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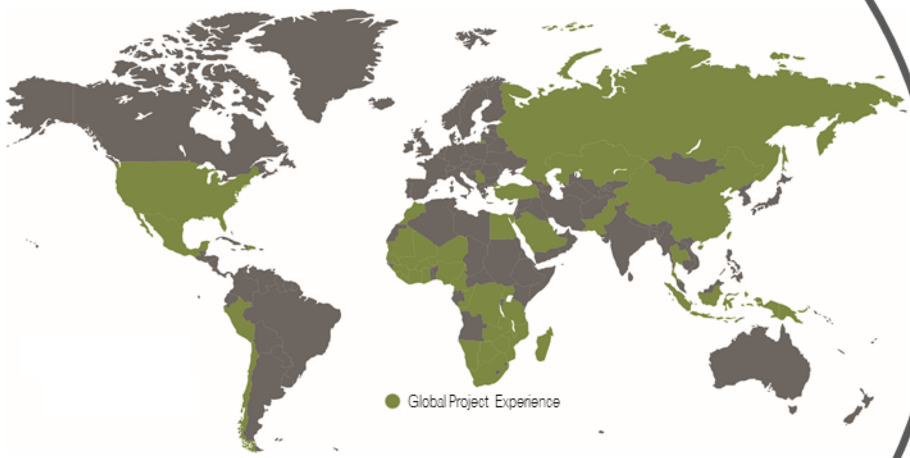

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1:50 and 1:100 Year Floodline Assessment for the Afritin Mine near Uis Town, Namibia

Surface Hydrology and Floodline Determination Study

Prepared for:
AFRTIN MINING

Project Number:
AFR7554

April 2022

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Project Name:	1:50 and 1:100 Year Floodline Assessment for the Afritin Mine near Uis Town, Namibia
Project Code:	AFR7554

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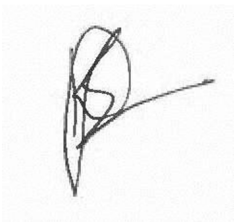
Kevin Bursey Pr.Sci.Nat.	Technical and Report Review		April 2022
Arjan van 't Zelfde	Report Review		April 2022

DETAILS AND DECLARATION OF THE SPECIALIST

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Brief Background of Specialist

Ofentse Mokonoto is a Hydrologist at Digby Wells Environmental with 8 years working experience. He holds a Master's Degree in Hydrology from the University of KwaZulu-Natal (South Africa). Mr. Mokonoto has been involved and led various projects relating to water resource assessments, flood hydrology, stormwater management plans and water and salt balance modelling. Ofentse has also undertaken surface water specialist studies for input into environmental impact assessments and environmental management plans, Integrated Water and Waste Management Plans (IWWMP), Water Use Licence Applications (IWULA) and auditing. Ofentse has working experience on projects within South Africa, Lesotho, Namibia and Botswana. Ofentse is also a Certified Natural Scientist - Water Resources Sciences (SACNASP).

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Registration(s):	South African Council for Natural Scientific Professionals: *Certified Natural Scientist* (Reg. No. 4)

I, **Ofentse Mokonoto**, declare that: –

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
  - I declare that there are no circumstances that may compromise my objectivity in performing such work;
  - I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of regulation 48 and is punishable in terms of section 24F of the Act.

	19-04-2022
Signature of the Specialist	*Date*

Findings, recommendations and conclusions provided in this report are based on the best available scientific methods and the author's professional knowledge and information at the time of compilation. Digby Wells employees involved in the compilation of this report, however, accepts no liability for any actions, claims, demands, losses, liabilities, costs, damages and expenses arising from or in connection with services rendered, and by the use of the information contained in this document.

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1 Introduction

Digby Wells Environmental (hereinafter Digby Wells) was appointed by AfriTin Mining (Namibia) (Pty) Ltd (hereinafter AfriTin) to undertake a floodline assessment for the Uis Mine as part of the Environmental Assessment (EA). The 1:50 and 1:100-year return period floodlines were determined for several drainage lines and rivers around the Uis Mine area.

Floodlines determination is used to indicate the level to which a certain flood magnitude will inundate an area along the stream or any watercourse, or which area of land will fall within the floodplain of a particular flood frequency. Flood frequency or the return period (T) is the average period over *n*-years, which an event repeats or exceeds itself; it may be described as the percentage of the annual probability of the occurrence of a flood event.

The process of floodline delineations includes initially calculating the required return period peak discharge value(s) and thereafter hydraulically simulating the peak discharge value along the respective drainage line reaches. As part of the hydraulic simulations, structures located within the drainage lines that are likely to impact the delineated floodlines were included in the hydraulic model (i.e., HEC-RAS).

1.1. Project Background

AfriTin mining recently completed a Definitive Feasibility Study (DFS) for the expansion of its Phase 1 Stage 1 project. The project is a precursor to the long-term Phase 2 expansion, which includes the expansion of the mining area, as well as the development of an additional, full-scale processing plant (AfriTin Mining, 2021). Presently the Phase 1 Stage I project produces approximately 65 tonnes of tin concentrate per month. The expansion of the pilot processing plant for Phase 1 Stage II will increase production to approximately100 tonnes of tin concentrate per month and the Phase 2 expansion plans to increase production to approximately 416 tonnes of tin concentrate per month (AfriTin Mining, 2021).

The focus of this report was to delineate the 1:50 and 1:100-year return period floodlines in the vicinity of the mine. A location map is presented in Figure 1-1.

1.2. Scope of Work

Based on the regulatory requirements, the Scope of Work (SoW) for the current study encompasses the following:

- Site characterisation at desktop level;
- Baseline hydrological assessment;
- Hydraulic modelling; and
- Floodlines determination and mapping

1.3. Assumptions and Limitations

The following are assumptions and limitations of this study:

- The floodlines were developed for environmental and indicative purposes only and not for detailed engineering design purposes;
- The main watercourses traversing through the project area has been considered for floodlines modelling, as it has a sizable contributing catchment. However, drainage lines north of the project area originating along the boundaries of the site were not modelled because they were deemed small and therefore could not collect any significant amount of runoff that can potentially cause flooding;
- It is assumed that survey data obtained from the client is accurate and an up-to-date representation of the ground level terrain;
- A steady-state (1-dimensional/1-D) hydraulic model was run, which assumes that flow is continuous at the determined peak flow rates. This is a conservative approach, which results in higher flood levels than if transient state modelling was performed;
- The lidar survey provided is assumed to represent the terrain/elevations and other features correctly (e.g., berms);
- The berms should cover all the areas that are prone to flooding, such as the open pit;
- The floodlines were modelled for sections of the unnamed streams traversing through the project area and only within the boundaries of the surveyed area;
- No abstractions from the river section or discharges into the river section were considered during flood modelling; this study only focuses on the floodlines scenarios and;
- Although flood calculations are executed with great care, the possibility always exists that a more severe flood could occur or that flooding as a result of non-hydrological events could take place.

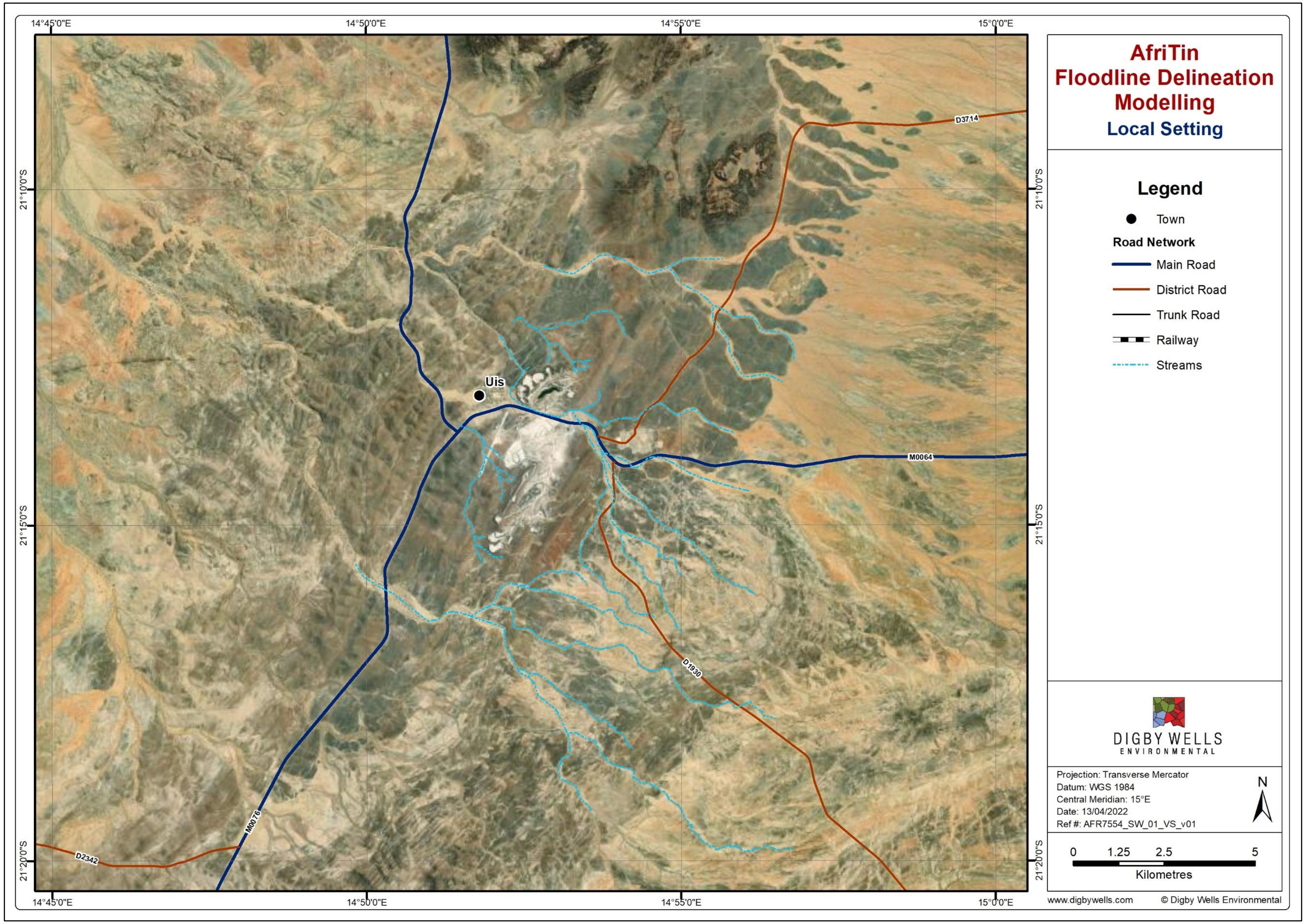


Figure 1-1: Locality of the Uis Mine Project Site Showing the Surrounding Streams

2. Relevant Legislation

There are no guidelines for developments in terms of floodlines in Namibia as such the South African National Water Act (Act 36 of 1998) (hereafter referred to as SA NWA) as well as the Government Notice 704 (Government Gazette 20119 of June 1999) (hereafter referred to as GN704), The British guidelines and the International Finance Corporation (IFC). The guidelines deemed applicable in this floodline assessment are presented below.

2.1. National Water Act

The National Water Act (Act No. 36 of 1998), states that "For the purposes of ensuring that all persons who might be affected have access to information regarding potential flood hazards, no person may establish any development unless the layout plan shows, in a form acceptable to the local authority concerned, lines indicating the maximum level likely to be reached by floodwaters on average once in every 100 years".

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

GN 704 was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. The main conditions of GN704 applicable to this project is:

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

2.2. International Finance Corporation (IFC) Guidelines: Environmental, Health and Safety Guidelines for Mining (2007)

The IFC guidelines does not provide guidance on floodline modelling and recurrence interval. However, it provides the following guidelines in terms of development within or near a flood line:

- Design specification should take into consideration the probable maximum flood event and the required freeboard to safely contain it (depending on site-specific risks) across the planned life of the tailings dam, including its decommissioned phase.
- Design of tailings storage facilities should consider the specific risks/hazards associated with geotechnical stability or hydraulic failure and the associated risks to downstream economic assets, ecosystems and human health and safety. Environmental considerations should thus also consider emergency preparedness and response planning and containment/mitigation measures in case of a catastrophic release of tailings or supernatant waters.

2.3. IFC Guidance Notes to Performance Standards on Environmental and Social Sustainability (2012)

The performance standards of the IFC Guidance noted that a "projects potentially subject to coastal or river flooding or landslides, should evaluate potential impacts due to predicted or observed changes in hydrology, including a review of reasonably accessible historical hydrologic information (including frequency and intensity of hydrologic events) and scientifically projected trends. The evaluation of climate-related risks should include a discussion of potential changes in hydrologic scenarios, and the resulting potential impacts and mitigation measures considered in the design and operation of the project. This evaluation shall be commensurate with the availability of data and with the scale of the potential impacts" (IFC, 2012).

2.4. British Columbia (BC) Flood Hazard Area: Land Use Management Guidelines (2018 Amendment)

BC (2018) indicates that flood assessments that pertain to development approval must comply with legislative requirements (federal and/or provincial). It further indicates that flood assessment reports must also comply with local bylaw requirements (recognizing that they typically include a formal process for variance or relaxation).

Standard requirements for ordinary watercourses

It should be noted that the natural boundary for watercourses includes the best estimate of the edge of dormant or old side channels. The standard requirements as per the BC guidelines are as follows:

- A flood plain map that delineates the area that can be expected to flood, on average, once every 200 years (called the 200-year flood) should be developed. In the context of this study, the 1:50 and 1:100-year floodlines were calculated and will be used as a guideline to measure the impact of flooding because of the non-perennial nature of the streams as well as the absence of a long record of streamflow data.
- Buildings should be setback at least 30-metres from the natural boundary of any watercourse. Where non-standard dikes exist, setbacks should be developed in consultation with the Inspector of Dikes in order to provide right-of-way for any future dike improvements and/or access.

3. Methodology

3.1. Baseline Hydrology

This section provides the methodology used in determining the hydrological characteristics of the project area and region. This includes climatic data (rainfall and temperature), calculations of the peak flows and floodlines modelling.

3.1.1. Climate

Climate data was obtained from the Climate Forecast System Reanalysis (CFSR). CFSR is a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system designed to provide the best estimate of the state of these coupled domains between 1979 to 2014 (National Centre for Atmospheric Research, 2022).

3.1.2. Catchment Delineation

Catchment delineation was undertaken in Ras Mapper using the lidar survey received from the Client. This dataset was stored in a raster GeoTIFF format referenced to the central meridian 33 Datum (UTM 33S Projection).

3.1.3. Peak Flows

Peak flow estimates for the delineated catchments were calculated using the Utility Program for Drainage (UPD) software. Widely used and recommended design flood estimation methods were used to calculate the 1:50-year and 1:100-year peak flows for the delineated catchments at the project site. The peak flow methods are summarised below:

Rational Method (Alternative 2): The Rational Method Alternative 2 (RM2) is described by the formula Q = CIA, where I is rainfall intensity, A is the runoff contributing area, C is the runoff coefficient and Q is the peak flow**.** RM2 uses the modified recalibrated Hershfield relationship to determine point rainfall. Design rainfall depths were calculated using the TR102 representative rainfall data (SANRAL, 2013).

Standard Design Flood Method: The Standard Design Flood (SDF) method is an empirical regionally calibrated version of the Rational Method (SANRAL, 2013). The runoff coefficient (C) is replaced by a calibrated value based on the subdivision of the country into 26 regions. The design methodology is slightly different and looks at the probability of a peak flood event occurring at any one of a series of similarly sized catchments in a wider region, while other methods focus on point probabilities (SANRAL, 2013). The information required in this method is the area of the catchment, the length and slope of the mainstream and the drainage basin in which it is located.

Unit Hydrograph: The Unit Hydrograph (UH) method is suitable for design flood estimation in catchments with areas ranging between 15 km^2 and 5 000 km^2. The UH Method is based mainly on regional analyses of historical data and is independent of personal judgement. The results are reliable, although (mainly in catchments smaller than 100 km^2) some natural variability in the hydrological occurrences is lost through the broad regional divisions and the averaged form of the hydrographs (SANRAL, 2013).

Midgley & Pitman: The Midgley and Pitman (MIPI), which is an empirical method, is based on correlation between peak flows and some catchment characteristics which include the effective catchment area, length to catchment centroid, MAP and a derived constant (K_T) for a T-year return period. Regional parameters are then mapped out for South Africa. However, MIPI is applicable in Namibia. These methods are mostly suitable for medium to large catchments (SANRAL, 2013). MIPI is particularly for obtaining an advance indication of the order of magnitude of peak discharges, serving as a rough check on the results of non-statistical methods (SANRAL, 2013).

3.1.3.1. Land Cover and Soils

Land cover and soil data are necessary for peak flow calculations since they determine the potential for infiltration and overland flow. Google Earth Imagery (2021) was used to determine the type of land cover across the delineated catchments. Soil information was inferred from the Soil Conservation Service – South Africa (SCS-SA) database.

3.2. Floodlines

Hydraulic modelling was conducted in HEC-RAS 6.0.2 which allows pre-processing within the in-built RAS Mapper module. A digital elevation model (DEM) was generated from the lidar survey for the area to make the topographic data compatible with RAS Mapper. The pre-processing involved generation of the channel geometry, including the river network, banks, flow paths and cross-sections. The new geometry was opened in HEC-RAS where hydraulic analysis occurred.

The HEC-RAS model simulates the 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 height 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 1:50-year and 1:100-year flows on all river sections.

Analyses are performed by modelling flows at the sub-catchment outlet of a particular stream or channel sections first, moving upstream. Manning's Roughness Coefficients (n) for the channels were set at 0.04, and those for riverbanks were determined to be 0.045 representing natural channels with reeds and brush on the banks (Chow, 1959). These coefficients were selected based on the Cowan Theory (Cowan, 1956) according to the following equation:

$$\boldsymbol{n = (nb + n1 + n2 + n3 + n4)m} \qquad \textbf{(1)}$$

where:

- n_b is a base value of roughness for a straight, uniform, smooth natural channel;
- n_1 is a correction factor for the effect of surface irregularities;
- n_2 is a value depicting channel cross-sectional area variations in shape and size;
- n_3 is a value for flow obstructions in the channel;

- n_4 is a value for vegetation and flow conditions, and
- m is a correction factor for the meandering of the channel.

Physical factors in the assessed channel were used to estimate roughness adjustment factors, as described in the aforementioned equation (Cowan, 1956).

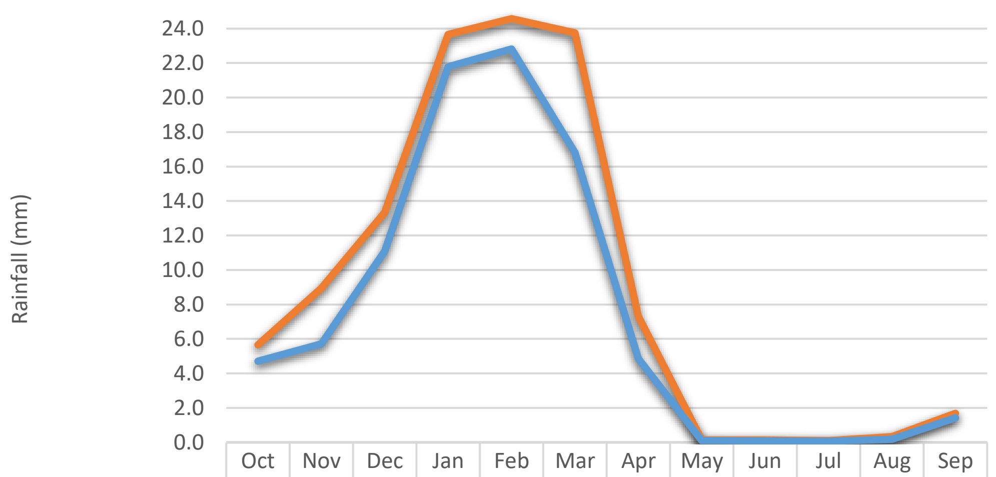
4. Baseline Hydrology

According to the Köppen climate classification, Uis is a hot desert climate (BWh). The BWh classification characterises areas where evaporation and transpiration exceed precipitation with hot to exceptionally hot (over 40°C) periods of the year. Climate data was collected from two weather stations around the project area, which have daily rainfall and temperature data between 1979 and 2014.

4.1.1. Rainfall

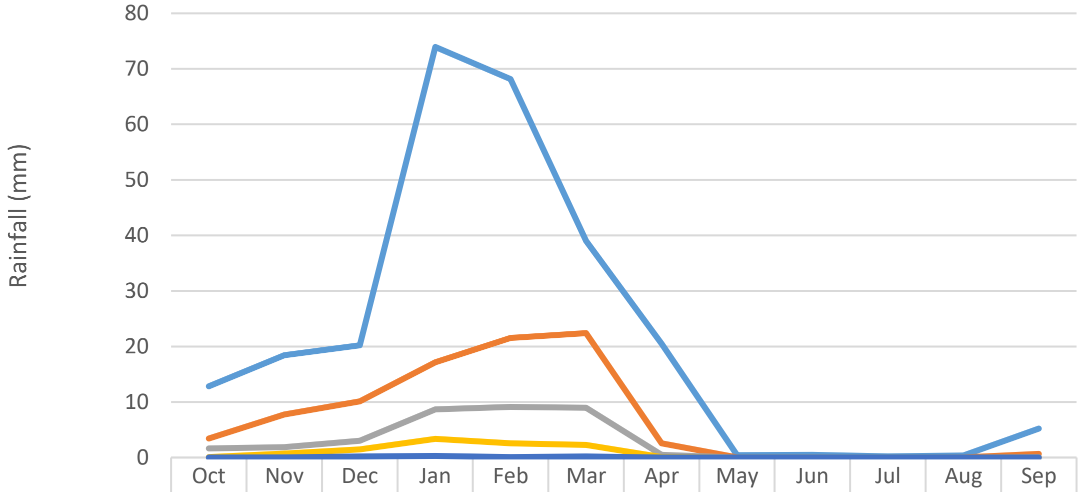
The distribution of rainfall is extremely seasonal with almost all the rain falling in summer (October to April) with the months of January to March receiving the highest rainfall while the remaining months mark the dry season. The rainfall data is presented in Figure 4-1. The Mean Annual Precipitation (MAP) for rainfall stations 211147 and 214150 is 83 mm/year and 90 mm/year, respectively. According to a report by AfriTin (AfriTin Mining, 2021), the project site receives a MAP ranging between 50 to150 mm, and the mean annual evaporation is between 3200 to 3400 mm. Therefore, the project site experiences extremely high annual evaporation compared to the annual rainfall.

Quantile rainfall distributions at the site indicate that the normal rainfall (70% of the events) for the wettest month will range between 22 mm and 25 mm, while extreme rainfall (10% of the events) will range between 74 mm and 98 mm. This implies that the region experiences low rainfall (see Figure 4-2 and Figure 4-3).



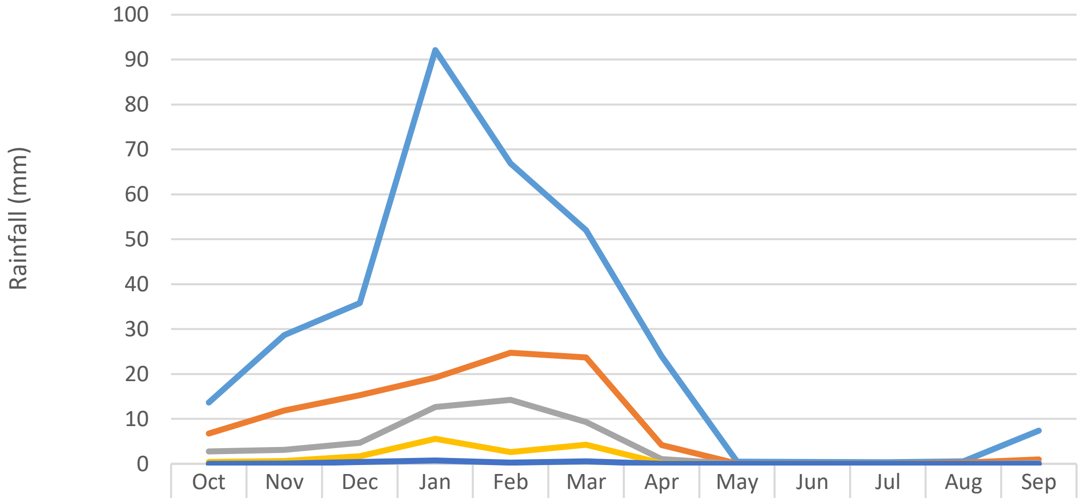
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Rainfall (mm) - Station 211147	5.7	8.9	13.3	23.7	24.6	23.8	7.3	0.1	0.1	0.1	0.3	1.7
Rainfall (mm) - Station 214150	4.7	5.7	11.1	21.8	22.8	16.8	4.9	0.1	0.1	0.1	0.2	1.4

Figure 4-1: Rainfall Trends of Rainfall Station 211147 and 215150



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
90 Percentile	13	18	20	74	68	39	21	0	1	0	0	5
70 Percentile	3	8	10	17	22	22	3	0	0	0	0	1
50 Percentile	2	2	3	9	9	9	1	0	0	0	0	0
30 Percentile	0	1	1	3	3	2	0	0	0	0	0	0
10 Percentile	0	0	0	0	0	0	0	0	0	0	0	0

Figure 4-2: Quantile Rainfall Distribution for the Project Site (Rainfall Station 214150)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
90 Percentile	14	29	36	92	67	52	24	0	0	0	1	7
70 Percentile	7	12	15	19	25	24	4	0	0	0	0	1
50 Percentile	3	3	5	13	14	9	1	0	0	0	0	0
30 Percentile	0	1	2	6	3	4	0	0	0	0	0	0
10 Percentile	0	0	0	1	0	1	0	0	0	0	0	0

Figure 4-3: Quantile Rainfall Distribution for the Project Site (Rainfall Station 211147)

4.1.2. Temperature

A summary of the temperature data obtained from CFSR is presented in Table 4-1. The monthly distribution of average daily maximum temperatures shows that the average midday temperatures range between 19.5°C in July to 29.9°C in March. The region records its coldest average temperatures during June and July with the temperature dropping to 11.8°C on average during the night. On average the hottest months are in the summer months between October to March.

Table 4-1: Temperature Data from 1979 – 2014

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average Temperature (°C)	25.3	26.3	26.9	25.1	22.0	19.5	19.8	21.6	23.9	24.5	24.9	24.8
Average Minimum Temperature (°C)	16.5	18.0	19.2	17.5	14.5	11.9	11.8	12.5	14.0	14.5	15.1	15.2
Average Maximum Temperature (°C)	34.1	34.6	34.7	32.7	29.6	27.1	27.8	30.6	33.7	34.5	34.8	34.5

4.2. Topography and Drainage

The town of Uis is located within the Uis River which is a tributary within the Ugab Catchment Area. The Uis River drains the project area in a north-westerly direction until it joins the Ugab River. The Ugab River is the main river that drains the Ugab Catchment which has an area of ~29 000 m^2 (AfriTin Mining, 2021). Although the town of Uis is located in the Ugab Catchment Area, the town receives water from the Omaruru River. The Omaruru River drains the Omaruru Catchment which has an area of ~11 500 m^2 and receives an annual rainfall of between ~300 - 350 mm from the mountainous region upstream (AfriTin Mining, 2021).

4.3. Catchment Delineation

Six catchments were delineated for modelling purposes for the streams that are in the vicinity project site (see Figure 4-4). The catchments' characteristics are shown in Table 4-2.

Table 4-2: Characteristics of the Delineated Catchments

Catchment	Area (km^2)	Length of longest watercourse (km)	Distance to catchment centroid (km)	Equal area height difference	Slope (m/m)
C1	83.3	20.7	11.0	204.1	0.013
C2	69.4	16.7	7.9	156.7	0.012
C3	12.1	10.2	4.5	97.0	0.032
C4	5.4	4.5	2.1	42.7	0.004
C5	0.2	0.8	0.4	6.4	0.011
C6	0.9	1.7	1.5	32.6	0.041

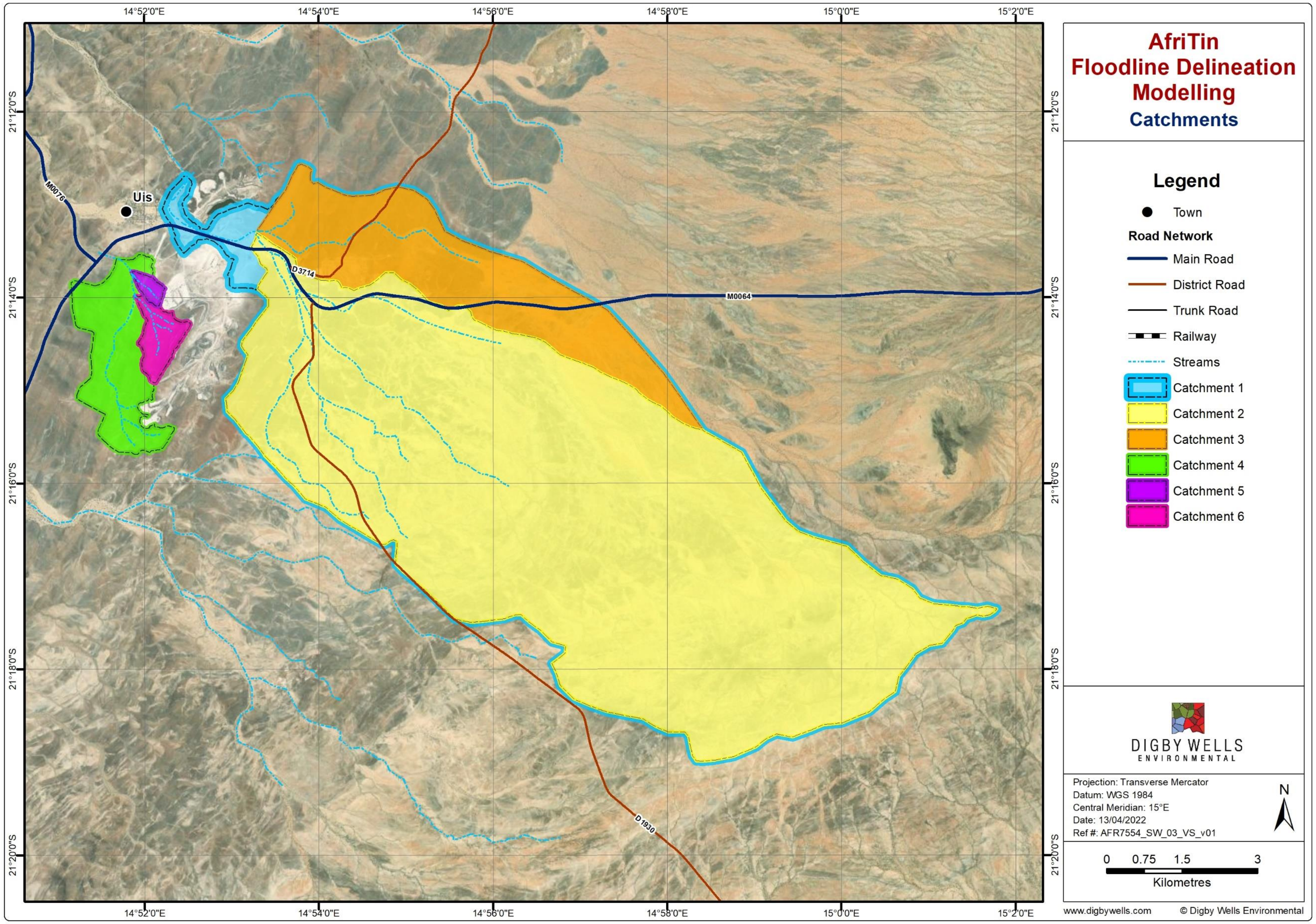


Figure 4-4: Delineated Catchments in the Vicinity of the Project Site

4.4. Design Rainfall Depths

Design rainfall depths, for a 24-hour duration, from the UPD were compared to the statistically derived rainfall depths from the daily rainfall stations obtained from the CFSR (see Table 4-3). The recent high rainfall events in Uis in January and February were included in the daily rainfall data received from CFSR to estimate the 24-hour duration design rainfall depths. On 19 January 2022 and 13 February 2022, Uis received about 30 mm and 40 mm of rainfall in a day, respectively.

From the results in Table 4-3, it is noted that the CFSR rainfall stations' design rainfall depths are almost similar to those of Rainfall Station 131639 W. Therefore, Rainfall Station 131639 W selected in the UPD was deemed to represent the design rainfall depths of the Uis region fairly well.

Table 4-3: 24-Hour Design Rainfall Depths

Return Period (Years)	2	5	10	20	50
Rainfall Station 131639 W	23.0	35.0	45.0	56.0	74.0
CFSR Rainfall Station 214150	15.4	31.5	45.2	61.4	87.7
CFSR Rainfall Station 211147	16.0	29.5	39.7	50.5	66.3

4.5. Peak Flows

Design peak flows for the 1:50 and 1:100-year recurrence interval storm events were computed for the watercourses in the study site using the methodologies listed in 3.1.3. This was undertaken to compare the results obtained by these methods. The comparison of the different flood peaks, using different methodologies can be seen in Table 4-4.

There is a wide range of peak discharge results obtained from the different methods. The differences in results from the deterministic methods, namely the Unit Hydrograph and Rational Methods, were expected given the difference in methods in determining point rainfall as well as catchment sizes. The Rational Method is best suited for catchment sizes of up to 15 km^2 as noted by the SANRAL Drainage Manual (2013). Additionally, slight changes in the input variables such as the areal reduction factor or the catchment C Factor can result in significant changes in the resultant peak discharge value. The Unit Hydrograph Method, on the other hand, was developed for catchment areas ranging between 15 and 5 000 km^2. The results of this method were found to be less conservative than those obtained from the Rational Method as well as the SDF and MIPI. The SDF results are considered conservative, particularly for the larger C1 and C2 catchments. The RM2 flood peaks are also conservative, and the peaks are not far-off from the SDF peaks.

Overall, because the RM2 method was developed for small rural catchments and produced conservative peak flows, those peaks were selected for use in HEC-RAS for hydraulic modelling.

Table 4-4: Peak Discharge Results for the Delineated Catchments

Catchment	Rational Method (RM2)		Unit Hydrograph (UH)		Standard Design Flood (SDF)		MIPI	
Return Period	1:50-year	1:100-year	1:50-year	1:100-year	1:50-year	1:100-year	1:50-year	1:100-year
	(m³/s)							
C1	51.0	61.2	29.1	40.6	53.8	68.2	34.4	43.7
C2	50.1	60.8	18.9	41.0	49.1	62.1	32.7	41.5
C3	14.9	18.0	6.0	8.5	12.2	15.5	10.0	12.7
C4	11.1	13.5	6.2	8.9	8.9	11.3	7.3	11.3
C5	1.0	1.2	0.2	0.3	0.8	1.1	1.1	1.4
C6	4.2	5.1	1.2	1.7	3.1	3.9	2.8	3.6

5. Floodlines Determination

Floodlines were modelled for the 1:50-year and 1:100-year flood events. The streams included in the analysis were those agreed upon by Digby Wells and the Client in the proposal phase of this study, augmented by the study boundary and the DEM. The inundation extents overlaid on the sections of these unnamed streams traversing through the proposed project boundary are indicated in Figure 5-1 and Figure 5-2. The HEC-RAS cross-sections are shown in Appendix A.

The results indicate that the modelled floods will mostly not inundate the mining area and surrounding infrastructure. The flood protection berms, shown in Figure 5 1, can divert floodwaters away from the mine property. For discussion purposes, the impacts of Berms 8, 2 and 4 are shown in Figure 5-3 to Figure 5-6. At Berm 8, the floodwaters are diverted away from the mining area which is situated at a lower elevation. However, where Berm 8 ends, the modelling indicates that both the 1:50 and 1:100-year floodlines would flood the pit (see Figure 5-4).

The lidar survey indicates that Berm 8 is at an elevation of 807 m Above Mean Sea Level (AMSL) and the natural ground is at an elevation of 805.6 m AMSL. Therefore, the modelling shows that the floodwaters would start flowing into the pit at the lower natural ground (just after Berm 8). To minimise the possibility of flooding into the pit area, it is recommended that Berm 8 is extended around the pit. Berm 2 and Berm 4, which are located near Uis town, also act as flood protection barriers which divert water away from the road and Uis town (see Figure 5-5 and Figure 5-6). The model also indicates that the culvert along the road (between Berm 7 and Berm 10) would be overtopped by both the 1:50 and 1:100-year floodlines. The culvert was likely designed for lower return period floodlines such as the 1:20 year return period.

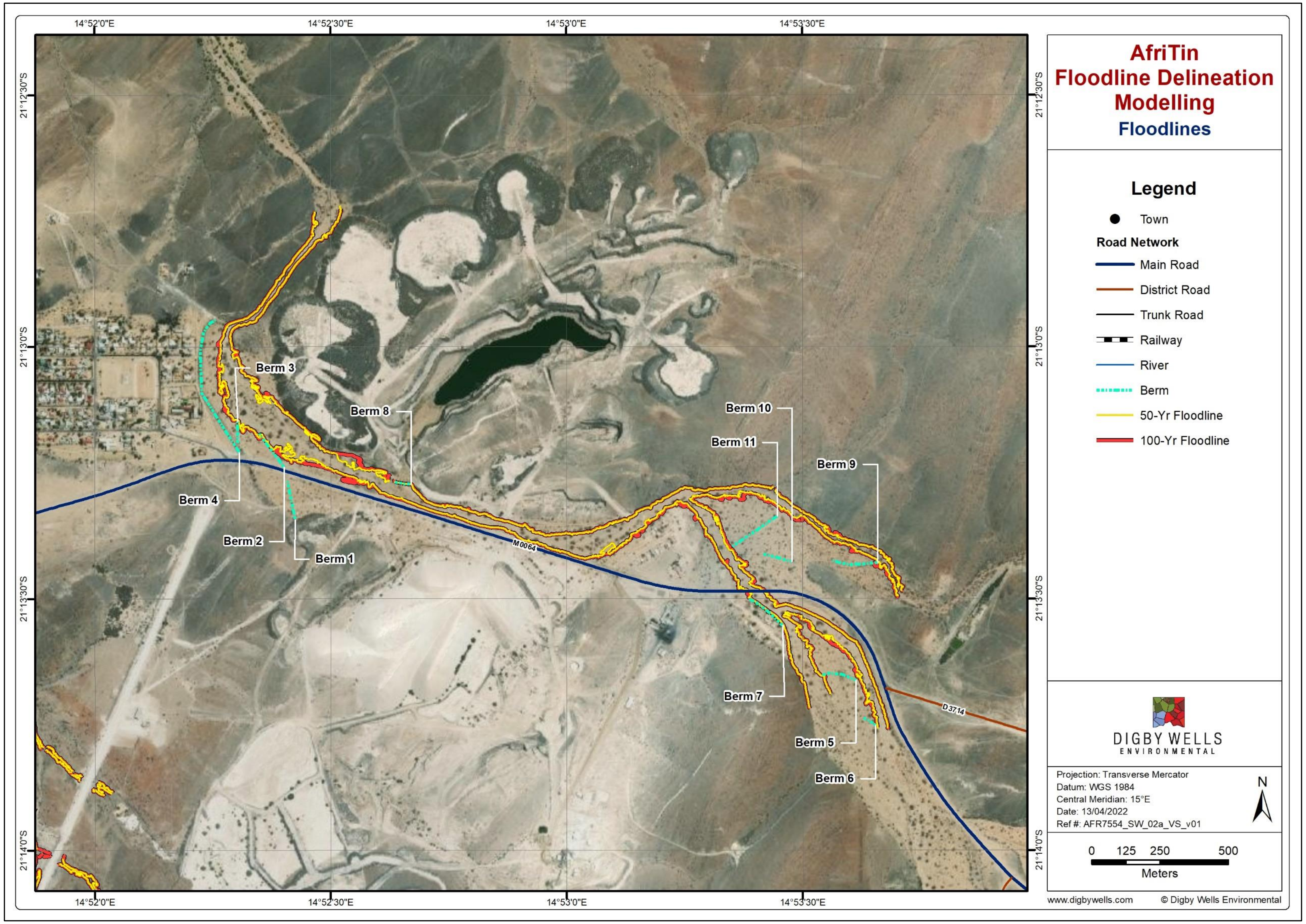


Figure 5-1: Floodlines for the 1:50-year and 1:100-Year Events (North of the M0064 Road)

Figure 5-2: Floodlines for the 1:50-year and 1:100-Year Events (South of the M0064 Road)

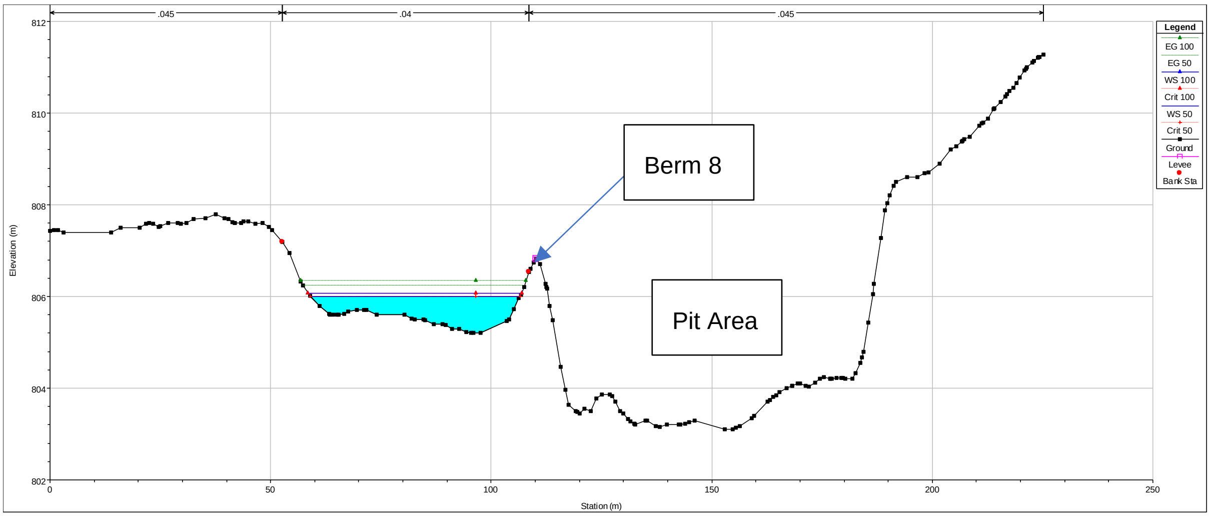


Figure 5-3: Modelled Floodwaters in the vicinity of Berm 8 (Represented by a Levee)

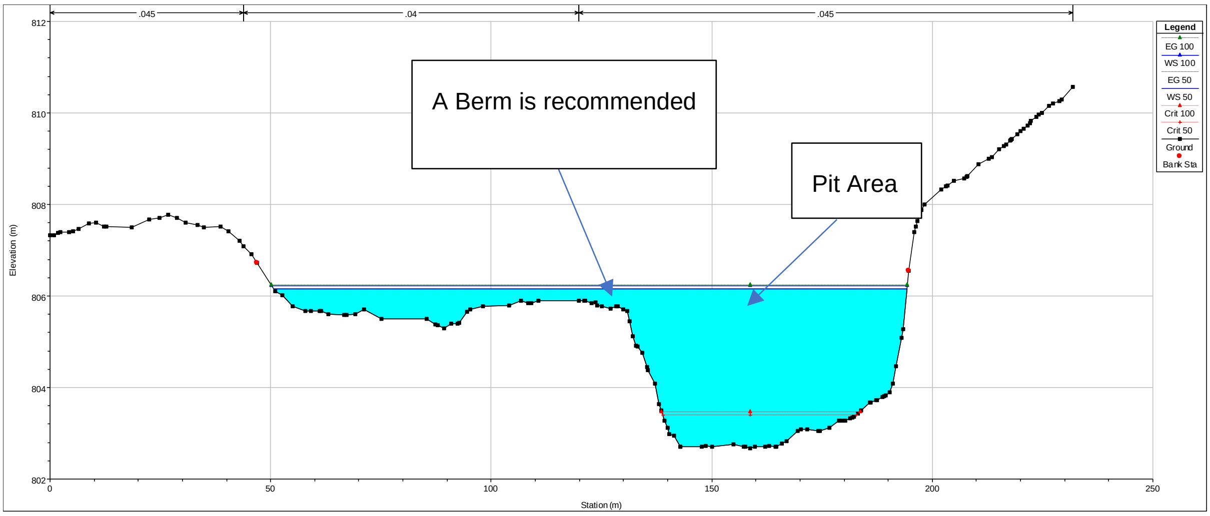


Figure 5-4: Modelled Floodwaters just Downstream of Berm 8

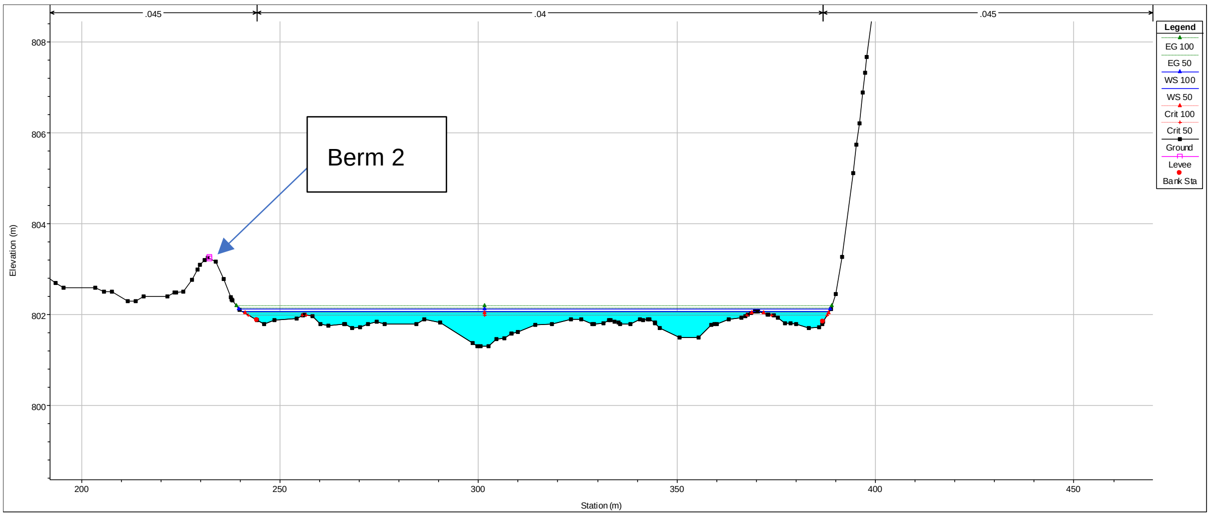


Figure 5-5: Modelled Floodwaters in the Vicinity of Berm 2 (Represented by a Levee)

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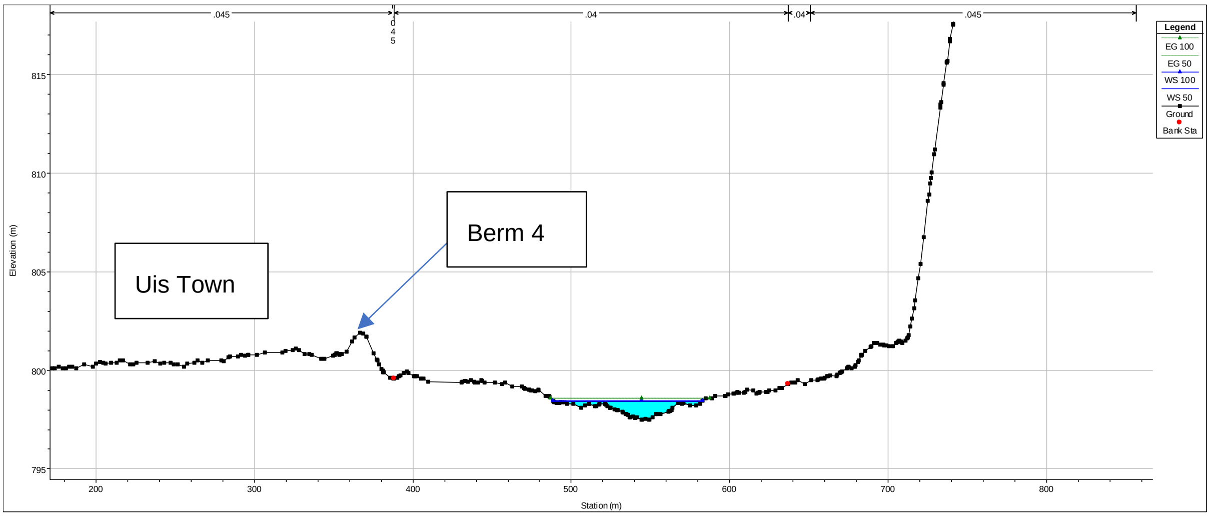


Figure 5-6: Modelled Floodwaters in the Vicinity of Berm 4

6. Conclusions and Recommendations

- The study has modelled the 1:50-year and 1:100-year flood events, which subsequently indicate the potential inundation of the modelled streams during these rainfall events;
- The 1:50 and 1:100-year return period peak discharge values for the identified streams were calculated using the Rational Method Alternative 2 (RM2) which was compared to other design rainfall estimation methods and its peak discharges were deemed conservative and representative of the study site;
- The modelled floodlines using the HEC-RAS model were deemed representative;
- The results of the HEC-RAS model indicate that the modelled floods will not inundate the mining area and its infrastructure;
- The flood protection berms that are in place are able to divert floodwaters away from the mine property;
- However, it is recommended that Berm 8 is extended around the open-pit area to divert floodwater away;
- The modelled floodlines will assist when determining the placement of infrastructure for the protection of water resources, as required by various legislations;
- The indicative floodline results presented in this study are as accurate as the lidar survey, but they should be sufficient to meet the relevant environmental requirements;
- It is recommended that should there be any changes in the terrain of the mining area, these floodlines should be updated.

7. References

AfriTin Mining. (2021). *Uis Tin MIne Phase 1- Potential Regional Groundwater Resources.* Namibia: AfriTin Mining.

Alexander, J. (2002). The Standard Design Flood. *South African Institution of Engineers*, 26-30.

ARC. (2006). *Land Types of South Africa.* Pretoria: Agricultural Research Council.

Chow. (1959). *Open Channels Hyadraulics.* USA: McGraw-Hill.

Cowan, W. (1956). Estimating hydraulic roughness coefficients. *Agricultural Engineering Journal 377*, 473-475.

Gericke and Du Plessis. (2012). Evaluation of the standard design flood method in selected basins in South Africa. *South African Institution of Civil Engineering*, 2309 - 8775.

Government Gazette No. 35517. (2012). *Water Management Areas for South Africa.* Pretoria: Department of Water and Sanitation.

JAXA. (2015). *ALOS World 3D – 30m (AW3D30) the global digital surface model (DSM) dataset.* Tokyo: Japan Aerospace Exploration Agency (JAXA).

National Centre for Atmospheric Research. (2022). *Climate Data Guide.* NCAR, https://climatedataguide.ucar.edu/climate-data.

National Geospatial Institute. (2013). *Maps and Geospatial Information.* Department of Rural Development and Land Reform.

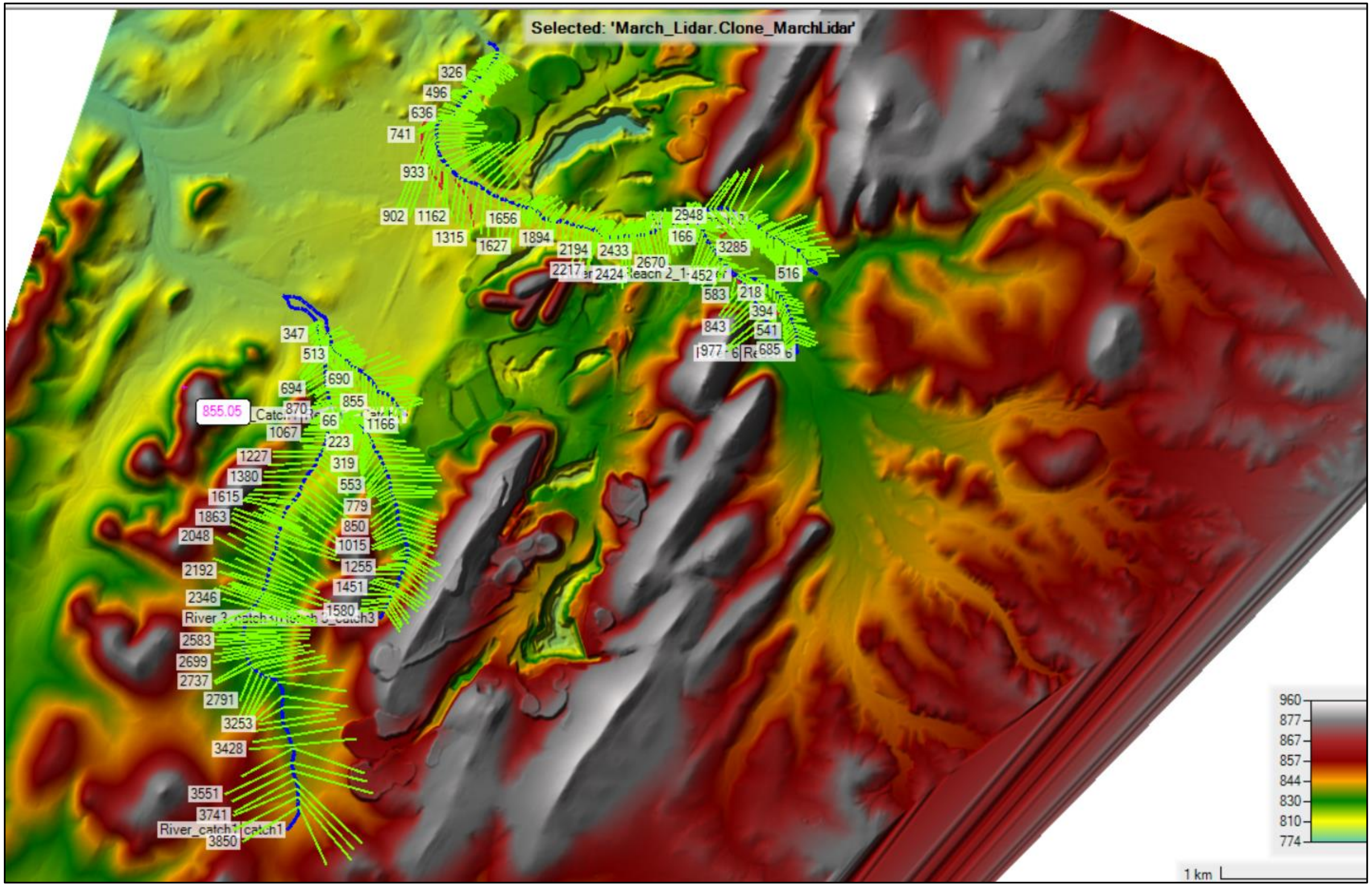
RAS Government Gazette No. 35517. (2012). *Water Management Areas for South Africa.* Pretoria: Department of Water and Sanitation.

SANRAL. (2013). *South African Drainage Manual.* Pretoria: SANRAL.

US Army Corps of Engineers. (1995). HEC RAS Hydraulic Modelling Software. Version 4.1. California.

WRC. (2015). *Water resources of South Africa 2012 study.* Pretoria: Water Research Commission.

Appendix A: HEC-RAS Cross-Sections



Appendix A1: Cross-Sections Along the Digitized Streams