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Cont. No.: WI26-00103
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Client reference:

Dear Charles

Re: HAIB COPPER OFF-CHANNEL STORAGE DAM BREACH ASSESSMENT MEMO

1.0 INTRODUCTION

Knight Piésold (KP) was appointed by Haib Minerals (Pty) Ltd, a subsidiary of Koryx Copper Inc (Koryx), to complete a pre-feasibility study for various engineering tasks related to the Haib Copper Project. Part of the engineering scope includes the design of an off-channel storage dam that will provide water supply water to the mine during operations. The proposed off-channel storage dam is located on a tributary of the Haib River, upstream of the confluence of the Haib and Orange Rivers, and is designed to store water abstracted from the Orange River to meet water demands of the Haib Copper Mine. The Orange River, an international watercourse between Namibia and South Africa, supports a number of commercial farming operations along its banks, including those at Vioolsdrift, Noordoewer, Rooiwal Sud and Aussenkehr, which could potentially be impacted by the downstream propagation of a dam breach flood wave (see Figure 1-1).

This memorandum outlines the dam breach assessment that has been conducted to quantify the potential downstream consequences along a reach of the Orange River in the event of a hypothetical failure of the dam. Results from the hydrodynamic model include inundation boundaries for two dam breach scenarios to inform an Emergency Response Plan.

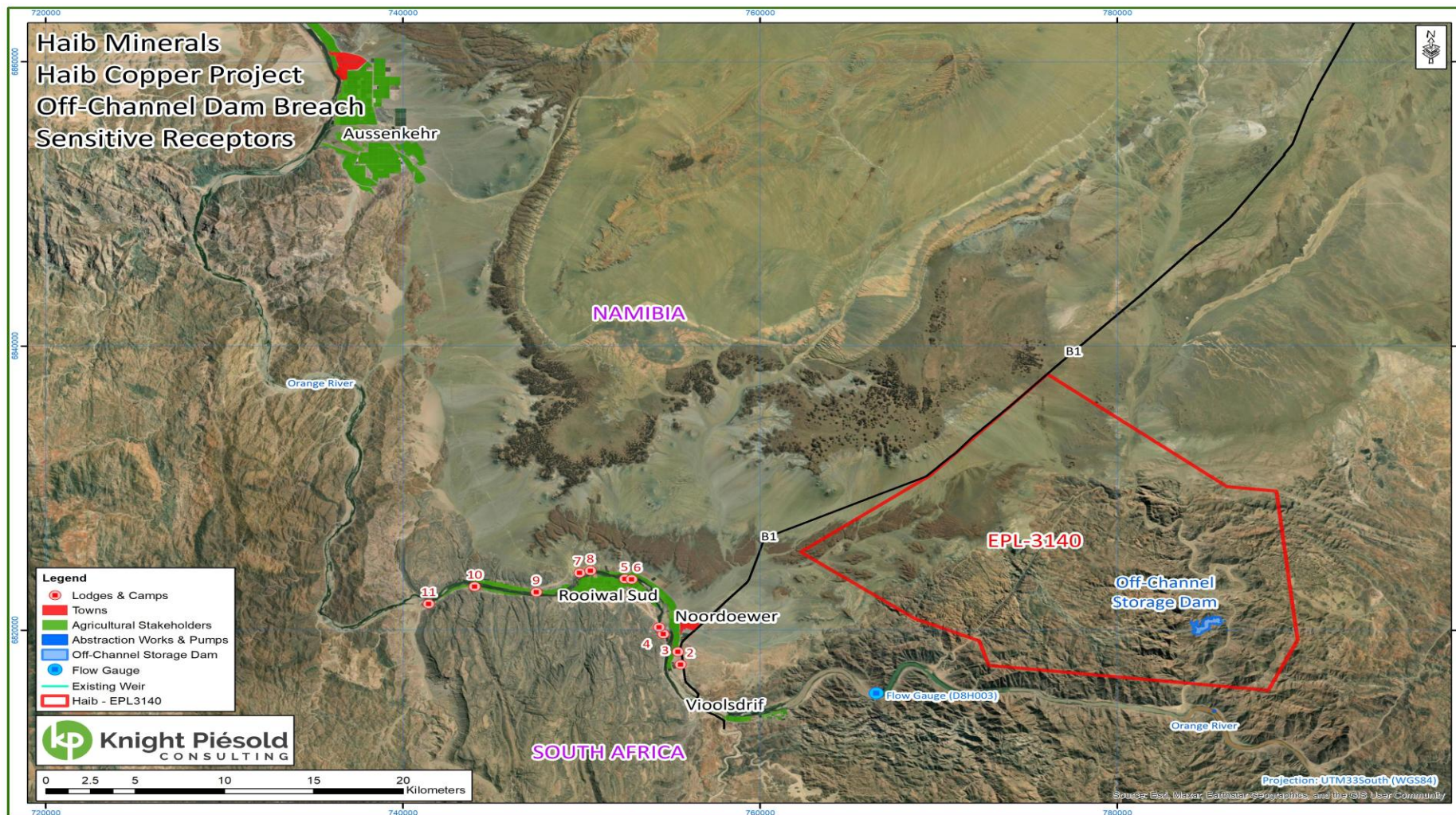


Figure 1-1: Off-channel Storage Dam relative to the Downstream Commercial Farmers

2.0 OBJECTIVES

The objectives of this study were:

- To generate flood lines for dam breach scenarios along the Haib River and Orange River
- To correlate the consequences of a hypothetical breach to existing flood risks along the selected reach.

3.0 HYDRODYNAMIC MODELLING OF DAM BREACH

3.1 HEC-RAS Hydrodynamic Model

A 2D hydrodynamic model was developed in HEC-RAS version 6.6 to assess the downstream impacts of the dam breach. The model comprises:

- A digital elevation model (DEM) of the study area with region specific land characteristics applied to the 2D flow area to provide realistic hydraulic parameters;
- Baseline flow conditions for the Orange River; and
- Breach characteristics for the Off-Channel Storage Dam.,

3.1.1 Digital Elevation Model

Survey Data

A topographical survey was carried out by Strydom & Associates in November of 2025 to generate high resolution LiDAR data which was then used to create a DEM with a 1 m resolution.

The spatial extent of the second stage Orange River model was constrained by the availability of suitable terrain data. The composite DEM, comprising PhotoSat survey data stitched with NGI topographic data, provided adequate resolution only within the reach extending upstream from the Haib Orange River confluence to the vicinity of the first commercial farming area downstream. Beyond this extent, the available terrain data was considered to have insufficient resolution to produce reliable hydrodynamic results, and the model boundary was therefore limited to the PhotoSat/NGI survey.

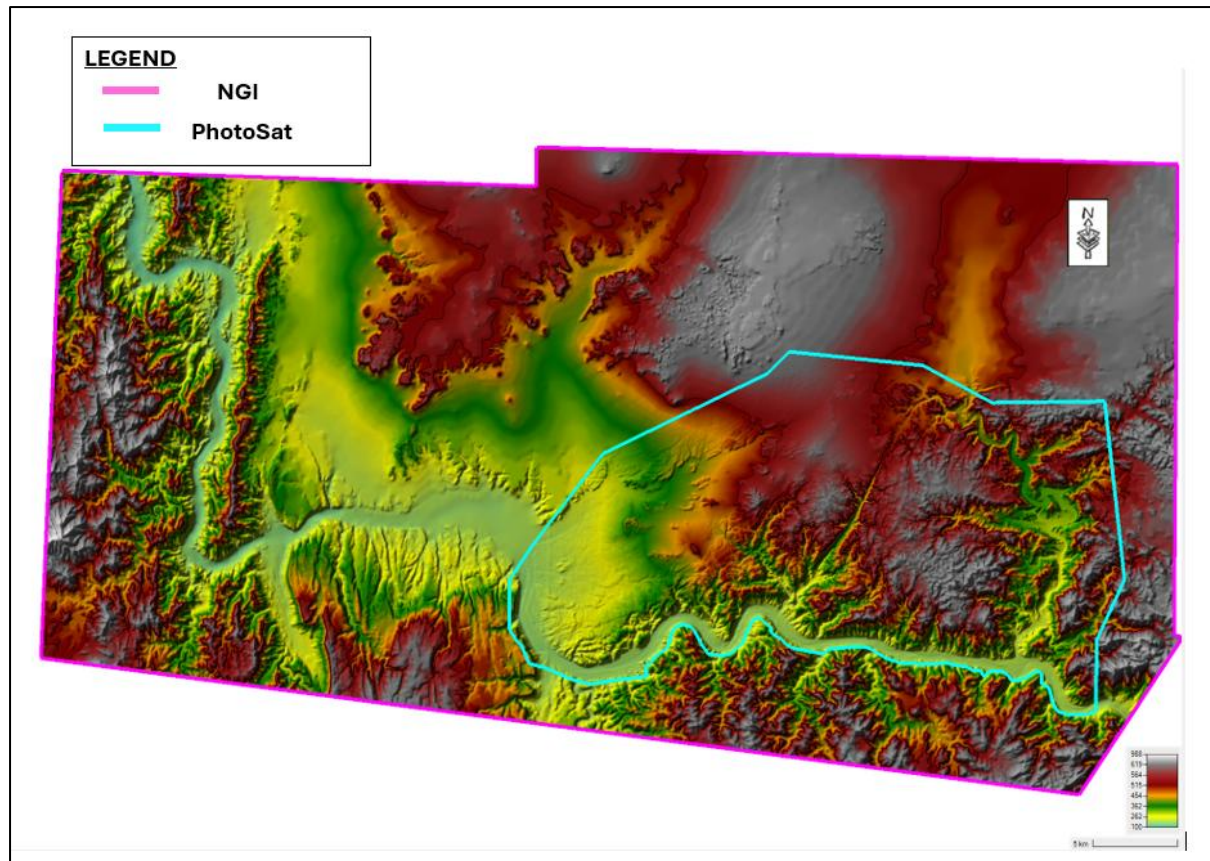


Figure 3-1: Composite Survey Data

Land Characteristics

The land characteristics applied to the model impact the hydraulic behaviour of the modelled breach water as it flows down the river. The characteristics typically apply to the hydraulic roughness of the flow paths (Manning's roughness coefficient), and the runoff characteristics as defined by the SCS method which in turn impacts the initial abstraction of surface flow to infiltration and the infiltration rate of the surface.

These characteristics are defined using regional information on the soil groups and areal imagery assessments. Based on the information available for this analysis, 4 land cover types were defined, with land cover characteristics as presented in 3-1.

3-1: Land Cover

Land cover	Manning n	Percent Impervious (%)	SCS Hydrological Soil Group	Curve Number	Abstraction Ratio	Minimum Infiltration Rate (mm/hr)
Rocky Steep Slopes	0.06	15	B	70	0.15	5.7
Sandy Basins	0.03	0	A	40	0.2	7.6
Cultivated Land	0.05	0	A	45	0.2	7.6
Water	0.035	100	A	100	0	0

3.1.2 2D Flow Area and Analysis Approach

To simplify the modelling process, the breach is modelled in two stages defined by two different 2D flow areas. The first area (Stage 1) models the flow from the breach location at the Off-Channel Dam site to the confluence of the Haib River and Orange River. The second area (Stage 2) models the flow from the confluence of the Haib River and Orange River down to the Noordoewer farms (limit of DEM as described in Section 3.1.1). Figure 3-2 and Figure 3-3 depict the 2D flow areas for each model area.

Stage 1 Model

The Off-Channel Dam is defined in the model by a storage area with characteristics that match the stage capacity curve for the dam. A breach is simulated which transfers the water from the storage area into the 2D hydrodynamic flow area (refer to Figure 3-2) which models the flow from the breach down the Haib River. An outflow boundary condition is built into the model to capture the flow from the stage 1 model which is then used as one of the inflow boundary conditions for the Stage 2 Model.

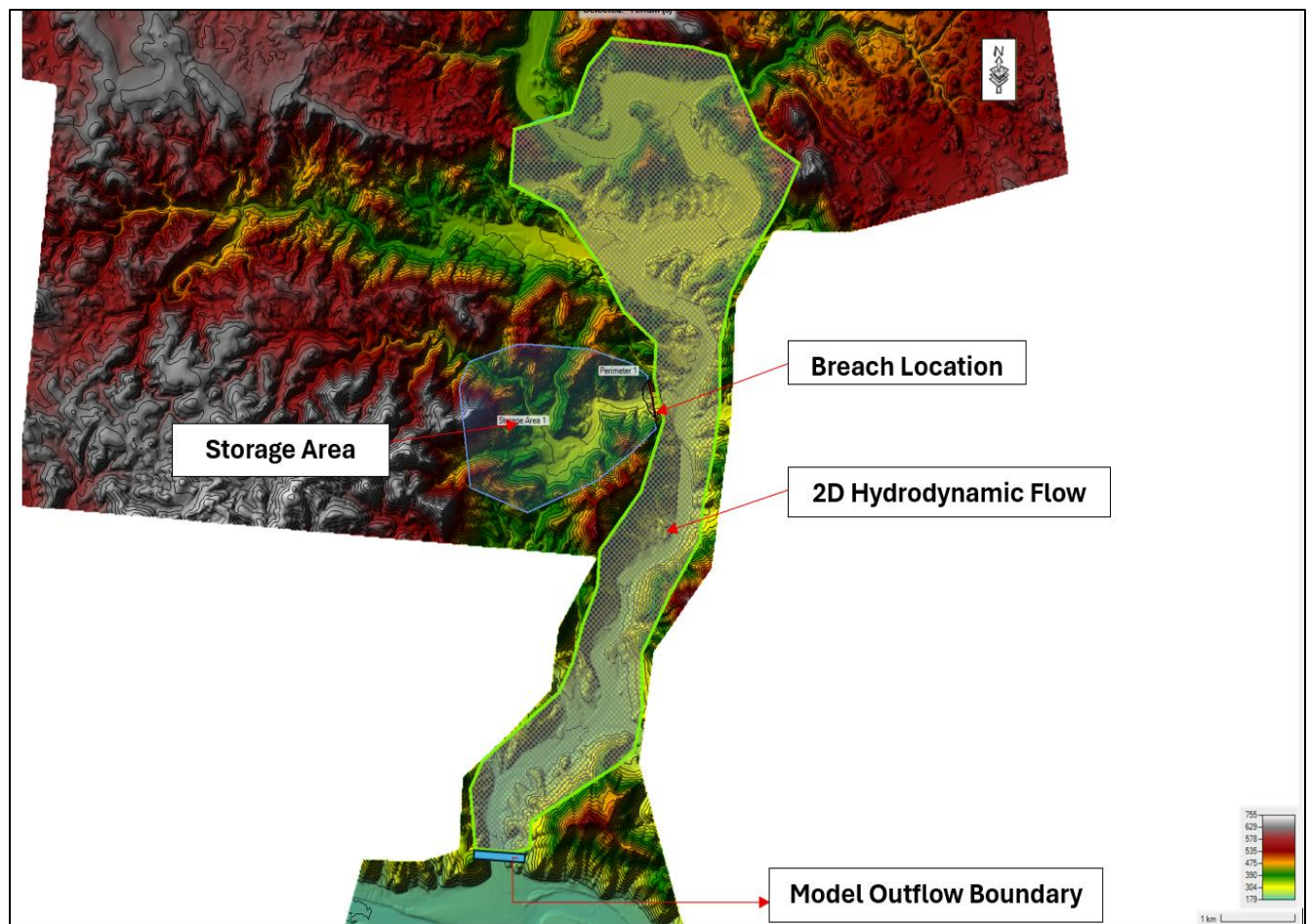


Figure 3-2: 2D Hydrodynamic Flow Area for the Dam Breach of the Off-channel Storage Dam

Stage 2 Model

The second stage modelled the flood hydrograph from the confluence with the Orange River down to the farms of interest (Noordoewer) at the extent of the survey data available (see **Figure 3-3**). Two model inflow (Inflow hydrograph) boundary conditions were defined. One was set far enough upstream to capture the extent of back water effects from the propagating flood wave on account of the dam breach. The second inflow (inflow hydrograph) boundary condition was set at the confluence of the Haib and Orange River at the point where the stage 1 model terminates. The outflow boundary condition for this 2D flow area was set at the extend of the reliable survey data for the DEM, with the boundary condition defined by the normal flow depth.

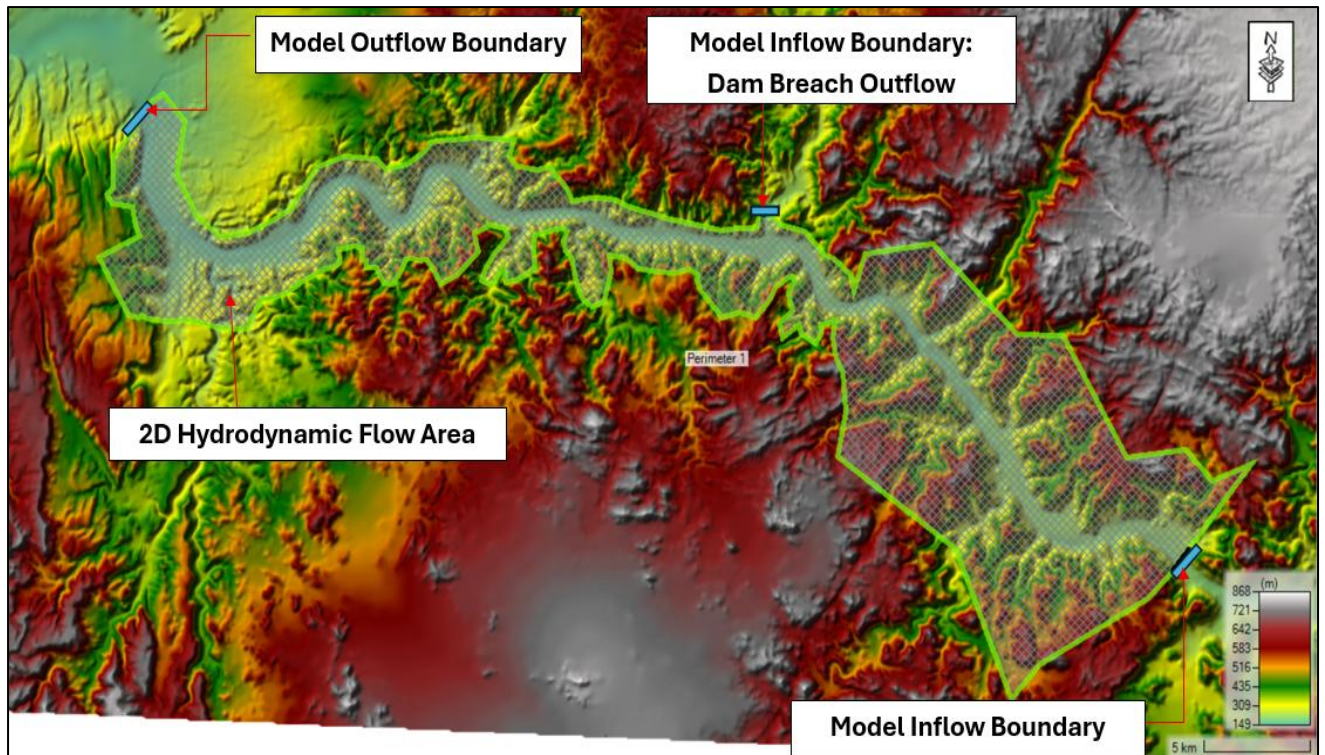


Figure 3-3: 2D Hydrodynamic Flow Area for Orange River

3.1.3 Breach Parameters

The breach development parameters directly influence the resultant breach hydrograph, including the magnitude of the peak discharge and time to peak. The combination of the breach development parameters and the dam stage storage curve produce the resulting breach hydrographs used in the hydraulic analysis.

A range of methods are available to estimate the parameters, with the appropriate method selected taking into consideration the geometry of the dam and valley, the dam material type, and factors such as concrete lining for the CFRD (Concrete Faced Rockfill Dam).

Two breach parameter scenarios were assessed to produce an envelope of possible breach hydrographs:

1. A piping failure with a peak outflow based on breach parameters defined by the MacDonald et al. empirical method, which is integrated within the HEC-RAS dam breach analysis module.
2. A piping failure with a peak outflow based on more conservative parameters (larger breach dimensions and rapid development time) but considered less likely to be applicable due to the concrete face affecting erosion rates typically associated with embankment dams. These conservative parameters were selected based on past experience and engineering judgement.

Table 3-2: Dam Breach Development Parameters

Parameter	Scenario 1 (Recommended)	Scenario 2 (Conservative)
Final Breach Bottom Width	3 m	218 m
Breach Bottom Elevation	277 mamsl	294.5 mamsl
Side Slopes (H:V)	0.5:1	1:1
Breach Formation Time	1.61 hrs	1.04 hrs

A piping failure was selected for the failure method as the design of the Off-Channel Storage Dam incorporates several features to make overtopping failure unlikely. Figure 3-4 shows the resulting hydrographs from each scenario. The conservative breach parameters result in a breach hydrograph that develops rapidly with a flood peak that is approximately 10 times that of the recommended breach parameters. Although this difference is substantial, the breach volume is the same and the results show that the natural storage in the Orange River will attenuate much of the flood peak (see results section 3.2).

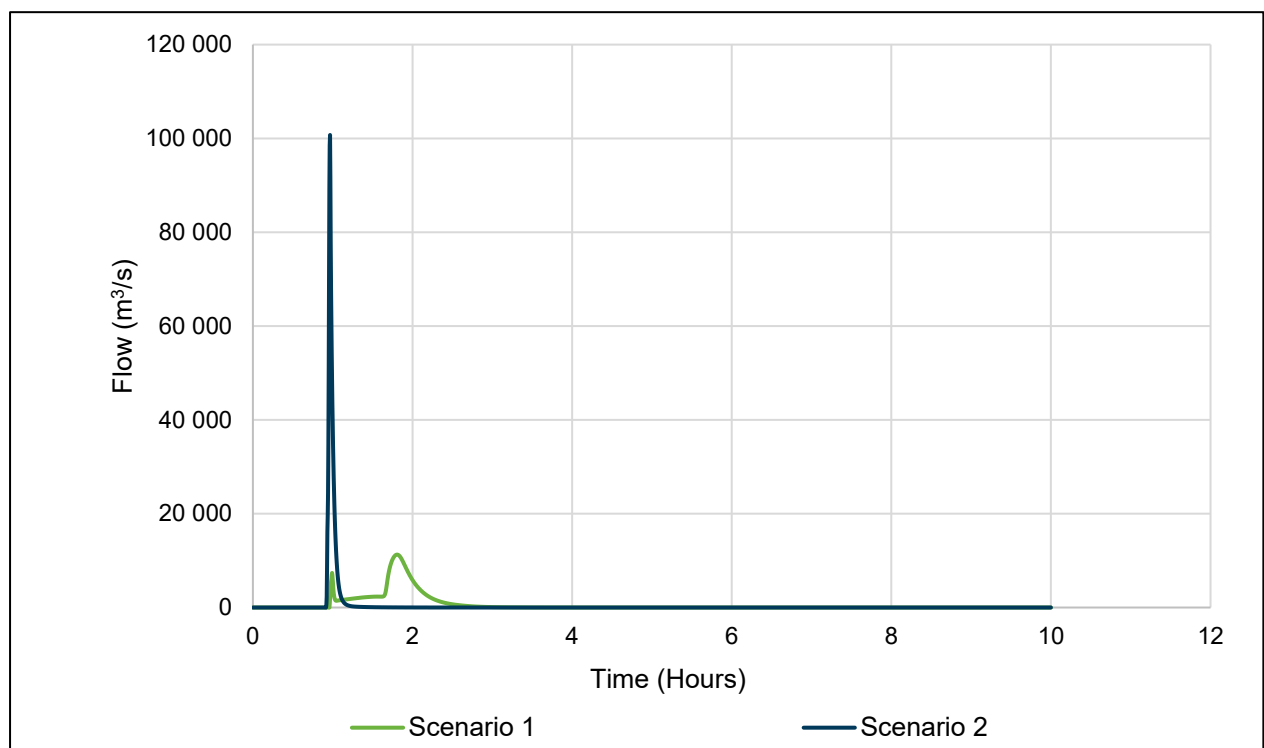


Figure 3-4: Inflow Hydrographs applied in Stage 2 Modelling for DBA Scenarios

3.1.4 Baseline Hydrology

Dam breach assessments are typically modelled taking into account the existing base flow in a receiving river or an appropriate flood level that coincides with the breach hypothetical breach occurrence. The selection of the appropriate flood requires hydrological judgment.

For this breach assessment, the breach is modelled during a sunny day event (piping failure) with the breach flowing into an ephemeral tributary of the Orange River (the Haib River). As such, the analysis is not considering a base flow in the Haib River.

The Orange River is however being modelled with a steady base flow equivalent to the 1:2-year Annual Recurrence Interval (ARI) flood peak to conservatively account for some natural flow that is not captured the survey data.

The selection of the 1:2-year ARI flood and not a larger flood event is based on several considerations.

- 1) The size of the catchment up to Vioolsdrift gauging station closest to the Haib/Orange confluence is approximately 289 000 km² (see Figure 3-5) with the flood hydrograph taking 13 days (312 hours) to reach its peak from the start of the flood (see Figure 3-6), compared to approximately 2 hours for the full duration of the dam breach (see Figure 3-4).
- 2) The nature of the dam is such that it is likely only going to be at FSL at the end of the wet-season once excess water in the Orange River has been pumped into the dam. The likelihood of a flood in the Orange River occurring at the same time that the Off-Channel Storage Dam is full, and that the dam breaches while full, and that the peak of the breach hydrograph coincides with the peak of the Orange River flood hydrograph is considered extremely low.
- 3) The base flow in the river is not captured in the survey and an unknown proportion of the flood would already be taken up in the base flow.

Based on these considerations, selecting a larger ARI flood is statistically unlikely and unrealistic. Given how large the catchment is in this case, the 2-year AEP flood was selected for the base flow (see Table 3-3), however the base flow was modelled with a constant flow rate to be conservative.

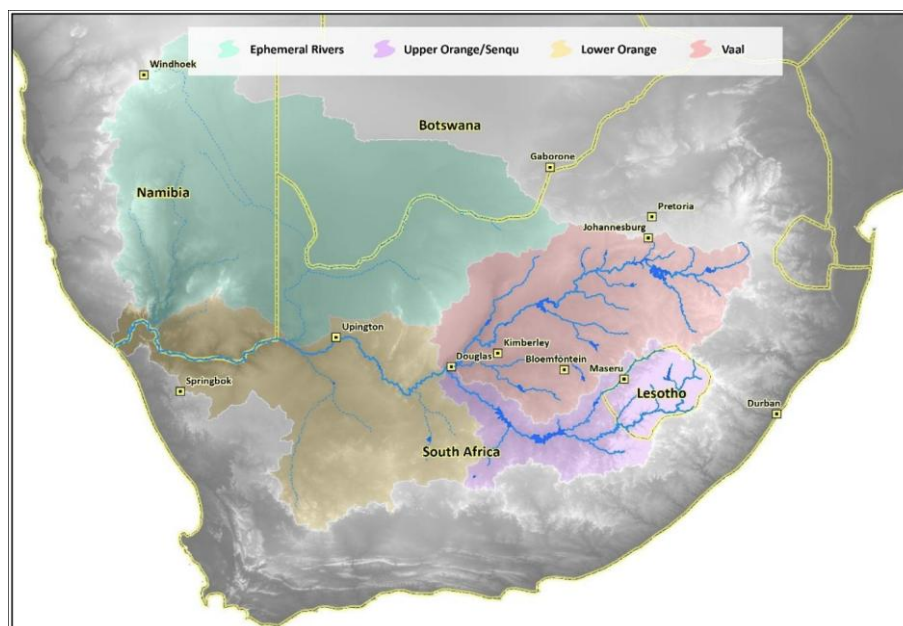


Figure 3-5: Overview of the Sub-Catchments Making Up the Greater Orange-Senqu River Basin

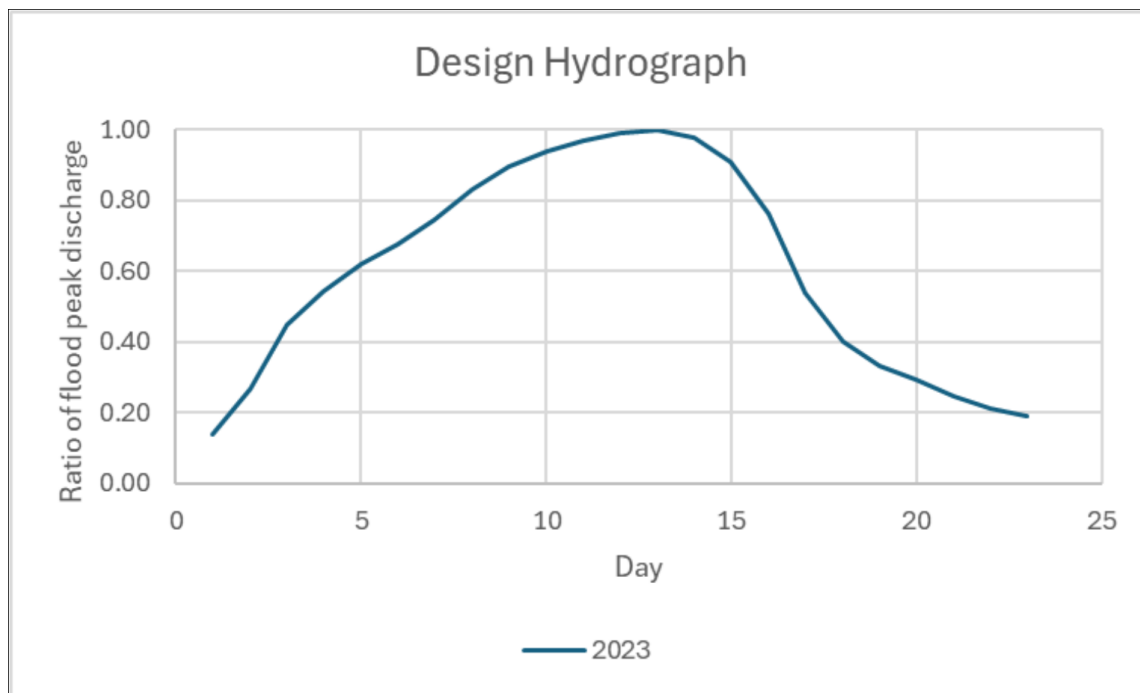


Figure 3-6: Dimensionless Flood Hydrograph

Table 3-3: Recommended Annual Recurrence Interval Flood Peaks (ASP Technology [2026])

Annual Recurrence Interval (ARI) (years)	Flood Peaks (m ³ /s)
2	1 000
10	3 600
20 (Design Flood)	4 800
50	8 000
100 (Check flood: Switchgear)	9 500
200	11 100
Regional maximum flood (RMF)	18 900

3.2 RESULTS

Hydrodynamic modelling was performed in HEC-RAS version 6.6 using the Diffusion Wave equation set, with flood inundation mapping carried out in RAS Mapper. The following results present the inundation boundaries of the respective dam breach scenarios propagating along the Orange River. These results will inform, emergency preparedness and land use planning decisions.

Figure 3-7 and Figure 3-8 show the computed flood lines for Scenario 1 and Scenario 2, respectively.

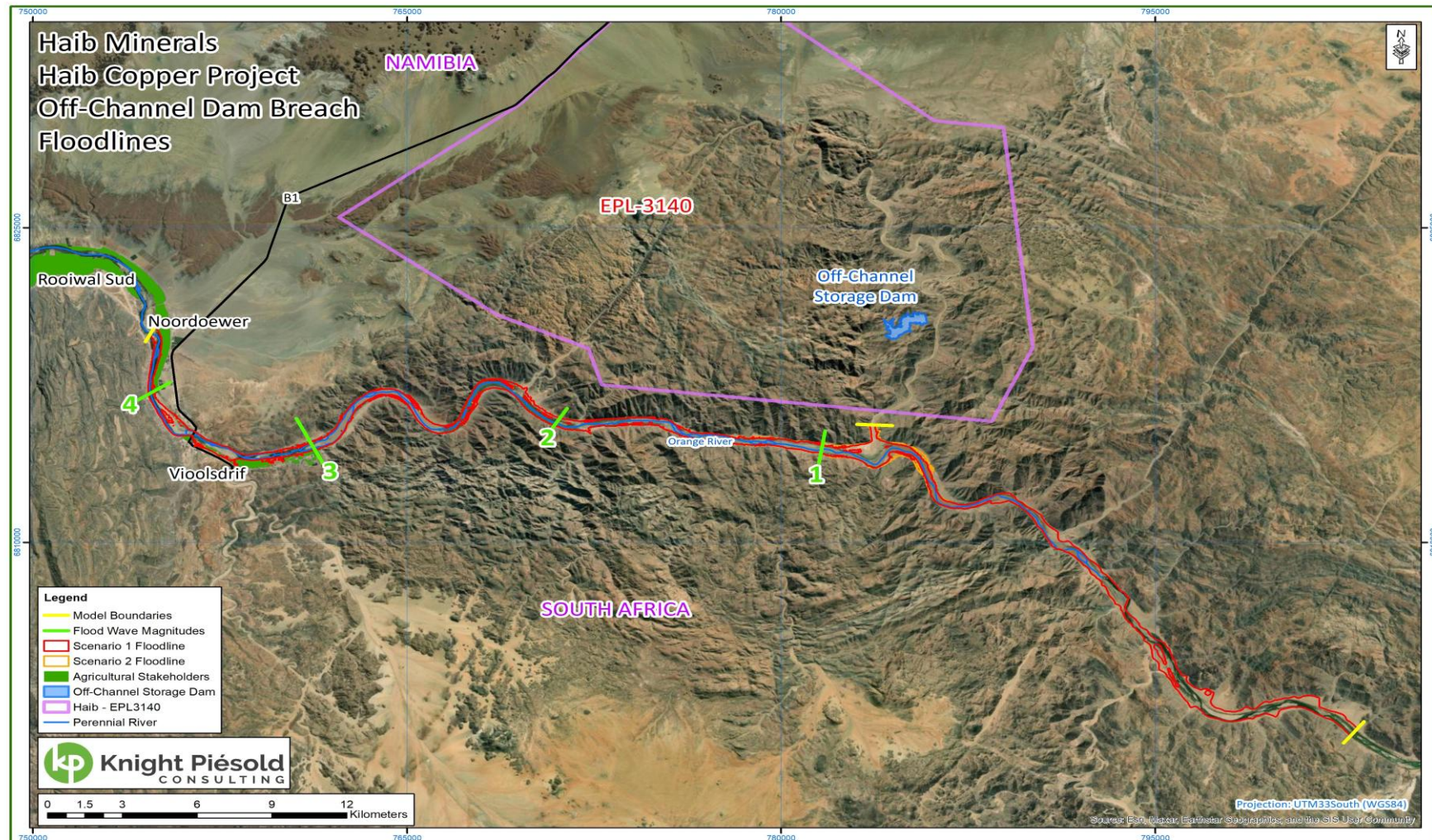


Figure 3-7: Flood Lines of Dam Breach Scenarios

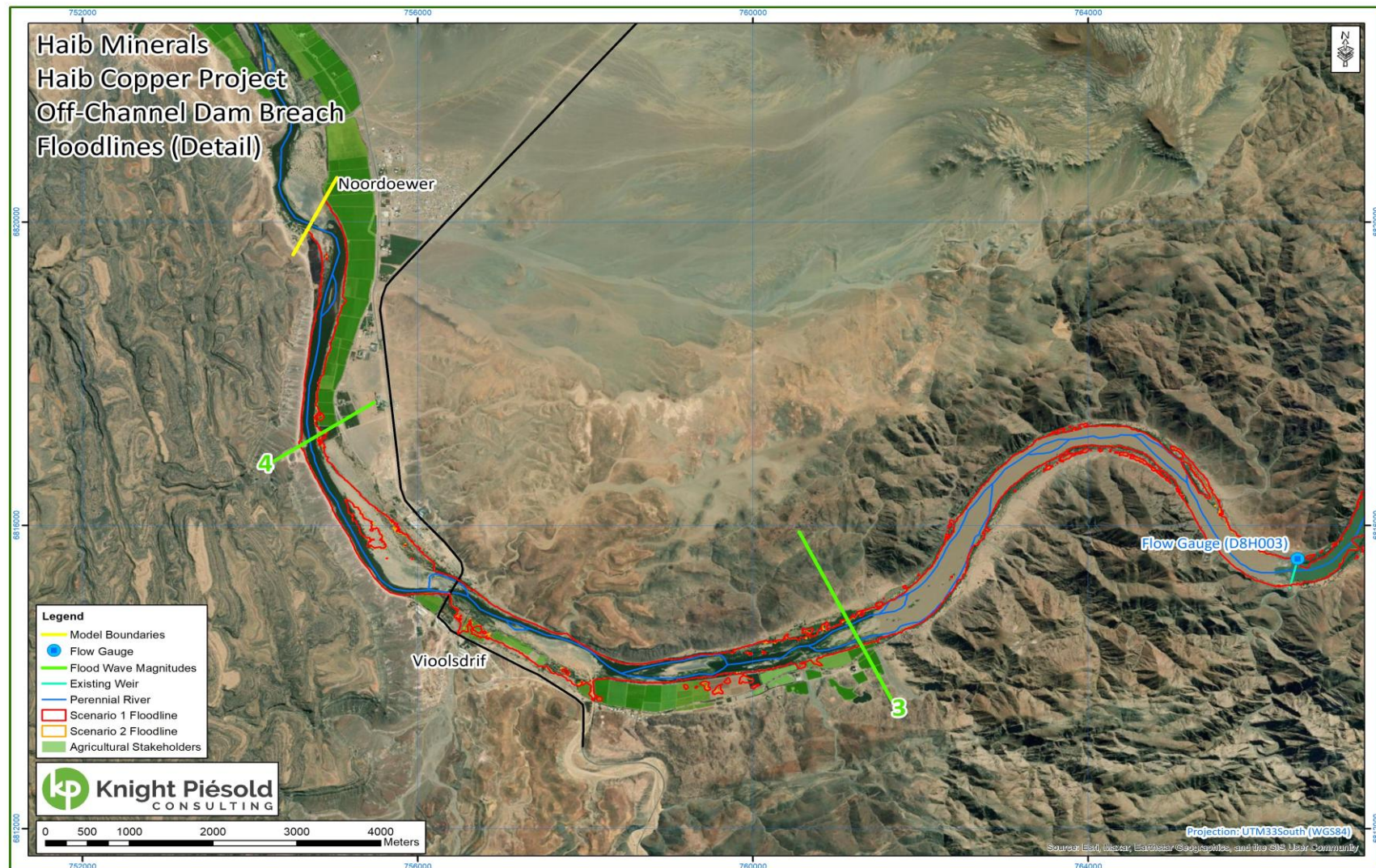


Figure 3-8: Flood Lines of Dam Breach Scenarios relative to Farmers

Four cross-sections have been selected along the Orange River to provide an indication of the flood wave propagating downstream relative to the Haib and Orange Confluence.

Table 3-4 and Table 3-5 summarize the peak flood and time of peak flood computed at the selected cross sections. The flood peaks are compared to the estimated flood peak for the Orange River, as calculated from the flow records for the Vioolsdrift Gauging Station (D8H003). This comparison gives context to the magnitude of the breach flood peaks compared to the existing inherent flood risks along the river.

Figure 3-9 and Figure 3-10 show the flood characteristics at the breach location and the locations of interest, for Scenarios 1 and 2, respectively. The results indicate progressive flood wave attenuation along the Orange River downstream of the Haib confluence for both breach scenarios.

Due to the proximity of location 1 and location 2 to the Haib/Orange River confluence, these sites experience higher flood peaks for Scenario 2 compared to Scenario 1 as there is less attenuation of the flood within this section of the Orange River reach.

As the flood waves propagate towards locations 3 and 4, the Scenario 2 flow is attenuated in the natural storage of the river banks, whereas the comparatively gradual development of the Scenario 1 flow sustains the flood peak for longer resulting in a more sustained flow. The impact of this is that the flood peak at sections 3 and 4 are more comparable to each other, suggesting that the sensitivity of the breach parameters is less consequential beyond at the points of interest (downstream of section 3).

Table 3-4: Estimated Flood Peaks for Scenario 1 DBA (Recommended)

No.	Location	Flood Peak (m ³ /s)	Time of Peak (hr)	Comparative Return Period relative to DH8003
1	Immediately Downstream of Confluence	7 565	2.0	Less than 50 years
2	Midway Downstream from Confluence	4 197	2.6	Less than 20 years
3	Commercial Farmers	3 177	3.8	Less than 10 years
4	Outflow point based on extents of model	2 841	4.7	Less than 10 years

Table 3-5: Estimated Flood Peaks for Scenario 2 DBA (Conservative)

No.	Location	Flood Peak (m ³ /s)	Time of Peak (hr)	Comparative Return Period relative to DH8003
1	Immediately Downstream of Confluence	17 572	1.05	Less than Regional Maximum Flood (RMF)
2	Midway Downstream from Confluence	4 253	1.67	Less than 20 years
3	Commercial Farmers	3 043	2.95	Less than 10 years
4	Outflow point based on extents of model	2 699	3.83	Greater than 5 years

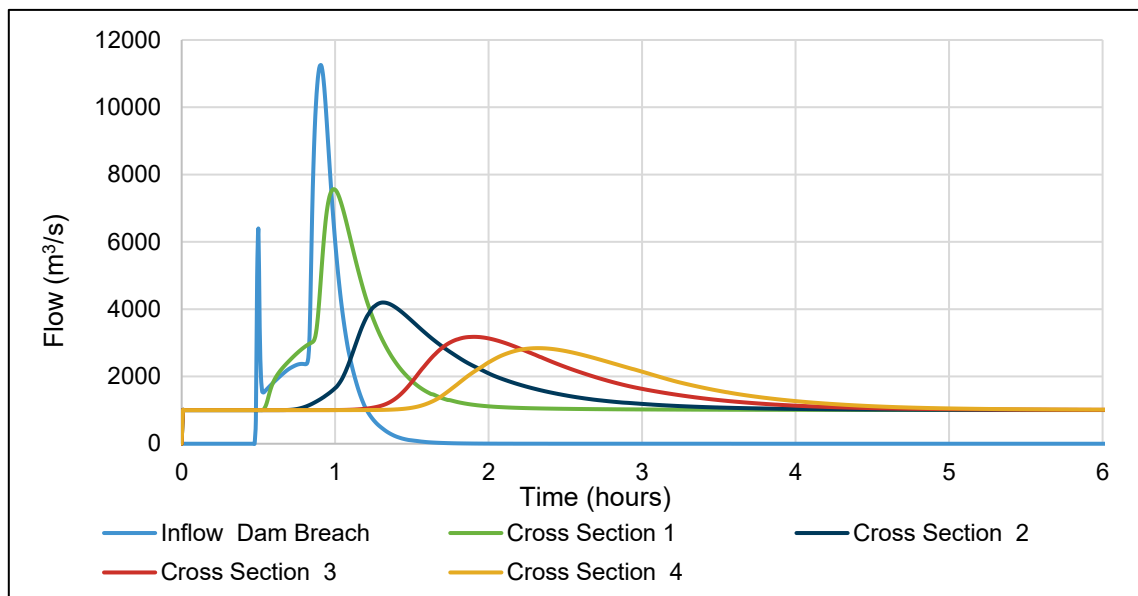


Figure 3-9: Flood peaks along Haib River at Respective Cross Sections for Scenario 1 Breach

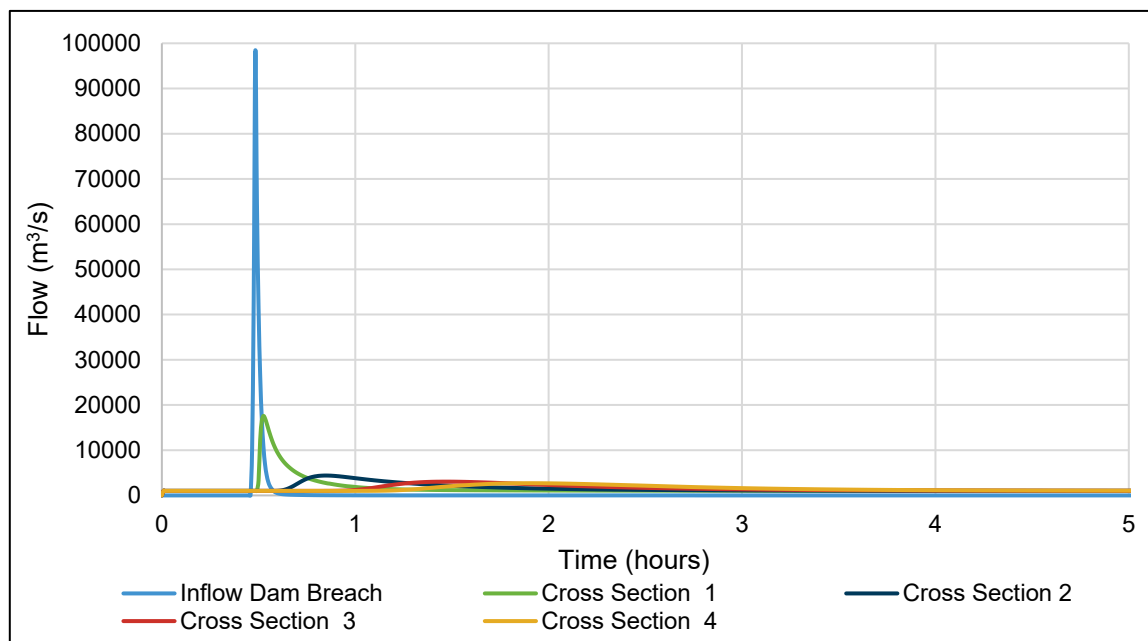


Figure 3-10: Flood Peaks Along Haib River at Respective Cross Sections for Scenario 2 Breach

4.0 SUMMARY

A dam breach assessment was conducted for the proposed Off-Channel storage dam at the Haib Copper Project to evaluate potential downstream impacts on commercial farming operations along the Orange River, including those at Vioolsdrift, Noordoewer.

A two-stage 2D hydrodynamic model was developed using HEC-RAS and RAS Mapper to simulate dam breach scenarios and generate flood hydrographs at the confluence of the Haib and Orange Rivers (Stage 1). The hydrographs derived from the Stage 1 dam breach scenarios were incorporated into a

downstream Orange River model (Stage 2) to assess the progression of the flood wave along the Orange River with a modelled steady baseline flow equivalent to the 1:2-year ARI flood peak (estimated to be 1,000 m³/s) included to provide conservative results.

Two breach parameter scenarios were assessed to produce a possible envelope of breach hydrographs, with computed peak outflows at the Haib-Orange confluence ranging from approximately 7 500 m³/s to 17 500 m³/s, while the peak flows near the Noordoewer farms ranging from 2 700 m³/s to 2 840 m³/s. The results show significant flood wave attenuation along the Orange River for both scenarios (62% and 85% for Scenarios 1 and 2, respectively) compared to the flow entering the Orange River at the Haib River confluence. At the commercial farming areas, peak flows are comparable to estimated floods at the Orange River with return periods of less than 10 years.

Although the hydraulic model extent did not reach Aussenkehr, the significant attenuation trend observed along the Orange River suggests that flood impacts at Aussenkehr would be of a lesser magnitude than those estimated at Noordoewer.

Flood inundation maps generated from this assessment will inform emergency preparedness planning and land use decisions for downstream stakeholders

5.0 REFERENCES

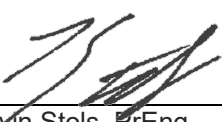
ASP Technology (Pty) Ltd, 2026. Raw water intake on the Orange River, Concept hydraulic design of intake works including pump selection

6.0 CERTIFICATION

Yours sincerely,

Knight Piésold Consulting (Pty) Ltd.

Prepared: 
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Reviewed: 
Kevin Stols, PrEng
Principal Engineer

Approval that this document adheres to Knight Piésold Quality Systems:

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Appendix A

INUNDATION BOUNDARIES AND WATER SURFACE ELEVATION MAPS

Pages A1 to A4

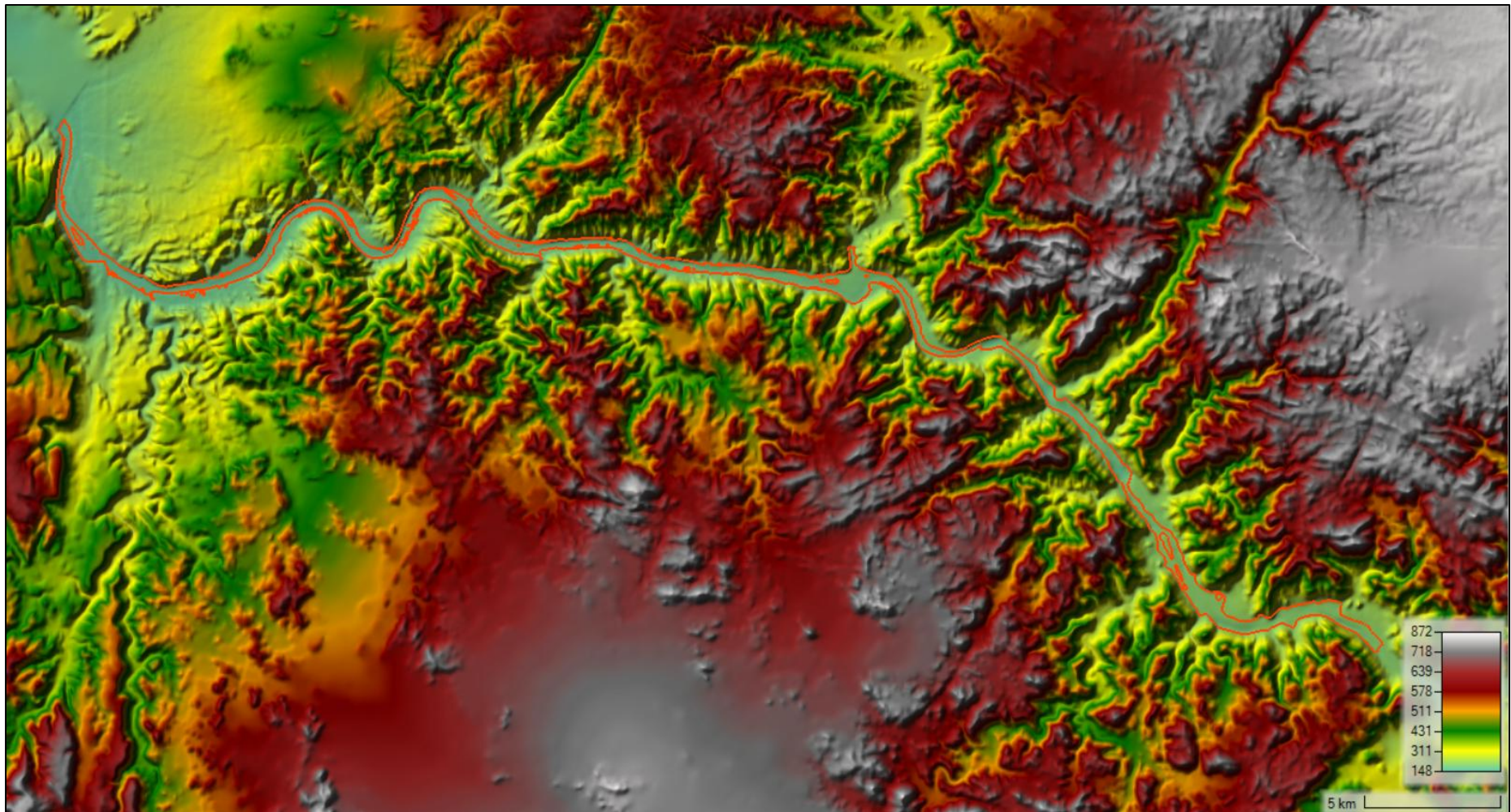


Figure A-1: Inundation Boundary along the Orange River for Scenario 1 Dam Breach

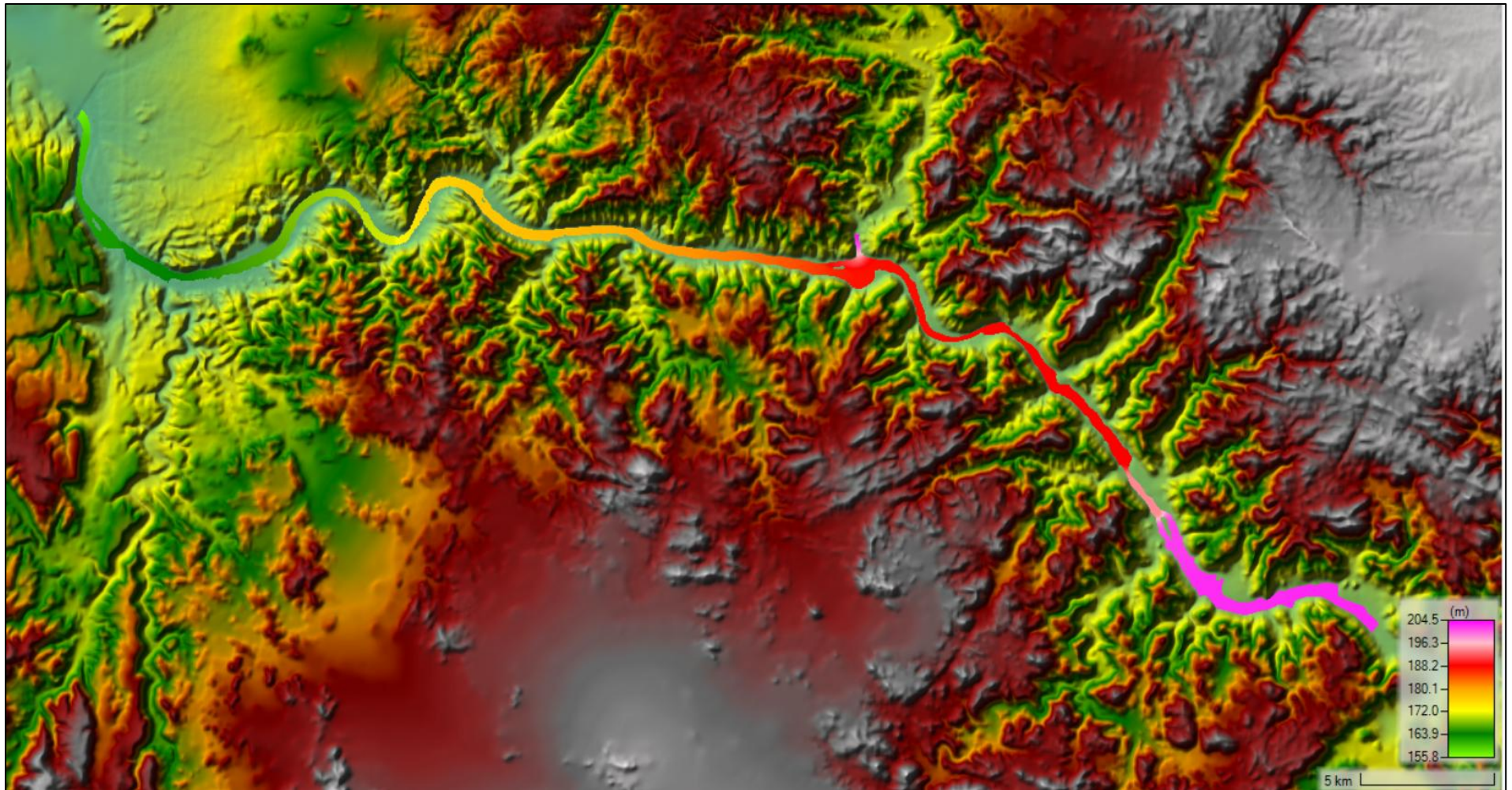


Figure A-2: Water Surface Elevations along the Orange River for Scenario 1 Dam Breach

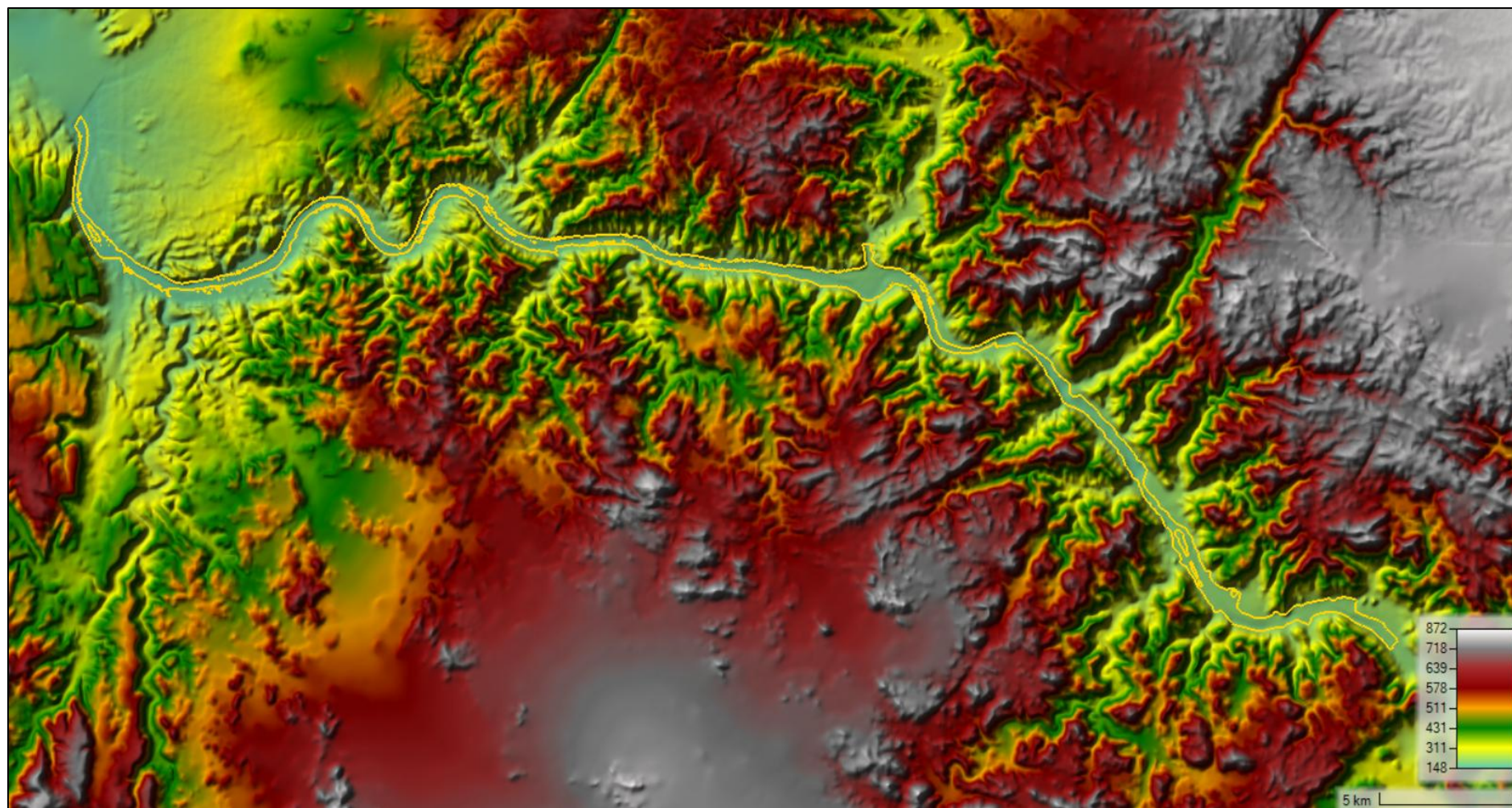


Figure A-3: Inundation Boundary along the Orange River for Scenario 2 Dam Breach

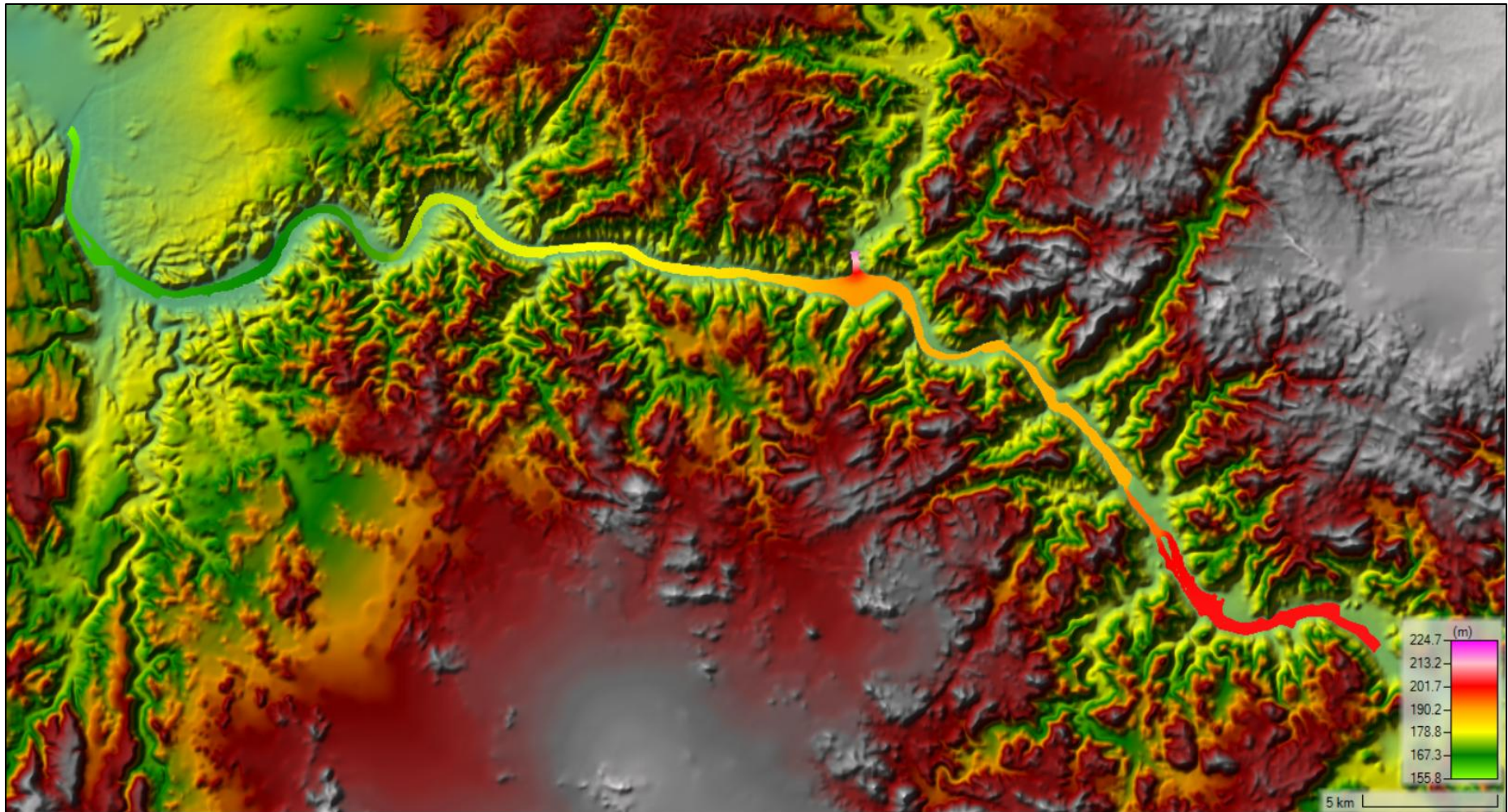


Figure A-4: Water Surface Elevations along the Orange River for Scenario 2 Dam Breach