

APPENDIX H

Geomorphology Report

Part 1 of 2

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

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Abbreviations

Abbreviation	Description
AEP	Annual Exceedance Probability
ARTC	Australian Rail Track Corporation
ASC	Australian Soil Classification
B2G	The Border to Gowrie Project
CC	Canning Creek
CG	The Queensland Coordinator-General
Ch	chainage
cm	centimetres
DEM	Digital Elevation Model
DS	Downstream
DTMR	Department of Transport and Main Roads
EIS	Environmental Impact Statement
EP	erosion potential
ETV	Erosion threshold velocities
FFJV	Future Freight Joint Venture
ha	hectares
kg/cm ²	kilograms per square centimetres
km	kilometres
km	square kilometres
kPa	kilopascal
m	metres
m AHD	metres above Australian Height Datum
m/s	metres per second
m ³ /s	cubic metres per second
MB	Macintyre Brook
MR	Macintyre River
NC	North Condamine
NS2B	North Star to Border
NSW	New South Wales
OC	Oakey Creek
QLD	Queensland
QR	Queensland Rail
QSpatial	Queensland Spatial Catalogue
SC	South Condamine (Back Creek)
SMU	Soil Management Unit
TRC	Toowoomba Regional Council
ULS	Ultimate Limit State
US	upstream
W/m ²	watts per square metre

Glossary

Term	Description
Developed Case	Hydraulic modelling case with Project in place
Permanent footprint	The permanent Project footprint has been established to encompass all permanent infrastructure required for the Project. Permanent infrastructure features include the new rail track, bridges and drainage structures, level crossings, road realignments, possible upgrades to adjacent roads and infrastructure, rail maintenance access roads, fencing and signage.
Construction (Project) footprint	The Project footprint includes the rail corridor and other permanent works associated with the Project (e.g. where changes to the road network are required) as well as the construction footprint where only temporary disturbance is proposed (e.g. laydown areas, compound sites, borrow pits and Whetstone material distribution centre). These particular construction facilities and activities are discussed in EIS Appendix AD: Borrow Pits: Supporting Technical Information and EIS Appendix AE: Whetstone Material Distribution Centre: Supporting Technical Information.
Existing Case	Hydraulic modelling case pre-Project (i.e. existing conditions)
The Project	The NSW/Queensland Border to Gowrie Project
Watercourse	The term 'watercourse' used in this document refers to any natural fluvial geomorphic drainage feature and is not a reference to 'watercourse' as defined in the <i>Water Act 2000</i> .

1 Introduction

The Queensland Office of the Coordinator-General have requested that a fluvial geomorphology assessment be undertaken as an additional information requirement for the Inland Rail – New South Wales (NSW)/Queensland (QLD) Border to Gowrie Project (the Project) to support the Revised draft Environmental Impact Statement (EIS). This document was prepared by Future Freight Joint Venture (FFJV) on behalf of the Australian Rail Track Corporation (ARTC) and sets out the methodology and assessment outcomes to meet the Office of the Coordinator-General fluvial geomorphology assessment requirements.

1.1 Project summary

The Project starts at the NSW/QLD Border at the median line of the Macintyre River, approximately 18 kilometres (km) to the south-east of Goondiwindi, near Kurumbul. The Project ends in Gowrie, before the Inland Rail connection to Queensland Rail's (QR) West Moreton Line on the south-eastern outskirts of Kingsthorpe. The Project comprises 217.48 km of new single-track railway, approximately 149.48 km of which is new rail corridor (greenfield) and 68.00 km of which is upgraded track (brownfield).

The Project design used in this assessment is the revised reference design that supports the Revised draft EIS. A summary of changes to the reference design (from the draft EIS) that stem from the additional information requests of the Coordinator-General which include specific temporary and permanent infrastructure changes, mitigation measures and strategies as part of the revised reference design; which is to be further developed in detailed design. Summary of design changes since the draft EIS is in EIS Chapter 5: Project Description and EIS Appendix B3: Changes to the reference design since draft EIS. For this Project, the rail alignment commences at the NSW/QLD Border (the median point of the Macintyre River), marked as chainage (Ch) 30.60 km (North Star to Border (NS2B)). Chainages increase in a northerly direction along the alignment to Ch 39.86 km (NS2B) within the South-Western Line rail corridor. From this point, standard gauge has fully transitioned to dual gauge rail, chainage coverts to Ch 0 km, and continues to increase in a northerly direction to Ch 208.20 km at the northern-most point of the Project.

For clarity, in this EIS, chainages south of the zero-point within the South-Western Line rail corridor are presented with the suffix '(NS2B)'. Chainages north of this point are presented without the suffix. For example, Ch 38.00 km (NS2B) and Ch 38.00 km relate to two different locations along the Project alignment (Figure 1.1).

The Project alignment crosses two major river basins, the Condamine River basin and the Border Rivers basin. Eighteen (18) defined watercourses are located along the Project alignment, as well as numerous smaller (undefined) watercourses; definition of the term watercourse for this assessment is in Section 1.2.

1.1.1 Project alignment design components

Details of the Project are contained in EIS Chapter 5: Project Description. The revised reference design comprises 149.48 km new rail corridor and 68 km existing rail corridor (Table 1.1).

Table 1.1 Chainage ranges of greenfield and brownfield sections of rail corridor

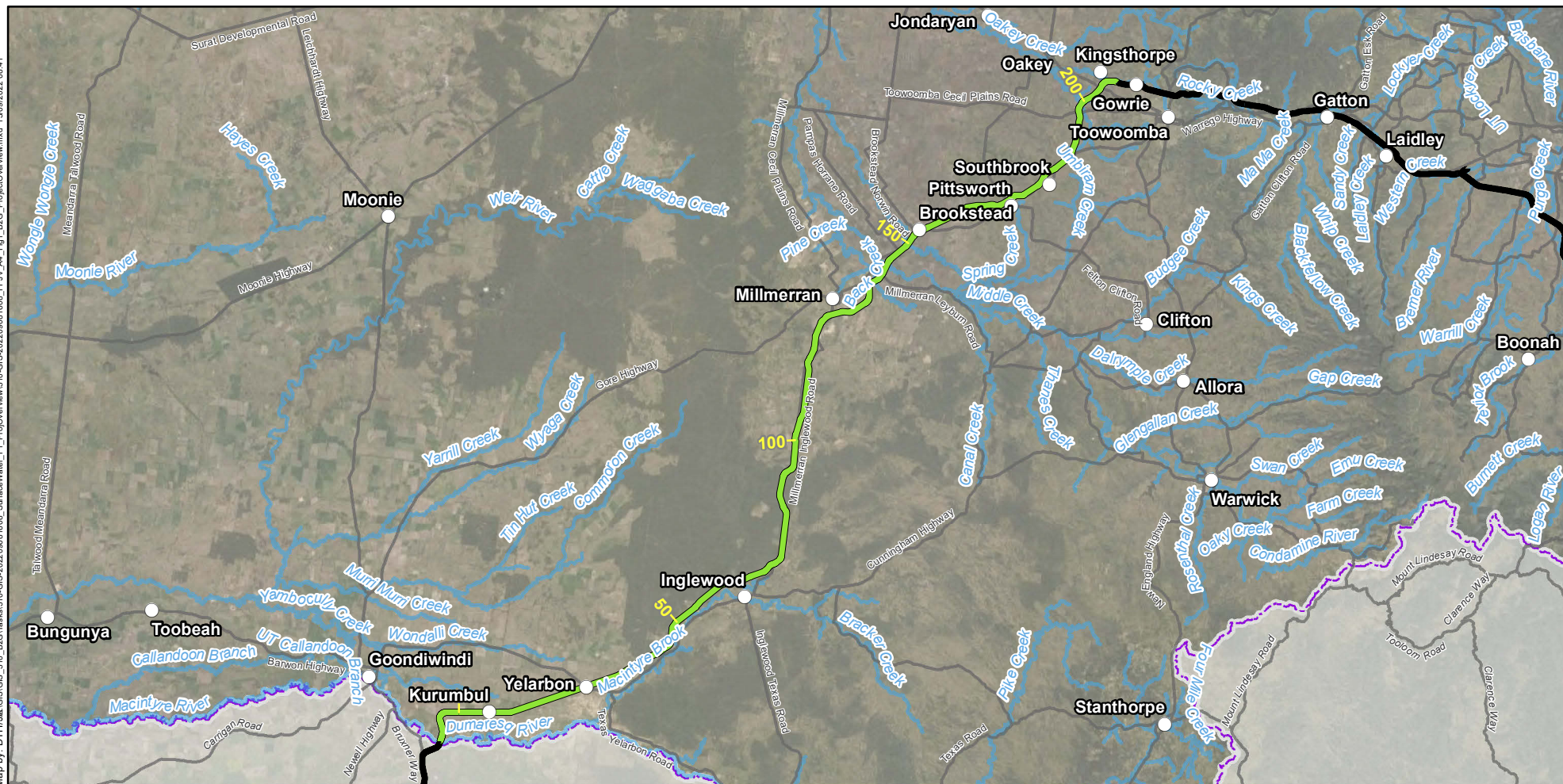
Chainage from (km)	Chainage to (km)	Length (km)	Greenfield/brownfield
30.60 (NS2B)	37.60 (NS2B)	7.00	Greenfield
7.00	44.54	46.80	Brownfield – QR South Western Line
44.54	140.0	95.45	Greenfield
140.00	152.00	12.00	Brownfield – QR Millmerran Branch Line
152.00	154.66	2.66	Greenfield
154.66	163.86	9.20	Brownfield – QR Millmerran Branch Line
163.86	208.22	44.37	Greenfield

The brownfield sections northeast and southwest of Brookstead (the latter crossing the Condamine River floodplain) follow part of the now abandoned Pittsworth – Millmerran section of the Southwest Rail Line that was opened on 18 October 1911. The Millmerran Branch Line is currently non-operational south of Brookstead as a result of damage sustained in the 2010/2011 flood events. These sections of existing rail provide useful information on over 100 years of fluvial geomorphic performance of infrastructure such as bridges and culverts that can be used to inform detailed design.

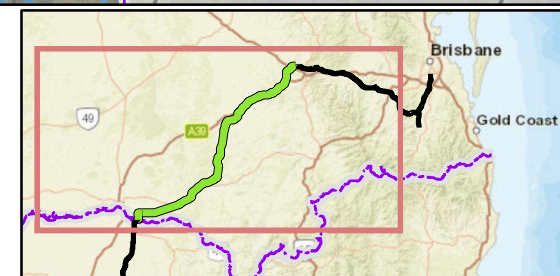
The revised reference design comprises the following:

- 37 bridge crossings, (Table B1 in Appendix B for details) including:
 - 18 watercourse bridges
 - 14 road bridges
 - 5 rail bridges
- Approximately 337 culvert sites with a total of 3,128 cells of reinforced concrete pipe and/or reinforced concrete box culverts.
- Two permanent diversion structures, (Table B2 in Appendix B) that divert two drainage features:
 - The two drainage features are defined as waterways under the *Fisheries Act 1994* (Qld), and not recognised under the *Water Act 2000* (Qld) (Water Act)
 - All diverted streams flow into downstream channels within the same catchments.
- Earthworks comprising cuttings, embankments and fill
- Two non-resident workforce accommodation sites are within the Project footprint, one near Yelarbon and the other near Inglewood. EIS Chapter 5: Project Description discusses the non-resident workforce accommodation facilities in further detail.
- One construction facility at Turallin, which intersects a drainage feature under the Water Act and does not require a permanent diversion.

Map by: DTH/UA/GIS/GIS_310_B2G/Tasks/310-GIS-2022/08/16/08_SurfaceWater_F1_ProjOverview/310-GIS-2022/08/16/08_FF_V4_A4_Fig1_B2G_ProjOverview.mxd 15/09/2022 08:41



- Project alignment with chainage (km)
- Adjoining alignments
- Major roads
- Watercourses
- - - QLD / NSW state border



A4 scale: 1:1,200,000
0 10 20 30 40 50 km

1.2 Objectives

The principal objective of this fluvial geomorphology assessment was to undertake an assessment of potential impacts to fluvial processes at watercourse¹ and floodplain crossing sites. Important fluvial geomorphic processes include sediment transport, erosion, deposition, channel and floodplain connectivity and floodplain landforms, changes to these may impact ecosystem stability along the Project alignment. This assessment was required to:

- Identify and describe existing watercourses and floodplains
- Identify potential risks to watercourses and floodplains posed by the Project
- Identify further work requirements and inform mitigation and management measures relevant to future project stages to maintain Existing Case geomorphological processes where practical or minimise change to allow the processes to continue to function into the future.

Importance of allowing processes to continue:

- The Project will occur in an environment that has always changed and will continue to change as it is a naturally dynamic fluvial environment and change is expected due to geomorphic processes.
 - Furthermore, changes to the existing fluvial geomorphic processes can result in upstream and downstream impacts that extend outside of the Project footprint.
- This assessment considers all geomorphic processes. However, it is not an assessment of erosion threshold velocity (ETV). Erosion threshold velocity aims to inform and guide erosion protection strategies for the Project. These strategies will reduce a watercourse's ability to transport its own sediment, leading to aggradation and reduced flood capacity.
- There may be opportunities to enhance the geomorphic environment, while taking into account:
 - Remediation of watercourses and floodplains requires a catchment wide, or at least sub-reach approach, which is outside the Project's influence and control, thus
 - Local opportunities for enhancement of the fluvial geomorphic environment within the Project footprint beyond those already in the revised reference design have been identified.

1.3 Scope

The scope of works to prepare the geomorphology assessment report included:

- Baseline assessment including a description of the existing fluvial geomorphic processes within, upstream and downstream of proposed watercourse crossings and floodplains
- Desktop assessment of the potential changes to channel characteristics as a result of the Project, including any proposed drainage diversions
- Field work assessment of representative locations as identified through the desktop assessment
- Risk assessment of alterations to geomorphic processes, including cumulative impacts, from Project infrastructure including local drainage culverts within watercourses and provide suitable mitigation and management measures
- Detailed assessment of potential changes of high-risk sites

¹ The term 'watercourse' used in this document refers to any natural fluvial geomorphic drainage feature (waterways/watercourses) and is not a reference to 'watercourse' as defined in the *Water Act 2000*.

The following additional detailed assessment will be completed as part of the geomorphology assessment scope prior to final EIS approvals:

- Supplementary testing using direct methods (flume testing), additional assessment and subsequent ETV determination based on revised results is currently underway at a number of potentially high-risk sites including on floodplains and overland flow paths
- Relevant mitigations including those relating to erosion treatment options within and external to the corridor will be reviewed and revised as necessary based on the updated analysis.

1.3.1 Overlap with flooding and hydrology

The hydrology and flooding (EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1) and geomorphological assessments undertaken as part of the revised draft EIS both overlap and have distinct differences.

In broad terms:

- The geomorphological assessment provides an overview of long-term trends occurring within waterways both naturally and in response to imposed change (e.g. catchment changes, floodplains works including, but not limited to the Project, etc.)
- The hydrologic/hydraulic assessment describes in very high levels of detail the hydraulic conditions (flow, speed, depth, etc.) over the length of the alignment for specific flood events and enables both structure design and flood mitigation works to be undertaken.

Hydrology and flooding have developed existing and design case hydraulic models and assessed potential changes due to the project against the Flood Impact Objectives (FIOs) for all flow within the 1% AEP extent. While the hydraulic models are fundamental design and assessment tools, they have no ability to model changes to the physical processes of waterways (erosion/deposition) in response to construction activities during the events modelled. Similarly, they are not used to assess potential changes associated with periods of low flow.

To assess the potential physical change in waterways as a result of background processes and works, it is necessary to undertake both geomorphological assessments and hydrologic/hydraulic assessments. More specifically, the geomorphology assessment is focused on fluvial geomorphic landforms where fluvial processes are occurring, watercourses with channels (Section 3.3.1.3) and geomorphic floodplains.

Whereas the geomorphology assessment was undertaken on landforms Key geomorphic processes include sediment transport (erosion and deposition), channel planform change and channel type change, as well as floodplain connectivity.

Overland flow pathways and very small watercourse headwaters (catchments less than 10 hectares (ha)) with no defined channels have not been assessed under geomorphology as these flow paths have no evidence of active fluvial geomorphic processes occurring. Very small watercourse headwaters (catchments less than 10 ha) with no channels have been classified and documented in the Geomorphology baseline assessment to identify the locations of these drainage features.

The FIO parameters are reproduced in Section 1.3.1.1 and include considerably more than a standard flooding assessment. The main potential impact of the Project on non-channelised flow is flow concentration potentially resulting in the development of erosion channels or gullies. The following FIOs are suitable for assessing this potential impact:

- Flood flow distribution - Aim to minimise changes in natural flow patterns and minimise changes to flood-flow distribution across floodplain areas.
- Velocities – Aim to minimise change in velocities where practical or minimise increases in velocities.

Soil types at cross drainage infrastructure have been taken into consideration in the revised reference design in regard to scour protection (EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1 (Appendix B)) for the cross drainage register with soil type and scour mitigation). As these channels have no evidence of sediment transport, deposition is not considered a potential impact.

Any exceedances in FIOs were noted and mitigation options identified within EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1. The mitigations were reviewed by a geomorphologist. Additional hydraulic modelling, detailed survey, soils testing and vegetation information will be gathered to inform detailed design. Further refinement and confirmation of site-specific mitigation measures will be undertaken during future detailed design, construction works and operations stages (Section 5.2).

1.3.1.1 Flood Impact Objectives

The nominated FIOs, as detailed in Table 1.2, have been developed to provide guidance as to the point at which a more detailed consideration of impacts is required when they are exceeded. The Project will target achieving the FIOs for events up to and including the 1% AEP (without climate change) for land, receptors, and/or infrastructure that is potentially impacted by the Project. Where it is not practicable or feasible to achieve the FIOs at flood sensitive receptors and/or the nominated land uses, acceptable impacts and/or appropriate mitigation measures will be determined on a case-by-case basis, including through consultation with stakeholders and landholders.

Table 1.2 Flood Impact Objectives

Parameter	Objectives					
Change in peak water levels (afflux) ¹	Existing habitable ² and/or commercial and industrial buildings/premises (e.g. dwellings, schools, hospitals, shops) and sensitive infrastructure ³	Yards or gardens of residential or commercial/ industrial properties/lots (excluding habitable ² dwellings/ buildings)	Existing non-habitable structures (e.g. agricultural sheds, pump-houses)	Existing local roads currently in use. Existing rail lines	State Controlled Roads	Agricultural and grazing land/forest areas and other non-agricultural land
	≤ 10 mm ⁴	≤ 50 mm ⁵	≤ 100 mm ^{4,6}	10 to 100 mm ⁷	10 to 20 mm ⁷	≤ 200 ⁸ mm with localised ⁹ areas up to 400 mm
	Changes in peak water levels are to be assessed against the FIOs. Changes in peak water levels can have varying impacts on different infrastructure/land. FIOs were developed to consider the flood sensitive receptors in the vicinity of the Project. It should be noted that in many locations the presence of existing buildings or infrastructure limits the change in peak water levels. For peak water levels assessed at any structure, the change in peak water level is measured relative to the existing floor level.					
Change in duration of inundation ^{1,4}	Identify changes to time of inundation by determining time of submergence (ToS) in Existing and Developed¹⁰ Cases. Assess impacts against the following objectives for habitable floors²: - Where existing flood inundation is less than 1 hour – up to 1 hour duration of inundation - Where existing flood inundation of 1 hour or more occurs – up to a 5% increase in duration of inundation For impacted roads/rail, the duration of inundation can increase by up to 10%, subject to the determination of the time of submergence (ToS) and consideration of impacts on accessibility/egress during flood events in consultation with the relevant authority. Assess impacts against the following objectives for all other land uses: - Where existing flood inundation is less than 1 hour – up to 1 hour duration of inundation - Where existing flood inundation of 1 hour or more occurs – up to a 10% increase in duration of inundation The duration performance targets do not apply to newly flooded land where compliant with afflux criteria (see also General Notes).					

Parameter	Objectives
Flood flow distribution ¹	Aim to minimise changes in natural flow patterns and minimise changes to flood-flow distribution across floodplain areas. This includes the objective of maintaining drainage paths that are conveying runoff from adjoining terrain, minor watercourses, and gullies, to avoid ponding of water and/or excessive duration of inundation. Identify any changes and justify acceptability of changes by assessing the risk with a focus on land use and flood sensitive receptors. The identification of changes to flow distribution is to include the consideration of a range of floods, from small (frequent) events (for conditions throughout the event) to large and extreme (infrequent) events. This exercise will be undertaken to identify (and where deemed necessary, mitigate) any increased risk to flood sensitive receptors associated with flow distribution changes.
Velocities ¹	Maintain existing velocities where practical or minimise increases in velocities. Identify changes to velocities and impacts on external properties. The ETV for natural ground surfaces should be established from a site-specific assessment by a suitably qualified specialist, and in consideration of engineering guidelines. For sealed surfaces, this same approach could be applied, or through reference to suitable guidelines/specifications. Assess against the following performance objectives: ■ Sealed surfaces (or surfaces otherwise protected against erosion): – For existing velocities equal to or greater than 1m/s (or the defined ETV), the increase in velocity is limited to 20% – For existing velocities (or velocities associated with new flowpaths) less than 1 m/s, the maximum design velocity is 1.2 m/s (or the defined ETV) ■ Natural ground surfaces including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas: – For existing velocities equal to or greater than 0.5 m/s (or the defined ETV), the increase in velocity is limited to 10% (or within an acceptable range as determined by geomorphological assessment) – For existing velocities (or velocities associated with new flowpaths) less than 0.5 m/s (or the defined ETV), the maximum design velocity is 0.5 m/s (or the defined ETV).
Hazard (velocity x depth product) ¹	Assess against the following objectives: Roads/rail, urban and commercial areas, dwellings: ■ A 10% increase in velocity x depth product. Other land: ■ A 20% increase in velocity x depth product. (In both cases where the velocity x depth product is below 0.15 m²/s in the Developed⁶ Case, no percentage change performance targets apply)
Extreme event risk management	Consider risks posed to neighbouring properties and emergency access/egress for events larger than the 1% AEP event to minimise unexpected or unacceptable impacts. At sites with existing sensitive infrastructure³, uses involving vulnerable people and/or any critical road network that was designed to be immune to flooding in any extreme event, the objective for increase in peak water level under the 0.2% AEP (1 in 500) is 10 mm¹¹. At existing habitable² dwellings and/or commercial and industrial buildings/premises under the 0.05% (1 in 2000) AEP event, a maximum increase in peak water level of 250 mm applies.
Sensitivity testing	Consider risks posed by climate change and blockage in accordance with Australian Rainfall and Runoff (ARR) 2019. Undertake assessment of impacts associated with project alignment for both scenarios.

Table notes:

1. These FIOs apply for events up to and including the 1% AEP event and relate to land outside the rail corridor (as well as roads and level crossings that lie within/traverse the rail corridor). Where transport corridors are shared or lie immediately adjacent to the Inland Rail corridor, relevant FIOs apply as outlined in Table 1 (i.e. for existing rail, State Controlled roads, local roads, etc.).
2. Habitable floors include all lawfully occupied dwellings regardless of land use zoning.
3. Sensitive infrastructure means infrastructure that is an essential service required to operate during emergency events, including water treatment facilities, telecommunications substations and electrical substations.
4. Data permitting and based on a review of calibration outcomes, where negative calibration bias is identified, a suitable tolerance (commensurate with the bias) will be added to the design flood levels to assess afflux and duration acceptability against the nominated FIO threshold.
5. This FIO reduces to ≤20 mm for developed lots that are less than 1,000 m² in area.
6. The current usage of non-habitable structures will be reviewed as design progresses and additional detail becomes available (e.g. animal shelter versus horticultural packing facility). This could influence the application of one of the other FIOs, which may be more suited to the specific usage of the structure.

7. Consultation will be undertaken with the relevant asset owner based on the application of the appropriate FIOs. This consultation will present all changes (>10 mm) across the road or rail network to identify specific roads or sections of rail that require local and/or route specific considerations. In flood sensitive locations this may entail a lower afflux threshold being adopted.
8. Where the alignment crosses the Condamine River and Lockyer Creek floodplains, this objective reduces to 100 mm (with localised⁹ areas up to 200 mm), in light of the combination of floodplain sensitivity, inundation duration, and land use (intensive horticulture).
9. Localised is defined as the lesser of <1.0 ha or 5% of an individual lot.
10. Developed scenario implies fully constructed/operational rail line and associated works.
11. The 0.2% AEP (1 in 500) event is only required to be assessed where adherence to the FIO cannot be inferred from the 1% AEP and 1 in 2000 AEP event results.

General notes:

- Justification must be provided in the selection of a governing QDL where two or more competing QDLs may apply – in the absence of such justification the most limiting of the applicable QDLs shall apply.
- Erosive Threshold Velocity means the velocity at which water movement has the potential to create scour or erosion. For natural surfaces, the erosive threshold of the soil/ground cover/vegetative conditions shall be established from an assessment by a suitably qualified specialist. In the absence of such assessment being undertaken an ETV of 0.5 m/s shall be assumed.
- The effects of any increased lateral spread of floodwaters (i.e. associated with permissible afflux) beyond 1 ha or 5% of the affected lot area should be considered on merit, taking into account affected receptors and land-usage (e.g. flood depth, flood duration, etc.).
- The term “Road” relates to the operational road surface.
- Within the rail corridor erosion protection measures will be installed (as required). This is with a view to managing the risk of scour propagating beyond the rail corridor boundary.
- Consultation shall be undertaken using the full suite of flood impact information (including afflux, velocity, duration and hazard). In locations where the afflux or velocity FIOs are exceeded, the change in flood hazard shall be communicated to the landholder with respect to the combined flood hazard classifications as defined in ARR 2019 and the velocity x depth product.

1.3.2 Study area

The study area for this geomorphology assessment includes all watercourses and floodplains intersected by the revised reference design. The revised reference design, intersects:

- Watercourse lines – Murray Darling drainage division (Department of Resources, 2021)
- Any additional watercourses identified from review of regional datasets and aerial imagery undertaken as part of this study
- Any additional watercourses identified by the watercourse verification works currently being undertaken for the Project, in consultation with Department of Regional Development, Manufacturing and Water (Qld)
- Floodplains of rivers that the Project alignment sidles along but does not directly cross the river channel
- 1% AEP flood extents from the regional hydraulic models
- Catchments of watercourses upstream of the Project.

1.4 Regulatory environment

The policies, standards, and guidelines relevant to this assessment are presented in Table 1.3.

Table 1.3 Applicable policies, standards, and guidelines

Policy, standard or guideline	Relevance to the Project
<i>Bridge Scour Manual: Supplement to Austroads Guide to Bridge Technology Part 8, Chapter 5: Bridge Scour</i> (Department of Transport and Main Roads (DTMR), 2019)	Channel Typologies: - References channel typologies to be used in Queensland after Saynor et al. (2008). There has been a progression in stream typology understanding through Erskine et al. (2005), Saynor et al. (2008), and most recently, Erskine et al (2017). The same authors have been involved in all these studies, and we have followed their 2017 version. Geomorphic factors - Geomorphic factors influencing bridge scour adapted from Melville and Coleman (2000) are listed. While a useful list, the methodology is for input into detailed design for bridge scour at watercourses with well-defined channels and is not directly relevant to the channel types in the Project footprint or EIS objectives. Therefore, the baseline assessment has included consideration of the geomorphic factors listed that are relevant for Project footprint channel types, the majority of which are poorly defined, with an adapted methodology to meet Project objectives. Considerations for scour assessment - Considerations for initial assessment of scour, geomorphic inputs required for detailed scour assessment. Methods for estimating scour at later project stages and design of scour countermeasures are also included.
<i>Stream Stability at Highway Structures</i> (United States Department of Transport - Federal Highway Administration (US Department of Transport), 2012)	Included as a reference in <i>Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures, Chapter 5 Bridge Scour</i> (Austroads, 2018, 2019) with the note that 'although the geomorphology of Australia rivers is different from that of rivers in North America, the basic concepts of fluvial geomorphology presented in this publication apply to any river'. This manual includes an approach to a qualitative geomorphic analysis (Level 1 analysis) for bridge failure, noting that the steps identified are generally applicable to most stream stability problems. The approach has generally been applied to this assessment, adapted for Project channel types and to meet Project objectives.
<i>Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures, Chapter 5 Bridge Scour</i> . Editions 2 and 2.1 (Austroads 2018, 2019)	The <i>Bridge Scour Manual</i> (DTMR, 2019) cross-references Edition 2 2018 version of this document. This document provides guidance on bridge scour characteristics, inputs such as Manning's 'n' values, methods for estimating scour, scour countermeasures and scour related to construction.
<i>Guide to Road Design Part 5: Drainage – General and Hydrology Considerations</i> (Austroads, 2021)	This document provides guidance on the elements that need to be considered in the design of a drainage system. Including for channels and culverts, erosion and sediment consideration for culvert performance, desirable maximum flow velocities in by soil types, scour protection measures.
<i>Guide to Road Design Part 5B: Drainage – Open Channels, Culverts and Floodways</i> , Edition 1.1 (Austroads, 2013)	This guidance describes the types of open channels, culvert and floodways and provides design procedures and guidance on best practice for the detailed design of these components.
<i>Australian Standard (AS) 7637:2014 Hydrology and Hydraulics</i> (Rail Industry Safety and Standards Board 2014)	Provides general hydraulic and mitigation requirements including where feasible, maintain the existing flow regime onto adjoining public or private property. Provides guidance on erosion and sedimentation mitigation for cross-drainage infrastructure.
<i>AS 5100.1-2017 Bridge design: Part 1: Scope and general principles</i> (Standards Australia, 2017)	Ultimate Limit State (ULS) and Serviceability Limit State events for the design of state-controlled roads (including bridges). Serviceability Limit State: 1% AEP, ULS: 0.05% AEP.
<i>Design Criteria for Bridge and Other Structures</i> (DTMR, 2018)	Design criteria for ULS and scour protection of piers as detailed below: - ULS design criteria for Queensland takes precedence, 0.05% AEP or overtopping event if less than 0.05% AEP, whichever is critical in terms of flood forces. - Design of bridge piers shall not rely on scour protection. Scour protection should not be installed around new bridge piers.

Policy, standard or guideline	Relevance to the Project
<i>AS/New Zealand (NZ) ISO 31000:2009 Risk management: Principles and guidelines</i> (Standards Australia and Standards New Zealand, 2009)	Approach used for Task 4 of this assessment
<i>Soil conservation guidelines for Queensland</i> (Department of Science, Information Technology and Innovation, 2015)	<i>Chapter 9 Waterways</i> (Carey et al., 2015a) This chapter is focused on design and stabilisation of natural and artificial waterways to reduce erosion for soil conservation. Geomorphic processes other than erosion, such as continuation of sediment transport, are not considered. Includes references to key contributing catchments characteristics, including, soil type, slope, land use and vegetation cover. <i>Chapter 13 Gully erosion</i> (Carey et al., 2015a) Provides practical information, tools and guidelines on assessment and mitigation measures for gully channel types in Queensland.
<i>Floodplain management for erosion control and high productivity on the Darling Downs</i> (Department of Primary Industries, 1988)	This guide describes the management practices that have been developed to control erosion and maintain high productivity on the floodplains of the Darling Downs and surrounding brigalow areas.
<i>Gully and Stream Bank Toolbox. A technical guide for gully and stream bank erosion control programs in Great Barrier Reef catchments</i> (Wilkinson, S., Hairsine, P.B., Bartley, R., Brooks, A., Pietsch, T., Hawdon, A., Shepherd, R., 2022)	Provides guidance on assessment and mitigation measures to reduce erosion, including for gully channel types.

2 Methodology

This methodology has been developed based on good practise, supported by guidance documents adapted for Project channel types and to meet Project objectives where relevant. Based on FFJVs review and as noted in the *Olive Downs Coking Coal Project Geomorphology Technical Study Report* (Fluvial Systems, 2018), there is no legislative or policy requirement regarding the methodologies to be applied in undertaking geomorphological investigations for the purpose of an EIS. However, some relevant guidance has been incorporated from bridge scour and bridge failure assessment documents (Table 1.3).

The geomorphology assessment has been undertaken on watercourses and their geomorphic floodplains. Overland flow pathways on hillslopes (flow with no associated fluvial geomorphic landform) were assessed under the hydrology and flooding EIS aspect against the FIOs, and any exceedances were noted, and mitigation options identified, within EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1.

A staged approach has been adopted for the fluvial geomorphology assessment for the Project, illustrated in Figure 2.1 and summarised in Section 2.1. Sections 2.2 to 2.4 include further detail on assessment methodology.

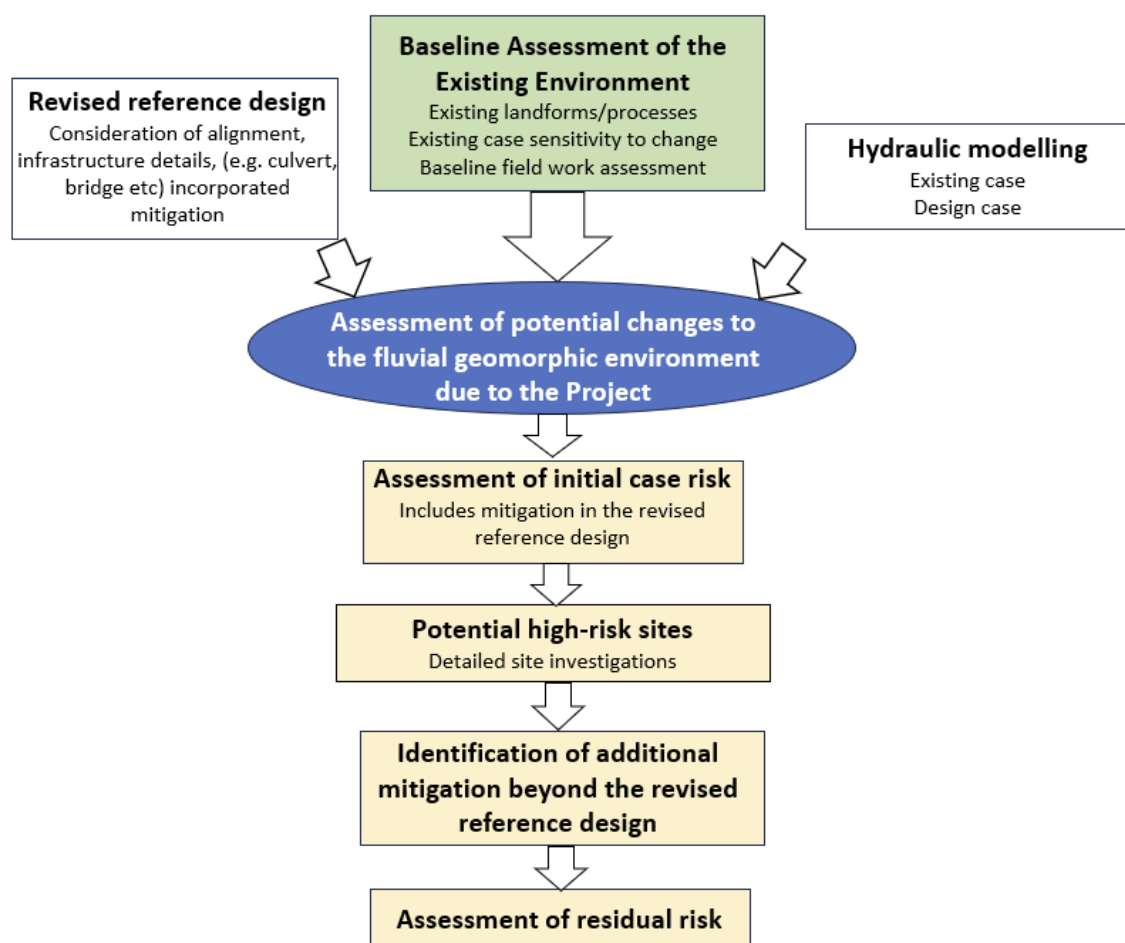


Figure 2.1 Fluvial geomorphology assessment methodology

2.1 Methodology summary

2.1.1 Assessment of baseline conditions

- The existing baseline geomorphic environment and fluvial processes are described following a cascading methodology that works from broad scale regional review to site-specific assessments
- The baseline includes classification of watercourse and floodplain landforms, assessment of processes and sensitivity to change
- The existing channel and floodplain landscapes traversed by the Project alignment are subject to extensive modification by agricultural activities and that these activities and other future modifications to the landscape by landholders beyond the rail corridor are likely to change water flows and stream conditions, particularly sedimentation that are outside of the Project's influence and control
- Field inspections were undertaken at representative sites to ground truth the baseline assessment. Site observations of existing geomorphic processes, such as locations and extents of erosion and deposition provide the best information on Existing Case conditions and potential future impacts.
 - Identification and classification of watercourses:
 - Existing watercourse data sets, aerial imagery, topographic and hydraulic data were reviewed to identify all potential watercourse crossings
 - Geomorphic factors for watercourse and sub-reach classification were assessed based on aerial imagery and field inspection. Channel typology follows recommendations in the *Bridge Scour Manual* (DTMR, 2019). The factors assessed were adapted for Project footprint channel types and Project objectives from *Bridge Scour Manual* (DTMR, 2019) and *Stream Stability at Highway Structures* (US Department of Transport, 2012), additional factors considered good practise were also collected.
 - High-level assessment of Project watercourse types were identified. These are linked to process zone and geomorphic baseline conditions and provides a relative context for all watercourses that cross the Project alignment irrespective of catchment.
 - Assessment of watercourse processes:
 - There is a strong link between channel typology and processes. The channel type is the physical manifestation of the fluvial processes acting on the watercourse, including water flow, sediment transport, deposition and erosion, for example the channel type gully has active gully erosion.
 - Evidence for geomorphic processes, including aggregation and erosion were assessed from aerial imagery and field inspections at representative sites
 - Assessment of channel type and channel planform change was undertaken by review of historic aerial imagery as well as available historic maps and documents (only identified in the Condamine area).
 - Assessment of watercourse sensitivity to change (also termed stream stability/instability in US Department of Transport (2012)):
 - A sensitivity to change criteria for Project watercourses has been developed incorporating consideration of the main components of stream stability included in the US Department of Transport (2012) for qualitative geomorphic assessment; overall stability, lateral stability and vertical stability
 - The criteria uses historic change in planform (including channel width) and channel type, together with current processes, soil erodibility rating, contributing catchment characteristics and human interventions to assess for overall, lateral and vertical sensitivity to change. Over time, vertical change in channel beds results in changes to channel width and planform.

- Identification and classification of floodplains:
 - Delineation of geomorphic floodplains in the Project footprint
 - Description of floodplain characteristics, including width, elevation, soils, vegetation cover, Strahler order of main watercourse and landforms based on aerial imagery review and field inspection
 - Classification of floodplain types after Nanson and Croke (1992), which includes consideration of floodplain landforms and processes, stream power and sediment types.
- Assessment of floodplain processes:
 - Description of floodplain processes by floodplain type
 - Description of any site-specific floodplain processes observed from aerial imagery review and field inspection, including human induced change.
- Assessment of floodplain sensitivity to change:
 - A sensitivity to change criteria for Project floodplains has been developed similar to the criteria developed for Project watercourses
 - The criteria use historic change in landforms, together with current processes, soil erodibility rating, contributing catchment characteristics and human interventions to assess for sensitivity to change.

2.1.2 Impact assessment

- Assessment of potential impacts for watercourses and floodplains within the temporary footprint for the pre-construction works, early works and construction works stages, and by individual watercourse and floodplain for the operations stage. The potential consequences of the impacts were assessed under the risk assessment.
- Potential impacts to the following key watercourse geomorphic processes were assessed:
 - Erosion
 - Deposition
 - Planform change
 - Channel type change
- Potential impacts to the following key floodplain geomorphic processes were assessed:
 - Erosion
 - Deposition
 - Reduced floodplain connectivity
- Criteria to assess for each operations stage potential impacts were identified. Operations stage potential impacts were assessed from the following:
 - Assessment of the potential impacts of the revised reference design infrastructure type/location/orientation, for example:
 - The location of embankments or bridge abutments relative to channels may lead to flow constriction or channel encroachment potential impacting channel type and planform. This may occur even when flow characteristics such as velocity and stream power remain similar to the Existing Case.
 - Location and orientation of culverts to flow. The proposed culverts may not be optimally located or aligned to the Existing Case conditions and may result in the potential for flow to be discharged out of the channel or focused against a channel bank.

- Manual hydraulic data extraction to assess potential changes in flow characteristics between the Existing Case and Design Case, in particular flow velocity and stream power
 - As the baseline field inspections occurred not long after an estimated 20% AEP event in the Condamine, potential impacts could be calibrated with 20% AEP Existing Case flows in this area.
- Criteria relating to potential flow velocity change were aligned with FIOs in that design flow velocities within 10 per cent of the Existing Case were considered within the error of the model and were not a change from existing
- Similar types of impacts were grouped to aid in the relative assessment of potential impacts.

2.1.3 Risk assessment

- A qualitative risk assessment has been undertaken following the methodology included in EIS Chapter 4: Assessment Methodology to identify and assess potential Project related impacts, in summary:
 - Initial case risk: Assess the potential impacts with the application of the revised reference design mitigation measures in place
 - Identify and implement additional mitigation measures
 - Residual risk: reassess impacts including additional mitigation measures.
- An assessment of cumulative impacts on catchment processes including sediment budget and other related potential impacts was undertaken based on the outcomes of the individual watercourse and floodplain assessment
- Likelihood assessment:
 - There is a relationship between flow frequency, the landform inundated and severity of flow events. The risk assessment framework includes some very frequent likelihoods, with associated low (or no) rainfall/flow, some of which are not relevant for fluvial geomorphology. A review was undertaken to identify appropriate likelihoods to include in the risk assessment based on the hydrological setting, Existing Case hydraulic data and Project fluvial geomorphic landforms.
- Consequence assessment:
 - Descriptions of potential consequences to the geomorphic environment, based on the Environmental Consequence descriptions from EIS Chapter 4: Assessment Methodology, was included to aid in the risk assessment
 - The consequence was assessed based on the potential impacts identified and the sensitivity to change of the individual watercourses and floodplains
 - Sensitivity to change does not directly relate to consequence. A site with an Existing Case (pre-Project) high sensitivity to change, such as a gully, can be subject to a low risk of adverse change through appropriate infrastructure design. These sites would still have a high sensitivity to change during operation of the Project, but the Project would have a low risk of contributing to the occurrence of erosion. Conversely, a site with low sensitivity to change can be subject to high risk of adverse change through 'inappropriate' infrastructure design. Hence, the design approach is the critical factor in achieving the desired outcome and reducing the potential impacts of the Project on the natural systems.

- Detailed assessments of potential changes at initial case high-risk sites were undertaken to better understand the geomorphic processes at these sites and inform additional mitigations. The initial risk was not updated for these sites based on the detailed assessment. The detailed assessments included the following:
 - Descriptions and photos (with scale) of bed and bank material, including any armouring, if present, evidence of sediment transport (erosion and/or deposition), channel geometry and characteristics, location and type of any bank failures, vegetation including woody debris and estimates of Manning's 'n' using the table in Appendix A of *Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures* (Austroads 2018, 2019).
 - Collection of representative samples for laboratory testing, including particle size distribution, Atterberg Limits and erodibility testing
 - Assessment of site ETVs in a combined approach including theoretic ETVs assessed from laboratory testing together with field observations
 - Updated assessment of the fluvial geomorphic landforms and processes based on field work
 - Identification of site-specific additional mitigation measures to be included in the assessment of residual risk.

2.2 Baseline assessment

This section includes further details on aspects of the baseline assessment methodology and should be read in conjunction with the Methodology Summary (Section 2.1).

2.2.1 Data sources

This geomorphology assessment was completed using a range of data sources. Key sources were reviewed to inform this assessment (Table 2.1 for a full list):

- Literature review and reports
- Aerial imagery
- Soil and geology
- Topographic and hydraulic data

Table 2.1 Data sources

Key topic	Data source
Literature review and reports:	■ FFJV and ARTC (2022). Border to Gowrie Draft Environmental Impact Statement. ■ FFJV and ARTC (2020). North Star to NSW/QLD Border Environmental Impact Statement. ■ Nanson, G.C. and Croke, J.C., (1992). A genetic classification of floodplains. In: G.R. Brakenridge and J. Hagedorn (Editors), <i>Floodplain Evolution</i>. Geomorphology, 4- 459-486. ■ Saynor, M.J., Erskine, W. and Lowry, J. (2008). Report: Geomorphology. In G.P. Lukacs and C.M. Finlayson (eds) 2008. <i>A Compendium of Ecological Information on Australia's Northern Tropical Rivers</i>. Sub-Project 1 of Australia's Tropical Rivers – an integrated data assessment and analysis (DET18). A report to Land & Water Australia. National Centre for Tropical Wetland Research, Townsville, Queensland. ■ SGM Environmental (SGM) (2022), <i>Inland Rail Border to Gowrie (B2G) Erosion Threshold Velocities Report</i>. ■ Erskine, W.D., Saynor, M.J., Erskine, L., Evans, K.G., & Moliere, D.R. (2005). A preliminary typology of Australian tropical rivers and implications for fish community ecology. <i>Marine and Freshwater Research</i>, 56, 253-267. Doi: 10.1071/MF04078. ■ Erskine, W., Saynor, M., & Lowry, J. (2017). Application of a new river classification scheme to Australia's tropical rivers. <i>Singapore Journal of Tropical Geography</i>, 38, 167-184. Doi: 10.1111/sjtg.12196. ■ Makaske, B. (2001). Anastomosing rivers: a review of their classification, origin and sedimentary products. <i>Earth-Science Reviews</i>, 53, 149-196.

Key topic	Data source
Aerial imagery:	- Queensland Government. Millmerran, QAP966 Frame 111 14 August 1959, from Queensland Government Qimagery database, https://qimagery.information.qld.gov.au/ - Bing aerial imagery, ArcGIS Online date modified 15 August 2013,.
Soils:	- Isbell (1992). Dominant soil orders of Queensland (31 December 2003) [Dataset]. Department of Environment and Science. - Commonwealth Scientific and Industrial Research Organisation. (2021). Australian Soil Resource Information System mapping. (2 November 2021) [Dataset]. <i>Soils: ASC Grid</i>. Accessed from ASRIS. www.asris.csiro.au/mapping/viewer.htm. - Bureau of Rural Sciences. (2009). Digital Atlas of Australian Soils. Bioregional Assessment Source Dataset. <i>Queensland Soils Atlas 2M</i>. Accessed from Australian Government. - Aurecon (2022). Inland Rail Border to Gowrie - Soil Assessment and Management plan..
Geology:	- Department of Resources, 2020. <i>1:2 million scale geological map</i>. State of Queensland (Department of Resources) Regional Geology. Accessed from Qspatial. - Department of Resources, 2020. <i>1:100,000 scale geological map</i>. State of Queensland (Department of Resources) Regional Geology. Accessed from Qspatial.
Topographic data:	Geoscience Australia. (2021). Elvis – Elevation and Depth – Foundation Spatial Data. Intergovernmental Committee on Surveying and Mapping.
Hydraulic data:	FFJV (2022). Latest 1% AEP flood extents for local catchment and regional and local floodplain models
Watercourses:	- Department of Resources. (2021). Watercourse lines – Murray Darling drainage division, Published by Department of Resources, Queensland Spatial Catalogue (Qspatial). - NSW Hydrolines. Accessed via https://link.fsd.org.au/dataset/nsw-hydro-line-dataset - Ordered Drainage 100k (23 June 2010) accessed via the Qspatial website.

2.2.2 Identification and naming of watercourses

Watercourses were identified for inclusion in the geomorphology assessment based on the Murray Darling Watercourse lines dataset. It was found to be the most accurate and representative of the locations of watercourses in the Study area. The geomorphology assessment also included the review of aerial imagery, topographic data and hydraulic modelling to identify additional watercourses that cross the alignment. Strahler order was locally updated to include additional watercourses identified as part of this Study.

The geomorphology assessment has used the names of watercourses rather than the culvert identification (ID) at watercourse crossings. The approach of focusing on watercourses for the geomorphology assessment rather than culverts, is so that watercourses without cross drainage are also included (e.g. watercourses in cuts). A review of cross drainage relative to watercourses was undertaken, and the design feature type (e.g. culvert, bridge, cut, diversion) is listed for each watercourse in Appendix C, and the specific culvert IDs for each watercourse are noted in Appendix H.

Nomenclature of unnamed watercourses and their contributing catchments are based on which sub-catchment they are located in, followed by a number:

- MR Macintyre River
- MB Macintyre Brook
- C CK Canning Creek
- SC South Condamine (Back Creek)
- NC North Condamine
- OC Oakey Creek
- Catchments <10 ha have 's' for small after the sub-catchment identification letters, MBs, OCs etc with Canning Creek shortened to CCs

- Back Creek² drains the southwest Condamine River valley side slopes and drains into the Condamine River downstream of the Project alignment.

2.2.3 Regional environment

It is considered good practise to describe the regional geomorphic environment. The regional environment provides the context for the baseline assessment and included description/assessment of the following:

- Regional Fluvial System – A description of which high-level fluvial zones occur in the Project footprint
- Topography
- Geology
- Regional geomorphic landforms – For this study, these were assessed and delineated in the Project footprint
- Climate
- Hydrological setting – Assessment and description of the hydrology of Project watercourses from publicly available data for geomorphic assessment, including flow regime characteristics such as no flow and low flow, seasonality, flood events and durations per year.

2.2.4 Factors included in watercourse classification.

The factors included in the classification of watercourses and sub-reaches and links to guidelines are included in Table 2.2. Flow regime and bankfull discharge are described at Project level.

Channels can be divided into reaches or sub-reaches, Erskine et al (2005) define river reaches as:

‘Homogenous lengths of stream within which hydrological, geological, and adjacent catchment surface conditions are sufficiently constant so that a uniform river morphology [...] is produced.’

This concept provides a useful way of separating reaches along the river of similar character.

Watercourse assessment was undertaken on Project watercourses. The sub-reach assessment includes assessment of additional geomorphic factors and was undertaken on:

- Watercourses with catchments greater than 10 hectares, and
- Watercourses with catchments less than 10 hectares with active erosion above normal geomorphic levels, including all gully sites.

Watercourses not included in the sub-reach assessment have non channelised valley floor flow channel types or washslope drainage features and most geomorphic factors included in the sub-reach assessment cannot be assessed for this drainage feature types.

² There is another Back Creek in the Study area, a tributary of Canning Creek on the Macintyre Brook catchment. This is referred to as ‘Back Creek 2’.

Table 2.2 Factors included in classification of watercourses and relevance to guidance documents

Assessment type	Geomorphic factor	Description	Bridge Scour Manual (DTMR, 2019) Table 5.2.3 (adapted from Melville and Coleman (2000))	Stream Stability at Highway Structures (US Department of Transport, 2012) Figure 2.6
1 –Watercourse Assessment	Channel type	Records the current channel form. The channel types encompass a range of geomorphic factors that can be collected individually. For the purpose of this assessment, channel typologies relevant to Queensland and recommended in Queensland DTMR have been used.	Not included. Channel type covers a high-level characterisation of stream width and variability, cross-section shape and degree of incision, presence of floodplains, sinuosity, presence of braids/anabranches and bars	Not included. Channel type covers a high-level characterisation of flow habitat, presence of floodplains, natural levees, apparent incision, channel boundaries, sinuosity, braided streams, anabranches streams, variability of width and development of bars.
	Strahler order	Provides information on the watercourses location within the wider fluvial system, considered good practise.	Not included	Not included, although stream size is. Strahler order and stream size are linked.
	Contributing catchment area	Catchment variables (such as area, slope and soil/rock cover) upstream of the Project alignment provide information on the flows and sediment (fluvial geomorphology) that the alignment will need to pass in order to maintain current geomorphic processes and landforms. Consideration of characteristics of contributing catchments is considered good practise. Contributing catchments are referred to in the <i>Soil conservation guidelines for Queensland Chapter 9 Waterways</i> (Carey et al, 2015a).	Not included	Not included directly, catchment area is a function of stream size and flow habitat, which are included.
	Contributing catchment gradient			
	Contributing catchment vegetation			
	Contributing catchment soils (including at watercourse crossing)	Soils data is summarised from regional ASC maps, as the detailed soils assessment is limited to sites within the Project footprint (EIS Appendix J: Soil Assessment Report).		
	Watercourse type	High-level watercourse types have been identified, linked to process zone, typical channel types/gradients/catchment areas etc. Provides a relative context for all watercourses in the Project footprint irrespective of catchment.	Not included	Not included

Assessment type	Geomorphic factor	Description	Bridge Scour Manual (DTMR, 2019) Table 5.2.3 (adapted from Melville and Coleman (2000))	Stream Stability at Highway Structures (US Department of Transport, 2012) Figure 2.6
2 – Sub-reach Assessment	Valley setting	Describes the valley either side of the channel, and the lateral space available for the channel to migrate across. Confined – watercourse is confined in a narrow valley floor or gorge and cannot move laterally. Semi-confined – watercourse is confined on one side, and unconfined on the other. Unconfined – watercourse is unconfined laterally.	Not included	Included
	Tributaries	Tributaries upstream and downstream of the Project alignment crossing as well as watercourse convergences are listed.	Hydraulic controls are included	Not included
	Planform	Classified based on sinuosity from Erskine <i>et al.</i> (2017): <1.05 are classed as straight, 1.05 to 1.35 are classed as low sinuosity rivers, 1.35 to 1.5 are classed as moderate meandering and >1.5 are classed as meandering rivers.	Included as sinuosity	Included as sinuosity
	Planform at alignment	Channel planform at the Project alignment, e.g. straight section, bend.	Not included	Not included
	Sinuosity	Along channel length divided by along valley length	Included	Included
	Channel gradient	Recorded as rise over run to four decimal places.	Included	Not included
	Soils	ASC soils classes at water crossing site are taken from the detailed soils assessment (EIS Appendix J: Soil Assessment Report). Regional ASC soils data has been used for sites with no detailed data.	Included	Included
	Channel processes	Channel processes identified from aerial imagery and field inspection	Bank slope stability are included	Not included
	Local man made hydraulic controls	Lists local hydraulic controls such as ponds and existing cross drainage.	Included	

2.2.5 Watercourse sensitivity to change

Sensitivity to change has been assessed for watercourses with sub-reach assessments. Sensitivity to change has been assessed from:

- Channel type, including natural channel evolution and natural sensitivity to change (Section 3.3.1.3)
- Geomorphic processes observed at a watercourse level from review of aerial imagery and site inspection (Appendix G)
- Historic changes documented from aerial imagery and maps, including natural geomorphic change and human made changes (Appendix G)
- Soils at the channel crossing location
- Catchment vegetation cover and soil type.

Change observed in historic aerial imagery, which generally covers the period of the last 70 years through to current conditions, captures a visual record of the complex interplay of geomorphic systems as recorded in resulting landforms. The oldest historic aerial imagery in the Project footprint is from the 1940s/1950s and is listed in Appendix E.

The sensitivity to change assessed is a tool to determine potential relative change to existing conditions. It does not consider more rare extreme events which may happen at any site, unless evidence for them can be interpreted from the available aerial imagery.

The following categories of sensitivity to change for the Project watercourses were identified:

1. No observed change in channel type or channel planform (including width) observed since earliest aerial imagery.
2. No observed change in channel type or channel planform (including width) since earliest aerial imagery at sites where geomorphic change might otherwise have been expected (e.g. cracking clays or soils with a high erodibility rating such as texture contrast soils), poor catchment vegetation cover such as grassland/crops).
3. Some natural historic channel change observed, such as meander cut-off, or downstream meander migration.
4. Human interventions in watercourses to create potentially unstable channel forms (e.g. straight sub-reaches, ponds/embankments resulting in or the potential for downstream scour. Channel widening occurring. Distributed flow channels on intact valley fill in sodosol soils, as there is evidence of gully development in these systems in the project area (Section 3.3.1.3).
5. Rapid channel or planform change such as avulsion or gully development, human induced or natural.

Category 1 sites have the lowest potential for change, through to Category 5 with the highest potential for change.

2.2.6 Floodplain sensitivity to change

Floodplain sensitivity to change has been determined using the same approach as for watercourses.

The following categories of sensitivity to change for Project floodplains were identified:

1. No observed change in floodplain geomorphic landforms since earliest aerial imagery.
2. No observed change in floodplain landforms since earliest aerial imagery at sites where geomorphic change might otherwise have been expected (e.g. soils with a high erodibility rating such as texture contrast soils, poor vegetation cover such as grassland/crops, some human intervention such as forestry or farm tracks or minor ponds).
3. Some mainly natural historic change observed, such as downstream meander migration. Some minor human intervention such as forestry or farm tracks or minor ponds.

4. Human interventions on floodplains with potential to create unstable landforms (e.g. straightening of main channel, ponds/embankments resulting in or the potential for downstream scour or floodplain disconnection).
 5. Rapid landform change such as avulsion or erosion channel development, human induced or natural.
- Category 1 sites have the lowest potential for change, through to Category 5 with the highest potential for change.

2.2.7 Baseline field work

Baseline field site locations were selected to represent the range of watercourse and floodplain types, channel types and soils in the Project footprint.

All sites were publicly accessible, private land was not accessed. Where sites could not be accessed by foot, estimates were made of channel geometry.

The following information was collected:

- Channel type, geometry, and in channel features, vegetation, behaviour, bed and bank material, floodplain features, vegetation, and behaviour.

For sites with existing cross drainage infrastructure, the following information was also collected:

- Infrastructure type and dimensions and performance.

2.3 Impact assessment

This section includes further details on aspects of the operation stage impact assessment methodology undertaken for individual watercourses and should be read in conjunction with the methodology summary (Section 2.1).

2.3.1 Operations stage potential impacts

Operations stage potential impacts were assessed for all individual watercourses included in the sub-reach assessment and all geomorphic floodplains. Watercourses not included in the sub-reach assessment have so little evidence of active fluvial geomorphology that they typically have no channel form where they cross the Project alignment and were assessed under the hydrology and flooding EIS aspect against the FIOs. Any exceedances were noted and mitigation options identified, within EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1. The mitigations were reviewed by a geomorphologist (Section 1.3.1).

The impact assessment has been undertaken on the greatest area of potential change along watercourses and floodplains due to the Project even though this often occurs inside of the Project footprint. This is because impacts in fluvial systems can have downstream and upstream implications, for example sediment eroded from within the Project footprint would be transported and deposited outside of the Project footprint.

Current criteria for bridge design (AS 5100.1-2017) (Standards Australia, 2017) includes geomorphic input for assessment of scour potential for the 0.05% AEP flood event, therefore assessment of proposed bridge sites at this less frequent and higher magnitude event were included.

2.3.2 Criteria to assess for potential impacts

Criteria to assess for potential impacts to the fluvial geomorphic environment are included in Table 2.3 and Table 2.4. A design flow velocity change of within 10 per cent of the existing case is considered unlikely to result in potential impacts due to the Project, as this change falls within the range of natural flow variability. This also aligns with FIOs targets for flow velocity of within 10 per cent of existing case for natural surfaces.

Where the criteria is met, the potential impact of the revised reference design on geomorphic processes at the site and the amount, type and location of potential change, is assessed. Meeting the criteria to assess for potential change does not mean that impacts may occur. Consequence levels are applied to the potential impact as part of the risk assessment.

Table 2.3 Criteria to assess for potential change to watercourses

Geomorphic process	Criteria to assess for potential change above Existing Case conditions
Erosion	Design flow velocities >10% of the Existing Case flow velocities
Deposition	Design flow velocities <10% of the Existing Case flow velocities.
Planform change	Design flow not aligned to natural landform, e.g. design cross drainage causes flow to occur against the edge of or outside of an existing channel. Rail embankment/bridge abutments within 5 m of a channel.
Channel type change	Rail embankment/bridge abutments within 5 m of a channel. Change from distributed flow, non-channelised valley floor or wash slope channel types, to point source flow where the design flow velocities are >10% than the existing. Changes from distributed to point source flow may initiate erosion and development of rilling/gullying when there is increased design flow.

Table 2.4 Criteria to assess for potential change to floodplains

Geomorphic process	Criteria to assess for potential change above Existing Case conditions
Erosion	Design flow velocities >10% of the Existing Case flow velocities. Design flow not aligned to flood channel, e.g. design cross drainage causes flow to occur against the edge of or outside of an existing flood channel.
Deposition	Design flow velocities <10% of the Existing Case flow velocities.
Reduced floodplain connection	Project alignment sidles along a floodplain and cuts off flow.

2.3.3 Hydraulic model data extraction

Flow velocity and stream power were extracted from the Existing Case and Design Case hydraulic modelling at the upstream and downstream ends of proposed cross drainage structures. The development of the hydraulic models are described in EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1. The hydraulic models will be further refined in later project stages with additional survey data and design updates.

While hydraulic models can provide an indication of potential changes to flow characteristics, they have some limitations and should be reviewed against aerial imagery and field data where available. Limitations include:

- Simplification of the complex real world site conditions
- Outputs comprise a raster with cells of varying sizes depending on the hydraulic modelling requirements
- They are static representations of the channel bed and banks that do not take into account the movement of these boundaries during flood conditions.

2.3.3.1 Stream power

When considering the geomorphic processes of alluvial river channels and floodplains, a useful concept is that of *stream power*. This is the rate of energy expenditure in flowing water and is a measure of the energy available to do geomorphic work along the channel. In fluvial geomorphology it is usually referred to as *specific stream power*, which is the amount of energy expended per unit area of the bed and is written:

$$w \text{ (W/m}^2\text{)} = gQs / W$$

Where, w = specific stream power in watts per square metre (W/m^2); g = specific weight of water; Q = discharge; s = water surface slope, w = water surface width and m^2 = square metres.

It can be calculated for any discharge, but in geomorphic studies is usually determined for the channel-forming discharge (typically the bankfull event). Typical values of specific stream power can range from a few tens of W/m^2 to several thousand W/m^2 . At low stream power, a fluvial system could be susceptible to deposition and aggradation of the stream bed. At high stream powers bed erosion is likely to occur.

Stream power is one of a group of related hydraulic flow characteristic measures and so may also be calculated as the product of bed shear stress and flow velocity. Bed shear stress depends upon flow depth, so in this manner specific stream power is capturing several significant aspects of channel flow including the amount of discharge, velocity of flow and the width and depth of flow.

Stream power data can be generated in hydraulic model outputs, although it is important to field check stream power outputs as spatial variations can be an artifact of the hydraulic modelling.

2.4 Risk assessment

This section includes further details on aspects of the risk assessment methodology and should be read in conjunction with the methodology summary (Section 2.1).

The risk assessment has been undertaken on the greatest area of potential change along watercourses and floodplains due to the Project even though this often occurs inside of the Project footprint. This is because impacts in fluvial systems can have downstream and upstream implications, for example sediment eroded from within the Project footprint would be transported and deposited outside of the Project footprint.

2.5 Magnitude of impacts

The risk matrix (Table 2.5) used for this assessment follows the risk assessment methodology outlined in EIS Chapter 4: Assessment Methodology

A commentary on the likelihood and consequence categories used for assessment of channels and floodplain are included in Table 2.6 and Table 2.7, with consideration of geomorphic principles.

Table 2.5 Risk matrix

Likelihood/consequence	Not significant	Minor	Moderate	Major	Extreme
Almost Certain	Medium	Medium	High	Extreme	Extreme
Likely	Low	Medium	High	Extreme	Extreme
Possible	Low	Low	Medium	High	High
Unlikely	Low	Low	Low	Medium	Medium
Rare	Low	Low	Low	Low	Medium

2.5.1 Likelihoods assessed for

There is a relationship between frequency and severity of flow events. More frequent flow events are driven by more frequent rainfall events, which are the least intense and produce the smallest flows, or in some cases are not even enough to initiate flow. The largest flows, capable of the highest consequences, would always be associated with the less frequent events. It is therefore not possible to have an extreme flow event occurring at frequent likelihoods.

The risk assessment framework includes some very frequent likelihoods, with associated low (or no) rainfall/flow, some of which are not relevant for fluvial geomorphology. The potential geomorphology consequences for the range of likelihoods in the risk assessment are summarised in Table 2.6. These potential consequences take into consideration the following:

- The fluvial geomorphic hydrology assessment
- The fluvial landforms likely to be impacted (e.g. within channel only, or floodplain inundation)
- Geomorphic processes, in particular at bankfull conditions, when the most geomorphic work is occurs.

Table 2.6 Geomorphic commentary on likelihood

Likelihood	Description	Frequency of occurrence	Flow modelling data	Typical flow distribution by landform
Almost Certain	Is expected to occur in most circumstances	Once per month if flow is occurring	No modelling data. No geomorphic events	Within channel flow only
Likely	Will probably occur in most circumstances	Between once a month and once a year if flow is occurring	No modelling data.	Within channel flow only
Possible	Might occur at some time	Between once a year and once in five years	Flow modelling data available for 1 in 5 year (20% AEP) event	Within channel with some localised floodplain flow. Within channel consequences will peak at bankfull conditions, estimated to be approximately 1 in 5 year event. Unlikely to have full floodplain engagement.
Unlikely	Could occur at some time	Between once in 5 years and once in 20 years	Flow modelling data available	Within channel and floodplain flow.
Rare	May occur in exceptional circumstances	Once in more than 20 years	Flow modelling data available	Within channel and floodplain flow.

Section 3.1.9 summarises the hydrological setting for the fluvial geomorphic assessment, which considers more frequent low flow conditions as well as more extreme flood events, of six of the largest watercourses in the Project footprint from publicly available data. This section includes information on frequent events including a summary of seasonal regimes and monthly flow data. At all sites the maximum flood flows stand out as being far greater than most other events. All of the watercourses assessed have ceased to flow at some stage. The majority (all but four) of the watercourse in the Project footprint are intermittent or ephemeral, and only flow temporarily in response to precipitation (outlined in Section 3.1.9). Flow magnitudes (m^3/s) are listed for a range of AEP% events in Table 3.7, from this we can see that flow magnitudes in the 35% AEP event (1 in 2.33 year event that is known as the ‘mean annual flood’) are roughly half of those for the 20% AEP events (1 in 5 year). More frequent events would have even smaller flows.

The AEP event associated with bankfull conditions is summarised in Section 3.3.1.2. For this assessment, bankfull is considered close to the 20% AEP event, this is the event where the most geomorphic ‘work’ (highest change potential) is done for channels because the channel is full with water flowing across the whole bed and along the full height of the bank. Events more frequent than bankfull would have in-channel flow, and those less frequent would result in floodplain inundation.

For the assessment of potential risk to the fluvial geomorphic environment, the consequences at likelihoods ‘possible’ and ‘rare’ have been assessed for the following reasons:

- Channel bankfull conditions occur around likelihood ‘possible’ (taken as the 20% AEP event).
- Floodplain impacts begin to occur from likelihood ‘possible’ (when some floodplain inundation may occur locally) and less frequent events.

- Full floodplain flow does not occur until likelihood 'rare', therefore floodplain impacts were assessed as 'rare' likelihood using the 1% AEP hydraulic data.

Conservative flow data has been taken for each likelihood bracket assessed which would result in the highest risk ratings for each likelihood:

- A 'possible' likelihood has an occurrence of between once a year (63% AEP) and once every 5 years (20% AEP). The 20% AEP flows, the largest flows within this likelihood bracket, were used in the assessment of consequences for a 'possible' likelihood.
- A 'rare' likelihood has a frequency of once in more than 20 years, equivalent to less frequent than the 5% AEP event. Flow data from the 1% AEP event has been used to assess the potential consequences for this likelihood. The 1% AEP event has larger magnitude flows than the 5% AEP event and inundates a larger area. Flood frequency and magnitude relationships assessed for four of the main Project watercourses (detailed in Table 3.5 indicate that the 1% AEP flows have a magnitude on the order of a third more to double the magnitude of flows for a 5% AEP event.

More frequent events than possible (almost certain and likely) would have minimal impacts on the fluvial geomorphic environment during the operations stage and have therefore not been included in the risk assessment:

- At likelihood 'almost certain' which occurs with a frequency of once per month, there would only be very minor flow in some watercourses, and no flow in the rest of the watercourses. Section 3.1.9 outlines a discussion of flow regime and provides a summary of the hydrological setting.
- Likelihood 'likely' which occurs with a frequency of once a month to once a year is more frequent than bankfull. Some minor within channel flow may occur at some watercourses.

Flow events at almost certain and likely likelihoods may have some impacts during the construction works stage between stripping and reinstatement/implementation of erosion controls at a site. However, the flows for monthly and annual events are very small, and many Project watercourses do not flow at all. Impacts during construction are more likely from less frequent events that actually result in flow. Therefore, construction works stage potential impacts on the fluvial environment have been assessed for likelihoods 'possible' and 'rare' (for floodplains).

During the construction works stage of the Project, the revised reference design will, in varying stages of construction, involve temporary works and be susceptible to flooding without mitigation measures fully implemented. During this stage of works, additional mitigation measures may be required to minimise impacts (Section 5.2.2).

2.5.2 Consequence Assessment Approach

A description of potential geomorphology consequences for each consequence level is included in Table 2.7 along with the environmental consequence (EIS Chapter 4: Assessment Methodology). Assessment of consequence level included consideration of the following:

- Baseline assessment including sensitivity to change. Sites with a higher sensitivity to change were assumed to require less change to result in the same consequence level as those with a lower sensitivity.
- Mitigation in the revised reference design, including scour protection.
- Outcomes of the impact assessment.

Sections 2.5.2.1 to 2.5.2.4 include additional factors taken into consideration when assessing potential consequence levels for various geomorphic processes.

Table 2.7 **Geomorphic commentary on consequence**

Consequence	Description	Geomorphology consequences
Not significant	Contained environmental damage – fully recoverable, no cost or ARTC action required	Geomorphic consequences that are already occurring in the environment. Estimated at approximately <10% change in flow characteristics for all soil types. This buffer covers natural variability and potential error in models and soil mapping resolution.
Minor	Isolated environmental damage – minimal ARTC remediation required	Direct consequences - Minor erosion or deposition at isolated culvert/bridge sites. - Examples may include immediate post construction (first 5 years) effects that need minimal remediation to address, minor design updates to culvert wingwalls, aprons etc may be required. Indirect/cumulative effects - Not significant as direct effects are isolated and minor
Moderate	Localised/clustered environmental damage – requiring remediation	Direct consequences - Minor to moderate erosion or deposition at clusters of sites. - Examples may include scour holes on the order of 5 m² and 0.5 m below the bed. Several metres of along bank erosion, < 0.5 m bank retreat, deposition downstream with minor infilling of existing pools. Indirect/cumulative effects - Indirect consequences starting to become apparent.
Major	Considerable environmental damage – requiring remediation	Direct consequences - Major erosion or deposition at an isolated culvert/bridge site or cluster of sites. - Examples may include scour holes on the order of 25 m² and 1 m below the bed. Tens of metres of along bank erosion, < 1 m bank retreat, deposition downstream with major infilling of existing pools. Indirect/cumulative effects - Indirect consequences may include new channels forming on the floodplain due to avulsion, bed aggradation, downstream adjustment of channel.
Extreme	Widespread long-term or permanent environmental damage – remediation required	Direct consequences - Extreme erosion or deposition at an isolated culvert/bridge site or cluster of sites. - Examples may include scour holes on the order of 100 m² and 2 m below the bed. Several tens of metres of along bank erosion, < 5 m bank retreat, avulsion forming a new channel, deposition downstream with major infilling of existing pools and possibly channels increasing future avulsion potential. Indirect/cumulative effects - Indirect consequences may include new channels forming on the floodplain due to avulsion, bed aggradation, downstream adjustment of channel.

2.5.2.1 Erosion

The following factors were taken into consideration when assessing increased erosion potential at a site due to the Project:

- The implementation of the revised reference design (including its scour protection and rehabilitation as per EIS Chapter 5: Project Description).
 - If increased flow velocity was identified as a potential impact, but was limited to the length of the scour protection, it was considered a minor consequence. If potential increased flow velocities extended beyond the scour protection, an assessment of consequence was made based on the flow velocity beyond the scour protection, baseline conditions and Existing Case sensitivity to change.

- Existing condition channel and floodplain ground cover has been used to identify where existing erosion is occurring in relatively frequent events, and inputs into the understanding of existing geomorphic processes. It has not been used to imply stream bank/planform stability during the construction works stage, where ground cover will be stripped prior to being reinstated.
- It is considered reasonable that the observed condition of the channel/floodplain from recent aerial imagery/site inspection reflects the geomorphic processes from a relatively frequent event such as the 20% AEP and is representative of the behaviour at Existing Case 20% AEP flow velocities.
- Consideration of the range of flow velocities across the same fluvial geomorphic landform, for example:
 - A design culvert may be in an area of a floodplain with below average Existing Case velocities (relative to the rest of the floodplain), and show a greater apparent increase in design flow velocities. Where design flow velocities at this culvert are consistent with Existing Case flow velocities elsewhere on the floodplain they are unlikely to result in elevated erosion potential.
 - Conversely, a channel may be showing signs of erosion under Existing Case conditions, with a high sensitivity to change. In this case even a small increase in design flow velocity would be likely to increase the erosion potential.
- The ETVs from SGM (2022) (Section 3.2.3) have been applied to the assessment of potential erosion due to the Project on floodplains as follows:
 - Where design flow velocities are within 10 per cent of the Existing Case, even if they are above the velocities in SGM (2022), the potential impact is assessed as not significant as change from existing processes is unlikely (Section 2.3.2).
 - Where design flows are greater than 10 per cent above the Existing Case, floodplain cross drainage sites meet the criteria for assessment of potential erosion due to the Project (Section 2.3.2). For these sites, the following velocity thresholds from SGM (2022) have been applied to assess for potential erosion in areas of the revised reference design without scour protection:
 - Erosion due to the Project is considered unlikely at sites with design flows greater than 10 per cent above existing but less than 0.4 m/s.
 - Erosion due to the Project is unlikely but may be a potential impact at some sites with design flows greater than 10 per cent above existing at design flow velocities between 0.4 and 0.5 m/s. Erosion potential at these design flow velocities is based on review of site-specific existing conditions and processes in particular, where there is evidence of Existing Case erosion at <0.5 m/s within the same landform.
 - Erosion has been considered a potential impact of the Project at all floodplains sites with design flows greater than 10 per cent above existing with design flow velocities greater than 0.5 m/s.
 - The consequence of the potential erosion is dependent on the site-specific existing conditions and processes.

Use of erosion threshold velocities for watercourses (channels)

Erosion threshold velocities are not typically used in fluvial geomorphic assessment as the natural environment is complex and dynamic. The ETVs are based on bed material samples and do not consider vegetation, slope, sinuosity, soil dispersity, armouring, volume of erosion, flow duration or geomorphic processes at the site and do not necessarily equate to the erosive potential. Areas of high flow velocity do not necessarily correspond to areas of erosion on the ground. The ETVs also do not consider existing sediment transport regimes, this is particularly important for channels with large bedloads that require a certain flow velocity to function. Reducing the flow velocities below the velocities required to transport a channel's bedload can cause deposition and may lead to blocked culverts and potentially avulsion. Design flow velocities should be sufficient to maintain existing sediment transport regimes. Site observations of existing geomorphic processes, such as locations and extents of erosion and deposition provide the best information on potential future impacts and site erosion potential.

Regional level ETVs for soils such as those in Table 9.1 in the *Soil conservation guidelines for Queensland* (Carey et al., 2015a) have not been used in this assessment as they do not reflect the Existing Case fluvial conditions for the following reasons:

- Fluvial systems are dynamic and natural fluvial processes require some erosion
- The ETVs are not representative of the erosive potential of a site
- The ETVs for bare soil range from 0.4 m/s to 0.7 m/s and are lower than the Existing Case 20% AEP flow velocities at 87 per cent of Project watercourses. These thresholds do not reflect field observations of geomorphologically stable channels.
- Imposing bare earth ETVs will reduce flow velocity from the Existing Case and may impact the sediment transport capacity of Project watercourses negatively and prevent natural fluvial geomorphic processes from occurring
- A reduction in the ability of a watercourse to transport sediment can lead to channel bed aggradation, change in channel and landform type (including avulsion) and reduced/loss of transport of woody debris. Woody debris has significant ecological importance as it has a role in carbon budgets and nutrient cycling, is a source of energy for aquatic ecosystems, provides habitat for terrestrial and aquatic organisms, and the presence of woody debris on gully floors can also reduce erosion.
- Areas of high flow velocity do not necessarily correspond to areas of erosion on the ground. Site observations of existing geomorphic processes, such as locations and extents of erosion and deposition provide the best information on potential future impacts and site erosion potential.

As per the Office of the Coordinator-General requirements (scope for this assessment, Section 1.3), detailed assessment has been undertaken for initial case high risk sites. As part of this detailed assessment, 'combined' ETVs were established for some sites. These 'combined' ETVs comprise a combination of 'theoretical' ETV assessment, based on laboratory testing, with site geomorphic observations. Refer to Section 2.5.3.1 for further details on this method.

ARTC propose to undertake further soil testing and ETV investigations, including flume testing, at potential high-risk geomorphological sites prior to final EIS approvals. Relevant mitigations including those relating to erosion treatment options within and external to the corridor will be reviewed and revised as necessary based on the updated analysis.

Flow duration and erosion potential

The amount of time water is flowing at velocities greater than the erosion threshold velocity can impact the amount of erosion produced. It is one among many of the factors that influence channel and floodplain erosion. Other relevant factors include bedload sediment size, shape and sorting characteristics; channel geometry and gradient; floodplain soils and vegetation cover; and channel and floodplain landforms. Given the complexity of, and interactions between these factors, there is no direct correlation between the length of time a flow exceeds an erosion threshold velocity and the extent of channel bed, bank, or floodplain erosion that may result. Assessing erosion potential based solely on time exceedance of erosion threshold values of soils is therefore unlikely to be representative of erosion potential.

Change in the time of inundation has been assessed under the hydrology and flooding EIS aspect against FIOs, and any exceedances were noted and mitigation options identified (EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1). The FIOs on inundation time do not consider changes to time by velocity. However, assessment of the changes in inundation duration shows that typically any change is due to afflux and most of these increased flows have very low velocities that are below Existing Case conditions. Some exceedances are likely a result of the maturity of the current cross-drainage design, and limited available information (i.e. survey).

In the Condamine River model change in time of inundation exceedances at private land outside the Permanent project footprint was mainly occurs along the floodplain fringes and in areas with slow moving floodwater. Flood duration exceedances may coincide with improvements in flood levels (i.e. reduced afflux) as a result of improved upstream floodwater retention. Future improvement in road and cross-drainage design maturity around Yandilla and west of Pampas is expected to mitigate the flood duration FIO exceedances. No exceedances in time of inundation were identified at Native Dog Creek or Cattle Creek, exceedances were identified in all other models with the largest increase in the Macintyre Brook Yelarbon to Inglewood Model.

It is important to note that the objective of this assessment is not to preclude erosion in all situations. Rather, the objective is to maintain Existing Case geomorphological processes of erosion, transport and deposition of sediment to ensure sustainable functioning of the fluvial geomorphic landform environment (Section 1.2).

For this qualitative assessment of potential impacts on the geomorphic environment, the approach taken identifies all sites with increased erosion potential. Conservatism within the risk assessment allows for potential increased erosion due to increased duration of flow above Existing Case flow velocities. Our assessment approach includes:

- Erosion has been assessed as a potential impact for all sites where design flow velocities are greater than the Existing Case by 10 per cent or more. Section 2.3.2 details the assessment methodology.
- Conservative hydraulic flow data has been taken for each likelihood bracket allowing for potential increased erosion due to increased duration of flow above Existing Case flow velocities:
 - A 'possible' likelihood has an occurrence of between once a year (63% AEP) and once every 5 years (20% AEP). The 20% AEP flows, the largest flows within this likelihood bracket, were used in the assessment of consequences for a 'possible' likelihood.
 - A 'rare' likelihood has a frequency of once in more than 20 years, equivalent to less frequent than the 5% AEP event. Flow data from the 1% AEP event has been used to assess the potential consequences for this likelihood. The 1% AEP event has larger magnitude flows than the 5% AEP event and inundates a larger area.

Hydraulic model refinement, detailed survey, soils testing and vegetation information will be gathered to inform detailed design. Using this additional detailed data, the assessment of differences in flow duration at elevated velocities for sites at increased risk of erosion may be considered at detailed design to inform site specific mitigations.

2.5.2.2 Deposition

The following factors were taken into consideration when assessing increased aggradation potential at a site due to the Project:

- Evidence for presence of bedload, as assessed from site field work and aerial imagery
- Almost all channels in the Project footprint are intermittent or ephemeral, and bed load (when present) is transported in pulses during a flow event
- Grassed channels were assumed to have a minimal bed load
- Sites with minimal bedload were unlikely to be at risk of increased aggradation
- Suspended sediment load was not taken into consideration in regard to increased aggradation potential, as suspended sediment component of sediment transport can be transported at very low velocities
- For sites with evidence of bedload, design flow velocities were compared to incipient motion velocities of the bedload material. Incipient motion is when the very first few particles in a soil begin to move, flow velocities required to transport the full bed load would be higher.

The incipient motion thresholds used were the highest of either Shields (1936), Ackers and White (1973) or Hanco (1971) for the largest grain-size within each bed-load type, resulting in a conservative approach. Appendix K provides further information on incipient motion of non-cohesive materials.

2.5.2.3 Planform change

The following factors were taken into consideration when assessing increased planform change potential at a site due to the Project:

- Existing condition planform change (including channel width) and channel type, based on aerial imagery review and site field work, sensitivity to change
- Location of bridge abutment relative to the fluvial landform. Bridges are typically located on watercourses with better defined channels
- Difference between Existing and Design Case velocities, as well as Design Case velocities on their own as even reduced flow velocities may be high enough to initiate planform change if flow is directed out of the channel or against the channel edge by design cross drainage
- Angle of the design culvert and flow relative to the existing channel as well as channel type.
 - Some of the channel types in the Project footprint are very wide, such as wash slopes which have no defined channel edge, and non-channelised valley floor which can be over 60 m wide. As these channels are so wide, a misaligned culvert will have a lower potential impact on planform change than a more defined, narrower channel type such as low sinuosity channel.

2.5.2.4 Channel type change

The following factors were taken into consideration when assessing increased channel type change potential at a site due to the Project:

- Historic channel type change, based on aerial imagery review and site field work
- Location of embankment abutment relative to the fluvial landform
- Change in existing to Design Case velocities
- Change from distributed flow, non-channelised valley floor or wash slope channel types, to point source flow where the design flow velocities are >10 per cent than the existing. Changes from distributed to point source flow may initiate erosion and development of rilling/gullying when there is increased design flow.
- The revised reference design (including scour protection and rehabilitation as per EIS Chapter 5: Project Description).

2.5.3 Detailed assessment for high-risk sites

2.5.3.1 'Combined' erosion threshold velocities approach

An ETV assessment was undertaken at high-risk sites as required by the Office of the Coordinator-General. The assessment of potential geomorphic impacts should never be based on ETV assessment alone but must also consider other geomorphic processes including sediment transport.

Geomorphic processes and characteristics have been a key component of the 'combined geomorphic ETV' assessment approach used for this assessment, which includes consideration of:

- Erosion threshold velocities assessed based on laboratory testing of bed material samples ('theoretical' ETVs)
- Existing Case hydraulic data
- Site-specific geomorphic mapping and assessment.

The methodology used for the assessment of theoretical ETVs undertaken as part of the high-risk site investigations is summarised in Section 2.5.3.2 and included in Appendix K, along with ETV outputs and a summary of existing ETV guidance values.

2.5.3.2 Theoretical ETV assessment approach

Theoretical ETVs are for bare soil conditions. In summary, there are two general approaches to the assessment of theoretical ETVs, those for non-cohesive soils and those for cohesive soils. Non-cohesive silts and sands are the most erodible soil types. Shields formula of incipient motion, based on the mean grain size of a soil, has been used as the basis for the ETV calculation for non-cohesive soils. The use of Shields incipient motion equation for theoretical ETV for non-cohesive soils is conservative and perceptible erosion will occur at higher velocities for the following reasons:

- Incipient motion is when the very first few median grain size particles in a soil begin to move and can occur at very low velocities
- While some movement of the median grain size may occur at incipient motion velocities, it is unlikely that they will be transported far
- In the natural world, soils include a range of grain sizes, and the median grain sized particles may be protected by larger particles which are more resistant to erosion, and therefore may not actually be transported at these low velocities
- As soils include a range of grain sizes, higher velocities would be required to mobilise and transport most of the particle sizes present in the soil, this is when visible erosion would occur.

The ETV for the D84 grain size (the grain size that 84 per cent of material is smaller than) has also been assessed for non-cohesive samples and is included in Appendix K. D84 represents the grain size when most of the sample will experience incipient motion.

Theoretical ETVs for cohesive materials are typically difficult to assess due to the increased number of variables, as a result there are very few methods available. The US Department of Transport *Scour in Cohesive Soils* (2015) method has been used for this assessment. The method requires several inputs including soil water content, fraction of fines, plasticity index and unconfined compressive strength to calculate critical shear stress, which is then converted to ETV with the input of Manning's roughness 'n' and water flow depth.

2.5.3.3 Combined geomorphic ETV assessment approach

The combined geomorphic ETV assessment takes account of the following three factors:

- Theoretical ETVs
 - These are derived from bulk samples
 - Vegetation of any kind is not included. Root mass is also not included, which would still be present on floodplains and vegetated channels even in severe drought conditions
 - Theoretical ETVs of bare soil represent the worst-case erodibility condition of a channel or floodplain, vegetation increases a soils resistance to erosion
 - Bare soil conditions are present at some channel types in Existing Case conditions. Bare soil conditions can be representative of erosion (e.g. the outside of an active meander bend), or they may not (e.g. due to the frequency of inundation, develop in-channel pools).
 - Overland flow pathways, washslopes and non-channelised valley floor flow typically do not have bare soil conditions, as they only flow in direct response to a rainfall event and have no formed channel which concentrates flow.
- Geomorphic field assessment
 - Identifies areas that are undergoing current erosion, are stable or where deposition is occurring, as well as confirming channel type, Mannings, geometry and any in channel or floodplain features, such as pools, bars or paleochannels
 - Field observations are based on the existing condition vegetation cover.

- Hydraulic modelling data

- For the 20% AEP Existing Case
- It is considered reasonable that the fluvial geomorphic processes observed at the site during field mapping are from a relatively frequent event such as the 20% AEP with maximum flow velocities on the order of those modelled for Existing Case conditions
- Hydraulic models represent our best understanding of flow conditions at this stage of the Project
- Field work conditions can change over very short distances, that can be smaller than the mesh size of the model. Thus model-derived flow velocities may not align with observed ground conditions. Professional judgement was required at these sites.

Figure 2.2 provides a flow diagram of the assessment process. The variability of soil types and vegetation distribution at sites makes correlation with areas of on ground erosion and patterns very difficult, and this was not able to be established for any of the high-risk sites assessed. Gully sites are particularly diverse. Typically, active gully development only occurs at channel heads, and downstream these features broaden out into a wider vegetated channel. Gully's typically form in texture contrast soils, such as sodosols, which include a non-cohesive upper soil horizon, and a cohesive lower soil horizon. A duricrust may also be present overlying the upper soil horizon.

The combined geomorphic ETV has been assessed for 20% AEP conditions. Theoretical ETVs for rare events such as the 1% AEPs may be higher, this is due to the impact of increased water depth increasing the ETV of a bare soil.

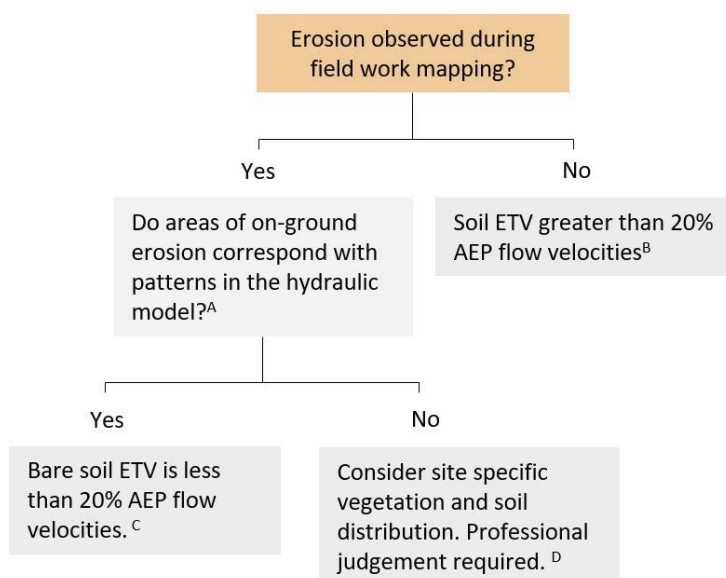


Figure 2.2 Combined Geomorphic ETV Assessment Approach

Figure notes:

- A Theoretical soil ETVs may be an important consideration for assessing fluvial geomorphic effects (e.g. is there a clear difference in modelled velocity between areas of erosion and areas of stable channel or deposition).
- B Theoretical soil ETV not relevant for interpreting potential geomorphic effects. If no erosion is occurring note if soil is vegetated or bare.
- C Assess distribution of soil types across eroding area/s. Use theoretical ETVs to inform assessment of potential fluvial geomorphic effects where soil erosion is currently occurring.
- D Erosion is occurring but does not align with hydraulic modelling outputs. Consider site specific information.

3 Baseline fluvial geomorphic assessment

3.1 Regional setting

3.1.1 Regional fluvial system

The fluvial system is the collection of hillslopes, channels and floodplains that convey rainfall off the land surface and eventually down to the sea. The fluvial landforms within this system provide boundary conditions within which other environmental and human systems operate such as river sediment transport systems, riparian wetlands and groundwater systems.

A useful organising concept of the fluvial system was proposed by Schumm (1977), which divides a river catchment up into three zones (Table 3.1):

- *Source zone* where water and sediment are delivered to the channel network. This occurs in the headwater parts of the watershed.
- *Transfer zone* through which water and sediment is being carried with the latter being temporarily stored in floodplains and terraces (long term storage), channel benches (medium term storage), and channel bars (short term storage)
- *Sink zone* where water is delivered to a lake, or the ocean and sediment permanently deposited in a delta or alluvial fan.

Table 3.1 Fluvial system process zones

Process zone	Landforms	Dominant fluvial process	Valley setting
Source	Typically, mountain ranges. In the Study area this zone comprises low relief soil covered hill country.	Erosion via vertical cutting; minimal sediment storage.	Confined or semi-confined.
Transfer	Hills, erosional piedmonts.	Erosion via lateral cutting; fluctuating sediment storage.	Semi-confined or unconfined with bedrock base.
Sink (accumulation)	Coastal plains, alluvial plains, depositional piedmonts, playas.	Deposition and net sediment accumulation.	Unconfined with fully alluvial channel boundaries.

Within the broad regional catchment setting, the Study area is located in the source zone of the Murray Darling River system that drains into the ocean at Adelaide. Locally the Study area includes source zones of numerous smaller drainage systems, several transfer zones, and a few sink zones where sediment is temporarily accumulating.

3.1.2 Topography

The Study area is near the eastern edge of the Australian continent where the large scale fluvial geomorphic environment is controlled by several continental scale topographic systems that bear witness to tens to hundreds of millions of years of landscape history. There is a discernible unity in the topography that varies from dramatic steep escarpments to apparently flat plains. Topographic variability is often related to the different rock types beneath the surface and the together these factors represent boundary conditions for the fluvial geomorphic systems that are the focus of this assessment.

Figure 3.1 shows the regional topographic setting and main river catchments of the Project alignment. From southwest to northeast the Project starts on low inland plains at approximately 225 m above Australian Height Datum (m AHD), then rises to approximately 475 m AHD at the divide between the Macintyre Brook and Condamine River catchments, drops down into the Condamine valley to approximately 380 m AHD then rises to 600 m AHD in the hill country near Toowoomba before ending at approximately 455 m AHD in the Gowrie valley.

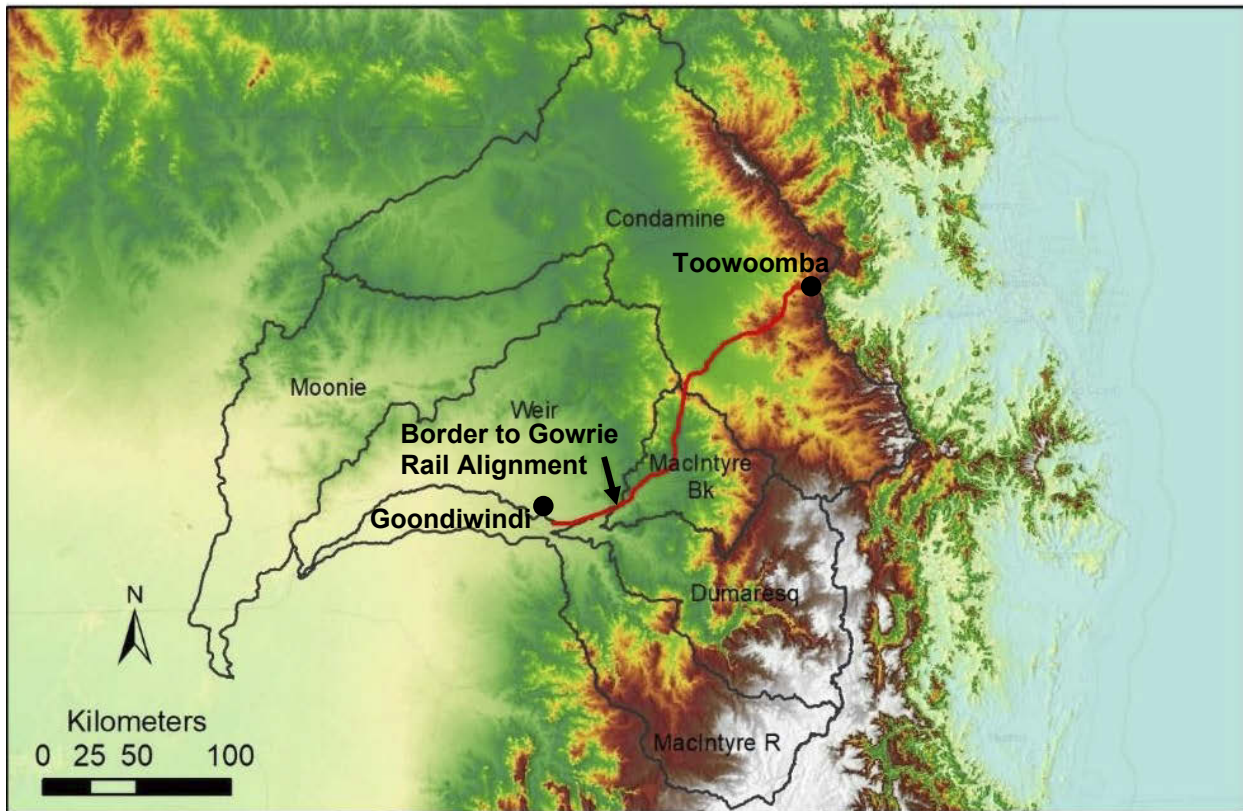


Figure 3.1 Digital elevation model of the Project region and main river catchment

The Digital Elevation Model (DEM) in Figure 3.1 shows the highest elevations in excess of 1,200 m AHD occur in the headwaters of the Macintyre, Dumaresq and Condamine Rivers. However, the relief difference between valley floors and the adjacent mountains is typically only a few hundred metres so that surface slopes are not great being mostly $<5^\circ$ and rarely $>10^\circ$. Away from the higher elevation areas there is much less relief difference between the valley floors and adjacent plains and hills with <10 m common along parts of the Project.

Thus, although the DEM gives the impression of a hilly and mountainous landscape it is in fact often flat and featureless when viewed at ground level, particularly along the Project alignment where of necessity the slopes are very gentle to provide for efficient rail transport.

Figure 3.2 shows the regional catchments and river main stems that will affect the fluvial geomorphic environments along the rail route. The topography along the Project alignment comprises eight environments:

1. Ch 30.6 km (NS2B) to Ch 41.0 km – After crossing the Macintyre River floodplain, the Project alignment traverses across level plains at 225 m AHD rising to 270 m AHD. These level plains are on or close to the indistinct catchment divide between the Weir, Macintyre and Dumaresq Rivers as there are very few organised channel systems here, few fluvial geomorphic effects are expected.
2. Ch 41.0 km to Ch 65.0 km (near Inglewood) - Crossing the lower slopes of low hills adjacent to the Macintyre Brook valley floor. Elevation varies up and down more than 65 m and reaches 340 m AHD at Ch 59.0 km. Several watercourses drain from these hills and cross the Project alignment.
3. Ch 65.0 km to Ch 116.0 km - Located up the axis of the Canning Creek valley, a tributary of Macintyre Brook. Here the topography is less variable while climbing steadily from approximately 290 m AHD to approximately 475 m AHD at the Macintyre Brook/Condamine River catchment divide. Numerous watercourses drain from low hill landscapes to the west cross the Project alignment.
4. Ch 116.0 km to Ch 140.0 km - The Project alignment drops into the Condamine River valley running down the Back Creek catchment (a tributary of the Condamine River) and lower valley side slopes. Several local catchments support watercourses that cross the Project alignment.

5. Ch 140.0 km to Ch 152.0 km - Crosses the Condamine River floodplain that includes the main stem and several anabranches. The flat topography is at approximately 380 m AHD, and the main stem and its associated anabranches are fed by water draining >7,000 square kilometres (km²).
6. Ch 152.0 km to Ch 165.0 km – The Project alignment climbs gentle valley side slopes on the north bank of the Condamine River floodplain, rising to 460 m AHD. The gentle lower slopes do not support watercourses, but in the last 5 km the topography steepens, and a few streams drain from the south across the Project alignment.
7. Ch 165.0 km to Ch 208.2 km - The Project alignment runs through the highest elevation and highest relief landscape of the entire route. It reaches 600 m AHD at Ch 180 km and at Ch 189 km crosses a watershed divide between the Condamine River and Oakey Creek catchments. The Project alignment rises and falls approximately 175 m along this section and numerous small watercourses cross the Project alignment.

Overall, along the 217.48 km Project alignment, within the study area, there are some 1,300 km² of slopes that direct water down towards the Project alignment. Most of them associated with environment 3 (Canning Creek, 618 km²) and environment 7 (Oakey Creek, 364 km²). These are small catchments, dwarfed by the 7,017 km² Condamine River catchment that crosses just 13 km of the Project alignment, and the 22,738 km² Macintyre River catchment that crosses just 12.6 km of the Project alignment.

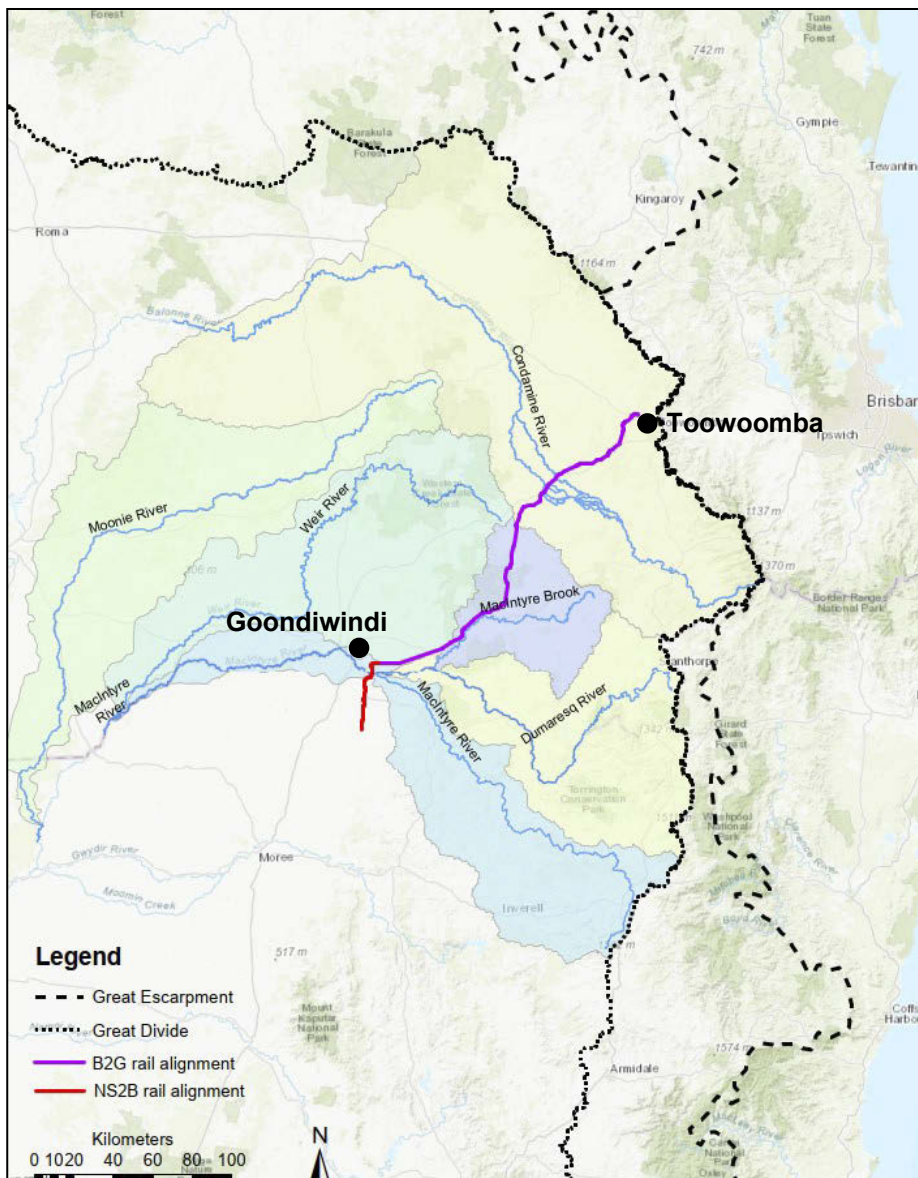


Figure 3.2 Regional catchments

3.1.3 Geology

The nature of the geological materials at or near the surface strongly influences landscape topography and the fluvial geomorphology processes and landforms that occur thereon. The surface geology along the Project is predominantly alluvial materials (56 per cent) that occur as old (35 per cent) and younger deposits (10 per cent). Deeply weathered old sedimentary rocks underlie 36 per cent of the route, and 19 per cent of the route is in basalt. At ground surface, rocks are weathered to residual soil.

The Regional Geomorphic Landscapes in the Study area are illustrated on Drawings Set A (Appendix A) and are effectively a geological map as the topographies developed on each of the rock types are distinctively different.

The following sections briefly describe the rock types and their distribution.

3.1.3.1 Mesozoic sedimentary rocks

The oldest rocks along the Project alignment are sedimentary strata laid down in terrestrial environments from 210 to 145 million years ago during the time that Australia was part of the Gondwanaland supercontinent. The geological period of their formation is known as the Jurassic which was middle part of the Mesozoic Era. They consist of sandstone, siltstone and mudstone and include the Walloon Coal Measures that are mined near Millmerran. They have been little deformed since deposition as they remain relatively flat lying. However, there has been much landscape change since then and these units have been deeply weathered so that hard ferricrete duricrusts have developed near the surface.

These rocks occur widely in the low hill country south of the Condamine River especially the western parts of the Canning Creek catchment. East of the Project alignment in the Macintyre Brook catchment, older Mesozoic aged rocks occur, and these extend eastwards into the headwaters of the Condamine, Dumaresq and Macintyre River catchments. However, these older rocks do not occur along the Project.

3.1.3.2 Tertiary alluvium

The Tertiary Period spans from 65 to 2.5 million years ago and is part of the Cenozoic Era. Approximately 40 million years ago (the Eocene Period), the regional landscape had developed to be not dissimilar to the present landscape and deposits of mainly river alluvium were laid down widely. Comprising mainly sand and gravel, the older deposits have been semi-consolidated and some silcrete duricrust development has occurred.

They occur widely on the lower flanks of the Condamine, Weir, and Macintyre River valleys where they form extensive gently sloping plains. They also occur at higher elevations either side of the Condamine River/Macintyre Brook drainage divide where they have been somewhat more dissected by erosion.

3.1.3.3 Tertiary basalt

The northern 44 km of the Project alignment passes over and through an extensive area of basalt. Basalt volcanism has occurred widely along the eastern edge of the Australian continent throughout the Tertiary Period and a particularly large expanse of it occurs around Toowoomba and southwest to Pittsworth. It is known as the Main Range Volcanics. Basalt lava has relatively low viscosity and when formed can flow for long distances down pre-existing valleys, hence its wide occurrence.

The volcanism occurred around 20 to 25 million years ago and since then has been weathered and eroded. Duricrust development occurs on the basalt through Toowoomba City. Erosion of the basalt has contributed sediment to the Condamine River valley floor allowing the development of black soils (or cracking clay soils).

3.1.3.4 Quaternary alluvium

The Quaternary Period covers the last 2.5 million years to the present day and the modern river valley floors and floodplains developed over this time span. The alluvium is mainly silt and clay with minor sand and gravel and it occurs along the floodplains. It represents bedload that has been deposited by the streams and rivers as they slowly migrated across the valley floors.

Quaternary alluvium occurs most extensively on the floodplains of the Condamine, Dumaresq, and Macintyre Rivers, but it is only at the Condamine River that the Project alignment runs across the floodplain, while the other floodplains are close to, but not directly impacted by the railway.

Alluvium also occurs along the Canning Creek and Macintyre Brook valley floors although the floodplains are constrained by the close approach of the valley sides. The Project alignment runs closely adjacent to and in places along these alluvial deposits.

3.1.4 Southern Queensland landscapes

The regional topographic, river systems and geological characteristics described above combine to define broad landscape elements that are an important context for understanding the fluvial geomorphic setting for the Project. These Southern Queensland landscapes are part of a large-scale continental pattern.

Three main landscape features dominate the eastern margin of the Australian continent:

1. Coastal Plain with Residual Hills rising above it. In Southern Queensland the coastal plain is approximately 125 km wide, and the residual hills rise 600 m to 700 m above the plain.
2. Great Escarpment that rises abruptly from the inner edge of the coastal plain. Between Withcott and Toowoomba the land rises 420 m in less than 5 km and there are distinctive approximately 100 m high cliffs at the top of the escarpment.
3. Eastern Uplands and the Great Dividing Range. The uplands are typically 100 to 200 km across and rise just a few hundred metres above the valleys that cut through them. The Great Dividing Range is generally many kilometres west of the Great Escarpment and is somewhat mis-named as it is not topographically 'great' and is often associated with flat-topped tablelands. However, it does mark a major continental-scale drainage divide with rivers on the eastern side draining to the Tasman Sea, and those on the west draining to the Murray-Darling system that flows into the Southern Ocean some 1,500 km to the southeast near Adelaide.

The highest landscape relief is associated with the residual hills and Great Escarpment where mountains can rise to over 1,000 m. In the Lamington National Park 90 km south of Brisbane, Bithongabel rises to 1,195 m, and the landscape is quite rugged. Once the Great Escarpment is crossed the landscape is much less dramatic and elevation falls away considerably to the west. The Project alignment is at approximately 600 m elevation near Toowoomba, but at the western end just 200 km away it has dropped to 230 m elevation. Relief is much lower with generally less than 200 m separating the highest and lowest parts of the landscape.

The landscapes described here extend along the whole eastern seaboard of the Australian continent and through most of this the Great Escarpment is well to the east of the Great Divide. This relates to the origin of the landform in an escarpment formed by rifting as Gondwanaland broke up >100 million years ago. Since then, the escarpment has been eroding its way west into the continent, forming the coastal plain and leaving behind the more resistant rocks as residual hills.

However, in the Study area the escarpment and the divide come close together and for some 240 km they are effectively co-located (Figure 3.2). Thus, the eastern Condamine River catchment divide marks the location of both the Great Escarpment and the Great Divide. This is the closest the Great Divide comes to the coast. The whole Study area is in the Eastern Uplands landscape province, and it all drains west to the Murray-Darling system.

3.1.5 Regional fluvial geomorphic landscapes

The Project is located within the Eastern Uplands and the landscape comprises four regional geomorphic landform types that have distinctive topography and geology. These are shown in Appendix A, Drawing Set A, which covers the area approximately 45 km either side of the Project alignment.

From youngest to oldest these landscapes are:

1. Valley floor floodplains - These are the presently active valley floors where most of the sites requiring fluvial geomorphic assessment are located. The topography is generally flat with less than 5 m of relief and the primary landforms are active and abandoned channels and adjacent floodplains. Although widely used for agriculture, these areas are still actively forming elements of the landscape and have been developing throughout the Quaternary Period (2.5 million years to present).
2. Alluvial plains - These occur in two groups: i) on lower valley side slopes adjacent to the valley floors, and ii) higher in the landscape in old valley systems within the low hills. The lower valley side slopes are wide flat river plains that formed over millions of years in the later part of the Tertiary Period (25 to 2.5 million years ago). They were formed after the main elements of the landscape had been established but are no longer actively forming and are mostly high enough to not be affected by floodwaters. They occur up to approximately 400 m elevation and may vary by approximately 50 m of elevation change, but the surface relief is typically <10 m reflecting the limited erosion that has occurred since they were formed. The higher alluvial plains are similar but are more constrained within the low hills landscape. Surface relief can be >10 m possibly indicating they are older, and as they occur above 400 m elevation in some places on catchment divides (such as between Canning Creek and the Condamine River valley) they are less obviously related to the present arrangement of the landscape. Given the low relief characteristics of these areas there has been limited watercourse development.
3. Moderate relief hills occupy the highest part of the landscape and are found around Toowoomba - These are formed in the Main Range Volcanics basalt lavas. There the surface relief can be up to approximately 150 m and there are numerous small hills and tablelands that rise >75 m above the surrounding country. The basalt was erupted 20 to 25 million years ago, and the surface has been eroded many 10s of metres since then and some deep weathering and duricrust development has occurred. The higher relief topography has allowed more development of watercourses fed by larger catchment areas.
4. Low relief hills are the oldest element of the landscape occurring widely in the Macintyre Brook catchments - Underlain by very old sedimentary rocks formed hundreds of millions of years ago they have been deeply weathered and tablelands and duricrusts occur widely in the western parts of the Canning Creek sub-catchments. There is generally more than 50 m of relief.

The total area included in the Regional Geomorphic Landforms Drawing Set A (Appendix A) covers approximately 20,000 km² (all within the Eastern Uplands), termed the Project region. The proportion of each landscape type is shown in Table 3.2. Low hills and alluvial plains are the most frequently occurring together comprising 68 per cent of the area. Valley floors within which much of the fluvial geomorphology occurs cover 14 per cent of the area. The mapped area includes a small part of the Great Escarpment landform east of Toowoomba, but this is not directly relevant to the Project.

Table 3.2 Landscape types of the Project region

Landscape type	Area (km ²)	% of Project region
Valley floors	2,808	14.1%
Alluvial plains	5,717	28.7%
Moderate hills	2,660	13.3%
Escarpment	981	4.9%
Low hills	7,764	39.0%

3.1.5.1 Regional geomorphic landscapes of the Border Rivers catchment

From the Macintyre River floodplain to Ch 116 km, the Project alignment passes through Border Rivers catchments to the watershed divide between Canning Creek and Back Creek (a small tributary of the Condamine River). Overall, the Project alignment rises from 231 m to 474 m elevation (243 m total), including a combined total climb of 642 m and a combined total fall of -399 m. In this distance it passes through four different areas.

1. Ch 30.6 (NS2B) km to Ch 33 km (B2G)- The Project alignment crosses the Macintyre River floodplain.
2. Ch 33 km to Ch 40 km - Gently rising plains along the Weir/Macintyre/Dumaresq drainage divide. The Project alignment crosses and re-crosses the divide so that there are effectively no runoff catchments and thus no organised drainage network. There are no channels requiring fluvial geomorphic assessment.
3. Ch 40 km to Ch 65 km, near Inglewood - The Project alignment enters the lower Macintyre Brook catchment where low hills on the west come down close to the valley floor. The route skirts along the lower slopes of these hills which support several small catchments with watercourses crossing the alignment. These are mostly small 1st and 2nd Strahler order streams with one 3rd order and one 4th order stream.
4. Ch 65 km to Ch 116 km - The Project alignment enters the Canning Creek catchment and runs near this stream close to the valley floor. It crosses low hills, alluvial plains and floodplains. The sub-catchments are larger and support larger watercourses with distinct channel landforms of 3rd, 4th and 5th Strahler order and these are named (Bringalily, Cattle, Back, Canning, Native Dog, Nicol, and Pariagara creeks).

3.1.5.2 Regional geomorphic landscapes of the Condamine River catchment

From Ch 116 km to the end of the Project alignment at Ch 208.2 km the route pass across the Condamine River catchment. There is an overall fall of just 17 m but there is a combined total fall of -596 m and a combined total climb of 579 m; so, it has more local relief change than the Border Rivers section. It passes through four different areas.

1. Ch 116 km to Ch 140 km - The route runs down the Back³ Creek catchment mostly across alluvial plains with some low hills in the upper catchment. This low relief landscape supports a few small sub-catchments and watercourses mostly of 1st and 2nd Strahler order, with a 4th and a 5th order streams about halfway down.
2. Ch 140 km to Ch 152 km - Here the route crosses the Condamine River floodplain which is very flat and forms a large flood basin. There are three main anabranches of the river that are fed by a very large 7,017 km² catchment.
3. Ch 152 km to Ch 165 km - Gently rising alluvial plains on the north side of the Condamine River floodplain. The Project alignment runs perpendicularly up this slope, and no mapped watercourses cross the alignment. However, several small catchments can be identified from contour patterns on topographic maps.
4. Ch 165 km to Ch 208.2 km - This final section of the route crosses the moderately hilly basalt landscape. It has numerous changes in elevation as it passes through the numerous hills in this landscape. Given the greater relief there are numerous catchments with watercourses crossing the Project alignment. These are mostly 1st and 2nd Strahler order along with one 3rd order and one 4th order stream. Despite the relative low Strahler order some of the streams are large enough to have been named (Westbrook Creek, Oakey Creek, Gowrie Creek, Dry Creek and One Mile Gully).

³ There is also a Back Creek in the Canning valley (referred to as 'Back Creek 2' in this report).

3.1.6 Relief inversion

Relief inversion is a landscape development process that occurs in the Study area. It is associated with the basalt lava flows and the duricrusts that develop in deep weathering profiles. In both situations, relatively hard geological materials occur in the landscape that can affect channel development and the calibre of the bedload carried by the streams.

There are relatively small outcrops of basalt in the low hill country south of the Condamine River immediately west of the Millmerran coal mine (Ch 122.0 km), Captains Mountain, West Ridge and South Ridge. There are weathered basalt hills east of the rail route in Mt Domville, Mount Basalt, and Clontarf. These form the highest parts of the local landscape at around 650 m elevation, some 150 m above the nearby valley floors. When the basalt was emplaced, it would have flowed down the valley floors and solidified in the lowest part of the local landscape.

Connecting the scattered outcrops together today they form a 20 km long meandering feature with at least one tributary branch that would have been the valley alignments when the eruptions occurred approximately 20 million years ago (assuming these basalts are similar age to the Toowoomba basalts on the north side of the Condamine River valley). The hard basalt lava would have resisted erosion while the adjacent valley sides would have continued to erode away so that what was once valley floor is today at the top of the landscape and what was previously the top of the landscape has been worn down to now be valley floor. This relief inversion process has resulted in >150 m of erosion in approximately 20 million years, an average landscape denudation rate of 0.0075 mm/yr., which is very slow.

The hard cemented duricrust features (ferricrete where the cementing is by iron, and silcrete where the cementing is by silica) also occur in the highest parts of the low hills landscape areas. The deep weathering that results in duricrust formation is understood to occur in the groundwater zone in valley floors and the same relief inversion process has resulted in the duricrust tablelands now being the highest parts of the local landscape. These tablelands also can be traced in channel like patterns as with the basalts ridge tops.

As well as demonstrating slow rates of landscape formation, these hard-rock elements of the landscape often contribute gravel bedload to local stream systems and being hard create knick points and even waterfall sites along the stream channels.

3.1.7 Land degradation

Land degradation denotes a range of land surface effects resulting in loss of soil and vegetation cover. Processing of specific concern include soil erosion and gullyng that result in loss of productive land and delivery of sediment to watercourses (an example is displayed in Figure 3.3).

While some level of land degradation is a natural process in the Study area environment, accelerated rates often follow in the decades after land is cleared of trees. Accelerated land degradation was observed during this review. This will have increased the volume of sediment being delivered to the watercourse.

The significance of this land degradation is that it is a response to the previous decades of land use practises that is only now becoming evident in the landscape. The sediment that is being delivered to the stream channels has yet to make its way fully down the system, and as it moves down valley, channel aggradation is likely to occur. Future management of watercourses in the Project footprint needs to consider the potential for increased sediment loads that are unrelated to the proposed Inland Rail Project activities, but which may result in reduced capacity of the channels to convey flood flows.

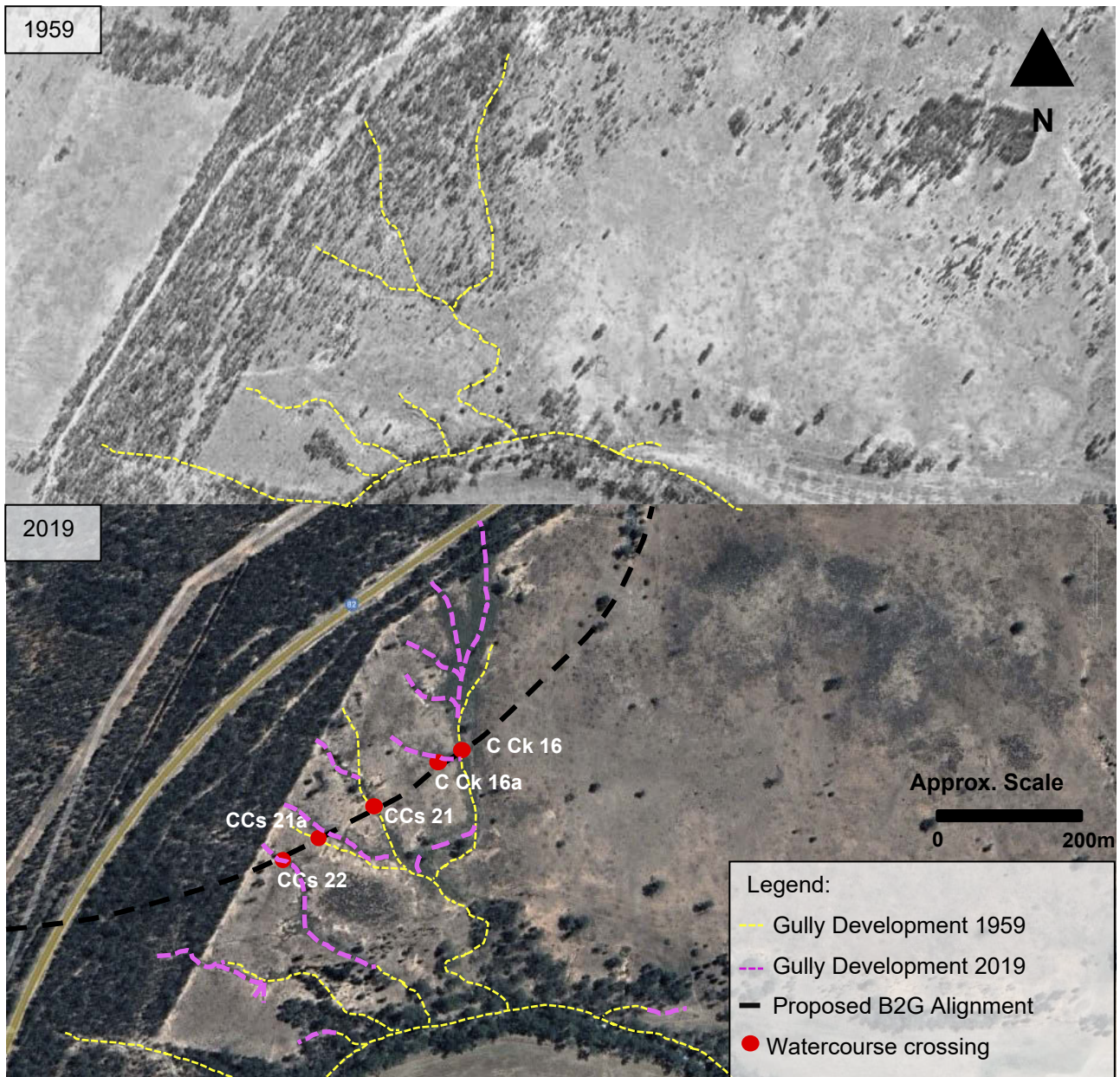


Figure 3.3 Example of land degradation resulting in gully development between 1959, upper image and 2019, lower image.

3.1.8 Climate

The key climate characteristic affecting fluvial geomorphology processes is rainfall. This is the ultimate source of runoff in the streams, whether by direct overland flow after rainfall (stormflow that feeds the ephemeral streams), or infiltration through the soil to groundwater which is slowly released to the stream network over following months or years (baseflow that feeds intermittent and perennial streams).

Figure 3.4 shows mean monthly rainfall⁴ along the Project alignment from northeast (Toowoomba) to Southwest (Goondiwindi). Annual rainfall declines to the southwest from an average of 713 mm/annum at Toowoomba to an average of 621 mm/annum at Goondiwindi. There is a marked dry season from April to December when on average 33 per cent of annual rainfall occurs. The wettest months are December to February and these months have also recorded the heaviest daily rainfalls (ranging from 150 mm to 190 mm, with the maximum recorded at Inglewood of 241.6 mm being considered an outlier).

⁴ Bureau of Meteorology data: Toowoomba Airport, Stn # 041529, 1996 to 2021; Pittsworth, Stn # 041082, 1886 to 2021; Millmerran Post Office, Stn # 041069, 1900-2014; Inglewood Post Office, Stn # 041047, 1883-2021; Goondiwindi Post Office, Stn # 041038, 1879-1991

In the dry season months rainfall is brought by frontal systems coming from the west and as these have travelled for a long distance over land, they generally do not bring heavy falls. The wet season winds are from the east – southeast associated with the southern edge of the tropical trade wind belt and coming from over the ocean they bring more rainfall and the occasional remains of tropical cyclones.

These rainfall pattern drive stream and river flow variability as discussed below.

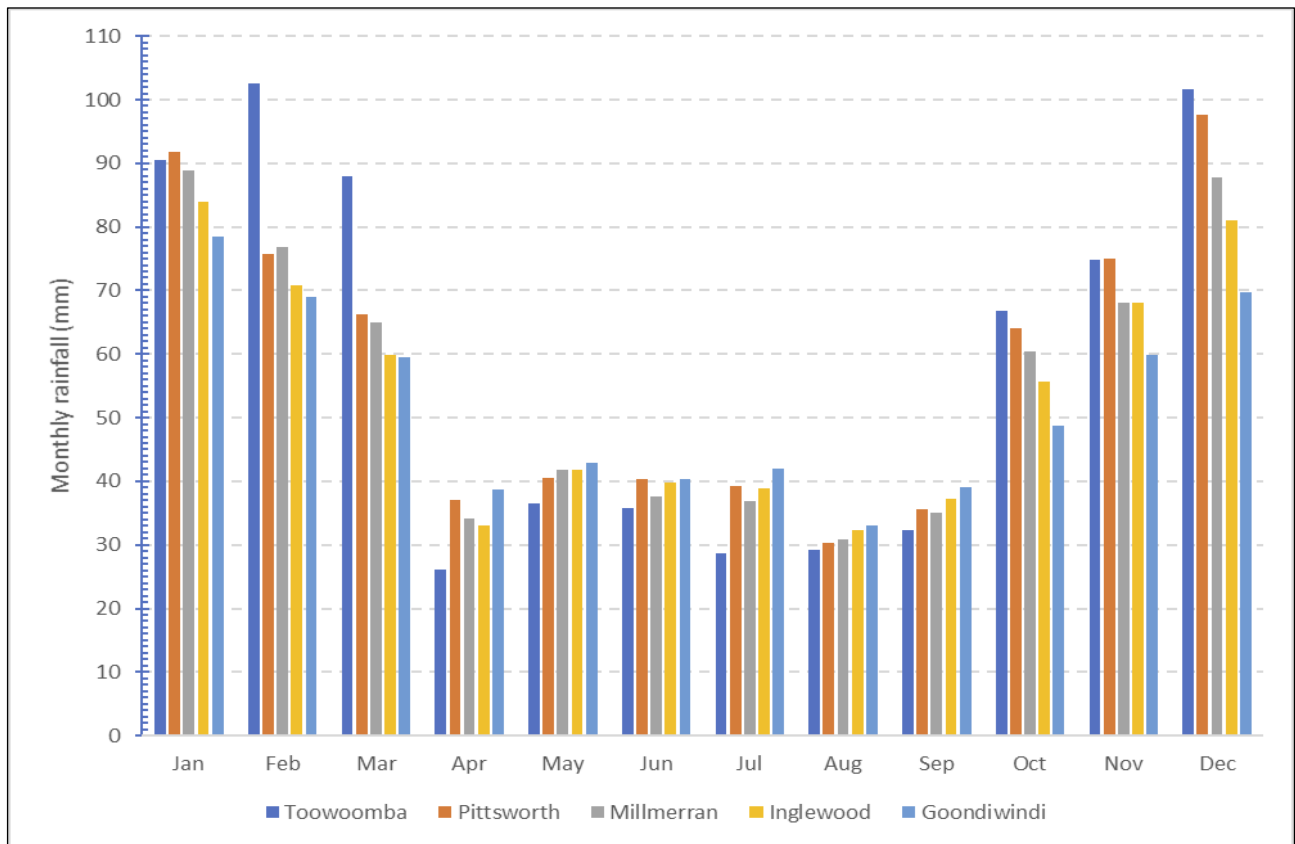


Figure 3.4 Mean monthly rainfall along the Project alignment

3.1.8.1 Climate change sensitivity

A climate change sensitivity analysis has been undertaken under the hydrology and flooding EIS aspect for the 1% AEP event at regional catchments to determine the sensitivity of the Project to the potential long-term changes in climate identified (EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1). The analysis reports on per cent increase in rainfall for the regional models and change in peak water levels at flood sensitive receptors. The Representative Concentration Pathway 8.5 (2090 horizon) climate change scenario has been adopted for the sensitivity analysis. The assessment was undertaken in accordance with ARR 2019.

An analysis on changes to flow velocity has been undertaken to determine the sensitivity of geomorphic process to potential long-term changes in climate (1% AEP event). To focus the assessment on potential changes in the area of design cross-drainage the assessment considers changes in the regional hydraulic models within the Project permanent footprint. The results of this sensitivity analysis are presented in Table 3.3, and summarised below:

- Potential flow velocity changes are within 0.1 m/s of the Existing Case for 44 to 95 per cent of the regional hydraulic models, little change is expected in these areas.
- 9 to 49 per cent of the regional hydraulic models have potential flow velocity changes of between 0.1 to 0.5 m/s of the Existing Case, some changes in geomorphic processes including deposition and erosion may occur in these areas where there is no scour protection.

- 9 of the 12 regional models have potential flow velocity changes of between 0.5 m/s to 1.0 m/s of the Existing Case, this ranges from <0.5 to 6 per cent of the Project's permanent footprint within the models. Changes in geomorphic process are likely in these areas.
- 8 of the 12 regional models have potential flow velocity changes of greater than 1 m/s of the Existing Case, this ranges from <0.5 to 1 per cent of the Project's permanent footprint within the models. Major changes to geomorphic process may occur in these areas.

There is a range in sensitivity to flow velocity due to climate change across the 12 regional hydraulic models. Westbrook Creek is the most sensitive and has the largest potential changes in flow velocity due to climate change. More than 50 per cent of the Westbrook Creek regional model within the Project's permanent footprint would likely experience changes to geomorphic processes as a result of climate change driven changes in flow velocity. Bringalily Creek, Gowrie Creek, Macintyre Brook, MB 7 and Pariagara Creek may experience geomorphic change in between 44 to 40 per cent of the area within the permanent Project footprint. Back Creek 1, Condamine River and Nicol Creek may experience geomorphic change in between 17 to 33 per cent of the area within the Project's permanent footprint. The least changes in flow velocity due to climate change are with the Cattle Creek, MB 6 and Native Dog Creek regional models, where geomorphic change may occur in between 5 to 10 per cent of the area within the Project's permanent footprint.

Table 3.3 Climate change flow velocity sensitivity assessment 1% AEP event

Regional Hydraulic Model Name	Changes to flow velocity due to climate by percentage of the permanent Project footprint			
	Within 0.1 m/s	Between 0.1 to 0.5 m/s	Between 0.5 to 1.0 m/s	Greater than 1 m/s change
Back Creek 1	79%	19%	2%	0% ¹
Bringalily Creek	60%	34%	5%	0% ¹
Watercourse MB 7 (Bybera Road Model)	58%	41%	0%	0%
Cattle Creek	90%	9%	1%	0%
Condamine River	83%	17%	0% ¹	0% ¹
Watercourse MB 6 (Cremascos Road Model)	95%	5%	0%	0%
Gowrie Creek	56%	40%	4%	0% ¹
Macintyre Brook	56%	40%	4%	0% ¹
Native Dog Creek	93%	7%	0%	0%
Nicol Creek	67%	32%	1%	0% ¹
Pariagara Creek	56%	43%	1%	0% ¹
Westbrook Creek	44%	49%	6%	1%

Table note:

1 <0.5% of the Permanent Project Footprint is affected.

3.1.9 Hydrological setting

The Project is situated across parts of two of the headwater catchments of the Murray-Darling Basin: the Condamine-Balonne catchment and the Border Rivers catchment.

The Condamine-Balonne catchment covers some 137,930 km² of which the Condamine River (30,528 km²) is the eastern part. Where the Condamine River crosses the Project, it is being fed by runoff from 7,017 km² of the upper catchment. Downstream of here the river flows in a broad arc to the northwest, then west and southwest to join the Balonne River >300 km downstream.

The Border Rivers area a group of smaller catchments to the south of the Condamine-Balonne catchments, including (from north to southeast) the Weir River (13,269 km²), Macintyre Brook (4,195 km²), Dumaresq River (9,755 km²) and Macintyre River (8,685 km²). They for this group because across 450 km, the main stems of these rivers (mainly Dumaresq, then Macintyre⁵ Rivers) form the NSW/Queensland Border. Altogether the catchments cover 35,905 km². The rivers flow west and northwest from the western slopes of the Great Dividing Range on both sides of the border. Macintyre Brook joins the Dumaresq River opposite Ch 25.0 km (6.5 km to the south), then the Dumaresq joins the Macintyre River opposite approximately 4 km upstream of the Macintyre River Viaduct (Ch 30.55 (NS2B) km). The Macintyre River is joined by the Weir River >150 km to the west to become the Barwon River and this is joined by the Balonne (Condamine) River approximately 70 km further to the southwest.

The Weir River and Macintyre Brook catchments are within Queensland while the Dumaresq is partly in Queensland and mostly in NSW and the Macintyre River is almost entirely in NSW. The Project crosses the Macintyre River floodplain and sidles the Macintyre Brook.

Flow data for some of the rivers and watercourses that cross the Project are available on the Queensland State Government's Water Information Portal (water-monitoring.information.qld.gov.au).

Large rivers:

- Condamine River @ Tummalville (upstream of the Project, Site 422323A, catchment area 6,475 km², 1961 to 2021) and Cecil Weir (downstream of the Project, Site 4222316A, catchment area 7,795 km², 1947 to 2021).
- Macintyre River @ Goondiwindi (20 km west of the Project, Site 416201A, catchment area 23,090 km², 1917 to 2021).

Large contributing catchment:

- Macintyre Brook @ Inglewood (near Ch 65.0 km, Site 416402B and 416402C, catchment area 3,430 km², 1953 to 1981, and 1981 to 2021).

Contributing catchments:

- Canning Creek @ Woodspring (near Ch 73.0 km, Site 416407A, 1,245 km², 1954 to 1980).
- Westbrook Creek @ Arcadia (near Ch 198.0 km, Site 422331A, catchment area 256 km², 1967 to 1981).
- Gowrie Creek @ Oakey (14.5 km west of the end of the Project, Site 422332B, catchment area 142 km², 1992 to 2021).

These sites provide an overview of the diversity of flow regimes along the Project.

3.1.9.1 Flow regime characteristics

Table 3.4 lists flow characteristics of the watercourses. The Macintyre River, with the largest catchment area upstream of the gauge site has the largest mean flow, and the largest flood flow. At all sites the maximum flood flows stand out as being far greater than most other events. All of the rivers and streams have ceased to flow at some stage.

Table 3.4 Flow characteristics of streams and rivers along the Project

Flow (m ³ /s)	Gowrie Creek	Westbrook Creek	Condamine River @ Tummalville	Condamine River @ Cecil Weir	Canning Creek	Macintyre Brook	Macintyre River
Maximum	118.3	65.7	1,394.2	1681.1	147.8	1,257.0	1,744.3
99 th per centile	4.5	6.2	122.9	211.9	24.3	40.7	566.0
90 th per centile	0.9	0.3	7.8	10.4	1.3	3.4	56.3
75 th per centile	0.5	0.1	2.6	2.2	0.1	0.8	21.2
Median	0.3	0.0	0.9	0.3	0.0	0.3	7.8

⁵ The Macintyre River is also known as the Barwon River downstream of the junction with the Weir River.

Flow (m ³ /s)	Gowrie Creek	Westbrook Creek	Condamine River @ Tummaville	Condamine River @ Cecil Weir	Canning Creek	Macintyre Brook	Macintyre River
Mean	0.6	0.3	7.0	10.5	1.1	2.9	32.3
25 th per centile	0.2	0.0	0.1	0.0	0.0	0.2	2.5
10 th per centile	0.1	0.0	0.0	0.0	0.0	0.1	0.5
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table note:

m³/s = cubic metres per second

Table 3.5 shows details of low flow (<250 litres per second), and no flow conditions in the streams and rivers. Although all show periods of no flow, Gowrie Creek, Macintyre Brook, and Macintyre River can all be classed as perennial streams that only cease to flow in drought conditions. All other streams have intermittent flow regimes.

Table 3.5 Low flow and no flow days in streams and rivers along the Project

Watercourse/watercourse	Record (years)	Days/yr. flow <250 l/s	Days/yr. no flow
Gowrie Creek	42.6	144.0	4.3
Westbrook Creek	11.0	328.5	98.3
Condamine River @ Tummaville	60.3	115.8	85.5
Condamine River @ Cecil Weir	74.1	177.2	150.2
Canning Creek	14.9	300.7	128.1
Macintyre Brook	40.8	148.5	18.6
Macintyre River	72.5	30.7	21.8

Seasonal flow regimes are shown in Figure 3.5 and Figure 3.6.

These are mean flows which tend to be artificially inflated by a few high flow years, so no months show zero flow. However, the general monthly pattern is considered representative. In the Macintyre River the highest mean monthly flows are in January and February, and the lowest in May and June.

The Condamine River likewise has highest mean flow in January and February, but the lowest flows are in August and September. The extended dry season evident in the rainfall data (Figure 3.4) does not show in these flow data reflecting the delayed runoff that passes through the groundwater system.

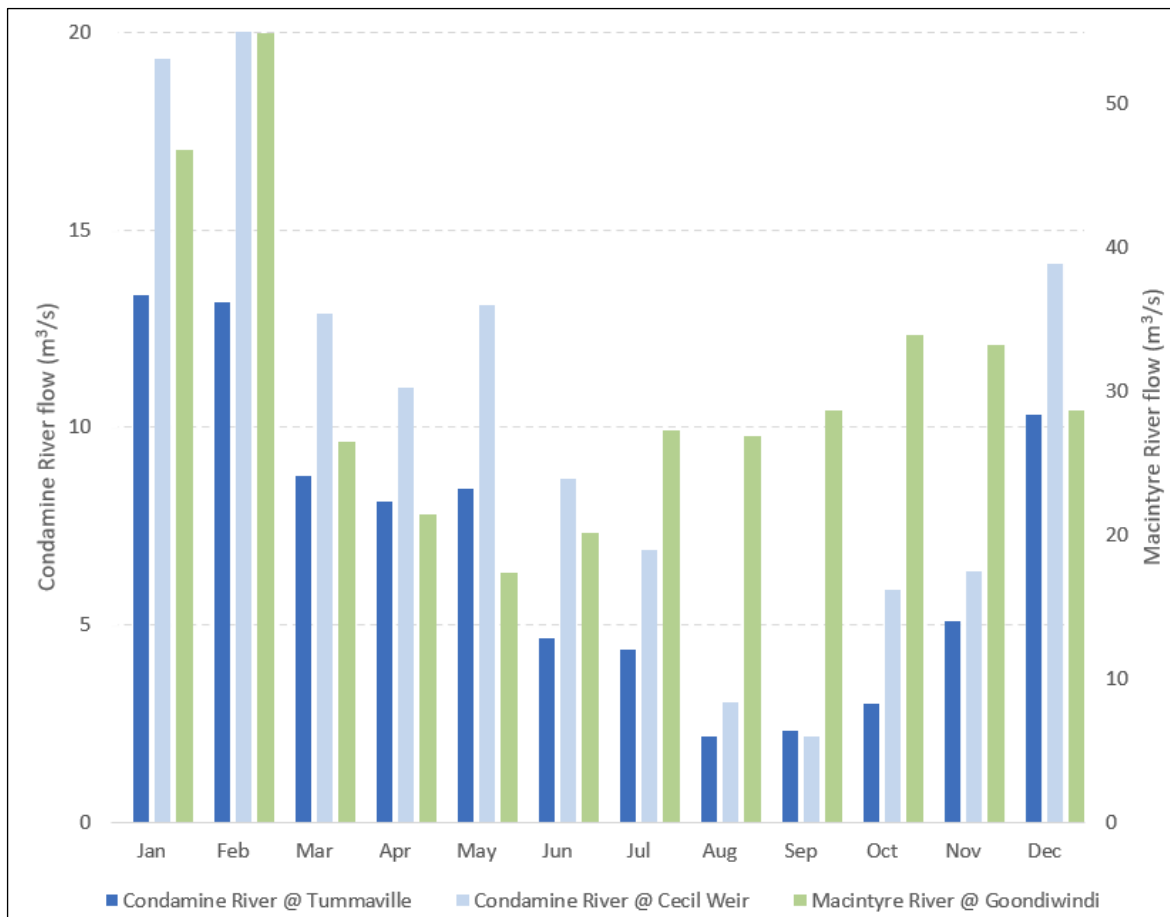


Figure 3.5 Monthly mean flows in the Condamine and Macintyre Rivers

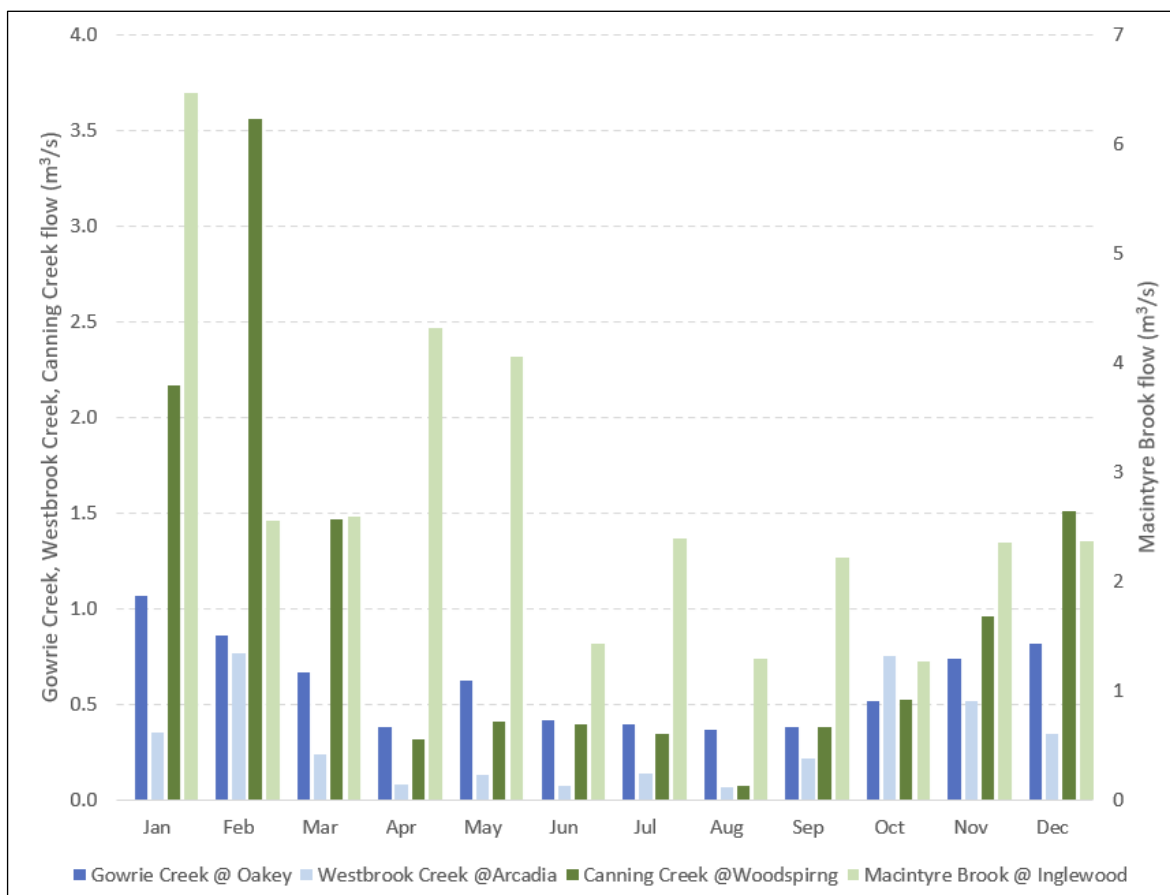


Figure 3.6 Monthly mean flows in contributing catchments

Macintyre Brook has a variable monthly mean flow regime with highest flows in January and April – May. July and September also experience reasonably high flows possibly due to its catchment area being further south and benefiting from frontal rainfall and winter and early spring.

The smaller contributing catchments have higher mean monthly flows in January and February and extended lower flows from April to September. Gowrie Creek has relatively high flows for its size as its headwaters benefit from orographically enhanced rainfall along the Great Escarpment/Great Divide. The greater flow in Canning Creek reflects its larger catchment size.

3.1.9.2 Flood regime characteristics

Flood magnitude, frequency and duration are important for fluvial geomorphology as it is flood events that drive channel and floodplain change. Flood hydrology and hydraulic modelling are included in EIS Chapter 14: Flooding and Geomorphology¹⁴.

More than 70 years of flood history has been captured in the site flow records for the Macintyre River at Goondiwindi and the Condamine River at Cecil Weir. Records for the smaller contributing catchments are much shorter but useful data can be extracted from the Macintyre Brook and Gowrie Creek catchments. All of these catchments have been affected by water storage schemes or irrigation takes so their flow records will not be entirely natural.

The Mean Annual Flood for the mean daily flow records from these sites was calculated⁶ as follows:

- Condamine River @ Cecil Weir: 326 m³/s
- Macintyre River @ Goondiwindi: 731 m³/s
- Macintyre Brook @ Inglewood: 99 m³/s
- Gowrie Creek @ Oakey: 10 m³/s.

At these threshold flows some fluvial geomorphic work will occur along the channels, but it is likely that the 20% AEP to 10% AEP events will be more important.

Table 3.6 shows floods occur a little more frequently in Gowrie Creek, presumably due to its small catchment area with headwaters in the higher rainfall Great Dividing Range hills. The two border rivers catchments (Macintyre Brook and River) have flood frequencies very close to the expected mean annual flood⁶ (4.29 events per decade), while the Condamine River has a slightly fewer floods than expected.

Table 3.6 Flood events greater than or equal to mean annual floods

Metric	Macintyre River @ Goondiwindi	Macintyre Brook @ Inglewood	Condamine @ Cecil Weir	Gowrie Creek @ Oakey
Number of events	31	19	28	23
Years	72.5	40.8	74.1	42.6
Events/decade	4.3	4.7	3.8	5.4

Analysis of these four flood records shows about one third occur simultaneously in both the Condamine and Border Rivers catchments. On average coincident floods occur approx. 1.5 times per decade, but this is not evenly distributed over the 70 years. Thus, four coincident floods occurred in the 1980s, and there have been two in 2021, including the recent December 2021 event.

Flood magnitude and frequency at these gauging sites are shown in Table 3.7. This was assessed from the available flow data using the Pearson Extreme Value Distribution. Very large events can occur in the Condamine River, Macintyre Brook and Macintyre River. The small catchment area of Gowrie Creek delivers smaller floods, but these are likely to be still capable of significant geomorphic work along the channel and floodplain.

⁶ The average of the annual peak flows for each year of record. Although it is called the Mean Annual Flood statistically it has an AEP of 35% (average recurrence interval of 2.33 years).

Table 3.7 Flood frequency and magnitude (m³/s)

Frequency (AEP%)	Macintyre River @ Goondiwindi	Macintyre Brook @ Inglewood	Condamine River @ Cecil Weir	Gowrie Creek @ Oakey
1	2,229	1,376	2,146	144
2	2,000	1,106	1,805	114
5	1,678	763	1,356	76
10	1,414	519	1,019	50
20	1,120	297	686	28
35	731	99	326	10

3.1.9.3 Condamine River floods

Since the mid-1960s water levels at the Tummalville gauge have been used to classify Condamine River floods affecting the floodplain crossed by the Project. Minor floods reach 5 m on the gauge, moderate floods 8 m, and major flood 9 m. The flow record is from 1961 to 2021 (60 years).

The upper part of Table 3.8 shows the number of days in each flood category since 1961. On average the Condamine River has been in flood 2.5 days/year, mostly at the minor level (77 per cent). Major floods have occurred on 0.4 days/year. The middle rows of Table 3.8 show the number of unique flood events in each category. There were 37 flood events that peaked in the minor category, and 11 that peaked as major floods. There were five very large floods (>10 m level) in 1975, 1976, 1996, 2010, and December 2021.

Mean flood duration increases with increasing peak flood level such that minor floods average 2.4 days, events that peak as moderate floods last 5.4 days and flood events that peak as major floods last 7 days. However, the floods generally only last 1 to 2 days in their peak category before dropping back to lower levels.

Table 3.8 Flood events, levels and seasons

Flood level	#Days	#days/yr	%	
Minor	150	2.49	77.3	
Moderate	21	0.35	10.8	
Major	23	0.38	19.6	
Total	194	3.22		
Flood events	# events	# events/year	Mean duration (days)	Maximum duration (days)
Minor	37	0.61	2.4	6
Moderate	5	0.08	5.4	13
Major	11	0.18	7.0	18
Total	53	0.88	3.7	
Flood event	Spring	Summer	Autumn	Winter
Minor	6	13	12	6
Moderate	1	2	2	0
Major	0	6	4	1
All	7 (13%)	21 (40%)	18 (34%)	7 (13%)

The lower part of Table 3.8 shows flood seasonality. While they can occur at any time of the year, 74 per cent of them are in Summer and Autumn. It is interesting to note that a major flood occurred in Winter 1983.

The minor floods are likely to be confined to the channels with little if any out of bank flow. The moderate and major floods will affect the floodplain.

3.2 Vegetation cover

A description of the Project vegetation cover and detail of the existing vegetation cover along with the potential impacts from the Project is discussed in EIS Chapter 11: Flora and Fauna.

The region is characterised by a dry subtropical climate transitioning to semi-arid further to the west, with a pronounced dry season and this is described in more detail below. The bioregion has experienced a long history of human disturbance as a result of agricultural practices and resource development. At a regional level, most remaining areas of vegetation are now fragmented, occurring on the rockier hilly areas of ranges, as part of the State-protected areas (State forests), as roadside vegetation, or as relatively small, isolated remnants.

The sub region has undergone significant land cover modification with most areas having 10 to 30 per cent of their pre-clearing vegetation (Welsh et al. 2014). One third of the Project length is located within brownfield areas, and the remaining greenfield portions extend largely through areas subject to agricultural land uses and are highly fragmented in nature (EIS Chapter 11: Flora and Fauna). There has been up to 70 per cent historical loss of wetlands across the Queensland Murray-Darling Basin (Welsh et al. 2014).

It is well established that land cover strongly affects slope erosion such that land use practices that reduce the percentage ground cover of vegetation in catchments, lead to adverse fluvial geomorphic effects including increased surface runoff and increased sediment loads in rivers. Increased sediment and can lead to aggradation and channel avulsion during flood events. These effects are likely to be present in the Study area given the long history of tree clearing to improve pasture for cattle grazing or provide land for cropping.

Relevant spatial data sets quantifying land cover change in the Study area have not been located. Thus, a qualitative contributing catchment vegetation cover assessment was developed by dividing vegetation cover into three broad groups based on their expected susceptibility to erosion that could contribute to fluvial geomorphic changes in the channel network.

The three types illustrated in Figure 3.7 are:

1. Grassland/crops - Mainly grass/crops/bare land, very minor bushes/scrub/trees. High sediment generation potential.
2. Grassland with some bush/trees - Mainly grassland but with some areas of bush/trees, often sparse. Moderate sediment generation potential.
3. Bush - Mix of bushes/trees with small pockets of grass/bare land. Low sediment generation potential.



Figure 3.7 Example catchment vegetation cover groups used in this baseline assessment

3.2.1 Soils

The main soil types, their distribution and geomorphic significance are summarised in Table 3.9 and shown on Drawing Set B, Appendix A. In this report, soils are defined as any non-consolidated material at the Earth's surface, rather than specifically unconsolidated material that supports plant growth.

Of particular concern are the high to very high erodibility rating soils that occur in catchments and along the Project alignment, in particular sodosols, and cracking clays/vertisols which can be difficult to remediate once disturbed (Section 3.2.4 for further discussion). EIS Chapter 9: Land Resources describes the existing geology and soil types along the Project alignment. The section below is largely summarised from that chapter.

The soils layer used for the baseline assessment was the Australian Soil Resource Information System (Dataset) Soils: ASC Grid (Commonwealth Scientific and Industrial Research Organisation, 2021). This is referred to as the 'regional ASC' layer. A soil assessment was undertaken within the Project footprint (EIS Appendix J: Soil Assessment Report), however, the regional ASC was used for describing the catchment soil group, as the detailed soils assessment is limited to the Project's footprint.

3.2.2 Site-specific soil assessment

A detailed site assessment of soils was undertaken along the Project alignment by Aurecon (2022) and is included as EIS Appendix J: Soil Assessment Report. The soils assessment included mapping and soil testing and was used to inform the development of the draft Soil management sub-plan (EIS Appendix AB: Earthworks Strategy and Draft Soil Management Plan). To compare this with the regional ASC used for our baseline catchment assessment, the site-specific ASC assessment was used (as opposed to other soil classifications). The regional ASC and site ASC are included in Appendix G for all potentially sensitive sites. In general, the two data sets are consistent. There were 28 sites that had a variance between the two layers, 15 of which were where the regional ASC was Sodosol and the site ASC a less erodible soil.

3.2.3 Soil unit erosion threshold velocities

An assessment of ETVs for Soil Management Unit (SMU) over a range of vegetation cover percentage categories from bare earth to 100 per cent vegetated was completed for the Project (detailed in EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1 - Appendix D1 Erosion Threshold Velocities Technical Report, SGM 2022). SGM recommend the ETVs in their report are not applied to Project watercourses.

A summary of the ETVs for the different SMUs along the Project is shown Figure 3.8. This shows the impact of varying vegetation cover on the erosion resistance of the soil. Highly erodible soils (SMU A and B) displayed lower ETVs for bare soil, when compared with the remaining soil groups (0.4 metres per second (m/s) to 0.5 m/s, vs 0.6 m/s). For sites with over 50 per cent vegetation cover, the allowable flow velocity for all SMUs is unaffected by the erodibility of the underlying soil.

The ETVs included in the SGM report (2022) are applicable for use for:

- Application to new drainage features that discharge to bare soils (i.e. where sheet flow is concentrated by new site drainage, and discharged to a new discharge location)
- Application to the design of culverts that do not discharge to watercourses.
- Constructed channels or drains.

The ETVs from SGM (2022) have not been used in this assessment as SGM recommend that they are not applied to watercourses. The ETVs from SGM (2022) have been applied to the assessment of potential change due to the Project on floodplain processes (Section 2.5.2.1).

As part of the detailed assessment of some high-risk sites, site ETVs were determined based on laboratory testing, site specific investigations and hydraulic data, see Section 2.5.3 for further details on methodology.

SMU	USC soil group	Erodibility class ^{1,2}	Bare soil ETV ³ (m/s)	Allowable flow velocity — 50% cover ⁴	Allowable flow velocity — 70% cover ⁴	Allowable flow velocity — 100% cover ⁴
A	CL – sandy lean clay	Highly erodible	0.40-0.50	0.9-1.2	1.2-1.5	1.6-2.1
B	CL – lean clay with sand	Highly erodible	0.40-0.50	0.9-1.2	1.2-1.5	1.6-2.1
C	SC – clayey sand	Moderately erodible	0.60	0.9-1.2	1.2-1.5	1.6-2.1
D	SM – silty sand	Moderately erodible	0.60	0.9-1.2	1.2-1.5	1.6-2.1
E	SC – clayey sand	Moderately erodible	0.60	0.9-1.2	1.2-1.5	1.6-2.1
F	SC – clayey sand	Moderately erodible	0.60	0.9-1.2	1.2-1.5	1.6-2.1
G	SC – clayey sand	Moderately erodible	0.60	0.9-1.2	1.2-1.5	1.6-2.1
H	SC – clayey sand	Moderately erodible	0.60	0.9-1.2	1.2-1.5	1.6-2.1
I	SM – silty sand	Moderately erodible	0.60	0.9-1.2	1.2-1.5	1.6-2.1
J	SM – silty sand	Moderately erodible	0.60	0.9-1.2	1.2-1.5	1.6-2.1

1. Where a SMU classification was uncertain (ie more than one soil group), the more erodible (conservative) class was chosen.

2. Where a SMU contained shallow (<30 cm) or waterlogged soils, the erodibility class was conservatively increased.

3. Based on Table A23 from the BPESC guidelines (IECA 2008).

4. Allowable flow velocity for each vegetation cover has been estimated from Table 3 for slopes up to 5%. *Estimate is not suitable for design and construction purposes.*

Figure 3.8 Summary erosion threshold values from SGM assessment (22B004)

Table 3.9 Australian Soil Classification Regional soil descriptors

Soil type and ASC	Soil description ASC	Occurrence in the landscape	Geomorphic significance	Erodibility rating
Vertosol- Uniform cracking clays. Black soils	Vertosols are high plasticity clays that shrink and crack open when dry and swell when wet. Gilgai micro relief is common. Parent materials range from intermediate, mafic to ultramafic in composition. High agricultural potential with high chemical fertility and water-holding capacity.	Moderate relief hill country around Toowoomba, old alluvial plains and across the Condamine River floodplain. Also occur in low hill landscapes either side of the Condamine/Macintyre Brook drainage divide associated with basalt outcrops in that area.	The clay-rich characteristics of vertosols mean they are cohesive and typically form stable channel banks. These soils are typically on gentle slopes so tend to be geomorphologically stable unless disturbed. Channels formed in vertosol may be more susceptible to geotechnical failure modes than those formed in non-cracking clays.	Low (2) to moderate (3)
Dermosol- Uniform and/or structured loams, clay loams and clays.	Dermosols have structured profiles with well-developed horizons and relatively high clay content. They do not display strong texture contrast or cracking clay characteristics. Dermosols generally have high agricultural potential with good structure.	Scattered occurrences in the moderate relief hill landscapes around Toowoomba, and valley floors and low hills in the lower Macintyre Brook catchment.	The clay-rich characteristics of these soils mean they are cohesive and typically form stable channel banks. These soils landscapes are typically on gentle slopes so tend to be geomorphologically stable unless disturbed.	Very low (1) to moderate (3)
Kandosol- Uniform and gradational sandy, loam and clay soils	Kandosols are uniform loams and clays with a massive to strong structure. Texture can grade down profile however, abrupt texture contrasts do not occur. They have low to moderate agricultural potential with moderate chemical fertility and water-holding capacity.	Minor areas mainly in Low relief hills in the Macintyre Brook and Canning's Creek Catchments.		Very low (1) to moderate (3)
Ferrosol	Ferrosols are structured highly permeable and hence well-drained soils with high iron content. Usually developed on volcanic rocks they have moderate to high fertility and water-holding capacity and are often used for intensive crops production.	Occur scattered amongst the vertosols through the moderate relief hills around Toowoomba.		Very low (1) to moderate (3)
Texture contrast soils: Sodosol, and Chromosol	Both Sodosols and Chromosols exhibit strong texture contrast between sandy or loamy A horizons and a dense clay-rich B horizon. In Sodosols the B horizon is strongly dispersive and disaggregates on contact with water. Chromosols have similar structure but are less dispersive or non-dispersive. They have moderate agricultural potential.	Associated with the low relief hill country and old alluvial plains in the Canning Creek and Macintyre Brook catchments. Chromosols are similarly distributed.	When the vegetation cover is disturbed these soils are susceptible to rilling, piping and gully erosion, and in extreme cases badlands erosion. High sediment load delivery to channels is likely with aggradation downstream.	High (4) to Very high (5) Moderate (3) to High (4)

Source: FFJV and ARTC (2021⁹), erodibility rating from DTMR Road Drainage Manual (2019)

3.2.4 Sodosols and vertosols

Sodosols and vertosols are highly susceptible to rapid on-set of rilling and gullying erosion if disturbed and can be difficult to revegetate. Vertosols include cracking clays, the shrink/swell characteristics of these soils means that mature woody vegetation does not generally occur, and re-establishing vegetation after disturbance can be problematic.

Cheetham and Walton (2014) summarise mitigation methods for waterway and gully stabilisation in vertosol soils in the Condamine Catchment, including a site on Dry Creek approximately 7.5 km upstream from the proposed alignment crossing. Key findings are listed below:

- Vegetation cover is the preferential treatment with a degree of earthworks
- Vetiver grass was agreed to be one of the best plants for stabilisation due to its ability to grow quickly in many environments and its deep roots, up to 5 m. Lomandra and Vetiver and Kikuyu grass are also mentioned to have worked well.
- Gully stabilisation design trials were carried out between 2012 and 2013 within the Condamine catchment. They included rock chutes with geofabric underlay and vertically placed marine ply or rubber sheeting upslope or beneath the rock chute and vegetation, either Lomandra or Vetiver. Under substantial flow, all trial sites failed to a degree. This was attributed to either poor design of the rock chutes or lack of vegetation or both.
- The drop structure at the Wallingford Road crossing across Fourteen Mile Creek is an example of a successful gully stabilisation in vertosols (Figure 3.9). Downstream bed levels are on the order of 4 to 5 m lower than upstream, incision and widening appears to have ceased and the reach appears relatively stabilised. Shrubs, small trees and grass are established on the banks.



Figure 3.9 Drop structure at Wallingford Road

Source: Cheetham and Walton (2014)

3.2.4.1 Existing cross drainage performance

The performance of existing cross drainage infrastructure in vertosol and sodosols provides real world examples of the ability to revegetate sites post construction and erosion performance.

There is well documented ongoing erosion at some cross drainage on the existing QR embankment in vertosols between the Condamine River and Grasstree Creek (Section 3.3.2.3). This erosion was established prior to the earliest aerial imagery and is due to inadequate design of cross drainage.

Review of more recently designed cross drainage in vertosols along the Gore Highway shows almost all of the culverts in the Condamine have established grass at culvert inlets and outlets, a small number have patchy grass with either bare soil or deposited silt or small areas of ponding (Figure 3.10 for an example). Culverts typically have a grass buffer of between 5 m and 40 m between the inlet/outlet and cropped land.

Trees are established adjacent to bridges on the Gore Highway over the Condamine Main Branch and north Condamine channel indicating that establishment of some larger vegetation on channel banks post construction is possible. Note that Grasstree Creek, the third anabranch of the Condamine River in the project area, joins the Main Condamine Branch upstream of the Gore Highway and the Gore highway does not cross it.

Refer Sections 3.5.2 and 3.5.3 for further discussion of the performance of a range of different types in infrastructure in different soil types along the proposed alignment based on site inspections.



Figure 3.10 Culvert on the Gore Highway at approximate chainage 145 km. Upper image is looking upstream, silt from bare cropland upstream has been deposited near the inlet, the grass buffer is less than 10m at the time of the photo. Lower image is looking downstream, wide grass buffer between culvert outlet and crop, approximately 40m. The small bare patch roughly halfway between the culvert and crops is a farm track.

3.3 Watercourses

3.3.1 Watercourse identification and classification

A total of 143 water courses were identified that cross the Project alignment. Ten watercourses were identified in addition to the Murray Darling Watercourse dataset based on review of imagery and hydraulic data.

Watercourse classification is included Appendix C. Sub-reach classification is included in Appendix G. Sections 3.3.1.1 to 3.3.1.4 summarise flow regime, bankfull discharge, channel types and watercourse types. Baseline fluvial geomorphic conditions are summarised in Section 3.6.

3.3.1.1 Flow regime

Stream flow regimes can be classified as perennial, intermittent, or ephemeral. Perennial streams flow all year round and are fed by baseflow (groundwater runoff) and some storm flow (surface or shallow subsurface runoff after rainfall). Intermittent streams are fed by storm flow, and some baseflow in the weeks or months after a rainfall event. Ephemeral streams are fed entirely by stormflow and only flow for a few hours after a rainfall event.

Only four watercourses in the Study area are listed as perennial in the Murray Darling Watercourse lines dataset: Macintyre River, Westbrook Creek, Condamine North Branch and the Condamine River. All other watercourses are listed as 'non perennial' and are either intermittent or ephemeral.

Intermittent and ephemeral flow regimes flow only temporarily in response to precipitation in the immediate vicinity. There is no groundwater-derived baseflow to sustain river discharge through the dry spells between floods. Channel-forming discharge events will be irregular and highly flashy in nature. This results in high variability of channel form in watercourses over a short distance, floodouts and temporary pool landforms.

3.3.1.2 Bankfull discharge

A stream or river channel carries water flow and in natural systems typically has a capacity sufficient to carry flows up to the magnitude of small floods, but for larger floods water will naturally overflow and spread out over the adjacent floodplain. The flow at which this overflow occurs is referred to as the bankfull discharge and is typically the discharge where the most geomorphic 'work' is done. While large floods are more dramatic, they do not tend to accomplish as much total work in the geomorphic environment as the bankfull discharge event.

Bankfull discharge for perennial streams is generally considered to be a relatively common event typically between 63.2% AEP and 18.13% AEP; that is floods that statistically occur on average every one to five years.

However, in intermittent/ephemeral streams in semi-arid environments, the channel-forming discharge events are likely to be less frequent. Sediment moves through intermittent/ephemeral system in highly variable and episodic pulses dependant on the nature of flood events. Only the largest, least frequent events are capable of flushing sediment completely through the system and opening up (widening or incising) channels that have become progressively choked with vegetation and sediment during smaller events (Levick et al., 2008).

A review of Existing Case hydraulic modelling data identified that bankfull conditions are close to the 20% AEP event, when some localised out of channel flow occurs (including adjacent to meander bends and flood channels), for a number of the Project watercourses adjacent to the alignment. The 20% AEP event is the most frequent flow event modelled. Note that AEPs that correlate to bankfull conditions can vary along a watercourse channel. Named watercourses where bankfull is close to the 20% AEP event include Gowrie Creek, Dry Creek, Four Mile Gully, One Mine Gully, Half Mile Gully, Nicol Creek, Bringalilly Creek, Native Dog Creek, Cattle Creek, Pariagara Creek and the Macintyre River. Watercourses with widespread floodplain flow during a 20% AEP event have bankfull conditions more frequently. These watercourses include the North Condamine River, Condamine River, Westbrook Creek, Grasstree Creek, Westbrook Creek, Back Creek 1 and Back Creek 2.

For the purposes of this assessment, the 20% AEP event has been considered close to bankfull.

3.3.1.3 Channel types in the Project footprint

The following channel types are present in the Study area derived from the scheme of Erskine *et al.*, (2017) and modified for Project-specific conditions. A high-level channel evolution model for each channel type is included and linked to sensitivity to change. Refer to Section 2.2.5 for the methodology for assessment of sensitivity to change, which includes site specific factors such as soils, geomorphic process, historic change and catchment characteristics.

Bedrock confined

A small number of localised sections of bedrock confined channels were observed. Bedrock confined and constrained rivers are those with channels impinged against and/or flowing over bedrock with less than 90 per cent but more than 10 per cent of channel in contact with bedrock. In some cases, other material of limited erodibility can form the confining and constraining media. These channel types typically have limited development of floodplain as pockets in localised expanses, in channel bars and benches often form where it is too narrow for a floodplain. These channels are unlikely to evolve and have a low sensitivity to change.

Anastomosing river

Anastomosing rivers have multiple channels and can be considered a type of anabranching river. These (anabranching rivers) are unconfined, have multiple channels (each channel referred to as an 'anabranch') separated by vegetated or otherwise stable alluvial islands that divide flows at discharges up to or greater than bankfull discharge stage (Nanson and Knighton, 1996). The individual channels are typically straight, sinuous or meandering; the island level is usually at about the same level as the floodplain; and with stable banks they persist for decades or centuries.

Anastomosing rivers comprise multiple interconnected channels that enclose flood basins, they generally form at or near a local baselevel. They can include straight to highly sinuous channel planforms are low gradient and have stable cohesive banks. Stream power is usually low ($<10 \text{ W/m}^2$). Modern channel classification schemes such as Erskine *et al.*, (2017) do not clearly differentiate anastomosing and anabranching rivers, but the Condamine River is a fine example of an anastomosing river having numerous highly sinuous channels and for this reason we use this terminology.

Anastomosing rivers evolve through avulsion events with relatively stable periods of increased meander sinuosity development between. Anastomosing channels are usually formed by avulsion whereby the river relatively quickly shifts from its existing channel to form a new one. The process is primarily driven by aggradation of the channel and strongly linked to (but not only due to) floodplain gradient. The anastomosing channels transport floodwaters, and typically have a small sediment load, therefore aggradation, if occurring, is a slow process. As a result, anastomosing channels are typically quite stable. Distribution of discharge over various channels reduced stream power in any one channel, resulting in relatively low stream power per channel, explaining why channels in anastomosing systems tend to be quite stable laterally (Makaske, 2001). The angle of avulsion from the existing channel can be acute to obtuse, and avulsion generally occur in two ways (Makaske, 2001):

- By forming a bypass
- By splitting of the diverted avulsive flow.

Channel sinuosity can indicate how frequently avulsive switching occurs, and how sensitive the channels are to change. If channels are subject to frequent avulsive switching, the meanders may not fully develop because time of channel-belt occupation is too short, indicating a higher sensitivity to change. In contrast highly sinuous channels indicate long term and very slow avulsion rates, which a lower sensitivity to change. Meander bends develop by erosion on the outside of the bend, and deposition on the inside. Over time, as the meander bend loops back on itself more and more, a meander cut-off can occur.

Low sinuosity river

Single channel with a sinuosity <1.35 , usually with a defined floodplain. The majority of the low sinuosity channels in the Project Area occur as very small discontinuous baseflow channels between ponds in chain of ponds channel types, or in non-channelised valley floor channels. The evolution of these channel types and their sensitivity to change are discussed in Sections Chain of Ponds and Non-channelised valley floors below.

There are four watercourses that cross the proposed alignment with larger and more developed low sinuosity channel types, Parigara Creek, Westbrook Creek, Dry Creek and One Mile Gully. These low sinuosity channels evolve through minor lateral migration and typically have a low sensitivity to change. However, bed lowering leading to channel widening and development of side erosion channels and gullies can occur, typically in reaches adjusting to long term changes within the catchment. Of the channel reaches that cross the proposed alignment, channel widening was observed only on One Mile Gully. Channel widening and side gully development was observed on Dry Creek upstream of the proposed alignment, however not along the reach that crosses the alignment. Low sinuosity channels that have active channel widening and side gully development have a high sensitivity to change, other reaches have a low to medium sensitivity to change.

Chain of ponds

Series of natural ponds unconnected by a continuous channel or connected by a small capacity continuous channel, typically low sinuosity. Many small watercourses in the Study area have multiple small dams along them so that they now function as chain of ponds streams. Interestingly, a tributary of Macintyre Brook to the east of the Study area is named Chain of Ponds Creek. It runs alongside the Cunningham Highway into Lake Coolmunda. These channel types do not have a coherent continuous channel and are typically low energy environments. Several chain of ponds channels in the Study area have a meandering planform, and paleo meander cut offs were observed in imagery. Little is known about the long-term evolution of this channel type. Based on observations of historic change and the lack of flow energy by which to drive change, they are considered low sensitivity to change.

Gully

Relatively deep, recently formed, steep-sided eroded channels that are cut into unconsolidated materials where no well-defined channel previously existed. Can be continuous or discontinuous. Gullies evolve through headward erosion and extension of the landform upstream; they have a high sensitivity to change. Most gully channel types along the alignment occur on alluvial plains of Tertiary age in sodosols along Canning Creek.

Non-channelised valley floors

Distributed flow drainage pathway. Swampy, unchanneled valley floors usually well vegetated and characterised by high water tables, at least during the wet season. Valley floors either without any channel or with a very small capacity channel that only contains baseflows. In the Study area, these are often identified by the relative greener colour of the vegetation together with review of elevation data.

Non-channelised valley floor channel types are typically relatively stable, they have functioned in the fluvial system without developing a coherent channel for a long period. However, they can develop into gullies which erode headward, in particular where they form in valley fill material and flows become concentrated. Valley fill deposits are likely to occur where Tertiary alluvium is mapped (Appendix A Drawing Set A Regional geomorphic landforms). A total of 17 non channelised valley floor channels occur in Tertiary alluvium (Appendix C), the majority of which occur between chainage 107.212 to 119.377 km. Along this chainage, the Millmerran Inglewood Road traverses the same watercourses in the same tertiary alluvium within ~1 km of the alignment. Gully development was not observed at the 17 channel locations, even at sites of cross drainage under the Millmerran Inglewood Road. The cross drainage typically comprises bridges over wider channels, or multi cell culvert groups with wingwalls and aprons. All but one of the 17 non channelised valley floor channels that occur in Tertiary alluvium are in vertosol soils, with one in sodosol. Gully development was observed between chainage 73.363 and 76.969 km extending up from Canning Creek on alluvial plains of Tertiary age, all in sodosols (Appendix C). This indicates that in the Project area the presence of valley fill alone may not necessarily mean that gully erosion may develop, but that gully erosion has, and is therefore may in the future, develop in non-channelised valley floor channel types in intact valley fills in sodosols.

Non-channelised valley floor channel types in intact valley fills in sodosols and vertosols have a medium to high sensitivity to change, in other soil types they have a low to medium sensitivity to change.

Washslopes

Washslopes are not channels as such, rather they are slopes that have overland flow across wide areas. Washslopes are not recognised by Erskine *et al.* (2017) as a channel type but were included in this study as they play a role in the hydrology and geomorphology of the area and occur in all landscape types, and a number of Strahler Stream Order 1⁷ flow paths are washslopes in the Murray Darling Watercourse dataset. The washslopes within the Murray Darling Watercourse dataset flow paths often develop into a recognised channel type downslope. As washslopes have distributed flow, it is likely that they would follow a similar evolution model as non-channelised valley floor channels. Washslopes on intact valley fills in sodosols have a medium to high sensitivity to change, in other soil types they have a low sensitivity to change.

⁷ Strahler Stream order describes the hierarchy of a stream system from the top of the catchment to the bottom of a catchment. A first (1) order stream has no other streams flowing into it, when two first order streams meet, the channel becomes a second order stream and so on.

3.3.1.4 Watercourse types

Five high-level watercourse types were identified from the 143 watercourses that intersect the Project alignment as summarised in Table 3.10 and illustrated in and Figure 3.11:

- Headwaters, 105 watercourses
- Local Stream – poorly developed channel, 22 watercourses
- Local Stream – developed channel sections, seven watercourses
- Local Stream – well developed channel, seven watercourses
- Main Stem Stream, two watercourses.

While headwaters are by far the most numerous watercourse type to intersect the Project alignment, their combined catchments are <1 per cent of the total contributing catchments.

Table 3.10 Watercourse types in the Study area

Watercourse type (process zone)	Number	Stream order range (mode)	Rail infrastructure ¹	Typical channel types	Floodplains	Catchment			
						Area (ha) mean (min-max)	Slope (rise/run) mean (min-max)	Vegetation cover %	Soil cover % ²
Headwater (source)	105	1 to 2 (1)	Cut 15 Diversion 2 ³ Bridge 4 Culverts 73 Embankment 10	Washeslopes, non-channelised valley floor. May have short sections of low sinuosity channel.	None	53 ha (<10 to 355.4)	0.0344 (0.0000 to 0.0915)	Bush 19% Grassland/bush 16% Grassland/crops 63% Grassland 2%	K 10% S 31% V 52% D 3 % D/V 4%
Local – poorly developed channel (transfer)	22	2 to 4 (2)	Bridge 7 Turallin facility 1 Culverts 13 Embankment 1	Non- channelised valley floor with some short sections of low sinuosity channel. Can have small natural pools along flow path.	Four with floodplains, remainder have none to local narrow floodplains.	50,958 ha (94 to 654,611)	0.0194 (0.0047 to 0.0783)	Bush 16% Grassland/bush 28% Grassland/crops 56%	K 4% S 24% V 48% D 16% V/F 4% K/C 4%
Local – developed channel sections (transfer)	7	2 to 4 (3)	Bridge 4 Culverts 3	Low sinuosity or chain of ponds with non-channelised valley floor or low sinuosity channel between.	Four with floodplains, remainder have local narrow floodplains.	2,707 (<10 to 9416)	0.0141 (0.0047 to 0.0271)	Bush 22% Grassland/bush 44% Grassland/crops 33%	K 11% S 44% V 33% V/S 11%
Local – well developed channel (transfer)	7	3 to 5 (4)	Bridge 7	Low sinuosity would form closely spaced chain of ponds in low flow.	All have floodplains	313,332 (4062 to 868,479)	0.0089 (0.0043 to 0.0156)	Grassland/bush 50% Grassland/crops 50%	S 38% V 50% C 13%
Main Stem (transfer/ temporary sink)	2	8	Bridge 2	Meandering channel form, main anabranch of multi-channel types.	All have broad floodplains	761,545 (654,611 to 868,479)	0.0050	Grassland with bush 100%	V 50% S 50%

Table notes:

1 Based on revised reference design

2 K = Kandosols, S = Sodosols, V = Vertosol, D = Dermosol, C = Chromosol, F = Ferrosol

3 Two diversions for three watercourses.



Figure 3.11 Examples of headwater, local stream – poorly developed channel watercourse types local stream – developed channel sections, well developed channels and main stem watercourse types

3.3.2 Watercourses geomorphic processes

All watercourse channels are subject to geomorphic changes arising from water flow. These changes may range from trivially small to catastrophic and can occur imperceptibly slowly to very rapidly. The Project will occur in an environment that has always changed and will continue to change as it is a naturally dynamic fluvial environment. Thus, to assess the potential for fluvial geomorphic change to occur because of the Project it is necessary to attempt to separate the changes that are naturally occurring now from changes to these fluvial systems potentially arising from the Project.

3.3.2.1 Types of watercourse processes

The main watercourse geomorphic processes include:

- Erosion
 - Bank retreat – the movement of a channel bank into the adjoining land caused by the action of channel flow
 - Scour holes – localised erosion features generated on a sediment surface by water
 - Bed degradation – lowering of the channel bed elevation over time by removal of bed material
 - Erosion of in-channel features – erosion of features such as in-channel bars, pools or sand sheets.
- Deposition
 - Bed aggradation – increase in the elevation of the channel bed over time due to the deposition of sediment
 - Bar aggradation – development of a bar, an elevated region of sediment, that has been deposited by water flow
 - Pond or pool infilling – infilling of pools or ponds in a watercourse channel, with sediment, woody debris or a combination of both.
- Planform change
 - Meander bend migration - movement, typically downstream, of meander bends by on-going erosion on the outside of the bend and deposition on the inside
 - Avulsion – when a watercourse relatively suddenly ‘jumps’ out of its existing channel to form a new one. The process is primarily driven by aggradation/blockage of the channel.
- Channel type change
 - Change from one channel type to another (e.g. development of a multi thread channel in a location where the channel was single thread), or development of a non-channelised valley floor into a gully

Note that ‘sediment transport’ is the erosion and deposition of sediment.

3.3.2.2 Project watercourse processes

There is a strong link between channel typology and processes. The channel type is the physical manifestation of the fluvial processes acting on the watercourse, including water flow, sediment transport, deposition and erosion, for example the channel type gully has active gully erosion.

Change observed in historic aerial imagery, which generally covers the period of the last 70 years through to current conditions, captures a visual record of the complex interplay of geomorphic processes as recorded in resulting landforms. It does not consider more rare extreme events which may happen at any site, unless evidence for them can be interpreted from the available aerial imagery.

Refer Appendix G for processes and historic change by watercourse. Significant historic change has occurred on the Condamine River channels, refer Section 3.3.2.3 for a more detailed description.

The following key observations on processes and historic change of Project watercourses were identified:

- Most sites show evidence of no/very minor fluvial geomorphic processes or change since the 1940/50s showing the fluvial geomorphic system under existing flow regimes in both greenfield and brownfield sites has generally been changing very slowly
- Changes that have occurred are usually due to human intervention particularly the construction of ponds and other water collection and storage reservoirs long channels/overland flow paths
- Channel straightening has occurred on the north Condamine, and a small number of other watercourses

- South Condamine is an active erosion feature downstream of the existing rail, and imagery shows ongoing erosion
- Channel straightening, construction of diversions and an avulsion event has occurred on the main Condamine River Channel (from historic records predating imagery)
- Natural channel planform changes have also occurred, such as increased sinuosity at Westbrook Creek and the 20 to 30 m downstream migration of two meander bends of the Macintyre River
- Gully erosion sites (C Ck 16, 16a, CCs 21, CCs 21a, CCs 22, CCs 19) were already present in the 1950s and have continued to develop since then (Section 3.1.7).

3.3.2.3 Historic change at Condamine River channels

The Condamine River main stem channel is near the middle of the valley floor, but there are several other branches of this large river across the 13 km wide 1% AEP floodplain landform as shown in Table 3.11. These anastomosing river channels are largely stable under natural conditions, but as discussed below there have been several constructed diversions that were for the purpose of controlling floods and other modifications as described below.

Table 3.11 Condamine River channels

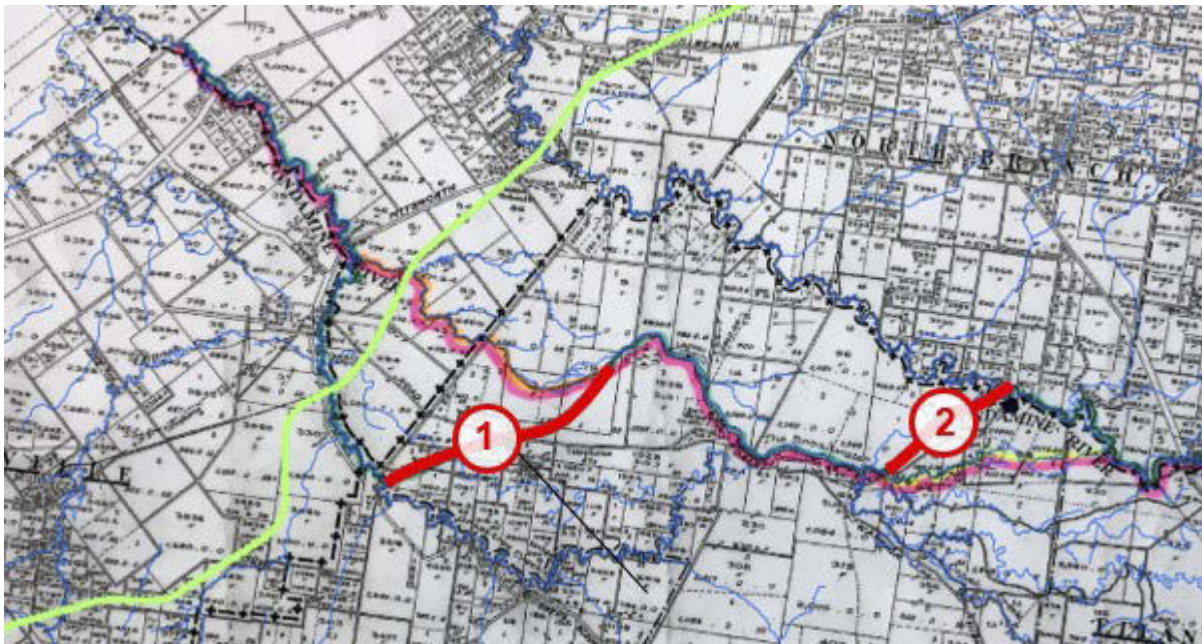
Channel	Chainage (km)	Description
Grasstree Creek	139.9	At southwest side of floodplain. An intermittently flowing tributary that carries Condamine flow in floods.
Un-named Condamine anabranch	141.03	Ephemeral floodplain channel.
Condamine River	144.20	Main channel of the Condamine River. Perennially flowing.
Condamine North Branch	149.90	Secondary channel of the Condamine River. Perennially flowing.

Main Condamine River channel

The Condamine River has undergone several man-made changes in recorded history (Figure 3.12). The following information comes from Uebergang (1992) and Fysh (1910 to 1945):

- 1873 diversion drain 1 was construction between what is now the Condamine River Main Branch (then the 'Broadwater', which used to come to a dead-end) and Grasstree Creek
- 1885-87 diversion drain 2 was construction between the Condamine North Branch and what is now the Condamine River Main Branch (then the 'Broadwater'). It 'scoured badly' and became the main Condamine River Channel. Fysh (1910 to 1945) has the construction timing of the diversion the other way around.
- 1886-7 Section of channel on what is now the Condamine River Main Branch formed downstream of diversion 1 after flooding
- 1908 by this time the channel of the Condamine River Main Branch upstream of diversion 2
- 1914 A tree fell across the mouth of the Condamine North Branch and resulted in sediment aggradation such that it 'closed the mouth completely'
- 1945 A tree fell across the Condamine River, diverting water from the Condamine down the Black Gully.

Anastomosing channels in cohesive material are typically laterally stable, however the historical changes include significant avulsion events triggered by woody debris. The current main channel that crosses the Project alignment appears to have been initiated by human intervention and will require continuous monitoring throughout the Project's life to minimise or avoid any risk of future impacts.



1 Diversion Drain. Drain 1 constructed in 1873, drain 2 constructed in 1885

- Condamine River Channel 1880s (including the diversions)
- Condamine River Channel that formed after 1886-7 floods
- Condamine River Channel after 1908
- Condamine River Channel 1945

Figure 3.12 Snapshot of 'Condamine River Tummalville to Pampas Environmental and Man-Made Changes 1873 to 1945' ('from Uebergang, 1992)

Figure note: The Project alignment is shown in pale green. Watercourses of the Murray Darling dataset are shown in blue

Condamine River South Branch

The Condamine River South Branch is not a formal channel. It is not included in the Murray Darling Watercourse lines dataset and has no geomorphic channel expression upstream of the existing QR embankment. Aerial imagery review shows the South Branch as channel features downstream of the existing QR embankment from Ch 142.0 km to Ch 143.0 km, taking the form of multiple small channels and less defined watercourses which come together to reoccupy a paleochannel approximately 400 m to 650 m downstream of the rail embankment before flowing into Grasstree Creek. The revised reference design has a bridge over a section of these erosional channels.

Based on desktop review, the South Branch falls near the centre of the flood basin between the Condamine River and Grasstree Creek, within the greater Condamine floodplain (Figure 3.13). This flood basin contains evidence of numerous paleochannels (only one of which has been included in the Murray Darling Watercourse database), that are only occupied during flood events when the whole flood basin would also be inundated.

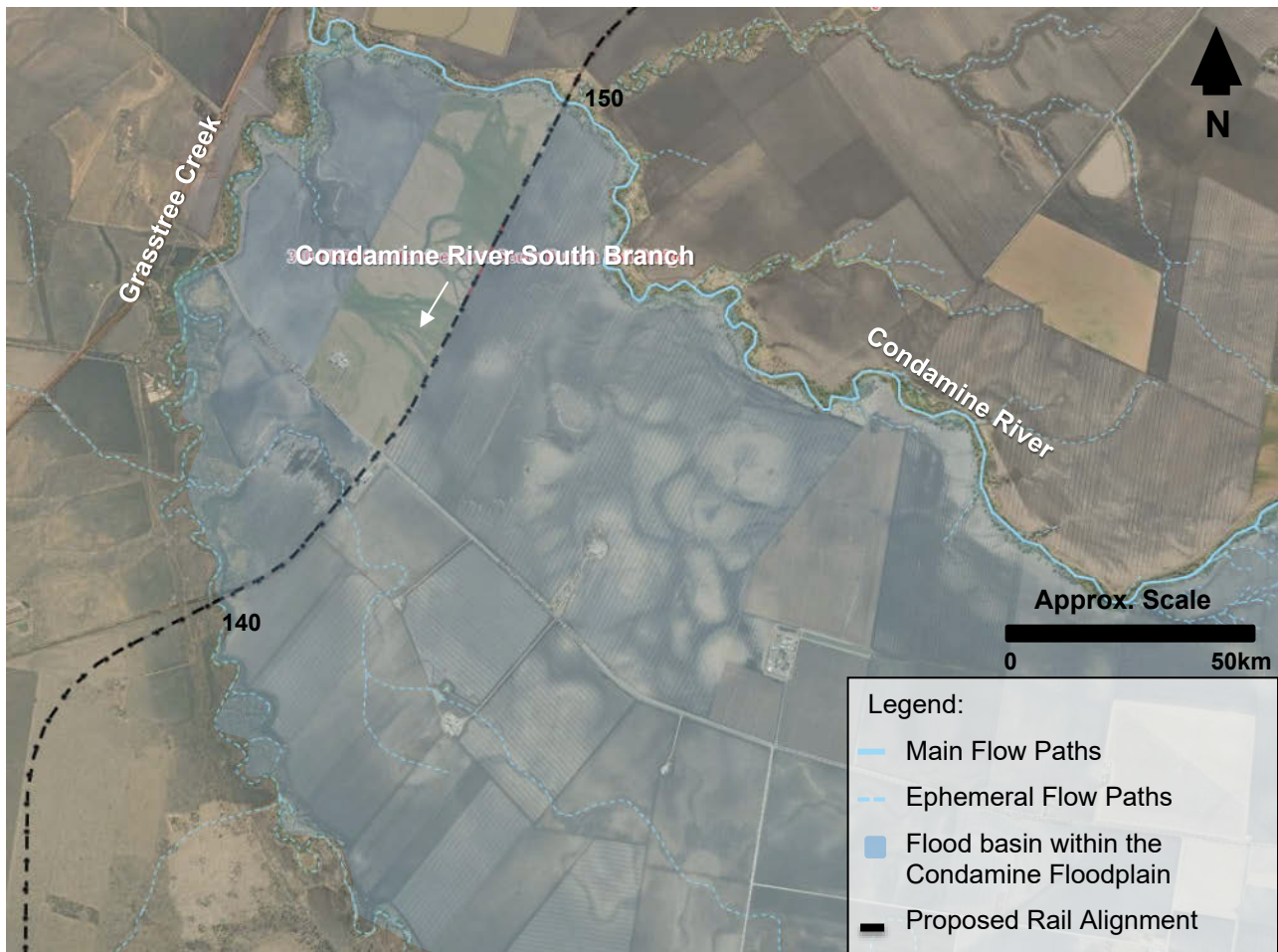


Figure 3.13 Condamine River South Branch location in the flood basin between the Condamine River and Grasstree Creek

Based on aerial imagery review, the South Branch has been divided into two areas of different erosion patterns, possibly due to the sizing and spacing of culverts in the existing QR embankment. Review of the earliest aerial imagery available (from 1959), shows the rail embankment and both of these erosion zones present. Figure 3.14 shows a comparison between 2016 and 1959 imagery. The two areas are described as follows:

- Northern area (Ch 142.6 km to Ch 143.0 km) in 2016 comprises nine distinct forked channels directly downstream of the rail embankment. These converge into three then one straight channel over a distance of 160 m. The straight channel then intersects a meandering paleochannel approximately 250 m downstream. The 1959 imagery shows the downstream straight channel and one or possibly two of the three-fork section, and none of the nine-forks are adjacent to the rail embankment. This suggests the channel system had started to form after the rail embankment had been constructed prior to 1959, with most development occurring after 1959. It is possible there were nine pipe culverts in the embankment to facilitate drainage of floodwaters out of the flood basin upstream of the Project alignment. The revised reference design has a bridge over this section
- Southern area (Ch 142.0 km to Ch 142.6 km) comprises 10 to 15 less-defined erosional watercourses that have a semi braided river appearance, and these converge into what was likely a paleochannel approximately 650 m downstream. The most defined channel occurs at Ch 142.06 km. The 1959 imagery faintly shows similar features, including the more defined channel at Ch 142.06 km. The revised reference design has culverts over this section.

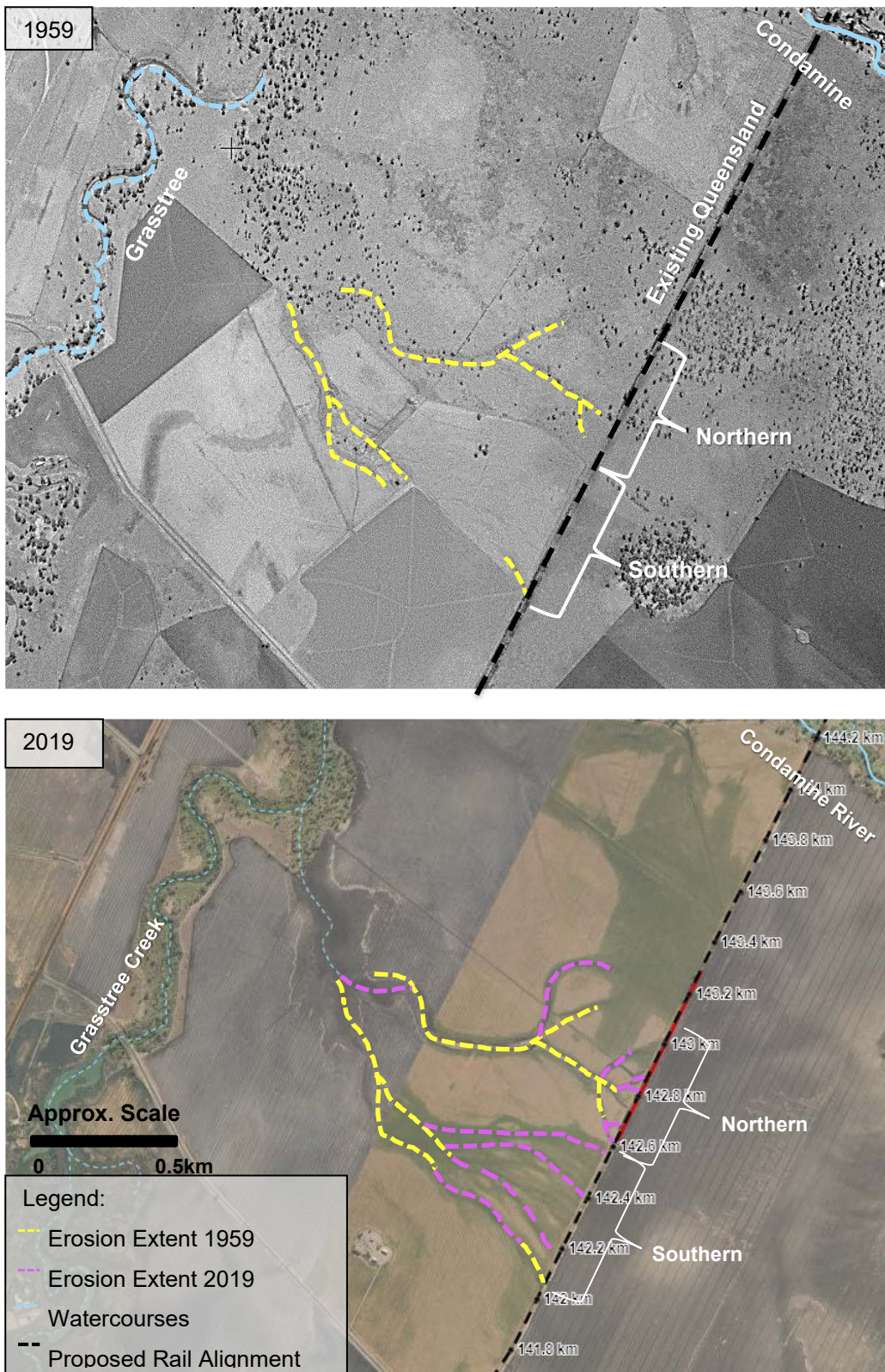


Figure 3.14 Condamine River South Branch, 2016 imagery (top) and 1959 imagery (bottom)

Figure note: Ploughing of land to the east of the Project alignment has accentuated downstream erosion channels in the 2016 imagery.

Condamine North Branch

Directly upstream from the Project alignment for approximately 1.75 km, the Condamine North branch channel has been realigned and straightened to flow between three human-made ponds, the larger two of which are about 10 ha each. The ponds and straightening occurred in stages between 1985 and 2001. The channel straightening has reduced the sinuosity of the channel and the associated volume of water accommodated in the channel over the same down valley distance, from its naturally highly sinuous 3.26 to a sinuosity of 1.40. The natural channel has a chain of ponds channel type, while the upstream realigned channel is effectively a low sinuosity channel type. Approximately 150 m downstream of the straightened channel section, just upstream of the Gore Highway bridge and in the location of the Project, a 40 m by 60 m pond has developed in the channel.

The channel straightening and construction of the adjacent water storage ponds have locally impacted floodplain processes as well as channel processes. The ponds effectively laterally constrain the channel and divert overbank flow.

The human-made channel has a sharp 90-degree bend in it approximately 430 m upstream of the Project alignment, adjacent to Pampas Pit Road. This sharp bend is directly downstream of about 1.2 km of straightened channel, along which greater than natural case velocities can occur due to its lower sinuosity. This bend represents an avulsion risk that could impact both the Gore highway and the Project.

3.3.3 Watercourses sensitivity to change.

As fluvial systems respond to changes in their catchments, the systems will change their processes and sensitivity to change over time from things outside of the Project's control or influence. These include potential future land use changes, such as changes in agricultural practices, construction of dams, vegetation change, or flow regime change. Therefore, the assessed sensitivity to change is a tool to determine relative potential change from current condition, and should not be used to indicate levels of existing sensitivity outside of this context or under different future conditions.

A wide range of channels occur in the Study area, thus there will be a wide range of sensitivities to changes in the existing environment prior to the Project. More geomorphic change will occur in high energy channel systems with erodible soils, than in low energy systems with vegetated channels. All sensitivity to change categories except category 4 occur under natural conditions.

Of the 86 potentially sensitive watercourses, the following existing condition sensitivity to change was assessed:

- Category 5 – 9 sites, including 6 gully erosion sites: The Condamine River, due to the historic human-induced avulsion event; Condamine South Branch, due to ongoing erosion; SC 7, which has been dammed, causing a cut-off of the natural channel and development of erosion channels downstream; MB 5 which has gully development approximately 200m upstream from alignment.
- Category 4 – 18 sites, mainly due to human straightening of the channel. Note the Condamine North Branch has been assessed separately upstream to downstream, and this category includes the North Condamine upstream.
- Category 3 – 4 sites, including the Macintyre River
- Category 2 – 42 sites, including the downstream Condamine North Branch
- Category 1 – 14 sites

Summary of the Condamine watercourses sensitivity to change:

- Grasstree Creek – Category 1 - largely unchanged in the Project footprint except for the road bridge
- Condamine anabranch – Category 4 - potentially unstable landforms due to human channel straightening
- Condamine South Branch - Category 5 - due to the erosion resulting from the existing rail
- Condamine River – Category 5 - due to the historic diversion resulting in an avulsion event. Note the channel has remained stable since the earliest imagery

- Condamine North branch:
 - Upstream – Category 4 - potentially unstable landforms due to human channel straightening
 - Downstream – Category 2 - largely unchanged in the Project footprint.

The sensitivity to change of the Condamine watercourses can be seen to be closely linked to human intervention and the modification of the channel shape and planform. Areas which have had little modification from the natural system are generally stable, and their high sinuosity indicates this has been the case for some time. The 'new' Condamine main channel has been largely stable since its formation following an avulsion event. Artificial channel modification and diversions act to significantly increase the watercourses sensitivity to change.

3.4 Floodplains

A floodplain is an area of generally flat terrain adjacent to a river channel that is covered by floodwaters when the bankfull discharge capacity of the channel has been exceeded. Two basic definitions of floodplains are recognised:

- The *hydraulic floodplain* is any surface adjacent to a channel that is subject to river flooding within a given return period; and
- The *geomorphic floodplain* that is an alluvial landform constructed by the flow regime of the present river and subject to flooding.

The hydraulic floodplain is an engineering concept that is mainly concerned with the extent of flooding, irrespective of what is being flooded. It does not consider alluvial processes that create landforms on the floodplain. The geomorphic floodplain is concerned both with the extent of flooding and the nature of the channel and floodplain landform in and over which this occurs. It treats the river discharge, channel and the floodplain as being interconnected and the discharge regime is the process agent that forms the channel and floodplain. In this way the floodplain is seen to be formed by the river flow regime. Any further reference to the 'floodplain' in this report refers to geomorphic floodplains.

3.4.1 Floodplain identification and classification

Seventeen geomorphic floodplains were identified in the Project footprint based on topography, geological maps and aerial imagery review. The Project traverses to the west of Canning Creek floodplain, and while it intersects several tributaries, the Project does not intersect Canning Creek floodplain. The tributaries have been included in this assessment under watercourses, but not Canning Creek floodplain. Bringalily Creek is a tributary to Canning Creek, and the Project intersects Bringalily Creek floodplain near its confluence with Canning Creek floodplain, this area has been assessed as part of Bringalily floodplain.

Floodplains are classified by type in Table 3.12. Floodplain types in the Project footprint are described in Section 3.4.1.1.

Table 3.12 Project floodplains classification

Floodplain	Chainage (km)	Watercourse type ¹	Floodplain type	Channel Strahler order
Macintyre River ²	30.60 (NS2B) to 36.00 (NS2B)	Main Stem	B3b/C2	8
Macintyre Brook	26.70 to 27.62 35.03 to 35.30 42.800 to 45.682	N/A	B3b	8
MB 6	55.30 to 55.66	Local – poorly developed channel	B3	4
Pariagara Creek	67.170 to 67.40	Local – well developed channels	B3	4
Cattle Creek	88.20 to 88.30	Local – developed channel sections	B3	4

Floodplain	Chainage (km)	Watercourse type ¹	Floodplain type	Channel Strahler order
Native Dog Creek	93.86 to 94.02	Local – poorly developed channel	B3 – C1	3
Back Creek 2	97.40 to 98.60	Local – poorly developed channel	B3	2
Bringalily Creek	95.03 to 99.63 99.63 to 100.69	Local – well developed channels	B3	5
Nicol Creek	104.34 to 104.42	Local – developed channel sections	B3	3
SC 7	120.31	Local - poorly developed channel	B3	3
SC 2	126.96	Local - developed channel sections	C1	4
Back Creek 1	127.95 to 128.19	Local – developed channel sections	C1	4
Condamine River	139.00 to 151.40	Main Stem	C2	8
One Mile Creek	193.10 to 193.14	Local – developed channel sections	C1	3
Four Mile Gully	196.73 to 197.40	Local – poorly developed channel	C1	3
Westbrook Creek	198.40 to 199.04	Local – well developed channels	C1	4
Dry Creek	199.11 to 199.32	Local – well developed channels		3

Table notes:

1 Watercourses that intersect the Project alignment only

2 Macintyre Floodplain chainage is only for the floodplain in Queensland, not NSW.

3.4.1.1 Floodplain types in the Project footprint

Nanson and Croke (1992) developed a classification for floodplain types, based in part on examples of Australian rivers, and which provides guidance on the way these landform systems can change as environmental systems change that is relevant for river management. The Project will cross floodplain areas along the Condamine River Basin and the Border Rivers and its tributaries.

The classification scheme links the floodplain with its associated channel and takes a force and resistance approach, with the force represented by stream power at bankfull discharge stage, and resistance represented by the relative cohesiveness of the floodplain and channel bank sediments. Sand and gravel sediments are treated as non-cohesive and slit and clay as cohesive.

Three floodplain classes are identified:

- **Class A** – high-energy non-cohesive $>300 \text{ W/m}^2$
- **Class B** – medium energy non-cohesive 10 to 100 W/m^2
- **Class C** – low energy cohesive $<10 \text{ W/m}^2$.

Within each class are several orders that can be identified on the basis of sediment loads, stream power, processes, landforms, and channel planform. Changes in environmental variables such as sediment supply and stream power may result in predictable shifts of floodplain behaviour, which can form a basis for management.

The following floodplain types are likely present in the Study area modified for Project specific conditions after Nanson and Croke (1992):

- **Low Energy Cohesive – Class C**
 - These floodplains are formed by regular flow-events along laterally stable single or anastomosing low-gradient channels. Two main subclasses are recognised, both occur in the Study area:
 - **Laterally stable, single-channel floodplains Class C1** – Floodplain comprised of abundant silts and clays with organics, erosional and depositional processes include overbank vertical accretion. Typical landforms include flat floodplains with low levees and backswamps with a single thread straight to meandering channel. Sediment load comprises abundant fine-grained material.

- **Anastomosing river floodplains Class C2** – Floodplain typically very low gradient and wide, comprised of gravel and sand with abundant silts and clays, erosional and depositional processes include overbank vertical accretion. Typical landforms include flat floodplains with extensive levees, island and flood basins, crevasse-channels and splays, with multiple anastomosing channels.

The Condamine River floodplain falls into this class and comprises an approximately 13 km wide 1% AEP floodplain. The Macintyre River also falls into the Class C2 comprising an approximately 11 km wide floodplain with multiple anabranches. A vertically exaggerated conceptual cross section of the floodplain of an anastomosing floodplain with flood basins is shown in Figure 3.15.

Flood basins may be very extensive and generally contain ‘saucer-like’ alluvial islands due to the bounding natural levees built up adjacent to channels, however in some systems, levees can largely be absent.

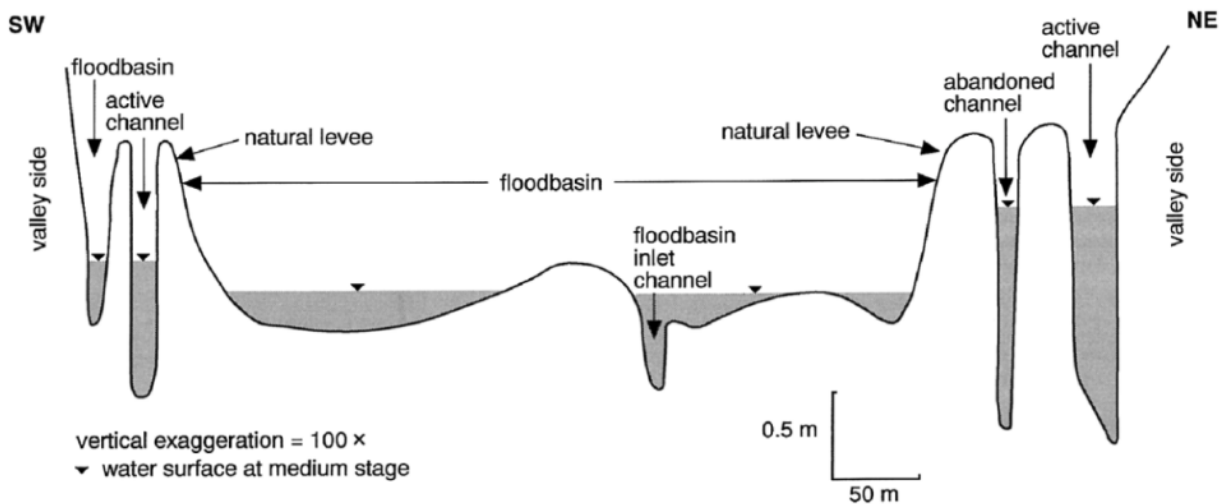


Figure 3.15 Topographic profile across the floodplain of an anastomosing river system including flood basins.

Source: Makaske, 2001

■ Medium energy non-cohesive – Class B

- These floodplains are formed by regular flow-events in relatively unconfined valleys. Three main subclasses are recognised, one occurs in the Study area:
 - **Meandering river, lateral migration floodplains Class B3** – Typical stream power of 10 to 60 W/m². Sediment comprises gravels, sand, silts and organics, although gravels can be absent. Erosional and depositional processes include cut-band erosion, lateral point-bar accretion, overbank vertical and abandoned-channel accretion, counterpoint accretion. Typical landforms include flat to undulating floodplain surface with ox-bows and backswamps.
- The presence and location of scroll bars landforms are indicative of floodplain sediments. Class B3 can be further divided based on the presence of scrolls and associated sediment as follows (Figure 3.16):
 - B3a – non-scrolled, gravel sand and silt floodplain
 - B3b – distinctly scrolled, sands and minor gravels floodplain
 - B3c – centrally scrolled with flanking backswamps, sands, silts and organics floodplain
 - B3d – concave benches scrolled floodplains, sands with abundant silts and organics floodplain.

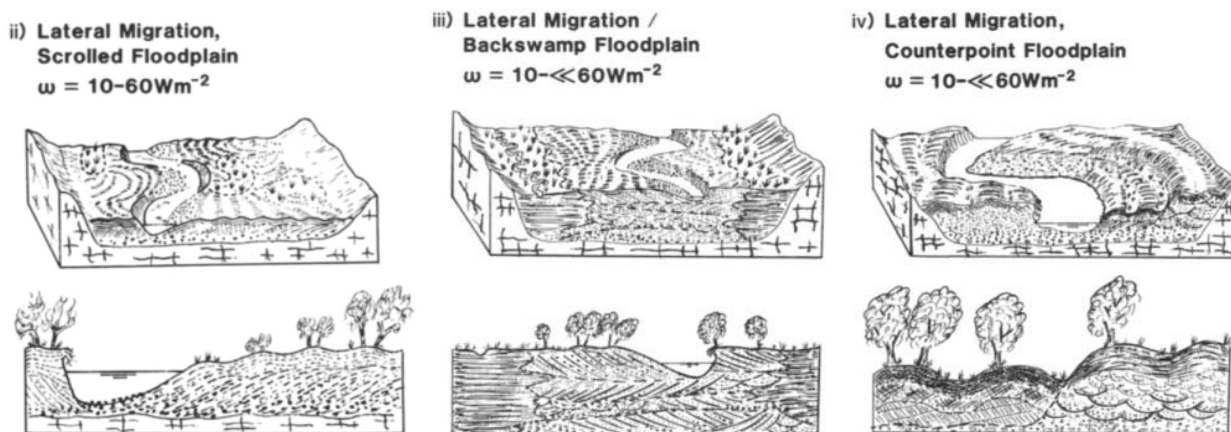


Figure 3.16 Subclasses of Class B3 floodplains, ii) Class B3b, iii) B3c, iv) Class B3d. Subclass B3a is not illustrated in Nanson and Croke (1992)

Source: Nanson and Croke (1992)

Many of the watercourses that cross the Project alignment have associated floodplains extending a few metres to hundreds of metres either side of the channels. For the smaller streams these may be termed 'hydraulic floodplains' where there is no alluvial landform, and the area is merely passively inundated during floods. 'Genetic floodplains' occur where alluvial sediment has been deposited to form a flat area that carries out of bank flow during floods and where fluvial landform development occurs.

3.4.2 Floodplains geomorphic processes

Floodplains result from the deposition and erosion of alluvial sediment by the river. Water out of the channel and flowing across the floodplain will deposit generally fine sand and silt as overbank deposits, or clay in very low energy systems such as the Condamine River. If the channel is migrating, it will erode the adjacent floodplain on the outside of channel bends while depositing material on the inside of bends. Several styles of channel deposition can therefore contribute to floodplain growth including lateral accretion, and oblique accretion.

Floodplain landforms include levees and scrolls, abandoned channels (paleo-channels), ox-bows and backswamps. Levees are low mounds of sediment built up above floodplain level at the junction of the channel and floodplain and are formed by deposition as floodwaters leave the channel. Scrolls are groups of former levees where the channel has migrated away. Abandoned channels occur where the main channel moves away from part of the floodplain often due to a single avulsion event where a flood breakout occurs, and a new river course is formed. These may become occupied by backswamps or ox-bow lakes.

3.4.2.1 Types of floodplain processes

Typical floodplain features and geomorphic process are included in the descriptions of floodplain type in Section 3.4.1.1. Floodplain landforms and processes, such as backswamps or ox-bow lakes which form important habitats for flora and fauna, require connectivity to the main channel/s to function. All of the geomorphic processes linked to these floodplain types occur in nature but can be influenced by land use change. In summary, the main floodplain geomorphic processes include:

- Erosion
 - Scour holes – localised erosion features generated on a sediment surface by water
 - Erosion of floodplain landforms such as wetlands, pond and flood channels, or the development of new ones
 - Floodplain stripping – removal of floodplain sediment and landforms by flood events over wide areas. Usually occurs as part of long-term cycles of sandy floodplain deposition/erosion.

- Deposition
 - Deposition can lead to floodplain accretion and infilling of floodplain landforms, such as flood channels, wetlands, ponds and pools
 - Natural levees can develop over time adjacent to channel edges on the floodplain when coarser sediments are deposited in near channel during overbank flow events.

3.4.2.2 Project floodplain processes

There is a strong link between floodplain typology and processes. The floodplain type is the physical manifestation of the fluvial processes acting on the landform, including water flow, sediment transport, deposition and erosion.

Refer to Appendix D for processes and historic change for floodplains other than the Condamine and Macintyre River floodplains. Significant historic change has occurred on the Condamine River Floodplain and the Macintyre River Floodplain, refer Sections below for baseline conditions.

The following key observations on processes and historic change of Project floodplains were identified:

- Most sites show evidence of no/very minor fluvial geomorphic processes or change since the 1940/50s showing the fluvial geomorphic system under existing flow regimes in both green and brownfield sites has generally been changing very slowly
- Changes that have occurred are usually due to human intervention particularly the construction of ponds and other water collection and storage reservoirs, as well as road embankments, cross drainage and fords
- South Condamine is an active erosion feature in a flood basin of the Condamine Floodplain downstream of the existing rail, and imagery shows ongoing erosion.

Condamine River floodplain

The Condamine River floodplain is a low energy, low relief, cohesive Class C2 type floodplain. The floodplain comprises two main permanently flowing anabranches and two that flow in floods, with flood basins between these channels (Figure 3.17). Type C floodplains are formed by overbank deposition and avulsion. The sinuosity of existing channels and state of preservation of abandoned (paleo) channels provides information on the lateral activity of the channels. The sinuous nature of the main channels of the Condamine, in particular the North Branch, indicates long term and very slow avulsion rates. The Condamine River main stem that crosses the Project alignment developed from an avulsion event in 1886-7 (Section 3.3.2.3). The sinuosity of the Condamine River main stem reduces approximately 4 km upstream of the alignment, in the area of what was the dead-end 'Broadwater' prior to the two diversions that were excavated in the 1870s and 1880s.

At and upstream of the Project alignment, the floodplain is approximately 13 km wide and the three main anabranches are the Condamine North Branch, Condamine River Main Branch and Grasstree Creek. Meandering paleochannels can be seen on the floodplain surface and these carry flow during flood events. They are evidence of past avulsion events. Between about 12 and 16.5 km upstream of the Project alignment the floodplain narrows to approximately 8.5 km wide and the number of anabranches increases.

Approximately 2 km downstream of the Project alignment, Grasstree Creek join the Condamine River, which then has two anabranches (Condamine River and North Branch) for 43 km downstream, with a flood basin and paleochannels between. Tributaries draining from the moderate relief hills on the eastern side of the Condamine River valley side slopes are very shallow and lose their channel form on the floodplain before reaching the Condamine River, in what functions as an extensive low angle alluvial fan system which drains the fertile vertosol soils to the east of the floodplain. There is very little to no evidence of paleo channels on this surface.

The Condamine River South Branch channels described above (Section 3.3.2.3) are located in a flood basin between Grasstree Creek and Condamine River. They have no geomorphic expression upstream of the existing QR alignment (Ch 142.0 km to Ch 143.0 km) and appear to have developed in response to the construction of the existing QR embankment and are thus considered not part of the natural system. The central part of the flood basin where the existing erosion is occurring corresponds with the highest maximum Existing Case flow velocities along the proposed alignment in the Condamine floodplain, between 0.50 and 0.67 m/s for the 20% AEP (Appendix H Culverts C142.61 to C142.07).

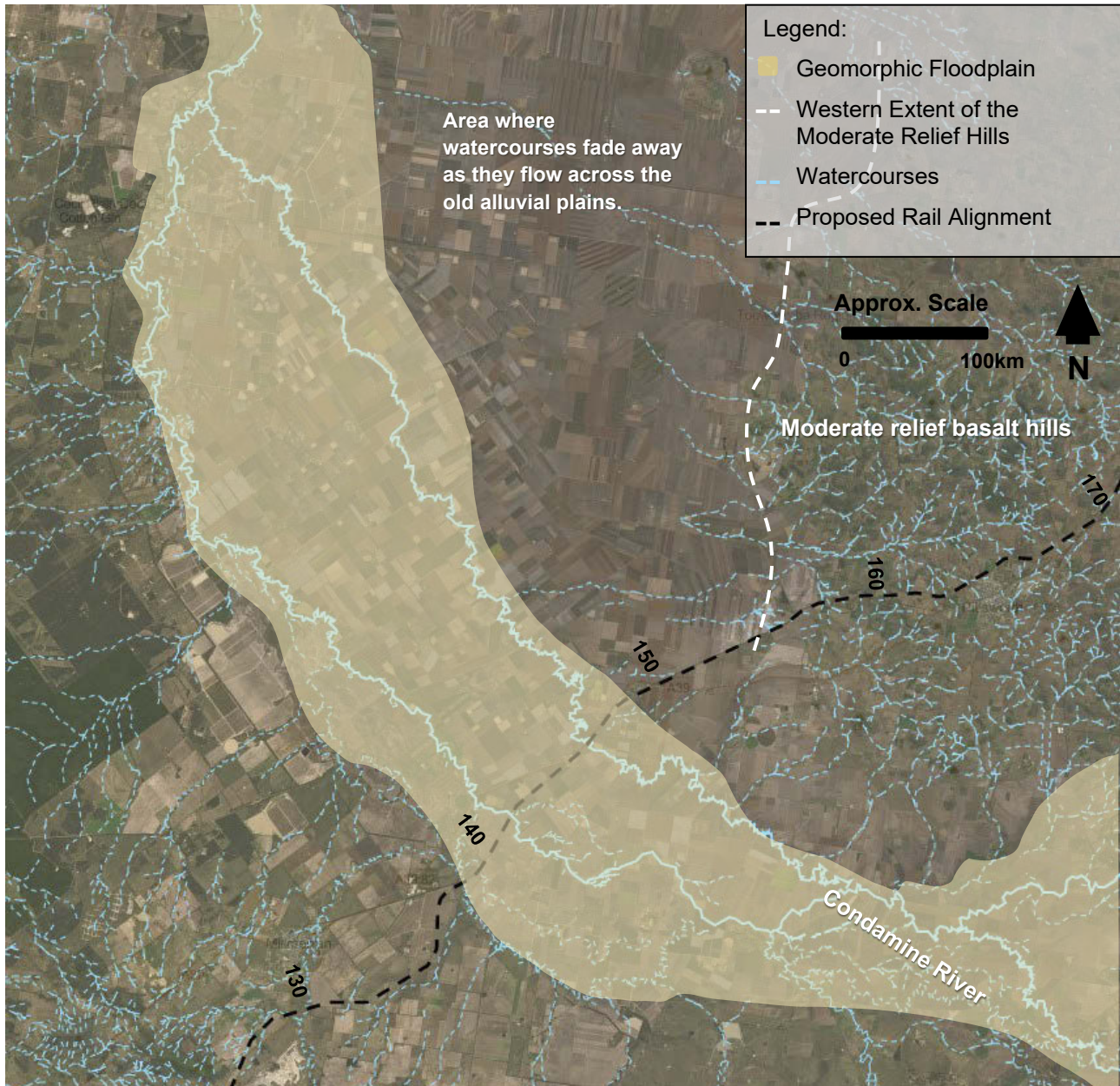


Figure 3.17 Condamine River floodplain

Figure note: Floodplain extents outlined in yellow dashed line.

Macintyre River floodplain

The Macintyre River floodplain straddles the NSW/QLD border which is defined by the Macintyre River channel (Figure 3.18). The approximately 11 km wide floodplain that crosses the Project alignment appears to be in a transition between a B3b and C2 floodplain:

- At and downstream of the Project alignment the Macintyre River is an anastomosing river floodplain with multiple anabranches. The floodplain comprises two permanently flowing anabranches Macintyre River and Whalan Creek (located in NSW) as well as flood channels. Evidence of past avulsion events and cut-off channels are visible on the floodplain surface.
- Upstream of the alignment approximately 4.4 km the Dumaresq River converges with the Macintyre River. There are visible point bars, vegetated scroll bars and other accretionary features visible in aerial imagery.

The Macintyre River gradient at the alignment is similar to the gradient of the Condamine River. The soils throughout the Macintyre floodplain comprise Sodosols, Chromosols and Vertosols.

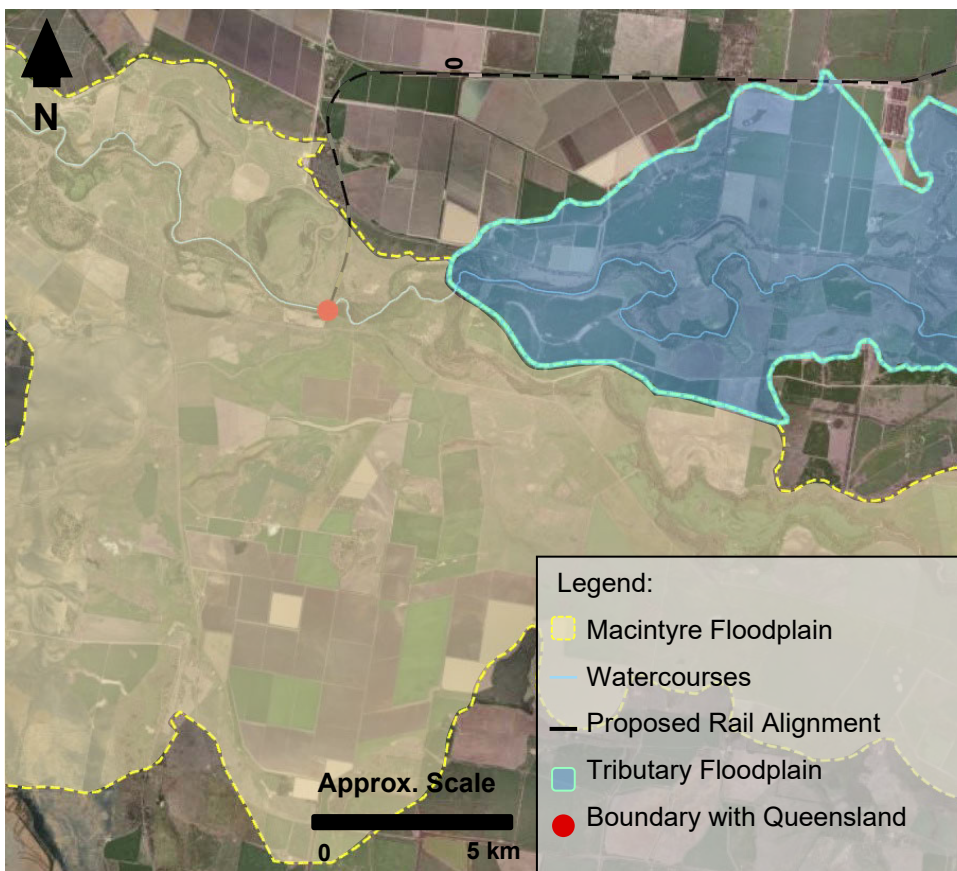


Figure 3.18 Macintyre River floodplain

3.4.1 Floodplains sensitivity to change

Of the 17 geomorphic floodplains in the Project footprint, the following existing condition sensitivity to change was assessed:

- Category 5 – 3 Floodplains, including the Condamine due to the historic human induced avulsion event, channel straightening, erosion related to the existing rail and large number of ponds, SC 7 which has been dammed causing a cut-off of the natural channel and development of erosion channels downstream and Macintyre Brook which has straightened floodplain channels
- Category 4 – 8 Floodplains including the Macintyre River Floodplain, all due to human made change potentially resulting in unstable landforms, including confining bridges and roads and straightening of main channels

- Category 3 – No floodplains were assessed as this category
- Category 2 – 6 floodplains
- Category 1 – No floodplains were assessed as this category.

The majority of floodplains have extensive human modifications which have either already resulted in rapid geomorphic change or have the potential to create unstable landforms. This is reflected by the large number of Project floodplains with category 4 or 5 sensitivity to change.

3.5 Baseline fieldwork assessment

A total of 55 field checking sites were investigated from 7 March to 11 March 2022 to confirm baseline conditions and document impacts of existing infrastructure on watercourse and floodplain processes. Field site IDs are either labelled BL for Baseline checking sites close to or at the Project alignment, or EP for sites further from the alignment dominantly visited to assess erosion potential. However, fluvial geomorphic observations on the watercourses and floodplains were gathered at all sites. As sites visited were accessible from public roads, some of the sites were not on the Project alignment, and due to lack of safe offroad parking, some sites were not able to be assessed.

The site inspections occurred shortly after a significant flood event and river levels were still receding at some sites. Future Freight Joint Venture hydrologists estimate that the flood events that occurred in the Condamine River in March 2022 were equivalent to approximately a 20% AEP event at Cecil Weir and potentially less than a 20% AEP around Yandilla. This was a flood event close to bankfull conditions for a number of watercourses, where some erosion on the outside of bends and deposition would be expected to occur under natural conditions away from infrastructure. The site works occurred approximately a week after this event.

Site descriptions and photos are included in Appendix F, maps showing the locations of the field sites are included in Appendix A, Drawing Set D. A summary of the sites visited is included below, noting the Condamine River sites are discussed separately in Section 3.5.4 as these locations were inspected following flooding in the Condamine River.

3.5.1 Baseline fieldwork sites summary

The baseline field work sites (23 total) were included to confirm the baseline assessment of channel and floodplain types. These sites were located on watercourses/floodplains that intersect the Project alignment and as close to the alignment as possible. Sites are discussed referencing both their baseline/erosion potential site IDs and associated catchment name. The baseline field work sites visited included:

- 19 watercourse sites
- Three floodplain sites
- One site that is both floodplain and watercourse.

3.5.1.1 Watercourse sites

Watercourse field work confirmed the baseline channel classifications, in summary:

- Three 'Headwater' sites were visited and confirmed as mainly Non-Channelised Valley Floor with sections of washslopes and some short sections of low sinuosity channel
- One 'Headwater' site was visited and confirmed as Non-Channelised Valley Floor with sections of low sinuosity channels and bedrock constrained channels
- Five 'Local – Poorly Developed Channel' sites were visited and confirmed as Non-Channelised Valley Floor with sections of low sinuosity channel

- Four 'Local – Developed Channel Sections' sites were visited and confirmed as low sinuosity channel to Non-Channelised Valley Floor, or chain of ponds, usually in meandering planform, or low sinuosity channel. Two of these sites were along Nicol Creek.
- Five 'Local – Well Developed Channel' sites were visited and confirmed as low sinuosity channel, and chain of ponds in meandering planform. Two of these sites were along the North Branch of the Condamine River.
- Two 'Main Stem' sites were visited along the Condamine River, and both were confirmed as meandering to low sinuosity channel (in area of old diversion).

3.5.1.2 Floodplain sites

At some floodplain baseline field work sites, visibility was poor due to vegetation (trees/bush). In summary it was identified at the three floodplain sites:

- Two type B3b floodplains (Macintyre Brook and Canning Creek) - Difficult to discern features due to vegetation, some paleochannels/flood channels and backswamp ponds observed, consistent with B3 floodplains
- One type C1 floodplain (Four Mile Gully) - Difficult to discern features due to vegetation, flat, appears stable
- One type B3b/C2 (Macintyre River floodplain) - Difficult to discern features due to vegetation however paleochannels evident in aerial imagery.

3.5.2 Erosion potential sites

There were 44 erosion potential sites inspected, and five additional baseline field work sites where impacts of infrastructure were observed. These sites were at a range of watercourse/infrastructure crossings, including watercourses that do not intersect the Project alignment.

3.5.2.1 Bridges

Eleven existing bridge sites were visited during the site inspections, ten of these watercourses also have bridges in the revised reference design (noting the Project alignment does not cross Gowrie Creek so that existing bridge will not be part of the Project). All the design bridges will be longer than the existing bridge sites inspected during site investigations by between 75 and 2,500 m, or between 3 and 90 times longer. This means the bridges for the Project are likely have less impact on the fluvial geomorphic environment than the existing bridges. However, it is acknowledged that not all of the proposed bridges will be direct replacements of existing bridges.

Table 3.13 summarises site observations at bridge sites, and includes the distance of the field site from the Project alignment, and the revised reference design bridge length and ID.

While the Condamine North Branch has a road bridge, there was no safe location to stop and inspect at this site. Two crossings of the Condamine North Branch were inspected in place of the Condamine North Branch location, (Site 1a and 1b, Section 3.5.4) upstream and downstream of the Project alignment; both of these sites are culvert crossings. The revised reference design length for the Condamine North Branch Bridge is 1,568 m, the current Road bridge at the Gore Highway (approximately 40 m from the alignment centreline) is just 30 m long.

The Condamine River and Grasstree River experienced close to bank full conditions (slightly above) the week prior to the site inspection, and erosion on river bends (natural) and adjacent to bridge structures was observed.

Of the other bridges (except Gowrie Creek), the largest impacts comprised change of channel type upstream to downstream and moderate to major consequence category erosion and deposition, and were observed at:

- Four Mile Gully
- Bringalily Creek (Figure 3.19)
- Whalan Creek Arm.

At all these three sites, the embankments of the existing bridge extended up to and possibly into the channel.

Minor to moderate erosion and deposition were observed at the following bridge sites:

- Westbrook Creek
- SC2
- Native Dog Creek
- Cattle Creek (Figure 3.20).

The Macintyre Road bridge on the Newell Highway near Goondiwindi was visited, however there was no safe location to stop and safely conduct an inspection.

The increased length of the bridges in the revised reference design against the existing bridges results in less likelihood of encroachment on the watercourses/floodplains (depending on abutment location), and a reduction in potential impacts.

Table 3.13 Summary of site observations of bridge sites

Bridge	Field site ID	Distance from the Project alignment	Site observations	Approximate length of bridge at field site (m) ¹	Notes of abutment location relative to channel of existing bridge	Bridge design length (m) and ID in revised reference design
Gowrie Creek	EP1a	125 m	Recent erosion on both banks, erosion and failure behind retaining wall. Deposition of silty sand material on inside of bends. Localised gravel dropout on inside of bend downstream of bridge on right side.	60 m	Floodplain encroachment	N/A
Four Mile Gully	14/EP3b	24 m	Recent deposition occurring at and downstream of bridge. Erosion occurring at bridge and site upstream of bridge (may be related to road crossing). There was indication that the bridge was overtopped from grass on surface.	17 m	May encroach channel	92 m 310-BR20 Toowoomba Cecil Plains Road Rail Bridge
Westbrook Creek	EP3a	880 m	Recent minor erosion noted on downstream banks. Some fines deposited in grass on fairway immediately upstream of bridge.	38 m	Embankments extend up to channel edge	230 m 310-BR31 Westbrook Creek Rail Bridge
Condamine Main Branch	1d/EP16	2,000 m	Recent erosion occurring on bends both upstream and downstream of bridge, deposition on banks/adjacent floodplain	70 m	Floodplain encroachment	2,577 m 310-BR25/26 Condamine River Main Branch
Grasstree Creek	EP17a	8,800 m	Difficult to confirm due to high water level. Aerial imagery shows change in channel type above and below bridge.	15 m	Embankments extend up to channel edge	1,330 m 310-BR21/22 Grasstree Creek Rail Bridge
SC 2	EP19	8 m	Water ponding. No obvious erosion.	12 m	Appears to encroach up to and possibly into channel	167 m 310-BR37 Millmerran Inglewood Road Rail Bridge #3
Bringalily Creek	5/EP29	40 m	Long-term bank erosion occurring downstream. Channel ponding occurs both upstream and downstream of the bridge.	34 m	Embankments extend up to channel edge	621 m 310-BR10 Bringalily Creek 3 Rail Bridge
Native Dog Creek	10/EP31	270 m	Local areas of very minor long-term erosion. Non channelised valley floor flow channel type.	60 m	Encroaches ~ 20 m into channel, (channel width 80 m)	184 m 310-BR07 Native Dog Creek Rail Bridge
Cattle Creek	2/EP34	65 m	Bridge has restricted non-channelised valley floor flow and resulted in minor long-term erosion/incision of a small channel downstream	46 m	Encroaches ~ 24 m into channel, (width 70 m)	138 m 310-BR06 Cattle Creek Rail Bridge

Bridge	Field site ID	Distance from the Project alignment	Site observations	Approximate length of bridge at field site (m) ¹	Notes of abutment location relative to channel of existing bridge	Bridge design length (m) and ID in revised reference design
Macintyre River	EP43	18,000 m	No obvious erosion/deposition, however, site team were not able to pull over and water level was high.	140 m	Encroaches floodplain	1,150 m Macintyre River Viaduct Span A
Whalan Creek Arm	EP44	1,290 m	Long-term erosion evident at bridge and upstream. Channel changes to non-channelised valley floor flow downstream of bridge.	18 m	Appears to encroach up to and possibly into channel	1,150 m Macintyre River Viaduct Span A

Table note:

1 Estimated from Google Earth Imagery



Figure 3.19 Bringalily Road bridge site inspection (EP29)



Figure 3.20 Cattle Creek Road bridge site inspection (2/EP34)

3.5.2.2 Culverts

Twenty-six culvert sites were inspected, ranging from single pipe culverts to sites with up to 17 culvert cells. Evidence for erosion or deposition at one site was unable to be gathered due to high water (EP18).

Eleven sites were classified as geomorphically stable, with no evidence for erosion or deposition. All these sites were in headwaters or local poorly developed channels, and all had vegetated channels. These sites were in a range of both sodosol and vertosols, for example refer site EP23 Appendix F.

Five culverts had minor erosion and deposition observed during the site visit. Another five culverts had minor to moderate erosion/deposition consequence category, typically causing ponding upstream and erosion downstream.

Four sites had channel type or width changes upstream to downstream, indicating moderate (over time) consequence category erosion/deposition (EP6, EP8, site 7a); figures are illustrated in Appendix F. Figure 3.21 is at site EP 6 (NC 2 catchment), where some erosion and undercutting were observed at the transition to natural bed, as well as ponding downstream of culvert. Minor to moderate erosion on true right bank downstream of culvert. Change in channel width upstream to downstream of the culvert from 1 to 2 m to 7 to 15 m wide.



Figure 3.21 Condamine North Branch NC 2 culvert site (EP6) site inspection Cattle creek (2/EP34)

3.5.2.3 Other sites

Other erosion potential sites inspected comprised:

- One weir on the Condamine River (site 1h/EP16), partial damming of the river upstream changing channel type and width downstream
- Fords, which typically caused ponding upstream, and can cause channel type change
- Road embankments, act as low embankment, causing ponding
- Culverted causeways, (one along Gowrie Creek which does not cross the Project alignment), low concrete structures with one or two culverts, causes erosion at interface downstream and ponding upstream.

3.5.3 Existing cross drainage impacts by bed/bank material type

Bed and bank material of channels is a consideration in assessing the baseline condition and change potential. Non-cohesive soils, in particular sands and non-cohesive silts and fine gravels, are generally more prone to erosion than cohesive soils such as clays/silts. Vegetated channels are the least susceptible to change.

Note that observations on bed/bank material were made from the road reserve and comprised visual estimates of grain size and colour only (not ASC, chemistry etc) and sampling/laboratory testing was not undertaken. This discussion includes all channels sites observed in both the baseline field work and erosion potential sites.

A review of existing infrastructure performance by ASC soils type has also been included. The ASC soil type at the site has been taken from the detailed soils assessment by Aurecon (2022), or regional field verified mapping if the site is outside of the area mapped (EIS Appendix J: Soil Assessment Report).

3.5.3.1 Sites where channels were vegetated, or bed/bank material was not able to be observed

Some channel types, such as non-channelised valley floor flow, are vegetated, and bed/bank material was not able to be observed. Also, many sites had water covering any areas of exposed bed/bank material, and these sites could not be assessed. A total of 29 sites had channels that were either vegetated or underwater during the inspection, and bed/bank material could not be observed. All sites that had vegetated channels were geomorphically stable (Figure 3.22).



Figure 3.22 Baseline field work site 19, Watercourse (NC 15) flow travels across the road left to right, channel type wash slope/ non-channelised valley floor flow, well vegetated, stable

3.5.3.2 Silt/clay bed channels

Silt/clay or 'mud' (combination of silt and clay) bed/bank material was observed at seven channels, all in the northern half of the Project alignment, between Ch 128.0 km (Back Creek 1, which drains into the Condamine) and Ch 205.0 km (Gowrie Creek, which is north of the alignment and does not cross). This does not mean that silt/clay bed watercourses do not occur south of Back Creek 1, only that they were not observed during the site field work. All floodplains associated with silt/clay bed channels were Class C (low energy), consistent with the observed bed/bank material.

Three of these channels occur in the Condamine and are discussed in Section 3.5.4. The other four channels (Dry Creek, Four Mile Gully, One Mile Gully Creek and SC5) were all mostly vegetated and stable away from the road infrastructure, indicating their vegetated state is a key component of reducing change potential. Adjacent to culvert/bridges, minor erosion and deposition was present (Figure 3.23).



Figure 3.23 Baseline field work site 8, Watercourse SC 5, channel type wash slope/ non-channelised valley floor flow, away from culvert vegetated and stable

3.5.3.3 Sand/silt bed channels

Fifteen sand/silt bed watercourses, including two sites along Gowrie Creek with sandy silt, were observed. They occur mainly in the southern half of the Project alignment, including south of the Macintyre River in NSW and between Ch 60.0 km to Ch 120.0 km. Sand/silt bed watercourses were observed at two sites north of Ch 120.0 km, baseline field work EP7 and EP6 (watercourses NC 2 and 3) which occur at Ch 186.2 km and Ch 184.8 km in the Condamine North Branch sub catchment. Pine Creek located at the Turallin facility away from the Project alignment also has a silt/sand bed. All floodplains associated with sand/silt bed channels were Class B3 (medium energy), with one Class B to Class C (medium to low energy), consistent with the observed bed/bank material.

Erosion or deposition was observed at all sites, ranging from minor erosion/deposition (typically at more vegetated sites, see Figure 3.24) to moderate deposition at SC6 (causing blockage of a culvert and ponding upstream, see Figure 3.25) and gully erosion at one site along watercourse MB5 (Figure 3.26). The sediment deposited in watercourse SC6 may have come from the human made pond upstream, which appears to have bare soil exposed, as the channel bed is well vegetated with no obvious scour or bedload. The field work assessment site for MB5 (BL12) was located 250 m upstream of the Project alignment, the gully erosion channel only occurred over a short distance before it developed into a washslope.

These sites were dominantly in highly erodible sodosols, but also included vertosols, dermosols and kandosol. The amount of erosion appears to be inversely associated with vegetation cover, such that sites with more vegetation cover had less erosion, but this has not been statistically tested. Site MB 5 did not follow this pattern being well vegetated yet exhibiting erosion. This may be due to high proportion of sand bed material, the highest of sites visited.



Figure 3.24 Baseline field work site 10, Native Dog Creek vegetated non-channelised valley floor flow channel with local areas of very minor erosion, site is also mapped as sodosols



Figure 3.25 Site 7a – SC 6, deposition has blocked culvert and caused deposition and ponding, indicates erosion occurring upstream of site



Figure 3.26 Site 12 – MB 5 approximately 200 m upstream from alignment, intermittent gully erosion occurring, downstream and at alignment channel is non-channelised valley floor with short section of low sinuosity channel

3.5.3.4 ASC soil types

The field work sites allows review of the performance of existing infrastructure in the Project Area by ASC soil type. Table 3.14 describes the soil types across the Project footprint. Further details are provided in EIS Appendix J: Soil Assessment Report. Of particular interest are ‘problem soils’ such as:

- Cracking-clay soils such as vertosols as they can be less stable once disturbed, which may impact rehabilitation of vegetation post construction
- Texture contrast soils, such as sodosols and chromosols have high to very high erodibility rating.

Mitigation strategies for these problem soils are included in both the revised reference design and future Project stages (Section 5).

Table 3.14 includes a summary of site observations of impacts on the fluvial geomorphic environment of existing infrastructure by ASC soil type. Most sites were in either sodosols or vertosols. From this data set, we can summarise that:

- Cross drainage structures occur in the existing environment in soils with moderate to very high erodibility ratings that have no observed erosion or impact on the fluvial geomorphic environment
- Many culvert inlets and outlets in problem soils, including vertosols sodosols, were vegetated with grass, indicating that revegetation of these soil types post construction can be successful and reduce future erosion potential.

Table 3.14 Summary of site observations at existing infrastructure by ASC soil type

ASC Soil Class	No. of sites	Cross drainage infrastructure	Site observations of impacts on the fluvial geomorphic environment
Sodosol	4	Fords	Some erosion visible at three ford sites. All banks are vegetated with grass and some spare trees.
	8	Culverts	Over half the sites appear stable. These are all vegetated with grass, and some also have trees and bush. Three sites had some ponding.
	5	Bridges	Minor erosion visible at three of the bridge sites. This is likely related to bridge channel constriction. All sites were grassed and some had sparse trees.
Sodosols/Vertosols	1	Bridge	High water level impacted onsite assessment. Appears to have minimal existing impacts. Channel appears vegetated with grass and trees.

ASC Soil Class	No. of sites	Cross drainage infrastructure	Site observations of impacts on the fluvial geomorphic environment
Vertosols	4	Bridges	Some minor erosion, deposition and scour observed. Banks are mostly vegetated with grass and some sparse trees.
	13	Culverts	Over half of the sites appear stable. Minor erosion or deposition at six of the existing culverts. All culvert sites are grassed and some have trees.
	3	Culverted Causeway	Some minor deposition and erosion observed. Sites are vegetated with grass.
	3	Fords	The sites appear stable with one site showing minor deposition. Sites are vegetated with grass and some trees.
	2	Road Embankments	Sites appear stable. Both sites are grassed.
	1	Weir	High water level impacted onsite assessment. Channel appears vegetated with grass and some trees.
Vertosols/rudosols	1	Culvert	Appears stable. Vegetated with long grass and some trees.
Vertosols/dermosols	1	Culvert	Some minor erosion and ponding. Waterway is grassed with some trees.
Chromosol/vertisol	1	Bridge	Some erosion at this bridge, remnants of historic wooden bridge. Watercourse mostly grassed with some small areas of sand/silt exposed.

3.5.4 Condamine River sites

It is estimated that the flood events that occurred in the Condamine River floodplain in March 2022 were equivalent to approximately the 20% AEP event at Cecil Weir, located on the Condamine River, and potentially less than a 20% AEP around Yandilla. This has provided a unique opportunity to relate hydraulic data to the impacts observed during the site walkover for the Condamine River.

Table 3.15 summarises the hydraulic data alongside site observations and consequence category (Section 2.4 for descriptions of consequence categories) for different field sites within the Condamine basin. There are associations between consequence category and maximum velocity, but associations between consequence categories moderate and major and stream power are less obvious. Note that field sites 1c, 1e, 1h, 1f, EP15 and EP17a were also located in the Condamine River floodplain, however these sites were either unable to be safely visited or were underwater during the inspection. These sites are further discussed below.

Examples of 'major' consequence category erosion on the Condamine River Main Branch are shown in Figure 3.27, note that erosion is occurring on the outside of channel bends during an event close to (but slightly above) bank full conditions, which is what would be expected under natural conditions. However, erosion adjacent to the bridge is likely to be associated with the infrastructure.

An example of 'moderate' consequence category erosion is shown in Figure 3.28. This erosion is occurring downstream of the bridge on a straight section of channel between two sharp meander bends and is therefore likely directly related to the bridge.

Figure 3.29 and Figure 3.30 illustrate 'minor' erosion and deposition consequence category. Note that the site in Figure 3.30 on Grasstree Creek, is on a meander bend that is currently being cut off, with the main flow bypassing this meander.

Table 3.15 Summary of hydraulic model outputs for field sites visited in the Condamine River floodplain

Field work site ID	Distance from Project alignment (m)	20% AEP (1-in-5 year event) ¹				Stream ID	Site observations	Consequence category
		Maximum velocity		Maximum SP				
		US	DS	US	DS			
1a	2415	1.04	0.8	25.4	13.35	Condamine North Branch	Erosion on upstream bank (approximately 8 m) and deposition of dark blackish brown silt/clay on downstream sides.	Moderate
1b	830	0.78	0.68	6.83	3.33	Condamine North Branch	Erosion in riprap at abutments, and minor erosion in natural banks. Banks at culvert are still partially inundated.	Minor
1d/ EP16	2010	1.5	1.87	18.41	20.19	Condamine Main Branch	Scour leading to bank failures approximately 20 to 30 m long on the outside of bends both upstream and downstream of the bridge, channel appears narrower upstream of bridge.	Major
EP17	5045	0.45	0.49	0.85	1.1	Grasstree Creek	Ponding directly upstream of the ford, channel is narrower directly downstream – may be due to natural chain of ponds channel type. Minor deposition, no obvious erosion	Minor

Table notes:

1 These velocities have been taken from the field work sites and may differ from the velocities at the Project alignment. As such the velocities may differ from those expected at the alignment.

SP = Stream Power

US = upstream

DS = downstream



Figure 3.27 Example of 'major' consequence category on Condamine River Main Branch (field sites 1d/EP16) approximately 2.2 km downstream from the Project alignment on Gore Highway



Figure 3.28 Example of 'moderate' consequence category on the Condamine North Branch (field site 1a) on Hanlon Road, approximately 3 km downstream of the Project alignment



Figure 3.29 Example of 'minor consequence category on the Condamine North Branch (field site 1b), approximately 800 m upstream of the Project alignment



Figure 3.30 Example of 'minor consequence category on Grasstree Creek (field site EP17), approximately 8.7 km upstream of the Project alignment

3.6 Summary baseline fluvial geomorphic conditions

Baseline fluvial geomorphic conditions are summarised in Sections 3.6.1 and 3.6.2 and detailed in the following appendices:

- Appendix A Drawings
- Appendix C Watercourse classification
- Appendix D Floodplain classification
- Appendix E Oldest aerial imagery review
- Appendix F Baseline field inspection site records and photos
- Appendix G Watercourse sub-reach assessment

3.6.1 Border Rivers Basin

3.6.1.1 The Macintyre River and its floodplain (Ch 30.6 (NS2B) to 6 km)

The Existing Case conditions are summarised in Table 3.16. The Macintyre River in the Project footprint is an anastomosing river system in an unconfined valley setting with two main channels, the Macintyre River and Whalan Creek (located in NSW). The two main anabranches appear largely unchanged in planform and location in the Project footprint since the earliest aerial imagery (1949), except for slight downstream migration of two meander bends on the Macintyre River.

Directly upstream of the Project alignment, there are two meander bends on the Macintyre River. These show the typical geomorphic process of point bar accretion on the inside of the bends and erosion on the outside and appear to have migrated approximately 20 to 30 m downstream since 1949. Downstream of the alignment, the Macintyre River is less sinuous for approximately 4 km, where it has historically cut off a large meander bend (at a time period prior to the earliest aerial imagery) which is now an ox-bow lake.

Five field checking sites occurred in the Macintyre River area, including one on the Macintyre River (EP43) 17.8 km downstream from the Project alignment crossing at the Newell Highway bridge near Goondiwindi. No obvious erosion or deposition was observed at the bridge, but water was still high. One site (BL21) was an overview of the floodplain, the other sites were on Whalan Creek in NSW.

Approximately 3.5 km downstream along Whalan Creek from the Project alignment, it is intersected by the Bruxner Highway Road ford crossing (field site EP45). This ford has resulted in ponding and wider channel development upstream. Approximately 1.3 km upstream from the alignment along Whalan Creek, the channel is crossed by two fords (EP44), and a further 500 m upstream by the Tucka Road bridge (EP44a). The Tucka Road bridge has a span of approximately 17 m, with a slight encroachment of its abutments into Whalan Creek channel. Two scour holes on the order of 1 m deep and 3 to 7 m wide have developed at the bridge.

Table 3.16 Existing Case geomorphic conditions Ch 30.9 km (NS2B) to Ch 6 km (B2G)

Feature	Description
Watercourses	1 Main Stem – Macintyre River <i>Anastomosing meandering channel type</i>
Floodplains	Macintyre River Floodplain <i>Class C2, becoming C1 downstream</i> Approximately 11.2 km wide and comprises multiple back channels and flood channels including Forrest Creek. Lagoons have developed in paleochannels. Evidence of past avulsion events and cut off channels are visible on the floodplain surface. Upstream of the confluence of the Macintyre and Dumaresq Rivers, approximately 4 km along river upstream from the Project alignment, the floodplain shows some medium energy (Class B3) characteristics.
Catchment area	868,480 ha

Feature	Description
Catchment soils	Sodosols, Chromosols and Vertosols
Catchment vegetation	Crops/grassland
Historic change	Largely unchanged except for approximately 20 to 30 m downstream migration since 1949 of two meander bends on the Macintyre River directly upstream of the Project alignment. Several large ponds have been constructed on the floodplain, some up to 100 ha, and over 100 km of drains have been constructed within 10 km upstream of the alignment.
Site checking	5 sites (EP43, EP44, EP44a, EP45 and BL21), ponding, erosion and scour holes observed adjacent to fords and bridges across Whalan Creek

3.6.1.2 Macintyre Brook floodplain sidling (Ch 6 km to 63.9 km)

The Existing Case conditions are summarised in Table 3.17. The Project sidles along the north-western edge of the Macintyre Brook floodplain, intersecting the floodplain for between lengths of 0.3 to 3 km at five locations. A total of 18 tributaries of the Macintyre River crosses the Project alignment over this section up until the confluence of the Macintyre Brook and Canning Creek.

Three field sites occurred along this section, two on the Macintyre Brook and its floodplain (BL15a and EP42), and one on a tributary of the Macintyre Brook, MB5 (BL12) 250 m upstream of the Project alignment. Access to publicly available field checking sites was limited by Bringalily State Forest. Minor bank erosion was observed along the Macintyre Brook near the Inglewood bridge (BL15a).

Minor bank erosion was observed downstream of the Cremascos Road Bridge (EP42) and slight channel widening was observed directly upstream. The site at MB5 had active gully erosion and deposition of sand, a clear channel form only occurred over a short distance before it developed into a washslope. Bed material was typically sand/silt with some gravel, banks are typically vegetated.

Table 3.17 Existing Case geomorphic conditions Ch 6 km to Ch 63.9 km

Feature	Description
Watercourses	18 tributaries of the Macintyre River comprising 11 headwaters, six local – poorly developed channel watercourses, and one local – developed channel sections <i>Non-channelised valley floor and low sinuosity channels in unconfined to semi confined valley settings</i>
Floodplains	Macintyre River Floodplain <i>Class B3b</i> Single main channel which is sinuous to meandering, paleo channels, backswamps and scroll bars.
Catchment area	From <10 ha to 6041 ha
Catchment soils	Kandosols
Catchment vegetation	Bush
Historic change	Aerial imagery review indicates no change in channel planform and location since 1949.
Site checking	3 sites (EP42, BL12 and BL15a), minor bank erosion and channel widening, gully erosion and sand deposition, washslopes observed adjacent to bridges.

3.6.1.3 Pariagara Creek and floodplain (Ch 64.7 km to Ch 68.7 km)

Over this section, the Project alignment crosses eight waterways including Pariagara Creek. The Existing Case conditions are summarised in Table 3.18.

Pariagara Creek has a 3 to 4 m deep and 15 to 25 m wide low sinuosity channel and an unconfined valley setting. The bed material is sand with some silt, and in channel features include bars and benches with ripple formations and sand sheets. Banks are vegetated with grass and trees. Approximately 1.6 km up channel from the Project alignment, Pariagara Creek is crossed by a ford which has resulted in upstream ponding and narrowing of the channel downstream. Local areas of bank erosion were noted downstream of the ford. Watercourse C Ck 20 has a vegetated channel, the road surface had eroded at this site, resulting in minor deposition near the watercourse.

Table 3.18 Existing Case geomorphic conditions Ch 64.7 km to Ch 68.7 km

Feature	Description
Watercourses	Eight watercourses including Pariagara Creek a local – well developed watercourse, one local – developed channel sections watercourse, and six headwaters ¹ .
Floodplains	Pariagara Creek Floodplain ² Medium energy floodplain with paleochannels and wetlands
Catchment area	23,320 ha
Catchment soils	Sodosols
Catchment vegetation	Grassland/crops and bush
Historic change	Aerial imagery review indicates channel planforms and locations are largely unchanged since 1949, one tributary appears to have developed a more defined channel, and some increase in riparian vegetation was noted.
Site checking	2 sites (EP40 and EP41), upstream ponding above ford and downstream channel narrowing and bank erosion, road surface eroded at C Ck 20 site.

Table notes:

1 Pariagara Creek – low sinuosity channel and an unconfined valley setting

2 Class B3

3.6.1.4 Canning Creek Sidling (Ch 72.9 km to Ch 85.4 km)

The Project traverses northward to the west of Canning Creek floodplain, crossing 19 tributaries, but not intersecting the Canning Creek floodplain landform. The Existing Case conditions are summarised in Table 3.19.

This section includes six active gully erosion channels. The gully floors are typically vegetated grasses and have woody debris and ponds, gully sides slopes comprise sand, silt and some gravel. Three field checking site occurred along this section, including one at watercourse C Ck 16, 260 m upstream from the Project alignment (EP38). At this site the channel is non-channelised valley flow, and minor erosion was observed adjacent to the road culvert outlet.

Two of these sites, CCs 21 and C Ck16 were further assessed with detailed field investigations as part of the assessment of initial high-risk sites (Appendix L). The other two field checking sites were on C Ck 14 and C Ck 15 (EP36 and 37). At one of the sites, the channel was vegetated and stable with no erosion or deposition associated with the culvert, at the other site minor erosion downstream of the culvert was observed.

Table 3.19 Existing Case geomorphic conditions Ch 72.9 km to Ch 85.4 km

Feature	Description
Watercourses	19 tributaries, all headwaters except for one local – poorly developed channel ¹
Floodplains	Canning Creek Floodplain ² Medium energy floodplain with paleochannels and scroll bars
Catchment area	Most <10 ha, largest 283 ha
Catchment soils	Sodosols
Catchment vegetation	Mainly grassland/crops with some bush

Feature	Description
Historic change	Six active gully erosion channels (watercourses CCs22, CCs21, CCs21a, CCK16a, CCK16 and CCs19) have shown upstream erosion of up to 210m since 1959. Other than the gully erosion sites, aerial imagery review did not identify any areas of channel planform or location change since 1949.
Site checking	3 sites (EP36, EP37, EP38), minor erosion adjacent and downstream to road culvert

Table notes:

- 1 Washslopes, non-channelised valley flow and active gully erosion channels
- 2 Class B3b

3.6.1.5 Cattle Creek and floodplain (Ch 87.2 km to Ch 88.3 km)

The Existing Case conditions are summarised in Table 3.20. Cattle Creek's channel is generally vegetated, with sand, silt and gravel exposed in the low sinuosity channel sections. Approximately 60 m upstream from the Project alignment (at site EP34), Cattle Creek is crossed by a 45 m long bridge of the Millmerran Inglewood Road.

The bridge has restricted non-channelised valley floor flow and resulted in minor erosion/incision of a small channel downstream.

Table 3.20 Existing Case geomorphic conditions Ch 87.2 km to Ch 88.3 km

Feature	Description
Watercourses	Cattle Creek, local – developed channel sections ¹ and two headwater tributaries ²
Floodplains	Cattle Creek Floodplain ³ Semi-confined valley setting and medium energy floodplain
Catchment area	6,506 ha
Catchment soils	Sodosols
Catchment vegetation	Bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since 1959.
Site checking	1 site (EP34), 45m long Millmerran Inglewood Road bridge has restricted non-channelised valley floor flow resulting in minor erosion/incision of a small channel downstream.

Table notes:

- 1 Cattle Creek – Non-channelised valley floor 70 m wide and 4 m deep, short sections of low sinuosity channel.
- 2 Headwaters – washslope and non-channelised valley floor
- 3 Class B3

3.6.1.6 Canning Creek Sidling (Ch 91.0 km to Ch 92.9 km)

The Existing Case conditions are summarised in Table 3.21. Over this chainage, the Project traverses to the west of Canning Creek floodplain, crossing three tributaries, but not intersecting the Canning Creek floodplain landform. Two tributaries are headwaters and one is a local; poorly developed channel watercourse type.

Two field sites occurred along this section (EP32 and 33). Both were within 100 m of the Project alignment, had non channelised valley floor channel types with well vegetated channels and stable channels with no erosion or deposition near culverts.

Table 3.21 Existing Case geomorphic conditions Ch 91.0 km to Ch 92.9 km

Feature	Description
Watercourses	Three tributaries, two headwaters and one local – poorly developed channel watercourse ¹
Floodplains	n/a
Catchment area	From <10 ha to 352 ha
Catchment soils	Sodosols

Feature	Description
Catchment vegetation	Bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since 1959.
Site checking	2 sites (EP32 and EP33), no erosion or deposition observed, including adjacent to culverts.

Table note:

1 Non-channelised valley floor and washslopes

3.6.1.7 Native Dog Creek and Floodplain (Ch 93.9 km to Ch 94.0 km)

The Existing Case conditions are summarised in Table 3.22. One field site was located on Native Dog Creek, approximately 350 m upstream of the Project alignment at the Millmerran Inglewood Road bridge (EP31).

At this site, Native Dog Creek channel type comprises an 80 m wide and 3 to 4 m deep vegetated non-channelised valley floor with minor (<5 m long) sections of low sinuosity channel, which exposes sand, silt and minor gravel bed material.

Table 3.22 Existing Case geomorphic conditions Ch 93.9 km to Ch 94.0 km

Feature	Description
Watercourses	One local – poorly developed channel watercourse ¹
Floodplains	Native Dog Creek Floodplain ² Medium to low energy floodplain with some backswamps
Catchment area	94 ha
Catchment soils	Sodosols
Catchment vegetation	Bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since 1959.
Site checking	1 site (EP31), Millmerran Inglewood Road bridge has minor ponding beneath it and channel widens downstream of the bridge.

Table notes:

1 Non-channelised valley floor with some sections of low sinuosity channels and washouts. Unconfined valley setting.

2 Class B3 to Class C!

3.6.1.8 Canning Creek tributary (Ch 95.1 km)

Over this chainage, the Project alignment crosses one tributary of Canning Creek, before crossing the confluence of Canning Creek and Bringalily floodplain. The Existing Case conditions are summarised in Table 3.23.

Table 3.23 Existing Case geomorphic conditions Ch 95.1 km

Feature	Description
Watercourses	One headwater tributary ¹ of Canning Creek
Floodplains	Crosses the confluence of the Canning Creek and Bringalily Floodplains (described in the section below Ch 96.2 km to Ch 100.6 km)
Catchment area	<10 ha
Catchment soils	Sodosols
Catchment vegetation	Grassland and bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery.

Feature	Description
Site checking	None

Table note:

1 Non-channelised valley floor with washslopes

3.6.1.9 Bringalily Creek and floodplain (Ch 96.2 km to Ch 100.6 km)

The Project alignment sidles along the western edge of Bringalily floodplain, crossing three of Bringalily Creeks tributaries, including Back Creek 2, before crossing Bringalily Creek itself. Existing Case conditions are summarised in Table 3.24.

Two field sites occurred along this section, one at Bringalily Creek (EP29) and one at Back Creek 2 (EP30), both are within 100 m of the alignment crossing.

Bringalily Creek has a chain of ponds channel type, with either narrow low-capacity channels or in rare cases, non-channelised valley floor between. The channel is typically 8 to 15 m wide. The channel is generally vegetated, with silt, sand, clay and minor gravel observed at the edge of ponds.

The Millmerran Inglewood Road crosses Back Creek 2 approximately 80 m upstream of the Project alignment crossing (field site EP 30), with a row of 14 culverts with a total span of approximately 16 m. No obvious erosion or deposition was observed at the site, which was vegetated. Back Creek 2 appears to have had two channels where Millmerran Inglewood Road crossed it, however culverts were only constructed at the southern channel.

Table 3.24 Existing Case geomorphic conditions Ch 96.2 km to Ch 100.6 km

Feature	Description
Watercourses	Bringalily Creek and three tributaries including Back Creek 2. Bringalily Creek is a local – well developed watercourse, Back Creek is a local – poorly developed watercourse and the remaining two are headwaters ¹
Floodplains	Bringalily Creek Floodplain ² Medium energy and some backswamps
Catchment area	From <10 ha to 18,790 ha
Catchment soils	Sodosols
Catchment vegetation	Grassland/crops and some bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery, although manmade ponds have been constructed upstream.
Site checking	Two sites (EP29 and EP30), approximately 45 m upstream of the Project alignment, Bringalily Creek is crossed by an approximately 25 m long bridge of the Millmerran Inglewood Road, (field site EP29). The bridge embankments extend up to the channel edge. Ponding occurs at the bridge with the channel widening from 8 m to 12 m upstream of the bridge and narrowing from 12 m to 1 m wide downstream of the bridge. Bank erosion is occurring downstream of the bridge on the outside of the bend as the channel changes from pond to low-capacity channel. A manmade pond approximately 60 x 60 m has been constructed 250 m upstream of the Project alignment in the Back Creek 2 flow path.

Table notes:

- 1 *Bringalily Creek – chain of ponds with either low-capacity channels or in rare cases non-channelised valley floor between:*
- Back Creek 2 – Non-channelised valley floor channel with sections of low sinuosity and small ponds
 - Headwaters – Non-channelised valley floor and washslopes

2 Class B3

3.6.1.10 Nicol Creek and floodplain (Ch 104.3 km to Ch 104.4 km)

Existing Case conditions are summarised in Table 3.25. Nicol Creek has a chain of ponds channel type and is generally vegetated, with silt and clay observed at the edge of ponds.

The Millmerran Inglewood highway crosses Nicol Creek approximately 1.7 km upstream of the Project alignment (field site EP 28), with a row of four culverts.

Table 3.25 Existing Case geomorphic conditions Ch 104.3 km to Ch 104.4 km

Feature	Description
Watercourses	Nicol Creek, local – developed channel sections watercourse ¹
Floodplains	Nicol Creek Floodplain ² Medium energy
Catchment area	3780 ha
Catchment soils	Vertosols and sodosols
Catchment vegetation	Grassland and bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery.
Site checking	One site (EP28), the Millmerran Inglewood highway crosses Nicol Creek approximately 1.7 km upstream of the Project alignment, with a row of four culverts. Ponding occurs directly upstream of the culverts and the channel width narrows downstream. Downstream of the culverts there is bank erosion on the outside of bends.

Table notes:

1 Chain of ponds channel type with either low-capacity channels or non-channelised valley floor between

2 Class B3

3.6.1.11 Nicol Creek headwaters (Ch 107.2 km to Ch 116.2 km)

The Existing Case conditions are summarised in Table 3.26. Five field checking sites occurred in this area along the Millmerran Inglewood Highway.

Table 3.26 Existing Case geomorphic conditions Ch 107.2 km to Ch 116.2 km

Feature	Description
Watercourses	Twenty-two watercourses, 20 headwaters ¹ and two local – poorly developed channel watercourses
Floodplains	n/a
Catchment area	From <10 ha to 214 ha
Catchment soils	Vertosols
Catchment vegetation	Grassland/crops and some bush
Historic change	One watercourse appears to have been straightened over a short distance and a number of small ponds have been constructed along flow paths of some watercourses, otherwise watercourse planforms appear unchanged since the earliest aerial imagery.
Site checking	Five sites (EP24, EP24a, EP25, EP26, and EP27), all well vegetated and stable with no erosion or deposition evident. Minor ponding occurred at two culvert sites.

Table note:

1 Washslope or non-channelised valley floor channel types

3.6.2 Condamine River Basin**3.6.2.1 Back Creek 1 headwaters (Ch 117.4 km to Ch 130.2 km)**

The Existing Case conditions are summarised in Table 3.27. SC 7 as well as SC 2 were assessed with detailed field investigations as part of the assessment of initial high-risk sites (Appendix L).

Eight field checking sites occurred in this area along Millmerran Inglewood Highway (EP18, EP19, EP21, EP22, EP22a, EP23, EP23a, BL7a). Three of these sites were along Back Creek 1 (EP18, EP 23 and EP 23a). EP18, the closest site to the Project alignment, comprised a road crossing with nine box culverts. Highwater was still receding during the site visit, and no erosion/deposition was observed.

Table 3.27 Existing Case geomorphic conditions Ch 117.4 km to Ch 130.2 km

Feature	Description
Watercourses	Back Creek 1 and 14 tributaries. Of the tributaries, 12 are headwaters ¹ , one is local – poorly developed channel ² , one is a local – developed channel sections ³ (as is Back Creek 1).
Floodplains	Back Creek 1 Floodplain ⁴ Low energy
Catchment area	Back Creek 1 9,416 ha Other local – developed channel section watercourse (SC2) 2127 ha All other watercourses between <10 ha to 720 ha
Catchment Soils	Vertosols and some sodosols
Catchment Vegetation	Grassland/crops and some bush
Historic change	For all watercourses except SC7, aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery. At SC 7 scour downstream of a manmade pond constructed directly upstream of the Project alignment has occurred.
Site Checking	Eight sites (EP18, EP19, EP21, EP22, EP22a, EP23, EP23a and BL7a). Field checking site BL7a, 370 m downstream of the Project alignment, occurred along watercourse SC 6 and comprised a culvert infilled with sandy silt. The sediment may have come from the human made pond upstream, which appears to have bare soil exposed, as the channel bed is well vegetated with no obvious scour or bedload. Minor local ponding and erosion was observed adjacent to culverts at other field checking sites, away from the culverts the channels were stable and generally vegetated.

Table notes:

- 1 Headwaters – washslope or non-channelised valley floor channel types
- 2 Local – poorly developed channel – non-channelised valley floor channel type with sections of low sinuosity channel
- 3 Local – developed channel section – chain of ponds channel type
- 4 Class C1

3.6.2.2 Grasstree Creek tributary (Ch 131.0 km)

The Existing Case conditions are summarised in Table 3.28. This section includes one headwater tributary to Grasstree Creek. The Project alignment crosses at the upstream extent of the channel.

A pond has been constructed in the flow path 400 m downstream. The channel is vegetated with sections of bare soil along the low sinuosity channel.

Table 3.28 Existing Case geomorphic conditions Ch 131.0 km

Feature	Description
Watercourses	One headwater ¹ tributary to Grasstree Creek
Floodplains	n/a
Catchment area	<10 ha
Catchment Soils	Vertosols
Catchment Vegetation	Grassland/crops
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery.
Site Checking	None

Table note:

- 1 Non-channelised valley floor channel type with a short section of low sinuosity channel

3.6.2.3 Condamine River and floodplain – (Ch 139.9 km to Ch 150.0 km)

The Condamine River is an anastomosing multi-channel river. Five watercourse features are recognised, as presented in Table 3.29. The Existing Case conditions are summarised in Table 3.30.

Table 3.29 **Condamine River channels**

Channel	Chainage (km)	Description
Grasstree Creek	139.85	Local stream with a well-developed channel. Meandering to chain of ponds channel types.
Un-named Condamine anabranch	141.03	Ephemeral floodplain channel.
Condamine South Branch	142.75	Erosion feature downstream of the existing rail embankment in a flood basin between Grasstree Creek and the Condamine River main branch. Not a formal channel and has no geomorphic channel expression upstream of the existing rail embankment.
Condamine River	144.20	Main stem stream and channel of the Condamine River. Meandering channel type.
Condamine North Branch	150.00	Local stream with a well-developed channel. Secondary channel of the Condamine River. Meandering channel type.

Anastomosing channels in cohesive material are typically laterally stable, however the historical changes include significant avulsion events triggered by diversions and accumulation of woody debris. The current main channel that crosses the Project alignment has been initiated by human intervention.

The Condamine main branch has a channel bed width of 10 to 20 m, and a full channel width of 30 to 50 m. Sand sheets were observed in the channel in aerial imagery. In low flow conditions, ponds occur with small connecting channels. The main channel upstream of the confluence of Grasstree Creek, in the Project footprint, is moderately meandering, while downstream it is sinuous.

The channel straightening along the North Condamine branch has reduced the sinuosity of the channel, and the associated volume of water accommodated in the channel over the same down valley distance. The straightened channel section includes a 90-degree bend approximately 430 m upstream of the Project alignment, adjacent to Pampas Pit Road. This sharp bend is directly downstream of about 1.2 km of straightened channel, along which greater than natural case velocities can occur due to its lowered sinuosity. This bend represents an avulsion risk that could impact both the Gore Highway and the Project.

Aerial imagery review shows the South Branch is a backward erosion features in a flood basin downstream of the existing embankment from Ch 142.0 km to Ch 143.0 km, which come together to reoccupy a paleochannel approximately 400 to 650 m downstream of the rail embankment before flowing into Grasstree Creek. The Condamine River floodplain is a low energy, low relief, cohesive Class C2 type floodplain. It is used for extensive agriculture. The floodplain comprises anabranches separated by flood basins. Type C floodplains are formed by overbank deposition and avulsion. The sinuosity of existing channels and state of preservation of abandoned (paleo) channels provides information on the lateral activity of the channels. The sinuous nature of the North Branch in particular, indicates long-term and very slow avulsion rates.

Table 3.30 **Existing Case geomorphic conditions Ch 139.9 km to Ch 150.0 km**

Feature	Description
Watercourses	Condamine River – anastomosing multi-channel river (Table 3.11)
Floodplains	Condamine River Floodplain ¹ Low energy, low relief
Catchment area	654,600 ha
Catchment soils	Vertosols
Catchment vegetation	Grassland/crops and some bush

Feature	Description
Historic change	The Condamine River channels have undergone several structural changes in recorded history. The following information comes from Uebergand (1992) and Fysh (written between 1910 and 1945): 1873 diversion drain 1 was constructed between what is now the Condamine River Main Branch (then the 'Broadwater', which used to come to a dead-end) and Grasstree Creek. 1885-87 diversion drain 2 was constructed between the Condamine North Branch and what is now the Condamine River Main Branch (then the 'Broadwater'). It 'scoured badly' and became the current main Condamine River Channel. Fysh (1910 to 1945) has the construction timing of the diversion the other way around. 1886-7 Section of channel on what is now the Condamine River Main Branch formed downstream of diversion 1 after flooding. 1914 A tree fall across the mouth of the Condamine North Branch and resulted in sediment aggradation such that it 'closed the mouth completely'. 1945 A tree fell across the Condamine River, diverting water from the Condamine down the Black Gully. Upstream from the Project alignment for ~1.75 km the Condamine North Branch channel has been realigned and straightened between 1985 and 2001 to flow between and around three constructed ponds, which are up to 10 ha each. The natural channel has a chain of ponds channel type, while the upstream realigned channel is effectively a low sinuosity channel type. Just upstream of the Gore Highway bridge near the Project alignment, a 40 by 60 m pond has developed in the channel. Ongoing erosion downstream of the existing rail embankment has occurred on the Condamine South branch since earliest aerial imagery.
Site checking	Five sites (BL 1a, BL1b, EP16, EP16a and EP 17), two on the Condamine North Branch, one on the Condamine Main Branch and one on Grasstree Creek. The inspections were undertaken in early to mid-March 2022, during the receding flows of what was estimated by FFJV hydrologists as a 20% AEP flow event at Cecil Weir, located on the Condamine River. Up to 8 m of along bank erosion was observed adjacent to bridges/culverts on the North Condamine River associated with infrastructure impacts. Up to 20 to 30 m of along bank erosion was observed on the outside of channel bends on the Condamine Main Branch, during an event close to (but slightly above) bankfull conditions, which is what would be expected under natural conditions. Minor deposition with no erosion was observed at the Grasstree Creek field site.

Table note:

1 Class C2

3.6.2.4 North Condamine headwaters (Ch 160.0 km to Ch 187.2 km)

Along this section the Project alignment crosses 24 watercourses. The Existing Case conditions are summarised in Table 3.31. Channel bed material ranged from vegetated to silt and sand with minor gravels. Watercourse NC 11 was further assessed with detailed field investigations as part of the assessment of initial high-risk sites (Appendix L).

Table 3.31 Existing Case geomorphic conditions Ch 160.0 km to Ch 187.2 km

Feature	Description
Watercourses	24 watercourses, 22 headwaters ¹ , two local – poorly developed channels ²
Floodplains	n/a
Catchment area	Eight <10 ha, up to 496 ha
Catchment soils	Vertosols and some dermosols
Catchment vegetation	Grassland/crops and some bush
Historic change	Except for NC 11, the planforms of the watercourses appear unchanged since the earliest aerial imagery. At watercourse NC 11, a pond constructed to the right of the channel has resulted in local changes to channel planform.

Feature	Description
Site checking	Five sites, minor erosion at the transition of natural bed and culverts was observed at two sites, one site had minor erosion on a downstream bank and one had minor silt deposition in the culvert.

Table notes:

- 1 Headwaters – washslope to non-channelised valley floor channel types
- 2 Local – poorly developed channels – non-channelised valley floor with some sections of low sinuosity channel with some small natural ponds

3.6.2.5 Westbrook Creek and floodplain (190.0 to 202.8 km)

The Existing Case conditions are summarised in Table 3.32. Channel bed material is silt/clay or vegetated.

Table 3.32 Existing Case geomorphic conditions Ch 190.0 km to Ch 202.8 km

Feature	Description
Watercourses	Eleven watercourses, two local – well developed channel watercourses ¹ (Westbrook Creek and Dry Creek), three local – poorly developed channels ² , one local – developed channel sections ³ and five headwaters ⁴
Floodplains	One Mile Gully Floodplain Four Mile Gully Floodplain Westbrook Creek Floodplain Dry Creek Floodplain <i>All Class C1</i> Low energy
Catchment area	From <10 ha to 20,550 ha (Westbrook Creek)
Catchment soils	Vertosols
Catchment vegetation	Grassland/crops
Historic change	Except for One Mile Creek, Westbrook Creek and Dry Creek, the planforms of the watercourses along this section appear unchanged since earliest aerial imagery. The channel of One Mile Creek has become slightly straighter, while the channel of Westbrook Creek has become slightly more sinuous. Both of these minor planform changes are within normal conditions. The channel of Dry Creek has been artificially straightened downstream of the Project alignment for approximately 330 m.
Site checking	Five sites (EP2, EP3a, EP3b, EP4 and BL9). Minor erosion was observed at the interface of all bridges/culverts and natural channels and ponding upstream of culverts was observed at two sites. Minor deposition was observed at two sites. The natural channels appeared stable.

Table notes:

- 1 Local – well developed channels – low sinuosity, would form chain of ponds in low flow
- 2 Local – poorly developed channels – non-channelised valley floor with some sections of low sinuosity channel with some washouts and small manmade ponds
- 3 Local – developed channel sections – non-channelised valley floor with sections of low sinuosity channels and washouts and a few natural pools
- 4 Headwaters – washslope to non-channelised valley floor channel types

3.6.2.6 Gowrie Creek Floodplain sidling (Ch 206.8 km to Ch 208.2 km)

Along this section, the Project alignment sidles along the edge of Gowrie Creek floodplain and crosses three watercourses, all of which are tributaries to Gowrie Creek. The Existing Case conditions are summarised in Table 3.33.

Table 3.33 Existing Case geomorphic conditions Ch 206.8 km to Ch 208.2 km

Feature	Description
Watercourses	Three watercourses all tributaries to Gowrie Creek, two headwaters and one local – poorly developed channel <i>Headwaters – washslope and non-channelised valley floor channels</i> <i>Local – poorly developed channel – non-channelised valley floor with some sections of low sinuosity channels and washouts</i>
Floodplains	Gowrie Creek Floodplain <i>Class C1</i> Low energy
Catchment area	From <10 ha to 733 ha
Catchment soils	Vertosols
Catchment vegetation	Grassland/crops
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery.
Site checking	None

3.6.2.7 Construction Camp Pine Creek

The Existing Case conditions are summarised in Table 3.34. One watercourse (PC 1) is located across the accessway to the Turallin facility.

Table 3.34 Existing Case geomorphic conditions: Turallin facility

Feature	Description
Watercourses	One watercourse (PC1), local – poorly developed channel <i>Non-channelised valley floor with some sections of low sinuosity channels and chain of ponds</i>
Floodplains	n/a
Catchment area	1,081 ha
Catchment soils	Sodosols
Catchment vegetation	Grassland and bush
Historic change	Aerial imagery review did not identify any areas of channel planform or location change since the earliest imagery.
Site checking	None

4 Potential impacts

Changes to existing condition processes may lead to potential impacts. Watercourse and floodplain geomorphic processes listed in Sections 3.3.2 and 3.4.2. In summary, potential impacts throughout Project stages include:

- Watercourse
 - Erosion
 - Deposition
 - Channel type change
 - Channel planform change
- Floodplains
 - Erosion
 - Deposition
 - Floodplain disconnection.

Floodplain processes may be impacted by the Project alignment where connectivity to the main channel/s is reduced or disconnected. This may occur in areas with no cross drainage included in the revised reference design where the Project alignment sidles along the edge of a floodplain (floodplain sidling), effectively forming a barrier between parts of the geomorphic floodplain and main channel/s.

4.1 Pre-construction, early works and construction works potential impacts

Mitigation measures identified and proposed in the previous section can act to reduce the likelihood and severity of potential impacts during preconstruction and construction. This period involves the greatest level of ground disturbance, and has potential impacts from the Project including:

- Increased erosion due to vegetation clearance of sites and access tracks
- Increased erosion due to disturbance of the soil surface and the creation of infiltration and erosion pathways
- Deposition leading to potential blockage of drainage pathways from improperly designed site layout or storage areas
- Sediment transport causing deposition and infilling of drainage infrastructure.

4.2 Operations stage potential impacts

Operations stage potential impacts were assessed for all watercourses included in the sub-reach assessment and all geomorphic floodplains.

Watercourses not included in the sub-reach assessment have so little evidence of active fluvial geomorphology that they typically have no channel form where they cross the Project alignment. These watercourses were assessed under the hydrology and flooding EIS aspect against the FIOs, and any exceedances were noted and mitigation options identified within EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1. The mitigations were reviewed by a geomorphologist. Refer Appendix H (Table H.6) for cross-references to the assessment results and mitigation assessed under Flooding and Hydrology.

Criteria to assess for potential impacts to the fluvial geomorphic environment are included in Table 2.3 and Table 2.4. Meeting the criteria to assess for potential change does not mean that impacts may occur. Where the criteria was met, the potential for an impact to occur was assessed taking into consideration:

- The revised reference design (including scour protection and rehabilitation, as per EIS Chapter 5: Project Description).
 - For example if increased flow velocity was identified as a potential impact, but it was limited to the length of the scour protection, it was considered a minor consequence. If potential increased flow velocities extended beyond the scour protection, an assessment of consequence was made based on the flow velocity beyond the scour protection, baseline conditions and Existing Case sensitivity to change.
 - Based on review of the hydraulic difference models, geomorphic impacts will reduce to undetectable by 100 m upstream and downstream of the Project alignment, with the highest impacts at the culvert outlet (Figure 4.1) typically within the area the scour protection measures will be located.
- Geomorphic baseline conditions, including processes at the site
 - For example aggregation is unlikely to be a potential impact at the site even if design flow velocities are reduced if there is no evidence of bedload.
- The amount, type and location of potential change.
 - For example, a design culvert may be in an area of a floodplain with below average Existing Case velocities (relative to the rest of the floodplain), and show a greater apparent increase in design flow velocities. Where design flow velocities at this culvert are consistent with Existing Case flow velocities elsewhere on the floodplain they are unlikely to result in elevated erosion potential.
 - Conversely, a channel may be showing signs of erosion under Existing Case conditions, with a high sensitivity to change. In this case even a small increase in design flow velocity would be likely to increase the erosion potential.

Enhancement opportunities

The following opportunities for the enhancement of the geomorphic environment were identified:

- Where existing bridges or existing rail embankment with culverts are to be replaced with longer bridges resulting in less encroachment on water flow:
 - Condamine North Branch - 310-BR27 Condamine River North Branch Rail Bridge
 - Condamine Main Branch - 310-BR25/26 Condamine River Main Branch
 - Grasstree Creek - 310-BR21/22 Grasstree Creek Rail Bridge
 - Condamine River South Branch Rail Bridge 310-BR24
- Mitigation of gully sites within the Project footprint:
 - CCs 22
 - CCs 21a
 - CCs 21
 - C Ck 16a
 - C Ck 16
 - CCs 19

- Culvert cross drainage across the Condamine floodplain:
 - Design cross drainage culverts result in a reduction from existing conditions flow velocities at most sites
 - Remediation could be undertaken at sites damaged by poorly performing existing cross drainage within the Project footprint.

4.2.1 Watercourse operations stage potential impacts

Operations stage potential impacts were assessed for 85 watercourse and are summarised in Table 4.1. They have been assessed by infrastructure type in Sections 4.2.1.1 to 4.2.1.5, including:

- Design bridges, 21 watercourses
- Design culverts, 55 watercourses
- Diversion, three watercourses at two diversions
- Design cut, three watercourses
- No design cross-drainage, three watercourses.

Two sites with sub-reach assessments (Appendix G) were assessed under the floodplain category as they are flood channels/basins (Condamine South Branch and Condamine anabranch) (Section 4.2.2).

Under each infrastructure type, potential impacts were then grouped into categories of similar types of impacts on the geomorphic environment (e.g. floodplain encroachment by one/both bridge abutments).

The most common potential impact is planforms change, this is largely driven by design bridge abutments that are very close to or within a channel, and design culverts not aligned to flow. Erosion and 'channel type change' potential impacts were identified at 18 watercourses where scour protection in the revised reference design was not assessed as sufficient to mitigate for increased erosion potential or was not present. The criteria to assess for deposition potential was triggered the most, at 61 of the 85 watercourses. However, as the majority of the Project watercourses have wash slope or non-channelised valley floor channel types with no evidence for bedload, deposition was only identified as a potential impact at 13 watercourses.

Table 4.1 Summary of operations stage potential impacts for watercourses, including the number of watercourses that meet impact assessment criteria (Table 2.3)

Design Infrastructure Potential Impact Category	Number of watercourses	Number of watercourses by potential impact (# of watercourses that met impact assessment criteria)			
		Erosion	Deposition	Planform change	Channel type change
Bridges					
1. No Encroachment	1	0 (0)	0 (0)	0 (0)	0 (0)
2. Floodplain encroachment by one/both abutments	8	2 (2)	0 (3)	0 (0)	0 (0)
3. Floodplain encroachment/sidling by one/both abutments	4	0 (0)	0 (0)	0 (0)	0 (0)
4. Floodplain encroachment by abutment up to channel edge	4	0 (2)	0 (2)	4 (4)	4 (4)
5. Watercourse encroachment by one/both abutments	4	1 (1)	0 (2)	4 (4)	4 (4)
Culverts					
1. Within 10% of existing flow	2	0 (1)	0 (0)	0 (0)	0 (0)
2. Upstream within 10% of existing flow, downstream decrease	4	0 (1)	2 (4)	3 (3)	0 (0)

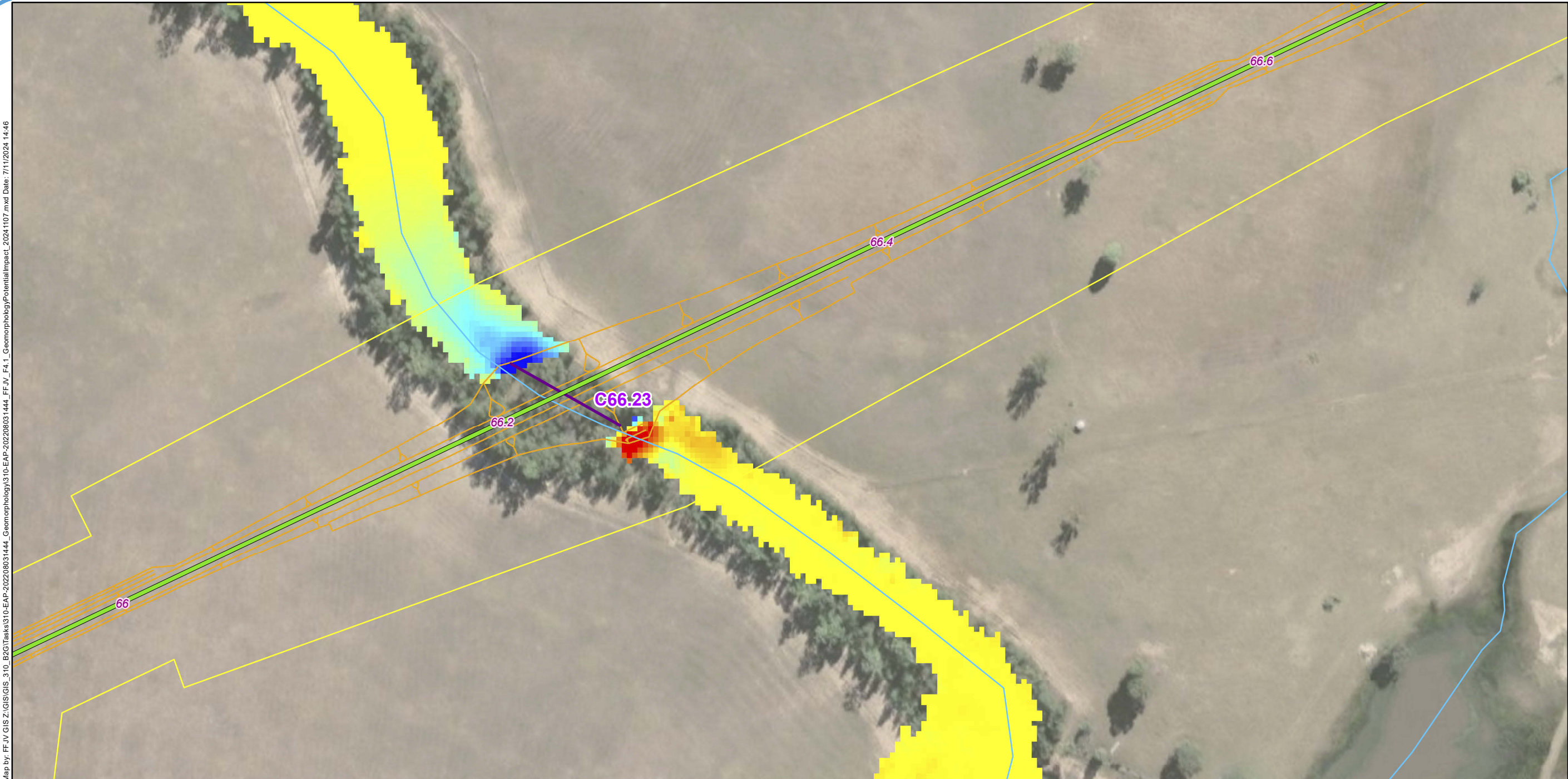
Design Infrastructure Potential Impact Category	Number of watercourses	Number of watercourses by potential impact (# of watercourses that met impact assessment criteria)			
		Erosion	Deposition	Planform change	Channel type change
3. Upstream within 10% of existing flow, downstream increase	1	1 (1)	0 (0)	1 (1)	1 (1)
4. Upstream decrease, downstream within 10% of existing flow	12	1 (5)	2 (12)	5 (5)	0 (0)
5. Upstream increase, downstream within 10% of existing flow	2	2 (2)	0 (1)	1 (1)	2 (2)
6. Upstream decrease in flow, downstream increase	15	1 (15)	1 (15)	9 (9)	1 (14)
7. Upstream and downstream decrease	15	0 (0)	4 (15)	7 (7)	0 (0)
8. Upstream and downstream increase	4	4 (4)	0 (0)	2 (2)	4 (4)
Diversions					
Upstream decrease in flow, downstream increase	3	3 (3)	1 (1)	2 (2)	2 (2)
Cut					
Upstream decrease in flow, downstream increase	3	0 (3)	0 (3)	0 (0)	0 (0)
No Cross Drainage					
Redirected flow path	3	3 (3)	3 (3)	3 (3)	0 (0)
TOTAL	85	18 (43)	13 (61)	41 (41)	18 (31)

Key used to identify magnitude of potential impacts discussed in Sections 4.2.1.1, 4.2.1.2 and 4.2.2 (and detailed in Table 4.3, Table 4.4 and Table 4.6) is summarised in Table 4.2.

Table 4.2 Potential impact outcome key for watercourse bridges, culverts and floodplains

Potential impact outcome	Key
Criteria not triggered	
Criteria triggered, impacts unlikely	
Criteria trigger, potential impact	

Map by: FF-JV GIS Z:\GIS\GIS_310_B2G\Tasks\310-EAP-2022\08031444_Geomorphology\Potential Impact_FF-JV_FF4_1_Geomorphology\Potential Impact_20241107.mxd Date: 7/11/2024 14:46



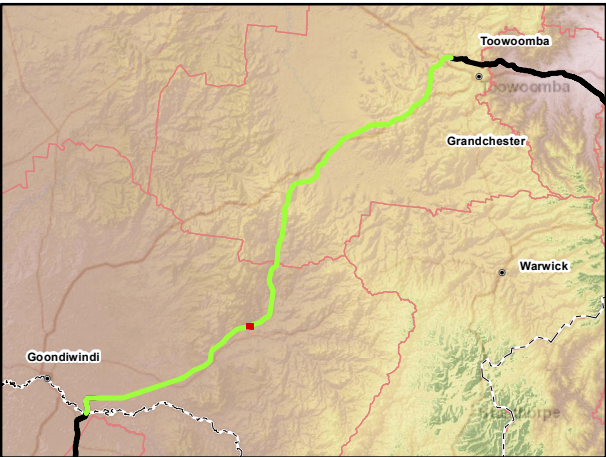
Legend

- 5 Chainage (km)
 - Border to Gowrie alignment
 - Waterways
 - NSW Qld border
 - Culvert
 - Rail Earthworks
- Impact assessment area**
- Temporary footprint

Difference in maximum flow velocity between existing and design case 1% AEP

- High : 1.07108
- Low : -1.91275
- no change

Example of impact extents of difference in flow velocities between the existing and design case.
Site C Ck 20.
Note: Watercourse flows from top of page to bottom.



A3 scale: 1:2,000

0 10 20 30 40 50 Metres



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Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.1

Geomorphology Potential Impacts - Culvert C6.23 - C Ck 20

4.2.1.1 Bridges

The potential impacts of bridges on Project watercourses are summarised in Table 4.3. Potential impacts of bridge piers have not been included in this assessment. The impact categories, with increasing potential impacts, comprise of:

- No encroachment – no impacts
 - Bridge embankments do not intersect the flow up to and including the 1% AEP (1-in-100 year) event.
- Floodplain encroachment by one/both abutments (Figure 4.2)
 - Bridge does not intersect flow during the bankfull event
 - During a 1% AEP event the floodplain at the bridge site is encroached by one or both abutments.
- Floodplain encroachment/sidling by one/both abutments
 - Bridge does not intersect flow during the bankfull event
 - During a 1% AEP event an encroaching embankment faces flow redirection along its edge.
- Floodplain encroachment by abutment up to channel edge (Figure 4.3)
 - During a 1% AEP event a floodplain encroaching embankment reaches the edge of a channel without encroaching the channel itself.
- Watercourse encroachment by abutment (Figure 4.4)
 - During a 1% AEP event an embankment encroaches up to and on to a watercourse.

Existing Case and Design Case maximum velocities and stream power for the 20% AEP and 1% AEP events at watercourse bridge sites are shown in Figure 4.5 to Figure 4.8.

Table 4.3 **Potential impacts – watercourse bridges**

Potential impact category	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Refer Table 4.2 for key				Comments
				Erosion	Deposition	Planform change	Channel type change	
1. No encroachment	Cattle Creek Rail Bridge (310-BR06)	Cattle Creek	2					Does not intersect watercourse or floodplain up to and including the 1% AEP event.
2. Floodplain encroachment by one/both abutments	Condamine River Main Branch Combined Rail Bridge (310-BR25/26)	Condamine River	5					Less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely.
	Grasstree Creek Rail Bridge (310-BR21/22)	Grasstree Creek	2					
	Native Dog Creek Rail Bridge (310-BR07)	Native Dog Creek	2					
	Westbrook Creek Rail Bridge (310-BR31)	Westbrook Creek	3					
	Macintyre River Viaduct Span A (270-BR11A)	Macintyre River	3					
	Condamine North Branch Rail Bridge (310-BR27)	Condamine North Branch	US - 4 DS - 2					Less than 10% change in maximum velocities for 20% flow event, impacts unlikely. In the 1% AEP event, design flow velocity upstream has an increase of more than 10%, while downstream has a decrease of more than 10%, potential erosion and deposition may occur.

Potential impact category	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Refer Table 4.2 for key				Comments
				Erosion	Deposition	Planform change	Channel type change	
	Back Creek Rail Bridge (310-BR38)	Back Creek 1	2					In the 20% AEP event, downstream design flow velocity has a reduction of more than 10%, however flow velocity is >1 m/s and sufficient to transport bedload, impacts are considered unlikely. In the 1% AEP event, downstream design flows show an increase of greater than 10% both upstream and downstream and erosion may occur.
	UT1 Macintyre Brook Rail Bridge (310-BR03)	MB 7	1					Less than 10% change in maximum velocities for 20% AEP, impacts unlikely. In the 1% AEP event, where change in design flow velocity has of more than 10% has occurred, it is within 10% of the Existing Case upstream or downstream flow velocity, and therefore impacts are considered unlikely. Design flows are sufficient to transport bedload.
3. Floodplain encroachment/ sidling by one/both abutments	Dry Creek Rail Bridge (310-BR32)	Dry Creek	4					Less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely.
	Bringalily Creek 3 Rail Bridge (310-BR10)	Bringalily	2					
	Pariagara Creek Rail Bridge (310-BR05)	C Ck 18	3					
		Pariagara Creek	3					
4. Floodplain encroachment by abutment up to channel edge	Toowoomba Cecil Plains Road Rail Bridge (310-BR20)	Four Mile Gully	2					Generally less than 10% change in maximum velocity, however impacts such as potential to change watercourse planform and channel type may occur due to location of abutment up to channel edge.
	Millmerran Inglewood Road Rail Bridge (310-BR37)	SC 2	2					20% AEP event SC 2 has a design flow velocity of more than 10% less than the Existing Case, however the design flow velocity is ~1.2 m/s and consider sufficient to transport any bedload present.

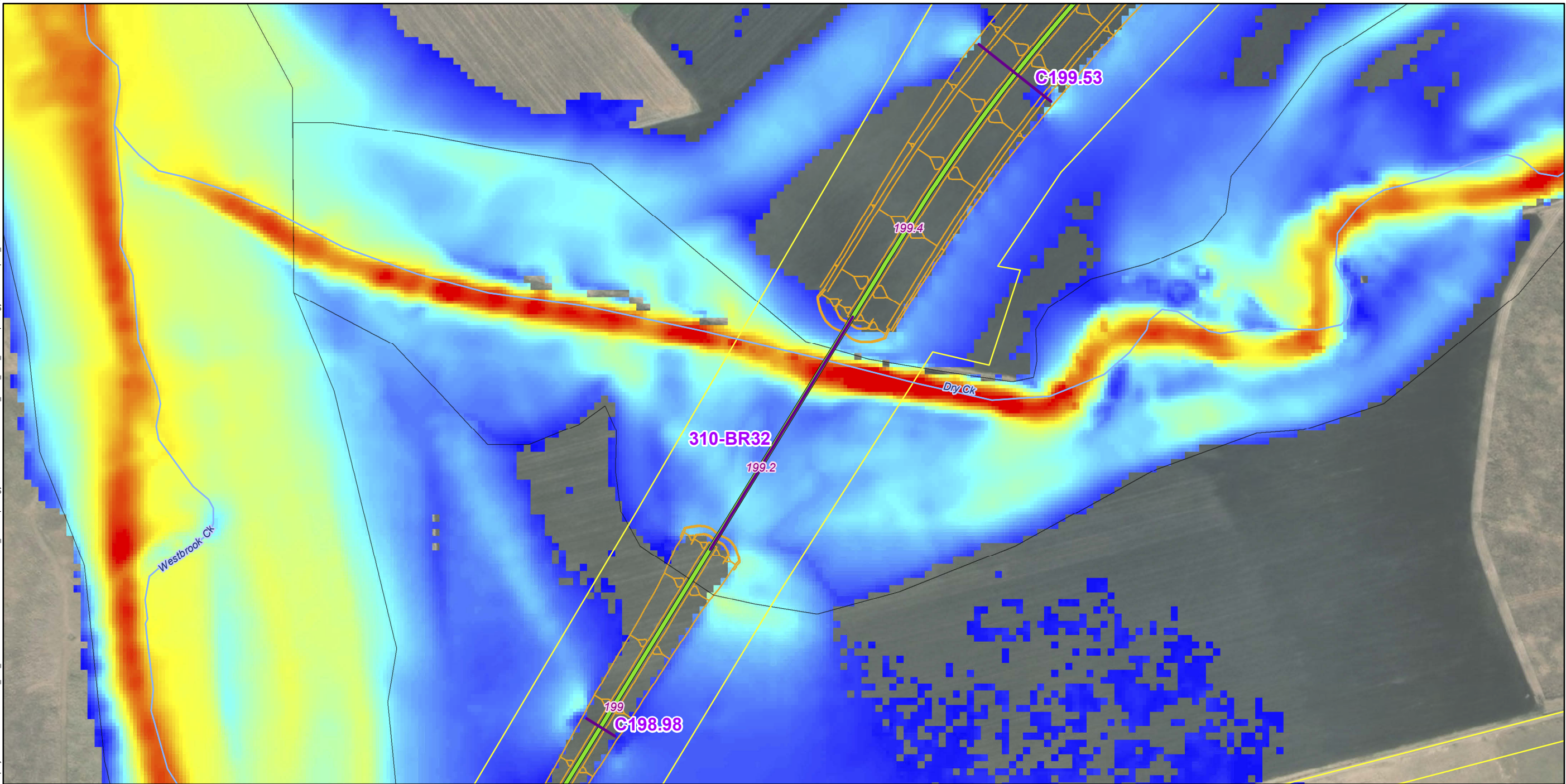
Potential impact category	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Refer Table 4.2 for key				Comments
				Erosion	Deposition	Planform change	Channel type change	
	Nicol Creek Rail Bridge (310-BR11)	Nicol Creek	2					1% AEP event, downstream erosion may occur at Four Mile Gully and upstream erosion may occur at SC 2. Back Creek 2 has a design flow velocity of more than 10% less than the Existing Case, however the design flow velocity is ~1.3 m/s and consider sufficient to transport any bedload present.
	Bringalily Creek 1 Rail Bridge (310-BR08)	Back Creek 2	2					
5. Watercourse encroachment by one/both abutments	Biddeston Southbrook Road Rail Bridge (310-BR42)	NC3	2					Less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely. However major impacts such as potential to change watercourse planform and channel type due to location of abutment in the channel.
	Milmeran Inglewood Road Rail Bridge #2 (310-BR28)	C Ck 2	4					
	Oakey Pittsworth Road Rail Bridge (310-BR30)	NC 9	4					Impacts such as potential to change watercourse planform and channel type due to location of abutment in the channel. Reduction in design flow velocity of more than 10% for both the 20% and 1% AEP events, however the watercourse has a Non-channelised Valley floor with no evidence for bedload, and therefore potential impacts of increased deposition are considered unlikely.
	UT2 Macintyre Brook Rail Bridge (310-BR04)	MB 6	2					

Table notes:

Minor to Moderate: the highest consequence has been used to derive the risk

Moderate to Major: the highest consequence has been used to derive the risk

Existing Case sensitivity to change: 1= Low; 5= High, in terms of potential for change, Section 3.4.1 provides further details.



Legend

- 5 Chainage (km)
- Border to Gowrie alignment
- Waterways
- NSW Qld border
- Culvert
- Rail Earthworks
- Geomorphic floodplains near the Project area

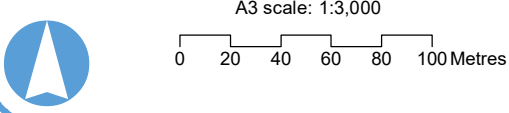
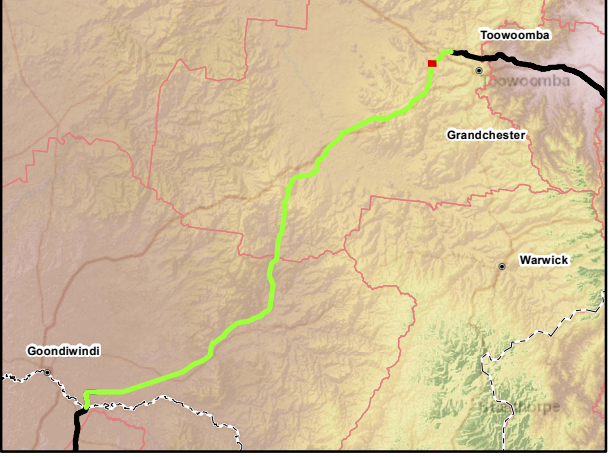
- Impact assessment area**
- Temporary footprint

Flow Velocity Design Case 1% AEP Event (m/s)

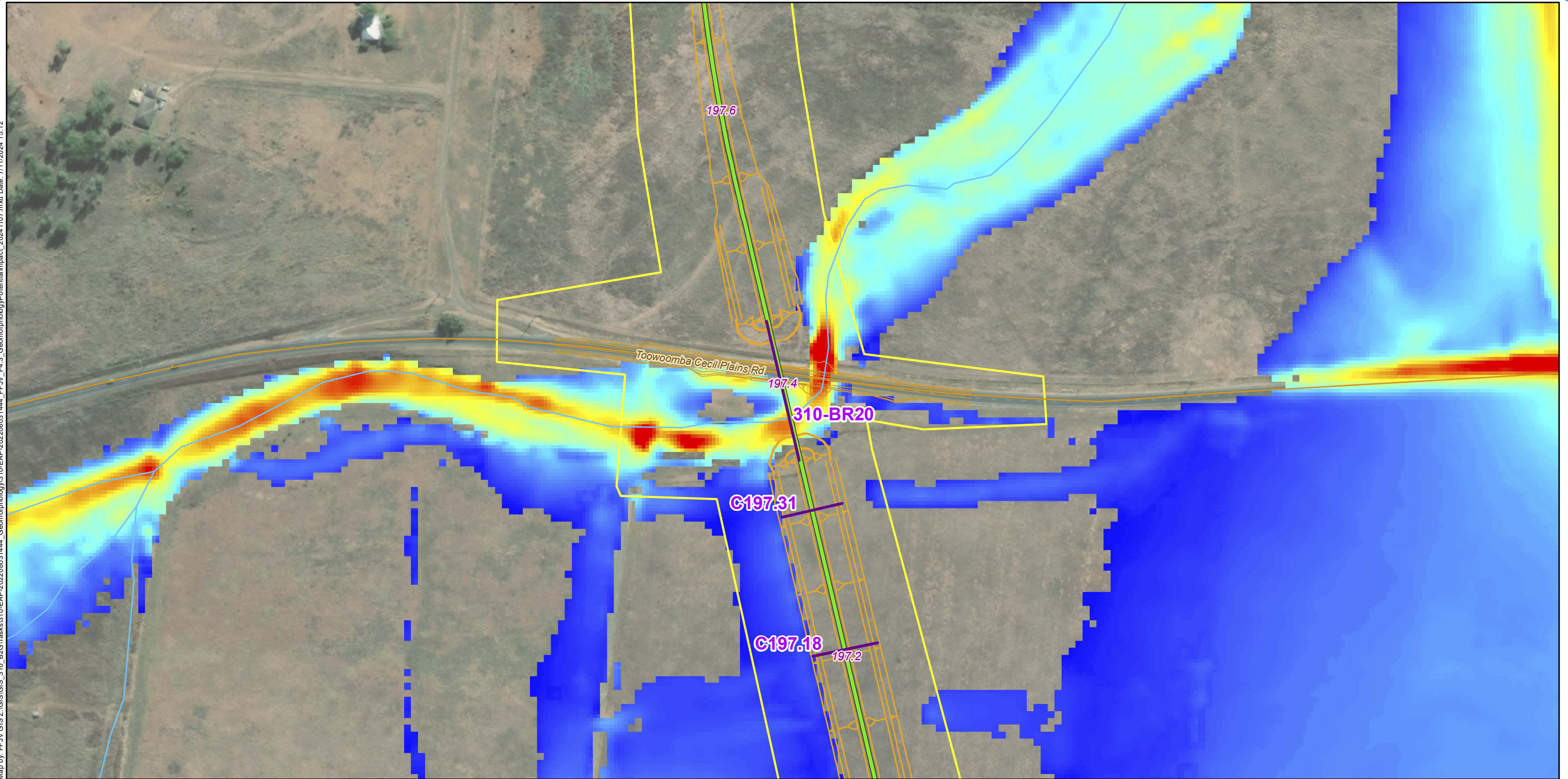
High : 3.74

Low : 0.03

Floodplain encroachment by one/both abutments – Dry Creek 1% AEP design hydraulic model
Note: Red colours represent the fastest flowing water and pick out the actively flowing channel.
Flow goes toward the top left of the page.



Map by: FF-JV GIS Z:\GIS\GIS_310_B2GIS\Tasks\310-EAP-2022\08031444_Geomorphology\Potential Impact_20241107.mxd Date: 7/11/2024 15:12



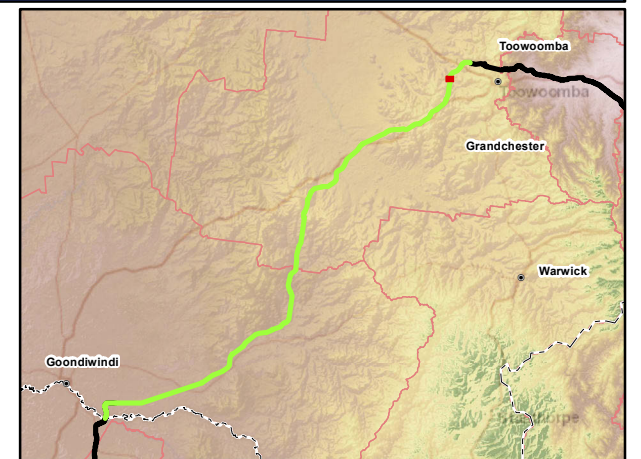
Legend

- 5 Chainage (km)
 - Border to Gowrie alignment
 - Minor roads
 - Waterways
 - NSW Qld border
 - Culvert
 - Rail Earthworks
- Impact assessment area**
- Temporary footprint

Flow Velocity Design Case 1% AEP Event (m/s)

High : 3.93
Low : 0.01

Floodplain encroachment by bridge abutment up to channel edge – Toowoomba Cecil Plains Road Rail Bridge (Four Mile Gully) 1% AEP design hydraulic model
Note: Design road earthworks shown in brown/green. Watercourse flows from left to right.



A3 scale: 1:3,000
0 20 40 60 80 100 Metres



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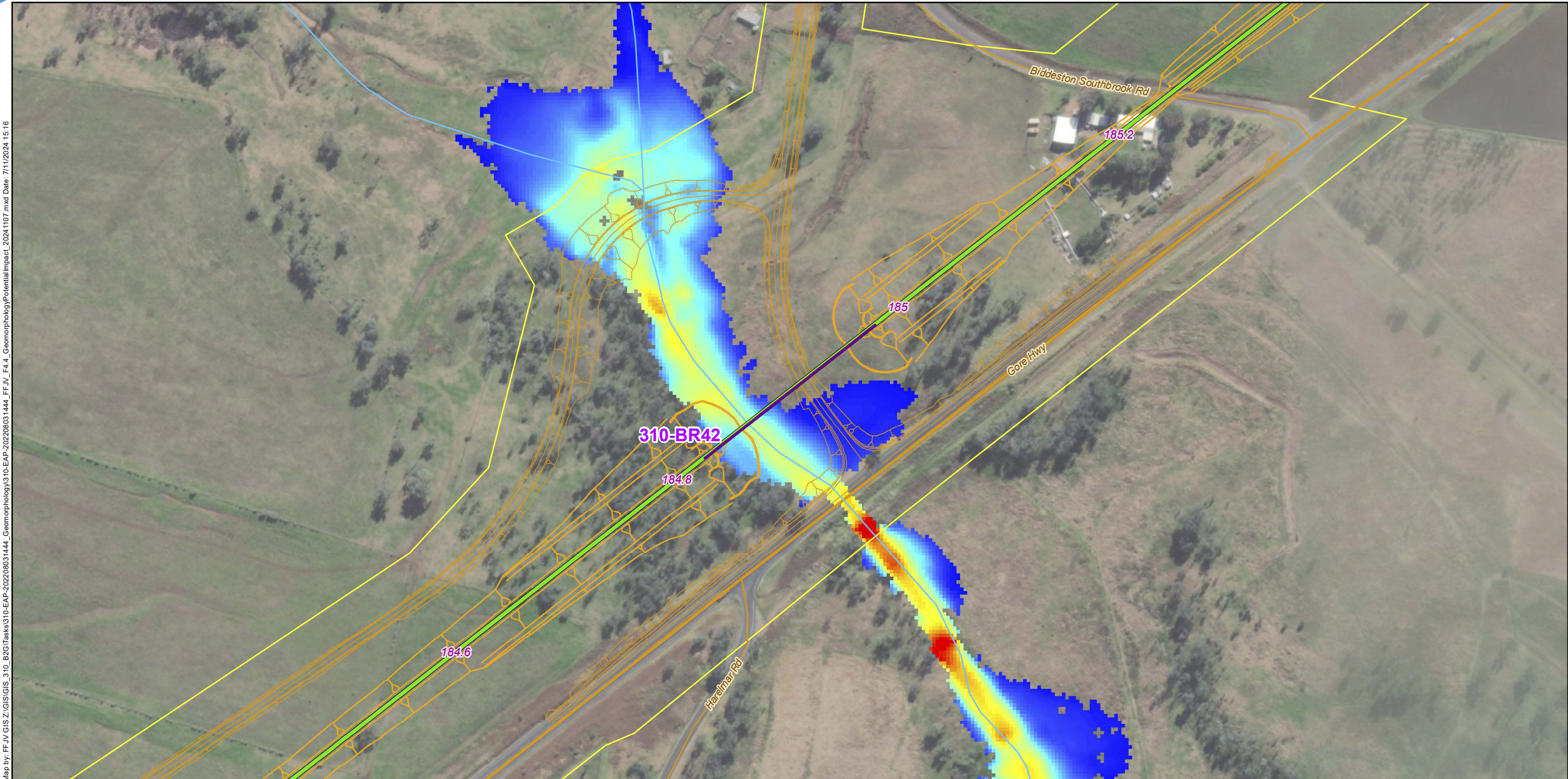
Issue date: 07/11/2024 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.3

Geomorphology Potential Impacts - Bridge 310-BR20 - Four Mile Gully

Map by: FF-JV GIS Z:\GIS\GIS_310_BR42\Tasks\310-EAP-202208031444_Geomorphology\Potential Impact_20241107.mxd Date: 7/11/2024 15:16



Legend

- 5 Chainage (km)
- Border to Gowrie alignment
- Major roads
- Minor roads
- Waterways
- NSW Qld border
- Culvert
- Road Earthworks
- Geomorphic floodplains near the Project area

- Impact assessment area
- Temporary footprint

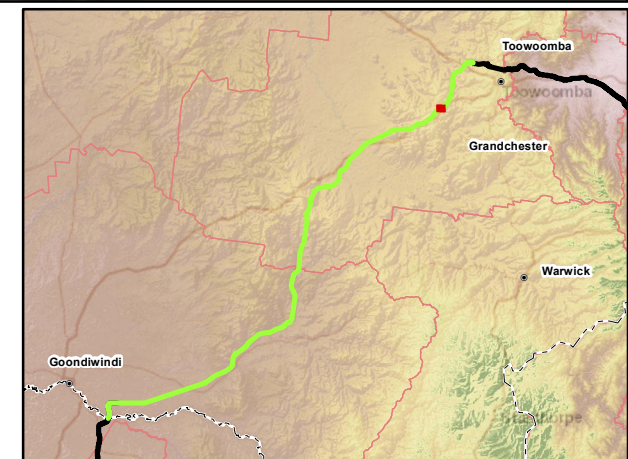
Flow Velocity Design Case 1% AEP Event (m/s)

High : 5.61

Low : 0.01

Watercourse encroachment by one abutment – Biddeston Southbrook Road Rail Bridge (watercourse NC3), 1% AEP design hydraulic model

Note: Design road earthworks shown in brown/green. Watercourse flows towards bottom of page.



A3 scale: 1:3,000

0 20 40 60 80 100 Metres



Issue date: 07/11/2024 Version: 2
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.4

Geomorphology Potential Impacts - Bridge 310-BR42 - NC 3

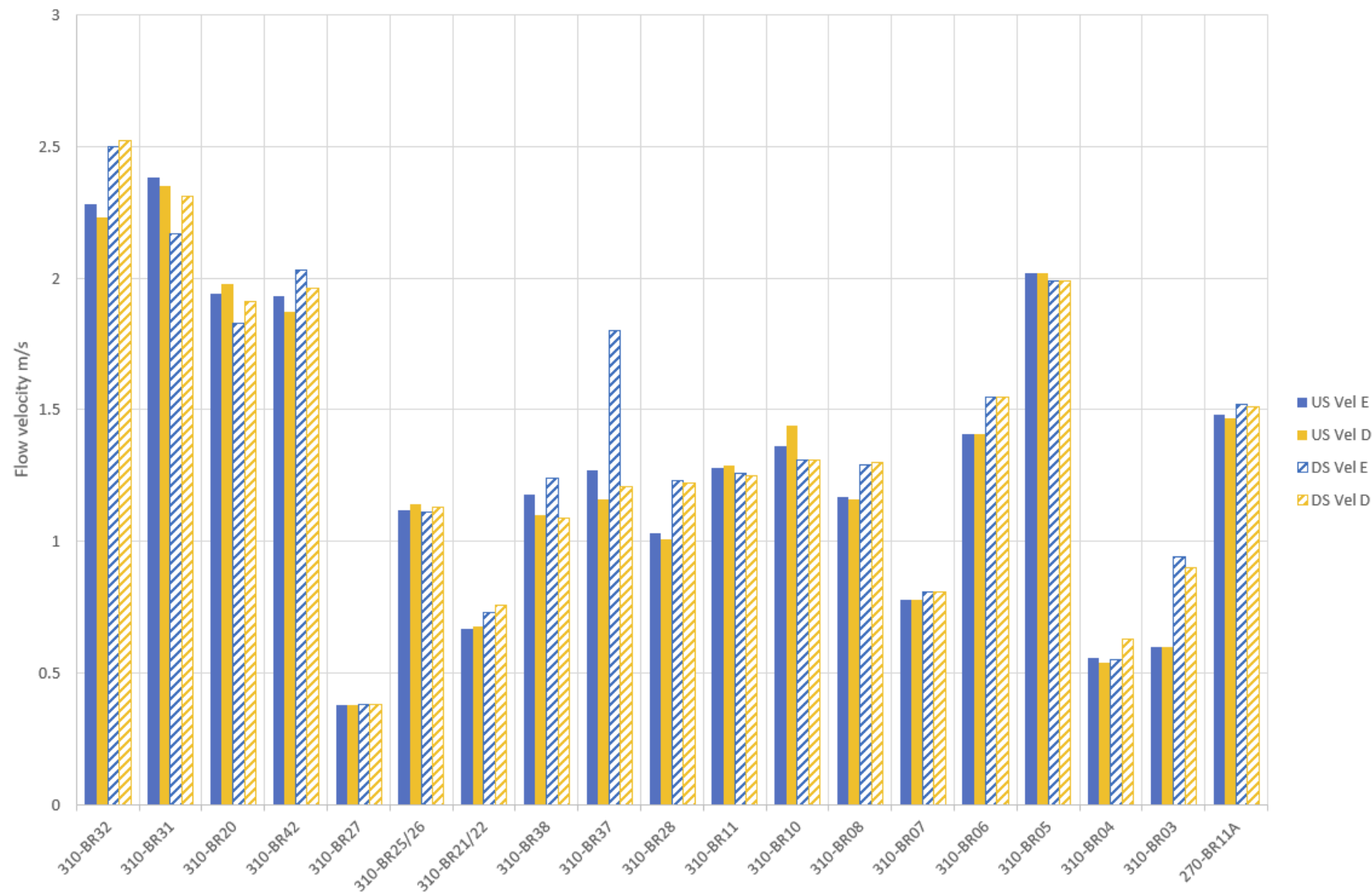


Figure 4.5 Maximum flow velocities upstream (US) and downstream (DS) during a 20% AEP event for existing (E) and design (D) cases for bridges

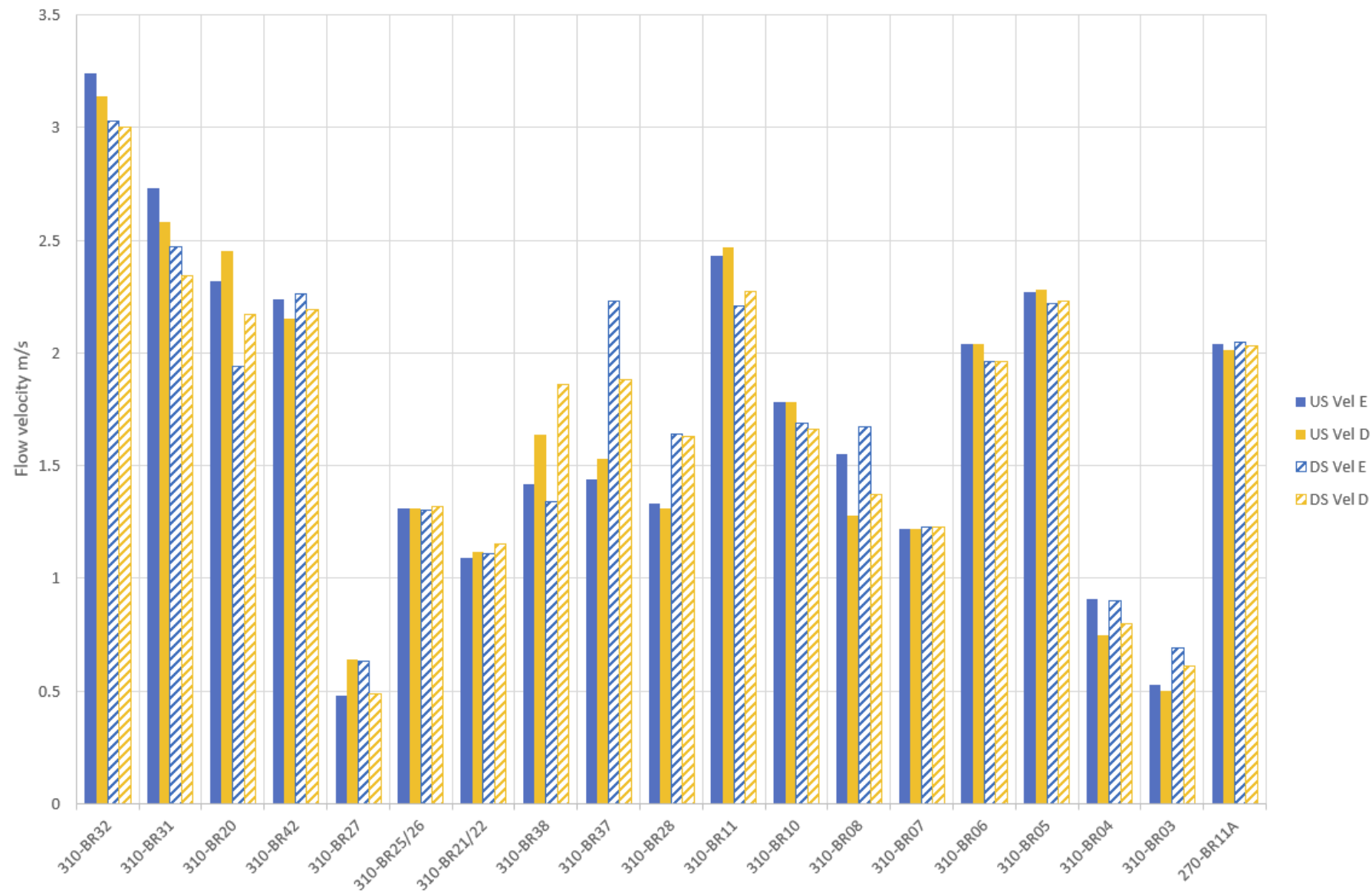


Figure 4.6 Maximum flow velocities upstream (US) and downstream (DS) during a 1% AEP event for existing (E) and design (D) cases for bridges

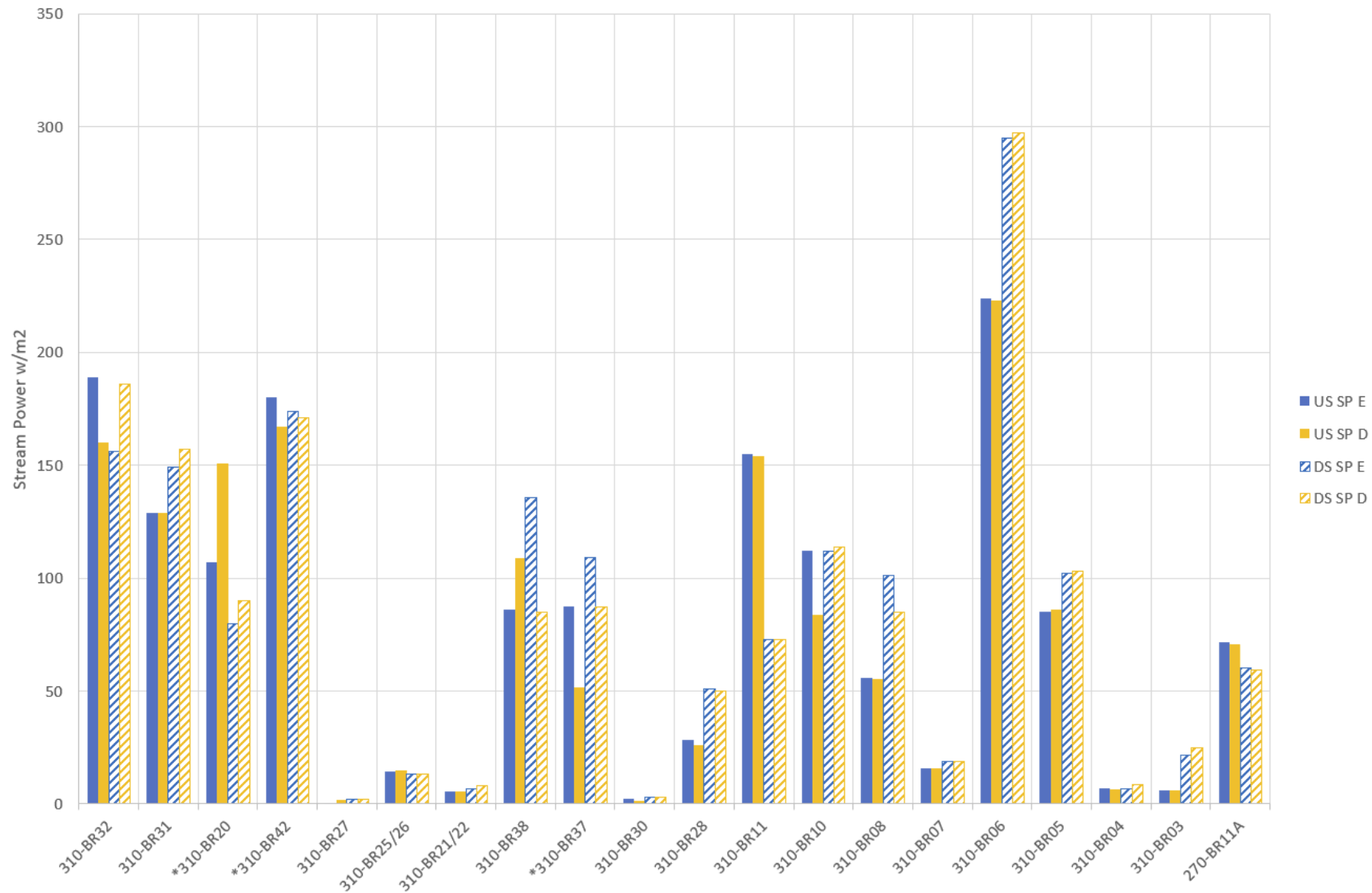


Figure 4.7 Maximum stream power upstream (US) and downstream (DS) during a 20% AEP event for existing (E) and design (D) cases for bridges

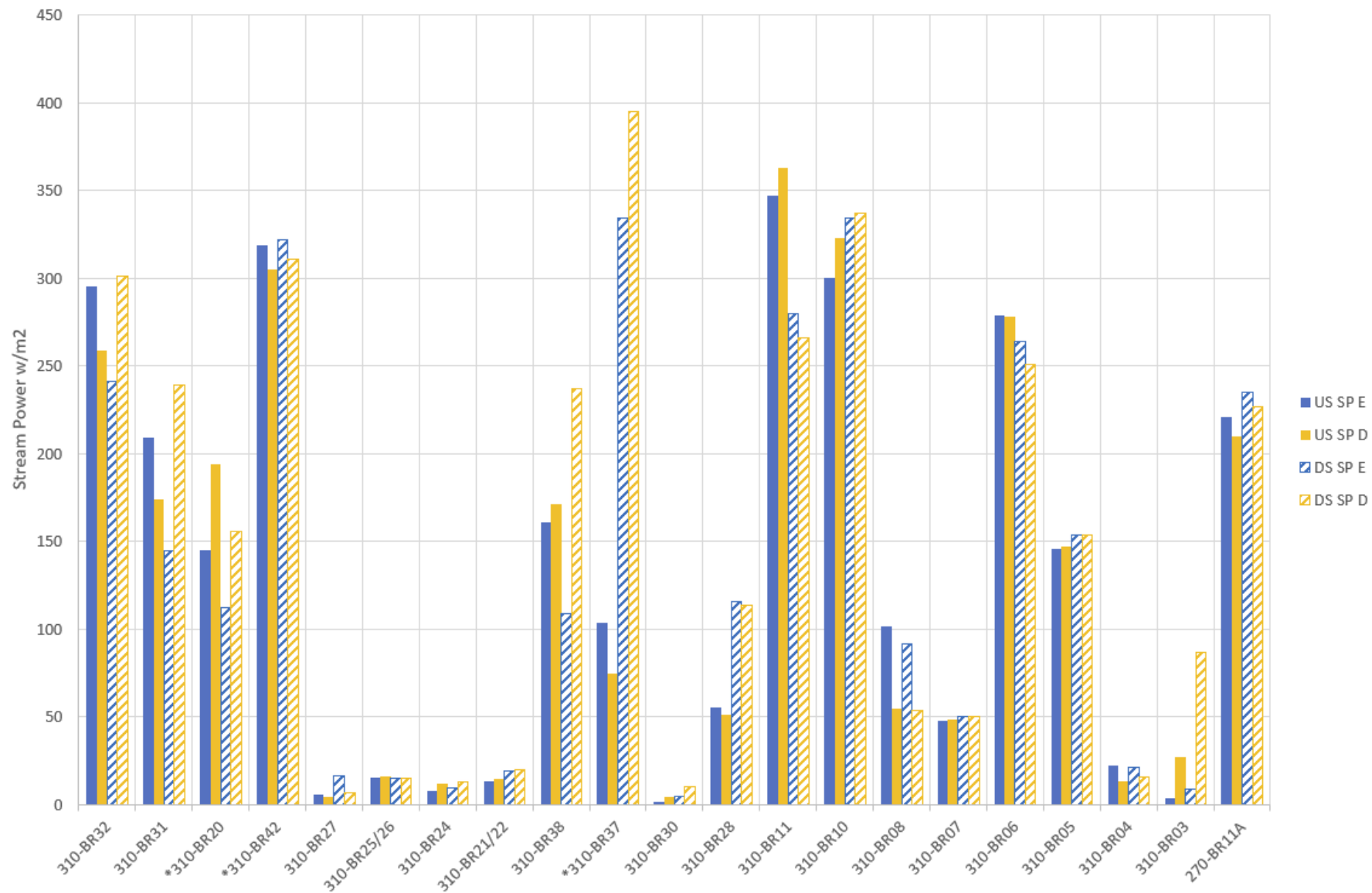


Figure 4.8 Maximum stream power upstream (US) and downstream (DS) during a 1% AEP event for existing (E) and design (D) cases for bridges

4.2.1.2 Culverts

Eight categories of potential impacts were identified for the 55 potentially sensitive watercourses with culverts and are summarised in Table 4.4:

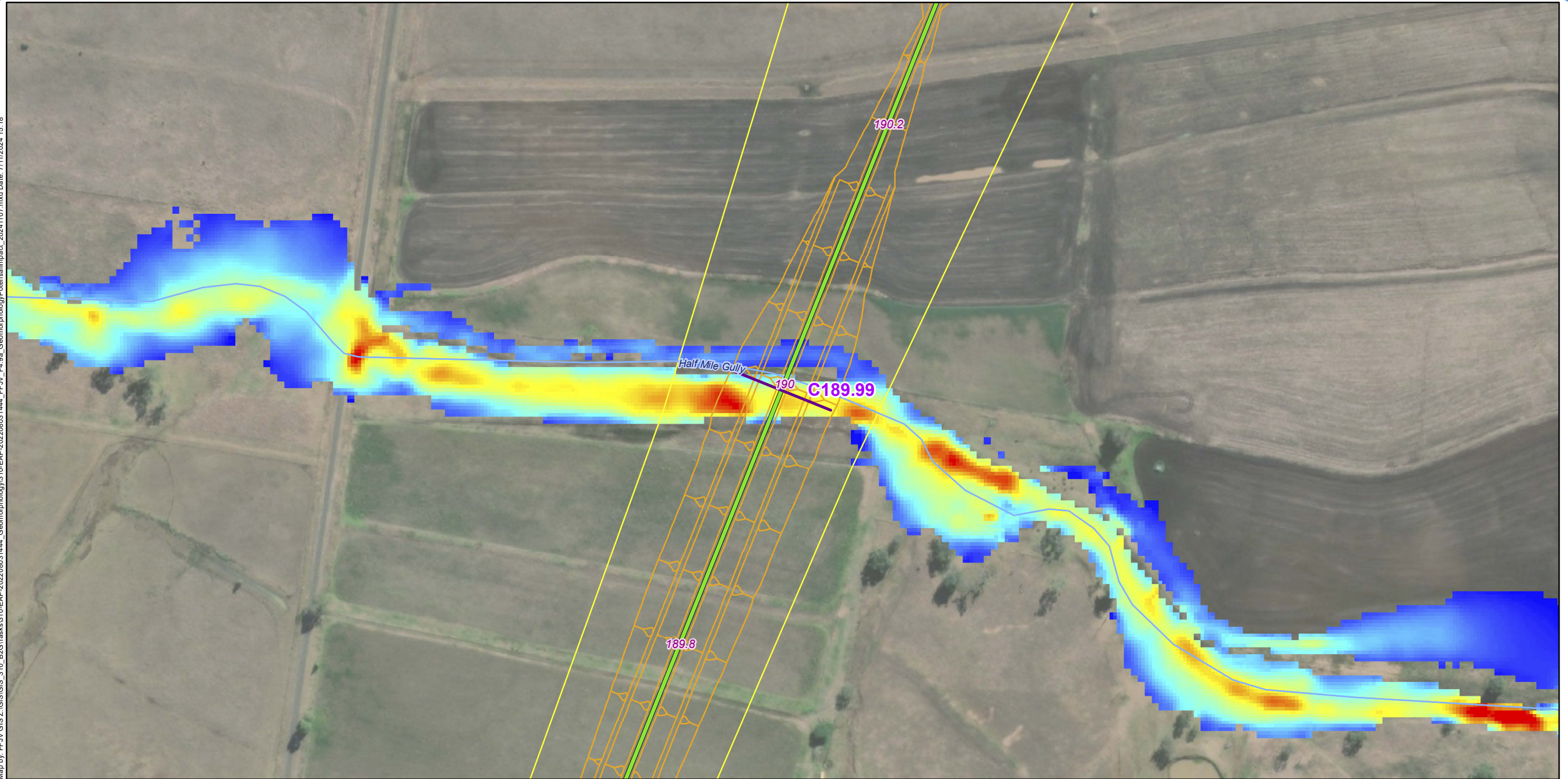
The eight categories are based on the 20% AEP case and include:

- Within 10 per cent of existing flow
- Upstream within 10 per cent of existing flow, downstream decrease
- Upstream within 10 per cent of existing flow, downstream increase
- Upstream decrease, downstream within 10 per cent of existing flow
- Upstream increase, downstream within 10 per cent of existing flow
- Upstream decrease in flow, downstream increase
- Upstream and downstream decrease
- Upstream and downstream increase.

Where culverts are not aligned to watercourse, example shown in Figure 4.9, they can concentrate flow to the edge of the channel or even outside of the channel on the floodplain, potentially changing channel planform. This was the most common potential impact for watercourses with culverts. Culvert alignment to watercourse is noted in Appendix H for potential mitigation and optimisation purposes.

Figure 4.10 to Figure 4.17 to show the Existing and Design Case velocities and stream power for the 20% AEP and 1% AEP events.

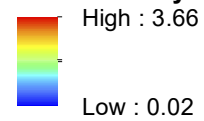
Map by: FF-JV GIS Z:\GIS\GIS_310_B2G\Tasks\310-EAP-2022\08031444_Geomorphology\310-EAP-2022\08031444_FF-JV_F4.9a_Geomorphology\PotentialImpact_20241107.mxd Date: 7/11/2024 15:18



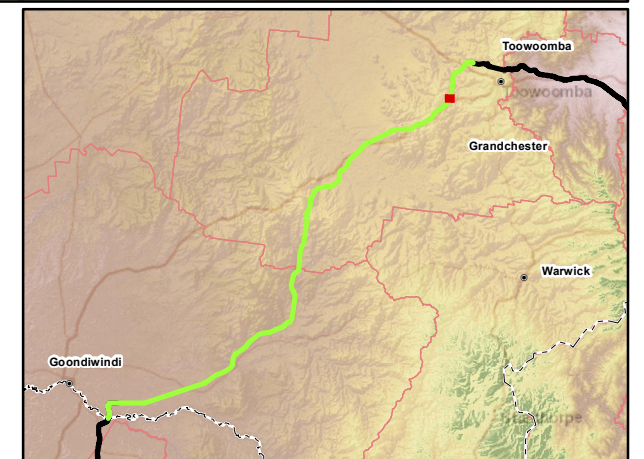
Legend

- 5 Chainage (km)
- Border to Gowrie alignment
- Waterways
- NSW Qld border
- Culvert
- Road Earthworks
- Impact assessment area
- Temporary footprint

Flow Velocity Existing Case 1% AEP Event (m/s)

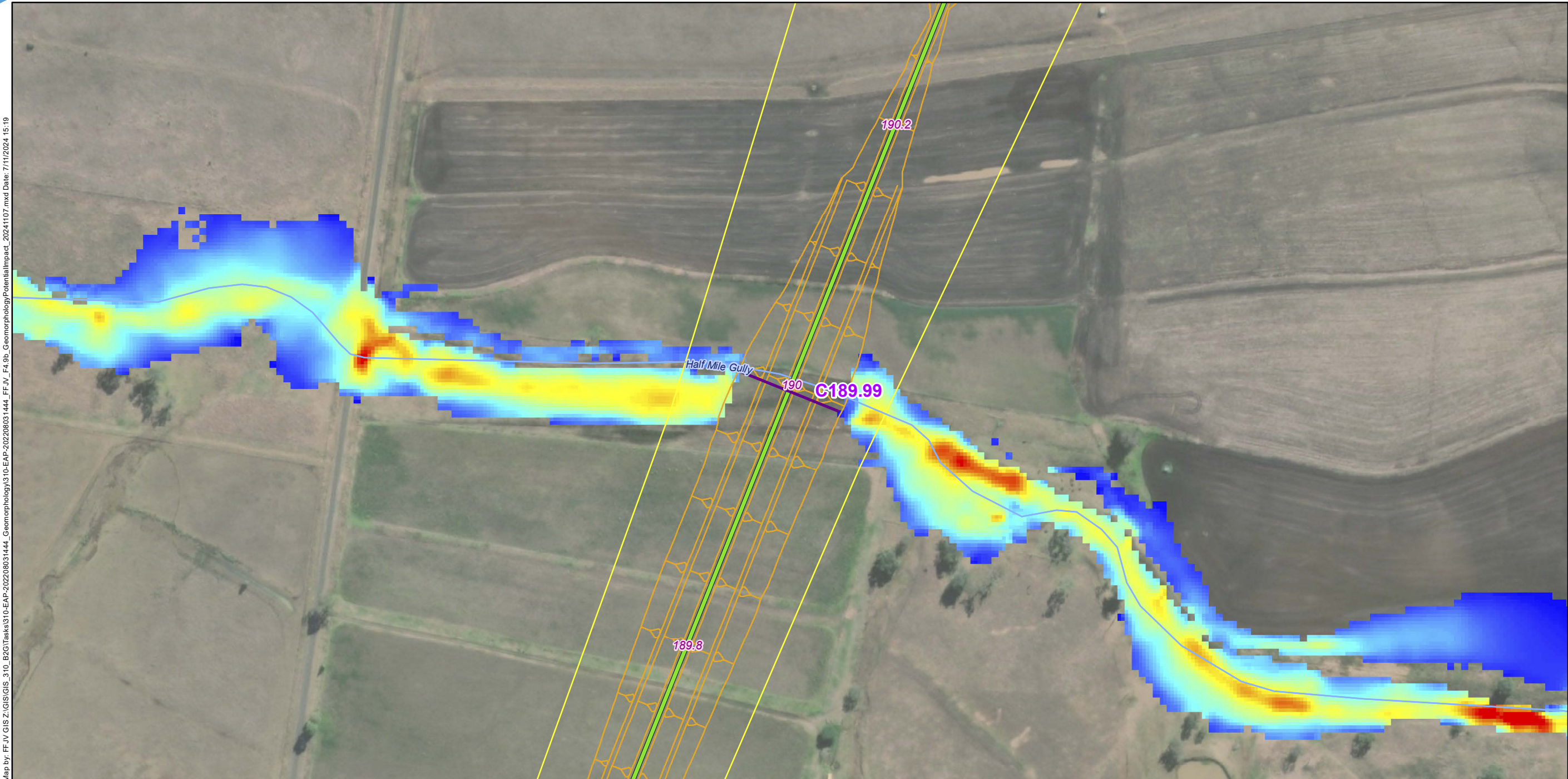


Culvert slightly oblique to watercourse OC5. 1% AEP event shown for the existing case
Note: Watercourse flows from left to right.



A3 scale: 1:3,000
0 20 40 60 80 100 Metres

Map by: FF-JV GIS Z:\GIS\GIS_310_B2G\Tasks\310-EAP-2022\08031444_Geomorphology\310-EAP-2022\08031444_FF-JV_F4.9b_Geomorphology\PotentialImpact_20241107.mxd Date: 7/11/2024 15:19



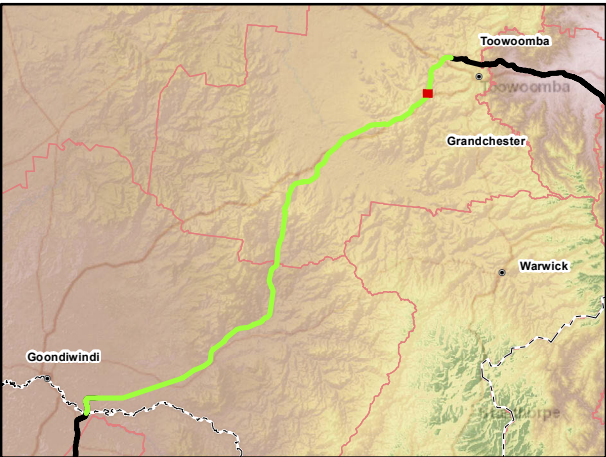
Legend

- 5 Chainage (km)
- Border to Gowrie alignment
- Waterways
- NSW Qld border
- Culvert
- Road Earthworks

- Impact assessment area**
- Temporary footprint

- Flow Velocity Design Case 1% AEP Event (m/s)**
- High : 3.66
 - Low : 0.02

Culvert slightly oblique to watercourse OC5. 1% AEP event shown for the design case
Note: Watercourse flows from left to right.



A3 scale: 1:3,000
0 20 40 60 80 100 Metres



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Border to Gowrie

Figure 4.9b

Geomorphology Potential Impacts - Culvert C189.99 - OC 5

Table 4.4 Potential impacts – watercourse culverts

Potential impact category (20% AEP event)	Culvert ID	Watercourse ID	Sensitivity to change	Refer Table 4.2 for key				Comments
				Erosion	Deposition	Planform change	Channel type change	
1. Within 10% of existing flow	C164.29	NC 14	2					Less than 10% change in maximum velocities for 20% AEP, impacts unlikely. In the 1% AEP event, downstream design flows show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and is unlikely to result in a potential impact.
	C125.48	SC 3	2					Less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely
2. Upstream within 10% of existing flow, downstream decrease	C193.10	One Mile Creek	4					Downstream increased potential planform change at all sites and deposition at One Mile Creek and C Ck 13 (based on evidence of bedload and design flow velocities). In the 1% AEP event, downstream design flows at One Mile Creek show an increase of greater than 10%, however the increased velocity occurs in the area of scour protection in the revised reference design and is unlikely to result in a potential impact.
	C87.37	C Ck 12	4					
	C84.38	C Ck 13	2					
	C30.60	MB 10	4					
3. Upstream within 10% of existing flow, downstream increase	C124.44	SC 4	1					Increased potential erosion, planform and channel type change downstream.
4. Upstream decrease, downstream within 10% of existing flow	C207.15	OC 1	4					Increased deposition upstream at C Ck 16 and MB 3, all other watercourses are wash slopes/non-channelised valley floor channel types with no evidence of bedload, therefore impacts are unlikely at these sites. Increased downstream planform change may occur where culvert is not aligned to flow. In the 1% AEP event, downstream design flows at NC 6, NC 8, SC 9, SC 10 and MB 3 show an increase of greater than 10%. However, in the area of increased flow velocity NC 6, NC 8, SC 9 and MB 3 have scour protection in the revised reference design and it is unlikely to result in a potential impact. SC 10 does not have scour protection, and up to major erosion may occur in the 1% AEP event.
	C186.16	NC1	4					
	C181.21	NC 6	2					
	C178.63	NC 7	2					
	C176.89	NC 8	2					
	C118.43	SC 9	2					
	C117.60	SC 10	2					
	C113.07	C Ck 7	4					
	C79.01	C Ck 15	4					
	C73.68	C Ck 16	5					

Potential impact category (20% AEP event)	Culvert ID	Watercourse ID	Sensitivity to change	Refer Table 4.2 for key				Comments
				Erosion	Deposition	Planform change	Channel type change	
	C61.90	MB 3	1					
	C61.60	MB 4	1					
5. Upstream increase, downstream within 10% of existing flow	C114.36	C Ck 3	4					Increased potential erosion upstream and channel type change. Increased planform change at C ck 10. Design flows at C Ck 3 in the 1% AEP have a reduction in flow velocity of greater than 10%, however watercourse is a non channelised valley floor with no bedload, therefore reduction of flow velocity unlikely to have any impact on sediment transport.
	C92.08	C Ck 10	4					
6. Upstream decrease in flow, downstream increase	C208.21	End Catchment	4					Potential deposition at CCs 21a, all other sites are wash slope/non-channelised valley floor with no bedload, therefore reduced design flow velocity unlikely to result in increased deposition. All but C Ck 17 and CCs 21a have scour in the revised reference design, which mitigates increased erosion and channel type change potential caused by the increase in downstream design flow velocity. For CCs 21a, in the 20% AEP event, downstream design flows show an increase of greater than 10%, however the increased velocity of 0.86 m/s is less than the Existing Case upstream velocity of 0.87 m/s along a straight channel, and increased in erosion potential from the Existing Case is unlikely. At C Ck 17, while an increase of more than 10% is modelled, design flows are still <0.2 m/s and erosion and channel type change are unlikely. Increased erosion and channel type change may occur in the 1% AEP event at this site. Channel type change at sites other than C Ck 17 unlikely as scour protection included in the revised reference design mitigates the increased erosion potential that drives change in channel type. Increased downstream planform change may occur where culvert is not aligned to flow.
	C202.8	OC 2	2					
	C186.16	NC 2	1					
	C181.78	NC 5	2					
	C164.16	NC 15*	2					
	C119.38	SC 8	4					
	C113.28	C Ck 6	2					
	C90.96	C Ck 11	2					
	C82.35	C Ck 14	2					
	C73.44	CCs 21a	5					
	C68.76	C Ck 17	2					
	C66.81	C Ck 19	2					
	C66.23	C Ck 20	2					
	C63.15	MB 1	1					
	C62.94	MB 2	1					

Potential impact category (20% AEP event)	Culvert ID	Watercourse ID	Sensitivity to change	Refer Table 4.2 for key				Comments
				Erosion	Deposition	Planform change	Channel type change	
7. Upstream and downstream decrease	C189.99	OC 5	2					Increased potential for deposition at three gully channels, C Ck 16, CCs 21 and CCs 22, and SC 7. CCs 19 is a gully with bed load, however while the design flow velocities are less than existing, they are still ~1 m/s and likely to be able to transport the bedload, therefore reduced design flow velocity is unlikely to result in increased deposition. Other sites are wash slope/non-channelised valley floor with no bedload, therefore reduced design flow velocity unlikely to result in increased deposition. Increased downstream planform change may occur where culvert is not aligned to flow.
	C182.99	NC 4	4					
	C171.90	NC 10	4					
	C169.89	NC 12	2					
	C165.06	NC 13	4					
	C120.31	SC 7	5					
	C109.43	C Ck 8	2					
	C107.22	C Ck 9	4					
	C74.97	CCs 19	5					
	C73.61	C Ck 16a	5					
	C73.53	CCs 21	5					
	C73.37	CCs 22	5					
	C60.44	MB 5	5					
	C48.41	MB 8	2					
	C43.16	MB 9	1					
8. Upstream and downstream increase	C194.69	OC 3	4					Increased potential upstream erosion and channel type change at all sites. Downstream increases in design flow velocities extend beyond the scour mitigation in the revised reference design at NC 11 and OC 3. There is no scour mitigation in the revised reference design for MR1. Increased downstream planform change may occur where culverts are not aligned to flow. MR1 has no flow in the 20% AEP event.
	C170.55	NC 11	4					
	C117.4	SC 11	4					
	C34.7 (NS2B)	MR 1	2					

Table notes:

* Culvert aligned to pass flows travelling along/adjacent to roadway

Minor to Moderate: the highest consequence has been used to derive the risk

Moderate to Major: the highest consequence has been used to derive the risk

Appendix H provides further details on scour protection included in the reference design at culverts

Existing Case sensitivity to change: 1= Low; 5= High, in terms of potential for change, Section 3.4.1 provides further details.

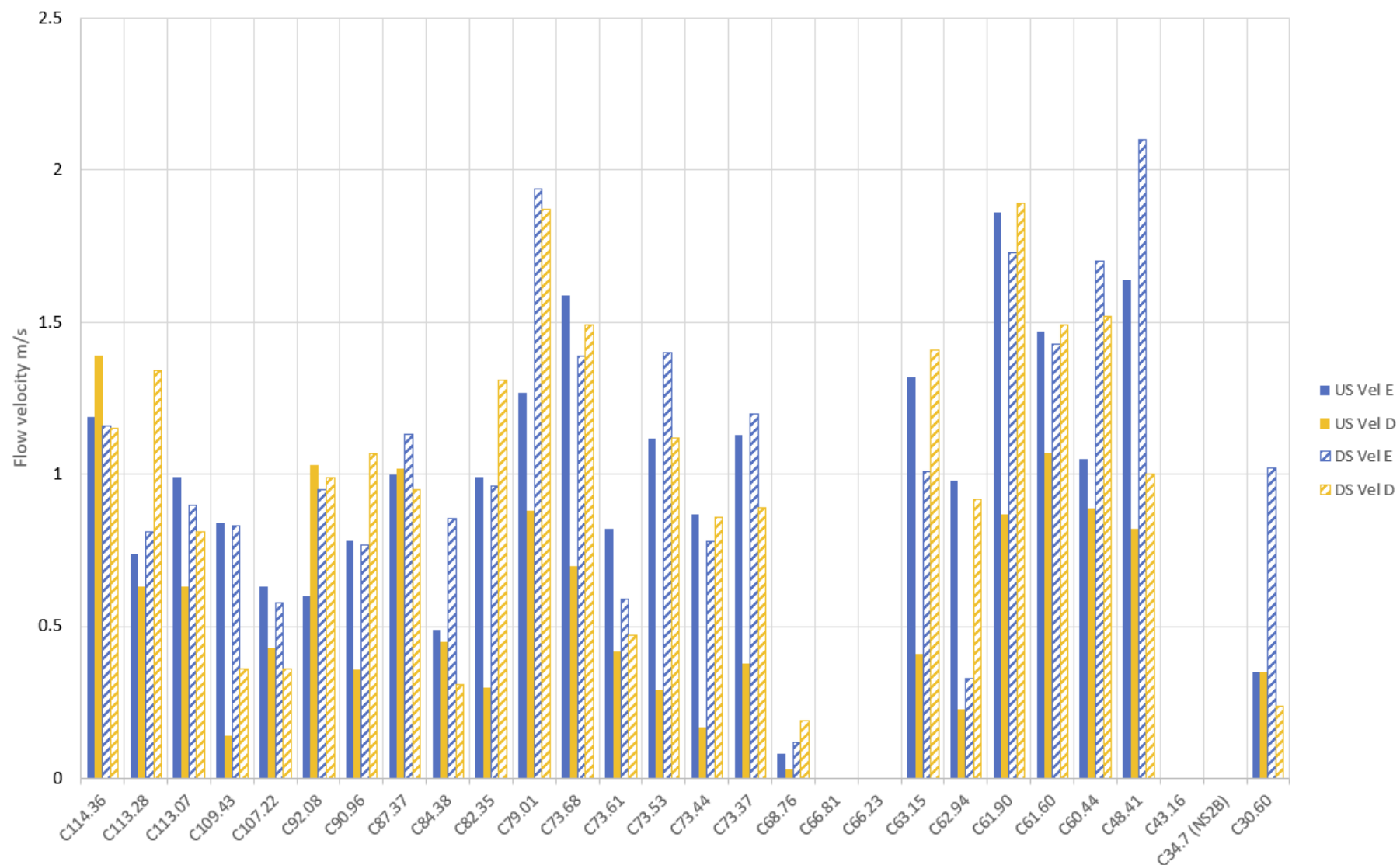


Figure 4.10 Maximum design flow velocities upstream (US) and downstream (DS) during a 20% flood event for existing (E) and design (D) cases for watercourse culvert sites (Border Rivers Basin)

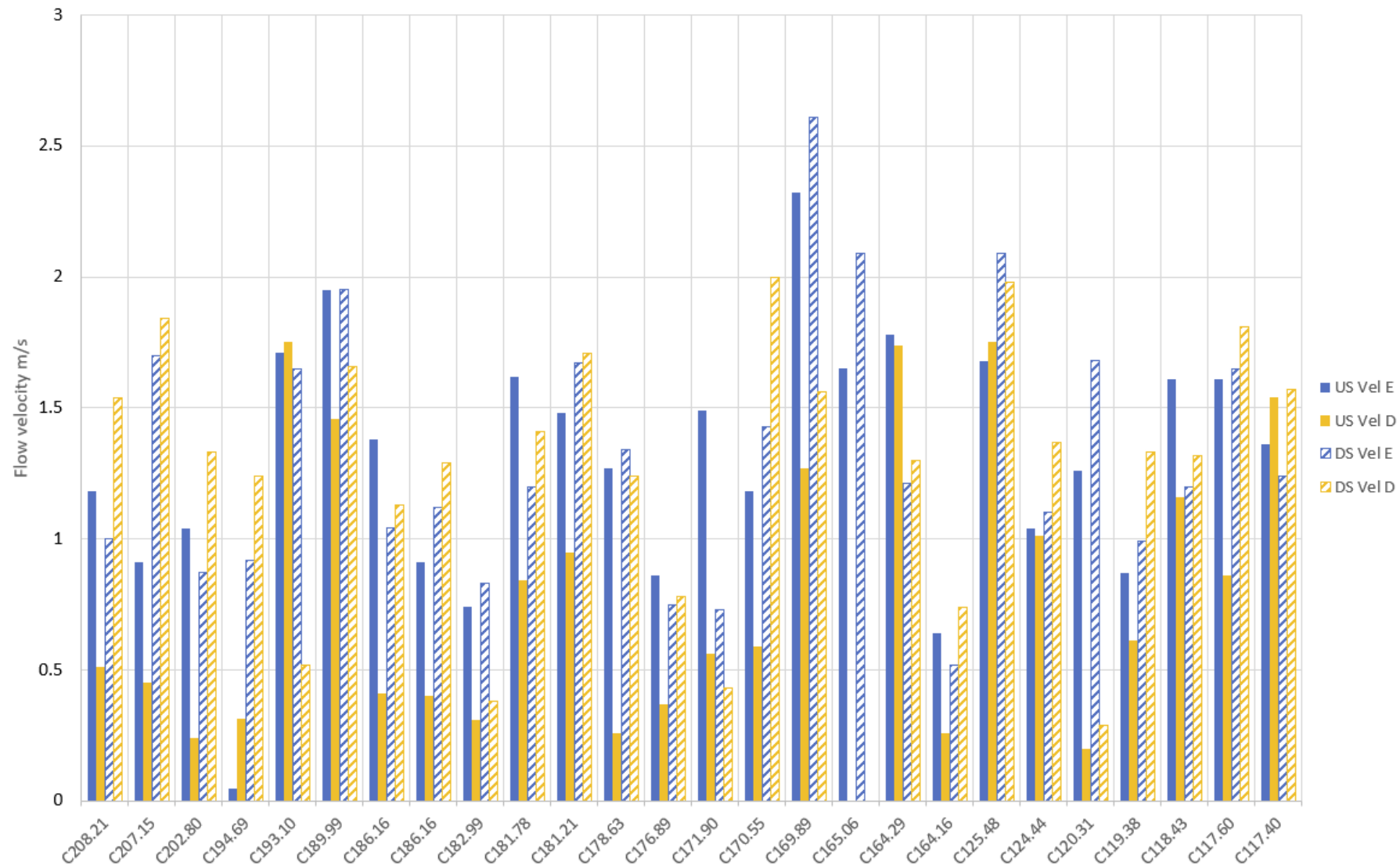


Figure 4.11 Maximum design flow velocities upstream (US) and downstream (DS) during a 20% flood event for existing (E) and design (D) cases for watercourse culvert sites (Condamine River Basin)

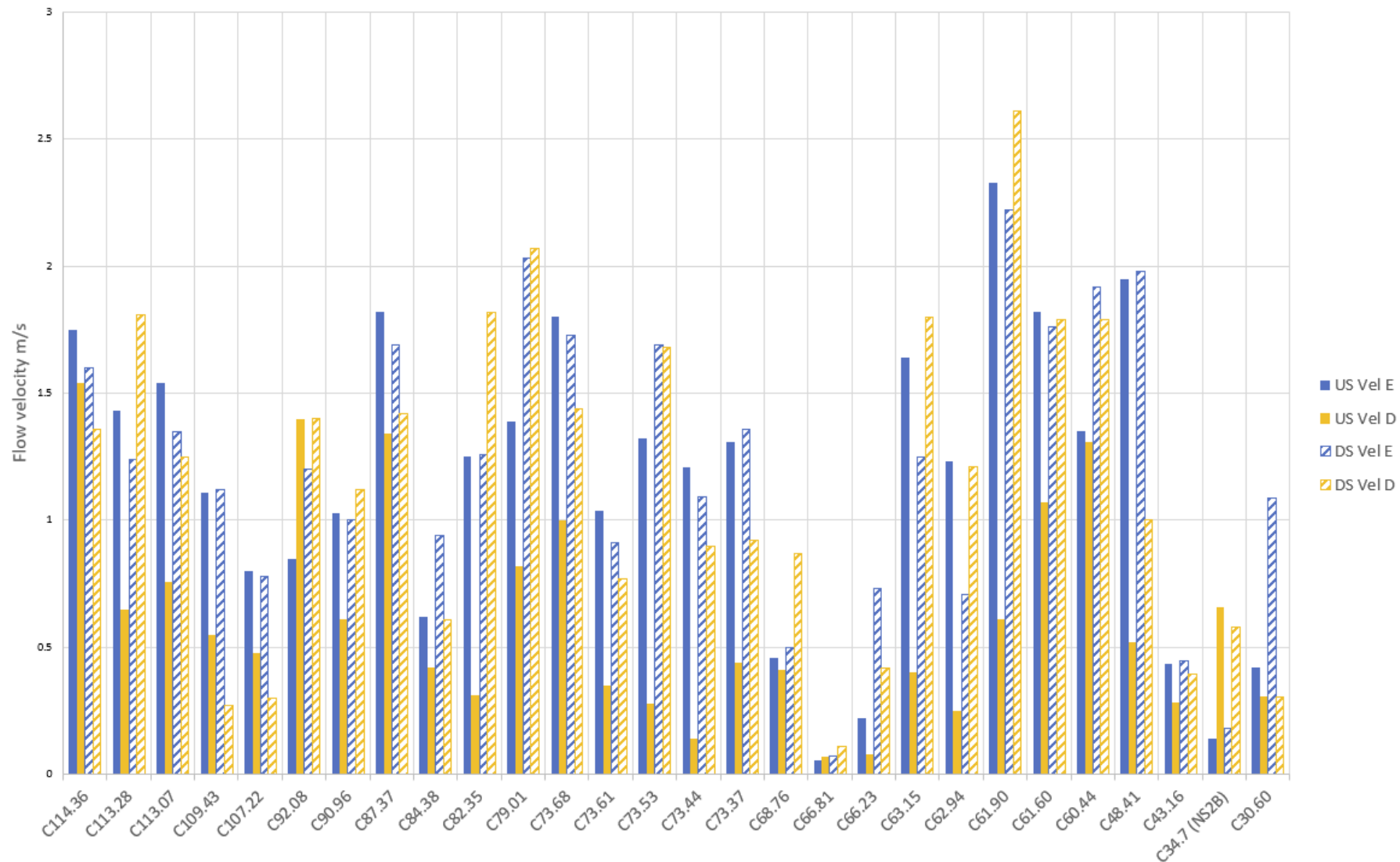


Figure 4.12 Maximum design flow velocities upstream (US) and downstream (DS) during a 1% flood event for existing (E) and design (D) cases for watercourse culvert sites (Border Rivers Basin)

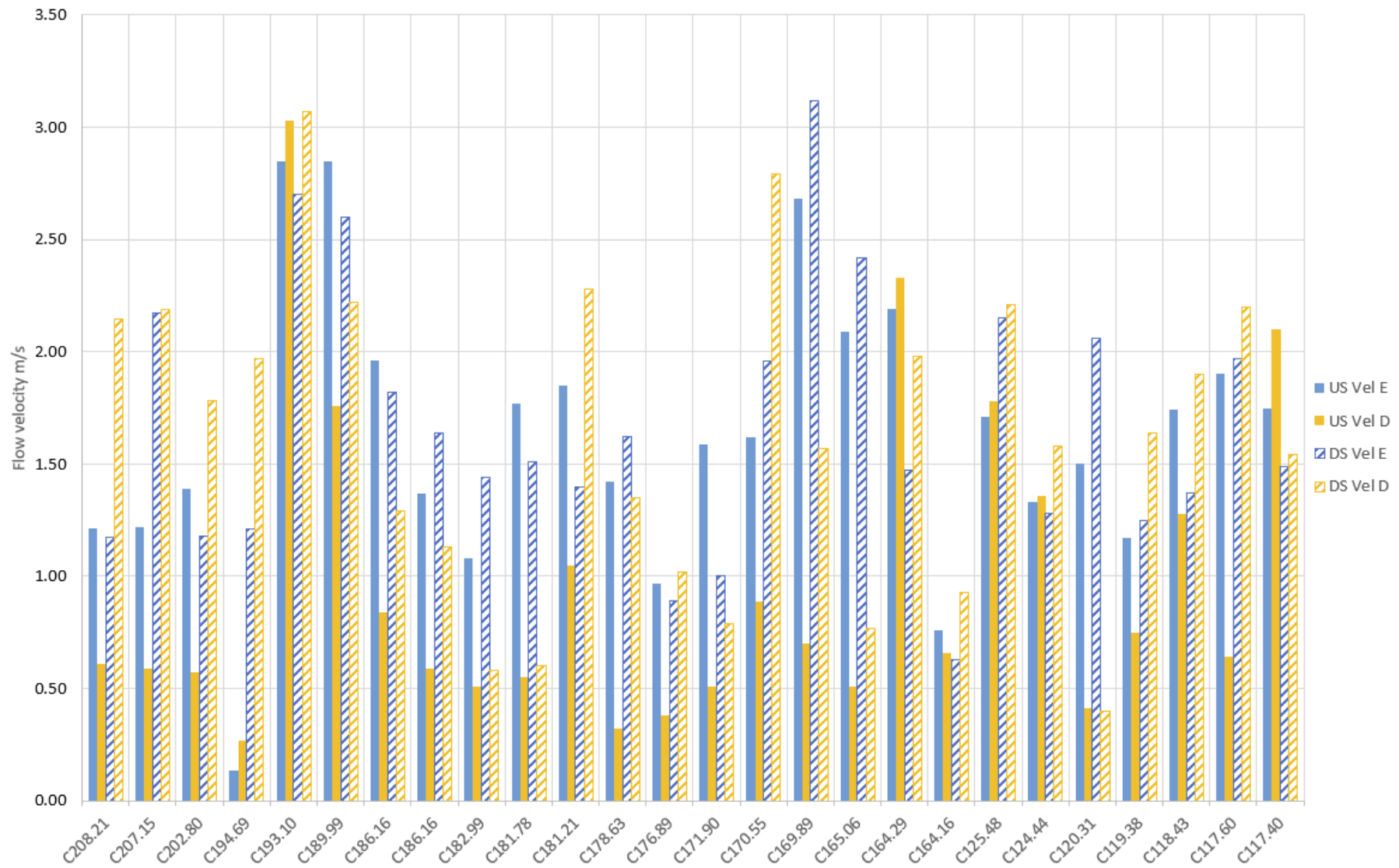


Figure 4.13 Maximum design flow velocities upstream (US) and downstream (DS) during a 1% flood event for existing (E) and design (D) cases for watercourse culvert sites (Condamine River Basin)

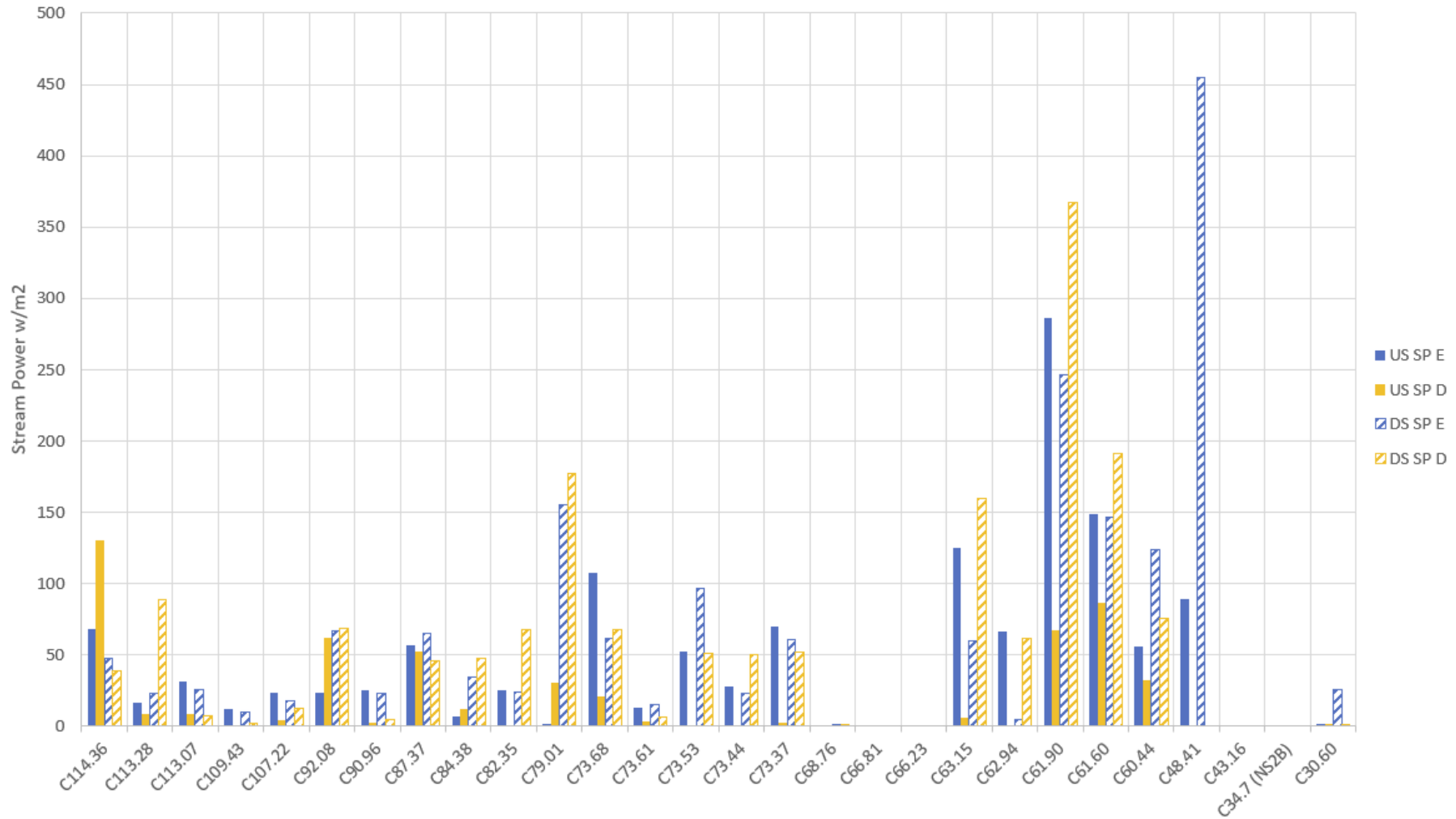


Figure 4.14 Maximum design stream power upstream (US) and downstream (DS) during a 20% flood event for existing (E) and design (D) cases for watercourse culvert sites (Border Rivers Basin)

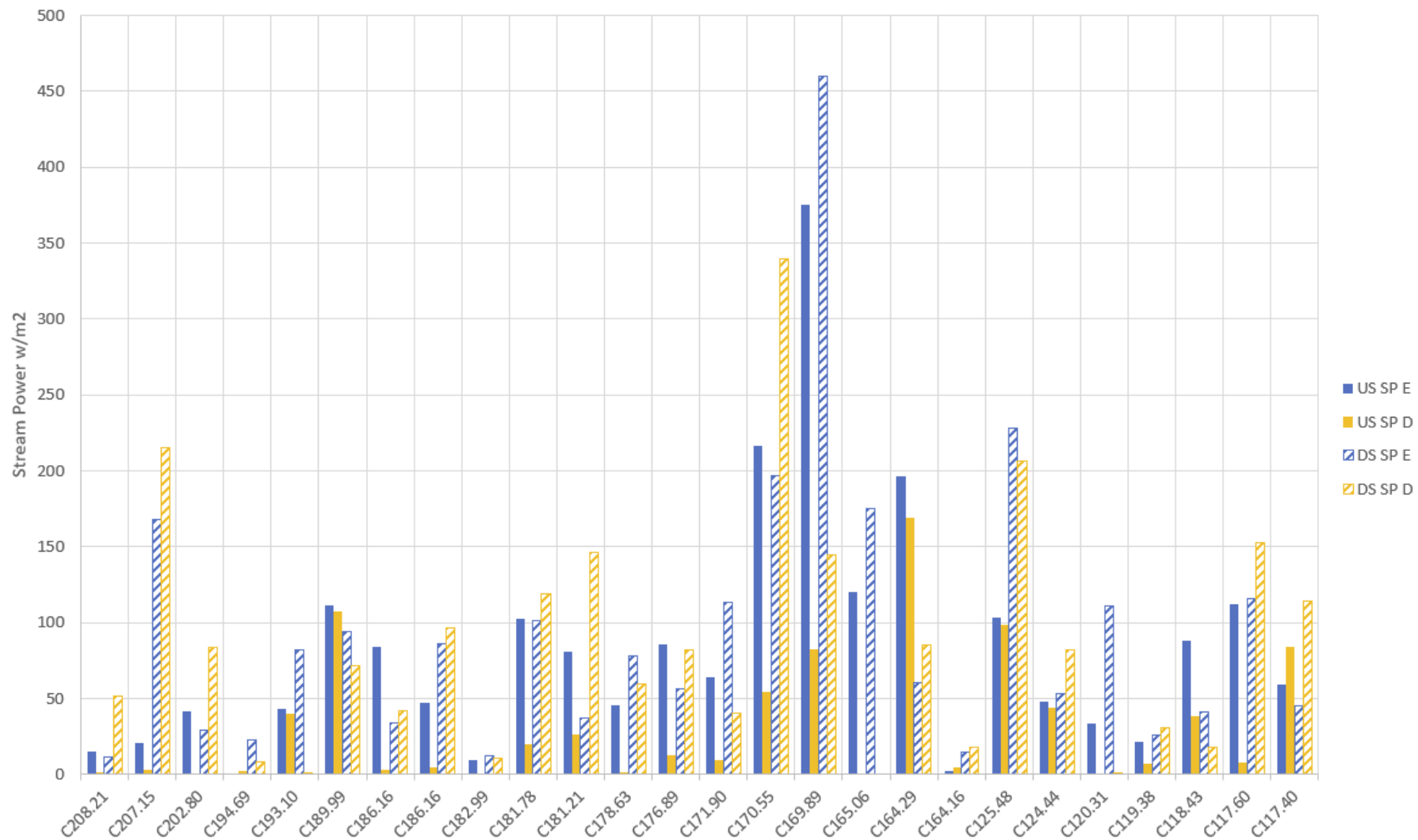


Figure 4.15 Maximum design stream power upstream (US) and downstream (DS) during a 20% flood event for existing (E) and design (D) cases for watercourse culvert sites (Condamine River Basin)

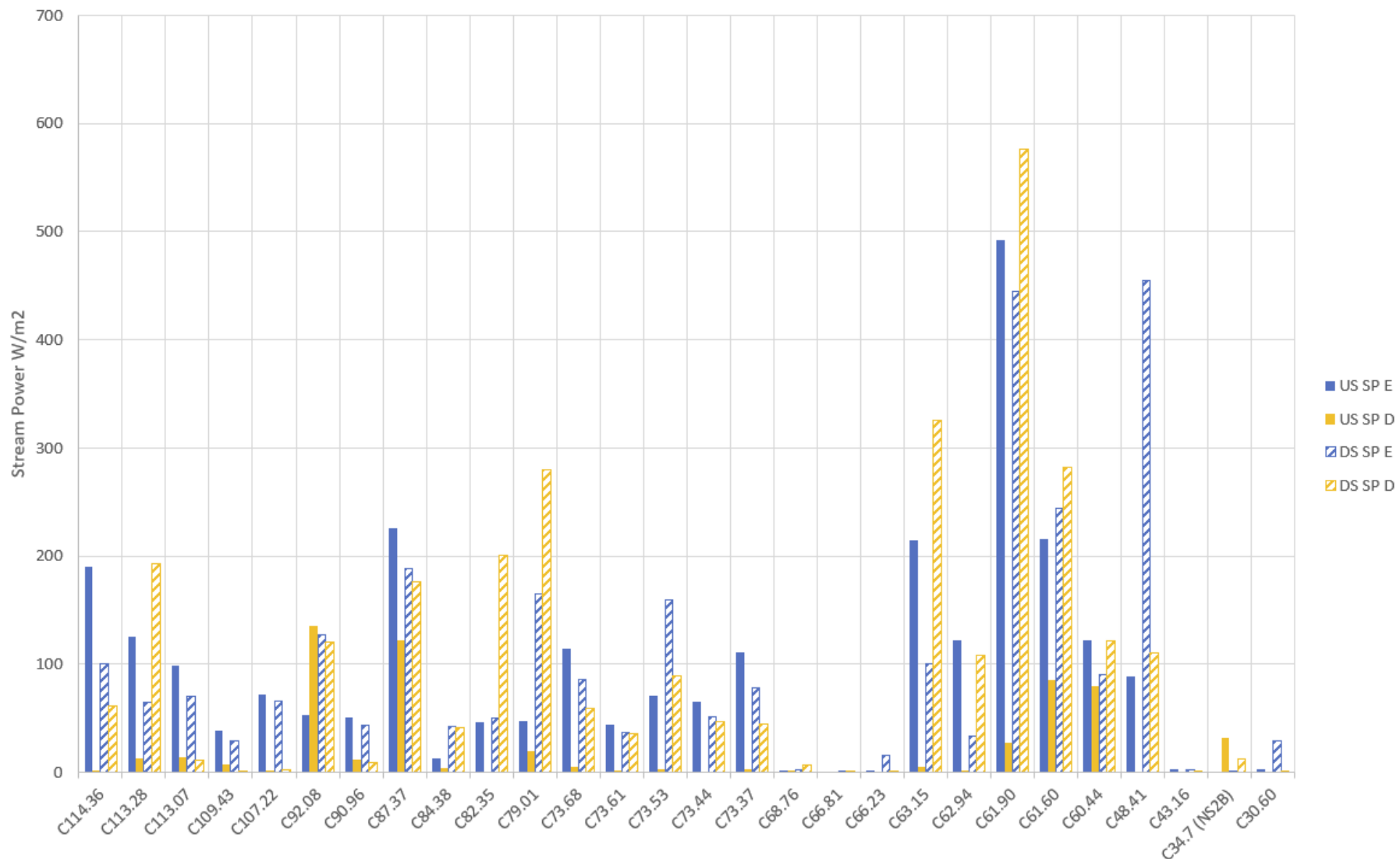


Figure 4.16 Maximum design stream power upstream (US) and downstream (DS) during a 1% flood event for existing (E) and design (D) cases for watercourse culvert sites (Border Rivers Basin).

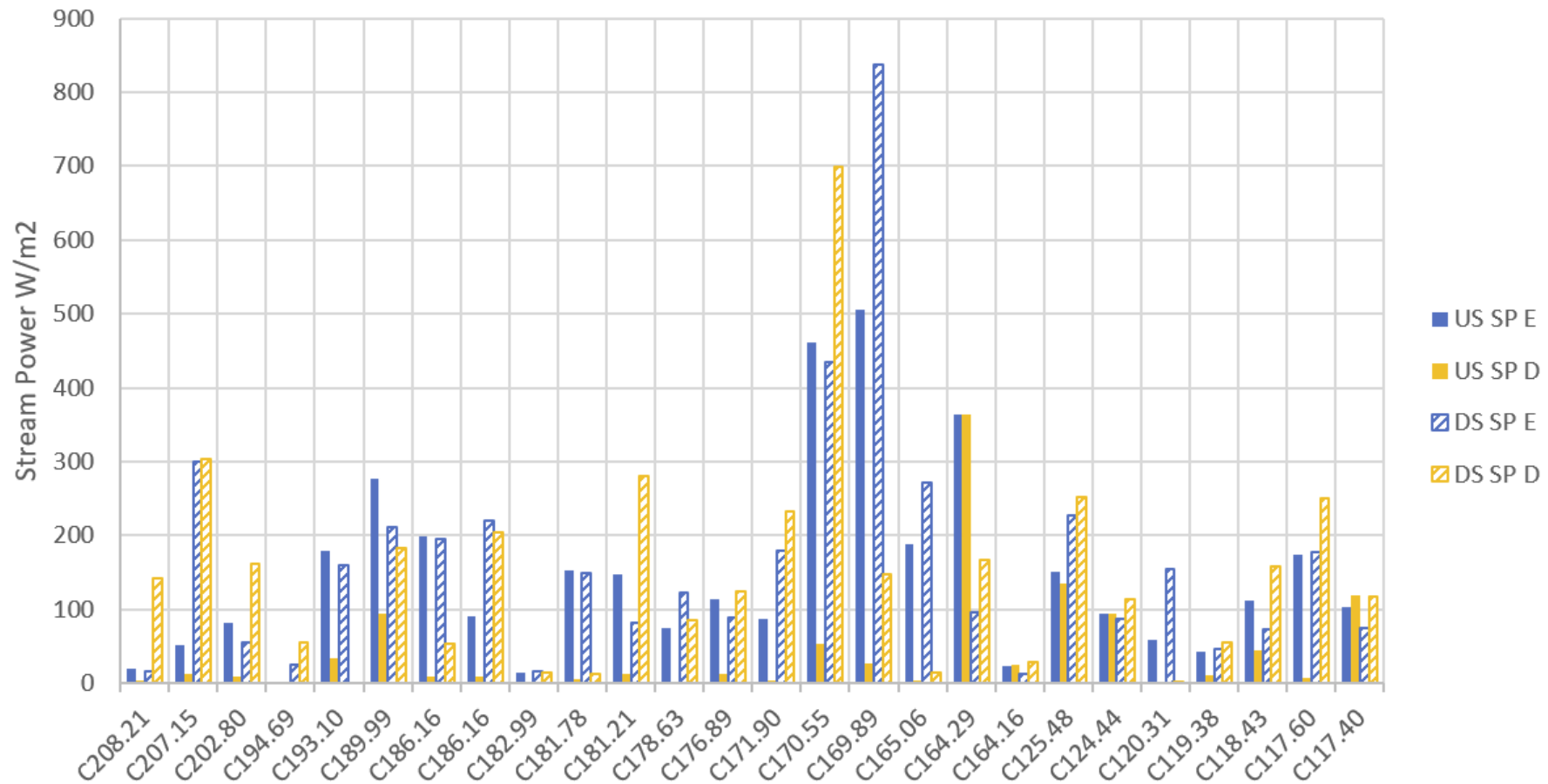


Figure 4.17 Maximum design stream power upstream (US) and downstream (DS) during a 1% flood event for existing (E) and design (D) cases for watercourse culvert sites (Condamine River Basin).

4.2.1.3 Diversions

There are two design diversions that impact three watercourses (drainage features):

- Ch 120.76 km to Ch 121.43 km, watercourses SC 5 (in cut) and SC 6, Culvert 120.77:
 - C120.77 has downstream scour protection for 10.8 m
 - Upstream and downstream design flow velocity are within 10 per cent of the Existing Case flow velocity
 - SC 5 does not appear to be in the hydraulic model, therefore the hydraulic model outcomes may not be representative of Design Case conditions. However, SC 5 is unlikely to have significant flow as the Project alignment intersects this Strahler order 1 watercourse near the upper end of its headwater, and it has two upstream human-made ponds, which would reduce flow in the watercourse.
 - Culvert not aligned to watercourse
 - Diversion includes a sharp channel bend of close to 90-degrees
 - SC 6 Potential impacts include erosion and downstream channel type and planform change
 - SC 5 Potential impacts include deposition and erosion.
- Ch 192.00 km, watercourse OC 4, Culvert C192.09:
 - C192.09 has downstream scour protection for 10.8 m
 - Upstream and downstream increase in flow velocity
 - Upstream increase in flow velocity occurs in constructed diversion channel, and downstream increase occurs mainly in the area of scour protection in the revised reference design
 - Culvert not aligned to watercourse at outlet
 - Diversion includes close to 90-degree angles
 - Potential impacts include erosion and downstream channel type and planform change.

Figure 4.18 shows the location of SC5 and SC6 along the Project alignment. These watercourses are headwaters, and the flow remains in the local catchment. SC 6 has been assessed under 'diversion' infrastructure as it receives the diverted design flow from SC 5, which its channel must accommodate, therefore has potential downstream impacts. SC 6 channel downstream of the alignment will take an increased flow volume for approximately 500 m, including passing under the Millmerran Inglewood Road, until its pre-Project intersection with SC 5 downstream.

Figure 4.19 shows the location of OC4 (also a headwater) being diverted north to cross the Project alignment.

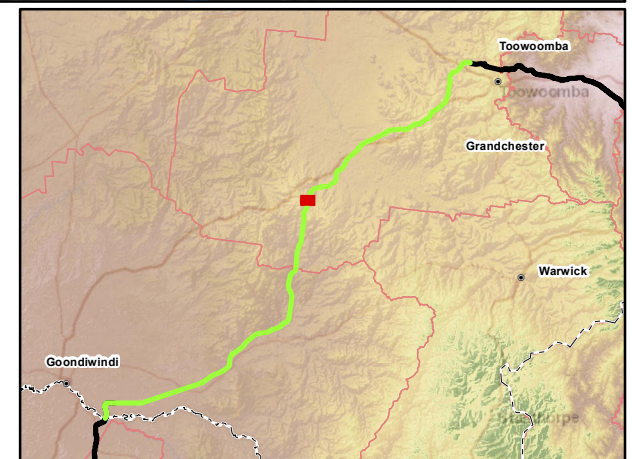
Map by: FF-JV GIS Z:\GIS\GIS_310_B2G\Tasks\310-EAP-2022\08031444_Geomorphology\PotentialImpact_20241107.mxd Date: 7/11/2024 15:21



Legend

- | | |
|----------------------------|------------------------|
| 5 Chainage (km) | Impact assessment area |
| Border to Gowrie alignment | Temporary footprint |
| Minor roads | |
| Waterways | |
| NSW Qld border | |
| Culvert | |
| Rail Earthworks | |

Diversion structure diverting SC 5 south to SC 6 where they both cross the alignment at Ch 120.77



A3 scale: 1:8,000
0 50 100 150 200 250 Metres



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Border to Gowrie

Figure 4.18

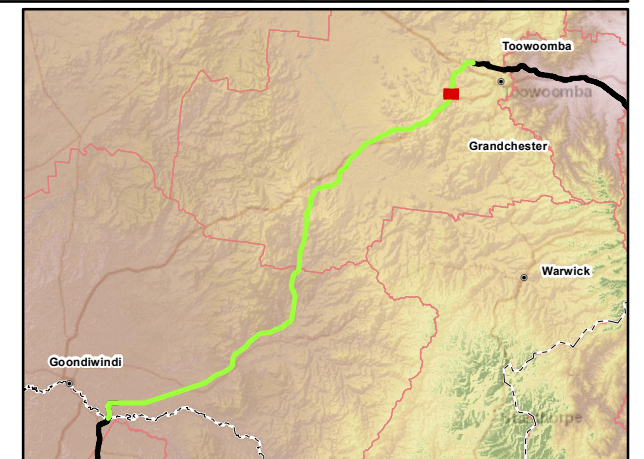
Geomorphology Potential Impacts - Chainage 120.6 - 122

Map by: FF-JV GIS Z:\GIS\GIS_310_B2G\Tasks\310-EAP-2022\08031444_Geomorphology\PotentialImpact_20241107.mxd Date: 7/11/2024 15:25



Legend

- | | |
|----------------------------|-------------------------------|
| 5 Chainage (km) | Impact assessment area |
| Border to Gowrie alignment | Temporary footprint |
| Waterways | |
| NSW Qld border | |
| Road Earthworks | |



Diversion structure diverting OC4 north to cross the alignment at Ch 192.09



A3 scale: 1:9,000
0 60 120 180 240 300 Metres



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Border to Gowrie

Figure 4.19

Geomorphology Potential Impacts - Chainage 190.8 - 192.4

4.2.1.4 Cuts

Three watercourses are in areas of cut along the Project alignment. Due to the impossibility of building culverts at these locations, cut drainage and embankment drainage has been incorporated into the revised reference design. The following watercourses are in cut:

- C Ck 4
- C Ck 5
- SC 1.

Drainage at a cut location will run along the cut until the next culvert. This results in potential for deposition upstream and erosion downstream, however these impacts are considered unlikely for the following reasons:

- These watercourses are headwaters with channel types of wash slope/non-channelised valley floor flow, they typically do not carry bedload and are unlikely to result in increased deposition
- The culverts the watercourses will drain to (C113.28 for C Ck 4 and 5, C133.02 for SC 1) have downstream scour protection included in the revised reference design.

There is no hydraulic model for these sites, and they are not included in Appendix H. Due to the lack of hydraulic models for these sites, drainage design will be assessed in more detail during detailed design.

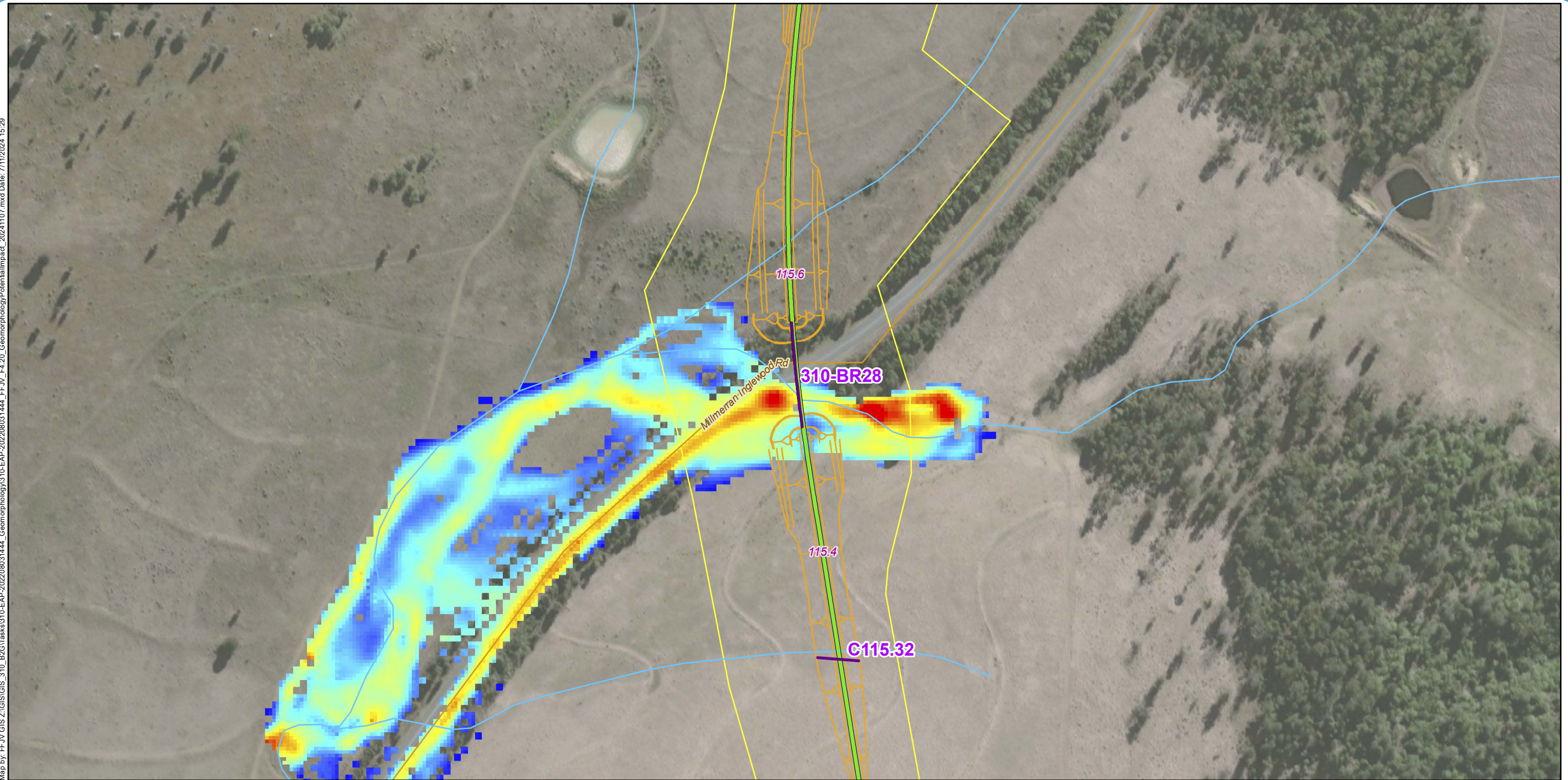
4.2.1.5 No cross drainage design

There are three watercourses with no drainage design that are not in cut.

- C Ck 1
 - C Ck 1 is a headwater with a 32 ha catchment
 - Its flow path intersects the revised reference design northern abutment of the Millmerran Inglewood rail-over-road Bridge (310-BR37) and then joins C Ck 2 to the west of the Project alignment. Design flow is redirected a short distance around the end of the northern abutment and flows under the bridge to its existing flow path at C Ck 2.
 - The revised reference design and design hydraulic model for the site is illustrated in Figure 4.20
 - C Ck 1 and C Ck 2 are currently impacted by flows concentrated along the Millmerran Inglewood Road.
- NC 16
 - A headwater with a 420.8 ha catchment
 - Located at the existing Southwestern Line rail embankment, Existing Case flow is directed along the Southwestern Line rail embankment towards the southwest
 - There is a humanmade pond directly upstream of the Project alignment, which likely reduced downstream flow
 - Existing Case conditions are highly modified.
- PC 1
 - A local – poorly developed channel with a 1,082 ha catchment
 - Located at the accessway to the Turallin facility.
- Potential impacts at these three sites include erosion, deposition and planform change.

These sites do not have hydraulic models with existing and design case and they are not included in Appendix H. Due to the lack of hydraulic models for these sites, drainage design will be assessed in more detail during detailed design.

Map by: FF-JV GIS Z:\GIS\GIS_310_BR28\Tasks\310-EAP-2022\08031444_Geomorphology\PotentialImpact_20241107.mxd Date: 7/11/2024 15:29



Legend

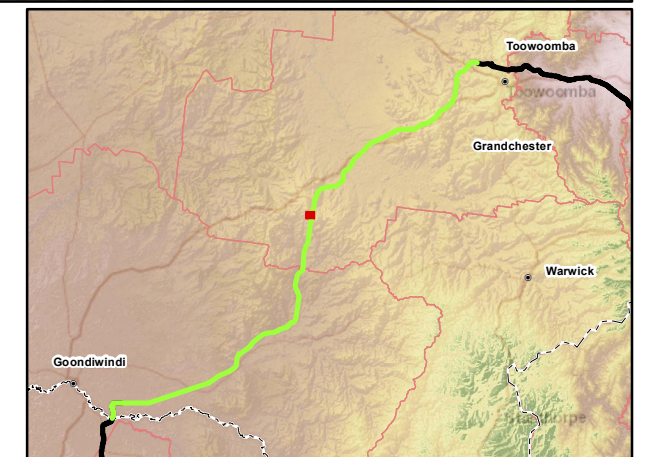
- 5 Chainage (km)
- Border to Gowrie alignment
- Minor roads
- Waterways
- NSW Qld border
- Culvert
- TRAN_RailEarthworks
- Road Earthworks

- Impact assessment area**
- Temporary footprint

Flow Velocity Design Case 1% AEP Event (m/s)

- High : 2.58
Low : 0.03

C Ck 1. Flow will be diverted around the northern abutment of the Millmerran Inglewood Road Rail Bridge.
Note: Design flow path of C Ck 1 illustrated by arrow. Flow towards the left.



A3 scale: 1:3,000
0 20 40 60 80 100 Metres

4.2.2 Floodplain operations stage potential impacts

Operations stage potential impacts were assessed for 17 geomorphic floodplains under four potential impact categories:

- No encroachment – no impacts
 - Bridge embankments do not intersect the flow on the geomorphic floodplain.
- Floodplain sidling
 - Embankment located within a floodplain, roughly perpendicular to direction of flow.
- Floodplain constriction
 - Embankment is located within a floodplain, and flow is semi-parallel to the embankment.
- Floodplain constriction and sidling
 - Embankment is located within the floodplain and both constriction and sidling occur due to relative changes in orientation of the floodplain and Project alignment.

As floodplain cross drainage typically comprises a range of design infrastructure types, including main channel bridges/culverts, floodplain bridges and floodplain culverts, potential impacts have been assessed for the entire floodplain.

Potential impacts are summarised in Table 4.5. The most common potential impact is erosion, which was identified as a possible impact at ten of the floodplains. However, only MB 6 had erosion as a potential impact for the 20% AEP event, the other floodplains only had erosion identified for the 1% AEP event. The potential impact of deposition was identified at three floodplains. All floodplain sites that triggered the criteria to assess for reduced floodplain connectivity had design cross drainage, mitigating this potential impact.

Table 4.6 provides further detail on which criteria to assess for potential impacts were triggered and if those impacts may occur taking with the implementation of the revised references design and baseline conditions. The proposed design cross drainage infrastructure for each floodplain is also listed in Table 4.6. Appendix H provides details for existing and Design Case hydraulic data including flow velocity and stream power for floodplain culverts and floodplain bridges.

4.2.2.1 Condamine floodplain

There is existing erosion occurring on the Condamine floodplain, most notably in the flood basin between the Condamine Main Branch and Grasstree creek between chainage 142.61 and 142.07km. The central part of the flood basin where the existing erosion is occurring corresponds with the highest maximum Existing Case flow velocities along the proposed alignment in the Condamine floodplain, between 0.50 and 0.67 m/s for the 20% AEP (Appendix H Culverts C142.61 to C142.07). Potential impacts due to the Project are unlikely in the flood basin area for the following reasons:

- Design Case maximum velocities at culverts in this area are less than 0.35 m/s for the 20% AEP event.
- Most design culverts have scour protection in the revised reference design.
- Design flow velocity at the flood basin bridge is within 10 per cent of Existing Case flow velocities, at 0.55 m/s.

Outside of the flood basin between the Condamine main branch and Grasstree Creek, Existing Case flow velocities are less than 0.5 m/s for the 20% AEP event and design flow velocities are less than 0.4 m/s and impacts due to the Project are unlikely.

Figure 4.22 shows maximum velocities at culverts across the Condamine floodplain in the 1% AEP event. Design flow velocities for many floodplain culverts are below 0.5 m/s for the 1% AEP event, except for two areas. One of these areas comprised four culvert sites, C149.02 to C147.82 and has design flow velocities within 10 per cent of the Existing Case and impacts are unlikely. The other area comprises three culvert sites, C141.46 to C141.38, and has downstream design flow velocities of up to 1.02 m/s for the 1% AEP, 0.38 m/s higher than the Existing Case and erosion may occur. Two of these culvert sites have downstream scour protection in the revised reference design, which largely mitigate any potential impacts of erosion.

Table 4.5 Summary of operations stage potential impacts for floodplains, including the number of floodplains that meet impact assessment criteria (Table 2.4)

Design Infrastructure Potential Impact Category	Number of floodplains	Number of floodplains by potential impact (# of floodplains that met impact assessment criteria)		
		Erosion	Deposition	Reduced connectivity
1. No Encroachment	1	0 (0)	0 (0)	0 (0)
2. Floodplain sidling	1	1 (1)	0 (1)	0 (1)
3. Floodplain constriction	12	6 (6)	2 (7)	0 (0)
4. Floodplain sidling and constriction	3	3 (3)	1 (3)	0 (3)
Total	17	10 (10)	3 (11)	0 (4)

Table 4.6 Operations stage Floodplain potential impacts (including all cross drainage infrastructure)

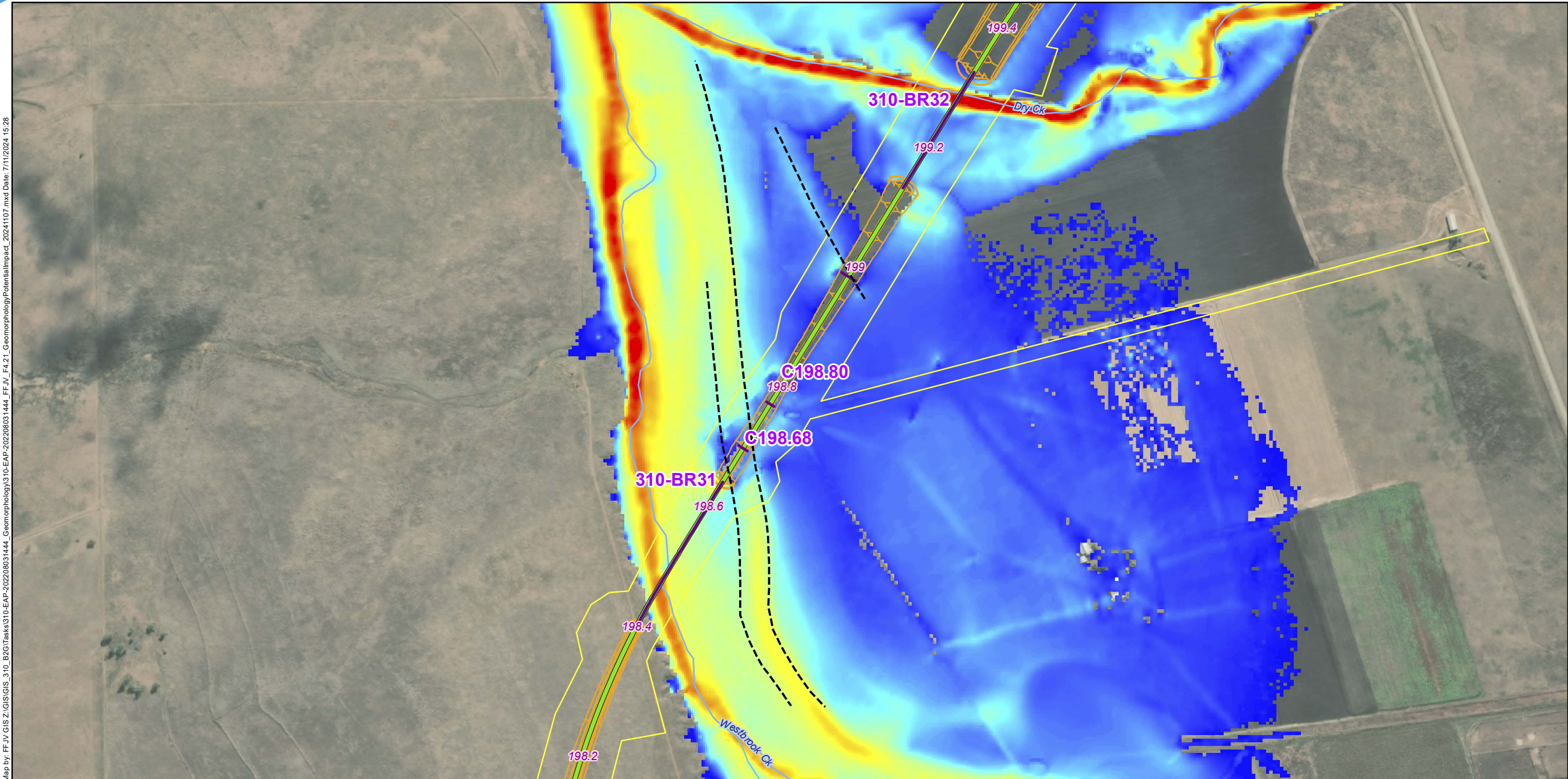
Potential impact category*	Floodplain	Design infrastructure	Sensitivity to change	Refer Table 4.2 for key			Comments
				Erosion	Deposition	Reduced connectivity	
1. No encroachment	Cattle Creek	Main channel bridge that also spans the geomorphic floodplain.	2				No rail infrastructure intersects the floodplain, impacts unlikely.
2. Floodplain sidling	Macintyre Brook	Project alignment does not cross main channel Floodplain culverts	5				20% AEP event, flows ranges from within 10% change from Existing case, no flow to more than 10% decrease in design flow, as these flow velocities are considered sufficient to transport any sediment, potential impacts are unlikely. 1% AEP event downstream flow velocities greater than 10% increase from existing extend beyond scour protection in revised reference design and up to major erosion may occur, minor erosion may also occur upstream on some culverts. Three areas of floodplain sidling all have design cross drainage to mitigation potential reduced connectivity: 31.44 to 32.03 (3 culvert sites) 35.03 to 35.60 (1 culvert site) 42.87 to 45.64 (23 culvert sites)
3. Floodplain constriction	Dry Creek	Main channel bridge	4				Less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely
	One Mile Creek	Main channel bridge	3				Less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely
	Native Dog Creek	Main channel bridge	2				Less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely
	Nicol Creek	Main channel bridge	2				Less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely
	Back Creek 1	Main channel bridge	2				In the 20% AEP event, downstream design flow velocity has a reduction of more than 10%, however flow velocity is >1 m/s and sufficient to transport bedload, impacts are considered unlikely. In the 1% AEP event, downstream design flows show an increase of greater than 10% both upstream and downstream and erosion may occur on the floodplain.

Potential impact category*	Floodplain	Design infrastructure	Sensitivity to change	Refer Table 4.2 for key			Comments
				Erosion	Deposition	Reduced connectivity	
	Four Mile Gully	Main channel bridge Floodplain culvert	2				Floodplain culvert, 20% and 1% AEP downstream reduction in flow velocity of more than 10%, however design flows are greater than Existing Case upstream flows, and impacts are unlikely. Bridge, 1% AEP event, erosion may occur on the floodplain.
	Westbrook Creek	Main channel bridge Floodplain culverts	3				Floodplain culverts, 20% AEP deposition possible. C198.98 has increased design flow velocity more than 10%, however impacts are unlikely as the design flow is only 0.37 m/s, and the culvert has scour protection in the revised reference design. 1% AEP reduction in flow velocity of more than 10%, however design flows assessed as sufficient to transport sediment. C198.98 has increased design flow velocity more than 10%, erosion may occur as the increased erosion extends beyond the scour protection in the revised reference design. Bridge, less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely.
	Condamine River	Bridges over 3 anabranches Flood basin bridge Floodplain culverts	5				Floodplain culverts, 20% AEP, a number of culverts do not flow, the maximum design flow velocity is <0.4 m/s impacts are unlikely. 1% AEP event, erosion may occur at some culvert sites. Floodplain bridge and main channel anabranch bridges, less than 10% change in maximum velocities except for the North Condamine bridge in the 1%, where erosion may occur on the floodplain.
	Back Creek 2	Main Channel Bridge	2				Less than 10% change in maximum velocities for 20% AEP, impacts unlikely. In the 1% AEP event, Back Creek 2 has a design flow velocity of more than 10% less than the Existing Case, however the design flow velocity is ~1.3 m/s and consider sufficient to transport any bedload present
	SC 2	Main Channel Bridge Floodplain culverts	2				Floodplain culverts, 20% AEP aligned to accommodate backflow from embankment. Design results in reduction in flow, particularly downstream (to <0.1 m/s), however as the culvert in this area flows directly back into the main channel, deposition is unlikely to occur during a flood event as any material will be mobilised by flows in the main channel. Bridge, 20% AEP event SC 2 has a design flow velocity of more than 10% less than the Existing Case, however the design flow velocity is ~1.2 m/s and consider sufficient to transport any bedload present. 1% AEP event, downstream erosion may occur on the floodplain.

Potential impact category*	Floodplain	Design infrastructure	Sensitivity to change	Refer Table 4.2 for key			Comments
				Erosion	Deposition	Reduced connectivity	
	SC 7	Main Channel Culvert Floodplain culvert	5				Floodplain culvert located on flood channel, reduction in design flow velocity of more than 10%, however as design flows are approximately 1m/s this reduction in flow will not impact floodplain sediment transport and impacts are unlikely. The natural channel for SC 7 has been impacted by the human made pond upstream and experiences reduced flows, most flow in the Existing Case now goes across the floodplain in the area of this floodplain culvert. Main channel culvert, design flow velocities are reduced and in channel deposition may occur, some deposition may also occur on the floodplain.
	Macintyre River	Main Channel Bridge Floodplain bridges Floodplain culverts	3				Floodplain culverts, 20% AEP, no flow. 1% AEP, increased design flow velocity more than 10%, erosion possible. Main channel and floodplain bridges, less than 10% change in maximum velocities except for one of the floodplain bridges in the 1% AEP, erosion may occur.
4. Floodplain constriction and sidling	MB 6	Main Channel Bridge Floodplain culverts	2				Floodplain culverts, 20% and 1% AEP erosion may occur. Bridge, 20% AEP event, an increase in flow velocity of more than 10% may result in erosion. For the 1% AEP flow event there is a reduction in design flow velocity of more than 10%, however the watercourse has a Non-channelised Valley floor with no evidence for bedload, and therefor potential impacts of increased deposition are considered unlikely. Area of floodplain sidling has design cross drainage to mitigation potential reduced connectivity: ■ 55.4 to 55.36 (2 culvert sites)
	Bringalily Creek	Main Channel Bridge Floodplain culverts	2				Floodplain culverts, 20% AEP, most have no flow. Some culverts have design flow changes greater than 10 per cent of the Existing Case flow velocities, impacts are unlikely due to flow reduction as velocities are sufficient to transport flood sediments, and where elevated, design flow velocities are only up to 0.4 m/s and there is also scour protection in the revised reference design. 1% AEP, deposition and erosion may occur. Bridge, less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely. Area of floodplain sidling has design cross drainage to mitigation potential reduced connectivity: ■ 97.29.03 to 100.69 (9 culvert sites)

Potential impact category*	Floodplain	Design infrastructure	Sensitivity to change	Refer Table 4.2 for key			Comments
				Erosion	Deposition	Reduced connectivity	
	Pariagara Creek	Main Channel Bridge Floodplain culverts	3				Floodplain culverts, 20% AEP, most have no flow. Some culverts have design flow changes greater than 10 per cent of the Existing Case flow velocities, impacts are unlikely as design flow velocities are 0.4 m/s or less and there is also scour protection in the revised reference design. 1% AEP, erosion may occur. Bridge, less than 10% change in maximum velocities for 20% and 1% AEP, impacts unlikely. Area of floodplain sidling has design cross drainage to mitigation potential reduced connectivity: 67.17 to 69.93 (18 culvert sites)

Map by: FF-JV GIS Z:\GIS\GIS_310_B2GIS\Tasks\310-EAP-2022\08031444_Geomorphology\PotentialImpact_20241107.mxd Date: 7/11/2024 15:28

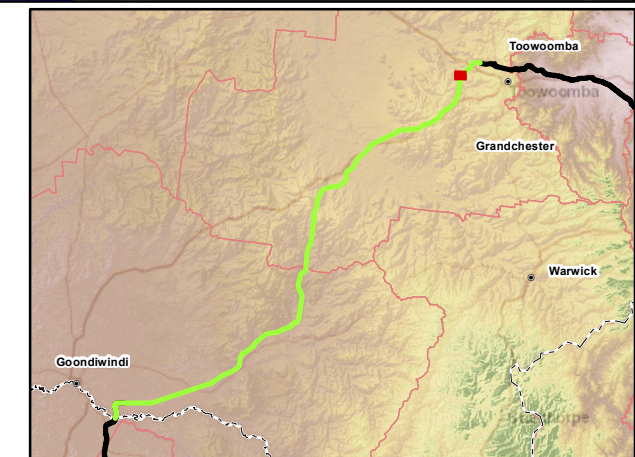


Legend

- 5 Chainage (km)
- Border to Gowrie alignment
- Waterways
- NSW Qld border
- Culvert
- Road Earthworks
- Watercourse potential changes**
- Flood channel

- Impact assessment area**
- Temporary footprint

- Flow Velocity Design Case 1% AEP Event (m/s)**
- High : 3.72
- Low : 0.02



Westbrook Creek floodplain, example of design culvert aligned obliquely to flood channel.



A3 scale: 1:6,000
0 40 80 120 160 200 Metres



Future Freight
Integrating Community, Environment and Engineering

Issue date: 22/08/2022 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure 4.21

Geomorphology Potential Impacts - Bridge 310-BR32, 310-BR31 - Dry Creek, Westbrook Creek

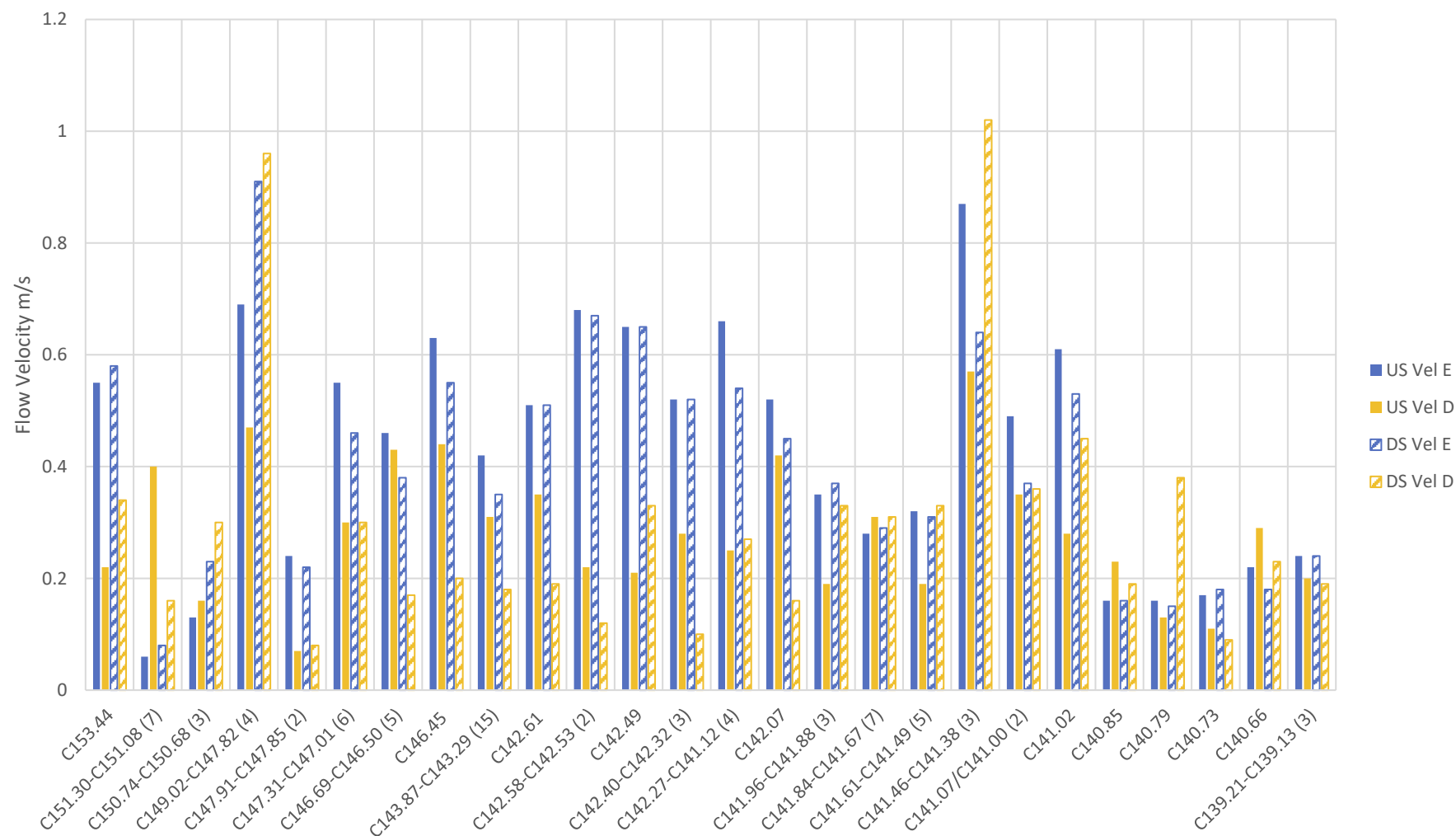


Figure 4.22 Maximum velocities experienced upstream (US) and downstream (DS) during a 1% AEP flood event for existing (E) and design (D) cases for culverts located within the Condamine River floodplain

5 Mitigation

5.1 Mitigation - revised reference design

Development of the revised reference design has progressed in parallel with the impact assessment process. As a result, design solutions for avoiding, minimising or mitigating impacts have been incorporated in the revised reference design as appropriate and where possible. Mitigation measures and strategies have been factored into the revised reference design and will also minimise impacts on the fluvial geomorphic environment as follows:

- The Project uses the existing Southwestern Line and Millmerran Branch Line rail corridors as far as possible to avoid introducing a new linear infrastructure corridor across floodplains and watercourses.
- Greenfield sections of the Project alignment were steered away from flood risk areas, where possible. For example, the Project alignment skirts around the 1% AEP regional floodplains of the Macintyre Brook and Gowrie Creek.
- The Project incorporates bridge and culvert structures to maintain existing flow paths and flood-flow distributions, such as across the Condamine River floodplain, where six bridges have been incorporated into the revised reference design with a combined opening width of greater than 6 km.
- The revised reference design has been developed to avoid the need to permanently divert watercourses, as defined and mapped under the *Water Act 2000*.
- Bridge and culvert structures were located and sized to avoid increases in peak water levels, flow distribution, velocities, duration of inundation and hazard in accordance with the FIOs.
- Watercourse crossing structure hierarchy where bridges are preferred to culverts to minimise impacts to watercourses, riparian vegetation and flora and fauna.
- Progressive refinement of bridge location/extents and culvert banks (location, number of barrels and dimensions) was undertaken as the Project design evolved. This refinement process has considered engineering requirements, as well as input and feedback from stakeholders, to achieve acceptable outcomes that address intent of the FIOs.
- A geomorphology assessment was undertaken to identify locations at high risk of alterations to geomorphic processes from Project infrastructure. Several mitigation measures to include in detailed design were identified as part of the geomorphology assessment, including the relocation of bridge abutments in some areas to avoid watercourse channels.
- Potential blockage of hydraulic structures caused by floodplain debris, as highlighted by stakeholders, has been factored into the revised reference design by allowing an additional 25 per cent flow capacity in culverts, and by placing bridges over major debris transportation paths.
- Stakeholder concerns regarding the dispersive nature of soils in floodplains were addressed in the revised reference design by incorporating scour and erosion protection measures into the design in areas determined to be at risk; such as around culverts headwalls, drainage discharge pathways and bridge abutments. A preliminary ETV assessment was undertaken to inform the scour and erosion protection strategy.
- The revised reference design includes 20 temporary sediment basins within the Project footprint during the construction stage. The number of sediment basins required for the final earthworks design will be confirmed during detailed design. All sediment basins are passive, which allows surface runoff from a catchment to flow into the sediment basin without the need for pumping.

- Scour and erosion protection downstream of culverts has developed since the reference design stage. During the initial reference design stage, the scour protection was designed in accordance with Austroads *Guide to Road Design Part 5B: Drainage—Open Channels, Culverts and Floodways* (2013). Scour protection was specified where the culvert outlet velocities for the 1% AEP event exceeded the recommended soil velocity thresholds. The scour protection length and minimum rock size (d50) were determined from Figure 3.15 and Figure 3.17 in *Guide to Road Design Part 5B: Drainage—Open Channels, Culverts and Floodways* (Austroads, 2013). The Expert Flood Panel identified additional assessment requirements in relation to managing changes to flood flow velocities, summarised below (further detail is included in EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1 (Sections 22.2.1 to 22.2.1.4)).
 - An impact assessment was undertaken against the FIOs using the Existing Case and Development Case hydraulic modelling results to define velocity exceedances on properties external to the permanent Project footprint, based on the revised reference design. A representative and conservative average bare soil ETV value of 0.5 m/s was adopted for the purposes of this impact assessment.
 - Unsealed surfaces likely to be impacted by a velocity FIO exceedance (measured against a target of 0.5 m/s) were identified and reported in the 'Flood Impact Objective Outcomes' sections of each floodplain/local catchment section of this report.
 - In addition to initial scour protection requirements identified, areas immediately downstream of culvert outlets that may experience FIO velocity exceedances were also identified, and additional scour protection allowed for within the revised reference design.
- EIS Appendix AB: Earthworks Strategy and Draft Soil Management Plan has been developed to guide the decision-making process for the management of spoil material generated by the Project. The purpose of the earthwork's strategy is to provide overarching principles to guide the storage, treatment, reuse or disposal of material (including contaminated material) generated during construction of the Project. The main objective of the soil management plan is to document measures that will enable soils to be returned to as near as practical to their pre-existing soil conditions by applying the principles of:
 - Avoiding, minimising, or mitigating impacts to soils
 - Maintaining topsoil quantity and quality
 - Restoring land use and capability
 - Returning the land to a stable, safe, and non-polluting landform (i.e. no subsidence or major erosion) with no greater management inputs than those required prior to land disturbance
 - Minimising the generation of dust from soil disturbing activities.
- The management measures specified in the Earthworks Strategy draft Soil Management Plan will be used to inform the development of the Soil Management Sub-Plan and the Landscape and Rehabilitation Sub-Plan, as components of the Construction Environmental Management Plan (CEMP)
- The draft Soil Management Plan (EIS Appendix AB: Earthworks Strategy and Draft Soil Management Plan) includes both general soil management measures not specific to a soil type as well as specific soil managing measures which include management measures by soil type (including soils that are sensitive to change, such as cracking clays or texture contrast soils)
- General soil management measures in the draft Soil Management Plan are detailed by Project stage. In summary general soil management measures include:
 - Design to reduce erosion potential
 - Development of a rehabilitation and landscaping management sub-plan
 - Development of a stripping procedure
 - Development of soil management plans
 - Development of an Erosion and Sediment Control Plan (ESCP) (concept ESCP).

- Specific soil management measures in the draft Soil Management Plan are included for similar SMUs.
- Suggested monitoring and recording parameters and corrective actions have been identified in Sections 4 and 5 of the draft Soil Management Plan (EIS Appendix AB: Earthworks Strategy and Draft Soil Management Plan). The lists of monitoring and recording parameters and corrective actions are not necessarily comprehensive but provide an indication of the nature and types of parameters and actions required.
- Specific management measures for the identified SMUs are included in EIS Appendix AB: Earthworks Strategy and Draft Soil Management Plan (Table 3-2). This includes Vertosols (black soils and cracking clays) which mainly occur between the Macintyre River and Whetstone, Koorongarra and Gowrie refer EIS Chapter 9 Land Resources (Figure 9-6) for ASC derived from detailed soils investigations within the Project Footprint. Management measures for sensitive and erodible soils such as vertosols (SMUs A1, A2, A3, A4, A5 and B) and sodosols (SMUs H and I) include:
 - Application of gypsum to improve soil structure, stability and workability and mitigate dispersion
 - Care should be taken to avoid exposure of excavated material to erosive flood events or to avoid interference with the normal flow of water
- Soils found on floodplains are susceptible to erosion due to waterlogging and other soil properties commonly found on floodplains (highly saline soils, easily detached sands and silts, etc.). The following management measures are recommended for different sections along the Project alignment that cross over floodplains:
 - Limiting the concentration of water through focus on reducing velocities by encouraging concentrated flows to spread out over the floodplain (location of infrastructure, diversion bunds, etc.)
 - Construction works on floodplains provide a high risk of erosion due to the nature of the works. Management practices, such as maintaining vegetative ground cover for as long as possible prior to earthworks, using tackifiers or spreading mulch, and/or hydromulching/seeding immediately post earthworks, should be considered
 - Construction equipment (i.e. bulldozers, excavators, etc.) can create wheel or track ruts in soil that can lead to concentrated flows and an increase in erosion. Manually ripping and levelling deep ruts or ensuring they are at right angles to the direction of flow can minimise their impacts.

5.2 Mitigation – future Project stages

Detailed design, construction works, and operations stage proposed mitigation and management measures relevant to geomorphology are included in the following EIS appendices:

- EIS Appendix AB: Earthworks Strategy and Draft Soil Management Plan
- EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1.

They have not been reproduced in full detail in this appendix but are listed below.

It is recognised that further refinement and confirmation of site-specific mitigation measures will be undertaken during future detailed design, construction works and operations stages. Where residual geomorphic impacts are not yet reduced to an acceptable level during the revised reference design were identified, ARTC will, in the first instance, investigate alternative design measures directly related to the Project's revised reference design to mitigate these impacts.

The Project's Fluvial Geomorphology Mitigation Framework for detailed design follows the mitigation framework of Flooding and Hydrology (EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1). Where residual risk is not yet reduced to low were identified, ARTC will, in the first instance, investigate alternative design measures directly related to the Project design to mitigate risk. The following mitigation process will be applied in detailed design:

- Step 1: Further design development and refinement
 - Refined flood models further in line with Expert Flood Panel recommendations

- Further detailed consideration of (or investigation into) geomorphic impacts to understand their consequences
- Develop the Project's hydraulic design further (e.g. through additional cross drainage structures, relocation or reconfiguration of cross-drainage structures) to eliminate or reduce geomorphic impacts further.
- **Step 2: Revised design treatments**
 - Introduce alternative cross drainage solutions (e.g. additional cells, alternative types of structures, changes to pipe/box angles, changes to invert levels/grades, spreading of culvert cells)
 - Scour and erosion protection measures
 - Modifications to bridge configurations to minimise encroachment into watercourse channels and geomorphic impacts
 - Flow energy dissipaters.
- **Step 3: Monitoring or adjust and refine**
 - Inspection and monitoring
 - Establish baseline ground conditions through a detailed survey
 - Identify (if any) non-conformances
 - Corrective action, if required.
 - Investigate non-conformances
 - Identification and implementation of corrective/preventative actions
 - Develop reporting, close-out and ongoing maintenance/monitoring requirements
 - Ongoing inspection, maintenance and reporting.

5.2.1 Detailed design

Hydraulic model refinement, detailed survey, soils testing and vegetation information will be gathered to inform detailed design.

Mitigation strategies were developed by ARTC to demonstrate how initial case potential risk may be reduced during detailed design. Modelling was undertaken to demonstrate viability and practicality of the proposed mitigation strategies. This process is summarised in Section 5.2.1.4, additional detail is provided in EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1.

Detailed geomorphic assessments have been undertaken at five sites to demonstrate the effectiveness of the detailed assessment methodology in improving the understanding of baseline conditions and providing input into site-specific future Project stage mitigation measures to reduce risk at potential high risk sites (Section 5.2.1.3).

5.2.1.1 Design

- Detailed design will be undertaken to bring design flow velocities and other FIOs closer to Existing Case to further reduce the risk of erosion/deposition/channel type and landform change. A list of the mitigation options that may be considered, including order of mitigation preference, are included in the EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1. These mitigation measures are for all cross drainage, including overland flow and non-channelised flow, and are summarised below:
 - Culvert locations and spread
 - Culvert grade and invert levels
 - Culvert inlet/outlet realignment to existing flow paths

- A reduction or increase in culvert cell numbers
 - Scour protection at bridge abutments and culvert inlets/outlets
 - Flow baffles/energy dissipators
 - Riparian vegetation.
- Any design modifications during the detailed design stage will be subject to re-runs of the updated existing flood models to demonstrate continued compliance with the design objectives of the Project, including for extent and time of inundation, afflux, hazard and flow velocities. The modelling updates that are required during detailed design, as stipulated by the Expert Flood Panel (and committed by ARTC) are summarised in each catchment chapter in EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1.
 - Reduce short radius bends in any permanent divisions and maintaining as close to natural channel orientation and geometry as possible
 - Consideration of hydraulic jumps will be undertaken during detailed design at locations where the proposed rail alignment is adjacent to existing cross drainage structures
 - Consideration of assessing differences in flow duration at elevated velocities for sites at increased risk of erosion to inform mitigations
 - Ecosystem restoration design, such as channel, pond and woody debris reinstatement, to be considered at detailed design for sites where existing rail infrastructure will be replaced
 - To ensure the dispersive nature of soils is carefully considered and assessed including those in some floodplains, the ETV for natural ground surfaces will be established from a site-specific assessment by a suitably qualified specialist. This site-specific assessment will be in accordance with agreed procedures involving both direct flume measurement and indirect methods where appropriate, in addition to consideration of engineering and soil erosion guidelines. Following the verification ETV testing undertaken in accordance with agreed procedures and in conjunction with the Environmental Monitor, erosion risks will be reassessed to inform the scour and erosion protection strategy. Drainage design, including bridge location/extents and culvert banks (location, number of barrels and dimensions) and flooding mitigations will be re-visited in detailed design in response to updated assessments in line with the Project's approach to the management of flooding; involving FIOs and the framework presented in the Draft Outline Environmental Management Plan (Draft Outline EMP) (EIS Chapter 24: Draft Outline Environmental Management Plan). This includes any erosion treatment, which may be required within and external to the Project footprint. The mitigations and protocols in the soil management plan will also be reviewed following ETV verification analysis.
 - Watercourses with no current hydraulic models to be further assessed at detailed design, including the watercourses listed below:
 - C Ck 4 – in cut
 - C Ck 5 – in cut
 - SC 1 – in cut
 - C Ck 1 – no cross drainage design
 - NC 16 – no cross drainage design
 - PC 1 – no cross drainage design
 - Move bridge embankments >5 m from channel edges for the following sites (Appendix L for geomorphic basis) setback distances to be confirmed during detailed design:
 - Four Mile Gully – Toowoomba Cecil Plains Road Rail Bridge (310-BR20)
 - Back Creek 2 – Bringalily Creek 1 Rail Bridge (310-BR08)
 - NC3 – Biddeston Southbrook Road Rail Bridge (310-BR42)

- C Ck 2 – Millmerran Inglewood Road Rail Bridge #2 (310-BR28)
- Nicol Creek - Nicol Creek Rail Bridge (310-BR11)
- Consider options to move the location of the embankment out of the meander bend in watercourse SC 2, and approximately 100 m west of bridge BR310-37 to reduce geomorphic impacts, setback distances to be confirmed during detailed design
- Design of stabilisation measures for active gully erosion areas within the Project's permanent footprint. The *Soil conservation guidelines for Queensland* includes a chapter on gully erosion and its control (Chapter 13, Carey et al., 2015b) and the *Gully and Stream Bank Toolbox* (Wilkinson et al., 2022), provides guidance on mitigation and management controls, including:
 - Monitor lands susceptible to gully erosion to detect early stages of gully formation
 - Gully reshaping and revegetation
 - Reduce surface runoff into gullies
 - Reduce slope gradient or use stabilising batters with erosion control to aid establishment of vegetation
 - Leave woody debris in the gully floor (unless it is blocking a drainage structure), this prevents further gully erosion and allows the floor to gradually silt up and reduce the fall over an upstream head
 - Fencing gully erosion to control stock access and managing stock water points
 - Porous check dams
 - Gully runoff diversion banks and drainage management
 - Management guidance for cropping lands
 - Monitoring and maintenance.
- Design for high sediment transport areas, such as those sites with active gully erosion, to allow for the sediment to pass through culverts, by such measures as:
 - Maintaining Existing Case flow velocities
 - Monitoring and removal of any sediment/woody debris build up adjacent to the infrastructure, or
 - Design of structures such as sediment inlet traps to manage potential sediment build-up such that it does not block the culvert.
- Supplementary testing using direct methods (flume testing), additional assessment and subsequent ETV determination based on revised results is currently underway at a number of potentially high-risk sites including on floodplains and overland flow paths. Relevant mitigations including those relating to erosion treatment options within and external to the corridor will be reviewed and revised as necessary based on the updated analysis.

5.2.1.2 Management Plans

- Development of the draft Soil management sub-plan that is included as EIS Appendix AB: Earthworks Strategy and Draft Soil Management Plan that includes the following relevant to the reduction of potential impacts on the fluvial geomorphic environment such as:
 - Specific management measures for the identified SMUs are included in EIS Appendix AB: Earthworks Strategy and Draft Soil Management Plan (Table 3-2). This includes Vertosols (black soils and cracking clays) which mainly occur between the Macintyre River and Whetstone, Koorongarra and Gowrie, refer EIS Chapter 9: Land Resources (Figure 9-6) for ASC derived from detailed soils investigations within the Project Footprint. Management measures for sensitive and erodible soils such as vertosols (SMUs A1, A2, A3, A4, A5 and B) and sodosols (SMUs H and I) include:
 - Application of gypsum to improve soil structure, stability and workability and mitigate dispersion

- Care should be taken to avoid exposure of excavated material to erosive flood events or to avoid interference with the normal flow of water
- Development of a Concept ESCP as a component of the CEMP soil management sub-plan that includes the following procedures and protocols relevant to potential impacts on the fluvial geomorphic environment:
 - Locations for specific temporary/permanent erosion and sediment control measures, such as: Sediment retention basins; scour protection included in the revised reference design; sediment fencing; berms and other surface flow diversions
 - Nomination of location-specific erosion controls will include consideration of site conditions, proximity to environmental receptors, adjoining land uses, climatic and seasonal factors, and will be based on an erosion risk assessment
 - Minimise the area of disturbance during each stage to that required to enable safe construction, operation and maintenance
 - Scheduling of works with consideration of periods of higher rainfall (summer months).
- Develop construction plans and schedules to include considerations to the adjacent waterways, such as:
 - Construction tasks scheduled to avoid, where possible, bulk earthworks within the 1% AEP level during periods of elevated flood risk
 - Plan work sites and equipment storage to minimise the chance that an unexpected flood could cause blockage of the channel
 - Develop contingency plans to prepare sites and remove equipment if significant weather events are forecast
 - Plan for inspections to be carried out during operation to monitor floodway and drainage system capacity.
- Develop a Rehabilitation and Landscaping Management Plan, to include:
 - Location-specific objectives for rehabilitation, reinstatement and/or stabilisation. Outside the rail corridor, property-specific and township-specific rehabilitation and landscaping requirements may apply. Within the rail corridor, maintaining operational safety and rail formation stability will be the driving factors.
 - Objectives and timeframes for rehabilitation and/or reinstatement/stabilisation works (including biodiversity, vegetation establishment and erosion and sediment control outcomes to be achieved)
 - Details of the actions and responsibilities to progressively rehabilitate, regenerate, and/or revegetate areas, while minimising the duration of exposure in disturbed areas
 - Include rehabilitation requirements such as:
 - Removal of any decommissioned culverts
 - Topsoiling and/or compost blanketing
 - Stabilisation and rehabilitation (e.g. planting and or seeding)
 - Native flora species endemic to the Darling Downs and Toowoomba regions or other suitable species appropriate to the landscape context and nursery/seed stock sources.
- Consideration of the controls detailed within the Department of Primary Industries (1988) *Floodplain management for erosion control and high productivity on the Darling Downs* document, will be undertaken during the detailed design stage to further refine management plans, in particular:
 - Permanently grass areas at culvert inlets and outlets to spread flow and reduce erosion potential, recommended grass species include, Water couch, Silk sorghum, or Native blue grass

- Mitigation of active gullies. Active gullies that are subject to concentrated flows can be stabilised and eventually repaired by the combined use of a series of low earth sills and stabilising grass species such as African star grass. The sills create ponding and cause local deposition of silt, an ideal environment for grass to grow and eventually stabilise the gully. Each sill should bank water up to the toe of the sill above. They should be grassed as soon as possible after construction to prevent erosion. An alternative to sills is to plant a vigorous grass species such as Silk sorghum along the edges of and in the gully. Soil caught in the vegetation will gradually reduce the gully depth. It is assumed that these are relatively newly formed shallow gullies.
- Additional fluvial geomorphology considerations for management plans
 - Re-instatement design to take into account the original landform setting, along with the new infrastructure to ensure sustainable functioning of runoff (i.e. slopewash, non-channelised flow, overland flow paths etc), channels, and floodplain environments in and around the ground disturbance areas
 - Where ground disturbance has occurred, return to a state that functions appropriately within the context of the pre-disturbance fluvial geomorphic (i.e. soil and landform) environment
 - Sodosols and vertosols are highly susceptible to rilling and gullying if disturbed, it is vital that ground cover is established quickly during construction. Consider methods to distribute flow and reduce direct downslope flow during construction such as surface contouring or temporary low brush fencing. Consider the use of grasses effective at stabilising vertosol soils.
 - As part of erosion and sediment controls, location-specific erosion and sediment control measures and a Rehabilitation and Landscape Management Sub-plans, revegetation establishment will be done with suitable, native species (e.g. Water couch and Native (Aussie) blue grass) appropriate to the landscape context and nursery/seed stock sources. Refinement of ESCP and Rehabilitation and Landscaping Management Plan will be undertaken during detailed design.

5.2.1.3 Detailed assessments summary

These assessments demonstrate the effectiveness of the detailed assessment methodology in improving the understanding of baseline conditions and providing input into site-specific future Project stage mitigation measures to reduce risk at potential high-risk sites.

Detailed assessments were undertaken at five sites (Appendix L). The mitigation measures identified from the detailed assessments include:

- NC11: The initial case was high risk due to erosion and channel type change potential impacts.
 - The design results in an increase in velocity for ~40 m downstream of the culvert. This could result in erosion in areas where the channel is formed in silty clay material, particularly where bare soil is exposed. Erosion is unlikely in rock-lined sections of channel.
 - Proposed mitigation measures for this site include additional culvert capacity to reduce flow velocity, channel protection and monitoring.
- SC7: The initial case high was risk due to the potential impact of deposition.
 - Detailed site assessment showed there is minimal bedload being transported in the channel, thus the reduced flow velocities in the design are unlikely to result in deposition.
- C Ck16: The initial case was high risk due to the potential impact of deposition.
 - Detailed site assessment showed design flow velocities are likely to transport almost all of the available bedload

- Large woody debris is present in the gully floor. Channel constriction may also lead to accumulation/blockage of the culvert from woody debris upstream that is too large to pass through the culvert. Routine maintenance would prevent this from having potential alterations to the geomorphic processes. The installation of screens/racks at the culvert inlet would aid collection and removal of woody debris, as the woody debris would be less likely to get jammed within the culvert.
- Gully erosion will continue to develop at this site, and the Project presents an opportunity to undertake mitigations works in this area to reduce this erosion. Additional proposed mitigation measures to minimise gully development are included in Section 5.2.1.1.
- C Cs21: The initial case was high risk due to the potential impact of deposition.
 - Detailed site assessment showed design flow velocities are likely to transport almost all of the available bedload
 - Large woody debris is present in the gully floor. Channel constriction may also lead to accumulation/blockage of the culvert from woody debris upstream that is too large to pass through the culvert. Review culvert dimensions during detailed design to consider transport of woody debris, as the revised reference design is for a single 1.35 m diameter pipe culvert, and woody debris up to 6 m long by 0.3 m diameter was observed in the channel. Routine maintenance would prevent this from having potential alterations to the geomorphic processes. The installation of screens/racks at the culvert inlet would aid collection and removal of woody debris, as the woody debris would be less likely to get jammed within the culvert.
 - Gully erosion will continue to develop at this site, and the Project presents an opportunity to undertake mitigation works in this area to reduce this erosion. Additional proposed mitigation measures to minimise gully development are included in Section 5.2.1.1.
- SC 2: The initial case was high risk due to planform and channel type change potential impacts at a modified and complex site.
 - Encroachment of the west bridge embankment at the apex of the meander bend approximately 100 m west of the crossing will stop southwards migration of the bend and may result in impacts to the long- term watercourse planform behaviour
 - The watercourse could avulse, and if so, the water would flow for 50 m along the side of the embankment. As such, the embankment would need some form of erosion protection. This would result in adverse geomorphic effects. However, this section of the channel has already been modified previously with an earth embankment to contain the flow, and no active erosion on the outside of the bend was observed. Therefore, the avulsion risk is considered to be very low in the short to medium term.
 - Options to move the embankment out of the channel are recommended to be considered during detailed design to reduce potential risk further if required.

5.2.1.4 Reduction in fluvial geomorphic risk afforded by design measures

The first step in the mitigation framework is to eliminate the risk where possible. Where the risk cannot be eliminated, design modifications can be undertaken to reduce the risk to acceptable levels. During the detailed design stage of the Project, design modifications will be an iterative process in which there will be re-runs of the existing models to demonstrate continued compliance with design objectives of the Project. As a part of this assessment, mitigation measures can be embedded within the Project design to further reduce potential impacts to the fluvial geomorphic environment across the Project alignment. Dependant on the outcomes of the detailed design modifications, the following mitigation measures will be further explored in order to mitigate and reduce potential impacts:

- Culvert location
- Culvert grade and invert levels

- Culvert inlet/outlet realignment to existing flowpaths
- A reduction or increase in culvert cell numbers.

To demonstrate the effectiveness of the design mitigation measures, a representative sample of culvert sites were selected and TUFLOW hydraulic model simulations conducted at these locations with varying degrees of mitigation applied. The outcomes of this assessment are detailed in EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1 and have been summarised below. These additional mitigations are not currently in the revised reference design and are for demonstration purposes.

Four sites (of multiple culvert locations) as listed in Table 5.1 were selected along the Project alignment to demonstrate the effectiveness of proposed mitigation measures. The sites include watercourses, geomorphic floodplains, and overland flow on hillslopes (assessed under the hydrology and flooding EIS aspect against FIOs).

The outcomes of the mitigations on afflux (increased upstream ponding) and flow velocity are most relevant for fluvial geomorphology and are summarised below in Table 5.2. The outcomes of the mitigations are reported on for all FIOs in EIS Appendix T1: Hydrology and Flooding Technical Report – Volume 1. The demonstration confirmed that the mitigation measures can result in reduced potential impacts at the sites.

Table 5.1 Mitigation modelling - Site selection

Site ID	Watercourse Type	Watercourse ID	Initial Case risk outcome – Fluvial Geomorphology	Culvert ID	FIO exceedances for all events up to and including the 1% AEP event
1	Headwater	MB 2	Medium ■ due to planform change	C62.94	Afflux, velocity, hazard, time of inundation
	Headwater	MB 1	Medium ■ due to planform change	C63.15	
2	Overland Flow on Hill slopes ¹	N/A	N/A	C77.20	Afflux, velocity, hazard, duration of inundation
	Headwater	CCs 19b	N/A ²	C77.47	
	Headwater	CCs 19a	N/A ²	C77.77	
3	Headwater	C Ck 13	N/A ²	C84.38	Afflux, velocity, hazard, duration of inundation
	Headwater	CCs 16		C85.35	
4	Overland Flow on Hill slopes ¹	N/A	N/A	C119.74	Velocity, hazard, duration of inundation
				C119.88	
				C120.08	
	Floodplain Type B3	SC7 - floodplain	Low ■ reduction in flow velocity	C120.25	
	Local - poorly developed channel	SC 7	High ■ due to increased deposition potential	C120.31	

Table notes:

- 1 Overland Flow on Hill slopes not assessed under geomorphology, assessed under the hydrology and flooding EIS aspect against FIOs.
- 2 Watercourses with very small catchments, <10 hectares, and no formed channel, assessed under the hydrology and flooding EIS aspect against FIOs.

Table 5.2 Summary of mitigations modelled and outcomes

Site ID	Amendments to culvert structure configurations	Largest post mitigation change in hazard
1	Increase in box culvert span Increase in culvert cell numbers and spread along the Project alignment Culvert inlet/outlet realignment to existing flow paths.	Reduction in maximum afflux from 344 to 39 mm Reduction in area impacted by afflux from 0.183 to 0.015 ha Reduction in maximum flow velocity and impacted area to within 10% of the Existing Case.
2	Increase culvert barrel numbers and spread along the Project alignment Culvert inlet/outlet realignment to existing flow path Modification of culvert invert levels Inlet/outlet works to direct runoff through culvert structures	Reduction in maximum afflux from 372 to 254 mm Reduction in area impacted by afflux from 0.322 to 0.133 ha Reduction in maximum change in flow velocity from 21.8% to 6.8% Reduction in area impacted by maximum change in flow velocity from 0.374 to 0.022 ha.
3	As for Site 2	Reduction in maximum afflux from 440 to 144 mm Reduction in area impacted by afflux from 0.596 to 0.044 ha Reduction in maximum change in flow velocity from 170.4% to 73.0% Reduction in area impacted by maximum change in flow velocity from 0.362 to 0.030 ha.
4	As for site 2	Reduction in maximum change in flow velocity from 92.1% to 22.2% Reduction in area impacted by maximum change in flow velocity from 1.122 to 0.463 ha.

5.2.2 Pre-construction works, early works and construction works

The following mitigations are for both watercourses and floodplains.

- Baseline survey as per EIS Appendix T: Hydrology and Flooding Technical Report – Volume 1 and 2. In summary, prior to any construction works, a baseline survey will first be undertaken at cross-drainage structures and any other relevant stormwater-related infrastructure, to confirm the occurrence of, or pre-existence of, scour. The survey shall include the following:
 - Topographic data
 - Collation of aerial imagery to depict the pre-existing terrain land usage and landforms
 - The width and lateral extent of the data listed in the previous two data points will include the permanent rail corridor and any temporary construction works zones and corridors. The minimum extent of this data upstream and downstream of the structures will be confirmed during the detailed design stage.
- Assess initial site conditions and install initial erosion and sediment controls to facilitate establishment works and to support pre-construction minor civil works (e.g. establishing laydown areas), in accordance with the approved Soil Management Plan
- Monitor the effectiveness of erosion controls installed as part of the environmental inspection schedule for the Project as detailed in the approved Construction Environmental Management Plan
- Controls that are found to be failing or not performing as intended will either be modified or replaced as required.

The following construction works mitigations are for both watercourses and floodplains.

- Completion of flood risk assessments including:
 - Prior to construction to determine any potential changes in flood risk as a result of staged construction activities that occur within the 1% AEP event floodplain

- The flood risk assessments will include frequent design storms (i.e. 2 Exceedances per Year (EY), 1 EY, 39% AEP, 20% AEP, capped at a 10% AEP event) given the temporary and short-term nature of construction activities
- Larger (rarer) flood events will be considered on a case-by-case basis, as deemed necessary and where the risk profile of the proposed construction works would warrant it
- Where there are interfaces between other Inland Rail projects, flood risk assessments will be undertaken in consultation with other projects to ensure consideration of the whole of Inland Rail impacts is undertaken rather than isolated cases.
- Construction works will be guided as part of the Flood Risk Assessments via the following principles:
 - No re-direction of flood water flow
 - No adverse increases to flood levels at flood sensitive receptors
 - Maintain existing velocities where practical
 - Erosion and sediment control is managed in accordance with the Construction ESCP.
- Reinstatement, stabilisation and rehabilitation of disturbed areas will be undertaken progressively, consistent with the Rehabilitation and Landscaping Management Plan
- The locations of the laydown areas have been chosen to avoid areas that are within the 1% AEP floodplains where possible. However, by virtue of the requirement of laydown areas for constructing bridges, some laydown areas must be within floodplains and near watercourses or drainage features. Laydown areas and other temporary construction facilities that are located within the 1% AEP event inundation extents will be short-term in use. In such instances, the following precautions will be taken:
 - The potential site will be surveyed prior to site establishment to understand the exact extent of potential flooding impact to facilities and storage areas
 - The earthworks and temporary drainage will be designed to minimise flooding impacts
 - Critical equipment would be placed on earthworks and plinths that raise it above the predicted 1% AEP water level
 - Hazardous goods will not be bulk stored in these locations
 - Fuel will only be stored on laydowns outside the 1% AEP water level
- Mobile plant will not be stored in the 1% AEP when not scheduled or in use for construction purposes
- A baseline survey will be undertaken at cross-drainage structures and any other relevant stormwater-related infrastructure, to confirm the occurrence of, or pre-existence of, scour. The future occurrence (or worsening) of scour associated with the construction or operation of the Project will be evident in comparison with the baseline survey. Equally, the pre-existence of scour in advance of any construction or operational works will also be evident in reviewing the baseline survey.
- Monitoring for scour at cross-drainage structures (and any other relevant stormwater-related infrastructure) during the construction works stage shall be undertaken on the following periodic basis:
 - Following rainfall events that have generated significant flow through either permanent or temporary cross-drainage structures (or at any other relevant stormwater-related infrastructure); or
 - Frequency is to be determined by ARTC during the detailed design stage.
- Where clear evidence of scour is observed as per the monitoring data, this will be contrasted against the baseline survey data to confirm whether it is: (a) pre-existing scour with no observed change; (b) pre-existing scour that has been clearly exacerbated; or (c) newly generated scour

- If the findings point to (b) or (c) above, as per requirements under the CEMP monitoring requirements (detailed in EIS Chapter 24: Draft Outline Environmental Management Plan), an engineer will document this in a report of their findings and recommend mitigation/remediation measures which will be implemented on-site as soon as practicable. This may include, but is not limited to:
 - Terrain remediation and/or stabilisation, including vegetation and/or revegetation strategies, or the introduction of other natural forms of energy dissipation
 - Dumped rock (riprap) (i.e. flexible erosion protection measures).
- Reinstatement, stabilisation and rehabilitation of disturbed areas will be undertaken progressively, consistent with the Rehabilitation and Landscaping Management Plan
- Excavation will be undertaken in a manner to prevent erosion or landslip, working faces will be limited to safe height and slopes, with surfaces drained to avoid ponding and erosion
- Monitor the effectiveness of erosion controls installed as part of the environmental inspection schedule for the Project, as prescribed in the CEMP. Controls that are found to be failing or not performing as intended will either be modified or replaced, as required.

5.2.2.1 Construction activities in defined watercourses

In some instances, it will be necessary to undertake construction works in defined watercourses. In-stream works will be undertaken in accordance with the requirements of the *Riverine Protection Permit Exemption Requirements* (Department of Regional Development, Manufacturing and Water, 2023):

- Disturbance areas will be minimised and work zones delineated to ensure areas of disturbance are limited
- Appropriate erosion and sediment controls will be implemented and monitored in accordance with the ESCP
- Excavation will be undertaken in a manner to prevent erosion or slip, working faces shall be limited to safe height and slopes, with surfaces drained to avoid ponding and erosion
- Reinstatement, stabilisation and rehabilitation of disturbed areas will be undertaken progressively and in accordance with the site Rehabilitation and Landscaping Management Plan
- Stockpiling of material will be undertaken away from defined watercourses in accordance with the ESCP
- In the event of wet weather, the following additional controls would be implemented:
 - Contractors subscribed to Bureau of Meteorology Flood Warning notifications
 - Protection of exposed bank areas by geofabrics or similar
 - Removal of any construction waste and equipment away from potential areas of inundation and watercourses.

5.2.3 Operations

During the operations stage of the Project, ongoing monitoring will occur to ensure impacts, including scour and erosion, due to the Project alignment are minimised. Inspections and monitoring will be undertaken in accordance with the outline construction works stage and operations stage 'Erosion Monitoring and Mitigation Plan' as detailed within EIS Chapter 24: Draft Outline Environmental Management Plan and EIS Chapter 14: Flooding and Geomorphology. The following monitoring programs may be implemented:

- Inspections will be carried out on waterway and drainage systems and erosion at prescribed intervals (frequency is to be determined by ARTC during the detailed design stage) pre-commencement of operations
- Physical inspection may be implemented in any defined high-risk or sensitive areas, or where it might be deemed preferable and more suitable

- Where clear evidence of scour is observed as per the monitoring data, this will be contrasted against the baseline survey data to confirm whether it is (a) pre-existing scour with no observed change, (b) pre-existing scour that has been clearly exacerbated, or (c) newly generated scour
- If the findings point to (b) or (c) above, as per the Operations EMP monitoring requirements (detailed in EIS Chapter 24: Draft Outline Environmental Management Plan), an engineer will document this in a report of their findings and recommend mitigation and/or remediation measures to ensure the integrity of the drainage system is reinstated and any impact outside the Project's permanent footprint rectified as soon as practicable and in consultation with the relevant landowner/asset manager.
- Where defects are identified and corrective actions are required, these works will be completed in accordance with the Outline EMP for the Project
- Asset inspections will be completed as soon as safe access can be achieved following a flood event.

6 Risk assessment

Initial risk assessment of potential alterations to geomorphic processes from the Project has been undertaken for the current revised reference design. A residual risk assessment of potential alterations to geomorphic processes from the Project was then undertaken after proposed mitigations, post-Project approval, have been implemented; including consideration flooding and hydrology mitigations, such as FIOs, where relevant.

Fluvial systems are dynamic, and change is expected under natural conditions. All the fluvial systems in the Project footprint are undergoing geomorphic change: some change very slowly and change has not been identified since the earliest aerial imagery was captured; some systems change more quickly. The risk assessment is focused on establishing the risk of the Project adversely altering the existing fluvial geomorphic processes. A site with an Existing Case (pre-Project) high sensitivity to change, such as a gully, can be subject to low risk of adverse change through appropriate infrastructure design. These sites would still have a high sensitivity to change during operation of the Project, but the Project would have a low risk of contributing to the occurrence of erosion. Conversely, a site with low sensitivity to change can be subject to high risk of adverse change through 'inappropriate' infrastructure design. Hence, the design approach is the critical factor in achieving the desired outcome and reducing the potential impacts of the Project on the natural systems.

The risk assessment of potential impacts on geomorphic processes by the Project is summarised in Table 6.1 including pre-construction activities and early works, construction works and operations stages. Sections 6.1 and 6.2 provide further detail on the risk assessments undertaken for individual watercourse and floodplains.

Pre-construction activities and early works, and construction works were initial case medium risk for erosion for both watercourses and floodplains. Other potential impacts had a low risk. Residual risk for erosion was medium.

Fourteen initial case high risk sites were identified for operations stage potential impacts on watercourses, including:

- Six sites with high initial risk of planform and channel type change.
- Six sites with high initial risk of deposition
- One site with high initial risk erosion and channel type change.
- One site with high initial risk of planform change.

The residual risk for all these sites is low. Thirty-two initial case medium risk sites were identified, the majority of these were for the potential impact of planform change, which can be mitigation by aligning the culvert to flow. All medium risk initial case sites have a low residual risk.

Operations stage potential impacts to floodplains are low for both initial case and residual risk. This is largely due to the fact that floodplains generally experience flow in less frequent events, where flows do occur in more frequent events, there is typically scour in the revised reference design, which drives the potential risk down.

Table 6.1 **Summary risk assessment**

Aspect	Potential Impact	Stage	Potential impacts of the Project on existing geomorphic processes					
			Initial risk ¹			Residual risk ²		
			Likelihood	Consequence	Risk ³	Likelihood	Consequence	Risk
Channel	Erosion: - Bank retreat - Scour holes - Bed degradation - Erosion of in-channel features, e.g. ponds, pools, woody debris, bars.	Pre-construction activities and early works, construction works	Possible	Moderate	Medium	Possible	Minor to Moderate	Medium
		Operations	Possible	Not-significant to major	74 Low	Possible	Minor	Low
					10 Medium			
					1 High			
	Deposition: - Bed aggradation - Bar aggradation - Pond, pool infilling.	Pre-construction activities and early works, construction works	Possible	Minor	Low	Possible	Minor	Low
		Operations	Possible	Not-significant to major	77 Low	Possible	Minor	Low
					2 Medium			
					6 High			
	Planform Change - Meander bend migration - Avulsion.	Pre-construction activities and early works, construction works	Possible	Not significant	Low	Possible	Not significant	Low
		Operations	Possible	Not-significant to major	50 Low	Possible	Moderate	Low
					28 Medium			
					7 High			
	Channel type change Change from one channel type to another, e.g. change from non-channelised valley floor to low sinuosity channel	Pre-construction activities and early works, construction works	Possible	Moderate	Medium	Possible	Minor to Moderate	Medium
		Operations	Possible	Not-significant to major	70 Low	Possible	Minor	Low
					9 Medium			
					6 High			

Aspect	Potential Impact	Stage	Potential impacts of the Project on existing geomorphic processes					
			Initial risk ¹			Residual risk ²		
			Likelihood	Consequence	Risk ³	Likelihood	Consequence	Risk
Floodplains	Erosion: - Scour holes - Floodplain stripping - Erosion of floodplain landforms such as wetlands, ponds. - Development of gullies/ bad lands	Pre-construction activities and early works, construction works	Possible	Moderate	Medium	Possible	Minor to Moderate	Medium
		Operations	Possible	Not significant to minor	Low	Possible	Not significant to minor	Low
	Deposition: - Deposition in drainage infrastructure - Infill of floodplain landforms such as flood channels, wetlands, ponds and pools - Fines in railway ballast.	Pre-construction activities and early works, construction works	Possible	Minor	Low	Possible	Minor	Low
		Operations	Possible	Not significant to minor	Low	Possible	Not significant to minor	Low
	Reduced floodplain connectivity	Pre-construction activities and early works, construction works	Possible	Not significant	Low	Possible	Not significant	Low
		Operations	Possible	Not significant	Low	Possible	Not significant	Low

Table notes:

- 1 Includes implementation of initial mitigation measures specified in Section 5.1
- 2 Assessment of residual risk once the Project's mitigation measures for future stages identified in Section 5.2 have been applied
- 3 Operations stage risk to watercourses and floodplains from the Project has been assessed individually (Section 6.1 and 6.2). Some watercourses may be high risk for more than one potential impact. Refer Section 6.1 for the risk listed by watercourse.

6.1 Operations stage risks– watercourses

The operations stage spans a longer time frame than the pre-construction and early works and construction works stage and has a higher likelihood of experiencing geomorphically significant events, namely bank full (20% AEP event) and full floodplain flow conditions (1% AEP event). Therefore, the risk assessment was undertaken on individual watercourses and floodplains for operations stage impacts.

The risk assessment methodology is outlined in Section 2. Likelihoods assessed for include 'possible' and 'rare', as these are the most geomorphically significant time periods, refer Section 2.5.1 for further details. As the main likelihoods to be assessed for are already established, the risk assessment mainly comprises deriving initial and residual consequence levels for the potential impacts identified in Section 4, and applying this to the risk matrix in Section 2.5 to derive initial and residual risk.

Operations stage risks for watercourses have been assessed by design infrastructure type, and are summarised in the following tables, Table 6.2 for bridges, Table 6.3 for culverts and Table 6.4 for diversions, cuts and watercourses with no design cross drainage.

Table 6.2 Operations stage risks– watercourses bridges

Potential impact category	Potential impacts on watercourse channel	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential risk of impacts of the Project on existing geomorphic processes					
					Initial risk ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
1. No encroachment	Impacts unlikely.	Cattle Creek Rail Bridge (310-BR06)	Cattle Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
2. Floodplain encroachment by one/both abutments	Impacts unlikely.	Condamine River Main Branch Combined Rail Bridge (310-BR25/26)	Condamine River	5	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
		Grasstree Creek Rail Bridge (310-BR21/22)	Grasstree Creek	2	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
		Native Dog Creek Rail Bridge (310-BR07)	Native Dog Creek	2	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
		Westbrook Creek Rail Bridge (310-BR31)	Westbrook Creek	3	Not Significant	Not Significant	Low	Minor-Moderate	Minor-Moderate	Low
		Macintyre River Viaduct Span A (270-BR11A)	Macintyre River	3	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
	20% AEP event impacts unlikely. 1% AEP erosion.	Condamine North Branch Rail Bridge (310-BR27)	Condamine North Branch	US - 4 DS - 1	Not Significant	Minor	Low	Not Significant	Minor	Low
	20% AEP event impacts unlikely. 1% AEP erosion.	Back Creek Rail Bridge (310-BR38)	Back Creek 1	2	Not Significant	Major	Low	Not Significant - Minor	Minor	Low
	Impacts unlikely.	UT1 Macintyre Brook Rail Bridge (310-BR03)	MB 7	1	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low

Potential impact category	Potential impacts on watercourse channel	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential risk of impacts of the Project on existing geomorphic processes					
					Initial risk ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
3. Floodplain encroachment/sidling by one/both abutments	Impacts unlikely.	Dry Creek Rail Bridge (310-BR32)	Dry Creek	4	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
		Bringalily Creek 3 Rail Bridge (310-BR10)	Bringalily	2	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
		Pariagara Creek Rail Bridge (310-BR05)	C Ck 18	3	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
			Pariagara Creek	3	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
4. Floodplain encroachment by abutment up to channel edge	20% Planform and channel type change 1% Planform and channel change (major) and erosion (minor/moderate)	Toowoomba Cecil Plains Road Rail Bridge (310-BR20)	Four Mile Gully	1	Major	Major	High	Minor	Minor	Low
		Milmeran Inglewood Road Rail Bridge (310-BR37)	SC 2	4	Major	Major	High	Minor	Minor	Low
	Planform and channel type change	Nicol Creek Rail Bridge (310-BR11)	Nicol Creek	2	Moderate to Major	Moderate to Major	High	Minor	Minor	Low
		Bringalily Creek 1 Rail Bridge (310-BR08)	Back Creek 2	2	Moderate to Major	Moderate to Major	High	Minor	Minor	Low

Potential impact category	Potential impacts on watercourse channel	Bridge name (Bridge ID)	Watercourse	Sensitivity to change	Potential risk of impacts of the Project on existing geomorphic processes					
					Initial risk ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
5. Watercourse encroachment by one/both abutments	Planform and channel type change MB 6 also has minor increased erosion potential in the 20% AEP event.	Biddeston Southbrook Road Rail Bridge (310-BR42)	NC3	1	Major	Major	High	Minor	Minor	Low
		Oakey Pittsworth Road Rail Bridge (310-BR30)	NC 9	4	Moderate	Major	Medium	Minor	Minor	Low
		Milmerran Inglewood Road Rail Bridge #2 (310-BR28)	C Ck 2	1	Moderate to Major	Moderate to Major	High	Minor	Minor	Low
		UT2 Macintyre Brook Rail Bridge (310-BR04)	MB 6	2	Moderate	Moderate to Major	Medium	Minor	Minor	Low

Table notes:

Minor to Moderate: the highest consequence has been used to derive the risk

Moderate to Major: the highest consequence has been used to derive the risk

Existing Case sensitivity to change: 1= Low; 5= High, in terms of potential for change, Section 2.2.5 provides further details.

¹ Includes implementation of initial mitigation measures specified in Section 5.1

² Assessment of residual risk once the Project's mitigation measures for future stages identified in Section 5.2 have been applied

Table 6.3 Operations stage risks– watercourses culverts

Potential impact category	Potential impacts	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
					Initial risk assessment ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
1. Within 10% of existing flow	Impacts unlikely.	C164.29	NC 14	2	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
		C125.48	SC 3	2	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
2. Upstream within 10% of existing flow, downstream decrease	20% AEP Deposition	C193.10	One Mile Creek	4	Minor to moderate	Major	Medium	Not Significant to Minor	Minor	Low
	Planform change	C87.37	C Ck 12	4	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
	Planform change Deposition	C84.38	C Ck 13	2	Minor	Moderate	Low	Not Significant to Minor	Minor	Low
	Planform change	C30.60	MB 10	4	Minor	Moderate	Low	Not Significant to Minor	Minor	Low
3. Upstream within 10% of existing flow, downstream increase	Erosion, planform and channel type change.	C124.44	SC 4	1	Moderate	Moderate to Major	Medium	Minor	Minor	Low
4. Upstream decrease, downstream within 10% of existing flow	Planform change	C207.15	OC 1	4	Minor to moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Planform change	C186.16	NC1	4	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Impacts unlikely.	C181.21	NC 6	2	Not Significant to Minor	Not Significant to Minor	Low	Not Significant to Minor	Not Significant to Minor	Low
	Impacts unlikely.	C178.63	NC 7	2	Not Significant to Minor	Not Significant to Minor	Low	Not Significant to Minor	Not Significant to Minor	Low
	Impacts unlikely.	C176.89	NC 8	2	Not Significant to Minor	Not Significant to Minor	Low	Not Significant to Minor	Not Significant to Minor	Low
	Planform change	C118.43	SC 9	4	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low

Potential impact category	Potential impacts	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
					Initial risk assessment ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
	Impacts unlikely at the 20% AEP. 1% AEP erosion.	C117.60	SC 10	2	Not Significant to Minor	Moderate to Major	Low	Minor	Minor	Low
	Impacts unlikely	C113.07	C Ck 7	4	Not Significant to Minor	Not Significant to Minor	Low	Not Significant to Minor	Not Significant to Minor	Low
	Planform change	C79.01	C Ck 15	4	Minor to moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Deposition	C73.68	C Ck 16	5	Moderate to Major	Moderate	High	Minor	Moderate	Low
	Deposition	C61.90	MB 3	1	Moderate	Moderate to Major	Medium	Minor	Moderate to Major	Low
	Planform change	C61.60	MB 4	1	Minor to moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
5. Upstream increase, downstream within 10% of existing flow	Erosion Channel type change	C114.36	C Ck 3	4	Moderate	Minor	Medium	Minor	Minor	Low
	Erosion Channel type change and planform change	C92.08	C Ck 10	4	Moderate	Moderate	Medium	Minor	Minor	Low
6. Upstream decrease in flow, downstream increase	Planform change	C208.21	End Catchment	2	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Planform change	C202.8	OC 2	2	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Planform change	C186.16	NC2	1	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Impacts unlikely	C181.78	NC 5	2	Not Significant - Minor	Not Significant - Minor	Low	Not Significant - Minor	Not Significant - Minor	Low
	Planform change	C164.16	NC 15*	2	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low

Potential impact category	Potential impacts	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
					Initial risk assessment ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
	Planform change	C119.38	SC 8	4	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Planform change	C113.28	C Ck 6	2	Minor - Moderate	Moderate - Major	Medium	Minor	Moderate	Low
	Impacts unlikely	C90.96	C Ck 11	2	Not Significant - Minor	Not Significant - Minor	Low	Not Significant - Minor	Not Significant - Minor	Low
	Impacts unlikely	C82.35	C Ck 14	2	Not Significant - Minor	Not Significant - Minor	Low	Not Significant - Minor	Not Significant - Minor	Low
	Deposition	C73.44	CCs 21a	5	Moderate - Major	Moderate to Major	High	Minor	Moderate	Low
	Erosion, planform change, channel change	C68.76	C Ck 17	2	Not significant	Moderate	Low	Not Significant	Minor	Low
	Impacts unlikely	C66.81	C Ck 19	2	Not Significant - Minor	Not Significant - Minor	Low	Not Significant - Minor	Not Significant - Minor	Low
	Impacts unlikely	C66.23	C Ck 20	2	Not Significant - Minor	Not Significant - Minor	Low	Not Significant - Minor	Not Significant - Minor	Low
	Planform change	C63.15	MB 1	1	Minor - Moderate	Moderate	Medium	Minor	Moderate	Low
	Planform change	C62.94	MB 2	1	Minor - Moderate	Moderate	Medium	Minor	Moderate	Low
7. Upstream and downstream decrease	Planform change	C189.99	OC 5	2	Minor to Moderate	Minor to Moderate	Medium	Not Significant to Minor	Minor	Low
	Planform change	C182.99	NC 4	4	Minor	Moderate	Low	Not Significant to Minor	Minor	
	Impacts unlikely	C171.90	NC 10	4	Not Significant to Minor	Not Significant to Minor	Low	Not Significant to Minor	Not Significant to Minor	
	Planform change	C169.89	NC 12	2	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low

Potential impact category	Potential impacts	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
					Initial risk assessment ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
	Planform change	C165.06	NC 13	4	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Deposition	C120.31	SC 7	5	Moderate - Major	Moderate	High	Minor	Moderate	Low
	Impacts unlikely	C109.43	C Ck 8	2	Not Significant to Minor	Not Significant to Minor	Low	Not Significant to Minor	Not Significant to Minor	
	Planform change	C107.22	C Ck 9	1	Minor	Minor	Low	Not Significant to Minor	Minor	
	Impacts unlikely	C74.97	CCs 19	5	Minor	Minor	Low	Minor	Minor	Low
	Planform change (major) Deposition (moderate)	C73.61	C Ck 16a	5	Moderate - Major	Moderate - Major	High	Minor	Moderate	Low
	Deposition	C73.53	CCs 21	5	Moderate to Major	Moderate to Major	High	Minor	Moderate	Low
	Deposition	C73.37	CCs 22	5	Moderate - Major	Moderate - Major	High	Minor	Moderate	Low
	Planform change	C60.44	MB 5	5	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Planform change	C48.41	MB 8	2	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Planform change	C43.16	MB 9	1	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
8. Upstream and downstream increase	Erosion Planform Change Channel type change	C194.69	OC 3	4	Minor to Moderate	Moderate	Medium	Not Significant to Minor	Minor	Low
	Erosion Channel type change	C170.55	NC 11	4	Major	Major	High	Minor	Moderate	Low

Potential impact category	Potential impacts	Culvert ID	Watercourse ID	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
					Initial risk assessment ¹			Residual risk ²		
					Consequence at		Risk	Consequence at		Risk
					20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
	Erosion Planform Change Channel type change	C117.4	SC 11	4	Minor to Moderate	Moderate to Major	Medium	Minor	Minor	Low
	Erosion Channel type change	C34.7 (NS2B)	MR 1	2	Not Significant	Minor	Low	Not Significant	Minor	Low

Table notes:

* Culvert aligned to pass flows travelling along/adjacent to roadway

Minor to Moderate: the highest consequence has been used to derive the risk

Moderate to Major: the highest consequence has been used to derive the risk

Appendix H provides further details on scour protection included in the reference design at culverts

Existing Case sensitivity to change: 1= Low; 5= High, in terms of potential for change, Section 2.2.5 provides further details.

1 Includes implementation of initial mitigation measures specified in Section 5.1

2 Assessment of residual risk once the Project's mitigation measures for future stages identified in Section 5.2 have been applied

Table 6.4 Operations stage risks– watercourses with diversions, in cut or with no cross drainage

Potential impact category	Potential impacts on watercourse channel	Watercourse	Sensitivity to change	Potential risk of impacts of the Project on existing geomorphic processes					
				Initial risk			Residual risk		
				Consequence at		Risk	Consequence at		Risk
				20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
Diversions	Deposition, erosion	SC 5	2	Minor to Moderate	Moderate	Medium	Minor	Minor	Low
	Erosion, planform and channel type change	SC 6	2	Moderate	Major	Medium	Minor	Minor	Low
	Erosion, planform and channel type change	OC 4	2	Moderate	Major	Medium	Minor	Minor	Low
Cut	Impacts unlikely.	C Ck 4	4	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
		C Ck 5	2	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
		SC 1	2	Not Significant	Not Significant	Low	Not Significant	Not Significant	Low
No cross drainage	Erosion, deposition and planform change	C Ck 1	2	Minor to Moderate	Moderate	Medium	Minor	Minor	Low
		NC 16	2	Minor	Minor	Low	Not Significant	Not Significant	Low
		PC 1	2	Minor	Minor	Low	Minor	Minor	Low

Table notes:

Minor to Moderate: the highest consequence has been used to derive the risk

Moderate to Major: the highest consequence has been used to derive the risk

Existing Case sensitivity to change: 1= Low; 5= High, in terms of potential for change, Section 2.2.5 provides further details.

6.2 Operations stage risks – floodplains

The operations stage spans a longer time frame than the pre-construction and early works, and construction works stage and has a higher likelihood of experiencing geomorphically significant events, namely bank full (20% AEP event) and full floodplain flow conditions (1% AEP event). Therefore the risk assessment was undertaken on individual watercourses and floodplains for operations stage impacts.

The risk assessment methodology is outlined in Section 2. Likelihoods assessed for include 'possible' and 'rare', as these are the most geomorphically significant time periods, refer Section 2.5.1 for further details. As the main likelihoods to be assessed for are already established, the risk assessment mainly comprises deriving initial and residual consequence levels for the potential impacts identified in Section 4, and applying this to the risk matrix in Section 2.5 to derive initial and residual risk.

Operations stage risks to geomorphic floodplains are included in Table 6.5.

Table 6.5 Operations stage risks – floodplains (including all cross drainage infrastructure)

Potential impact category*	Potential impacts	Floodplain	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
				Initial risk assessment			Residual risk assessment		
				Consequence at		Risk	Consequence at		Risk
				20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
1 No encroachment	Impacts unlikely.	Cattle Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
2. Floodplain sidling	20% AEP, impacts unlikely. 1% AEP, erosion	Macintyre Brook	5	Not significant	Minor to Major.	Low	Not significant	Minor to moderate	Low
3. Floodplain constriction	Impacts unlikely.	Dry Creek	4	Not significant	Not significant	Low	Not significant	Not significant	Low
		One Mile Creek	3	Not significant	Not significant	Low	Not significant	Not significant	Low
		Native Dog Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
		Nicol Creek	2	Not significant	Not significant	Low	Not significant	Not significant	Low
	20% AEP, impacts unlikely. 1% AEP, erosion.	Back Creek 1	2	Not significant	Major	Low	Minor	Minor	Low
	20% AEP, impacts unlikely. 1% AEP, erosion.	Four Mile Gully	2	Not significant	Major	Low	Not significant	Minor	Low
	20% AEP, deposition 1% AEP, erosion	Westbrook Creek	3	Not significant to minor	Minor to Moderate	Low	No flow to minor	Minor	Low
	20% AEP, impacts unlikely. 1% AEP, erosion.	Condamine River	5	Not significant to minor.	Minor to moderate	Low	Not significant	Minor	Low
	Impacts unlikely.	Back Creek 2	2	Not significant	Not significant	Low	Not significant	Not significant	Low
	20% AEP, impacts unlikely. 1% AEP, erosion.	SC 2	2	Not significant	Minor to moderate	Low	Minor Not significant	Minor	Low
	20% AEP, deposition	SC 7	5	Minor	Minor	Low	Minor	Minor	Low
	20% AEP, impacts unlikely. 1% AEP, erosion.	Macintyre River	3	Not significant	Minor to moderate	Low	Not significant	Minor	Low

Potential impact category*	Potential impacts	Floodplain	Sensitivity to change	Potential impacts of the Project on existing geomorphic processes					
				Initial risk assessment			Residual risk assessment		
				Consequence at		Risk	Consequence at		Risk
				20% AEP Possible likelihood	1% AEP Rare likelihood		20% AEP Possible likelihood	1% AEP Rare likelihood	
4. Floodplain constriction and sidling	Erosion	MB 6	2	Minor	Minor	Low	Minor	Minor	Low
	20% AEP, impacts unlikely. 1% AEP, erosion and deposition.	Bringalily Creek	2	Not significant	Moderate erosion at C97.38, not significant to minor elsewhere	Low	Not significant	Minor	Low
	20% AEP, impacts unlikely. 1% AEP, erosion.	Pariagara Creek	3	Not significant	Moderate to major for culverts C69.80 to C68.89, not significant to minor elsewhere	Low	Not significant	Minor	Low

Table note:

* Assessment does not take into consideration local effects of bridge piers.
 Minor to Moderate: the highest consequence has been used to derive the risk
 Moderate to Major: the highest consequence has been used to derive the risk

6.3 Cumulative impacts on catchment processes

Key catchment processes include sediment budget change, channel change, changing flood and flow regime, dam construction, land use change and flood control works including levees. Many of these impacts have historically occurred in the Project footprint catchments and will continue to occur outside of the Project Study area (influence area). Fluvial responses due to catchment impacts can have time lags of decades or more, meaning that catchment impacts occurring prior to and unrelated to the Project construction and operation may not be realised for some time after construction.

Sustainable approaches to catchment management minimise morphological changes that threaten water resource assets, but also include measures that accommodate the normal range of variability in channel form by allowing 'room for the river' (Downs and Piegay, 2019). The revised reference design, namely preference of bridges over culverts, and oversized bridges provide more 'room for the river' than existing infrastructure.

Impacts of the Project on sediment budget change and channel change were included in the risk assessment for all potentially sensitive watercourses and floodplains, residual risk for the operations stage for all except one site is low and as such cumulative catchment impacts are also assessed as low.

Impacts, mitigation and management measures on the flood regime are included in EIS Chapter 14: Flooding and Geomorphology. The Existing Case conditions were used as the basis to compare the developed case against to determine potential impacts and then derive appropriate mitigation measures.

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APPENDIX H

Geomorphology Report

Appendix A Drawings

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Appendix A

Drawings

Drawing Set A

Drawing Set A. 1 Regional Geomorphic Landforms CH0-CH103

Drawing Set A. 2 Regional Geomorphic Landforms CH102-CH217.6

Drawing Set B

Drawing Set B. 1 ASC Soils

Drawing Set B. 2 ASC Soils

Drawing Set B. 3 ASC Soils

Drawing Set B. 4 ASC Soils

Drawing Set B. 5 ASC Soils

Drawing Set B. 6 ASC Soils

Drawing Set B. 7 ASC Soils

Drawing Set C

Drawing Set C. 1 Catchments and Stream Order

Drawing Set C. 2 Catchments and Stream Order

Drawing Set C. 3 Catchments and Stream Order

Drawing Set C. 4 Catchments and Stream Order

Drawing Set C. 5 Catchments and Stream Order

Drawing Set C. 6 Catchments and Stream Order

Drawing Set C. 7 Catchments and Stream Order

Drawing Set D

Drawing Set D. 1 Field Assessment locations and initial risk

Drawing Set D. 2 Field Assessment locations and initial risk

Drawing Set D. 3 Field Assessment locations and initial risk

Drawing Set D. 4 Field Assessment locations and initial risk

Drawing Set D. 5 Field Assessment locations and initial risk

Drawing Set D. 6 Field Assessment locations and initial risk

Drawing Set D. 7 Field Assessment locations and initial risk

Drawing Set D. 8 Field Assessment locations and initial risk

Drawing Set D. 9 Field Assessment locations and initial risk

Drawing Set D. 10 Field Assessment locations and initial risk

Drawing Set D. 11 Field Assessment locations and initial risk

Drawing Set E – High risk site detailed assessment

Drawing Set E. 1 NC 11 Hydraulic Characteristics 1% AEP

Drawing Set E. 2 NC 11 Hydraulic Characteristics 20% AEP

Drawing Set E. 3 NC 11 Geomorphology Map

Drawing Set E. 4 SC 7 Hydraulic Characteristics 1% AEP

Drawing Set E. 5 SC 7 Hydraulic Characteristics 20% AEP

Drawing Set E. 6 SC 7 Geomorphology Map

Drawing Set E. 7 C Ck 16 & CCs 21 Hydraulic Characteristics 1% AEP

Drawing Set E. 8 C Ck 16 & CCs 21 Hydraulic Characteristics 20% AEP

Drawing Set E. 9 C Ck 16 & CCs 21 Geomorphology Map

Drawing Set E. 10 SC 2 Hydraulic Characteristics 1% AEP

Drawing Set E. 11 SC 2 Hydraulic Characteristics 20% AEP

Drawing Set E. 12 SC 2 Geomorphology Map 1

Drawing Set E. 13 SC 2 Geomorphology Map 2

Drawing Set F - High risk sites without detailed assessment

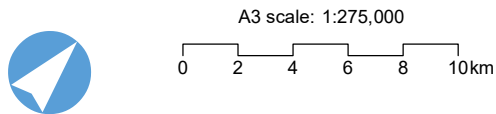
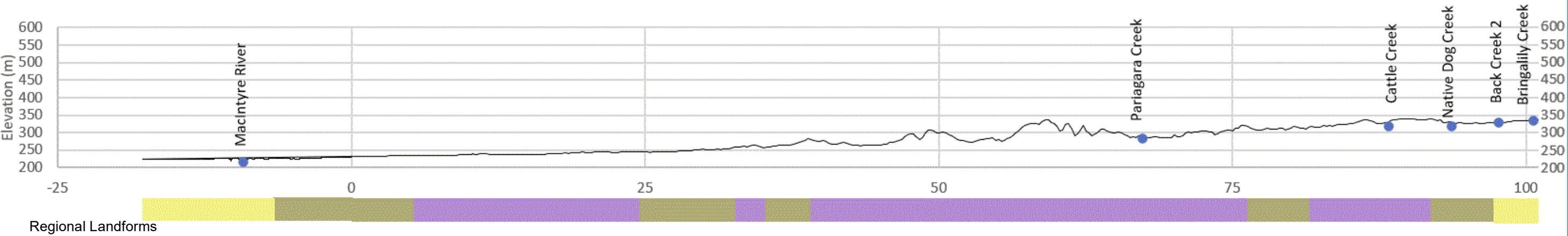
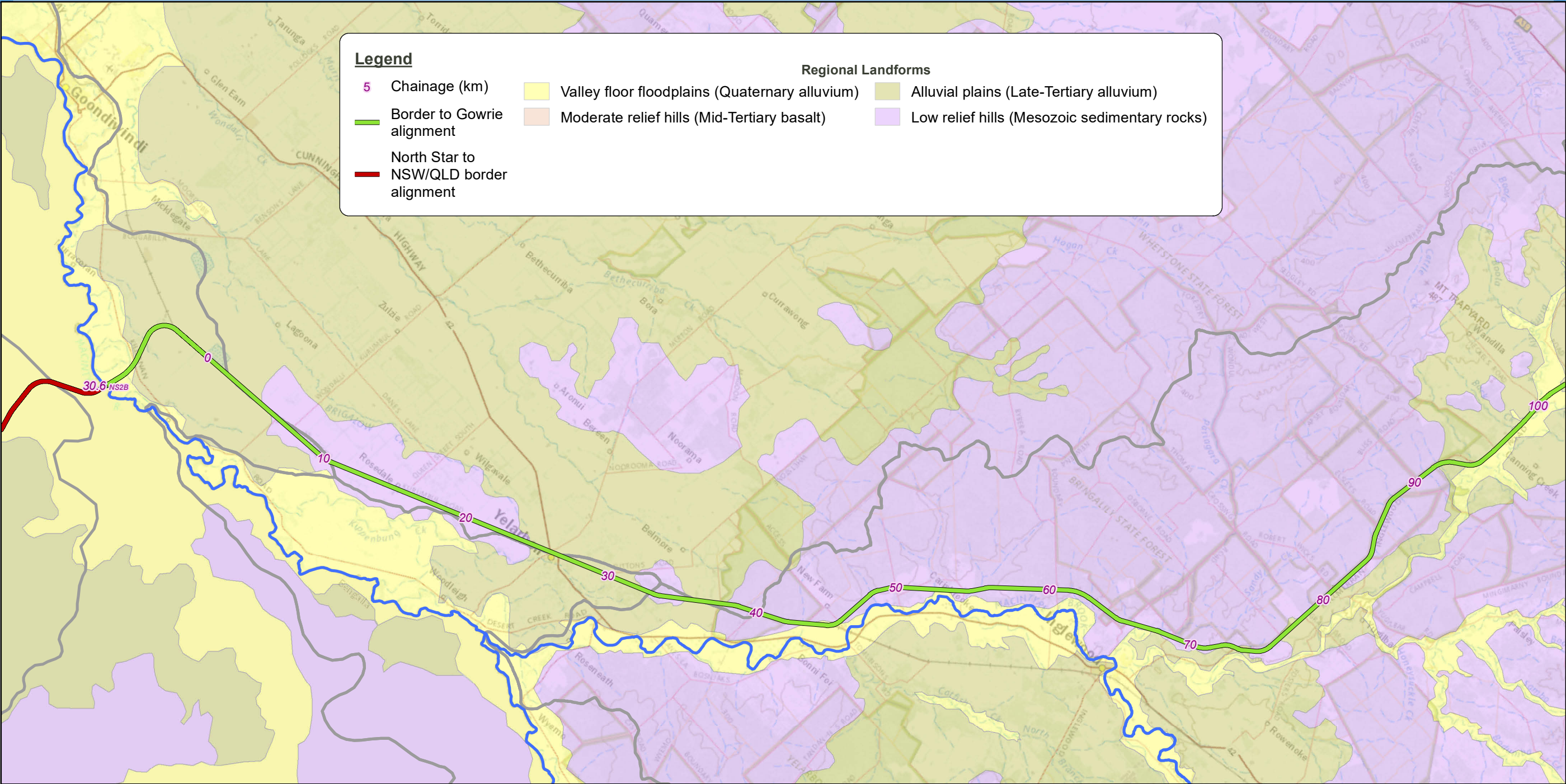
Drawing Set F. 1 C Ck 2 Bridge abutment offset from channel

Drawing Set F. 2 Four Mile Gully Bridge abutment offset from channel

Drawing Set F. 3 NC 3 Bridge abutment offset from channel

Drawing Set F. 4 Back Creek 2 Bridge abutment offset from channel

Map by: FF JV GIS L:\Legacy\Projects\Interoffice\60553814_BNE\5 CAD GIS\06_Working\20220523_AdditionalCatchmentIB2G_Draft_Overview01_FF JV_20240403updated.mxd Date: 3/04/2024 13:26



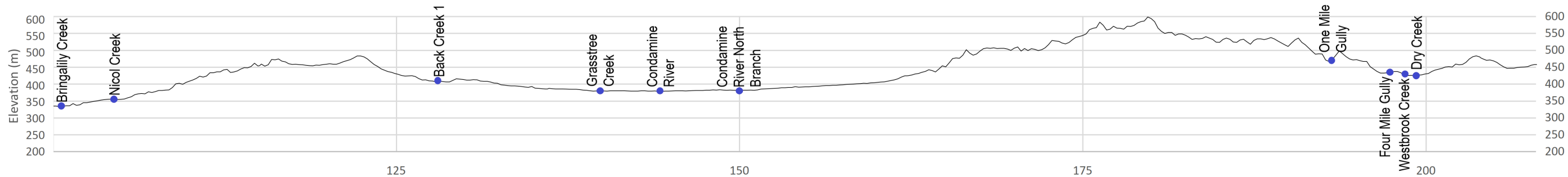
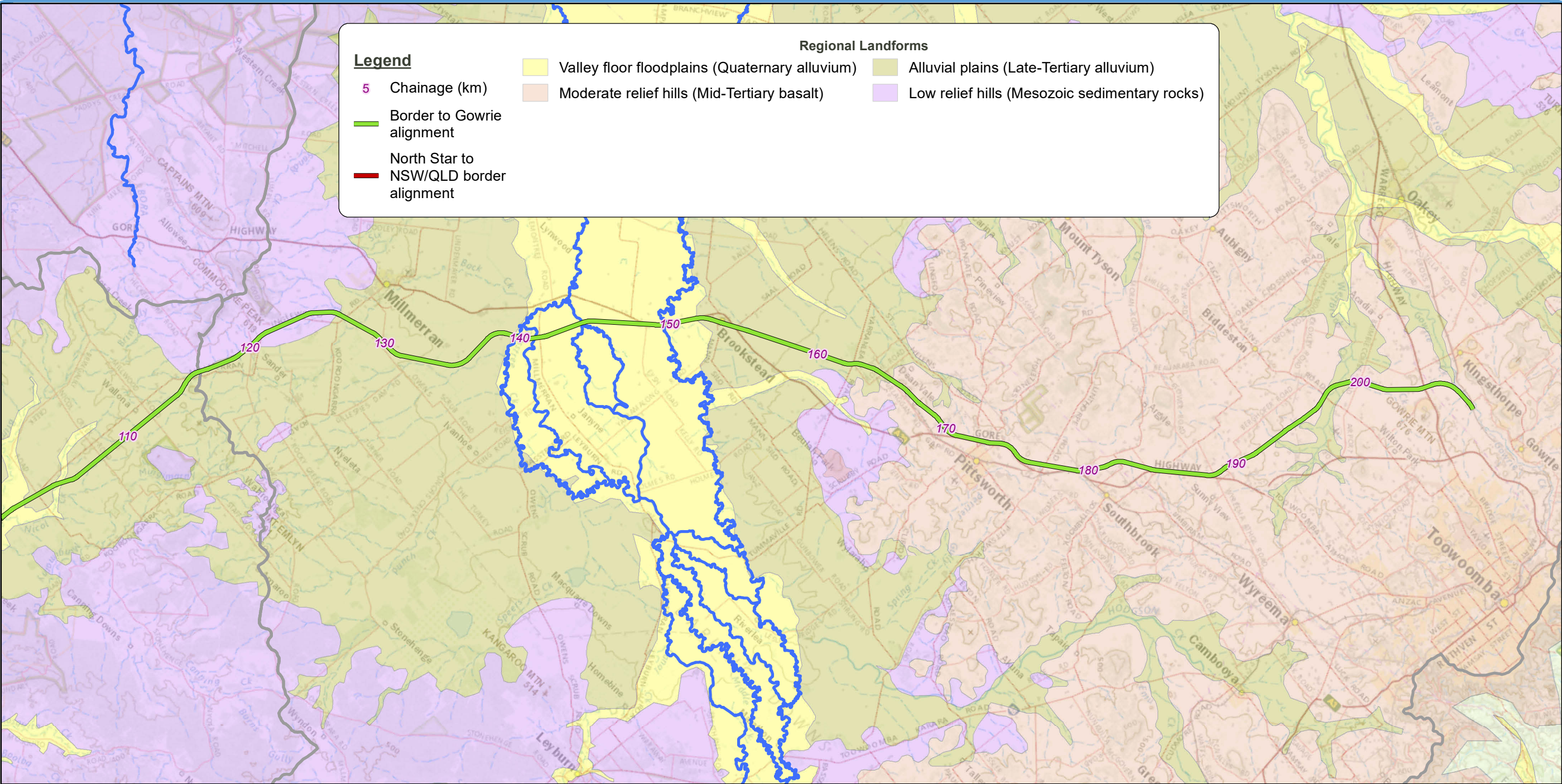
Future Freight
Integrating Community, Environment and Engineering

Issue date: 3/04/2024 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure : A.1

Regional Geomorphic Landforms



A3 scale: 1:275,000

0 2 4 6 8 10km



Future Freight
Integrating Community, Environment and Engineering

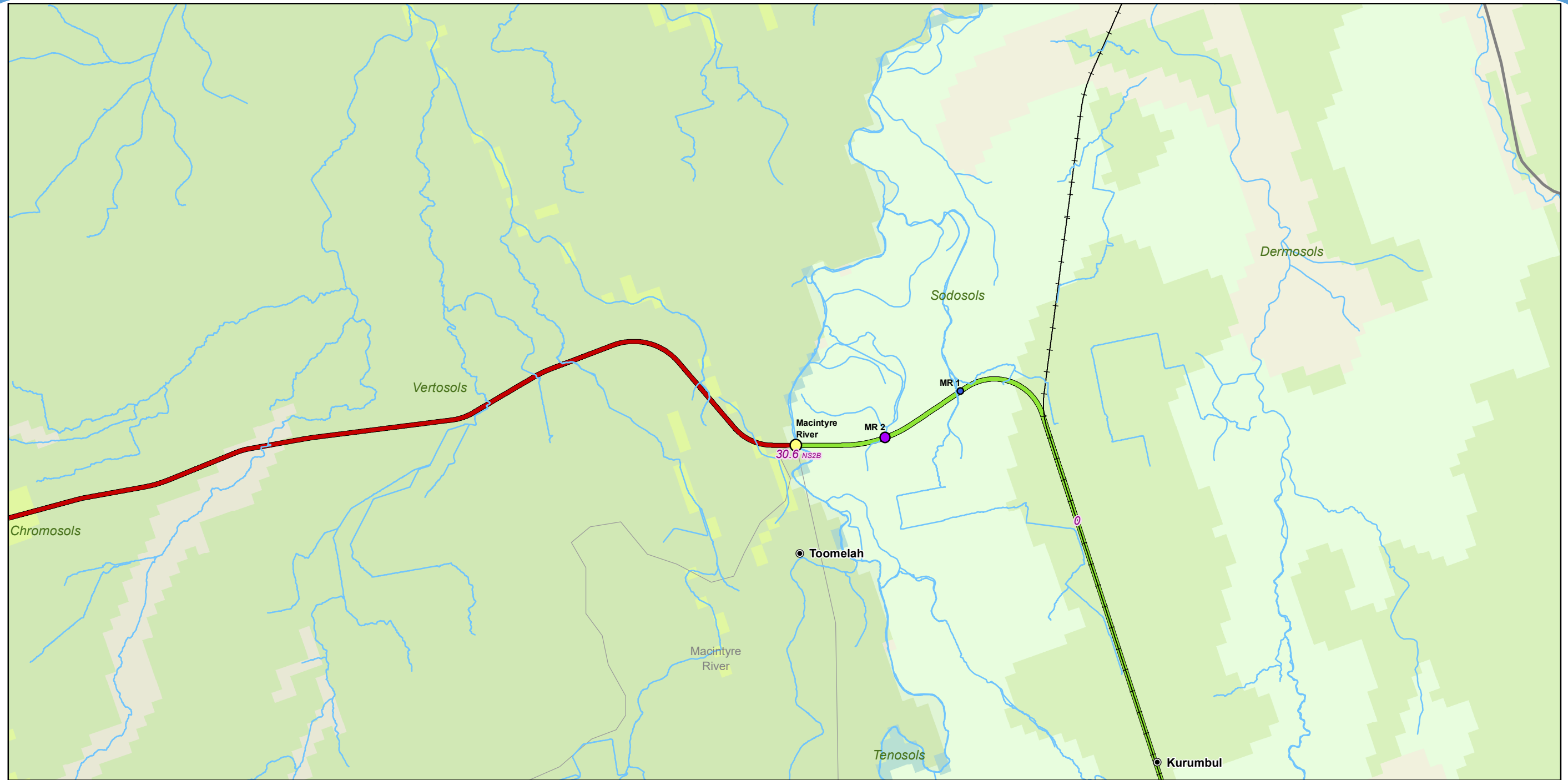
Issue date: 3/04/2024 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Figure : A.2

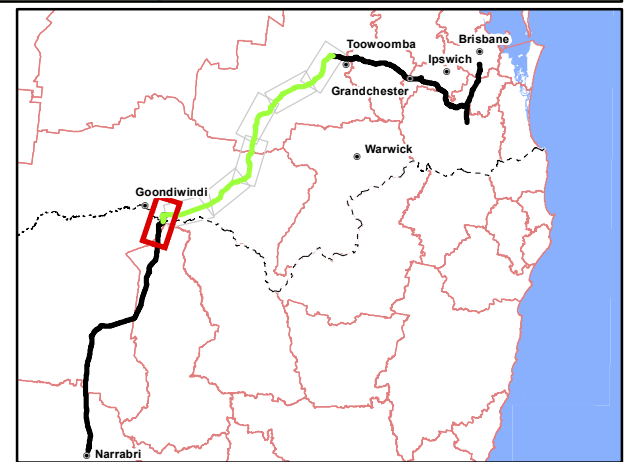
Regional Geomorphic Landforms

Map by: FF:IV GIS L:\Legacy\Projects\Interface\60553814_BNE\5 CAD GIS\06_Working\2024\04\03 Updates\B2G_DraftMapSeries_ASC_Soils_FF:IV_2024\04\03 updated.mxd Date: 30/04/2024 16:28



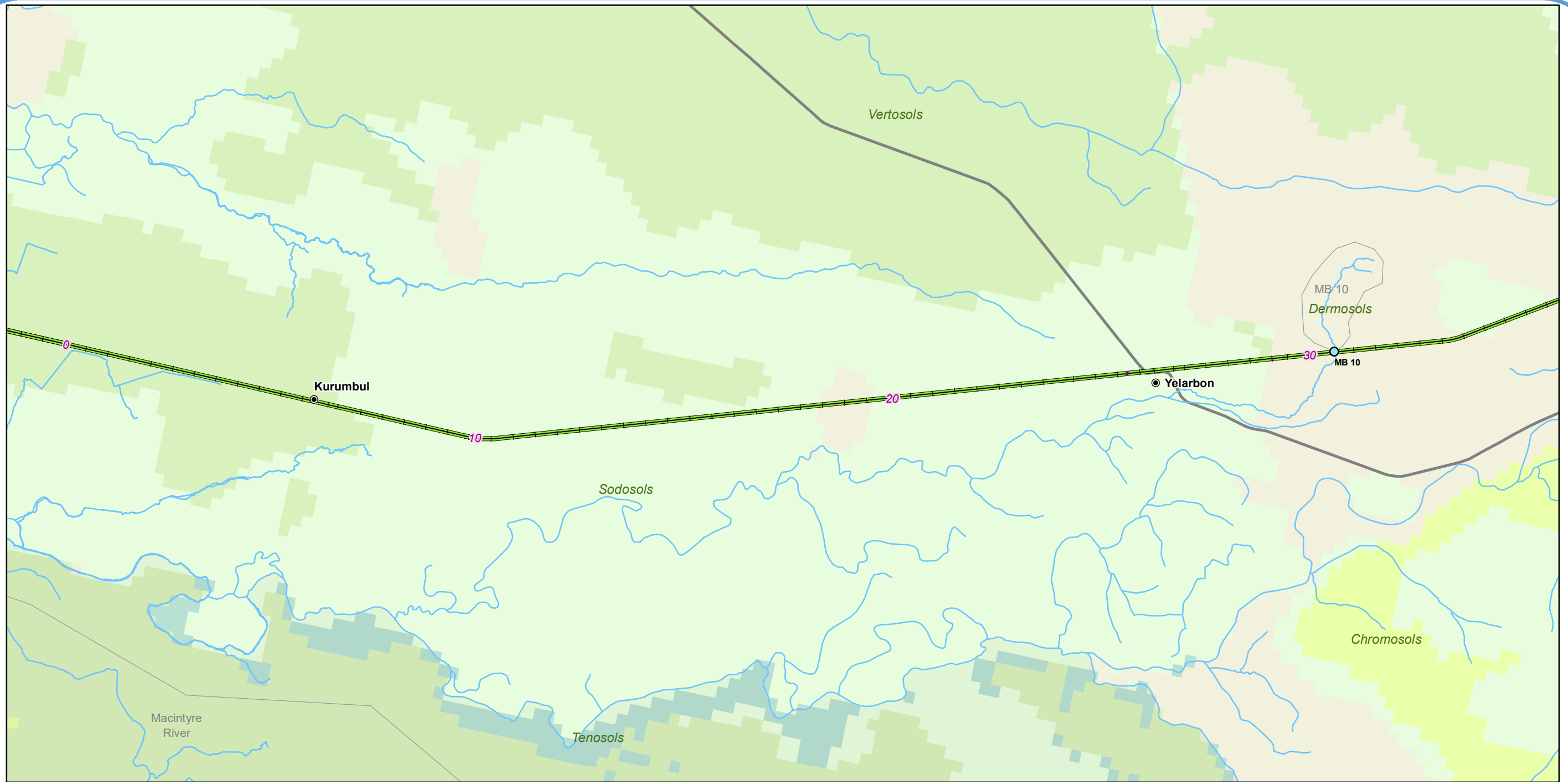
Legend

- | | | | | | | | | | | | | | | |
|---|--|---|-------------|------------|-----------|-----------|-----------|-----------|----------|----------|----------|----------|----------|-----------|
| <ul style="list-style-type: none">5 Chainage (km)LocalitiesProposed B2G bridgesNorth Star to NSW/QLD border alignmentBorder to Gowrie alignmentExisting rail (operational)Major roadsSub-catchment upstream of the alignment | <p>Watercourse Type</p> <ul style="list-style-type: none">HeadwaterLocal - developed channel sectionsLocal - poorly developed channelLocal - well developed channelMain StemWatercourses | <p>Soils (ASC Grid)</p> <table border="0"><tr><td>Calcarosols</td><td>Chromosols</td><td>Dermosols</td><td>Ferrosols</td><td>Hydrosols</td><td>Kandosols</td></tr><tr><td>Kurosols</td><td>Podosols</td><td>Rudosols</td><td>Sodosols</td><td>Tenosols</td><td>Vertosols</td></tr></table> | Calcarosols | Chromosols | Dermosols | Ferrosols | Hydrosols | Kandosols | Kurosols | Podosols | Rudosols | Sodosols | Tenosols | Vertosols |
| Calcarosols | Chromosols | Dermosols | Ferrosols | Hydrosols | Kandosols | | | | | | | | | |
| Kurosols | Podosols | Rudosols | Sodosols | Tenosols | Vertosols | | | | | | | | | |



A3 scale: 1:100,000
0 1 2 3 4 Kilometers

Map by: FF:IV GIS L:\Legacy\Projects\InterOffice\60553814_BNEIS CAD GIS\06_Working\2024\04\03 Updates\B2G_DraftMapSeries_ASC_Soils_FF:IV_2024\04\03 updated.mxd Date: 30/04/2024 16:28



Legend

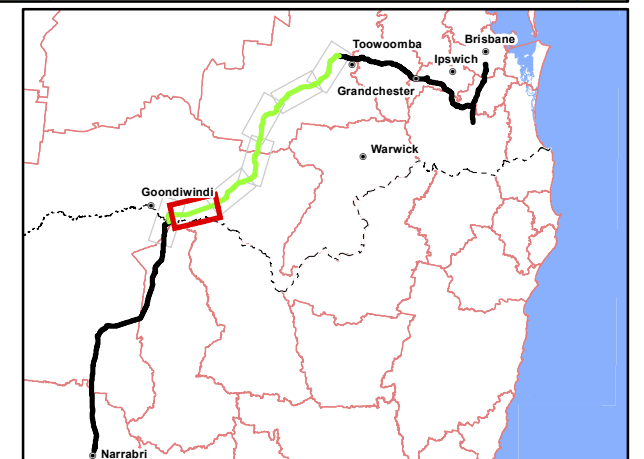
- 5 Chainage (km)
- Localities
- Proposed B2G bridges
- North Star to NSW/QLD border alignment
- Border to Gowrie alignment
- Existing rail (operational)
- Major roads
- Sub-catchment upstream of the alignment

Watercourse Type

- Headwater
- Local - developed channel sections
- Local - poorly developed channel
- Local - well developed channel
- Main Stem
- Watercourses

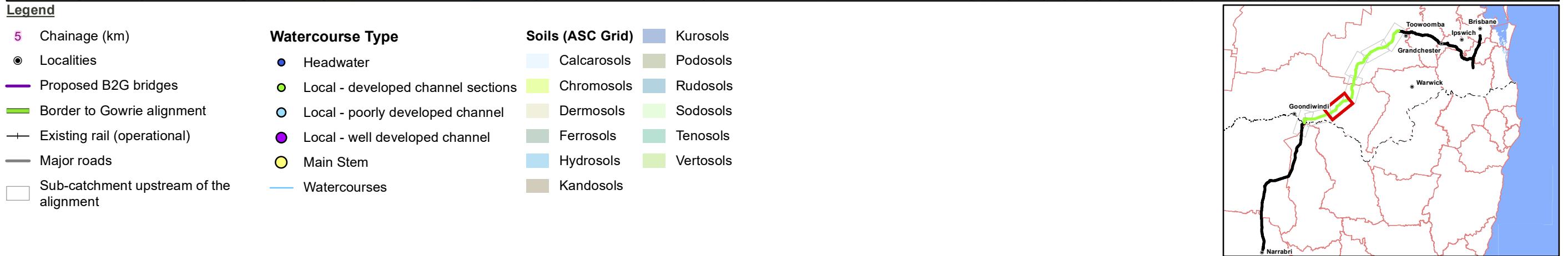
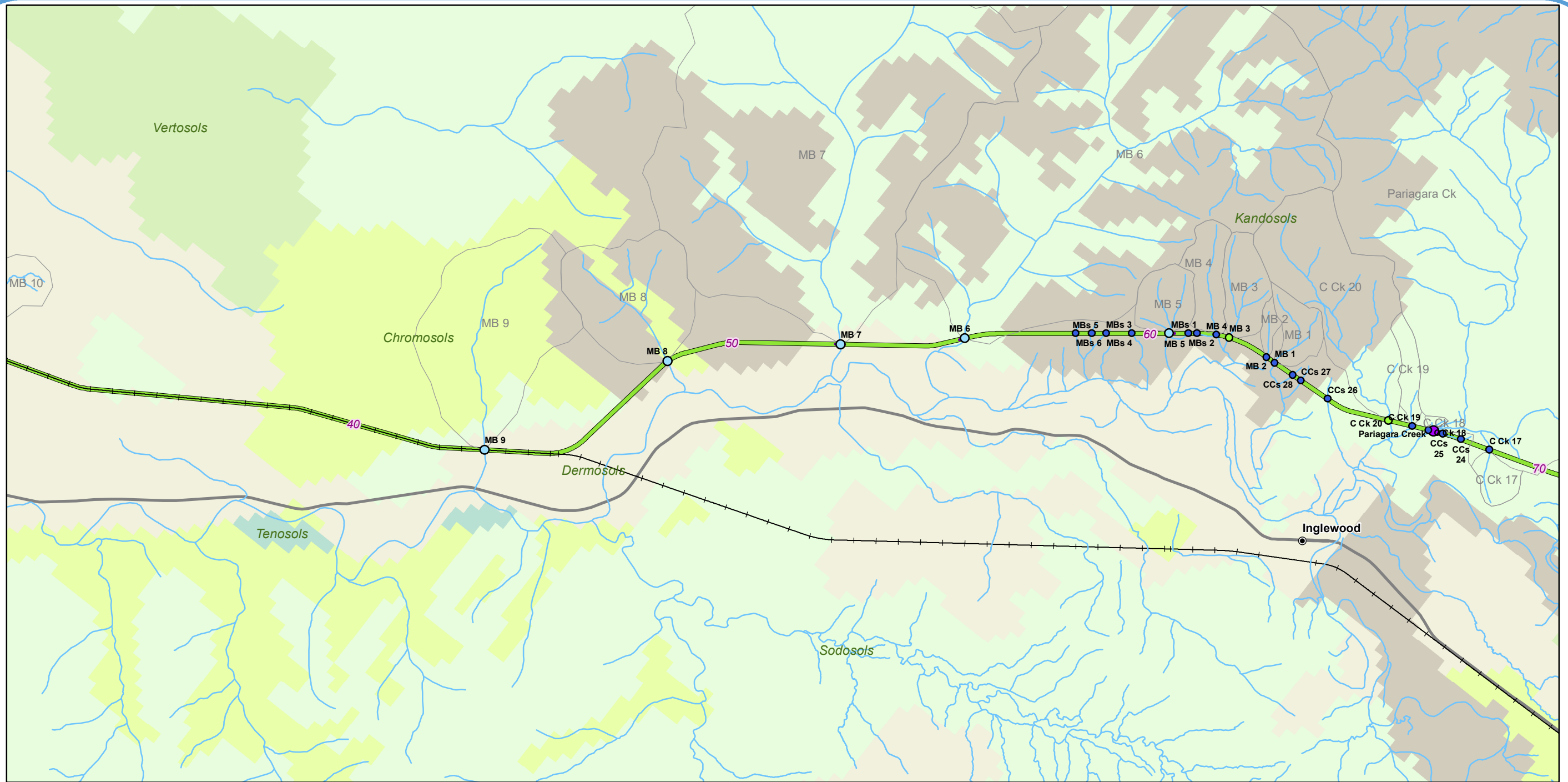
Soils (ASC Grid)

- Calcarosols
- Chromosols
- Dermosols
- Ferrosols
- Hydrosols
- Kandosols
- Kurosols
- Podosols
- Rudosols
- Sodosols
- Tenosols
- Vertosols



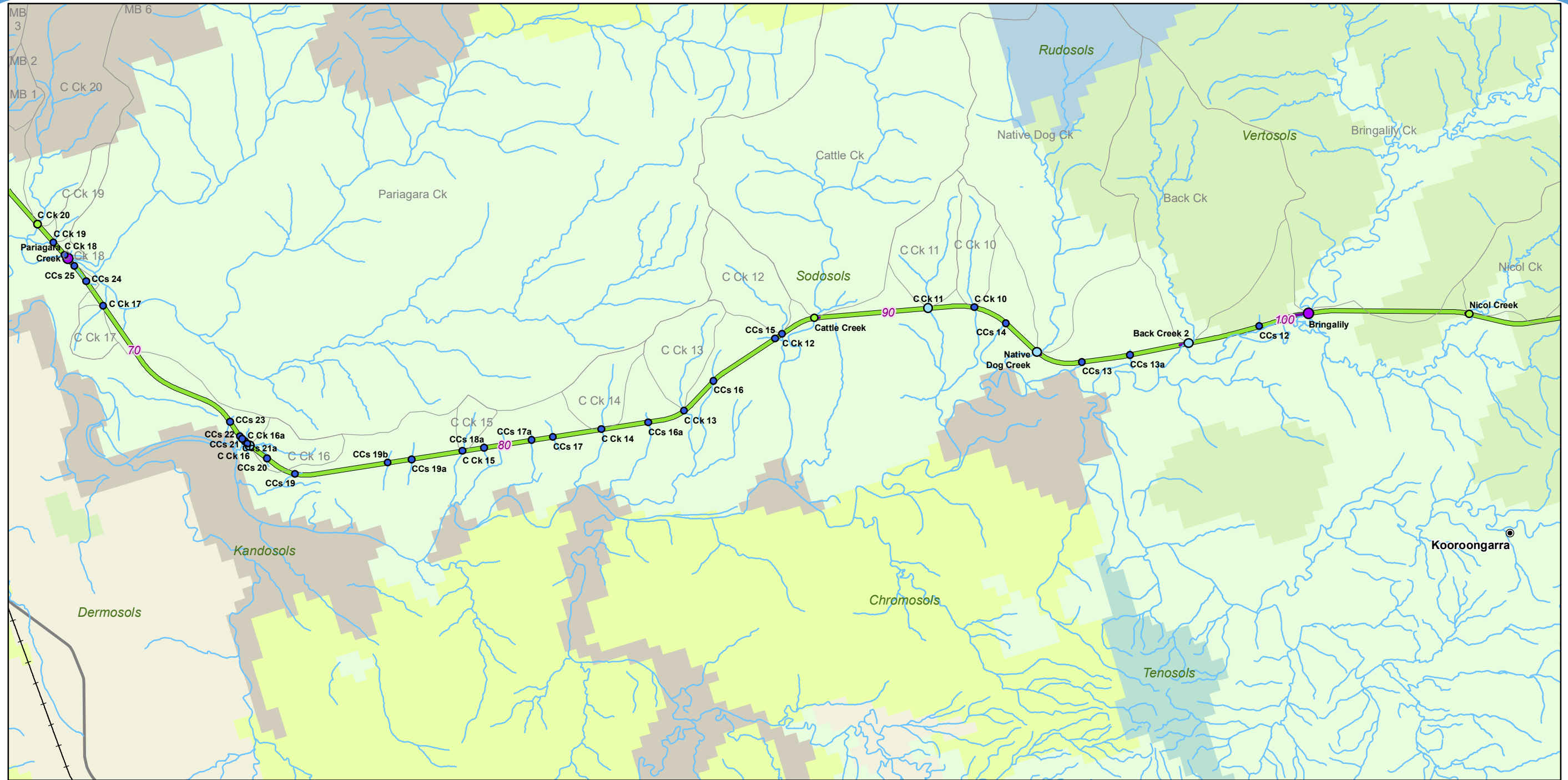
A3 scale: 1:100,000
0 1 2 3 4 Kilometers

Map by: FF:IV GIS L:\Legacy\Projects\InterOffice\60553814_BNE\5 CAD GIS\06_Working\2024\04\03 Updates\B2G_DraftMapSeries_ASC_Soils_FF:IV_2024\04\03 updated.mxd Date: 30/04/2024 16:28



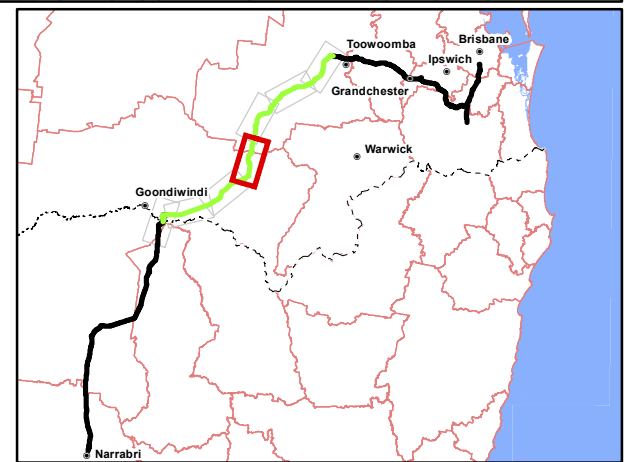
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0 1 2 3 4 Kilometers

Map by: FF:IV GIS L:\Legacy\Projects\Interface\60553814_BNE\5 CAD GIS\06_Working\2024\04\03 Updates\B2G_DraftMapSeries_ASC_Soils_FF:IV_2024\04\03 updated.mxd Date: 30/04/2024 16:28



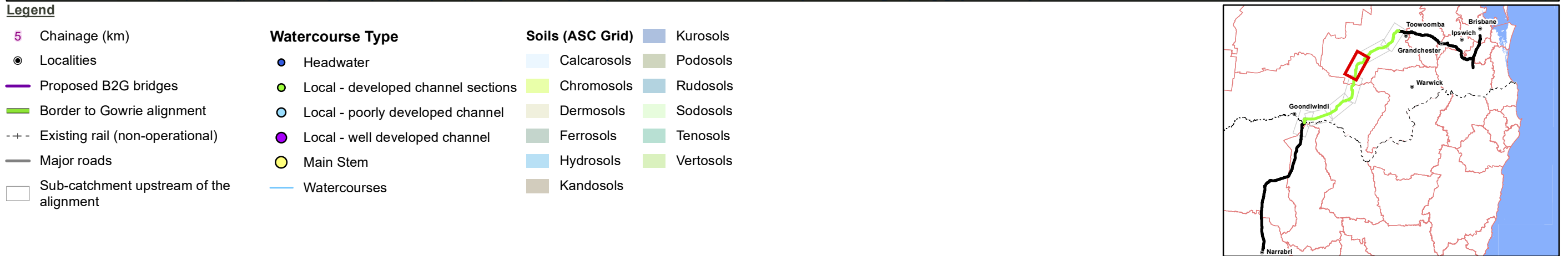
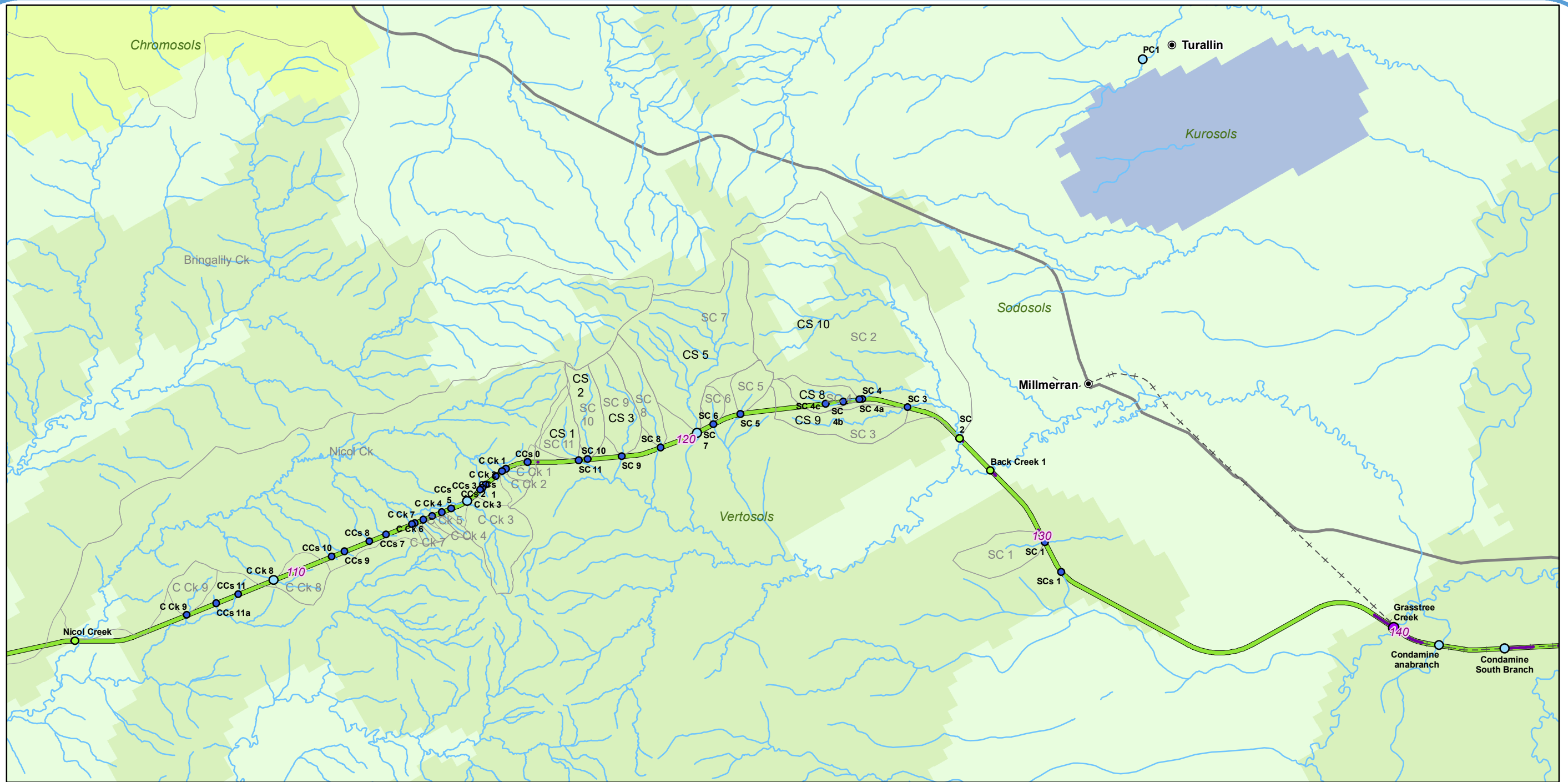
Legend

- | | | | |
|---|------------------------------------|-------------------------|-----------|
| 5 Chainage (km) | Watercourse Type | Soils (ASC Grid) | Kurosols |
| Localities | Headwater | Calcarosols | Podosols |
| Proposed B2G bridges | Local - developed channel sections | Chromosols | Rudosols |
| Border to Gowrie alignment | Local - poorly developed channel | Dermosols | Sodosols |
| Existing rail (operational) | Local - well developed channel | Ferrosols | Tenosols |
| Major roads | Main Stem | Hydrosols | Vertosols |
| Sub-catchment upstream of the alignment | Watercourses | Kandosols | |

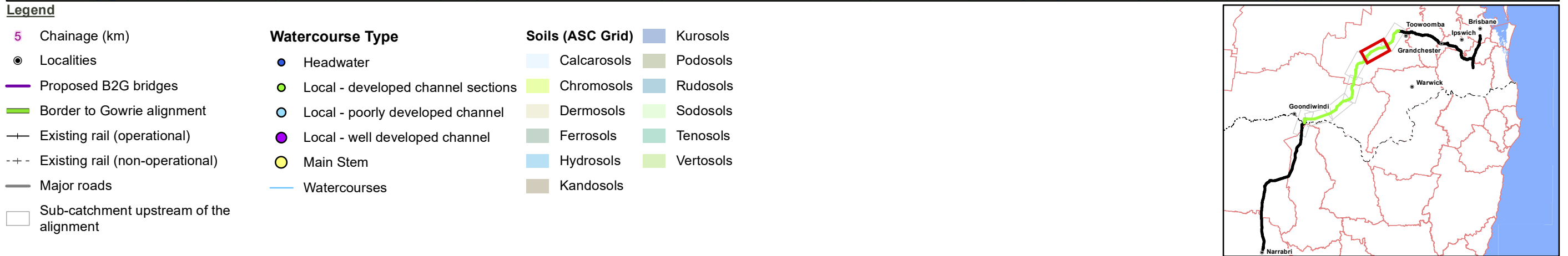
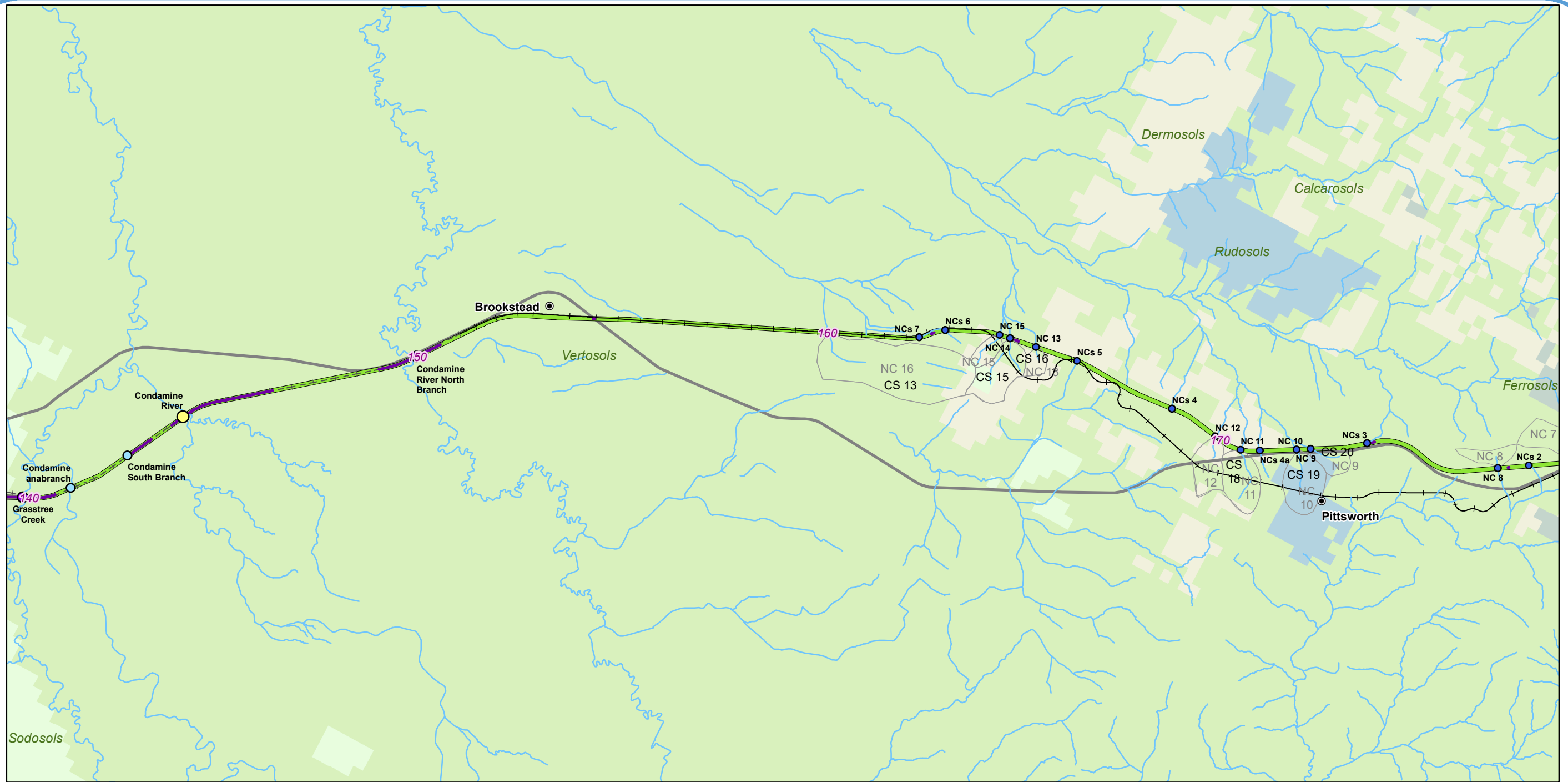


A3 scale: 1:100,000
0 1 2 3 4 Kilometers

Map by: FF:IV GIS L:\Legacy\Projects\InterOffice\60553814_BNE\5 CAD GIS\06_Working\2024\04\03 Updates\B2G_DraftMapSeries_ASC_Soils_FF:IV_2024\04\03 updated.mxd Date: 30/04/2024 16:28

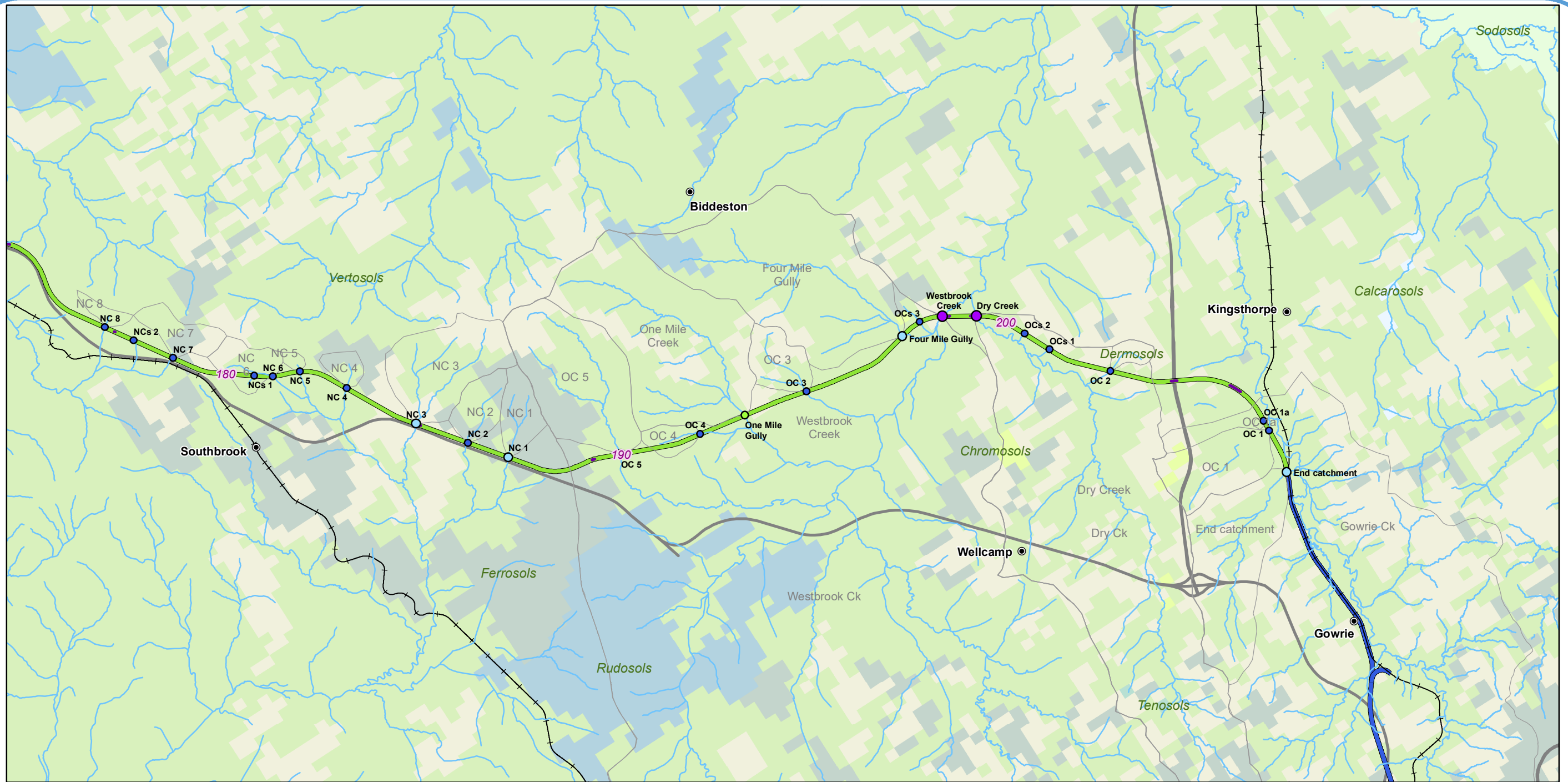


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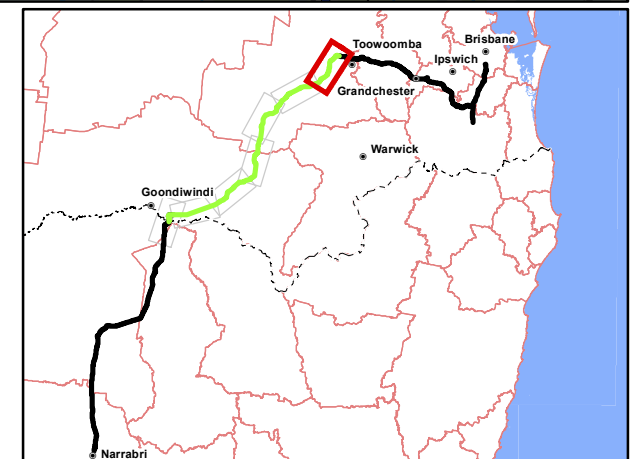
A3 scale: 1:100,000
0 1 2 3 4 Kilometers

Map by: FF:IV GIS L:\Legacy\Projects\Interface\60553814_BNE\5 CAD GIS\06_Working\2024\04\03 Updates\B2G_DraftMapSeries_ASC_Soils_FF:IV_2024\04\03 updated.mxd Date: 30/04/2024 16:28

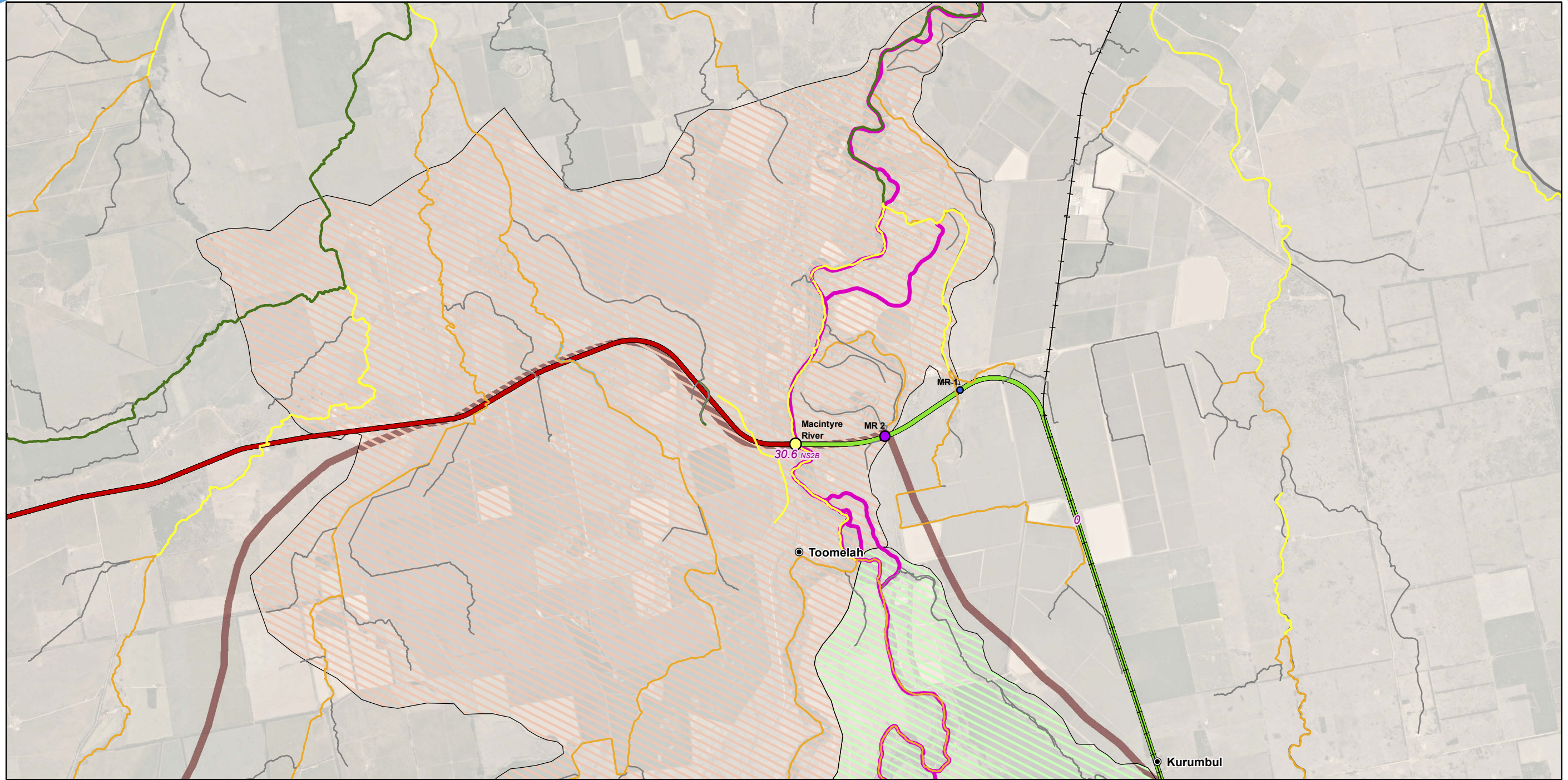


Legend

- | | | | | | | | | | | | | | | |
|--|---|--|-------------|----------|------------|----------|-----------|----------|-----------|----------|-----------|----------|-----------|-----------|
| <ul style="list-style-type: none">5 Chainage (km)LocalitiesProposed B2G bridgesBorder to Gowrie alignmentGowrie to Helidon alignmentExisting rail (operational)Major roadsSub-catchment upstream of the alignment | Watercourse Type <ul style="list-style-type: none">HeadwaterLocal - developed channel sectionsLocal - poorly developed channelLocal - well developed channelMain StemWatercourses | Soils (ASC Grid) <table border="0"><tr><td>Calcarosols</td><td>Kurosols</td></tr><tr><td>Chromosols</td><td>Podosols</td></tr><tr><td>Dermosols</td><td>Rudosols</td></tr><tr><td>Ferrosols</td><td>Sodosols</td></tr><tr><td>Hydrosols</td><td>Tenosols</td></tr><tr><td>Kandosols</td><td>Vertosols</td></tr></table> | Calcarosols | Kurosols | Chromosols | Podosols | Dermosols | Rudosols | Ferrosols | Sodosols | Hydrosols | Tenosols | Kandosols | Vertosols |
| Calcarosols | Kurosols | | | | | | | | | | | | | |
| Chromosols | Podosols | | | | | | | | | | | | | |
| Dermosols | Rudosols | | | | | | | | | | | | | |
| Ferrosols | Sodosols | | | | | | | | | | | | | |
| Hydrosols | Tenosols | | | | | | | | | | | | | |
| Kandosols | Vertosols | | | | | | | | | | | | | |



A3 scale: 1:100,000
0 1 2 3 4 Kilometers



Legend

- 5 Chainage (km)
- Localities
- Proposed B2G bridges
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Major roads

Sub Catchments (ha)

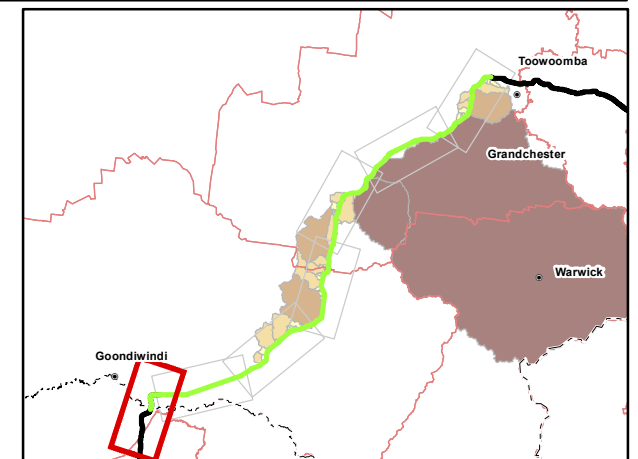
- 11 - 1000
- 1001 - 10000
- 10001 - 40000
- > 40000

Watercourse Types

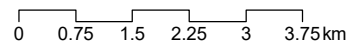
- Headwater
- Local - developed channel sections
- Local - poorly developed channel
- Local - well developed channel
- Main Stem

Watercourse Strahler Order Floodplain Classification

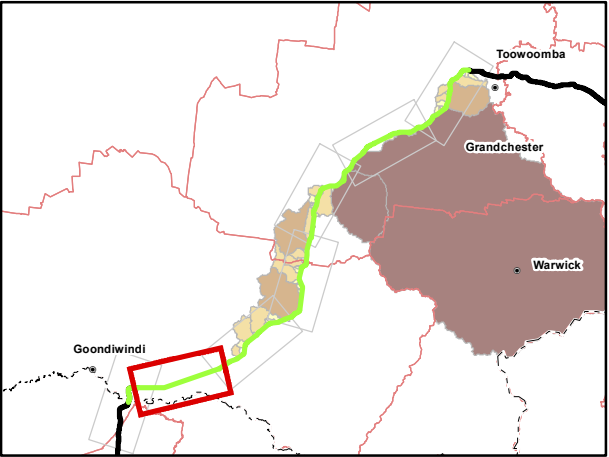
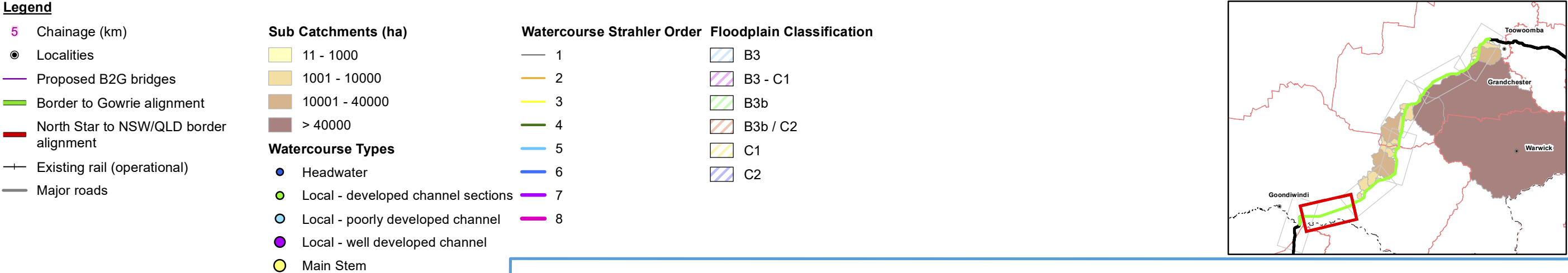
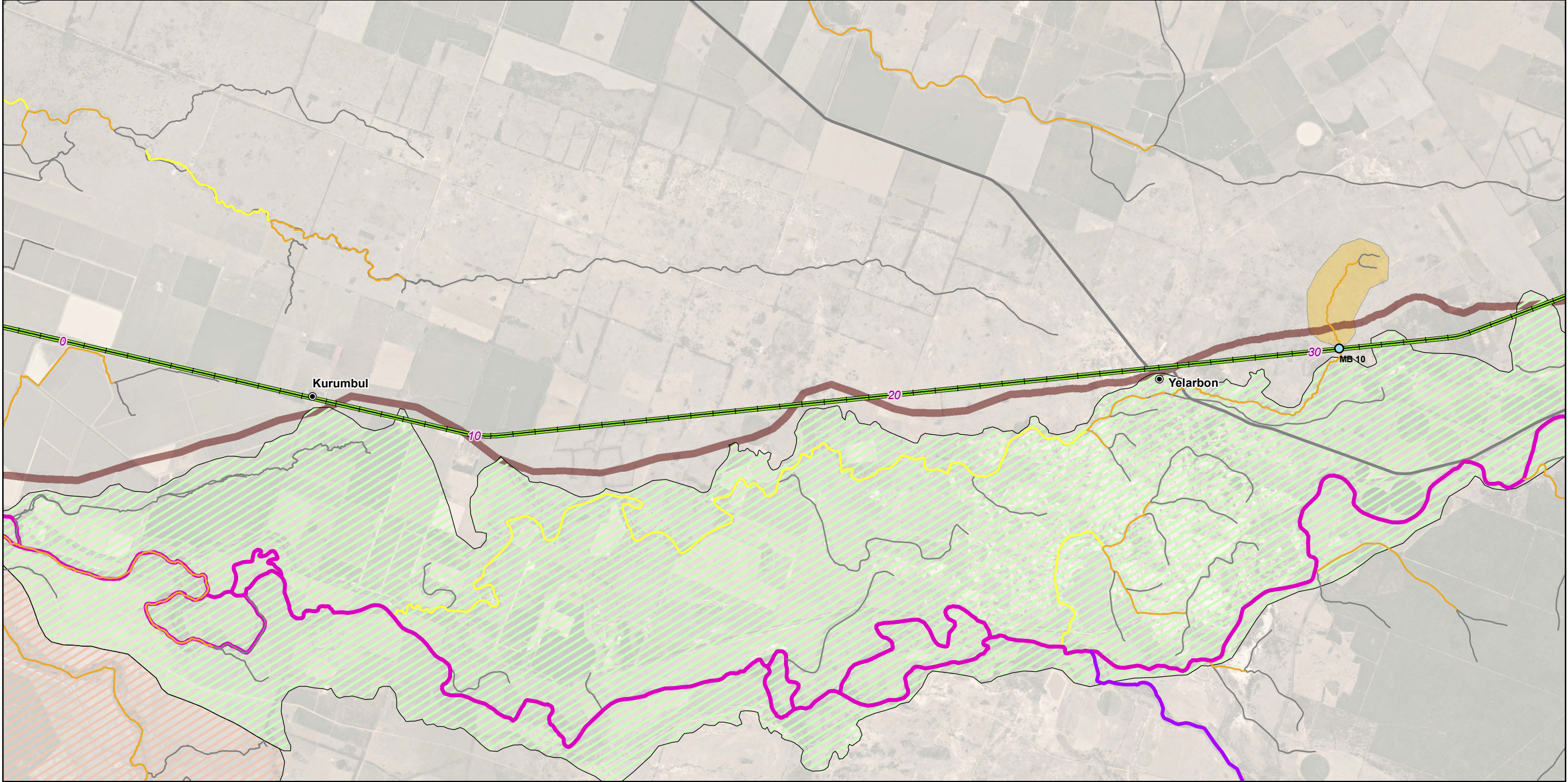
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- B3
- B3 - C1
- B3b
- B3b / C2
- C1
- C2



A3 scale: 1:100,000



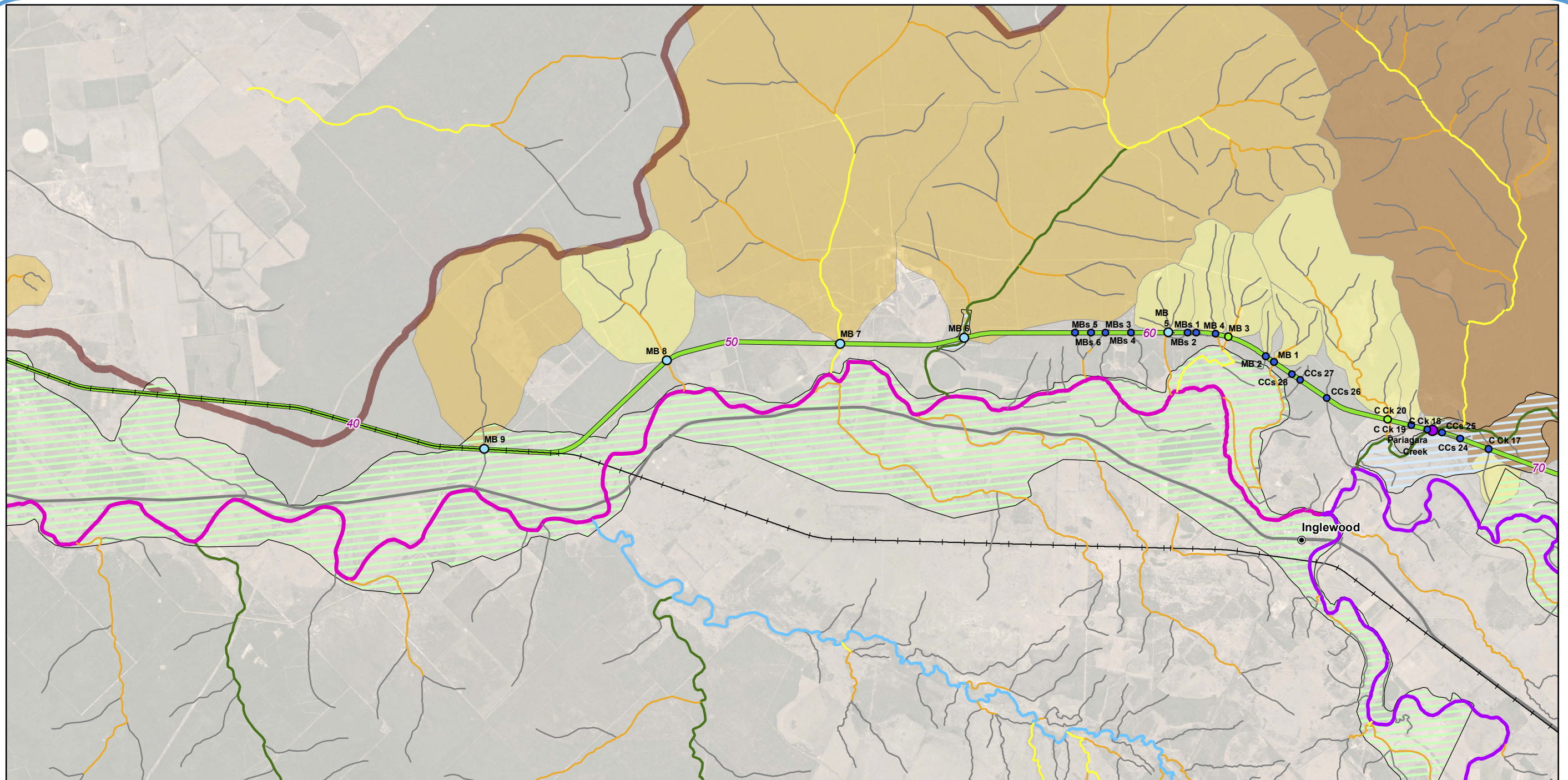
Issue date: 1/05/2024 Version: 1
Coordinate System: GDA 1994 MGA Zone 56



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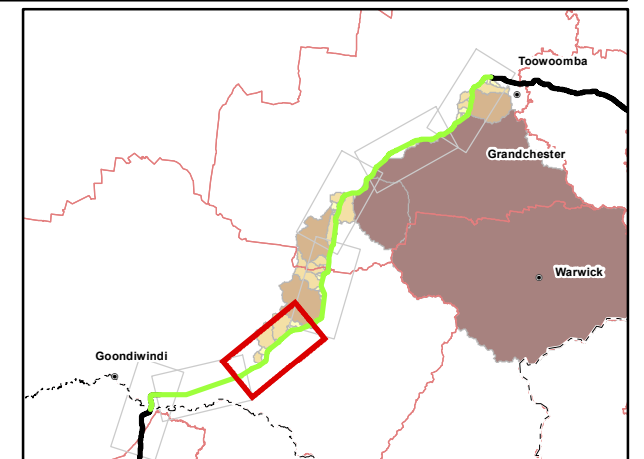


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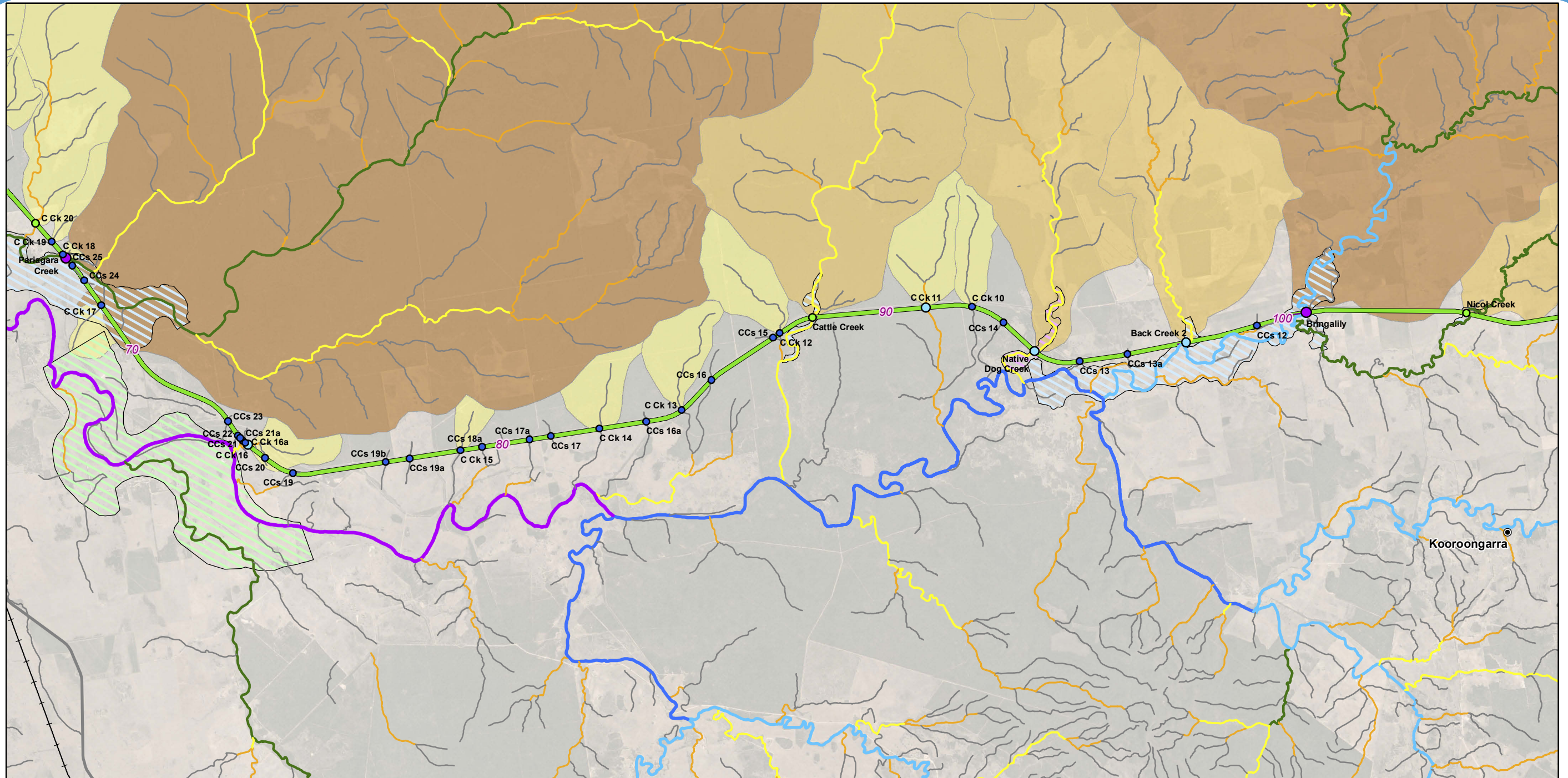


Legend

- | | | |
|---|--|--|
| <ul style="list-style-type: none">5 Chainage (km)● LocalitiesProposed B2G bridgesBorder to Gowrie alignmentNorth Star to NSW/QLD border alignmentExisting rail (operational)Major roads | <p>Sub Catchments (ha)</p> <ul style="list-style-type: none">11 - 10001001 - 1000010001 - 40000> 40000 <p>Watercourse Types</p> <ul style="list-style-type: none">● Headwater● Local - developed channel sections● Local - poorly developed channel● Local - well developed channel● Main Stem | <p>Watercourse Strahler Order</p> <ul style="list-style-type: none">12345678 <p>Floodplain Classification</p> <ul style="list-style-type: none">B3B3 - C1B3bB3b / C2C1C2 |
|---|--|--|



A3 scale: 1:100,000
0 0.75 1.5 2.25 3 3.75 km



Legend

- 5 Chainage (km)
- Localities
- Proposed B2G bridges
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Major roads

Sub Catchments (ha)

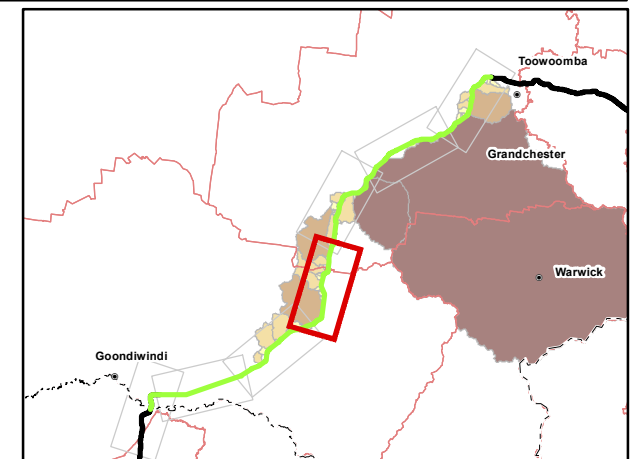
- 11 - 1000
- 1001 - 10000
- 10001 - 40000
- > 40000

Watercourse Types

- Headwater
- Local - developed channel sections
- Local - poorly developed channel
- Local - well developed channel
- Main Stem

Watercourse Strahler Order Floodplain Classification

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- B3
- B3 - C1
- B3b
- B3b / C2
- C1
- C2



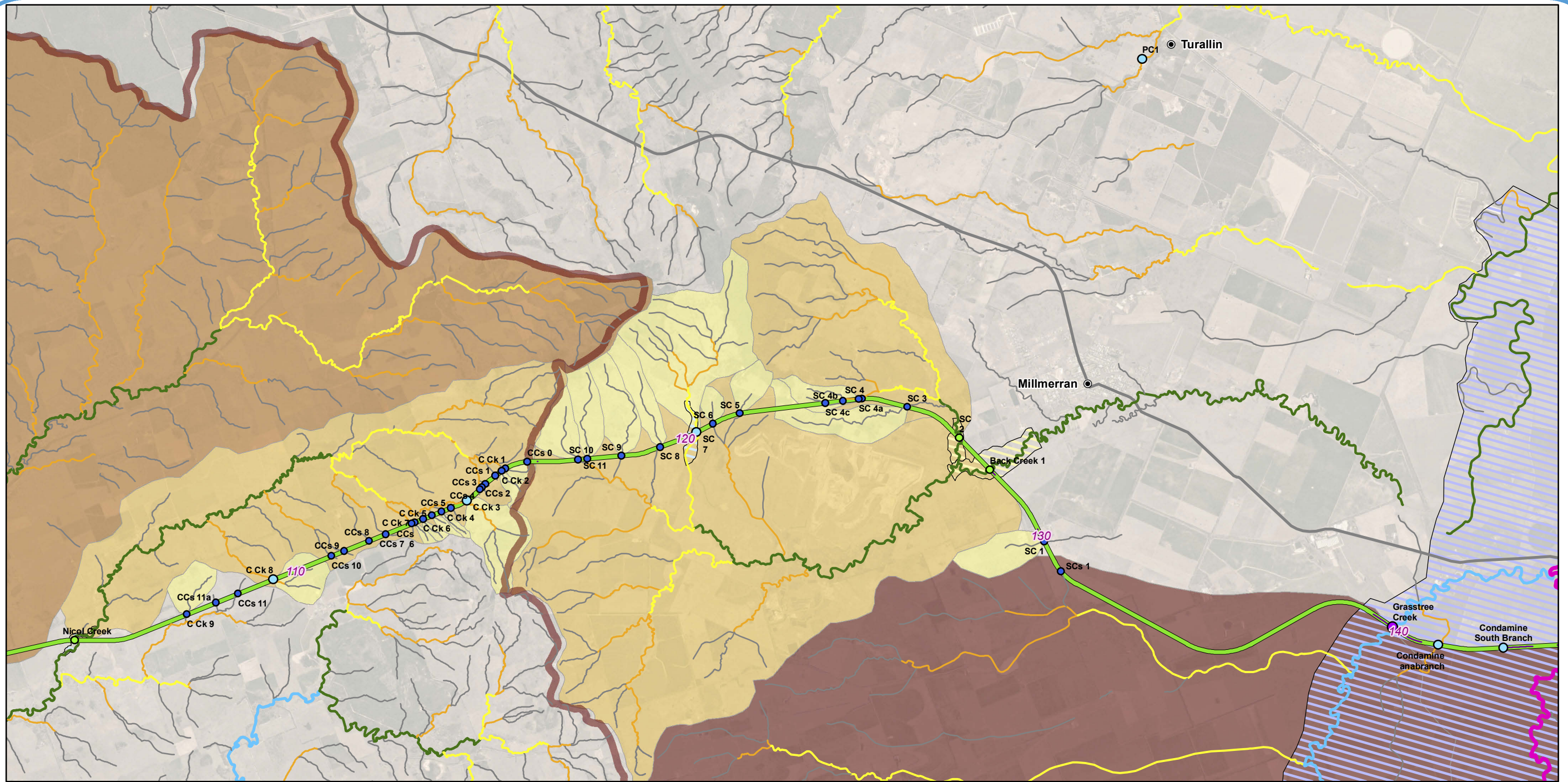
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0 0.75 1.5 2.25 3 3.75km



Issue date: 1/05/2024 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie
Drawing Set C. 4 of 7
Catchments & Stream Order



Legend

- 5 Chainage (km)
- Localities
- Proposed B2G bridges
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Major roads

Sub Catchments (ha)

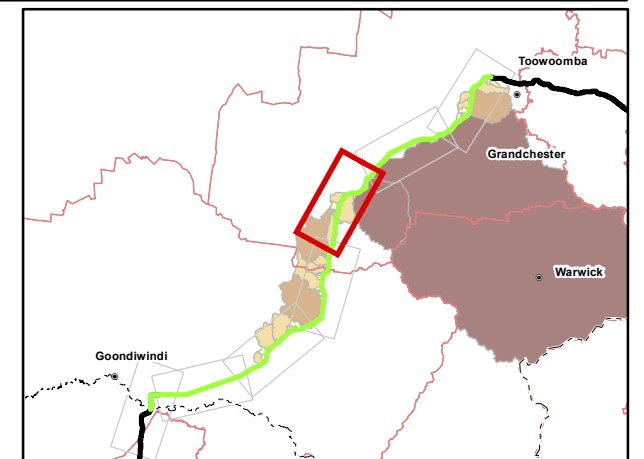
- 11 - 1000
- 1001 - 10000
- 10001 - 40000
- > 40000

Watercourse Types

- Headwater
- Local - developed channel sections
- Local - poorly developed channel
- Local - well developed channel
- Main Stem

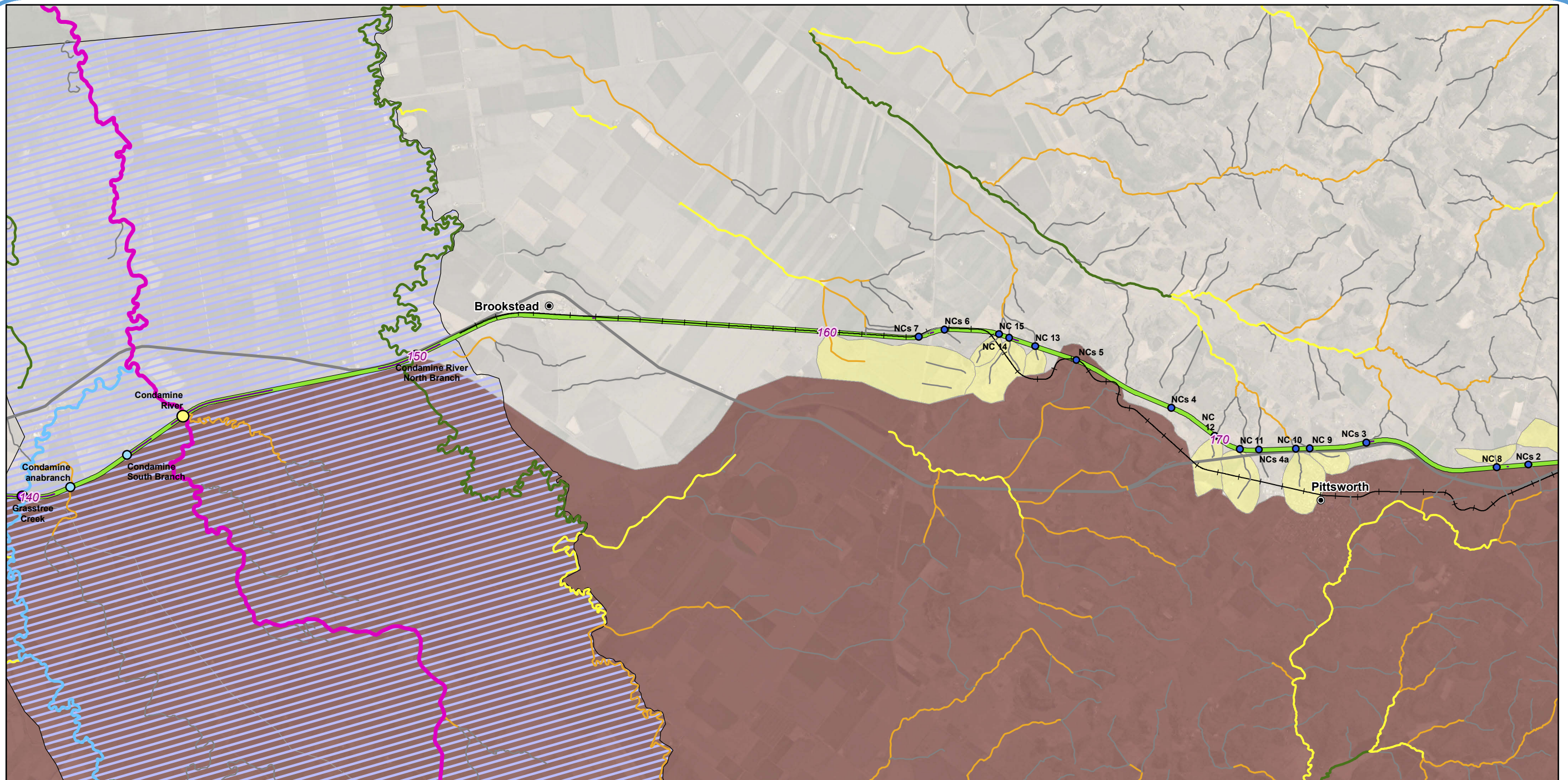
Watercourse Strahler Order Floodplain Classification

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- B3
- B3 - C1
- B3b
- B3b / C2
- C1
- C2



A3 scale: 1:100,000

0 0.75 1.5 2.25 3 3.75 km



Legend

- 5 Chainage (km)
- Localities
- Proposed B2G bridges
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Major roads

Sub Catchments (ha)

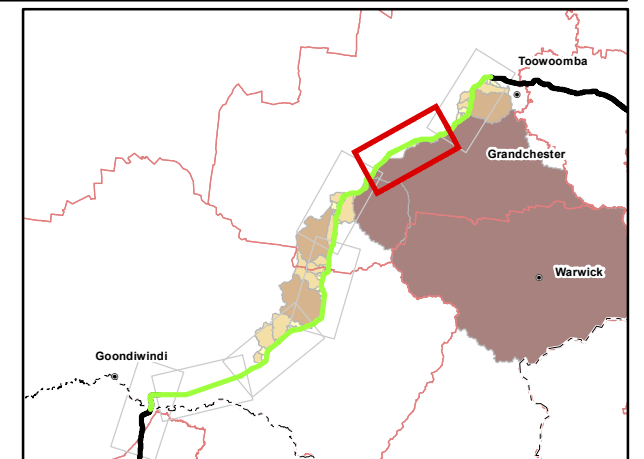
- 11 - 1000
- 1001 - 10000
- 10001 - 40000
- > 40000

Watercourse Types

- Headwater
- Local - developed channel sections
- Local - poorly developed channel
- Local - well developed channel
- Main Stem

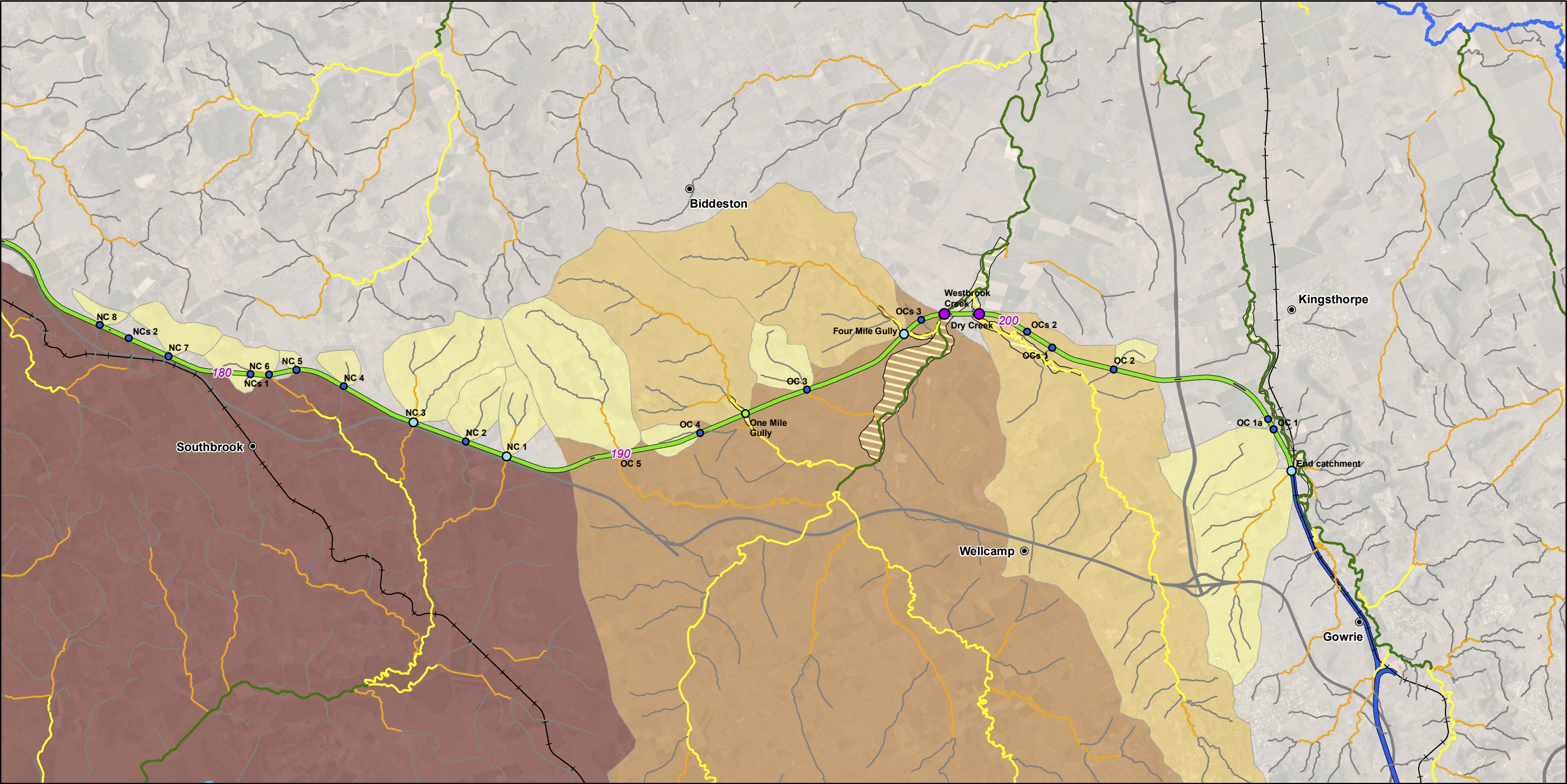
Watercourse Strahler Order Floodplain Classification

- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- B3
- B3 - C1
- B3b
- B3b / C2
- C1
- C2



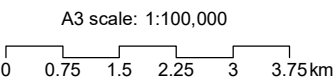
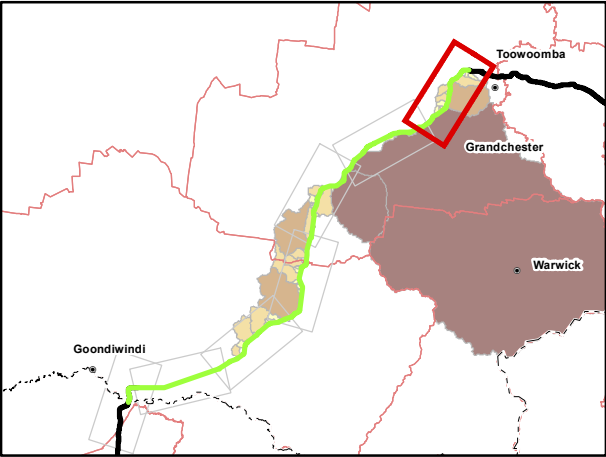
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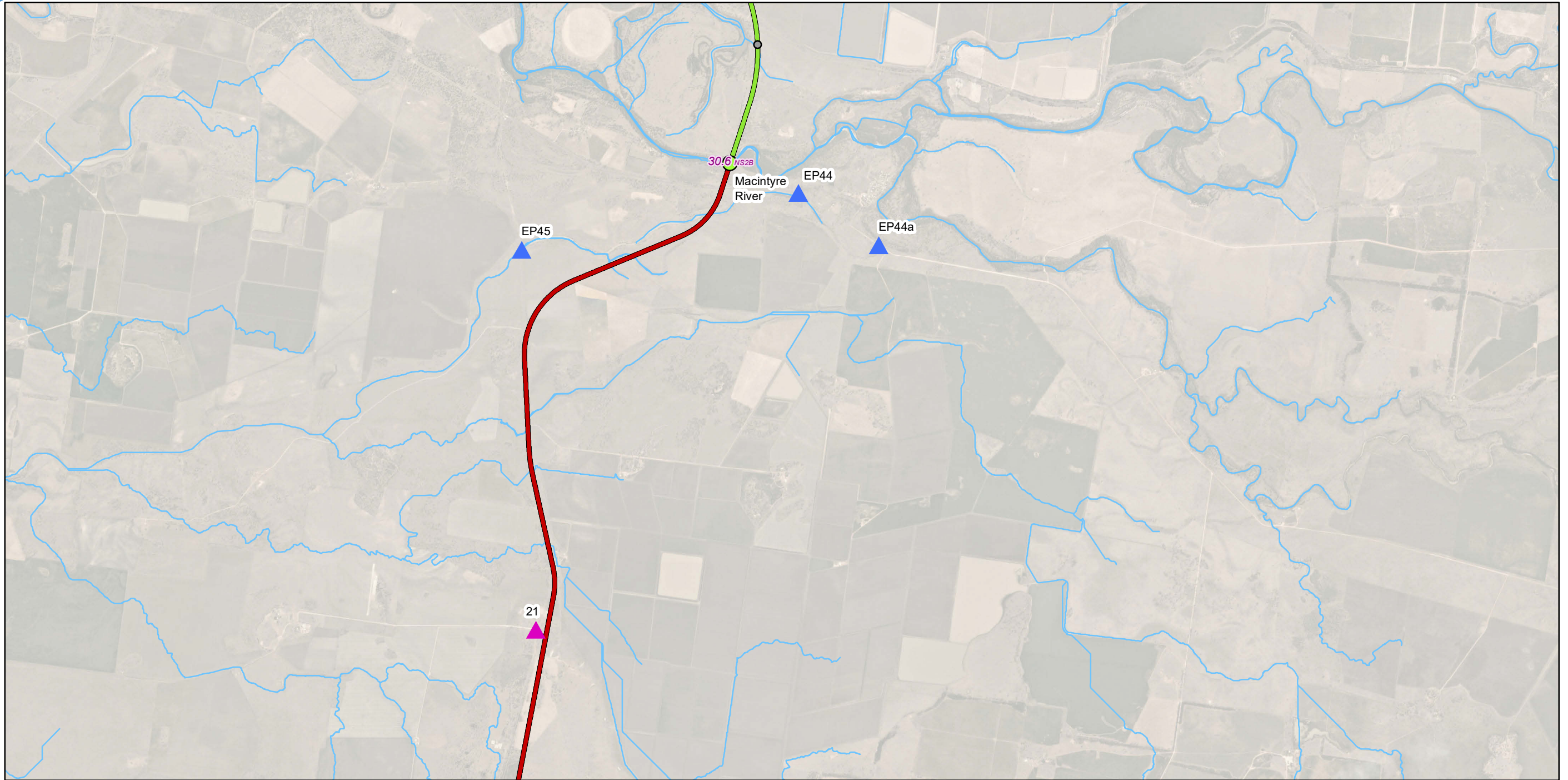
0 0.75 1.5 2.25 3 3.75 km



Legend

- | | | |
|---|--|--|
| <ul style="list-style-type: none">5 Chainage (km)LocalitiesProposed B2G bridgesBorder to Gowrie alignmentNorth Star to NSW/QLD border alignmentExisting rail (operational)Major roads | <p>Sub Catchments (ha)</p> <ul style="list-style-type: none">11 - 10001001 - 1000010001 - 40000> 40000 <p>Watercourse Types</p> <ul style="list-style-type: none">HeadwaterLocal - developed channel sectionsLocal - poorly developed channelLocal - well developed channelMain Stem | <p>Watercourse Strahler Order</p> <ul style="list-style-type: none">12345678 <p>Floodplain Classification</p> <ul style="list-style-type: none">B3B3 - C1B3bB3b / C2C1C2 |
|---|--|--|





Legend

Watercourses - Initial Risk

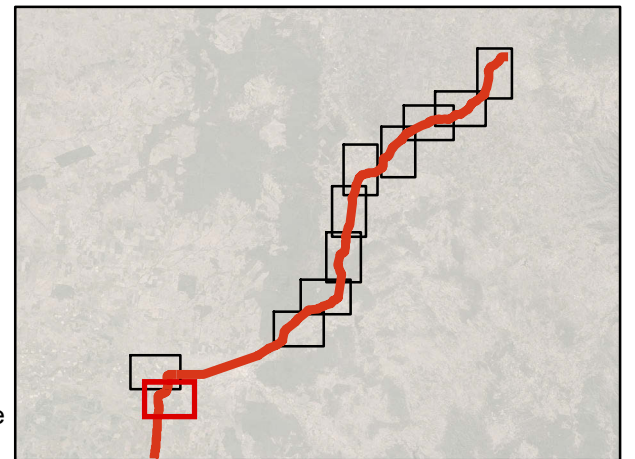
- High
- Medium
- Low
- Assessed Under Flooding

Field Checking

- Baseline
- Erosion Potential

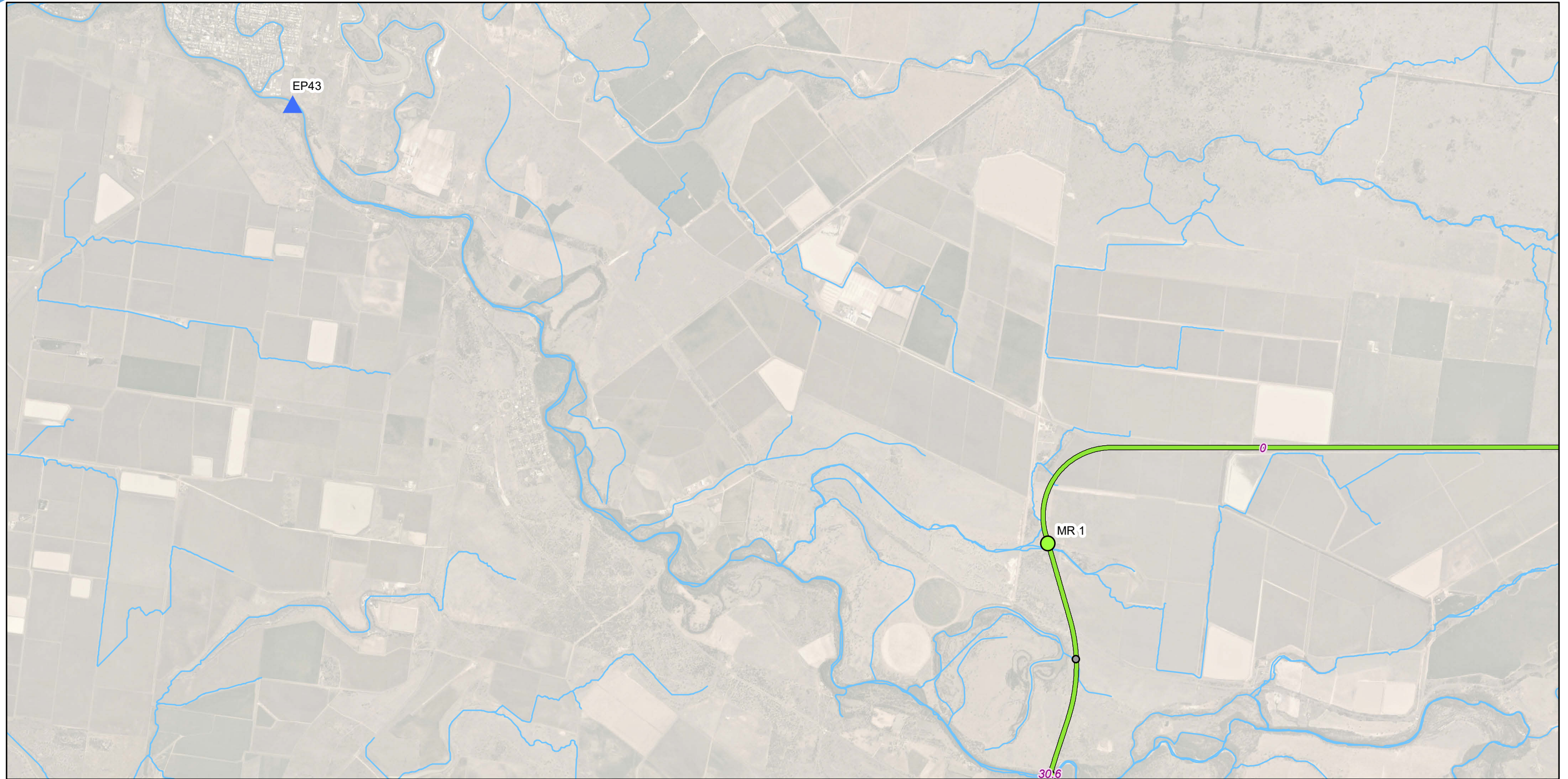
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.



A3 scale: 1:73,840

0 0.6 1.2 1.8 2.4 3km



Legend

Watercourses - Initial Risk

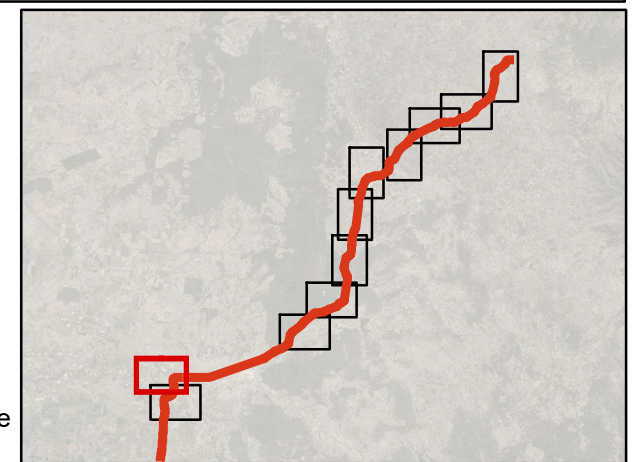
- High
- Medium
- Low
- Assessed Under Flooding

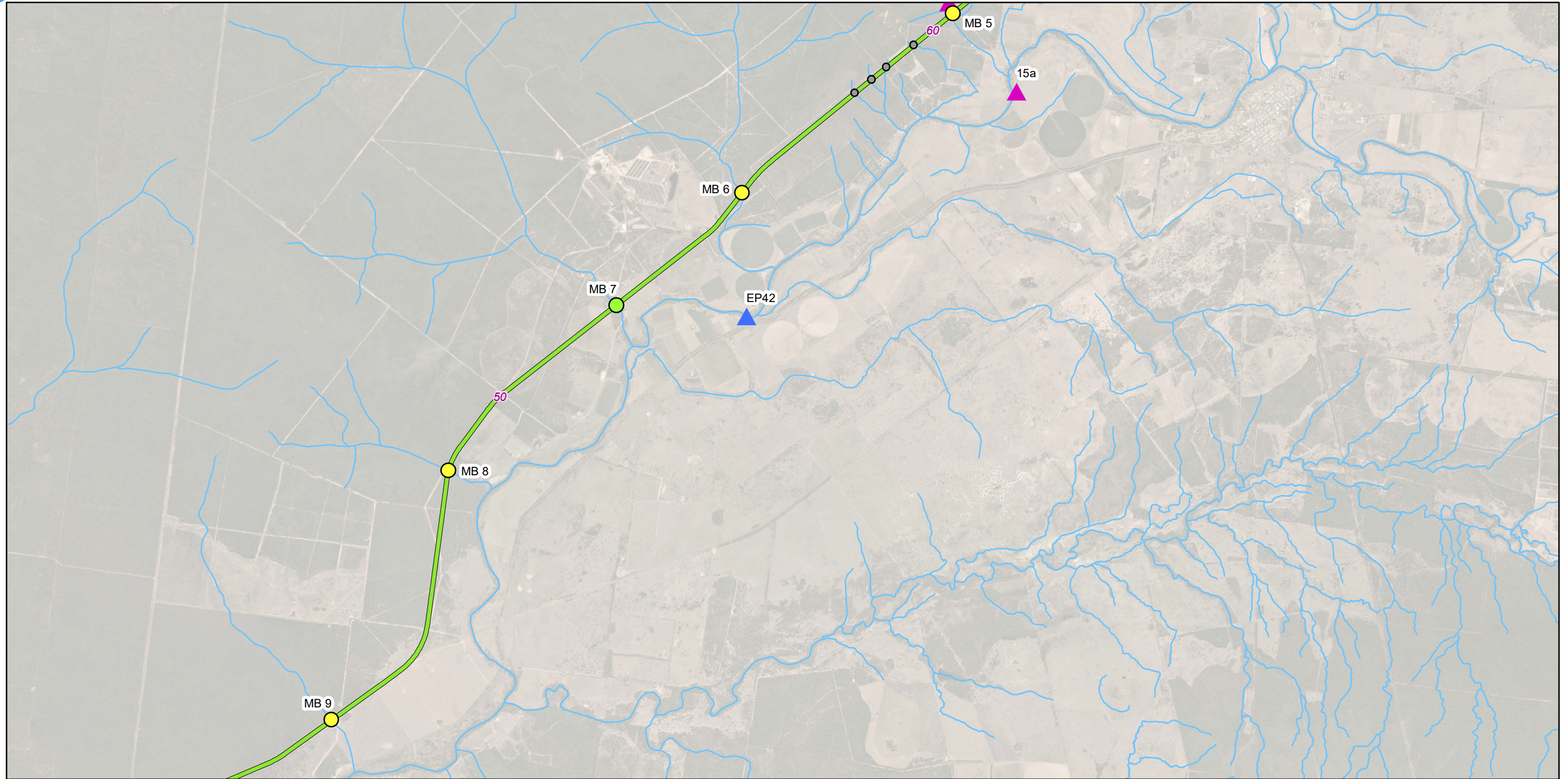
Field Checking

- Baseline
- Erosion Potential

- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.





Legend

Watercourses - Initial Risk

- High
- Medium
- Low
- Assessed Under Flooding

Field Checking

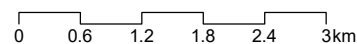
- Baseline
- Erosion Potential

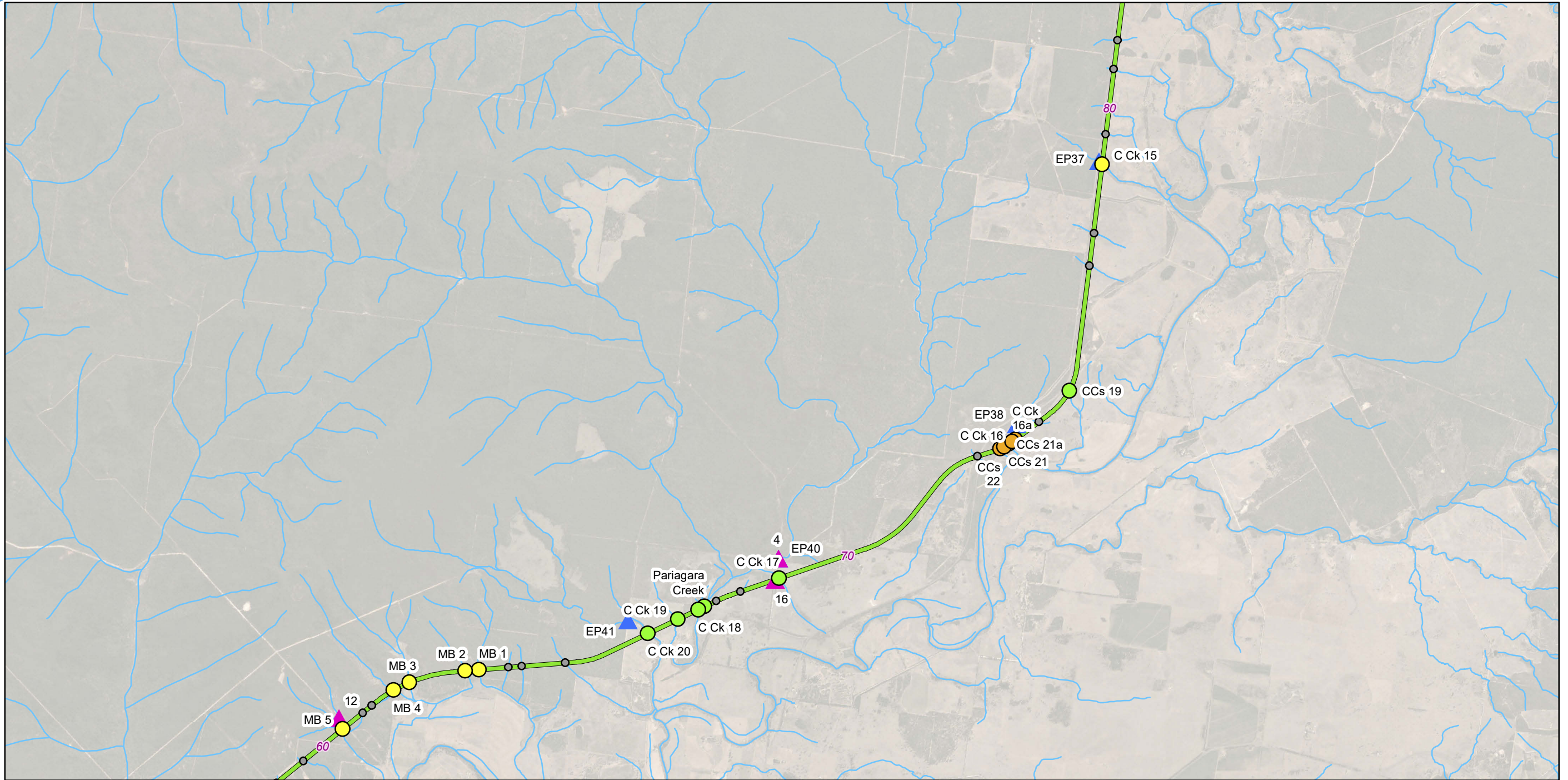
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.



A3 scale: 1:73,840





Legend

Watercourses - Initial Risk

- High
- Medium
- Low
- Assessed Under Flooding

Field Checking

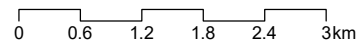
- ▲ Baseline
- ▲ Erosion Potential

- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.

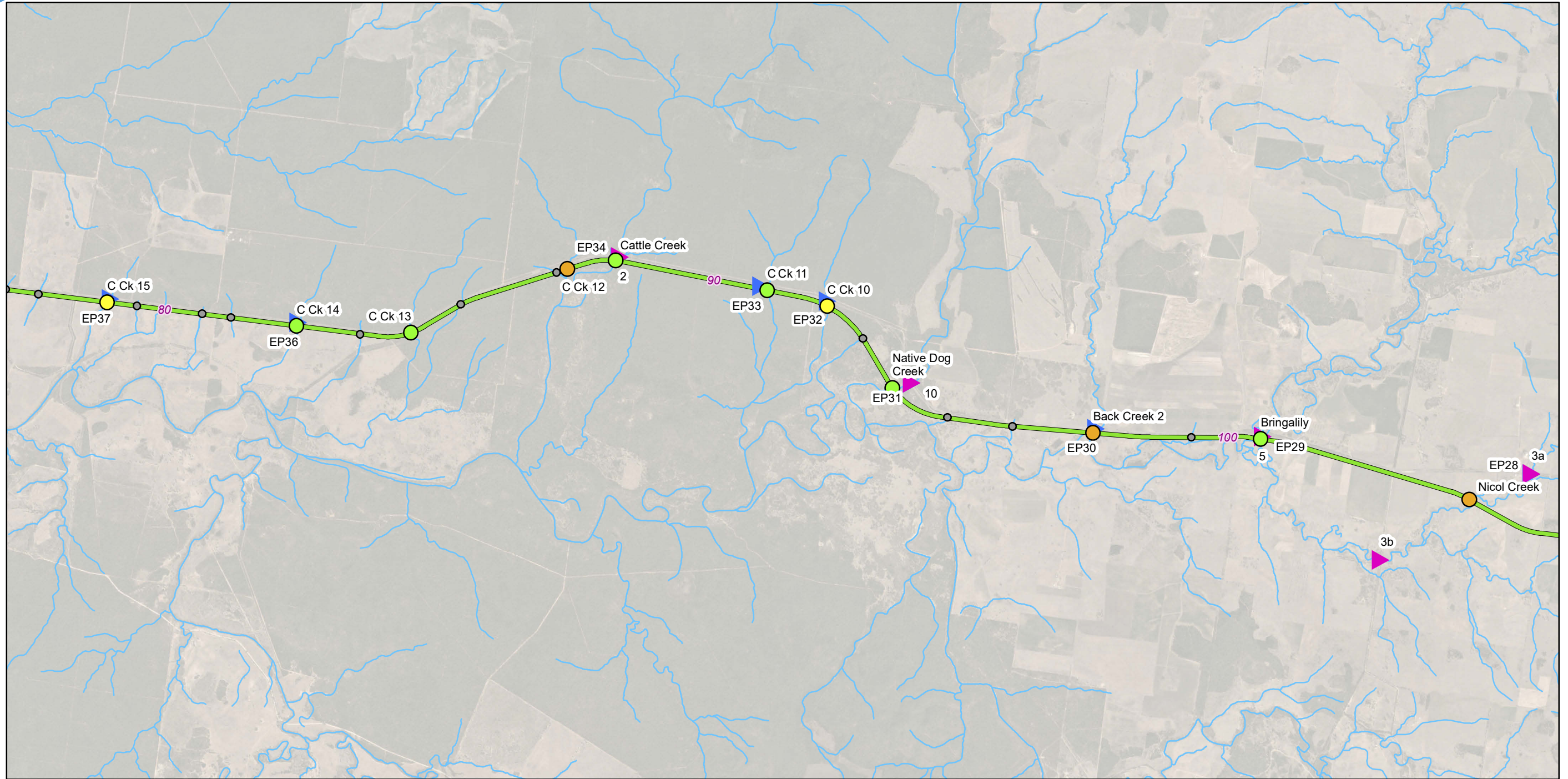


A3 scale: 1:73,840



Issue date: 1/05/2024 Version: 1
Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie
Drawing Set D. 4 of 11
Initial Site Risk and Visited Sites



Legend

Watercourses - Initial Risk

- High
- Medium
- Low
- Assessed Under Flooding

Field Checking

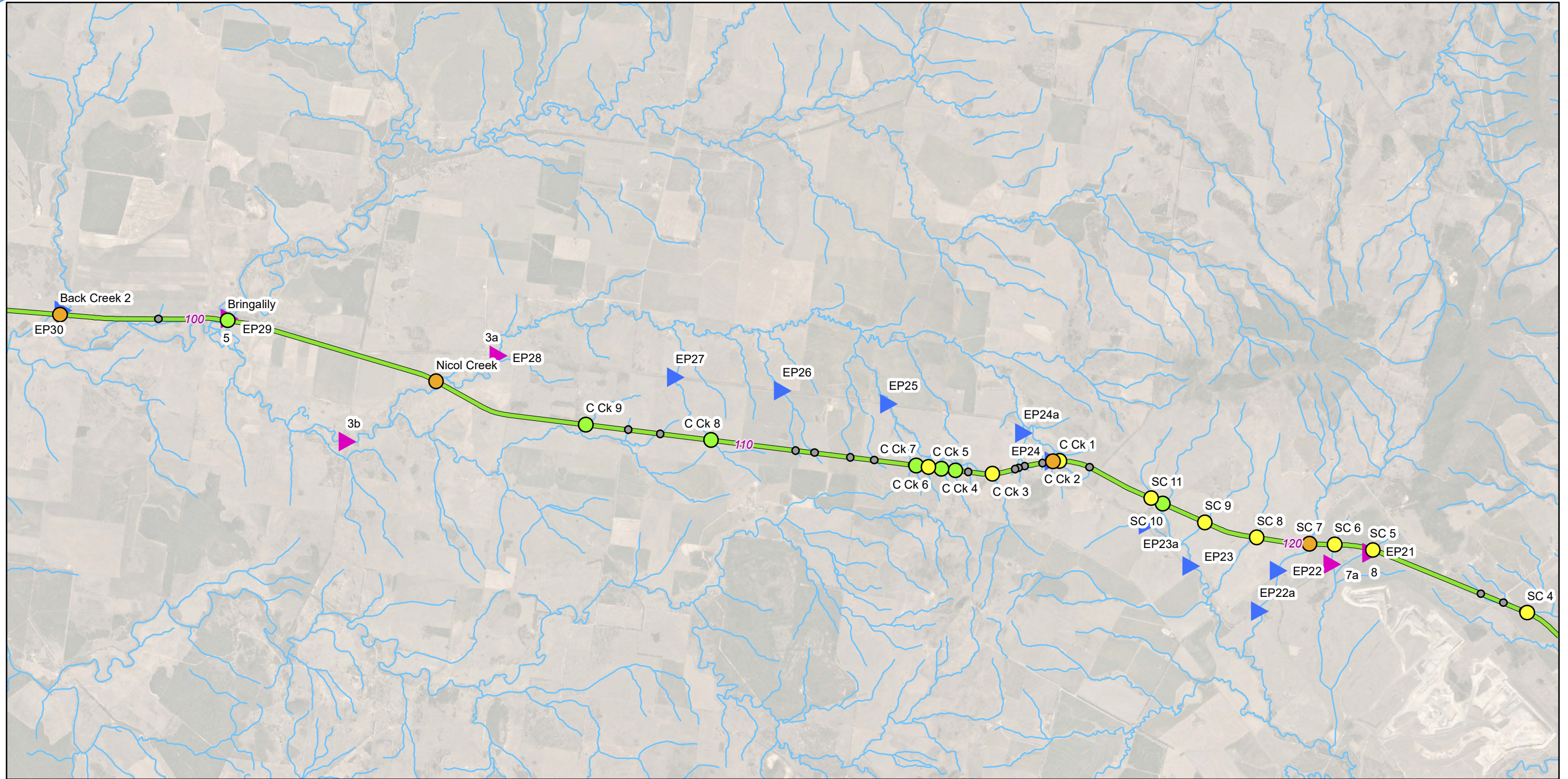
- Baseline
- Erosion Potential

- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.

A3 scale: 1:73,840

0 0.6 1.2 1.8 2.4 3km



Legend

Watercourses - Initial Risk

- High
- Medium
- Low
- Assessed Under Flooding

Field Checking

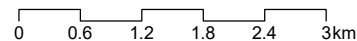
- ▲ Baseline
- ▲ Erosion Potential

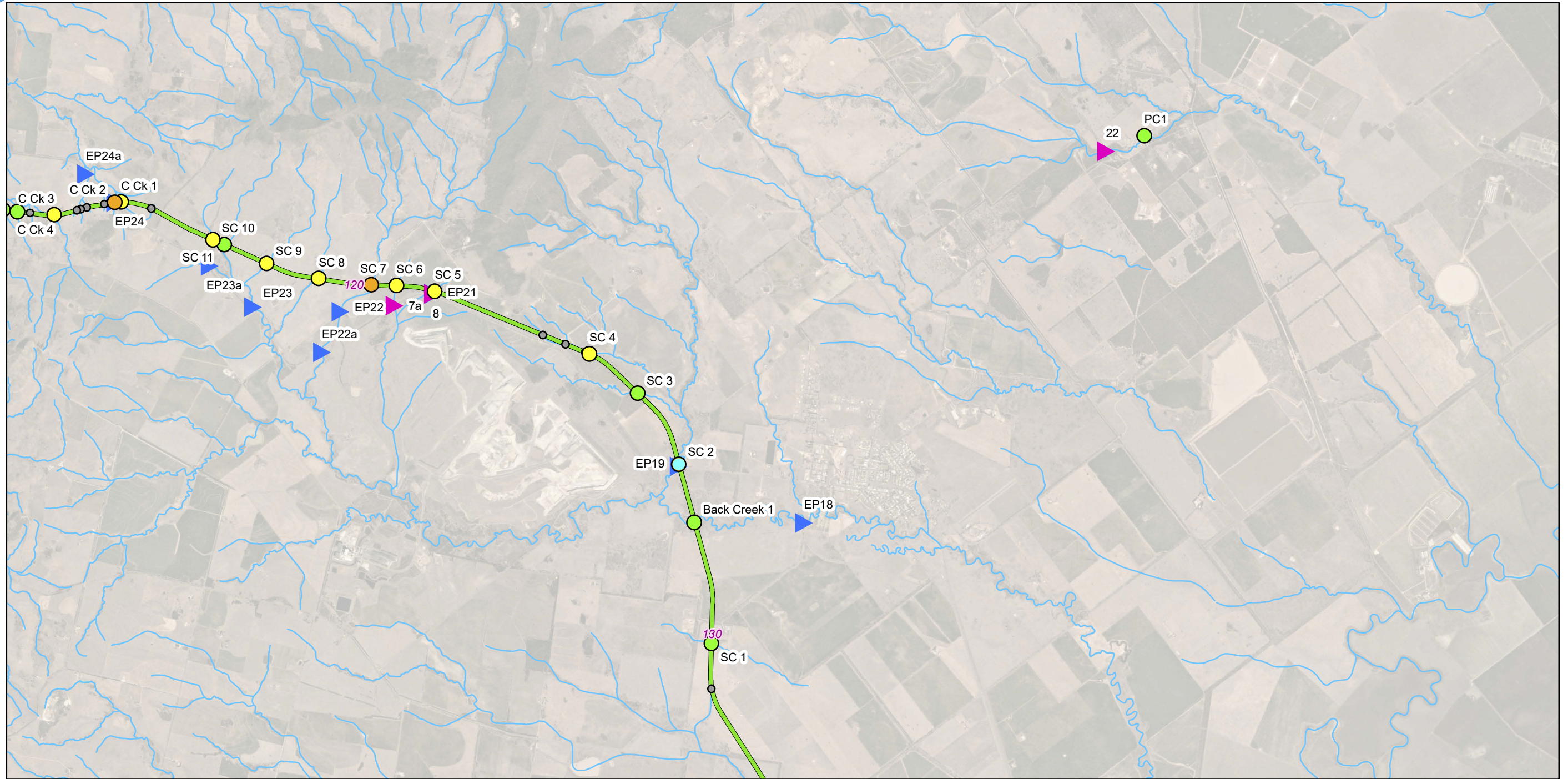
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.



A3 scale: 1:73,840





Legend

Watercourses - Initial Risk

- High
- Medium
- Low
- Assessed Under Flooding

Field Checking

- ▲ Baseline
- ▲ Erosion Potential

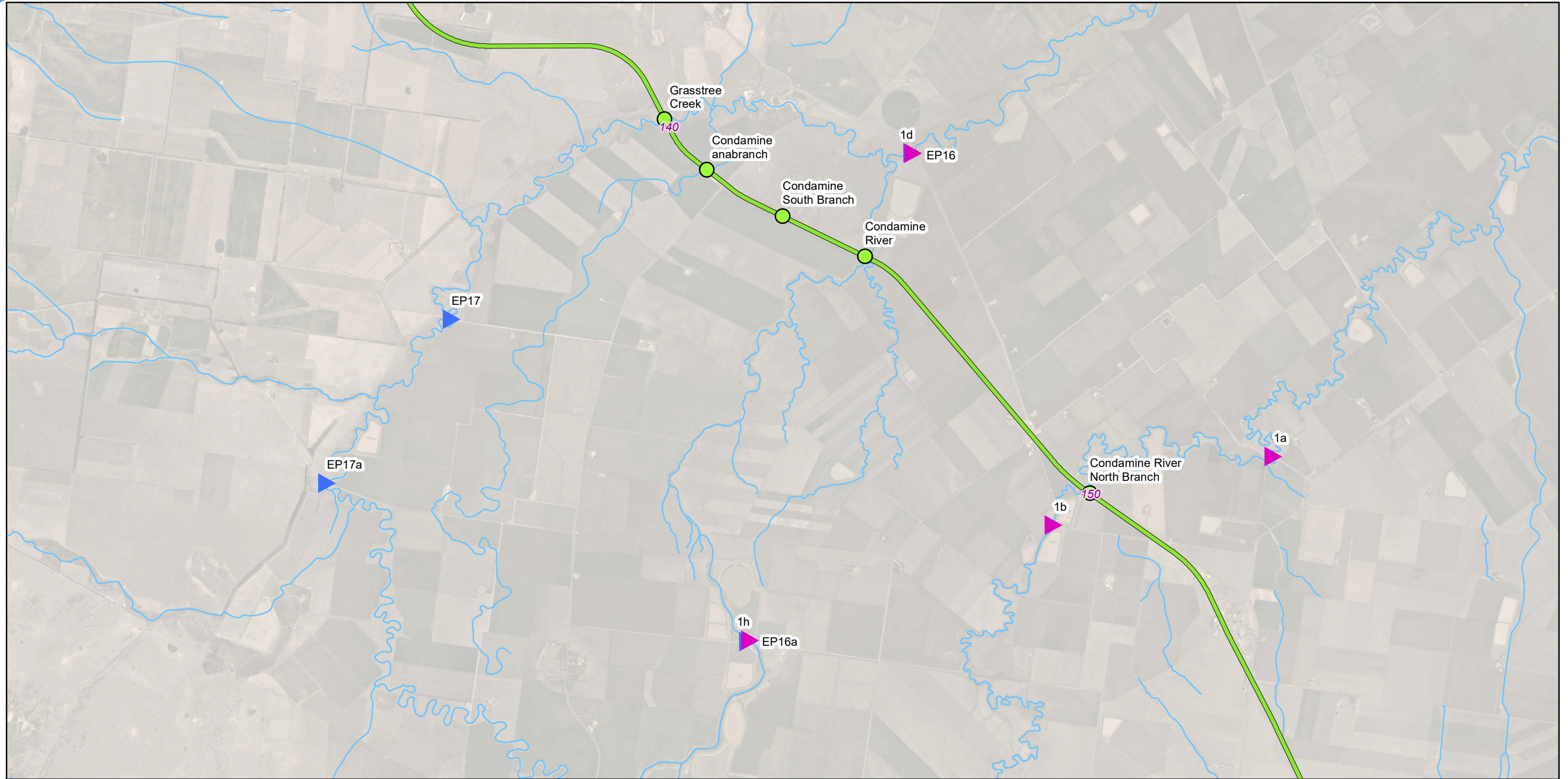
- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.



A3 scale: 1:73,840

0 0.6 1.2 1.8 2.4 3km



Legend

Watercourses - Initial Risk

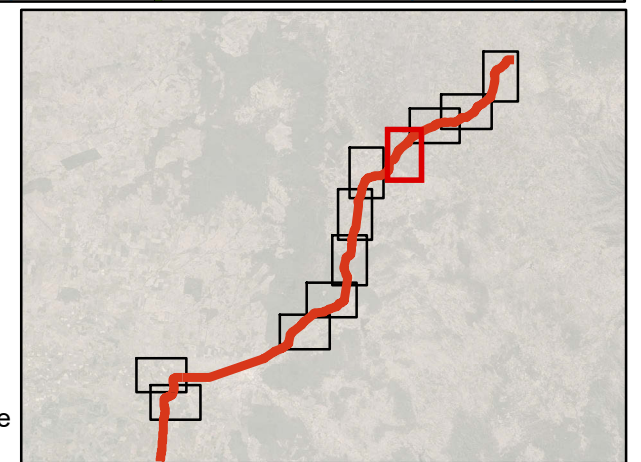
- High
- Medium
- Low
- Assessed Under Flooding

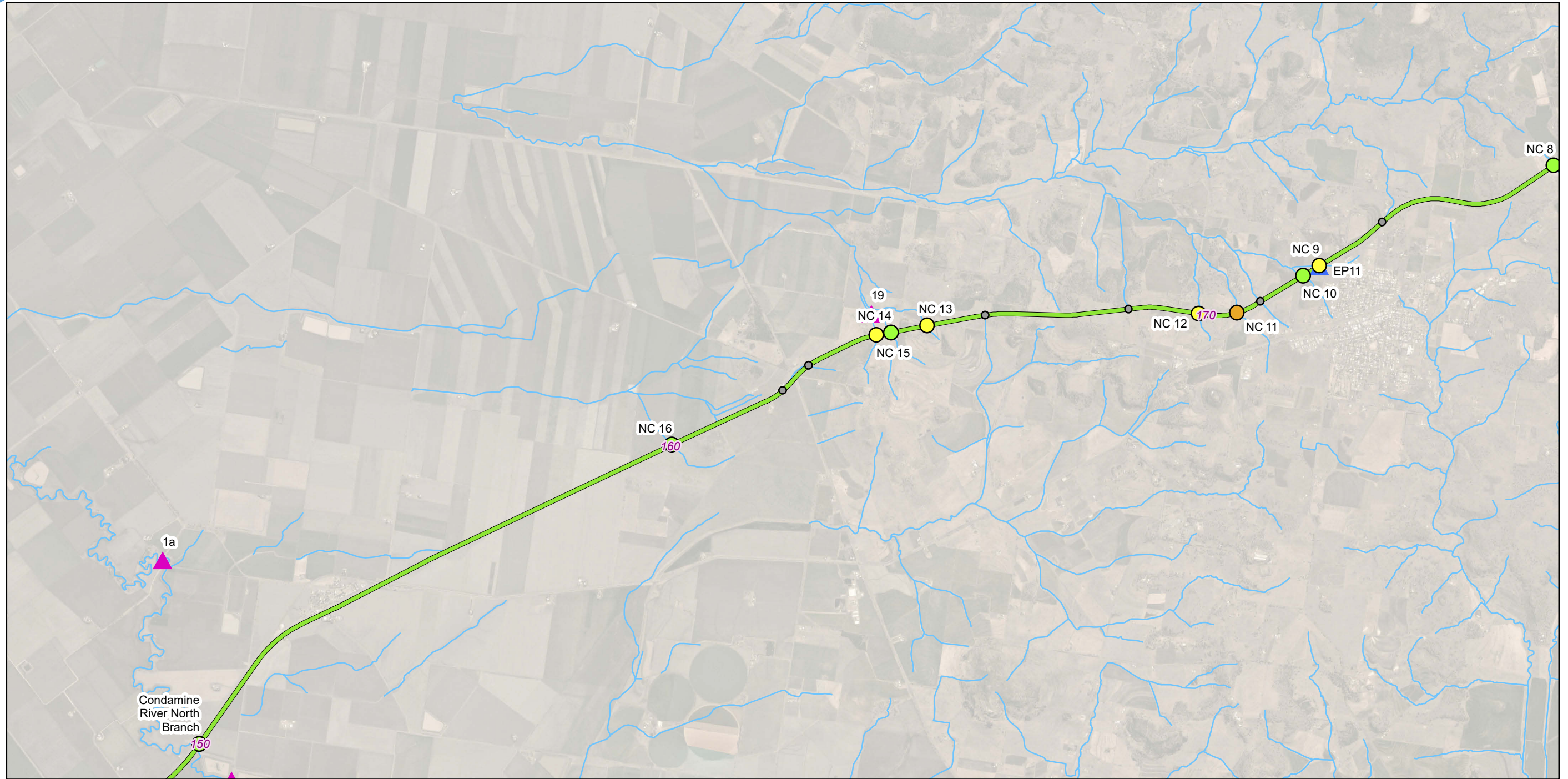
Field Checking

- Baseline
- Erosion Potential

- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.





Legend

Watercourses - Initial Risk

- High
- Medium
- Low
- Assessed Under Flooding

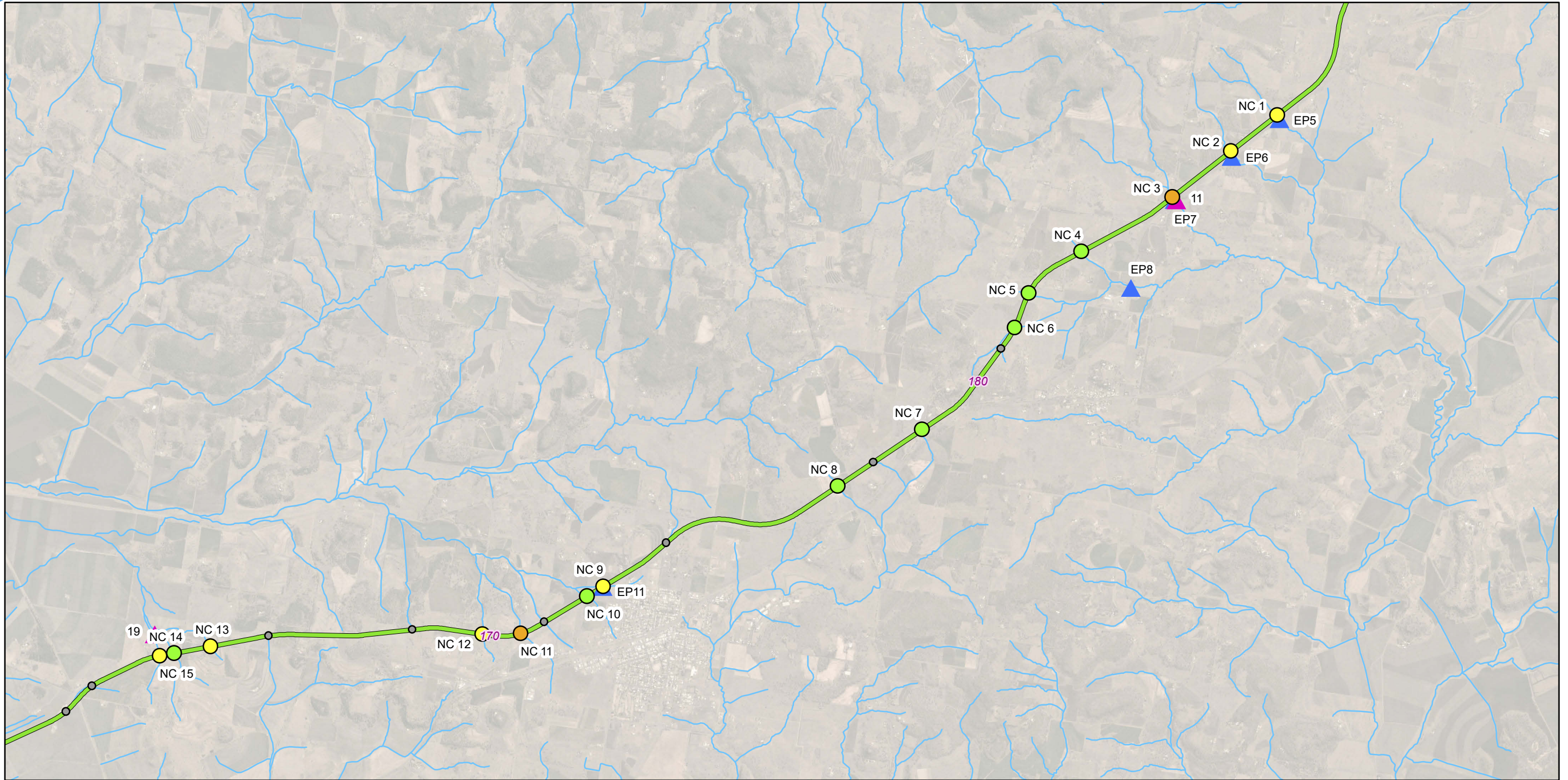
Field Checking

- Baseline
- Erosion Potential

- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.





Legend

Watercourses - Initial Risk

- High
- Medium
- Low
- Assessed Under Flooding

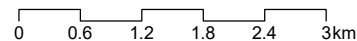
Field Checking

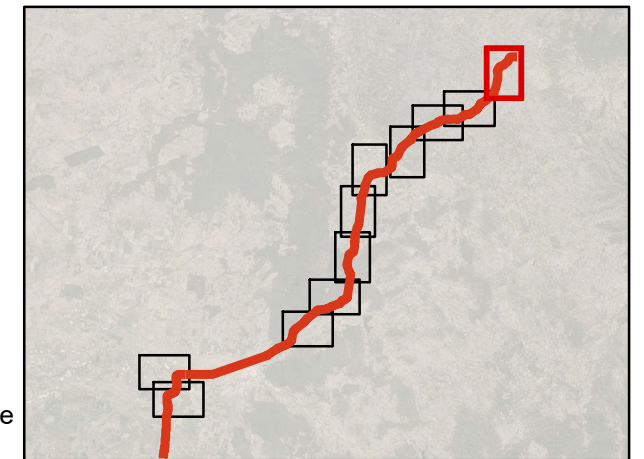
- ▲ Baseline
- ▲ Erosion Potential

- Border to Gowrie alignment
- North Star to NSW/QLD border alignment
- Watercourses

Note: The initial risk is the risk of potential impacts to the existing geomorphic process from the project. This includes existing mitigation measured already in the revised reference design.

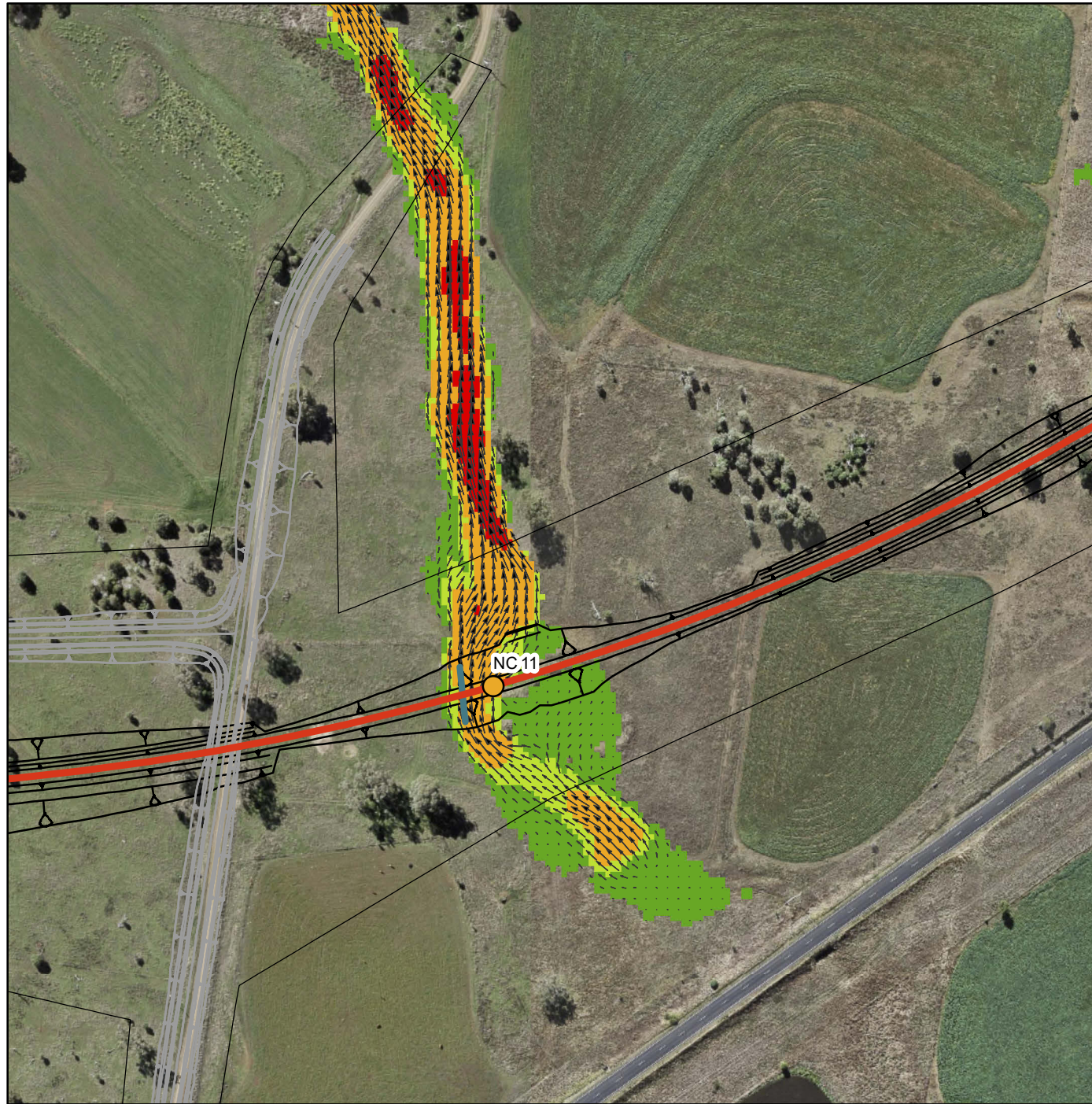
A3 scale: 1:73,840



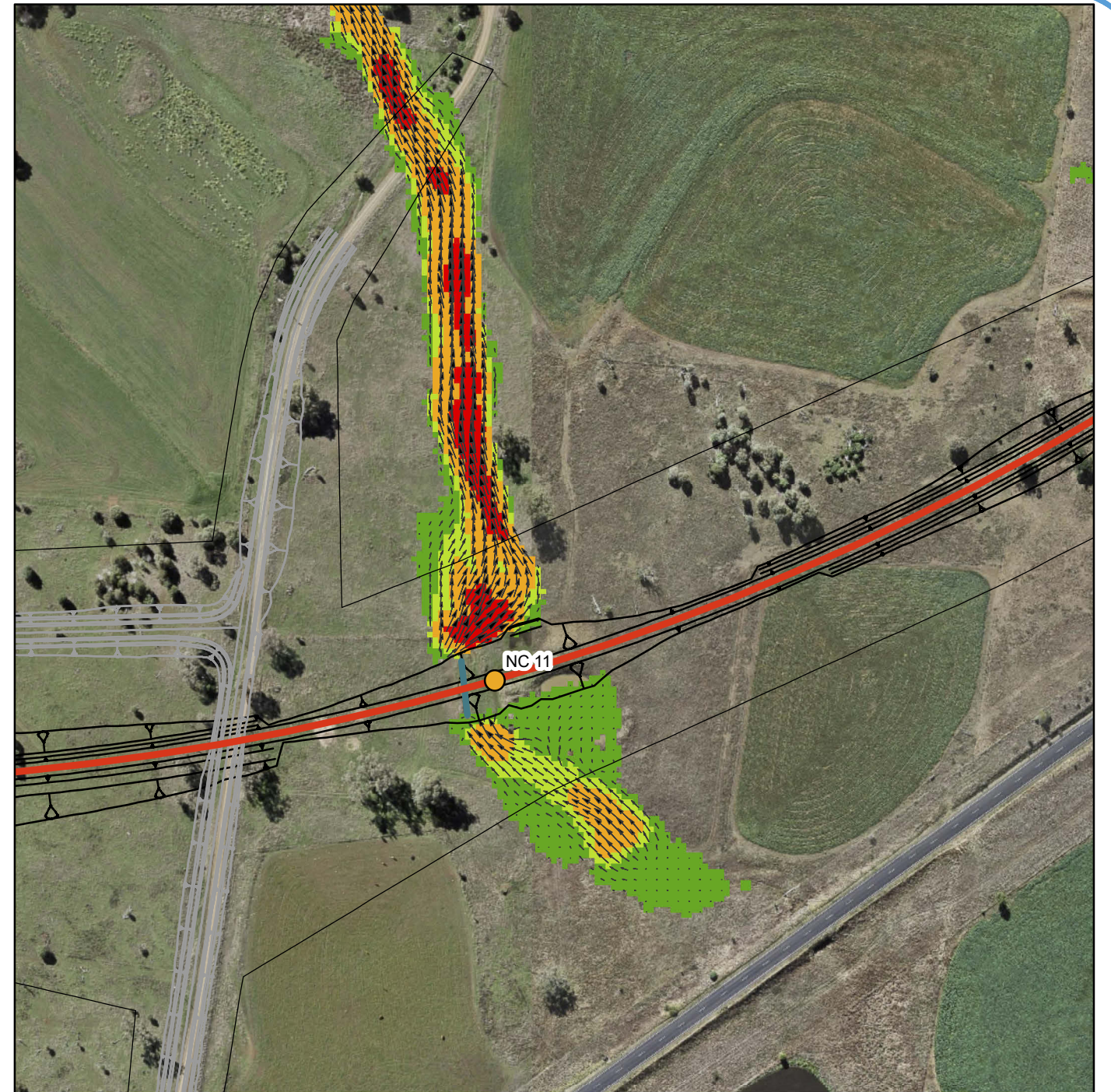


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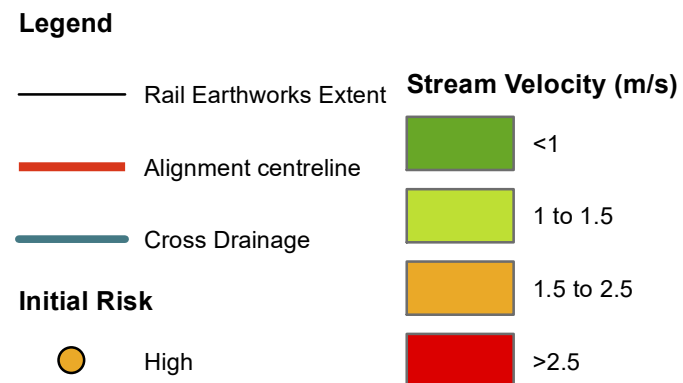
Border to Gowrie
Drawing Set D. 11 of 11
Initial Site Risk and Visited Sites



Existing Case



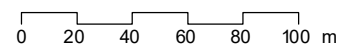
Design Case



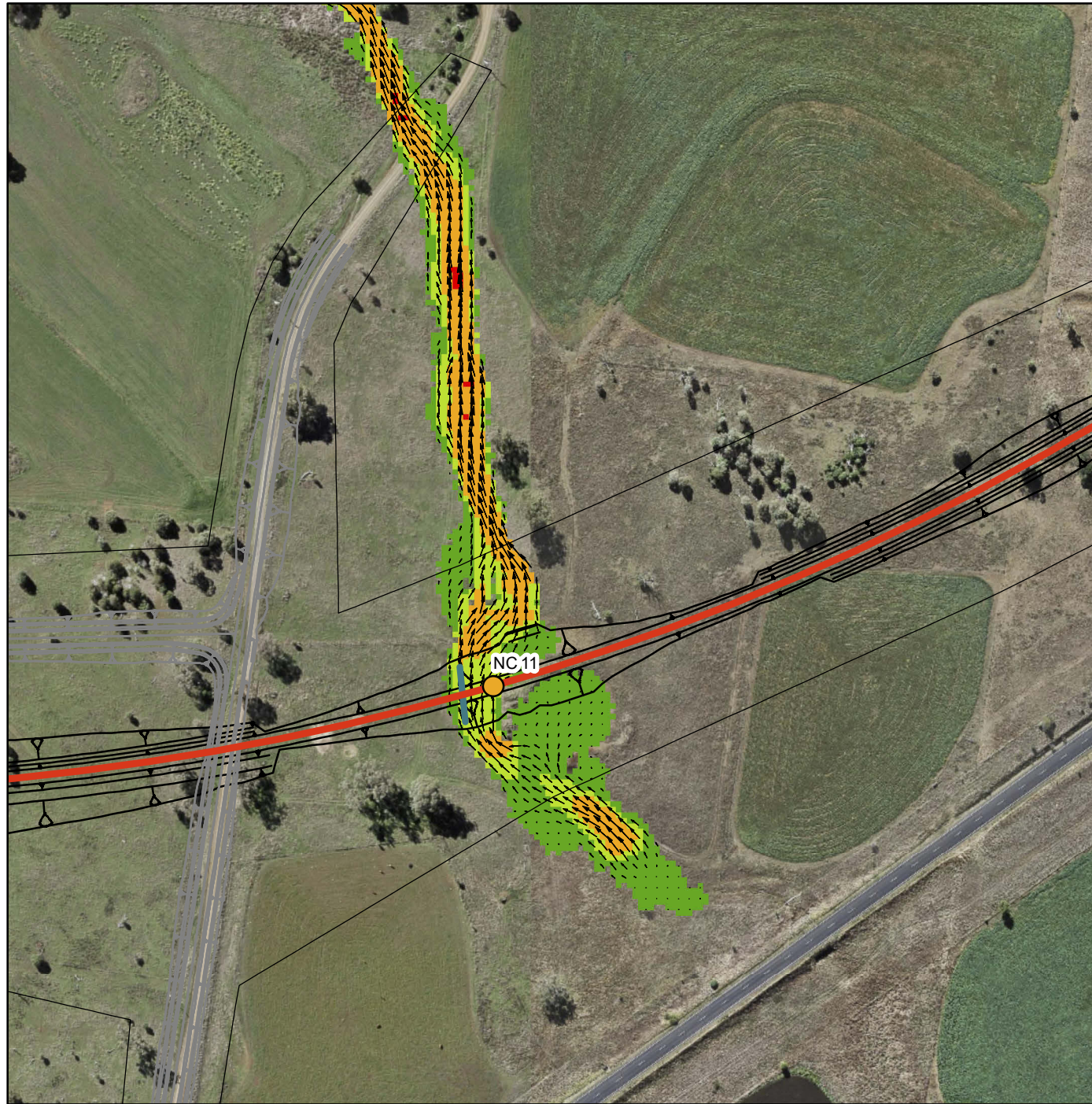
Note:
Flow direction is from bottom to top of page



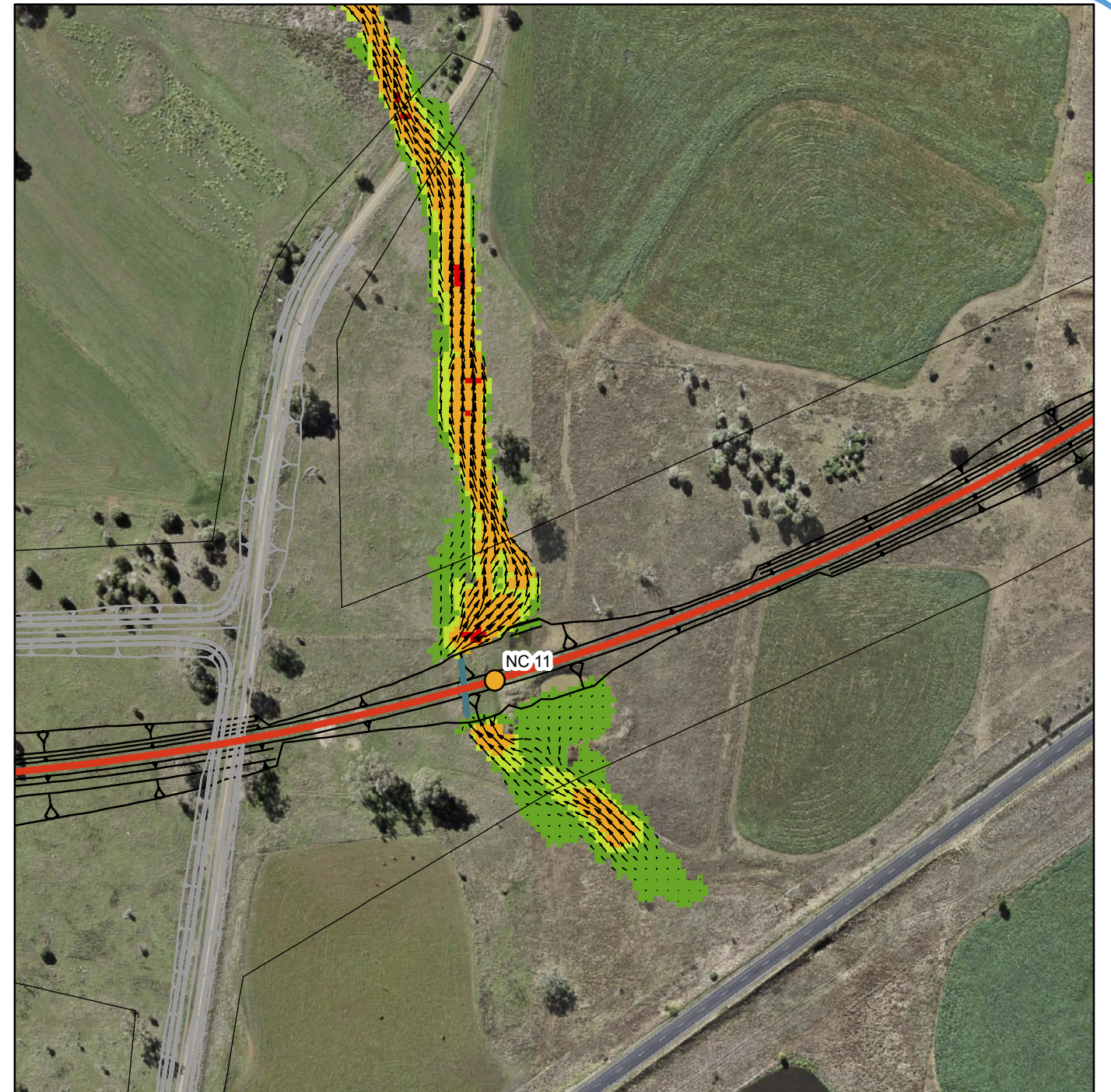
A3 scale: 1:2,730



Issue date: 31/08/2022 Version: 1
Coordinate System: GDA 1994 MGA Zone 56



Existing Case



Design Case

Legend

Initial Risk

● High

— Rail Earthworks Extent

— Alignment centreline

— Cross Drainage

Stream Velocity (m/s)

■ <1

■ 1 to 1.5

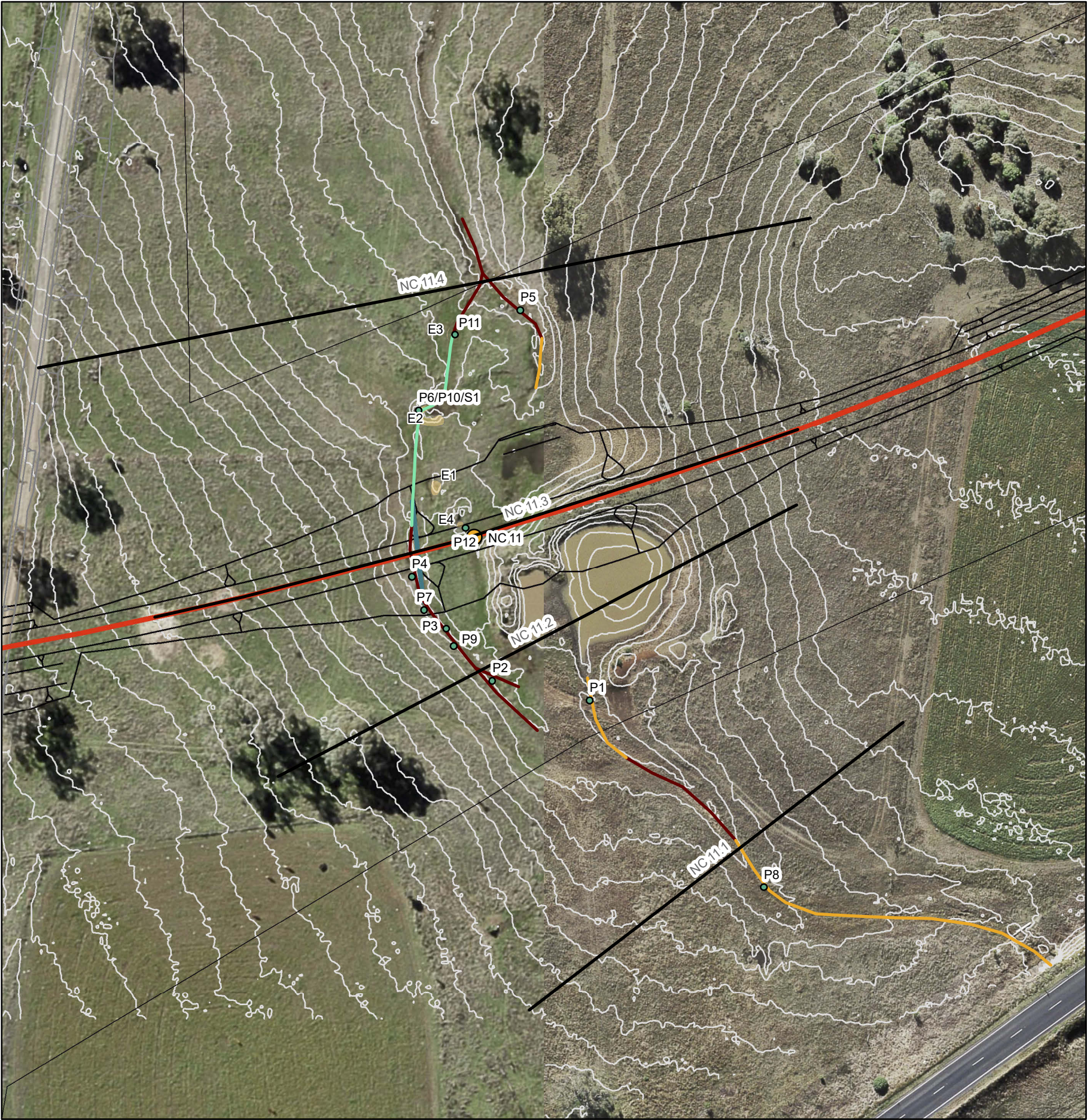
■ 1.5 to 2.5

■ >2.5

Note:
Flow direction is from bottom to top of page



A3 scale: 1:2,730
0 20 40 60 80 100 m



Geomorphology Notes:

E1 - Scoured hole approximately 0.4 m deep, 3 m long, 2 m wide with ponding water and gravel.

E2 - Area of erosion in soil with 0.7 m to 1 m high banks, grassed channel u/s not very well defined, 1 m base level change at head of area, central section is slightly built up and grassed. Channel d/s of area is 1 m wide, 0.1-0.2m deep.

E3 - Bank erosion on the true left in soil above rock channel, 0.4 m high bank, channel is approx 2 m wide at this location.

E4 - Approx 2 m x 2m x 2m hole on floodplain. May not be natural.

Map indicates channel bed composition, the line does not define the channel extent.

Sample S1 comprised two bags labelled S1 and S2 however this is the same material.

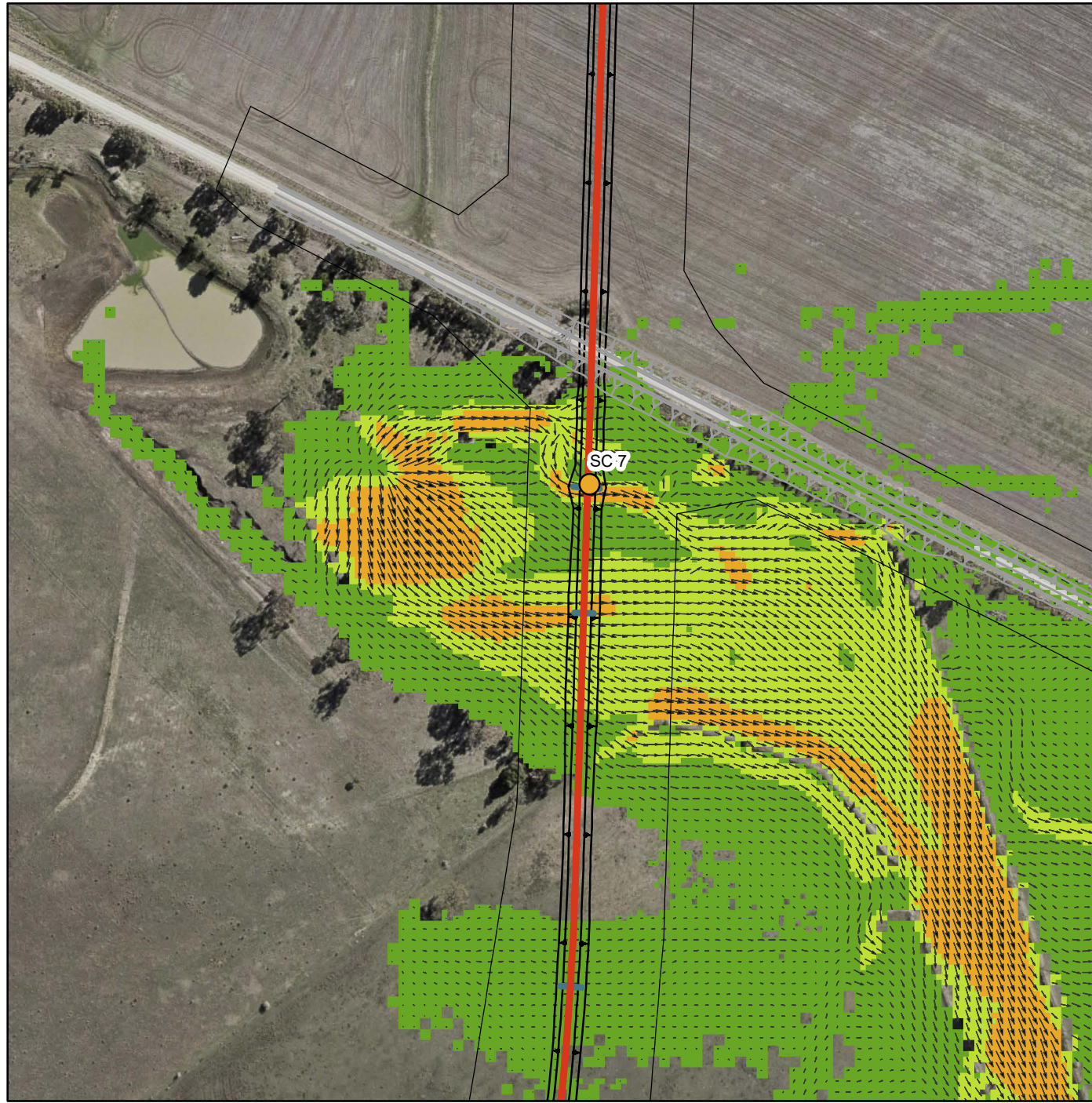
Legend

Initial Risk

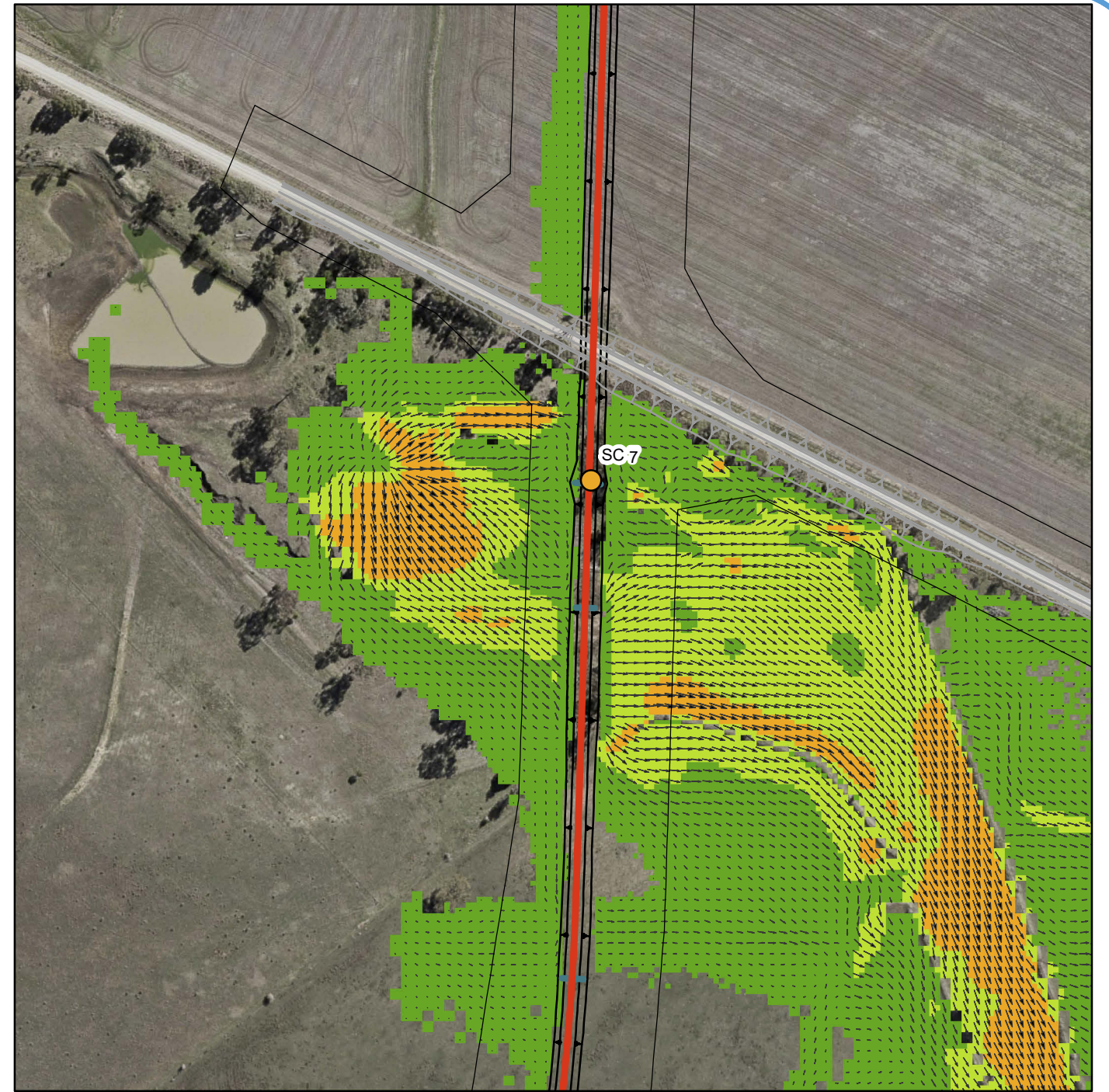
- High
- Gravel lined channel
- Soil or grass lined channel
- Rock lined channel
- Erosion
- Photo location
- Alignment centreline
- Cross Drainage
- Rail Earthworks Extent
- 0.5 m Contour

A3 scale: 1:1,130

0 10 20 30 40Meters



Existing Case



Design Case

Legend

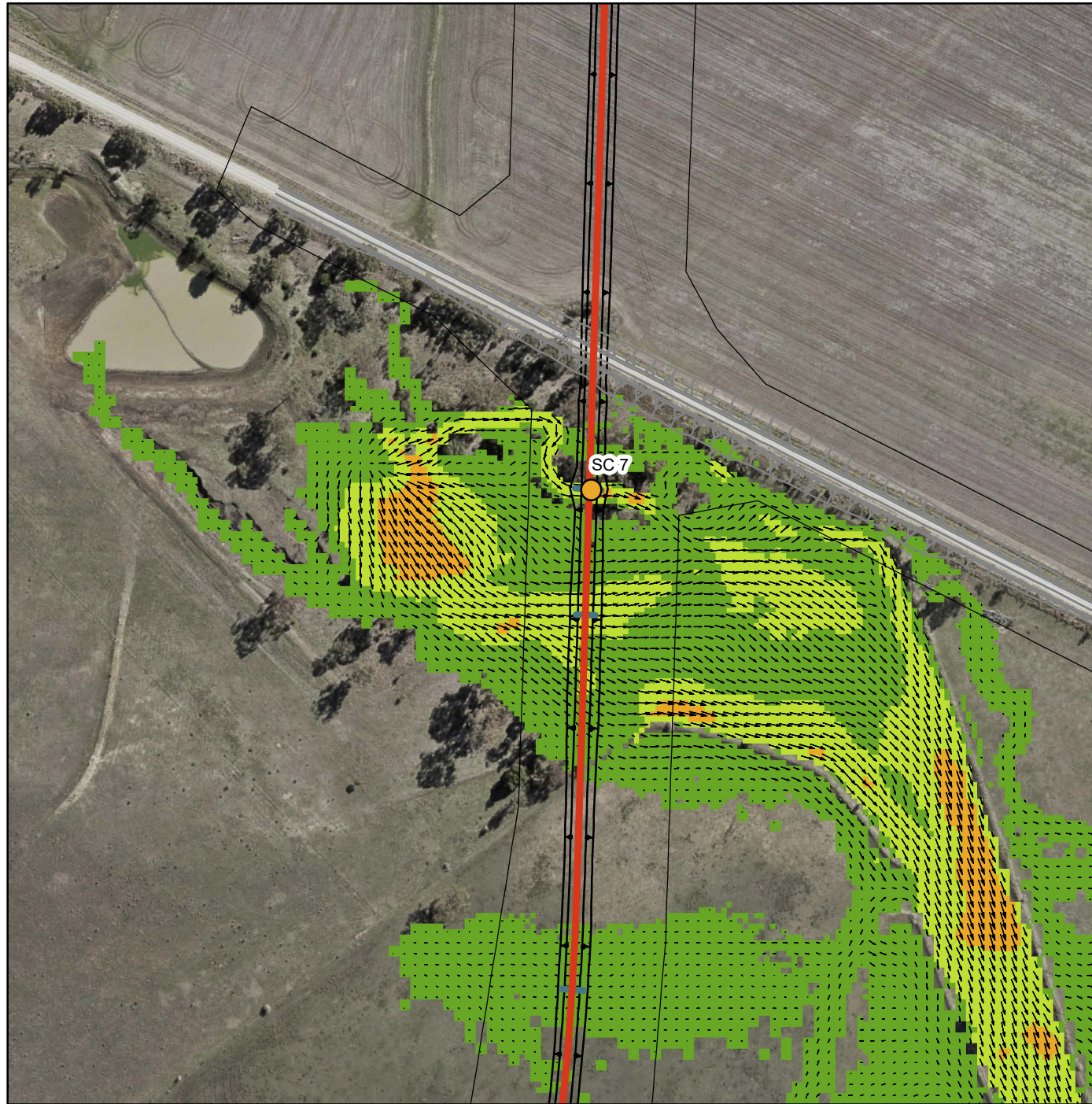
- Rail Earthworks Extent
- Alignment centreline
- Cross Drainage
- Initial Risk**
- High
- Stream Velocity (m/s)**
- <1
- 1 to 1.5
- 1.5 to 2.5

Note:
Flow direction is from left to right of page

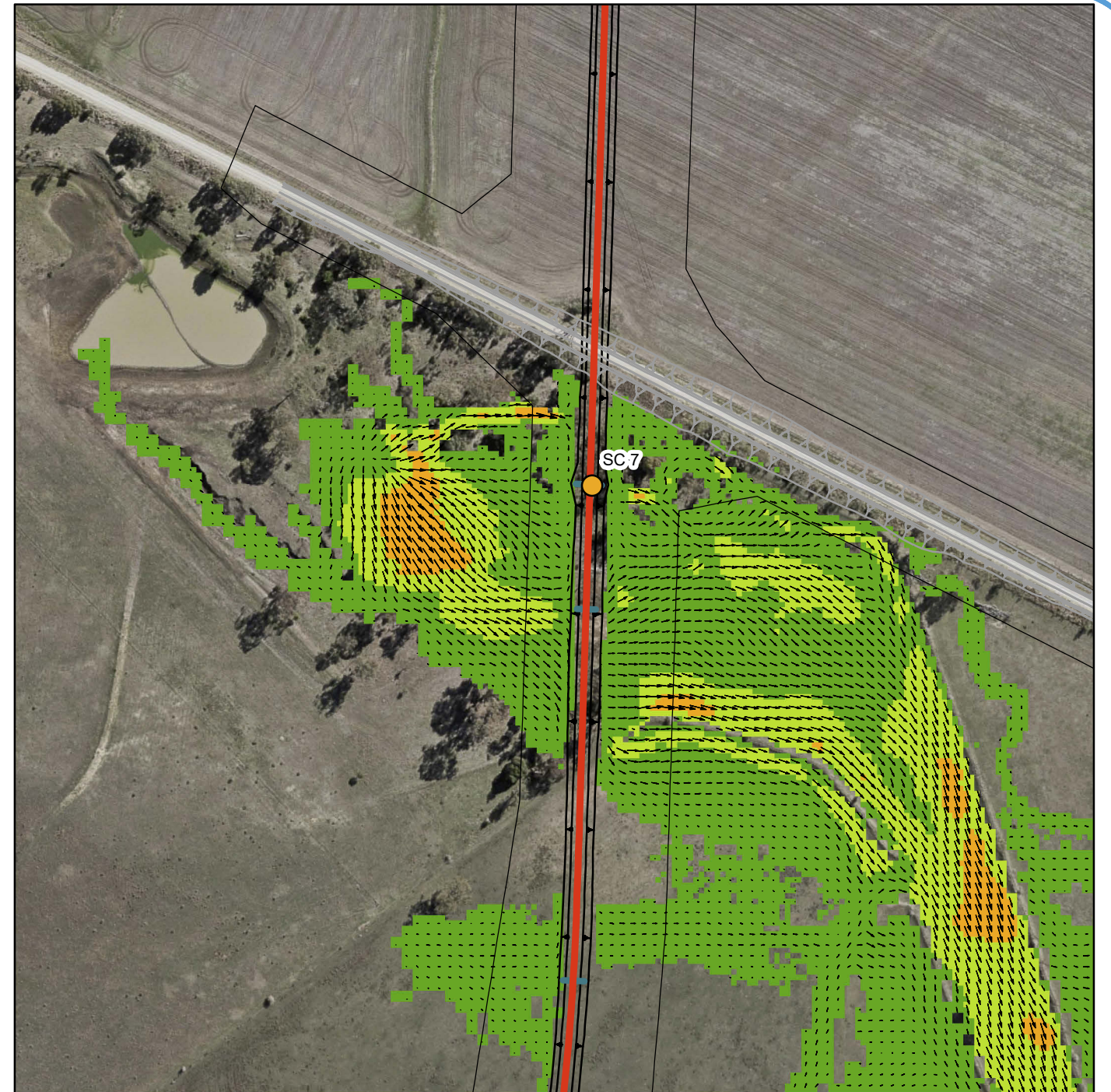


A3 scale: 1:2,730

0 20 40 60 80 100 m



Existing Case



Design Case

Legend

Initial Risk

High

Rail Earthworks Extent

Alignment centreline

Cross Drainage

Stream Velocity (m/s)

<1

1 to 1.5

1.5 to 2.5

Note:
Flow direction is from left to right of page

A3 scale: 1:2,730

0 20 40 60 80 100 m



Legend

Initial Risk

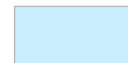
● High

● Photo/ sample location

— Bank Erosion



Area of historical scour



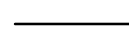
Ponding water



Alignment centreline



Cross Drainage



Rail Earthworks Extent



0.5 m Contour

Geomorphology Notes:

Area of historical scour - Area with historical scour observed in aerial imagery but not observed on site as it has been reworked. This area was likely the result of the 2010-11 floods.

E1 - Approximately 40 m length of minor bank erosion in black soils, up to approximately 0.4 m in height.

A3 scale: 1:1,030

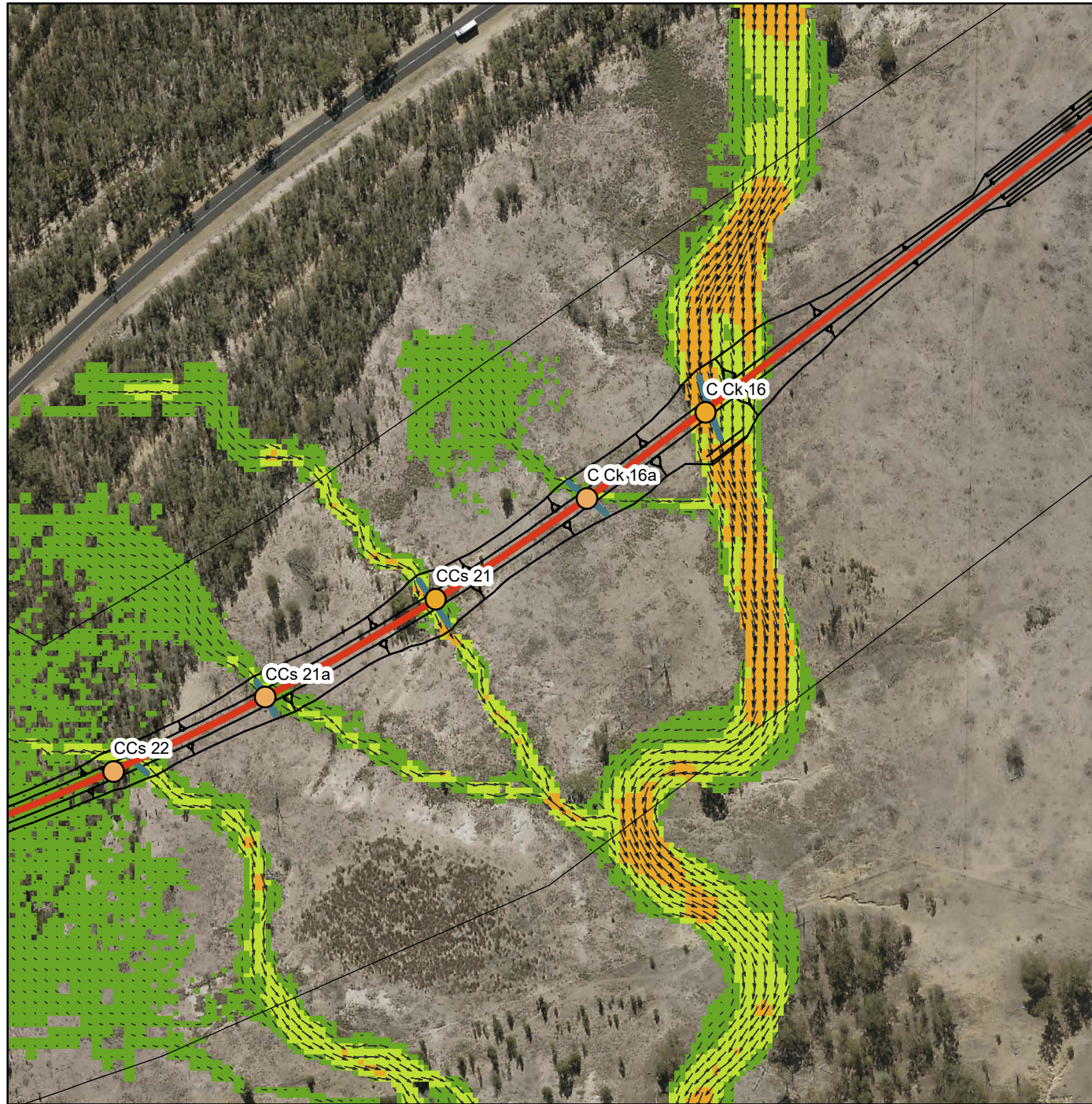
0 10 20 30 40Meters



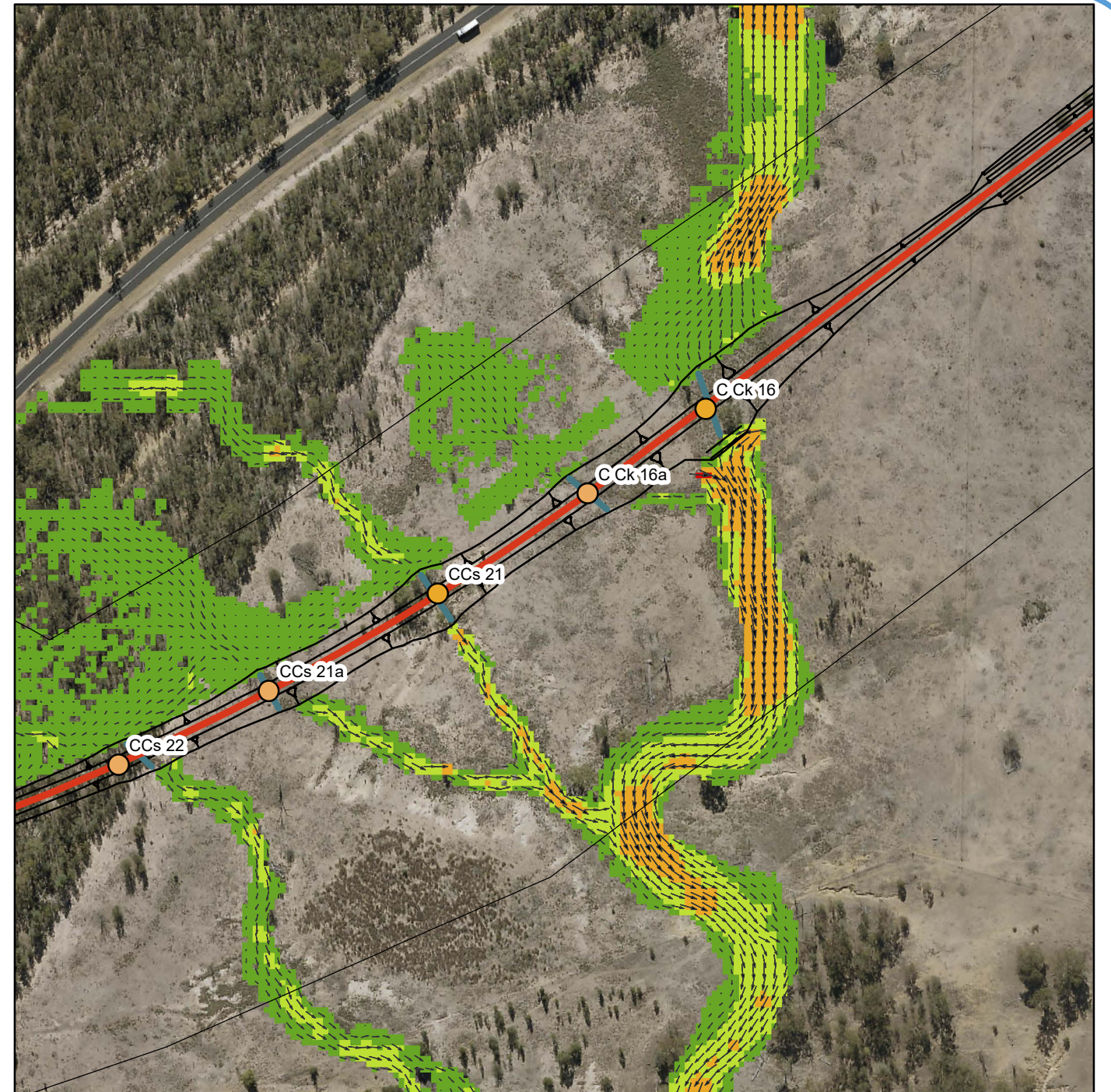
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Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie
Drawing Set E.6 of 13
SC 7 Geomorphology Map

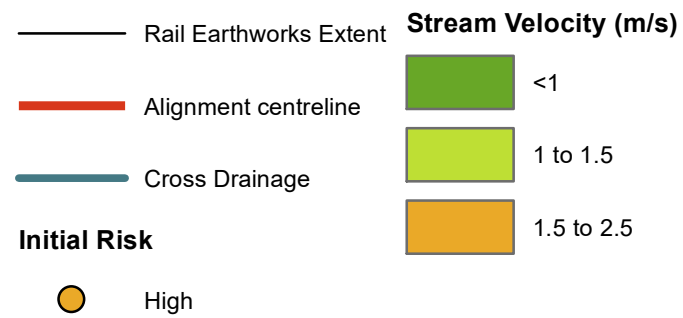


Existing Case



Design Case

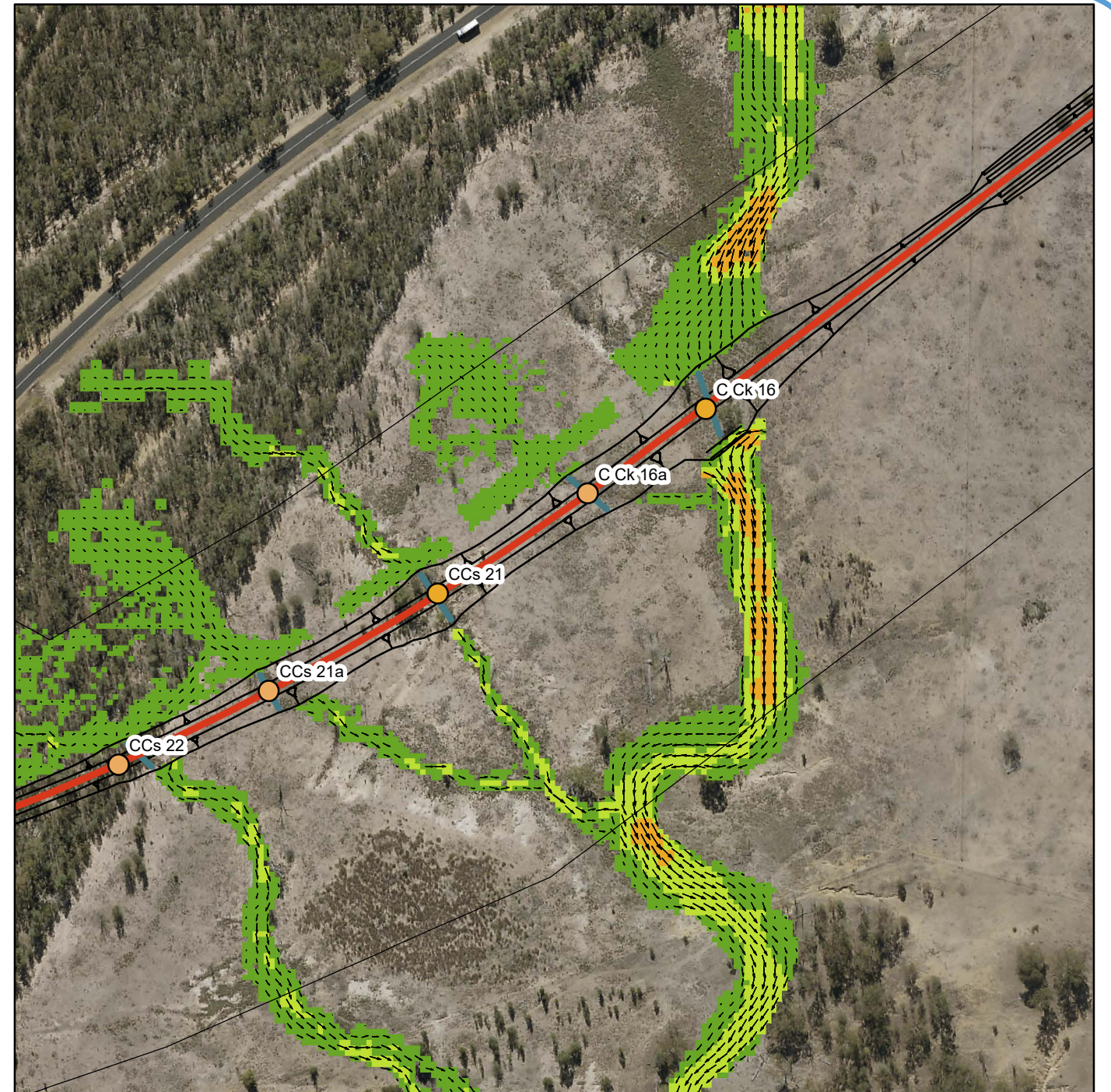
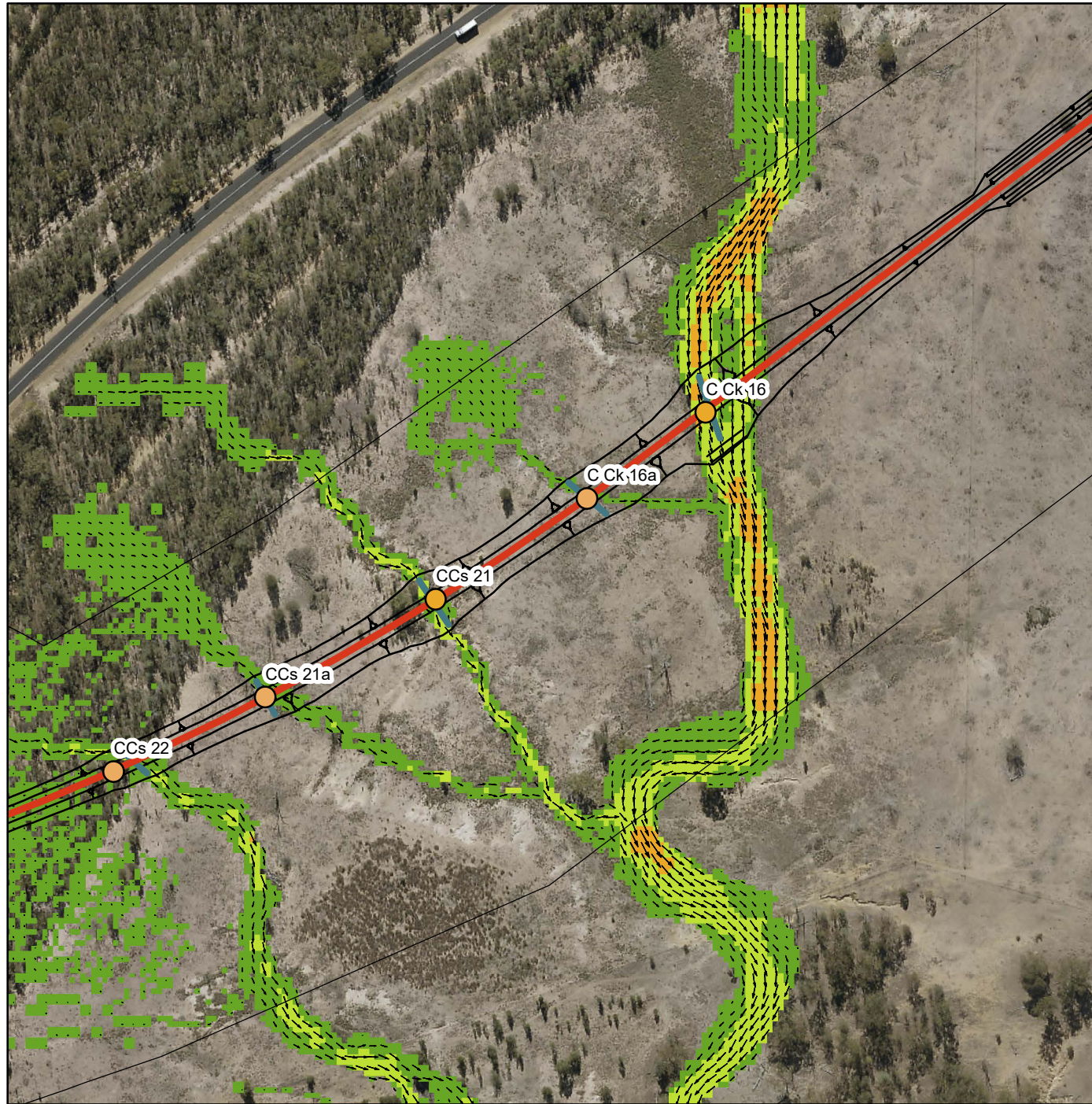
Legend



Note:
Flow direction is from top to bottom of page



A3 scale: 1:2,730
0 20 40 60 80 100 m



Legend

Initial Risk

● High

— Rail Earthworks Extent

— Alignment centreline

— Cross Drainage

Stream Velocity (m/s)

■ <1

■ 1 to 1.5

■ 1.5 to 2.5

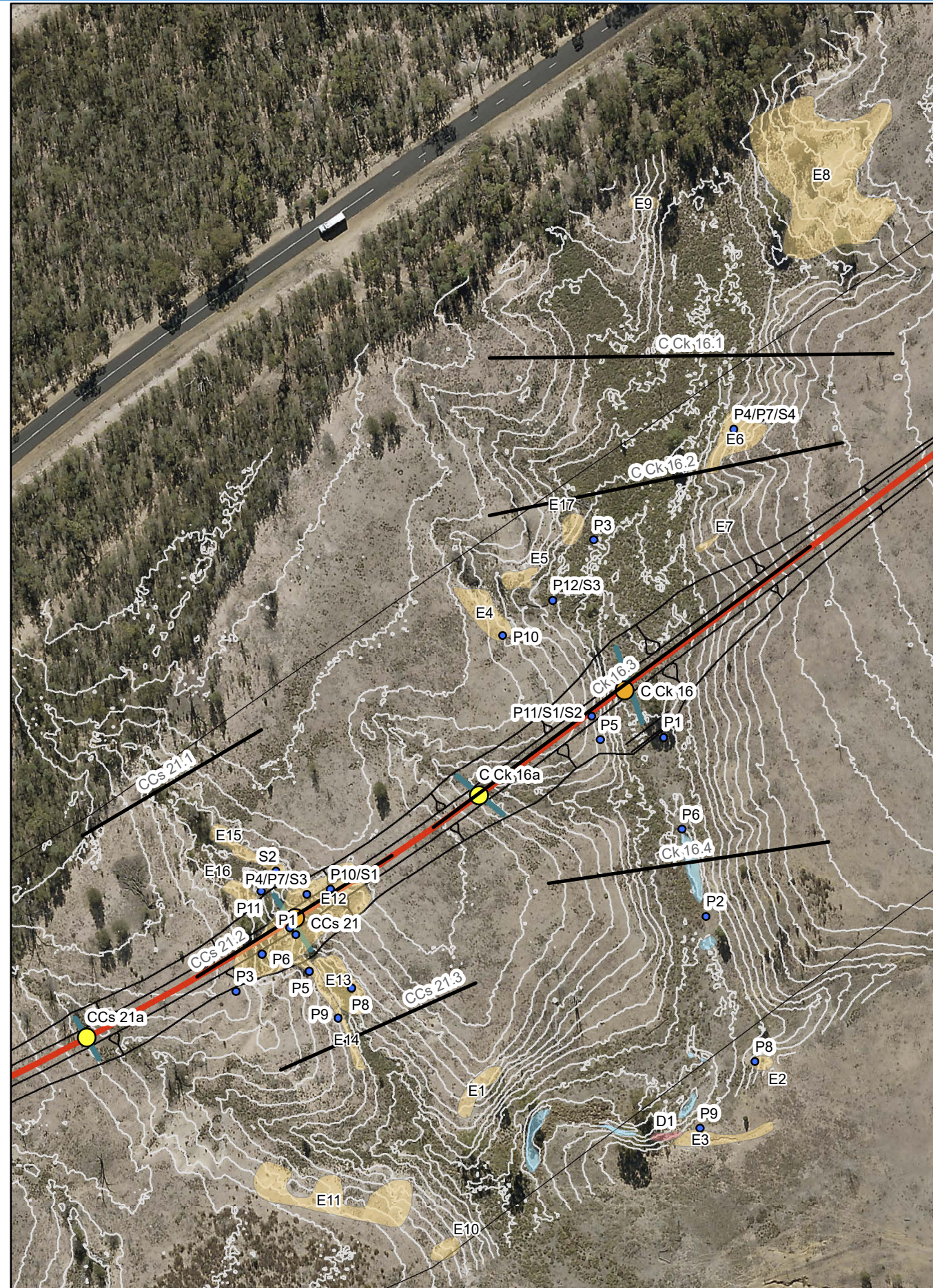
Note:
Flow direction is from top to bottom of page

Existing Case

Design Case



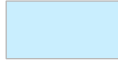
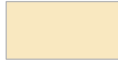
A3 scale: 1:2,730
0 20 40 60 80 100 m



Geomorphology Notes:

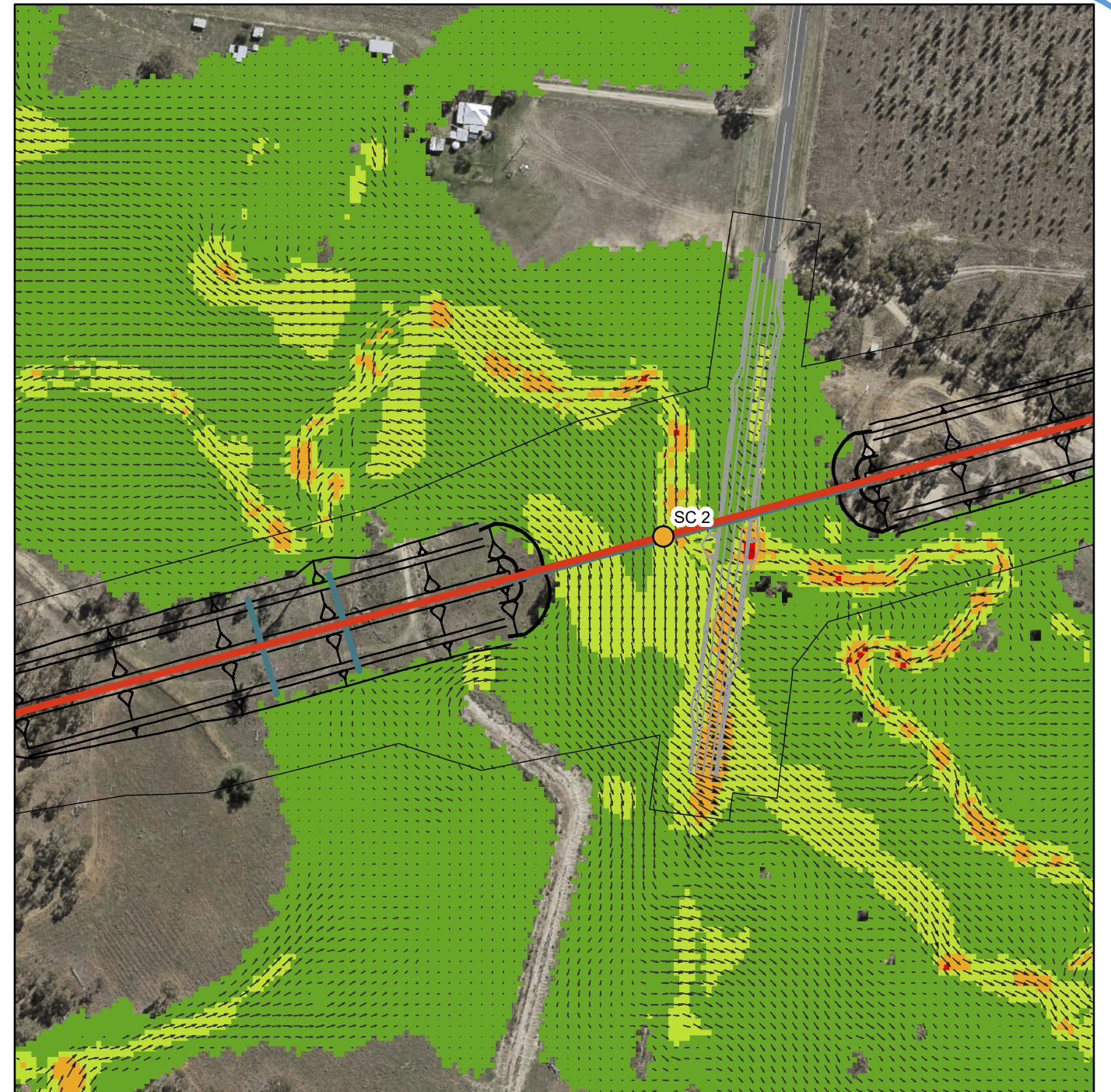
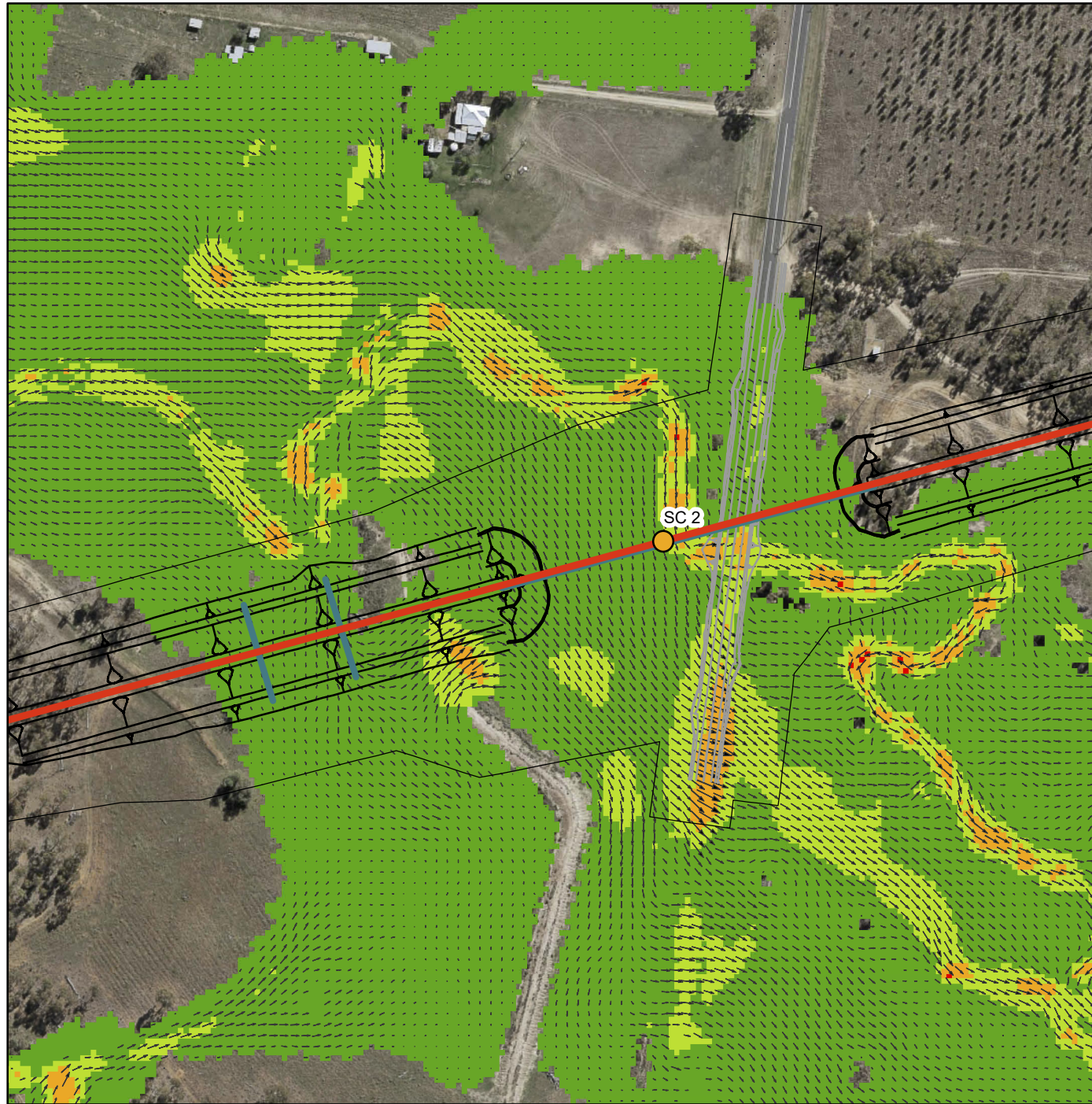
- E1 - Surface erosion, approx. 0.4 m deep, approx 5 m wide.
- E2 - Surface erosion, approx. max 0.3 m deep, 3 to 4 m wide, 6-7 m in length.
- E3 - Gully erosion from surface runoff into main channel, incised up to 1.5 m deep, ranges from 2-3 m wide, widens at downstream end. Silty sand overlying HW-CW sandstone?
- E4 - Surface erosion along bank edge, 0.3 m deep, material is silty fine sand.
- E5 - Surface erosion, 0.4 m deep, material is silty fine sand.
- E6 - Surficial bank erosion with scoured channels ranging from 0.5 to 0.8 m deep. Material is silty sand, with fine to coarse gravel armouring.
- E7 - Scoured channel from surface runoff, leading into main channel. Approx. 5 m long, 0.3-0.4 m deep. Fine to medium sand with gravel armouring.
- E8 - Large area of surficial erosion on bank.
- E9 - Gully erosion on bank of channel approx. 4 m long, 0.4 m deep. Fine sand and silt, very dry, some fine gravel armouring.
- E10 - Surficial erosion.
- E11 - Surficial erosion.
- E12 - Significant surface erosion, with clayey silt ridges that are less erodible, 0.2 to 0.5 m in height.
- E13 - Bank erosion, up to 0.7 m high, some side gullies coming into channel from surface runoff, minor slumping of bank edges.
- E14 - Surface and bank erosion, some side gullies coming into channel from surface runoff, minor slumping of bank edges with clayey silt ridges that are less erodible.
- E15 - Surface erosion along bank edge, partially vegetated.
- E16 - Surface erosion, partially vegetated.
- E17 - Bank erosion, approx 5 m length 200 mm height. Bank material is sand.
- D1 - Thin layer of sand deposited within grassed channel from eroded gully.

Legend

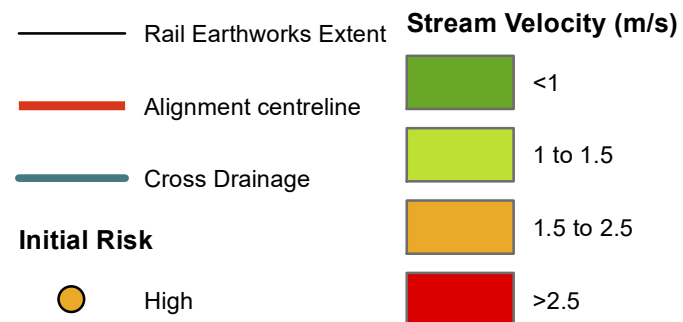
Initial Risk			
●	High	 Ponding water	 Alignment centreline
●	Medium	 Deposition	 Cross Drainage
		 Erosion	 Rail Earthworks Extent
		●	Photo location
		—	0.5 m Contour

A3 scale: 1:1,960

0 20 40 60 80Meters



Legend



Note:
Flow direction is from left to right of page

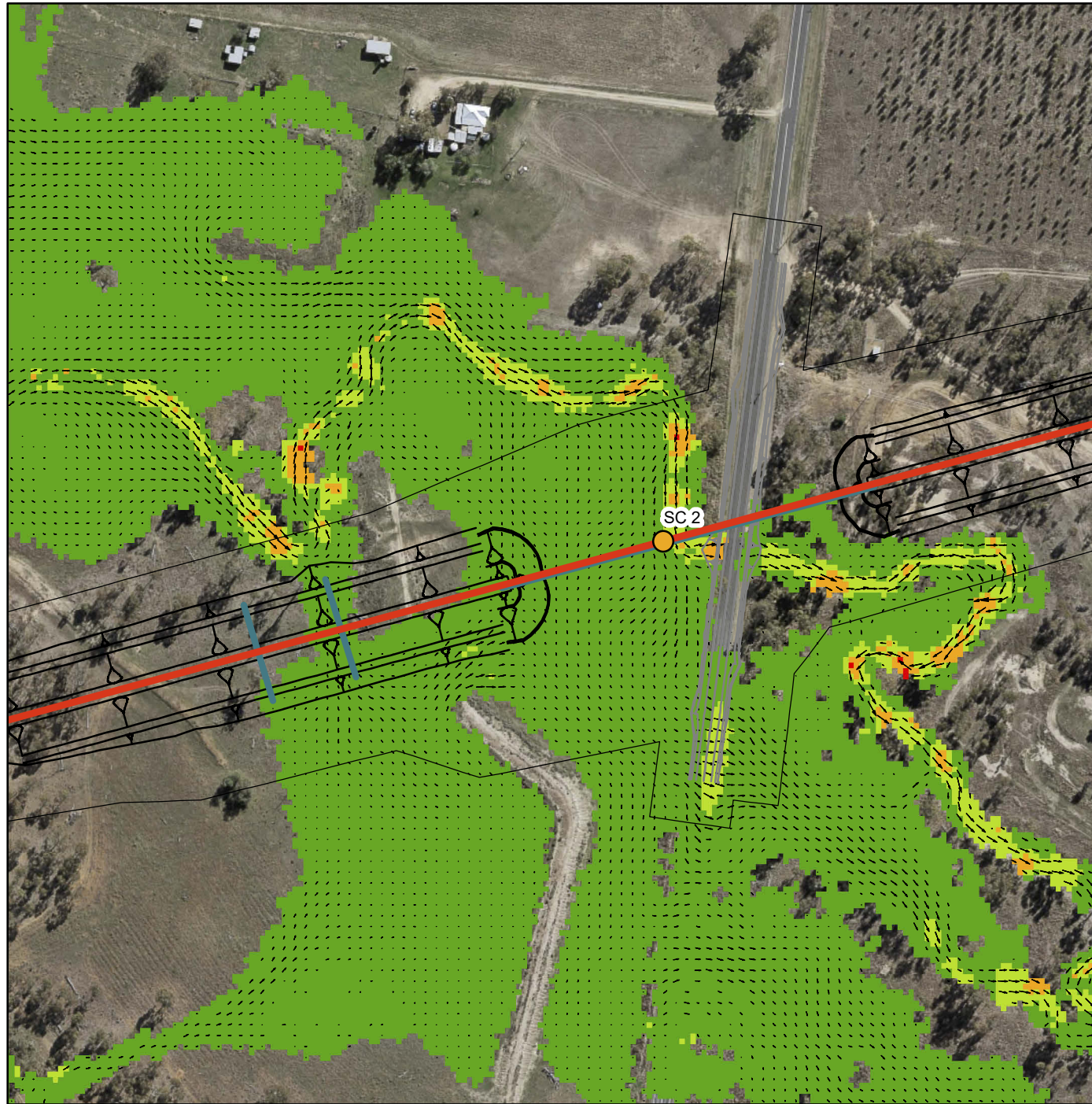
Existing Case

Design Case

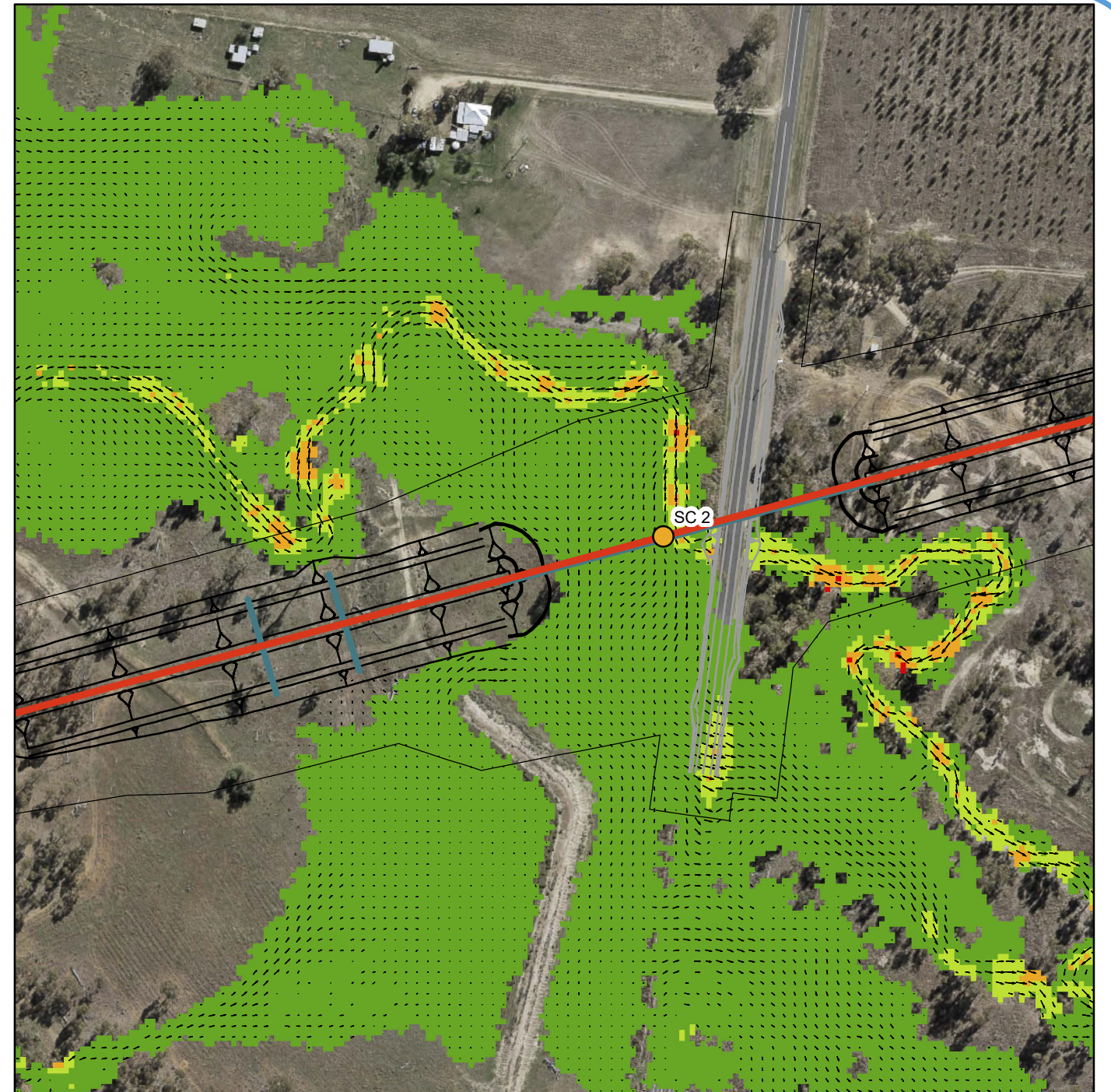


A3 scale: 1:2,730

0 20 40 60 80 100 m



Existing Case



Design Case

Legend

Initial Risk

High

Rail Earthworks Extent

Alignment centreline

Cross Drainage

Stream Velocity (m/s)

<1

1 to 1.5

1.5 to 2.5

>2.5

Note:
Flow direction is from left to right of page



A3 scale: 1:2,730
0 20 40 60 80 100 m



Legend

Initial Risk

● High

● Photo/ sample location

— Bank Erosion

Deposition

— Alignment centreline

— Cross Drainage

— Rail Earthworks Extent

— 0.5 m Contour

Geomorphology Notes:

E1 - Erosion/slumping on true right bank at bend where track crosses. Approximately 4 m section with approximately 1.5 m high subvertical bank.

E2 - Erosion on true left bank on outside of bend, approximately 5 m length, 1.5 - 2 m high bank. Bank material is silty sand.

E3 - Bank erosion/slumping on true left on outside of bend, approx 20 m section, bank approximately 1.5 m in height, partially vegetated.

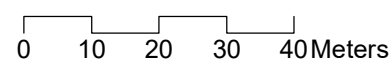
E4 - Extensive bank erosion and slumping on both sides of the channel, woody debris has caused a natural dam at the upstream extent of this erosion, which has resulted in a local change in baselevel and initiated downstream erosion of the bed and banks for 50-60 m downstream on both sides. Banks range from approximately 1-2 m in height.

D1 - Fine to medium sand deposited on inside of bend.

D2 - Sand deposition, grassed with woody debris, approximately 0.5 m in height.



A3 scale: 1:1,120



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Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie
Drawing Set E.12 of 13
SC2 Geomorphology Map 1



Geomorphology Notes:

E2 - Erosion on true left bank on outside of bend, approximately 5 m length, 1.5 - 2 m high bank. Bank material is silty sand.

D1 - Fine to medium sand deposited on inside of bend.

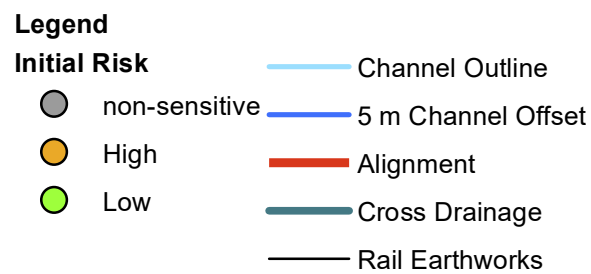
D2 - Sand deposition, grassed with woody debris, approximately 0.5 m in height.

Legend

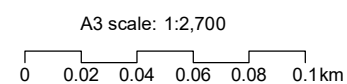
- Photo/ sample location
- Alignment centreline
- Bank Erosion
- Cross Drainage
- Deposition
- Rail Earthworks Extent
- 0.5 m Contour

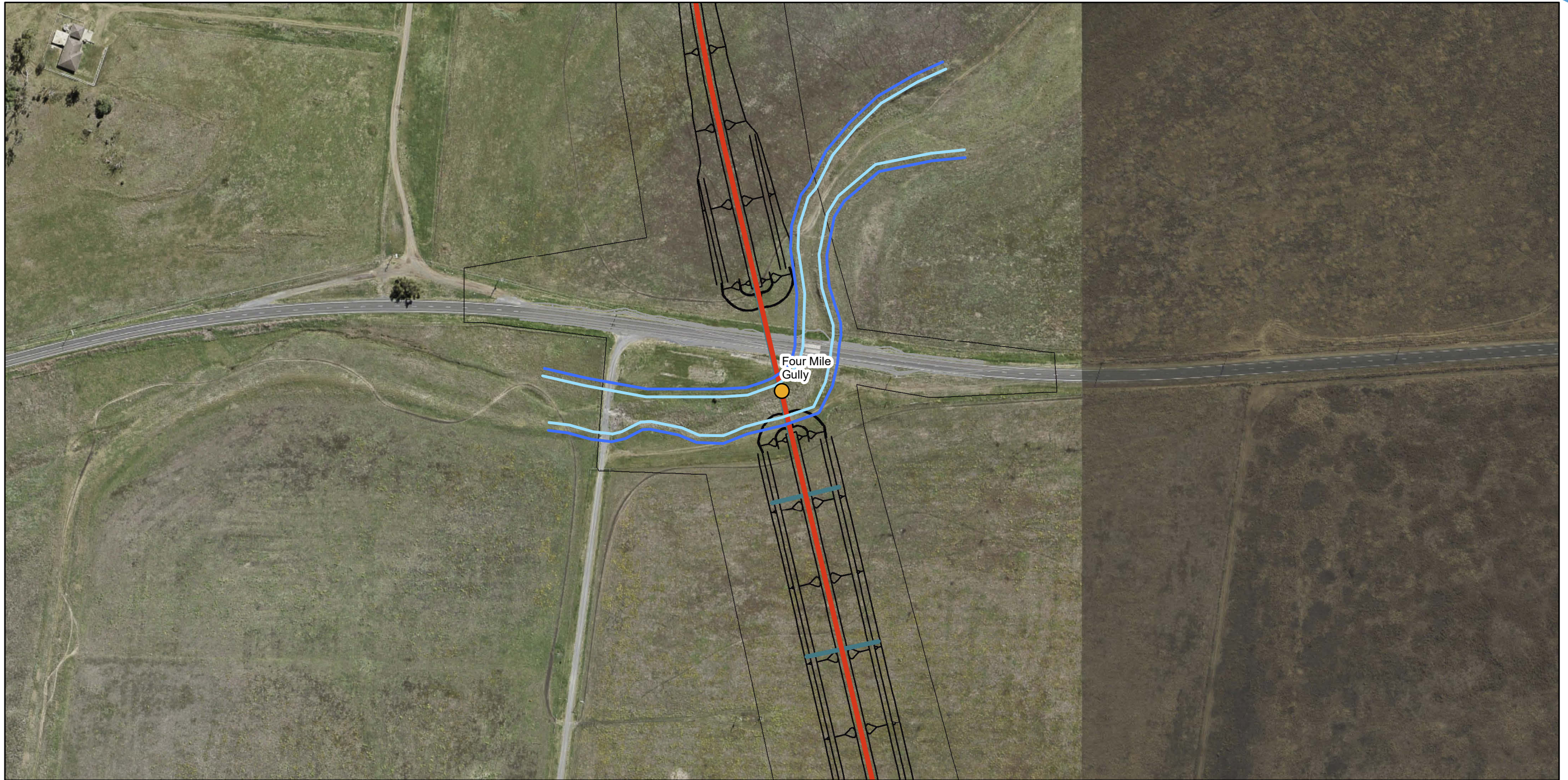
A3 scale: 1:570

0 9 18 27 36Meters



The channel has been outlined with the extent of the available lidar only, channels extended further upstream and downstream of this.





Legend

- Initial Risk**
- Channel Outline
 - High
 - 5 m Channel Offset
 - Alignment
 - Cross Drainage
 - Road Earthworks
 - Rail Earthworks

Note:

The channel has been outlined with the extent of the available lidar only, channels extend further upstream and downstream of this.

A3 scale: 1:2,710

0 0.02 0.04 0.06 0.08 0.1 km



Legend

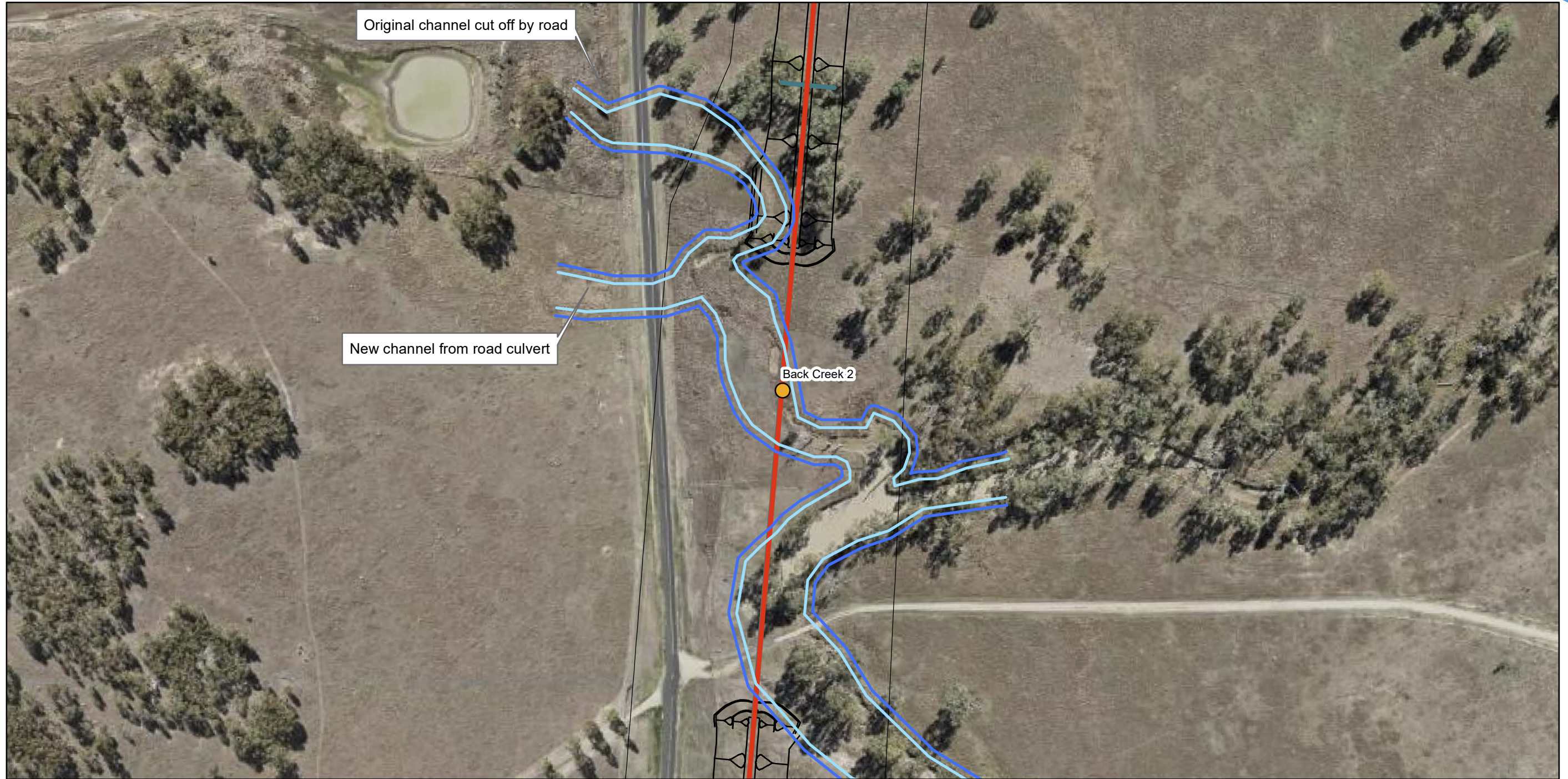
- Initial Risk**
- Channel Outline
 - 5 m Channel Offset
 - High
 - Alignment
 - Cross Drainage
 - Road Earthworks
 - Rail Earthworks

Note:

The channel has been outlined with the extent of the available lidar only, channels extend further upstream and downstream of this.

A3 scale: 1:2,710

0 0.02 0.04 0.06 0.08 0.1 km



Legend

Initial Risk

● High

— 5 m Channel Offset

— Channel Outline

— Alignment

— Cross Drainage

— Rail Earthworks

Note:

The channel has been outlined with the extent of the available lidar only, channels extended further upstream and downstream of this.

A3 scale: 1:2,700

0 0.02 0.04 0.06 0.08 0.1km



Legend

Initial Risk

● High

— 5 m Channel Offset

— Channel Outline

— Alignment

— Cross Drainage

— Rail Earthworks

Note:

The channel has been outlined with the extent of the available lidar only, channels extended further upstream and downstream of this.

A3 scale: 1:2,700

0 0.02 0.04 0.06 0.08 0.1 km



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Coordinate System: GDA 1994 MGA Zone 56

Border to Gowrie

Drawing Set F. 5 of 5

Bridge abutment offset from channel

APPENDIX H

Geomorphology Report

Appendix B Supporting tables

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Appendix B

Supporting tables

Table B1 **Bridge crossings**

Bridge name	Chainage start (km)	Chainage end (km)	Crossing type	Bridge length (m)
Macintyre River Viaduct ¹	30.6 (NS2B)	30.7 (NS2B)	Watercourse	100
	30.7 (NS2B)	31.1 (NS2B)	Watercourse	435
Macintyre Floodplain #1 Rail Bridge	31.4 (NS2B)	31.6 (NS2B)	Watercourse	140
Macintyre Floodplain #2 Rail Bridge	32.2 (NS2B)	32.8 (NS2B)	Watercourse and road	546
Cunningham Highway Bridge	25.6	25.7	Rail	104
Macintyre Brook Rail Bridge 1	52.5	52.7	Watercourse	207
Macintyre Brook Rail Bridge 2	55.4	55.6	Watercourse	207
Bybera Road Rail Bridge	60.5	60.6	Road	75
Pariagara Creek Rail Bridge	67.2	67.5	Watercourse	345
Cattle Creek Rail Bridge	88.2	88.3	Watercourse	138
Native Dog Creek Rail Bridge	93.8	94.0	Watercourse	184
Bringalily Creek 1 Rail Bridge	97.4	97.7	Watercourse	299
Bringalily Creek 3 Rail Bridge	100.1	100.7	Watercourse	621
Nicol Creek Rail Bridge	104.3	104.4	Watercourse	92
Millmerran–Inglewood Road Rail Bridge #2	115.5	115.6	Road	75
Heckendorf Road Bridge	116.4	116.5	Rail	59
Commodore Peak Road Bridge	123.9	124	Road	75
Millmerran–Inglewood Road Rail Bridge #3	126.9	127.1	Road	167
Back Creek Rail Bridge	127.9	128.2	Watercourse	230
Owens Scrub Road Bridge	129.8	130.0	Rail	72
Grasstree Creek Rail Bridge	139.3	140.6	Watercourse	1,330
Condamine River South Branch Rail Bridge	142.6	143.3	Watercourse	658
Condamine River Main Branch Rail Bridge (combined rail bridge)	143.9	146.4	Condamine River	2,577
Condamine River North Branch Rail Bridge	149.1	150.6	Condamine River North Branch	1,568
Gore Highway Bridge	153.4	153.5	Rail	108
Yarranlea Road Rail Bridge	162.5	162.6	Road	69
Roche Road Rail Bridge	164.5	164.6	Road	121
Oakey Pittsworth Road Rail Bridge	172.2	172.3	Road	69
Lochaber Road Rail Bridge	173.7	173.8	Road	75
Linthorpe Road Bridge	177.2	177.2	Rail	66
Biddeston–Southbrook Road Rail Bridge	184.8	185.0	Road	144
Athol School Road Rail Bridge	189.3	189.4	Road	75
Toowoomba–Cecil Plains Road Rail Bridge	197.3	197.4	Road	92
Westbrook Creek Rail Bridge	198.4	198.6	Watercourse	230
Dry Creek Rail Bridge	199.1	199.3	Watercourse	184

Bridge name	Chainage start (km)	Chainage end (km)	Crossing type	Bridge length (m)
Brimblecombe Road Rail Bridge	199.9	200.0	Road	75
Warrego Highway Rail Bridge	204.3	204.4	Road	132
Chamberlain Road Rail Bridge	205.7	206.0	Road	299

Table B2 **Permanent diversions**

Chainage (km)	Culvert location in chainage (km)	Watercourses intersected (km)
120.77 to 121.93	120.75	SC6 Ch(1 st order) 120.81, SC5 (1 st order)Ch 121.44
190.66 to 190.81	190.81	OC4 Ch(1 st order) 191.95

APPENDIX H

Geomorphology Report

Appendix C Watercourse classification

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Chainage (m)	Proposed rail infrastructure	Strahler order	Erskine 2017 Channel Classification	Watercourse Types	Subreach assessment ²	Catchment name	Catchment area (ha)	Catchment Slope (rise/run)	Catchment Vegetation	Catchment Soil Type ¹ - ASC order	Catchment Soil Erodibility	Regional Landform
30600 (NS2B)	Bridge - stream	8	Main anabranch of the Macintyre River, two permanently flowing anabranches. Evidence of past avulsion events and cut-off channels are visible on the floodplain surface.	Main Stem	y	Macintyre River	868479.8	0.0047	Grassland with bush	Sodosols	High (4) to Very high (5)	Valley flood floodplains (Quaternary alluvium)
32700 (NS2B)	Bridge - stream	2	Washslope, adjacent to cut off of Macintyre River	Local - poorly developed channel	n	MR 2	<10	0.0046	Grassland/crops	Sodosols	High (4) to Very high (5)	Valley flood floodplains (Quaternary alluvium)
34800 (NS2B)	Culvert	1	Non-Channelised valley Floor with sections of low sinuosity channels. Some side gully development.	Headwater	y	MR 1	9837	0.0046	Grassland/crops	Sodosols	High (4) to Very high (5)	Valley flood floodplains (Quaternary alluvium)
30595	Culvert	2	Non-Channelised Valley Floor	Local - poorly developed channel	y	MB 10	1180	0.0104	Grassland with bush	Dermosols	Very low (1) to Moderate (3)	Valley flood floodplains (Quaternary alluvium)
43212	Culvert	2	Washslope to Non-Channelised Valley Floor	Local - poorly developed channel	y	MB 9	1288.2	0.0105	Grassland with bush	Dermosols	Very low (1) to Moderate (3)	Valley flood floodplains (Quaternary alluvium)
48396	Culvert	2	Non-Channelised Valley Floor	Local - poorly developed channel	y	MB 8	753.2	0.0200	Bush	Kandosols/Chromosols	Very low (1) to Moderate (3) / Moderate (3) to High (4)	Low Relief Hills (Mesozoic sedimentary rocks)
52599	Bridge - stream	3	Low Sinuosity Channel	Local - poorly developed channel	y	MB 7	5498.5	0.0053	Grassland with bush	Dermosols	Very low (1) to Moderate (3)	Valley flood floodplains (Quaternary alluvium)
55619	Bridge - stream	4	Non-Channelised Valley Floor with short section of low sinuosity channel	Local - poorly developed channel	y	MB 6	6041.3	0.0091	Grassland with bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
58236	Embankment	1	Washslope	Headwater	n	MBs 6	<10		Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
58613	Embankment	1	Washslope	Headwater	n	MBs 5	<10		Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
58960	Cut	1	Washslope	Headwater	n	MBs 4	<10		Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
59575	Cut	1	Washslope	Headwater	n	MBs 3	<10		Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
60465	Culvert	2	Non-Channelised valley Floor with short section of low sinuosity channel	Local - poorly developed channel	y	MB 5	189.5	0.0323	Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
60915	Cut	1	Washslope	Headwater	n	MBs 2	<10		Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
61118	Cut	1	Washslope	Headwater	n	MBs 1	<10		Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
61590	Culvert	1	Washslope to Non-Channelised Valley Floor	Headwater	y	MB 4	208	0.0300	Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
61900	Culvert	2	Low sinuosity channel	Local - developed channel sections	y	MB 3	223.1	0.0270	Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
62911	Culvert	1	Non-Channelised Valley Floor	Headwater	y	MB 2	39.9	0.0466	Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
63148	Culvert	2	Non-Channelised Valley Floor	Headwater	y	MB 1	153.5	0.0375	Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
63666	Embankment	1	Washslope	Headwater	n	CCs 28	<10		Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
63906	Cut	1	Washslope	Headwater	n	CCs 27	<10		Bush	Kandosols	Very low (1) to Moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
64670	Embankment	1	Washslope	Headwater	n	CCs 26	<10		Bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
66225	Culvert	2	Non-Channelised Valley Floor with short section of low sinuosity channel	Local - developed channel sections	y	C Ck 20	990.2	0.0172	Grassland with bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
66811	Culvert	1	Wash slope, becoming chain of ponds downstream	Headwater	y	C Ck 19	106.9	0.0241	Grassland/crops	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
67209	Bridge - Stream	2	Washslope to Non-Channelised Valley Floor	Headwater	y	C Ck 18	11.6	0.0081	Grassland with bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
67328	Bridge - stream	4	Low sinuosity channel	Local - well developed channel	y	Pariagara Creek	23323.3	0.0081	Grassland with bush	Sodosols	High (4) to Very high (5)	Valley flood floodplains (Quaternary alluvium)
67573	Culvert	1	Washslope	Headwater	n	CCs 25	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
68017	Culvert	1	Washslope	Headwater	n	CCs 24	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
68734	Culvert	1	Non-Channelised Valley Floor with short section of low sinuosity channel	Headwater	y	C Ck 17	99	0.0037	Grassland/crops	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
72941	Cut	1	Washslope, non channelised Valley Floor	Headwater	n	CCs 23	<10		Grassland with bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
73363	Culvert	1	Gully	Headwater	y	CCs 22	<10		Bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
73529	Culvert	1	Gully	Headwater	y	CCs 21a	<10		Grassland with bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
73531	Culvert	1	Gully	Headwater	y	CCs 21	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
73614	Culvert	1	Gully	Headwater	y	C Ck 16a	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
73682	Culvert	2	Gully	Local - poorly developed channel	y	C Ck 16	166.1	0.0095	Grassland/crops	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
74197	Cut	1	Washslope	Headwater	n	CCs 20	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
74969	Culvert	1	Gully	Headwater	y	CCs 19	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
77466	Culvert	1	Washslope, non channelised Valley Floor	Headwater	n	CCs 19b	<10	0.0133	Bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
77750	Culvert	1	Washslope, non channelised Valley Floor	Headwater	n	CC s 19a	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
78997	Culvert	1	Non-Channelised Valley Floor with low sinuosity channel downstream	Headwater	y	C Ck 15	75.5	0.0081	Grassland with bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
79500	Culvert	1	Washslope, non channelised Valley Floor	Headwater	n	CCs 18a	<10	0.0000	Bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)

Chainage (m)	Proposed rail infrastructure	Strahler order	Erskine 2017 Channel Classification	Watercourse Types	Subreach assessment ²	Catchment name	Catchment area (ha)	Catchment Slope (rise/run)	Catchment Vegetation	Catchment Soil Type ¹ - ASC order	Catchment Soil Erodibility	Regional Landform
79981	Culvert	1	Washslope	Headwater	n	CCs 18	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
80673	Culvert	1	Washslope, non channelised Valley Floor	Headwater	n	CCs 17a	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
81187	Culvert	1	Washslope, non channelised Valley Floor	Headwater	n	CCs 17	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
82348	Culvert	1	Non-Channelised Valley Floor	Headwater	y	C Ck 14	216.9	0.0092	Grassland with bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
83480	Culvert	1	Washslope, non channelised Valley Floor	Headwater	n	CCs 16a	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
84385	Culvert	1	Low sinuosity channel	Headwater	y	C Ck 13	283.5	0.0095	Bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
85392	Culvert	1	Washslope, non channelised Valley Floor, short sections of channel may be present	Headwater	n	CCs 16	<10		Bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
87174	Culvert	1	Washslope?	Headwater	n	CCs 15	<10		Bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
87370	Culvert	1	Low sinuosity, possibly some non-channelised valley floor	Headwater	y	C Ck 12	355.4	0.0150	Bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
88241	Bridge - stream	3	Non-Channelised Valley Floor with short section of low sinuosity channel	Local - developed channel sections	y	Cattle Creek	6506.4	0.0083	Bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
90961	Culvert	2	Non-Channelised Valley Floor	Local - poorly developed channel	y	C Ck 11	351.9	0.0055	Bush	Sodosols	High (4) to Very high (5)	Low Relief Hills (Mesozoic sedimentary rocks)
92064	Culvert	1	Washslope, non channelised Valley Floor, short sections of channel may be present	Headwater	y	C Ck 10	215	0.0231	Bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
92913	Culvert	1	Washslope, non channelised Valley Floor, short sections of channel may be present	Headwater	n	CCs 14	<10		Grassland with bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
93927	Bridge - stream	3	Non-Channelised Valley Floor with some sections of low sinuosity channels	Local - poorly developed channel	y	Native Dog Creek	93.652	0.0092	Bush	Sodosols	High (4) to Very high (5)	Valley flood floodplains (Quaternary alluvium)
95064	Culvert	1	Washslope, non channelised Valley Floor	Headwater	n	CCs 13	<10		Grassland with bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
96200	Culvert	1	Washslope, non channelised Valley Floor	Headwater	n	CCs 13a	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
97638	Bridge - stream	3	Non-Channelised Valley Floor with some sections of low sinuosity channels	Local - poorly developed channel	y	Back Creek 2	1840.6	0.0109	Grassland/crops	Sodosols	High (4) to Very high (5)	Valley flood floodplains (Quaternary alluvium)
99372	Culvert	1	Non-channelised Valley floor	Headwater	n	CCs 12	<10		Grassland/crops	Sodosols	High (4) to Very high (5)	Valley flood floodplains (Quaternary alluvium)
100598	Bridge - stream	5	Chain of ponds with either narrow low sinuosity channel or in rare cases, non-channelised valley floor between ponds.	Local - well developed channel	y	Bringalily	18788.3	0.0135	Grassland with bush	Sodosols	High (4) to Very high (5)	Valley flood floodplains (Quaternary alluvium)
104429	Bridge - stream	4	Chain of ponds in meandering planform.	Local - developed channel sections	y	Nicol Creek	3777.7	0.0134	Grassland with bush	Vertosol/Sodosol	Very low (1) to Moderate (3) / High (4) to Very high (5)	Valley flood floodplains (Quaternary alluvium)
107212	Culvert	1	Washslope to Non-Channelised Valley Floor	Headwater	y	C Ck 9	92.8	0.0270	Grassland with bush	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
107964	Culvert	1	Washslope, minor non channelised Valley Flood	Headwater	n	CCs 11a	<10		Grassland	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
108532	Culvert	1	Washslope, minor short sections of channel may be present	Headwater	n	CCs 11	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
109437	Culvert	2	Washslope to Non-Channelised Valley Floor	Local - poorly developed channel	y	C Ck 8	110.2	0.0129	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
110934	Culvert	1	Washslope	Headwater	n	CCs 10	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
111264	Culvert	1	Non-channelised Valley floor with some sections of low sinuosity channels and washslopes	Headwater	n	CCs 9	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
111901	Cut	1	Washslope	Headwater	n	CCs 8	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
112329	Culvert	1	Washslope	Headwater	n	CCs 7	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
112997	Culvert	1	Washslope	Headwater	n	CCs 6	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
113069	Culvert	1	Non-channelised Valley floor with some sections of low sinuosity channels	Headwater	y	C Ck 7	11	0.0386	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
113289	Culvert	1	Non-channelised Valley floor	Headwater	y	C Ck 6	14.3	0.0343	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
113513	Cut	1	Non-channelised Valley floor with some sections of low sinuosity channels	Headwater	y	C Ck 5	13.5	0.0459	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
113768	Cut	1	Wash slope, Non-channelised Valley floor with sections of low sinuosity channel.	Headwater	y	C Ck 4	13.4	0.0836	Grassland with bush	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
113997	Cut	1	Washslope	Headwater	n	CCs 5	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
114420	Culvert	2	Non channelised valley floor, some visible low sinuosity channel features in places.	Local - poorly developed channel	y	C Ck 3	214.2	0.0783	Grassland with bush	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
114832	Embankment	1	Washslope	Headwater	n	CCs 4	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
114900	Culvert	1	Washslope to Non-Channelised Valley Floor	Headwater	n	CCs 3	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
115010	Culvert	1	Washslope	Headwater	n	CCs 2	<10		Grassland with bush	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
115327	Culvert	1	Washslope	Headwater	n	CCs 1	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
115511	Bridge - Road	1	Non-Channelised Valley Floor, some visible low sinuosity channel features in places.	Headwater	y	C Ck 2	29.2	0.0915	Grassland with bush	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
115623	Embankment	1	Washslope to Non-Channelised Valley Floor	Headwater	y	C Ck 1	32	0.0483	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)

Chainage (m)	Proposed rail infrastructure	Strahler order	Erskine 2017 Channel Classification	Watercourse Types	Subreach assessment ²	Catchment name	Catchment area (ha)	Catchment Slope (rise/run)	Catchment Vegetation	Catchment Soil Type ¹ - ASC order	Catchment Soil Erodibility	Regional Landform
116169	Cut	1	Washslope, Non-channelised Valley floor	Headwater	n	CCs 0	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
117390	Culvert	1	Non-Channelised Valley Floor with some sections of low sinuosity channels	Headwater	y	SC 11	111.4	0.0688	Grassland with bush	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
117650	Culvert	1	Non-channelised Valley floor.	Headwater	y	SC 10	130.5	0.0724	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
118421	Culvert	1	Non-Channelised Valley Floor with some sections of low sinuosity channels	Headwater	y	SC 9	165.3	0.0648	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
119377	Culvert	1	Non-Channelised Valley Floor with some sections of low sinuosity channels	Headwater	y	SC 8	131.7	0.0567	Grassland with bush	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
120333	Culvert	3	Non-Channelised Valley Floor with short section of low sinuosity channel	Local - poorly developed channel	y	SC 7	719.8	0.0356	Grassland with bush	Vertosol	Low (2) to moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
120756	Diversion	1	Non-Channelised Valley Floor, very short sections (2m) of low sinuosity channel.	Headwater	y	SC 6	35.7	0.0716	Grassland/crops	Vertosol	Low (2) to moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
121442	Diversion	1	Non-Channelised Valley Floor with short section of low sinuosity channel	Headwater	y	SC 5	77.6	0.0806	Grassland/crops	Vertosol	Low (2) to moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
123494	Embankment	1	Washslope, Non-channelised Valley floor	Headwater	n	SC 4c	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
123918	Bridge - Road	1	Washslope, Non-channelised Valley floor	Headwater	n	SC 4b	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
124297	Embankment	1	Non-channelised Valley floor, with occasional small pond	Headwater	n	SC 4a	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
124372	Culvert	1	Non-channelised Valley floor	Headwater	y	SC 4	89	0.0651	Grassland/crops	Vertosol	Low (2) to moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
125479	Culvert	1	Non-channelised Valley floor with sections of low sinuosity channels, no channel downstream of man made ponds in flow path	Headwater	y	SC 3	218.1	0.0420	Grassland/crops	Vertosol	Low (2) to moderate (3)	Low Relief Hills (Mesozoic sedimentary rocks)
126960	Bridge - road	4	Chain of ponds with low sinuosity channel between	Local - developed channel sections	y	SC 2	2127.1	0.0271	Grassland with bush	Sodosols	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
128017	Bridge - stream	4	Non-Channelised Valley Floor to chain of ponds in meandering planform	Local - developed channel sections	y	Back Creek 1	9416.4	0.0086	Grassland with bush	Vertosol	High (4) to Very high (5)	Alluvial plains (Late-Tertiary alluvium)
130182	Cut	1	Washslope to Non-Channelised Valley Floor	Headwater	y	SC 1	150.2	0.0084	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
130987	Cut	1	Non-channelised Valley floor with some short sections of low sinuosity channels and washslopes	Headwater	n	SCs 1	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
139851	Bridge - stream	5	Chain of ponds in meandering planform.	Local - well developed channel	y	Grasstree Creek	48360.1	0.0043	Grassland with bush	Vertosol	Low (2) to moderate (3)	Valley flood floodplains (Quaternary alluvium)
141032	Culvert	2	Non-Channelised Valley Floor with short section of low sinuosity channel	Local - poorly developed channel	y	Condamine anabranh	654611.1		Grassland/crops	Vertosol	Low (2) to moderate (3)	Valley flood floodplains (Quaternary alluvium)
142600	Bridge - stream		Not a watercourse, flood channels located within flood basin, erosion channels developed downstream of the existing rail embankment	Local - poorly developed channel	y	Condamine South Branch			Grassland/crops	Vertosol	Low (2) to moderate (3)	Valley flood floodplains (Quaternary alluvium)
144215	Bridge - stream	8	Meandering to sinuous channel	Main Stem	y	Condamine River	654611.1	0.0052	Grassland with bush	Vertosol	Low (2) to moderate (3)	Valley flood floodplains (Quaternary alluvium)
149990	Bridge - stream	4	US - low sinuosity channel DS - Chain of ponds in meandering planform.	Local - well developed channel	y	Condamine North Branch	654611.1	0.0053	Grassland with bush	Vertosol	Low (2) to moderate (3)	Valley flood floodplains (Quaternary alluvium)
160033	Embankment	2	Washslope to Non-Channelised Valley Floor	Headwater	y	NC 16	420.8	0.0234	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
162208	Culvert	1	Washslope, Non-channelised Valley floor with short sections of channel downstream of the alignment, man made ponds	Headwater	n	NCs 7	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
162849	Culvert	1	Washslope, Non-channelised Valley floor with short sections of channel downstream of the alignment, man made ponds	Headwater	n	NCs 6	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
164158	Culvert	1	Non-Channelised Valley Floor / wash slope.	Headwater	y	NC 15	33.4	0.0361	Grassland/crops	Vertosol	Very low (1) to Moderate (3) / Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
164418	Culvert	1	Non-Channelised Valley Floor	Headwater	y	NC 14	119.2	0.0307	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
165072	Culvert	1	Non-channelised Valley floor with some short sections of low sinuosity channels	Headwater	y	NC 13	27.8	0.0131	Grassland/crops	Vertosol	Low (2) to moderate (3)	Alluvial plains (Late-Tertiary alluvium)
166108	Culvert	1	Non-channelised Valley floor with some short sections of low sinuosity channels and washslopes	Headwater	n	NCs 5	<10		Grassland with bush	Dermosol/Vertosol	Very low (1) to Moderate (3) / Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
168636	Culvert	1	Washslope, Non-channelised Valley floor, man made pond in flow path downstream of alignment	Headwater	n	NCs 4	<10		Grassland with bush	Vertosol	Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
169873	Culvert	1	Non-channelised valley floor	Headwater	y	NC 12	81.2	0.0642	Grassland/crops	Dermosols	Very low (1) to Moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
170561	Culvert	1	Non-channelised valley floor with sections of low sinuosity channels and bedrock constrained channel	Headwater	y	NC 11	107.8	0.0609	Grassland/crops	Dermosols	Very low (1) to Moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
171000	Culvert	1	Non-channelised Valley floor with some short sections of low sinuosity channels and washslopes, man made pond upstream of alignment	Headwater	n	NCs 4a	<10		Grassland/crops	Dermosols	Very low (1) to Moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
171900	Culvert	1	Non-channelised Valley floor with some short sections of low sinuosity channels, man made pond upstream of alignment	Headwater	y	NC 10	114.8	0.0137	Grassland/crops	Vertosol	Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
172232	Bridge - Road	1	Non-channelised Valley floor with some short sections of low sinuosity channels, wash slope downstream	Headwater	y	NC 9	42.7	0.0178	Grassland/crops	Vertosol/ Rudosols	Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
173588	Culvert	1	Washslope, Non-channelised Valley floor with man made ponds in flow path downstream of alignment	Headwater	n	NCs 3	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
176907	Culvert	1	Washslope to Non-Channelised Valley Floor	Headwater	y	NC 8	42.1	0.0414	Grassland/crops	Vertosol	Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
177658	Culvert	1	Low sinuosity, washslopes downstream	Headwater	n	NCs 2	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
178689	Culvert	1	Washslope, man made ponds in flow path both upstream and downstream of alignment	Headwater	y	NC 7	141	0.0073	Grassland/crops	Vertosol	Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
180696	Embankment	1	Washslope, Non-channelised Valley floor	Headwater	n	NCs 1	<10		Grassland/crops	Vertosol	Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)
181139	Culvert	2	Non-Channelised Valley Floor with short section of low sinuosity channel	Headwater	y	NC 6	140.5	0.0570	Grassland/crops	Vertosol	Low (2) to moderate (3)	Moderate Relief Hills (Mid-Tertiary basalt)

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APPENDIX H

Geomorphology Report

Appendix D Floodplain classification

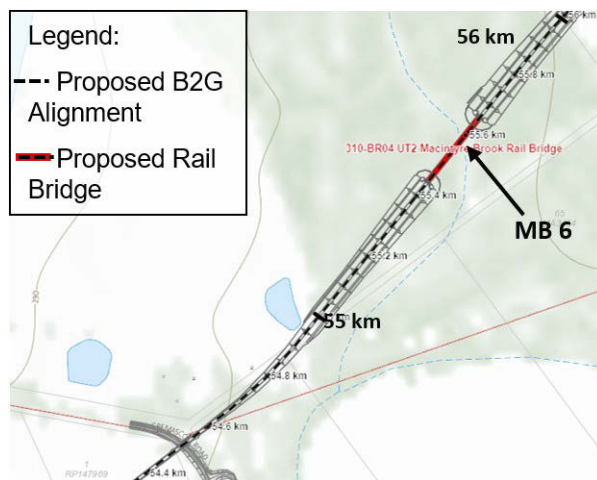
BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Appendix D

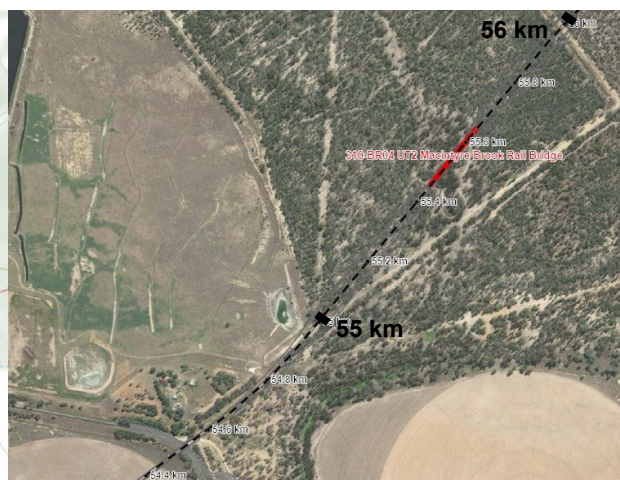
Floodplain classification

Table D1 Macintyre Brook floodplain summary

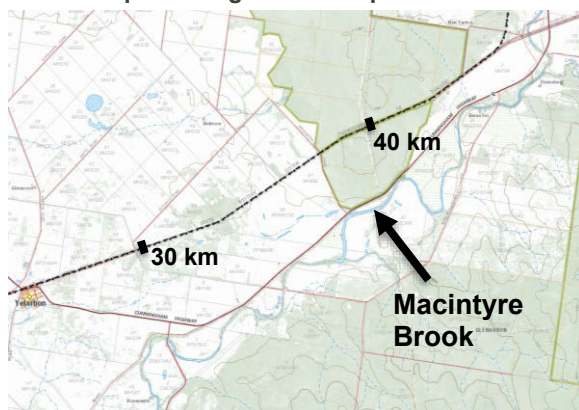
	Macintyre Brook	MB 6
Maximum Width	3,100 m	210 m
Elevation at the Project alignment (m AHD)	270-290 m	280 m
Elevation at the top of the catchment (m AHD)	742 m	380 m
Soil Summary	Chromosol/Kandosol/ Dermosol/Sodosols (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)	Sodosols (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	Scroll bars, some evidence of paleochannels and backswamps.	Difficult to assess as bush covered.
Vegetation	Grassland with bush	Grassland with bush
Characterisation	B3b	B3
Stream Order	8	4
Historic change	Circular irrigation and manmade ponds constructed on floodplain, straightened floodplain channels. Roads and bridges constructed across the floodplain.	Manmade pond, some forestry/farm tracks.
Sensitivity to change	5	2



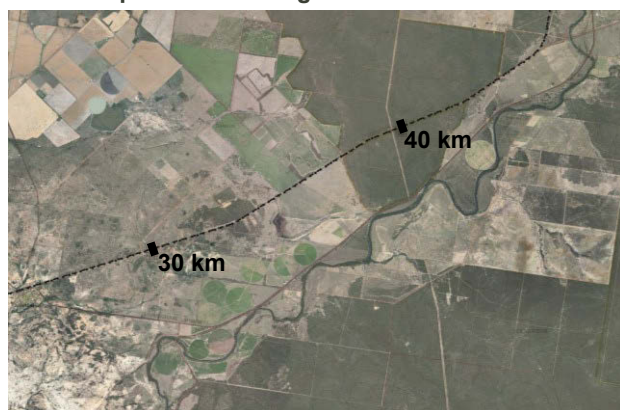
MB6 floodplain Image Location plan



MB6 floodplain Aerial image



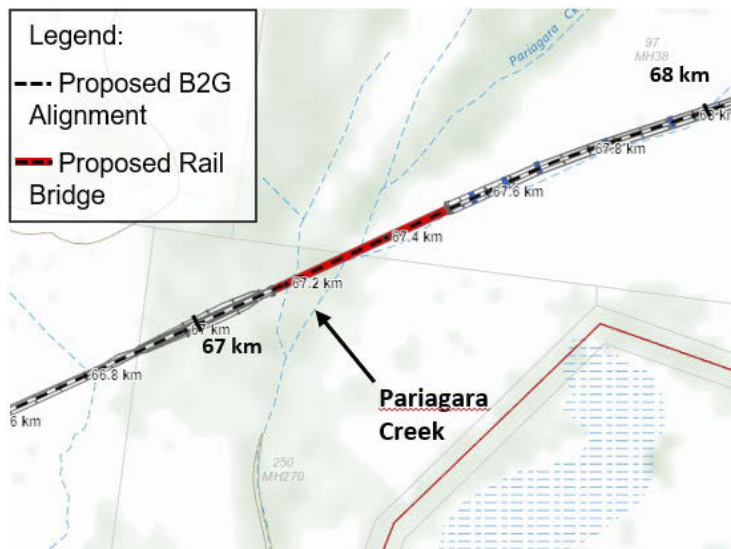
Macintyre Brook floodplain Image Location plan



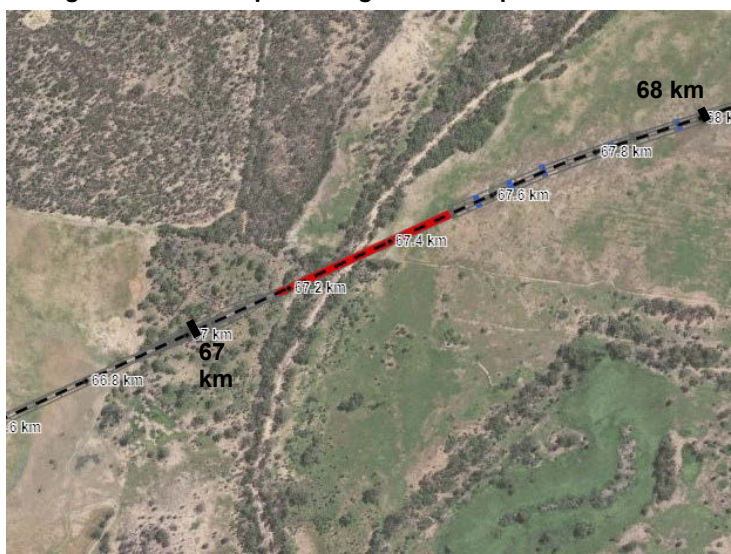
Macintyre Brook floodplain Aerial image

Table D2 **Pariagara Creek floodplain summary**

Pariagara Creek	Details
Maximum Width	150 m
Elevation at the Project alignment (m AHD)	285 m
Elevation at the top of the catchment (m AHD)	460 m
Soil Summary	Sodosol (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	The floodplain is confined to the west. There is evidence of paleochannels on the floodplain, and backswamps/wetlands.
Vegetation	Grassland with bush
Characterisation	B3
Stream Order	4
Historic change	Some forestry and farm tracks
Sensitivity to change	2



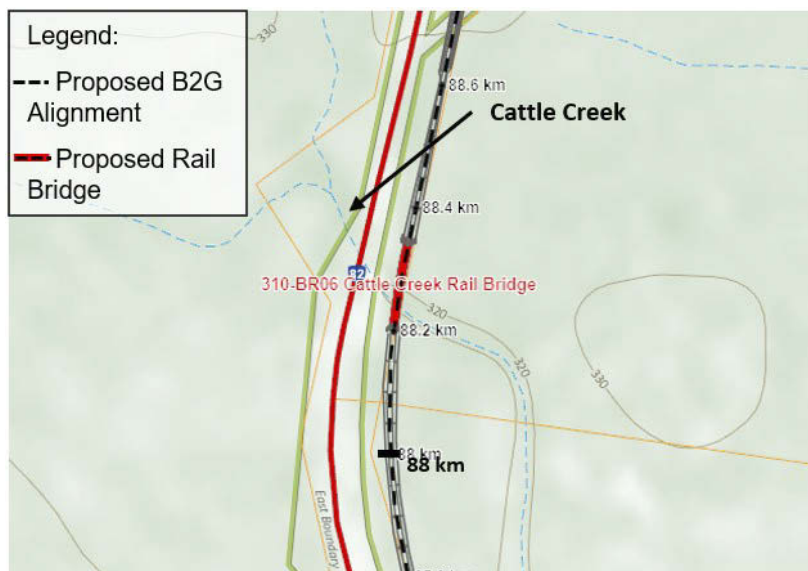
Pariagara Creek floodplain Image Location plan



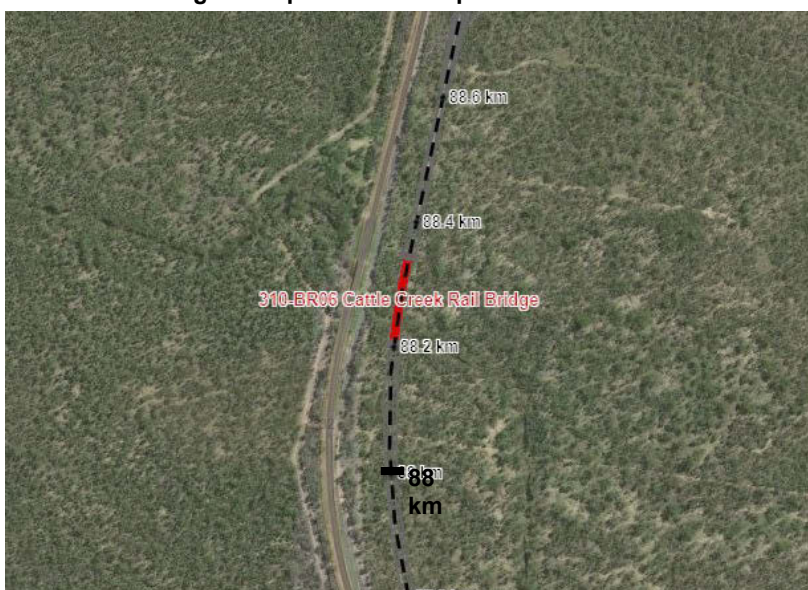
Pariagara Creek floodplain Aerial image

Table D3 Cattle Creek floodplain summary

Cattle Creek	Details
Maximum Width	70-150 m
Elevation at the Project alignment (m AHD)	320 m
Elevation at the top of the catchment (m AHD)	460 m
Soil Summary	Sodosol (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	Difficult to assess as bush covered. Single channel floodplain.
Vegetation	Bush
Characterisation	B3
Stream Order	4
Historic change	Millmerran Inglewood road has a bridge which confines the floodplain
Sensitivity to change	4



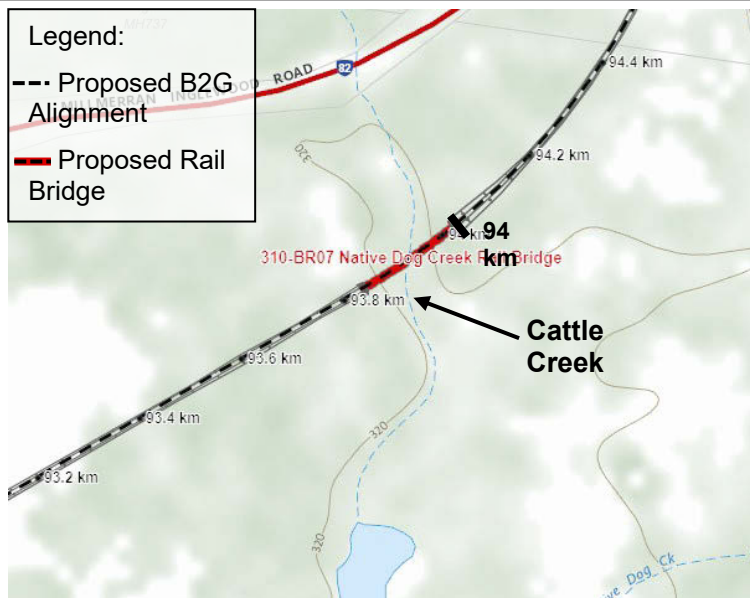
Cattle Creek Image floodplain Location plan



Cattle Creek floodplain Aerial image

Table D4 Native Dog Creek floodplain summary

Native Dog Creek	Details
Maximum Width	50-120 m
Elevation at the Project alignment (m AHD)	320 m
Elevation at the top of the catchment (m AHD)	400 m
Soil Summary	Sodosol (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	Difficult to assess as bush covered, appears to have some remnant backswamps.
Vegetation	Bush
Characterisation	B3 - C1
Stream Order	3
Historic change	Road bridge confines the floodplain
Sensitivity to change	4



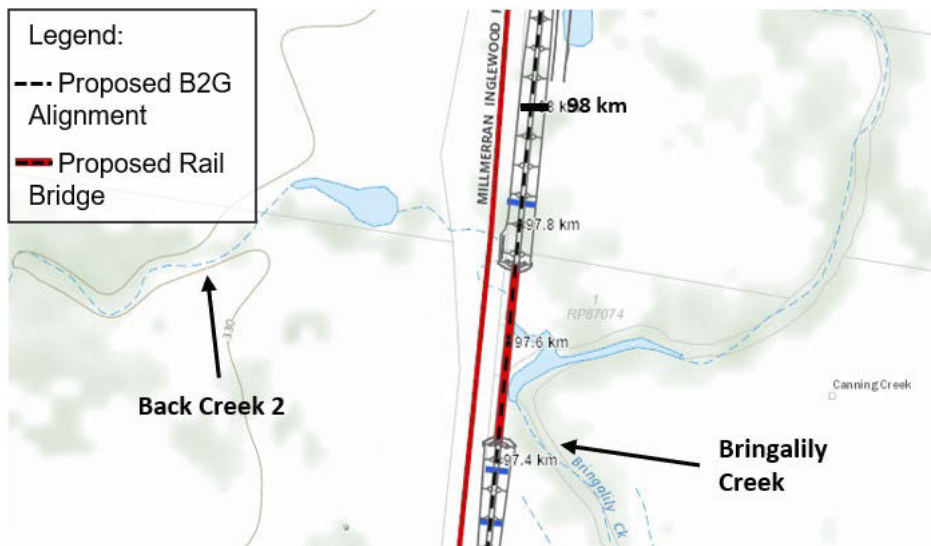
Native Dog Creek floodplain Image Location plan



Native Dog Creek floodplain Aerial image

Table D5 Bringalily Creek and Back Creek 2 floodplain summary

Bringalily Creek and Back Creek 2	Details
Maximum Width	170-300 m
Elevation at the Project alignment (m AHD)	330 m
Elevation at the top of the catchment (m AHD)	Bringalily Creek - 440 m Back Creek 2 - 410 m
Soil Summary	Sodosol (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	The Project runs across the confluence between Back Creek and Bringalily Creek. The floodplain is semiconfined to the west by an existing road. Upstream floodplain cut-off feature with ponding on Bringalily, floodplain backflow area.
Vegetation	Grassland with bush and Grassland/crops
Characterisation	B3
Stream Order	5 and 2
Historic change	Manmade ponds constructed on floodplain. Semiconfined by existing road.
Sensitivity to change	4



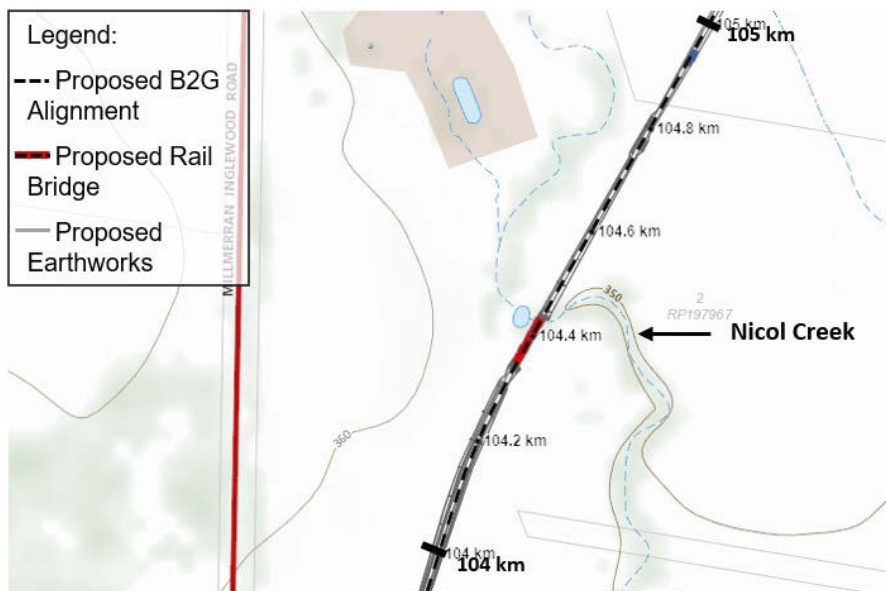
Bringalily Creek and Back Creek 2 floodplain Image Location plan



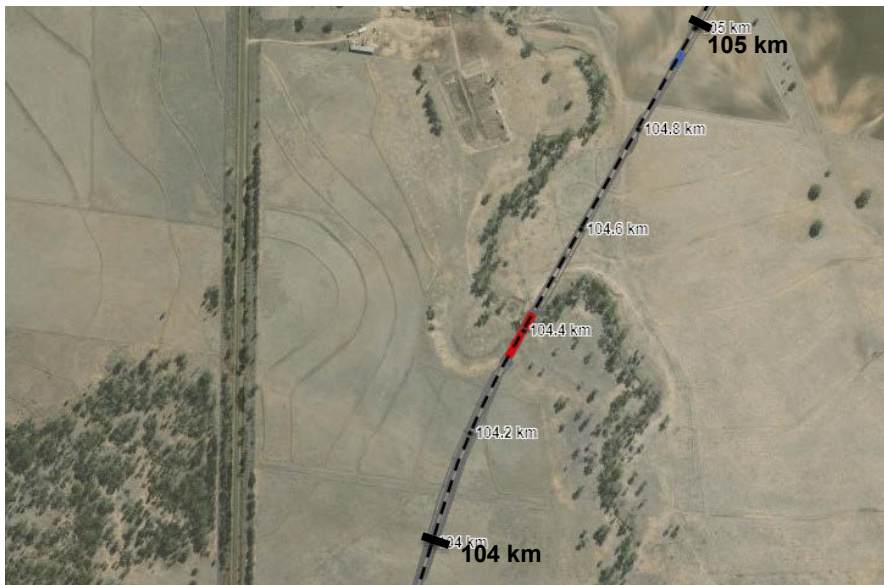
Bringalily Creek and Back Creek 2 floodplain Aerial image

Table D6 Nicol Creek floodplain summary

Nicol Creek	Details
Maximum Width	210 m
Elevation at the Project alignment (m AHD)	355 m
Elevation at the top of the catchment (m AHD)	570 m
Soil Summary	Vertosols (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	It has one main channel, evidence of meander cut-offs and ponding.
Vegetation	Grassland with bush
Characterisation	B3
Stream Order	3
Historic change	Manmade pond in the river channel
Sensitivity to change	2



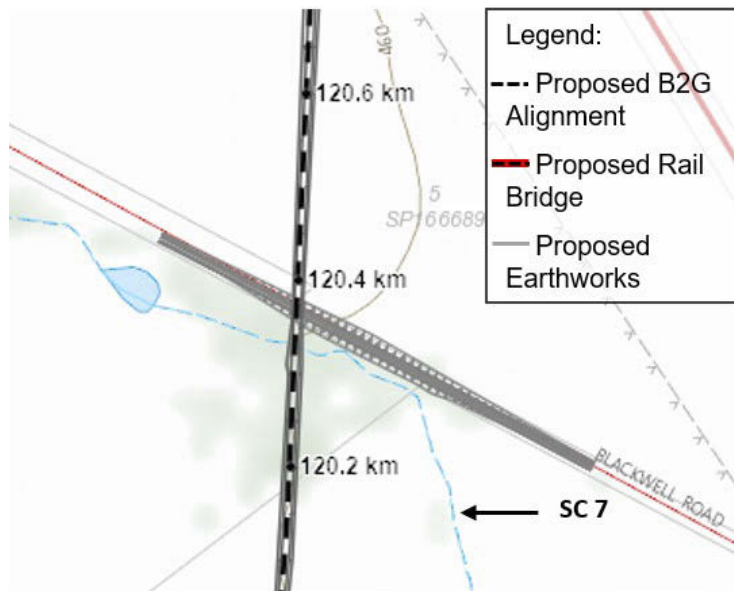
Nicol Creek floodplain Image Location plan



Nicol Creek floodplain Aerial image

Table D7 SC 7 floodplain summary

SC 7	Details
Maximum Width	200 m
Elevation at the Project alignment (m AHD)	460 m
Elevation at the top of the catchment (m AHD)	620 m
Soil Summary	Vertosol (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	Grassed channel has been modified upstream of culvert, waterway flows into dam. Downstream of dam, the channel is well defined, sinuous, and grassed with some areas of ponding water.
Vegetation	Grassland with bush
Characterisation	B3
Stream Order	3
Historic change	Manmade pond located approximately 160 m upstream. Scour channels formed from pond overtopping.
Sensitivity to change	5



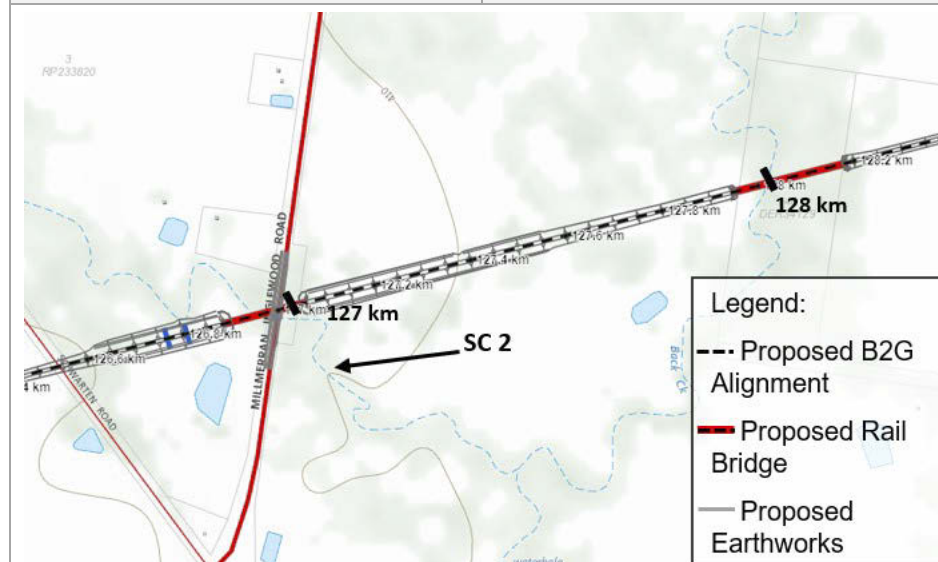
SC 7 floodplain Image Location plan



SC 7 floodplain Aerial image

Table D8 SC 2 floodplain summary

SC 2	Details
Maximum Width	27 5m
Elevation at the Project alignment (m AHD)	415 m
Elevation at the top of the catchment (m AHD)	610 m
Soil Summary	Sodosols (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	Modified channel around bend, a grassed embankment/dammed area has been constructed to restrict flow to the east. Sinuous channel, incised, with banks up to 2 m in height.
Vegetation	Grassland with bush
Characterisation	C1
Stream Order	4
Historic change	Manmade pond located within floodplain (approximately 70 m by 40 m), one branch of main channel dammed.
Sensitivity to change	4



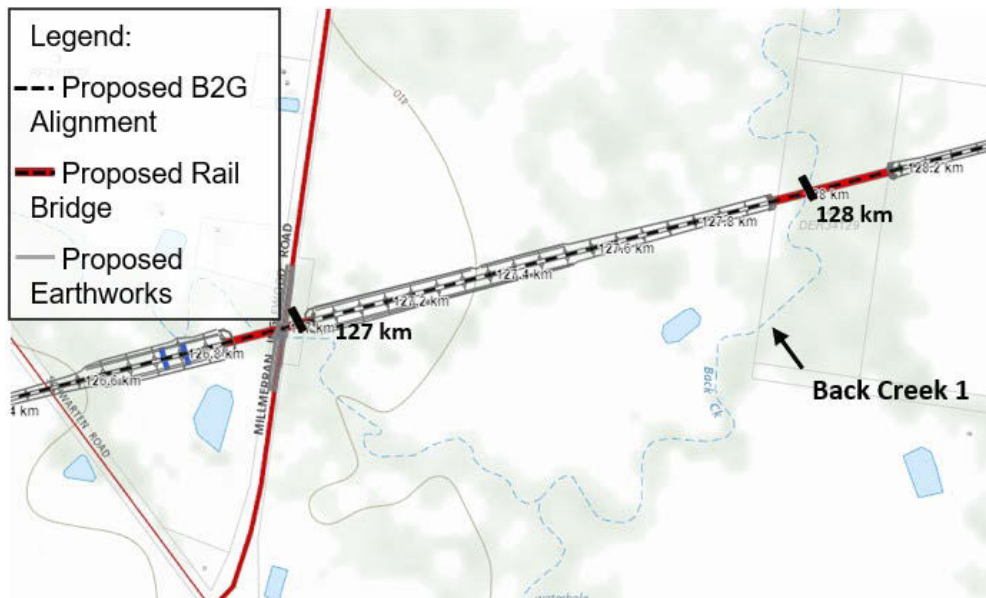
SC 2 floodplain Image Location plan



SC 2 floodplain Aerial image

Table D9 Back Creek 1 floodplain summary

Back Creek 1	Details
Maximum Width	600 m
Elevation at the Project alignment (m AHD)	410 m
Elevation at the top of the catchment (m AHD)	510 m
Soil Summary	Sodosols (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	Single main channel, bush in floodplain area makes assessment of features difficult. Meander cut-offs visible.
Vegetation	Grassland with bush
Characterisation	C1
Stream Order	4
Historic change	Man-made ponds located within the floodplain.
Sensitivity to change	2



Back Creek 1 floodplain Image Location plan



Back Creek 1 floodplain Aerial image

Table D10 One Mile Gully floodplain summary

One Mile Creek	Details
Maximum Width	25 m
Elevation at the Project alignment (m AHD)	470 m
Elevation at the top of the catchment (m AHD)	560 m
Soil Summary	Vertosols (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	Relatively straight to slightly sinuous single channel. Slightly confined to the north and south. Evidence of paleochannels and bank erosion.
Vegetation	Grassland/crops
Characterisation	C1
Stream Order	3
Historic change	Farmers ponds, crops grown adjacent to channel.
Sensitivity to change	2

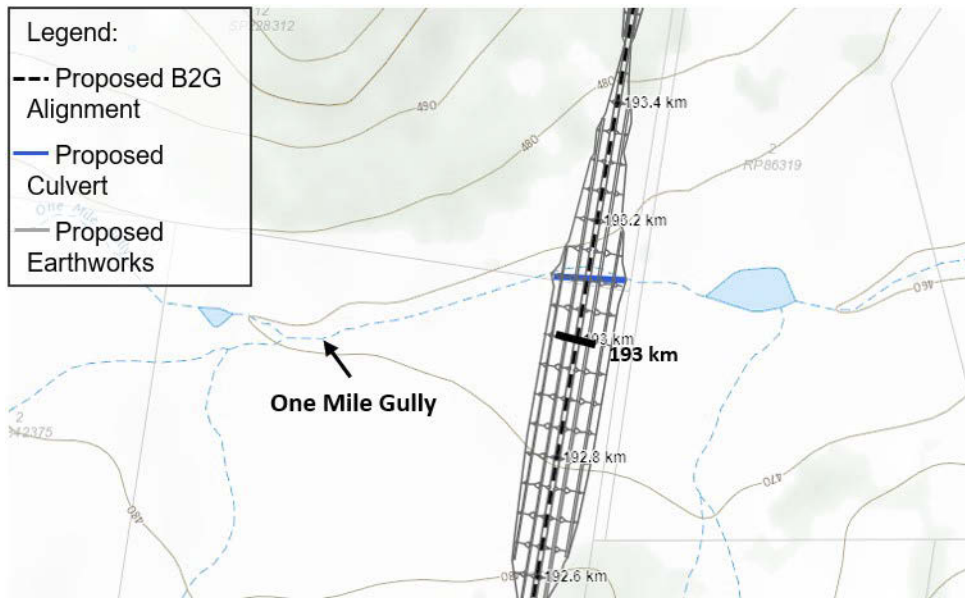
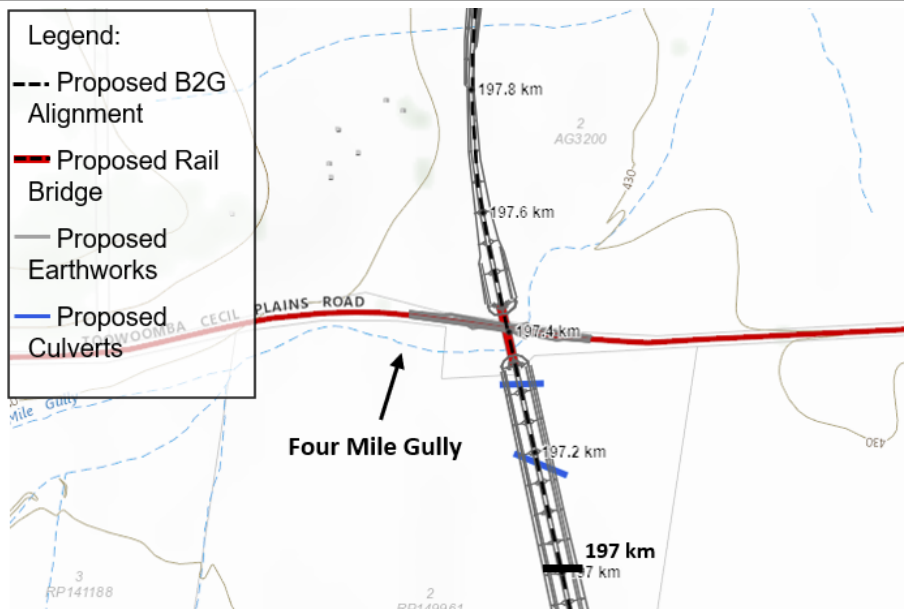


Table D11 Four Mile Gully floodplain summary

Four Mile Gully	Details
Maximum Width	90 m
Elevation at the Project alignment (m AHD)	435 m
Elevation at the top of the catchment (m AHD)	560 m
Soil Summary	Vertosol (Regional ASC and Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	Singe meandering channel. Evidence of paleochannels. Confined to the northeast. Four Mile Gully Creek is a tributary to Westbrook Creek
Vegetation	Grassland/crops
Characterisation	C1
Stream Order	3
Historic change	Confined by existing road and bridge
Sensitivity to change	4



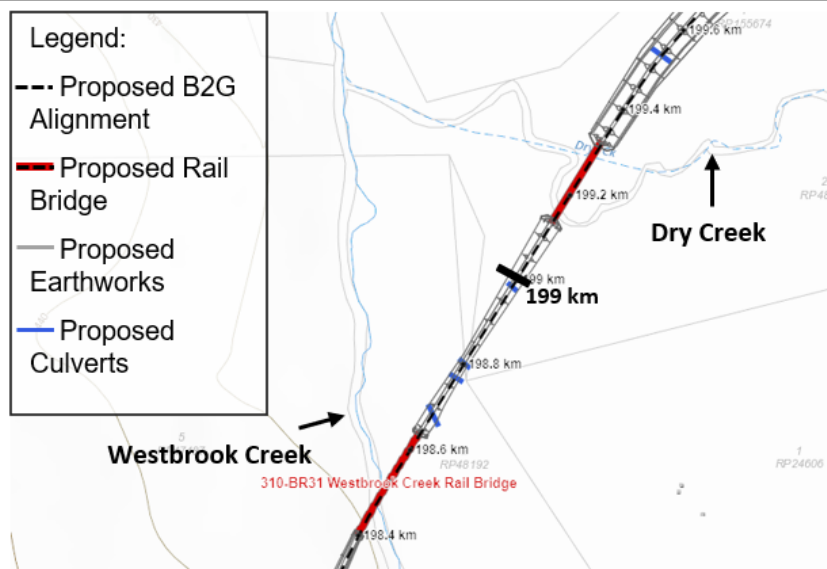
Four Mile Gully floodplain Image Location plan



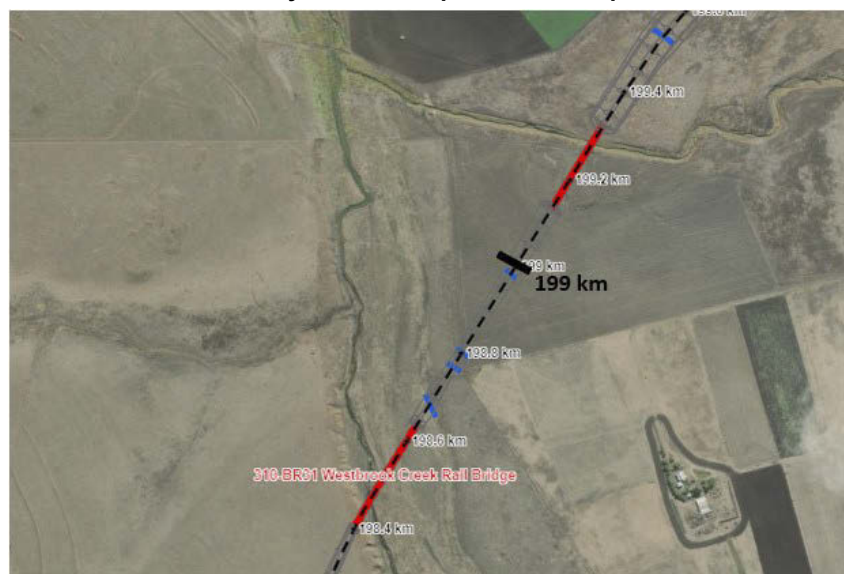
Four Mile Gully floodplain Aerial image

Table D12 Westbrook Creek and Dry Creek floodplain summary

Westbrook Creek and Dry Creek	Details
Maximum Width	250 m
Elevation at the Project alignment (m AHD)	Westbrook Creek - 430 m Dry Creek – 425 m
Elevation at the top of the catchment (m AHD)	Westbrook Creek - 680 m Dry Creek – 650 m
Soil Summary	Chromosols and Dermosols (Regional ASC), Vertosols, Ferrosols, Calcarosols, Dermosols (Project soil investigations EIS Appendix J: Soil Assessment Report)
Geomorphic features	Floodplain is in semi-confined on the western side. Evidence of paleochannels and chain of ponds. Dry Creek has been straightened.
Vegetation	Grassland/crops. Floodplain is non vegetated. Very isolated shrubs along the creek edge.
Characterisation	C1
Stream Order	4 and 3
Historic change	Farm tracks, straightening of Dry Creek.
Sensitivity to change	2 Westbrook Creek. 4 Dry Creek



Westbrook Creek and Dry Creek floodplain Location plan



Westbrook Creek and Dry Creek floodplain Aerial image

APPENDIX H

Geomorphology Report

Appendix E Oldest historic aerial imagery reviewed

BORDER TO GOWRIE REVISED DRAFT ENVIRONMENTAL IMPACT STATEMENT

Oldest Imagery of Watercourses

Chainage (m)	Watercourse	Oldest aerial image/s reviewed	Date captured	Capture height (m)
30596	MB 10	QAP0009053	11/07/1949	3901
43212	MB 9	QAP0009011	12/07/1949	3901
48396	MB 8	QAP0032033	21/08/1949	3962
52599	MB 7	QAP0031108	19/08/1949	3840
55619	MB 6	QAP0031107, QAP0031108, QAP0031047	19/08/1949	3840
60465	MB 5	QAP0031027	19/08/1949	3840
61590	MB 4	QAP0031027	19/08/1949	3962
61900	MB 3	QAP0031027	19/08/1949	3840
62911	MB 2	QAP0031027	19/08/1949	3840
63148	MB 1	QAP0031027	19/08/1949	3840
66225	C Ck 20	QAP0032142	21/08/1949	3840
66811	C Ck 19	QAP0032142	21/08/1949	3840
67209	C Ck 18	QAP0032142	21/08/1949	3840
67328	Pariagara Creek	QAP0032142	21/08/1949	3840
68734	C Ck 17	QAP0032142	21/08/1949	3840
73363	CCs 22	QAP0972056	19/08/1959	3962
73529	CCs 21a	QAP0972056	19/08/1959	3962
73531	CCs 21	QAP0972056	19/08/1959	3962
73614	C Ck 16a	QAP0972056	19/08/1959	3962
73682	C Ck 16	QAP0972056	19/08/1959	3962
78997	C Ck 15	QAP0971128	18/08/1959	3962
82348	C Ck 14	QAP0971101	18/08/1959	3962
84385	C Ck 13	QAP0971101	18/08/1959	3962
87370	C Ck 12	QAP0971056	18/08/1959	3962
88241	Cattle Creek	QAP0995014	14/12/1959	3962
90961	C Ck 11	QAP0971024	18/08/1959	3962
92064	C Ck 10	QAP0971023	18/08/1959	3962
93927	Native Dog Creek	QAP0969144	17/08/1959	3962
97638	Back Creek 2	QAP0969098	17/08/1959	3962
100598	Bringalily	QAP0969098	17/08/1959	3962
104429	Nicol Creek	QAP0969019	17/08/1959	3962
107212	C Ck 9	QAP0995019	14/12/1959	3962
109437	C Ck 8	QAP0968109	17/08/1959	3962
113069	C Ck 7	QAP0968064	17/08/1959	3962
113289	C Ck 6	QAP0968064	17/08/1959	3962
113513	C Ck 5	QAP0968064	17/08/1959	3962
113768	C Ck 4	QAP0968064	17/08/1959	3962
114420	C Ck 3	QAP0968064	17/08/1959	3962
115511	C CK 2	QAP0968064	17/08/1959	3962
115623	C CK 1	QAP0968064	17/08/1959	3962
117390	SC 11	QAP0968022	17/08/1959	3962
117650	SC 10	QAP0968022	17/08/1959	3962
118421	SC 9	QAP0968022	17/08/1959	3962
119377	SC 8	QAP0968022	17/08/1959	3962
120333	SC 7	QAP0967104	16/08/1959	3962
120756	SC 6	QAP0967104	16/08/1959	3962
121442	SC 5	QAP0967104	16/08/1959	3962
124372	SC 4	QAP0967064	16/08/1959	3962
125479	SC 3	QAP0967065	16/08/1959	3962
126960	SC 2	QAP0967064	16/08/1959	3962
128017	Back Creek 1	QAP0967064	16/08/1959	3962

130182	SC 1	QAP0967024	16/08/1959	3962
139851	Grasstree Creek	QAP0966140	16/08/1959	3962
141032	Condamine anabranh	QAP0966140	16/08/1959	3962
142600	Condamine South Branch	QAP0966111	16/08/1959	3962
144215	Condamine River	QAP0966111	16/08/1959	3962
149990	Condamine North Branch	QAP0493069	20/05/1955	4115
160033	NC 16	QAP0447132	30/10/1954	4115
164158	NC 15	QAP0485009	7/05/1955	4115
164418	NC 14	QAP0485009	7/05/1955	4115
165072	NC 13	QAP0485010	7/05/1955	4115
169873	NC 12	QAP0485012	7/05/1955	4115
170561	NC 11	QAP0485012	7/05/1955	4115
171900	NC 10	QAP0485013	7/05/1955	4115
172232	NC 9	QAP0485013	7/05/1955	4115
176907	NC 8	QAP0484141	7/05/1955	4115
178689	NC 7	QAP0484140	7/05/1955	4115
181139	NC 6	QAP0484095	7/05/1955	4115
181795	NC 5	QAP0484095	7/05/1955	4115
182992	NC 4	QAP0484095	7/05/1955	4115
184866	NC 3	QAP0484096	7/05/1955	4115
186179	NC 2	QAP0484097	7/05/1955	4115
187207	NC 1	QAP0484095	6/05/1955	4115
190005	OC 5 (Half Mile Gully)	QAP0487074	7/05/1955	4115
191956	OC 4	QAP0487075	7/05/1955	4115
193127	One Mile Creek	QAP0487075	7/05/1955	4115
194694	OC 3	QAP0484020	6/05/1955	4115
197376	Four Mile Gully	QAP0487078	7/05/1955	4115
198477	Westbrook Creek	QAP0487078	7/05/1955	4115
199289	Dry Creek	QAP0487078	7/05/1955	4115
202794	OC 2	QAP0483017	6/05/1955	4115
207146	OC 1	QAP0483017	6/05/1955	4115
30550 (NS2B)	Macintyre River	QAP0016089	7/08/1949	3658
34800 (NS2B)	MR 1	QAP0016081	7/08/1949	3658
N/A	PC1	QAP0966103	17/08/1959	3962

Oldest Imagery of Floodplain

Start Chainage (m)	End Chainage (m) ²	Floodplain	Oldest aerial image/s reviewed	Date captured	Capture height (m)
30.6	36	Macintyre River	QAP0016089, QAP0016081, QAP0009053	7/08/1949, 7/08/1949, 11/07/1949	3658, 3658, 3901
26.7	45.682	Macintyre Brook	QAP0016089, QAP0016081, QAP0009053, QAP0009011	7/08/1949, 7/08/1949, 11/07/1949, 12/07/1949	3658, 3658, 3901, 3901
55.3	55.66	MB 6	QAP0031107, QAP0031108, QAP0031047	19/08/1949, 19/08/1949, 19/08/1949	3840, 3840, 3840
67.17	67.4	Pariagara Creek	QAP0032142	21/08/1949	3840
88.2	88.3	Cattle Creek	QAP0995014	14/12/1959	3962
93.86	94.02	Native Dog Creek	QAP0969144	17/08/1959	3962
97.4	98.6	Back Creek 2	QAP0969098	17/08/1959	3962
95.03	100.69	Bringalily Creek	QAP0969098	17/08/1959	3962
104.34	104.42	Nicol Creek	QAP0969019	17/08/1959	3962
120.31	120.31	SC 7	QAP0967104	16/08/1959	3962
126.96	126.96	SC 2	QAP0967064	16/08/1959	3962
127.95	128.19	Back Creek 1	QAP0967064	16/08/1959	3962
139	151.4	Condamine River	QAP0966140, QAP0966111, QAP0493069	16/08/1959, 16/08/1959, 20/05/1955	3962, 3962, 4115
193.1	193.14	One Mile Gully	QAP0487075	7/05/1955	4115
196.73	193.14	Four Mile Gully	QAP0487078	7/05/1955	4115
198.4	199.04	Westbrook Creek	QAP0487078	7/05/1955	4115
199.11	199.32	Dry Creek	QAP0487078	7/05/1955	4115