12 CREEK DIVERSIONS

Creek diversions have 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. These operational diversions and associated flood bunds have been designed to convey the nominated design flows without uncontrolled overtopping of pit crests.

For Closure the diversion designs and associated hydraulic behaviour should be sufficient to maintain acceptable sediment transport, erosion and deposition rates and not pose a risk of pit capture due to overtopping, erosion, or lateral channel migration. Where possible, creek diversions should exhibit similar hydraulic and sediment transport behaviour to pre-mining conditions.

The primary focus of the SPS was to:

- review existing diversions and develop design upgrades where required for closure, and
- develop designs for new diversion channels.

Designs were developed to mitigate identified risk areas and establish a stable Closure landform design. Most of the diversions at Yandi are associated with minor creeks, so the design upgrades are minor when compared with other elements of the Closure design and pose a lower relative failure risk. Therefore, for the SPS, the diversions have been assessed and designs developed at an appropriate level of accuracy for the project, as described below.

Basis of Design	
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-year flood event (0.01% AEP). • **Intermediate Diversions:** Diversions to accommodate predicted flow rates for the 1:1,000-year flood event (0.1% AEP). • **Minor Diversions:** Diversions to accommodate predicted flow rates for the 1:100-year flood event (1% AEP). 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. Diversions to include rock protection (where required) to prevent against scour and erosion from respective design flood events. Rock sizes will be based on rock classes in Austroads (1994). Scour protection materials sourced from durable and geochemically stable sources.	Austroads, 1994 ACARP, 2014 DNRME, 2019

Trade-off studies of the diversions were not completed as part of the SPS, however the following recommendations from the IPS have been incorporated into the design development:

- Undertake a site visit to inspect the existing minor drainages, landbridges and representative analogues (Section 6.1)

- Identify upgrades of existing minor diversions needed to reinstate more natural geomorphic form in diversions (sinuosity, bed grades, alluvium depths, cross-section variability and features)
- Update minor diversion designs based on geomorphic design criteria
- Conduct confirmation hydraulic modelling of all minor diversions and confirm compliance with the SPS Basis of Design.

For existing diversions, preliminary hydraulic modelling was undertaken where required to determine higher risk areas of high flow velocity where rock protection would be required to prevent erosion and scour, that has the potential to lead to channel migration and pit capture. The width, length, sinuosity and bed grades of existing diversions was also compared with pre-mining creeks to determine the differences in geomorphological characteristics and the likely impact that may have on hydraulics and long-term stability at Closure. Diversion design upgrades were then developed to address risk areas and establish a stable landform at Closure.

Additional creek diversions required at Closure were also identified and designs developed to a suitable level of accuracy for the SPS.

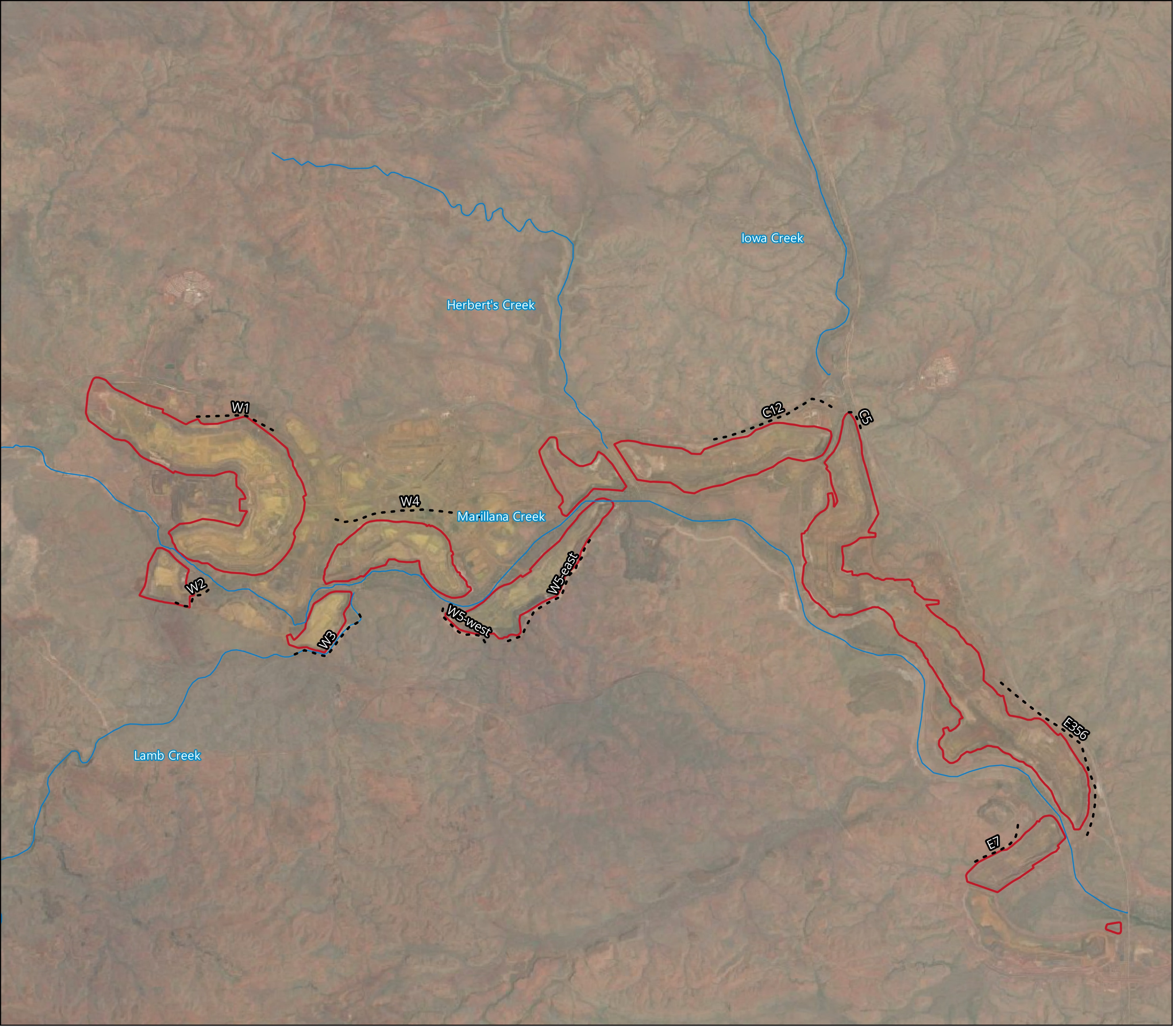
The assessed diversions are presented in Figure 12-1 and are discussed in the following sections.

12.1 E1 and E4 Diversions

The E1 and E4 diversions of Marillana Creek were designed as part of the Yandi CCO Project, for Operations and Closure. The diversions have been constructed and site inspections suggest they are functioning as intended, without the need for further upgrades at Closure.

Yandi Closure Landform

FIGURE 12-1 CREEK DIVERSION ASSESSMENT



Legend

- Yandi Tenements
- Pits
- Waterways
- Diversions

0 1,000 2,000 m

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Projection: YAN94

BHP Advisian

I:\PROJECTS\311012-01707 YANDI CLOSURE LANDFORM SPS\5_ENGINEERING\HY-HYDROLOGY\08_HYDRAULIC_STUDYAREA\03_TUFLOW_MINOR_TRIBS\202401_TUFLOW_MINOR_CATCHMENTS_JW_FIGURES.QGZ FIGURE 12-1 CREEK DIVERSION ASSESSMENT

12.2 W1/W4 Diversion

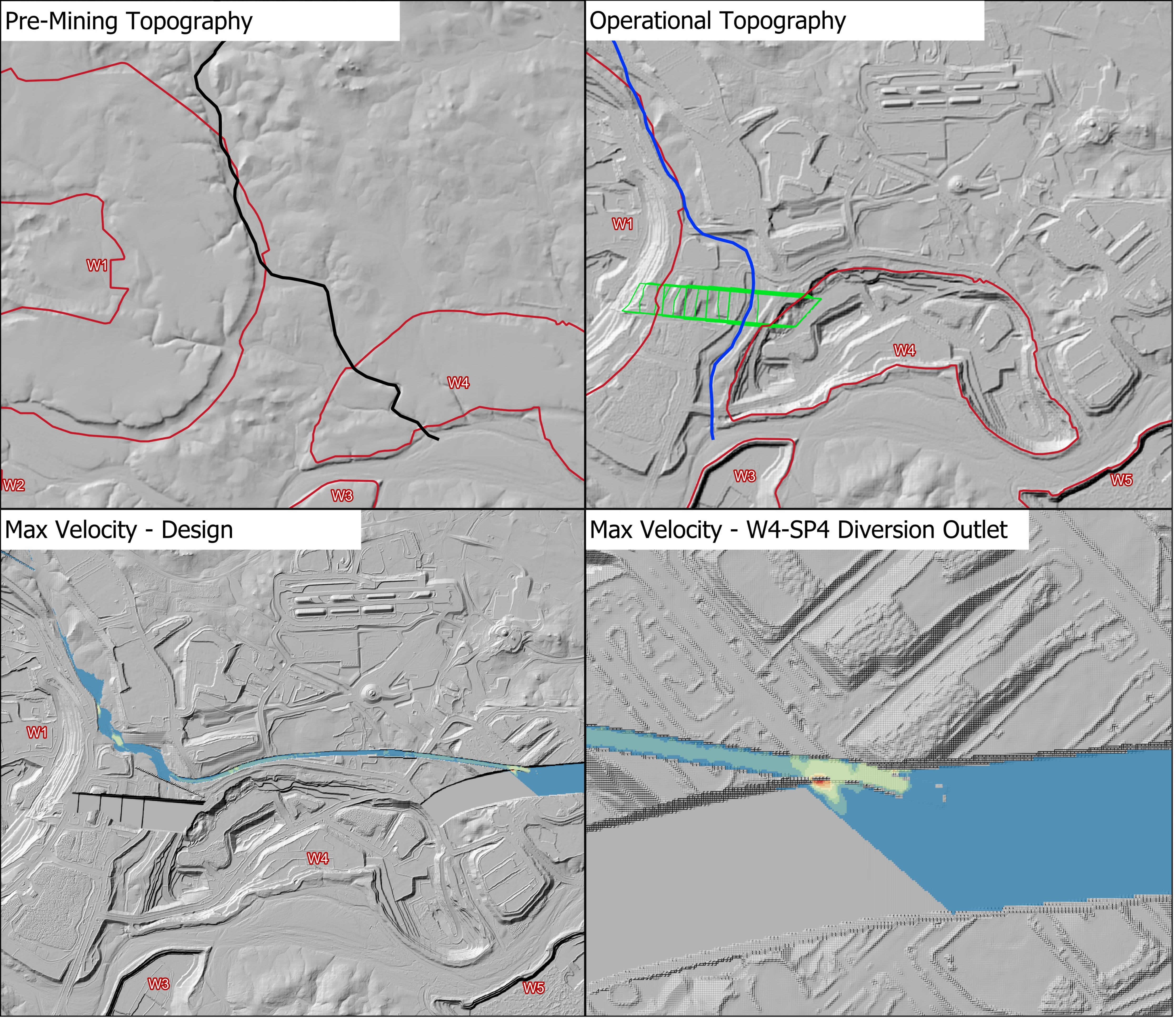
The W1/W4 diversion is a diversion that will need to be constructed at Closure to redirect flows past the northern boundary of W4 into the W4-SP4 flood channel (Figure 12-2). Prior to mining, two separate creeks flowed either side of the W4 footprint, but these are combined in the W1/W4 Closure diversion owing to the location of the flood channels.

The IPS design alignment followed the eastern edge of W4, discharging into Marillana at the upstream end of W5 however the adoption of the W4-SP4 flood channel design required a realignment of the diversion to the east. The diversion connects to W4-SP4 downstream of the spill point, ensuring all flows connect with Marillana Creek and there is no discharge into the W5 pit.

The location of the confluence requires optimisation at the DPS stage as currently it has a drop of several meters into the flood channel. This presents an erosion and head-cutting risk however relocating the confluence further downstream requires significant cut and must avoid the W6-1 flood bund. Confirmation of the geology through this area, and associated optimisation of the W4-SP4 design, will provide further clarity on the diversion confluence design.

Hydraulic modelling of the diversion channel was undertaken and identified that the majority of the flow velocities were low, and depending on the material the system, the system represents a low erosion risk.

However, the design is largely uniform, and optimisation is required in the DPS to achieve variability in cross-section morphology and produce a natural looking system. As outlined above, optimisation of the diversion in the DPS is dependent on the W4-SP4 design and once this design is established, the hydraulics and geomorphic parameters of the diversion should be revisited.



Yandi Closure Landform

FIGURE 12-2 W1/W4 DIVERSION

Legend

- Pre-mining Creek
- Diversion
- Pit Outlines
- SP3 Design

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)

0 300 600 m

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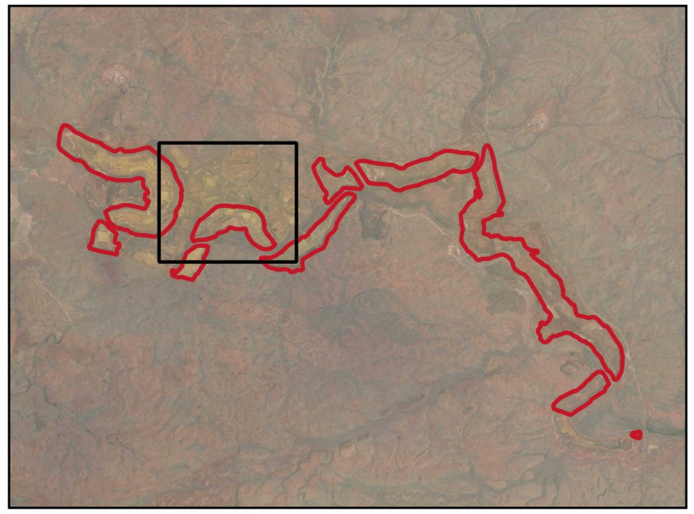

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BHP Advisian

12.3 W2 Diversion

The existing W2 diversion conveys flow from the catchment upstream of W2 south and east to Marillana Creek. The pre-mining creek alignment was south to north, flowing through the W2 pit footprint to a confluence upstream of the Marillana Creek haul road crossing (Figure 12-3). The characteristics for each channel are provided in Table 12-1.

Table 12-1 W2 Diversion Characteristics

Parameter	Pre-Mining Creek	W2 Diversion
Creek Length (m)	560	520
Slope	0.007	0.004
Sinuosity	1.090	1.049
Typical Channel Width (m)	33	25
Maximum 1% AEP Velocity (m/s)	-	4.7

The natural analogue for the W2 diversion channel is further upstream in the catchment where the channel features a width of approximately 20 m wide with trees on the side of alluvium base. This morphology and vegetation would be anticipated through the pre-mining creek reaches.

Immediately upstream of the diversion, the creek is largely constrained by the geology, with a deep, narrow, channel with no vegetation. The diversion channel retains this narrow width to the Marillana Creek confluence, and the bank material consists of weathered dolerite in places and CID in the section of deepest cut. The deepest section of cut and adjacent to the flood bund, has CID exposed at the surface of the bed. The current performance of the diversion is heavily influenced by the haul road crossing and associated culverts as noted in the site visit (Appendix A). Dense vegetation was observed immediately upstream of the culverts which was attributed to backwater and deposition of sediment.

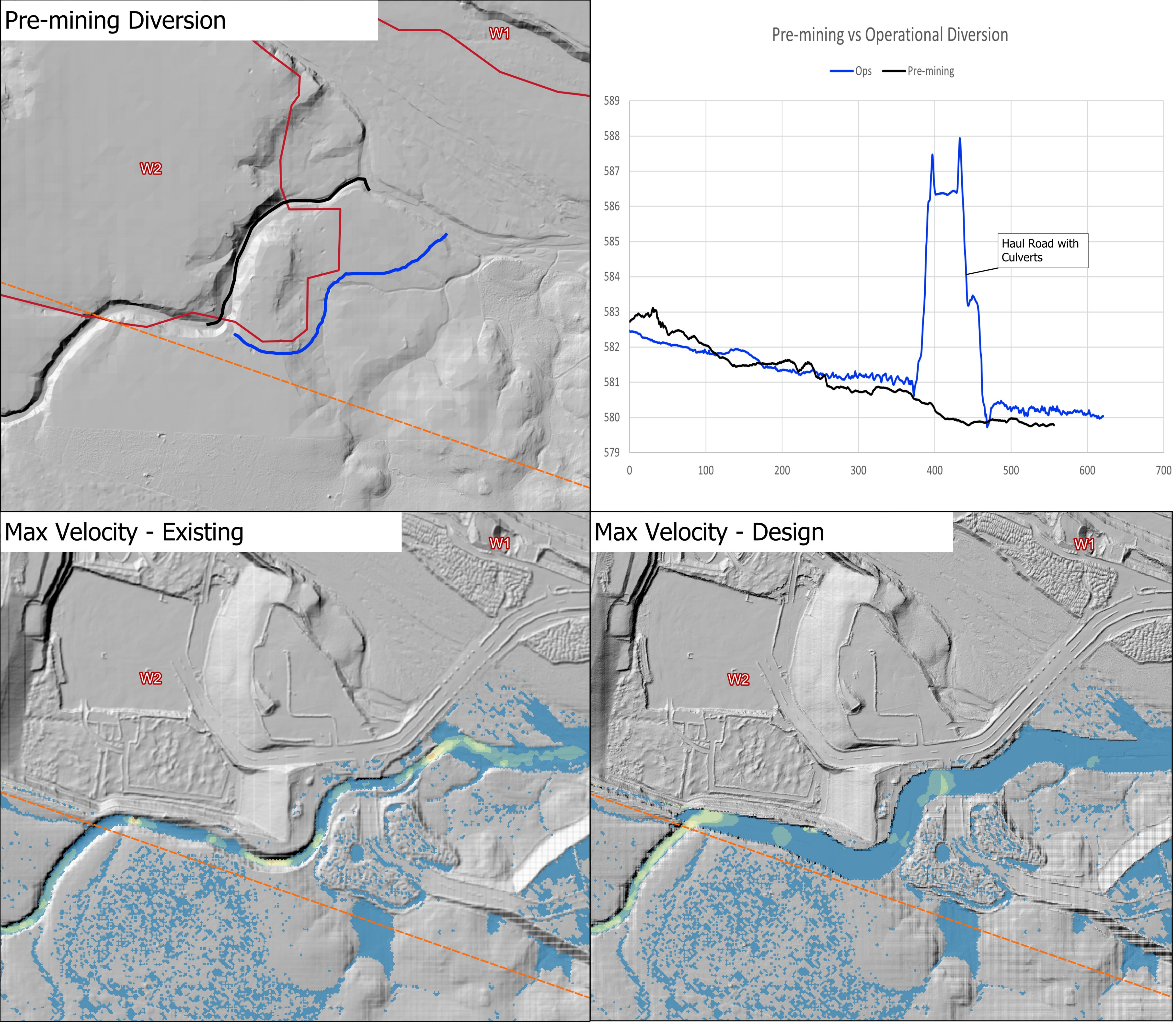
Despite the influence of the culverts, and the decrease in channel slope (reducing the potential for erosion) the site inspection noted that the side walls of the diversion were eroding in places. Hydraulic modelling was undertaken to confirm flow velocities within the diversion with the assumption that the haul road would be removed for closure. Velocities greater than 4 m/s were identified in several locations.

Options for modifying the diversion channel is limited by the tenement boundary and distance to Marillana Creek. The channel width was adjusted to 60 m to lower the flow velocities as shown in Figure 12-3. Velocities are typically less than 2 m/s which significantly reduces the potential for erosion. An area for optimisation in the DPS is the upstream end of the diversion where the confined natural channel enters. Flows here are directed at the bund protecting the pit and remain high.

Further modifications of the diversion channel should also consider creating an aquifer to encourage vegetation growth similar to the natural analogue upstream though this may be difficult to achieve where CID is exposed at the bed surface in the deepest section of cut.

Yandi Closure Landform

FIGURE 12-3: W2 DIVERSION



Legend

- Pre-mining Creek
- Diversion
- Tenemant Boundary
- 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)

0 100 200 m

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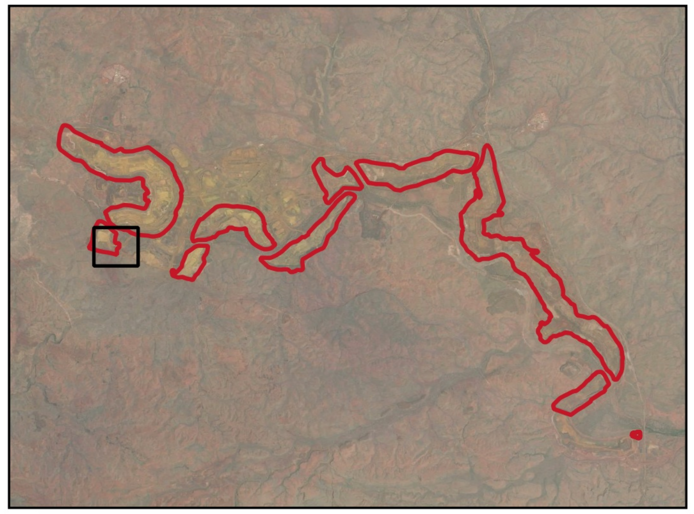

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12.4 W3 Diversion (Lamb's Creek)

The W3 diversion redirects Lamb's Creek around the western edge of the pit, including near right angled turns around the W3 pit. The operational diversion has been designed for the 1% AEP event but as it is one of the intermediate tributaries of Marillana Creek it requires an upgrade to convey the 0.1% AEP event at closure.

The W3 diversion is located close to the pre-mining Lamb's Creek alignment, and the confluence with Marillana Creek for both channels is similar. The similarity is demonstrated in the basic geomorphic features presented in Table 12-2.

Table 12-2 W3 Diversion Characteristics

Parameter	Pre-Mining Creek	W3 Diversion
Creek Length (m)	2,095	2,390
Slope	0.004	0.004
Sinuosity	1.06	1.04
Typical Channel Width (m)	90	84
Maximum 0.1% AEP Velocity (m/s)		6.7

Hydraulic modelling of the diversion is provided in Figure 12-4, with observed high velocities attributed to the 0.1% AEP design event attributed to the diversion being sized for the 1% AEP event. As also demonstrated in the modelling, the 0.1% event overtops the existing flood bund and flows into the pit. This is due to the limited capacity of the diversion.

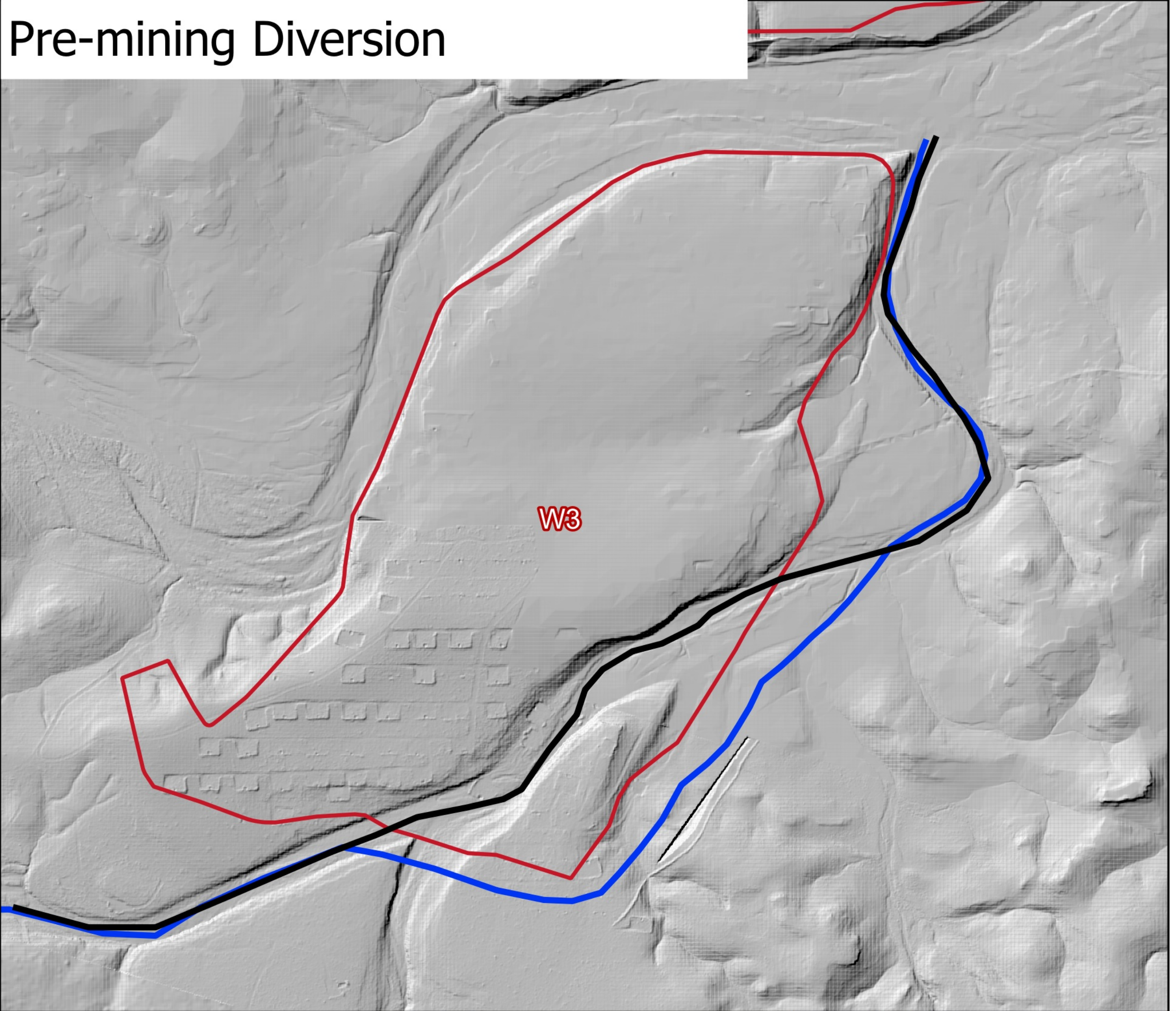
Widening of the diversion channel was considered to remove the constriction and reduce these high velocity hot spots, however the location of the diversion with respect to the pit edge and tenement boundary limits the opportunities to significantly modify the channel morphology.

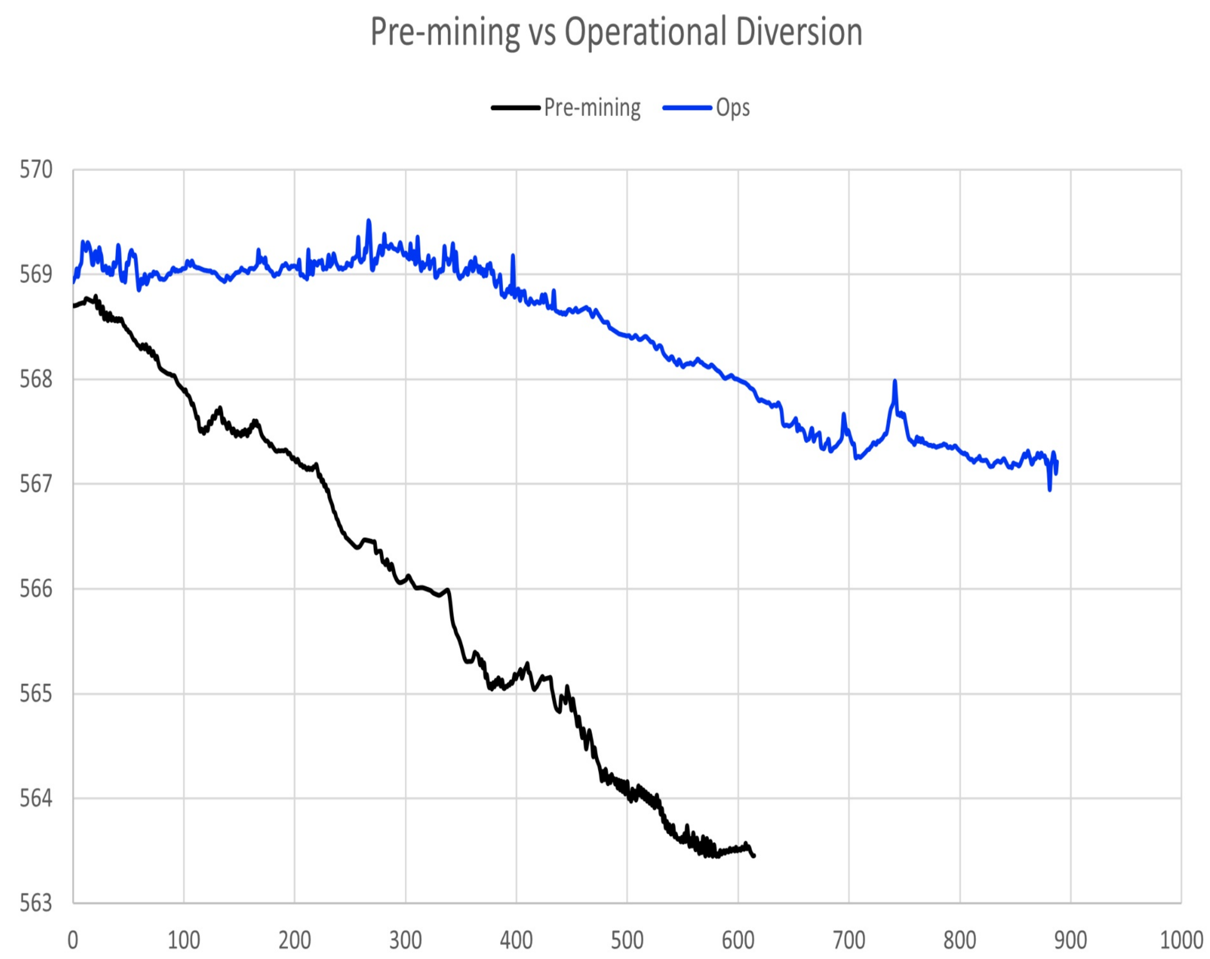
As shown in Figure 12-4, the channel was widened to 140 m on the south to north alignment, however the upstream end of the channel is constrained by the tenement boundary. Consequently, the velocity (approximately 4 m/s) cannot be reduced at the location of the existing bund. The operational design features ½ tonne rock protection (Drawing No. 660-C-12920_0) which is adequate for this velocity based on Section 11.2.2, though the impinging direction of the flow requires consideration in the DPS design. In the constricted sections of diversion cut that cannot be widened, the competency of the geology should be assessed along with the peak velocities to assess scour and erosion and risk of lateral channel migration, and whether rock protection is required. Following widening, the upstream bund does not overtop, however there is no freeboard for the design event and therefore it may require upgrades with consideration of the other diversion modifications at DPS.

Immediately downstream where the diversion channel turns north, velocities remain very high (>6 m/s) despite several design configurations assessed in the hydraulic model. Previously geotechnical investigations (Drawing No. 201012-00636-CI-DSK-0006_B) have noted that this area is colluvium over CID. Further investigations are required to assess the condition of the CID for exposure to high flow velocities and the need for rock protection.

Yandi Closure Landform

FIGURE 12-4 W3 DIVERSION



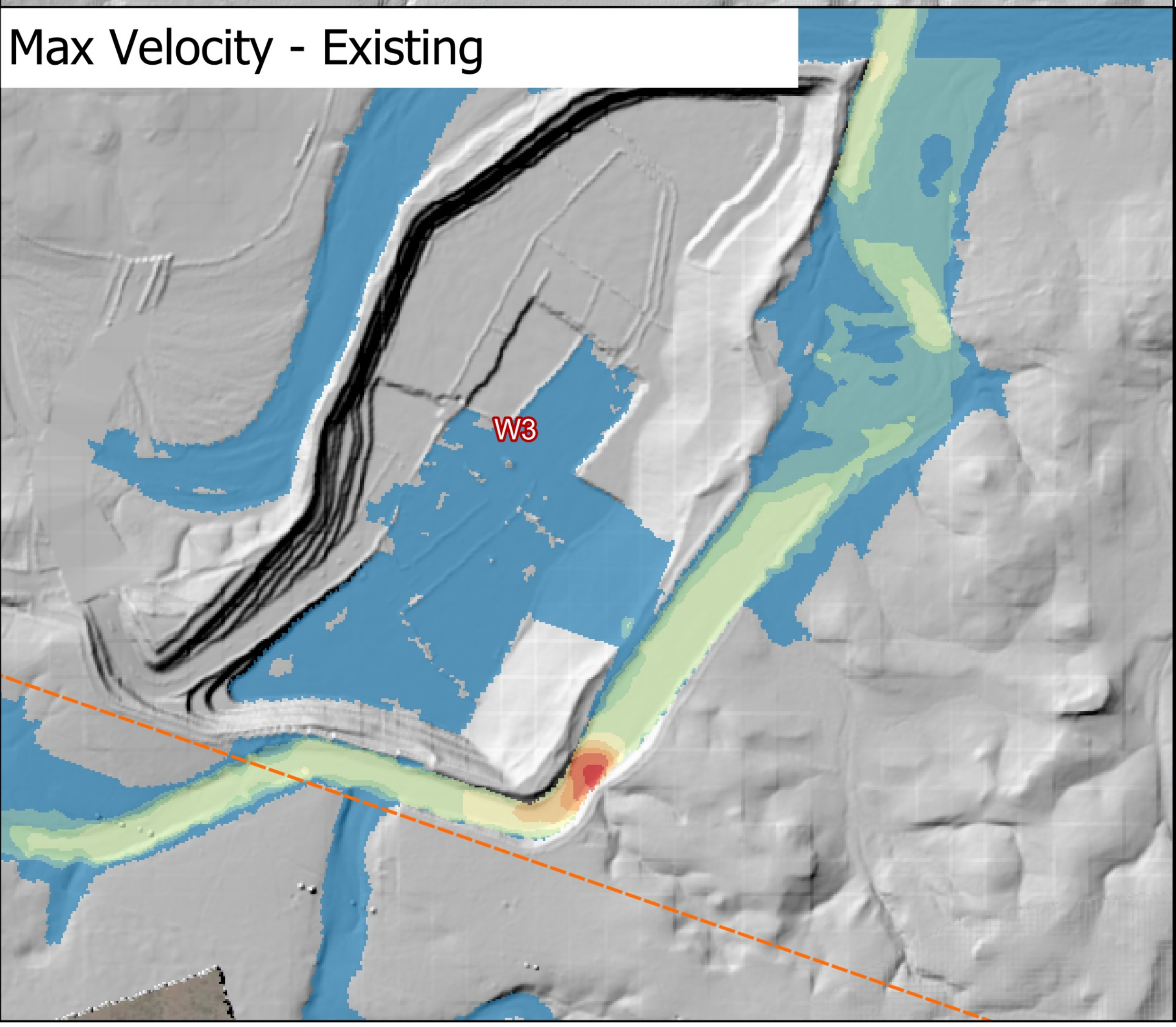


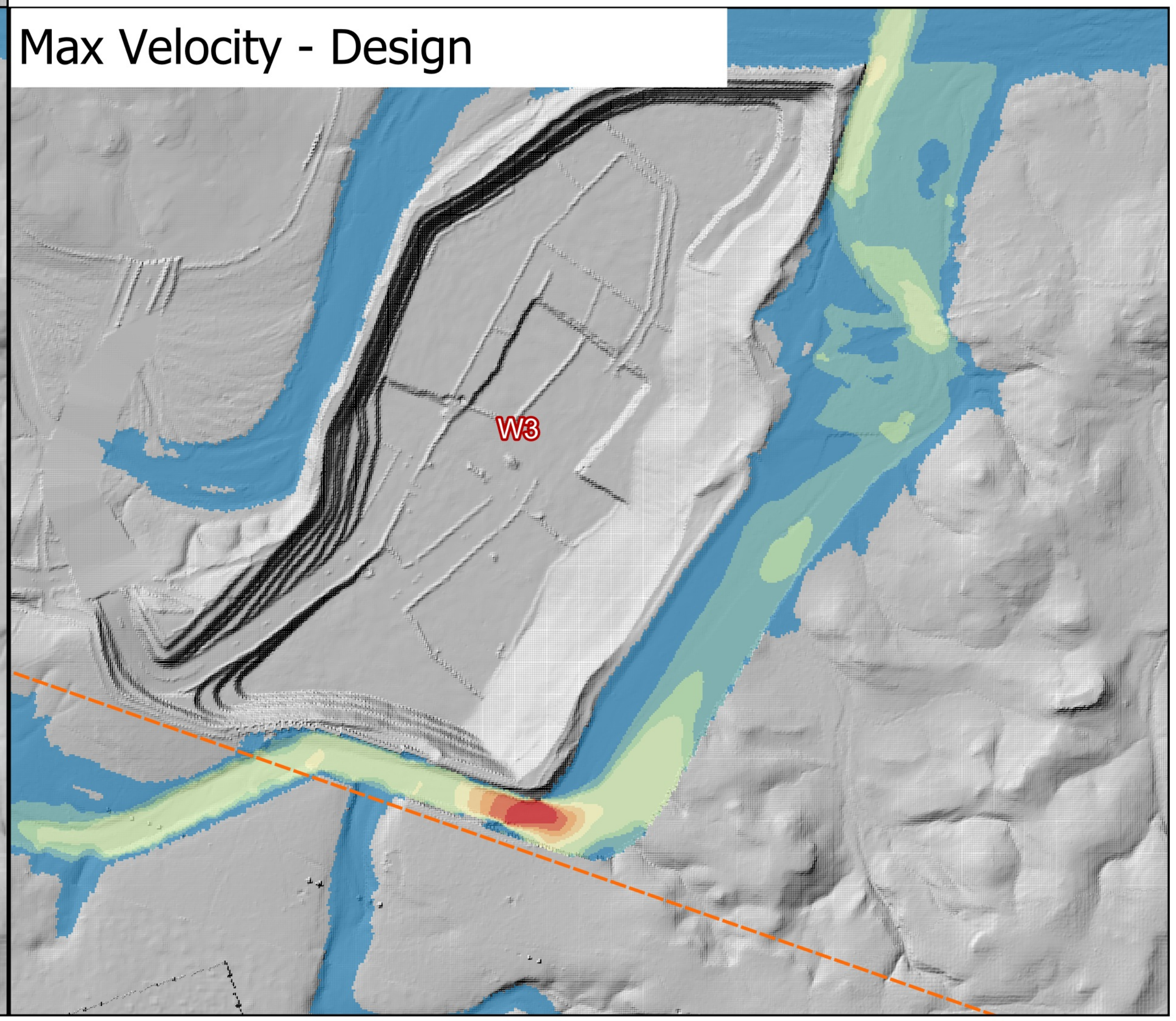
Legend

- Pre-mining Creek
- Diversion
- Tenemant Boundary
- 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)





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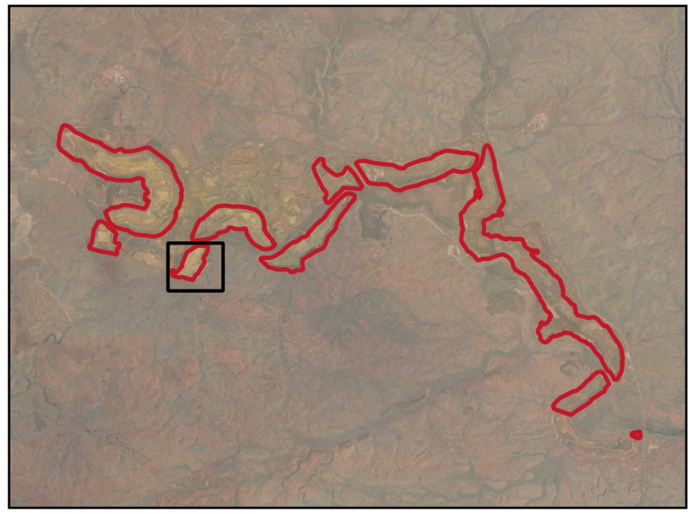

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12.5 W5 West Diversion

The W5 West diversion redirects a minor creek that flowed northwards to Marillana Creek prior to mining at the W5 pit (Figure 12-5). The diversion redirects the flows to the western side of W5, taking a longer route as outlined in Table 12-3.

Table 12-3 W5 West Diversion Characteristics

Parameter	Pre-Mining Creek	W5 Diversion
Creek Length (m)	670	1,062
Slope	0.010	0.003
Sinuosity	1.014	1.025
Typical Channel Width (m)	32	24
Maximum 1% AEP Velocity (m/s)	-	3.25

The pre-mining creek has a steeper grade and shorter length when compared with the operational diversion channel, however the W5 diversion channel is narrower.

Manning's calculations suggest that over a range of flow scenarios, the W5 diversion has lower peak velocities when compared with pre-mining conditions. This suggests that the W5 diversion channel has relatively lower potential for erosion and sediment transport when compared with pre-mining conditions. We would therefore expect to see some deposition of sediment within the W5 diversion over time.

Site inspection (Appendix A) noted that there is limited alluvium and trees present within the central section of the W5 diversion where it is in deeper cut and there is bedrock exposed at the base of the channel. It is recommended that the channel bed is ripped or excavated and replaced with alluvium to allow riparian vegetation to establish.

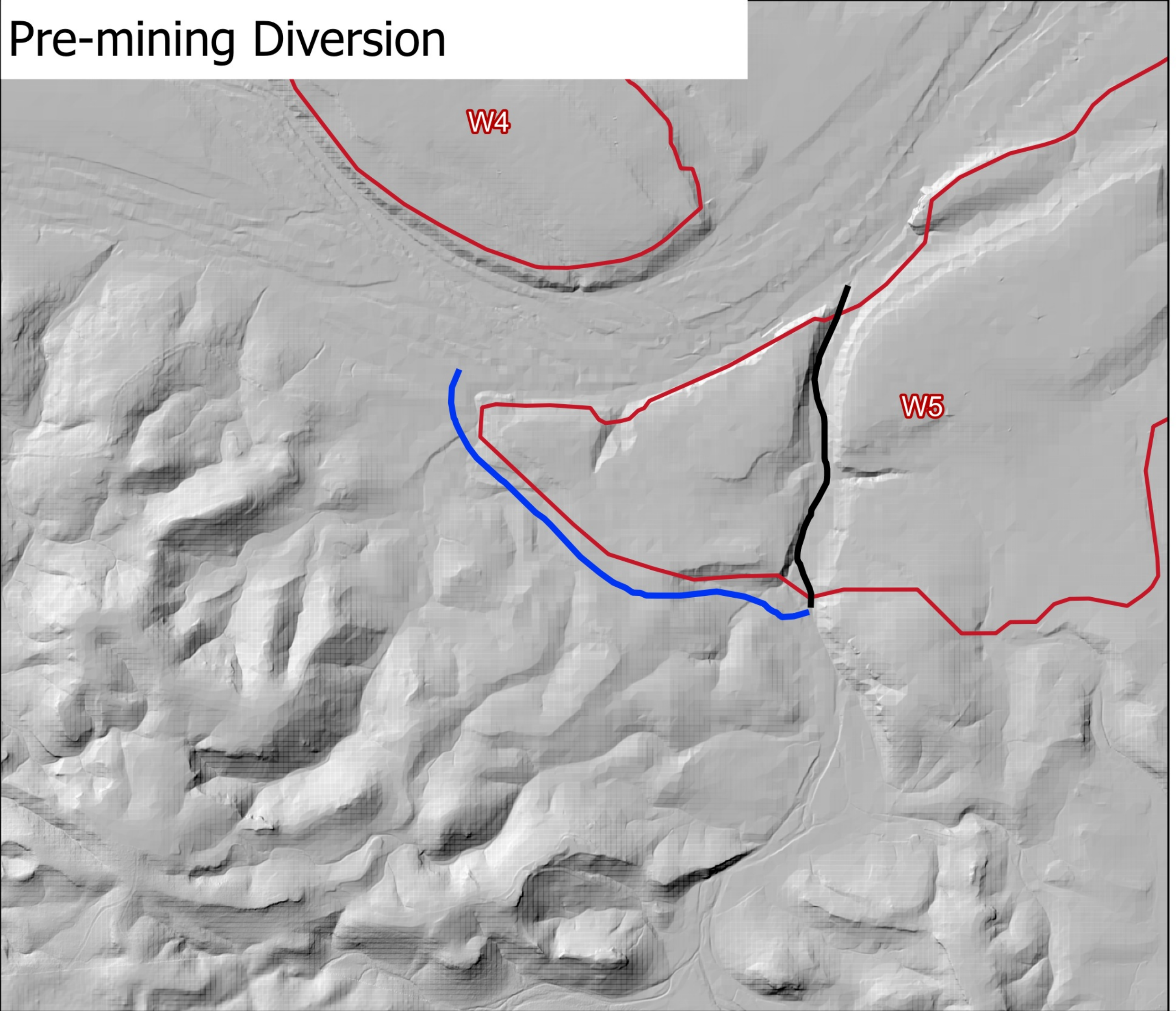
The site inspection also noted several areas of erosion within the diversion channel, which would be anticipated as the material adjacent to the pit is highly weather dolerite and BIF. More competent CID is located closer to the pit edge, though the extent is limited.

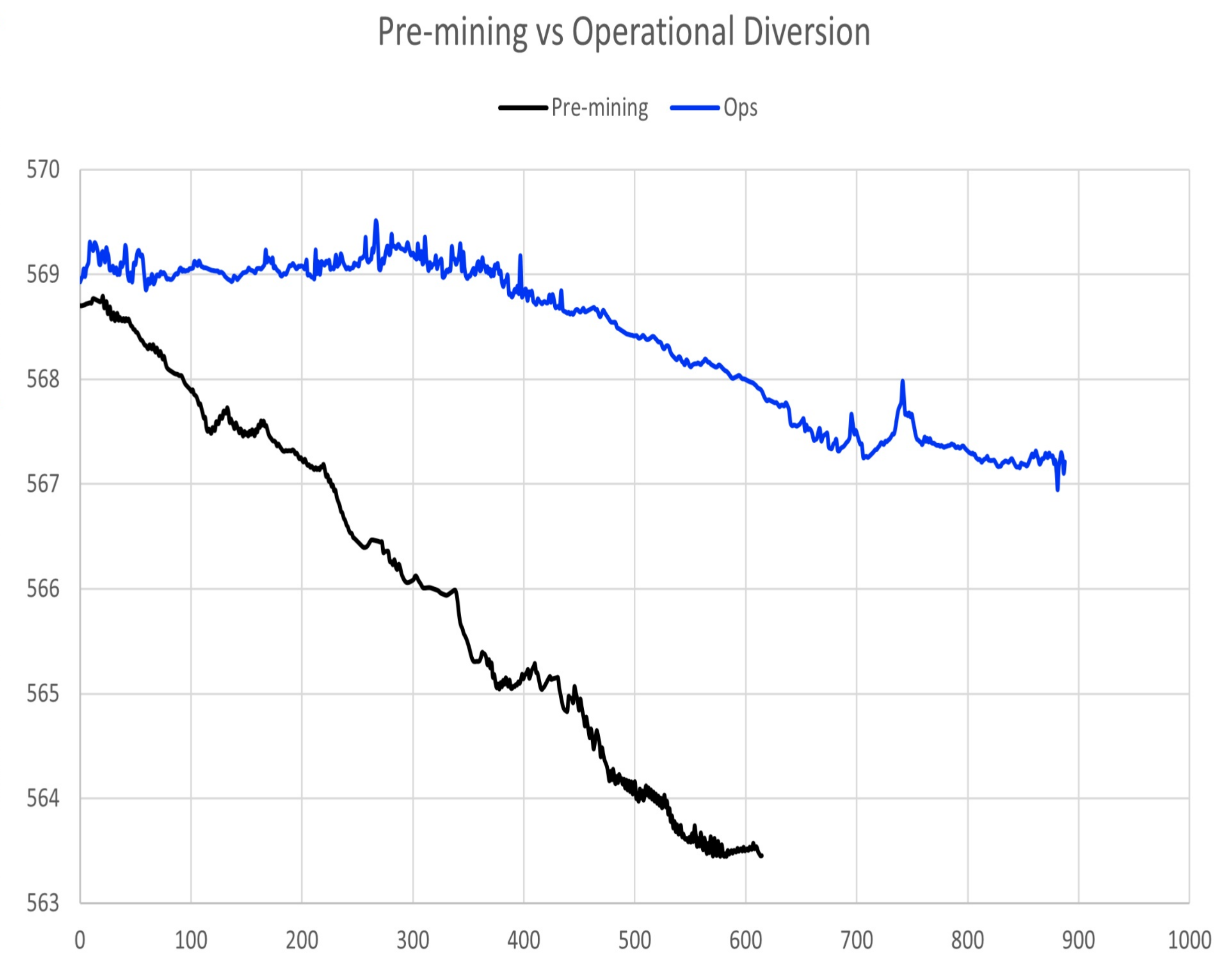
Site observations and hydraulic modelling of the current W5 diversion (Figure 12-5) shows areas with elevated hydraulics in areas where there is a potential risk of lateral channel migration and pit capture. As shown in Figure 12-5, when the W5 diversion channel is widened to a typical width of 40 m, the maximum velocity within the diversion is reduced to around 2.2 m/s, which would help reduce risk of lateral channel migration and need for rock protection.

Therefore, it is recommended that locations with elevated hydraulics and high potential for lateral channel migration are widened to 40 m to reduce risk. The need for channel widening is dependent on the cut material properties which will need to be confirmed in the DPS and the results used to inform the W5 diversion upgrades.

Yandi Closure Landform

FIGURE 12-5 W5 WEST DIVERSION



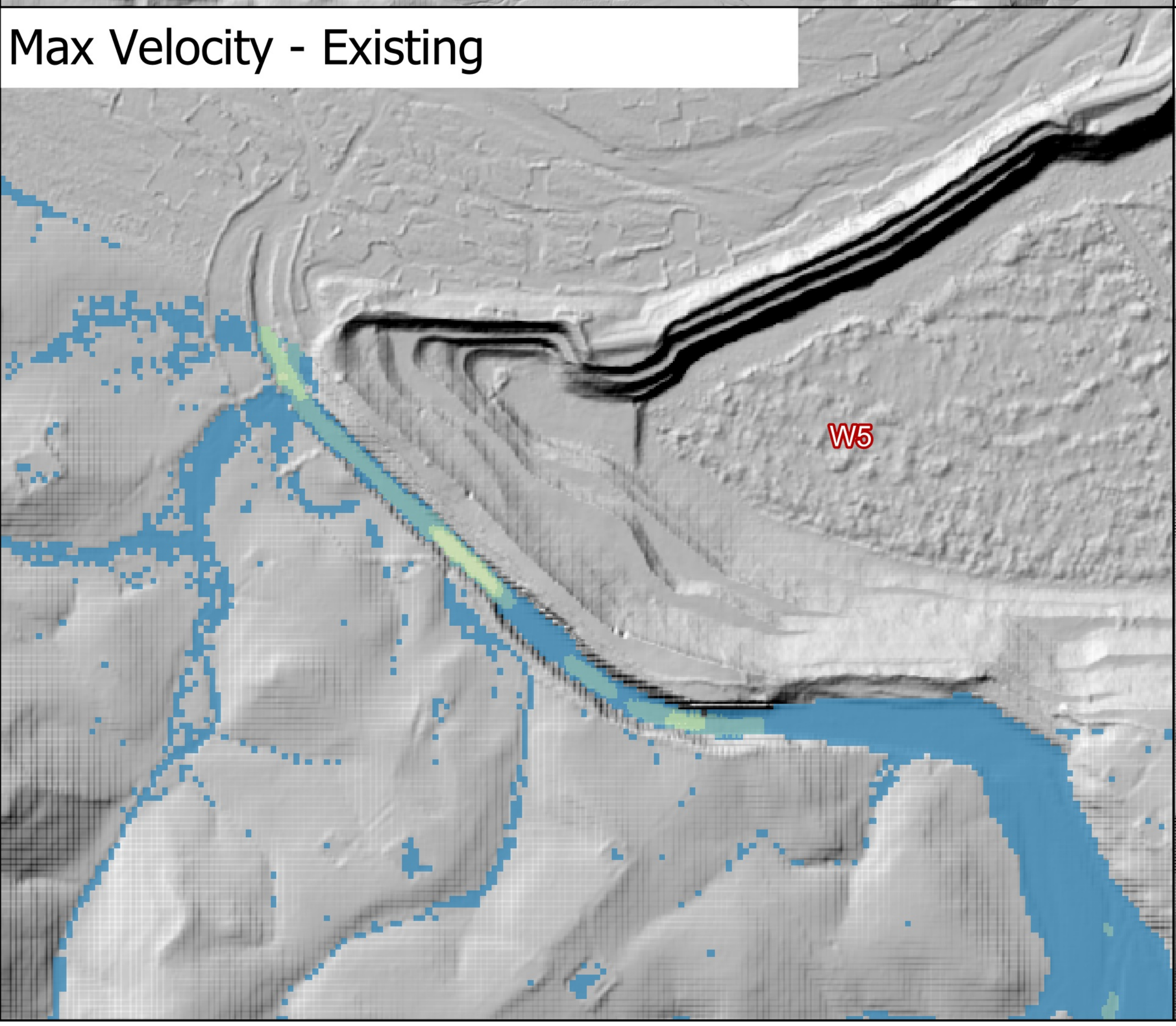


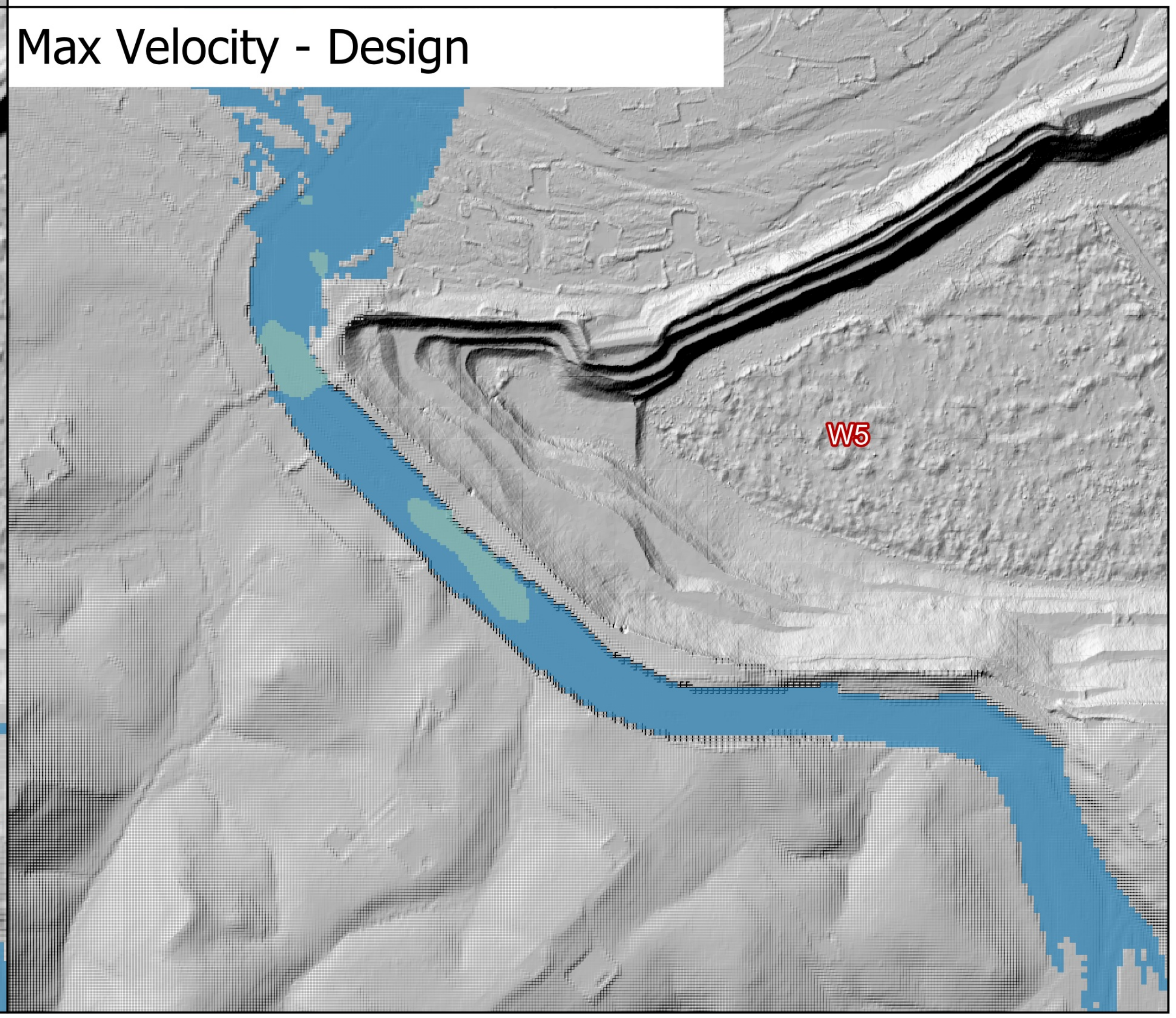
Legend

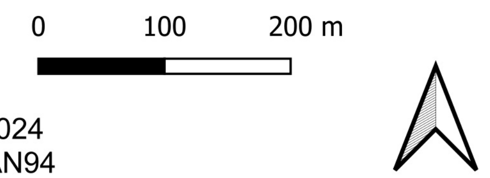
- Pre-mining Creek
- Diversion
- Pit Outlines

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)







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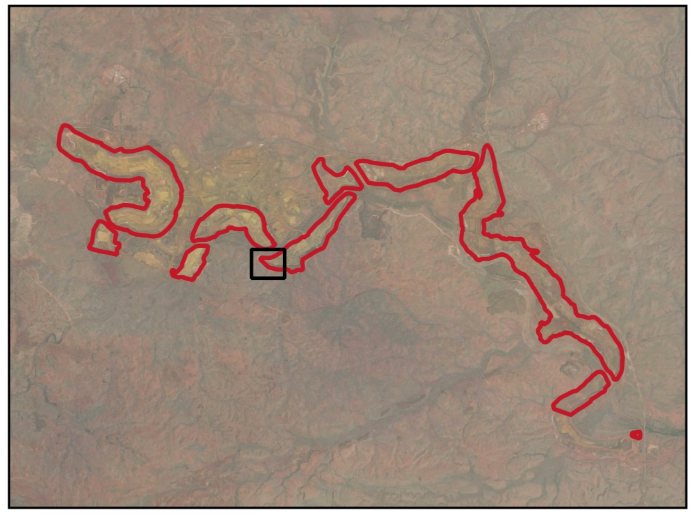

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12.6 W5 East Diversion

The W5 East diversion replicates a pre-mining creek that partially flowed over the pit footprint before discharging into Marillana Creek downstream of the pit. As shown in Figure 12-6, the diversion channel ties back into the natural creek approximately 1 km upstream of the Marillana Creek confluence. A comparison of the geomorphic features is provided in Table 12-4.

Table 12-4 W5 East Diversion Characteristics

Parameter	Pre-Mining Creek	Operational Diversion
Creek Length (m)	1,360	1,280
Slope	0.008	0.007
Sinuosity	1.07	1.01
Typical Channel Width (m)	33	24
Maximum 1% AEP Velocity (m/s)	-	5.8

The geomorphic parameters for the pre-mining creek and diversion, particularly the length, slope and sinuosity are similar however the former is largely a valley-confined system. For both system, deep alluvium is unlikely to form, and vegetation wouldn't be anticipated throughout the steeper sections of creek. This was confirmed in the site inspection where exposed bedrock was identified in several reaches and aerial imagery confirms there is little vegetation growth in the diversion.

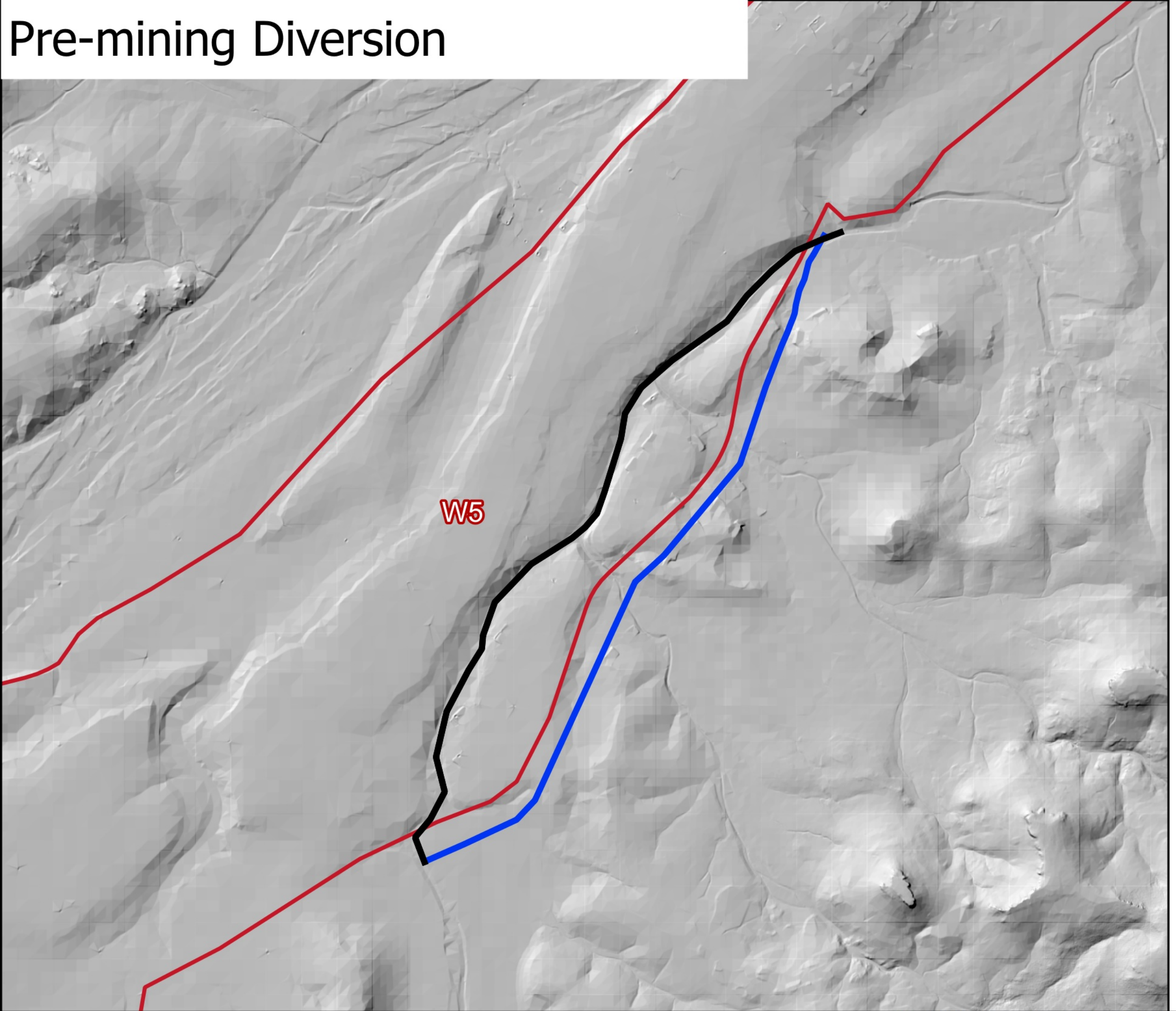
The erosion through the channel was a key takeaway of the site inspection (Appendix A). It was documented as significant and, as the diversion is within 30 m of the pit crest, there is an inherent risk for the channel to migrate towards the pit from this instability. As the diversion has a similar sinuosity and slope to the pre-mining creek, widening the channel was determined to be the most effective modification to reduce velocities and associated erosion risks.

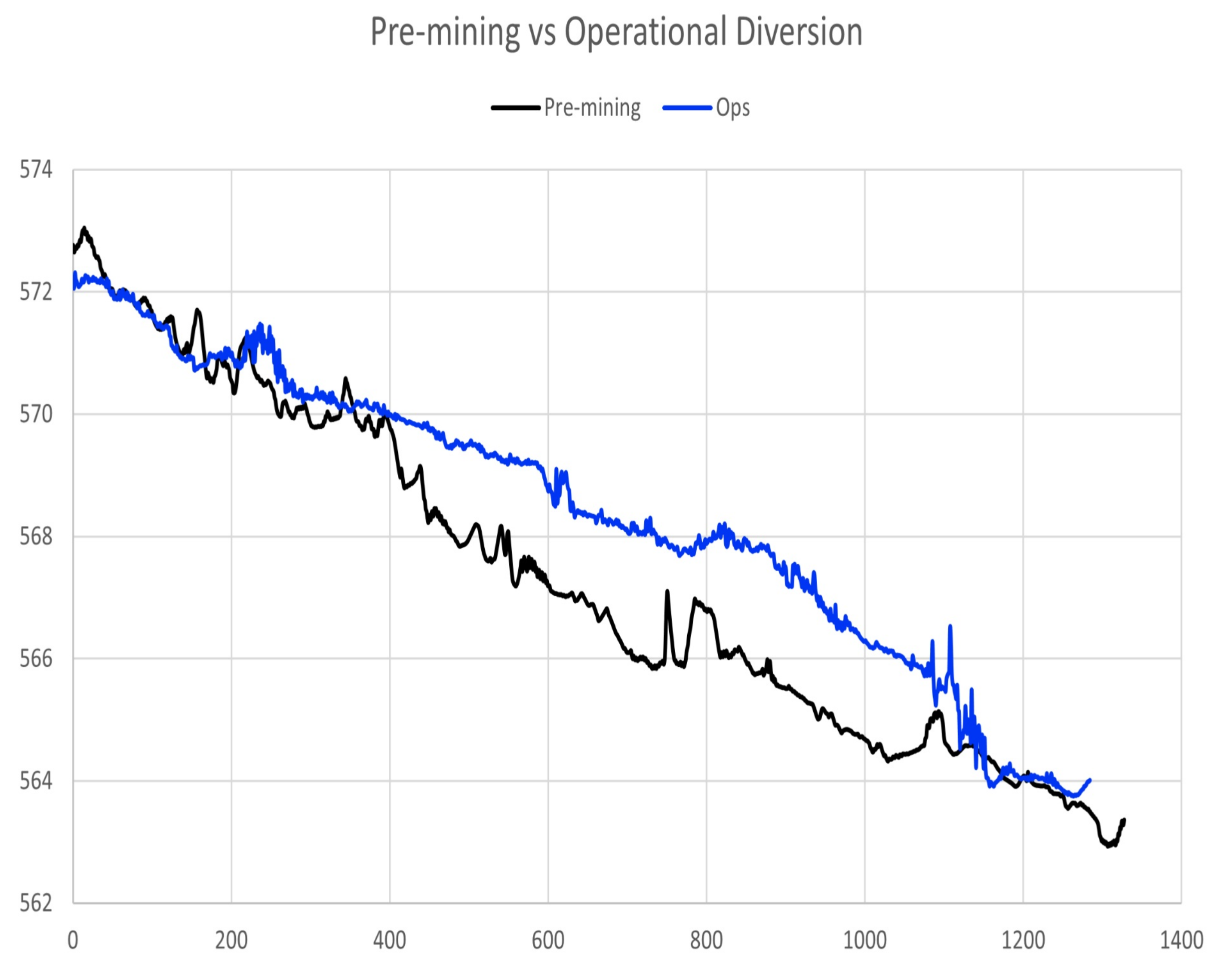
The diversions channel width was increased to 65 m in the hydraulic model to reduce the flow velocities. Results are provided in Figure 12-6, and velocities are generally below 2.5 m/s with two small reaches around 3.0 m/s. These higher velocity hot spots should be addressed in the optimisation of the channel as part of the DPS.

Another factor with this diversion channel is the uniformity of the SPS design. As part of optimisation works, variety in the channel cross-section should be explored encourage deposition of alluvial material and to increase habitats. This design optimisation should also be informed by confirmation of the cut material properties.

Yandi Closure Landform

FIGURE 12-6 W5 DIVERSION



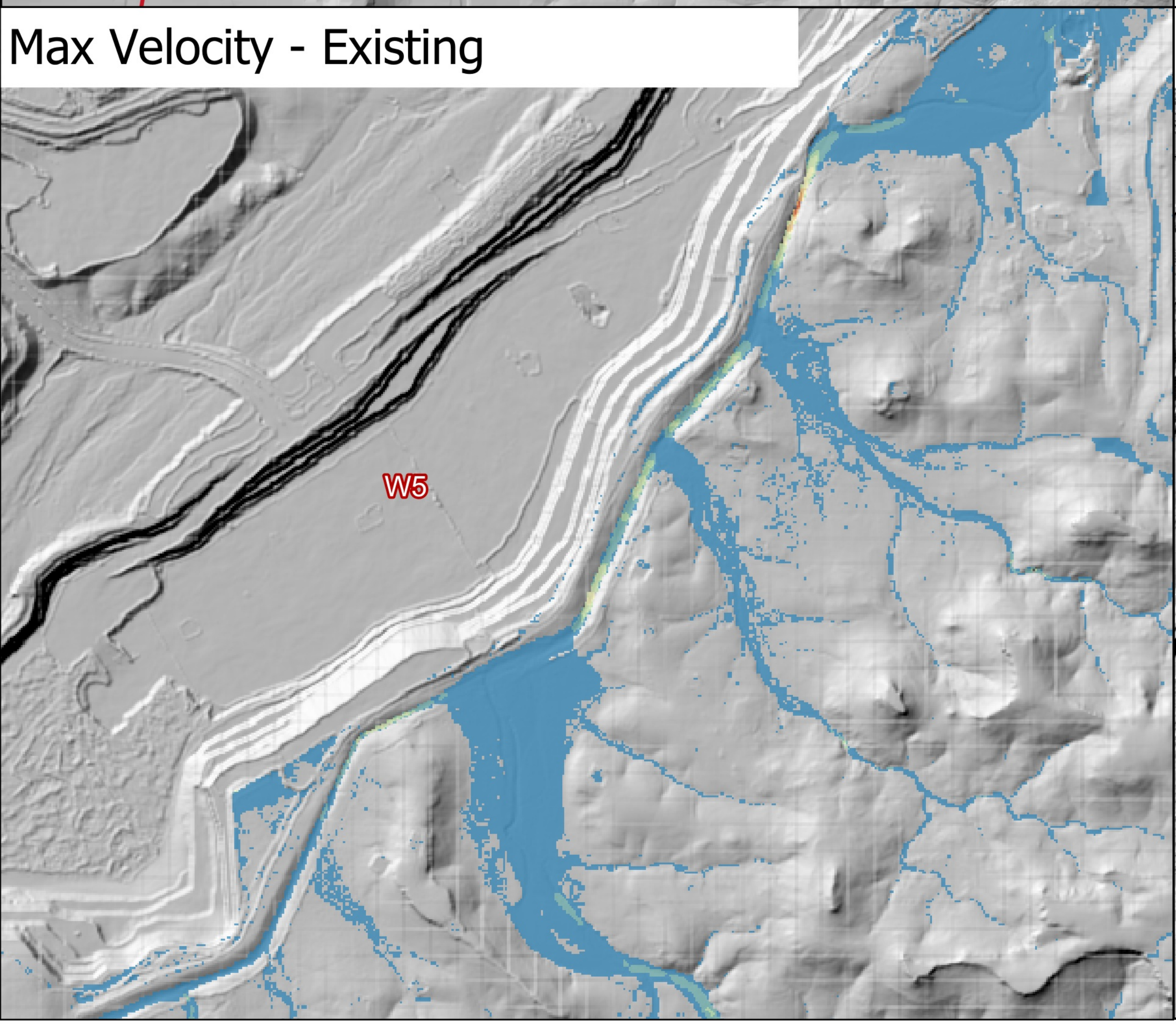


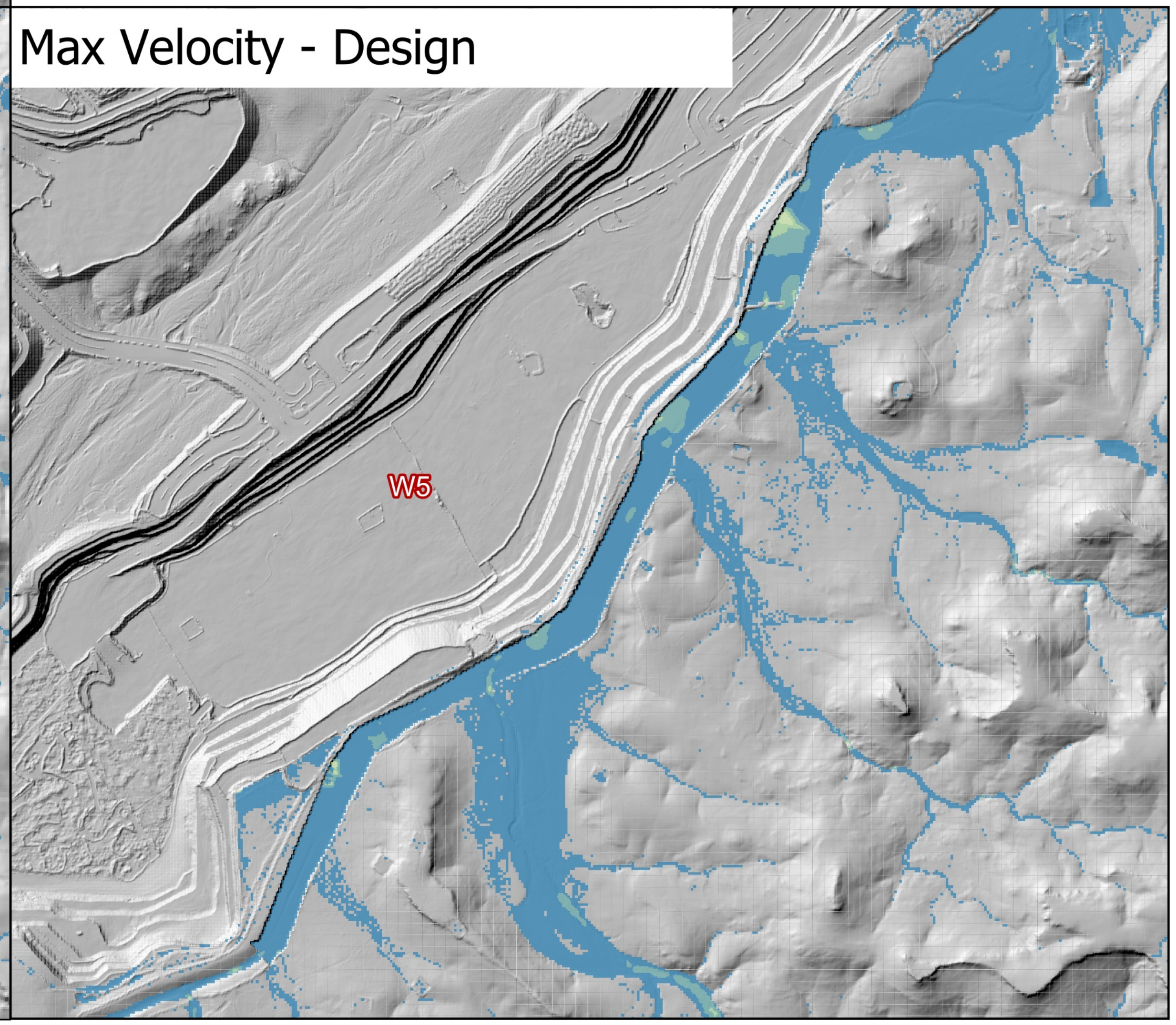
Legend

- Pre-mining Creek
- Diversion
- 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)





0 500 1,000 m

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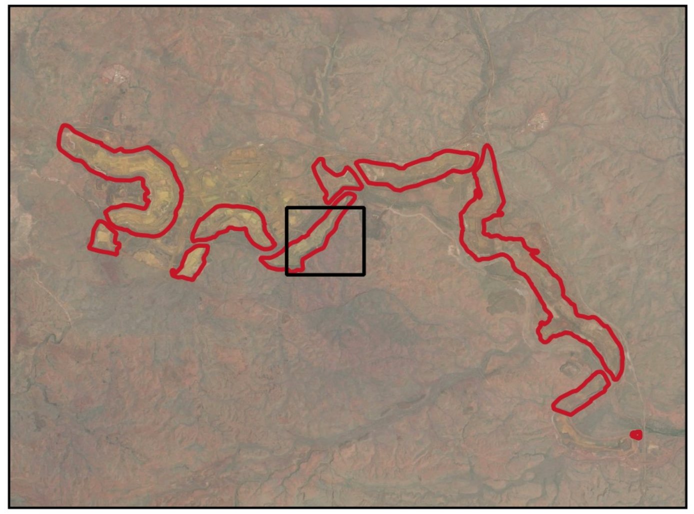

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12.7 C12 Diversion

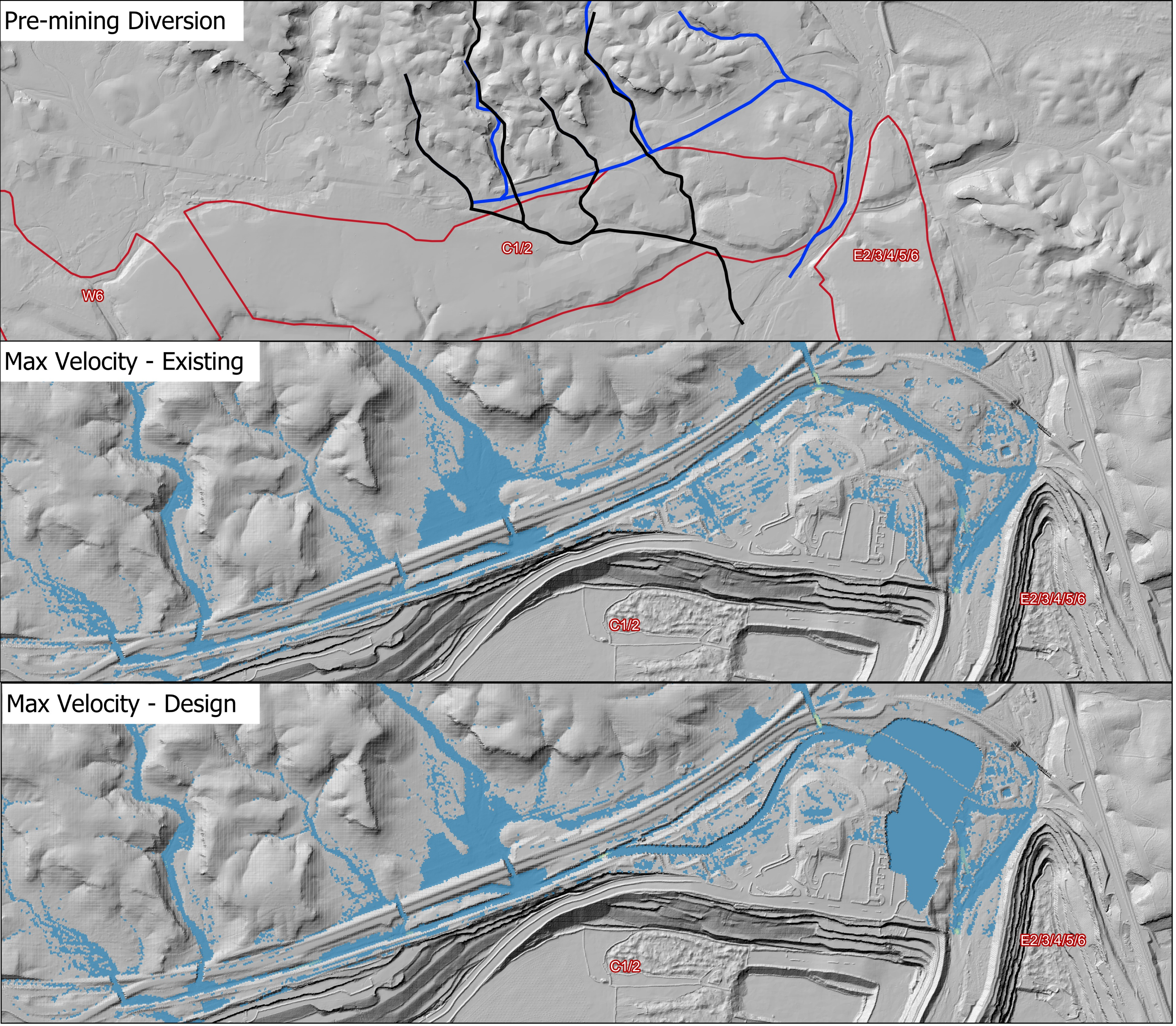
The C12 diversion is an operation diversion north of the C12 pit that conveys catchment flows east to Iowa Creek, upstream of the natural landbridge. Prior to mining these catchments flowed north to south, either to Herbert's Creek or through the C12 pit footprint to Iowa Creek downstream of the landbridge (Figure 12-7). The C12 diversion acts as a cut-off drain that is orientated perpendicular to the pre-mining flows. This configuration means there the pre-mining creeks are not an appropriate analogue for the diversion.

To assess the stability of the diversion channel, hydraulic modelling was undertaken to determine flow velocities and erosion risks. It was assumed that the state road that runs parallel and upstream to the drain would be retained at Closure. A combination of the road culverts attenuating catchment flows and the diversion design results in low velocity throughout and minimal erosion risk.

The key risk area is the channel is at the downstream end near the confluence with Iowa Creek. The diversion flows (with low velocities) over the proposed C6 pit which is assumed to be backfilled at closure. The backfill design, as part of the DPS, will need to be designed with a slope away from the pit, or a bund should be installed to prevent uncontrolled flows from the C12 diversion and Iowa Creek into C12.

This configuration assumes that the mine plan can be staged to accommodate the diversion during operations through to closure. An alternative configuration, which should be explored as part of forward works, is to realign the diversion around the northern side of C6, running between the pit and the railway.

Owing to the low flow velocities and lack of suitable analogue, the requirements for Closure design modifications are limited to aesthetic improvements to appear as a more natural channel. The diversion channel is relatively straight between where it is constrained by the pit, road, and rail, further limiting opportunities for improve the channel design. However downstream there is an area to install a wider meander, as shown in Figure 12-7. The meander increases the likelihood of variation in cross-sectional form and associated habitats. The meander design should be optimised during the DPS.



Yandi Closure Landform

FIGURE 12-7 C12 DIVERSION

Legend

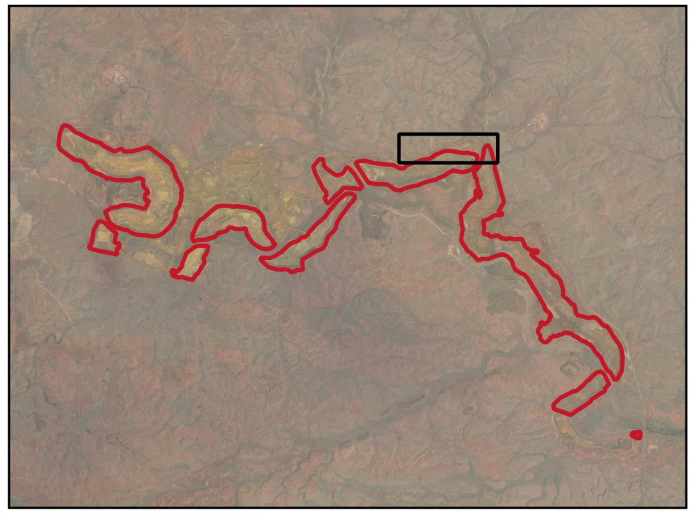
- Pre-mining Creek
- Diversion
- Pit Outlines

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)

0 100 200 m

Date: 31/01/2024
Projection: YAN94



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12.8 C5 Diversion (Slim's Creek)

The C5 diversion diverts flows around the northern end of Pit C5, whereas the pre-mining creek flowed east to west across the pit footprint (Figure 12-8). The geomorphic characteristics are provided in Table 12-5.

Table 12-5 C5 Diversion Characteristics

Parameter	Pre-Mining Creek	C5 Diversion
Creek Length (m)	529	498
Slope	0.006	0.003
Sinuosity	1.07	1.10
Typical Channel Width (m)	40	15
Maximum 1% AEP Velocity (m/s)	-	4.1

The operation diversion channel design is constrained by the railway that runs parallel to the diversion and pit. These features have resulted in a relatively narrow, straight channel that runs perpendicular to the pre-mining creek.

Previous site visits conducted as part of the Yandi CCO Diversion Project, identified locations where weathered dolerite exposed in the bed and banks has eroded during flood events, resulting in undercutting the significant slope failures (Figure 12-8). Steep banks and collapsed blocks, typical of undercutting by frequent flows, indicate erodible material and an instable system. A section of the diversion channel has migrated north towards the railway and ongoing monitoring and potentially maintenance implemented during operations to protect the infrastructure from damage.

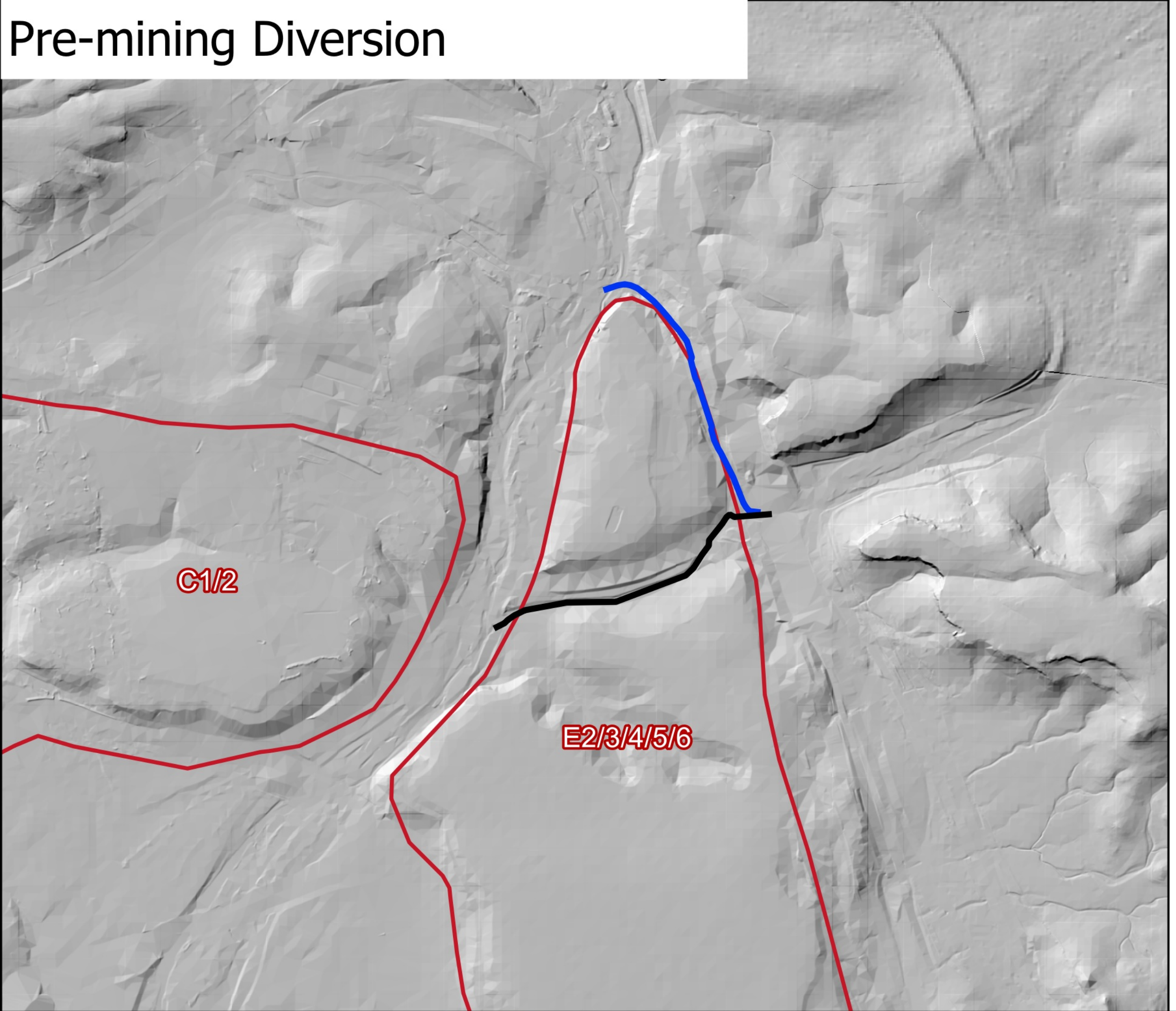
Hydraulic modelling was undertaken to determine flow velocities and erosion potential. Two sections of high velocity were identified, upstream and downstream of the actively eroding section that has widened as described above.

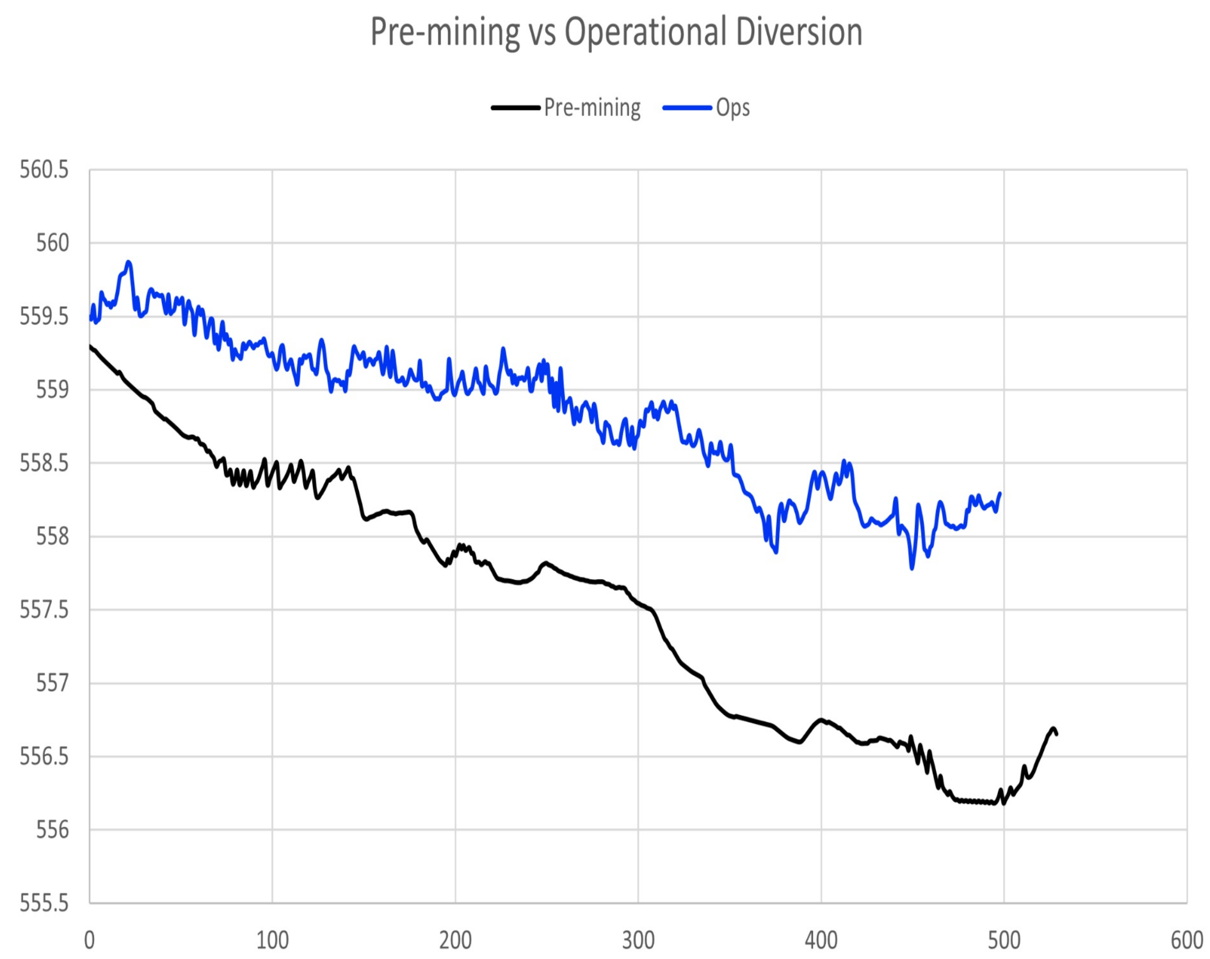
At Closure it is assumed that the railway will be removed, allowing for the channel to be widened to the north, beyond the current alignment. The diversion was widened to 35 m and resulting modelling results are presented in Figure 12-8. Flow velocities are generally below 2.5 m/s reducing the potential for erosion however it is noted that the presence of erodible material may require additional treatments to manage the erosion at Closure.

For DPS design the material through the diversion should be further classified to inform design operation. A site inspection should also be undertaken to confirm the presence of a shallow aquifer, alluvium, and riparian vegetation. These features, if present in the diversion or a local analogue, should be replicated in the Closure design.

Yandi Closure Landform

FIGURE 12-8 C5 DIVERSION



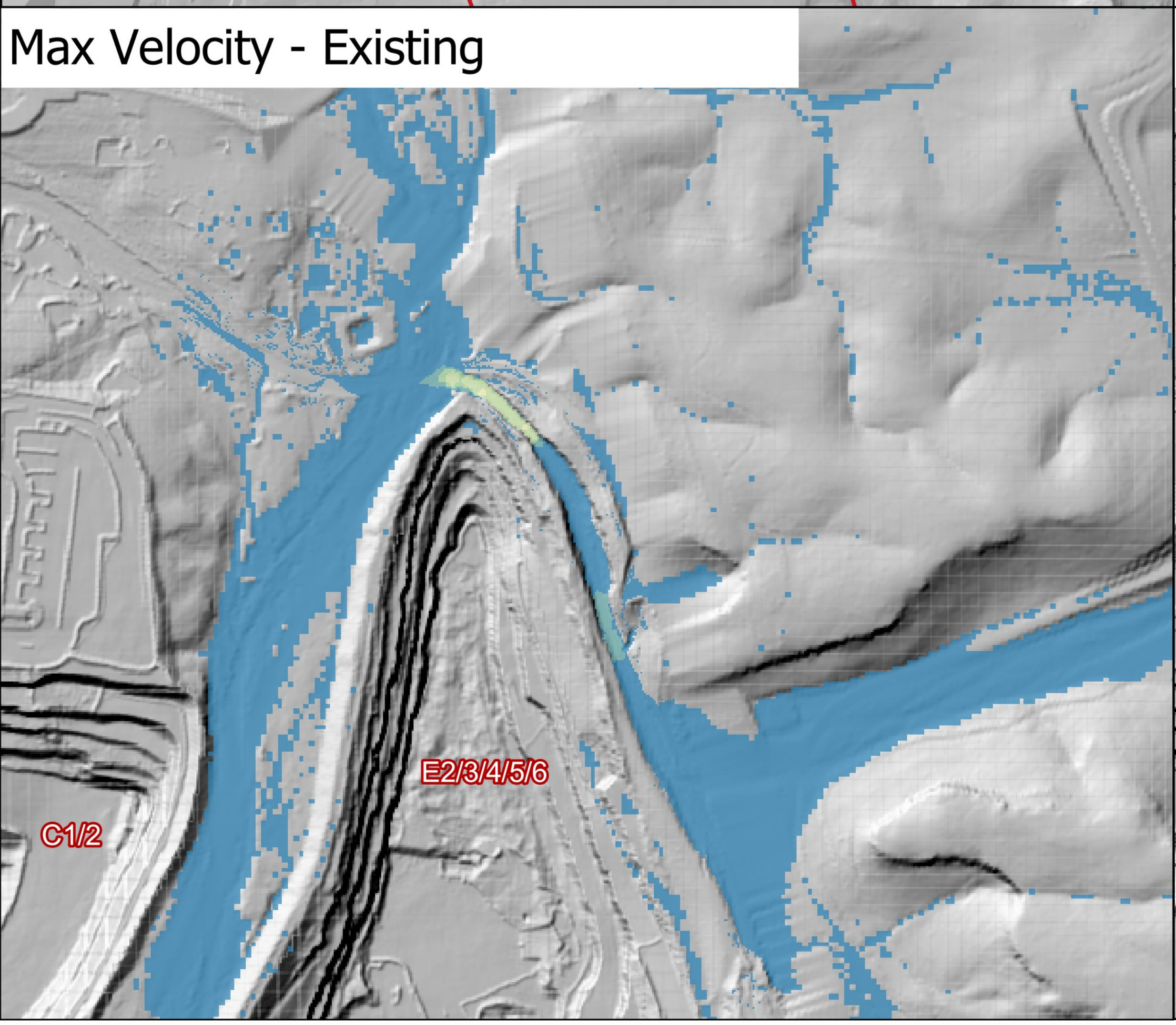


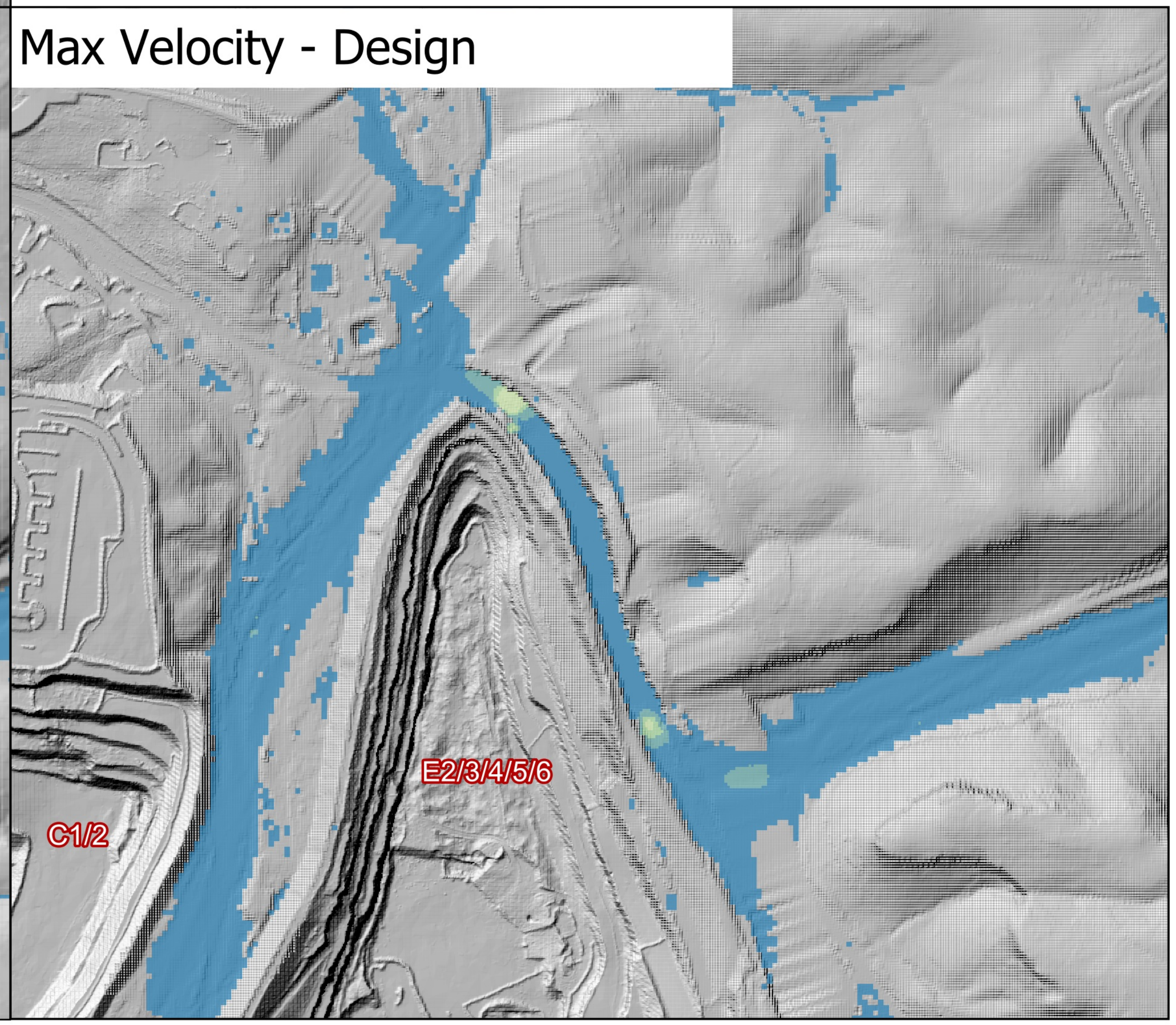
Legend

- Pre-mining Creek
- Diversion
- 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)





0 200 400 m

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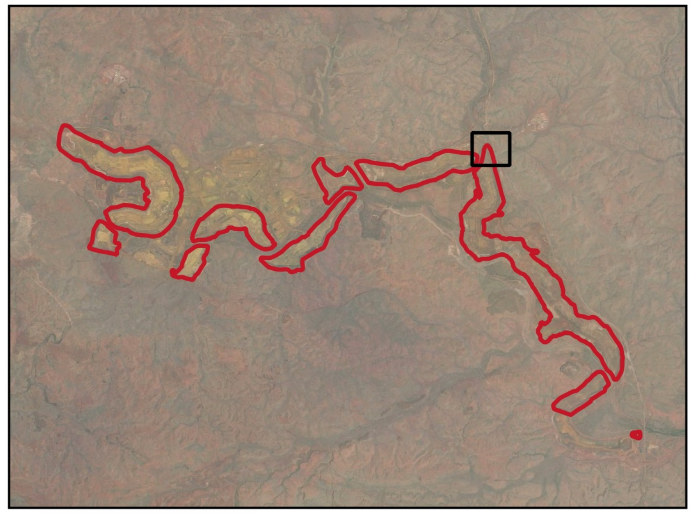
Projection: YAN94



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12.9 E356 Diversion

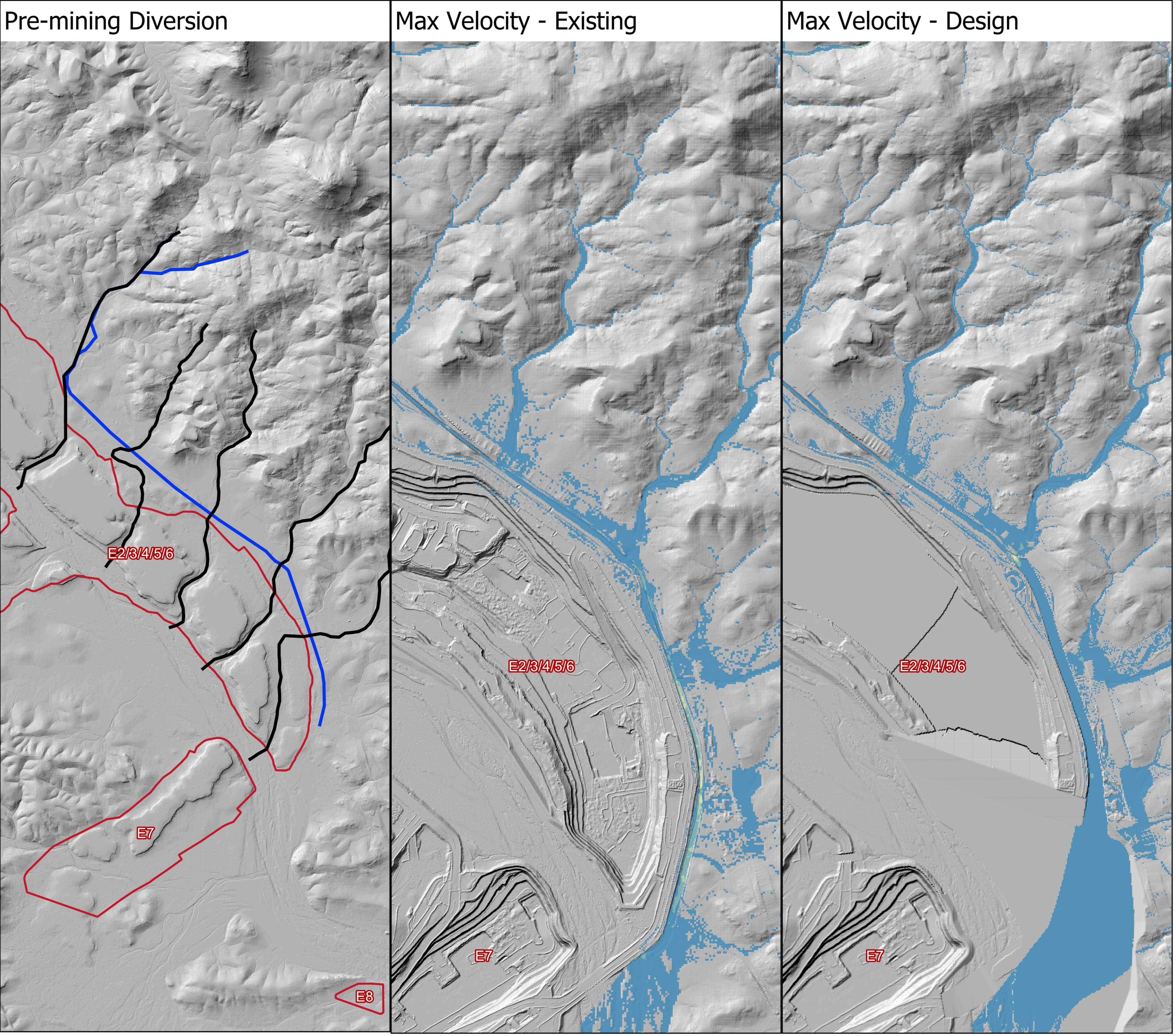
The existing E356 diversion flows north to south between the pit and BHP rail, conveying runoff from several minor catchments. Prior to mining, these small catchments would discharge across the pit footprint to Marillana Creek (Figure 12-9). The diversion therefore acts as a cut-off drain which is significantly longer than the pre-mining creeks and does not have a natural analogue to guide design.

The adopted straight, uniform diversion channel is due to the available space between the BHP rail, haul roads and the pit. It is also located at the foot of surrounding hills, further limiting opportunities to modify the planform design. Hydraulic modelling of the 1% AEP design event indicates that flow velocities increase significantly (>3 m/s) in the final 1 km before the confluence with Marillana Creek. This reach receives flows from additional tributaries but has the same width as upstream reaches of the diversion.

These high flow velocities can be managed by widening the diversion, similar to other operational diversion at Yandi. As shown in Figure 12-9, widening the downstream reach of the diversion to 50 m reduces maximum flow velocities to below 2 m/s. This reduces erosion risks. However, the presence of erodible material should be confirmed through site inspections and geotechnical assessment so that any additional risks can be managed at closure.

Reducing the flow velocities at the confluence with Marillana allows for opportunities to tie diversion channel in with the E6 floodplain landform (Section 10.2.1.3). Low-velocity, dispersed flows over the backfill will reduce the potential for scour and damage to the backfill and frequent flows may allow for the establishment of unique habitats on the floodplain landform.

Small meanders, constrictions or selected widening upstream should be considered in the DPS design of the diversion channel to establish cross-section variability and habitats.



Yandi Closure Landform

FIGURE 12-9 E356 DIVERSION

Legend

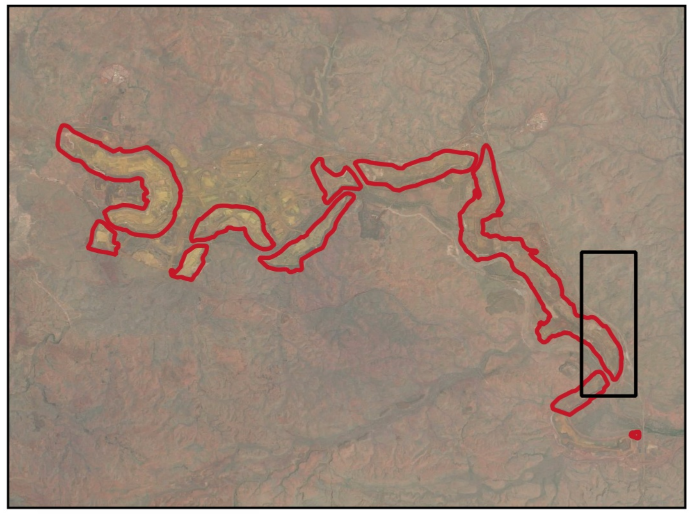
- Pre-mining Creek
- Diversion
- Pit Outlines

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)

0 100 200 m

Date: 31/01/2024
Projection: YAN94



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12.10 E7 Diversion

The E7 diversion is an operational diversion that intercepts a creek which prior to mining would flow through the pit footprint and discharge to Marillana Creek. The diversion intercepts the creek and diverts flows north of the pit to Marillana Creek. The pre-mining creek and the diversion are shown in Figure 12-10, with characteristics summarised in Table 12-6.

Table 12-6 E7 Diversion Characteristics

Parameter	Pre-Mining Creek	E7 Diversion
Creek Length (m)	2,730	2,640
Slope	0.008	0.007
Sinuosity	1.21	1.08
Typical Channel Width (m)	35	25
Maximum 1% AEP Velocity (m/s)	-	3.5

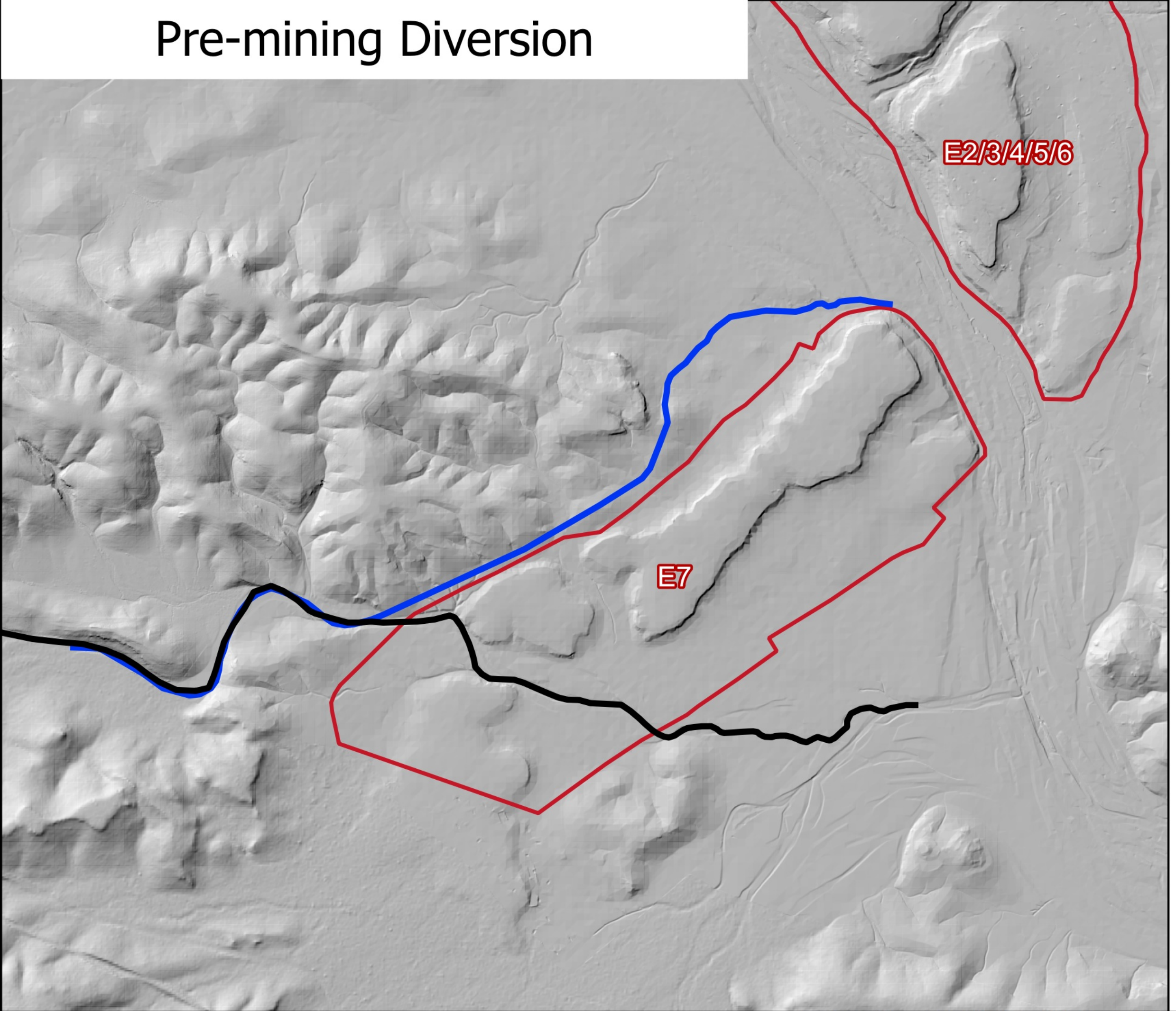
The existing diversion is similar to C12 and E356 as it acts as a cut-off drain and is largely constrained by the pit edge and adjacent steep topography. This has resulted in a relatively straight, uniform channel. Hydraulic modelling, presented in Figure 12-10 confirms minimal variation in the flow velocities through the straight diversion channel. At the downstream end as the diversion moves away from the pit the flow velocities increase prior to dispersing at Marillana Creek.

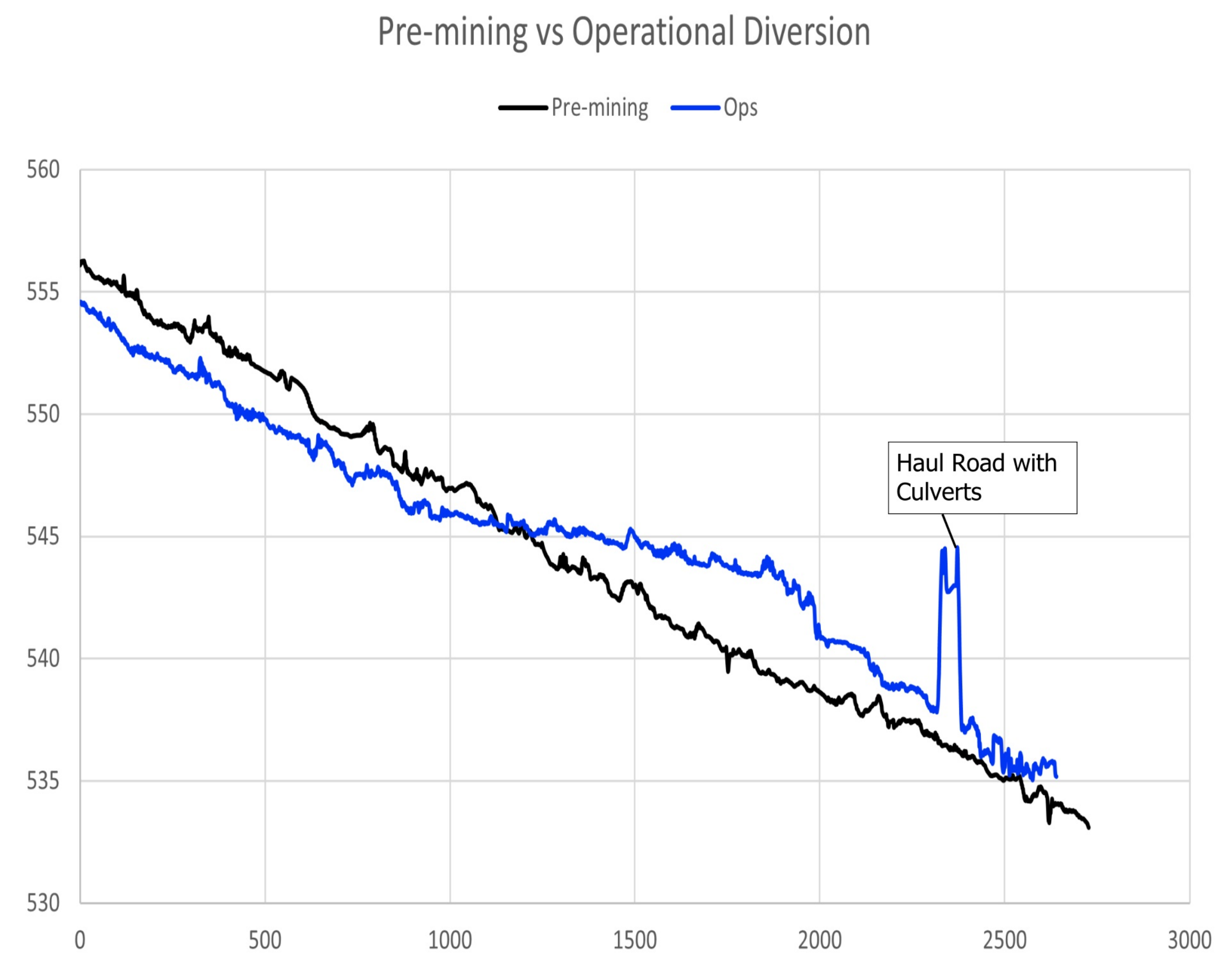
The potential for erosion through this reach is dependent on the local material which requires confirmation in the DPS phase. To alleviate this risk, the channel can be widened in this location, as shown in Figure 12-10. Widening the diversion from 25 m to 40 m reduces the velocities to approximately 2.0 m/s.

Opportunities for improving the natural aesthetic of the diversion are limited by the space available between the pit and steeper topography. Creating meanders and variable cross-section morphology in the straight section of the diversion would require significant cut material for minimal gain.

Yandi Closure Landform

FIGURE 12-10 E7 DIVERSION



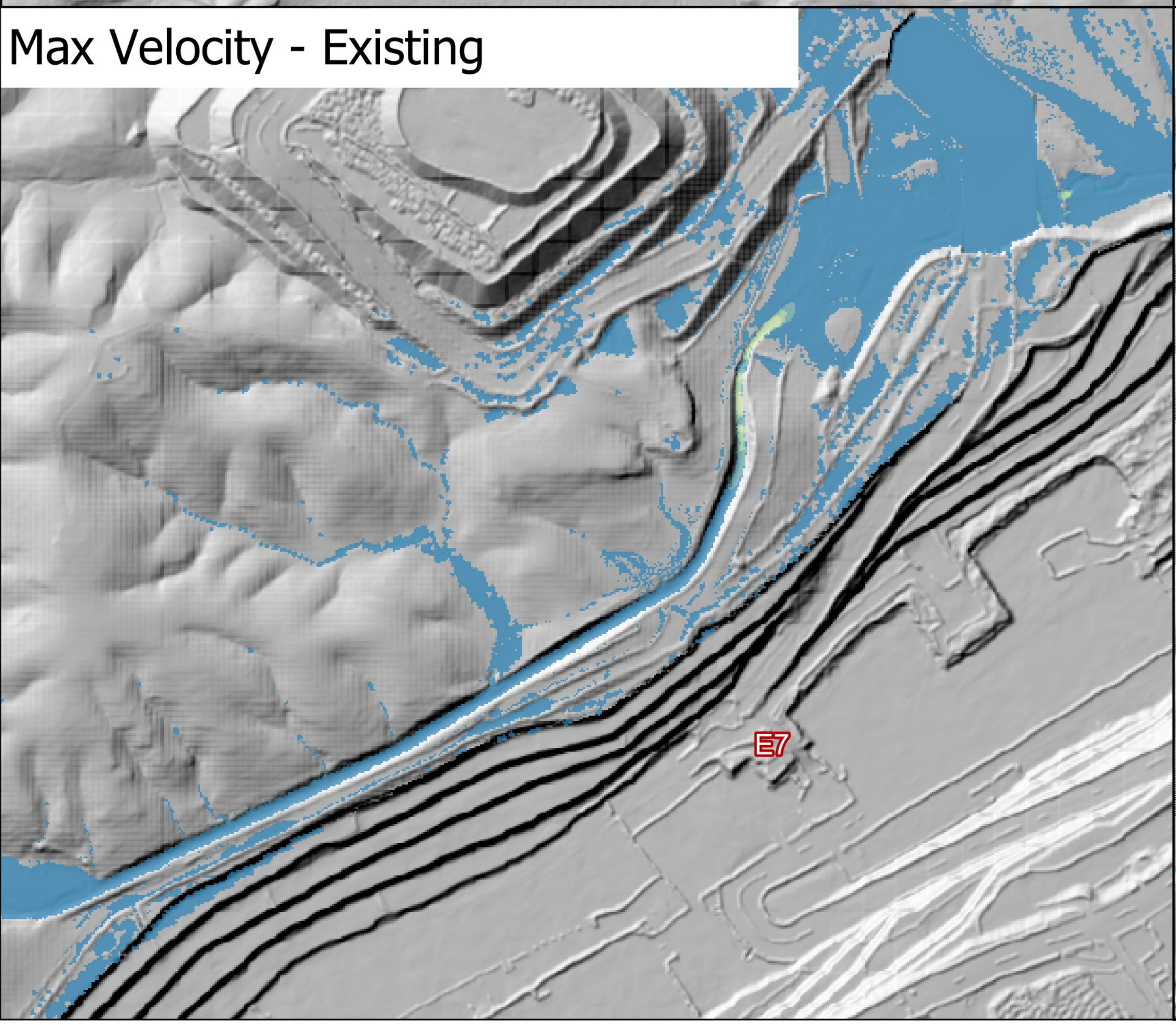


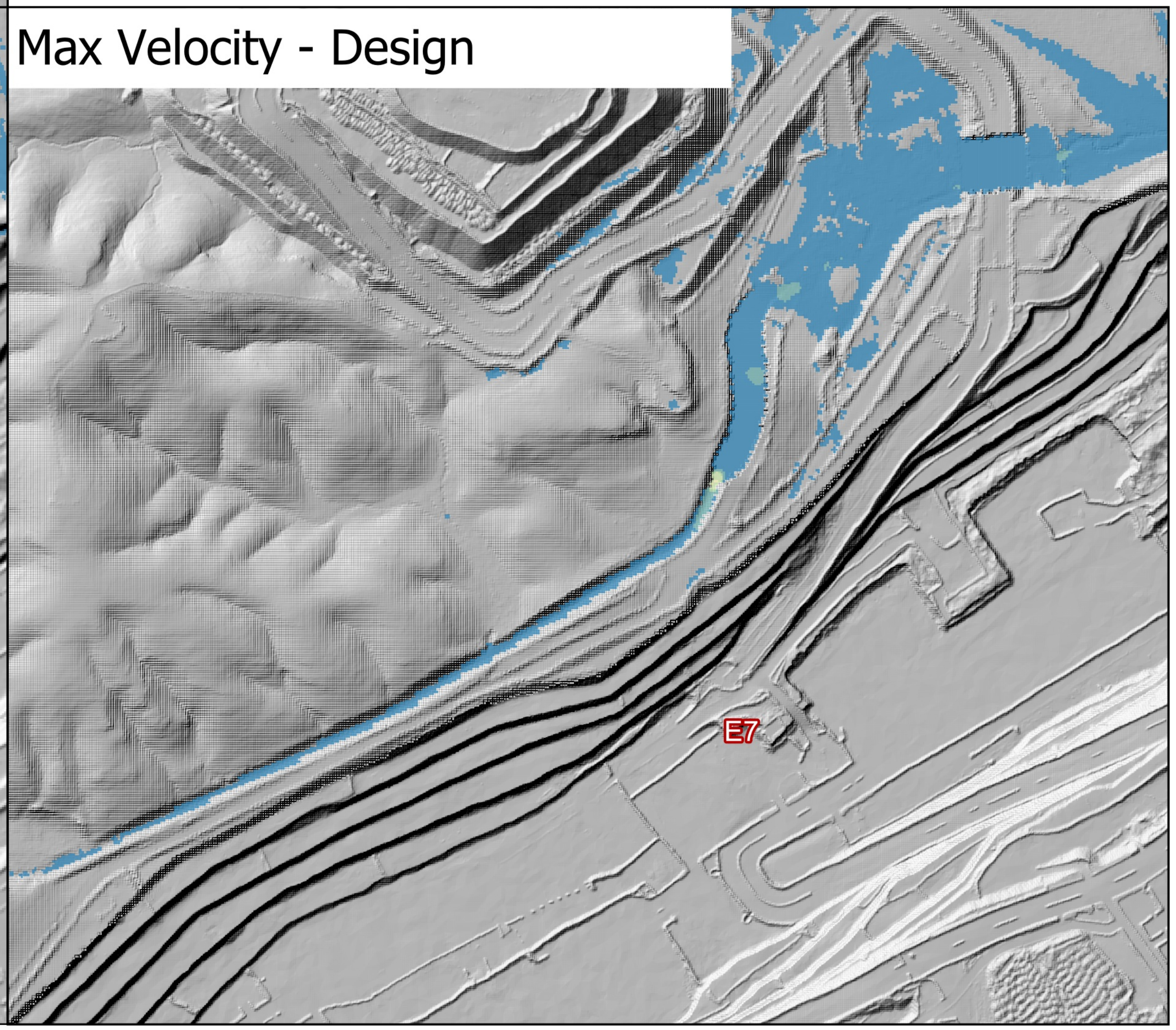
Legend

- Pre-mining Creek
- Diversion
- 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)





0 200 400 m

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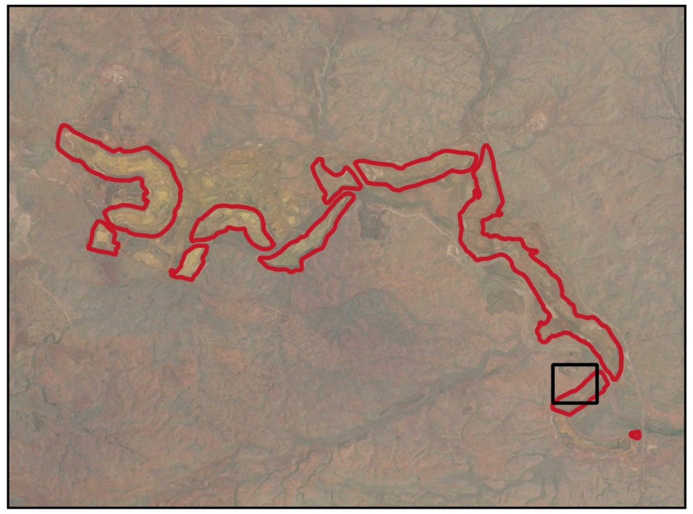

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12.11 Other Diversions

The following operation diversions or IPS diversion have not been assessed in detail in the SPS design as they are either minor or dependent on confirmation of design of more significant surface water management landforms.

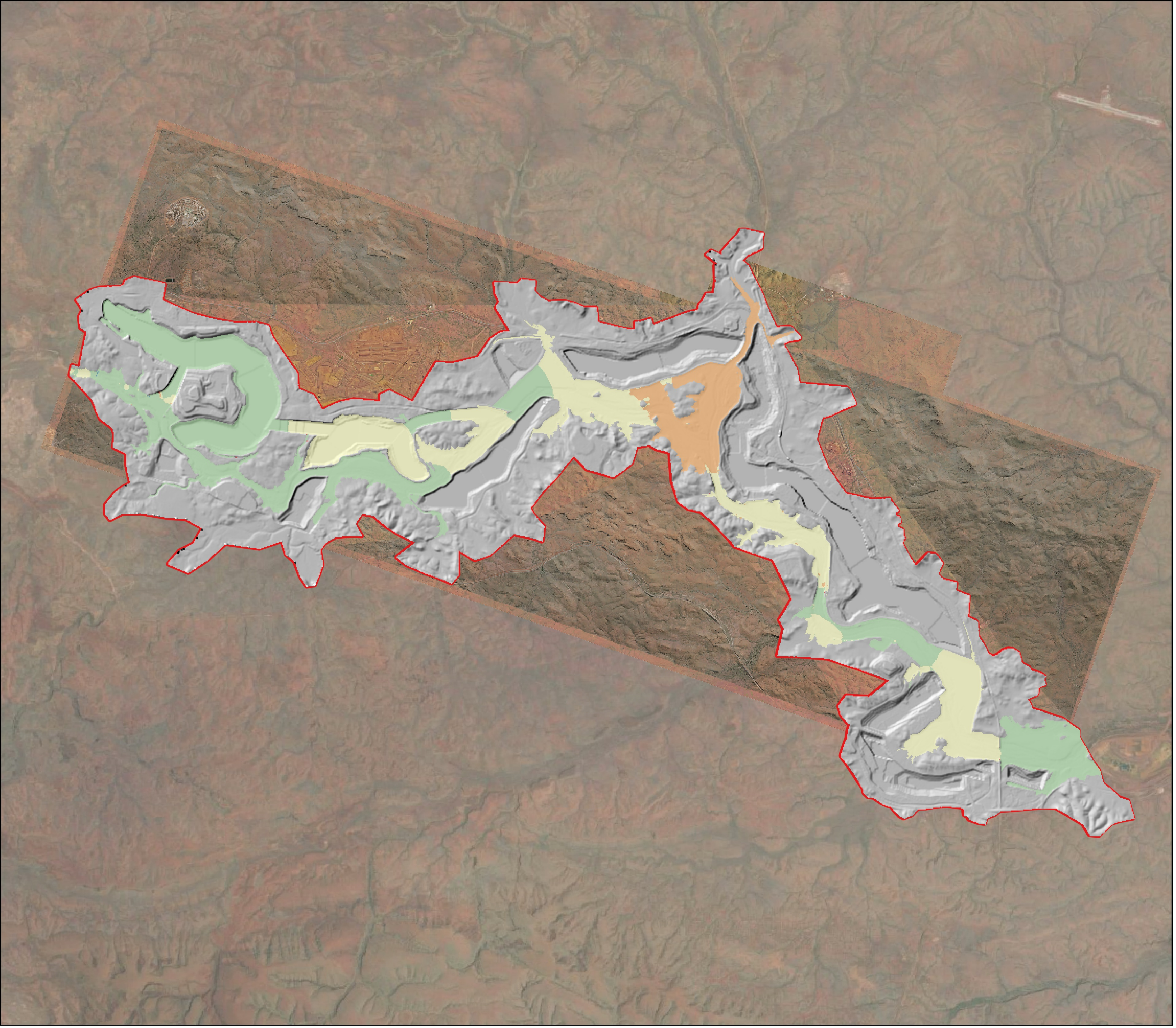
- The W1 diversion is south of the W1 pit and diverts flows away from the W1-SP0 flood channel to ensure connection with Marillana Creek (Figure 9-4). The design of W1-SP0 has been progressed from the IPS but requires additional geotechnical investigations targeting the eastern portion of the structure near the inlet where it intersects the creek that the W1 diversion redirects (Section 14.1). This diversion is relatively minor as it does not pose a risk to pit stability but should be established in the DPS design of W1-SP0 to ensure flows into Marillana Creek are maintained.

- Diversions around the E8 pit have not been considered in the SPS design but require integration with adjacent operator's mine planning to determine the Closure form of operation diversions and pre-mining creeks. As E8 will be backfilled to surface, there is minimal risk of pit capture associated with BHP pits.

13 SENSITIVITY ANALYSIS

Sensitivity analyses were conducted to investigate the impact of climate change on the closure design, simulating future climate conditions for 2075 for the 1:10,000 AEP event. The climate change assessment in the BHP Yandi Baseline Hydrology Study (PREP-1200-C—12141) was utilised, applying the climate change flow hydrographs to the site wide TUFLOW model. These hydrographs were developed by applying climate change factored IFD depths to the baseline hydrologic models, which yielded increases in peak flow rates when compared with present day conditions, including a 10% increase in the peak flow for the Flat Rocks inflow (Advisian, 2023a).

The differences in peak flood level and velocity were calculated, shown in Figure 13-1 and Figure 13-2 respectively. Figure 13-1 indicates that peak flood level increases of up to 1.0 m is estimated across the site. However, pit capture does not occur due to the flood protection bund freeboard of 1.0 m. Figure 13-2 shows that velocity increases of up to 1 m/s are estimated as a result of the increased flow rates. This increase is observed on all flood channels and in Marillana Creek adjacent to W5 pit and in the E1 and E3 diversion channels. This results in an increased risk of erosion of the flood channels as stream power increases, along with the risk of scour of the flood protection bunds along Marillana Creek.



Yandi Closure Landform

FIGURE 13-1:FLOOD LEVEL DIFFERENCE - CLIMATE CHANGE

Legend

Model boundary

Flood Level Difference (m)

<= 0.00

0.00 - 0.50

0.50 - 0.75

0.75 - 1.00

> 1.00

0 1,000 2,000 m

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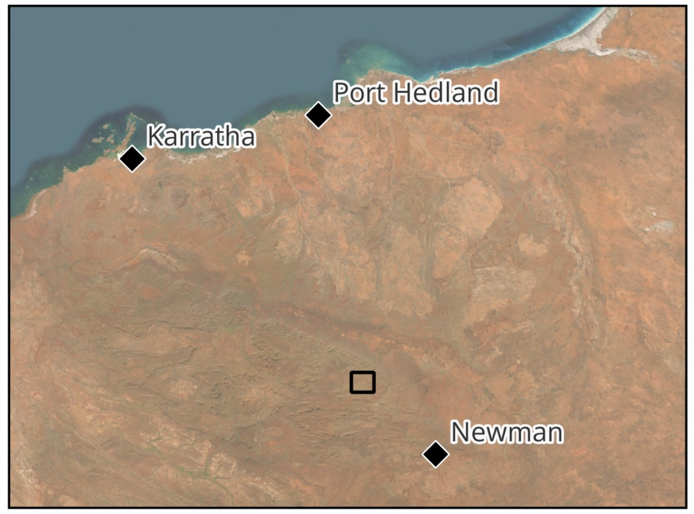

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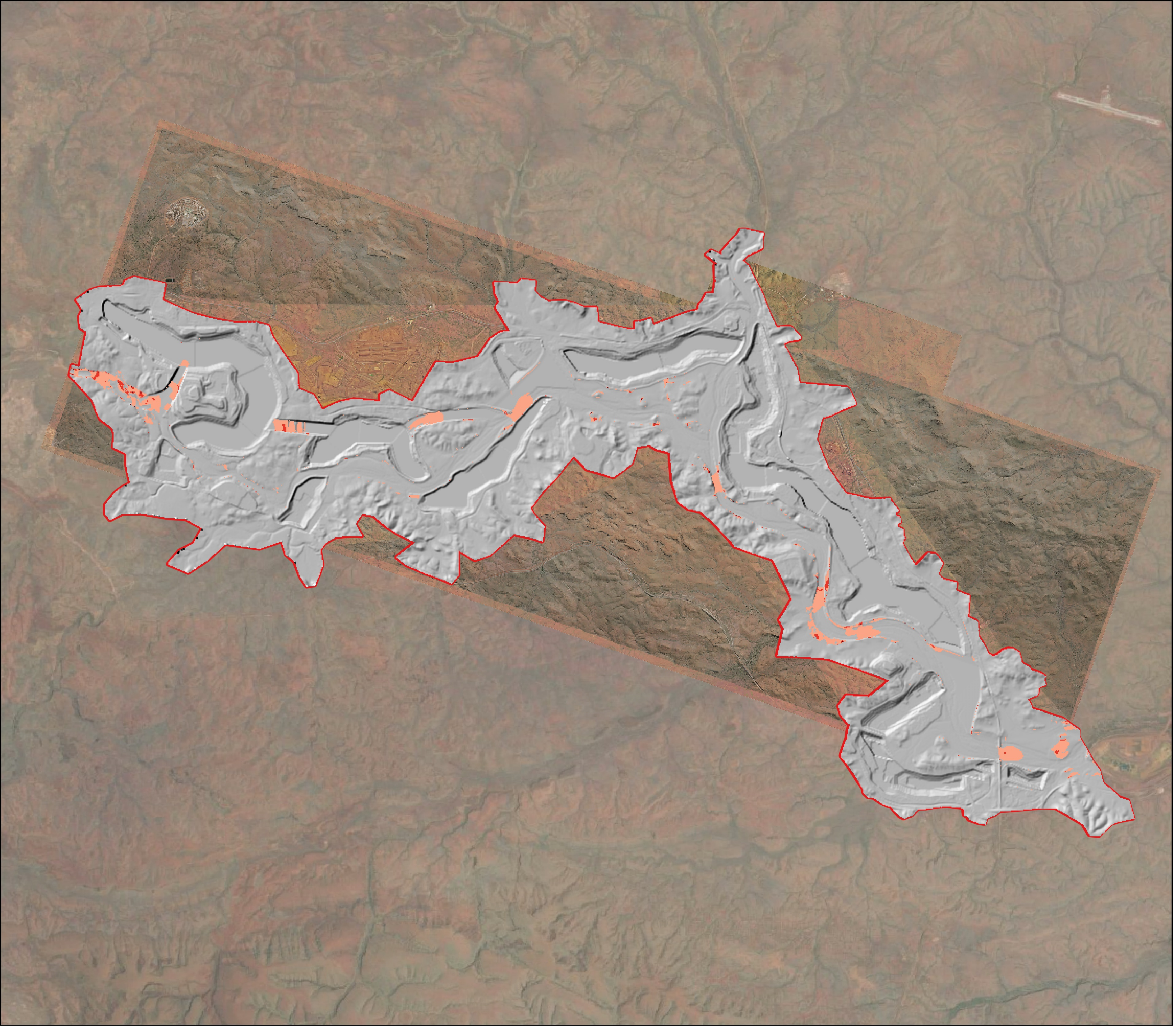

Yandi Closure Landform

FIGURE 13-2:FLOOD VELOCITY DIFFERENCE - CLIMATE CHANGE

Legend

Model boundary

Flood Velocity DIfference (m/s)

- <= 0.20
- 0.20 - 0.50
- 0.50 - 1.00
- > 1.00

0 1,000 2,000 m

Date: 31/01/2024
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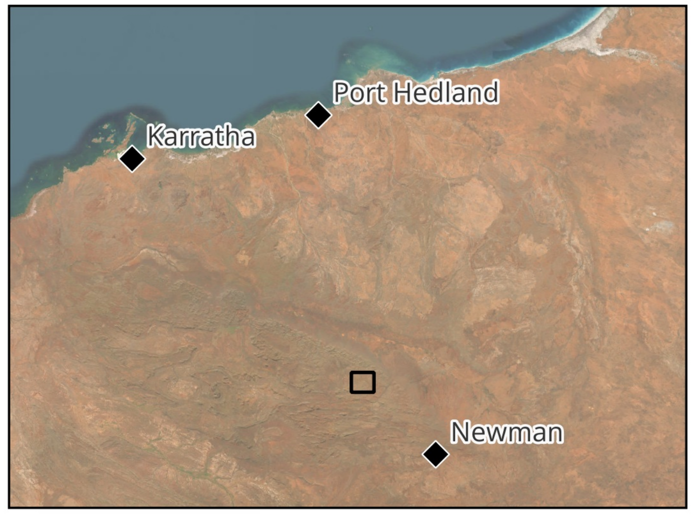

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14 FORWARD WORKS

The following forward works are recommended to address remaining risks and uncertainties, realise potential cost saving opportunities, and finalise the DPS landform design for Closure.

14.1 Flood Channels

- There is limited geotechnical data at the W1-SP3 and W4-SP4 flood channel locations. Geotechnical drilling to obtain geological data along W1-SP3 and W4-SP4 flood channels and down to the required depths to inform and optimise the design. Use results to determine the stream power thresholds for flood channel design

- As the W1-SP0 alignment has moved east post completion of the SPS geotechnical investigation additional boreholes are recommended, targeting the eastern portion of the structure and near the inlet, to collect information on geological conditions including material erodibility. Upon completion of the intrusive site investigation, the interpretive geotechnical elements including geological long section(s) and cross section(s), erodibility, cut slope stability, kinematics, and material reuse should be updated.

- 2D Hydraulic and 3D CFD modelling of all flood channels and use results and estimated geotechnical stream power thresholds to inform and optimise the design

- Geotechnical stability modelling and assessments to inform design of flood channels

- The trade-off study assessing the W1-SP3 (Section 9.1.4) recommended that the W1-SP3 & W4-SP3 flood channels be adopted for SPS design, to utilise both W1 and W4 pits for attenuation of flow. Subsequently, the W4-SP4 design was adopted as preferable to W1-SP3. However, this assumes that the geological / geotechnical properties of the cut material at W4-SP4 are highly resistive to erosion. As there is limited data at the W4-SP4 flood channel, it is recommended that this location is investigated first to collect additional geological and geotechnical data to assess and confirm that the in-situ material is suitable for the flood channel. Contingency should be made for geotechnical investigations and assessments at the alternative outlet flood channel location (W1-SP4) in the event the results from W4-SP4 are found to be unfavourable

- 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. It is recommended that an alternative flood channel is considered 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. Investigation of this flood channel, or other alternative flood channels at Herbert's Creek landbridge would require geotechnical investigations to obtain sufficient geological and geotechnical data needed to inform the flood channel design. There is currently limited data to inform the design.

14.2 Floodplain Landforms

- Inspection of the remnant CID at proposed in-pit floodplain landform locations, to determine the condition and suitability for flood protection at Closure. For this assessment it is assumed that all CID is suitable however this assumption should be supported by a field inspection and geotechnical assessments

- Settlement modelling and analysis should be completed for the in-pit floodplain landforms, to estimate the depth of settlement following Closure. Allowance should be made in the design to accommodate the estimated settlement depths

- Optimisation of the floodplain landforms is recommended with iterative hydraulic modelling. Optimising the floodplain landforms will potentially reduce the fill requirements, representing significant cost-savings for the project

- Seepage and stability analysis and modelling should be completed on all widened floodplain locations described in Section 10 and the results used to inform the DPS designs

- The risk of scour and erosion of the floodplain surface should be assessed, and design measures included where required to mitigate risk

- The Closure design of Herbert's Creek is dependent on the configuration of the W6 backfilling. A Closure design for this landbridge (and backfilling) should be prepared, considering erosion and scour risks associated with flows onto the backfill and stability risks for the existing landbridge. Options for Closure should be explored prior to PFS owing to the criticality of this location to the overall Closure design

- The interface between the floodplain landforms and adjacent creeks should be optimised to prevent local erosion and scour

- The floodplain designs and pit wall buttressing designs will need to be designed together and geotechnical stability and seepage analysis completed to inform the design.

14.3 Flood Bunds

- Geotechnical inspections and investigations should be completed at proposed flood bund locations or locations where bund upgrades are or may be required, to collect required data needed to inform the DPS design. Seepage and stability analysis modelling using flood hydrographs to inform the design. This includes existing flood bunds that need to be upgraded and new flood bund locations, where there is no available / site specific geotechnical data

- Many of the existing flood bunds are associated with minor creeks, have not been inspected on site, and/or have limited to no available design information, so design upgrades were not developed for the SPS. It is recommended that detailed investigation and assessment of existing flood bunds is conducted in the DPS, to identify all flood bunds and necessary design upgrades for Closure. As the risk associated with overtopping of pit crests along Marillana Creek or existing flood bunds are significant, for the DPS it is recommended that they are assessed in a higher level of detail when compared with bunds on minor tributaries.

- Complete hydraulic analysis and scour modelling to inform the DPS rock protection design, including consideration of scour from more frequent events in tributaries without backwater impacts from Marillana Creek.

- The SPS designs assume that if the 1:10,000 AEP event does not overtop existing pit crests then the in-situ material is suitable for Closure, without the need for additional flood bunds. In addition, if the freeboard along in-situ sections of pit crest are less than 1m, then this is also considered suitable for Closure without the need for flood bunds. These assumptions should be assessed and confirmed through onsite inspections and geotechnical assessments in the DPS

- Geotechnical and hydraulic assessments to be completed to confirm upstream and downstream raise assumptions and rock protection requirements (retain, remove-reuse or replace)

- Complete sensitivity analysis modelling assuming +/-10% on the design flow as well as +/- adjustments to the channel roughness adopted for Marillana Creek. Use results to assess freeboard and risk

- Optimise the tie in of flood bunds with existing creek and floodplain surfaces to minimise local scour and erosion risks and ensure construction will not impact heritage features

- Erosion protection for the backslope (downstream slope) has not been completed as part of the SPS and should be determined in the DPS phase.

14.4 Herbert's Creek Landbridge

- The Herbert's Creek Landbridge and associated flood channels will need to be assessed in detail to inform the DPS Closure design and identify any necessary upgrades. This would include detailed geotechnical, hydrological/hydraulic, and geomorphological assessments of the current landbridge, intrusive geotechnical investigations along flood channel routes, seepage and stability analysis and modelling, incipient motion modelling, scour estimation and rock protection design. The need for a geosynthetic liner would also need to be assessed as well as the risks associated with tree growth and long-term stability.

14.5 Creek Diversions

- Complete hydrological, hydraulic, geomorphological, and geotechnical assessments to identify necessary design upgrades for existing creek diversions or designs for new diversions, and develop DPS designs, inclusive of the diversion channel and associated flood bund

- Complete any necessary intrusive geotechnical investigations needed to inform the DPS design
- Assess risk of lateral channel migration using results from geotechnical investigations and/or assessment of existing data. Update diversion designs as required to mitigate risk
- Optimise the diversions geomorphic designs to include significant variation in cross-section morphology with consideration of erosion and deposition processes.
- Determine the W1 diversion (south of W1) tie-in with the W1-SP0 following optimisation of flood channel design
- Confirm the mine planning requirements for C6 and optimise the configuration of C12 across the backfill, including either sloping the landform or installing an additional bund
- Optimise the design of the W3 diversion with sufficient rock protection and diversion capacity at the tenement boundary
- Design of shallow alluvial aquifer or overshot blast aquifer in diversions if/as required to establish a suitable substrate that will retain water and support the establishment of riparian vegetation in the diversions.

15 REFERENCES

Advisian, 2017a, Selection Phase Study; WAIO Project – Constrained Creek Ore W5 Quarry Geotechnical Site Investigation. PREP-610-G-00006.

Advisian, 2017b. Definition Phase Study; WAIO Project – Creek Constrained Ore Project Hydraulic Design Report. PREP-1200-G-12413.

Advisian, 2017c, Selection Phase Study; WAIO Project – Creek Constrained Ore Project Sediment Transport Modelling Report. PREP-1200-G-12414.

Advisian, 2019. Identification Phase Study, WAIO Project – Yandi Spillways Drilling Campaign Factual Report. PREP-1210-C-12041.

Advisian, 2020. Yandi Closure Identification Phase Study – Surface Water Engineering Memorandum. HY-MEM-0001.

Advisian, 2023a, Selection Phase Study; WAIO Project – Baseline Hydrology Report. PREP-1200-C-12141.

Advisian, 2023b, Selection Phase Study; WAIO Project – Yandi Closure Landform Constructability Review Report. PREP-1200-C-12148.

Advisian, 2024, Selection Phase Study; WAIO Project – Geotech Engineering Report. PREP-1200-C-12140.

Austroads, 1994. Waterway Design: A Guide to the Hydraulic Design of Bridges, Culverts, and Floodways.

Austroads, 2019. Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures.

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

Blench, T., 1969. Mobile-Bed Fluviology: A Regime Theory Treatment of Canals and Rivers for Engineers and Hydrologists.

Department of Public Works California, 1960. Bank and Shore Protection in California Highway Practice.

Faraday, R.V., and Charlton, F.G., 1983. Hydraulic Factors in Bridge Design.

Lacey, G., 1930. Stable Channels in Alluvium, Proceedings of the Institute of Civil Engineers, vol 299, pp. 259-292. Cited in Pemberton, E.L. and Lara, J.M. 1984. Computing Degradation and Local Scour.

Pells, S.E., 2016. Erosion of Rock in Spillways. PhD thesis, UNSW Sydney

U.S. Geological Survey (USGS), 1986. Rock Riprap Design for Protection of Stream Channels near Highway Structures, Volume 2 – Evaluation of Riprap Design Procedures.

van Schalkwyk, A., Jordaan, J.M., Dooge, N., 1994. Die erodeerbaarheid van verskillende rotsformasies onder varierende vloeitoestande (No. WNK Verslag No. 302/1/95). Verslag aan die waternavorsingskommissie deur die Departement of Geologie, Universiteit van Pretoria, South Africa.

Wibowo, J.L., Yule, D.E., Villanueva, E. Temple, D.M., 2005. Earth and Rock Surface Spillway Erosion Risk Assessment. Proceedings of the American Rock Mechanics Association Rock Mechanics Symposium, Anchorage, Alaska.

APPENDIX A – SITE VISIT PRESENTATION

Yandi Closure Landforms SPS

Surface Water Landforms Site Visit

Matthew Rafty, Stuart Atkinson, Mark Orr

14 to 17 August 2023

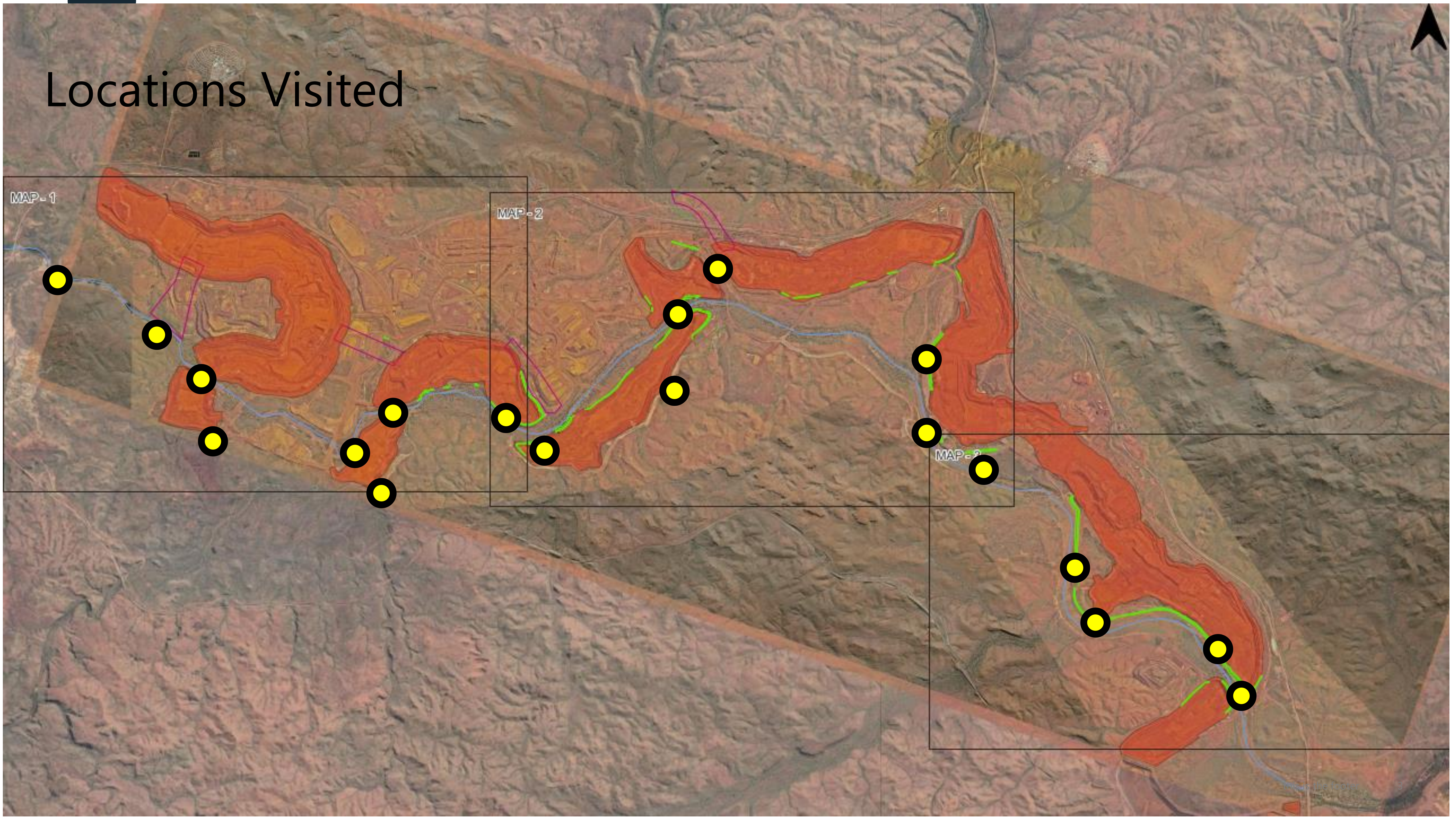
Advisian
Worley Group

advisian.com

Outline of Yandi Site Visit Presentation

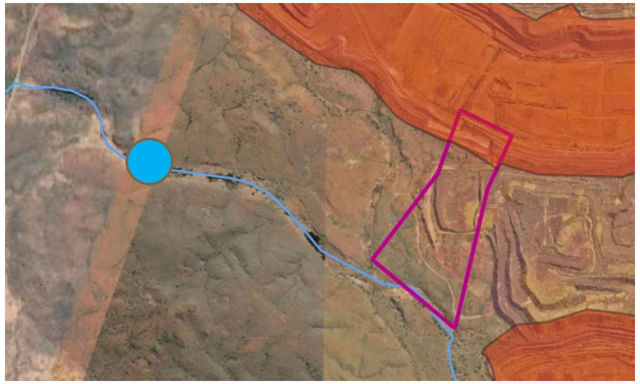
1. Overview
2. Location by Location Observations
3. Summary and conclusions

Locations Visited



Flat Rocks - Day 1

- There are several natural features observed at Flat Rocks that could be replicated / mimicked / used for inspiration for design of the flood channel, including:
  - small vertical steps ~1.0 m – 1.5 m height in direction of flow, also on sides of channel
  - undulating surface of bare, smooth rock (dolerite)
  - Gently sloping (1:1) channel slopes of ~10 m height, with loose rock and spinifex and shrubs vegetation.



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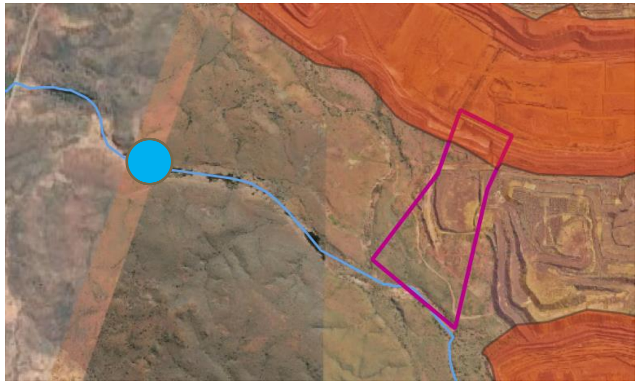
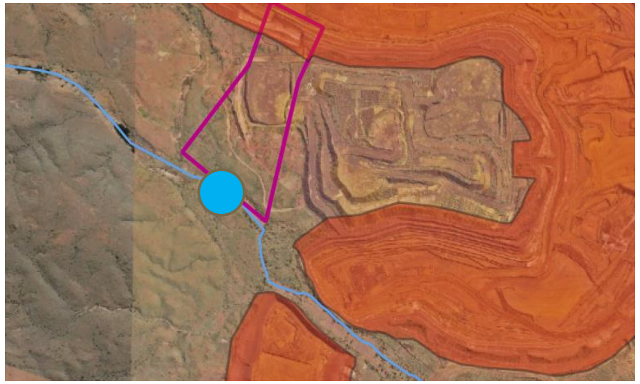


W1 Flood Channel - Day 2

- Plenty of natural features to mimic or possibly even leave in place to prevent inadvertent access to flood channel. Small vertical drops / boulders of 1.0 m – 1.5 m height
- Upstream bund to direct flow into flood channel will have construction challenges. Lots of large rock throughout channel at this point which will need to be moved prior to construction. Access will not be easy. Bund could potentially be set back a little further to avoid very high velocity hitting the bund, requiring large armour rock.



W1-W2 Landbridge – Day 2

- Remnant CID on edge of W1-W2 natural landbridge contains fractures, several large failures, loose blocks and caves/overhangs.

- Creek is visibly narrower here than other constrictions. It is not surprising that the recent trade-off study found this area overtops if the flood channel is removed.

W1-W2 Landbridge – Day 2

- Top of CID could not be inspected for width and suitable to build bund on top, but previous analysis indicates it is likely not feasible. Building bunds into the creek here would not be sensible due to lack of space available.

- This section has little vegetation in the channel due to high velocities - trees present on edge and immediately downstream where water slows down.

W2 Diversion – Day 4

- Downstream 50 m of diversion immediately upstream of culverts was densely vegetated, with a further 200 m of vegetation. Due to sediment deposition caused by backwater from small culverts which has allowed vegetation to grow.
- Side walls of diversion are eroding, some are weathered dolerite. Overlying BIF could fail after further erosion.
- Further upstream the channel is deep, steep side cuts with a very narrow base (~6 m) with no aquifer. CID crops out across base of diversion here creating a barren, desolate section devoid of vegetation.