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WATER MANAGEMENT

WARATAH COAL

Rail Corridor Cross Drainage

Galilee Coal Project SEIS Technical Report

November 2012

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www.engeny.com.au
P: 07 3221 7174 | F: 07 3236 2399
Lvl 11, 344 Queen st Brisbane QLD 4000 | PO Box 10183 Brisbane QLD 4000

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Abbreviations

AHD – Australian Height Datum

ALS – Aerial Laser Scanning

ARI – Average Recurrence Interval

BOM – Bureau of Meteorology

CMP – Corrugated Metal Pipe

DEHP – Department of Environment and Heritage Protection

DEM – Digital Elevation Model

DERM – Department of Environment and Resource Management

DNRM – Department of Natural Resources and Mines

DTMR – Department of Transport and Main Roads

EIS – Environmental Impact Statement

EPC – Exploration Permit Coal

GIS – Geographic Information Systems

IFD – Intensity Frequency Duration

MCF – Multi Cargo Facility

MGA – Map Grid of Australia

Mtpa – Million Tonnes Per Annum

MLA – Mining Lease Application

SEIS – Supplementary Environmental Impact Statement

RCBC – Rectangular Concrete Box Culvert

RL – Reduced Level

ROM – Run of Mine

1. INTRODUCTION

Waratah Coal has commissioned Engeny Water Management (Engeny) to undertake a preliminary assessment of the cross drainage requirements associated with the Galilee Coal Project railway. This report provides conceptual level assessment to support the submission of the SEIS and address stakeholder concerns raised during the EIS public consultation process. It builds on the previous baseline flood assessment undertaken as part of the EIS (Engeny, 2011).

1.1 Background

Waratah Coal proposes to mine 1.4 billion tonnes of raw coal from existing tenements (EPC 1040 and EPC1079) approximately 30 km north of Alpha within the Galilee Basin. The annual ROM coal production will be 56 Mtpa to produce 40 Mtpa of saleable export steaming coal to international markets.

The processed coal will be transported by a new standard gauge railway system approximately 453 km in length that runs from the project site to the existing Port of Abbot Point. The railway will initially be built to transport 60 Mtpa, and will ultimately cater for a capacity of 400 Mtpa. The main components of the railway include:

- A rail balloon loop for train loading at the mine;
- Two road over rail bridge crossings of the Gregory Development Road and Bowen Development Road;
- A rail corridor with an average easement width of approximately 50 m and inclusion of a service road[1];
- Progressively up to 16 passing loops and then full duplication with additional holding roads to facilitate the number of proposed train movements at maximum capacity;
- A rolling stock yard for maintenance, storage, refuelling and marshalling;
- Communication and signalling infrastructure;
- Construction phase infrastructure including construction camps, lay down areas and quarries along the alignment.

The proposed rail alignment is provided within Appendix A. Option 3 as detailed in Appendix A is the current railway alignment. Options 1 and 2 are also provided on this Figure to show possible changes.

[1] The final railway easement will have an average width of 50 m calculated by dividing the total of the rail corridor (2215 ha) by the length of the rail (453 km).

Until recently there was a commitment to utilise coal terminal, stockpile and loading facilities being assessed by the North Queensland Bulk Ports as part of the their T4-T9 and MCF proposals. However, given the recent Queensland Government directive to defer the approvals process for the expansion of Abbot Point until the end of 2012, and the associated uncertainty over the T4-T9 and MCF proposal, the limit of the assessment for this project is currently defined as the western boundary of the Abbot Point State Development Area.

1.2 Scope of Works

This report has been prepared to assess the impacts of the railway on existing flooding and drainage regimes. The study has been undertaken to address government and specific stakeholder concerns raised during the EIS public consultation. The following scope of works has been adopted to address these concerns:

- Develop design criteria to assist in the design of all cross drainage structures to minimise impacts to flow regimes and existing landholders;
- Provide input into the preliminary design of all major cross drainage structures based on the existing 100 year ARI flood levels determined as part of the EIS (Engeny, 2011);
- Assess the performance of major waterway crossing designs using two-dimensional hydraulic modelling and the flood flows determined as part of the EIS (Engeny, 2011);
- Utilise the base case 100 year ARI flood results (Engeny, 2011) to quantify impacts (afflux and velocity) associated with all major waterway crossings;
- Identify additional locations for minor culverts along the entire alignment of the railway and estimate design flow rates reporting to culvert locations;
- Utilise design flow rates for minor culverts to determine a preliminary opening sizing required to convey the 100 year ARI flood event.

1.3 Study Area

The proposed rail alignment runs from the proposed mine, near the township of Alpha in a north-easterly direction to the Abbot Point State Development Area and the Port of Abbot Point with a total rail length of 453 km from the beginning of the rail loop at the mine to the state development area boundary. The rail alignment intersects two major drainage basins, namely the Burdekin River and Don River Basins, and crosses 10 major waterways. The catchment areas contributing to these major waterway crossings are discussed below. Maps detailing the proposed alignment are provided in Appendix A.

1.3.1 Sandy Creek and Belyando River

The catchments for these systems cover a combined area of some 15,046 km² and are located in the north-east of the Barcaldine Regional Council and the south-western tip of Isaac Regional Council, Queensland.

Both Sandy Creek and the adjacent Native Companion Creek flow in a northerly direction and eventually merge with the Belyando River downstream of the proposed railway alignment.

1.3.2 Lascelles Creek and Mistake Creek

The contributing catchments for Lascelles and Mistake Creek cover an area of some 469 km² and 4,855 km² respectively, and are located in the central to south-eastern regions of the Isaac Regional Council.

The overall catchment is located in the Burdekin River basin and is transected by the Gregory Developmental Road in the upper regions of the Mistake Creek catchment and Clermont Alpha Road. Lascelles Creek is a tributary of Mistake Creek, which eventually joins the Belyando River some 65km downstream of the proposed rail alignment crossing.

1.3.3 Suttor River

There are two crossings of the Suttor River along the proposed rail alignment, one in the far upper reaches of the catchment and one further downstream, some 35 km before the confluence with the Belyando River. Contributing areas to these two crossings cover an area of 252 km² and 10,330 km² respectively and the overall catchment lies in both the Isaac Regional Council and Whitsunday Regional Council Local Government areas.

The Suttor River catchment is located within the Burdekin River basin and is transected by the Bowen Developmental Road and Suttor Developmental Road in the north, and Peak Downs Highway and the Wotonga Blair Athol Mine Branch Railway in the far south eastern extents of the catchment.

1.3.4 Bowen River and Pelican Creek

The proposed rail alignment crosses both the Bowen River and Pelican Creek waterways. The contributing Bowen River and Pelican Creek catchments cover an area of some 6,583 km² and 528 km² respectively. The Bowen River and Pelican Creek catchments lie in the Mackay Regional Council, Whitsunday Regional Council and Isaac Regional Council Local Government areas.

Both the Bowen River and Pelican Creek catchments are located within the Burdekin River basin. Both catchments are transected by the Bowen Developmental Road and the Goonyella to Abbot Point Railway. The township of Collinsville is located within the mid reaches of the Pelican Creek catchment.

1.3.5 Bogie River and Sandy Creek

Both the Bogie River and Sandy Creek are crossed by the proposed rail alignment and have contributing catchment areas of 455 km² and 140 km² respectively. Both catchments lie within the Whitsunday Regional Council Local Government area.

The Bogie River and Sandy Creek catchments are the most northern catchments within the study area located within the Burdekin River basin. The Bogie Creek catchment is transected by the Bowen Developmental Road as well as the Goonyella to Abbot Point Railway. There are no major population centres in either contributing catchment areas.

1.3.6 Elliot River

The rail alignment crosses the Elliot River which has a contributing catchment area of approximately 147 km². The Elliott River catchment lies within the Whitsunday Regional Council Local Government area. The Elliott River is located within the Don River basin and there are no major population centres in the contributing catchment area.

2. METHODOLOGY

2.1 Cross Drainage Classification

In order to minimise environmental impacts of the railway a variety of cross drainage structures have been utilised. These different structures have been matched to the crossing type which is generally dictated by catchment area, geomorphic characteristics, surrounding land use, velocity and stream flow.

2.1.1 Bridge Crossings

Where practical, bridge crossings have been provided at all major waterways to prevent realignment of active channels and maintain existing features such as pool and riffle sequences. Bridges will have little to no impediment to flow especially under low flow conditions, allowing maintenance of geomorphic processes and environmental flows. The use of bridges will also allow for terrestrial and aquatic fauna habitat connectivity.

Preliminary design of bridges has been undertaken with a bridge soffit level located a minimum 500 mm above the 100 year ARI flood level. Preliminary design drawings of these bridges are provided in Appendix B. Further consideration for pier and abutment scour protection and bridge flood loading will be undertaken as part of the detailed design process. Preliminary bridge design in most cases has been undertaken using a standard 2.20 m thick girder at a 25 m span combined with a 1.0 m diameter pile and 1.2 m wide headstock.

2.1.2 Major Culverts

Major culverts will be provided where the construction of bridges is not feasible or there is insufficient depth of flow for the use of a bridge. Major culverts will be provided in groups (if required) with similar barrel dimensions and will typically be used to traverse active channels of waterways to maintain flow connectivity and fauna passage. Culverts will be skewed if required to maintain flow connectivity and limit erosion potential. Culverts will be constructed generally using circular steel pipes (CMP) or where there is insufficient cover slab link box culverts will be utilised. All major culverts are proposed to be a minimum opening of 1200 mm diameter (1200x1200 mm RCBC) to facilitate terrestrial fauna passage during dry periods and minimise the potential for blockage. Outlet scour protection will be provided on all culverts with the exact configuration to be determined based on outlet velocities, during the detailed design phase.

2.1.3 Minor Culverts

Minor culverts will be provided to maintain flow connectivity within all minor watercourses along the alignment. Minor culverts will be typically used to convey the 100 year ARI flood flow from catchments less than 25 km² in area. All minor culverts will be provided with outlet scour protection and will be a minimum opening of 1200 mm diameter (1200x1200 mm RCBC) for fauna passage and minimise potential for blockage.

2.1.4 Floodplain Relief Culverts

The nature of floodplains is that flood water is not concentrated in one main channel at high depth, but rather water spreads out slowly over a wide area at shallow depth once the main channel banks have been breached. It is therefore proposed that in the major flood plains single barrel culverts with a minimum diameter of 1200 mm will be nominally provided at approximately 100 m centres or closer.

Each relief culvert will be provided with outlet protection to prevent scour and aid the lateral spread of flow from the culvert outlet. The culverts will be located in depressions where water will likely pond against the railway embankment. It is also proposed to keep vegetation disturbance downstream of the railway alignment to an absolute minimum to restore natural flow paths as quickly as possible. Minor earthworks to direct flows to these culverts will be undertaken where required.

2.1.5 Environmental Culverts

Additional environmental culverts will be provided in locations where there is no clearly defined flow path. The purpose of these small culverts will be to maintain existing overland flow conditions and fauna passage. It is proposed that environmental culverts will be a minimum of 600 mm diameter for small terrestrial fauna passage (DTMR, 2010). The exact locations and spacing of environmental culverts will be determined during the detailed design phase of the project.

2.2 Hydraulic Structure Design Criteria

Cross drainage design criteria has been developed to ensure that the railway will have appropriate immunity against flood inundation and that the impacts of the railway on waterway functionality, fauna passage and the community will be minimised. The railway is proposed to have an immunity equivalent to the 100 year ARI flood level with additional provision for freeboard. Table 2.1 presents the assessment criteria used to assess the performance of the proposed cross drainage structures.

Table 2.1 Environmental Assessment Criteria

Assessment Criteria	Land Use			
	Pasture/Grazing/Cropping	Existing Infrastructure (Dwellings, Roads etc.)	Environmentally Sensitive Areas	No Defined Use
Design Event Afflux	Ensure afflux is typically no greater than 0.5m. Landholders to be consulted to seek agreement.	Ensure that any afflux is limited to areas that will not adversely impact existing infrastructure	Subject to site specific environmental conditions.	Ensure that afflux will not result in possible impacts to the hydrological regime of an existing system such as inducing breakouts into adjacent systems upstream.
	Ensure that afflux does not encroach on a property that was not previously identified as flood prone prior to the construction of railway.	Where the 100 year ARI flood currently enters properties the crossings design must fully consider the impacts of any afflux generated and design accordingly.	Ensure increase of inundation duration will not result in adverse impacts to existing vegetation.	Ensure that afflux does not encroach on a property that was not previously identified as flood prone prior to the construction of railway.
	Ensure increase in inundation depth or duration will not result in impacts to existing farming activities.			
Flow Connectivity	Ensure flow connectivity is maintained to existing farm water storages located downstream of the rail formation.	Flow connectivity to mimic natural conditions as much as possible to prevent the redirection of water to existing infrastructure.	Where practicable the bed of the culvert reproduce the natural conditions of the watercourse bed, and ideally be recessed below natural bed levels.	Where practicable the bed of the culvert reproduce the natural conditions of the watercourse bed, and ideally be recessed below natural bed levels.
			Where possible provide small diameter environmental culverts to prevent 'water shadow'.	Where practicable provide floodplain relief culverts at nominal spacing to mimic the natural floodplain and maintain connectivity of braided channels.
			Where practicable provide floodplain relief culverts at nominal spacing to mimic the natural floodplain and maintain connectivity of braided channels.	

Assessment Criteria	Land Use			
	Pasture/Grazing/Cropping	Existing Infrastructure (Dwellings, Roads etc.)	Environmentally Sensitive Areas	No Defined Use
Fauna Passage and Land Access	Large box culverts to be provided for passage of cattle and vehicles beneath railway formation. Requirements to be determined in conjunction with land holders.	Large box culverts or arches to be provided for passage of vehicles beneath railway formation. Requirements to be determined in conjunction with land holders.	Culverts located within the main channel of rivers and creeks should be depressed below the natural surface to prevent the need for fish to jump an obstruction.	Culverts located within the main channel of rivers and creeks should be depressed below the natural surface to prevent the need for fish to jump an obstruction.
			A minimum pipe diameter of 1200mm to be adopted to allow for fauna passage. Internal ledges within nominated culverts to be provided to allow for dry passage during low flow conditions.	A minimum pipe diameter of 1200mm to be adopted to allow for fauna passage. Internal ledges within nominated culverts to be provided to allow for dry passage during low flow conditions.
Flow Velocity	Maximum culvert outlet velocities based on site specific conditions: • 1.5 m/s for erodible of soils (sand, silty clay or loam); • 2.5 m/s for stiff clay or vegetated cover; • 4.5 m/s maximum velocity with appropriately sized scour protection; • 6 m/s maximum barrel velocity.	Maximum culvert outlet velocities based on site specific conditions: • 1.5 m/s for erodible of soils (sand,, silty clay or loam); • 2.5 m/s for stiff clay or vegetated cover; • 4.5 m/s maximum velocity with appropriately sized scour protection; • 6 m/s maximum barrel velocity.	Velocities to be limited based on site specific soil characteristics to prevent sediment mobilisation and changes to existing geomorphic condition. Alternative energy dissipation structures to be provided where velocities may impact existing vegetation.	Velocities to be limited based on site specific soil characteristics to prevent sediment mobilisation and changes to existing geomorphic condition. Alternative energy dissipation structures to be provided where velocities may impact existing vegetation.
	Maximum velocities at bridges not to exceed existing velocity by more than 20%	Maximum velocities at bridges not to exceed existing velocity by more than 20%		

2.3 Relevant Legislation and Guidelines

2.3.1 Water Act 2000

The *Water Act 2000* is the primary statutory document that establishes a system for planning, allocating and use of water within Queensland. The Act is administered by DNRM and specifies requirements for works impacting the bed or banks of a watercourse. Consequently the proposed cross drainage structures within watercourses (as defined by the Act) may require licensing through the application of a Riverine Protection Permit prior to construction to authorise excavation and filling within a watercourse.

2.3.2 Sustainable Planning Act 2009

The *Sustainable Planning Act 2009* seeks to achieve sustainable planning outcomes through managing the process by which development takes place, managing the effects of development on the environment and continuing the coordination and integration of local, regional and state planning. Construction of the railway may require a planning approval for operational works or easement acquisition.

2.3.3 Fisheries Act 1994

The purpose of *Fisheries Act 1994* is to provide for the conservation of fisheries resources and fish habitats through ecologically sustainable development. The Act provides for the appropriate powers to control impacts of development on fisheries. Under Section 76G of the Act will require application to the chief executive for waterway barrier works.

2.3.4 Environmental Protection Act 1994

The *Environmental Protection Act 1994*, administered by DEHP is the overarching legislation defining the identification of environmental values through the Environmental Protection (Water) Act 2009. The proposed cross drainage structures have been designed and will be operated to minimise environmental impact downstream to maintain existing environmental values.

2.3.5 TMR Road Drainage Design Manual

The Queensland Department of Transport and Main Roads Road Drainage Design Manual provides guidance in the planning, design, operation and maintenance of road drainage infrastructure in all urban and rural environments. Although the manual is focussed on drainage associated with roads the principles of cross drainage design and construction are considered relevant for railway crossings of waterways. The manual has been used to determine design criteria associated with cross drainage structures.

2.3.6 Afflux Design Guidelines

There are currently no standards or guidelines to determine acceptable afflux values. The majority of the existing Queensland Rail track network (including QR National) was built unknown flood immunity and afflux criteria. It has only been since more detailed flooding modelling has become available as an engineering tool (early 1990's) that more definitive values have been used for estimating flood impacts.

The current best practice used by the existing railway infrastructure owners in Queensland is for an afflux not to exceed 500 mm for new design. It is arguable that the majority of existing rail infrastructure in Queensland, due to the historic development, generates an afflux of greater than 500 mm even during moderate flooding events. It should be also noted that DTMR do not have specified afflux criteria, with waterway crossings assessed individually based on economic implications and surrounding land use.

2.4 Previous Reports

This report has been prepared utilising data or results provided in the following previous reports which were prepared as part of the EIS or feasibility studies for the project:

- Waratah Coal Abbot Point Railway Corridor – Preliminary Flooding Investigation (Worley Parsons, 2009) – was undertaken to ascertain approximate flood extents for a large corridor (50-100 km wide) between Alpha and the Abbot Point terminal. The results of this investigation have been used by Waratah Coal to identify the preferred horizontal rail alignment;

- Heavy Haul Rail Corridor Flood Study (Engeny, 2011) – This report was prepared to support the EIS phase of the project. It identified locations along the preferred horizontal alignment where major crossings of watercourses would be required. Hydrological modelling was used to determine design flow rates for use within hydraulic modelling. These hydraulic models were used to estimate the existing 100 year ARI flood level and flooding characteristics at each of the crossing locations. This information was used to assist in development of the preliminary vertical alignment of the railway.

2.5 Project Data

2.5.1 Topographic Data

A 2 m DEM was developed from ALS survey undertaken by Fugro Spatial Solutions in 2010 with a 250 mm vertical accuracy data for a 1.6 km wide corridor along the proposed rail alignment. This DEM has been utilised to define the topography within the hydraulic modelling area.

Topographic data used for the development of the hydrologic models (including catchment and sub catchment delineation) was a 25 m resolution DEM supplied by DEHP. This data was deemed to be of adequate accuracy for hydrology assessment purposes.

2.5.2 Stream Gauging Data

A review of the DNRM's stream flow gauging database indicated a number of stream flow gauging stations on major watercourses along the rail alignment. This data was obtained for the purposes of flood frequency analysis and hydrologic model validation. Data was obtained from DNRM for the full years of gauge operation for the following stations:

- Native Companion Creek at Violet Grove – 120305A;
- Suttor River at Eaglefield – 102304A;
- Mistake Creek at Charlton – 120306A.

2.5.3 Aerial Imagery

Aerial imagery of the rail corridor was acquired by Fugro Spatial Solutions in 2010. This imagery was used to determine surface roughness throughout the study areas within the hydraulic model as well as in the presentation of flood mapping. Additional satellite aerial imagery (Bing Aerial) was also used to interrogate areas of interest outside the rail corridor.

2.5.4 Land Use Mapping

Land use data for the study area has been based on review of the Geoscience Australia native vegetation mapping dataset and aerial imagery. These datasets were used as the basis for development of catchment parameters as part of the hydrologic and hydraulic modelling works.

3. CATCHMENT HYDROLOGY

3.1 Hydrologic Modelling

Hydrologic modelling was undertaken for the major watercourses using the XP-RAFTS software package. Flood hydrographs have been determined for the 100 year ARI flood event using a range of storm durations to estimate the relevant design event peak flow rates at the crossing locations.

The model estimates design hydrographs from an individual sub-catchment based on rainfall intensities, losses and temporal patterns, and the definition of a series of parameters that describe the sub-catchment characteristics. These parameters include the sub-catchment area, slope, roughness and fraction of impervious area which have been defined using the Burdekin River 25 m DEM and aerial photography.

Sub-catchment outflow hydrographs are routed downstream through the model via links. Routing links perform Muskingum-type channel routing calculations and require cross section dimensions, slope and the length of the channel. These cross section dimensions and slope have been taken from the Burdekin River basin 25 m DEM.

Model input data, parameters and all assumptions for the hydrologic models created for this study are detailed below.

3.1.1 Design Rainfall

Design rainfall estimates for the 100 year ARI design storm event were derived based upon the procedures outlined in Australian Rainfall and Runoff (IEAust, 2001). Areal reduction factors have been applied to these design rainfall estimates in accordance with Australian Rainfall and Runoff due to the large contributing catchment area. Temporal patterns for all ARIs were sourced from Australian Rainfall and Runoff (IEAust, 2001).

3.1.2 Hydrologic Model Summary

A total of eight individual hydrological models, some with multiple water systems have been used to estimate design flow rates at the major waterway crossings. Catchment size and model descriptions for each of the models developed for this study are summarised in Table 3.1.

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Table 3.1 Hydrologic Model Summary

Model ID	Total Catchment Area (km²)	No of Sub-Catchments	Contributing Watercourses
Belyando River S1	6,062	17	Sixteen Mile Creek, Lascelles Creek, Mistake Creek and Miclere Creek
Belyando River S2	14,980	39	Belyando River, Sandy Creek, Lagoon Creek, Native Companion Creek, Bottle Tree Creek, Pebbly Creek and May Creek
Suttor River	10,330	33	Suttor River, Brown Creek, Logan Creek, Diamond Creek, Eaglefield Creek, Suttor Creek and Verbena Creek
Elliott River	147	5	Elliot River, Butchers Creek and Stockyard Creek
Bogie River North	440	11	Bogie River and Terry Creek
Bogie River South	140	7	Sandy Creek
Pelican Creek	612	15	Strathmore Creek, Pelican Creek, Tea Tree Creek, Oakey Creek, Two Mile Creek and Coral Creek
Bowen River	6,562	29	Bowen River, Broken River, Parrot Creek, Rosella Creek, Hazelwood Creek, Eastern Creek and Kangaroo Creek

Design loss parameters for the XP-RAFTS model were based on values described in Australian Rainfall and Runoff (IE Aust, 2011). These losses have then been adjusted accordingly to match the validation results described in the following Sections. The model storage coefficient (β_x) has been used to adjust the model to achieve a suitable fit for validation. These adopted parameters for the modelling are summarised in Table 3.2.

Table 3.2 Hydrologic Model Parameters

Model ID	β_x Value	Initial Loss (mm)	Continuing Loss (mm/hr)
Belyando River_S1	1.4	30	2.5
Belyando River_S2	1.2	25	2.5
Suttor River	0.9	0	1.0
Elliott River	1.0	0	1.0
Bogie River	1.0	0	1.2
Sandy Creek – Bogie System	1.0	0	1.0
Pelican Creek	1.0	0	1.5
Bowen River	1.0	0	1.0

3.2 Hydrologic Model Validation

Due to the large catchments contributing to the rail corridor study area the hydrologic models have been validated against a number of stream flow gauging stations operated by DNRM. The models have been validated using a flood frequency analysis based on five stream flow gauging stations within the study area. The annual peak flows were provided by DNRM and the Log Pearson Type 3 (LPIII) distribution was fitted to the data as per Book 4 of Australian Rainfall and Runoff. The peak 100 year ARI flow rates for each stream gauge (LPIII) are provided in Table 3.3 along with the modelled peak flows from the XP-RAFTS hydrologic models.

Table 3.3 LPIII Flood Frequency Summary for Available Gauging Stations

Gauge No.	Gauge Name	No. of Years of Record	LPIII Estimated 100 Year ARI Peak Discharge (m^3/sec)	Modelled 100 year ARI Peak Flow (m^3/s)
120305A	Native Companion Creek at Violet Grove	44	2,325	2,277
120306A	Mistake Creek at Charlton	25[1]	715	805
120304A	Suttor River at Eaglefield	44	2,425	2,490
120005B	Bogie River at Strathbogie	28[1]	5,000[2]	2,232
120205A	Bowen River at Myuna	51	18,000[2]	18,501

1. Closed station.
2. Flood frequency results from Worley Parsons flood frequency analysis (Worley Parsons, 2009)

It should be noted that the stream gauging station at Strathbogie (12005B) is located a significant distance downstream from the outlet of the hydrologic model, hence the disparity between the flood frequency results and modelled results. The hydrologic model has therefore been validated by scaling of the flood frequency peak flow rates based on catchment area using the following equation:

$$Q_u = \left(\frac{A_u}{A_g}\right)^b Q_g$$

Where Qu is the estimated peak flow for the ungauged catchment, Au is the area for the ungauged portion of the catchment (440 km²), Ag is the catchment area for the stream gauging station (1,031 km²) and Qg is the peak flow for the gauging station determined from the flood frequency analysis. The exponent b (0.644) has been determined from the regional flood frequency regression analysis undertaken by the Queensland Department of Transport and Main Roads (Palmen & Weeks, 2009). The scaled down peak flow rate of 2889 m³s yields a much closer match with the XP-RAFTS modelled value of 2,232 m³/s.

As there are no stream flow gauging stations on the Elliot River the flood frequency results for both stream flow gauging stations at Strathbogie (12005B) and Myuna (120205A) were scaled down to assist in validating the Elliot River peak flow estimates.

Although both stations are located in different catchments the characteristics and climate are similar. The results of this analysis yielded 100 year ARI peak flow estimates of 1,481 m³s and 1,426 m³s for the Myuna and Strathbogie gauges respectively. These results are consistent with the 100 year ARI hydrologic model estimate of 1,918 m³s.

3.3 XP-RAFTS Results

Table 3.4 below summarises the hydrologic model peak flow rates at the major waterway crossings. The critical duration for all inflows varies between 12 hours and 72 hours.

Table 3.4 100 year ARI Peak Flow Summary – Major Waterway Crossings

Major Waterway Crossing	100 year ARI Peak Flow (m^3/s)
Mistake Creek	1,329
Lascelles Creek	158
Sandy Creek	925
Belyando River	6,528
Upper Suttor River	530
Lower Suttor River	9,835
Elliot River	1,918
Bogie River	2,232
Sandy Creek	742
Pelican Creek	2,780
Bowen River	18,501

3.4 Minor Culvert Hydrology

A total of 292 additional minor crossing locations have been identified along the rail corridor. Design flow rates contributing to these locations have been estimated using the DTMR regional flood estimation method for Queensland (Palmen & Weeks, 2009). Using this analysis the 50 year and 100 year ARI flow rates have been estimated based on contributing catchment area and site specific design rainfall data for each location.

These flow rates have been used to estimate the opening area required within the rail formation to convey the 100 year ARI event using a Queensland Rail (and QR National) preliminary sizing method (Area = Q_{50}/2.1). Hydraulic modelling to determine crossing configuration, flood afflux and outlet velocity will be undertaken during the detailed design phase of the project. A summary of the minor culvert design flows and opening areas is provided in Appendix D.

4. HYDRAULIC MODEL DEVELOPMENT

4.1 Modelling Software

Estimation of flood behaviour at each of the major crossings has been carried out using the TUFLOW software package. TUFLOW is an industry standard software package that is highly suited to the investigation of flood behaviour in complex flow scenarios. The software can simulate unsteady hydrodynamic flow in two directions on a rectilinear grid as well as one dimensional unsteady hydrodynamic flow through waterway structures such as culverts and bridges. The model is based on a robust finite difference solution scheme able to compute both subcritical and supercritical flow regimes.

4.2 Hydraulic Model Construction and Parameters

The TUFLOW models constructed for each of the major waterway crossing locations consists of a number of modelling inputs and parameters, all of which affect the accuracy of the model outputs. Model inputs and parameters used in this study are detailed in the following sections.

4.2.1 Two Dimensional Topographic Grid

The 2D model topography was created using the discrete 2 m DEM's constructed from the ALS data for the rail corridor. Through review of initial modelling results, simulation times and the required level of modelling detail, it was determined that a grid size of 5 m was appropriate for all of the hydraulic models. The 2D hydraulic models are based on a horizontal datum of Map Grid of Australia 1994 (MGA94) Zone 55 and use Australian Height Datum (AHD) for elevation. It should be noted that the extent of the modelling areas is limited to the 1.6 km wide rail corridor. Therefore in a number of cases the upstream extent of flood afflux caused by the railway has not been determined.

4.2.2 One Dimensional Hydraulic Structures

Drainage structures such as culverts have been modelled in a 1D environment in TUFLOW to allow for increased accuracy in representation of the structure characteristics such as outlet velocity and afflux. The proposed rail embankment will impact on existing flooding behaviour and as such one dimensional model elements have been included within the post rail hydraulic models. Details of the proposed one dimensional hydraulic structure requirements for each major waterway crossing are outlined within Section 5.

4.2.3 Two Dimensional Hydraulic Structures

Proposed bridge structures within the post rail hydraulic models have been modelled using TUFLOW's layered flow constriction capability. Layered flow constrictions allow spatially varying blockage and form loss attributes to be applied to the structure (i.e. under obvert, bridge deck, above deck). Details of proposed bridges included within the post rail hydraulic models are outlined within Section 5.

4.2.4 Model Boundary Conditions

All the waterway systems modelled as part of this investigation are classified as non-perennial (except for Bowen River) with no significant standing water at the model outlets, and hence a normal depth boundary condition was adopted for the TUFLOW models. Due to the flat nature of the topography at most of the crossing locations and modelling areas, adopted boundary slopes generally ranged from 0.001 m/m to 0.01 m/m in the steeper coastal systems.

Inflow hydrographs for each of the TUFLOW models were derived from the hydrologic models created for each contributing catchment area for the 100 year ARI design flood event. These hydrographs were then directly applied to the representative TUFLOW 2D model domains for each major water system.

4.2.5 2D Model Roughness

Definition of the various floodplain roughness characteristics was undertaken using a combination of aerial imagery, site notes and photographic record. The Manning's 'n' roughness parameters adopted in the model ranged from 0.015 for water bodies through to 0.3 for immovable constructed objects. Table 4.1 summarises the Mannings 'n' roughness parameters assigned to each land use type identified in the study areas.

Table 4.1 Adopted Roughness Parameters

Land Use Description	Manning's 'n' Roughness
Water Body	0.015
Road Carriageway	0.025
Cleared Land/Agriculture	0.040
Generally Cleared Land/Light Vegetation	0.050
Medium Density Vegetation	0.065
High Density Vegetation/Bushland	0.080
Thick Bushland/Riparian Vegetation	0.100
Buildings/Homestead (area of no flow)	0.300

5. HYDRAULIC MODELLING RESULTS

Hydraulic modelling for the 100 year ARI event has been undertaken for existing conditions (Engeny, 2011) and with the rail formation and inclusion of preliminary hydraulic structures. This has been used to assess the rail immunity, changes to flood behaviour and performance against the specified environmental assessment criteria outlined in Section 2.2. The following sections provide summary of the hydraulic modelling results. Details of the preliminary bridge designs are provided in Appendix B while flood impact mapping for the 100 year ARI event is provided in Appendix C.

5.1 Elliot River

5.1.1 Existing Case Results

The proposed crossing over the Elliott River is approximately 22 km from its outlet to Abbot Bay. The Elliot River is characterised by a well-defined channel with steep banks. The main channel is heavily vegetated while the overbank areas are only moderately vegetated with a moderate tree cover.

The results for the 100 year ARI event predict depths in excess of 4m in the Elliot River and depths between 2 and 4 m in the side tributary to the west of Elliot River. The predicted peak velocities within the Elliot River are in excess of 2 m/s, while 0.4 to 0.8 m/s are experienced in the overbank areas. The tributary to the west of Elliot River experiences velocities in the main channel between 0.4 and 1.2 m/s along the proposed rail alignment.

5.1.2 Post Rail Results

To ensure the existing flood conveyance is maintained for the Elliott River crossing a bridge design has been included within the hydraulic model. Table 5.1 presents details of the proposed bridge design included within the Elliot River hydraulic model.

Table 5.1 Elliott River Bridge Design Summary

Major Crossing Location	Span Distance (m)	No. of Spans	Pier Diameter (m)	No. of Piers	Soffit Level (mAHD)	Deck Thickness (m)	Deck Width (m)
Elliott River	25	17	1.0	16	39.54	2.95	10.675

Results of the post rail hydraulic modelling indicate that the existing flooding conditions are not significantly affected as a result of the inclusion of the rail formation and bridge design. Compliance with the environmental assessment criteria has been achieved at the Elliott River crossing with the proposed bridge design (Table 5.2).

Table 5.2 Elliot River Compliance Assessment

Watercourse Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Elliott River	Compliant	Compliant	Compliant

5.2 Bogie River and Sandy Creek

5.2.1 Existing Case Results

The rail alignment bisects Bogie River in the north and runs along the meander of Sandy Creek to the south. The crossing over Bogie River is some 70 km upstream from the confluence with the Burdekin River. The surrounding topography is steep with a deep, well defined channel. The Bogie River has medium to dense vegetation within the channel and overbanks. The main channel of Sandy Creek is heavily vegetated with some overbank areas shown to be relatively clear and used for grazing.

The results for the 100 year ARI event predict depths in excess of 6 m in Bogie River and 8 m in Sandy Creek. The predicted peak velocity within the Bogie River is in excess of 2.5 m/s, while the peak velocities in Sandy Creek are approximately 2.2 m/s.

5.2.2 Post Rail Results

To ensure the existing flood conveyance and connectivity is maintained within the Bogie River and Sandy Creek, three bridge designs have been undertaken and input into the hydraulic model. One bridge has been designed to cross the Bogie River and the other bridges cross Sandy Creek. Table 5.3 presents details of the proposed bridge designs.

Table 5.3 Bogie River and Sandy Creek Bridge Design Summary

Major Crossing Location	Span Distance (m)	No. of Spans	Pier Diameter (m)	No. of Piers	Soffit Level (mAHD)	Deck Thickness (m)	Deck Width (m)
Bogie River	25	16	1	15	141.860	2.95	10.675
Sandy Creek	25	6	1	5	144.492	2.95	10.675
Sandy Creek	25	12	1	11	144.492	2.95	10.675

Results of the post rail hydraulic model indicate that the existing flooding conditions are not affected as a result of the inclusion of the rail formation and bridge designs. Table 5.4 presents the compliance with the environmental assessment criteria.

Table 5.4 Bogie River and Sandy Creek Compliance Assessment

Creek Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Bogie River	Compliant	Compliant	Compliant
Sandy Creek	Compliant	Compliant	Compliant

5.3 Pelican Creek and Strathmore Creek

5.3.1 Existing Case Results

The proposed crossing over Pelican Creek is approximately 15 km south west of Collinsville township and is some 17 km upstream from the confluence with the Bowen River. An existing mine site is located approximately 1 km to the east of the proposed alignment. Several tributaries to the north of Pelican Creek including Strathmore Creek have also been modelled in this study.

Pelican Creek is characterised by a well-defined channel while the tributaries to the north are less defined and results predict more expansive floodplain inundation in these areas. The main channel of Pelican Creek is heavily vegetated while the cleared northern overbank areas are used for grazing. The tributaries of Strathmore Creek have less defined waterways and the overbank areas have sporadic medium density vegetation with some areas of bare earth.

Model results predict inundation depths of approximately 10.5 m for the 100 year ARI event. Peak depths in the floodplain areas to the north (unnamed creek) are predicted to be 0.4 to 0.8 m deep with the main channel experiencing depths greater than 4 m in the 100 year ARI event. The predicted peak velocities across Pelican Creek range up to 2.5 m/s in the 100 year ARI event, whilst lower velocities of between 0.4 to 0.8 m/s are predicted in the floodplain areas to the north around the unnamed creeks during the 100 year ARI event.

5.3.2 Post Rail Results

The railway is proposed to utilise two bridges and a series of major and floodplain relief culverts. One bridge has been designed to cross Pelican Creek and the other bridge crosses Strathmore Creek. Table 5.5 presents details of the proposed bridge designs. Major culvert and floodplain relief culverts are required at each of the unnamed creek crossings and details are included in Table 5.6.

Table 5.5 Pelican Creek and Strathmore Creek Bridge Design Summary

Major Crossing Location	Span Distance (m)	No. of Spans	Pier Diameter (m)	No. of Piers	Soffit Level (mAHD)	Deck Thickness (m)	Deck Width (m)
Pelican Creek	25	8	1	7	126.436	2.95	10.675
Strathmore Creek	25	3	1	2	124.319	2.95	10.675

Table 5.6 Pelican Creek and Strathmore Creek Major Culvert Schedule

Major Crossing Location	Major Culverts	Floodplain Relief Culverts
Pelican Creek		6x1200 CMP @ 100m Centres
Unnamed Creek 1	2x2700 CMP	7x120 CMP @ 100m Centres
Strathmore Creek		90x1200 CMP @ 100m Centres
Unnamed Creek 2	4x3000 CMP	15x1200 CMP @ Centres

Results of the post rail hydraulic model indicate that the existing flooding conditions are not significantly affected as a result of the inclusion of the rail formation and bridge/culvert designs. There are a number of isolated locations with flood afflux greater than 0.5 m with the largest impact only propagating 150 m upstream. These locations are associated with the major culvert crossings of the two unnamed creeks. It should be noted that the locations where significant afflux is estimated there is unlikely to be impacts to existing properties as there is no infrastructure or farming activities occurring in these areas. Compliance with environmental assessment criteria has been achieved for the Pelican Creek system crossings with the results summarised in Table 5.7.

Table 5.7 Pelican Creek and Strathmore Creek Compliance Assessment

Creek Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Pelican Creek	Compliant	Compliant	Compliant
Strathmore Creek	Non-Compliant[1]	Compliant	Compliant
Unnamed Creek 1	Non-Compliant[1]	Compliant	Compliant
Unnamed Creek 2	Compliant[1]	Compliant	Compliant

1. Approximately 600 mm peak afflux for limited duration around culvert entrances only propagating upstream a maximum of 100m during the 100 year ARI event.

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5.4 Bowen River and Parrot Creek

5.4.1 Existing Case Results

For the Bowen River hydraulic analysis, the proposed rail alignment was assessed at three locations, Parrot Creek to the south, the Bowen River and a small tributary of the Bowen River to the north. The crossing at the Bowen River is situated approximately 67 km upstream from the confluence with the Burdekin River. The Bowen River and its banks are densely vegetated while the floodplain to the south is used for grazing and has sporadic moderate density vegetation with some areas of bare earth.

The results for the 100 year ARI event predict depths in excess of 20 m in the main channel of the Bowen River for the 100 year ARI event. Parrot Creek was also shown to have significant flood depths of approximately 9.5 m during the 100 year ARI event.

The predicted peak velocities within the main Bowen River waterway are predicted to be over 4 m/s during the 100 year ARI event. Parrot Creek was predicted to have peak velocities in the order of 3 m/s for the 100 year ARI event.

5.4.2 Post Rail Results

To ensure the existing flood conveyance is maintained for the Bowen River, Parrot Creek and unnamed creek crossings, two bridge designs and a series of major and floodplain relief culverts have been modelled. Two bridges have been designed to cross the Bowen River and the other bridge crosses Parrot Creek. Table 5.8 and Table 5.9 present the details of the proposed bridge designs and culvert requirements for the rail crossing respectively.

Table 5.8 Bowen River and Parrot Creek Bridge Design Summary

Major Crossing Location	Span Distance (m)	No. of Spans	Pier Diameter (m)	No. of Piers	Soffit Level (m AHD)	Deck Thickness (m)	Deck Width (m)
Bowen River	25[1]	25	1	24	122.129	2.95	10.675
Bowen River	25	8	1	7	121.433	2.95	10.675
Parrot Creek	25	6	1	5	147.497	2.95	10.675

1. One 40 span located across the main channel.

Table 5.9 Bowen River and Unnamed Creek Major Culvert Schedule

Major Crossing Location	Major Culverts	Floodplain Relief Culverts
Bowen River	35x1500 CMP	90x1200 CMP @ 50m Centres
Bowen River	70x1800 CMP	
Unnamed Creek	5x2100 CMP	10x1200 CMP @ 100m Centres

Results of the post rail TUFLOW model indicate that the existing flooding conditions are not significantly affected as a result of the inclusion of the rail formation and structure design. Flood impacts greater than 0.5 m are observed in the immediate vicinity upstream of some of the proposed major culverts at the Bowen River and unnamed creek rail crossing locations. There is no clearly defined land use in these areas as the flood extent remains within the existing floodplain. These areas will need to be further investigated at detailed design of the railway. Table 5.10 below presents the compliance with the environmental assessment criteria.

Table 5.10 Bowen River and Parrot Creek Compliance Assessment

Creek Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Bowen River	Compliant	Compliant	Compliant
Parrot Creek	Compliant	Compliant	Compliant
Unnamed Creek	Non-Compliant[1]	Compliant	Compliant

1. Peak afflux greater than 0.5 m only experienced around entrances to culverts with propagation upstream and laterally extending less than 100 m.

5.5 Upper Suttor River

5.5.1 Existing Case Results

The Suttor River is the main tributary within the Belyando Basin. This crossing is located in the very upper reaches of the Suttor River, with the lower Suttor River Crossing occurring some 150 km downstream of this crossing location.

The crossing location is high in the catchment and therefore the waterway is well defined and vegetation cover is denser than in many of the other crossing locations.

Model results for the 100 year ARI event predict peak flood depths to be over 8 m in some areas. This is due to the well-defined nature of the waterway at this location. Peak velocities are predicted to be approximately 1.5 m/s with some discrete areas above 2 m/s.

5.5.2 Post Rail Results

To ensure the existing flood conveyance is maintained for the Upper Suttor River rail crossing, a bridge design has been included within the hydraulic model. Table 5.11 presents details of the proposed bridge design included within the post rail TUFLOW model.

Table 5.11 Upper Suttor River Bridge Design Summary

Major Crossing Location	Span Distance (m)	No. of Spans	Pier Diameter (m)	No. of Piers	Soffit Level (m AHD)	Deck Thickness (m)	Deck Width (m)
Upper Suttor River	25	15	1	14	332.22	2.95	10.675

Results of the post rail hydraulic model indicate that the existing flooding conditions are not significantly affected as a result of the inclusion of the rail formation and bridge design. Table 5.12 below presents the compliance assessment results for upstream Suttor River crossing.

Table 5.12 Upper Suttor Compliance Assessment

Creek Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Upper Suttor River	Compliant	Compliant	Compliant

5.6 Lower Suttor River

5.6.1 Existing Case Results

The Suttor River is the main tributary within the Belyando Basin. The confluence of the Belyando and Suttor Rivers occurs some 35 km downstream of this crossing location.

The crossing is located in a rural area and within a region of the floodplain where a vast number of low flow channels occur with flat surrounding topography. This in combination with the large flow rates from the catchment result in expansive flood extents, with a width of some 5 km in the 100 year ARI event.

Model results for the 100 year ARI event predict average peak flood depths across the floodplain to be approximately 4 m. Localised channels within the floodplain experience depths of up to 6 m during the 100 year ARI event. Peak velocities are predicted to be on average approximately 1.0 m/s in the floodplain areas, whilst within the channels near the downstream model boundary where flow is more confined within the channels, velocities are predicted to reach up to 1.5 m/s for the 100 year ARI event.

Review of aerial photography indicates that there is a farm house located approximately 220 m upstream of the hydraulic model extent. This location is outside the available ALS data and has not been included within the modelling. However the water level results indicate that this property may be affected by existing flood waters from Suttor River.

5.6.2 Post Rail Results

The lower Suttor River crossing is proposed to be traversed by two bridges and a series of major and floodplain relief culverts. Table 5.13 presents details of the proposed bridge designs while major culvert and floodplain relief culverts proposed are presented in Table 5.14.

Table 5.13 Lower Suttor River Bridge Design Summary

Major Crossing Location	Span Distance (m)	No. of Spans	Pier Diameter (m)	No. of Piers	Soffit Level (mAHD)	Deck Thickness (m)	Deck Width (m)
Lower Suttor River	25	62	1	61	193.74	2.95	10.675
Lower Suttor River	25	11	1	10	193.443	2.95	10.675

Table 5.14 Lower Suttor River Major Culvert Schedule

Major Crossing Location	Major Culverts	Floodplain Relief Culverts
Lower Suttor River	19x3600x3600 RCBC	135x1200x1200 RCBC @ 50 m Centres.
Lower Suttor River	15x1500x1500 RCBC	60x3000x3000 RCBC @ 50 m Centres
Lower Suttor River	30x1800x1800 RCBC	60x3600x3600 RCBC @ 50 m Centres
Lower Suttor River	15x2100x2100 RCBC	
Lower Suttor River	15x2400x2400 RCBC	
Lower Suttor River	15x2700x2700 RCBC	

Results of the post rail TUFLOW modelling indicate that the existing flooding conditions are not significantly affected as a result of the inclusion of the rail formation and bridge/culvert design. Flood impacts greater than 0.5 m are observed directly upstream of the major culverts for approximately 200 m. Flood impacts greater than 0.5 m are observed upstream of the floodplain relief culverts at the north eastern portion of the rail crossing for approximately 280 m.

Additional work will need to be undertaken at the detailed design phase adequately quantify impacts to the existing dwelling with the structure designed accordingly. Compliance with all environmental assessment criteria has been achieved at the Lower Suttor River crossing with the proposed bridge and culvert design, refer to Table 5.15.

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Table 5.15 Lower Suttor River Compliance Assessment

Creek Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Lower Suttor River	Non-Compliant[1]	Compliant	Compliant

1. Peak afflux of 800 mm observed directly upstream of central culverts (between 2 bridges) with no impact on increase in flood extent.

5.7 Mistake Creek

5.7.1 Existing Case Results

Mistake Creek lies within the Belyando basin, and is a tributary of the Belyando River, which it joins some 19 km downstream of the crossing location. The crossing location is in a rural area with regions of cropping and associated water storages present.

The main Mistake Creek channel is shown to be slightly elevated compared to the surrounding topography, and as such the modelling results suggest the inundation in the floodplain areas to the north of the main channel are in fact slightly separate from the flows in the main channel itself. For this reason a creek breakout model was undertaken upstream of the hydraulic model extent to predict the flows entering Mistake Creek and flows entering the floodplain due to the breakout upstream of the study area. Results of this creek breakout model indicate approximately 560 m^3/s breaks out from Mistake Creek upstream of the study area with approximately 780 m^3/s discharging to the main channel of Mistake Creek.

Modelling results predict peak flood depths of between 5 m at the downstream boundary and 8 m at the upstream boundary in the main Mistake Creek channel. Peak flood depths up to 2 m are predicted for the within the floodplain area to the north of the main channel alignment. Peak velocities are predicted to be up to 1 m/s for the in the cleared floodplain areas and 2 m/s within the main Mistake Creek channel.

5.7.2 Post Rail Results

The main channel of Mistake Creek is proposed to be bridged, with a number of additional major culverts provided to convey floodplain flows and maintain connectivity. The bridge design summary of major culvert schedule is provided in Table 5.16 and Table 5.17 respectively.

Table 5.16 Mistake Creek Bridge Design Summary

Major Crossing Location	Span Distance (m)	No. of Spans	Pier Diameter (m)	No. of Piers	Soffit Level (m AHD)	Deck Thickness (m)	Deck Width (m)
Mistake Creek	25	1	N/A	0	211.05	2.95	10.675

Table 5.17 Mistake Creek Major Culvert Schedule

Major Crossing Location	Major Culverts
Mistake Creek	3x2100 CMP
Mistake Creek	25x3600x2100 RCBC
Mistake Creek	99x3600x2400 RCBC
Unnamed Creek	18x1200 CMP
Unnamed Creek	7x1500 CMP

Results of the post rail hydraulic modelling indicate localised flood afflux in the floodplain to the west of Mistake Creek. This is due to filling associated with the rail formation and the inability to locate culverts in this area due to limited depth of fill. Flood afflux greater than 0.5 m is observed in the breakout channel to the east of Mistake Creek upstream of the major culverts for approximately 200 m. Flood afflux greater than 0.5 m in the unnamed creek to the north east will be refined at detailed design of the railway. Refer to Table 5.18 for a summary of the compliance assessment for Mistake Creek.

Table 5.18 Mistake Creek Compliance Assessment

Creek Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Mistake Creek	Non-Compliant[1]	Compliant	Compliant
Unnamed Creek	Non-Compliant[1]	Compliant	Compliant

1. Peak afflux of 600mm at isolated locations for limited duration during the 100 year ARI event.

5.8 Lascelles Creek

5.8.1 Existing Case Results

Lascelles Creek lies within the Belyando Suttor sub-basin, and is a tributary of Mistake Creek, which joins the Belyando River some 95 km downstream of the crossing location. The crossing location is in a rural area and topography at the crossing location is flat with a small number of low flow channels of some 30 m in width that interconnect through the rail corridor. Flood extents are therefore typically shallow and expansive due to the nature of the topography.

Model predictions suggest peak depths to be in the order of 3 m and 2.5 m respectively in the main channel of the floodplain. Peak depths of up to 1 m were evident in the overbank areas immediately adjacent to the main channel. Peak velocities are predicted to be approximately 0.5 m/s in the cleared floodplain areas whilst within the main channel velocities are predicted to be up to 1 m/s. Results generally suggest that whilst the main channel through the crossing area has higher velocities and deeper flow depths, a significant proportion of the catchment discharge is still conveyed in the floodplain areas due to the small capacity of the main channels.

5.8.2 Post Rail Results

Due to the relatively small flow rates and shallow depth of flow it is not feasible to construct a bridge for the Lascelles Creek Crossing. It is proposed to utilise one bank of major culverts in the main channel combined with floodplain relief culverts to maintain flow connectivity.

Table 5.19 Lascelles Creek Major Culvert Schedule

Major Crossing Location	Major Culverts	Floodplain Relief Culverts
Lascelles Creek	5x2100 CMP	60x1200 CMP @ 100 m Centres

The post rail modelling results suggest an isolated area upstream of the embankment is observed to have flood afflux greater than 0.5 m which propagates approximately 50 m upstream. There is no clearly defined farming activities (possible grazing) or infrastructure within the vicinity of this afflux. The results of the Lascelles Creek compliance assessment are provided in Table 5.20.

Table 5.20 Lascelles Creek Compliance Assessment

Creek Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Lascelles Creek	Non-Compliant[1]	Compliant	Compliant

1. Peak afflux exceeds 0.5m for limited duration during the 100 year ARI event only propagating 50 m upstream with limited lateral impact.

5.9 Belyando River

5.9.1 Existing Case Results

The Belyando River represents one of the main waterway crossings at the southern end of the alignment. The river lies within the Belyando Suttor Sub Basin, and joins the Suttor River some 175 km downstream of the crossing location.

Flood depths in the main channel regions of up to 8.5 m for the 100 year ARI event are predicted in the main Belyando River channels. Peak velocities within the main channel are predicted to be in the order of 3.5 m/s during the 100 year ARI event. In the floodplain areas of the Belyando River, depths of approximately 2 m are predicted to occur with lower flow velocities of approximately 1 m/s. The width of the Belyando floodplain is in excess of 4 km.

5.9.2 Post Rail Results

Due to the large flow rates and depth of flow in the Belyando River it is proposed to utilise a combination of bridges and major culverts to traverse the watercourse. A summary of the bridge design requirements and culvert schedule is provided in Table 5.21 and Table 5.22 respectively.

Table 5.21 Belyando River Bridge Design Summary

Major Crossing Location	Span Distance (m)	No. of Spans	Pier Diameter (m)	No. of Piers	Soffit Level (m AHD)	Deck Thickness (m)	Deck Width (m)
Belyando River	25	24	1	23	264.05	2.95	10.675
Belyando River	25	27	1	26	264.05	2.95	10.675

Table 5.22 Belyando River Major Culvert Schedule

Major Crossing Location	Major Culverts
Belyando River	80x3600x3300 RCBC
Belyando River	411x3600x2100 RCBC
Belyando River	15x1800x1800 RCBC

Results of the post rail hydraulic modelling indicate that the existing flooding conditions are not significantly affected as a result of the inclusion of the rail formation, bridge and culvert design. Table 5.23 below presents the compliance with the design criteria identified for the Belyando River crossing.

Table 5.23 Belyando River Compliance Assessment

Creek Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Belyando River	Compliant	Compliant	Compliant

5.10 Sandy Creek

5.10.1 Existing Case Results

Sandy Creek lies within the Belyando Suttor Sub Basin, and is a tributary of the Belyando River, which it joins some 16 km downstream of the crossing location. The crossing location is in a cleared rural area and flood extents are typically expansive due to the flat nature of the surrounding topography.

Model results for the 100 year ARI event predict peak depths to be in the order of 4 m in the main Sandy Creek channels, with depths of around 1.8 m in the floodplain areas to the north of the main channel alignment. During the 100 year ARI event, peak velocities are predicted to be approximately 2.5 m/s in the cleared floodplain areas where the limited vegetation cover enables faster flow velocity. Within the main Sandy Creek channel, velocities are predicted to be in the order of 1.5 m/s due to the thicker vegetation present.

5.10.2 Post Rail Results

To provide immunity and conveyance for the Sandy Creek crossing it is proposed to utilise a bridge to traverse the main channel in conjunction with culverts to convey the floodplain flow. The preliminary design requirements for these structures are provided in Table 5.24 and Table 5.25.

Table 5.24 Sandy Creek Bridge Design Summary

Major Crossing Location	Span Distance (m)	No. of Spans	Pier Diameter (m)	No. of Piers	Soffit Level (m AHD)	Deck Thickness (m)	Deck Width (m)
Sandy Creek	25	12	1	11	279.3	2.95	10.675

Table 5.25 Sandy Creek Major Culvert Schedule

Major Crossing Location	Major Culverts	Floodplain Relief Culverts
Sandy Creek	65x1200x1200 RCBC	120x1200x1200 RCBC
Sandy Creek	25x3000x3000 RCBC	

The results of the post rail hydraulic modelling indicate the proposed design is capable of meeting the design criteria in the 100 year ARI event with the compliance assessment summarised in Table 5.26.

Table 5.26 Design Criteria Compliance Assessment

Creek Crossing	Design Event Afflux	Flow Connectivity	Flow Velocity
Sandy Creek	Compliant	Compliant	Compliant

5.11 Flood Inundation Time

Flood inundation time as a result of the proposed railway embankment and hydraulic structures has been identified as a critical issue for landholders along the alignment. These concerns relate to the impacts to grazing and cropping areas as a result of increased time of inundation. To due time constraints for submission of this report and long model run times the increase to inundation time has not been undertaken for all cross drainage structures. Therefore one representative crossing has been selected that utilises a combination of culverts and a bridge. The crossing selected was Pelican Creek, with results for 100 year ARI water level summarised in Figure 5.1. Review of these results indicates there is very little change to inundation time with an increase of less than 20 hours. It should also be noted this increase is also at a depth of less than 300 mm.

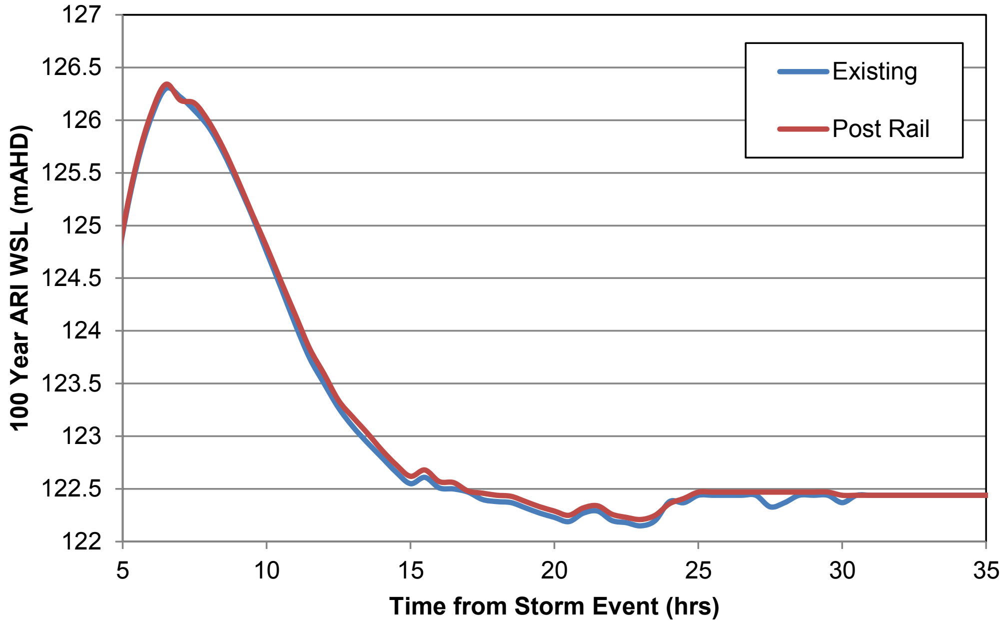

Figure 5.1 100 Year ARI Inundation Time Pelican Creek

6. CONCLUSIONS

This study has been undertaken to provide a conceptual level assessment of railway cross drainage requirements to support the submission of the SEIS and address stakeholder concerns raised during the public consultation process of the Galilee Coal Project EIS. The following key points in relation to the cross drainage requirements are summarised below:

- The railway is proposed to have flood immunity from the 100 year ARI flood event with preliminary vertical alignment and design of structures undertaken based on existing hydraulic modelling (Engeny, 2011);
- Design criteria have been developed to limit the impact of the railway on existing watercourses, property owners and infrastructure. This design criteria is based on maintaining flow connectivity, minimising afflux and structure outlet velocity;
- Hydraulic modelling of the major watercourse crossings has been undertaken to assess the hydraulic performance and compliance against the environmental design criteria. The results of this assessment indicate that all major structures are typically compliant, with some areas of localised afflux associated with some culvert crossings. These crossings will be addressed during the detailed design phase of the project in order to limit afflux further, where requested by landholders;
- A total of 292 additional minor culvert crossings have been identified along the full length of the rail alignment. Hydrologic analysis has been undertaken to estimate design flow rates and preliminary structure opening requirements. These additional crossings will need to be assessed further during the detailed design phase to determine compliance with the environmental design criteria.

7. QUALIFICATIONS

a. In preparing this document, including all relevant calculation and modelling, Engeny Management Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

b. Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

c. Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (i) additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (ii) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

d. Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

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f. If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

8. REFERENCES

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APPENDIX A

Rail Corridor Maps

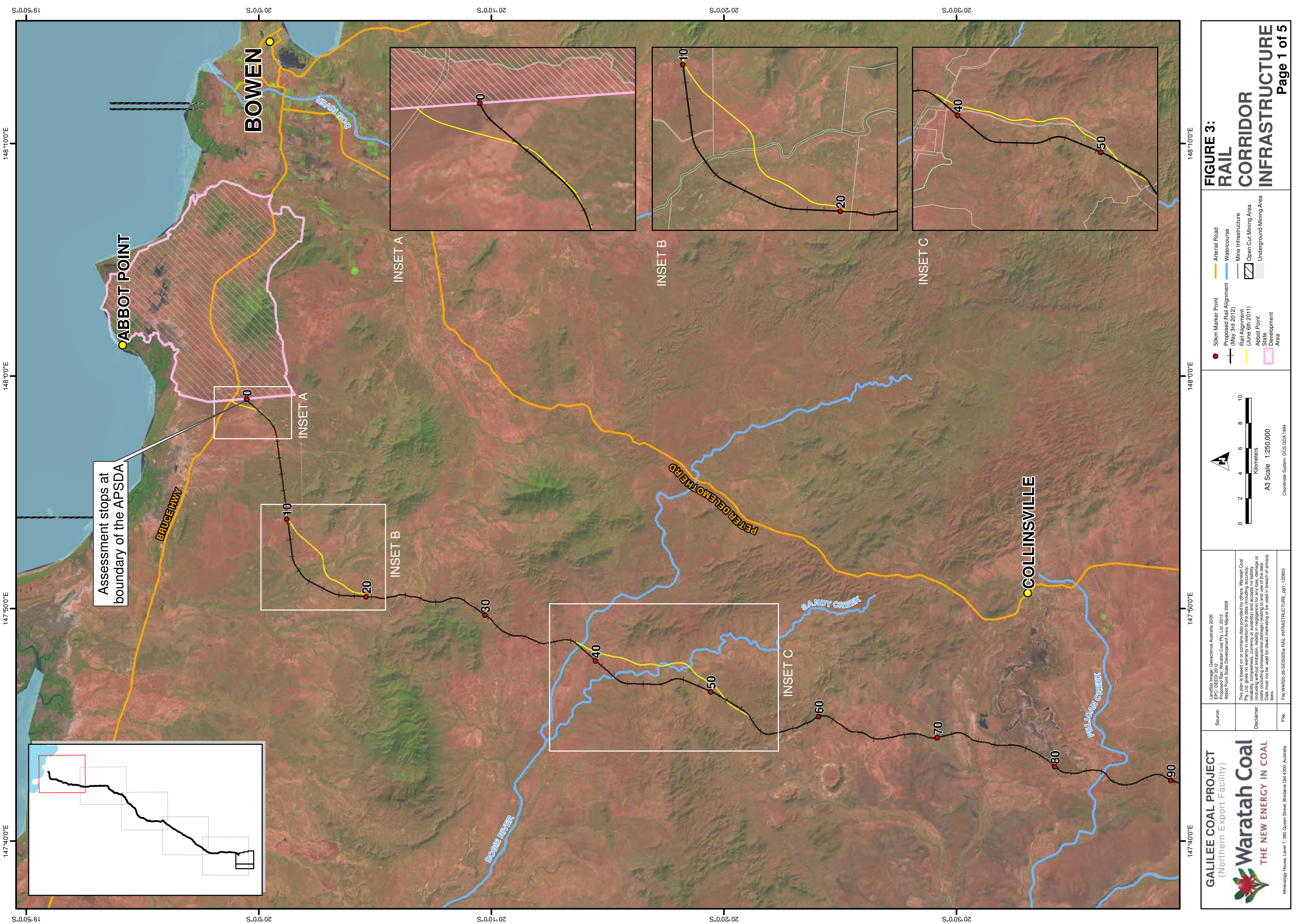
FIGURE 3:
RAIL CORRIDOR INFRASTRUCTURE
Page 1 of 5
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
BOWEN
ABBOT POINT
COLLINSVILLE
DON RIVER
BOGIE RIVER
SANDY CREEK
PELICAN CREEK
BRUCE HWY
PETER DELEMOTHE RD
INSET A
INSET B
INSET C
Assessment stops at boundary of the APSDA
50km Marker Point
Proposed Rail Alignment (May 3rd 2012)
Rail Alignment (June 6th 2011)
Abbot Point State Development Area
Arterial Road
Watercourse
Mine Infrastructure
Open Cut Mining Area
Underground Mining Area
A3 Scale 1:250,000
Kilometers
Coordinate System: GCS GDA 1994

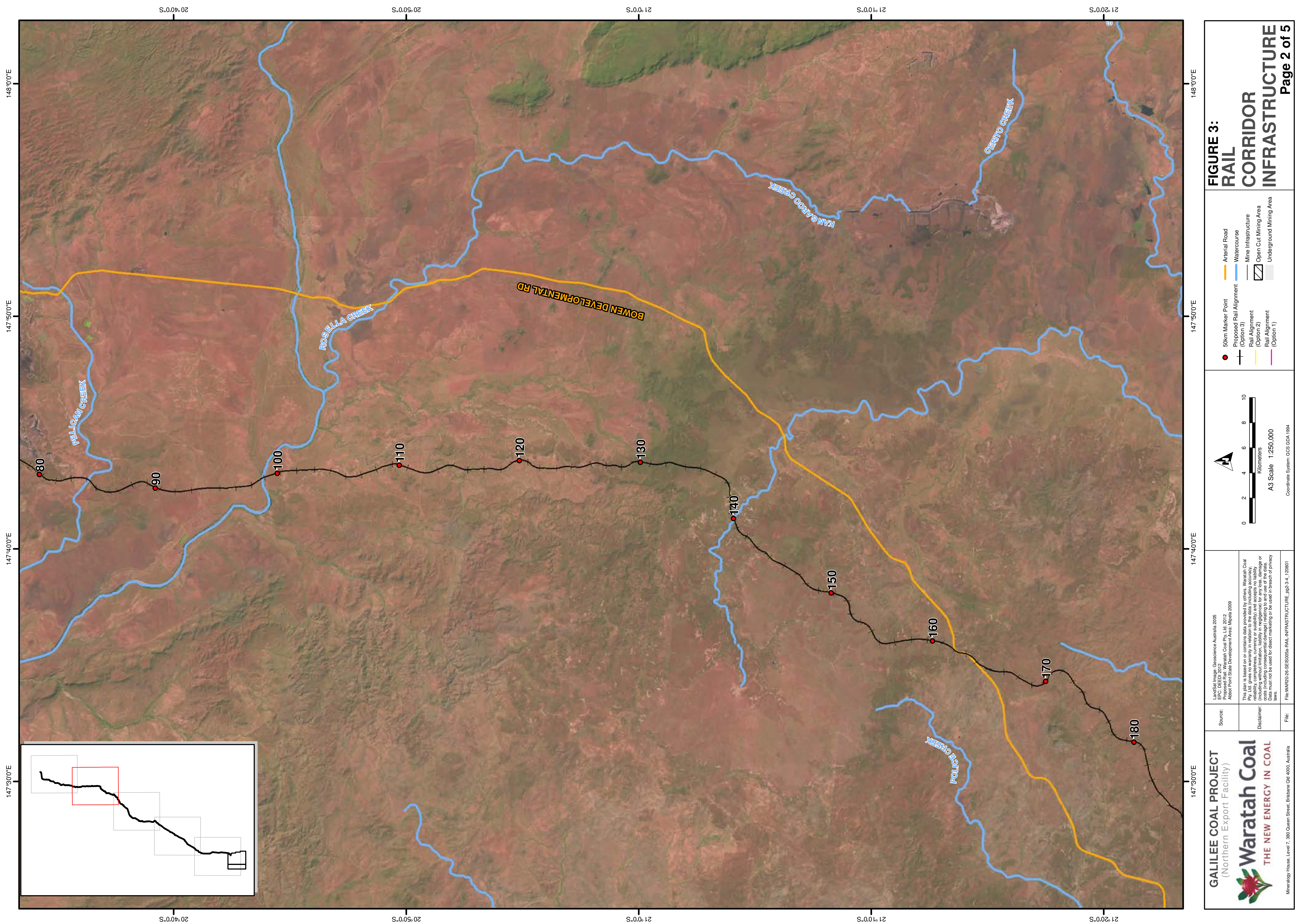

FIGURE 3:
RAIL CORRIDOR INFRASTRUCTURE
Page 2 of 5
50km Marker Point
Proposed Rail Alignment (Option 3)
Rail Alignment (Option 2)
Rail Alignment (Option 1)
Arterial Road
Watercourse
Mine Infrastructure
Open Cut Mining Area
Underground Mining Area
Kilometers
A3 Scale 1:250,000
Coordinate System: GCS GDA 1994
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
BOWEN DEVELOPMENTAL RD
ROSELLA CREEK
PELICAN CREEK
KANGAROO CREEK
CERITO CREEK
POLICE CREEK
80
90
100
110
120
130
140
150
160
170
180
20°40'0"S
20°50'0"S
21°0'0"S
21°10'0"S
21°20'0"S
148°0'0"E
147°50'0"E
147°40'0"E
147°30'0"E

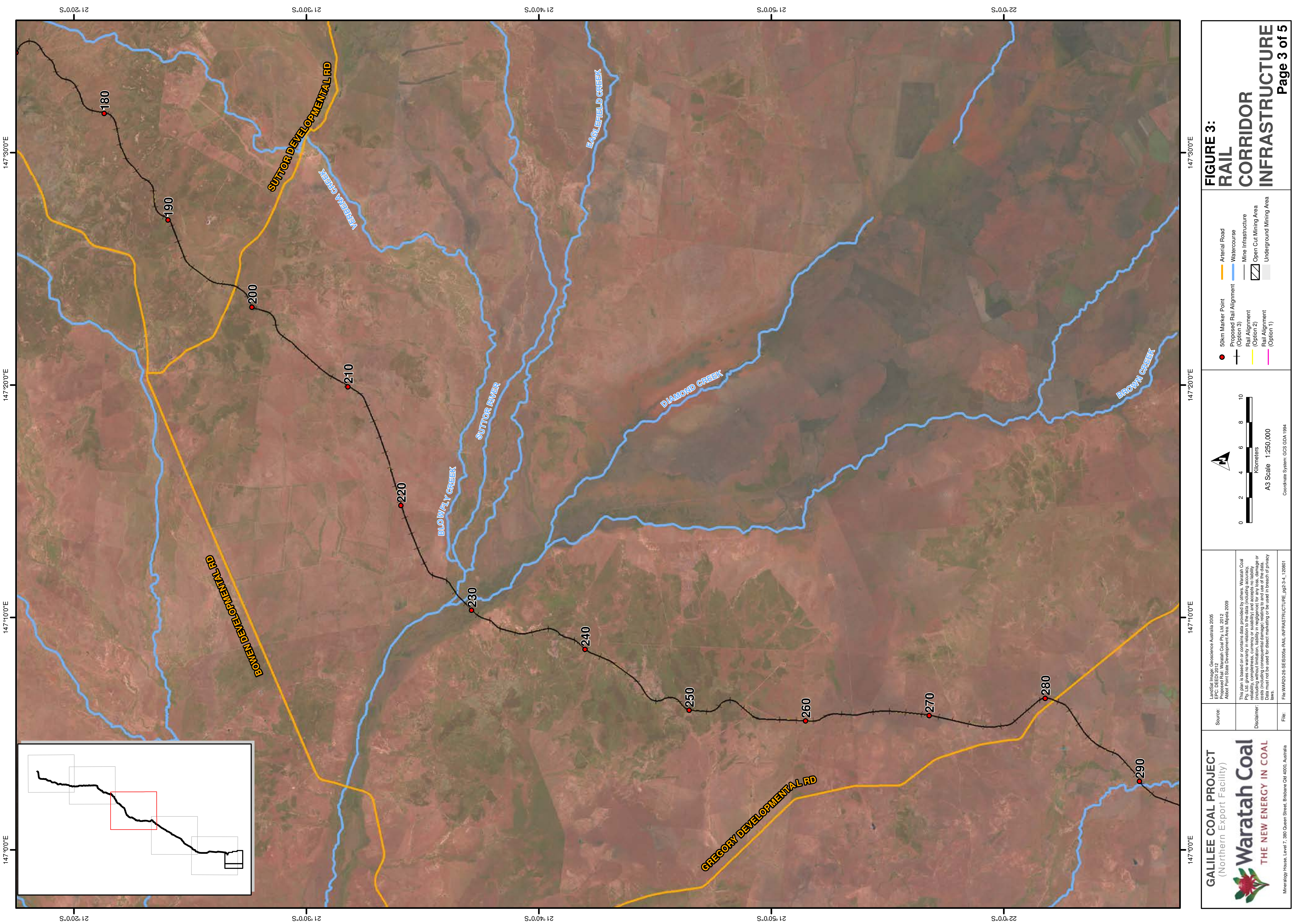

FIGURE 3:
RAIL CORRIDOR INFRASTRUCTURE
Page 3 of 5
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
50km Marker Point
Proposed Rail Alignment (Option 3)
Rail Alignment (Option 2)
Rail Alignment (Option 1)
Arterial Road
Watercourse
Mine Infrastructure
Open Cut Mining Area
Underground Mining Area
Kilometers
A3 Scale 1:250,000
Coordinate System: GCS GDA 1994
SUTTOR DEVELOPMENTAL RD
BOWEN DEVELOPMENTAL RD
GREGORY DEVELOPMENTAL RD
VERBENA CREEK
EAGLEFIELD CREEK
SUTTOR RIVER
BLOWFLY CREEK
DIAMOND CREEK
BROWN CREEK
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270
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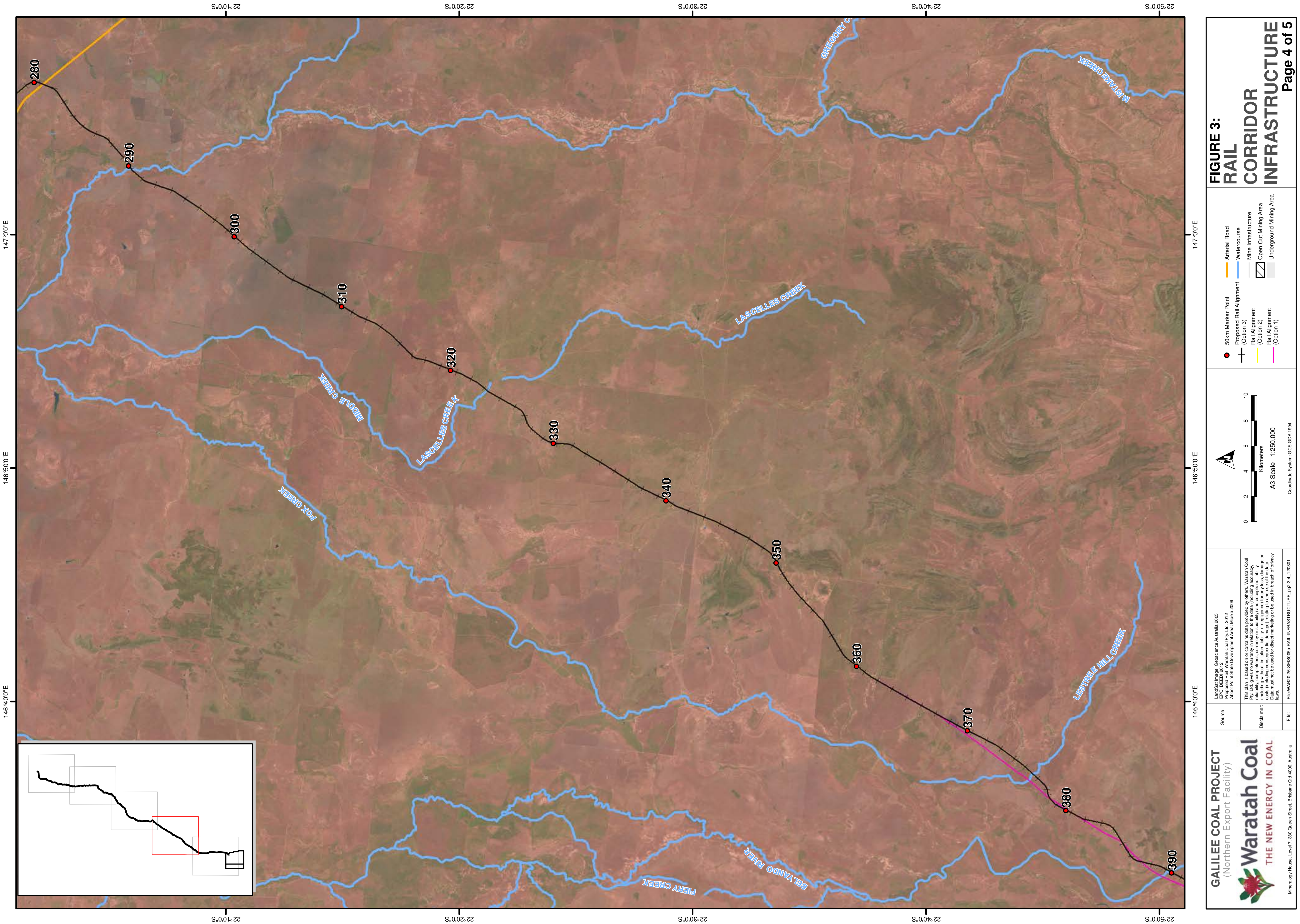
FIGURE 3:
RAIL CORRIDOR INFRASTRUCTURE
Page 4 of 5
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
50km Marker Point
Proposed Rail Alignment (Option 3)
Rail Alignment (Option 2)
Rail Alignment (Option 1)
Arterial Road
Watercourse
Mine Infrastructure
Open Cut Mining Area
Underground Mining Area
A3 Scale 1:250,000
Kilometers
Coordinate System: GCS GDA 1994
LASCELLES CREEK
MIDDLE CREEK
FOX CREEK
BELYANDO RIVER
FIERY CREEK
LESTREE HILL CREEK
GREGORY CREEK
ALISTAIR CREEK
280
290
300
310
320
330
340
350
360
370
380
390
22°10'0"S
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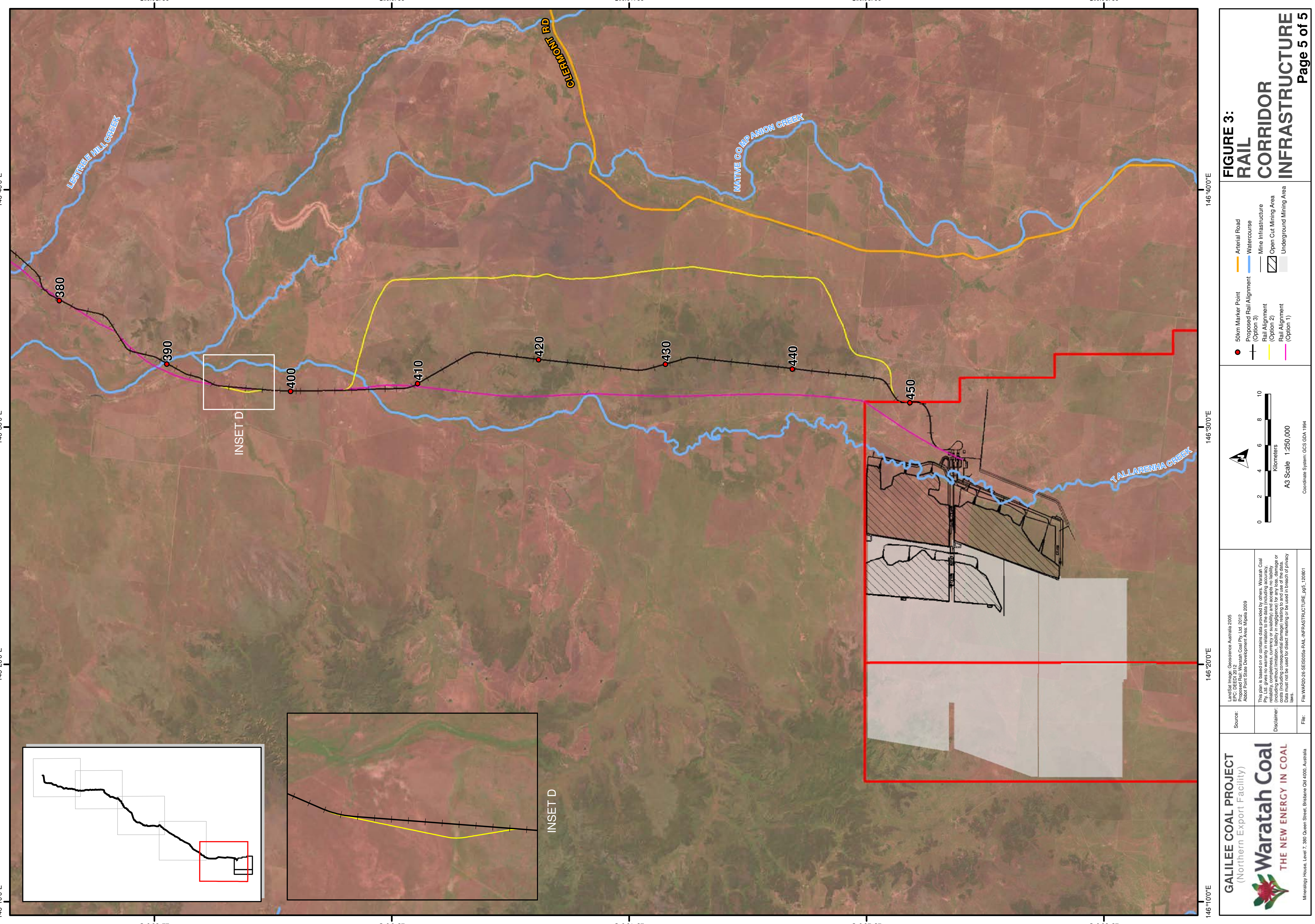
FIGURE 3:
RAIL CORRIDOR INFRASTRUCTURE
Page 5 of 5
50km Marker Point
Proposed Rail Alignment (Option 3)
Rail Alignment (Option 2)
Rail Alignment (Option 1)
Arterial Road
Watercourse
Mine Infrastructure
Open Cut Mining Area
Underground Mining Area
0 2 4 6 8 10
Kilometers
A3 Scale 1:250,000
Coordinate System: GCS GDA 1994
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
Mineralogy House, Level 7, 380 Queen Street, Brisbane Qld 4000, Australia
Source:
LandSat Image: Geoscience Australia 2005
EPC: DEEDI 2012
Proposed Rail: Waratah Coal Pty. Ltd. 2012
Abbot Point State Development Area: Mipela 2009
Disclaimer:
This plan is based on or contains data provided by others. Waratah Coal Pty. Ltd. gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to and use of the data. Data must not be used for disect marketing or be used in breach of privacy laws.
File:
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LESTREE HILL CREEK
CLERMONT RD
NATIVE COMPANION CREEK
TALLARENHA CREEK
380
390
400
410
420
430
440
450
INSET D
146°40'0"E
146°30'0"E
146°20'0"E
146°10'0"E
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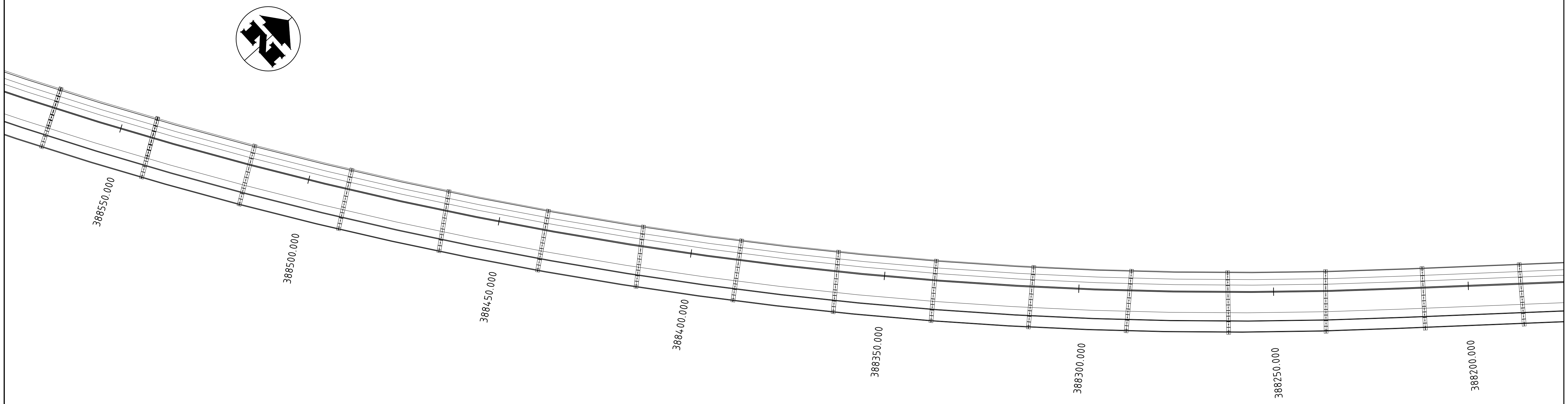
APPENDIX B

Preliminary Bridge Design Drawings



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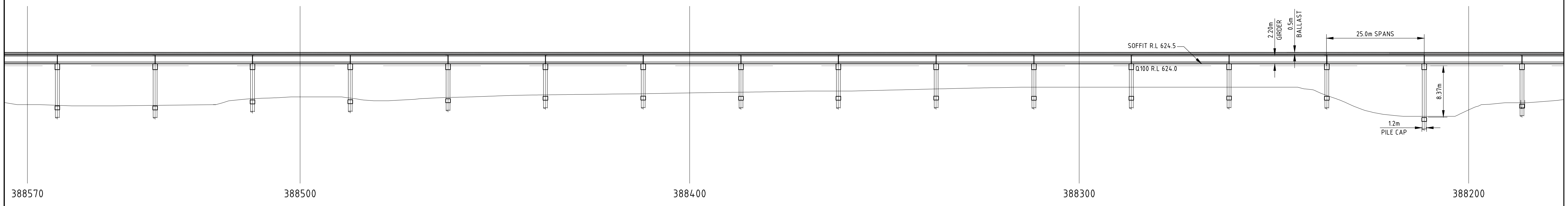
JOINTS SK114

JOINTS SK116



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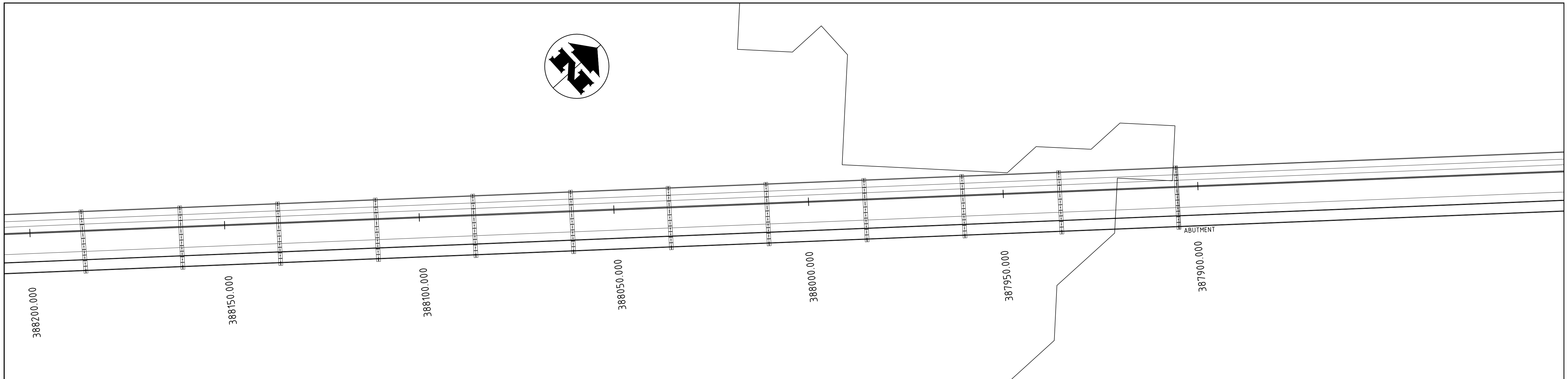

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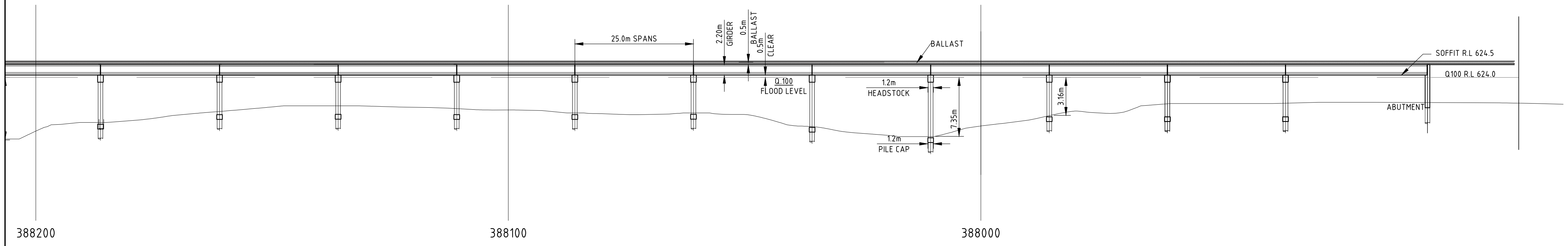

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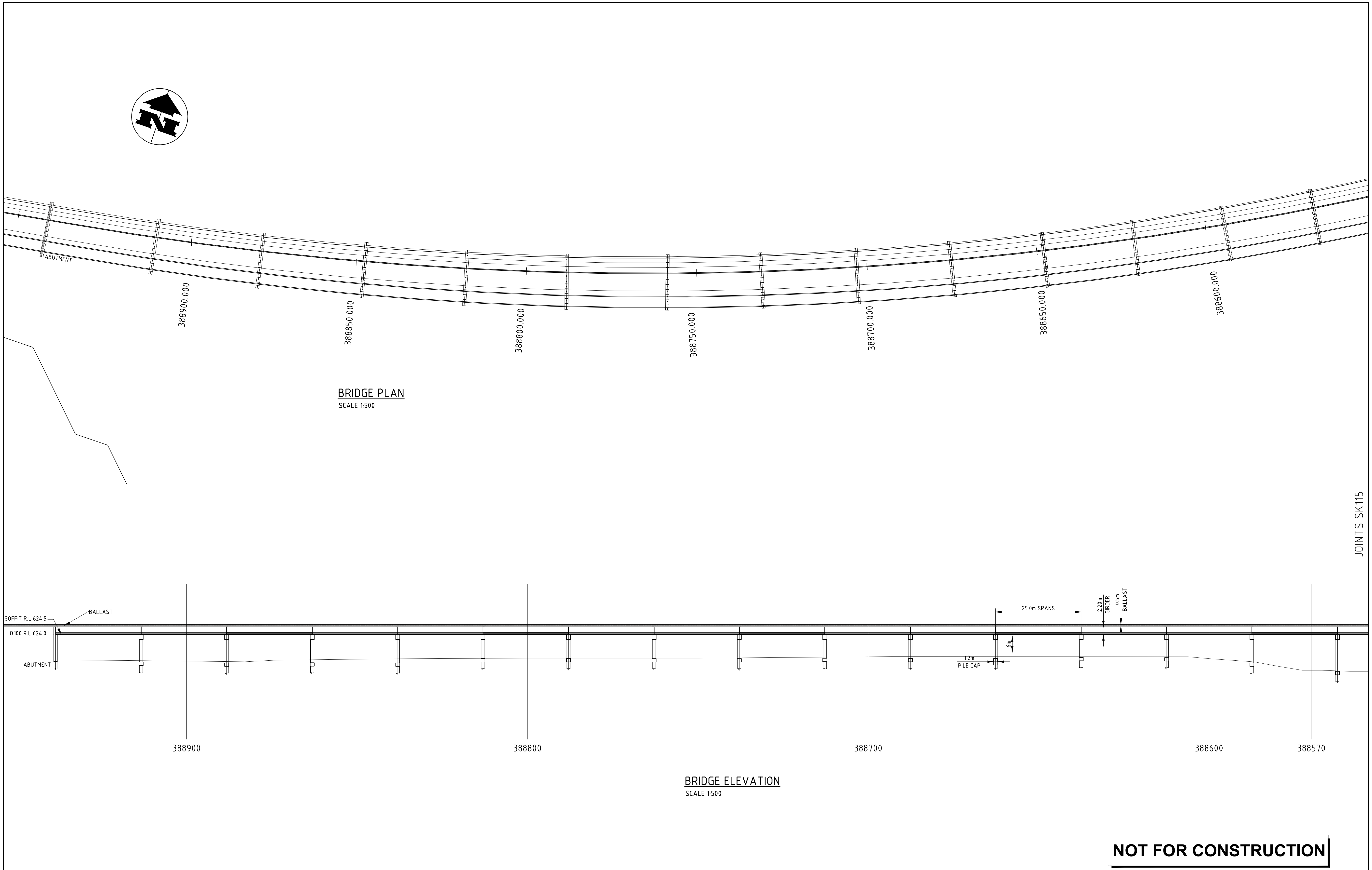

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ORIGINAL SHEET SIZE A1

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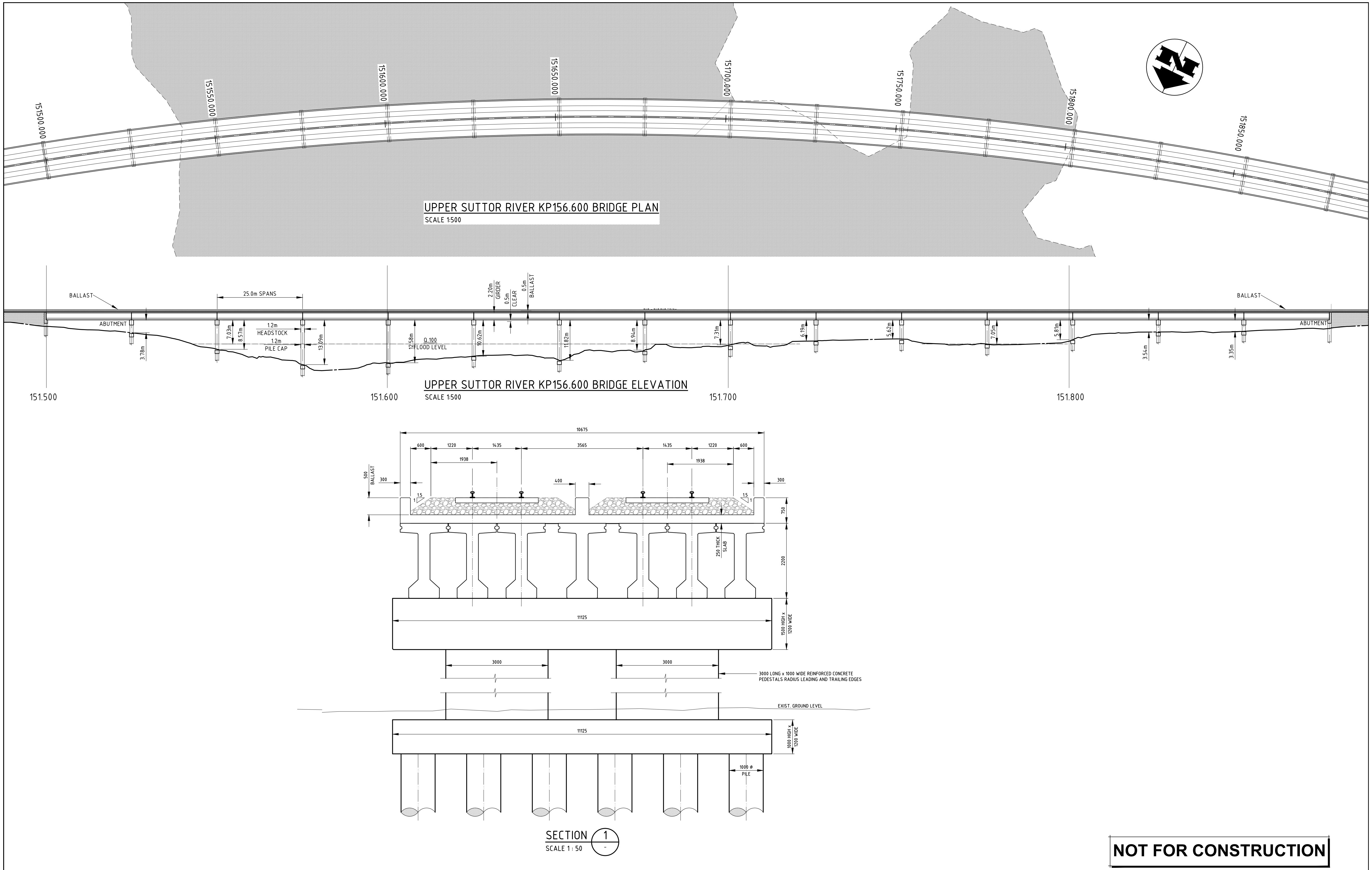

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ORIGINAL SHEET SIZE A1

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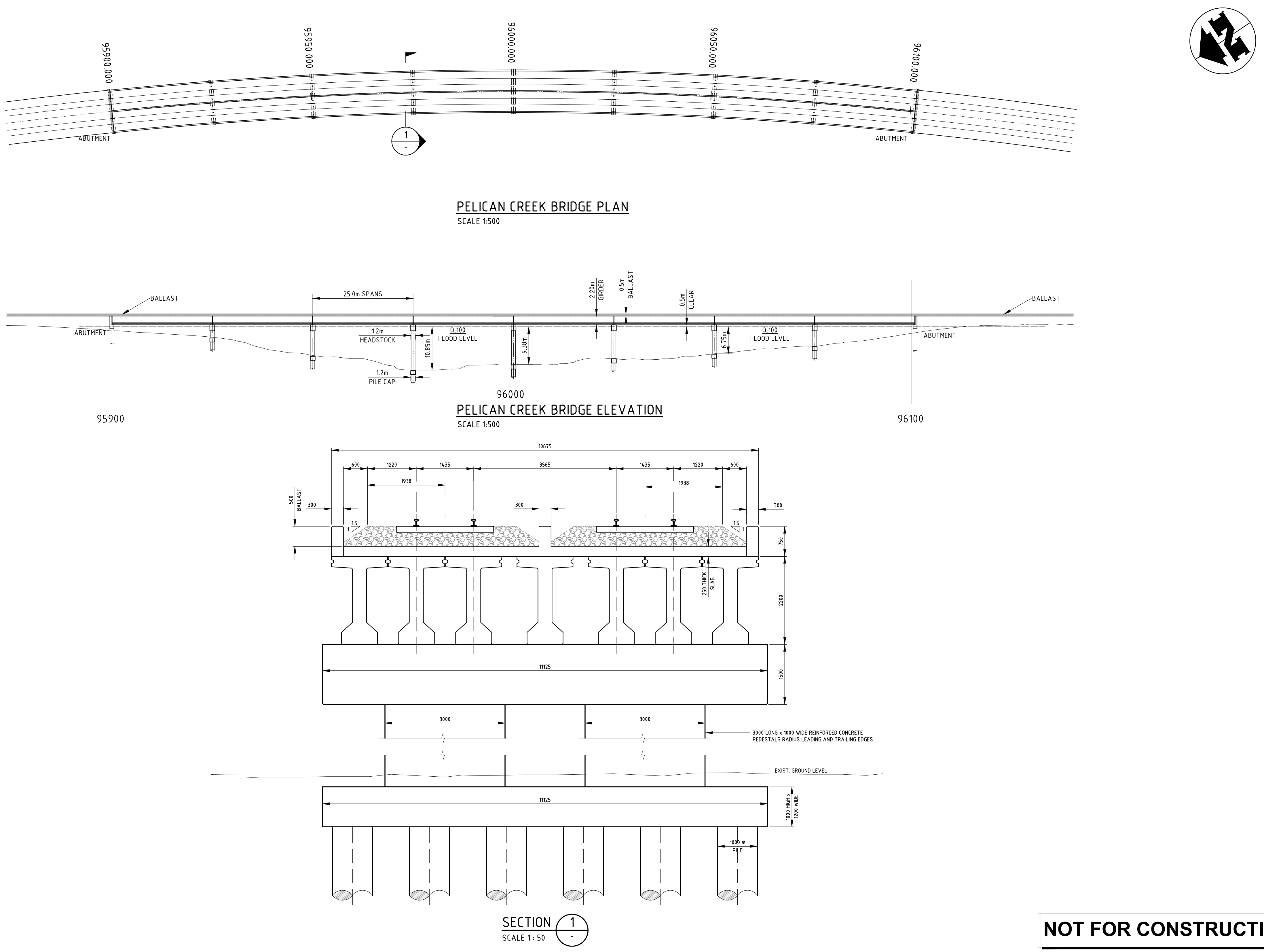

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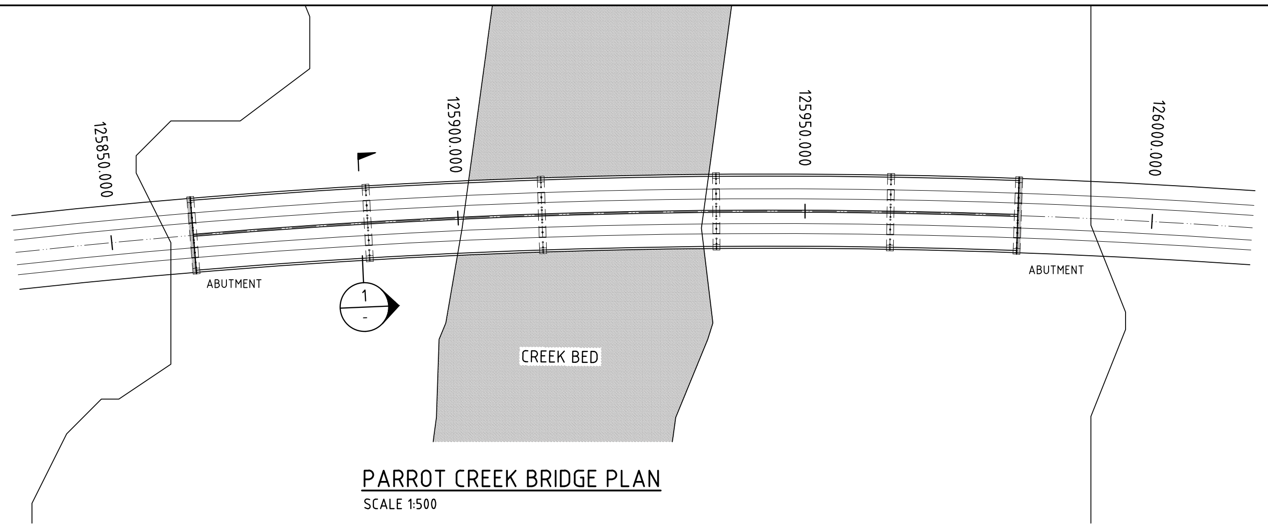

PARROT CREEK BRIDGE PLAN
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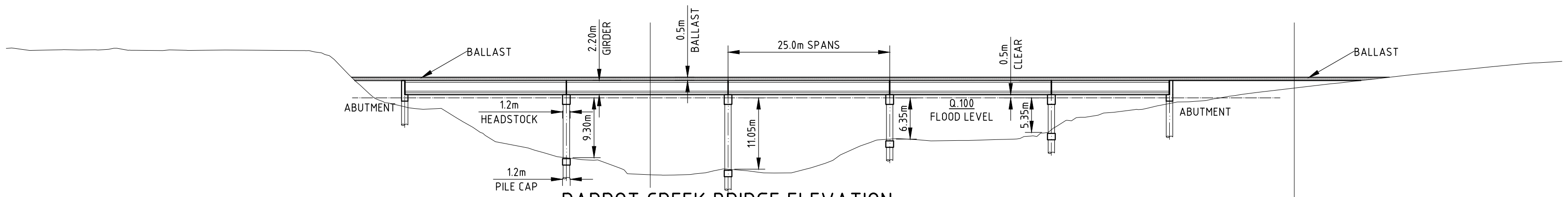

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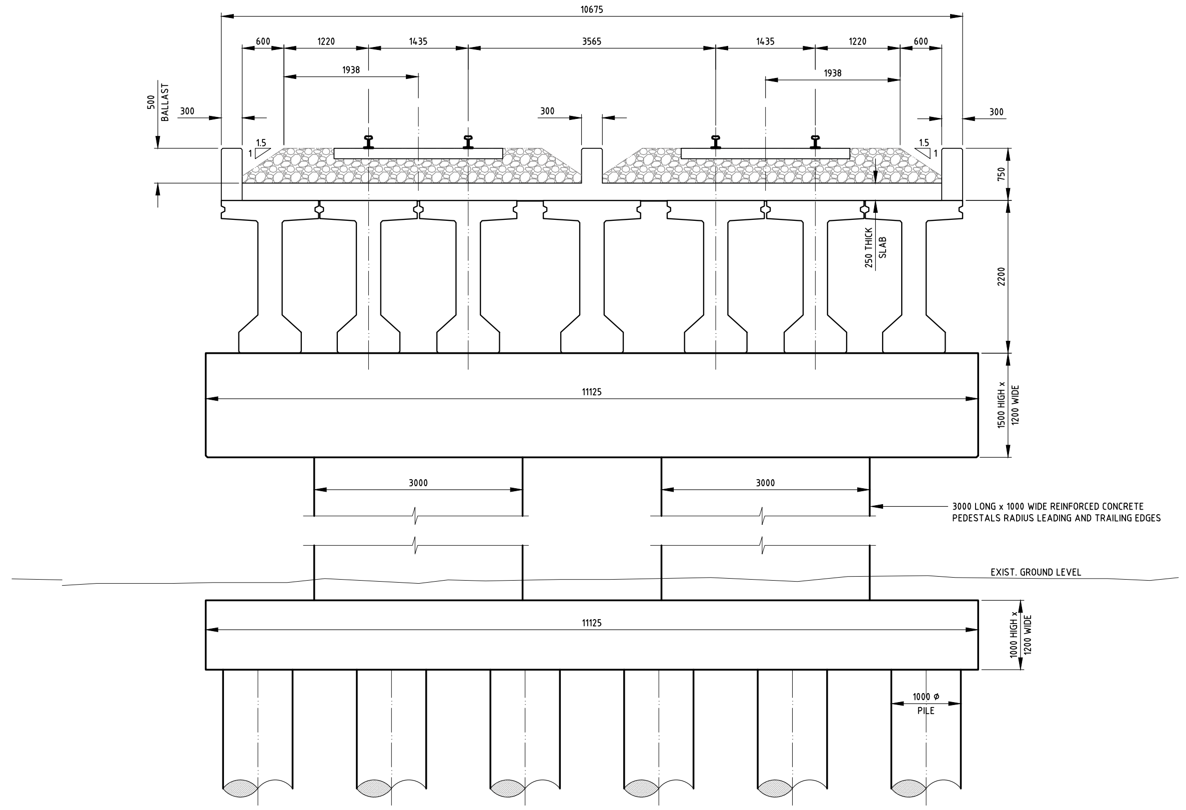

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PROJECT: ROAD BRIDGE OVER BOYNE RIVER PIONEER DRIVE

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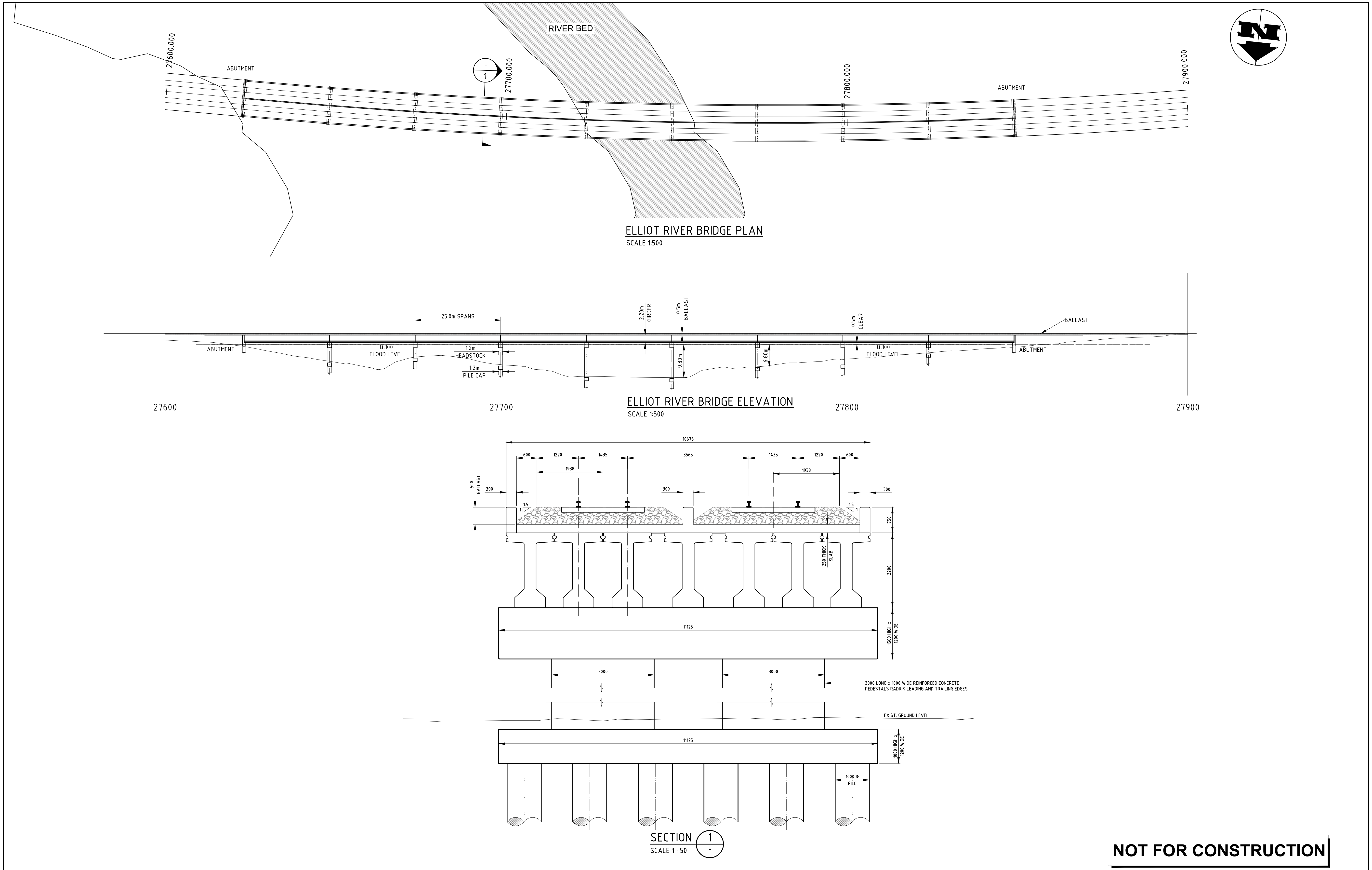

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PIONEER DRIVE

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TITLE
BRIDGE CONCEPT OVER ELLIOT RIVER
KP-29

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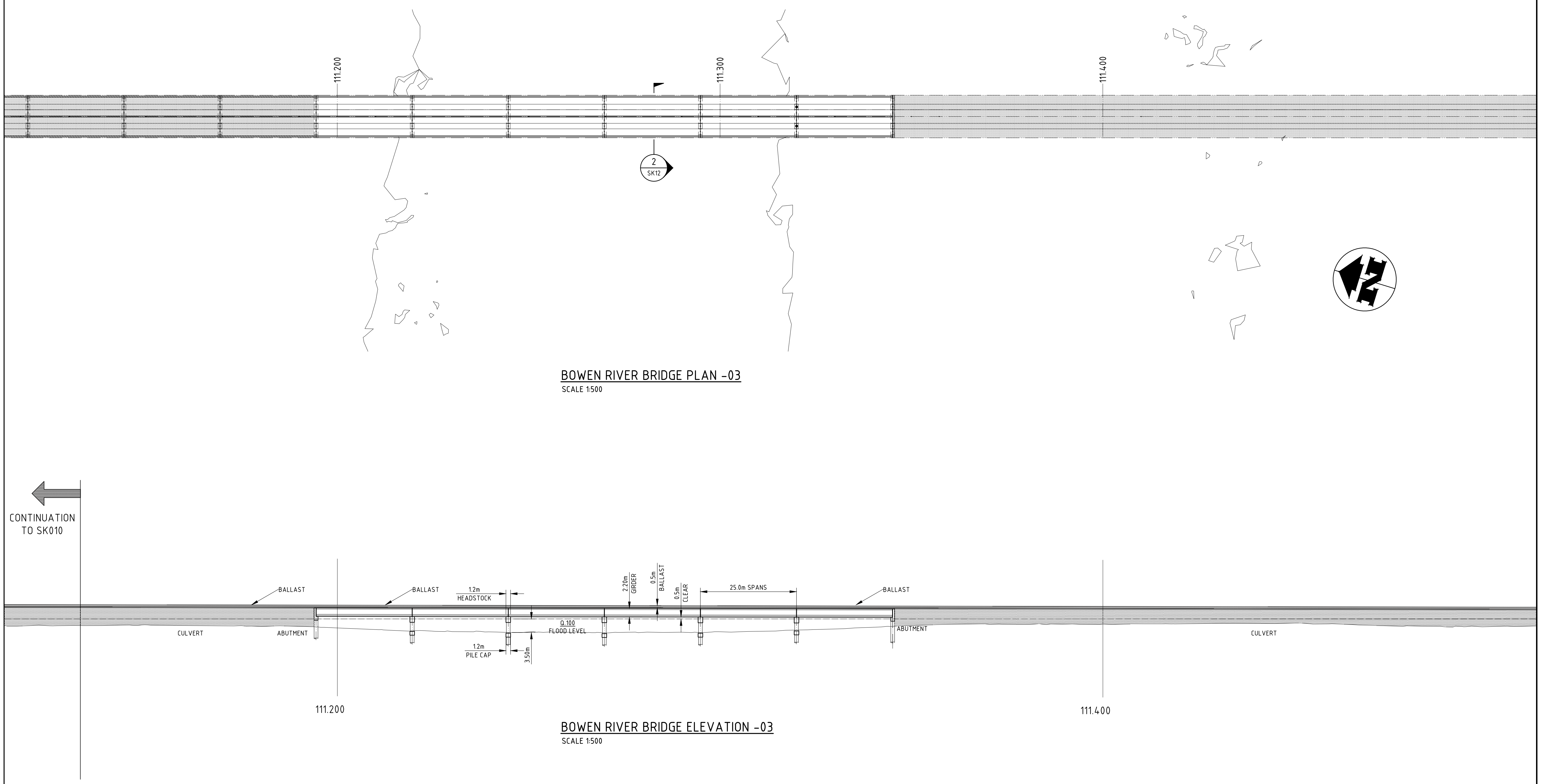

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PROJECT: ROAD BRIDGE OVER BOYNE RIVER PIONEER DRIVE

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TITLE: BRIDGE CONCEPT OVER BOWEN RIVER KP-110.400_03

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APPROVED

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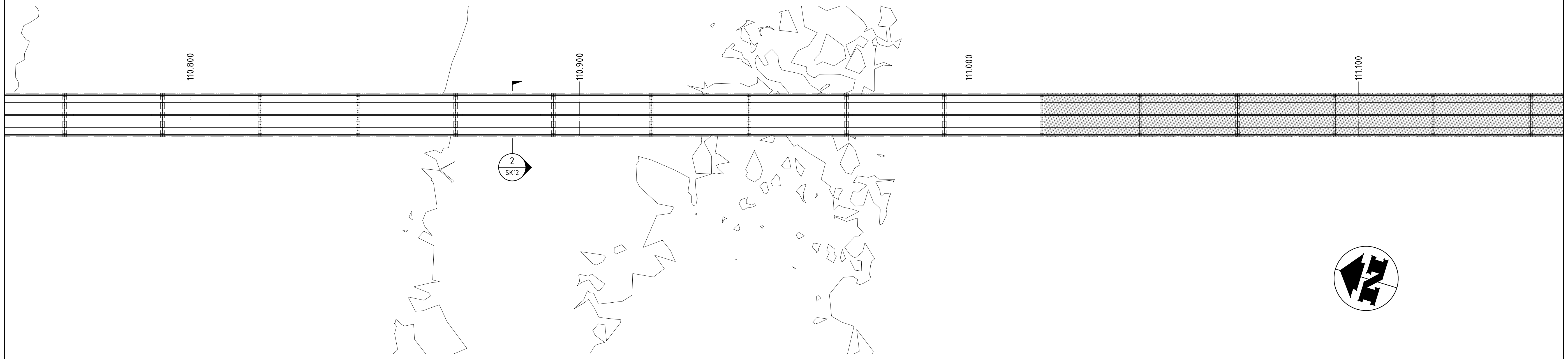

BOWEN RIVER BRIDGE PLAN -02

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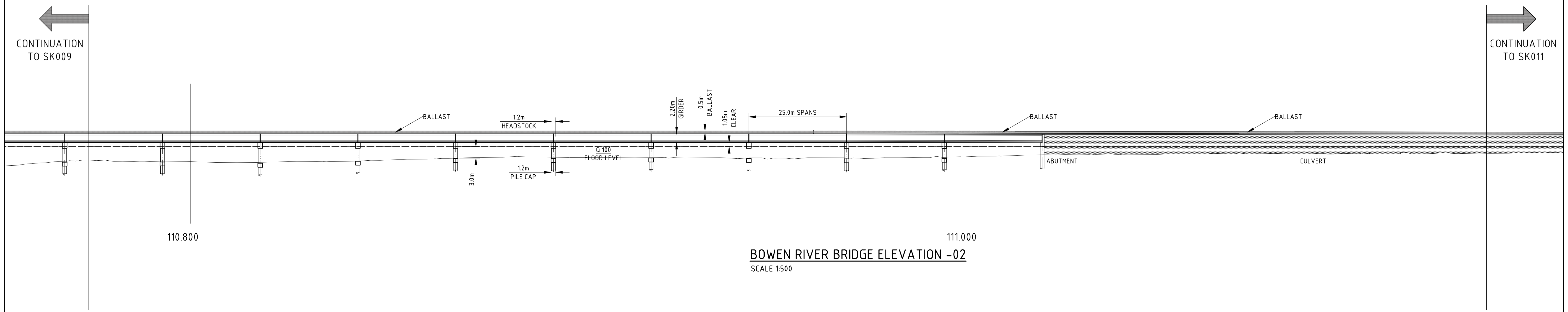

BOWEN RIVER BRIDGE ELEVATION -02

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PROJECT ROAD BRIDGE OVER BOYNE RIVER PIONEER DRIVE

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TITLE BRIDGE CONCEPT OVER BOWEN RIVER KP-110.400_02 SECTION

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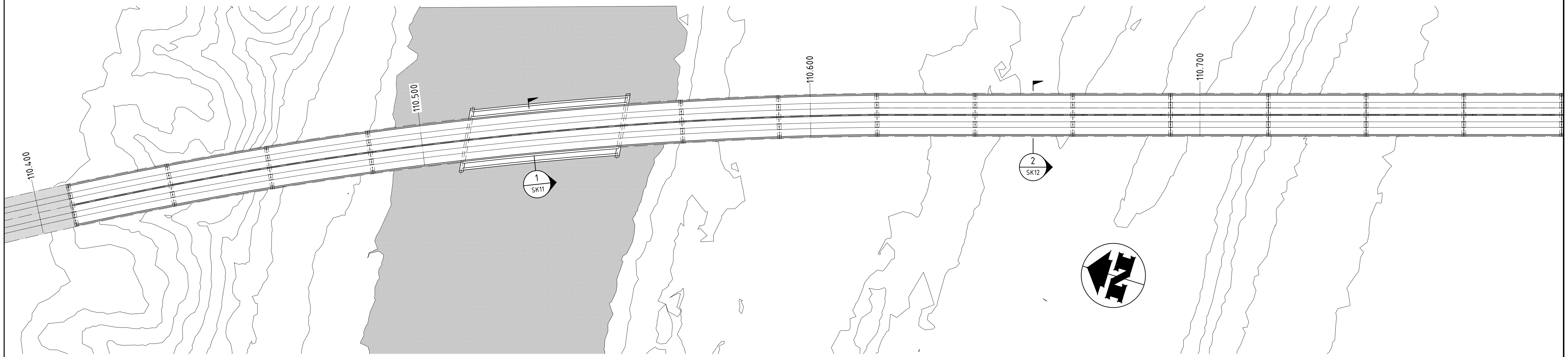

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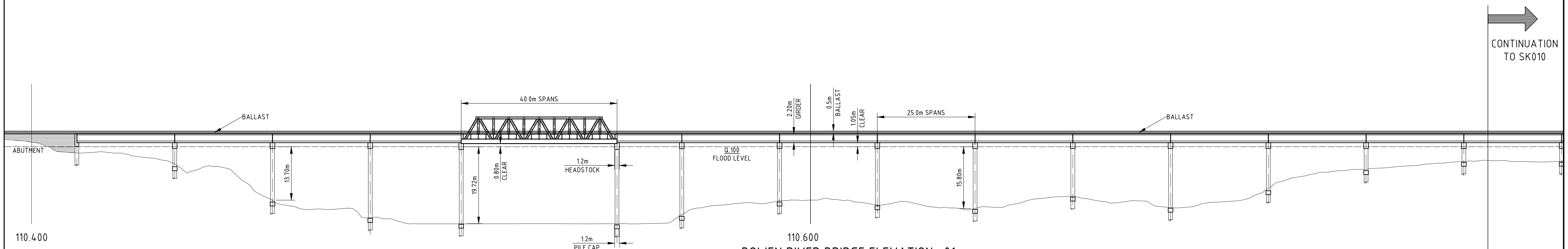

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KP-110.400_01

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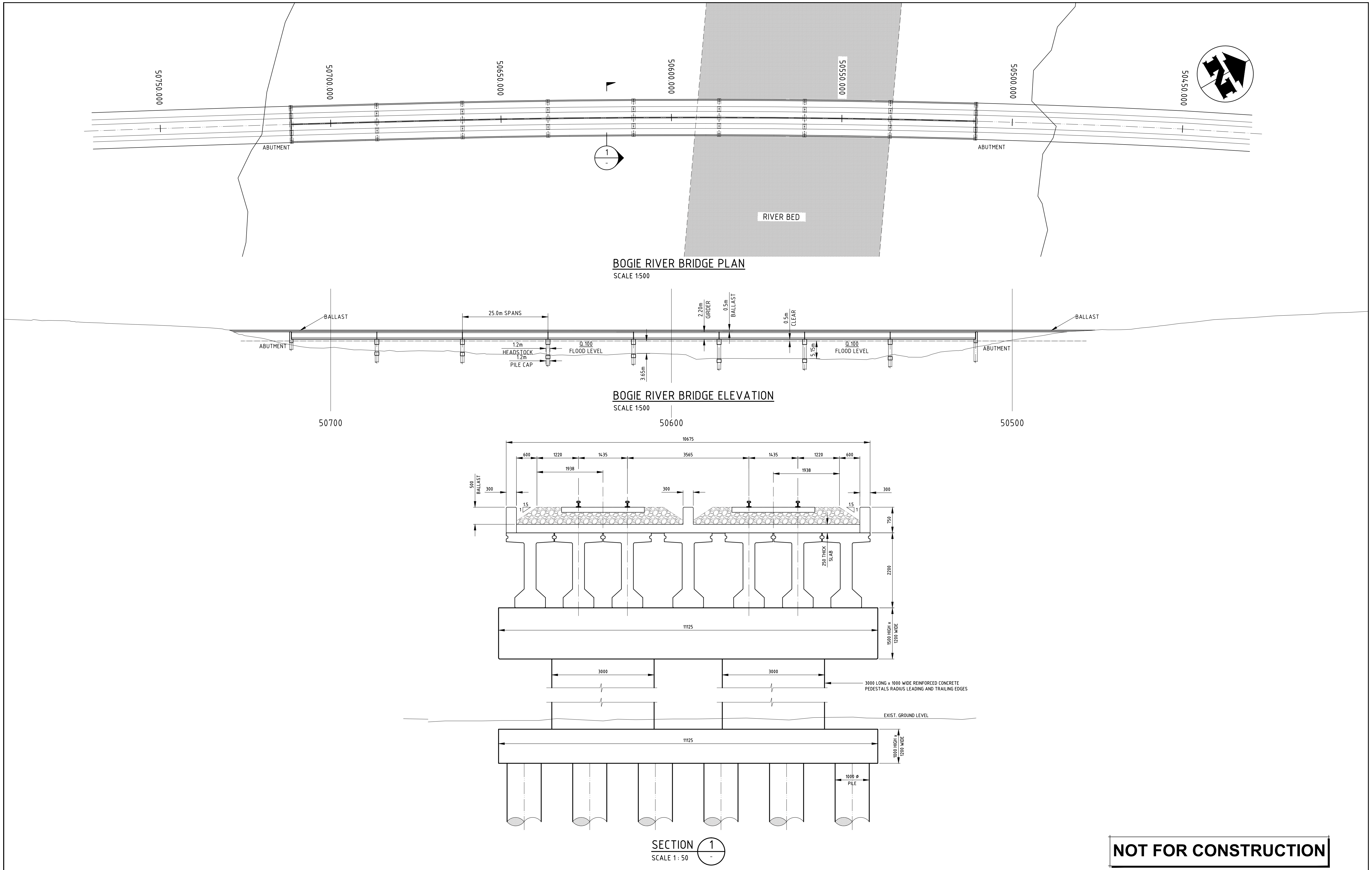

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PIONEER DRIVE

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TITLE
BRIDGE CONCEPT OVER BOGIE RIVER
KP43

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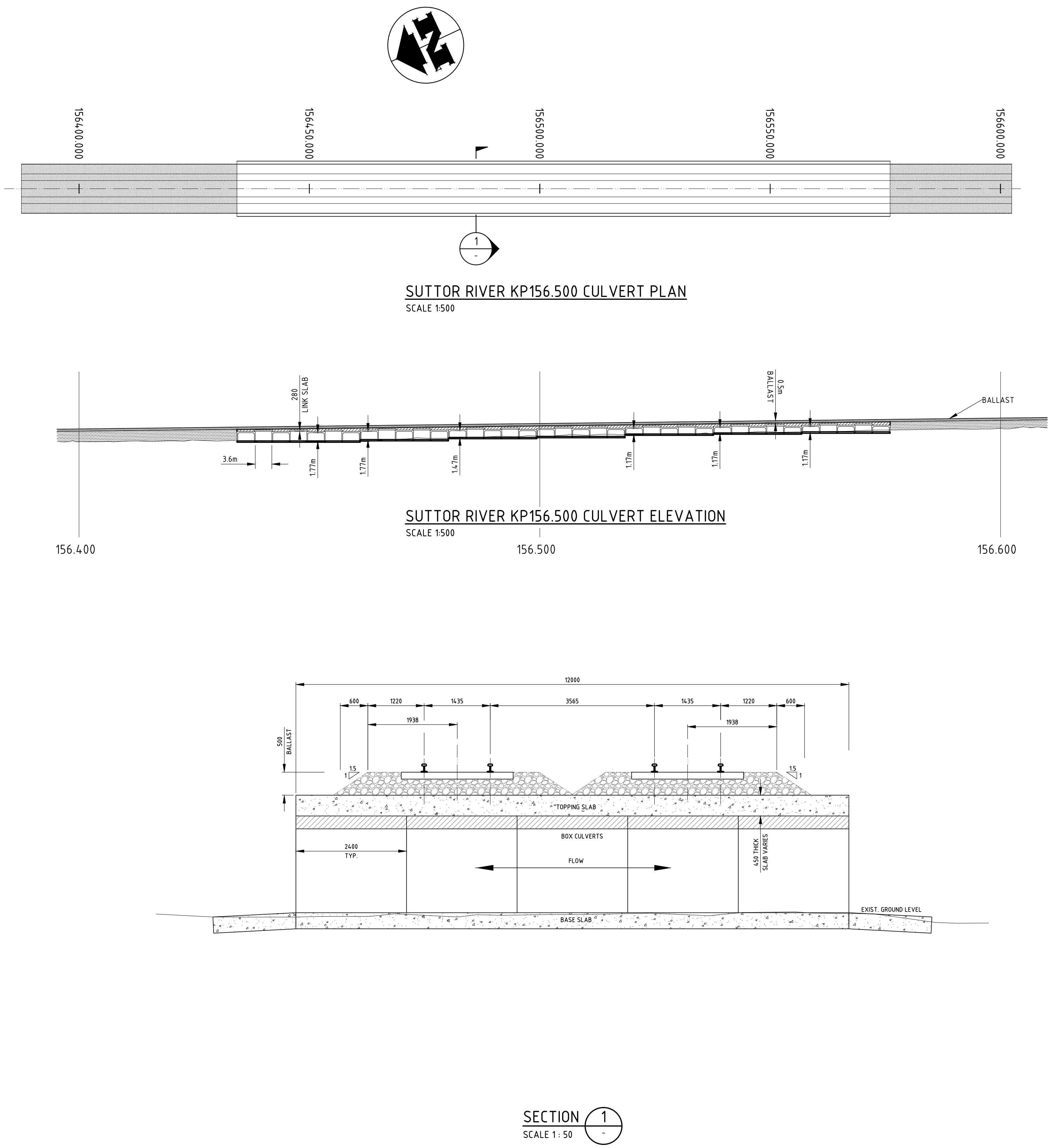

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CLIENT: WARATAH COAL

PROJECT: CONCEPTUAL DUAL RAIL BRIDGES GALILEE COAL PROJECT

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TITLE: BOX CULVERT CONCEPT OVER SUTTOR RIVER KP-156.500

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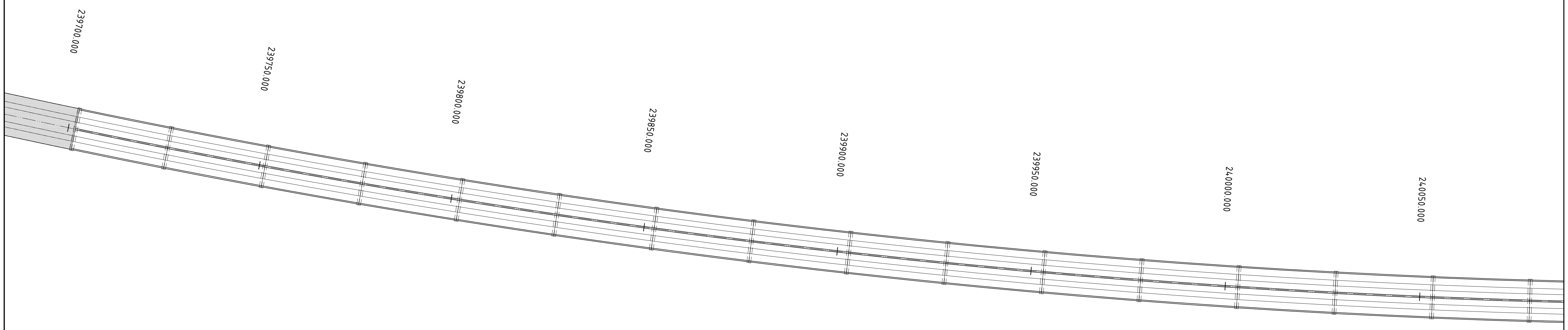
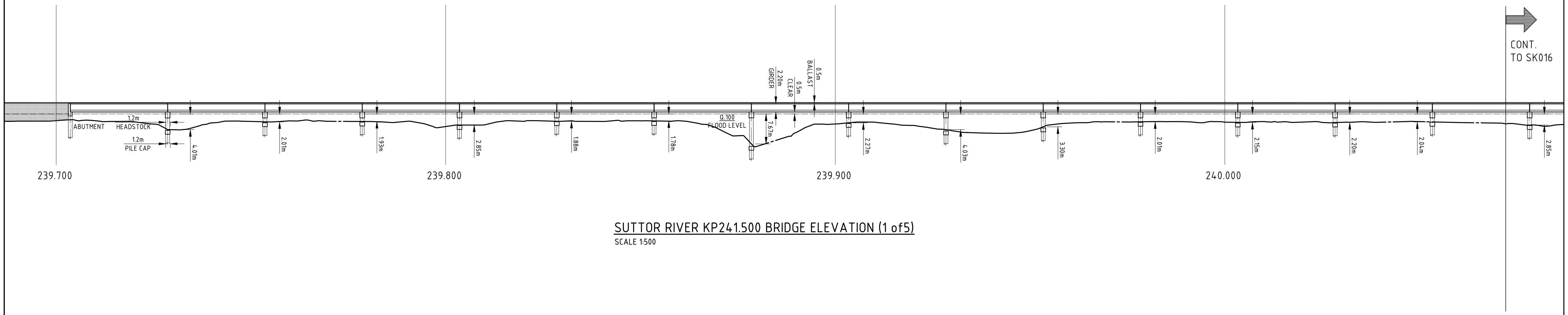
YPB 0126	SK014	01



SUTTOR RIVER KP241.500 BRIDGE PLAN (1 of5)
SCALE 1:500



SUTTOR RIVER KP241.500 BRIDGE ELEVATION (1 of5)
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PROJECT CONCEPTUAL DUAL RAIL BRIDGES
GALILEE COAL PROJECT

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TITLE BRIDGE CONCEPT OVER SUTTOR RIVER
KP-241.500
1 OF 4

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DRAWN	T.N		DEC 2011

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PROJECT NUMBER	DRAWING NUMBER	REVISION
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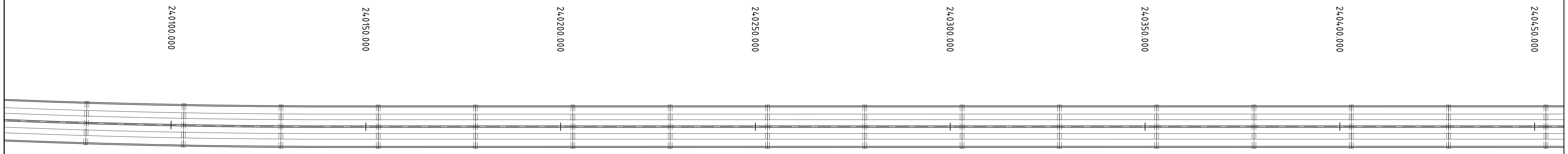
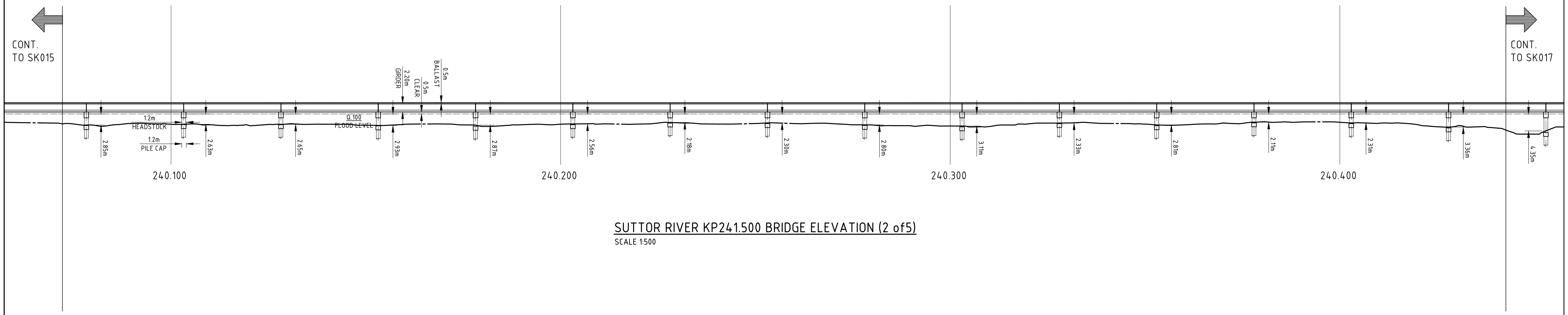


SUTTOR RIVER KP241.500 BRIDGE PLAN (2 of5)
SCALE 1:500



SUTTOR RIVER KP241.500 BRIDGE ELEVATION (2 of5)
SCALE 1:500

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TITLE: BRIDGE CONCEPT OVER SUTTOR RIVER KP-241.500 2 OF 5

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PROJECT NUMBER	DRAWING NUMBER	REVISION
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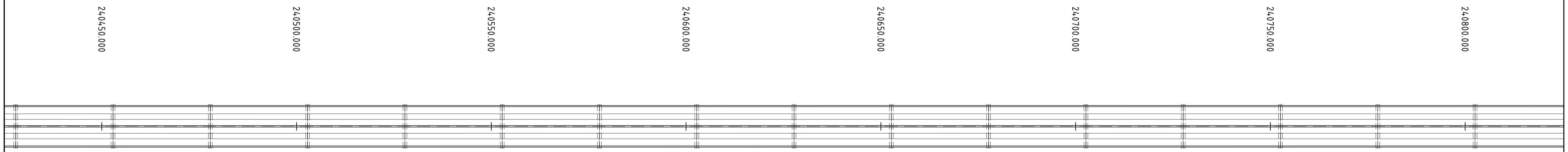
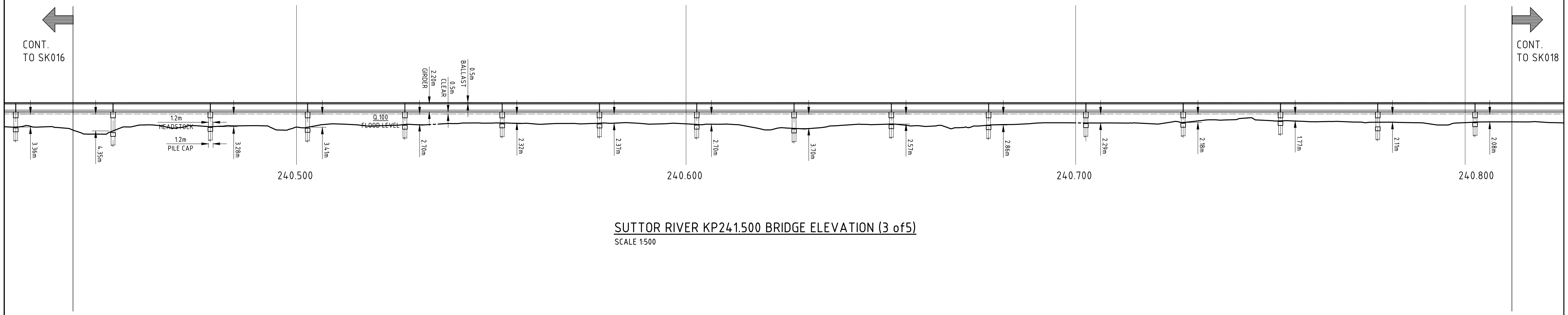


SUTTOR RIVER KP241.500 BRIDGE PLAN (3 of5)

SCALE 1:500



SUTTOR RIVER KP241.500 BRIDGE ELEVATION (3 of5)

SCALE 1:500

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TITLE BRIDGE CONCEPT OVER SUTTOR RIVER KP-241.500 3 OF 4

TASK	BY	INITIAL	DATE
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DRAWN	T.N		DEC 2011

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PROJECT NUMBER	DRAWING NUMBER	REVISION
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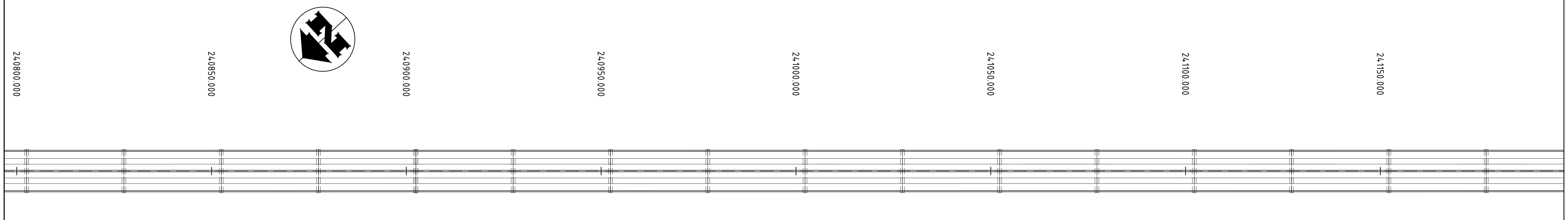
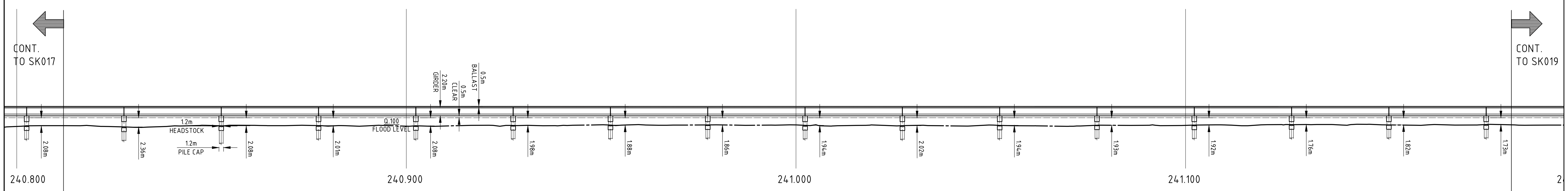


SUTTOR RIVER KP241.500 BRIDGE PLAN (4 of5)
SCALE 1:500



SUTTOR RIVER KP241.500 BRIDGE ELEVATION (4 of5)
SCALE 1:500

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TASK	BY	INITIAL	DATE
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DESIGN	T.G		DEC 2011
DRAWN	T.N		DEC 2011

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PROJECT NUMBER	DRAWING NUMBER	REVISION
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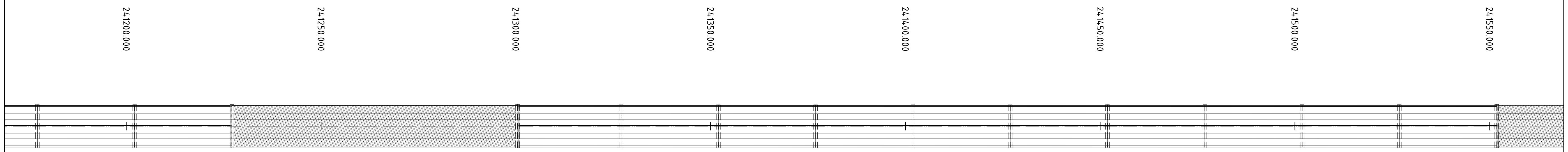
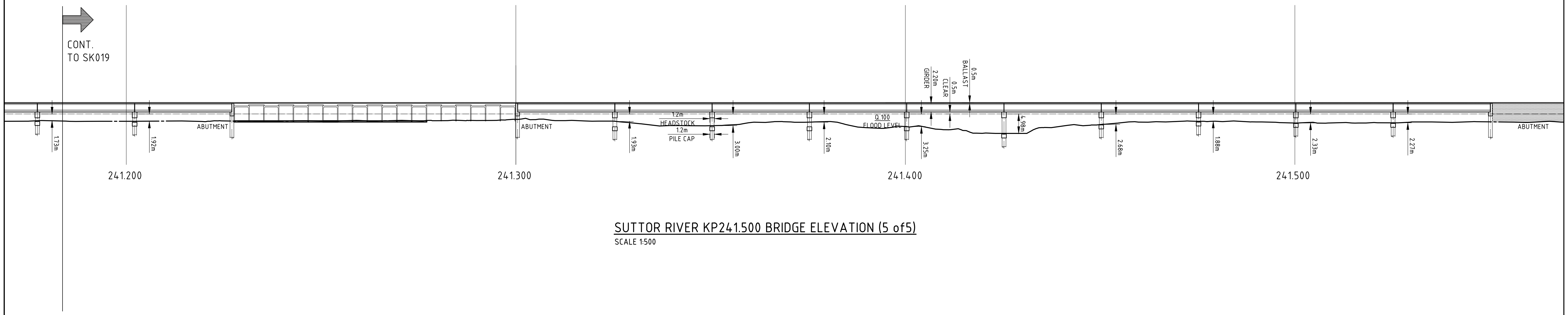


SUTTOR RIVER KP241.500 BRIDGE PLAN (5 of5)

SCALE 1:500



SUTTOR RIVER KP241.500 BRIDGE ELEVATION (5 of5)

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TASK	BY	INITIAL	DATE
REVIEW	XXX		XXX 2011
DESIGN	T.G		DEC 2011
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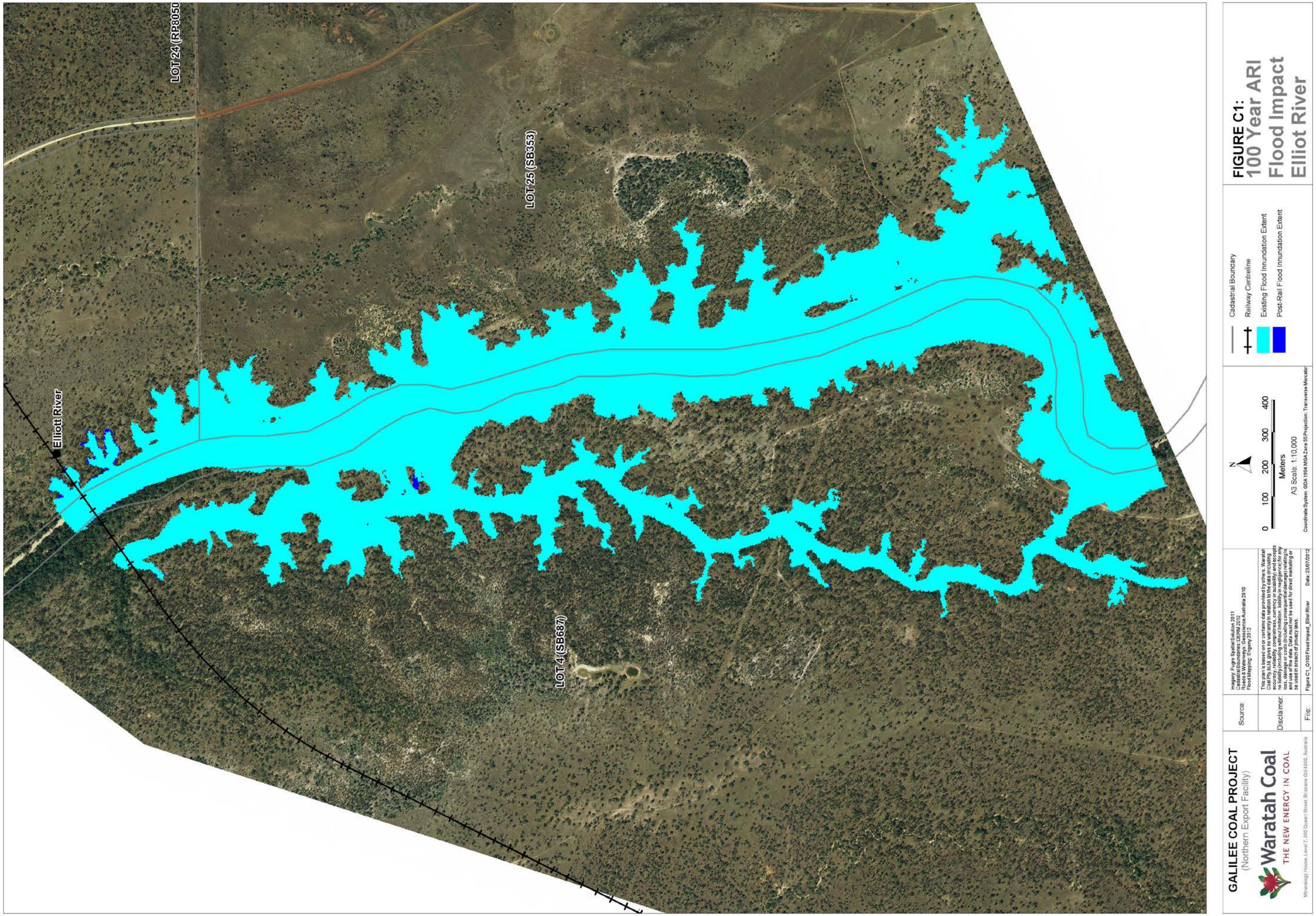
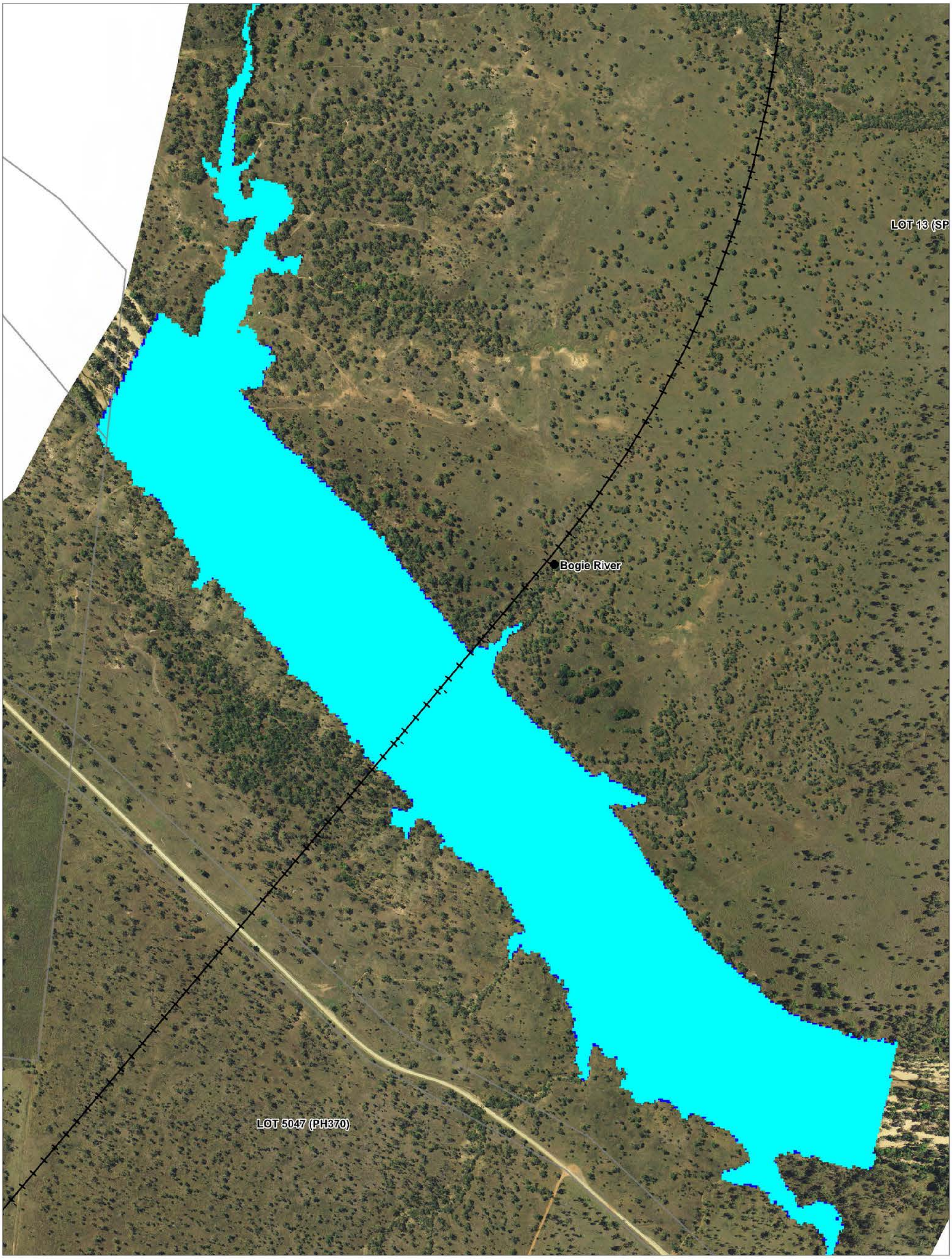
YPB 0126	SK019	01

APPENDIX C

100 Year ARI Flood Impact Mapping


LOT 24 (RP8050
LOT 25 (SB353)
LOT 4 (SB687)
Elliott River
FIGURE C1:
100 Year ARI
Flood Impact
Elliot River
Cadastral Boundary
Railway Centreline
Existing Flood Inundation Extent
Post-Rail Flood Inundation Extent
0 100 200 300 400
Meters
A3 Scale: 1:10,000
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator
Source:
Disclaimer:
File:
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL



GALILEE COAL PROJECT
(Northern Export Facility)

Waratah Coal
THE NEW ENERGY IN COAL

Mineralogy House, Level 7, 360 Queen Street, Brisbane Qld 4000, Australia

Source:	Imagery: Fugro Spatial Solution 2011 Cadastral Boundaries: DERM 2012 Roads & Waterways: Geoscience Australia 2010 Flood Mapping: Engeny 2012
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File:	Figure C2_Q100 Flood Impact_Bogie River Date: 23/07/2012

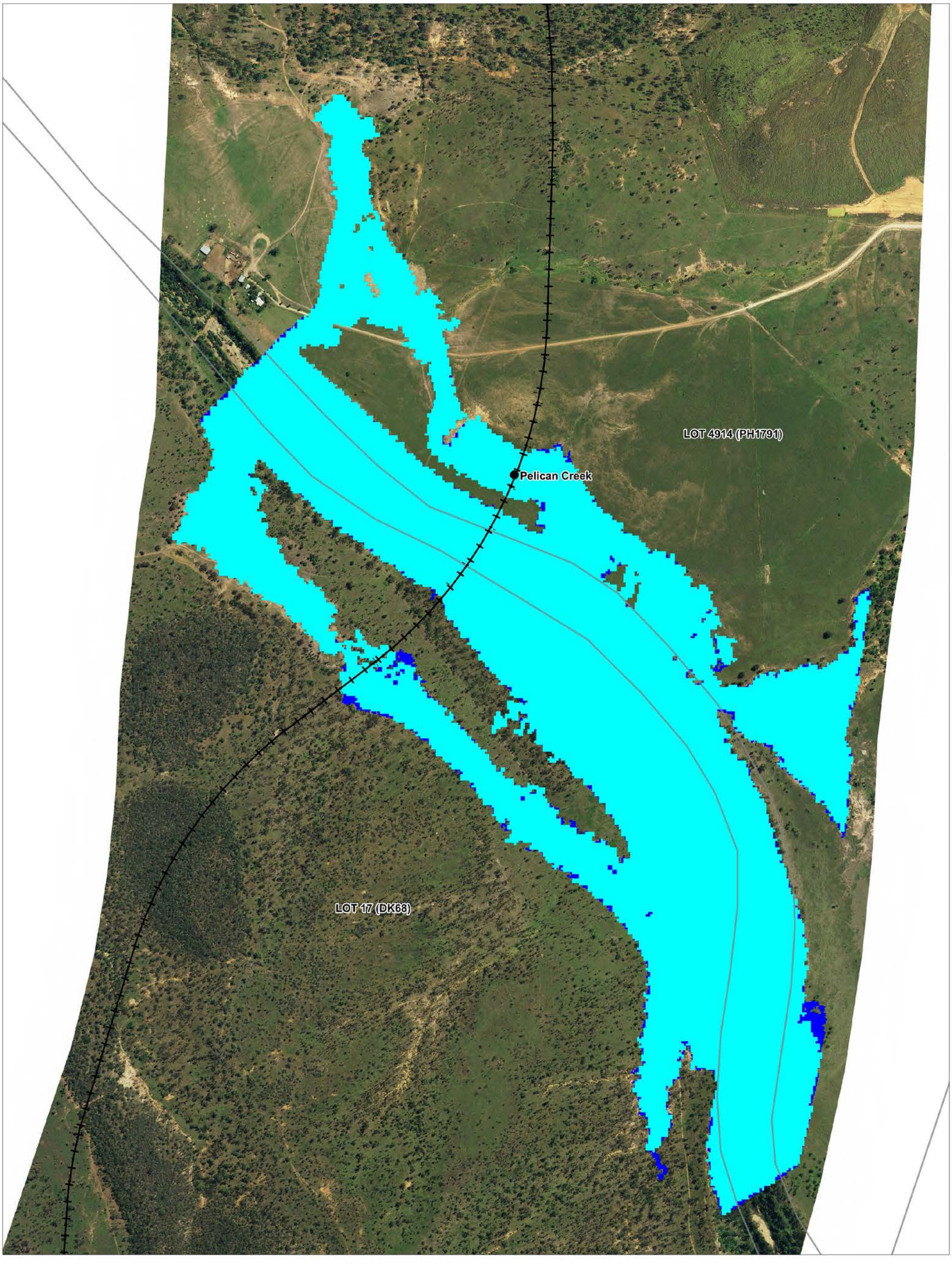
N

0 50 100 150 200
Meters
A3 Scale: 1:5,000

Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator

Cadastral Boundary
Railway Centreline
Existing Flood Innundation Extent
Post-Rail Flood Innundation Extent

FIGURE C2:
100 Year ARI Flood Impact Bogie River



GALILEE COAL PROJECT
(Northern Export Facility)

Waratah Coal
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Source:	Imagery: Fugro Spatial Solution 2011 Cadastral Boundaries: DERM 2012 Roads & Waterways: Geoscience Australia 2010 Flood Mapping: Engeny 2012
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File:	Figure C3_Q100 Flood Impact_Pelican Creek Date: 23/07/2012

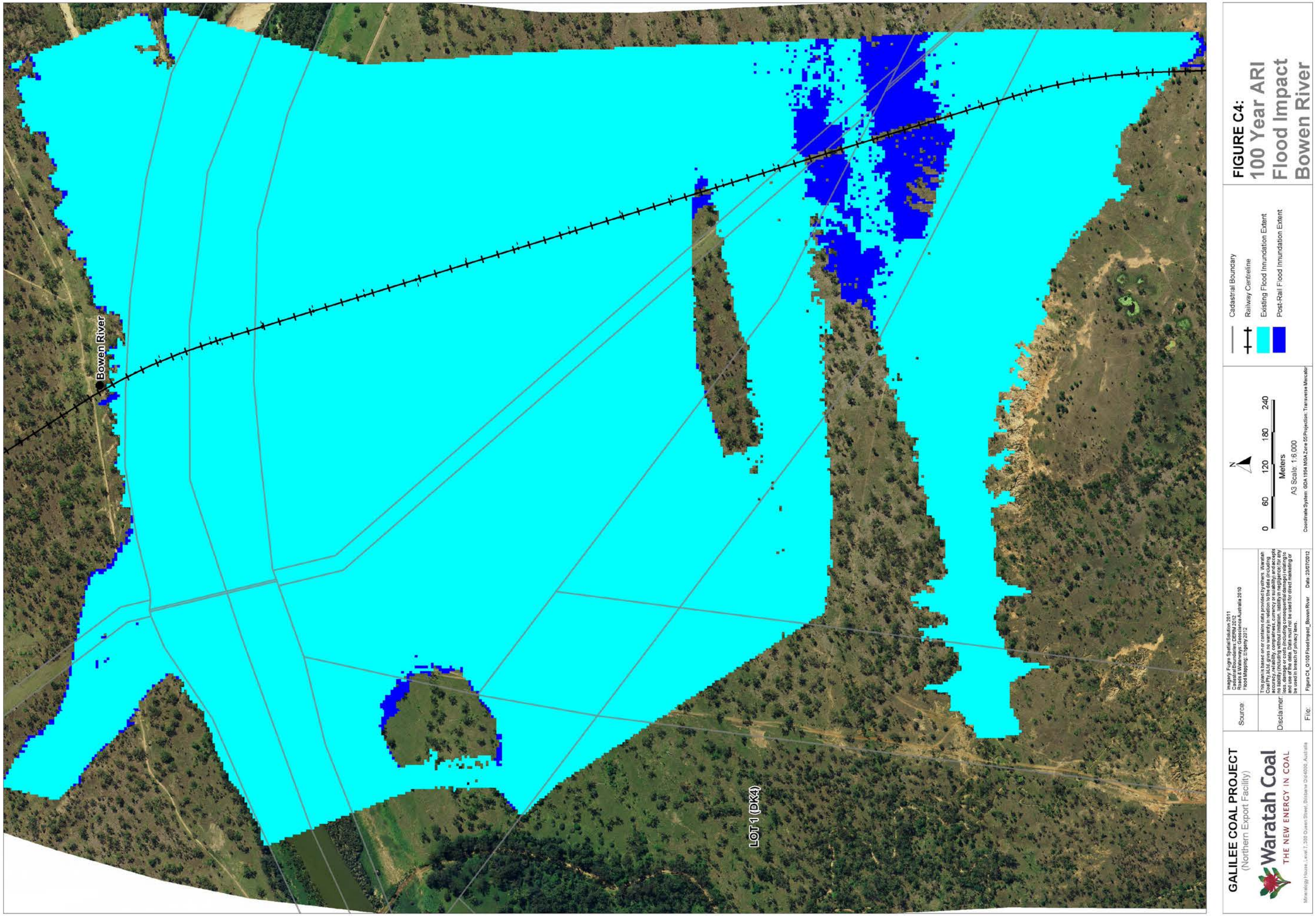
N

0 75 150 225 300
Meters
A3 Scale: 1:7,500

Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator

Cadastral Boundary
Railway Centreline
Existing Flood Innundation Extent
Post-Rail Flood Innundation Extent

FIGURE C3:
100 Year ARI
Flood Impact
Pelican Creek


Bowen River
LOT 1 (DK1)
FIGURE C4:
100 Year ARI
Flood Impact
Bowen River
Cadastral Boundary
Railway Centreline
Existing Flood Inundation Extent
Post-Rail Flood Inundation Extent
N
0 60 120 180 240
Meters
A3 Scale: 1:6 000
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator
Source:
Imagery: Fugro Spatial Solution 2011
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
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File:
Figure C4_Q100 FloodImpact_Bowen River
Date: 23/07/2012
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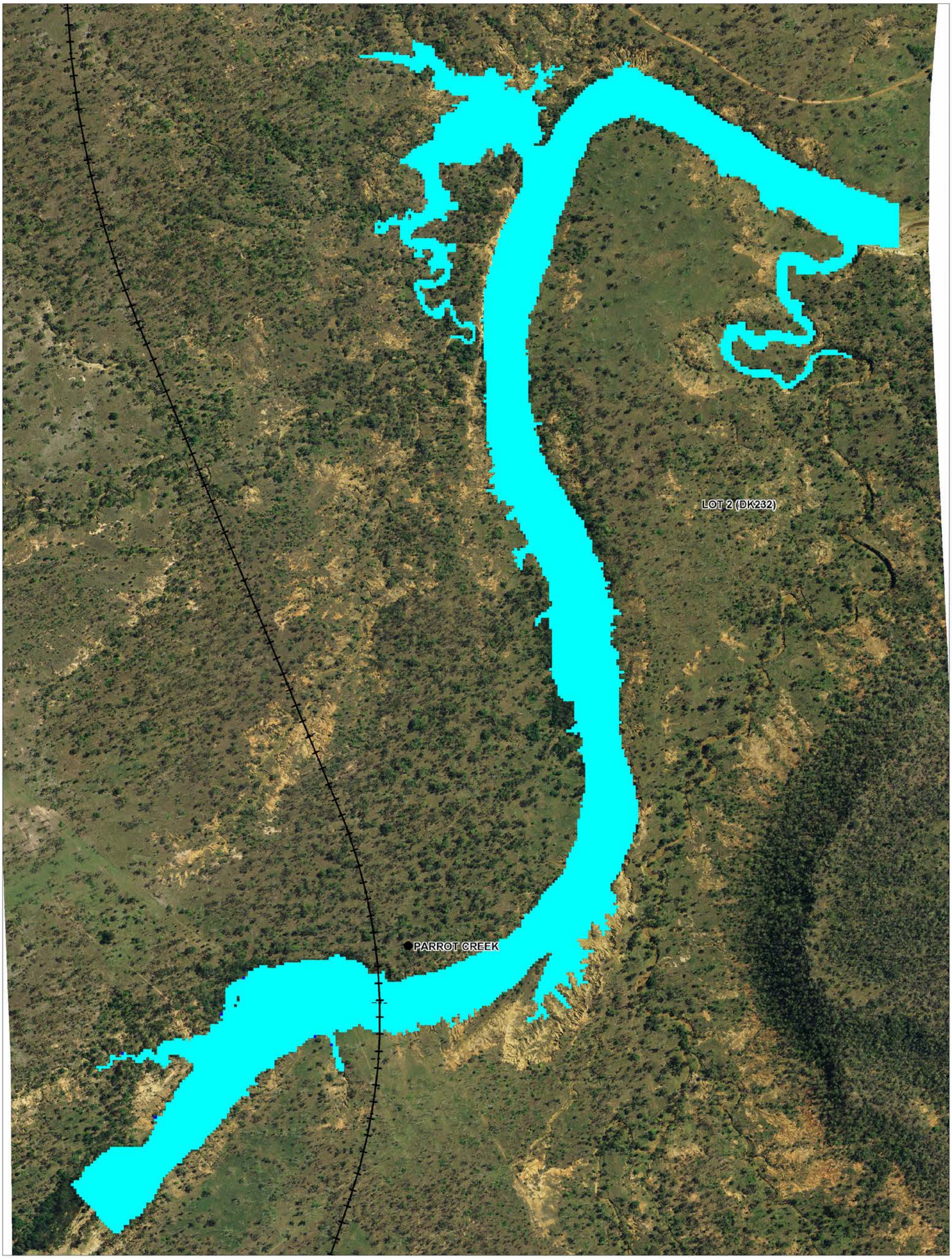
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
Mineralogy House, Level 7, 300 Queen Street, Brisbane Qld 4000, Australia



GALILEE COAL PROJECT
(Northern Export Facility)

Waratah Coal
THE NEW ENERGY IN COAL

Mineralogy House, Level 7, 380 Queen Street, Brisbane Qld 4000, Australia

Source:	Imagery: Fugro Spatial Solution 2011 Cadastral Boundaries: DERM 2012 Roads & Waterways: Geoscience Australia 2010 Flood Mapping: Engeny 2012
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File:	Figure C5_Q100 Flood Impact_Parrot Creek Date: 23/07/2012

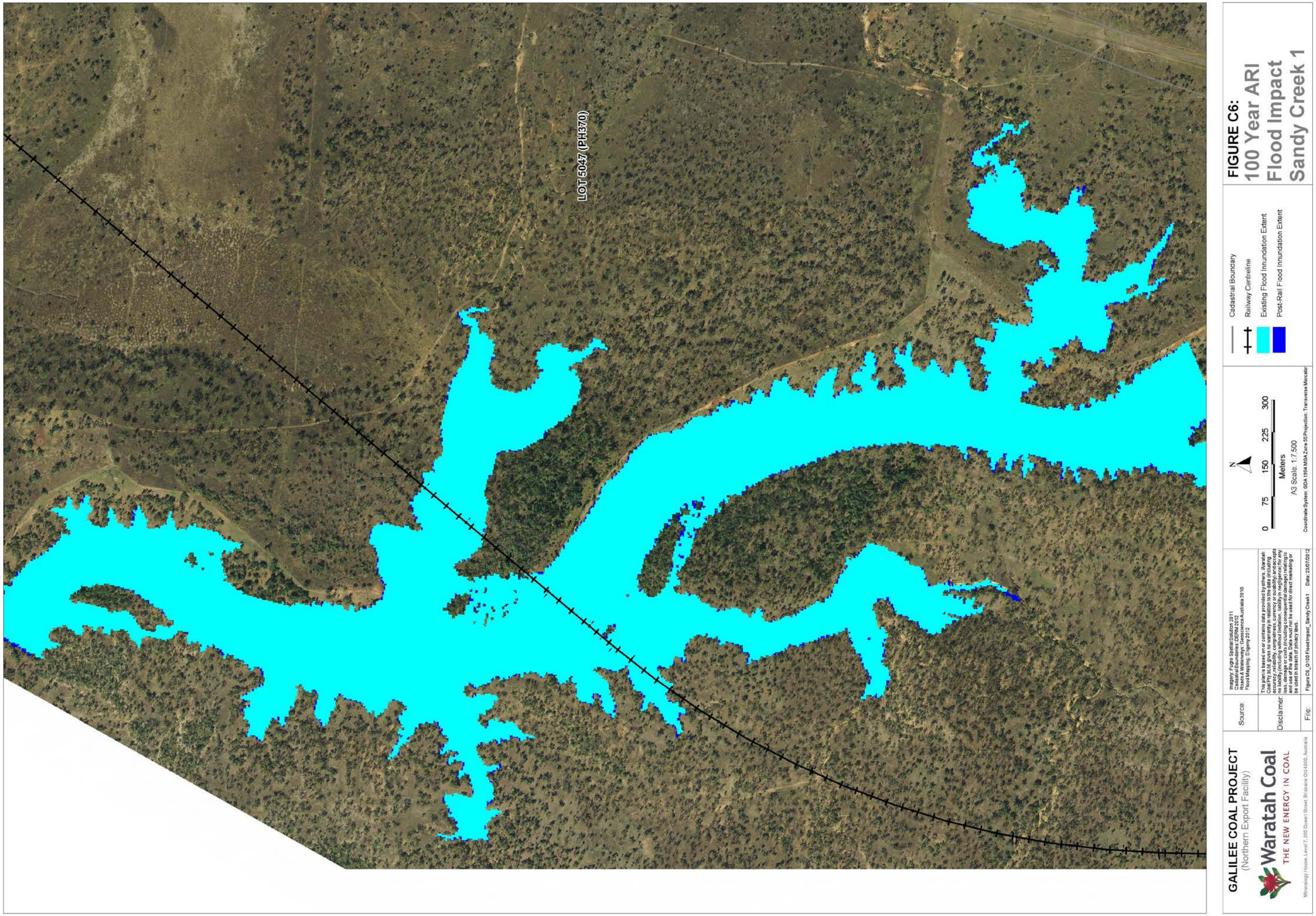
N

0 60 120 180 240
Meters
A3 Scale: 1: 6,000

Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator

- Cadastral Boundary
- Railway Centreline
- Existing Flood Innundation Extent
- Post-Rail Flood Innundation Extent

FIGURE C5:
100 Year ARI Flood Impact Parrot Creek


LOT 5047 (PH370)
FIGURE C6:
100 Year ARI
Flood Impact
Sandy Creek 1
Cadastrial Boundary
Railway Centreline
Existing Flood Innundation Extent
Post-Rail Flood Innundation Extent
N
0 75 150 225 300
Meters
A3 Scale: 1:7,500
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator
Source:
Imagery: Fugro Spatial Solution 2011
Cadastral Bounderies: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012
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File:
Figure C6_Q100 Flood Impact_Sandy Creek 1
Date: 23/07/2012
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(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
Mineralogy House, Level 7, 300 Queen Street, Brisbane Qld 4000, Australia

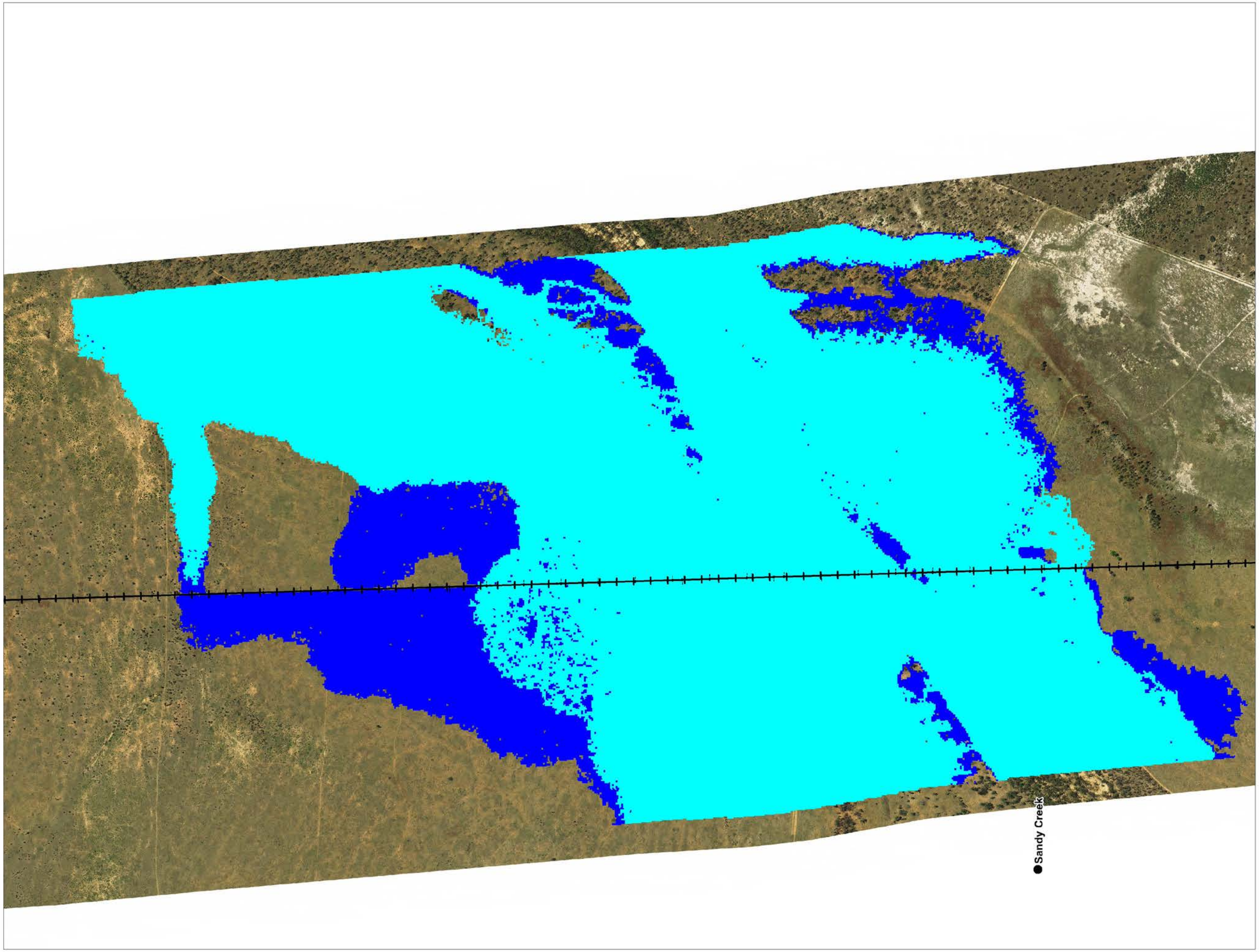

FIGURE C7:
100 Year ARI Flood Impact Sandy Creek 2

Cadastral Boundary
Railway Centreline
Existing Flood Innundation Extent
Post-Rail Flood Innundation Extent

N

0 90 180 270 280
Meters
A3 Scale: 1:9,000
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator

Source: Imagery: Fugro Spatial Solution 2011
Cadastral Boundaries: DERM 2012
Roads & Waterways: Geoscience Australia 2010
Flood Mapping: Engeny 2012

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File: Figure C7_Q100 Flood Impact_Sandy Creek2 Date: 23/07/2012

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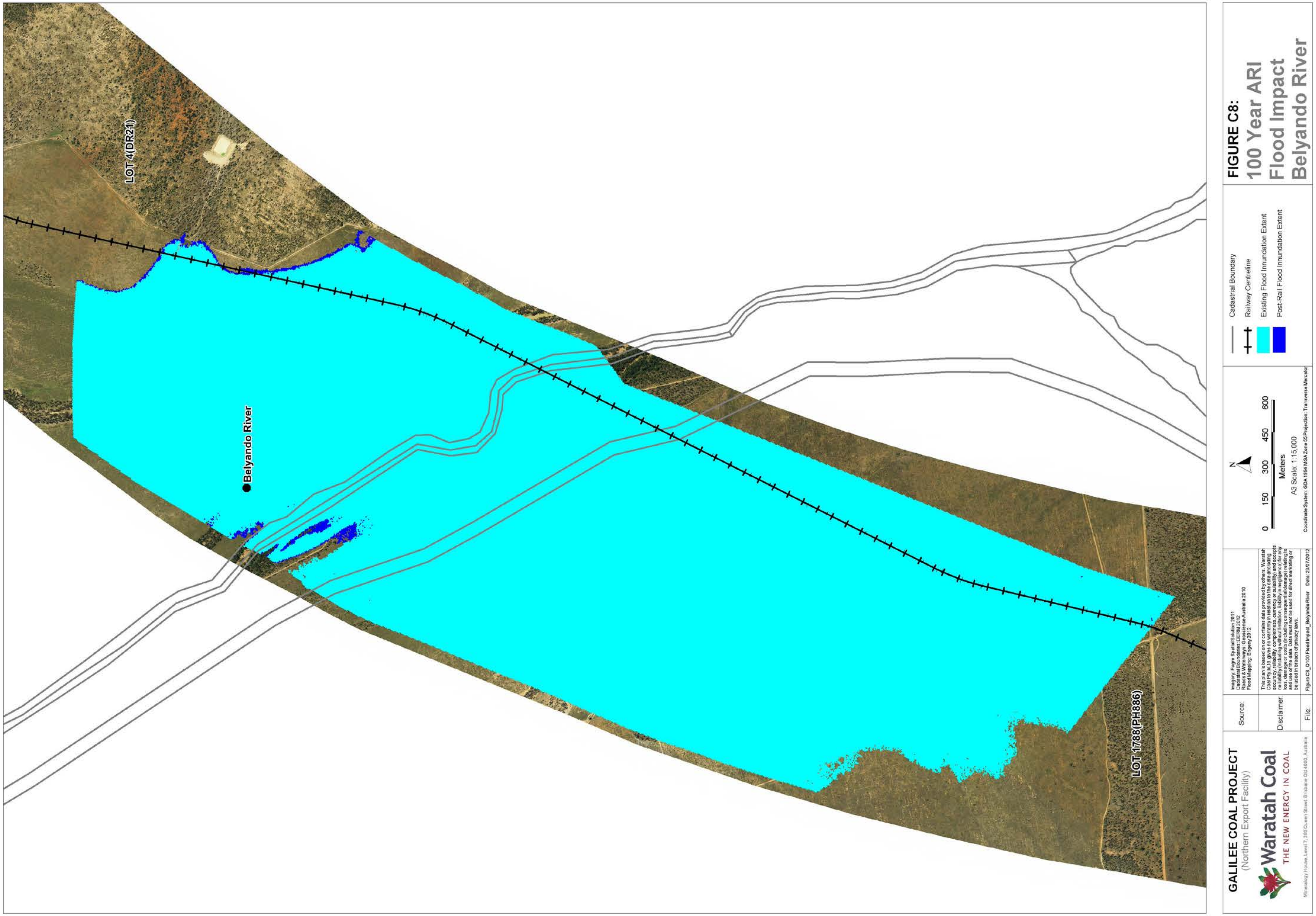
LOT 4(DR21)
Belyando River
LOT 1788(PH886)
FIGURE C8:
100 Year ARI Flood Impact Belyando River
Cadastral Boundary
Railway Centreline
Existing Flood Inundation Extent
Post-Rail Flood Inundation Extent
N
0 150 300 450 600
Meters
A3 Scale: 1:15,000
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator
Source: Imagery: Fugro Spatial Solution 2011 Cadastral Boundaries: DERM 2012 Roads & Waterways: Geoscience Australia 2010 Flood Mapping: Engeny 2012
Disclaimer:
File: Figure C8_Q100 Flood Impact_Belyando River Date: 23/07/2012
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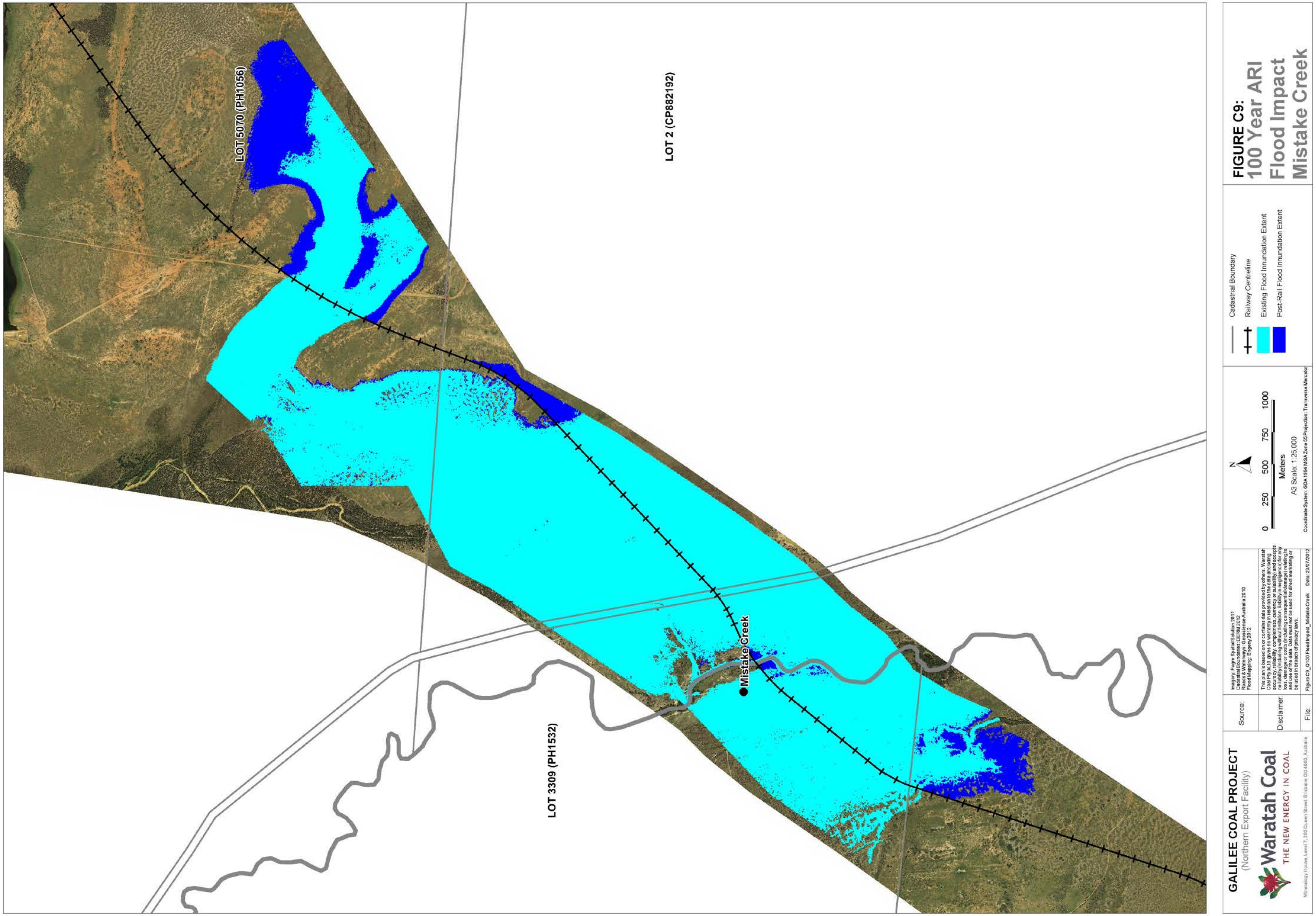
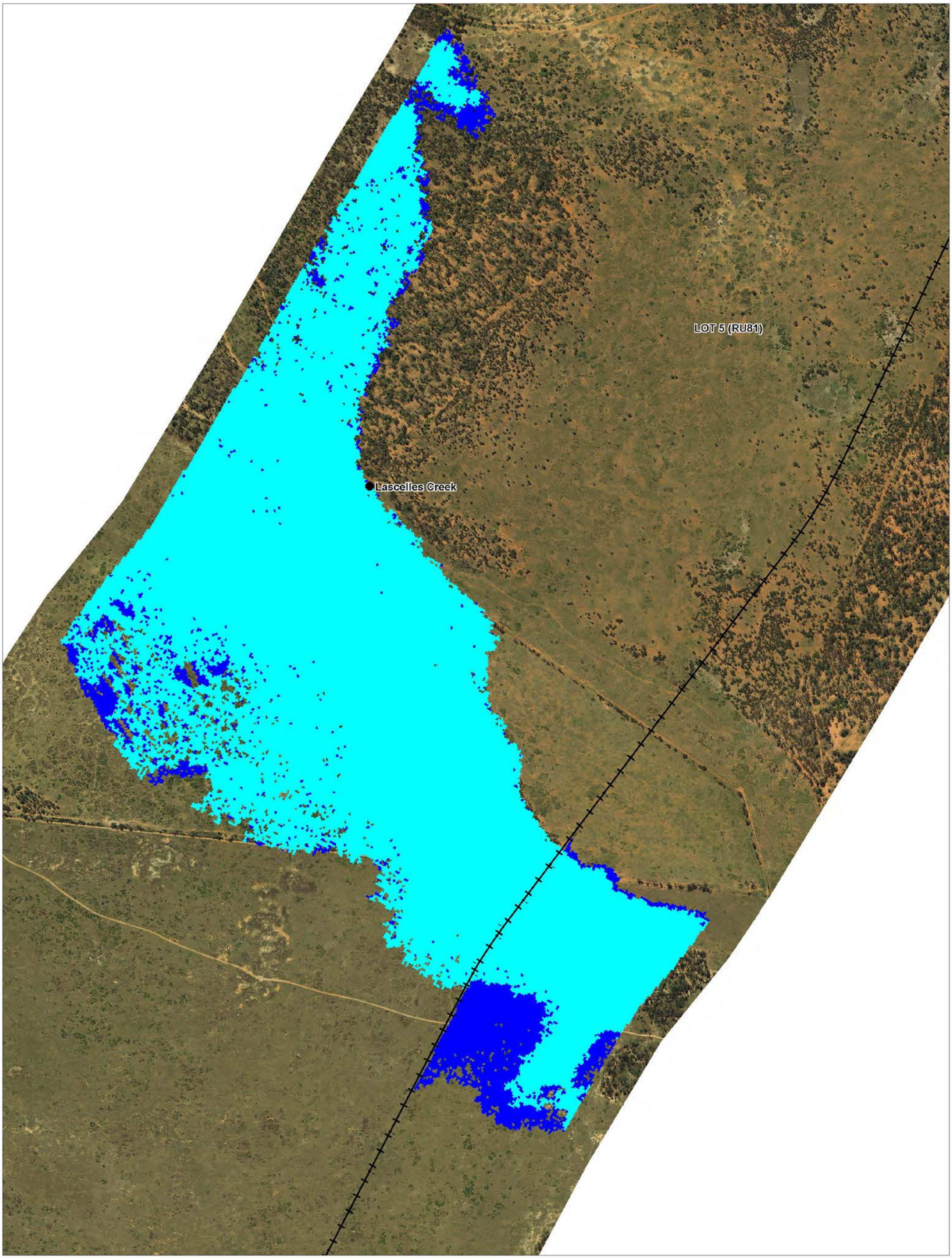
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL


LOT 5070 (PH1056)
LOT 2 (CP882192)
LOT 3309 (PH1532)
Mistake Creek
FIGURE C9:
100 Year ARI
Flood Impact
Mistake Creek
Cadastral Boundary
Railway Centreline
Existing Flood Inundation Extent
Post-Rail Flood Inundation Extent
N
0 250 500 750 1000
Meters
A3 Scale: 1:25,000
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
Source:
Disclaimer:
File:



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Source:	Imagery: Fugro Spatial Solution 2011 Cadastral Boundaries: DERM 2012 Roads & Waterways: Geoscience Australia 2010 Flood Mapping: Engeny 2012
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File:	Figure C10_Q100 Flood Impact_Lascelles Creek Date: 23/07/2012

N

0 75 150 225 300
Meters
A3 Scale: 1:7,500
Coordinate System: GDA 1994 MGA Zone 55 Projection: Transverse Mercator

Cadastral Boundary
Railway Centreline
Existing Flood Innundation Extent
Post-Rail Flood Innundation Extent

FIGURE C10:
100 Year ARI Flood Impact Lascelles Creek

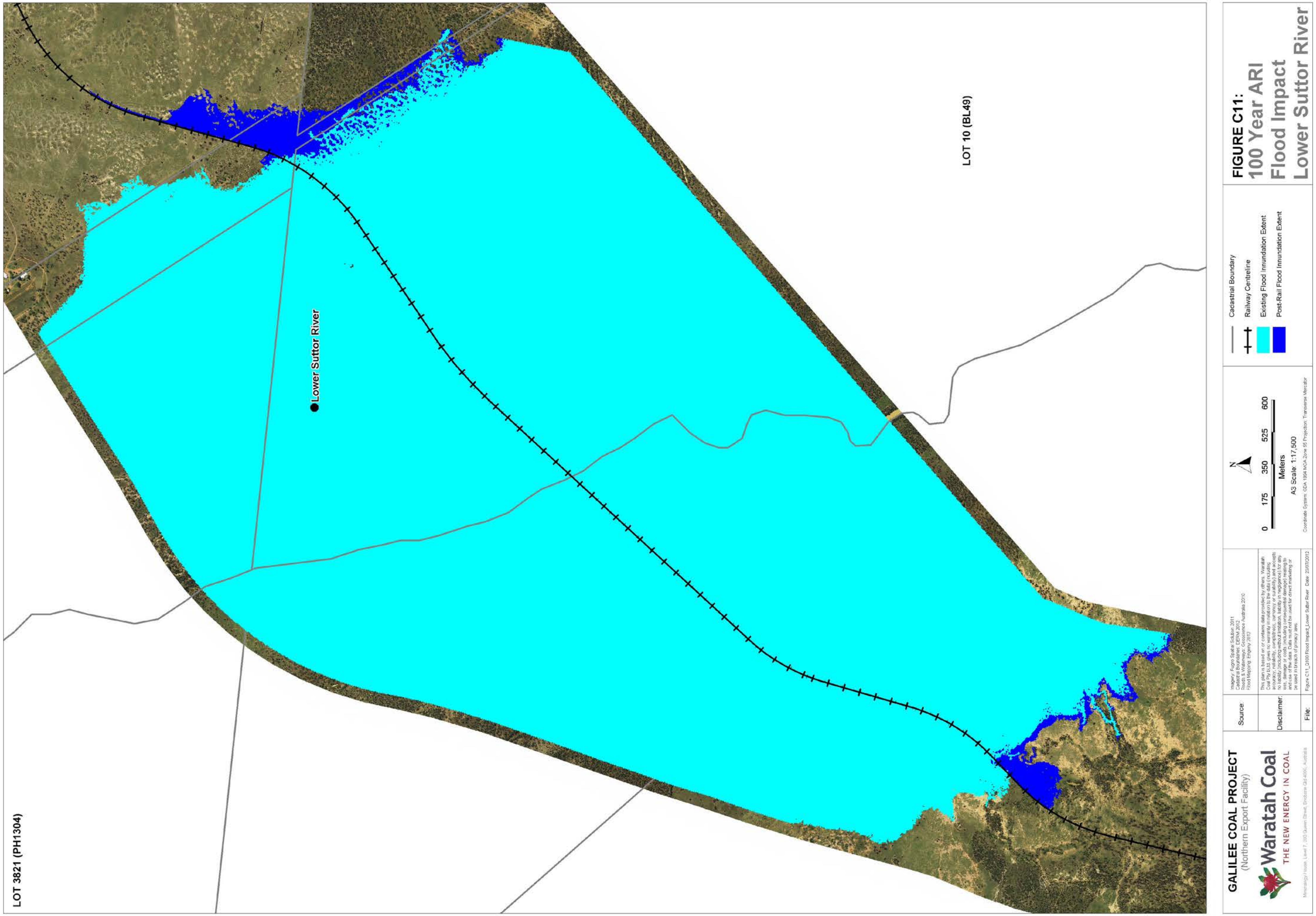
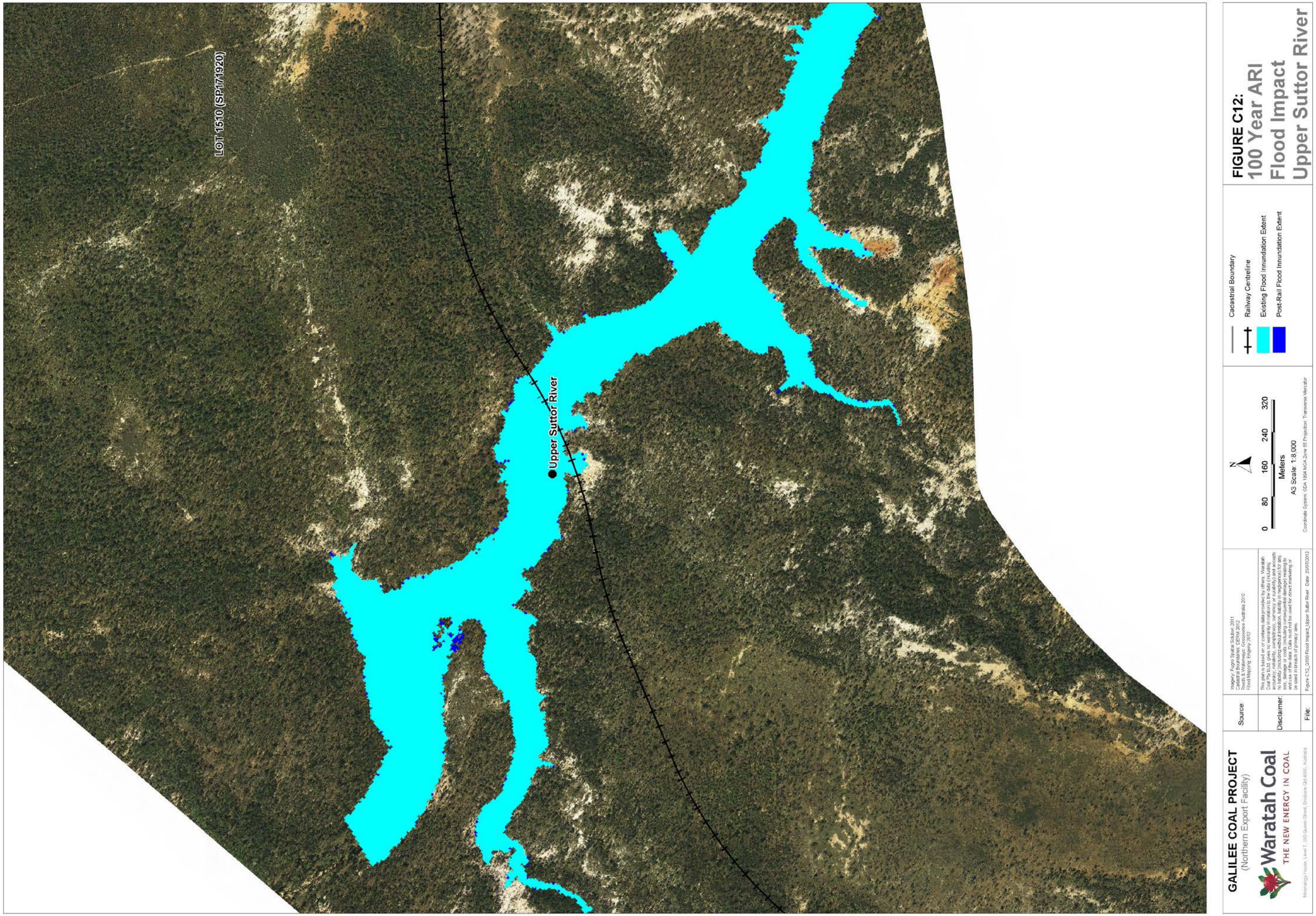


FIGURE C11:
100 Year ARI
Flood Impact
Lower Suttor River
Cadastral Boundary
Railway Centreline
Existing Flood Inundation Extent
Post-Rail Flood Inundation Extent
Meters
A3 Scale: 1:17,500
GALILEE COAL PROJECT
(Northern Export Facility)
Waratah Coal
THE NEW ENERGY IN COAL
Source:
Disclaimer:
File:
LOT 10 (BL49)
LOT 3821 (PH1304)
Lower Suttor River


LOT 1510 (SP171920)
Upper Suttor River
FIGURE C12:
100 Year ARI
Flood Impact
Upper Suttor River
Cadastrial Boundary
Railway Centreline
Existing Flood Innundation Extent
Post-Rail Flood Innundation Extent
N
0 80 160 240 320
Meters
A3 Scale: 1:8,000
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Source:
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File:

APPENDIX D

Minor Culvert Schedule

WARATAH COAL

RAIL CORRIDOR CROSS DRAINAGE

ENGENY WATER MANAGEMENT

Culvert ID	Catchment Area (km^2)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m^3s)	100 Yr ARI Peak Flow Rate Estimate (m^3s)	Preliminary Waterway Opening Size (m^2)
C3100	6.85	7.74	121.2	152.8	57.7
C3300	0.09	7.74	7.1	9.4	3.4
C4500	18.28	7.74	230.8	287.5	109.9
C5100	0.84	7.74	30.7	39.7	14.6
C5700	0.42	7.74	19.4	25.3	9.2
C6310	1.34	7.74	41.5	53.3	19.8
C6400	0.03	7.74	3.6	4.8	1.7
C6600	0.51	7.74	22.1	28.7	10.5
C6800	0.08	7.74	6.4	8.5	3.0
C7300	3.54	7.74	78.5	99.8	37.4
C7700	0.28	7.74	14.9	19.6	7.1
C8100	1.87	7.74	51.7	66.2	24.6
C8310	0.47	7.74	21.0	27.3	10.0
C9300	0.36	7.74	17.5	22.8	8.3
C9600	0.28	7.74	14.8	19.4	7.1
C9900	6.72	7.74	119.7	150.9	57.0
C10100	5.37	7.74	103.3	130.6	49.2
C11400	3.07	7.74	71.6	91.1	34.1
C12500	0.78	7.74	29.1	37.7	13.9
C18900	0.11	7.74	7.9	10.5	3.8
C19400	0.08	7.74	6.5	8.6	3.1
C19700	0.08	7.74	6.8	9.0	3.2
C20200	0.05	7.74	5.0	6.7	2.4
C20400	0.05	7.74	5.0	6.7	2.4
C21100	0.17	7.74	10.8	14.2	5.1

WARATAH COAL
RAIL CORRIDOR CROSS DRAINAGE

ENGENY WATER MANAGEMENT

Culvert ID	Catchment Area (km^2)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m^3s)	100 Yr ARI Peak Flow Rate Estimate (m^3s)	Preliminary Waterway Opening Size (m^2)
C22200	0.08	7.74	6.6	8.8	3.1
C22300	0.14	7.74	9.6	12.7	4.6
C22800	0.04	7.74	4.4	5.9	2.1
C22900	0.03	7.74	3.6	4.9	1.7
C23200	0.17	7.74	10.6	14.0	5.0
C23700	0.02	7.74	2.5	3.4	1.2
C23800	0.01	7.74	1.9	2.6	0.9
C23900	0.05	7.74	4.7	6.2	2.2
C24500	0.03	7.74	3.3	4.4	1.6
C24600	0.10	7.74	7.7	10.3	3.7
C25300	1.55	7.74	45.8	58.8	21.8
C25400	0.06	7.74	5.3	7.0	2.5
C25500	0.01	7.74	2.0	2.7	1.0
C25600	0.02	7.74	2.6	3.5	1.2
C25700	0.02	7.74	3.0	4.0	1.4
C26100	0.42	7.74	19.4	25.3	9.2
C26200	0.03	7.74	3.1	4.2	1.5
C26300	0.31	7.74	15.8	20.6	7.5
C26700	0.02	7.74	2.8	3.8	1.3
C26900	0.82	7.74	30.1	38.9	14.3
C27800	0.06	7.74	5.6	7.5	2.7
C29200	0.34	7.74	17.0	22.2	8.1
C29900	2.52	7.74	62.9	80.3	30.0
C30600	1.59	7.74	46.6	59.8	22.2
C30900	0.02	7.74	2.3	3.1	1.1

WARATAH COAL

RAIL CORRIDOR CROSS DRAINAGE

Culvert ID	Catchment Area (km²)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m³s)	100 Yr ARI Peak Flow Rate Estimate (m³s)	Preliminary Waterway Opening Size (m²)
C30900	0.02	7.74	2.8	3.8	1.3
C31510	0.35	7.74	17.2	22.5	8.2
C31700	0.06	7.74	5.2	7.0	2.5
C32100	0.09	7.74	7.3	9.7	3.5
C32500	0.62	7.74	25.1	32.6	12.0
C34100	0.26	7.74	14.3	18.8	6.8
C34300	0.16	7.74	10.4	13.7	4.9
C35100	0.26	7.74	14.1	18.6	6.7
C35700	15.20	7.74	204.5	255.3	97.4
C36200	1.11	7.74	36.8	47.4	17.5
C36800	0.57	7.74	23.8	30.9	11.3
C37300	1.00	7.74	34.3	44.2	16.3
C39900	0.17	7.74	10.8	14.3	5.2
C46500	0.03	7.74	3.7	4.9	1.7
C46600	0.09	7.74	7.0	9.3	3.3
C47100	0.09	7.74	7.1	9.4	3.4
C47300	0.07	7.74	5.8	7.7	2.7
C47400	0.50	7.74	21.8	28.3	10.4
C47600	0.02	7.74	2.8	3.8	1.4
C47800	0.08	7.74	6.7	8.9	3.2
C48100	0.05	7.74	5.1	6.8	2.4
C48300	0.37	7.74	17.7	23.2	8.4
C48400	0.03	7.74	3.3	4.5	1.6
C48600	0.09	7.74	7.0	9.4	3.4
C49200	3.12	7.74	72.3	92.1	34.4

Culvert ID	Catchment Area (km²)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m³s)	100 Yr ARI Peak Flow Rate Estimate (m³s)	Preliminary Waterway Opening Size (m²)
C49800	0.15	7.74	9.8	12.9	4.7
C50200	14.45	7.91	202.0	252.0	96.2
C50600	0.05	7.91	4.7	6.3	2.2
C50900	7.58	7.91	132.3	166.4	63.0
C51200	0.04	7.91	4.0	5.3	1.9
C51500	0.01	7.91	1.9	2.6	0.9
C52400	2.70	7.91	67.2	85.6	32.0
C52700	0.95	7.91	33.9	43.7	16.1
C52900	0.36	7.91	18.1	23.5	8.6
C54100	0.18	7.91	11.2	14.7	5.3
C54200	0.04	7.91	3.9	5.3	1.9
C54300	0.06	7.91	5.4	7.2	2.6
C56100	6.60	7.91	120.8	152.1	57.5
C56700	0.01	7.91	1.7	2.3	0.8
C57100	0.10	7.91	7.9	10.5	3.8
C57400	0.01	7.91	2.1	2.9	1.0
C57600	5.01	7.91	100.8	127.4	48.0
C57800	0.01	7.91	1.2	1.7	0.6
C57900	0.01	7.91	1.5	2.1	0.7
C57900	0.01	7.91	1.1	1.5	0.5
C58600	0.07	7.91	5.8	7.8	2.8
C59500	0.45	7.91	20.6	26.8	9.8
C59600	0.03	7.91	3.2	4.3	1.5
C59900	0.95	7.91	34.0	43.8	16.2
C60500	4.23	7.91	90.2	114.2	43.0

WARATAH COAL
RAIL CORRIDOR CROSS DRAINAGE

ENGENY WATER MANAGEMENT

Culvert ID	Catchment Area (km²)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m³s)	100 Yr ARI Peak Flow Rate Estimate (m³s)	Preliminary Waterway Opening Size (m²)
C61200	9.01	7.91	148.2	185.9	70.6
C64100	2.13	7.91	57.4	73.3	27.4
C64700	0.41	7.91	19.5	25.4	9.3
C64900	0.13	7.91	9.1	12.1	4.3
C65500	0.13	7.91	9.1	12.1	4.4
C65700	0.10	7.91	7.6	10.1	3.6
C65900	0.10	7.91	7.9	10.5	3.8
C66200	0.33	7.91	16.9	22.1	8.1
C67300	0.24	7.91	13.8	18.0	6.6
C68200	5.75	7.91	110.3	139.2	52.5
C69400	31.19	7.91	334.6	413.6	159.3
C80300	0.54	7.91	23.4	30.4	11.2
C81700	0.43	7.91	20.2	26.3	9.6
C82800	3.04	7.91	72.6	92.3	34.6
C83300	0.68	7.91	27.3	35.3	13.0
C85200	0.31	7.91	16.1	21.0	7.7
C85600	0.13	7.91	9.1	12.0	4.3
C86500	0.65	7.91	26.3	34.1	12.5
C87500	1.39	7.91	43.5	55.9	20.7
C89900	1.19	7.91	39.3	50.5	18.7
C90600	1.60	7.91	47.6	61.0	22.7
C93900	14.82	7.91	205.4	256.1	97.8
C95500	6.78	7.91	122.9	154.7	58.5
C96500	2.42	7.91	62.5	79.6	29.7
C96700	0.57	7.91	24.3	31.5	11.6

Culvert ID	Catchment Area (km^2)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m^3s)	100 Yr ARI Peak Flow Rate Estimate (m^3s)	Preliminary Waterway Opening Size (m^2)
C97900	1.10	7.91	37.2	47.9	17.7
C105600	0.26	4.9	9.1	12.4	4.3
C106600	0.15	4.9	6.2	8.5	3.0
C106900	7.69	4.9	84.0	109.2	40.0
C107800	1.01	4.9	22.1	29.4	10.5
C107900	0.11	4.9	5.3	7.3	2.5
C108600	0.19	4.9	7.5	10.1	3.6
C108900	0.16	4.9	6.7	9.1	3.2
C109100	0.16	4.9	6.6	8.9	3.1
C109600	0.83	4.9	19.4	25.9	9.3
C110100	0.15	4.9	6.4	8.8	3.1
C110200	0.01	4.9	1.1	1.6	0.5
C110300	0.03	4.9	2.3	3.2	1.1
C110500	0.11	4.9	5.2	7.1	2.5
C110700	0.16	4.9	6.8	9.2	3.2
C110800	0.04	4.9	2.8	3.8	1.3
C111100	0.10	4.9	4.8	6.5	2.3
C111900	3.68	4.9	51.8	67.9	24.7
C112800	0.95	4.9	21.3	28.4	10.2
C113400	0.39	4.9	11.8	15.9	5.6
C115100	2.77	4.9	43.0	56.6	20.5
C117100	0.22	4.9	8.1	10.9	3.8
C117600	2.49	4.9	40.1	52.8	19.1
C118500	0.93	4.9	20.9	27.9	10.0
C119900	1.90	4.9	33.5	44.3	16.0

WARATAH COAL

RAIL CORRIDOR CROSS DRAINAGE

ENGENY WATER MANAGEMENT

Culvert ID	Catchment Area (km²)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m³s)	100 Yr ARI Peak Flow Rate Estimate (m³s)	Preliminary Waterway Opening Size (m²)
C120100	3.27	4.9	47.9	62.9	22.8
C120800	3.05	4.9	45.8	60.2	21.8
C120900	2.54	4.9	40.6	53.4	19.3
C121100	1.79	4.9	32.2	42.6	15.4
C121400	1.41	4.9	27.6	36.6	13.1
C123300	8.99	4.9	93.0	120.7	44.3
C124100	0.03	4.9	2.3	3.2	1.1
C124100	0.01	4.9	1.2	1.6	0.6
C124200	0.02	4.9	1.6	2.2	0.8
C124300	0.03	4.9	2.2	3.1	1.1
C124300	0.07	4.9	4.0	5.5	1.9
C124500	0.04	4.9	2.5	3.5	1.2
C124600	0.15	4.9	6.4	8.7	3.0
C125200	0.17	4.9	6.8	9.3	3.3
C125600	0.28	4.9	9.7	13.1	4.6
C126200	0.12	4.9	5.5	7.5	2.6
C127200	0.49	4.9	13.7	18.4	6.5
C127700	0.39	4.9	11.9	16.1	5.7
C128100	0.04	4.9	2.5	3.5	1.2
C128100	0.04	4.9	2.5	3.5	1.2
C128200	0.06	4.9	3.6	5.0	1.7
C129700	1.97	4.9	34.4	45.4	16.4
C129900	0.50	4.9	13.9	18.7	6.6
C130800	0.19	4.9	7.3	9.9	3.5
C131100	1.83	4.9	32.7	43.3	15.6

Culvert ID	Catchment Area (km^2)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m^3s)	100 Yr ARI Peak Flow Rate Estimate (m^3s)	Preliminary Waterway Opening Size (m^2)
C131400	0.12	4.9	5.5	7.5	2.6
C132100	0.02	4.9	1.5	2.0	0.7
C132500	0.80	4.9	19.0	25.3	9.0
C132700	0.91	4.9	20.7	27.5	9.8
C137600	0.74	4.9	18.0	24.1	8.6
C138200	0.81	4.9	19.3	25.7	9.2
C140900	0.13	4.9	5.8	7.9	2.8
C141700	1.65	4.9	30.6	40.4	14.6
C142700	3.71	4.9	52.1	68.3	24.8
C143400	1.54	4.9	29.2	38.7	13.9
C144700	0.96	4.9	21.5	28.6	10.2
C145700	0.38	4.9	11.7	15.7	5.5
C145900	0.23	4.9	8.4	11.3	4.0
C146900	2.50	4.9	40.2	52.9	19.1
C151100	1.65	5.2	32.4	42.8	15.4
C153200	2.20	5.2	39.2	51.5	18.7
C156100	1.12	5.2	25.2	33.4	12.0
C156700	0.98	5.2	23.1	30.6	11.0
C157400	0.96	5.2	22.7	30.2	10.8
C160400	2.15	5.2	38.6	50.7	18.4
C160700	0.18	5.2	7.5	10.2	3.6
C161200	2.31	5.2	40.5	53.1	19.3
C164600	2.04	5.2	37.3	49.0	17.8
C164900	1.67	5.2	32.6	43.0	15.5
C166100	1.19	5.2	26.1	34.6	12.4

ENGENY WATER MANAGEMENT

WARATAH COAL
RAIL CORRIDOR CROSS DRAINAGE

Culvert ID	Catchment Area (km²)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m³s)	100 Yr ARI Peak Flow Rate Estimate (m³s)	Preliminary Waterway Opening Size (m²)
C167900	4.08	5.2	58.7	76.6	28.0
C168400	0.09	5.2	4.7	6.4	2.2
C168800	0.58	5.2	16.4	21.8	7.8
C170200	3.79	5.2	56.0	73.0	26.6
C170600	11.63	5.2	116.7	150.3	55.6
C171400	1.21	5.2	26.5	35.0	12.6
C172300	0.57	5.2	16.2	21.6	7.7
C173100	0.17	5.2	7.2	9.7	3.4
C173900	0.36	5.2	12.0	16.1	5.7
C174800	0.36	5.2	12.0	16.1	5.7
C175800	1.76	5.2	33.8	44.5	16.1
C175900	0.33	5.2	11.2	15.1	5.4
C176900	0.34	5.2	11.6	15.6	5.5
C177500	0.11	5.2	5.5	7.5	2.6
C177800	0.13	5.2	6.2	8.5	3.0
C178400	0.20	5.2	8.1	10.9	3.8
C178900	0.93	5.2	22.3	29.6	10.6
C179500	0.16	5.2	7.0	9.4	3.3
C180200	0.08	5.2	4.6	6.3	2.2
C180600	0.55	5.2	15.8	21.1	7.5
C181500	0.40	5.2	12.9	17.3	6.1
C181200	0.90	5.2	21.8	28.9	10.4
C183100	0.67	5.2	18.0	23.9	8.6
C184400	0.77	5.2	19.6	26.1	9.3
C184900	1.27	5.2	27.3	36.0	13.0

WARATAH COAL

RAIL CORRIDOR CROSS DRAINAGE

ENGENY WATER MANAGEMENT

Culvert ID	Catchment Area (km^2)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m^3s)	100 Yr ARI Peak Flow Rate Estimate (m^3s)	Preliminary Waterway Opening Size (m^2)
C185300	2.81	5.2	46.0	60.3	21.9
C185500	0.03	5.2	2.3	3.2	1.1
C185700	0.15	5.2	6.7	9.1	3.2
C185900	0.47	5.2	14.2	19.0	6.8
C188100	1.70	5.2	33.1	43.6	15.7
C188400	0.65	5.2	17.6	23.4	8.4
C192100	0.89	5.2	21.7	28.8	10.3
C194200	2.13	5.2	38.3	50.3	18.2
C195300	1.70	5.2	33.0	43.5	15.7
C196200	7.41	5.2	86.8	112.4	41.3
C200100	0.56	3.96	12.3	16.7	5.9
C200700	1.36	3.96	21.9	29.5	10.4
C201700	2.83	3.96	35.4	47.3	16.9
C233600	6.29	3.96	59.9	79.2	28.5
C235300	11.48	3.96	88.9	116.7	42.3
C237000	1.60	3.96	24.4	32.7	11.6
C237700	0.07	3.96	3.1	4.3	1.5
C238300	0.05	3.96	2.4	3.4	1.1
C238400	0.67	3.96	13.9	18.8	6.6
C239500	1.36	3.96	21.9	29.5	10.4
C240600	1.13	3.96	19.4	26.2	9.2
C241200	28.22	3.96	160.4	208.2	76.4
C243400	2.24	3.96	30.4	40.7	14.5
C246300	0.47	3.96	11.0	15.0	5.2
C247900	0.69	3.96	14.0	19.0	6.7

WARATAH COAL

RAIL CORRIDOR CROSS DRAINAGE

Culvert ID	Catchment Area (km^2)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m^3s)	100 Yr ARI Peak Flow Rate Estimate (m^3s)	Preliminary Waterway Opening Size (m^2)
C249600	0.61	3.96	12.9	17.6	6.1
C251100	4.21	3.91	45.5	60.4	21.7
C253700	0.64	3.91	13.3	18.0	6.3
C254800	3.27	3.91	38.5	51.4	18.4
C256600	2.14	3.91	29.1	39.1	13.9
C258700	2.62	3.91	33.3	44.5	15.8
C261000	5.79	3.91	56.0	74.2	26.7
C264400	41.56	3.91	204.2	264.1	97.2
C269000	4.57	3.91	48.0	63.8	22.9
C272300	6.09	3.91	57.9	76.7	27.6
C275600	3.40	3.91	39.5	52.7	18.8
C276000	0.31	3.91	8.3	11.3	3.9
C292100	1.67	3.91	24.7	33.3	11.8
C295600	1.90	3.91	27.0	36.2	12.8
C307400	22.43	3.83	133.6	174.3	63.6
C308800	11.60	3.83	86.7	114.0	41.3
C312000	50.64	3.83	227.9	294.4	108.5
C316000	1.29	3.83	20.5	27.7	9.8
C319900	10.04	3.83	78.8	103.9	37.5
C320400	0.68	3.83	13.5	18.4	6.4
C327100	1.96	3.83	27.0	36.3	12.9
C328700	0.63	3.83	12.8	17.5	6.1
C339800	3.14	3.83	36.8	49.1	17.5
C340300	322.00	3.83	766.8	969.1	365.1
C345400	7.72	3.83	66.3	87.7	31.6

WARATAH COAL
RAIL CORRIDOR CROSS DRAINAGE

ENGENY WATER MANAGEMENT

Culvert ID	Catchment Area (km²)	72 hr 50 yr ARI Rainfall Intensity (mm/hr)	50 Yr ARI Peak Flow Rate Estimate (m³s)	100 Yr ARI Peak Flow Rate Estimate (m³s)	Preliminary Waterway Opening Size (m²)
C351000	4.33	3.73	44.3	59.0	21.1
C351400	0.18	3.73	5.6	7.7	2.7
C352600	3.17	3.73	36.1	48.3	17.2
C353100	1.77	3.73	24.6	33.2	11.7
C354300	2.04	3.73	27.0	36.4	12.9
C358300	89.71	3.73	323.2	415.5	153.9
C360300	4.68	3.73	46.6	62.0	22.2
C360900	27.47	3.73	148.7	193.9	70.8
C361500	6.06	3.73	55.1	73.2	26.3
C363300	11.78	3.73	85.3	112.4	40.6
C365100	7.23	3.73	61.9	82.1	29.5
C365900	6.67	3.73	58.8	77.9	28.0
C373600	388.50	3.73	845.4	1067.9	402.6
C379000	12.64	3.73	89.4	117.6	42.6
C381800	14.06	3.73	95.8	126.0	45.6
C383900	2.93	3.73	34.3	45.9	16.3
C386900	2.20	3.73	28.3	38.1	13.5

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