0.0036
SDF Basin	3	3

These inputs may be applied in the modelling the peak flows.

4.3 METHODOLOGY

The objective of this study is to determine the 1:100-year floodlines for the section of the Mutale River and the Tributary that intersect the proposed 132 KV powerline. The river exhibits a closed contour pattern, with increasing depth from the perimeter towards a central area of maximum depth, where water accumulates.

Flood peaks for the three catchments selected for flood modelling were estimated by the following methods: using the Utility Programs for Drainage (UPD) software, 2007 with the methods detailed in SANRAL, 2013:

- Standard Design Flood Method (Deterministic)
- Rational Method (Deterministic)

- Alternative Rational Method (Deterministic)

These methods provide a framework for estimating flood peaks in the selected catchments, allowing for a comprehensive analysis of flood risk and the determination of the 1:100-year floodlines.

4.3.1 Rational Method

This method is based on the conservation of mass and is applicable for catchment areas below 15 km^2. Aerial and time distributions of rainfall in this method are assumed to be uniform throughout the catchment. Flood peaks and empirical hydrographs can be determined by this method.

Where: The peak flow is obtained from the following relationship:

$$Q = \frac{CIA}{3.6}$$

Where: Q = peak flow (m^3/s)

C = runoff coefficient (dimensionless)
I = average rainfall intensity over the catchment (mm/hour)
A = effective runoff area of the

4.3.2 Alternative Rational Method

This method is based on the rational method with the point precipitation being adjusted using the Design Rainfall Estimation Methodology developed by Smithers and Schulze (2003) to consider local South African conditions. This method can work for large catchments without any limitation.

The Smithers and Schulze method of DDF rainfall estimation is considered more robust than previous single site methods. WRC Report No. K5/1060 provides further detail on the verification and validation of the method. Table 3-2-2 presents DDF rainfall estimates that were derived from the Smithers and Schulze method.

Table 4-3: Design Rainfall inputs to ARM

Weather Service station	RAMBUDA
Weather Service station no.	0766827_W
Mean annual precipitation	1034mm
Coordinates	22⁰ 5′ & 23⁰ 11′

Duration (m/h/d)	**Return Period (Years)**						
	2	**5**	**10**	**20**	**50**	**100**	**200**
1 d	77.9	110	132.5	154.8	185.1	208.9	233.5
2 d	98.3	138.6	166.7	194.7	232.6	262.2	292.8
3 d	110	156.3	188.6	221	265.2	299.9	335.9
4 d	120.9	173.1	210	247.2	298.1	338.3	380.3
5 d	128	184.3	223.7	263.3	317.1	359.6	403.6
6 d	137.1	198.1	240.4	282.5	339.4	383.8	429.8
7 d	145.3	209.8	254.2	298.1	356.9	402.3	449.1

4.3.3 Standard Design Flood

The standard design flood method (SDF) was developed to address the uncertainty in flood prediction under South African conditions. It is based on historical data to adequately describe the flood frequency relationships. The runoff or discharge coefficient (C) is replaced by a calibrated value based on the subdivision of the country into 29 regions of WMAs. This method can work for large catchments without any limitation.

The SDF method requires catchment area and slope in addition to the specification of the site as lying within SDF Basin number 3. The station information is summarized below:

Table 4-4: Rainfall Station in the study

Station No.	Latitude	Longitude	Record	MAP	MAE	M	R	C2	C100
	(°)	(°)	(Years)	(mm)	(mm)	(mm)	(d)	(%)	(%)
760324	22º 54′	23º 11′	61	470	1700	58	20	10	70

4.4 PEAK FLOW ESTIMATES

The resulting peak flows from the catchment are presented in Table 4-5. It was decided to use the average of all methods for the flood modelling.

Table 4-5: Flood peaks

Catchment	Calculation Method	Return Periods	
		50	100
1	Rational Method (m^3/s)	233.70	645.80
	SDF Method (m^3/s)	978.22	1256.59
	Alternative Rational Method (m^3/s)	317.40	459
2	Rational Method (m^3/s)	120.69	333.51
	SDF Method (m^3/s)	329.49	423.25
	Alternative Rational Method (m^3/s)	175.41	253.89

4.4.1 Recommended Flood Peak for the catchments.

The flood final flood peaks were calculated by applying the following algorithm:

QT = [RMDWA + RMAL + SDF + HRU] / N

With:

QT = Flood peak for return period T
T = Return Period
RMDWA = Rational method DWA
RMAL = Rational method Alternative algorithm
SDF = SDF method
N = 4

The recommended flood peaks in cumec (cubic meter per second) at the site are listed in Table 4-6 below:

Figure 4-6: Recommended Flood Peaks

Catchment	Return Period (m^3/s)	
	1:50	**1:100**
1	394.93	615.59
2	208.53	336.88

5 FLOOD MODELLING

5.1.1 Choice of Software

HEC-RAS 4.0 and ArcGIS Pro 2.9 was used for the purpose of modelling the flood elevation profile for the 1: 100-year flood event. HEC-RAS is a hydraulic program designed to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

ArcGIS Pro is a GIS desktop mapping software that also provides methods for describing the physical components of a surface. The hydrologic tools allow you to identify sinks, determine flow direction, calculate flow accumulation, delineate watersheds, and create stream networks and create flood models.

5.1.2 Topographic Profile Data

A Triangulated Irregular Network (TIN) from the 20m contour datasets forms the foundation for the ArcGIS Pro model and was used to extract elevation data for the river profile together with the elevation points. However, the survey points only encompassed the northern bank The 20m contour lines were then derived from survey elevation points provided by the client. The TIN was also used to determine placement positions for the cross-sections along the river and can be accurately modelled to the resolution of the provided topographical data.

5.1.3 Hydraulic Structures

A survey of the hydraulic structures was undertaken for one culvert, along catchment 1, where the tributary intersects with the proposed powerline.

The floodlines determined in most areas are comparable to the floodplain's extents observed during the site assessments undertaken and are therefore adequate for environmental purposes. It is important to note that the hydraulic structures identified were only within catchment 2. The observed hydraulic structures are presented below in Table 5-1.

Table 5-1: hydraulic Structure information

Site ID	Opening Width (m)	Opening Height (m)	No of piers/pipes	No of pipe Openings	Pier Width (m)	Pier Spacing	Road Width
Catchment 2 Calvert	7m	2.4m	20	10	1	0.8m	7m

5.2 Model Development

HEC-RAS 4.0 and ArcGIS Pro 2.9 was used for the purpose of modelling the flood elevation profile for the 1:100 year flood event. HEC-RAS. ArcGIS Pro is a GIS desktop mapping software that also provides methods for describing the physical components of a surface. The hydrologic tools allow you to identify sinks, determine flow direction, calculate flow accumulation, delineate watersheds, and create stream networks and create flood models.

Development of the hydraulic model included the following steps:

- Creation of a TIN from the contour data.

- Digitising the pan storage area polylines and flow paths using ArcGIS pro.
- Generating cross-sections approximately 10m apart through the storage area using ArcGIS Pro.
- Importing geometric data into HEC-RAS.
- Entering the Manning's values, peak flows, and storage and downstream slope boundary conditions in HEC-RAS.
- Performing steady, mixed-flow regime hydraulic modelling within HEC-RAS to generate flood levels at modelled cross-sections; and
- Importing flood levels and studying levels onto the TIN using HEC-GeoRAS to determine the flood inundation areas.

5.3 FLOODLINES

The results of the flood elevations in HEC-RAS output table are presented in Table 5-3

As noted, the floodlines extent coarsely determine from the 20m contours will overtop the floodplains and some of the cultivated land around the proposed construction sites. This results in a wider floodline towards the northern banks of the Mutale River (Catchment 1).

It is important to note that the floodlines determination methodology used is conservative and considered a worst-case scenario given up to a 1:100-year flood peak. The 1:100-year floodlines are indicated on **Figure 5-1**:

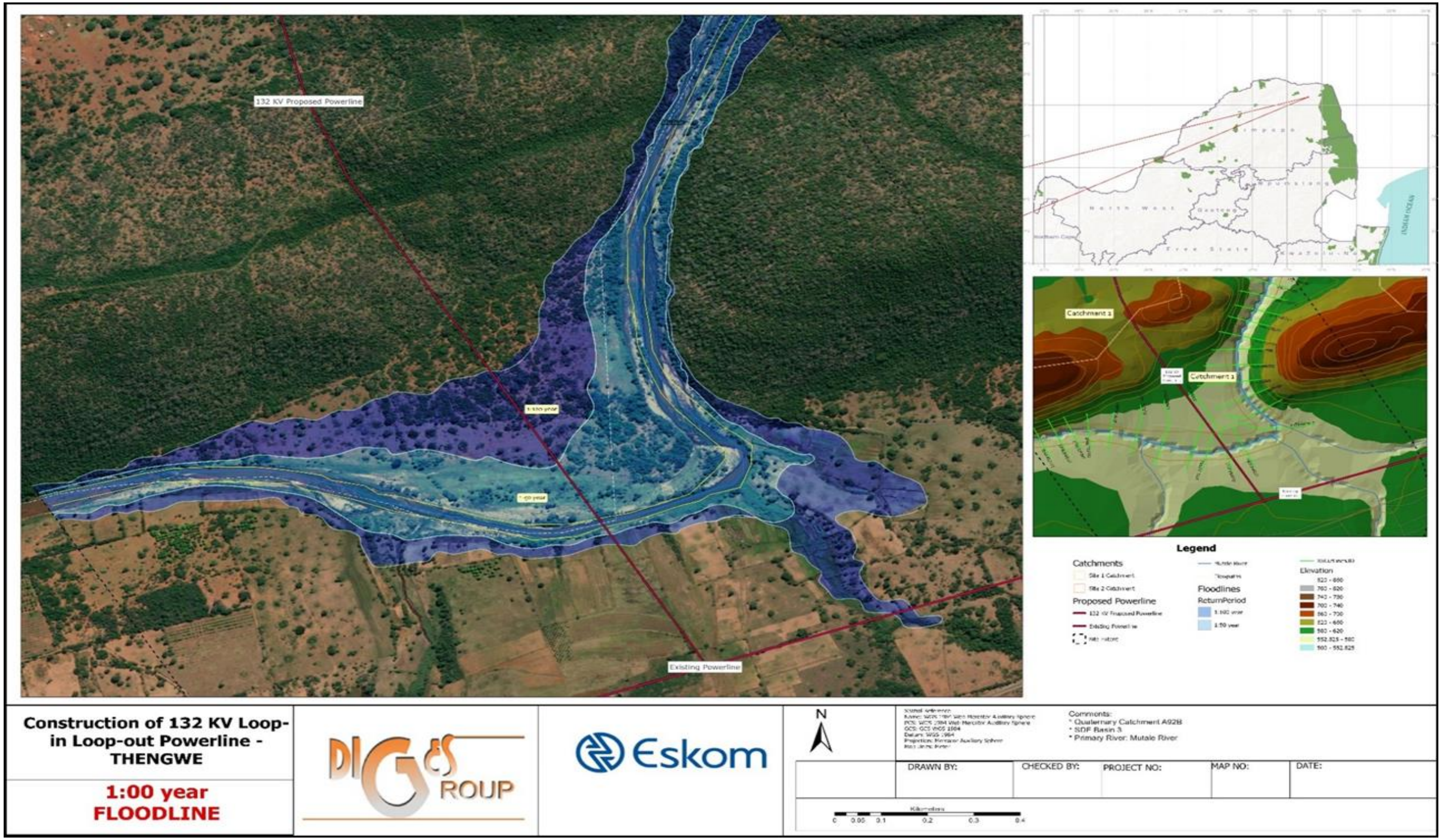

Figure 5-1: 1:100-year floodline for Corridor 1 of the 132 KV powerline.

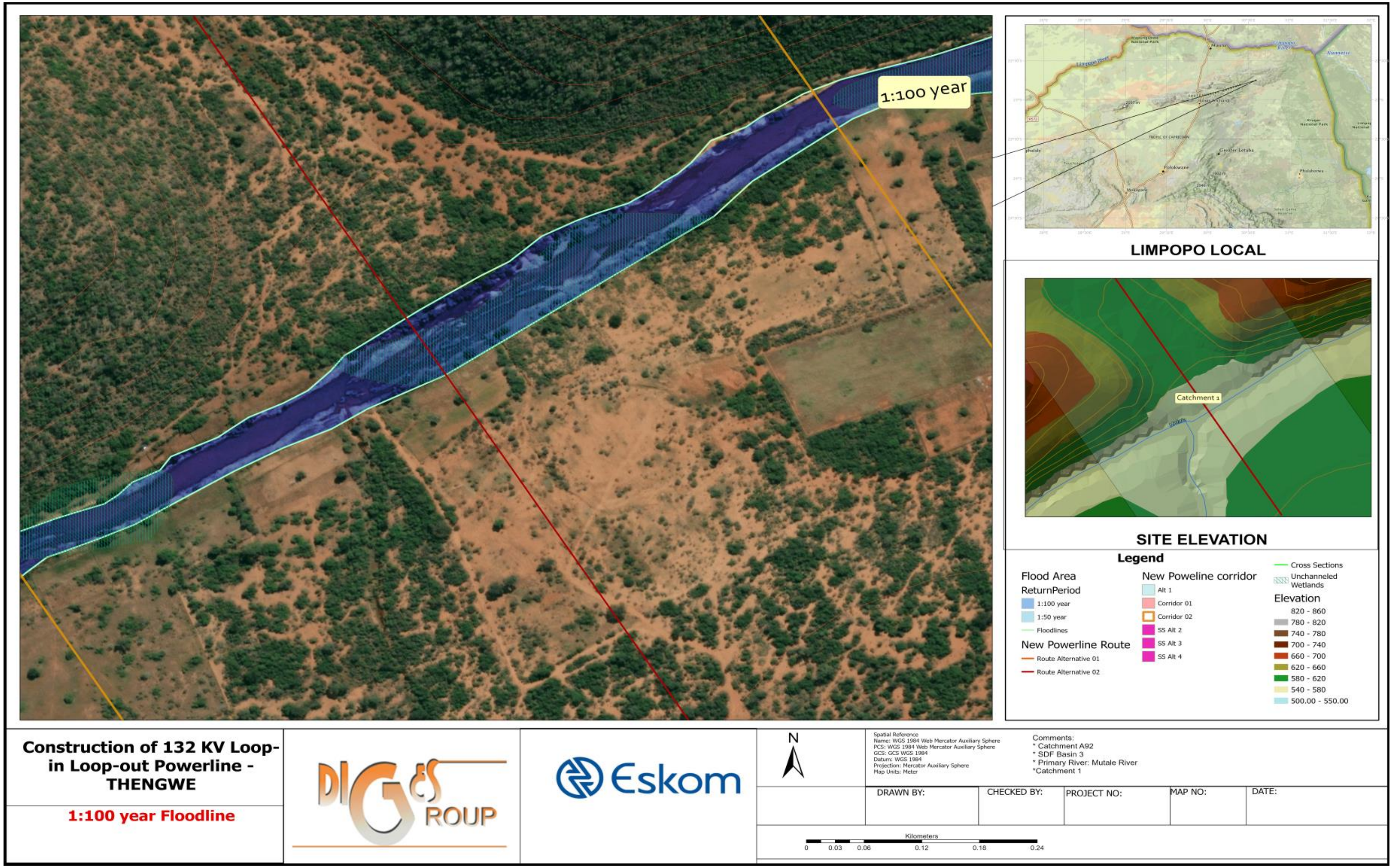

Figure 5-2: 1:100-year floodline for Corridor 2 of the 132 KV powerline.

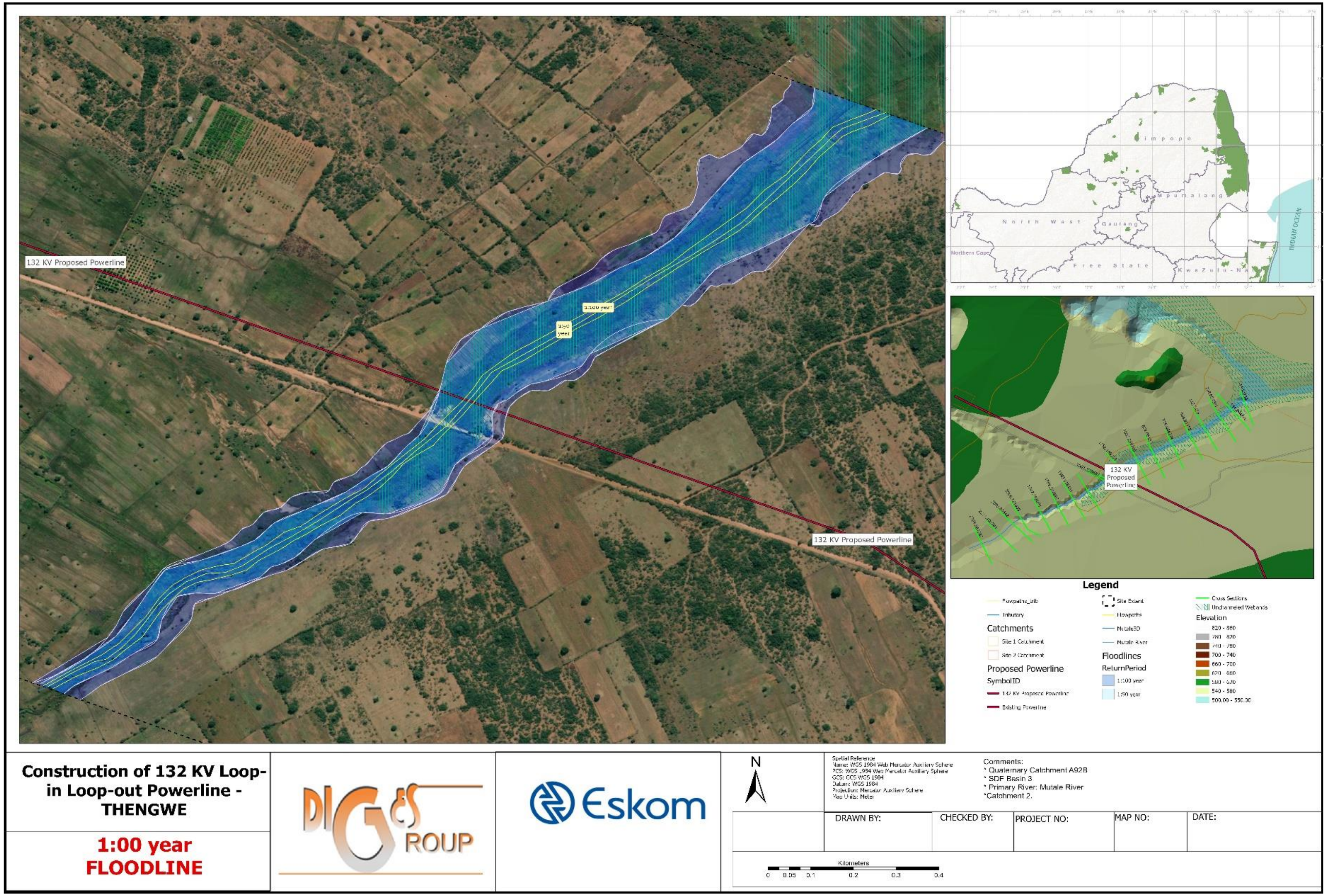

Figure 5-3: Upstream 1:100-year floodline for the 132 KV powerline in catchment 2. Alternative route 1 and 2 share the same path within this catchment.

6 IMPACT ASSESSMENT

6.1 INTRODUCTION

Informed by the baseline hydrology and study description, the potential impacts of the proposed activities which may impact the surrounding land use and environmental resources are discussed in this section.

The Impact Assessment process is not to provide an incontrovertible rating of the significance of various aspects, but to provide a; structured, traceable, and defendable methodology of rating the relative significance of impacts in a specific context. This gives the study proponent a greater understanding of the impacts of the proposed construction and the issues which need to be addressed by mitigation and give the regulators information on which to base their decisions.

6.1.1 Impact Rating

The impact rating process is designed to provide a numerical rating of various environmental impacts identified by use of the Input-Output model.

The equations and calculations were derived using Aucamp (2009).

The significance rating process follows the established impact/risk assessment formula:

$$Significance = Consequence\ x\ Probability$$

$$WhereConsequence = Severity + Spatial\ Scale + Duration$$

$$AndProbability = Likelihood\ of\ an\ impact\ occurring$$

The matrix calculates the rating out of 147, whereby severity, spatial scale, duration, and probability are each rated out of seven. The weighting is then assigned to the various parameters for positive and negative impacts in the formula. Impacts are rated prior to mitigation and again after consideration of the mitigation measure proposed in the EMP.

6.2 IMPACT ASSESSMENT AND MITIGATION MEASURES

The impacts of the construction of the proposed 132 KV powerline and infrastructure are assessed based on the impact's magnitude, as well as the receptor's sensitivity, culminating in impact significance for the most important impacts that require management.

The following activities are likely to have significant impact to surface water during the construction phases:

- Wetland and flood plain Soil erosion enhanced by construction process.
- Temporary impedance of surface water flow during construction.
- Hydrocarbon contamination on surface water during construction of the proposed 132KV Powerline.
- Debris run off into the catchment streams.
- Emergence of alien invasive fauna, post construction.

The proposed study design incorporates various mitigation and design measures, which are essential in minimizing the potential drainage impacts on the environment. Without these measures, the detrimental effects would be significantly higher.

The water resources within the Mutale catchment face moderate pressures due to the utilization of groundwater and surface water systems. The catchment's wetland system is particularly affected by erosion, sedimentation, the presence of undesirable plant species, and infestations of aquatic fauna. The increase in subsistence farming within the catchment has led to the prominence of artificial drainages. It is crucial to engage in judicious planning and management practices to ensure the equitable allocation of available water resources and prevent their depletion. Moreover, it is necessary to address the artificial drainage channels that have been created, either through development or historical agricultural practices, in order to prevent the drainage of wetland areas resulting from other land use activities.

In this section, the potential unmitigated impacts, which represent an unrealistic worst-case scenario, and the residual water impacts of the study are qualitatively assessed after considering the proposed design mitigation measures. These assessments are presented in Table 6-2 along with the proposed mitigation strategies.

It is important to regularly review all implemented measures for impact mitigation as a best practice and to comply with various licenses issued by authorities, including Water Use Licenses (WULs).

Figure 6-1: Rating of potential impacts

Impact	Pre-mitigation:						Recommended mitigation	Post-mitigation:					
	Duration	Extent	Intensity	Consequence	Probability	Significance		Duration	Extent	Intensity	Consequence	Probability	Significance
Water pollution from sewer water from nearby Mutale River (catchment 1) and Tributary (catchment 2)	Long term	Local	low negative	Slightly detrimental	likely	Negligible - negative	- Use dust suppressants like water where appropriate to reduce dust during construction - Ensure erosion control measures are in place and collect eroded water for settling from the construction sites - Prevent water from flowing through the areas under construction by temporary diversion as well as undertaking the work in the dry season if possible	Short term	Limited	Low - negative	Slightly detrimental	Improbable	Negligible - negative

Impact	Pre-mitigation:						Recommended mitigation	Post-mitigation:					
	Duration	Extent	Intensity	Consequence	Probability	Significance		Duration	Extent	Intensity	Consequence	Probability	Significance
Wetland and flood plain pollution and erosion	Medium term	Local to regional	Moderate to high	Moderate	Likely	Moderate	According to Wetland NFEPAs or portions thereof should not be drained or filled in - Cut-off drains should be in such a way that the zone of influence (the area affected by the drain – these drains divert surface and sub-surface flow in a certain direction, and lead to drawdown over a wide area) is well away from any wetland NFEPA. The area of influence should be determined by a Hydrogeologist. - No roads should be constructed through or around more than 20% of the edge of wetland NFEPA or their buffers. - No land-user should drain or cultivate any wetland or area within the flood zone of any watercourse (including its buffer), except in terms of a written permit in terms of the National Water Act. - The diversion of natural stormwater runoff away from wetland NFEPA and into a stormwater management system should be avoided wherever possible.	Short to long term	Limited	Low negative	Slightly detrimental	Improbable	Negligible

Impact	Pre-mitigation:						Recommended mitigation	Post-mitigation:					
	Duration	Extent	Intensity	Consequence	Probability	Significance		Duration	Extent	Intensity	Consequence	Probability	Significance
Hydrocarbon contamination on surface water during construction of the proposed 132KV Powerline	Beyond study life	Municipal Area	Low - negative	Moderate to low	Likely	Moderate - negative	- The vehicles should regularly undergo maintenance - Ensure that the construction and service vehicles are fitted with drip trays - Where the storage of materials is on site, the storage areas should be on bunded, hard surfaces with collection points.	construction Life cycle	Limited	Moderate - negative	Moderately detrimental	Unlikely	Negligible - negative
Temporary impedance of surface water flow during construction.	Short term	Local	Moderate - negative	Moderately detrimental	Highly probable	Minor - negative	- Ensure that the identified river crossings by the road or river have the bridges/culverts of sufficient capacity to drain in extreme design flood events -ensure that the construction of the proposed powerline is carried out during dry periods where there is no storm flow, alternatively done in phases to allow temporary diversion of flow during construction -Ensure that even small drainage channels are identified and incorporated to design sufficient capacity.	Short term	Local	Moderate - negative	Slightly detrimental	Highly probable	Minor - negative

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7 RECOMMENDATIONS AND CONCLUSION

7.1 RECOMMENDATION

The following are the recommendations:

1. **Corridor 1:** In catchment 1 (Alternative Route 1), this corridor experiences a larger area of inundation as it is in the transfer zone of the Mutale River, with multiple tributaries feeding into the river near the proposed construction site. This aspect may pose implications for the feasibility of construction and, consequently, impact the hydrological setting within the corridor, including river flow rates, water levels, drainage patterns, and overall behaviour of the water system. Please refer to **Figure 5-1**. Both corridors follow the same path in catchment 2. Therefore, the construction's impacts on the hydrological elements of catchment 2 are negligible if the recommended mitigations are implemented.

   Corridor 2: This corridor has a smaller area of inundation, with water levels not encroaching upon the powerline construction. Peak flows of 615.59 cubic meters per second and 336.88 cubic meters per second in catchment 1 and catchment 2, respectively, have been observed. It is important to note that the construction of the powerline will have minimal to no impact on the hydrological elements of the watercourse in question, including river flow rates, water levels, drainage patterns, and overall behaviour of the water system. Please refer to **Figure 5-2**.

2. Use best management practices for erosion and sediment control: Implement best management practices for erosion and sediment control, such as silt fences, sediment basins, and sediment traps. This will help to prevent soil erosion and sedimentation into the river during construction.
3. Runoff from dirty areas should not be allowed to flow into the stream, unless DWS discharge authorisation and compliance with relevant discharge standards as stipulated in the NWA is obtained.
4. Prevent water from flowing through the areas under construction by temporary diversion as well as undertaking the work in the dry season if possible.
5. Use non-toxic materials for construction, such as non-toxic lubricants and hydraulic fluids, to reduce the impact on the environment.
6. Remove alien invasive plants, along the floodplains (catchment 1), to encourage channelled drainage.
7. Minimize the clearing of vegetation: Clear only the minimum amount of vegetation required for the construction of the powerline. This will help to minimize the impact on the ecosystem and reduce soil erosion and sedimentation into the river.
8. Construction of the proposed powerline is carried out during dry periods where there is no storm flow, alternatively done in phases to allow temporary diversion of flow during construction.
9. Ensure that even small drainage channels are identified and incorporated to design sufficient capacity.
10. Ongoing surface water monitoring is imperative during all phases of the project life and post closure to allow for early detection of potential contaminants that may cause unforeseen negative impacts on the receiving environment.

7.2 CONCLUSION

Based on the available map and modelled floodlines, the estimated 1:100-year flood events for catchment 1 and catchment 2 are at 581 and 573 meters above mean sea level (m.a.m.s.l.), respectively. These flood levels have been observed to remain below the existing settlements and the proposed 132KV utility infrastructure, indicating that they do not pose a direct threat to these areas.

For **Corridor 1**, located in catchment 1, it experiences a larger area of inundation as it lies in the transfer zone of the Mutale River with multiple tributaries feeding into the river around the proposed construction site **(see Figure 5-1).** This may have implications for the feasibility of construction and the hydrological setting within the corridor. It is crucial to carefully consider the potential risks and ensure that all infrastructure and construction-related activities are situated outside the maximum stipulated flood levels to prevent inundation and safeguard the proposed project.

In the case of **Corridor 2**, which intersects the Mutale River mid-segment (Catchment 1), wider floodlines are observed across the pediment with a south-eastern direction. These floodlines encroach upon cultivated land along the north banks of the Mutale River segment (**Figure 5-2**). However, it is important to note that upstream storage and wetlands contribute to flood attenuation, resulting in lower peak flows downstream. This indicates that the impact of the proposed powerline construction on the hydrological setting of corridor 2 is minimal to negligible.

In addition, there are no hydrological impacts at the substations close to catchment 2, as they are situated further away from any water course. This positioning ensures that the substations are not affected by the hydrological elements of the nearby catchment, such as river flows and flood levels. Therefore, the substations' location remains unaffected by potential flooding events, contributing to the overall safety and stability of the powerline infrastructure in catchment 2.

In conclusion, by adhering to the recommended precautions and situating all infrastructure outside the maximum flood levels, the proposed powerline project can effectively mitigate potential risks. Corridor 2 can be developed with minimal impact on the hydrological elements and ensuring the safety of the surrounding areas.

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