



Report

Site 12 Pool Catchment Waterways Hydrological Assessment

North Star Extension

10 April 2025

NS-5700-RP-WM-0003

Rev: 1

EXECUTIVE SUMMARY

Fortescue proposes to expand its operations in North Star (NS) with a proposed development known as North Star Magnetite Project Extension (NSE). The proposed development consists of additional pits, expansion of the existing waste rock dump (WRD) and associated mining infrastructure. The project would extend to the south of existing approved operations. The footprint of NSE encompasses three catchments, namely Turner River, Shaw River and Strelley River catchment. This study will focus on the waterways hydrological assessment to the Strelley River catchment, as a result of the expansion of the WRD for NSE.

The primary objective of this study is to assess the waterways flow regime of Site 12 Pool catchment, which is part of the broader Strelley River catchment. An impact assessment is also completed to quantify the change in waterways flow regime from the proposed NSE development.

The catchment flow regimes were analysed using hydraulic software package TUFLOW. The methodology adopted is similar to the *North Star Magnetite Project Extension — Baseline Hydrology Report* (Worley, 2024 (a)), which is in line with industry standards. The hydraulic model was developed to simulate catchments under Baseline and NSE conditions. The results indicates that the critical durations of the catchment for events that produces peak flows are short (less than 6 hours) whereas the duration for storms that produces the largest amount of runoff are typically long (greater than 24 hours).

The impact assessment illustrate that the southern tributary will observe the largest reduction in peak flow post NSE development. This is because the WRD expansion would encroach on the upper catchments of the southern tributary. The peak flow reduction due to NSE at Site 12 Pool is estimated to be approximately 8% for the 50% AEP event. Volumetric assessment shows that a reduction of 14% in flow volume is predicted at Site 12 Pool due to 0.5 km² of catchment reduction from the WRD expansion.

The WRD at NS and NSE are designed to redirect runoff from its top lift to the Site 12 Pool catchment at closure. Desktop assessment of the amount of runoff produced for the frequent to rare design annual exceedance probabilities (AEP) was completed. The results indicates that the runoff from the most frequent event assessed (50% AEP) is sufficient to fill up Site 12 Pool. Additional runoff from the WRD would increase the flow volume to Site 12 Pool post closure compared to operational scenario.

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1 INTRODUCTION

1.1 Background

The North Star Magnetite Iron Ore Mine is located approximately 110 km south of Port Hedland in the Pilbara region of Western Australia. Fortescue proposes to expand this site as additional magnetite resources is known to occur south of the current approved development envelop (DE).

The proposed development is known as North Star Magnetite Project Extension (NSE) in this assessment. NSE consists of additional mine pits, expansion of the approved WRD and associated mining infrastructure. The DE of NSE intersects with three catchment areas, namely the Turner River, Shaw River and Strelley River. The extent of the NSE DE is illustrated in Figure 1-1. Hydrological assessment of Turner River and Shaw River focussing on the area within the vicinity NSE DE was completed by Worley (2024 (a)) and (2024 (b)). The extent of the catchments assessed by Worley is illustrated in Figure 1-1 as Pit Catchment and WRD Catchment.

This report will focus on characterising the waterways contributing to Site 12 Pool, which is part of the Strelley River catchment. This includes the hydrological impact assessment for the waterways within Site 12 Pool catchment as a result of NSE development. The area of interest for this study (herein referred as the Study Area) is depicted in Figure 1-1. The Study Area encapsulates:

- the catchment area upstream and immediate downstream of Site 12 Pool;
- The WRD footprint (approved NS and proposed NSE); and
- the area upstream of the approved and proposed WRD.

1.2 Objectives

The primary objective of this study is to characterise the catchment flow regime of Site 12 Pool catchment under Baseline and NSE scenarios. Baseline scenario is defined as the approved mining operations, issued with Ministerial Statement (MS) 993 in conjunction with North Star Stage 2 Mining Proposal Revision 4 (Registration ID: 118381). NSE scenario is defined as an extension to the approved mining proposal which includes additional pits, extension of WRD and ancillary infrastructure.

Impacts from the proposed NSE is quantified by comparing the changes in hydrological regime between Baseline and NSE scenarios. The findings of the impact assessment are documented in Section 7.

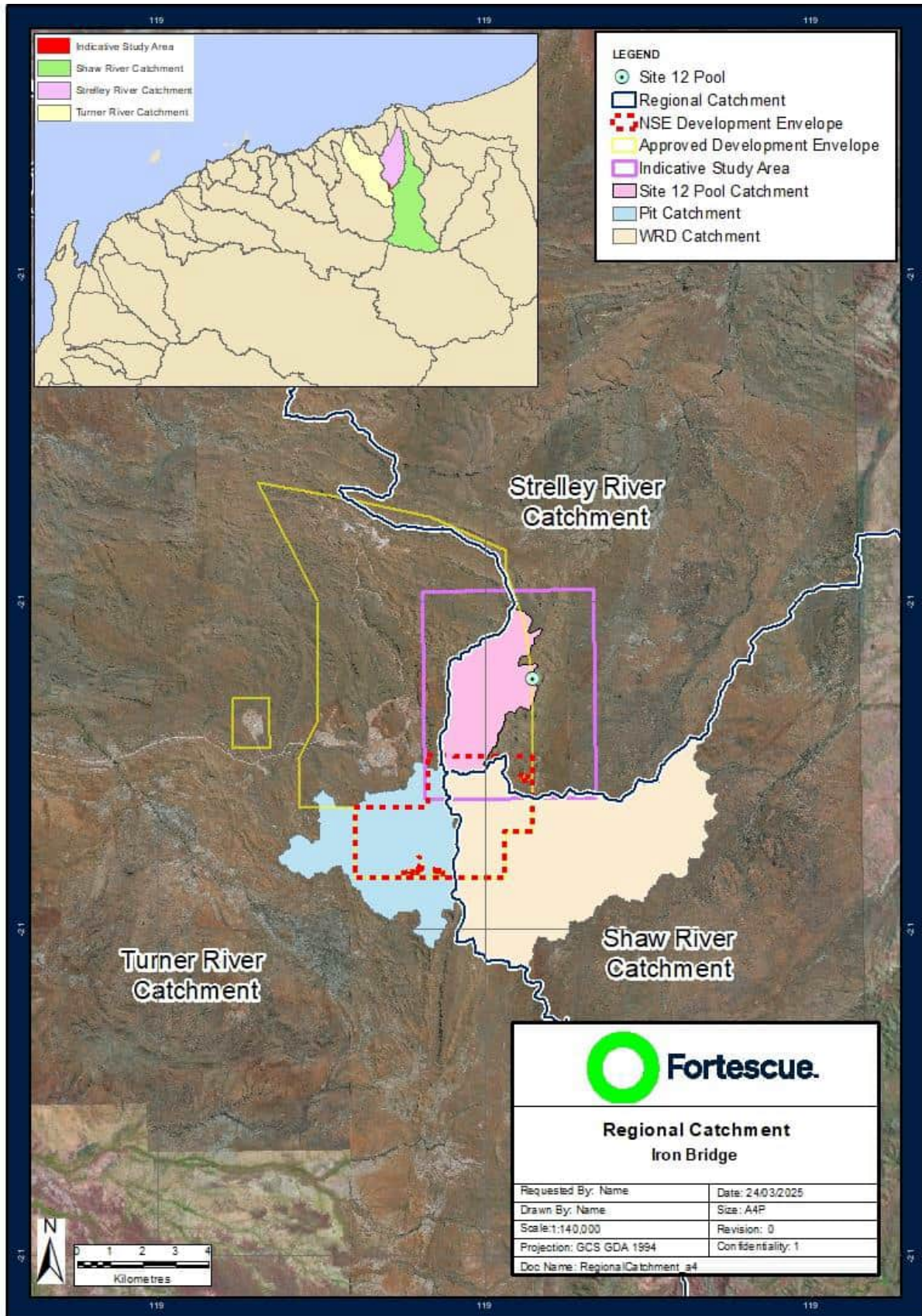


Figure 1-1 Regional catchment locality
 Site 12 Pool Catchment Waterways Hydrological Assessment

2 STUDY AREA

The Study Area is located within the Six Mile Creek catchment, which is a sub-catchment of the Strelley River Catchment. The catchment drains northerly towards the coast and it consists of steep upper catchments with well-defined channels. The catchment drains into Site 12 Pool and merges with Six Mile Creek approximately 5 km further downstream, as shown in Figure 2-1. The elevation of the Study Area ranges from approximately 400 mAHD at the top of the catchment, dropping to approximately 250 mAHD at the Study Area outlet.

Site 12 Pool is within a gorge that consists of a series of small pools over a linear distance of approximately 650 m. The deepest pool is approximately 2.5 m deep. Site 12 Pool has been identified as an environmentally and culturally significant site. A summary of Site 12 Pool's catchment characteristics is documented in Table 2-1.

Table 2-1 Site 12 Pool catchment characteristics

Catchment Characteristics	
Area (km ²)	8.2
Length (km)	5.3
Centroid Latitude (°S)	-21.249
Centroid Longitude (°E)	119.074
Equal Area Slope (m/km)	-33.1
Shape Factor	0.38

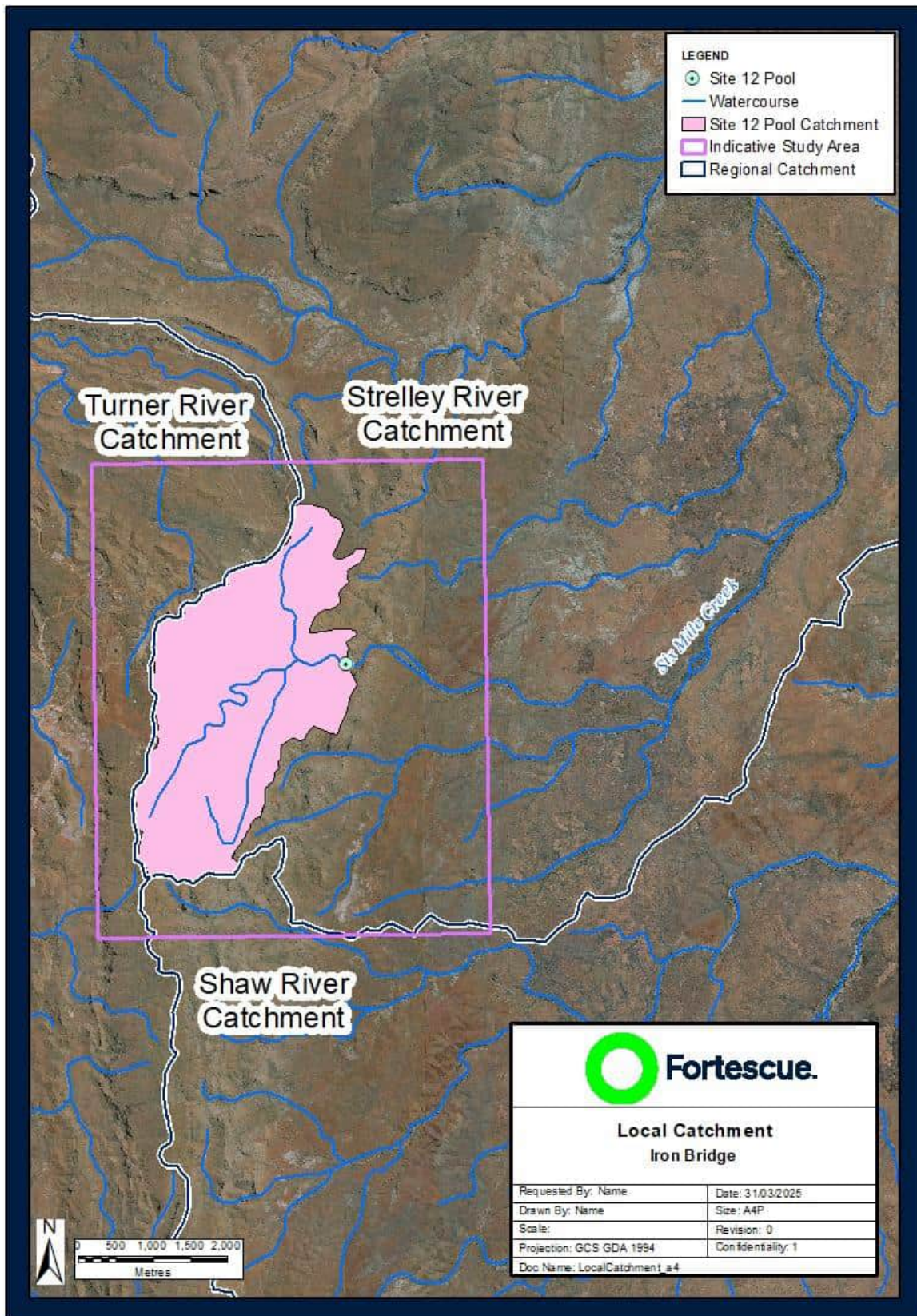


Figure 2-1 Indicative Study Area locality

3 CATCHMENT HYDROLOGY

The Study Area is located adjacent to the Turner River and Shaw River catchment which are assessed as part of the North Star Magnetite Project Extension – Baseline Hydrology Report (Worley, 2024 (a)). The catchment characterisation from Worley’s assessment are applicable to the Study Area due to their close proximity.

Two catchments, NSE Pit Catchment and WRD Catchment were assessed in the Baseline Hydrology Report (Worley, 2024 (a)). The Pit Catchment and WRD Catchment are located in the Turner River and Shaw River catchments respectively. Design flood quantiles were estimated at these catchments’ outlets using a combination of regional estimate and transposition of gauged data. The Regional Flood Frequency Procedure (RFFP) and the Regional Flood Frequency Estimation Model (RFFE) provides flow estimates for the 50% AEP to 1 % AEP events. Flood frequency analysis (FFA) was completed for five of the closest stream gauges to the Study Area. The length of record for the gauges ranges between 26 to 57 years. While the area for Pit Catchment and WRD Catchment is 15.3 km² and 30.2 km² respectively, the catchment areas for the stream gauges is at least an order of magnitude larger, ranging from 120 km² to 6,501 km².

A hydrological model (RORB) was developed to define the loss parameters of the study catchments. The design flow estimates from RORB were compared to the estimates from the regional methods and FFA. The assessment found that design IL of 20 mm and CL of 4.3 mm/hr is appropriate for the study catchment. The adopted IL and CL is within the reasonable loss values used to inform the ARR estimates (Worley, 2024 (a)).

These loss parameters were validated against historical flood event from December 2020. For historical events, the IL is dependent on antecedent rainfall. Given the amount of rainfall that was recorded prior to the event selected, an IL value of 20 mm was used. The primary objective of the validation exercise is to match the main burst flood response and peak, which in this instance, occurred towards the end of the storm. Hence, replication of this event’s flood response will be dependent on the CL parameter. The proposed CL of 4.3 mm/hr shows good agreement between recorded data and hydraulic modelling results.

Given that the desktop flood quantile estimates and proposed loss parameters are in reasonable alignment, IL of 20 mm and CL of 4.3 mm/hr is considered suitable for design flood estimates of the Study Area.

4 HYDRAULIC ASSESSMENT

4.1 Modelling Approach

A design event based modelling approach have been adopted to quantify the flooding characteristics (flood depth, flow rates, velocity, etc) of the Study Area. This approach assumes that the model inputs are probability neutral, ie the inputs adopted for a 1 in X AEP event would produce a 1 in X AEP flood. Each design events were simulated in an ensemble approach to account for probability neutrality in the model inputs, as shown in Figure 4-1.

To produce flood maps that represent the peak flood levels catchment wide, the results are an amalgamation of the maximum of the median for each duration simulated. Typically, the critical duration in the upper catchment is shorter than the lower reaches.

In addition, ARR 2016 (Ball, et al., 2019) recommends applying an areal reduction factor (ARF) as a correction factor to design point rainfall depth for catchments between 1 km² and 30,000 km². This is because larger catchments are less likely to experience high intensity storm across the whole catchment simultaneously. Applying ARFs would preserve probability neutral transition between the design rainfall and the design flood characteristics. In this assessment, the TUFLOW model was set up with varying ARFs to account for the varying storm intensity across the catchment. This approach is also consistent with the methodology described above to calculate the representative peak flood levels across the entire catchment.

The design events simulated ranges from the 50% AEP to the probable maximum flood (PMF). These design events covers the typical AEPs used for a range of studies, from infrastructure designs to closure assessments.

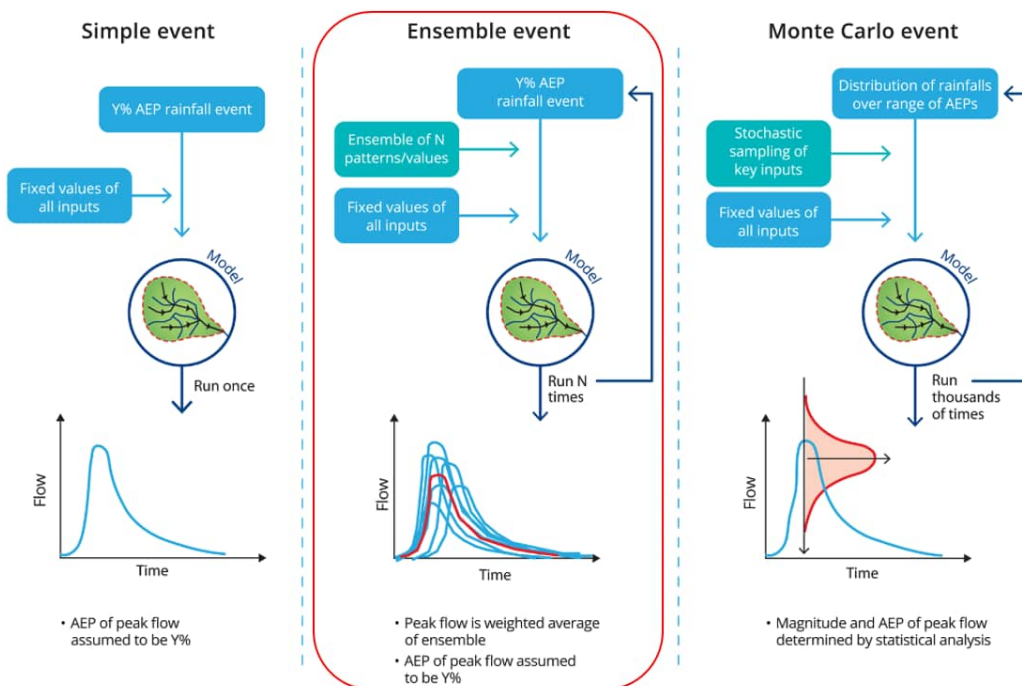


Figure 4-1 Catchment scale modelling conceptual approach (Ball, et al., 2019)

4.2 Model Development

TUFLOW is a hydraulic modelling software package adopted for this study. TUFLOW simulates movement of water in both 2D and 1D domains by solving the shallow water equations using the finite difference method. The version of TUFLOW used in this study is 2023-03-AE.

4.2.1 Model Scenarios

The Baseline and NSE scenarios were simulated using a hydraulic model to develop an understanding of the catchment hydrological regimes under the various scenarios. The details of the scenarios analysed in TUFLOW are summarised in Table 4-1.

Table 4-1 Scenarios assessed in this study

Scenario	Description
Baseline	<ul style="list-style-type: none"> – Includes all NS approved mine development landform within Study Area catchment. – The berms of the WRD are back-sloping and incident rainfall on the WRD will be retained on the landform.
NSE	<ul style="list-style-type: none"> – Includes all approved mine development landform within Study Area catchment. – Include proposed landform in NSE that is within the Study Area catchment – The berms of the WRD are back-sloping and incident rainfall on the WRD will be retained on the landform.

4.2.2 Design Event

The design events included in this assessment range from frequent (50% AEP) to probable maximum flood (PMF). The wide range of design events would be suitable for a variety of planning and design purposes. For example, frequent design events are typically used in assessing impacts to the catchment of interest during operations. Conversely, extreme events are important for closure considerations. The hydraulic model was set up to simulate events ranging from 10 minutes to 3 hours.

4.2.3 Model Extent

To achieve the objective of characterising the flow regime to Site 12 Pool under Baseline and NSE conditions, the TUFLOW model extent was developed to encompass all areas that contributes flow to Site 12 Pool. The model catchment includes the natural upstream catchment of Site 12 Pool and extends 1.8 km downstream of the pool. It also includes the footprint of the approved and proposed WRD and its corresponding upstream catchment area. The model extent is approximately 14 km² and is illustrated in Figure 4-3.

4.2.4 Model Parameters

4.2.4.1 Inflow

Catchment inflows were applied in the form of rain-on-grid (RoG) to the catchment domain. Rainfall is applied to selective areas of the model domain. In the Baseline and NSE scenarios,

the WRDs are located at the top of Site 12 Pool catchment. Since they have been designed to contain runoff during operations, rainfall was only applied downstream of the WRD’s footprint.

4.2.4.2 Outflow

Outflow boundaries are set up as water level versus flow (HQ) boundaries where TUFLOW generates a flow against water level curve based on an assigned slope at the boundary. The slope at each boundary was calculated based on topographic data. The locations of the boundaries are set a fair distance downstream of any area of interest to mitigate boundary effects, as shown in Figure 4-3.

4.2.4.3 Digital Elevation Model & Model Resolution

A digital elevation model (DEM) was created using a combination of LiDAR dataset and landform designs. The dataset used in the model are presented in Table 4-2. The WRDs are designed to contained runoff during operations with back-sloping berms.

Table 4-2 Topographic dataset used in TUFLOW

Data	Type
PIL_ELEV_FMG_IRON_BRIDGE_1M_DEM_NOV2023.tif	LiDAR
PIL_ELEV_FMG_IRON_BRIDGE_1M_DEM_MAR2024.tif	LiDAR
lea99_wlfd_r08_ramps_with_top_gradient_cut.ft	Approved WRD design
nts99_00_dump_cut_r001_csur.tif	Proposed WRD design

A 5 m grid was applied to the entire model domain, with sub-grid sampling (SGS) at 1 m interval. SGS is a technique where the DEM is constructed with each cell containing a stage-storage curve sampled at a finer resolution. The application of SGS allows catchment flow conveyance to be represented more accurately at a lower grid resolution.

4.2.4.4 Design Rainfall Depths

Point design rainfall depths for the 1 in 2 AEP to 1 in 2000 AEP at the centroid of the study catchment (-21.249, 119.074) was extracted from BOM’s Design Rainfall Data System webpage. Since the catchment area is less than 20 km², a spatial pattern was not applied to the model domain as per ARR’s recommendation. Due to the small catchment size, the critical duration of the catchment of interest is likely to be short (less than 6 hours). Thus, the design rainfall depths of up to 6 hours are presented in Appendix A.

The probable maximum precipitation (PMP) is the theoretical greatest precipitation depth possible over a catchment area. Since the PMP is beyond the limit of probable extrapolation of observed data, it is estimated based on the current understanding of extreme events and the metrological forces that produce them. The PMP rainfall depths are calculated using Generalised Short-Duration Method (GSDM) and the calculations are presented in Appendix B. The AEP of the PMP is estimated to be 1 in 10,000,000 AEP.

4.2.4.5 Temporal Patterns

Temporal pattern describes how rainfall falls over time. To represent the natural variability of rainfall events, a set of 10 temporal patterns were adopted for each rainfall duration in this study. Rangeland West point temporal patterns provided by ARR Data Hub was adopted for frequent to rare events (up to the 1% AEP). Point temporal patterns were used as the Study Area is less than 75 km². For events rarer than 1% AEP with short rainfall duration, the ensemble temporal patterns from Jordan et. al. (Growth curves and temporal patterns of short duration design storms for extreme events, 2005) have been adopted as per the recommendation by ARR guideline.

4.2.4.6 Pre-Burst

Pre-burst rainfall is antecedent to the main burst and varies by AEP and duration. The median pre-burst depths varies greatly across Australia. For the Pilbara, the median pre-burst depth can make up a significant portion of the total rainfall depth. The median pre-burst depth at the Study Area ranges from 0% to 22% of the burst depth. For frequent to very rare events (50% AEP to 1 in 2000 AEP), the model is set up to simulate a complete storm which includes pre-burst. For these events, the median pre-burst depth was applied. Pre-burst values are duration and AEP dependent. To simulate a complete storm, the value of the pre-burst is subtracted from the storm initial loss (IL_S). The effective loss applied is IL_B as illustrated in Figure 4-2.

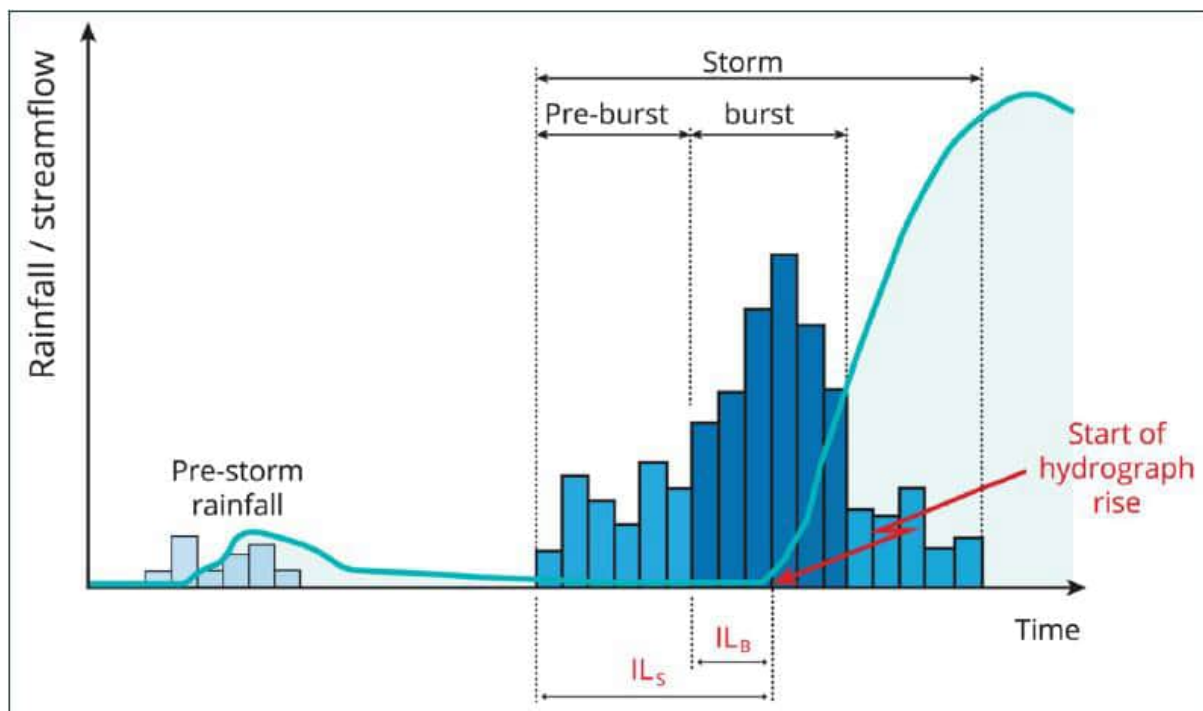


Figure 4-2 Conceptualisation of the difference between Storm and Burst Initial Loss (Ball, et al., 2019)

For the extreme events (probable maximum precipitation flood (PMPF) and PMF), only the main burst was simulated. Therefore, pre-burst have been excluded.

4.2.4.7 Loss Parameters

An initial loss (IL) and continuing loss (CL) model was adopted in this assessment. Empirical loss models prioritise capturing the overall effects of loss processes on flow generation rather than focusing on a detailed replication of the physical loss mechanisms themselves.

Therefore, unless there is a precise and thorough understanding of the spatial variability in infiltration capacity and other mechanisms that cause loss in a catchment, it is common to use a single set of parameters to represent the broader impact of potential variability in surface materials and other loss factors. This approach is generally accepted as a limitation in design event flood modeling.

A probability neutral loss parameter of IL 20 mm and CL 4.3 mm/hr was derived for the neighbouring Turner River and Shaw River catchments (Worley, 2024 (a)). This set of loss values are applied for the frequent events up to and including the 1 in 2000 AEP event.

Given that only the design burst is modelled for the PMPF and PMF, ARR 2019 Book 8 (Ball, et al., 2019) recommends that an IL_b of 0 mm to be adopted for PMPF and PMF in the Pilbara region. For the PMPF, a CL of 4.3 mm/hr was adopted while the PMF adopts a CL of 1 mm/hr (Ball, et al., 2019).

The loss parameters are applied through soil infiltration in TUFLOW. This approach would subtract the defined loss parameters through each wet cells within the model domain. A sensitivity check performed between application of losses through rainfall excess versus soil infiltration found that there is no noticeable difference between the two approaches (Worley, 2024 (a)).

4.2.4.8 Areal Reduction Factor

To account for the effect of varying ARF within the Study Area, three critical locations/junctures have been identified. Two of these locations are from the three main tributaries upstream of Site 12 Pool as shown in Figure 4-3. The main tributary to the west of Site 12 Pool have been excluded in this assessment as this catchment has been replaced by the WRD footprint. During operations, no flow is expected from the WRD. The catchment areas adopted for the ARF calculations are summarised in Table 4-3.

Table 4-3 Catchment area adopted in ARF calculations

Catchment	Baseline Scenario Catchment Area (km ²)	ARF Scenario Catchment Area (km ²)
North	1.8	1.3
South	1.4	1.4
Site 12 Pool	4.1	3.6

A single ARF is applied to the areas of upstream of each of these junctures to simplify the modelling process. The ARF catchment area adopted for the model is illustrated in Figure 4-3. As a result, the areas upstream of these locations is expected to slightly underestimate the design rainfall depth whereas areas downstream of these locations would have the opposite effect.

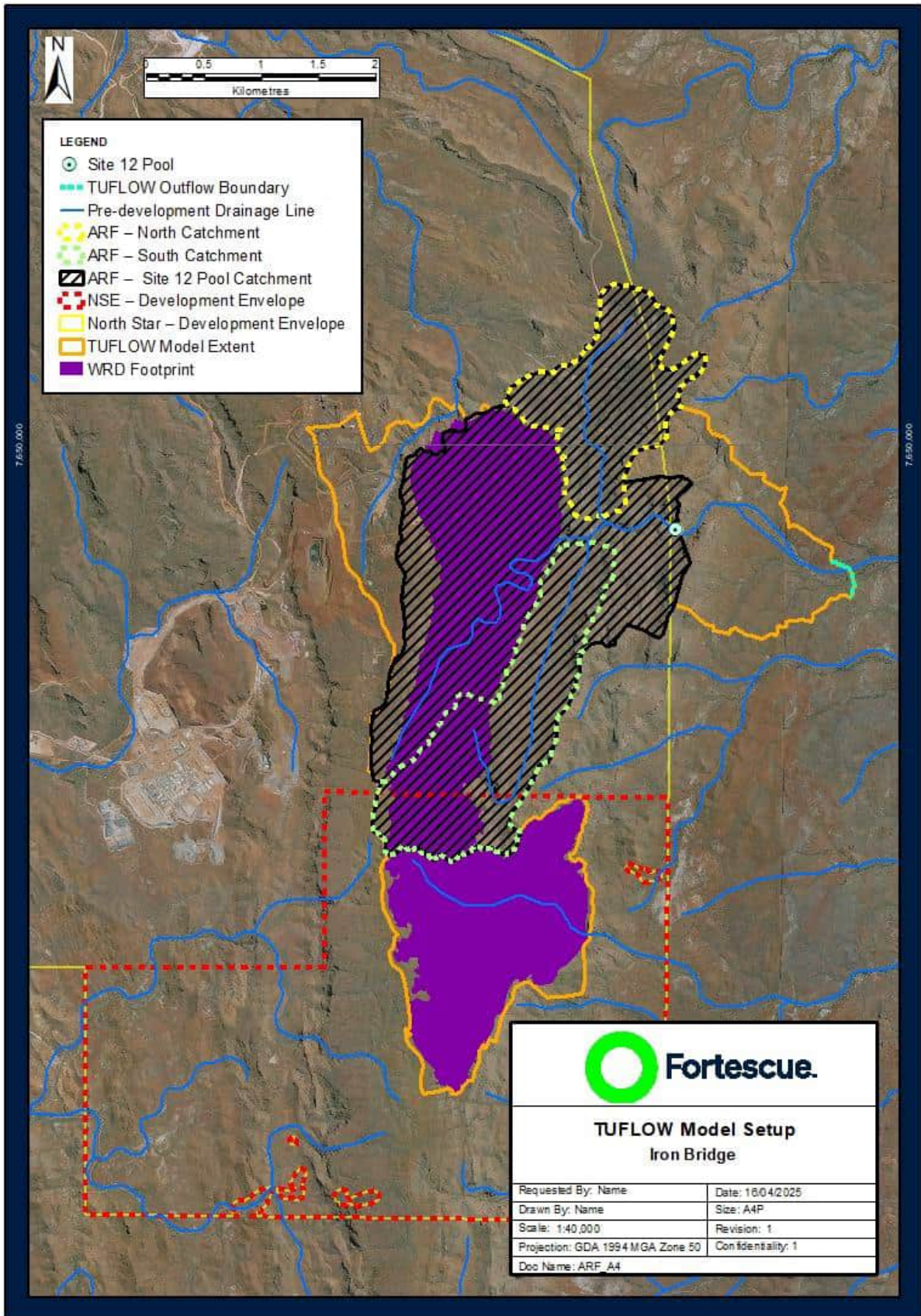


Figure 4-3 TUFLOW model setup

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4.2.4.9 Roughness

Manning’s ‘n’ is used as a proxy to infer the roughness of the terrain. The Manning’s n adopted in this assessment is summarised in Table 4-4. The Manning’s ‘n’ of the study area was derived from the imagery from the European Space Agency (ESA) Sentinel-2 satellite. This satellite carries the Multispectral Imager (MSI) and delivers 13 spectral bands ranging from 10 m to 60 m resolution. A normalised difference vegetation index (NDVI) grid was created using the 10 m resolution data collected on the 16/05/2023 by ESA. The NDVI grids shows the spatial variation of vegetation density across the Study Area. An area with higher vegetation density is likely to have higher hydraulic roughness as well.

A comparison of the NDVI grids from May and October of 2023 was done by Worley (North Star Magnetite Project Extension — Baseline Hydrology Report, 2024 (a)). It was concluded that the imagery from May provides a more representative vegetation density in during the wet season where most likely flow would occur. An example of a typical roughness classification within the model domain is depicted in Figure 4-4.

Table 4-4 Manning’s ‘n’ adopted in TUFLOW

Manning’s ‘n’ (Depth Layer 1 (m), Manning’s n Layer 1, Depth Layer 2 (m), Manning’s n Layer 2)	Land Cover
0.1, 0.1, 0.2, 0.035	Mostly clear alluvial areas
0.1, 0.1, 0.2, 0.04	Typical Pilbara hillslopes w/tussock
0.1, 0.1, 0.2, 0.05	Low density vegetation
0.1, 0.1, 0.2, 0.06	Medium density riparian vegetation
0.1, 0.1, 0.2, 0.08	High density riparian vegetation

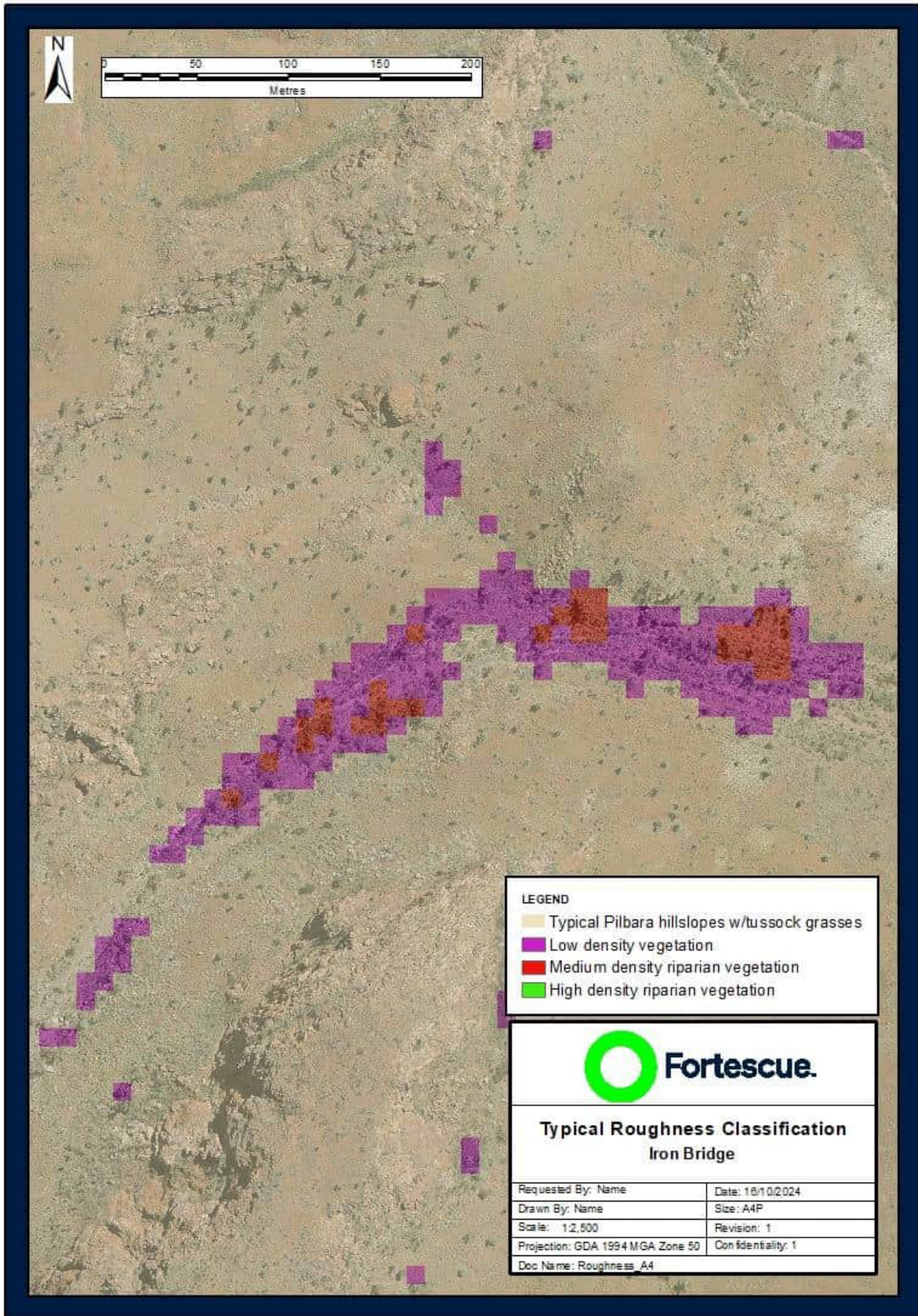


Figure 4-4 Example of a roughness classification

4.3 Sensitivity Analysis

4.3.1 Hydraulic Roughness

A sensitivity analysis of hydraulic roughness was undertaken to quantify the effects on flood characteristics due to uncertainty in the model Manning's 'n' parameters. The high variability of annual rainfall experienced in the region and the seasonality in rainfall patterns cause both seasonal and annual variance in catchment vegetation density. Vegetation density is a key driver of surface roughness and thus influences flood behaviour.

The sensitivity analysis was undertaken using both a 25% increase and decrease in the design Manning's 'n' values (the upper depth value for depth-varying roughness) specified in Section 4.2.4. These increased and decreased roughness parameters provide a comprehensive estimate of the possible range of peak flows and flood depths experienced by the catchment.

Adopted Manning's 'n' values used in the sensitivity analysis are presented in Table 4-5.

Table 4-5: Adopted hydraulic roughness and sensitivity analysis values

Description	Adopted Manning's 'n' Design Value	Manning's 'n' Sensitivity Values (+ / - 25%)
Mostly clear alluvial areas	0.035	0.04375 / 0.02625
Typical Pilbara hillslopes w/tussock	0.04	0.05 / 0.03
Low density vegetation	0.05	0.0625 / 0.0375
Medium density riparian vegetation	0.06	0.075 / 0.045
High density riparian vegetation	0.08	0.1 / 0.06

Results from the hydraulic roughness sensitivity analysis are presented in Section 6.1.3.1.

4.3.2 Climate Change

An assessment of model sensitivity to climate change impacted design rainfall has been undertaken in accordance with ARR2019 Book 1 Interim Climate Change Guidance. Based on the estimated project lifespan, a 2050 climate/design horizon was adopted. The use of Representative Concentration Pathways (RCP) 4.5 and 8.5 predictions were used as the basis for climate projection for the 2050 design horizon. RCPs represent potential future pathways for greenhouse gas concentrations in the atmosphere for a broad range of climate outcomes.

"The RCPs are designated as 2.6, 4.5, 6.0 and 8.5, and are named according to radiative forcing values ($W m^{-2}$) in the year 2100 relative to pre-industrial levels. Use of RCPs 4.5 and 8.5 (low and high concentrations, respectively) is recommended for impact assessment." (Ball et al., 2019)

In accordance with ARR2019 guidelines, and to remain consistent with the original assessment undertaken for the baseline study of North Star Stage 2 Mining Proposal Revision 4 (Registration ID: 118381), RCPs 4.5 and 8.5 were used for this assessment. Estimated changes to the BoM design rainfall depths based on the 2050 design horizon are presented in Table 4-6.

Table 4-6: Adopted design rainfall factors for climate change assessment

Design Horizon (Year)	RCP 4.5	RCP 8.5
2050	7.7%	10.3%

These increased rainfall depths were simulated in the hydraulic model to determine the impacts of 2050 future climate scenarios on flood flow, depth and velocity estimates.

Results for the climate change sensitivity assessment are presented in Section 0.

5 VOLUMETRIC ASSESSMENT

A desktop assessment was completed to quantify the volume of runoff at specific reporting locations within the Study Area. These reporting locations are illustrated in Figure 5-1. The runoff generated by a catchment is a mass balance exercise as the key variables in determining runoff volume are rainfall excess and catchment area. While the effect of micro storage cannot be fully reflected in the desktop assessment, the IL parameter adopted to calculate rainfall excess would have considered the effect of storage from the uneven topography. In addition, the impact of this feature would be reflected in both the Baseline and NSE scenarios. For both the Baseline and NSE operational scenarios, the loss parameters discussed in Section 4.2.4.7 was adopted for the volumetric assessment.

The volumetric assessment has also been completed for the closure scenarios — Baseline and NSE. For closure, the top lift of the WRD is designed to direct runoff towards Site 12 Pool via a discharge point. The locations of the discharge points are shown in Figure 5-2. Since the WRD is a man-made structure, the infiltration capacity is different to that of a natural undisturbed catchment. Based on infiltration testing conducted in 2018, the material used to construct the WRD has an estimated steady state infiltration rate of 18.8 mm/hr. The details of the WRD infiltration assessment is provided in Appendix C.

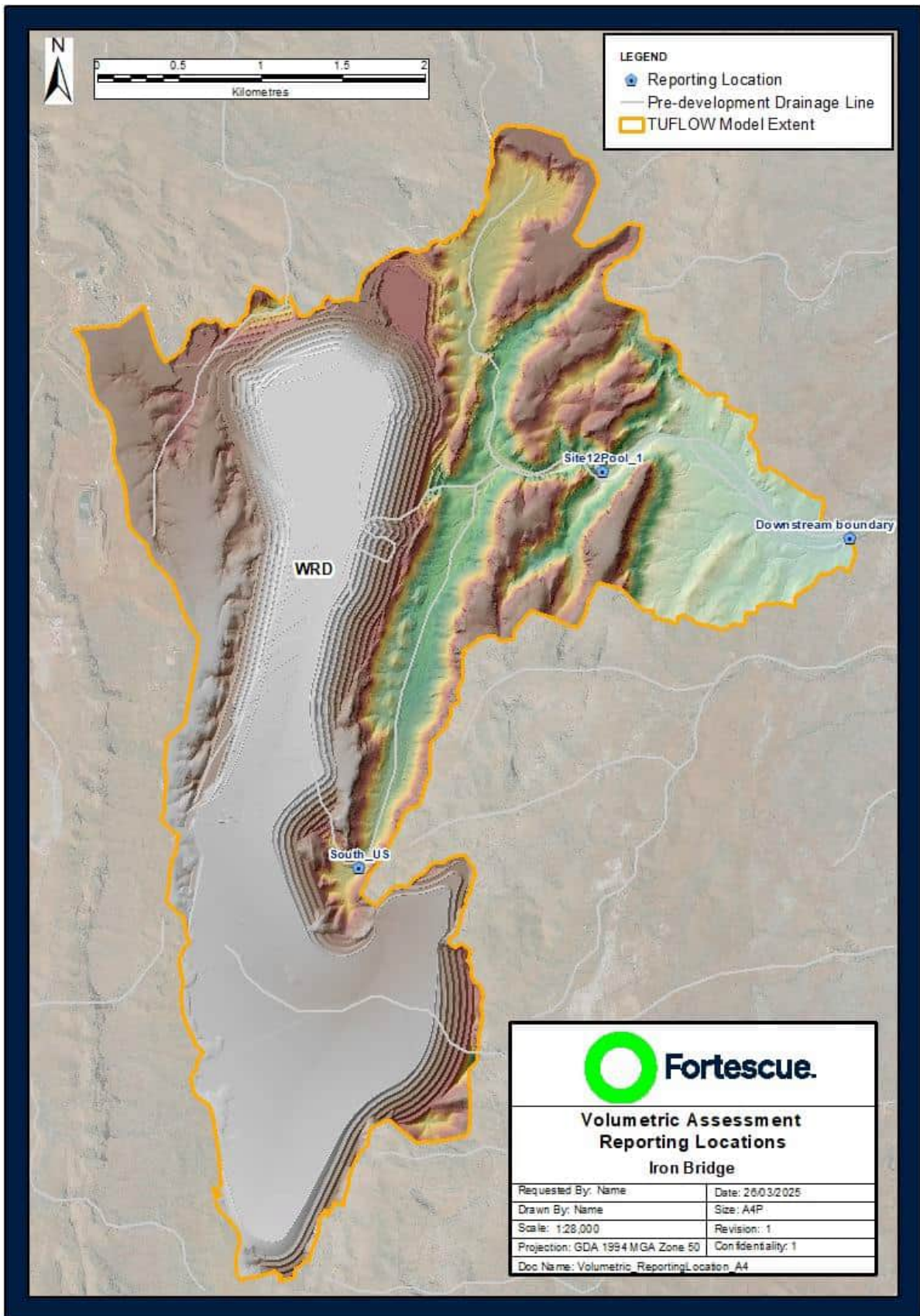


Figure 5-1 Volumetric assessment reporting locations
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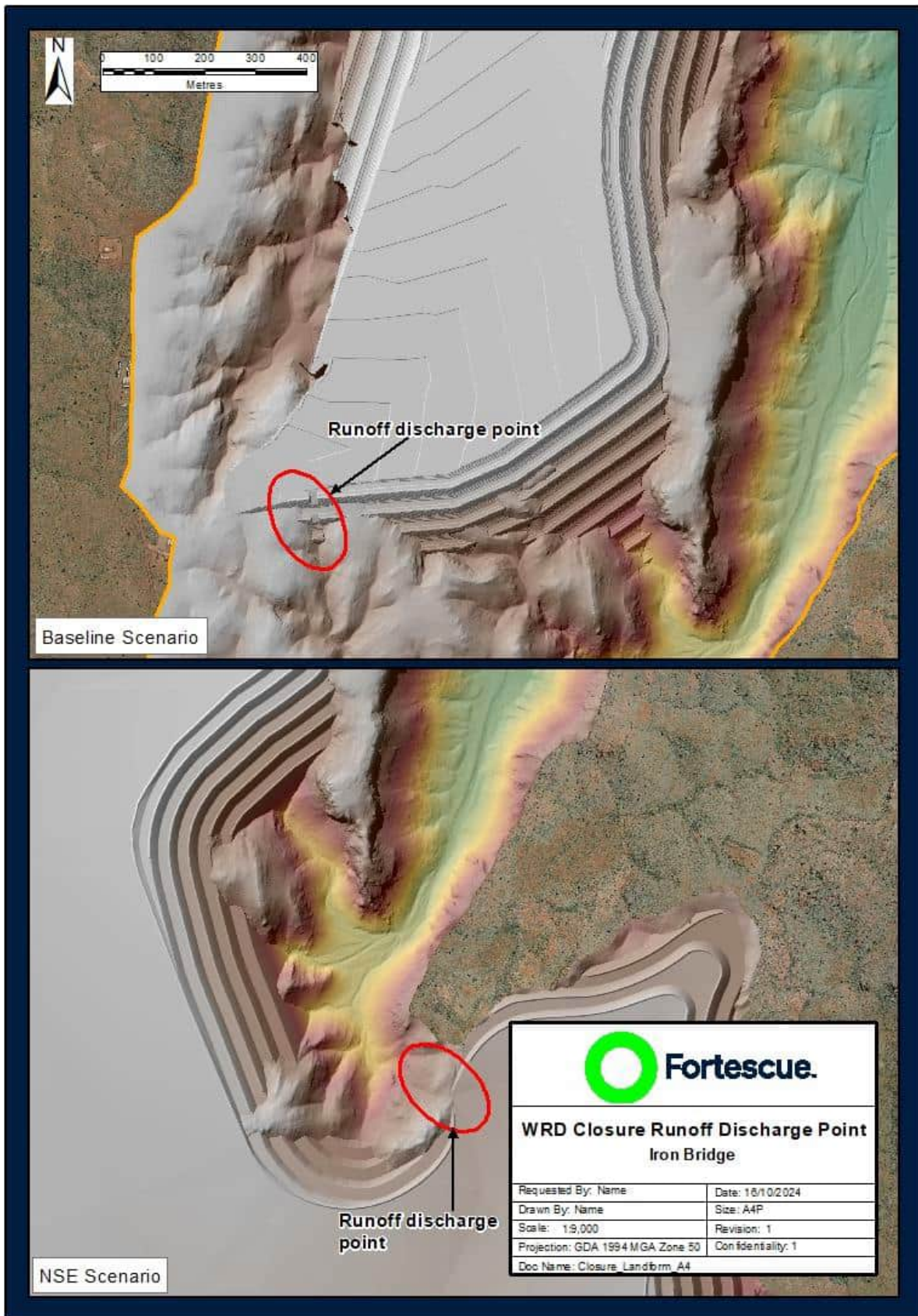


Figure 5-2 WRD runoff discharge point at closure

6 RESULTS

The results from the hydraulic model and the volumetric assessment are discussed in this section of the report. The upper median peak flow from the ensemble temporal patterns were selected as the representative design flow for a particular storm duration. The upper median peak flow for each duration were then compared and the maximum is selected as the critical duration flow. The data presented in this section is the critical duration flow at each reporting location as shown in Figure 6-2 and Figure 6-4. The hydrological regime of Site 12 Pool is not within the scope of this study, it is assessed as part of the *North Star Magnetite Project Extension — Inland Waters: Pool Hydrological and Water Quality Assessment* (Worley, 2025).

6.1 Baseline Scenario

6.1.1 Hydraulic Modelling Results

Figure 6-2 shows the DEM adopted for the Baseline scenario and the reporting locations. In the Baseline Scenario, most of the catchment to the east of the TUFLOW model domain is replaced by the WRD footprint. During operation, the WRD structure is expected to retain incidental rainfall and no runoff is expected from the WRD to Site 12 Pool. The tributary at South_US and North are partially impacted by the WRD footprint in the Baseline scenario.

The peak flows and critical durations for the Baseline scenario is summarised in Table 6-1 and Table 6-2 respectively. The results shows that the southern tributary contributes more flow to Site 12 Pool than the northern undisturbed catchment. The critical duration ranges between 15 minutes to 120 minutes. In general, the more frequent events have a longer critical duration. The primary driver of this is because longer duration is needed for frequent events to satisfy the initial loss (20 mm) before runoff can be produced. In addition, the larger contributing catchment has a longer critical duration. Reporting location Site12Pool_3 has the longest critical duration as it is located furthest downstream.

Figure 6-1 shows the variation in peak flows at reporting location Site12Pool_3 (downstream of Site 12 Pool) based on durations and temporal patterns. The box plot shows that peak flow variation between temporal patterns is larger for more extreme events, especially in the longer duration storms. There is minimal variation in peak flows between temporal patterns for very short duration events because the catchment runoff response is dominated by the high initial loss values.

Table 6-1 Peak flow for Baseline scenario

Design Event (AEP)	Peak Flow (m ³ /s)			
	North	South	South_US	Site12Pool_3
50%	7.3	9.4	5.7	17.8
20%	16.6	19.4	11.7	37.9
10%	22.1	25.4	14.0	53.1
5%	28.9	32.7	18.7	69.6
2%	37.7	46.5	23.5	89.6
1%	44.9	55.0	28.7	111.1

1 in 200	54.2	65.5	36.4	132.8
1 in 500	68.5	87.2	43.6	163.6
1 in 1000	78.7	102.7	55.8	190.9
1 in 2000	91.0	117.8	65.0	216.9
PMPF	259.1	363.5	222.0	724.5
PMF	260.8	364.7	222.6	728.2

Table 6-2 Critical duration for Baseline scenario

Design Event (AEP)	Critical Duration (minutes)			
	North	South	South_US	Site12Pool_3
50%	90	90	60	120
20%	60	60	60	90
10%	60	60	45	90
5%	45	45	30	90
2%	45	45	30	45
1%	45	45	30	45
1 in 200	30	30	30	45
1 in 500	30	30	30	45
1 in 1000	30	30	15	45
1 in 2000	30	30	15	45
PMPF	60	30	15	60
PMF	60	30	15	60

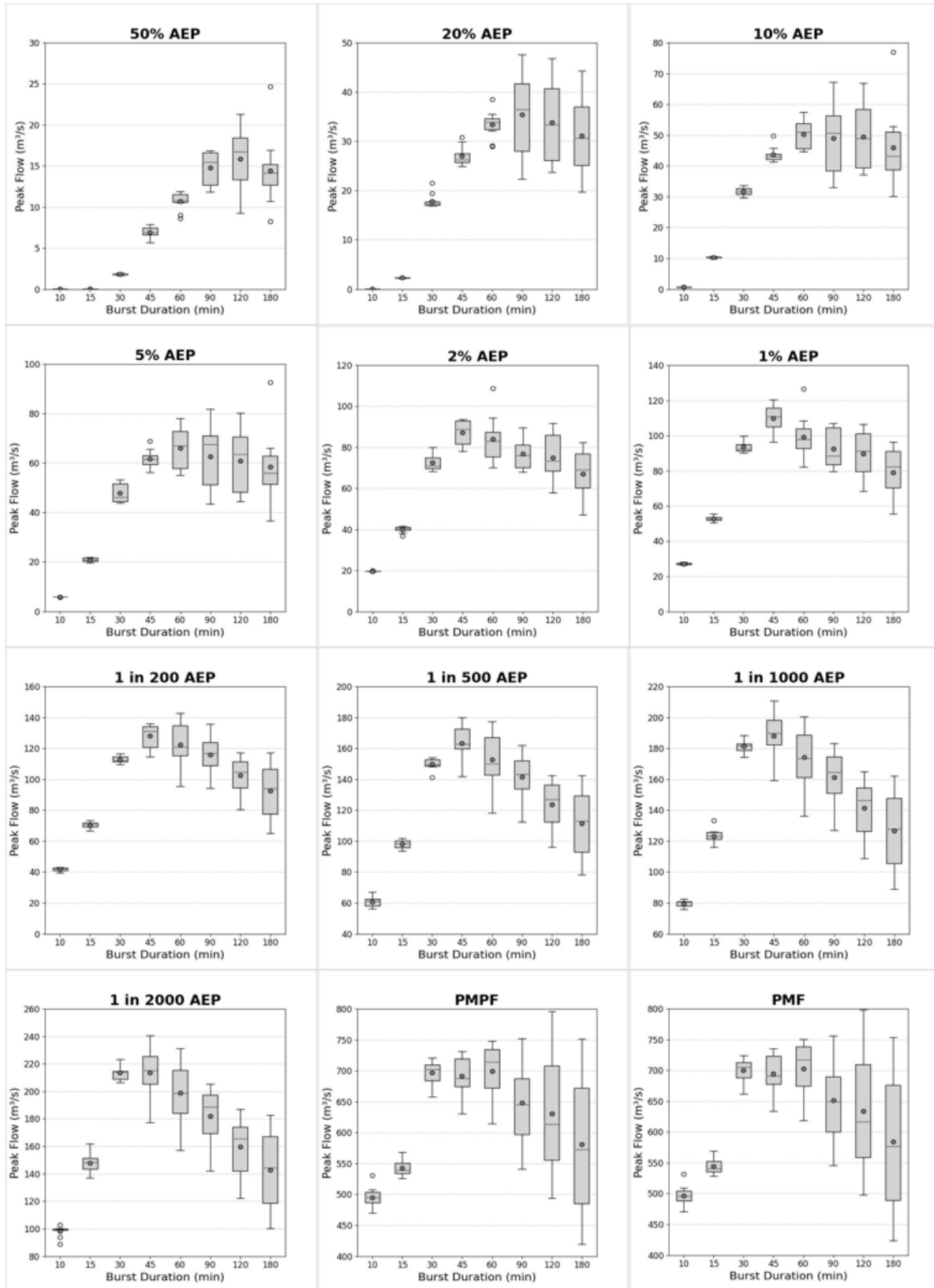


Figure 6-1 Box plots of the peak flows at reporting location Site12Pool_3 for the Baseline scenario

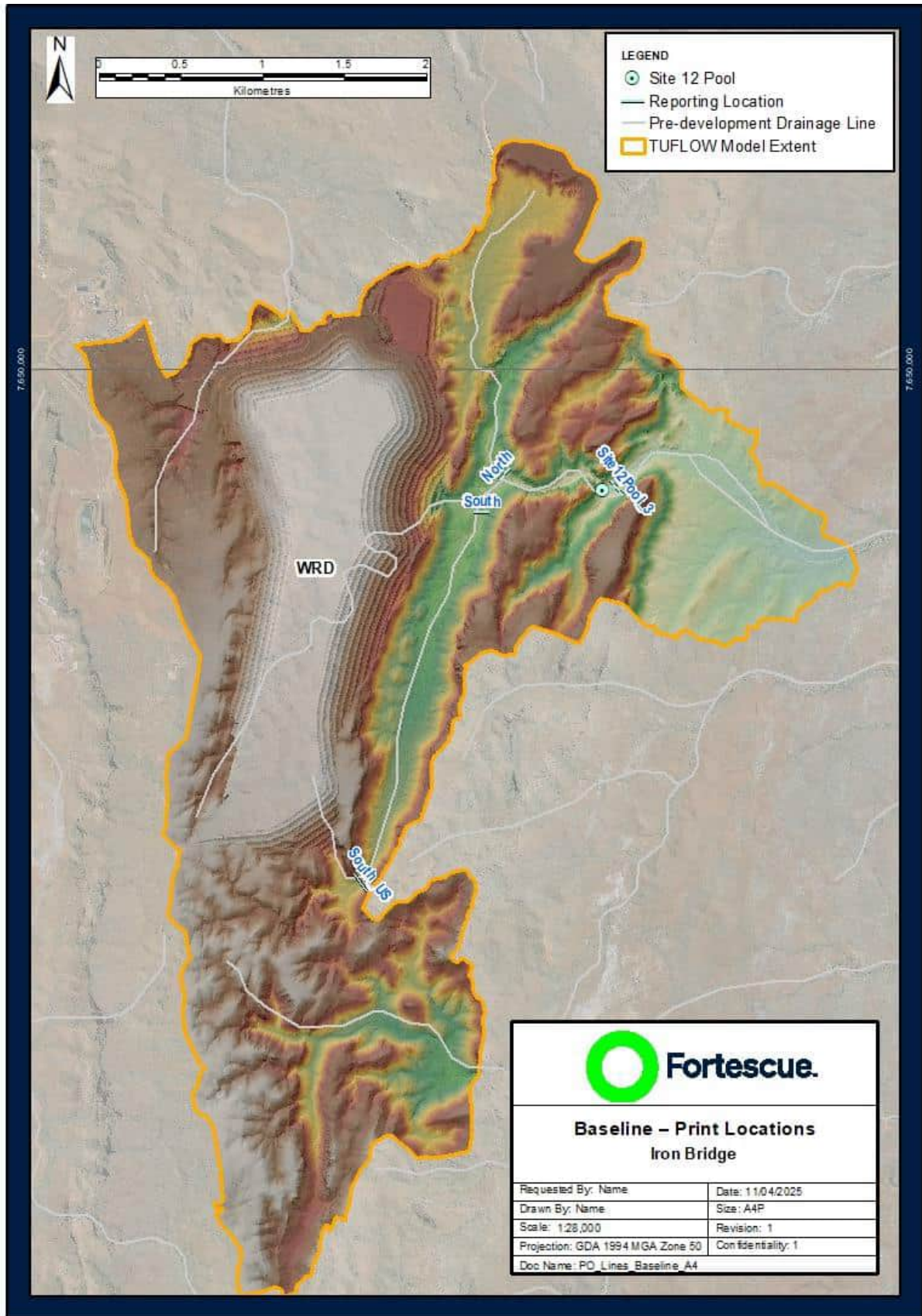


Figure 6-2 reporting location in the Baseline Scenario
 Site 12 Pool Catchment Waterways Hydrological Assessment

6.1.2 Catchment Runoff Volume

Runoff volume is estimated at three locations within the Study Area as shown in Figure 5-1. The contributing catchment areas of the reporting locations are calculated based on the assumption that all runoff from the WRD will be contained within the berms during operation. Hence, the effective contributing catchment of the reporting locations are summarised in Table 6-3.

Table 6-3: Runoff volume catchment areas - Baseline scenario

Reporting Location	Contributing Catchment Area (km ²)
South_US	0.7
Site 12 Pool_1	3.7
Downstream Boundary	6.1

The peak runoff volume for the Baseline scenario is documented in Table 6-4. The critical durations that produce maximum volume are considerably longer (greater than 12 hours) than the critical durations that produces peak flow. For more frequent events, the peak volume critical durations tend to be longer than the rarer events to overcome the large IL (20 mm) threshold. Runoff volume is also proportional to the size of the contributing catchment area. This is evident as the Downstream Boundary reporting location recorded the largest runoff volume due to its largest contributing catchment area.

Table 6-4: Baseline scenario catchment runoff volume estimates and the corresponding critical storm duration

Reporting Location	Runoff Volume (ML)					
	50% AEP (Critical Duration)	20% AEP (Critical Duration)	10% AEP (Critical Duration)	5% AEP (Critical Duration)	2% AEP (Critical Duration)	1% AEP (Critical Duration)
South_US	18 (168 hour)	50 (168 hour)	72 (72 hour)	100 (72 hour)	132 (36 hour)	165 (36 hour)
Site 12 Pool_1	92 (168 hour)	265 (168 hour)	371 (72 hour)	522 (72 hour)	693 (36 hour)	865 (36 hour)
Downstream Boundary	153 (168 hour)	438 (168 hour)	609 (72 hour)	862 (72 hour)	1142 (36 hour)	1425 (36 hour)

6.1.3 Sensitivity Analysis

6.1.3.1 Hydraulic roughness

The complete ensemble of storms for the 1% AEP flood event were simulated with increased (+25%) and decreased (-25%) hydraulic roughness parameters as detailed in Section 4.3.1. Impacts of the increased and decreased hydraulic roughness on peak flows have been extracted from the TUFLOW models and are presented in Table 6-5. Impacts to peak flood depth are presented in afflux GIS mapping in Appendix G.

Table 6-5: Hydraulic roughness sensitivity test results - peak flow

Reporting Location ID	Peak Flow (m ³ /s)		
	1% AEP (Baseline)	+ 25% Roughness (% Change)	- 25% Roughness (% Change)
North	45	42 (-7%)	50 (+11%)
South	55	53 (-4%)	60 (+9%)
Site12Pool_1	99	91 (-8%)	107 (+8%)
Site12Pool_2	25	23 (-8%)	26 (+4%)
Site12Pool_3	112	99 (-12%)	122 (+9%)
South_US	29	27 (-7%)	34 (+17%)
North_US_1	29	25 (-14%)	30 (+3%)
North_US_2	23	22 (-4%)	23 (~0%)
North_US3	2	2 (~0%)	2.1 (+5%)

The usage of increased Manning's 'n' roughness parameters by 25% saw minor reductions in peak flow across the reporting locations. Reductions in peak flow ranged from 5 – 15% from baseline conditions. Throughout the Site 12 Pool catchment, peak flood depths typically increased by 50 – 100 mm. At the Site 12 Pool location itself, peak depths increased by 100 – 150 mm.

The adoption of 25% reduced Manning's 'n' values resulted in minor increases in peak flow across the reporting locations, ranging from an additional 3 – 17% flow. Conversely, peak flood depths generally reduced throughout the catchment by 30 – 150 mm. At the Site 12 Pool, peak flood depths reduced by 150 – 200 mm compared to the baseline conditions.

These results indicate a 350 mm range of uncertainty in 1% AEP peak flood depth resulting from credible natural variation in catchment vegetation density. Climate Change

Two future climate scenarios for the year 2050 were simulated in the TUFLOW model using the estimated increases to design rainfall depths detailed in Section 4.3.2. The full ensemble of storm durations and temporal patterns were simulated for the 1% AEP event. Peak flows at key reporting locations were extracted to quantify model sensitivity to the two climate change

scenarios. Peak flow results at each reporting location are presented in Table 6-6. Impacts to peak flood depths are presented in afflux GIS mapping in Appendix G.

Table 6-6: 2050 Design horizon climate change sensitivity test results - peak flow

Reporting Location ID	Peak Flow (m ³ /s)		
	1% AEP (Baseline)	1% AEP 2050 RCP4.5 (% Change)	1% AEP 2050 RCP8.5 (% Change)
North	45	50 (+11%)	51 (13%)
South	55	62 (+13%)	63 (15%)
Site12Pool_1	99	110 (+11%)	114 (15%)
Site12Pool_2	25	28 (+12%)	29 (16%)
Site12Pool_3	112	124 (+11%)	128 (14%)
South_US	29	34 (+17%)	36 (24%)
North_US_1	29	31 (+7%)	32 (10%)
North_US_2	23	25 (+9%)	26 (13%)
North_US3	2	2.3 (15%)	2.4 (20%)

The sensitivity test results indicate that peak flows for the 1% AEP event are likely to increase by 7 – 17% by 2050 in the RCP 4.5 scenario and 10 – 24 % in the RCP 8.5 scenario. At the Site 12 Pool, peak flood depths increased by up to 130 mm in the RCP 4.5 scenario and 150 mm in the RCP 8.5 scenario.

6.2 NSE Scenario

6.2.1 Hydraulic Modelling Results

In the NSE scenario, the proposed WRD footprint has expanded to the south and would reduce the catchment area contributing to Site 12 Pool by 0.5 km². During operations, the WRD is design to retain incidental rainfall, and will not contribute flow to Site 12 Pool.

The peak flow and critical duration of the design events assessed for the NSE scenario is summarised in Table 6-7 and

Table 6-8. The contribution of flow to Site 12 Pool is similar between the northern and southern tributaries. In general, the critical duration is shorter for rarer events.

Figure 6-3 illustrates the variation in peak flow at reporting location Site12Pool_3 caused by temporal patterns and storm durations. Similar to the Baseline scenario, there is minimal variation in peak flows between temporal patterns for short duration storm as the catchment runoff response is dominated by the effect of a high IL.

Table 6-7 Peak flow for NSE scenario

Design Event (AEP)	Peak Flow (m ³ /s)			
	North	South	South_US	Site12Pool_3
50%	7.3	6.8	1.5	16.3
20%	16.6	14.8	2.9	34.5
10%	22.1	19.4	3.7	50.5
5%	28.9	25.4	5.6	65.0
2%	37.7	33.6	7.4	83.0
1%	44.9	40.5	8.4	100.8
1 in 200	54.2	50.1	10.0	118.5
1 in 500	68.5	64.3	14.1	150.9
1 in 1000	78.7	74.8	16.5	173.8
1 in 2000	91.0	84.1	19.3	201.7
PMPF	253.2	269.4	54.2	651.5
PMF	253.7	270.6	54.4	654.2

Table 6-8 Critical duration for NSE Scenario

Design Event (AEP)	Critical Duration (minutes)			
	North	South	South_US	Site12Pool_3
50%	90	90	60	120
20%	60	60	60	90
10%	60	60	45	60
5%	45	45	30	60
2%	45	45	15	45
1%	45	30	15	45
1 in 200	30	30	30	45
1 in 500	30	30	15	45
1 in 1000	30	30	15	30
1 in 2000	30	30	15	30
PMPF	60	30	30	15
PMF	60	30	30	15

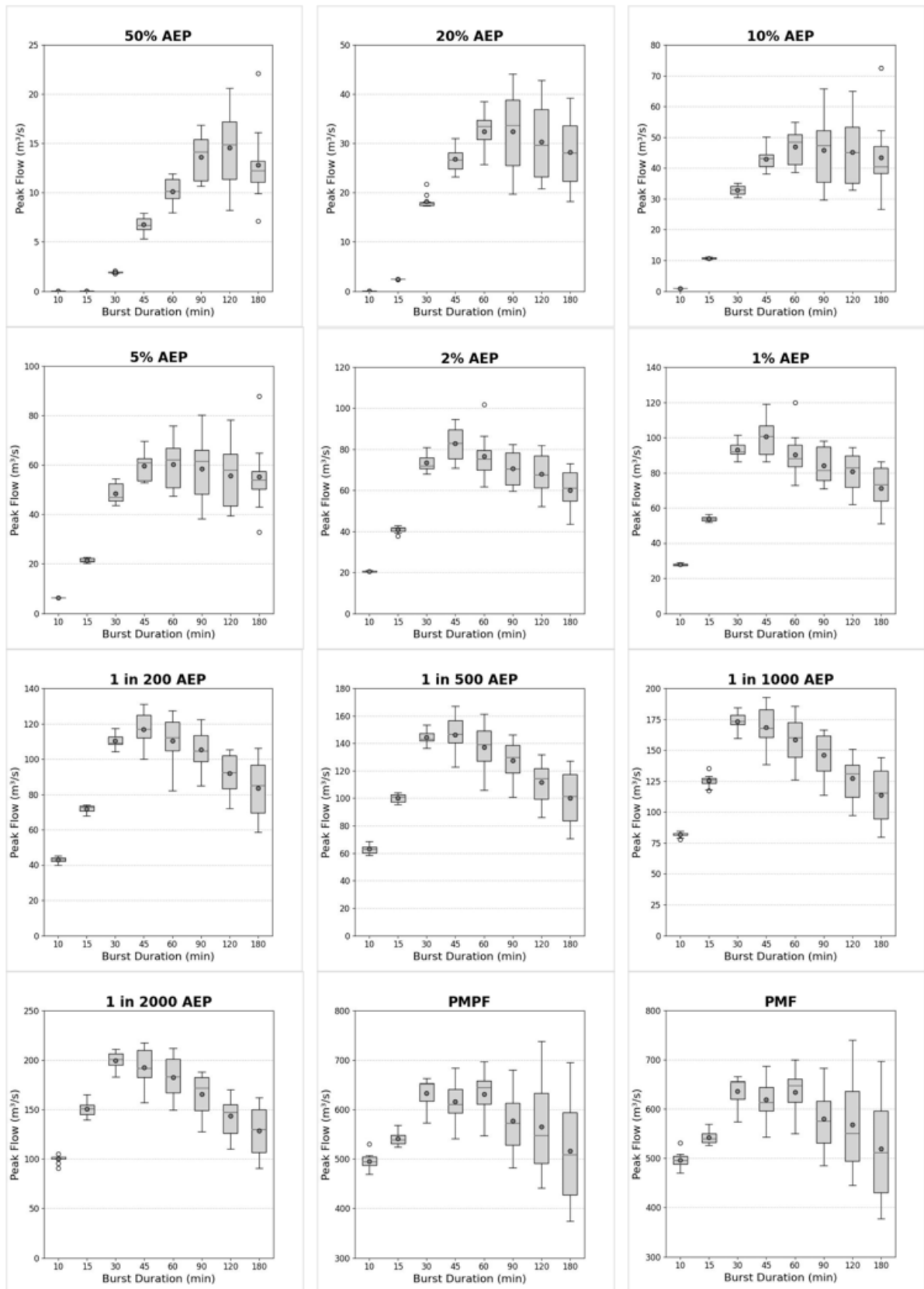


Figure 6-3 Box plots of the peak flows at reporting location Site12Pool_3 for the NSE scenario

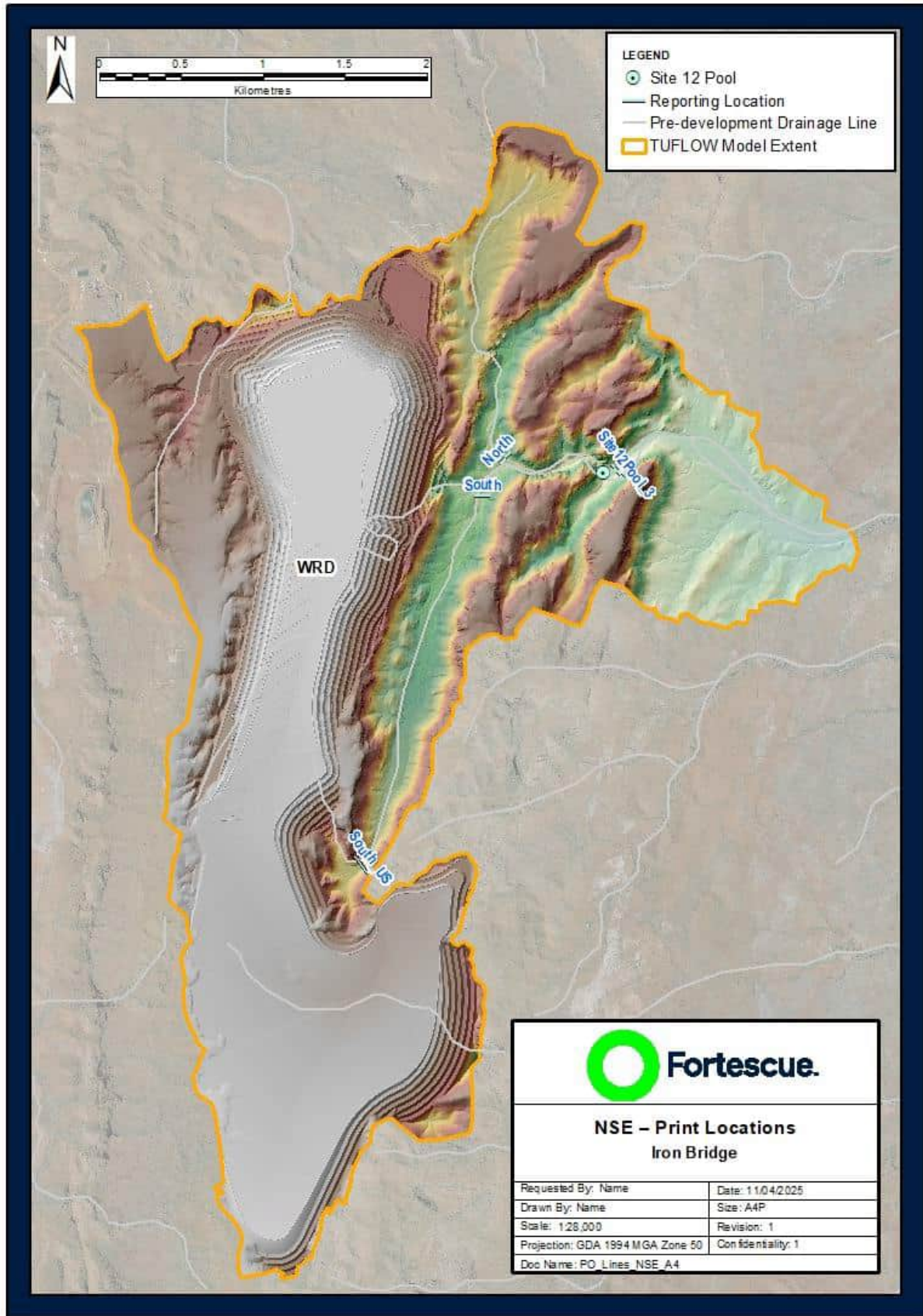


Figure 6-4 Reporting location in NSE Scenario

Site 12 Pool Catchment Waterways Hydrological Assessment

NS-5700-RP-WM-0003

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6.2.2 Catchment Runoff Volume

Runoff volume is estimated at three locations within the Study Area as shown in Figure 5-1. The contributing catchment areas to the reporting locations have reduced compared to the Baseline scenario due to the expansion of the proposed WRD. The size of the contributing catchment areas is summarised in Table 6-9.

Table 6-9: Runoff volume catchment areas - NSE scenario

Catchment ID	NSE Catchment Area (km ²)
South_US	0.2
Site 12 Pool_1	3.1
Downstream	5.6

The runoff volume estimated at the reporting locations for the NSE scenario is tabulated in Table 6-10. The magnitude of the runoff volume is greater for reporting locations that have a larger contributing catchment area. The reporting locations have the same critical storm duration for each assessed AEP and the general trend is that the rarer design events has a shorter critical storm duration.

Table 6-10: NSE scenario catchment runoff volume estimates and the corresponding critical storm duration

Reporting ID	Runoff Volume (ML)					
	50% AEP (Critical Duration)	20% AEP (Critical Duration)	10% AEP (Critical Duration)	5% AEP (Critical Duration)	2% AEP (Critical Duration)	1% AEP (Critical Duration)
South_US	4 (168 hour)	12 (168 hour)	17 (72 hour)	23 (72 hour)	31 (36 hour)	39 (36 hour)
Site 12 Pool_1	79 (168 hour)	227 (168 hour)	318 (72 hour)	447 (72 hour)	592 (36 hour)	740 (36 hour)
Downstream	139 (168 hour)	400 (168 hour)	556 (72 hour)	786 (72 hour)	1042 (36 hour)	1301 (36 hour)

6.3 Closure Scenarios

The WRD for the approved NS and proposed NSE is designed to direct runoff from the top lift of the dump into Site 12 Pool catchment. The top lift of the dump for Baseline and NSE scenarios are 1.2 km² and 3.8 km² respectively. The estimated volume of runoff from the WRD to Site 12 Pool catchment is summarised in Table 6-11.

Due to the high CL (18.8 mm/hr) adopted for the WRD, a high intensity storm is required to create rainfall excess. These types of storms typically have a shorter duration with an intense burst. As a result, the critical storm duration to produce runoff from the WRD is shorter than that of an undisturbed catchment.

Table 6-11 Runoff volumes from the top lift of WRD

Scenario	Runoff Volume (ML)					
	50% AEP (Critical Duration)	20% AEP (Critical Duration)	10% AEP (Critical Duration)	5% AEP (Critical Duration)	2% AEP (Critical Duration)	1% AEP (Critical Duration)
Baseline	18 (30 minutes)	33 (1 hour)	44 (1 hour)	59 (3 hour)	77 (1.5 hour)	98 (9 hour)
NSE	60 (30 minutes)	108 (1 hour)	143 (1 hour)	193 (3 hour)	253 (1.5 hour)	323 (4.5 hour)

The volume of Site 12 Pool has been estimated to be approximately 2.4 ML (Worley, 2025). The most frequent design event analysed in this study is the 50% AEP event, where the estimated runoff volume from the WRD for both approved NS and proposed NSE scenarios would be able to fill Site 12 Pool.

7 IMPACT ASSESSMENT

The expansion of the WRD would reduce the contributing catchment to Site 12 Pool by approximately 15% between Baseline and NSE scenario. The changes in peak flow caused by the expansion of the WRD in NSE is summarised in Table 7-1. There is minimal change in peak flow at the reporting location North for the frequent to very rare design events assessed. Minor changes in peak flow are predicted at the North reporting location for the extreme events (PMPF and PMF).

For the southern tributary, a catchment reduction of 0.5 km² is expected due to the proposed expansion of the WRD. Peak flow reduction is the most apparent at South_US, ranging between 68% to 76% as it is immediately downstream of the WRD. The reporting location South observes a reduction in peak flow between 22% and 28%. The effect of catchment reduction on peak flow reduces as the reporting location is further away from the WRD. Peak flow reduction is predicted to be approximately 10% immediately downstream of Site 12 Pool (Site12Pool_3).

Table 7-1 Changes in peak flow between Baseline and NSE scenarios

Design Event (AEP)	Change in Peak Flow			
	North	South	South_US	Site12Pool_3
50%	0%	-28%	-74%	-8%
20%	0%	-24%	-75%	-9%
10%	0%	-24%	-74%	-5%
5%	0%	-22%	-70%	-7%
2%	0%	-28%	-69%	-7%
1%	0%	-26%	-71%	-9%
1 in 200	0%	-24%	-73%	-11%
1 in 500	0%	-26%	-68%	-8%
1 in 1000	0%	-27%	-70%	-9%
1 in 2000	0%	-29%	-70%	-7%
PMPF	-2%	-26%	-76%	-10%
PMF	-3%	-26%	-76%	-10%

The change in flood depth for the design events assessed are presented in Appendix F. In general, the largest change in flood depth is expected on the southern tributary, downstream of the NSE WRD (within the vicinity of reporting location South_US) where the tributary will be removed due to expansion of the WRD. The largest peak flood depth in that tributary for the 50% AEP event is approximately 1.5 m and will be completely removed in the NSE scenario. Similarly for the 1% AEP event, the greatest reduction in flood depth is estimated to be at the tributary that will be replaced by the WRD. The largest estimated afflux at this tributary is approximately 2 m.

For the floodplain around Site 12 Pool, the modelling results suggest that a reduction in flood depth of less than 0.1 m (from a maximum peak flood of depth of approximately 1.1 m in the Baseline scenario) for the 50% AEP design event. For the 1% AEP, a maximum reduction of

approximately 0.2 m is estimated (from a maximum peak flood of depth of approximately 3.7 m in the Baseline scenario).

The proposed NSE development would reduce runoff volume at South_US, Site12Pool_1 and Downstream Boundary by 77%, 14% and 9% respectively across all AEPs. The proportion of volume reduction is proportional to catchment reduction. South_US is expected to have the largest reduction in flow volume as the contributing catchment to this reporting would experience the largest reduction due to the expansion of the WRD.

8 CONCLUSION

This report presents the waterways assessment of the contributing catchment to Site 12 Pool under Baseline and NSE conditions. The assessment includes characterising the catchment conditions prior to and post NSE developments. An impact assessment was completed to quantify the change in hydrological regime of the waterways from the proposed NSE development. The assessment methodology adopted in this study is in line with ARR2019 (Ball, et al., 2019) which is similar to the approach used in *North Star Magnetite Project Extension — Baseline Hydrology Report* (Worley, 2024 (a)) and *North Star Magnetite Project Extension — Hydrological Impact Assessment Report: Waterways* (Worley, 2024 (b)) .

The Study Area is located at the top of the Strelley River catchment which consist of steep, well defined flow paths merging into a single drainage pathway towards Site 12 Pool. A WRD occupies the ridge of the catchment which is expected to expand as part of the NSE development. The expanded WRD would reduce the contributing catchment area to Site 12 Pool by approximately 0.5 km² (14%) compared to Baseline.

The catchment's flood response under Baseline conditions consists of two tributaries, a northern and southern tributary, flowing towards Site 12 Pool. The WRD expansion is expected to replace the upper catchment of the southern tributary, reducing overall flow towards Site 12 Pool. The impact assessment illustrates that in the 50% AEP event, an 8% reduction in peak flow is expected at the reporting location downstream of Site 12 Pool and a 14% volume reduction is predicted at Site 12 Pool. The floodplain around Site 12 Pool would experience a reduction in flood depth of approximately 9% and 5% for the 50% and 1% AEP events respectively.

Volumetric assessment is completed for the Closure scenario because the top lift of WRD have been designed to direct runoff towards Site 12 Pool. Due to high CL of the WRD material, runoff producing events are favoured towards shorter events with high rainfall intensity. The estimated runoff from the 50% AEP event is sufficient to fill up Site 12 Pool. Runoff from the WRD post closure would increase flow volume to Site 12 Pool compared during operational phase of mining.

9 REFERENCES

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- Jordan, P., Nathan, R., Mittiga, L., & Taylor, B. (2005). Growth curves and temporal patterns of short duration design storms for extreme events. *Australian Journal of Water Resources*, 9(1), 69-80.
- Worley. (2024 (a)). *North Star Magnetite Project Extension — Baseline Hydrology Report*.
- Worley. (2024 (b)). *North Star Magnetite Project Extension — Hydrological Impact Assessment Report: Waterways*.
- Worley. (2025). *North Star Magnetite Project Extension — Inland Waters: Pool Hydrological and Water Quality Assessment*.

DOCUMENT CONTROL

Site 12 Pool Catchment Waterways Hydrological Assessment		
Status	IFR - Issued for Review	16-Apr-25
Summary of Changes	Insert summary of changes IF updating to new revision e.g. Rev 1, 2 etc.	
Author	Hui Min Lee	_____ Signature
Checked or Squad Review# (if applicable)	Insert First Name Surname here OR FMG-SQ#	_____ Signature
Approved	Ying Yu	_____ Signature
Next Review Date (if applicable)	Enter a date	

APPENDIX A DESIGN RAINFALL DEPTH



Duration	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	1 in 200 AEP	1 in 500 AEP	1 in 1000 AEP	1 in 2000 AEP	PMP
10 min	14	20.1	24.4	28.8	34.7	39.2	44.9	53.5	60.5	68	184
15 min	18	25.9	31.4	37	44.5	50.3	57.6	68.7	77.6	87.2	220
30 min	25.3	36.2	43.9	51.5	61.7	69.7	79.7	94.8	107	120	326
45 min	29.6	42.3	51.2	60	72	81.4	93.1	111	125	140	414
1 hours	32.6	46.8	56.6	66.4	79.7	90.4	103	123	138	155	488
1.5 hours	36.9	53.4	64.8	76.3	92	105	120	142	160	179	622
2 hours	40.2	58.5	71.4	84.4	102	117	134	159	179	201	728
3 hours	45.1	66.8	82.3	98	120	138	158	188	212	238	878
4.5 hours	50.8	76.8	95.6	115	142	165	189	225	255	287	1054
6 hours	55.4	85	107	130	162	188	216	258	292	329	1174



APPENDIX B PMP DEPTH CALCULATION

GSDM calculation sheet

User Input

Catchment Area	10.1 km ²
Zone	Coastal
Limits	1000 km ² 6hrs
Roughness	1
EAF	1
MAF	1.05

Select catchment area

Select rainfall zone (generally coastal for the Pilbara)

Note limits of calculation

Roughness factor (generally smooth for the Pilbara). Smooth = 0, Rough = 1

Elevation Adjustment Factor <1500m = 1, >1500m reduce by 0.05 for every 300m over 1500m

Moisture Adj.

Smooth curves lookup table used to populate values

0.25	0.50	0.75	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0
209	311	394	464	529	593	631	663	727	784	831

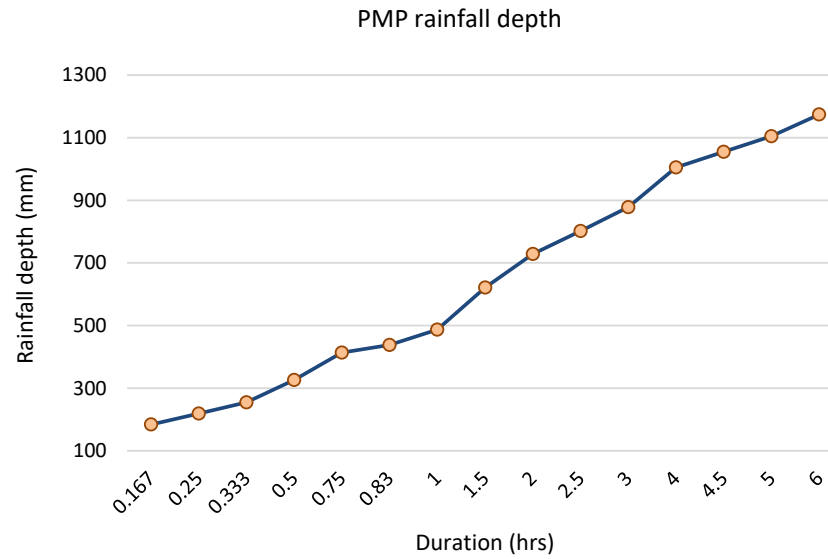
Rough curves lookup table used to populate values

0.25hr	0.5hr	0.75hr	1hr	1.5hr	2hr	2.5hr	3hr	4hr	5hr	6hr
209	311	394	464	592	694	764	836	957	1052	1118

Preliminary PMP Depth

0.25	0.50	0.75	1.0	1.5	2.0	2.5	3.0	4.0	5.0	6.0
219	327	414	487	622	729	802	878	1005	1105	1174

Duration (hrs)	Rainfall depth (mm)	Rainfall intensity (mm/hr)
0.167	184	1102.5
0.25	219	877.8
0.333	255	765.5
0.5	327	653.1
0.75	414	551.6
0.83	438	525.8
1	487	487.2
1.5	622	414.4
2	729	364.4
2.5	802	320.9
3	878	292.6
4	1005	251.2
4.5	1054.7	234.4
5	1105	220.9
6	1174	195.7





APPENDIX C WRD INFILTRATION TEST

Brett Stinton

From: Evan Howard <howarde@landloch.com.au>
Sent: Friday, 7 December 2018 8:39 AM
To: David Westwater; Justin Dixon
Subject: RE: Ironbridge Testing

Hi Dave,

For the data below, the steady rate is the final figures in the table: 24.7mm/hr and 12.9mm/hr. For modelling I suggest running them both or averaging the two.

The value is calculated from data collected from application of simulated rain. Rainfall is applied as a steady and known rate and runoff is measured at regular intervals. Infiltration is the difference between steady rain and the measured runoff. The steady rainfall rate is that value listed at time=0 minutes (101.81mm/hr for Plot 2 and 110.61mm/hr for Plot 3). These rainfall rates are calibrated against physical measures of rain from rain gauges positioned at the edges of the test plots (average of 4 measures).

Regards
Evan

From: David Westwater <dwestwater@fmgl.com.au>
Sent: Friday, December 7, 2018 7:08 AM
To: Justin Dixon <jdixon@fmgl.com.au>; Evan Howard <howarde@landloch.com.au>
Subject: RE: Ironbridge Testing

Hi Evan

This is really useful data.

Can you please provide the steady infiltration rate, and advise how you calculated that?

Thanks

Dave

Dr David Westwater

Principal Surface Water Engineer | Long Term Planning

Fortescue Metals Group Ltd

Level 2, 87 Adelaide Terrace East Perth WA 6004

P: +61 8 6218 8888 | D: +61 61 8 9230 1317 | M: 0458 581 539

Twitter: @FortescueNews | www.fmgl.com.au



From: Justin Dixon
Sent: Thursday, 6 December 2018 4:10 PM
To: David Westwater
Subject: FW: Ironbridge Testing

From: Evan Howard <howarde@landloch.com.au>
Sent: Thursday, 6 December 2018 4:09 PM
To: Justin Dixon <jdixon@fmgl.com.au>
Subject: RE: Ironbridge Testing

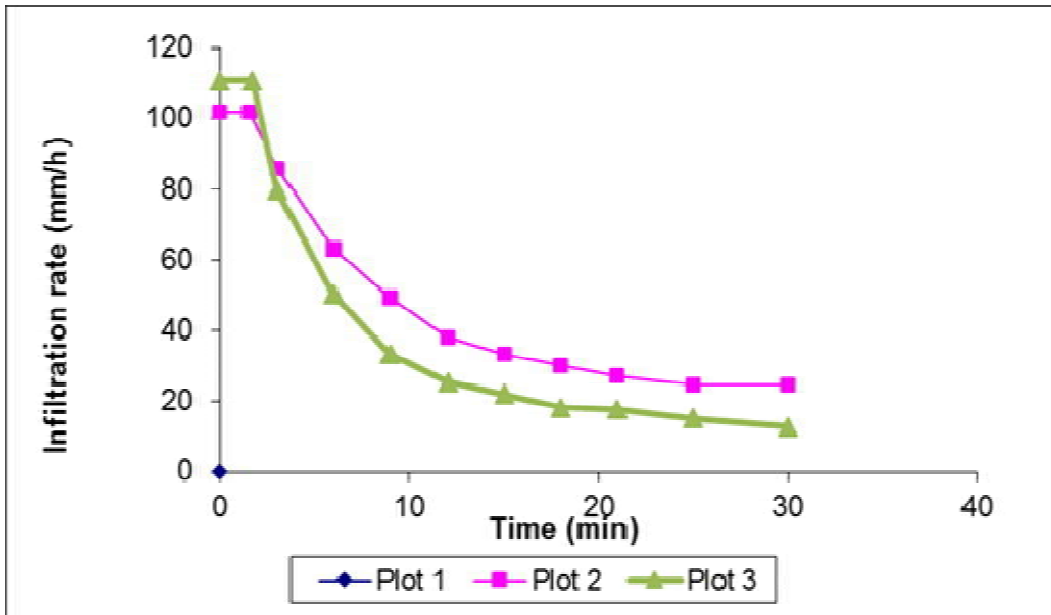
To generate the hydraulic conductivity we first get a steady state infiltration. I could supply those. Here is the data for the oxides. We did duplicate plots known as Plot 2 and 3 in the data I gave below (that's just the way our standard lab templates describe them).

Plot 2

Time from start (min)	Runoff rate (mm/h)	Infiltrn rate (mm/h)
0	0	101.81
1.5	0.0	101.8
3.0	16.0	85.9
6.0	38.6	63.2
9.0	52.5	49.3
12.0	63.6	38.2
15.0	68.4	33.4
18.0	71.6	30.3
21.0	74.6	27.2
25.0	77.0	24.8
30.0	77.1	24.7

Plot 3

Time from start (min)	Runoff rate (mm/h)	Infiltrn rate (mm/h)
0	0	110.61
1.67	0.0	110.6
3.0	30.7	79.9
6.0	60.2	50.4
9.0	77.2	33.4
12.0	85.2	25.4
15.0	88.5	22.1
18.0	92.3	18.3
21.0	92.9	17.7
25.0	95.5	15.1
30.0	97.7	12.9



From: Justin Dixon <jdixon@fmgl.com.au>
Sent: Thursday, December 6, 2018 3:46 PM
To: Evan Howard <howarde@landloch.com.au>
Subject: Ironbridge Testing

Hi Evan,

Do you recall if an infiltration test was completed for the IB Oxides?

There is a result for the coarse rejects results, but only an effective hydraulic conductivity for the oxides.

Regards,

Justin Dixon
 Long Term Planning / Principal Geotechnical Engineer

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ASSESSMENT OF THE GROWTH MEDIA AND EROSION POTENTIAL OF SELECTED WASTES AND SOILS

IB Operations Pty Ltd
December 2018



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1 INTRODUCTION

This document summarises the studies undertaken by Landloch Pty Ltd (Landloch) for Iron Bridge Operations Pty Ltd (IBO) for the characterisation of materials planned for use in rehabilitation of proposed landforms at the iron ore mine (North Star).

North Star is located in the Pilbara region of Western Australia, approximately 110km south-east of Port Hedland and 70km west of Marble Bar. Mining produces waste rock that is stored within a permanent waste rock dump (WRD). The ore is processed via crushing, screening, and magnetic separation. Processing produces tailings and a dry rejects waste material that is stored in a permanent dry rejects landform (DRL).

The characterisation of materials undertaken by Landloch was conducted in two parts:

1. Characterisation of small (~5kg) grab samples regarding their plant growth potential; and
2. Characterisation of large (~250-1,000kg) bulk samples regarding their infiltration capacity and/or erosion potential.

It is understood that IBO is in the process of developing rehabilitation designs for North Star. The results of this material characterisation and long-term erosion modelling will be used to inform this process.

The overall objectives of the study are to:

- Determine the plant growth potential of soils, dry rejects, oxides wastes, and tailings at North Star.
- Develop rehabilitated landform surface shapes that are erosionally stable in the long-term. To achieve this objective, Landloch has completed the following:
 - Characterisation of a sample of dry rejects for infiltration capacity in order to confirm that its use as a material that underlies the surface cover will not cause instability at the surface
 - Characterisation of a sample of oxide waste for erodibility and sediment properties, calibration of the Water Erosion Prediction Project (WEPP) runoff/erosion model, and modelling of long-term erosion.

1.1 Report structure

The report will first provide the results and an interpretation of the grab samples used to assess the potential for the soils, dry rejects, oxide wastes, and tailings to support vegetation. The results of the characterisation of the stockpiled soils, dry rejects, oxides, and tailings will be compared against those measured for the undisturbed soils as previously reported (GHD 2011). Landloch's experience that stems from the assessment of soils on a wide variety of sites across the Pilbara (and further afield) is also used.

The report then provides detail of the methods used to assess the infiltration and erodibility of the bulk samples, and the results of the WEPP runoff/erosion modelling.

2 GROWTH MEDIA POTENTIAL

2.1 Samples collected

A total of thirty seven (37) grab samples of soils, oxides, dry rejects, and tailings were sampled and characterised for properties related to plant growth. Samples were collected by B. Bessen of Fortescue Metals Group Limited and supplied to Landloch along with details of each sample. A list of the samples collected, and the details as provided are shown in Table 1. Of the 37 grab samples:

- 12 samples were soils from existing stockpiles (4 from the Gatehouse, 4 from East of Pit, and 4 from Japal);
- 15 samples were oxides from the waste rock dump;
- 5 samples were dry rejects from the existing DRL; and
- 5 samples were tailings from the existing trial plant tailings dam.

2.2 Testing regime

All samples were initially processed for their particle size distribution (rock, pebble, coarse gravel, gravel, fines). The fines (<2mm diameter) were then analysed for:

- Material pH_{1.5};
- Electrical conductivity (EC_{1.5});
- Exchangeable cations (Ca²⁺, Mg²⁺, Na⁺, K⁺, and Al³⁺);
- Effective Cation Exchange Capacity (ECEC);
- Exchangeable Sodium Percent (ESP);
- Particle size distribution (coarse sand, fine sand, silt, clay);
- Total N and P;
- Available (Colwell) P and K;
- Organic carbon; and
- Available (KCl) S.

Soils for IBO were previously assessed by GHD in 2011 (GHD 2011). The disturbance areas for the open pit, WRD, and DRL are located within the Capricorn land system as mapped by Van Vreeswyk *et al* (2004). Therefore, soils from this land system will be considered as the primary source for baseline characterisation data; soils for other land systems are considered as a secondary source.

Table 1: Smalls samples collected (map datum GDA94)

Sample ID	Easting (m)	Northing (m)	Description
Topsoil Samples			
GH01	712661	7650552	Topsoil - Gatehouse
GH02	712695	-	Topsoil - Gatehouse
GH03	712739	7650448	Topsoil - Gatehouse
GH04	712781	7650430	Topsoil - Gatehouse
EP01	713725	7649038	Topsoil – East of Pit
EP02	713690	-	Topsoil – East of Pit
EP03	713727	7649112	Topsoil – East of Pit
EP04	713766	7649095	Topsoil – East of Pit
JP01	707966	7648122	Topsoil - Japal
JP02	707908	7648121	Topsoil - Japal
JP03	707926	7648084	Topsoil - Japal
JP04	707925	7648106	Topsoil - Japal
Oxide Samples			
OX01	713889	7649392	Oxide
OX02	713888	7649415	Oxide
OX03	713883	7649448	Oxide
OX04	713882	7649477	Oxide
OX05	713887	7649493	Oxide
OX06	713901	7649486	Oxide
OX07	713913	7649479	Oxide
OX08	713940	7649459	Oxide
OX09	713961	7649441	Oxide
OX10	7139975	7649420	Oxide
OX11	713975	7649395	Oxide
OX12	713975	7649370	Oxide
OX13	713908	7649283	Oxide
OX14	713922	7649308	Oxide
OX15	713936	7649343	Oxide
Dry Rejects Samples			
RJ01	-	-	Dry Rejects
RJ02	-	-	Dry Rejects
RJ03	-	-	Dry Rejects
RJ04	-	-	Dry Rejects
RJ05	-	-	Dry Rejects
Tailings Samples			
TL01	713653	7649478	Tailings
TL02	713685	7649544	Tailings
TL03	713675	7649600	Tailings
TL04	713664	7649545	Tailings
TL05	713653	7649479	Tailings

2.3 Characteristics of undisturbed soils

Information in this section is sourced from GHD (2011) unless otherwise stated.

Topsoils are commonly shallow (~5cm) and are covered in a stony mantle. Topsoils contain a high percentage of coarse fragments. Subsoils are usually absent. However, when they are present they contain a high percentage of hard, weathered and unweathered rock. Soils have been classified predominantly as tenosols or rudosols. Tenosols have weak pedological development and tend to capture a wide range of soils that do not fit the requirements of other soil orders within the Australian Soil Classification Scheme (Isbell 1996). Similarly, rudosols have little pedological development though they tend to be younger in terms of their development than tenosols.

Based on the data available from GHD (2011), Landloch summarises the key characteristics of the soils as follows:

- Soil pH_{1:5} (H₂O) is moderately acidic to neutral in some areas and alkaline in others. The mean pH_{1:5} value for topsoils was 6.8. Soils tend to increase in pH with depth. Measured pH values range from 5.7 to 8.7 for topsoils. For this study, pH_{1:5} (H₂O) values of 6.0-8.5 were considered suitable.
- A threshold EC_{1:5} value of 1.2dS/m is used, with values greater than that indicating a saline soil. This is consistent with Van Vreeswyk *et al* (2004) threshold value for subsoils. It is noted that for topsoils Van Vreeswyk *et al* (2004) used a threshold of 0.4dS/m and 0.8dS/m for non-saline and moderately saline topsoils. For this study, EC_{1:5} of <1dS/m was used to denote a non-saline soil.
- Total N values were not measured. However, values >300mg/kg were used to define materials with suitable Total N values.
- Available P values ranged from <2-24mg/kg. Values >2mg/kg were considered suitable.
- Available K values ranged from 75-179mg/kg. Values in that order were considered suitable.
- Available S values ranged from 1.1-13.8mg/kg. Values in that order were considered suitable.
- Exchangeable sodium percentage (ESP) >6% was considered an indicator of the potential for structural decline (including tunnel erosion) when it was coupled with a clay content >10%, ECEC values >3meq/100g, and an exchangeable sodium concentration >0.3meq/100g.

These values serve as a useful benchmark against which the characteristics of the oxides, dry rejects, and tailings can be compared.

2.4 Results

The results of the characterisation of the grab samples is given in Tables 2-4. Cells shaded in orange indicate values that differ from the characteristics of the undisturbed soils used as a benchmark in this report.

Table 2: Characterisation results for small samples – Soils

Sample ID		GH01	GH02	GH03	GH04	EP01	EP02	EP03	EP04	JP01	JP02	JP03	JP04	
pH _{1:5} (H ₂ O)	pH units	6.63	5.98	6.13	6.14	7.14	7.39	6.50	7.1	7.88	8.30	8.39	8.84	
EC _{1:5}	dS/m	0.05	0.05	0.06	0.03	0.02	0.02	0.01	0.02	0.07	0.13	0.10	0.19	
Nutrients	Total N	mg/kg	544	592	1032	755	171	169	154	157	733	657	705	150
	Total P	mg/kg	182	206	260	235	353	598	395	441	84	133	90	1376
	Avail. P	mg/kg	5.4	11.8	6.7	6.2	1.0	1.9	3.4	1.5	4.5	11.2	3.4	<1
	Avail. K	mg/kg	192.00	185.00	<10	192.00	<10	53.70	<10	<10	152.00	92.10	74.50	103.00
	Avail. S	mg/kg	4.1	5.2	4.1	3.6	5.2	4.0	4.0	3.4	4.9	13.5	8.5	107
	Organic C	%	0.52	0.49	1.29	0.90	0.09	0.12	0.03	0.06	0.90	1.24	0.88	1.59
Exchangeable Cations	Extraction Method		15A1	15A1	15A1	15A1	15A1	15C1	15A1	15A1	15C1	15C1	15C1	15C1
	ECEC	meq/100g	4.1	4.7	6.2	8.7	11.6	17.4	21.8	31.0	26.7	26.9	29.7	5.2
	ESP	%	1.1	0.9	0.7	6.9	6.5	1.7	2.6	4.1	0.2	0.2	0.2	4.5
	Ca	meq/100g	2.34	2.39	3.41	2.01	4.68	5.73	6.96	11.68	17.83	21.83	22.57	1.55
	Mg	meq/100g	0.94	1.42	1.41	1.81	6.13	11.38	14.17	17.83	8.23	3.86	6.77	1.21
	K	meq/100g	0.72	0.80	1.32	4.26	0.03	0.03	0.13	0.19	0.62	1.16	0.35	2.24
	Na	meq/100g	0.04	0.04	0.04	0.60	0.75	0.30	0.56	1.27	0.04	0.04	0.04	0.24
	Al	meq/100g	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Particle Size Distribution (All sizes)	Rock	%	2	0	9	2	0	7	4	2	2	2	0	8
	Pebble	%	9	3	9	7	5	13	8	15	5	16	12	9
	Coarse Gravel	%	25	30	33	37	39	40	43	52	28	42	43	39
	Gravel	%	31	39	19	26	30	20	26	15	21	14	19	19
	Fines	%	33	28	29	29	27	21	20	16	44	26	27	26
Particle Size Distribution (Fines only)	Coarse Sand	%	43.9	53.8	42.7	44.9	56	43.2	40.5	40.6	43.8	39.2	39.4	68.0
	Fine Sand	%	31.2	24.1	37.0	32.7	19.2	28	28.8	31.6	34.7	39.6	39	24.3
	Silt	%	7.1	5.5	9.2	7.0	9.3	13.1	13.1	15.2	7.5	9.3	5.7	1.5
	Clay	%	14.3	16.5	11.0	15.4	15.6	15.7	17.6	12.1	13.9	11.9	15.9	6.2

Note: ECEC: Effective Cation Exchange Capacity; ESP: Exchangeable Sodium Percentage; Rock: >50mm; Pebble: 25-50mm; Coarse gravel: 5-15mm; Gravel: 2-5mm; Fines: <2mm; Coarse sand: 0.2-2.0mm; Fine sand: 0.02-0.2mm; Silt: 0.002-0.02mm; Clay: <0.002mm.

Table 3: Characterisation results for small samples – Oxides

Sample ID		OX01	OX02	OX03	OX04	OX05	OX06	OX07	OX08	OX09	OX10	OX11	OX12	OX13	OX14	OX15		
pH _{1:5} (H ₂ O)	pH units	7.20	6.83	6.66	6.71	6.86	6.49	6.59	6.45	6.55	6.68	6.88	6.45	7.72	7.62	7.73		
EC _{1:5}	ds/m	0.21	0.05	0.02	0.02	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.02	0.03	0.03		
Nutrients	Total N	mg/kg	226	248	235	195	509	266	253	248	231	231	183	225	212	231	193	
	Total P	mg/kg	213	213	249	227	148	266	156	144	188	206	315	306	202	110	105	
	Avail. P	mg/kg	7.4	4.4	5.8	3.0	7.3	9.6	8.2	8.2	9.8	3.1	2.3	1.9	4.8	5.9	10	
	Avail. K	mg/kg	91.50	79.50	97.90	84.80	63.90	65.90	59.20	72.30	71.90	58.90	142.00	53.90	47.60	56.90	46.70	
	Avail. S	mg/kg	19.6	9.6	5.9	8.2	11.8	11.2	7.6	9.1	11.4	7.4	<3.0	12.8	<3.0	4.8	6.8	
	Organic C	%	0.10	0.16	0.14	0.10	0.13	0.19	0.18	0.14	0.19	0.15	0.06	0.14	0.15	0.25	0.15	
Exchangeable Cations	Extraction Method		15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15A1	15C1	15C1	15C1	
	ECEC	meq/100g	3.3	2.0	3.6	8.1	3.9	3.8	3.1	2.9	3.7	5.5	12.7	10.8	3.1	2.5	1.8	
	ESP	%	5.5	2.1	1.8	1.7	1.1	1.7	1.4	1.5	1.2	0.8	2.1	2.7	1.4	1.7	2.4	
	Ca	meq/100g	1.11	0.79	1.22	3.12	2.02	1.91	1.53	1.40	1.44	1.58	3.50	2.81	0.51	0.76	0.54	
	Mg	meq/100g	2.00	1.16	2.26	4.82	1.84	1.83	1.52	1.42	2.21	3.81	8.86	7.65	2.48	1.67	1.21	
	K	meq/100g	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	Na	meq/100g	0.18	0.04	0.06	0.14	0.04	0.07	0.04	0.04	0.04	0.04	0.26	0.29	0.04	0.04	0.04	
	Al	meq/100g	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
Particle Size Distribution (All sizes)	Rock	%	0	4	0	0	0	0	0	0	2	0	0	0	0	0		
	Pebble	%	2	10	9	19	6	4	13	6	9	7	3	9	4	4	0	
	Coarse Gravel	%	16	25	37	40	34	34	32	31	30	27	30	34	35	16	14	
	Gravel	%	22	22	20	18	26	27	23	27	26	23	26	21	21	22	20	
	Fines	%	59	39	34	23	34	35	31	36	33	42	41	36	40	58	66	
Particle Size Distribution (Fines only)	Coarse Sand	%	46.9	54.0	46.0	48.4	42.6	45.6	44.1	45.4	42.9	33.6	44.8	48.2	40.2	37.0	53.9	
	Fine Sand	%	26.5	21.0	23.4	20.7	26.6	21.8	21.7	24.0	26.4	21.2	26.1	20.9	21.5	31.6	28.7	
	Silt	%	12.7	14.7	12.9	13.0	13.0	11.1	12.9	12.7	12.9	20.2	13.0	13.0	18.3	14.8	5.4	
	Clay	%	13.9	10.3	17.7	17.9	17.8	21.5	21.3	17.5	17.8	25.0	16.0	17.9	20.1	16.6	10.8	

Note: ECEC: Effective Cation Exchange Capacity; ESP: Exchangeable Sodium Percentage; Rock: >50mm; Pebble: 25-50mm; Coarse gravel: 5-15mm; Gravel: 2-5mm; Fines: <2mm; Coarse sand: 0.2-2.0mm; Fine sand: 0.02-0.2mm; Silt: 0.002-0.02mm; Clay: <0.002mm.

Table 4: Characterisation results for small samples – Rejects and tailings

Sample ID			RJ01	RJ02	RJ03	RJ04	RJ05	TL01	TL02	TL03	TL04	TL05
pH _{1:5} (H ₂ O)		pH units	8.87	8.78	8.67	8.90	8.45	9.24	8.83	8.88	8.86	8.60
EC _{1:5}		dS/m	0.22	0.24	0.34	0.19	0.10	0.09	0.79	0.55	1.07	1.66
Nutrients	Total N	mg/kg	154	160	148	145	741	145	152	145	157	151
	Total P	mg/kg	920	737	844	753	128	737	722	557	749	726
	Avail. P	mg/kg	<1	<1	<1	<1	4.2	1.4	1.9	1.4	<1	1.27
	Avail. K	mg/kg	129.00	121.00	134.00	85.90	92.70	<10	127.00	64.40	139.00	242.00
	Avail. S	mg/kg	143	145	276	106	8.5	24.6	541	385	901	1097
	Organic C	%	1.66	2.05	1.88	1.51	2.11	0.91	0.72	0.66	0.79	0.53
Exchangeable Cations	Extraction Method		15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1	15C1
	ECEC	meq/100g	5.3	6.9	6.9	7.3	28.9	4.5	9.1	6.9	13.4	14.8
	ESP	%	5.8	5.5	6.6	6.1	0.2	4.1	15.6	9.7	19.6	14.6
	Ca	meq/100g	1.63	2.49	2.24	2.37	24.93	1.08	1.73	1.62	2.43	2.44
	Mg	meq/100g	1.60	2.04	1.80	2.14	3.30	1.27	3.30	2.52	4.56	5.93
	K	meq/100g	1.79	2.00	2.42	2.34	0.63	1.93	2.66	2.05	3.74	4.24
	Na	meq/100g	0.31	0.38	0.46	0.45	0.04	0.19	1.42	0.67	2.62	2.17
	Al	meq/100g	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Particle Size Distribution (All sizes)	Rock	%	0	0	0	0	0	0	0	0	0	0
	Pebble	%	0	0	0	0	0	0	0	0	0	0
	Coarse Gravel	%	0	0	0	0	0	0	0	0	0	0
	Gravel	%	16	17	14	14	14	0	0	0	0	0
	Fines	%	83	83	86	86	86	100	100	100	100	100
Particle Size Distribution (Fines only)	Coarse Sand	%	66.1	67.0	63.2	64.7	36.7	6.9	7.9	1.7	0.3	0.2
	Fine Sand	%	24.2	25.1	25.3	23.7	37.8	81.4	75.9	83	77.1	79
	Silt	%	1.8	1.8	3.6	5.5	9.5	3.7	5.5	5.3	15.9	16
	Clay	%	8.0	6.2	7.9	6.2	16.0	8	10.7	10.1	6.7	4.9

Note: ECEC: Effective Cation Exchange Capacity; ESP: Exchangeable Sodium Percentage; Rock: >50mm; Pebble: 25-50mm; Coarse gravel: 5-15mm; Gravel: 2-5mm; Fines: <2mm; Coarse sand: 0.2-2.0mm; Fine sand: 0.02-0.2mm; Silt: 0.002-0.02mm; Clay: <0.002mm.

2.4.1 Stockpiled soils

Stockpiled soils from the Gatehouse, East of Pit, and Japal were assessed. These materials generally have suitable soil $pH_{1.5}$ and are non-saline. They contain appreciable gravel contents. Based on their ESP, they are generally not prone to clay dispersion, though the low $EC_{1.5}$ values may mean that they are prone to hard setting. Two materials did have elevated ESP values and sufficient clay and ECEC for them to present a risk of dispersion. However, the rocky nature of the soils will act to mitigate some of the potential structural decline.

The nutrient status of the stockpiled soils is lower for the East of Pit soils than measured for undisturbed soils and when compared to typical values for soils in the Pilbara region. Addition of N, P, and K may improve plant growth for the East of Pit soils. The values measured for the Gatehouse and Japal areas seem reasonable.

2.4.2 Oxides

Oxide wastes have suitable soil $pH_{1.5}$ and are non-saline. They are not prone to clay dispersion and hence are at low risk of tunnel erosion.

The oxides have generally suitable fertility except for low Total N values. It is Landloch's experience that addition of N can assist in plant establishment. Application amount could aim for an increase in total N values of 100mg/kg. This would be equivalent to an application of ~0.3t/ha of urea mixed into the surface 0.1m.

2.4.3 Dry rejects

Dry rejects are non-saline alkaline compared to the soils, with $pH_{1.5}$ values ranging from 8.67-8.90 and averaging 8.8. This is similar to the pH of the most alkaline soils reported by GHD (2011). However, on average the pH of the soils was lower (6.8). The high pH of these materials may impact on the growth of some plants. Detail on pH effects on specific native species in the Pilbara is scarce. There are two courses of action that could be considered:

1. Establishment of a pot trial that investigates the impact of alkaline dry rejects on plant germination and growth; or
2. Placement of another material with lower pH (e.g. soils or oxide wastes) over the dry rejects to create a root zone with lower pH.

The dry rejects have low Total N and Available P and high Available S values compared to the soils. Plant establishment and development issues with Sulphur are more related to sulphur deficiencies rather than toxicities. Therefore, the high S value may not require management. The low N and P values could be amended through application of fertiliser. Application amount could aim for an increase in total N values of 200mg/kg and available P by 10mg/kg. This could be achieved by addition of a combination of urea and DAP (diammonium phosphate). Applications of ~0.5t/ha of urea and 0.1t/ha of DAP mixed into the surface 0.1m could be considered. It is noted that fixation of P in the dry rejects could be considerable and these rates would require verification via pot trials before they could be considered optimal application rates.

2.4.4 Tailings

Tailings are similar in many ways to the dry rejects, though the tailings tend to be more saline. This is likely due to their higher fine sand content which will make them less free draining. Leaching of salts from the tailings will be less efficient than from the dry rejects. The salinity of the tailings may affect germination and growth of salt sensitive species, but is unlikely to affect all plant growth.

The tailings are alkaline compared to the soils, with $\text{pH}_{1:5}$ values ranging from 8.60-9.24 and averaging 8.9. The high pH of these materials may impact on the growth of some plants. As for the dry rejects, management of these materials could include determination of the effect of high pH on plant growth via a pot trial followed by their use on the basis of that assessment, or placement of another material with lower pH (e.g. soils or oxide wastes) over the tailings to create a root zone with lower pH.

Two of the five tailings samples had elevated ESP values. They also had appreciable clay, though they are still dominated by fine sands. These materials may be considered prone to structural decline and tunnel erosion through clay dispersion. Further, the very high combined fine sand, silt and clay contents means that structural decline and tunnel erosion may occur even when the clay fraction is not dispersive and ESP is not elevated.

The tailings have low Total N and Available P and high Available S values compared to the soils. As discussed for the dry rejects, high S value may not require further management. The low N and P values could be amended through application of fertiliser. Fertiliser types and rates would be similar to those for the dry rejects: ~0.5t/ha of urea and 0.1t/ha of DAP mixed into the surface 0.1m. It is reiterated that the fixation of P in the tailings could be considerable and these rates would require verification via pot trials before they could be considered optimal application rates.

3 ERODIBILITY ASSESSMENT

3.1 Samples tested

An oxide waste was tested for erodibility and sediment properties using laboratory-based methods. These methods are detailed below. A sample of dry rejects was also tested for effective hydraulic conductivity only.

3.2 Measuring erodibility

Within WEPP, erodibility is described via several specific parameters:

- Interrill erodibility (K_i);
- Rill erodibility (K_R);
- Critical shear for rill initiation (τ_c); and
- Effective hydraulic conductivity (K_e).

Interrill erodibility (K_i) describes the detachment and movement of particles by the combined action of raindrops and shallow overland flows. Rill erodibility (K_R) describes the detachment of particles by shear stresses caused by concentrated flows. Critical shear for rill initiation (τ_c) is the shear stress applied by concentrated flows to the surface above which particle detachment and transport by flow rapidly increases and rills form. Within WEPP, effective hydraulic conductivity (K_e) defines the rate of water movement through a defined soil profile in response to wetting by rainfall, and is derived through analysis of a material's steady infiltration and runoff rates. Effective hydraulic conductivity is that required within the van Genuchten water retention model, and is different to saturated hydraulic conductivity.

The calibrated WEPP erodibility parameters for the oxide was derived from data collected using laboratory-based experimental methods involving the application of:

- Simulated rain and measurement of runoff rate and sediment loads in runoff to obtain estimates of K_i and K_e ;
- Concentrated surface water flows and measurement of flow characteristics and sediment loads to obtain estimates of K_R and τ_c ; and
- Settling columns to obtain estimates of settling velocity that in turn was used in the model to describe sediment particle size and density distributions.

Interrill erosion was measured by applying simulated rain with known rainfall intensity to simulation plots 0.75m wide and 0.75m long (Figure 1). Rill erosion was measured by applying overland flow to simulation flumes 0.4m wide and 2.0m long (Figure 2).

Estimates of erosion rates are sensitive to the particle size and density distributions of the eroded sediment. The version of the WEPP model available for general use has been coded to estimate sediment properties solely on the basis of input soil particle size distribution data. However, Landloch has access to a version of WEPP not otherwise available that specifically allows input of detailed sediment particle size and density distributions. This modified version of the WEPP has been applied in this study because it can more accurately predict erosion. Settling columns (Figure 3) were used to develop equivalent sand size distributions for the sediment (Loch 2001). This approach is particularly useful as it integrates both particle size and density distributions into a data set that can be readily entered into the WEPP model. Consequently, several samples of the rain-impacted surface of all samples were taken using sampling and handling methods described by Loch (1994). Images from the simulations undertaken are provided in Appendix A.

The dry rejects sample was subjected to simulated rain only in order to obtain a measurement of effective hydraulic conductivity. The oxide sample was subjected to both simulated rain and overland flows, and settling columns. Hence all erodibility and sediment parameters were collected for this sample.

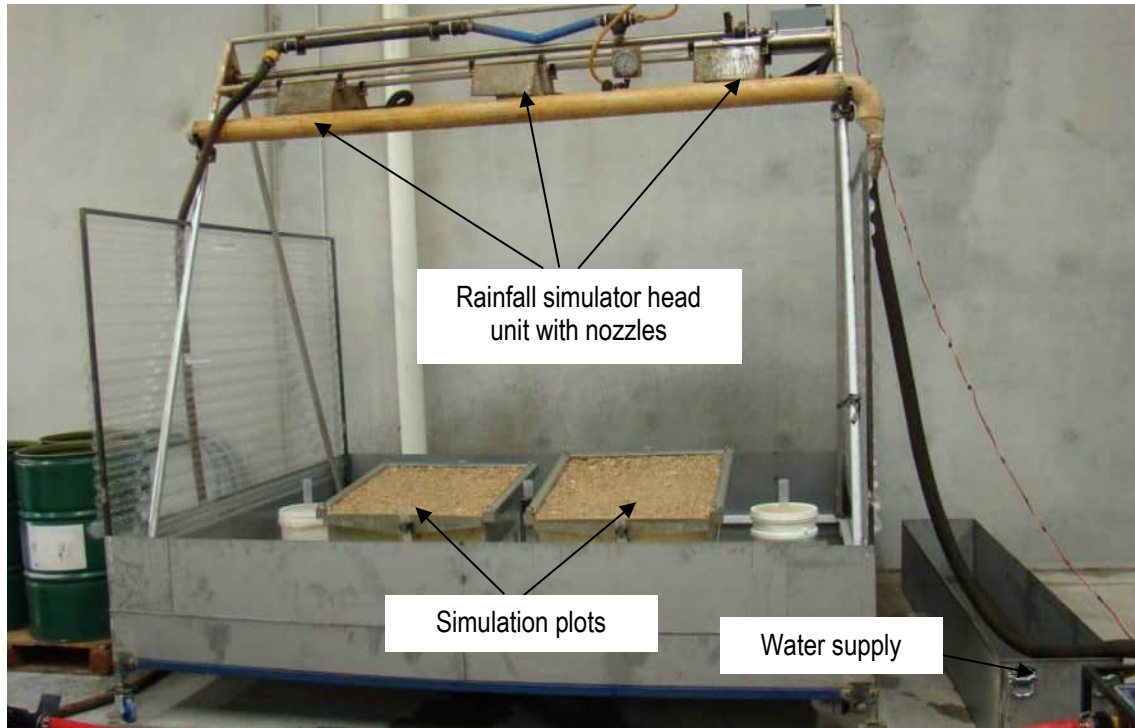


Figure 1: Laboratory-based rainfall simulator installation.

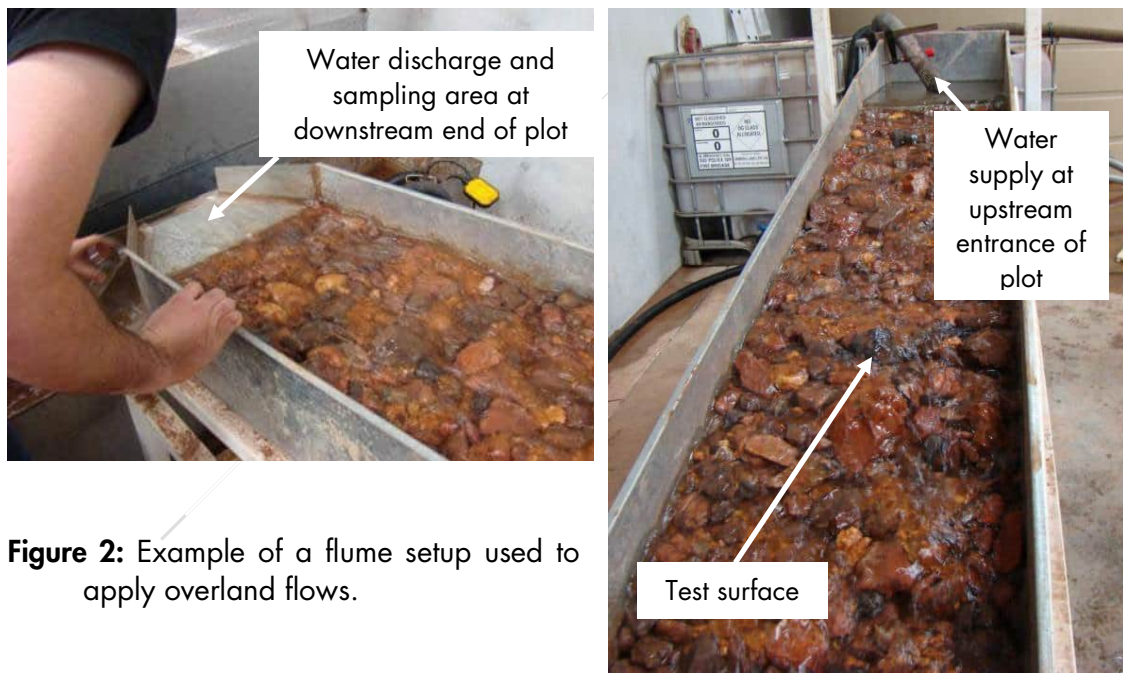


Figure 2: Example of a flume setup used to apply overland flows.



Figure 3: Landloch's automated settling columns deployed on site in support of field-based rainfall simulation.

4 EROSION MODELLING

4.1 Rehabilitation objectives

Landform rehabilitation is an essential part of mine closure. The Department of Mines, Industry Regulation and Safety (DMIRS) require rehabilitated waste landforms to be safe, stable, non-polluting, and completed to an agreed end land use.

A landform's erosional stability typically refers to:

- No significant rill or gully erosion that could undermine the integrity of the landform cover, prevent vegetation establishment, or create concentrated sediment fans at the bottom of the gully that may bury vegetation;
- No sedimentation of local drainage lines; and
- The presence of vegetation.

4.2 Acceptable rates of erosion

Some degree of erosion will always occur from any rehabilitated landform. In setting an "acceptable" level of erosion from rangelands, it is most appropriate to adopt values below which rilling and gullying is minimised. Where rilling is minimised, the tendency for surface water to concentrate and drive the formation of gullies is greatly reduced. Further, slopes with lower erosion potential will more readily allow vegetation

to germinate and establish, and develop a functional vegetation assemblage, assuming suitable depths and quality of growth media are applied. Acceptable rates of erosion for this project were set based on the findings of the *Acceptable erosion rates for mine waste landform rehabilitation modelling in the Pilbara, Western Australia* (Landloch 2018). This is summarised by the matrix shown in Figure 4. The acceptable rate of erosion for use in modelling is defined by the risk rating for the landform in question. The risk rating that is adopted is based on the consequence of the potential impact of sediment movement from the waste landform and the potential for gully development. The potential for gully initiation is linked to the surface material's Critical Rock Diameter (CRD). The CRD is the mean particle size (D_{50}) of the material placed at the surface and is set such that materials with a larger D_{50} than the CRD are not prone to gully initiation, whereas materials that have an increasingly small CRD become increasingly prone to gully initiation. The CRD listed in Landloch (2018) are shown in Table 5 below.

The matrix also assumes that hostile materials such as potentially acid forming materials are suitably encapsulated.

Figure 4: Matrix of likelihood and consequence used to determine risk ratings for waste landform design.

Likelihood of high rates of erosion			Consequence		
			Potential environmental impact of high rates of sediment movement from a waste landform*		
			Localised impact but not affecting wider ecosystem function	Ongoing & expanding ecosystem impairment (degradation not loss)	Loss of high value species, habitat or ecosystem value
Potential for active gullying	$D_{50} \leq 50\%$ of CRD ^A	Likely	Moderate	High	High
	50% of CRD $< D_{50} <$ CRD	Possible	Low	Moderate	High
	$D_{50} \geq$ CRD	Unlikely	Low	Low	Moderate

* Matrix assumes hostile (e.g. PAF) wastes are suitably encapsulated.

^A: Critical Rock Diameter. To avoid having a small number of very large particles bias the D_{50} estimates, it is also stipulated that D_{80} should be no larger than 3 times D_{50} .

Table 5: Critical Rock Diameters (CRD) for a range of lift heights under Pilbara conditions, gradient of 18 degrees, and assumed rock wet density of 2.8 g/cc.

Lift Height (m)	Critical Rock Diameter (CRD) (mm)
60	125
20	70
10	55
5	45

The rates deemed acceptable for the different levels of risk are:

Risk Rating	Mean Average Annual Erosion (t/ha/y)	Mean Peak Annual Erosion (t/ha/y)
Low	9	18
Moderate	6	12
High	3	6

Based on the measured particle size distribution (PSD) data, the D50 of the oxide is ~10mm (Table 2). Given that this D50 value is well below the CRD value (and less than half the CRD too), the risk matrix indicates that the potential of active gully erosion is likely, and hence either the moderate or high erosion thresholds should be adopted. For the purposes of this report, the acceptability of modelling results is reported using both the moderate and high risk threshold values. From there, Fortescue can consider the potential for environmental impact due to sediment, and select the appropriate results.

4.3 WEPP modelling

4.3.1 Model description

WEPP is a tool that can be used to determine the characteristics of waste landform batters that meet the acceptable erosion rates listed above. The WEPP model was developed by the United States Department of Agriculture to predict runoff, erosion, and deposition on hillslopes. It is a simulation model with a daily input time step, although internal calculations on days when rainfall occurs use shorter time steps. Plant and soil characteristics important to the erosion processes are updated every day. When rainfall occurs, those plant and soil characteristics are considered in determining the likelihood of runoff. If runoff is predicted to occur, the model computes sediment detachment, transport, and deposition at points along the slope profile.

The erosion component of the WEPP model uses a steady-state sediment continuity equation as the basis for the erosion computations. Soil detachment in interrill areas is calculated as a function of the effective rainfall intensity and runoff rate. Soil detachment in rills is predicted to occur if the flow hydraulic shear stress is greater than the soil's critical shear stress, and when the sediment load of the flow is below its transport capacity. Deposition in rills is computed when the sediment load is greater than the capacity of the flow to transport it.

4.3.2 Climate sequence

All WEPP model simulations completed by Landloch used a 100-year stochastic climate sequence for the site developed from observed daily and sub-daily data from nearby weather stations. For each day of simulation, WEPP required ten daily weather variables:

- Precipitation (mm);
- Precipitation duration (hr);

- Peak storm intensity;
- Time to storm peak;
- Average minimum temperature;
- Average maximum temperature;
- Dew point temperature;
- Solar radiation;
- Wind speed; and
- Wind direction.

Of these, the four rainfall-related variables (underlined in the list above) are of particular importance because previous studies have shown that predicted runoff and erosion are most sensitive to these rainfall variables (Nearing et al. 1990; Chaves and Nearing 1991).

For most sites around the world, complete historical weather data on these variables are not available. To use WEPP for runoff and erosion predictions, synthetic weather sequences that statistically preserve the mean and variations in the historical observations are required.

CLIGEN is a stochastic weather generator that can be used to provide WEPP climate input files. CLIGEN has been extensively assessed for a wide range of climates in Australia, and it was found that CLIGEN was most suitable in providing the required climate input for WEPP to predict runoff and erosion in Australia (Yu 2003).

Data Drill daily climate data was sourced from the Bureau of Meteorology for the years 1900-2008. The Data Drill accesses grids of data derived by interpolating the Bureau of Meteorology's observed station records. Interpolations are calculated by splining and kriging techniques (Rayner *et al.* 2004). The data in the Data Drill are all synthetic, however the use of Data Drill data is appropriate in situations such as this, where no long records of observed data exists for the location. Pluviograph (rainfall intensity) data is available from the BOM's Port Hedland weather station (118.58° E, -20.31° S), approximately 107km north of IBO. The Port Hedland rainfall intensity dataset was used to generate the necessary rainfall intensity parameters.

Using the two data sets, the following parameter values were computed and used to develop the synthetic climate sequence:

- Mean daily rainfall on wet days for each month;
- Standard deviation and skewness coefficient of daily rainfall for each month;
- Probability of a wet day following a dry day for each month;
- Probability of a wet day following a wet day for each month;
- Mean daily maximum temperature for each month;
- Standard deviation of daily maximum temperature for each month;
- Mean daily minimum temperature for each month;
- Standard deviation of daily minimum temperature for each month;
- Mean maximum 30-min rainfall intensity for each month; and
- Probability distribution of the dimensionless time to peak storm intensity.

These parameter values were assembled to create a CLIGEN parameter file for the site. Wind data (used to calculate soil evaporation) were not synthesised by CLIGEN because Priestley-Taylor's method for estimating the potential evaporation will automatically be used by WEPP. A 100-year climate sequence was generated using CLIGEN version 5.1 (Yu 2002).

A comparison between the climate sequence developed and the observed data used to develop it is given in Figure 5.

The CLIGEN sequence has a mean annual rainfall of 313mm, compared to 318mm for the Data Drill Data. This a 1.6% difference in mean annual rainfall. For the mean monthly rainfall values, the average monthly error in rainfall is 1mm, and this difference is typically less than 5% of the monthly values of the observed data. The Annual Exceedance Probability (AEP) of the daily rain closely matches the observed data. This is important because it is these larger and less frequent events that cause the majority of runoff events and, hence, also cause the majority of erosion.

4.3.3 WEPP model assumptions

WEPP simulations were conducted on the oxide material using the following model settings:

- a) Rill spacing was set at 2.5m.
- b) Surface roughness was set at 3cm, consistent with the value used when calibrating the model runoff predictions using the rainfall simulator infiltration data.
- c) No allowance was made for vegetation effects on erosion. This is consistent with observations of contact cover levels achieved in the Pilbara; contact cover levels in the arid zone tend to be too low to effectively contribute to reducing erosion of steep batter slopes.

No allowance was made for water from the top of the landform to discharge onto the batter slopes. Retention of water on top of the landform will considerably reduce potential erosion rates.

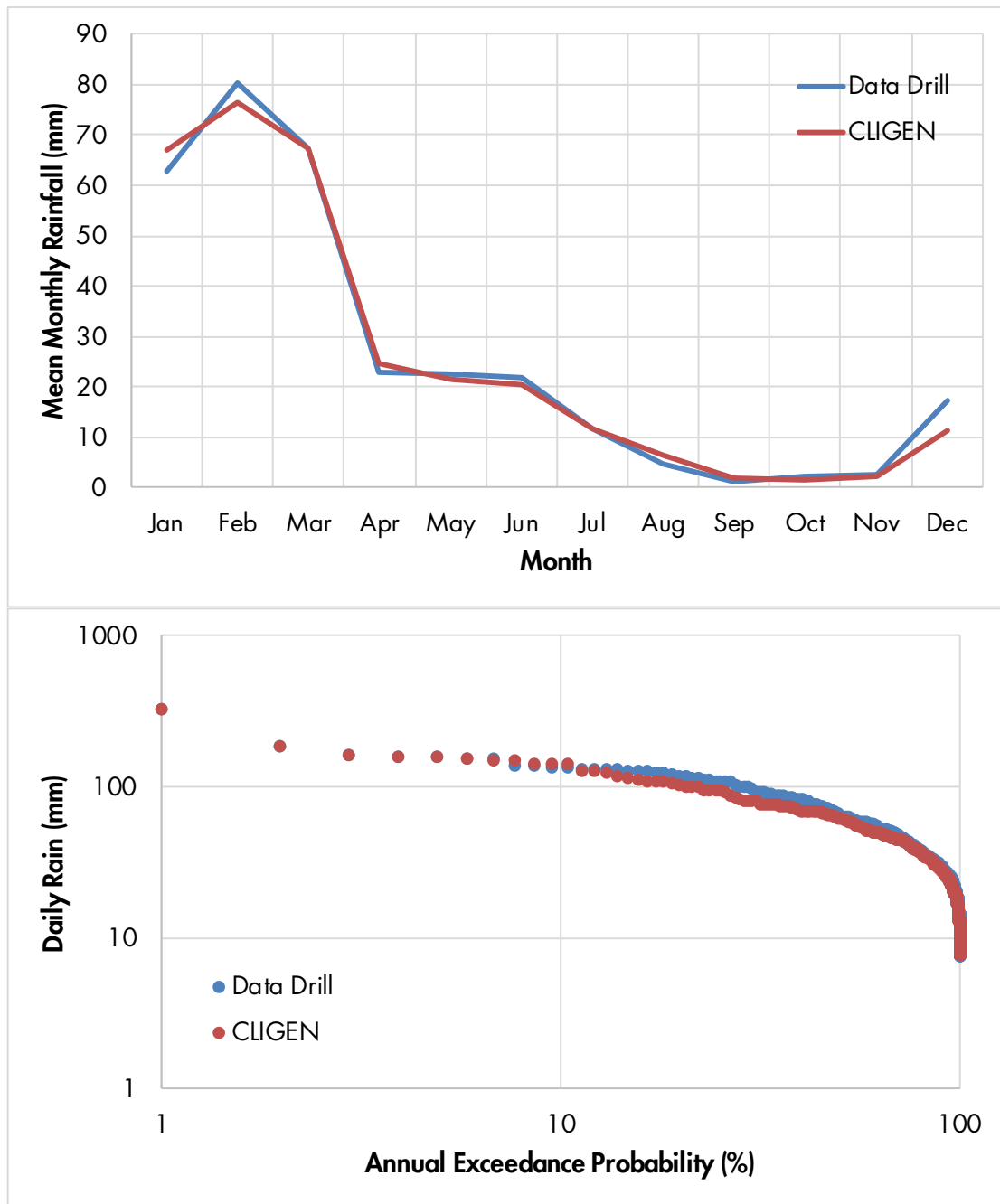


Figure 5: Data Drill and CLIGEN simulated mean monthly rainfall for the site (top). Maximum daily rainfall amount versus Annual Exceedance Probability (bottom).

4.3.4 Batter configurations considered

The batter configurations listed in Table 6 were supplied to Landloch by Fortescue for consideration. They include a range of profile shapes (linear, concave), and a range of height and gradients. All batters considered did not contain berms.

Table 6: Batter slope configurations considered

Simulation No.	Height (m)	Gradient (°)	Rationale
1	40	37	Angle of repose, maximum possible slope gradient
2	30	37	
3	20	37	
4	10	37	
5	10	18	Common Pilbara configurations
6	20	18	
7	10	16	
8	20	16	
9	10	10	Lower bounds of typical gradients
10	20	10	
11	100	5	Long, water shedding slope
12	50	5	
13	30	37-20-10	Nominal 3-part concave slope, each part 10m vertical height
14	20	37-25	Nominal 2-part concave slope, each part 10m vertical height
15	10	37-25	Nominal 2-part concave slope, each part 5m vertical height
16	20	37-25	Nominal 2-part concave slope, 15m vertical height upper section, 5m vertical height lower section

5 INFILTRATION OF THE DRY REJECTS

Effective hydraulic conductivity for the dry rejects was derived using data from the rainfall simulation. It incorporates effects of seal development at the soil surface. A Green-Ampt equation (Green and Ampt 1911) is a common equation that describes a material's infiltration rate. A material's infiltration rate is a function of its effective hydraulic conductivity, antecedent moisture content, soil water potential at the wetting front, and the cumulative depth of water infiltrated. Rainfall was applied to duplicate plots, and the steady infiltration rate and the derived effective hydraulic conductivities are provided in Table 7.

Table 7: Steady infiltration rate and effective hydraulic conductivity of the dry rejects

Plot	Steady infiltration rate (mm/hr)	Effective hydraulic conductivity (mm/hr)
1	22	14
2	11	6
Average	16	10

6 EROSION PREDICTIONS

6.1 WEPP parameters

6.1.1 Erodibility parameters

WEPP erodibility parameters were derived using data collected from the rainfall and overland flow simulations. The derived WEPP erodibility parameters are provided in Table 8.

Table 8: WEPP parameters derived from laboratory testing for the oxide

Material	Effective hydraulic conductivity, K_e	Interrill erodibility, K_i	Rill erodibility, K_R	Critical shear, τ_c
	mm/h	kg.s/m ⁴	s/m	Pa
Oxide	12	302,986	0.00597	37

6.1.2 Sediment properties

Equivalent sand PSD curves for the oxide sediment (bulk sample) are provided in Figure 6. A total of 4 samples were assessed and these curves are shown in grey. The average distributions for each material were inputted to the WEPP model to inform the sediment transport equation (shown in red in Figure 6).

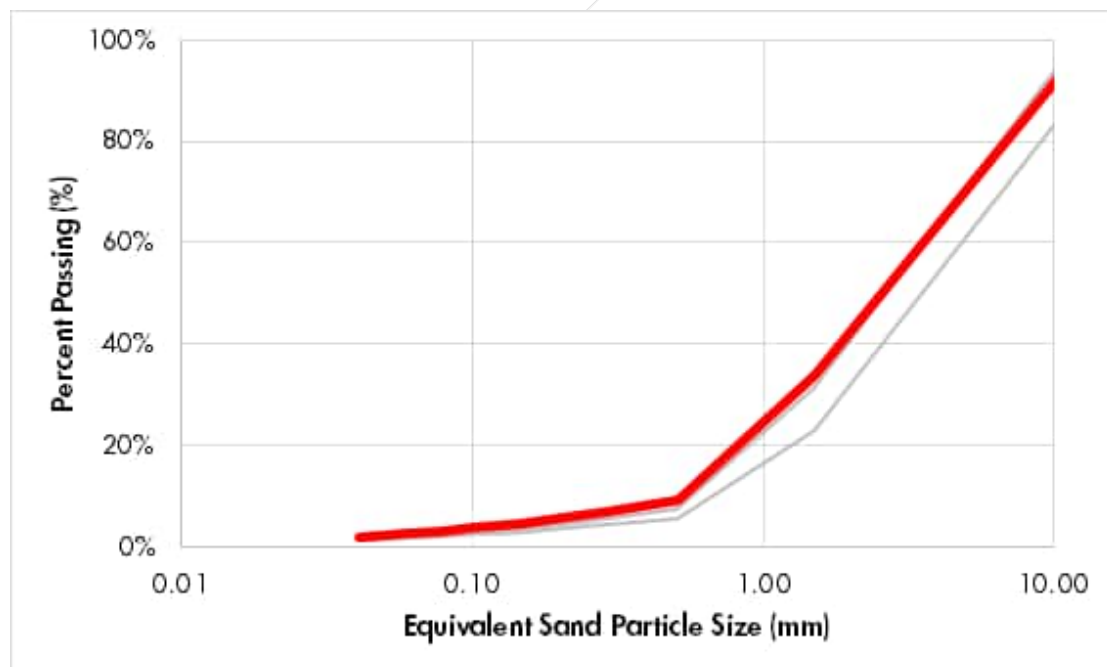


Figure 6: Equivalent sand particle size distribution curves for the oxide material

6.2 WEPP modelling results

6.2.1 Influence of presence dry rejects under the oxides

The effective hydraulic conductivity of the dry rejects (Table 7) is similar to that of the oxides (Table 8). Therefore, it is unlikely that the presence of the dry rejects below the oxides will lead to saturation and a loss of cohesion of the oxides during large rainfall events. Based on this, the risk that the oxides will slip from a surface underlain by dry rejects is low.

6.2.2 Pattern of erosion

In order to describe the pattern of erosion along a typical batter slope length, WEPP was used to predict erosion for a 20m high linear lift with a gradient of 18 degrees (Figure 7).

Erosion is initiated after approximately 7m of vertical batter height, at which time the rates of erosion rapidly increase. This pattern is consistent with a material for which erosion is controlled by the detachability of materials from the surface as opposed to being controlled by capacity of runoff to transport the detached sediment. Erosion for materials that are detachment limited tend to be sensitive to slope length/gradient, and often benefit from the use of concave batter shapes.

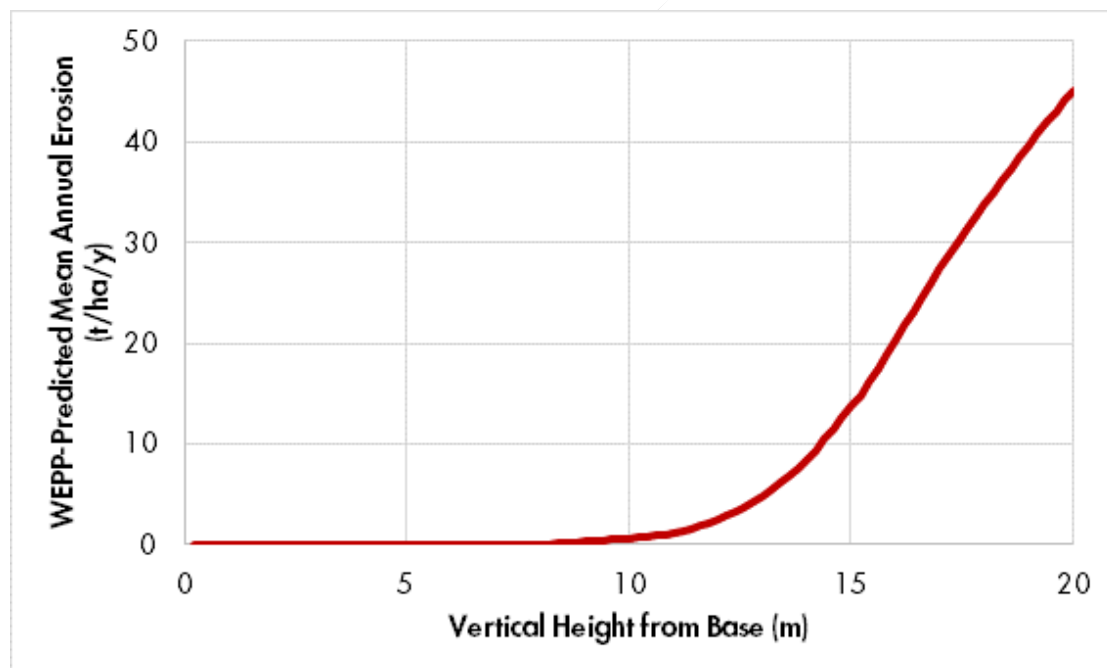


Figure 7: WEPP predicted mean annual erosion for the oxide.

6.2.3 Predicted long-term rates

The WEPP model results for the batters listed in Table 6 are presented in Tables 9 and 10. Table 9 displays data where the cells shaded green indicate batter configurations that achieve acceptably low erosion potential when the moderate risk thresholds are used. Cells shaded orange have configurations that do not achieve acceptably low erosion potential. The values shown are WEPP-predicted mean and peak average annual erosion rates. Table 10 presents the same data, but the shading is based on the high risk erosion thresholds. The results are further summarised in Table 11.

The oxides are sensitive to slope length and gradient. For angle of repose slopes, the predicted rates of erosion decrease dramatically as slope length reduces. For linear (uniform gradient) lifts of similar height, erosion rates reduce as gradients decrease.

The results indicate that use of concave profiles (simulations 13-16) has a positive effect of erosion. When the results showing the 'moderate risk' thresholds are considered, a 30m high concave profile is acceptable whereas 20m high linear profiles with gradients ranging from 10-18 degrees are not.

When the results showing the 'high risk' thresholds are considered, a maximum permissible height of 10m is predicted, with longer slope lengths being unacceptably stable due to high rates of erosion occurring towards the toe of the slope. This finding indicates that further rock armouring of the lower sections could yield favourable results if the high risk thresholds are adopted. Further modelling could be in this circumstance if required.

Table 9: WEPP-predicted erosions for 16 batter configurations. Cell shading is based on 'moderate risk' erosion thresholds.

Simulation No.	Height (m)	Gradient (°)	WEPP-Predicted Long-Term Mean Annual Erosion (t/ha/y)	
			Mean	Peak
1	40	37	46	125
2	30	37	29	100
3	20	37	12	56
4	10	37	0.6	5.0
5	10	18	0.4	3.6
6	20	18	9.0	45
7	10	16	0.3	2.7
8	20	16	7.5	40
9	10	10	0.1	0.6
10	20	10	2.5	19
11	100	5	3.4	9.9
12	50	5	3.1	12
13	30	37-20-10	1.4	11
14	20	37-25	4.8	30
15	10	37-25	0.2	1.0
16	20	37-25	3.6	21

Table 10: WEPP-predicted erosions for 16 batter configurations. Cell shading is based on 'high risk' erosion thresholds.

Simulation No.	Height (m)	Gradient (°)	WEPP-Predicted Long-Term Mean Annual Erosion (t/ha/y)	
			Mean	Peak
1	40	37	46	125
2	30	37	29	100
3	20	37	12	56
4	10	37	0.6	5.0
5	10	18	0.4	3.6
6	20	18	9.0	45
7	10	16	0.3	2.7
8	20	16	7.5	40
9	10	10	0.1	0.6
10	20	10	2.5	19
11	100	5	3.4	9.9
12	50	5	3.1	12
13	30	37-20-10	1.4	11
14	20	37-25	4.8	30
15	10	37-25	0.2	1.0
16	20	37-25	3.6	21

Table 11: Summary of WEPP model results

Simulation No.	Height (m)	Gradient (°)	Suitable batter configurations based on an acceptable erosion threshold consistent with sites that are:	
			Moderate Risk	High Risk
1	40	37	x	x
2	30	37	x	x
3	20	37	x	x
4	10	37	✓	✓
5	10	18	✓	✓
6	20	18	x	x
7	10	16	✓	✓
8	20	16	x	x
9	10	10	✓	✓
10	20	10	x	x
11	100	5	✓	x
12	50	5	✓	x
13	30	37-20-10	✓	x
14	20	37-25	x	x
15	10	37-25	✓	✓
16	20	37-25	x	x

7 DISCUSSION

7.1 Suitable batter configurations

The suitability of a batter configuration is dependent on the risk rating adopted.

For the situation where the risk is assessed as moderate, the following configurations can be used with oxide as the sheeting material:

- Batter height of 10m, and a uniform slope with a gradient of 37°.
- Batter height of 10m, and a uniform slope with a gradient of 18°.
- Batter height of 10m, and a uniform slope with a gradient of 16°.
- Batter height of 10m, and a uniform slope with a gradient of 10°.
- Batter height of 100m, and a uniform slope with a gradient of 5°.
- Batter height of 50m, and a uniform slope with a gradient of 5°.
- Batter height of 30m, and a 3-part concave slope with the upper 10m being 37°, the middle 10m being 20°, and the lower 10m being 10°.
- Batter height of 10m, and a 2-part concave slope with the upper 5m being 37° and the lower 5m being 25°.

For the situation where the risk is assessed as high, the following configurations can be used with oxide as the sheeting material:

- Batter height of 10m, and a uniform slope with a gradient of 37°.
- Batter height of 10m, and a uniform slope with a gradient of 18°.
- Batter height of 10m, and a uniform slope with a gradient of 16°.
- Batter height of 10m, and a uniform slope with a gradient of 10°.
- Batter height of 10m, and a 2-part concave slope with the upper 5m being 37° and the lower 5m being 25°.

The results indicate that the oxides respond favourably to the use of concave slopes, with batter heights up to 30m being assessed to be stable (when the correct gradients and slope lengths are also adopted). There is potential to consider further concave profile options to achieve higher batter heights and possibly reduce the slope lengths.

7.2 Landform top

For the recommended batter profiles to be stable and sustainable, it will be critical to retain runoff on the top of the rehabilitated landform. Discharge of concentrated flows from the top of waste landforms onto the outer batter slopes is a very common cause of gullying and landform failure. The risk of uncontrolled discharge of surface water from the dump top can be managed by:

- a) installing crest bunding that can control extreme rainfall events,
- b) installing appropriate cross-bunding that are slightly smaller than the height of the crest bunds; and
- c) increasing the infiltration capacity and water use of vegetation on the dump top.

7.3 Batter slopes

To achieve long-term stability of batter slopes, it is critical that flow concentration be minimised. Concentration of overland flow can be prevented by:

- a) Minimising the size of cross-slope rip lines where used; and
- b) Ensuring the thorough mixing of the rock into the soil on the batter slopes where a soil/rock mixture is required.

Rip lines should be no deeper than 300mm from peak to trough of the rip line once settlement has occurred. To achieve this, it is likely that an unconsolidated rip line ~500mm in depth will be required. Ripping will also be desirable to incorporate fertiliser to encourage vegetation growth (if added) and to remove machinery track marks that are a common cause of erosion. Given the critical importance of minimising flow concentration on the batter slopes, it will be essential that construction does not create flow-concentrating features. Of particular concern are:

- Rip lines off contour;
- Laterally irregular batter slope shapes not consistent with the rehabilitation design (Figure 8); and
- Sharp corners which render ripping on the contour extremely difficult.

If possible, equipment used for shaping batters should have precision guidance systems installed. Operators should be highly skilled and experienced. It is noted that rehabilitation earthworks are significantly different to earthworks typically conducted by mining staff, and requires great precision and adherence to the specified designs if landform stability is to be achieved.



Figure 8: Example of a laterally irregular batter slope shapes. Irregularity caused by poor construction and was not part of the rehabilitation design.

In the case where angle of repose slopes are used, cross ripping will not be possible. In these instances flow concentration caused by sub-optimal rip lines will not be an issue. Neither will flow concentration caused by machinery track marks. The major potential cause of flow concentration is the accuracy of the material dumping. The material should be dumped in such a way as to produce a final surface that achieves the required rehabilitation profile shape and is also as uniform as possible laterally across the slope.

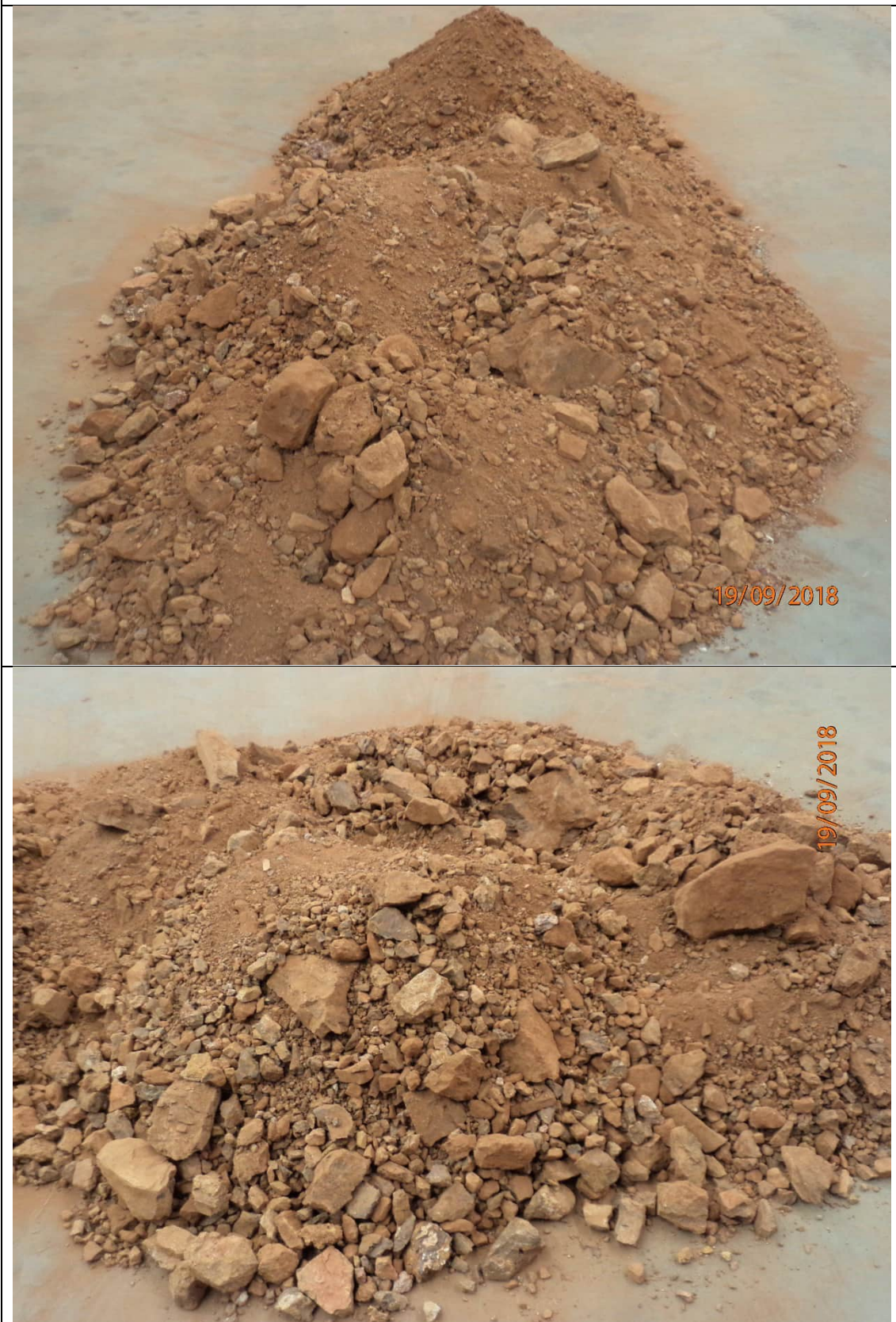


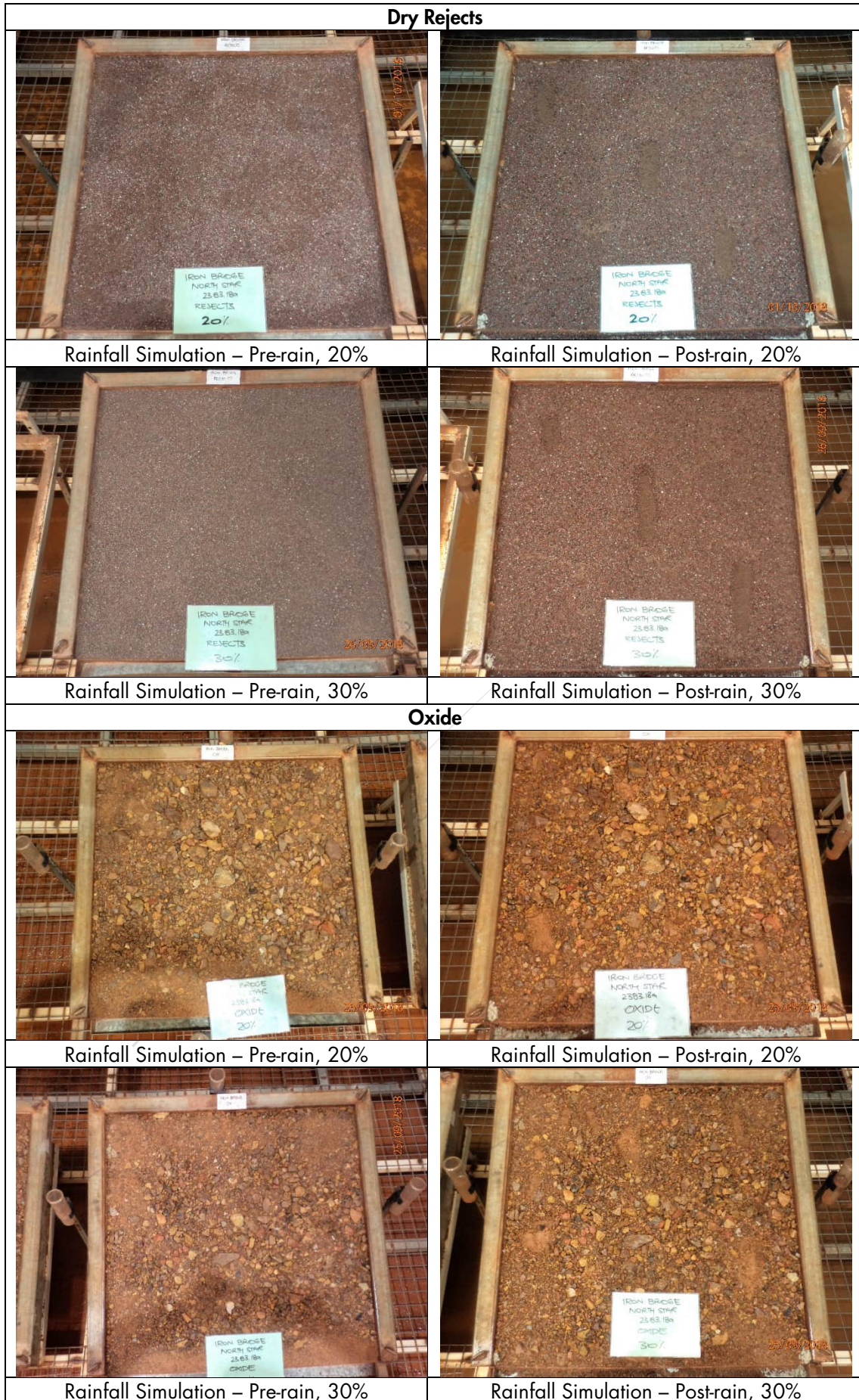
REFERENCES

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APPENDIX A: LABORATORY IMAGES

Oxide as Received

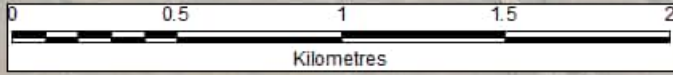








APPENDIX D BASELINE CONDITION FLOOD MAPPING



LEGEND

● Site 12 Pool

▭ TUFLOW Model Extent

Peak Flood Depth (m):

▭ < 0.05

▭ 0.05 - 0.1

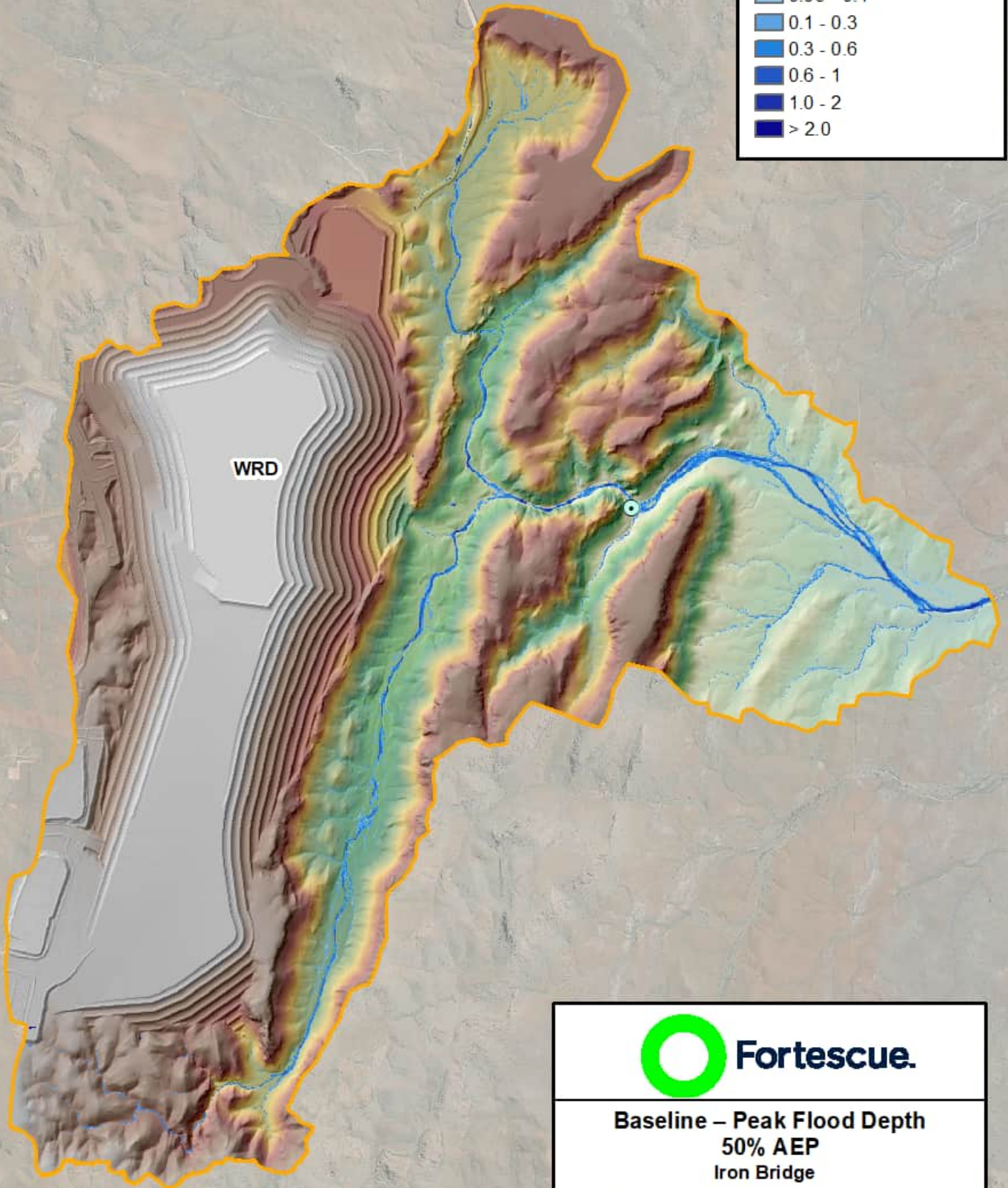
▭ 0.1 - 0.3

▭ 0.3 - 0.6

▭ 0.6 - 1

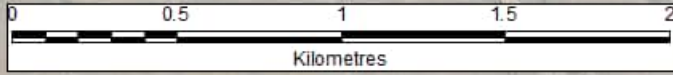
▭ 1.0 - 2

▭ > 2.0










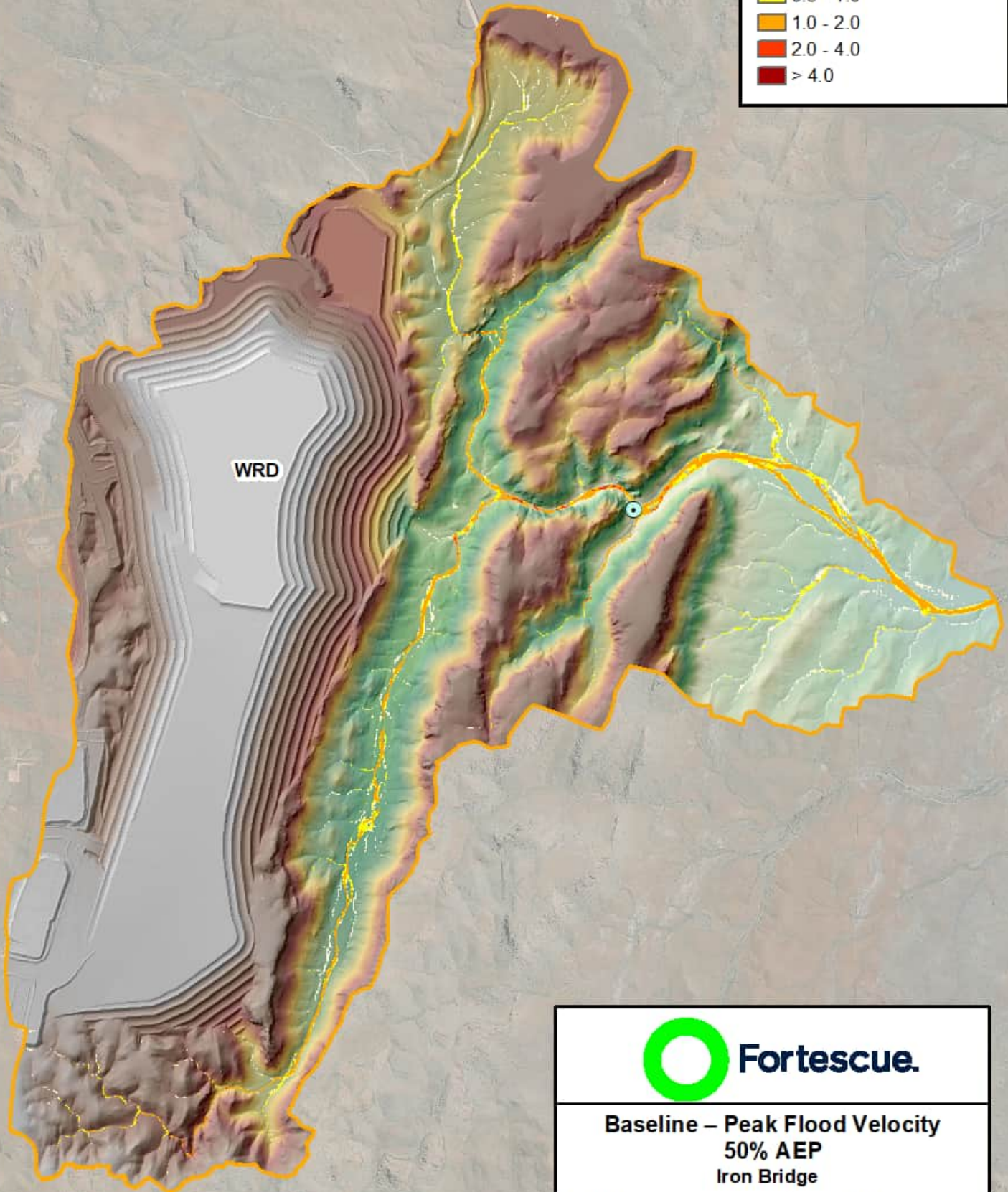
**Baseline – Peak Flood Depth
50% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



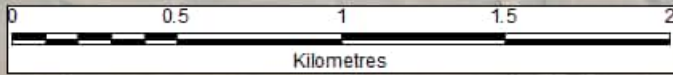
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












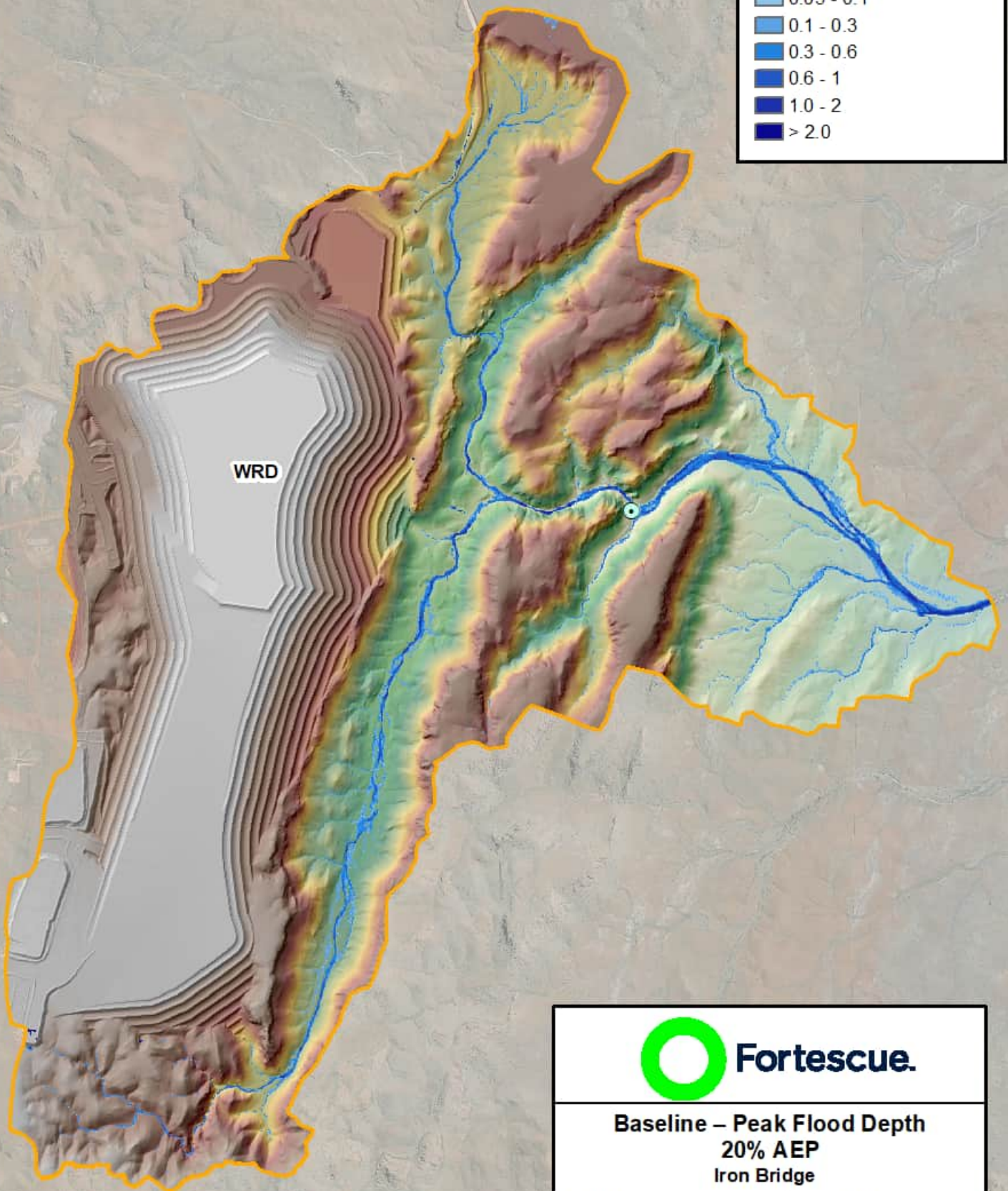
**Baseline – Peak Flood Velocity
50% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



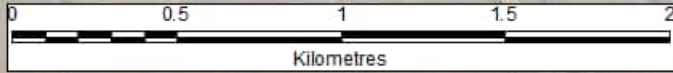
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










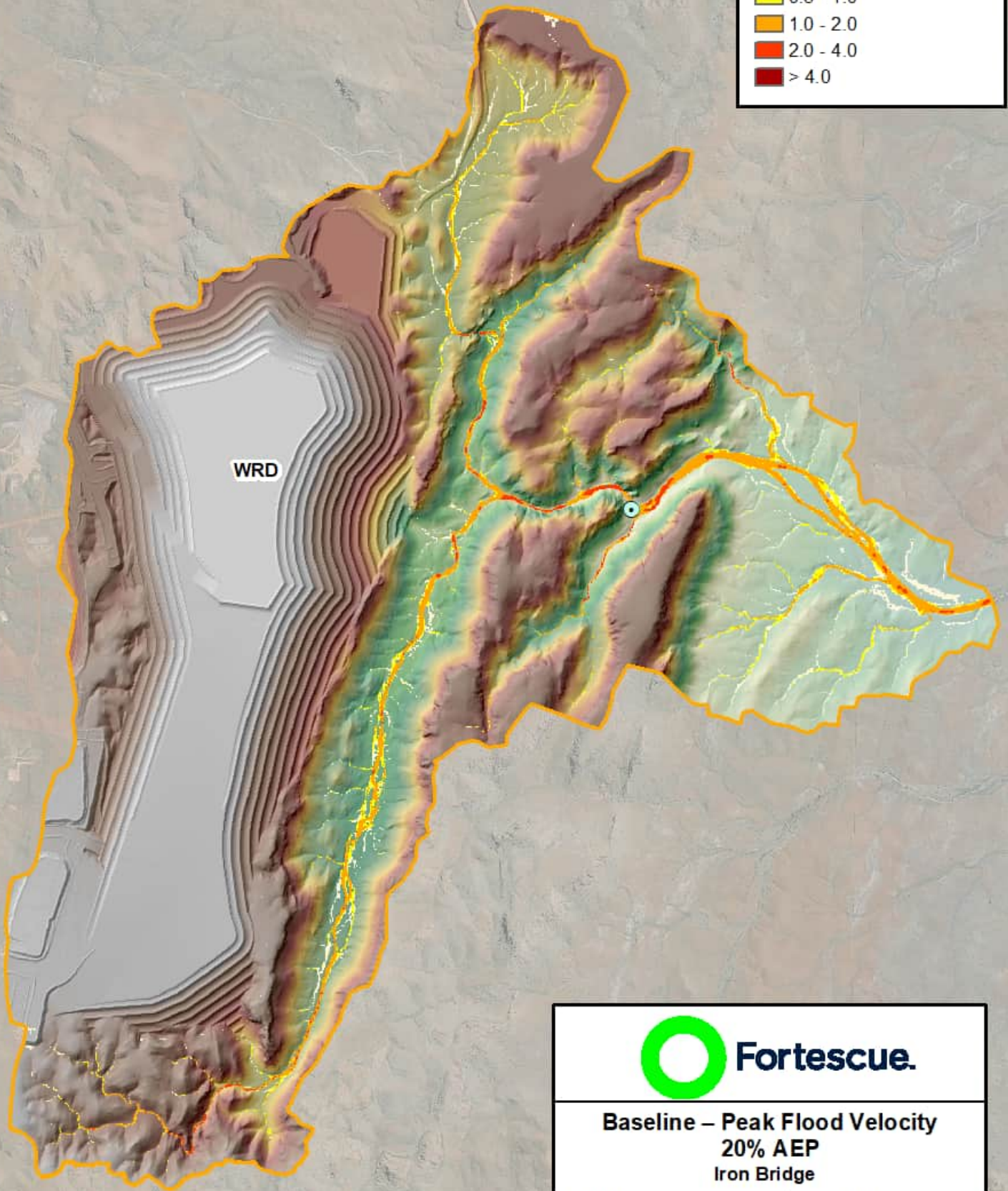
**Baseline – Peak Flood Depth
20% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



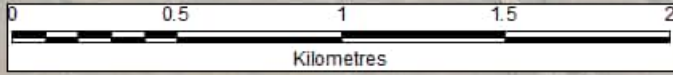
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












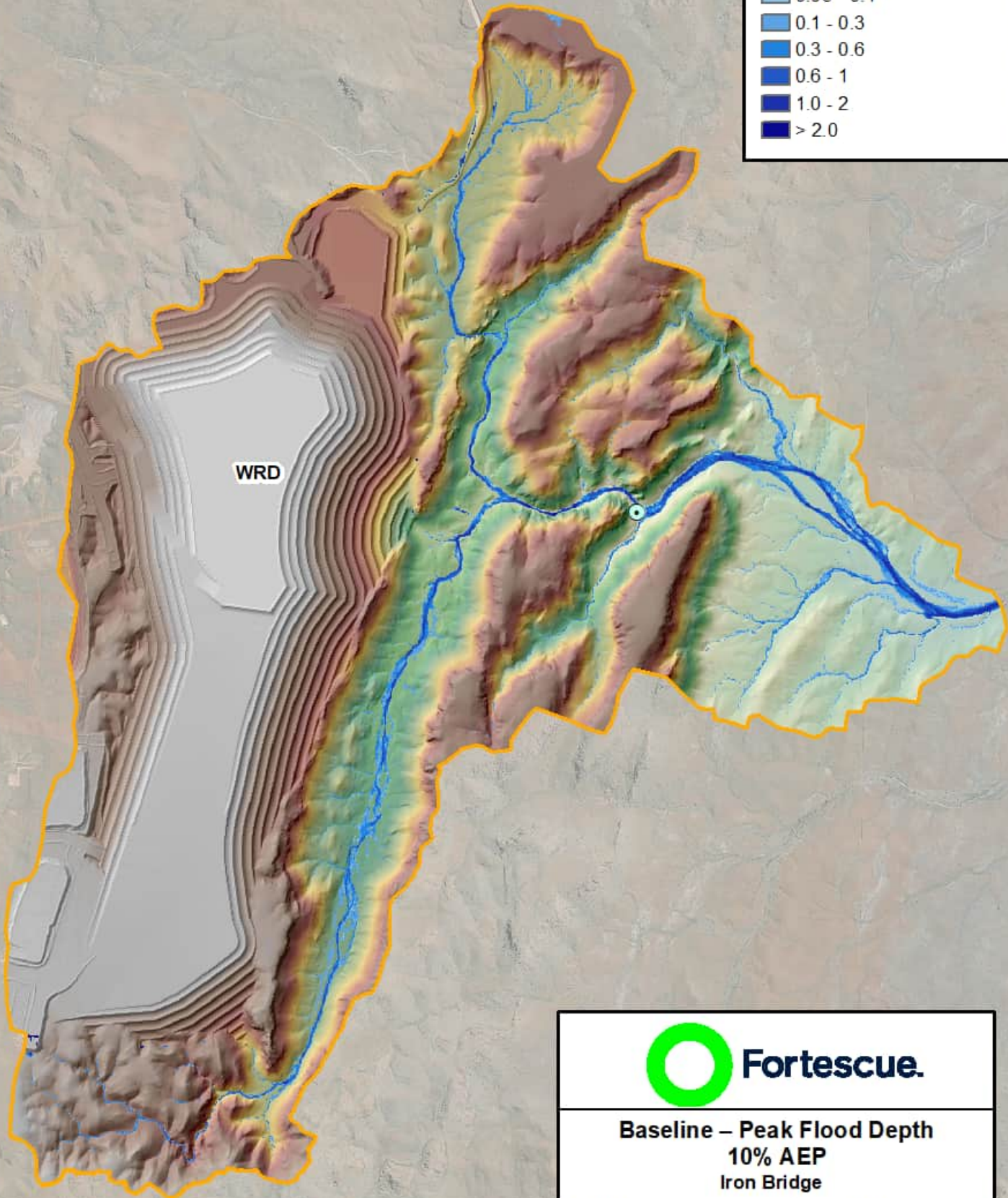
**Baseline – Peak Flood Velocity
20% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



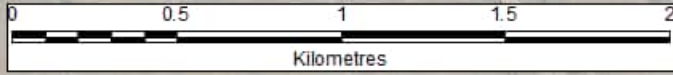
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










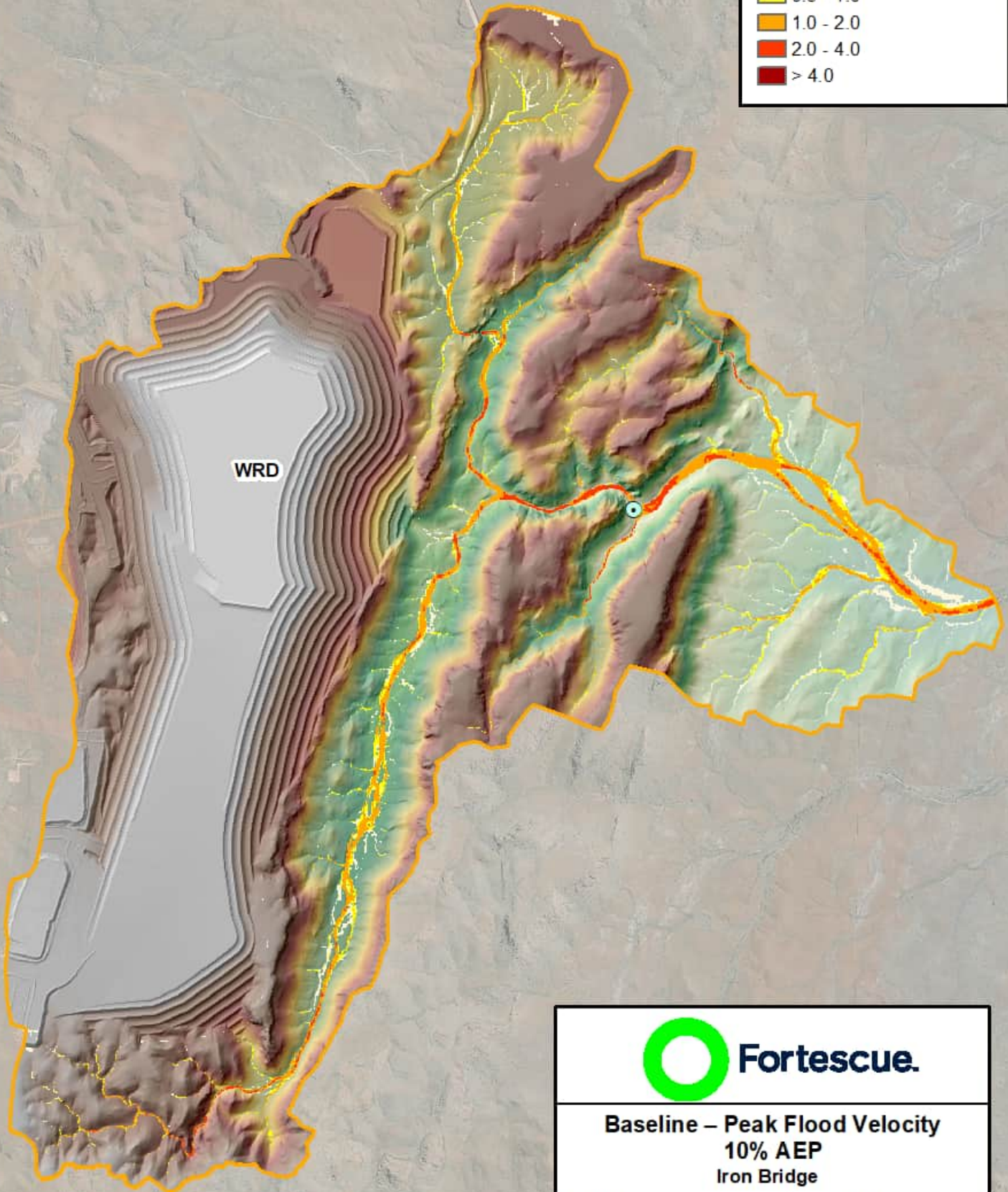
**Baseline – Peak Flood Depth
10% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



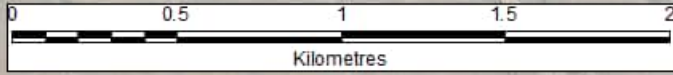
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












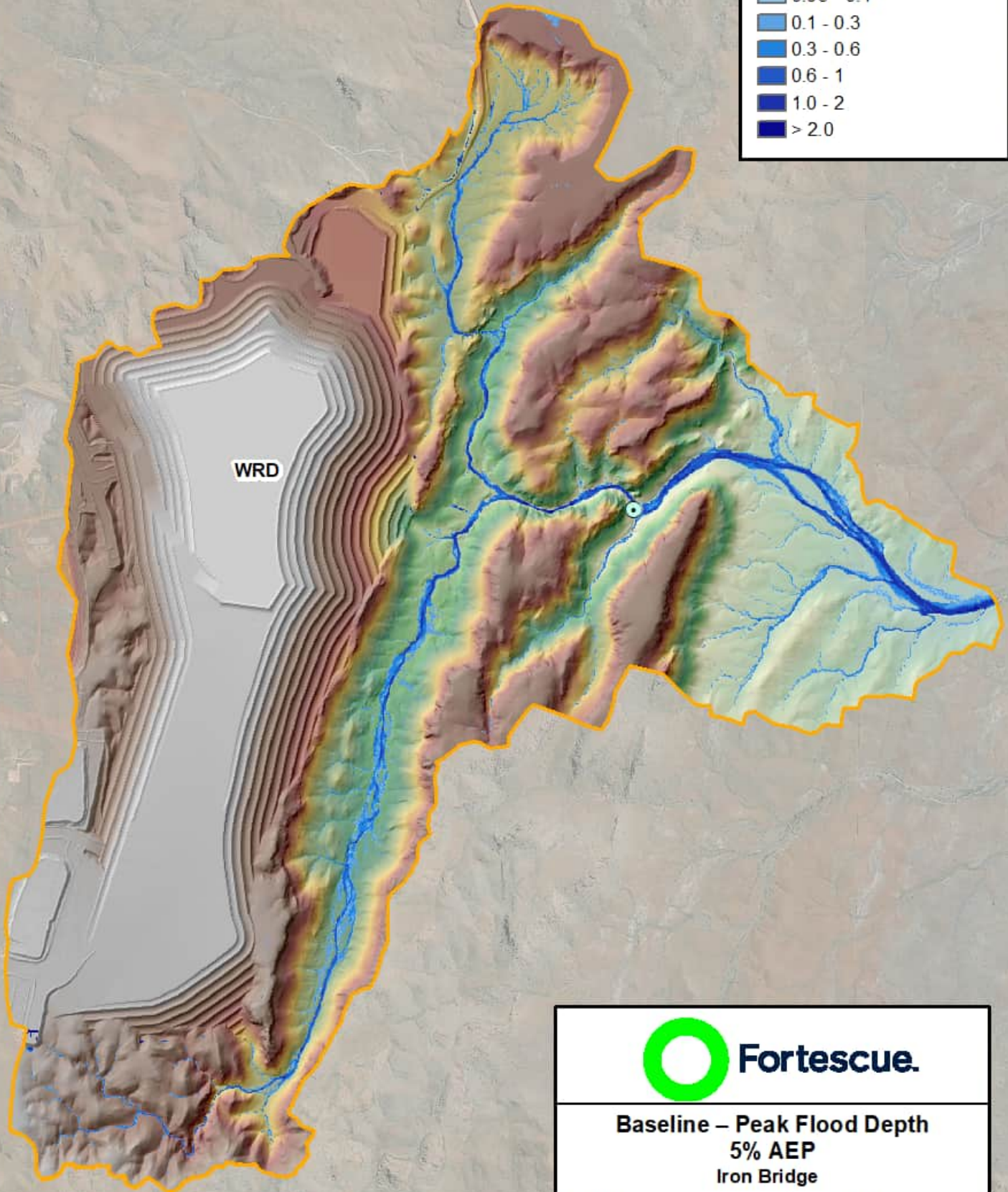
**Baseline – Peak Flood Velocity
10% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



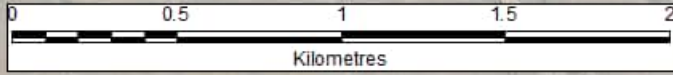
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










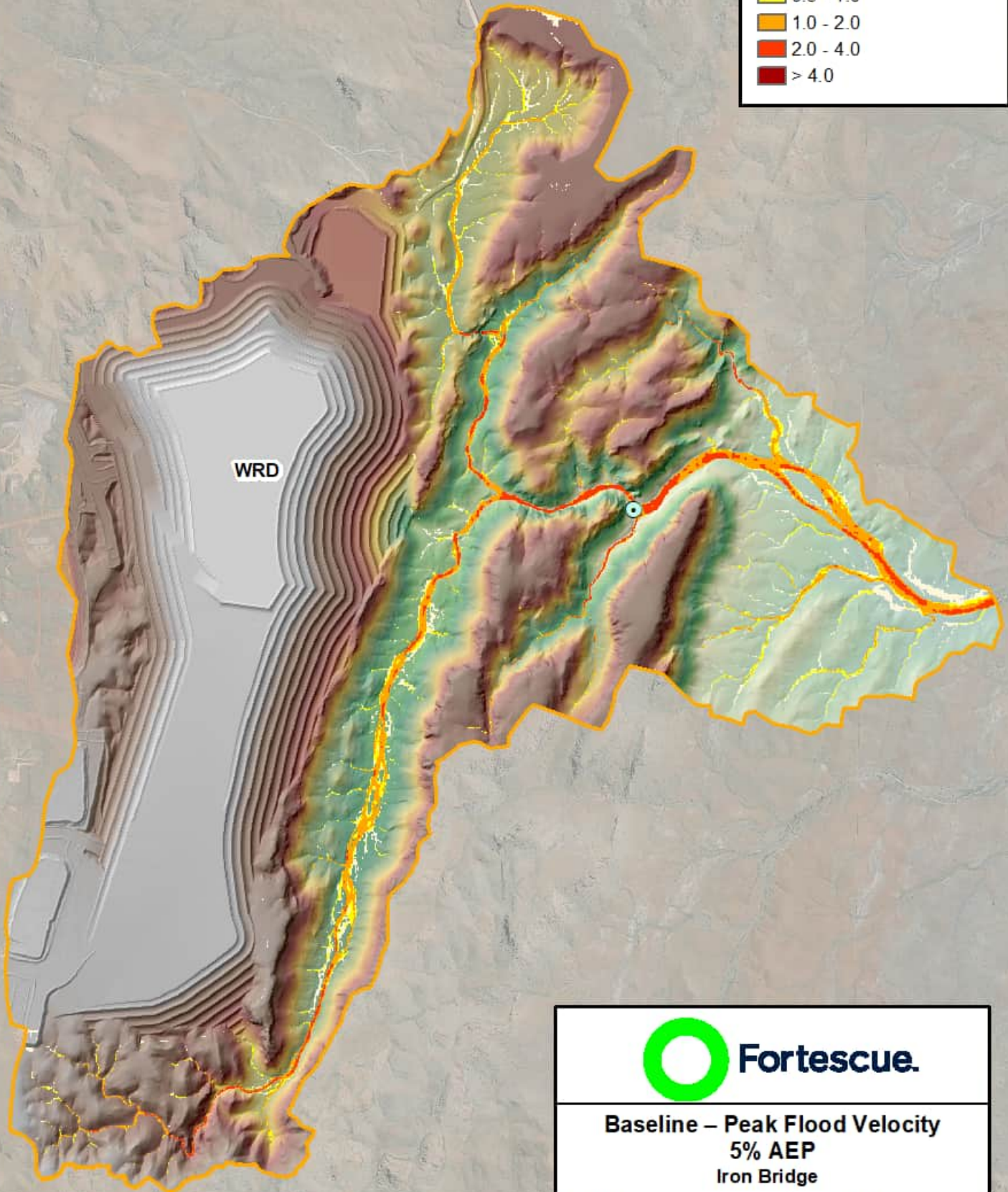
**Baseline – Peak Flood Depth
5% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



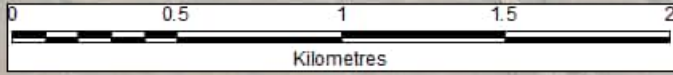
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












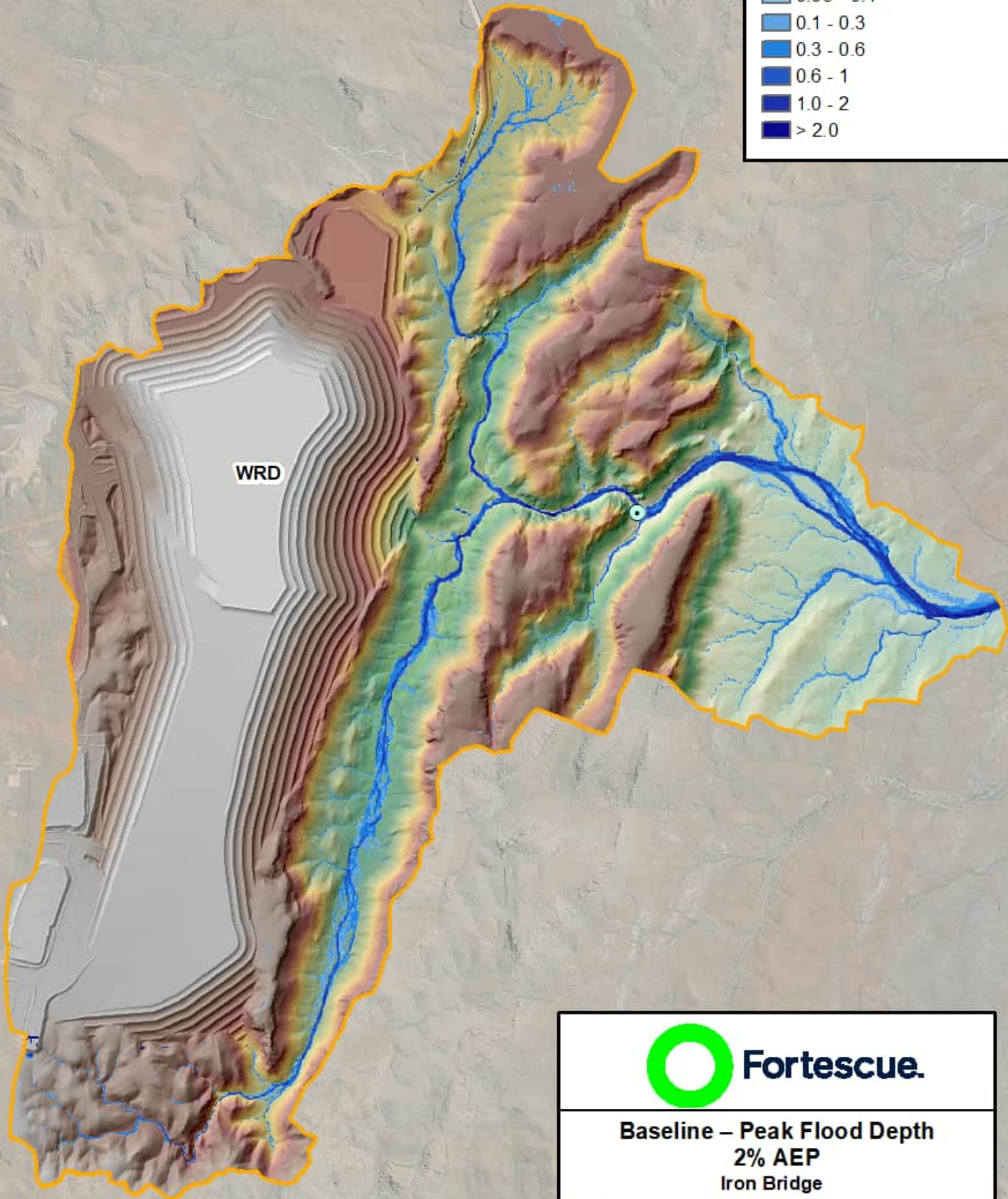
**Baseline – Peak Flood Velocity
5% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



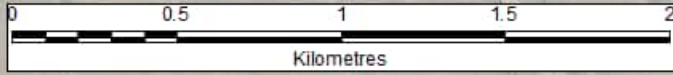
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










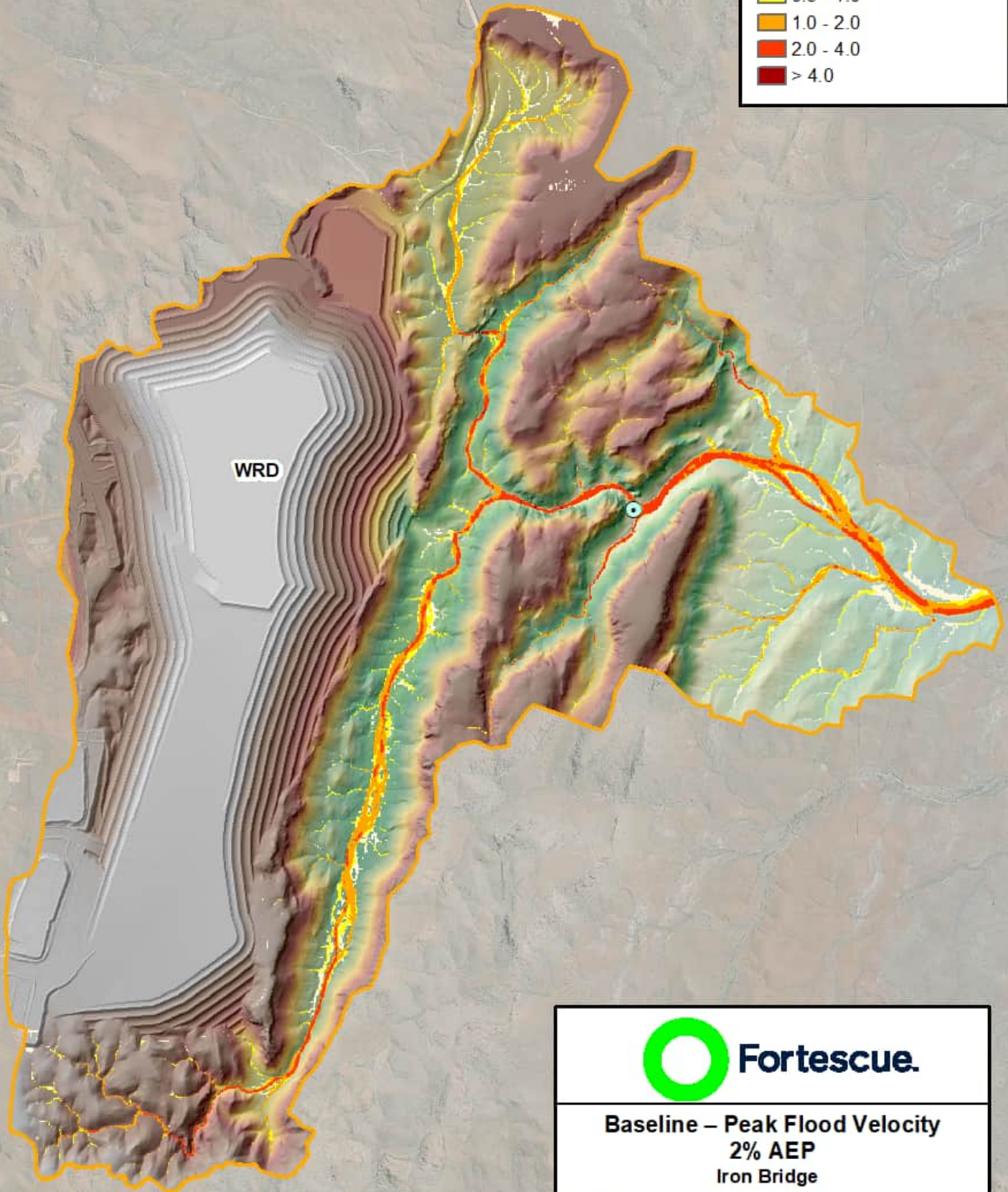
**Baseline – Peak Flood Depth
2% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



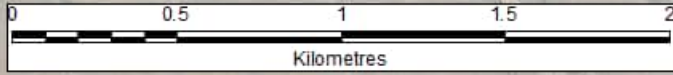
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












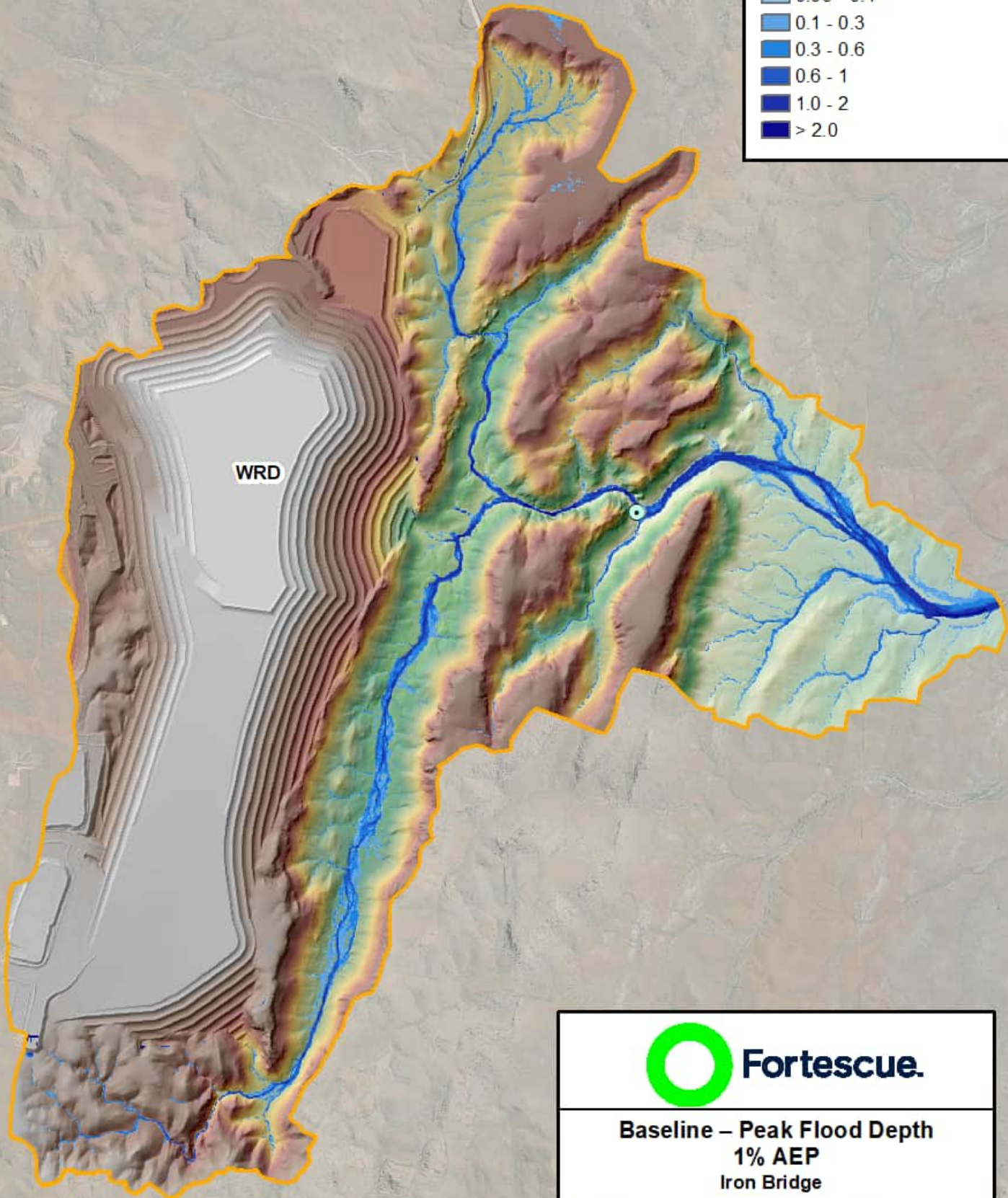
**Baseline – Peak Flood Velocity
2% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



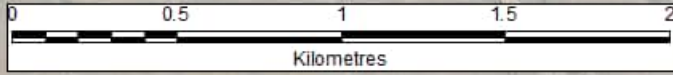
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










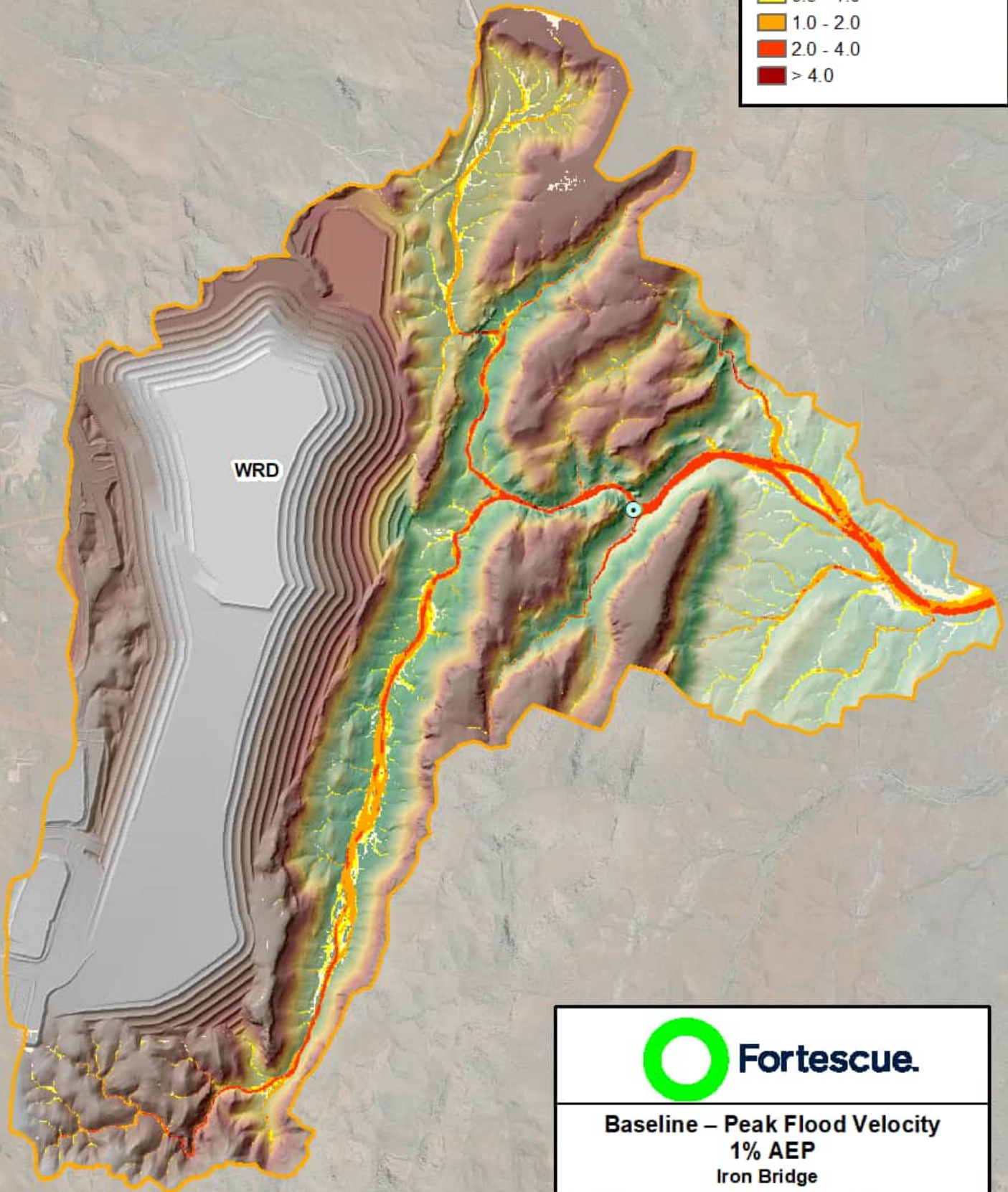
**Baseline – Peak Flood Depth
1% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



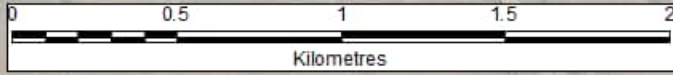
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












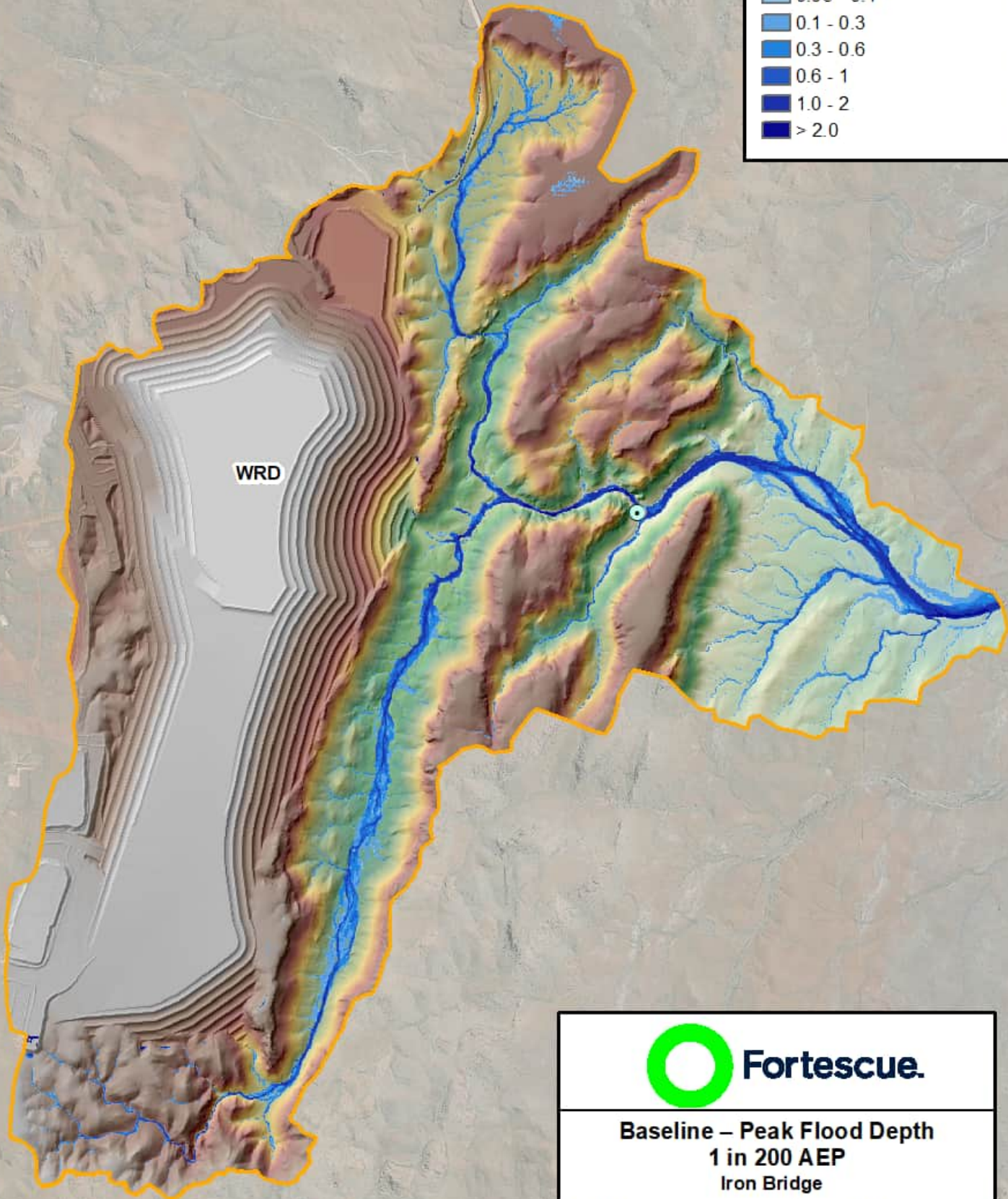
**Baseline – Peak Flood Velocity
1% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



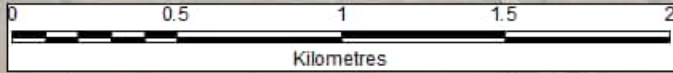
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










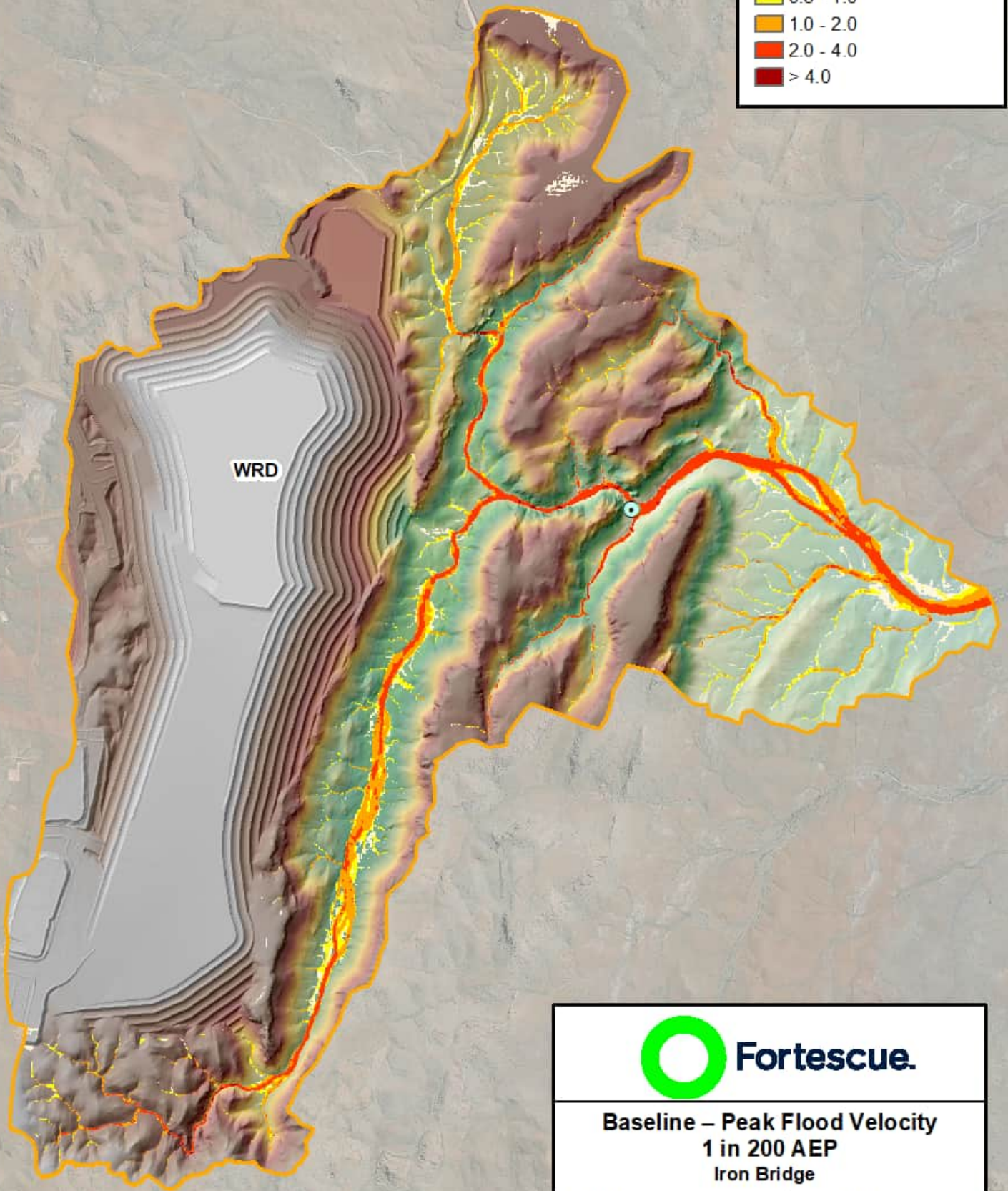
**Baseline – Peak Flood Depth
1 in 200 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



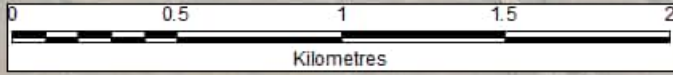
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












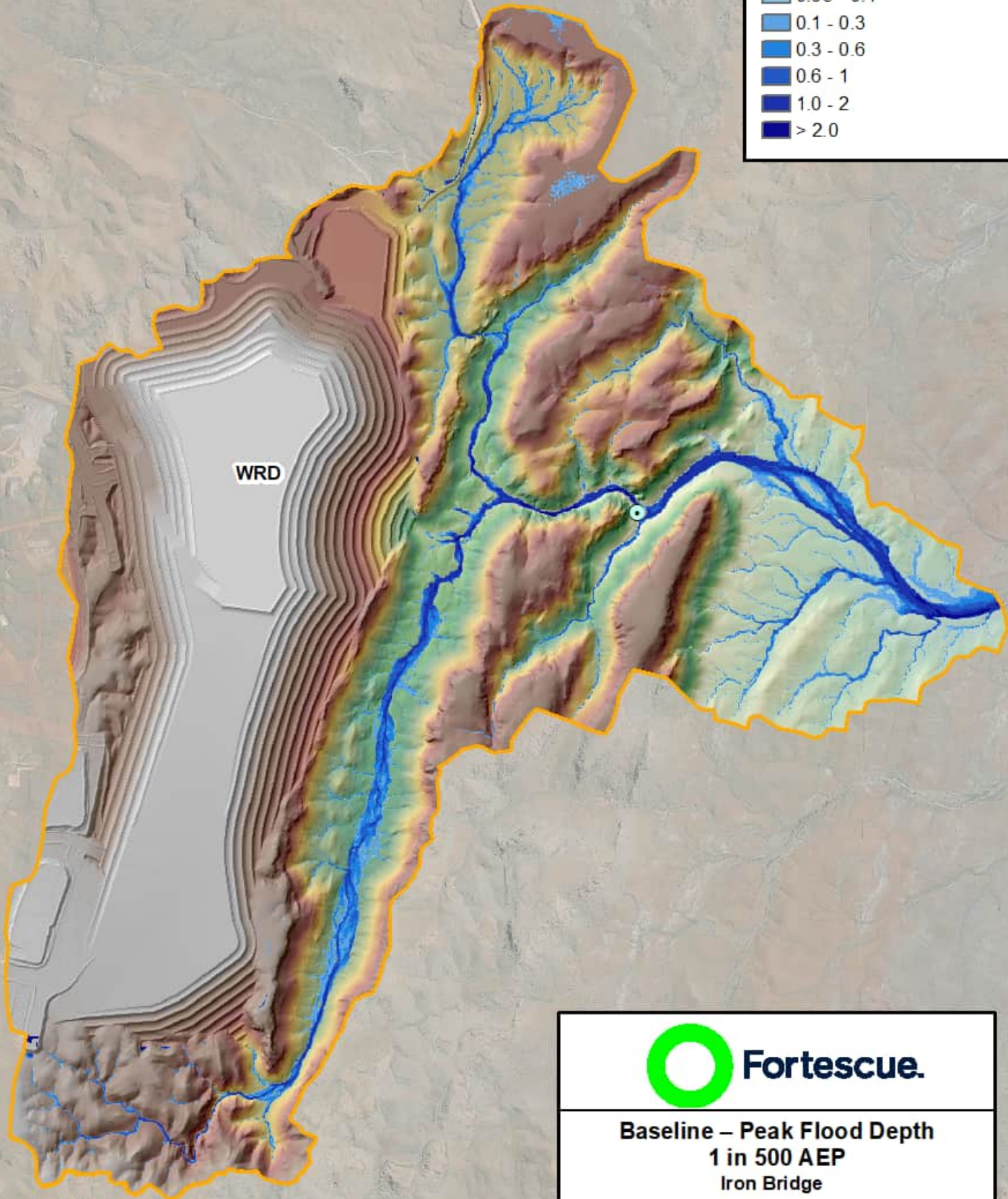
**Baseline – Peak Flood Velocity
1 in 200 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



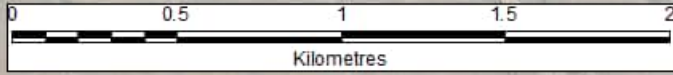
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










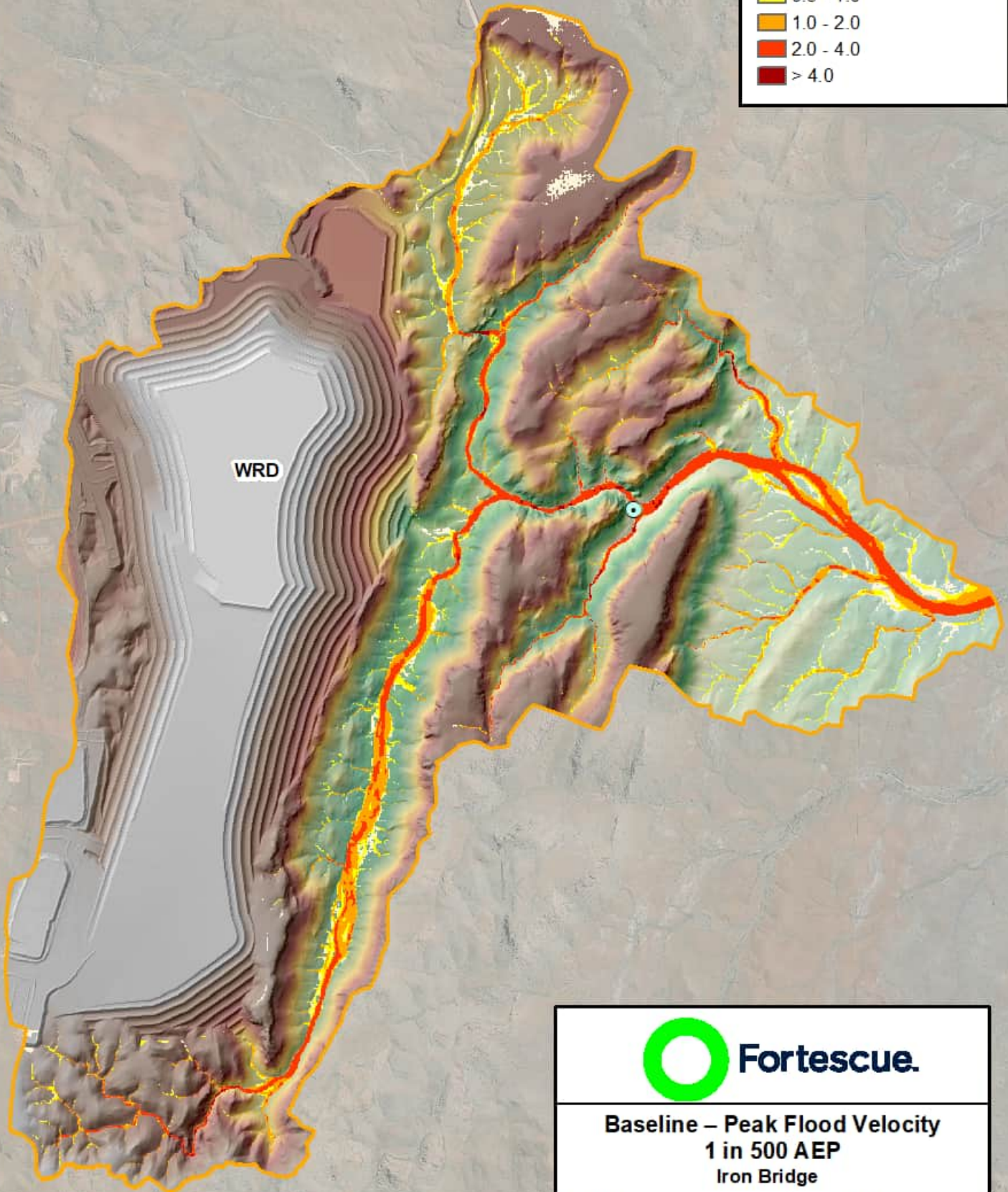
**Baseline – Peak Flood Depth
1 in 500 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



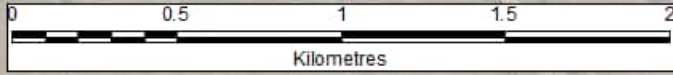
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
 -  0 - 0.5
 -  0.5 - 1.0
 -  1.0 - 2.0
 -  2.0 - 4.0
 -  > 4.0












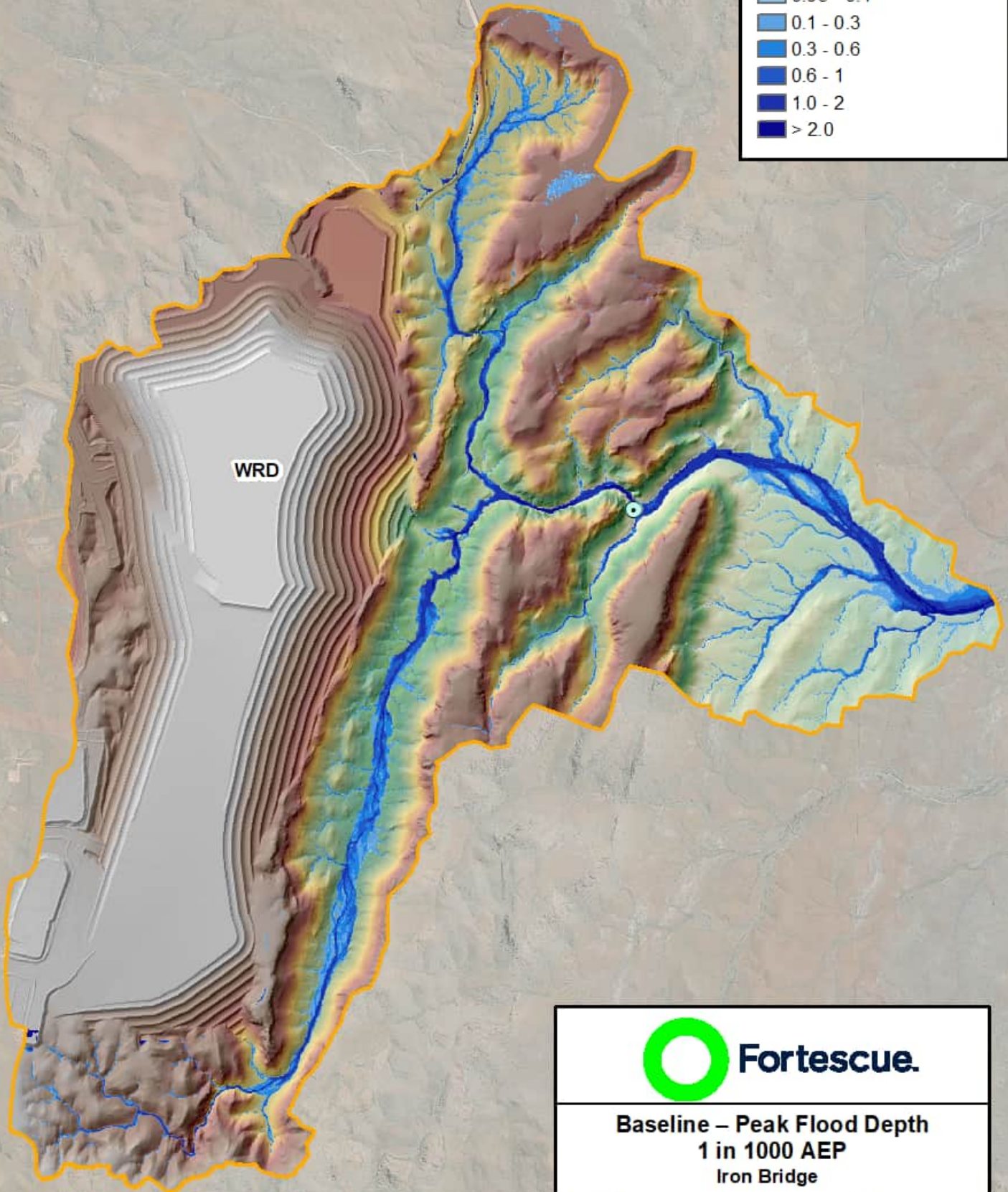
**Baseline – Peak Flood Velocity
1 in 500 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



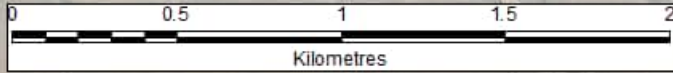
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










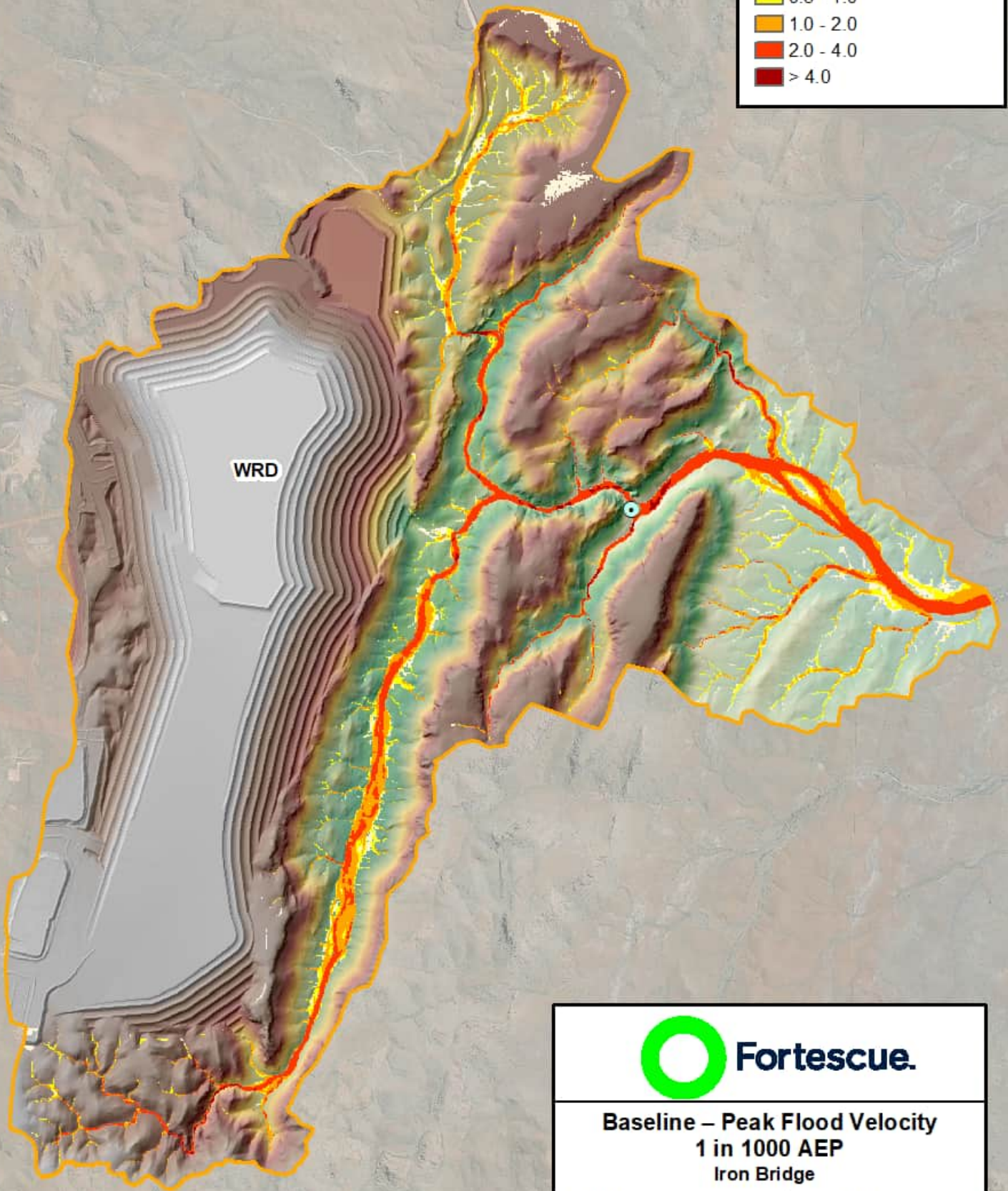
**Baseline – Peak Flood Depth
1 in 1000 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



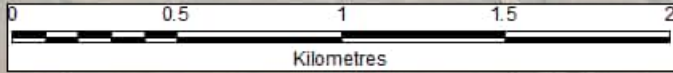
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0











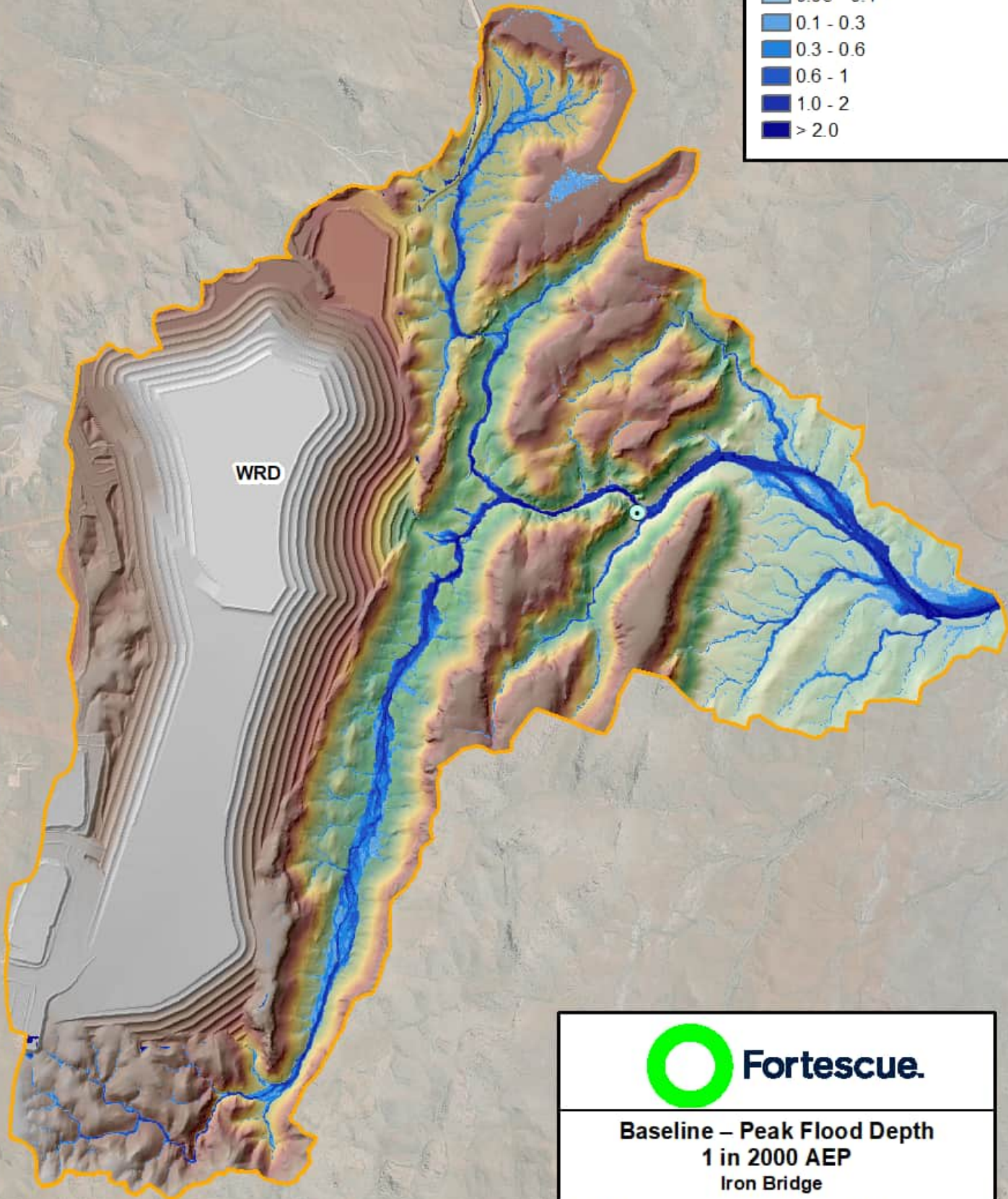
**Baseline – Peak Flood Velocity
1 in 1000 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



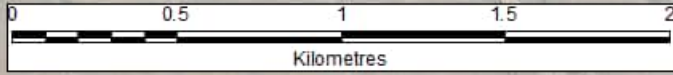
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










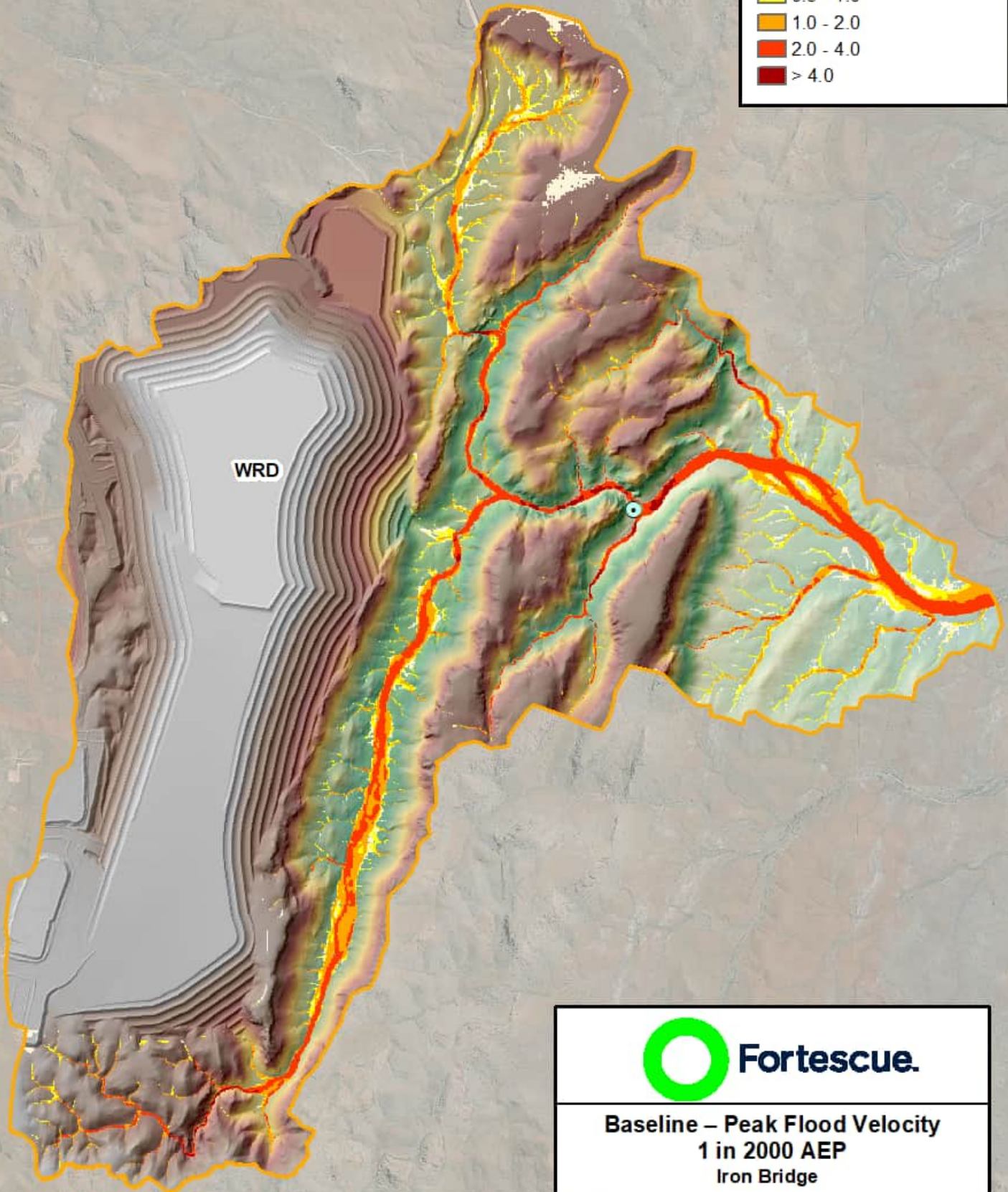
**Baseline – Peak Flood Depth
1 in 2000 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



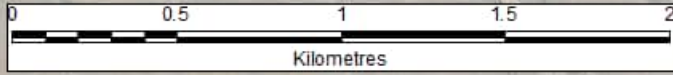
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












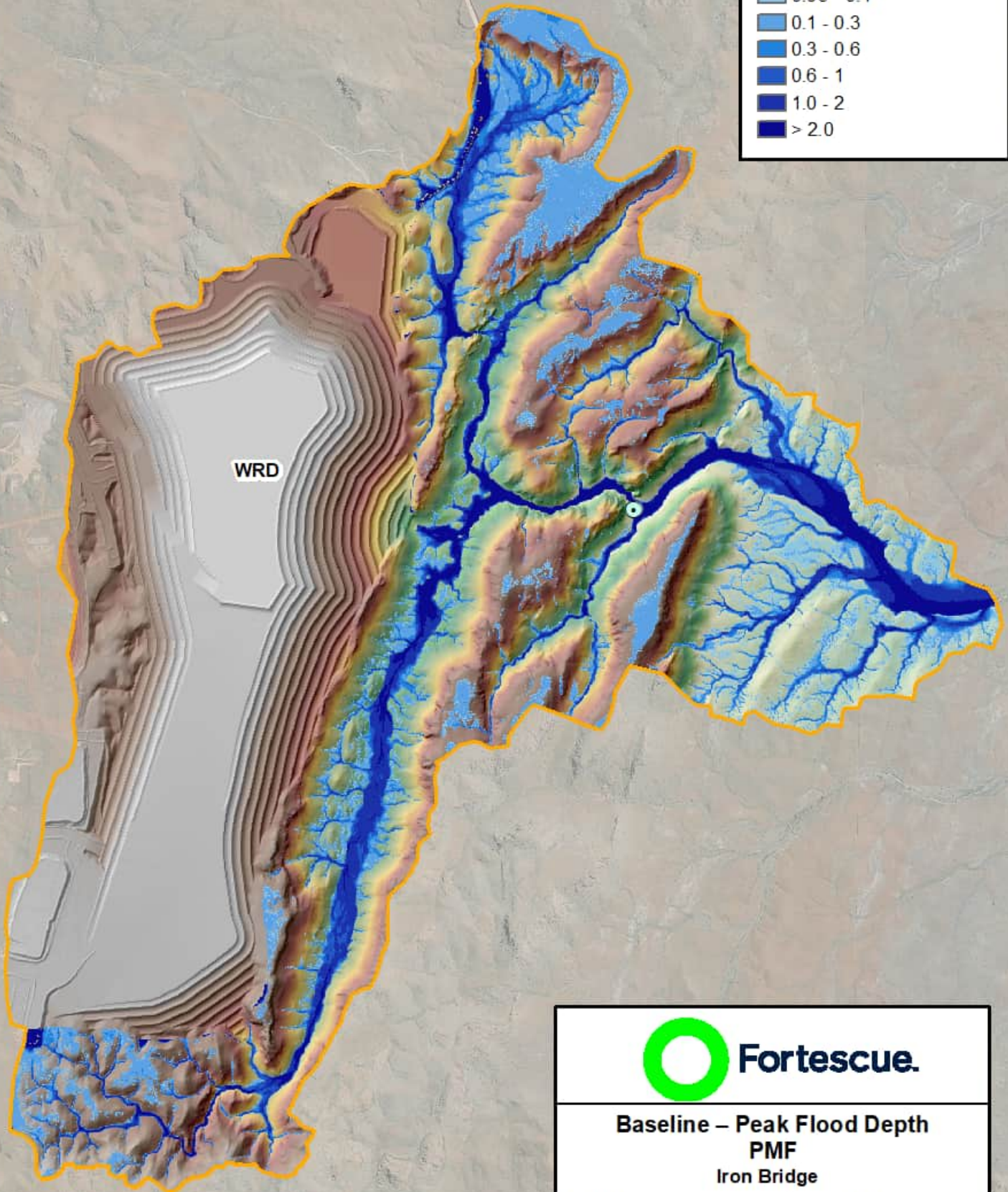
**Baseline – Peak Flood Velocity
1 in 2000 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



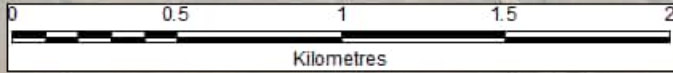
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










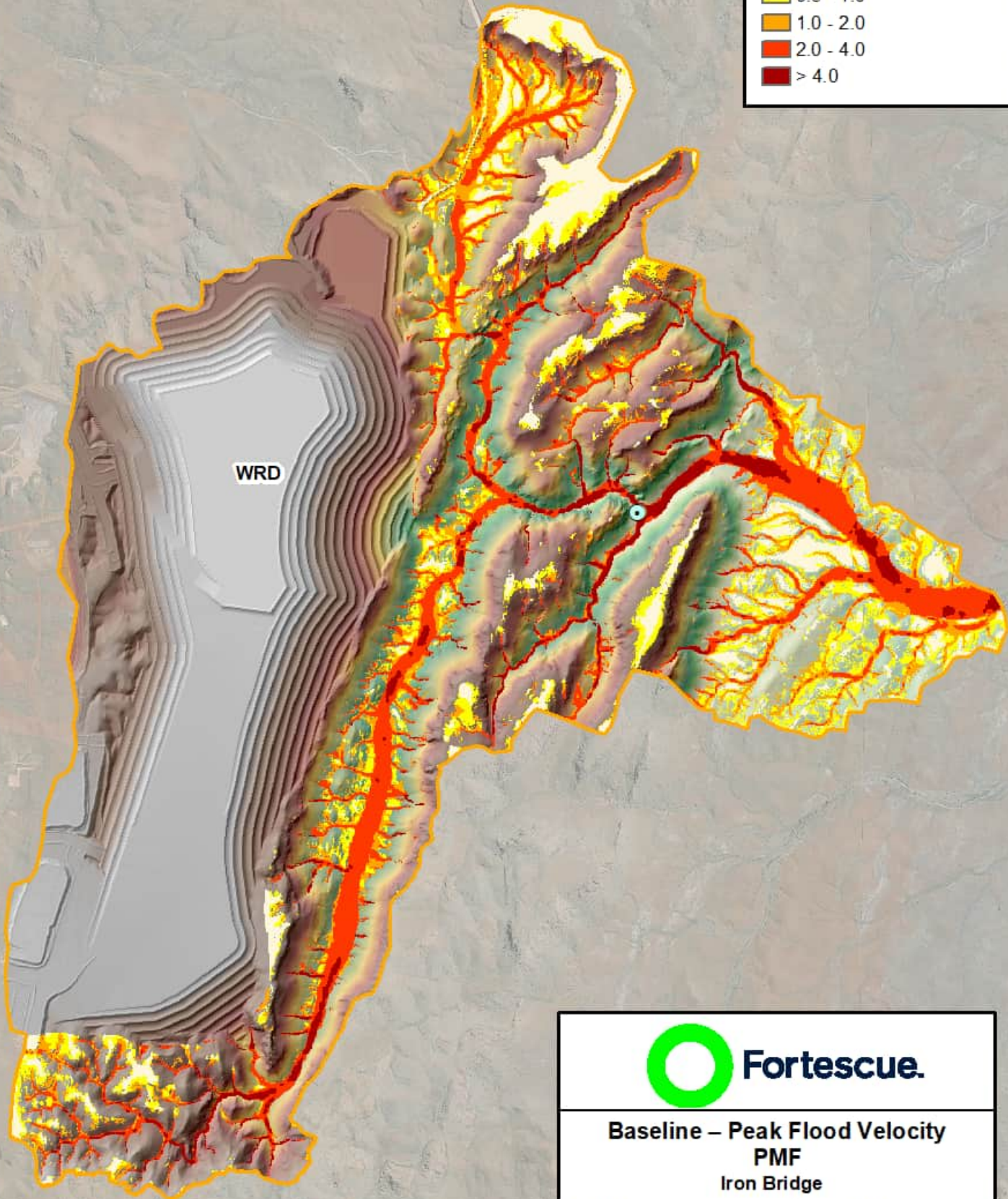
**Baseline – Peak Flood Depth
PMF
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



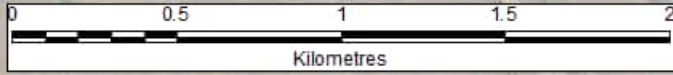
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












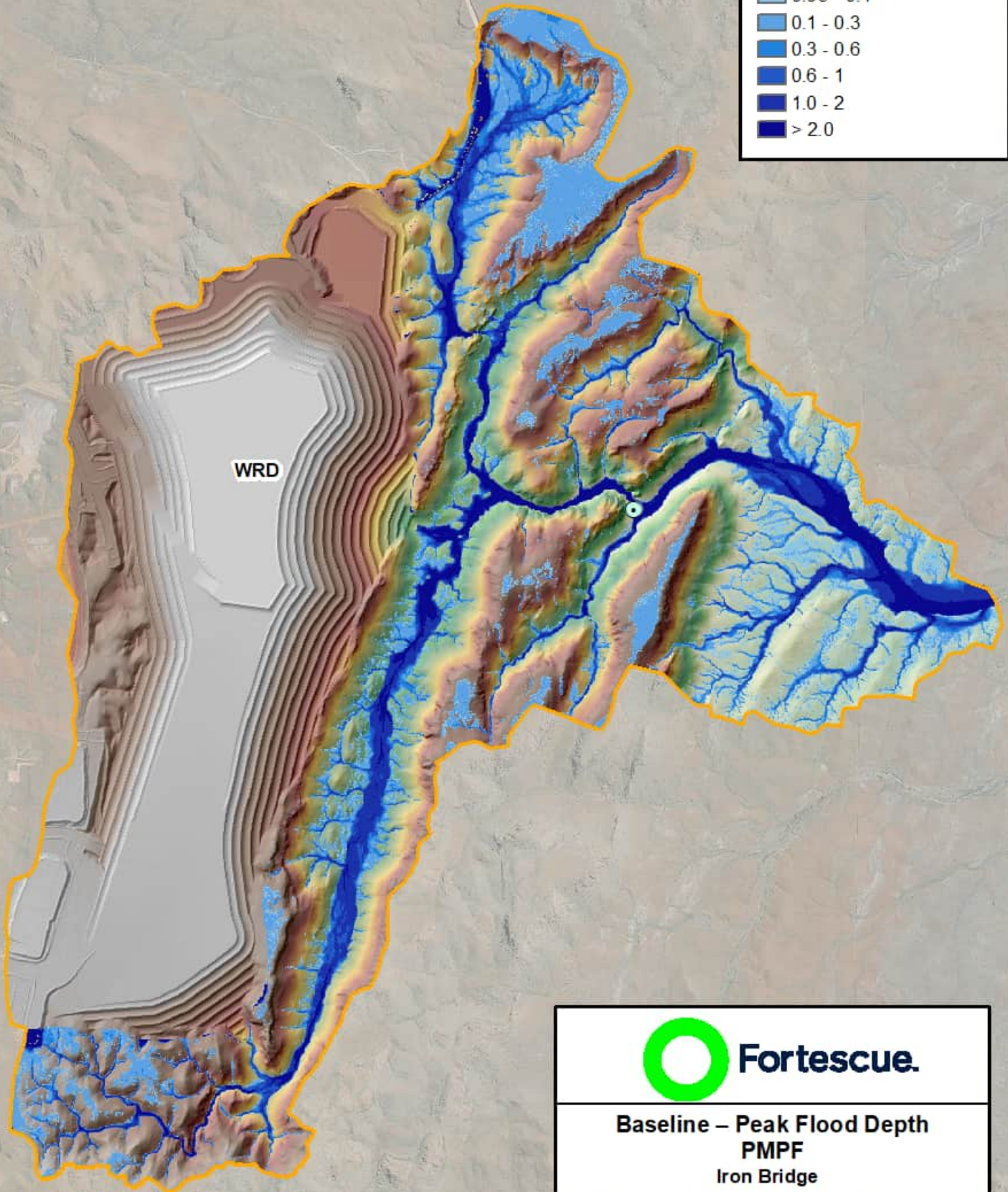
**Baseline – Peak Flood Velocity
PMF
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	



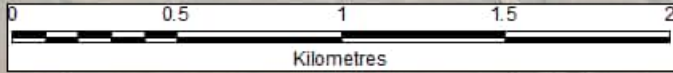
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










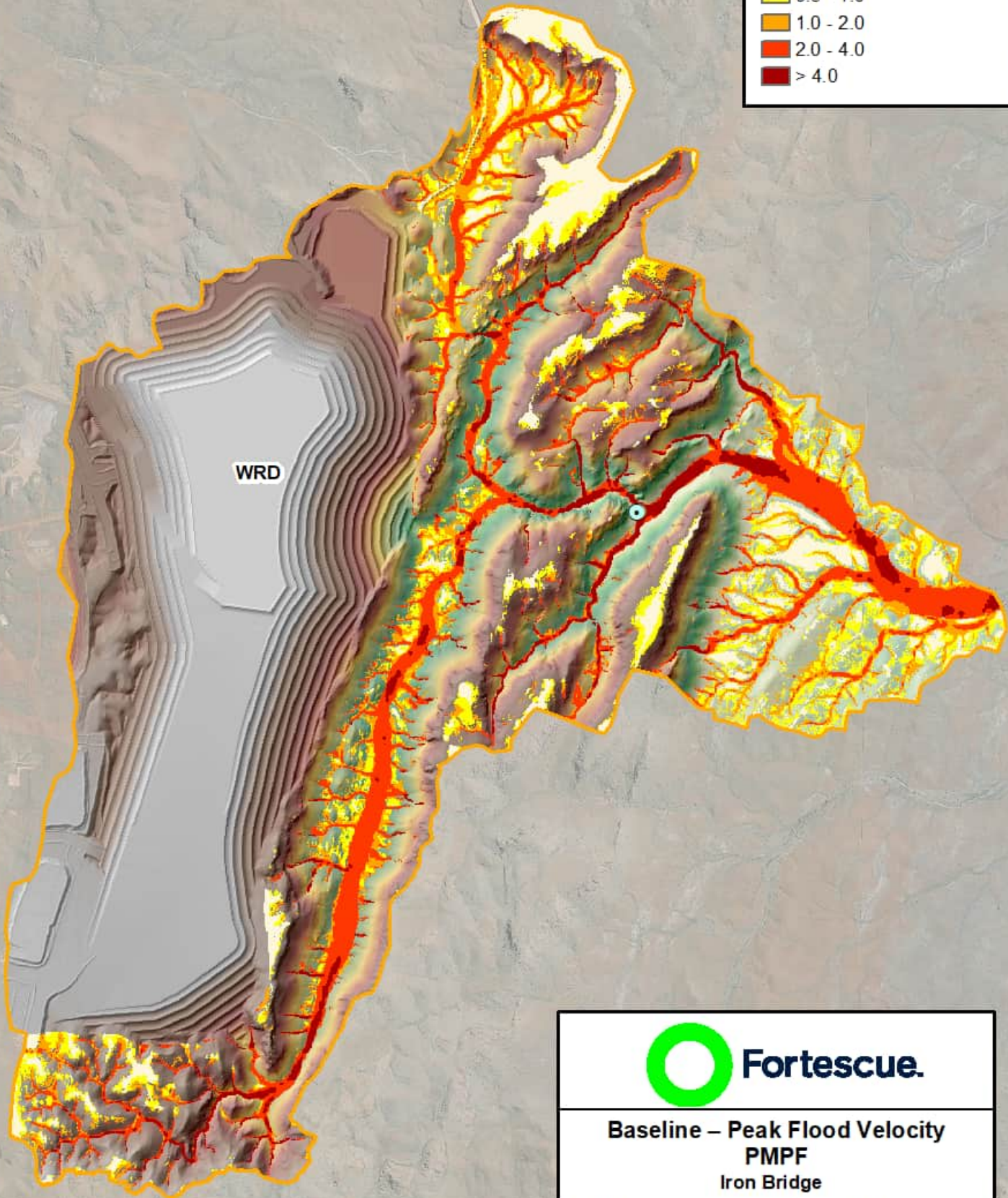
**Baseline – Peak Flood Depth
PMPF
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Baseline_A4	



LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
 -  0 - 0.5
 -  0.5 - 1.0
 -  1.0 - 2.0
 -  2.0 - 4.0
 -  > 4.0

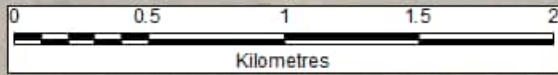


**Baseline – Peak Flood Velocity
PMPF
Iron Bridge**










Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_Baseline_A4	

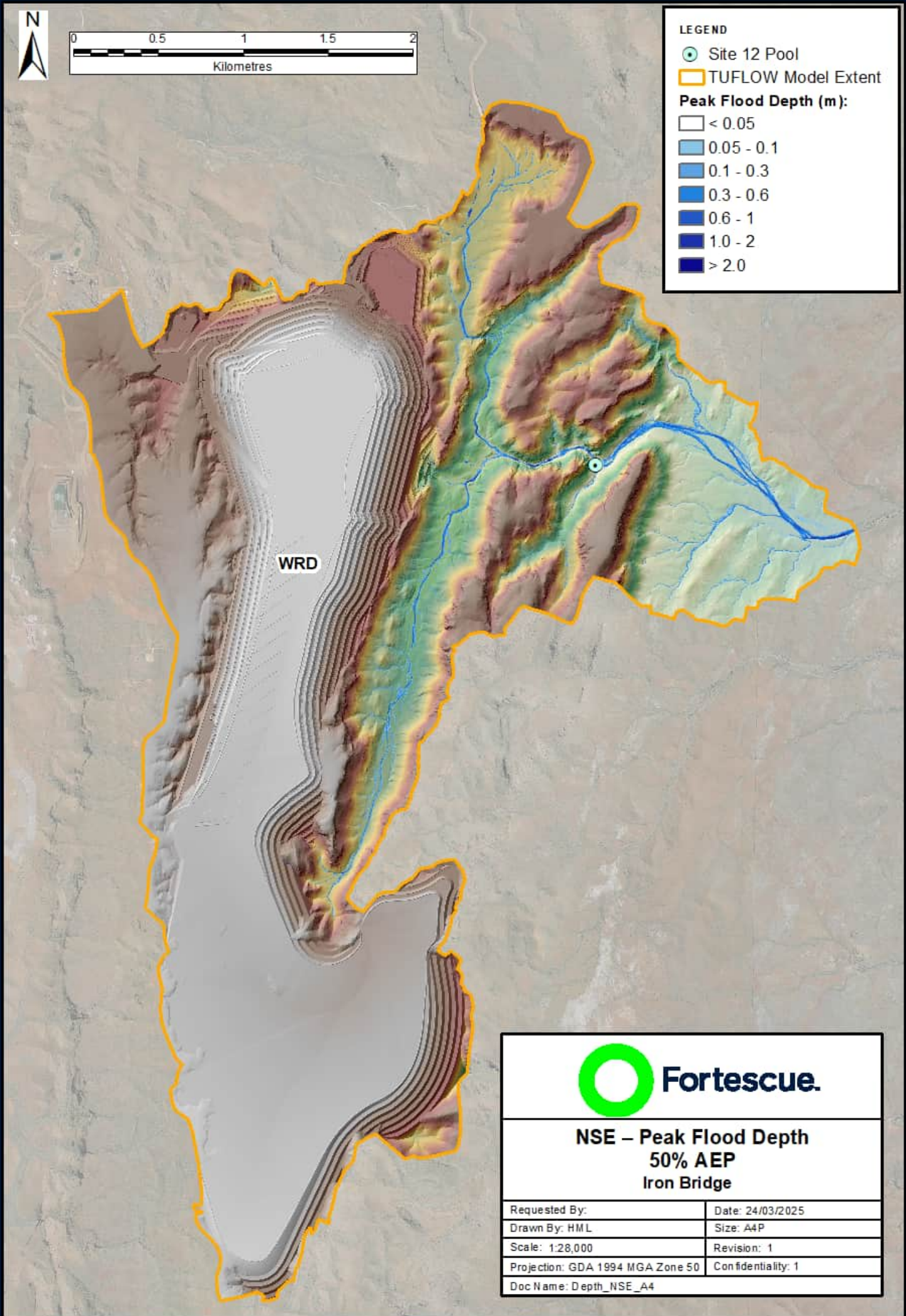


APPENDIX E NSE CONDITION FLOOD MAPPING



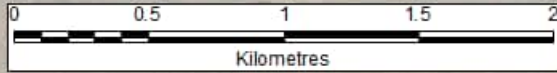
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










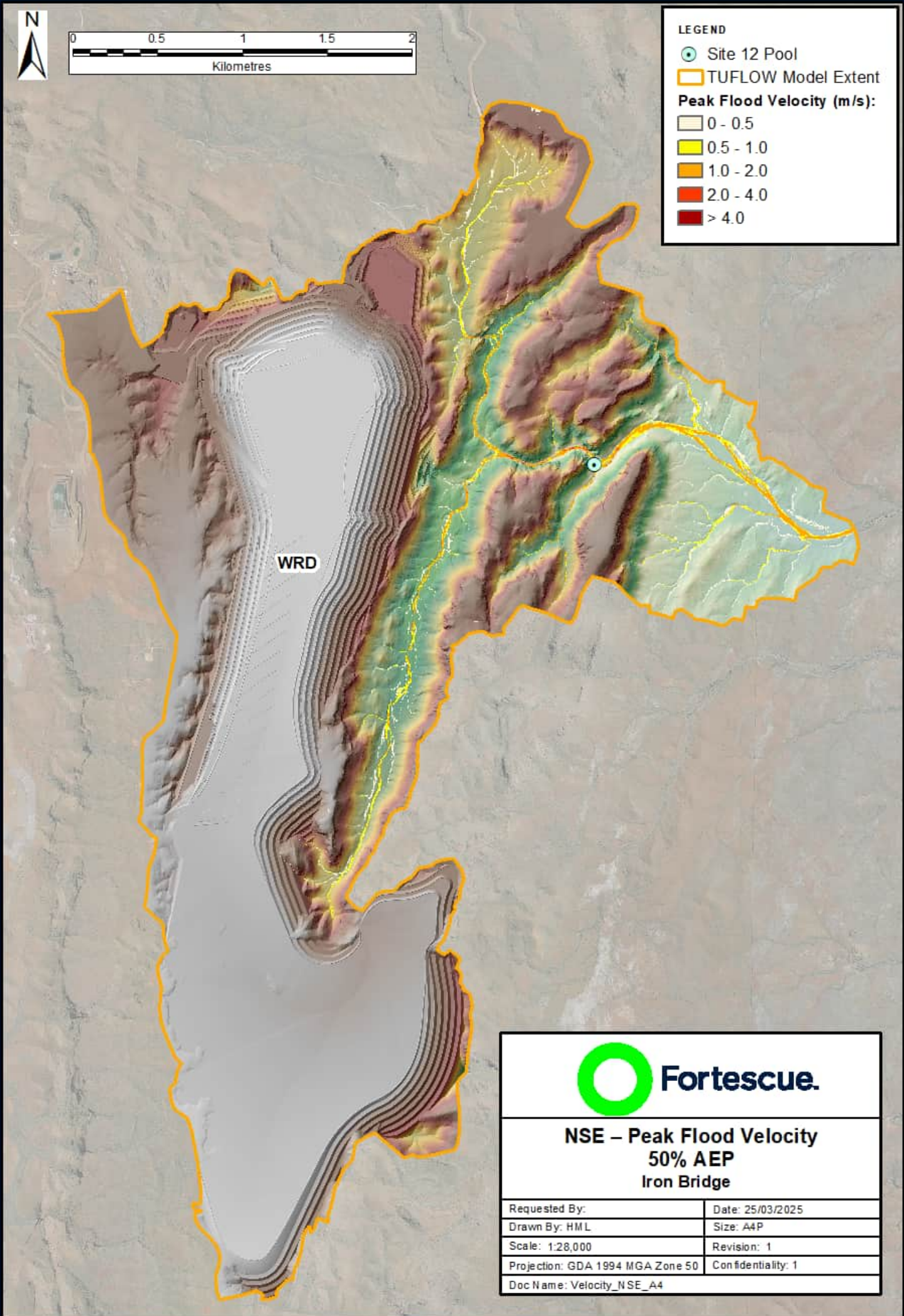
**NSE – Peak Flood Depth
50% AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



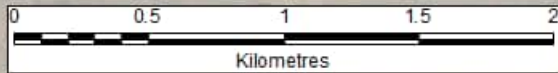
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












**NSE – Peak Flood Velocity
50% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



LEGEND

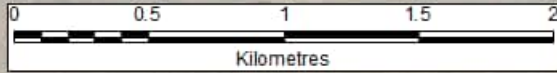
-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0

WRD










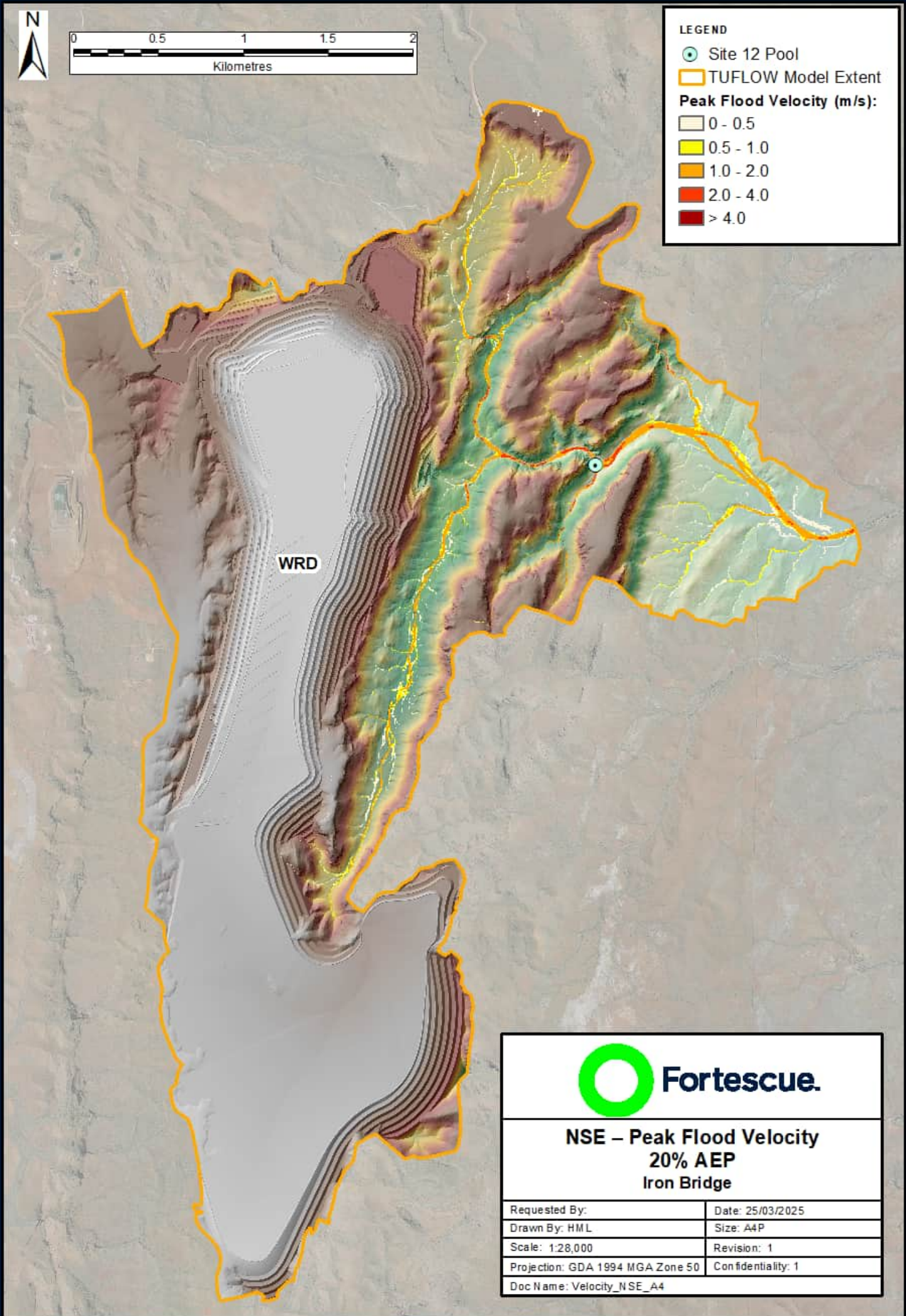
**NSE – Peak Flood Depth
20% AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



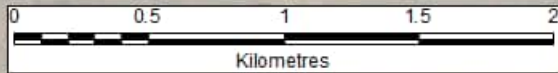
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
 -  0 - 0.5
 -  0.5 - 1.0
 -  1.0 - 2.0
 -  2.0 - 4.0
 -  > 4.0












**NSE – Peak Flood Velocity
20% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



LEGEND

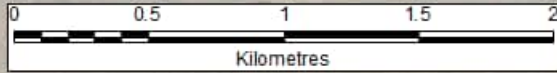
-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0

WRD










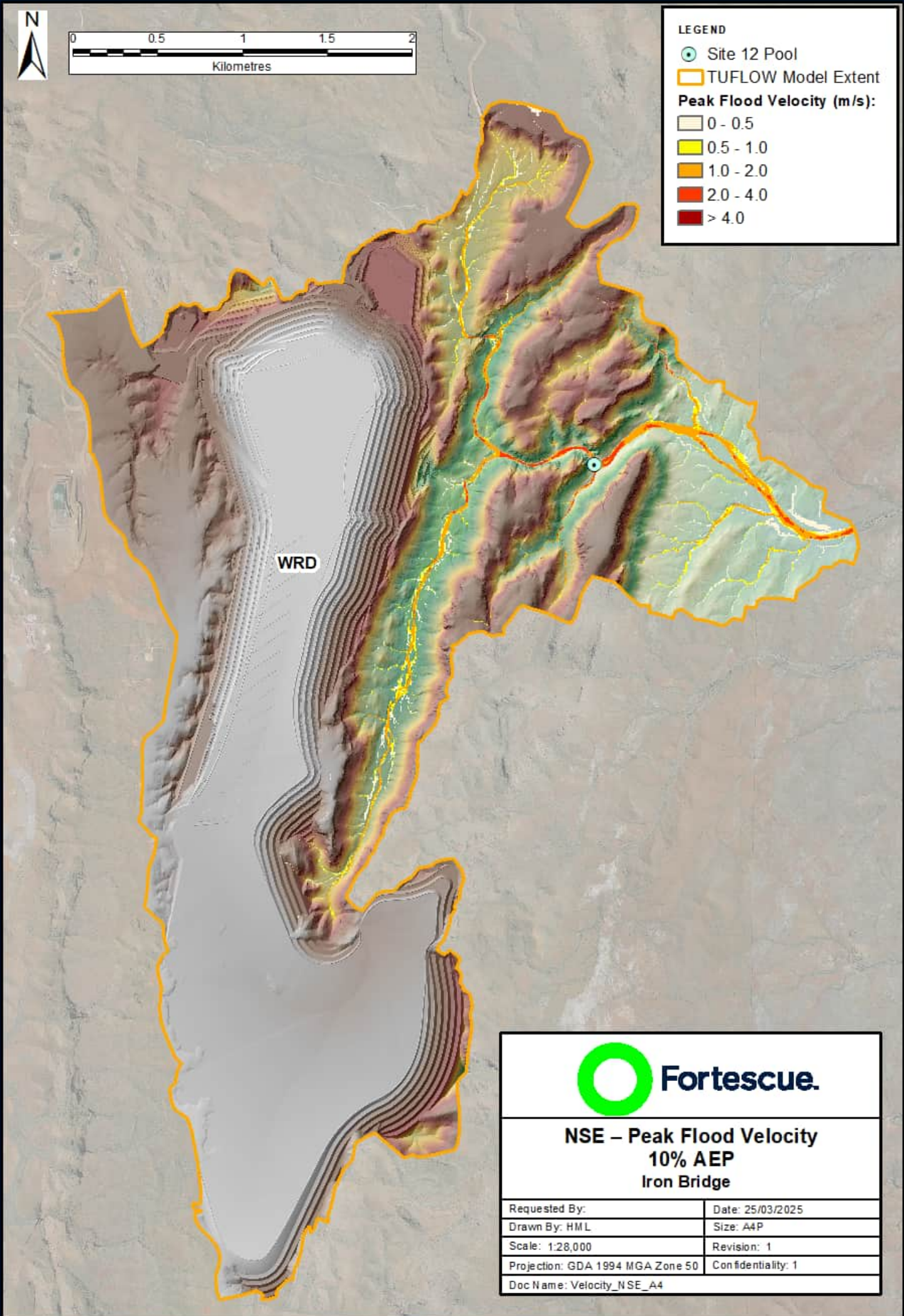
**NSE – Peak Flood Depth
10% AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



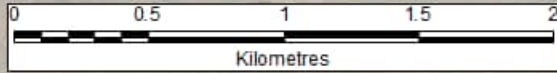
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












**NSE – Peak Flood Velocity
10% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



LEGEND

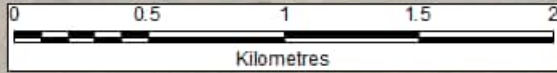
-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0

WRD










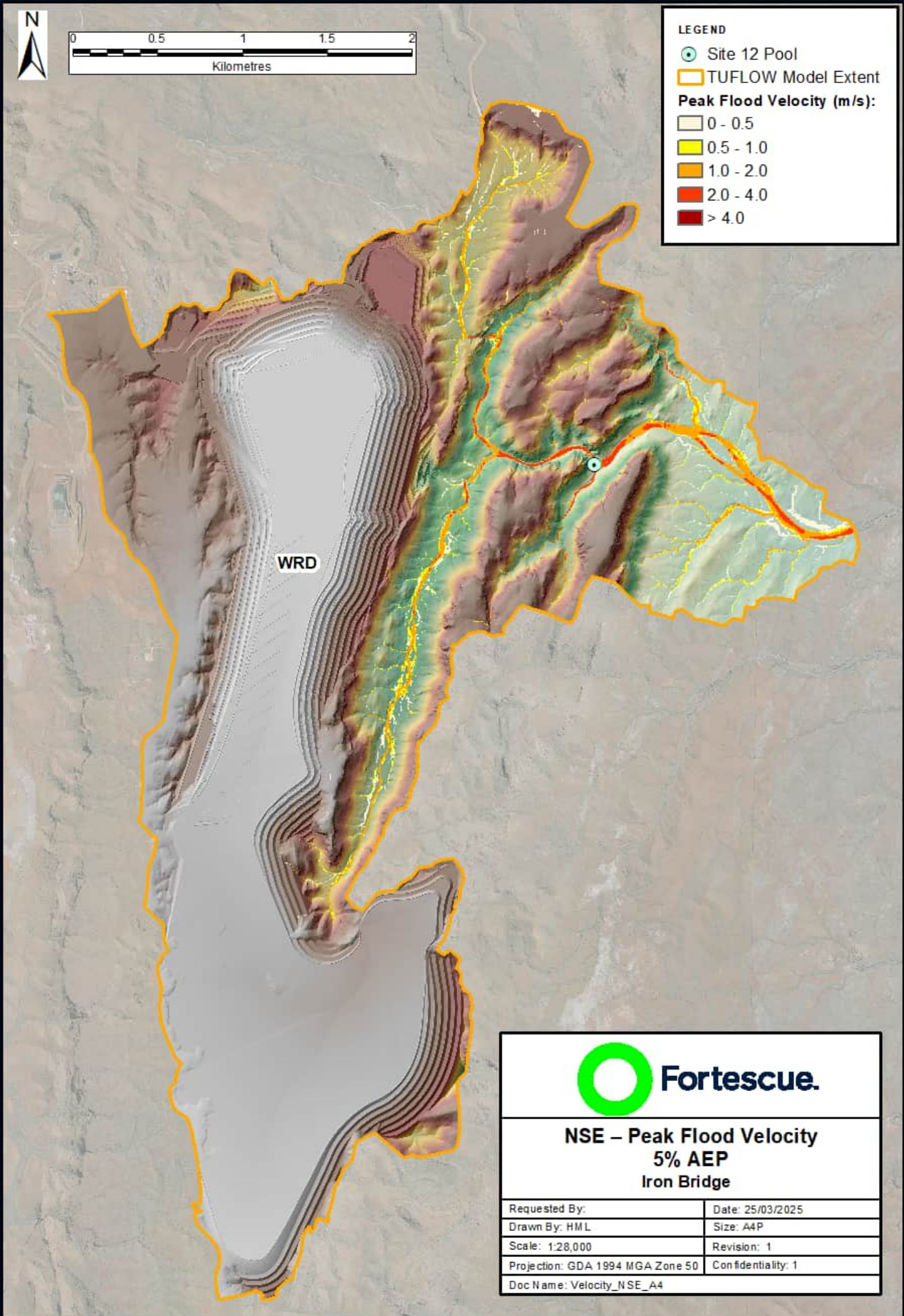
**NSE – Peak Flood Depth
5% AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



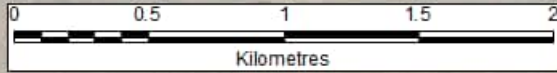
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












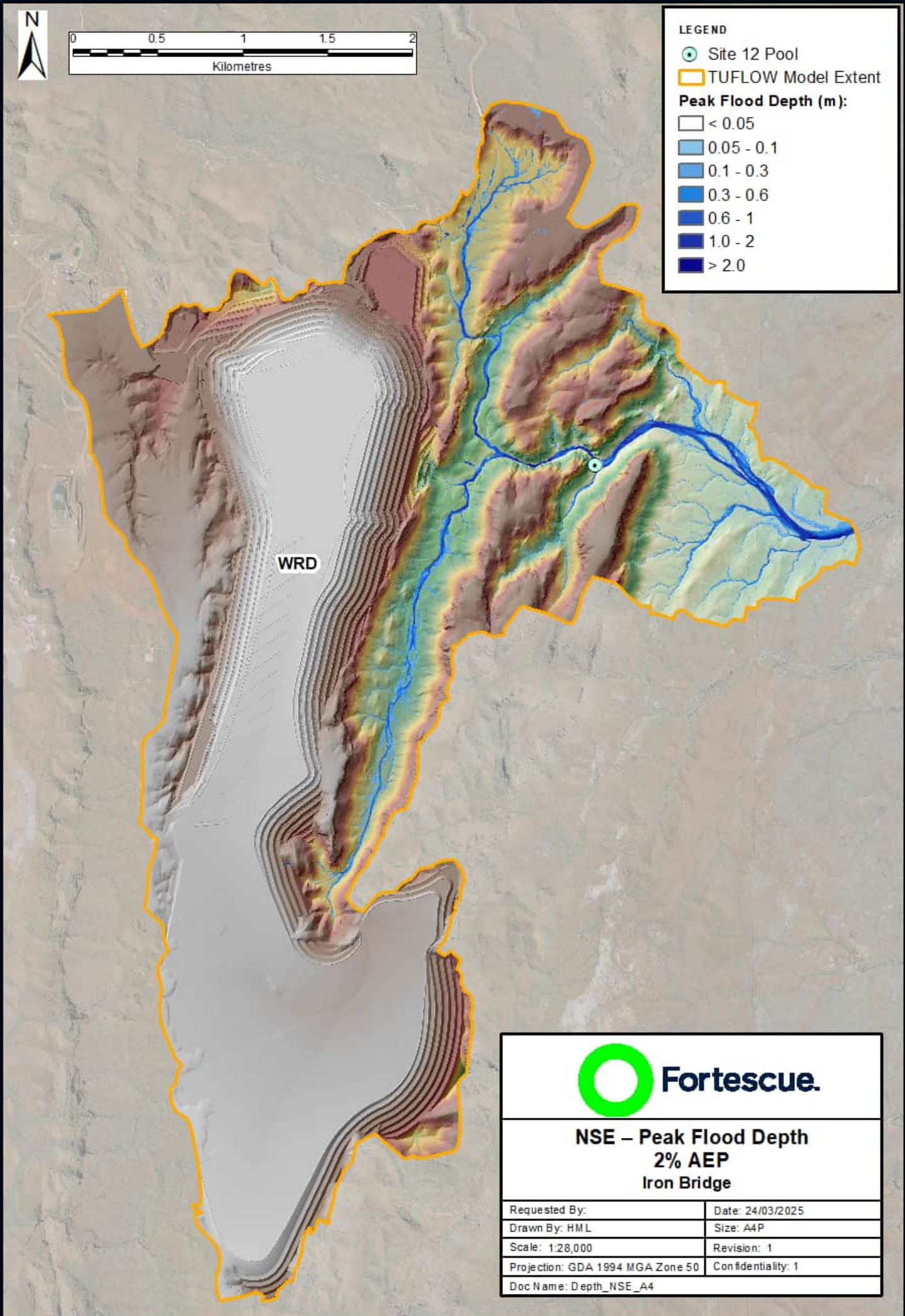
**NSE – Peak Flood Velocity
5% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



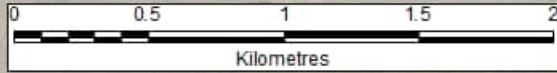
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










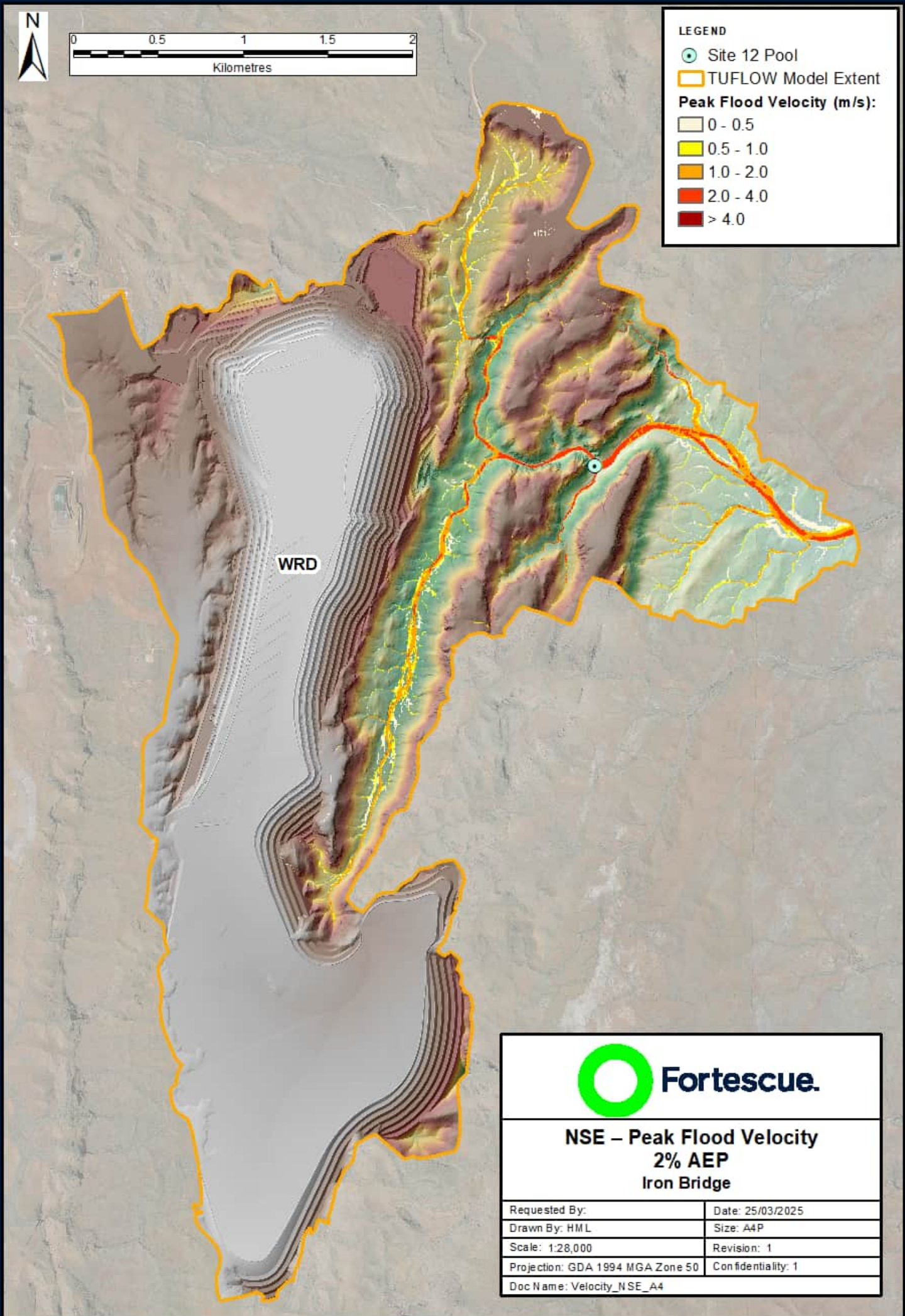
**NSE – Peak Flood Depth
2% AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



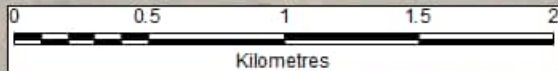
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












**NSE – Peak Flood Velocity
2% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



LEGEND

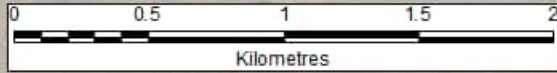
-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0

WRD










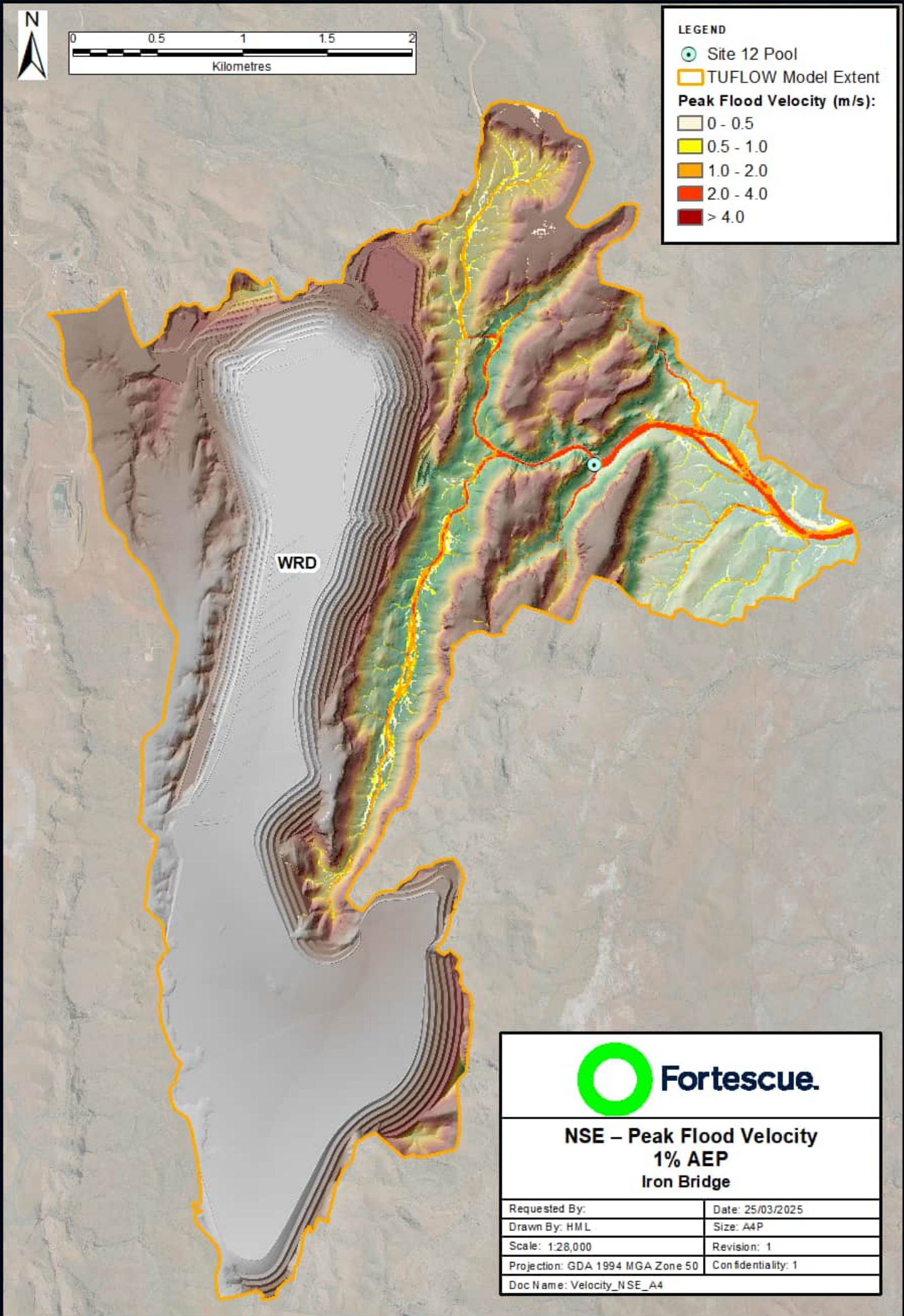
**NSE – Peak Flood Depth
1% AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



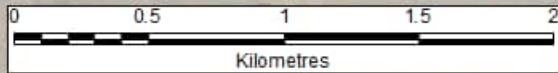
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












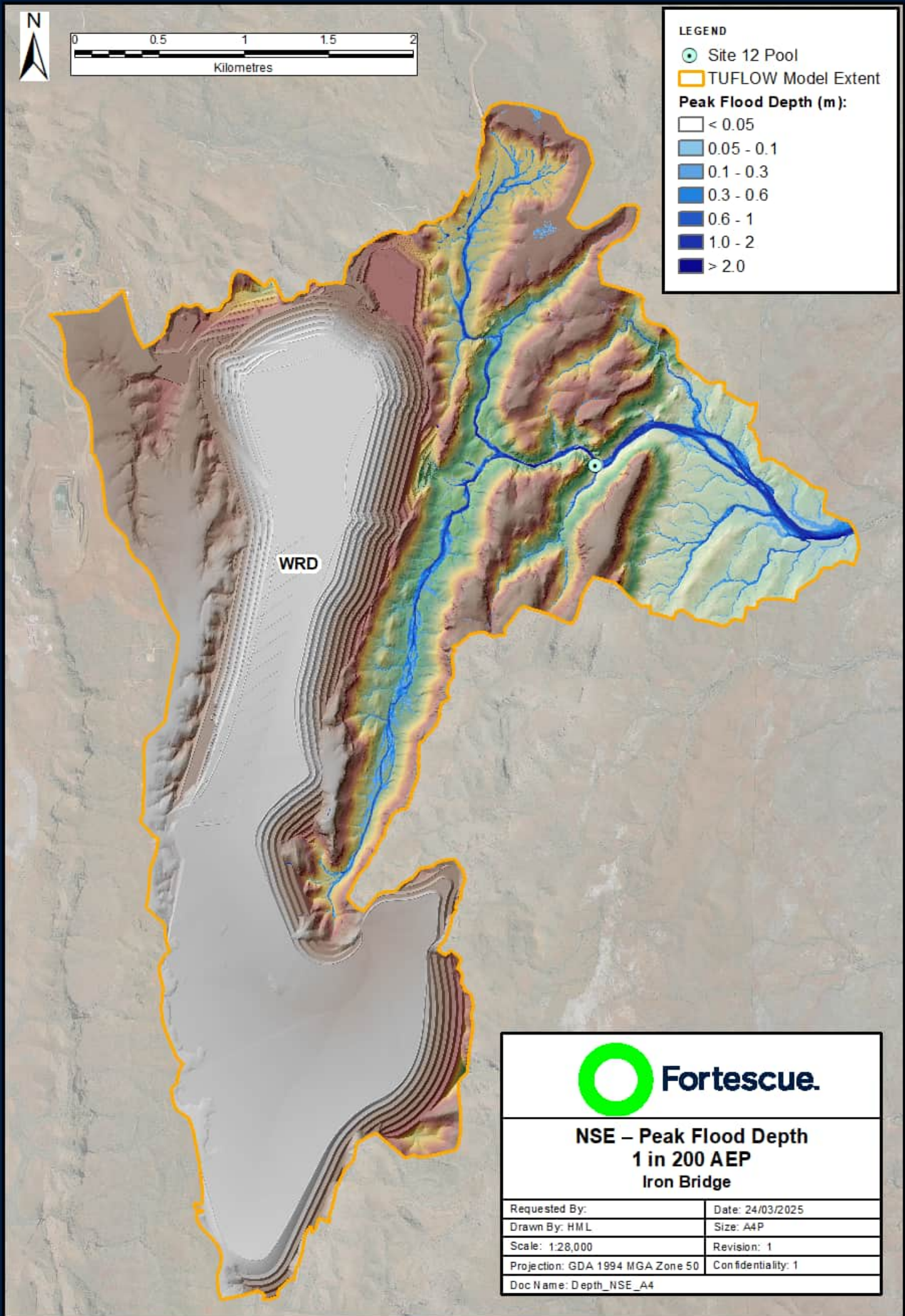
**NSE – Peak Flood Velocity
1% AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



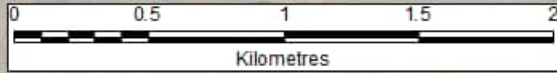
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










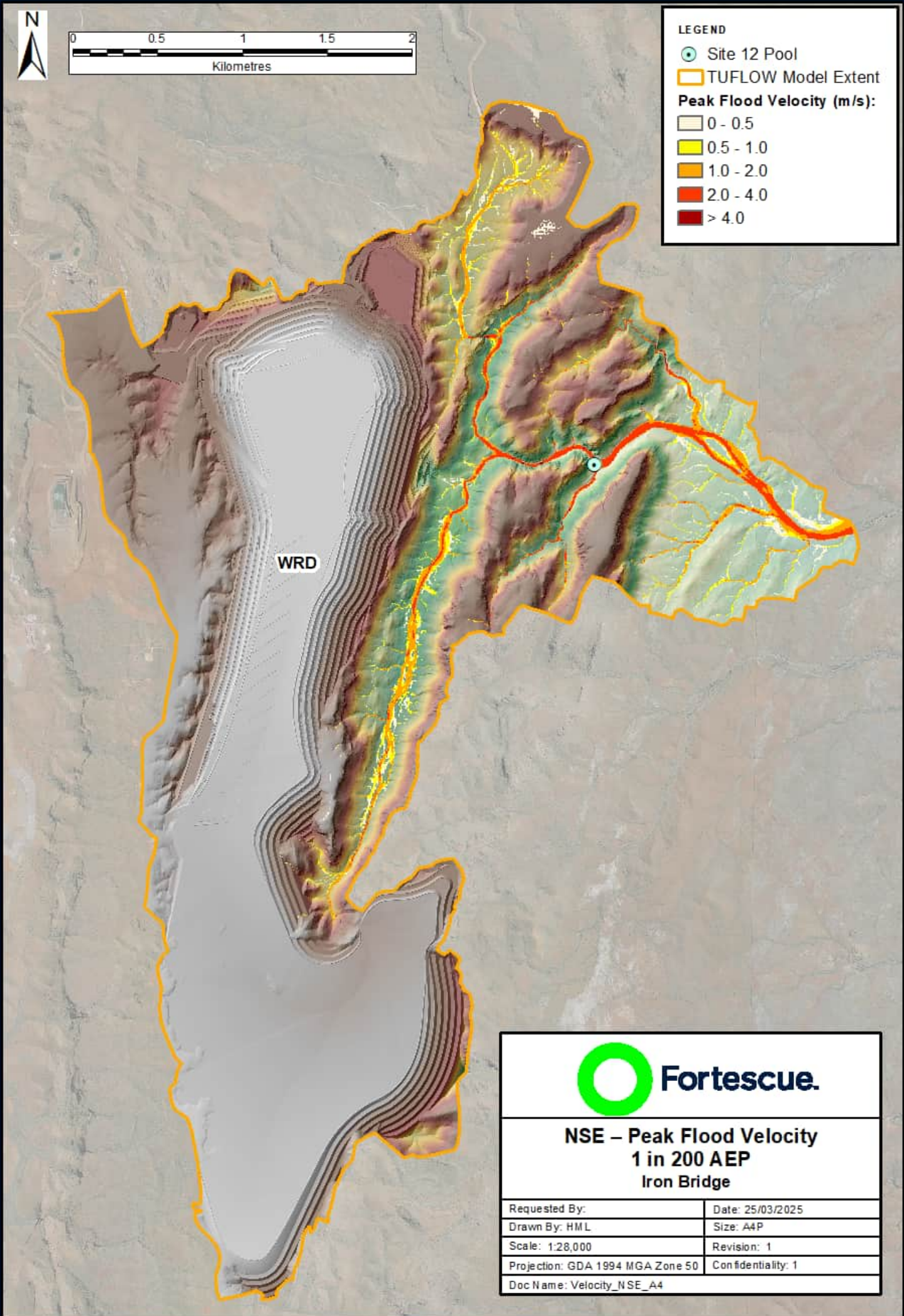
**NSE – Peak Flood Depth
1 in 200 AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



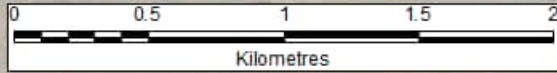
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












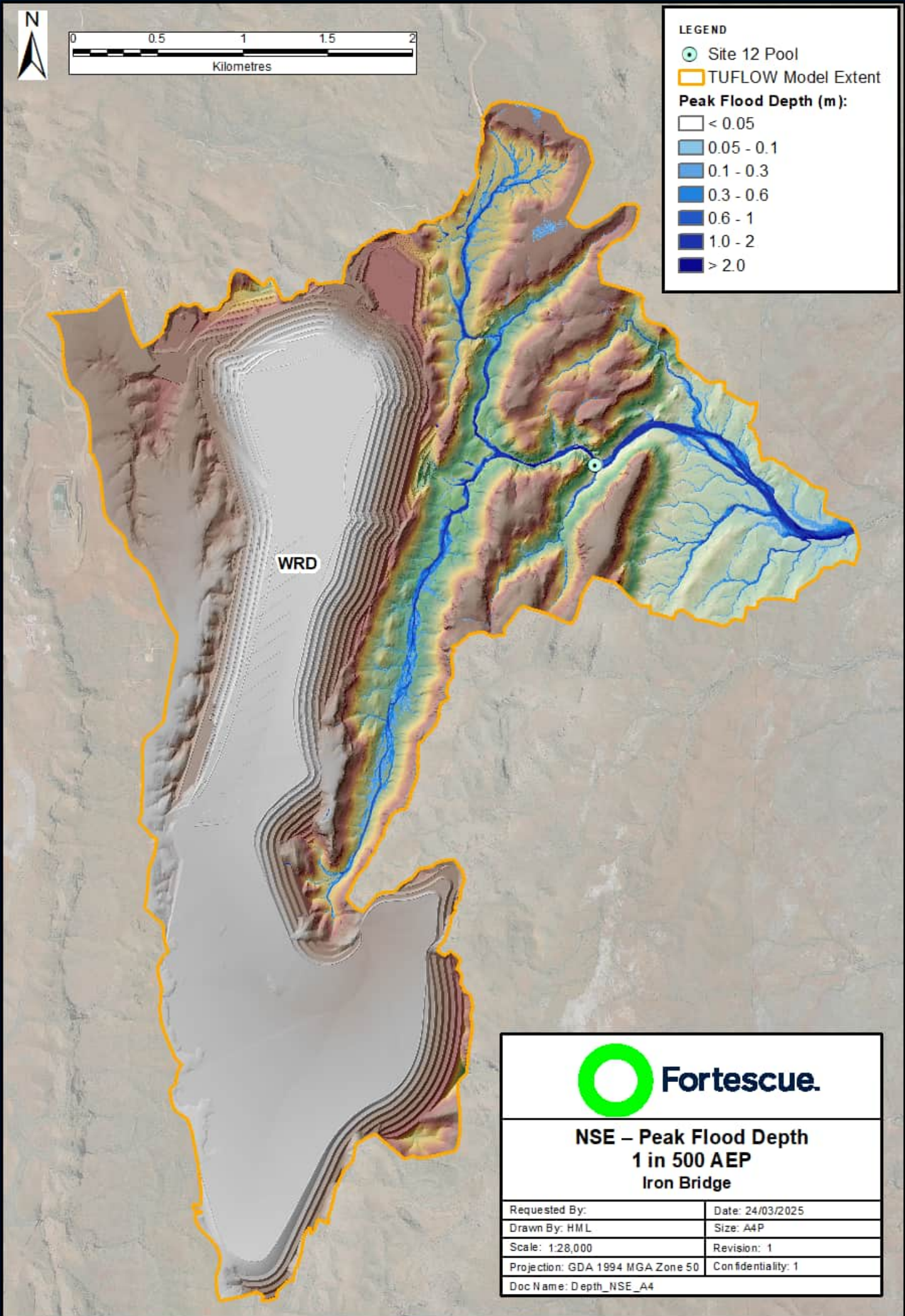
**NSE – Peak Flood Velocity
1 in 200 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



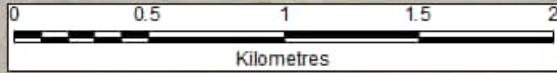
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










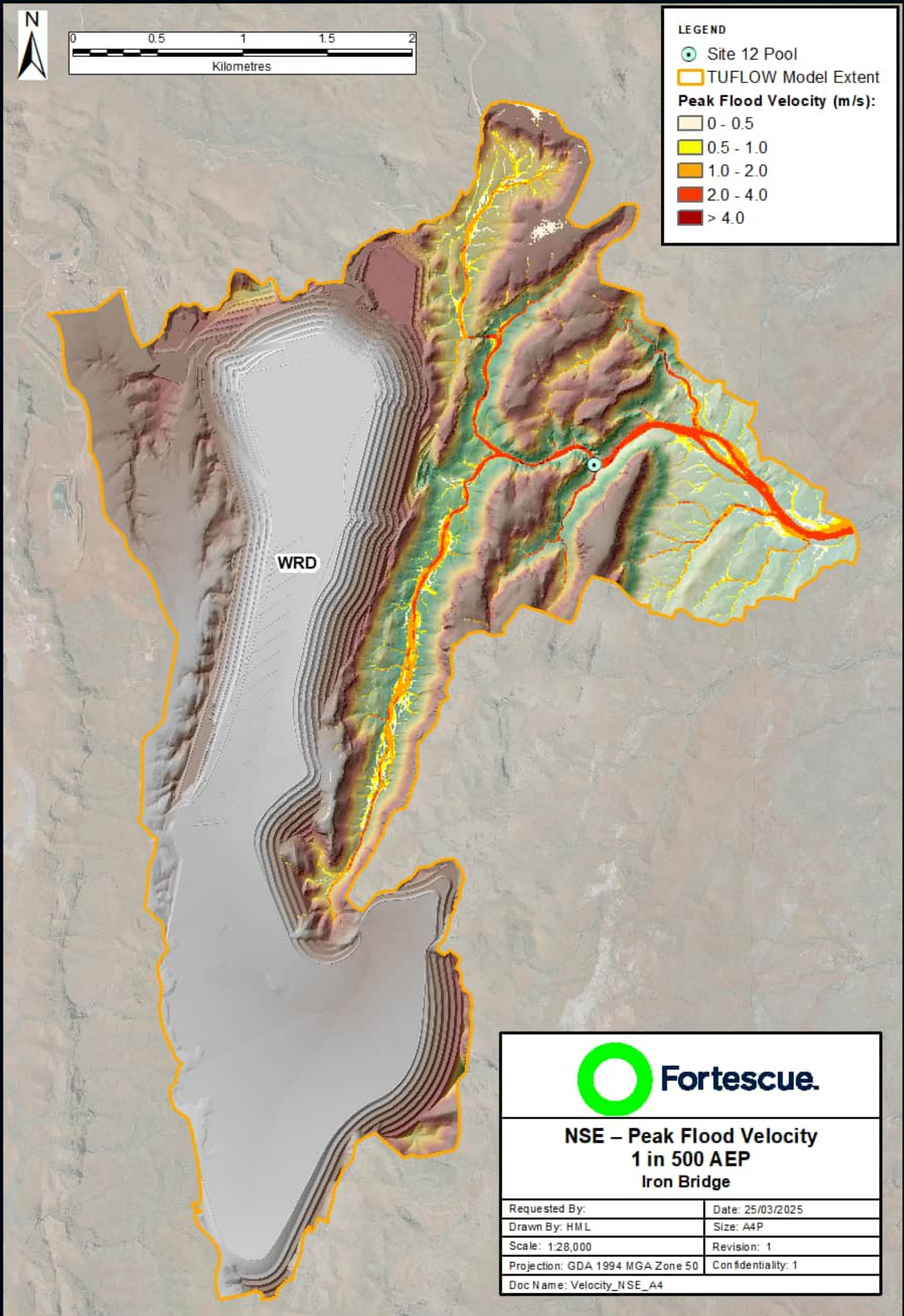
**NSE – Peak Flood Depth
1 in 500 AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



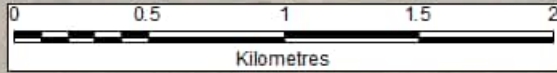
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












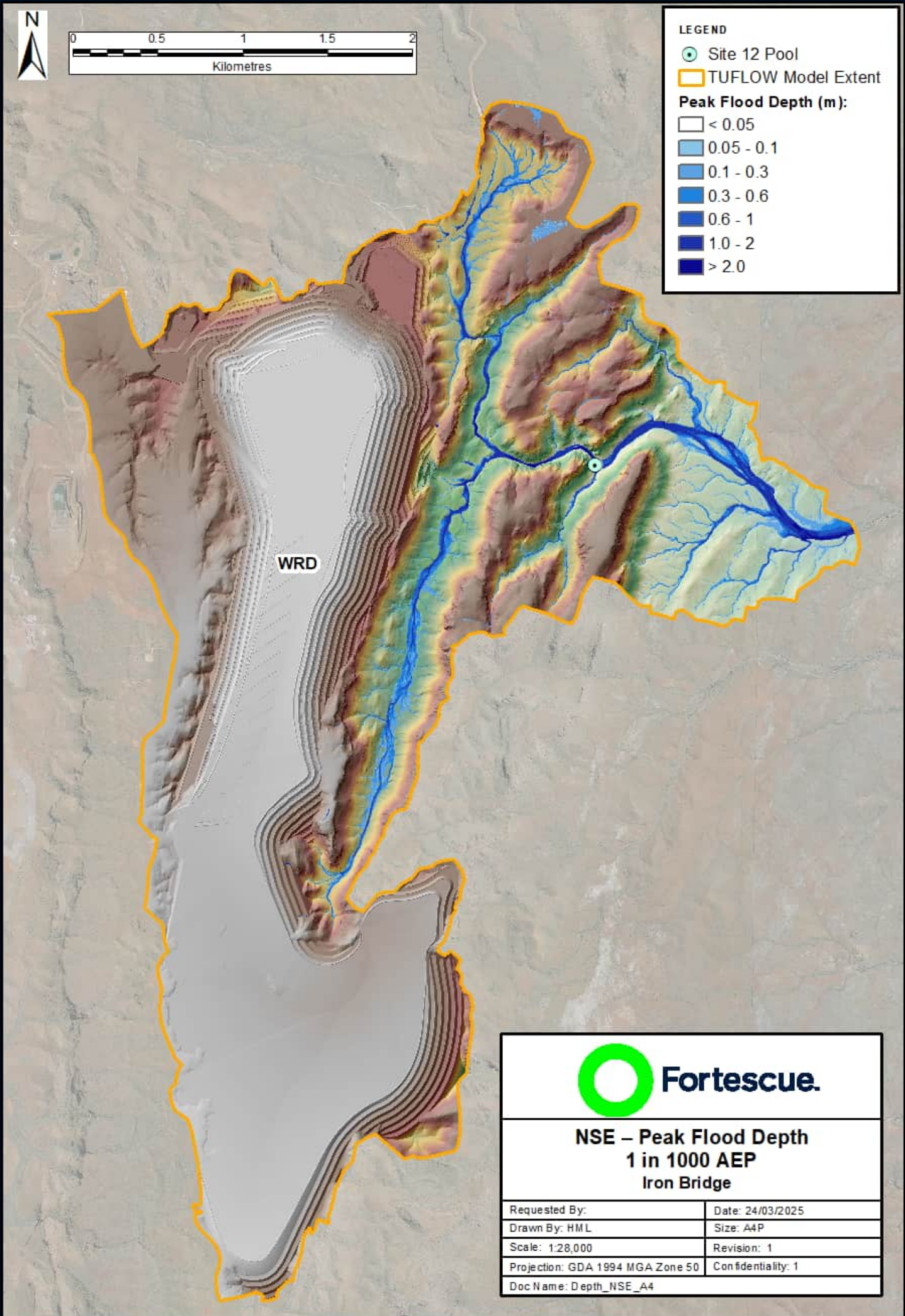
**NSE – Peak Flood Velocity
1 in 500 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



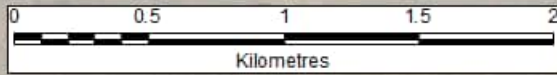
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










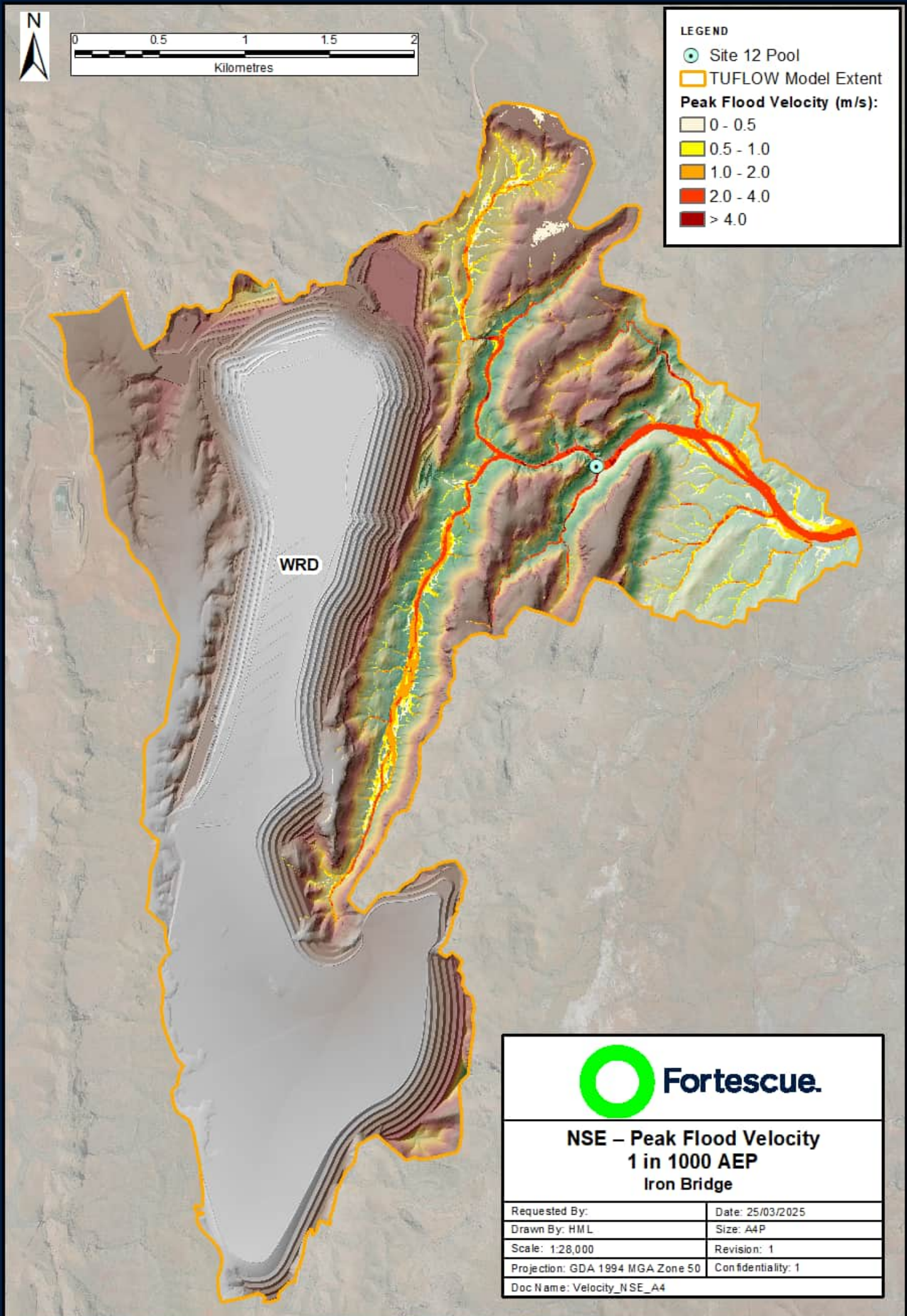
**NSE – Peak Flood Depth
1 in 1000 AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



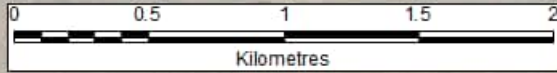
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0



**NSE – Peak Flood Velocity
1 in 1000 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



LEGEND

● Site 12 Pool

▭ TUFLOW Model Extent

Peak Flood Depth (m):

▭ < 0.05

▭ 0.05 - 0.1

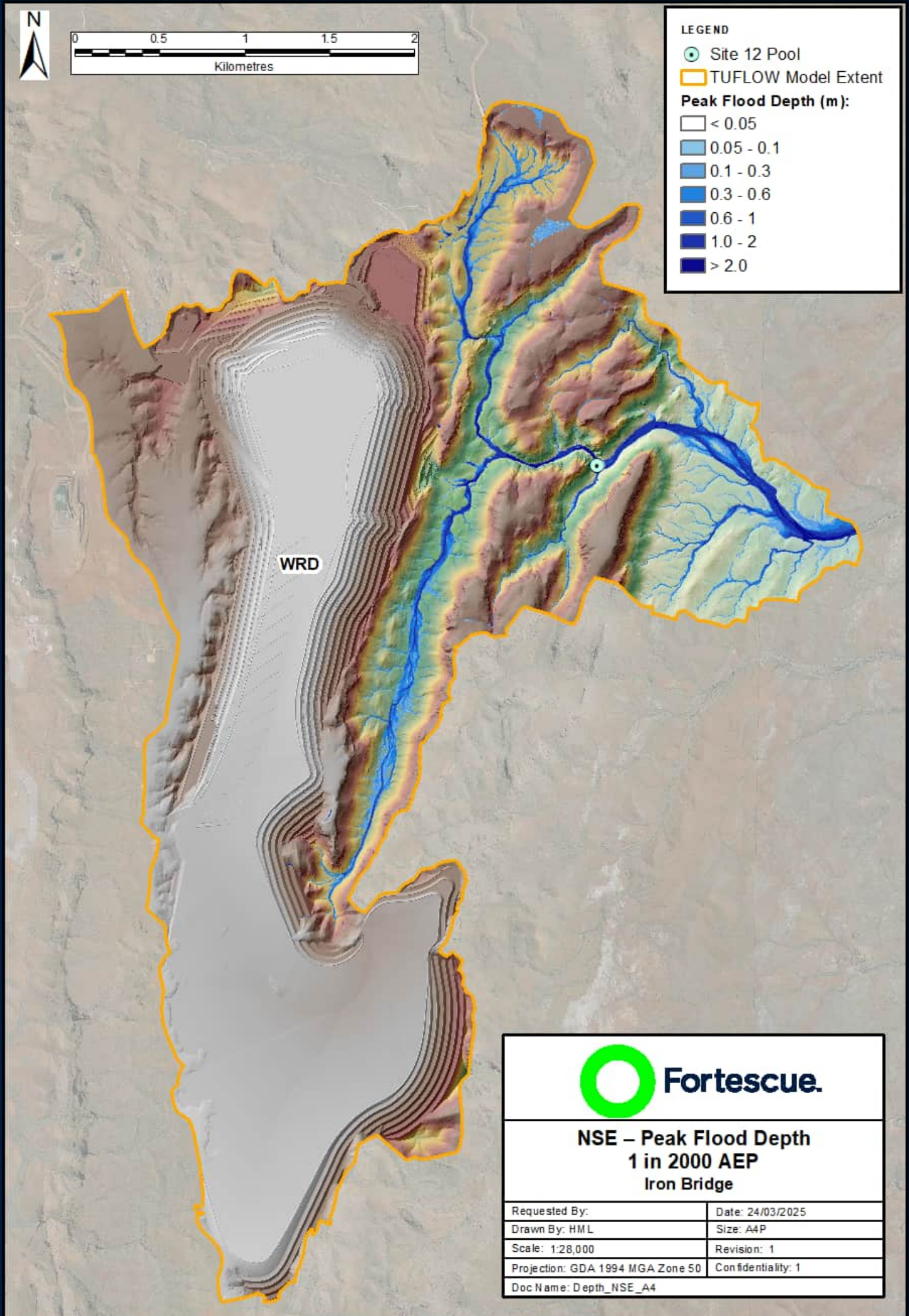
▭ 0.1 - 0.3

▭ 0.3 - 0.6

▭ 0.6 - 1

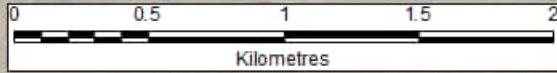
▭ 1.0 - 2

▭ > 2.0










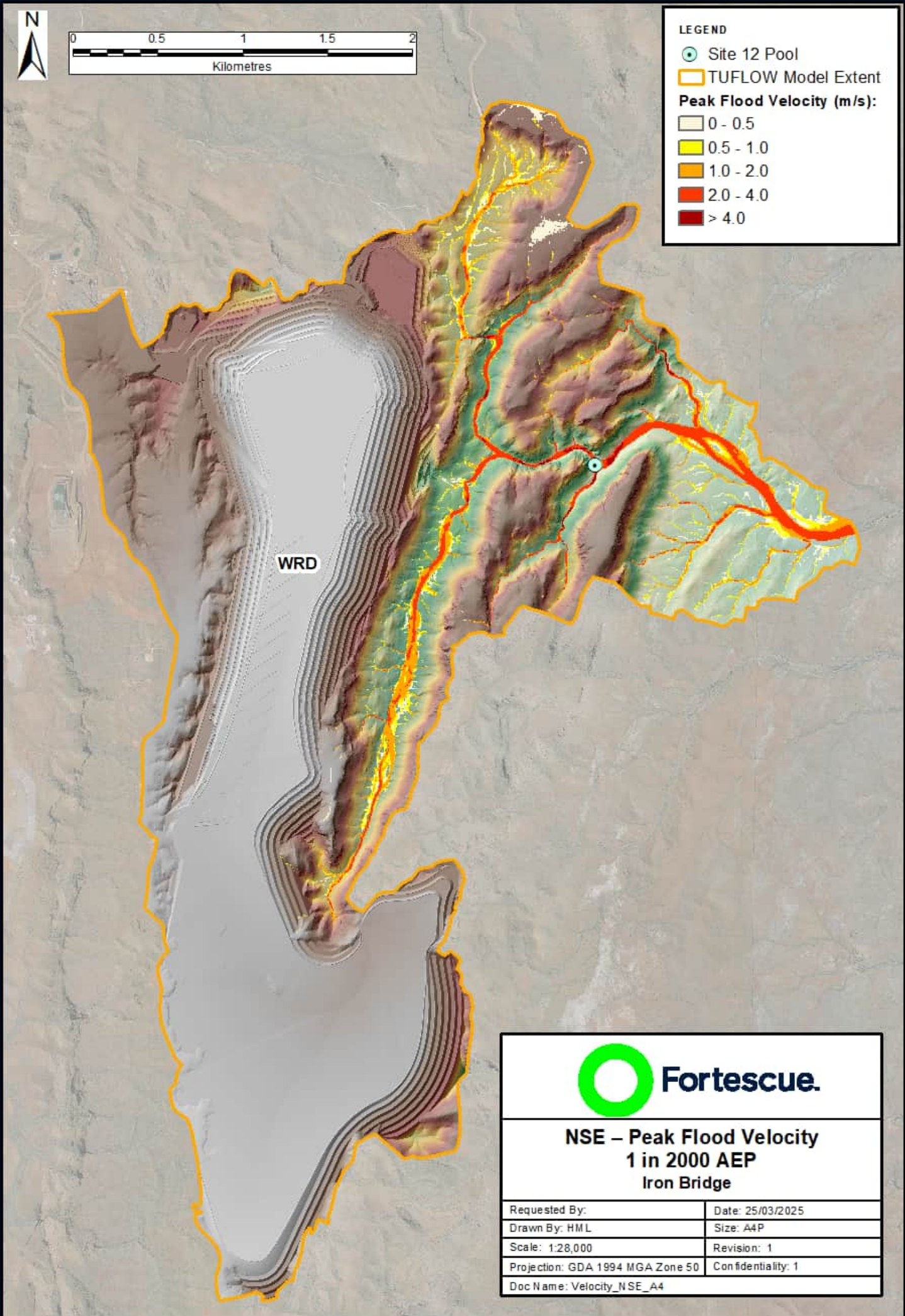
**NSE – Peak Flood Depth
1 in 2000 AEP
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



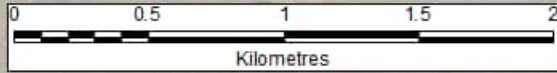
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












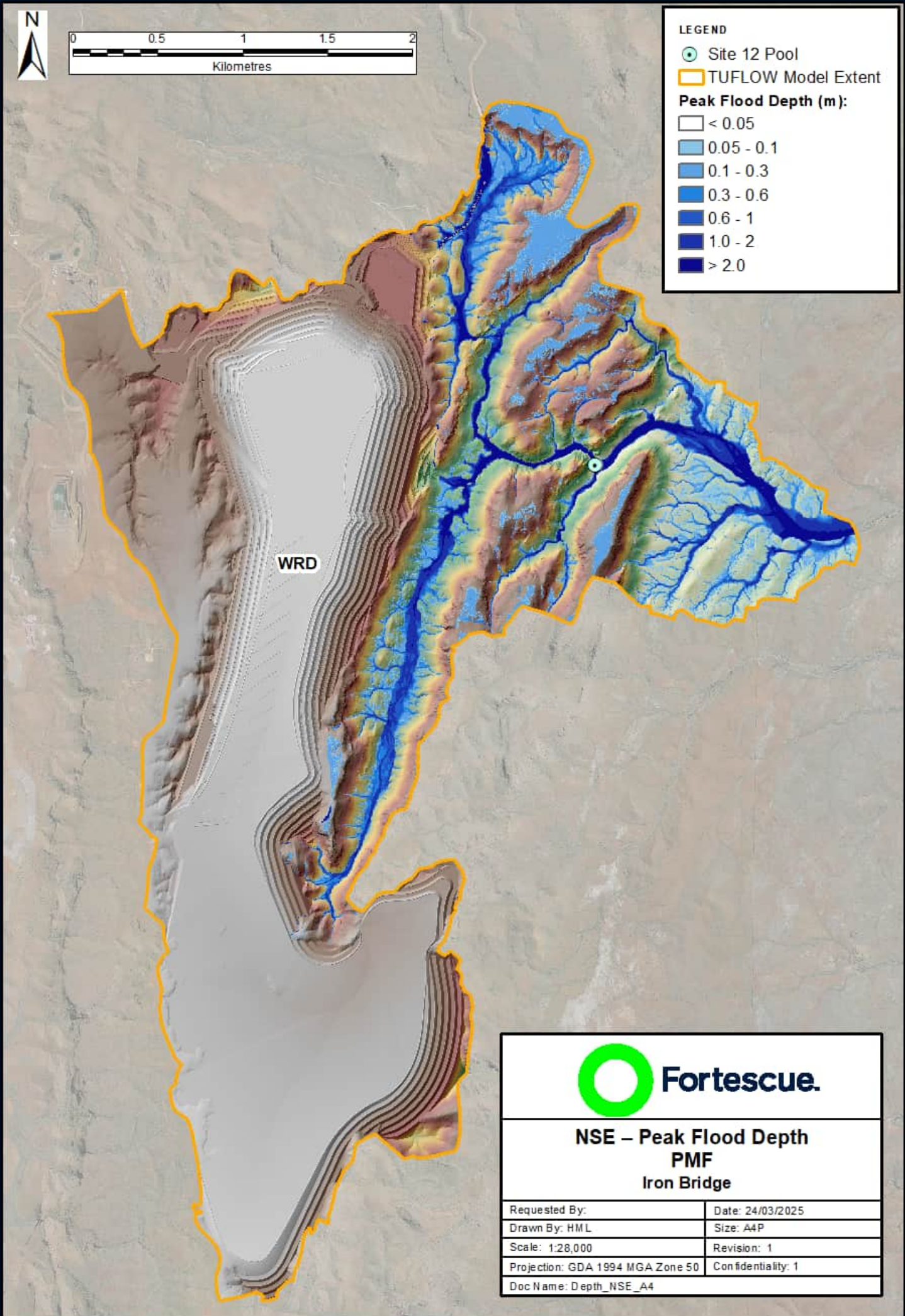
**NSE – Peak Flood Velocity
1 in 2000 AEP
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



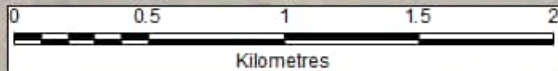
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0










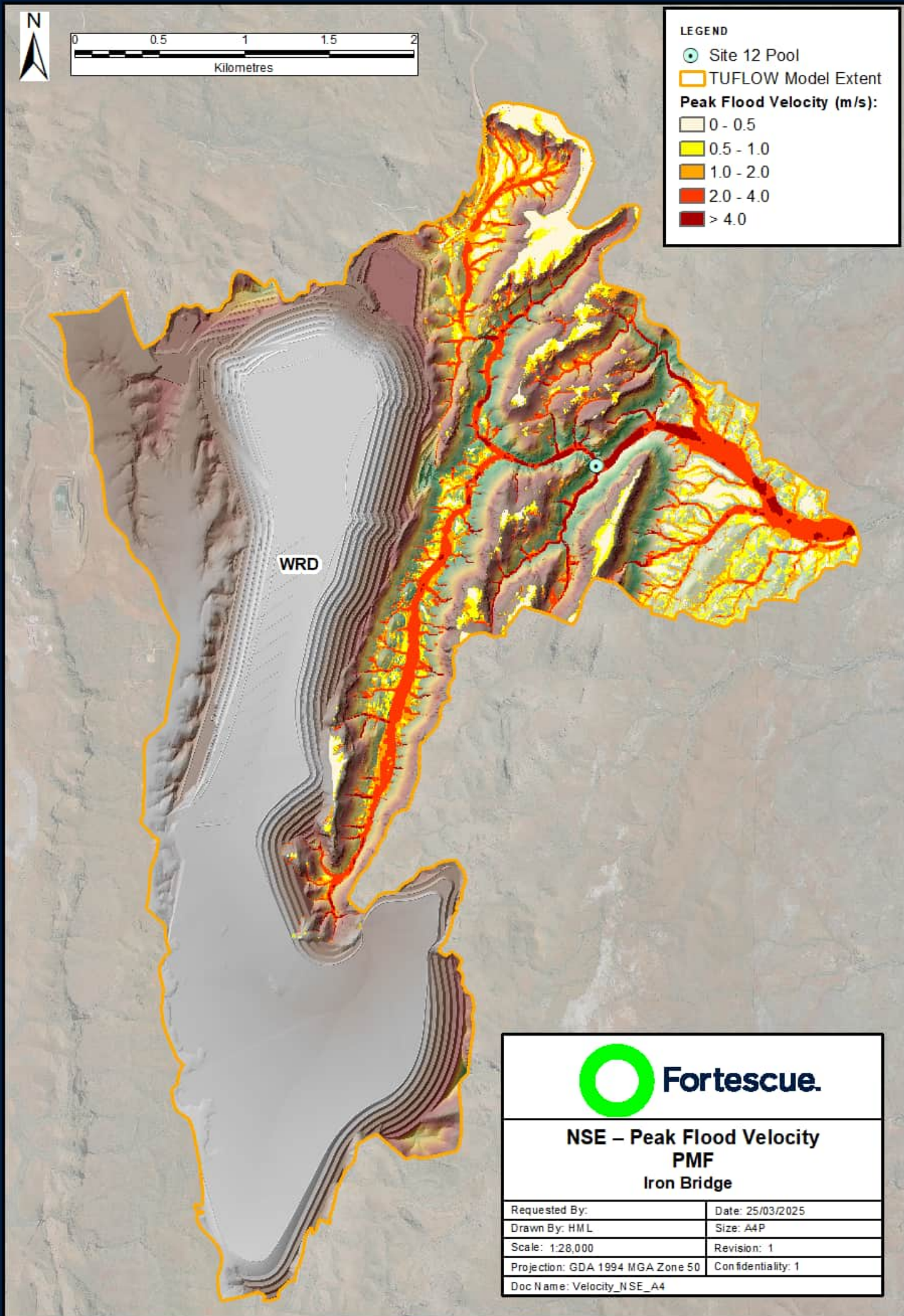
**NSE – Peak Flood Depth
PMF
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



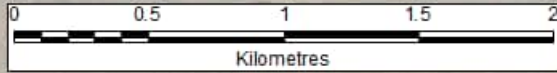
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
-  0 - 0.5
-  0.5 - 1.0
-  1.0 - 2.0
-  2.0 - 4.0
-  > 4.0












**NSE – Peak Flood Velocity
PMF
Iron Bridge**

Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	



LEGEND

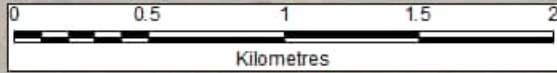
-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Depth (m):**
-  < 0.05
-  0.05 - 0.1
-  0.1 - 0.3
-  0.3 - 0.6
-  0.6 - 1
-  1.0 - 2
-  > 2.0

WRD










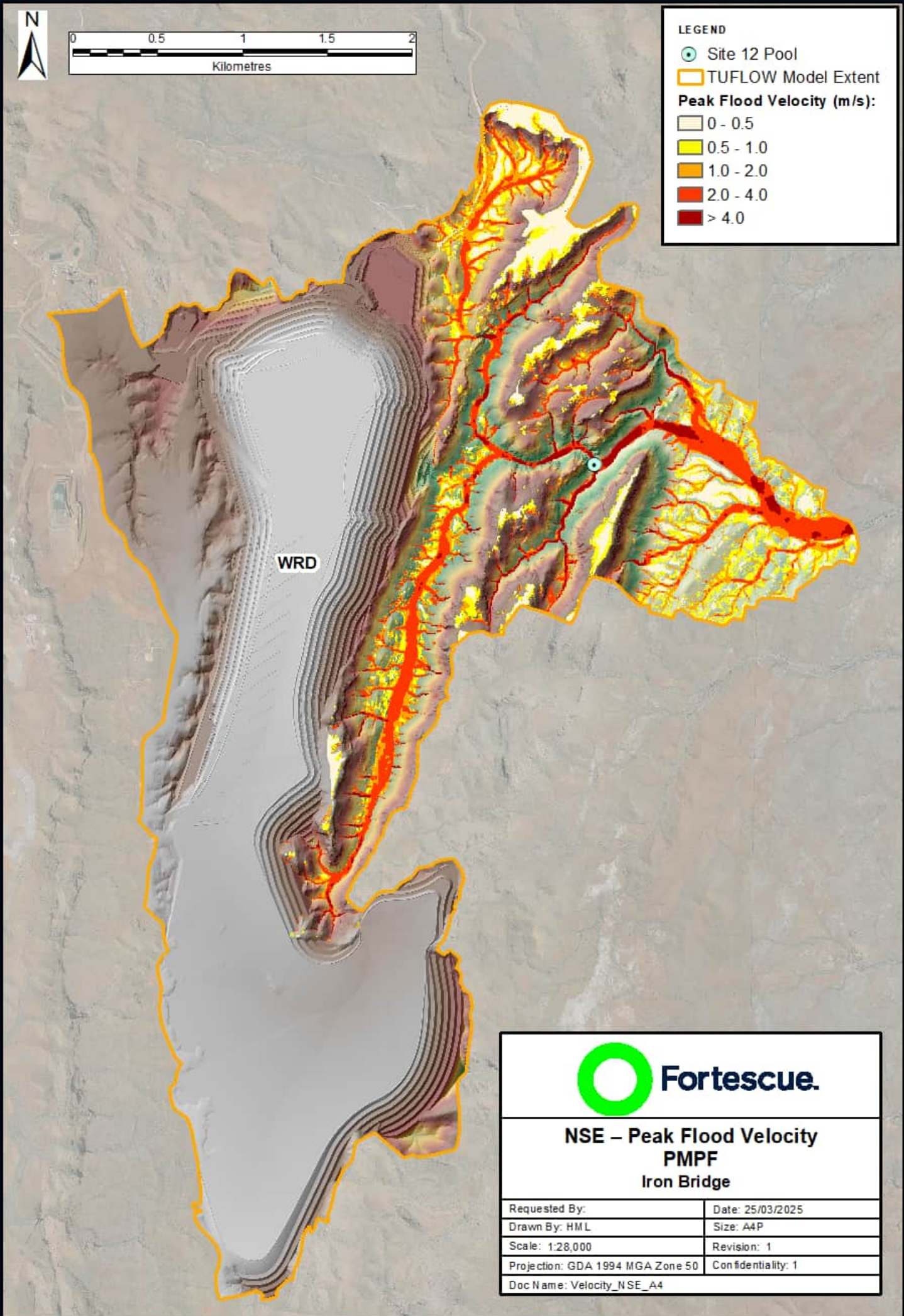
**NSE – Peak Flood Depth
PMPF
Iron Bridge**

Requested By:	Date: 24/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_NSE_A4	



LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Peak Flood Velocity (m/s):**
 -  0 - 0.5
 -  0.5 - 1.0
 -  1.0 - 2.0
 -  2.0 - 4.0
 -  > 4.0

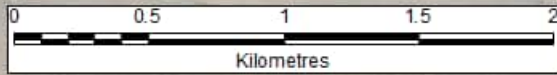


**NSE – Peak Flood Velocity
PMPF
Iron Bridge**
















Requested By:	Date: 25/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Velocity_NSE_A4	

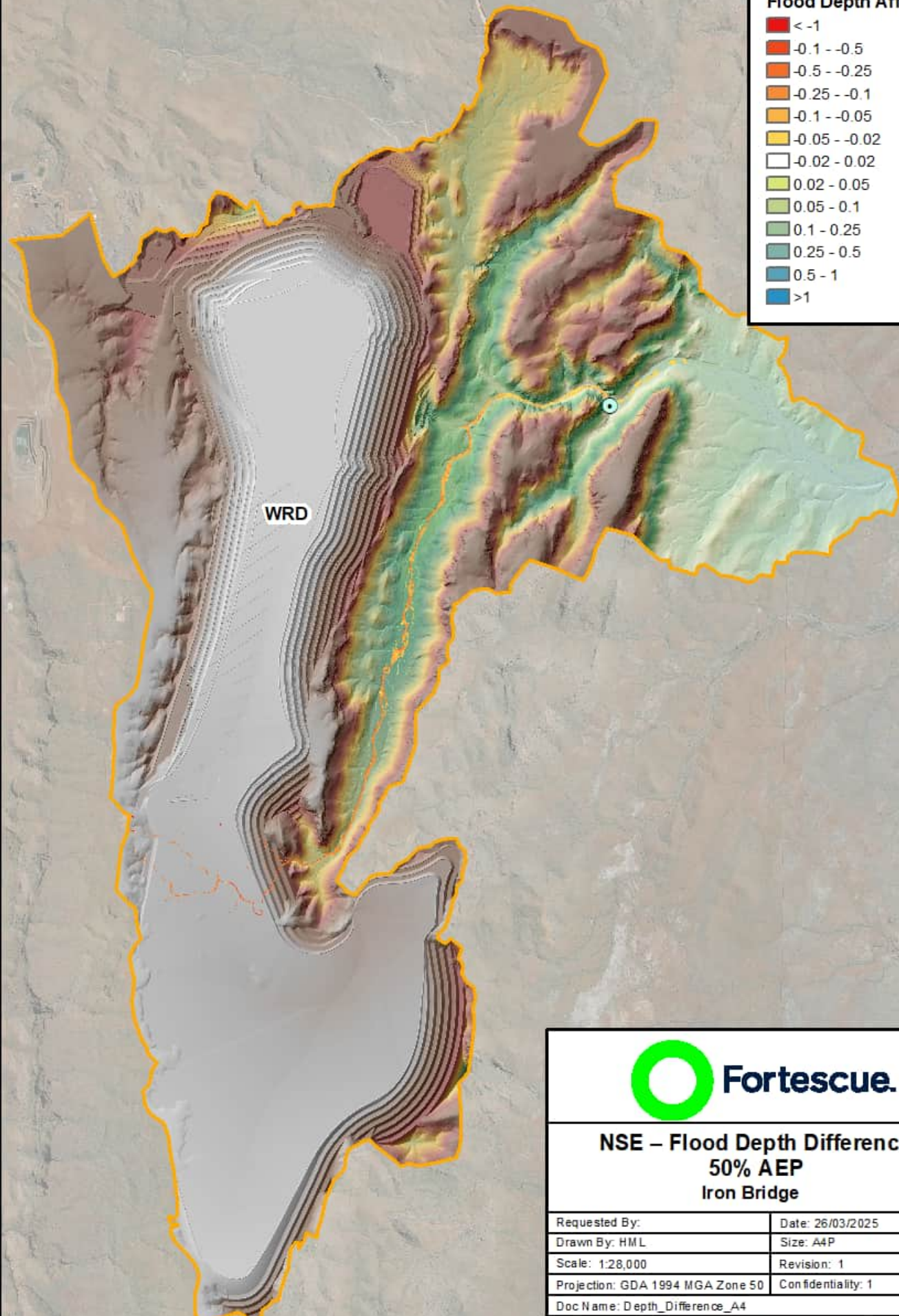


APPENDIX F FLOOD AFFLUX MAPPING



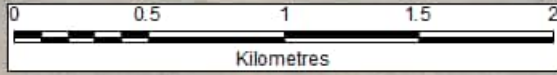
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1


















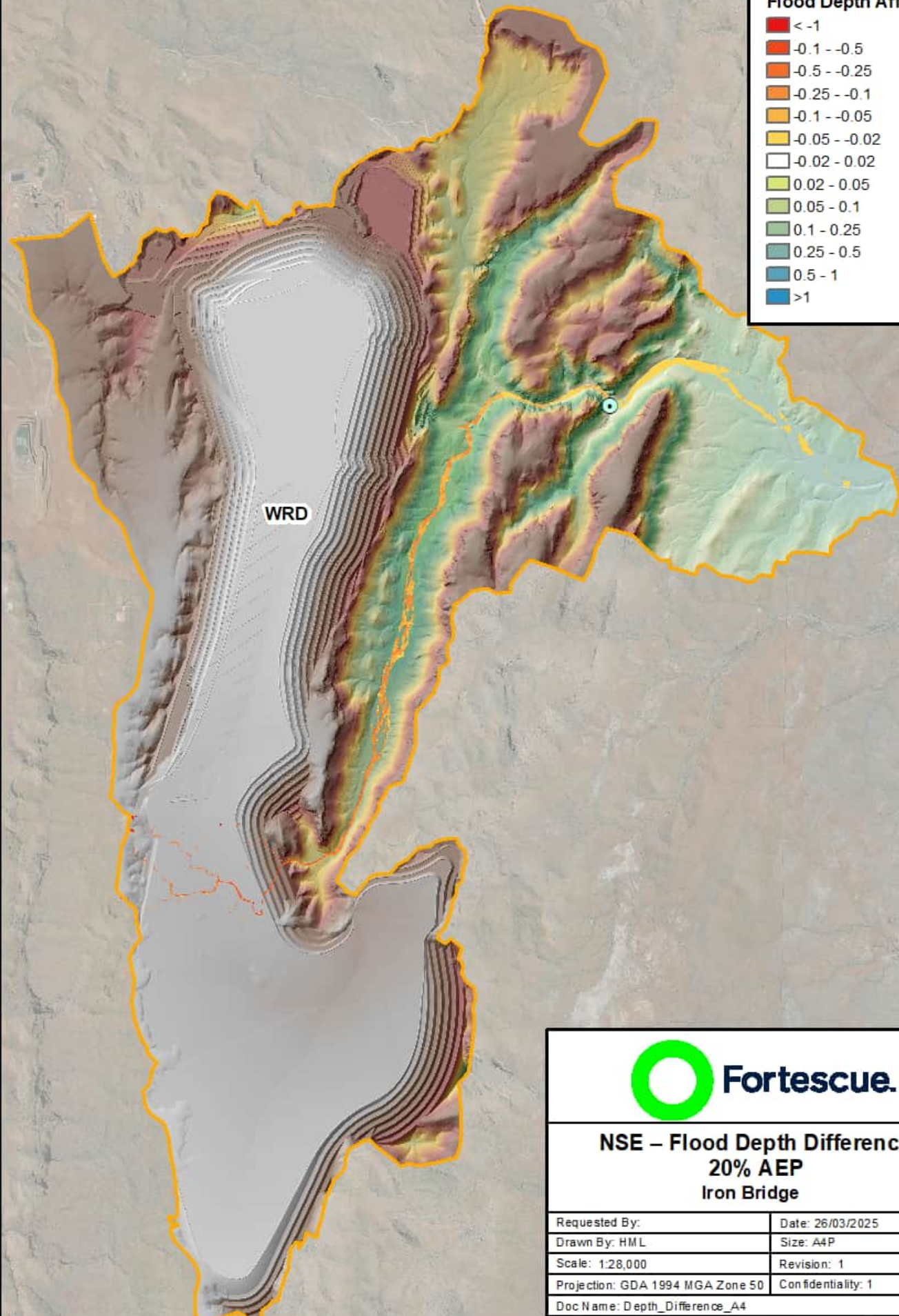
**NSE – Flood Depth Difference
50% AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	



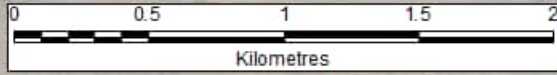
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1


















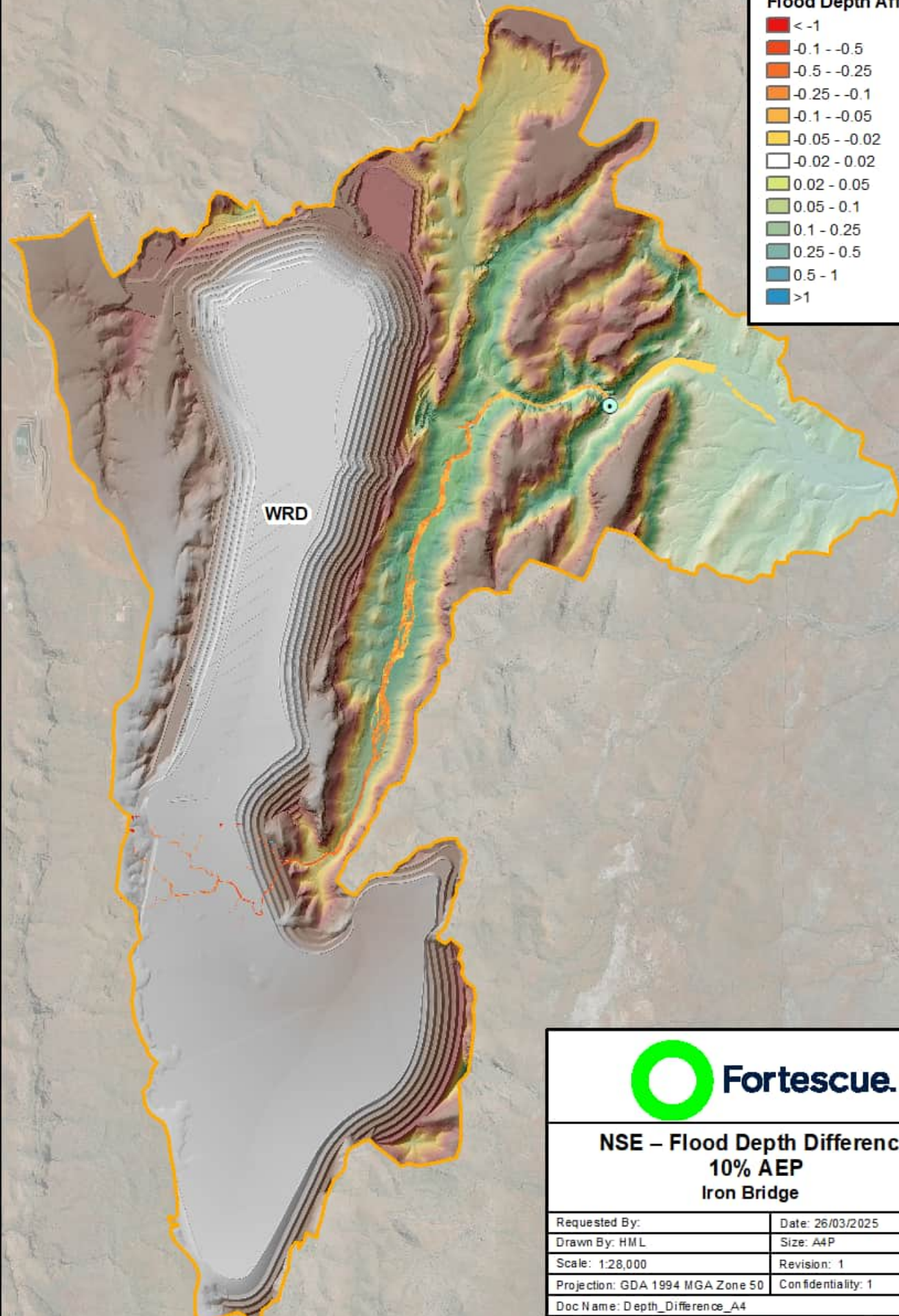
**NSE – Flood Depth Difference
20% AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	



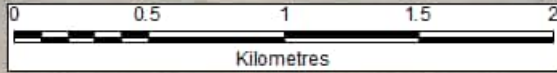
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1




**NSE – Flood Depth Difference
10% AEP
Iron Bridge**





Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	

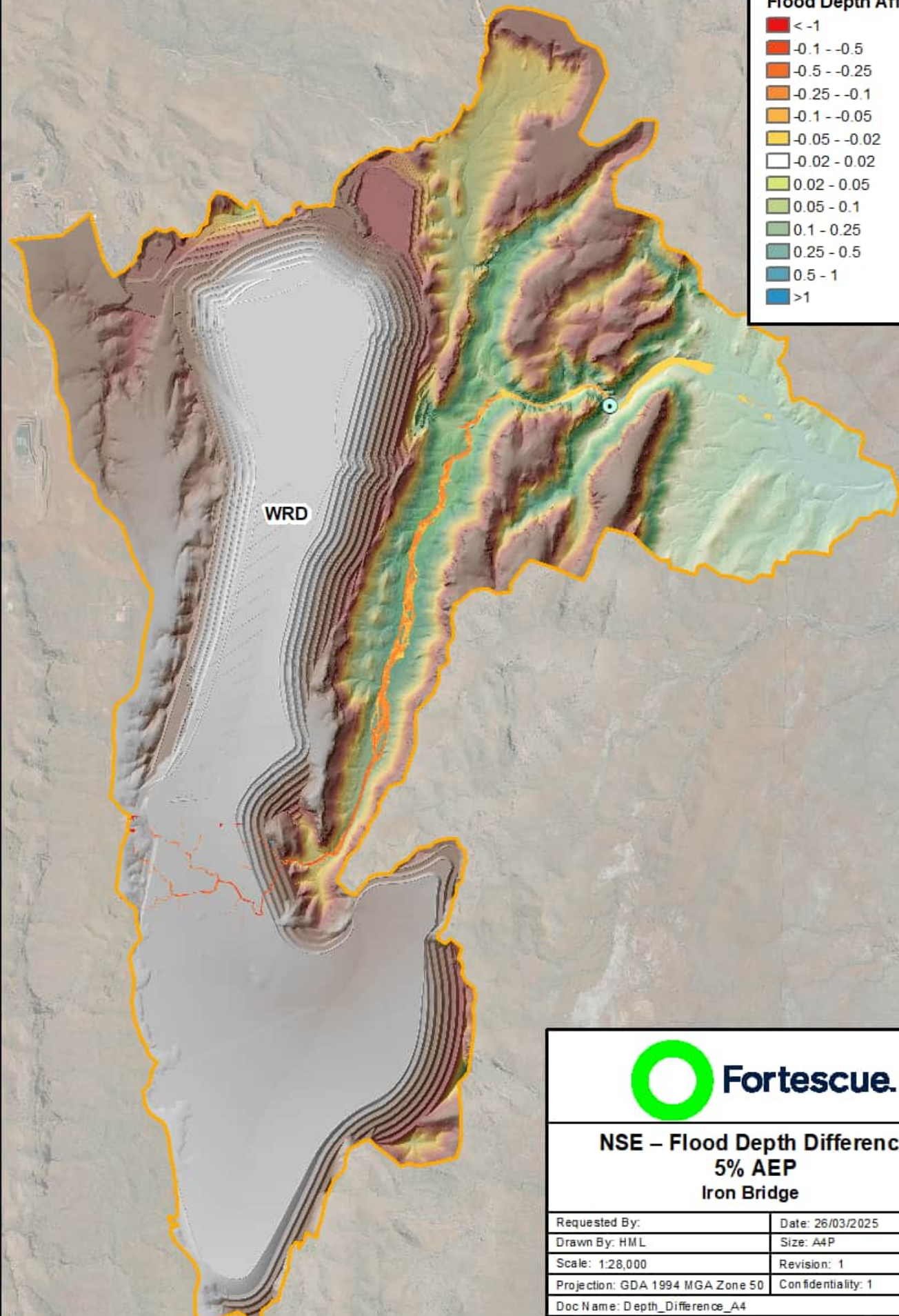


LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent

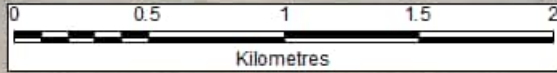
Flood Depth Afflux (m):

-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1


















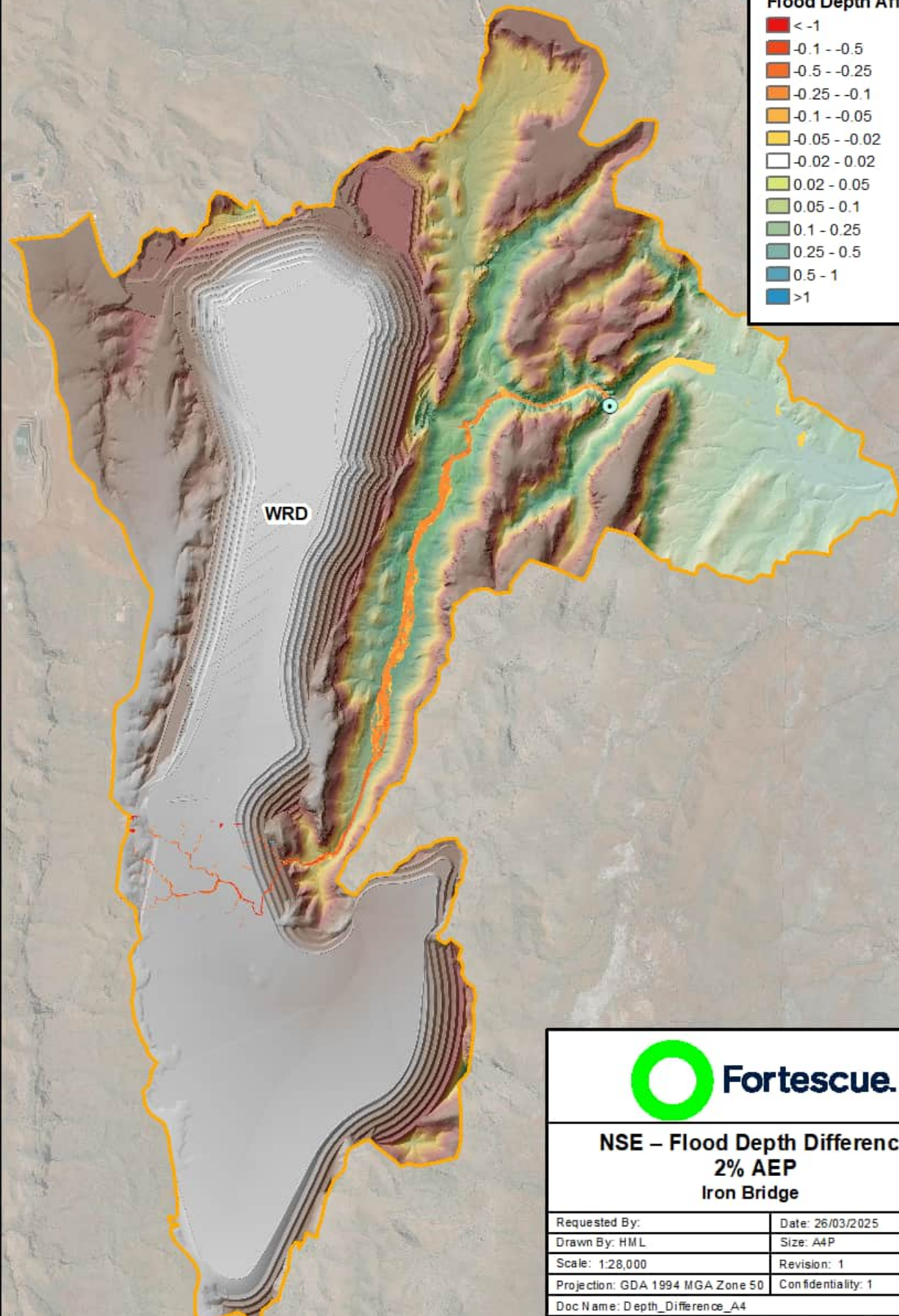
**NSE – Flood Depth Difference
5% AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	



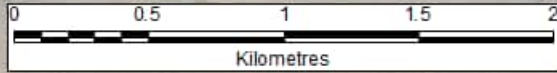
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1


















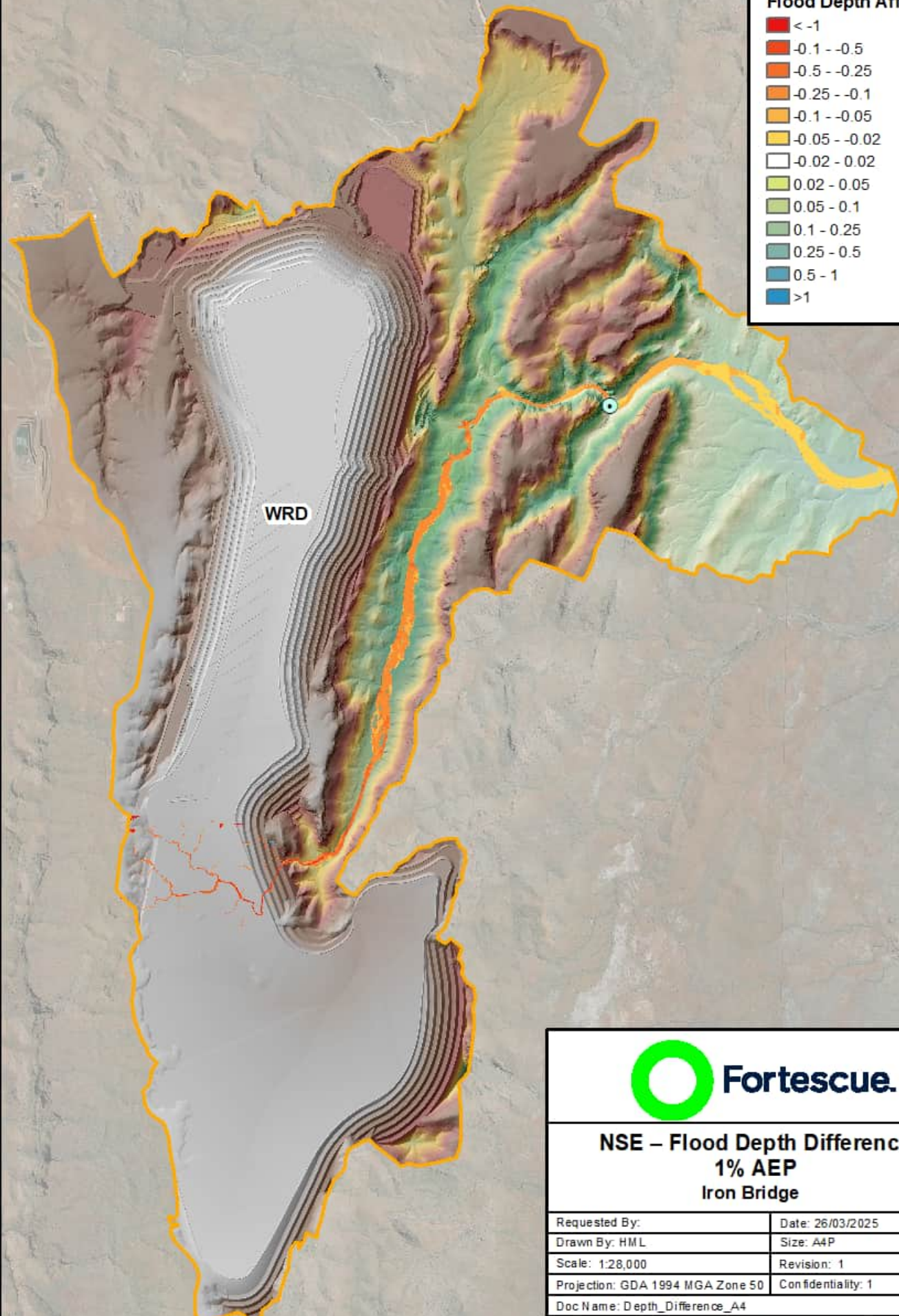
**NSE – Flood Depth Difference
2% AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	



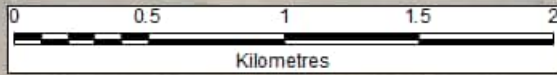
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1


















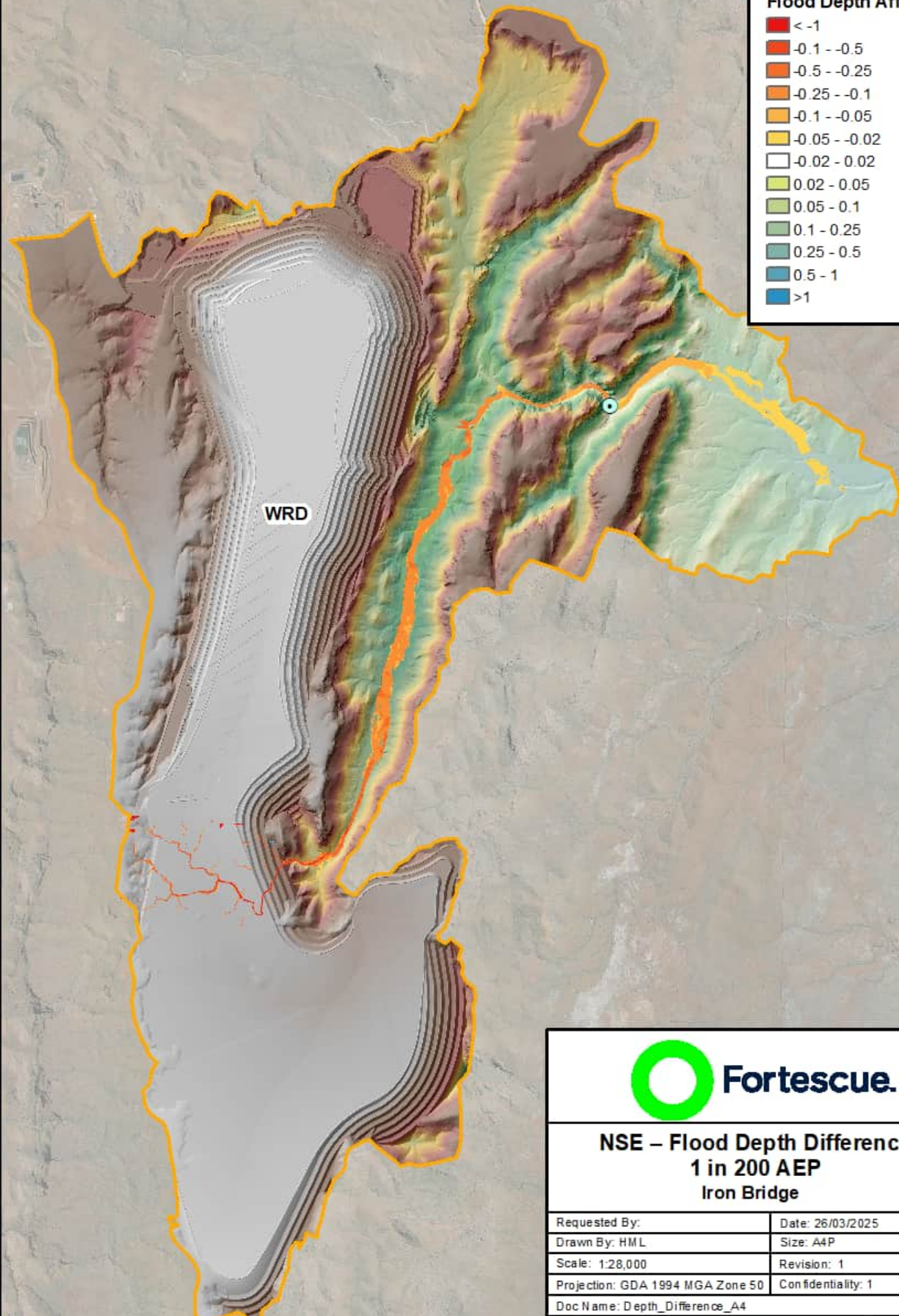
**NSE – Flood Depth Difference
1% AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	



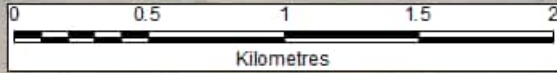
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1




**NSE – Flood Depth Difference
1 in 200 AEP
Iron Bridge**








Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	

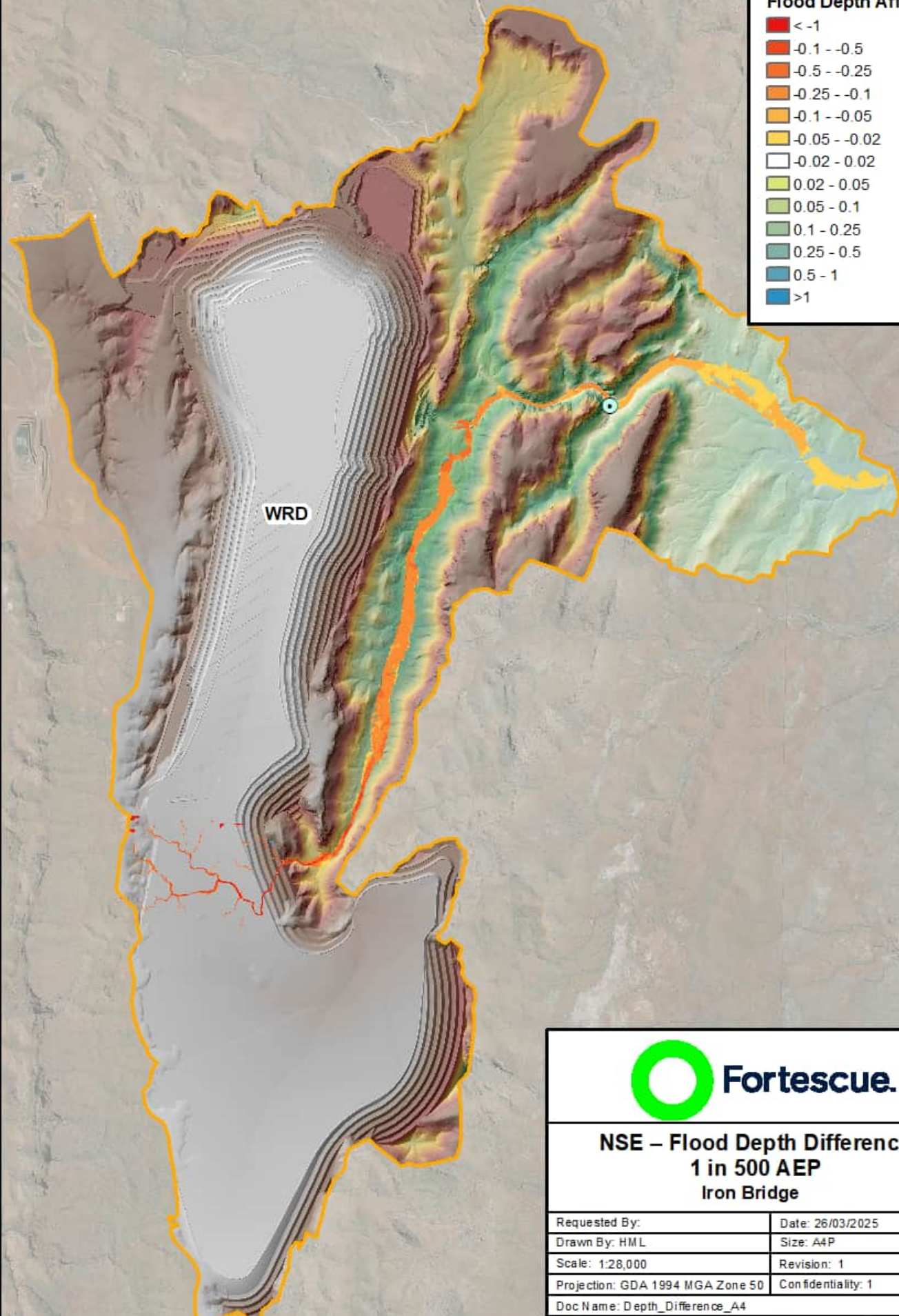



LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent

Flood Depth Afflux (m):

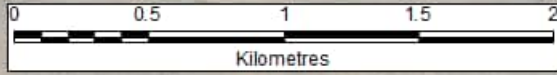
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1


















**Fortescue.**

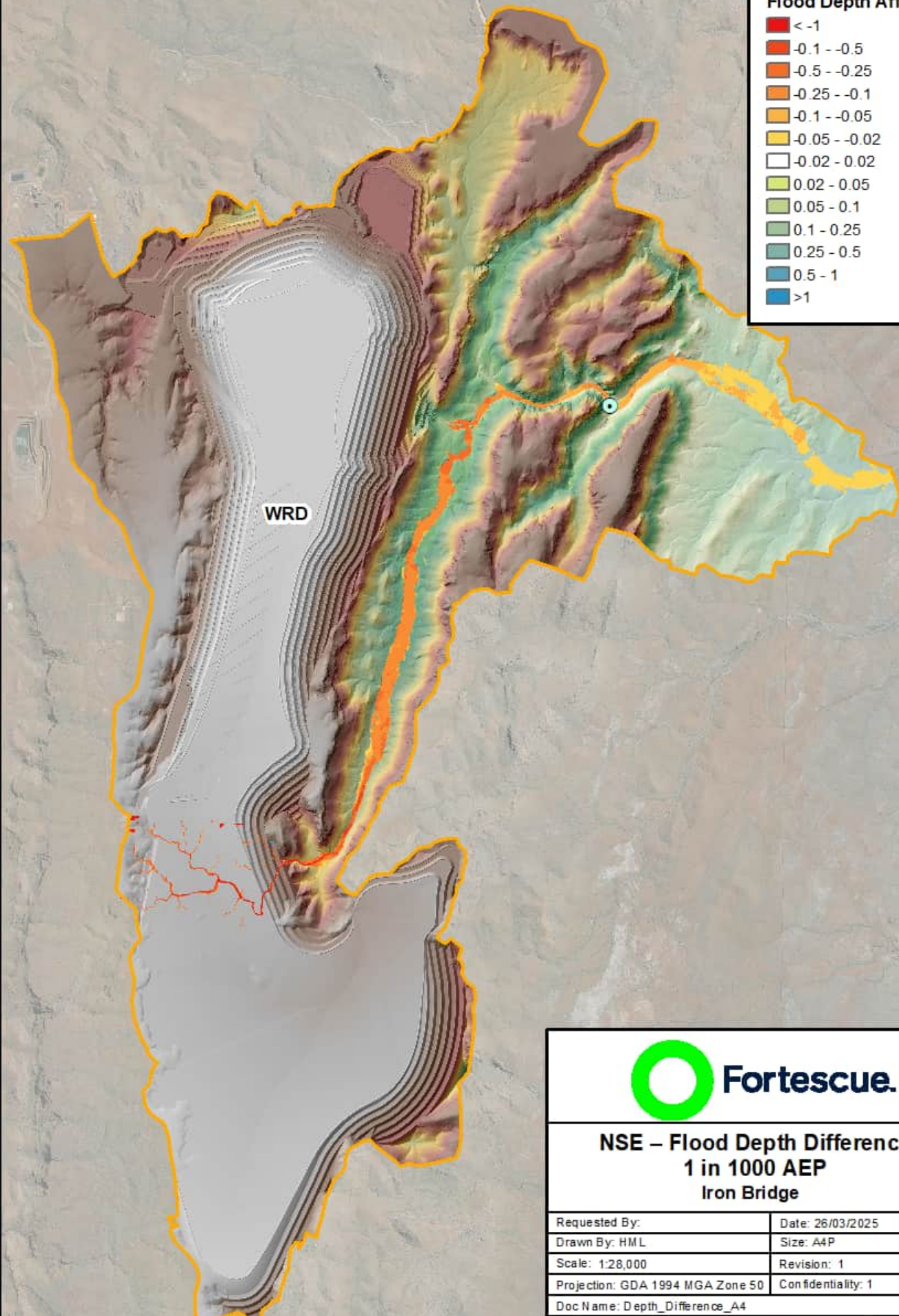
**NSE – Flood Depth Difference
1 in 500 AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	



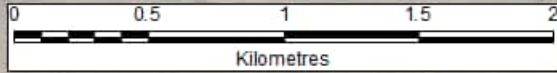
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1


















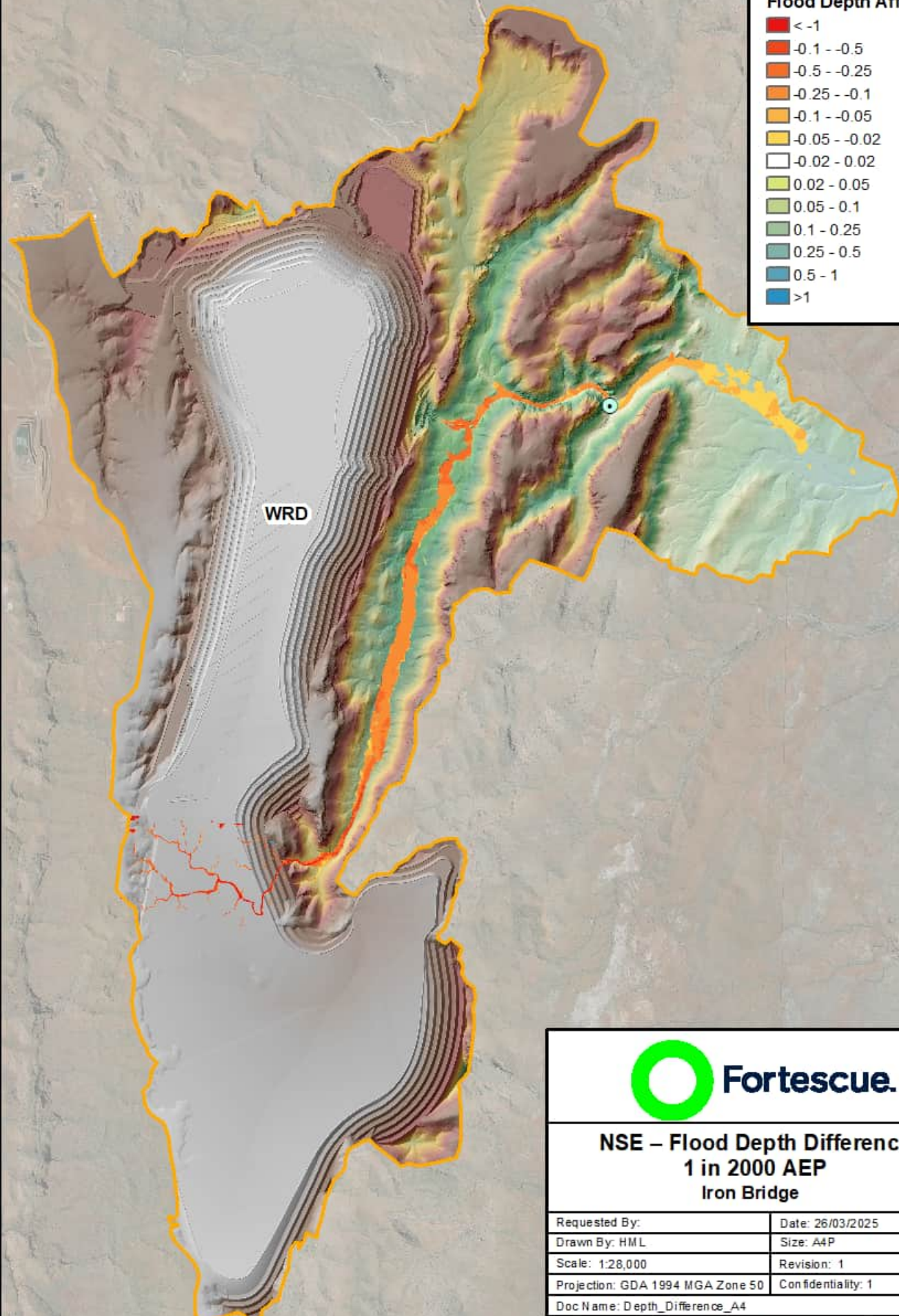
**NSE – Flood Depth Difference
1 in 1000 AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	



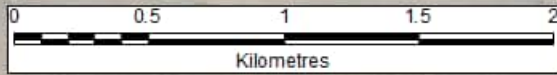
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1



**NSE – Flood Depth Difference
1 in 2000 AEP
Iron Bridge**









Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	

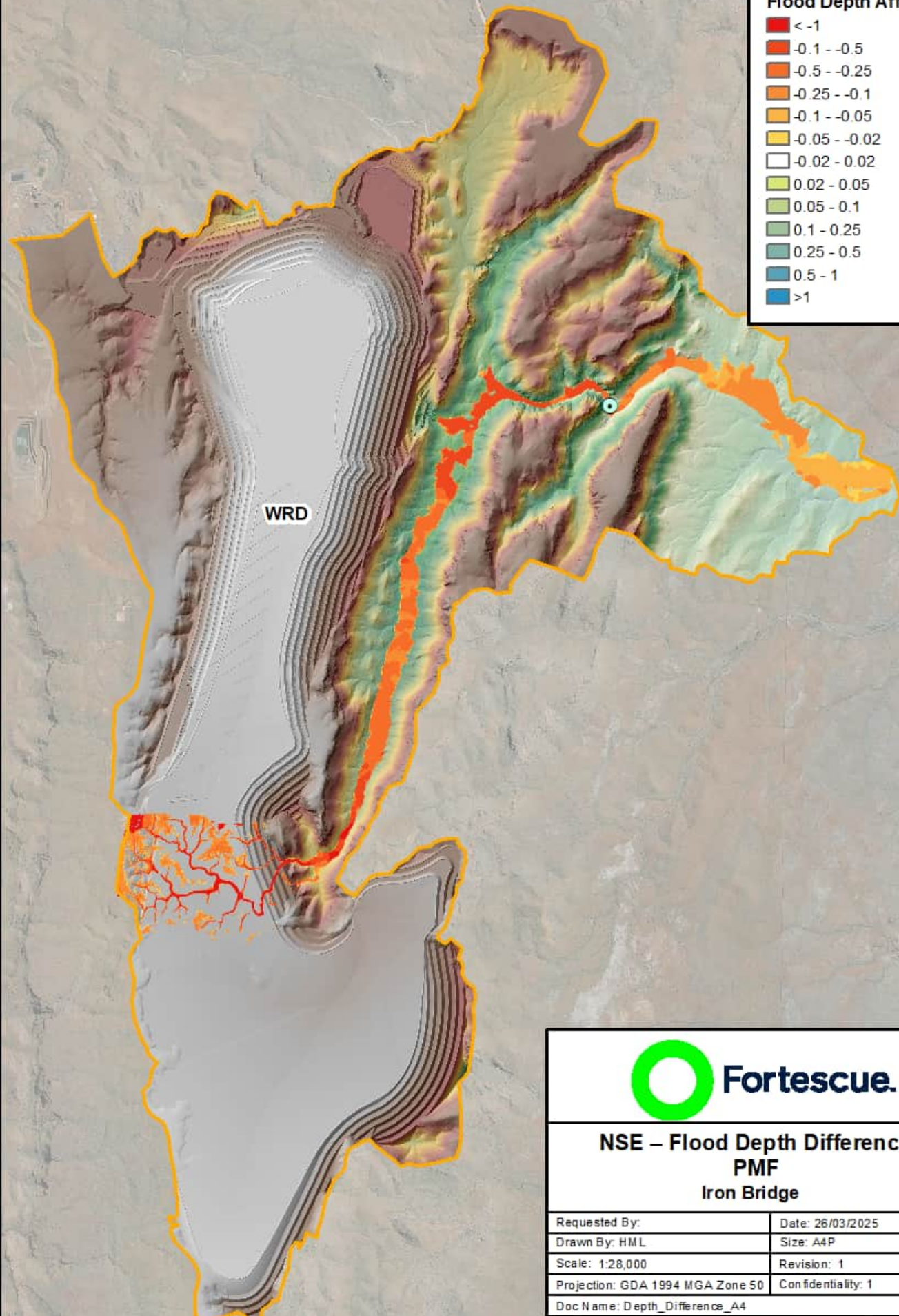



LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent

Flood Depth Afflux (m):

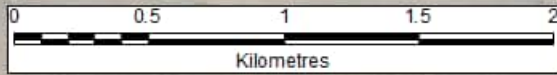
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1


















**Fortescue.**

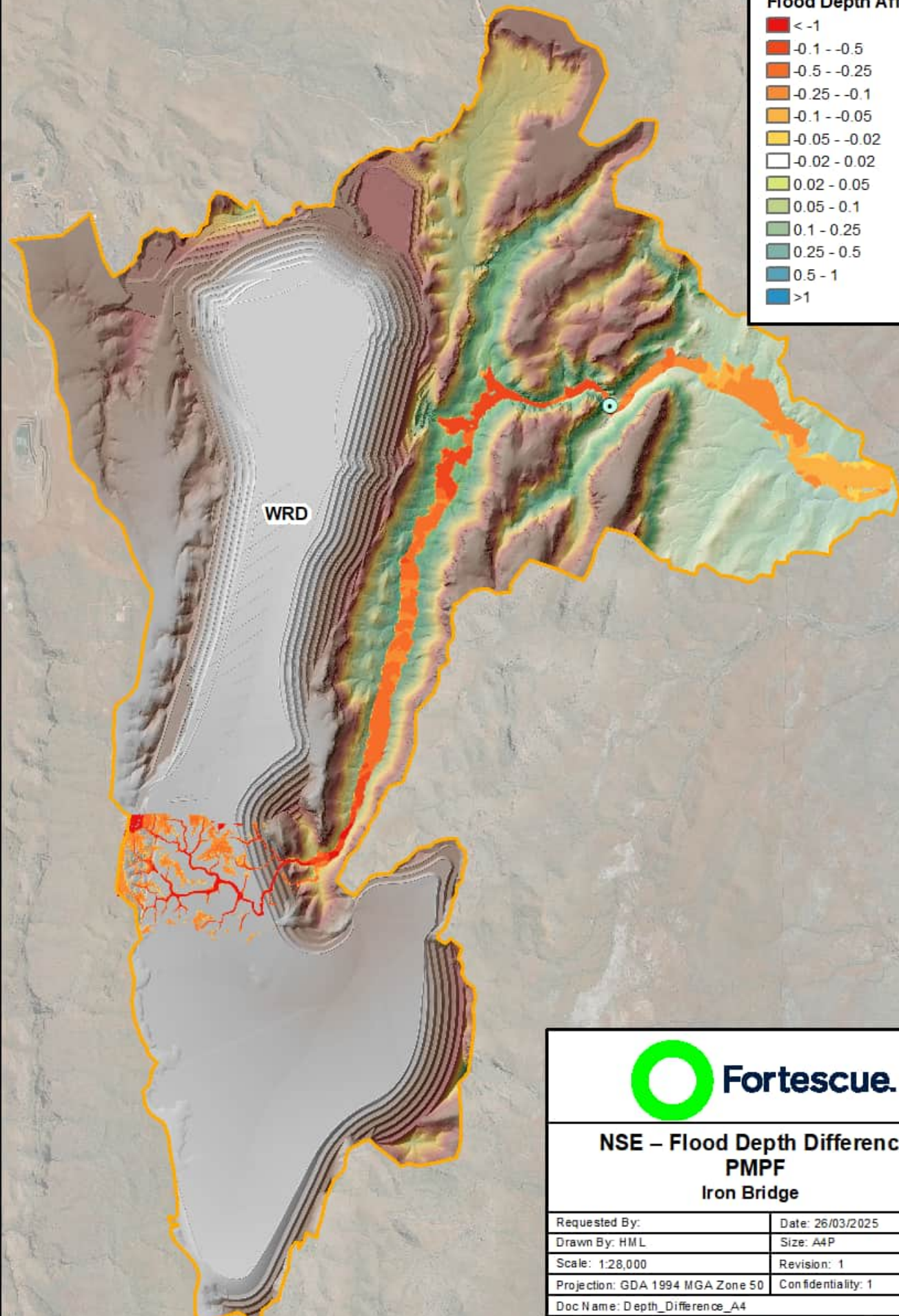
**NSE – Flood Depth Difference
PMF
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	



LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1

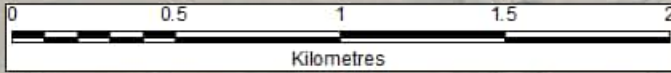


**NSE – Flood Depth Difference
PMPF
Iron Bridge**
















Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:28,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Depth_Difference_A4	

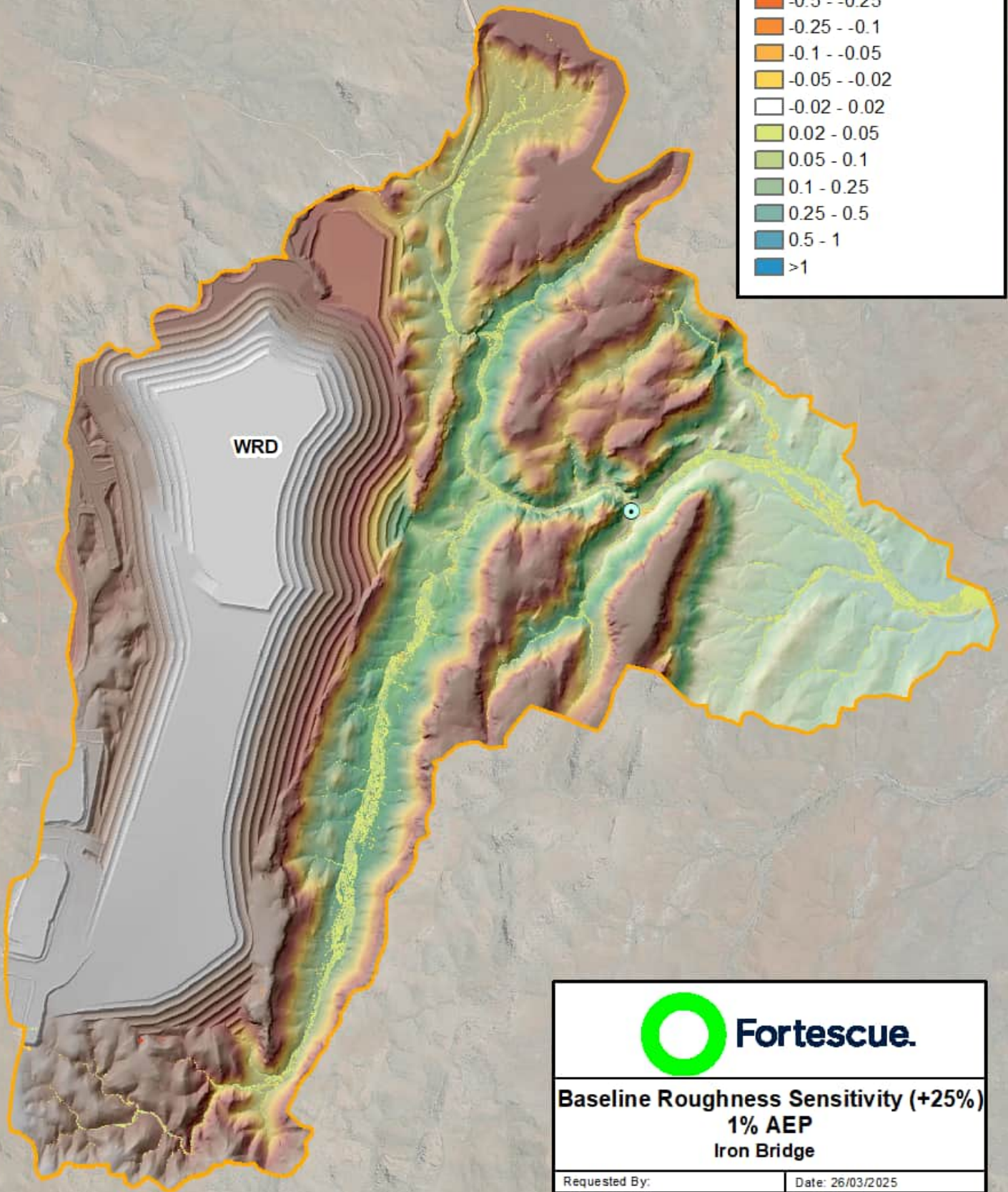


APPENDIX G SENSITIVITY ANALYSIS AFFLUX MAPPING



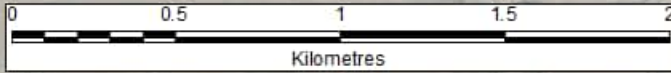
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1


















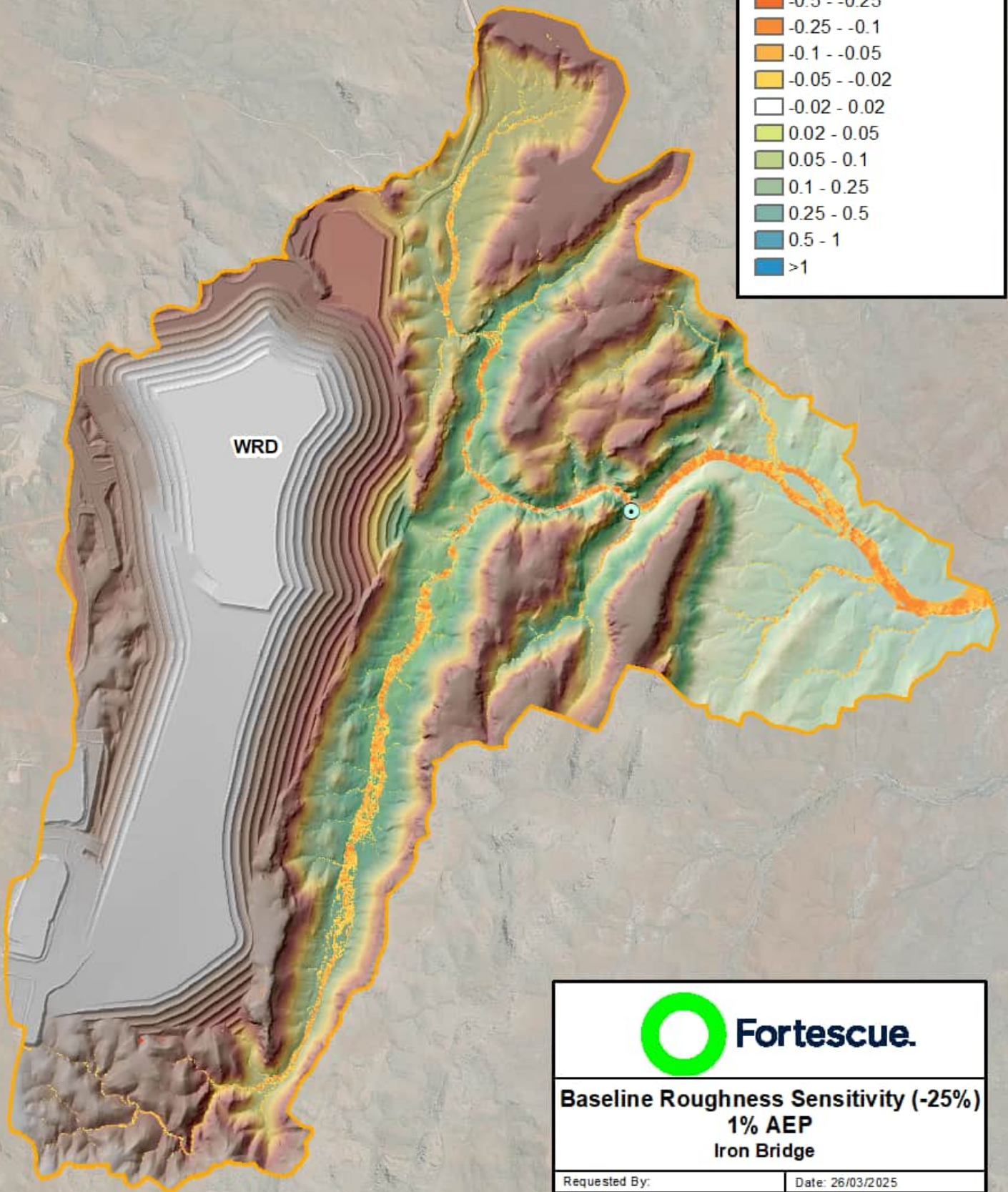
**Baseline Roughness Sensitivity (+25%)
1% AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Sensitivity_Mapping_A4	



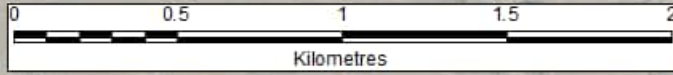
LEGEND

-  Site 12 Pool
-  TUFLOW Model Extent
- Flood Depth Afflux (m):**
-  < -1
-  -0.1 - -0.5
-  -0.5 - -0.25
-  -0.25 - -0.1
-  -0.1 - -0.05
-  -0.05 - -0.02
-  -0.02 - 0.02
-  0.02 - 0.05
-  0.05 - 0.1
-  0.1 - 0.25
-  0.25 - 0.5
-  0.5 - 1
-  >1



**Baseline Roughness Sensitivity (-25%)
1% AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Sensitivity_Mapping_A4	



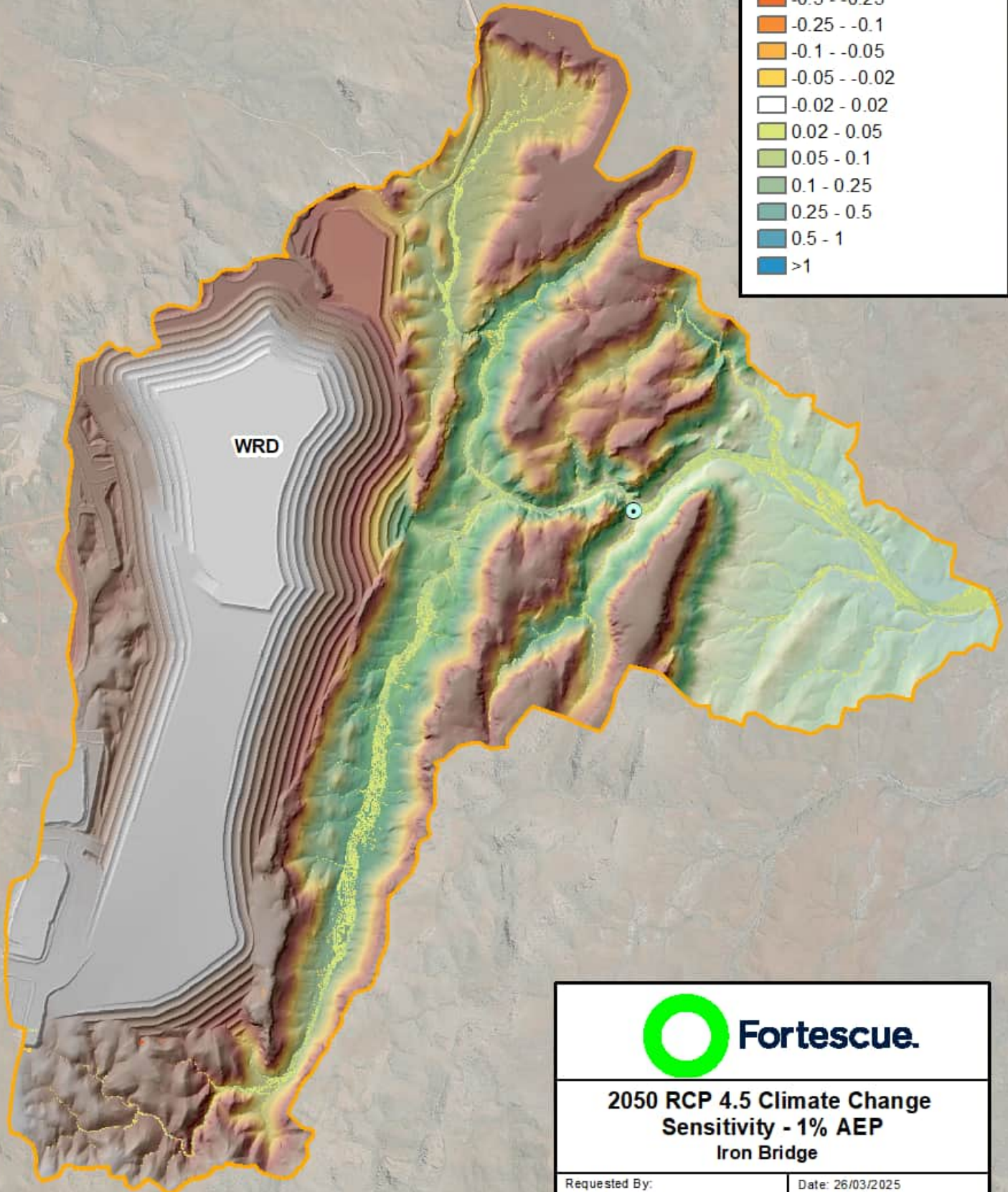
LEGEND

● Site 12 Pool

□ TUFLOW Model Extent

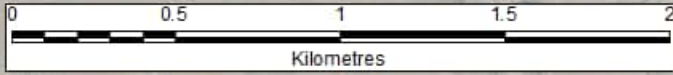
Flood Depth Afflux (m):

- < -1
- -0.1 - -0.5
- -0.5 - -0.25
- -0.25 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- -0.02 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- >1



**2050 RCP 4.5 Climate Change
Sensitivity - 1% AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Sensitivity_Mapping_A4	



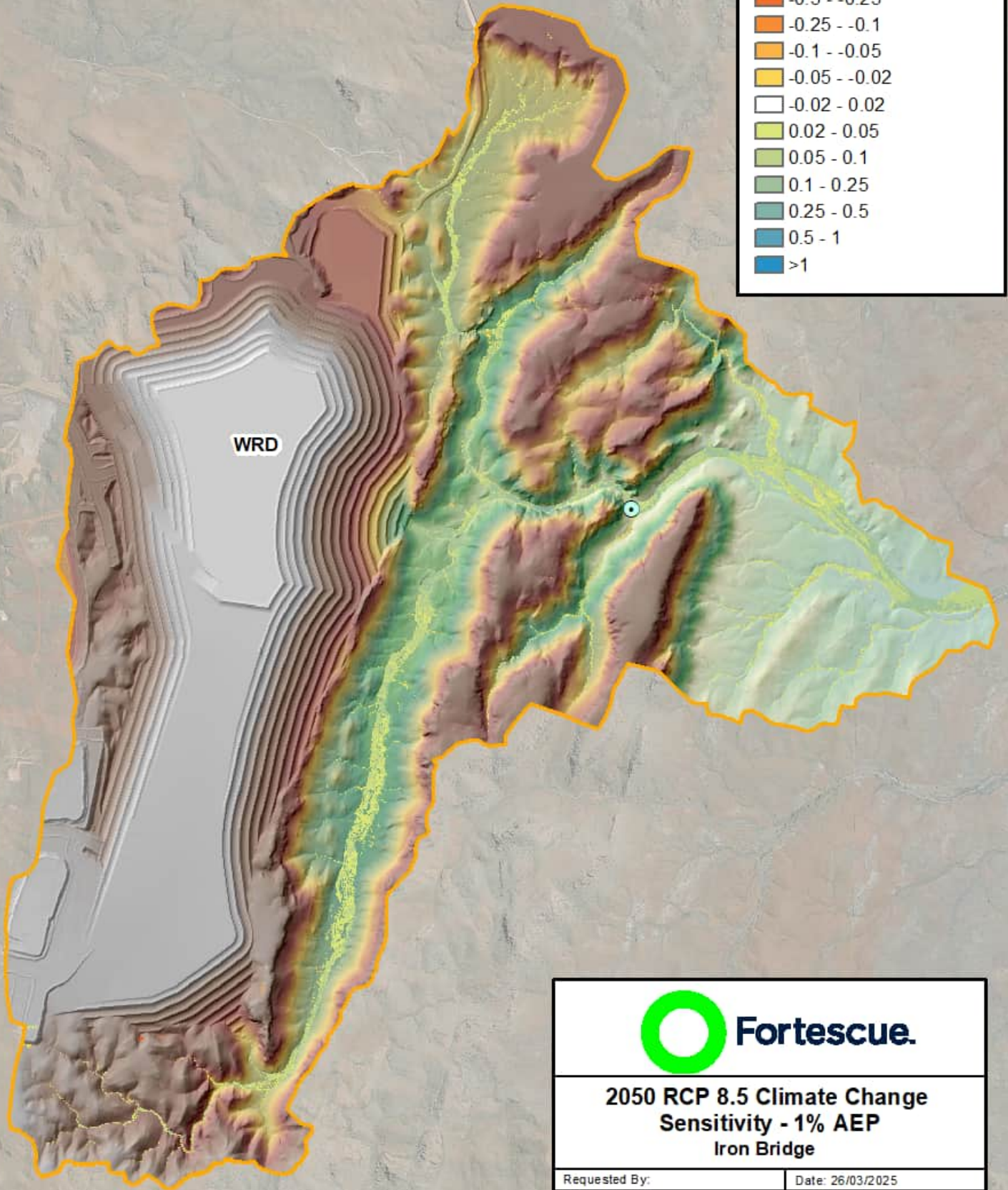
LEGEND

● Site 12 Pool

□ TUFLOW Model Extent

Flood Depth Afflux (m):

- < -1
- -0.1 - -0.5
- -0.5 - -0.25
- -0.25 - -0.1
- -0.1 - -0.05
- -0.05 - -0.02
- -0.02 - 0.02
- 0.02 - 0.05
- 0.05 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- >1



**2050 RCP 8.5 Climate Change
Sensitivity - 1% AEP
Iron Bridge**

Requested By:	Date: 26/03/2025
Drawn By: HML	Size: A4P
Scale: 1:23,000	Revision: 1
Projection: GDA 1994 MGA Zone 50	Confidentiality: 1
Doc Name: Sensitivity_Mapping_A4	