

East Pilbara Generation Hub

Baseline Hydrology Study

Fortescue Future Industries

17 October 2022

311012-01491

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PROJECT 311012-01491 - EPGH-HYD-REP-001: East Pilbara Generation Hub - Baseline Hydrology Study












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Executive summary

A hydrologic assessment was required in order to form a baseline understanding of surface water behaviour within and surrounding the East Pilbara Generation Hub (EPGH) Wind Farm 1 (WF1) and Wind Farm 2 (WF2) areas (the study area). The baseline hydrologic assessment is intended to support preliminary layout/design of infrastructure and initial regulatory approval submissions.

The EPGH site is located 100 km east of the Iron Bridge mine site. This will allow renewable energy to be efficiently inserted into Fortescue's existing transmission network, through the Iron Bridge and North Star Junction substations. Two wind farm locations are proposed, situated in the headwaters of the Camel Creek catchment (WF1) and Yandicoogina Creek (WF2), part of the De Gray River basin. The wind farm site will be supported by other infrastructure including an infrastructure corridor running north along Marble Bar Road, to connect the proposed site to porting facilities, and energy transmission corridors to the west.

As there are no streamflow gauges in the EPGH project area, regional characterisation of the rainfall-runoff relationship was undertaken through Flood Frequency Analysis (FFA) of two nearby streamflow gauges at Marble Bar and Nullagine, as well as the development of two RORB rainfall-runoff models of the same catchments. This resulted in the validation of a set of empirical loss model parameters for use in the hydrologic analysis of the study area catchments.

Rainfall-runoff and hydraulic behaviour predictions for the base (existing) case in the study area were undertaken using two rain-on-grid TUFLOW hydraulic models. Design rainfall events including the 50%, 20%, 10%, 5%, 2% and 1% AEP events were assessed for the WF1 and WF2 study areas. Only conceptual wind turbine layouts were provided by FFI at the time of the assessment, and it was shown that the conceptual locations were typically outside the 1% AEP peak flood extent, particularly on the main creek systems. Some conceptual turbine locations were shown to be within the predicted flood extent on minor creek systems within WF1, with some locations in WF2 shown to be in more significant flowpaths. It is expected the results of this baseline hydrologic assessment will inform turbine location optimisation as the design process matures.

Sensitivity analysis was also undertaken to predict peak flood behaviour sensitivity to the predicted impacts on rainfall in the 2050 future climate scenario. This sensitivity was assessed for both the 1% AEP 2050 RCP4.5 and RCP8.5 scenarios. Model results predicted that increases in peak flood levels were typically below 200 mm for most of the study area, even in the RCP8.5 scenario. Similarly, assessment of model results to increased floodplain roughness was also undertaken, with model results showing similar increases in peak flood levels. As a result, it is expected that the uncertainties and associated risks relating to future climate hydrologic uncertainty and the exact floodplain roughness across the study area and could be mitigated by adoption of a standard design freeboard of 300 mm.

Acronyms and abbreviations

Acronym/abbreviation	Definition
1D	One-dimensional
2D	Two-dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AM	Annual Maximum
ARF	Areal Reduction Factor
ARR1987	Australian Rainfall and Runoff (1987)
ARR2019	Australian Rainfall and Runoff (2019)
BoM	Bureau of Meteorology
CL	Continuing Loss
DEM	Digital Elevation Model
DWER	Department of Water and Environment Regulation
EPGH	East Pilbara Generation Hub
FFA	Flood Frequency Analysis
FFI	Fortescue Future Industries
IFD	Intensity Frequency Duration
IL _B	Burst Initial Loss
IL _S	Storm Initial Loss
LP III	Log Pearson III
MRWA	Main Roads Western Australia
PILF	Potentially Influential Low Flows
RCP	Representative Concentration Pathway
RFFA	Regional Flood Frequency Analysis
RFFE	Regional Flood Frequency Estimation Model
RFFP	Regional Flood Frequency Procedure
SILO	Scientific Information for Landowners
TEC	Threatened Ecological Communities
WF1	Wind Farm 1

Acronym/abbreviation	Definition
WF2	Wind Farm 2

1 Introduction

1.1 Background

Fortescue Future Industries, a wholly owned subsidiary of Fortescue Metals Group, is leading the company's decarbonisation and green product export agendas by developing a portfolio of projects, centred on producing renewable energy and other value-adding green export products, primarily hydrogen and ammonia. This portfolio of projects proposes to achieve 100% decarbonisation of Fortescue's operations by 2030.

A key element to achieving this objective is the proposed East Pilbara Generation Hub (EPGH), which will support development of a combination of wind and solar power generation. This will allow renewable energy to be transmitted back into Fortescue's power network, to decarbonise existing iron ore operations and provide renewable energy to support the potential for large-scale conversion to a hybrid hydrogen electric fleet.

The identified EPGH site (the focus of this study) is located 100 km east of the Iron Bridge mine site. This will allow renewable energy to be efficiently inserted into Fortescue's existing transmission network, through the Iron Bridge and North Star Junction substations. The site sits within both a native title determination area (Nyamal People #1) and an undetermined area the subject of a registered native title claim (Nyamal #1). The entire area is on the Corunna Downs pastoral lease. Two wind farm locations are proposed, Wind Farm 1 (WF1) is situated in the headwaters of the Camel Creek catchment and Wind Farm 2 (WF2) is situated in the headwaters of Yandicoogina Creek, part of the De Gray River basin. The wind farm site will be supported by other infrastructure including an infrastructure corridor running north along Marble Bar Road, to connect the proposed site to porting facilities, and energy transmission corridors to the west.

A hydrologic assessment is required in order to form a baseline understanding of surface water behaviour within and surrounding the WF1 and WF2 areas (the study area) as presented in Figure 1-1. The proposed transmission corridor is to be assessed in later studies and does not form part of this assessment (although regional hydrologic characterisation works undertaken in this study include the Coongan River crossing of the transmission corridor). This baseline hydrologic assessment will support preliminary layout/design of infrastructure and initial regulatory approval submissions.

This report provides a summary of the baseline hydrologic assessment works including site characteristics, design event hydrology and hydraulic modelling results.

1.2 Scope of works

The scope of works for this assessment are:

1. Review existing publicly available and Fortescue generated hydrological data, surrounding environmental settings, potential sensitive receptors nearby, that would inform the development of the hydrological models and model boundaries, as in Task 2.
2. Develop hydrological/hydraulic models for surface water catchment/s for surface water assessment and quantification of stream flow resulting from rainfall-runoff.
 - a. The assessment methodologies shall comprise of regional and rainfall-runoff routing methods/models including the Regional Flood Frequency Procedure (RFFP), Regional Flood

- Frequency Estimation tool (RFFE), RORB and TUFLOW, determined to be appropriate for the complexity of the hydrological regime of the catchment area, and the objectives of the study.
- b. The assessment shall determine the critical rainfall duration and temporal rainfall patterns, and flood estimates at the locations of interest for the purpose of regulatory reporting. Additionally, critical duration and temporal patterns shall be determined, or models developed that would enable future their determination, for localised proposed infrastructure areas such that future design work can be performed.
 - c. The assessment shall be performed for design rainfall events ranging from 50% to 1% Annual Exceedance Probability (AEP), as well as implications from climate change.
 - d. The assessment shall be performed in accordance with the guidelines of the latest (2019) version of Australian Rainfall & Runoff (ARR2019) (Ball et al., 2019).
 - e. The extent of the hydrological/hydraulic model/s shall consider the proposed transmission corridor and any sensitive surface water receptors such that the baseline models can be used to inform future surface water impact assessments.
3. Calibrate/verify the hydrological model, or parameters thereof within the model, where data exists.
 4. Develop a baseline hydrological assessment report documenting the catchment setting and surrounding environment, methodologies, justification for suitability of the adopted methodologies and model parameters, and results including flood mapping (flood depth and velocities) of the area for the 20%, 5% and 1% AEP design rainfall events, suitable for regulatory approval submission (this document).

2 Information and data

2.1 FFI provided information

A summary of the key information provided by FFI for this assessment is presented in Table 2-1.

Table 2-1: Data utilised in this assessment

Data / Information	Description	File / Format
Aerial Imagery and Topography		
Digital Elevation Model (DEM)	1 m photogrammetrically derived DEM captured February 2022	PIL_ELEV_FMG_FFI_1M_DEM_FEB2022.tif
Planning		
Development areas	Proposed project development areas	EAST_PILBARA_DEV_ENV_REV2.DXF EAST_PILBARA_PHASE1.DXF EAST_P_DEV_ENV_REV2_CORUNNA.DXF
Infrastructure layout	Indicative wind turbine layout	EP_All_Towers_DevEnv.shp
Background Information		
Reports	Nil	

As shown in Figure 2-1, the Digital Elevation Model (DEM) extends for a significant distance outside the project area and includes most of the proposed transmission corridor to Iron Bridge.

2.2 Publicly available data

Hydrology datasets including stream gauging and rainfall data were sourced from the Department of Water and Environmental Regulation (DWER), Bureau of Meteorology (BoM), and ARR2019 Datahub. These datasets are described in Section 4.

EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY

FIGURE 2-1

DIGITAL ELEVATION MODEL EXTENT

Legend

- Townsite
- State Road
- Local Road
- Miscellaneous Road
- Major Waterway
- Minor Waterway
- Project Development Envelope
- Proposed Wind Tower Location

FFI provided Digital Elevation Model

(mAHD)

- High : 750
- Low : 150

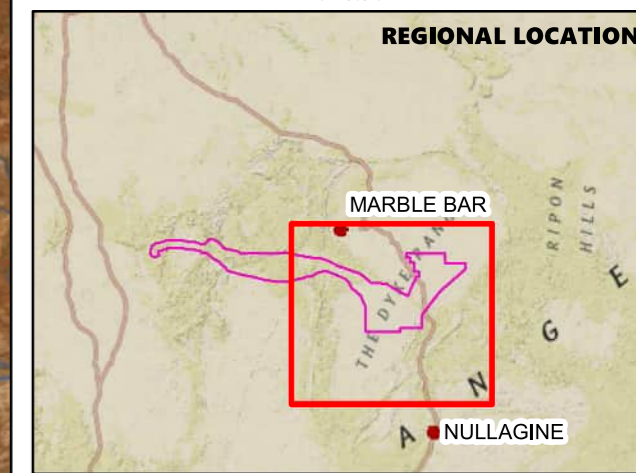
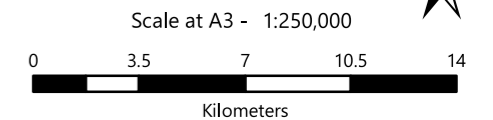
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Projection: Transverse Mercator

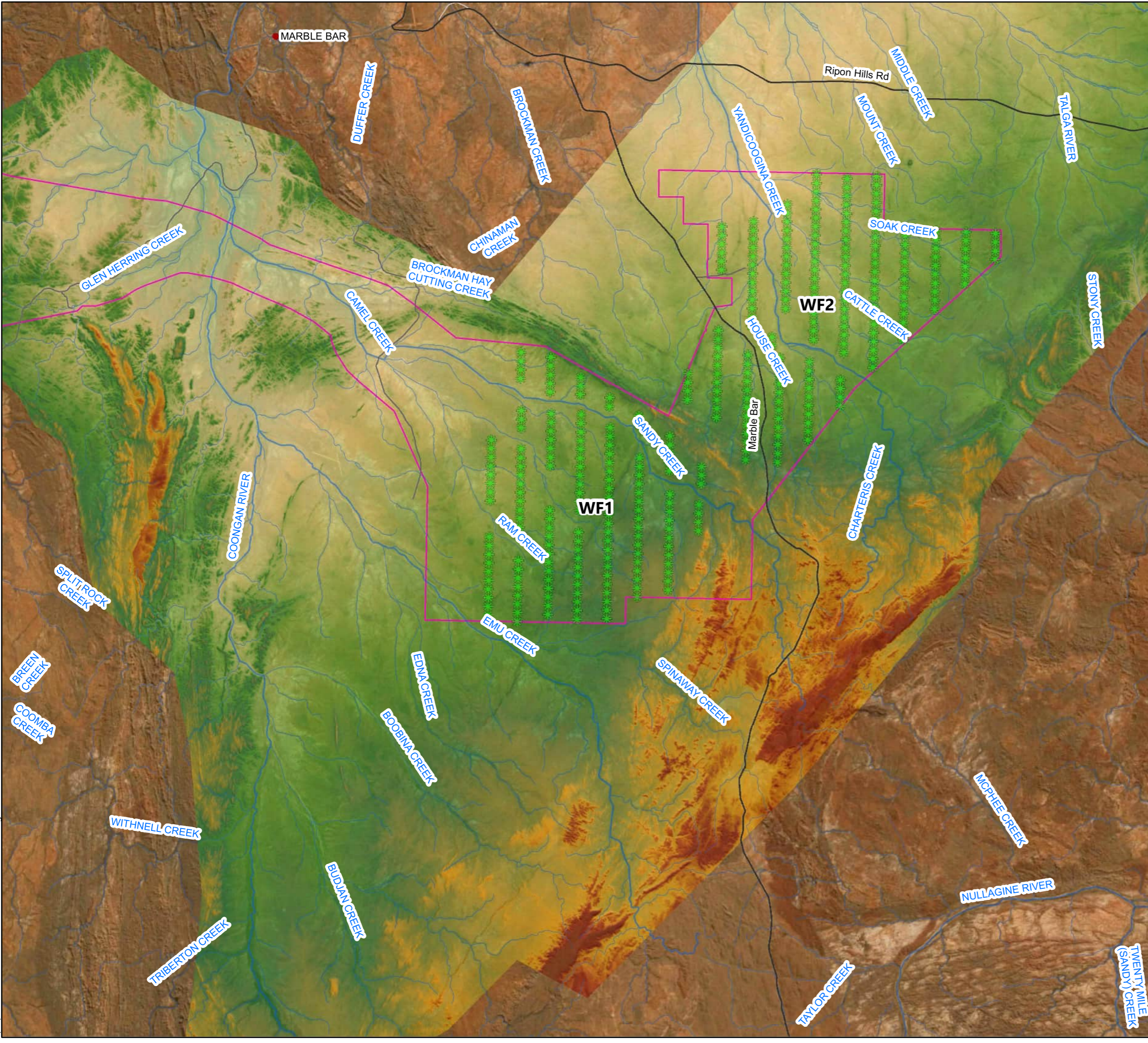
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Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User

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3 Catchment characterisation

The hydrologic behaviours of the contributing catchments to the Study Area are governed by the climate and physical characteristics of the catchment. This section provides a description of the catchment characteristics that informed the hydrologic and hydraulic modelling.

3.1 Catchments

The Study Area is located in the headwaters of Cane Creek (a tributary of Coongan River) and Yandicoogina Creek (a tributary of Talga River). Talga River discharges into the Coongan River approximately 55 km downstream of the Study Area, with the Coongan River ultimately discharging into the De Grey River.

The main creek systems of the Study Area are presented in Figure 3-1. The contributing catchments of the Study Area drain generally in a northwesterly direction. General catchment characteristics for the main creek systems contributing to the Study Area are presented in Table 3-1.

Table 3-1: Study Area catchment details

Catchment Name	Area (km ²)	Mainstream Length (km)	Centroid Latitude (°S)	Centroid Longitude (°E)	EA slope (m/km)	Shape Factor, L ² /A
Emu Creek	412	40.01	21.57	119.99	2.50	4.60
Ram Creek	69.8	16.90	21.47	119.91	3.32	4.09
Camel Creek	51.5	18.06	21.46	119.95	3.67	6.33
Sandy Creek	161	27.03	21.49	120.05	4.13	4.54
Yandicoogina Creek	173	30.63	21.44	120.15	3.88	5.42
Cattle Creek	54.2	15.17	21.36	120.17	3.27	4.24
Soak Creek	58.5	14.99	21.31	120.20	3.55	3.84

3.2 Climate

The Pilbara climate is characterised by very hot summers, mild winters and low and variable rainfall (Sudmeyer, 2016). The BoM Koppen climate classification system (Stern et al., 2000) defines the Study Area as a hot desert area with winter drought. Rainfall therefore occurs predominantly in the summer wet season (approximately November to March) from passing ex-tropical cyclones and low-pressure systems localised isolated convective thunderstorm activity. Owing to these mechanisms, rainfall is highly variable and extended periods of low rainfall are common.

Point data has been obtained from the Scientific Information for Landowners (SILO) database to enable long term review of rainfall and evaporation data. SILO is a database of Australian climate data from 1889 to the present. It provides daily meteorological datasets for a range of climate variables in ready-to-use formats suitable for biophysical modelling, research and climate applications. SILO datasets are constructed from observational records provided by the Bureau of Meteorology. SILO

interpolates the raw data, which may contain missing values, to derive datasets which are both spatially and temporally complete.

The variability of rainfall is demonstrated in Figure 3-2 with mean monthly and annual rainfall totals at Marble Bar (ID: 004020). The annual rainfall average (360.8 mm) is provided for the October to September water year. Mean monthly pan evaporation for Marble Bar (available from 1970 onwards) consistently exceeds mean monthly rainfall, signifying a water limited environment (Table 3-2).

EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY

FIGURE 3-1

STUDY AREA CATCHMENTS

Legend

- WF1 Overall Hydrologic Study Area
- WF2 Overall Hydrologic Study Area
- Main Development Area Catchments
- Project Development Envelope
- State Road
- Local Road
- Miscellaneous Road
- ✱ Proposed Wind Tower Location
- Major Waterway
- Minor Waterway

Shuttle Radar Topography Mission DEM (mMSL)

- High : 750
- Low : 150

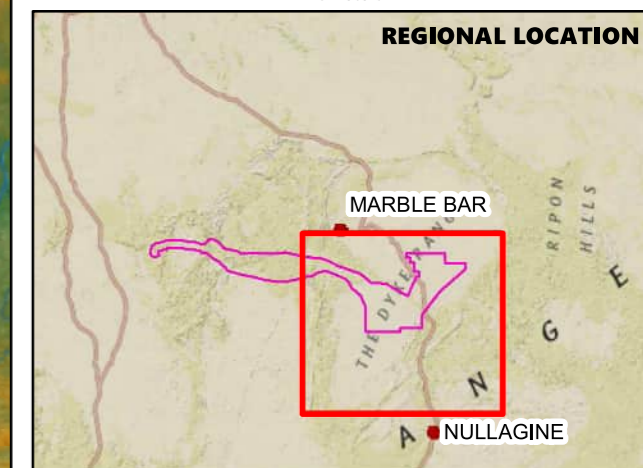
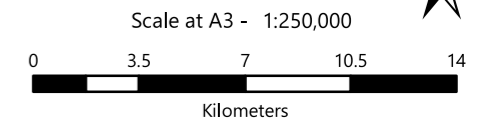
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Projection: Transverse Mercator

Datum: GDA 1994

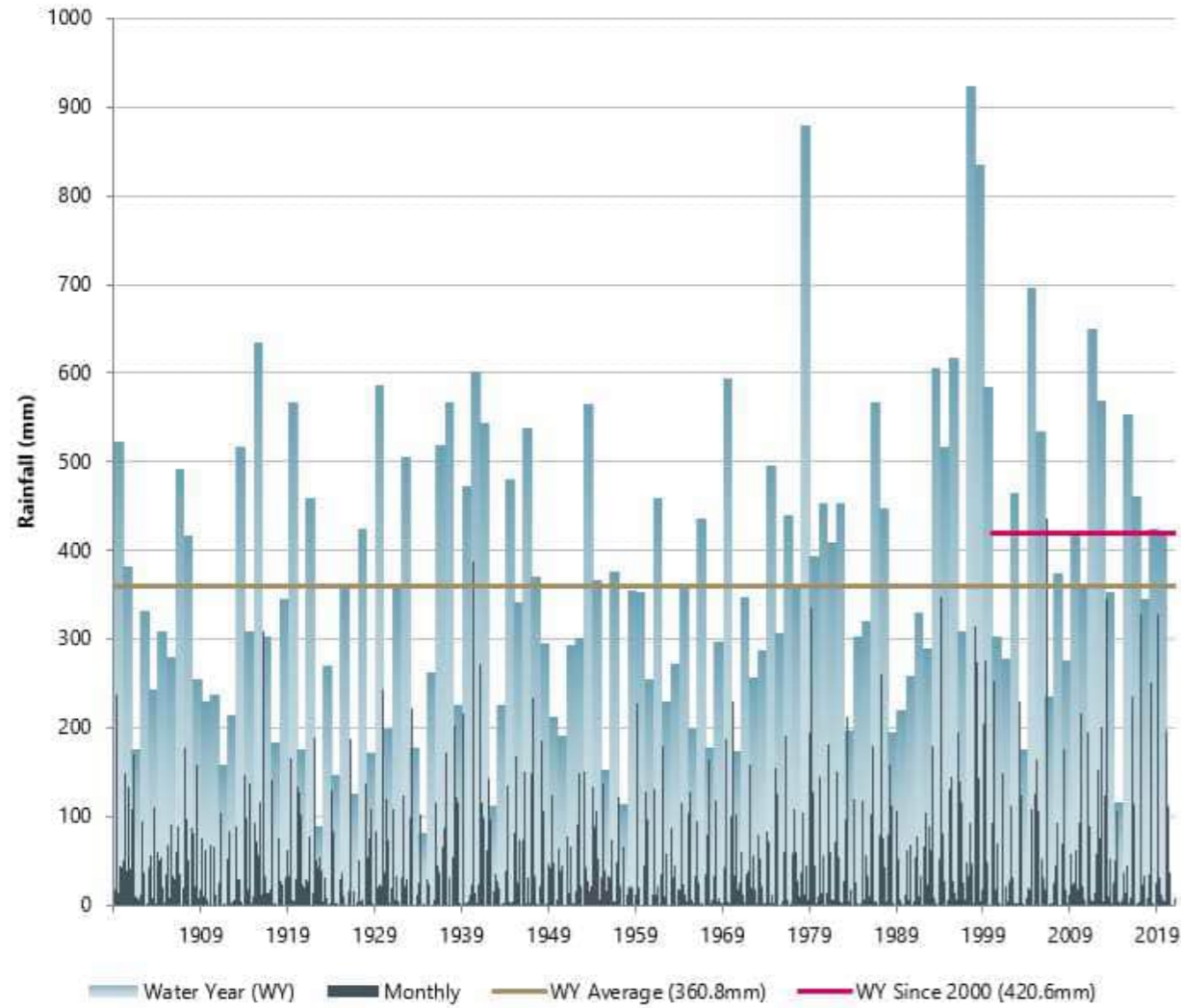
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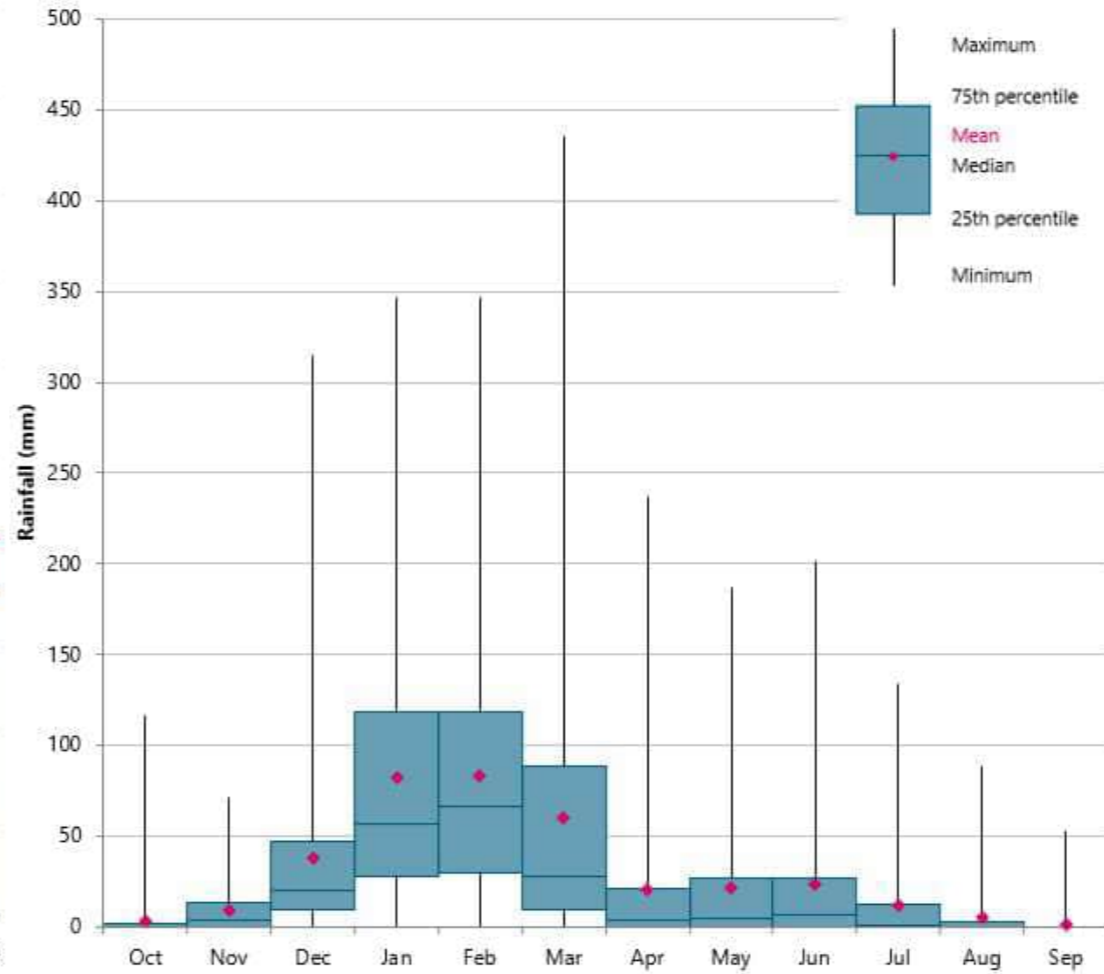
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Average Water Year and Monthly Rainfall Data



Monthly Rainfall Data



**EAST PILBARA GENERATION HUB
BASELINE HYDROLOGY STUDY**

FIGURE 3-2

STUDY AREA CLIMATE DATA

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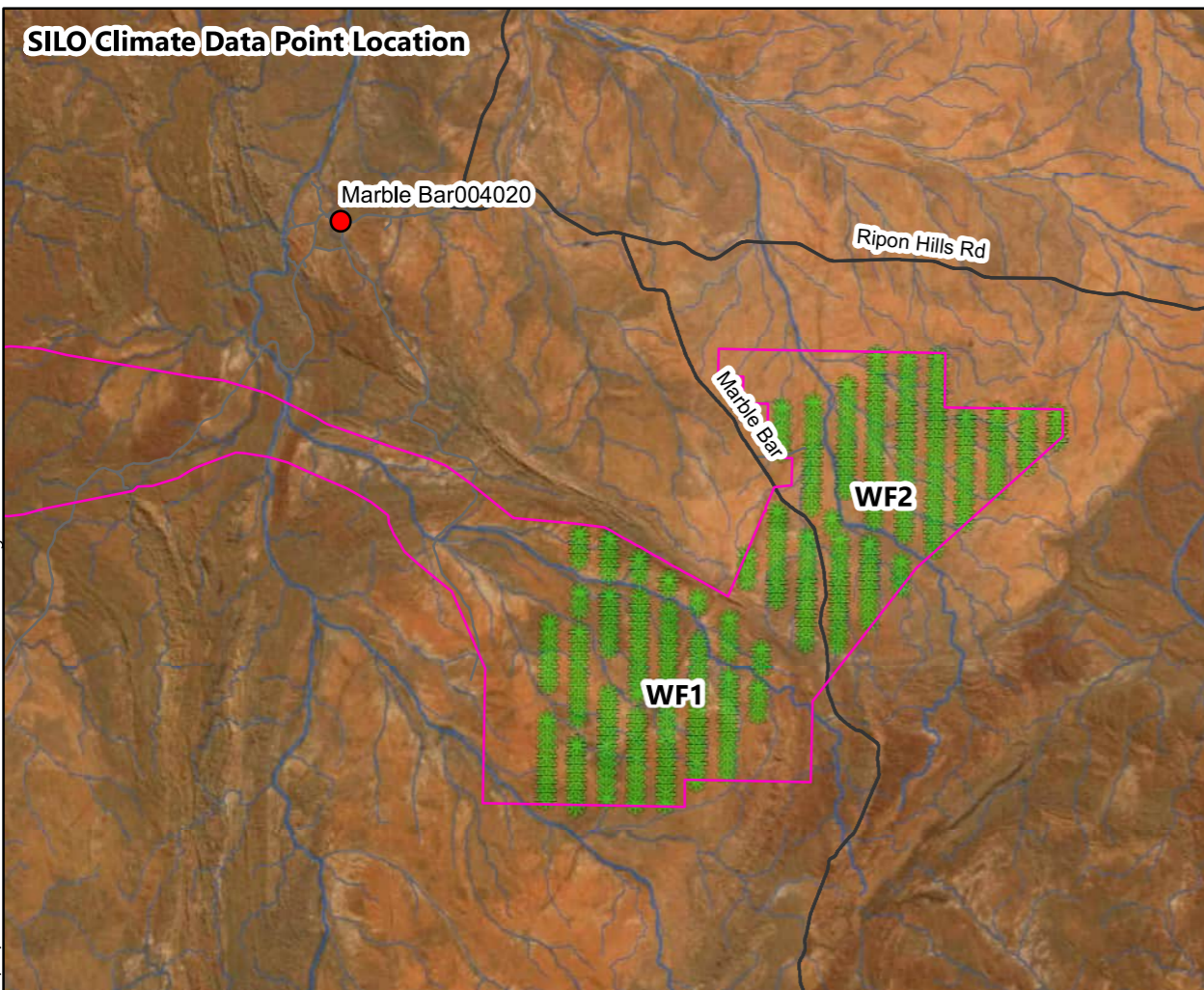
- Climate Data Gauge Site
- Project Development Envelope
- State Road
- Local Road
- Miscellaneous Road
- Proposed Wind Tower Location
- Major Waterway
- Minor Waterway

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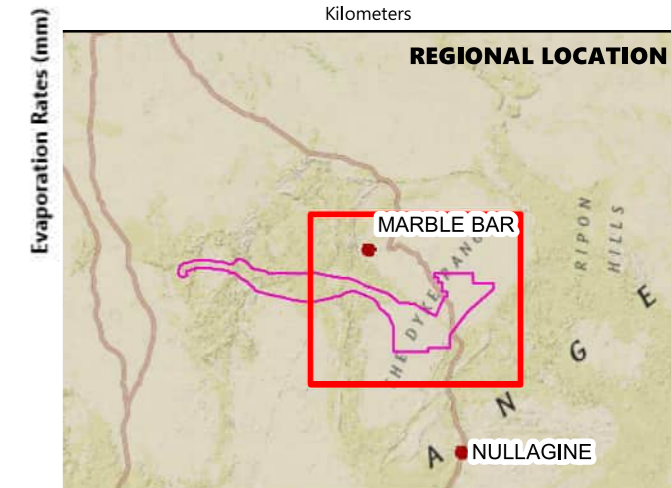
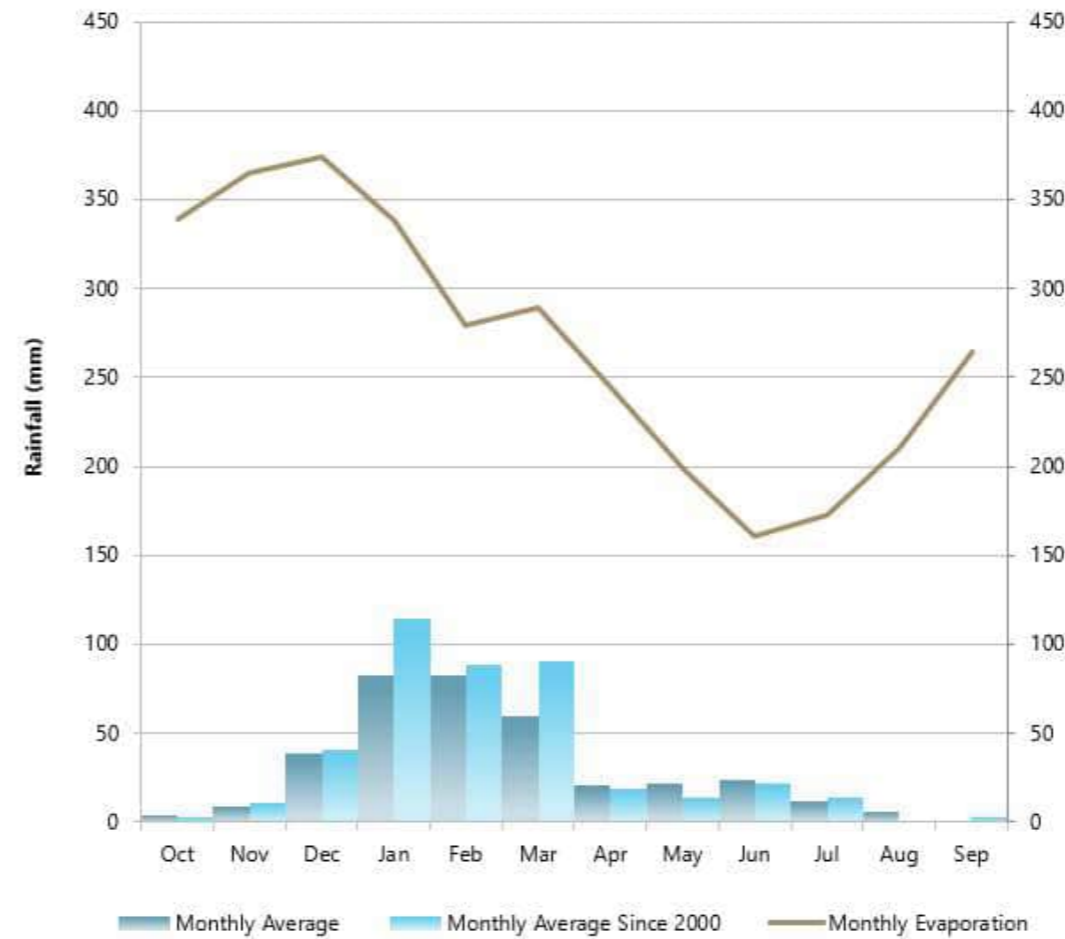
Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
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SILO Climate Data Point Location



Average Monthly Rainfall and Evaporation Data



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User

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Table 3-2: Monthly evaporation and rainfall data (BoM, 2022)

Data	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Mean pan evaporation (mm) at Marble Bar*	339	365	374	338	279	289	245	199	161	172	211	264	3,237
Mean rainfall (mm) at Marble Bar	3.6	9.1	38.5	82.8	83.1	59.9	20.4	21.7	23.3	11.6	5.5	1.3	360.8
Highest Rainfall (mm)	116.3	71.2	314.9	346.5	347.2	435.4	237.3	186.7	200.9	133.9	88.9	52.9	797.9
Lowest Rainfall (mm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.4
Median Rainfall (mm)	0.0	3.3	20.3	57.2	66.7	28.2	3.5	4.6	6.9	0.9	0.0	0.0	342.7
Highest Daily Rainfall (mm)	84.3	60.5	150.4	151.6	121.4	304.8	168.8	91.4	104.6	105.6	73.1	30.4	304.8
Mean no. rain days > 10 mm	0.1	0.3	1.1	2.5	2.5	1.5	0.5	0.6	0.7	0.3	0.2	0.0	9.8

*Pan evaporation data (since 1970)

3.3 Soils

Soils within the Study Area are variable, with stony soils dominating the headwater areas which consist of the predominately hillier terrain in the Nullagine Hills Zone (Tille, 2006). This consists of Stony soils with Red shallow loams and sands with spinifex grasslands with kanji and snappy gum.

The lower plains of the study are typified by the Abydos Plains and Hills Zone. This includes Red deep sandy duplexes and Red shallow loams with Stony soils, Red sandy earths and Red loamy earths. Vegetation consists of typically Spinifex grasslands with kanji (and some tussock grasslands).

The key soil landscapes of the Study Area are presented in Figure 3-3.

EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY

**FIGURE 3-3
REGIONAL SOIL MAPPING**

Legend

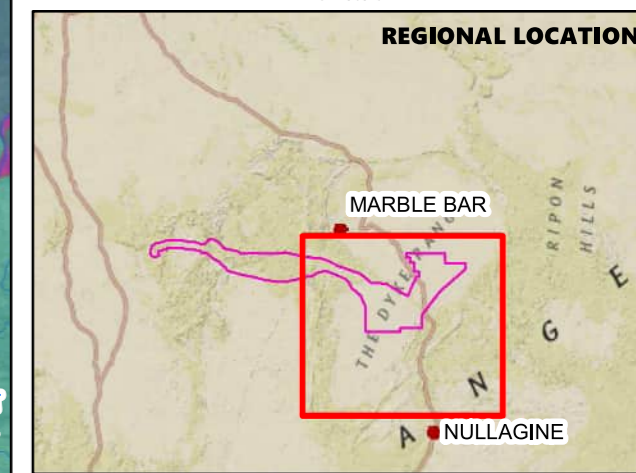
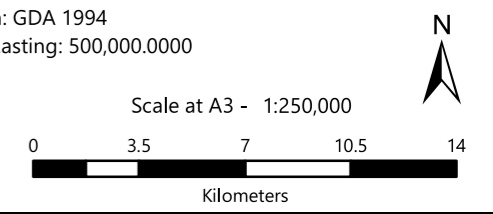
- WF1 Catchment
- WF2 Catchment
- Project Development Envelope
- State Road
- Local Road
- Miscellaneous Road
- ✱ Proposed Wind Tower Location
- Major Waterway
- Minor Waterway

Soil Group

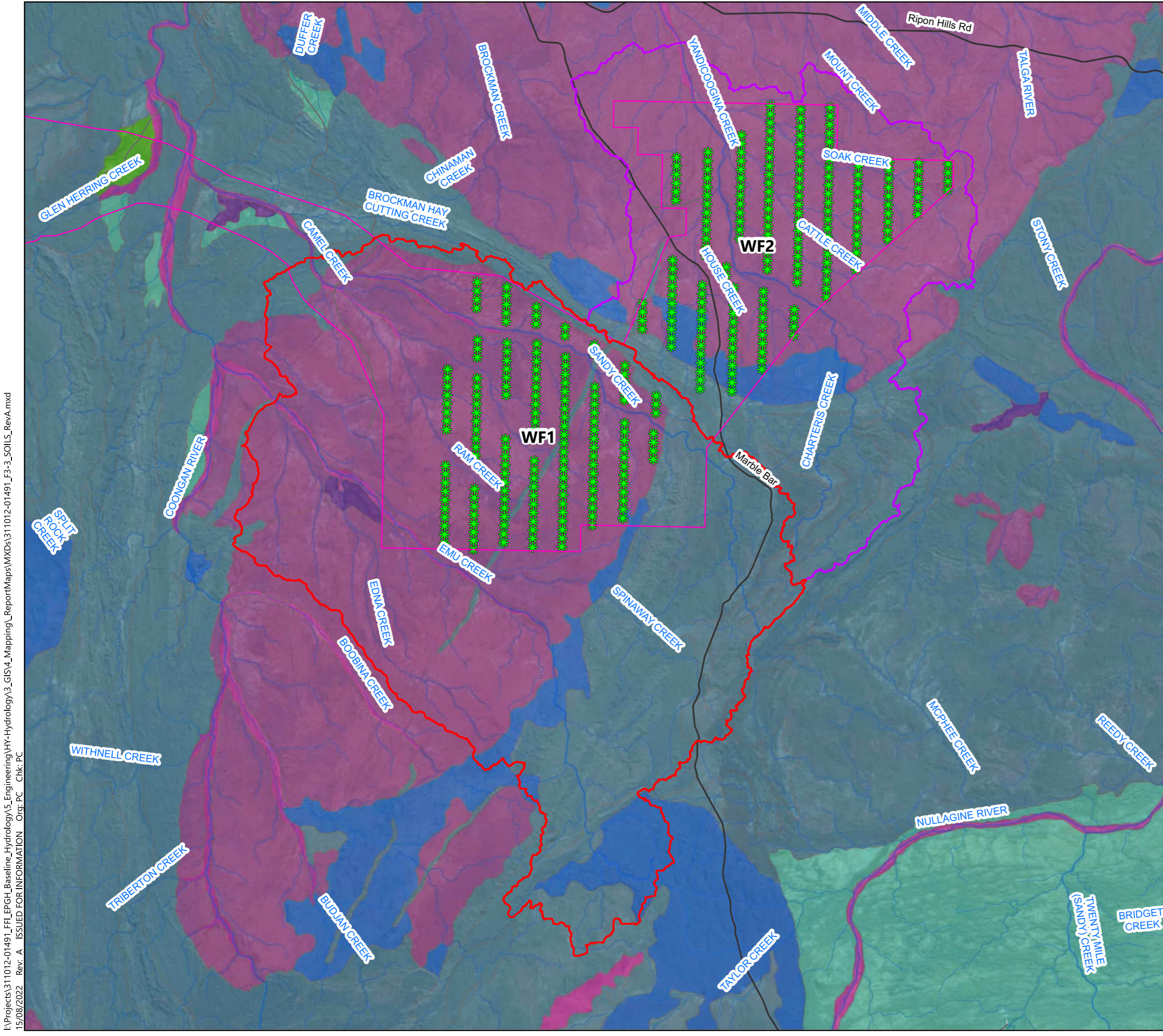
- Calcareous shallow loam
- Red deep sand
- Red deep sandy duplex
- Red shallow loam
- Red shallow sand
- Red/brown non-cracking clay
- Stony soil

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Coordinate System: GDA 1994 MGA Zone 50
 Projection: Transverse Mercator
 Datum: GDA 1994
 False Easting: 500,000.0000



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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 15/08/2022 Rev: A ISSUED FOR INFORMATION Orig: PC Chk: PC

3.4 Infrastructure

Existing infrastructure within the Study Area is limited to:

- Marble Bar Road;
- Local access tracks; and
- Small regional airstrips located at Corunna Downs and Corunna Downs 2.

3.5 Environmental and cultural values

Flows through the Study Area support environmental habitats including within the riparian corridors. Although unlikely, potential changes to surface water flows downstream of the proposed renewable energy activities due to proposed infrastructure has the potential to impact vegetation in the respective communities. There are no Threatened Ecological Communities (TEC) within the study area according to the Department of Water and Environmental Regulation (DWER) mapping data.

The site sits within both a native title determination area (Nyamal People #1) and an undetermined area the subject of a registered native title claim (Nyamal #1). The entire area is on the Corunna Downs pastoral lease.

4 Regional rainfall-runoff characterisation

4.1 Background

Several hydrologic modelling approaches were used to aid in characterising design event discharges and ultimately hydraulic behaviours in the Study Area. To enable the best estimate of empirical loss model parameters for the design event hydrologic assessment in the study area, characterisation of the regional rainfall-runoff relationship was undertaken using the surrounding gauged watercourses. This approach used Flood Frequency Analysis (FFA) and two RORB rainfall-runoff models. This approach is recommended by ARR in preference to regional estimates obtained from the ARR Datahub (Babister et al., 2016)

Each of the hydrologic modelling approaches, input parameters, methodology and results of each of the approaches are presented in the following sections.

4.2 Flood frequency analysis

Historic streamflow gauging records from the Coongan River and Nullagine River catchments were available to aid in regional characterisation of catchment response to rainfall.

These data were analysed to produce FFA quantiles. These quantiles were then compared to the RORB hydrologic model Monte Carlo peak flow quantiles for the same locations to derive a best estimate of empirical loss parameters for use in the study area.

4.2.1 Historic streamflow data

A summary of the DWER streamflow records utilised in this assessment is presented in Table 4-1. Gauge locations and associated catchment areas are presented in Figure 4-1.

The FFA was undertaken for the gauged data using the TUFLOW FLIKE FFA software using Annual Maxima (AM) data for respective water years (October to September). There is a reasonable length of record available at the gauges (26-56 years) with only small periods of missed recordings.

The gauges have daily maximum discharge recordings available which were used to derive the water year AM for use in the FFA.

Table 4-1: Stream gauges used in this assessment










DWER Stream Gauge	Catchment Area (from DWER) (km ²)	Start Date	End Date	Water Years
Coongan River – Marble Bar (710204)	3,736	11/12/1966	-	56
Nullagine River - Nullagine (710004)	875	13/03/1997	-	26

EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY



FIGURE 4-1

FFA GAUGE LOCATIONS & CONTRIBUTING CATCHMENTS

Legend

-  Streamflow Gauge Site
-  Coongan River Catchment
-  Nullagine River Catchment
-  State Road
-  Local Road
-  Miscellaneous Road
-  Major Waterway
-  Minor Waterway
-  Project Development Envelope

Shuttle Radar Topography Mission DEM (mMSL)

-  High : 750
-  Low : 150

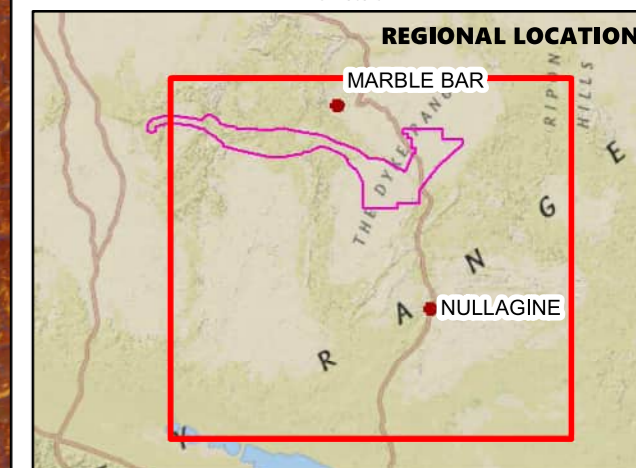
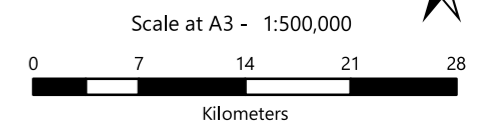
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Coordinate System: GDA 1994 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA 1994

False Easting: 500,000.0000



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User



4.2.2 Streamflow data review

Upon undertaking the FFA analysis, review of all publicly available information was undertaken for each of the gauge sites.

Both gauging sites are typified by mobile alluvial beds, however Marble Bar site does show a mixture of alluvium and a stable rock base (including what appears to be a scour hole adjacent to the gauge in aerial imagery). This means there may be some variability in the relationship between gauge height and a corresponding flow estimate (rating curve) that are derived from manual ratings at different times. An example of this is presented in Figure 4-2, with all historic rating curves at the Marble Bar gauge site presented for flows up to 300 m³/s.

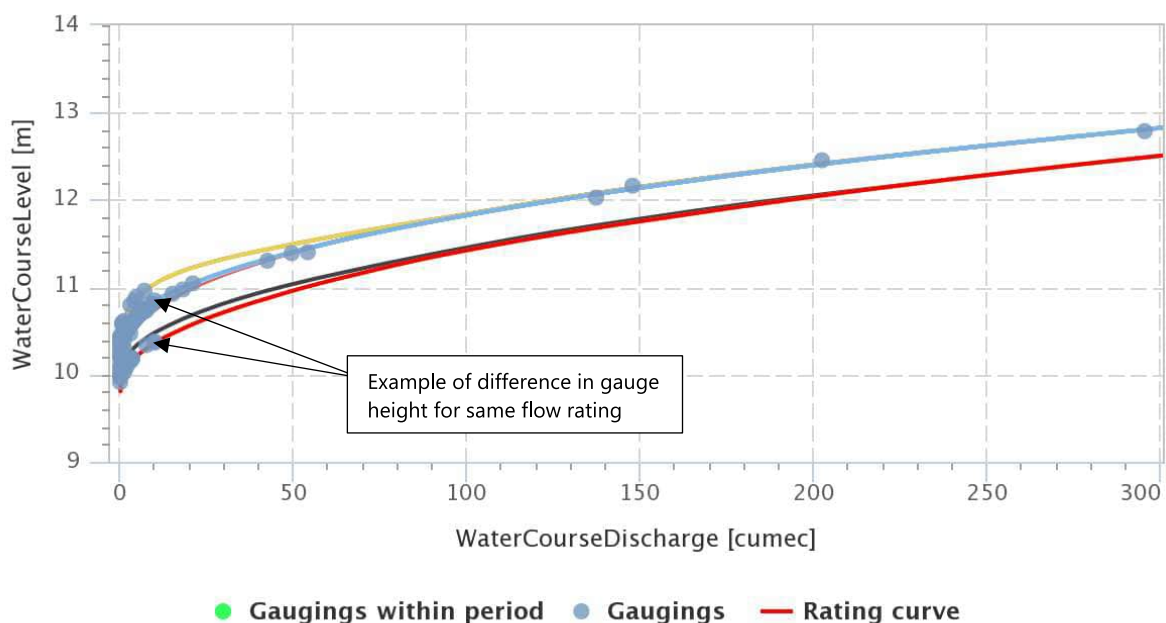


Figure 4-2: Example of low flow rating variability at Marble Bar gauge site (from BoM)

This can impact low magnitude flow estimates based on variances in alluvial aggradation at the gauge site before, during and after each flow event.

Both sites have had relatively low manual flow ratings undertaken when considered in the context of design flows of this study. This is typical for the gauges in the Pilbara where access to gauge sites during times of flood is difficult due to safety considerations and low flood immunities typically associated with regional roads. The largest manual ratings at each site are:

- 295 m³/s in 1971 at Marble Bar
- 4 m³/s in 2018 at Nullagine

This means that there is significant extrapolation from manually rated flows up to the rare events assessed in this study based on a DWER derived rating curve (derived typically from DWER modelling). Most of the AM flow events recorded at the gauging sites are noted by DWER as having a relative uncertainty of +/- 20%.

No detailed topographic data was available of the gauge sites and surrounding areas to enable a validation of the DWER rating curves to estimates derived from detailed two-dimensional hydraulic modelling results.

4.2.3 Periods of missed recordings

Manual review of periods of missed recording were undertaken for both gauges. This resulted in the 1967, 1972 and 1978 water years being excluded from the analysed Coongan River record due to large periods of missed recordings over the peak wet season. The first incomplete 1997 water year for the Nullagine River gauge record was also excluded.

4.2.4 Low flow censoring

Runoff in the Study Area is ephemeral, mostly in direct response to rainfall and is therefore highly seasonal and variable. This means that there are often years in which there are no floods. The annual maximum records from these years are therefore not representative of the population of floods and can unduly influence the fit of the right-hand tail (larger magnitude events) of the frequency distribution. These lower magnitude flows are often referred to as Potentially Influential Low Flows (PILF). Censoring of PILFs was undertaken for the gauge record using the multiple Grubbs-Beck test as described in Book 3 Chapter 2 ARR2019 (Ball et al., 2019).

The PILF threshold derived from the multiple Grubbs-Beck test was then manually adjusted by trial and error for an appropriate low flow threshold until a satisfactory fit was achieved in the right-hand tail with consideration to expected growth in the rare to very rare event range. This resulted in a PILF threshold of:

- 53.5 m³/s at Marble Bar (6 years of data out of 52 available years)
- 11.9 m³/s at Nullagine (5 years of data out of 24 available years)

4.2.5 FFA results

The FFA results for each gauge are presented in Appendix A whilst tabulated results are presented in Table 4-2. Data for both sites were fit using the Log Pearson III (LPIII) probability model and L-Moments inference method.

Table 4-2: FFA quantile estimates

DWER Stream Gauge	50% AEP (m ³ /s)	20% AEP (m ³ /s)	10% AEP (m ³ /s)	5% AEP (m ³ /s)	2% AEP (m ³ /s)	1% AEP (m ³ /s)
Coongan River – Marble Bar (710204)	508	1,148	1,736	2,463	3,721	4,972
Nullagine River - Nullagine (710004)	237	734	1,161	1,593	2,140	2,522

4.3 Regional rainfall-runoff modelling

Rainfall-runoff modelling software RORB (version 6.45) was used to simulate rainfall-runoff in the regional Coongan River and Nullagine River catchments for a range of Annual Exceedance Probability (AEP) events.

As these regional watercourses do not flow through the Study Area, the RORB modelling was used as a basis to derive and validate empirical loss model parameter estimates for both catchments to derive a regional relationship to inform loss selection in the study area (where no streamflow gauges are located to allow for a localised assessment).

The two RORB models were set up with the outlets at the respective streamflow gauge sites. The RORB model schematisation including the nodal-network arrangement for both models are presented in Figure 4-3.

Sub-catchment areas were delineated using Shuttle Radar Topography Mission Hydrologically Enforced (SRTM-H) topographic data and manually inspected for conformance to expected catchment divides (aerial imagery).

4.3.1 Model inputs and parameters

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 storage-discharge relationships which are detailed below.

4.3.1.1 Design rainfall data

The latest IFD data were obtained from the BoM Design Rainfall Data System (BoM, 2016) for use in the study. Point rainfall data was obtained for the centroid of both catchments. The centroid locations and resultant IFD values adopted in this assessment are presented in .

As the catchments are larger than 20 km², consideration of spatial variability of rainfall was undertaken. Regionalised gridded IFD data was extracted for the full catchment to assess spatial variability of the design rainfall estimates in the model. The mean gridded IFD value was checked for the 1% AEP critical duration events for each model (24 hours for the 1% AEP event in both catchments) and showed the centroid values closely replicated the mean gridded values for the total catchment area.

Further manual inspection of IFD grids was undertaken to assess whether predicted event depths were shown to show a consistent grade across the catchment. This was done to ensure that higher intensities were not predicted at one end of the catchment compared to the other (which may not present itself in the catchment mean vs. point centroid analysis). The grids showed no consistent or marked gradation across the subject catchments due to orographic or other effects.

The centroid values were therefore considered appropriate to adopt in the loss validation assessment.

EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY

FIGURE 4-3

RORB MODEL ARRANGEMENTS

Legend

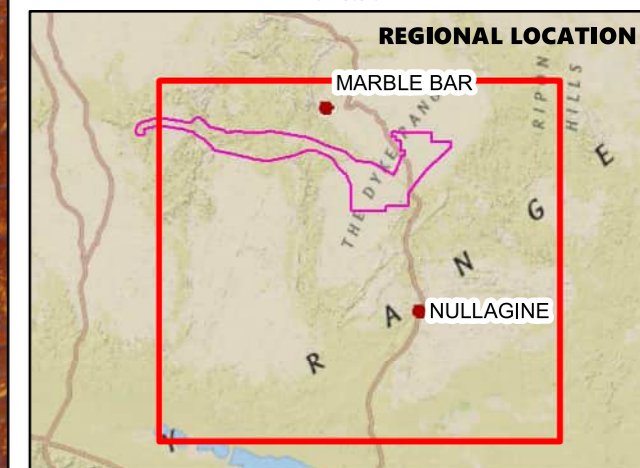
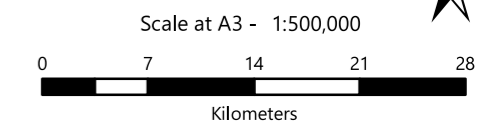
- ▲ RORB Junction Node
- RORB Sub Area Node
- RORB Model Outlet
- RORB Routing Link
- Nullagine River Sub Area
- Coongan River Sub Area
- Townsite
- State Road
- Local Road
- Miscellaneous Road
- Major Waterway
- Minor Waterway
- Project Development Envelope

Shuttle Radar Topography Mission DEM (mMSL)

- High : 750
- Low : 150

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Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User

Coongan River Model	
Sub area ID	Area (km ²)
A	250.2
B	256.6
C	219.4
D1	62.7
D2	132
E1	107
E2	141
F	162.5
G	201.8
H	83.7
I	86.9
J	130
K1	151
K2	214
L	145.4
M	241.8
N	111.6
O	160.7
P	256.4
Q	146.4
R	207.9
S	187
T	81.1
Total	3737.1

Nullagine River Model	
Sub area ID	Area (km ²)
A	55.6
B	87
C	78.2
D	93.6
E	124.3
F	82.6
G	118.5
H	63
I	48.7
J	41.2
K	35.8
L	44.3
Total	872.8

Table 4-3: 24 hour (critical duration) 1% AEP design rainfall estimate comparison

Catchment	Centroid Point Value	Mean Catchment Value	Difference
Coongan River – Marble Bar	187 mm	192 mm	2.6%
Nullagine River - Nullagine	210 mm	211 mm	0.5%

Median pre-burst rainfall depths were extracted from ARR Datahub (Babister et al., 2016). Pre-burst rainfall was removed from the Storm IL (IL_S) prior to simulation in the model to represent the Burst IL (IL_B).

4.3.1.2 Areal reduction factors

Given the large size of the subject catchment, it is unlikely that the spatial coverage of a high intensity storm burst will be consistent across the entire catchment area. To address this issue, it is typical to apply an Areal Reduction Factor (ARF) to the IFD estimates to ensure the preservation of a probability neutral transition between the design rainfall and the design flood characteristics (ARR2019) (Ball et al., 2019). The procedures outlined in ARR2019 (and automated in RORB) were adopted to determine ARFs for both catchments.

4.3.1.3 Loss model

An Initial/Continuing Loss (IL/CL) empirical loss model has been adopted for the regional loss validation assessment. Adopted values are discussed in Section 4.3.2.

4.3.1.4 Storage-discharge parameterisation

RORB is characterised by two additional parameters to enable calculation of its 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.

The standard m value of 0.8 was adopted in the RORB models, as was used in the work undertaken by Pearcey et al. (2014). Through historic event calibration to streamflow records at a number of DWER gauging sites through the Pilbara, Pearcey et al. (2014) estimated the reach-storage relationship for a number of catchments including the Coongan River and Nullagine River. These are:

- $C_{0.8} = 0.48$ for Coongan River to Marble Bar
- $C_{0.8} = 0.58$ for Nullagine River to Nullagine

Using the calibrated $C_{0.8}$ values from Pearcey et al. (2014), K_c for the developed RORB models were derived by the following equations :

$$K_c = 0.48 \times d_{av} \text{ (Coongan River)}$$

$$K_c = 0.58 \times d_{av} \text{ (Nullagine River)}$$

Where d_{av} represents the average distance from each sub area to the catchment outlet. This resulted in a K_c of 29.7 and 19.0 for the Coongan and Nullagine River RORB models, respectively.

When using this relationship, the K_c values derived in this study may not exactly match those derived by Pearcey et al. (2014) due to potential differences in model schematisation and its effects on d_{av} . To limit the magnitude of this potential difference, Advisian ensured that a similar number of sub areas were used to that used in Pearcey et al. (2014) for both catchments.

4.3.1.5 Temporal patterns

Given the size of the catchment areas, all events were simulated using the Rangelands areal ensemble temporal patterns extracted from the ARR Datahub (Babister et al., 2016).

4.3.1.6 Simulation approach

The assessment of the catchment response to rainfall for both catchments has used a Monte Carlo assessment approach for flood quantile estimation.

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) (ARR2019) (Ball et al., 2019). The approach is conceptualised in Figure 4-4.

For this assessment, temporal patterns and initial loss have been stochastically sampled.

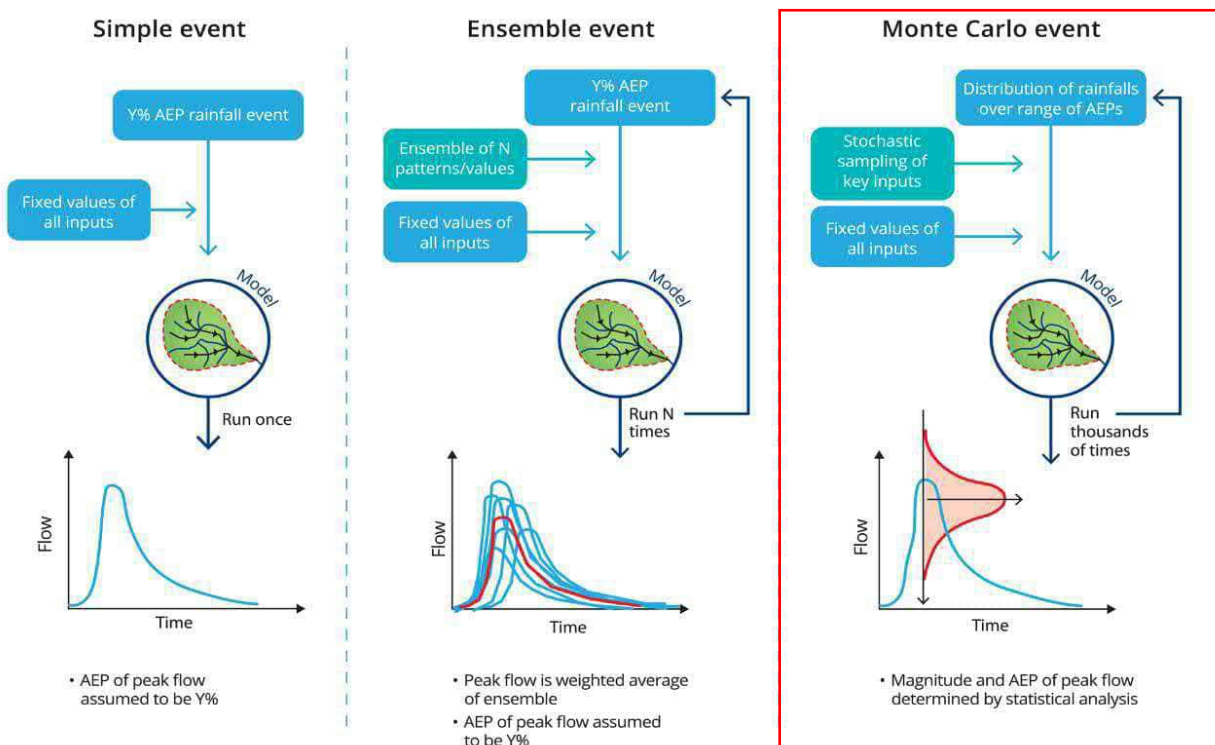


Figure 4-4: Monte Carlo approach conceptual model (Ball et al., 2019)

4.3.2 Results discussion

4.3.2.1 Coongan River

Coongan River is typified by large alluvial deposits for much of its mainstream length. This makes the replication of the rainfall-runoff relationship for low magnitude events inherently difficult, as transmission losses can be highly variable depending on antecedent conditions (and seasonal baseflow). Conversely for rare events, the gauge period of record means that confidence limits render a relatively wide confidence interval for this event magnitude (refer Appendix A).

It was therefore agreed with FFI that for the Coongan River model loss validation exercise, that replication of intermediate event quantiles (e.g., around the 10% and 5% AEP events) would be the main focus of the assessment, with the rare and frequent event quantile replication deemed less imperative due to the aforementioned limitations.

It was found after a number of trial-and-error iterations using regional experience as a basis for the initial loss parameter selection, that adoption of a Storm Initial Loss (IL_s) of 20 mm and Continuing Loss (CL) of 6.5 mm/hr resulted in the best fit of intermediate event quantiles. It is noted that no reasonable set of loss parameters was able to replicate the growth curves predicted by the FFA quantiles in the RORB model.

Table 4-4 presents the tabulated comparison of FFA and RORB Monte Carlo flow quantiles, whilst these are also graphically presented in Appendix A.

Table 4-4: Predicted peak flow quantiles at Marble Bar gauge

Design Storm	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
RORB MC					
Peak flow quantile (m ³ /s)	639	1,520	2,732	4,703	6,473
FFA					
Peak flow quantile (m ³ /s)	1,148	1,736	2,463	3,721	4,972

4.3.2.2 Nullagine River

The Nullagine gauge site is in the headwaters of the Nullagine River catchment and represents a much smaller catchment area than that contributing to the Marble Bar gauge site on the Coongan River.

Hence whilst the mainstream also has alluvial deposits and associated infiltrative capacity, the smaller scale of the waterway alluvial deposits compared to the Coongan River (and hence alluvial infiltrative capacity) means that continuing loss estimates for this system were expected to be lower than that predicted for the Coongan River. This assumption is also supported by regional soil mapping in the hillslope areas, with the catchment exhibiting geomaterials of typical Pilbara stony soils, whereas Coongan River exhibited some regions of deep sands. FFA also estimated reasonably large flow quantiles per unit area for the contributing catchment when compared to Marble Bar.

As a result, starting loss parameter estimates were based on the lower limits of Region 2 loss values. After a number of trial-and-error iterations, adoption of a Storm Initial Loss (IL_s) of 20 mm and Continuing Loss (CL) of 3.0 mm/hr resulted in a strong match to all event quantiles.

Table 4-5 presents the tabulated comparison of FFA and RORB Monte Carlo flow quantiles, whilst these are also graphically presented in Appendix A.

Table 4-5: Predicted peak flow quantiles at Nullagine gauge

Design Storm	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
RORB MC					
Peak flow quantile (m ³ /s)	729	1,160	1,611	2,258	2,761
FFA					
Peak flow quantile (m ³ /s)	734	1,161	1,593	2,140	2,522

4.3.3 Design loss adoption for study area

Results from the Coongan River and Nullagine River regional loss validation exercise showed generally good regional consistency for the derived IL_s value of 20 mm and hence this was approved for adoption after discussion with FFI.

The same analysis also showed a reasonable variance in CL values between the two catchments. The Coongan River was noted as having a larger impact from expansive alluvial deposits compared to Nullagine River. Additionally, regional soil mapping (only mapping available) showed that the Nullagine River catchment to the gauge site typically consisted of 'Stony soils' and some 'Hard cracking clays'. Coongan River also exhibited typically 'Stony soils', but some regions in the north-eastern area of the catchment trended toward some large areas of deep red sands (prevalent in the lower half of both WF1 and WF2 project catchment areas).

It was agreed with FFI that due to the limited geotechnical information available across the development area to support any adoption of spatially varying loss parameterisation, the Region 2 median gridded loss of 4.3 mm/hr was selected. This value sits near the middle between the derived values of 3 mm/hr and 6.5 mm/hr and hence serves as a reasonable CL value selection for the study area design event hydrology assessment.

The final adopted loss parameters for the study are design event hydrology determined from the regional loss validation exercise are presented in Table 4-6.

Table 4-6: Adopted design event loss parameters for use in the study area

Parameter	Value
Storm Initial Loss (ILs)	20 mm
Continuing Loss (CL)	4.3 mm/hr

5 Study area design event hydrology

5.1 General approach

As baseline hydrology results were required across the entire Study Area, hydrologic and hydraulic modelling of the local catchments in the development areas was undertaken using TUFLOW (version 2020-10-AC). 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).

For the WF1 study area, Emu Creek flows through the far southwestern corner of the development envelope. As the detailed topographic data coverage did not extent to the top of the Emu Creek catchment, a local RORB model was developed for the Emu Creek catchment and used to develop inflow hydrographs (and local sub area rainfall excesses) for application to the TUFLOW model.

The assessment has used two separate TUFLOW models for the respective WF1 and WF2 areas. The general adopted model extents and local Emu Creek RORB model general layout is presented in Figure 5-1.

5.2 Simulation approach

The assessment of the catchment response to rainfall for the RORB and TUFLOW models has used an ensemble assessment approach 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). A range of design storm durations were simulated in the TUFLOW model to determine the critical storm duration (the storm duration resulting in the highest peak flow) at various locations in the catchments. The approach is conceptualised in Figure 5-2.

5.3 Design events

Table 5-1 summarises the design storms assessed in the TUFLOW and RORB models. The longest storm durations were assessed to ensure that the critical duration in the main flowpaths across the study area was identified.

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

Storm detail	Events assessed
Annual Exceedance Probabilities (AEPs)	1%, 2%, 5%, 10%, 20% and 50%
Design Storm Durations (minutes)	60, 120, 180, 270, 360, 540, 720, 1080

EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY

FIGURE 5-1

STUDY AREA MODEL ARRANGEMENT

Legend

- Project Development Envelope
- WF1 TUFLOW model extent
- WF2 TUFLOW model extent
- RORB Sub Area Node
- ▲ RORB Junction Node
- RORB Outlet Node
- Emu Creek RORB sub area
- RORB Routing Link
- State Road
- Local Road
- Miscellaneous Road
- ✱ Proposed Wind Tower Location
- Major Waterway
- Minor Waterway

Shuttle Radar Topography Mission DEM (mMSL)

High : 750
Low : 150

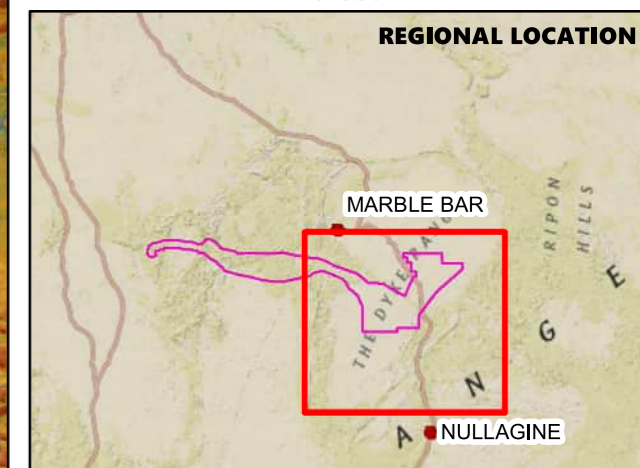
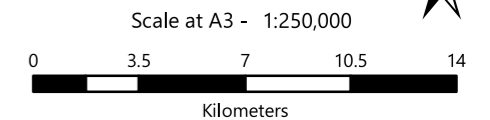
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Coordinate System: GDA 1994 MGA Zone 50

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Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User

Emu Creek Model	
Sub area ID	Area (km ²)
A	64.6
B	28.1
C	50
D	25.8
E	44.1
F	27.3
G	34.5
H	35.4
I	19.3
J	36.1
K	25.8
L	21.1
M	40.6
N	60.6
O	78.7
Total	592

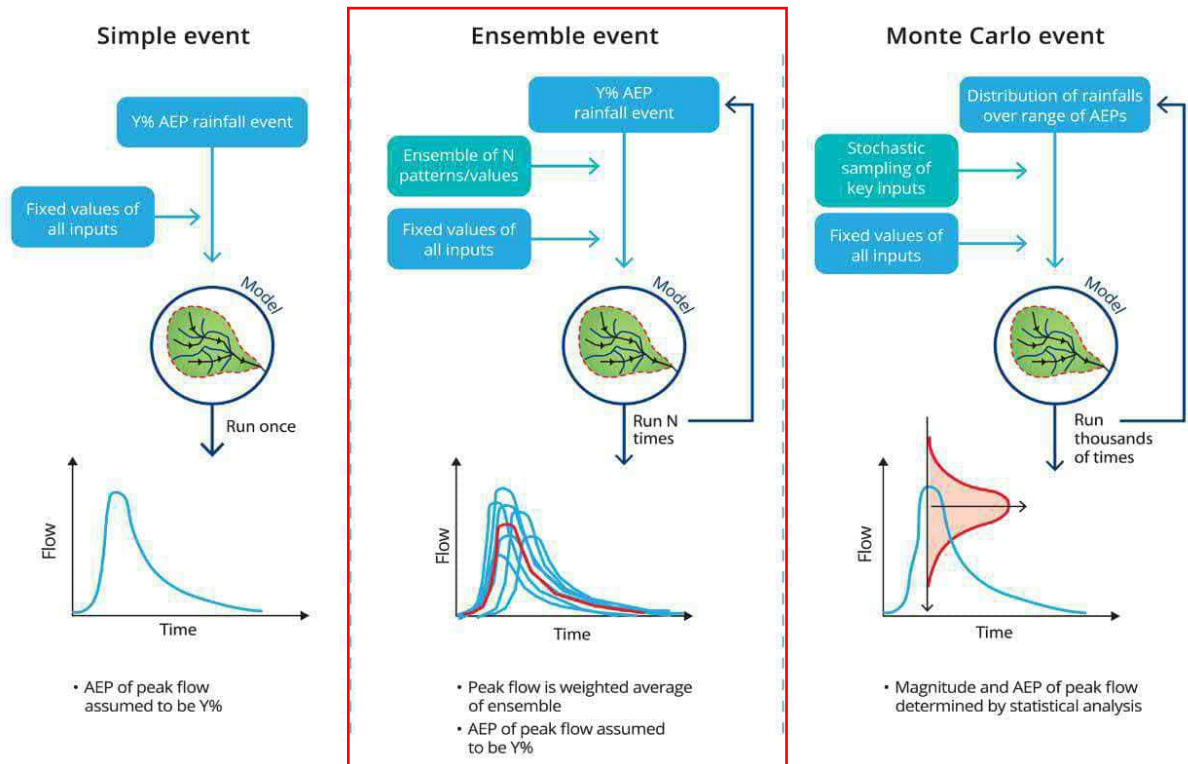


Figure 5-2: Ensemble approach conceptual model (Ball et al., 2019)

5.4 Emu Creek rainfall-runoff model

As per the regional hydrologic characterisation works, RORB (version 6.45) was used to simulate rainfall-runoff in the Emu Creek

RORB model parameters for the local Emu Creek model are summarised in Table 5-2.

Table 5-2: RORB model parameter summary

Item	Emu Creek
Rainfall	Extracted from BoM Design Rainfall Data System (BoM, 2016)
Rainfall depths	Assessment as per Section 4.3.1.1 was undertaken to ensure catchment centroid values were representative of the catchment area
Pre-burst	Median pre-burst rainfall depths were extracted from ARR Datahub (Babister et al., 2016). Pre-burst rainfall was removed from the Storm <i>IL</i> (<i>IL_S</i>) prior to simulation in the model to represent the burst <i>IL</i> (<i>IL_B</i>).
Losses	ILs: 20 mm CL: 4.3 mm/hr

Item	Emu Creek
Temporal patterns	Areal – Rangelands (N.B Point patterns were also simulated used to satisfy inflow boundary conditions requirements of TUFLOW model, however these events were not critical for this system)
ARF	The procedures outlined in ARR2019 (and automated in RORB) were adopted to determine the AEP and duration varying ARFs
Assessment type	Ensemble (to maintain consistency with TUFLOW model simulation type)
Nodal-network details	
Sub area extents	Developed from 1 m photogrammetrically derived DEMs (described in Section 2.1) and supplemented by SRTM-H data in the very upper extent of the catchment
Routing link type	Natural – length determined from 1m DEM data

5.5 TUFLOW models

The TUFLOW models are characterised by a number of input parameters which are summarised in Table 5-3. Areal reduction factors, floodplain roughness and culverts are discussed further in Sections 5.5.1, 5.5.2 and 5.5.3 respectively.

The model terrain was developed using 1 m photogrammetrically derived DEMs (described in Section 2.1). Due to the large model domain sizes (~620 km²), the models were simulated with relatively coarse grid size (20 m) due to the large number of simulations required to determine the critical design storm over a such a large project area (high computational demand and run time) using the ensemble approach.

To fill the observed micro storages in the DEM that were considered to be a result of photogrammetry noise, a 10 mm rainfall depth was simulated through the TUFLOW models prior to simulating design storms. The model was simulated over a long duration after the rainfall to ensure runoff had fully drained from the domains. The final timestep water level grid was then used as an initial water level (IWL) during the design event simulations. It is noted that due to the well-defined channels and topographic variation of the catchments, that pre-wetting resulted in a negligible number of wet cells at simulation commencement.

Table 5-3: TUFLOW model parameter summary

Item	WF1	WF2
Rainfall		
Rainfall depths	Extracted from BoM Design Rainfall Data System (BoM, 2016) using TUFLOW ARR2016 QGIS plugin for each model area	
Pre-burst	Median pre-burst rainfall depths were extracted from ARR Datahub (Babister et al., 2016). Pre-burst rainfall was removed from the Storm <i>IL</i> (<i>IL_S</i>) prior to simulation in the model to represent the burst <i>IL</i> (<i>IL_B</i>). Where pre-burst exceeded <i>IL_S</i> an <i>IL_B</i> of zero was adopted for simplification. It is noted that this approach was only	

Item	WF1	WF2
	relevant for the 6 hour duration event for the 2% and 1% AEP events. The 6 hour duration event was not typically the critical duration on the main watercourses in the study area.	
Losses	ILs: 20 mm CL: 4.3 mm/hr Approach: Rainfall excess (materials layer)	
Pre-wetting catchment	10 mm of rainfall (no losses adopted) simulated over a long simulation period with the final timestep read in as an initial water level raster for the design event runs.	
Temporal patterns	Areal TPs adopted for catchments greater than 75 km ² and point TPs for catchments less than 75 km ²	
ARF	Determined using parameters extracted from the ARR Datahub (Babister et al., 2016) for the Northern Coastal region and based on catchment areas within model domains (described further in Section 5.5.1)	
Terrain		
Terrain	Developed from 1 m photogrammetrically derived DEMs (described in Section 2.1)	
Total model area	621 km ²	615 km ²
Grid size (SGS sample distance)	20 m (1 m)	
Manning's 'n' value (Depth Layer 1 (m), Manning's 'n' Layer 1, Depth Layer 2 (m), Manning's 'n' Layer 2)	Typical Pilbara grasslands/main catchment areas (0.1, 0.1, 0.2, 0.04) Medium density riparian vegetation (0.06) Higher density riparian vegetation (0.08)	
External Boundary conditions		
Inflow boundary	Hydrographs (QT) and sub area rainfall excess (SA) from Emu Creek RORB model	N/A
Direct rainfall	Applied using ARFs as detailed in Section 5.5.1 (refer Figure 5-4 for adopted area values).	
Outflow boundary	Automated stage-discharge curve (HQ) with stream bed slope used as a proxy for water surface slope	

5.5.1 Areal reduction factors

AEP and duration varying ARFs were determined using parameters extracted from the ARR Datahub (Babister et al., 2016) for the Northern Coastal region.

Given the baseline nature of the study scope and high spatial variability of proposed project infrastructure across different catchments in the Study Area, several representative catchment sizes for ARF derivation were adopted in each model domain in consultation with FFI. A comparison of ARF

values for the 50% AEP and 1% AEP are shown in Figure 5-3 whilst the actual and adopted catchment areas are presented in Figure 5-4.

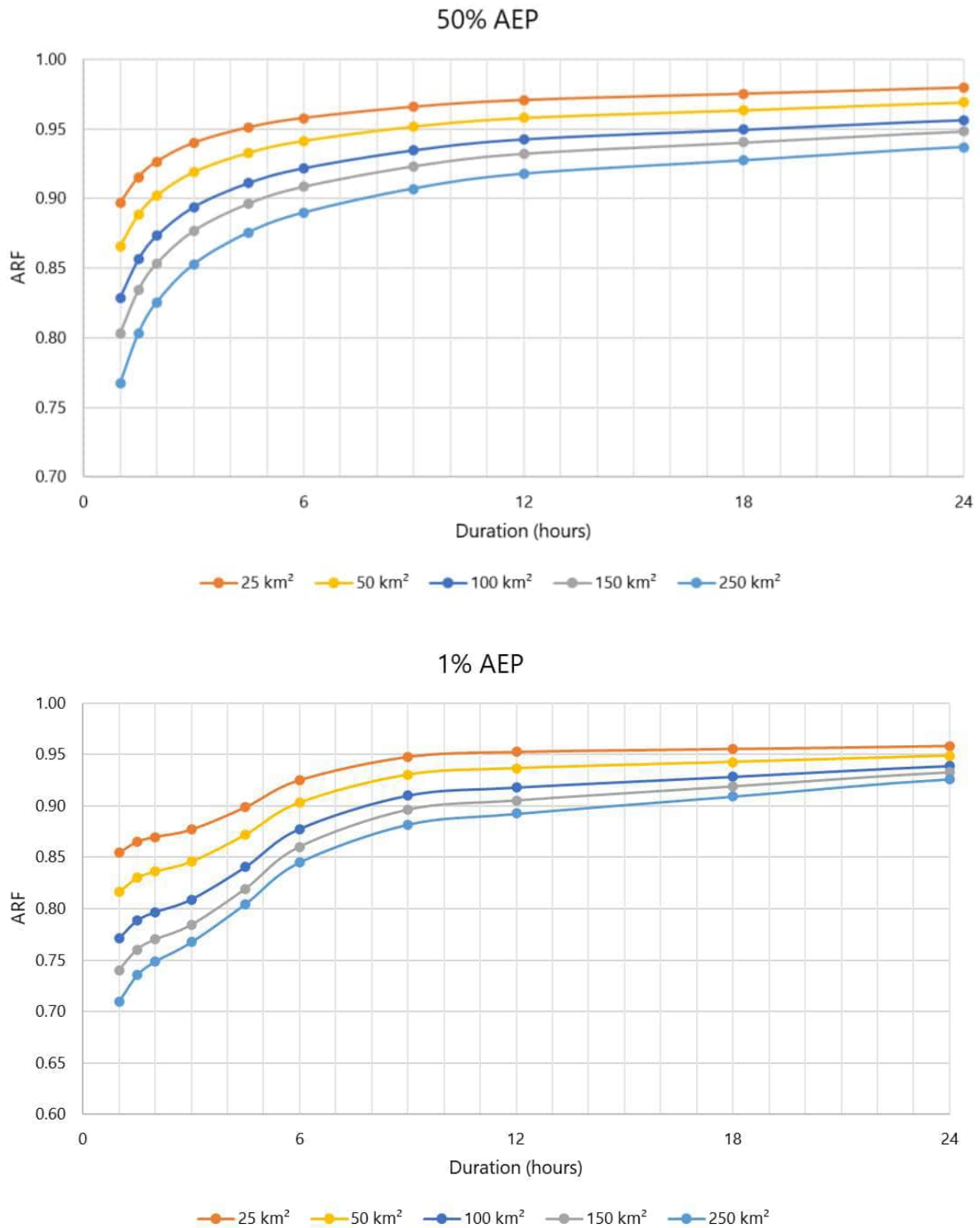


Figure 5-3: Comparison of adopted ARFs for different catchment sizes for the 50% AEP (top) and 1% AEP (bottom) events

5.5.2 Floodplain roughness

Floodplain roughness delineation was undertaken using Sentinel-2 satellite data. Sentinel-2 carries the Multispectral Imager (MSI). This sensor delivers 13 spectral bands ranging from 10 to 60m 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 5-3). As the riparian vegetation roughness areas were typically associated with higher flow depths and were typically of limited coverage, these areas were assigned a single (not depth-varying) value.

This approach allows for a consistent floodplain 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. Cross reference against higher resolution aerial imagery (12 July 2022) was also undertaken to ensure extents were representative of expected changes in roughness. Little variance was observed between wet season and dry season data captures from Sentinel-2.

An example of the classified vegetation index grid and aerial imagery is presented in Figure 5-5.

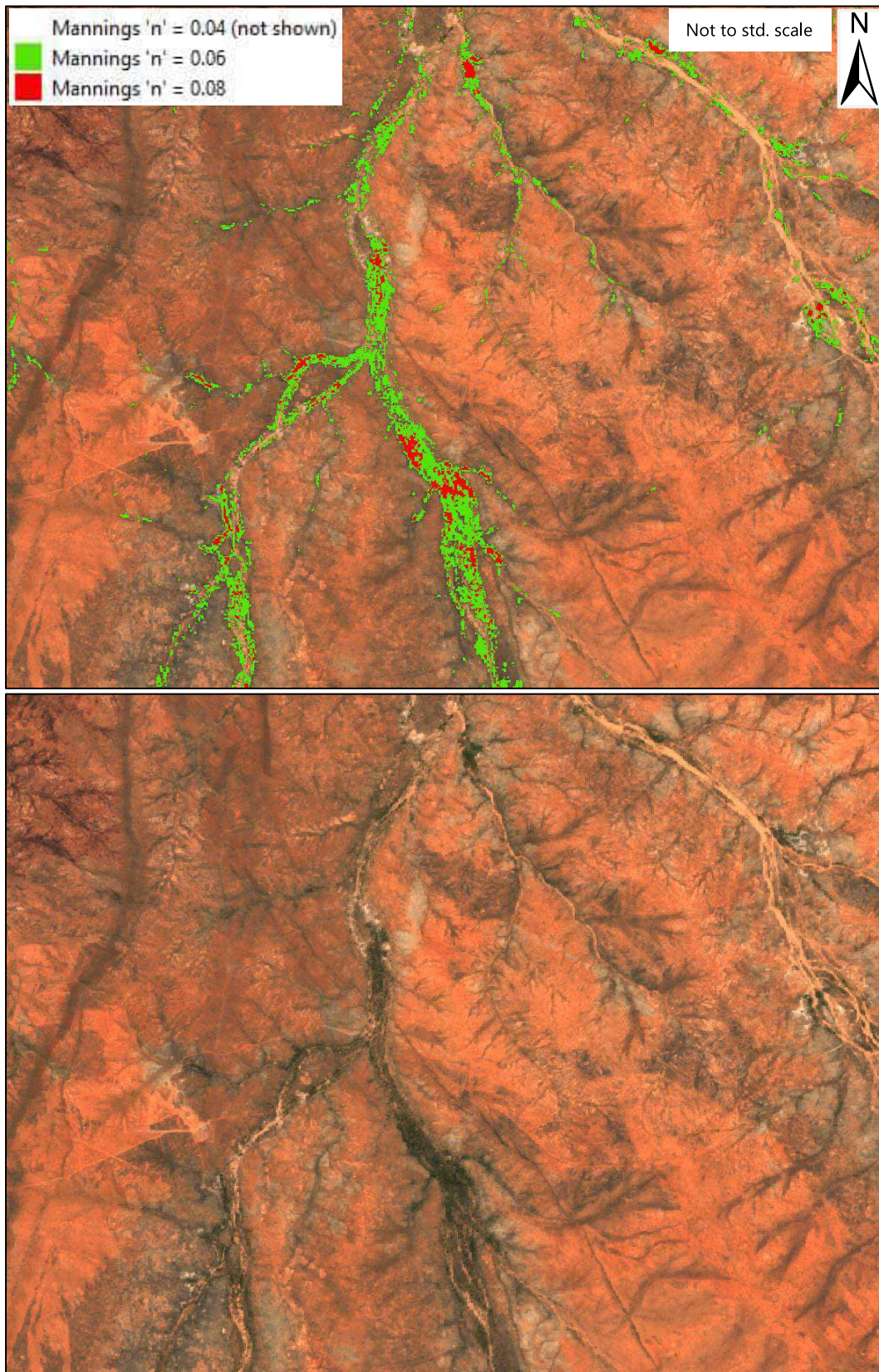


Figure 5-5: Example of spatial roughness delineation using Sentinel-2 data (above) and aerial (below)

5.5.3 Culverts

Main Roads WA (MRWA) controlled crossings of watercourses in the Study Area (such as Marble Bar Road) were inspected against the provided high resolution DEM and any publicly available drainage structure information.

Review of the data indicated all crossings in the Study Area were representative of at-grade floodways (representing little to no flood immunity) with small culvert features (if present). Given the regional nature of this assessment and that these features will have likely an intangible impact on peak flow rates in the Study Area for the design events considered in this study, there has been no inclusion of any low-flow culvert structures.

5.6 Sensitivity analysis

5.6.1 Climate change

The assessment of sensitivity to climate change impacted design rainfall has been undertaken utilising the predicted 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 predictions (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 Watts per square metre (W/m²) in 2100 (reaching a CO₂ concentration of 940 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 predicted changes to rainfall intensities extracted from the ARR Data Hub for the 2050 design horizon are presented in Table 5-4 and were applied to the design rainfall burst depths (as presented in Appendix C).

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

Design Horizon (Year)	RCP 4.5	RCP 8.5
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 would have tangible impact on flood elevations and extents and hence pose any additional flood risk to proposed infrastructure localities.

Results from the climate change sensitivity assessment are presented in Section 6.1.2.

5.6.2 Floodplain roughness

The model sensitivity to Manning’s ‘n’ roughness was tested by simulating the 1% AEP event with an increase in Manning’s ‘n’ values of a nominal 25%. This was applied to the adopted design hydraulic roughness values (i.e., upper depth value for depth-varying areas) to assess hydraulic sensitivity to Manning’s ‘n’ parameters.

It is noted that as the model uses the rain on grid approach, this sensitivity assessment will still result in some impact to peak flow estimates as well as hydraulic results (e.g., peak flood elevation).

This sensitivity analysis was used to determine if increase in flood levels as a result of increases in floodplain roughness would have a significant impact on flood elevations and extents and hence pose any additional potential flood risk to proposed infrastructure localities.

Table 5-5: Adopted floodplain roughness values and sensitivity analysis values

Description	Manning’s ‘n’ Design value	Manning’s ‘n’ Sensitivity value
General Pilbara catchment	0.040	0.050
Medium density riparian vegetation	0.060	0.075
Thick density riparian vegetation	0.080	0.100

Results from the floodplain roughness sensitivity assessment are presented in Section 6.4.

6 Results

6.1 Hydrology

A number of comparison locations have been selected across the respective model areas to quantify peak flows and allow comparison to desktop-based regional methods. This includes comparison to the Regional Flood Frequency Procedure (RFFP) (Flavell, 2012), Regional Flood Frequency Estimation Model (RFFE) (ARR2019) and the Pilbara Regional Flood Frequency Analysis (RFFA) (Davies & Yip, 2014) to ensure there are no significant differences between the model predictions and regional desktop-based methods. The comparison locations detailed below for both Wind Farm 1 and Wind Farm 2 are presented in Figure 6-1.

6.1.1 Wind Farm 1

The mean of the ensemble peak flow estimates and critical durations at reporting locations COO11 (Emu Creek), COO36 (Ram Creek), COO44 (Camel Creek) and COO21 (Sandy Creek) in Table 6-1.

Table 6-1: Ensemble mean peak flow (m³/s) results – Wind Farm 1

Reporting Location	Results	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
COO11 (Emu Creek) (348 km ²)	Mean peak flow (m ³ /s)	113	442	690	1,036	1,396	1,732
	Critical duration (hours)	12	12	12	12	12	12
	RFFP (m ³ /s)	128	267	443	710	1,318	2,111
	RFFE (m ³ /s)	66	181	286	418	590	748
	Pilbara RFFA (m ³ /s)	68	220	374	568	914	1,282
COO36 (Ram Creek) (70 km ²)	Mean peak flow (m ³ /s)	29	89	149	211	312	382
	Critical duration (hours)	6	6	6	6	4.5	4.5
	RFFP (m ³ /s)	46	92	149	235	427	672
	RFFE (m ³ /s)	24	64	102	149	210	266
	Pilbara RFFA (m ³ /s)	24	77	132	200	321	451
COO44 (Camel Creek) (52 km ²)	Mean peak flow (m ³ /s)	23	65	104	147	217	264
	Critical duration (hours)	6	9	6	6	6	6
	RFFP (m ³ /s)	24	57	104	183	332	521
	RFFE (m ³ /s)	19	52	83	120	170	215
	Pilbara RFFA (m ³ /s)	20	64	108	164	264	370

Reporting Location	Results	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
COO21 (Sandy Creek) (161 km ²)	Mean peak flow (m ³ /s)	61	248	391	532	738	905
	Critical duration (hours)	12	12	12	12	12	12
	RFFP (m ³ /s)	91	189	313	497	913	1,450
	RFFE (m ³ /s)	39	107	169	247	348	441
	Pilbara RFFA (m ³ /s)	41	133	227	344	553	776

**EAST PILBARA GENERATION HUB
BASELINE HYDROLOGY STUDY**

FIGURE 6-1

FLOW REPORTING LOCATIONS

Legend

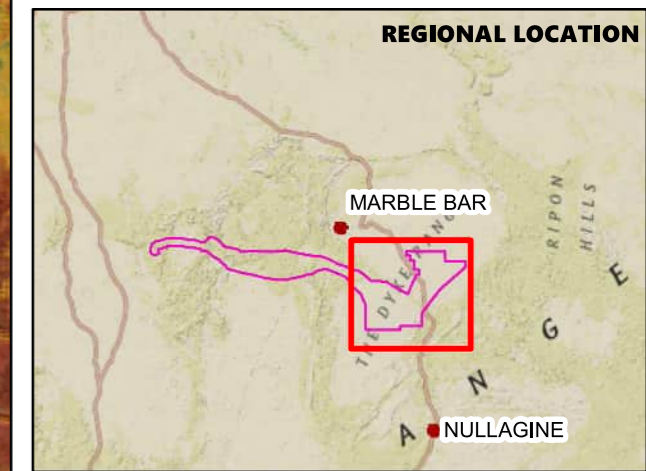
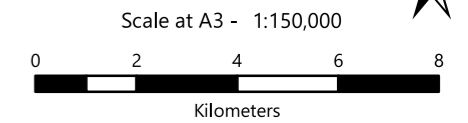
- Flow Reporting Location
- WF1 TUFLOW model extent
- WF2 TUFLOW model extent
- Project Development Envelope
- State Road
- Local Road
- Miscellaneous Road
- * Proposed Wind Tower Location
- Major Waterway
- Minor Waterway

Shuttle Radar Topography Mission DEM (mMSL)

- High : 750
- Low : 150

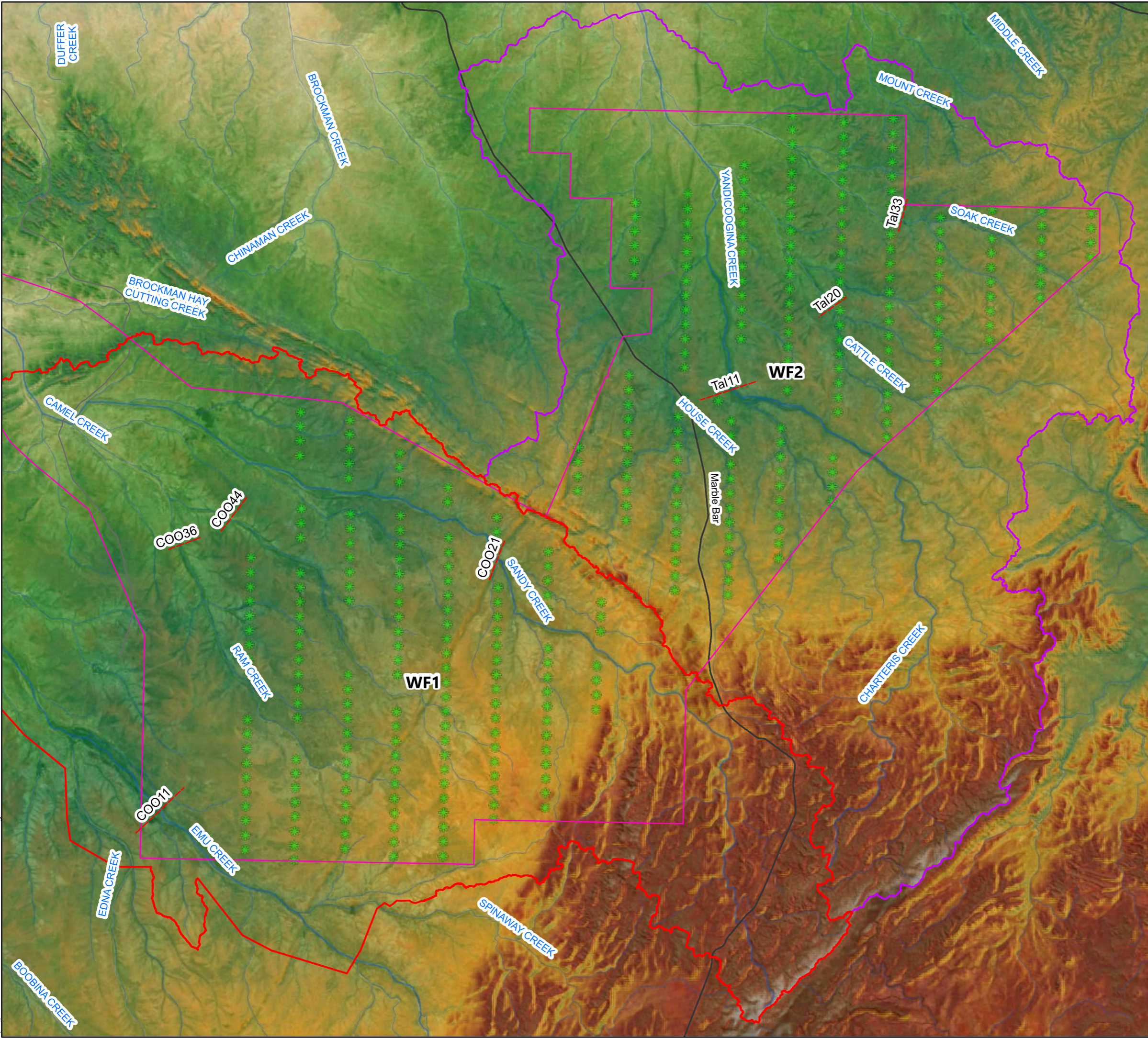
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Coordinate System: GDA 1994 MGA Zone 50
 Projection: Transverse Mercator
 Datum: GDA 1994
 False Easting: 500,000.0000



Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User

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6.1.2 Wind Farm 2

The mean of the ensemble peak flow estimates and critical durations at reporting locations TAL11 (Yandicoogina Creek), TAL20 (Cattle Creek) and TAL33 (Soak Creek) in Table 6-2.

Table 6-2: Ensemble mean peak flow (m³/s) results – Wind Farm 2

Reporting Location	Results	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
TAL11 (Yandicoogina Creek) (173 km ²)	Mean peak flow (m ³ /s)	79	245	377	516	725	891
	Critical duration (hours)	12	12	12	12	12	12
	RFFP (m ³ /s)	83	184	319	510	938	1,491
	RFFE (m ³ /s)	41	111	175	256	359	456
	Pilbara RFFA (m ³ /s)	43	140	238	360	580	813
TAL20 (Cattle Creek) (54 km ²)	Mean peak flow (m ³ /s)	22	68	110	154	230	276
	Critical duration (hours)	6	9	6	6	6	6
	RFFP (m ³ /s)	42	84	137	215	389	611
	RFFE (m ³ /s)	20	54	85	124	175	222
	Pilbara RFFA (m ³ /s)	20	66	112	169	272	382
TAL33 (Soak Creek) (58 km ²)	Mean peak flow (m ³ /s)	31	94	145	197	298	375
	Critical duration (hours)	6	4.5	4.5	4.5	3	3
	RFFP (m ³ /s)	53	104	163	257	466	732
	RFFE (m ³ /s)	23	63	99	145	203	258
	Pilbara RFFA (m ³ /s)	21	69	117	178	286	401

6.1.3 Peak flow results discussion

Peak flow results presented in both Table 6-1 and Table 6-2 across the Wind Farm 1 and 2 model areas show that peak flow estimates typically align well with the three commonly adopted regional desktop-based methods.

Peak flow estimates from the model are typically shown to lie within the middle to upper estimate limits of the three approaches. Variances from the regional methods were typically shown to be based on growth differences through the AEP range rather than consistent over or under estimation. This is mostly presented in the Emu Creek (Wind Farm 1) results through the intermediate AEP event results (approximately 20% to 5% AEP), where higher peak flow estimates are derived from the model compared to the regional methods. It is noted that good agreement to the regional methods occurs in the same catchment in the frequent and rare event ranges.

6.2 Sensitivity analysis – climate change

The mean of the ensemble peak flow estimates and critical durations at the previously reported locations for Wind Farm 1 and 2 study areas for the design case 1% AEP and 2050 future climate 1% AEP RCP4.5 and RCP8.5 scenarios is presented in Table 6-3.

Descriptions of hydraulic impacts as a result of the predicted peak flow increases in the 2050 future climate scenarios are discussed in Section 6.4.1.

Table 6-3: 2050 design horizon climate change sensitivity results

Wind Farm	Reporting Location	Results	1% AEP	1% AEP 2050 RCP4.5	1% AEP 2050 RCP8.5
Wind Farm 1	COO11 (Emu Creek) (348 km ²)	Mean peak flow (m ³ /s)	1,732	1,929 (+11%)	1,993 (+15%)
		Critical duration (hours)	12	12	12
	COO36 (Ram Creek) (70 km ²)	Mean peak flow (m ³ /s)	382	424 (+11%)	439 (+15%)
		Critical duration (hours)	4.5	4.5	4.5
	COO44 (Camel Creek) (52 km ²)	Mean peak flow (m ³ /s)	264	292 (+11%)	301 (+14%)
		Critical duration (hours)	6	4.5	4.5
	COO21 (Sandy Creek) (161 km ²)	Mean peak flow (m ³ /s)	905	996 (+10%)	1,026 (+13%)
		Critical duration (hours)	12	12	12

Wind Farm	Reporting Location	Results	1% AEP	1% AEP 2050 RCP4.5	1% AEP 2050 RCP8.5
	TAL11 (Yandicoogina Creek) (173 km ²)	Mean peak flow (m ³ /s)	891	980 (+10%)	1,011 (+13%)
		Critical duration (hours)	12	12	12
Wind Farm 2	TAL20 (Cattle Creek) (54 km ²)	Mean peak flow (m ³ /s)	276	305 (+11%)	315 (+14%)
		Critical duration (hours)	6	4.5	4.5
	TAL33 (Soak Creek) (58 km ²)	Mean peak flow (m ³ /s)	375	418 (+11%)	433 (+15%)
		Critical duration (hours)	3	3	3

In both the Wind Farm 1 and 2 study areas, results show that the predicted increase in rainfall intensity for the 1% AEP 2050 future climate scenario using the RCP4.5 and RCP 8.5 scenarios resulted in increases in peak flow that were higher than the corresponding rainfall intensity increase.

For the 1% AEP 2050 RCP4.5 scenario, increases of approximately 11% were common in both study areas at the nominated reporting locations. In the 1% AEP 2050 RCP8.5 scenario, increases in peak flow of up to 15% were also common for both wind farm areas.

6.3 Hydraulics

6.3.1 Accuracy limitations

The assessment outcomes and associated data in this report is based on information sourced from FFI, external sources, as well as that 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 the available input data. For example, the spatially varying vertical accuracy of the photogrammetry-derived DEMs across the model domain may have an impact on the absolute vertical accuracy of peak flood level results would be commensurate with the accuracy of the baseline topographic dataset.

6.3.2 GIS mapping

Peak flood depth and velocity mapping for the 1%, 5% and 20% AEP events is presented in Appendix D.

The presented data has undergone a filtering process to aid in improved visualisation of key drainage features across the sites (depths of less than 20 mm not being presented).

Given the high spatial variability of flood modelling results across the Study Area, generalised descriptions are provided in the following sections. For detailed analysis of specific locations, interrogation of model result raster GIS data is recommended.

6.3.3 Wind Farm 1

Sandy Creek, which runs along the northern extent of Wind Farm 1, is predicted to have the highest hydraulic intensities in the Wind Farm 1 Study Area. Peak depths in the 1% AEP are predicted to approach 4 m in the more incised mid-reaches of the Study Area, with accompanying peak velocities exceeding 3 m/s at the same locations. Emu Creek, which crosses the far southwestern corner of the development exhibits similar hydraulic behaviours albeit over a wider flood extent. Ram Creek and Camel Creek through the centre of the Wind Farm 1 development area are predicted to have less intense hydraulic behaviours (typically peak depths of below 2 m and velocities below 2 m/s) due to the smaller contributing catchment areas (and hence lower peak flows compared to Emu and Sandy Creeks).

For the smaller magnitude events such as the 20% AEP event, hydraulic intensities are reduced in Emu and Sandy Creeks due to the flow magnitude reduction, with peak flood depths typically below 2 m and peak velocities below 2 m/s except for a number of discrete areas of more constrained flood behaviour due to the natural landforms.

6.3.4 Wind Farm 2

Yandcoogina Creek is predicted to have the highest hydraulic energies in the Wind Farm 2 study area. In the 1% AEP event, peak flow depths of over 4 m are predicted in a number of locations in the mid to lower reaches and with associated peak velocities of over 3 m/s in some locations.

Due to their smaller catchment size and hence runoff generating potential, the other creeks flowing through Wind Farm 2, such as Cattle Creek and Soak Creek, are predicted to have lower hydraulic energies with peak 1% AEP flow depths typically under 2 m and peak velocities similarly just exceeding 2 m/s in only a few discrete locations.

For the smaller magnitude events such as the 20% AEP event, hydraulic intensities are reduced in Yandcoogina Creek with peak depths typically below 3 m and peak velocities typically below 2 m/s. Cattle and Soak Creeks are both predicted to have peak depths typically below 1.5 m and peak velocities below 1.5 m/s in the 20% AEP event.

6.3.5 Conceptual wind turbine locations

A number of the provided conceptual wind turbine locations provided by FFI are predicted to be within or near the invert of a number of creek systems and hence are subject to flood risk in their current proposed location. As no individual wind turbine identification was included in the provided shapefile, no individual listing of proposed asset IDs can be provided. The turbines that were predicted to be located in flood depths of greater than 100 mm have been presented in Appendix E.

In Wind Farm 1, wind turbines located within the 1% AEP flood extent were typically shown to be in the headwater areas where hydraulic intensities were not as high as the main creek systems.

In Wind Farm 2, all of the main creek systems (or tributaries) were shown to have a select number of wind towers located within the 1% AEP flood extent within incised waterways.

It is understood that the outcomes of this baseline hydrology study will help inform optimisation of the wind turbine layouts and hence eliminate, reduce or mitigate this flood risk to project infrastructure, pending other design constraints.

6.4 Sensitivity analysis

6.4.1 Climate change

The peak flow increases as detailed in Section 6.2 for the 2050 future climate correspondingly result in increases in peak flood levels.

For the 1% AEP 2050 RCP4.5 scenario in both Wind Farm 1 and Wind Farm 2, increases in peak flood levels are predicted to be typically up to 150 mm in the main creeks flowing through the project. For the 1% AEP 2050 RCP8.5 scenario, peak flood level increases are predicted to increase slightly to be up to approximately 200 mm in the main creek systems. Some discrete areas of typically between 250 mm and 300 mm peak flood level increase are predicted in the lower reaches of Yandicoogina Creek in the lower extents of the Wind Farm 2 study area.

Based on the results of the assessment, it is expected that the uncertainty and risk associated with the future climate and general hydrologic uncertainty in the study area could be typically mitigated by adoption of a standard design freeboard of 300 mm.

6.4.2 Floodplain roughness

The adoption of a 25% increase in floodplain roughness across the model areas has resulted in increased flood levels in the main creek systems, as is to be expected.

Within the major creeks in Wind Farm 1, this increase in floodplain roughness typically only results in increases in peak flood levels of up to approximately 200 mm. The small increase in peak flood elevation means the peak flood extent remains comparable to the adopted floodplain roughness results.

Similar results are evident in the major creek systems in Wind Farm 2, with most areas of increased peak flood level below 200 mm.

Based on the results of the assessment, it is expected that the uncertainty and risk associated with the any difference between the adopted and actual floodplain roughness values across the study area could be mitigated by adoption of a standard design freeboard of 300 mm.

7 Conclusions

This study represents a baseline assessment of the hydrologic and hydraulic conditions throughout the Study Area using the latest in industry assessment methods and data.

The assessment has used regional characterisation of losses to determine appropriate design event loss parameterisation and a combination of rainfall-runoff modelling and rain-on-grid hydraulic modelling to estimate the hydrologic and resultant hydraulic conditions.

The assessment approach and methods are consistent with ARR2019 (Ball et al., 2019), the latest industry guidance on the derivation of hydrologic estimates and flood risk.

It can be concluded from the analysis that:

- There is no streamflow gauging sites located in the Study Area, making assessment of the rainfall-runoff relationship for the Study Area reliant on regional characterisation of the rainfall-runoff relationship to inform model parameterisation estimates.
- RORB models developed for the Coongan River and Nullagine River catchments were simulated in a Monte Carlo environment and were validated to FFA quantiles from streamflow gauges for the catchment areas. The works resulted in a consistent IL_5 value of 20 mm for both catchments which was adopted for use in the design event analysis for the study area. Some difference was observed between the two regional catchments with respect to derived CL, however once catchment landforms and waterways was considered, it was agreed with FFI that the ARR median gridded continuing loss of 4.3 mm/hr for Region 2 would be adopted. This value was approximately the mean value of the two regional catchment derived values through the FFA/RORB validation procedure.
- Within the Wind Farm 1 Study Area, higher hydraulic intensities were typically limited to the Sandy Creek and Emu Creek watercourses due to their larger contributing catchment areas and hence higher runoff generating potential. These systems had peak flood depths of up to 4 m in the 1% AEP event. Other creeks such as Ram Creek and Camel Creek were predicted to be generally of lower hydraulic intensity, with peak flood depths typically below 2 m for the same event.
- Flood behaviour in the Wind Farm 2 development area is typified by higher hydraulic intensities in Yandicoogina Creek due to the large upstream catchment area. Peak depths in Yandicoogina Creek were predicted to be over 4 m in some locations in the 1% AEP event, with peak velocities in the smaller creek systems flowing through the development site are predicted to have typically lower hydraulic intensities.
- Provided conceptual locations of Wind Turbines suggests that a select number of proposed turbine locations were shown to be within the predicted 1% AEP flood extent within the WF1 and WF2 study areas.
- Sensitivity assessment of the 2050 future climate scenario using predicted rainfall intensity increases for the RCP4.5 (intermediate scenario) and RCP8.5 (worst-case scenario) in the modelling identified an increase in the predicted 1% AEP peak flows within Wind Farm 1 of between 11% and 15% respectively.
- Sensitivity assessment of the future climate scenario as well as increased floodplain roughness typically showed peak flood level increases of up to approximately 200 mm and hence it is expected that the uncertainties and associated risks relating to both the exact floodplain

roughness across the study area and future climate hydrologic uncertainty could be mitigated by adoption of a standard design freeboard of 300 mm.

8 Recommendations

Considering the data review, technical assessment and conclusions of this study, the following recommendations are made to support further planning and design:

- Where conceptual placement of wind turbine infrastructure is proposed within the flood extents developed as part of this assessment, alternate placement of wind turbines should be considered.
- Given the predicted range of soils in regional mapping across the study area, Infiltrometer or similar testing should be undertaken for a number of sample locations as part of further geotechnical studies to facilitate a better understanding of infiltration potential in the upper soil profile and further validate hydrologic model parameterisation.
- Undertake LiDAR capture of the development areas and associated local catchments to improve resolution of hydraulic results and absolute vertical accuracy.
- Future calibration and refinement to the regional RORB models should be undertaken to new observed flood events to either validate or update K_c derived from Pearcey et al.'s (2014) published $C_{0.8}$ values for the respective catchments
- The TUFLOW models should be adopted by FFI as an assessment tool and refined with additional data that becomes available for the site.
- Discrete areas of higher hydraulic model resolution using Quadtree functionality is recommended for future project stages where more detail is required such as the detailed design of critical flood mitigation infrastructure.
- Further testing of TUFLOW model sensitivities to input parameters should be undertaken in later project phases. This should include the effects of changes to lower level roughness parameters.
- Flood resilience of various infrastructure may need to be considered including locality of key/critical infrastructure based on the outcomes of this assessment.

9 References

Babister, M., Trim, A., Testoni, I. and Retallick, M. (2016). *The Australian Rainfall and Runoff Datahub*, 37th Hydrology and Water Resources Symposium Queenstown NZ

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2019), *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia (Geoscience Australia)

Bureau of Meteorology (2016), *Design Rainfall Data System*. Retrieved from <http://www.bom.gov.au/water/designRainfalls/revised-ifd/>

Bureau of Meteorology (2022), *Climate Data Online*. Retrieved from <http://www.bom.gov.au/climate/data/>

Davies, J.R. and Yip, E. (2014), Pilbara Regional Flood Frequency Analysis, Proc. Hydrology and Water Resources Symposium, Perth, February 2014, Engineers Australia, pp: 182-189.


Flavell, D. (2012), *Design Flood Estimation in Western Australia*, Australian Journal of Water Resources, 16(1), 1-20.

Pearcey, M., Pettett, S., Cheng, S., and Knoesen, D. (2014), *Estimation of RORB K_c parameter for ungauged catchments in the Pilbara Region of Western Australia*, Proceedings of the 2014 Hydrology and Water Resources Symposium, 24 - 27 February, Perth.

SILO (2022) Retrieved from <https://www.longpaddock.qld.gov.au/silo/view-point-data/>

Stern, H., de Hoedt, G. and Ernst, J. *Objective classification of Australian climates*. Aust. Met. Mag. 49 (2000) 87-96.

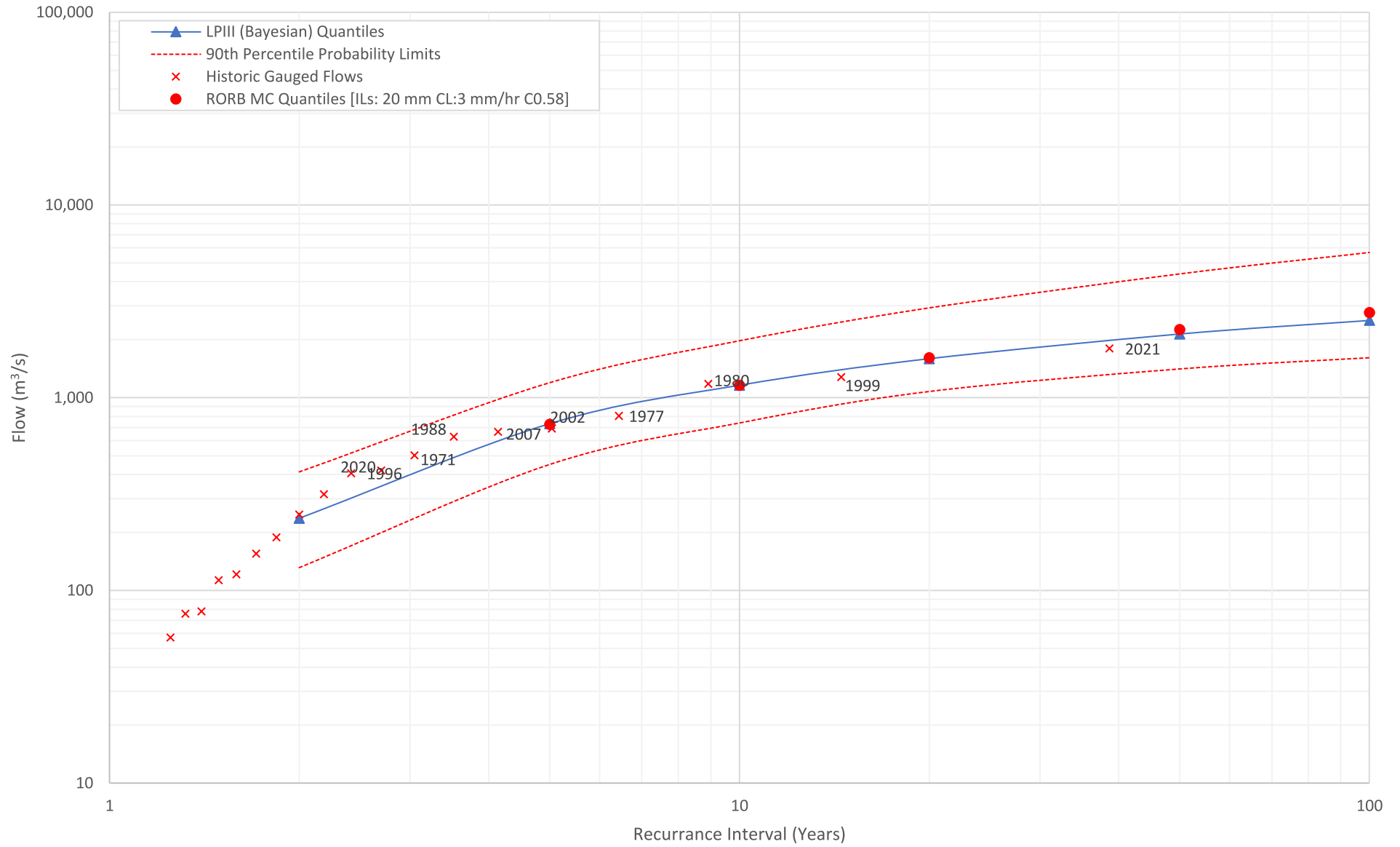
Tille, P J. (2006), *Soil-landscapes of Western Australia's rangelands and arid interior*, Department of Agriculture and Food, Western Australia, Perth. Report 313.




Appendix A

Flood Frequency Analysis Plots

Nullagine Gauge Site FFA





Appendix B
Design Rainfall (IFD) Data – Regional Models

Coongan River Point IFD

Duration	Rainfall Depth (mm)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
12 hour	55.4	84.7	106	129	161	187
18 hour	61.6	95.6	121	147	184	214
24 hour	66.3	104	131	160	200	232
36 hour	73.2	115	145	177	220	254
48 hour	78.1	122	154	187	231	264
72 hour	84.9	132	165	198	240	273

Coongan River Median Pre-Burst

Duration	Rainfall Depth (mm)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
12 hour	0	1.3	2.2	3.0	9.4	14.4
18 hour	0	0.5	0.8	1.0	7.6	12.
24 hour	0	0.6	0.9	1.3	3.4	4.9
36 hour	0	0	0	0	1.1	2.0
48 hour	0	0	0	0	0	0
72 hour	0	0	0	0	0	0

Nullagine River Point IFD

Duration	Rainfall Depth (mm)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
12 hour	54.3	82.4	103	125	155	181
18 hour	61.3	94.2	118	144	180	210
24 hour	66.6	103	129	157	197	229
36 hour	74	115	144	174	218	252
48 hour	79.1	122	153	184	228	263
72 hour	85.5	131	163	194	238	271

Nullagine River Median Pre-Burst

Duration	Rainfall Depth (mm)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
12 hour	0	0.7	1.1	1.5	8.6	13.9
18 hour	0	0.3	0.4	0.6	7.0	11.8
24 hour	0	0.4	0.7	1	3.4	5.2
36 hour	0	0	0	0	0.7	1.2
48 hour	0	0	0	0	0	0
72 hour	0	0	0	0	0	0



Appendix C

Design Rainfall (IFD) – Local Models

Wind Farm 1 Point IFD

Duration	Rainfall Depth (mm)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
1 hour	28.1	39.4	47	54.5	64.4	71.9
2 hour	34.5	48.9	58.8	68.7	82.1	92.5
3 hour	38.4	55.2	67	78.9	95.1	108
4.5 hour	42.7	62.4	76.5	90.9	111	127
6 hour	46.1	68.2	84.3	101	124	142
9 hour	51.3	77.4	96.6	117	145	167
12 hour	55.4	84.7	106	129	161	187

Wind Farm 1 Median Pre-Burst

Duration	Rainfall Depth (mm)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
1 hour	0.7	1.1	1.4	1.7	2.3	2.8
2 hour	0	0.2	0.3	0.4	2.2	3.6
3 hour	0	1.0	1.7	2.4	9.3	14.5
6 hour	0	1.5	2.5	3.4	20.7	33.6
12 hour	0	1	1.7	2.4	9.0	14.0

Wind Farm 2 Point IFD

Duration	Rainfall Depth (mm)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
1 hour	28.3	39.7	47.4	55.1	65.2	72.9
2 hour	34.2	48.5	58.4	68.3	81.7	92.1
3 hour	37.8	54.3	65.9	77.6	93.6	106
4.5 hour	41.7	60.9	74.6	88.6	108	124
6 hour	44.8	66.3	81.8	97.8	120	138
9 hour	49.7	74.9	93.4	113	140	162
12 hour	53.6	81.9	103	125	155	180

Wind Farm 2 Median Pre-Burst

Duration	Rainfall Depth (mm)					
	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
1 hour	0.6	1.0	1.2	1.5	2.2	2.8
2 hour	0	0.2	0.3	0.4	2.2	3.6
3 hour	0	1.0	1.6	2.2	8.6	13.4
6 hour	0	1.5	2.5	3.4	22.5	36.7
12 hour	0	1.3	2.2	3.0	10.3	15.7



Appendix D








Design Event Flood Mapping

EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY






FIGURE 1

WF1 STUDY AREA EXISTING CASE 1% AEP PEAK FLOOD DEPTH

Legend

-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

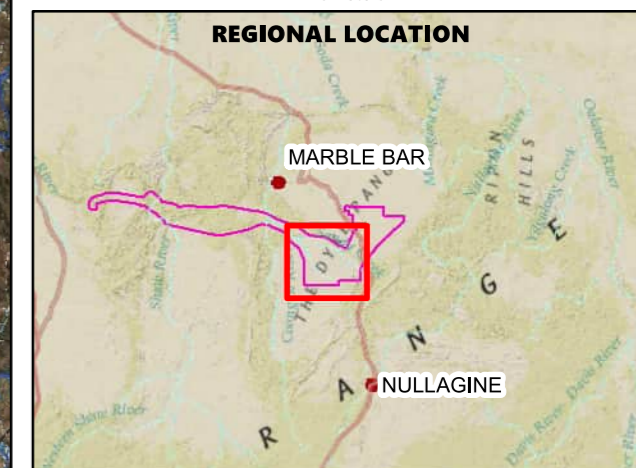
Peak Flood Depth (m)

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-  0.02 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  1 - 3
-  >3

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Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

Scale at A3 - 1:100,000



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
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EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY







FIGURE 2

WF2 STUDY AREA EXISTING CASE 1% AEP PEAK FLOOD DEPTH

Legend

-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

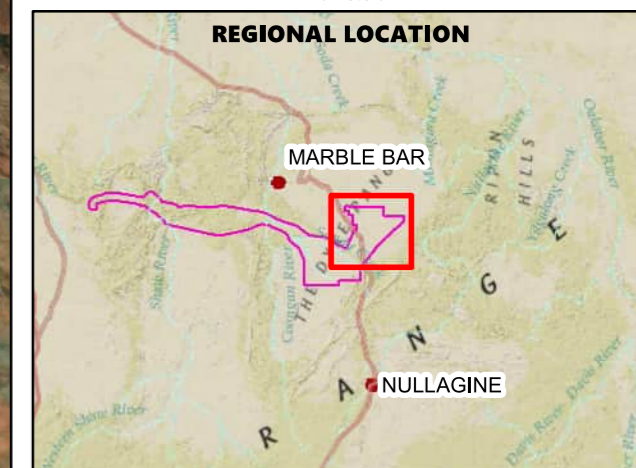
Peak Flood Depth (m)

-  <0.02 (not shown)
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-  1 - 3
-  >3

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Scale at A3 - 1:100,000










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




FIGURE 3

WF1 STUDY AREA EXISTING CASE 5% AEP PEAK FLOOD DEPTH

Legend

-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

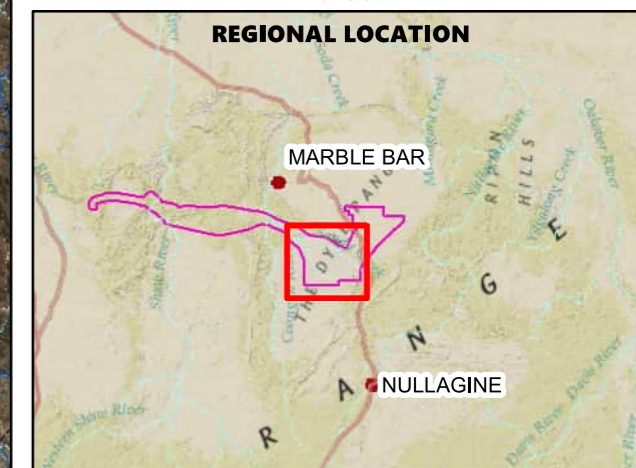
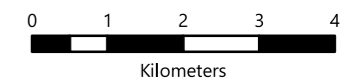
Peak Flood Depth (m)

-  <0.02 (not shown)
-  0.02 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  1 - 3
-  >3

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Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

Scale at A3 - 1:100,000



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




FIGURE 4

WF2 STUDY AREA EXISTING CASE 5% AEP PEAK FLOOD DEPTH

Legend

-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

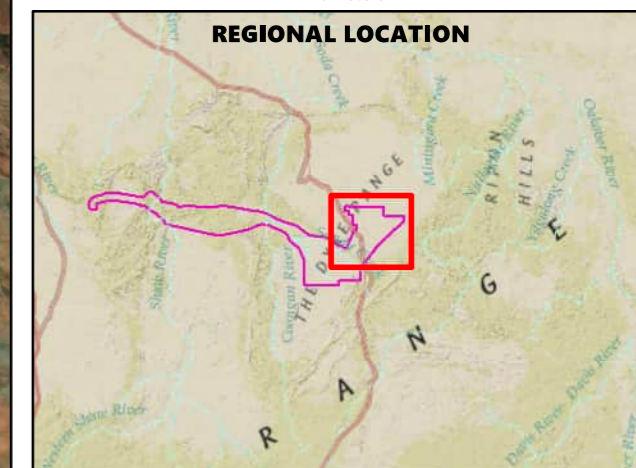
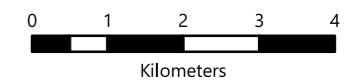
Peak Flood Depth (m)

-  <0.02 (not shown)
-  0.02 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  1 - 3
-  >3

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Datum: GDA 1994
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Scale at A3 - 1:100,000










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



FIGURE 5

WF1 STUDY AREA EXISTING CASE 20% AEP PEAK FLOOD DEPTH

Legend

-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

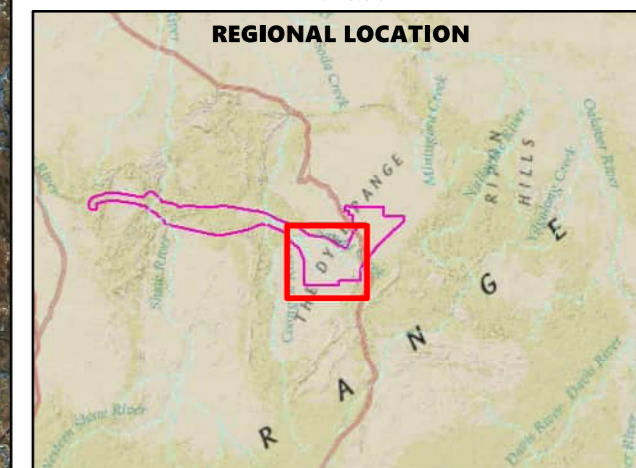
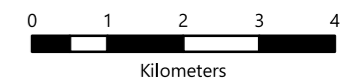
Peak Flood Depth (m)

-  <0.02 (not shown)
-  0.02 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  1 - 3
-  >3

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Coordinate System: GDA 1994 MGA Zone 50
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Datum: GDA 1994
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Scale at A3 - 1:100,000



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EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY

FIGURE 6

WF2 STUDY AREA EXISTING CASE 20% AEP PEAK FLOOD DEPTH

Legend

- Project Development Envelope
- ✱ Proposed Wind Tower Location
- Hydraulic Model boundary
- Ground Surface Contour (2 m interval)
- State Road
- Local Road
- Miscellaneous Road

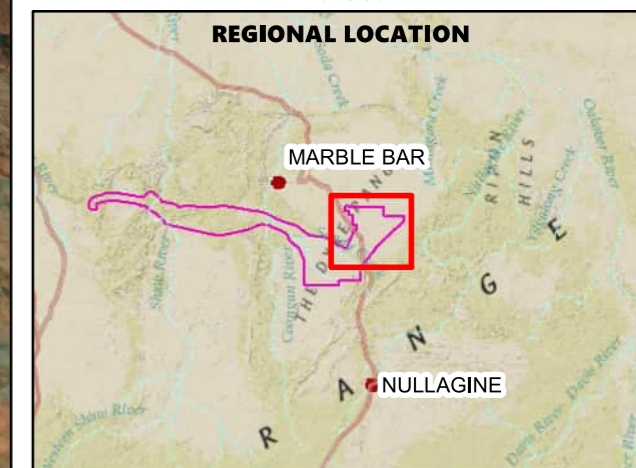
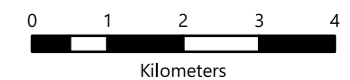
Peak Flood Depth (m)

- <0.02 (not shown)
- 0.02 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 3
- >3

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Scale at A3 - 1:100,000



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EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY

FIGURE 7

WF1 STUDY AREA EXISTING CASE 1% AEP PEAK FLOOD VELOCITY

Legend

-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

Peak Flood Velocity (m/s)

-  0 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  1 - 2
-  2 - 3
-  >3

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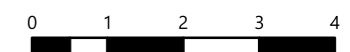
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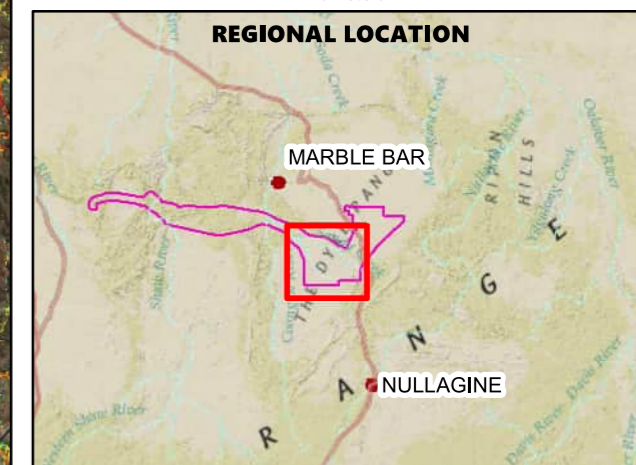
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False Easting: 500,000.0000

Scale at A3 - 1:100,000



Kilometers



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National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,



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EAST PILBARA GENERATION HUB BASELINE HYDROLOGY STUDY

FIGURE 8

WF2 STUDY AREA EXISTING CASE 1% AEP PEAK FLOOD VELOCITY

Legend

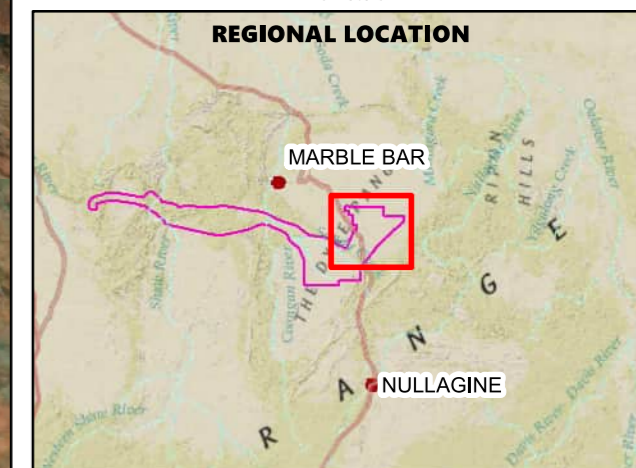
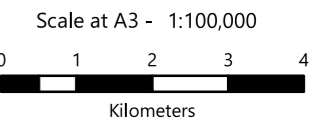
- Project Development Envelope
- ✱ Proposed Wind Tower Location
- Hydraulic Model boundary
- State Road
- Local Road
- Miscellaneous Road
- Ground Surface Contour (2 m interval)

Peak Flood Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- >3

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Coordinate System: GDA 1994 MGA Zone 50
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Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
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
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

FIGURE 9

WF1 STUDY AREA EXISTING CASE 5% AEP PEAK FLOOD VELOCITY

Legend

-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

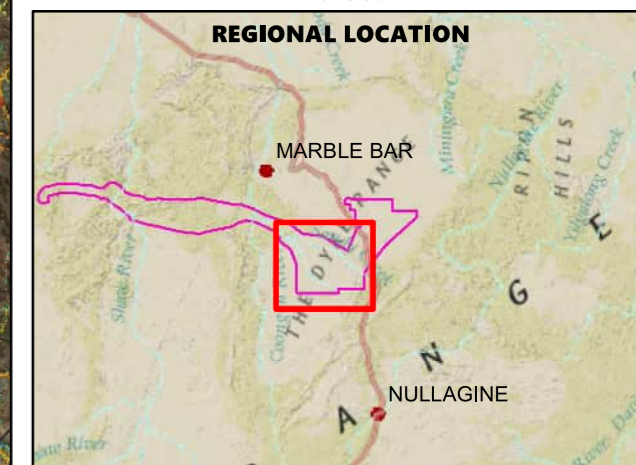
Peak Flood Velocity (m/s)

-  0 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  1 - 2
-  2 - 3
-  >3

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Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

Scale at A3 - 1:100,000



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

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FIGURE 10

WF2 STUDY AREA EXISTING CASE 5% AEP PEAK FLOOD VELOCITY

Legend

- Project Development Envelope
- ✱ Proposed Wind Tower Location
- Hydraulic Model boundary
- State Road
- Local Road
- Miscellaneous Road
- Ground Surface Contour (2 m interval)

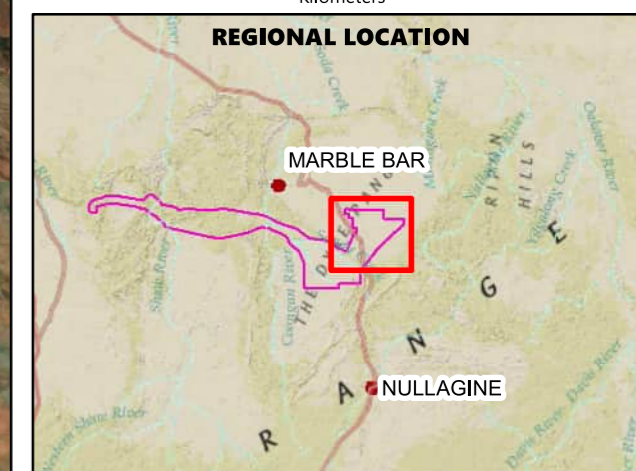
Peak Flood Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- >3

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Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

Scale at A3 - 1:100,000



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
National Geographic, Esri, Garmin, HERE, UNEP-WCMC, USGS, NASA, ESA, METI, NRCAN, GEBCO,

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FIGURE 11

WF1 STUDY AREA EXISTING CASE 20% AEP PEAK FLOOD VELOCITY

Legend

- Project Development Envelope
- * Proposed Wind Tower Location
- Hydraulic Model boundary
- State Road
- Local Road
- Miscellaneous Road
- Ground Surface Contour (2 m interval)

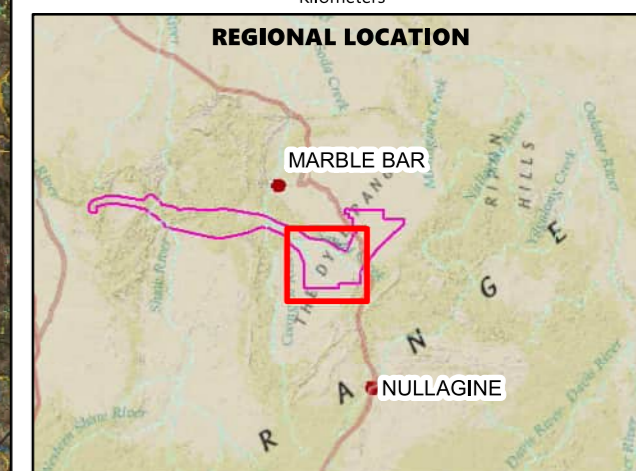
Peak Flood Velocity (m/s)

- 0 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 2
- 2 - 3
- >3

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Coordinate System: GDA 1994 MGA Zone 50
Projection: Transverse Mercator
Datum: GDA 1994
False Easting: 500,000.0000

Scale at A3 - 1:100,000



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FIGURE 12

WF2 STUDY AREA EXISTING CASE 20% AEP PEAK FLOOD VELOCITY

Legend

-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

Peak Flood Velocity (m/s)

-  0 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  1 - 2
-  2 - 3
-  >3

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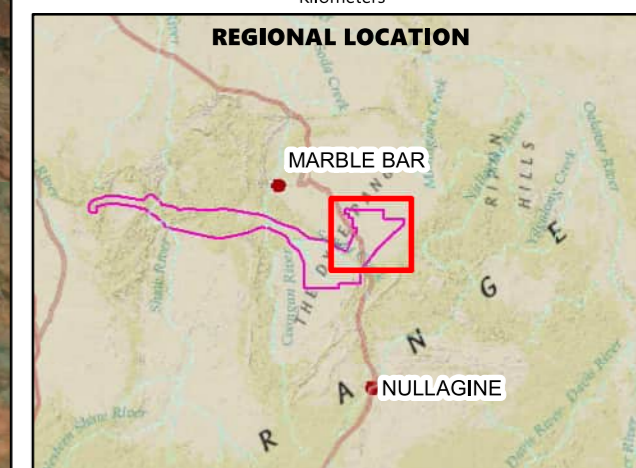
Coordinate System: GDA 1994 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA 1994

False Easting: 500,000.0000

Scale at A3 - 1:100,000



Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community
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Appendix E
Inundated Conceptual Turbine Locations

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FIGURE 1

WF1 STUDY AREA EXISTING CASE 1% AEP PEAK FLOOD DEPTH AND INUNDATED TURBINE LOCATIONS

Legend

-  Turbine Locations in >100 mm Flood Depth
-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

Peak Flood Depth (m)

-  <0.02 (not shown)
-  0.02 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  1 - 3
-  >3

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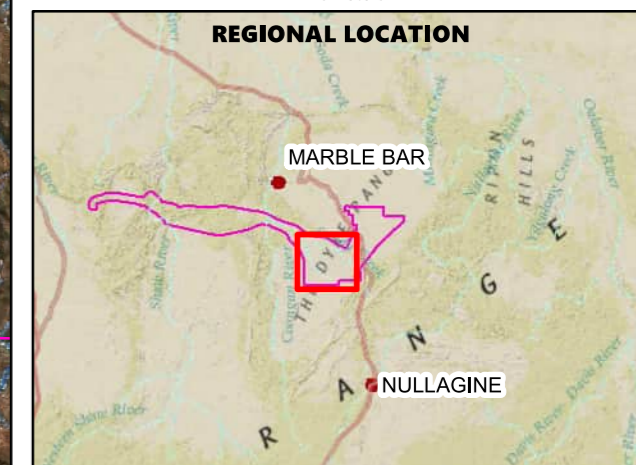
Coordinate System: GDA 1994 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA 1994

False Easting: 500,000.0000

Scale at A3 - 1:75,000



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




FIGURE 2

WF2 STUDY AREA EXISTING CASE 1% AEP PEAK FLOOD DEPTH AND INUNDATED TURBINE LOCATIONS

Legend

-  Turbine Locations in >100 mm Flood Depth
-  Project Development Envelope
-  Proposed Wind Tower Location
-  Hydraulic Model boundary
-  Ground Surface Contour (2 m interval)
-  State Road
-  Local Road
-  Miscellaneous Road

Peak Flood Depth (m)

-  <0.02 (not shown)
-  0.02 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  1 - 3
-  >3

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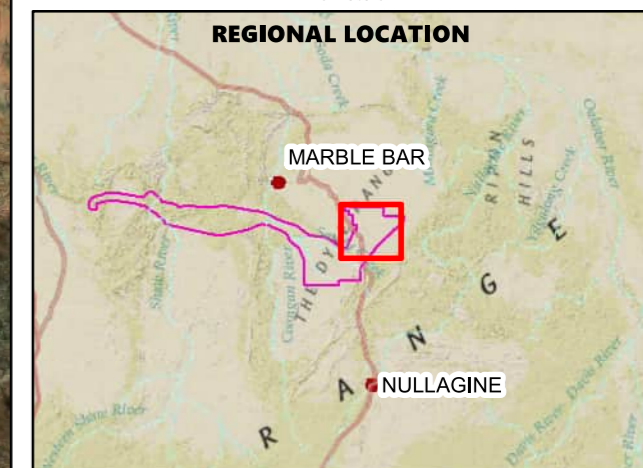
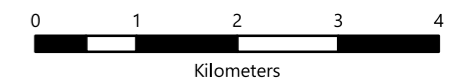
Coordinate System: GDA 1994 MGA Zone 50

Projection: Transverse Mercator

Datum: GDA 1994

False Easting: 500,000.0000

Scale at A3 - 1:75,000



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