Level 4, 56 William Street
Perth WA 6000

Tel +61 8 9322 9733
www.aq2.com.au

AQ2 Pty Ltd
ABN 38 164 858 075

Memo

To	Dr Rob Ramsay	**Company**	CZR Resources
From	Wendy McCarthy	**Job No.**	385C
Date	31/08/2021	**Doc No.**	005a
Subject	CZR Robe Mesa – Preliminary Surface Water Modelling		

Rob,

Following on from the scoping study, we are pleased to present the outcomes of the preliminary surface water modelling for the CZR Resources (CZR) Robe Mesa Project (Project, Robe Mesa) herein.

1. INTRODUCTION

1.1 Project

The Robe Mesa Project is a part of the Yarraloola Iron Ore Project, which is a joint venture between Zanthus Resources Ltd for CZR (85%) and ZanF Pty Ltd (15%).

The Yarraloola Iron Ore Project is located approximately 140km southwest of Karratha, between the Rio Tinto owned Mesa-A and Mesa-J iron ore mines. The project is also close to the township of Pannawonica, a support town for the nearby Rio Tinto operations, and is 110km east of Onslow. Yarraloola is accessible by the North West Coastal Highway.

The Robe Mesa Deposit is a "Channel Iron Deposit (CID)' ore-type and is hosted by two flat sheets of pisolitic ironstone (i.e. Robe Pisolite) that overlie each other, with the upper sheet containing 24 Mt of higher-grade ore. Mining at Robe Mesa is currently focussed on the upper CID sheet, with proposed pits located above the water table and the floor of the Robe River Valley. The Project is currently proposed to produce around 2Mtpa by a Direct Shipping Ore (DSO) mining method. Trucking the ore through ports between Onslow and Dampier are being explored.

1.2 Surface Water Studies

With respect to surface water management for the project, one key issue for the proposed Project identified in the scoping study included:

- A number of relatively large surface water drainage lines (including the Robe River) flow through, and in proximity to, the proposed project area. These present a flooding risk to the project and access routes to the project. Flood modelling is required to identify the peak flood levels (for the 1% AEP). There is an opportunity to identify areas with lower flood risk where critical infrastructure could be positioned. Following a review of hydraulic model results, flood management options (such as elevating or relocation of infrastructure or flood bunding) or acceptance of the flood risk could be considered in more detail.

Flood modelling was proposed to be completed in two stages, suitable for the level of detail required at various stages of the Project:

- Preliminary Modelling to give the 'upper 1% AEP flood level risk' is based on adopting the 1% AEP peak flow estimation from the DWER Robe River gauging station as a constant inflow for the Robe River to the model upstream of the Project Site. Flood Frequency Analysis of DWER Robe River gauging station data is required as part of the project to estimate Robe River peak flows for various AEP events (including the 1% AEP) for input into the hydraulic model. For Red Hill Creek inflows, the adoption of peak flow estimates published in the scoping study (based on regional methods) as constant inflows was recommended. The preliminary model is intended to provide conservative flood level estimates with further refinement as required.
- In future stages of work, a hydrology model of the Robe River maybe be required to develop a time series hydrograph (river flow rate varying with time) for the Robe River and Red Hill Creek for use in a more detailed Feasibility Study FS Hydraulic Modelling. The hydrology model could be used to estimate the extreme events such as the 1:1000 year or Probable Maximum Flood (PMF) related to closure planning for the project (if any infrastructure is to remain close to the base of the mesa).

This report summarises the Preliminary Modelling stage methodology and results for the main Project Area (excluding areas of the access Haul Road outside of the available DTM). As background to this report, the hydrology context from the scoping study is summarised below, and for other details refer to the scoping study report.

2. REGIONAL HYDROLOGY CONTEXT

The project is located adjacent to the Robe River (Figure 1) and is within the DWER surface water management area for the Robe River and its tributaries. The Robe River is a significant river system in the region and drains east to west through the high relief areas of the Hamersley Ranges, then between Mesa formations on the Southern Peneplain, and onto the gently sloping coastal plain prior to discharging into the ocean (Ruprecht, 2000 and Beard, 1975). The Robe River has a minor ocean outlet with discharge to a marsh flat on the coastal plain (Ruprecht, 2000).

The nearest gauged catchment to the site is located on the Robe River at Yarraloola gauging station (DWER station 707002, 2021b), only 20km downstream of the Project and at the North West Coastal Hwy crossing. The catchment area draining to the gauging station is about 7,185km^2, with a mainstream river length of 208km (Figure 1). Significant peak flood levels and flows have been measured by DWER since 1972 (DWER, 2021a), including in 2004 (Cyclone Monty) and in 2009, which are useful for determining project flood risk from the Robe River. The maximum recorded flow at the gauging station was 12,200 m^3/s in 2009 (DWER, 2021a).

At the project location, the Robe River has eroded a 690 m wide gap in the mesa formation (i.e. between the project area mesa and the mesa to the north-east). The Robe River catchment to the Project area is 6,800km^2, which is 95% of the catchment to the gauging station (Figure 1), and therefore is likely to be subject to similar flow rates as those recorded at the gauging station.

Red Hill Creek, one of the major Robe River tributaries, flows through the Project Tenement area from south to north and around the northern part of the Robe Mesa (Figure 2). The confluence of Red Hill Creek channel and the Robe River is nearby the proposed pit and process plant area, posing a significant risk of flooding adjacent to the base of the Robe Mesa.

3. HYDROLOGY - PEAK DESIGN FLOWS

3.1 Robe River Peak Flow Assessment

Flood Frequency Analysis of the Yarraloola gauging station flow data from 1989-2021 was used to estimate Robe River peak flows for various AEP events (including the 1% AEP). Statistical analysis was completed in FLIKE software, with results of Log Pearson Type III estimation technique (including the 90% confidence limits) shown in Figure 3. Peak flow estimates are also shown in Table 1.

Table 1: Robe River Design Peak Flow Estimates (m^3/s)

Catchment	Annual Exceedance Probability (AEP)			
	10%	5%	2%	1%
Robe River –to Yaraloola	3,000	5,870	11,480	17,100

3.2 Local Catchments and Flow Paths

Local catchment boundaries (i.e., Red Hill Creek) have been estimated to the downstream end of the project area (Figure 2) based on the provided DTM data and SRTM elevations where DTM data is absent. Catchment areas for key catchments A to C are shown in Table 1. Runoff from Catchments A, B and C combine prior to discharging to the Robe River, with a total catchment area of 1,519km^2.

Topographic contours based on the DTM are shown on Figure 4. Due to flat terrain and limited DTM extent there is some uncertainty in the catchment definition between catchments A and B. In particular, runoff from a 35km^2 area (B1) of Catchment B (upstream of camp) may report to either:

- Catchment B through a defined channel to the east of the camp; or
- Catchment A and not impact the camp; or
- Between the defined channels within Catchments A and B as a shallow but wide floodplain extent with flow predominantly immediately to the west of the camp.

The uncertainty in the catchment boundary between A and B has limited impact on the mine plant infrastructure but needs to be taken into consideration when assessing flood risk to the proposed camp location. This uncertainty is accounted for within Section 4 through modelling two Catchment B1 flow scenarios; with flow either to the east of the camp footprint within Catchment B, or flow across the wide floodplain between defined drainages of Catchment A and B.

The Regional Flood Frequency Procedure (RFFP2000) developed by Flavell (2012) was used to provide estimates of peak design flow rates for local Red Hill Creek catchments. The estimates of peak flows may be refined during the feasibility study if the definition of runoff rates is critical to sizing infrastructure.

Table 2: Red Hill Creek Subcatchment Areas and Peak Flow Estimates (m^3/s)

Subcatchment ID	Area (km^2)	Annual Exceedance Probability (AEP)			
		10%	5%	2%	1%
A	876	250	555	1,050	1,680
B	103	55	105	190	300
C	540	230	470	880	1,390

For the purposes of hydraulic modelling (discussed in Section 4), catchment C has been further split into C1 and C2 sub-catchment areas of 455km^2 and 85km^2, with 1% AEP peak flows being 1170m^3/s and 220m^3/s on a prorate area basis. Similarly, catchment B can be split into B1 and B2 sub-catchment areas of 35km^2 and 68km^2, with 1% AEP peak flows being 100m^3/s and 200m^3/s on a prorated area basis.

4. HYDRAULIC FLOOD MODELLING

As identified in the scoping study, hydraulic 2D flood modelling of Robe River and Red Hill Creek has been completed to estimate inundation of the Project Tenement area. The 2D flood model was developed using HEC-RAS V6.0.0 modelling software.

4.1 HEC-RAS Modelling

The Hydrologic Engineering Center's (HEC) River Analysis System (HEC-RAS) software is capable of simulating one-dimensional (1D), two-dimensional (2D), and combined 1D-2D unsteady surface water flow through a full network of open channels, floodplains, and alluvial fans. The system comprises a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities (US Army Corps of Engineers, 2021). The 2D grid mesh can be modified in regions to provide variable grid sizes over the model domain and can incorporate irregular shapes. The two-dimensional computational module can solve using 2D Diffusion Wave equations or the 2D shallow water equations (also known as the 2D Saint Venant Full Momentum equations). The software also contains tools for performing inundation mapping directly inside the software (US Army Corps of Engineers, 2021).

4.2 2D Model Set-Up

A 2D model was set up to cover the extent of the pre-development DTM data shown in Figure 4 (which currently contains no infrastructure) to predict inundation areas resulting from the 1% AEP estimated design storm flows. The model boundary was extended beyond the DTM extents to include downstream north-eastern floodplains and the Robe Valley to the Highway crossing to ensure any model backwater effects did not impact flood estimates in the Project area. SRTM terrain was used where DTM was not available (with a minor vertical shift to match the DTM at the interface).

The general model build details are as follows:

- 50m x 50m grid with orientation refined by 'breakline' alignments along the river and tributary channels.
- Model inflows described in 4.2.1
- A Roughness manning's 'n' value varied according to flood depth (0.05 for depth>1m, 0.08 for depths 0.2 to 1m, and 0.12 to simulate sheet flow less than 0.2m deep.)

- Outflows along Downstream Boundary at Highway = normal depth using slope of the downstream average hydraulic grade line (0.002, assumed to be equal to the average slope of creek bed at outlets).
- Solve Method = Eulerian-Lagrangian Shallow Water Equation Method
- Variable timestep calculated internally in the model using a maximum Courant Number of 2.

4.2.1 Model Inflows

Flooding around the project area can occur either from Robe River flooding or from local Red Hill Creek flows. The timing of the Robe River peak flows and localised Red Hill Creek peak flows are unlikely to occur at the same time. To account for this, separate hydrology/model inflow scenarios (listed below) were set up and run through the 2D Model, then the maximum flood results from all scenarios was extracted from the model to present a single maximum flood map result. The scenarios included:

1. Robe River 1% AEP Peak Flow as a constant inflow
2. Red Hill Creek Catchment 1% AEP Peak Flow – as per Section 3.2, with Robe River inflow as a backwater condition (such that the flow rate at the downstream location is approximately equal to the 1% AEP Robe River flow).
3. Red Hill Creek Catchment 1% AEP Peak Flow – same as above except catchment B1 inflow is added from the south of the camp.

4.3 Pre-Development Results and Flood Risk

The 1% AEP event flood depth predictions from the pre-development model are shown in Figure 5 relative to the proposed infrastructure footprints.

Key observations from the 1% AEP flood predictions are:

- The mapping shows the potential for inundation from Robe River and Red Hill Creek near the proposed infrastructure location. The process plant and ROM infrastructure has been located outside of the 0.5m flood depth area, with only shallow flow <0.5m potentially within a small corner of the plant footprint.
- The Haul Road alignment between the process plant and the camp crosses Red Hill Creek floodplain with flood inundation predictions summarised as:
    - Flood depths exceeding 0.5m over a 4km length, with flood depths up to 3.5m at the deepest location.
    - Sheet flow with flood depths less than 0.5m over a further 2.6km length.
- Adjacent to the camp area, a significant portion of Catchment B flow is contained within the vicinity of the creekline. Some flood protection for the camp is provided by natural high points in the landscape to the south and east. Flow up to 0.5m deep is predicted within the camp which would potentially need to be managed. A low bund around the camp (or raised earth pad for camp construction) could be considered.
- The eastern most extent of the resources outline extends into the inundation area (noting that the full extent of the resources outline may not be mined, and actual pit outlines are not shown).
- The maximum flood depth of the Robe River in the main channel to the north-east (through the gap in the mesas) is predicted to be about 8m, and in the nearby pools is up to 10m.

- A velocity result map is shown in Figure 6 which provides an indication of areas subject to potential scour. Within the planned disturbance areas, it is noted that any inundation in the proposed plant footprint (or flows against any flood protection bunding) is only predicted to be subject to low flow velocities (<0.5m/s). The velocity where Red Hill Creek crosses the proposed road alignment is predicted to be between 1.5 and 2.0m/s.

5. DISCUSSION

Generally, flood mitigation measures for planned or potential infrastructure could include:

- install infrastructure on a pad above the flood levels or install flood protection bunding, or
- reconsidering the location of the infrastructure to be outside of the floodplain, or
- accept a higher level of flood risk for temporary infrastructure depending on the severity of the impact on operations and other consequences.

Model results show key infrastructure areas have been placed in locations outside the floodplains of the major adjacent creeks or where flow depths are manageable (<0.5m). Where the flood plain extends over infrastructure footprints, the following flood mitigation measures could be considered by CZR:

- Plant area – predevelopment flood levels are predicted to extend marginally over the lowest points of the plant footprint. Clearing and levelling of the area for construction is likely to raise the footprint above the predicted flood levels.
- Eastern resource outline – flood mitigation measures may be required if the pit is planned to be extended to cover the full eastern part of the resource outline.
- Camp area – potential inundation of the camp area could be managed by a low flood protection bund around the perimeter of the camp.
- Road crossing of Red Hill Creek – creek crossing may be constructed as a combination of a flood way with culverts to provide some degree of trafficability in lower flow events.

For context, the likelihood (or risk) of a flood event exceeding a range of AEP design criteria over the planned operational lifetime of the mine of (6 years) is presented in Table 3 below. For example, a nominal maximum exceedance probability threshold of 20% over the 6-year life of the mine for the project, corresponds to a minimum 2% AEP design flow event. The risk taken may be different for different project infrastructure; for example, flooding and temporary closure of non-critical roadways may be acceptable whilst infrastructure areas such as the process plant may require stricter design criteria.

Table 3: Exceedance Probability

Mine Life	**Probability of Exceedance (%) for AEP**					
(years)	**50%** (1 in 2)	**20%** (1 in 5)	**10%** (1 in 10)	**5%** (1 in 20)	**2%** (1 in 50)	**1%** (1 in 100)
6	98%	74%	45%	26%	11%	6%

Local runoff from the mesa area has not been modelled, but management of this runoff will still be required. For example, runoff from the Robe Mesa will need to be managed by localised drainage within the plant footprint.

No footprints for waste dumps were provided for the assessment on the basis that little waste material will be produced by the mining operation, and any waste that is produced would backfill the pit. The management of erosion of any dumped material would need to be considered during operations and closure.

DMIRS currently require flood events greater than a 1% AEP flood, such as a Probable Maximum Precipitation (PMP) event, be considered in closure designs in a flood-risk area. Flood levels from an extreme runoff event may need to be considered in relation to disturbance areas that are to remain post-closure (any potential waste dumps or pits) during future phases of the project study development.

We trust that this surface water assessment memo meets your requirements. Please contact us if you require additional information regarding this assessment.

Regards

Wendy McCarthy

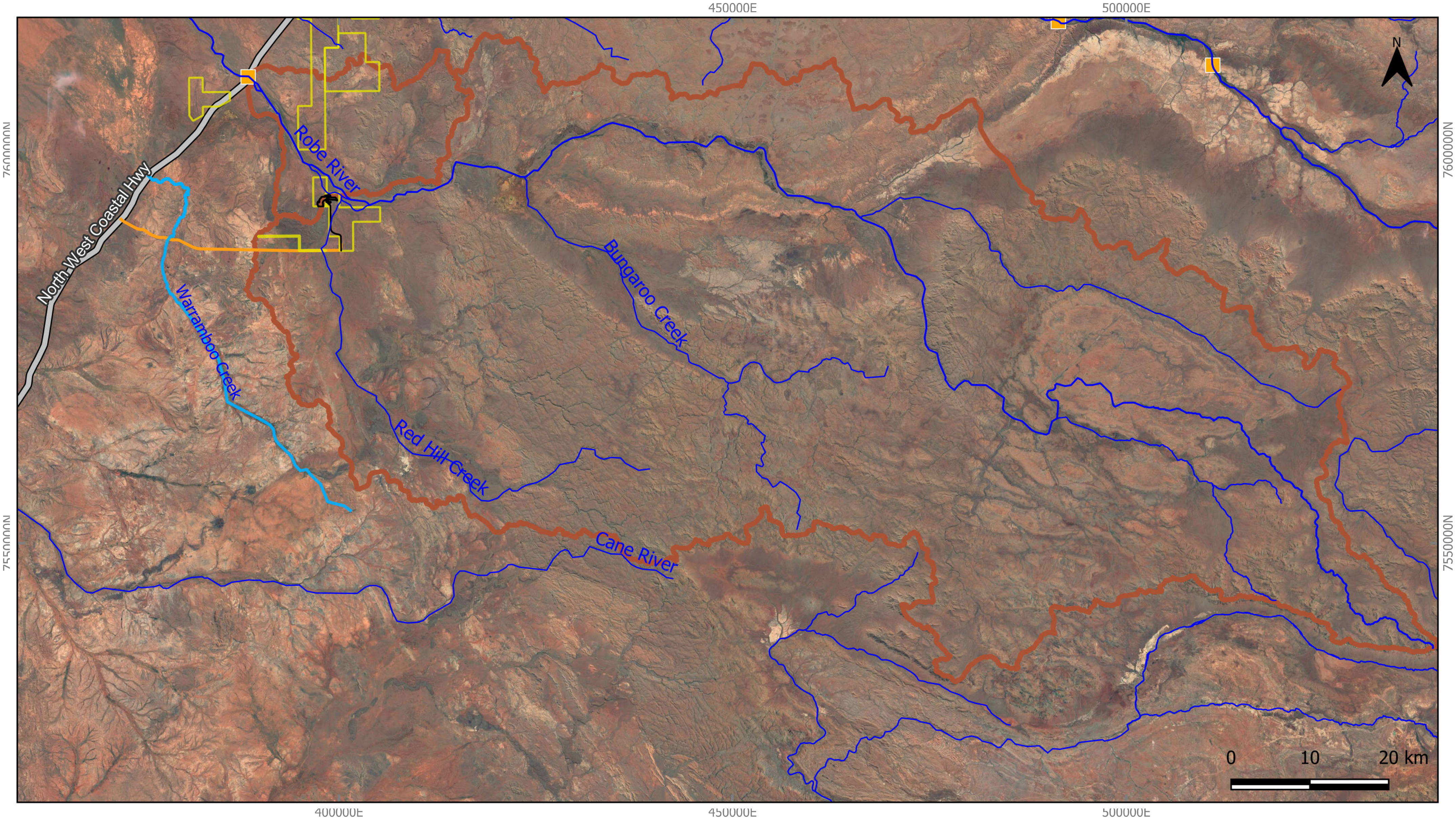
Consulting Hydrologist

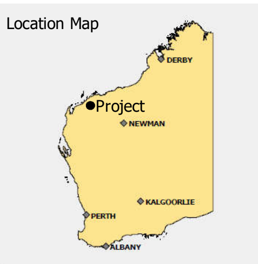
Mark Nicholls

Consulting Water Resources Engineer

Author: WM (16/08/21)
Checked: KP (16/08/21)
Reviewed: MN (31/08/21)

Figures





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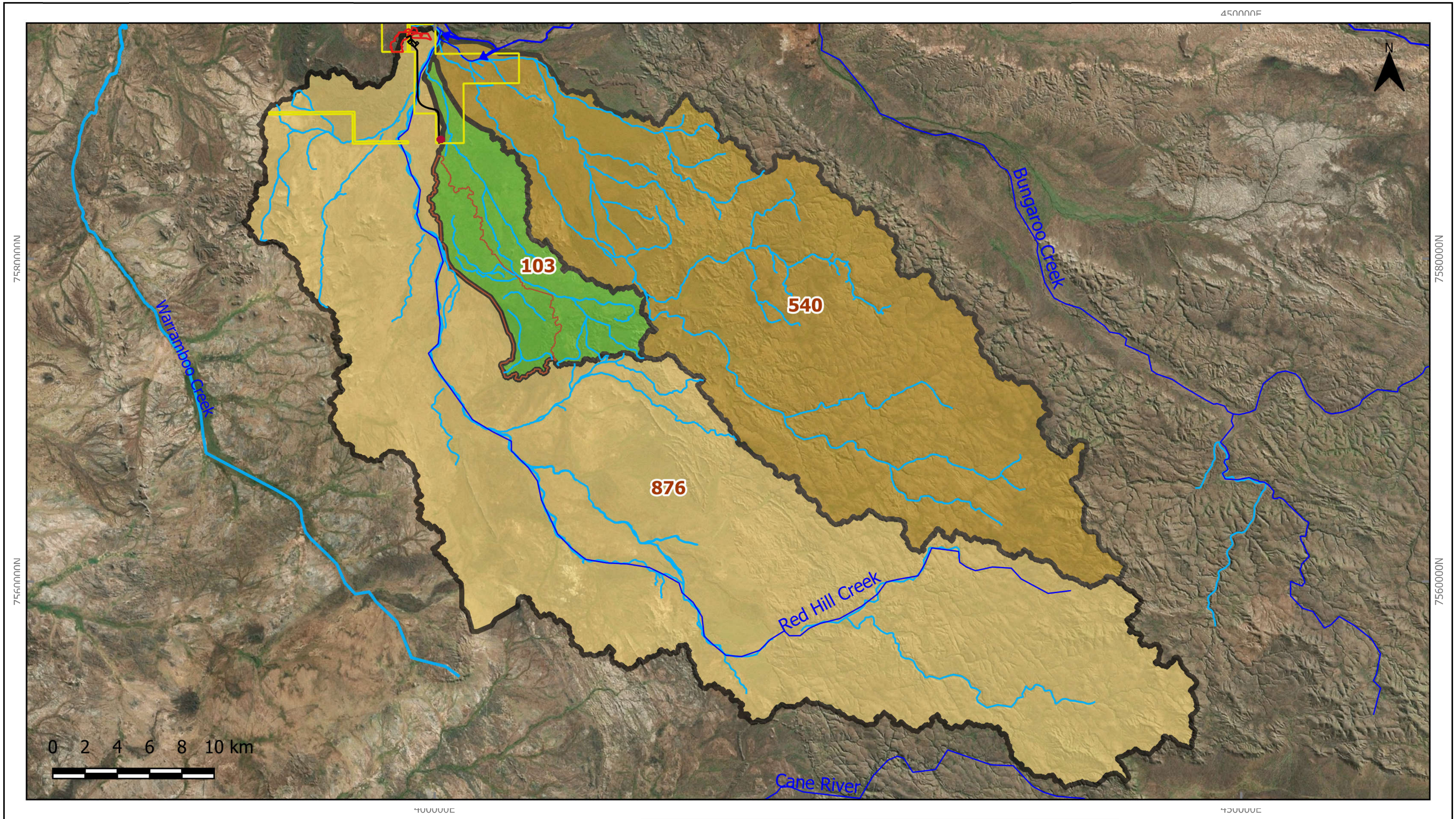
Legend	
Tenements	North West Coastal Hwy
Robe Mesa Resource outlines	Proposed Road Alignment 3
Infrastructure Plan (DRAFT)	Robe River Catchment
Stream Gauging Station - Yarraloola	Major Rivers and Creeks
Other Key Minor Creeks	

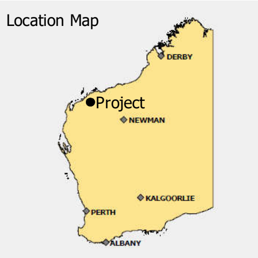
AUTHOR: WM
DRAWN: WM
DATE: 25/6/2021

REPORT No: 005a
JOB No: 385C
Coordinates: GDA94 MGA Zone 50

Notes and Data Sources:
Project layout and topograpy supplied by CZR Resources
Bing (2021) Aerial
DWER (2021) Regional Hydrography

Figure 1:
Robe River Catchment to Gauging Station





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- Tenements
- Robe Mesa Resource outlines
- PFS Robe Mesa Proposed Campsite
- Infrastructure Plan (DRAFT)
- Major Rivers and Creeks
- creeks and flow paths
- Robe Flood Flow Direction

Subcatchments to Mine, Area (km2)

- A 876
- B 103
- C 540

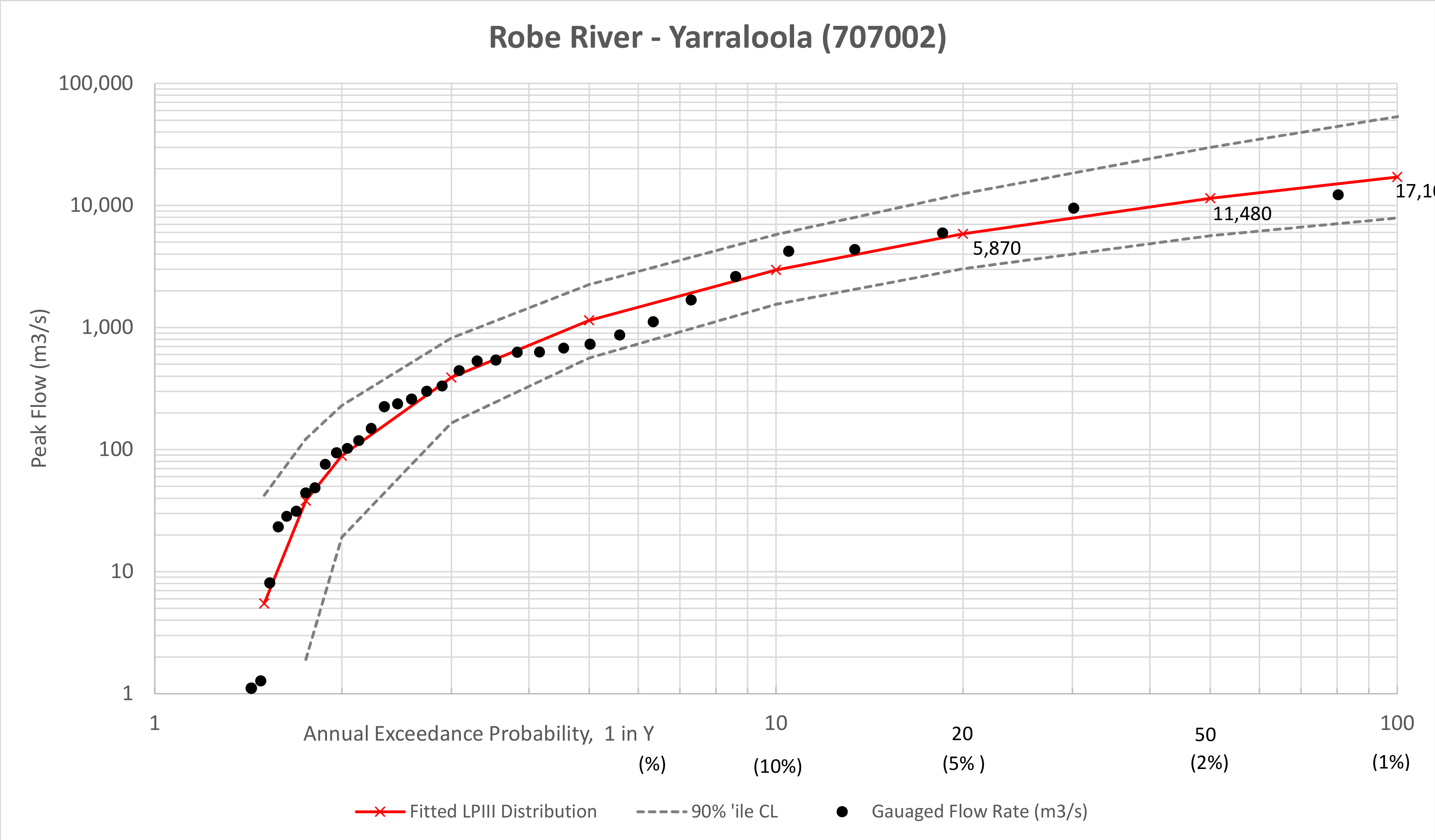
Subcatchment with uncertain flow direction (35km2)

AQ2

AUTHOR: WM	REPORT No: 005a	Notes and Data Sources:
DRAWN: WM	JOB No: 385C	Project layout supplied by CZR Resources Bing (2021) Aerial DWER (2021) Regional Hydrography
DATE: 25/6/2021	Coordinates: GDA94 MGA Zone 50	

Figure 2:

Red Hill Creek Subcatchments to Mine Area



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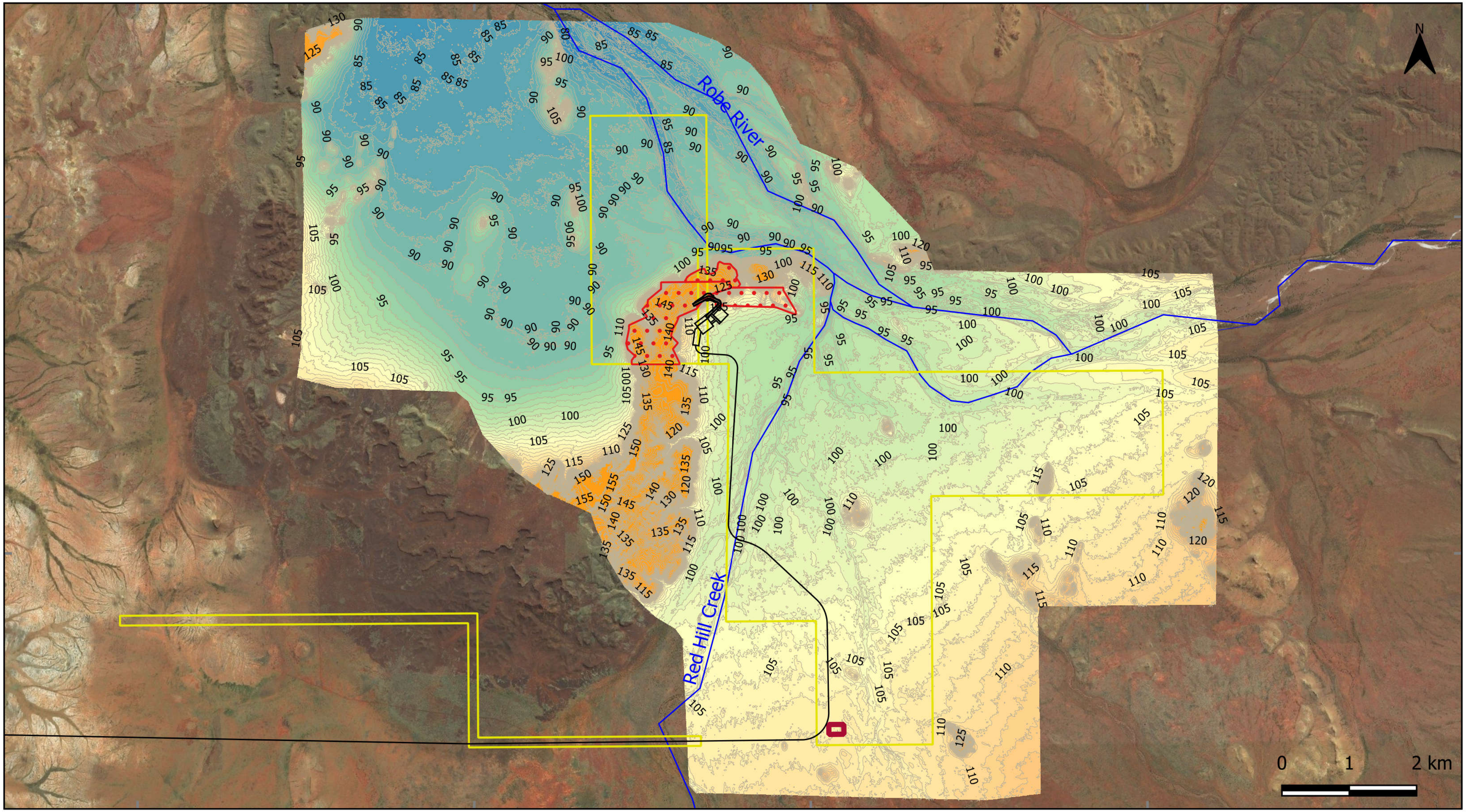
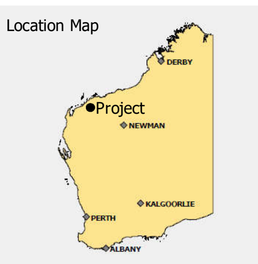
Yarraloola (707002) Flood Frequency Analysis FIGURE 3





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Tenements

Robe Mesa Resource outlines

Proposed Haul Road and Infrastructure

PFS Robe Mesa Proposed Campsite

Topographic 1m Contours

Major Creeks

DTM (mAHD)

- <= 81
- 85
- 90
- 95
- 100
- 105
- > 140

AUTHOR: WM

DRAWN: WM

DATE: 25/6/2021

REPORT No: 005a

JOB No: 385C

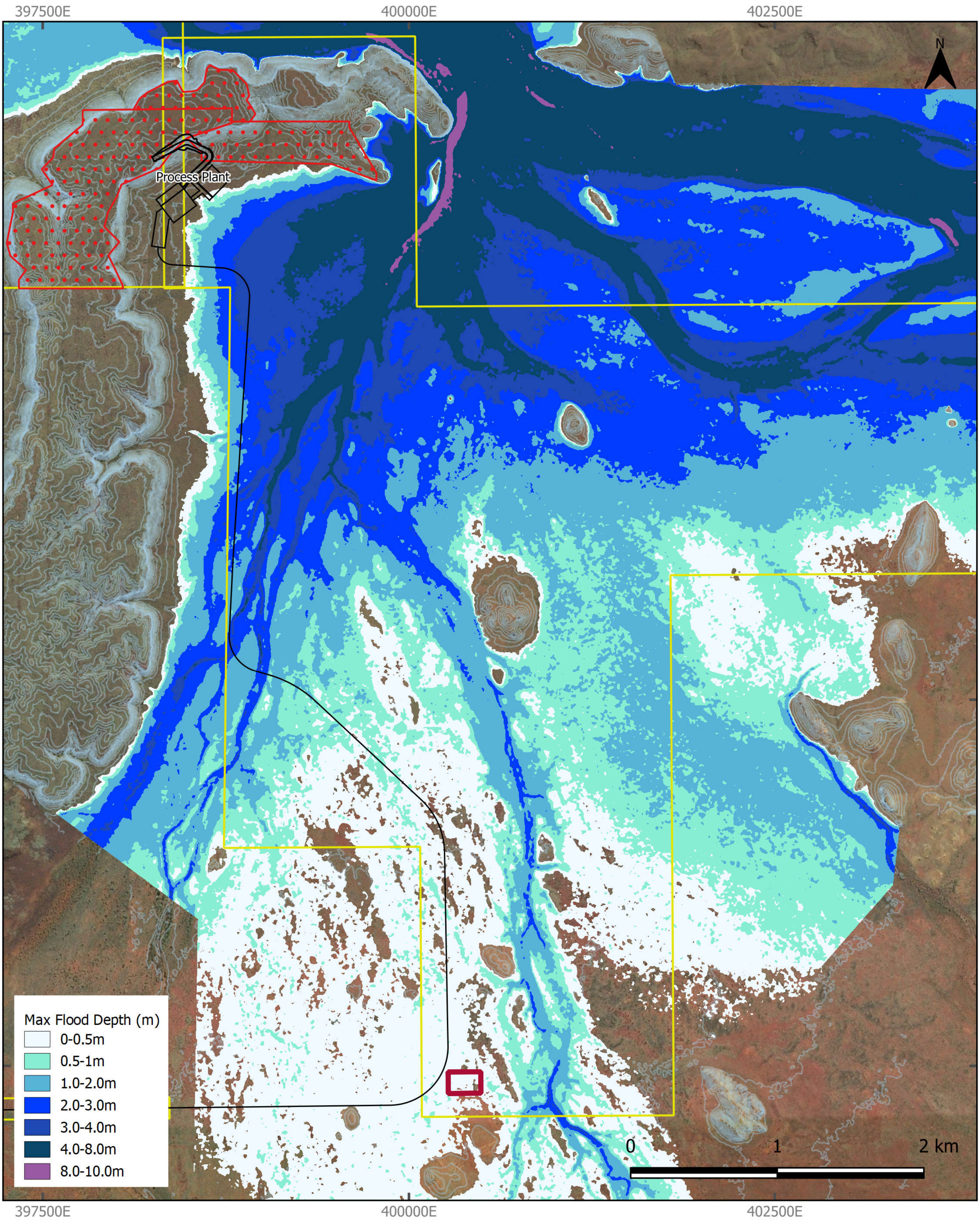
Coordinates: GDA94 MGA Zone 50

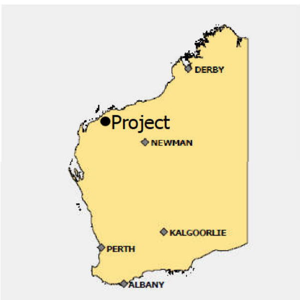
Notes and Data Sources:

Project layout and topograpy supplied by CZR Resources
Bing (2021) Aerial
DWER (2021) Regional Hydrography

Figure 4:

Topographic 1m Contours and DTM





Tenements
Robe Mesa Resource Outlines
Robe Mine Infrastructure Plan July 2021
PFS Proposed Campsite Draft Feb 2021
Topographic 2m Contours

AQ2

Figure 5

1% AEP Flood Depth Map

AUTHOR: WM	REPORT NO: 005a	Notes and Data Sources: Results from 2D Hydraulic Model, 1% AEP fllood levels from both Robe River flow and Red Hill Creek flow Scenarios. Infrastructure Layout from CZR (2021)
DRAWN: WM	JOB No: 385C	
DATE: 16/08/2021	Coordinates: MGA Zone 50	

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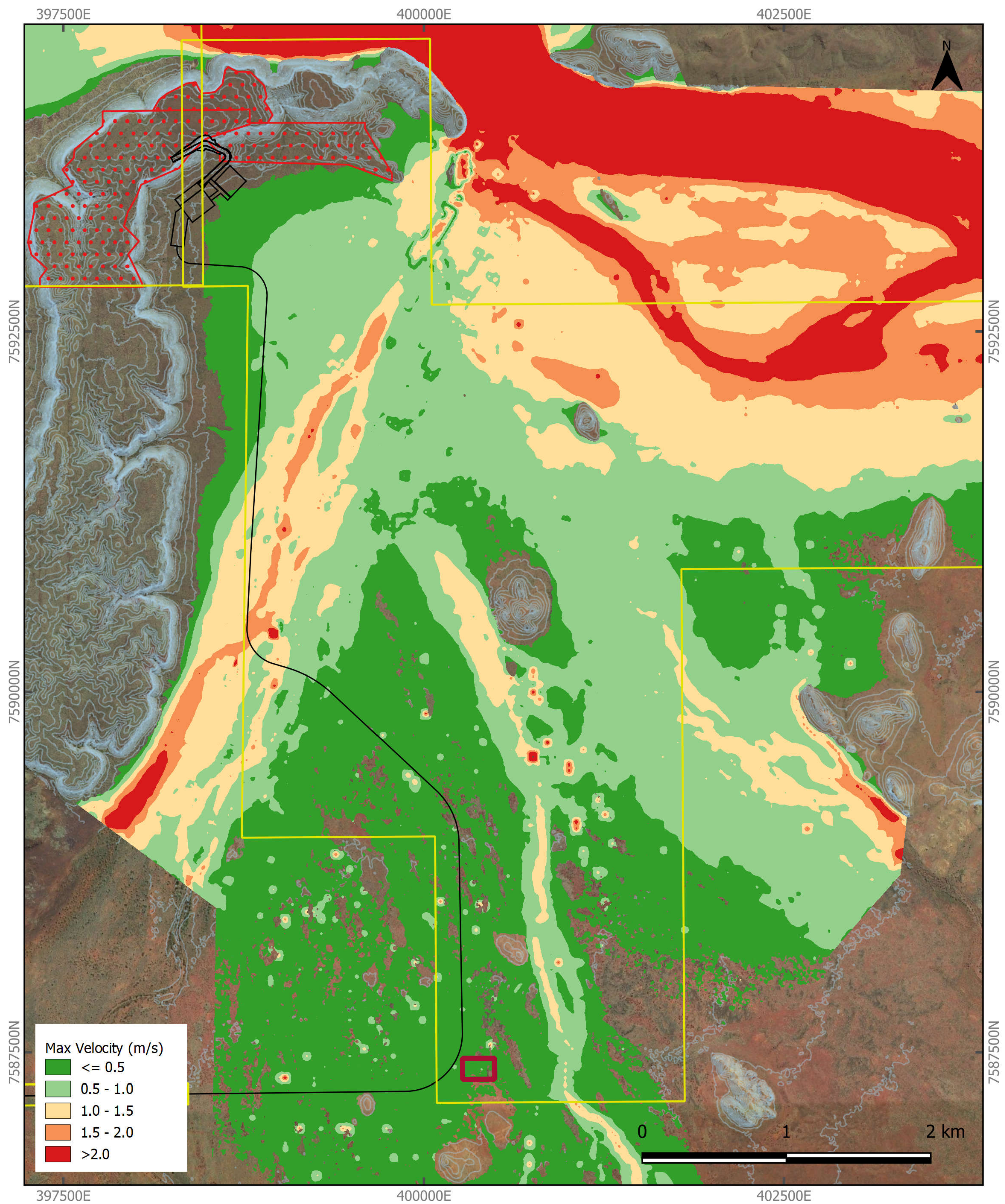

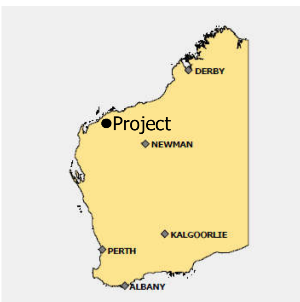

Tenements
Robe Mesa Resource Outlines
PFS Proposed Campsite (Draft)
Robe Mine Infrastructure Plan July 2021

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Figure 6

1% AEP Max Velocity Map

AUTHOR: WM	REPORT NO: 005a	Notes and Data Sources:
DRAWN: WM	JOB No: 385C	Results from HECRAS 2D Hydraulic Model Proposed Infrastructure from CZR (2021)
DATE: 16/08/2021	Coordinates: MGA Zone 50	

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