Future Freight Joint Venture
Level 8, 540 Wickham Street, Fortitude Valley QLD 4006
PO Box 1307 Fortitude Valley QLD 4006

T +61 7 3553 2000
F +61 7 3553 2050

Technical Note

To	**John Carr (ARTC)**	From	**Trinity Graham (FFJV)**
Copy	**Ben Lippett (ARTC)**	Reference	**2-0001-270-IHY-10-TN-0011_Rev 1**
Date	**5 November 2021**	Pages (including this page)	**22**
Subject	**Response to DPIE RFI regarding further modelling and assessment of velocities through culverts**		

1 Overview

DPIE issued an RFI (11/06/21) seeking further modelling and assessment of velocity through culverts to understand the likely impacts from erosion and scour on adjoining properties to the rail corridor and the potential for mitigation. The following items were requested:

- Modelling of velocities through culverts by using a finer grid scale model such as a conventional TUFLOW grid not larger than 2m or the Quadtree enhancement with a sufficient number of subdivisions.
- Identifying areas of non-compliance with the N2NS scour/erosion potential QDL;
- Proposed mitigation measures to meet the QDLs at the boundary of the project; and
- Identifying residual impacts that would require erosion protection measures on adjoining properties.

From the meeting with DPIE (17/05/21), it was determined that DPIE were seeking:

- Confidence that the proposed project corridor footprint is sufficient to allow the magnitude of velocities to be reduced to permissible levels and an understanding of potential scour/erosion impacts on private land.
- Examples of proposed mitigation measures – what is the proposed range of engineering solutions and what would the likely outcomes be as the project progresses into detailed design.

2 N2NS QDL

The N2NS scour/erosion QDL as used in the PIR is outlined in Table 1. A number of proposed amendments have been discussed between DPIE and ARTC with the current version of the QDL presented after Table 1. This revised version of the QDL has been applied in this Technical Note.

Table 1 N2NS scour/erosion QDL

Parameter	Location or Land Use	Limit
Scour/Erosion Potential i.e increase in flood velocity resulting from implementation of CSSI.	Ground surfaces that have been sealed or otherwise protected against erosion. This includes roads, most urban, commercial, industrial, recreational and forested land	20% increase in velocity where existing velocity already exceeds 1m/s
	Other areas including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas	No velocities to exceed 0.5m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. In addition, the increase in velocity is limited to 20% where the existing velocity already exceeds 0.5m/s

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Revised Scour/erosion potential QDL

The erosion threshold is to be set to 0.5m/s in the absence of site assessments (as per the requirements outlined below). Permissible changes to existing velocities are as follows:

- *Where existing velocities are < 0.5m/s, limit any increases to 0.5m/s*
- *Where existing velocities are > 0.5m/s, limit any increases to 10%*

The 0.5m/s erosion threshold can be increased subject to the following process:

- *Site specific assessment(s) conducted by an experienced geotechnical or scour/erosion specialist to establish an increased erosion threshold accounting for soil conditions and/or ground cover*
- *Where the assessment identifies an increased erosion threshold above 0.5m/s, the increase in existing velocity cannot exceed the lower of:*
  - *(i) The erosion threshold, where existing velocities are less than the erosion threshold*
  - *(ii) The existing velocity plus 10%, where existing velocities are greater than the erosion threshold*
  - *(iii) An increase in existing velocity of up to 50%*

Note 1: For new flowpaths, velocities should be limited to 70% of the erosion threshold
Note 2: Irrespective of erosion threshold, existing (or new flowpath) velocities can be increased up to 0.5m/s without any percentage change limits applying

3 Modelling approach

The following modelling steps have been undertaken to address the requirement of the RFI. It should be noted that in detailed design this work would be reviewed in consultation with an experienced geotechnical/ geomorphologist or scour/erosion specialist. The steps followed were:

- Development of two sub-models with Sub-model 1 (SM1) covering the main floodplain area and Sub-Model 2 (SM2) covering the southern tributaries including Forest Creek, Mobbindry Creek and Back Creek. The extents of both sub-models are presented in Figure 1.
- Rerunning the 30m grid model with PO lines at proposed sub-model boundaries to provide boundary conditions for the 1976 flow scenario and the 1% AEP event.
- Cross-check of sub-model results with floodplain wide model results to ensure consistency.
- Introduction of Quadtree to apply reduced grid spacing in the vicinity of the proposed rail corridor. The use of 1.875m and 3.75m has been tested along the rail corridor and final approach is discussed in further in Section 4.2.
- Revision of drainage structure connections in hydraulic sub-models to allow for finer the grid spacing.
- Revision of topography modifiers representing embankment for existing and proposed rail lines.
- Modelling of Existing Case to determine base conditions in both sub-models.
- Modelling of Reference Design as assessed in the EIS. Modelling of 1976 flow scenario (SM1) and 1% AEP event (SM2).
- Confirmation of impacts of Reference Design at rail corridor boundary and determination of areas in which mitigation measures may need to be applied.
- Testing of mitigation measures and development of a more refined drainage design, where required.

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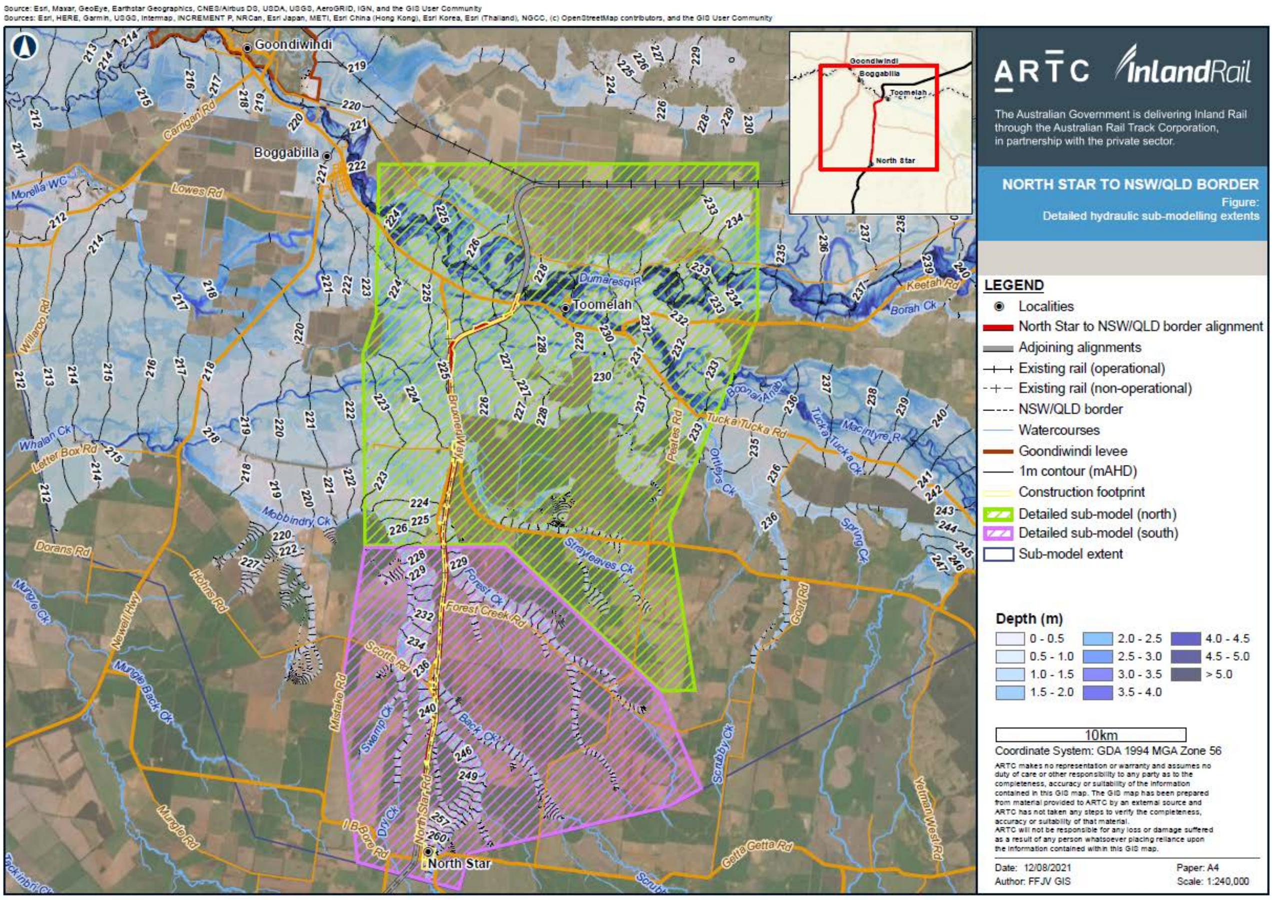

Figure 1 Extents of hydraulic sub-models

The following sections presents the further details on the development of the sub-models and the results of the detailed sub-modelling along the rail corridor in relation to the N2NS scour/erosion QDL.

4 Validation of sub-model results

Before the introduction of Quadtree into the sub-models the modelling results from the floodplain wide model were compared against the sub-model results to confirm that the sub-models produce similar results. The following sections present the outcomes of this validation exercise.

4.1 Afflux comparison

As a check the change in peak water levels (afflux) results from both of the sub-models were compared against those previously reported in the PIR for the floodplain wide model. As can be seen in

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Figure 2 (Sub-model 1) and

Figure 3 (Sub-model 2), a good match was achieved giving confidence in the ability of the sub-models to replicate the larger model results.

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Figure 2 Afflux comparison Floodplain Wide Model to Sub-Model 1

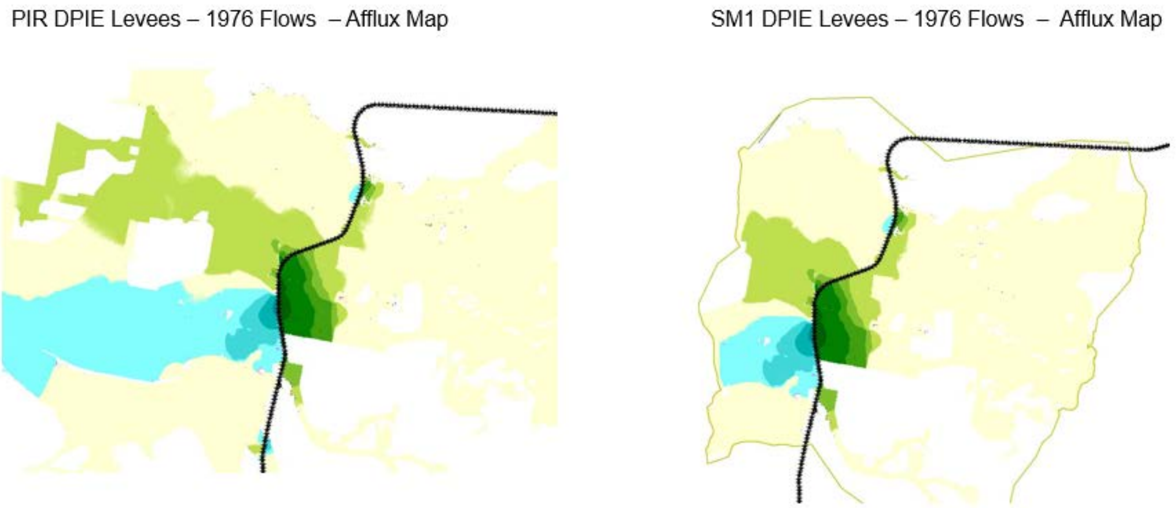
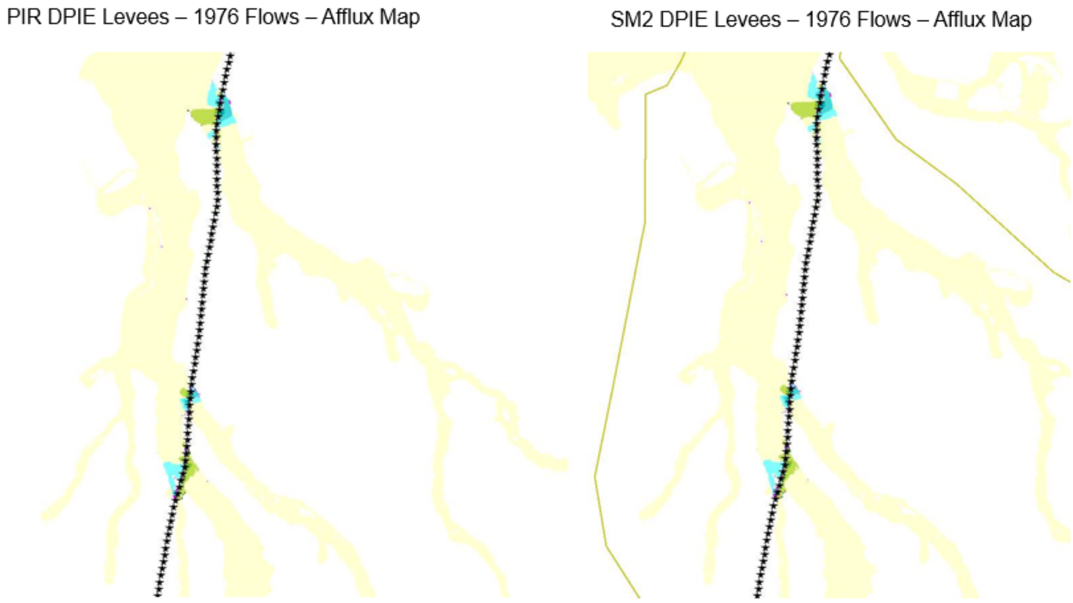


Figure 3 Afflux comparison Floodplain Wide Model to Sub-Model 2



4.2 Discharge comparison

A comparison of the flows through the Reference Design culverts between the hydraulic sub-models and the PIR floodplain wide hydraulic model was carried out. The outcomes are presented in Table 2 and generally a good match in the culvert flows between the floodplain wide model and the sub-models has been confirmed.

It should be noted that refinement of the culvert (1D-2D) connections in the hydraulic sub-models was undertaken to take account of the smaller grid size and this has improved the representation of the structures and led to some flow redistribution. Overall, all good match is demonstrated.

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Table 2 Comparison of culvert flows between the PIR floodplain model and the sub-models

Chainage (km)	Structure details	Approximate bridge or culvert length (m)	PIR floodplain model culvert flow (m^3/s)	Sub-model culvert flow (m^3/s)
5.58	2/1.05m RCP	17	2.0	2.1
6.08	7/2.1m RCP	18	13.9	11.5
6.12	7/2.1m RCP	16	14.3	11.1
6.53	6/2.1m RCP	17	4.5	4.9
6.58	5/2.1m RCP	17	2.6	3.9
15.33	10/1.2x1.2m RCBC	8	3.9	3.5
15.52	10/1.2x1.2m RCBC	10	5.8	5.7
15.67	10/1.2m RCP	13	9.9	8.9
15.83	20/1.2m RCP	14	22.8	22.0
15.90	20/1.2m RCP	14	20.2	20.1
15.98	20/1.2m RCP	16	16.6	16.7
16.08	20/1.2m RCP	15	15.3	15.5
16.60	8/1.2m RCP	17	11.9	9.9
16.83	8/1.2m RCP	17	6.7	6.2
21.35	3/1.35m RCP	28	5.3	5.2
22.27	3/1.2m RCP	13	7.4	7.6
22.86	25/1.2m RCP	14	58.0	50.9
23.22	25/1.2m RCP	16	64.6	61.3
23.70	25/1.2m RCP	15	48.0	53.1
23.80	25/1.2m RCP	15	54.4	54.5
24.03	8/1.05m RCP	16	9.9	10.1
24.20	5/0.9m RCP	16	6.8	7.1
24.62	35/1.2x0.9m RCBC	18	58.8	63.2
24.71	35/1.2x0.9m RCBC	22	58.8	63.1
24.85	35/1.2x0.9m RCBC	30	60.0	63.4
27.06	10/1.2m RCP	15	0.7	0.9

5 Application of Quadtree

A number of refinements were applied to both sub-models in association with the application of Quadtree. These refinements and the assessment of the optimal grid spacing are discussed in the following sections.

5.1 Grid spacing

The application of Quadtree in the vicinity of the rail corridor was tested to determine the optimum extent and grid spacing that could be applied in the sub-models. In terms of extent Quadtree has been applied over the proposed rail corridor (including the Bruxner Way deviation) and also over the 10 metres on the upstream and downstream sides of the rail corridor. For SM2 the extent has been truncated to exclude areas that are not inundated by flooding.

There were several practical factors that were considered when selecting the grid spacing to be applied using Quadtree. The primary consideration was the level of detail achieved in the vicinity of the rail corridor and around structures. TUFLOW (TUFLOW User Manual, Build 2016-03-AA) provides the following guidance regarding 2D grid cell size.

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Level 8, 540 Wickham Street, Fortitude Valley QLD 4006
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3.3 Model Resolution

3.3.1 2D Cell Size

The cell sizes of 2D domains need to be sufficiently small to reproduce the hydraulic behaviour, yet be large enough to minimise run times to meet project deadlines. At the start of a project, the modeller should determine the minimum cell size required to model the hydraulics accurately enough to meet the study objectives. Preferably at least three to four cells across the major flow paths is recommended.

The distance between the culvert outlets and the rail corridor boundary will range from approximately 15m to 25m. Using Quadtree at Level 4, the grid spacing is 3.75m. This provides between 4 and 6 cells over this extent and complies with the TUFLOW manual guidelines.

Upon review of the 3.75m grid modelling results it was determined that the detail being represented in the sub-model gives a good level of information on velocities within and at the rail corridor boundary and that further refinement of the grid spacing to 1.875m (Level 5) would give limited benefit.

It is also noted that utilising the largest most suitable grid size provides better performance for:

- Hydraulic model simulation times:
  - Adopting 1.875m grid spacing means that each 30m cell is replaced by 256 cells.
  - Adopting 3.75m grid spacing means that each 30m cell is replaced by 64 cells.

  The more grid cells in the model the more time is required for each run and as multiple model runs are required for both sub-models, and for the full range of design events, a realistic timeframe needs to be adopted.
- Output file sizes – The result files for the 3.75m grid spacing are already very large (and the 1.875m would be even larger), with individual files (one per result theme) being of the order of 7 to 8Gb for SM2. Options to reduce the size of files were investigated (including reduction of simulation time and optimised file output types). With output files now around 4Gb each for SM2 and 8Gb each for SM1.

Therefore, the 3.75m grid spacing has been adopted for this stage of assessment and if deemed necessary localised areas of 1.875m could be potentially be included in future stages at select crossing locations.

5.2 Set up and refinement of model detail for Sub-models

A number of components from the floodplain wide PIR hydraulic model were refined for use on the sub-models as discussed in the following sections.

5.2.1 Boundaries

For the sub-models boundaries were extracted from the floodplain wide hydraulic model. Boundaries were defined as:

- Flow versus time (QT) for upstream areas entering the sub-model
- Water level versus time (HT) for flow leaving the sub-model area

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Plot output locations were added to the overall floodplain wide model and the model rerun to provide details. Boundaries were then extracted from the plot output results for inclusion in the sub-models. The following is noted:

- For the 1% AEP event and the 1976 flow scenario, the Existing Case boundaries were suitable for application for both the Existing and Developed Case models as the difference in water level at the downstream sub-model boundary is minimal. For larger events both Existing and Developed Cases would be simulated to replicate downstream tailwater levels suitably.
- In the 1% AEP event and the 1976 flow scenario, the full floodplain is inundated, and the downstream boundaries have been selected to cover this extent. For small events, e.g. 20% AEP, where inundation is generally within defined watercourses, the downstream boundaries require splitting to represent the inundated extent. Therefore, the boundary representation may vary to represent the varying flow patterns for the range of AEP events ultimately modelled.

5.2.2 Quadtree extent

Quadtree has been applied along the alignment including at all culverts and bridges in the hydraulic sub-models. In sub-model 2 where the flows are more contained to existing watercourses Quadtree has been applied at each crossing location. For sub-model 1 where the inundation in large events is widespread it has been applied for the full floodplain width. The width of the quadtree model is the rail corridor plus a 10m buffer applied to each side. The Quadtree extents are presented in Figure 4 and

Figure 5.

Figure 4 Sub-model 1 Quadtree extent

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Figure 5 Sub-model 2 Quadtree extent

5.2.3 Culverts

The Reference Design 1D culverts have been applied as per the overall floodplain model. Culvert inverts were reviewed with the revised connection locations and found to be representative. The 1D connections to the 2D model have been adjusted to align with the 3.75m grid.

5.2.4 Embankment representation

It should be noted that the Reference Design rail embankment across the main floodplain area is currently conservatively wide as it allows for the presence of a passing loop. The passing loop is now proposed to be relocated from this area and as part of detailed design the embankment will be narrower and allow for increased distance from the culvert outlets to the rail corridor boundary. This will give more space for velocities to dissipate beyond that currently shown in the modelling.

In addition, in future stages the embankment DEM would be able to be refined to better define the headwalls for culvert banks and provide better representation of the space from the culvert outlets to the rail corridor boundary.

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Level 8, 540 Wickham Street, Fortitude Valley QLD 4006
PO Box 1307 Fortitude Valley QLD 4006
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5.2.5 LiDAR

For sub-model 1, the topography data is based on the 2019 LiDAR with the DPIE levees overlain on this dataset. This LiDAR data was collected in November 2019 to provide details of current topographic conditions.

The LiDAR 2019 data was specified with the following metadata:

- Vertical = 0.15 m (95 per cent confidence level or 2 sigma).

5.2.6 Additional outputs

As per the request of DPIE stream power and shear stress have been added to the model result outputs and are available for review as required.

6 Sub-modelling results

6.1 Reference Design velocities at rail corridor boundary

6.1.1 Culvert crossings

Table 3 presents a summary of peak velocities at the rail corridor boundary for the floodplain culverts for the Existing Case and the Reference Design as presented in the EIS. Table 3 shows the following:

- Peak velocities for the Existing Case and where these velocities are above 0.5 m/s (yellow highlight),
- Peak velocities for the Reference Design case and the approximate AEP at which the floodplain flow culverts start to operate, and
- Assessment of compliance with the revised scour/erosion QDL (refer Section 2) for the critical flood event (1% AEP or 1976 flow scenario with BRVFMP levees).

From Table 3 it can be seen that:

- There are two main culvert bank extents where the Reference Design does not comply with the erosion/scour potential QDL. These occur at:
  - The three banks of 35/1.2x0.9m RCBC around Ch 24.6 to 24.8km (near the Bruxner Way deviation)
  - The four banks of 25/1.2m RCP around Ch 22.8 to 23.8km

Mitigation options for these locations are discussed and assessed in the following sections.

Table 3 Review of culvert velocities at rail corridor boundary – Reference Design

Chainage (km)	Culvert details	Approx culvert length (m)	Approx AEP at which floodplain flows start	Existing d/s peak velocity at rail boundary (m/s)	Reference Design d/s peak velocity at rail boundary (m/s)	QDL velocity limit (m/s)	Compliant with QDL?
5.58	2/1.05m RCP	17	-	0.36	0.32	0.50	Yes
6.08	7/2.1m RCP	18	-	0.32	0.35	0.50	Yes
6.12	7/2.1m RCP	16	-	0.48	0.40	0.50	Yes
6.53	6/2.1m RCP	17	-	0.46	0.42	0.50	Yes
6.58	5/2.1m RCP	17	-	0.42	0.44	0.50	Yes
15.33	10/1.2x1.2m RCBC	8	-	0.16	0.27	0.50	Yes
15.52	10/1.2x1.2m RCBC	10	-	0.34	0.37	0.50	Yes

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Chainage (km)	Culvert details	Approx culvert length (m)	Approx AEP at which floodplain flows start	Existing d/s peak velocity at rail boundary (m/s)	Reference Design d/s peak velocity at rail boundary (m/s)	QDL velocity limit (m/s)	Compliant with QDL?
15.67	10/1.2m RCP	13	-	0.34	0.35	0.50	Yes
15.83	20/1.2m RCP	14	-	0.38	0.43	0.50	Yes
15.90	20/1.2m RCP	14	-	0.40	0.44	0.50	Yes
15.98	20/1.2m RCP	16	-	0.34	0.43	0.50	Yes
16.08	20/1.2m RCP	15	-	0.31	0.41	0.50	Yes
16.60	8/1.2m RCP	17	-	0.70	0.37	0.77	Yes
16.83	8/1.2m RCP	17	-	0.10	0.32	0.50	Yes
21.35	3/1.35m RCP	28	20%	0.21	0.47	0.50	Yes
21.97	3/1.05m RCP	20	20%	0.10	0.16	0.50	Yes
22.27	3/1.2m RCP	13	2%	0.16	0.31	0.50	Yes
22.86	25/1.2m RCP	14	2%	0.34	0.87	0.50	No
23.20	25/1.2m RCP	15	2%	0.57	1.30	0.63	No
23.70	25/1.2m RCP	15	2%	0.59	0.93	0.65	No
23.80	25/1.2m RCP	15	2%	0.35	0.81	0.50	No
24.03	8/1.05m RCP	16	2%	0.35	0.29	0.50	Yes
24.2	5/0.9m RCP	16	2%	0.23	0.34	0.50	Yes
24.62	35/1.2x0.9m RCBC	18	5%	0.64	0.54	0.70	Yes
24.71	35/1.2x0.9m RCBC	22	5%	0.34	0.66	0.50	No
24.85	35/1.2x0.9m RCBC	30	5%	0.36	0.54	0.50	No
27.06	10/1.2m RCP	15	10%	0.32	0.35	0.50	Yes

6.1.2 Bridge crossings

It is noted that the RFI only requests consideration of the culvert structures along the proposed NS2B alignment, however we have extended this to include a review of the velocities at the rail corridor boundary for the eleven proposed bridges.

Table 4 presents a summary of peak velocities at the rail corridor boundary for the proposed bridge crossing locations for the Existing Case and the Reference Design as presented in the EIS.

Table 4 shows the following:

- Peak velocities for the Existing case and where these velocities are above 0.5 m/s (yellow highlight),
- Peak velocities for the Reference Design case, and
- Assessment of compliance with the scour/erosion QDL for the critical event (1% AEP or 1976 flow scenario with BRVFMP levees).

Table 4 shows that several bridge locations have existing velocities above 0.5 m/s as would be expected as many of these bridges cross existing significant waterways. Review of Table 4 shows that there are four Reference Design bridges where the velocities at the rail corridor boundary do not meet the QDL.

To demonstrate that engineered mitigation measures could be applied to meet the QDL, mitigation measures at two of these bridge locations have been modelled and this is detailed in the following sections. This mitigation assessment has been undertaken for BR06 (floodplain flows) and BR03 (Back Creek).

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Level 8, 540 Wickham Street, Fortitude Valley QLD 4006
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Table 4 Review of bridge velocities at rail corridor boundary – Reference Design

Chainage (km)	Event	Structure details	Approximate bridge length (m)	Existing d/s peak velocity at rail boundary (m/s)	Reference Design d/s peak velocity at rail boundary (m/s)	QDL velocity limit (m/s)	Compliant with QDL?
5.76	1% AEP	Bridge (BR01) Mobbindry Creek	111	0.87	0.77	0.96	Yes
6.23	1% AEP	Bridge (BR02) Mobbindry Creek	182	0.64	0.72	0.70	Very close
8.11	1% AEP	Bridge (BR03) Back Creek	70	1.01	1.26	1.11	No
16.29	1% AEP	Bridge (BR04) Forest Creek	154	0.36	0.49	0.50	Yes
20.73	1976 flows	Bridge (BR05) Strayleaves Creek	137	0.60	1.0	0.66	No
25.34	1976 flows	Bridge (BR06)	160	0.60	0.87	0.66	No
25.80	1976 flows	Bridge (BR07)	114	0.44	0.76	0.50	No
26.09	1976 flows	Bridge (BR08)	183	0.34	0.51	0.50	Very close
27.56	1976 flows	Bridge (BR09)	126	0.76	0.80	0.84	Yes
28.03	1976 flows	Bridge (BR10)	126	0.44	0.54	0.50	Yes
30.35	1976 flows	Bridge (BR11) Mac River	1748	3.17	3.11	3.49	Yes

6.2 Mitigation assessment

Where the detailed modelling indicates it may be required, a range of engineered mitigation solutions could be considered including:

- Splitting and spreading out larger culvert banks to into smaller groups
- Additional culvert capacity or bridge length, and/or
- Inclusion of rock as scour protection and velocity reduction mechanisms downstream of culverts.

In future stages of design advice from an experienced geomorphologist would assist in refining the overall design including consideration of scour protection measures such as low profile bed sills, large wood structures, enhanced vegetation or the use downstream baffles or dissipators (noting the effectiveness of this approach depends on the tailwater level and/or head loss across the structure).

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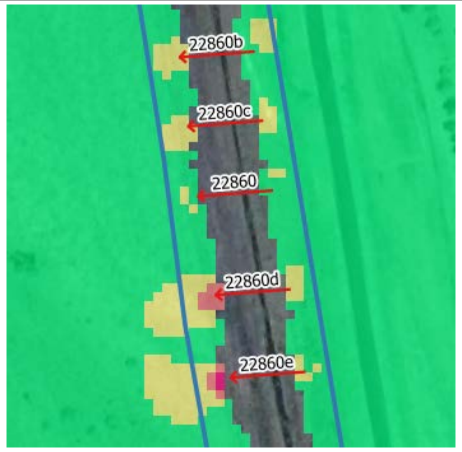
6.2.1 Culvert mitigation assessment

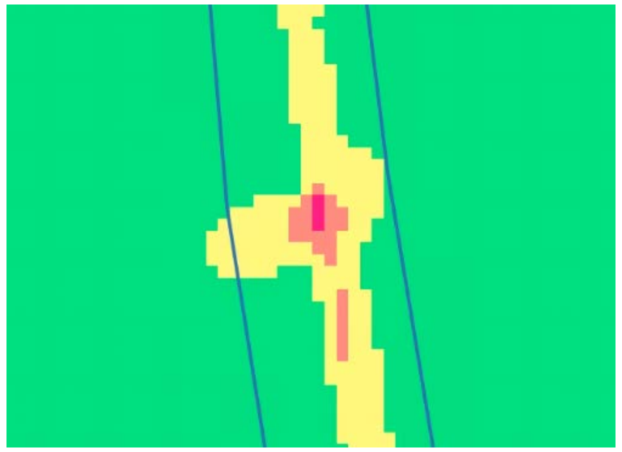
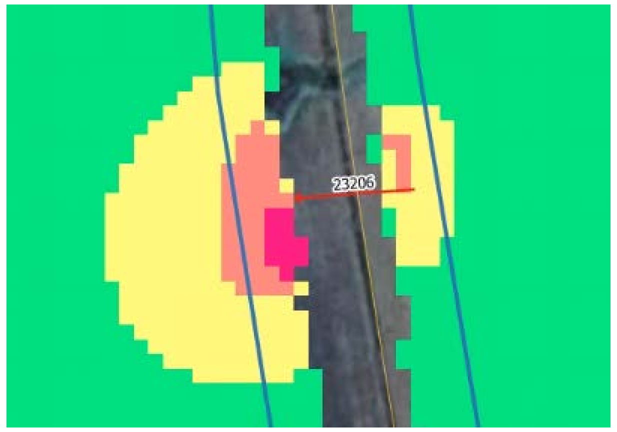
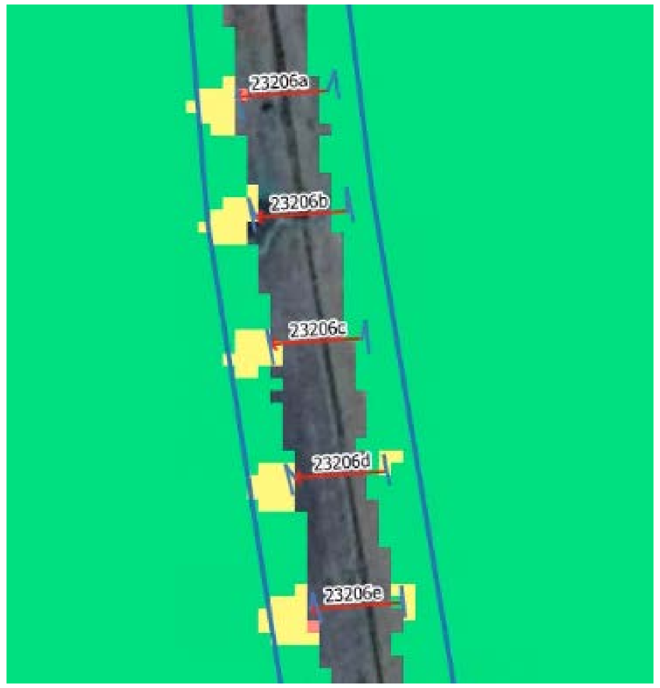
Based on the results in Table 3, the two culvert bank locations that did not comply with the QDL have been assessed with a range of engineering mitigation options tested as presented in Table 5.

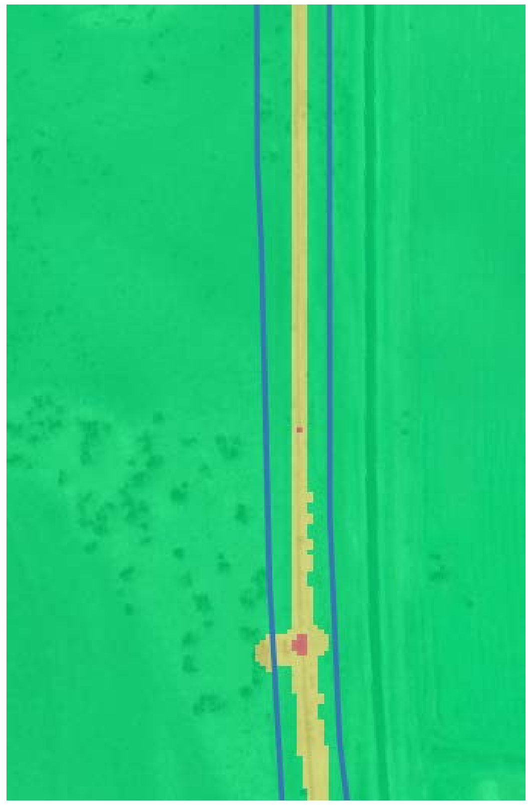
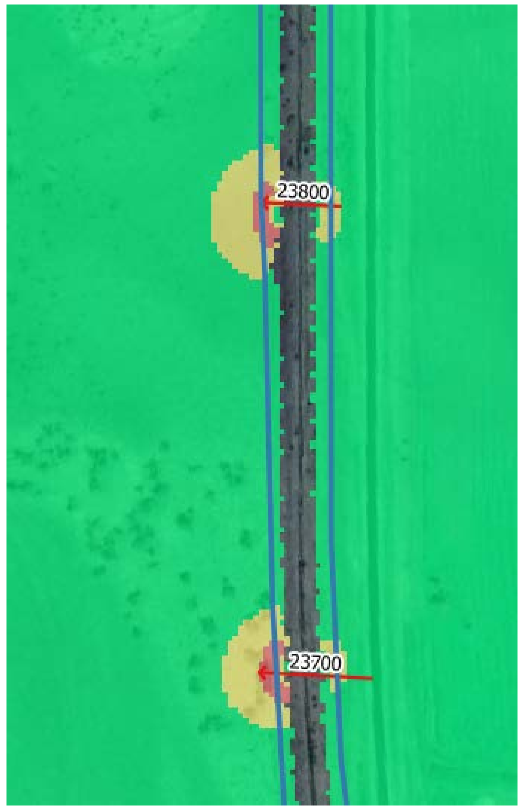
The outcomes presented in Table 5 show that spacing of the culvert banks and minor additional culverts will ensure the design meets the scour/erosion QDL.

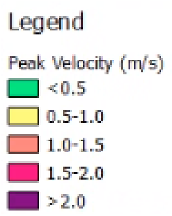
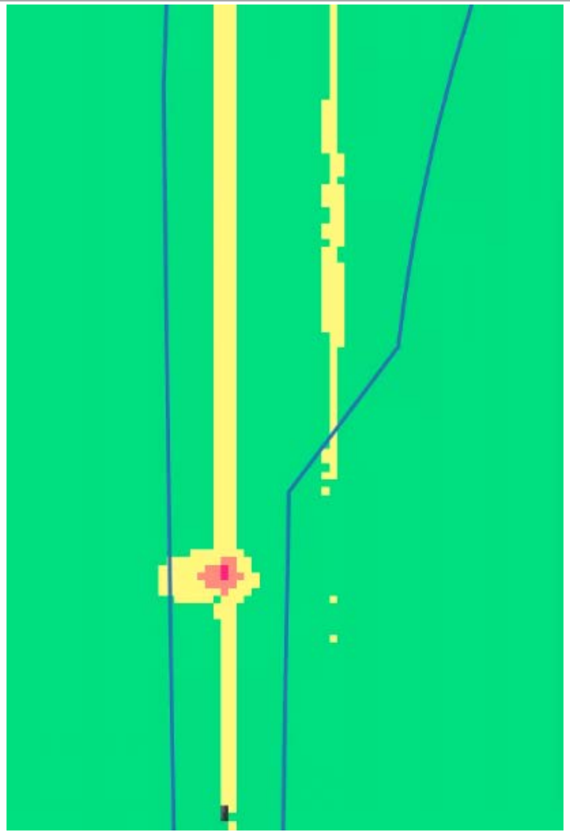
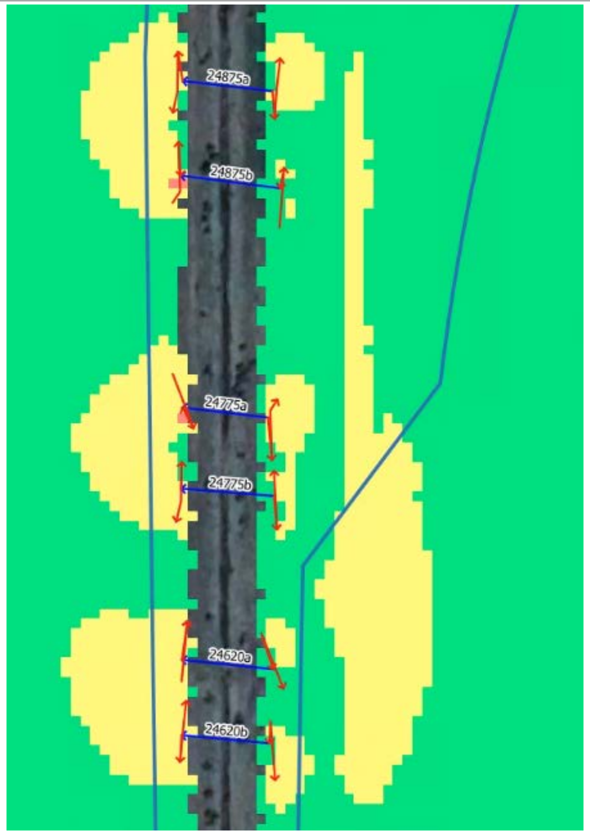
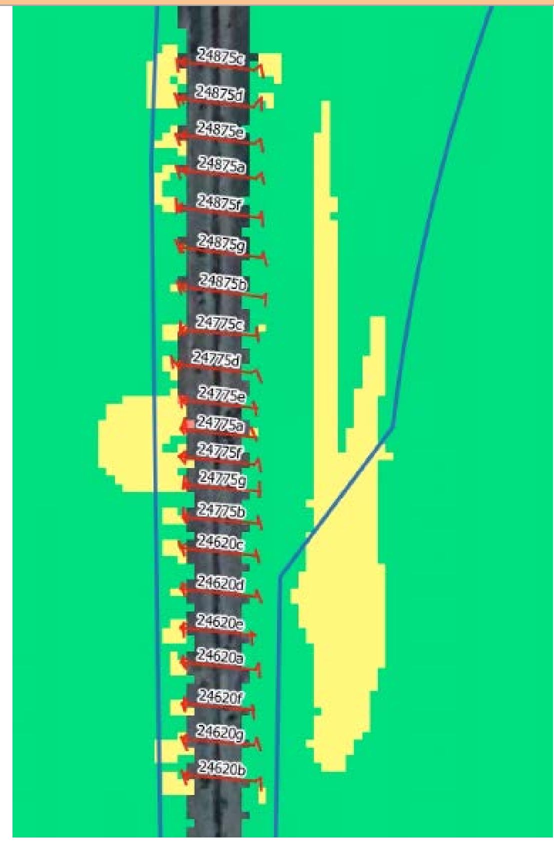
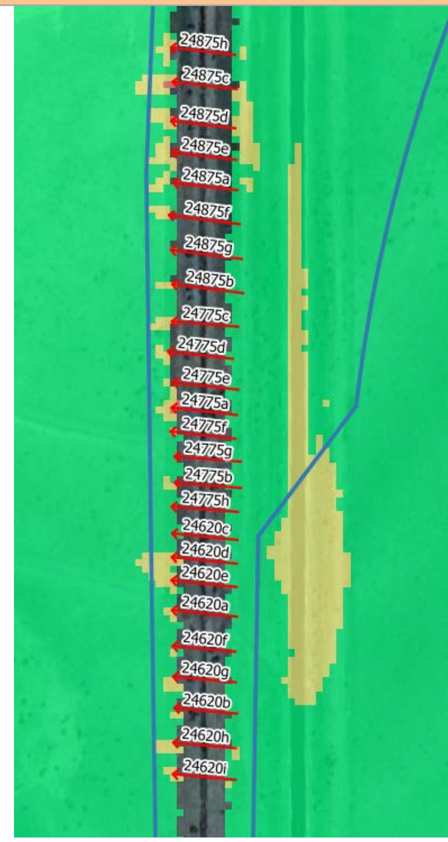
It should be noted that the embankment width currently shown for these culverts includes a passing loop and the actual embankment will be narrower with the impacts therefore all contained within the rail corridor boundary.

Table 5 Velocity results for culvert locations – scenarios assessed

Scenario	Existing Case – 1976 flow scenario	Reference Design – 1976 flow scenario 25/1.2m RCPs in one bank	Mitigation Option #1 ▪ C22.86 a,b,c – 5/1.2m RCPs ▪ C22.86 d,e – 7/1.2m RCPs	Mitigation Option #2 ▪ C22.86 e,d,g,h,I,j – 2/1.2m RCPs ▪ C22.86 a,c,f – 4/1.2m RCPs C23.20 b – 5/1.2m RCPs
Chainage 22.86km Legend Peak Velocity (m/s) <0.5 0.5-1.0 1.0-1.5 1.5-2.0 >2.0				

Scenario	Existing Case – 1976 flow scenario	Reference Design – 1976 flow scenario 25/1.2m RCPs in one bank	Mitigation Option #1 5 banks of 5/1.2m RCPs at 31m spacing	Mitigation Option #2 ▪ C23.20 a,b – 4/1.2m RCPs ▪ C23.20 c – 3/1.2m RCPs ▪ C23.20 d,e,f,g,h,i,j – 2/1.2m RCPs
Chainage 23.20km Legend Peak Velocity (m/s) <0.5 0.5-1.0 1.0-1.5 1.5-2.0 >2.0				

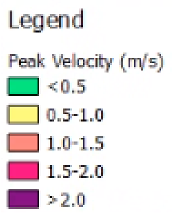
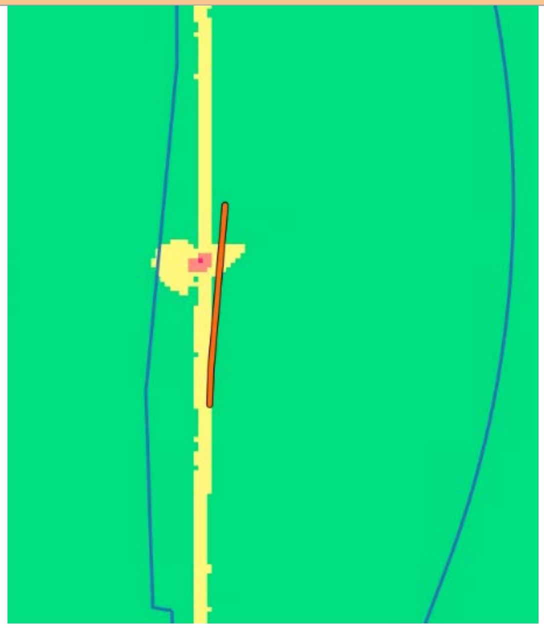
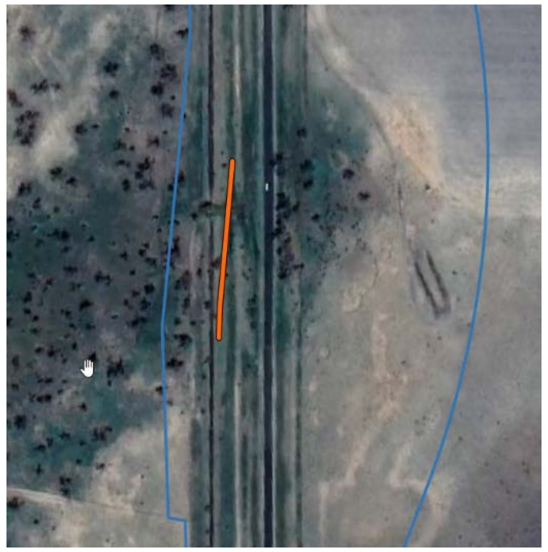
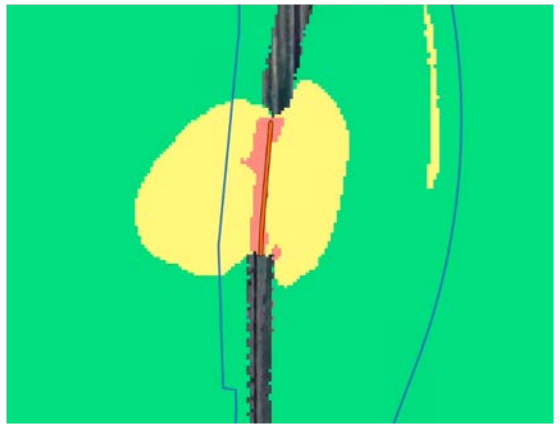
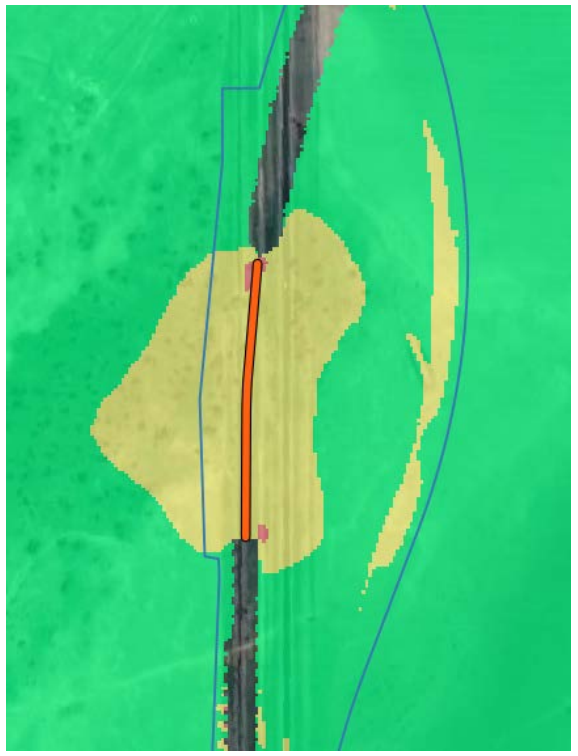
Scenario	Existing Case – 1976 flow scenario	Reference Design – 1976 flow scenario 25/1.2m RCPs in one bank	Mitigation Option #1 - C23.70 a,b,c,d,e – 6/1.2m RCPs - C23.80 a,b,c,d,e – 6/1.2m RCPs	Mitigation Option #2 - C23.70 a,b,c,d,f,h,i,j,k,l,o,n – 2/1.2m RCPs - C23.80 a,b,c,d,e,g,h,I,j – 3/1.2m RCPs
Chainage 23.70km and 23.80km Legend Peak Velocity (m/s) <0.5 0.5-1.0 1.0-1.5 1.5-2.0 >2.0				

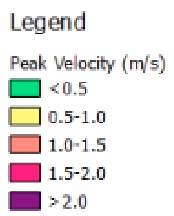
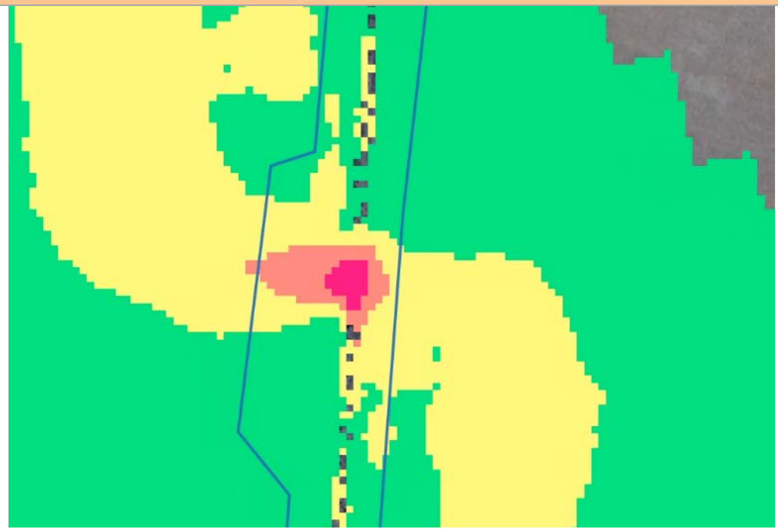
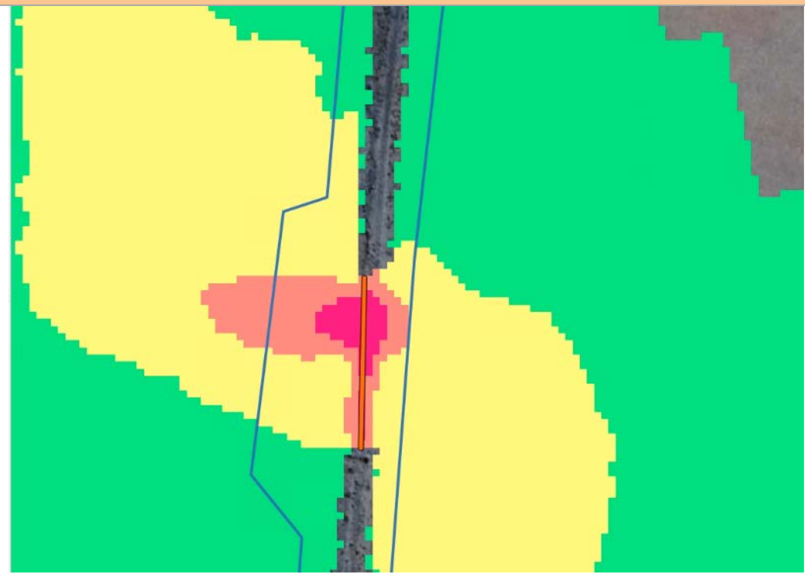
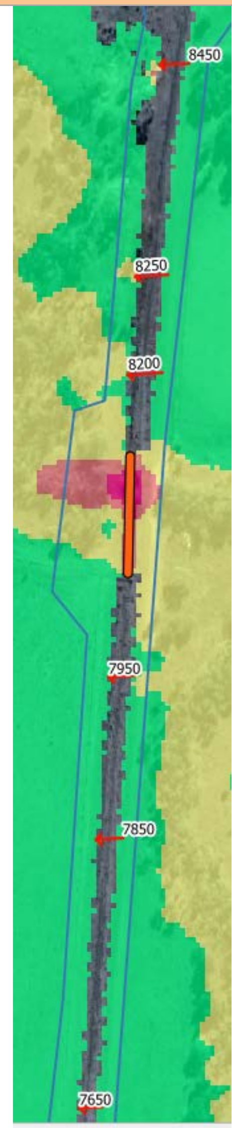
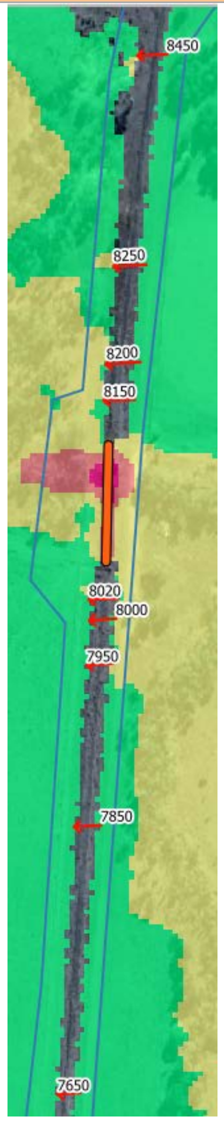
Scenario	Existing Case – 1976 flow scenario	Reference Design – 1976 flow scenario	Mitigation Option #1	Mitigation Option #2
		▪ C24.62 – 35/1.2 x 0.9 RCBCs ▪ C24.71 – 35/1.2 x 0.9 RCBCs ▪ C24.85 – 35/1.2 x 0.9 RCBCs	Each bank of 35 culverts split into 7 banks of 5/1.2 x 0.9 RCBCs with 11m spacing	▪ C24.62 a,b,c,d,e,f,g,h,i – 4/1.2 x 0.9 RCBCs ▪ C24.71 b,c,d – 5/1.2 x 0.9 RCBCs ▪ C24.71 a,e,f,g – 3/1.2 x 0.9 RCBCs ▪ C24.71 h – 4/1.2 x 0.9 RCBCs ▪ C24.85 a,b,c,d,e,f,g,h – 5/1.2 x 0.9 RCBCs
Chainage 24.6km to 24.9km 				

6.2.2 Bridge mitigation assessment

As discussed in Section 6.1.2, two example bridge locations have been selected with mitigation options tested as presented in Table 6. BR06 was selected to represent a bridge structure that conveys floodplain overbank flows whilst BR03 was selected to represent a bridge located on a dedicated waterway.

Table 6 Velocity results for select bridge locations – scenarios assessed

Scenario	Existing Case – 1976 flow scenario	Reference Design	Mitigation Option #1 Extend bridge 40m to the south (length 200m)	Mitigation Option #2 Extend bridge 140m to the south (length 300m)
Ch 25.34km – BR06 	 	1976 flow event  1% AEP event 	1976 flow event 	1976 flow event 

Scenario	Existing Case – 1% AEP event	Reference Design	Mitigation Option #1 3 culvert banks added to the north and 3 culvert banks added to the south of the bridge (each bank consists of 3/1.05m RCPs)	Mitigation Option #2 4 culvert banks added to the north and 5 culvert banks added to the south of the bridge (each bank consists of 3/1.05m RCPs)
Ch 8.11km – BR03 – Back Creek 	 			

Future Freight Joint Venture
Level 8, 540 Wickham Street, Fortitude Valley QLD 4006
PO Box 1307 Fortitude Valley QLD 4006

T +61 7 3553 2000
F +61 7 3553 2050

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6.2.3 Summary of mitigated structures

6.2.3.1 Culverts

The outcomes of the mitigation measures that have been applied to the Reference Design culverts are summarised in Table 7.

Table 7 Review of culvert velocities at rail corridor boundary – Mitigated Reference Design

Chainage (km)	Culvert details[b]	Approx culvert length (m)	Approx AEP at which floodplain flows start	Existing d/s peak velocity at rail boundary (m/s)	Mitigated Design d/s peak velocity at rail boundary (m/s)	QDL velocity limit (m/s)	Compliant with QDL?
22.86	4/1.2m RCP 5/1.2m RCP 4/1.2m RCP 4/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP	14	2%	0.34	0.52	0.50	Yes[a]
23.20	2/1.2m RCP 2/1.2m RCP 4/1.2m RCP 4/1.2m RCP 2/1.2m RCP 3/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP	15	2%	0.57	0.48	0.63	Yes
23.70	2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP 2/1.2m RCP	15	2%	0.59	0.56	0.65	Yes
23.80	3/1.2m RCP 3/1.2m RCP 3/1.2m RCP 3/1.2m RCP 3/1.2m RCP 3/1.2m RCP 3/1.2m RCP 3/1.2m RCP 3/1.2m RCP	15	2%	0.35	0.66	0.50	Yes[a]

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Chainage (km)	Culvert details[b]	Approx culvert length (m)	Approx AEP at which floodplain flows start	Existing d/s peak velocity at rail boundary (m/s)	Mitigated Design d/s peak velocity at rail boundary (m/s)	QDL velocity limit (m/s)	Compliant with QDL?
	3/1.2m RCP						
24.62	4/1.2x0.9m RCBC 4/1.2x0.9m RCBC 4/1.2x0.9m RCBC 4/1.2x0.9m RCBC 4/1.2x0.9m RCBC 4/1.2x0.9m RCBC 4/1.2x0.9m RCBC 4/1.2x0.9m RCBC 4/1.2x0.9m RCBC	18	5%	0.64	0.54	0.70	Yes
24.71	5/1.2x0.9m RCBC 5/1.2x0.9m RCBC 3/1.2x0.9m RCBC 3/1.2x0.9m RCBC 3/1.2x0.9m RCBC 3/1.2x0.9m RCBC 5/1.2x0.9m RCBC 4/1.2x0.9m RCBC	22	5%	0.34	0.49	0.50	Yes
24.85	5/1.2x0.9m RCBC 5/1.2x0.9m RCBC 5/1.2x0.9m RCBC 5/1.2x0.9m RCBC 5/1.2x0.9m RCBC 5/1.2x0.9m RCBC 5/1.2x0.9m RCBC 5/1.2x0.9m RCBC	30	5%	0.36	0.61	0.50	Yes[a]

[a] Reference design embankment wider than now proposed, residual impact would be mitigated with the reduction in embankment width.

[b] Spread of culverts as shown in Table 5.

6.2.3.2 Bridges

Table 8 presents the outcomes of the mitigation assessment at BR06 (main floodplain) and BR03 (Back Creek). With the adoption of the wider bridge at BR06 and the additional culverts at BR03 the peak velocities comply with the QDL and show that engineering mitigation solutions can be applied to achieve the QDL. As the design progresses and field survey and soil information is obtained this design will be reassessed to take account of this information.

The demonstration of application of engineering mitigation measures at these locations confirms that the same approach could be applied at the remaining bridge structures that do not currently comply with the QDL.

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Table 8 Review of bridge velocities at rail corridor boundary – Mitigated Reference Design

Chainage (km)	Structure details	Approximate bridge length (m)	Existing d/s peak velocity at rail boundary (m/s)	Mitigated Design d/s peak velocity at rail boundary (m/s)	QDL velocity limit (m/s)	Compliant with QDL?
8.11	Bridge (BR03) Back Creek plus 9 banks of 3/1.05m RCP	70	1.01	1.11	1.11	Yes
25.34	Bridge (BR06)	300	0.60	0.66	0.66	Yes

6.2.4 Afflux results

Figure 6 presents the 1976 flow scenario afflux for the Reference Design and Figure 7 present the updated afflux for the Mitigated Design as detailed in Section 6.2.3.

As can be seen with the mitigation measures in place there is a slight reduction in the afflux upstream of the alignment. The overall afflux pattern does not significantly alter.

Figure 6 Afflux Map for Reference Design (SM1)

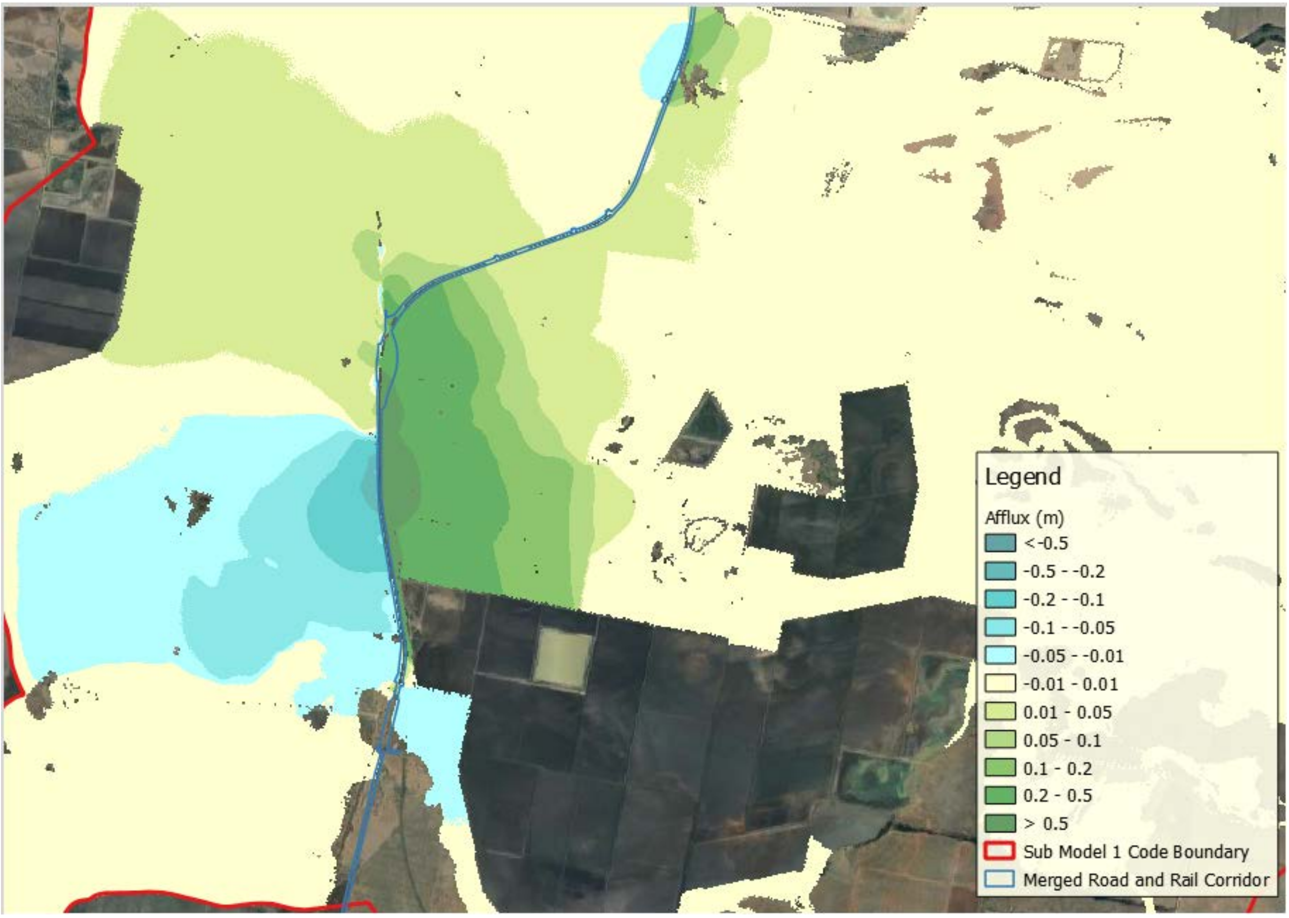

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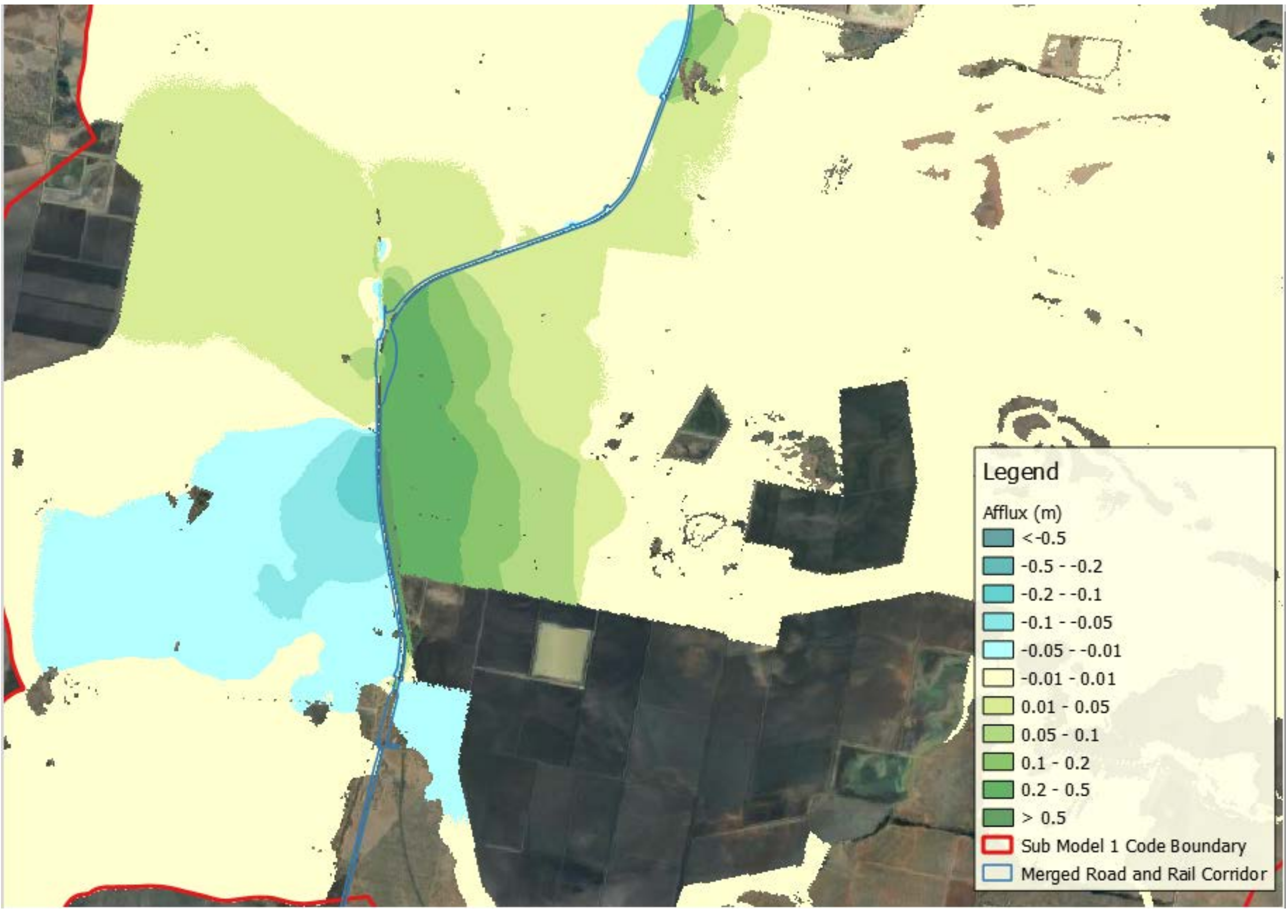
Figure 7 Afflux Map for Mitigated Design (SM1)



7 Conclusions

The Major RFI has requested the following items. A summary of responses is provided against each item:

- Modelling of velocities through culverts by using a finer grid scale model such as a conventional TUFLOW grid not larger than 2m or the Quadtree enhancement with a sufficient number of subdivisions;
  - Modelling using a 3.75m grid spacing (Quadtree level 4) within the rail corridor boundary and upstream/downstream of the corridor for 10 m has been carried out. The 3.75m spacing is consistent with the TUFLOW manual recommendations and provides good representation of velocities as flow exits the drainage structures and approaches and passes the rail corridor boundary.
  - Given the project is currently at Reference Design stage, it would be considered reasonable that the assessment adopted a cell size that is both suitable for the nature of the flow paths being represented, the perceived risk of impact and the ability of the modelling to demonstrate the application of mitigation measures. As such, the adopted 3.75m grid spacing provides both a high level of understanding with regards to the potential impacts considering the maturity of the Reference Design and the fact that the design will be refined further using local field survey and soil details in the next stages of design.

Future Freight Joint Venture
Level 8, 540 Wickham Street, Fortitude Valley QLD 4006
PO Box 1307 Fortitude Valley QLD 4006

T +61 7 3553 2000
F +61 7 3553 2050

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- Identifying areas of non-compliance with the N2NS scour/erosion potential QDL;
  - Table 3 and Table 4 present an assessment of the culvert and bridge velocities at the rail corridor boundary against the scour/erosion QDL. The last column in each table identifies areas which do not currently comply with the QDL. This includes two of the main groups of culvert banks on the floodplain and four of the eleven proposed bridges. For the purposes of this Technical Note, further assessment has been undertaken on the more stringent QDL currently under discussion with ARTC and DPIE.
- Proposed mitigation measures to meet the QDLs at the boundary of the project;
  - Potential engineering mitigation measures are discussed in Section 6.2. Assessment of mitigation measures has been undertaken for the Reference Design culvert locations that did not comply with the scour/erosion QDL with Table 5 presenting the options consider and the resulting velocity distributions.
  - Table 6 presents the assessment that has been undertaken for two representative bridge locations to show that engineered mitigation measure can also be applied for bridges.
  - Other mitigation measures, including soil investigation and energy dissipation have not been included in this Technical Note, but would be investigated in future stages.
- Identifying residual impacts that would require erosion protection measures on adjoining properties.
  - Table 7 presents a summary of the performance of the mitigated culverts against the scour/erosion QDL and this demonstrates that there are no residual impacts outside the limits of the QDL.
  - Table 8 presents a summary of the performance of the mitigated bridges and shows that application of engineering mitigation measures at these two bridge locations confirms that the same approach could be applied at the remaining bridge structures that do not currently comply with the QDL.

As required by the DPIE RFI, detailed modelling has been undertaken along the rail corridor through the development of two hydraulic sub-models and application of the TUFLOW Quadtree tool to refine the grid spacing to 3.75m. This grid spacing has enabled demonstration of the applied of engineering mitigation measures than can achieve the requirements of the nominated scour/erosion potential QDL.