Australian Government

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ARTC InlandRail

Inland Rail Programme

Narrabri to North Star Project

Environmental Impact Statement

Technical Report 6: **Hydrology and Flooding Assessment**

Technical Report 7: **Water Quality Assessment**

Image: Newell Highway north of Narrabri, NSW

Technical Report 6:
Hydrology and Flooding Assessment

Image: Railway and Newell Highway north of Narrabri, NSW

Australian Rail Track Corporation

Inland Rail - Narrabri to North Star

Hydrology and Flooding Assessment

October 2017

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Abbreviations

Abbreviation	Explanation
AEP	Annual exceedance probability
AHD	Australian Height Datum
ARI	Average recurrence interval
ARR	Australian Rainfall and Runoff
ARTC	Australian Rail Track Corporation
BoM	Bureau of Meteorology
DEM	Digital Elevation Model
DPI	NSW Department of Primary Industries
EIS	Environmental Impact Statement
EMA	Emergency Management Australia
EMP	Environment Management Plan
EPA	Environmental Protection Agency
GHD	GHD Pty Ltd
IFD	Intensity-Frequency-Duration
LiDAR	Light Detection and Ranging
AHD	Australian Height Datum
MDB	Murray-Darling Basin
NARCLiM	NSW and ACT Regional Climate Model
NSW	New South Wales
NWQMS	National Water Quality Management Strategy
OEH	Office Environment and Heritage
RCBC	Reinforced concrete box culvert
RCP	Reinforced concrete pipe
RORB	Runoff Routing model
RFFE	Regional Flood Frequency Estimation
SEARs	Secretary's Environmental Assessment Requirements
SRTM	Shuttle Radar Topography Mission

Glossary

Term	Explanation
Afflux	A rise in flood level as a result of an obstruction to flow.
Alluvial plain	A large relatively flat area formed by deposition of sediment over an extended period.
Alluvial sediment	Loose sediments mobilised and deposited by non-marine water actions (e.g. floodplain soils).
Annual Exceedance Probability (AEP)	The chance of a flood if a nominated size occurring in a particular year. The chance of the flood occurring is expressed as a percentage and, for large floods, is the reciprocal of the ARI. For example, the 1 per cent AEP flood event is equivalent to the 100 year ARI flood event.
Australian Height datum (AHD)	National survey datum closely corresponding to mean sea level.
Average Recurrence interval (ARI)	The long term average number of years between the occurrence of a flood of a nominated size.
Ballast	Rock placed under the rail ties (sleepers) to provide stable support for a rail line.
Bidirectional	Allowing train travel in either direction according to the infrastructure and system of safe working in use.
Brownfield	Development areas that have been previously developed.
Calcic soil	A soil containing a relatively high concentration of secondary calcium carbonate.
Catchment	The catchment at a particular point is the area of land that drains to that point.
Cell	Culvert design term meaning single opening.
Cess	Space between the outermost rail and the rail corridor boundary.
Chainage	A measure of distance along the rail corridor from Sydney. The nominated values are not exact distances as there are some local adjustments made to reflect progressive changes to the rail as works are progressively implemented to, for example, ease bends.
Channelized fill	Channelized fill systems are generally laterally, stable channels of low sinuosity incised within flat and featureless floodplains.
Chert	A hard, dark opaque rock composed of silica with a microscopically fine grained texture.
Critical duration	The design rainfall duration that provided the greatest predicted flow rate in a catchment area.
Design flood	A flood event, based on a design storm of a specific duration (critical duration) that creates the greatest volume of rainfall-runoff for a given probability of occurrence.
Design storm	A synthetic storm event used for modelling purposes, derived using the methods outlined in ARR.
Dispersive	A characteristic of soil indicating the potential for the breakdown of clay minerals into single clay particles in solution.

Term	Explanation
Embankment	An earth or stone bank, built to support a rail line or provide flood protection.
Ephemeral	Temporary, short-lived (for example, “ephemeral creek”).
Existing rail corridor	The area of land that is identified for the continued operation of the rail line between Narrabri to North Star.
Flood	Relatively high river, creek or water way flow which overtop the natural or artificial banks to inundate surrounding areas in an uncontrolled manner.
Flood depth	The depth of floodwater above ground level.
Flood plain	Land adjacent to a river, creek or waterway that is periodically inundated due to floods. The floodplain includes all land that is susceptible to inundation during the probable maximum flood event.
Flood-prone land	Land susceptible to inundation by the probable maximum flood.
Flood storage	Floodplain area that is important for the temporary storage of floodwaters during a flood.
Floodway	A flow path natural or artificial that carries floodwater during a flood.
Formation	The earthen embankment that supports the ballast, ties and rail associated with a railway.
Hardsetting	A soil in which the topsoil sets hart when dry.
Hillslope	An area of land that flanks a valley and the margins of upslope steeper areas.
Historical flood	A flood that has occurred at some point in the past.
Hydraulic	The study of water flow in natural or artificial water ways.
Hydrograph	A graph showing water flow of a river, creek or water way over time.
Hydrology	The study or rainfall and runoff process.
Kaolin	A mineral within clay.
Lithosol	A group of soils that lack a defined soil structure.
Loam	A fertile soil comprising a mix of sand, silt and clay.
Local catchment	The area of land that lies upslope from a specified point.
Major under track structure	Has a design flow greater than 50 m^3/s.
Minor structure	Has a design flow less than 50 m^3/s.
Morphology	The form, shape and structure of a catchment.
Multicell	Multiple number of openings within a structure.
Perennial	Permanent, enduring (for example, “perennial river”).
Permeability	A measure of the ability of the soil to transmit water.
Pineena	The NSW Government water database.
Probable maximum flood	An extreme flood deemed to be the maximum flood likely to ever occur.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Proposal	The construction and operation of the Narrabri to North Star project.

Term	Explanation
Proposal site	The area that would be directly affected by construction works. The proposal site is considered to have a width of 30 metres, providing for a 15 metre buffer on each side of the alignment centreline. It includes the location of proposal infrastructure, the area that would be directly disturbed by the movement of construction plant and machinery, and the location of the storage areas/compounds sites that would be used to construct that infrastructure.
Rail overtopping	Flood waters rising above the level of the rail.
Regional Flood Frequency	A method of estimating flood flows for small ungauged basins.
Reinforced concrete box culvert	A drainage structure that has a rectangular cross sectional shape and is manufactured from concrete with steel reinforcing in the concrete walls.
River style	A classification of a watercourse based on character, behaviour, condition and recovery potential.
Runoff	The amount of rainfall from a catchment that actually ends up as flowing water in the river or creek.
Salinity	Refers to the amount of salt present in the soil solution.
Salting	The formation of a salt layer on the soil surface.
Sandstone	A sedimentary rock composed mainly of sand.
Siltstone	A sedimentary rock composed mainly of silt.
Sinuosity	Capacity to curve.
Sodic soil	Sodicity is a term that indicates the amount of sodium present in a soil.
Soffit	Underside of a bridge.
Stable channel	A watercourse that is not subject to significant changes in channel geometry.
Stage-storage	The relationship between water depth and storage volume within a dam or other water storage.
Stoniness	The tendency for presence of stones in soil.
Stream order	A measure of the relative size of a watercourse.
Structure	An underbridge or culvert under the rail line passing over a watercourse, pathway, floodway or some other similar feature.
Study area	The total area that may be impacted by construction and operation of the proposal.
System of safe working	An integrated system of operating procedures and technologies used for safe operation of trains and the protection of people and property.
Subsoil	The layer of soil below the topsoil.
Topsoil	The upper or outermost soil layer. Typically 5 to 20 cm thick.
Track	The combination of rails, rail connectors, sleepers, ballast, points, crossings and any substitute devices.
Triangular hydrograph	A synthetic hydrograph, based on the estimated peak flood flow rate.
Underbridge	A bridge supporting the track and passing over a watercourse, roadway, pathway, floodplain or some other similar feature.

Term	Explanation
Unidirectional	Allowing train travel in a single direction according to the infrastructure and system of safe working in use.
Watercourse	A flow path that may operate during times of surface runoff. Generally the flow path will have a defined cross sectional shape.
Waterlogging	A soil that contains the maximum practical amount of water.
Water take	The extraction of surface or groundwater interception.
Weir	A structure that partially retains water, regulating water levels upslope of the structure.
Valley fill	Unconsolidated deposits of sediment within a valley, typically eroded from the surrounding hillslopes.
Velocity	The speed at which the floodwaters are moving.

Executive summary

The proposal

Australian Rail Track Corporation Ltd (ARTC) is seeking approval to construct and operate the Narrabri to North Star section of Inland Rail ('the proposal').

The proposal would involve upgrading the existing rail line for a distance of 188 kilometres between Narrabri and North Star via Moree, including new crossing loops, track realignment and new sections of rail line, new river crossings, and new road over rail bridges at Jones Avenue and Newell Highway.

Ancillary work would include works to level crossings, signalling and communications, signage, fencing, and services and utilities.

This report

This report forms supporting documentation for the environmental impact statement (EIS) for the proposal and specifically addresses the environmental assessment requirements of the Secretary of the Department of Planning and Environment (the SEARs) regarding hydrology, hydraulics and flooding.

The proposal site

The proposal site is located within the Gwydir, Mehi and Macintyre river catchments. The Namoi and Macintyre rivers are considered to have a substantially lower level of interaction compared with the Gwydir and Mehi rivers. It crosses several named watercourses. The majority of the watercourses are ephemeral and there is a minimal amount of water quality data to describe the existing conditions. Soils within the proposal site are generally identified as being highly erodible.

Design methodology

The design development process included an integration of the track formation design, structure sizing, and analysis of the potential impacts of the proposal. Structures were sized using predicted flows that would arise from rainfall events over the local catchment areas.

Structures under the formation were sized to provide a target performance requirement of conveying the one annual exceedance probability (AEP) flow while not having the upstream one per cent AEP ponding level above the top of formation where reasonably practicable.

In addition to the study of local catchments by GHD, a flood impact assessment of Moree floodplain was undertaken by Jacobs on behalf of GHD. These assessments were undertaken with the aim to inform the status of compliance with the Secretary's Environmental Assessment Requirements (SEARs). These studies identified the local and regional river (Gwydir/Mehi) flood impacts on the reliability of the proposal.

Risk assessment

The hydrology and flooding risk assessments identified the following to be the main potential risks emanating from construction and operation of the proposal:

- Changes to flow paths across the rail corridor.
- Change to fish passage through culvert structures.

- Changes to flow rates and levels of surface waters and groundwater due to water extraction during construction.
- Changes to flood levels and flooding durations, associated with both local and regional scale flood events, both upstream and downstream of the proposal with impacts upstream of the proposal being the more significant.
- Potential erosion effects in watercourses downstream of culverts.

The most noticeable change to flooding conditions would be a reduction in the frequency and extent of overtopping of the rail level as the proposal would result in a raising, in most areas, of the rail formation. In large floods this will force more water through culverts.

As the proposal includes, as far as practical, a like for like replacement of the rail line (with respect to both crossing structures and rail level), regional scale flooding within the Gwydir and Mehi River system within the vicinity of Moree is expected to remain generally consistent with current flood patterns. No appreciable changes to flood hazards within residential areas of Moree is expected.

Mitigation measures

An extensive list of measures was incorporated into the design to mitigate adverse impacts, as much as practical, while achieving the design criteria of the proposal. Impact mitigation measures that were either implemented in the design, or are proposed, include:

- Maintaining culverts across the rail corridor at, or very close to existing locations to maintain the existing flow paths across the rail corridor.
- Maintaining culvert capacities as close as practical to the existing capacity to restrict the extent and amount of increased risk exacerbating downstream flooding conditions and erosion risks while not excessively exacerbating upstream flooding risks.
- Including a general raising of the rail level to remove the uncontrolled overtopping of the rail line for events of a magnitude up to the one per cent AEP magnitude except at a limited number of level crossings and within the vicinity of Moree during regional scale flood events.
- Using pre-cast box culverts for the construction to minimise the amount of onsite concrete work and reduce the amount of water required on site during construction, and to speed the construction process.
- Sourcing the water required for construction from several locations to minimise the impact at the extraction locations.

Residual risks of proposal

Even with the implementation of these mitigation measures, some adverse effects of the proposal would remain, including:

- Changes to the upstream flooding regime. The magnitude of these changes are quantified in this document and vary along the length of the proposal, with modelled one per cent AEP flood levels for the design conditions being on average approximately equal to the existing conditions, with changes in levels ranging from increases of up to about 1.6 metres and decreases of up to about three metres. The assessment indicated there would be some changes in flood levels and flood extents upstream of the proposal site. These changes would largely be a result of the lifting of the level of the rail formation; this would be partly counteracted by the provision of larger culverts under the rail formation, which (where practical) are designed to convey the one per cent AEP flood event. There will also be an increase in the flooding duration upstream of the proposal in some locations because all floodwater has to drain through the provided culverts.
- The proposal would overtop at seven level crossings where the formation has only a minimal lift. These locations are identified in this report. Additional analysis may help to identify design improvements that could reduce the extent of modelled formation overtopping. The largest depth of overtopping is predicted as being 370 mm adjacent to Burrington Road south of Moree, with 240 mm depth of overtopping adjacent to Murrumbilla Lane and Newell Highway, 250 mm depth of overtopping at Ten Mile Lane and 290 mm depth of overtopping near two unnamed level crossings. The remaining overtoppings were no greater than 200 mm deep. Of these seven locations, six are currently expected to overtop during flood events.

An examination of potential public road closures was completed for the area within the available LiDAR survey. The road closure locations were similar in location to those for the existing conditions but the depths of water creating the closure did change, with the duration of road closures estimated to change by no more than about an hour. The analysis showed that six roads would close in design events at a distance from the proposal site due to the longitudinal grading of the road.

1. Introduction

1.1 Overview

The Australian Government has committed to delivering a significant piece of national transport infrastructure by constructing a high performance and direct interstate freight rail corridor between Melbourne and Brisbane. The Inland Rail programme (Inland Rail) involves the design and construction of a new inland rail connection, about 1,700 km long, between Melbourne and Brisbane. Inland Rail is a transformational rail infrastructure initiative that will enhance Australia's existing national rail network and serve the interstate freight market.

Australian Rail Track Corporation Ltd (ARTC) is seeking approval to construct and operate the Narrabri to North Star section of Inland Rail ('the proposal'), which consists of 188 kilometres of upgraded rail track and associated facilities.

The proposal requires approval from the NSW Minister for Planning under Part 5.1 of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act). The proposal is also a controlled action under the Commonwealth *Environment Protection Biodiversity Conservation Act 1999* (EPBC Act), and requires approval from the Australian Minister for the Environment and Energy.

This report has been prepared by GHD Pty Ltd (GHD) as part of the environmental impact statement (EIS) for the proposal. The EIS has been prepared to accompany the application for approval of the proposal, and addresses the environmental assessment requirements of the Secretary of the Department of Planning and Environment (the SEARs), issued on 8 November 2016.

1.2 The proposal

1.2.1 Location

The proposal is generally located in the existing rail corridor between the town of Narrabri and the village of North Star, via Moree. The location of the proposal is shown in Figure 1.1.

1.2.2 Key features

The key features of the proposal involve:

- Upgrading the track, track formation, and culverts within the existing rail corridor for a distance of 188 kilometres between Narrabri and North Star via Moree.
- Realigning the track where required within the existing rail corridor to conform with required platform clearances for Inland Rail trains.
- Providing five new crossing loops within the existing rail corridor at Bobbiwaa, Waterloo Creek, Tycannah Creek, Coolleearllee and Murgo.
- Providing a new section of rail line at Camurra about 1.6 kilometres long to bypass the existing hairpin curve ('the Camurra bypass').
- Removing the existing bridges and providing new rail bridges over the Mehi and Gwydir rivers and Croppa Creek.

- Realigning about 1.5 kilometres of the Newell Highway near Bellata and providing a new road bridge over the existing rail corridor ('the Newell Highway overbridge').
- Providing a new road bridge over the existing rail corridor at Jones Avenue in Moree ('the Jones Avenue overbridge').

The key features of the proposal are shown in Figure 1.2.

Ancillary work would include works to level crossings, signalling and communications, signage and fencing, and services and utilities.

Further information on the proposal is provided in the EIS.

1.2.3 Timing

Subject to approval of the proposal, construction is planned to start in early to mid 2018, and is expected to take about 24 months. Existing train operations along the Narrabri to North Star line would continue following construction. Inland Rail as a whole is expected to be operational in 2025.

1.2.4 Operation

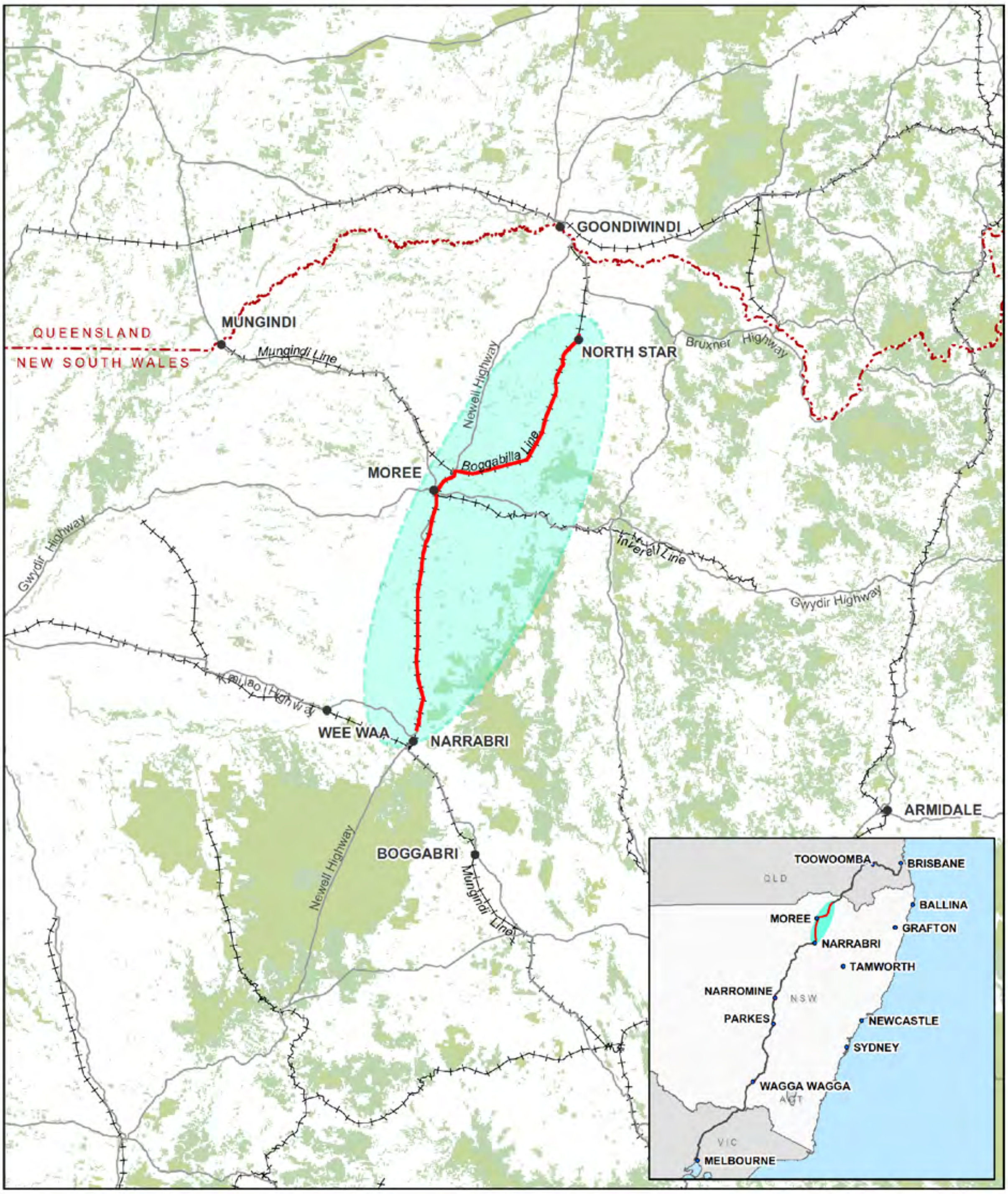
Prior to the opening of Inland Rail as a whole, the proposal would be used by existing rail traffic, which includes trains carrying passengers and grain at an average rate of about four trains per day. It is estimated that the operation of Inland Rail would involve an annual average of about 10 trains per day travelling north of Moree (between North Star and Moree) and 12 trains per day travelling south of Moree (between Moree and Narrabri) in 2025. This would increase to about 19 trains per day north of Moree (between North Star and Moree) and 21 trains per day south of Moree (between Moree and Narrabri) in 2040. The trains would be a mix of grain, intermodal (freight), and other general transport trains.

Once operational in 2020, the proposal would enable increased train running speeds in many areas that are currently the subject of restrictions due to local track conditions. Daily average train volumes are not expected to significantly change until Inland Rail through connection in 2025.

1.3 Purpose and scope of this report

This report provides the results of the hydrologic, hydraulic and flooding impact assessment of the proposal as required by the SEARS, Section 2.5.5 and Section 2.6.4. The report:

- Provides a brief overview of the proposal.
- Provides a brief overview of the available data.
- Describes the existing environmental conditions.
- Documents the hydrologic, hydraulic and flooding impacts of the proposal. Water quality issues and impacts are described in a separate report titled ARTC Inland Rail – Narrabri to North Star Water Quality Report (GHD 2017).
- Identifies proposed ongoing monitoring programs for the verification of predicted water extraction and flood impacts.



LEGEND

- Proposal site
- Proposal location
- Main road
- Railway
- State border

Paper Size A4

0 10 20 40 60

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Australian Rail Track Corporation
Inland Rail Track Alignment

Job Number 22-17916
Revision 0
Date 02 Jun 2017

Location of the proposal

Figure 1-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

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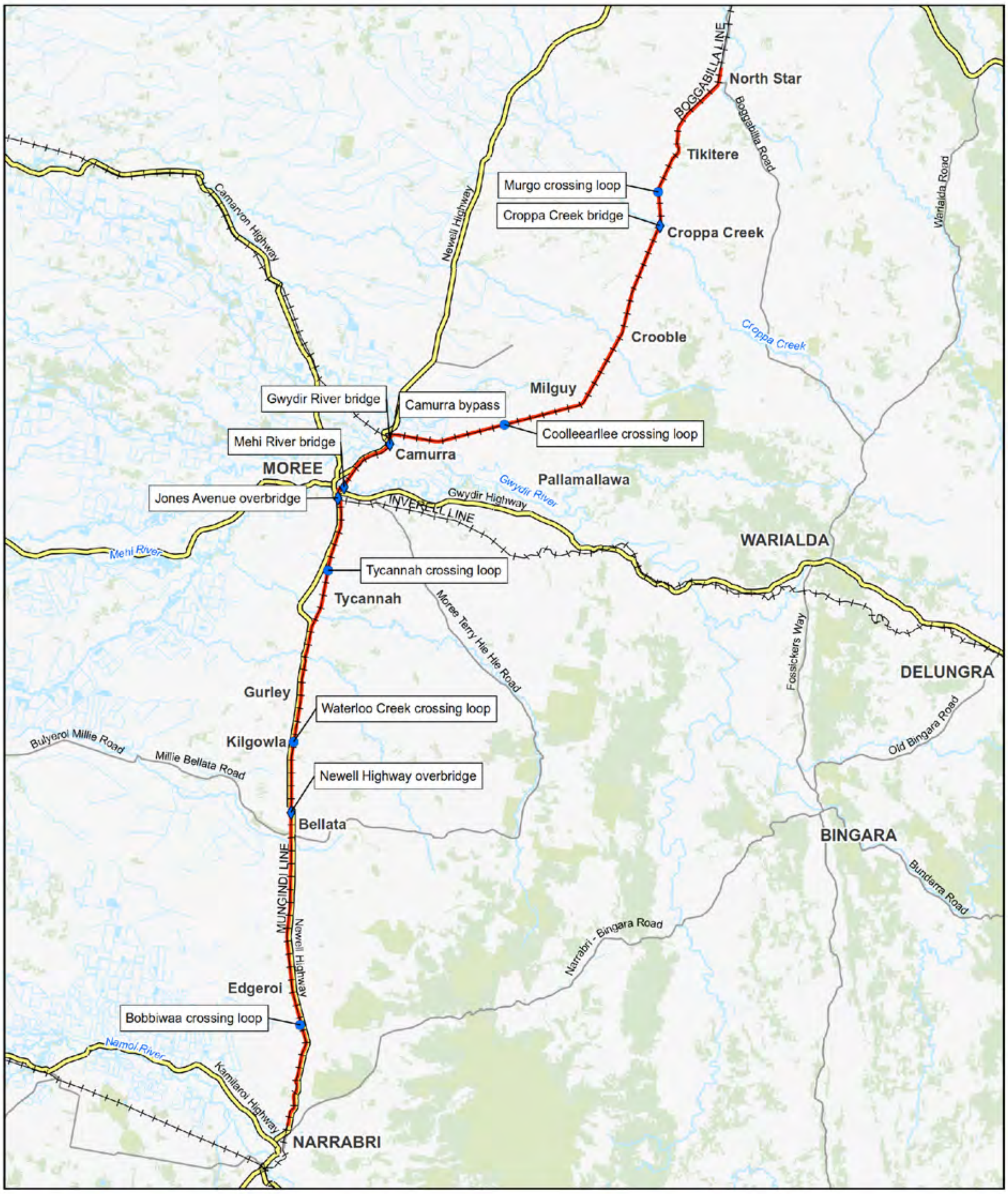
Data source: Commonwealth of Australia (Geoscience Australia), 250K Topographic Data Series 3, 2006. Created by: tmorton, kpsrcba



LEGEND

- New bridge
- Crossing loop
- The proposal
- Railway
- Highway
- Road

Paper Size A4

0 3 6 12 18 24

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Australian Rail Track Corportion
Inland Rail Track Alignment

Job Number	22-17916
Revision	0
Date	01 Aug 2017

Key features of the proposal

Figure 1-2

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

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Data source: Commonwealth of Australia (Geoscience Australia), 250K Topographic Data Series 3, 2006. Created by: gmcdiarmid, tmorton, kpsroba

1.5 Structure of this report

The structure of the report is provided in Table 1.1.

Table 1.1 Report structure

Section	Details
1	Provides an introduction to the report.
2	Describes the methodology for the assessment.
3	Provides available data and a summary of the physical characteristics of the proposal site.
4	Describes the existing hydrology, flooding and water quality of the proposal site.
5	Provides a hydrologic and hydraulic risk assessment for the proposal.
6	Describes the hydrologic and flooding impacts of the proposal and recommended measures to manage construction and operational impacts.
7	Describes hydrologic and hydraulic monitoring conditions.
8	Provides conclusions from the investigation.

2. Assessment approach and methodology

2.1 Definitions

2.1.1 Study area

The study area for the hydrology and flooding investigation is considered the area that may be affected (directly or indirectly) by the proposal. The analysis focussed on watercourses and associated floodplains that the proposal would cross.

Regional floods, typically due to flooding from major rivers and watercourses from rainfall, affect a significant portion of the three river basin catchments in the study area – the Namoi River basin, Gwydir River basin and Macintyre River basin as detailed in Section 3.8.1. It should be noted that the Gwydir River catchment includes the Mehi River, with an overlapping floodplain near Moree.

2.1.2 Terminology

Hydrology

Hydrology refers to the estimation of runoff from a catchment. Runoff is generated when rainfall hits the ground. For any given catchment, the relationship between rainfall and runoff can be used to predict peak flow rates at a nominated discharge point by considering the catchment's characteristics including, but not limited to, its terrain, soil type, shape, land use, vegetation coverage, areas of inundation and water storage.

Surface water in the study area mainly comprises ephemeral watercourses and a small number of perennial major river systems (regional catchments) that pass through the study area.

Flood event

A flood event can be either:

- An historical flood event that has occurred and for which flood levels and rainfall data may have been gauged.
- A design flood event, which is generated based on a design storm of a specific duration (critical duration) that creates the greatest volume of rainfall-runoff for a given probability of occurrence.

Historical flood events may be compared with a design event of a similar size to indicate the likelihood of that specific event occurring. Design flood events are generally referenced to a probability using the term Annual Exceedance Probability (AEP).

The AEP relates to the chance of a flood of a given size (or larger) occurring in any one year, usually expressed as a percentage. For example, a five per cent AEP flood event has a five per cent (or one in 20) chance of occurring in any one year.

Structure

A structure in this report usually refers to a circular or rectangular culvert or underbridge that allows water to pass under an embankment (such as a rail embankment). Structures many either be single cell (one opening) or multi-cell (multiple openings).

2.2 Design objectives

In summary, the design objective for the proposal is to upgrade the rail line from near Narrabri to North Star to achieve an acceptable performance standard while remaining cost effective for the forecast increased loadings, considering both an anticipated increase in the train frequency and an increase in the axle loading of carriages. This objective requires:

- Reconstructing embankments
- Replacing structures
- Easing rail curves
- Building new crossing loops

Inland Rail is customer-centric infrastructure that will offer freight customers on the east coast competitive pricing, 98% reliability, a transit time from Melbourne to Brisbane of less than 24 hours, flexibility for faster and slower services and freight that is available when the market wants. The availability targets are a summation of all factors that would affect the availability of the rail line, such as flooding, breakdowns, maintenance and other factors.

2.2.1 Design requirements

Technical Note ETD-10-02 provides the design requirements for greenfield and brownfield rail developments. Generally, the design requirements for hydraulic performance of the proposal (as outlined by ETD-10-02) are as follows:

- The flood immunity is defined as the level of impact during one per cent AEP event flood, which is taken as being equivalent in magnitude to the 100 year Average Recurrence Interval (ARI) event.
- The flood immunity and serviceability limit state AEP is taken as being the one per cent AEP event flood level at the shoulder corner of the formation capping (i.e. top of formation).

Key infrastructure should not be located within the one per cent AEP flood prone area, or, where this is not possible, to design for a flood immunity of one per cent AEP. These requirements are primarily concerned with local catchment flood events, rather than regional flood events. A regional flood event is considered as being one in the Namoi, Gwydir or Mehi Rivers and adjacent floodplains that has been caused by rainfall over a significant portion of the upstream catchment area.

It should be noted that ETD-10-02 does not require that brownfield developments be immune to the one per cent AEP flood event. Instead, areas that are affected by the one percent AEP flood event are identified.

The combined upstream catchment area is made up of a number of smaller catchments that do not directly interact with the project infrastructure. The potential flow interaction of regional flood events with the local catchments was not considered during this assessment with the exception of the Gwydir River and Mehi River around Moree, as outside of this area the dominant flood mechanism is considered to be local catchment flooding. Within this area, the immunity of the proposal to regional flood events is considered.

2.3 Design

2.3.1 Form

Engineering features of the proposal that would impact the hydrology and hydraulics would primarily be the raising of the existing rail embankment along the majority of the rail corridor across the floodplain. The embankment and upgraded structures would be required to permit an appropriate flow to minimise adverse flooding impacts.

The design process included initial flood modelling to identify the necessary locations for raising the track and upgrading structures to meet the adopted drainage performance requirements (refer to Section 2.2.1). The proposed design track level considers the required track level for flood immunity as well as other design requirements (such as maintaining the existing track elevation at level crossings).

Figure 2.1 provides the existing natural surface along the main corridor between Narrabri and North Star and the design track long section together with the location and quantities of lift between the existing track level and the design track level. No (or minimal) lift was applied at existing level crossings.

The location of proposed structures along the same length of the proposal site are shown in Figure 2.2. The level of the structures on this figure are offset eight metres below the track level for clarity. This figure also shows locations where the design includes no rail lift.

Figure 2.2 shows the locations of proposed culverts in plan view for the section of rail between Narrabri to North Star to assist with their location. The proposed structures are all located at, or very close to, the locations of the existing culverts.

2.3.2 Proposal boundaries or assessment – Narrabri to North Star

The entire Inland Rail program extends from Melbourne and Brisbane. The proposal being considered within this report is the existing rail corridor between Narrabri, at approximately chainage 569.240 km and North Star, at chainage 758.571 km.

2.4 Relativity of conditions and impacts

2.4.1 Surface and below surface impacts

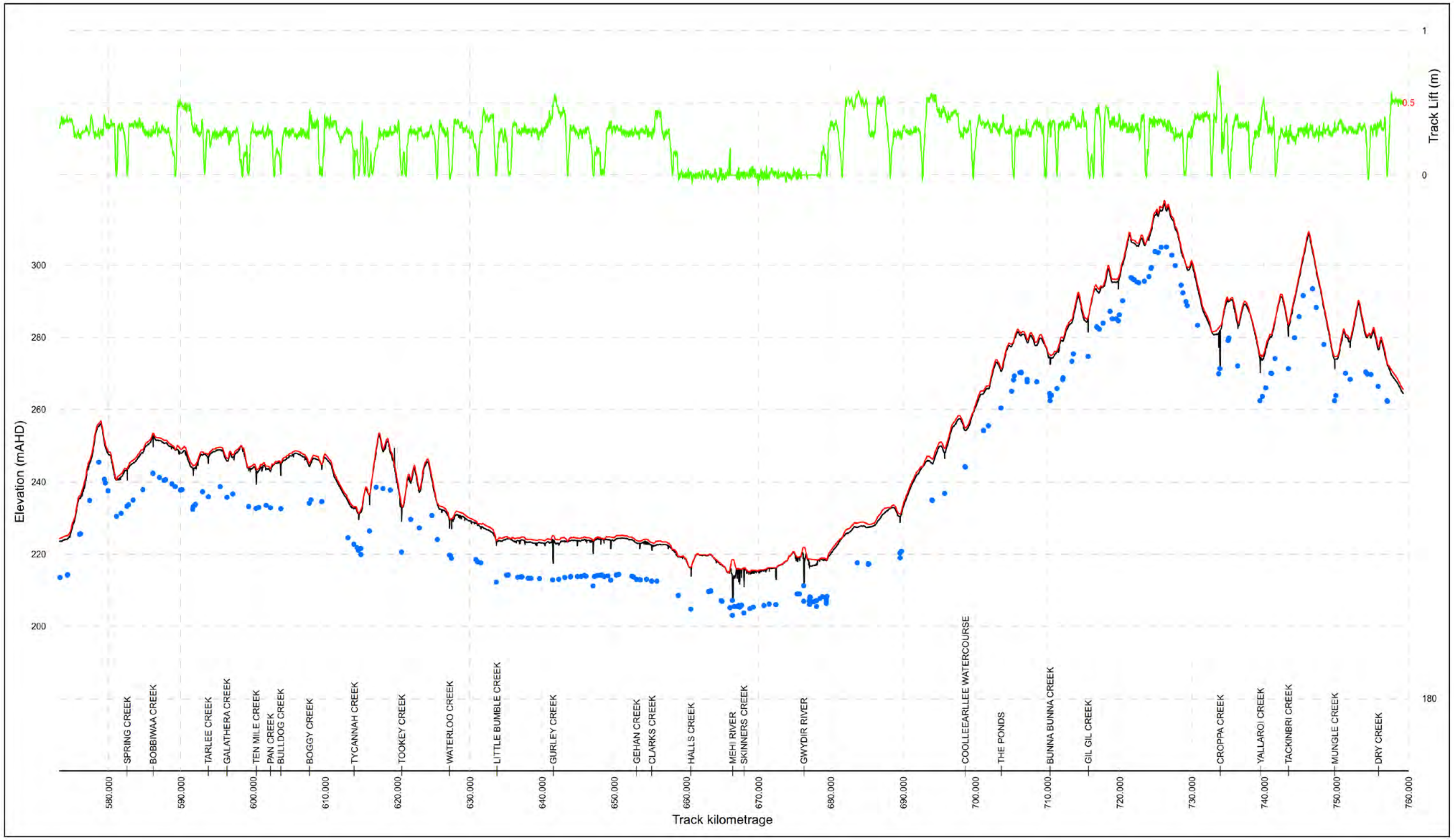
The proposal, as described in Section 2.3.1, primarily involves the construction of track and formation, culverts and other surface infrastructure, at or close to the ground surface. There would be a limited amount of below groundwork, which would be confined to structure foundations.

Because of this, this report focuses on the surface hydrology and flooding issues and impact assessment more than the below ground conditions and impacts.

2.4.2 Relativity of flow and flooding impacts

The proposal has the potential to impact surface flow and flooding conditions, impacting:

- Local catchment runoff and flooding conditions
- Large river regional catchment flows and flooding conditions



Paper Size A3

LEGEND
- Design
- Natural Surface
- Track Lift
- Culverts

Australian Rail Track Corporation
Inland Rail Route- Narrabri to North Star

Job Number	22-17916
Revision	0
Date	16 Aug 2017

Design Track Alignment

Figure 2-1

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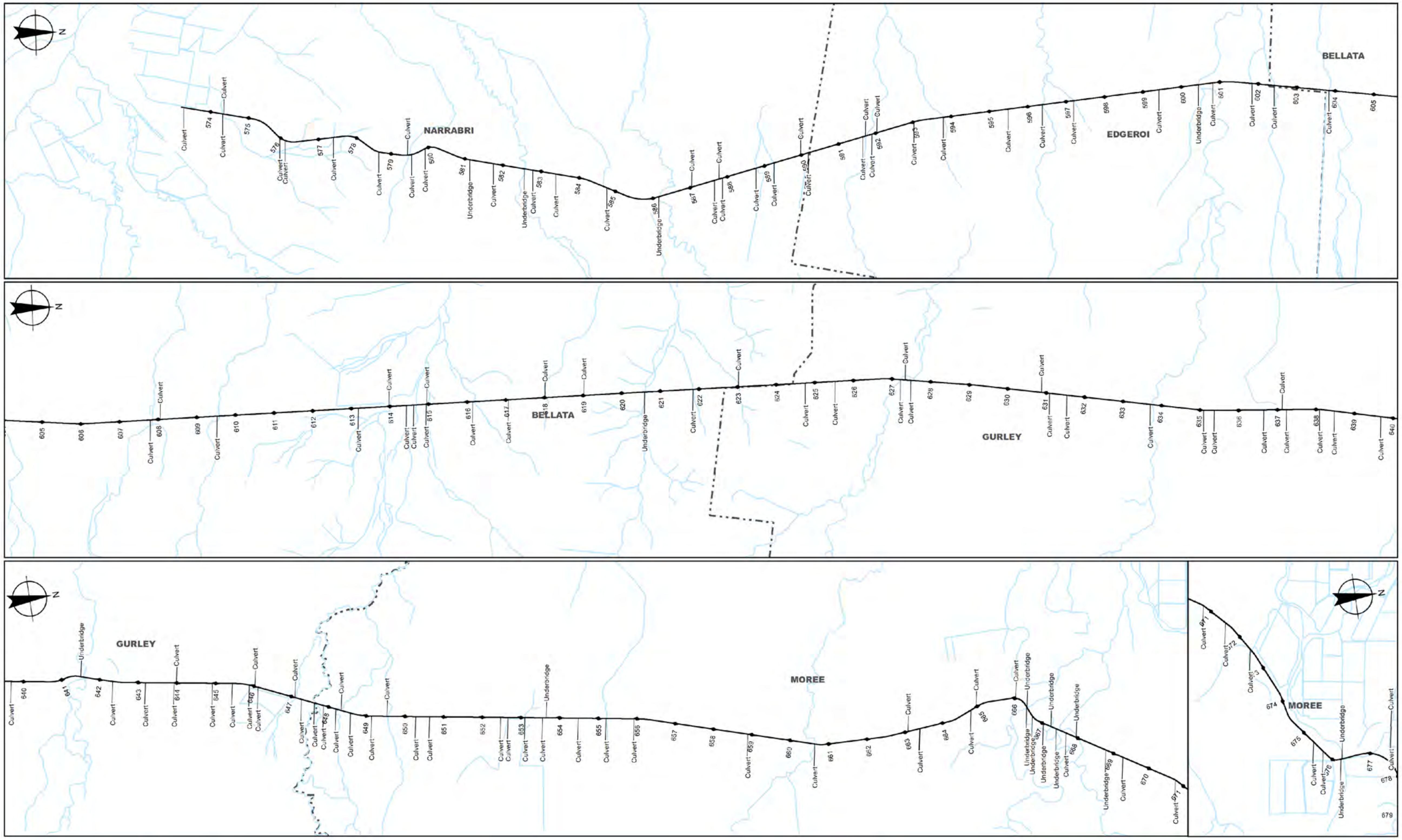
180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: LPI: Watercourses, 2012. ARTC: Aerial lidar, 2015. Created by:gmcdiarmid



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

Rail Centreline
Watercourse
Suburb boundary

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number	22-17916
Revision	0
Date	16 Aug 2017

Proposed Culvert Locations- Sheet 1 Figure 2-2a

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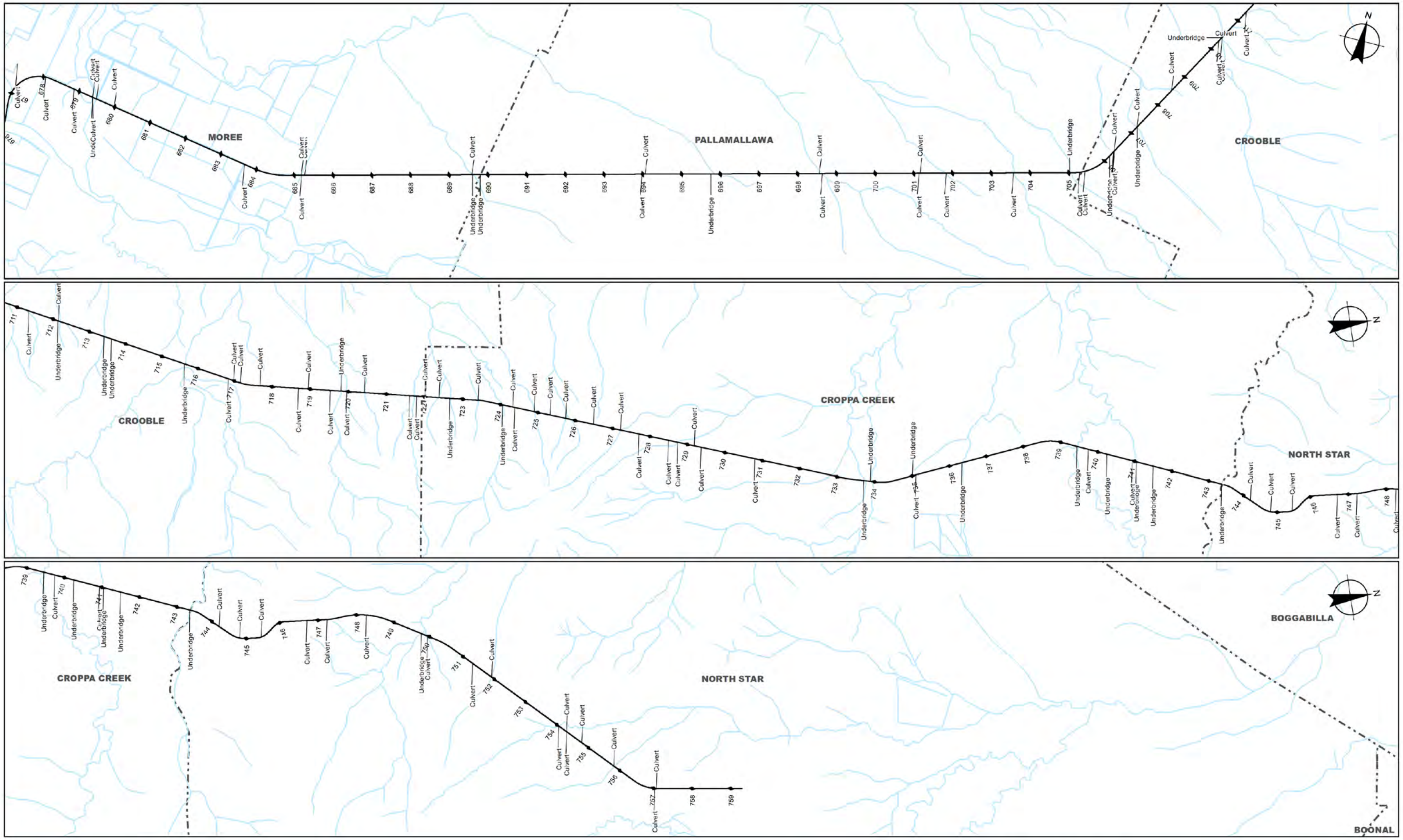
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND
Rail Centreline
Watercourse
Suburb boundary

GHD

Australian Rail Track Corporation
Inland Rail - Narrabri to NorthStar

Job Number	22-17916
Revision	0
Date	16 Aug 2017

Proposed Culvert Locations - Sheet 2 Figure 2-2b

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Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba

The proposal is designed to consider and mitigate where practicable, predicted impacts that would occur because of local catchment rainfall and runoff events. In this context, a local catchment is taken to represent one that is not a major river (Namoi, Gwydir and Macintyre rivers). The three major river systems would potentially flood the proposal. It is considered impractical to use hydrologic and flooding for all of the regional rivers, with the exception of the Gwydir and Mehi River systems and the Namoi River and Narrabri Creek systems, which pass through the regional centres of Moree and Narrabri respectively, and therefore warrant additional assessment. It was considered impractical to use hydrologic modelling due to the extensive scale required to model these systems. The Namoi and Macintyre rivers are considered to have a substantially lower level of interaction compared with the Gwydir and Mehi rivers. This means production of large scale models to check this limited effect would be of little value to the proposal.

2.5 Hydrology

2.5.1 Methodology – local catchment surface water assessment

Estimated local catchment surface flow rates arriving at structures were developed based on the contributing catchment area and application of a design rainfall of varying duration to that catchment area.

For some localised areas, it was found that flows from adjacent local catchments would interact prior to flowing over the rail line. In these locations, the hydrologic and hydraulic assessment was required to consider the coincident flows from the adjacent local catchment areas.

Two flow configurations arose:

- Where the peak flow at a structure could pass through the structure without either the track overtopping or the catchment boundary being overtopped into the adjacent catchment (flow parallel to rail alignment), the flood level was determined based on the capacity of the structure in a particular catchment area.
- Where flow could not pass through the structure and the predicted water level resulted in overtopping of the rail level or overtopping of the adjacent catchment boundary – or both of the above conditions – the calculations were expanded to obtain a flood level that considered the hydraulic capacity of the structure. The resulting flow over the rail and/or the resulting flow into the adjacent catchment concurrently acknowledging all resulting outflow relationships to establish the resulting flood level of the initial structure and those subsequently affected. Flow over the top of the rail was assessed as a weir.

A detailed description of the hydrologic analysis assessment is provided in Appendix A. In summary, the process involved:

- Identification of the existing structures for the establishment of the base (existing) flooding conditions. For the design conditions, this involved identification of each watercourse and natural depression along the study area and assigning a structure to each location.
- Extraction of the existing structure geometry, level and form from existing ARTC data for the existing base case conditions.
- Determination of the local catchment area draining to each of the structure locations.

- Application of design rainfalls to each local catchment to determine the peak rate of runoff from the catchments for a broad range of design rainfall durations. The analysis of the peak flow rates, initially made using flows estimated from the Probabilistic Rational Method of calculations, were adjusted to better replicate comparative flows established using a RORB hydrologic model established for selected localised culverts.
- Establishment of a stage-storage volume relationship for the area immediately upstream of each rail crossing assuming a horizontal water surface extended from the rail line to the upslope intersection with the natural water surface.
- Formation of triangular hydrographs from the above peak flow rates; these were then routed through each stage-storage volume with the outlets from that catchment being through the structure (culvert or bridge), over the rail line if the flood level exceeded the minimum track level and potentially into the adjacent catchments.
- Repetition of the routing process for different rainfall durations to establish the one giving the highest flood level for each AEP when allowing, if required, flow interaction between catchments. This step directly linked to the hydraulic and flooding assessment.
- Progressively increasing the number of barrels forming a culvert for the design case, using the standard structure sizes, until desired design criteria were achieved.

The identification of the required combination of structure upgrade (i.e. inclusion of additional barrels) and local formation lift was undertaken using the process summarised in Figure 2.3. Initially, the feasibility of replacing the existing structures with similarly sized replacement culverts was assessed. If these like-for-like structures met the performance requirements (refer to Section 2.2.1), the structure was considered adequate. If the performance requirements were not met, additional barrels were added and the upgraded structure reassessed (Cycle A: refer to Figure 2.3) or the additional lifts added to the formation (Cycle B: refer to Figure 2.3). This process is repeated until the performance requirements are met, or it is identified that the performance requirements cannot be reasonably met without excessive lifting of the formations (considered to be greater than one metre) or significant increase in the number of culvert barrels (considered to be 12 barrels).

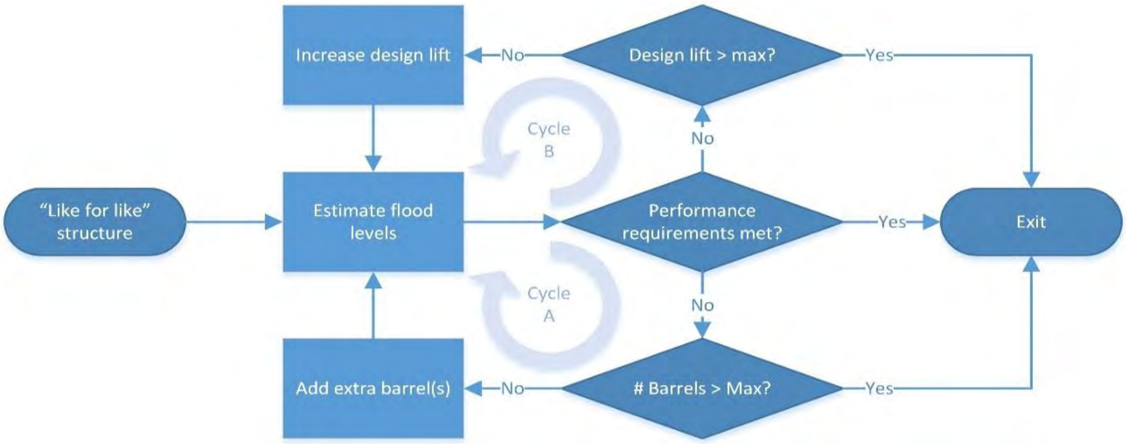


Figure 2.3 Formation and culvert size – selection process

Probable maximum flood

The method above was used to estimate the likely response of the culverts to the probable maximum flood (PMF) based on the estimated peak rainfall intensity of the probably maximum precipitation (PMP). The PMP was estimated using either the *Generalised Short Duration Method* (GSDM) for critical storm duration less than six hours (BOM 2003) or the *Generalised Tropical Southeast Australia Method* (GTSMR) for longer storm durations (BOM 2004).

2.5.2 Limitations of local catchment surface water analysis method

The adopted analysis contained a number of simplifications that should be removed during further design development. Details of the simplifications are provided in 0.

These simplifications should be removed for future design through:

- Obtaining a broader and more reliable terrain representation upstream of the existing rail corridor to permit a more reliable definition of flow paths connecting adjacent catchments.
- Adoption of more comprehensive and rigorous hydrologic and hydraulic analysis techniques to represent better the catchment response to rainfall and the catchment flow paths, directions and velocities for overland flows and watercourses. A more comprehensive hydraulic analysis technique would also permit a more rigorous assessment of the extent of upstream flood extents and impacts as the current analysis adopted a horizontal flood surface upstream of the existing rail corridor and upstream of the proposal.
- Consideration of effects of downstream flood levels on the culvert flows. In this current assessment, the downstream effects have not been considered due to the interaction between downstream catchments, extent and quality of terrain definition and potential for local farm works that could impact flow conditions. Downstream impacts are expected to be minimal where culverts and formation are replaced like for like. At some locations where curve easing results in a change in alignment (e.g. Cumurra), new culverts have been selected and located to preserve the existing flow paths and minimise the potential impacts to flood depths upstream and downstream.
- Consideration of the potential flow interaction of regional flood events with the local catchments. The current local catchment analysis has only considered flood events resulting from rainfalls on individual and small groups of catchments immediately upstream of the existing rail corridor.

2.5.3 Methodology – regional flood impact assessments

Overview

A regional flood impact assessment was undertaken for the Gwydir and Mehi rivers and associated floodplains. This was undertaken for the purpose of determining what works would be required to lift the existing rail alignment above the one per cent AEP event whilst ensuring that there is no significant increase in flooding levels within the regional centres of Moree and Narrabri respectively. These regional centres include residential, commercial and industrial areas that are typically more sensitive to flood impacts than the surrounding rural areas.

Moree area

Moree Plains Shire Council provided an existing flood model for the Gwydir and Mehi rivers and the associated floodplains around Moree for the flood impact assessment. The model was developed as part of the Review of Moree and Environs Flood Study/Floodplain Risk Management Study and Plan (WRM, December 2016) and was in a draft form at the time of undertaking the flood assessment.

This model contains estimated flood discharges at Moree derived from:

- The recorded flows at the Gwydir River at Gravesend stream gauge (GS418013) to estimate upper Gwydir River catchment flows.
- An XP RAFTS rainfall runoff model (XP Software, 2013) of the residual catchment downstream of Gravesend

The abovementioned hydrology (XP-RAFTS) model, along with the associated flood model (refer to Section 2.6.2) was used to assess the potential impacts of the proposal on flooding within the vicinity of Moree.

Narrabri area

Narrabri Shire Council has recently had a draft study, titled *Narrabri Flood Study – Namoi River, Mulgate Creek and Long Gully* (WRM 2016) placed on their web site. Results from that assessment were considered in this investigation as they represent the most recent flood level and condition results for the Narrabri area.

Project specific modelling and analysis has not been completed for regional flooding conditions adjacent to Narrabri, as the regional flood mapping included in the *Narrabri Flood Study – Namoi River, Mulgate Creek and Long Gully* indicates that the proposal site is located outside of the regional flooding extents.

2.5.4 Methodology – groundwater assessment

The methodology applied to the groundwater assessment included identification of the geological formations, the main groundwater sources, the characteristics of the sources and licensed extraction points from the groundwater. The potential impacts on groundwater were qualitatively assessed.

2.5.5 Outcomes sought in relation to hydrology

Hydrologic outcomes identified by government agencies as being required in the assessment are detailed in Table 2.1.

2.6 Flooding

2.6.1 Methodology – local catchment analysis

The proposal includes the raising or reconstruction of significant lengths of rail across large, relatively flat areas, including floodplains. During small floods, flows are conveyed through the defined incised channels, where they exist, while for larger flow rates the water flow would occur within the incised channels and over the floodplain areas. As a minimum, a structure was retained at or near the location as in the existing case to minimise potential hydrologic and hydraulic impacts of any redirections of flow or creation of new flood ponding areas that could not drain. At a few locations, the culvert position was repositioned by a few metres to better position the culvert at the low point along the rail corridor. The flood management objectives of conveying flow across the rail corridor and the culvert size were considered in conjunction with the selection of the rail formation level along the length of the proposal.

Table 2.1 Required hydrologic outcomes

Agency	Desired performance outcome	Requirement	Where Addressed
DP&E	Long term impacts on surface water and groundwater hydrology are minimised. Environmental values of nearby, connected and affected water sources, groundwater and dependent ecological systems are maintained (where values are achieved) or improved and maintained (where values are not achieved). Sustainable use of water resources.	• Describe the existing hydrologic regime for surface and groundwater resources likely to be impacted by the proposal, including stream orders. • Assess (and model if appropriate) the impact of the proposal (including ancillary facilities) during construction and operation on surface and groundwater hydrology, including: – Natural processes within rivers, wetlands, and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health, aquatic connectivity and access to habitat for spawning and refuge. – Direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses. – The effects of proposed water management during construction and operation on natural hydrologic attributes and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems. – Water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation.	Section 3.8.2, Table 3.4 and Figure 3.5 Section 2.5/0 Table 3-3, Section 6.2 and Section 6.3 Table 5-1 and Section 6.3 Section 3.4 and Section 3.6
DPI	DPI Fisheries needs to be consulted with regards to the crossing methodology and site-specific mitigation measures for replacement of culverts and bridges in watercourses that are considered to be Key Fish Habitat.	• Design and construct bridges, culverts and temporary access tracks across all watercourses in accordance with appropriate guidelines. • Replace watercourse crossings with minimal impact on the aquatic environment. • Provide details on methods duration and timing of dredging, and the proposed mitigation measures to protect riparian and aquatic habitat. • Minimise temporary watercourse crossings for heavy machinery. • Consult with DPI Fisheries in regard to any temporary measures that would result in blocking fish passage.	Sections 6.2.1, 6.2.2, 6.2.4 Sections 6.3.3 and 6.3.4 Sections 6.2.1, 6.2.2, 6.2.4 Sections 6.2.1, 6.2.2, 6.2.4 Noted

The flood impacts attributable to the proposal were identified by quantifying the flooding behaviour of the base case and comparing that with the flooding behaviour for the case with the proposal constructed.

Local catchment flood behaviour of the proposal was established using the assessment methodology as described in Appendix A.

The flooding assessment considered flood flows generated within the local catchment areas upslope of the proposal, with no consideration of the influence of downstream flooding on tailwater conditions. Downstream impacts are expected to be minimal where culverts locations are retained. At some locations where curve easing results in a change in alignment (e.g. Camurra), new culverts have been selected at locations that preserve the existing flow paths and minimise the potential impacts to flood depths upstream and downstream. It should be noted that the existing culverts under the Camurra hairpin would be retained, assisting in maintaining the existing flow paths and flood depths downstream of the rail corridor.

Downstream tailwater effects will be considered during subsequent design phases. Tailwater effects on the flooding upstream of the existing rail corridor would only occur when the tailwater level was sufficiently high that it would impact the adopted culvert inlet control conditions and cause higher upstream flood levels to occur. At times when tailwater conditions do influence the culvert flow there is a need for correct quantification of the tailwater level, as this level will directly influence the flood level upstream of the culvert.

There were a number of reasons for only considering the upstream flood effects, principally:

- The site is generally brownfield, and culvert and bridge locations were being generally maintained, therefore the pattern of flooding and drainage downstream of the track was expected to remain largely unaffected.
- The modelling of local (upstream) catchment flooding was considered to represent the conditions under which the track would have the greatest influence on flood levels. Under these conditions flood extents would only increase on the upstream side with negligible impact or improvement in flood extents on the downstream side.
- By assuming free-flowing outlet conditions, the maximum flow velocities through each culvert could be estimated, assisting in the identification of scour protection requirements, as well as simplifying the issue of tailwater conditions, which would otherwise require extending the modelling area significantly downstream. Suitable scour protection measures are to be included downstream of each culvert to assist in dissipating discharges, protecting the downstream watercourses and receiving environment from erosion and scouring.

Changes to flooding behaviour derived from the assessment were used to define the proposal impacts. These areas were then overlaid on aerial photography and available information to identify the impacts on public and private property including built-up areas, farm infrastructure, cropping areas, grazing and forested areas, likely evacuation routes and flood refuges.

This process allowed identification of the magnitude of the predicted impacts for a range of flooding parameters and flood magnitudes. Based on these identified impacts, the proposal was assessed against the flood management objectives.

Stakeholder engagement meetings were undertaken following the initial flooding assessment to obtain feedback on the assessment of the predicted existing condition flood levels and extents. Landowner feedback is provided in diagrammatic form in Chapter 4.

2.6.2 Flood impact assessment – regional analysis near Moree

A flood impact assessment was undertaken for Gwydir and Mehi rivers and associated floodplains around Moree. This was undertaken utilising a flood model (and hydrology models: refer to Section 2.5.3) that was previously developed and calibrated by Moree Plains Shire Council.

It was agreed with Council and the NSW Office of Environment and Heritage that the draft flood model would be suitable to assess relative impacts of the proposed upgrade and future assessments on subsequent phases of design.

The flood model was updated to include additional existing structures, and enhanced representation of the rail embankment and the proposed structures. Following the update, the model was used to quantify flooding conditions for the existing, design and a limited number of alternate design forms. The alternate design forms do not form part of the proposal.

The model output included flood levels, velocities and identified changes in operation of the floodplain because of a modelled scenario.

The updated model and report has been provided to Moree Plains Shire Council for consideration as part of ARTC’s ongoing engagement with Council regarding the potential impacts of the proposal.

2.6.3 Flood impact assessment – regional analysis near Narrabri

Design regional flooding conditions in the proximity of Narrabri were extracted from the previously identified report prepared by others.

2.6.4 Outcomes sought in relation to flooding

Flooding outcomes from the assessment are detailed in Table 2.2 against the agency requesting the outcome.

Table 2.2 Required flooding outcomes

Agency	Desired performance outcome	Requirement	Where Addressed
DP&E	The proposal minimises adverse impacts on existing flooding characteristics. Construction and operation of the proposal avoids or minimises the risk of, and adverse impacts from, infrastructure flooding, flooding hazards, and dam failure.	• Assess and model impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (including potential climate change impacts) and quantify:	Section 6
		– Detrimental increases in the potential flood affectation of other properties, assets and infrastructure.	Sections 6.3.1, 6.3.4, 6.3.5, 6.3.6 and 6.3.7
		– Consistency (or inconsistency) with applicable council floodplain risk management plans.	Section 2.7.3
		– Compatibility with the flood hazard of the land.	Sections 4.3.5 and 6.3.6
		– Compatibility with the hydraulic conveyance in floodways and storage areas of the land.	Sections 4.3.4 and 6.3.4
		– Downstream velocity and scour potential.	Sections 4.3.4 and 6.3.4
		– impacts of the proposal on existing emergency management arrangements for flooding, and consultation with State Emergency Services and council.	Sections 4.3.6 and 6.3.6
		– Any impacts the proposal may have on social and economic costs to the community as consequence of flooding.	Section 6.3.6
OEH	Flooding impacts are minimised.	• Define and map features as described in the Floodplain Development Manual (DIPNR 2005) including: – Flood-prone land – Flood planning area – Hydraulic categorisation	Sections 4 and 6
		• Describe the flood assessment undertaken to assess the design flood levels for events, including a minimum of the 1 in 10 year and 1 in 100 year flood levels, and the probable maximum flood, or an equivalent extreme event.	Sections 6, Appendices A, E, H and J
		• Assess the effect of the proposal (including fill) on the flood behaviour under the following scenarios: – Current flood behaviour for a range of design events as identified earlier. This includes the 1 in 200 and 1 in 500 year flood events as proxies for climate change effects – Design forms.	Sections 6, Appendices A, E, H and J

Agency	Desired performance outcome	Requirement	Where Addressed
		• Consider and document:	Section 6
		– Impacts of the full range of flood events including up to the probable maximum flood.	Sections 4 and 6
		– Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affectation of other developments or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories.	Section 6
		– Relevant provisions of the NSW Floodplain Development Manual (DIPNR 2005).	Section 2.7.3
		• Assess the impacts on the proposal on flood behaviour, including:	
		– Any detrimental increases in the potential flood affectation of other properties, assets and infrastructure.	Sections 6.3.1, 6.3.4, 6.3.5 6.3.6 and 6.3.7
		– Consistency with council floodplain risk management plans.	Section 2.7.3
		– Compatibility with the flood hazard of the land.	Sections 4.3.6 and 6.3.6
		– Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land.	Sections 4.3.4 and 6.3.4
		– Potential for adverse effect to beneficial inundation of the floodplain environment.	Sections 4.3.4 and 6.3.4
		– Any direct or indirect increase in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses.	Sections 4.3.4 and 6.3.4
		– Any impacts upon existing community emergency management arrangements for flooding.	Sections 4.3.6 and 6.3.6
		– Any specific measures to manage risk to life from flood.	
		– Emergency management, evacuation and access, and contingency measures considering the full range or flood risk.	Sections 4.3.6 and 6.3.6
		– Social and economic costs resulting from flooding.	Section 6.3.6

2.7 Legislation, policy and guideline context

A range of legislation, policy and guidelines directs the way water resources are managed in NSW. Key documents relevant to the proposal are outlined below.

2.7.1 General

Water Management Act

Two key pieces of legislation for management of water within NSW are the *Water Management Act 2000* and the *Water Act 1912*. These Acts control the extraction of water, the use of water, the construction of works such as dams and weirs and the carrying out of activities in or near water sources in NSW. The provisions of the *Water Management Act 2000* are being progressively implemented to replace the requirements of *Water Act 1912*. Since 1 July 2004, the new licensing and approvals system has been in effect in those areas of NSW covered by commenced water sharing plans.

A controlled activity approval under the *Water Management Act 2000* is required for certain types of developments and activities that are carried out in or near waterfront land. However, under section 115ZG of the EP&A Act, an activity approval (including a controlled activity approval) under section 91 of the *Water Management Act 2000* is not required for State significant infrastructure. However, the design and construction of the proposal would take into account the NSW Office of Water's guidelines for controlled activities on waterfront land. Development on floodplains is managed under Part 8 of the *Water Act 1912.* Part 8 makes provisions for 'controlled works' defined as works that affect, or are likely to affect, flooding and/or floodplain functions. Part 8 was amended in 1999 to allow for more strategic control of such works through the preparation of suitably developed floodplain management plans. This allows for a broader consideration of issues in the approval of existing and proposed controlled works. Eventually, the *Water Management Act 2000* will contain all of the floodplain management provisions in Part 8; however, until Part 8 is repealed, both pieces of legislation are referenced.

Following introduction of the *Water Management Act 2000*, water sharing plans were developed that cover part of all of the proposal:

- Gwydir Regulated River Water Sources
- Gwydir Unregulated and Alluvial Water Sources
- Lower Gwydir Groundwater Source
- Namoi Unregulated and Alluvial Water Sources
- Upper and Lower Namoi Groundwater Sources
- NSW Border Rivers Regulated River
- NSW Murray-Darling Basin Porous Rock Groundwater
- NSW Great Artesian Basin Groundwater Sources
- NSW Great Artesian Basin Shallow Groundwater Sources.

A water sharing plan is generally in place for 10 years, but may be suspended from time to time under Section 49(a) of the Act due to severe water shortages.

To preserve water resources in river and groundwater systems for the future, the competing needs of the environment and water users are to be balanced. Water sharing plans establish rules for sharing water between the environmental needs of the river or aquifer and water users (for town water supply, rural domestic water supply, stock watering, industry and irrigation).

Australian Rainfall and Runoff

Australian Rainfall and Runoff (Pilgrim et al., 1987; Ball et al., 2016) is a national guideline for the estimation of design flood characteristics in Australia. The approaches presented in Australian Rainfall and Runoff are essential for policy decisions and projects involving:

- Infrastructure such as roads, rail, bridges, dams and stormwater systems
- Flood management plans for urban and rural communities
- Flood warnings and flood emergency management
- Estimation of extreme flood levels

Reference was made to Australian Rainfall and Runoff in developing the methodological framework for assessing impacts on hydrology, flooding and water quality.

2.7.2 Floodplain development

Primary requirements for floodplain development are detailed in the Floodplain Development Manual (DIPNR 2005). Key policy and guidelines documents focusing on specific needs of the community and stakeholder in relation to floodplain development are summarised below.

Floodplain development manual

The Floodplain Development Manual (DIPNR 2005) was gazetted as the manual pertaining to the development of flood-liable land. The manual highlights the requirements consistent with the *Water Act 1912* to manage the risks resulting from natural hazards in order to reduce the impact of flooding on individual owners and occupiers of flood-prone property and to reduce private and public losses resulting from floods.

The Floodplain Development Manual encourages the completion of floodplain works to be completed so that:

- The passage of floodwaters is unobstructed
- Temporary pondage of floodwaters is maintained

Local government requirements

Local government requirements are consistent with the principles established in the Floodplain Development Manual in respect to the location and permissible impacts of development projects. However, for some developments, local government authorities have minimum development requirements.

The previously prepared floodplain risk management plans for Moree (Parsons Brinkerhoff 2008) is to be updated following the recent completion of flood study review (WRM 2016). A floodplain risk management plan for Narrabri is yet to be prepared following the review of the flood study (URS 2014).

Hazard

Flood preparedness, flood hazard and emergency management guidelines have been developed and are available from the State Emergency Services (SES 2012, 2013, 2014). Emergency Management Australia (EMA 1999, 2009a, 2009b, 2009c) and Australian Rainfall and Runoff (Engineers Australia 2015) also provide guidelines in respect to hazard categorisation and management.

These guidelines would be considered in the assessment of changes to potential road closures and road safety.

ARTC guidelines

The ARTC's *Engineering Practices Manual, Civil Engineering, Track Drainage - Design and Construction (ARTC 2013)* details minimum design criteria and construction practices expected by ARTC throughout the planning, design, construction and operation of the rail line.

3. Available data

This chapter presents a discussion on the physical characteristics of the study area. It is based on information in available reports and studies along with information supplied by ARTC and NSW and Australian government departments in support of the proposal.

3.1 Local government areas

The proposal is located within the Narrabri Shire Council, Moree Plains Shire Council and Gwydir Shire Council local government areas.

3.2 Climate

The Central West region of NSW has a warm temperate climate, with large variations between summer and winter temperatures. Summers are hot and sunny with rainfall typically occurring as thunderstorms or short and intense storm events. Winters are cool and sunny with occasional cold fronts that bring periods of prolonged light rainfall.

A number of long-term Bureau of Meteorology (BoM) meteorological recording stations are located within or adjacent to the study area, as listed in Table 3.1.

Table 3.1 Meteorological recording stations

Region	Name	Number	Latitude	Longitude	Starting Year
Narrabri	Narrabri Bowling Club	054120	30.32	149.78	1870
Narrabri	Narrabri West Post Office	053030	30.34	149.76	1891
North Star	North Star (Bonanza)	053076	28.95	150.26	1966
Moree	Moree Aero	053115	29.49	149.85	1995
Moree	Mallowa (Narba)	053070	29.62	149.377	1967

The mean annual rainfall recorded at these stations varies along the alignment. The average annual rainfall is about 640 mm. Rainfall occurs relatively uniformly throughout the year.

3.2.1 Design rainfalls

Design rainfall data was obtained from the BoM Intensity Frequency Duration (IFD) generation process based on Australian Rainfall and Runoff (Pilgrim *et al.*, 1987 and Ball *et al.*, 2016). The rainfall IFD patterns for Narrabri and North Star are effectively the same for both ends of the proposal. Therefore, the section of proposed track between Narrabri and North Star could be adequately represented by a single rainfall IFD pattern. A comparison of the 1987 and 2013 IFD data showed only minor differences.

3.2.2 Climate change impacts

The New South Wales and Regional Climate Model (NARCLiM) models provide recent projections for the potential climate change impacts for the New England North West region, which include the study area. Of particular importance is the predicted precipitation (rainfall) changes from 1990-2009 through to 2020–2039 and 2060–2079. The data is summarised in Table 3.2.

Table 3.2 NARCLiM data summary

Parameter	Projected change (%) to 2020–2039	Projected change (%) to 2060–2079
Annual mean rainfall change	-9 to 13	-8 to 24
Summer rainfall	-15 to 14	-10 to 42
Autumn rainfall	-9 to 47	-1 to 49
Winter rainfall	-26 to 15	-29 to 30
Spring rainfall	-11 to 19	-21 to 28

From the available NARCLiM modelling, climate change was assessed by adopting an increase in adopted rainfall IFD intensity varying from 10 to 30 per cent to account for estimated rainfall changes. This estimate is consistent with advice from Department of Environment and Climate Change (DECC 2007).

As indicated in the SEARs, consideration of the 0.5 per cent and 0.2 per cent ARI events were used as a surrogate for the specific evaluation of climate change impacts.

3.3 Terrain

Three sets of topographical data covering the study area were obtained:

- Survey model obtained through LiDAR survey and aerial imaging
- Digital Elevation Model (DEM) obtained through Shuttle Radar Topography Mission (SRTM)
- Localised site survey at early work locations supplied to selected culvert locations

The adopted terrain model is presented in Figure 3.1, which shows the general landform adjacent to the study area. This was formed from LiDAR (where available) and SRTM outside the LiDAR corridor. The higher portion of the rail corridor is toward the southern end.

3.3.1 LiDAR

A topographic survey model (0.5 points per square metre) was obtained through LiDAR imaging and provided by ARTC. Data validation showed the largest array of data set points had a mean difference of 0.348 metres and a standard deviation of 0.056 metres.

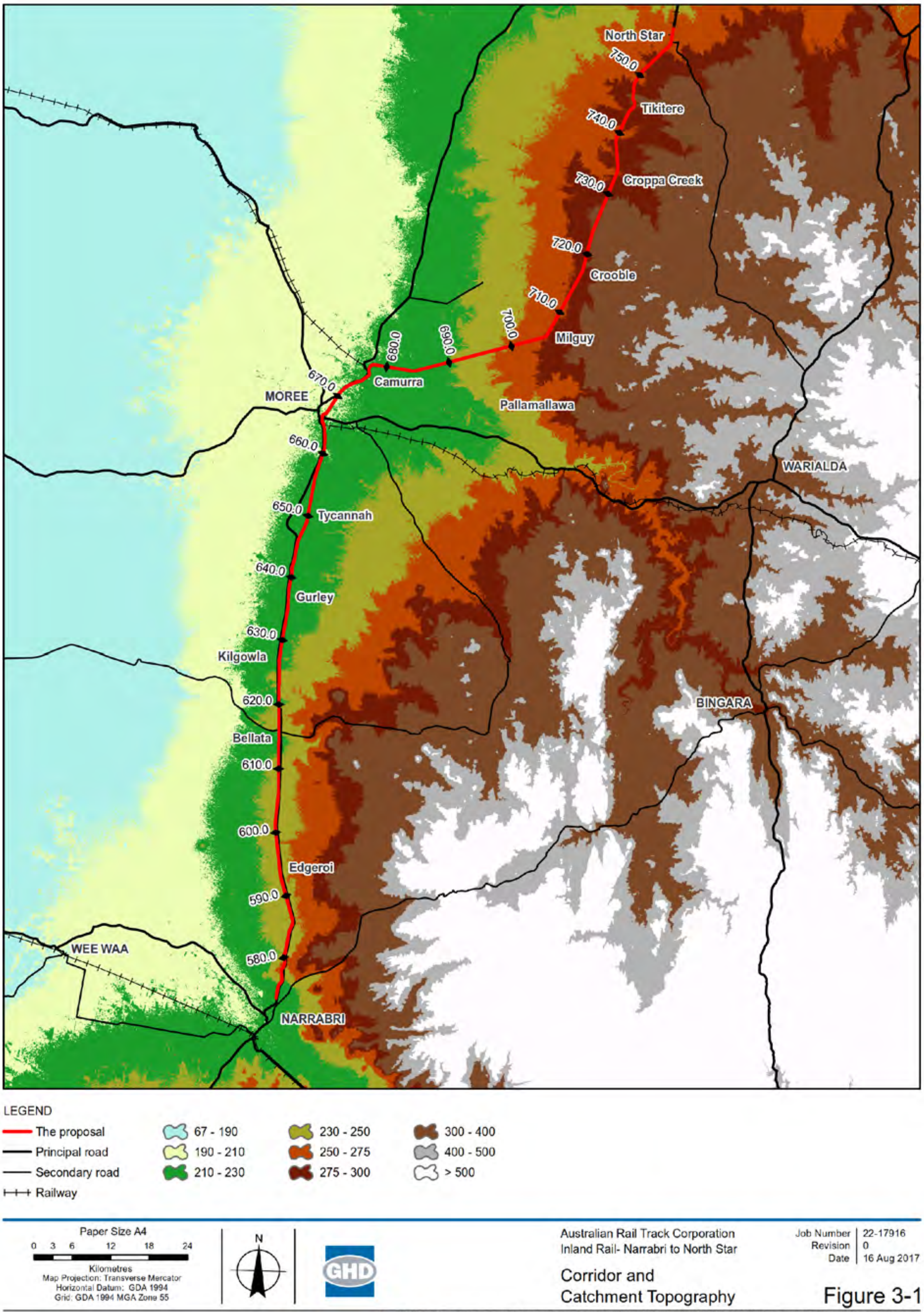
Catchment boundaries and rail track level were defined using the developed terrain model. Flood extents were mapped by extending the predicted flood levels upstream of the rail corridor until the terrain surface is reached. Flood extents were restricted to the LiDAR survey model extent, as extrapolation into the SRTM area was unreliable for mapping flood extents.

3.3.2 Shuttle radar

Topographic data generated by the SRTM program was used for terrain outside the LiDAR corridor where necessary to define catchment boundaries that extend beyond the supplied information. The resolution of the Digital Elevation Model is 30 metres. The reported vertical accuracy of the data is plus or minus 10 metres; however, the accuracy is expected to exceed this figure given the generally flat landscape. The SRTM data was used to form the terrain model outside the LiDAR corridor.

3.3.3 Site survey

ARTC provided a limited amount of field survey data adjacent to a very limited number of culvert locations. The provided survey data comprised of a few spot levels at each culvert location.



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Inland Rail- Narrabri to North Star

Job Number | 22-17916
Revision | 0
Date | 16 Aug 2017

Corridor and Catchment Topography

Figure 3-1

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH004_NNS_CatchmentTopography_0.mxd

Data source: LPI, DCDB, 2015; Geoscience Australia, 250K Topographic Data Series 3. Created by: gmcdiarmid, tmorton, kpsroba

3.3.4 Adopted levels

The different data sets gave differing levels for the existing top of the ballast and track. Since this assessment began when only the LiDAR survey was available, it was adopted as the standard with all other survey levels adjusted to match these levels as closely as possible.

Figure 2.1 provides a long section that was derived from the adopted terrain model along the rail corridor. This long section was extracted from the developed terrain model. The long section also shows, offset vertically by eight metres, the proposed structure locations.

3.4 Water demands

Estimated water demand for construction of the proposal may be in the order of 150 megalitres (up to about 75 megalitres per year) for earthworks and dust control. Potential water sources were identified, subject to the gaining of applicable approvals and access agreements and there being sufficient water at each site. These water sources are:

- Narrabri Shire Council (Waste water) – five megalitres
- Multiple Private bores within five kilometres of the alignment – about five to ten megalitres per bore
- Several Private dams within 10 kilometres of the alignment – about 20 megalitres each site
- Namoi River – 10 to 15 megalitres
- Gwydir River – 10 to 15 megalitres
- Mehi River – 10 to 15 megalitres
- Moree Shire Council (Wastewater) – five megalitres

The actual water sources and demand will be confirmed at the time of construction and will be highly dependent upon matters including the final design, weather and the adopted construction methodology.

3.5 Geology and soils

3.5.1 General

The study area is located generally within the Lachlan Fold Belt. Near surface materials include Tertiary to Quaternary alluvium and colluvial deposits over Jurassic sedimentary rocks with Cainozoic mafic volcanic outcrops intermittently along the rail corridor.

Deep riverine deposits of black and red clayey silt, sand and gravels are predominantly associated with the near level terrain surrounding Moree, with alluvial deposits of gravel, sand, silts and clays with sandstone outcrops associated with the undulating terrain surrounding Narrabri.

3.5.2 Soil groups and characteristics

Soil characteristics along the length of the proposal were determined from the eSpade database. Table 3.3 provides information on dominant soil groups along the length of the proposal. The dominant Great Soil Groups are shown in Figure 3.2.

Given soils in the study area are predominantly clays that have limited water storage potential, the initial and continuing infiltration losses associated with the catchment are expected to be low. As a result, the catchments will show a rapid and continuous response to rainfall given the low rainfall losses which will generate relatively high runoff rates.

3.5.3 Acid sulfate soils

The proposal site is not located within the risk areas for acid sulfate soils, as mapped by OEH (1998).

Table 3.3 Major soil groups

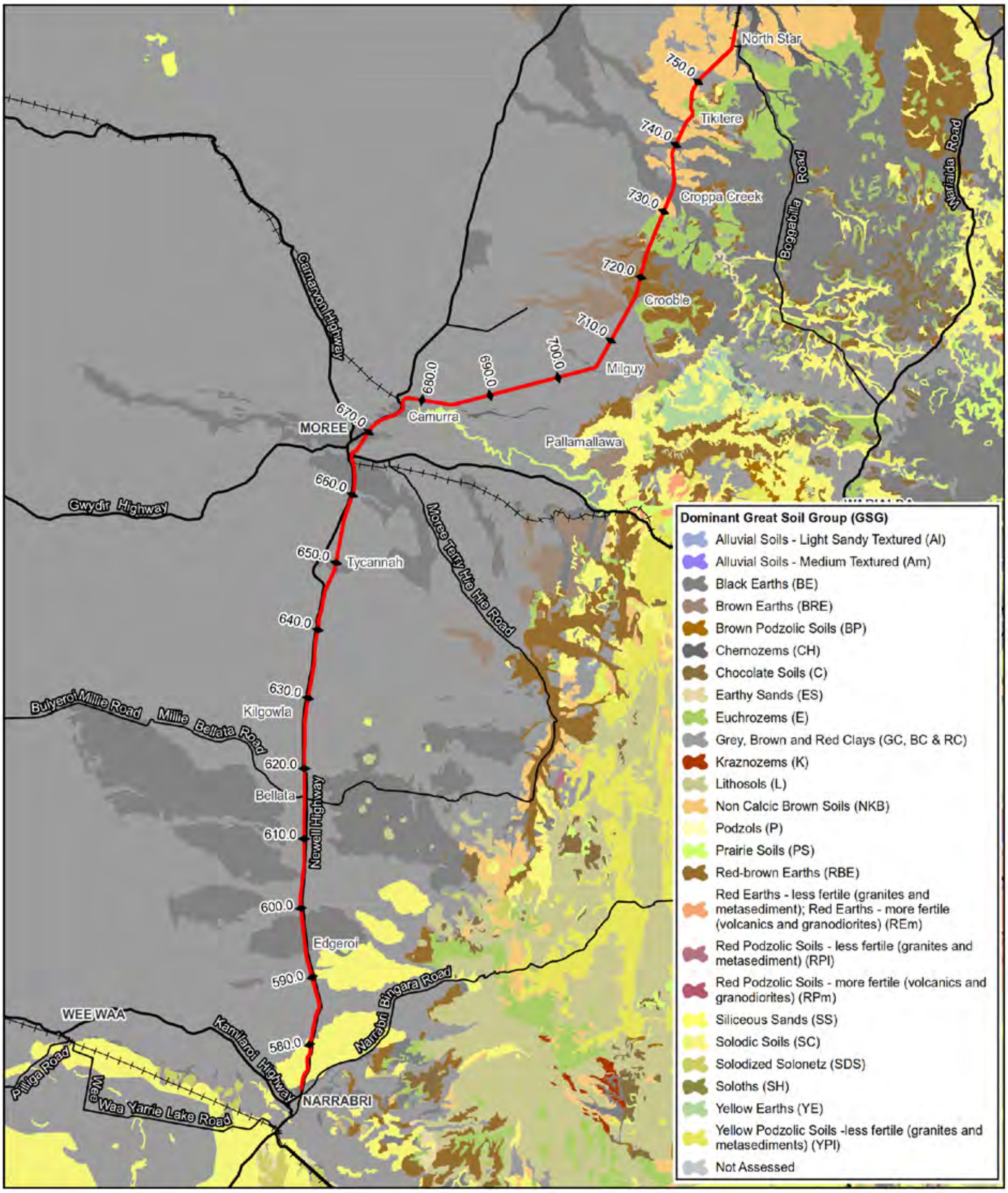
Range Soil Type Occurs (chainage)	Classification / Profile No.	Location	Soil types	Soil Characteristics	Erosion/Salinity
CH 573 - 575	337, 340, 342, 344, 7, 6, 336, 8, 6	Narrabri	Shallow (<15 cm) imperfectly drained Red-Brown earth occurs on hill crests, and imperfectly drained Prairie Soils occur in open depressions. Isolated areas of shallow (<3 cm) sandy loam also occur. Very deep (< 289 cm) poorly drained Grey Clay occurs in area.	Cracks evident Low to moderate soil erodibility	Slight erosion hazard on plains Moderate erosion hazard on slopes, with sheet erosion action occurring No salting evident
CH 575 - 578	9, 1, 5	North of Narrabri	Deep (<100 cm) imperfectly drained Red-Brown Earth occurs on lower slopes and within drainage depressions. Deep (<100 cm) imperfectly drained Solodic Soils and moderately well drained Red-Brown Earth occurs on upper slopes.	Cracks evident in clay layers Low to moderate soil erodibility on upper slopes, and low soil erodibility on lower slopes Moderate run-off from slopes	Slight to moderate erosion hazard on upper slopes Minor to moderate sheet erosion occurs on slopes Minor wind erosion No salting evident
CH 578 - 585	210, 2, 193, 175, 192	North of Narrabri	Moderately deep (<65 cm) loamy sandy top soil, with deep medium clay layers below extending to 273 cm. Deep (<273 cm) Solodic Soils and Brown Clays, deep (<341 cm) Grey Clay layers	Cracks evident in clay layers Seasonal cracking when dry	Erosion and salinity hazards not identified
CH 585 - 595	157, 158, 140, 293, 122	North of Narrabri to Edgeroi	Shallow (<10 cm) silty and sandy clay loam topsoil. Deep (<275 cm) imperfectly drained Brown Clay, Grey Clay and Alluvial Soils.	Cracks evident in clay layers Low run-off from plains	Slight erosion hazard No salting evident

Range Soil Type Occurs (chainage)	Classification / Profile No.	Location	Soil types	Soil Characteristics	Erosion/Salinity
CH 595 - 600	5, 87, 279, 69	North of Edgeroi	Deep (<120 cm) to very deep (<262 cm) imperfectly drained Grey Clay and very deep (<295 cm) Black Earth.	Low run-off from plains	Slight erosion hazard No salting evident
CH 600 - 615	278, 52, 34, 17, 90, 669, 470	Between Edgeroi and Bellata	Very deep (<271 cm) imperfectly to very poorly drained Brown Clay.	Cracks evident in clay layers Self-mulching when dry High run-off from plains near Bellata	Slight erosion hazard No salting evident
CH 615 - 630	662, 49, 276, 50, 1, 4	North of Bellata	Moderately deep (<82 cm) poorly drained Black Earth occurs on plains. Deep (<120 cm) moderately well drained Grey Clay and deep (<150 cm) well drained Yellow Earth occurs on upper and flat plains.	Cracks evident in clay layers Black Earth is hardsetting when dry Clays on flat plains are self-mulching when dry Low to moderate runoff	Slight erosion hazard No salting evident
CH 630 - 645	416, 417, 657, 438, 16, 413, 412	North of Bellata to Gurley	Deep (<140 cm) very poorly drained Grey Clay and deep (<120 cm) imperfectly drained Brown Clay occur on flat plains. Deep (<132 cm) very poorly drained Grey Clay occurs in open drainage depressions.	Seasonal cracking when dry, with some clays hardsetting when dry High runoff in open drainage depressions Low run-off occurs in plains	Slight erosion hazards on plains High erosion hazard in open drainage depressions, with moderate rill erosion and severe sheet erosion No salting evident

Range Soil Type Occurs (chainage)	Classification / Profile No.	Location	Soil types	Soil Characteristics	Erosion/Salinity
CH 645 - 650	10, 411, 7, 9	Near Gurley creek	Deep (<117 cm) poorly drained Black Earth occurs on alluvium floodplains and drainage depressions.	High run-off in drainage depressions Gilgai-like drainage features that are very poorly drained Clays in drainage depressions can be self-mulching when dry	Slight erosion hazard No salting evident
CH 650 - 660	408, 407	Between Gurley Creek and Moree	Deep (<130 cm) very poorly drained Grey Clay occur on flat plains.	Seasonal cracking when dry Low run-off occurs in plains	Slight erosion hazard No salting evident
CH 660 - 680	655, 636, 634, 276, 1, 2, 277, 27	Moree to Gwydir River	Deep (<130 cm) very poorly drained Black Earth occurs on high banks of rivers. Very deep (<295 cm) clay occurs in open drainage depressions. Deep (<140 cm) poorly to very poorly drained Black Earth occurs on flat alluvium plains.	Moderate to high run-off on river banks and drainage depressions Low run-off occurs in plains Some clays hardsetting, self-mulching or surface crusting when dry	High erosion hazard on river banks Slight erosion hazard on flat plains No salting evident
CH 680 - 690	72, 68, 411, 412	North east of Moree	Shallow (<8 cm) sandy clay loam topsoil for Red-brown Earth. Deep (<120 cm) moderately well drained Red-brown Earth and poorly to imperfectly drained Grey Clay occur on flat plains.	Cracks evident in Grey Clay ranging from <5 to 20 mm Self-mulching and seasonal cracking when dry	Slight erosion hazard No salting evident

Range Soil Type Occurs (chainage)	Classification / Profile No.	Location	Soil types	Soil Characteristics	Erosion/Salinity
CH 690 - 710	413, 70, 112, 418, 419	South west of Crooble	Shallow (<30 cm) sandy clay loam topsoils on mid-slopes. Deep (<140 cm) imperfectly drained Brown Clay and poorly drained Red-Brown Earth occur on mid-slopes. Shallow (<10 cm) sandy loam and sandy clay loam topsoil occurs on flat plains. Deep (<120 cm) imperfectly drained Brown Clay and Grey Clay occurs on flat plains.	Low run-off Self-mulching and seasonal cracking when dry	Slight erosion hazard No salting evident
CH 710 - 725	23, 24, 20	Crooble	Shallow (<8 – 41 cm) topsoils on flat plains of silty clay loam, clay loam and loamy sand. Deeper layers (<181 cm) of imperfectly drained medium silty clay, medium sandy clay and medium clay.	Low run-off Sands are loose when dry Seasonal cracking occurs in clays when dry	Slight erosion hazard No salting evident
CH 725 - 735	2, 109, 25, 26	Croppa Creek	Deep (<150 cm) Grey Clay occurs on flat floodplains and upper slopes. Deep (<124 cm) layers of moderately well drained medium silty clay also occur on hillslopes. Moderate (<44 cm) layers of imperfectly drained silty loam occur on Croppa Creek bank slopes.	Low runoff on hillslopes and creek banks Cracking occurs on Grey Clay upper slopes Loam has surface crusting and clays can be self-mulching when dry	Slight erosion hazard on flat floodplains and hillslopes. Minor scald erosion on hillslopes (stable) Extreme erosion hazard on upper slopes. Severe active sheet, rill and wind erosion Moderate erosion hazard on Coppa Creek bank slopes. Minor scalding (stable), moderate sheet erosion (partly stabilised) and minor rill erosion (partly stabilised) No salting evident

Range Soil Type Occurs (chainage)	Classification / Profile No.	Location	Soil types	Soil Characteristics	Erosion/Salinity
CH 735 - 758	34, 108, 1a, 1b	Croppa Creek to North Star	Shallow (<10 cm) silty clay loam topsoil on mid-slopes. Deep (<135 cm) moderately well drained Brown Clay occurs on mid-slopes. Deep (<130) Black Earth occurs on flat plains and floodplains.	Brown Clay is self-mulching when dry Black Earth has seasonal cracking when dry Low to moderate runoff on mid-slopes	Slight erosion hazard No salting evident



LEGEND

- The proposal
- Principal road
- Secondary road
- Railway

Paper Size A4

0 3 6 12 18 24

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Soil Landscape

Figure 3-2

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Data source: LPI, DCDB, 2015; Geoscience Australia, 250K Topographic Data Series 3. OEH: Greater Soil Group, 2014. Created by: gmcdiarmid, tmorton, kpsroba

3.5.4 Bore data

Searches of the NSW Groundwater Bore Database (DPI Water 2016a) (undertaken on 1 June 2016) and of the DPI Water Waterinfo Pinneena Database were undertaken to identify registered bores within a 250 metre radius of the proposal. The search identified 104 registered bores. Bore locations are shown in Figure 3.3 and details are provided in Appendix B.

A number of the identified bores had cancelled licences. Of the identified bores, the majority (47) were registered for stock, domestic, recreation or irrigation purposes. The remaining bores were registered as monitoring bores or test bores (30); town water supply or public/municipal water (9), industrial or commercial use (6), groundwater remediation (3), farming (1) and 8 were unknown.

3.5.5 Groundwater sharing plans

The proposal lies within the Water Sharing Plans for the NSW Great Artesian Basin Groundwater Sources (NSW Government 2008), Lower Gwydir Groundwater Source, NSW Great Artesian Basin Shallow Groundwater Source (NSW Government 2011), Namoi Unregulated and Alluvial Water Sources (NSW Government 2012) and the Upper and Lower Namoi Groundwater Source (NSW Government 2003).

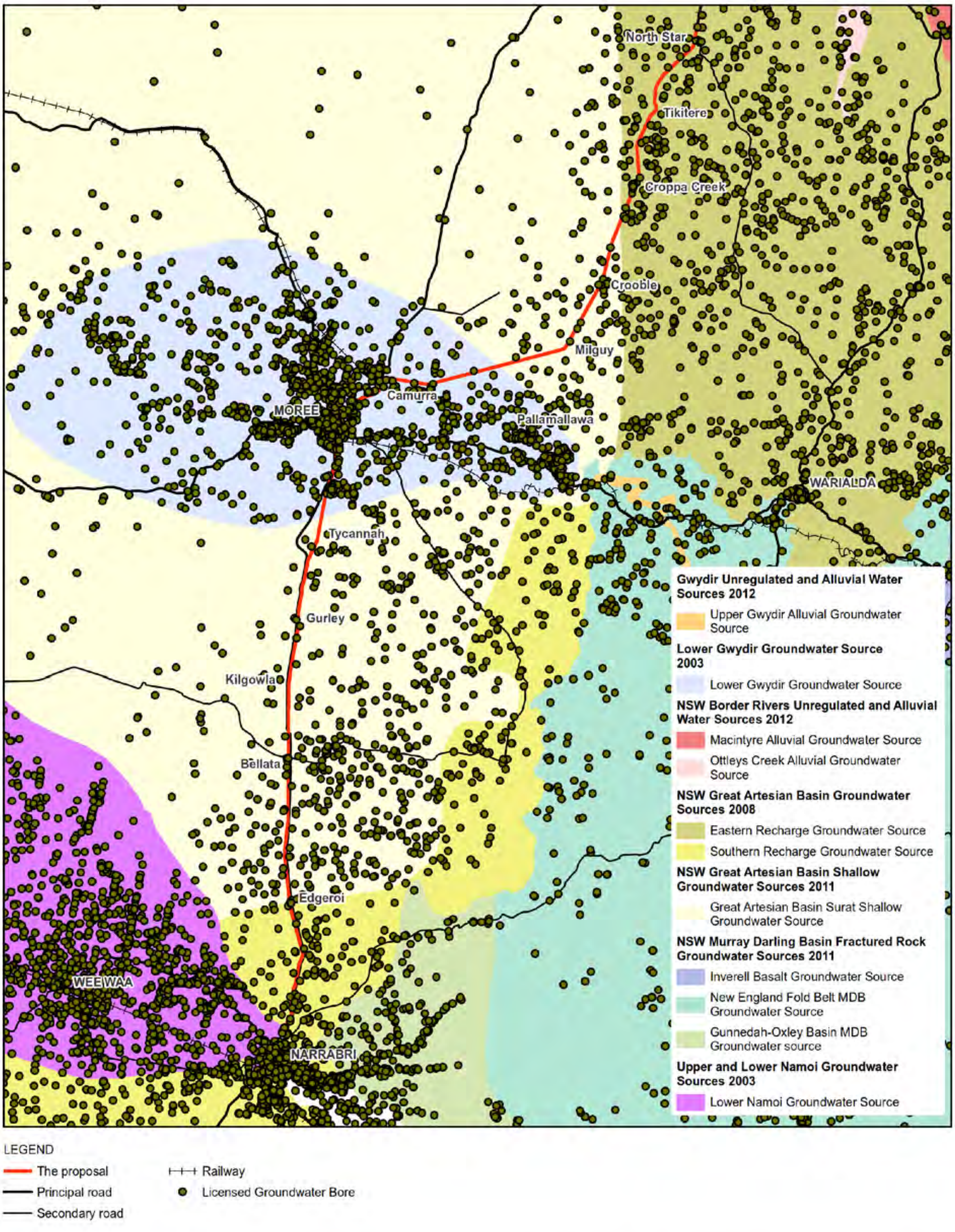
The Water Sharing Plan for the NSW Great Artesian Basin Groundwater Sources commenced in July 2008 and regulates the interception and extraction of water from the sandstone aquifers of the Great Artesian Basin within the boundaries of the water sharing plan.

The Water Sharing Plan for the NSW Great Artesian Shallow Groundwater Sources commenced in November 2011 and regulates interception and extraction of water from alluvium and all other geological formations to a maximum depth of 60 metres below ground surface within the boundaries of the water sharing plan. Groundwater sources that are included in other water sharing plans are excluded from the Water Sharing Plan for the NSW Great Artesian Shallow Groundwater Sources.

The Water Sharing Plan for the Lower Gwydir Groundwater Source commenced in October 2006 and regulates the interception and extraction of water from the alluvial aquifer associated with the Gwydir River and its tributaries within the boundary of the water sharing plan. This water sharing plan is due for extension/replacement in July 2017 and is currently undergoing a formal review (DPI Water 2016b).

The Water Sharing Plan for the Upper and Lower Namoi Groundwater Source commenced in November 2006 and regulates the interception and extraction of water from the alluvial aquifers associated with the Namoi River and its tributaries within the boundaries of the water sharing plan.

The Water Sharing Plan for the Namoi Unregulated and Alluvial Water Sources commenced in October 2012 and regulates interception and extraction of water from surface water and alluvial aquifers within the boundaries of the water sharing plan. This water sharing plan does not cover alluvial groundwater associated with the Namoi River and its tributaries as this is covered by the Water Sharing Plan for the Upper and Lower Namoi Groundwater Source.



Paper Size A4

0 3 6 12 18 24

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Licensed Groundwater Bores

Figure 3-3

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Data source: OOW, Pineena, Groundwater, 2010; LPI, DCDB, 2015; Geoscience Australia, 250K Topographic Data Series 3. Created by: gmodiarmid, tmorton

3.6 Water sources

3.6.1 Licensed extraction points

A search of the NSW Water Register (DPI – Water 2016c) was undertaken to identify the number of Water Access Licences available for each surface water source. The information available on the NSW Water Register does not identify the location of the Water Access Licence and does not provide any information regarding licences issued under the *Water Act 1912.* The results of the search of the NSW Water Register are summarised in Appendix C.

The results of the search of the NSW Water Register identify that the surface water sources intersected by the proposal site are potentially utilised for stock, domestic and town water supply. The results of the search also indicated that there are a number of water access licences for extraction of water from unregulated rivers.

3.7 Land uses

Most of the proposal would be built within the existing rail corridor for the Narrabri to North Star line.

Beyond the rail corridor the study area and surrounding land is dominated by agricultural uses, particularly cotton, wheat, and livestock. These industries have resulted in significant clearing when compared to native bushland. This clearing has an impact on the resulting storm flows by lowering the catchment roughness (a measure by which surface flow in impaired by the surface type), which quickens the catchment's response time to rainfall and results in shorter, more intense catchment flows.

In addition to the agricultural land uses, scattered areas of retained bushland in the form of national park or State forest result in relativity small pockets of uncleared native vegetation within the contributing catchments.

Relatively small and localised pockets of urban areas exist centred around the regional townships of Narrabri, Bellata, Moree, Croppa Creek, North Star.

Figure 3.4 shows the land uses along the rail corridor along with forestry reserves, conservation reserves and national parks. As shown, the flatter portions of the catchments are generally used for agricultural uses.

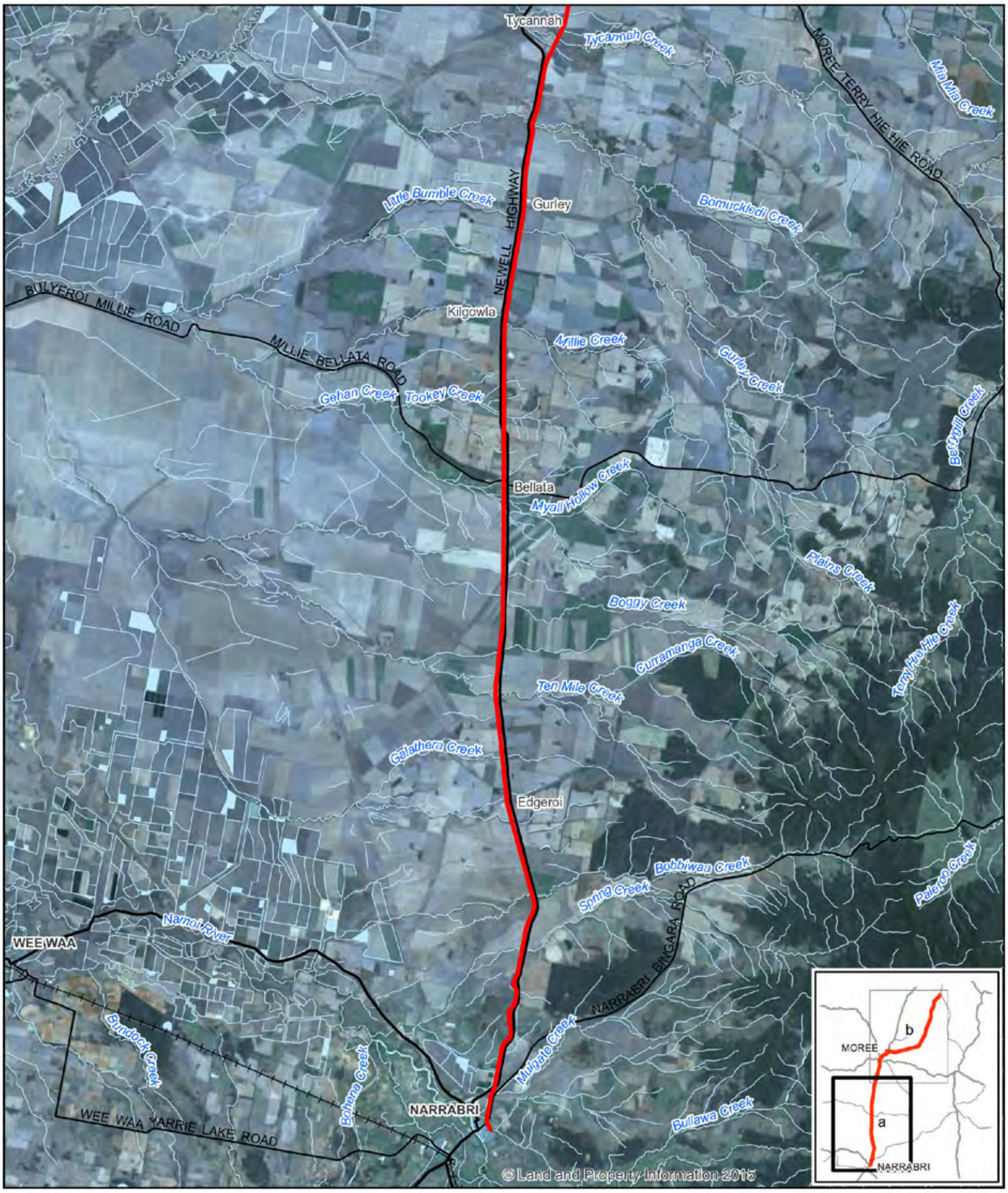
3.8 Watercourses

3.8.1 Major river and basin systems

The proposed works are located within the major regional water catchments of the Namoi River Basin, Gwydir River Basin and the Macintyre River Basin.

The Namoi River starts in the western slopes of the Great Dividing Range flowing westwards through Lake Keepit towards Boggabri, Narrabri (and the proposed alignment) and Wee Waa, before meeting the Barwon River at Walgett. The Barwon River is a tributary of the Murray – Darling Basin (MDB), meeting the Darling River near Bourke.

The Gwydir River starts west of Armidale, fed by the Rock River and Booroolong Creek. The Gwydir River flows north west to Lake Copeton, before turning west to Bingara and Moree, passing under the proposed alignment, before continuing westwards, meeting the Barwon River north of Collarenebri.



LEGEND

- The proposal
- Principal road
- Secondary road
- Railway
- Watercourse
- Waterbody

Paper Size A4

0 1.5 3 6 9 12

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Land Use - Sheet 1

Figure 3-4a

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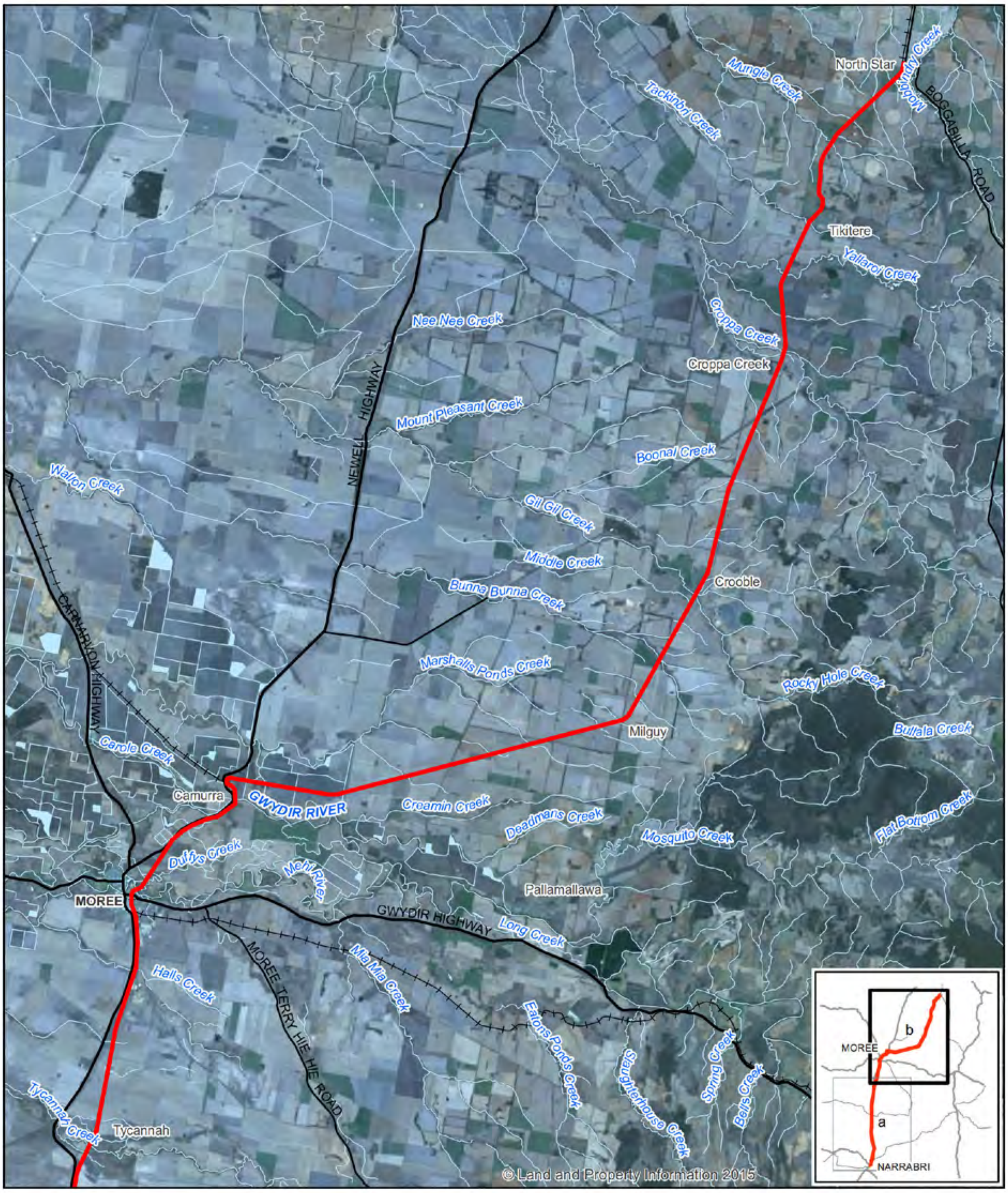
Data source: Geoscience Australia, 250K Topographic Data Series 3; LPI, Imagery, 2015. Created by: gmcdiarmid, kpsroba



LEGEND

- The proposal
- Principal road
- Secondary road
- Railway
- Watercourse

Paper Size A4

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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GHD

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Land Use - Sheet 2

Figure 3-4b

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Data source: Geoscience Australia, 250K Topographic Data Series 3; LPI, Imagery, 2015. Created by: gmcdiarmid, kpsroba

The Macintyre River starts west of Glencoe, flowing in a north west direction towards the NSW – Queensland border near Boggabilla. The Macquarie River catchment includes the Croppa Creek and Gil Gil Creek, both of which pass under the proposed alignment south of North Star.

3.8.2 Watercourses

Surface water within the study area is predominately comprised of ephemeral waterways, excluding the major perennial river systems identified in Section 3.8.1. This is a resultant of the size of the contributing watercourse catchment area, rainfall pattern experienced in the region and no base flow resulting from groundwater expression.

Minor rivers (those less than 1000 square kilometres) listed in the OEH (undated) include:

- Bobbiwa Creek
- Ten Mile Creek
- Boggy Creek
- Gehan Creek
- Waterloo Creek
- Little Bumble Creek
- Gurley Creek
- Halls Creek
- Mehi River
- Gil Gil Creek
- Croppa Creek
- Yallaroi Creek
- Mungle Creek

Figure 3.5 and Table 3.4 provide details on the main watercourses crossed by the rail corridor including:

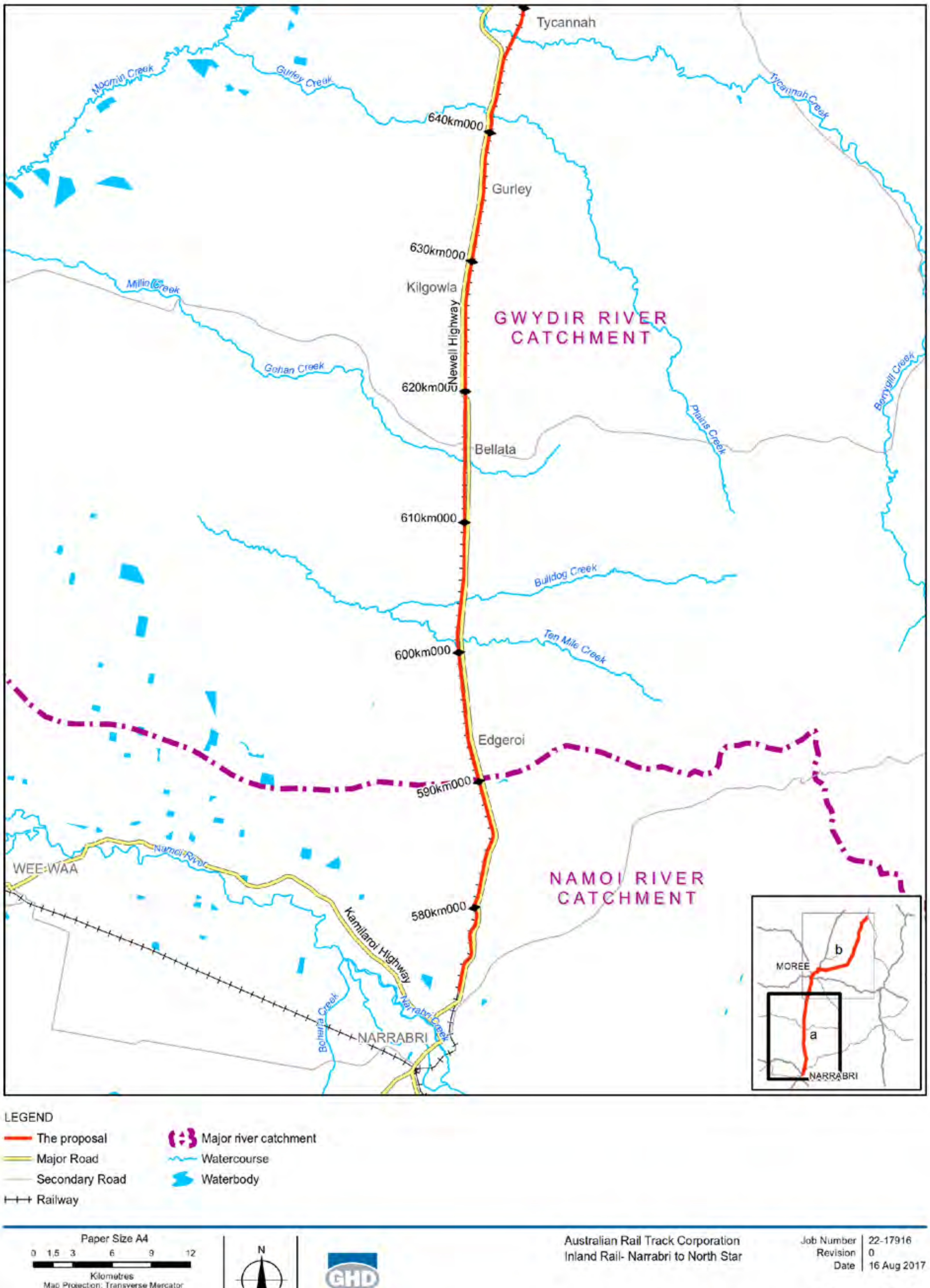
- Stream order as derived from the topographic LPI Hydroline dataset
- The form and geomorphic condition of watercourses as assessed from aerial imagery and based on the River Styles framework (Brierley and Fryirs, 2005)

The watercourses assessed included all named watercourses and all un-named watercourses with stream order greater than third order.

The morphology of watercourses crossed by the rail corridor is characterised by three stream types, as follows:

- Low sinuosity fine grained systems – exhibit relatively straight channels surrounded by continuous floodplains. The banks of this stream type are relatively stable due to the presence of cohesive fine grained materials. During periods of low rainfall, the stream type typically holds water in isolated pools of water.
- Channelized fill systems – generally laterally, stable channels of low sinuosity incised within flat and featureless floodplains. During periods of high flow, unprotected banks are prone to erosion.
- Valley fill systems – relatively flat, featureless valley floor surfaces, lacking a continuous, well defined channel. Typically, the substrate comprises of fine alluvial silts and muds vertically deposited out of suspension.

Most watercourses are considered to be in good geomorphic condition and are typically stable and well-vegetated.



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Major Waterways - Sheet 1

Figure 3-5a

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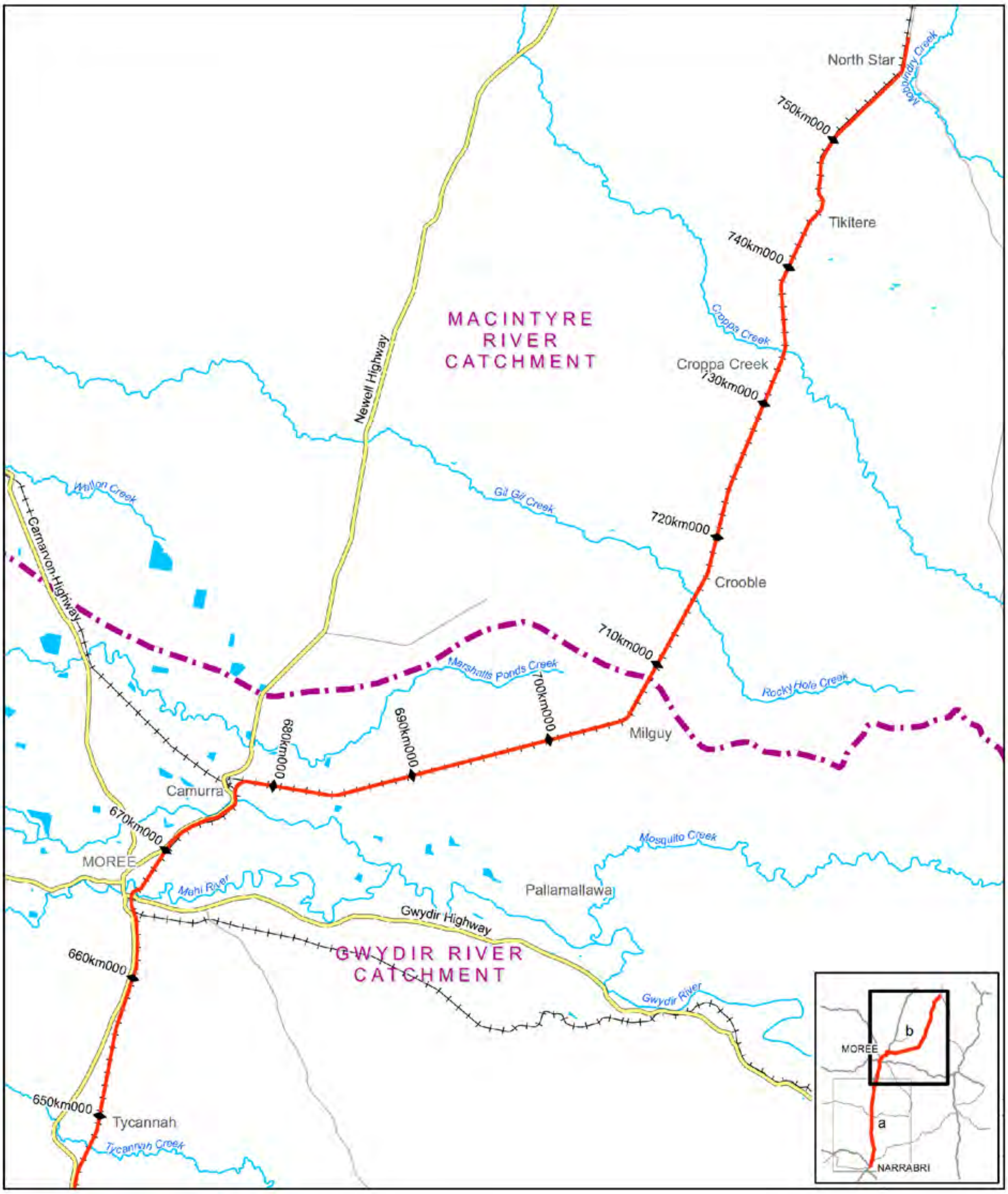
Data source: DECCW: Catchment, 2012. Geoscience Australia, 250K Topographic Data Series 3; LPI,DTDB, 2015. Created by: gmcdiarmid, kpsroba



LEGEND

- The proposal
- Major Road
- Secondary Road
- Railway
- Major river catchment
- Watercourse
- Waterbody

Paper Size A4

0 1.5 3 6 9 12

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Major Waterways - Sheet 2

Figure 3-5b

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Data source: DECCW: Catchment, 2012. Geoscience Australia, 250K Topographic Data Series 3; LPI,DTDB, 2015. Created by: gmcdiarmid, kpsroba

A small number of watercourses are considered to be in moderate geomorphic conditions because of historical disturbances associated with agricultural practices. This includes clearing of vegetation, stock grazing impacts, construction of online farm dams and drainage improvements (e.g. channelising watercourses through excavation or bunding).

Typically, poor condition reaches have been channelised to improve drainage and limit flood extents. These reaches can also display evidence of ongoing channel erosion.

The rail corridor and associated infrastructure has had only minor localised impacts on watercourse form. This consists primarily of an increased propensity for scour and erosion immediately downstream of a few watercourse crossing structures.

Table 3.4 Watercourses crossed by the proposal site

Catchment	Chainage (km)	Watercourse	Flow regime	Stream Order	River Style	Condition	Comments
Namoi	574.75	Un-named	Ephemeral	3	Valley fill	Moderate	Stable, grassed valley with no defined channel.
Namoi	583.05	Spring Creek	Ephemeral	4	Low sinuosity fine grained	Poor	Unstable channel upstream with eroding banks. Eroded sediment being deposited on downstream side of existing railway. Downstream channel grassed and stable.
Namoi	586.55	Bobbiwa Creek	Ephemeral	4	Low sinuosity fine grained	Good	Stable, well vegetated channel.
Thalba Creek	594.3	Tarlee Creek	Ephemeral	1	Valley fill	Moderate	Stable, undefined drainage line.
Thalba Creek	596.85	Galathera Creek	Ephemeral	2	Valley fill	Moderate	Stable at crossing with channel incision and headcutting present about 100 metres downstream of existing railway.
Thalba Creek	600.9	Ten Mile Creek	Ephemeral	5	Low sinuosity fine grained	Good	Stable, poorly defined channel set within broad depression. Occasional near permanent ponds present.
Thalba Creek	602.85	Pan Creek	Ephemeral	2	Valley fill	Poor	Stable although constrained with floodway berms.
Thalba Creek	604.3	Bulldog Creek	Ephemeral	4	Low sinuosity fine grained	Moderate	Generally stable with some bank erosion. Occasional small ponds.
Thalba Creek	608.25	Boggy Creek	Ephemeral	3	Low sinuosity fine grained	Moderate	Stable, grassed channel.
Thalba Creek	614.5	Gehan Creek	Ephemeral	4	Valley fill	Moderate	Stable, grassed valley with no defined channel.

Catchment	Chainage (km)	Watercourse	Flow regime	Stream Order	River Style	Condition	Comments
Thalba Creek	621.05	Tookey Creek	Ephemeral	3	Valley fill	Good	Stable, grassed valley with no defined channel.
Thalba Creek	627.65	Waterloo Creek	Ephemeral	4	Low sinuosity fine grained	Good	Stable, grassed channel.
Thalba Creek	634.2	Little Bumble Creek	Ephemeral	2	Valley fill	Good	Stable, grassed valley with no defined channel.
Mehi River	642	Gurley Creek	Ephemeral	5	Low sinuosity fine grained	Good	Stable, poorly defined channel set within broad depression. Occasional near permanent ponds present.
Mehi River	648.1	Tycannah Creek	Ephemeral	6	Low sinuosity fine grained	Good	Stable, well vegetated, low capacity channel. Anabranches.
Mehi River	655.65	Clarks Creek	Ephemeral	1	Valley fill	Moderate	Stable, grassed valley with no defined channel.
Mehi River	661	Halls Creek	Ephemeral	2	Valley fill	Moderate	Shallow, stable depression with occasional pools.
Mehi River	666.9	Mehi River	Permanent	5	Low sinuosity fine grained	Good	Stable channel with long permanent pools.
Mehi River	667.7	Duffys Creek	Ephemeral	NA	Valley fill	Good	Shallow, stable depression. Ananbranch of Gwydir River.
Gwydir River	668.45	Skinners Creek	Ephemeral	NA	Valley fill	Moderate	Shallow, stable depression. Ananbranch of Mehi River.
Gwydir River	676.75	Gwydir River	Permanent	8	Low sinuosity fine grained	Moderate	Channel subject to meander migration. Gentle bend at crossing. Long permanent pools.
Gil Gil Creek	699.05	Coolleearlee Watercourse	Ephemeral	2	Channelised fill	Moderate	Stable incised valley fill.
Gil Gil Creek	704.05	The Ponds	Ephemeral	2	Valley fill	Moderate	Stable although constrained with floodway berms.

Catchment	Chainage (km)	Watercourse	Flow regime	Stream Order	River Style	Condition	Comments
Gil Gil Creek	705.55	Marshalls Ponds Creek	Ephemeral	2	Valley fill	Moderate	Stable although constrained with floodway berms.
Gil Gil Creek	710.85	Bunna Bunna Creek	Ephemeral	3	Low sinuosity fine grained	Moderate	Stable, poorly defined channel set within broad depression.
Gil Gil Creek	716.15	Gil Gil Creek	Ephemeral	5	Low sinuosity fine grained	Moderate	Stable, poorly defined channel set within broad depression.
Whalan Creek	734.4	Croppa Creek	Ephemeral	6	Low sinuosity fine grained	Good	Stable, well-vegetate channel.
Whalan Creek	739.9	Yallaroi Creek	Ephemeral	4	Low sinuosity fine grained	Moderate	Generally stable with some evidence of past channel incision. Occasional small ponds.
Whalan Creek	743.8	Tackinbri Creek	Ephemeral	2	Low sinuosity fine grained	Good	Shallow, stable depression, well vegetated.
Whalan Creek	750.3	Mungle Creek	Ephemeral	3	Low sinuosity fine grained	Good	Stable, poorly defined channel set within broad depression.
Whalan Creek	756.35	Dry Creek	Ephemeral	1	Valley fill	Poor	Undefined drainage in cropping paddocks.

3.9 Flow rates

Historical flood level and flow data was extracted from publicly available databases (http://waterinfo.nsw.gov.au/ and Pineena). The extracted data was then subject to a flood frequency analysis to determine the magnitude of design floods based on the historical data.

3.9.1 Gauging data

The gauging stations considered in the analysis are listed in Table 3.5.

Table 3.5 Flow gauging station considered in assessment

Station No	Station Name	Latitude	Longitude	Start Date	End Date	Catchment Area (km^2)
Namoi River Basin						
419002	Namoi at Narrabri	30.33	149.77	1/01/1913	13/08/2008	25100
419003	Narrabri Creek at Narrabri	30.33	149.78	1/01/1891	29/07/2015 [A]	25,400
419032	Coxs Creek at Boggabri	30.76	149.98	5/06/1965	29/07/2015 [A]	4040
419033	Coxs at Tambar Springs	31.35	149.89	16/06/1981	29/07/2015 [A]	1450
419052	Coxs Creek at Mullaley	31.10	149.90	2/10/1972	31/01/1989	2370
419072	Baradine at Kienbri	30.85	149.03	17/06/1981	13/08/2008	1000
419085	Bomera Creek at Tambar Road	31.38	149.87	6/06/1995	29/07/2015 [A]	610
419086	Bundella Creek at Bundella	31.57	149.98	5/12/1995	29/07/2015 [A]	150
Gwydir River Basin						
418002	Mehi River at Moree	29.47	149.85	18/03/1937	29/07/2015 [A]	1,000,000
418010	Gwydir River at Bingara	29.90	150.63	1/01/1937	13/08/2008	6423
418011	Carole Creek DS Regulator	29.41	149.89	9/05/1979	29/07/2015 [A]	1,000,000
418032	Tycanna at Horseshoe	29.67	150.04	24/05/1979	20/01/2014	866
418036	Gwydir DS Boolooroo	29.41	149.88	1/10/1980	16/12/2015 [A]	12,830
418037	Mehi River DS Combadello	29.56	149.66	9/06/1977	29/07/2015 [A]	2700
418051	Gwydir River at Boolaroo Weir storage	29.41	149.89	1/06/1989	29/07/2015 [A]	12,000 [B]
418086	Carole at Midkin	29.32	149.78	6/10/2005	29/07/2015 [A]	1,000,000 [B]

Station No	Station Name	Latitude	Longitude	Start Date	End Date	Catchment Area (km^2)
Macintyre River Basin						
416020	Ottleys at Coolatai	29.23	150.76	28/02/1967	29/07/2015 [A]	402
416034	Croppa Creek at Tulloona Bore	28.93	150.11	1/01/1972	16/02/1989	1280

[A] Current monitoring station. Date reflects date of collection and analysis.
[B] Estimate of catchment area only

A regional flood frequency analysis (Engineers Australia 2016) was undertaken based on the above gauging stations to provide a means of checking the magnitude of flood flows estimated by the hydrological methods adopted (refer to Section 4.2.1).

3.10 Flooding conditions

3.10.1 Flooding causes

Flooding for the study area may be influenced by floods from two sources (or a combination of these sources):

- Flooding caused by high flows in the major rivers (Namoi, Gwydir or Macintyre). These events are termed regional floods in this report and would result from rainfall over a significant portion of the respective river basin catchment.
- Flooding because of rainfall over the local catchment draining to an individual underbridge or group of culverts in isolation of the regional flooding behaviour.

The flooding causes and their consideration within this assessment are summarised in Table 3.6.

Table 3.6 Flooding causes

Flooding source	Details	Note
Flooding from major river systems	Major regional river flood extents Namoi and Gwydir River catchment	Considered in the flooding assessment
Flooding from local catchments	Local rainfall and runoff events of catchments upstream of the proposal	Considered in the flooding and water quality assessment

At several locations along the proposal corridor, flow can discharge from one local catchment into the next prior to overtopping the rail. This effect has been considered through a flow redistribution approach.

Backwater effects for water ponding on the downslope side of the track were not considered due to the significant increase in variables introduced into the analysis through their inclusion. (Refer to Section 2 for further details on the why backwater effects were not assessed.)

3.10.2 Historical flooding

At the commencement of this investigation publicly available historical flood information was sourced. Available information was limited to the major rivers within the study area. During this investigation there has been consultation with Councils, agencies and landowners to obtain further information on both historical flooding, design flood predictions and current studies. As part of the detailed design, consultation is to be undertaken with Councils, landowners, and government agencies to continue to obtain detailed, localised flood knowledge that would inform the detailed design of each section of the proposal. Information sourced through the landowner consultation is discussed at length in Section 4.2.5.

Below is a summary of the publicly available historical flood data available at the start of the investigation for the major river systems.

Draft Floodplain Management Plan for the Gwydir Valley Floodplain

This report (DPI Water 2015) describes the existing flood regimes within the Gwydir Valley, as well as describing flood works, including levees, access roads, channels and stock refuges, that have been undertaken within the catchment. It also includes envelope mapping of historical flooding within the catchment, which indicates that the numerous areas of the rail corridor are historically influenced by flooding, in particular those north of Moree.

Narrabri Flood Study Review

This report (URS 2014) has provided recent information on a revision of the design flood flows at Narrabri, based upon a review for the analysis of historical flow rates, reported on the updating of hydraulic modelling, using the MIKE11 (one dimensional flood model) software, for the local area and also lead to the development of updated flood mapping around Narrabri.

The updated design flood levels from the URS model were generally consistent with earlier predicted levels for the larger flood. However, there were some localised differences for the smaller five per cent and 10 per cent AEP design events.

Flood maps were developed during that study and these have been adopted as the basis of design flood levels in the immediate area in and around Narrabri.

Narrabri Flood Study Namoi River, Mulgate Creek and Long Gully

WMR (2016) have prepared a draft flood study for Narrabri Shire Council. The study was prepared to define the flooding conditions for local catchment flooding and regional flooding from the Namoi River.

The technical approach included derivation of upstream Namoi River design flows from flood frequency analysis, development of an XP-RAFTS model to estimate local runoff hydrographs for inclusion into a hydraulic model, development and calibration of a MIKE-FLOOD (two dimensional) hydraulic model and evaluation of a range of design flood conditions (depths, levels, velocities and hazards) in the area around Narrabri.

Review of Moree and Environs Flood Study/Floodplain Risk Management Study and Plan

Moree Plains Shire Council has an ongoing project that will provide an update the predicted flood levels in the area immediately at and around Moree. Results from the first phase of the hydraulic modelling for that study are reported by WRM (2016) for the model calibration.

A key component of this study was the refinement of an earlier OEH modelling of the Gwydir floodplain near Moree.

The calibration of the hydraulic model was reported as being acceptable. It did give good predictions of instream floods with the largest differences occurring for the larger design floods.

Results from this study are not yet available for the prediction of design flooding conditions.

3.11 Sensitive ecological areas

Wetlands

The Gwydir Wetlands, were formed on the very flat floodplain of the Gwydir River. The wetlands consists of a complex network of flow paths and floodways. The Gwydir Wetlands are located approximately 60 km west to northwest of Moree. Segments of the wetland are listed under the Ramsar Convention, the Directory of Important Wetlands in Australia and the NSW reserve system.

Vegetation

A detailed ecologic assessment of the proposal route is reported in the *Aquatic Ecology Assessment* (Umwelt 2017a) and *Biodiversity Assessment Report* (Umwelt 2017b). The following is extracted from that report.

The southern end of the proposal site is located immediately north of Narrabri on an embankment above the Namoi River. The proposal site traverses the Gwydir River floodplain. The northern end of the proposal site, at North Star, is located south of the Macintyre River within the Border Rivers basin. The proposal site crosses a number of large watercourses, including rivers (Mehi River and Gwydir River), larger creeks (such as Mulgate Creek, Bobbiwa Creek, Gehan Creek, Tookey Creek and Gil Gil Creek) and other intermittent watercourses and canals constructed to convey irrigation waters.

Patches of native vegetation exist sporadically within and around the proposal site, and are typically associated with travelling stock reserves, road reserves or farm woodland remnants. These patches generally comprised a woodland community, with the dominant canopy species including bimble box (*Eucalyptus populnea*), belah (*Casuarina cristata*), silver-leaved ironbark (*Eucalyptus melanophloia*), and white cypress pine (*Callitris glaucophylla*). Extensive areas of natural grasslands also exist.

Aquatic Ecology

The Mehi and Gwydir rivers have both been identified as ‘class 1 key fish habitat’ in accordance with the *Policy and guidelines for fish habitat conservation and management* (DPI 2013). As a result, the design and construction of the project will have to consider the requirements of the NSW *Fisheries Management Act* (1994). A number of other watercourses are identified as having moderate fish community value.

Some of the watercourses intersected by the rail corridor comprise important aquatic ecosystems, in particular NSW DPI identified the Mehi River as good fish community value; while Gehan Creek, Waterloo Creek and Gil Gil Creek were identified as having moderate fish community value but with a high alien presence.

Native fish species reported as being likely to occur in the Mehi and Gwydir rivers include golden perch, spangled perch, Murray cod, freshwater catfish, purple spotted , olive perchlet, Australian smelt, bony bream, carp gudgeon, unspecked hardyhead and Murray-Darling rainbow fish (DPI 2015).

Groundwater Dependent Ecosystems

A review of the Australian Government's National Atlas of Groundwater Dependent Ecosystems identified the following groundwater dependent ecosystems in the study area:

- Watercourses and riparian vegetation either side of the proposal site along Gurly Creek, Gehan Creek, Mehi River, Gwydir River, and Croppa Creek.
- Riparian vegetation along Gil Gil Creek is identified as having a low potential for groundwater dependent ecosystems, while upstream of the proposal site there is a higher potential for groundwater dependent ecosystems.
- Floodplain waterbodies associated with Tycannah Creek upstream and downstream of the proposal site are mapped as groundwater dependent ecosystems.
- The Gwydir River wetlands.

A detailed evaluation of the ecology of the area and ecological impacts is being provided in a separate report (Umwelt 2017a).

4. Existing environment

4.1 Regional context

4.1.1 Catchments

The study area includes numerous watercourses within portions of the Namoi, Gwydir and Macintyre River basins, all of which are within the Murray-Darling Basin (MDB).

Watercourse catchments crossed by the proposal range in size from small, unnamed tributaries of less than a square kilometre to large rivers. These regional catchments (large river catchments) extend in some instances to the Great Dividing Range and encompass large areas. Catchments for the major river systems (Namoi River and Gwydir River, including the Mehi River) extend eastward to the Great Dividing Range. Most of the small catchments draining to the majority of structures under the rail line are located nearer to the rail corridor and have a modest topographic relief.

As discussed in Section 3, land use in the catchment areas has undergone significant change with the progressive move to more intensive cropping practices, general development and construction of major water storage dams.

4.1.2 Climate

Examination of the historical rainfall and river flow data indicates that the region has experienced a variety of significant climatic conditions, varying from severe droughts to large and significant floods. An indication of the climatic variability is demonstrated in Figure 4.1 which provides a diagrammatic representation of the years with complete rainfall records for Narrabri between 1870 and 2010. The minimum annual rainfall recorded in that period was 217 millimetres while the maximum was about 1,312 mm and the average was about 650 mm of rainfall. As indicated in Figure 4.1, there have been a number of periods with consecutive years of below average rainfall.

The Narrabri site has reported a relatively uniform monthly distribution of the mean rainfalls varying from a high of 80.2 mm in January to a low of 37.4 mm in August.

Because of the relatively low annual rainfall and a relatively high evaporation rate being in the order of 1,600 to 1,900 mm per annum most of the watercourses are ephemeral in nature.

The climatic variability has been reflected in the frequency, persistence and magnitude of streamflows.

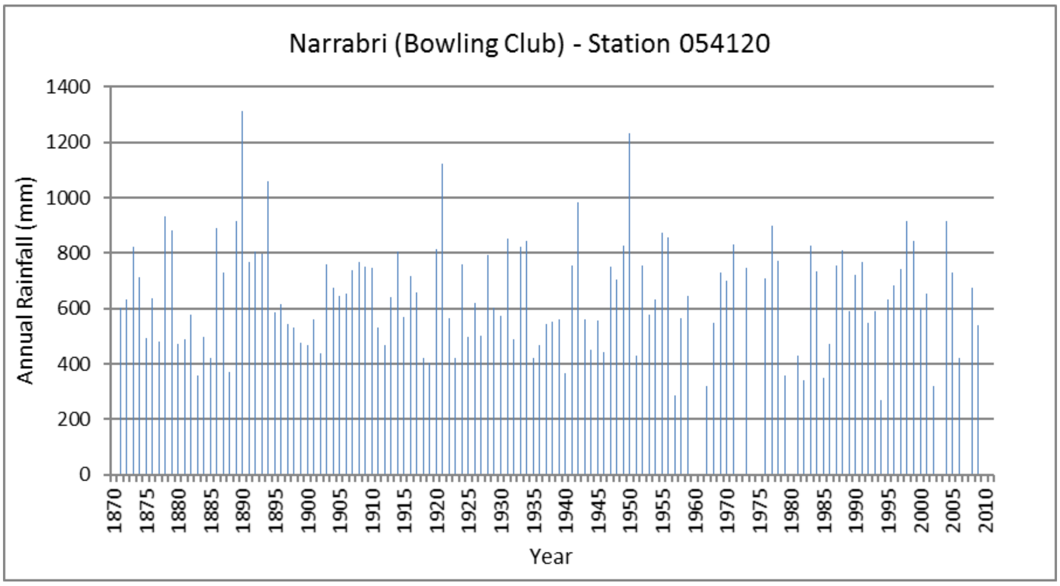


Figure 4.1 Narrabri rainfall

4.1.3 Terrain and land use

The study area is characterised by relatively flat catchments (gradient of up to five per cent) with some locally steeper proportions. Floodplain slopes are generally about one-half to one per cent gradient. Along the length of the rail alignment, terrain has a gradual fall from about 240 mAHD at Narrabri to a low point within the vicinity of Moree or about 210 mAHD, before rising to an elevation of 310 mAHD north of Crooble.

Most catchments include cleared areas used for agriculture, grazing and rural residential land uses. Relative to the overall catchment area the urbanised portions are minor in nature and mostly located near Narrabri and Moree.

4.2 Hydrology

4.2.1 Surface water – local catchments

Most watercourses in the study area are ephemeral, with temporary or intermittent flow. Flow occurs during and after rainfall events, with the watercourses drying out in between rainfall events. However, the major river systems, the Namoi River, Macintyre and Gwydir River (including the Mehi River), are perennial systems.

As surface water flow in the study area is primarily related to rainfall, the associated rainfall and runoff process of the catchment is the main contributor to watercourse flow along the Narrabri to North Star rail line. Adopting the delineated catchment areas for the nominated watercourses, catchment flow rates were established using the scaled Probabilistic Rational Method (PRM) (refer 0). PRM provides a simple means of estimating the likely peak runoff rate from a catchment, based on the catchment area. Watercourses are labelled in accordance with the identified structures under the existing Narrabri to North Star rail line.

The scaled PRM method provided a means of assessing the likely flood effected areas for the length of the proposal, identifying areas where upgrades may be required (i.e. additional culverts and raising of the formation) to reduce the risk of rail overtopping during flood events. It is expected that more localised, detailed modelling will be undertaken during the detailed design stage to ensure that the proposed structures and rail levels meet the design objectives.

Appendix D summarises the existing structure type and configuration along with the predicted design flood levels. Flood levels are provided to the nearest 0.01 mAHD for comparison purposes, with results for the design condition, and they should not be interpreted as having that level of accuracy.

The developed flow rates were compared to the available gauging flow data reported in Section 3.9.1.

Comparative design flow estimates

Comparative design flow estimates arriving at selected culvert locations were compared to those predicted using the Regional Flood Flow (RFF) estimates method (Engineers Australia, 2016). The flow rates summarised in Table 4.1 show significant variability. However, the RORB model results were considered to be the more likely to represent the local flood response, as it is based on dynamic modelling of the design storm event and includes estimates of the initial and continuing infiltration losses. The PRM estimates were therefore adjusted (using a multiplier) to better match the RORB results (refer to Table 4.2).

Table 4.1 Comparative flow estimates – local catchments

Culvert chainage	Event (% AEP)	Original PRM flow (m^3/s)	RORB flow (m^3/s)	RFF (m^3/s)	RORB/PRM
581.18	50	2.6	7.4	-	2.8
	20	5.0	14.1	-	2.8
	10	7.3	20.8	14.6	2.8
	2	17.7	50.1	-	2.8
	1	25.2	66.1	47.4	2.6
696.99	50	1.8	5.2	-	2.9
	20	3.4	9.2	-	2.7
	10	5.1	13.6	10.5	2.7
	2	12.2	33.0	-	2.7
	1	17.4	43.9	34.9	2.5
704.79	50	1.7	5.7	-	3.4
	20	3.2	10.0	-	3.1
	10	4.8	14.4	10.6	3.0
	2	11.5	35.5	-	3.1
	1	16.4	47.1	35.4	2.9
709.74	50	0.6	2.6	-	4.6
	20	1.1	4.5	-	4.1
	10	1.6	6.5	2.7	4.0
	2	3.9	15.9	-	4.1
	1	5.6	21.2	9.0	3.8

Culvert chainage	Event (% AEP)	Original PRM flow (m^3/s)	RORB flow (m^3/s)	RFF (m^3/s)	RORB/PRM
755.97	50	0.3	1.4	-	4.0
	20	0.7	2.1	-	3.2
	10	1.0	2.9	1.6	2.9
	2	2.4	7.7	-	3.2
	1	3.4	10.2	5.3	3.0

Table 4.2 PRM multipliers – local catchments

Event (% AEP)	PRM multiplier
50	1.4
20	1.5
10	1.5
5	1.7
2 (and greater)	2.0

4.2.2 Surface water – regional catchment

The catchment flow rates extracted from the supplied Moree hydrology model were adopted for this study. These flows rates were based on a flood frequency analysis of historical flows within the Mehi and Gwydir Rivers.

4.2.3 Groundwater

The results of the bore search and review of groundwater sharing plans (refer Section 3.5.5) identified that groundwater sources in the proposal corridor include alluvial sediments associated with the Gwydir River near Moree. Based on the results of the bore search, the alluvial sediments extend to over 40 metres below ground level. Alluvial groundwater associated with the Gwydir River would be recharged by rainfall infiltration and surface flows. Groundwater levels would be expected to rise following periods of above average rainfall and fall following periods of below average rainfall.

Near Narrabri, the proposal corridor may be underlined by alluvial sediments associated with the Namoi River. The results of the bore search identified two bores near Narrabri. One of these two bores extended to a depth of more than 50 metres below ground level and was identified as extracting groundwater from alluvial sediments.

The alluvial aquifer is underlined by fractured rock. This fractured rock overlies the Great Artesian Basin aquifer. The fractured rock outcrops outside of the extent of the alluvial aquifer. There is potential for there to be perched groundwater in the fractured rock above the Great Artesian Basin. This perched groundwater system, if present, would expected to be low yielding. The bore search did not identify any registered bores that are likely to be extracting from this geological formation.

Outside the extent of the alluvial aquifers, the results of the bore search identified that the majority of registered bores extend to depths of greater than 100 meters below ground level. These bores are likely to be extracting from the Great Artesian Basin aquifer.

Shallow alluvial sediments of depth of less than 10 to 20 metres below ground level may be intercepted along creek lines intercepted by the proposal. These perched shallow groundwater sources would be recharged by rainfall infiltration with groundwater levels expected to rise following rainfall events.

4.2.4 Existing culvert locations and levels

The location and level of structures were extracted from existing information. Figure 4.2 shows the locations of the existing culverts between Narrabri and North Star. Appendix D provides a tabulation of the existing structure form for each structure. A second table in Appendix D provides the design flow rates.

4.2.5 Landowner feedback on predicted flood conditions for the existing rail corridor

Groups of landowners were consulted during the study process to obtain specific information on historical flood levels and historical flood extents. At the time of consultation, there were flood extent figures available and these were shown to residents as a means of conveyance of information. The landowner feedback on the local and regional catchments flood mapping is summarised on Figure 4.3.

Feedback from the landowners indicated:

- There has been significant flooding along the existing rail corridor in 1976, 2001, 2011 and 2012.
- Damage to both ballast, formation and culverts was reported by landowners for these same historical events.
- The adopted analysis method gave reasonable representation of the flooding behaviour but there were areas identified where the identified historical flooding extent exceeded the predicted extents. Further analysis would be required to confirm the cause for this but partial culvert blockage, unknown flow diversions and the analysis method itself could have been contributing factors to the differences. There were no areas where the flooding extent was reported as being less than the predicted extent.

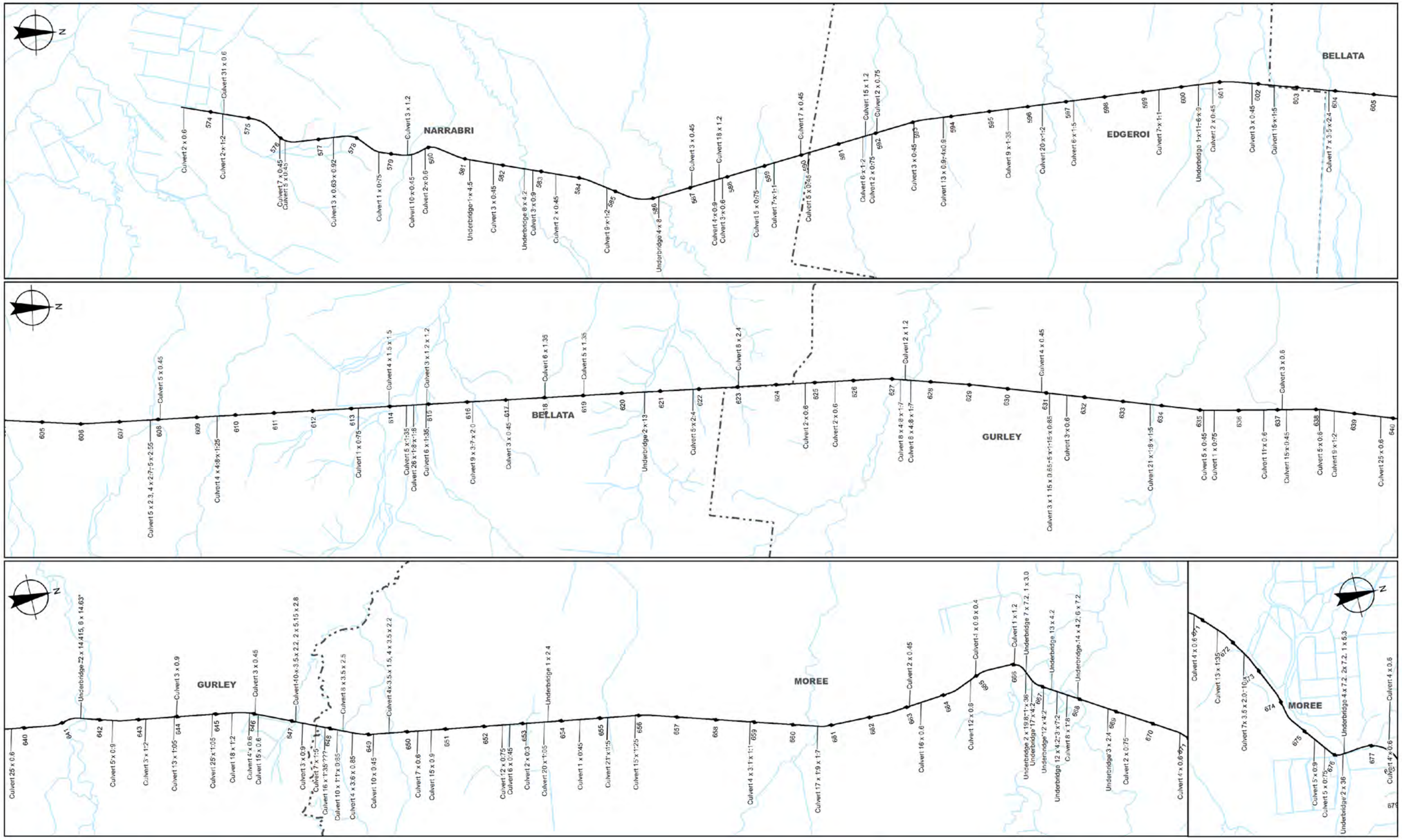
The above feedback should be considered in future hydrologic and hydraulic assessments for the proposal.

Regional flooding impacts were discussed with Moree Plains Shire Council on a number of occasions during the update of the regional flood model. Moree Plains Shire Council provided a number of historical photographs and other anecdotal information of flooding within the region, which was used in the preparation of the flood study (WRM 2016a).

A maximum benefit of the community feedback would be achieved through a comprehensive data gathering exercise (collecting rainfalls, more accurate definition of flood levels, greater terrain detail) and incorporating that information into future design advancement hydrologic and hydraulic analysis for the detailed design phase for the proposal.

4.3 Flooding – local catchments

Existing condition flood levels, flood behaviour and impacts were assessed for local catchment rainfall and runoff events through combined hydrologic and hydraulic flood modelling and interpretation of the data. The hydrologic and hydraulic modelling methodology used for this assessment is detailed in Appendix A.



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Rail Centreline
- Watercourse
- Suburb boundary

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number	22-17916
Revision	0
Date	16 Aug 2017

Exisiting Culvert Locations - Sheet 1 Figure 4-2a

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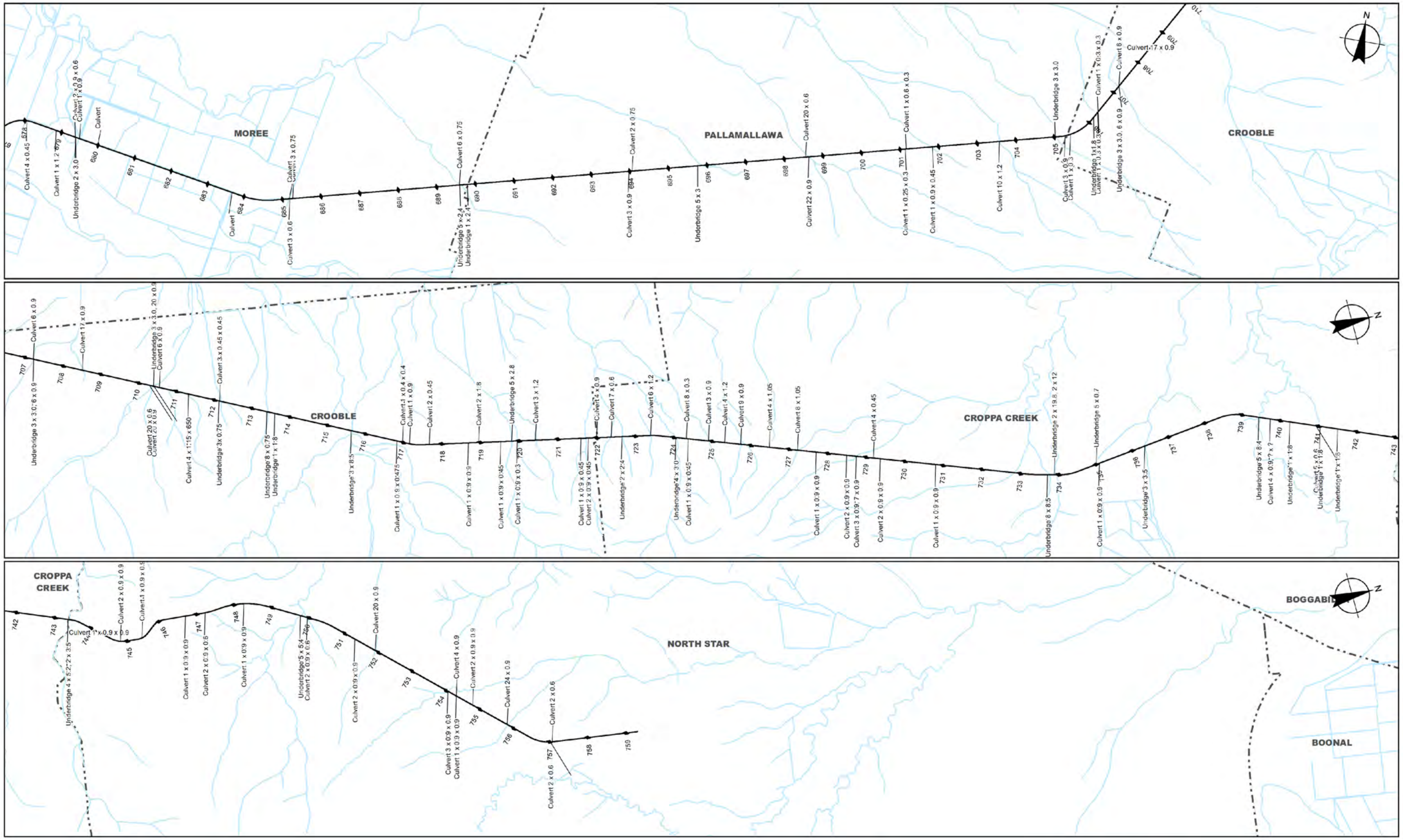
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



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0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

— Rail Centreline

— Watercourse

Suburb boundary

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number	22-17916
Revision	0
Date	16 Aug 2017

Existing Culvert Locations- Sheet 2 Figure 4-2b

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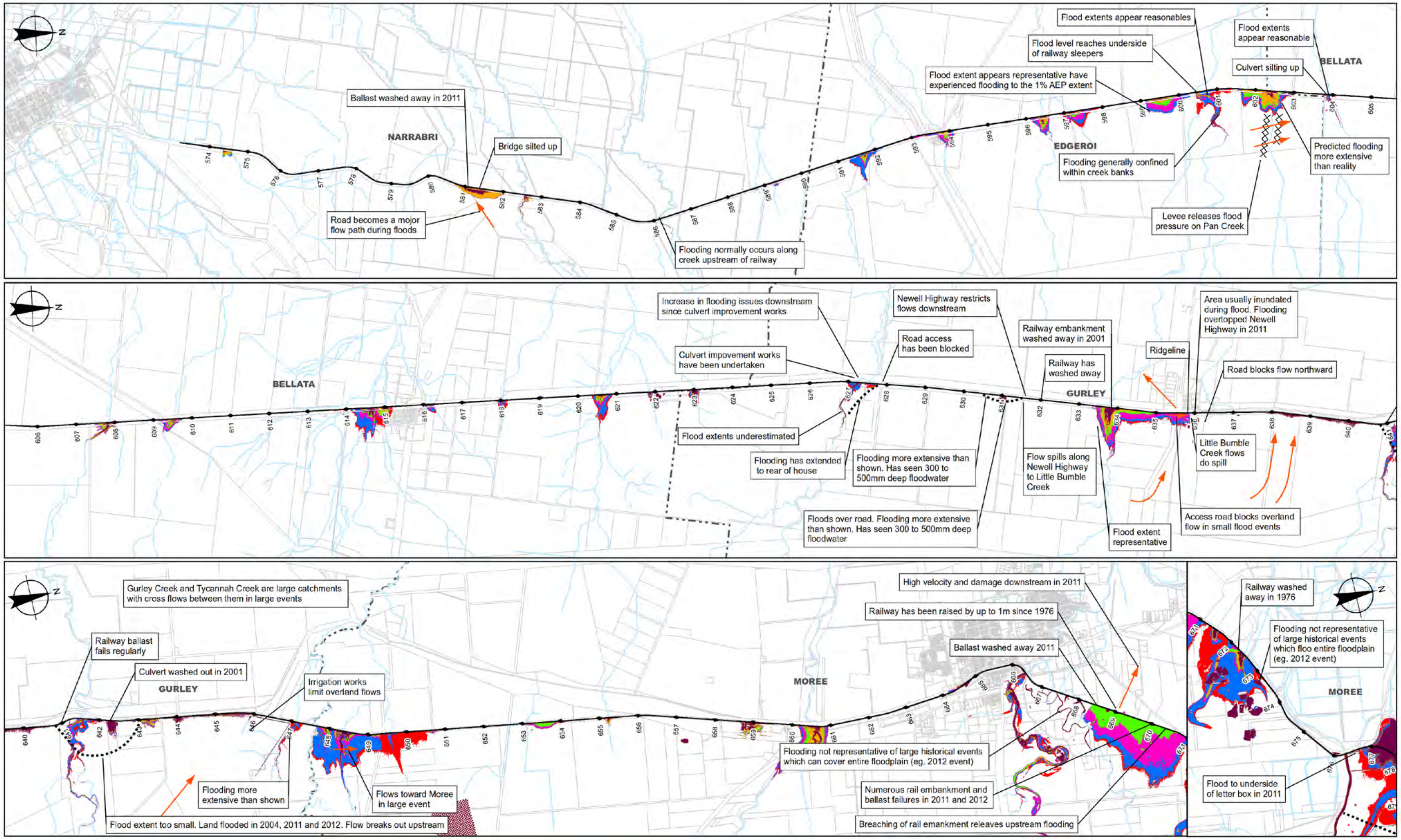
Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Inland Rail
- Watercourse
- Lot boundary
- Suburb boundary
- XXXX Removed soil conservation levees
- Overland flow path
- Community estimated flood extent
- Ridgeline
- 50% AEP
- 20% AEP
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP

GHD

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number	22-17916
Revision	1
Date	16 Aug 2017

Existing Flood Impact Areas Community Feedback - Sheet 1

Figure 4-3a

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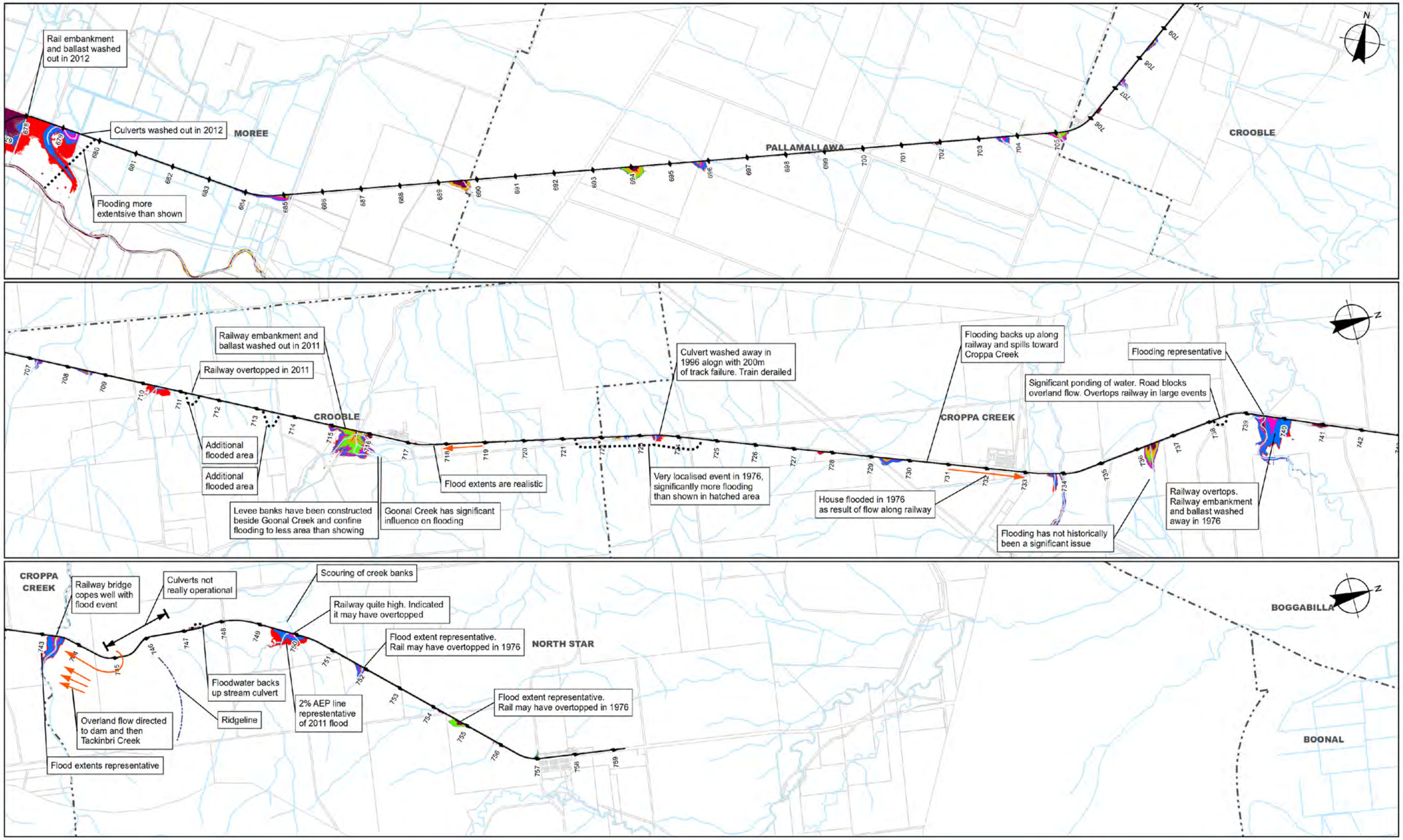
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DCDB/DTDB, 2012. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Inland Rail
- Watercourse
- Lot boundary
- Suburb_LPI_DCDB_2012
- Removed soil conservation levees
- Overland flow path
- Community estimated flood extent
- Ridgeline
- 50% AEP
- 20% AEP
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number 22-17916
Revision 1
Date 16 Aug 2017

Existing Flood Impact Areas
Community Feedback - Sheet 2

Figure 4-3b

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Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: DCDB/DTDB, 2012. Created by: gmcdiarmid, kpsroba, tmorton

4.3.1 Flood level analysis - local catchments

The local catchment flood levels were predicted using the methodology detailed in 0. Appendix E includes the design flood levels (fifty per cent, twenty per cent, ten per cent, five percent, two per cent, one per cent, one half per cent and one fifth per cent AEP) along with the probably maximum flood (approximated as having a flow equal to three times the one per cent flow) for each culvert.

Results of the analysis indicated that the existing track would regularly overtop for rainfall over local catchments adjacent to the existing track. In some locations, the overtopping was predicted to extend for several consecutive kilometres of track. The extent of the overtopping and impacts of the overtopping are discussed in Section 4.3.1.

4.3.2 Rail overtopping and formation non-compliance - local catchments

Locations and extents of rail overtopping - local catchments

The flood modelling gave predictions that the rail line would overtop at specific locations for a range of design flood events. The overtopping locations for the one per cent AEP local catchment event are shown by the red indicators in Figure 4.4, which indicate that an extensive length of the track is predicted to overtop in the local catchment one per cent AEP event. Appendix F provides details of the catchments for one per cent AEP rail overtopping and the catchment having rail overtopping for lesser events.

The extent and maximum depth of rail line overtopping is summarised in Table 4.3. This table indicates predicted depths of rail overtopping of 661 mm being reached in the five per cent AEP event with there being significant lengths of track overtopped for all considered events of up to twenty per cent AEP magnitude.

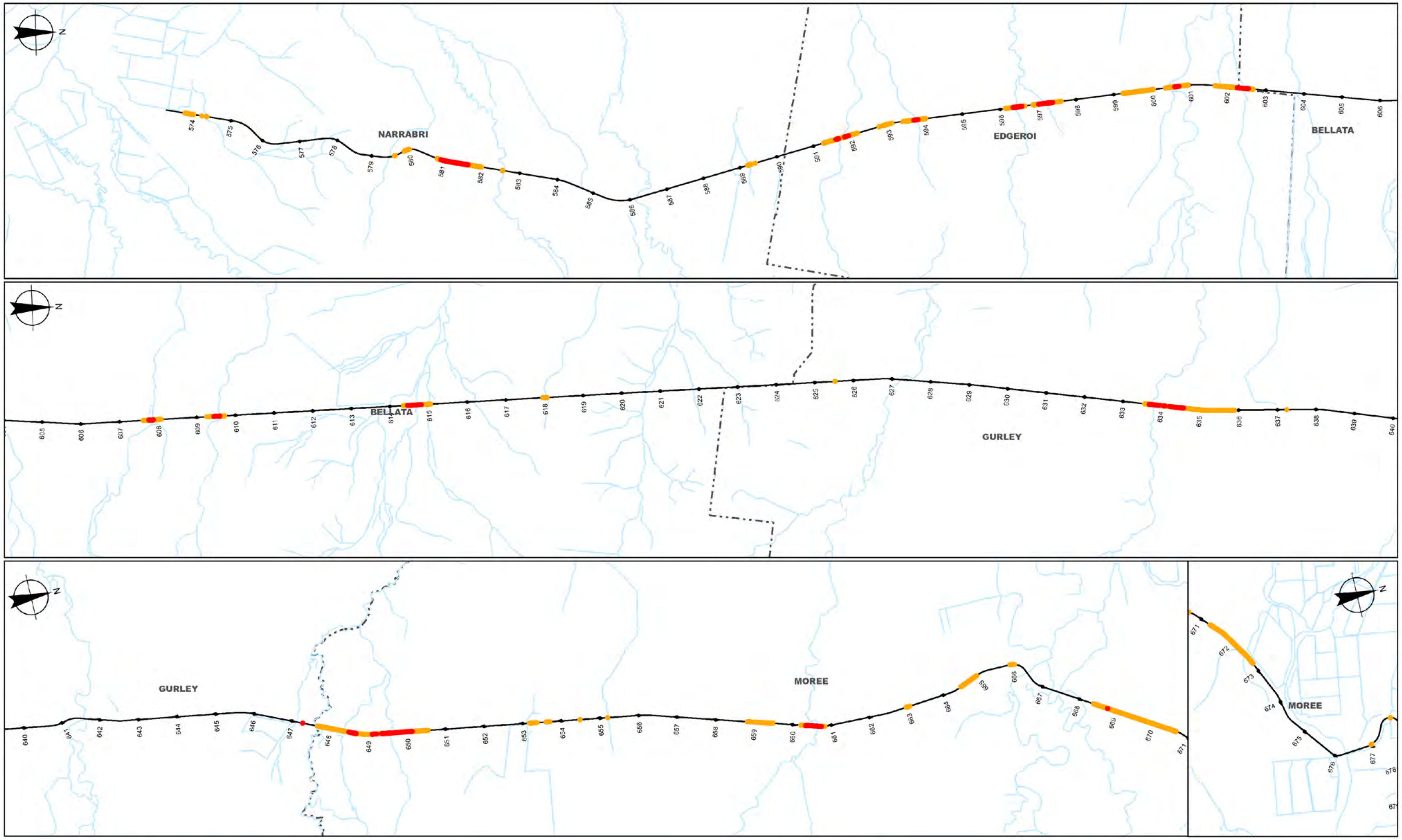
Table 4.3 Existing rail overtopping – local catchments

Design event (% AEP)	Overtopping Length (m)	Maximum overtopping depth (m)
50	122	-
20	872	0.629
10	1240	0.642
5	2457	0.661
2	6722	0.737
1	11,124	0.749

Compliance to indicative ETD-10-02 requirements - local catchments

Technical Note ETD-10-02 is not strictly applicable to the existing formation condition as the combined ballast depth, sleeper depth and rail size is less than that for the design condition. An evaluation of the compliance for four assumed depths has been determined to provide a basis for comparison to the design condition.

Table 4.4 provides a summary of the extent of compliance to the nominated Technical Note, which requires the upstream floodwaters to be below the top of shoulder of the formation for four assumed depths of ballast, sleeper and rail. The analysis has been completed this way since the actual depth to the top of formation has not been specifically quantified, however field estimates of existing ballast depths ranged from less than 400 mm up to about 720 mm. A typical existing ballast depth was therefore considered to be within this range. Appendix G provides details on the predicted results. As would be expected, smaller events result in less non-conformance of the track, at fewer locations.



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

Overtopped - rail
Flood level above formation
Watercourse
Suburb boundary

Australian Rail Track Corporation
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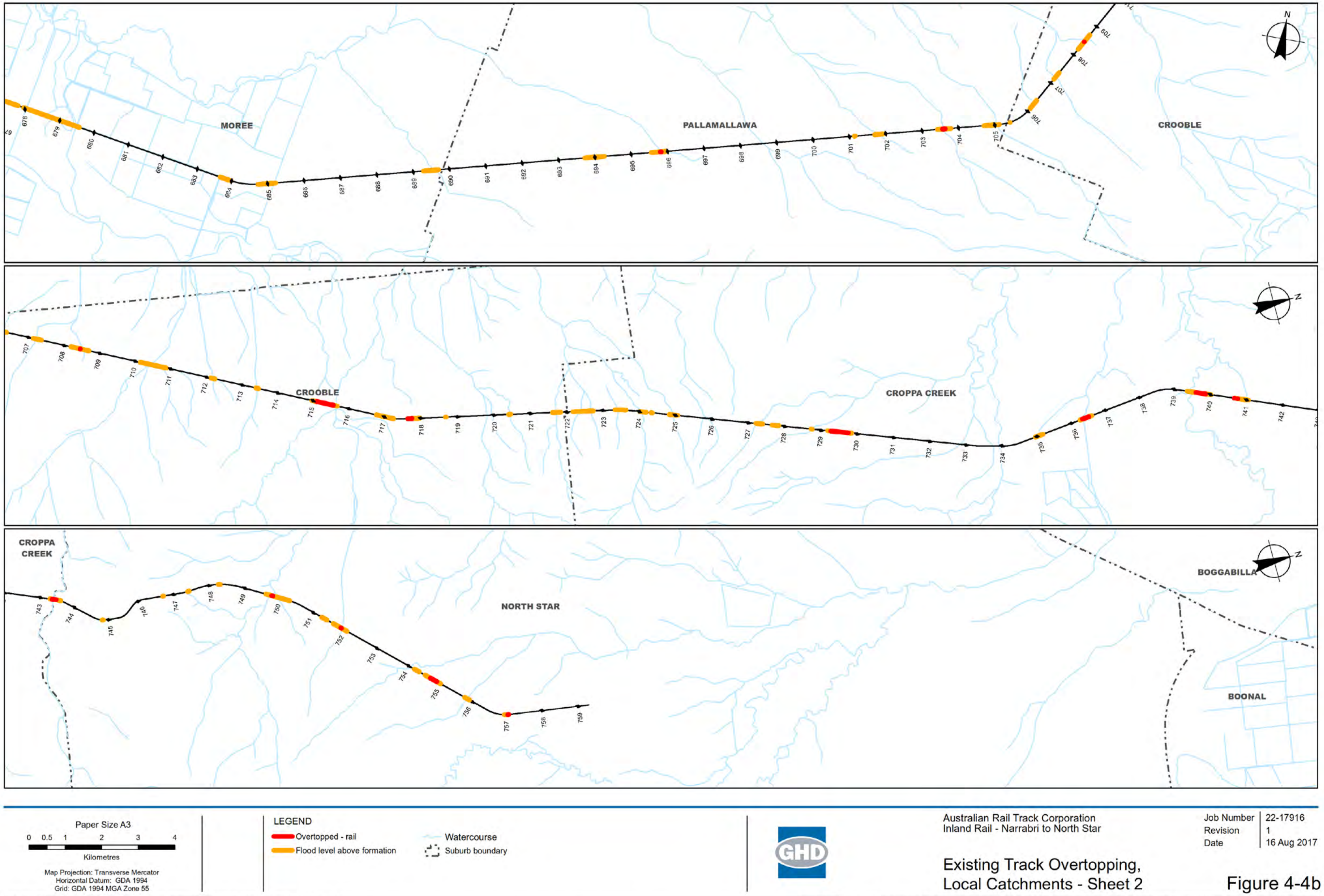
Existing Track Overtopping, Local Catchments - Sheet 1

Figure 4-4a

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH011_NNS_FloodStatus_Existing_100yr_Sht1_1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

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Revision 1
Date 16 Aug 2017

Existing Track Overtopping, Local Catchments - Sheet 2

Figure 4-4b

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH011_NNS_FloodStatus_Existing_100yr_Sht2_1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba

Table 4.4 Existing formation non-compliance – local catchments

Design event (% AEP)	Extent of formation non-conformance (km) - local catchments			
	Assumed 720 mm depth to top formation	Assumed 600 mm depth to top formation	Assumed 582 mm depth to top formation	Assumed 400 mm depth to top of formation
50	2.94	1.74	1.63	0.94
20	5.48	3.38	3.14	1.84
10	8.22	5.18	4.78	2.74
5	15.97	11.41	10.77	6.62
2	25.83	20.79	20.16	14.00
1	34.73	28.79	27.81	20.36

Level crossings – local catchments

The predicted flood levels indicate that several public road crossings of the rail corridor would be overtopped for the various design events. Table 4.5 provides a summary of the level crossings that are expected to be overtopped in the various local catchment design conditions. Note that this does not include potential flooding of public roads adjacent to the project, which are discussed in Section 4.3.4.

Table 4.5 Existing level crossings overtopped – local catchments

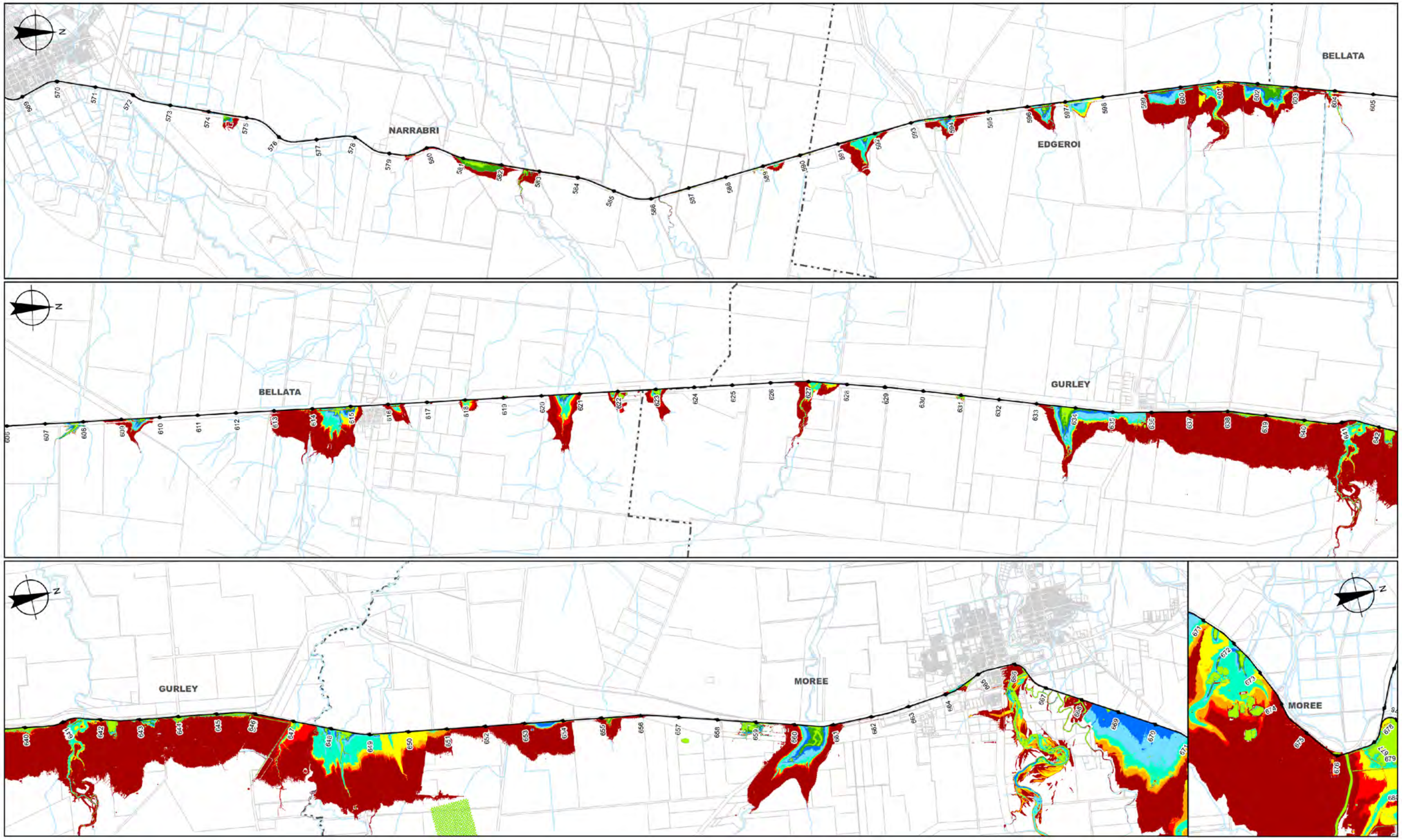
Chainage	Public Level Crossing	Level crossing maximum overtopping depth (m)					
		50 % AEP	20% AEP	10% AEP	5% AEP	2 % AEP	1 % AEP
634.49	Unnamed road	-	-	-	-	-	0.12
649.35	Unnamed road	-	-	-	-	-	0.02
716.36	Gil Gil Creek Road	-	-	-	-	0.02	0.16
718.835	Crooble Road	-	-	0.07	0.08	0.10	0.11
758.24	IB Bore Road	-	0.03	0.20	0.25	0.49	0.61

4.3.3 Adjacent land impacts – local catchments

The predicted flood levels for the existing conditions were examined for a range of design events from the 50 per cent AEP through to the Probable Maximum Flood (PMF) event. Within this range, the 0.5 per cent and 0.2 per cent were considered to represent a potential climate change impact assessment.

Upstream flood impact – local catchments

Figure 4.5 shows the predicted upstream flood extents in a diagrammatic form for events that have been evaluated while Table 4.6 lists the areas of existing local catchment inundation for flood events up to the PMF. Figure 4.5 should not be read to imply that flooding does not occur downstream of the rail corridor – rather, this downstream area has not been mapped as the flood extent would not be expected to change (refer to Section 2.6.1).



Paper Size A3

0 0.5 1 2 3 4
Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Existing Rail
- Watercourse
- Lot boundary
- Suburb boundary
- 50% AEP
- 20% AEP
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP
- 0.5% AEP
- 0.2% AEP
- PMF

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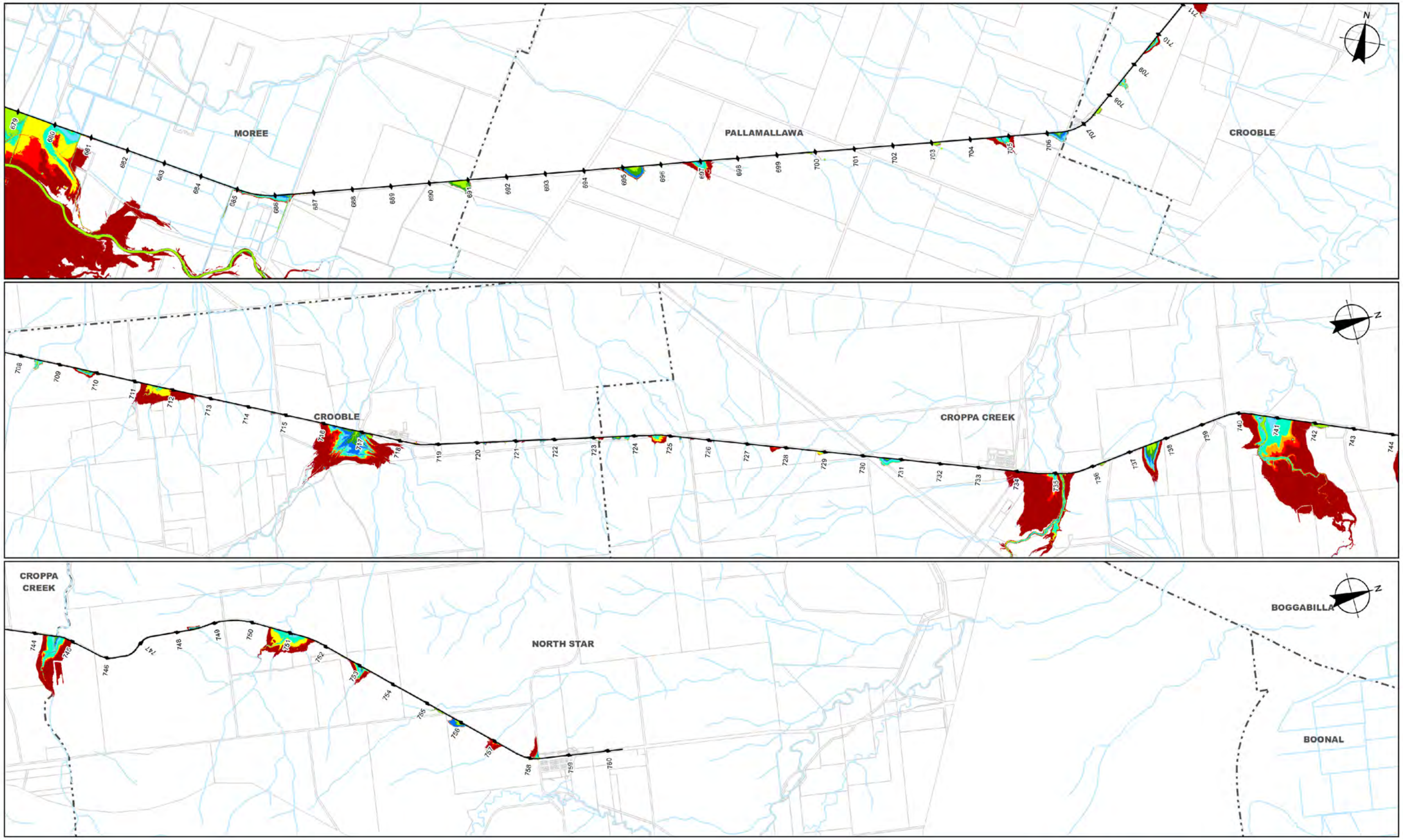
Existing Flood Impact Areas, Local Catchments - Sheet 1

Figure 4-5a

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH010_NNS_FloodExtents_Existing_Sht1_1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Existing Rail
- Watercourse
- Lot boundary
- Suburb boundary
- 50% AEP
- 20% AEP
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP
- 0.5% AEP
- 0.2% AEP
- PMF

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

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Existing Flood Imact Areas, Local Catchments - Sheet 2

Figure 4-5b

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH010_NNS_FloodExtents_Existing_Sht2_1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton

Table 4.6 Existing upstream inundation area – local catchments

Design event (% AEP)	Area of inundation (ha)
50	401.8
20	554.1
10	852.8
5	1373.0
2	2093.5
1	2668.9
0.5	3031.8
0.2	3414.9
PMF	9591.7

Upstream flood velocities – local catchments

When the existing track is not overtopped, the flow velocities on the floodplain would generally be low. Immediately upstream of a culvert on the floodplain there would be a localised increase in velocity as the water approaches and enters the respective structure. The approach velocities on the floodplain are not expected to exceed a value of about 1.5 metres per second.

The upstream velocity in defined watercourses would be larger than that on broad floodplain areas. For these locations, the velocity is predicted to be less than two metres per second except in very localised areas where the watercourse is constricted.

When the track overtops, some floodwater passes over the rail embankment instead of through the culverts, with the embankment acting as a levee. This would result in an increased flow velocity over the floodplain areas downstream of the rail embankment.

Upstream period of flooding - local catchments

Periods of flooding for local catchment flood events vary with the size of the local catchment but are predicted to be generally less than about nine hours (for upstream flood depths to fall to less than 0.1 metre) for the smaller catchments and extending to about 36 hours for some of the larger conditions under most design storm events over the local catchment areas. The existing data suggests that some areas of flooding in the most low-lying areas, for regional flood events, could extend over several days or weeks.

Upstream watercourses - local catchments

The predicted low velocities described above are not anticipated to result in watercourse instability.

Downstream flood effects - local catchments

Downstream of the rail corridor flood levels are generally reduced for more frequent flood events (i.e. up to the one per cent AEP event) as the rail formation retains flood water upslope and slowly discharges the retained flood water into the downstream areas via culverts and bridges, and localised areas of overtopping.

Downstream flood velocities - local catchments

When the track level is not being overtopped, the flow downstream of the bridges and culverts would generally be confined within the individual watercourses.

At times when flooding overtops the rail level (assuming the ballast does not erode), there would be a localised relatively high velocity of flow down the downstream face of the embankment. Since the embankment is generally not very high, it is anticipated that the velocity on the face of the embankment is unlikely to exceed a value of about 2.5 metres per second. This could create an erosion of the downstream face of the embankment.

Historical records show the rail ballast would generally fail and wash out, at least for part of the overtopping length, prior to, or about the same time as the overtopping of the rail. Under this circumstance, there could be a flow on the downstream formation of the rail line of up to about two metres per second.

Downstream periods of Inundation - local catchments

Watercourses downstream of culverts would be inundated for periods similar to the upstream areas.

Downstream watercourses - local catchments

Watercourses located downstream of many existing bridges and culverts exhibit signs of erosion. This is inferred as being the result of progressive stream instability due to the increased watercourse flow velocity, the historical increased frequency of flow and the lengthening of the periods of saturation as compared to that prior to construction of the existing rail corridor.

At most locations, the length of the watercourse instability does not exceed about 50 metres. However, there are some localised areas where the effects extend further downstream of the individual structures.

4.3.4 Road flooding - local catchments

An analysis was undertaken to assess the locations and potential depths of road overtopping that would occur under existing local catchment conditions. The locations where the predicted levels overtop the roads within the LiDAR corridor are listed in Table 4.7. This analysis considered the roads identified in the functional hierarchy as being higher than local roads.

The maximum flood level in each catchment was assessed and then the lengths of roads impacted were determined by applying a horizontal design water surface and comparing the road levels to the design flood levels. Application of this method indicates the potential for some roads to have a higher maximum inundation depth than that at the location where the same road crosses the rail line.

Table 4.7 Existing public road overtopping – local catchments

Road	Maximum Depth overtopping (m) - local catchments					
	50% AEP	20 % AEP	10% AEP	5% AEP	2% AEP	1% AEP
Gil Gil Creek Road	-	-	-	-	0.17	0.30
Gurley Road	-	-	-	-	0.41	0.96
Mosquito Creek Road	-	-	-	-	0.00	0.00
Newell Highway (multiple locations)	-	0.14	0.27	0.33	0.57	0.73
Oregon Road	0.09	0.90	1.40	1.65	1.89	2.03
Railway Parade	-	0.24	0.25	0.27	0.30	0.31

Extensive proposal consultation was undertaken including with the relevant Councils (refer to EIS), and emergency management arrangements during flooding was not raised as an issue for the proposal. However, these predicted closure locations are in close agreement with information from the SES (SES 2014a), which indicate road closure at or near those indicated in Table 4.7.

The maximum depth of water predicted for the road closures did not necessarily occur where the public road crossed the rail line at the level crossing location, as the maximum depth was dependent upon the road profile within the flooded area.

Overtopping of public roads under existing and design conditions is addressed in more detail in Section 6.4.4.

4.3.5 Building impacts - local catchments

An inspection of the imagery indicated that 16 buildings were located within the area where the modelling indicates the existing rain line affects flood levels during the one per cent AEP local catchment flood events, consisting of:

- 1 house
- 5 businesses
- 9 garages or shed
- 1 park structure/public amenity area

This does not include the flood-affected dwellings within Moree, which are impacted by the large regional floods within the Gwydir and Mehi Rivers.

4.4 Flooding - regional catchments

4.4.1 Flood level analysis – regional catchments

Gwydir River and Mehi River

Anecdotal information from the Moree area has indicated that flooding from the Gwydir and Mehi Rivers overtop the rail alignment. Detailed flood modelling of the Gwydir and Mehi Rivers (between kilometerages 657.000 and 686.000) undertaken by Jacobs (2017) indicates that the rail would overtop in events in excess of the 20 per cent AEP event.

The maximum modelled flood depths and extents associated with the one percent and ten per cent AEP flood events within the Gwydir and Mehi Rivers is included in Figure 4.6 and Figure 4.7 respectively. These figures indicate that regional flooding results in much more extensive flooding compared to the local catchment flooding. Appendix E includes design flood levels for the one per cent AEP regional flood event.

Namoi River and Narrabri Creek

Modelling indicated that that flooding from the Namoi River is not expected to overtop the rail formation for the length of the proposal within the vicinity of Narrabri (URS 2014: refer to Figure 4.8).

4.4.2 Rail overtopping and formation non-compliance – regional catchments

Figure 4.6 and Figure 4.7 indicate the locations where the existing rail line level (as surveyed by track LiDAR) and existing rail is overtopped and formation is non-conforming.

The total length of overtopped rail because of flooding within the Gwydir and Mehi Rivers for the existing conditions is summarised in Table 4.8.

The total length of formation non-conformance because of flooding within the Gwydir and Mehi Rivers for the existing conditions is summarised in Table 4.8 assuming that the top of rail is about 582 millimetres above the formation capping layer.

Table 4.8 Existing rail overtopping and formation non-compliance – regional catchments

Design event (% AEP)	Overtopping Length (m)	Extent of non- compliance [A] (km)
10	2975	5.66
1	6310	12.38

[A] Assumes a ballast depth of 582 millimetres

4.4.3 Adjacent land impacts – regional catchments

Figure 4.6 and Figure 4.7 show the predicted regional flood extents for the one per cent and ten per cent AEP flood event respectively. From these figures it can been that a regional flood event is expected to affect a much larger area than the local catchments (Figure 4.5).

The regional flood modelling indicates that for the one per cent AEP flood event affects approximately 270 square kilometres upstream of the rail corridor (Figure 4.6), and principally consists of the floodplain associated with the Mehi and Gwydir Rivers.

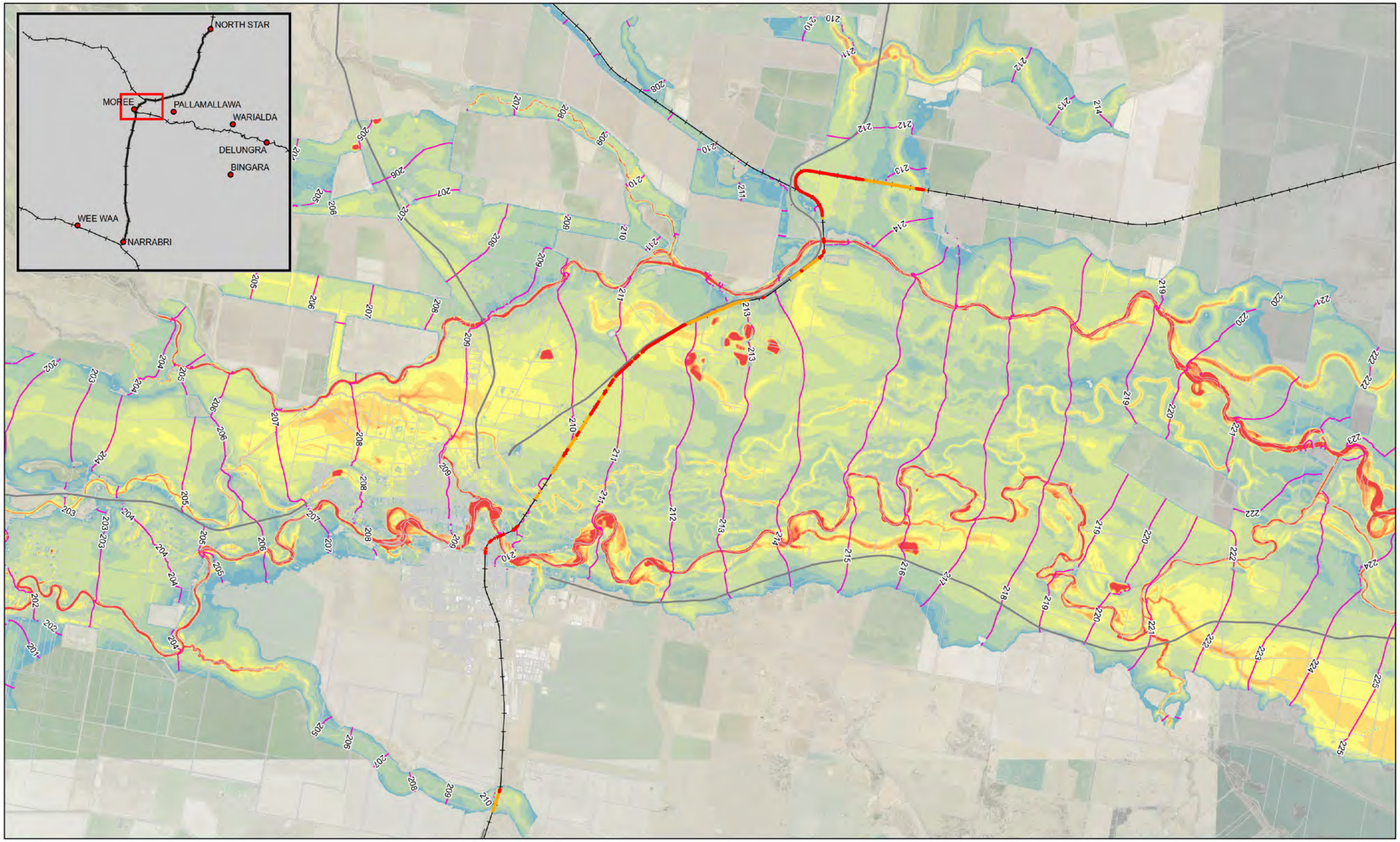
The modelling indicates that within the overbank and floodplain areas (i.e. outside of the main channels associated with the Mehi and Gwydir Rivers), flood flow velocities are typically less than about 0.5 metres per send (Jacobs 2017). Nearer to the Mehi and Gwydir Rivers, flow velocities increase to above one metre per second, with some sections exceeding two metres per second.

4.4.4 Road flooding – regional catchments

The Newell Highway passes through Moree, and includes bridges over both the Mehi and Gwydir Rivers. The regional modelling (Jacobs 2017) indicated that at some locations the one per cent AEP flood depths over the Newell Highway are about 1.5 to two metres. Therefore, the Newell Highway is considered non-trafficable during major regional flood events.

4.4.5 Building impacts – regional catchments

The regional modelling indicated that nine properties could be affected by the ten per cent AEP flood event, with an average flood depth at these properties of about 0.3 metres (Jacobs 2017). The regional flood modelling indicates that this increases to 976 properties during the one per cent flood event, with an average depth of about 0.7 metres (Jacobs 2017).



Paper Size A3

0 375 750 1,500 2,250 3,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Highway
- Existing railway
- Cadastre
- Water Level Contour (1m)
- Overtopped rail
- Overtopped formation

Flood Depth (m)

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 - 5
- > 5

GHD

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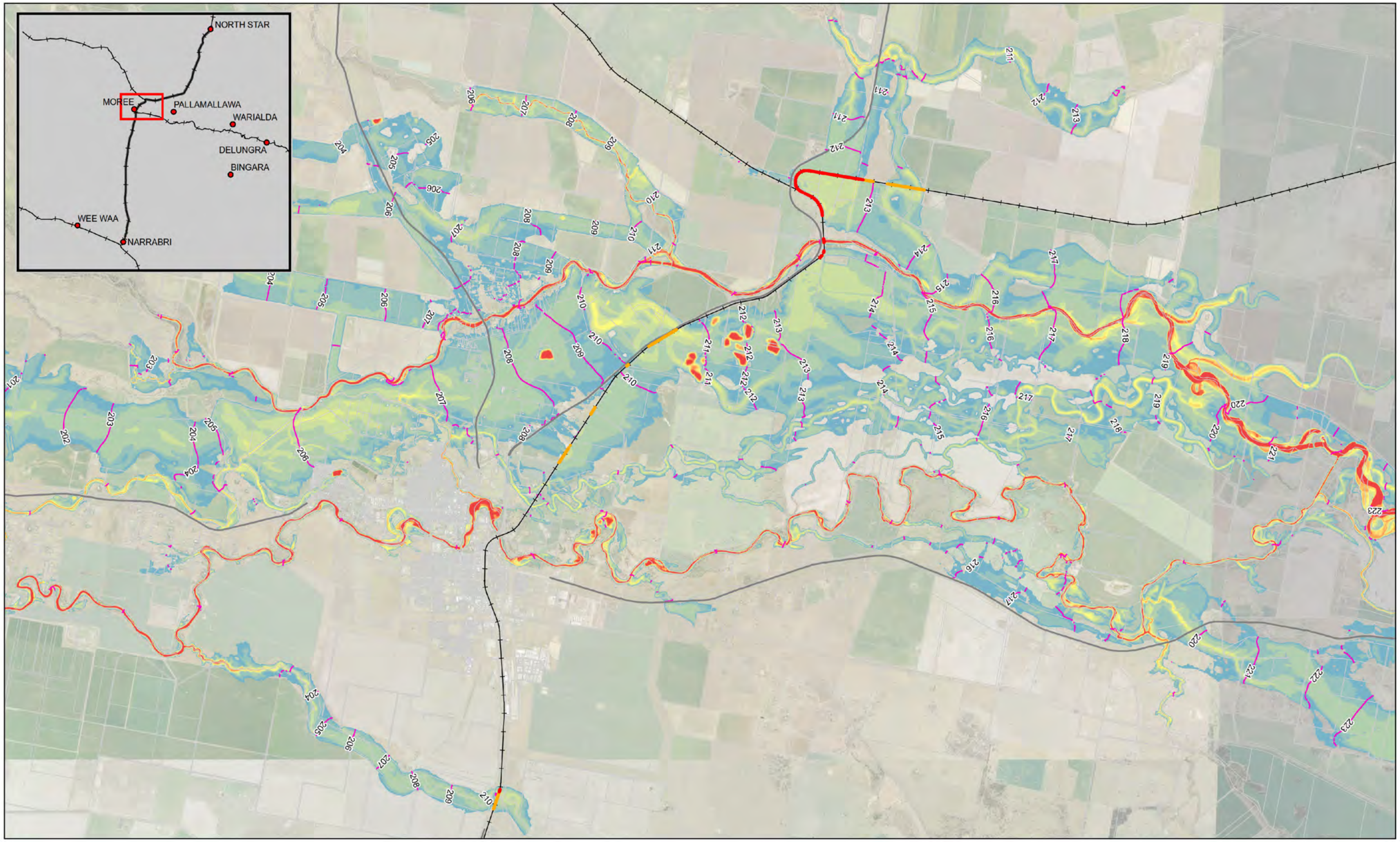
Existing Flood Depths and Track Overtopping - Gwydir and Mehi Rivers (Regional) 1% AEP Event

Figure 4-6

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH032_NNS_MoreeFlooding_100yr_TL_1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI, DTDB/DCDB, 2012. Jacobs, Flood depth, 2017. Created by: kpsroba, gmcdiarmid



Paper Size A3

0 375 750 1,500 2,250 3,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

Highway	Water Level Contour (1m)	
Existing railway	Overtopped rail	
Cadastre	Overtopped formation	

Flood Depth (m)		
0 - 0.1	1 - 1.5	3.5 - 4
0.1 - 0.25	1.5 - 2	4 - 4.5
0.25 - 0.5	2 - 2.5	4.5 - 5
0.5 - 1	2.5 - 3	> 5
	3 - 3.5	

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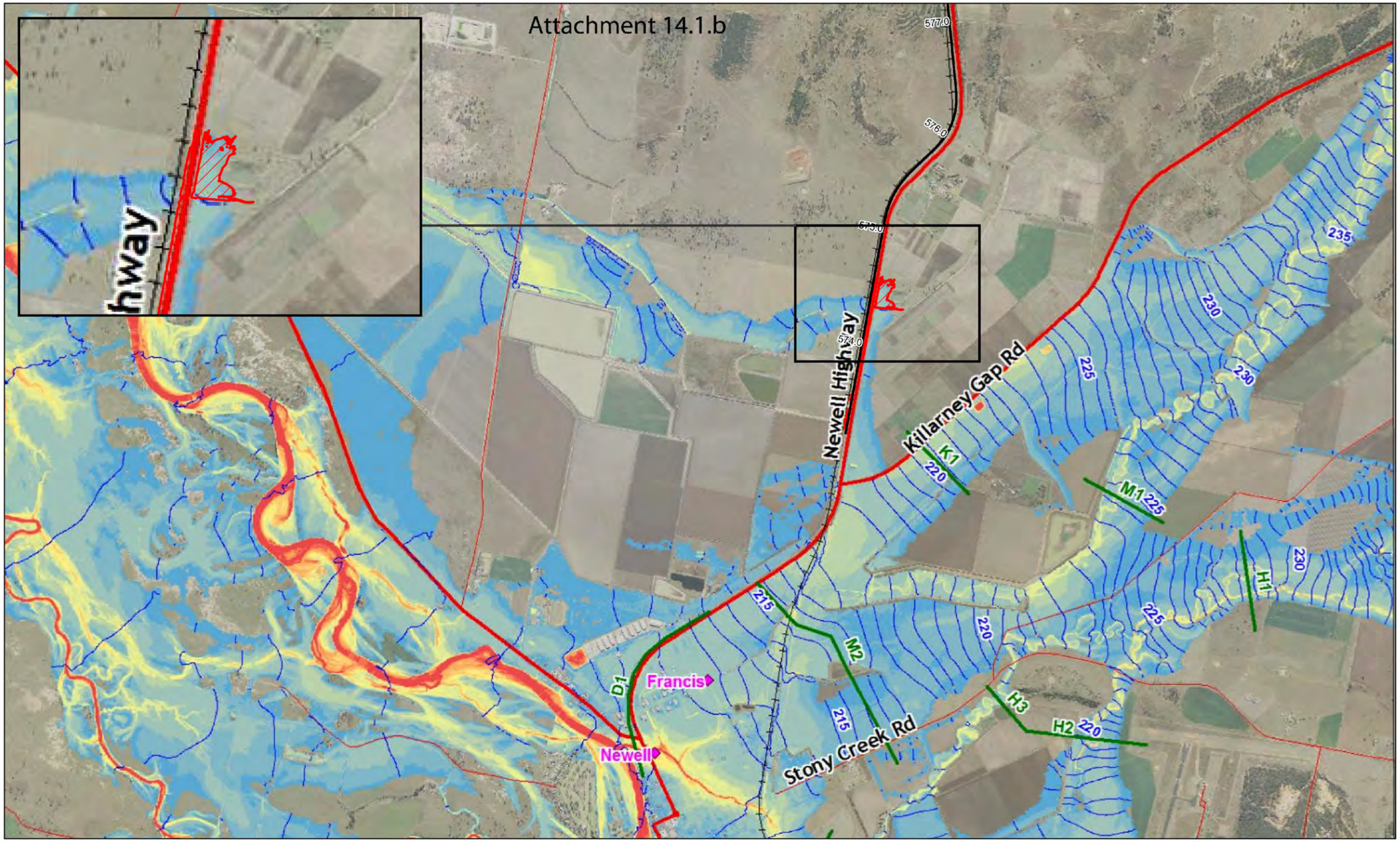
Existing Flood Depths and Track Overtopping - Gwydir and Mehi Rivers (Regional) 10% AEP Event Figure 4-7

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH033_NNS_MoreeFlooding_10yr_TL_1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI, DTDB/DCDB, 2012. Jacobs, Flood depth, 2017. Created by: kpsroba, gmcdiarmid



Paper Size A3

0 125 250 500 750 1,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Rail centreline
- Existing 1% AEP
- Water Level Contour (0.5m)
- Discharge Reporting Location
- Local Road
- Water Level Reporting Location
- Highway

Flood Depth (m)

>5.00
4.50
4.00
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.25
0

GHD

Australian Rail and Track Corporation
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Comparison of Narrabri Flood (Regional) Study to Existing 1% AEP event

Figure 4-8

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH027_NNS_NarrabriFlooding_100yr_1.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: Narrabri Flood Study, Namoi River, Mulgate Ceek and Long Gully. Created by: kpsroba, gmcdiarmid

4.5 Flooding – combined local and regional catchments

4.5.1 Flood level analysis – combined local and regional catchments

The maximum modelled flood depths and extents for local and regional flood events are addressed in Sections 4.3.1 and 4.4.1 respectively. Appendix E includes design flood levels for the local and regional flood events. By combining both local and regional flood mechanisms, the extent of existing track that is considered to be impacted by flooding further increases (Section 4.5.2).

4.5.2 Rail overtopping and formation non-compliance – combined local and regional catchments

Figure 4.9 indicates the locations where the existing rail line level (as surveyed by track LiDAR) and existing rail is overtopped and formation is non-conforming for both the local and regional catchment flooding. Combining the regional flood ballast flood results (Table 4.8 with the ballast flooding estimates for local catchment flooding (Table 4.4) provides an overall estimate of the length of the existing rail that does not currently comply with ETD-10-02 (refer to Table 4.9).

Table 4.9 Existing rail overtopping and formation non-compliance – combined local and regional catchments

Design event (% AEP)	Overtopping Length (m)	Extent of non-conformance [A] (km)
10	3810	11.90
1	12,725	39.93

[A] Assumes a ballast depth of 582 millimetres

4.5.3 Adjacent land impacts – combined local and regional catchments

Figure 4.10 compares the flood affectation areas estimated for the local catchments (Figure 4.5) and regional catchments (Figure 4.6 and Figure 4.7).

From Figure 4.10 it is can be seen that within the vicinity of Moree, larger floods are expected to occur as a result of the regional flood events. Outside of Moree however, catchments are typically smaller and less influenced by regional scale flood mechanisms.

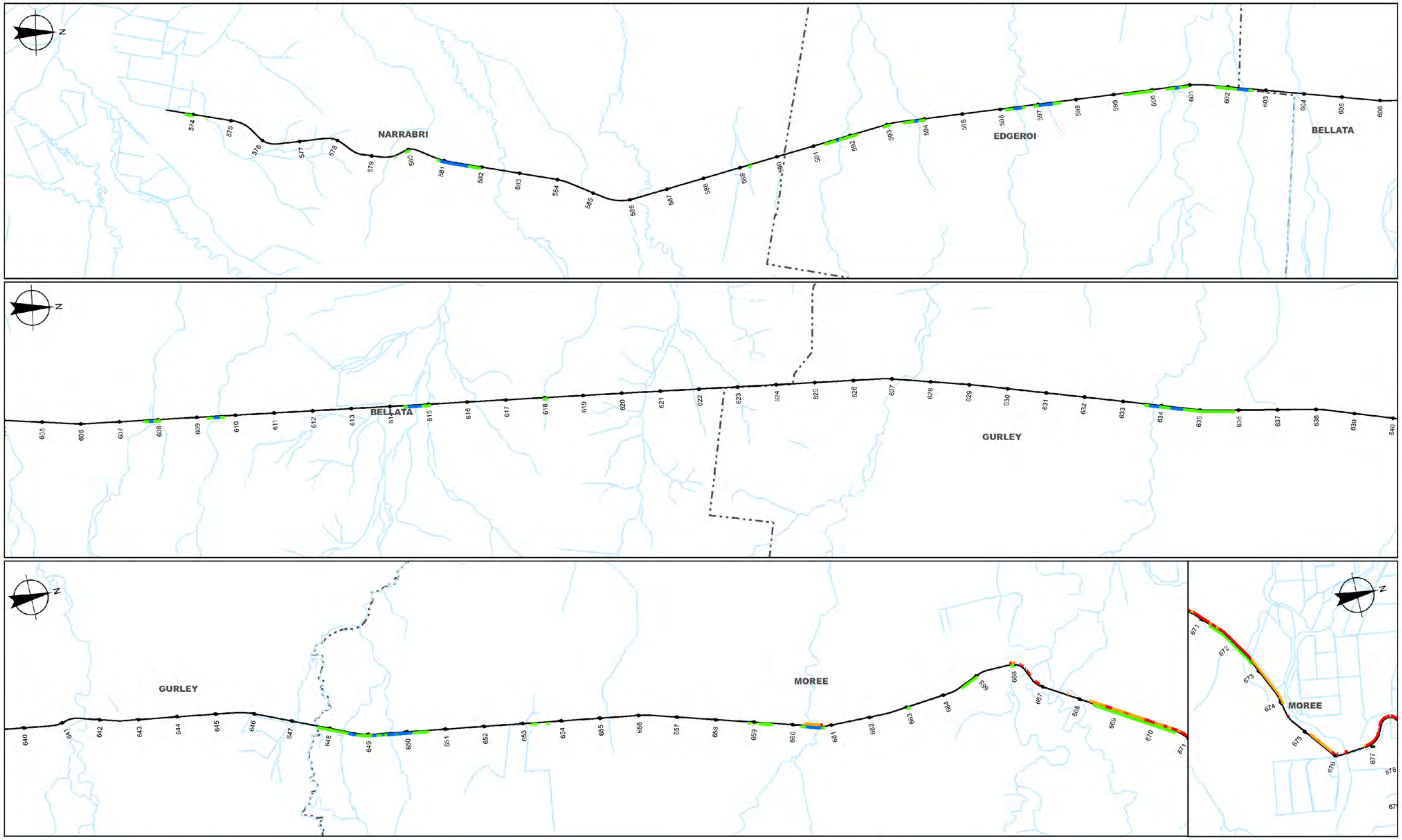
Details of flood extents and velocities for the local and regional catchment flood events are addressed in Sections 4.3.3 and 4.4.3 respectively.

4.5.4 Road flooding – combined local and regional catchments

As discussed within Section 4.4.4, the principal road through Moree is considered flood prone during regional flood events. Outside of Moree, a number of roads are likely to be affected by local flood events (Section 4.3.4).

4.5.5 Building impacts – combined local and regional catchments

The modelling indicates that significantly more properties are considered to be flood prone as a result of regional flooding than local flooding, with an estimated 976 properties affected by the regional one per cent AEP flood event (Section 4.4.5) and an estimated 16 properties affected by the local one per cent AEP flood event (Section 4.3.5).



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Overtopped rail (local)
- Overtopped formation (local)
- Overtopped rail (regional)
- Overtopped formation (regional)
- Watercourse
- Suburb boundary

GHD

Australian Rail Track Corporation
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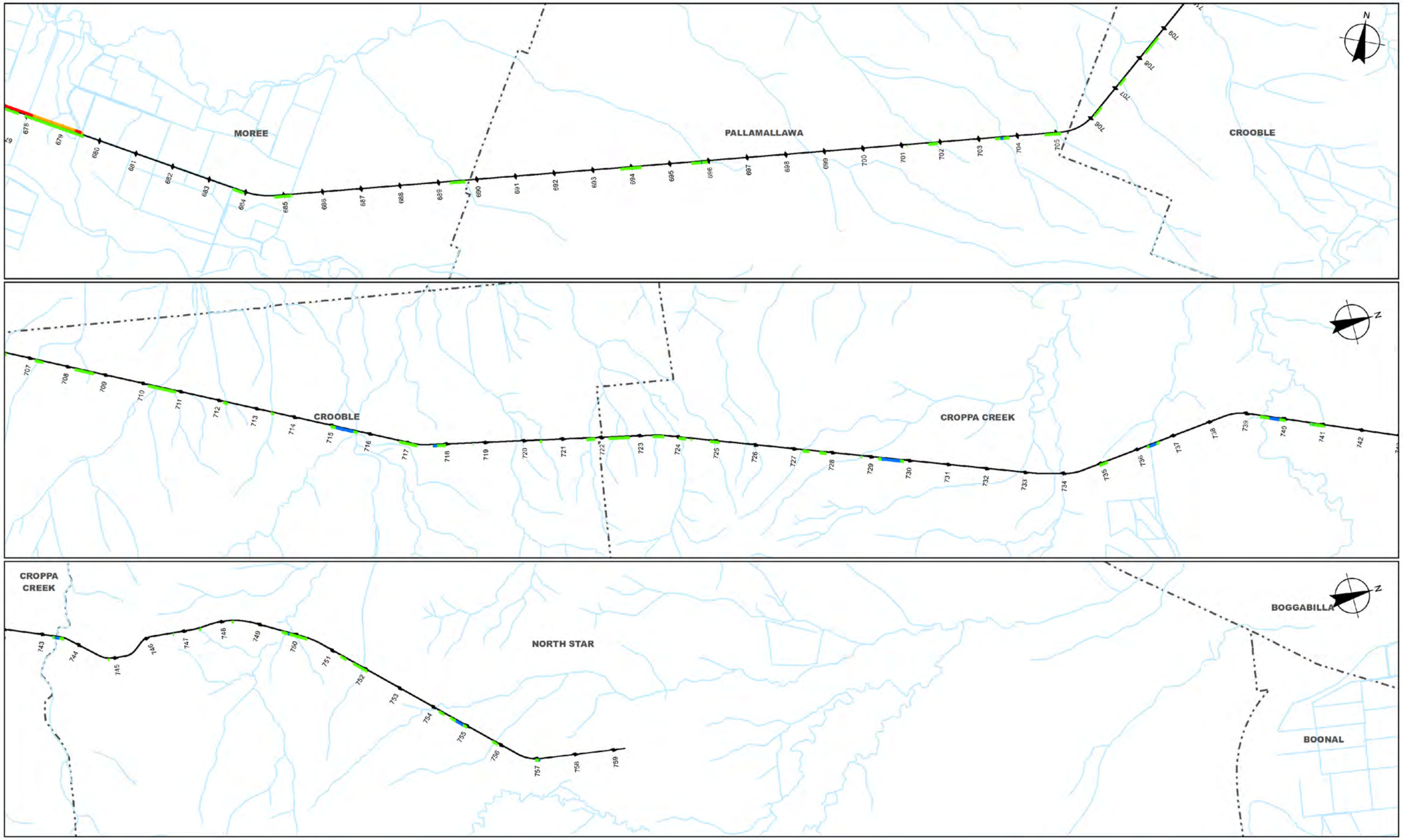
Existing Track Overtopping, Local and Regional Catchments - Sheet 1

Figure 4-9a

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH040_NNS_Flooding_Combined_100yr_v2_sh1_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Overtopped rail (local)
- Overtopped formation (local)
- Overtopped rail (regional)
- Overtopped formation (regional)
- Watercourse
- Suburb boundary

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

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Existing Track Overtopping, Local and Regional Catchments - Sheet 2

Figure 4-9b

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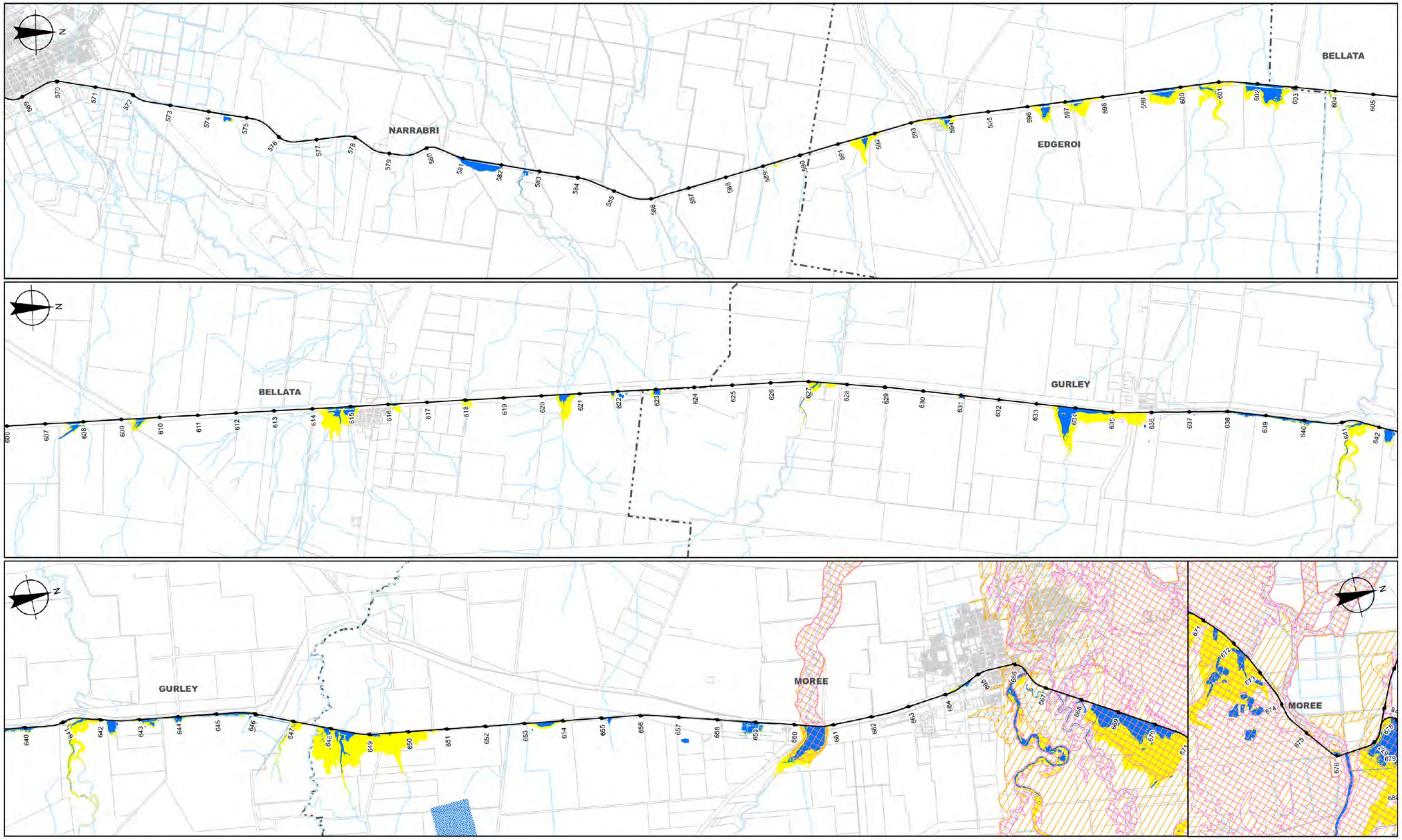
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Existing Rail
- Watercourse
- Lot boundary
- Suburb boundary
- 10% AEP local flood extent
- 1% AEP local flood extent
- 10% AEP regional flood extent
- 1% AEP regional flood extent

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number	22-17916
Revision	0
Date	16 Aug 2017

Existing Flood Impact Areas, Local and Regional Catchments - Sheet 1

Figure 4-10a

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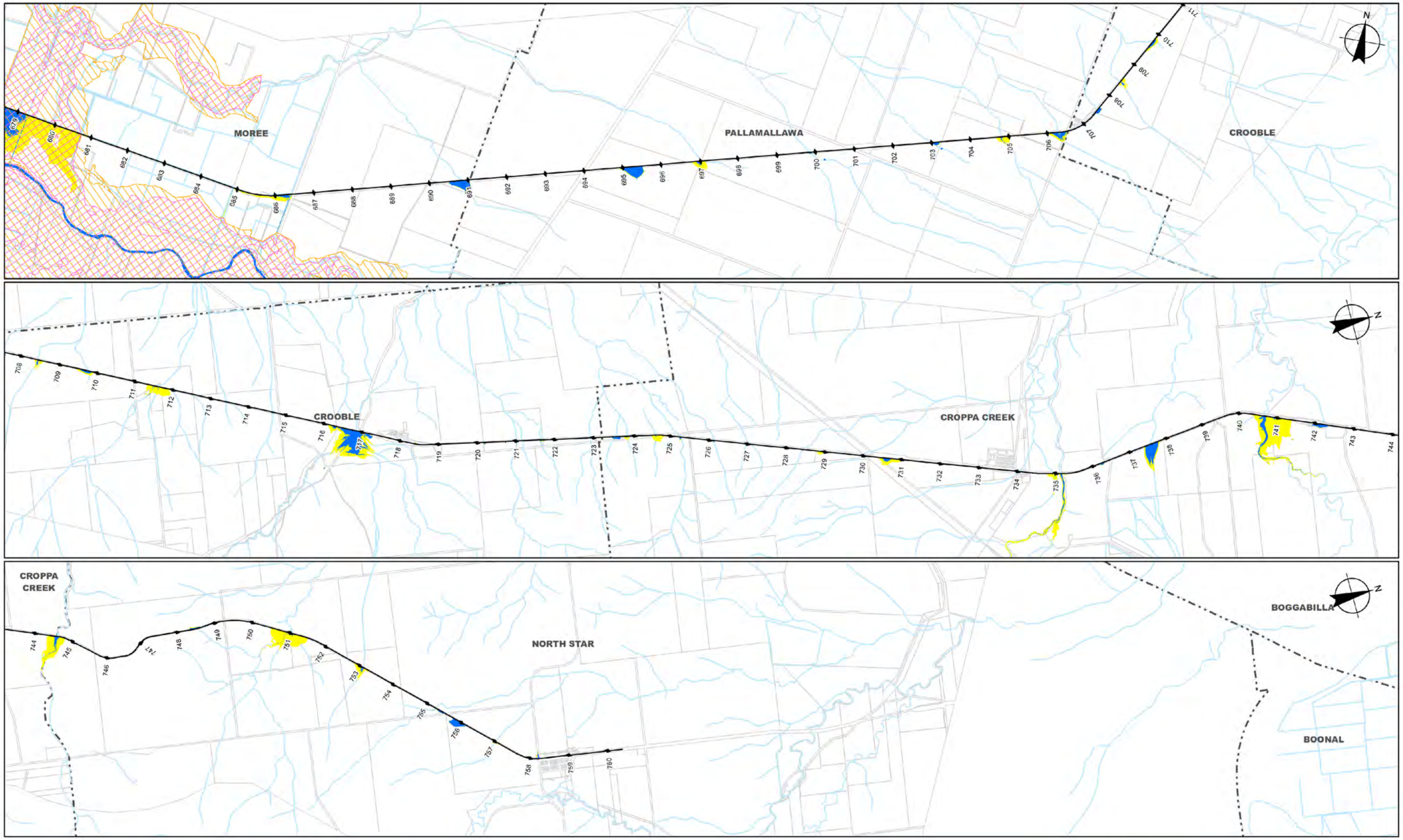
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

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Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

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Existing Flood Imact Areas, Local and Regional Catchments - Sheet 2 Figure 4-10b

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Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

5. Risk assessment

5.1 Background

The hydrologic and hydraulic/flooding risk assessments considered potential impacts during both construction and operation. The assessments analysed changes to the surface flow paths and rates, and groundwater flow paths and rates that could result from the proposal.

5.2 Risk assessment – hydrology

An assessment of the potential hydrologic risks, and measures to avoid, mitigate or minimise them, is provided in Table 5.1. The risks and impacts listed in Table 5.1 are discussed in the following sections.

Table 5.1 Hydrologic risks, potential impacts and mitigation measures

Risk	Potential hydrologic impacts	Measures to avoid, mitigate or minimise impacts
Construction period Impact on surface water flow in watercourses	• Modified surface flow volume or rate downstream of the rail corridor	• Maximise the manufacture of concrete structures off site at locations where water is readily available. • Select concrete mixes that minimise water requirements. • Minimise the volume of surface water extracted for construction. • Minimise the installation of culverts that create localised surface water ponding.
	• Changed surface flow paths across the rail corridor	• Install a culvert structure at each low point along the rail corridor when low point cannot be removed through grading within corridor. • Minimise regrading of terrain along the rail corridor. • Install appropriately sized culvert and bridge structures along the corridor.
Construction period Impact on surface water flow in irrigation channels or constructed drains	• Restricted water passage along irrigation drains or constructed channels	• Maximise the manufacture of as many concrete structures off site at locations where water is readily available. • Select concrete mixtures that minimise water requirements. • Minimise the volume of groundwater extracted for construction. • Install appropriately sized structures where each irrigation channel or constructed drain is crossed. • Minimise new crossings of irrigation channels or constructed drains.

Risk	Potential hydrologic impacts	Measures to avoid, mitigate or minimise impacts
Construction period Impact on groundwater flow	• Modified groundwater flow volume or rate downstream of the rail corridor	• Maximise the manufacture of concrete structures off site at locations where water is readily available. • Minimise the installation of culverts that permanently or intermittently intercept groundwater. • Minimise the volume of water extracted from groundwater for construction. • Minimise groundwater extraction at individual sites.
Operational period Impact on natural surface flow in watercourse	• Modified surface flow volume or rate downstream of the rail corridor	• Avoid installation of culverts that create localised surface water ponding. • Select structure sizes to match the existing flow regime. • Avoid any track crossings of watercourses that can create ponding.
	• Changed surface flow paths across rail corridor	• Install a culvert structure at each low point along the rail corridor where the low point cannot be removed through grading within the rail corridor. • Minimise regrading of terrain along the rail corridor. • Install appropriately sized culvert along the rail corridor.
Operational period Impact on surface water flow in irrigation and other channels/drains	• Restricted water passage along irrigation drains or constructed channels	• Install appropriately sized structures where each irrigation channel or constructed drain is crossed. • Minimise new crossings of irrigation channels or constructed drains.
Operational period Impact on groundwater	• Modified groundwater flow volume or rate downstream of the rail corridor	• Avoid installation of culverts that permanently or intermittently intercept groundwater. • Avoid installation of culverts that create localised surface water ponding where surface water infiltrates into the groundwater. • Avoid any track crossings of watercourses that can create ponding.

5.2.1 Potential hydrologic impacts – construction

Impact of modified surface flow volumes or rates downstream of the rail corridor

Construction of the proposal could modify flow volumes and rates downstream of the rail corridor through the extraction of surface water, which could reduce the availability of water to landowners (the extraction of water from storages would be subject to approvals and agreements). In addition, changing the flow rate and/or duration of flow through bridges or culverts that are constructed could create additional erosion either upstream or downstream of the respective culverts where flow conditions are modified significantly.

Impact of surface flow paths across the rail corridor

Construction of the proposal could modify flow paths across the rail corridor (cross drainage) through the installation of replacement or additional culverts and bridge structures. Changes to such structures could change the pattern of cross drainage from the upslope to downslopes areas, which may result in changes to patterns of erosion and scouring both within existing watercourses and drainage lines as well as within the broader floodplain area.

The proposal has been designed, and drainage elements sized, to minimise the number of locations and extents of track where the rail formation would overtop. The design has been developed to prevent formation overflow, except at a limited number of level crossings, for events up to the one per cent AEP event for local catchment runoff. This would reduce the extent of formation overtopping during flood events and restrict the flow crossing points to the proposed culvert locations.

Repositioning culverts – hence changing the locations where floodwater crosses the rail corridor – would have the following potential impacts:

- Creation of new erosion areas downstream of the rail corridor at each new culvert location.
- Loss of cropping areas downstream of the rail corridor (unless flow diversions are provided).
- Redirection of frequent flows away from existing water storage dams downstream of the rail corridor and loss of a water supply to the farms.
- Low areas immediately upstream of the rail corridor would not completely drain, leading to new areas of ponding immediately after each runoff event. To maintain existing flow paths it may be necessary to redirect flows upstream of the corridor in some very isolated areas.

Impact of restricted water passage along irrigation drains or channels

During construction, there is the potential for temporary partial blockage of irrigation drains because of material slumping, temporary cofferdams or other works within the irrigation drains. Such blockages could reduce the amount of water available for irrigation while flow is constricted. Construction methods, including placement of material stockpiles, should be designed to minimise the potential for blockages to occur.

Impact of modified groundwater flow volume or rate downstream of the rail corridor

Construction of the proposal could modify groundwater flow volumes and rates downstream of the rail corridor through the extraction of groundwater, used for construction purposes and interaction of construction activities with alluvial groundwater. Extraction of groundwater could reduce the availability of water to landowners (the extraction of water from bores would be subject to appropriate approvals and agreements).

Bridge design will be targeted at minimising, as much as practical, any ongoing groundwater impacts. The design would involve a residual redirection of alluvial flows around the piers but this impact would not extend more than five metres radially from each pier.

5.2.2 Potential hydrologic impacts – operation

Impact of modified surface flow volume or rate downstream of the rail corridor

During operation, ongoing modification to flow volumes and rates downstream of the rail corridor could occur because of changes to the flow rate and/or duration of flow through culverts that are constructed for the proposal. This could create additional erosion either upstream or downstream of the culverts where flow conditions are modified significantly.

Impact of modified surface flow paths across the rail corridor

The repositioning of culverts or bridge abutments during construction could affect surface flow paths across the rail corridor during operation. As described in Section 5.2.1 the repositioning of culverts or bridge abutments – hence changing the locations where floodwater crosses the rail corridor – would have the following potential impacts:

- Creation of new erosion areas downstream of the rail corridor at each new culvert location.
- Loss of cropping areas downstream of the rail corridor (unless flow diversion is provided).
- Redirection of frequent flows away from existing water storage dams downstream of the rail corridor and loss of a water supply to the farms.
- Low areas immediately upstream of the rail corridor would not completely drain, leading to new areas of ponding immediately after each runoff event. To maintain existing flow paths it may be necessary to redirect flows upstream of the corridor.

These ongoing impacts during operation would be generally more significant than those during the relatively short construction period.

Impact of restricted water passage along irrigation drains or channels

Irrigation drains and channels may be partially blocked by debris falling from the formation, such as ballast material or litter from passing trains. The potential impacts of partial blockage of irrigation drains during the life of the proposal could reduce the amount of water available for irrigation. The proposal design avoids this potential impact by nominating that any irrigation drain would have a replacement culvert constructed with a capacity matching the existing capacity.

Impact of modified groundwater flow volume or rate

Groundwater flow volumes and rates downstream of the corridor could be modified because of ongoing extraction of water for the operation of the rail corridor. However, ongoing water extraction is not planned during operation of the proposal.

5.3 Risk assessment – hydraulics and flooding

An assessment of the potential flooding risks, and measures to avoid, mitigate or minimise them, is provided in Table 5.2. The risks and impacts listed in Table 5.2 are discussed in the following sections.

Table 5.2 Flooding risks, potential impacts and mitigation measures

Risk	Potential hydraulic impacts	Measures to avoid, mitigate or minimise impacts
Construction period Impact of raising the rail formation	• Increased upstream flooding depths and extents • Increased upstream flood durations • Increased impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures) • Additional impacts downstream of structures	• Install each structure prior to or concurrent with rail formation construction to minimise potential adverse impacts.
Construction period Impact of reducing watercourse (culvert) capacity	• Increased upstream flooding depths and extents • Increased upstream flood durations • Increased upstream impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures)	• Select structure sizes and capacities as close to the current situation as practical to restrict impacts on adjacent land and infrastructure. • Do not reduce watercourse flow areas. • Locate spoil mounds where they do not impact on flow paths and patterns.
Operational period Impact of raising the rail formation height on increased flooding	• Increased upstream flooding depths and extents • Increased upstream flood durations • Increased upstream impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures) • Additional impacts downstream of structures	• Retain structure sizes and capacities as close to the current situation as practical to restrict impacts on adjacent land and infrastructure while balancing with the raised formation level.
Operational period Impact of reducing watercourse (culvert) capacity	• Increased upstream flooding depths and extents • Increased upstream flood durations • Increased upstream impacts on buildings • Increased impacts on adjacent infrastructure (e.g. road closures)	• Select structure sizes and capacities as close to the current situation as practical to restrict impacts on adjacent land and infrastructure. • Do not reduce watercourse flow areas. • Locate spoil mounds where they do not impact on flow paths and patterns.

Risk	Potential hydraulic impacts	Measures to avoid, mitigate or minimise impacts
Operational period Impact of increased watercourse (culvert) capacity	• Reduced upstream flooding depths and extents • Increased downstream flood depths • Increased downstream building impacts • Increased impacts on adjacent downstream infrastructure (e.g. road closures) • Increased downstream watercourse scour	• Select structure sizes and capacities as close to the current situation as practical to restrict impacts on adjacent land and infrastructure. • Minimise any increase in watercourse flow areas.

5.3.1 Potential hydraulic and flooding impacts – construction

Impact of raising the rail formation

The proposal includes raising the formation level at a number of locations by up to about 1.4 metres. Raising the rail formation level could create several potential impacts:

- It could increase the upstream flood level and flood extent because of the increased head required to pass the flow through replacement structures. Increasing the size of the replacement culverts, or providing a greater number of culverts, could reduce this impact but it would increase the potential impacts downstream of the rail corridor.
- It could prevent the flows up to at least the one per cent AEP event from overtopping the rail corridor. Under existing conditions, many areas of the rail corridor overtop in relatively small design rainfall events. Raising the formation level would reduce the extent and frequency of any overtopping. Reducing the extent of areas where flood water crosses the line could:
  - Reduce upstream flow velocities should the upstream flood levels be increased
  - Reduce the uncontrolled flow of water over the rail formation
  - Increase the risk of erosion downstream of the culverts
  - Redirect flood flow paths immediately downstream of culverts
  - Increase the duration of flooding upstream of the culverts

Impact of reduced watercourse area at culverts

Many of the impacts of reducing the watercourse area and flow capacity at culverts (by reducing the size of the culverts) would be essentially the same as those identified for raising of the formation height. Reducing culvert sizes could increase upstream flood levels and flood extents because of the increased head required to pass the flow through replacement structures; to achieve the same performance criteria would create the need for higher formation levels.

Reducing culvert sizes could also create an increased flow velocity through the culverts and increase the risk of additional downstream scour. Forcing this water to cross the line at a restricted number of locations could:

- Reduce upstream flow velocities should the upstream flood levels be increased
- Increase the risk of erosion downstream of the culverts

- Redirect flood flow paths immediately downstream of culverts
- Increase the duration of flooding upstream of the culverts

During construction, should a flood event occur, there would be periods when there may be redirections of floods around the end of sections of raised embankment. It is not possible to predict whether this would happen.

5.3.2 Potential hydraulic and flooding impacts – operation

Impact of raising the rail formation

Raising the rail formation level would have similar impacts on flooding as those identified during construction (refer to Section 5.3.1).

Impact of reduced watercourse area at culverts

Reducing the watercourse area and flow capacity at culverts (by reducing the size of the culverts) would have similar impacts on flooding as those identified during construction (refer to Section 5.3.1).

Impact of increased watercourse area at culverts

Increasing the watercourse area at culverts (by the installation of larger culverts) could:

- Reduce upstream flood levels and flood extents because of the reduced head required to pass the flow through replacement structures, which would permit floodwater to pass downstream more quickly than currently.
- Create a potentially increased flow velocity through the culverts, which would increase the risk of additional downstream scour.
- Increase upstream flow velocities towards the culvert and increase the upstream scour risk.

6. Proposed mitigation measures and benefits

6.1 Background

The proposal design includes design measures to minimise hydrology and flooding impacts. This chapter assesses the effectiveness and benefits of these measures, and the predicted residual impacts, where applicable.

6.2 Design control measures

6.2.1 Formation level and profile

The proposed formation level would generally be above the predicted one per cent AEP catchment event and would therefore comply with internal ARTC requirements and control the frequency of uncontrolled track overflows.

The design of the formation level has also considered the volume of materials along the track, the complexity of excavation along the track and the potential for reuse of excavated materials to minimise the need to import material to create the new formation.

Benefits

These measures would have the following benefits:

- Reduce the extent and frequency of the track overtopping. The overtopping would be restricted to areas at level crossings for the one per cent AEP event. No other rail overtopping is predicted to occur for events up to the magnitude of the one per cent AEP event. This approach would still create residual effects, as described below.
- Minimise the volume of waste material created by the formation construction.
- Minimise the need for importation of fill material.
- Minimise the potential high flow velocities across downstream farmed areas and erosion of downstream agricultural areas (as the rail line is not predicted to overtop for events up to the magnitude of the one per cent AEP event).

Residual impacts of measure

The selected formation level would result in:

- Increased area of upstream flood affectation
- An increased number of impacted upstream buildings, as discussed in Section 6.4.5
- An impact on the flooding of upstream roads, as discussed in Section 6.4.4

Each of these potential impacts is examined below in the following sections.

6.2.2 Culvert form

The proposed culvert form has been selected to facilitate quick construction and minimise construction period impacts. The selected culvert form is a complete pre-cast four-sided box culvert that would be transported to site and placed in position. The only onsite concrete usage and placement would be for the aprons and headwalls at each culvert structure. Erosion protection has been provided downstream of each culvert apron to minimise the flow velocity as it exits off the culvert apron.

Benefits

This measure would have the following benefits in terms of the hydrology, hydraulics and flooding objectives:

- It would require less site excavation and foundation preparation and, therefore, speed up culvert placement and minimise the potential for extended construction periods. The shorter construction periods would also enhance opportunities to undertake construction between runoff events in the ephemeral watercourses.
- It would reduce the amount of water required along the route of the proposal for concrete placement. An estimated 150 megalitres of water would be needed for construction, as described in Section 3.4, which would be used primarily for dust suppression.
- Erosion protection would mitigate the potential effect to some extent. To enhance protection against this effect it would be necessary to extend the rock protection further toward the rail corridor boundary. The proposed rock erosion protection would reduce the increase in flow velocity within the rail corridor to 0.5 metres per second and reduce the effect on adjacent private property.

Residual impacts

- The assessment has indicated a potential residual erosion risk at about 15 culvert locations (of 228 culverts assessed) for a distance of about 100 metres from the extent of the rock protection and after that distance the risk is predicted to become minimal. The predicted widening of the small incised watercourses has been assessed at a maximum of about 30 per cent of the existing watercourse width when the watercourses are narrower than about 10 metres. The predicted potential widening then decreases inversely with the width of the watercourse, to be minimal when the watercourse width exceeds about 20 metres.
- The maximum widening is predicted to potentially occur over a period of about five to 10 significant floods.
- Historical records show the rail ballast would generally fail and wash out, at least for part of the overtopping length, prior to or about the same time as the overtopping of the rail. When this happens, there could be a flow on the downstream formation of the rail line of up to about two metres per second.

6.2.3 Culvert locations

New or replacement culverts across the rail corridor would be located at the terrain low points along the proposal. This will place them at, or adjacent to, existing structures to avoid the creation of new flow paths across the rail line.

Benefits

This approach would:

- Prevent the formation of significant new flow paths and potential soil erosion areas downstream of the rail corridor
- Minimise excavation for new structures
- Restrict the potential for new scour areas and significantly reduce the extent of existing erosion areas
- Maintain flow paths and watercourses to maintain their existing ecological and drainage functionality

6.2.4 Culvert levels and size

The proposed culvert invert levels would match the existing invert levels to mitigate the creation of blockages to flow and fish passage (during times of stream flow) at culverts. The structures have been sized to minimise the increase in flow velocity through the culverts, as described in Appendix A. Details of the proposed culverts are summarised in Appendix H.

Benefits

Selecting invert levels to match the existing levels would:

- Facilitate fish passage through the structure during times of water flow
- Minimise the risk of downstream erosion by matching the level to the downstream soil level and avoiding a level drop and associated energy loss

Residual impacts of measure

There would be a minimal increase in the flow velocity through some structures during relatively low flow conditions, relative to the current conditions. This would result from the culverts providing a hydraulically more efficient flow cross-section than the existing structures.

The increased upstream flood levels at culverts will also increase the flow velocity through the culverts for the larger flows when, for the existing rail formation, the track would overtop. The maximum increase in velocity is expected to range between 0.5 metres per second and 1 metre per second.

Maintaining the culvert inverts to match the existing invert levels would minimise the potential for creation of a scour hole at the downstream end of the culverts.

Provision of fish passage through the culverts has the potential to alter hydraulic performance of the culvert. This will be investigated further during details design.

6.2.5 Construction access and tracks

Construction access to the rail corridor would be carefully controlled and co-ordinated to minimise site disturbance and inconvenience to landholders. Access to the proposal area is planned to be from public roads and existing tracks.

An access track exists along the majority of the proposal within the current rail corridor. Where necessary, this would be upgraded at watercourses. New access tracks may include new watercourse crossings, which have the potential to induce erosion and scouring within the watercourses because of vehicles disturbing the watercourse bed and banks. Any new access along the corridor would be formed and stabilised with a gravel blanket to minimise the risk of the watercourse being substantively damaged by vehicles. The design form would conform to guidelines for the maintenance of fish passage (reference the Controlled Activity guidelines). The gravel layer would be as thin as practical for stability.

Should it be necessary at any location to permit a continuous water flow across the access track, then a pipe would be placed in the water and gravel placed around the pipe to keep vehicle tyres out of the water. The pipe and gravel would be removed at the end of the construction period to accord with requirements to minimise impacts on watercourses and fish access.

Benefits

These measures would minimise the potential disturbance of watercourses where they are crossed by construction traffic.

6.2.6 Construction compounds

Two types of construction compounds are proposed – minor storages that will be used for temporary storage of items such as concrete box culverts and turnouts and larger compounds. The larger compounds would comprise amenities, parking, refuelling areas, stockpiles and material storage areas.

The minor storages will be located within the rail corridor. Larger compounds may require local regarding works to provide a level work area. These regrading works will likely include filling of lower areas of the site which have the potential to alter local flow patterns including flooding. The larger compounds will be located at least 50 m from watercourses and where possible outside the 5 per cent AEP flood extent to minimise the potential for flood impacts on surrounding lands.

The final construction compound locations will be selected by the contractor and will be in the Construction Environmental Management Plan.

Benefits

Restricting the number and size of the compounds would minimise the construction disturbance area. Positioning them at distance from watercourses would minimise the potential for flooding.

6.2.7 Stockpiles

Stockpiles of excess material (spoil mounds) would be located as close as practical to the source of the material. The final location and sizing of the spoil mounds would be undertaken as part of detailed design, however it is likely that there would be spoil mounds along the majority of the length of the proposal. Spoil mounds have the potential to remove local flood storage and divert surface water flows from existing flow paths, which could affect local flooding. The mounds would be positioned so that they had gaps between adjacent mounds to permit drainage away from the track and they would be located where there would be no induced flooding impact.

Spoil mound locations would be developed as the design is advanced and documented in the Construction Environmental Management Plan.

Benefits

Implementation of this strategy would minimise the potential for changes to flooding conditions along the corridor. No adverse flooding impact is expected from the placement of spoil mounds.

6.2.8 Construction water use

As described in Section 3.4 water would be required for dust control, soil compaction and vegetation establishment. The required volume of water for these uses would be dependent upon the climatic conditions at, and following, construction.

Likely sources of water would be external to the rail corridor and are identified in Section 3.4, and include the potential extraction of surface water and groundwater from pre-approved locations. The potential impacts from the extraction of surface and/or groundwater are discussed in Section 5.2.1. Water would also be trucked to the proposal site.

Benefits

Water used during construction would be sourced from various sources to minimise hydrologic impacts at a single location.

Residual impacts of measure

Extraction of water would reduce the volume of stored water until volumes are replenished again by rainfall/recharge. This would have a minor short-term impact on the available surface water volumes.

6.2.9 Potable water use

Potable water for human consumption would be supplied via bottled water or potable water tanks. Non-potable wash water would be supplied by the use of trailer-mounted storage tanks.

6.3 Summary of hydrological impacts and benefits

6.3.1 Surface water flows

The majority of surface water impact would result from any new ponding areas formed adjacent to proposed structures. This impact is likely to be minimal, and generally associated with existing ponding areas. Local drainage works may be included in the final design to minimise the impacts associated with these potential ponding areas.

The proposed structures under the rail formation have been selected and sized to convey flows at rates similar to existing structures, which would minimise surface water redirections or restrictions.

Cumulative impacts on the existing surface water regime would be localised to areas along the rail corridor.

Construction of the proposal would not affect the low discharge flow paths across the rail line. Consequently, the existing surface water flows would continue as they currently occur. The proposed culvert inverts and sizes have been selected to maintain any existing fish passage across the rail corridor.

6.3.2 Surface water sources

The proposal is expected to have some local impacts during construction because of surface water extractions to supply construction water. During operations, no appreciable ongoing impact on surface water resources is expected because of the proposal.

6.3.3 Groundwater sources

The majority of groundwater impact along the rail corridor would occur during the construction period when water is being sourced for dust suppression and general construction work. A number of extraction locations have been identified to minimise localised effects and a monitoring program has been developed to mitigate the extent of any impact. Groundwater will generally be extracted under existing groundwater access licences by arrangement with the licence holder.

It is possible the proposal will have a short-term impact on flows within the alluvial layer because of water used during the construction period. The lateral extent of the projected impacts would be localised around any individual extraction location and is unlikely to extend more than about 50 metres from the extraction point.

Ongoing operation of the proposal would not require the sourcing of groundwater so the long-term groundwater impact would be negligible.

6.4 Flooding – Local catchments

6.4.1 Flood level analysis – local catchments

Predicted design flood levels for each local catchment are provided in Appendix H. Figure 6.1 provides a plot of the design flood levels along the existing corridor for the one per cent AEP event. Appendix H also contains a tabulation of the design flood levels for all design AEP events and the changes in design flood levels from those for the existing conditions.

Because of the analysis method the design long section plot shows as a series of horizontal water surfaces with changes in level being caused where flow passes from one catchment to the adjacent catchment.

The top half of Figure 6.1 shows the change in design flood level from that for the base or existing case. Along much of the alignment, it is seen that there is a minimal change in the upstream flood levels. However, there are locations where the change in design flood level approaches half a meter. At some locations, the modelling indicates that flood levels are likely to reduce because of the proposal. This is the result of the improved hydraulic efficiency of the new culvert structures compared to the existing structures.

The predicted levels show variances to those for the existing (base case) situation (Appendix E) because of:

- The increased culvert sizes being required to keep, where possible, the design upstream level below the top of the formation level to maximise compliance with ETD-10-02 (ARTC 2016).
- The raised formation height, which, to achieve operational reliability, creates a barrier to overland flows for events up to the one per cent AEP magnitude.
- The raised formation height, which increases flood levels for events greater than those for the existing conditions for events larger than the structure design capacity.

The impacts of the raised flood levels are discussed in the following sections.

6.4.2 Rail overtopping and formation non-conformance– local catchments

Locations and extents of rail overtopping – local catchments

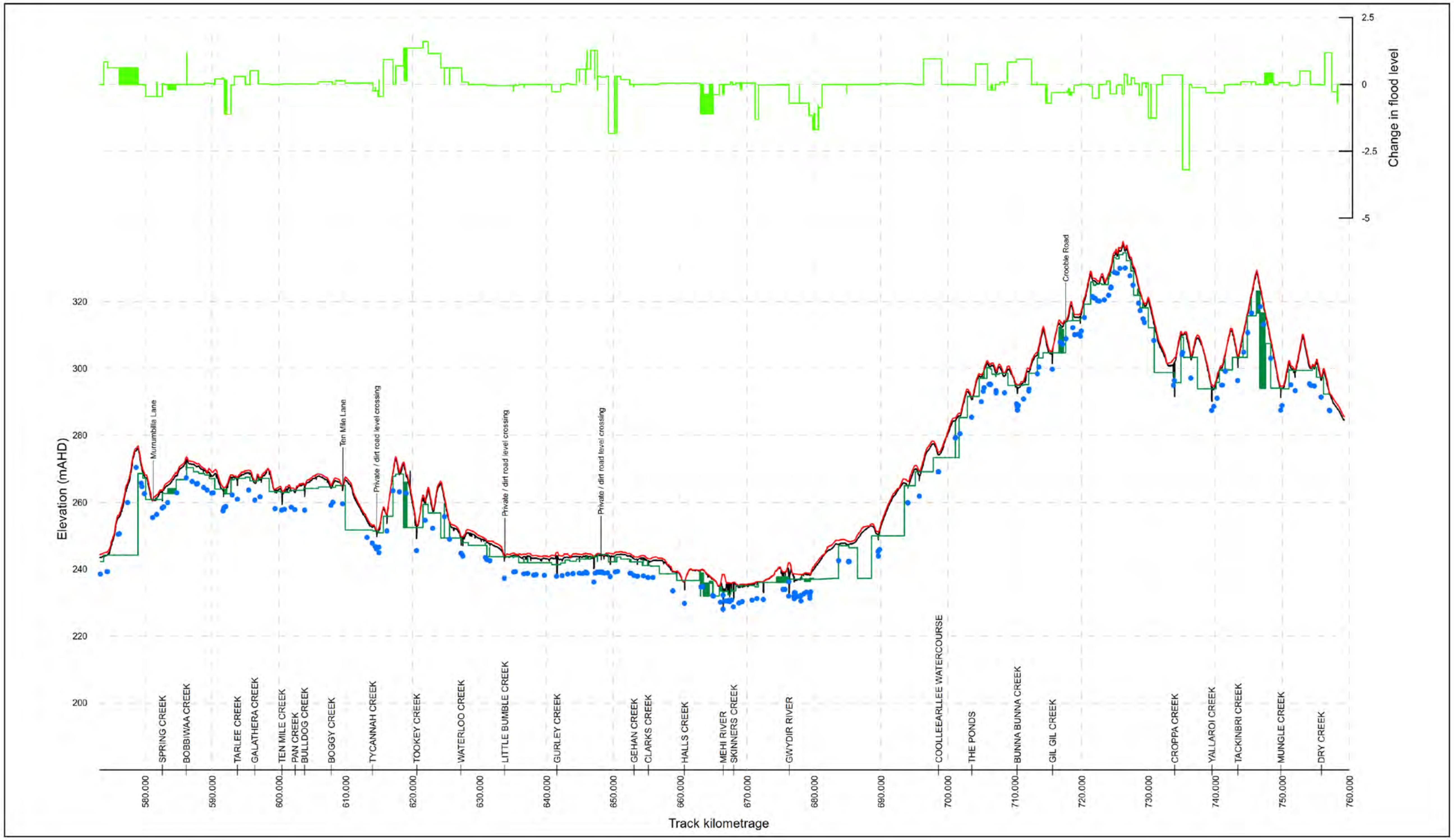
The flood modelling for post proposal conditions gave predictions that the rail line would overtop at specific locations for a range of design flood events. The overtopping locations for the one per cent AEP event are shown by the red indicators in Figure 6.2.

The predicted local catchment rail overtopping only occurs at road level crossings while the remainder of the formation would be elevated above the one per cent AEP level. During the concept design it was decided that public road level crossings would not be raised and this lead to the rail overtopping in areas where there was a significant depth of existing and future flooding.

It is predicted that approximately 1.3 kilometres of rail line would overtop for the one per cent AEP event, as shown in Table 6.1, compared with approximately 11.1 kilometres under the existing conditions (refer to Table 4.3).

Table 6.1 Design rail overtopping – local catchments

Chainage	1% AEP event rail overtopping			Concept track design
	Length (m)	Maximum depth (m)	Average depth (m)	
581.06 to 581.24	187	0.24	0.14	No design lift – adjacent to Murrumbilla Lane and Newell Highway
596.51 to 596.58	90	0.07	0.03	Approximately 0.3 m design lift
609.46 to 609.62	165	0.25	0.014	No design lift - adjacent to Ten Mile Lane Crossing to the north
614.63 to 614.70	71	0.09	0.05	No design lift – adjacent to Bellata Siding to the north and a number of level crossings
633.69 to 633.79	94	0.12	0.07	No design lift - adjacent to unnamed road crossing
647.24 to 647.25	4	0.02	0.01	Approximately 0.2 m design lift
648.12 to 648.71	478	0.29	0.14	No design lift – adjacent to level crossings
660.28 to 660.66	375	0.37	0.21	No design lift within the vicinity of Moree
696.98 to 697.07	91	0.08	0.03	Approximately 0.4 m design lift
704.75 to 704.89	137	0.16	0.07	Approximately 0.4 m design lift, limited by no lift at County Boundary Road crossing to the east
709.60 to 709.68	63	0.11	0.03	No design lift – adjacent to Alma Lane crossing to the north
718.86 to 718.89	33	0.07	0.03	Approximately 0.4 m design lift, limited by no lift at Crooble Road crossing to the south
757.00	1	0.01	0.01	No design lift – adjacent to North Star Road crossing to the north



Paper Size A3

LEGEND
- Design
- Natural Surface
- Culverts
- Design flood level

Australian Rail Track Corporation
Inland Rail Route- Narrabri to North Star

Design Track Alignment with Change in 1% AEP Flood Levels - Local Catchments

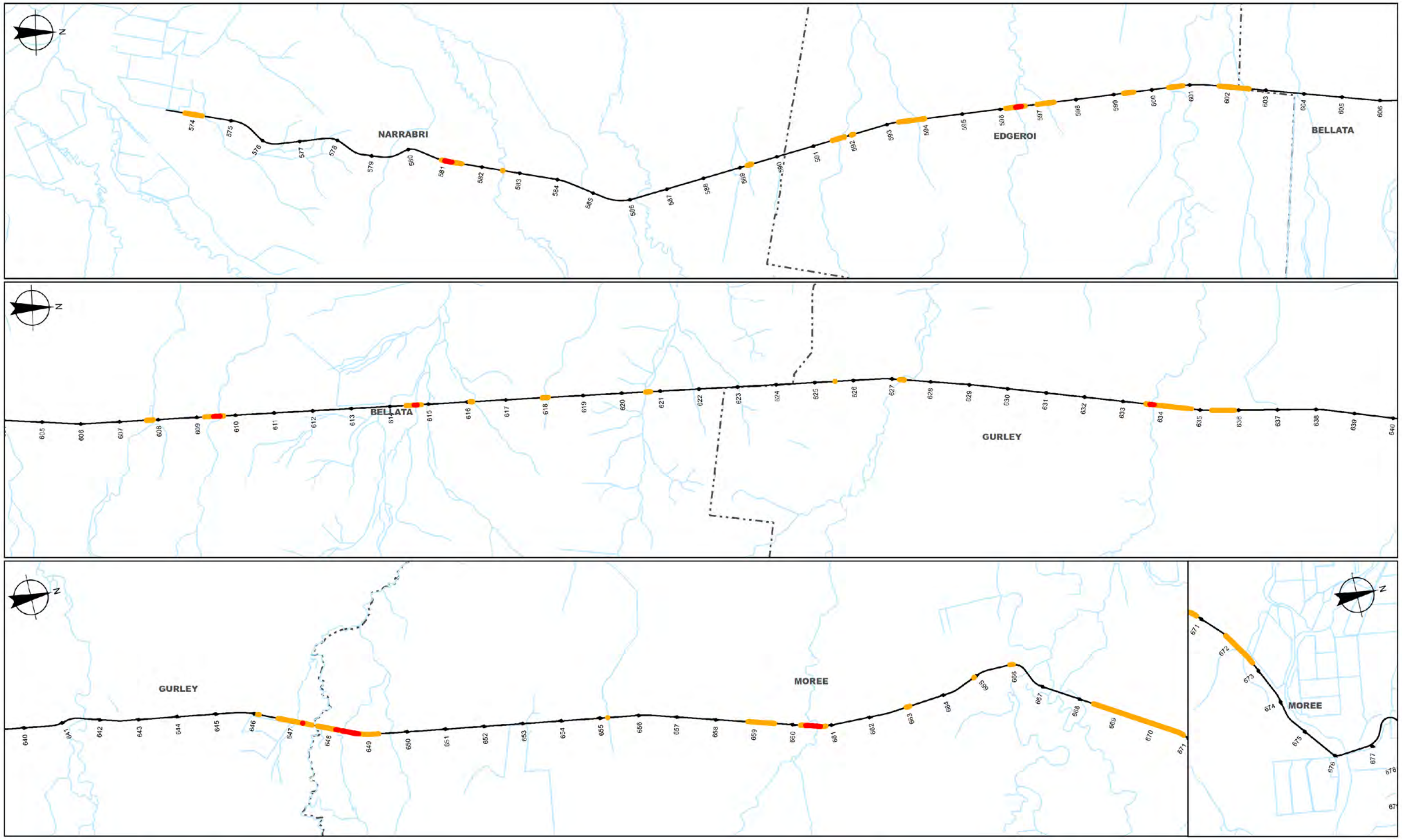
Job Number	22-17916
Revision	0
Date	16 Aug 2017

Figure 6-1

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH020_NNS_LongSection_FloodLevel_0.mxd

180 Lonsdale Street Melbourne VIC 3000 Australia T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com

Data source: LPI: Watercourses, 2012. ARTC: Aerial lidar, 2015. Created by gmcdiarmid



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

Overtopped - rail
Flood level above formation
Watercourse
Suburb boundary

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number	22-17916
Revision	0
Date	16 Aug 2017

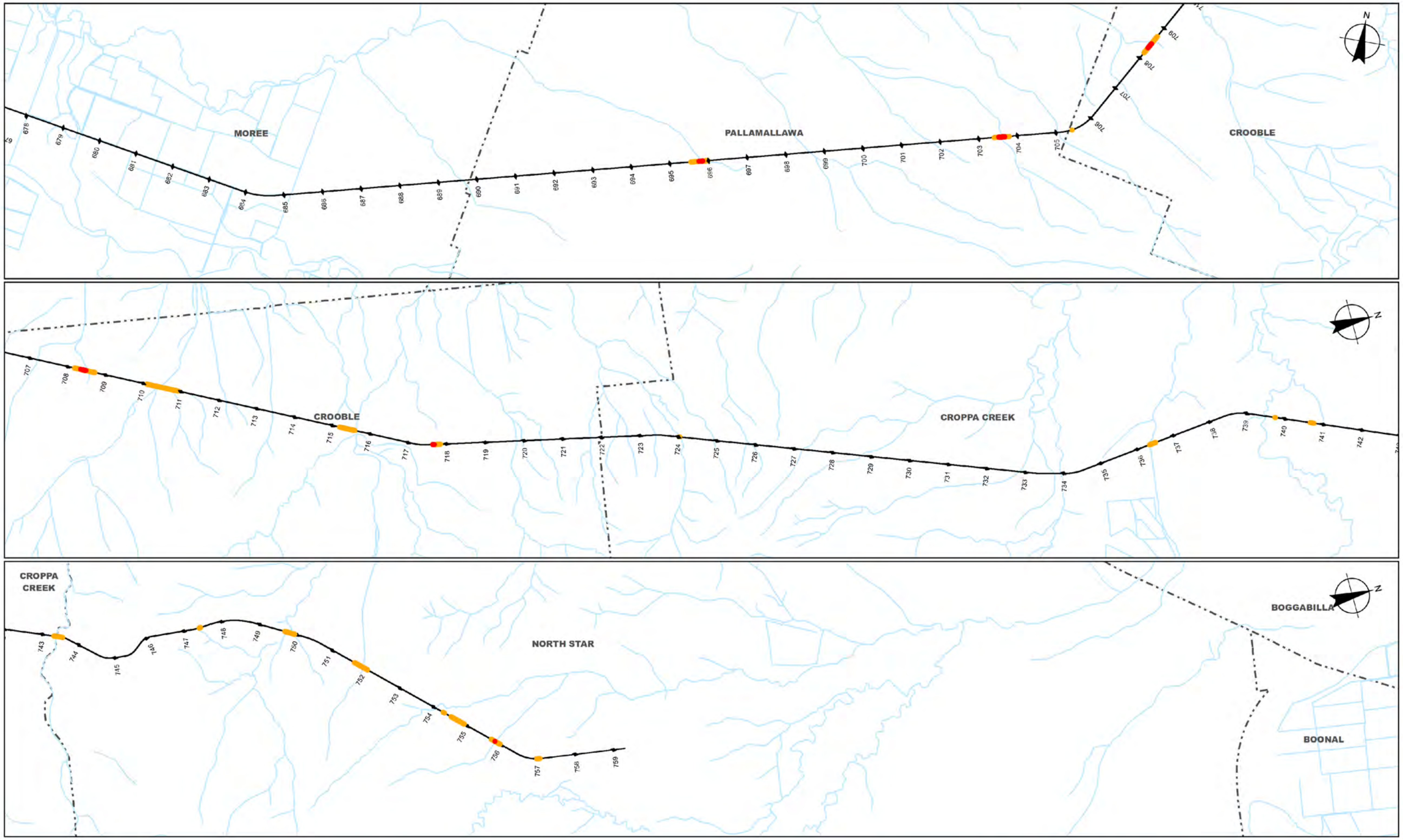
Rail Overtopping 1% AEP
Local Catchment Event - Sheet 1

Figure 6-2a

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH013_NNS_FloodStatus_Design_100yr_Sht1_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND
- Overtopped - rail
- Flood level above formation
- Watercourse
- Suburb boundary

GHD

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number 22-17916
Revision 0
Date 16 Aug 2017

Rail Overtopping 1% AEP
Local Catchment Event - Sheet 2

Figure 6-2b

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH013_NNS_FloodStatus_Design_100yr_Sht2_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba

As shown in Figure 6.2, approximately 88 per cent less track is predicted to overtop in the local catchments one per cent AEP event, compared to the existing condition (Figure 4.4). Appendix J provides details of the catchments of one per cent AEP rail overtopping and the catchment having rail overtopping for lesser events.

Figure 6.3 shows the design long section together with the depth of water through or over the top of rail (as a line) on the top half of Figure 6.3. When the line at the top of Figure 6.3 is green it means the water is ponding above the base of the ballast and when the line is shown as orange the rail is predicted to be overtopping. At approximately half of the locations where water is within the ballast the depth of water exceeds half the ballast depth.

Possible refinement of level crossing rail overtopping – local catchments

The modelled depth and extent of these level crossings overtopping locations is summarised in Table 6.1 for the one percent AEP event for the proposed conditions.

The predicted depth of overtopping of the rail is less than 0.1 m for six of the 13 overtopping locations. Subsequent analysis during the detailed design stage may identify minor additional local track lifts (or additional culvert barrels) that could be adopted to minimise the track overtopping at these locations (refer to Table 6.2). Slightly higher track lifts (up to 0.15 m) may be required to alleviate the modelled track overtopping at two other locations, whilst a third may require up to 0.2 m (refer to Table 6.2).

Table 6.2 Potential level crossing design refinements – local catchments

Chainage	Potential design modifications	
	Track Lift	Culvert configuration
581.06 to 581.24	Up to approximately 0.3 m lift over affected track length	Increase from 10 x C1800 to an estimated 14 x C2100
596.51 to 596.58	Small additional lift over (< 0.1 m) affected track length	-
609.46 to 609.62	Up to approximately 0.3 m lift over affected track length	Increase from 10 x B1300 to an estimated 12 x B1500
614.63 to 614.70	Small additional lift over (< 0.1 m) affected track length	-
633.69 to 633.79	Minor additional lift (< 0.15 m) over affected track length	-
647.24 to 647.25	Small additional lift over (< 0.1 m) affected track length	-
648.12 to 648.71	Up to approximately 0.3 m lift over affected track length	Increase from 24 x C2400 to an estimated 24 x C2700
660.28 to 660.66	Minimal lift through Moree	Increase from 16 x C1800 to an estimated 36 x C1800
696.98 to 697.07	Small additional lift over (< 0.1 m) affected track length	-
704.75 to 704.89	Additional lift over (< 0.2 m) affected track length, potentially requiring modifications to County Boundary Road	-
709.60 to 709.68	Minor additional lift (< 0.15 m) over affected track length, potentially requiring modifications to Alma Lane	-

Chainage	Potential design modifications	
	Track Lift	Culvert configuration
718.86 to 718.89	Small additional lift (< 0.1 m) over affected track length, potentially requiring modifications to Crooble Road	-
757.00	Small additional lift (< 0.1 m) over affected track length, potentially requiring modifications to North Star Road	-

Four level crossing overtopping locations include overtopping depths greater than 0.2 metres, each occurring at location where track lift was prohibited by adjacent level crossings or concerns about flooding impacts on the adjacent Newell Highway. In order to alleviate rail overtopping, these four overtopping locations will likely require additional track lifts of more than 0.3 metres, combined with increased culvert configurations as shown in Table 6.2. These track lifts would necessitate modifications to the adjacent level crossings and may exacerbate flooding within the local upslope areas.

A description of each modelled level crossing overtopping location is included in the sections below.

581.06 km to 581.24 km

Located within the vicinity of the Murrimbulla Lane – Newell Highway intersection, changes to local track levels were minimised in order to minimise the potential for increased flood levels on the adjacent Newell Highway. As a result, the modelling indicates that the design track could overtop by up to approximately 0.24 metres during the one per cent AEP flood event.

It is estimated that an additional track lift of up to approximately 0.3 metres along the flood affected portion of the track, combined with an increase in the number of culvert barrels (from 10 to 14) and culvert height (from 1.8 metres to 2.1 metres) would likely alleviate the local rail overtopping.

It should be noted that this additional track lift has the potential to influence the adjacent Murrimbulla Lane – Newell Highway intersection and may require additional road works in order to maintain a comparable flood risk profile on the adjacent public roads.

596.51 km to 596.58 km

The modelling indicates only minor rail overtopping, with depths of up to approximately 0.07 metres over a length of approximately 90 metres. This predicted overtopping might be removed with more rigorous analysis in design advancement.

609.46 km to 609.62 km

Track lifts at this location were restricted by the adjacent Ten Mile Lane level crossing. Given the interaction with the adjacent catchments, a very large number of culverts would be required (estimated to be greater than 50 barrels) to make this portion of the track flood free during the one percent AEP flood event without further track lift. The analysis indicated that the incremental improvement to the maximum-modelled flood level diminished with subsequent culverts, therefore the number of culverts included within the concept design was limited to that which achieved the most of the flood level reductions, with consideration of what could reasonably be expected to be installed within a single possession period to ensure continuity of service.

It is estimated that the most efficient means of achieving a flood-free status at this location is to raise the rail level by up to approximately 0.3 metres over a length of approximately 170 metres, with an increase in the number of culverts (from 10 to 12) and culvert height (from 1.3 metres to 1.5 metres). This would require modifications to the Ten Mile Lane crossing and adjacent sections of road.

614.63 km to 614.70 km

The modelling indicates only minor rail overtopping, with depths of up to approximately 0.09 metres over a length of approximately 71 metres. More rigorous analysis during design advancement may remove that predicted overtopping.

633.69 km to 633.79 km

The modelling indicates only minor rail overtopping, with depths of up to approximately 0.12 metres over a length of approximately 94 metres. More rigorous analysis during design advancement may remove that predicted overtopping.

647.24 km to 647.25 km

The modelling indicates only minor rail overtopping, with depths of up to approximately 0.02 metres over a length of approximately 4 metres. More rigorous analysis during design advancement may remove that predicted overtopping.

648.12 km to 648.71 km

Track lifts at this location were restricted by a number of unnamed level crossings. The analysis indicated that a very large number of culverts would be required (estimated to be greater than 40 barrels) to make this portion of the track flood free during the one percent AEP flood event. The analysis indicated that the incremental improvement to the maximum-modelled flood level diminished with subsequent culverts, therefore the number of culverts included within the concept design was limited to that which achieved the most of the flood level reductions, with consideration of what could reasonably be expected to be installed within a single possession period to ensure continuity of service.

It is estimated that the most efficient means of achieving a flood-free status at this location is to raise the rail level by up to approximately 0.3 metres over a length of approximately 480 metres, with an increase in culvert height (from 2.4 metres to 2.7 metres). This would require modifications to the unnamed levels crossings and adjacent sections of road.

660.28 km to 660.66 km

Track lifts at this location were restricted to minimise the potential flood impacts to Moree. Given the interaction with the adjacent catchments, the analysis indicated that a very large number of culverts would be required (estimated to be approximately 36 barrels) to make this portion of the track flood free during the one percent AEP flood event. The analysis indicated that the incremental improvement to the maximum-modelled flood level diminished with subsequent culverts, therefore the number of culverts included within the concept design was limited to that which achieved the most of the flood level reductions, with consideration of what could reasonably be expected to be installed within a single possession period to ensure continuity of service.

Without track lift, it is estimated that in order to achieving a flood-free status at this location, the number of culverts would need to increase from 16 to approximately 36.

696.98 km to 697.07 km

The modelling indicates only minor rail overtopping, with depths of up to approximately 0.08 metres over a length of approximately 91 metres. Application of a more rigorous analysis method during design advancement may remove this predicted overtopping.

704.75 km to 704.89 km

This section included a design lift of approximately 0.4 metres, however this was limited the nearby County Boundary Road crossing, where no lift was applied. The modelling indicates only minor rail overtopping, with depths of up to approximately 0.16 metres over a length of approximately 137 metres.

It is estimated that a minor lift of approximately 0.2 metres over the flood affected track would achieve a flood-free status at this location, however this will require some track lift at the Nearby County Boundary Road crossing. This will be confirmed during detailed design.

709.60 km to 709.68 km

The modelling indicates only minor rail overtopping, with depths of up to approximately 0.11 metres over a length of approximately 63 metres. Application of a more rigorous analysis method during design advancement may remove this predicted overtopping.

718.86 km to 718.89 km

The modelling indicates only minor rail overtopping, with depths of up to approximately 0.07 metres over a length of approximately 33 metres. Application of a more rigorous analysis method during design advancement may remove this predicted overtopping.

757.00 km

The modelling indicates only minor rail overtopping, with depths of up to approximately 0.01 metres over a length of approximately 1 metre. Application of a more rigorous analysis method during design advancement may remove this predicted overtopping.

Compliance with indicative ETD-10-02 requirements – local catchments

Table 6.3 shows the extent of noncompliance with the nominated Technical Note (ETD-10-02: ARTC 2016) which requires the upstream floodwaters to be below the top of shoulder of the formation assuming a total depth of ballast, sleeper and rail of 750 millimetres.

Table 6.3 Design formation non-compliance – local catchments

Design event (% AEP)	Extent of noncompliance to ETD-10-023 (km) Assumed 750 mm depth to top formation
50	0.55
20	0.90
10	1.16
5	2.42
2	9.86
1	17.95

The smaller flood events would overtop less of the track at a reduced number of locations when compared to the existing conditions.

Comparing the predicted results for the existing rail formation and the design formation shows there is a reduction in both the extent of rail overtopping and the non-compliance with the requirements of ETD-10-02 (ARTC 2016). A more comprehensive listing of the non-compliances is provided in Appendix K.

Further assessment would be undertaken during detailed design to identify opportunities to improve flood immunity. This assessment would include consideration of culverts adjacent to flood overtopping areas, as well as additional track raising, which may improve the flood immunity of the overtopping areas.

6.4.3 Adjacent land - local catchments

Local catchments

The predicted flood levels for the post proposal conditions were examined for a range of design events from the 50 per cent AEP through to the PMF event. Within this range, the 0.5 per cent and 0.2 per cent were considered as representing a potential climate change impact assessment.

Upstream flood impact – local catchments

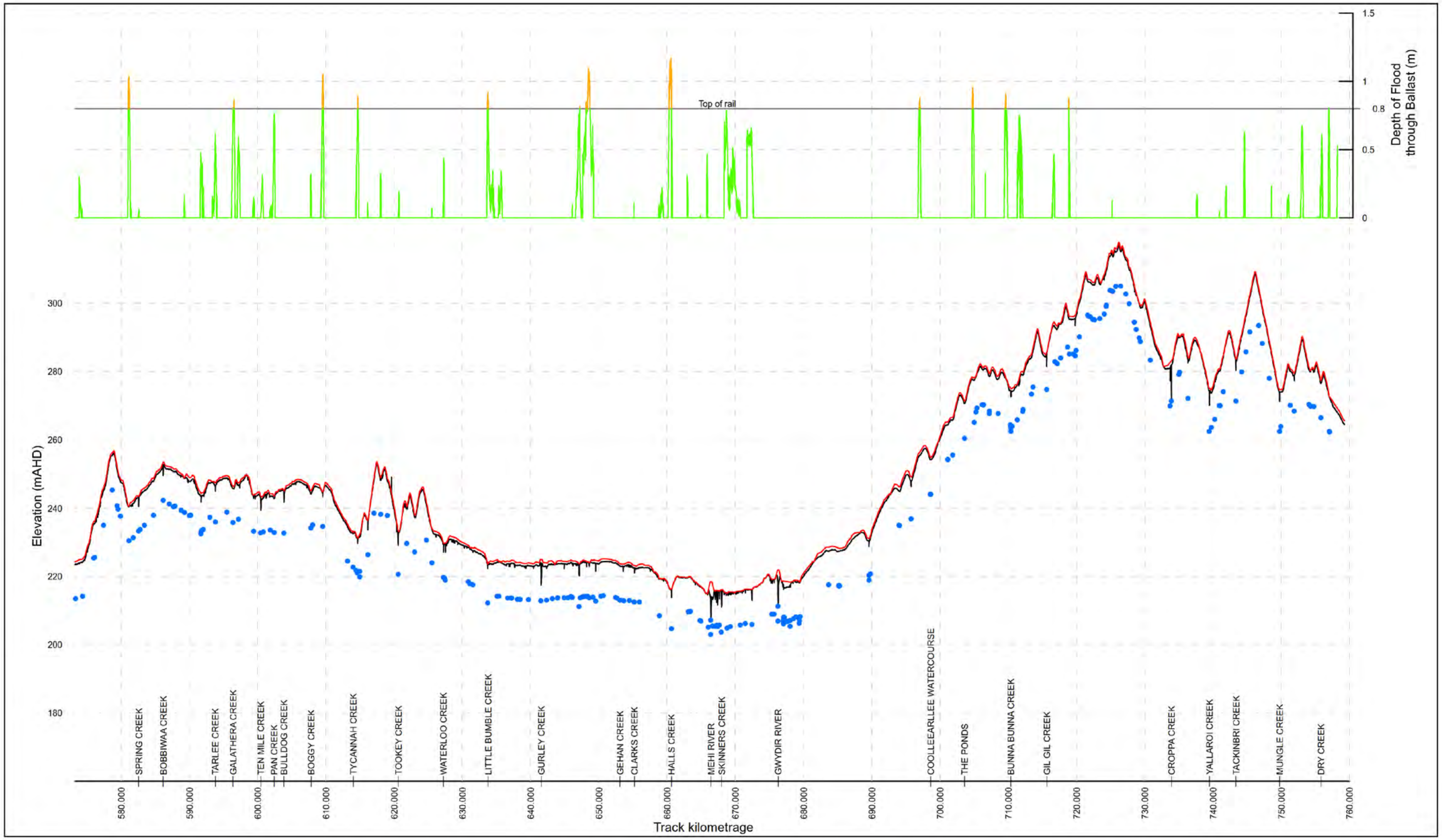
Figure 6.4 shows the predicted upstream flood extents in a diagrammatic form for events that have been evaluated while Table 6.4 provides numeric values for the flood affected areas for various design events. Table 6.4 also provides the change in the flood affected area relative to that predicted for the existing track level. The modelled change in flood affectation areas is summarised in Table 6.4. From Table 6.4 it can be seen that the proposal is expected to result in reduced areas of upstream flooding for all but one (0.2 per cent AEP event) design storm event. It should be noted that as flow paths are to be generally preserved, no appreciable change to the function of existing infrastructure for the interception and storage of surface water for agricultural purposes is expected.

The predicted change in upstream flood affectation area is shown in plan in Appendix L while the numerical increase in flood levels and change in flood levels are provided in Appendix I.

The analysis was undertaken by applying the predicted relevant flood levels along the corridor and intersecting them, as horizontal water surfaces, with the adjacent terrain. This gave the area of upstream flood affectation.

Table 6.4 Design upstream inundation areas – local catchments

Design event (% AEP)	Area of inundation – existing conditions (ha)	Area of inundation – proposed conditions (ha)	Change
50	401.8	383.8	- 4.5 %
20	554.1	496.6	- 10.4 %
10	852.8	627.1	-26.5 %
5	1373.0	1009.1	- 26.5 %
2	2093.5	1777.3	- 15.1 %
1	2668.9	2515.3	- 5.8 %
0.5	3031.8	2893.7	- 4.6 %
0.2	3414.9	3465.5	+ 1.5%
PMF	9591.7	9159.6	- 4.5 %



Paper Size A3

LEGEND
- Design
- Natural Surface
- Culverts
- Flood through ballast
- Flood through ballast - overtopping rail

Australian Rail Track Corporation
Inland Rail Route- Narrabri to North Star

Job Number	22-17916
Revision	0
Date	16 Aug 2017

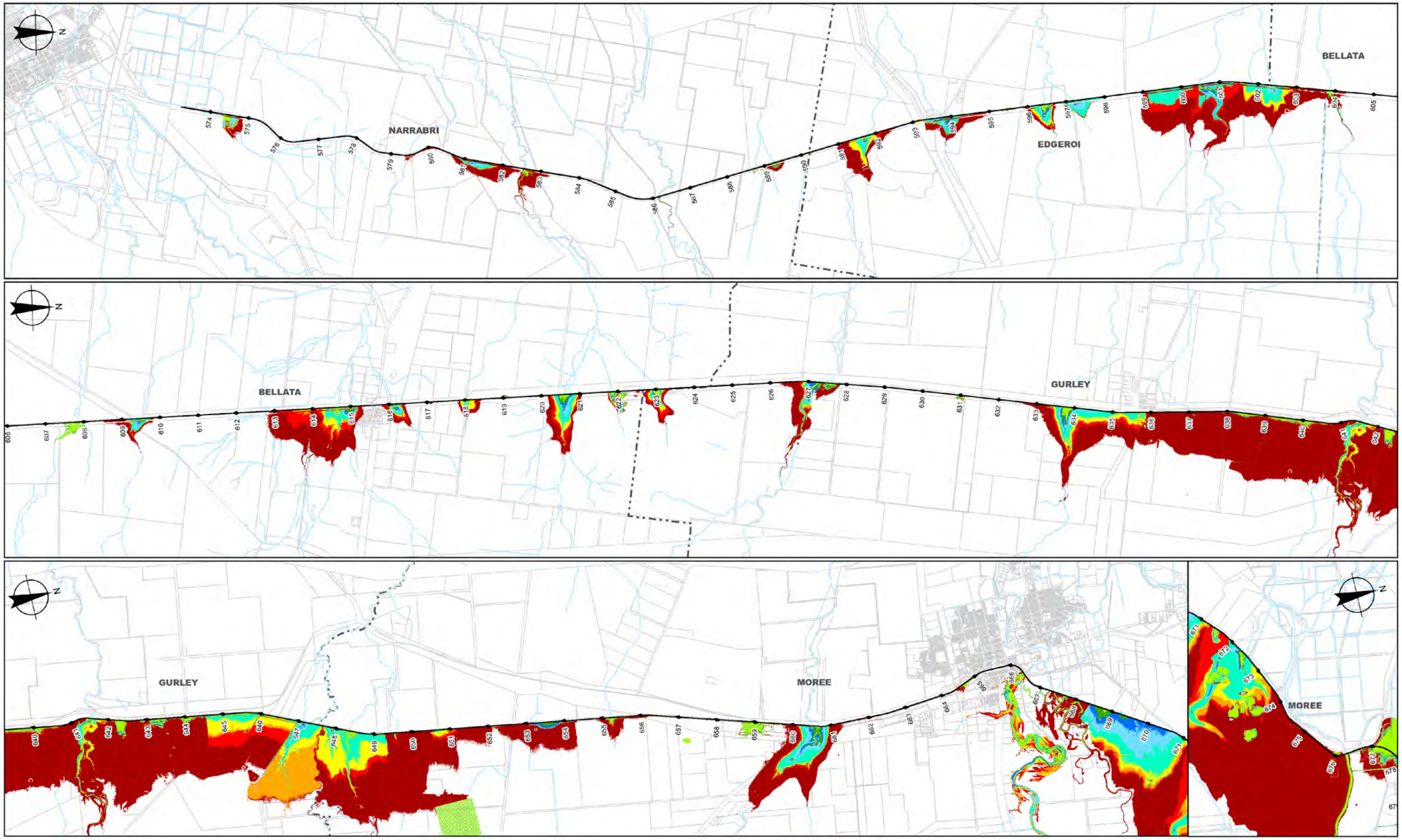
Design Track Alignment and Flooding of Ballast - Local Catchments

Figure 6-3

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH022_NNS_LongSection_Design_BallastFlooding_0.mxd

180 Lonsdale Street Melbourne VIC 3000 T 61 3 8687 8000 F 61 3 8687 8111 E melmail@ghd.com W www.ghd.com.au

Data source: LPI: Watercourses, 2012. ARTC: Aerial lidar, 2015. Created by: gmcdiarmid, kpsroba



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Inland Rail
- Watercourse
- Lot boundary
- 50% AEP
- 20% AEP
- 10% AEP
- 5% AEP
- 2% AEP
- 1% AEP
- 0.5% AEP
- 0.2% AEP
- PMF

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number	22-17916
Revision	0
Date	16 Aug 2017

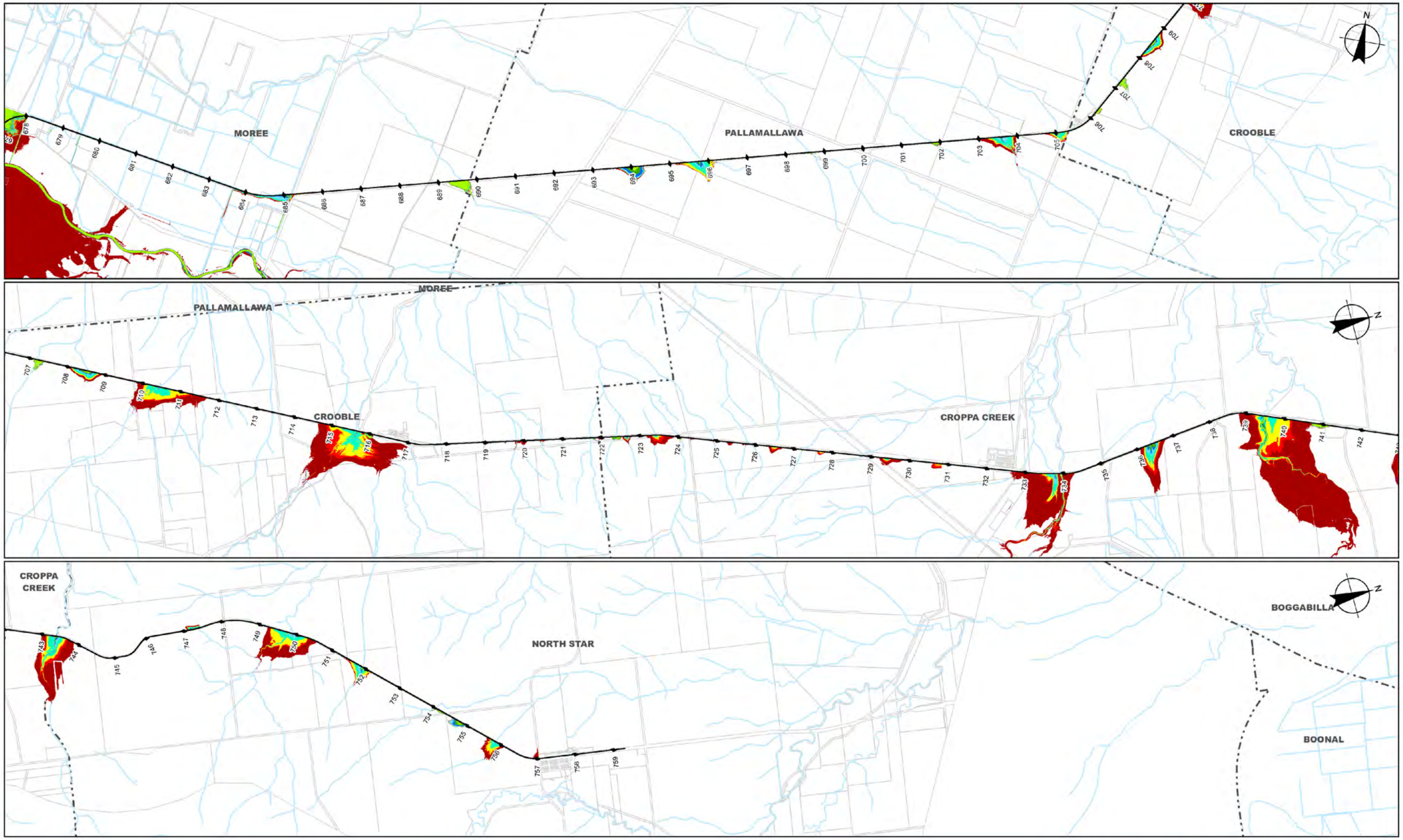
Design Flood Impact Areas
Local Catchment - Sheet 1

Figure 6-4a

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH014_NNS_FloodExtents_Design_Sht1_0.mxd

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

Inland Rail	50% AEP	1% AEP
Watercourse	20% AEP	0.5% AEP
Lot boundary	10% AEP	0.2% AEP
Suburb boundary	5% AEP	PMF
	2% AEP	

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number 22-17916
Revision 0
Date 16 Aug 2017

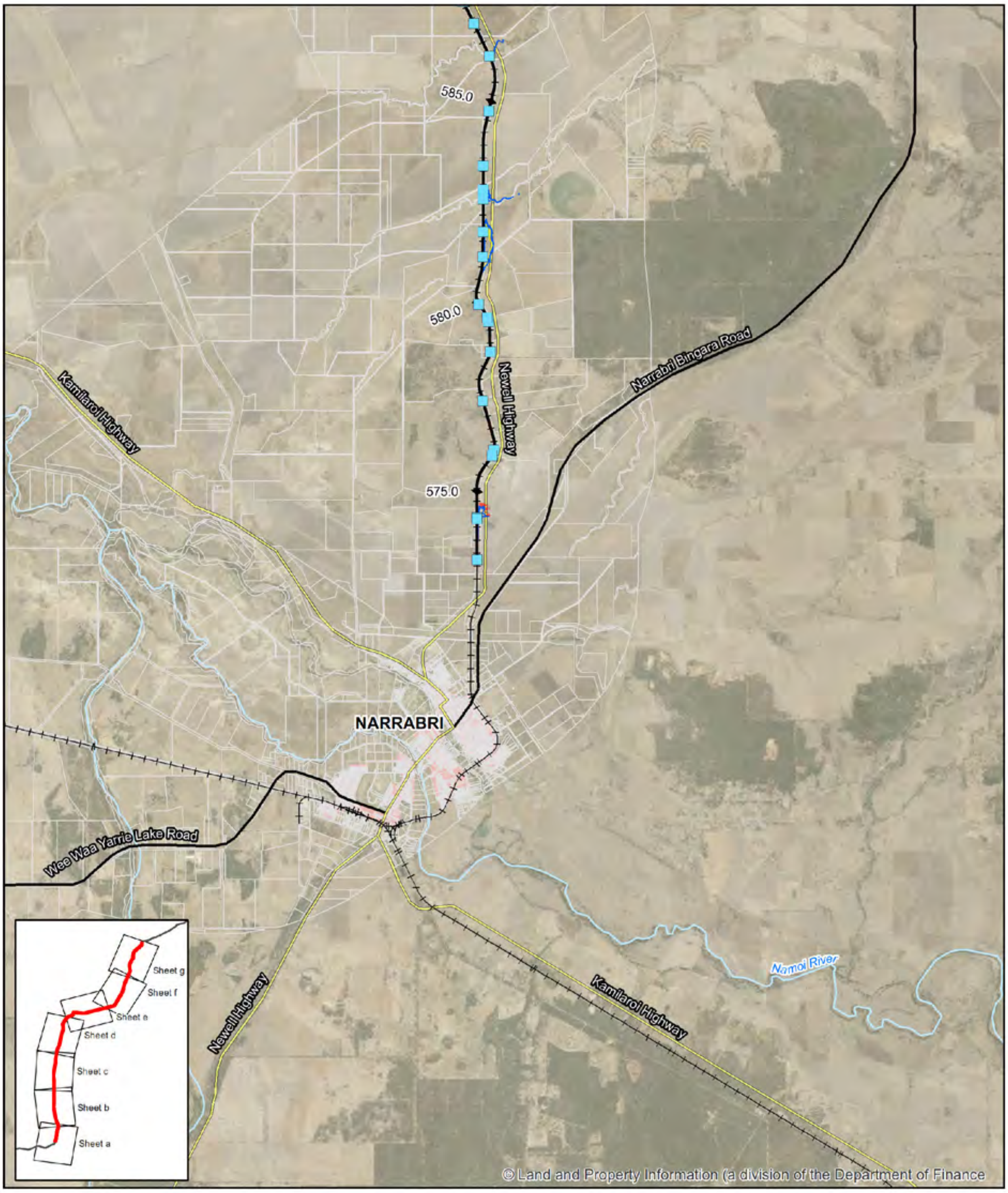
Design Flood Impact Areas
Local Catchment - Sheet 2

Figure 6-4b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH014_NNS_FloodExtents_Design_Sht2_0.mxd

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



LEGEND

The proposal	Railway
Culvert / underbridge location	Highway
Cadastre	Major road
	Watercourse
Increase in local flood extent	
Reduction in local flood extent	
Existing 1% AEP local flood extent	

Paper Size A4
0 500 1,000 2,000 3,000 4,000
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number 22-17916
Revision 1
Date 16 Aug 2017

Detailed Changes to the 1% AEP Flood Level Impact Extents

Figure 6-5a

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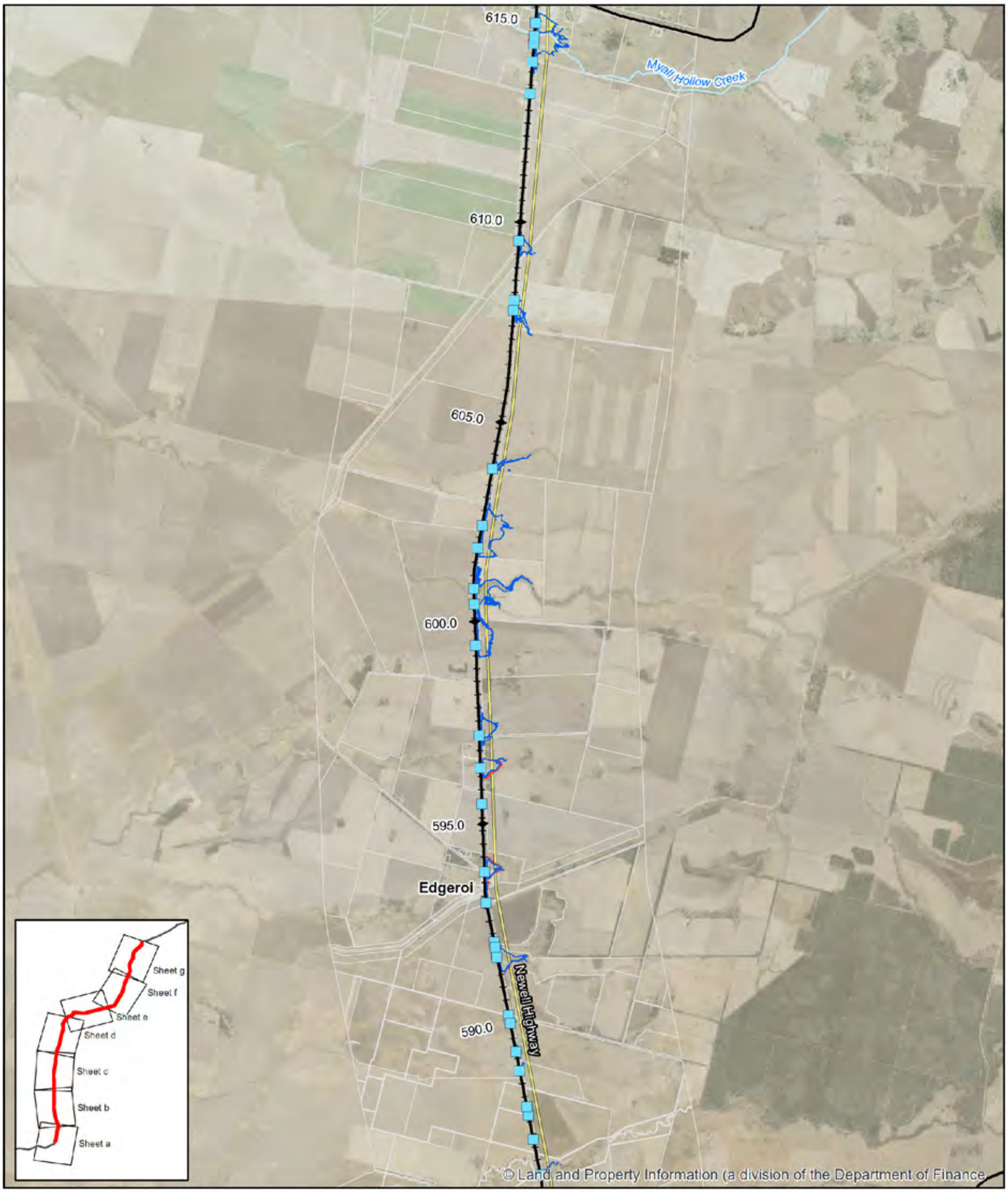
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, aerial imagery, 2014; LPI, DCDB/DTDB, 2012. Created by: gmcdiarmid, tmorton, kpsroba



LEGEND

- The proposal
- Culvert / underbridge location
- Cadastre
- Railway
- Highway
- Major road
- Watercourse
- Increase in local flood extent
- Reduction in local flood extent
- Existing 1% AEP local flood extent

Paper Size A4

0 5001,000 2,000 3,000 4,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number	22-17916
Revision	1
Date	16 Aug 2017

Detailed Changes to the 1% AEP Flood Level Impact Extents

Figure 6-5b

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH037_NNS_FloodExtentChange_report_1.mxd

Data source: ARTC, aerial imagery, 2014; LPI, DCDB/DTDB, 2012. Created by: gmcdiarmid, tmorton, kpsroba

LEGEND

- The proposal
- Culvert / underbridge location
- Cadastre
- Railway
- Highway
- Major road
- Watercourse
- Increase in local flood extent
- Reduction in local flood extent
- Existing 1% AEP local flood extent

Paper Size A4

0 500 1,000 2,000 3,000 4,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number	22-17916
Revision	1
Date	16 Aug 2017

Detailed Changes to the 1% AEP Flood Level Impact Extents

Figure 6-5c

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

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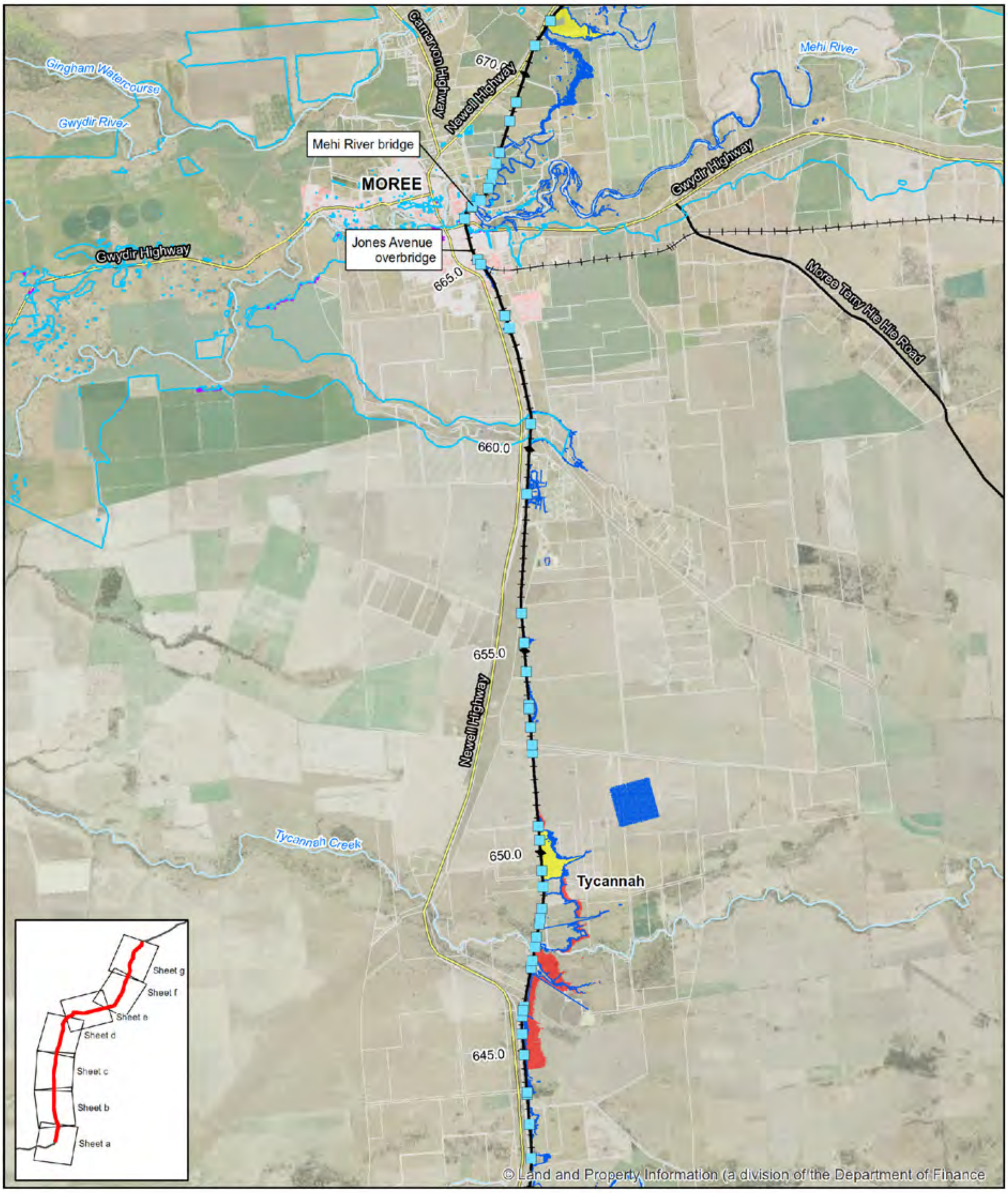
Data source: ARTC, aerial imagery, 2014; LPI, DCDB/DTDB, 2012. Created by: gmcdiarmid, tmorton, kpsroba



LEGEND

- The proposal
- Culvert / underbridge location
- Cadastre
- Railway
- Highway
- Major road
- Watercourse
- Increase in local flood extent
- Reduction in local flood extent
- Existing 1% AEP local flood extent
- Increase in regional flood extent
- Reduction in regional flood extent
- Existing 1% AEP regional flood extent

Paper Size A4
0 500 1,000 2,000 3,000 4,000
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number 22-17916
Revision 1
Date 16 Aug 2017

Detailed Changes to the 1% AEP Flood Level Impact Extents

Figure 6-5d

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

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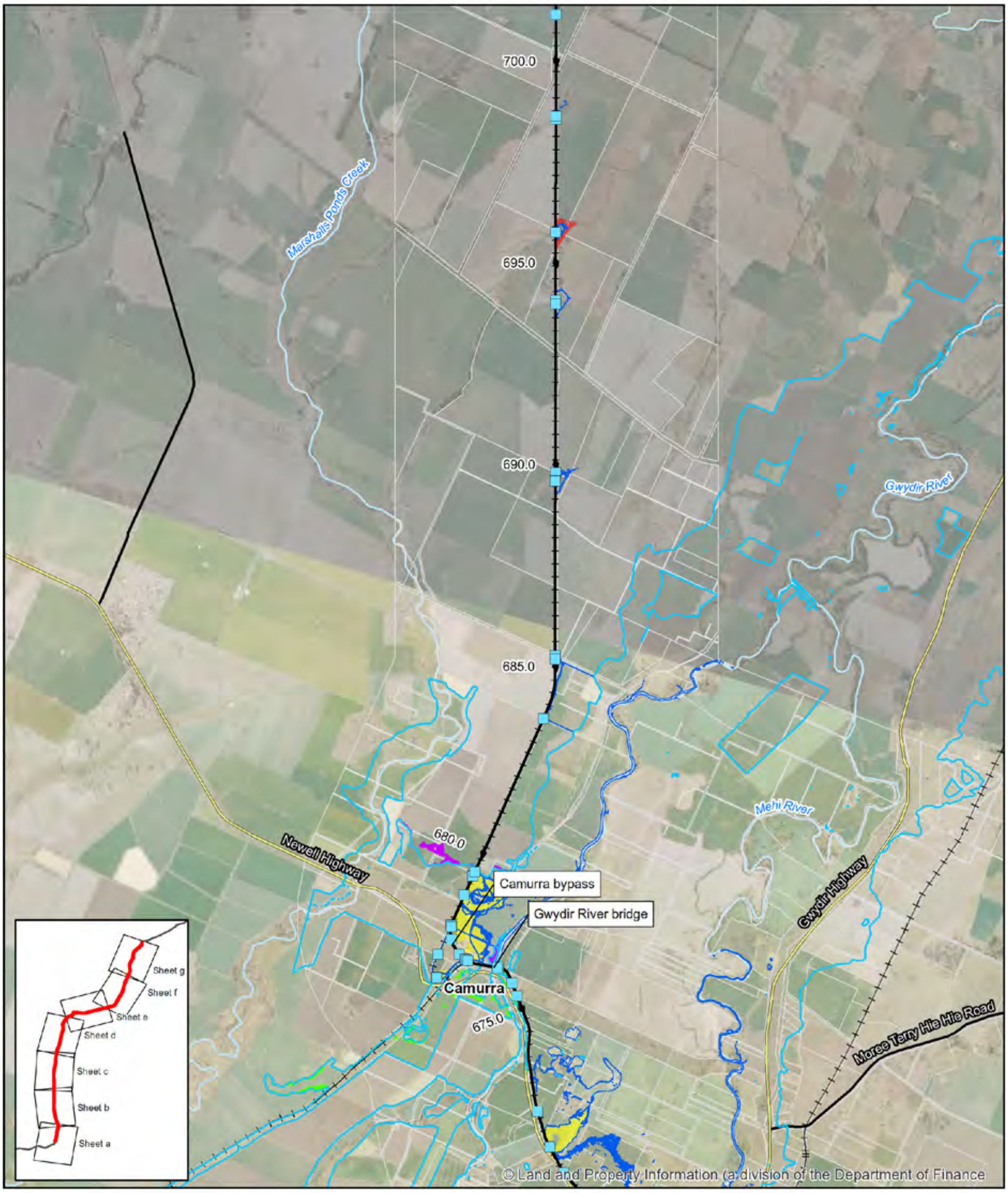
Data source: ARTC, aerial imagery, 2014; LPI, DCDB/DTDB, 2012. Created by: gmcdiarmid, tmorton, kpsroba



LEGEND

The proposal	Railway	Increase in local flood extent	Increase in regional flood extent
Culvert / underbridge location	Highway	Reduction in local flood extent	Reduction in regional flood extent
Cadastre	Major road	Existing 1% AEP local flood extent	Existing 1% AEP regional flood extent
	Watercourse		

Paper Size A4
0 500 1,000 2,000 3,000 4,000
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

Job Number 22-17916
Revision 1
Date 16 Aug 2017

Detailed Changes to the 1% AEP Flood Level Impact Extents

Figure 6-5e

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au
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Data source: ARTC, aerial imagery, 2014; LPI, DCDB/DTDB, 2012. Created by: gmcdiarmid, tmorton, kpsroba

LEGEND

The proposal	Railway	Increase in local flood extent
Culvert / underbridge location	Major road	Reduction in local flood extent
Cadastre	Watercourse	Existing 1% AEP local flood extent

Paper Size A4
0 500 1,000 2,000 3,000 4,000
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

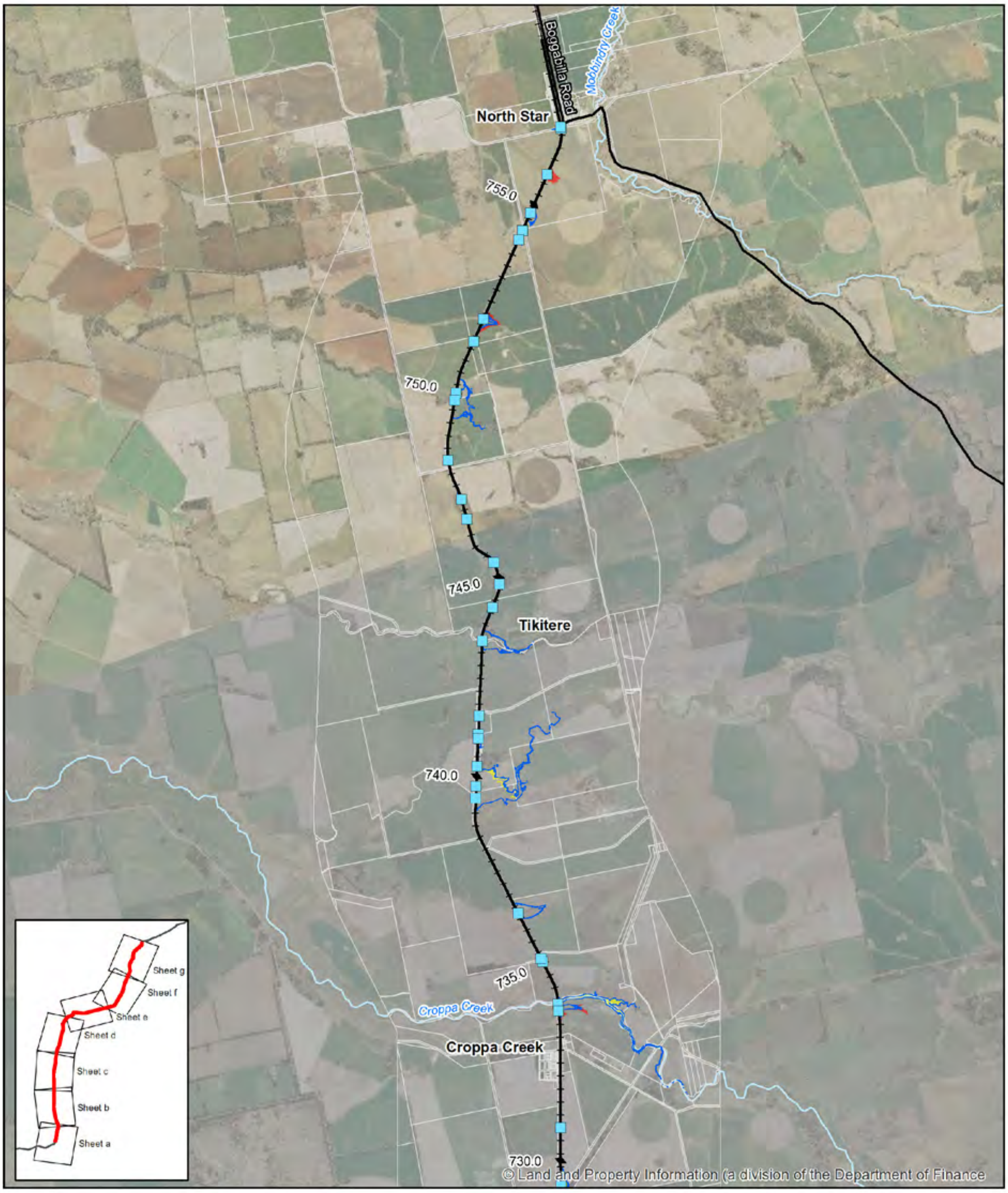
Job Number 22-17916
Revision 1
Date 16 Aug 2017

Detailed Changes to the 1% AEP Flood Level Impact Extents

Figure 6-5f

Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au
G:\22\17916\GIS\Maps\Deliverables\N2NS\HydrologyHydraulics\2217916_HH037_NNS_FloodExtentChange_report_1.mxd

Data source: ARTC, aerial imagery, 2014; LPI, DCDB/DTDB, 2012. Created by: gmcdiarmid, tmorton, kpsroba



LEGEND

The proposal	Railway
Culvert / underbridge location	Major road
Cadastre	Watercourse
Increase in local flood extent	
Reduction in local flood extent	
Existing 1% AEP local flood extent	

Paper Size A4
0 500 1,000 2,000 3,000 4,000
Metres
Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

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Detailed Changes to the 1% AEP Flood Level Impact Extents

Figure 6-5g

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Data source: ARTC, aerial imagery, 2014; LPI, DCDB/DTDB, 2012. Created by: gmcdiarmid, tmorton, kpsroba

Upstream flood velocities

When the proposed rail level is not overtopped, the flow velocities on the floodplain would generally be low. Immediately upstream of a culvert on the floodplain there would be a localised increase in velocity as the water approaches and enters the respective structure. The approach velocities on the floodplain are not expected to exceed a value of about 1.5 metres per second, which is comparable to the existing conditions.

The upstream velocity in defined watercourses would be larger than that on broad floodplain areas. For these locations, the velocity is predicted to be less than two metres per second except in very localised areas, which is comparable to the existing conditions.

When the rail line overtops in an extreme event or at level crossings, there would be flow over the rail, which would be acting as a weir. This would mean there would not be a localised increase in the flow velocity over the floodplain areas in the larger events, as compared to those for the smaller events when downstream floodplains are effectively flooded by almost still water.

Even in the extreme events when formation overtopping occurs, flow velocity would be generally comparable to those associated with the existing conditions.

Further analysis, to be undertaken as part of detailed design, would help to refine the impacts of the proposal on flow velocities and identify the requirement for any supplementary erosion and scour protection works required to further mitigate impacts.

Upstream period of flooding – local catchments

Local catchment flood events are predicted to have a critical duration (i.e. the rainfall duration that will provide the greatest local catchment runoff rate) of generally between 12 hours and around 36 hours (slightly increased from between 9 hours and 36 hours for the existing conditions). Local catchment runoff hydrographs for these rainfalls would expect to last for around 40 to 150 hours when not considering the effect of local ponding within the individual catchments.

For comparison purposes for this study, flooding has been taken as having ceased when the predicted flow through a structure has reduced to less than 0.1 metres deep at the respective culvert.

The increased inundation period from the existing duration of flooding would be generally less than two hours.

The actual duration of flooding is dependent upon the temporal rainfall pattern and in conditions when there are days of rainfall the durations could extend longer than for the critical duration design storms.

During extended periods of rainfall, the duration of flooding may exceed this estimate. During these extended periods of flooding, the influence of the proposal on flood duration is expected to be minimal. Similarly, a more rigorous analysis undertaken as part of design advancement for the project could provide longer inundation periods because of a better definition of localised depressions in the terrain or a greater flow interaction between adjacent catchments.

The existing data suggests that some catchments, for regional flood events, flooding of land could extend over several weeks.

Upstream watercourses – local catchments

The predicted low velocities described above are not anticipated to create watercourse instability. The changes in the average velocities to the new structures was assessed as generally comparable to existing velocities (i.e. within approximately 0.1 metres per second of the existing conditions).

Downstream flood level effects – local catchments

Downstream of the rail line there is expected to be generally little change compared to the existing conditions for events up to the one per cent AEP event in most areas. This is due to culverts being selected to (as far as practical) offset the flow capacities lost as a result of the raised formation level (i.e. reducing areas of overtopping) with additional culvert barrels. There may be localised changes in levels immediately downstream of replacement structures but these are likely to be confined closely to the rail corridor due to the proposed design measures.

Downstream flood velocities and erosion potential – local catchments

While upstream velocities are not expected to change appreciably, downstream of the culverts there is the potential for peak flow velocities to increase because of the increased flood levels upstream at some structures. Where the size (width) of the existing culvert is to be increased, flows would be distributed over a wider area, which could assist in minimising the potential increase in discharge velocities. A rock energy dissipation layer (a rock blanket) is proposed across the full width of the culverts to reduce the flow velocity of water exiting the culverts prior to discharging onto the ground. This blanket would assist in stabilising the soil and reduce the amount and extent of downstream soil erosion and, thereby this control measure would:

- Provide an improved transition from the flat concrete apron to the more irregular profile of the ground surface.
- Provide a location for trapping some of the sediment load and provide a relatively stable area for seed germination and vegetation establishment adjacent to the apron.
- Quickly stabilise the immediate area against erosion during the period of disturbance while the blanket is being placed.

However, there remains a risk of further downstream erosion watercourses downstream of each new culvert because of increased flow rates, flow volumes and flow velocities for flood events.

Where new culverts are proposed (i.e. at the Cumarra bypass), culverts would be located within existing drainage lines and would include outlet scour protection to minimise erosion and scouring downstream. As the existing Cumarra hairpin (downstream of the proposed Cumarra bypass) would be retained, it is expected that flow velocities further downstream would be comparable to the existing conditions.

Downstream periods of flooding – local catchments

Watercourses downstream of culverts would be inundated for periods similar to the upstream areas.

6.4.4 Road flooding – local catchments

The analysis of public road overtopping was undertaken using the same methodology as for the existing track profile. Design flood levels along the corridor were determined and intercepted, assuming horizontal water surfaces, with the adjacent landform.

The locations where the predicted levels overtop the roads within the LiDAR corridor are listed in Table 6.5. Figure 6.6 shows the locations of the overtopping. In this analysis, we have considered the roads identified in the functional hierarchy as being higher than local roads.

The maximum flood level in each catchment was assessed and then the lengths of roads impacted were determined by applying a horizontal design water surface and comparing the road levels to the design flood levels. This method indicated the potential for some roads to have a higher maximum inundation depth than at the location where the same road crosses the rail line.

Table 6.5 Design public road overtopping – local catchments

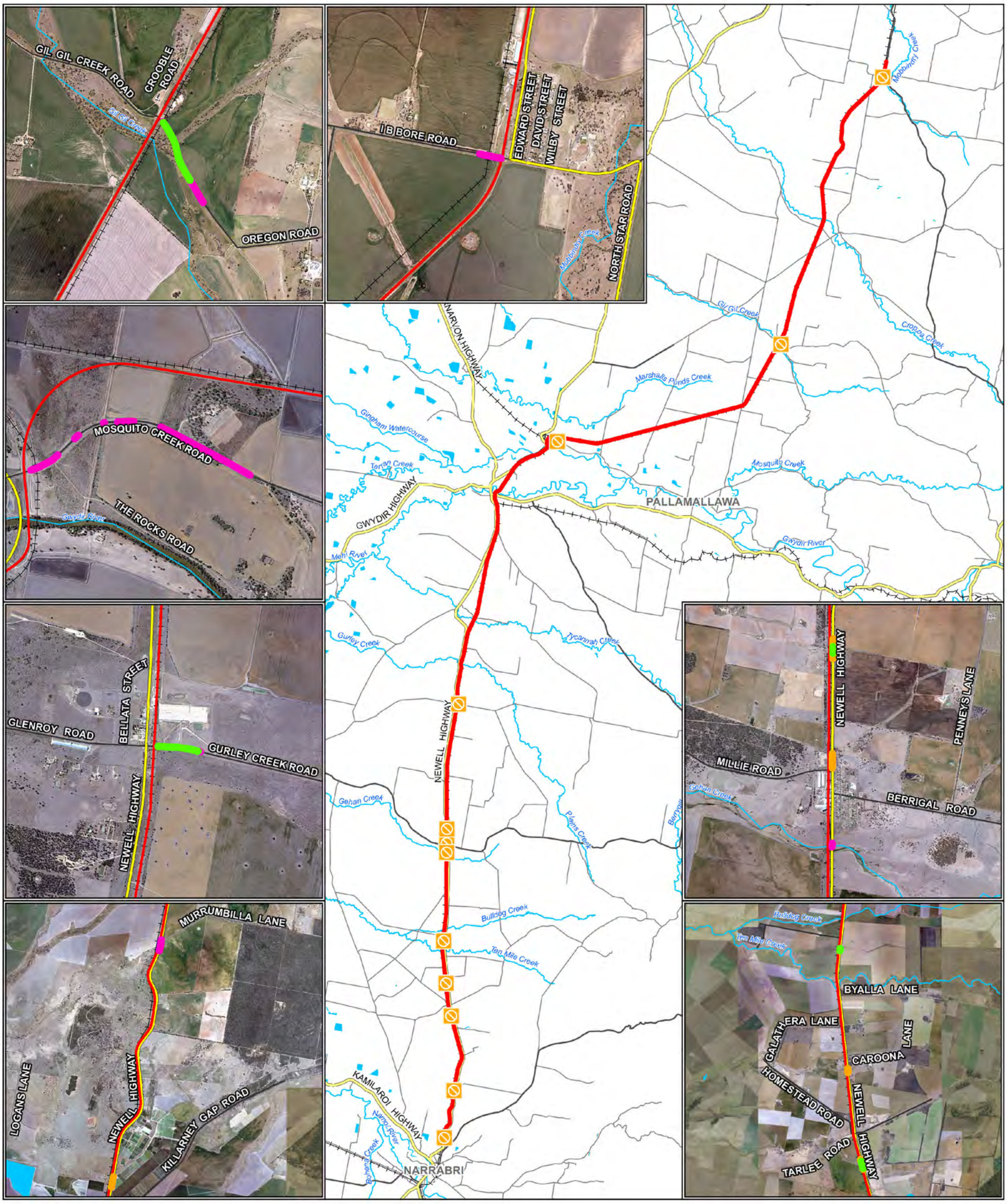
Road	Maximum Depth overtopping (m)					
	50% AEP	20 % AEP	10% AEP	5% AEP	2% AEP	1% AEP
Gil Gil Creek Road	-	-	-	0.27	1.11	1.73
Gurley Creek Road	-	-	-	-	-	0.24
Mosquito Creek Road	-	-	-	-	-	0.00
Newell Highway (various locations)	-	-	-	0.28	0.39	0.43
IB Bore Road	-	-	0.08	0.21	0.64	0.83
Railway Parade	-	-	-	-	-	0.15

The assessment found that the maximum depth of water predicted for the closures did not necessarily occur where the public road crossed the rail line, at the level crossing location, as the maximum depth was dependent upon the road profile within the flooded area.

Comparing the results in Table 6.5 to those for the existing conditions, Table 4.7, it can be seen that the potential impacts on the closure depths and locations would be minimal, with one per cent AEP flood depths over the roads exceeding 0.3 metres (the flood depth above which vehicles become unstable: NSW Government 2005) at three locations; Gil Gil Creek Road, Newell Highway (various locations) and IB Bore Road. Mosquito Creek Road and Oregon Road are predicted to be flood free, whilst Railway Parade and Gurley Creek Road are expected to be passable with care, or cut off for only a short period, during the one per cent AEP flood.

Figure 6.3 shows the locations and extent of the predicted local road closures for both the existing conditions and the design form.

The predicted depths of road overtopping for the one per cent AEP event do change from the existing case to the design case with increases in depths of water over the road at Gil Gil Creek Road and decreases in depths at Gurley Road, Railway Parade and some sections of the Newell Highway. While the depth at Gil Gil Creek Road would increase by 1.43 metres during the one per cent AEP, the road is closed during existing conditions so there would be no change in the road closure status. Local road upgrades may however be considered to improve the flood immunity of Gil Gil Road. Gurley Road and Railway Parade Road are currently closed during existing conditions so the proposal would improve conditions along these roads by making them passable with care during the one per cent AEP event. The proposal would cause road closure during the one per cent AEP at IB Bore Road, which is not closed during existing conditions but Oregon Road would no longer be closed.



LEGEND

- Flooded road
- Road flooded - existing and design scenarios
- Road flooded - design scenario only
- Road flooded - existing scenario only
- Narrabri to North Star Rail Line
- Major Road
- Secondary Road
- Minor Road
- Railway
- Watercourse
- Waterbody

Paper Size A3

0 2.5 5 10 15 20

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

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Major Roads Impacted by Floodwaters in 1% AEP Flood Event - Local Catchments **Figure 6-6**

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Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: DCDB, LGA, 2012, roads, 2006; ARTC, railway, 2012. Created by: tmorton, kpsroba, gmcdiarmid

It is considered that the overall impact of the proposal on road closures would not impact the operation of the SES and emergency planning measures currently being implemented. The modelling indicates that flood depths at some local sections of public roads increase, whilst others decrease. However, the modelling generally indicates that the potential for public roads to be flooded remains relatively unchanged.

Given that the increase in flood levels would only occur at areas already subject to flooding (with the exception of IB Bore road), the proposal would not require changes to existing community emergency management arrangements for flooding and there would not be increased social and/or economic costs to the community as consequence of flooding.

Ongoing liaison with local councils, Roads and Maritime Services and emergency services would be undertaken as part of the detailed design phase to identify potential opportunities to improve the impacts of the proposal on road flooding.

6.4.5 Building impacts – local catchments

An inspection of the imagery indicated that 20 structures that may be impacted for the predicted one per cent AEP local catchment flood levels, consisting of:

- 3 houses (additional 2 houses: refer to Section 4.3.5)
- 6 businesses (additional 1 business: refer to Section 4.3.5)
- 10 garages or sheds (additional 1 garage or shed: refer to Section 4.3.5)
- 1 park structure/public amenity (no change from existing: refer to Section 4.3.5)

Appendix L contains figures that provide detailed views of the modelled flood impacts to properties within the vicinity of the proposal, including the location of the additional structures affected by flooding. A total of seven structures are expected to experience increased flooding impacts as a result of the proposal, whilst three structures are expected to experience reduced flooding impacts as a result of the proposal.

Three of the affected buildings are located approximately 15 kilometres north of Narrabri at Edgeroi (refer to Figure L-3 of Appendix L), and include:

- A weatherboard and corrugated steel residential dwelling, presumably on bearers and joists (i.e. could potentially be raised)
- A shed associated with a petrol station, presumably slab on ground
- An agricultural shed or outbuilding

Four of the affected buildings are located on the northern edge of Bellata (refer to Figure L-6 of Appendix L), and include:

- A fibro and corrugated steel residential dwelling, presumably on bearers and joists (i.e. could potentially be raised).
- A fibro and corrugated steel residential dwelling, presumably on bearers and joists (i.e. could potentially be raised), with two adjacent agricultural sheds.

This does not include the flood-affected dwellings within Moree, which are impacted by the large regional floods within the Gwydir and Mehi Rivers.

A summary of the change in the estimated one per cent AEP flood levels (at the nearest rail corridor culvert) at these affected properties is included in Table 6.6.

Table 6.6 Design flood levels at affected properties – local catchments

Location	Lot and DP	1% AEP flood level [A]		
		Existing (mAHD)	Design (mAHD)	Change (metres)
Edgeroi	DP394753-X (dwelling)	241.91	242.20	+ 0.29
	DP753952-61 (shed)			
	DP753952-73 (shed)			
Bellata	DP758081-1 (dwelling)	229.90	230.82	+ 0.92
	DP708391-2 (dwelling and two sheds)			

[A] estimated flood level at the adjacent rail corridor culvert

Further modelling would be undertaken during detailed design to determine how the proposal can be modified so that the existing flooding characteristics concerning property inundation are not worsened. Design modifications would likely consist of culvert resizing and potentially changes to the proposed formation height near the properties identified above.

6.5 Flooding – Regional

6.5.1 Flood level analysis –regional catchments

Detailed flood modelling was undertaken by Jacobs (2017) for the area surrounding Moree. This was undertaken as the proposal had the potential to significantly impact on flood levels at numerous private dwellings upstream and downstream of the alignment. The detailed food modelling considered a number of conceptual formation designs and culvert configurations however each resulted in significant changes to the maximum modelled flood depths upstream and downstream of the proposal. Therefore it was determined that the embankment heights should be retained and culverts replaced on a like for like basis (as far as practical) so that there is no substantive change of the operation of the floodplain hydraulics within the vicinity of Moree.

The maximum modelled flood depths and extents associated with the one percent and ten per cent AEP flood events within the Gwyder and Mehi Rivers for the proposed conditions are included in Figure 6.7 and Figure 6.8 respectively. These figures indicate that regional flooding results in much more extensive flooding compared to the local catchment flooding. The modelling indicates that there is no appreciable change in the extent of regional flooding when comparing the design conditions (refer to Figure 6.7 and Figure 6.8) to the existing conditions (refer to Figure 4.6 and Figure 4.7. During the one per cent AEP regional flood event there are some locations where the modelling indicates that maximum modelled flood depths may increase by up to about 200 millimetres, however these are generally limited to isolated areas to the north of Moree, with no appreciable impact to flood durations.

Detailed views of the modelled changes to the regional flood impact areas are included in Figure 6.5 and Appendix L.

6.5.2 Rail overtopping and formation non-conformance –regional catchments

Figure 6.7 and Figure 6.8 also indicate the locations where the proposed rail line and formation are expected to be overtopped.

The total length of overtopped rail because of flooding within the Gwydir and Mehi Rivers for the design conditions is summarised in Table 6.7. Table 6.7 also includes a summary of the estimated change in rail overtopping compared to the existing conditions (Table 4.8), which indicates that for the one per cent AEP regional flood event, there is a slight increase (about 6.5 per cent) in the length of rail overtopped. This increase is however considered to be within the accuracy of the modelling, and is therefore considered to indicate a negligible change in rail overtopping. For more frequent flood events such as the ten per cent AEP regional flood event however, the modelling indicates that the design conditions are expected to remove almost all track overtopping (Figure 6.8).

The total length of formation overtopping because of flooding within the Gwydir and Mehi Rivers for the design conditions is summarised in Table 6.8, assuming that the top of rail is about 750 millimetres above the formation capping layer.

Table 6.8 also includes an estimate of the change in ballast flooding due to regional flooding compared to the existing conditions (Table 4.8), indicating a general reduction in the extent of formation overtopping. This appears to be the result of the reduced track and formation flooding north of Moree (refer to Figure 6.7).

Table 6.7 Design rail overtopping – regional catchments

Design event (% AEP)	Overtopping Length (m)	Change from existing (m)
10	70	- 2905 (- 97.6%)
1	6720	+ 410 (+ 6.5%)

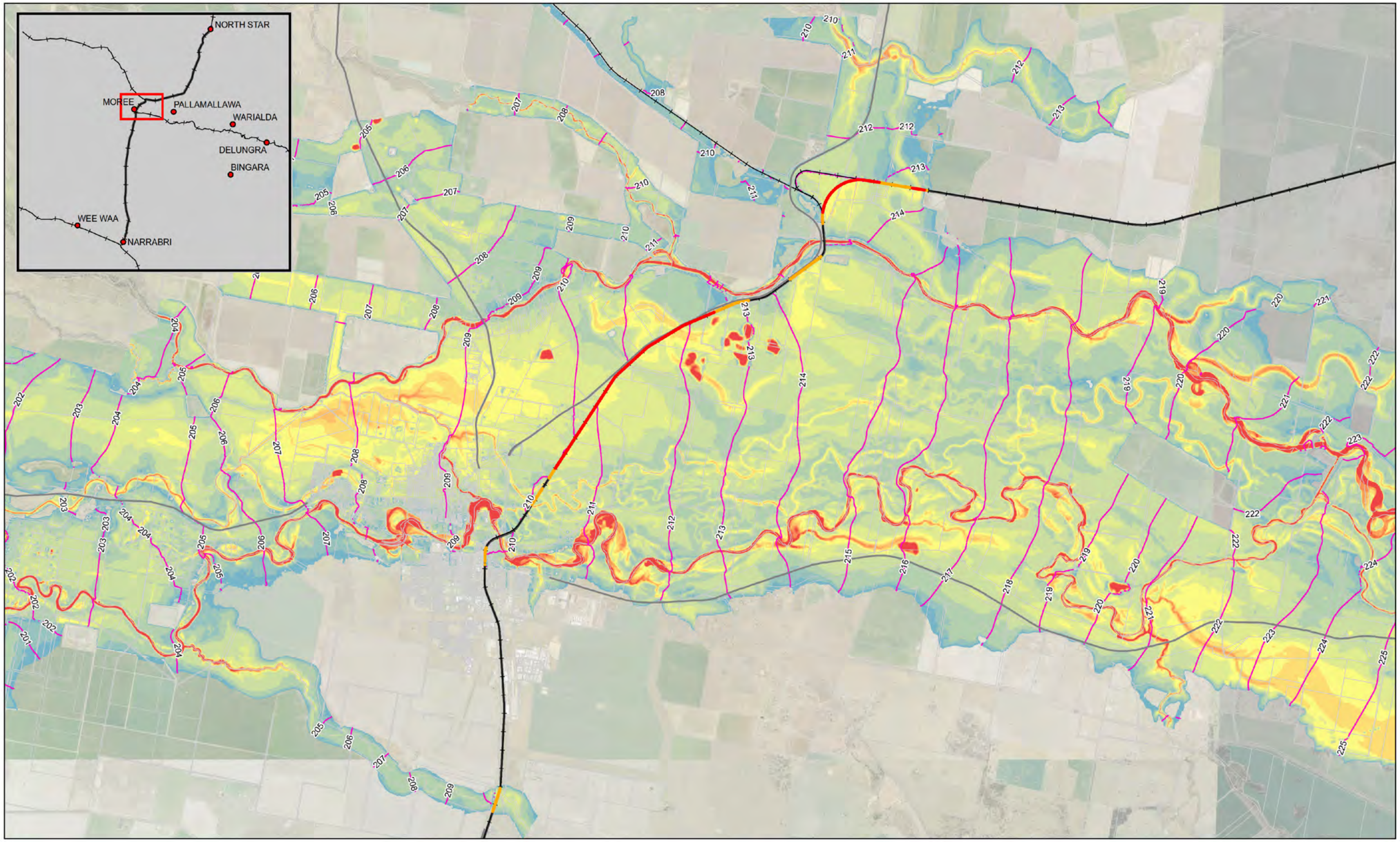
Table 6.8 Design formation non-compliance – regional catchments

Design event (% AEP)	Length of formation overtopping (km)	Change from existing (km)
10	5.24	- 0.42 (- 7.4%)
1	10.87	- 1.51 (- 12.2%)

6.5.3 Adjacent land impacts –regional catchments

The regional flood modelling indicates that the maximum modelled flood extent for the design conditions (Figure 6.7 and Figure 6.8) remains comparable to the existing conditions (Figure 4.6 and Figure 4.7). This is a result of the design rail level and culvert crossings being, as far as practical, being replaced "like for like". The modelling indicates that the design condition increases flood depths for the one per cent AEP flood event of less than about 0.1 metres within the populated areas of Moree (Jacobs 2017). Localised areas of larger increases in the maximum modelled flood depths are associated with the Camurra bypass, which includes a new embankment which affects the local flood response. Between the Camurra bypass and the existing rail corridor, the modelling indicates reduced flood levels.

The regional flood modelling indicates that the design conditions generally have little effect on the maximum modelled flood velocities, with increases typically limited to about 0.1 m/s (Jacobs 2017). Within some isolated areas, such as the relocated and additional culverts located at the Camurra bypass, the modelled velocities increase by more than one metre per second however, the extent of these increases is generally constrained to the areas immediately upstream and downstream of the proposed culverts.



Paper Size A3

0 375 750 1,500 2,250 3,000

Metres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

N

LEGEND

- Highway
- Existing railway
- Proposed railway
- Cadastre
- Water Level Contour (1m)
- Overtopped rail
- Overtopped formation

Flood Depth (m)

- 0 - 0.1
- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 1
- 1 - 1.5
- 1.5 - 2
- 2 - 2.5
- 2.5 - 3
- 3 - 3.5
- 3.5 - 4
- 4 - 4.5
- 4.5 - 5
- > 5

GHD

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Proposed Flood Depths and Track Overtopping - Gwydir and Mehi Rivers (Regional) 1% AEP Event

Figure 6-7

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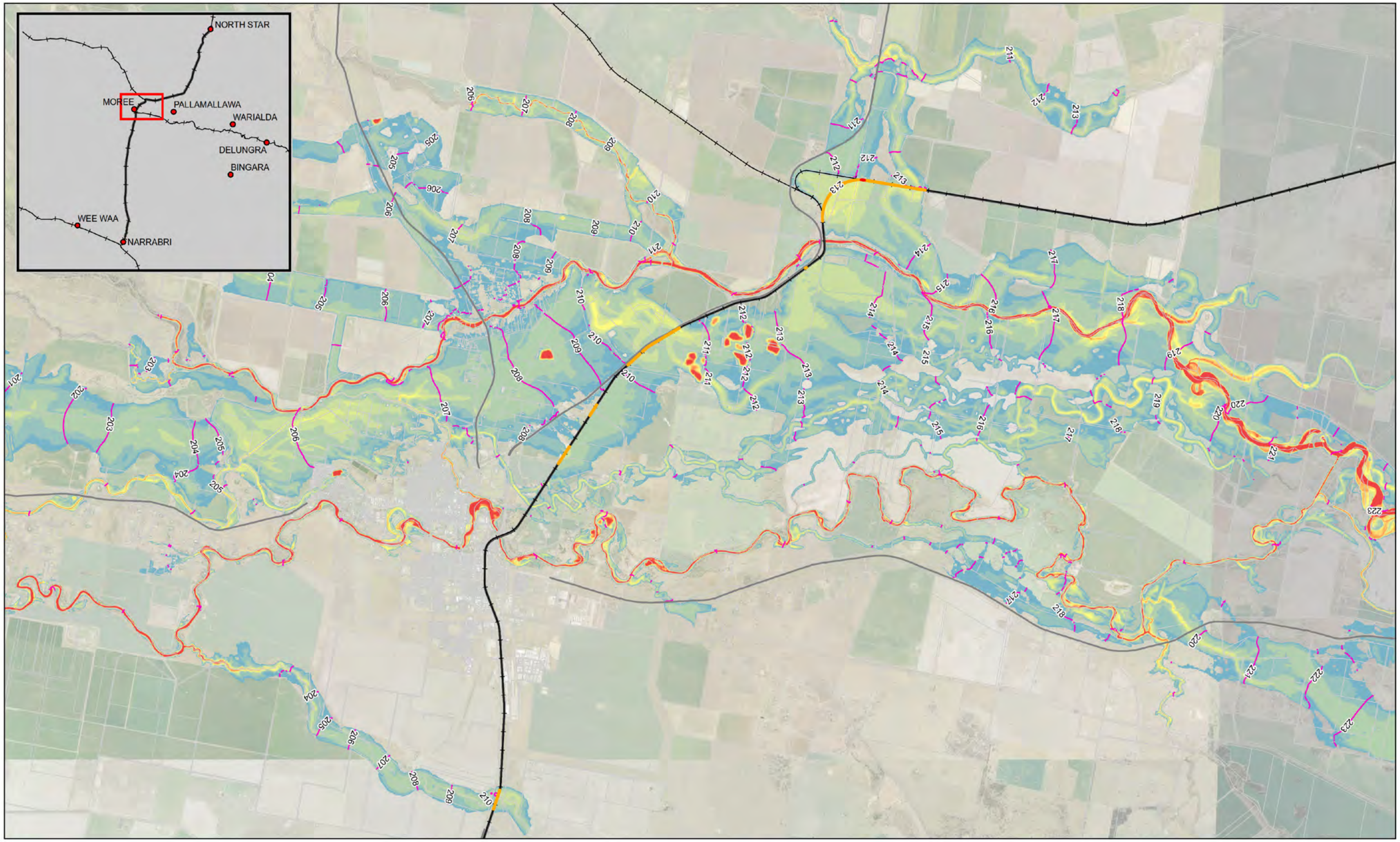
Data source: LPI, DTDB/DCDB, 2012. Jacobs, Flood depth, 2017. Created by: kpsroba, gmcdiarmid



Australian Rail and Track Corporation
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Proposed Flood Depths and Track Overtopping - Gwydir and Mehi Rivers (Regional) 10% AEP Event Figure 6-8

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Data source: LPI, DTDB/DCDB, 2012. Jacobs, Flood depth, 2017. Created by: kpsroba, gmcdiarmid

6.5.1 Road flooding –regional catchments

The regional modelling (Jacobs 2017) indicated that at some locations the one per cent AEP flood depths over the Newell Highway increase by up to about 0.07 metres (compared to existing conditions: Section 4.4.4). However, as flood depths are about 1.5 to 2.0 metres, the Newell Highway is expected to remain non-trafficable during major regional flood events.

6.5.2 Building impacts –regional catchments

The regional modelling (Jacobs 2017) indicated that for the ten per cent AEP flood event, no additional dwellings were flooded above the estimated floor level. The regional flood modelling (Jacobs 2017) also indicates that an additional 23 properties (of 999 affected properties) could be impacted during the one per cent flood event, however these properties are located at the outer edges of the modelled flood extents, and impacts to the dwellings located on these properties is expected to be minimal. Additional modelling at detailed design would be required to confirm these impacts (including a survey of floor levels of the affected properties) and, if necessary, identify mitigation measures that may be required.

6.6 Flooding – combined local and regional catchments

6.6.1 Flood level analysis – combined local and regional catchments

Predicted design flood levels for both the local and regional catchments are provided in Appendix H. Appendix H also contains a tabulation of the design flood levels for all design AEP events and the changes in design flood levels from those for the existing conditions.

Figure 6.9 indicates the locations where the design rail line level is expected to be overtopped by both the local or regional catchment flood events, and where the formation is non-complying for the local and regional catchment flooding.

6.6.2 Rail overtopping and formation non-complying – combined local and regional catchments

Figure 6.9 shows the extents of the combined local and regional rail overtopping and formation non-conformance. The depth of flooding over the rail and formation for both the local and regional catchments is summarised in Figure 6.10.

Combining the regional flood rail overtopping (Table 6.8) with the rail overtopping estimates for local catchment flooding (Table 6.3) provides an overall estimate of the length of the design rail that does not currently comply with ETD-10-02 (refer to Table 6.9).

Comparing the cumulative rail overtopping for the design conditions to the existing conditions (Table 4.9), the combined modelling (local and regional scale) indicates that the design generally reduced the length of rail overtopping (Table 6.9).

Table 6.9 Design rail overtopping – combined local and regional models

Design event (% AEP)	Overtopping Length (m)	Change from existing (m)
10	70	- 3740 (- 98.2%)
1	8505	- 4220 (- 33.2%)

Combining the regional flood ballast flood results (Table 6.8) with the ballast flooding estimates for local catchment flooding (Table 6.3) provides an overall estimate of the length of the design rail that does not currently comply with ETD-10-02 (refer Table 6.10).

Comparing the cumulative ballast flooding for the design conditions to the existing conditions (Table 4.9), the combined modelling (local and regional scale) indicates that the design generally reduced the length of flood affected ballast (Table 6.10).

Table 6.10 Design formation non-compliance – combined local and regional models

Design event (% AEP)	Length of formation overtopping (km)	Change from existing (km)
10	9.85	- 2.05 (- 17.2%)
1	26.61	-13.32 (- 33.4%)

6.6.1 Adjacent land impacts – combined local and regional catchments

Figure 6.11 compares the flood affectation areas estimated for the local catchments (Figure 6.4) and regional catchments (Figure 6.7 and Figure 6.8).

The regional modelling indicated that the under the design conditions, the extent of flooding for the regional catchments (i.e. Gwydir and Mehi Rivers) is comparable to comparable to those estimated for the existing conditions (Section 6.5.3).

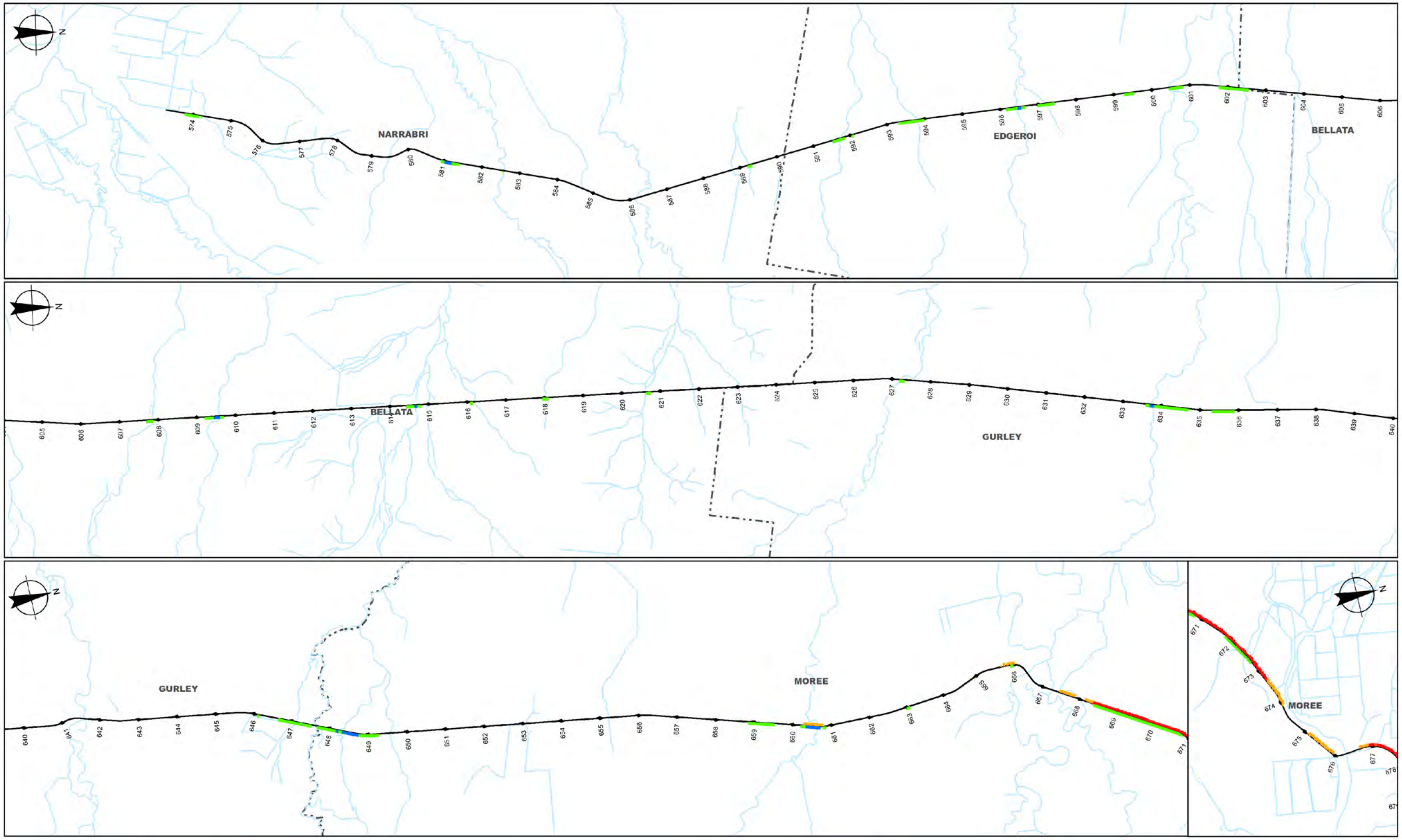
Therefore, principal changes to flood extents is expected to be the result of the local catchment flooding outside of Moree (Section 6.4.3).

6.6.2 Road flooding – combined local and regional catchments

The regional modelling indicated that under the design conditions, the main road through Moree (i.e. the Newell Highway) would continue to be inundated during larger flood events (Section 6.5.1). Outside of the Moree area, the local catchment modelling indicated that the design conditions have the potential to alleviate flooding at a number of level crossings, whilst increasing depths at others (Section 6.4.4).

6.6.3 Building impacts – combined local and regional catchments

The regional flood modelling indicated that an additional 23 properties (of 999 affected properties) could be impacted during the one per cent flood event, however these properties are located at the outer edges of the modelled flood extents, and impacts to the dwellings located on these properties is expected to be minimal (Section 6.5.2). Outside of Moree, the local catchment modelling indicated that four additional properties could be affected by flooding because of the design conditions (Section 6.4.5).



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Overtopped rail (local)
- Overtopped formation (local)
- Overtopped rail (regional)
- Overtopped formation (regional)
- Watercourse
- Suburb boundary

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

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Design Track Overtopping, Local and Regional Catchments - Sheet 1

Figure 6-9a

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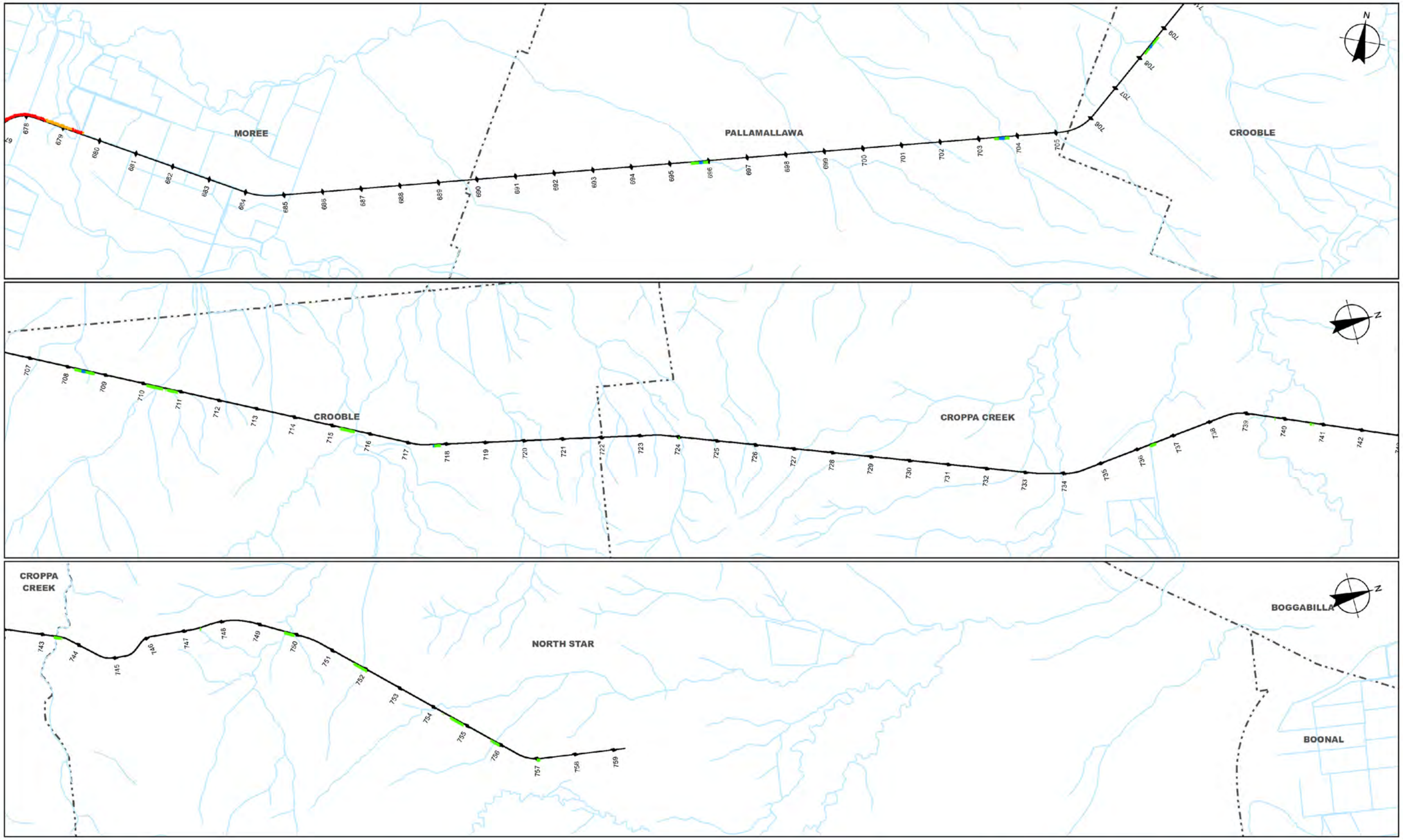
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Overtopped rail (local)
- Overtopped formation (local)
- Overtopped rail (regional)
- Overtopped formation (regional)
- Watercourse
- Suburb boundary

Australian Rail Track Corporation
Inland Rail - Narrabri to North Star

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Design Track Overtopping, Local and Regionall Catchments - Sheet 2

Figure 6-9b

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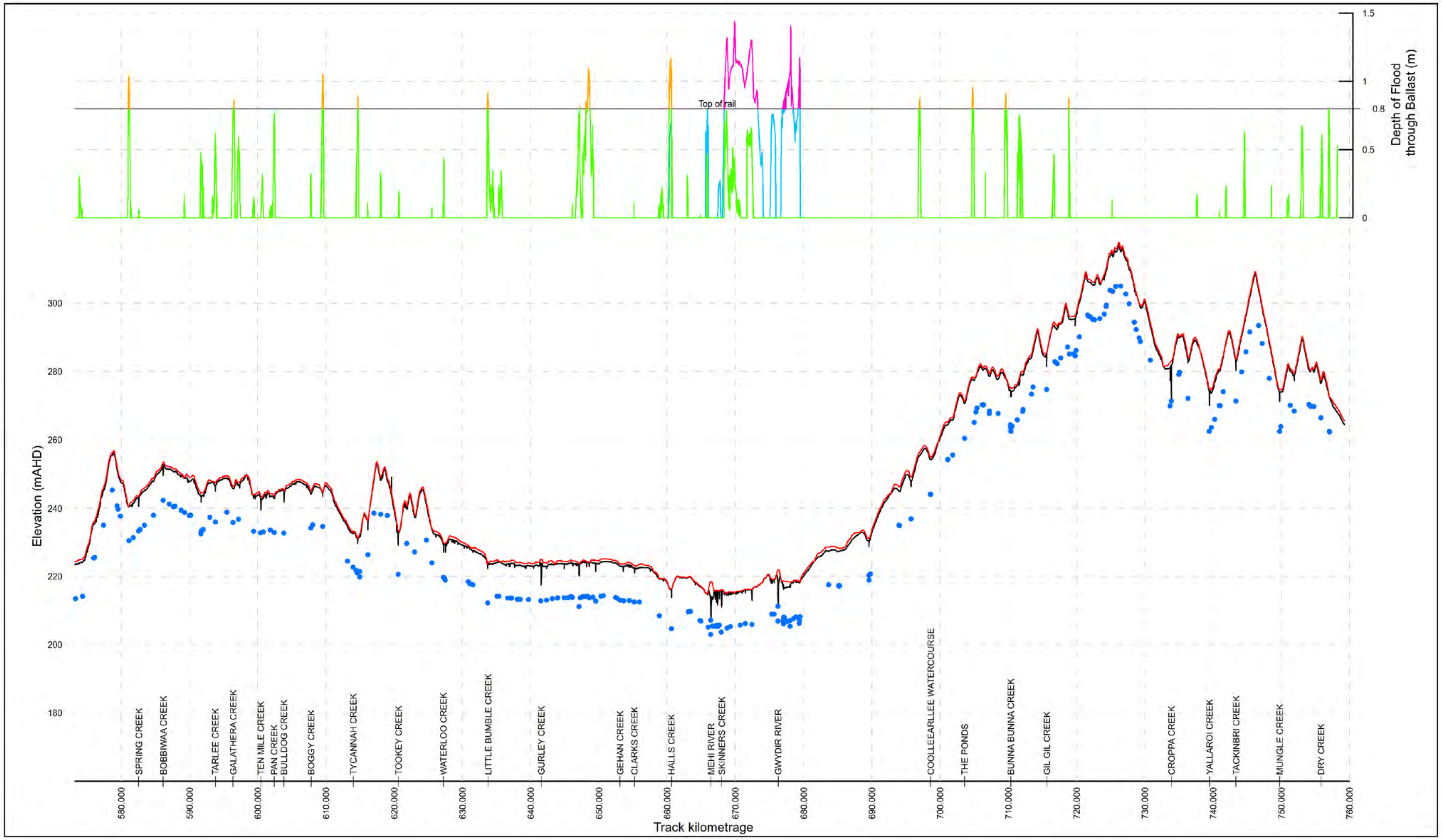
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba



Paper Size A3

LEGEND
- Design
- Natural Surface
- Culverts
- Local flood through ballast
- Local flood through ballast - overtopping rail
- Regional flood through ballast
- Regional flood through ballast - overtopping rail

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Date	16 Aug 2017

Design Track Alignment for Local and Regional Catchment Flooding of Ballast Figure 6-10

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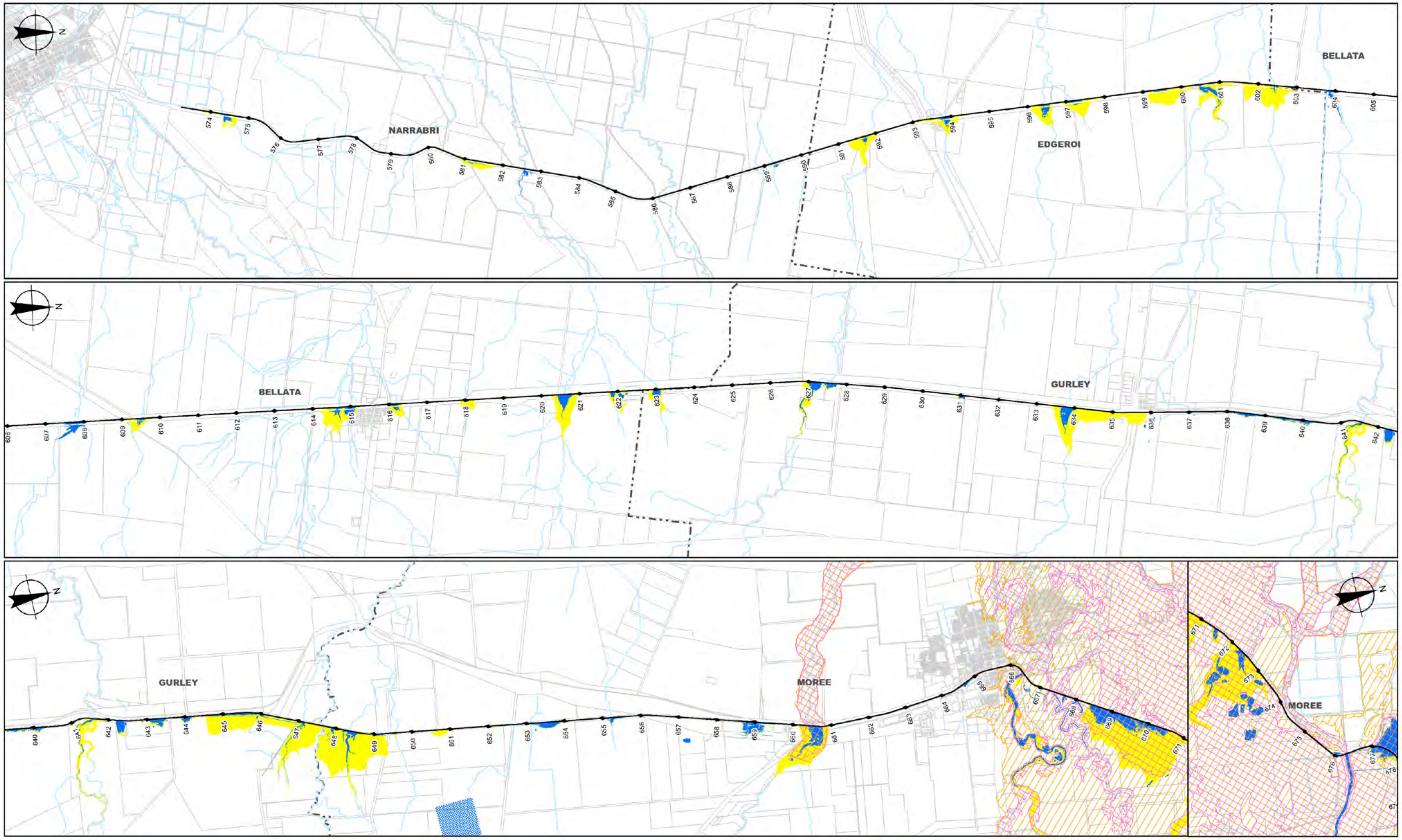
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 T 61 2 4979 9999 F 61 2 4979 9988 E ntlmail@ghd.com W www.ghd.com.au

Data source: LPI: Watercourses, 2012. ARTC: Aerial lidar, 2015. Created by: gmcdiarmid, kpsroba



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Inland Rail
- Watercourse
- Lot boundary
- 10% AEP local flood extent
- 1% AEP local flood extent
- 10% AEP regional flood extent
- 1% AEP regional flood extent

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Design Flood Impact Areas, Local and Regional Catchments - Sheet 1

Figure 6-11a

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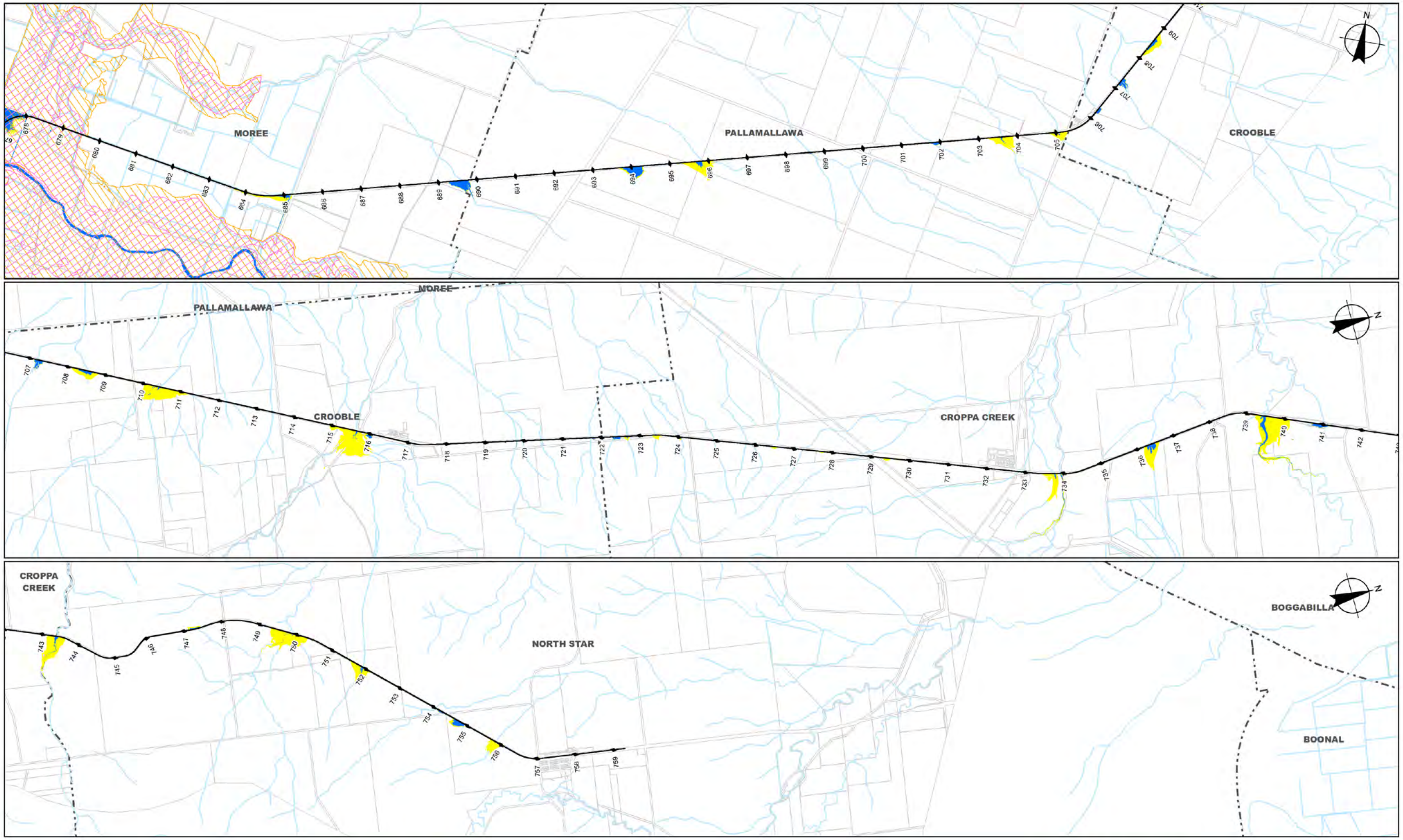
Level 3, GHD Tower, 24 Honeysuckle Drive, Newcastle NSW 2300 **T** 61 2 4979 9999 **F** 61 2 4979 9988 **E** ntlmail@ghd.com **W** www.ghd.com.au

Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton



Paper Size A3

0 0.5 1 2 3 4

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 55

LEGEND

- Inland Rail
- Watercourse
- Lot boundary
- Suburb boundary
- 10% AEP local flood extent
- 1% AEP local flood extent
- 10% AEP regional flood extent
- 1% AEP regional flood extent

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Design Flood Impact Areas Local and Regionl Catchments - Sheet 2

Figure 6-11b

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Data source: ARTC, imagery, 2014. Created by: gmcdiarmid, kpsroba, tmorton

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7. Monitoring program

7.1 Flood event monitoring

It would be impractical to monitor the flood impacts during the any individual flood event. Therefore, a more feasible monitoring program is proposed in this section.

7.1.1 Flooding during the construction

Should a flood event occur during the construction phase then the following would be undertaken to verify the design performance and impact predictions, or to refine the design should there be a significant difference between the actual and predicted flood impacts and behaviour. The following steps would be implemented:

- The construction area would be inspected for damage and any required maintenance completed.
- The presence of any culvert blockages in the construction area, if present, would be recorded and cleaning undertakes as required.
- Where there is a significant variance between the predicted flood levels and the observed levels on the recently constructed stage of the works, landowners would be consulted to improve the understanding of the local flow and flooding behaviour.
- Any areas, and extent, of any erosion downstream of culverts would be recorded to compare to predicted values for the recently constructed stage of the works.
- The locations of any rail overtopping or damage would be recorded together with any maintenance required and form of works.
- Decisions would be made on the need to refine the design of works yet to be installed and the need to undertake required mitigation measures.
- The form and location of any implemented mitigation measures would be recorded.

7.1.2 Flooding following commencement of operation

As soon as practical, if the rail corridor is closed, after the track is considered to be safe:

- The track would be inspected and the flood levels along the length of the rail corridor would be recorded for verification against the predicted flood levels.
- The presence of any culvert blockages would be recorded.
- Where there is a significant variance between the predicted flood levels and the observed levels, landowners would be consulted to improve the understanding of the local flow and flooding behaviour.
- Any areas, and extent, of any erosion downstream of culverts would be recorded to compare to predicted values.
- The locations of any rail overtopping or damage would be recorded together with any maintenance required and form of works.

- Decisions would be made on the need to refine the design of works yet to be installed and the need to undertake required mitigation measures.
- The form and location of any implemented mitigation measures shall be recorded.

7.2 Surface water extraction monitoring

Monitoring of surface water extraction would be undertaken at each extraction location during the extraction period to determine and confirm the total volume of extracted water. The monitoring would also confirm the volumetric extraction impact on each extraction location.

Potential water sources are identified in Section 3.4. The extraction of water from these sources would be subject to necessary licensing that would be obtained by the contractor prior to construction.

The monitoring process and program would include recording the extraction volume for each load of water to confirm the volume extracted from each location.

Where an extraction is undertaken from a farm dam, the maximum extractable volume would be confirmed as part of the initial landowner consultation and extraction would terminate should the volume of the recorded extraction reach the agreed volume.

7.3 Groundwater extraction monitoring

Groundwater monitoring would be undertaken at each extraction location during the period of the extraction and at a less frequent period following the cessation of extraction at each location to identify the groundwater recovery process.

Potential water sources are identified in Section 3.4. The extraction of water from these sources would be subject to necessary licensing that would be obtained by the contractor prior to construction.

The monitoring process and program would include:

- Installation, if not already present, of a water level monitor at each agreed and approved extraction location prior to any extraction being undertaken.
- Prior to each load of extracted water, the groundwater level would be measured and recorded, along with the time and date of the start of the extraction.
- For each load of extracted water, the extracted volume of water and the groundwater level would be recorded at the completion of the extraction.

The above data would indicate if there is a significant drawdown in the groundwater level or rebound in groundwater level between extractions.

In the event of a groundwater drawdown without rebound between consecutive extraction days exceeding a value of 0.3 metres then further extractions from that location would be suspended until the rebound has shown a recovery of the groundwater level of not more than 0.1 metres. In the event that the appropriate recovery is not achieved then no further extractions would be made from that site.

8. Conclusion

This report presents an assessment of the existing hydrologic and hydraulic conditions along the length of the proposal and identifies the existing flooding regime and the extents of impacts of existing flooding.

8.1 The design development process

The design development process included an integration of the track formation design and structure sizing, and an assessment of the potential impacts of the proposal. Structures were sized based on the predicted flows that would arise from rainfall events over the local catchment areas. Detailed examination of the flooding impacts within the vicinity of Moree has been undertaken to investigate the potential impacts of the proposal on the residential areas within Moree.

Structures under the formation were then sized to provide a target performance requirement of conveying the one per cent AEP flow while not having the upstream one per cent AEP ponding level above the top of the rail formation. That target performance was not achieved at all locations and exceptions to the requirement are identified in this report.

The structure sizing was based on the evaluation of the required number of pre-cast box culvert units, of selected standard sizes, to achieve the required hydraulic performance. The discharge capacity of the structures was assessed based on the assumption that the discharge rate was directly related to the flood level immediately upstream of the culverts and ignored the downstream effects. This approach was necessary to establish a potential design solution as consideration of downstream backwater effects would have made the analysis impractical. The analysis, while considering flow through structures, also considered, where appropriate, the flow over the rail line and the interaction of flows between adjacent local catchments upstream of the rail corridor.

The assessment method provides a reasonable means of estimating the potential flood impacts associated with the proposal however additional analysis is recommended within sensitive areas during detailed design to ensure the proposal results in minimal impacts on surrounding land users.

8.1.1 Future works

A number of additional works have been identified during this assessment that are to be completed as part of the detailed design process, including:

- Detailed flood modelling of major structures (or adjacent structures) to:
  - Minimise the regional flooding impacts.
  - Better represent the catchment response to rainfall and the catchment flow paths, directions and velocities for overland flows and watercourses.
  - Provide improved estimations of the extent of upstream flood extents and impacts, including flow velocities, shear stress and duration may be required to identify suitable erosion and scour protection measures.
  - Estimate the potential for erosion and scour around bridge piles, and scour protection measures that may be required.

- Assist in identifying refinements to the design (both rail lift and culvert configurations) to either reduce the estimated impacts (including those on buildings and properties) so that the existing flooding characteristics are not worsened and/or the reliability of the proposal is improved.
  - Potentially include consideration of flows through, and possibly under, the ballast and formation.
  - Consider of effects of downstream flood levels (i.e. tailwater control conditions) on flows through the culverts.
- Investigate potential upgrades to the road level crossings and other roads that may be affected by flooding as a result of the project. This is intended to reduce the impacts of flooding on track reliability as well as improve emergency access and egress on public roads during flood events.
- Investigate the potential to include additional rail lifts to make the ballast flood free for the full length of the rail corridor (i.e. meet the requirements of ETD-10-02: ARTC (2016)).
- Obtaining a broader and more reliable terrain representation upstream of the existing rail corridor to permit a more reliable definition of flow paths, catchment boundaries, connections (overflows) between adjacent catchments and other hydraulic features. This would also allow for a more accurate representation of storage effects upslope of the culverts.
- Undertake watercourse specific inspections and tailored modelling and analysis to understand better the flow interactions between catchments, tailwater influences and flooding duration.

8.2 Impact assessment

The proposal was assessed to identify specific impacts, including changes to flooding levels and extents, impacts on adjoining road and land (such as public road closures, extents of flooding and level crossing closures of the rail line).

The assessment found that:

- There are a number of locations where the proposal does not meet the flood immunity requirement. If necessary, additional analysis may be undertaken to identify design improvements to remove some or all locations where the flood immunity requirement is not met. Such design improvements may include additional structures, local drainage works, or further raising the rail formation. Potential modifications to the proposal will be considered further during the detailed design process.
- There would be some changes in local flood levels upstream of the proposal. These changes would largely be a result of the lifting of the level of the rail formation, with this, in part, being counteracted by the provision of one per cent AEP culverts under the rail formation. The impacts associated with changes to flood levels, including increased flood levels within private properties at a number of locations, would depend on land use and private infrastructure within the affected area. Additional discussions with the owners of the affected properties would be undertaken to determine the consequences of the expected impacts and, where necessary, identify mitigation measures to reduce the impacts.

- Regional flooding within the Gwydir and Mehi Rivers near Moree is not expected to be significantly impacted, largely due to the like for like replacement of the existing rail and culvert structures. As a result, changes to flood hazards within Moree, as defined by the floodplain risk management plan, are not expected to be appreciably impacted by the proposal. The regional flood modelling should be updated as part of the detailed design process to better understand the final flood impacts.
- The proposal would overtop at a limited number of level crossings where the rail formation would only be raised minimally. The modelling indicates however that these level crossings are generally subject to flooding under existing conditions.
- Some of the predicted public road closures would be observed at locations that are not immediately adjacent to the proposal. The modelling indicates however, there is not a significant increase in the number and scale of expected road closures due to flooding because of the proposal, compared to existing conditions.

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