LAMB CREEK PROJECT
SURFACE WATER MANAGEMENT PLAN

Prepared for
Mineral Resources Ltd.

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AQ2 Pty Ltd
Level 4, 56 William Street
Perth 6000

T: 08 9322 9733
www.aq2.com.au

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Prepared by:	**AQ2 Pty Ltd** **(ABN 38 164 858 075)**	**Prepared for:**	**Mineral Resources Ltd** **(ABN 33 118 549 910)**
T:	(08) 9322 9733	T:	(08) 9329 3600
E:	Brieland.Jones@aq2.com.au	E:	Carl.Paton@mrl.com.au
W:	www.aq2.com.au	W:	www.mineralresouces.com.au
Author:	Brieland Jones		
Reviewed:	Mark Nicholls		
Approved:	Mark Nicholls		
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Table of Abbreviations

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
ASS	Acid Sulfate Soils
BoM	Bureau of Meteorology
DMIRS	Department of Mines, Industry Regulation and Safety
DWER	Department of Water and Environmental Regulation
DTM	Digital Terrain Model
EY	Exceedances per Year
HECRAS	Hydrologic Engineering Centre's River Analysis System
IFD	Intensity-Frequency-Duration
PMP	Probable Maximum Precipitation
PMF	Probable Maximum Flood
RFFP	Regional Flood Frequency Procedure
ROM	Run-of-Mine
SRTM	Shuttle Radar Topographic Mission
WRD	Waste Rock Dump

1 BACKGROUND

Mineral Resources Limited (MRL) proposes developing the Lamb Creek Iron Ore Mine, herein referred to as the Project. The Lamb Creek Deposit is located approximately 90km northwest of Newman, in the Hamersley Ranges of the Pilbara region of Western Australia (Figure 1.1). The site is approximately 12km north of BHP’s Area C Mine, 14km southwest of the BHP’s Yandi Mine and 11km from the Great Northern Highway. The orebody is located in close proximity to an unnamed creek, herein referred to as Mine Creek. Mine Creek is a tributary of Marillana Creek which in turn flows into the Fortescue Marsh. Lamb Creek, which the mine is named after, is located 7km to the east of the orebody.

As part of an overall feasibility study and to support environmental approvals for the Project, a Hydrological Assessment and Surface Water Management Plan for the Project is required. This report has been prepared for the currently proposed mine development plan including the Access Haul Road from the Great Northern Highway to the Site and covering a potential future extension of the haul road between the Project and a separate potential mining area located to the east.

This surface water management plan has been completed consistent with relevant DMIRS (2020) Guidelines for mine proposals and the EPA 2018 Inland Water guideline and includes the following:

- Characterisation of the regional climate and hydrology.
- Description of the surface hydrology of the project area and downstream environment.
- Description of the environmental values and beneficial uses of surface water.
- Water quality characteristics of the surface hydrology of the area.
- Flooding characteristics of the Project area, and if flooding presents a risk to the Project.
- Identification of any potential impacts and risks that the proposed development may have on the surface water regime.
- Recommended management/mitigation measures, including conceptual design of these measures.

2 SITE DESCRIPTION

2.1 Proposed Site Layout

Proposed mine pits and site infrastructure layout have been provided by MRL for use in this project. The Project is located in the Pilbara between the Yandi and Mining Area C mine sites, approximately 11km east of the Great Northern highway. The layout of the mining area is presented in Figure 2.1 and includes the following:

- Development of a single open cut pit.
- Additional supporting mine infrastructure including two Waste Rock Dumps (WRD), RoM, Plant and Stockyard areas, an Office/Workshop, and Topsoil Stockpiles.
- Camp located to the west of the mining area.
- Access Road that extends about 12km to Great Northern Highway to the west from the site.
- Potential future extension of a Haul Road to a separate potential project 14km to the east.
- Borrow pit locations south of the camp and along the Access Road.

The project area lies a few hundred metres east of an unnamed creek (named “Mine Creek” for this study), with the proposed pit footprint located in between two tributaries of Mine Creek that drain from the east.

The life of mine is expected to be approximately 26 months after completion of construction, commissioning, and ramping up to full production.

2.2 Topography

Local topographic elevation data was provided by MRL covering the mine and immediate area around the Project. The elevation data is shown on Figure 2.2.

The project site is situated in a valley where Mine Creek drains to the north. Elevations in the area range from around 702mRL in Mine Creek to approximately 1,015mRL at the top of the hill to the east of the Project.

2.3 Regional Climate

The climate of the region is typically arid, with hot summers and cool winters. Temperatures can range from below 0°C in winter, to over 45°C in summer. At Marillana, 60km north-east of the Lamb Creek Project site, a weather station has measured rainfall data since 1936, providing 84 years of rainfall data. There are three additional BoM weather stations within approximately 60km of the site (refer Figure 1.1) plus the Newman Airport station is within 120km of the site and is the closest weather station containing temperature measurements; details for these weather stations are presented in Table 2.1.

Marillana has recorded an average rainfall of 328.9mm per annum (BoM Site 005009, 2020). The rainfall is highly variable, with the larger rainfall events typically as a result of rainfall from cyclones and tropical lows during summer (for example 255mm recorded on 26 January 2003). Average temperature and evaporation data from Newman and rainfall statistics from Marillana are displayed in Figure 2.3. Average evaporation exceeds average rainfall for each month of the year.

Table 2.1: Nearby BoM Rainfall Gauges

Site Name	BoM Site Number	Commencement Date	Distance from Project Site (km)	Operational Status
Marillana	005009	1936	60	Open
Karijini	005098	2018	53	Open
Auski Munjina Roadhouse	005093	1998	53	Open (rainfall stopped reporting in 2014)
Rhodes Ridge	007169	1971	60	Closed (stopped reporting in 2011)
Newman	007176	1971	117	Open

2.4 Probability Terminology

Probability terminology from the 2019 Australian Rainfall and Runoff (Bell et al, 2019) has been adopted. In particular, the terms Annual Exceedance Probability (AEP) and Exceedances per Year (EY) are adopted rather than the previous ARR 1987 terminology of Average Recurrence Interval (ARI). The equation below (BoM http://www.bom.gov.au/water/designRainfalls/ifd-arr87/glossary.shtml) shows how the terms relate to each other.

$$AEP = 1 - exp\left(\frac{-1}{ARI}\right)$$

AEP is defined as the probability of a rainfall event being equalled or exceeded within a year, usually expressed as a percentage (%) or for frequent events as EY. It is the chance that a rainfall event of a given size or larger will occur in any given year; for example a 1 in 100 AEP event has a 1% chance of occurring this year, while a 1 in 50 AEP event has a 2% chance of occurring. ARI is defined as the average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration.

2.5 Rainfall IFD and PMP Data

Intensity-Frequency-Duration (IFD) data characterises storm rainfall intensities and is available from BoM. IFD data was extracted from the BoM website for the Project from the 2016 datasets and is presented in Table 2.3. The data shows the depth of rainfall which is estimated to fall at the site under different design rainfall events for rainfall probabilities consistent with ARR 2019 Guidelines.

Table 2.2: Project Rainfall Intensity-Frequency-Duration Data

	AEP	50%	20%	10%	5%	2%	1%
	ARI (year)	**1.44**	**4.48**	**10**	**20**	**50**	**100**
Duration	1 min	1.93	2.75	3.31	3.86	4.59	5.15
	2 min	3.13	4.37	5.2	6	7.07	7.88
	3 min	4.43	6.23	7.43	8.6	10.2	11.4
	4 min	5.67	8.01	9.6	11.1	13.2	14.8
	5 min	6.81	9.67	11.6	13.5	16.1	18
	10 min	11.3	16.2	19.5	22.7	27	30.4
	15 min	14.4	20.5	24.7	28.9	34.3	38.5
	20 min	16.7	23.7	28.6	33.3	39.6	44.3
	25 min	18.5	26.3	31.6	36.8	43.6	48.9
	30 min	19.9	28.3	34	39.6	46.9	52.6
	45 min	23.2	32.9	39.5	46	54.5	61.1
	1 hour	25.6	36.3	43.6	50.7	60.3	67.7
	1.5 hour	29.1	41.4	49.9	58.3	69.7	78.5
	2 hour	31.7	45.5	55	64.5	77.6	87.8
	3 hour	36	52.2	63.7	75.3	91.4	104
	4.5 hour	40.9	60.4	74.4	88.9	109	126
	6 hour	45	67.2	83.6	101	125	145
	9 hour	51.5	78.6	99	121	151	177
	12 hour	56.8	87.8	112	137	173	203
	18 hour	65	102	131	163	206	243
	24 hour	71.1	113	146	182	230	271
	30 hour	75.9	121	157	196	248	291
	36 hour	79.9	127	165	207	261	306
	48 hour	85.8	137	177	222	279	324
	72 hour	93.5	148	191	238	295	340
	96 hour	98.3	155	198	246	302	345
	120 hour	102	159	203	250	305	348
	144 hour	104	162	206	253	309	352
	168 hour	107	165	210	257	313	357

Closure of mines requires contemplation of rare storm events that could occur in time undefined after closure. In this regard, DMIRS has suggested the use of the PMP, which is an estimate of the upper physical bound to the precipitation that the atmosphere can produce.

BoM has developed the following methods for estimating PMP rainfall depths depending on storm duration for the Project region:

- GSDM – Generalised Short Duration Method, implemented for storm durations up to 6 hours.
- GTSMR – Generalised Tropical Storm Method Revised, developed for storm durations greater than or equal to twenty-four hours.

Results from the PMP estimation methods (GSDM and GTSMR) for the Project location are shown in Table 2.3, along with other rare IFD's sourced from BoM (2020) for context.

Table 2.3: PMP and Rare Event IFD Data for Lamb Creek Project

Duration / AEP (1 in X)	1 hr Rainfall (mm)	3 hr Rainfall (mm)	24 hr Rainfall (mm)	48 hr Rainfall (mm)	72 hr Rainfall (mm)
1,000	103	159	413	488	501
2,000	115	178	463	543	555
PMP (Point Location)	500	860	890	1200	1450

2.6 Regional Hydrology

The project site is located within the DWER surface water management area for 'Upper Fortescue River' and sub-management area 'Fortescue Marsh'. The Upper Fortescue River catchment drains a large portion of the eastern Pilbara area and terminates at the Fortescue Marsh (Figure 2.4). The Goongarrie Hills separate the Upper and Lower Fortescue Rivers, with water levels in the Fortescue Marsh unlikely to overtop and flow through the Goongarrie Hills area into the Lower Fortescue River catchment. The total Fortescue Marsh (Upper Fortescue River) catchment area is around 29,750km^2 (EPA, 2013).

Creeks within the Pilbara are ephemeral, with runoff events triggered by significant rainfall events. The project site is located in close proximity to Mine Creek, which drains through a valley from south to the north and is a tributary of Marillana Creek. Marillana Creek flows into Weeli Wolli Creek about 60km downstream of the site. Weeli Wolli Creek passes through a gap in the Hamersley Ranges then transitions to a series of flood out channels with an alluvial fan floodplain before discharging to the Fortescue Marsh. The total Weeli Wolli Creek catchment discharging to Fortescue Marsh is around 4,220km^2.

2.7 Stream Gauging Station Data

Two stream gauging sites are located downstream of the Project, one on Marillana Creek at 'Flat Rocks', and one on Weeli Wolli Creek at 'Waterloo Bore' (Figure 2.4). The 'Tarina' gauging site on Weeli Wolli Creek is upstream of the confluence of Marillana Creek (Figure 2.4).

The Flat Rocks Gauging Station is located about 24km downstream of the project on Marillana Creek and in proximity to a series of pools. The gauging station has an upstream catchment area of 1,370km^2 (Figure 2.5). Streamflow at Flat Rocks on Marillana Creek is seasonal, with flows occurring in response to heavy rainfall events. On average, Marillana Creek flows for 10 days a year. The maximum flow recorded by the gauge is in the order of 1,300m^3/s. Mining activities occur in proximity to Marillana Creek immediately downstream of the gauging station.

A CSIRO (2015) study analysed measured streamflow at Flat Rocks during the period 1967 to 2012. The average annual streamflow was 11,100ML with a maximum value of 155,450ML measured during 1976 and a minimum value of 0.51ML measured during 2010. The average annual streamflow equates to an average catchment yield of around 2.5% of average annual runoff.

2.8 Potential Environmental Receptors

Environmental features of the regional area which are also potential hydrological receptors include the following:

- Mine Creek – potentially contains sparse riparian vegetation dependent on surface water flows.
- Marillana Creek – hosts riparian vegetation and semi-permanent pools in the Flat Rocks area (about 24km downstream of the Project). It is noted that Marillana Creek is impacted by BHP and RTIO mining operations.
- Weeli Wolli Creek – hosts riparian vegetation and semi-permanent pools. The main environmentally sensitive feature on Weeli Wolli Creek is Weeli Wolli Spring, which is considered to have high ecological, social and cultural value (EPA 2001, Kendrick 2001b, Gardiner 2003, van Leeuwen 2009) due to the presence of permanent water which is rare in the region. The spring is located upstream of the confluence of Weeli Wolli Creek with Marillana Creek and therefore is not impacted by the project. Surplus dewatering discharge from Hope Downs is discharged into Weeli Wolli Creek with the surface expression of the discharge extending past the confluence with Marillana Creek.
- Approximately 100km downstream of the mining area is the Fortescue Marsh (described further below).
- It is understood that there are potentially some areas of vegetation (such as Mulga species) that depend on sheetflow runoff to maintain their ecological function in proximity to the Project. Maintenance of runoff regimes in these areas will be important to reduce the impact of the Project on vegetation health.
- Mapping of Threatened Ecological Community buffer zones in the area (Figure 2.5) shows the only TECs located downstream of the Project Site are situated on Weeli Wolli Creek and the Fortescue Marsh.

The location of the regional receptors are shown on Figure 2.5.

The Fortescue Marsh is an extensive, episodically inundated samphire marsh, approximately 100km long and 10km wide (Kendrick 2001a, DEC 2009). It is the largest ephemeral wetland in the Pilbara region and is listed on the Directory of Important Wetlands of Australia as regionally and nationally significant (DBCA, 2018). The Marsh itself extends over approximately 1,050km^2 within a management area of 5,800km^2, and a broader catchment area of the upper Fortescue River of around 29,750km^2 (EPA, 2013). The Project is outside of the Fortescue Marsh Management Area, however mining activities have the potential to directly or indirectly impact the Marsh. The Marsh is rich in plant and animal species of high conservation value and is part of an array of alluvial aquifers and groundwater systems (EPA, 2013). It is currently listed as a draft proposed RAMSAR wetland.

The Project is not in the vicinity of Public drinking water supply areas. The above hydrological features (Marillana Creek, Weeli Wolli Springs/Creek and Fortescue Marsh) are also likely to hold cultural value to the Traditional Owners.

3 PROJECT HYDROLOGY

3.1 Overview

An assessment of the hydrology of the Project area has been completed, including defining key catchment areas for the Project and estimating peak design flows from these key catchments. Hydrology assessments have been completed for the following potential risk areas:

- <u>Mine Creek:</u> Mine Creek (and its eastern tributary) may cause flooding within the Project area. To assess this risk, the following has been completed:
  - Estimation of peak flows through Mine Creek and its main tributaries within the Project area.
  - 2D flood modelling of Mine Creek to assess inundation risk from Mine Creek.
  - Assess impacts of flood management measures on the hydrological regime of the Mine Creek.
- <u>Localised Mine Area:</u> Small local catchments are intercepted by the mine site infrastructure. The following tasks have been completed:
  - Define localised catchments.
  - Estimate peak runoff flows.
  - Identify conceptual management measures.
- <u>Access and Haul Road:</u> The Access and Haul Road alignments cross multiple surface water flow paths. For major catchments, the following tasks have been completed:
  - Define catchment areas.
  - Estimate peak runoff flows.

For the above areas, the hydrological analysis (catchment delineation and flow estimation) is presented further below in Section 3, hydraulic analysis using 2D flood modelling for the Mine Creek is presented in Section 4 and environmental impacts and management measures are discussed in Sections 5 and 6.

3.1.1 Catchment Delineation Methodology

Catchment delineations were carried out using the following datasets:

- DTM –Digital Terrain Model data provided by MRL;
- SRTM - used in areas with no DTM coverage; and
- Aerial photography of local catchments.

These datasets were imported into GIS packages for interpretation and for delineation of the catchment boundaries and drainage lines. The geometry and other characteristics of each catchment and drainage line were extracted and documented using GIS packages.

3.1.2 Exceedance Probability

To determine an appropriate range of AEP to be used for this study, the likelihood of a flood event exceeding an AEP design criteria over the operational lifetime of the mine has been calculated. The current pit life is 26 months (2.2 years). In the event the mine infrastructure remains longer to service other deposits (not currently proposed), the exceedance probability for a nominal 10-year duration has also been calculated. The exceedance probability is computed using the following equation (as per ARR):

$$p = 1 - \exp\left(-\frac{L}{Y}\right)$$

Where:

Y = the return period of a given flood event (ARI)
L = the design life in years
P = the exceedance probability during the design life

Table 3.1: Exceedance Probability

Mine Life (years)	Probability of Exceedance (%) for AEP					
	39.4% (2yr ARI)	18.1% (5yr ARI)	10% (10yr ARI)	5% (20yr ARI)	2% (50yr ARI)	1% (100yr ARI)
2.2	78%	38%	19%	10%	4%	2%
10	>99%	89%	63%	39%	18%	10%

Based on adopting a nominal maximum exceedance probability threshold of 20% over the life of the mine, a minimum 10% AEP flow event will be considered in the following hydrological assessments. Based on this nominal criteria, this report has focused on runoff events of 10% AEP to 1% AEP.

3.2 Mine Creek

3.2.1 Mine Creek Catchments

Mine Creek and its eastern tributary are located in close proximity to project infrastructure and flooding of these drainage lines may impact the Project. The Mine Creek main channel drains from the south with an estimated catchment of approximately 81km^2 upstream of the Project (Figure 3.1). A tributary to Mine Creek (Catchment B and a side branch Catchment C) is located just south of the proposed Pit and drains from the east with a combined catchment of approximately 7km^2. Catchment C has been delineated separate to B as it's floodplain is undefined and may partially spill to the north and away from Catchment B. Catchment details are shown in Table 3.2.

The Mine Creek drainage channel is broad and generally well defined, with several braided channels. Large flows are likely to overtop the channel, even though the main channel area is relatively wide and deep. The bed slopes are moderate (0.006m/m).

Table 3.2: Mine Creek Catchment Details (Upstream of Project)

Catchment ID	Area (km²)	Mainstream Length (km)	Equal Area Slope (m/km)
A (excluding B and C)	74	14	9
B (eastern tributary)	6	6	23
C (eastern tributary branch)	1.4	2.4	23
D (northeastern tributary)	5.1	4.9	17
Mine Creek (A+B+C)	81	14	9

3.2.2 Mine Creek Peak Flows

Four common industry runoff estimation methods were used to develop a range of estimations for peak flow for the mine creek catchment. The following flow estimation methods were used:

- Flavell (2012) Pilbara Regional Flood Frequency Procedure (RFFP2000).
- Regional Flood Frequency Estimation (RFFE) Model 2015 from ARR 2019 (RFFE2015).
- Rational Method described in ARR 1998.
- Index Flood Method described in ARR 1998.

Results of the peak flow analysis are shown in Tables 3.3 and 3.4 for the 10% AEP and 1% AEP respectively. The runoff estimates produced by RFFP2000 and RFFE2015 and the Index Flood Method are within the same order of magnitude for the 10% AEP event, whilst the Rational Method is typically greater. For the 1% AEP event, the estimated runoff rates for the RFFP2000 and RFFE2015 methods are generally consistent, but the Rational Method and Index Flood Method typically estimated much higher peak flow rates. Given that all flow estimation methods in the Pilbara are based on limited data, there is a high degree of uncertainty inherent in all flow estimate methods.

Note RFFE2015 provides an "estimated" peak flow (shown in Table 3.3 and 3.4), plus lower and upper bound estimates to reflect the uncertainty in the extrapolation methods used (not shown). For example, for the 1% AEP peak flow estimate of Mine Creek, the lower and upper confidence limits range from 45 to 1,160m^3/s. As an input to the flood modelling associated with this SWMP, estimates from RFFP2000 have been used.

Table 3.3: Mine Creek Catchment Peak Flow 10% AEP Estimates (m^3/s)

Sub-catchment	Flavell RFFP2000 (m^3/s)	RFFE Model 2015 (m^3/s)	Rational Method (m^3/s)	Index Flood (m^3/s)
A	86	87	309	227
B	13	23	50	24
C	4	10	14	8
D	10	14	30	23

Table 3.4: Mine Creek Sub-catchment Peak Flow 1% AEP Estimates (m^3/s)

Sub-catchment	Flavell RFFP2000 (m^3/s)	RFFE Model 2015 (m^3/s)	Rational Method (m^3/s)	Index Flood (m^3/s)
A	390	230	551	2175
B	62	62	83	125
C	18	27	23	37
D	46	58	175	90

The peak flows from the RFFP shown in Table 3.3 for catchments A, B and C were used as an inflow rate to the 2D hydraulic model boundary, with rain-on-grid methods used to simulate runoff from within the model footprint (including Catchment D).

3.3 Localised Mine Area

Catchments and flow paths intercepted by Mine Infrastructure are shown in Figure 3.3, with details shown in Table 3.5. Peak flow estimates using the Flavell RFFP2000 method are shown in Table 3.6. The values in Table 3.6 should be considered as indicative of the order of magnitude of flows which could be generated by the catchments in the study area.

Table 3.5: Catchment Details (Upstream of Infrastructure)

Catchment ID	Area (km^2)	Mainstream Length (km)	Equal Area Slope (m/km)
L1	0.30	0.60	147.7
L2	0.17	0.73	11.7
L3	0.29	0.61	145.6
L4	0.19	0.44	132.4

Table 3.6: Design Flows (m^3/s) (Upstream of Infrastructure)

Catchment ID	Annual Exceedance Probability			
	10%	5%	2%	1%
L1	4	6	11	17
L2	1	1	2	3
L3	4	6	10	16
L4	3	5	8	12

3.4 Access Road

Catchments and flow paths intercepted by the Access Road are shown in Figure 3.4, with catchment parameters presented in Table 3.7.

Future potential borrow pit locations along the Access Road were provided by MRL and are shown in Figure 3.4. Approaches to surface water management of the borrow pits has been considered, however flood modelling in the vicinity of the borrow pits was not completed. It is noted that the layout of the borrow pits is still under development, but the general approaches (refer Section 6) to surface water management discussed would be applicable regardless of location/layout.

Several catchments are intercepted by the proposed Access Road alignment; Table 3.7 shows all catchment parameters for those catchments intercepted by the Access Road alignment.

Table 3.7: Access Road Catchment Details

Catchment ID	Area (km²)	Mainstream Length (km)	Equal Area Slope (m/km)
AR1	5.9	4	26
AR2	8.9	4	26
AR3	0.8	1	99
AR4	3.4	4	25
AR5	3.3	3	42
AR6	1.9	2	73
AR7	1.6	2	74
AR8	4.3	4	29
AR9	5.0	4	28
AR10	3.0	2	42

3.5 Haul Road

There are several catchments and flow paths intercepted by the potential future Haul Road alignment, which extends approximately 14km east of the proposed Project development. All catchments are shown in Figure 3.5, with parameters of only catchments greater than 1km^2 presented in Table 3.8. The parameters for all potential future Haul Road catchments, including the smaller catchments not included in Table 3.8, are shown in Appendix A.

Table 3.8: Haul Road Catchment Details

Catchment ID	Area (km²)	Mainstream Length (km)	Equal Area Slope (m/km)
HR7	1.0	1.57	77.3
HR9	1.2	2.2	55.7
HR12	1.8	2.9	51.2
HR 17	1.5	3.16	32.6
HR18	32.0	8.4	12.44
HR23	1.1	1.9	34.3
HR31	5.8	4.899	43.44

Note: Mine Creek catchment to access road shown separately in Table 3.2.

The Flavell RFFP2000 method was used to estimate peak flow rates of design flood events for catchments intercepted by the Access Road (Table 3.9) and potential future Haul Road (Table 3.10). The peak flow rates should be considered as indicative of the order of magnitude of flows which could be generated by the catchments in the study area.

Table 3.9: Access Road Catchment Peak Flow Estimations (m^3/s)

Catchment ID	Area (km^2)	Annual Exceedance Probability			
		10%	5%	2%	1%
AR1	5.9	15	24	42	68
AR2	8.9	25	39	69	113
AR3	0.8	7	11	18	27
AR4	3.4	8	15	25	39
AR5	3.3	12	19	33	50
AR6	1.9	12	18	31	47
AR7	1.6	9	13	23	34
AR8	4.3	13	19	34	52
AR9	5.0	14	22	38	59
AR10	3.0	17	25	44	67

Table 3.10: Haul Road Peak Flow Estimations (m^3/s)

Catchment ID	Area (km^2)	Annual Exceedance Probability			
		10%	5%	2%	1%
HR7	1.0	7	10	18	27
HR9	1.2	5	9	15	23
HR12	1.8	7	12	21	32
HR 17	1.5	4	9	15	23
HR18	32.0	54	85	146	220
HR23	1.1	5	7	12	18
HR31	5.8	18	29	49	75

4 HYDRAULIC FLOOD MODELLING

As identified in Section 3.1, hydraulic 2D flood modelling of Mine Creek under Pre Development Conditions has been completed to characterise potential inundation of the Project from Mine Creek. Further to this, potential flood mitigation measures associated with Mine Creek and catchment reduction due to the Project development has been modelled as a Post Development scenario to quantify the impacts on the hydrological regime (discussed in Section 5). The 2D flood models were developed using HEC-RAS-5 modelling software.

4.1 HECRAS 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 is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities (US Army Corps of Engineers, 2016). 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 Saint Venant Full Momentum equations (also known as the 2D shallow water equations). The software also contains tools for performing inundation mapping directly inside the software (US Army Corps of Engineers, 2016).

4.2 2D Model Set-Up

A 2D model was set up from the pre-development DTM data (i.e., containing no infrastructure) and subsequently from a post-development DTM (modified by AQ2 to reflect terrain changes due to pits/WRDs etc.) to predict inundation areas resulting from the 10% AEP and 1% AEP estimated design storm flows.

The model has been set up to simulate flow events from the following mechanisms:

- Runoff generated from the Mine Creek catchment upstream of the Project (Catchments A, B and C), simulated as a constant inflow rate to the model boundary using the flow rates outlined in Table 3.3.
- Local runoff within the 2D model boundary (including Catchment D), simulated as rain-on-grid runoff. Rainfall loss and catchment roughness parameters were adjusted so that peak runoff rates from Catchment D approximated those estimated in Table 3.3.

The model was run with the rain-on-grid runoff process simulated at commencement of the model run and, subsequently, the constant inflows from Catchments A, B and C commence once the peak flows from the local runoff start to subside. This approach has been taken to account for the differing response times expected from the small local catchments compared to the larger Mine Creek catchment.

The general model build details are as follows:

- 10m x10m grid along creek and tributary channels, whilst 20m x 20m grid elsewhere for overbank flow.

- Inflows from upgradient catchments for the 10%, 5%, 2% and 1% AEP events as per Table 3.3 were applied at the Model boundary at a constant rate for catchments A, B and C.
- Rain-on-Grid hydrology was used for remainder of the mine development area (refer Figure 3.2 for model boundary), including the eastern catchment reporting to Mine Creek just downstream of the proposed mine infrastructure.
- A Manning's 'n' value of 0.07 was applied across the model domain (flood plain).
- Outflows along Downstream Boundary = Normal depth using slope of creek bed at outlets (0.002).
- Variable timestep calculated internally in the model.
- Solve Method = 2D Diffusion Wave equations (sensitivity tests showed similar result for full momentum equation).
- Model simulation duration = 4 hours. Peak flow was reached prior to end of simulation.

4.3 Pre-Development Results and Flood Risk

4.3.1 1% AEP

The 1% AEP event flood depth predictions using the Pre-Development terrain surface from the model are shown in Figure 4.1 relative to the proposed infrastructure footprints. The mapping shows the potential for inundation from the Mine Creek and its tributary to impact on the proposed mining operations in the 1% AEP event.

Key observations from the 1% AEP flood predictions are:

- A natural bank on the eastern side of the main drainage channel confines the runoff from the Mine Creek from spilling out and through the pit areas in the southern part of the Project Development. As the bank becomes less defined to the north, flow can break out from the main channel and flow through the north western corner of the Project. The model estimates that 68m^3/s (15%) of the total Mine Creek inflow (465m^3/s) overtops towards the east across the north-west corner of the proposed infrastructure location, primarily affecting the Access Road and Plant infrastructure. Along this flow path, (Section 2 shown on Figure 4.1), depths up to 0.7m and flow velocities up to 0.75m/s are predicted.
- Overtopping also occurs over the western bank of Mine Creek and flows as sheet flow in a north-westerly direction. This is likely to impact the stockpile footprint that is proposed adjacent to Mine Creek, NPI infrastructure and access roads. The camp and borrow pit are located outside of the break-out flow area but is impacted by localised runoff from the south of the camp.
- Flows from the upper branch of the eastern tributary of Mine Creek (Catchment B and C) may break out and flow towards the pit and southern WRD. Note that the predictions shown on Figure 4.1 are conservative as a portion of the tributary floodplain was excluded from the model due to the limit of the DTM provided (and therefore the extent of the model). Across Section 1 (i.e., towards the pit), the model predicts a total peak flow of 15m^3/s and flood depths generally less than 0.4m. Velocities were generally less than 0.5m/s.

- The flow channel that drains the catchment to the northeast of the proposed development (Catchment D) appears to be intercepted by the northern stockpile footprint. Pre-development flow depths at this location reach approximately 1.3m. Approximately 500m downstream, this same channel is intercepted by the NPI infrastructure boundary.
- Given the terrain upgradient of the pit and eastern WRD, there are several small drainage channels that are likely to flow into the pit and be intercepted by the bunding surrounding the eastern WRD.

4.3.2 10% AEP

The 10% AEP event flood depth predictions using the Pre-Development terrain surface are shown in Figure 4.2 relative to the proposed infrastructure footprints.

Key observations from the predictions shown on Figure 4.2 are:

- Generally, in the 10% AEP event Mine Creek flows are contained within the incised channel area. This indicates that inundation of the infrastructure (plant and stockpile) area from overtopping of the eastern bank of the Mine Creek channel starts to occur at events at or greater than the 10% AEP event.
- Flows from the upper branch of the eastern tributaries of Mine Creek (Catchments B and C) breakout and flow through the proposed Mine Pit footprint, southwest WRD and stockpile areas. Across the full length of Section 1 (shown on Figure 4.2), the model predicts a total flow of about 2m^3/s and flood depths generally less than 0.2m (but up to 0.5m).

Flood mitigation measures are discussed in Section 6 and potential bunding simulated in Section 4.4.

4.4 Post-development Flood Modelling

A post-development flood model was prepared by changing the pre-development DEM as follows:

- Pit, WRD and stockpile footprints were bunded such that:
  - Runoff external to these footprints could not flow through the footprints.
  - Runoff generated by rain-on-grid processes within these footprints could not leave the footprints and contribute to downstream flow rates. This assumes that runoff from stockpile and WRD areas will not contribute to peak flows from the local catchments as they will need to be captured and diverted through sedimentation basins prior to release downstream.
- Where flood protection bunding and drains were identified as being recommended, the DEM was modified to simulate the impact of nominal drains/bunds.

The post-development flood modelling was completed to identify changes to the hydrological regime due to the Project development, including surface water management measures (i.e., diversions). These flow diversions are:

- D1 - along the eastern edge of the Topsoil Stockpile (west of Mine Creek).
- D2 - Along the southern boundary of the pit and southern WRD to deflect flow from Catchment B and C away from the pit and WRD.

- D3 – Along the eastern side of Mine Creek where the potential for flow to overtop the eastern bank and flood the plant was identified.
- D4 - Around the north-east side of the Project area to protect stockpiles and mine infrastructure from flooding from Catchment D.

The 1%, 2% and 5% AEP event Mine Creek flow rates were modelled in the Post-Development model with model prediction results shown in Figures 4.3-4.5, respectively.

These management measures potentially increase the flow depths within Mine Creek by constricting the flood plain available to convey peak flows and by containing breakout flow. Estimates of the potential impact on flood elevations have been completed in the Post-Development flood model.

Note that the impact of haul roads on flood extents and depths will be dependent on culvert/floodway designs (not yet determined) and have not been modelled. This is particularly the case where roads cross Mine Creek; crossing has the potential to increase the flood levels upstream of the road and therefore the elevation of the flood mitigation measures proposed.

A map of the change in flood depths between the Pre and Post Development predictions for the 1% AEP event is shown in Figure 4.6. Predicted flood depth changes are generally limited to the vicinity of proposed flood management measures (Figure 4.6). The areas downstream of the northern and western stockpiles may result in minor water shadow as shown in Figure 4.6; however, release of clean water from sediment basins just upstream of these locations (not modelled) will reduce the reduction in flow in these areas. The proposed diversion to the south of the pit results in a small increase to water levels in Mine Creek and the Catchment B tributary. Through Mine Creek, the proposed project development will constrict the flood plain which is predicted to increase the 1% AEP Mine Creek flood levels by up to 0.4m. These water level changes are localised and taper off to less than 0.1m within approximately 500m downstream (of Mine Creek) of the development.

Velocity changes due to the Mine Creek flood plain constriction are predicted to be less than 0.25m/s across the inundation area.

5 ENVIRONMENTAL RISKS, IMPACTS AND MITIGATION MEASURES

The potential impacts that could occur on hydrological receptors (identified in Section 2.5) as a result of proposed mining operations at the Project have been identified. Mitigation strategies are discussed for each potential impact.

5.1 Mining Operations

General mining operation activities and the associated potential environmental impacts on surface hydrology are identified in Table 5.1. The potential impacts to the hydrological environment and mitigation strategies are discussed in more detail in the following sections.

Table 5.1: General Mining Activities and their Associated Potential Hydrological Impacts

Mining Activity	Potential Environmental Impact	Typical Mitigation Measure
Construction of mining infrastructure such as development of the mine pit, WRD, access/haul roads, and other mine infrastructure	Modification and interruption of the existing hydrological regime, including water shadows due to interruption of surface and shallow groundwater flow paths.	Diversions, Levees and/or Culverts/floodways
	Erosion of exposed surfaces by wind, water and construction activities generating sediment loads in surface water runoff flows.	Sediment basins at downstream locations
Storage, handling and transport of workshop/wash-down/hazardous substances. Generation of contaminated leachate from mine pit, stockpiles, ROM pad and waste dump	Generation and transport of contaminated discharge from mine sites and associated infrastructure to nearby surface water and/or groundwater environments.	Standard site runoff containment measures.
Mine dewatering	Discharge of excess water into the environment, which could cause changes to hydrologic regimes of the downstream environment water courses and other receptor areas.	Reuse dewatering in processing activities.
Dust suppression activities	Discharge of water and wash-off of sediments into surrounding environments.	Fresh water used. Over-watering roads avoided.

5.2 Modification of Existing Hydrological Regime

5.2.1 Potential Impacts

Generally, construction of mine pits, waste dumps, haul roads and other associated infrastructure for proposed mines potentially could affect existing surface water drainage features, including local catchments, pools and flood plains. Modification of the existing drainage channels can reduce the volume and distribution of runoff to some areas, creating water shadows and increasing flows and periods of ponding in others. This disturbance has the potential to adversely impact downstream vegetation due to water starvation, drowning and/or sedimentation.

Haul roads located in relatively flat areas of the floodplain or across shallow drainage areas have the potential to impede flow and create water shadows on the downstream side of the road. The dynamic loads imposed by heavy traffic loads potentially can result in compaction of the subgrade potentially decreasing permeability. The development of mine pits adjacent to or within major drainage channels poses significant flood risk to the mine pits and potential for water starvation downstream.

Runoff from waste dumps and cleared or disturbed areas may increase the volume of runoff and adversely impact water quality.

5.2.2 Mitigation Measures

The design and implementation of works should incorporate management features to minimise or mitigate the adverse changes to existing flow regimes, flood characteristics, scour, siltation and erosion of the drainage channels, inundation of areas upstream and water starvation of areas downstream of the construction.

Maintenance of the existing flow regimes will be considered when designing drainage structures. Where linear infrastructure (such as the haul roads) cross flow paths or floodways, any culverts will need to be maintained to allow continuity of the existing flooding characteristics of the floodplain. Floodways may also be required along the haul road alignment.

Minor waterway crossings will be installed, where required, to ensure areas upstream of the crossings are not unduly inundated, and that waterways at crossings are protected from erosion. Structures should be designed to impede flood flows as little as possible. Each crossing and its release zone should be designed to minimise erosion and potential head cutting of the stream bed.

The current layout of the Mine infrastructure (and any associated dirty water capture bunding) should allow for the majority flow from intercepted catchments to be deflected around the infrastructure. Runoff collected by the dirty water capture bunding will be released to the downstream catchment (following sediment removal). From Figure 4.4, there are some locations upstream of the eastern waste dump where runoff is likely to become trapped at local low points and won’t contribute to downstream flow. Since the majority of flow is expected to pass downstream, the proposed development is expected to have a negligible effect on the volume of surface water runoff downstream.

The footprint area of the proposed pit (including small localised external catchments draining to the pits), and potentially the top surface of the WRDs, will reduce the catchment area of Marillana Creek. Additionally, some external flow from catchments intercepted by mine pits, borrow pits and WRDs will not be able to be diverted around the infrastructure and would be lost to the downstream environment. The combined loss of catchment area due to the LOM development footprint is approximately 1.23km^2 and comprises 0.08% of the overall catchment area to Flat Rocks (1,370km^2). This represents a small reduction in the overall Flat Rocks catchment area and therefore is unlikely to affect the hydrology of the pools in that area. The percentage reduction in catchment area further reduces for the receptors further downstream (Fortescue Marsh and Weeli Wolli Creek).

As discussed in Section 4, a portion of the proposed mine development is located within the floodplain of Mine Creek. The mine development may constrict the flood plain and increase the flood levels and velocities in Mine Creek. The Post-Development flood modelling completed predicted that the flood levels may locally increase by up to 0.4m, but the impact would be confined to within a few hundred meters of the mine development. Outside of the local area, the project development is not predicted to impact the hydrological regime at the downstream receptors.

The potential risks, impacts, and controls related to alterations of the hydrological regimes are summarised in Table 7.1.

5.3 Sediment Generation

5.3.1 Potential Impacts

The proposed Project will cause some ground disturbance, which will tend to increase sediment loads transported in runoff. The potential impacts of increased sediment in runoff, could result in sedimentation of vegetated areas and other sensitive ecological areas.

5.3.2 Mitigation Measures

Where runoff from waste dumps, stockpiles and borrow pit areas can discharge to the environment, capture bunding will be installed to collect runoff and direct it to sedimentation traps which will be located at key positions on the downstream sides of the mine disturbance area (including WRDs and stockpiles) to treat the surface water runoff prior to discharge to the natural watercourse. In areas where surface water is likely to pond at local low points, these locations would act as 'trapped' sediment basins, with runoff either evaporating or infiltrating into the ground.

Sedimentation traps should be designed to drop sediment particles greater than or equal to 75µm (fine sand/silt) out of suspension during a 10% AEP storm event prior to discharging into the environment, and to contain the critical 20% AEP (0.2 EY) 20-minute duration storm event (first flush event).

The potential risks, impacts, and controls related to sediment generation are summarised in Table 7.1.

5.4 Water Quality

5.4.1 Potential Impacts

There is potential for adverse changes to surface and groundwater quality due to:

- Spillage of hydrocarbons and chemicals stored, handled or transported on site;
- Runoff from the mine pit, stockpiles, ROM pad and waste dump areas containing metals or other elements; and
- Discharge of water used for dust suppression.

Contaminated discharges have the potential to impact on vegetated areas, pools and other sensitive ecological areas downstream if allowed to enter nearby waterways.

5.4.2 Mitigation Measures

Hydrocarbons and chemicals will be managed to avoid leaks and spills. Fuel handling areas will be bunded to capture spills and located outside of floodplains or appropriately elevated to avoid the risk of flood inundation.

Stormwater runoff from workshop pavements, fuel unloading and storage areas and from vehicle washdown areas should be directed to grit and oil interceptors to remove hydrocarbons prior to re-use or release. Accidental spills outside containment areas should be cleaned up immediately to avoid risk of contamination.

The potential risks, impacts, and controls related to water quality are summarised in Table 7.1.

Hydrocarbons

Hydrocarbons should be managed to avoid leaks and spills. Fuel handling areas should be bunded to capture any spills for remediation and be located outside of floodplains or appropriately elevated to avoid the risk of flood inundation. Bunds should be capable of containing the combined volumes from a 20-year ARI (5% AEP) 72-hour duration design flood event and 110% of the tank contents in accordance with the DoW Water Quality Protection Guidelines (2000).

The potential risks, impacts, and controls related to hydrocarbons are summarised in Table 7.1.

Dust Suppression Water

Dust suppression water has the potential to impact surrounding vegetation if not managed appropriately. Dust suppression activities need to avoid overspray. Dust suppression will be sourced from local groundwater supplies, which are likely to be fresh and therefore the risk of dust suppression impacting vegetation is minimal.

The potential risks, impacts, and controls related to use of dust suppression water are summarised in Table 7.1.

5.5 Mine Dewatering Discharge/Reuse

5.5.1 Potential Impacts

The proposed pit development is located partially below the groundwater table, and therefore dewatering of groundwater from the pit will likely be required.

Incident rainfall that collects within the pit may be required to be pumped out following a large rainfall event.

5.5.2 Mitigation Measures

Dewatering management will be according to an approved DWER licence. This minimises any impacts as water can be used for mining purposes rather than discharge of excess water into the environment. The hydrogeological assessment (PSM, 2021) predicted scenarios with no excess groundwater dewatering discharges to be the most likely, with water extraction from production bores needed to make up deficits in production water requirements over the life of the project.

Surface water captured within the pits following a large rainfall event is likely to be only from the area within pit and localised external catchment areas. Captured water may be reused within the mine site area, but under rare events may require short-term discharge to a localised drainage line (following discharge through a sediment trap).

The potential risks, impacts, and controls related to mine dewatering discharge/reuse are summarised in Table 7.1.

6 SURFACE WATER MANAGEMENT MEASURES

Storm water runoff around the mine area and associated infrastructure must be managed to limit the environmental impacts of the mine operations on the surface water regime and reduce the impacts of flooding on the mine operations. Designs for surface water management infrastructure must incorporate measures to avoid excessive scour, erosion and sediment transport. Drainage around operational areas should be designed to prevent prolonged ponding following rainfall events. Flood mitigation measures are required to prevent flood ingress to open pits and mine infrastructure areas.

The following section covers potential flood mitigation to be considered during mine operations, design standards and proposed conceptual mitigation measures required within the Mine Area. A summary of the recommended mitigation measures is provided in Table 7.1.

6.1 Flood Mitigation

Taking into consideration flood mapping results and catchment runoff intercepted by infrastructure, flood mitigation measures may include (refer Figure 6.1):

- A potential Flood Protection Levee along the western boundary of the stockpile and plant area for flood protection from Mine Creek. Note that:
    - Flow events exceeding 10% AEP are predicted to be required to cause breakout flow from Mine Creek to flow through the stockpile/plant area.
    - The likelihood of this event happening over the 2.2-year mine life is less than 19%, but increases to 39% and 63% over 5 and 10-year operating periods, respectively.
    - Dirty water containment bunding is proposed around the development footprint, which would also provide a level of protection from Mine Creek breakout flow entering the area.
    - When the area is cleared and levelled for construction of the mine infrastructure, the resulting pad may be at a higher elevation than the existing ground level and therefore reduce the risk of inundation during flood events.
    - The consequence of flooding through stockpile/plant area on the operations should be considered to determine if additional flood protection is warranted. Given the potential for a large amount of sediment to be mobilised if flood flow through this area occurs, it is felt that a flood levee is required.
- A diversion is recommended along the southern side of the pit to prevent breakout flow from the Mine Creek tributary (Catchment B and C) from being captured within the pit.
- A diversion is recommended along the eastern boundary of the topsoil stockpile located adjacent to Mine Creek.
- A diversion is recommended along the northern boundary of the development, where Catchment D runoff is intercepted by the proposed development.
- A majority of the infrastructure footprints only intercept small, local catchments which can be managed by standard drainage measures (nominal diversions/bunds). The conceptual design of these measures are discussed below.

6.2 Design Standards

The following design standards are proposed for the future design of flood mitigation and surface water management measures for the Project site:

- Open Cut Pit - small flows from Catchments B and C tributary and other small local catchments are intercepted by the pit footprint. Where flows are chosen to be diverted around the pit nominal diversion bunding (i.e., typically 1m in height) would be adequate. For small catchments not related to Catchments B and C, and where diversions are not practical, surface water runoff may be captured within the pit.
- The required flood protection bunding either side of Mine Creek should be sized to contain the 2% AEP at a minimum, which has a likelihood of exceedance of 4% with the currently planned 2.2-year operating period and 18% with a 10-year operating period. These flood bunds protect areas of material stockpile where the potential consequence of large surface water flows during flood events is the mobilisation of large amounts of sediment into the downstream environment.
- Similarly, the proposed bunding around the northern side of the Project to divert runoff from Catchment D should be sized for a 2% AEP event at a minimum, to provide protection to the stockpile areas.
- Minimum 10% AEP for the design of all other levees, drainage channels, haul road culverts/floodways, diversion drains. Drainage channels shall be positively sloped to daylight.
- The Access Road crossing of Mine Creek to be designed so as not to increase the flood risk to the proposed Mine Development area.
- Allowance for a minimum of 0.5m freeboard in all drainage channels and flood bunding to account for uncertainties, debris and rough construction.
- Sedimentation traps are to be designed to drop sediment particles greater than or equal to 75µm out of suspension prior to release into the environment during a 10% AEP flood event. The sedimentation traps will also be able to capture the runoff during the first flushing event.
- Settling ponds, sediment traps and waste dumps are to be placed outside the 1% AEP flood plain of major drainage lines.

6.2.1 Surface Water Management Concepts

The following general surface water management concepts should be adopted and incorporated into designs:

- Where possible, runoff from undisturbed catchment areas (i.e., "clean" runoff) will be diverted around mine disturbance areas to prevent contamination and the requirement to treat larger quantities of runoff.
- Runoff captured from the waste dump and other sediment yielding infrastructure such as Stockpile Areas and ROM pad will be diverted through sedimentation traps prior to release to the natural watercourse. The borrow pit located upstream of the camp is assumed to be free-draining given the terrain on which it is proposed; as a result, internal bunding is assumed to be constructed to direct runoff to a sediment basin prior to discharging downstream.

- In general, "dirty" runoff is treated close to the source disturbance area to reduce the volume of runoff requiring treatment and is kept separate from clean runoff from external catchment areas.
- Equipment maintenance and fuel handling areas, where there is significant risk of hydrocarbon spillage, should be bunded and runoff directed to grit and oil interceptors prior to re-use of this water.
- Oil interceptors will require regular monitoring and maintenance to maintain their performance particularly during the wet season.

The final waste dump batter faces will be designed to reduce runoff erosion. Stabilisation of batter slopes at closure will reduce erosion in the long-term. During active mining, runoff from the waste dump batters will be captured and treated in sediment basins prior to discharge to the downstream environment.

6.3 Conceptual Surface Water Management Infrastructure

6.3.1 Catchment Diversions

Diversions will be used to divert runoff from undisturbed sites around proposed mining infrastructure to maintain environmental flows, reduce flood risk to infrastructure and prevent contamination of "clean" runoff. The location of the proposed diversions are shown in Figure 6.1 and are discussed in more detail below.

A conceptual diversion drain design is presented in Figure 6.2. Drains would be either trapezoidal or v-shaped (dependent on base width requirements) with nominal 1:3 side slopes. Material excavated to construct the drain should be placed alongside and down gradient of the drain and compacted to form a bund with nominal 1:3 side slopes.

Flood protection bunds/levees should be built with nominal 1:3 side slopes and a minimum top width of 3m.

Water velocities in diversions should be kept below 2m/s to prevent the need for rock armouring throughout the diversion. Rock aprons should be installed at the downstream end of diversions to prevent scour and erosion.

6.3.2 Sedimentation Basins

Surface water runoff from sediment generating areas will be passed through sedimentation basins/traps during mining operations. Conceptual locations for 'dirty flow' drainage and sedimentation basins are presented in Figure 6.1. Given the compact nature of the proposed mine development, it is proposed that dirty water capture bunding be installed around the downstream perimeter of the site and direct dirty runoff to sedimentation basins at select low point(s).

The basins are proposed to be designed to drop sediment particles greater than or equal to 75μm out of suspension, prior to release of the "clean" water into the environment during, at minimum, a 10% AEP flood event. A higher concentration of fines are likely to be mobilised during the first flush rainfall, this is the equivalent to the 20% AEP, 20 minute duration flood event. As there is likely to be a high percentage of fines and salt within this first flush, sedimentation basins should be able to capture the first flush event completely.

The basins should be constructed with nominal 1:3 side slopes and 3m wide at the crest. A nominal 0.5m storage depth should be allowed for sediment accumulation before clean out is required. Sediment levels should be monitored following significant flood events and sediment accumulation should be removed on a regular basis.

6.4 Pit Surface Water Management

The pit is proposed to be protected from inflow via a diversion to deflect runoff from a portion of external catchment L3 (diverted catchment area of 0.08km^2), plus break-outflows from Mine Creek East Tributary. The remainder of the catchment, approximately 0.21km^2, would be allowed to enter the pit.

If a diversion is installed around the pit, a nominal bund is required.

An estimate of the volume of water which may discharge into the pit from the pit catchment (including the LOM pit footprint itself) has been completed for different design rainfall events based on the following assumptions:

- 24-hr rainfall event depths.
- Assumed volumetric runoff coefficients for steep small catchments in the Pilbara.
- Contributing catchment areas as per Table 6.1.

Depending on the pit development/progression plans, the catchment areas reporting to each pit and the pit footprint areas may vary as the mine develops. Additionally, the requirement to remove collected runoff from the pit will be dependent on the capacity of stormwater collection sumps to contain the runoff within the pit and pit priority/active mining areas.

Table 6.1: Estimated Pit Storm Runoff Volumes (m^3)

Catchment Area	AEP Event					
	50%	20%	10%	5%	2%	1%
Pit Footprint (0.45km^2)	13,800	22,900	32,900	45,100	66,300	85,400
Non-diverted portion of External Catchment L3 (0.21 km^2)	3,500	6,000	9,200	13,400	21,300	28,500
Total (m^3)	17,200	28,800	42,000	58,400	87,500	113,800

To assist MRL with selecting design capacity for any stormwater pumping system that may be required, estimates of the required pumping duration to remove different runoff volumes from the pit at different pumping rates have been estimated (refer Table 6.2). Used in conjunction with Table 6.1, this indicates an estimated pump out duration of approximately 4 weeks to remove a 1% AEP event if the stormwater pumping system had a capacity of 50L/s.

Table 6.2: Pumping Duration Required to Remove Runoff (Days)

Pumping Rate (L/s)	Runoff Volume (m^3)					
	10,000	20,000	50,000	75,000	100,000	150,000
25	4.6	9.3	23	35	46	69
50	2.3	4.6	11.6	17.4	23	35
75	1.5	3.1	7.7	11.6	15.4	23.1
100	1.2	2.3	5.8	8.7	11.6	17.4
200	0.6	1.2	2.9	4.3	5.8	8.7

6.5 Access Road Floodways/Culverts

The proposed Access and Haul Road alignments cross multiple drainage lines. Large catchments upslope of the larger floodway locations are shown on Figures 3.4 and 3.5 and peak flow estimates using the RFFE Flavell (2012) method for these locations are given in Table 3.8 (runoff calculations for all catchments is provided in Appendix A). Note that the Access and Haul Roads may intercept smaller drainage lines which also require management over and above the larger catchments shown on Figure 3.4 and 3.5.

Flood management for the crossing of Mine Creek should ensure that the flood risk to Mine Infrastructure areas upstream of the road aren't increased.

Management of runoff at these crossings can be addressed through the use of floodways or culverts. Floodways should be cement stabilized to reduce scour and, where required, have rock protection on the downstream side of the road to prevent head cutting and erosion.

Culverts can be used instead of or in conjunction with floodways. Culverts are to be no smaller than 450mm diameter to ensure that they do not get frequently blocked.

6.6 Closure

General surface water management of the site at Closure should consist of the following:

- The Pit void will remain in place, with abandonment bunding along the pit perimeter. Where abandonment bunding is required to divert surface water, it shall be constructed in line with flood bund construction requirements.
- Final WRD surfaces will be shaped to reduce runoff velocities and the potential for erosion from the WRD face.
- Removal and rehabilitation of stockpiles, plant, camp and road alignments.
- Where required, protect toe of WRD from erosive velocities of floodwater from extreme events (including flooding of Mine Creek).
- Diversion bunds and drains will remain in place to provide continued protection of the rehabilitated landforms in the immediate post-closure phase.

7 MANAGEMENT SUMMARY

Downstream hydrological receptors were identified and described in Section 2 and are shown on Figure 2.5. The receptors include the following:

- Mine Creek.
- Marillana Creek.
- Weeli Wolli Creek.
- Fortescue Marsh.

Potential risks to downstream hydrological receptors from mining activities were identified in Section 5 and included:

- Modification and interruption of the existing hydrological regime, including reduction of flows downstream of mining areas.
- Water shadows due to interruption of surface and shallow groundwater flow paths.
- Runoff with elevated contaminants (sediments, hydrocarbons, metals and other elements released to the environment).

A summary of the key conceptual mitigation measures to reduce risks to receptors identified in Section 5 and 6 are listed below:

- Divert clean flows around the mine disturbance areas (where practical).
- Return diverted flows to the original catchment downstream of infrastructure.
- Dirty water runoff to be captured and passed through sediment basins prior to release back into the catchment.
- Reduction in catchment areas is generally restricted to the pit and its immediate area, plus possibly the top of waste dump footprint areas. The size of catchments being removed are insignificant compared with the total catchment areas of the downstream receptors.
- Floodways or culverts to transfer flow across road alignments. Where roads intercept sheet flow drainage (particularly upstream of sheetflow dependent vegetation), smaller culverts installed at frequent intervals will be required to reduce water shadowing on the downstream side of the road.

In addition to the above mitigation measures, the mine site is generally situated away from Mine Creek, other than some encroachment onto the floodplain. Distances to surface receptors range from approximately 20km for Marillana Creek to 100km for Fortescue Marsh GDE.

The impact of potential surface water diversions along Mine Creek were estimated by comparing Pre and Post Development flood modelling results, which indicated that impact to flood depths was localised to within 500m of the Mine development area.

As such, with the proposed management measures outlined in this Surface Water Management Plan, the proposed Project presents a low risk to the hydrological regime of the downstream surface water environment.

The hydrological environment also has the potential to impact the mining environment.

The potential risks and impacts to the environment associated with the proposed Lamb Creek development are summarised in Table 7.1. The table highlights the identified activity, the potential impact, and the mitigation measure recommended to reduce the environmental risk associated with that activity.

Table 7.1: Impact and Mitigation Measures Summary

	ID	Risk Pathway/Unwanted Event	Description of Impact	Mitigation Measure/Further Assessment
Modification of Hydrological Regime	1	Construction of flood protection for the mine	Diversions (D1 to D4) required to protect mine alters the hydrological regime.	Impact of the diversion on the flood depths is predicted to be limited to 500m of the diversion based on comparison of pre development and post development flood mapping (Refer Figure 4.6).
	2	Construction of Haul/Access Roads in path of drainage lines	Ponding on upstream side of road. Water shadow on downstream side of road.	Construct waterway crossings (i.e. culvert, floodway) at appropriate locations along impacted alignment to allow continuity of the existing flow regime.
	4	Construction of mine infrastructure (pit and waste dumps) reduces runoff to downstream environment	Runoff collected within the pit and waste dump footprints will reduce the runoff to the downstream environment. This may impact water availability in the downstream environment.	Impact restricted to immediately downstream of the infrastructure area. Loss of catchment (1.4km^2) small compared to catchment areas of Marillana Creek (2,230km^2) and Weeli Wolli Creek (4,220km^2)
	5	Capture of adjacent drainage from Mine Creek Tributary (Catchments B and C) into the open pit.	Potential for the capture of the adjacent drainage channel by the pit during large rain events, creating water shadows downstream	Construction of diversion D2 along the southern side of the pit.
Sediment Control	6	Construction of waste dump in path of drainage channel	Erosion of toe of waste dump potentially leading to dump failure and transport of large amount of sediment to downstream environment.	Construction of diversion D2 around waste dump and erosion protection of waste dump toe. Waste dump closure designs.
	7	Sediment-laden runoff from face of waste dump	Ongoing sediment release to downstream environment from frequent rainfall events impacting downstream water quality.	Construction of containment bunding and sediment basins (as per Figure 6.1) to remove particles greater than 75um from a 10% AEP event prior to discharge downstream.
	8	Construction of Western Stockpile in path of Mine Creek	Potential to mobilise large quantities of sediment from the Stockpile and impact downstream water quality.	Construction of diversion D1 around perimeter to divert clean flows around Western Stockpile. Diversion capacity 1% AEP.
	9	Release of hydrocarbons that are stored, handled or transported on site to the environment.	Pollution of downstream environment leading to environmental damage.	Fuel handling areas to be located outside floodplain area and bunded to capture spills. Runoff from wash bays and fuel storage/handling areas to be directed to grit and oil separators prior to discharge to downstream environment. Bunds to contain volume from 20-year ARI (5% AEP) 72-hour duration design flood event and 110% of the tank contents.
Water Quality	11	Dust suppression water to runoff to environment.	Vegetation adversely affected by runoff water.	Don't overwater roads. Use of fresh water for dust suppression water.
Impact to Operations	12	External runoff to the pit (Catchments B and C)	Flooding of Pit impacting operations.	Where feasible, diversion of upstream catchment around pit footprint.
	13	Construction of Stockpile and Plant area adjacent to Mine Creek	Inundation and damage to infrastructure by flood waters.	Construct Flood Protection Levee D3 and D4 along western boundary of stockpile/plant area.
	14	Construction of Haul/Access Roads in path of drainage lines	Damage to road infrastructure by, or delay to operations due to, flood waters.	Construct floodways/culverts under roads to allow runoff to flow unimpeded

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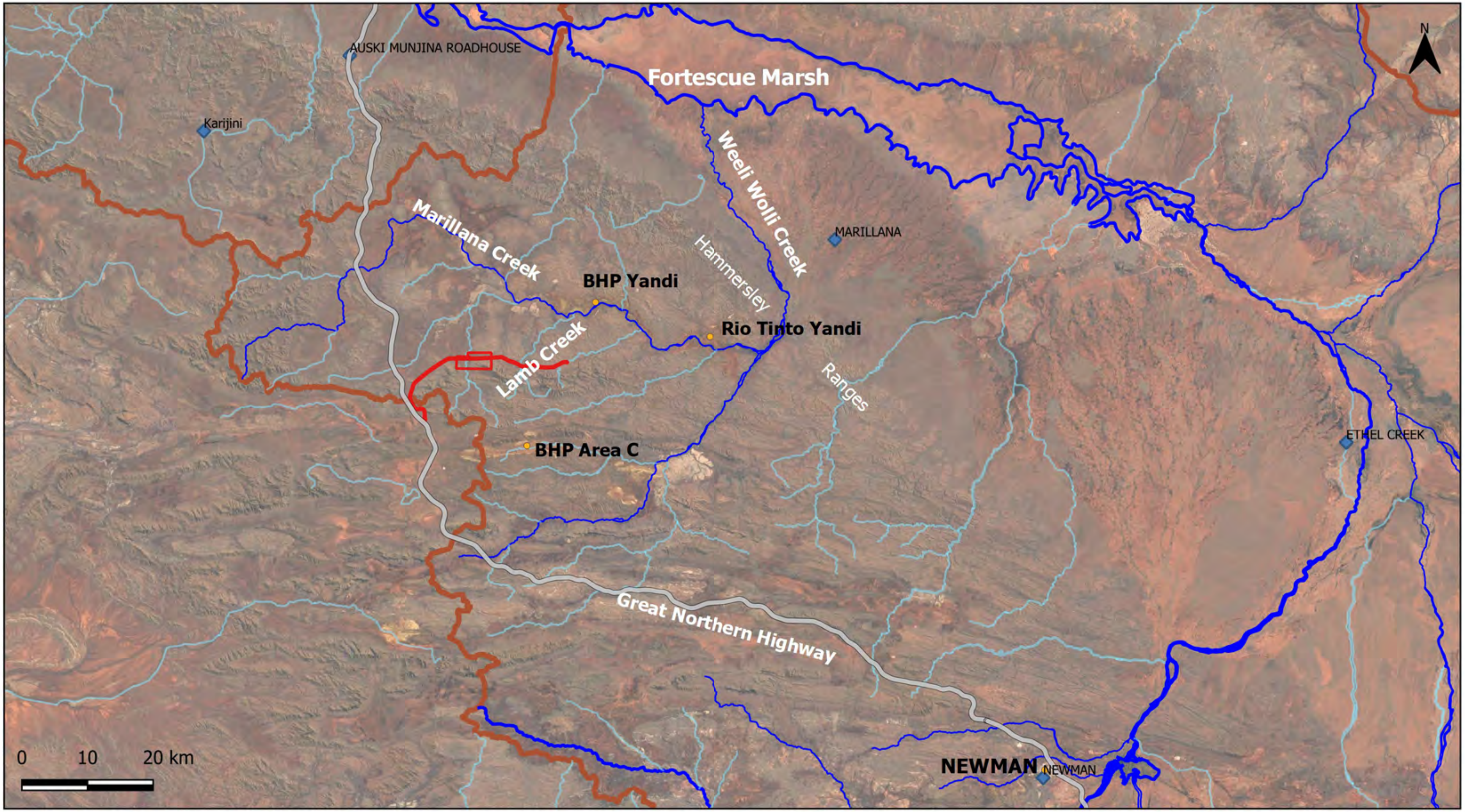
FIGURES



Project Site and Access/Haul Roads
Great Northern Highway
Major Drainage Channel
Minor Drainage Channel
Regional Catchment Boundary
BoM Rainfall Stations

AUTHOR: WM
DRAWN: WM
DATE: 24/08/2021

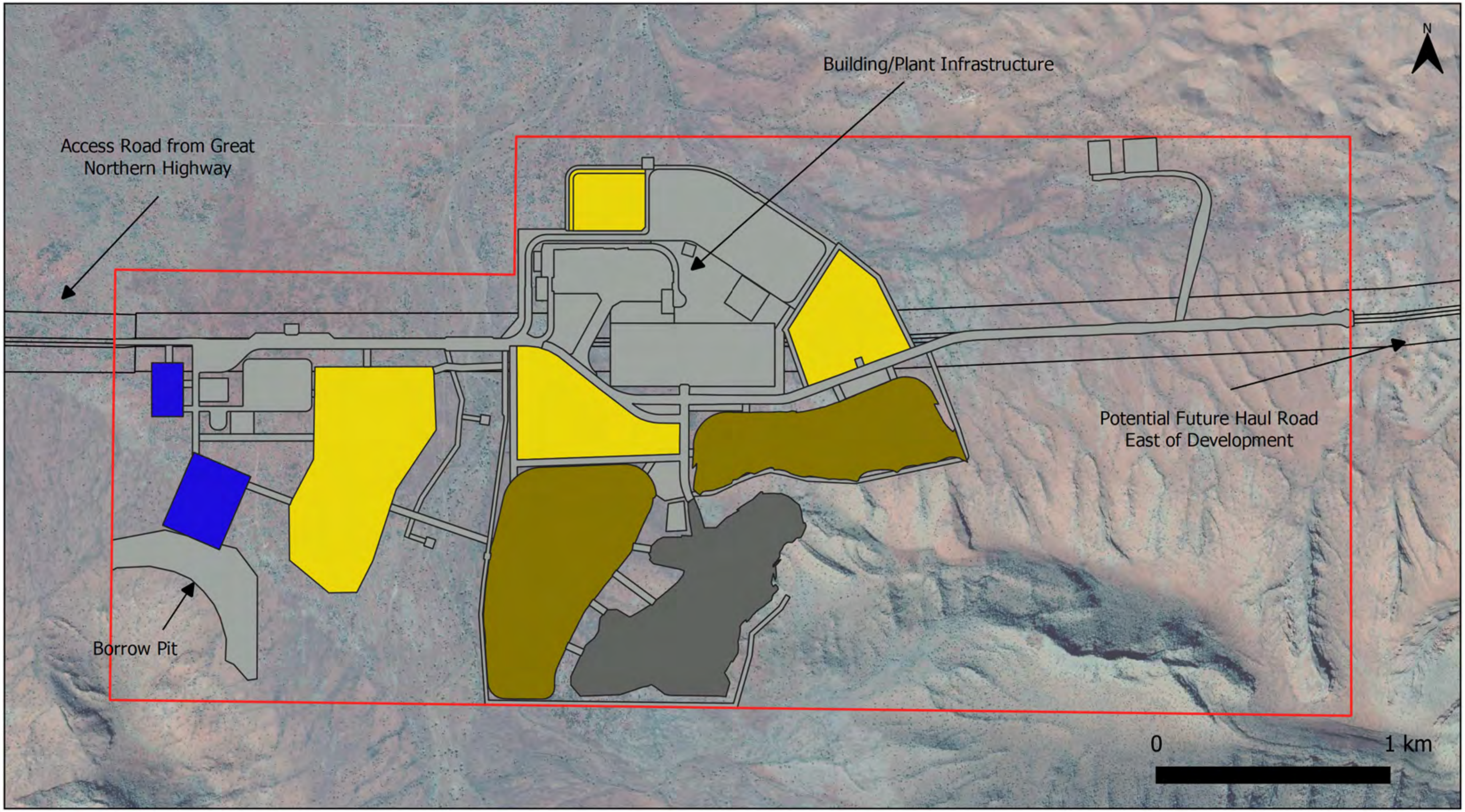
REPORT No: 004b
JOB No: 326
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google Imagry (2020)
Hydrography data sourced from DWER Online Catalogue

AQ2

Figure 1.1
Location Plan

F:\326\4.GIS\Workspaces\SW\Figure 1.1 - Site Location Plan.qgz

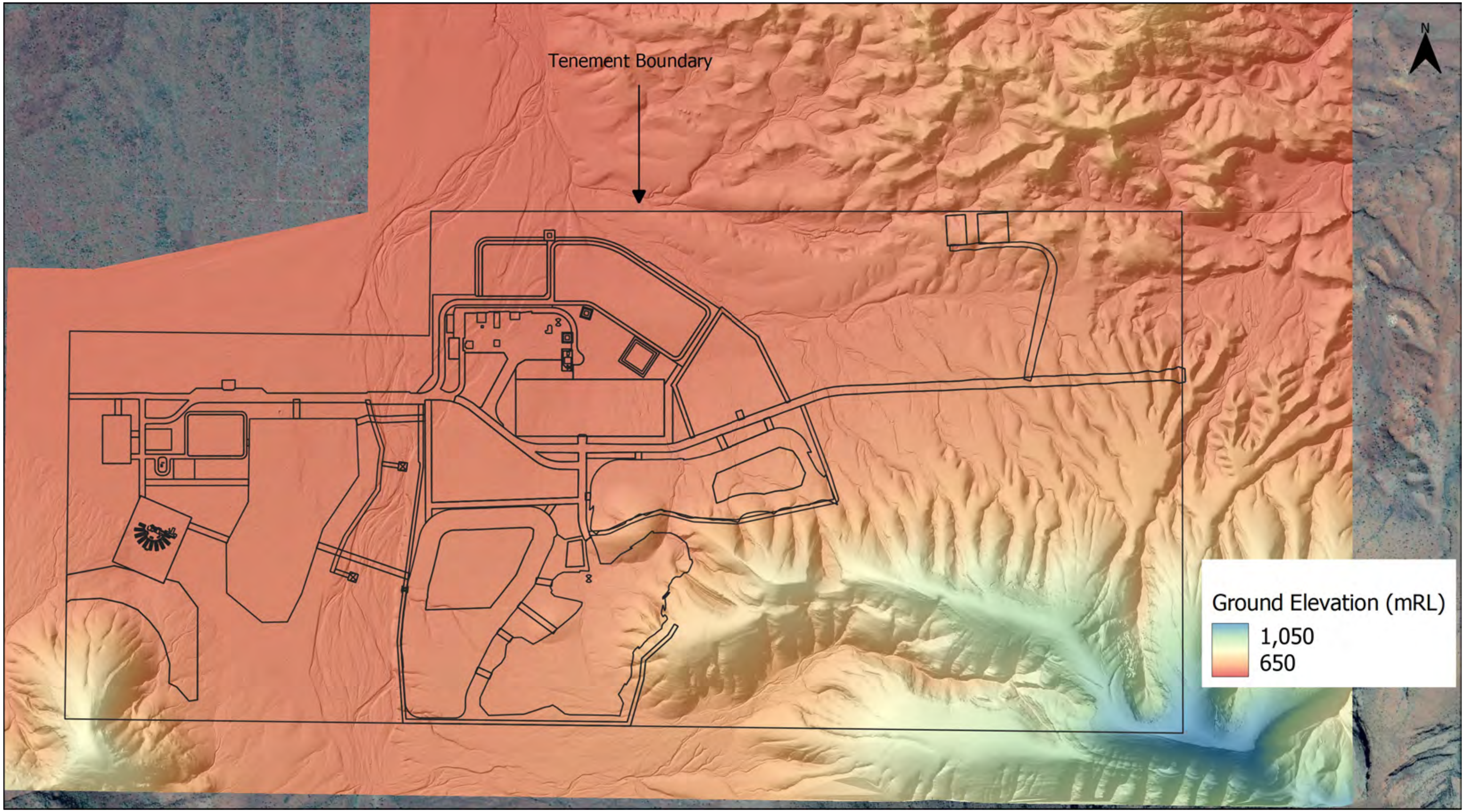


F:\326\4.GIS\Workspaces\D Task\Rev C\Figure 2.1 - Proposed Site Layout.qgz

Project Tenement	Pit Footprint	Accommodation
Great Northern Highway	Stockpile	Other Infrastructure
Mine Infrastructure	Waste Dump	

AUTHOR: WM	REPORT No: 004c	Notes and Data Sources:
DRAWN: BJ	JOB No: 326	Aerial Imagery sourced from Google (2020)
DATE: 01/11/2021	Coordinates: MGA Zone 50	Mine Infrastructure layout provided by MRL (July 2021)

Figure 2.1
Proposed Site Layout



F:\326\4.GIS\Workspaces\SW\Rev B\Figure 2.2_Topography.qgz

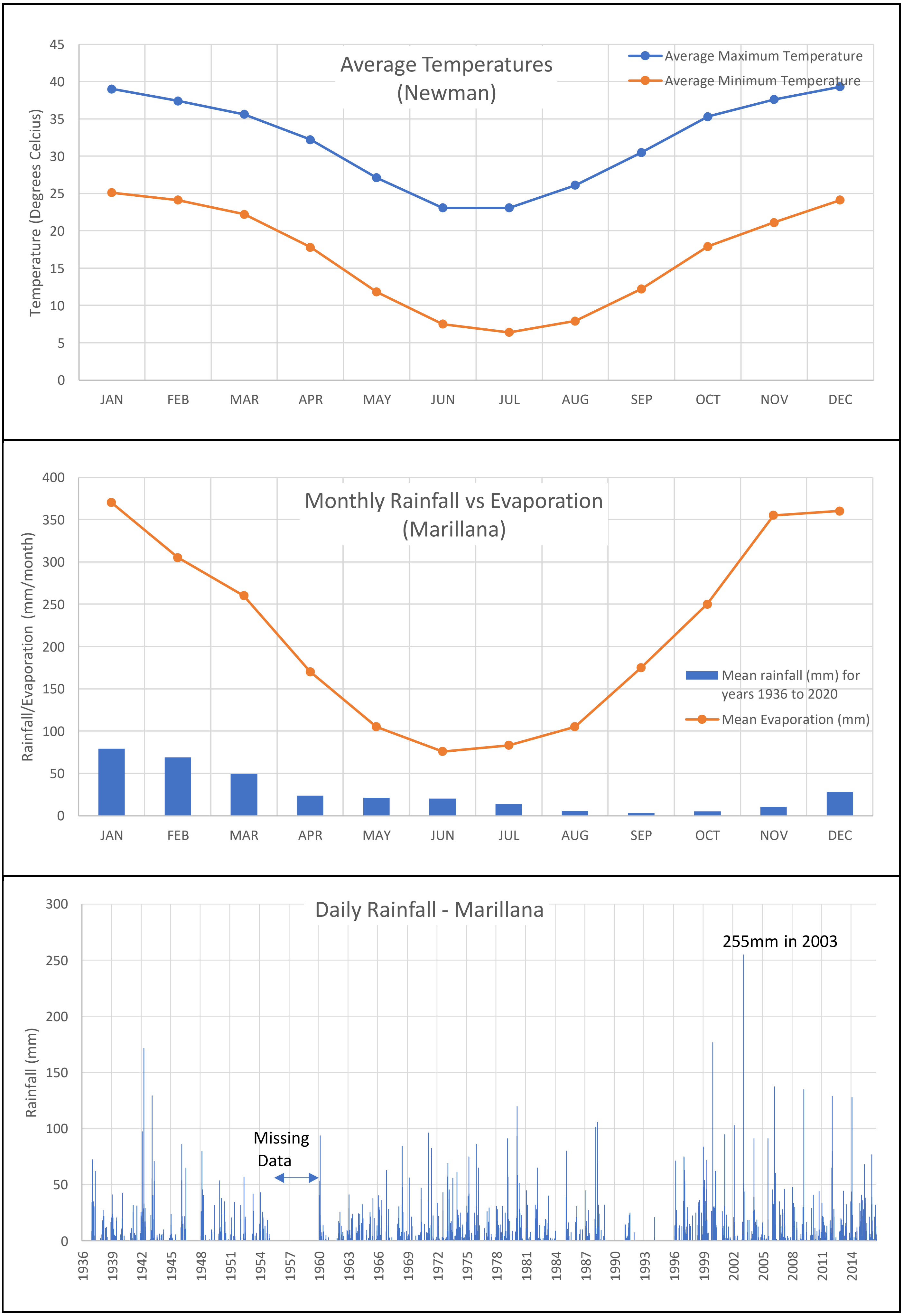
—— Infrastructure Layout

0 250 500 m

AQ2

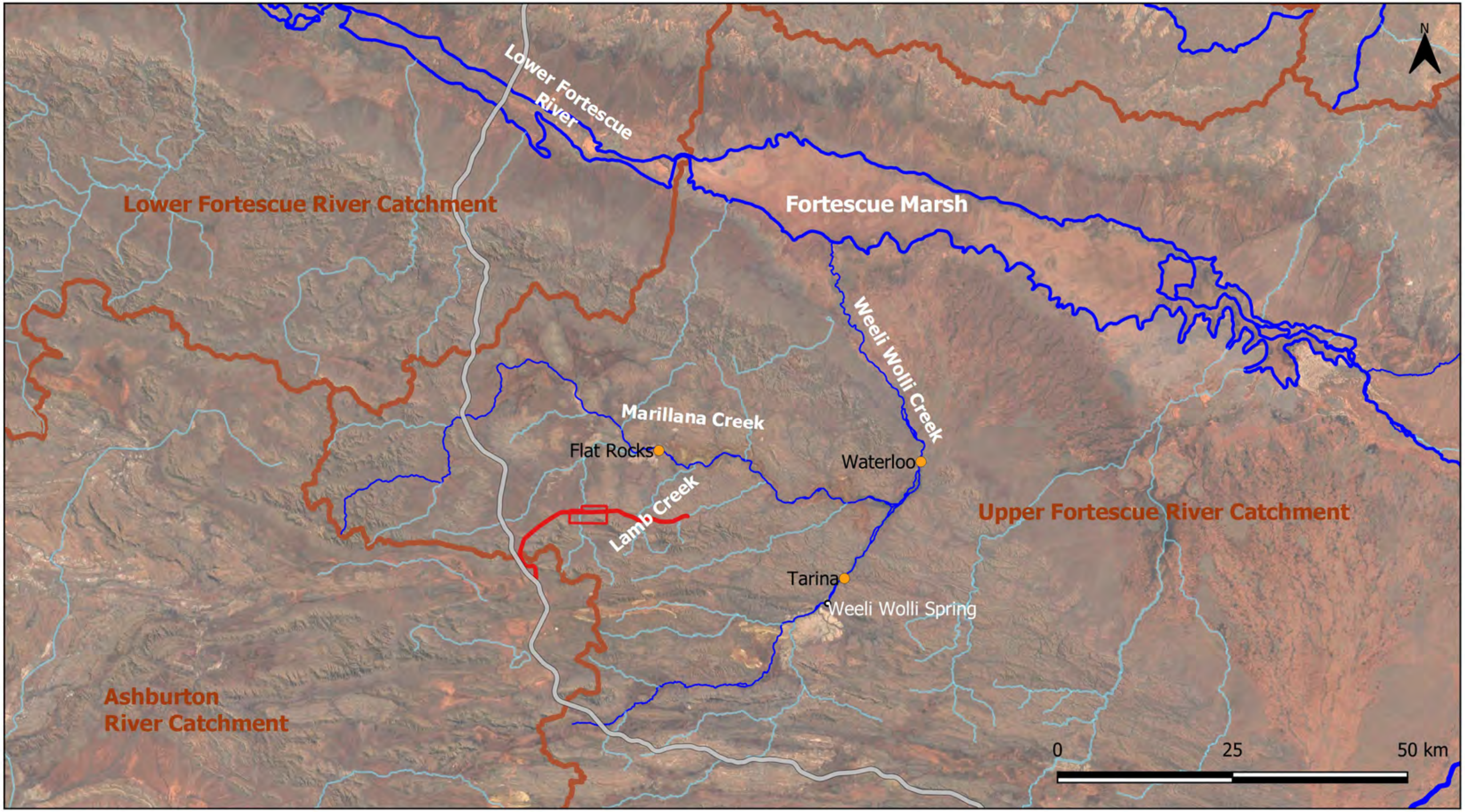
Figure 2.2:
Topography

AUTHOR: WM	REPORT No: 004b	Notes and Data Sources:
DRAWN: WM	JOB No: 326	DTM Topography provided by MRL, captured by AAM in 2010 using ALS.
DATE: 29/7/2021	Coordinates: MGA Zone 50	



Climate Data FIGURE 2.3

F:\326\2.TECH\Analysis\SW\[Figure2.3_Climate.xlsx]Figure



F:\326\4.GIS\Workspaces\SW\Rev B\Figure 2.4_RegionalHydrology.qgz

Project Site and Access/Haul Roads
Great Northern Highway
Major Drainage Channel
Minor Drainage Channel
Regional Catchment Boundary
Stream Gauging (DWER)

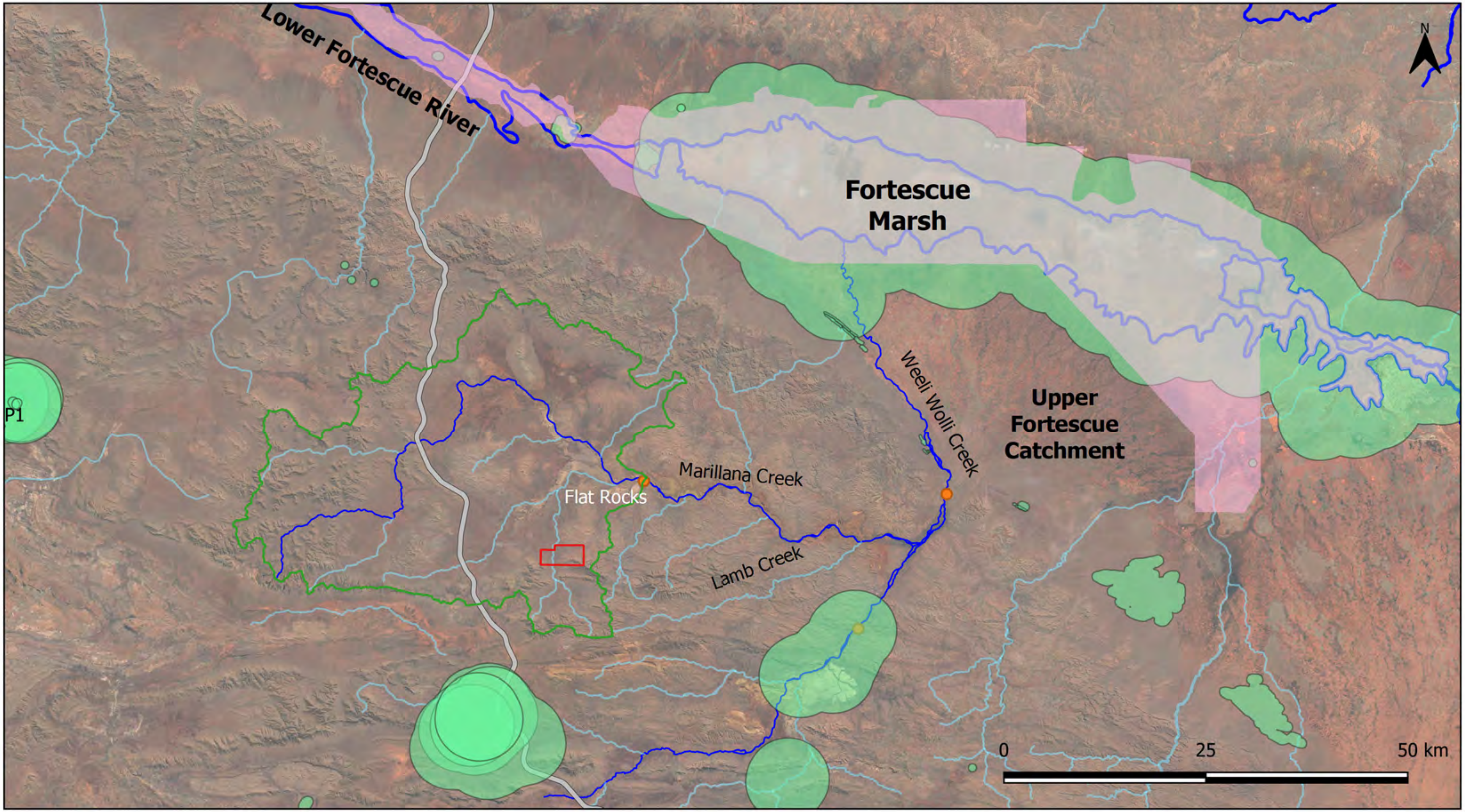
AUTHOR: WM
DRAWN: WM
DATE: 25/08/2021

REPORT No: 004b
JOB No: 326
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google Imagry (2020)
Hydrography data and gauging stations sourced from DWER Online Catalogue

AQ2

Figure 2.4
Regional Hydrology



Location Map

Project Site
Great Northern Highway
Threatened Ecological Community (TEC)
Major Drainage Channel
Minor Drainage Channel
Flat Rocks Subcatchment
Stream Gauging Sites
Draft Ramsar Sites (DBCA-010)

AQ2

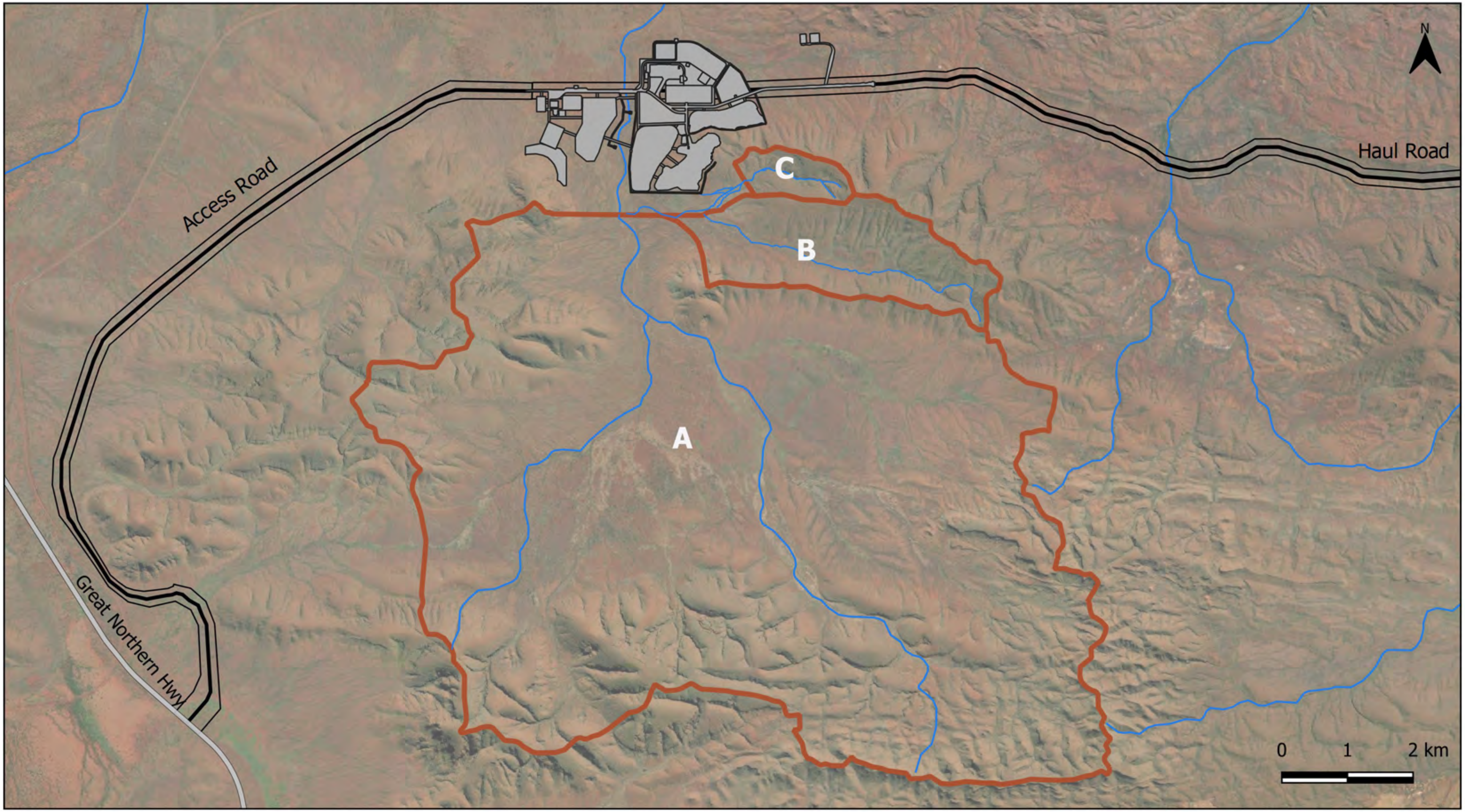
AUTHOR: WM
DRAWN: BJ
DATE: 16/07/2016

REPORT No: 004a
JOB No: 326
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google (2020)
TEC data, Hydrography and gauging sites obtained from DWER online catalogue
RAMSAR sites from DBCA online catalogue

Figure 2.5
Environmental Receptors

F:\326\4.GIS\Workspaces\SW\Figure 2.5 Environmental Receptors.qgz



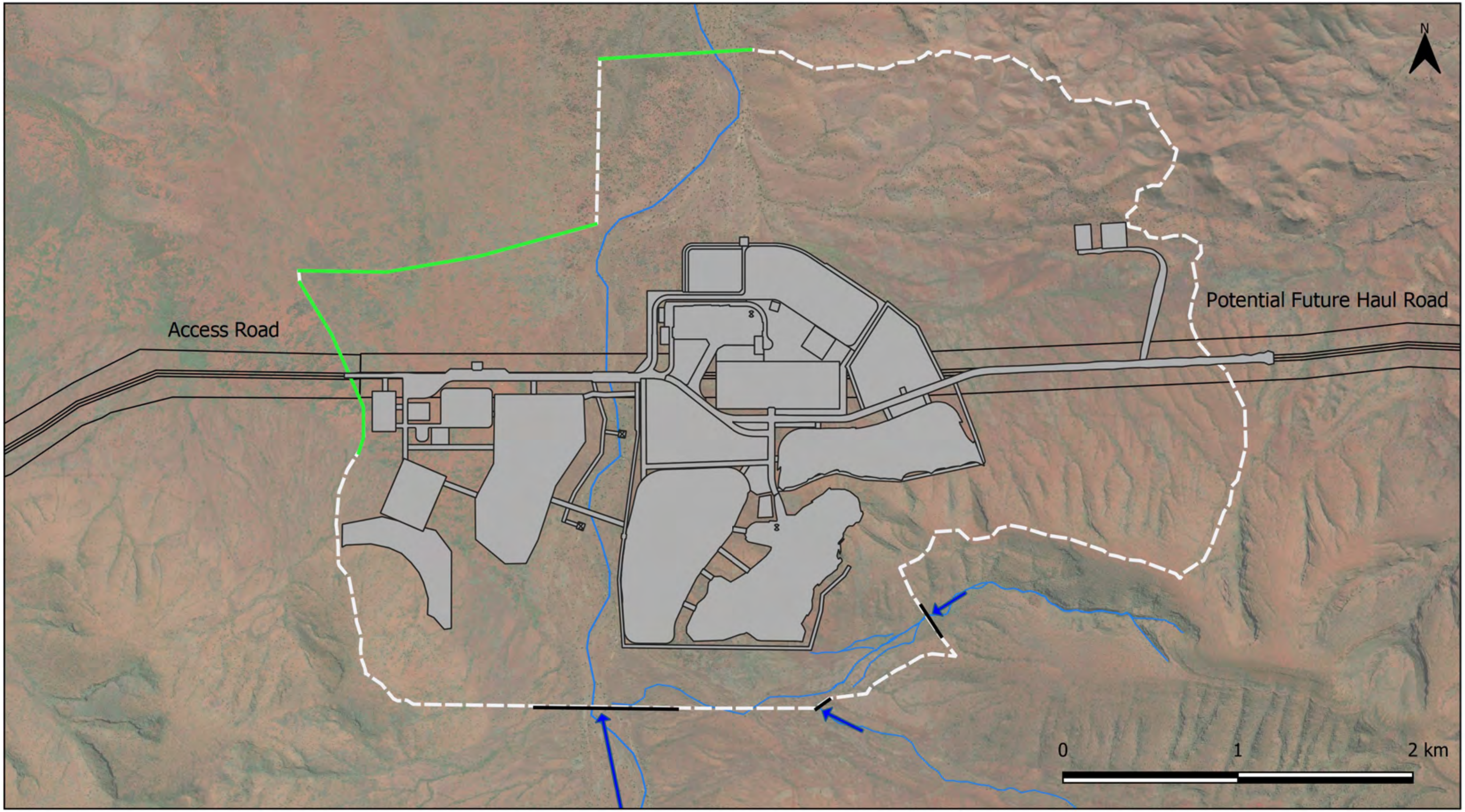
F:\326\4.GIS\Workspaces\SW\Rev B\Figure 3.1_ExistingCatchments.qgz

Infrastructure Layout
Catchments Mine Creek
Great Northern Highway
Creeks

AUTHOR: WM	REPORT No: 004b	Notes and Data Sources:
DRAWN: BJ	JOB No: 326	Aerial Imagery sourced from Google (2020) Mine Infrastructure layout provided by MRL (July 2021)
DATE: 27/7/2021	Coordinates: MGA Zone 50	

AQ2

Figure 3.1:
Mine Creek Catchments



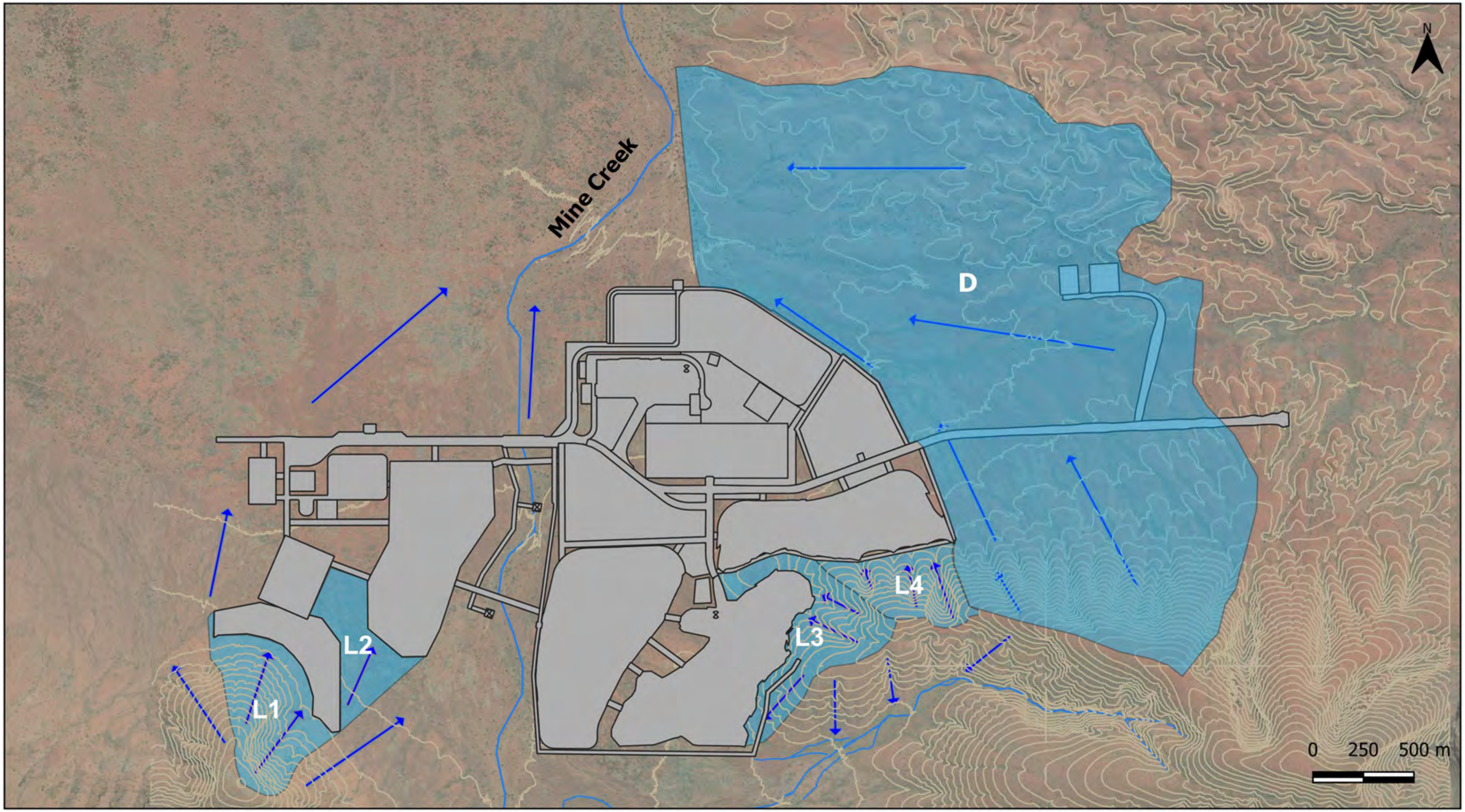
F:\326\4.GIS\Workspaces\D Task\Rev C\Figure 3.2_Model Boundary.qgz

Infrastructure Layout	Inflow Boundary
Creeks	Outflow Boundary
2D Model boundary	Mine Creek/Tributary Flow Direction

AQ2

Figure 3.2:
2-D Model Boundary

AUTHOR: WM	REPORT No: 004c	Notes and Data Sources:
DRAWN: BJ	JOB No: 326	Aerial Imagery sourced from Google (2020)
DATE: 01/11/2021	Coordinates: MGA Zone 50	Mine Infrastructure layout provided by MRL (July 2021)



Location Map

F:\326\4.GIS\Workspaces\SW\Rev B\Figure 3.2_ExistingCatchmentsMine.qgz

Infrastructure Layout
Mine Creek and Eastern Tributary
Topographic 10m Contours
Catchment

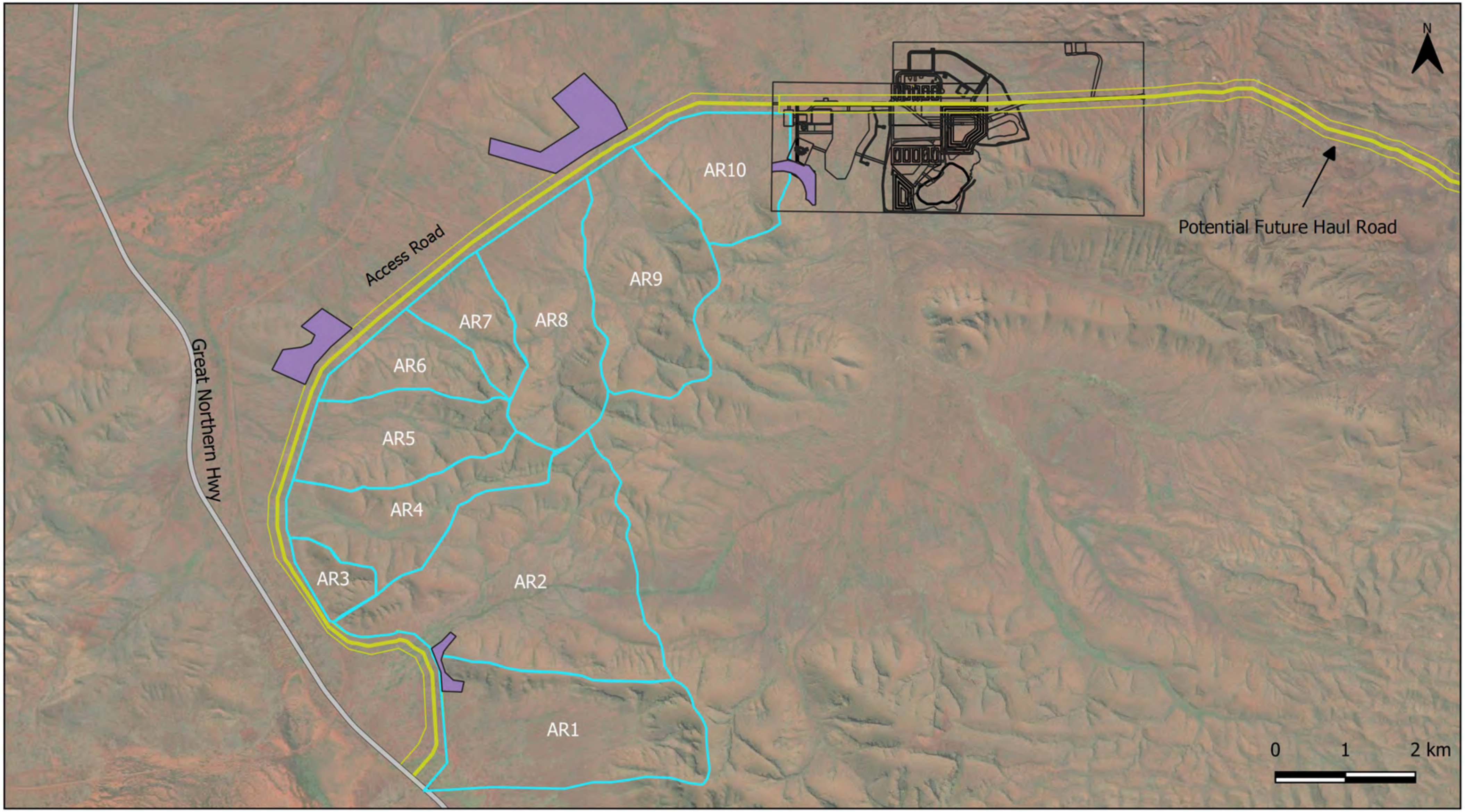
AUTHOR: BJ
DRAWN: BJ
DATE: 25/08/2021

REPORT No: 004b
JOB No: 326
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google (2020)
Mine Infrastructure layout and Topography provided by MRL (July 2021)

AQ2

Figure 3.3:
Catchments to Infrastructure



Location Map

Great Northern Highway
Catchment to Haul/Access Road
Haul/Access Road Corridor
Mine Infrastructure
Borrow Pit

AQ2

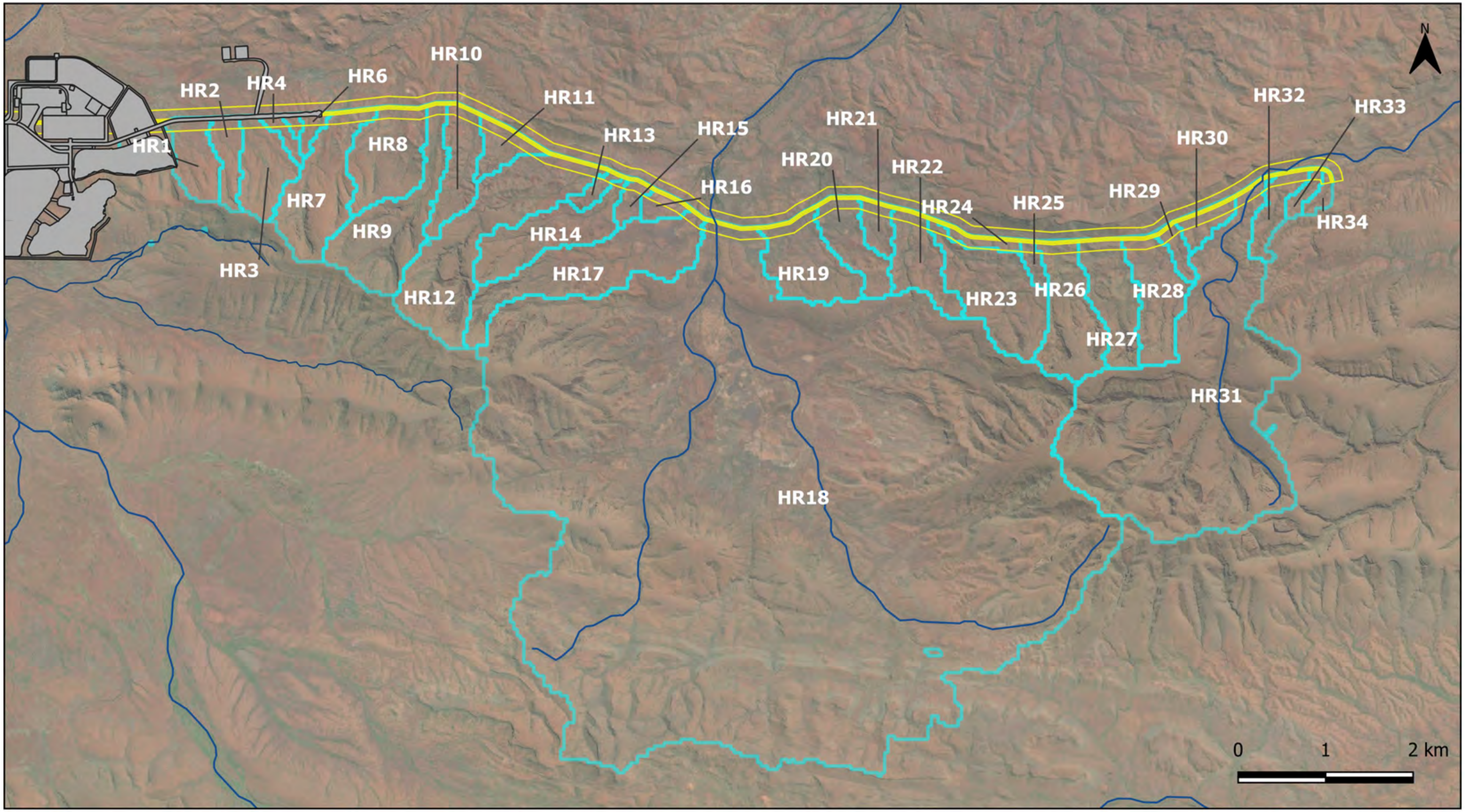
Figure 3.4:
Existing Drainage and Catchments to Access Road

AUTHOR: WM
DRAWN: BJ
DATE: 01/11/2021

REPORT No: 004c
JOB No: 326
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google (2020)
Mine Infrastructure layout provided by MRL (July 2020)

F:\326\4.GIS\Workspaces\D Task\Rev C\Figure 3.4 Access Road Catchments.qgz



Location Map

F:\326\4.GIS\Workspaces\D Task\Rev C\Figure 3.4_Haul Road Catchments.qgz

Infrastructure Layout
Creeks
Haul Road Catchment

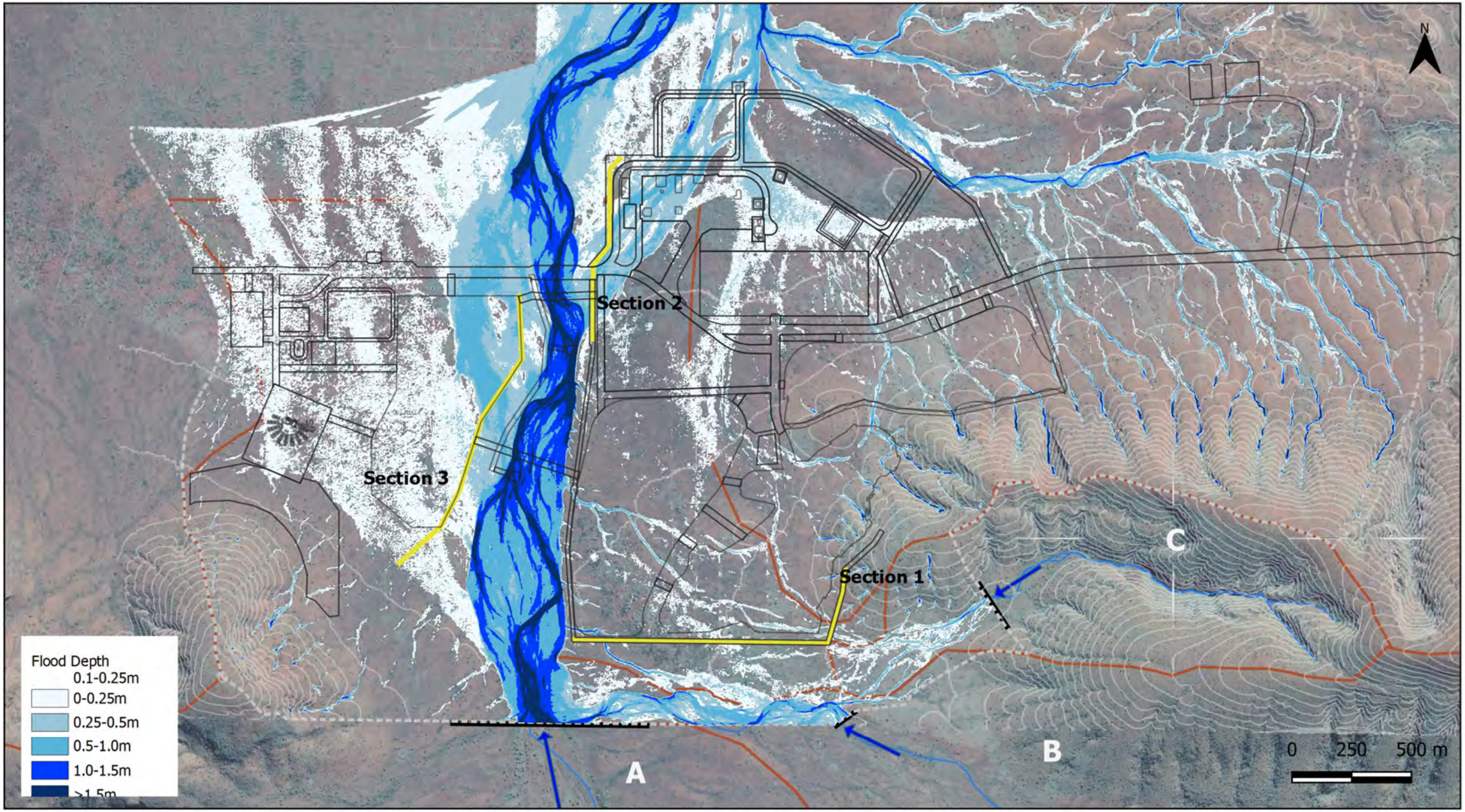
AUTHOR: WM
DRAWN: BJ
DATE: 01/11/2021

REPORT No: 004c
JOB No: 326
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google (2020)
Mine Infrastructure layout provided by MRL (July 2021)

AQ2

Figure 3.5:
Potential Future Haul Road Catchments



Location Map

F:\326\4.GIS\Workspaces\D Task\Rev C\Figure 4.1.qgz

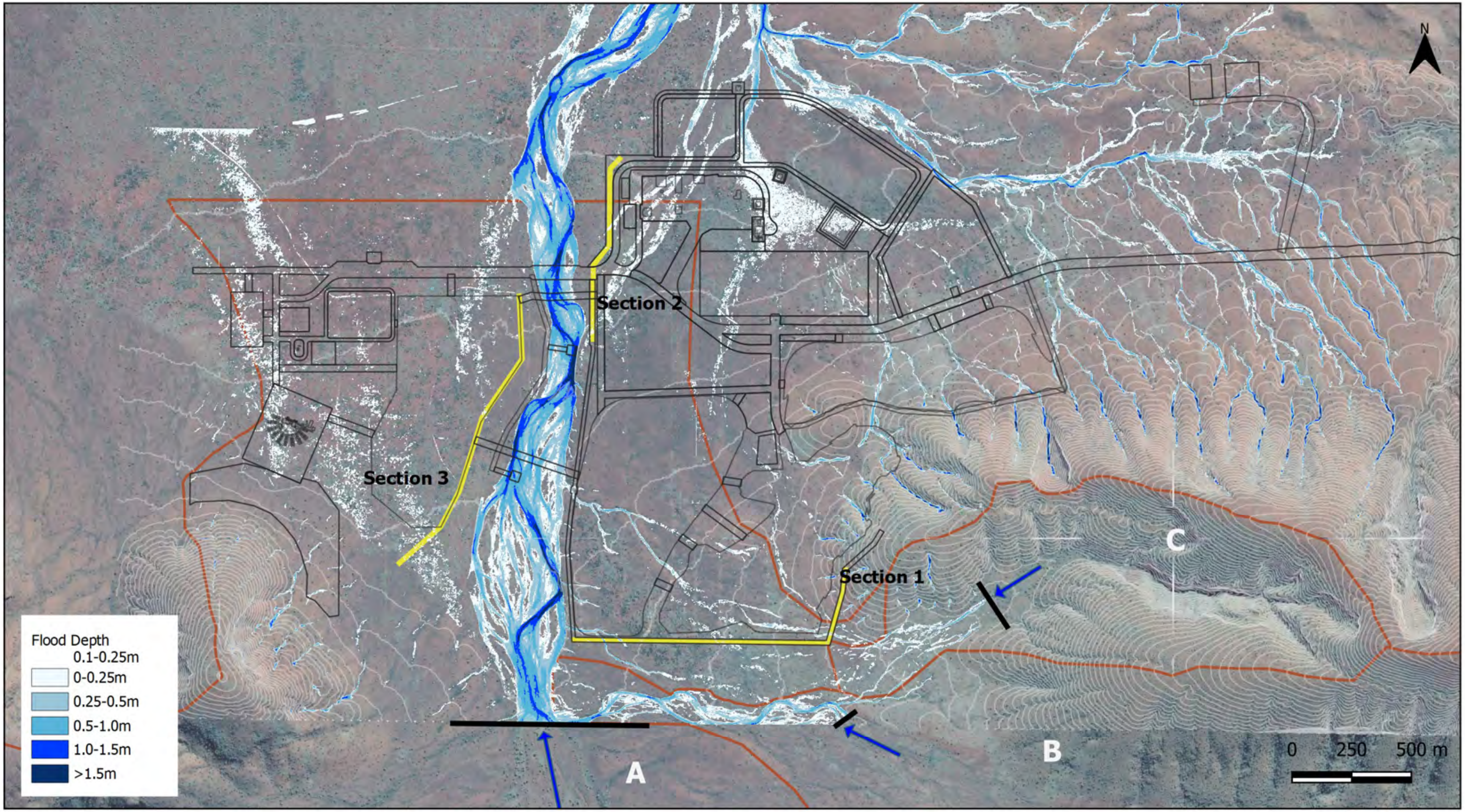
Infrastructure Layout
Inflow from subcatchments
Mine Creek Subcatchments
2D Hydraulic Model Boundary
Section Locations
Boundary Conditions (Inflow)
Boundary Conditions (Outflow)

AQ2

AUTHOR: WM	REPORT No: 004c	Notes and Data Sources:
DRAWN: WM	JOB No: 326	Aerial Imagery sourced from Google (2020)
DATE: 01/11/2021	Coordinates: MGA Zone 50	Mine Infrastructure layout provided by MRL (July 2021)

Figure 4.1:

Mine Creek Predevelopment 1% AEP Flood Map Revised Infrastructure



Location Map

Project

Infrastructure Layout

Inflow from subcatchments

Section Locations

Boundary Conditions (Inflow)

AUTHOR: WM

DRAWN: WM

DATE: 01/11/2021

REPORT No: 004c

JOB No: 326

Coordinates: MGA Zone 50

Notes and Data Sources:

Aerial Imagery sourced from Google (2020)

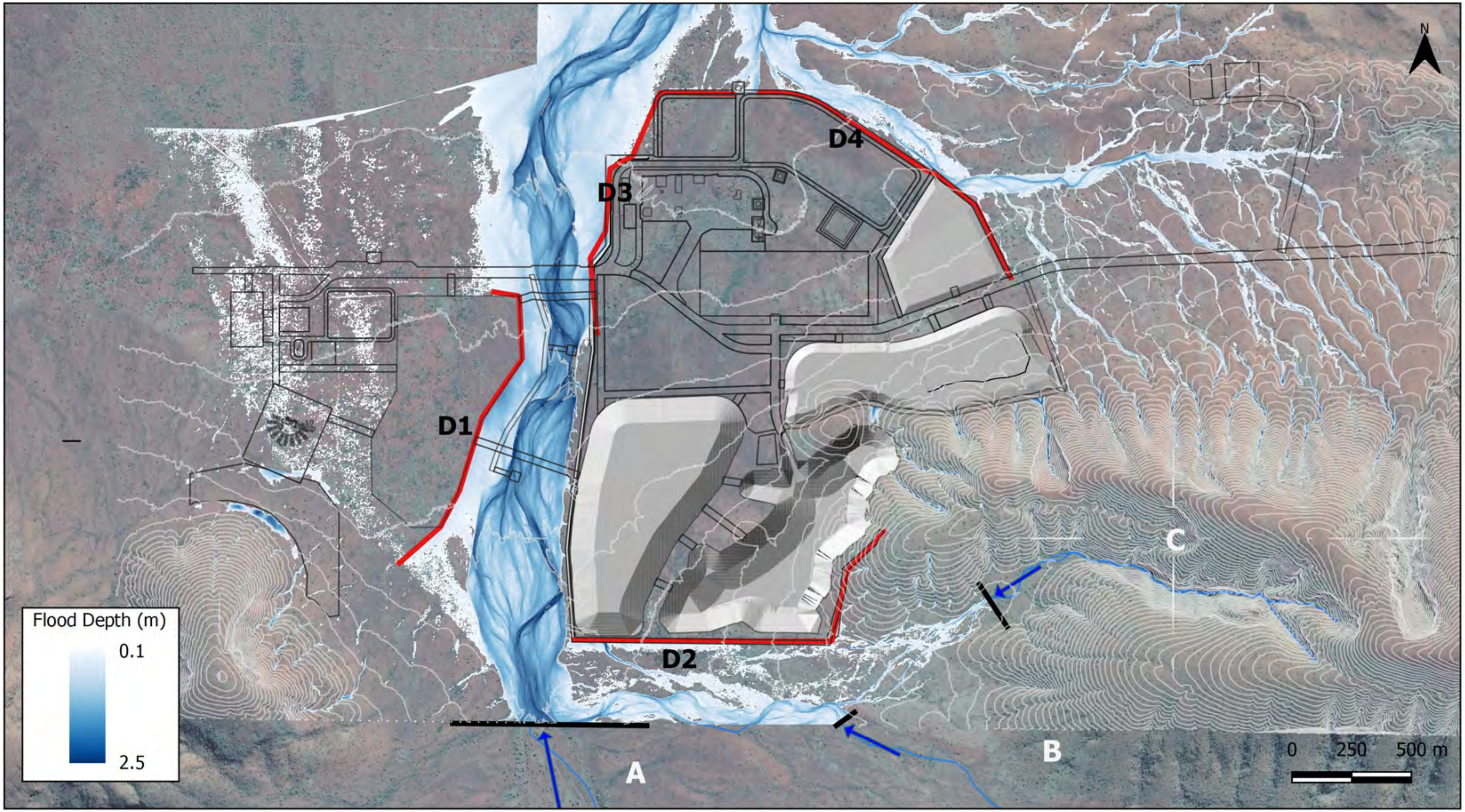
Mine Infrastructure layout provided by MRL (July 2021)

F:\326\4.GIS\Workspaces\D Task\Rev C\Figure 4.2_10pct AEP Predevelopment.qgz

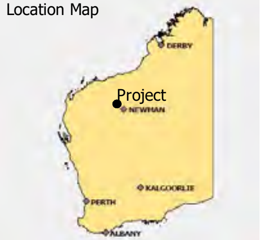
AQ2

Figure 4.2:

Mine Creek Predevelopment 10% AEP Flood Map Revised Infrastructure



Location Map



F:\326\4.GIS\Workspaces\D Task\Rev C\008a Figure 4.5 PostDev.qgz

Infrastructure Layout	Diversions included in 2-D Model
Inflow from subcatchments	Boundary Conditions (Inflow)
Mine Creek Subcatchments	

AUTHOR: WM

DRAWN: WM

DATE: 01/11/2021

REPORT No: 004c

JOB No: 326

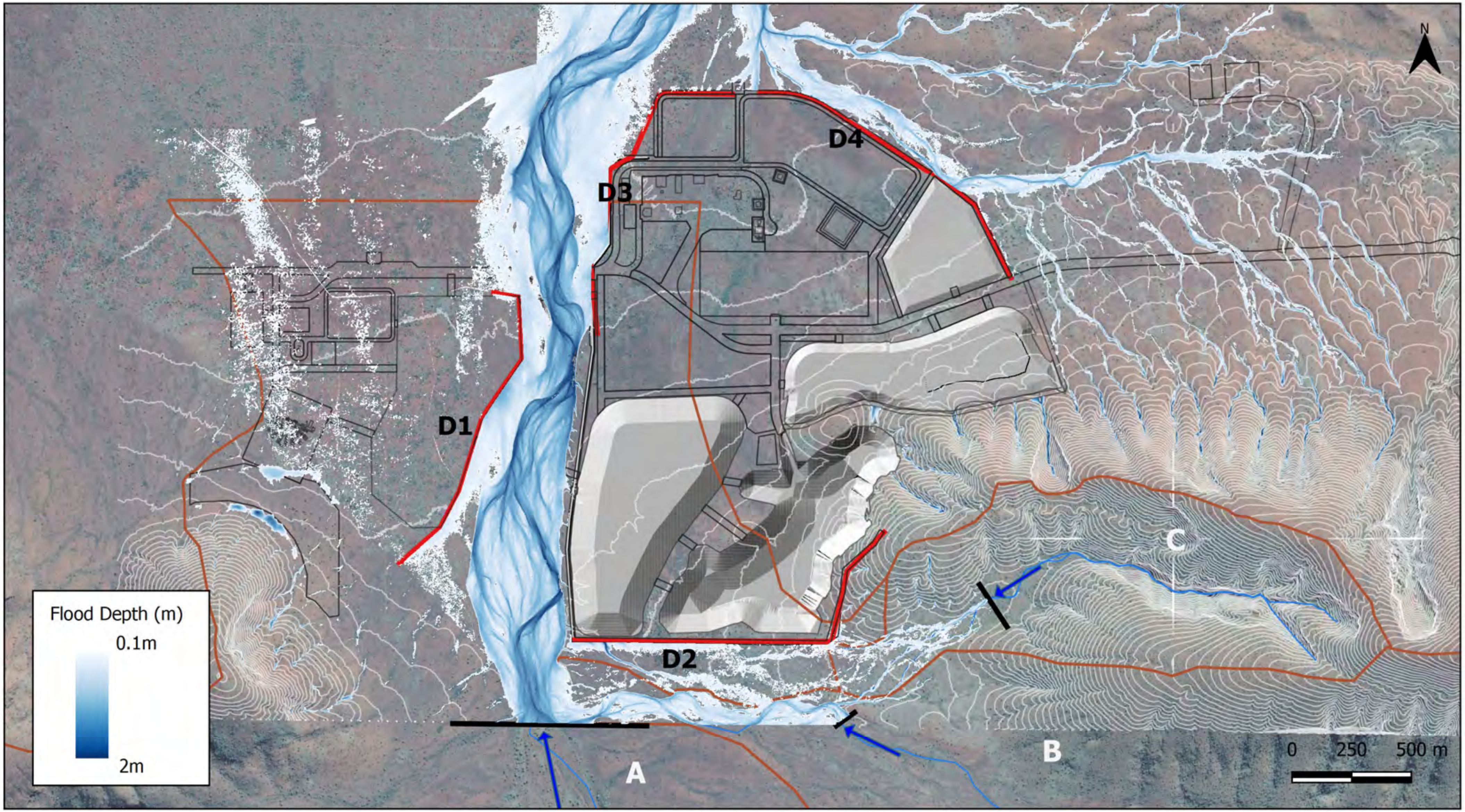
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google (2020)
Mine Infrastructure layout provided by MRL (July 2021)

AQ2

Figure 4.3:

Mine Creek Post-development 1% AEP Flood Map Revised Infrastructure



Location Map

Project

Infrastructure Layout

Inflow from subcatchments

Mine Creek Subcatchments

Diversions included in 2-D Model

Boundary Conditions (Inflow)

AQ2

AUTHOR: WM

DRAWN: WM

DATE: 12/10/2021

REPORT No: 004c

JOB No: 326

Coordinates: MGA Zone 50

Notes and Data Sources:

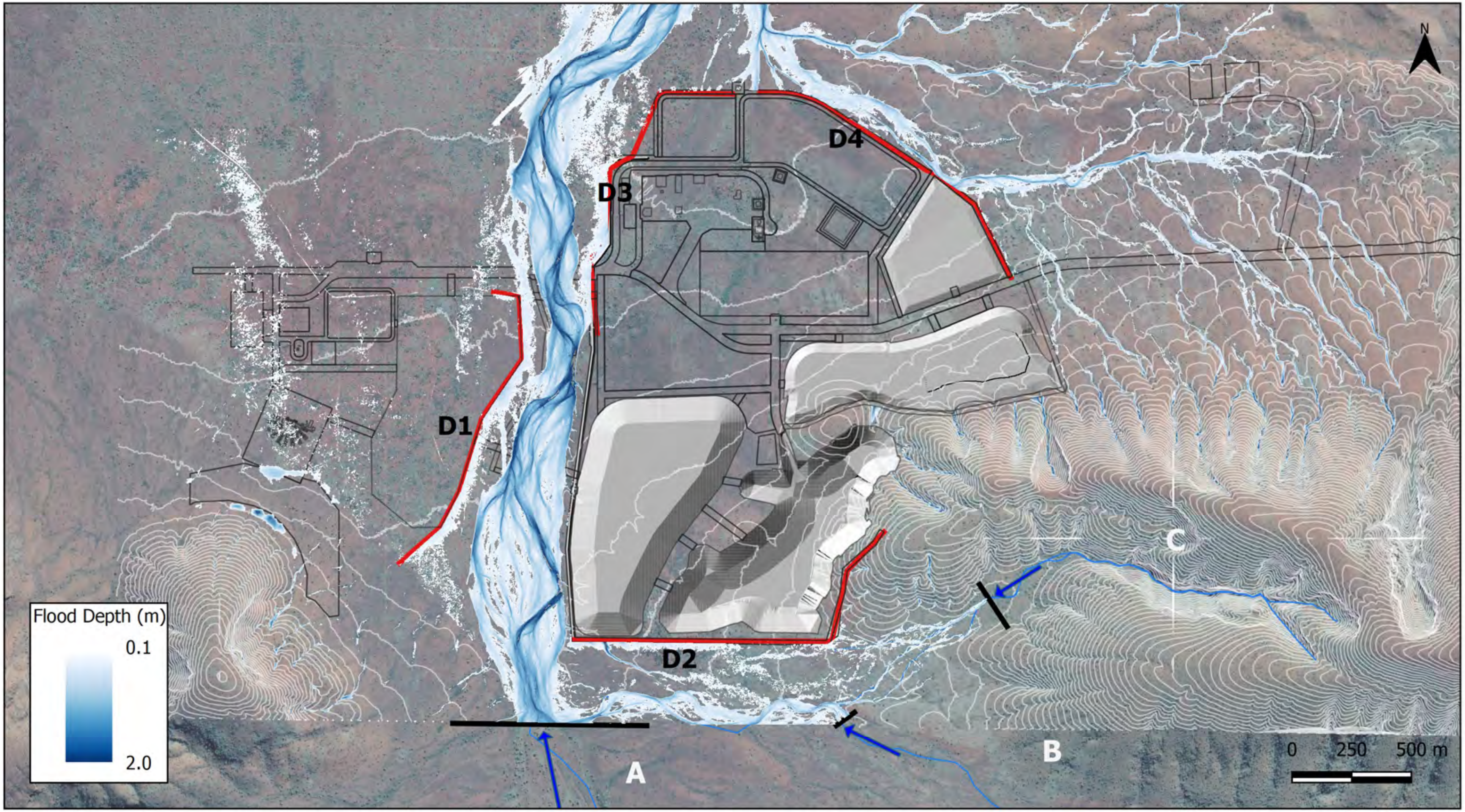
Aerial Imagery sourced from Google (2020)

Mine Infrastructure layout provided by MRL (July 2021)

Figure 4.4:

Mine Creek Post-development 2% AEP Flood Map Revised Infrastructure

F:\326\4.GIS\Workspaces\D Task\Rev C\004c Figure 4.4 PostDev_2% AEP.qgz



Location Map

Project

F:\326\4.GIS\Workspaces\D Task\Rev C\004c Figure 4.4 PostDev_5% AEP.qgz

Infrastructure Layout
Inflow from subcatchments
Mine Creek Subcatchments
Diversions included in 2-D Model
Boundary Conditions (Inflow)

AUTHOR: WM
DRAWN: WM
DATE: 01/11/2021

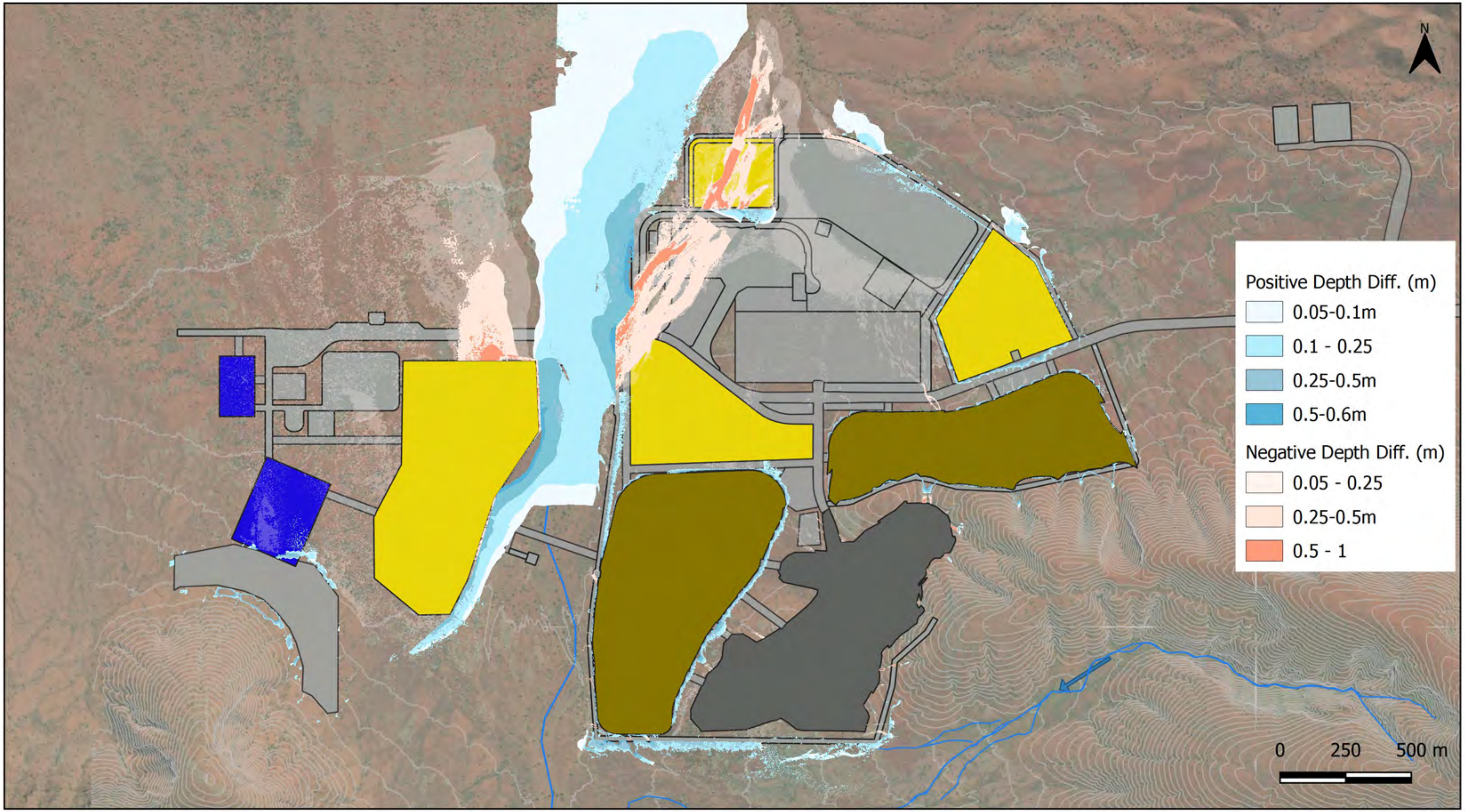
REPORT No: 004c
JOB No: 326
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google (2020)
Mine Infrastructure layout provided by MRL (July 2021)

AQ2

Figure 4.5:

Mine Creek Post-development 5% AEP Flood Map Revised Infrastructure



F:\326\4.GIS\Workspaces\SW\Rev B\Figure 4.4.qgz

Mine Creek Flow Direction
Mine Creek and Eastern Tributary
Pit Footprint
Other Infrastructure
Stockpile
WRD
Accommodation

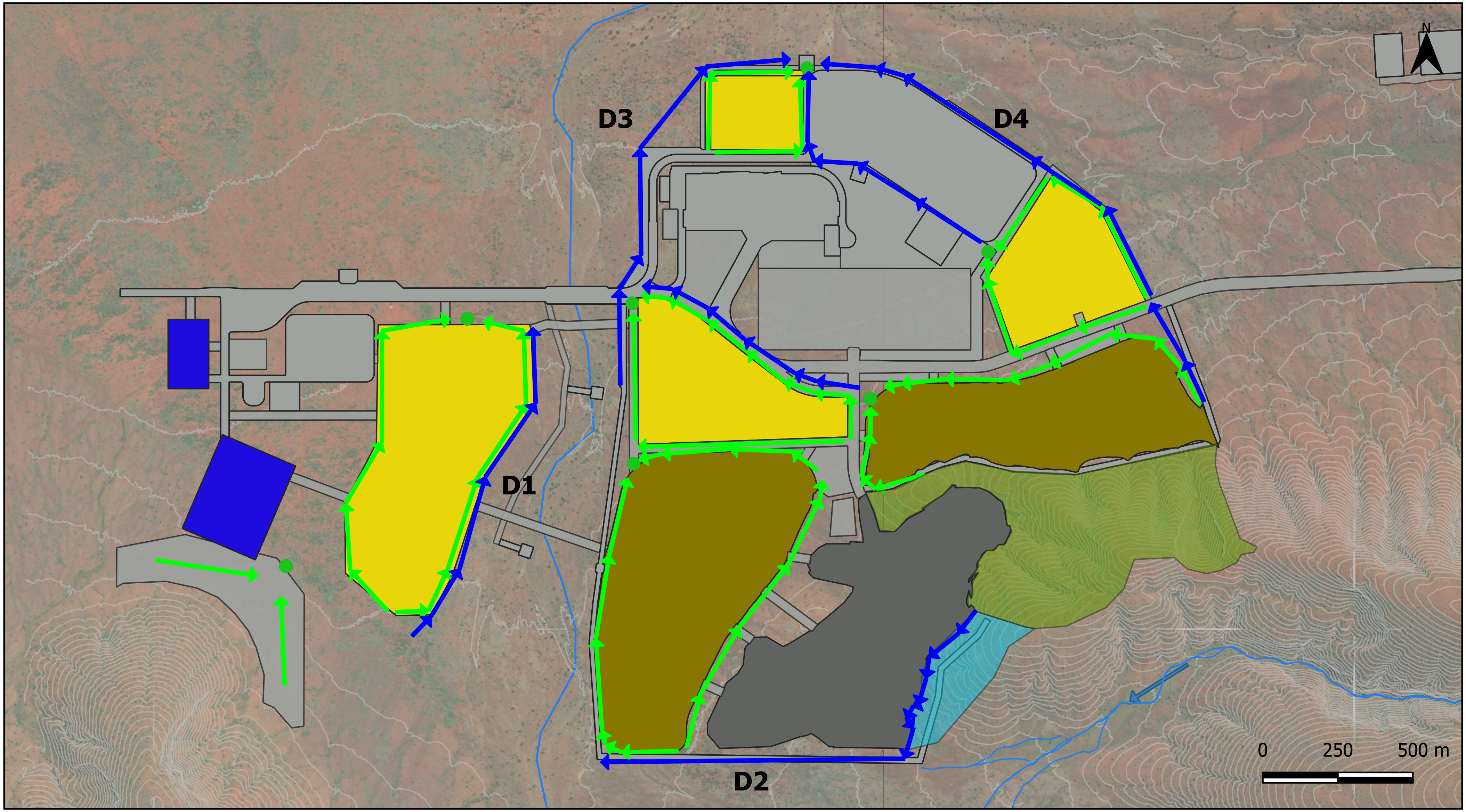
AUTHOR: WM
DRAWN: WM
DATE: 11/03/2021

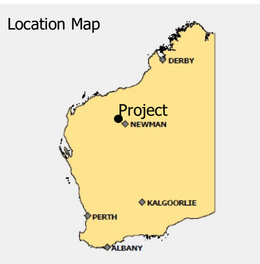
REPORT No: 004c
JOB No: 326
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google (2020)
Mine Infrastructure layout and Topography provided by MRL (July 2021)

AQ2

Figure 4.6:
Difference Map
Pre and Post-Development
1% AEP





F:\326\4.GIS\Workspaces\D Task\Rev C\Figure 6.1.qgz

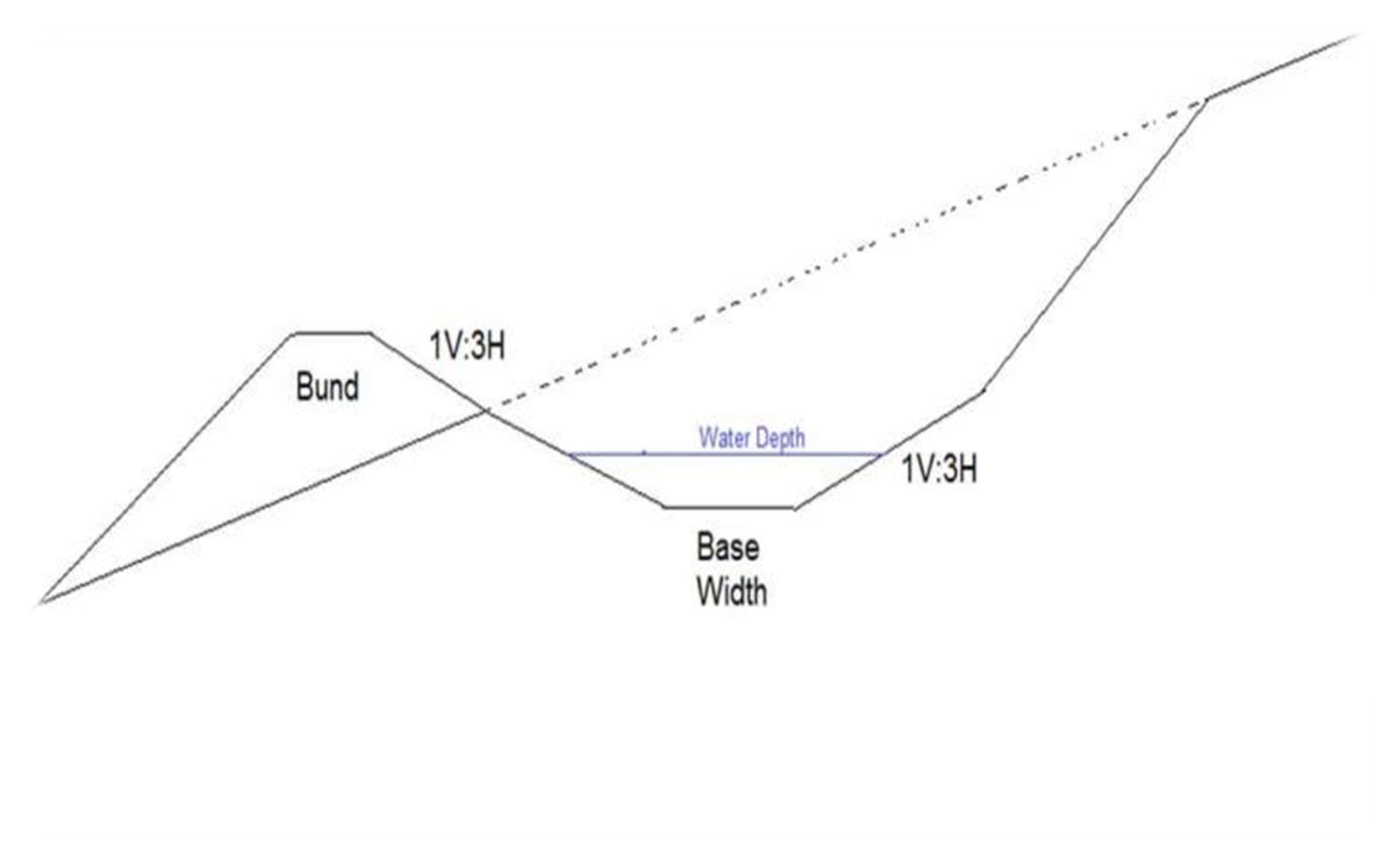
- Infrastructure Layout
- Topographic 10m Contours
- Mine Creek and Eastern Tributary
- Mine Creek Flow Direction
- Dirty Water Containment
- Clean Water Diversions
- Sediment Basins
- Diverted Catchment
- Captured Catchment
- Pit Footprint
- Stockpile
- Waste Dump
- Other Infrastructure
- Accommodation

AUTHOR: WM
DRAWN: WM
DATE: 02/03/2022

REPORT No: 004d
JOB No: 326
Coordinates: MGA Zone 50

Notes and Data Sources:
Aerial Imagery sourced from Google (2020)
Mine Infrastructure layout and Topography provided by MRL (July 2021)

Figure 6.1:
Surface Water Management Plan



Conceptual design of diversion drains and waste dump drainage **FIGURE 6.2**

APPENDIX A

Table A-1: Haul Road Catchment Parameters

Catchment ID	Area (km²)	Mainstream Length (km)	Equal Area Slope (m/km)
HR1	0.44	0.677	33.7
HR2	0.297	0.74	50.8
HR3	0.557	0.97	56.8
HR4	0.108	0.23	38.1
HR5	0.042	0.12	66.9
HR6	0.103	0.11	51
HR7	1.026	1.57	77.3
HR8	0.849	1.1	44.6
HR9	1.163	2.2	55.7
HR10	0.554	1.2	21.3
HR11	0.289	0.48	28.5
HR12	1.797	2.9	51.2
HR13	0.113	0.23	7.7
HR14	0.835	1.904	33.72
HR15	0.141	0.334	29.67
HR16	0.148	0.168	23.9
HR17	1.5	3.16	32.6
HR18	31.99	8.4	12.44
HR19	0.797	1.12	22.7
HR20	0.517	1.156	27.5
HR21	0.208	0.35	35.4
HR22	0.577	1.11	33.8
HR23	1.1	1.9	34.3
HR24	0.13	0.266	143
HR25	0.106	0.168	40
HR26	0.905	1.298	66.67
HR27	0.705	1.38	68.9
HR28	0.718	1.3	64.11
HR29	0.149	0.373	22.79
HR30	0.21	0.358	75
HR31	5.78	4.899	43.44
HR32	0.31	0.676	54.3
HR33	0.11	0.312	79.7
HR34	0.1	0.2	120.4

Table A-2: Haul Road Catchment Peak Flows

Catchment ID	Flavell RFFP 10% AEP Peak Flow (m3/s)	Flavell RFFP 1% AEP Peak Flow (m3/s)
HR1	3	13
HR2	2	9
HR3	4	16
HR4	2	6
HR5	1	4
HR6	3	11
HR7	7	27
HR8	6	23
HR9	5	23
HR10	2	9
HR11	3	10
HR12	7	32
HR13	1	3
HR14	3	15
HR15	1	5
HR16	2	9
HR17	4	23
HR18	54	220
HR19	4	16
HR20	3	10
HR21	2	9
HR22	3	13
HR23	5	18
HR24	3	11
HR25	2	7
HR26	7	25
HR27	5	18
HR28	5	19
HR29	1	5
HR30	3	12
HR31	18	75
HR32	3	11
HR33	2	6
HR34	3	10