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ENGINEERING DOCUMENT

# PROJECT REPORT	PAGE 1 of 114
NUMBER PREP-1200-C-12142/B	
DESCRIPTION STUDY PHASE WAIO PROJECT YANDI CLOSURE LANDFORM SPS SURFACE WATER ENGINEERING DESIGN REPORT	
OFFICE OF ORIGIN ADVISIAN **AUTHOR** Ross Perrigo **TITLE OF AUTHOR** Principal Water Resources Engineer **CHECKER** Stuart Atkinson **TITLE OF CHECKER** Principal Consultant	**SPO PROJECT CODE:** FX.00.O.15586

STATUS ACCEPTED BY BHP

SIGNED

ACCEPTED
(Alpha or Numeric) ____________________

ACCEPTED AS NOTED
(Alpha or Numeric) ____________________

REVISE AND RESUBMIT
(Alpha or Numeric) ____________________

AUTHORISED BY (BHP)
(Alpha or Numeric)

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Rev.	Date	Description	Author	Checker
A	29/01/2024	ISSUED FOR INTERNAL REVIEW	RP	SA
B	31/1/2024	ISSUED FOR REVIEW	RP	SA

Appendices

1 INTRODUCTION

1.1 Project Background

BHP's Marillana Creek mining operation, herein referred to as "Yandi", is located approximately 100 km northwest of Newman in the Pilbara region of Western Australia (Figure 1-1). Yandi operates under the Marillana Creek State Agreement, which expires in 2054.

Yandi Operations commenced in 1991 with an iron ore production capacity of 5 Mtpa. The Hub has subsequently undergone several expansions, enabling a production capacity of 80 Mtpa. The orebody supporting the Yandi Hub is a near-surface, channel iron deposit (CID).

Yandi Operations are proceeding to ramp down as the resource approaches depletion and production at South Flank ramps up to replace it. In accordance with regulatory approval for the Marillana Creek (Yandi) Mining Operations, outlined in Ministerial Statement 1039 (MS 1039), BHP "shall ensure that the proposal is decommissioned and rehabilitated in an ecologically sustainable manner".

Marillana Creek is a significant watercourse that flows through the current mining operation. At Closure, floodwater in Marillana Creek must be conveyed safely through the mine area using a combination of flood channels, creek diversions, floodplain landforms created by backfilling pits and flood protection bunds, to maintain landform stability and prevent uncontrolled overtopping of floodwater into pit voids. The flood channels act as engineered relief points during large flood events, allowing controlled discharge of a portion of floodwater into the pit voids. Several flood bunds and creek diversions are already in place to divert floodwater around the pits and shall be upgraded as required at Closure.

This report summarises the outcomes of engineering work undertaken in the Selection Phase Study (SPS) phase of the Project, to identify and develop Closure designs for surface water management structures. These structures include flood channels, creek diversions, floodplain landforms and flood protection bunds.

1.2 Purpose of the Report

The purpose of this report is to summarise the surface water engineering scope of work undertaken by Advisian, the Engineering Services Provider (ESP), during the SPS.

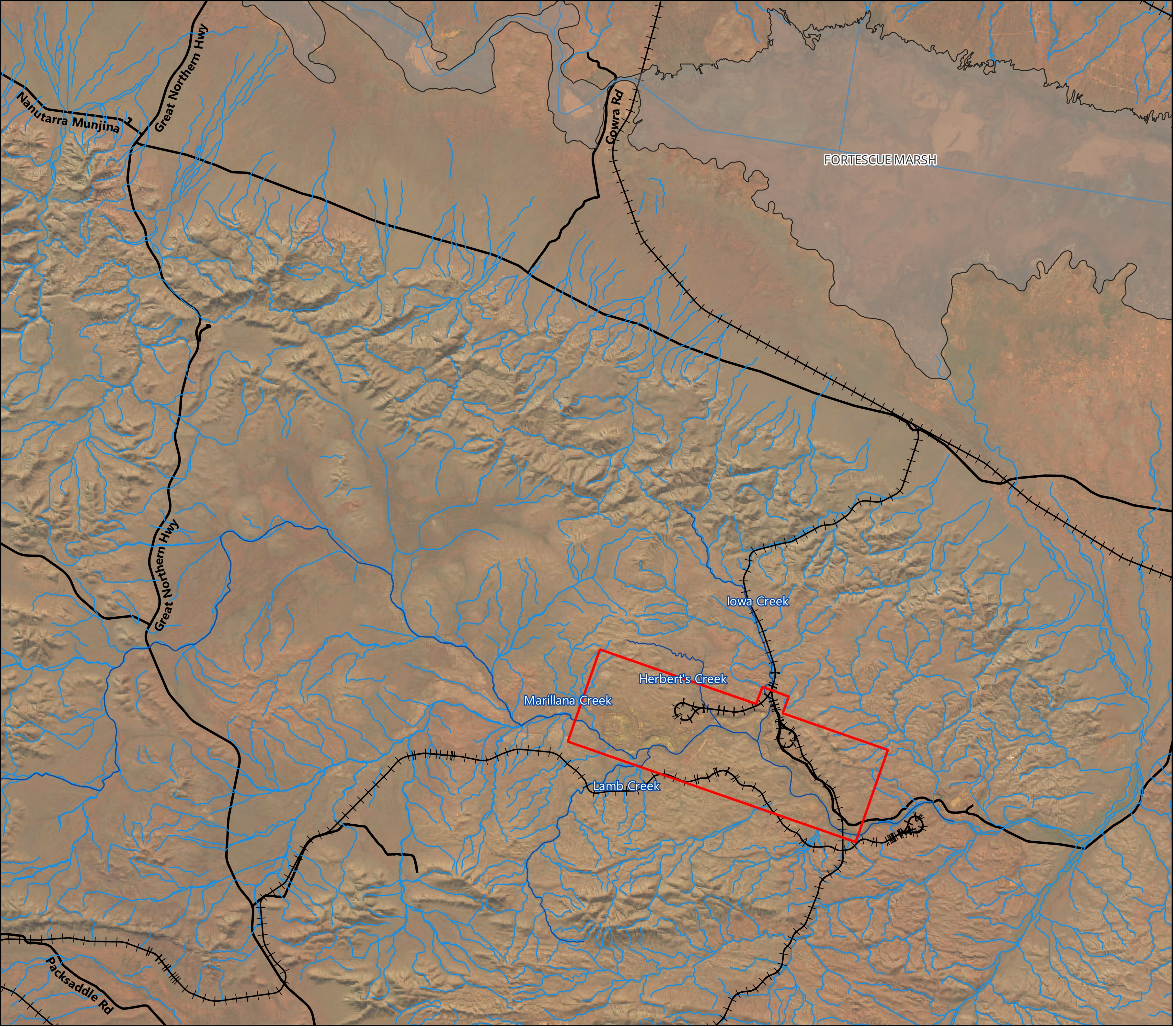
1.3 Scope and Objectives

The objective of the SPS engineering design was to further define and optimise the design of the surface water structures identified in the IPS phase. Surface water structures are a significant component of the overall Closure costs, and the value engineering and trade-off studies were undertaken to realise value.

The SPS engineering design Scope of Work summarised in this report includes the following in accordance with SOW-1220-C-00005/J.

Yandi Closure Landform

FIGURE 1-1 LOCATION PLAN

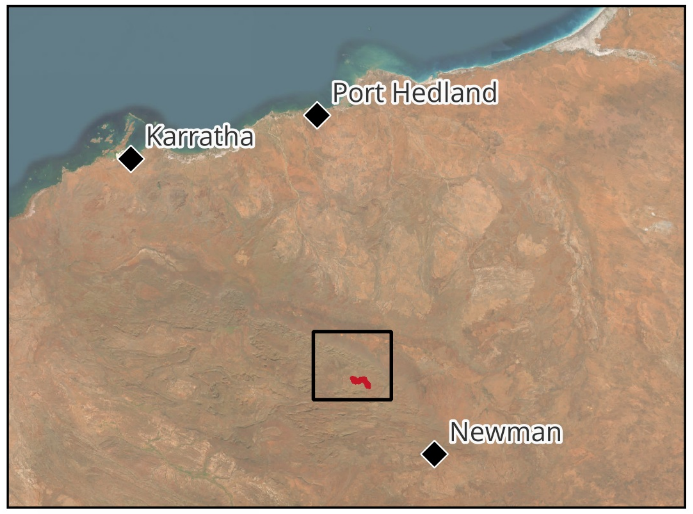


Legend

- Yandi Mine
- Fortescue Marsh
- Waterways
- Main Streams
- Road Network
- Rail Network

0 5,000 10,000 m

Date: 31/01/2024
Projection: Yandi 94



BHP Advisian

\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 1-1 LOCATION PLAN

1.3.1 Flood Channels

a) Conduct value engineering of the flood channels[1] considering:

i. The interpretation of the geology at each location

ii. The results of 2D hydraulic modelling (TUFLOW) and computational fluid dynamics (CFD) modelling.

b) Assess the risk of scour and erosion of the flood channels, energy dissipators, pit backfill and pit walls, and undertake engineering design required to mitigate the risk.

c) Consider the risk of access and lack of egress to/from the flood channels and possible engineering controls to mitigate these risks.

d) Conduct TUFLOW and CFD modelling to test hydraulic performance of final SPS designs with respect to the SPS Basis of Design (Landform)[2]:

iii. Not exceeding threshold stream powers

iv. Flood channels pass required flow rates for a range of design flood events.

e) Engage with BHP Operations to provide early input into the design:

i. Ensure the design is constructible and consideration is given for construction access requirements

ii. Obtain input on achievable construction tolerances and the effect of these on construction cost

iii. Obtain advice on the requirements for generating armour rock from the dolerite and the effect of any of these requirements on cost

iv. Obtain input on safety aspects.

f) Review the risk of failure of the flood channels in terms of consequence and timeframes, using available site data.

g) Sensitivity analysis of flood channels for higher flow rates, including specific flow rates estimated for future time horizons.

1.3.2 Flood Protection Bunds

a) Conduct a site visit to inspect the existing Marillana Creek bunds as well as other flood protection bunds associated with other diversions that will be amended/adjusted and/or rock armour amended (rock armour size and quality).

b) Undertake engineering design of the flood protection bunds based on:

[1] For the SPS, the term ‘Flood Channel’ rather than ‘Spillway’ has been adopted. In earlier documents, including the trade-off studies, the term ‘Spillway’ may still be found.
[2] This was only completed for W1-SP0 owing to available data. This is discussed further in Section 9.

i. the results of the site visit
ii. the updated pit setback analysis
iii. 2D hydraulic modelling (TUFLOW) of the site (flood levels and velocity).

c) Investigate options for sourcing rock armour: generate from flood channel excavation or alternative sources.

d) Consider the need for erosion protection on the downstream (pit side) slope.

e) Sensitivity analysis of bunds for higher flow rates, including specific flowrates estimated for future time horizons.

1.3.3 Diversions and Minor Drainage

a) Complete a site visit to inspect existing diversions, landbridges and representative analogues. The landbridges include the Herbert's Creek landbridge as well as the landbridges formed from mining either side of Iowa and Marillana Creek.

b) Identify upgrades of existing diversions (where required) needed to reinstate more natural geomorphic form in diversions (sinuosity, bed grades, alluvium depths, cross sectional variability & features).

c) Update diversion designs (new and existing) based on geomorphic design criteria and include minor drainage paths around processing areas (primary channel and secondary flow paths), including evaluation of approvals requirements for creek disturbance / permitting.

d) Conduct confirmation modelling of all diversions in 1D and 2D (as appropriate) and confirm compliance with the SPS Basis of Design (Landform).

e) If required, ensure that the performance of the E1 and E4 diversions of Marillana Creek is consistent with the Basis of Design (Landform) development for these diversions.

f) Sensitivity analysis of diversions for higher flow rates, including specific flowrates estimated for future time horizons.

g) Prepare Drawings for the flood channels, diversions, and flood protection bunds, including general arrangements, plan and profiles, long sections, and cross sections.

h) Prepare an SPS Surface Water Engineering Report that documents the hydraulic and geomorphological studies and analysis undertaken and the design outcomes.

1.4 Revised Project Schedule

Note that BHP advised Advisian on 20 December 2023, that the original project schedule was to be shortened by several weeks. For certain elements of the SPS Closure design, the adjusted schedule has limited the level of detail presented in this report. The focus of this report is on the key landform designs relating to surface water management. A summary of the forward works is provided to address information gaps, reduce uncertainty, and realise cost saving opportunities in the DPS phase of the project.

1.5 Abbreviations and Acronyms

Table 1-1: List of abbreviations and acronyms

Acronym	Meaning / Definition
ACARP	Australian Coal Association Research Program
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR2019	Australian Rainfall and Runoff 2019
bgl	below ground level
BH	Borehole
BHPBIO	BHP Billiton Iron Ore Pty Ltd
BIF	Banded Iron Formation
BOD	Basis of Design
CALTRAN	California Department of Public Works – Division of Highways
CCO	Creek Constrained Ore
CFD	Computational Fluid Dynamics
CID	Channel Iron Deposit
DEM	Digital Elevation Model
DNRME	Department of Natural Resources, Mines and Energy
DPS	Definition Phase Study
DW	Distinctly Weathered Dolerite
ESP	Engineering Service Provider
FW	Fresh Dolerite
HW	Highly Weathered Dolerite
IPS	Identification Phase Study
LCID	Lower Channel Iron Deposit
LiDAR	Light Detection and Ranging
Mtpa	Million Tonnes Per Annum
OSA	Overburden Storage Area
PSD	Particle size distribution
RL	Reduced Level
RMEI	Rock Mass Erodibility Index
SPS	Selection Phase Study

1.6 Battery Limits

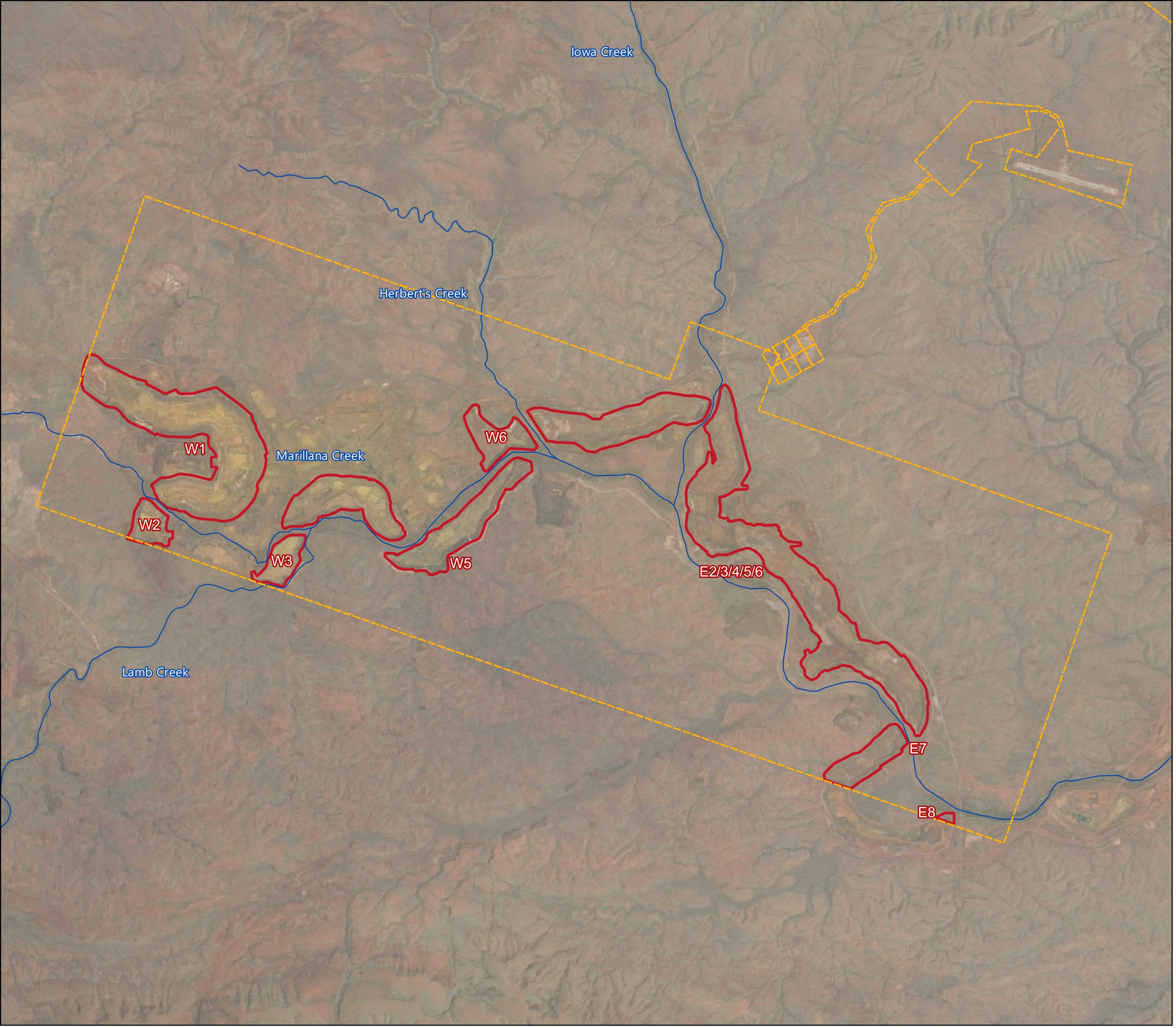
Yandi is situated within Mining Lease M270SA; General Purpose Leases 47/12 to 47/19; Miscellaneous Licences 47/118, 47/667 and 47/771; Crown Leases K843924 and K843924. These areas, shown on Figure 1-2, collectively represent the geographical battery limits for the Scope of Service for the SPS, except for the following constraints and exclusions summarised from Table 3-2 of SOW-1220-C-00005/J:

- Yandi processing and non-processing infrastructure
- Yandi Operations
- Yandi contaminated sites
- Rehabilitated Overburden Storage Areas (OSAs)
- Tenement boundary
- Resource definition, availability, and commercial optionality
- Data knowledge gaps
- Lack of precedent
- Existing approvals and regulatory conditions
- Traditional Owner engagement
- Uncertainty associated with long term modelling and cumulative impacts
- Heritage.

The Yandi Closure Landforms Project considers Closure and rehabilitation of Yandi mine voids, non-rehabilitated OSAs, surface water diversion structures and construction of all other landforms required at Closure.

Yandi Closure Landform

FIGURE 1-2 TENEMENT BOUNDARIES

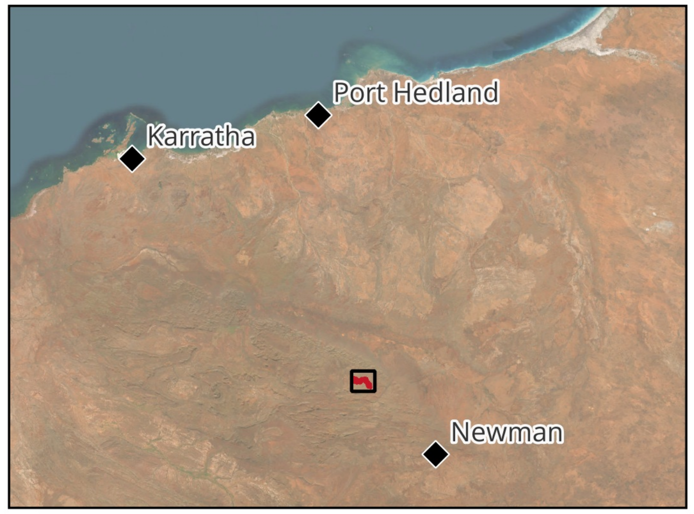


Legend

- Main Streams
- Yandi Tenements
- Pit Outlines

0 1,000 2,000 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 1-2 TENEMENT BOUNDARIES

BHP Advisian

2 DATA REVIEW

Most data required for the SPS was carried over from the IPS phase. Where required, additional information was requested from BHP via ACONEX and stored electronically on Advisian's secure project file available to study personnel. Relevant information has been referenced where required throughout this report. A summary is also provided in Table 2-1 below.

Table 2-1 Data utilised for the surface water engineering

Data / Information	Format	Description
Aerial Imagery and Topography		
DEM	20230426_LiDAR_1m_DEM_YAN94.flt	April 2023 1 m LiDAR covering Marillana Creek
	Yandi_October2022_LIDAR_1m_YAN.flt	October 2022 1 m LiDAR. Covers portions of the model domain not captured by April 2023 LiDAR.
	Yandi_Terrain_YAN94.flt	1 m topography data covering downstream portion of model domain, in proximity to E8 pit.
	OSA1_Pre-Mining_1m_DEM_ClippedToTopo.flt	Pre-mining topography. Derived March 2023.
Imagery	YCLP_Gap_Analysis_Imagery_15cm_Mosaic.ecw	15 cm detailed imagery. Captured Mar – Jun 2023.
GIS		
Environmental	WAIO Environment and Potable Water Bore Exclusion Areas.shp	BHP Environmental exclusions zones
Heritage	yan_heritage_moderate_risk.shp yan_heritage_high_risk.shp yan_heritage_very_high_risk.shp	Heritage areas within the Yandi mine extent.
Tenement boundary	Yandi_Tenement_Boundary.dxf	BHP Yandi Tenement boundary extent
Rail	yandi_rail_v2.dxf	BHP Rail
Pit Shells	c30000_pd_v02_p.dxf	C3 pit shell dxfs projected YAN94
	c60101_pd_v03_p.dxf	C6 pit shell dxfs projected YAN94
Backfill Data	C1_Backfill_Area_1_20230814140040	C1 Area 1 Backfill
	C1_Backfill_Area_2_20230814140207	C1 Area 1 Backfill
	C2_Backfill_Area_1_20230814142150	C2 Backfill

Data / Information	Format	Description
	E2_Backfill_Area_1_20230814142347	E2 Backfill
	W1_Backfill_Area_1_20230811124542	W1 Backfill
	W1_South_Backfill_Area_1_20230814134208	W1 South Backfill Area 1
	W1_South_Backfill_Area_2_20230814133754	W1 South Backfill Area 2
	W1_South_Backfill_Area_3_20230814134616	W1 South Backfill Area 3
	W4_Backfill_Area_1_20230814134737	W4 Backfill
	W5_Backfill_Area_1_20230814135049	W5 Backfill Area 1
	W5_Backfill_Area_2_20230814135223	W5 Backfill Area 2
Background Information		
Report	PREP-1200-C—12141_C.pdf	BHP Yandi Baseline Hydrology Study (Advisian, 2023a).
Trade-off studies	311012-01707-CI-PRE-0013_C	W1-SP3 Trade-off Study
	311012-01707-CI-PRE-0009_C	Bund Slope and Rock Armour
	Asbestos 311012-01707-CI-PRE-0003_C	Asbestos Risk at W1-SP0
	311012-01707-CI-PRE-0008-C	Submerged vs Launchable Toe
	311012-01707-CI-PRE-0007_C	E1 E4 Replace or Reuse Armour Rock Protection
	311012-01707-CI-PRE-0005_C	Backfill pits to lower bunds
	311012-01707-CI-PRE-0002_C	Steps Vs Slopes
	311012-01707-CI-PRE-0001_C	Flood Channel Width
	311012-01707-CI-PRE-0010_C	Pit Access
	311012-01707-CI-MEM-0006_B	Pit and Pit Wall Revegetation
	311012-01707-CI-PRE-0006_C	Buttress Eastern Pits
	311012-01707-CI-PRE-0012_C	Pit Wall Reprofiling and Cut Slope Flattening
	311012-01001-CI-PRE-0002_C	Bunds Vs Flood Channels
Memo	PREP-1220C-12046_C	IPS Yandi Closure Landform Flood Channels Technical Memorandum

Data / Information	Format	Description
Models		
Hydraulic Model	YANDI_SPS_SP4_~s1~_~e1~_022.tcf Yandi_Closure_SPS_06_~s1~_~e1~.tcf	W1-SP4 Flood Channel TUFLOW Model Yandi IPS TUFLOW Model
Hydrological Models	Lamb_02_ENS.par	Lamb Creek RORB Model
	Herberts_Creek_03_ENS.par	Herbert's Creek RORB Model
	IOWA_CK_DEC1990_001.par	Iowa Creek RORB Model
	Marillana_FINAL_ENS_Using_Goodfit2000AEP_Kc_IFD_WholeCatch_Spatial_Dist_GTSMR_1in10000_2500km2TPs_UpdateAEPofPMP.par	Marillana Creek RORB Model
BHP Supplied Information		
Background Data	RPD NPH 20150505 Yandi Existing Flood Bunds.xlsx	BHP Yandi Existing Bund Table

3 HYDROLOGY

3.1 Catchment characteristics

Marillana Creek is a major tributary of Weeli Wolli Creek, discharging into upper Fortescue Marsh and hence forms part of the Fortescue River catchment. Marillana Creek flows in an easterly direction before discharging into the lower reaches of Weeli Wolli Creek (immediately downstream of Rio Tinto's Yandicoogina Iron Ore Operations) and flowing north into the Fortescue Marsh.

General catchment characteristics for key locations within the Marillana Creek catchment as well as its larger tributaries are presented in Table 3-1 and Figure 3-1.

Table 3-1 Catchment details

Name	Area (km^2)	Mainstream Length (km)	Centroid Latitude (°S)	Centroid Longitude (°E)
Marillana Creek to Flat Rocks	1,375	75.97	-22.72	118.76
Marillana Creek to BHP Rail Crossing	1,839*	100.64	-22.72	118.83
Lamb Creek	91	21.01	-22.81	118.97
Herbert's Creek	29	10.21	-22.70	119.04
Iowa Creek	100	15.82	-22.65	119.07

** Denotes pit areas excluded from total*

Herbert's Creek and Lamb Creek are the larger tributaries of Marillana Creek within the Yandi Mine area that have been diverted, so are defined here as intermediate creek diversions. Herbert's Creek has been diverted through a pit void via an engineered landbridge structure, while Lamb Creek has been diverted around the pit using a constructed channel and flood bund structure.

Iowa Creek is another large tributary of Marillana Creek that flows between pits mined on either side. Iowa Creek has not been diverted however mining of adjacent CID has created a natural landbridge and reduced the maximum flow capacity.

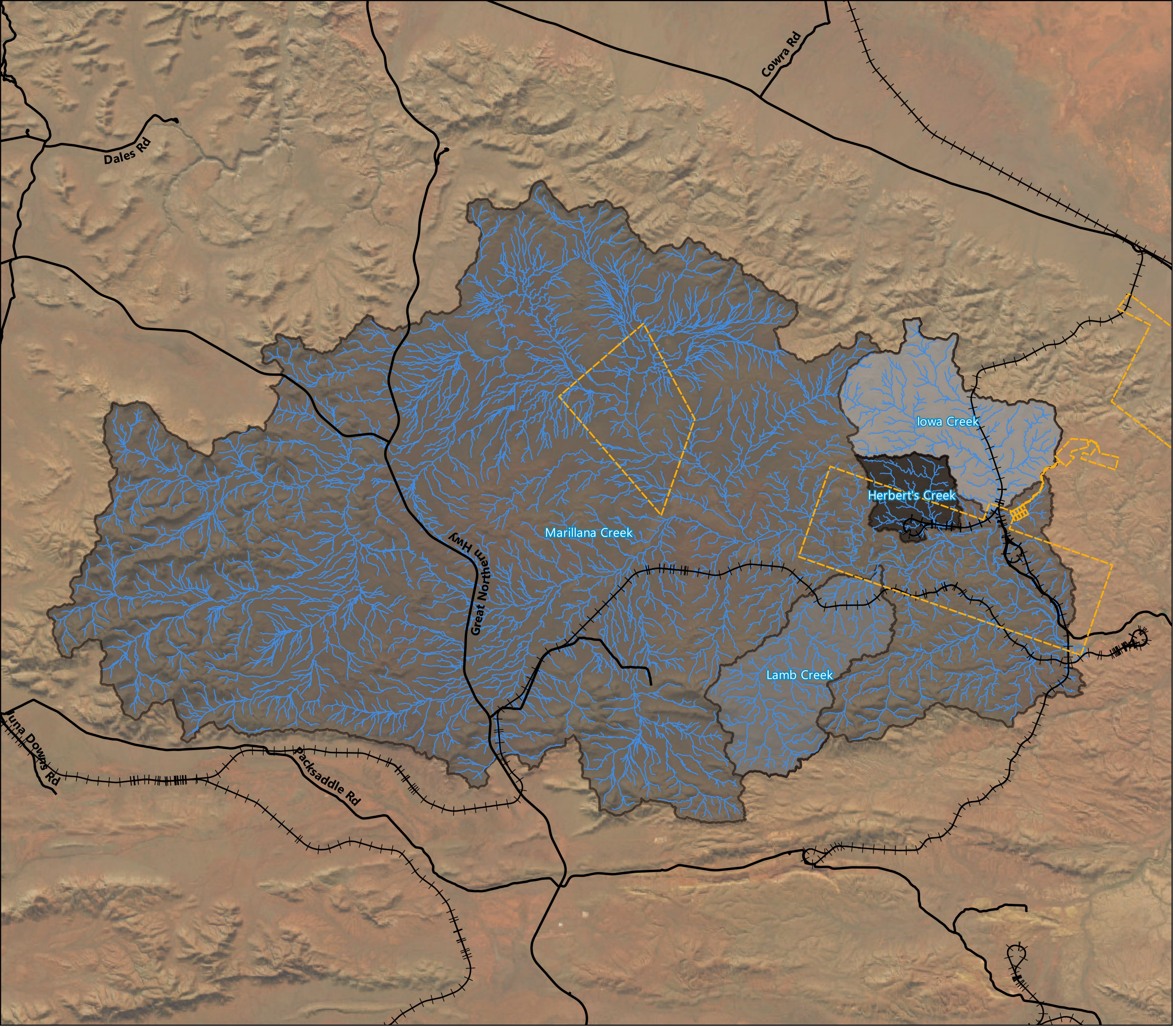
Several other minor creeks have been or will need to be diverted to maintain flows to Marillana Creek at Closure.

3.2 Baseline conditions

A baseline hydrology study (PREP-1200-C—12141) was completed by Advisian (2023a) to quantify and characterise the baseline hydrology of Marillana Creek and its tributaries in accordance with the recommendations in Australian Rainfall and Runoff (ARR2019) (Ball et al., 2019). The peak flows estimated at key locations within the Marillana Creek catchment are summarised in Table 3-2, with complete results presented in the baseline study (Advisian, 2023a). The flow hydrographs developed as part of the baseline study were used to inform hydraulic modelling and the engineering designs of surface water management measures for the Yandi Closure SPS.

Yandi Closure Landform

FIGURE 3-1 MAJOR CATCHMENTS IN STUDY AREA

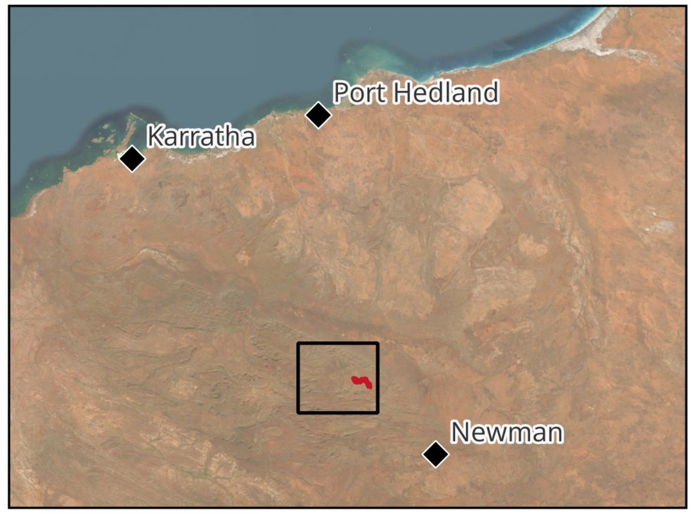


Legend

- Waterways
- Rail Network
- Road Network
- Yandi Mining Tenements
- Herberts Creek
- Iowa Creek
- Lamb Creek
- Marillana Creek

0 5,000 10,000 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 3-1 CATCHMENTS

Table 3-2 Adopted design event peak flows (Advisian, 2023a)

Location	AEP event								
	10% (m^3/s)	5% (m^3/s)	2% (m^3/s)	1% (m^3/s)	1 in 200 (m^3/s)	1 in 500 (m^3/s)	1 in 1,000 (m^3/s)	1 in 2,000 (m^3/s)	1 in 10,000 (m^3/s)
Marillana Creek									
Flat Rocks	493	849	1,398	1,898	2,457	3,345	4,055	4,825	7,244
Lamb Creek confluence	508	929	1,573	2,129	2,736	3,698	4,469	5,296	7,978
Herbert's Creek confluence	513	956	1,634	2,209	2,833	3,820	4,612	5,459	8,232
Iowa Creek confluence	523	1,016	1,769	2,387	3,046	4,087	4,925	5,813	8,785
Unnamed Creek confluence	528	1,047	1,840	2,480	3,158	4,227	5,088	5,998	9,074
BHP Rail	532	1,071	1,895	2,553	3,245	4,335	5,214	6,140	9,297
Adopted Design Storm	36-hr TP09	24-hr TP04	24-hr TP04	24-hr TP01	24-hr TP01	24-hr TP08	24-hr TP10	24-hr TP10	24-hr Jan 1974 (GTSMR)
Major Tributaries									
Lamb Creek outlet	156	265	384	484	616	776	893	-	-
Adopted Design Storm	12-hr TP01	12-hr TP01	12-hr TP01	12-hr TP01	6-hr TP01*	6-hr TP01*	6-hr TP01*	-	-
Herbert's Creek outlet	92	138	205	248	276	332	375	-	-
Adopted Design Storm	6-hr TP04	6-hr TP08	6-hr TP10	6-hr TP10	6-hr TP10	6-hr TP02	6-hr TP02	-	-
Iowa Creek outlet	244	374	534	646	811	981	1,109	-	-
Adopted Design Storm	12-hr TP10	12-hr TP03	12-hr TP03	12-hr TP03	6-hr TP01*	6-hr TP01*	6-hr TP01*	-	-

4 ENGINEERING CONSIDERATIONS

During the engineering design, safety and sustainability in design elements were considered and incorporated into the design to reduce risk and uncertainty. Key considerations were made in the following areas.

4.1 Safety in Design

The post-Closure land use for the site may include access for the public including the Traditional Owners of the area, the Banjima People. Public access could result in people having access to backfilled pits, pit lakes, flood channels and/or other areas of the site. Safe access will need to be provided for both authorised and unauthorised public access. All rehabilitated areas will need to meet the agreed minimum safety requirements set by regulations.

4.2 Stakeholder Expectations and Social Value

During SPS, BHP conducted ongoing consultation with the Banjima People and other relevant stakeholders to define the optimal landform designs that will be necessary to realise stakeholders' vision for the future. The integrity and access to places of cultural significance and or future non-mining ventures will need to be maintained in the Closure design.

Heritage and social values were considered throughout the SPS design process. As part of constraints mapping, heritage information provided by BHP was referenced. Design footprints of engineered landforms were altered where necessary to ensure that heritage resources were avoided.

During previous engagement with the Banjima People, a preference for seasonal expressions of water was identified and remains a key aspect of the backfill design. Additional considerations that have been incorporated into the SPS engineering design because of knowledge gained from BHP's engagement activities are:

- a preference for natural looking landforms (e.g., Flat Rocks as a natural analogue for a flood channel)
- retention of mature trees (e.g., strategies for controlling flows into Marillana Creek that minimise disturbance of existing trees and or enhance tree health).

Final rehabilitated landforms will need to be compatible with local Pilbara landforms and complement the surrounding / natural topography, meeting the expectations of the Banjima People and other stakeholders. During the site visit, natural analogues were observed at various landscape positions (including Flat Rocks) for the purpose of informing landform design and rehabilitation / revegetation planning.

5 TRADE-OFF STUDIES

As part of the SPS several trade-off studies were undertaken to assess selected IPS Closure designs and compare with alternative design options. The results were used to select the design options to investigate and progress further in the SPS.

The relevant trade-off studies are summarised in Table 5-1, along with reference in this report where outcomes are incorporated into the respective design process.

Table 5-1 Trade-off Studies summary

Trade-off Study	Summary	Reference
Flood Channel Width 311012-01707-CI-PRE-0001	This trade off study evaluated the hydraulic forces and rock erodibility indices for sloped and stepped flood channel options with the objective of identifying the optimal width. Some degree of erosion of the flood channel can be tolerated as the likelihood of the design flood event occurring is very low, and there is a significant distance between the energy dissipator and Marillana Creek A more aggressive reduction in flood channel width is not recommended at this stage due to the level of uncertainty in many aspects of the hydraulics and rock strength. The current geotechnical dataset does not sufficiently cover the flood channel alignment and will need to be re-evaluated as new data becomes available and more detailed analysis is undertaken.	9.2.1
Steps v Slopes 311012-01707-CI-PRE-0002	This trade-off study evaluated the hydraulic forces, rock erodibility indices and potential risks and uncertainties for sloped and stepped flood channel options with the objective of identifying a suitable type of energy dissipator. The sloped flood channel has high energy at the outlet, with several associated risks, however these risks are not deemed significant enough to outweigh the $18 M difference in direct cost and safety risks compared with the stepped dissipator. It is recommended that a natural analogue dissipator be adopted for the W1-SP0 flood channel, for example a slope with smaller steps to represent natural drop features.	9.2.1
Asbestos Risk at W1-SP0 311012-01707-CI-PRE-0003	This trade off study identified risks related to the IPS W1-SP0 flood channel design and alignment, and recommended and communicated possible design and alignment changes that could mitigate asbestos exposure risk. Key risks are exposure during construction of W1-SP0 using drill and blast methods; exposure to rock armour sourced from W1-SP0 excavation potentially containing fibrous materials; and exposure to fibrous seams outcropping in W1-SP0 excavation (including seams exposed in future following erosion during flooding). The trade-off study concluded it is not possible to eliminate the risk of exposure to naturally occurring fibrous (asbestos) materials associated with the W1-SP0 flood channel. Mitigating some of the risks for a period is possible, but some risks do not appear to be able to be mitigated.	9.2.1
Backfill Pits to Lower Flood Bunds 311012-01707-CI-PRE-0005	This trade-off study assessed the feasibility of partially backfilling pit voids to surface level to create a wider floodplain, to reduce the size and cost of flood bunds and rock protection. A key assumption in this trade-off study was that for the base case IPS design, flood bunds could be constructed on top of	10.2.1

Trade-off Study	Summary	Reference
	remnant CID material along pit crests, without the need to encroach into Marillana Creek. That assumption was subject to the outcomes from the site visit and constructability review. The trade-off study concluded that the only metric for which the Backfill Design is improved over the IPS Design is on the issue of rock armour. Despite these conclusions however, and following further flood protection bund design and modelling, consideration of stakeholder values associated with Marillana Creek, and discussion with BHP regarding cost, it was determined that the risks associated with constructing flood protection bunds in constricted areas of Marillana Creek outweighed the benefits, and the Backfill Design was adopted in specific areas (e.g., at W5, W6 and E6).	
Buttress Eastern Pits 311012-01707-CI-PRE-0006	This trade-off study assessed alternative downstream raising option (towards the pits) at E1, E4 & E7 flood bunds and compare with upstream raising (towards the creek) base case (IPS). Downstream flood bund raises were recommended at E1-2, E1-3, E1-4, E4-1, E4-2, and upstream raising is recommended for northern section of E1-1, as it avoids cost of additional buttressing. A downstream raise of E4-3 was recommended as the cost of buttressing is relatively low compared to the negatives of the upstream option. A downstream raise at E7-1 recommended as it does not impact on the creek though construction complexities were also identified.	11.2
Replace or Re-use Rock Armour 311012-01707-CI-PRE-0007	Following on the Buttress Eastern Pits trade-off study, this trade-off study assessed options for removal or re-use of rock armour where upstream (towards the creek) and downstream (towards the pit) raise occurs. It is identified that covering existing rock fill (armouring) is the more practical approach and provided cost benefits over removal or reuse.	11.2.2
Rock Armour Toe for Bunds: Submerged Toe vs Launchable Toe 311012-01707-CI-PRE-0008	Following on the Buttress Eastern Pits and Replace or Re-use Rock Armour trade-off studies, this study compared the extended rock and launchable toe rock options and selected the preferred option for SPS design. The E4-3 Flood Bund was selected as the basis for assessment. The extended rock option is preferred as it is cheaper ($6.6 M versus $8 M for the E4-3 Flood Bund trade-off assessment) and provides greater certainty in terms of protection from scour, erosion and undercutting of flood bund.	11.2.3
Bund Slope and Armour Rock Size and Volume 311012-01707-CI-PRE-0009	This study determined the feasibility of reducing (flattening) the IPS slope design for flood protection and using a different-sized armour rock to provide the same level of erosion protection. Rock protection design is determined by the adopted method for sizing rock; several methods were considered. Austroads (1994 & 2019) rock sizing tables were developed using the CALTRAN (1960) method which accounts for batter slope, though it is unclear how CALTRAN has been used in conjunction with practical experience and factors of safety to develop the Austroads (1994) tables. The Austroads (1994) tables have been widely adopted for rock protection design of waterway structures in the Pilbara region for many years. Bund slope is also not a factor across all rock sizing methods considered. Therefore, it was	11.2.2

Trade-off Study	Summary	Reference
	concluded that the Austroads (1994) tables should be adopted for rock protection design, and there is no firm basis for reducing rock size when/if adopting flatter bund slopes.	
Bunds vs Flood Channels 311012-01001-CI-PRE-0002	This trade-off study was completed in the later stages of the IPS and looked at the cost and risk of controlling surface water flows using only flood protection bunds, versus the design for the preferred investment alternative that includes flood channels. The study confirmed that the preferred approach to managing surface water at Closure is to have flood channels in the design. The preferred design including flood channels was carried forward into SPS.	9.2
Revisit the W1-SP3 Flood Channel 311012-01707-CI-PRE-0013	This trade-off study determined the costs and benefits of utilising the additional storage available in W4 Pit via the W1-SP3 flood channel, versus relying only on W1 Pit for flood attenuation and passing overflow back to Marillana Creek from an outlet location in W1 Pit. A cost comparison of the two scenarios revealed a cost saving of $27 M for the W1-SP4 scenario (excluding buttress costs, which could be significant). Considering the flood modelling analysis, associated risks and costs, it is recommended that the W1-SP3 flood channel be adopted for the SPS landform design. The W1-SP3 flood channel design was later modified to further reduce risk at Closure	9.2.2

6 SITE VISIT AND CONSTRUCTABILITY REVIEW

A site visit was conducted by Advisian personnel between the 14 and 17 August 2023 to inspect the proposed locations for creek diversions, flood channels and flood protection bunds and identify any potential constructability issues associated with access, competency of in-situ material, proximity to pit voids and environmental constraints. Findings are presented in this section.

6.1 Site Visit

Site photos were collected on site and the results presented to BHP and discussed. A copy of the presentation is provided in Appendix A.

The key findings from the site walkover are summarised below:

Positives

- There were several natural features observed that could be replicated / copied / used for inspiration for design of the W1 flood channel
- Performance of E1 and E4 diversions suggests they will require little or no intervention for Closure
- CID in some locations appears suitable as erosion protection and/or has room to construct a bund on top, if required
- Potential for the E4 diversion rock bar to be modified to create an ephemeral pool if required.

Challenges

- W5 and W6 Pit remnant CID is in poor condition and may require extensive and difficult works to make suitable for Closure, likely requiring large disturbance to the creek. Many mature trees grow hard up against the CID, presenting a challenge for construction if to be protected
- Several minor diversions are in poor condition and will require upgrades to be suitable for Closure
- Herbert's Creek land bridge will require works to upgrade to Closure. Scour hole at outlet identified as an area of potential concern for Closure due to head cutting, subject to geotechnical review/assessment
- Creek Constrained Ore (CCO) flood bunds will require upgrades. Evidence of erosion/undercutting of rock armour already, likely caused by a very small flood event.

6.2 Constructability Review

A constructability review was completed after the site visit which involved further assessment of topographic survey data and site photos, and identification of constructability issues. A detailed description of the review and findings is provided in the Yandi Constructability Review Report (PREP-1200-C-12148), with the key findings summarised below.

The review identified several issues associated with construction of flood bunds on top of remnant CID at several locations at Yandi, particularly along the constrained sections of Marillana Creek between the W4/W5, W5/W6 and E6/E7 pits. The outcome of the constructability review was that the bunds would need to be constructed in Marillana Creek adjacent to the remnant CID, further constraining the already constrained section of creek. Hydraulic modelling was used to inform the bund designs, which resulted in incrementally higher flood bunds and larger rock protection due to the reduction in creek flow area. Increasing the bunds resulted in further encroachment into the creek, to the point that construction of flood bunds within the constrained sections of Marillana Creek (i.e., between W4/W5, W5/W6 and E6/E7 pits) was deemed to be unfeasible.

The alternative option of partially backfilling W5, W6 and E6 pit voids to create floodplain landforms, reduce flood depths and velocities was then explored. The results showed the adoption of floodplain landforms resulted in a significant reduction in number of flood bunds required at Closure as well as a reduction in rock protection where required. The floodplain landform option was subsequently adopted for SPS design (Section 10).

7 BASIS OF DESIGN

The SPS surface water engineering Basis of Design includes the following design criteria in accordance with DESB-1200-G-00075/C. Note only a velocity-based approaches for rock armouring (protection) was adopted, consistent with the Trade-off study (311012-01707-CI-PRE-0009).

Table 7-1 Surface Water Design Criteria

Design Criteria	Source
OSAs and Infrastructure Areas	
Integration of landform with engineered drainage features and natural topography through comparison with pre-mining topography, where it exists, or with the surrounding natural surface.	Kemp, 2017 Taylor et al., 2016
Final landform profiles to resemble as close as practicable the natural, undisturbed landform.	
Creek and waterway diversions	
Diversions to be safe, stable, non-polluting, and not require ongoing care and maintenance. They should foster the development of a sustainable ecosystem and sustain an appropriate surface water flow regime to the key environmental receptors of Fortescue Marsh, Weeli Wolli Creek and Marillana Creek. • **Major Diversions (Marillana Creek)**: Diversions to accommodate predicted flow rates for the 1:10,000 AEP flood event (0.01% AEP). • **Intermediate Diversions (Iowa Creek, Herbert's Creek, Lamb Creek):** Diversions to accommodate predicted flow rates for the 1:1,000 AEP flood event (0.1% AEP). • **Minor Diversions:** Diversions to accommodate predicted flow rates for the 1:100 AEP flood event (1% AEP).	Austroads, 1994 ACARP, 2014 DNRME, 2019
Diversion design bank slope factor of safety minimum of 1.5 for overall slope stability under static conditions and minimum of 1.2 under seismic conditions, including consideration to sensitivity of the predicted material strength and groundwater conditions.	
Flood protection bunds	
Bunds to be safe, stable, and non-polluting and not require ongoing care and maintenance. They should prevent unplanned and uncontrolled creek capture into pit voids during rainfall events. • **Major Diversion Bunds (Marillana Creek):** Bunds to accommodate predicted flood levels and velocities for the 1:10,000 AEP flood event. • **Intermediate Diversion Bunds (Iowa Creek, Herbert's Creek, Lamb Creek):** Bunds to accommodate predicted flood levels and velocities for the 1:1,000 AEP (0.1% AEP) flood event. • **Minor Diversion Bunds:** Bunds to accommodate predicted flood levels and velocities for the 1:100 AEP (1% AEP) flood event.	Austroads, 1994
Design bund slope factor of safety minimum of 1.5 for overall slope stability under static conditions and minimum of 1.2 under seismic conditions, including consideration to sensitivity of the predicted material strength and groundwater conditions	
Armour rock protection to be included (where required) on upstream face of bund for respective design flood event. Rock sizes will be based on rock classes in Austroads (1994).	
Toe depth of the rock protection to be based on estimated scour depths in the adjacent creek channel (primary low flow channel) or respective design flood events.	
Bund crest levels to have 1 m freeboard to the flood level of the respective design flood event.	
Bund crest width to be a minimum of 5 m.	
Both fill and scour protection materials sourced from durable and geochemically stable sources.	

Design Criteria	Source
Flood Channels	
Flood Channels to be safe and stable, constructed in competent rock resistant to erosion to minimise the risk of failure. Floods less than the 1:20 AEP (5% AEP) event: • No flow from Marillana Creek to pass over flood channels – all to be retained in creek. • No flow from other tributaries to pass over flood channels if possible.	
1:20 – 1:100 AEP (5% – 1% AEP) events: • Maintain similar hydraulics in the Marillana Creek diversions compared to the Constrained Creek Ore (CCO) DPS Basis of Design. (i.e., the diversions still behave as a similar fluvial system to Marillana Creek) • Minimise the number of flood channel activated during rare (1:20 to 1:100 AEP) flood events. • Majority of flood channels flow to pass through the most robust channels(s) (e.g., a flood channel cut in fresh competent rock).	
1:100 – 1:500 AEP (1% – 0.2% AEP) events: • Minimise the risk of creek capture by mine pits. • Minimise the number of flood channels activated during very rare (1:100 – 1:500 AEP) flood events. • Majority of flood channels flow to pass through the most robust flood channels(s) (e.g., a flood channel cut in fresh dolerite)	
1:500 – 1:10,000 AEP (0.2% - 0.01% AEP) events: • Minimise the risk of creek capture by mine pits. Global factor of safety of >1.5 for flood channel cut slopes.	
Flood channel geometry to be designed to minimise the stream power of a 1:10,000 AEP flood event and thereby reduce likelihood of significant erosion in in-situ rock. Flood channels to be located within area of most competent rock (informed by results from geotechnical drilling) where feasible.	

8 ENGINEERING DESIGN

Surface water engineering design for Closure includes a combination of:

- flood channels
- floodplain landforms constructed by partially backfilling pit voids
- new flood protection bunds with rock protection
- upgrade of existing flood protection bunds with rock protection
- new creek diversions, and
- upgrade of existing diversions

The assessment and potential upgrade of the Herbert's Creek landbridge was removed from the SPS scope of work so remains in its current form for SPS design.

This section outlines the design process and adopted SPS designs.

8.1 Background

The Yandi Closure Identification Phase Study (IPS) engineering design was completed in 2020 (311012-00024-HY-MEM-0001/C). The IPS Closure design, presented in Figure 8-1, included the following features:

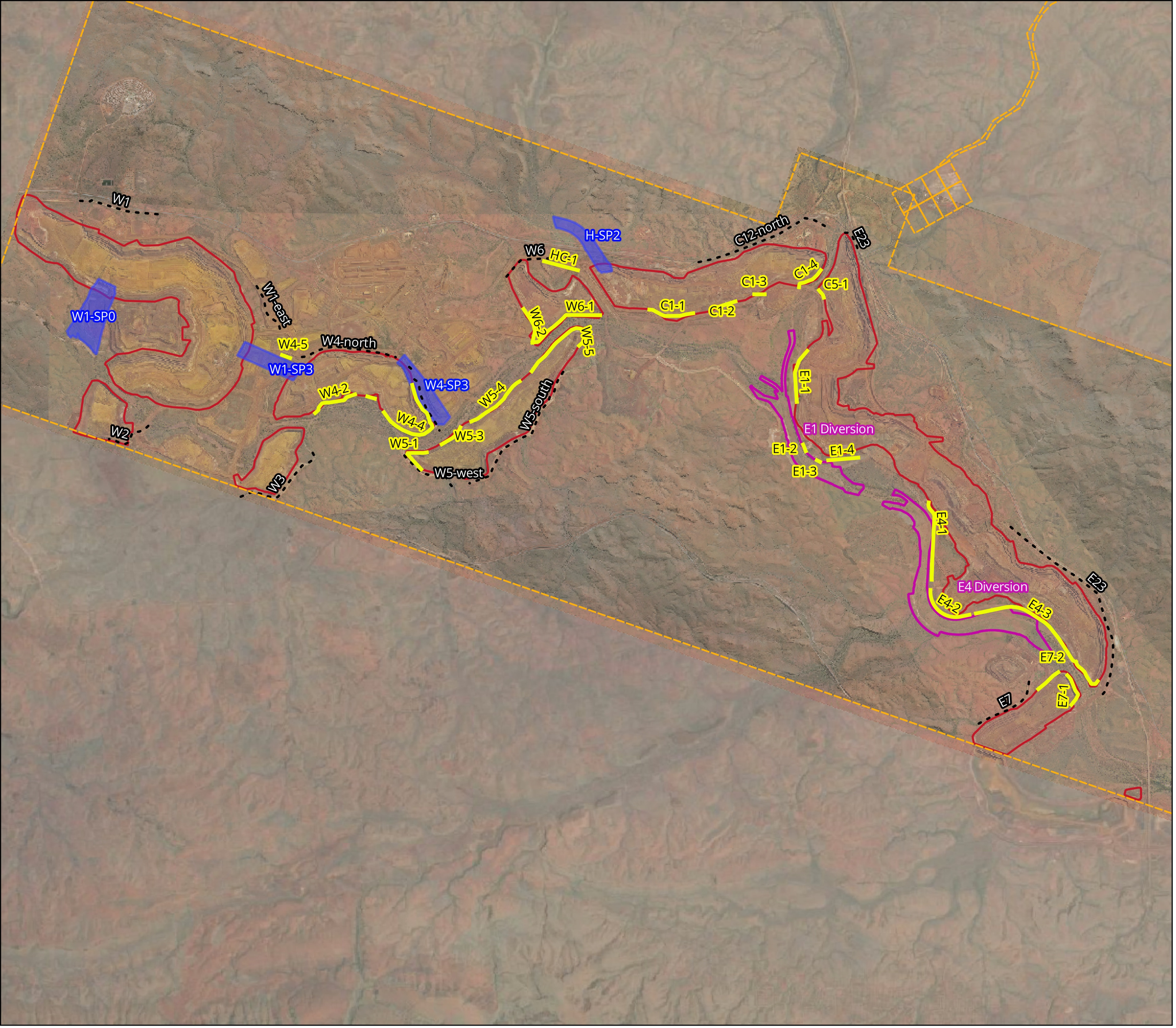
- Flood channels to direct excess floodwater during extreme flood events into pit voids at W1 and Herbert's Creek to protect the E1 and E4 diversions.
- Diversions and flood bunds surrounding pit voids (where required) to prevent uncontrolled inflow and potential creek capture:
    - two larger diversions of Marillana Creek (E1 and E4) and associated flood bunds
    - several minor creek diversions and associated flood bunds.
- Nominal allowance for rock protection upgrades along Herbert's Creek landbridge, assuming a flood channel is constructed upstream.

Flood channels were included in the IPS Closure design because without them, there would be uncontrolled overtopping of 1:10,000 AEP floodwater into pit voids at Closure. It was not considered feasible to construct flood bunds and landforms to contain all 1:10,000 AEP floodwater within Marillana Creek due to limited available waste material for construction. This is discussed further in Section 10.

Forwards-works identified in the IPS, including trade-off studies (Section 5), site visit (Section 6) and additional technical investigations have been addressed as part of the SPS and are presented in subsequent sections.

Yandi Closure Landform

FIGURE 8-1 IPS SURFACE WATER DESIGN

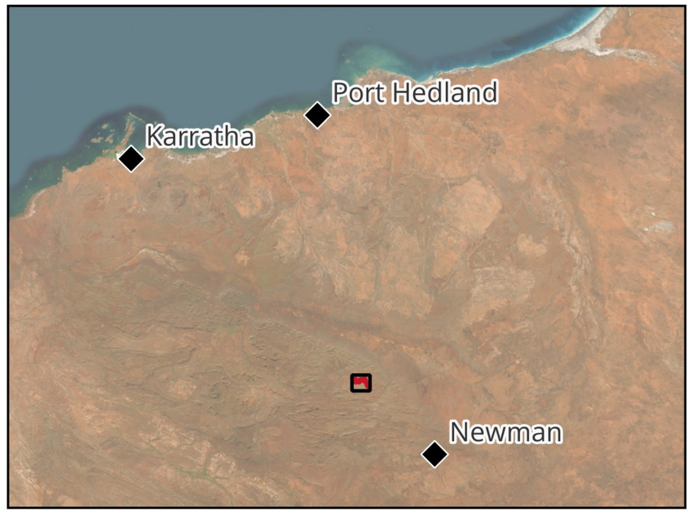


Legend

- Existing Diversion Drains
- IPS Flood Bunds
- Yandi Mining Tenements
- CCO Diversion Drains
- Pit Outlines
- Flood Channels

0 1,000 2,000 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 8-1 IPS SURFACE WATER DESIGN

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8.2 Hydraulic Model

Hydraulic analysis of closure designs was done using the 2D modelling program TUFLOW (version 2023-03-AB). This allowed for the analysis of flood channels, floodplain landforms, flood bunds and creek diversions using hydraulic parameters such as water depth, velocity, and stream power. Several model parameters were adopted from the BHP Yandi Baseline Hydrology Study (Advisian, 2023a) (PREP-1200-C-12141), with updates made to represent Closure conditions.

Two different modelling approaches were adopted for the different design features. The flood channels, floodplain landforms and flood bunds were modelled in a site-wide model whereas the creek diversions were analysed using smaller localised models. These different approaches are described in this section.

8.2.1 Site Wide Model

The TUFLOW model created in the Baseline Hydrology Study (Advisian, 2023a) was adopted for the analysis of flood channels, floodplain landforms and flood protection bund, with the following modifications:

- 3D designs that were developed in civil design software were converted to a grid incorporated in the model topography.
- Breaklines were added to the crest of flood protection bunds and natural CID along pit edges
- Haul road crossings along Marillana Creek were manually removed
- Assignment of roughness values was modified to reflect closure landforms and any areas of modified terrain.

A description of the model parameters is presented in Table 8-1 and the model setup shown in Figure 8-2.

Table 8-1: TUFLOW model parameters for site wide model

Parameter	Description
Terrain	1 m DEM derived from LiDAR captured in April 2023
Cell size	5m
Sub-Grid Sampling (SGS) distance	1m
Roughness (Manning's '*n*')	Marillana Creek main channel and flood channels: 0.035 Minor creeks main channel: 0.04 Sparse vegetation: 0.05 Medium vegetation: 0.055 Overbank: 0.06 Thick vegetation: 0.065
Inflow boundary condition	Flow vs Time (QT) – Flat rocks inflow hydrograph Source/Area (SA) – intermediary hydrograph additions on mainstream

Parameter	Description
Design storm	1 in 10,000 AEP: 24-hour duration (adopted from BHP Yandi Baseline Hydrology Study (Advisian, 2023a))
Outflow boundary	Automated stage-discharge curve (HQ), with bed slope set as water surface slope. Located 2km downstream of BHP rail bridge

8.2.2 Creek Diversion Modelling

The creek diversions were modelled at a catchment scale to calculate the critical duration and representative storm. These models were simulated in an ensemble environment using rain-on-grid, simulating ten (10) temporal patterns for different storm durations and calculating the median peak flow at the diversion inlet. The duration and temporal pattern that results in the maximum of the median peak flows were then adopted as the critical storm for each diversion. These storms were then simulated in a finer resolution model to assess hydraulic parameters in greater detail and for channel modifications where necessary.

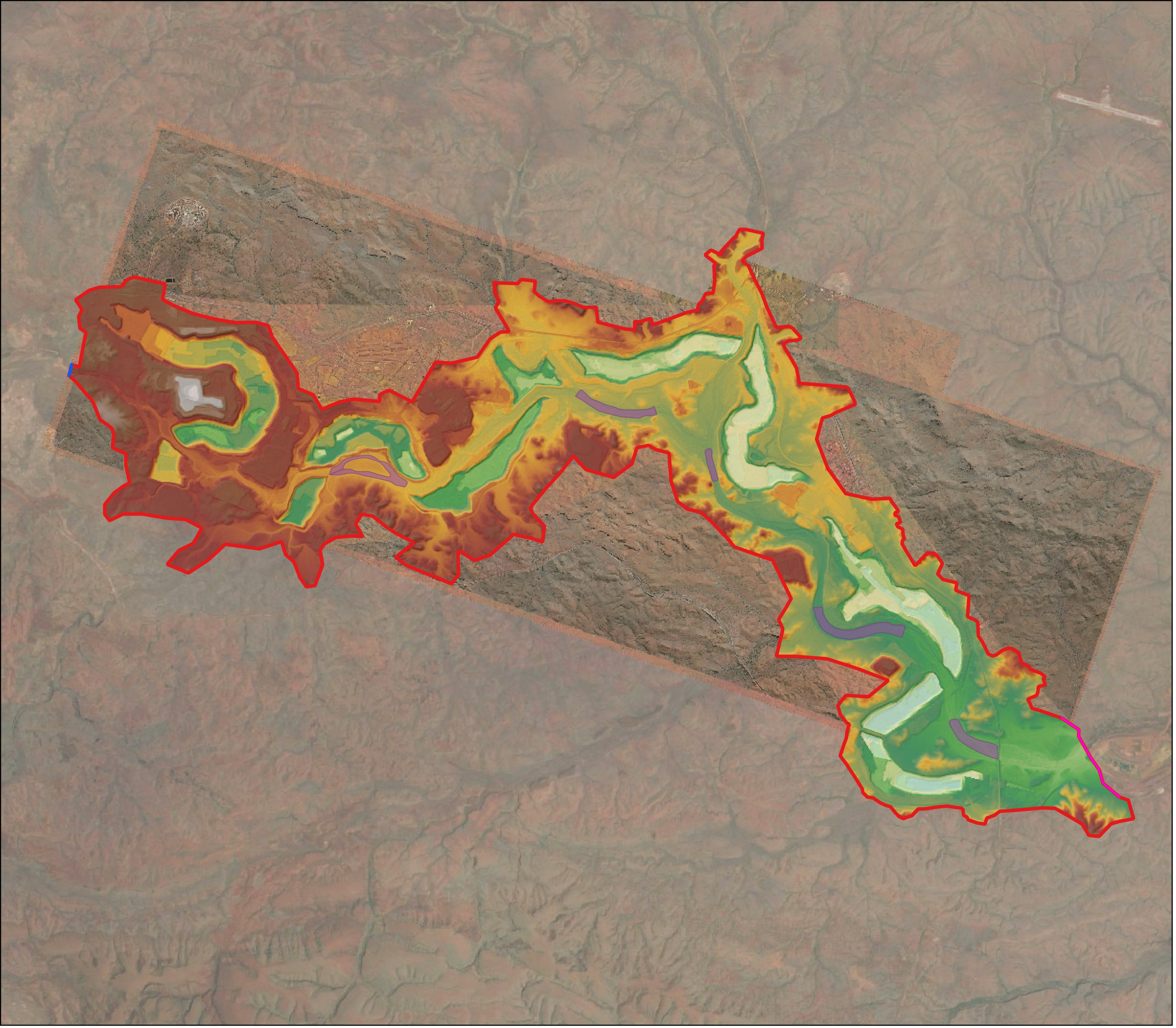
General model parameters are provided in Table 8-2.

Table 8-2: TUFLOW model parameters for creek diversion models

Parameter	Description
Terrain	1 m DEM derived from LiDAR captured in April 2023
Cell size	Catchment models: 8 m (Quadtree in channels: 2 m) Detailed models: 5 m
Sub-Grid Sampling (SGS) distance	1 m
Roughness (Manning's '*n*')	Refer to Table 8-1
Pre-burst	Median pre-burst depths obtained from ARR Data Hub (2016)
Design Events	Intermediate creeks: 0.1% AEP Minor Creeks: 1 %AEP
Rainfall Losses	Initial Loss: 50 mm Continuing loss: 6 mm/hour
Initial Water Level	20% AEP 12-hour storm (water level from last timestep of simulation)
Inflow boundary condition	Catchment models: rain-on-grid Detailed models: Source/Area using results from the catchment models
Outflow boundary	Automated stage-discharge curve (HQ), with bed slope set as water surface slope. Located downstream of respective diversions

Yandi Closure Landform

FIGURE 8-2: TUFLOW MODEL SETUP



Legend

- Inflow boundary (Flat Rocks)
- Outflow boundary
- Tributary inflows
- Model boundary

Model DEM (mAHD)

670

490

0 1,000 2,000 m

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I:\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS_SH.QGZ FIGURE 8-1: TUFLOW SETUP_V1

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9 FLOOD CHANNEL DESIGN

Flood channels (previously referred to as spillways) were introduced in the IPS design to divert a portion of floodwater from Marillana Creek to pit voids during rare and extreme events, which acts to attenuate peak flows downstream. This has the benefit of reducing flood bund heights along Marillana Creek and associated rock protection requirements. The IPS design included four flood channels shown in Figure 8-1 in Section 8.1: W1-SP0, W1-SP3, W4-SP3 and H-SP2. Further analysis of these flood channels was undertaken in the SPS, utilising updated hydrological inputs, modelling, and geotechnical data.

9.1 Trade-Off Studies

As part of the SPS, several trade-off studies were undertaken to investigate and compare the costs and benefits of alternative flood channel design options. The outcomes of these trade-off studies were used to progress the flood channel designs. The purpose, methodology and outcomes of each trade-off study is outlined below, and the adopted design options summarised.

9.1.1 Flood Channel Width (GEN.05 311012-01707-CI-PRE-0001)

The Flood Channel Width trade-off study investigated reductions in the W1-SP0 flood channel width from the original 300 m width in the IPS design without increasing the risk of creek capture in Marillana Creek beyond an acceptable level. This assessment was undertaken though hydraulic modelling and analysis of the in-situ rock based on data obtained from geotechnical investigations. Geotechnical data from the IPS was used as the SPS drilling campaign was in progress at the time this trade-off study.

The type of energy dissipation over the flood channel (via sloped or stepped channel) influences its width and hence, these two dissipator types were also investigated. Flood channel designs of different widths ranging from 100 m to 300 m were developed with both stepped and sloped channels and modelled in both 2D using the program TUFLOW and 3D (CFD) using the Ansys-CFX (3D modelling was limited to 100 m and 300 m widths). A step height of 3 m was adopted, based on CFD modelling outcomes from the IPS. The unit stream power dissipation over the structures were calculated using the modelling results and compared to the erosion indices of the in-situ rock. Three different erodibility assessment methods were investigated in this manner: Wibowo (2005), Van Shalkwyk (1994) and Pells (2016). Results of the erodibility assessment using the Pell’s method, along with associated erosion classes are shown in Figure 9-1.

The outcome of this trade-off study indicated that a 200 m wide stepped flood channel or a 100 m wide sloping flood channel can be implemented with minor to moderate erosion expected under the Pells classification system.

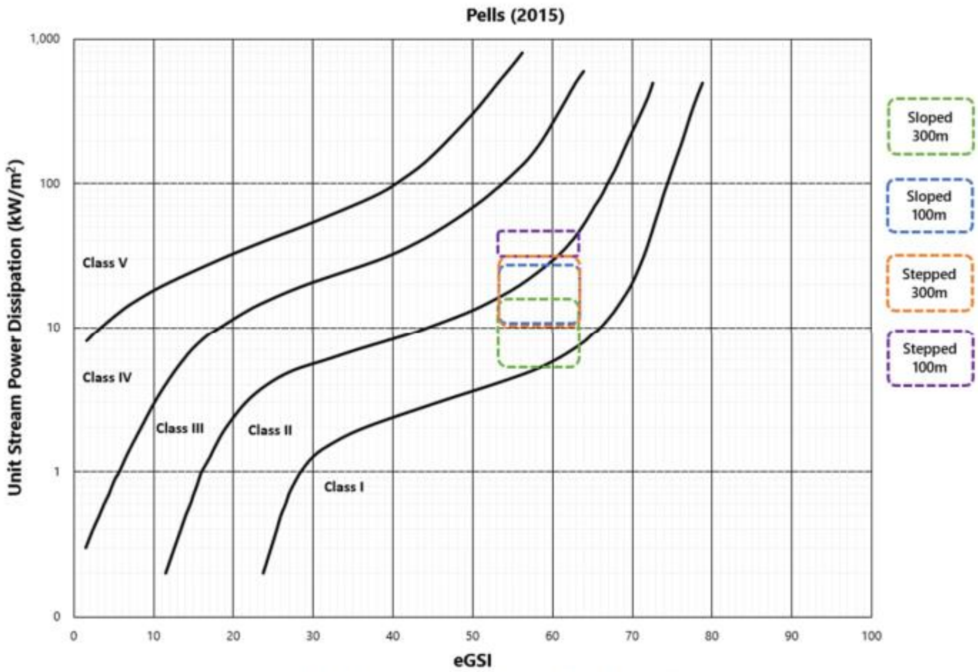


Table 1. Erosion classes, as adopted by Pells, 2015.

Maximum erosion depth *m*	General erosion extent *m³ per 100 m²*	Erosion class	Erosion descriptor
< 0.3	< 10	I	Negligible
0.3 to 1	10 to 30	II	Minor
1 to 2	30 to 100	III	Moderate
2 to 7	100 to 350	IV	Large
> 7	> 350	V	Extensive

Figure 9-1: Erodibility assessment of W1-SP0 width options using Pells (2016)

9.1.2 Flood Channel Energy Dissipator: Steps vs. Slopes (GEN.06 311012-01707-CI-PRE-0002)

The flood channel energy dissipator trade-off study was undertaken to select an appropriate dissipator geometry (stepped or sloped), using the outcomes of the Flood Channel Width Trade-off Study (Section 9.1.1). The section of a suitable energy dissipation considered the expected hydraulic performance, cost, and risk of the two different options.

The risks that were discussed qualitatively included:

- Erosion of pit backfill material through exposure to high velocity flows
- Construction of stepped surfaces and associated blasting
- Safety hazards for vehicles and pedestrians that gain access inadvertently following Closure
- Opposite pit wall failure through exposure to high velocity flows

- Undercutting of the flood channel outlet and subsequent head-cut erosion.

An alternative dissipation geometry was also considered. This geometry would resemble the natural features reflective of the local area, with small drops and uneven ground, conforming more with the natural landscape of the Flat Rocks region and improving the stakeholder views of the design. An example of such naturally occurring landform features is depicted by the photograph in Figure 9-2, which was taken at Flat Rocks during the site visit described in Section 6. Thus, a 150 m wide "natural analogue" structure resembling closely to the sloping flood channel with small energy dissipation features was chosen as the preferred option.

Figure 9-2: Natural energy dissipation features at Flat Rocks

9.1.3 Asbestos Risk Management at W1-SP0 (GEN.07 311012-01707-CI-PRE-0003)

Naturally occurring fibrous material has been recorded within dolerite at Yandi during the Constrained Creek Ore W5 Quarry Geotechnical Site Investigation (PREP-610-G-00006) and at W1-SP0 during the Yandi Spillways Drilling Campaign (PREP-1201-C-12041). Risk assessments during the IPS identified the need to review the geological data and identify engineering controls that could be incorporated into the W1-SP0 design to reduce the risk of exposure to naturally occurring fibrous materials during and after construction of W1-SP0. This SPS trade-off study identified risks related to the IPS W1-SP0 design and alignment and recommended measures to mitigate asbestos risk. The methodology involved a review of SPS geotechnical drilling data and a qualitative risk assessment.

The trade-off study concluded that it is not possible to eliminate the risks of exposure to naturally occurring asbestos fibrous materials associated with the W1-SP0 flood channel. However, mitigation of risks for a period of time is possible through construction management, designing entrance barriers in the form of cut and post-construction geological mapping to identify seams that could be sealed to provide medium term mitigation. Further detail is provided in the Geotechnical Assessment Report (No. PREP-1200-C-12140).

9.1.4 Revisit W1-SP3 Flood Channel (GEN.07 311012-01707-CI-PRE-0013)

The W1-SP3 flood channel connects the W1 and W4 pits to utilise the combined storage capacity of both features, with the W4-SP3 flood channel outlet to direct excess water back into Marillana Creek (Figure 9-3).

A trade-off study was undertaken to determine the costs and benefits of utilising this combined W1-W4 pit storage via the W1-SP3 flood channel versus only utilising the storage in W1 pit and having an alternative flood channel outlet (W1-SP4). A design of this alternative flood channel was developed and modelled in the 2D hydraulic modelling program TUFLOW to assess performance and impacts upstream and downstream.

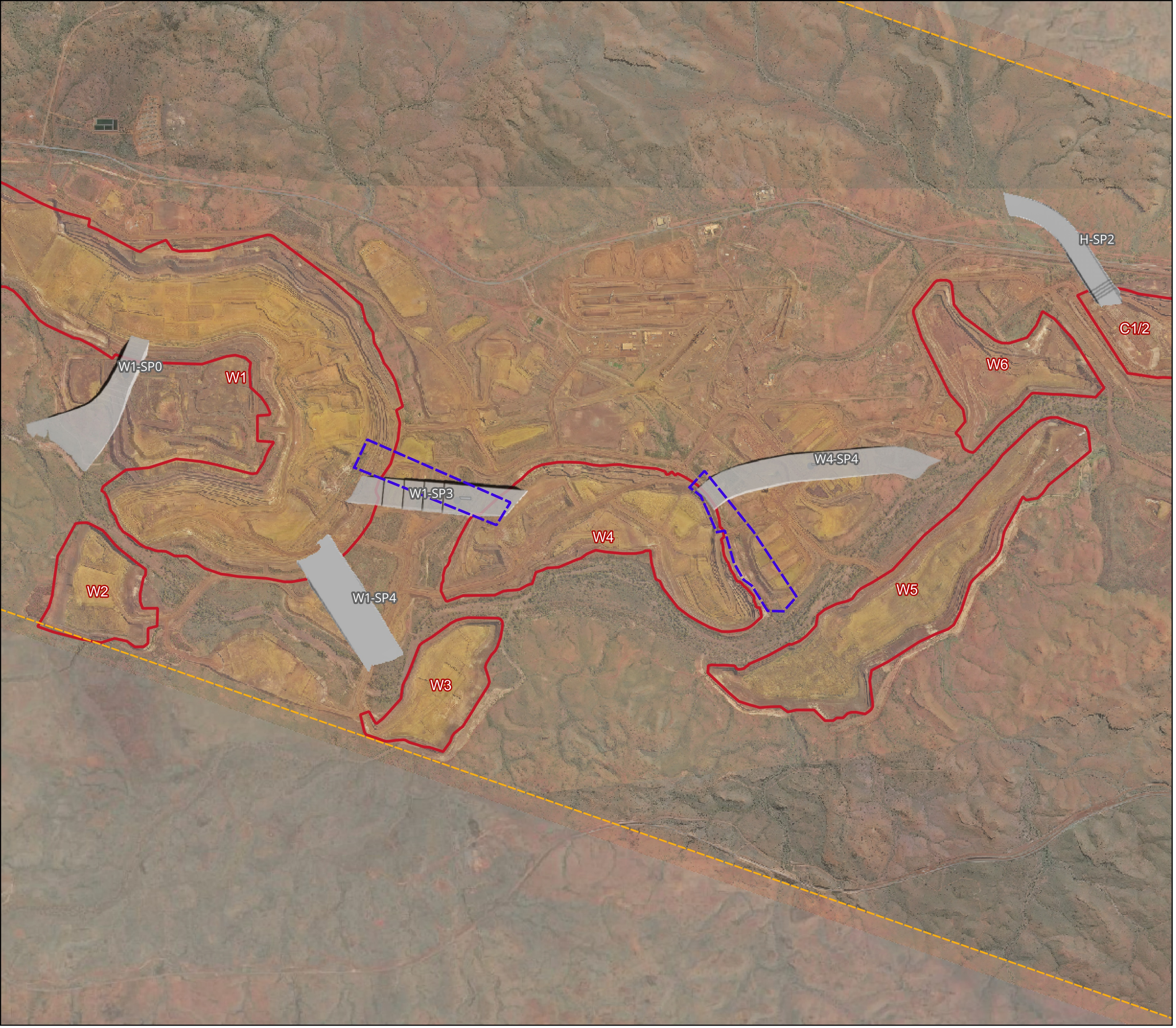
The outcome of this trade-off study was that the preferred option is the W1-SP3 & W4-SP3 flood channels utilising both W1 and W4 pits for attenuation of flow. This is predominantly due to the risks posed by increased flood levels and velocities through the constrained section of Marillana Creek between W4 and W5 pits and the need to construct additional flood bunding along the W3 pit crest.

9.1.5 Adopted Design Options

The trade-off studies were conducted to determine optimum design solutions through analysis of benefits, drawbacks, and costs of different design options. Through this analysis, the following conclusions were made:

- The optimum width of the W1-SP0 flood channel is 100 m with a sloping channel or 200 m with a stepped channel.
- The preferred energy dissipation method for the W1-S0 flood channel is the adoption of a geometry resembling the natural landscape of the surrounding region, with a width of 150 m.
- The risk of encountering naturally occurring asbestos cannot be eliminated, however, mitigation measures such as construction, entrance barriers and post-construction monitoring can be implemented to reduce the risk of exposure to fibrous materials.
- The W1-SP3 flood channel connecting W1 and W4 pits is the preferred option over discharging water from W1 to the Marillana Creek due to the height of CID material around W3 pit being insufficient and the inherent construction challenges of constructing a flood protection bund on top of the CID material.

The W1-SP0 with small energy dissipation features to replicate the “natural analogue” structure at Flat Rocks, and the W1-SP3 and W4-SP3 flood channel options from the IPS were selected for further investigation and design development in the SPS.



Yandi Closure Landform

FIGURE 9-3 FLOOD CHANNEL CONFIGURATION

Legend

- Pit Outlines
- IPS Design
- Yandi Tenement
- SPS Design

0 250 500 m

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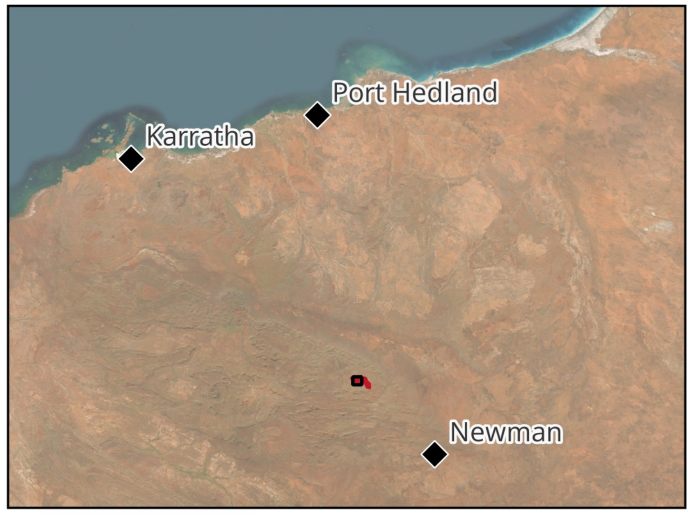

\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 9-3 FLOOD CHANNEL CONFIGURATION

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9.2 Design Development

The adopted flood channel designs were developed using updated geotechnical data from the SPS drilling campaign, revised hydrology and detailed 2D hydraulic modelling. The designs were developed to ensure that the flood channels aesthetically conformed with the surrounding landscape, are constructed in locations with rock units that are resistive to erosion (fresh dolerite and BIF) and have optimised cut volumes.

Basis of Design

Flood Channels to be safe and stable, constructed in competent rock resistant to erosion to minimise the risk of failure.

<u>Floods less than the 1:20 AEP (5% AEP) event:</u>

- No flow from Marillana Creek to pass over flood channels – all to be retained in creek.
- No flow from other tributaries to pass over flood channels if possible.

<u>1:20 – 1:100 AEP (5% – 1% AEP) events:</u>

- Maintain similar hydraulics in the Marillana Creek diversions compared to the Constrained Creek Ore (CCO) DPS Basis of Design. (i.e., the diversions still behave as a similar fluvial system to Marillana Creek)
- Minimise the number of flood channel activated during rare (1:20 to 1:100 AEP) flood events.
- Majority of flood channels flow to pass through the most robust channels(s) (e.g., a flood channel cut in fresh competent rock).

<u>1:100 – 1:500 AEP (1% – 0.2% AEP) events:</u>

- Minimise the risk of creek capture by mine pits.
- Minimise the number of flood channels activated during very rare (1:100 – 1:500 AEP) flood events.
- Majority of flood channels flow to pass through the most robust flood channels(s) (e.g., a flood channel cut in fresh dolerite)

<u>1:500 – 1:10,000 AEP (0.2% - 0.01% AEP) events:</u>

- Minimise the risk of creek capture by mine pits.

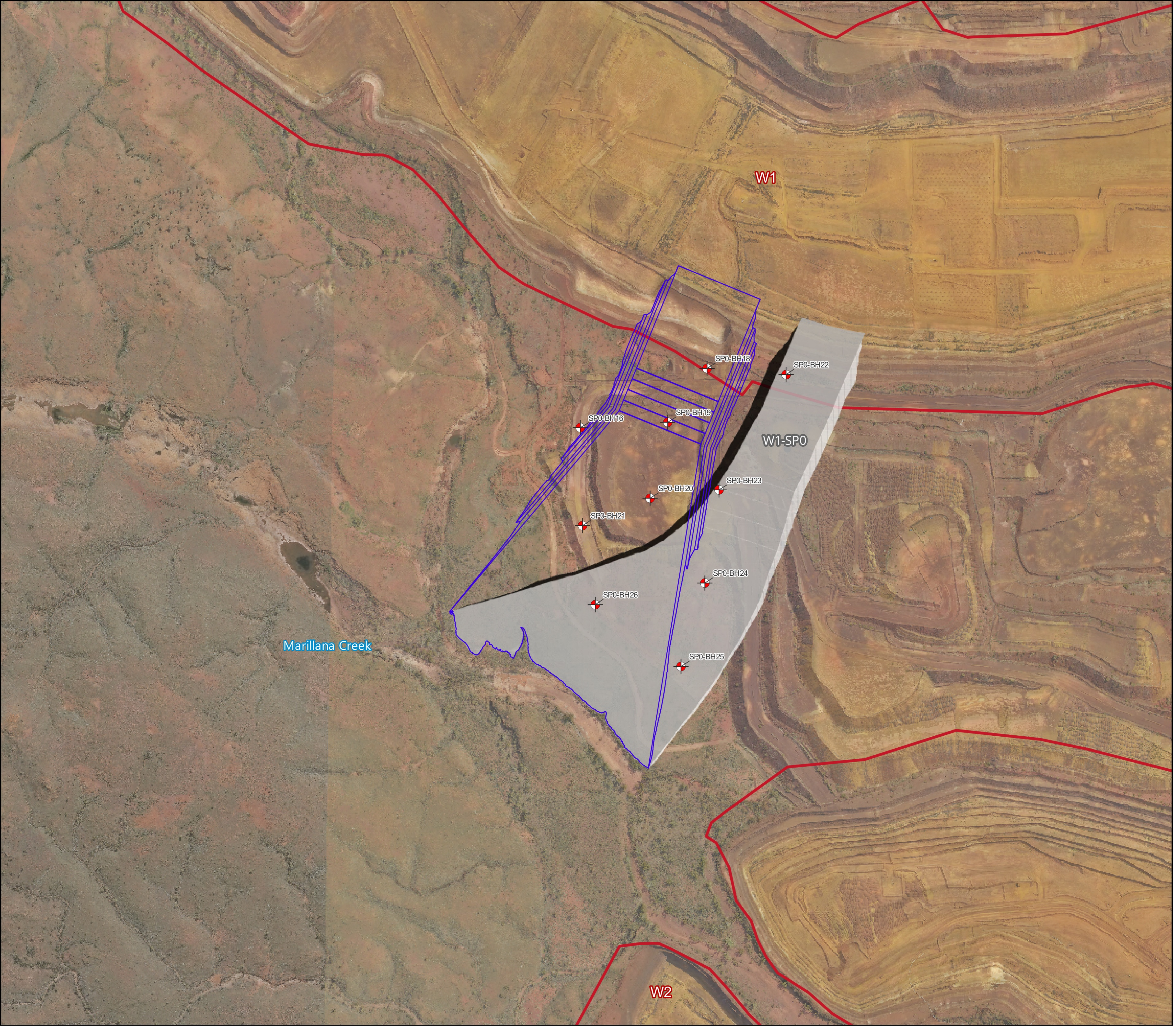
Global factor of safety of >1.5 for flood channel cut slopes.

Flood channel geometry to be designed to minimise the stream power of a 1:10,000 AEP flood event and thereby reduce likelihood of significant erosion in in-situ rock. Flood channels to be located within area of most competent rock (informed by results from geotechnical drilling) where feasible.

9.2.1 W1-SP0 Flood Channel

The W1-SP0 flood channel design was updated from the IPS design by modifying the invert levels to target competent rock, adopting a sloping channel grade with small energy dissipation features to replicate the “natural analogue” structure at Flat Rocks, and introducing curvature in the channel. This is illustrated in the plan view in Figure 9-4 and in the geological long-section along the centreline in Figure 9-5.

The geological section in Figure 9-5 illustrates the invert of the flood channel that the invert of the flood channel is predominantly located in fresh dolerite (FR), with the first step and the outlet (at distance of 900 m from the entrance) located in distinctly weathered (DW) and highly weathered (HW) dolerite. Noting that DW represents MW-HW, SW-MW and SW in Figure 9-6, erosion up to Class V in the Pells (2016) classification system may occur in these regions.



Yandi Closure Landform

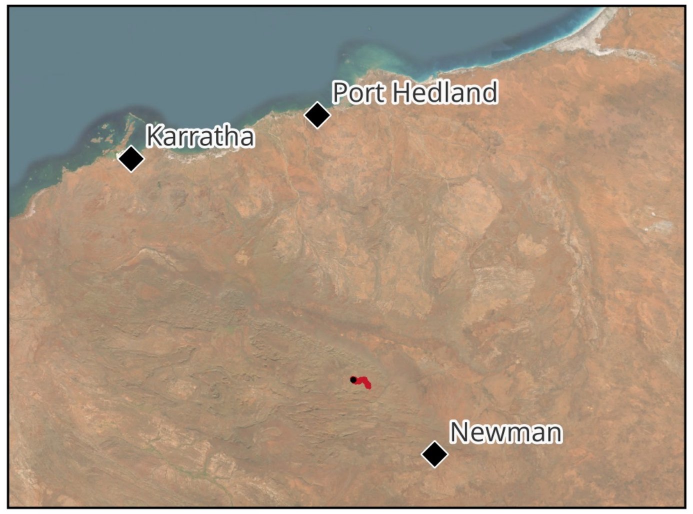
FIGURE 9-4 W1-SP0 FLOOD CHANNEL ALIGNMENT

Legend

- SPS Boreholes
- IPS Design
- Pit Outlines
- W1-SP0

0 100 200 m

Date: 31/01/2024
Projection: Yandi 94



BHP Advisian

\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 9-4 W1-SP0 FLOOD CHANNEL ALIGNMENT

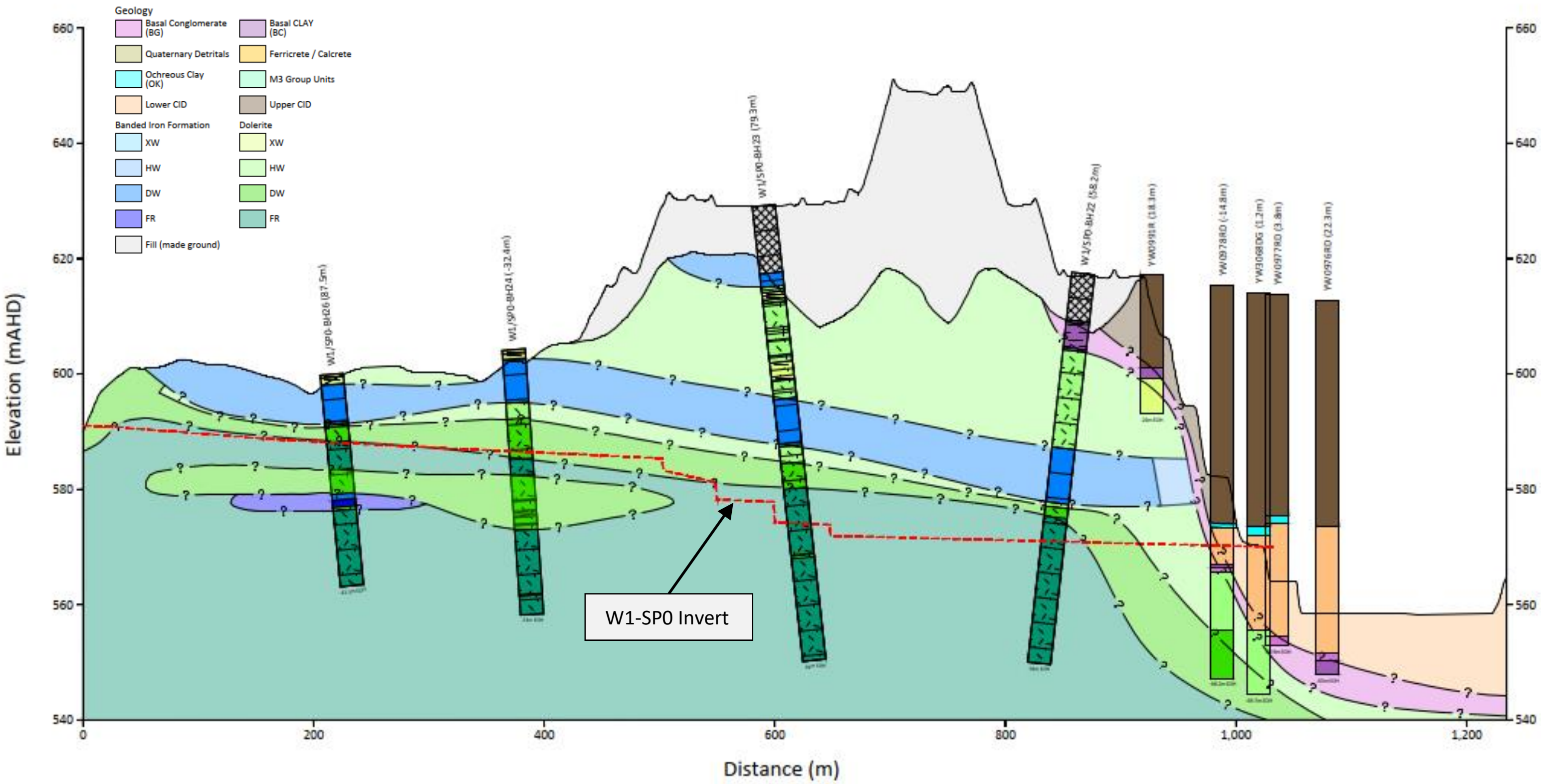


Figure 9-5: W1-SP0 geological long-section along centreline (adapted from PREP-1200-C-12140)

The outlet at the pit is cut into highly weathered dolerite. Due to this variability in geological units near the outlet, relatively higher localised erosion may be expected at the outlet when compared with elsewhere along the flood channel. However, due to the depths of fresh dolerite found in boreholes W1/SP0-BH22, BH23, BH24 and BH26, this erosion is unlikely to propagate further upstream and is expected to mitigate head-cut erosion risk.

Hydraulic modelling of this configuration was performed to estimate the stream power over this design. This was then compared to the rock mass indices for each rock unit intersecting the flood channel invert. This allowed for the estimation of the potential level of erosion of the structure following a 1 in 10,000 AEP event. Comprehensive description of the methods used for this analysis are provided in the Geotechnical Assessment Report (No. PREP-1200-C-12140). The estimated stream power over the structure, as calculated from TUFLOW modelling is between 6 to 12 kW/m^2. Using the Pells (2016) classification system, the expected levels of erosion in dolerite for this range of stream power is shown in Figure 9-6.

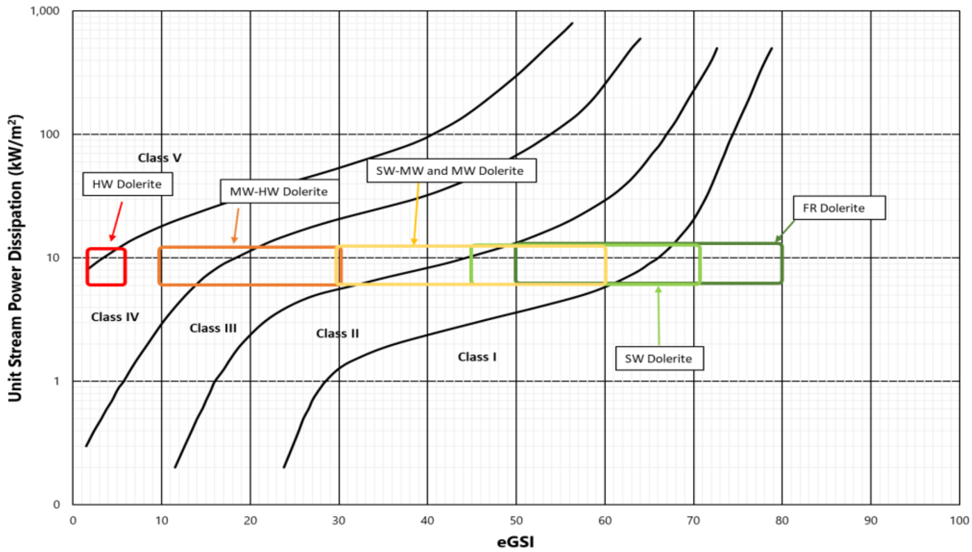


Table 1. Erosion classes, as adopted by Pells, 2015.

Maximum erosion depth *m*	General erosion extent *m³ per 100 m²*	Erosion class	Erosion descriptor
< 0.3	< 10	I	Negligible
0.3 to 1	10 to 30	II	Minor
1 to 2	30 to 100	III	Moderate
2 to 7	100 to 350	IV	Large
> 7	> 350	V	Extensive

Figure 9-6: Erosion assessment of W1-SP0 for dolerite using Pells (2016)

9.2.2 W1-SP3 Flood Channel

The W1-SP3 flood channel linking the W1 and W4 pits was modified by rotating the alignment to help reduce the potential long term stability risks along the W4 southern pit wall. Steps were also included in the flood channel design for energy dissipation and the invert level at the outlet adjusted to tie in with the SPS pit backfill level in W4. A plan view of this flood channel alignment is provided in Figure 9-7 and geological long-section along the centreline provided in Figure 9-8.

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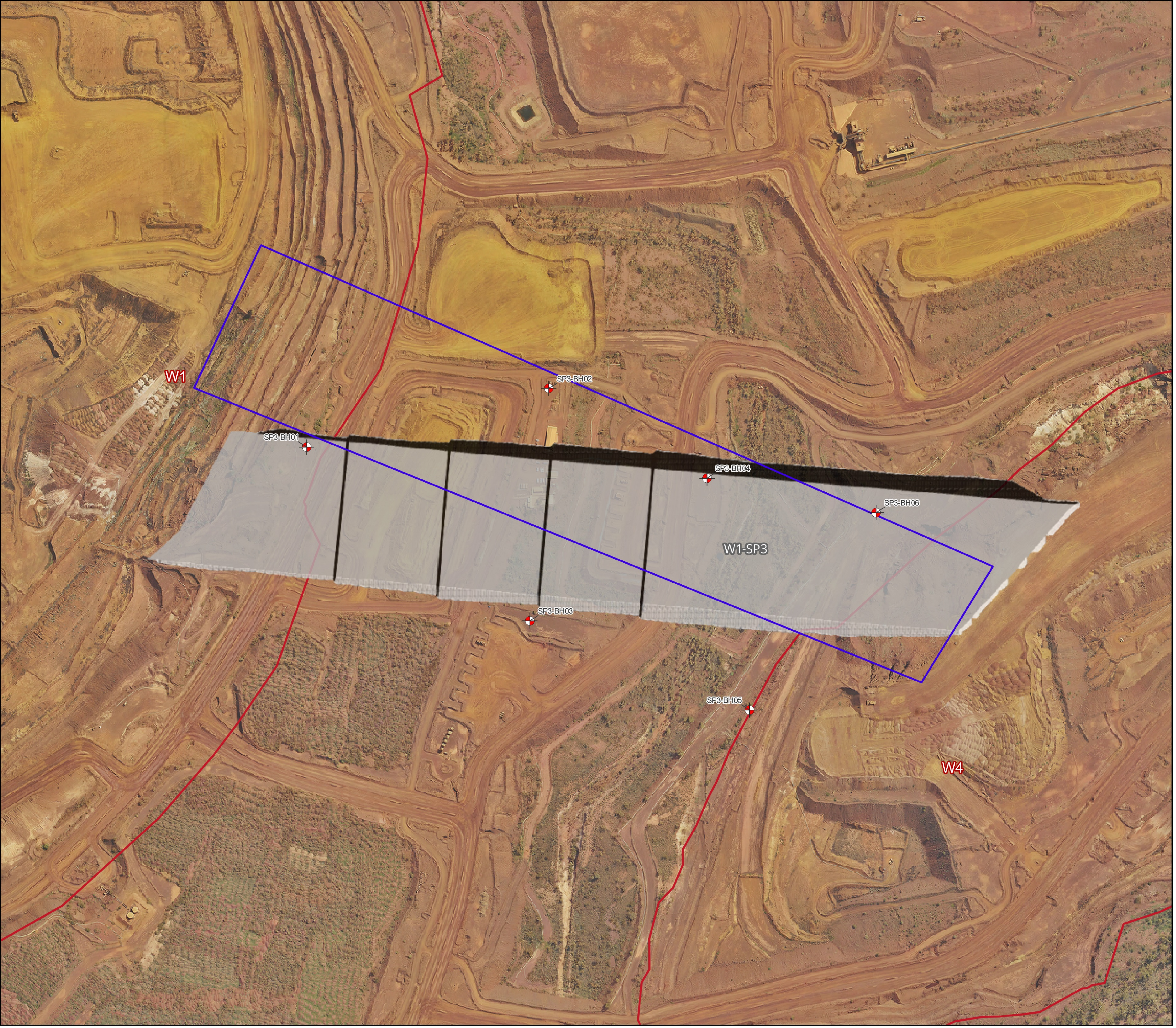
FIGURE 9-7 W1-SP3 FLOOD CHANNEL ALIGNMENT



Legend

- SPS Boreholes
- Pit Outlines
- IPS Design
- W1-SP3

0 100 200 m

Date: 31/01/2024
Projection: Yandi 94

\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 9-7 W1-SP3 FLOOD CHANNEL ALIGNMENT

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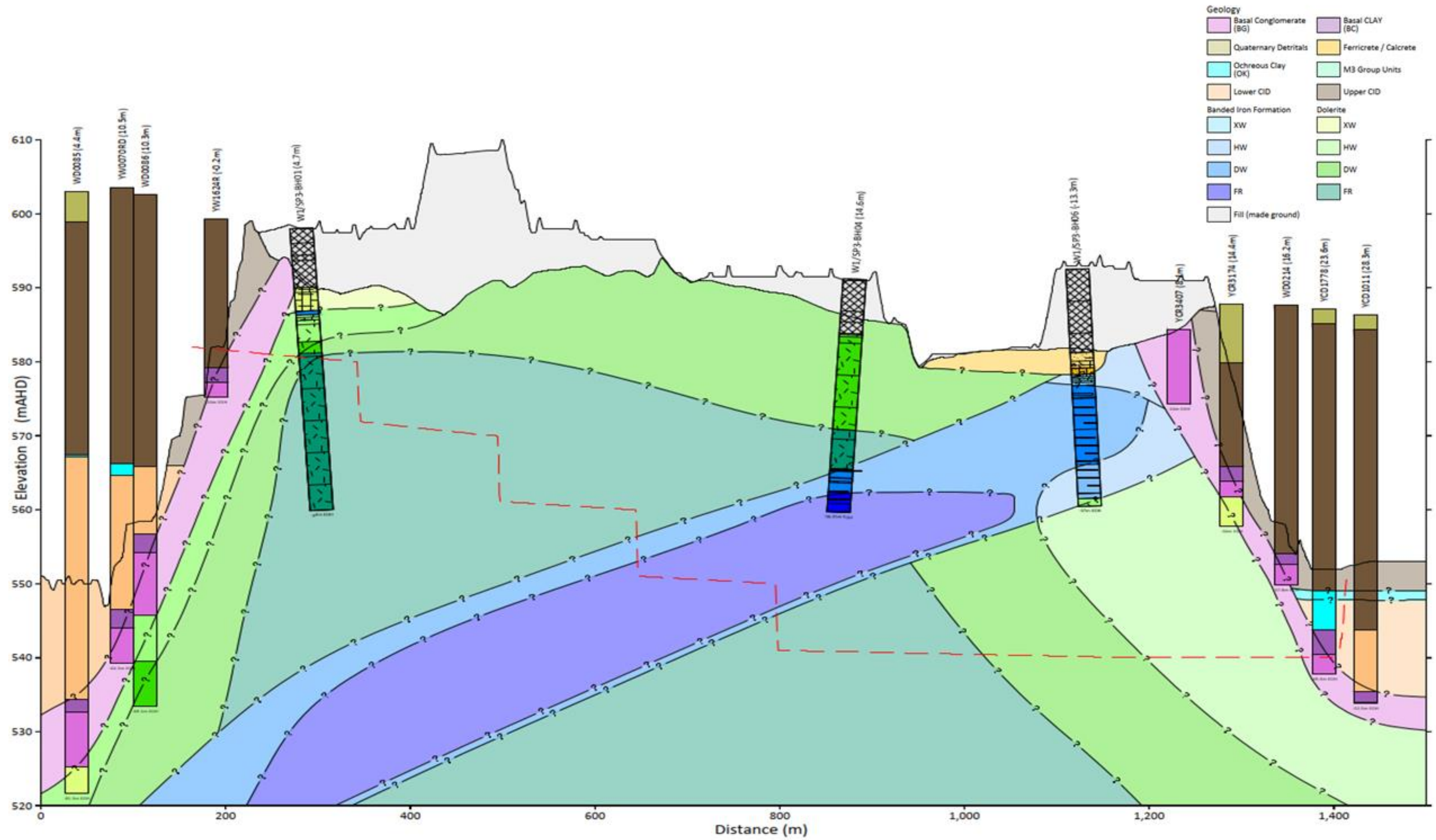


Figure 9-8: W1-SP3 geological long-section along centreline (adapted from PREP-1200-C-12140)

Step heights of 10 m were nominally adopted in this study. The interpreted geology in Figure 9-8 suggests that the top two steps are located in fresh dolerite, however, the third step intersects a region of distinctly weathered BIF (DW) at chainage 700 m. In addition, the outlet of the flood channel intersects regions of highly weathered (HW) dolerite. It is recognised that there are some gaps in the geotechnical/geological data along this flood channel alignment, so additional drilling and investigation is required to confirm the geology and geotechnical conditions and further optimise the design.

Hydraulic modelling of this design was performed to obtain the estimated stream power over the structure, which was calculated to be between 8 to 14 kW/m^2. Using the Pells (2016) classification system, the expected levels erosion in dolerite for this range of stream power is shown in Figure 9-4.

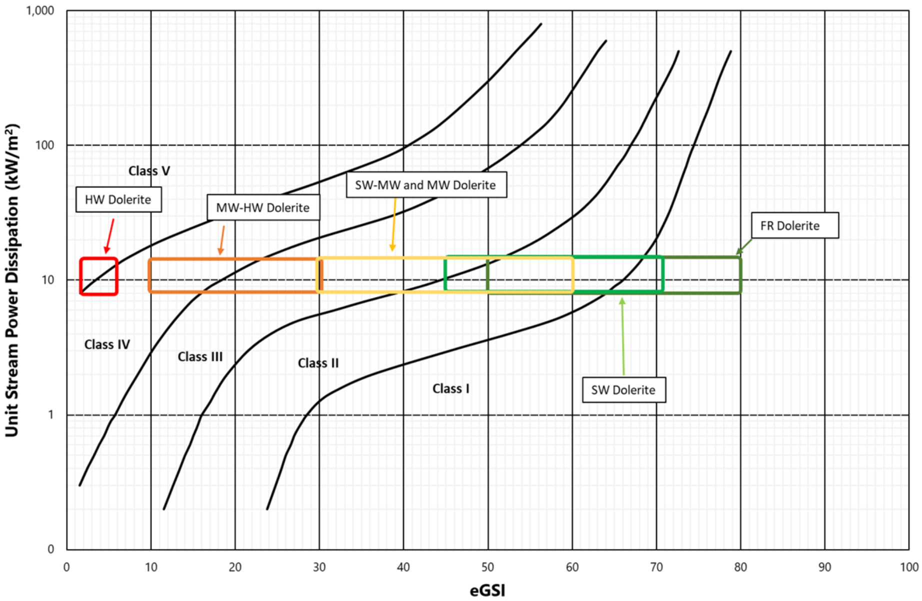


Table 1. Erosion classes, as adopted by Pells, 2015.

Maximum erosion depth m	General erosion extent m^3 per 100 m^2	Erosion class	Erosion descriptor
< 0.3	< 10	I	Negligible
0.3 to 1	10 to 30	II	Minor
1 to 2	30 to 100	III	Moderate
2 to 7	100 to 350	IV	Large
> 7	> 350	V	Extensive

Figure 9-9: Erosion assessment of W1-SP3 for dolerite using Pells (2016)

Figure 9-6 indicates erosion up to Class V can be expected at the outlet and up to Class IV expected near the third step. Further refinement of the step geometry design, targeting the FR dolerite (which encompasses Class I and Class II in Figure 9-6) can reduce the erosion in the flood channel.

9.2.3 W4-SP4 Flood Channel

The W4-SP4 flood channel allows excess floodwater in W4 pit to discharge back into Marillana Creek in a controlled manner. The geology at the W4-SP4 flood channel location was assessed using the IPS design and 2D hydraulic modelling, to assess the risk posed by scour and erosion. While there is limited available geological and geotechnical data at this flood channel location, the available data suggests the IPS design will be cut into material that is susceptible to erosion during flow events. This presents a risk of head-cut erosion which has the potential to result in pit capture of Marillana Creek.

To address risk, the W4-SP4 flood channel alignment was modified to pass through more favourable geology. The spill crest was also set at a location and elevation where competent rock resistive to erosion is more likely to be encountered. The spill crest was set 700 m away from the pit edge to reduce the risk of head cut erosion and pit capture. The optimised flood channel shown in Figure 9-10, is a sloping structure of approximately 1.7 km length, at a grade of 0.6% and 200 m width. The flood channel requires minor flood bunds at the inlet and outlet to contain the design flow.

Limited geological data is available along the alignment so the design of the W4-SP4 flood channel will need to be reviewed and optimised in the DPS, using the results of intrusive geotechnical investigations and testing along the alignment.

9.2.4 H-SP2 Flood Channel (IPS)

Floodplain landforms were developed to eliminate the need for flood bunds at constrained locations as discussed in Sections 6 and 10, which included a floodplain landform over W6 and E6 pits as well as a small portion of W5 (west).

In the IPS design, a H-SP2 flood channel was included to protect the Herbert's Creek landbridge during extreme flood events.

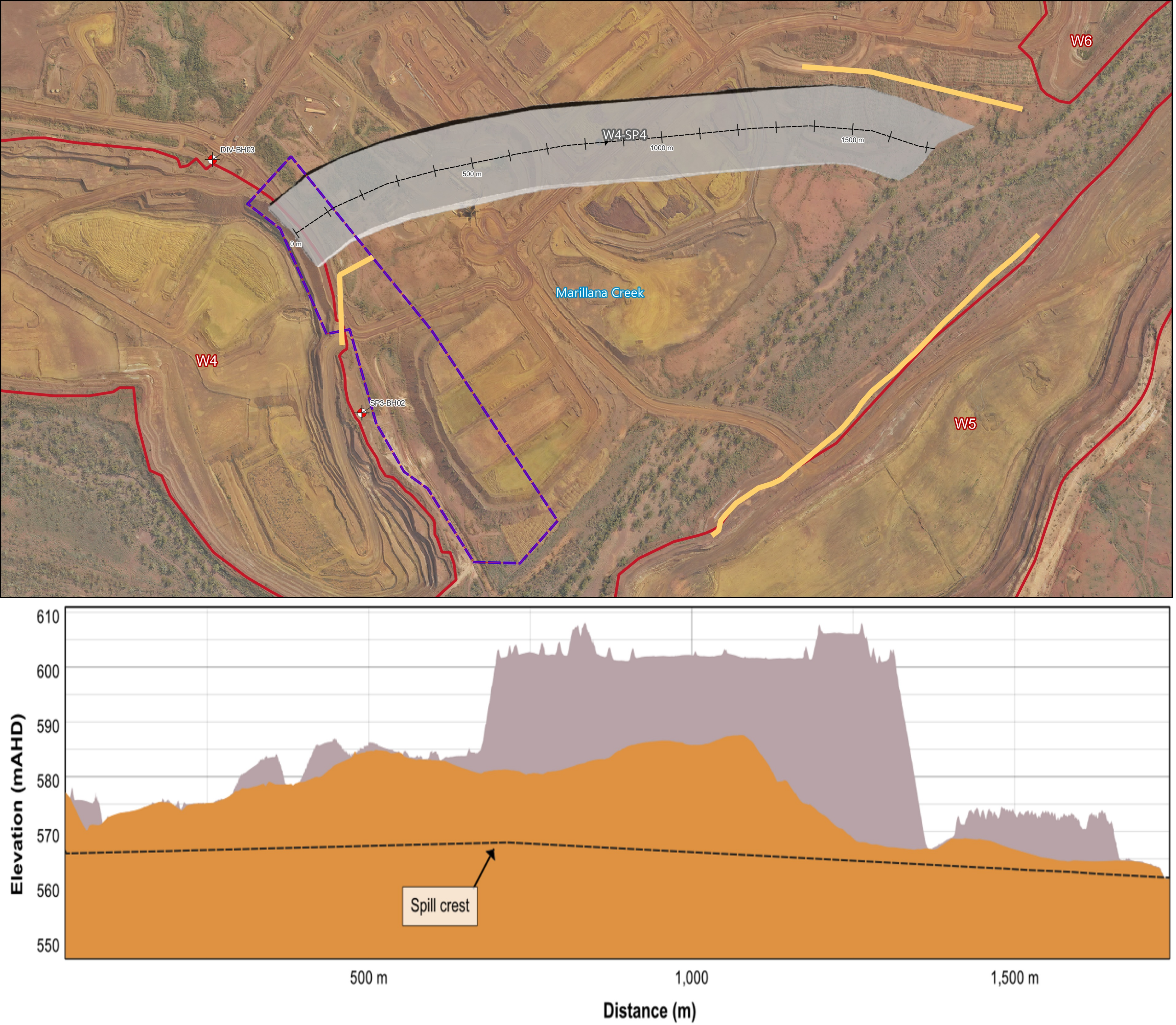
For the SPS design, the H-SP2 flood channel was removed, and the Herbert's Creek Landbridge upgrades excluded from scope of work. The SPS design assumes that excess floodwater in Herbert's Creek will spill west onto the W6 floodplain and into Marillana Creek.

Although not included in the SPS design, inclusion of the W6 floodplain adjacent to Herbert's Creek landbridge, provides the opportunity to construct an alternative flood channel upstream of the landbridge which ties into the W6 floodplain. During extreme flood events, the flood channel could convey excess flows from Herbert's Creek across the W6 floodplain and into Marillana Creek. The flood channel would have lower grade and substantially lower cut volumes when compared with the H-SP2 flood channel adopted in the IPS design. It would also have lower scour/erosion risk when compared with the current SPS design (where it overtops the landbridge and flows west onto W6 floodplain). The peak velocities, stream power and shear are also far lower in the alternative flood channel, reducing long term stability risk to the final landform design.

The Herbert's Creek Landbridge and associated flood channels (if required) will be assessed, and any design upgrades identified and developed in the DPS phase of the Project.

Yandi Closure Landform

FIGURE 9-10 W4-SP4 FLOOD CHANNEL ALIGNMENT

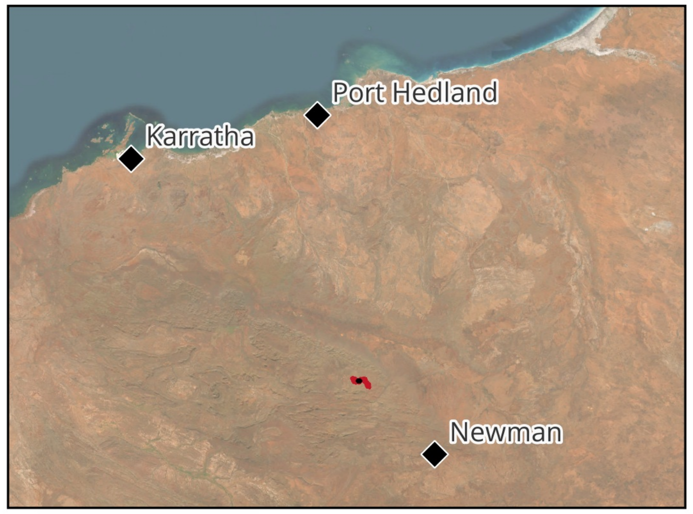


Legend

- SPS Boreholes
- W4-SP4 Invert
- SPS Flood Bunds
- Pit Outlines
- IPS Design
- W4-SP4
- Existing Topography
- Pre-mining Topography

0 250 500 m

Date: 31/01/2024
Projection: Yandi 94



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\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 9-10 W4-SP4 FLOOD CHANNEL ALIGNMENT

10 FLOODPLAIN LANDFORM DESIGN

There are several constrained reaches of Marillana Creek between the pits, such as W1/W2, W3/W4, W4/W5, W5/W6 and E6/E7 shown in Figure 8-1, which experience deep flows and high flow velocities during the extreme flood events. Under pre-development (pre-mining) conditions, the pit crests adjacent to these highly constrained sections of Marillana Creek comprise in-situ CID material at a height that prevents overtopping, and which extends down below and under the creek bed. This in-situ CID material is resistive to erosion and is likely to provide suitable protection from scour and erosion during the 1:10,000 AEP flood event.

Mining has removed most of the CID material at Yandi. CID material has been retained at the pit crests to act as flood protection bunds during Operations and designed to prevent overtopping in the 1:100 AEP event. Most of the pit crests are set to the 1:100 AEP flood level plus 1 m of freeboard to protect mining Operations.

At Closure, flood protection bunds are required (Section 11) at several locations within the constrained sections of creek, to prevent uncontrolled overtopping of pit crests and inflows to pit voids during the 1:10,000 AEP event. Uncontrolled overtopping would lead to creek capture of Marillana Creek and/or other tributaries with significant associated environmental and social impacts.

The deep flows and high flow velocities experienced in the constrained sections require bund designs with significant rock armour (rock protection). The site visit and constructability review found that at most locations, it was not feasible to construct the flood bund on top of remnant CID (Section 6). The outcome of the constructability review was that the bunds would need to be constructed in Marillana Creek adjacent to the remnant CID, further constraining the already constrained section of creek. Owing to the height of the bunds and associated batter slopes, the bunds encroach into the creek, further constraining the creek. Along with the clearing of the creek footprint, additional clearing, and excavation to bury rock protection in response to scour would further damaging riparian vegetation.

Based on these considerations and constraints, opportunities to widen the Marillana Creek floodplain were explored with the aim of reducing flood depths, flow velocities and where possible, eliminate the requirement for bunds altogether.

10.1 Trade-Off Studies

Prior to the site visit and constructability review, selective backfilling of pit areas to create a floodplain, lower bund levels and reduce Closure risk was assessed in a trade-off study (311012-01707-CI-PRE-0005/C). Two locations for floodplain widening were considered, between W5/W6 and between E6/E7, as shown in Figure 10-1. These sections are constrained by remnant CID and higher water levels (>10 m) and flow velocities (>5 m/s) require significant bunds to prevent creek capture.

A key assumption in this trade-off study was that for the base case IPS design, flood bunds could be constructed on top of remnant CID material along pit crests, without the need to encroach into Marillana Creek. That assumption was subject to the outcomes from the site visit and constructability review.

The trade-off study determined basic backfill surfaces in the respective pits, with the aim of grading levels to prevent creek capture and removed the requirement for flood bunds on the backfilled areas. The designs for W5/W6 featured partial backfilling of W5 along with removal of remnant CID (Figure 10-1). At E6/E7, the eastern side of the landbridge (E7) was backfilled, grading from the north-west to the south-east. The 1:10,000 AEP design event was modelled to determine flood levels and flow velocities and assess rock protection requirements at each site.

The results of the trade-off study are summarised in Table 10-1, with a comparison of the key parameters for the backfill scenario and flood bund approach.

As outlined in Table 10-1, the backfilling option requires significantly more material and has higher associated costs. The trade-off study identifies the reduction of rock protection as the major benefit to this backfilling approach, however these were overwhelming offset by the overall cost. Therefore, the backfill design was not supported, and the flood bund option (constructed on top of CID) was selected for further investigation and SPS design.

As discussed above, the site visit and constructability review were completed after the trade-off study which found that it is not feasible to construct bunds on existing CID or construct the bunds in Marillana Creek adjacent to the CID pit crests. Therefore, the alternative constructed floodplain option was explored and adopted for SPS design.

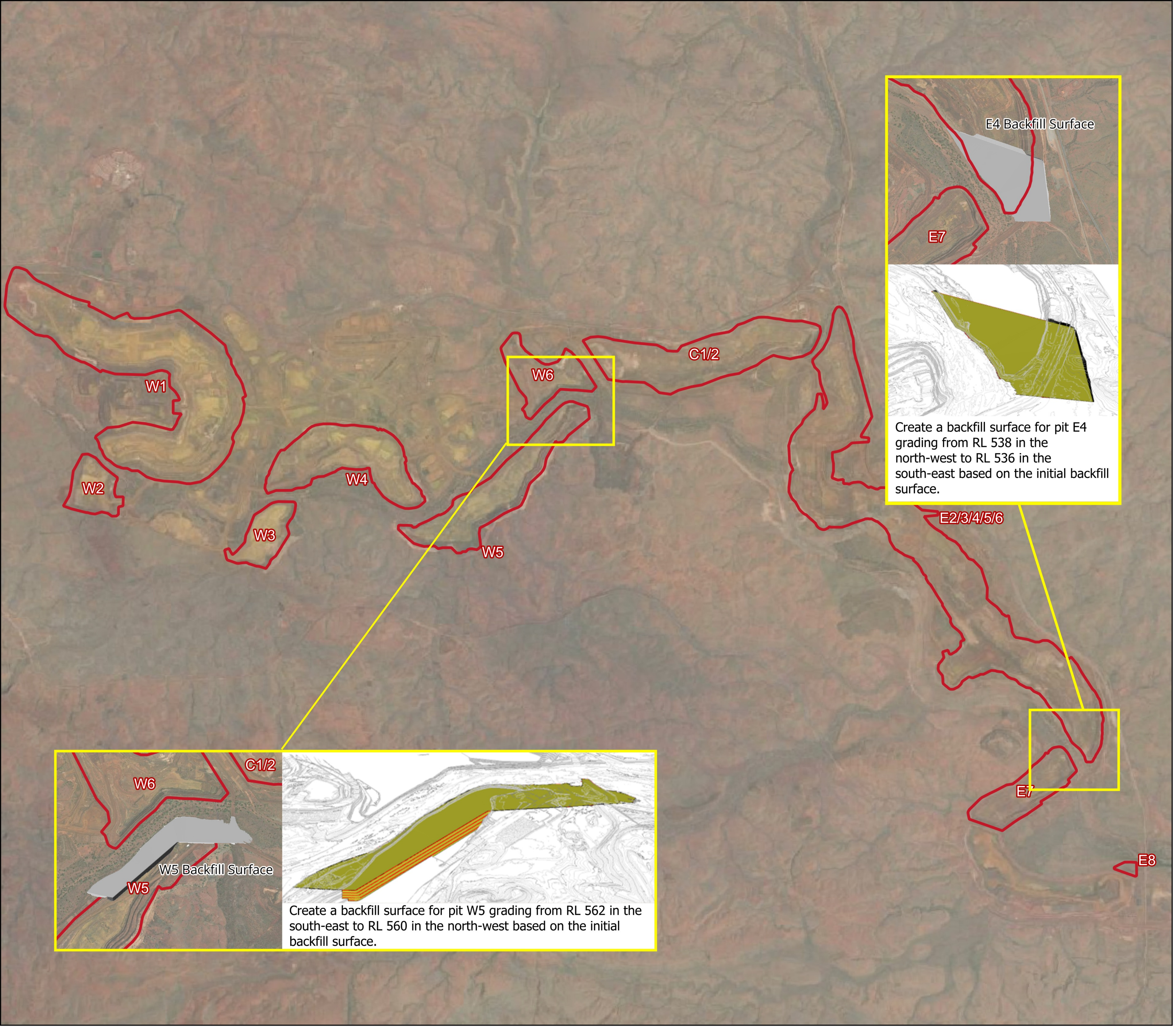
Table 10-1 Backfilling trade-off studies results

Parameter	Flood Bunds Scenario (IPS design)	Backfilling Scenario
W5/W6		
Flood depths (m)	7.5 – 12.0	5.0 – 9.5
Flow velocity (m/s)	>5.0	3.0 – 4.0
Rock protection size	1T – 4T	¼T – ½T
Rock protection volume (m^3)	43,310	16,860
Bund fill volume (m^3)	112,171	58,457
Backfill volume (m^3) ^	-	2,932,294
CID removal volume (m^3)	-	393,521
Total Cost ($M) *	12	42
E6/E7		
Flood depths (m)	6.0 – 11.0	3.5 – 8.5
Flow velocity (m/s)	>5.5	3.0 – 4.0
Rock protection size	Light – 4T	½T – 2T
Rock protection volume (m^3)	76,377	47,055
Bund fill volume (m^3)	302,286	141,510
Backfill volume (m^3)	-	3,872,950
CID removal volume (m^3)	-	17,969
Total Cost ($M) *	23	53

^ includes cut and fill volumes
*based on unit rates provided by BHP.

Yandi Closure Landform

FIGURE 10-1 TRADE-OFF STUDY BACKFILL AREAS

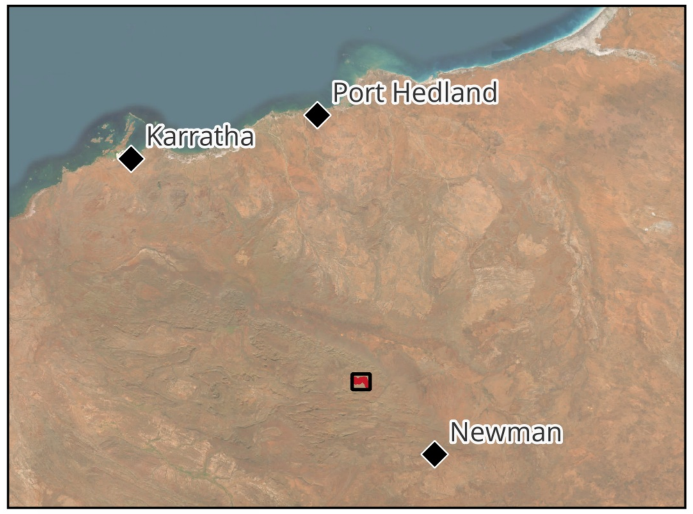


Legend

- Pit Outlines
- Backfill

0 1,000 2,000 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 10-1 TRADE OFF STUDY BACKFILL AREA

10.2 Design Development

The design considered two approaches to widening the floodplain, backfilling in pits and removal of fill material, as discussed below.

10.2.1 In-Pit Floodplain Widening

Backfilling of pit voids was considered at the following locations to widen the floodplain along the constrained sections of Marillana Creek:

- W5/W6 Floodplain
- W4/W5 Floodplain
- E6/E7 Floodplain.

The design work completed at each of these locations is discussed below. All in-pit floodplain options will need to account for settlement in the design. This will need to be explored and assessed in detail in the DPS phase of the project.

10.2.1.1 W5/W6 Floodplain

At W5/W6 the following options for in-pit floodplain widening were explored, and depicted in Figure 10-2:

- Partial backfilling of W5 at the constriction
- Partial backfilling of W6
- A combination of backfilling W5 and W6.

The scenarios were assessed with 2D hydraulic modelling and intended to meet the following two objectives:

- Remove the requirement for a bund on the opposite bank of the channel, and
- Reduce flow velocities to limit scour and erosion, and associated rock protection.

For all scenarios, the natural landform was approximately 2 m above the adjacent creek constructed by trimming down the in-situ CID around the pit crest down to the required floodplain level. This would ensure that the frequent flood events are contained in the main Marillana Creek channel, with the floodplain only activated in the larger flood events. Retaining the in-situ CID on the margins of the creek also protects the constructed floodplain from scour, erosion, and lateral channel migration.

The cross-section in Figure 10-3 shows the reduction in water levels achieved at W5-W6. Key outcomes of the assessment are summarised below:

- Backfilling of W5 did not eliminate the requirements for a bund at W6 (flood levels only reduced by <1 m)

- There were minimal differences (<0.5 m) in flood level between the scenario where W5 and W6 were backfilled together, and where W6 was backfilled alone.

- Backfilling of W6 eliminates the requirement for additional bunds along the western side of W5 assuming the in-situ CID is sufficient for flood protection (subject to further geotechnical investigations – refer to Forward Works in Section 14.2).

The corresponding velocities for each scenario are provided in Figure 10-4, demonstrating a minor reduction in the velocities through this reach, however the W6 backfilling configuration, by eliminating a W5 bund, removes the requirement for rock protection. This scenario therefore reduces the risks associated with erosion and scour at Closure.

The additional benefit with backfilling W6 alone, is that it provides additional buttressing to the Herbert's Creek landbridge. It can also be incorporated into the Herbert's Creek flood channel as discussed in Section 9.2.4.

The assessment therefore concluded that the backfilling of W6 along was preferable to backfilling of W5 or relying on flood bunds for protection of W5 and W6. The preliminary, comparative material estimates and costs for this option are provided in Table 10-2. Note that the W6 backfill design has subsequently been refined through civil design.

Table 10-2 Material estimates for W5/W6 floodplain landform

Category	Unit Rate	W5 Backfill	W6 Backfill	W5 & W6 Backfill
Backfill	$10/m^3	5,184,710	10,277,150	15,461,860
Cut	$10/m^3	920,755	1,539,860	2,460,615
Bund Fill^	$30/m^3	84,285	-	-
Rock protection^	$200/m^3	10,270	-	-
Total cost		$62,000,200	$118,170,100	$179,224,750

^ determined from the IPS design

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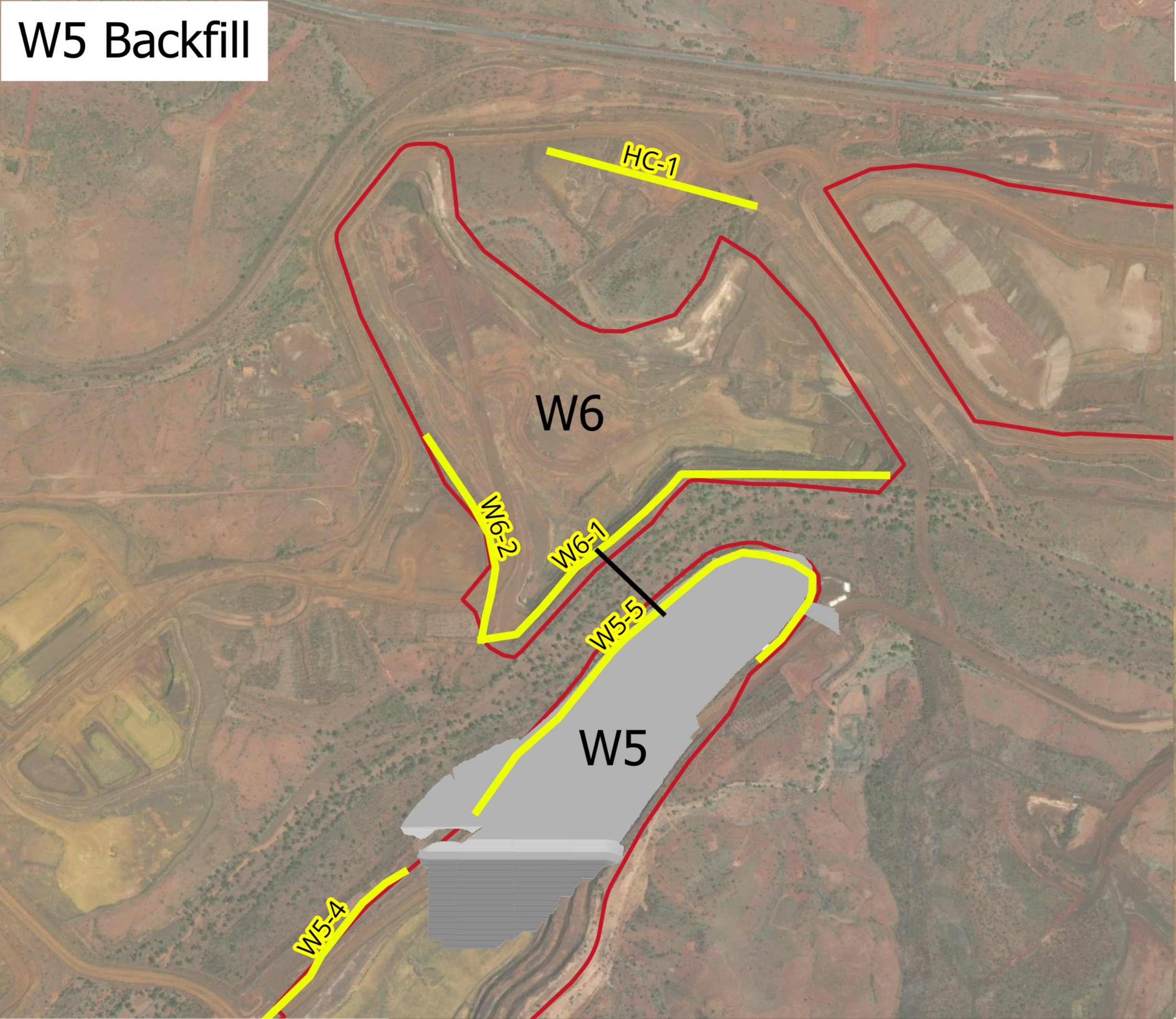
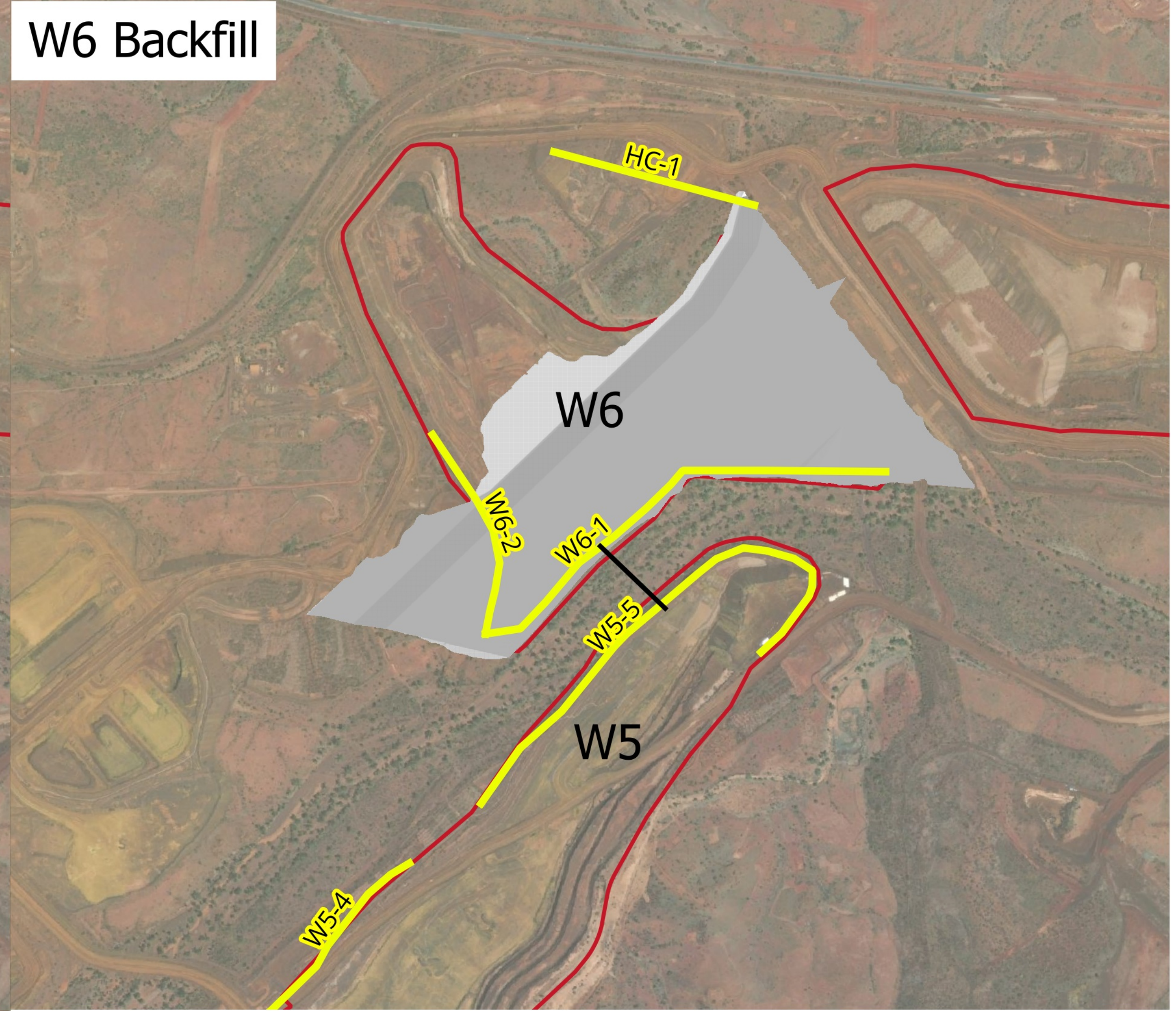
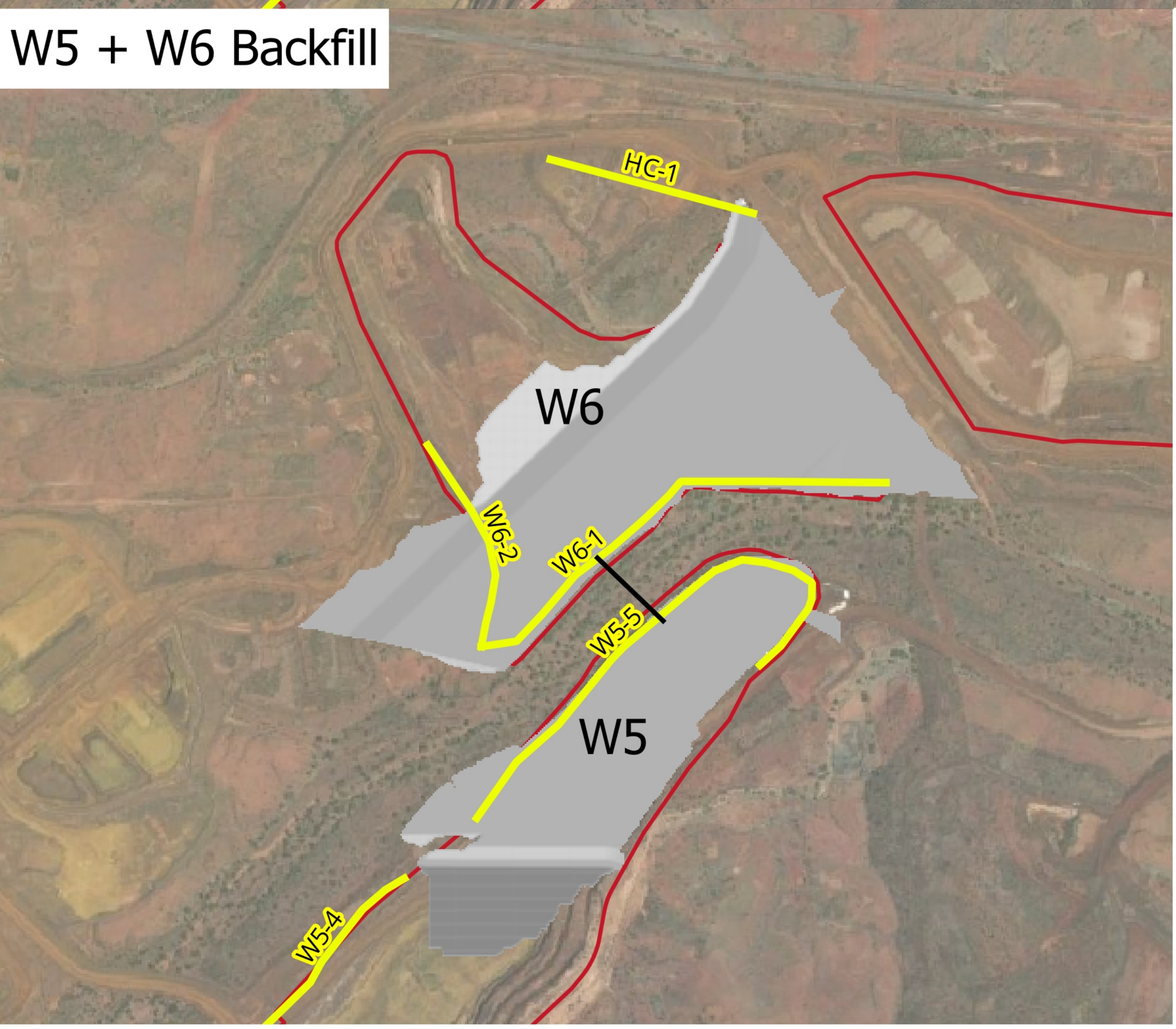
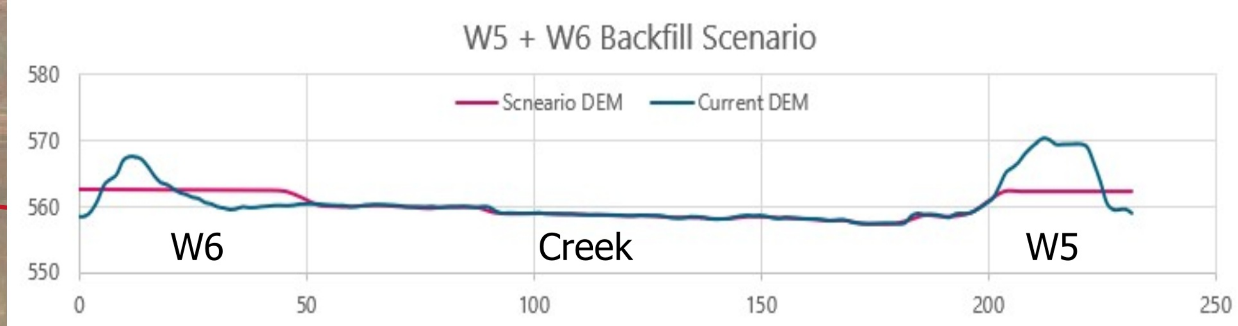
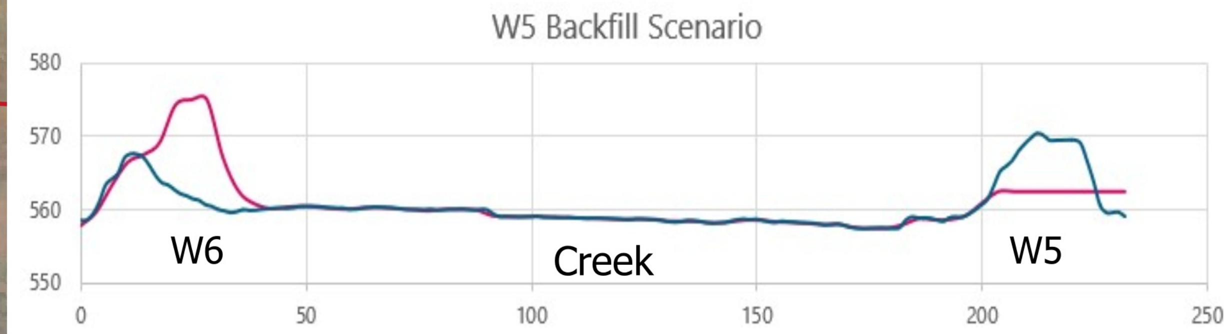
FIGURE 10-2 W5-W6 FLOODPLAIN LANDFORM SCENARIOS

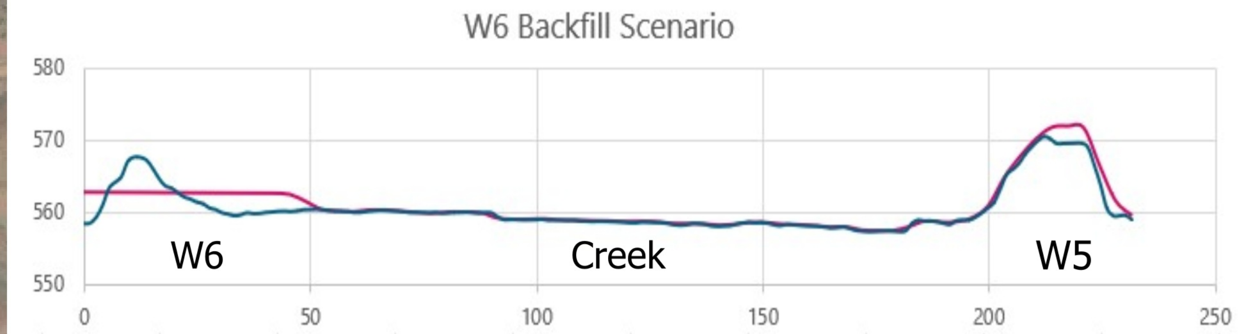










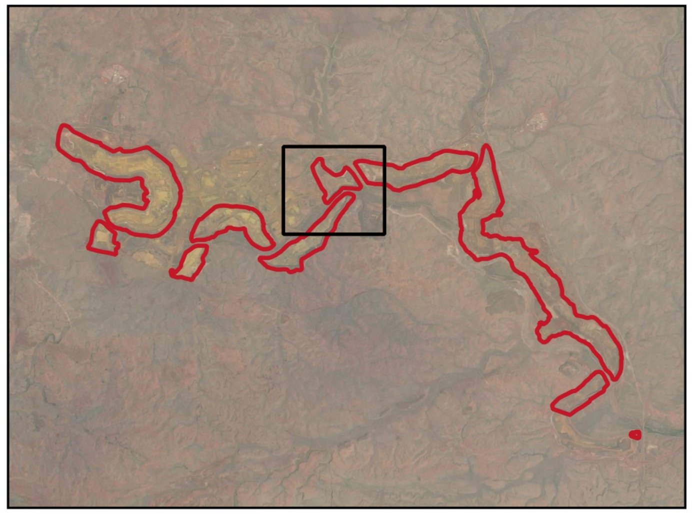


Legend

- Surface Cross-Section
- IPS Bunds
- Pit Outlines
- Scenario Backfill

0 500 1,000 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 10-2 W5-W6 FLOODPLAIN LANDFORM SCENARIOS

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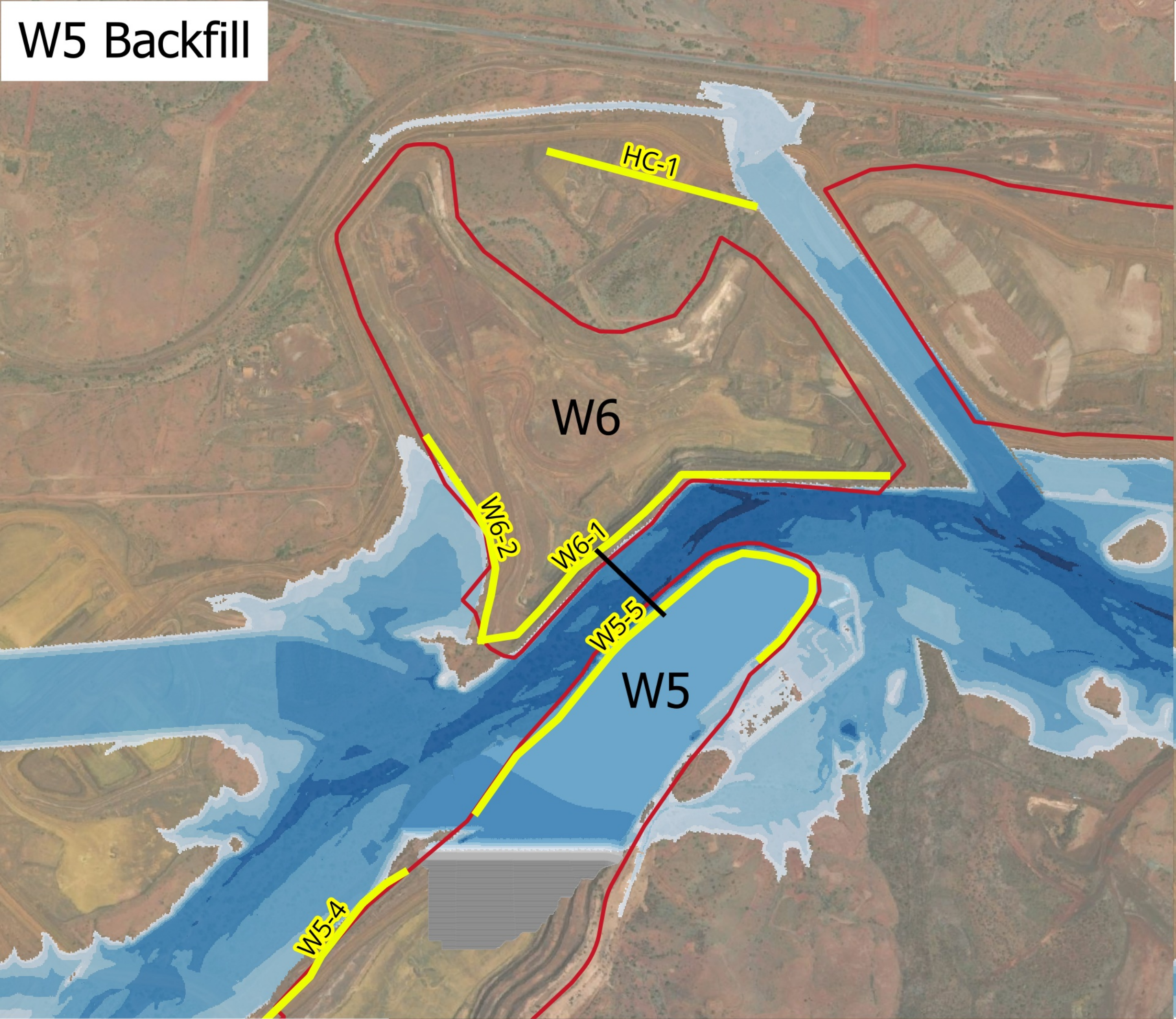
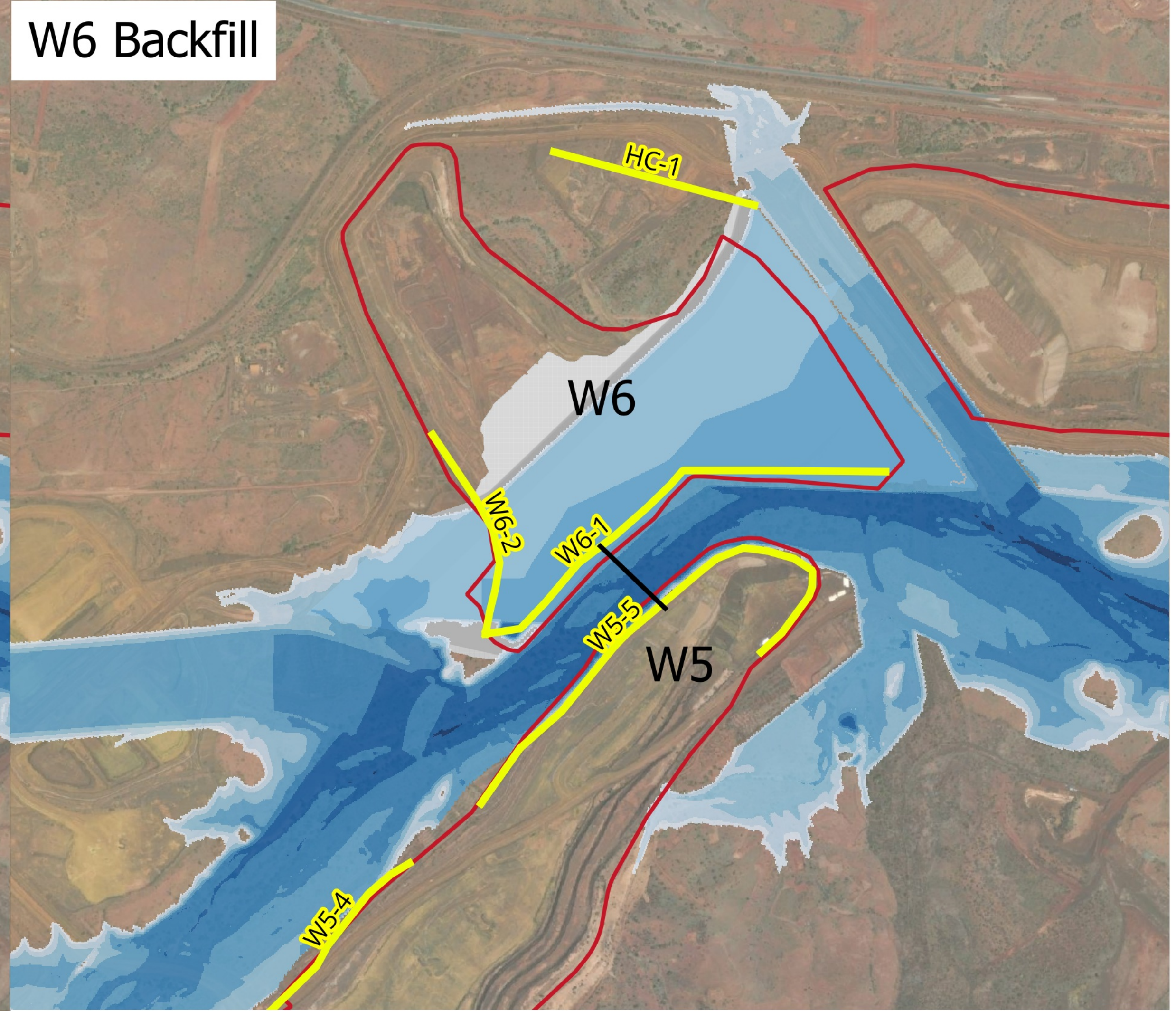
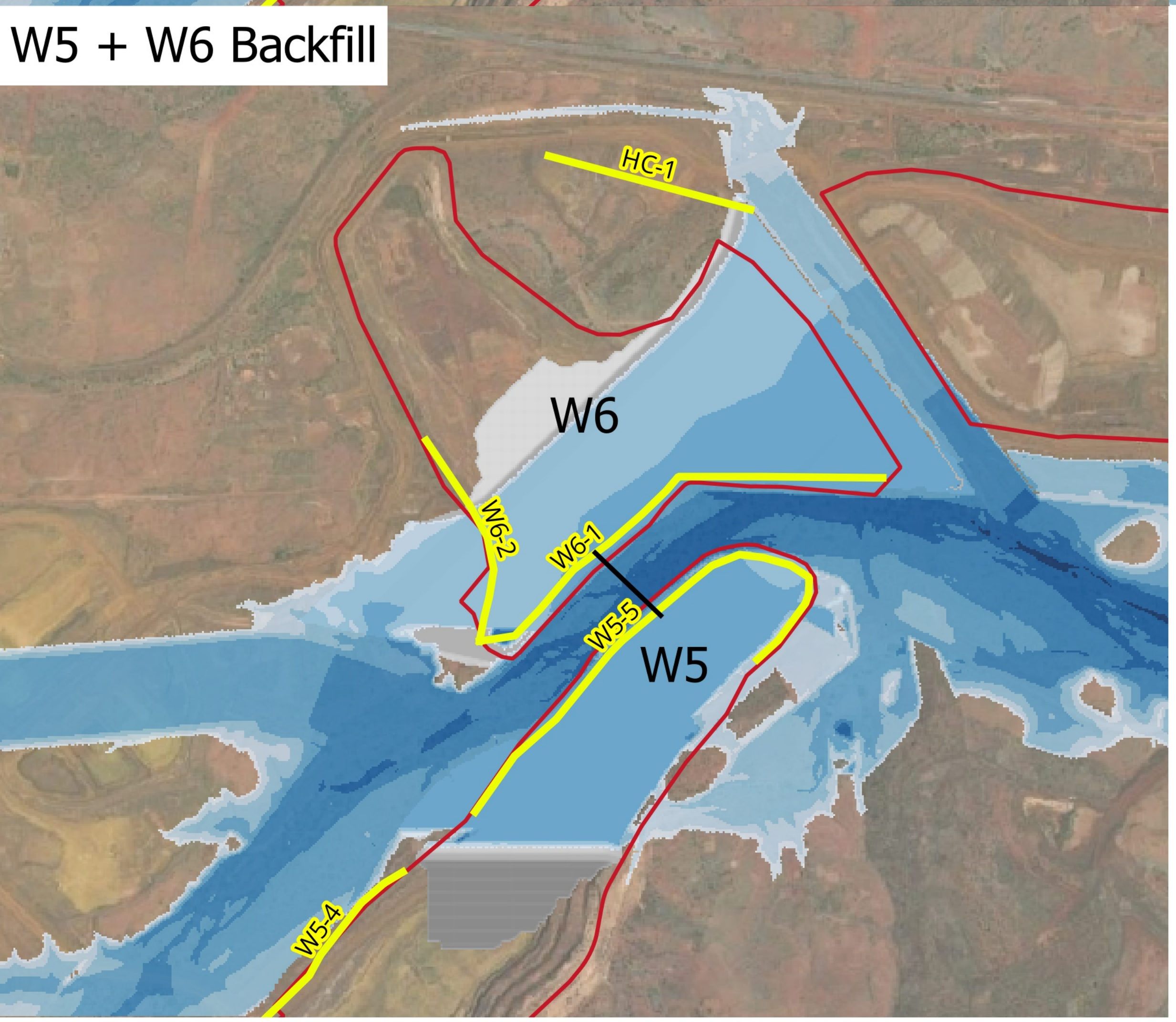
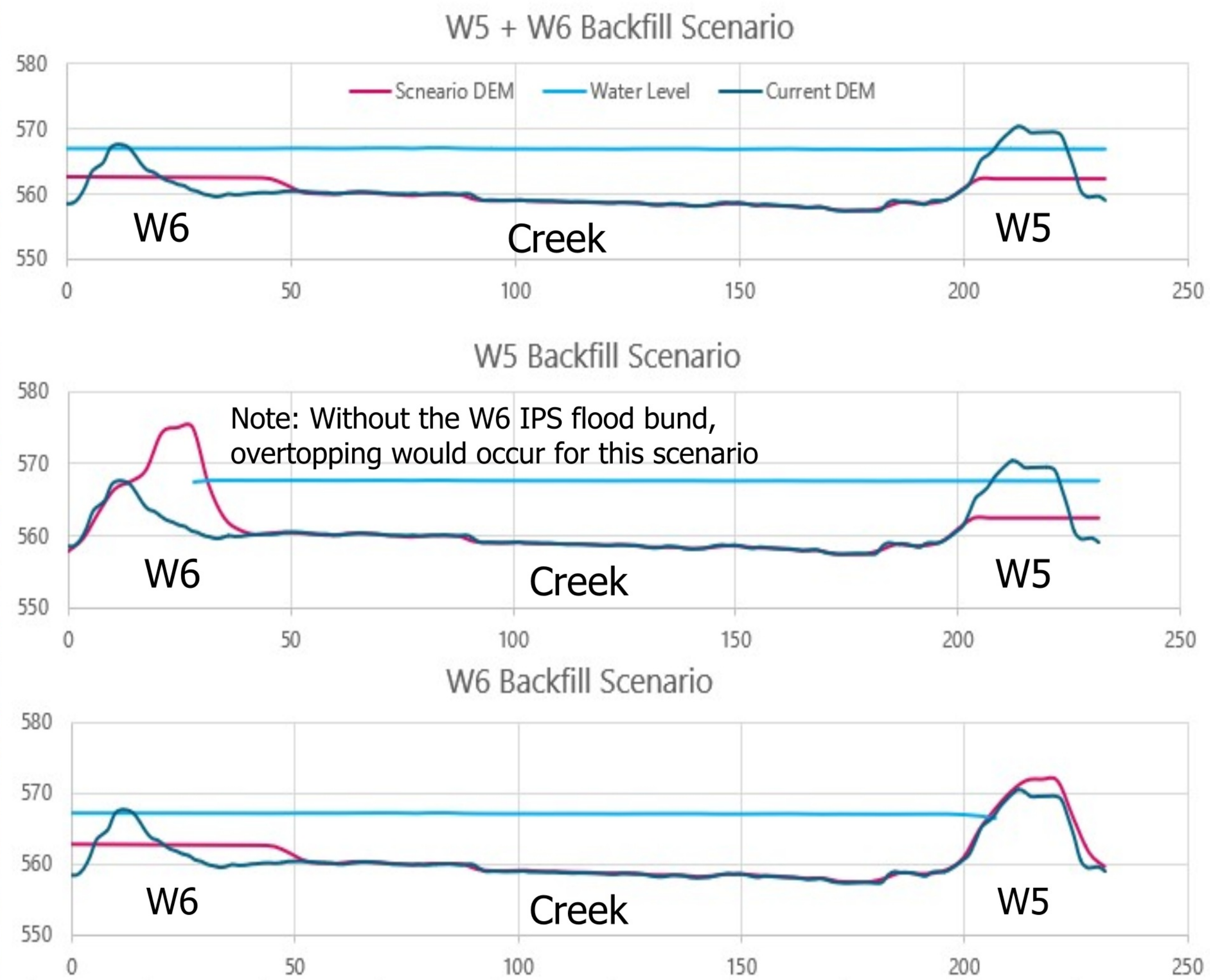
Yandi Closure Landform

FIGURE 10-3: W5-W6 FLOODPLAIN LANDFORM FLOOD DEPTH ASSESSMENT









Legend

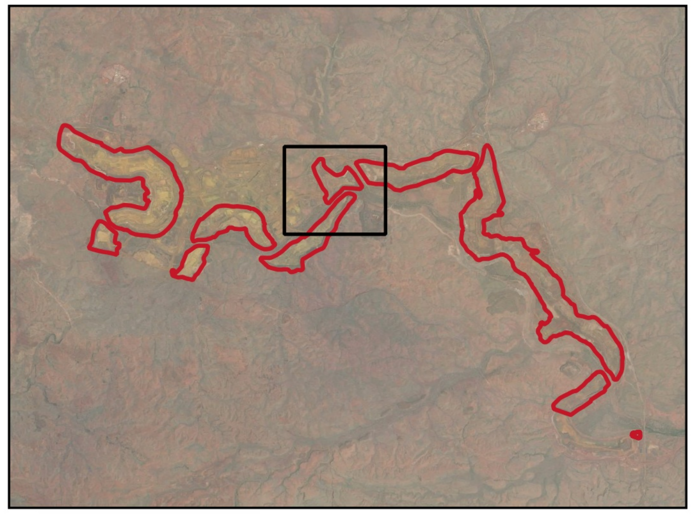
- IPS Bunds
- Surface Cross Section
- Pit Outlines
- Scenario Backfill

Flood Depth (m)

- <= 0.05
- 0.05 - 0.5
- 0.5 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

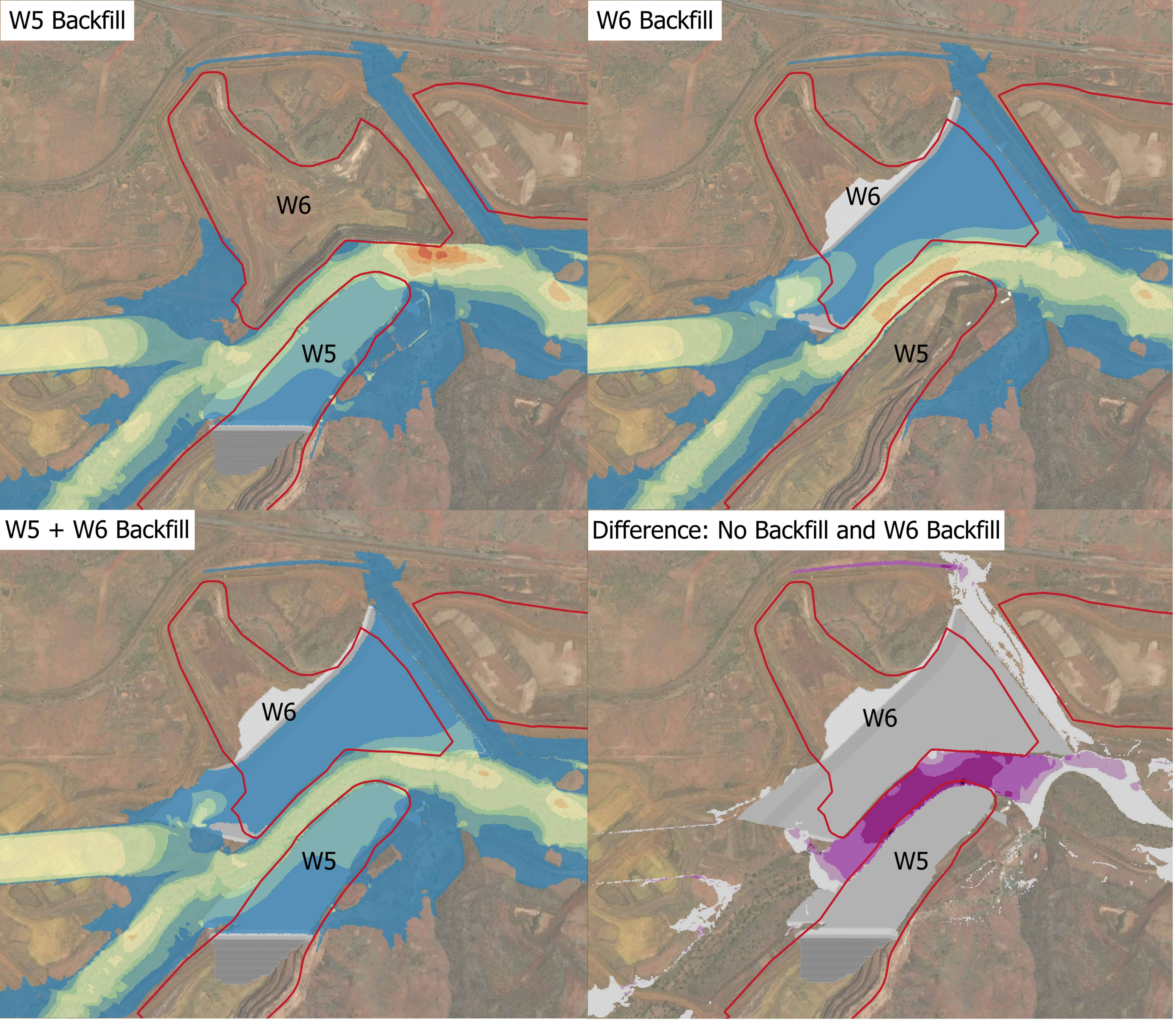
0 500 1,000 m

Date: 31/01/2024
Projection: Yandi 94



BHP Advisian

\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 10-3: W5-W6 FLOODPLAIN LANDFORM FLOOD DEPTH ASSESSMENT



Yandi Closure Landform

FIGURE 10-4: W5-W6 FLOODPLAIN LANDFORM FLOW VELOCITY ASSESSMENT

Legend

- Pit Outlines
- Scenario Backfill

Flow Velocity (m/s)

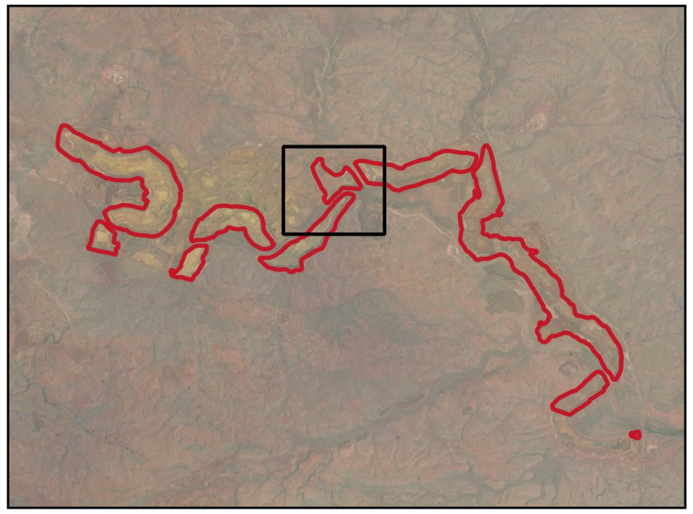
- < 2 (None)
- 2.0 - 2.6 (Facing)
- 2.6 - 2.9 (Light)
- 2.9 - 3.9 (1/4 Tonne)
- 3.9 - 4.5 (1/2 Tonne)
- 4.5 - 5.1 (1.0 Tonne)
- 5.1 - 5.7 (2.0 Tonne)
- 5.7 - 6.4 (4.0 Tonne)
- > 6.4 (Special)

Velocity Diff (m/s)

- 0.0 - 0.5
- 0.5- 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- > 3.0

0 500 1,000 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 10-4: W5-W6 FLOODPLAIN LANDFORM FLOW VELOCITY ASSESSMENT COPY

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10.2.1.2 W4/W5 Floodplain

Although the flood channel configuration outlined in Section 9 eliminates the requirement for bunds on the W4 pit crest, Marillana Creek is still constrained between the W4 and W5 pits (Figure 10-5) and modelling suggests overtopping of floodwater into the western corner of W5 pit in the 1:10,000 AEP event.

The W4/W5 floodplain widening option involves partially backfilling the western corner of W5 pit. This option was designed and tested using the 2D hydraulic model. The proposed in-pit floodplain landform design is sloped and does not require a flood bund to prevent inflow into the pit. The in-situ CID is assumed to remain in place around the pit crest protecting the floodplain from scour, erosion, and lateral channel migration.

The results presented in Figure 10-6 shows the in-pit floodplain containing the 1:10,000 AEP flood event without ingress into W5 pit. The floodplain removes the requirement for flood bunds and associated rock protection at Closure.

Table 10-3 Material estimates for W4/W5 in-pit floodplain landform

Category	Unit Rate	W5 Backfill
Backfill	$10/m^3	583,000
Cut volume	$10/m^3	40
Total cost		$5,830,400

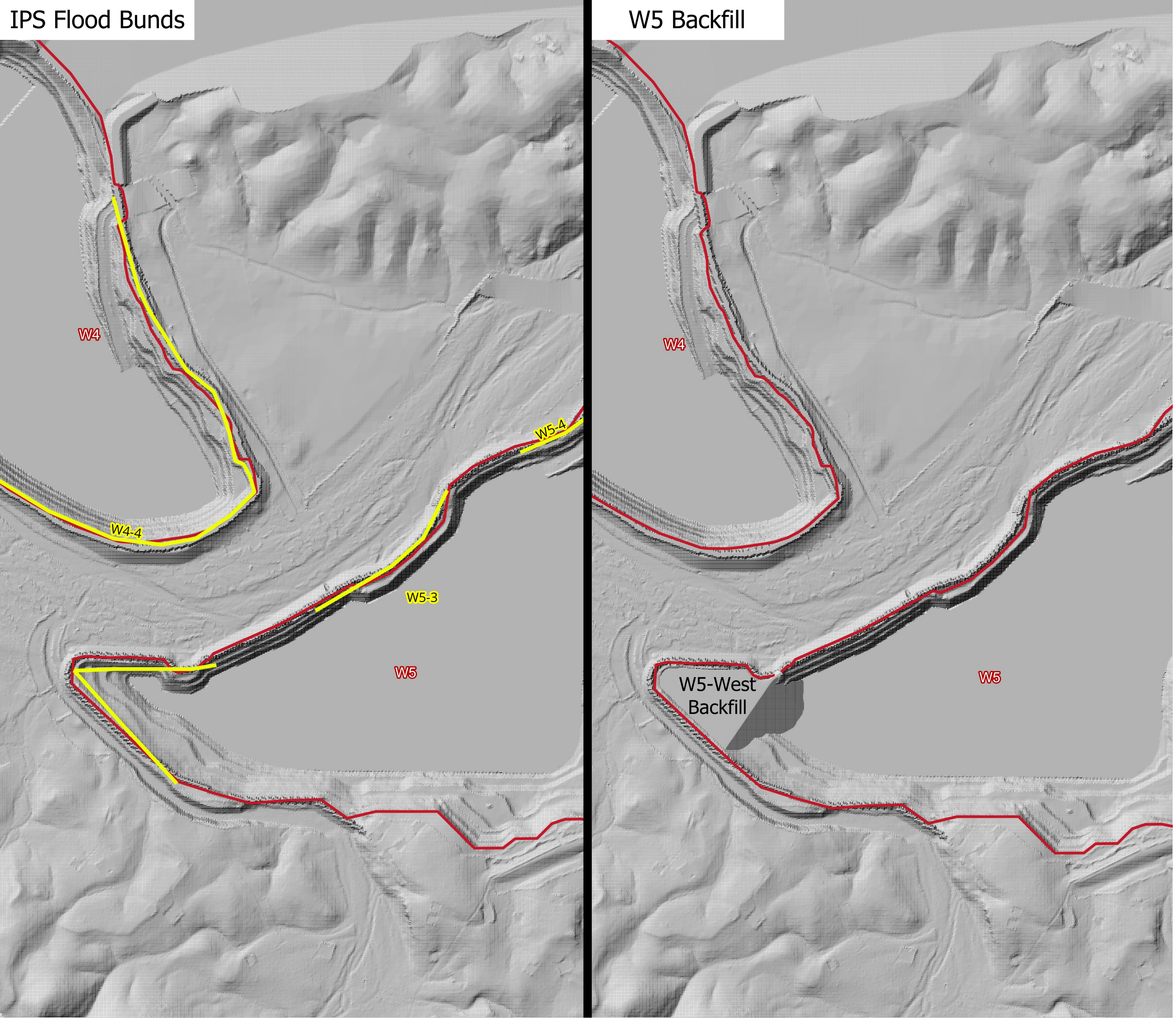
10.2.1.3 E6/E7 Floodplain

The E6/E7 floodplain widening option involves partially backfilling a portion of E6 pit, as well as some additional floodplain widening along the northern bank of Marillana Creek downstream of E6/E7, as shown in Figure 10-7. This option was designed and tested using the 2D hydraulic model.

The proposed in-pit floodplain landform design is sloped and does not require a flood bund to prevent inflow into the pit. The in-situ CID is assumed to remain in place around the pit crest protecting the floodplain from scour, erosion, and lateral channel migration.

The modelling results are presented in Figure 10-8 which suggests the floodplain design eliminates most flood bunds. The results also show a substantial reduction in the depth of flow and peak velocities through the constriction between E6/E7. However, one small flood bund is still required to prevent floodwater ingress at the north-eastern corner of the E7 pit. The introduction of the floodplain results in a significant reduction in size of rock protection required to protect the bund from scour and erosion.

The SPS design assumes a new bund will be constructed, though encroaching on the creek will have a limited impact with the widened floodplain on the opposite bank.



Yandi Closure Landform

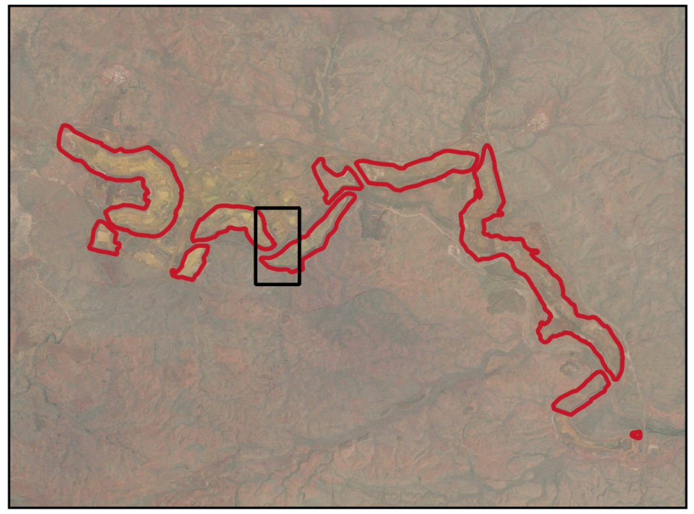
FIGURE 10-5: W4-W5 FLOODPLAIN LANDFORM CONFIGURATION

Legend

- Pit Outlines
- Scenario Backfill
- IPS Bunds

0 100 200 m

Date: 31/01/2024
Projection: Yandi 94



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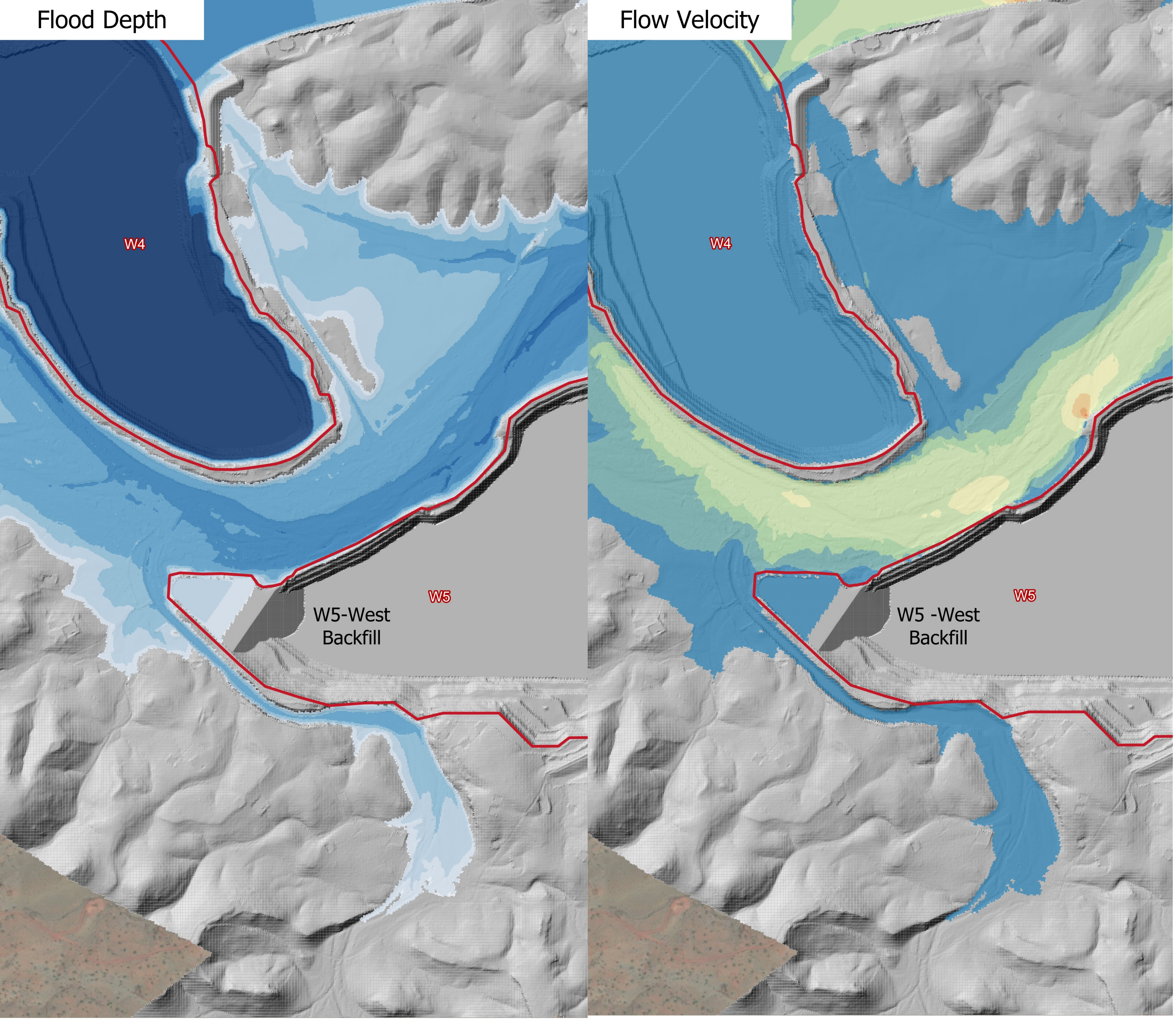


Yandi Closure Landform

FIGURE 10-6: W4-W5 FLOODPLAIN LANDFORM ASSESSMENT

Legend

Pit Outlines

Flow Velocity (m/s)

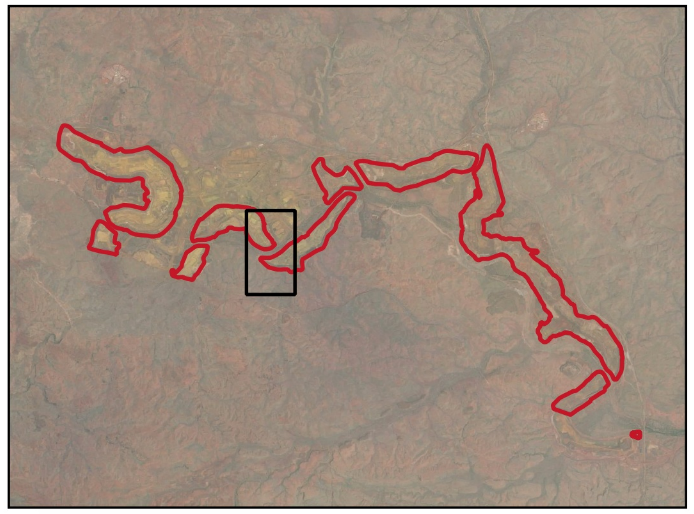
- < 2 (None)
- 2.0 - 2.6 (Facing)
- 2.6 - 2.9 (Light)
- 2.9 - 3.9 (1/4 Tonne)
- 3.9 - 4.5 (1/2 Tonne)
- 4.5 - 5.1 (1.0 Tonne)
- 5.1 - 5.7 (2.0 Tonne)
- 5.7 - 6.4 (4.0 Tonne)
- > 6.4 (Special)

Flood Depth (m)

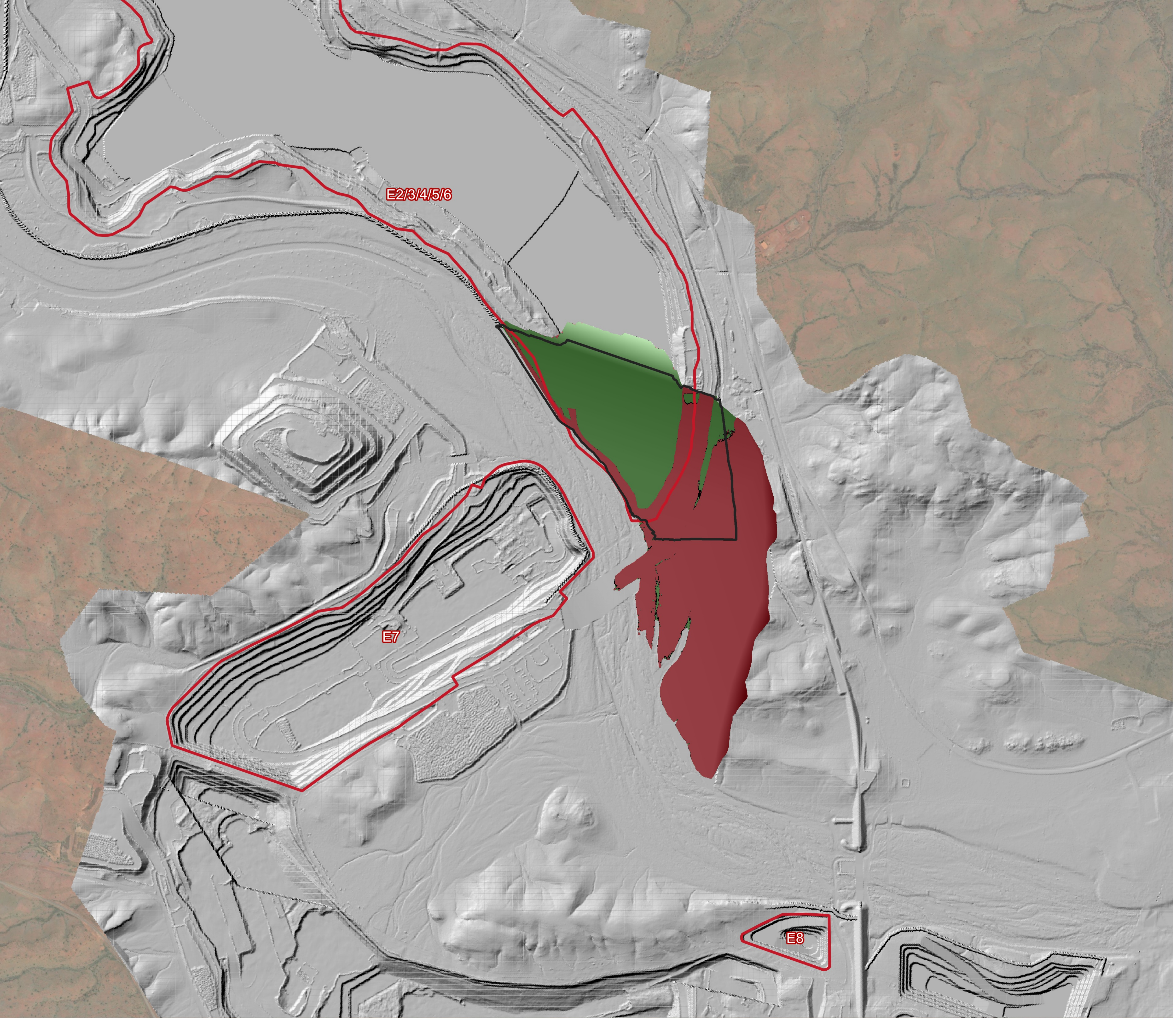
- <= 0.05
- 0.05 - 0.5
- 0.5 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

0 100 200 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 10-6: W4-W5 FLOODPLAIN LANDFORM ASSESSMENT



Yandi Closure Landform

FIGURE 10-7: E6-E7 FLOODPLAIN LANDFORM CONFIGURATION

Legend

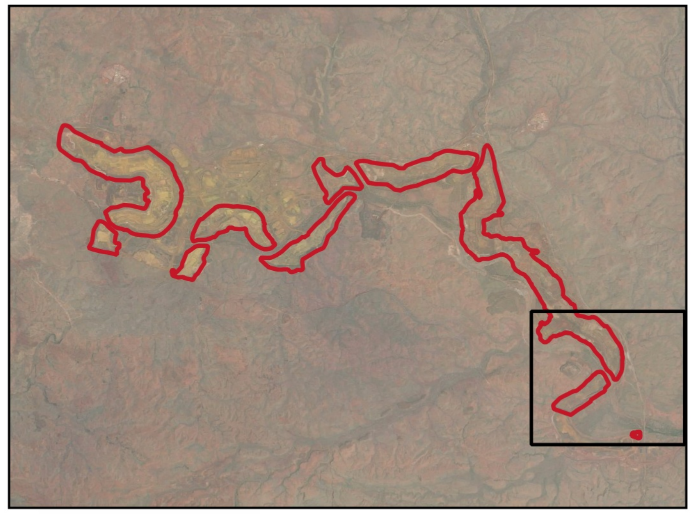
- Pit Outlines
- Trade-off Study Backfill

E6 Backfill

- <= 0.0 (Cut)
- > 55.0 (Fill)

0 250 500 m

Date: 31/01/2024
Projection:

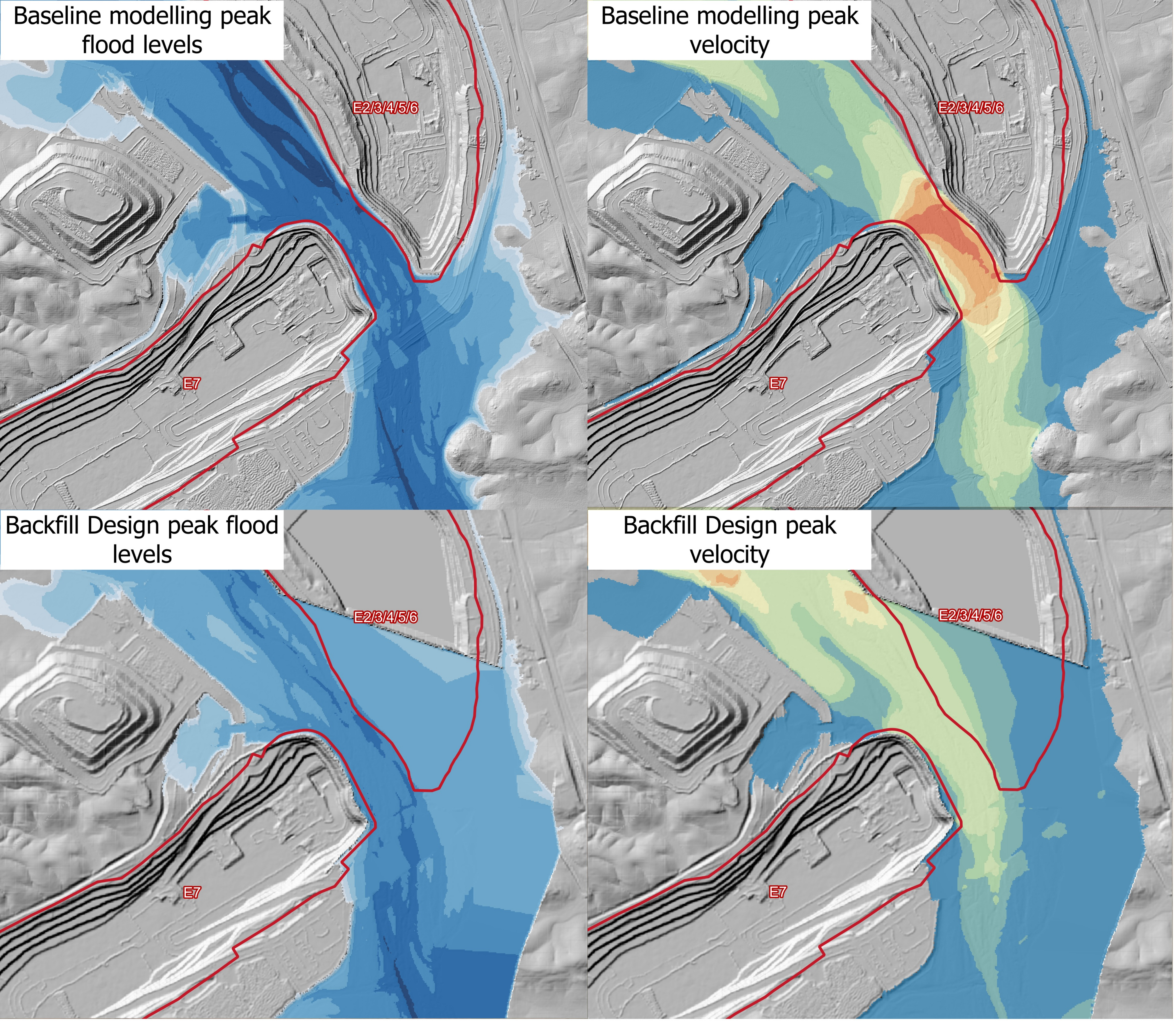


BHP Advisian Worley Group

\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 10-7: E6-E7 FLOODPLAIN LANDFORM CONFIGURATION

Yandi Closure Landform

FIGURE 10-8: E6-E7 FLOODPLAIN LANDFORM ASSESSMENT



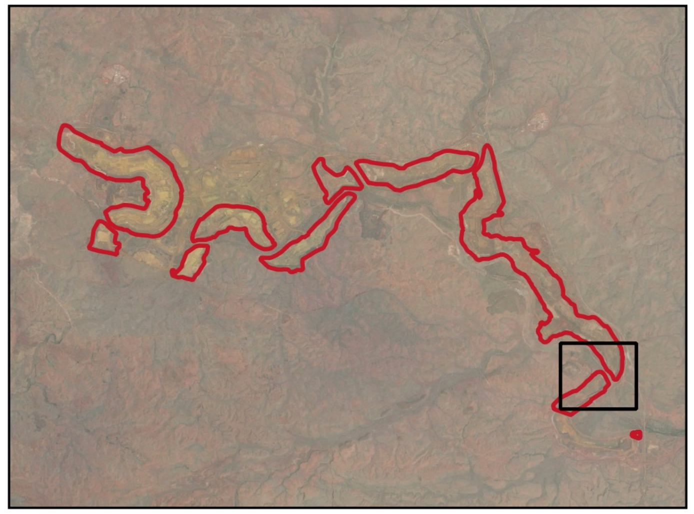
Legend

Pit Outlines

Flow Velocity (m/s)	Flood Depth (m)
< 2 (None)	<= 0.05
2.0 - 2.6 (Facing)	0.05 - 0.5
2.6 - 2.9 (Light)	0.5 - 2.0
2.9 - 3.9 (1/4 Tonne)	2.0 - 4.0
3.9 - 4.5 (1/2 Tonne)	4.0 - 6.0
4.5 - 5.1 (1.0 Tonne)	6.0 - 8.0
5.1 - 5.7 (2.0 Tonne)	8.0 - 10.0
5.7 - 6.4 (4.0 Tonne)	> 10.0
> 6.4 (Special)	

0 250 500 m

Date: 31/01/2024
Projection: Yandi 94



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\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 10-8: E6-E7 FLOODPLAIN LANDFORM ASSESSMENT

The material and cost estimate for the preferred E6/E7 in-pit floodplain option, are provided in Table 10-4.

Table 10-4 Material estimates for the E6/E7 in-pit floodplain landform

Category	Unit Rate	Flood bunds at E6-E7 (IPS design)	E6 Backfill
Bund fill	$30/m^3	302,290	42,650
Backfill	$10/m^3	-	6,337,295
Cut volume	$10/m^3	-	3,590,180
Rock protection	$200/m^3	47,380	15,120
Total cost		$12,498,900	$103,578,250

10.2.2 Floodplain Widening

Floodplain widening (external to the pit voids) was considered at the following location:

- Middle Section of W5

The design optimisation work completed at this location is discussed below.

2D flood modelling results were used to identify any other potential locations that could potentially benefit from floodplain widening. However, no other locations were identified as providing significant benefit so other locations were not explored further.

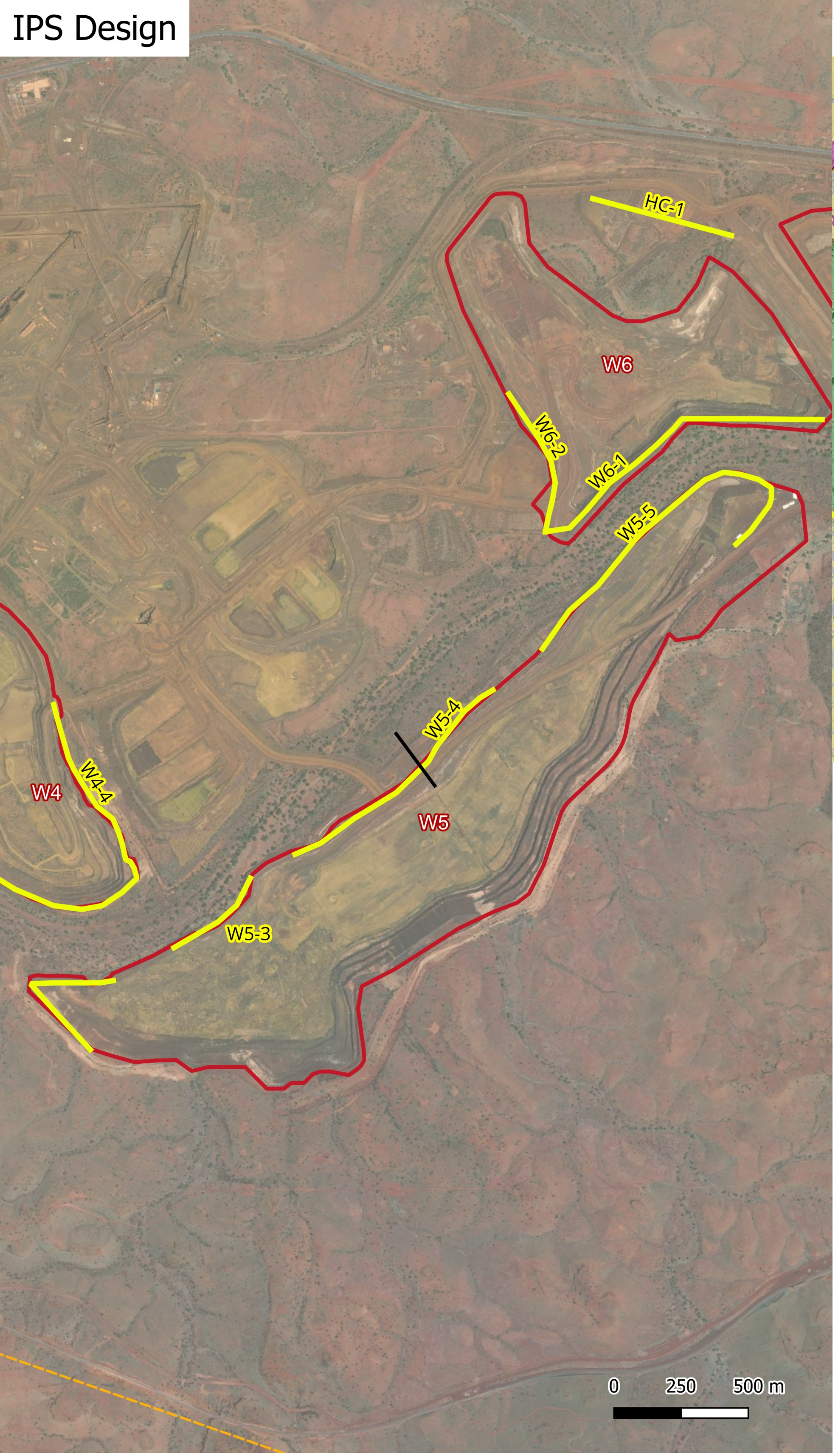
10.2.2.1 Middle Section of W5

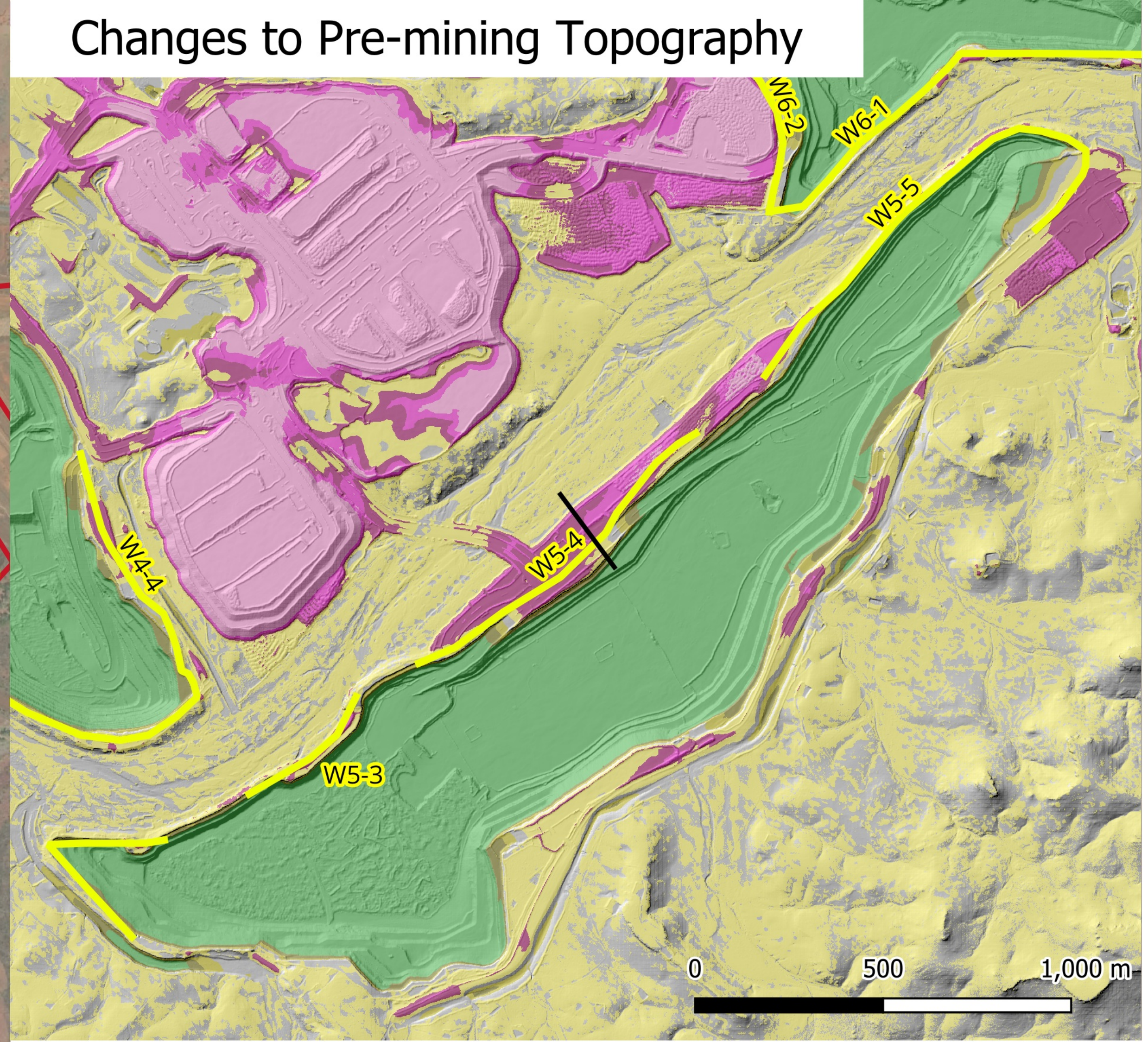
The middle section of W5, shown in Figure 10-9, was identified as an opportunity for floodplain widening. Historical mining activities placed fill material on the northern side of W5 pit, encroaching on the pre-development floodplain. 2D hydraulic modelling suggests that this fill material is currently acting to prevent 1:100 AEP floodwater from entering the pit, but is overtopped in the 1:10,000 AEP event. Therefore, a flood protection bund must be constructed in this fill area to protect the W5 pit void.

The existing fill material is not a suitable foundation for the flood bund and must be removed at Closure, prior to construction of the flood bund. This presents an opportunity to reinstate some of the pre-development floodplain (floodplain widening) at Closure.

This reach of Marillana Creek features alluvial material that extends to the pit edge, presenting a seepage risk that is assessed in detail in the corresponding Geotechnical Assessment Report (No. PREP-1200-C-12140). Owing to these risks the flood bunds cannot be placed at the pit edge and must be offset as shown in Figure 10-9. This alignment has been assessed with regards to seepage, though further optimisation of the alignment is possible through iterative flood and seepage modelling.

A comparison of the flood levels and flow velocities is presented in Figure 10-10. The baseline scenario has the existing fill material in place (constraining the floodplain), and the widened floodplain scenario has the bund located closer to the pit edge.





Yandi Closure Landform

FIGURE 10-9: MID-SECTION OF W5 BUND ALIGNMENT

Legend

- IPS Bunds
- W5 Mid-Section Line
- Pits Outline

Difference (m)

- 0 - 3.0
- 3.0 - 6.0
- 6.0 - 10.0
- > 10.0

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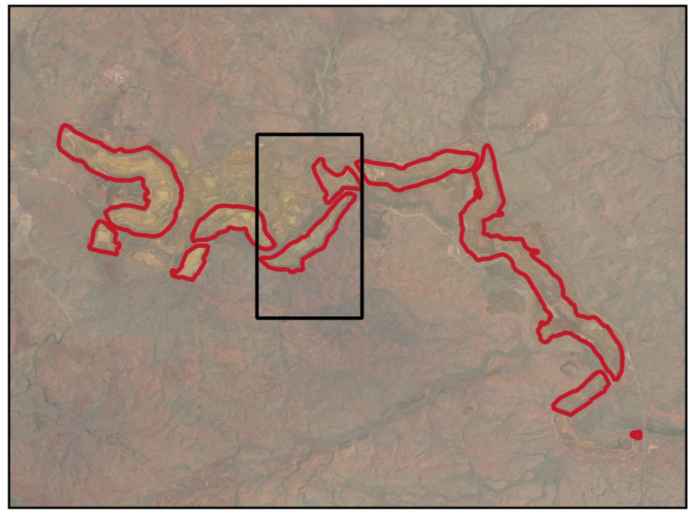
Projection: Yandi 94



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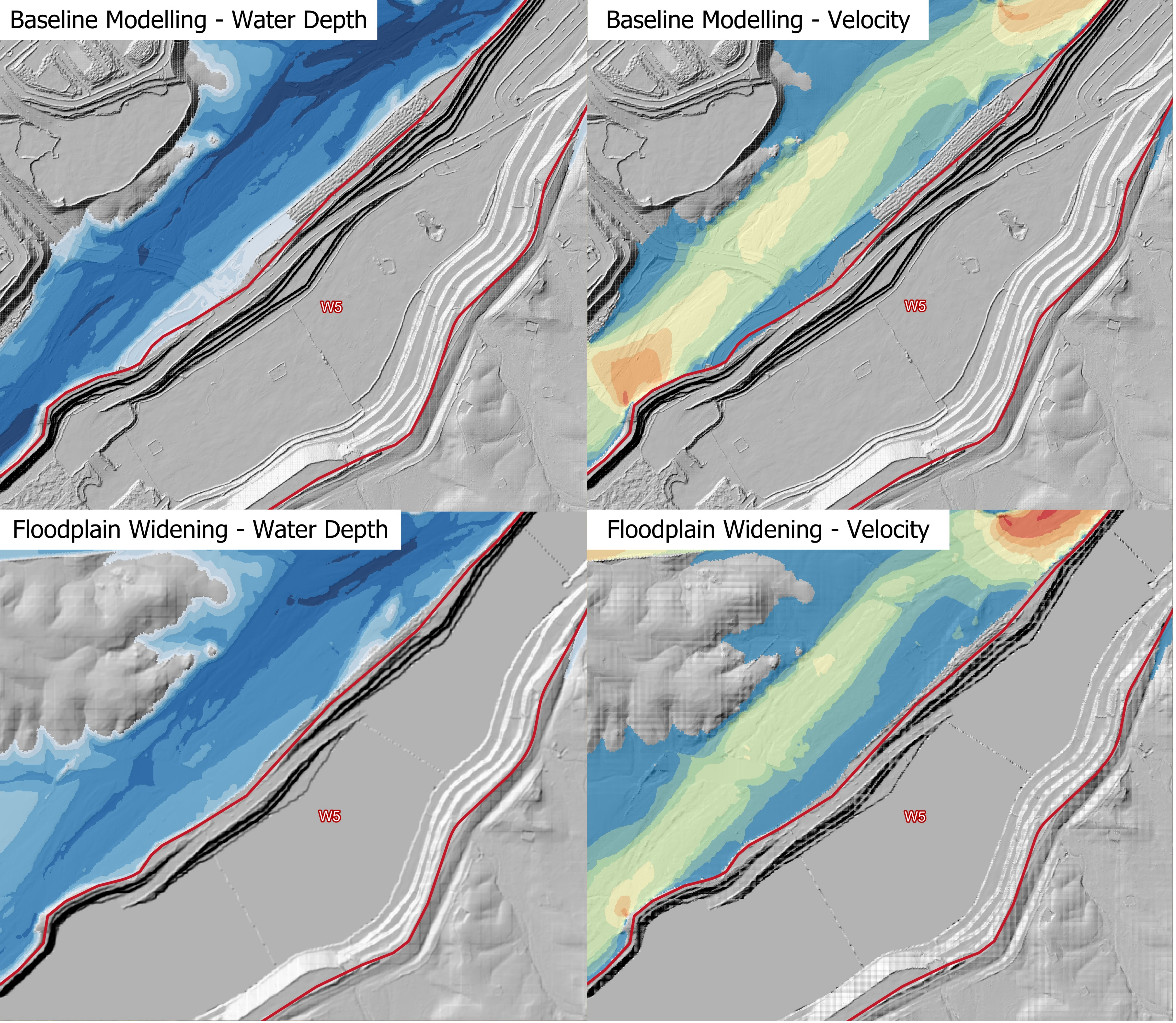
\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 10-9: MID-SECTION OF W5 BUND ALIGNMENT

Yandi Closure Landform

FIGURE 10-10: MID-SECTION OF W5 ASSESSMENT



Legend

Pit Outlines

Flow Velocity (m/s)

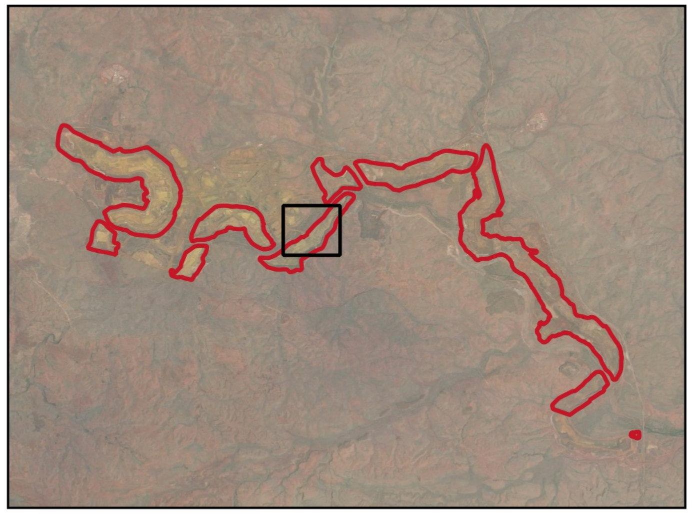
- < 2 (None)
- 2.0 - 2.6 (Facing)
- 2.6 - 2.9 (Light)
- 2.9 - 3.9 (1/4 Tonne)
- 3.9 - 4.5 (1/2 Tonne)
- 4.5 - 5.1 (1.0 Tonne)
- 5.1 - 5.7 (2.0 Tonne)
- 5.7 - 6.4 (4.0 Tonne)
- > 6.4 (Special)

Flood Depth (m)

- <= 0.05
- 0.05 - 0.1
- 0.1 - 0.5
- 0.5 - 1.0
- 1.0 - 2.0
- 2.0 - 3.0
- > 3.0

0 250 500 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 10-10: MID-SECTION OF W5 ASSESSMENT

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The results show a considerable reduction in flow velocity and associated rock protection with the widened floodplain scenario. Therefore, the widened floodplain scenario and associated flood bund design was adopted for SPS design.

11 FLOOD BUND DESIGN

At Closure, flood protection bunds are required at locations across the mine site to prevent uncontrolled overtopping of pit crests and inflows to pit voids during the 1:10,000 AEP event. Uncontrolled overtopping would lead to creek capture of Marillana Creek and/or other tributaries with significant associated environmental and social impacts.

Marillana Creek is a system with a highly mobile, braided channels meaning the primary low flow channels can migrate over time, leading to scour, erosion, and deposition. Flood bunds are therefore designed based on geotechnical assessments to determine stable batter slopes and 2D hydraulic modelling to determine flood heights, flow velocities, rock protection and scour depths. The hydraulic design process is outlined in the following section, including improvements to the IPS design.

Existing flood bunds at Yandi have been designed to prevent scour, erosion and overtopping in the 1:100 AEP event with 1 m of freeboard. These bunds require design upgrades for Closure to prevent scour, erosion and overtopping in the 1:10,000 AEP event. New flood bunds are also required at Closure to prevent overtopping into pits and maintain long term stability of the final landform design.

Therefore, the primary focus of the SPS deign of flood bunds was to:

- review existing flood bunds and develop design upgrades where required for closure, and
- develop designs for new flood bunds.

The risk associated with overtopping of pit crests along Marillana Creek or significant existing flood bunds (such as E1 and E4 bunds) are significant and therefore was of primary focus for the SPS. Other existing flood bunds are present along Marillana Creek and its tributaries which have also been assessed but to a reduced level of detail which is considered appropriate for SPS level accuracy. In many cases there is limited available information available for existing flood bunds preventing detailed assessment.

Trade-off studies were completed on the IPS flood bund designs to compare with alternative design options. The results from the trade-off studies are summarised below.

Further development of the flood bunds designs took place after the trade-off studies and required consideration of the effects of revised flood channels, widened floodplain landforms as well as other considerations from the updated hydrology, site visit and constructability review. The results of this design development work is also described below.

11.1 Trade-Off Studies

Trade-off studies were completed as part of the SPS to progress the flood bund configuration and designs. A summary of these is provided below.

11.1.1 Buttress Eastern Pits (GEN.10 311012-01707-CI-PRE-0006)

The IPS design assumed that existing E1, E4 and E7 flood bunds upgraded at Closure and would involve:

- Increasing the height of the bunds via an upstream raise and extending the bund into the creek, to provide 1 m of freeboard to the 1:10,000 AEP flood level.
- Upgrading of rock protection to prevent scour and erosion in the 1:10,000 AEP event.

The upstream raise extends the bund into Marillana Creek, potentially increasing the hydraulics and associated size of rock protection. It also requires removal of the existing rock protection and replacing the rock on the upgraded bund.

The objective of this trade-off study was to assess and compare the base case IPS assumption of upstream raise of bunds (into the creek) with the option of a downstream raise (towards the pit).

The difference in crest level between the upstream IPS design and the existing flood bund was estimated to be approximately 5 m. For the assessment, the downstream toe of the IPS design was extended by 5 m and compared with the pit stability exclusions zones to determine feasibility. The following recommendations were made from the trade-off study:

- Downstream bund raises are recommended at E1-2, E1-3, E104, E4-1 and E4-2
- E7-2 has not been constructed and therefore can be constructed as per the Closure design
- For E1-1 upstream raising is recommended for the northern section of E1-1 as it avoids the cost of additional buttressing, but downstream raising for the southern section does not require additional buttressing
- Downstream raise of E4-3 is recommended as the cost of buttressing is relatively low compared to the negatives of the upstream option
- For E7-1 a downstream raise is recommended as it does not impact the creek, construction may have complexities associated with potential settlement risks of constructing flood bunds across CID and buttress/backfill.

11.1.2 Replace or Re-Use Rock Protection (GEN.11 311012-01707-CI-PRE-0007)

The objective of this trade-off study was to assess whether the existing rock protection should be removed, stockpiled, and reused or left in-situ and covered by rock fill material. This is applicable to bunds where bunds are raised upstream (towards the creek, away from the pit). Bunds E1-1 and E4-3 were assessed, and it was assumed that they would be raised 2 m above existing crest height (based on the IPS design).

The trade-off study identified that covering existing rock fill (protection) is the more practical approach and provided cost benefits over removal and reuse.

11.1.3 Submerged Toe vs Launchable Toe Rock Protection (GEN.12 311012-01707-CI-PRE-0008)

Naturally occurring scour within the mobile Marillana Creek bed requires extension of rock protection below the existing creek bed to protect the bund toe from erosion. IPS designs of flood bunds assumed that the rock protection was extended 3 m below the base of the primary low flow channel (or until rock is encountered). This approach requires excavation and potentially dewatering of the superficial aquifer to install the rock protection to the required depth.

An alternative approach is to adopt a launchable toe where additional rock protection is placed at the base of the bund. If there is scour and erosion at the toe of the bund, the rock protection falls into the scour hole limiting the propagation of the scour and erosion and potential for undercutting failure of the bund. A limitation with this approach is that there is no geofabric protection at depth to prevent washing out of fines, and there is no mechanical interlocking of rock. During the launching process rock can be lost downstream, therefore additional material is required.

The trade-off study considered both approaches, including the associate costs and constructability. It was determined that buried rock protection was preferable due to the lower costs and greater certainty of outcome associated with interlocking the rock and geofabric. The volume of rock lost downstream using a launchable toe is difficult to quantify and therefore monitoring and maintenance may be required to function effectively long term.

11.1.4 Trade-off Study Bund Slope and Rock Size and Volume (GEN.13 311012-01707-CI-PRE-0009)

The IPS bund design assumed batter slopes of 1V:2H and adopted rock classes of up to 4 Tonne (d50 = 1.45 m). This trade-off study assessed whether flatter bund batter slopes would reduce the associated size and class of rock protection. A literature review was completed to examine the basis for commonly used design guidelines and assess the influence of slope in the associated equations.

The Austroads (1994) guideline [published more recently in Austroads (2019)] is a commonly used method for sizing rock protection on hydraulic structures in Western Australia and has been widely adopted in the Pilbara region for ~30 years. The method is used to select rock class and thickness for a corresponding flow velocity. The method, often repeated in Australian guidelines, is derived from the CALTRAN method (California Department of Public Works – Division of Highways, 1960). The CALTRAN method allows for rock sizing based on empirical equations (or a nomograph) and accounts for bund batter slope in determining rock protection size.

There is uncertainty associated with how the Austroads (1994) method was developed using the CALTRAN method, with several unpublished assumptions and the conversion from imperial to metric units. Therefore, given the uncertainty, there is no clear method for modifying the Austroads (1994) design table based on slope, and therefore no changes to the design approach were implemented.

The Austroads (1994) approach has been used since 1994 for the design of hydraulic structures in the Pilbara and is considered therefore to be effective. It was therefore retained as the preferred method for sizing rock protection for SPS bund design.

11.2 Design Development

Design of flood bunds was conducted using the 2D hydraulic model, after the trade-off studies to capture the cumulative effects of revised flood channels, widened floodplain landforms as well as other considerations from the site visit and constructability review.

The hydraulic modelling outputs were used to:

- locate flood bunds to reduce risk of scour/erosion and overtopping
- set the bund crest heights based on flood depths, providing 1 m freeboard to the 1:10,000 AEP event (in Marillana Creek)
- rock protection requirements based on peak velocities in the 1:10,000 AEP event:
    - rock class/size,
    - rock thickness, and
    - depth of rock below ground level to protect from scour and erosion of the toe. Scour depth estimates were made using the hydraulic modelling outputs and used to set the depth of rock.

The resulting designs were provided to the geotechnical and civil team to finalise the flood bund designs, using the methodology described in the Geotechnical Assessment Report (No. PREP-1200-C-12140). The resulting bund designs are provided in subsequent sections and design drawings.

Basis of Design

Bunds to be safe, stable, and non-polluting and not require ongoing care and maintenance. They should prevent unplanned and uncontrolled creek capture into pit voids during rainfall events.

• **Major Diversion Bunds** (Marillana Creek): Bunds to accommodate predicted flood levels and velocities for the 1:10,000 AEP flood event.

• **Intermediate Diversion Bunds**: Bunds to accommodate predicted flood levels and velocities for the 1:1,000-year flood event (0.1% AEP).

• **Minor Diversion Bunds**: Bunds to accommodate predicted flood levels and velocities for the 1:100-year flood event (1% AEP).

Design bund slope factor of safety minimum of 1.5 for overall slope stability under static conditions and minimum of 1.2 under seismic conditions, including consideration to sensitivity of the predicted material strength and groundwater conditions

Bund crest levels to have 1 m freeboard to the flood level of the respective design flood event.

Bund crest width to be a minimum of 5 m.

11.2.1 Flood Bund Configuration

The bunds included in the SPS design are listed in Table 11-1 and their locations presented in Figure 11-1. The table includes details on whether they are new bunds or upgraded bunds. Upgraded bunds are classified as requiring either an upstream or downstream raise (based on results of trade off studies) and where the rock protection can be retained or replaced.

Compared with the IPS design (Figure 8-1), the SPS refinements of the flood channels has removed the requirement for bunds near W4 and lowered flood levels and associated bund requirements along the E2356 pit. The floodplain widening described in Section 10 has also eliminated the need for flood bunds at W5-1, W5-3, W5-5, W6-1, W6-2 pits as well as along a portion of E7-1 pit and where bunds are required, rock protection requirements (size/class) have also been reduced.

The 2D hydraulic modelling results presented in Figure 11-2 and Figure 11-3 demonstrate that the bunds, in conjunction with our measures, prevent uncontrolled flows from Marillana Creek into the pits during the 1:10,000 AEP event. The performance of tributaries is discussed further in Section 12, and detailed mapping provided in Appendix B.

A sketch of the typical design is provided in Figure 11-4. The bund geometry ties in with existing landforms accounting for the location of existing bunds and/or CID to reduce the fill material requirements.

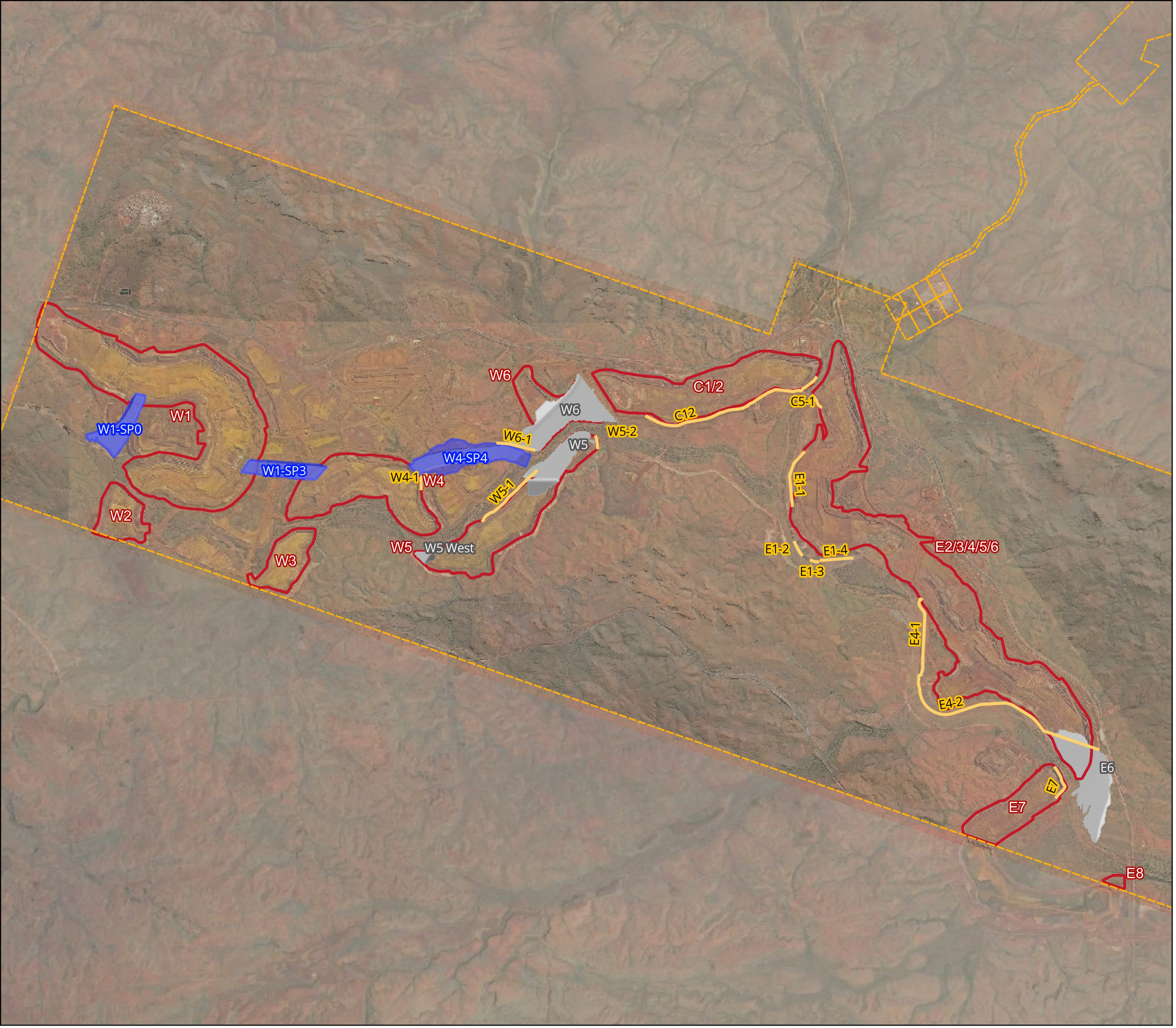
Table 11-1 IPS bund register

IPS Name	SPS Name	SPS Status	New bund, Upstream or Downstream Raise	Re-used Rock Protection
W1-1	-	Not assess (see Section 12.11 regarding W1 diversion)	-	-
W1-2	-		-	-
W1-3	-	Removed as the W1-SP0 design has been modified	-	-
W1-4	-		-	-
W4-1	-	Removed as the W1 & W4 storage reduces the flood depths through this reach.	-	-
W4-2	-		-	-
W4-3	-		-	-
W4-4	-	Removed. W4-SP4 configuration eliminates this bund.	-	-
W4-5	-	Removed due to realignment of W1-SP3	-	-
W5-1	-	Replaced with floodplain landform.	-	-
W5-3	-	Removed. W4-SP4 configuration eliminates this bund.	-	-
W5-4	W5-1	Revised alignment accounting for fill material removal.	New	-
W5-5	W5-2	Mostly removed owing to W6 floodplain landform.	New	-
W6-1	-	Removed. Floodplain landform eliminates this bund.	-	-
W6-2	-	Removed. Floodplain landform eliminates this bund.	-	-
-	W6-1	New bund at outlet of W4-SP4 to prevent flows onto the W6 floodplain landform.	New	-
HC-1	-	Retained, noting that the design requires confirmation at DPS in conjunction with Closure designs for the landbridge.	New	-
C1-1	C1-1	The configuration of these bunds has been consolidated with the revised hydrology, flood channels and floodplain landforms.	New	-
C1-2				
C1-3	C1-2			

IPS Name	SPS Name	SPS Status	New bund, Upstream or Downstream Raise	Re-used Rock Protection
C1-4				
C5-1	C5-1	New bund extended from the IPS design.	New	-
E1-1	E1-1	Extension of existing bund.	Upstream	No
E1-2	E1-2	New bund modified from the IPS design.	New	-
E1-3	E1-3	New bund modified from the IPS design.	New	-
E1-4	E1-4	New bund modified from the IPS design.	New	-
E4-1	E4-1	Modified from the IPS design.	Downstream	-
E4-2	E4-2	New bund modified from the IPS design.	New	-
E4-3	E4-2	Modified from the IPS design and shortened by the E6 floodplain landform.	New	-
E7-1	E7-1	Modified from the IPS design.	New	-
E7-2	-	Removed owing to the E6 backfill	-	-

Yandi Closure Landform

FIGURE 11-1 SPS FLOOD BUND CONFIGURATION

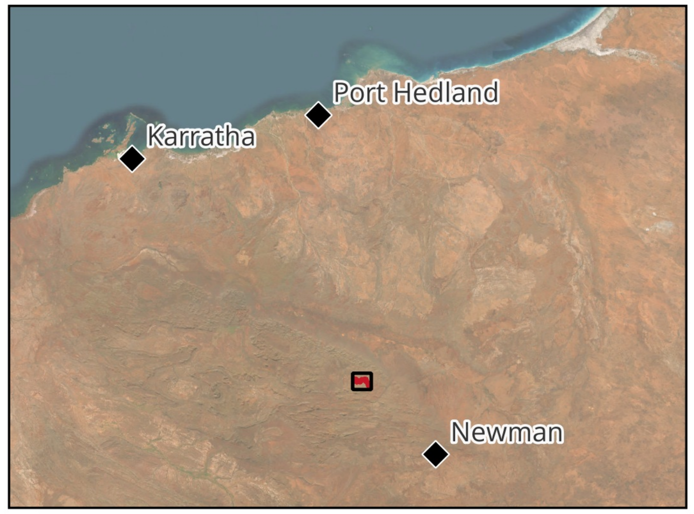


Legend

- SPS Flood Bunds
- Pit Outlines
- Yandi Tenemant
- Backfill
- Flood Channels

0 1,000 2,000 m

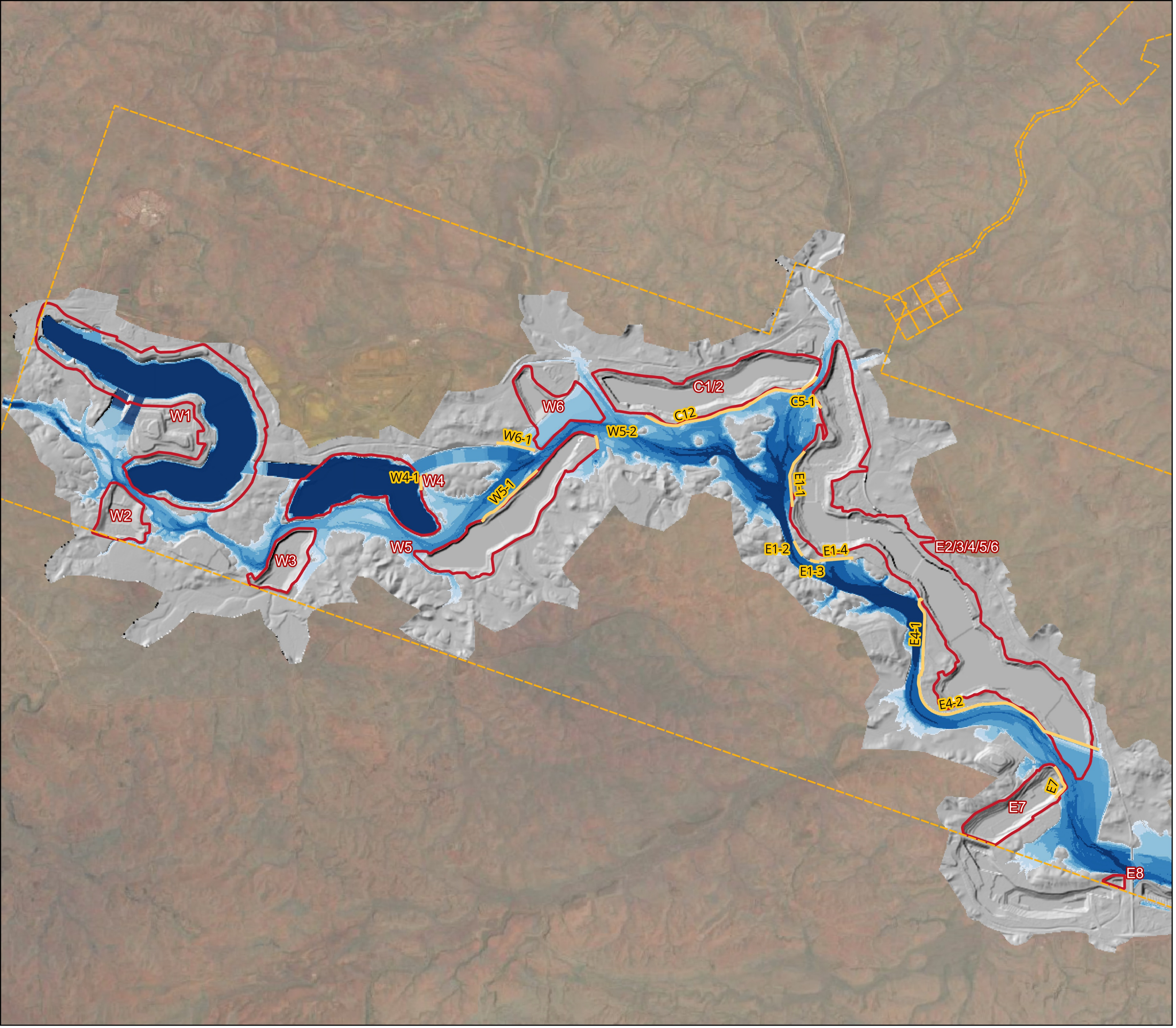
Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 11-1: SPS FLOOD BUND CONFIGURATION

Yandi Closure Landform

FIGURE 11-2 1:10,000 AEP FLOOD DEPTHS



Legend

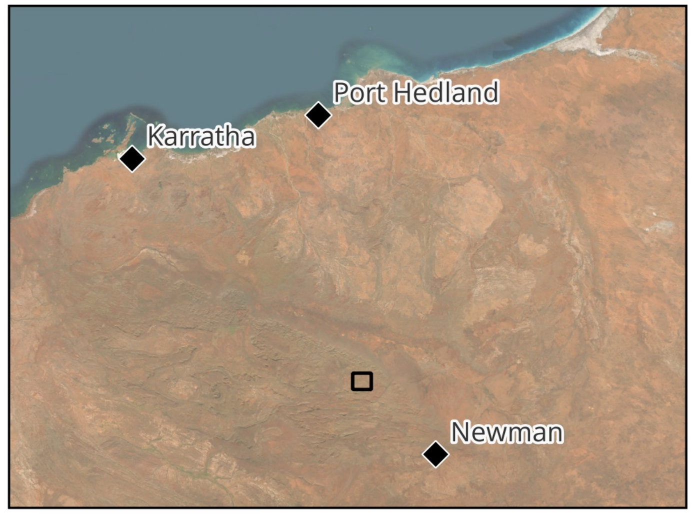
- Pit Outlines
- SPS Bunds
- Yandi Tenemant

Flood Depth (m)

- <= 0.05
- 0.05 - 0.5
- 0.5 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- > 10.0

0 1,000 2,000 m

Date: 31/01/2024
Projection: Yandi 94

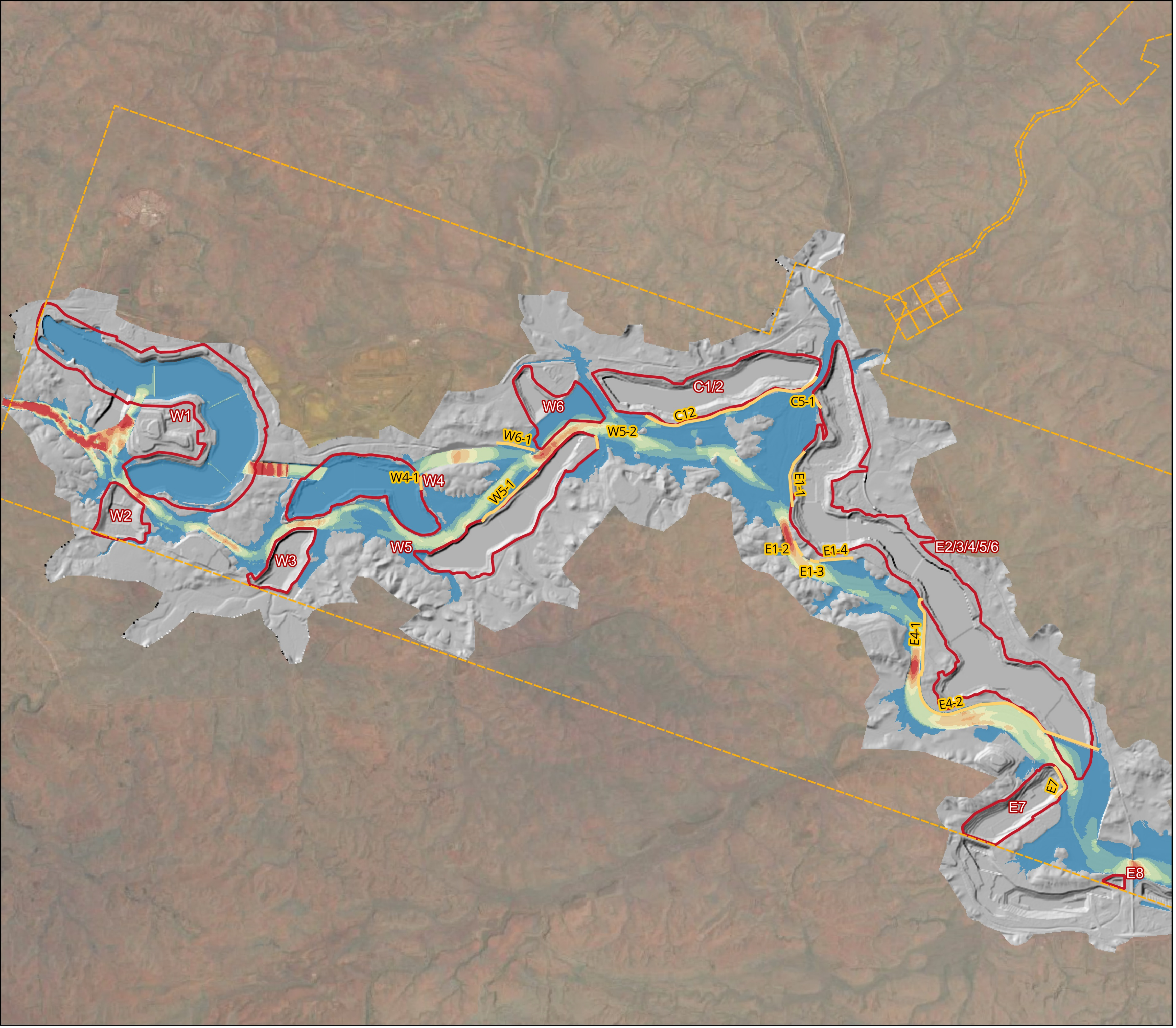


BHP Advisian

\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 11-2: 1:10,000 AEP FLOOD DEPTHS

Yandi Closure Landform

FIGURE 11-3: 1:10,000 AEP FLOW VELOCITIES



Legend

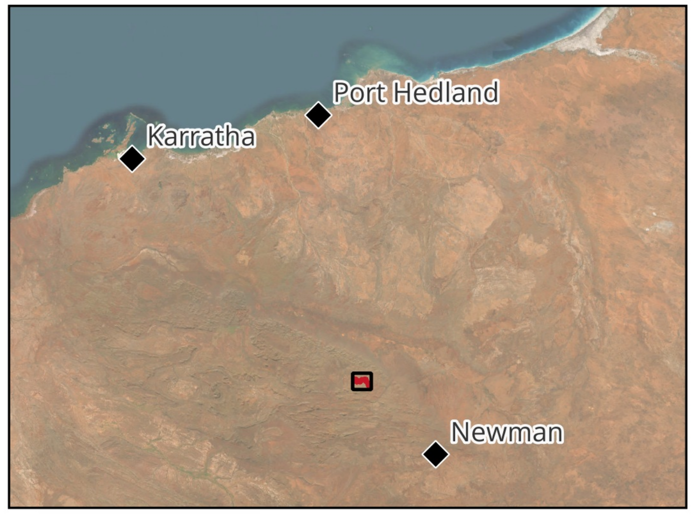
- Pit Outlines
- SPS Bunds
- Yandi Tenemant

Flow Velocity (m/s)

- < 2 (None)
- 2.0 - 2.6 (Facing)
- 2.6 - 2.9 (Light)
- 2.9 - 3.9 (1/4 Tonne)
- 3.9 - 4.5 (1/2 Tonne)
- 4.5 - 5.1 (1.0 Tonne)
- 5.1 - 5.7 (2.0 Tonne)
- 5.7 - 6.4 (4.0 Tonne)
- > 6.4 (Special)

0 1,000 2,000 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 11-3: 1:10,000 AEP FLOW VELOCITIES

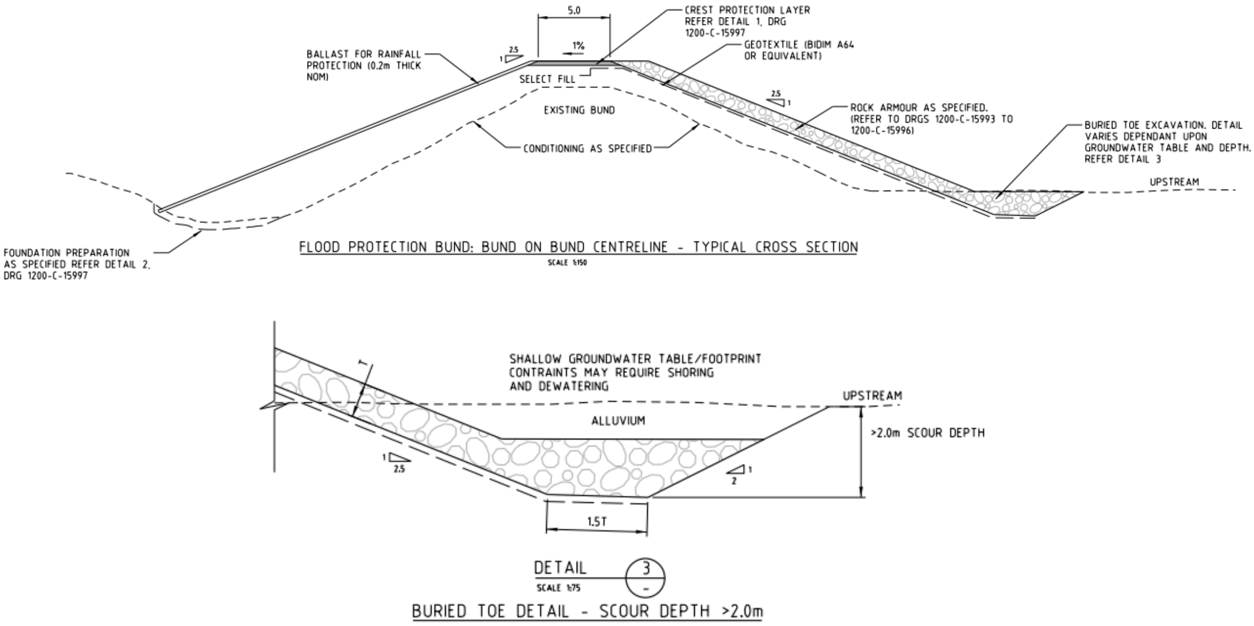


Figure 11-4: Typical bund cross-sections

11.2.2 Rock Protection

Rock is required to protect flood bunds against scour of the adjacent creek bed, erosion of banks and lateral creek migration. Without sufficient rock protection, scour and erosion may lead to bund failure and creek capture.

Basis of Design	
Armour rock protection to be included (where required) on upstream face of bund for respective design flood event. Rock sizes will be based on rock classes in Austroads (1994). Both fill and scour protection materials sourced from durable and geochemically stable sources.	Austroads, 1994

Austroads (1994) was adopted for selection and sixing of rock protection on bunds, as the method has been widely used for the design of hydraulic structures in the Pilbara region of Western Australia since 1994 (~30 years). Peak velocities were extracted from the 2D hydraulic models developed for the Project and used along with Austroads (1994) to locate, size, and select rock classes for SPS design.

Shear based methods were not adopted in this study. These methods are generally preferred conceptually over velocity-based methods as shear stress is closely related to erosion. However, there are no practical guidelines for implementing these in Western Australia, including in Austroads (2019) or Australian Rainfall and Runoff 2019 (Ball et al., 2019). Previous experience on the Yandi project (Advisian, 2017a), comparing and assessing available shear-based methods with Austroads (1994), resulted in the adoption of Austroads (1994) across all bunds (Yandi Creek Constrained Ore Project DPS, Report No. PREP-1200-G-12413)

The adopted approach to rock sizing is the Austroads (1994) method, whereby flow velocities in the creek are converted to rock size and thickness as shown in Table 11-2.

Table 11-2 Rock class (Austroads, 1994)

Velocity (m/s)	Class of Rock Protection (tonne)	Section Thickness (m)
<2	None	-
2.0 – 2.6	Facing	0.50
2.6 – 2.9	Light	0.75
2.9 – 3.9	¼	1.00
3.9 – 4.5	½	1.25
4.5 – 5.1	1.0	1.60
5.1 – 5.7	2.0	2.00
5.7 – 6.4	4.0	2.50
>6.4	Special	-

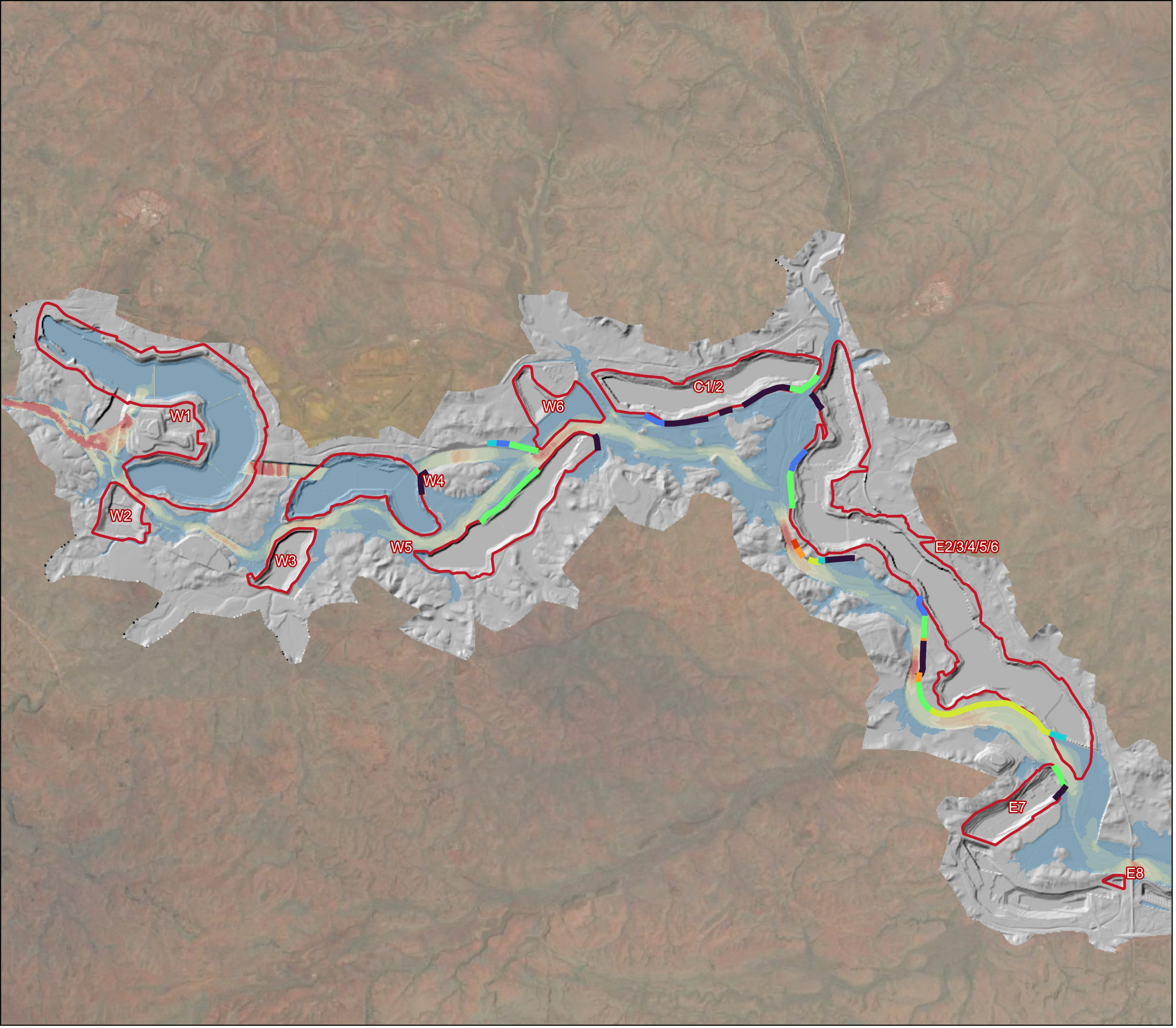
The rock protection is therefore derived from the flow velocity mapping presented in Figure 11-3. The selection of appropriate rock requires interpretation to flow velocities to consider the following factors:

- The design velocity is generally selected as the maximum velocity that occurs across the floodplain rather than adjacent to the bund. The low-flow channel, where maximum velocities are generally recorded can migration over time, resulting in higher velocities at the bund. This is more likely to occur in braided or sections of the creek where the bed is highly mobile, or constrained areas where the floodplain is narrow. Where the floodplain extends hundreds of meters from the low flow channel it is unlikely to migrate to the bund without changing the hydraulics and lowering the flow velocity.

- The CALTRAN method, which the Austroads (1994) method is based, includes factors for parallel (2/3) or impinging flows (4/3). These factors conceptually make sense as bunds lying perpendicular to the creek flows would be subjected to greater forces than a bund parallel to the same flows. A review of the CALTRAN method (USGS, 1986) concluded there was no data or reference to justify the values for the parallel and impinging factors. Noting this, factors were not applied to the flow velocities, however where results were close to two rock classes, the lower was selected for parallel flows and higher for impinging flows.

- The constructability of the bunds is also a factor in selecting rock sizes. Flow velocities can vary significantly along a bund, resulting in a different rock class every 20 m to 50 m which adds to the complexity of construction. Therefore, rock classes were determined to minimise the number of difference classes on each bund whilst ensuring there is adequate protection.

The rock protection requirements are presented in Figure 11-5 and Appendix C with associated types and volumes, including for scour protection, provided in Section 11.2.3. Further refinement of the rock protection is possible in future work with updates to hydraulic modelling and bund designs, along with consideration of other factors such as the duration of peak flow.



Yandi Closure Landform

FIGURE 11-5: ROCK PROTECTION REQUIREMENTS

Legend

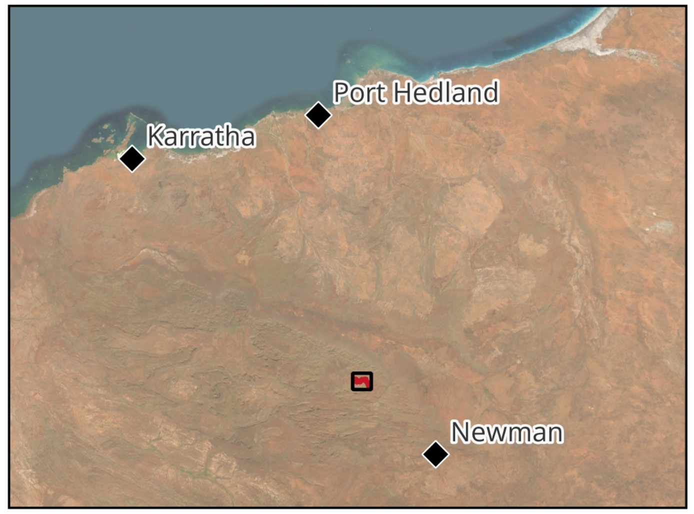
Pit Outlines

Flow Velocity (m/s)
- None
- Facing
- 1/4 Tonne
- 1/2 Tonne
- 1.0 Tonne
- 2.0 Tonne
- 4.0 Tonne

Rock Protection Estimates
- None
- Facing
- Light
- 1/4 Tonne
- 1 Tonne
- 2 Tonne
- 4 Tonne

0 1,000 2,000 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 11-5: ROCK PROTECTION REQUIREMENTS

11.2.3 Scour protection

Rock protection is also required to account for scour of the mobile creek bed and potential undercutting of the bunds.

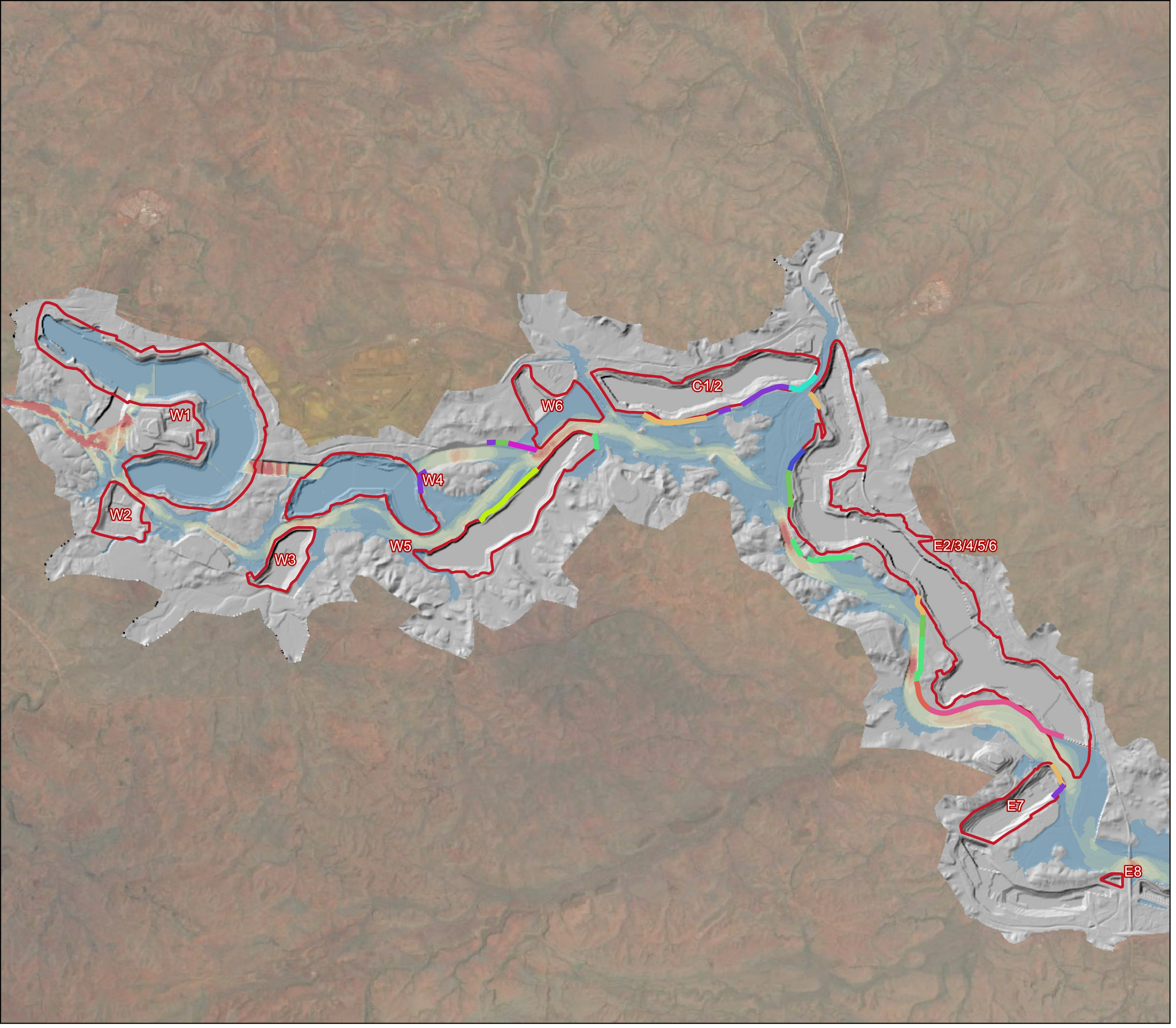
Basis of Design	
Toe depth of the rock protection to be based on estimated scour depths in the adjacent creek channel (primary low flow channel) or respective design flood events.	Austroads, 1994
Both fill and scour protection materials sourced from durable and geochemically stable sources.	

In the absence of any guidelines for scour estimation in the Pilbara region of Western Australia, scour depth estimates were developed using the following three equations, hydraulic model outputs (peak velocities and depths) and particle size distribution (PSD) data (D50 and D90) for Marillana Creek (Yandi Creek Constrained Ore Project, Report No. PREP-G-12414):

- Lacey (1930)
- Blench (1969)
- Faraday and Charlton (1983).

The Faraday and Charlton equation was selected for scour depth estimation as it was derived using material that is most similar to the alluvial material found in Marillana Creek. The scour depth estimates in the primary low flow channels adjacent to the bunds were used to estimate the scour elevation (mAHD) which was then projected to the bund location. The flood bund rock protection was then extended to the scour elevation in the SPS design. The depth of scour throughout Marillana Creek is presented in Figure 11-6, with further details provided in Appendix D.

During construction, this rock protection should be extended to the required depth or until competent rock is encountered. The resulting rock protection extends between 1.0 m and 4.5 m below ground level at each of the bund locations. Note that mapping along Bunds E4-1 and E4-2 is restricted to a maximum depth of 2 m below the low flow channel owing to the presence of rock identified through the Geotechnical Assessment Report (No. PREP-1200-C-12140).



Yandi Closure Landform

FIGURE 11-6: SCOUR DEPTHS

Legend

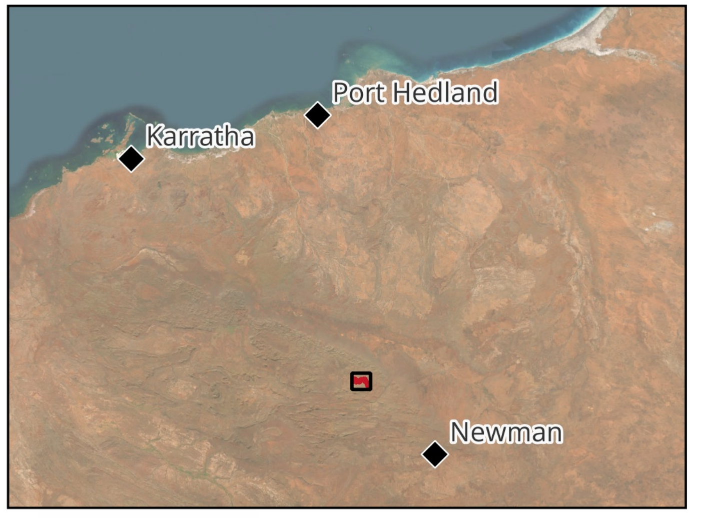
Yandi Mine

Scour Depths
- 1.0
- 2.0
- 2.5
- 3.0
- 3.7
- 3.8
- 3.9
- 4.0
- 4.5
- N/A

Flow Velocity (m/s)
- < 2 (None)
- 2.0 - 2.6 (Facing)
- 2.6 - 2.9 (Light)
- 2.9 - 3.9 (1/4 Tonne)
- 3.9 - 4.5 (1/2 Tonne)
- 4.5 - 5.1 (1.0 Tonne)
- 5.1 - 5.7 (2.0 Tonne)
- 5.7 - 6.4 (4.0 Tonne)
- > 6.4 (Special)

0 1,000 2,000 m

Date: 31/01/2024
Projection: Yandi 94



\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 11-6: SCOUR DEPTH

11.2.4 Summary

The design process for the flood bunds determined their location with regards to other flood management landforms and met the requirements to provide a safe, stable, and non-polluting landform that does not require ongoing care and maintenance by considering erosion and scour factors. Table 11-3 provide a summary of the SPS flood bunds with key design features.

Table 11-3 SPS Bund summary

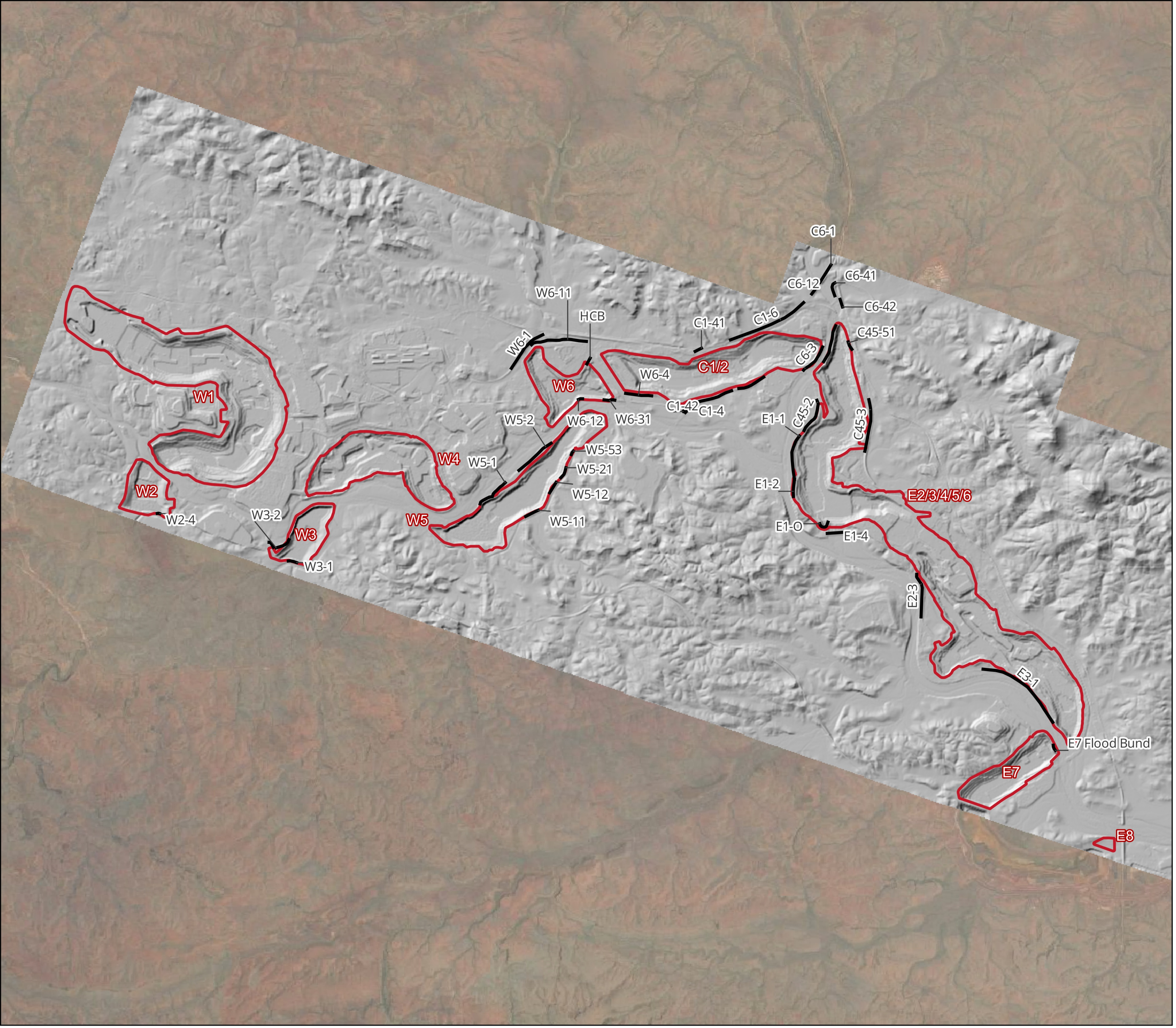
Name	Design event (AEP)	Length (m)	Typical Height (m)	Rock Protection Size	Typical Scour Depth (m)
W4-1	1:10,000	345	12.0	None	1.0
W5-1	1:10,000	1,365	6.0	¼ Tonne	3.8
W5-2	1:10,000	530	6.0	None	1.0
W6-1	1:10,000	610	7.0	Facing / Light / ¼ Tonne	3.0
C12	1:1,000/1:10,000	3,090	4.0	None / ¼ Tonne	1.5
C5-1	1:10,000	305	7.0	None	2.0
E1-1	1:10,000	965	5.0	Facing / ¼ Tonne	2.5
E1-2	1:10,000	120	7.0	2 Tonne / 4 Tonne	None*
E1-3	1:10,000	140	5.0	1 Tonne	None*
E1-4	1:10,000	495	7.0	Light / None	None*
E4-1	1:10,000	1,275	9.0	Light / None / Facing / ¼ Tonne / 2 Tonne	3.0
E4-2	1:10,000	2,510	12.0	1 Tonne / Light	4.5
E7	1:10,000	510	4.0	¼ Tonne / None	2.0

11.3 Other Existing Flood Bunds

Other existing flood bunds been constructed at Yandi to protect pits from flooding during Operations and to maintain flows reporting to Marillana Creek from larger tributaries and minor creeks. Figure 11-7: Existing flood bunds shows the location of existing flood bunds identified using design drawings/information provided by BHP, site observations and aerial photograph and LiDAR analysis. Table 11-4 Minor bund register provides details on identified flood bunds, including location and whether design drawings and/or geotechnical design information is available. Table 11-4 Minor bund register suggests there are many flood bunds which are likely to have been constructed some time ago and the design information is lacking. It is also possible that there are additional minor flood bunds present on site, that have not been identified.

Yandi Closure Landform

FIGURE 11-7 EXISTING FLOOD BUNDS

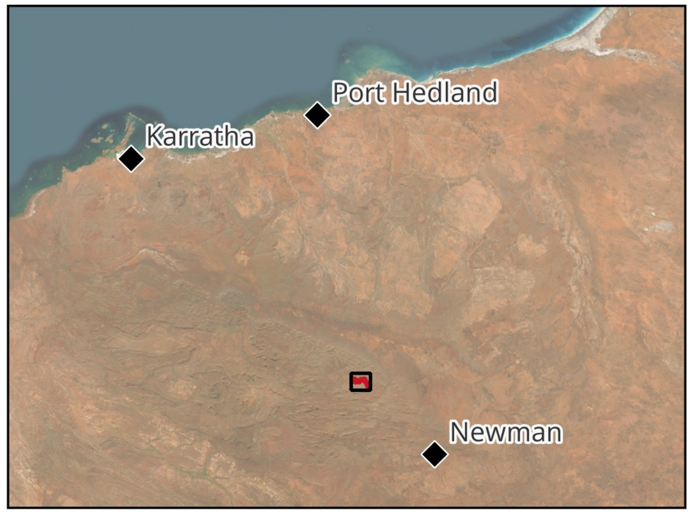


Legend

- Pit Outlines
- Existing Bunds

0 1,000 2,000 m

Date: 31/01/2024
Projection: Yandi 94



BHP Advisian

\\AUPDCWPNAS01\INFSTRUCLIB\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\BHP_YANDI_CLOSURE_SPS.QGZ FIGURE 11-7: EXISTING FLOOD BUNDS

As the majority of existing flood bunds are associated with minor creeks that have not been inspected on site and/or have limited to no available design information, design upgrades have not been developed for the SPS. It is recommended that detailed site investigation and assessment of existing flood bunds is conducted in the DPS, to identify all flood bunds and necessary design upgrades for Closure, as discussed in Section 14.3.

Table 11-4 Minor bund register

ID	Easting	Northing	Design Information (Y/N)	Geotechnical Design Information (Y/N)
W2				
W2-4	4630	83583	660-C-12874	No
W3				
W3:1	6789	82793	600-C-12916	Yes
W3:2	7200	82918	600-C-12918	Yes
W5				
W5:W1	9806	83596	660-C-12922	Yes
W5:W2	9279	83335	660-C-12923	Yes
W5:W2	9679	83004	660-C-12924	Yes
W5-1	10187	83970	No	No
W5-10	9965	83804	No	No
W5-11	10756	83570	No	No
W5-12	11080	83991	No	No
W5-2	10811	84549	No	No
W5-21	11259	84232	No	No
W5-53	11390	84576	No	No
W6-1	10597	86257	No	No
W6-11	11106	86401	No	No
W6-12	11500	8544	No	No
W6-31	11955	85417	No	No
W6-32	12044	85424	No	No
W6-4	12473	85501	No	No
Herbert's Creek				
HCB	11535	86176	660-C-12882	Yes
C12				
C1-4	13555	85412	No	No
C1-42	13252	85312	No	No
C1-63	14323	85660	No	No
C3-1	15601	86300	No	No

ID	Easting	Northing	Design Information (Y/N)	Geotechnical Design Information (Y/N)
C45-2	15336	85112	No	No
C45-51	15908	86311	No	No
C6-1	15557	87544	No	No
C6-3	15347	86066	No	No
E2356				
E1-O	15502	83362	No	No
E1-1	14985	84619	No	No
E1-2	14999	84044	No	No
E1-4	15756	83258	No	No
E3-1	18709	80816	660-C-12504	Yes
E4	15502	83362	No	No
E7	19246	79748	660-C-12831	Yes