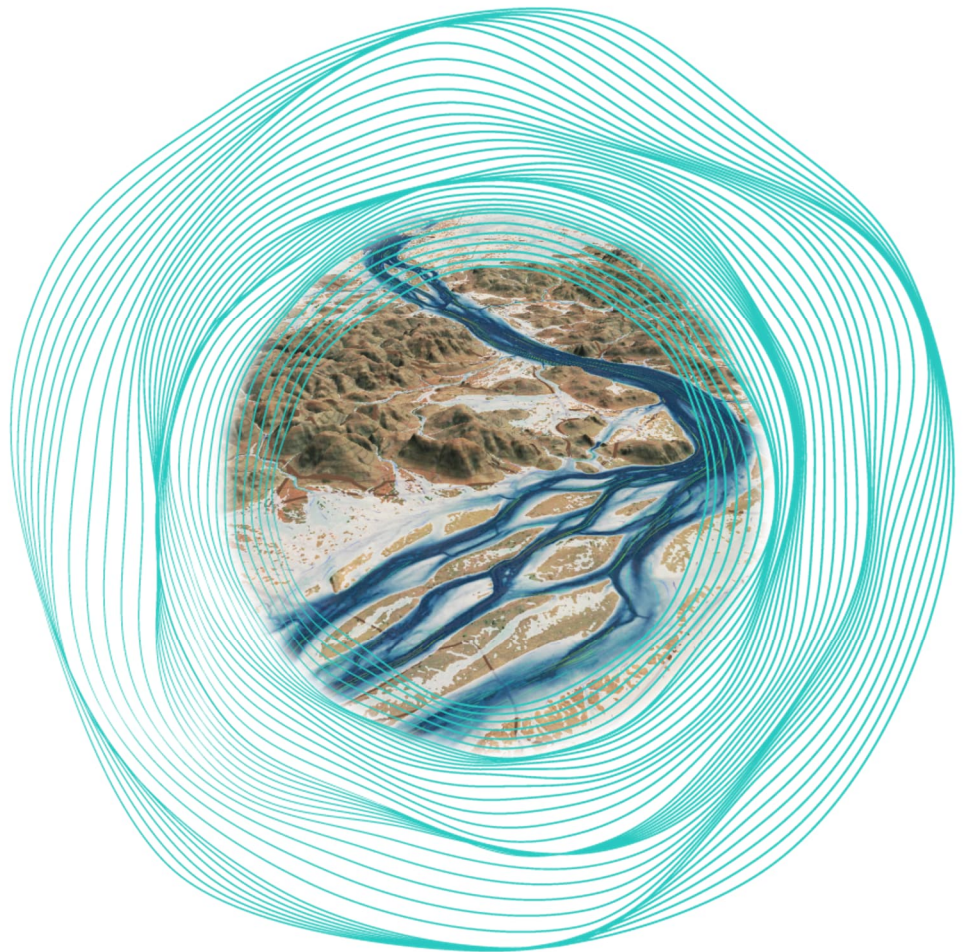


AZURE MINERALS

Andover Lithium Baseline Hydrology Study

Final Report

Document no. Rev 0: REP-HYD-0001



14 February 2024

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Synopsis

A baseline hydrological assessment of the Andover Project (The Project) was required to develop an understanding of surface water behaviour within and surrounding The Project area. The study has been undertaken in support of regulatory approval submissions and to allow for conceptual mine planning development. The proposed Andover Project is located immediately south of the town of Roebourne and 35 km southeast of Karratha. This report provides a summary of the baseline hydrological assessment works including site characteristics, design event hydrology and hydraulic modelling results as well as detailed recommendations for further works.

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PROJECT 311012-02075 - REP-HYD-0001: Andover Lithium Baseline Hydrology Study - Final Report

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Executive summary

The Andover Project (The Project) is located in the West Pilbara region of Western Australia, immediately south of the town of Roebourne and 35 km southeast of Karratha.

Nickel-focused exploration has previously discovered several significant bodies of nickel, copper and cobalt sulphide mineralisation with two deposits drilled to Mineral Resource Estimate status. Azure has also since recognised the potential for Andover to host significant lithium mineralisation. To aid in development of the nickel and lithium resources and associated regulatory body submissions, baseline environmental studies are required. This study details the baseline hydrologic (surface water) setting of The Project.

Hydrologic and hydraulic modelling has been undertaken for The Project in accordance with ARR2019 (Ball et al., 2019), the latest industry guidance on the derivation of hydrological estimates and flood risk. The assessment has used a combination of RORB rainfall runoff modelling and TUFLOW direct rainfall modelling to estimate the hydrological and resultant hydraulic conditions across The Project area using data obtained from several sources, including key information from Water Corporation relating to Harding Dam.

The assessment identified that The Project is in a hydrologic setting that is potentially subject to inundation from a number of sources:

- Regional catchment flooding associated with the Harding River. This results in significant flow rates within the Harding River mainstream which bisects the lithium target area and has prolonged durations of flow.
- Local catchment flooding associated with the various headwater areas that typify the project site. These catchments and associated minor creek systems show a quicker response time and hence are dominated by shorter duration, high intensity events (like those typically associated with convective thunderstorm activity).
- Storm tides up to the 1% AEP event have been predicted to not impact on design flood levels within the Harding River mainstream at the lithium target area. However, storm tides may impact on any future infrastructure proposed in the northern extent of tenement E 47/4701, which is located on the periphery of the intertidal zone.
- Peak flow predictions from Harding Dam are subject to the adopted dam level at the onset of the design storms. This study has used the commonly adopted approach of assuming the dam is at FSL at the onset of the design storms and hence the peak flows detailed in this study for the Harding River mainstream could be considered slightly conservative.

Future climate sensitivity analysis for the 2050 design horizon has predicted that:

- Peak flow rates are predicted to increase through The Project due to increase rainfall intensity and hence increased flood risk is evident.
- Peak flow rates in Harding River at the lithium target area are predicted to increase between 13% (2050 RCP4.5 scenario) and 16% (2050 RCP8.5 scenario), with peak flood levels predicted to increase between approximately 240 mm and 310 mm respectively.

The following recommendations are made regarding the baseline hydrology works undertaken in this study:

- It is recommended that detailed LiDAR topographic data is collected for The Project and ensure the collection extent extends a sufficient distance upstream (to an area adjacent to just upstream of the lore grounds, where the Harding River becomes unconstrained) to better define waterway topographic variation and confirm bifurcation flow split estimates.

- High resolution hydraulic modelling will be required for the headwater areas associated with the project target areas to accurately define hydraulic behaviours in these smaller creek systems (and allow for accurate derivation of flood risk management features and definition of design levels for proposed infrastructure).
- Should the project adopt an open-pit approach to resource extraction, appropriate offsets from the Harding River mainstream should be maintained, including allowance for appropriate flood protection bund elevations and batters.
- Consideration and early planning should be given to mine closure planning and associated design flood standard requirements. Typical regulatory mine closure flood standards are extreme events and early consideration is key to allow for appropriate planning in terms of pit shell design (in the case of open cut operations) and appropriate material classification and stockpiling.
- Appropriate design freeboards should be derived to inform the project basis of design considering hydraulic and hydrologic model parameter uncertainty and climate non-stationarity.

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Acronyms and abbreviations

Acronym / Abbreviation	Meaning / Definition
1D	One-dimensional
2D	Two-dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
ARR1987	Australian Rainfall and Runoff (1987)
ARR2019	Australian Rainfall and Runoff (2019)
BoM	Bureau of Meteorology
BG	Bridge Geometry
CL	Continuing Loss
DEM	Digital Elevation Model
DTM	Digital Terrain Model
DSM	Digital Surface Model
DWER	Department of Water and Environmental Regulation
EGM96	Earth Gravitational Model 1996
ESTRY	TUFLOW hydraulic model 1D solver
FSL	Full Supply Level
GDA94	Geocentric Datum Australia 1994
GDA2020	Geocentric Datum Australia 2020
GL	Gigalitre
GTSMR	Revised Generalised Tropical Storm Method
HAT	Highest Astronomical Tide
ICSM	Intergovernmental Committee on Surveying and Mapping
IFD	Intensity Frequency Duration
IL _B	Burst Initial Loss
IL _S	Storm Initial Loss
km	Kilometre
km ²	Square kilometre
m	Meters
mAHD	Meters Australian Height Datum (elevation)
m ³ /s	Cubic meters per second
MGA	Map Grid of Australia
MSL	Mean Sea Level
MRWA	Main Roads Western Australia
NWCH	North West Coastal Highway
RCP	Representative Concentration Pathway
RORB	Runoff Routing Burroughs (rainfall-runoff hydrology modelling software)
TUFLOW	Hydraulic modelling software
WMS	Web Mapping Service
WPWSS	West Pilbara Water Supply Scheme

Terminology

This report uses the terminology Annual Exceedance Probability (AEP) to define the likelihood of design flood events. Average Recurrence Interval (ARI) was previously used to define the probability of design flood events (ARR1987). In the 2016 and subsequent 2019 revisions of Australian Rainfall and Runoff (ARR2019), the terminology to define event probabilities was changed to AEP. This new terminology meets the requirements of Engineers Australia's National Committee on Water Engineering and provides clarity of meaning, technical correctness and practicality and acceptability.¹

To aid in non-technical reader comprehension and understanding, the event equivalencies between ARI, AEP as well as the nomenclature adopted for this report is presented below.

Annual Exceedance Probability (AEP)	Average Recurrence Interval (ARI)	Nomenclature adopted in this report
50%	1.4 years	50% AEP
20%	4.5 years	20% AEP
10%	9.5 years	10% AEP
5%	~20 years	5% AEP
2%	~50 years	2% AEP
1%	~100 years	1% AEP
0.2%	~500 years	1 in 500 AEP

¹ Australian Rainfall and Runoff Revision Project <http://book.arr.org.au/s3-website-ap-southeast-2.amazonaws.com/>

1. Introduction

1.1 Project background

The Andover Project (The Project) is located in the West Pilbara region of Western Australia, immediately south of the town of Roebourne and 35 km southeast of Karratha.

Nickel-focused exploration has previously discovered several significant bodies of nickel, copper and cobalt sulphide mineralisation with two deposits drilled to Mineral Resource Estimate status. Azure has also since recognised the potential for Andover to host significant lithium mineralisation, with the identification of abundant spodumene-bearing, lithium-rich pegmatites within an area of 9 km (east-west) and up to 5 km (north-south). Surface sampling returned numerous high grade lithium assays between 1% to 5% lithium oxide.

To aid in development of the nickel and lithium resources and associated regulatory body submissions, baseline environmental studies are required. This study details the baseline hydrologic (surface water) setting of The Project and its immediate surrounds, to support the approvals process as well as develop datasets to aid in conceptual mine planning.

This report provides a summary of the baseline hydrological assessment works including site characteristics, design event hydrology and hydraulic modelling results as well as detailed recommendations for further works as the project matures.

1.2 Scope of works

A summary of the scope of works for this baseline hydrologic assessment is as follows:

- Review the project extents, existing publicly available hydrological data and surrounding potential sensitive receptors that would inform the development of the hydrological and hydraulic models and model boundaries.
- Undertake rainfall-runoff modelling of the Harding River catchment (inclusive of Harding Dam) to determine design flood hydrographs entering the project area.
- Undertake hydraulic modelling to assess the baseline hydraulic regimes of the project area. The extent of the model will consider any proposed infrastructure and any sensitive surface water receptors such that they can be used to inform future surface water impact assessments.
- Undertake calibration/verification of the hydrological and hydraulic models, or parameters thereof within the models, where data exists.
- Conduct sensitivity analysis on key inputs or parameters within the models, such as Manning's 'n' roughness, downstream boundary conditions and climate change influences etc, to assess and quantify changes to design flows.
- Flood inundation mapping for the 1 in 500, 1%, 5% and 20% AEP design events.
- Develop a baseline hydrological assessment report (this report) documenting in detail all data, methods, parameters, and relevant findings of the assessment, including recommendations for further works.

The general Study Area is presented in Figure 1-1.

Andover Lithium Baseline Hydrology Study

Figure 1-1: Study Area

Legend

- Exploration and miscellaneous licences
- Pending exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/Tracks
- Water Pipeline

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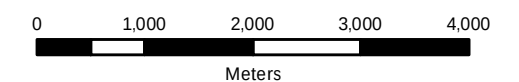
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2. Data

A summary of the key data provided by Azure Minerals or obtained from the public domain and used in this assessment are presented in Table 2-1.

Table 2-1: Summary of data used to inform this assessment

Data / Information	Description	File / Format	Source
Terrain			
Digital Terrain Model (DTM)	1 m rectilinear resolution orthophoto-derived terrain model of the proposed mine area (tenements) and surrounds	AN_DTM_1m_EPSG7850.TIF [MGAz50 GDA2020, meters Australian Height Datum (mAHD)]	Azure Minerals
Digital Terrain Model (DTM)	5 m rectilinear resolution orthophoto-derived terrain model of the wider study area	Roebourne_2356_Jul_2014_5m_DEM_GDA2020.TIF (MGAz50 GDA2020, mAHD)	Landgate
Digital Elevation Model (DEM)	1 arc-second rectilinear resolution satellite-derived, hydrologically enforced DEM of the project's regional setting	TIFF file from online portal (MGAz50 GDA2020, MSL)	Intergovernmental Committee on Surveying and Mapping (ICSM)
Aerial Imagery			
High resolution aerial imagery	100 mm resolution areal imagery of the project area	A7154_Andover_100mm_RG BI_UCEP100_MGA2020z50_22-Mar-2021.ecw	Azure Minerals
Public domain aerial imagery	Google satellite imagery ESRI satellite imagery	XYZ tile Web Mapping Service (WMS)	www.google.cn server.arcgisonline.com
Remote Sensing			
Satellite Data	Sentinel-II satellite data from the European Space Agency	Multiple sensor files in georeferenced .jp2 format	https://dataspace.copernicus.eu/browsers/
Hydrologic Data			
Streamflow data	Department of Water and Environmental Regulation (DWER) streamflow data for Marmurrina Pool and Cooya Pooya gauge sites	Comma delimited tabular format	Department of Water and Environmental Regulation
Rainfall data	DWER & Bureau of Meteorology (BoM) for sites within and surrounding the Harding River catchment	Comma delimited tabular format	Department of Water and Environmental Regulation
Dam level data	Harding Dam water level logger	Comma delimited tabular format	Water Corporation via BoM online portal
Reports			
Roebourne Townsite Stormwater and Flood Management Plan	A Stormwater and Flood Management Plan undertaken by Essential Environmental (2013) for the Shire of Roebourne	RSP-StormwaterandFloodManagementPlan.pdf	www.karratha.wa.gov.au
Harding Dam Flood Study Update 2022	Water Corporation of Western Australia hydrologic assessment of Harding Dam	R3516 Harding Dam Flood Study Update 2022 Memo.docx	Water Corporation

3. Catchment characterisation

3.1 Project and catchment setting

The Andover project is located within the Harding River catchment, which forms part of the Port Hedland Coast drainage basin.

The headwaters of Harding River are situated in the Chichester Ranges, with the dominant flow direction of the various creek systems being northward toward Lake Poongkaliyarra (commonly known as Harding Dam) and ultimately the Roebourne township and the flat intertidal zone which dominates the coastal fringe. Headwater elevations associated with tributaries in Millstream Chichester National Park approach 350-400 m (EGM96). The catchment setting is presented in Figure 3-1.

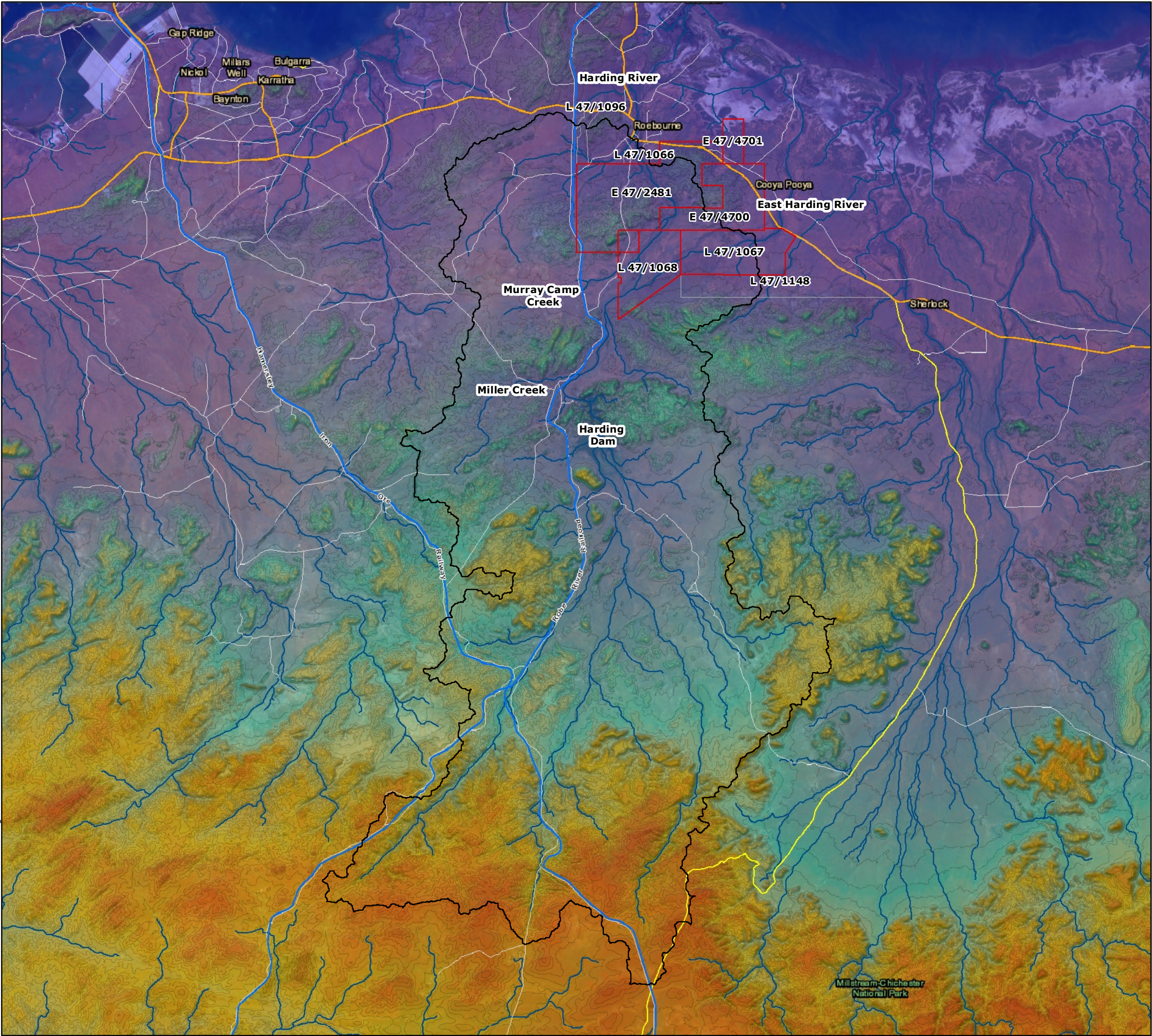
The majority (1,068 km² or approximately two-thirds) of the total Harding River catchment drains to the main hydrologic control of the catchment, Harding Dam. The construction of Harding Dam began in February 1982 and was officially commissioned in May 1985. The dam has a total storage capacity of 63.8 GL at Full Supply Level (FSL) with an additional flood routing storage (the storage available between the spillway crest and top of embankment) of 874.2 GL. It is noted that ongoing accretion of alluvium in the floor of the dam (mobilised during more significant flood events) will likely have resulted in minor reductions to these values since the dam was commissioned.

Given the high annual variability of rainfall (and hence variable water levels in the dam and available storage below the spillway), peak flows from the upper catchment may be stored completely (in the case of minor flows and dam levels being below FSL at the time of the rain event) or are attenuated significantly due to a combination of filling the available flood storage and flood routing effects. This ultimately reduces peak flow rates entering the lower Harding River system when compared to the natural (pre-dam) system. Tropical or ex-tropical cyclone events are likely to be the main drivers responsible for more significant Harding River mainstream flood events, as they provide the quantum and duration of rainfall required to both satiate the available storage and significant flood routing effects of Harding Dam, as well as satisfy the meteorological conditions required to maximise catchment response to rainfall in the larger catchment areas (both above and below the dam).

Below Harding Dam, a number of major (e.g., Miller Creek) and minor contributing tributaries contribute further runoff to the Harding River mainstream. The most significant feature of the lower Harding River system that impacts the project site is the bifurcation of Harding River located approximately 8 km upstream of the Andover tenement boundary, with floodwaters diverging between Harding River (flowing north to the project site and Roebourne township) and East Harding River (flowing northeast to the uninhabited coastal fringe and intertidal zone).

Locally within the Andover project, well defined local watercourses are evident due to geologic features which typify the project area, namely steep well incised hillslopes. The size of these local catchments is typically small (often less than 1 km²) and as such catchment response to rainfall in these local catchments is expected to be fast, with short duration high intensity

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Andover Lithium Baseline Hydrology Study

**Figure 3-1:
Harding River Catchment Setting**

Legend

- Harding River Catchment (to Project)
- Exploration and miscellaneous licences
- Pending exploration and miscellaneous licences
- Waterway
- 10 m Ground Surface Contour

Shuttle Radar Topography Mission DEM

Value

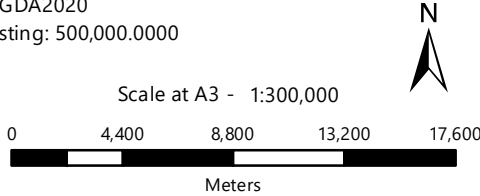
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storms (such as that associated with convective thunderstorm activity) the likely driver of peak catchment response to rainfall.

Given the mix of meteorological mechanisms and catchment types contributing to the project area, there are two distinct forms of fluvial inundation risk to the project in the form of 'regional' catchment flooding (associated with Harding River mainstream flows) and 'local' catchment flooding, associated with the well-defined local catchments within the project area.

3.2 Climate

The Pilbara climate is characterised by very hot summers, mild winters and low and variable rainfall (Sudmeyer, 2016). The BoM Köppen climate classification system (Stern et al., 2000) defines the Harding River catchment as either hot persistently dry grassland (upper Harding River catchment) or hot persistently dry desert (lower Harding River catchment). Vegetation is typified by Mulga shrublands and spinifex grasslands (with some tussock grasslands and halophytic shrublands) (Tille, 2006).

The average annual rainfall for the water year October to September is 302.2 mm using a combined Roebourne (station ID: 04035) and Roebourne Aero (station ID: 04090) gauge record (123 years of combined data). Rainfall at the site occurs predominantly in the summer wet season (approximately January to March) from passing tropical and ex-tropical cyclones and low-pressure systems, with localised isolated convective thunderstorm activity also common. Tropical cyclones are responsible for most of the extreme rainfall events and generate 25–34% of the total annual rainfall near the Pilbara coast (Charles et al., 2015).

Southern cold fronts can also extend north to the Pilbara in late autumn, winter, and early spring, bringing rains to the region, most commonly to western parts. This is reflected in the minor uplift in average monthly rainfall totals in the months of May and June. However, the northward extent of fronts shows a long-term decreasing trend in recent decades (Charles et al., 2015).

There is some indication that the trends in total rainfall are more related to trends in high intensity rainfall (particularly 99th percentile daily rainfall) than the number of rain-days or the average rain-day intensity (Charles et al., 2015). As such, annual rainfall is highly variable and extended periods of low rainfall are common. This is supported by BoM's index of variability, with the variability of annual rainfall classified as high for the majority of the catchment, whilst variability in the wettest months [January to March, typically producing approximately 61% of average annual rainfall (BoM)] reaches extreme classification (>2) in the lower catchment areas.

The variability of rainfall is demonstrated in Figure 3-2 for the combined Roebourne and Roebourne Aero gauge record. As suggested by Charles et al (2015), in some particularly dry years, annual daily maximum rainfalls can inform a large portion of the annual total (e.g., 2002). The gauge record presents a general trend from a drier to wetter climate over the 20-year period 1990 to 2010, with drier than usual periods in the 1970s and 1980s and wetter than usual periods throughout the 1960s and 2000s. The start of the 2010s signals a recent trend back to drier than average conditions with the 10-year moving average dropping back below the long-term average annual rainfall.

Recorded annual daily maxima which are a reasonable meteorological indicator of a likely flood-inducing event seemingly remain more consistent, albeit following similar trends, further highlighting the link between discrete intense rainfall events and the annual totals.

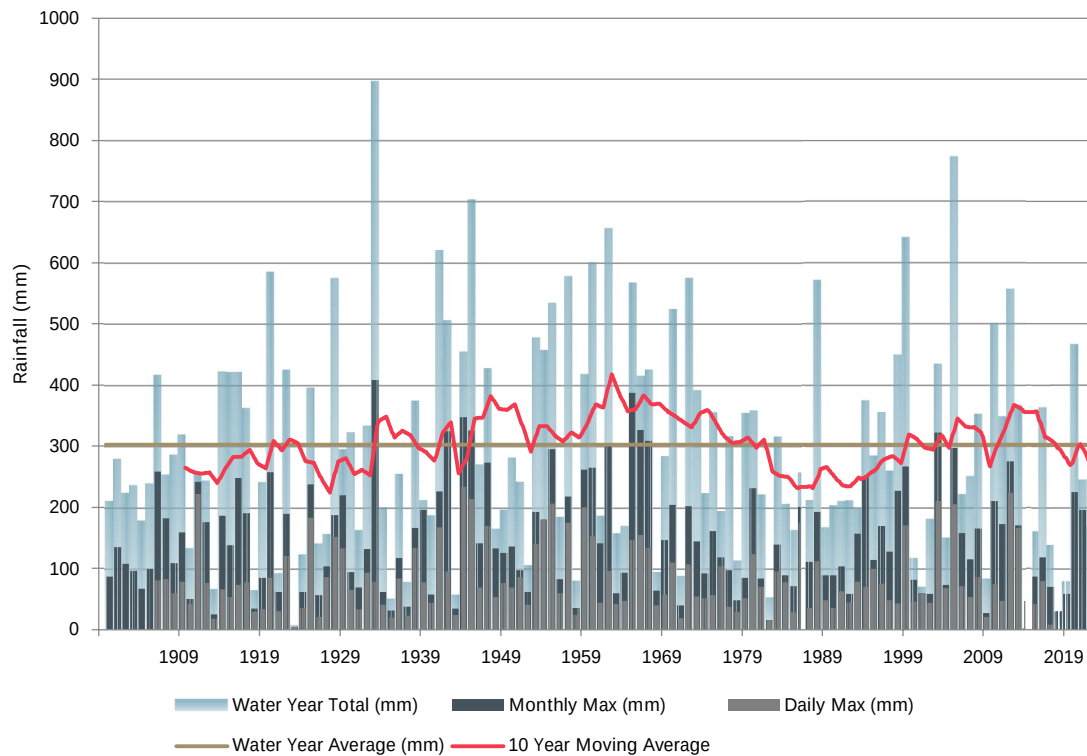


Figure 3-2: Combined Roebourne & Roebourne Aero rainfall gauge rainfall history maximum daily, monthly and annual totals (water year)

Rainfall, temperature and evaporation data for Roebourne are presented in Figure 3-4.

3.3 Soils

The highest probability soils mapping from Department of Primary Industries and Regional Development (2019) was reviewed for the catchment in order to gain an understanding of likely surface geomaterials. This helps inform expected infiltrative capacity, a component of empirical loss estimation (discussed in Section 4.11).

The mapping suggests soils within the Harding River catchment are variable, with classifications ranging from 'stony soils' which dominate the catchment headwaters and hillslopes, trending to 'shallow loams' and 'clays shallow loamy duplexes' in the valley settings. Below Harding Dam, 'stony soils' in headwater areas still dominate the landscape whilst sands are predicted in the Harding and East Harding River valleys suggesting more significant alluvial deposits and potential for sub-surface storage and flows and potentially higher transmission losses. These soil types and accretion or more significant alluvial deposits in the lower reaches are consistent with surrounding catchments and the general regional setting.

An example of the 'stony soil' types observed in the site visit in December 2023 is presented in Figure 3-3, whilst the highest probability soils mapping from Department of Primary Industries

and Regional Development (2019) for the catchment and surrounding regions is presented in Figure 3-5.



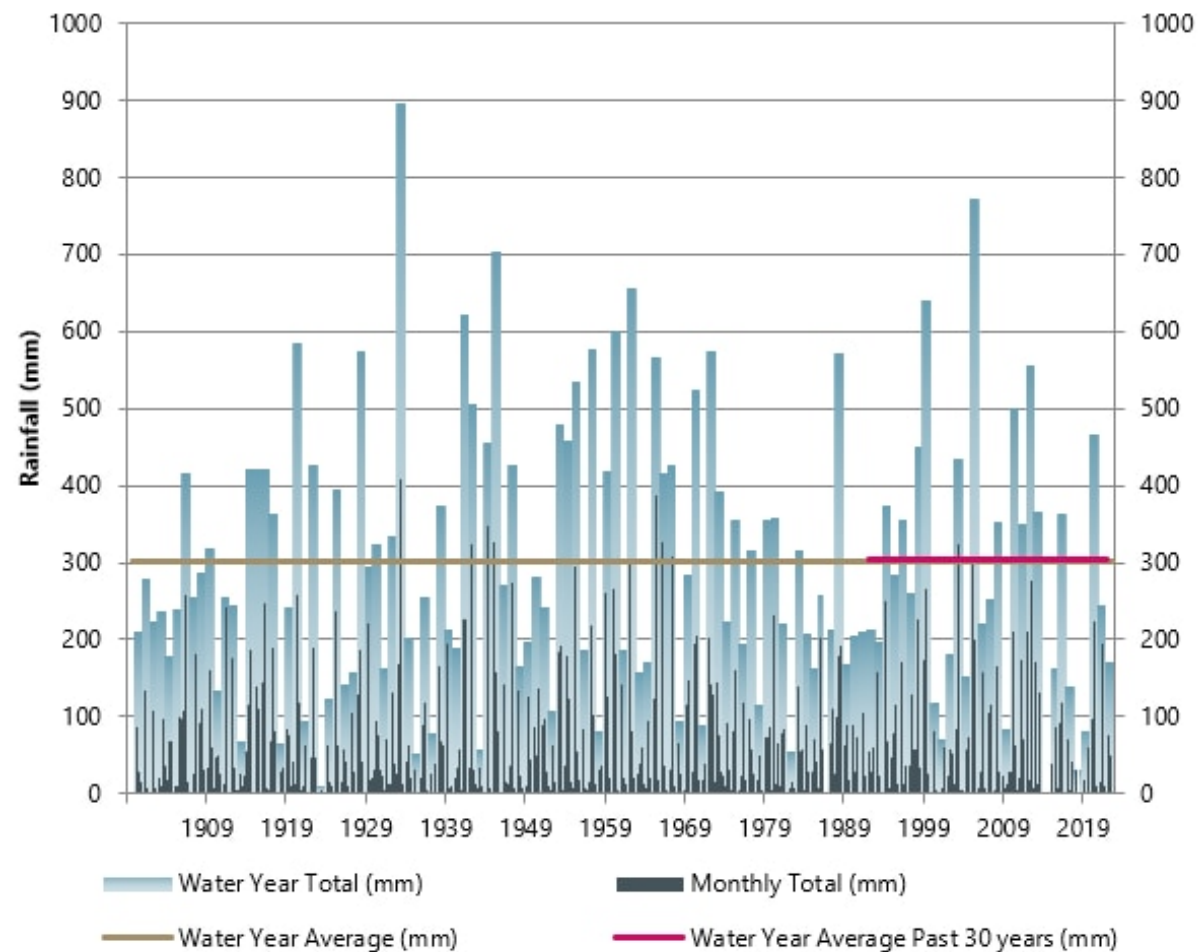
Figure 3-3: Common Pilbara hillslope surface geomaterials ('stony soils') as observed on site

3.4 Infrastructure

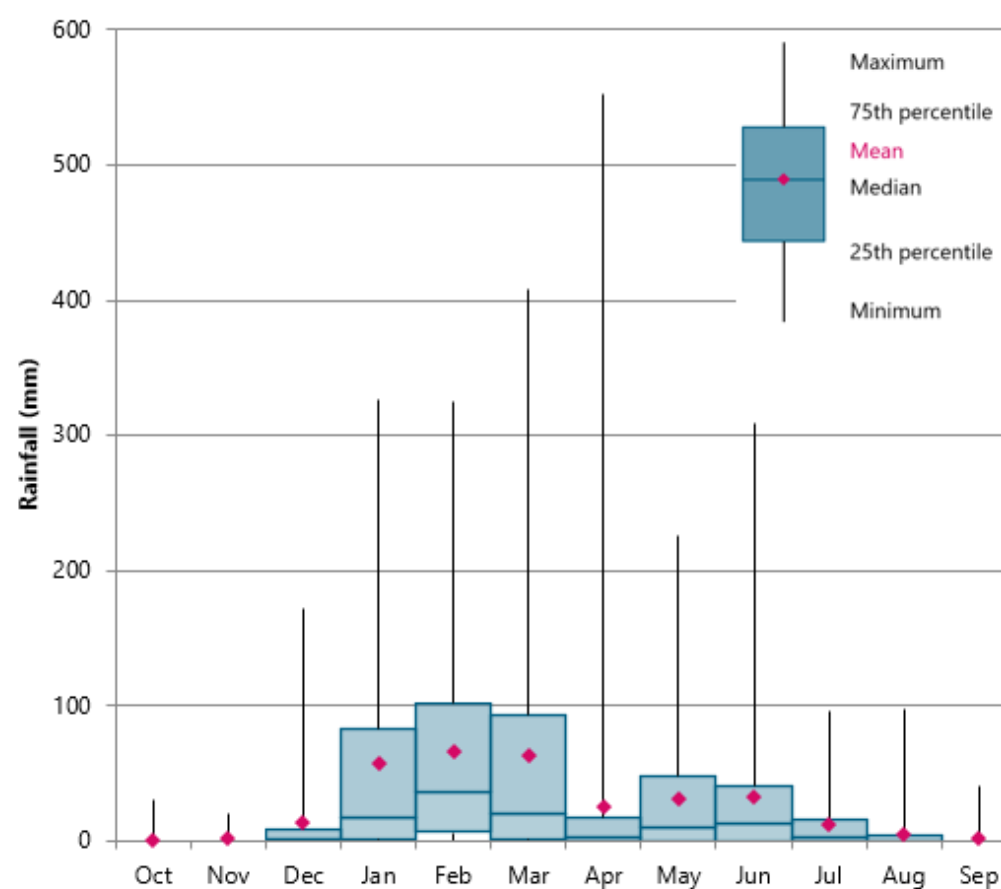
The major infrastructure (and associated asset owner) located within the Study Area is noted as:

- The North-West Coastal Highway (Main Roads WA)
- Heavy Haul Rail line (Rio Tinto Iron Ore)
- The Roebourne township and associated local infrastructure (City of Karratha)

Water Year and Monthly Rainfall Data



Monthly Box Plot - Water Year



Andover Lithium Baseline Hydrology Study

Figure 3-4 Climate Data

Legend

- Climate Data Sites
- Exploration and miscellaneous licences
- Pending exploration and miscellaneous licences

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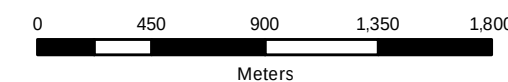
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

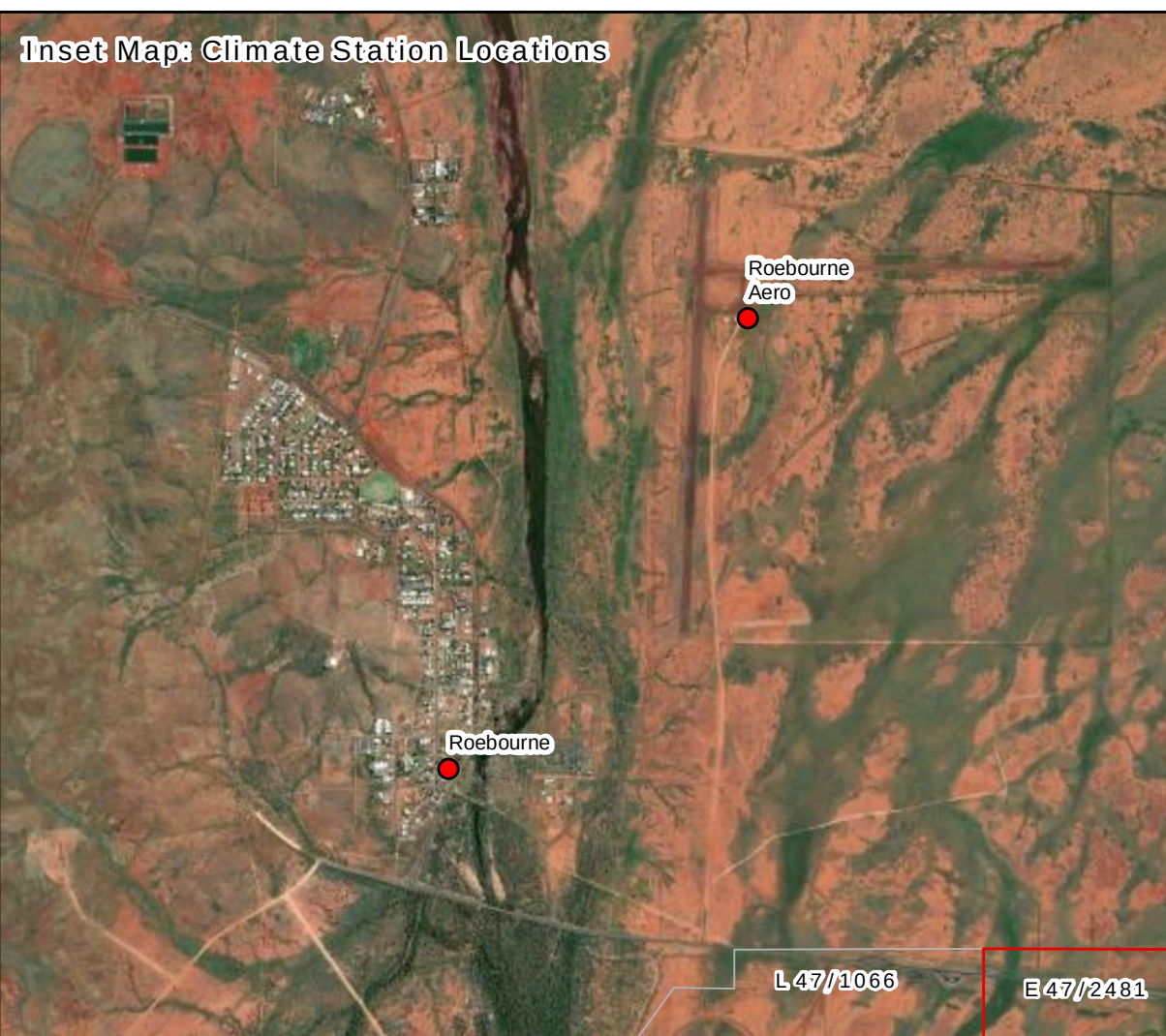
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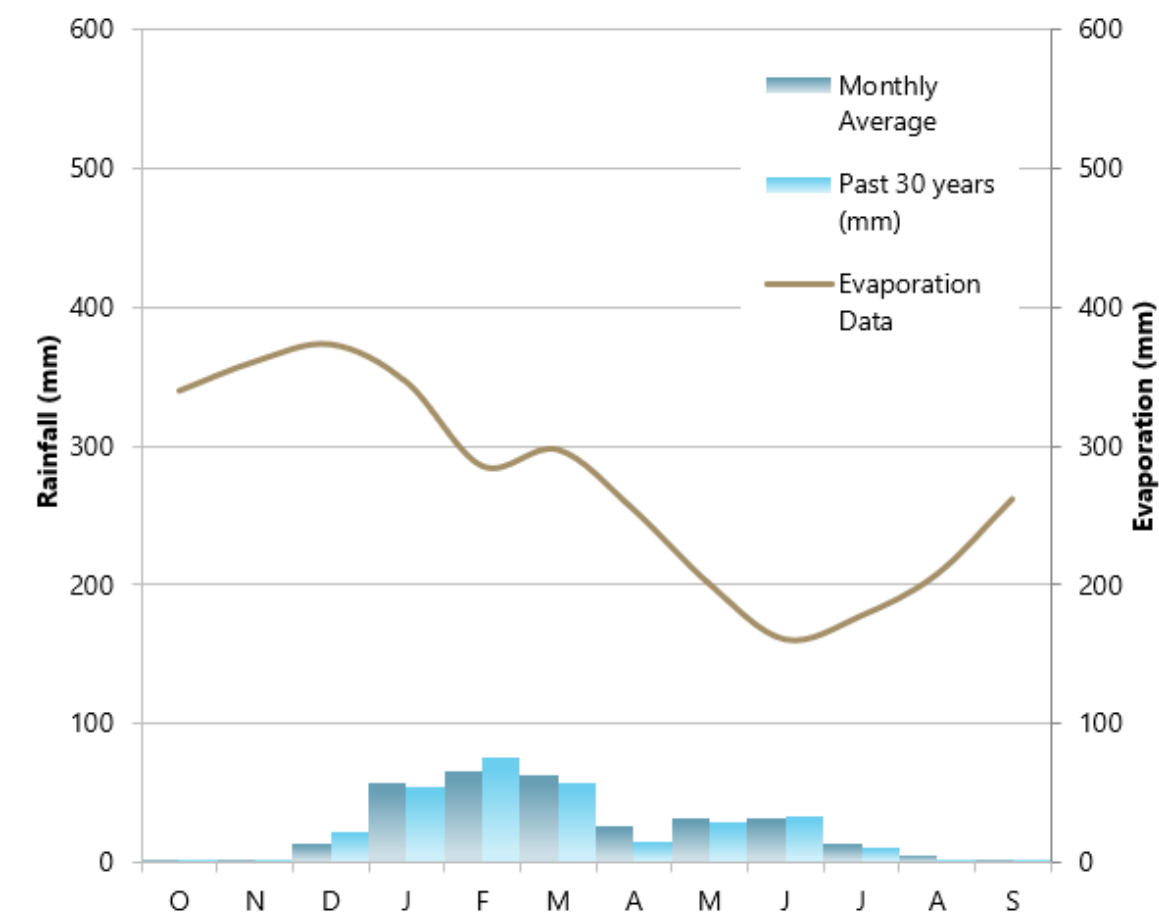


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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Inset Map: Climate Station Locations



Average Monthly Rainfall and Evaporation Data - Water Year



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Figure 3-5: Regional Soil Mapping

Legend

- Harding River Catchment (to Project)
- Exploration and miscellaneous licences
- Pending exploration and miscellaneous licences
- Waterway alignment

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Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:300,000

0 4,400 8,800 13,200 17,600
Meters



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Legend

- No Information, not cropping soil (700, 701, 703, 704)
- Saline wet (100, 101, 102, 104, 105, 702)
- Semi-wet soils (103)
- Shallow sand (420, 422, 423, 424)
- Shallow loam (520, 521, 522, 523)
- Gravels (300, 301, 302, 303)
- Shallow sandy duplexes (404, 406, 408)
- Alkaline shallow duplex (402, 503)
- Deep sandy duplexes (400, 401, 403, 405, 407, 409)
- Deep loamy duplexes and earths (505, 506, 540, 541, 543, 544, 545)
- Calcareous loamy earths (542)
- Coloured sands (441, 445, 446)
- Pale sands (440, 443, 444)
- Clays & shallow loamy duplexes (500, 501, 502, 504, 507, 508, 600, 601, 620, 621, 622)
- Stony soils (200, 202, 203, 304)
- Sandy earths (460, 461, 462, 463, 464, 465)
- Calcareous sands (421, 442)
- Self-mulching clays (602)
- Bare rock (201)

4. Rainfall-runoff model – Harding River

4.1 Background

Design flow estimates within Harding River and its major tributaries has been undertaken using a combination of rainfall-runoff modelling for the upper catchment areas (where no detailed topographic data is available) and direct rainfall modelling in the lower catchment (The Project) areas which is covered by either 1 m or 5 m resolution orthophoto-derived DEMs.

Rainfall-runoff model parameterisation (particularly design rainfall) is applicable to a single point of interest only. Hence given the large catchment, extent of the Study Area and combination of model approaches used, model parameterisation and setup has been carefully considered as well as the proposed approach to design flow estimation.

To this end, model setup and parameterisation for the Harding River mainstream flows have been developed for the reach of the Harding River which bisects the live tenement (E 47/2481) with the target lithium resource (refer Figure 1-1).

All relevant model inputs, parameters and approaches are detailed in the following sections.

4.2 Previous studies

Harding Dam is a Water Corporation of Western Australia (herein referred to as WaterCorp) asset, providing a water source for the West Pilbara Water Supply Scheme (WPWSS). The WPWSS provides water to Karratha, Dampier, Roebourne, Wickham and Point Samson.

WaterCorp were contacted at the commencement of this study to obtain relevant design aspects of the dam, as well as to gain an understanding of relevant hydrologic assessments that may have been undertaken.

WaterCorp (Sullivan, 2022) had recently undertaken a hydrologic assessment of the dam catchment as a case study forming part of the 'Climate Change R&D project'. WaterCorp supplied the following information to aid in the hydrologic assessment being undertaken in this study:

- Stage-storage information for Harding Dam.
- A combined stage-discharge curve representing the primary (60 mAHD crest) and auxiliary (65.2 mAHD crest) spillways.
- Calibrated empirical loss (Initial and Continuing Loss) and storage-discharge parametrisation estimates based on calibration to 57 years of continuous record (N.B., a combined pre and post dam flow record).
- Design flow estimates for events including and rarer than the 2% AEP.
- A memorandum summarising the assessment.

Given the extensive calibration works undertaken, the information provided by WaterCorp (Sullivan, 2022) formed the basis of the parameter selection for the model developed for this study, with further validation and checks presented in the following relevant sections.

4.3 Software

Runoff Routing Burroughs (RORB) (version 6.45) has been used to estimate the Harding River catchment rainfall-runoff response.

RORB is a general runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other channel inputs. It subtracts losses from rainfall to produce rainfall-excess and routes this through catchment storage to produce the hydrograph. The model is areally distributed, nonlinear, and applicable to both urban and rural catchments. It makes provision for temporal and areal variation of rainfall and losses and can model flows at any number of gauging stations.² RORB has been extensively used in the Pilbara, Australia and internationally to derive design flows. It is noted WaterCorp also used RORB for its internal Harding Dam hydrologic assessment.

The model (and catchment) extent as well as the nodal-network conceptualisation as well as proposed direct rainfall modelling area which represents the overall Harding River modelling approach is presented in Figure 4-1.

RORB models are characterised by a number of input parameters such as rainfall, rainfall losses, temporal patterns, areal reduction factors and pre-burst rainfall as well as two additional parameters to derive reach storage-discharge relationships. These inputs are detailed in the following sections.

4.4 Sub-catchment definition

The overall Harding River catchment contributing to the Project Area has been detailed by the definition of 35 individual sub-catchments. Sub-catchment definition was based on the only available dataset that covered the entire catchment area, namely the hydrologically enforced Shuttle Radar Topography Mission (SRTM-H) DEM. Sub-catchment areas are presented in Table 4-1 and Figure 4-1.

Table 4-1: Harding River RORB model sub-catchment areas

Sub-area ID	Area (km ²)	Sub-area ID	Area (km ²)	Sub-area ID	Area (km ²)
A	71.1	M	45.5	Y	93.3
B	70.1	N	68.4	Z	45.6
C	38.7	O	51.1	AA	19.1
D	45.3	P	42.6	AB	24.6
E	47.5	Q	61.2	AC	12.7
F	64.0	R	42.8	AD	18.6
G	37.2	S	50.6	AE	14.1
H	20.9	T	67.3	AF	22.4
I	31.9	U	10.3	AG	57.2
J	9.72	V	61.0	AH	32.1
K	65.8	W	35.6	AI	42.4
L	47.3	X	45.3	-	-

² [RORB software for runoff routing - Civil Engineering | Monash](#)

I:\Projects\31.10.12-02.075 Andover Baseline Hydro\04_GIS\06_ArcMapping\02_Report_Ph\31.10.12-02.075_F4-1_RORB_Rev0.mxd
9/02/2024 Rev: 0 ISSUED FOR INFORMATION Org: PC Chk: PC

Andover Lithium Baseline Hydrology Study

Figure 4-1:
RORB Hydrologic Model Arrangement

Legend

- Exploration and miscellaneous licences
- Pending exploration and miscellaneous licences
- RORB sub area
- RORB junction node
- RORB outlet node
- RORB storage node
- RORB sub area node
- RORB routing link
- TUFLOW hydraulic model extent

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Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:300,000

0 4,400 8,800 13,200 17,600
Meters



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



4.5 Storage-discharge parameterisation

4.5.1 Background

RORB is characterised by two critical parameters to enable calculation of its reach storage-discharge relationship. These are the exponent m , often referred to as the non-linearity parameter and the coefficient K_C , often referred to as the reach storage parameter. These parameters can have a significant impact on estimating a catchment's runoff response (both peak flow estimates and hydrograph shape). Producing accurate estimates for these parameters is therefore critical in producing accurate design flow estimation.

Importantly, accurate storage-discharge parameter estimation also aids in producing accurate empirical loss parameter estimates, as these loss parameters can often be used to compensate for inaccurate storage-discharge parameterisation when comparing peak flow estimates to FFA quantiles or through historic event calibration. For natural channels as is representative of the Study Area (besides the 'drowned' reaches associated with Harding Dam) the relationship between storage and outflow in RORB is given by:

$$S_i = \frac{k_c}{d_{av}} L_i Q_i^m$$

Where:

S_i = sub area storage (m^3)

K_C = empirical coefficient

d_{av} = average distance from each sub area to the catchment outlet (or defined 'dummy' gauging station at user-defined points of interest)

L_i = reach length

Q_i = sub-area discharge (m^3/s)

m = non-linearity parameter

4.5.2 Non-linearity parameter (m) and reach storage parameter (K_C)

The WaterCorp study for Harding Dam produced a calibrated m value of 0.85 and K_C value of 10 for the catchment area contributing to Harding Dam. As these values were derived based on calibration to 57 years of streamflow/storage level and historic rainfall information, there was considered no reasonable basis to inform a change from these values.

Due to advancements in modelling techniques and computing power, alternate methods are also available to aid in assessing and estimating K_C by using regional rain-on-grid two-dimensional (2D) modelling. However, given the availability of only regional-scale topographic data in the catchment (~30 m resolution) and considering the size of waterways within the upper Harding River catchment, this approach was not considered to provide any additional benefit or reliable information that would inform a change to the WaterCorp derived and historically calibrated K_C value.

Within the lower catchment (below Harding Dam), the dominant means of routing sub-area rainfall excess hyetographs is within the TUFLOW 2D hydraulic model (refer Section 5). As such, the accurate definition of m and K_c in these reaches is less critical. Nonetheless, review of d_{av} for the lower reaches was undertaken and the same $C_{0.85}$ equivalent K_c value was adopted for these lower reaches.

4.6 Harding Dam design information

WaterCorp (Sullivan, 2022) supplied relevant stage-storage and stage-discharge information for Harvey Dam to allow for inclusion in the developed RORB model. Inclusion of the dam storage and spillway details and associated flood routing characteristics is critical in determining accurate design flow estimates for the lower Harding River system which is heavily influence by the storage and flood routing effects of the dam on peak flows.

Figure 4-2 and Figure 4-3 detail the stage-storage and stage-discharge characteristics of Harding Dam as supplied by WaterCorp, with data also provided in tabular format for inclusion in the RORB model.

The dam was assumed to be at full supply level (a water level of 60 mAHD) at the onset of the design events to determine design outflows. This is a common, if not slightly conservative approach to design flood estimation. Based on historical water logger data (presented in Figure 4-4), the mean water level in the dam is approximately 57.25 mAHD. The impact of the assumed dam water level on peak dam outflow predictions is presented in Section 4.13.

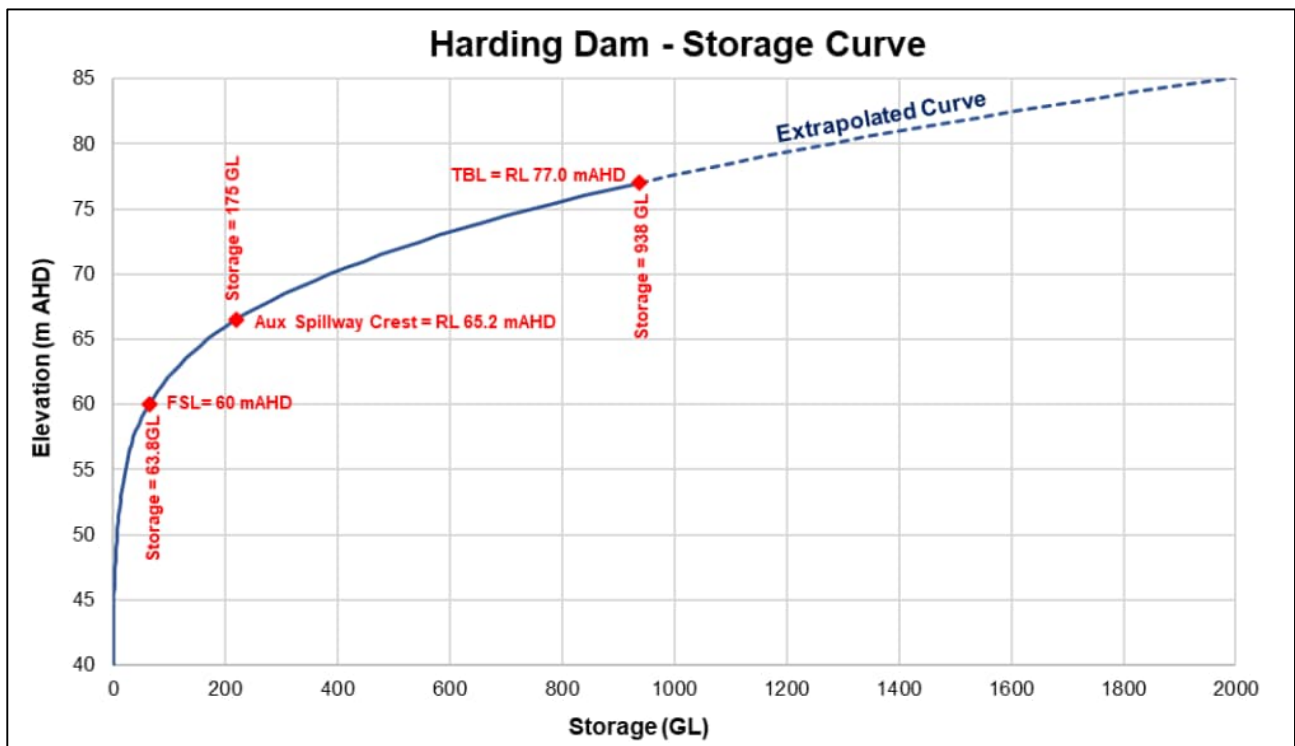


Figure 4-2: Harding Dam storage curve (Source: WaterCorp, 2022)

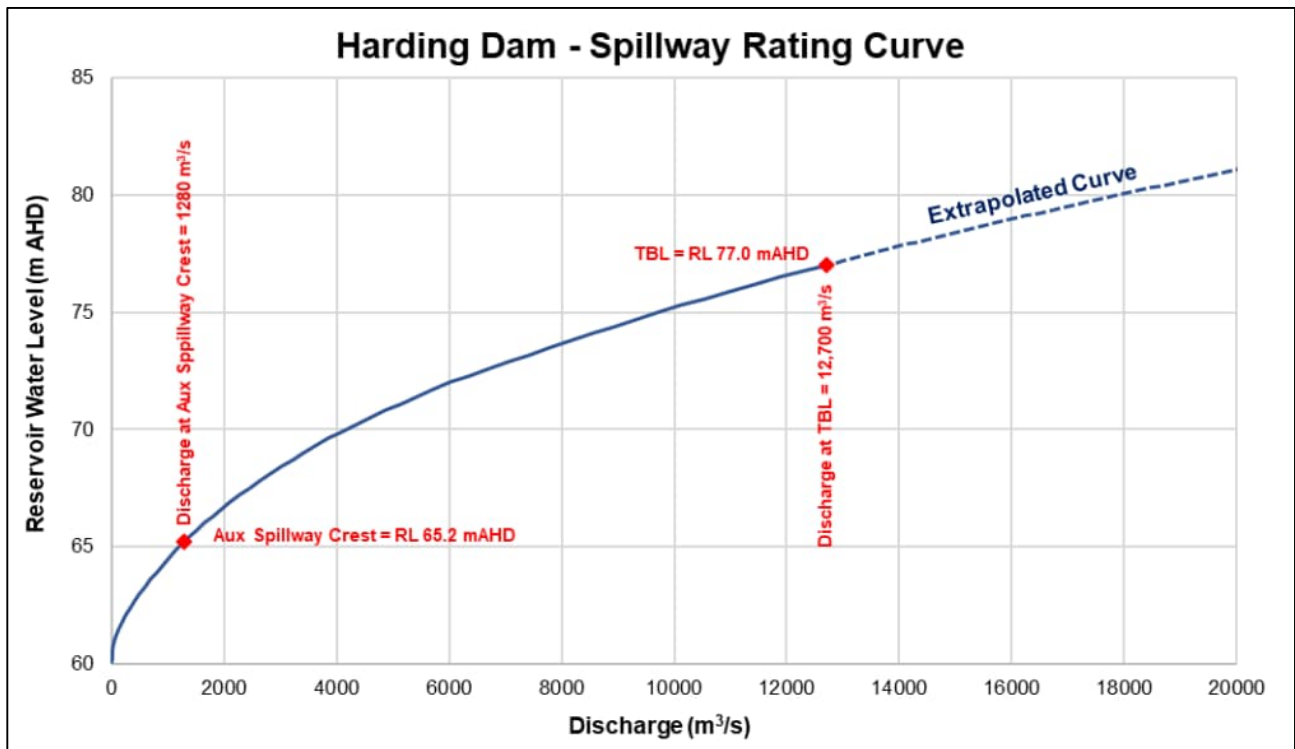


Figure 4-3: Harding Dam combined spillway rating curve (Source: WaterCorp, 2022)

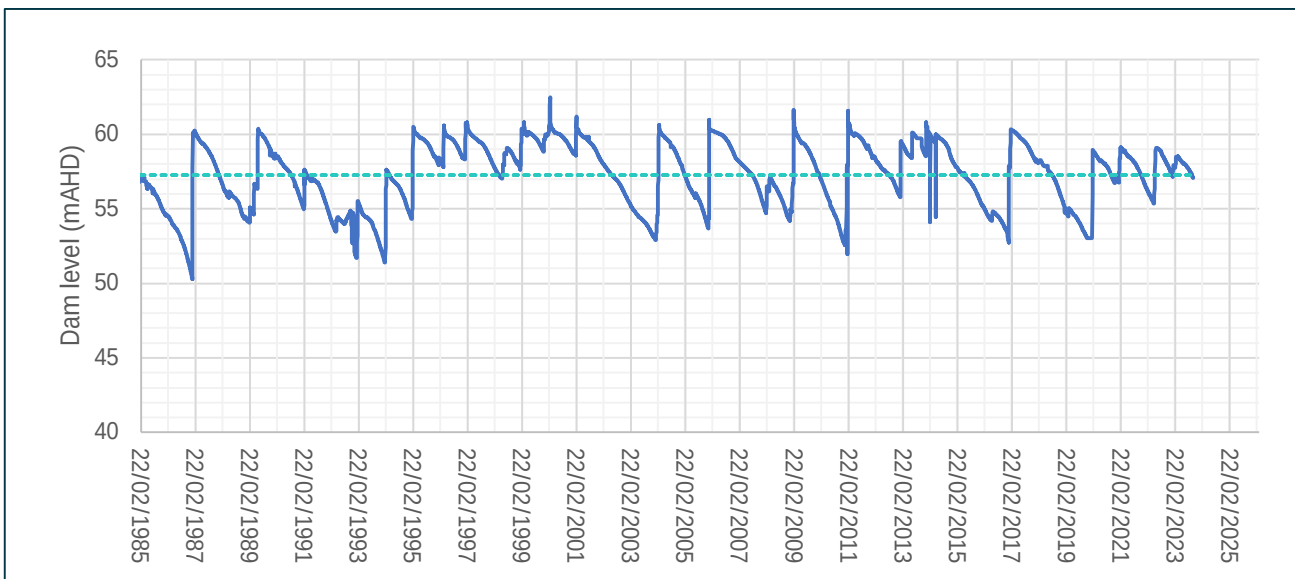


Figure 4-4: Harding Dam long term water level logger data (Source: BoM)

4.7 Design rainfall data

The latest Intensity Frequency Duration (IFD) data were obtained from the BoM Design Rainfall Data System (BoM, 2016).

Point rainfall data was obtained for the centroid of the total Harding River catchment. A separate centroid estimate was also obtained for the Harding Dam catchment area to enable a

like-for-like comparison to WaterCorp peak flow estimates at Harding Dam to ensure model performance was appropriate.

The IFD values adopted in this assessment for the overall Harding River catchment are presented in Appendix A.

The point IFD was also assessed against catchment mean values derived from gridded design rainfall datasets (BoM) for the critical 1% AEP events, which showed that there is minimal difference in design rainfall estimates between the two approaches. This is presented in Table 4-2.

Table 4-2: Harding River design rainfall comparison (centroid vs catchment mean) – 1% AEP

1 % AEP event storm duration	Catchment centroid event depth	Catchment mean event depth	Difference
720 minute (12 hour)	249 mm	245 mm	1.6%
1080 minute (18 hour)	295 mm	292 mm	1.0%
1440 minute (24 hour)	326 mm	325 mm	0.3%

Spatial distribution of rainfall within the RORB model is discussed in Section 4.10.

4.8 Areal reduction factors

Given the size of the Harding River catchment, it is not reasonable to assume that the spatial coverage of a high intensity storm burst will be uniform across the entire catchment area. To address this issue, it is typical to apply an Areal Reduction Factor (ARF) to the point IFD estimates to ensure the preservation of a probability neutral transition between the design rainfall and the design flood characteristics (Ball et al., 2019).

The procedures outlined in ARR2019 Book 2 (and automated in RORB) were adopted to determine AEP and duration varying ARFs to accurately inform design rainfall estimates. The Harding River catchment area to the middle of the live tenement which is bisected by the Harding River was used as the basis for ARF determination, given this is the key location of interest – an estimated catchment area of 1,362 km².

4.9 Temporal patterns

Given the size of the overall Harding River catchment (significantly greater than 75 km²), all events were simulated using the Rangelands West areal ensemble temporal patterns extracted from the ARR Datahub (Babister et al., 2016) in accordance with ARR2019 Book 2 recommendations.

For the 1 in 500 AEP event, the Rangelands West areal ensemble patterns were adopted in place of the Revised Generalised Tropical Storm Method (GTSMR) historic ensemble patterns. This was done to maintain smooth quantile growth through the AEP transition from rare to very rare event magnitude. Given the event is the only event assessed in the very rare range, a switch of temporal pattern source may introduce temporal bias for this event.

Comparisons to WaterCorp peak flow estimates [N.B. which used GTSMR temporal patterns due to the intent of the assessment (assessing very rare to extreme floods)] are presented in

Section 4.12.1. This was done to ensure there were no significant variances in the 1 in 500 AEP event design flow estimates when comparing temporal pattern sources.

4.10 Spatial distribution

As the Harding River catchment is larger than 20 km², spatial distribution of point rainfall was included in the assessment as recommended in Book 2 of ARR2019. Regionalised gridded IFD data was extracted from the BoM portal for the full catchment area and surrounds to assess spatial variability of the design rainfall estimates across the catchment.

Each sub area was sampled off the IFD raster grid, with the sub area mean design rainfall compared to the point value to obtain a spatial factor to the catchment mean. This was done for the 1% AEP event for the design storm durations which were shown to be informing the critical duration throughout the AEP range (12, 18 and 24 hour). Design event IFD grids for different AEP events for these storm durations were shown to exhibit similar gradations across the catchment and hence this approach was deemed suitable for replicating the predicted spatial variability of rainfall within the catchment and follows the recommendations detailed in ARR2019 Book 2.

4.11 Loss model

An Initial/Continuing Loss (*IL/CL*) empirical loss model has been adopted for this study.

The continuing loss (*CL*) is the average loss rate throughout the remainder of the rainfall event after the initial losses (*IL*) are satisfied. ARR2019 states constant loss models are most applicable to large storm events, where a significant portion of rainfall becomes runoff. This is conceptualised in Figure 4-5 with the factors influencing loss values presented in Figure 4-6.

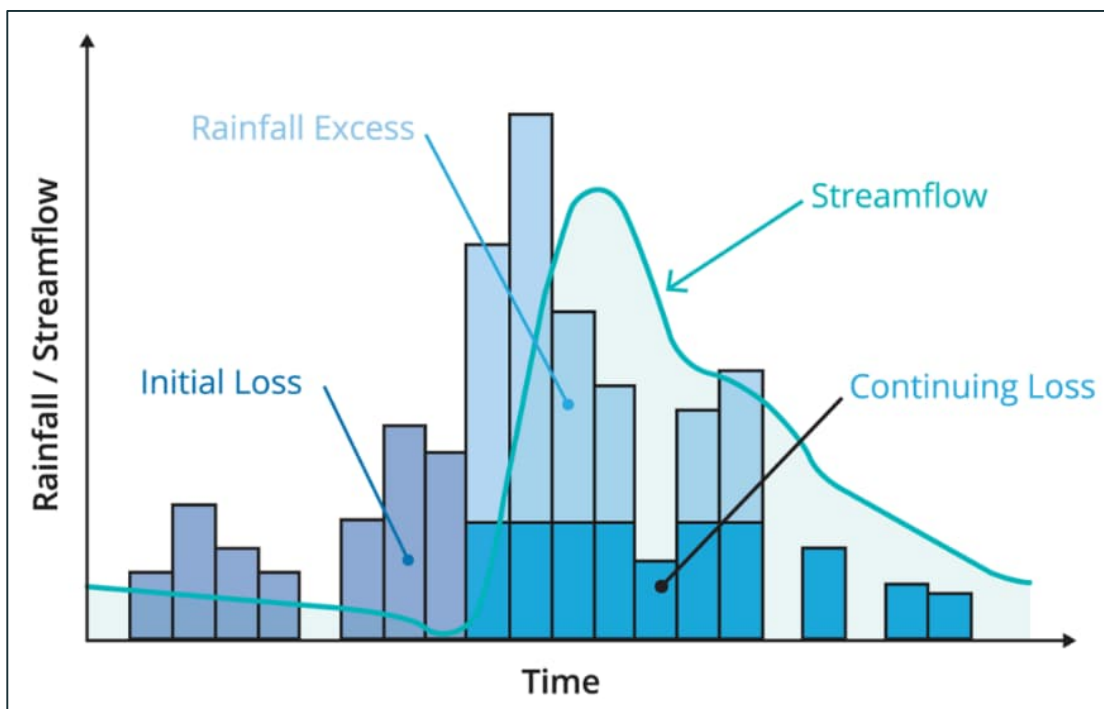


Figure 4-5: Conceptualisation of the empirical Initial/Continuing Loss model (Ball et al., 2019)

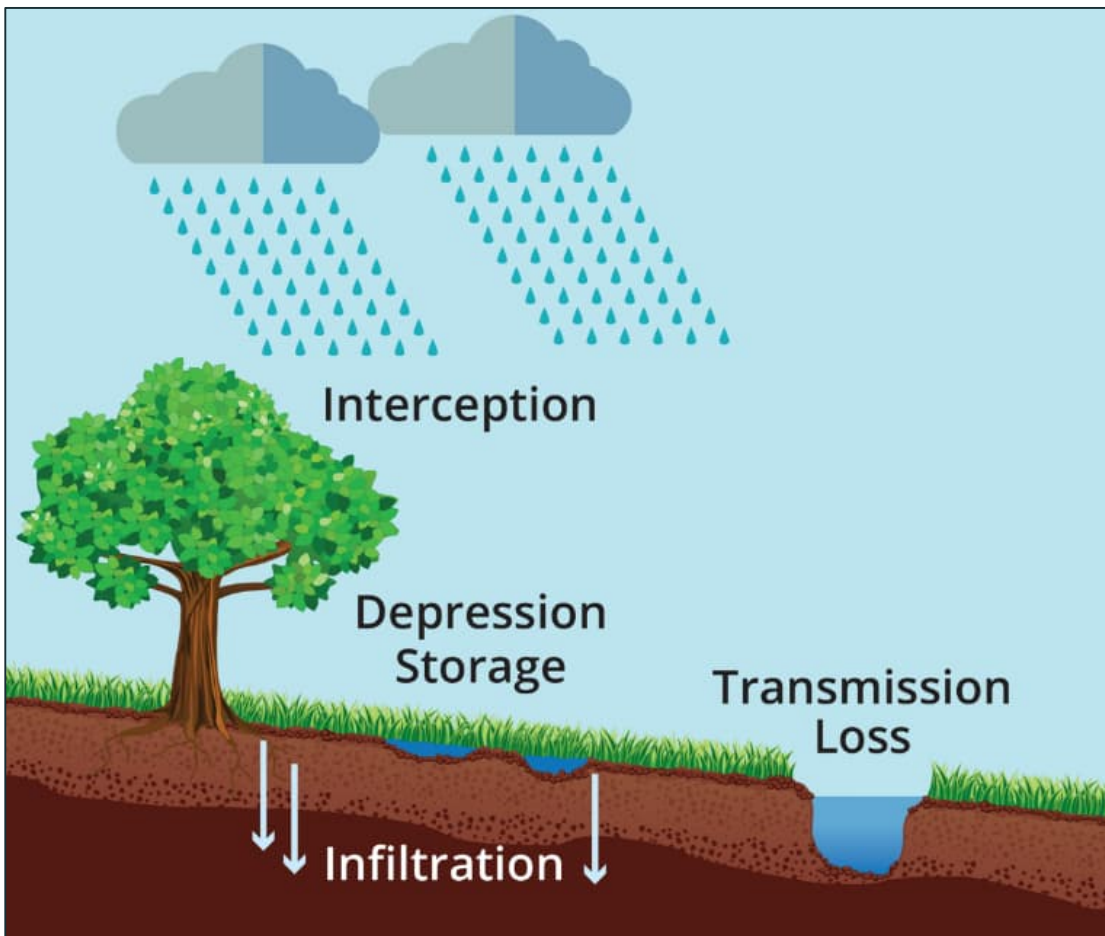


Figure 4-6: Factors influencing empirical loss values (Ball et al., 2019)

4.11.1 Pre burst rainfall

Median pre-burst rainfall depths were extracted from ARR Datahub (Babister et al., 2016). Pre-burst values are AEP and duration dependant. Where pre-burst rainfall is less than the storm initial loss (IL_S), the value of the pre-burst rainfall is removed from the IL_S prior to simulation in the model to represent the resultant burst initial (IL_B). This approach is conceptualised in Figure 4-7.

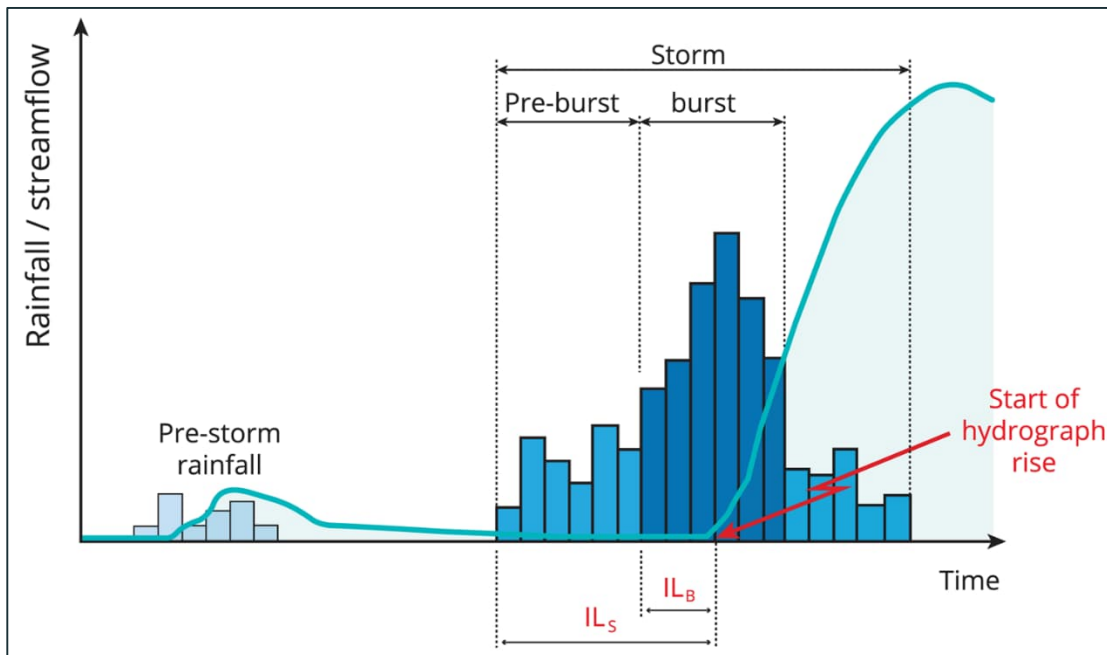


Figure 4-7: Conceptualisation of the distinction between Storm and Burst Initial Loss (Ball et al., 2019)

4.11.2 Loss parameters

The Harding Dam Flood Study Update undertaken by WaterCorp (Sullivan, 2022) adopted an *IL/CL* model as is proposed in this study. However, it is noted that the *IL* value adopted by WaterCorp represents a Burst Initial Loss value (IL_B) rather than a Storm Initial Loss (IL_S) value.

As such, the WaterCorp parameter value of 25 mm IL_B was considered in the context of the design events and critical durations reported in that study, as well as consideration of the events of focus for this study. It was determined that the addition of the median pre-burst values for the critical storm events resulted in an approximation of a corresponding IL_S of 40 mm. The continuing loss value was left unamended due to insufficient data to warrant a change from this calibrated value.

The adopted empirical loss parameters for the Harding River catchment are presented in Table 4-3. These values are regionally consistent with those obtained in other studies in the region using rainfall runoff modelling and loss reconciliation to long term stream gauge records and Flood Frequency Analysis (FFA). The adopted parameter set presented in Table 4-3 was validated by peak outflow quantile comparison to the WaterCorp study, presented in Section 4.13.

Table 4-3: Adopted empirical loss parameters for the Harding River catchment

Parameter	Value
Storm Initial Loss (IL_S)	40 mm
Continuing Loss (CL)	4 mm/hr

4.12 Simulation approach

4.12.1 Model schematisation validation

The validation of empirical loss selection for the Harding River catchment has used a Monte Carlo assessment approach for flood quantile estimation and comparison to WaterCorp's design event estimates.

The Monte Carlo approach provides a framework for simulating the natural variability in the key processes that influence flood runoff: all important flood producing factors are treated as stochastic variables, and the less important ones are fixed. The primary advantage of the method is that it allows the exceedance probability of the flood characteristic to be determined without bias (subject to the representativeness of the selected inputs) (Ball et al., 2019). The approach is conceptualised in Figure 4-8. For this assessment, temporal patterns and initial loss have been stochastically sampled.

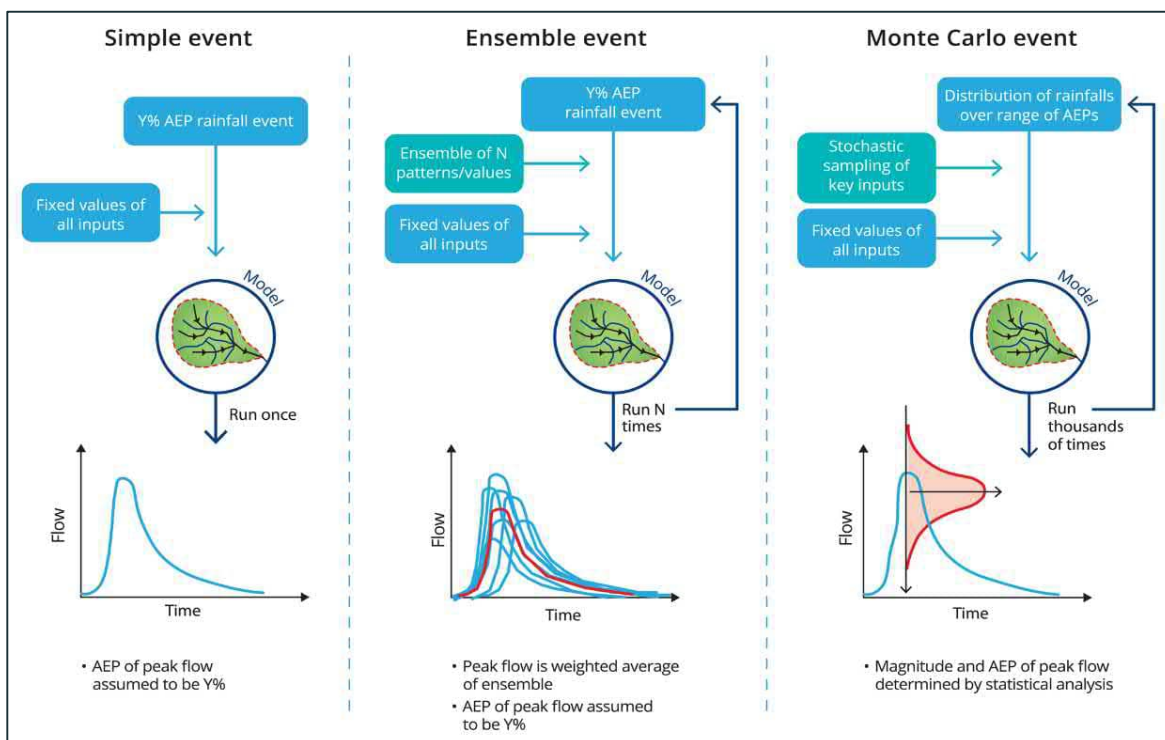


Figure 4-8: Monte Carlo and ensemble event approach conceptual models (Ball et al., 2019)

4.12.2 Design event assessment

For the assessment of design event flows (and resultant design flood levels and other characteristics) an ensemble assessment approach has been adopted for flood quantile estimation. Flood magnitudes are generally very sensitive to temporal patterns and thus the ensemble approach provides a straightforward means of avoiding the introduction of bias due to this source of variability (Ball et al., 2019).

The main area of interest is a significant distance downstream of Harding Dam (where additional tributaries contribute to design flows at the project site and hydraulic influences

such as the bifurcation of the Harding River affect design flows at the project site). Hence, the ensemble approach also enables ease of incorporation of RORB and direct rainfall (TUFLOW) simulation approaches.

Given the contribution of sub areas downstream of Harding Dam may potentially inform the critical design flood event at the project site (that may be different to that which informs the peak outflow at the Harding Dam spillway), a range of design storm durations (12 hour to 24 hour) were simulated in RORB for use in the TUFLOW model to determine the critical storm duration (the storm duration resulting in the highest mean peak flow and hence flood level from the 10 temporal patterns) at the key point of interest in the project area.

4.13 Harding Dam design outflow estimates

As the Harding River flows at the project site are heavily influence by hydraulic controls associated with the bifurcation of the Harding River upstream, Harding Dam is the only reasonable point of flow derivation and comparison from the RORB nodal-network model.

Given the focus of the WaterCorp study was very rare to extreme events, events less than the 2% AEP were not assessed and hence cannot be compared. Additionally, and as previously noted, different temporal patterns were adopted in the WaterCorp study [from the Revised Generalised Tropical Storm Method (GTSMR) (BoM 2003)] due the focus of the study being in the rare to extreme event range.

Table 4-4 presents the design outflows from Harding Dam using the Monte Carlo simulation approach, for the dam at both FSL as well as the long term mean level of 57.25 mAHD. WaterCorp design flow estimates for all available comparative events are also presented (N.B. also adopting dam starting level at FSL).

There is a strong agreement between the rare and very rare (2% AEP to 1 in 500 AEP) quantile estimates between the WaterCorp study and this study (when the dam is assumed to be at FSL at the storm onset), even when using differing temporal pattern inputs. As would be expected, predicted peak outflow quantiles are reduced when the dam water level is lowered to its long term mean level of 57.25 mAHD at the onset of the design storms. This is due to the storage uptake of the runoff volume within the rising limb of the inflow hydrograph which occurs until the storage deficit is satisfied, and the remaining inflow hydrograph is routed though the dam and spillway. It can be seen lower magnitude events do not produce sufficient runoff volume to fulfil the available storage within the dam in this scenario.

It is noted that due to the nature of Monte Carlo assessment approach, expected quantile values do vary slightly between each simulation – a result of the stochastic sampling approach.

Table 4-4: Harding River Dam outflow peak flow estimate comparison

Event	Harding Dam peak outflow with dam level at 57.25 mAHD (critical storm duration)	Harding Dam peak outflow with dam at FSL (critical storm duration)	WaterCorp Harding Dam Flood Study Update 2022 peak outflow with dam at FSL (critical storm duration)
50% AEP	0 m ³ /s	10 m ³ /s (24 hour)	N/A
20% AEP	0 m ³ /s	140 m ³ /s (24 hour)	N/A
10% AEP	120 m ³ /s (24 hour)	360 m ³ /s (24 hour)	N/A
5% AEP	370 m ³ /s (24 hour)	650 m ³ /s (24 hour)	N/A
2% AEP	835 m ³ /s (24 hour)	1,085 m ³ /s (24 hour)	1,095 m ³ /s (24 hour)
1% AEP	1,180 m ³ /s (24 hour)	1,420 m ³ /s (24 hour)	1,415 m ³ /s (24 hour)
1 in 500 AEP	2,090 m ³ /s (24 hour)	2,295 m ³ /s (24 hour)	2,310 m ³ /s (24 hour)

4.14 Climate change sensitivity assessment

The assessment of sensitivity to climate change impacted design rainfall was undertaken utilising the projected changes to rainfall intensity in accordance with ARR2019 guidance for the 2050 climate horizon using the Representative Concentration Pathways (RCP) 4.5 and 8.5 projections (Ball et al., 2019).

“RCPs are prescribed pathways for greenhouse gas and aerosol concentrations, together with land use change, that are consistent with a set of broad climate outcomes used by the climate modelling community. The pathways are characterised by the radiative forcing produced by the end of the 21st century. Radiative forcing is the extra heat the lower atmosphere will retain as a result of additional greenhouse gases, measured in Watts per square metre (W/m²).” (Climate Change in Australia, 2020)

There are four pathways: RCP8.5, RCP6, RCP4.5 and RCP2.6. The numbers in each RCP refer to the amount of radiative forcing produced by greenhouse gases in 2100. For example, in RCP8.5 the radiative forcing is 8.5 (W/m²) in 2100 [reaching a CO₂ concentration of 940 parts per million (ppm)]. For the RCPs specifically considered in this assessment:

- RCP4.5 is described by the Intergovernmental Panel on Climate Change (IPCC) as an intermediate scenario. Emissions in RCP4.5 peak around 2040, then slowly decline; and
- For RCP8.5, emissions continue to rise throughout the 21st century. RCP8.5 is generally taken as the basis for worst-case climate change scenario.

The projected changes to rainfall intensities extracted from the ARR Data Hub for the 2050 design horizon are presented in Table 4-5 and were applied to the design rainfall burst depths (as presented in Appendix A).

Table 4-5: Adopted design rainfall factors for climate change

Design Horizon	RCP4.5	RCP8.5
2050	7.7 %	10.3 %

This sensitivity analysis was used to determine if the predicted increase in flow estimates in the 2050 future climate scenarios had tangible impact on flood elevations and extents and hence would pose any additional flood risk to future proposed infrastructure localities. Results from the climate change sensitivity assessment are presented in Section 6.3.1.

5. Hydraulic model – project site and surrounds

5.1 Background

The hydrologic estimates as detailed in Section 4 have ultimately been derived for use as inflow boundary conditions into a hydraulic model to detail flood behaviour through the Project Area.

As baseline hydrology results are required across the entire Study Area (and surrounds), hydrological and hydraulic modelling of the local catchments and regional inflows was undertaken using TUFLOW (version 2023-03-AB). TUFLOW is a linked 1D/2D hydrodynamic computational engine for simulating free-surface long wave propagation processes (tides, floods, tsunamis, dam breaks) by solving the full one and two-dimensional versions of the Navier-Stokes equations incorporating all physical terms including inertia (1D and 2D) and sub-grid turbulence (2D) (BMT, 2018).

5.2 Hydrologic simulation approach

As detailed in Section 4.12.2, the assessment of design event catchment response to rainfall for the TUFLOW models has used an ensemble assessment approach for flood quantile estimation.

5.3 Design events

Table 5-1 summarises the design storms assessed in the TUFLOW models to accurately detail design flood behaviours across the large study area. Storm durations of 720 minutes and greater were simulated using the same design rainfall inputs as the RORB model to maintain a consistent input approach.

Table 5-1: Design storms assessed in TUFLOW and RORB models

Storm detail	Events assessed
Annual Exceedance Probabilities (AEPs)	1 in 500 AEP, 1%, 2%, 5%, 10%, 20% and 50%
Design Storm Durations (minutes)	45, 60, 90, 120, 180, 360, 720, 1080, 1440

5.4 Model setup

The TUFLOW model is characterised by a number of input parameters which are summarised in Table 5-2. Areal reduction factors, floodplain roughness and culverts are discussed further in Sections 5.4.1, 5.4.2 and 5.4.3.1 respectively.

The model terrain was developed using a mosaic of the Azure Minerals provided 1 m orthophoto derived DEM and the 5 m Landgate orthophoto derived DEM (as described in Section 2).

Due to the study area and hence required model domain (961 km²) and required number of simulations, the models were simulated with relatively coarse base grid size (20 m) for the areas utilising the less accurate Landgate 5 m DEM, with discrete areas of higher resolution (10 m) over the study area and linear infrastructure such as the North West Coastal Highway

and Rio Tinto railway. Sub Grid Sampling (SGS) functionality was used to sample the baseline topographic data at 1 m resolution (where available) and maximise hydrologic routing accuracy and hence result convergence between cell sizes. Where required (typically along linear infrastructure), break lines were enforced within the model to prevent inter-cell 'leaking' due to the adoption of SGS functionality.

Table 5-2: TUFLOW model parameter summary

Item	Model detail
Rainfall	
Rainfall depths for direct rainfall boundary condition	Extracted from BoM Design Rainfall Data System (BoM, 2016) using TUFLOW QGIS plugin. Due to the small catchment sizes (<20 km ²) and consistent design rainfall across the project site, no spatial distribution was undertaken.
Pre-burst	Median pre-burst rainfall depths were extracted from ARR Datahub (Babister et al., 2016). Pre-burst rainfall was removed from the storm initial loss (<i>IL_s</i>) prior to simulation in the model to represent the burst initial loss (<i>IL_B</i>)
Losses	<i>IL_s</i> : 40 mm <i>CL</i> : 4 mm/hr Approach: Rainfall excess (materials layer)
Pre-wetting catchment	Pre-wetting was used to fill what was considered to be artificial depression storage from DEM noise in the model areas covered by the Landgate 5 m DEM. No pre-wetting was used in the model areas covered by the high resolution 1 m DEM.
Temporal patterns	Point temporal patterns were adopted for catchments less than 75 km ² . For the longer duration assessments associated with the regional Harding River design flow events, Areal TPs were adopted to be consistent with the RORB inflow boundary conditions. All temporal patterns adopted were for the Rangelands region.
ARF	Determined using parameters extracted from the ARR Datahub (Babister et al., 2016) for the Northern Coastal region and based on assessments as described in Section 5.4.1.
Model terrain	
Terrain data	Derived from 1 m and 5 m datasets
Base grid size (SGS sample distance) Quadtree grid sizes (SGS sample distance)	20 m (5 m) – Outer study area (model periphery) 10 m (1 m) – General tenement areas, roads and rail
Manning's 'n' value (Depth Layer 1 (m), Manning's 'n' Layer 1, Depth Layer 2 (m), Manning's 'n' Layer 2) N.B. Depth for all layers is relative to the bed	Typical Pilbara hillslopes (0.1, 0.1, 0.2, 0.04) Medium density creek line & riparian vegetation (0.1, 0.1, 0.2, 0.06) Higher density riparian vegetation (0.1, 0.1, 0.2, 0.08) Thick riparian vegetation [0.1 (non depth-varying)]
External boundary conditions	
External inflow boundary	RORB-derived inflow hydrographs (QT boundary type)
Outflow boundary	A combination of a static tailwater level boundary condition (HT) (as discussed in Section 5.4.3) for the inter-tidal area and automated stage-discharge curve (HQ) for minor creeks at the eastern extent of the model (N.B. no influence on project area).

5.4.1 Areal reduction factors

Areal reduction factors for the Harding River RORB modelling (regional catchment) have been previously described in Section 4.8. These ARF values were used for the same event design event direct rainfall databases to ensure uniformity across the different approaches.

The project target areas are located within well-defined headwater areas and hence short duration design events are the dominant source of peak flood behaviour in these areas. To enable a reasonable estimate of flood quantiles and hence flood risk across the entire Study Area, a duration dependant ARF approach was adopted.

Initial modelling works for the 1% AEP event were undertaken to assess the point of transition between critical durations (and associated contributing catchment areas) as well as the point of transition to regional catchment dominance. Based on the observed transition points between critical durations and consideration of the range of AEP's being assessed, the duration-varying ARFs presented in Table 5-3 were adopted for this study.

Table 5-3: Duration varying areal reduction factors

Design storm duration	Adopted ARF catchment area
45 and 60 minute	Point rainfall
90 and 120 minute	5 km ²
180 minute	10 km ²
270 minute	20 km ²
360 minute	30 km ²

5.4.2 Culverts and bridges

Structure details for Main Roads WA (MRWA) controlled crossings of watercourses in the Study Area (NWCH) were obtained from MRWA and verified through site inspection in December 2023. Data available from MRWA consisted of culvert locations, sizes, number of barrels and culvert material. Invert levels were estimated using the provided topographic data and site observations.

All features on the RioTinto Iron Ore heavy haul rail alignment were visually inspected during the site visit, with sizes either directly measured or estimated through observation and cross reference with detailed aerial imagery. Required safety offsets from the rail line limited the number of culverts able to be directly measured (particularly smaller culverts, due to typically small embankment width at these locations and hence smaller offset from the rail, preventing access).

All culvert features were included in the hydraulic model as 1D (ESTRY) inserts within the TUFLOW model. Table 5-4 summarises the parameters used for the various culvert types observed in the Study Area.

Table 5-4: Adopted culvert hydraulic parameters

Culvert detail	Manning's 'n'	Adopted Inlet Loss (K_E)	Adopted Outlet Loss (K_O)
CSP / Protruding (no headwall)	0.024	0.9	1
CSP / Protruding (no headwall) - lined	0.018	0.9	
RCP / Concrete headwall with wingwalls	0.013	0.5	
RCBC / Concrete headwall with wingwalls		0.4	
Arch (alluvial bed)	0.030	0.9	



Figure 5-1: Example of arch structure with alluvial bed located on Rio Tinto Iron Ore Railway

Two bridges are located within the study area, located at the NWCH crossings of the Harding River and East Harding River. Design drawings for the bridges were obtained from MRWA and verified during site inspection. The bridges were modelled in the 2D domain within TUFLOW using the BG layer approach. Form losses for below-soffit areas were derived using the procedures defined in Hydraulic Design of Safe Bridges (FHWA, 2012). Given the debris availability in the Harding River system, some allowance for debris accumulation on the piers was adopted, with pier widths in the aforementioned calculations increased slightly to replicate approximated potential debris fields around the piers.

It is noted that due to topographic data limitations at East Harding River, it is not expected that the modelling results replicate true hydraulic performance of this structure.

Exact replication of head loss across either bridge structure to anecdotally observed historic or surveyed flood levels was beyond the scope of this assessment.



Figure 5-2: NWCH bridge crossing of Harding River at Roebourne

5.4.3 Tailwater condition

For all events assessed, a static tailwater condition of Highest Astronomical Tide (HAT) has been adopted for the assessment. The HAT estimate was obtained from 'Developing Better Predictions of Extreme Water Levels' (Pattiaratchi et al., 2018) study and associated modelling and output data³. HAT at the coastal fringe was predicted to be 2.94 mAHd.

Other datasets were also consulted to confirm the validity of the HAT prediction, with the Australian National Tide Tables (2023) predicting a HAT of 2.86 m above Mean Sea Level (MSL) at Port Walcott and 3.03 mMSL at Depuch Island. It is noted that for comparative purposes, MSL was assumed to be representative of AHD (discussed further below). Given the close agreement between datasets, the predictions by Pattiaratchi et al. (2018) were

³ <https://sealevelx.ems.uwa.edu.au/about.php>

considered representative of still water lunar tide elevations in the study area and hence were adopted for use in the modelling.

No allowance for sea level rise between the time of AHD definition and current day has been allowed for (N.B. AHD adopted in May 1971 based on tidal data between 1966 and 1968). A plot of annual tidal data for Port Hedland (obtained from the National Oceanography Centre Permanent Service for Mean Sea Level⁴) presented in Figure 5-3 shows the approximate quantum of sea level rise to the present day of 100 mm since AHD was defined (N.B. at Port Hedland). It is noted that a detailed study would be required to define the quantum of sea level rise to current day at the project site, as well as accurately predict expected storm tide levels.

It is noted that current day mean sea level elevation increase estimation of approximately 100 mm as outlined above from long term tidal observations at Port Hedland aligns closely with the 2030 sea level rise predictions of 120 mm for both Port Hedland and Onslow as detailed in *Western Australian climate projections* (DWER, 2021).

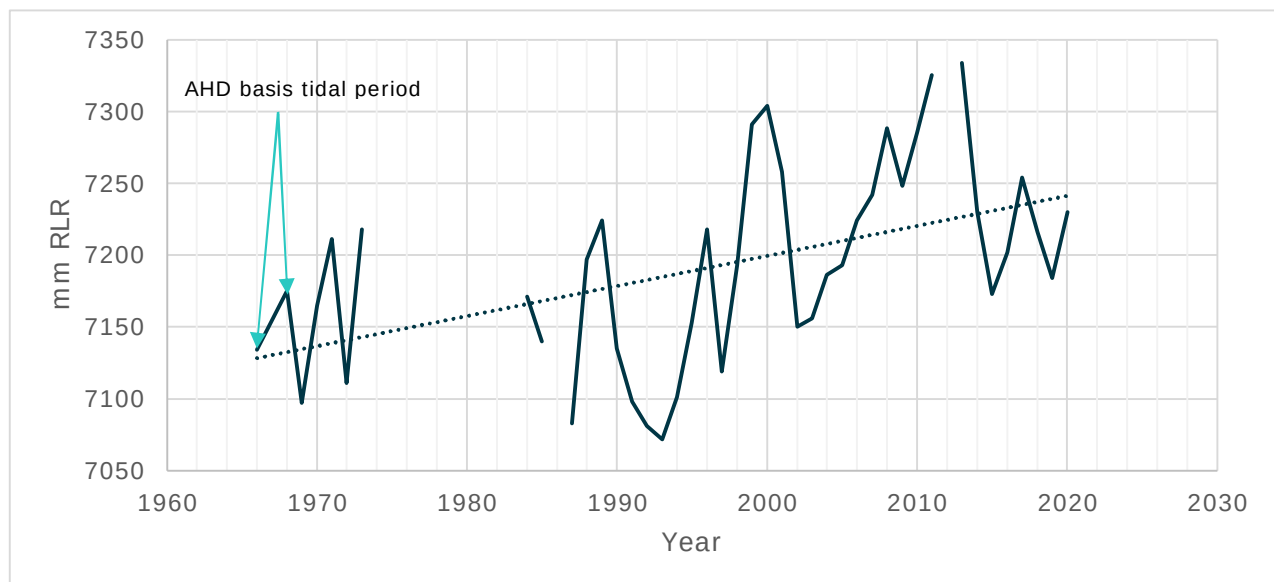


Figure 5-3: Annual tidal data at Port Hedland with trend line

5.4.3.1 Joint probability assessment

Floods in estuarine and coastal fringe locations (such as the study area) can be caused by runoff generated by an extreme rainfall event, an elevated ocean level generated by a storm tide and/or a high astronomical tide, or a combination of both processes occurring simultaneously or in close succession. Research in Australia and internationally has shown that extreme rainfall and storm surge processes are statistically dependent, and therefore their interaction needs to be considered for areas affected by both processes (ARR, 2019). This is graphically presented in Figure 5-4.

⁴ <https://psmsl.org/>

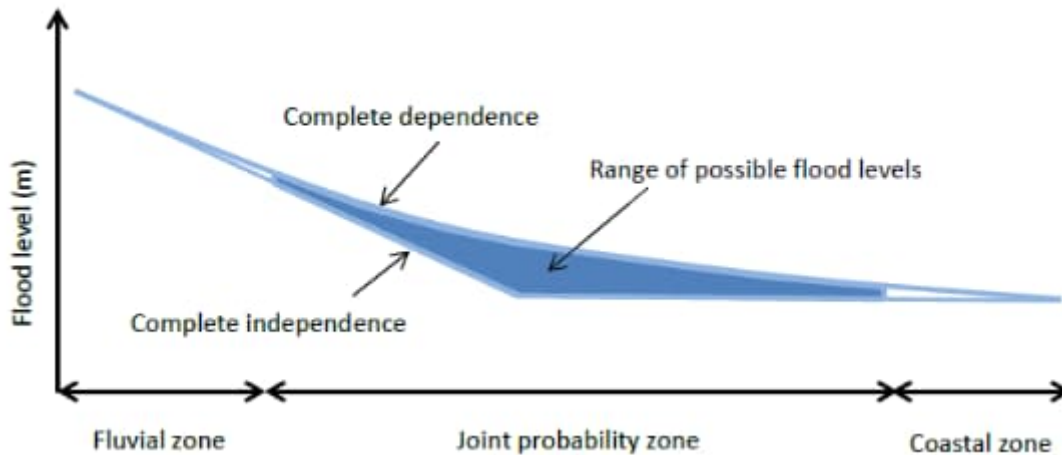


Figure 5-4: Schematic of hypothetical water levels from dependent and independent events (Source: Ball et al., 2019)

Initial screening of the sensitivity of the project area (with particular focus on the lithium target area and the Harding River mainstream) to the impacts of a storm tide tailwater condition was undertaken by simulating the 1% AEP flood event with a 1% AEP storm tide (a complete dependence scenario). This was undertaken for the critical regional flood event (which dominates flood behaviour in the Harding River mainstream at the project site), with 1% AEP storm tide predictions taken from Pattiaratchi et al. (2018), resulting in a tailwater condition of 5.0 mAHD. It is noted that predictions from Pattiaratchi et al. (2018) ranged from approximately 4.5 mAHD to 5.5 mAHD along the coastal fringe area covered by the hydraulic model developed for this study.

It was predicted that the increased tailwater condition resulted in no tangible increase in flood levels at the site due to the elevation differences between the site and the predicted joint probability and coastal zones. A long section of the Harding River mainstream presenting the respective peak flood surfaces for the 1% AEP event with the two different tailwater conditions is presented in Figure 5-5.

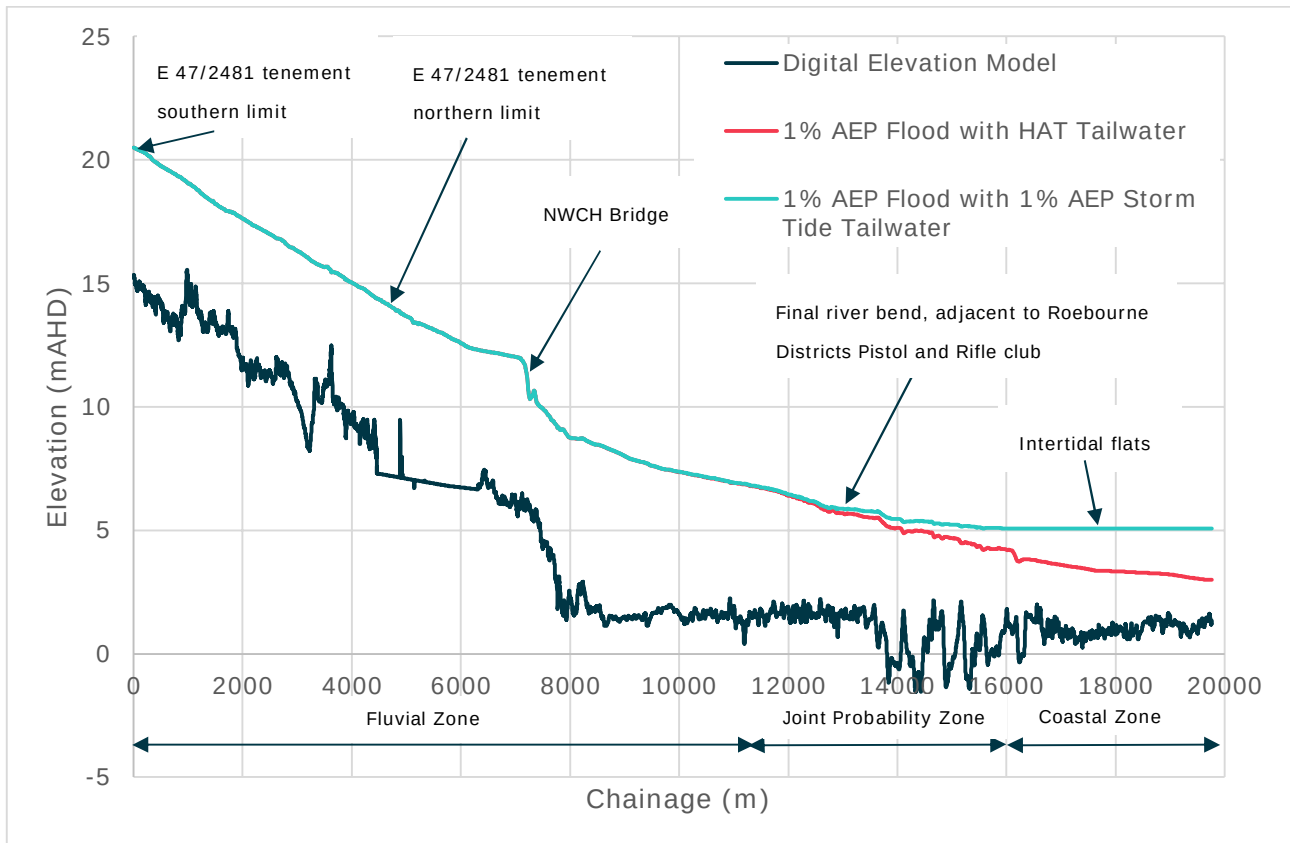


Figure 5-5: Harding River mainstream long section – tailwater sensitivity

Determination of site-specific storm tide predictions was outside the scope of this assessment, and hence the results reflect the sensitivity of flood levels at the project site using the latest publicly available information. Based on the observed hydraulic control provided by the NWCH bridge crossing, it could be reasonably expected that any minor increases in storm tide magnitude predictions would still not result in design flood level sensitivity in the project area (on the Harding River mainstream). Significant increases in storm tide predictions may need to be tested further to confirm design flood level sensitivities.

At the time of preparation of this report, it is understood that no works are proposed seaward of the NWCH as part of the project. Any proposed infrastructure located on the coastal fringe in the live tenement areas would need to consider inundation risks associated with storm tides.

5.4.4 Hydraulic roughness

Hydraulic roughness delineation was undertaken using Sentinel-2 satellite data (ESA, 2021). Sentinel-2 carries the Multispectral Imager sensor which delivers 13 spectral bands ranging from 10 m to 60 m resolution.

10 m resolution data of the Study Area consisting of B4 (red) and B8 (visible and near infrared [VNIR]) bands was used to create a normalised vegetation index grid.

This was then compared to aerial imagery to define classification bands to assign areas of similar vegetative density a material ID (used in TUFLOW) and ultimately an associated Manning's 'n' roughness value. Most of the delineation and classification centred around

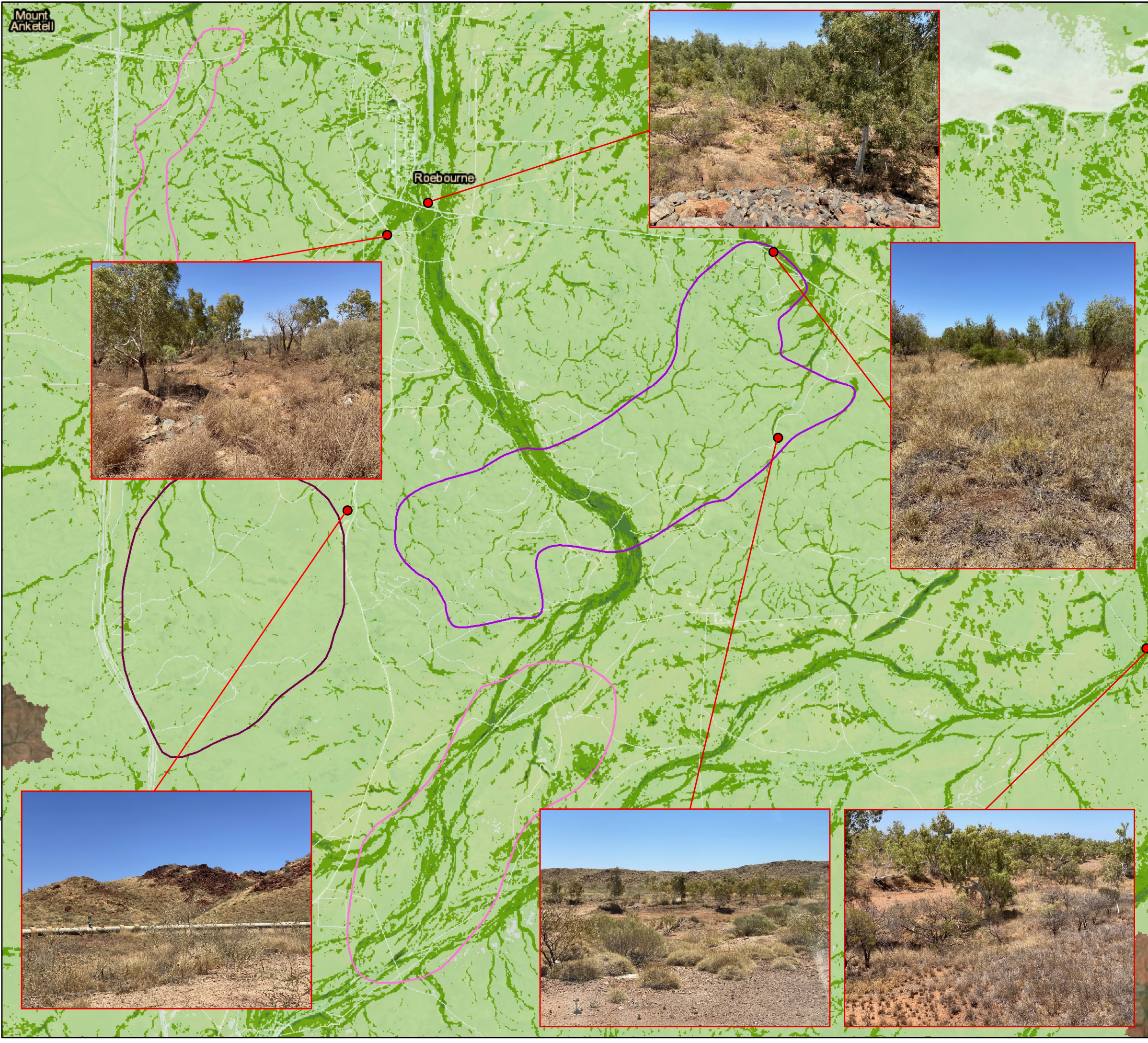
riparian vegetation, with most hillslope areas adopting the global upper-level Manning's 'n' value of 0.04 (as defined in Table 5-2) using the depth varying approach.

This approach allows for a consistent hydraulic roughness delineation and parameterisation methodology to be adopted across the entire extensive model area. This is preferred to a manual delineation approach which can be subject to user interpretation and inconsistency.

Some minor variance was observed between wet season and dry season data captures from Sentinel-2 however this was not deemed significant enough to result in any major changes to adopted classification bands or extents.

Cross reference against Azure Minerals-provided high resolution aerial imagery was also undertaken to ensure extents were representative of expected changes in roughness. Site validation of roughness parameters was further undertaken during the field trip in the December 2023. The adopted model roughness and site validation photographs are presented in Figure 5-6.

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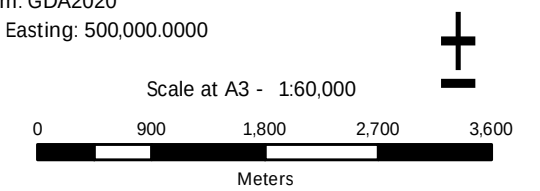
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Figure 5-6:
Adopted Hydraulic Model Roughness

- Legend**
- Ground Water Target Area
 - Lithium Target Area
 - Nickel Target Area
 - Road/rail/cleared areas/pools (Mannings 'n' 0.025)
 - General hillslope areas (L2 Mannings 'n' 0.04)
 - Medium density vegetation (L2 Mannings 'n' 0.06)
 - Dense riparian vegetation (L2 Mannings 'n' 0.08)
 - High density riparian vegetation (L2 Mannings 'n' 0.1)

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Projection: Transverse Mercator
Datum: GDA2020
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5.5 Sensitivity analysis

5.5.1 Climate change

5.5.1.1 Design rainfall

Design rainfalls for the direct rainfall coverage areas for the 1% AEP event were factored using the same approach as detailed in Section 4.14 for the catchment areas covered by the direct rainfall modelling approach.

As the model resolution within the target headwater areas of the project is not sufficiently detailed enough to accurately resolve likely hydraulic changes due to increased rainfall intensity, the assessment has focused on the potential impacts of climate change on the Harding River mainstream flows and associated future climate sea level rise as discussed in Section 5.5.1.2.

The assessment of flood risk for the potential 2050 future climate scenarios will aid in quantifying increases in flood risk to any proposed infrastructure localities.

5.5.1.2 Sea level rise

Sea level rise has also been included in the 2050 future climate assessment, although as noted in Section 5.4.3.1 peak flood elevations in the area of interest are not typically affected by the adopted tailwater condition.

Sea level rise estimates were obtained from *Western Australian climate projections* (DWER, 2021). The maximum value for the Onslow and Port Hedland locality predictions were adopted, although they are noted as being very similar for both scenarios (within 10 mm). The predictions for the 2030 and 2090 climate horizons and the interpolated 2050 climate horizon as used in this study is presented in Table 5-5. It is noted that the 2050 design horizon interpolated values are from linear interpolation between the 2030 and 2090 values.

Table 5-5: Adopted sea level rise predictions at project site

RCP Scenario	2030	2050 (modelled scenario)	2090
RCP4.5	0.12 m	0.23 m*	0.46 m
RCP8.5	0.13 m	0.29 m*	0.62 m

* denotes linearly interpolated value

For the 1% AEP future climate scenario model simulations, a resultant HAT tailwater condition of 3.17 mAHD and 3.23 mAHD was therefore adopted for the 2050 RCP4.5 and RCP8.5 scenarios respectively.

5.5.2 Hydraulic roughness

The model sensitivity to Manning's 'n' roughness was tested by simulating the critical 1% AEP event for the Harding River mainstream within the live tenement area with Manning's 'n' values +/- 25%.

This was applied to the adopted design hydraulic roughness values (i.e., upper depth value for depth-varying areas, with the lower roughness value unchanged) to assess hydraulic sensitivity to Manning's 'n' parameters.

This sensitivity analysis was used to determine the quantum of expected flood level change as a result of potential natural inter-seasonal variance in vegetative density (and hence hydraulic roughness that may be expected in the study area). Significant impacts on flood elevations and extents due to minor changes in hydraulic roughness may identify additional potential flood risk to proposed infrastructure localities that may need to be managed through an appropriate design freeboard.

6. Assessment results

6.1 Design event flow estimates

Several flow reporting locations were selected across the model area to quantify peak design flows for the 1 in 500, 1%, 5% and 20% AEP events.

The flow reporting locations are presented in Table 6-1 with key locations of interest and a general discussion on hydrologic estimates included below.

Table 6-1: Peak design flow estimates

Location ID	AEP event			
	1 in 500 (critical duration)	1 % (critical duration)	5 % (critical duration)	20 % (critical duration)
Harding Rv 1	2776 m ³ /s (24 hours)	1748 m ³ /s (24 hours)	817 m ³ /s (24 hours)	231 m ³ /s (18 hours)
Harding Rv 2	2375 m ³ /s (18 hours)	1576 m ³ /s (18 hours)	741 m ³ /s (24 hours)	222 m ³ /s (18 hours)
Harding Rv 3	2255 m ³ /s (24 hours)	1561 m ³ /s (24 hours)	741 m ³ /s (24 hours)	216 m ³ /s (18 hours)
Harding Rv 4	2316 m ³ /s (24 hours)	1572 m ³ /s (24 hours)	750 m ³ /s (18 hours)	212 m ³ /s (18 hours)
Harding Rv 5	2583 m ³ /s (24 hours)	1894 m ³ /s (24 hours)	934 m ³ /s (24 hours)	265 m ³ /s (18 hours)
Harding Rv 6	2756 m ³ /s (24 hours)	1989 m ³ /s (24 hours)	967 m ³ /s (24 hours)	276 m ³ /s (18 hours)
Harding Rv E1	852 m ³ /s (24 hours)	490 m ³ /s (24 hours)	251 m ³ /s (24 hours)	83 m ³ /s (18 hours)
Harding Rv E2	1200 m ³ /s (24 hours)	736 m ³ /s (24 hours)	351 m ³ /s (24 hours)	102 m ³ /s (24 hours)
Harding Rv Overbank	400 m ³ /s (24 hours)	82 m ³ /s (24 hours)	23 m ³ /s (6 hours)	7 m ³ /s (6 hours)
Murray Camp Creek	596 m ³ /s (18 hours)	327 m ³ /s (18 hours)	191 m ³ /s (12 hours)	109 m ³ /s (12 hours)
West Arm	1241 m ³ /s (12 hours)	850 m ³ /s (12 hours)	470 m ³ /s (12 hours)	204 m ³ /s (18 hours)
Site Ck 1	67 m ³ /s (2 hours)	47 m ³ /s (6 hours)	33 m ³ /s (6 hours)	14 m ³ /s (6 hours)
Site Ck 2	127 m ³ /s (1 hour)	82 m ³ /s (6 hours)	57 m ³ /s (6 hours)	25 m ³ /s (6 hours)
Site Ck 3	149 m ³ /s (2 hours)	103 m ³ /s (6 hours)	69 m ³ /s (6 hours)	30 m ³ /s (6 hours)
Site Ck 4	66 m ³ /s (2 hours)	41 m ³ /s (1 hour)	28 m ³ /s (6 hours)	13 m ³ /s (6 hours)
Site Ck 5	94 m ³ /s (1 hour)	57 m ³ /s (1 hour)	41 m ³ /s (6 hours)	19 m ³ /s (6 hours)
Site Ck 6	62 m ³ /s (0.75 hours)	38 m ³ /s (1 hour)	24 m ³ /s (6 hours)	12 m ³ /s (6 hours)

Location ID	AEP event			
	1 in 500 (critical duration)	1 % (critical duration)	5 % (critical duration)	20 % (critical duration)
Site Ck 7	41 m ³ /s (0.75 hours)	25 m ³ /s (0.75 hours)	16 m ³ /s (3 hours)	8 m ³ /s (6 hours)
Site Ck 8	196 m ³ /s (3 hours)	143 m ³ /s (6 hours)	93 m ³ /s (6 hours)	32 m ³ /s (6 hours)
Site Ck 9	101 m ³ /s (6 hours)	65 m ³ /s (6 hours)	33 m ³ /s (6 hours)	8 m ³ /s (6 hours)
Site Ck 10	135 m ³ /s (6 hours)	85 m ³ /s (6 hours)	56 m ³ /s (6 hours)	31 m ³ /s (6 hours)
Site Ck 11	101 m ³ /s (0.75 hours)	62 m ³ /s (1 hour)	43 m ³ /s (6 hours)	20 m ³ /s (6 hours)
Site Ck 12	62 m ³ /s (0.75 hours)	39 m ³ /s (1 hour)	26 m ³ /s (6 hours)	13 m ³ /s (6 hours)

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Figure 6-1:
Peak Flow Reporting Locations

Legend

- Exploration and miscellaneous licences
- Pending exploration and miscellaneous licences
- TUFLOW hydraulic model extent
- Peak flow reporting location
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/Tracks
- Water Pipeline

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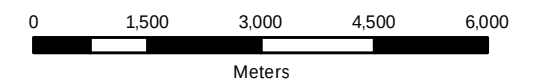
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

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Scale at A3 - 1:100,000



Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



6.1.1 Peak flow validation

6.1.1.1 Harding River

Peak flow validation for the Harding River to Harding Dam has been previously presented in Section 4.13, showing strong agreement to the WaterCorp Harding Dam Flood Study (2022) peak flow quantiles for the 1 in 500, 1% and 2% AEP design events as were assessed in the WaterCorp study.

Comparison of peak flow quantiles for the larger sub catchment areas below the dam is more complex, as most of these sub areas contributing to the Harding River mainstream have been parameterised for the mainstream flows (i.e., design rainfall inputs) as well as being influenced by hydraulic controls associated with the Rio Tinto Iron Ore Railway embankment and associated culvert capacities. Additionally, discharges can be subject to complex flow behaviour such as cross catchment interactions.

As the dominant source of peak flow and hence flood risk within the Harding River mainstream at the site remains a result of discharges from Harding Dam (with some supplementary runoff contribution from lower sub areas), and these flow predictions are in alignment with the calibrated estimates from WaterCorp, it is considered that the flow estimates for the Harding River mainstream are suitable for adoption in this baseline hydrologic assessment.

6.1.1.2 Local project area catchments

Peak flows for local catchments within the target project area have been validated to the Regional Flood Frequency Estimation (RFFE)⁵ model and the Regional Flood Frequency Procedure (RFFP) (Flavell, 2012).

The validation of local site catchment peak flows is presented in Table 6-2 with the selected representative comparison locations previously presented in Figure 6-1. The validation locations were chosen based on their close proximity to the target project areas.

⁵ <https://rffe.arr-software.org/>

Table 6-2: Local site catchment peak flow validation

Catchment ID	Peak Flow		
	1 % AEP (RFFP) [RFFE]	5 % AEP (RFFP) [RFFE]	20 % AEP (RFFP) [RFFE]
Site Ck 1	47 m ³ /s (99 m ³ /s) [70 m ³ /s]	33 m ³ /s (37 m ³ /s) [39 m ³ /s]	14 m ³ /s (17 m ³ /s) [16 m ³ /s]
Site Ck 2	82 m ³ /s (99 m ³ /s) [87 m ³ /s]	57 m ³ /s (38 m ³ /s) [48 m ³ /s]	25 m ³ /s (14 m ³ /s) [20 m ³ /s]
Site Ck 4	41 m ³ /s (54 m ³ /s) [56 m ³ /s]	28 m ³ /s (22 m ³ /s) [31 m ³ /s]	13 m ³ /s (8 m ³ /s) [13 m ³ /s]
Site Ck 5	57 m ³ /s (76 m ³ /s) [68 m ³ /s]	41 m ³ /s (28 m ³ /s) [38 m ³ /s]	19 m ³ /s (12 m ³ /s) [16 m ³ /s]
Site Ck 6	38 m ³ /s (39 m ³ /s) [35 m ³ /s]	24 m ³ /s (15 m ³ /s) [19 m ³ /s]	12 m ³ /s (6 m ³ /s) [8 m ³ /s]
Site Ck 7	25 m ³ /s (35 m ³ /s) [37 m ³ /s]	16 m ³ /s (13 m ³ /s) [20 m ³ /s]	8 m ³ /s (6 m ³ /s) [9 m ³ /s]
Site Ck 12	39 m ³ /s (55 m ³ /s) [51 m ³ /s]	26 m ³ /s (21 m ³ /s) [28 m ³ /s]	13 m ³ /s (8 m ³ /s) [12 m ³ /s]

It can be seen from the tabulated results that the peak flow predictions from the direct rainfall TUFLOW model using the parameters as detailed in Section 5 typically align well with the regional method estimates, with no significant differences or outliers observed, besides for Site Ck 1 in the 1% AEP event. Peak flow rate estimates for Site Ck1 in the 1% AEP event were shown to be below regional estimates, but comparable for the 5% AEP and 20% AEP events. This was consistent at a select number of other locations (noting that the 1% AEP estimate was closer to the regional estimates in these locations), most commonly due to expansive overbank engagement and storage effects in the larger magnitude events.

Where model predictions are below those from the regional methods, consideration of catchment characteristics such as transitions from constrained to expansive shallow overbank flows in larger magnitude events as well as catchment storages are typically noted as being the likely sources of these differences. Conversely, where model predictions are greater than the regional estimates, this was often associated with well constrained, higher hydraulic energy systems where catchment storage and routing effects are less dominant. It is noted that confidences in regional estimates for large magnitude events (1% AEP) are limited by the accuracy of the FFA of the streamflow gauging data used.

Differences between modelled results and regional methods are always evident due to differences between the subject catchment and the catchments used to inform the regional method equations. Most catchments used to inform the RFFP and RFFE methods are well over 10 km² in size (typically in the order of hundreds of square kilometres) and as such minor

catchment nuances such as catchment and stream geometry, surface geomaterials and storage/routing effects all play a role in determining a catchment's peak rainfall response.

Regional methods by their nature have associated limitations but perhaps more importantly they require (to various degrees) the assumption of catchment homogeneity between the baseline dataset used to inform the methods and the subject catchment. The methods are therefore typically used to inform reasonable estimates of peak catchment discharge where no other data is available. They do not replace the need for detailed rainfall-runoff modelling which accounts for site specific catchment nuances.

6.1.2 Peak flow discussion

6.1.2.1 Harding River

The peak flow values presented in Table 6-1 shows that there are complex flow behaviours which influence peak flows between Harding Dam and the Harding River mainstream flowing through the project tenement and lithium target area.

Most notably, the bifurcation of Harding River into the East Harding River results in a reduction in peak flow entering the lithium target area within the Harding River mainstream. The contribution of local catchment runoff from Miller Creek and Murray Camp Creek to peak flow totals (even with consideration of hydrograph peak timing differential) makes the designation of the exact flow split at the Harding River bifurcation difficult. A general trend is observed in that the reduction in peak flow between the outlet of Harding River from the foothills (just upstream of the 'lore grounds' – refer Figure 1-1) into the expansive section of the river with multiple flowpaths and associated bifurcation does reduce with event magnitude. Similar peak flows are recorded at both locations in the lower magnitude events, suggesting that reductions in peak flows from the lore grounds to the project site due to floodplain storage uptake and flow routing as well as the bifurcation is offset by local catchment contributions in these lower magnitude events.

In the larger magnitude events such as the 1% AEP, the reduction in peak flows between the same locations due to the same hydraulic influences is predicted to be in the order of 8.5%. This suggests that the loss of flow into the East Harding River due to hydraulic behaviours at the bifurcation is greater than the contribution available from local contributing sub areas to the Harding River mainstream.

It is noted that the topographic data available to inform the hydraulic modelling at the bifurcation was limited to the Landgate 5 m resolution DTM data. As such, the model's ability to accurately depict the hydraulic behaviours at this location and associated impact on peak flows is limited by the accuracy of the underlying topographic dataset.

6.1.2.2 Local project catchments

Peak catchment response within the target area headwater catchments are (as expected) typically shown to be dominated by short duration, high intensity rainfall events.

For the larger magnitude events (1% and 1 in 500 AEP), mean peak flows in many reporting locations were similar across a number of design storm durations indicating that the use of the

ensemble approach has eliminated temporal bias in the results. Hence whilst the tabulated results in Table 6-1 suggest critical durations for some of the local target area catchments can reach up to 6 hours, peak flows for much shorter durations (e.g., 60 or 90 minutes) were often observed to be similar with only a few cubic meters per second differential in estimated peak flows.

For the lower magnitude events (20% and 5% AEP), a trend to the slightly longer durations towards 6 hours was common. This was considered likely due to the larger mean pre-burst rainfall in this event, and hence a lower IL_B value for this duration when compared to the shorter duration events where more of the design event rainfall total is lost to satiating the initial loss value.

6.1.3 Climate Change Sensitivity Analysis

The critical storm duration for the Harding River mainstream within the lithium target area (24 hours) was simulated using the factored design rainfall as detailed in Section 4.14, with the mean of the ensemble peak flow estimates for the current climate 1% AEP and 2050 future climate 1% AEP RCP4.5 and RCP8.5 scenarios presented in Table 6-3.

Table 6-3: Current and future climate Harding River peak design flow estimates

Location ID	1 % AEP current climate peak flow	1 % AEP 2050 future climate RCP4.5 scenario peak flow (% increase)	1 % AEP 2050 future climate RCP8.5 scenario peak flow (% increase)
Harding Rv 3	1561 m ³ /s	1758 m ³ /s (13%)	1817 m ³ /s (16%)

The tabulated results suggest that predicted increases in rainfall intensity in the 2050 future climate will result in increases in Harding River mainstream peak flows at the lithium target area of between 13% and 16% (depending on climate trajectory and alignment with either RCP scenarios).

Hydraulic impacts resulting from the projected peak flow increases in the 2050 future climate scenarios are discussed in Section 6.3.1.

6.2 Design event hydraulic behaviour

6.2.1 Accuracy limitations

The assessment outcomes and associated data in this report are based on information sourced from Azure Minerals, external sources (including Landgate), a series of informed hydrological input assumptions based on engineering judgement as well as other data that was available in the public domain at the time or times outlined in this report.

The results of the hydraulic assessment are therefore inherently reliant on the accuracy of all the available input data. For example, toward the extent of the 1 m DEM, the interface with the Landgate 5 m DEM was shown to contain discrepancies to the primary dataset with respect

to elevation (up to 2 m in some areas). As such, adjustment of the Landgate terrain was undertaken to better align vertically with the 1 m dataset.

Additionally, the source of the photogrammetry-based DEMs is subject to influence from vegetation and other artefacts that, whilst to a certain degree is managed through sophisticated filtering algorithms, cannot be removed completely and can result in both high levels of terrain smoothing and occasional artefacts resulting from larger groups of vegetative communities when compared to LiDAR derived topographic datasets.

The datasets and their relative vertical accuracies and potential differences will therefore impact on the absolute vertical accuracy of the modelled flood results. This should be considered when utilising the output data as a design basis.

6.2.2 GIS mapping

Peak flood depth, velocity, elevation, hazard vulnerability classification (Smith et al., 2014) and flood source mapping for the 1 in 500, 1%, 5% and 20% AEP events are presented in Appendix B.

The raw output model data was draped over the supplied 1 m terrain data to aid in improved visualisation of key drainage features across the sites. It is noted that this baseline hydrologic assessment intends to characterise baseline hydrologic and hydraulic behaviours across the site and the region in general. As such, accurate hydraulic definition of minor drainage features within the deposit areas is not the intent of this study. It is considered that detailed analysis of hydraulic behaviours of minor creek lines and smaller drainage features across the headwater areas associated with the project target areas will be undertaken once more detailed topographic data is obtained (i.e., LiDAR derived DEM) and project designs are established and more detailed assessments of these creek systems is required.

6.2.3 Hydraulic behaviour descriptions

Given the inherent spatial variability of flood modelling results across the project area, generalised descriptions are provided in the following sections. For detailed analysis of specific locations within the project area, interrogation of model result data is recommended in a GIS environment.

6.2.3.1 Harding River

Peak flood depths within the lithium target area for the 1% AEP flood event typically range between 3 – 4 m, with isolated regions of greater depth (greater than 6 m) associated with low flow channels and flood runners. Due to the flat longitudinal grade of the mainstream (~1.5 m/km), riparian vegetation and available floodplain width, peak flood velocities are typically predicted to be in the order of 1 m/s to 1.5 m/s with isolated regions of greater velocity toward 2 m/s.

In lower magnitude events such as the 20% AEP event, the degree of overbank engagement decreases, with peak flood depths in the engaged floodplain areas between 1 - 2 m, with isolated areas of 3 – 4 m depth associated with low flow channels. Peak flood velocities in

overbank areas in this event are typically below 1 m/s, with low flow channels only occasionally exceeding 1 m/s.

With respect to the sites immediate regional setting, the bifurcation upstream of the tenement area and the NWCH bridge and approaches downstream of the site provide the main hydraulic controls influencing Harding River flood behaviour. Right hand overbank (eastern) flow breakouts from the Harding River mainstream are observed in larger events, flowing over the NWCH. This may cause prolonged road closure of the NWCH and site access restrictions in the case of a large magnitude (e.g., 1% AEP) flood event.

6.2.3.2 Local project catchments

As has been previously described, due to the required model area associated with this baseline study as well as the topographic data used to inform the modelling, detailed descriptions of the hydraulic behaviours of headwater areas and minor creeks would be inherently subject to modelling limitations.

General review of hydraulic behaviours however suggests well-constrained creek lines in the headwater areas, often flowing onto dispersive alluvial fans before joining the respective main creek lines and river systems.

Perhaps of note for this study is the relative low flood immunity of the NWCH, which serves as the main access route to the lithium target area. The series of floodways and low-capacity culverts results in overtopping for all events assessed, although the extent of overtopping and flat longitudinal grade of the road (and typically small contributing catchment areas) suggest it would likely become trafficable relatively quickly after a local rainfall event (subject to MRWA regional office observations and classification).

6.3 Sensitivity analysis results

6.3.1 Climate Change

The peak flow increases as detailed in Section 6.1.3 for the 2050 future climate scenarios correspondingly result in increases in peak flood levels. Peak flood elevation and velocity afflux (difference) maps showing the predicted changes in hydraulic behaviours for the 2050 future climate when compared to the current climate are presented in Appendix C.

In the 2050 RCP4.5 future climate scenario, increases of approximately 240 mm in peak flood levels in Harding River mainstream through the lithium target areas are predicted. In the 2050 RCP8.5 future climate scenario, increases in peak flood levels of approximately 310 mm are predicted in the lithium target area.

Increases in peak flood velocity of less than 0.1 m/s are typically predicted for both scenarios due to the flat longitudinal grade of the mainstream.

6.3.2 Hydraulic roughness

The adoption of a 25% increase in hydraulic roughness across the model areas resulted in increased flood levels in the Harding River mainstream, with an associated decrease in peak

flood velocities, as is to be expected. For the 1% AEP event, the increase in hydraulic roughness typically results in peak flood level increases of up to a maximum of approximately 350 mm within the mainstream in the lithium target area. Due to the spatial variability of hydraulic roughness parameters, changes in peak velocity are more spatially variable with the largest reductions in peak velocity predicted to be approximately 0.2 m/s.

Conversely, a reduction of 25% in hydraulic roughness results in decreases in peak flood levels and increases in peak flood velocities. A reduction in peak flood levels of up to approximately 460 mm was predicted with the mainstream in the lithium target area, with peak velocities predicted to increase by approximately 0.3 m/s.

Vegetative density can vary seasonally and as such a large flood event occurring at the end of an above average wet season may encounter higher hydraulic roughness (due to vegetation growth) than a flood occurring after a prolonged dry period and associated reduction in vegetative density. Based on the results of the assessment, any inter-seasonal variability of hydraulic roughness and associated flood risk could typically be mitigated by adoption of a design freeboard of 400 mm (N.B. to mitigate risks associated with hydraulic roughness uncertainty only).

7. Conclusions

This study represents a baseline assessment of the hydrological and hydraulic conditions within the Andover Project target areas, as well as throughout the wider Andover Project regional setting using the latest industry assessment methods and data. The assessment methods are consistent with ARR2019 (Ball et al., 2019), the latest industry guidance on the derivation of hydrological estimates and flood risk.

The assessment has used a combination of RORB rainfall runoff modelling and TUFLOW direct rainfall modelling to estimate the hydrological and resultant hydraulic conditions across the study area using data obtained from a number of sources, including key information from WaterCorp relating to Harding Dam.

It can be concluded from the analysis that:

- The project is located in a hydrologic setting that is potentially subject to inundation from a number of sources:
 - o Regional catchment flooding associated with the Harding River. This results in significant flow rates within the Harding River mainstream which bisects the lithium target area and has prolonged durations of flow. This flooding source would typically require a tropical or ex-tropical cyclone to achieve the required quantum and duration of rainfall required to maximise catchment response and hence discharges.
 - o Local catchment flooding associated with the various headwater areas that typify the project site. These catchments and associated minor creek systems show a quicker response time and hence are dominated by shorter duration, high intensity events (like those typically associated with convective thunderstorm activity).
 - o Storm tides up to the 1% AEP event have been predicted to not impact on design flood levels within the Harding River mainstream at the lithium target area. However, storm tides may impact on any future infrastructure proposed in the northern extent of tenement E 47/4701, which is located on the periphery of the intertidal zone.
- The RORB rainfall-runoff hydrologic model developed for the Harding River has used key design information obtained from WaterCorp for Harding Dam and has been shown to strongly replicate WaterCorp peak flow quantile predictions in the rare to very rare event range. The WaterCorp hydrologic modelling (also using RORB) has been calibrated to a combined 57 years of pre and post dam gauge record and hence serves as a reliable point of reference.
- Peak flow predictions from Harding Dam are inherently subject to the adopted dam level at the onset of the design storms. This study has used the commonly adopted approach of assuming the dam is at FSL at the onset of the design storms and hence the peak flows detailed in this study for the Harding River mainstream could be considered slightly conservative. Modelling has shown that adoption of the long-term mean dam level at the onset of the design storms results in reductions in peak flow predictions from Harding Dam for the larger events, with no discharges from lower magnitude events (20% and 50% AEP) due to the available storage within the dam between the starting water level and the spillway crest.
- The TUFLOW hydraulic model, using the available topographic data, has successfully detailed the complex flow arrangements and bifurcation of Harding River that occur upstream of the project area. This modelling has hence allowed for a stronger understanding of peak flows and associated hydraulic behaviours within the mainstream through the target area. Previous studies of the area have not undertaken this modelling

and hence flow splits and model parameterisation have been often based on anecdotal evidence.

- The sensitivity analysis undertaken has shown that:
 - o Predicted future climate (2050 design horizon) changes to rainfall intensity using either RCP4.5 or RCP8.5 scenarios will result in increases in peak flow rates through the site and hence increased flood risk through increases in peak flood levels, depths and velocities. Peak flow rates in Harding River at the lithium target area are predicted to increase between 13% (RCP4.5) and 16% (RCP8.5), with peak flood levels predicted to increase between approximately 240 mm (RCP4.5) and 310 mm (RCP8.5). Similarly to the risk associated with uncertainties surrounding hydraulic roughness, mitigation of future climate risk could be undertaken through adoption of an appropriate design freeboard in the initial design works. Alternatively, in order to minimise start-up CAPEX requirements, ongoing augmentation of flood risk management infrastructure could be undertaken once revenue from the project is generated, and a stronger understanding of climatic trajectory is realised.
 - o Peak flood levels are reasonably sensitive to hydraulic roughness parameterisation (inter-seasonal variability of vegetative density) in the Harding River mainstream. In the scenario of an increased vegetative density state or under-estimate of actual current hydraulic roughness (+25% hydraulic roughness scenario), peak flood levels are predicted to increase within the Harding River mainstream through the lithium target area by approximately 350 mm. This risk would be able to be mitigated through the adoption of an appropriate design freeboard.

8. Recommendations

The following recommendations are made regarding the baseline hydrology works undertaken in this study:

- The study has used a mosaic of photogrammetry derived elevation models. It is expected that once the project matures and more accurate elevation models are required that LiDAR-based topographic data would be collected. It is recommended that the LiDAR collection area in this instance extend a sufficient distance upstream (to an area adjacent to just upstream of the ore grounds, where the Harding River becomes unconstrained) to better define waterway topographic variation and confirm bifurcation flow split estimates.
- Due to the large assessment area required as part of this study, hydraulic model resolution cannot resolve minor creek like hydraulic behaviours to a sufficient level to inform design development. As such, high resolution hydraulic modelling will be required for the headwater areas associated with the project target areas to accurately define hydraulic behaviours in these smaller creek systems (and allow for accurate derivation of flood risk management features and definition of design levels for proposed infrastructure).
- It is unknown if resource extraction will be via underground operations or open cut approach. Should the project adopt an open-pit approach to resource extraction, appropriate offsets from the Harding River mainstream should be maintained, including allowance for appropriate flood protection bund elevations and batters.
- Similarly, consideration and early planning should be given to mine closure planning and associated design flood standard requirements. Typical regulatory mine closure flood standards are extreme events and early consideration is key to allow for appropriate planning in terms of pit shell design and appropriate material classification and stockpiling.
- Appropriate design freeboards should be derived to inform the project basis of design considering hydraulic and hydrologic model parameter uncertainty and climate non-stationarity.

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Appendix A. Intensity Frequency Duration (IFD) data Harding River RORB/TUFLOW data

Harding River RORB & TUFLOW model point rainfall IFD

Event Duration	AEP event						
	50 %	20 %	10 %	5 %	2 %	1 %	1 in 500
720 minute	63.4 mm	104 mm	135 mm	167 mm	212 mm	249 mm	343 mm
1080 minute	71.6 mm	120 mm	157 mm	195 mm	250 mm	295 mm	405 mm
1440 minute	77.6 mm	131 mm	172 mm	216 mm	277 mm	326 mm	448 mm
1800 minute	82.4 mm	140 mm	184 mm	231 mm	296 mm	349 mm	482 mm
2160 minute	86.1 mm	147 mm	193 mm	242 mm	310 mm	365 mm	504 mm

Project local catchments TUFLOW model point rainfall IFD

Event Duration	AEP event						
	50 %	20 %	10 %	5 %	2 %	1 %	1 in 500
45 minute	23.5 mm	34.4 mm	41.9 mm	49.4 mm	59.5 mm	67.4 mm	92.2 mm
60 minute	26 mm	38.3 mm	46.8 mm	55.2 mm	66.7 mm	75.7 mm	104 mm
90 minute	29.9 mm	44.4 mm	54.5 mm	64.7 mm	78.5 mm	89.6 mm	122 mm
120 minute	32.9 mm	49.4 mm	61 mm	72.7 mm	88.8 mm	102 mm	139 mm
180 minute	37.8 mm	57.9 mm	72.2 mm	86.8 mm	107 mm	123 mm	169 mm
270 minute	43.7 mm	68.6 mm	86.6 mm	105 mm	131 mm	152 mm	209 mm
360 minute	48.7 mm	77.9 mm	99.2 mm	121 mm	153 mm	178 mm	245 mm

Appendix B. Flood Mapping

1 in 500, 1%, 5% and 20% AEP peak flood depth, velocity, elevation, hazard and source mapping

Andover Lithium Baseline Hydrology Study

Figure 1:
1 in 500 AEP Peak Flood Depth

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

Peak Flood Depth (m)

- <0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

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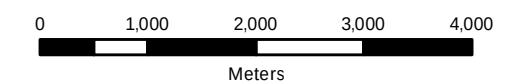
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Andover Lithium Baseline Hydrology Study

Figure 2:
1 in 500 AEP Peak Flood Velocity

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

Peak Flood Velocity (m / s)

- <0.3
- 0.3 - 0.6
- 0.6 - 1
- 1 - 1.5
- 1.5 - 2
- >2

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Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000

0 1,000 2,000 3,000 4,000
Meters



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Andover Lithium Baseline Hydrology Study

Figure 3:
1 in 500 AEP Peak Flood Elevation

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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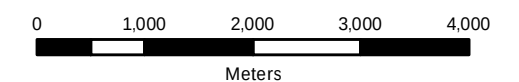
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Projection: Transverse Mercator

Datum: GDA2020

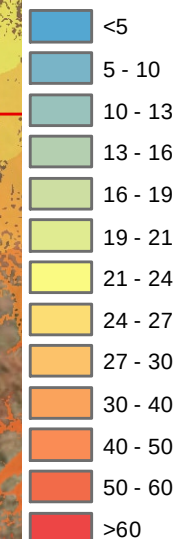
False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Peak Flood Elevation (mAHD)



Andover Lithium Baseline Hydrology Study

Figure 4:
1 in 500 AEP Peak Flood Hazard

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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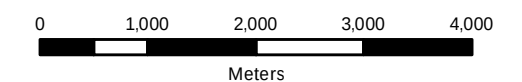
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Peak Flood Hazard (Smith et al. 2014)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

Andover Lithium Baseline Hydrology Study

Figure 5:
1 in 500 AEP Peak Flood Source

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline
- Local catchment dominant (<720 min storm duration)
- Regional catchment dominant (>720 min storm duration)

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Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000

0 1,000 2,000 3,000 4,000
Meters



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Andover Lithium Baseline Hydrology Study

Figure 6:
1 % AEP Peak Flood Depth

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

Peak Flood Depth (m)

- <0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

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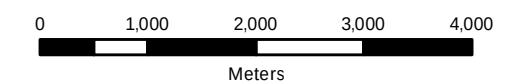
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Andover Lithium Baseline Hydrology Study

Figure 7:
1 % AEP Peak Flood Velocity

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

Peak Flood Velocity (m / s)

- <0.3
- 0.3 - 0.6
- 0.6 - 1
- 1 - 1.5
- 1.5 - 2
- >2

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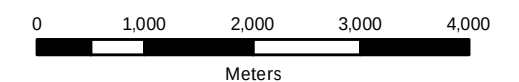
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Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

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Andover Lithium Baseline Hydrology Study

Figure 8:
1 % AEP Peak Flood Elevation

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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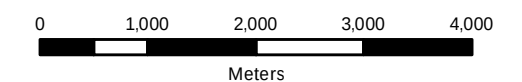
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

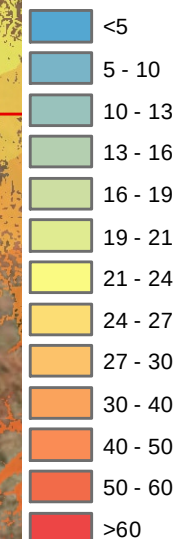
Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



Peak Flood Elevation (mAHD)



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Andover Lithium Baseline Hydrology Study

Figure 9:
1 % AEP Peak Flood Hazard

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000

0 1,000 2,000 3,000 4,000

Meters



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Peak Flood Hazard (Smith et al. 2014)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

Andover Lithium Baseline Hydrology Study

Figure 10:
1 % AEP Peak Flood Source

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline
- Local catchment dominant (<720 min storm duration)
- Regional catchment dominant (>720 min storm duration)

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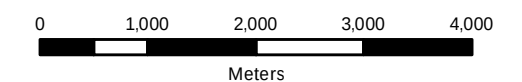
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Andover Lithium Baseline Hydrology Study

Figure 11:
5 % AEP Peak Flood Depth

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

Peak Flood Depth (m)

- <0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

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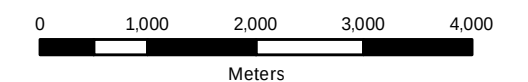
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Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Andover Lithium Baseline Hydrology Study

Figure 12:
5 % AEP Peak Flood Velocity

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

Peak Flood Velocity (m / s)

- <0.3
- 0.3 - 0.6
- 0.6 - 1
- 1 - 1.5
- 1.5 - 2
- >2

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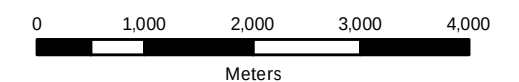
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Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Andover Lithium Baseline Hydrology Study

Figure 13:
5 % AEP Peak Flood Elevation

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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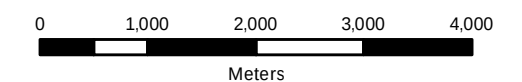
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Peak Flood Elevation (mAHD)

- <5
- 5 - 10
- 10 - 13
- 13 - 16
- 16 - 19
- 19 - 21
- 21 - 24
- 24 - 27
- 27 - 30
- 30 - 40
- 40 - 50
- 50 - 60
- >60

Andover Lithium
Baseline Hydrology Study

Figure 14:
5 % AEP Peak Flood Hazard

- Legend
- Exploration and miscellaneous licences
 - Ground Water Target Area
 - Lithium Target Area
 - Nickel Target Area
 - Rio Tinto Railway
 - Roads/tracks
 - Water Pipeline

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Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020
False Easting: 500,000.0000

Scale at A3 - 1:70,000

0 1,000 2,000 3,000 4,000

Meters



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Peak Flood Hazard (Smith et al. 2014)

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

Andover Lithium Baseline Hydrology Study

Figure 15:
5 % AEP Peak Flood Source

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline
- Local catchment dominant (<720 min storm duration)
- Regional catchment dominant (>720 min storm duration)

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Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000

0 1,000 2,000 3,000 4,000
Meters



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Andover Lithium Baseline Hydrology Study

Figure 16:
20 % AEP Peak Flood Depth

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

Peak Flood Depth (m)

- <0.3
- 0.3 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- 3 - 5
- >5

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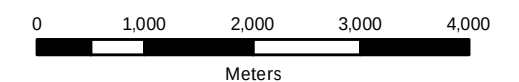
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Andover Lithium Baseline Hydrology Study

Figure 17:
20 % AEP Peak Flood Velocity

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

Peak Flood Velocity (m / s)

- <0.3
- 0.3 - 0.6
- 0.6 - 1
- 1 - 1.5
- 1.5 - 2
- >2

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Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000

0 1,000 2,000 3,000 4,000
Meters



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Andover Lithium Baseline Hydrology Study

Figure 18:
20 % AEP Peak Flood Elevation

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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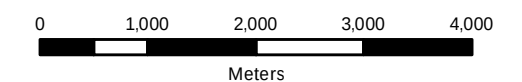
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



Peak Flood Elevation (mAHD)



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Andover Lithium Baseline Hydrology Study

Figure 19:
20 % AEP Peak Flood Hazard

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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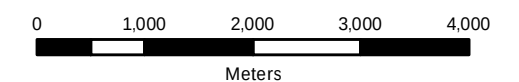
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Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Peak Flood Hazard (Smith et al. 2014)

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- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

Andover Lithium Baseline Hydrology Study

Figure 20:
20 % AEP Peak Flood Source

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline
- Local catchment dominant (<720 min storm duration)
- Regional catchment dominant (>720 min storm duration)

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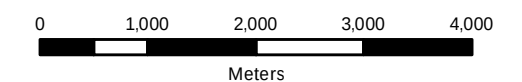
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Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Appendix C. Sensitivity Analysis Flood Afflux Mapping 2050 future climate sensitivity analysis and floodplain roughness sensitivity analysis

Andover Lithium Baseline Hydrology Study

Figure 1:
Sensitivity Analysis
Manning's 'n' + 25 %
1 % AEP Peak Flood Level Afflux

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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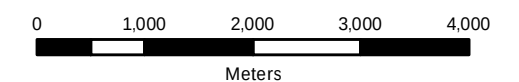
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Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

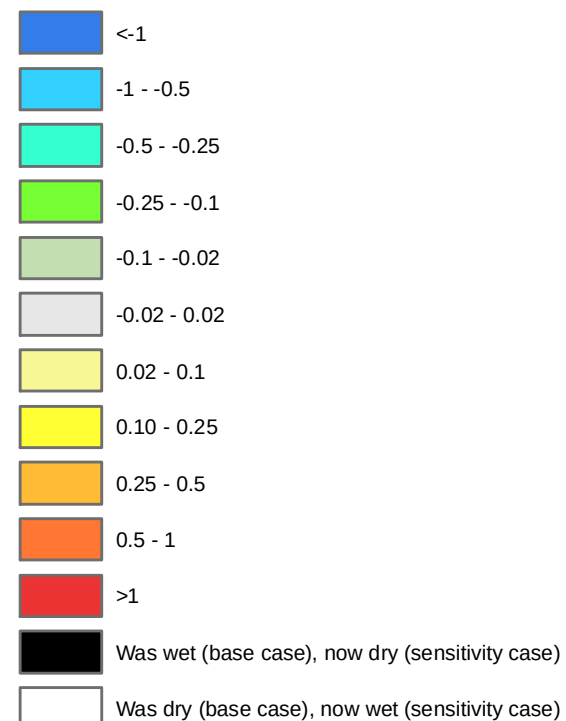
Scale at A3 - 1:70,000



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Peak Flood Level Afflux (m)



Andover Lithium Baseline Hydrology Study

Figure 2:
Sensitivity Analysis
Manning's 'n' +25 %
1 % AEP Peak Flood Velocity Afflux

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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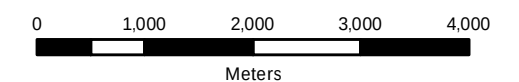
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Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Peak Velocity Afflux (m / s)

- <-0.5
- 0.5 to -0.25
- 0.25 to -0.1
- 0.1 to 0.1
- 0.1 to 0.25
- 0.25 to 0.5
- >0.5
- Was wet (base case), now dry (sensitivity case)
- Was dry (base case), now wet (sensitivity case)

Andover Lithium Baseline Hydrology Study

Figure 3:
Sensitivity Analysis
Manning's 'n' -25 %
1 % AEP Peak Flood Level Afflux

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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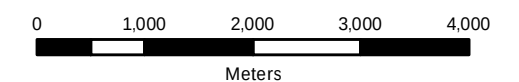
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Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Peak Flood Level Afflux (m)

- <-1
- 1 - -0.5
- 0.5 - -0.25
- 0.25 - -0.1
- 0.1 - -0.02
- 0.02 - 0.02
- 0.02 - 0.1
- 0.10 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- >1
- Was wet (base case), now dry (sensitivity case)
- Was dry (base case), now wet (sensitivity case)

Andover Lithium Baseline Hydrology Study

Figure 4:
Sensitivity Analysis
Manning's 'n' -25 %
1 % AEP Peak Flood Velocity Afflux

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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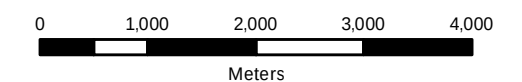
Coordinate System: GDA2020 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Peak Velocity Afflux (m / s)

- <-0.5
- 0.5 to -0.25
- 0.25 to -0.1
- 0.1 to 0.1
- 0.1 to 0.25
- 0.25 to 0.5
- >0.5
- Was wet (base case), now dry (sensitivity case)
- Was dry (base case), now wet (sensitivity case)

Andover Lithium Baseline Hydrology Study

Figure 5:
Sensitivity Analysis
2050 Future Climate RCP4.5 Scenario
1 % AEP Peak Flood Level Afflux

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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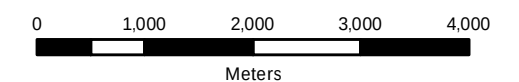
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Projection: Transverse Mercator

Datum: GDA2020

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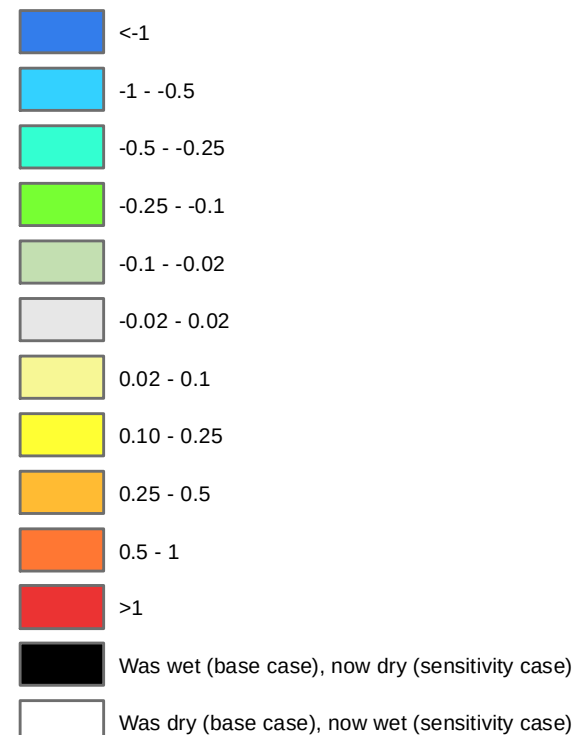
Scale at A3 - 1:70,000



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Peak Flood Level Afflux (m)



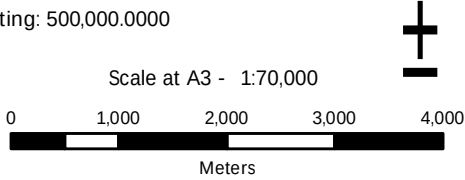
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13/02/2024 Rev: 0 ISSUED FOR INFORMATION Org: PC Chk: PC

Andover Lithium Baseline Hydrology Study

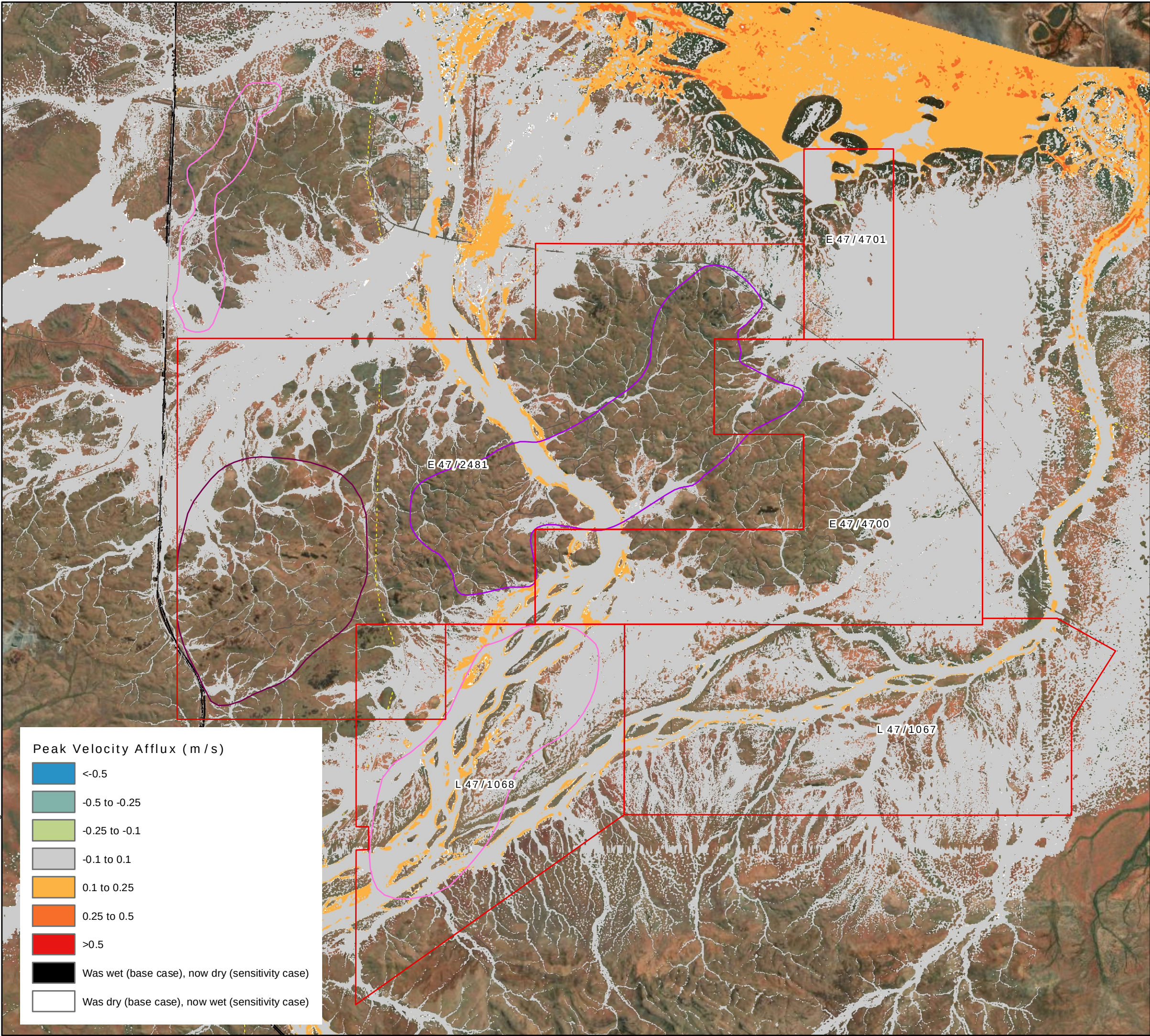
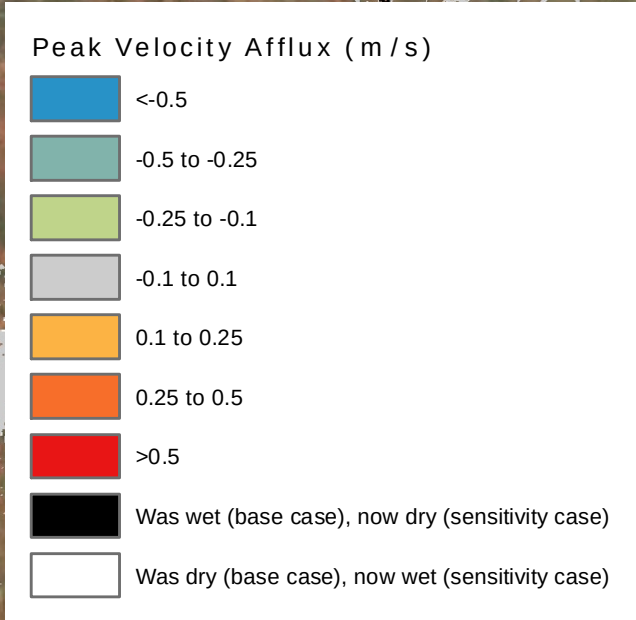
Figure 6:
Sensitivity Analysis
2050 Future Climate RCP4.5 Scenario
1 % AEP Peak Flood Velocity Afflux

- Legend
- Exploration and miscellaneous licences
 - Ground Water Target Area
 - Lithium Target Area
 - Nickel Target Area
 - Rio Tinto Railway
 - Roads/tracks
 - Water Pipeline

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Coordinate System: GDA2020 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA2020
False Easting: 500,000.0000



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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community



Andover Lithium Baseline Hydrology Study

Figure 7:
Sensitivity Analysis
2050 Future Climate RCP8.5 Scenario
1 % AEP Peak Flood Level Afflux

Legend

- Exploration and miscellaneous licences
- Ground Water Target Area
- Lithium Target Area
- Nickel Target Area
- Rio Tinto Railway
- Roads/tracks
- Water Pipeline

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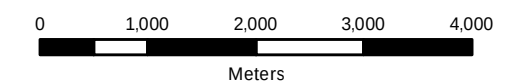
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Projection: Transverse Mercator

Datum: GDA2020

False Easting: 500,000.0000

Scale at A3 - 1:70,000



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Peak Flood Level Afflux (m)

- <-1
- 1 - -0.5
- 0.5 - -0.25
- 0.25 - -0.1
- 0.1 - -0.02
- 0.02 - 0.02
- 0.02 - 0.1
- 0.10 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- >1
- Was wet (base case), now dry (sensitivity case)
- Was dry (base case), now wet (sensitivity case)

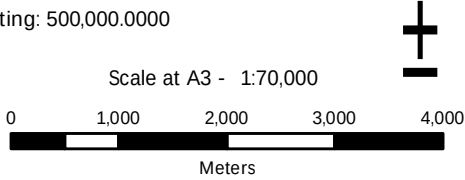
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13/02/2024 Rev: 0 ISSUED FOR INFORMATION Org: PC Chk: PC

Andover Lithium Baseline Hydrology Study

Figure 8:
Sensitivity Analysis
2050 Future Climate RCP8.5 Scenario
1 % AEP Peak Flood Velocity Afflux

- Legend
- Exploration and miscellaneous licences
 - Ground Water Target Area
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 - Nickel Target Area
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Datum: GDA2020
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