Inland Rail: North Star to NSW/QLD Border

Preferred Infrastructure Report – Hydrology and Flooding

Australian Rail Track Corporation

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Glossary

The following terms and acronyms are used within this document:

Term or Acronym	Description
1D	One dimensional
2D	Two dimensional
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARF	Areal Reduction Factor
ARR 2019	Australian Rainfall and Runoff Guidelines – 2019 edition
ARTC	Australian Rail Track Corporation
BoM	Bureau of Meteorology
BRVFMP	Border Rivers Valley Floodplain Management Plan
CSSI	Critical State Significant Infrastructure
DEA	Design Event Approach
Developed Case	Hydraulic modelling case with proposal in place
DNRME	Department of Natural Resources, Mines and Energy (Qld)
DPIE	Department of Planning, Industry and Environment
DRDMW	Department of Regional Development, Manufacturing and Water (Qld)
EIS	Environmental Impact Statement
Existing Case	Hydraulic modelling case pre-proposal
FFA	Flood Frequency Analysis
FFJV	Future Freight Joint Venture
FMOs	Flood Management Objectives
FSR	Flood Sensitive Receptor
GEV	Generalised Extreme Variable
GRC	Goondiwindi Regional Council
H	Hours
IFD	Intensity-Frequency-Duration
km	kilometres
LGA	local government area
LiDAR	Light Detection and Ranging
LPIII	Log-Pearson Type III
m	metres
mm	millimetres
m AHD	metres above Australian Height Datum
N/A	Not Applicable
N2NS	Narrabri to North Star
NS2B	North Star to Border
NSW	New South Wales
PIR	Preferred Infrastructure Report
PMP	Probable Maximum Precipitation

Term or Acronym	Description
QLD	Queensland
QDLs	Quantitative Design Limits
RAFTS	Hydrological Model: runoff-routing which converts rainfall excess into flow
RCBC	Reinforced concrete box culvert
RCP	Reinforced concrete pipe
SEARs	Critical State Significant Infrastructure Standard Secretary's Environmental Assessment Requirements
SGS	Sub-Grid Sampling
the proposal	The North Star to Border proposal
TUFLOW	Hydraulic Model: 2-Dimensional numerical model
URBS	Hydrologic Model: Unified River Basin Simulation runoff-routing models which converts rainfall excess into flow
VBF	Volume Below Full
V x d	Velocity-Depth product (m^2/s) ~ flood hazard indicator

Executive summary

This Preferred Infrastructure Report (PIR) assesses the impact the North Star to Queensland Border (NS2B) Inland Rail project under various flow scenarios. The PIR proposes Flood Management Objectives (FMOs) and an impact mitigation methodology for the project that provide a suitable basis for assessment and determination as a Critical State Significant Infrastructure Project and its subsequent construction and operation.

The project presented is as it is described in the Environmental Impact Statement (EIS) with the clarifications and revisions included in the Response to Submissions (RtS) Report. This is analysed against the following scenarios:

(a) Verified 2019 levees using validated 1976 flows across the project extent
(b) BRVFMP levees using factored flows across the project extent
(c) BRVFMP levees using validated 1976 flows across the area of the BRFVMP
(d) Verified 2019 levees using 1% AEP flows for the southern tributaries
(e) BRVFMP levees using 1% AEP flows for the southern tributaries

The PIR proposes the impacts of the NS2B proposal are considered under cases (a) and (d).

ARTC has completed an assessment of the 1976 Border Rivers Flood Event against the Quantitative Design Limits (QDLs) used in the neighbouring N2NS Phase 1 project. For development assessment the Border River Floodplain Management Plan (BRVFMP) 1976 flows and Development layers (levees) were required for use in the assessment process. This case is referred to as the “BRVFMP levees and BRVFMP factored flows”.

During the North Star to Border EIS (2020), both the modelling prepared by ARTC and the modelling used from the BRVFMP was subject to an independent review (BMT Commercial Australia Pty Ltd) and a further review by Goondiwindi Regional Council. These reviews produced several recommendations including that the BRVFMP hydrologic model be updated to improve its representation of catchment conditions and hydrological modelling be updated to be Australian Rainfall and Runoff (ARR 2019) compliant. This has been completed as part of this report. Additionally, the updated 1976 flows scenario is also presented for assessment against the N2NS FMOs. This case is referred to as the “BRVFMP levees with validated 1976 flows” case.

From community feedback it was concluded that the BRVFMP development layers (constructed and approved levees to limited and unlimited approval heights) significantly alter the flow across the floodplain during large flood events and do not provide a true representation of what is on the floodplain in the existing condition. ARTC commissioned LiDAR survey in 2019 to produce a snapshot of the floodplain topographic conditions. This is referred to as the “verified 2019 levees with validated 1976 flows”. This case provides both the most accurate representation of the topography and hydrologic flows into the assessment area. For this reason, ARTC assign this as the base case for the floodplain.

The BRVFMP factored flows and validated 1976 event flows were found to generally compare well in terms of flood extent and overall flood volume on the Macintyre River floodplain. At a more granular level, it was found that better detail was available on flows and flow timing from the updated hydrology. This outcome was informed by additional historical data not included in the BRVFMP. This has resulted in a more robust calibration in the updated hydrology across three historical events (1976, 1996 and 2011) and hence can give more confidence in the assessment of the results (i.e. in comparison to the BRVFMP modelling).

For this reason, ARTC submits that the updated modelling is more robust with a more detailed demonstration of catchment flows and should be used for the assessment of the proposal.

The N2NS Phase 1 QDLs are conditioned in the N2NS Phase 1 approval as applying up to and including 1% Annual Exceedance Probability (AEP). Within the N2NS Phase 1 extents there are many watercourses, typically varying from minor, ephemeral overland flowpaths, to large creek systems. Through rigorous analysis, the 1976 flood event on this major floodplain has been determined as having approximately a 1 in

200 AEP (0.5%). It results in inundation at all of the affected flood sensitive receptors in the existing case (without the Inland Rail design).

The PIR presents updated FMOs that address any inconsistencies in the N2NS Phase 1 QDLs and include a second category of FMOs for project specific performance targets for individual localised impacts in rare events such as the 1976 event. The assessment has demonstrated that there is generally minimal change across the floodplain.

Some localised exceedances of the FMO thresholds are still present, and these have been discussed directly with the impacted landholders and included in this report. A mitigation framework has been proposed to capture this discussion to ensure that appropriate mitigation measures at the impacted properties are provided as the project advances through detailed design.

With the updated ARR 2019 compliant modelling and the inclusion of the impact mitigation framework, the proposal can be considered for approval.

1 Introduction

1.1 Inland Rail Program

Inland Rail is a once-in-a-generation Program connecting regional Australia to domestic and international markets, transforming the way we move freight around the country. It will complete the 'spine' of the national freight network between Melbourne and Brisbane via regional Victoria, New South Wales and Queensland. This new 1,700 kilometres (km) line is the largest freight rail infrastructure project in Australia and is expected to commence operations in 2025.

1.2 North Star to NSW/QLD Border proposal

The Inland Rail section between North Star in New South Wales (NSW) and the NSW and Queensland (QLD) Border (known as the 'NS2B' proposal) will cross the Macintyre River and its floodplain which are a part of the Border Rivers catchment. The proposal alignment runs through Moree Plains local government area (LGA), Gwydir LGA and Goondiwindi LGA.

Key features of the proposal include:

- Approximately 30 km of new, single line, standard gauge track (trains travelling in both directions share the same track)
- Upgrade to approximately 25 km of non-operational corridor and 5 km of new greenfield rail corridor to the NSW/QLD Border (Ch 30.6 km)
- Bridges to accommodate topographical variation, crossings of waterways and other infrastructure
- Reinforced concrete pipe culverts and reinforced concrete box culverts
- Rail crossings including level crossings, grade separations/rail or road overbridges, occupational/private crossings
- Removal of non-operational rail line up to southern side of Whalan Creek
- Roadworks including realignment and drainage structures on Bruxner Way

For the purpose of the hydrology and flooding investigation the following was incorporated into the design:

- An additional approximate 6 km of new, single line, standard gauge track within new greenfield corridor within the Border Rivers Floodplain to Ch 36.04 (Border to Gowrie (B2G) alignment).

A draft EIS for the proposal was submitted to the Department of Planning, Industry and Environment (DPIE) in August 2020. This was followed by a six-week public exhibition period between August and October 2020.

1.3 Scope of Preferred Infrastructure Report

Based on a review of the draft EIS and submissions received during the exhibition period, DPIE have requested that ARTC prepare a Preferred Infrastructure Report (PIR) that:

a) reassesses the hydrology and flooding impacts of the project, as presented in the EIS, using the greater of, the large design flood as defined in the Border Rivers Valley Floodplain Management Plan (1976 flood event), or the 1% AEP flood,

b) reconsiders the proposed mitigation measures to address impacts identified in a),

c) assesses the impacts in a) against the Quantitative Design Limits (QDLs) specified in the Narrabri to North Star Infrastructure Approval, unless otherwise agreed to by the Department,

d) includes a framework outlining the process for determining appropriate mitigation, where the QDLs cannot be met, in consultation with the affected landowners.

This PIR document fulfils the requirements of the PIR and addresses items raised during the Exhibition Period as outlined in Table 1-1.

Table 1-1 Items addressed in Preferred Infrastructure Report

Topic/aspect	Section addressed
Reassessment of the hydrology and flooding impacts of the project, as presented in the EIS, using the greater of, the large design flood as defined in the Border Rivers Valley Floodplain Management Plan (1976 flood event), or the 1% AEP flood	Section 7
Proposed mitigation measures to address impacts	Section 8
Assessment of impacts against the Quantitative Design Limits (QDLs) specified in the Narrabri to North Star Infrastructure Approval	Section 7
Framework outlining the process for determining appropriate mitigation, where the QDLs cannot be met, in consultation with the affected landowners	Section 8
Update of hydrologic and hydraulic modelling to address concerns raised from Submissions including details in Independent Peer Review completed for Goondiwindi Regional Council (GRC)	Section 3, Appendix A, Appendix B and Appendix H

1.4 Independent peer review

A further Independent Peer Review of the modelling work undertaken for the PIR has been completed by BMT Commercial Australia Pty Ltd. This review has considered the hydrologic and hydraulic modelling updates including the revised calibration and design event modelling and review of the flood frequency analysis of the Boggabilla stream gauge (416002). A copy of the Independent Peer Review Report is provided in Appendix G.

2 Assessment methodology

2.1 Background

For the EIS assessment, DPIE provided the following existing information developed for the Border Rivers Valley Floodplain Management Plan (BRVFMP 2020):

- Existing 1976 and 1996 URBS hydrologic models for the Macintyre River, Dumaresq River and Macintyre Brook catchments
- Existing 1976 and 1996 RAFTS hydrologic models for Ottleys Creek catchment
- Existing 1976 and 1996 TUFLOW hydraulic models for the Border Rivers Valley floodplain

For the EIS, hydrologic and hydraulic modelling was undertaken using the provided information with the following amendments:

- Creation of a TUFLOW hydraulic sub-model based on the provided BRVFMP hydraulic model which covers an area of approximately 1.1 million hectares extending from approximately 50 km upstream of Boggabilla to 40 km downstream of Mungindi. The TUFLOW hydraulic sub-model has the same upstream boundary and extends to 18 km downstream of Goondiwindi (refer Figure B1, Appendix B).
- Inclusion of an additional historical, more recent, calibration event being the January 2011 event
- Sourcing and inclusion of current LiDAR survey data across the floodplain to obtain details of current ground levels and levee heights/locations to support assessment of proposal. This information was included in the hydraulic sub-model based on community feedback that the BRVFMP levee layer was not representative of current topographic conditions.
- Reduction in hydraulic model grid spacing from 40m to 30m
- Inclusion of Goondiwindi town levee heights based on information provided by Goondiwindi Regional Council (GRC) to replace the unlimited heights used in the BRVFMP model

The performance of the hydraulic sub-model was validated against a range of information collected for the three historical flood events (1976, 1996 and 2011) including:

- Stream gauge level and flow hydrographs
- Flood markers
- Flood event photography from landholders
- Aerial flood photography
- Landholder and community observations of the flood events

This base modelling was used to develop the proposal alignment design and assess the impacts on peak water levels, flood flow distribution, velocities and duration of inundation. The impacts of the refined design were documented in the EIS Chapter 13 and associated EIS Appendix H Hydrology and Flooding Technical Report.

The impact assessment was carried out primarily against the 1% AEP event with the levees based on the 2019 LiDAR data. In addition, modelling of the 1% AEP event with the BRVFMP levees and the 1976 flows with levees based on the 2019 LiDAR data was undertaken and documented in the EIS.

2.2 Revised modelling approach

Whilst the hydrologic and hydraulic modelling undertaken for the EIS is based on the existing BRVFMP hydrologic and hydraulic modelling, an Independent Peer Review was undertaken for Goondiwindi Regional Council (GRC) which identified that there were a number of potential limitations with the modelling including that it was not reflective of current best practice including requirements of the recently updated Australian Rainfall and Runoff Guidelines (ARR 2019).

The methodology followed for the updated the hydrologic and hydraulic modelling to address PIR scope and the issues raised in the GRC Independent Peer Review included:

- Compliance to Australian Rainfall and Runoff Guidelines 2019 in relation to hydrologic and hydraulic modelling guidelines for major infrastructure
- Extension of the existing URBS hydrologic models to form one linked hydrologic model that includes:
  - The four major upstream catchments to within the hydraulic model boundary – Macintyre River, Macintyre Brook, Dumaresq River and Ottleys Creek
  - The wider floodplain area down to Goondiwindi
  - The southern tributaries catchments – Mobbindry Creek, Back Creek, Strayleaves Creek and Forest Creek
  - The Brigalow Creek catchment
- Review and update of available rainfall and streamflow data used to represent the three historical calibration events (1976, 1996 and 2011)
- Refinement of major upstream catchments URBS models to use common modelling parameters for each catchment (apart from loss rates and dam details relevant to date of historical flood event)
- Refinement of southern tributaries URBS modelling
- Update of the TUFLOW hydraulic model used for the EIS to include the following:
  - Revised flows from the updated URBS hydrologic model with no factoring of flows for historical events
  - Refinement of upstream inflow locations into the hydraulic model
  - Review and update of existing drainage structures under the non-operational Camurra-Boggabilla rail line, Bruxner Way and North Star Road using available information
- Joint calibration of the hydrologic model and hydraulic sub-model including:
  - Validation against the available all discoverable recorded stream gauge, recorded flood markers and anecdotal data for the 1976, 1996 and 2011 historical flood events
  - Comparison against the BRVFMP calibration outcomes
- 1% AEP design event modelling and reconciliation to flood frequency analyses (FFA) of key stream gauges in the upper catchments and at Boggabilla.
- Modelling of the Existing Case and Developed Case (including the proposal design) for the 1976 flows scenario for the following cases, being:
  - Verified 2019 levees and validated 1976 flows
  - BRVFMP levees and validated 1976 flows
  - BRVFMP levees and factored flows
  - Verified 2019 levees and 1% AEP flows
  - BRVFMP levees and 1% AEP flows
- Determination of critical event for crossing locations, ie either 1976 flow scenario or 1% AEP flows

- Assessment of the performance of the proposal alignment design against the Floodplain Management Objectives as detailed in Section 2.3

Details on the refinement of the hydrologic and hydraulic modelling, including the updated calibration process and outcomes, are provided in Appendix A – Hydrologic Model Updates, Appendix B – Hydraulic Model Updates and Appendix H – Design event modelling.

2.3 Floodplain Management Objectives

In Chapter 13 of the EIS, the impact of the proposal upon the existing flood regime was quantified and compared against flood impact objectives as detailed in Table 13.7. These objectives were developed to address the requirements of the SEARs and were used to guide the proposal design with the intent that ongoing discussion would occur with stakeholders and landholders to confirm acceptability.

DPIE have now requested that the impacts of the proposal be assessed against the Quantitative Design Limits (QDLs) specified in the Narrabri to North Star (N2NS) Phase 1 Infrastructure Approval as outline in Table 2-1.

It is noted that acceptable impacts may ultimately be determined on a case by case basis including interaction with stakeholders/landholders through the community engagement process leading to formal third-party agreements. This process will consider flood sensitive receptors and land use within floodplain areas.

Table 2-1 N2NS Phase 1 Quantitative Design Limits (QDLs)

Parameter	Location or Land Use	Limit
Afflux i.e. increase in flood level resulting from implementation of CSSI	Habitable floors[4]	10mm increase[5]
	Non-habitable floors	20mm increase
	Other urban and recreational	100mm increase
	Agriculture	200mm increase
	Forest and unimproved grazing land	300mm increase
	Highways and sealed roads >80km/hr[6]	No increase in depth where aquaplaning risk exists and remains unmitigated. Otherwise 50mm increase
	Unsealed roads and sealed roads <80km/hr[6]	100mm increase
Scour/Erosion Potential i.e increase in flood velocity resulting from implementation of CSSI.	Ground surfaces that have been sealed or otherwise protected against erosion. This includes roads, most urban, commercial, industrial, recreational and forested land	20% increase in velocity where existing velocity already exceeds 1m/s
	Other areas including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas	No velocities to exceed 0.5m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. In addition, the increase in velocity is limited to 20% where the existing velocity already exceeds 0.5m/s
Flood Hazard i.e. increase in velocity-depth product (vd) and/or flood hazard category resulting from implementation of CSSI (Does not apply where vd>0.1m^2/s).	Urban, commercial, industrial, highways[6] and sealed roadways[6]	10% increase in vd where H1 or H2 category. 0% increase in vd where in H3 or greater category.
	Elsewhere	20% increase in vd

Parameter	Location or Land Use	Limit
Flood duration i.e. increase in duration of inundation resulting from implementation of CSSI. (Does not apply to inundated areas less than 100m^2).	Habitable floors[4]	No increase in inundation duration above floor level. 10% increase in inundation duration where below floor level and when existing duration exceeds one hour. Otherwise inundation duration not to exceed one hour.
	Highways and sealed roads >80km/hr[6]	10% increase in inundation duration.
	Elsewhere	10% increase in inundation duration when existing inundation duration exceeds one hour. Otherwise inundation duration not to exceed one hour.

Table notes:

These QDLs are only applicable beyond the CSSI corridor, unless otherwise noted.

4 Habitable floors/rooms are defined consistent with the use of this term in the NSW Floodplain Development Manual. In a residential situation this comprises a living or working area such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom. In an industrial, commercial or other building, this comprises an area used for and office or to store valuable possessions, goods or equipment susceptible to flood damage in the event of a flood.

5 10mm has been set to provide a margin for modelling uncertainties/tolerances. The intent of this requirement is that existing flood levels above floor level do not increase.

6 Including where located within the CSSI corridor.

There are two key concerns with applying the N2NS QDLs verbatim, being:

- the N2NS QDLs were applied to catchments with different characteristics to the Border Rivers catchment and floodplain; and
- the N2NS QDLs were assessed against a 1% AEP event.

The N2NS Conditions of Approval state:

> *E27 The CSSI must meet the QDLs in Appendix A – FLOODING QUANTITATIVE DESIGN LIMITS AND MODELLING REQUIREMENTS. Unless otherwise noted, these QDLs apply outside the rail corridor except for level crossings. These QDLs apply in any flood event* ***up to and including the 1% AEP****, and in any duration.*

The 1976 flood event has been assessed as approximately a 1 in 200 AEP event (refer Appendix H), a larger event than a 1 in 100 (1%) AEP event.

ARTC generally agree with the objectives when applied to the broader floodplain, however it is thought unreasonable to expect the project infrastructure to be designed for up to a 1 in 200 AEP event as would be required to achieve the impact objectives as presented. Therefore, it is believed that some adjustment of the FMO limits should be considered for the NS2B project for localised areas immediately adjacent to the rail corridor in such a relatively rare event.

Updated FMOs are presented in Table 2-2 that address any inconsistencies in the N2NS Phase 1 QDLs and include a second category of FMOs for project specific performance targets for individual localised impacts in rare events (i.e. greater than a 1% AEP).

Key points to note are:

- The NS2B floodplain wide FMO targets (Column 4) are generally in agreement with the N2NS Phase 1 limits except where the limits are not consistent with the other FMOs (e.g. zero change in flood hazard when change to flood level and velocity are permissible)
- The NS2B project specific performance FMO targets (Column 5) recognise that some impact will occur in rare events, such as the 1 in 200 AEP, in the vicinity of the proposal, i.e. within in an approximate assessment area of 3km upstream and 1 km downstream of the proposal alignment
- NS2B floodplain wide FMO targets would apply outside of the proposed assessment area for the 1976 event, and for all events up to and including the 1% AEP

Justification of the proposed targets is provided in Table 2-2. However, it is noted that assessment against rare events such as the 1 in 200 AEP for approvals is not common and it is difficult to source precedents.

Table 2-2 Proposed Floodplain Management Objectives (FMOs)

Parameter	Location or land use	N2NS QDLs (up to and including 1% AEP)	NS2B floodplain wide FMO targets (up to and including 1% AEP, and outside of local corridor in 1976 event)	NS2B project specific FMO targets for 1976 event (approximate assessment area – 1km d/s and 3km u/s) - (recognises the infrequency/AEP of the 1976 event)	Justification/details
Afflux i.e. increase in flood level resulting from implementation of CSSI	Habitable floors	10mm increase	10mm increase	50mm Where inundation is above floor level in the existing case, higher afflux can be acceptable where damage to property is not above what would be experienced in the existing case	Consistent with Gwydir and Moree, Part 7, Section 7.6 Flood Planning of Moree LEP - (5) In this clause, ***flood planning level*** means the level of a 1:100 ARI (average recurrence interval) flood event plus 0.5 metre freeboard. Precedence in NSW shows 50mm afflux to have been permitted on habitable floors for 1% AEP (W2B EIS) See Footnote #1 wrt localised FMO for 1976 event
	Non-habitable floors	20mm increase	20mm increase	100mm Where inundation is above floor level in the existing case, higher afflux can be acceptable where damage to property is not above what would be experienced in the existing case	See Footnote #1 wrt localised FMO for 1976 event
	Other urban and recreational	100mm increase	100mm increase	200mm increase	See Footnote #1 wrt localised FMO for 1976 event
	Agriculture	200mm increase	200mm increase	400mm increase	See Footnote #1 wrt localised FMO for 1976 event
	Forest and unimproved grazing land	300mm increase	300mm increase	500mm increase	See Footnote #1 wrt localised FMO for 1976 event

Parameter	Location or land use	N2NS QDLs (up to and including 1% AEP)	NS2B floodplain wide FMO targets (up to and including 1% AEP, and outside of local corridor in 1976 event)	NS2B project specific FMO targets for 1976 event (approximate assessment area – 1km d/s and 3km u/s) - (recognises the infrequency/AEP of the 1976 event)	Justification/details
	Highways and sealed roads >80km/hr	No increase in depth where aquaplaning risk exists and remains unmitigated. Otherwise 50mm increase	50mm increase If not trafficable then the increase should be on a case by case assessment with no change to the network trafficability of that road - aligns with duration approach	100mm increase If not trafficable then the increase should be on a case by case assessment with no change to the network trafficability of that road - aligns with duration approach	In addition to consideration of afflux on a site-specific basis, the approach also focuses on network trafficability/immunity (including where afflux may exceed the flood management objective, but can be justified from a network trafficability/immunity perspective) See Footnote #1 wrt localised FMO for 1976 event
	Unsealed roads and sealed roads <80km/hr	100mm increase	100mm increase If not trafficable then the increase should be on a case by case assessment with no change to the network trafficability of that road - aligns with duration approach	200mm increase If not trafficable then the increase should be on a case by case assessment with no change to the network trafficability of that road - aligns with duration approach	In addition to consideration of afflux on a site-specific basis, the approach also focuses on network trafficability/immunity (including where afflux may exceed the flood management objective, but can be justified from a network trafficability/immunity perspective) See Footnote #1 wrt localised FMO for 1976 event
Scour/ Erosion Potential i.e increase in flood velocity resulting from implementation of CSSI.	Ground surfaces that have been sealed or otherwise protected against erosion. This includes roads, most urban, commercial, industrial, recreational and forested land	20% increase in velocity where existing velocity already exceeds 1m/s	No velocities to exceed 1.0m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. 20% increase in velocity where existing velocity already exceeds 1.0m/s	No velocities to exceed 1.0m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. 20% increase in velocity where existing velocity already exceeds 1.0m/s	Accepting of baseline approach – however deviation from these thresholds can be permitted under the advice of geotechnical or scour/erosion specialist, or through implementation of appropriate mitigation measures

Parameter	Location or land use	N2NS QDLs (up to and including 1% AEP)	NS2B floodplain wide FMO targets (up to and including 1% AEP, and outside of local corridor in 1976 event)	NS2B project specific FMO targets for 1976 event (approximate assessment area – 1km d/s and 3km u/s) - (recognises the infrequency/AEP of the 1976 event)	Justification/details
	Other areas including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas	No velocities to exceed 0.5m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. In addition, the increase in velocity is limited to 20% where the existing velocity already exceeds 0.5m/s	No velocities to exceed 0.5m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. In addition, the increase in velocity is limited to 20% where the existing velocity already exceeds 0.5m/s	No velocities to exceed 0.5m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. In addition, the increase in velocity is limited to 20% where the existing velocity already exceeds 0.5m/s	Accepting of baseline approach – however deviation from these thresholds can be permitted under the advice of geotechnical or scour/erosion specialist, or through implementation of appropriate mitigation measures.
Flood Hazard i.e. increase in velocity-depth product (vd) and/or flood hazard category resulting from implementation of CSSI (Does not apply where vd>0.1m^2/s).	Urban, commercial, industrial, highways and sealed roadways	10% increase in vd where H1 or H2 category. 0% increase in vd where in H3 or greater category.	10% for all categories (taking into consideration land use and impacted receptors)	20% for all categories (taking into consideration land use and impacted receptors)	Objectives not consistent with other criteria which allow some degree of change (i.e. "0% increase in vd where in H3 or greater category"). Rational approach is to propose a percentage tolerance across all categories, but which would consider land use and impacted receptors in determining acceptability. See Footnote #1 wrt localised FMO for 1976 event.
	Elsewhere	20% increase in vd	20% increase in vd	30% increase in vd	See Footnote #1 wrt localised FMO for 1976 event.
Flood duration i.e. increase in duration of inundation resulting from implementation of CSSI. (Does not apply to inundated areas less than 100m^2).	Habitable floors	No increase in inundation duration above floor level. 10% increase in inundation duration where below floor level and when existing duration exceeds one hour. Otherwise inundation duration not to exceed one hour.	10% increase in inundation duration above floor level. 15% increase in inundation duration where below floor level and when existing duration exceeds one hour. Otherwise inundation duration not to exceed one hour.	10% increase in inundation duration above floor level. 15% increase in inundation duration where below floor level and when existing duration exceeds one hour. Otherwise inundation duration not to exceed one hour.	Objectives not consistent with other criteria which allow some degree of change (i.e. "No increase in inundation duration above floor level"). Rational approach is to propose a percentage tolerance across all categories. See Footnote #1 wrt localised FMO for 1976 event.

Parameter	Location or land use	N2NS QDLs (up to and including 1% AEP)	NS2B floodplain wide FMO targets (up to and including 1% AEP, and outside of local corridor in 1976 event)	NS2B project specific FMO targets for 1976 event (approximate assessment area – 1km d/s and 3km u/s) - (recognises the infrequency/AEP of the 1976 event)	Justification/details
	Highways and sealed roads >80km/hr	10% increase in inundation duration.	10% increase in inundation duration. If not trafficable then the increase should be on a case by case assessment with no worsening to the network trafficability of that road – aligns with afflux approach	20% increase in inundation duration. If not trafficable then the increase should be on a case by case assessment with no worsening to the network trafficability of that road – aligns with afflux approach	In addition to consideration of inundation duration on a site-specific basis, the approach also focuses on network trafficability/immunity (including where duration may exceed the flood management objective but can be justified from a network trafficability/immunity perspective). See Footnote #1 wrt localised FMO for 1976 event.
	Elsewhere	10% increase in inundation duration when existing inundation duration exceeds one hour. Otherwise inundation duration not to exceed one hour.	20% increase in inundation duration when existing inundation duration exceeds one hour. At new or fringe inundation - consider land use and resultant effects of inundation	30% increase in inundation duration when existing inundation duration exceeds one hour. At new or fringe inundation - consider land use and resultant effects of inundation	Proposed percentage increase recognises flood behaviour and the lengthy duration of inundation that occurs in the floodplain following regional events (i.e. typically multiple days) See Footnote #1 wrt localised FMO for 1976 event

Table note:

1 Flood impact risk is deemed a function of event probability and the flood impact threshold. Maintaining the same flood impact risk profile implies that a reduction in event probability is balanced through an increase in flood impact threshold.

The proposal impacts have been assessed against both the N2NS QDLs and the Proposed FMOs for the 1976 flow scenario and/or the 1% AEP as detailed in Section 6.

3 Summary of updated modelling

3.1 Aims of updated modelling

As noted in Section 2, a number of issues with the EIS modelling based on the BRVFMP hydrologic and hydraulic modelling were identified in the GRC Independent Peer Review and raised in the submissions during the Exhibition Period.

To address these issues and updated hydrologic and hydraulic modelling has been undertaken with the following aims:

- Achieve compliance with the guidelines for hydrologic and hydraulic modelling as set out in ARR 2019 thus producing models that are based on best current modelling practice
- Develop models that use all available survey, stream gauge and rainfall data that is discoverable and reliable in 2021. Using this data obtain the best calibration outcomes possible across the 1976, 1996 and 2011 historical events.
- Achieve improved representation of ground levels, levees and therefore flood conditions on floodplain through the use of newly released software upgrades. Thus, developing the best tool to be used to assess impacts of proposed NS2B works.
- Provide an updated suite of models that can be considered for use by the Councils and DPIE going forward – with robust and best practice hydrologic and hydraulic modelling and reduced uncertainties giving greater stakeholder confidence in modelling and assessment outcomes

3.2 Updated modelling summary

Full details of the updates to the hydrologic and hydraulic modelling are provided in Appendix A (Hydrologic Model Updates), Appendix B (Hydraulic Model Updates) and Appendix H (Design Event Modelling).

Key updates to the modelling include:

- Extension of the URBS hydrologic model to form one linked model that includes the upstream catchments (Dumaresq River, Macintyre Brook, Macintyre River and Ottleys Creek), the lower floodplain area, the smaller southern tributaries (Mobbindry Creek, Forest Creek, Back Creek and Strayleaves Creek) and Brigalow Creek
- Development of consistent parameters for the hydrologic model across the historical calibration events and then onto design event modelling
- Update of the hydraulic model with revised inflow locations, updated flows from the hydrologic model, review of existing drainage structures and use of new software versions to enable improved representation of flow conveyance
- Joint calibration of the updated hydrologic and hydraulic models for the 1976, 1996 and 2011 historical flood events, including:
  - Review of all currently available daily rainfall, pluviography and stream gauge data and identification of a wider dataset than previously used in the calibration process
  - No factoring of flows between the hydrologic and hydraulic model to achieve successful calibration outcomes
  - Iteration between the hydrologic and hydraulic model to achieve best combined calibration outcomes
- Revised design event modelling using the updated hydrologic and hydraulic models consistent with ARR 2019 guidelines

Full details of the modelling updates, the joint calibration process and calibration performance are presented in Appendix A and B. Details of the design event modelling are presented in Appendix H.

Overall a significant improvement in the calibration of both the hydrologic and hydraulic models has been achieved with good matches achieved at stream gauges throughout the upper catchments, at Boggabilla (refer to Appendix B, Figure B.2 to Figure B.7) and at Goondiwindi (refer to Appendix A, Figure B.9 to Figure B.14). Table 3-1 presents a comparison of recorded data at the Boggabilla stream gauge against the hydraulic modelling outcomes for each of the three historical events. The same information is presented in Table 3-2 for the Goondiwindi stream gauge.

Typically, the aim of calibration is to be within +/- 0.15m of recorded stream gauge levels. At Boggabilla, all modelled peak water levels are matched within 50mm (0.05m) which is an excellent outcome. At the Goondiwindi stream gauge, refer Table 3-2, the modelled levels are on the upper bounds of this range however given the good match at Boggabilla, the smaller size of the 1996 event, the constrained channel capacity near Goondiwindi, it is believed a good calibration has been achieved.

Table 3-1 Comparison of results at the Boggabilla stream gauge

Event	Recorded stream gauge data			TUFLOW model results		
	Level (m AHD)	Flow US of Boggabilla	Flow DS of Boggabilla	Level (m AHD)	Flow US of Boggabilla	Flow DS of Boggabilla
1976	221.27	n/a[a]	3,700 m^3/s (319,600 ML/d)	221.22 (-0.05m)	n/a[a]	3,680m^3/s (317,952 ML/d)
1996	221.03	3,486 m^3/s (301,200 ML/d)	2,485 m^3/s[b] (214,700 ML/d)	220.98 (-0.05m)	3,470 m^3/s (299,808 ML/d)	2,791 m^3/s (241,142 ML/d)
2011	221.12	3,803 m^3/s (328,600 ML/d)	n/a	221.11 (-0.01m)	4,493m^3/s (388,195 ML/d)	3,197 m^3/s (276,221 ML/d)

Table notes:

a 1976 event rating curve only considered flows at Boggabilla and not the full floodplain (refer Section 4.2 for more details)
b From flow measurement data

Table 3-2 Comparison of results at the Goondiwindi stream gauge

Event	Recorded level (m AHD)	TUFLOW model flood level (m AHD)	Rated gauge flow (m^3/s)	Rated gauge flow (ML/D)	TUFLOW model flow (m^3/s)	TUFLOW model flow (ML/day)
1976	218.08	218.37 (+0.29)	1,560	134,784	2,128	183,859
1996	218.19	218.34 (+0.15)	1,767	152,669	1,987	171,677
2011	218.195	218.36 (+0.16)	1,767	152,669	2,128	183,859

In addition, a good calibration against the available historical flood markers has also been achieved with Figures B2, B3 and B4 (Appendix B) presenting the calibration outcomes for the 1976, 1996 and 2011 historical events respectively. Table 3-3 presents a summary of the calibration to the historical flood markers for each event. The historical flood markers come from a range of sources including the Border Rivers Floodplain Management Plan (DPIE, 2020), the Goondiwindi Environs Study (Lawson and Treloar, 2007) and recent field survey on a landholder's property. The quality of the majority of these flood markers is unknown with a number of adjacent flood markers varying significantly. Therefore, a review of the flood markers was undertaken with a number excluded from the tabulated comparison. These are nominated as outliers in Table 3-3. Typically, the aim of calibration is to match recorded flood markers within +/- 0.3m.

Table 3-3 Summary of calibration against recorded flood markers

Model accuracy range (m)	1976 event		1996 event		2011 event	
	No of flood markers	% in range	No of flood markers	% in range	No of flood markers	% in range
Flooded but predicted to be dry	0	0%	0	0%	1	2%
<0.3	8	30%	0	0%	4	9%
-0.3 to -0.2	3	11%	0	0%	5	11%

Model accuracy range (m)	1976 event		1996 event		2011 event	
	No of flood markers	% in range	No of flood markers	% in range	No of flood markers	% in range
-0.2 to -0.1	3	11%	0	0%	7	16%
-0.1 to 0	3	11%	4	57%	5	11%
0 to 0.1	2	7%	0	0%	6	14%
0.1 to 0.2	3	11%	1	14%	5	11%
0.2 to 0.3	3	11%	1	14%	7	16%
>0.3	2	7%	1	14%	4	9%
Outliers removed*	12	-	1	-	8	-
Total number of markers	39	-	8	-	52	-

Table notes:

*Outliers – inconsistent with adjacent flood markers or near hydraulic model boundary.

With 2011 being the most recent event on the floodplain, and most representative of current floodplain conditions, it was deemed important that this event be considered the primary calibration event for the modelling. As can be seen from Table 3-3 there is a good match with 79% of flood markers within the +/- 0.3m range.

Given the size and the recognition of the 1976 event amongst the community and its use in development control/planning, this event is a key calibration event. The calibration achieved is reasonable as shown in Table 3-3 with 62% of flood markers in the +/- 0.3m range. This takes into account the age of the event, the changes to the floodplain since this event, uncertainties regarding the quality of the flood marker data and changes to stream gauges since the event occurred.

For the 1996 event, 85% of the flood markers lie within the +/- 0.3m range although this event has a reduced number of flood markers to compare against.

As presented and discussed in detail in Appendix A and Appendix B, a significantly improved calibration of the hydrologic and hydraulic models has been achieved for the Macintyre River floodplain including the avoidance of factoring up flows. An independent peer review has been undertaken of the revised hydrologic and hydraulic calibration. The report is presented in Appendix G. On calibration the findings are in agreement of the benefit of the updated calibration for representing the 1976 flood event:

" *The latest calibration is more robust than previous model calibrations and is more defendable in terms of its accuracy, and its basis using current best practice methods*."

3.3 Comparison against the BRVFMP calibration

There are a number of elements of the updated modelling that can be compared to the analysis undertaken to support the BRVFMP. This includes:

- Peak flows from the four major upstream catchments
- Inflow hydrographs from the four major upstream catchments with regards to volume, timing and shape
- The match to the recorded flood markers for the 1976 and 1996 events

Table 3-4 presents a comparison of the flows from the updated hydrologic model that are directly applied in the updated hydraulic model (ie no factoring) against the BRVFMP URBS flows that are factored up to achieve the BRVFMP hydraulic model flows.

Table 3-4 Comparison of BRVFMP flows and validated 1976 flows

Waterway	1976 Flows (m^3/s)			1996 Flows (m^3/s)			2011 Flows (m^3/s)
	Updated URBS Flows	BRVFMP URBS Flows	BRVFMP Hydraulic Model Flows	Updated URBS Flows	BRVFMP URBS Flows	BRVFMP Hydraulic Model	Updated URBS Flows
Macintyre River	2859	3255	3910[a]	1109	1462	2370[b]	1479
Dumaresq River	3083	2653	3180[a]	1331	1154	1870[b]	3630
Macintyre Brook	2016	1698	2040[a]	823	760	1220[b]	723
Ottleys Creek	1524	-	400	599	-	380	60

Table notes:

a – factor of 1.2 applied, b – factor of 1.6 applied

It is important to consider more than just the comparison of peak flows. Figure 1 presents a comparison of the inflow hydrographs for each of the four major catchments for the updated modelling and the BRVFMP hydraulic model for the 1976 event.

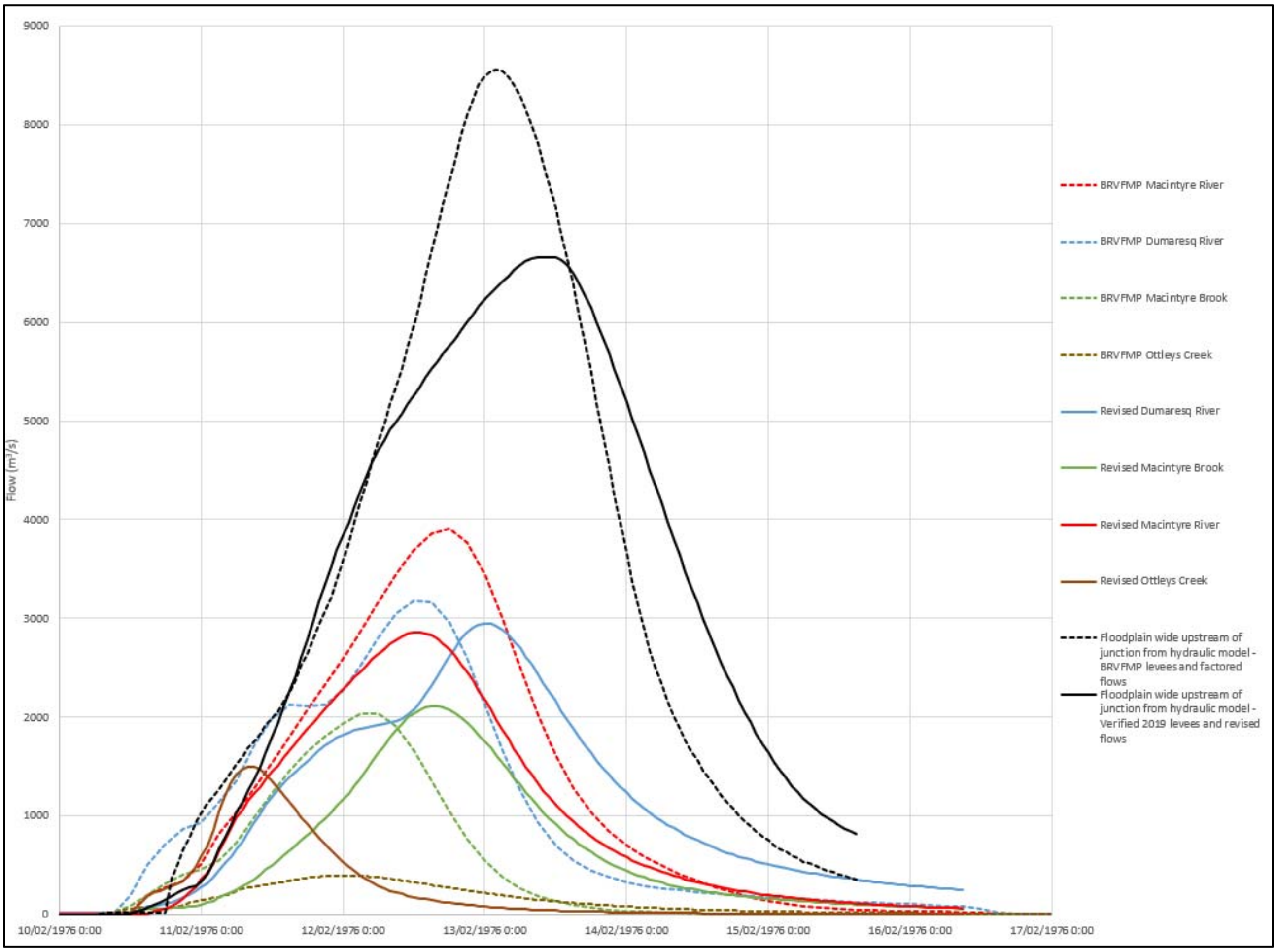


Figure 1 Comparison of hydraulic model inflow hydrographs

Key differences noted are:

- The Macintyre Brook and the Dumaresq River peak later in the revised modelling as compared to the BRVFMP modelling
- The combination of the peaks from the three major upstream catchments is be lower in the revised modelling. This is considered more realistic and representative of the 1976 event given the more accurate

matching of the timing of the flood hydrograph through each upstream catchment as detailed in Appendix A.

- Ottleys Creek peaks earlier and at a higher flow in the updated modelled as compared to the BRVFMP modelling. It is believed this response is more appropriate given the location and size of this catchment and the recorded rainfall data.

Using the hydrographs presented in Figure 1, a volume comparison has been undertaken for the validated 1976 flows and the BRVFMP factored flows as presented in Table 3-5. The variation in flow volumes is due to the improved rigour in the calibration of the updated hydrologic model with all discoverable rainfall and stream flow data used to improve the calibration outcomes throughout the upstream catchments.

Also presented is a comparison of total 1976 event flood volume from the hydraulic models from a section that covers the full inundated floodplain width just upstream of the junction of the rivers. This comparison shows that the validated 1976 flows result in the same volume passing through the floodplain as used in the BRVFMP modelling with factored flows (only 1% difference).

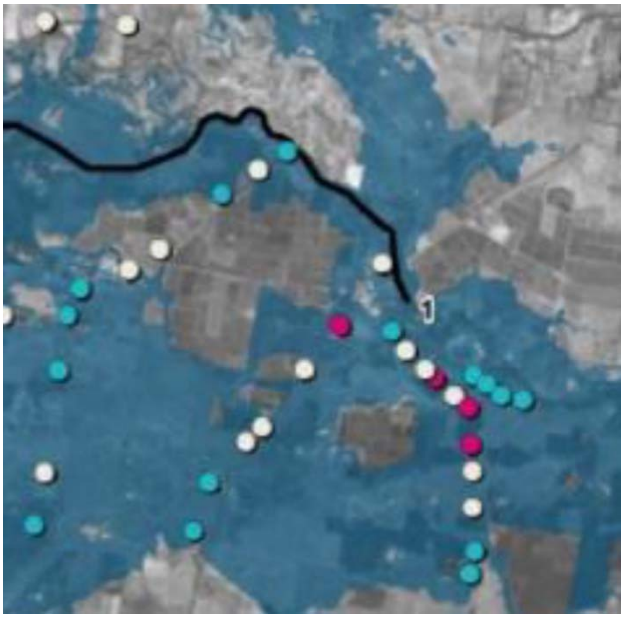
Table 3-5 Volume comparison

Catchment/Location	Verified 2019 levees and validated 1976 flows (Flood volume in ML)	BRVFMP levees and factored flows (Flood volume in ML)	Difference (%)
Dumaresq River	596,014	541,177	+10%
Macintyre River	502,236	642,669	-22%
Macintyre Brook	329,119	265,910	+24%
Ottley's Creek	131,927	80,820	+63%
Extracted from hydraulic model across full floodplain just upstream of junction of rivers	1,507,783	1,487,899	+1%

A further comparison that has been undertaken is a comparison of the matches achieved against the historical flood markers for the 1976 event. Figure 2 and Figure 3 present figure extracts that show the performance of the BRVFMP modelling and the revised modelling, respectively, against the flood markers for the 1976 calibration event. A very similar outcome is achieved with the updated modelling having two more flood markers lying within the +/- 0.3m band.

Table 3-6 Comparison of match to recorded 1976 event flood markers

Accuracy Range (m)	BRVFMP (DPIE, 2020) No of flood markers	Updated model at comparable points – No of flood markers
<0.3m (blue dots)	15	15
+/- 0.3m (white dots)	12	14
>0.3m (red dots)	4	2



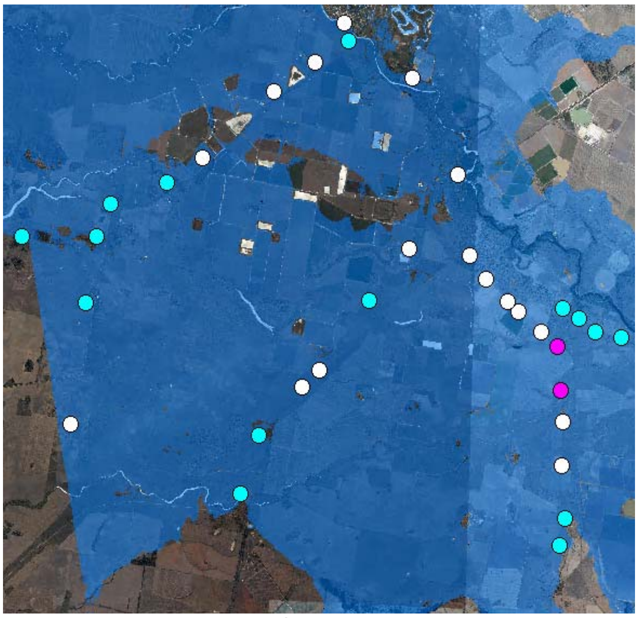


Figure 2 **Extract from Figure 3-4 – 1976 Flood Event Calibration, Appendix 6 – Background Document to BRVFMP 2020 – Appendices**

Figure 3 **Extract from Figure B2 (Appendix B) 1976 Calibration outcomes – updated modelling**

3.4 Summary

Both the updated modelling and the BRVFMP modelling use the same historical datasets (e.g. rainfall) and have been calibrated to a number of historical events using the same stream gauge data and recorded flood markers. Overall, the updated modelling and the BRVFMP modelling result in similar flood inundation extents, floodplain volumes and calibration outcomes.

The updated modelling has approached the hydrologic and hydraulic modelling with more rigour and has followed the hydrologic and hydraulic modelling guidelines set out in ARR 2019 which are current best practice. Key improvements included in the updated modelling, as compared to the BRVFMP modelling, are:

- Use of all discoverable rainfall and stream gauge data, recorded flood markers and landholder information to improve the calibration achieved for both the revised hydrologic and hydraulic models
- Revised flows from the updated hydrologic model used in the hydraulic model that are not factored. Individual upstream catchment flows have appropriate flood hydrograph timing based on an improved calibration that uses all discoverable streamflow and rainfall data.
- Extension of the hydrologic model to provide inflows from the lower floodplain catchment areas. Though it was noted that the inclusion of these flows only raised flood levels in the vicinity of the alignment by 20mm.

4 Existing Case modelling

4.1 Modelled scenarios

Modelling of the Existing Case, i.e. current state of development on the floodplain, has been undertaken to provide a base case against which the introduction of the proposed rail alignment and associated drainage structures can be assessed. The hydraulic sub-model has been used to assess two levee scenarios, being:

- BRVFMP Levees – all constructed and/or approved levees from the BRVFMP. These levees are modelled as either fixed heights or unlimited heights as approved under the BRVFMP, and
- Verified 2019 Levees – levee heights and extents drawn from the 2019 LiDAR. New LiDAR was flown and processed November 2019 to provide a snapshot of current topographic conditions, including current levee heights and floodplain features.

To assess development on the floodplain, the BRVFMP hydraulic modelling adopts flows derived for the 1976 event from the BRVFMP hydrologic model and factors them up by 1.2. This approach is aimed at improving the calibration to historical 1976 event recorded data on the floodplain, noting that the lower floodplain catchment was not implicitly include in the modelling, and to improve the downstream performance of the hydraulic model.

With the recent significant update of the hydrologic and hydraulic modelling (as outlined in Appendices A and B) addressing the items raised in the GRC Independent Peer Review and complying with ARR 2019 guidelines, revised flows for the 1976 event have been determined without the need to include any factoring and these flows have been applied with the current levee case.

A further combination has been considered with the updated hydraulic model and revised 1976 flows combined with the BRVFMP levees. This is aimed at representing the BRVFMP planning approach with an unfactored realistic representation of the 1976 event flows. Application of the BRVFMP factored flows to the updated hydraulic model is not considered appropriate as adjustments have been made to the hydraulic model to achieve calibration without the need for factoring of flows.

Therefore, three cases have been considered, being:

- Verified 2019 levees and validated 1976 flows
- BRVFMP levees and factored flows
- BRVFMP levees and validated 1976 flows

Existing Case mapping has been prepared including:

- Provided in Appendix C:
  - Figure C1 – Existing Case – Verified 2019 levees and validated 1976 Flows – Peak water levels
  - Figure C2 – Existing Case – Verified 2019 levees and validated 1976 Flows – Velocities
  - Figure C3 – Existing Case – Verified 2019 levees and validated 1976 Flows – Duration of inundation
  - Figure C4 – Existing Case – Verified 2019 levees and validated 1976 Flows – Hazard categories
  - Figure C5 – Existing Case – Verified 2019 levees and validated 1976 Flows – Velocity x depth product
- Provided in Appendix D:
  - Figure D1 – Existing Case – BRVFMP levees and factored flows – Peak water levels
  - Figure D2 – Existing Case – BRVFMP levees and factored flows – Velocities
  - Figure D3 – Existing Case – BRVFMP levees and factored flows – Duration of inundation
  - Figure D4 – Existing Case – BRVFMP levees and factored flows – Hazard categories
  - Figure D5 – Existing Case – BRVFMP levees and factored flows – Velocity x depth product

- Provided in Appendix E:
  - Figure E1 – Existing Case – BRVFMP levees and validated 1976 Flows – Peak water levels
  - Figure E2 – Existing Case – BRVFMP levees and validated 1976 Flows – Velocities
  - Figure E3 – Existing Case – BRVFMP levees and validated 1976 Flows – Duration of inundation
  - Figure E4 – Existing Case – BRVFMP levees and validated 1976 Flows – Hazard categories
  - Figure E5 – Existing Case – BRVFMP levees and validated 1976 Flows – Velocity x depth product

4.2 Estimation of AEP of historical flood events

A flood frequency analysis (FFA) of the Macintyre River stream gauge records at Boggabilla has been used to provide an estimate of the Annual Exceedance Probability (AEP) of the historical flood events used for calibration. Flow estimates at the stream gauges are dependent on the reliability of the rating curves used to translate recorded water level to an equivalent flow with the reliability of the gauge ratings having an impact on the FFA.

The Macintyre River gauge at Boggabilla has been in operation since 1894. The gauge rating is based on 603 gaugings recorded between 1924 and 2019. The gauge ratio between the highest gauged stage (level at which stream flow was physically recorded) and highest recorded flood level is 98% and is considered to be excellent, although it is noted that a significant proportion of high flows are carried out of channel over a wide floodplain. In high flow events (nominally above ~220 m AHD at the gauge), flow from Macintyre River breaks out into the Morella Watercourse and Whalan Creek systems upstream of the gauge location. The high-flow section of the current rating is strongly influenced by four flow measurements obtained during the 1996 flood, the highest three of which include an estimate of the breakout flows. The current rating should therefore be considered to give the total flow arriving upstream of Boggabilla, rather than the remaining flow in the Macintyre River at the actual gauge location downstream of Boggabilla.

The Boggabilla gauge rating curve (flow versus level) has been updated on numerous occasions and it is understood that the Boggabilla gauge site has physically changed locations on several occasions, including in response to the construction of the Boggabilla Weir.

Appendix F includes a detailed discussion on the Boggabilla stream gauge and the rating curves that have been developed and used over time. This discussion highlights the complexity of assigning an AEP for historical events and it should be noted that this AEP would vary across the Macintyre River floodplain and within the contributing tributaries.

Based on total Macintyre River flows upstream of Boggabilla (i.e. including breakout flows into Whalan Creek and Morella Watercourse), the estimated range of AEP of each historical event is presented in Table 4-1, as is the source of the flood waters for each event.

Table 4-1 Estimated AEP of historical events for Macintyre River flows upstream of Boggabilla

Historical event	Estimated AEP range	Source of flooding	Approximate duration
February 1976	Approximately 1 in 200	Concurrent Dumaresq River, Macintyre Brook and Macintyre River flooding	≈ 6 days
January 1996	Between 1 in 30 and 1 in 50	Concurrent Dumaresq River and Macintyre River flooding	≈ 4 days
January 2011	Between 1 in 60 and 1 in 75	Predominately Dumaresq River flooding	≈ 5 days

4.3 Design event modelling

Design event modelling for the 1% AEP event has been undertaken with full details on the assessment methodology and outcomes provided in Appendix H. The PIR scope requires ARTC to:

- Reassesses the hydrology and flooding impacts of the project, as presented in the EIS, using the greater of, the large design flood as defined in the Border Rivers Valley Floodplain Management Plan (1976 flood event), or the 1% AEP flood

In discussions with DPIE it was agreed that the greater event would be determined using peak flows. Table 4-2 presents the peak flows on each of the southern tributaries for the 1976 calibration event and the 1% AEP event. As can be seen the 1% AEP event is the larger event on each waterway. Therefore, the 1% AEP event has been used to assess impacts in these locations as details in Section 6.

Table 4-2 Comparison of flows on southern tributaries

Location	1976 event flow (m^3/s)	1% AEP event flow (m^3/s)
Strayleaves Creek	44	45
Forest Creek	130	156
Back Creek	103	149
Mobbindry Creek	153	211

For the 1% AEP event, Existing Case mapping has been prepared including:

- Provided in Appendix I:
  - Figure I1 – Existing Case – Verified 2019 levees and 1% AEP Flows – Peak water levels
  - Figure I2 – Existing Case – Verified 2019 levees and 1% AEP Flows – Velocities
  - Figure I3 – Existing Case – Verified 2019 levees and 1% AEP Flows – Duration of inundation
  - Figure I4 – Existing Case – Verified 2019 levees and 1% AEP Flows – Hazard categories
  - Figure I5 – Existing Case – Verified 2019 levees and 1% AEP Flows – Velocity x depth product
- Provided in Appendix J:
  - Figure J1 – Existing Case – BRVFMP levees and 1% AEP flows – Peak water levels
  - Figure J2 – Existing Case – BRVFMP levees and 1% AEP flows – Velocities
  - Figure J3 – Existing Case – BRVFMP levees and 1% AEP flows – Duration of inundation
  - Figure J4 – Existing Case – BRVFMP levees and 1% AEP flows – Hazard categories
  - Figure J5 – Existing Case – BRVFMP levees and 1% AEP flows – Velocity x depth product

5 Developed Case modelling

5.1 Design structures and mitigation measures

The Developed Case incorporates the proposal design (embankment, drainage structures and associated works) into the Existing Case hydraulic model. The proposed drainage structures are summarised in Table 5-1 and presented in Figure 4.

Table 5-1 Flood structure locations and details

Chainage (km)	Waterway	Structure type	No of culvert cells	Diameter/width of culvert or bridge length (m)	Culvert height (m) or soffit level (m AHD)	Culvert length (m)
5.58	Mobbindry Creek	RCP	2	1.05	-	17
5.76		Bridge (BR01)	-	109	243.3	-
6.08		RCP	7	2.10	-	18
6.12		RCP	7	2.10	-	16
6.23		Bridge (BR02)	-	170	242.91	-
6.53		RCP	6	2.10	-	17
6.58		RCP	5	2.10	-	17
8.11	Back Creek	Bridge (BR03)	-	67	238.6	-
15.33		RCBC	10	1.2	1.2	8
15.52		RCBC	10	1.2	1.2	10
15.67		RCP	10	1.2	-	13
15.83		RCP	20	1.2	-	14
15.90		RCP	20	1.2	-	14
15.98		RCP	20	1.2	-	16
16.08		RCP	20	1.2	-	15
16.29	Forest Creek	Bridge (BR04)	-	40	229	-
16.49		RCBC	1	3	2.4	9
16.60		RCP	8	1.2	-	17
16.83		RCP	8	1.2	-	17
20.73	Strayleaves Creek	Bridge (BR05)	-	131	227.1	-
21.35		RCP	3	1.35	-	28
21.97		RCP	3	1.05	-	20
22.27		RCP	3	1.2	-	13
22.86	Whalan Creek	RCP	10	1.2	-	25
23.22		RCP	10	1.2	-	25
23.70		RCP	10	1.2	-	25
23.80		RCP	10	1.2	-	25
24.03		RCP	8	1.05	-	26
24.2		RCP	5	0.9	-	28
24.62		RCBC	35	1.2	0.9	27
24.71		RCBC	35	1.2	0.9	26

Chainage (km)	Waterway	Structure type	No of culvert cells	Diameter/width of culvert or bridge length (m)	Culvert height (m) or soffit level (m AHD)	Culvert length (m)
24.85		RCBC	35	1.2	0.9	30
25.34		Bridge (BR06)	-	131	227.77	-
25.8		Bridge (BR07)	-	104	229.9	-
26.09		Bridge (BR08)	-	156	230.4	-
27.06		RCP	10	1.2	-	15
27.56		Bridge (BR09)	-	116	227.7	-
28.03		Bridge (BR10)	-	117	227.7	-
30.35	Macintyre River	Bridge (BR11)	-	1748	230	-
31.26		RCP	10	1.8	-	32
31.32		RCP	10	1.8	-	30
31.52		Bridge (BR12)	-	144	227.46	-
31.87		RCP	15	0.9	-	14
31.97		RCP	15	0.9	-	15
32.55		Bridge (BR13)	-	521	225.71	-

Key mitigation measures that have been included in the proposal design include:

- Bridge and culvert structures being located to maintain existing flow paths and flood flow distributions
- Bridge and culvert structures have been located and sized to avoid minimise in peak water levels, velocities and/or duration of inundation, and changes flow distribution in accordance with the flood impact objectives
- Progressive refinement of bridge extents and culvert banks (number of barrels and dimensions) as the proposal design evolved. This refinement process has considered engineering requirements as well as progressive feedback from stakeholders to achieve acceptable outcomes that address the flood impact objectives.
- Scour and erosion protection measures have been incorporated into the design in areas determined to be at risk, such as around culvert headwalls, drainage discharge pathways and bridge abutments

For the hydraulic modelling the adjacent B2G proposal alignment has been included in the Developed Case to quantify cumulative impacts.

5.2 Modelled scenarios

As per the Existing Case, the Developed Case model was run for the following scenarios:

- Verified 2019 levees and validated 1976 flows
- BRVFMP levees and factored flows
- BRVFMP levees and validated 1976 flows
- Verified 2019 levees and 1% AEP flows
- BRVFMP levees and 1% AEP flows

The results of each Developed Case scenario have been compared against the related Existing Case to determine the impacts of the proposal under each scenario. Developed Case mapping has been prepared including:

- Provided in Appendix C:
  - Figure C6 – Developed Case – Verified 2019 levees and validated 1976 flows – Change in peak water levels
  - Figure C7 – Developed Case – Verified 2019 levees and validated 1976 flows – Percentage change in velocities
  - Figure C8 – Developed Case – Verified 2019 levees and validated 1976 flows – Percentage change in duration of inundation
  - Figure C9 – Developed Case – Verified 2019 levees and validated 1976 flows – Hazard Categories
  - Figure C10 – Developed Case – Verified 2019 levees and validated 1976 flows – Percentage change in velocity x depth product
- Provided in Appendix D:
  - Figure D6 – Developed Case – BRVFMP levees and factored flows – Change in peak water levels
  - Figure D7 – Developed Case – BRVFMP levees and factored flows – Percentage change in velocities
  - Figure D8 – Developed Case – BRVFMP levees and factored flows – Percentage change in duration of inundation
  - Figure D9 – Developed Case – BRVFMP levees and factored flows – Hazard categories
  - Figure D10 – Developed Case – BRVFMP levees and factored flows – Percentage change in velocity x depth product
- Provided in Appendix E:
  - Figure E6 – Developed Case – BRVFMP levees and validated 1976 Flows – Change in peak water levels
  - Figure E7 – Developed Case – BRVFMP levees and validated 1976 Flows – Percentage change in velocities
  - Figure E8 – Developed Case – BRVFMP levees and validated 1976 Flows – Percentage change in duration of inundation
  - Figure E9 – Developed Case – BRVFMP levees and validated 1976 Flows – Hazard categories
  - Figure E10 – Developed Case – BRVFMP levees and validated 1976 Flows – Percentage change in velocity x depth product
- Provided in Appendix I:
  - Figure I6 – Developed Case – Verified 2019 levees and 1% AEP Flows – Change in peak water levels
  - Figure I7 – Developed Case – Verified 2019 levees and 1% AEP Flows – Percentage change in velocities
  - Figure I8 – Developed Case – Verified 2019 levees and 1% AEP Flows – Percentage change in duration of inundation
  - Figure I9 – Developed Case – Verified 2019 levees and 1% AEP Flows – Hazard categories
  - Figure I10 – Developed Case – Verified 2019 levees and 1% AEP Flows – Percentage change in velocity x depth product

- Provided in Appendix J:
  - Figure J6 – Developed Case – BRVFMP levees and 1% AEP Flows – Change in peak water levels
  - Figure J7 – Developed Case – BRVFMP levees and 1% AEP Flows – Percentage change in velocities
  - Figure J8 – Developed Case – BRVFMP levees and 1% AEP Flows – Percentage change in duration of inundation
  - Figure J9 – Developed Case – BRVFMP levees and 1% AEP Flows – Hazard categories
  - Figure J10 – Developed Case – BRVFMP levees and 1% AEP Flows – Percentage change in velocity x depth product

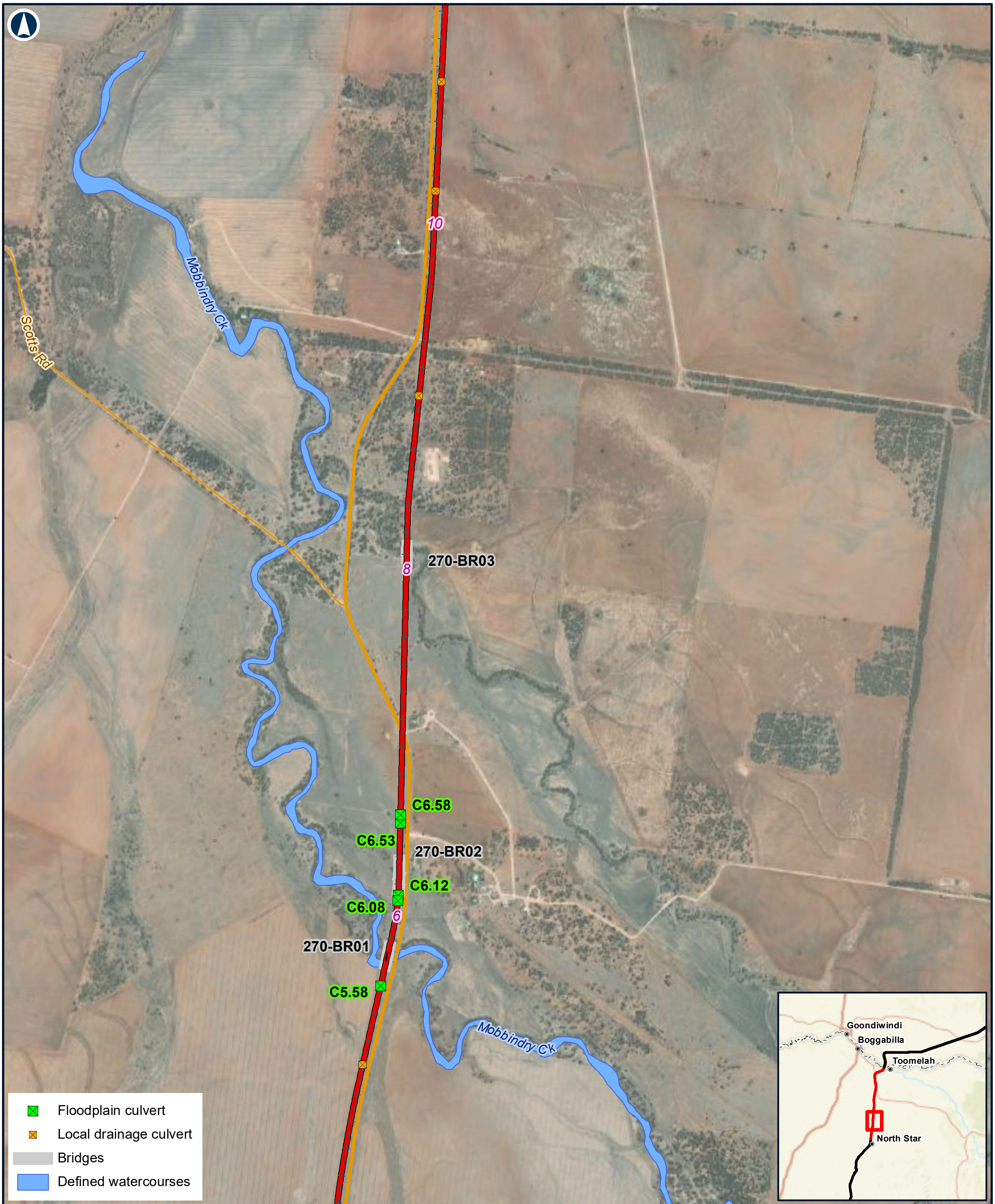


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Figure 4a: Floodplain and drainage structures

NORTH STAR TO NSW/QLD BORDER

1 km

Coordinate System: GDA 1994 MGA Zone 56

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LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

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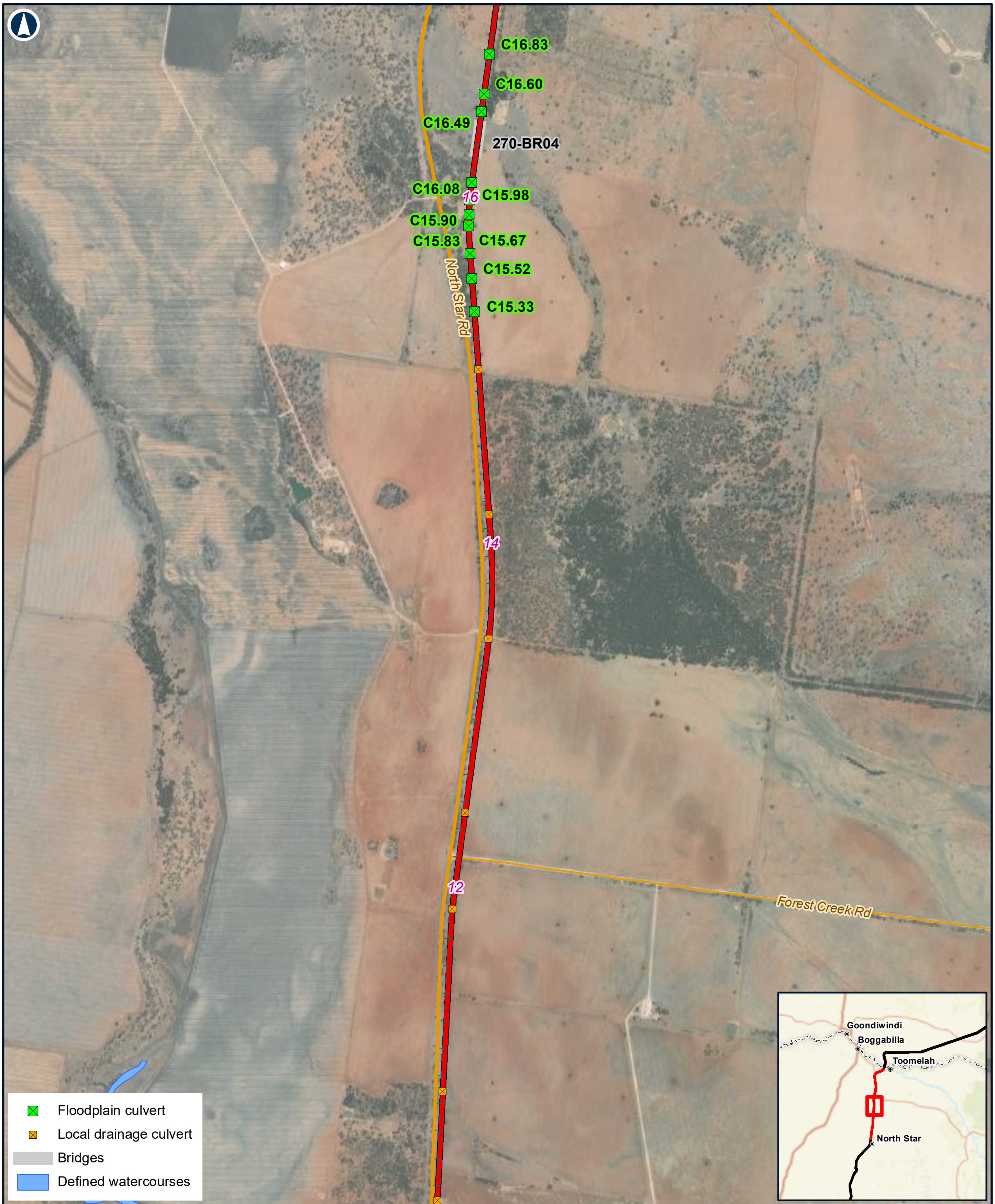

Figure 4b: Floodplain and drainage structures

NORTH STAR TO NSW/QLD BORDER

1 km

Coordinate System: GDA 1994 MGA Zone 56

Date: 12/03/2021 Paper: A4
Author: FFJV GIS Scale: 1:30,000

LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

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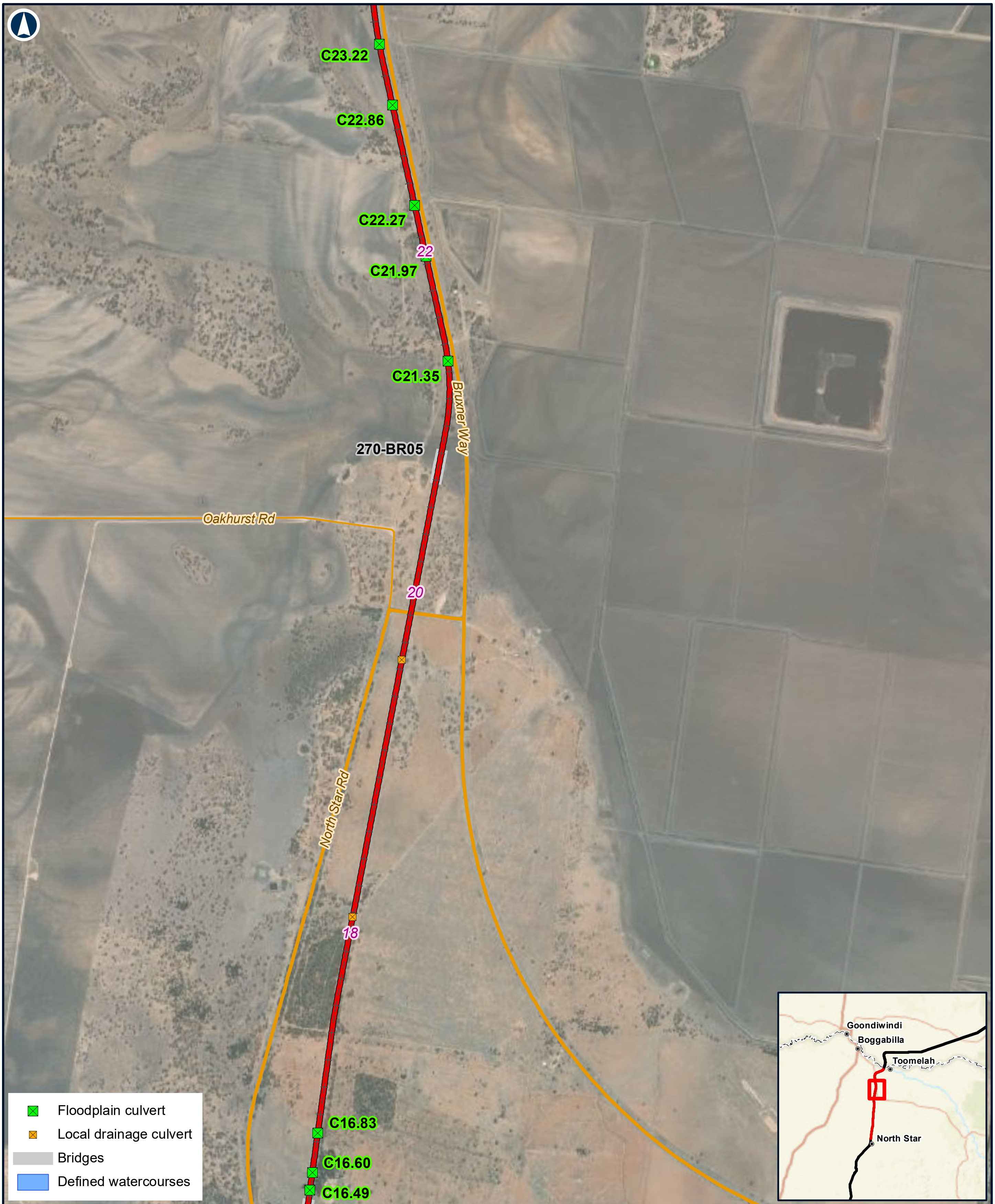

Figure 4c: Floodplain and drainage structures

NORTH STAR TO NSW/QLD BORDER

1 km

Coordinate System: GDA 1994 MGA Zone 56

Date: 12/03/2021 Paper: A4
Author: FFJV GIS Scale: 1:30,000

LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

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Figure 4d: Floodplain and drainage structures

NORTH STAR TO NSW/QLD BORDER

1 km

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LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

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Figure 4e: Floodplain and drainage structures

NORTH STAR TO NSW/QLD BORDER

1 km

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LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

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6 Impact assessment

The following sections outline how the proposal design performs against the Floodplain Management Objectives (FMOs) for N2NS Phase 1 project and the proposed floodplain wide and project specific FMOs set out in Section 2.3 for each of the modelled scenarios. Those locations where the impact exceeds the N2NS FMOs are highlighted in bold. Where an impact exceeds both the N2NS FMOs and the proposed FMOs, the values have been highlighted in orange.

The impact assessment has been against the 1976 flow scenarios for the main Macintyre River floodplain and the 1% AEP event for the southern tributaries where the 1% AEP flows are larger than the 1976 flows.

As previously discussed, that the N2NS FMOs were used to consider impacts under 1% AEP event with many of the N2NS creek crossings being over smaller waterways. For NS2B, which crosses a large major floodplain, the 1976 flows are being used (in accordance with the BRVFMP and as requested by DPIE), with the AEP of the 1976 event being estimated at 1 in 200 AEP (refer Appendix H for full details). This should be considered when reviewing the identified impacts for the NS2B proposal in relation to the N2NS FMOs.

6.1 Increase in flood levels

The FMOs have varying limits on increases in peak water levels for a range of locations and/or land uses as shown in Table 6-1. Figures C6, D6 and E6 present the change in peak water levels for each of the three 1976 modelled scenarios. Figures I6 and J6 present the change in peak water levels for the 1% AEP modelled scenarios.

Table 6-1 Increase in flood level FMOs

Parameter	Location or Land Use	N2NS QDLs – for up to and including 1% AEP event	NS2B project specific FMO targets – for events greater than 1% AEP
Afflux i.e. increase in flood level resulting from implementation of CSSI	Habitable floors	10mm increase	50mm increase
	Non-habitable floors	20mm increase	100mm increase
	Other urban and recreational	100mm increase	200mm increase
	Agriculture	200mm increase	400mm increase
	Forest and unimproved grazing land	300mm increase	500mm increase
	Highways and sealed roads >80km/hr	No increase in depth where aquaplaning risk exists and remains unmitigated. Otherwise 50mm increase	100mm increase If not trafficable then the increase should be on a case by case assessment with no change to the network trafficability of that road - aligns with duration approach
	Unsealed roads and sealed roads <80km/hr	100mm increase	200mm increase If not trafficable then the increase should be on a case by case assessment with no change to the network trafficability of that road - aligns with duration approach

6.1.1 Impact at FSRs

Table 6-2 summarises flood level increases at impacted flood sensitive receptors (FSRs) for the 1976 flows. Flood sensitive receptors are identified in Figure 5 and are also shown on all the impact maps. It is noted that floor levels survey has not been obtained for these receptors. The depths are based on the LiDAR survey of ground level at the receptor. Therefore, the receptors may not be impacted above floor level and the increase noted is conservative as it excludes any freeboard to structures due to mounds, slabs or stumps etc.

Table 6-2 Increase in flood levels at FSRs under 1976 flow scenario

Flood sensitive receptor number	Description	Verified 2019 levees and validated 1976 flows		BRVFMP levees and validated 1976 flows		BRVFMP levees and factored flows		FMO Target N2NS/ Proposed (mm)
		Existing Depth (m)	Increase in flood levels (mm)	Existing Depth (m)	Increase in flood levels (mm)	Existing Depth (m)	Increase in flood levels (mm)	
1	Sheds	0.54	+150	0.51	+146	0.52	+157	20/100
3	House	0.60	+3	0.56	+7	0.70	**+13**	10/50
8	House	0.52	**+11**	0.58	**+22**	0.63	**+48**	10/50
9	Sheds	0.74	+11	0.82	**+21**	0.99	**+48**	20/100
12	House	0.13	+68	0.60	+252	0.86	+453	10/50
32	Pump Shed	0.57	+818	0.57	+857	0.57	+1310	20/100
41	Unsealed landing strip	0.26	+5	0.32	+13	0.49	+29	100
73	House	1.68	+1	1.97	**+12**	2.00	**+25**	10/50
74	Shed	0.78	+1	1.08	+12	1.11	**+26**	20/100
75	Shed	1.72	+1	1.84	+12	1.85	**+25**	20/100
99	Shed	0.31	+2	0.82	+15	0.98	**+32**	20/100
100	House	0.23	+2	0.70	**+15**	0.78	**+31**	10/50
101	Shed	0.11	+3	0.39	+14	0.38	**+30**	20/100
149	Pump	7.70	+14	7.68	+15	5.50	**+27**	20/100

Table notes:

+150 – Impact exceeds both FMOs **+11** – Impact exceeds N2NS FMOs

Table 6-2 presents impacts at FSRs that experience greater than 10mm increase in peak water levels under any of the three 1976 modelled scenarios. There are no FSRs impacted on the southern tributaries under the 1% AEP event or the 1976 flows event. The following summary discusses the impacts and their acceptability status:

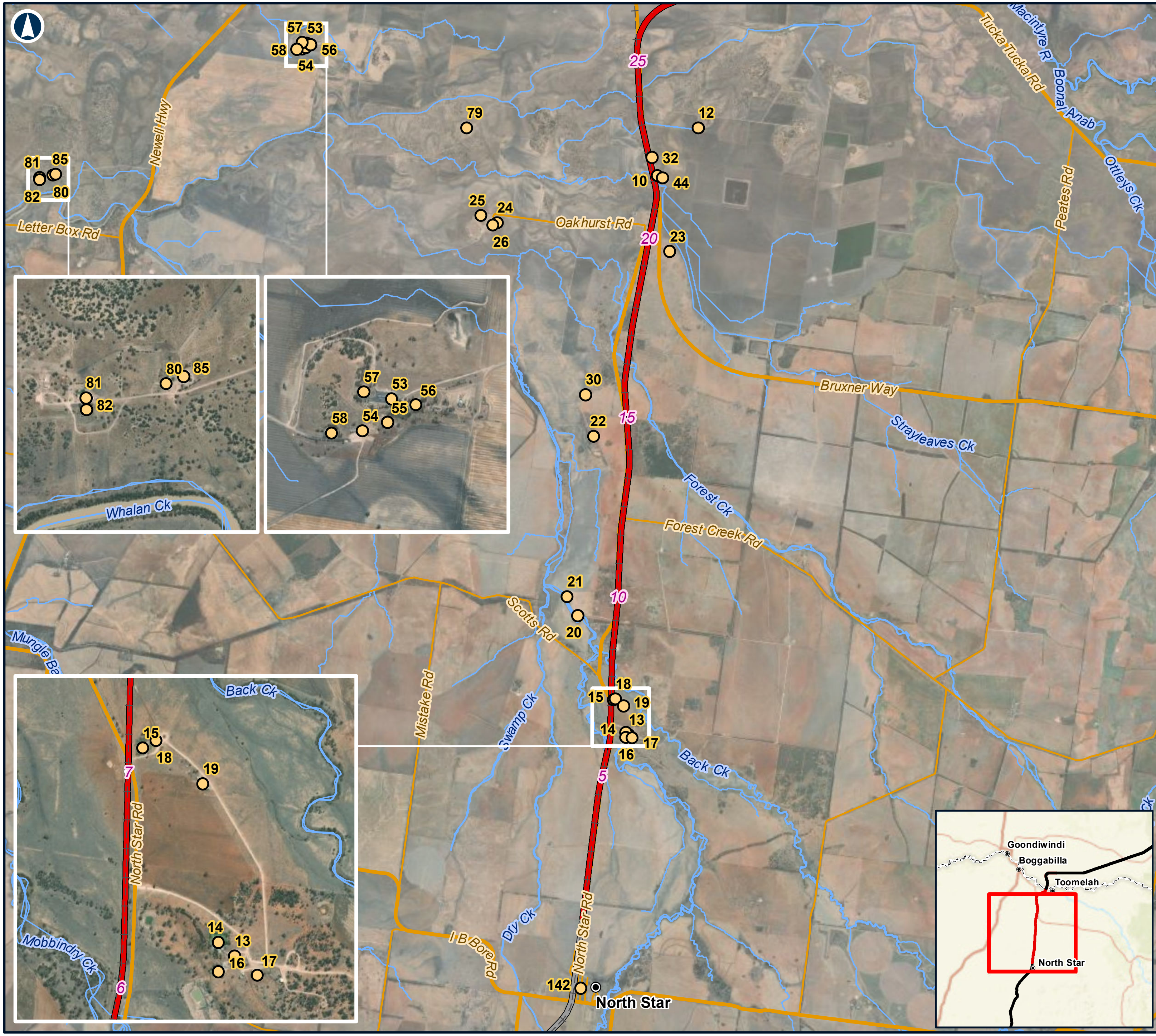
- FSR 1 is a shed located very close to the proposal alignment in Queensland and will be assessed through the Queensland EIS process
- FSR 3 is a house located approximately 2.4 km downstream of the proposed alignment with a minor increase in flood levels predicted in the BRVFMP case only (+13mm). Existing flood depths are 0.6m. Survey of floor levels of these structures will need to be obtained, with the landholder's approval, to determine the impact of this small increase.
- FSR 8 (house) and FSR 9 (shed) are approximately 3.6 km downstream of the proposal alignment and in all three cases have a minor increase in flood levels over existing flood depths of 0.5m to 1m. Survey of floor levels of these structures will need to be obtained, with the landholder's approval, to determine the impact of this small increase.
- FSR 12 is a house already protected by an existing levee. This levee is predicted to overtop in the Existing Case and opportunity exists to raise the levee around the house improving existing flood

immunity and protecting against the predicted increases in flood levels. Discussions with landholders are already underway as detailed in Section 8.

- FSR 32 is an irrigation pump located in a shed adjacent to and existing levee bank. Survey levels of the infrastructure including power supply would need to be obtained to confirm options for adjustment of this structure and equipment. Discussions with landholders are already underway as detailed in Section 8.
- FSR 41 is the unsealed landing strip outside Goondiwindi and increases in level under all modelled scenarios are within the FMO limit
- The remaining FSRs (73, 74, 75, 99, 100, 101 and 149) all experience minor flood level increases, and many have significant existing flood depths. Survey of floor levels of these structures will need to be obtained, with the landholders' approval, to determine the impact of these small increases.

It should be noted that many of these impacts are not significantly higher than the N2NS FMOs, and most are below the Proposed FMOs.

Figure 5a-c Flood Sensitive Receptors



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NORTH STAR TO NSW/QLD BORDER

Figure 5a:
Location of flood sensitive receptors

LEGEND

- 100 Flood sensitive receptor
- 5 Chainage (km)
- Localities
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Watercourses

5km

Coordinate System: GDA 1994 MGA Zone 56

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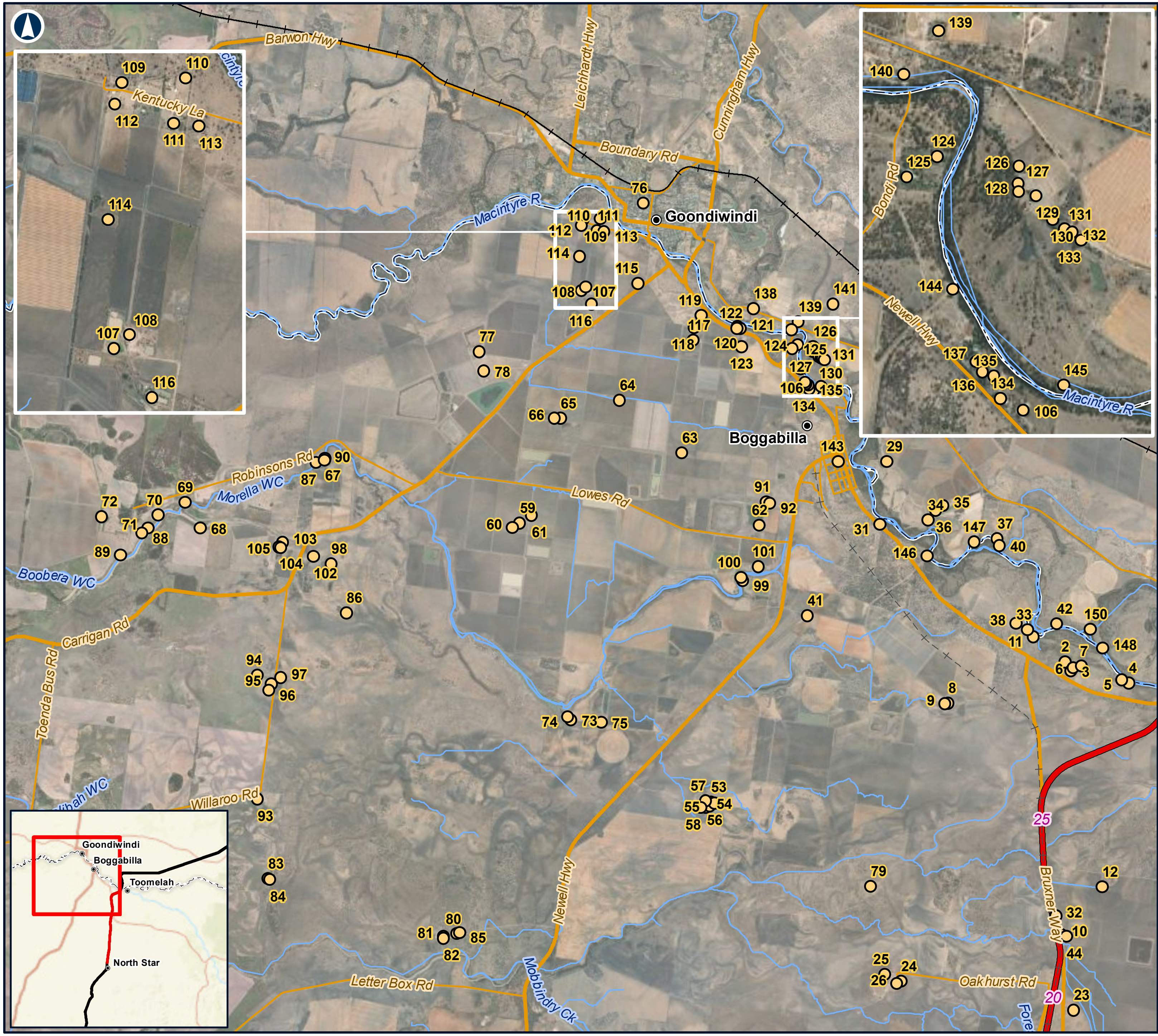

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NORTH STAR TO NSW/QLD BORDER

Figure 5b:
Location of flood sensitive receptors

LEGEND

- 100 Flood sensitive receptor
- 5 Chainage (km)
- Localities
- North Star to NSW/QLD border alignment
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Watercourses
- NSW/QLD border

5km

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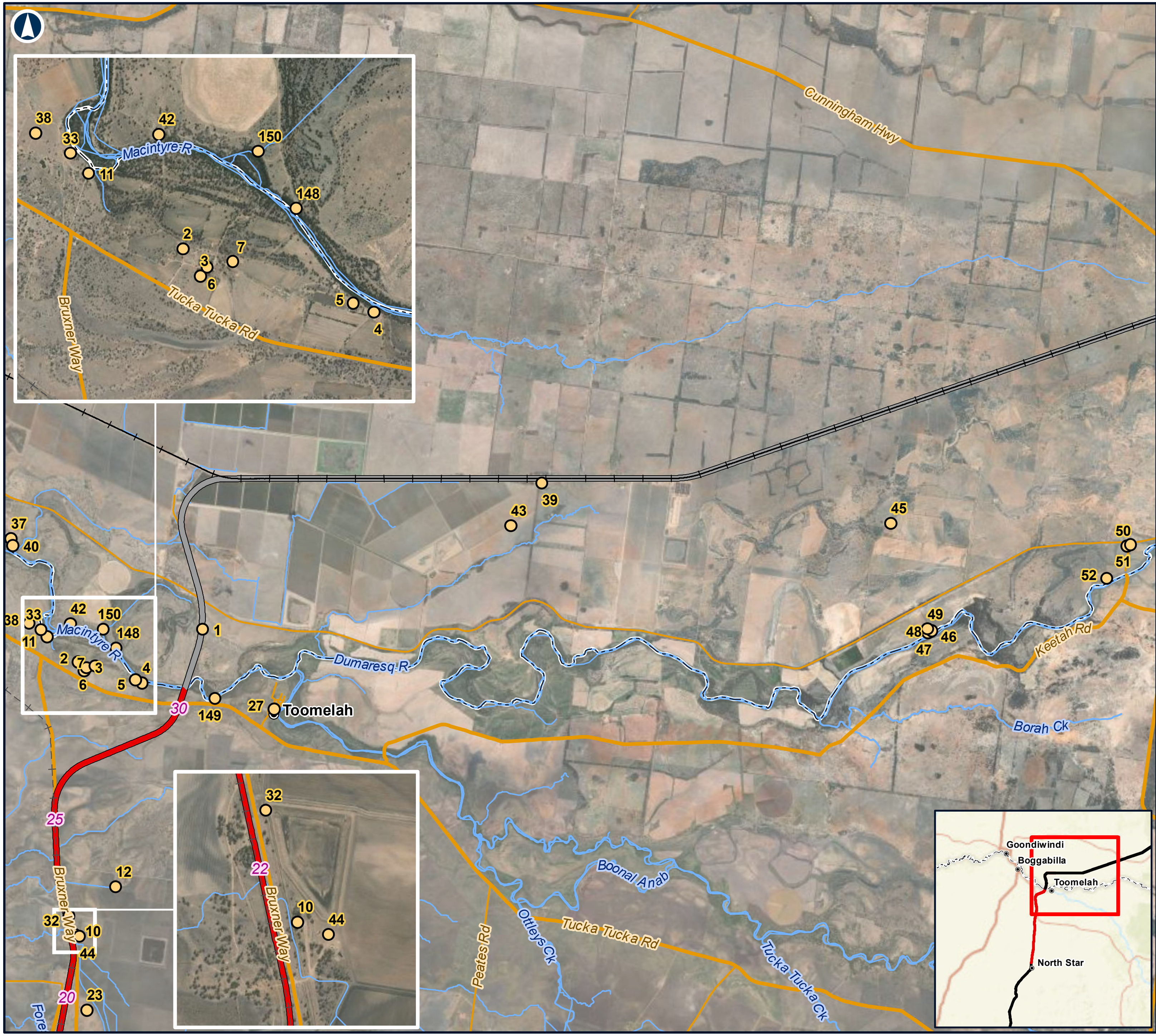

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NORTH STAR TO NSW/QLD BORDER

Figure 5c:
Location of flood sensitive receptors

LEGEND

- 100 Flood sensitive receptor
- 5 Chainage (km)
- Localities
- North Star to NSW/QLD border alignment
- Adjoining alignments
- Existing rail (operational)
- Existing rail (non-operational)
- Major roads
- Minor roads
- Watercourses
- NSW/QLD border

5km

Coordinate System: GDA 1994 MGA Zone 56

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6.1.2 Impact on roads

The increase in peak water levels on roads on the floodplain has been assessed and is summarised in Table 6-3 for the three 1976 modelled scenarios and Table 6-4 for the two modelled 1% AEP event scenarios on the southern tributaries. Figure 6 presents the road inspection locations referred to in Table 6-3 and Table 6-4.

It is noted that most of the roads on the floodplain have a low level of flood immunity and as such are subject to significant depths of inundation during moderate to large flood events.

Table 6-3 Increase in flood levels at road inspection locations – 1976 flow scenarios

Road Inspection ID	Verified 2019 levees and validated 1976 flows		BRVFMP levees and validated 1976 flows		BRVFMP levees and factored flows		Estimated N2NS QDLs/ NS2B project specific FMO targets (mm)
	Existing Depth (m)	Increase in flood levels (mm)	Existing Depth (m)	Increase in flood levels (mm)	Existing Depth (m)	Increase in flood levels (mm)	
Access Rd 1	0.94	0	0.98	0	0.21	-40	100/200
Access Rd 2	1.12	+420	1.27	+530	1.49	+800	100/200
Access Rd 3	0.12	+90	0.19	**+120**	Dry	Dry	100/200
Access Rd 4	0.59	+530	0.83	+640	0.95	+960	100/200
Access Rd 5	1.07	-10	1.09	0	1.31	+10	100/200
Access Rd 6	0.94	+10	0.93	+40	1.02	+100	100/200
Access Rd 7	1.22	+20	1.19	+50	1.29	**+140**	100/200
Access Rd 8	0.53	0	0.51	0	0.58	0	100/200
Access Rd 9	0.55	0	0.52	0	0.63	0	100/200
Access Rd 10	0.84	0	0.81	+10	0.96	+10	100/200
Access Rd 11	0.96	0	0.93	+10	1.12	+10	100/200
Access Rd 12	0.61	0	0.58	0	0.68	+10	100/200
Access Rd 13	0.49	0	0.47	0	0.57	+10	100/200
Access Rd 14	0.43	+10	0.79	+20	0.96	+40	100/200
Access Rd 15	1.14	0	1.01	+10	1.26	+20	100/200
Access Rd 16	1.14	0	1.06	+10	1.08	+10	100/200
Access Rd 17	1.24	0	1.49	+10	1.42	+30	100/200
Access Rd 19	0.66	0	0.72	0	0.72	0	100/200
Bruxner Wy 1	Dry	Dry	Dry	Dry	Dry	Dry	50/100
Bruxner Wy 2	Dry	Dry	Dry	Dry	Dry	Dry	50/100
Bruxner Wy 3	0.44	+610	0.50	+540	Dry	Dry	50/100
Bruxner Wy 4	1.02	+500	0.98	+620	1.15	+950	50/100
Bruxner Wy 5 Developed	1.31	+390	1.29	+450	1.43	+750	50/100
Bruxner Wy 5 Existing	1.31	+310	1.28	+360	1.54	+640	50/100
Bruxner Wy 6	1.21	+140	1.19	+170	1.33	+220	50/100
Bruxner Wy 7	0.54	+20	0.51	+30	0.56	**+70**	50/100
Bruxner Wy 8	1.54	+10	1.51	+20	1.54	+40	50/100
Bruxner Wy 9	1.23	+10	1.19	+10	1.21	+30	50/100
Bruxner Wy 10	1.20	+10	1.17	+10	1.24	+20	50/100

Road Inspection ID	Verified 2019 levees and validated 1976 flows		BRVFMP levees and validated 1976 flows		BRVFMP levees and factored flows		Estimated N2NS QDLs/ NS2B project specific FMO targets (mm)
	Existing Depth (m)	Increase in flood levels (mm)	Existing Depth (m)	Increase in flood levels (mm)	Existing Depth (m)	Increase in flood levels (mm)	
Bruxner Wy 11	0.19	0	0.08	0	0.05	0	50/100
Cemetry Rd	0.67	0	0.98	0	0.72	0	50/100
Gunsynd Wy	0.97	0	0.86	0	0.90	0	50/100
Kentucky Ln	0.58	0	0.64	0	0.58	0	50/100
Mungindi Goondiwindi Bdg Rd	0.59	0	0.59	0	0.13	0	50/100
N Star 1	0.79	-10	0.77	0	Dry	Dry	50/100
N Star 2	0.87	0	0.87	0	Dry	Dry	50/100
N Star 3	0.58	+10	0.53	+10	Dry	Dry	50/100
N Star 4	0.40	0	0.47	-10	Dry	Dry	50/100
Newell Hwy 1	0.79	0	1.22	0	1.36	+10	50/100
Newell Hwy 2	1.42	0	1.65	+10	1.56	+30	50/100
Newell Hwy 3	0.40	0	0.20	0	0.26	0	50/100
Newell Hwy 4	0.54	0	0.76	0	0.79	0	50/100
Newell Hwy 5	0.50	0	0.42	0	0.40	0	50/100
Oakhurst Rd 1	0.29	0	0.48	-10	0.27	**+80**	50/100
Oakhurst Rd 2	Dry	Dry	0.24	-10	0.12	0	50/100
Oakhurst Rd 3	0.40	0	0.79	0	0.75	-90	50/100
Scotts Rd	0.13	0	0.12	0	Dry	Dry	50/100
Tucka Tucka Rd 1	0.53	+10	0.51	+10	0.48	+10	50/100
Tucka Tucka Rd 2	2.51	+20	2.60	+20	2.58	+30	50/100
Tucka Tucka Rd 3	0.71	0	0.83	+10	0.41	+10	50/100

Table notes:

+150 – Impact exceeds both FMOs **+11** – Impact exceeds N2NS FMOs

Table 6-4 Increase in flood levels at road inspection locations – 1% AEP flows

Road Inspection ID	Verified 2019 levees and 1% AEP flows		BRVFMP levees and 1% AEP flows		Estimated N2NS QDLs/ NS2B project specific FMO targets (mm)
	Existing Depth (m)	Increase in flood levels (mm)	Existing Depth (m)	Increase in flood levels (mm)	
Access Rd 3	0.20	**+190**	0.29	**+208**	100/200
Bruxner Wy 1	Dry	Dry	Dry	Dry	100/200
N Star 1	0.74	+45	0.71	+53	100/200
N Star 2	0.99	-2	0.99	-2	100/200
N Star 3	0.72	+3	0.70	+3	100/200
Scotts Rd	0.23	0	0.22	0	100/200

Table notes:

+150 – Impact exceeds both FMOs **+11** – Impact exceeds N2NS FMOs

Most existing roads are unaffected by the proposal alignment in all modelled scenarios. Most road locations are considered not trafficable in the existing case based on the existing depth alone (greater than 250mm). Roads inspection locations with an existing depth less than 250mm are not impacted by change in water levels, except for Access Rd 3 in the 1% AEP flood event. This impact will be discussed with the affected landholder.

As evident in Figures C6, D6 and E6 there is an increase in peak water levels under the 1976 flow scenarios between Ch 20 km and Ch 25 km where flood waters are constrained by the proximity of the proposal alignment to existing levees.

This increase in peak flood levels affects a number of roads including:

- Bruxner Way
- Access Roads 2 and 4, and
- Oakhurst Road (for BRVFMP levees and factored flows only)

In the affected locations, in particular on the Bruxner Way and Access Roads 2 and 4, the roads are already subject to significant inundation depths (up to and over one metre) in the Existing Case. This depth of inundation, and the extent over which it occurs, means that these roads are not able to be used for egress during flood events and this closure would occur over a significant period. Therefore, this additional depth of water would not impact upon the ability to use these roads as they are already non-accessible.

The associated impact on duration of inundation and velocities is discussed in the following sections.

6.1.3 Impacts on land

As is the case for the roads, the land upstream of the proposal alignment between Ch 20 km and 25 km is affected by the close proximity of the alignment to existing levees. Figures C6, D6 and E6 present the increase in peak water levels in these areas for the three 1976 modelled scenarios.

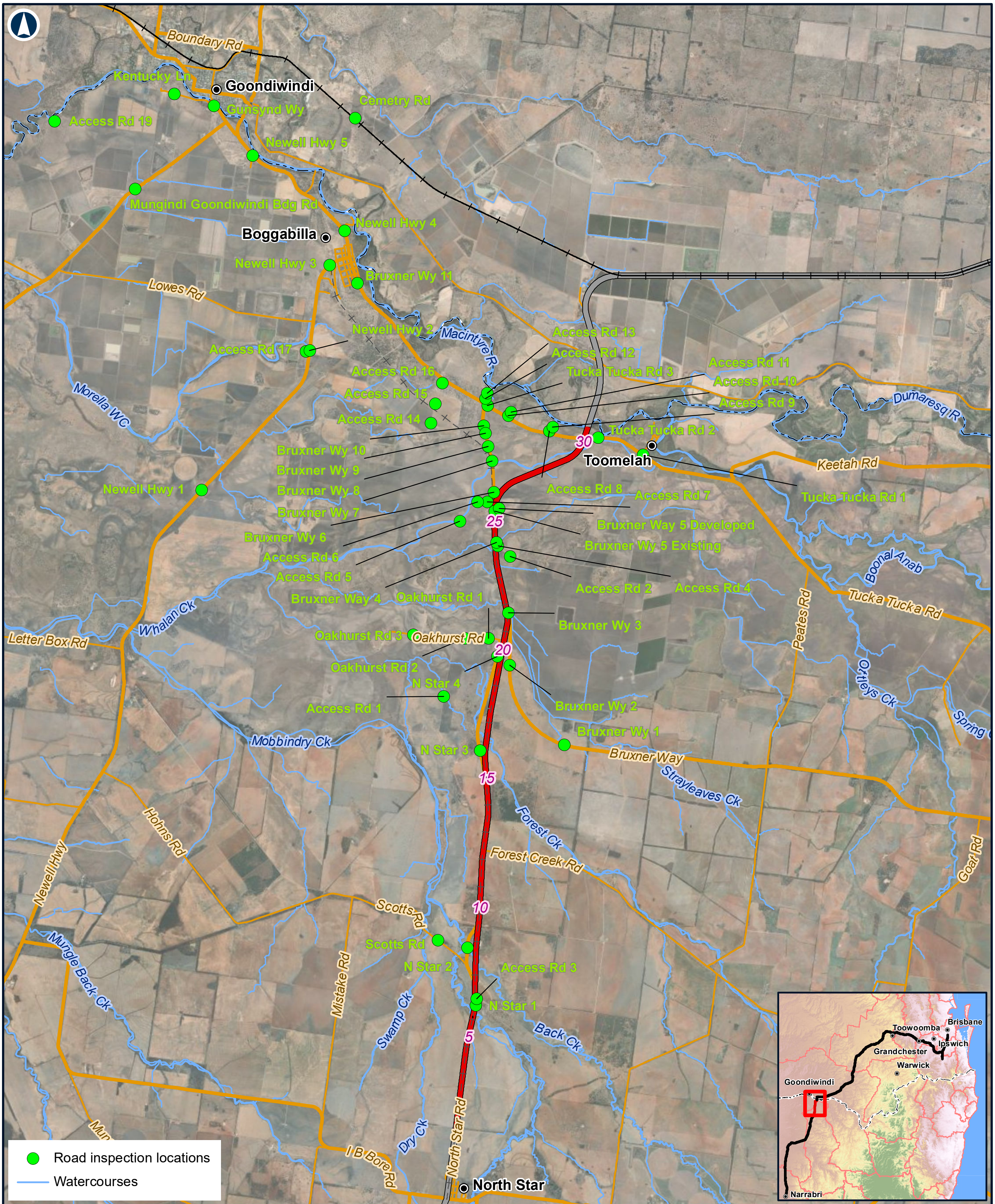
A significant portion of the land is protected by levee banks and is used for agricultural purposes. It is believed that land to the north of the levee banks is used for grazing purposes. This gives an FMO target of 200 mm (N2NS) or 400mm (proposed FMOs).

The area of land impacted by an increase in peak water level for the three cases above 200 mm and 400 mm is presented in Table 6-5. This includes the area between the alignment and the farm levees and Bruxner Way.

Table 6-5 Impacts on land above 200 mm and 400 mm

Location	Verified 2019 levees and validated 1976 flows		BRVFMP levees and validated 1976 flows		BRVFMP levees and factored flows	
	Area above 200mm Afflux (ha)	Area above 400mm Afflux (ha)	Area above 200mm Afflux (ha)	Area above 400mm Afflux (ha)	Area above 200mm Afflux (ha)	Area above 400mm Afflux (ha)
Chainage 20 km to chainage 25 km	530.9	241.7	622.2	281	1190	696
Chainage 31 km to 32 km	7.3	0.6	5.8	0.01	14.3	0.7

Discussions are in progress with relevant stakeholders to determine what these impacts mean for each area and land use.



Source: Esri, Maxar, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Figure 6: Road inspection locations

NORTH STAR TO NSW/QLD BORDER

5km

Coordinate System: GDA 1994 MGA Zone 56

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Date: 12/03/2021 Paper: A4
Author: FFJV GIS Scale: 1:200,000

LEGEND

- 5 Chainage (km)
- Existing rail (operational)
- Existing rail (non-operational)
- North Star to NSW/QLD border alignment
- Adjoining alignments
- NSW/QLD border
- Major roads
- Minor roads

ARTC InlandRail

The Australian Government is delivering Inland Rail through the Australian Rail Track Corporation, in partnership with the private sector.

Map by: DTH Z:\GIS\GIS_270_NS2B\Tasks\270-IHY-202102151444_Hydrology_and_Flooding_PIR\270-IHY-202102151444_ARTC_Fig6_RoadInspect_A4P_v1.mxd Date: 14/03/2021 12:17

6.2 Increase in flood velocities

The FMOs have varying limits on increases in flood velocities that relate to sealed/unsealed surfaces and existing velocities as shown in Table 6-6. Figures C2, D2, E2, I2 and J2 present the existing case velocities across the floodplain for the modelled scenarios. Figures C6, D6 and E6 present the percentage change in velocities for each of the three 1976 modelled scenarios. Figures I6 and J6 present the percentage change in velocities for each of the two 1% AEP modelled scenarios.

Table 6-6 Increase in flood velocities FMOs

Parameter	Location or Land Use	N2NS QDLs – for up to and including 1% AEP event	NS2B project specific FMO targets – for events larger than 1% AEP
Scour/Erosion Potential i.e increase in flood velocity resulting from implementation of CSSI.	Ground surfaces that have been sealed or otherwise protected against erosion. This includes roads, most urban, commercial, industrial, recreational and forested land	20% increase in velocity where existing velocity already exceeds 1m/s	No velocities to exceed 1.0m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. 20% increase in velocity where existing velocity already exceeds 1.0m/s
	Other areas including watercourses, agricultural land, unimproved grazing land and other unsealed or unprotected areas	No velocities to exceed 0.5m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. In addition, the increase in velocity is limited to 20% where the existing velocity already exceeds 0.5m/s	No velocities to exceed 0.5m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. In addition, the increase in velocity is limited to 20% where the existing velocity already exceeds 0.5m/s

6.2.1 Impacts on roads

The FMO criteria specify a limit of 20% increase in velocities on sealed surfaces, such as roads, where the existing velocity already exceeds 1m/s. It is understood that where velocities remain below 1m/s then this is an acceptable outcome.

Review of Table 6-7 and Table 6-8 shows that only under the BRVFMP levees and factored flows scenario does the Developed Case velocity exceed 1m/s in two locations and the percentage increase is greater than 20%. This occurs at Bruxner Way 5 (Existing) and Bruxner Way 6. In detailed design a site-specific assessment will be conducted by an experienced geotechnical or scour/erosion specialist for these locations.

The road inspection locations have been taken as representative locations of potential changes on the roads that are located on the Macintyre River floodplain including the southern tributaries.

Table 6-7 Increase in velocities at road inspection locations – 1976 flow scenarios

Road Inspection ID	Verified 2019 levees and validated 1976 flows		BRVFMP levees and validated 1976 flows		BRVFMP levees and factored flows	
	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)
Access Rd 1	0.23	0.23 (-0.1)	0.23	0.23 (0.2)	0.03	0.05 (52.2)
Access Rd 2	0.26	0.18 (-31.6)	0.25	0.16 (-36.4)	0.40	0.22 (-44.4)
Access Rd 3	0.09	0.13 (40.0)	0.15	0.14 (-3.8)	Dry	Dry
Access Rd 4	0.25	0.17 (-30.3)	0.24	0.20 (-17.4)	0.43	0.27 (-37.8)

Road Inspection ID	Verified 2019 levees and validated 1976 flows		BRVFMP levees and validated 1976 flows		BRVFMP levees and factored flows	
	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)
Access Rd 5	0.44	0.44 (0.2)	0.42	0.44 (3.7)	0.60	0.59 (-1.2)
Access Rd 6	0.27	0.28 (2.6)	0.26	0.27 (5.4)	0.36	0.43 (20.6)
Access Rd 7	0.34	0.33 (-4.1)	0.34	0.33 (-2.4)	0.43	0.50 (15.2)
Access Rd 8	0.30	0.30 (-0.3)	0.30	0.30 (0.0)	0.44	0.44 (-0.2)
Access Rd 9	0.31	0.31 (-0.1)	0.31	0.31 (0.0)	0.47	0.47 (-0.6)
Access Rd 10	0.18	0.18 (0.0)	0.19	0.19 (0.0)	0.28	0.28 (-0.3)
Access Rd 11	0.19	0.19 (0.3)	0.19	0.19 (0.8)	0.27	0.27 (0.8)
Access Rd 12	0.28	0.28 (0.2)	0.28	0.28 (0.4)	0.38	0.38 (1.0)
Access Rd 13	0.26	0.26 (0.0)	0.25	0.25 (0.2)	0.36	0.36 (0.3)
Access Rd 14	0.39	0.39 (0.5)	0.31	0.31 (1.6)	0.39	0.41 (4.2)
Access Rd 15	0.17	0.17 (0.4)	0.21	0.21 (1.0)	0.25	0.25 (1.8)
Access Rd 16	0.23	0.23 (0.2)	0.22	0.22 (0.7)	0.33	0.33 (1.3)
Access Rd 17	0.23	0.23 (0.1)	0.22	0.22 (1.2)	0.28	0.28 (0.3)
Access Rd 19	0.28	0.28 (0.0)	0.28	0.28 (0.0)	0.38	0.38 (0.0)
Bruxner Wy 1	Dry	Dry	Dry	Dry	Dry	Dry
Bruxner Wy 2	Dry	Dry	Dry	Dry	Dry	Dry
Bruxner Wy 3	0.19	0.18 (-2.8)	0.15	0.29 (93.3)	Dry	Dry
Bruxner Wy 4	0.25	0.20 (-19.3)	0.30	0.22 (-25.5)	0.46	0.37 (-19.8)
Bruxner Wy 5 Developed	0.33	0.40 (21.3)	0.32	0.39 (23.1)	0.48	0.56 (16.8)
Bruxner Wy 5 Existing	0.46	0.86 (86.9)	0.47	0.90 (90.9)	0.60	1.33 (120.9)
Bruxner Wy 6	0.34	0.79 (132.3)	0.34	0.80 (136.2)	0.49	1.02 (108.3)
Bruxner Wy 7	0.14	0.08 (-43.5)	0.08	0.08 (-2.8)	0.06	0.16 (159.6)
Bruxner Wy 8	0.43	0.43 (0.8)	0.44	0.45 (1.2)	0.59	0.60 (1.4)
Bruxner Wy 9	0.38	0.38 (0.5)	0.39	0.39 (0.3)	0.52	0.52 (0.8)
Bruxner Wy 10	0.45	0.45 (-0.1)	0.46	0.46 (-0.2)	0.63	0.63 (-0.4)
Bruxner Wy 11	0.09	0.09 (0.4)	0.06	0.06 (1.2)	0.13	0.13 (0.9)
Cemetry Rd	0.25	0.25 (0.4)	0.21	0.21 (0.0)	0.45	0.45 (0.0)
Gunsynd Wy	0.32	0.32 (0.0)	0.29	0.29 (0.0)	0.30	0.30 (-0.1)
Kentucky Ln	0.35	0.35 (0.0)	0.27	0.27 (0.0)	0.38	0.38 (0.0)
Mungindi Goondiwindi Bdg Rd	0.17	0.17 (0.0)	0.07	0.07 (0.0)	0.06	0.06 (0.0)
N Star 1	0.57	0.65 (14.4)	0.54	0.61 (13.6)	Dry*	Dry*
N Star 2	0.39	0.38 (-2.8)	0.39	0.38 (-2.5)	Dry*	Dry*
N Star 3	0.32	0.32 (-1.2)	0.28	0.28 (-1.3)	Dry*	Dry*
N Star 4	0.03	0.03 (1.6)	0.04	0.04 (-4.8)	Dry*	Dry*
Newell Hwy 1	0.31	0.31 (0.0)	0.33	0.33 (0.6)	0.46	0.47 (1.3)
Newell Hwy 2	0.67	0.67 (-0.4)	0.58	0.59 (0.9)	0.99	0.99 (-0.1)
Newell Hwy 3	0.40	0.40 (0.0)	0.24	0.24 (0.1)	0.53	0.53 (0.2)
Newell Hwy 4	0.32	0.32 (0.0)	0.36	0.36 (0.0)	0.50	0.50 (0.4)

Road Inspection ID	Verified 2019 levees and validated 1976 flows		BRVFMP levees and validated 1976 flows		BRVFMP levees and factored flows	
	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)
Newell Hwy 5	0.40	0.40 (0.0)	0.37	0.37 (0.0)	0.69	0.69 (0.0)
Oakhurst Rd 1	0.47	0.47 (-0.3)	0.33	0.32 (-2.0)	0.35	0.39 (11.1)
Oakhurst Rd 2	Dry	Dry	0.10	0.10 (-4.3)	0.12	0.12 (0.3)
Oakhurst Rd 3	0.26	0.26 (-0.1)	0.17	0.17 (-0.5)	0.21	0.19 (-11.0)
Scotts Rd	0.15	0.15 (0.0)	0.15	0.15 (0.0)	Dry*	Dry*
Tucka Tucka Rd 1	0.30	0.30 (0.1)	0.30	0.30 (0.2)	0.50	0.50 (0.0)
Tucka Tucka Rd 2	0.62	0.62 (-0.2)	0.63	0.63 (-0.4)	0.83	0.83 (0.0)
Tucka Tucka Rd 3	0.20	0.20 (0.0)	0.20	0.20 (0.7)	0.30	0.30 (-0.8)

Table notes:

1. * BRVFMP modelling does not include any flows on the southern tributaries, so the results are shown as dry.
2. In several locations, the existing and developed velocities appear the same due to the very small variation in velocity as demonstrated by the percentage change values.

Table 6-8 Increase in velocities at road inspection locations on southern tributaries – 1% AEP flow scenarios

Road Inspection ID	Verified 2019 levees and 1% AEP flows		BRVFMP levees and 1% AEP flows	
	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)	Existing Velocity (m/s)	Developed Velocity (m/s) (% Change)
Bruxner Wy 1	Dry	Dry	Dry	Dry
N Star 3	0.34	0.33 (-2.6)	0.32	0.31 (-3.9)
N Star 2	0.47	0.44 (-6.8)	0.46	0.43 (-5.5)
N Star 1	0.65	0.76 (17.3)	0.60	0.69 (15.6)
Scotts Rd	0.24	0.24 (0.0)	0.24	0.24 (0.0)
Access Rd 3	0.12	0.14 (18.6)	0.19	0.17 (-11.0)

Table notes:

1. In several locations, the existing and developed velocities appear the same due to the very small variation in velocity as demonstrated by the percentage change values.

6.2.2 Impacts on floodplain area

For unsealed areas, including waterways, grazing land and agricultural land, the FMOs require that velocities are not to exceed 0.5m/s unless justified by site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist.

Figures C2, D2, E2, I2 and J2 present the existing case velocities across the floodplain and review of these figures shows that existing velocities are generally under 0.5m/s, except at the following locations:

- Mobbindry Creek (BR01 and BR02),
- Back Creek (BR03),
- Forest Creek (BR04),
- Strayleaves Creek (BR06),

- Macintyre River/Whalan Creek (BR11), and
- Macintyre River northern overbank (BR12)

In locations where the existing velocities exceed 0.5m/s the increase in velocity is limited to 20%.

Table 6-9 and Table 6-10 present the existing and developed velocities and the percentage change at the above locations for the 1976 flow scenarios and the 1% AEP event respectively. Where the percentage change exceeds 20% it is shown in bold.

These locations will therefore require a site-specific assessment conducted by an experienced geotechnical or scour/erosion specialist. Figures C7, D7, E7, I7 and J7 present the percentage change velocity at each of these locations for the modelled scenarios.

Table 6-9 Increase in velocities at waterways where existing velocity >0.5m/s – 1976 flow scenarios

Waterway	Verified 2019 levees and validated 1976 flows			BRVFMP levees and validated 1976 flows			BRVFMP levees and factored flows		
	Existing Velocity (m/s)	Developed Velocity (m/s)	Change in Velocity (%)	Existing Velocity (m/s)	Developed Velocity (m/s)	Change in Velocity (%)	Existing Velocity (m/s)	Developed Velocity (m/s)	Change in Velocity (%)
Mobbindry Creek (BR01)	0.61	0.70	14.0	0.61	0.71	16.5	Dry*	Dry*	Dry*
Mobbindry Creek (BR02)	0.57	0.54	-4.6	0.54	0.51	-5.4	Dry*	Dry*	Dry*
Back Creek (BR03) - Location A	1.23	1.23	0.05	1.23	1.23	0.1	Dry*	Dry*	Dry*
Back Creek (BR03) - Location B	0.67	1.00	49.0	0.67	1.00	48.8	Dry*	Dry*	Dry*
Forest Creek (BR04) - Location A	0.62	0.50	-19.8	0.61	0.49	-19.7	Dry*	Dry*	Dry*
Forest Creek (BR04) - Location B	0.24	0.55	128.1	0.22	0.53	141.9	Dry*	Dry*	Dry*
Forest Creek (BR04) - Location C	0.31	0.45	45.9	0.29	0.44	50.5	Dry*	Dry*	Dry*
Strayleaves Creek (BR06)	0.64	1.02	58.7	0.64	1.04	62.7	0.68	1.70	149.4
Macintyre River/ (BR11) – Location A	2.04	1.87	-8.5	2.04	1.87	-8.6	2.30	2.37	2.9
Whalan Creek (BR11) – Location B	1.38	1.38	0.2	1.38	1.38	0.1	1.69	1.67	-1.1
Macintyre River northern overbank (BR12)	0.56	0.73	29.5	0.56	0.72	28.9	0.70	0.89	26.9

Table notes:

1. * BRVFMP modelling does not include any flows on the southern tributaries, so the results are shown as dry.
2. In several locations, the existing and developed velocities appear the same due to the very small variation in velocity as demonstrated by the percentage change values.

Table 6-10 Increase in velocities at waterways where existing velocity >0.5m/s – 1% AEP flow scenarios

Waterway	Verified 2019 levees and 1% AEP flows			BRVFMP levees and 1% AEP flows		
	Existing Velocity (m/s)	Developed Velocity (m/s)	Change in Velocity (%)	Existing Velocity (m/s)	Developed Velocity (m/s)	Change in Velocity (%)
Mobbindry Creek (BR01)	0.61	0.82	35.1	0.62	0.82	32.7
Mobbindry Creek (BR02)	0.63	0.67	6.6	0.59	0.63	5.5
Back Creek (BR03) - Location A	1.38	1.39	0.8	1.38	1.39	0.8
Back Creek (BR03) - Location B	0.93	1.17	25.7	0.93	1.17	25.7
Forest Creek (BR04) - Location A	0.81	0.56	-31.6	0.79	0.57	-27.9
Forest Creek (BR04) - Location B	0.23	0.58	157.3	0.20	0.59	195.8
Forest Creek (BR04) - Location C	0.30	0.51	69.3	0.27	0.52	89.4
Strayleaves Creek (BR06)	0.55	0.53	-3.7	0.56	0.56	0.0

Table notes:

1. In several locations, the existing and developed velocities appear the same due to the very small variation in velocity as demonstrated by the percentage change values.

At several of the waterway crossings above, multiple reporting locations have been documented in the tables. This is because wider bridge openings are required in the developed case as compared to the existing case. This means that there is some redistribution of flow which affects the percentage change in velocities across the new bridge opening as compared to the existing case. In these locations, additional points have been reported (i.e. Location B or C) to capture impacts across the modified crossing.

For crossings where the existing velocities are predicted to be highest (i.e. BR03 – Location A, BR11 – Location A, BR11 – Location B) the proposed structures are not increasing velocities.

For the additional locations within the wider structure (i.e. BR03 – Location B, BR04 – Location B and C) higher velocities are predicted than existing case at these locations. However, the developed case velocities are not higher than the existing main channel velocity (Location A).

In the BRVFMP levees and factored flows scenario (refer Figure D7) there is an area where the percentage change in velocity is over 30%. This area is around approximate chainage 20 km. In this scenario there are no southern tributary flows, resulting in this area being affected by backwater rather than flow from Strayleaves Creek. The existing velocity is very low (0.07 m/s) with the developed velocity increasing to 0.14m/s. Therefore, a high percentage change is mapped even though the actual velocities are very low.

6.3 Increase in duration of inundation

The FMOs have varying limits on increases in duration of inundation depending upon local and/or land use as shown in Table 6-11. The existing duration of inundation on the floodplain is presented in Figures C3, D3 and E3 for the 1976 modelled scenarios and Figures I3 and J3 for the 1% AEP modelled scenarios. The existing duration of inundation in all locations exceeds 1 hour.

Figures C7, D7, E7, I7 and J7 present the percentage change in duration of inundation for each of the modelled scenarios.

Table 6-11 Increase in duration of inundation FMOs

Parameter	Location or Land Use	N2NS QDL - for up to and including 1% AEP event	NS2B project specific FMO targets - for events larger than 1% AEP
Flood duration i.e. increase in duration of inundation resulting from implementation of CSSI. (Does not apply to inundated areas less than 100m^2).	Habitable floors[4]	No increase in inundation duration above floor level. 10% increase in inundation duration where below floor level and when existing duration exceeds one hour. Otherwise inundation duration not to exceed one hour.	10% increase in inundation duration above floor level. 15% increase in inundation duration where below floor level and when existing duration exceeds one hour. Otherwise inundation duration not to exceed one hour.
	Highways and sealed roads >80km/hr[6]	10% increase in inundation duration.	20% increase in inundation duration. If not trafficable then the increase should be on a case by case assessment with no worsening to the network trafficability of that road – aligns with afflux approach
	Elsewhere	10% increase in inundation duration when existing inundation duration exceeds one hour. Otherwise inundation duration not to exceed one hour.	30% increase in inundation duration when existing inundation duration exceeds one hour. At new or fringe inundation - consider land use and resultant effects of inundation

The Macintyre River floodplain is a broad floodplain with a large upstream contributing catchment producing long flood durations. Therefore, existing inundation periods exceed one hour in all modelled scenarios.

For habitable floors there is no increase in inundation duration above 10% for any case.

Between chainages 20 km to 27 km there are increases in inundation duration on Bruxner Way above 10% for the 1976 flow scenarios. The impacted section was assessed between chainages 20km north to Whalan Creek (approximate Chainage 27 km). The areas impacted are identified in Table 6-12.

Table 6-12 Change in Duration of inundation on Bruxner Way – 1976 flow scenarios

Approximate alignment chainage	Verified 2019 levees and validated 1976 flows		BRVFMP levees and validated 1976 flows		BRVFMP levees and factored flows		N2NS QDLs/ NS2B project specific FMO targets (%)
	Existing Time of Duration (hrs)	Change in Time of duration (%)	Existing Time of Duration (hrs)	Change in Time of duration (%)	Existing Time of Duration (hrs)	Change in Time of duration (%)	
21.6	Dry	Dry	104	-5	35	**15**	10%/20%
22.5	98	**11**	97	**11**	66	-21	10%/20%
25.25	100	-14	96	-6	69	**21**	10%/20%
25.85	84	5	96	-4	73	**23**	10%/20%

Approximate alignment chainage	Verified 2019 levees and validated 1976 flows		BRVFMP levees and validated 1976 flows		BRVFMP levees and factored flows		N2NS QDLs/ NS2B project specific FMO targets (%)
	Existing Time of Duration (hrs)	Change in Time of duration (%)	Existing Time of Duration (hrs)	Change in Time of duration (%)	Existing Time of Duration (hrs)	Change in Time of duration (%)	
27	83	6	84	**12**	60	8	10%/20%
Maximum existing duration of inundation between Ch 20 km and 27 (hrs)	119	-	125	-	89	-	

Table notes:

+21 – Impact exceeds both FMOs **+11** – Impact exceeds N2NS FMOs

Bruxner way is significantly overtopped in the existing case with durations of inundation up to 89 to 125 hours for the three 1976 scenarios. While there are exceedances in duration of inundation above 10% in all three cases shown the resulting duration of inundation does not exceed the maximum existing duration of inundation for this section of Bruxner Way.

In detailed design it is proposed to apply the new Quadtree modelling technique to improve the representation of this section of Bruxner Way and enable a more detailed investigation, including of duration of inundation.

There are no other highways or sealed roads with a change of duration of inundation greater than 10% for the three cases.

For the 1976 flow scenarios elsewhere on the broader floodplain changes in the duration of inundation are less than 10%. There is one location of localised increase above 20% at chainage 25 km of the proposal. Discussions with landholders are already underway as detailed in Section 8.

For the 1% AEP flows on the southern tributaries there are two locations (Mobbindry Creek and Forest Creek) downstream of the rail alignment where a localised increase in duration of inundation exceeds 20%. These will be discussed with affected landholders to determine the actual impact of this increase.

6.4 Change in flood hazard

For roadways, flood hazard is considered in two ways, firstly through consideration of the hazard category and secondly through consideration of the velocity x depth product as shown in Table 6-13. For other areas the FMOs limit the increase in velocity x depth product to 20% or 30%.

These FMOs do not apply to areas where the velocity x depth product is less than 0.1 m^2/s. These areas have been identified and excluded from the prepared mapping.

Table 6-13 Change in flood hazard FMOs

Parameter	Location or Land Use	N2NS QDL - for up to and including 1% AEP event	NS2B project specific FMO targets - for events larger than 1% AEP
Flood Hazard i.e. increase in velocity-depth product (vd) and/or flood hazard category resulting from implementation of CSSI (Does not apply where vd<0.1m^2/s).	Urban, commercial, industrial, highways[6] and sealed roadways[6]	10% increase in vd where H1 or H2 category. 0% increase in vd where in H3 or greater category.	20% for all categories (taking into consideration land use and impacted receptors)
	Elsewhere	20% increase in vd	30% increase in vd

6.4.1 Flood hazard categories

The Australian Disaster Resilience Handbook Flood Hazard Guideline 7-3 (2017) produced by the Australian Institute for Disaster Resilience (AIDR) provides guidelines for the categorisation of flood hazard as shown in Figure 7. Using these guidelines flood hazard mapping has been prepared for the Existing Case (Figures C4, D4, E4, I4 and J4) and Developed Case (Figures C9, D9, E9, I9 and J9).

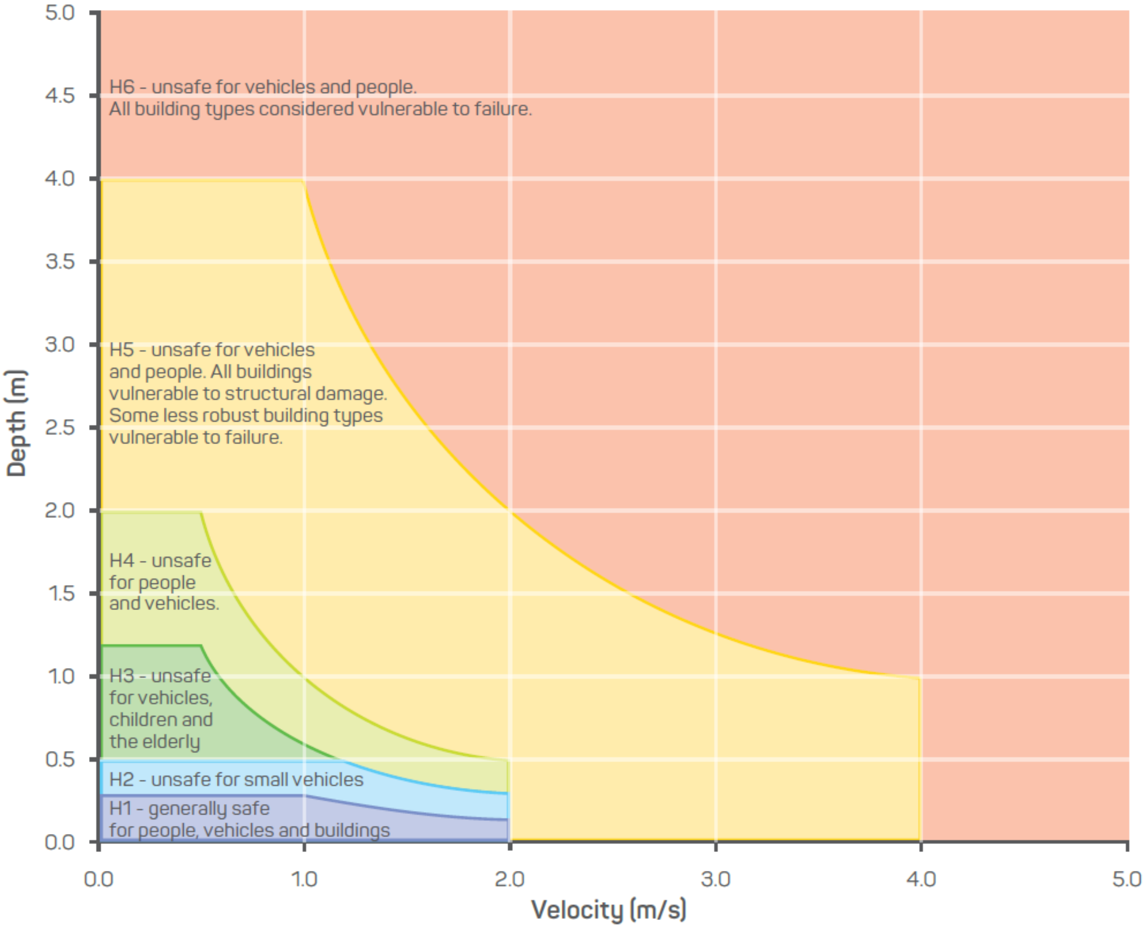

Figure 7 Flood hazard classification, Australian Disaster Resilience Handbook – Guideline 7-3 (AIDR 2017)

As can be seen from the results the lower hazard classifications (H1 to H3) generally apply across the majority of the floodplain area with the higher (H5) classifications occurring in the creek and river channels were the flow is higher. The highest classification (H6) applies along the deeper waterways, in particular on the Macintyre River and Whalan Creek, due to higher flood depths and velocities than on the floodplain areas.

6.4.2 Increase in velocity x depth product on roads

An assessment of the increase in velocity x depth (v x d) product has been undertaken at each of the road inspection locations (refer Figure 6) as shown in Table 6-14 and Table 6-15. For each of the modelled scenarios, the hazard category at each inspection location has been determined and the associated FMO limit.

Table 6-14 shows that as many parts of the floodplain are subject to high depths of inundation (even with low velocities) that the existing hazard category is mainly H3 or H4. The N2NS FMOs for this category do not permit any change in velocities. In many locations only a very small percentage change is predicted and yet this is deemed not permissible. The proposed FMOs account for this with applying a limit of 10% across all hazard types for roads and a 30% increase in v x d elsewhere. Locations that exceed both the N2NS and proposed FMOs will be assessed further in detailed design. This included the locations on Bruxner Way that will have quadtree modelling undertaken to assesses this location in detail.

6.4.3 Increase in velocity x depth product elsewhere

Floodplain wide mapping has been prepared for velocity x depth for the existing case (Figures C5, D5 and E5, I5, J5, and the percentage change in velocity x depth (Figures C10, D10 and E10, E10, I10 and J10). Across the floodplain there is little change in velocity x depth for all three cases. There are some localised increases (above 20% and 30%) around the proposed alignment (approximate chainage 25km) and localised at the structures on the southern tributaries with 1% AEP flows.

Table 6-14 Change in velocity x depth at road inspection locations – 1976 flow scenarios

Road Inspection ID	Verified 2019 levees and validated 1976 flows			BRVFMP levees and validated 1976 flows			BRVFMP levees and factored flows		
	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ N2NS QDLs/ NS2B project specific FMO targets (%)	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ N2NS QDLs/ NS2B project specific FMO targets (%)	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ N2NS QDLs/ NS2B project specific FMO targets (%)
Access Rd 1	0.23	-0.17	H3 – 0%/20%	0.24	-0.24	H3 – 0%/20%	Dry	Dry	N/A – Dry
Access Rd 2	0.33	-11.29	H4 – 0%/20%	0.34	-25.66	H4 – 0%/20%	0.60	-33.94	H4 – 0%/20%
Access Rd 3	0.03	-	N/A <0.1 m^2/s	0.06	-	N/A <0.1 m^2/s	Dry	Dry	N/A – Dry
Access Rd 4	0.19	-45.44	H3 – 0%/20%	0.21	-31.03	H3 – 0%/20%	0.41	-7.44	H3 – 0%/20%
Access Rd 5	0.98	**0.46**	H4 – 0%/20%	0.97	**2.51**	H4 – 0%/20%	1.01	**5.29**	H4 – 0%/20%
Access Rd 6	0.27	**4.54**	H3 – 0%/20%	0.25	**9.82**	H3 – 0%/20%	0.37	**32.50**	H3 – 0%/20%
Access Rd 7	0.43	-3.14	H4 – 0%/20%	0.42	**1.20**	H4 – 0%/20%	0.56	**28.02**	H4 – 0%/20%
Access Rd 8	0.20	-0.67	H3 – 0%/20%	0.19	**0.50**	H3 – 0%/20%	0.26	**0.06**	H3 – 0%/20%
Access Rd 9	0.20	-0.44	H3 – 0%/20%	0.19	0.00	H3 – 0%/20%	0.30	-0.96	H3 – 0%/20%
Access Rd 10	0.17	**0.20**	H3 – 0%/20%	0.17	**0.96**	H3 – 0%/20%	0.27	**1.21**	H3 – 0%/20%
Access Rd 11	0.20	**0.91**	H3 – 0%/20%	0.19	**1.34**	H3 – 0%/20%	0.30	**2.03**	H3 – 0%/20%
Access Rd 12	0.19	**0.47**	H3 – 0%/20%	0.18	**1.12**	H3 – 0%/20%	0.26	**2.15**	H3 – 0%/20%
Access Rd 13	0.14	**0.03**	H3 – 0%/20%	0.13	**0.75**	H3 – 0%/20%	0.21	**0.93**	H3 – 0%/20%
Access Rd 14	0.24	**2.17**	H3 – 0%/20%	0.31	**3.52**	H3 – 0%/20%	0.39	**8.49**	H3 – 0%/20%
Access Rd 15	0.21	**1.06**	H3 – 0%/20%	0.23	**2.20**	H3 – 0%/20%	0.31	**6.98**	H4 – 0%/20%
Access Rd 16	0.28	**0.47**	H4 – 0%/20%	0.26	**1.39**	H3 – 0%/20%	0.36	**2.68**	H3 – 0%/20%
Access Rd 17	0.34	**0.03**	H4 – 0%/20%	0.37	**1.07**	H4 – 0%/20%	0.39	**3.18**	H4 – 0%/20%
Access Rd 19	0.20	**0.01**	H3 – 0%/20%	0.21	**0.26**	H3 – 0%/20%	0.22	**0.46**	H3 – 0%/20%
Bruxner Wy 1	Dry	Dry	N/A – Dry	Dry	Dry	N/A – Dry	Dry	Dry	N/A – Dry

Road Inspection ID	Verified 2019 levees and validated 1976 flows			BRVFMP levees and validated 1976 flows			BRVFMP levees and factored flows		
	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ N2NS QDLs/ NS2B project specific FMO targets (%)	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ N2NS QDLs/ NS2B project specific FMO targets (%)	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ N2NS QDLs/ NS2B project specific FMO targets (%)
Bruxner Wy 2	Dry	Dry	N/A – Dry	Dry	Dry	N/A – Dry	Dry	Dry	N/A – Dry
Bruxner Wy 3	0.11	110.50	H3 – 0%/20%	0.11	233.83	H3 – 0%/20%	Dry	Dry	N/A – Dry
Bruxner Wy 4	0.30	-39.17	H3 – 0%/20%	0.34	-39.04	H3 – 0%/20%	0.53	-17.38	H3 – 0%/20%
Bruxner Wy 5 Developed	0.44	**10.26**	H4 – 0%/20%	0.42	**16.68**	H4 – 0%/20%	0.68	**27.62**	H4 – 0%/20%
Bruxner Wy 5 Existing	0.79	113.73	H4 – 0%/20%	0.78	125.17	H4 – 0%/20%	1.14	193.46	H5 – 0%/20%
Bruxner Wy 6	0.51	39.87	H4 – 0%/20%	0.49	45.16	H4 – 0%/20%	0.64	64.10	H4 – 0%/20%
Bruxner Wy 7	0.11	-11.80	H3 – 0%/20%	0.09	-	N/A <0.1 m^2/s	0.05	-	N/A <0.1 m^2/s
Bruxner Wy 8	0.77	**1.37**	H4 – 0%/20%	0.76	**2.11**	H4 – 0%/20%	0.90	**4.25**	H4 – 0%/20%
Bruxner Wy 9	0.51	**0.92**	H4 – 0%/20%	0.50	**1.60**	H4 – 0%/20%	0.62	**3.37**	H4 – 0%/20%
Bruxner Wy 10	0.61	**0.28**	H4 – 0%/20%	0.61	**0.50**	H4 – 0%/20%	0.79	**1.22**	H4 – 0%/20%
Bruxner Wy 11	0.03	0.01	H1 – 0%/20%	0.02	-	N/A <0.1 m^2/s	0.03	-	N/A <0.1 m^2/s
Cemetry Rd	0.23	**0.01**	H4 – 0%/20%	0.21	**0.44**	H4 – 0%/20%	0.32	**0.12**	H4 – 0%/20%
Gunsynd Wy	0.43	**0.01**	H4 – 0%/20%	0.34	0.00	H3 – 0%/20%	0.34	**0.20**	H3 – 0%/20%
Kentucky Ln	0.21	**0.01**	H3 – 0%/20%	0.23	**0.04**	H3 – 0%/20%	0.24	**0.17**	H3 – 0%/20%
Mungindi Goondiwindi Bdg Rd	0.13	**0.29**	H3 – 0%/20%	0.03	-	N/A <0.1 m^2/s	0.01	-	N/A <0.1 m^2/s
N Star 1	0.60	**14.69**	H4 – 0%/20%	0.56	**14.55**	H3 – 0%/20%	Dry	Dry	N/A – Dry
N Star 2	0.69	**0.41**	H4 – 0%/20%	0.70	**0.47**	H4 – 0%/20%	Dry	Dry	N/A – Dry
N Star 3	0.24	-0.17	H3 – 0%/20%	0.20	-0.32	H3 – 0%/20%	Dry	Dry	N/A – Dry
N Star 4	0.01	-	N/A <0.1 m^2/s	0.02	-	N/A <0.1 m^2/s	Dry	Dry	N/A – Dry
Newell Hwy 1	0.28	**0.01**	H3 – 0%/20%	0.44	**0.91**	H4 – 0%/20%	0.67	**1.74**	H4 – 0%/20%

Road Inspection ID	Verified 2019 levees and validated 1976 flows			BRVFMP levees and validated 1976 flows			BRVFMP levees and factored flows		
	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ N2NS QDLs/ NS2B project specific FMO targets (%)	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ N2NS QDLs/ NS2B project specific FMO targets (%)	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ N2NS QDLs/ NS2B project specific FMO targets (%)
Newell Hwy 2	0.87	-7.33	H4 – 0%/20%	0.79	-3.22	H4 – 0%/20%	0.94	**0.81**	H4 – 0%/20%
Newell Hwy 3	0.20	**0.01**	H2 – 10%/20%	0.07	-	N/A <0.1 m^2/s	0.20	**0.64**	H1 – 10%/20%
Newell Hwy 4	0.35	**0.01**	H3 – 0%/20%	0.48	**0.16**	H4 – 0%/20%	0.50	**0.54**	H3 – 0%/20%
Newell Hwy 5	0.32	**0.01**	H3 – 0%/20%	0.23	0.00	H3 – 0%/20%	0.30	0.09	H2 – 10%/20%
Oakhurst Rd 1	0.23	-0.89	H2 – 10%/20%	0.25	-3.98	H3 – 0%/20%	0.10	-	N/A <0.1 m^2/s
Oakhurst Rd 2	Dry	Dry	N/A – Dry	0.04	-	N/A <0.1 m^2/s	0.01	-	N/A <0.1 m^2/s
Oakhurst Rd 3	0.14	0.01	H2 – 10%/20%	0.17	-0.56	H3 – 0%/20%	0.18	-22.89	H3 – 0%/20%
Scotts Rd	0.04	-	N/A <0.1 m^2/s	0.04	-	N/A <0.1 m^2/s	Dry	Dry	N/A – Dry
Tucka Tucka Rd 1	0.27	**1.05**	H3 – 0%/20%	0.27	**1.15**	H3 – 0%/20%	0.29	**2.02**	H3 – 0%/20%
Tucka Tucka Rd 2	1.71	**0.47**	H5 – 0%/20%	1.79	**0.20**	H5 – 0%/20%	2.28	**0.92**	H5 – 0%/20%
Tucka Tucka Rd 3	0.22	**0.25**	H3 – 0%/20%	0.23	**1.12**	H3 – 0%/20%	0.17	1.65	H2 – 10%/20%

Table notes:

+21 – Impact exceeds both FMOs **+11** – Impact exceeds N2NS FMOs

Table 6-15 Change in velocity x depth at road inspection locations – 1% AEP flow scenarios

Road Inspection ID	Verified 2019 levees and 1% AEP flows			BRVFMP levees and 1% AEP flows		
	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ FMO Target (%)	Existing V x D (m^2/s)	Change in V x D (%)	Hazard Category/ FMO Target (%)
Bruxner Wy 1	Dry	Dry	N/A – Dry	Dry	Dry	N/A – Dry
N Star 3	0.28	-2.26	H4 – 0%/20%	0.25	-3.52	H4 – 0%/20%
N Star 2	0.76	-0.56	N/A <0.1 m^2/s	0.76	1.06	N/A <0.1 m^2/s
N Star 1	0.77	22.17	H3 – 0%/20%	0.69	21.04	H3 – 0%/20%
Scotts Rd	0.10	0.03	H4 – 0%/20%	0.10	-0.01	H4 – 0%/20%
Access Rd 3	0.05	71.11	H3 – 0%/20%	0.10	17.82	H3 – 0%/20%

Table notes:

+21 – Impact exceeds both FMOs **+11** – Impact exceeds N2NS FMOs

6.5 Variation in flow distribution as per BRVFMP

The BRVFMP uses a series of discharge calculations locations to review changes in flow distribution associated with development on the floodplain areas. The location closest to the proposal alignment is the long section shown in Figure 8 extracted from Appendix 6 of the BRVFMP.

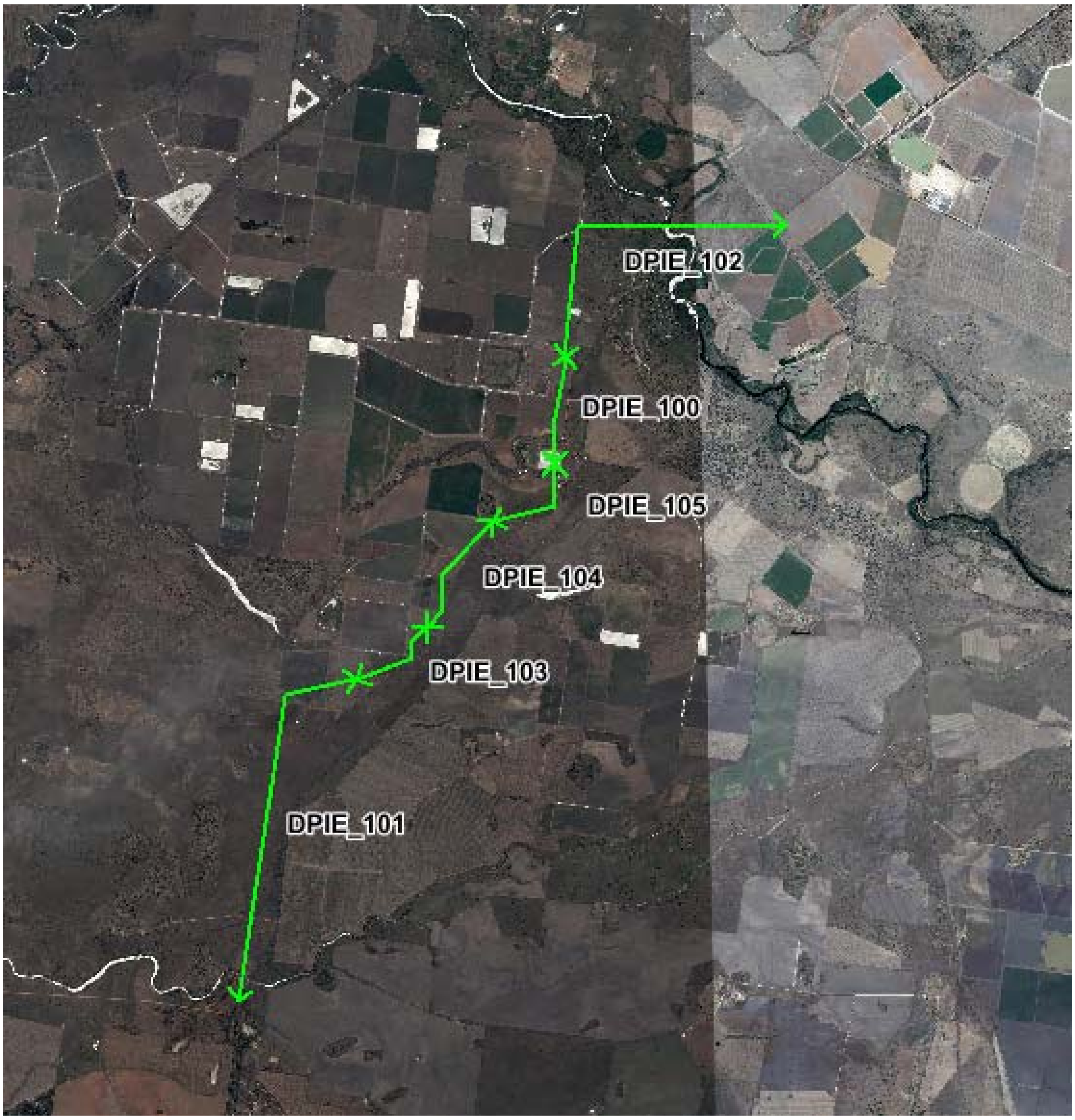

Figure 8 Section 1 from BRVFMP

The details of Section 1 were obtained digitally from DPIE and used to extract flows within each section for the following scenarios:

- Verified 2019 Levees and validated 1976 flows
- BRVFMP Levees and factored flows
- BRVFMP levees and validated 1976 flows

The BRVFMP requires that there is no more than a 5% change in flow distribution between the Existing and Developed Cases (noting the Developed Case includes the proposed rail alignment and associated works).

Table 6-16 presents the flows for each segment of Section 1 for both cases and the percentage change. As can be seen there for all three modelled scenarios the percentage changes values are all less than the 5% limit, with the majority around 0 to 2%. It should be noted that this assessment has been undertaken on peak flows and that consideration of flood volume is likely to result in closer volumes between the three cases.

Table 6-16 Peak flow variation assessment along Section 1

Segment of Section 1	Verified 2019 levees and validated 1976 flows		BRVFMP levees and factored flows		BRVFMP levees and validated 1976 flows	
	Existing Case flows (m^3/s)	Developed Case flows (m^3/s) and % Change	Existing Case flows (m^3/s)	Developed Case lows (m^3/s) and % Change	Existing Case flows (m^3/s)	Developed Case flows (m^3/s) and % Change
DPIE_100	430	431 (0%)	503	514 (2%)	402	406 (1%)
DPIE_101	1721	1682 (-2%)	3236	3136 (-3%)	2228	2193 (-2%)
DPIE_102	3520	3521 (0%)	3776	3784 (0%)	3362	3366 (0%)
DPIE_103	265	265 (0%)	234	238 (2%)	193	195 (1%)
DPIE_104	583	588 (1%)	520	534 (3%)	380	386 (1%)
DPIE_105	150	152 (1%)	155	162 (4%)	121	124 (2.5%)

6.6 Summary of impact assessment

The project has been assessed against the N2NS Phase 1 QDLs and the proposed NS2B FMOs for the 1976 flow scenario on the Macintyre River floodplain and the 1% AEP event on the southern tributaries.

The NS2B project specific FMOs are proposed as being a more suitable tool for assessment against the 1976 flow scenario which is in the order of a 1 in 200 AEP event as compared to the N2NS Phase 1 QDLs that have been applied to the 1% AEP event.

This due to the fact that flood impact risk is considered a function of event probability and the flood impact threshold. Maintaining the same flood impact risk profile between the 1976 flow scenario (1 in 200 AEP) and the 1% AEP implies that the reduction in event probability is balanced through an increase in the flood impact threshold.

Key findings of the assessment are summarised into the following:

- Impacts across the floodplain have been minimised by the project with no significant impacts predicted against FMO's away from the alignment. **There are no impacts at the townships of Toomelah, Boggabilla and Goondiwindi in any of the cases presented.**
- **There are no significant changes in variation to flow** distribution across the floodplain demonstrating that flow distribution patterns are maintained in all cases.
- Generally, impacts are within the NS2B project specific FMO targets with only a few occurrences outside of the FMOs. These areas have been identified and will be taken forward through application of the mitigation framework.

7 Mitigation framework

ARTC has developed an additional mitigation framework to support the proposed Reference Design. This will supplement the impact assessment undertaken and completed in Chapter 13 of the EIS and informs our response to the NS2B PIR Letter regarding the 1976 Flood (dated 10 December 2020).

As discussed within this PIR, the proposal has now incorporated the 1976 flood event and further assessed the impacts against the current reference design. The AEP of the 1976 flood event is estimated to be approximately a 1 in 200 AEP event (Refer to Appendix F or Section 4.2 for more details).

The proposal has been designed to a set of hydraulic design criteria suitable for the functionality of the rail against a range of flood scenarios. ARTC will apply mitigation measures to scenarios that have used the validated 1976 flows.

The mitigation framework set out in Figure 9 is implemented where an impact of the proposal exceeds the proposed limits.

An overview of the process is outlined below:

- **Step 1: Is the impact within proposed limit:** If the degree of change is within the Flood Management Objective thresholds then this is deemed acceptable. No mitigation is required. Where exceedances occur, move to Step 2.
- **Step 2: Is the impact real:** This stage is acknowledging that while an exceedance may be identified, the actual on ground impact may not be material in the broader context of the overall floodplain dynamics. Where this can be justified, no further mitigation is required. Where the impact is material, move to step 3.
- **Step 3: Engagement with impacted stakeholders – is the impact acceptable with no mitigation:** The proponent will engage with impacted stakeholders to present and discuss property specific impacts (ie. flood performance beyond the thresholds set in the FMOs). This step will determine if the changes in flood behaviour have any detrimental impact to their operations and whether they are a perceived impact. If the stakeholder does not perceive an impact or if a significant environmental impact does not exist, then no additional mitigation is required. If this is not the case, move to Step 4.
- **Step 4: Stakeholder engagement – proposed mitigations:** If during Step 3 it is identified that a change in flood behaviour impacts on the stakeholder, this will require mitigation. It will be discussed with the landowner to determine if a reasonable and practical solution can be achieved. The proposed mitigation will either achieve the project FMOs or be an acceptable environmental impact through at-property mitigation. If the impact cannot be mitigated proceed to Step 5.
- **Step 5: Conduct socio-economic assessment:** If localised impacts are present and the no agreement can be reached with the affected stakeholder, a comparison of re-design (at-source mitigation) vs cost to mitigate (at-property mitigation) will be undertaken. Where the socio-economic outcome justifies that the design remain as is, the focus will be on at-property mitigation. Where the socio-economic outcome cannot clearly justify that the design remains as it is, the focus will be on redesign (i.e. at-source mitigation – return to Step 1).

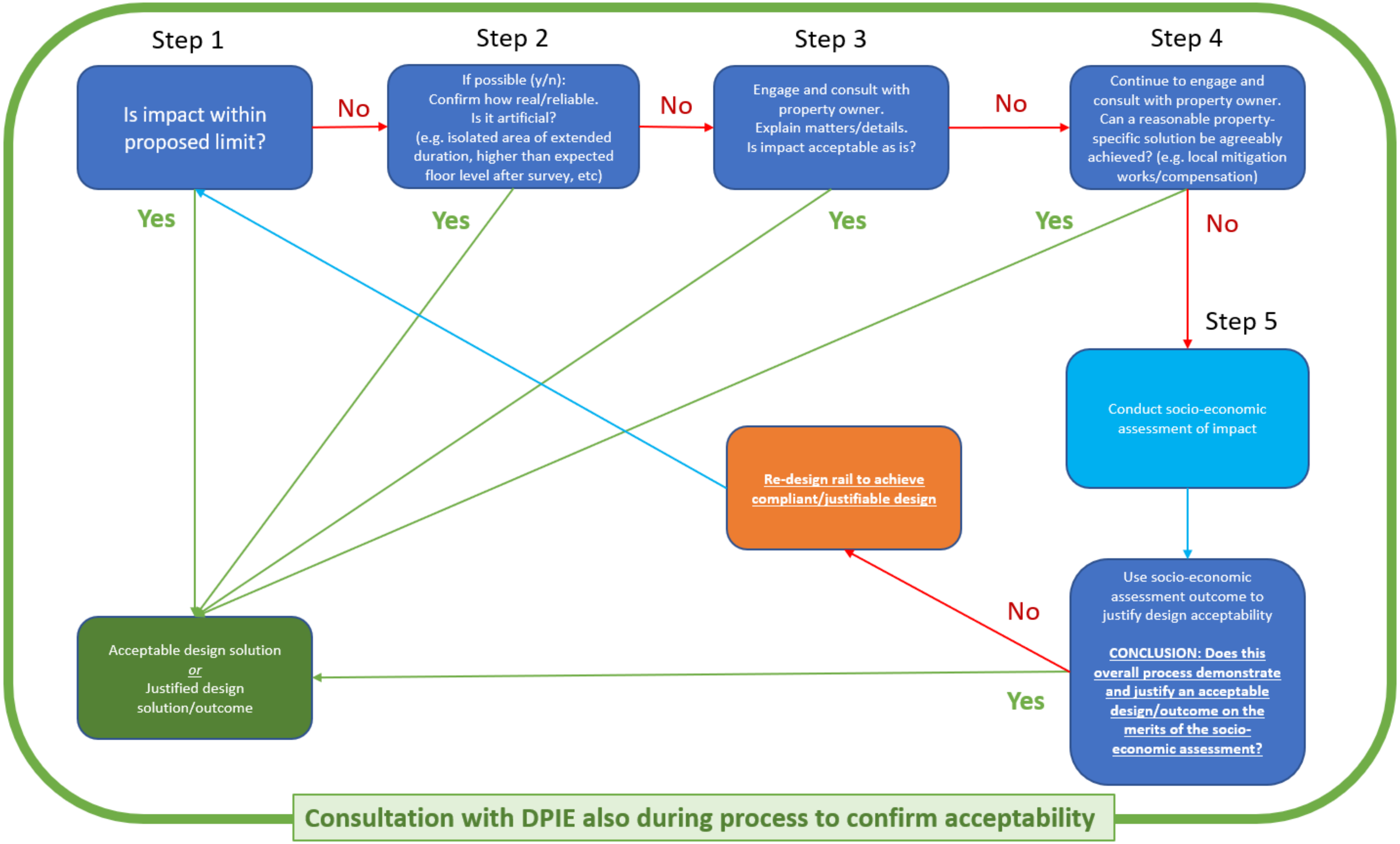

Figure 9 **Mitigation Framework where FMOs cannot be met or otherwise justified.**

8 Engagement

8.1 Introduction

The project team recently met with directly affected NS2B landowners to present the updated Macintyre River 1976 flood model result (incorporating the 2019 LiDAR, BRFMP approved levees and ARR 2019 guiding principles) and the newly determined Flood Management Objectives (FMOs) for the project.

The updates to the Macintyre River flood modelling, the adoption of the FMOs and the requirement to use the 1976 flood event as the design event, are a direct result of consultation with DPIE and the NS2B community.

8.2 Background

Extensive consultation has been held with the NS2B landowners and the community regarding the Macintyre River flood modelling and the proposed crossing solution in line with the Project's SEARs. This has included implementing regular technical working groups (which included impacted landowners), involvement from the three local councils, regular meetings with DPIE, input from TfNSW and involvement from the local flood specialists. We have supported GRC to facilitate an independent review of the Macintyre River Flood modelling and Reference Design, which has determined the proposed crossing solution will not have a negative flooding impact on the local communities, however did recommend ARTC incorporate the ARR 2019 guiding principles into the flood modelling.

During the recent public exhibition of the EIS, several submissions recommended that the NS2B project team adopt the 1976 flood event as the design event. DPIE supported this suggestion and directed ARTC to use the 1976 flood event as the design event and address its impacts for the proposal. In addition to this, DPIE have directed ARTC to assess the design performance against the Narrabri to North Star FMOs.

With the recent directives from DPIE, additional consultation has been undertaken to complete the hydrology consultation with the NS2B landowners.

8.3 Objectives

The objective of the hydrology consultation was to present the NS2B landowners with an update on the Macintyre River flood modelling, present an overview of the FMOs and follow the mitigation framework as discussed in Section 7. Activities undertaken included:

- Consultation with landowners whose properties were identified as having a change to their existing flood conditions where it exceeded the FMOs during a 1976 flood event, and
- Seeking landholder feedback on the acceptability of these impacts and where possible, gain feedback from landowners on potential 'at property' mitigation solutions.

During this consultation, directly affected landowners were informed that ARTC was not proposing to redesign the Reference Design to mitigate the potential exceedances of the FMOs based on a socio-economic justification given the project meets the level of flood immunity required for the operational rail.

Landowners were informed that ARTC was seeking feedback on the acceptability of these exceedances, inputs and suggestions on potential 'at property' mitigations that would manage these exceedances, and to assure them where exceedances could not be mitigated, these impacts would form part of property agreements, either via acquisition or entering into deeds.

The proposal has adopted this approach (as discussed in Section 9) as to mitigate impacts is not considered reasonable and practical, and that mitigations at property or via property agreements can achieve a more beneficial socio-economical solution.

To support these conversations and to ensure directly impacted landowners were provided the information required to make informed responses, landowners were presented with the following:

- An update on the hydrology requirements for the NS2B project
- An overview of FMOs for the project
- Overarching project afflux map
- Individual property lot maps consisting of Existing and Developed Cases representing:
  - Changes to peak water levels
  - Changes to time of inundation
  - Changes to velocities
  - Changes to hazard
- Identification of exceedances to the FMOs
- Sought advice regarding potential mitigations that may negate areas of exceedance from a landowner operational impact

8.4 Outcomes of hydrology consultation

Many of the impacted landowners raised minimal concerns regarding the FMOs, the updated flood modelling, potential flood impacts predicted for their individual properties and the predicted exceedances to the FMOs caused by the alignment. Several landowners expressed a desire to work with the project to investigate alternate 'at property' solutions to mitigate the flooding impacts, which potentially may improve the current flooding conditions (for example additional erosion control using private property).

Overview of recent hydrology consultation where landowners raised minimal concerns about the FMOs exceedances include:

- One landowner believed the exceedances were acceptable and no additional mitigations were required
- Two landowners believed that mitigations could be applied locally to FMO exceedances to make them acceptable. Where increases in peak water levels and time of inundation was identified it was agreeable that these could be discussed via property agreements with ARTC.
- Two landowners, those with the greatest hydraulic and hydrologic change, believed no mitigations could be applied to their properties to make the impacts acceptable. There was appreciation that this could be solved via a property agreement or another means that may be acceptable to both parties.

Overarching outcomes of the discussions with impacted landowners were:

- Confirmation that the increase in time of inundation, velocities and peak water levels would have minimal impact on existing farming operations for all but two landowners
- Collaborative approach to developing 'at property' mitigations, such as securing additional land to allow for additional scour protection would be desirable
- The understanding and acceptance of the rationale for the socio-economic justification to mitigate property impacts through landowner's property negotiations as opposed to redesigning the reference design where there were exceedances of the FMOs
- Willingness to work with the project to achieve broad benefit outcomes for the community
- Concerns however were raised by two landowners where managing the increase in peak water levels and time of inundation could not be mitigated through 'at property' solutions. It was explained to these landowners that these exceedances would be either justified as acceptable (via using existing guidelines or factual evidence of acceptability) or through their property negotiations or other property agreement mechanisms.

In summary, the recent hydrology consultation with landowners raised the following with regard to flood management and design performance:

- Understand the rationale for the socio-economic justification to mitigate property impacts through landowner's negotiations as opposed to redesigning the reference design where there were exceedances of the FMOs for the 1976 event.
- Did not accept the FMO exceedances are reasonable
- Accepted proposed approach to compensate the justified FMO exceedances, providing the compensation amount was agreed to by the landowner
- Did not accept the updated model or the predicted ML/day at the junction (too low)
- Belief the actual flooding impacts are not accurately represented
- Increase in peak water levels from the 1976 flood event for one landowner would result in an increased risk to stock during a flood event

8.5 Mitigation framework outcomes from consultation

Following the impacted landowner engagement, the existing design can minimise impact via meeting N2NS FMOs, justify where their impact is reasonable relevant to the event, or mitigation can achieve the desirable outcomes. Through applying localised soil assessment (from a suitably qualified soil scientist or relevant skillset) and property agreement mechanisms the current degree of impact is believed reasonable.

For the one of the landowners, who has the four flood sensitive receivers which experience exceedances of the FMOs, no proposed mitigations were suggested. Therefore, the proposal would commit to, at detailed design providing solutions that mitigate the 1976 impact. This may include items such as raising houses, raising of existing bunds around houses, minor realignments of infrastructure (i.e. pumps/sheds) so as to achieve flood immunity. These solutions can be further explored during the next phase of the project.

One landowner was not amicable to mitigation, therefore for the purpose of this assessment the justification of why the current design is considered reasonable will be discussed further in the socio-economical section of this report.

9 Socio-economic considerations

The proposal as part of its original EIS submission designed and mitigated to the 1% AEP flood event. This PIR now considers the 1976 event as an additional assessment factor.

Inland Rail is a significant public infrastructure project which has been heavily scrutinised for its cost-benefit, feasibility and public outcomes. To that end, the identification of suitable and appropriate flood impact mitigation measures must also bear a modicum of public interest outcomes – this necessitates a balancing between mitigation costs (private landholder and public expenditure), and the cost of impact rectification. This section discusses the selection of reasonable and feasible mitigation approaches in the context of the public cost of such mitigations and the achievement of a reasonable outcome for landholders, local community and the broader Australian public. Based on the outcomes of the flood modelling as presented in this report it is not deemed a justifiable socio-economic outcome to provide at source mitigations that would require via costly significant design amendments, with associated design and construction costs (greatly increase structures and cross drainage).

To justify this approach, the proposal has undertaken a review of socio-economic aspects against other environmental, flood risk, emergency management and heritage considerations. The following applicable socio-economic considerations include:

- The Border Rivers 1976 flood event is considered to be approximately a 1 in 200 AEP flood event (refer Appendix F).
- Additional costs to the Federal Government in providing a 1976 flood event mitigated event.
- The project is committed to mitigating where FMO exceedances occur on landowner's sensitive receivers via at property mitigations for the four locations. These mitigations will be applied where appropriate and reasonable to mitigate these impacts.

Given the above, it is the perspective of this assessment that to do an at source, re-design of the proposed floodplain crossing would result in an unreasonable socio-economical outcome. ARTC will commit to either doing an at property mitigation in consultation with the landowner. In the event where mitigations cannot be agreed a property specific compensation and registration of easement may be utilised. If an amicable solution cannot be achieved, the land will be acquired given proposed mitigations are considered unreasonably to mitigate.

10 Conclusions

The PIR scope requires ARTC to:

- Reassesses the hydrology and flooding impacts of the project, as presented in the EIS, using the greater of, the large design flood as defined in the Border Rivers Valley Floodplain Management Plan (1976 flood event), or the 1% AEP flood

In discussions with DPIE it was agreed that the greater event would be determined using peak flows. Modelling has determined that the peak flows on the southern tributaries are larger for the 1% event than for the 1976 calibration event. Elsewhere on the floodplain the 1976 event results in larger flows.

ARTC has completed an assessment of the NS2B proposal against the N2NS Phase 1 QDLS and against the proposed NS2B project specific FMO targets. Five scenarios were assessed against the targets:

- Verified 2019 levees and validated 1976 flows
- BRVFMP levees and factored flows
- BRVFMP levees and validated 1976 flows
- Verified 2019 levees and 1% AEP event
- BRVFMP levees and 1% AEP event

The BRVFMP refers to a "1976 flood event" which was determined using factored flows and hydrological modelling which was not consistent with the ARR 2019 guidelines. ARTC has assessed its impacts consistent with the BRVFMP using the BRVFMP levees and factored flows.

ARTC considers that the verified 2019 levees and validated 1976 flows, that have been developed using ARR 2019 guidelines and utilising all available data, results in a tool that is robust and accurate for representing the 1976 flood event than what is presented in the BRVFMP. Therefore, it should be adopted for determining the impacts within the floodplain.

The assessment further recommends adoption of the N2NS Phase 1 QDLs where a 1% AEP governs and the adoption of the proposed NS2B project specific FMO targets where the 1976 (1 in 200 AEP) flows govern.

This is endorsed by the BMT Peer Review provided in Appendix G.

Key findings of the assessment are summarised into the following:

- Impacts across the floodplain have been minimised by the project with no significant impacts predicted against FMO's away from the alignment. **There are no impacts at the townships of Toomelah, Boggabilla and Goondiwindi in any of the cases presented**.
- **There are no significant changes in variation to flow** distribution across the floodplain for each case demonstrating that flows distribution patterns are maintained in all cases
- Some localised exceedances of the FMO thresholds are still present, and these have been discussed directly with the impacted landholders and included in this report. A mitigation framework has been proposed to capture this discussion to ensure that appropriate mitigations at the FSR properties are provided as the project advances through detailed design.

This report demonstrates that with the updated ARR 2019 compliant modelling and the inclusion of the impact mitigation framework, the proposal can be considered for approval.

11 Limitations

This assessment is based on the TUFLOW model developed by DPIE for the Border Rivers Floodplain Management Plan. It is noted that the addition of the 2011 calibration event and the design flow analysis provides some further confidence in the ability of the hydraulic model to replicate flows independent of further refinements to the BRVFMP model.

FFJV has prepared this report in accordance with the usual diligence and thoroughness of the consulting profession with reference to current standards, procedures and practices.

This report should be read in full and no excerpts are to be taken as representative of the findings. No responsibility is accepted by FFJV for use of any part of this report in any other context.

This report was prepared for the exclusive use of the proposal. FFJV accepts no liability or responsibility whatsoever for, any use of, or reliance upon, this report by any third party.

This report was prepared based on information available at the time of writing. The models detailed in this report are based on LiDAR survey taken generally in 2014/15 and 2019. Therefore, any development or topographical change occurring within the catchment after the surveys taken is not included in this investigation, unless specifically specified.

There are a number of limitations that apply to the modelling to date, some of which include:

- Stakeholder engagement will continue during detailed design, construction and operation. As such proposed impacts and structural solutions still need to be confirmed with relevant stakeholders. Modelling may need to be updated as a result of any ongoing stakeholder engagement.

ARR 2019 outlines several fundamental themes which are also particularly relevant to this investigation:

- All models are coarse simplifications of very complex processes. No model can therefore be perfect, and no model can represent all of the important processes accurately.
- Model accuracy and reliability will always be limited by the accuracy of the terrain and other input data
- Model accuracy and reliability will always be limited by the reliability/uncertainty of the inflow data
- No model is ‘correct’ therefore the results require interpretation
- A model developed for a specific purpose is probably unsuitable for another purpose without modification, adjustment, and recalibration. The responsibility must always remain with the modeller to determine whether the model is suitable for a given problem.
- Recognition that no two flood events behave in exactly the same manner
- Design floods are a best estimate of an “average” flood for their probability of occurrence

The interpretation of results and other presentations in this report should be done with an appreciation of any limitations in their accuracy, as noted above.

Unless otherwise stated, presentations in this report are based on peak values of water surface level, flow, depth and velocity. Therefore, using water levels as an example, the peak level does not occur everywhere at the same time and, therefore, the values presented are based on taking the maximum value which occurred at each computational point in the model during the entire flood event. Hence, a presentation of peak water levels does not represent an instantaneous point in time, but rather an envelope of the maximum values that occurred at each computational point over the duration of the flood event.

Digitisation of the levees based on 2019 LiDAR data capture was undertaken to represent the current topographic conditions. Levees were manually digitised from upstream of the model to downstream of Goondiwindi to ensure the heights were captured in the hydraulic model. Digitisation was focused on key levees that impact the flood flows and are within the floodplain. It is noted that the area for capture is significant and that detail was extracted at a high level to allow efficient development of the data set. Some levees may not be included in the digitisation, but all levees are included in the 2019 LiDAR that is incorporated as a dataset in the model. The digitised levee lines are draped over the 2019 lidar to “force” the elevations in the model grid to ensure no gaps occur in the levees within the model topography based on the 30 m grid cell. To ensure the highest point was included along the levee a buffer was added to the line to capture the high points where the manually digitised line lies off the crest. For the 30 m grid scale of this model this is considered suitable to provide a representation of the topographic features. There may be some resulting inconsistencies in the elevations at each point and the elevation from the LiDAR at that location as a result of this process. These have been spot checked and found to be minor.

12 References

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