APPENDIX C SURFACE HYDROLOGY AND FLOOD INUNDATION REPORT

Core Lithium Ltd,
Finniss Lithium Project

BP33 Underground Mining Proposal: surface hydrology and flood inundation modelling

Final report

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March 2020

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Executive Summary

The report assesses the potential changes in stream flow and flood inundation associated with development of the proposed BP33 underground mine on ML(A) 32346. The proposed mine site is located on the Cox Peninsula, approximately 2.7 km southwest of the Cox Peninsula Road in the Charlotte River/Bynoe Harbour catchment. Catchments were delineated that affect the lease. These are referred to as Catchments A and B. Catchment A is a large right bank sub-catchment of the Charlotte River. The main channel in sub-catchment A is 6.5km in length, measured from the Observation Hill Dam (OHD) spillway to the confluence with the Charlotte River. The main channel in Catchment B is 4.5km to the confluence with the Charlotte River. The channels become incised before entering their mangrove lined tidal channels near their confluence with the Charlotte River. All streams on ML(A) 32346 are ephemeral.

Because of the steep terrain in the Bynoe Harbour catchments, it is unlikely storm surge will have an impact on the mine infrastructure. The outlet of mine affected catchments in Catchment A is at ≈5.4mAHD, and Catchment B is at ≈2.9mAHD. The HAT at Burge Point is 3.6mAHD. The lowest point in the proposed mine infrastructure is 23mAHD at the southwest corner of the boxcut bund.

Hydrologic modelling and flood inundation modelling showed a slight decrease in discharges for the mining scenario. The slight decrease is probably due to the modelling assumption that no rainfall on the mine infrastructure leaves the mine site. This assumption is based on the conceptual design which includes best practice procedures, such as sediment retention basins, to ensure that all water is retained on-site. Flood risk analysis showed that there is no increased danger to humans, livestock or native wildlife due to the mine site. Flood inundation modelling indicated that there is little difference to the natural flow regime caused by the mine site. Catchment discharges for the 1%AEP event are 237 m^3s^{-1} for the pre-mining and 236.3 m^3s^{-1} for the mining scenario and Engineers Australia Regional Flood Frequency Estimated discharge is 298 m^3s^{-1}.

Table of contents

1 Contents

List of Figures

List of Tables

1 Introduction

The Core Lithium Ltd Lithium resource is located at 694081m East, 8594222m North, GDA94/MGA52, near Berry Springs, Northern Territory. This report focuses on ML(A)32346 (*Figure 1*) but the wider catchment includes the Observation Hill Dam (OHD) catchment (*Figure 2*).

EcOz Environmental Consultants commissioned Surface Water & Erosion Solutions to undertake a hydrological and flood inundation assessment of the proposed mine site, both before mining and with proposed mine infrastructure in place. The assessment comprises:

1. Catchment hydrologic modelling; and
2. Inundation risk modelling of a 1%Annual Exceedance Probability (AEP) design rainfall event.

2 Site Description

Desktop analysis of aerial imagery provided an understanding of the stream catchments in the area and the general channel network. A field inspection was not conducted for this study but was previously conducted and reported (EnviroConsult Australia Pty Ltd, 2018a).

2.1 Stream Catchments

There are 2 sub-catchments of the Charlotte R. impacted by ML(A)32346 (*Figure 2*). These have been named catchment A and catchment B. These catchments have been further divided into sub-catchments for the pre-mine hydrologic model. Most of the natural drainage on the lease drains south towards a right-bank tributary of the Charlotte R. Details of the catchments are given in *Table 1*. All channels are ephemeral. The large catchment A upstream was included because high discharges in that stream may cause backflow into the catchment containing infrastructure.

Catchment thalwegs (*Figure 3*) have a gentle slope of ≈0.5% to their confluence with Charlotte River through tidal, mangrove-lined channels.

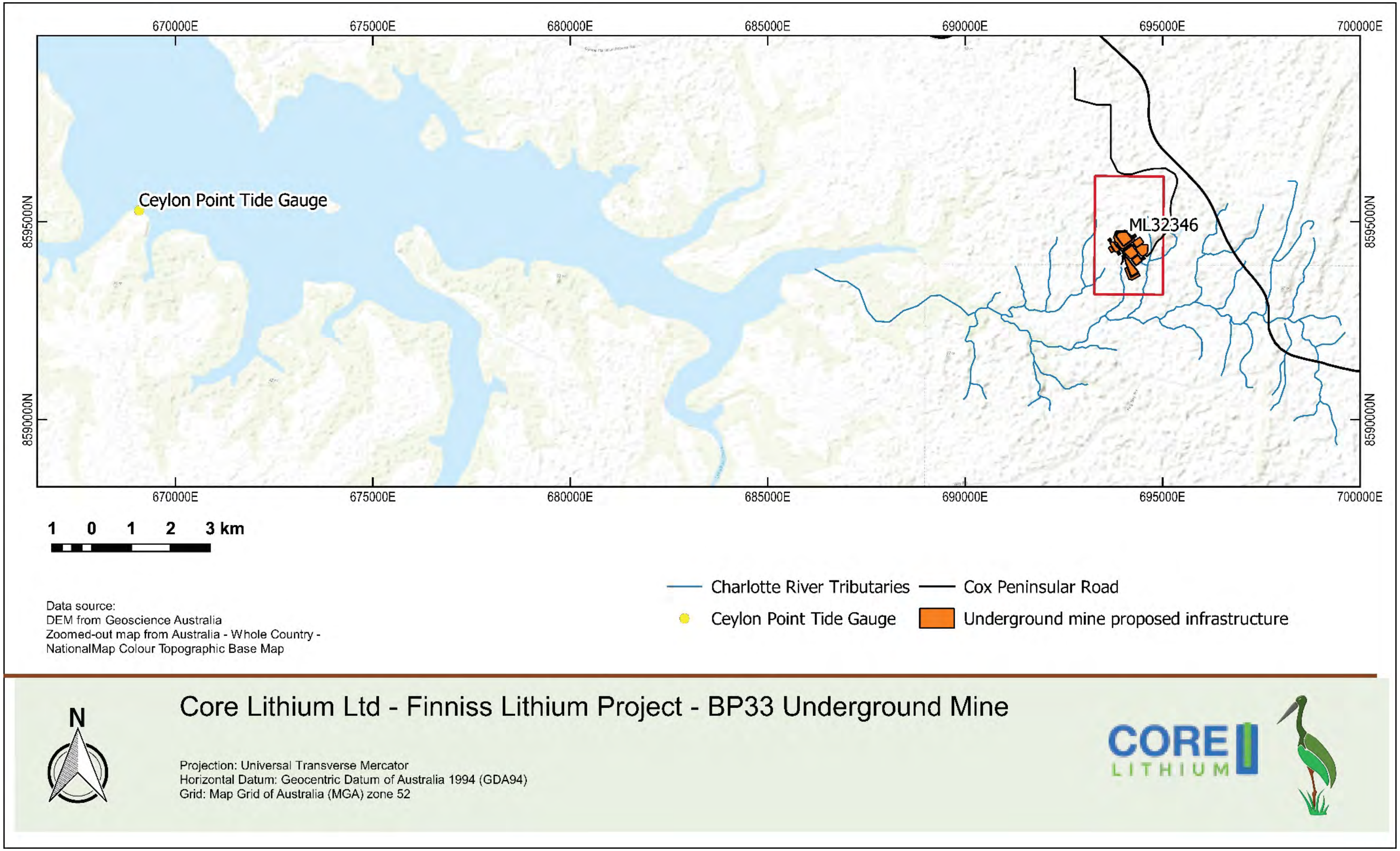

Figure 1. Location of ML(A)32346 and Ceylon Point tide gauge.

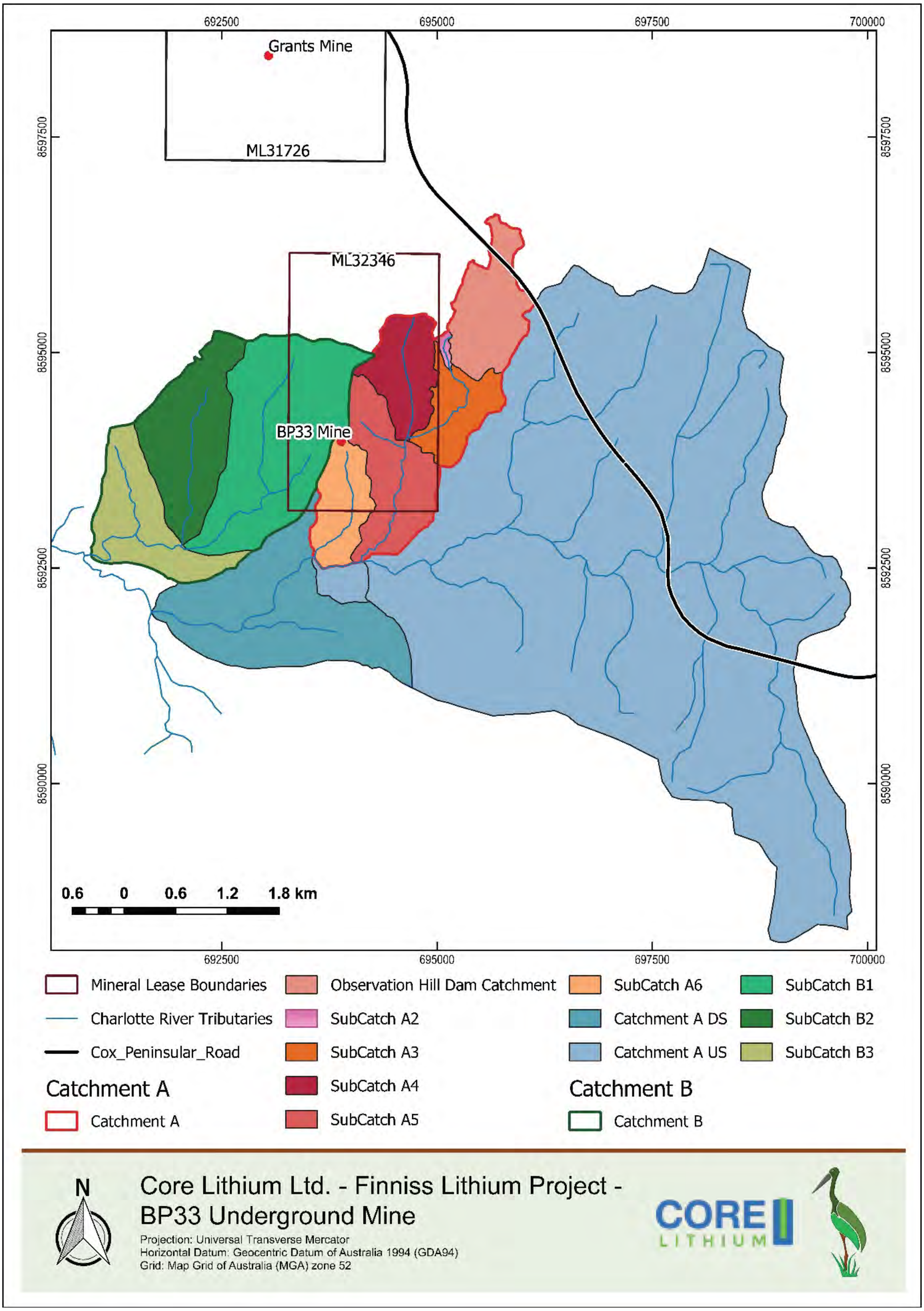

Figure 2. Layout of the pre-mine catchments delineated for this study.

Table 1 Catchment areas and locations pre-mine (based on MGA Zone 52).

Catchment	Area (ha)	Catchment Outlet	
		Easting (m)	Northing (m)
A2	4.7	695162	8594791
A3	74.7	694634	8593975
A4	69.4	694683	8593970
A5	111.7	694084	8595229
A6	78.6	693579	8592637
A upstream	2382.6	693573	8592615
A downstream	291.5	691686	8591979
B1	303.0	692050	8592746
B2	169.8	692050	8592746
B3	134.0	690989	8592637

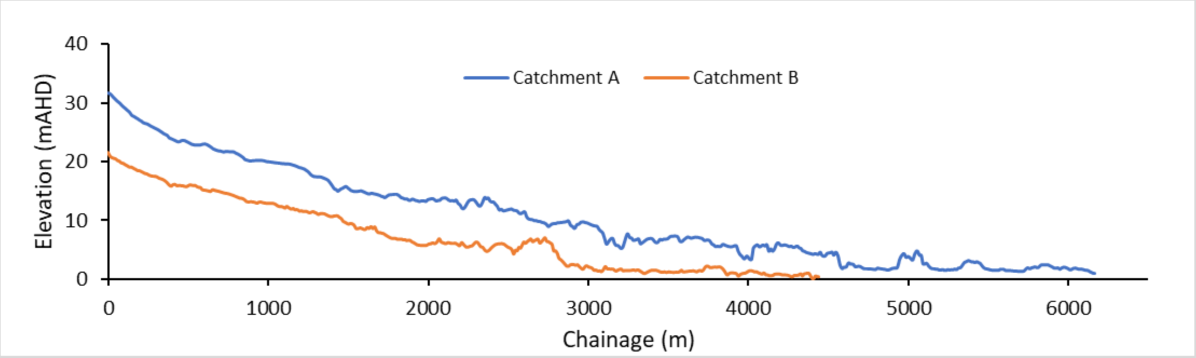

Figure 3. Long-section of the thalwegs of the catchments intersected by ML 32346.

3 Existing Site Hydrology

Information available for this project is listed below:

- GIS-based topographic information, which provided information on waterways and waterbodies, the location of proposed infrastructure and ML(A)32346,
- A 10m digital elevation model was purchased from the Northern Territory Government (NTG) and this allowed delineation of catchments and streamlines,
- A 0.5m pre-mining and infrastructure DEM provided by Core,
- ESRI Satellite (ArcGIS/World Imagery) aerial photography accessed through Quantum GIS,
- Silo rainfall data, and
- Online storm tide inundations maps for Darwin Harbour and Bynoe Harbour.

3.1 Regional Rainfall and Evaporation

SILO data from 1971 to 2018 were used for surface water modelling to maintain consistency with previous surface water modelling (EnviroConsult Australia Pty Ltd, 2018a). Only 24-hour rainfall from SILO were available. SILO products provide national coverage, mostly based on BOM data, with interpolated infills for missing data and the rainfall data. At the location coordinates, 694081m East, 8594222m North, GDA94/MGA52, used in this study, data are interpolated.

The average monthly rainfalls and evaporation based on SILO data at the Core site are shown in *Figure 4*.

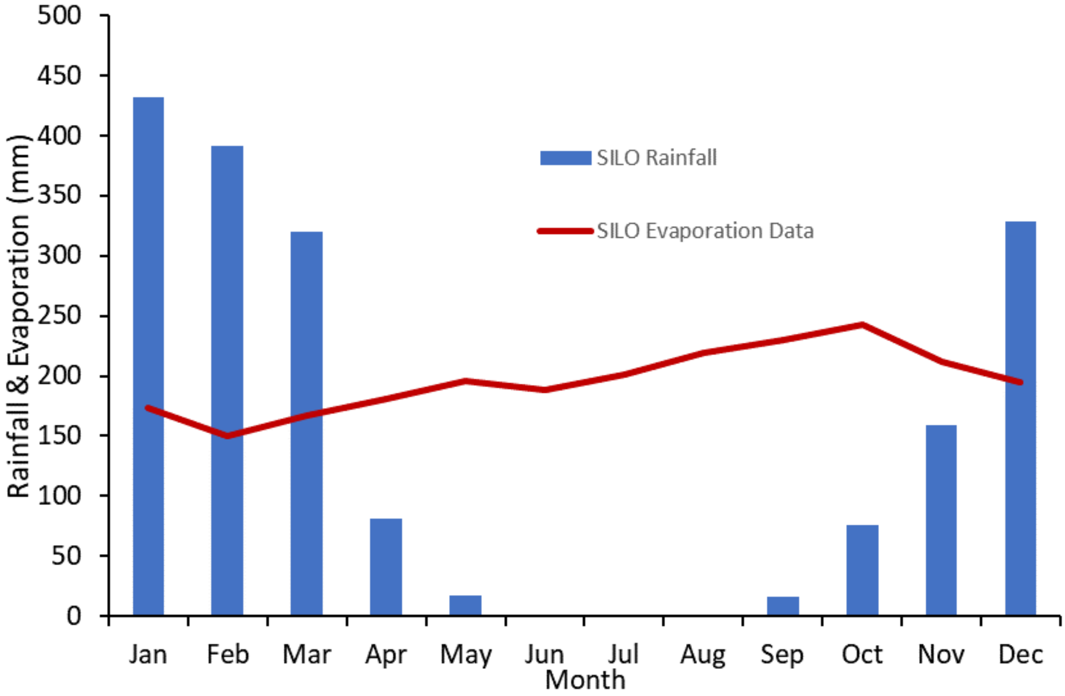

Figure 4 Average monthly rainfall and evaporation for SILO data from 1971 to 2018 for the Core site.

3.2 Design Rainfall Events

Inundation risk modelling for a 1%AEP[1] rainfall event will be used for the flood inundation modelling. The 2019 Intensity–Frequency–Duration (IFD) design rainfalls for the site are provided by the BOM for use in conjunction with the 2019 edition of Australian Rainfall and Runoff (ARR2019, http://arr.ga.gov.au/arr-guidelines) to derive the probable rainfall runoff characteristics of such events required for the inundation risk modelling. The derivation of the design event was completed using the hydrologic model, RORB.

Figure 5 shows the more frequent event IFD curves used for derivation of the design event.

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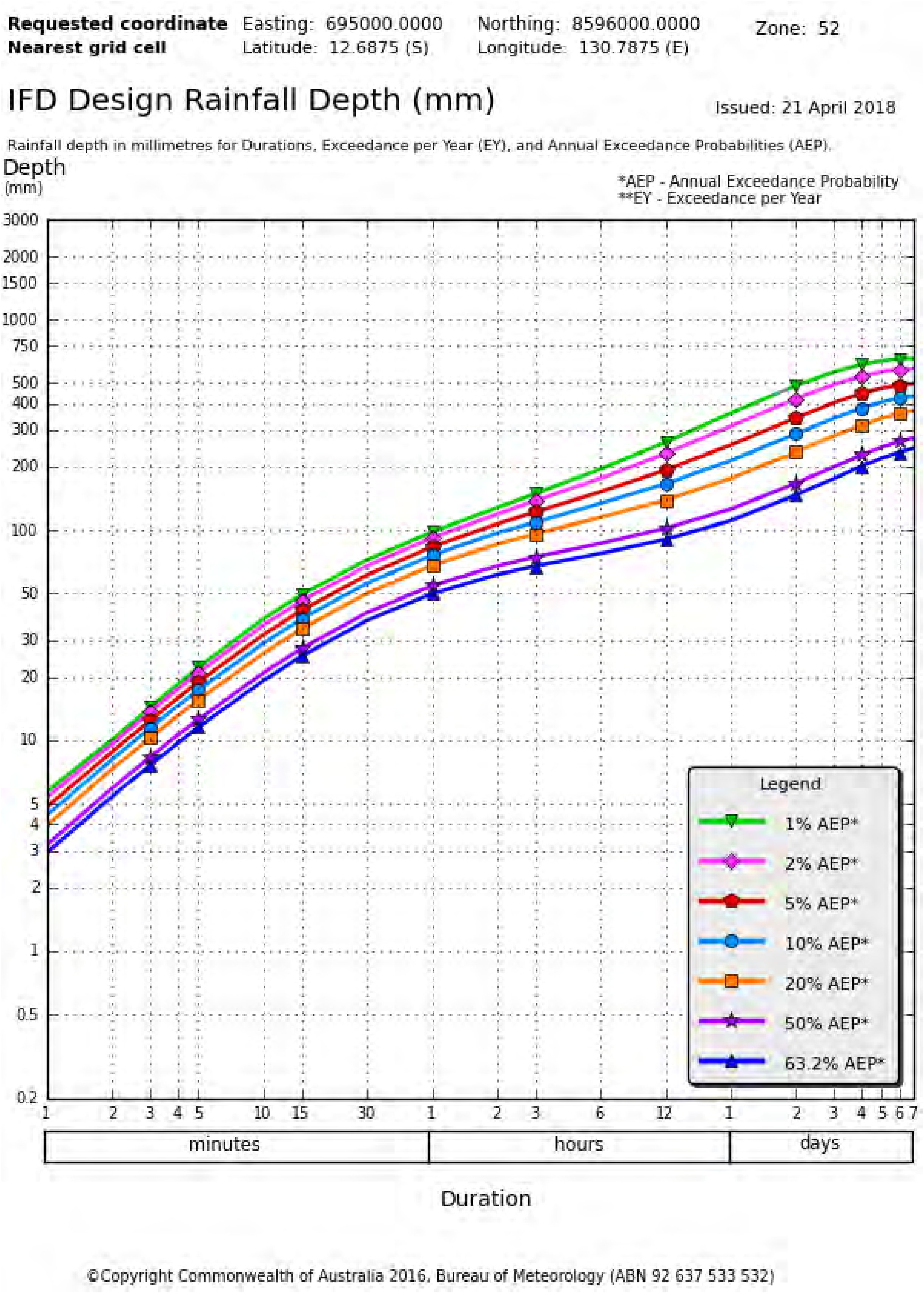
[1] This is the current terminology recommend by Engineers Australia for the return interval of rainfall events. 1%AEP is 1 in 100 or Q100 and 0.1%AEP is 1 in 1000 or Q1000.



Requested coordinate Easting: 695000.0000 Northing: 8596000.0000 Zone: 52
Nearest grid cell Latitude: 12.6875 (S) Longitude: 130.7875 (E)

IFD Design Rainfall Depth (mm)

Issued: 21 April 2018

Rainfall depth in millimetres for Durations, Exceedance per Year (EY), and Annual Exceedance Probabilities (AEP).

*AEP - Annual Exceedance Probability
**EY - Exceedance per Year

Figure 5. BOM intensity, frequency, duration curves for design rainfall up to a 1%AEP event at ML 32346.

3.3 The Observation Hill Dam

The Observation Hill Dam (OHD) is in the upper reaches of Catchment A draining towards Bynoe Harbour (*Figure 2*). This dam has been previously described (EnviroConsult Australia Pty Ltd, 2018c).

3.4 Storm Surge

Storm surge data are available from the NTG for Darwin Harbour and parts of Bynoe Harbour. The Bynoe Harbour data were reported by CO_2 Australia and Seafarms, in their environmental assessment report to the NTEPA for commercial development (https://ntepa.nt.gov.au/__data/assets/pdf_file/0020/382403/draft_eis_seadragon_core_breeding_centre_appendix_17_water_tech_reports.pdf). Storm tide heights for the primary surge 1%AEP and secondary surge 0.1%AEP events are shown in *Table 2*. Storm surge extents for the 2010 and 2100 primary storm surge are shown in *Figure 6.*

Table 2. Storm surge levels in Bynoe Harbour.

Year	Bynoe Harbour	
	Primary storm tide (mAHD)	Secondary storm tide (mAHD)
2010	3.7	4.7
2050	4.1	5.6
2100	4.6	6.2

Figure 6 shows that there is little penetration of the storm surge into mine affected catchments apart from a small amount in the lower tidal reaches. The level of the 2100 primary storm tide is 4.6mAHD. The outlet of mine affected catchments in Catchment A is at ≈5.4mAHD, and Catchment B is at ≈2.9mAHD. The highest astronomical tide (HAT) at Burge Point is 3.6mAHD. The lowest point in the proposed mine infrastructure in 23mAHD at the southwest corner of the boxcut bund and is ≈2km upstream from the storm tide level in Charlotte River. So, it is unlikely that storm surge will affect the proposed mine infrastructure and ML(A)32346.

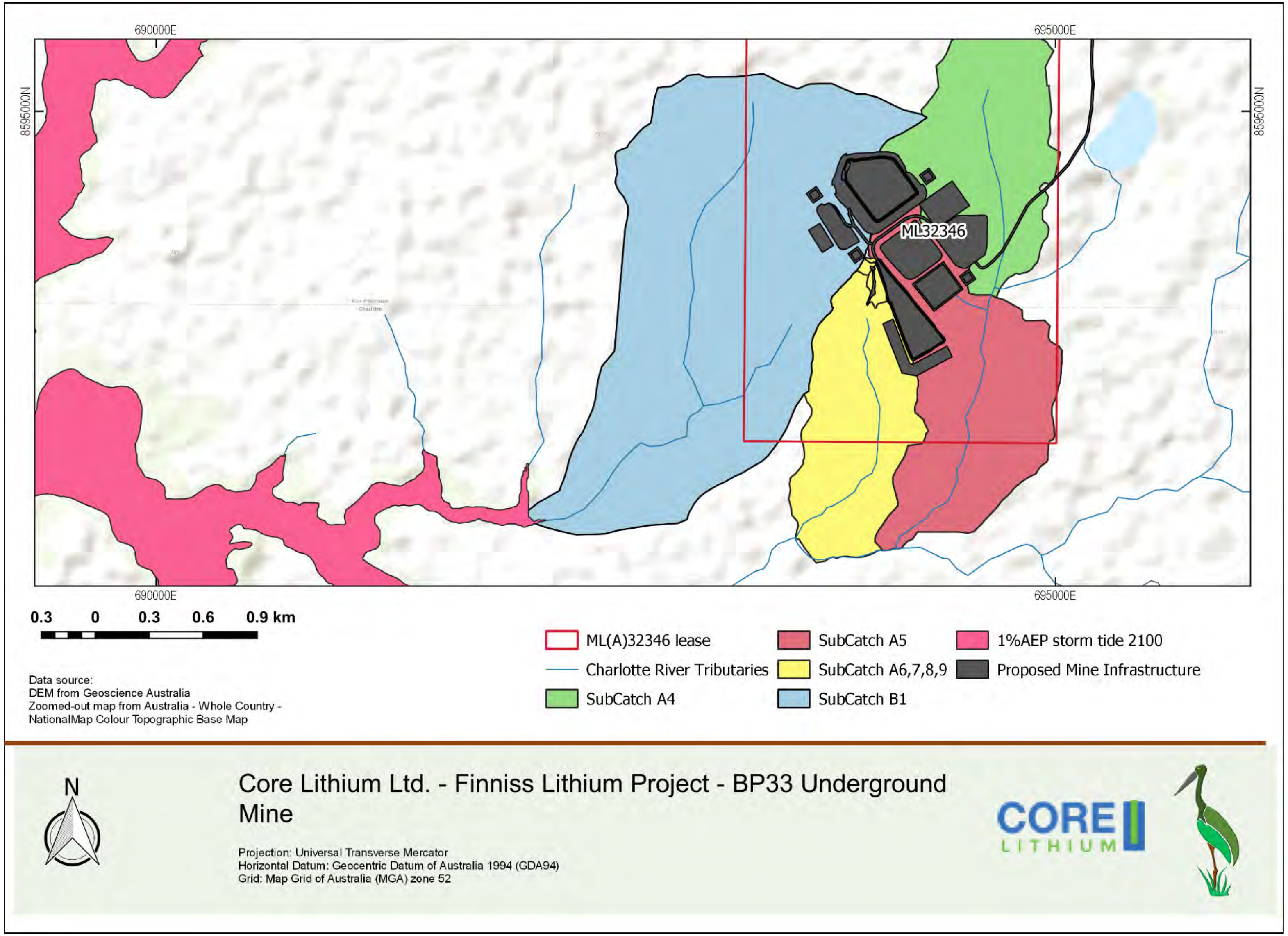


Figure 6. Estimated 2100 1%AEP surge inundation extent near the outlets of Catchments A and B.

4 Catchment hydrology

4.1 Introduction

This section assesses the effects of the mine site infrastructure on catchment hydrology. In this study, a HEC-HMS model was used to determine changes to environmental flow and discharge caused by the proposed mine infrastructure. The HEC-HMS model was previously calibrated and validated (EnviroConsult Australia Pty Ltd, 2018a; EnviroConsult Australia Pty Ltd, 2018b) and input parameters values determined.

4.1.1 Methodology

The methods used where:

1. Delineation of the sub-catchments for the mine affected catchments using the Quantum Geographic Information System (QGIS),
2. Applying the calibrated hydrology model, HEC-HMS (EnviroConsult Australia Pty Ltd, 2018a) to the mining lease and environs to determine rainfall runoff volumes for the ML(A) for the pre-mining topographic condition for a low, average and high rainfall year,
3. For the same rainfall scenarios, applying HEC-HMS to the proposed mine construction topography i.e. including the boxcut, waste rock dump, bund/haul road and run-of-mine pad to assess changes in catchment hydrology due to the mine infrastructure.

4.1.2 Simulation scenarios

Using the HEC-HMS model, 3 annual rainfall scenarios were simulated:

- Low rainfall year (1st January to 31st December 1979)
- High rainfall year (1st January to 31st December 2011)
- Average rainfall year (1st January to 31st December 1991)

SILO 24-hour rainfall data was used. Each simulation was run including antecedent rainfall from 1st July to 31st December the previous year to include the entire wet season and thereby account for saturation of the catchment at the time the annual rainfall starts (refer to EnviroConsult Australia Pty Ltd, 2018 for details). For example, for 1979 the rainfall input was from 1 July 1978 to 31 December 1978 and then 1979 was run. The total annual rainfall for each scenario is shown in *Table 3*.

Table 3. Selected low, average and high rainfall years.

Rainfall scenario	Total Rainfall (mm)	Annual Exceedance Probability	Probability of an equal or lower annual rainfall depth occurs in a 5-year period
Low rainfall year (1979)	919	0.99	0.05
Average rainfall year (1991)	1652	0.50	0.97
High rainfall year (2011)	2766	0.01	1.00

The monthly evaporation as listed in Section 3.1 was applied to each catchment and a daily seepage rate of 2.3 mm/day (EnviroConsult Australia Pty Ltd, 2018b) was applied to the Boxcut.

4.1.3 Catchment Delineation

The calibrated HEC-HMS model was used to simulate surface water discharge for all catchments intersected by ML(A) 32346 and relevant upstream catchments for the low, average and high rainfall years.

The pre-mining catchments are shown in *Figure 7*. Red dots (*Figure 7*) indicate locations where the total discharge was determined using HEC-HMS (see Section 4.2). The catchments were delineated using QGIS and a 10m digital elevation model (DEM) provided by the NTG.

The mining infrastructure catchment delineation and changed flow paths are shown in *Figure 8.* The only change was made to sub-catchments directly bordering mine infrastructure, all other catchments remain as displayed in *Figure 7*. The mining DEM, the DEM for the mine infrastructure: boxcut, waste rock dump, topsoil store, bund, contractor area and the run-of-mine (RoM) pad, was supplied by Core. Changes to catchment areas and outlet locations are shown in *Table 4*.

The total area covered by infrastructure is ≈31.4ha only about 3.3% of study catchments (946ha). The conceptual design includes best practice procedures for all infrastructure to be water-shedding structures and retention of all water on site. These methods include diversion banks, water channels and sediment retention basins. In reality, not all rainfall on the infrastructure will be retained and especially during the wet season some run-off will occur. However, the actual runoff volume directly depends on the design (i.e. storage volume) of the ponds and dams. As the design is only conceptual at this point, all hydrological model simulations were run assuming that all rainfall on the infrastructure is retained and there is no direct runoff from the infrastructure to undisturbed parts of the catchments. For simulations it was assumed that the boxcut was empty at the start of simulations and that all direct rainfall to the boxcut was lost from the system. But the model treated the water as being stored in the boxcut.

The HEC-HMS models are shown in Appendix A.

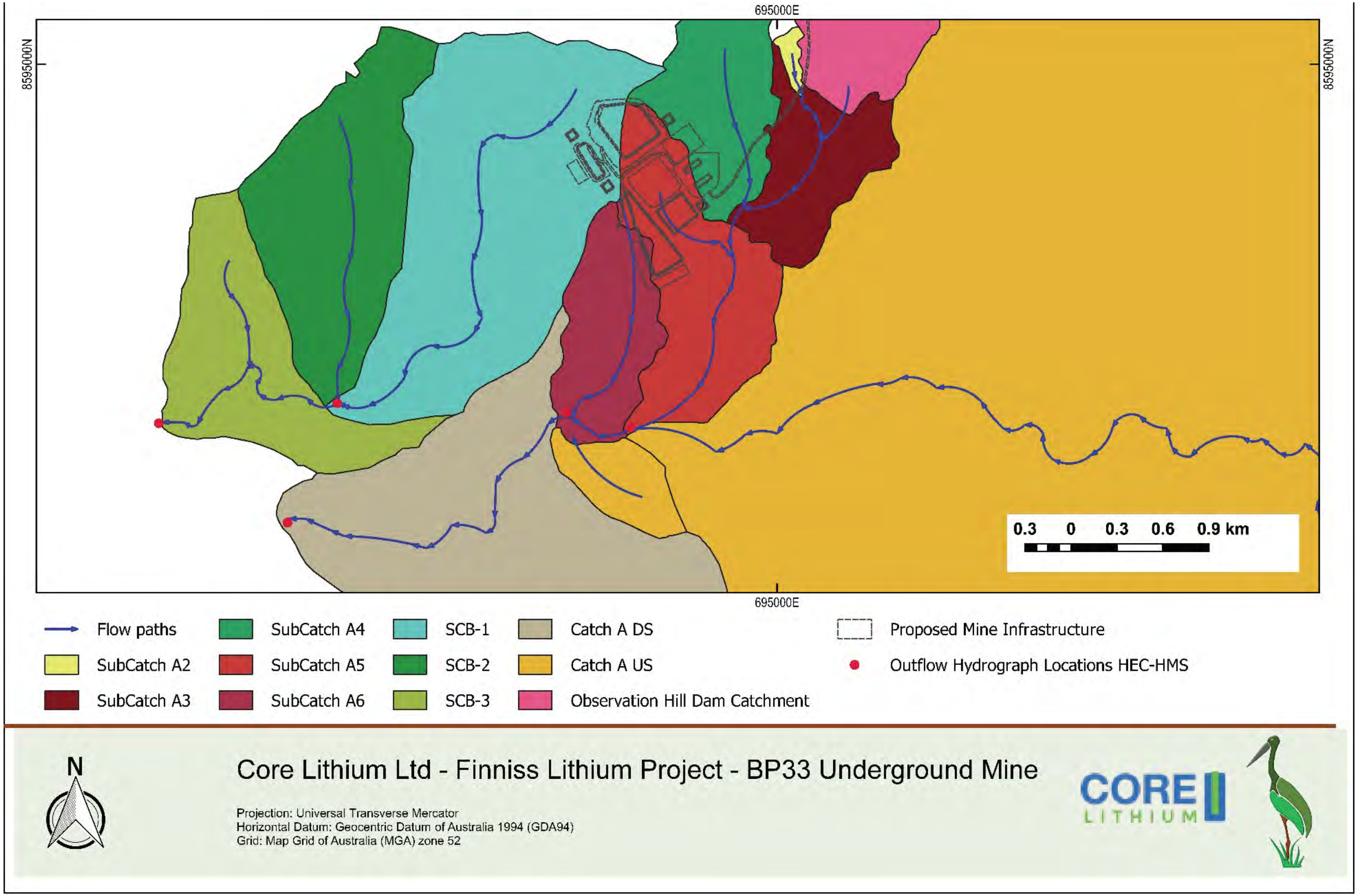


Figure 7. Pre-Mine flow paths and sub-catchments

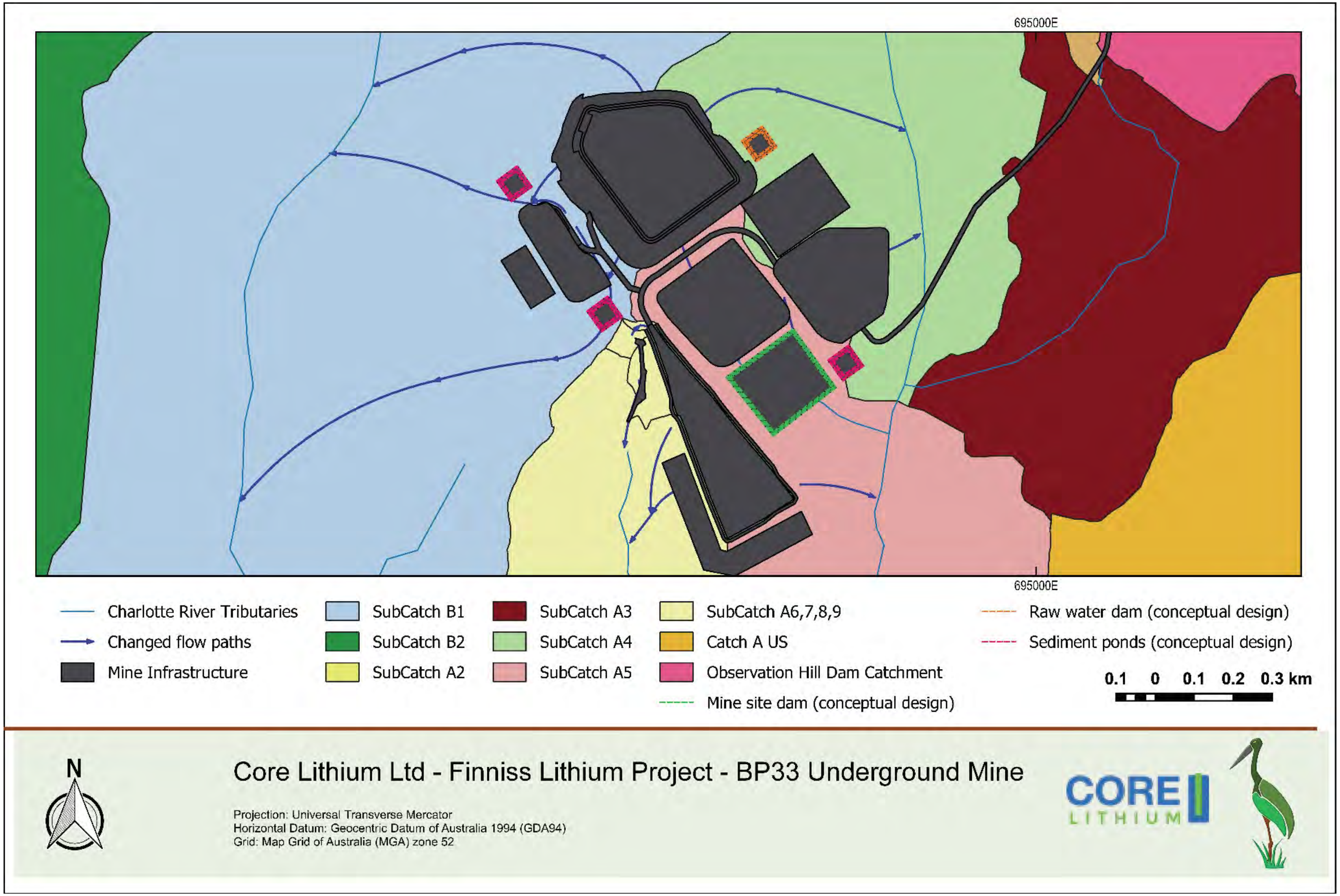


Figure 8. Catchments affected by mine infrastructure, changed flow paths and location of mine infrastructure

Table 4 Catchment areas and locations (based on MGA Zone 52).

Catchment	Area (ha)		Catchment Outlet Premining		Catchment Outlet with mining	
	Pre-mining	With infrastructure	Easting (m)	Northing (m)	Easting (m)	Northing (m)
A2	4.7	4.7	695162	8594791	695162	8594791
A3	74.7	74.7	694634	8593975	694634	8593975
A4	69.4	95.2	694683	8593970	694683	8593970
A5	111.7	111.7	694084	8595229	694084	8595229
A6	78.6	0.15	693579	8592637	694014	8594171
A7	-	5.5	-	-	693965	8594095
A8	-	1.6	-	-	693997	8593915
A9	-	78.8	-	-	693579	8592637
A upstream	2382.6	2382.6	693573	8592615	693573	8592615
A downstream	291.5	291.5	691686	8591979	691686	8591979
B1	303.0	302.5	692050	8592746	692050	8592746
B2	169.8		692050	8592746	692050	8592746
B3	134.0		690989	8592637	690989	8592637
Boxcut & bund	-	7.3	-	-	694014	8594171

4.2 Simulation Results

4.2.1 Annual Catchment Discharges

Annual discharge was simulated at the outlet of the main catchments (Catchment A and B) and at relevant points within the catchments (*Figure 7 and Figure 8*). *Table 5*, *Table 6* and *Table 7* show the resulting total annual outflow volumes for pre-mining and mining conditions at the measured points for the wet, dry and average rainfall years respectively. *Figure 9* to *Figure 14* show the simulated hydrographs relative to rainfall at the outlets of catchment A and B for the pre-mining and mining scenarios.

The results indicate that the proposed mine infrastructure has little impact on the natural flow regimes. There is a slight decrease in total flow volume at the outlet of Catchment B for the mining scenario of around 2% for all rainfall scenarios, when compared to pre-mining conditions. The results for the mining scenario at the outlet of Catchment A also show a small decrease in total flow volume of around 1% for all rainfall scenarios when compared to pre-mining conditions. Compared to the overall flow volume, very little flow is stored in the boxcut (on average 0.26% of the total flow).

The reduction in flow volume is mainly due to water being retained on site in sediment ponds and the boxcut. As indicated above the percentage in flow reduction at the catchment outlets is minimal and appears to have no significant impact on the natural flow regime.

Table 5. Results of catchment hydrology modelling for the wet year scenario.

Outflow Location	Drainage Area (km^2)		Pre-Mine		During Mining	
	Pre-Mining	During Mining	Streamflow (ML)	Losses (ML)	Streamflow (ML)	Losses (ML)
Catchment A5	4.04	3.97	9744	11173	9088	1885
Catchment A6	0.79	0.81	1971	222	1956	272
Catchment A	30.99	30.92	77346	8358	76639	8886
Catchment B1	3.03	3.02	7586	794	7278	1078
Catchment B	6.07	6.06	15209	1577	14910	1852
Boxcut	-	0.08	-	-	-	193

Table 6. Results of catchment hydrology modelling for the dry year scenario.

Outflow Location	Drainage Area (km^2)		Pre-Mine		During Mining	
	Pre-Mining	During Mining	Streamflow (ML)	Losses (ML)	Streamflow (ML)	Losses (ML)
Catchment A5	4.04	3.97	1738	1974	1607	2039
Catchment A6	0.79	0.81	391	337	391	349
Catchment A	30.99	30.92	15344	13131	15206	13210
Catchment B	6.07	6.06	3057	2520	2995	2575
Catchment B1	3.03	3.02	1528	1257	1461	1315
Boxcut	-	0.08	-	-	-	59

Table 7. Results of catchment hydrology modelling for the average year scenario.

Outflow Location	Drainage Area (km^2)		Pre-Mine		During Mining	
	Pre-Mining	During Mining	Streamflow (ML)	Losses (ML)	Streamflow (ML)	Losses (ML)
Catchment A5	4.04	3.97	4678	1995	4355	2200
Catchment A6	0.79	0.81	988	322	976	354
Catchment A	30.99	30.92	38543	12644	38187	12893
Catchment B	6.07	6.06	7622	2403	7462	2549
Catchment B1	3.03	3.02	3802	1203	3645	1345
Boxcut	-	0.08	-	-	-	114

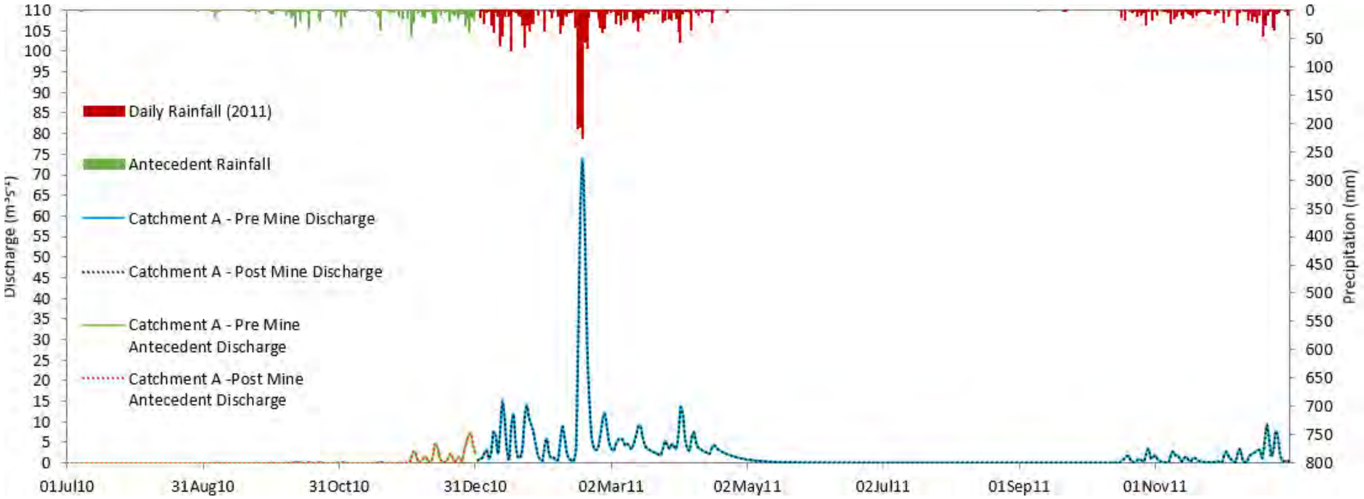


Figure 9. High rainfall year simulation result – Catchment A

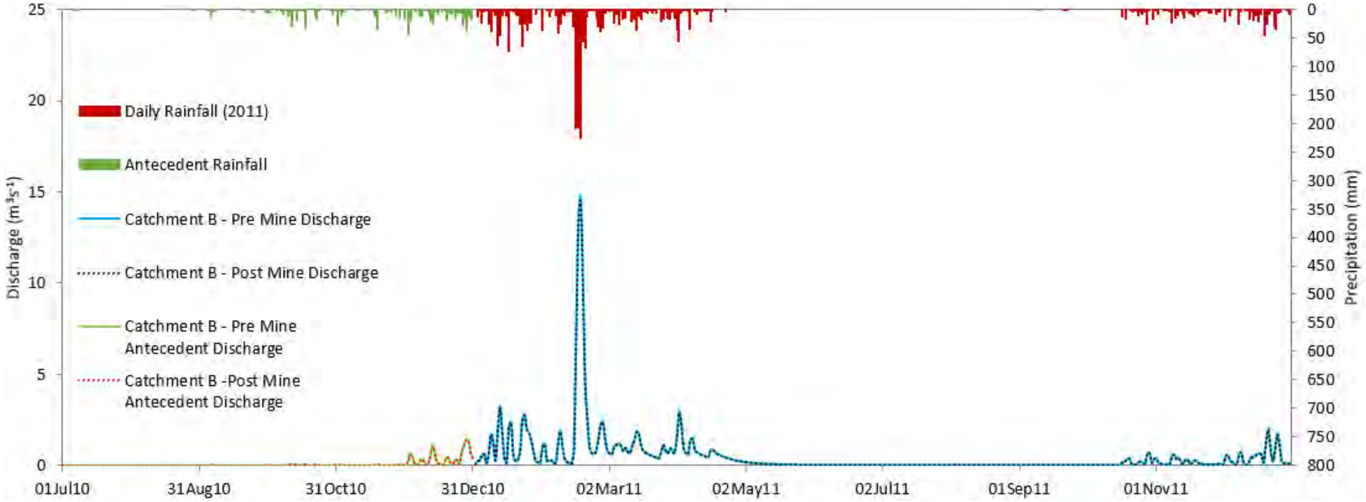


Figure 10 High rainfall year simulation result – Catchment B

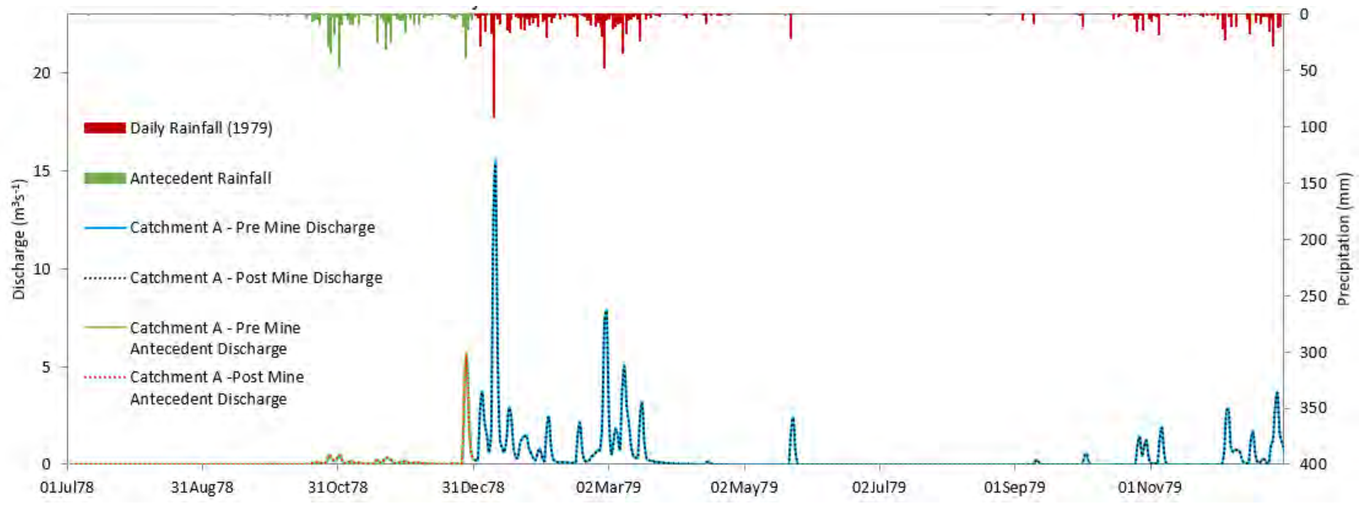


Figure 11. Low rainfall year simulation result – Catchment A

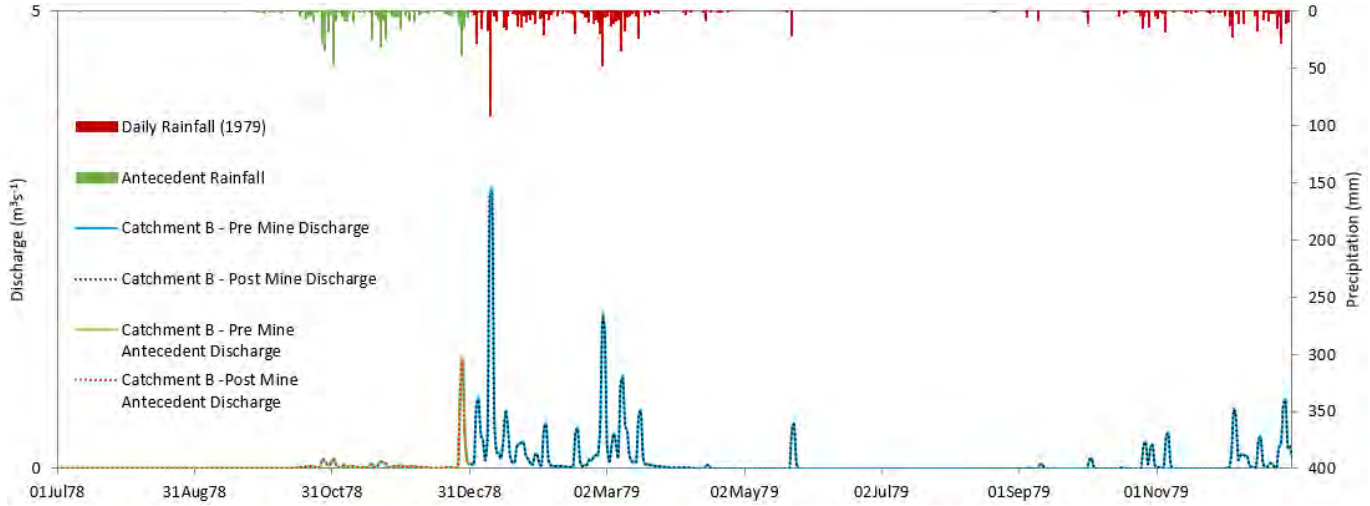


Figure 12. Low rainfall year simulation result – Catchment B

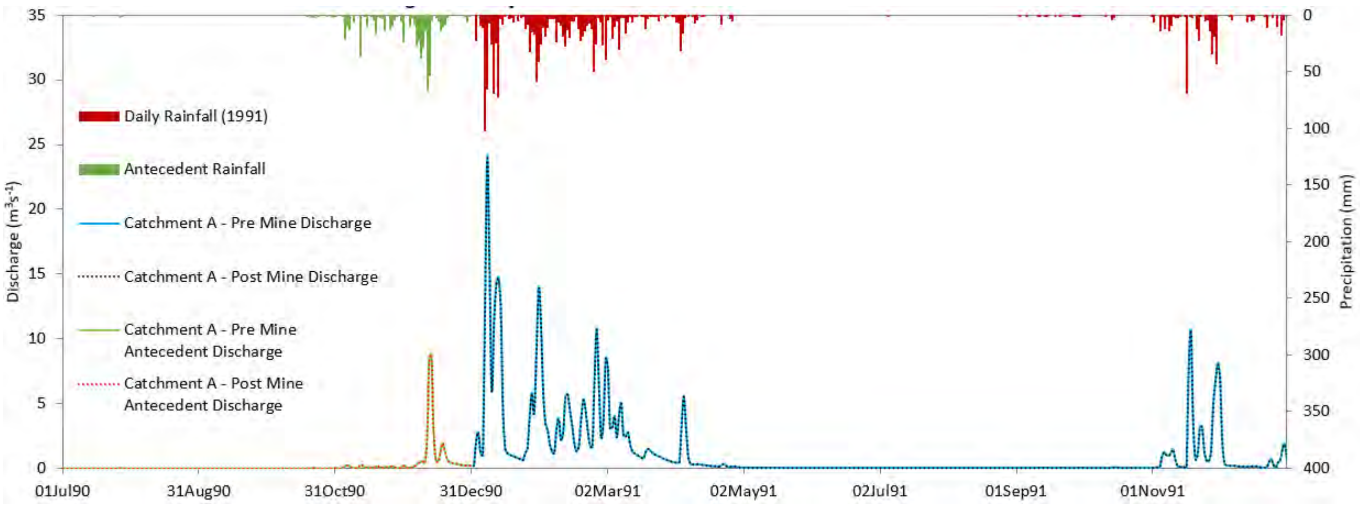


Figure 13. Average rainfall year simulation result – Catchment A

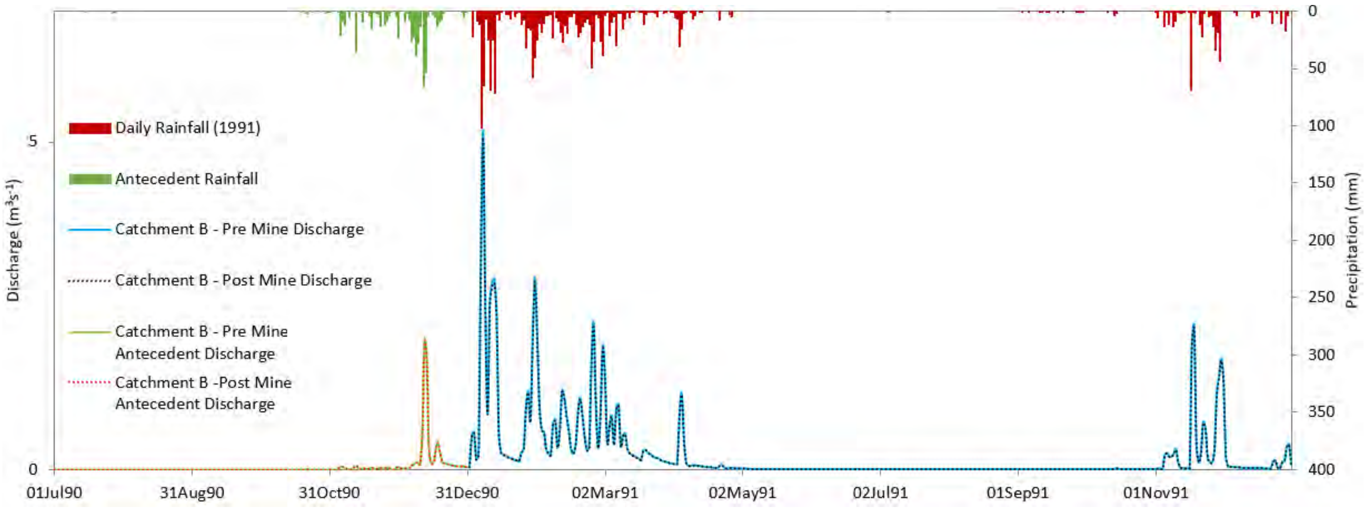


Figure 14. Average rainfall year simulation result – Catchment B.

4.2.2 Boxcut daily inflows and storage

Figure 15 to Figure 17 show the daily inflows into the Boxcut during the high, low and average rainfall years. The maximum inflow into the Boxcut is 16420 m^3d^{-1} for the high rainfall scenario, 7780 m^3d^{-1} for the average rainfall scenario and 6920 m^3d^{-1} for the low rainfall scenario. On average, the inflows into the boxcut during the high, average and low rainfall years are 440 m^3d^{-1}, 270 m^3d^{-1} and 157 m^3d^{-1} respectively. Most of this inflow is caused by direct rainfall on the boxcut. Very little inflow occurs from upstream catchment A9 along the boxcut entrance.

Figure 18 to Figure 20 show the water stored in the boxcut and the water surface elevation in the boxcut during the three rainfall scenarios during periods of rainfall and evaporation. The maximum water stored in the boxcut is 203 000 m^3 for the high rainfall scenario, 120 830 m^3 for the average rainfall scenario and 74 660 m^3 for the low rainfall scenario. For the high rainfall scenario, the maximum water level rises to 31.3 above the boxcut base level. The maximum water depth for the average and low rainfall scenario is 25.3 m and 21.0 m.

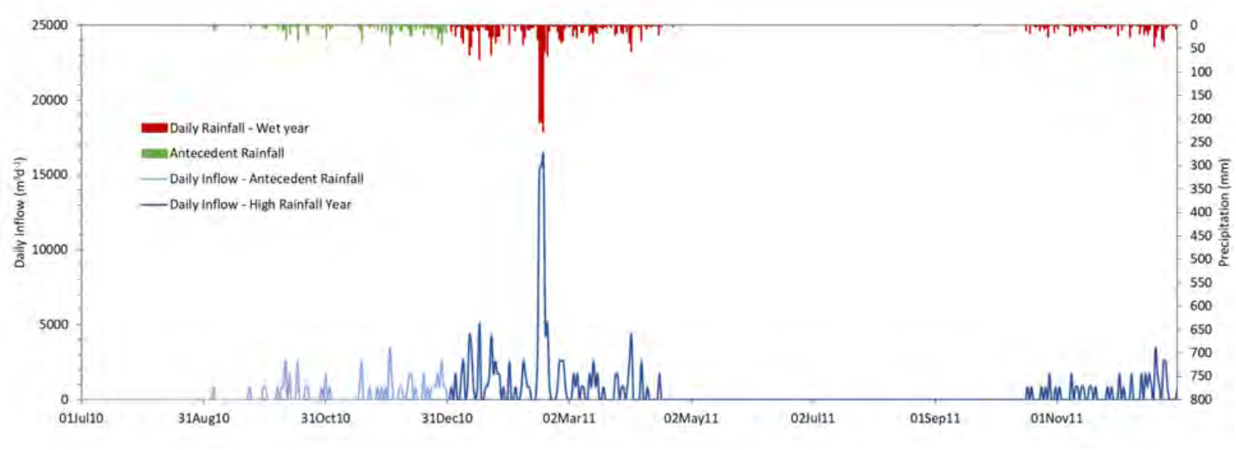


Figure 15. Daily Inflow into the Boxcut for the high rainfall year scenario

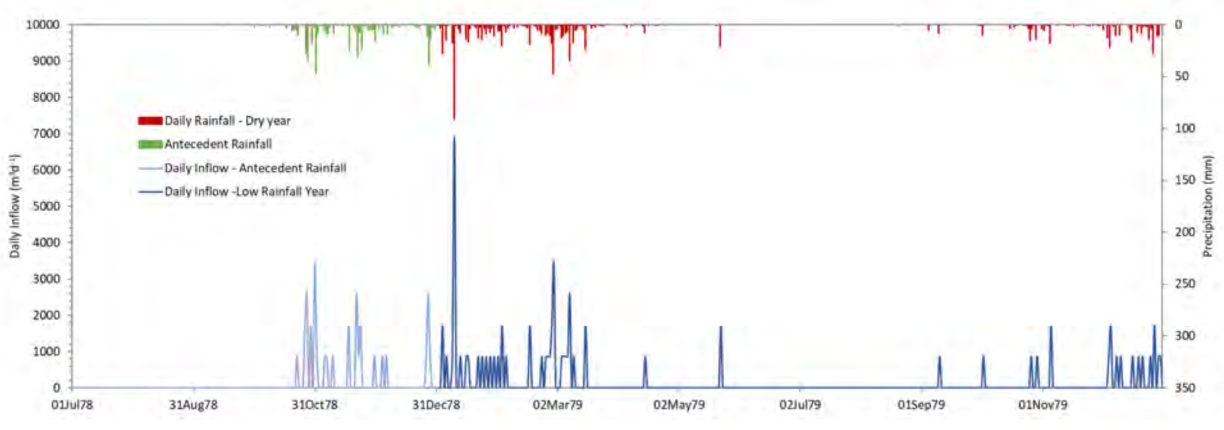


Figure 16. Daily inflow into the Boxcut for the low rainfall year scenario

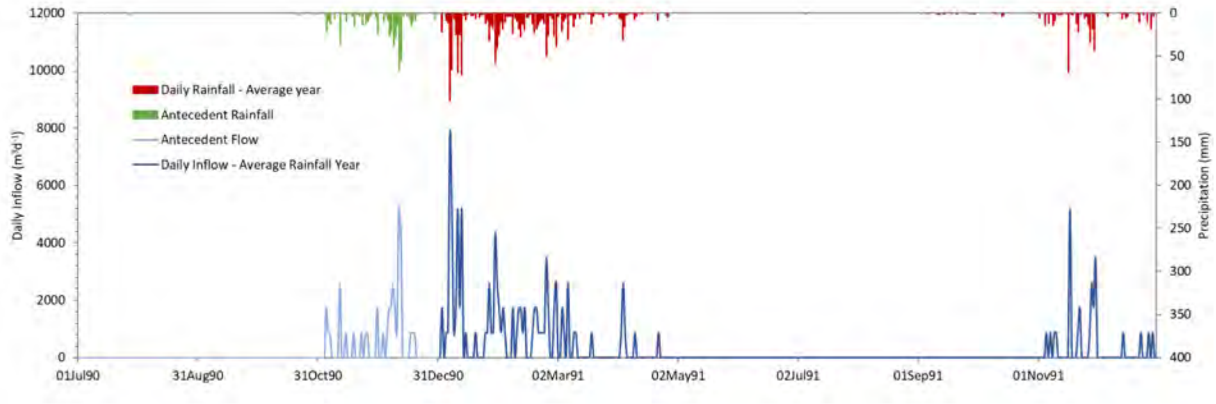


Figure 17. Daily inflow into the Boxcut for the average rainfall year scenario

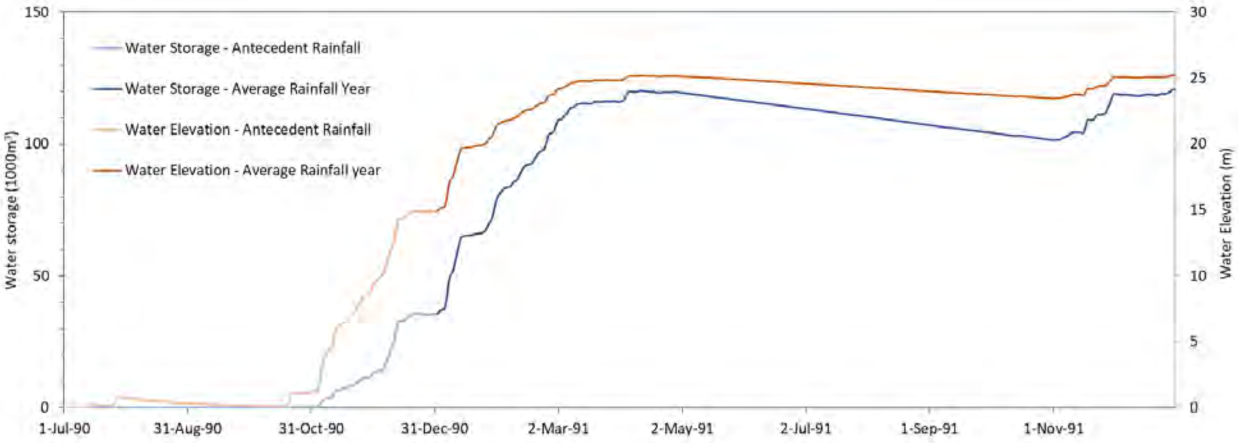


Figure 18. Water Storage and Elevation in the Boxcut for the high rainfall year scenario

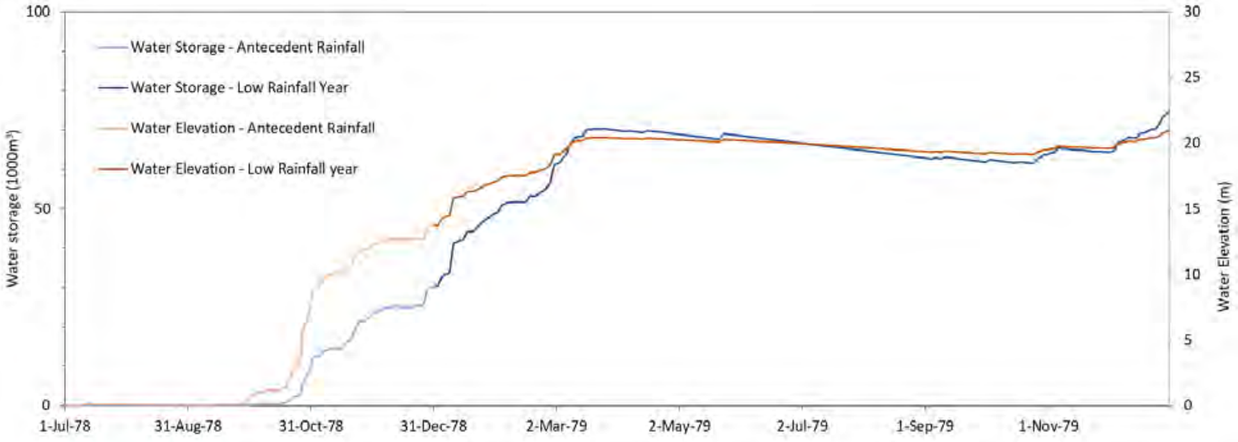


Figure 19. Water Storage and Elevation in the Boxcut for the low rainfall year scenario

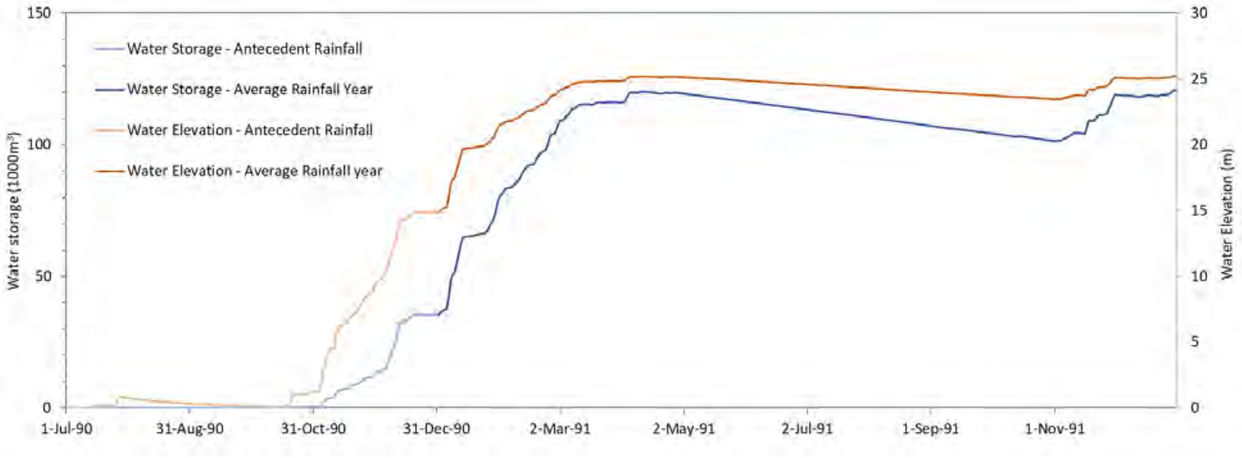


Figure 20. Water Storage and Elevation in the Boxcut for the average rainfall year scenario

5 Flood Inundation Modelling

A 1%AEP (Annual Exceedance Probability) rainfall event was used to assess flood inundation in the mine affected catchments. Two models are used for this analysis. The first is the RORBwin hydrology model which uses *Monte Carlo* simulations to determine rainfall and runoff causing the most probable peak discharge (Q) for the studied AEP event. The second is the HEC-RAS hydrodynamic model which uses the RORBwin output hydrographs and RORBwin most probable rainfall hyetograph to simulate flood inundation across the affected catchments.

5.1 Methodology

Methods used were:

1. Determine the hydrology of the undisturbed catchments (*Figure 7*) for a 1%AEP rainfall event,
2. Determine the hydrodynamic flow in the mine infrastructure catchments (*Figure 8*) for a 1%AEP rainfall event,
3. Compare the extent of inundation caused by a 1%AEP event in the pre-mining and mining catchments.

5.2 Digital Elevation Model

The following terrain data were available to use for simulations:

1. A pre-mining Cox Peninsula Northern Territory Government 10m digital elevation model (DEM) (EnviroConsult Australia Pty Ltd, 2018b) which was extended for this study,
2. A 0.5m DEM for the mine infrastructure comprising boxcut, waste landform (WL), contractors' area, run of mine pad (RoM) provided by Core Lithium Ltd, and
3. A 1m pre-mining DEM provided by Core Lithium Ltd.

5.3 Derivation of the 1%AEP hydrograph

A 1%AEP (annual exceedance probability) rainfall event is a recommended design event for major developments and roadways. For ungauged catchments, a probabilistic method to determine storm duration and intensity is recommended. RORBwin uses *Monte Carlo* simulations to determine critical duration and temporal distribution of the rainfall event causing the probable peak discharge (Q) for the design event in the catchment of interest.

5.3.1 RORBwin

RORB hydrological modelling was conducted to determine the 1% AEP inflows form undisturbed areas to the HEC-RAS mesh area. RORB is a runoff and streamflow routing program that calculate flood hydrographs from rainfall depths. The model is aerially distributed, nonlinear, and applicable to both urban and rural catchments.

The runoff catchments in *Figure 2* (pre-mine catchment) were divided into smaller sub-catchments to develop runoff routing networks for RORB modelling. *Figure 21* below presents the sub-catchments and runoff routing networks for RORB modelling. The sub catchment areas are summarized in *Table 8* below.

Table 8 RORB sub-catchment areas

Catchment	Area (Ha)	Catchment	Area (Ha)	Catchment	Area (Ha)
E1	464	**N2**	26	**N4**	16
E2	118	**N3**	17	**N9**	25
E3	71	**N5**	31	**N6**	89
E4	115	**N7**	10	**N8**	22
E5	375	**S1**	32	**C1**	37
E6	338	**S2**	114	**C4**	19
E7	308	**S3**	159	**C5**	62
E8	255	**W1**	329	**C3**	13
E9	322	**W2**	196	**C2**	70
N1	43	**W3**	112	**-**	-

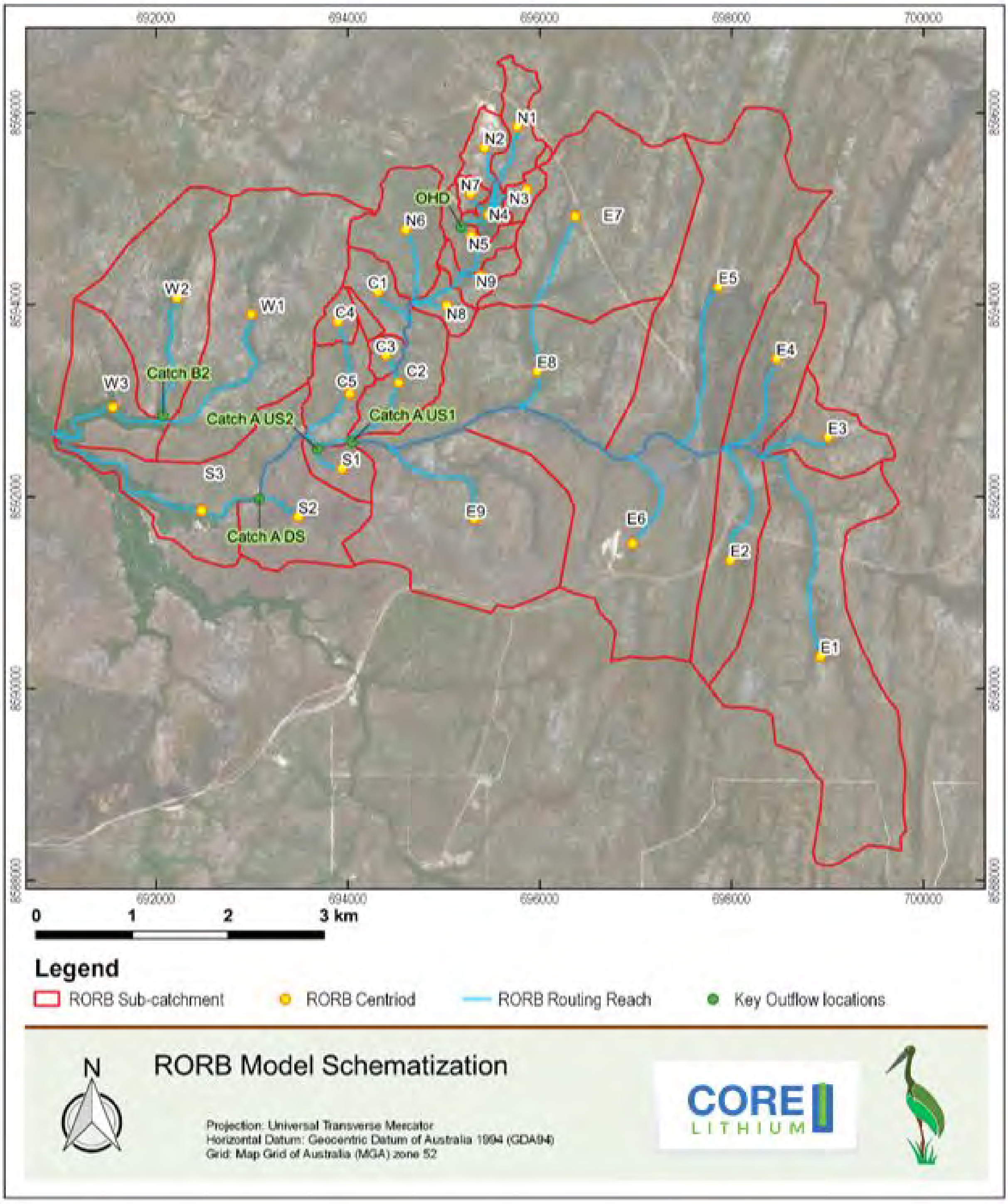


Figure 21. RORB Model Schematization

5.3.2 Design Rainfall

Design rainfall depths, temporal patterns and Areal Reduction Factors (ARF) for the 1% AEP storm events were sourced from the Australian Rainfall and Runoff (ARR 2016) online data hub.

Table 9 shows the 1% AEP design rainfall depths for various storm durations.

Table 9 1% AEP design rainfall depths

Storm event duration	Rainfall depth (mm)	Storm event duration	Rainfall depth (mm)
1.5 hour	114	**12 hour**	260
2 hour	127	**18 hour**	312
3 hour	148	**24 hour**	356
4.5 hour	173	**30 hour**	393
6 hour	194	**36 hour**	426
9 hour	229	**48 hour**	481

5.3.3 RORB model parameters

The rainfall losses are modelled using an initial loss and a continuing loss parameter. The catchment storage and attenuation effect were determined by a K_C parameter and the length of RORB reaches. The catchment linearity was represented by a m parameter. In the absence of good quality at-site gauging data for calibration the regional rainfall losses are sourced form ARR (Ball, et al., 2019) online data hub. The RORB routing parameter Kc was estimated using the regional equation recommended by RORB (Pearse, 2002). The adopted parameter values are in *Table 10*.

Table 10 Adopted RORB model parameter values

Parameter	Adopted value
Initial loss (IL)	39 mm/hr
Continuing loss (CL)	5 mm/hr
K_C	7.96
m	0.8 (default)

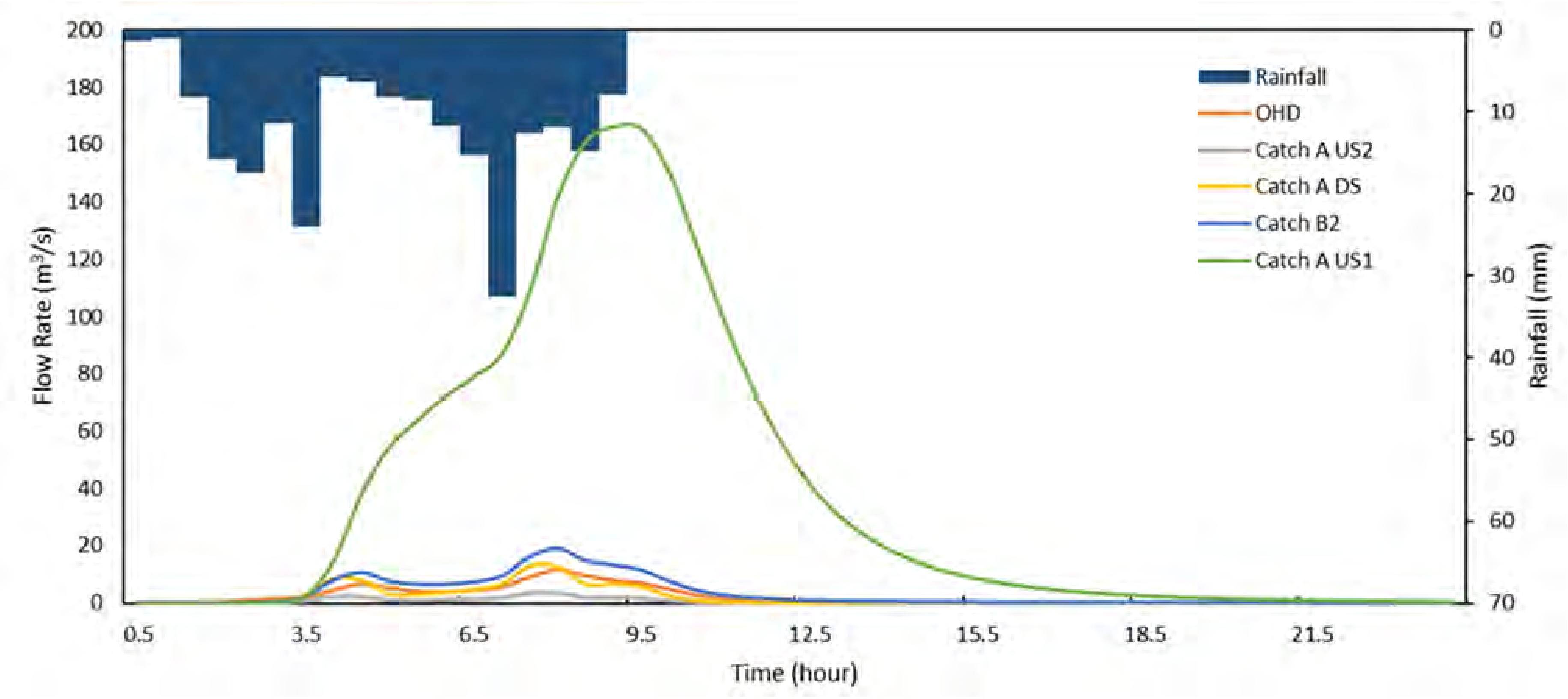
5.3.4 Design flood hydrograph simulation

The 1% AEP design flood was determined using RORB *Monte Carlo* simulations. Many simulations were conducted. For each simulation, the input parameters (rainfall losses and temporal patterns) were varied randomly to consider the natural variability of rainfall and catchment conditions. Review of the *Monte Carlo* simulation results at key outflow locations (*Figure 21*) indicate the critical storm duration for the mining site location is 9 hours. The 1% AEP 9-hour storm event *Monte Carlo* Peak discharges at the key outflow locations are summarised in *Table 11* below.

Table 11 1% AEP 9-hour storm event Mote Carlo Peak discharges at the key outflow locations

Location	Peak flow (m^3/s)
OHD	13.4
Catch A US1	177.1
Catch A US2	5.2
Catch A DS	19.0
Catch B2	22.7

Ensemble simulations were conducted for the 1% AEP 9-hour storm event using 10 temporal patterns. The temporal pattern that resulted in the peak flow closest to the *Monte Carlo* simulation result at the key outflow locations was selected as the representative temporal pattern for determining design flood hydrographs. The adopted outflow hydrographs are presented in *Figure 22* below.



28.

Figure 22. 1%AEP Design Flood Hydrographs

5.4 Inundation modelling

HEC-RAS was used to model flood inundation on the site and determine the effects of the proposed mine infrastructure on the inundation extent and the natural flow regime around the mine site. The following 2 scenarios were simulated:

1. Local inundation in the pre-mine catchments A and B for the 1%AEP rainfall event,
2. Local inundation in the mining catchment A and B for the 1%AEP rainfall event.

As discussed in Sub-section 3.4, a primary storm tide occurring in Bynoe Harbor is unlikely to affect the flood inundation across the mine site and was therefore not modelled. It was assumed that all rainfall on the infrastructure was retained on-site (see Section 4.1.3).

5.4.1 HEC-RAS model set-up

5.4.1.1 Mesh and boundary conditions

The HEC-RAS meshes were developed for pre-mining and mining scenarios to cover the expected inundation extent. The model meshes were constructed from available topographic and bathymetric data (Section 5.2) and refined through detailed digitising in QGIS. The HEC-RAS model meshes are made up of 15m×15m squares which uses vertices to capture ground elevations. The simulated RORBwin hydrographs at selected nodes were used as input boundary conditions to account for upstream inflow to the mesh. The model mesh and input nodes for pre-mine scenario is shown in Figure *23*. The input hydrographs for each node in *Figure 23* are shown in *Figure 22*. The model mesh and input locations for mining scenario is shown in *Figure 24*. The input hydrographs for each node in *Figure 24* are shown in *Figure 22*. In addition to the input hydrographs, the rain on grid method was used to simulate rainfall across the mesh using the most probable 1%AEP rainfall intensity and duration generated by RORBwin. The boundary condition at the downstream outlet was set as normal depth.

5.4.1.2 Model roughness parameter

The roughness parameter represents the ground surface condition which affects the behaviour (velocity and depth) of flow in the model. A previous study (EnviroConsult Australia Pty Ltd, 2018c) showed that using 2 roughness values to represent the roughness of channel and floodplain is sufficient for HEC-RAS flood inundation modelling (Zhu L, 2018). The roughness parameter used in HEC-RAS is Manning's n. The spatial distribution of Manning's n values in HEC-RAS is represented by inputting a land cover map with Manning's n zones delineated using satellite photography. The land cover map is shown in *Figure 25*. The Manning's n values are set as 0.06 for channel and channel bank and 0.10 for floodplain and other regions. These values were selected from the typical ranges of 2D roughness parameters provided in Australian Rainfall and Runoff (ARR) report (ARR, 2012).

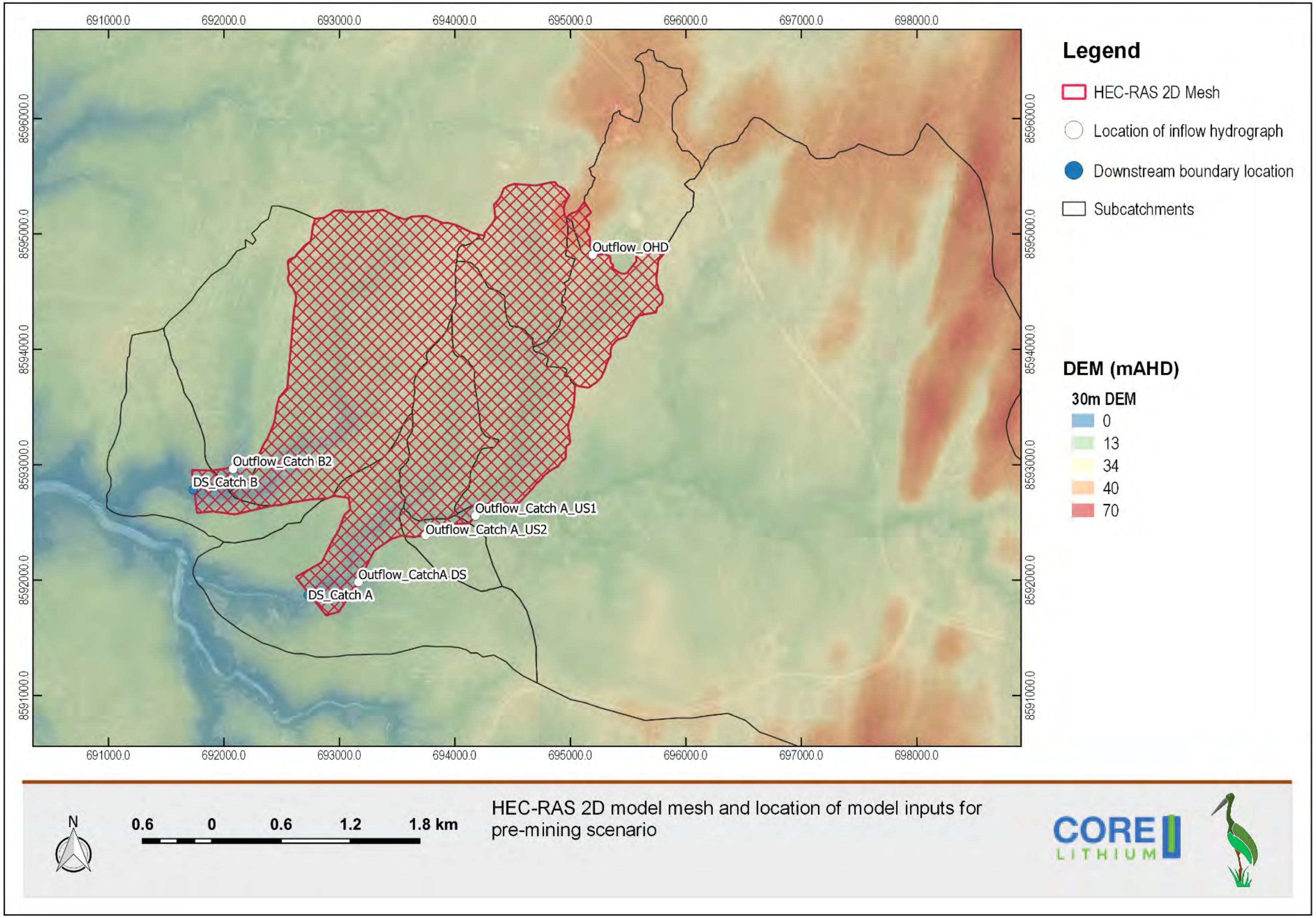


Figure 23. HEC-RAS 2D model mesh and location of model inputs for pre-mining scenario.

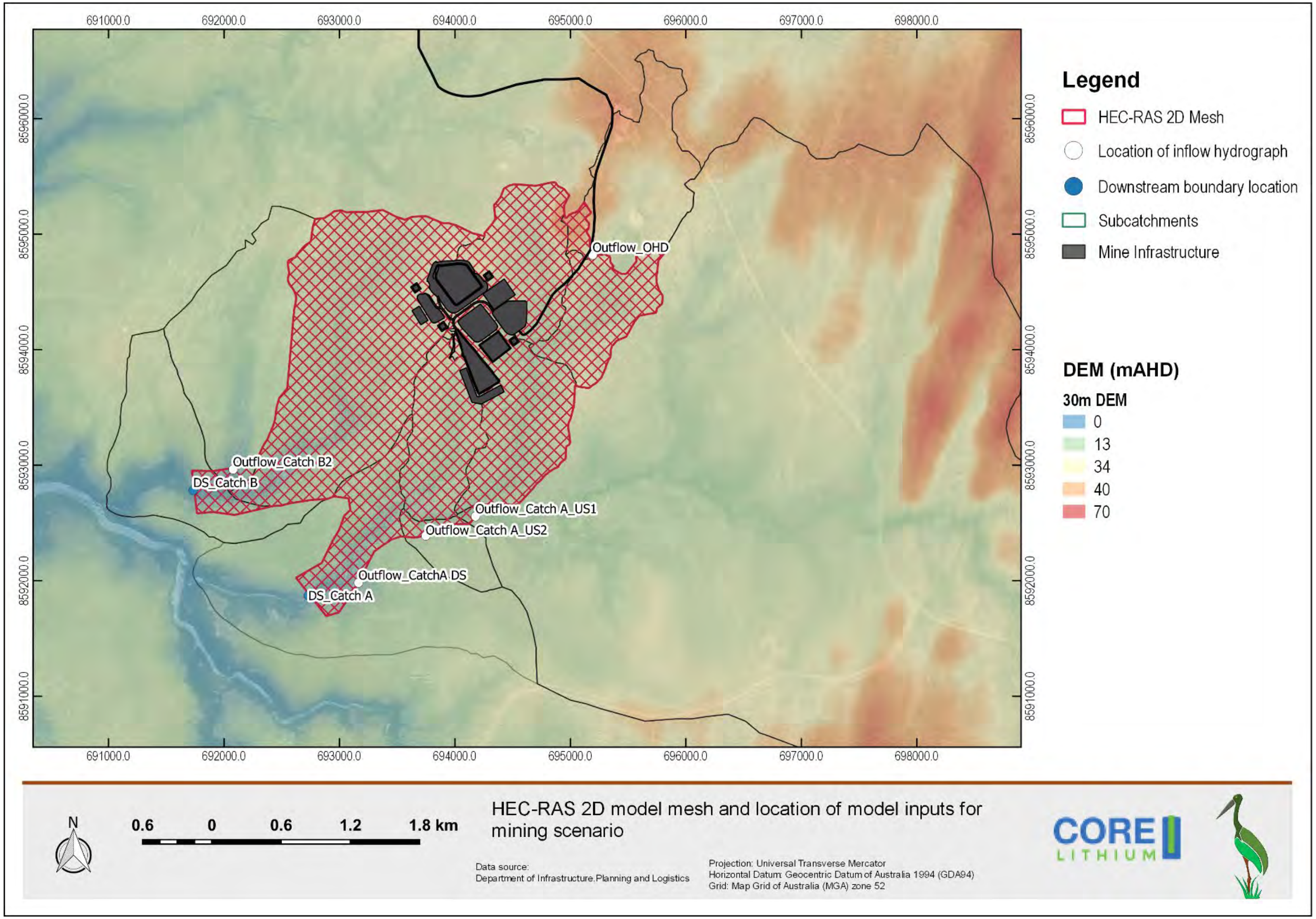


Figure 24. HEC-RAS 2D model mesh and location of model inputs for mining scenario.

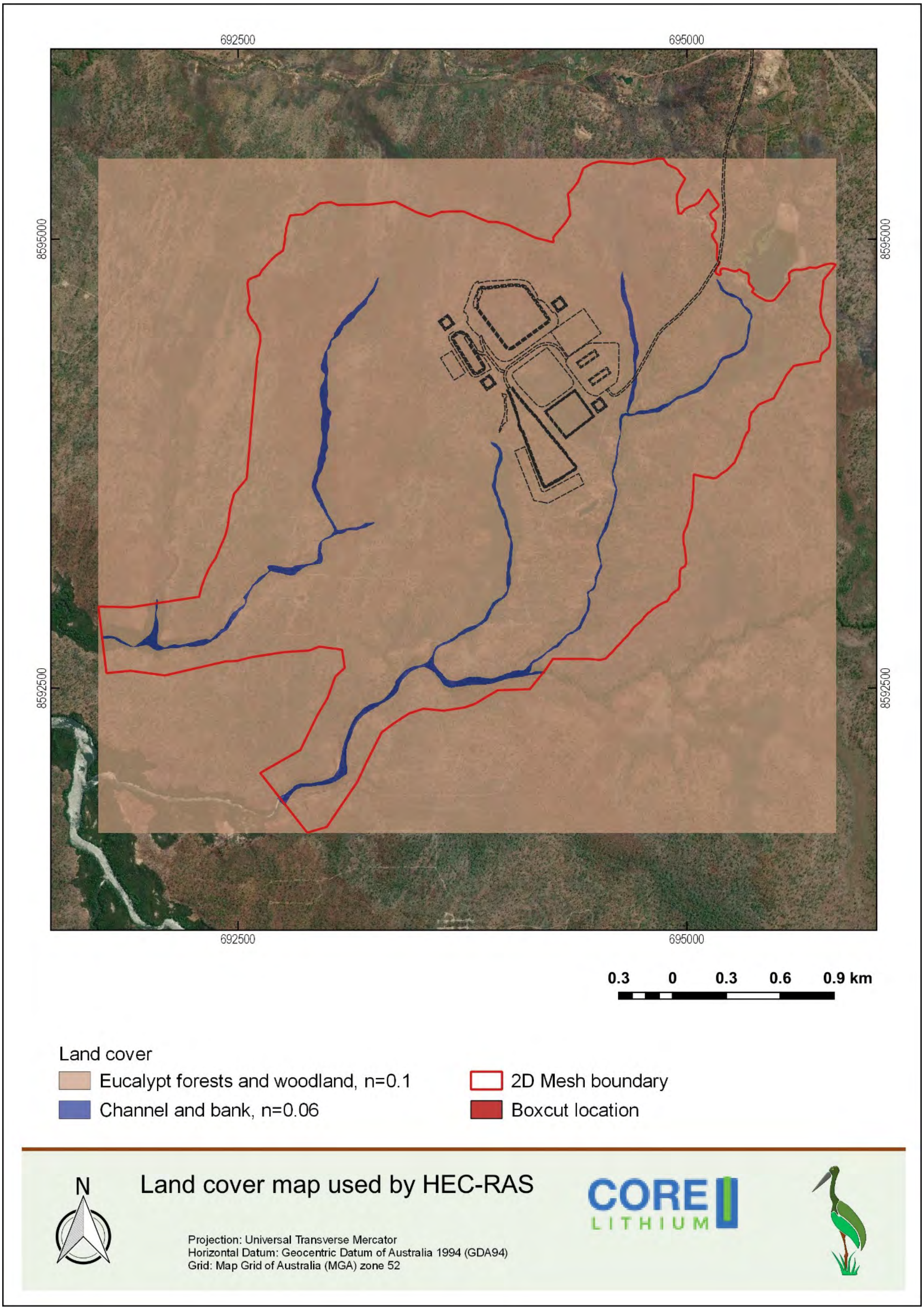


Figure 25. Land cover map used in HEC-RAS

5.4.2 Simulation results

5.4.2.1 Catchment inundation

Figure 26 shows the pre-mine maximum flood inundation levels for the 1%AEP rainfall event for the studied catchments. *Figure 27* shows the mining scenario maximum flood inundation levels for the 1%AEP rainfall event for the studied catchments. These figures show the maximum flood levels at all points during the simulation, but these maximum levels don't necessarily occur at the same time. There is very little difference between the pre-mining and mining scenario inundation levels in the downstream reaches (*Figure 28*). Initial modelling, which did not include detailed assessment of the dam and spillway, indicates that there may small areas where there is <200mm maximum water depth at the downstream toe of the dam wall. It is likely this will only be there for a short time and results from direct rainfall. This should be considered during final design of the dam wall. There is some water accumulation in the boxcut which is to be expected. This is not the final design so inundation levels and locations across the mine site may change. The water shown in the boxcut is not through flooding but accumulation of direct rainfall.

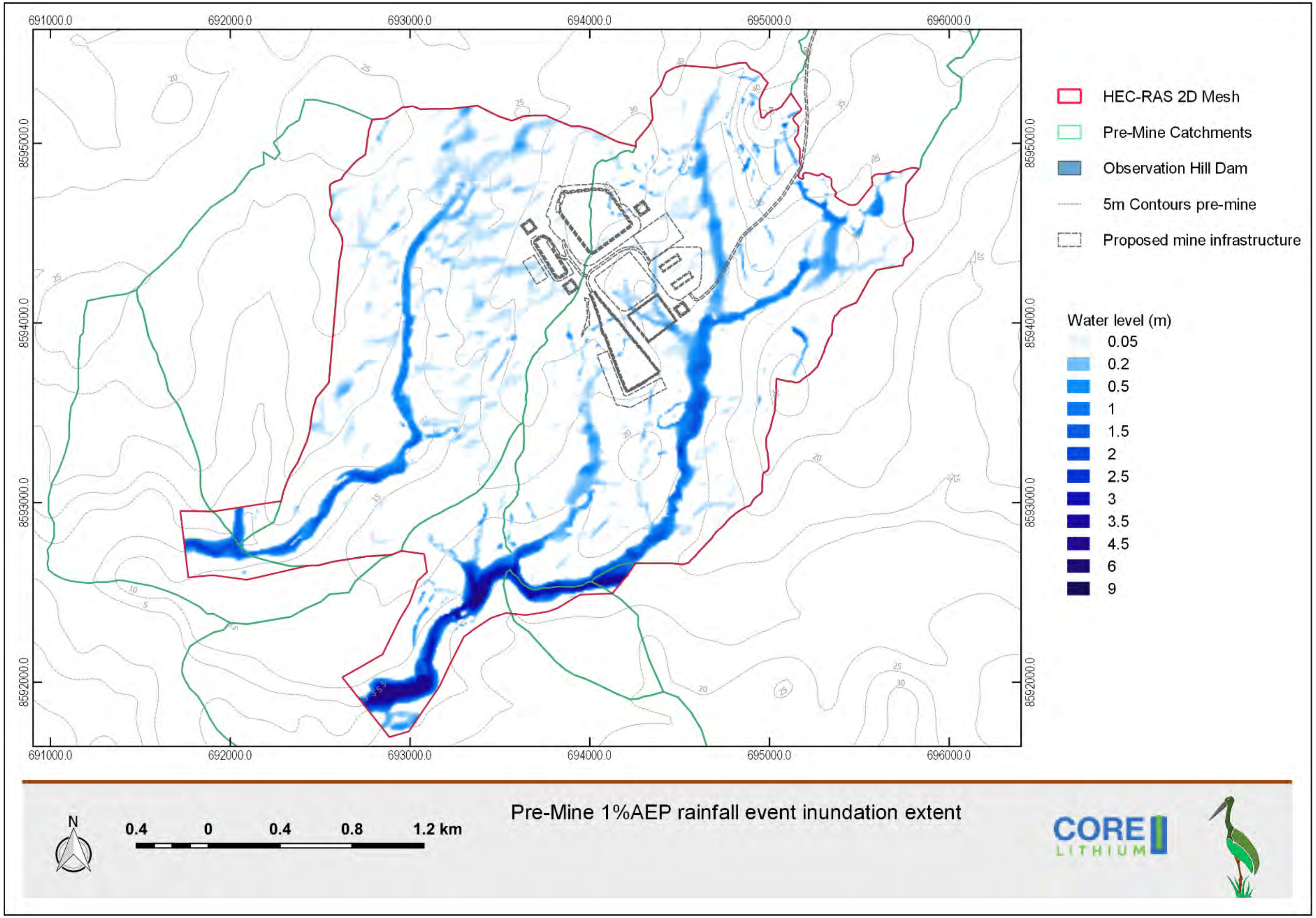


Figure 26. Pre-mining 1%AEP flood inundation extent

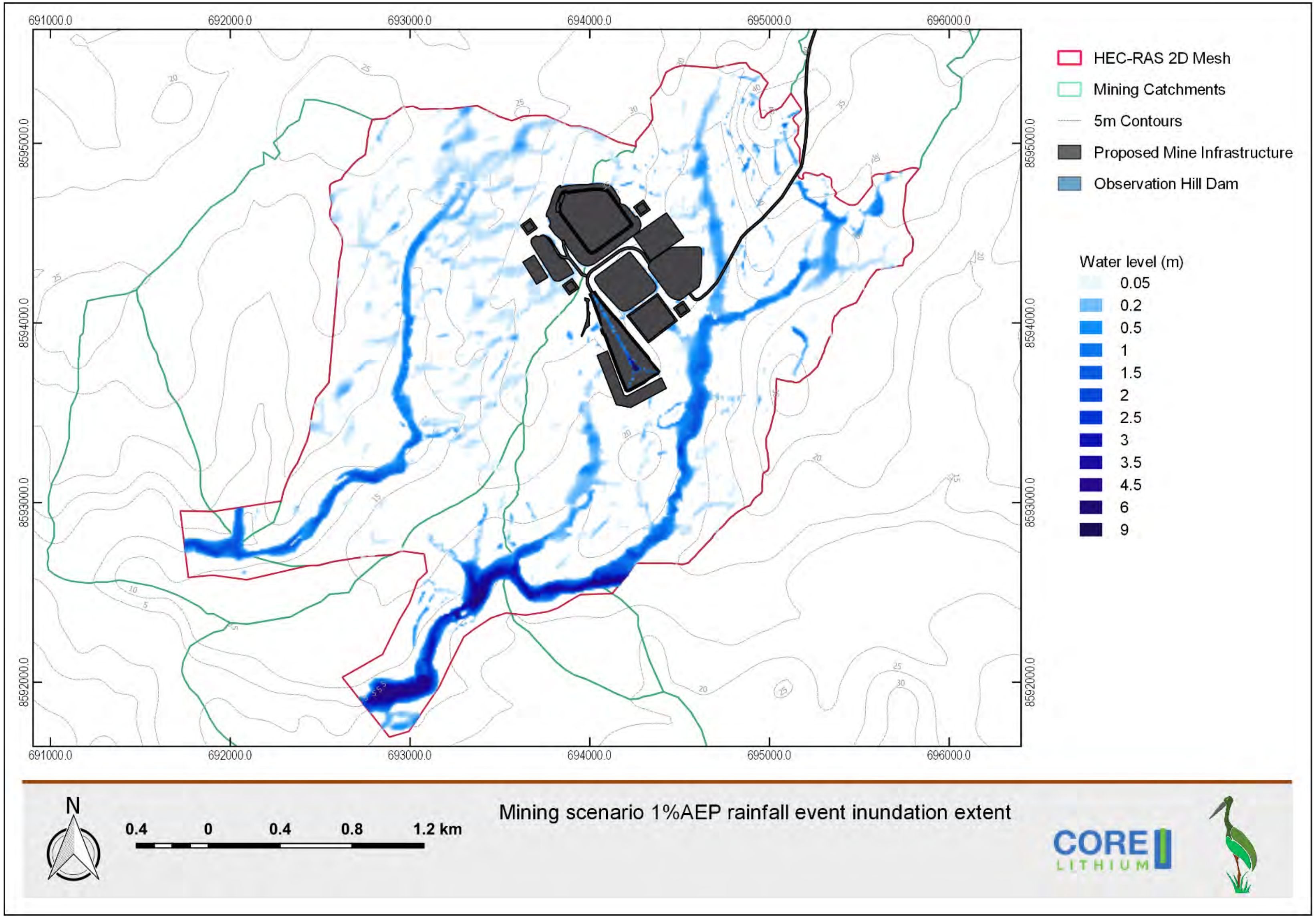


Figure 27. Mining scenario 1%AEP flood inundation extent

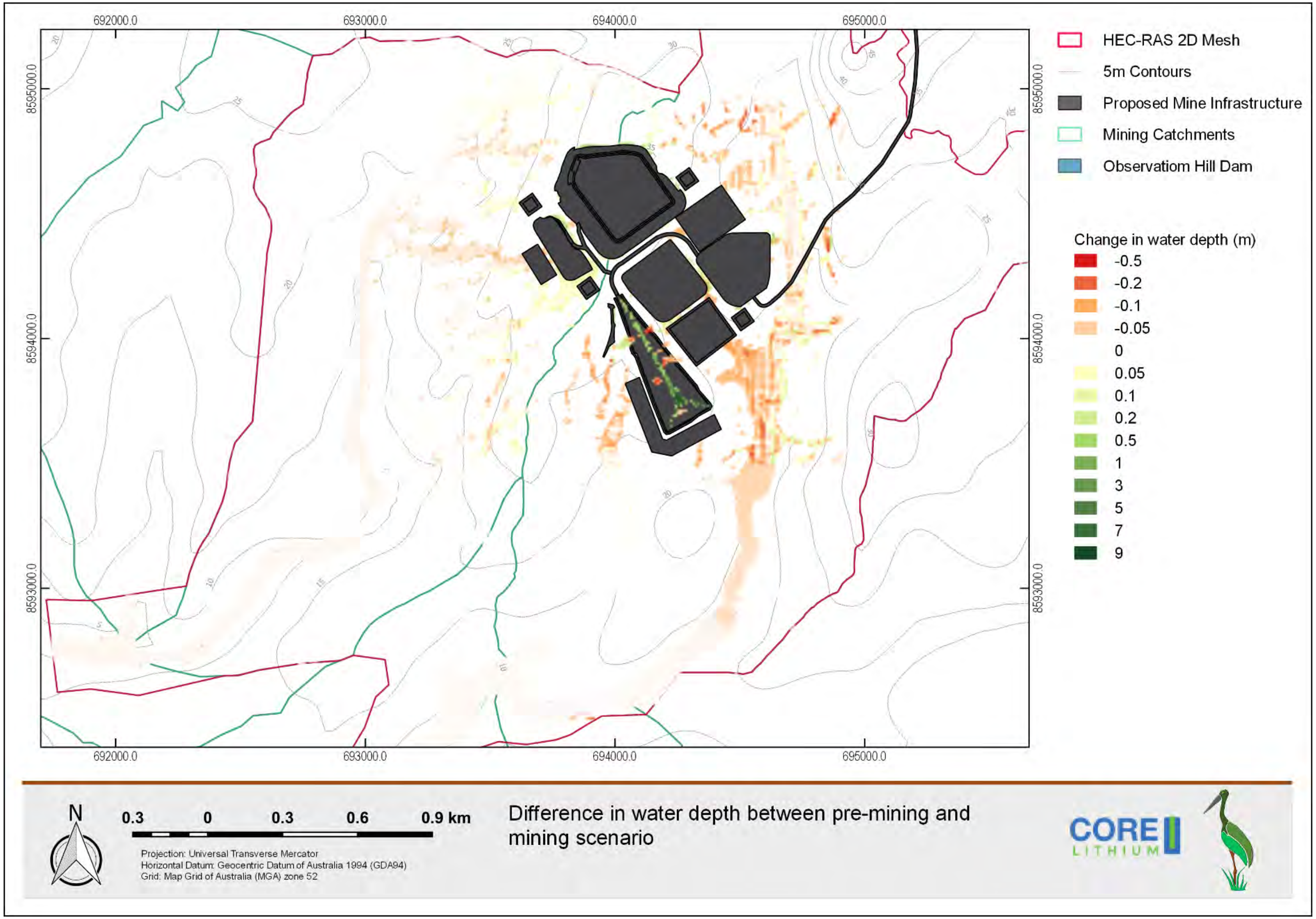


Figure 28. Change of water depth for the mining scenario compared with pre-mining scenario

5.4.2.2 Flood hazard

There is no increased risk to people, livestock, or wildlife during flood events. Flood hazard maps were prepared (AIDR, 2017) (*Figure 29* and *Figure 30*) for the 1%AEP and these showed that the mine infrastructure has little effect on flood levels or flood hazard. Flood hazard is the product of flow velocity (V) and depth (D). The flood hazard in the lower reaches is slightly less post-mining than pre infrastructure. This is because there is a reduction in peak discharge downstream as more water is retained on site for the post-mining scenario.

Surface water across the mine site is very shallow and has very small velocity posing no risk to the mining operations. In this area where water is shown in contact with the proposed infrastructure, depths are low and hazard level low. This should be considered during final design and diversion drain used if necessary.

All water bodies and the boxcut are bunded which will prevent access by humans and livestock. The bunds may not prevent access by smaller native animals.

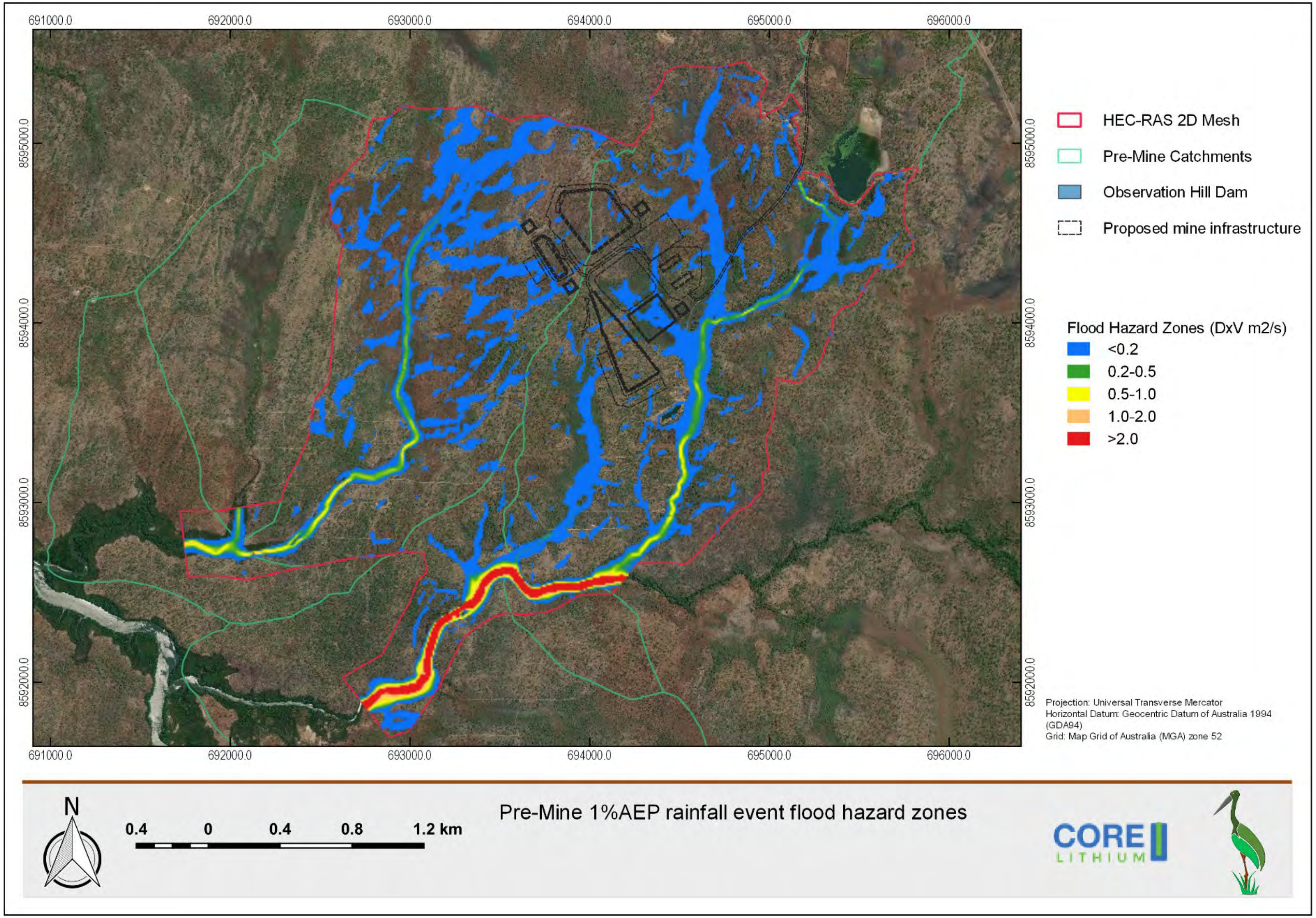


Figure 29. Flood hazard zones for the pre-mining scenario for a 1%AEP rainfall event

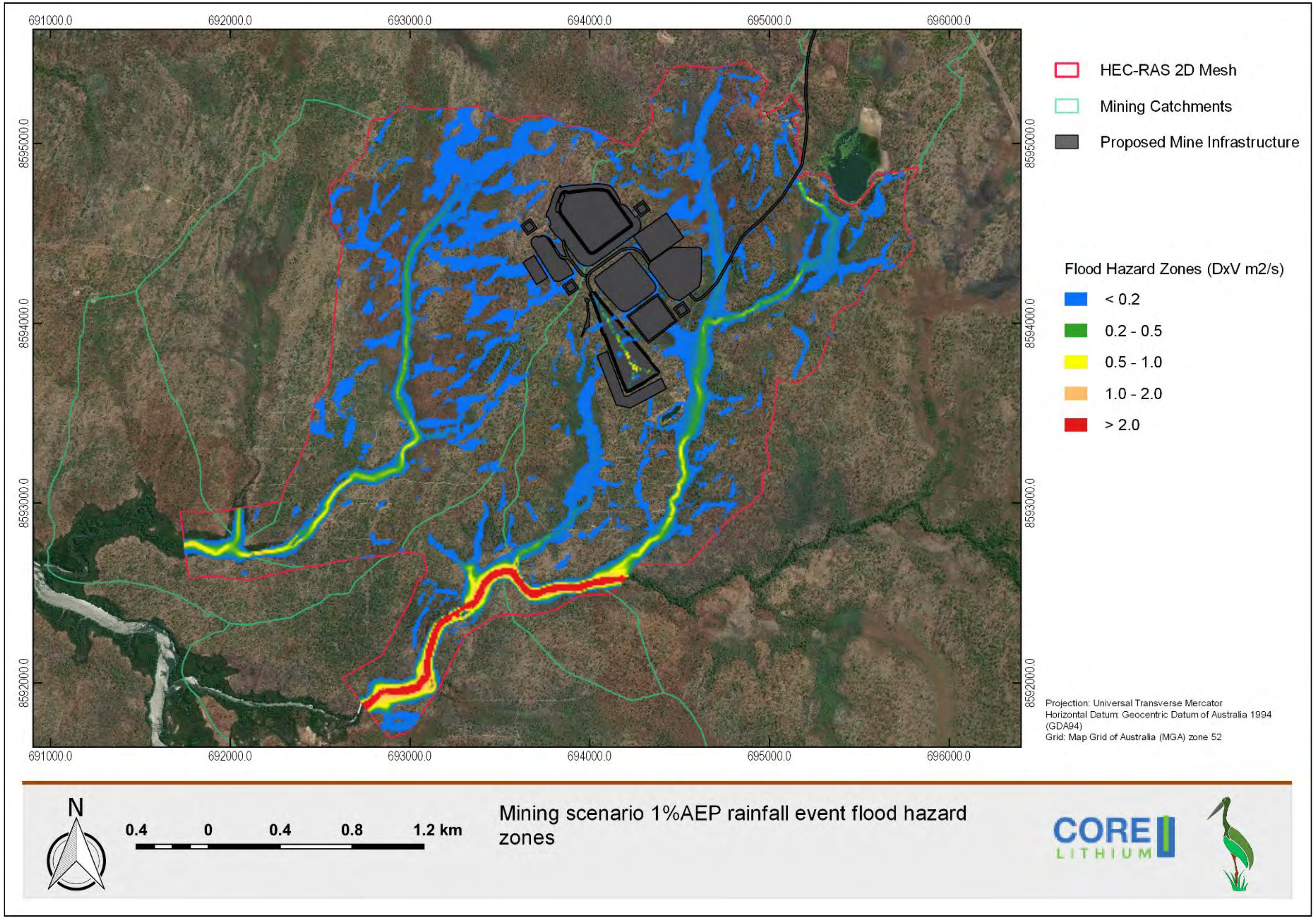


Figure 30. Flood hazard zones for the mining scenario for a 1%AEP rainfall event

5.4.2.3 Maximum discharge

Table 12 shows the maximum discharges at the mesh outlet for the pre-mining and mining scenario and estimated peak discharges from the Regional Flood Frequency Estimation (RFFE) method for the simulated 1%AEP event. The RFFE method is an online tool developed by Engineers Australia to estimate design flood peak discharge. Inputs are catchment outlet, centroid co-ordinates and catchment area. RFFE was used to determine the peak discharge at the outlet of the catchments for 1%AEP rainfall event. The peak discharge values are used as a calibration/validation tool for the inundation risk modelling.

As shown in *Table 12*, the simulated discharges for the pre-mining and mining scenarios closely correlate with the RFFE estimated peak discharges and lie well within the upper (95%) and lower (5%) confidence limits. *Table 12* also shows that the difference between pre-mining and mining scenario peak discharges are less than 1 m^3s^{-1}, indicating that the mine infrastructure has very little influence on the natural flow regime.

Table 12. Pre-mining and mining simulation and RFFE peak discharges at the mesh outlet for the 1%AEP event

	Pre-mining scenario	Mining scenario	RFFE estimation		
			Estimated discharge	5% confidence limit	95% confidence limit
Maximum discharge (m^3s^{-1})	237	236	298	96	883

5.4.2.4 Cross-sections

Four cross-sections were taken to plot the differences in water surface elevation between pre-mining and mining simulations. The location of the cross-sections is shown in *Figure 31* to *Figure 35.* These figures show water surface elevation across the pre-mining and mining terrain for the simulated 1%AEP event. There are no significant differences in water surface elevation between the pre-mining and mining scenario outside the areas occupied by mine infrastructure.

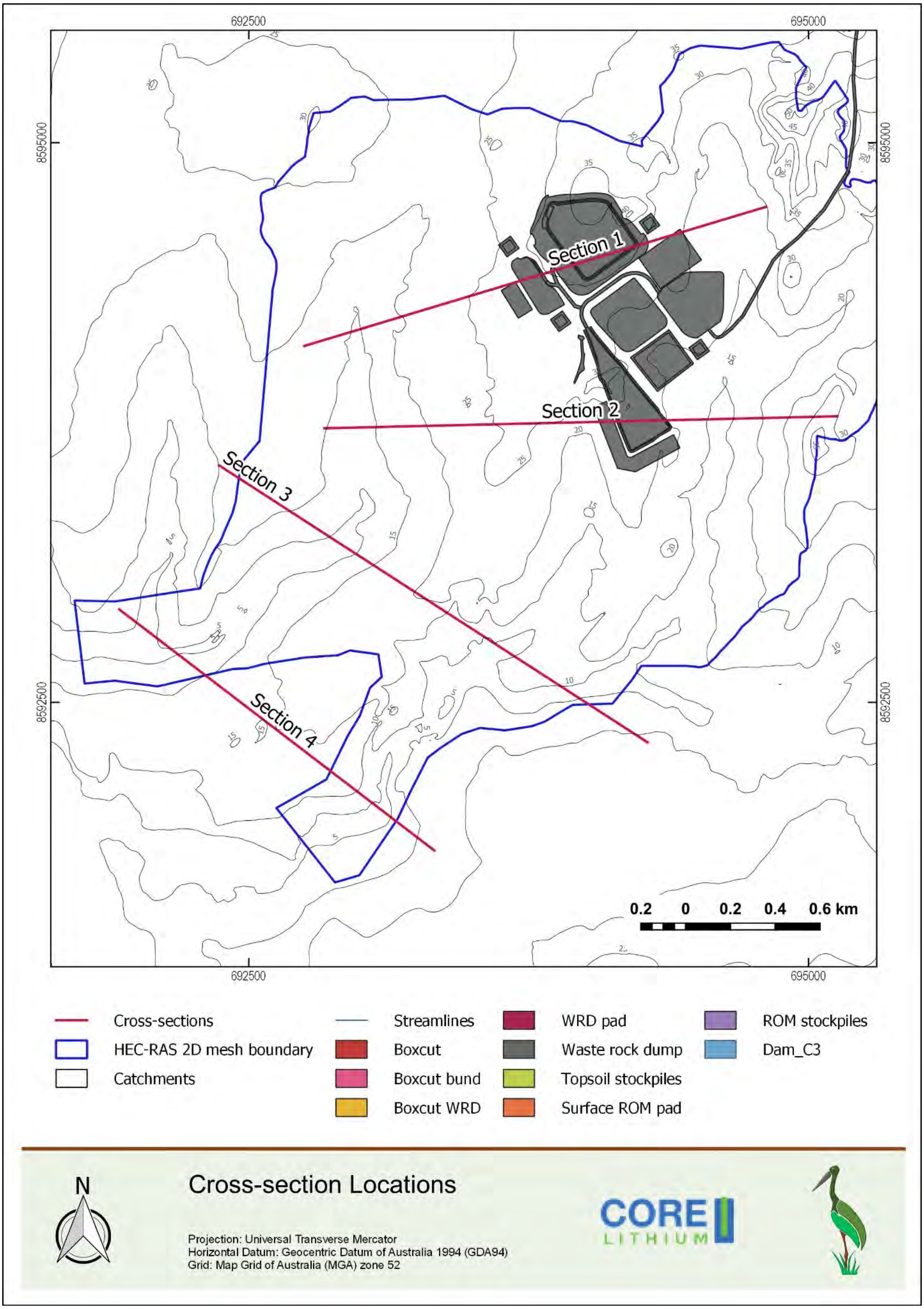


Figure 31. Location of cross-sections showing water depth for the pre-mining and mining scenario

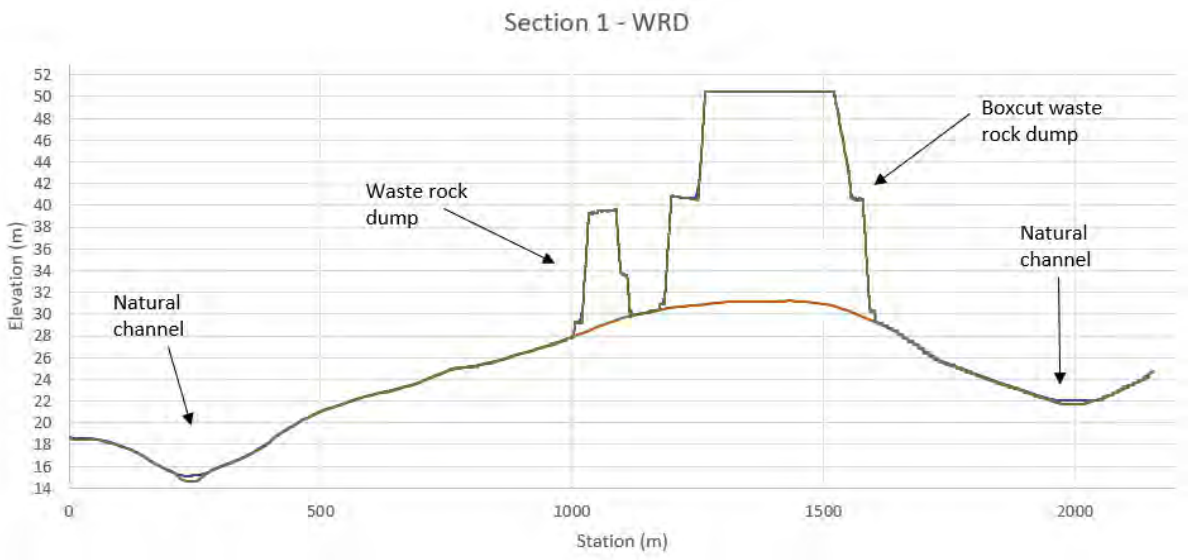


Figure 32. Cross-section 1 through waste rock dump showing pre-mine and mine scenario water depths for the 1%AEP event

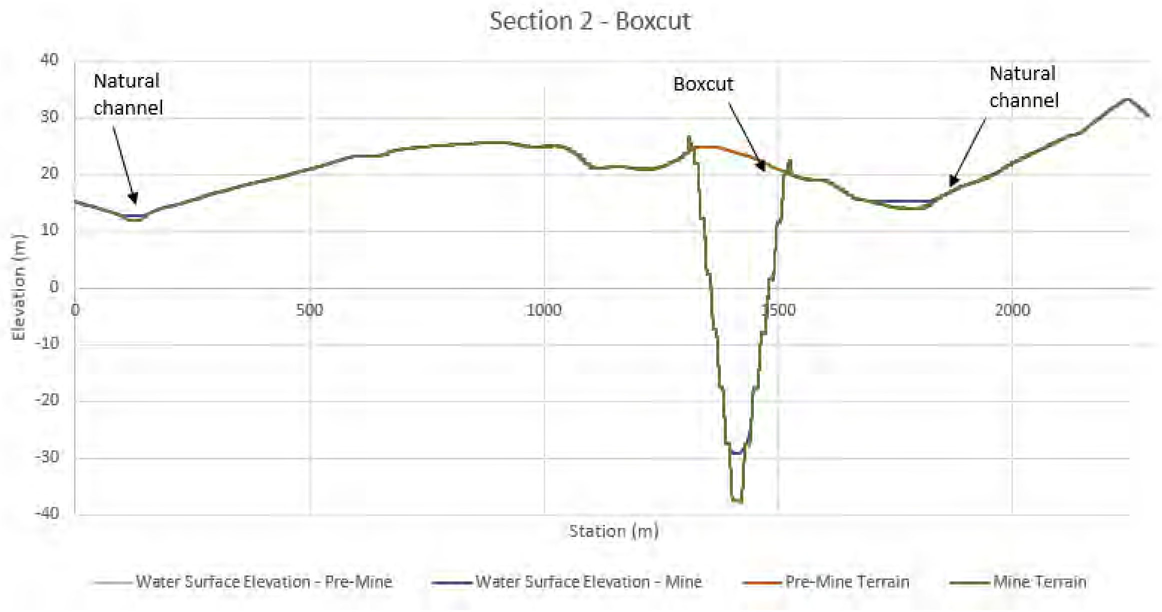


Figure 33. Cross-section 2 through boxcut showing pre-mine and mine scenario water depths for the 1%AEP event

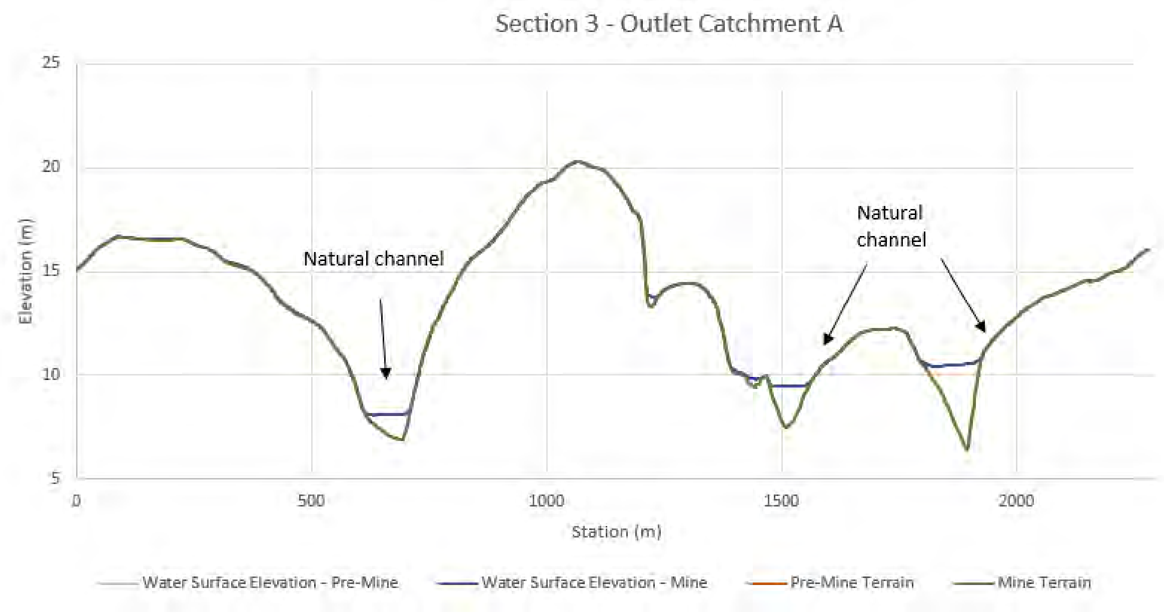


Figure 34. Cross-section 3 near catchment A outlet showing pre-mine and mine scenario water depths for the 1%AEP event

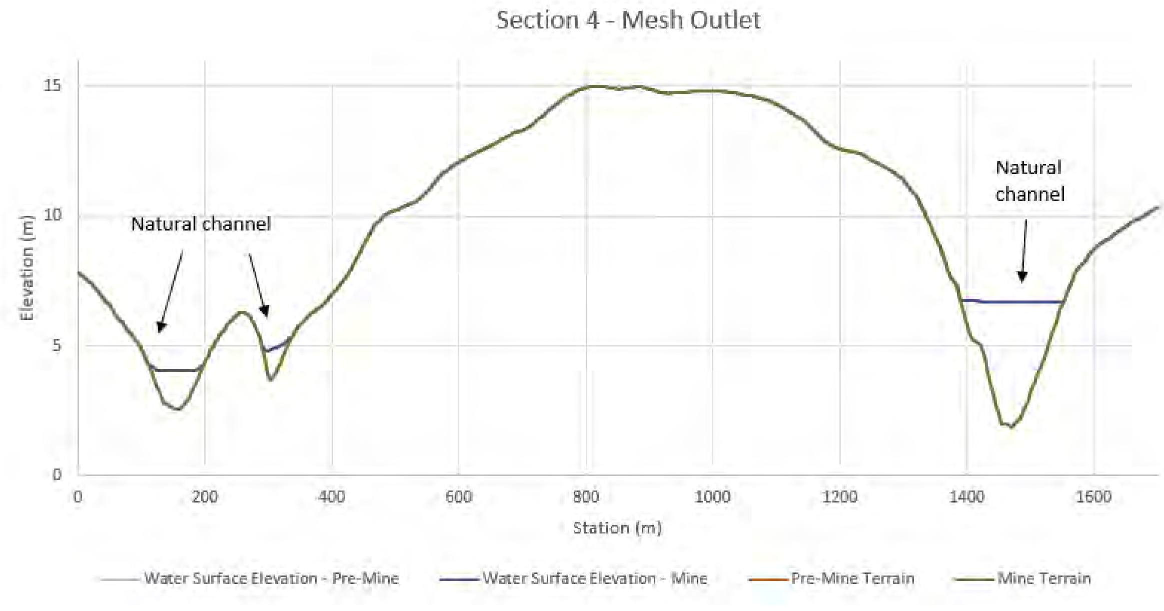


Figure 35. Cross-section 4 near mesh outlet showing pre-mine and mine scenario water depths for the 1%AEP event

6 Summary

Hydrologic modelling with HEC-HMS for wet, average and dry rainfall years showed very little difference between the pre-mining and mining conditions. The largest change was a 2% decrease in discharge for the mining condition from catchment B. For catchment A, the decrease in discharge was around 1% for the mining condition. The decreased discharge for the mining condition results from applying the assumption that all rain on the site is retained in sediment ponds and mine site dams. There is no impact on environmental flows.

The maximum inflow into the Boxcut is 16420 m^3d^{-1} for a high rainfall scenario, 7780 m^3d^{-1} for the average rainfall scenario and 6920 m^3d^{-1} for the low rainfall scenario. On average, the inflows into the boxcut during the high, average and low rainfall years are 440 m^3d^{-1}, 270 m^3d^{-1} and 157 m^3d^{-1} respectively. Most of this inflow is caused by direct rainfall on the boxcut. Very little inflow occurs from upstream catchments.

For three-year rainfall scenarios, the maximum water stored in the boxcut is 203 000 m^3 for the high rainfall scenario, 120 830 m^3 for the average rainfall scenario and 74 660 m^3 for the low rainfall scenario. For the high rainfall scenario, the maximum water level rises to 31.3 above the boxcut base level. The maximum water depth for the average and low rainfall scenario is 25.3 m and 21.0 m.

Flood inundation modelling indicated that there is little difference in inundation between pre-mining and mining conditions apart from some rainfall being stored in the boxcut. For floodplain inundation, further downstream, there is negligible difference between pre-mining and mining conditions.

Flood hazard mapping showed no increased risk to humans, wildlife or livestock for the mining condition. Flood hazard is less post-mining because more water is retained on site, slightly reducing peak flow downstream. The only risk from surface water to the mining operations is through direct rainfall. Groundwater inflow has not been considered in this study.

7 References

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Appendix A – HEC-HMS Models

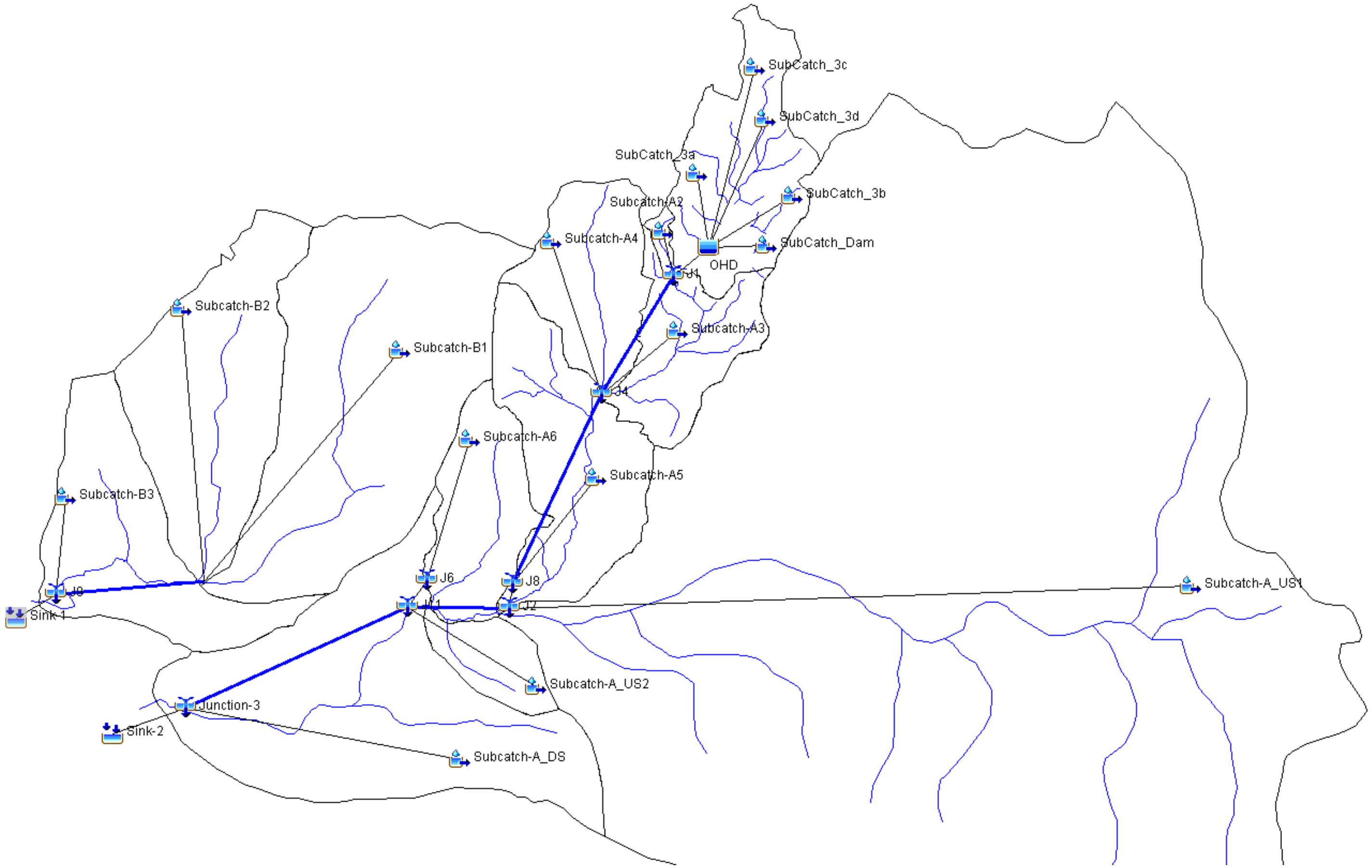

Figure 36. Pre-mining HEC-HMS Model

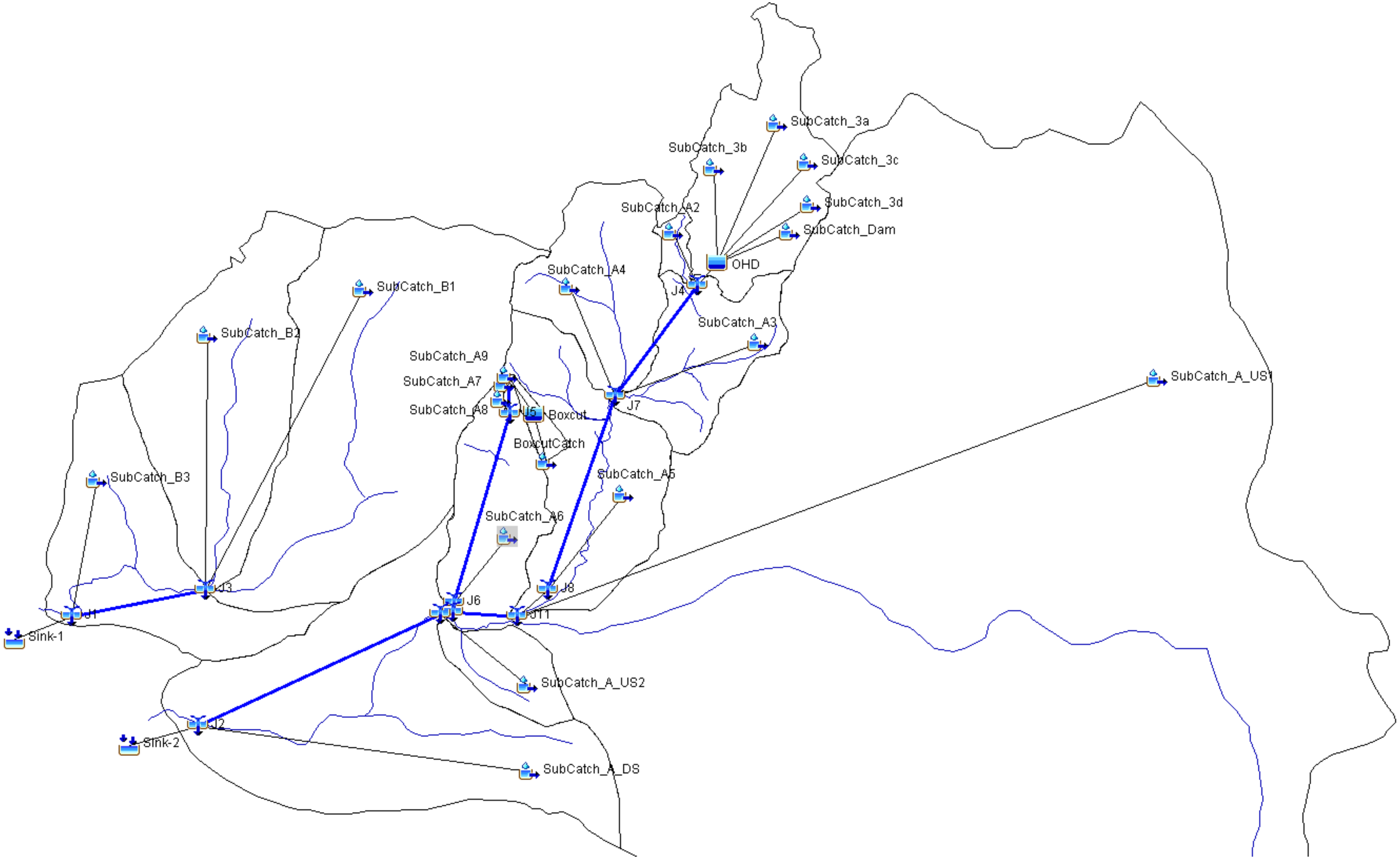

Figure 37. Mining scenario HEC-HMS model

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Description	Author	Checked by	Approved for Issue		
			Name	Signature	Date
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Revision 1	Ken Evans		Ken Evans		
Final	Ken Evans	Ken Evans	Ken Evans	KG Evans	22/04/2020