WARATAH COAL

Heavy Haul Rail Corridor Flood Study

1st February 2011

M1700_001

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WARATAH COAL
HEAVY HAUL RAIL CORRIDOR FLOOD STUDY

ENGENY
WATER MANAGEMENT

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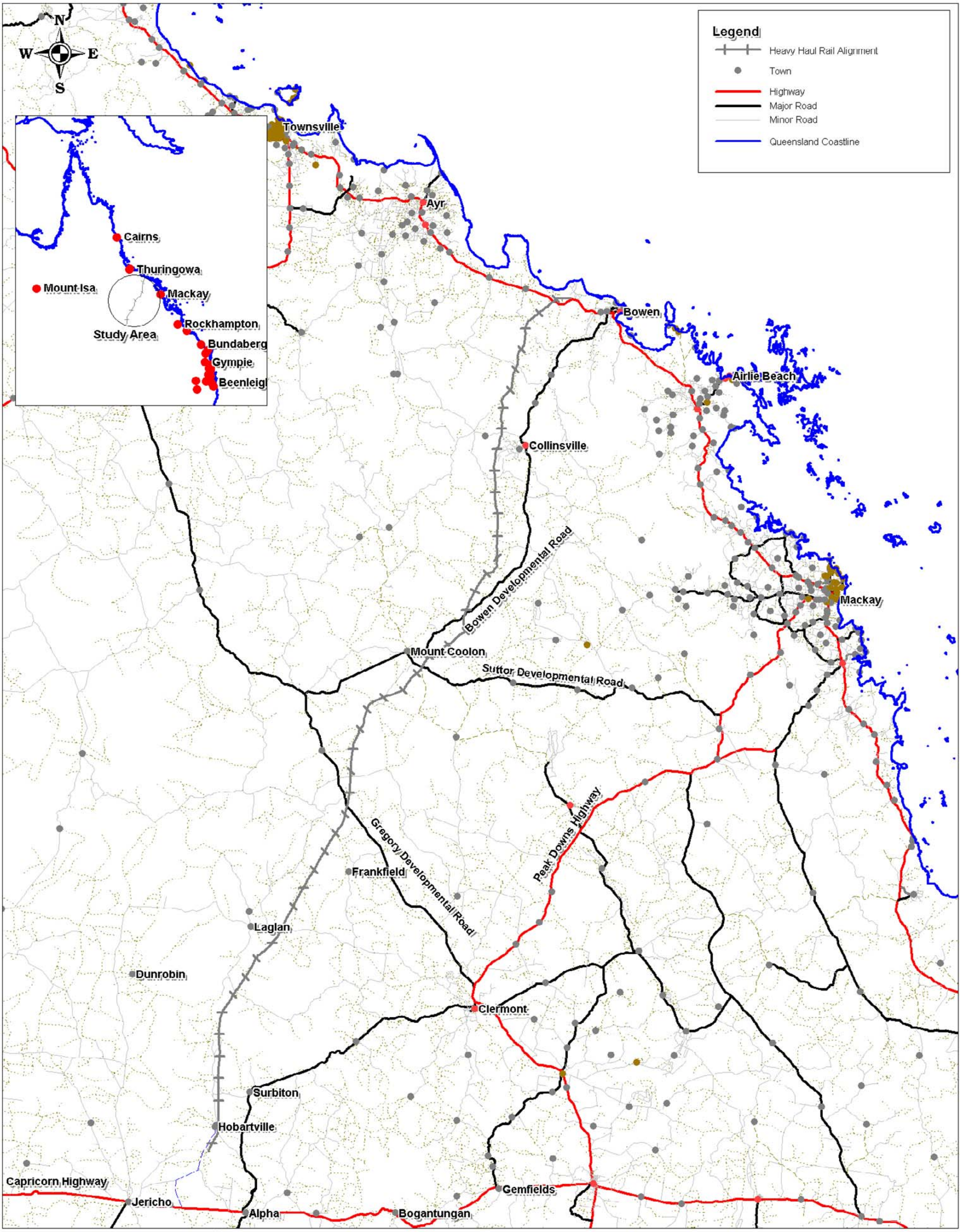
1. INTRODUCTION

Waratah Coal proposes to develop its substantial coal resources in central Queensland. The coal reserves occur in the south western extents of the Burdekin River Basin and post extraction need to be transported to the proposed export terminal at Abbott Point via a proposed Heavy Haul Rail system.

Previously, a preliminary study entitled *"Waratah Coal Abbot Point Railway Corridor"* (WorleyParsons, 2009) was undertaken to ascertain approximate flood extents for a large corridor (between 50 – 100km wide) between Alpha and the Abbot Point terminal. Using the results of this investigation, Waratah Coal have identified a preferred rail alignment and now require a more detailed analysis of flood behaviour at the major waterway crossings along the proposed rail route.

Engeny has therefore been commissioned by Waratah Coal to undertake a detailed investigation into flooding behaviour at a select number of waterway crossings along the proposed rail route. The regional flooding analysis has been undertaken using the latest industry practices and techniques, including the use of the XP-RAFTS hydrologic and TUFLOW hydraulic modelling packages to determine flood extents and behaviour. Results from the existing case analysis of flood behaviour will be used by Waratah Coal in the progression of the detailed design of the rail system.

This assessment has provided a detailed assessment of existing surface water behaviour at a select number of locations representing the major waterway crossings of the rail alignment. Figure 1-1 shows the waterway systems and proposed rail alignment as well as other areas of interest that are referenced within this report.



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Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:1,500,000 (A3)

0 30 60
Kilometers

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Heavy Haul Rail Corridor Flood Study

Figure 1-1

Study Area

Waratah Coal

2. DATA

Data used to predict flood behaviour at the major waterway crossings along the rail route has been obtained from a variety of sources. The following sub-sections summarise the data that have been used as part of this investigation.

2.1 Topographic Data

2.1.1 Hydrologic Modelling Topographic Data

Topographic data used for the development of the hydrologic models (including catchment and sub catchment delineation) was a 25m resolution Digital Elevation Model (DEM) supplied by the Department of Environment and Resource Management (DERM). The data were deemed to be of adequate accuracy for hydrology assessment purposes, however were not deemed to be of sufficient accuracy or detail for the purposes of preparing the detailed regional-scale hydraulic models.

2.1.2 Hydraulic Modelling Topographic Data

Waratah Coal has collected Aerial Laser Scanning (ALS) data for a 1.6km wide corridor along the proposed rail alignment.

The ALS data was manipulated into a series of fine scale (2m resolution) discrete DEMs at each of the modelled river crossings. These DEMs were used as the base topographic dataset for the hydraulic models.

All datasets were based upon a horizontal datum of Map Grid of Australia 1994 (MGA94) Zone 55 and a vertical datum of Australian Height Datum (AHD).

2.2 Rainfall

The design rainfall Intensity-Frequency Duration (IFD) data for all of the design storm events analysed in this study were derived based upon the procedures outlined in Book 2 of Australian Rainfall and Runoff (AR&R) 2001 edition.

Section 4 summarises the procedures used to create the rainfall datasets.

2.3 Imagery – Land Use & Roughness Mapping

Land use data for the study area has been based on review of the Queensland Land use Mapping Project (QLUMP, 1999) and aerial imagery freely available from Google™ Earth.

These datasets were reviewed to determine catchment parameters as part of the hydrologic modelling works, as well as determining appropriate surface roughness throughout the individual hydraulic modelling areas. These values were confirmed through site inspection and oblique photographic record.

2.4 Geographic Information System (GIS) Data

Generic freely available GIS information for the study area was sourced to aid in the completion of the flooding investigations. This data has been sourced from the Queensland Government. This information has been utilised specifically for catchment hydrology, hydraulic analysis and mapping tasks. In particular, the following GIS information was used:

- GeoScience Australia – native vegetation layers & watercourse lines
- Queensland Land Use Mapping Project (QLUMP) – Catchment land use
- General detail – towns, roads, existing rail alignments.

2.5 Drainage Structures

Details of structures within major waterways and within the modelling areas were obtained from site inspections. Where access to creek systems or roadway crossings was limited, detailed review of aerial and oblique photography from aerial site inspection was undertaken in conjunction with review of surrounding topography.

Any large scale regional drainage infrastructure (i.e. bridges, large-scale culvert structures etc) within the modelling areas have been included. This was shown to be limited to the Caley Valley Wetlands modelling area. These structures are summarised in Section 5.2.2.

3. HEAVY HAUL RAIL ALIGNMENT SUMMARY

3.1 General Characteristics

The proposed rail alignment runs from near the township of Alpha in a north-northeast direction to the proposed Abbot Point Coal Terminal with a total rail length of some 448km. The proposed rail alignment intersects two major drainage basins, namely the Burdekin River and Don River Basins, and crosses over 11 major waterways (as classified by the GeoSciences Australia dataset). The catchment areas contributing to these major waterway crossings are discussed below.

Within the Burdekin River Basin, the proposed rail alignment crosses the Belyando-Suttor sub basin. A significant proportion of the proposed heavy haul rail alignment lies within this sub basin, which is classified as a semi-arid landscape with typically non perennial waterways and a dry variable climate. Rainfall predominately falls during the December – April period with generally no to minimal flows recorded during the May – November period.

The following sections identify catchment characteristics in more detail for each of the major waterway systems whilst flooding history within the study area is discussed in Section 4.3.

3.2 Sandy Creek, Belyando River and Lestree Hill Creek

The catchments for these systems cover a combined area of some 15,046km² and are located in the north-east of the Barcaldine Regional Council and the south-western tip of Isaac Regional Council, Queensland. Individually, the Sandy Creek, Belyando River and Lestree Hill Creek catchments cover approximate areas of 2,890km², 11,690km² and 470km² respectively.

The catchments are located in the Burdekin River basin with the Sandy Creek and Belyando River catchments being transected by the Capricorn Highway and Central Railway, with the Clermont Alpha Road also crossing the Belyando River catchment. There are no major population centres within the contributing catchment areas.

Both Sandy Creek and the adjacent Native Companion Creek flow in a northerly direction and eventually merge with the Belyando River upstream of the proposed railway alignment. The Belyando River continues its northern flow direction before eventually discharging into the Coral Sea. Lestree Hill Creek is a tributary of Mistake Creek, which eventually joins the Belyando River some 150km downstream of the rail alignment.

All of the aforementioned waterways are classified as non-perennial waterways, and therefore flow only during periods of significant rainfall. The catchments land use is mostly defined as “production from relatively natural environments”, with some discrete areas of “conservation and natural environments” as described by the Queensland Land Use Mapping Project (QLUMP, 1999).

3.3 Lascelles Creek and Mistake Creek

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

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, which travels in a north-west direction along the Mistake Creek catchment boundary. Lascelles Creek is a tributary of Mistake Creek, which eventually joins the Belyando River some 65km downstream of the rail alignment crossing. There are no major population centres within either contributing catchment areas.

All of the aforementioned waterways are classified as non-perennial waterways, and therefore flow only during periods of significant rainfall. The catchments land use is mostly defined as “production from relatively natural environments”, with some discrete areas of “production from dry land agriculture and plantations”.

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 35km before the confluence with the Belyando River. Contributing areas to these two crossings cover an area of 252km² and 10,330km² 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. There are no major population centres within the contributing catchment area.

Suttor River is a non-perennial waterway and therefore flows only during periods of significant rainfall. The predominant land use in the catchment is described as “production from relatively natural environments” and “production from dry land agriculture and plantations”, with some discrete areas of “Intensive Use”.

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 6,583km² and 528km² respectively. The Bowen River catchment lies in the Mackay Regional Council, Whitsunday Regional Council and Isaac Regional Council Local Government areas, whilst the Pelican Creek catchment is purely within the Whitsunday Regional Council boundary.

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 Collinsville Newlands Branch Railway. The township of Collinsville which is a major population centre is located within the mid reaches of the Pelican Creek catchment. The Bowen River is a perennial waterway and therefore flows year round, whilst Pelican Creek is a non-perennial waterway and therefore only flows during periods of significant rainfall. The predominant land use in the catchments is described as "production from relatively natural environments"; however there are significant areas of "conservation and natural environments".

3.4 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 455km² and 140km² 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 still located within the Burdekin River basin. The Bogie Creek catchment is transected by the Bowen Developmental Road as well as the Collinsville Newlands Branch Railway. There are no major population centres in either contributing catchment areas.

Both Bogie River and Sandy Creek are non-perennial waterways and therefore only flow during periods of significant rainfall. The predominant land use in the catchments is described as "production from relatively natural environments.

3.5 Elliot River and Caley Valley Wetlands

The rail alignment crosses the Elliot River and travels adjacent to the Caley Valley Wetlands in a west to east direction. The Elliott River catchment has a contributing catchment area of 147km². The contributing catchment area for all the minor creeks that contribute to the railway alignment running adjacent to the wetlands is approximately 172km². Both catchments lie within the Whitsunday Regional Council Local Government area.

The Elliott River and Caley Valley Wetlands and their contributing catchments lie within the Don River basin. The Caley Valley Wetlands and its contributing catchments are transected by the Bruce Highway and North Coast Railway, and there are no major population centres in either contributing catchment areas.

The Elliott River and the minor streams contributing to the Caley Valley Wetlands are non-perennial waterways and therefore only flow during periods of significant rainfall. The predominant land use in the catchments is described as "production from relatively natural environments" with some "production from irrigated agriculture and plantations".

3.6 Flooding History

The Bureau of Meteorology provides a brief summary of flooding within the Burdekin and Don River Basins whilst a detailed summary of historical flooding from 1950 to present within the Burdekin River and Don River basins has been included in Table 3-1. General flood summaries for the Burdekin and Don River Basins from the Bureau of Meteorology state that:

'Burdekin River: Major floods, causing inundation of properties and closure of main roads, can occur along the major rivers both upstream and downstream of the Burdekin Falls Dam. Downstream of the Dam, major flooding in the Ayr and Home Hill areas results from either flood waters travelling down from the upper Burdekin and Belyando basin or from intense rain in areas below the Dam.

Don River: Since settlement in 1861, historical records indicate that major floods occurred in 1869, 1870, 1884, 1910, 1916, 1918, 1928, 1940, 1946 and 1955. The highest recorded flood was in 1946 with rises to 9.70 metres on the flood gauge at Warden Bend. In recent years, major levels were reached in January 1970, February 1979, January 1980, March 1988, February 1991 and February 2008.' (BoM 2010)

Table 3-1 Flooding History in the Don River and Belyando River Basins

Event Date	Description
April 1950	Heavy rains from 1st to 8th over the central interior resulted in much low level flooding and traffic disabilities. Strong stream rises also occurred in Cooper Creek, Barcoo, Thomson, Bulloo, Paroo, Warrego, Belyando, Flinders, Mackenzie, Dawson and Isaacs rivers. The general rains of 10th and 11th over the southern interior caused freshes in the Condamine and Balonne rivers. Many main traffic bridges were under water for several days and the discharge from the Belyando River and adjacent smaller streams kept the Burdekin River just under bridge level for most of the month. Fairly extensive traffic disabilities were also experienced on the north tropical coast during the first half of the month due to the heavy rains that fell during this period.
July 1950	Following the heavy rains of the previous 5 to 6 months, the persistent wet weather and record rainfalls during the month caused State wide flooding reports except in the Carpentaria and far western border areas. In all other parts of the State traffic disabilities and low level flooding was extensive and considerable flood water damage and stock and crop losses were reported, particularly in the southern interior. Flooding was most severe in the Maranoa, Macintyre, Condamine and Balonne rivers with record or near record levels. The Maranoa River at Mitchell peaked on 27th, (highest on record). The Macintyre River at Goondiwindi peaked on 30th, the highest since March 1890. The

Event Date	Description
	Balonne River at St George peaked on 31st, (highest on record). Other main streams which reached moderate to high flood levels were the Warrego, Thomson, Barcoo, Belyando, Dawson, Mackenzie, Nogoa and Mary rivers.
November 1950	State wide stream rises were reported in the third week of the month resulting from the heavy widespread rains during this period. These rises were only moderate in the South Coast streams, Condamine and Macintyre river systems and the lower Burdekin River. In all other streams, particularly the Nogoa, Mackenzie, Dawson, Belyando, Warrego, Thomson and Barcoo river systems, record or near record flood levels were reported. By the close of the month all these streams were still carrying heavy flood run-off. Low level flooding dislocation and property damage was extensive and some stock losses were reported, whilst it appears likely that one life was lost in the Nogoa River.
December 1950	Due to the heavy flood rains of November all streams in the central, southern and south-west interior were carrying heavy flood run-off early in December. By the end of the first week all these streams had reached their peak heights and were falling. Heavy rains on the tropical coast in the first week of the month caused further traffic disabilities and considerable damage to sugar cane crops was reported. Flood rains from 19th to 21st, giving several totals of 150 to 225mm in the north-western parts of the State, caused strong stream rises in the Flinders River and other Gulf streams and further rises in the Thomson and Barcoo rivers and the Cooper Creek system. By the end of the month the Flinders River downstream at Milgarra was still rising and in western Queensland floodwaters were still hampering surface traffic.
January 1952	The 125 to 300mm rains over the eastern central highlands and adjacent parts of the South Coast Curtis district caused sharp stream rises and local flooding in the Dawson, Don and Callide rivers and the upper reaches of the Fitzroy River. One life was lost at Wowan.
January 1956	From 16th to 19th flooding was reported in western Peninsula streams, mainly the Gilbert, Norman and Mitchell rivers. Practically state-wide rains resulted in flooding of most catchments during the last 10 days of the month, when moderate flooding was reported in the Fitzroy, Kolan, Burnett and upper Brisbane rivers, and freshes occurred in other south coast streams. Slight flooding was also reported in the Flinders, Thomson and Belyando rivers.

Event Date	Description
March 1960	In the Burdekin River catchment a fresh in the Belyando River from 1st to 3rd and moderate flooding in the upper Burdekin on 11th and 12th resulted in some rises in the lower Burdekin from 11th to 15th. Peaks in the upper Burdekin were Green Valley and Clarke River, both on 12th.
February 1962	This condition of swollen streams and widespread traffic disruption, which extended along the north coast as far south as Mackay by 20th, continued throughout the month. The Fitzroy, Belyando and Burdekin systems were all affected, whilst flooding in the Herbert River from 27th submerged traffic bridges at Long Pocket and North Gairloch. Flooding however was only minor.
March 1963	The heavy rain period near the end of the month produced moderate rises in other rivers over a wide area of the State. In the Fitzroy River catchment large volumes of water moved down all tributaries with the highest levels being recorded in the western parts of the catchment. Other systems affected were the Flinders, Belyando, Condamine, Balonne, Moonie, Maranoa and Paroo rivers. Huge volumes of flood run-off, with rivers up to 35 kilometres wide in places, were moving south towards New South Wales and South Australia at the end of the month, particularly in the Cooper Creek and Bulloo systems.
March 1965	Flooding in the Cloncurry, Corella and Gilbert rivers followed general rainfalls of 50 to 100mm in Carpentaria districts between 8th and 12th. The area of rain also extended south into the central lowlands, where freshes were produced in the Thomson, Barcoo and Belyando rivers, and west into the Northern Territory, where a moderate flood occurred in the Georgina River. Associated heavier falls on the northern catchment of the Burdekin River produced a slight flood which peaked at Clare on 14th.
January 1966	Heavy rainfall on the central coast on the 24th and 25th produced rises in the northern tributaries of the Fitzroy River system and the southern tributaries of the Burdekin River system. Near the end of the month flooding occurred in the Mackenzie, Isaacs, Belyando, Bogie and Burdekin rivers.
January 1970	As a result of Cyclone "Ada", major flooding was experienced in the Pioneer River, particularly at Mackay on 19th, and in the Don River at Bowen on 19th and 20th. Severe local flooding occurred in coastal streams affecting towns between Sarina and Bowen. Major flooding occurred in the Bowen and Broken rivers in the Burdekin basin, but only moderate flooding occurred in the lower Burdekin River. Major flooding was experienced also in the upper catchments of the Isaacs and Connors rivers and in Funnel Creek, all far northern tributaries in the

Event Date	Description
	Fitzroy basin. However only moderate flooding occurred in the lower Mackenzie River, and only river rises below flood level resulted in the Fitzroy River.
February 1970	A fresh in the Burdekin River was complemented by rains of up to 110mm in the lower catchments, causing minor flooding downstream of Dalbeg on 5th and early 6th. Scartwater on the Belyando River recorded moderate flood heights on 4th, 5th and 9th. However the effects were localised as stations both upstream and downstream were just below flood heights.
December 1970	Flooding occurred in most rivers in south-east Queensland, in the area south from the Comet and Belyando rivers and east from the Warrego River. In the second week, flooding also occurred in Brisbane City metropolitan creeks and streams. The rivers, together with the degree of flooding, were Belyando [minor], Comet [moderate], Dawson [major], Mary [minor], Stanley [moderate], upper Brisbane, Lockyer and Bremer [minor], Pine, Albert and Logan [moderate], Nerang [minor], Condamine and Balonne [major], Maranoa [moderate], Macintyre and Weir [major], Warrego and Moonie [moderate], and Barcoo [major].
February 1973	In the north of the State, minor to moderate flooding occurred in the Fitzroy system in the Connors River and Funnel Creek, extending into the lower Isaacs River, with traffic disabilities for up to two days. Minor flooding also occurred in the Belyando, lower Burdekin and Flinders rivers.
January 1980	The overland track of the tropical low, which became tropical Cyclone"Paul", caused one of the highest floods this century in the Don River catchment, resulting in the river changing its course in the lower reach and washing away two homes. The cost due to the extensive damage to the market garden industry is estimated to be several million dollars. Major flooding also occurred in the Pioneer and Proserpine river catchments and the lower reach of the Haughton River. Other streams also to reach flood levels from heavy rains during the period when Cyclone "Paul" was on the synoptic charts were the Thomson River, Connors River and tributaries and the Burdekin River. Flood levels in these streams were minor to moderate, and apart from traffic disabilities, no damage reports were received.
March 1985	During the afternoon of the 14th, minor flooding occurred in the lower Don and Proserpine rivers, decreasing below minor flood levels during

Event Date	Description
	the morning of the 15th
December 1987	On 29th, in the lower reaches of the Paroo River, minor to moderate flooding, and minor flooding in the lower reaches of the Bulloo River. Both continued till the end of the month. On 30th, moderate flooding and traffic disabilities started in the Belyando and Cape rivers in the Burdekin Dam catchment and continued till 31st. Moderate flooding in the Georgina River around the Glenormiston area on 31st.
January 1988	Continuing from the previous month, minor flooding in the Paroo, Belyando and Cape rivers till 4th. Moderate flooding in the Georgina River till 7th and minor flooding continued in Eyre Creek till 14th.
April 1989	Major flooding occurred overnight and produced a peak of 7.8m at Mackay early on Wednesday 5th. Major flooding in the Proserpine River and moderate flooding in the Don River occurred during the 4th. Moderate flooding occurred in the Burdekin River below the dam from heavy tributary runoff causing a moderate flood peak of 10.0m at Inkerman Bridge.
April 1990	Major flooding also occurred in the Thomson River and Cooper Creek, the Bulloo and Paroo rivers, Nebine, Wallam and Mungallala creeks, Balonne, Macintyre Nogoa, Dawson and Belyando rivers, with heights approaching record levels in a number of these streams.
December 1990	General southwest movement of Cyclone "Joy" and eventual landfall in the Ayr region, led to severe local flooding along the Central Coast. Major flooding occurred on the 27th in the Pioneer, Don and Haughton rivers, with minor flooding in the Lower Burdekin Rive
January 1991	Continued heavy rainfalls caused by ex Cyclone "Joy" along coastal areas caused minor to moderate flooding to develop in all coastal streams between Cairns and Gladstone during January. Flooding in the Tully, Herbert, Haughton, LowerBurdekin, Don, and Pioneer rivers caused widespread traffic hazards, flooding of low lying properties and isolation of towns for several days. Serious flooding occurred in the small township of Giru on the HaughtonRiver as floodwaters broke their banks and flooded many houses and streets of the town in early January.
January 1996	Later in the month tropical Cyclone "Celeste" caused minor flooding on the DonRiver around Bowen. One fatality was reported when a man drowned trying to cross a fast flowing coastal stream near Bowen.
February 1997	Don River: During 24th to 25th, minor flooding occurred in the Don River.

Event Date	Description
	Burdekin River: The heavy rainfall from Cyclone "Ita" resulted in some heavy rainfalls in the headwaters of the Bowen River which resulted in some minor to moderate flooding in the Burdekin River below Burdekin Falls Dam.
August 1998	Don River : The heavy rain of Friday 28th and Saturday 29th resulted in rapid river rises in the Don River upstream of Bowen on the afternoon of the 29th. An initial flood warning was issued at 1510 on 29th for minor flooding throughout the catchment. Flood levels peaked at Bowen Pump Station late Saturday night at 3.25 metres with minor flooding occurring all along the Don River. The flood warning was finalised on the 30th.
February 1999	Don River : Heavy overnight rainfall on the 16th caused rapid rises in the Don River to Bowen. River levels peaked at Bowen on the 16th causing moderate flooding.
December 1999	Tully, Johnstone, Herbert, Haughton and Don Rivers : Heavy rainfall ending on 24 December caused significant river rises in the Tully and Johnstone Rivers. This resulted in moderate flooding in the Tully but the Johnstone River at Innisfail peaked just below the minor flood level. The low pressure system which caused this heavy rainfall moved southward over the new few days and caused significant river rises in most smaller coastal rivers and stream to the NSW border and minor flooding in the Herbert, Haughton and Don Rivers. Flood warnings were finalised by 27th December.
February 2000	Don River: Moderate flooding occurred on three separate occasions in the Don River during February. In early February, moderate flooding occurred at Bowen with two separate flood peaks on the 7th and 8th. Later in the month, a flood of similar magnitude to the larger of the two earlier events, occurred on 24th February. Burdekin River: The initial flood warning was issued for the Burdekin River on 22nd February and was not finalised until the end of the month. During this period, minor flooding occurred in the Cape River, lower parts on the Belyando with some significant runoff from the upper Burdekin River. Coupled with heavy local rainfall, this resulted in minor flooding in the lower reaches of the Burdekin River.
December 2000	At the beginning of December, flood warnings were current for four river basins in western Queensland, as a result of widespread rainfall in November. In the middle of December, more heavy rainfall occurred, again in western Queensland, due to TC Sam with flood warnings issued for six river basins. Flood warnings were also issued for the Don

Event Date	Description
	River on the north tropical coast at the end of the month. A total of 103 flood warnings were issued for 8 river basins during December. Don River: Heavy rainfall overnight on the 28 December and the following day resulted in river rises and moderate flooding in the lower reaches of the Don River at Bowen. Flood warnings were issued on the 29 December and finalised on the 31 December.
November 2001	The first significant river rises for this wet season commenced in the latter half of November. Localised rises were reported in various rivers including the lower Belyando, Dawson, Balonne, Thomson, Alice and Paroo Rivers.
February 2002	Don River: Rainfall totals between 100 and 175 mm were recorded in the Don River on Thursday 14th February and resulted in a moderate flood in the lower reaches that afternoon. Burdekin River and tributaries: Very heavy rainfalls were recorded in the upper Burdekin and Cape Rivers during the period 13th to 18th February with the highest total of just over 800 mm at Paluma with widespread falls between 300 and 400 mm. Major flooding resulted in the upper Burdekin and Cape River with the flooding in the Cape system being amongst the highest ever recorded. Minor flooding occurred along the lower Burdekin River from Monday 18th and continued to Thursday 21st February.
February 2003	Heavy rainfall occurred in the Capricornia and Southern Highlands during the beginning of the month, resulting in flooding in the Don River of the Fitzroy River system and also the upper reaches of the Burnett River. Rain gradually became more widespread throughout Queensland and flooding occurred in a number of the western rivers.
January 2005	Don River: Heavy rainfall in the Don River catchment of up to 100 mm during the day of 23 January resulted in sharp river rises and minor to moderate flooding in the upper reaches of the Don River. The river level at Bowen Pump Station peaked overnight on the 23 January with moderate flooding easing during the following day. Burdekin River: Very heavy falls occurred in the catchment of the Burdekin River during 24 January, with over 400 mm recorded at Paluma for the 48 hours to 9am 24 January. Minor to moderate flooding developed in the upper Burdekin River and Cape River and minor flooding in the lower Burdekin River and coastal tributaries during the 25 January. The Burdekin Falls Dam started spilling on 25 January and maintained the minor flood levels downstream at Inkerman Bridge until 28 January before easing

Event Date	Description
April 2006	At the beginning of the month, storms caused moderate flooding in the Don River. Widespread rainfall in the western part of the State resulted in floods in the Thomson and Barcoo Rivers which extended down to Cooper Creek well into May. Cyclone Monica dumped heavy rain on the Cape and on the North Tropical Coast during the middle of April with flooding resulting in Cape York rivers and most of the coastal rivers and streams from the Daintree to the Tully Rivers. A total of 61 flood warnings were issued for seven river basins during the month. Don River: Very heavy rainfall occurred on the afternoon of Friday 7th April in the Don River with totals up to 150mm recorded in a few hours. As a result, river levels in the lower reaches of the Don River rose sharply causing moderate flooding. The Don River peaked at the Pump Station late Friday night and fell away quickly during Saturday.
January 2008	Don River: Flooding occurred in the lower reaches of the Don River downstream from Ida Creek following a monsoon depression that settled over the east coast between 21st to the 25th. The 72 hour rainfall totals to 9am on 24th of between 90 to 140mm were recorded across the catchment. Minor flood warnings were issued on 23rd and 24th.
January 2008	Widespread intense rainfall was recorded across many catchments along the Central Queensland coast as the low continued to slowly drift southwards towards the headwaters of the Thomson River, Barcoo River and Cooper Creek during 16th January, producing very intense rainfall over the Belyando River in the Burdekin River basin, Nogoa River and Theresa Creek in the Fitzroy River basin, and very heavy rainfall to other inland and coastal areas. The low continued its southward movement on 17th January producing further intense rainfalls as it tracked over the western parts of the Fitzroy River basin around Emerald, and then along the Warrego River through to Charleville. Very heavy rainfall occurred along the Queensland coast between Townsville and Mackay and inland over the Coalfields and Central Interior between the 10th and 20th January. This rainfall produced widespread flooding across Central Queensland including the Ross River, Haughton River, Don River,and Pioneer River, however the most pronounced and intensive rainfall occurred over the Nogoa River and Theresa Creek within the Fitzroy River Basin and the Belyando River within the Burdekin River Basin. Intense rainfall of 143mm fell on Giru over 2 hours, whilst the heaviest daily rainfall totals exceeded 300mm causing flash flooding in the Proserpine and Airlie Beach area. Bogantungun situated to the west of the city of Emerald recorded a 4-day rainfall total of nearly 700mm.

Event Date	Description
January 2010	Don River: Following the path of Ex OLGA south, the monsoon trough produced moderate to heavy falls in the Don River catchment. A minor flood peak was recorded at Bowen during the morning of the 31st.
March 2010	Severe TC Ului crossed the Queensland east coast near Proserpine early on the 21st of March, then continued to move in west south-west direction across the south-east tropics in a weakening mode. The system produced widespread heavy rainfall and showers on its southern side over the Don, Burdekin, Pioneer, Haughton and Fitzroy River Catchments. Flood warnings were required for the Connors and Isaac Rivers in the Fitzroy River Catchment and also the Don, Haughton and Burdekin Rivers, with only six major flood warnings, namely for the Pioneer River and Funnel Creek and the Connors River in the Fitzroy catchment.
September 2010	Belyando River: Heavy rainfall recorded in the Carnarvon region during September produced rises in Native Companion Creek and major flooding further downstream at Albro station. A Flood Warning for major flooding was issued on the 20th of September and finalised on the 27th. Dawson River: Heavy rainfall in the upper Dawson and Don Rivers and in Juandah Creek produced minor to moderate flooding along the Dawson River. A localised major flood peak of 6.03m was recorded in the Taroom area.

Source: Bureau of Meteorology (2010)

4. HYDROLOGIC MODELLING

4.1 Hydrologic Model Development

A series of nine (9) XP-RAFTS hydrologic models were created to predict the various catchment responses for use in the hydraulic models developed as part of this study.

All hydrologic models were simulated for the 10, 50 and 100 year Average Recurrence Interval (ARI) design rainfall events using a range of storm durations to estimate the relevant design event peak flows.

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

4.1.1 Hydrologic Model Summary

Catchment size and model descriptions for each XP-RAFTS model developed for this study are summarised in Table 4-1.

Table 4-1 Hydrologic Model Details

Model ID	Total catchment area (km^2)	No of sub-catchments	Remarks
Belyando River S1	6,062	17	Includes Sixteen Mile Creek, Lascelles Creek, Mistake Creek and Miclere Creek
Belyando River S2	14,980	39	Includes Belyando River, Sandy Creek, Lagoon Creek, Native Companion Creek, Bottle Tree Creek, Pebbly Creek and May Creek
Suttor River	10,330	33	Includes Suttor River, Brown Creek, Logan Creek, Diamond Creek, Eaglefield Creek, Suttor Creek and Verbena Creek
Caley Valley	145	10	Includes Kangaroo Creek, Plain Creek and Splitters Creek
Elliott River	147	5	Includes Elliot River, Butchers Creek and Stockyard Creek

Model ID	Total catchment area (km^2)	No of sub-catchments	Remarks
Bogie River North	440	11	Includes Bogie River and Terry Creek
Bogie River South	140	7	Includes Sandy Creek
Pelican Creek	612	15	Includes Strathmore Creek, Pelican Creek, Tea Tree Creek, Oakey Creek, Two Mile Creek and Coral Creek
Bowen River	6,562	29	Includes Bowen River, Broken River, Parrot Creek, Rosella Creek, Hazelwood Creek, Eastern Creek and Kangaroo Creek

4.1.2 Rainfall data

In order to undertake design rainfall event modelling, rainfall Intensity-Frequency Duration (IFD) data for the 10, 50 and 100 year ARI design storm events are required.

A unique IFD dataset for each of the catchment models was derived based upon the procedures outlined in Book 2 of Australian Rainfall and Runoff (AR&R 2001). Table 4-2 summarises the different parameters used to create the IFD datasets, whilst Figure 4-1 shows the location of the different hydrologic models.

Table 4-2 IFD data for respective hydrologic models

Hydrologic Model Name	2 yr ARI Intensities (mm/hr)	50 yr ARI Intensities (mm/hr)	Skewness and Geographical Factors
Belyando River_S1	${}^{2}I_{1}$ = 42.09	${}^{50}I_{1}$ = 81.57	Skewness G = 0.1 Geographical Factor F_2 = 4.03 F_{50} = 16.62
	${}^{2}I_{12}$ = 6.23	${}^{50}I_{12}$ = 12.47	
	${}^{2}I_{72}$ = 1.85	${}^{50}I_{72}$ = 3.73	
Belyando River_S2	${}^{2}I_{1}$ = 38.73	${}^{50}I_{1}$ = 79.97	Skewness G = 0.09
	${}^{2}I_{12}$ = 5.95	${}^{50}I_{12}$ = 11.99	

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Hydrologic Model Name	2 yr ARI Intensities (mm/hr)	50 yr ARI Intensities (mm/hr)	Skewness and Geographical Factors
	$^{2}I_{72} = 1.56$	$^{50}I_{72} = 3.47$	Geographical Factor $F_2 = 4.04$ $F_{50} = 16.33$
Suttor River	$^{2}I_{1} = 44.75$	$^{50}I_{1} = 75.97$	Skewness G = 0.11 Geographical Factor $F_2 = 4.02$ $F_{50} = 16.91$
	$^{2}I_{12} = 6.50$	$^{50}I_{12} = 12.86$	
	$^{2}I_{72} = 1.69$	$^{50}I_{72} = 3.87$	
Caley Valley	$^{2}I_{1} = 52.68$	$^{50}I_{1} = 94.52$	Skewness G = 0.10 Geographical Factor $F_2 = 4.0$ $F_{50} = 17.46$
	$^{2}I_{12} = 9.98$	$^{50}I_{12} = 22.55$	
	$^{2}I_{72} = 3.35$	$^{50}I_{72} = 7.7$	
Elliott River	$^{2}I_{1} = 52.08$	$^{50}I_{1} = 93.73$	Skewness G = 0.09 Geographical Factor $F_2 = 4.0$ $F_{50} = 17.4$
	$^{2}I_{12} = 10.06$	$^{50}I_{12} = 23.45$	
	$^{2}I_{72} = 3.73$	$^{50}I_{72} = 8.07$	
Bogie River North & South	$^{2}I_{1} = 49.55$	$^{50}I_{1} = 91.31$	Skewness G = 0.10 Geographical Factor $F_2 = 4.0$ $F_{50} = 17.35$
	$^{2}I_{12} = 9.44$	$^{50}I_{12} = 19.29$	
	$^{2}I_{72} = 2.92$	$^{50}I_{72} = 6.81$	
Pelican Creek	$^{2}I_{1} = 44.82$	$^{50}I_{1} = 86.24$	Skewness G = 0.10 Geographical Factor $F_2 = 4.01$ $F_{50} = 17.29$
	$^{2}I_{12} = 7.58$	$^{50}I_{12} = 15.48$	
	$^{2}I_{72} = 2.65$	$^{50}I_{72} = 4.9$	
Bowen River	$^{2}I_{1} = 43.4$	$^{50}I_{1} = 76.31$	Skewness G = 0.12 Geographical Factor $F_2 = 4.03$ $F_{50} = 17.32$
	$^{2}I_{12} = 6.77$	$^{50}I_{12} = 13.28$	
	$^{2}I_{72} = 1.87$	$^{50}I_{72} = 4.19$	

Note: ARI is the Average Recurrence Interval in years of a design rainfall event (100 Year ARI = 0.01 Average Exceedance Probability).

4.1.3 Areal Reduction Factors

The derived rainfall intensities presented in Table 4-2 from AR&R Book 2 (2001) are only applicable to the discrete location for which the rainfall data has been derived.

The derived design event rainfall will not be consistent over the large catchment areas represented by each of the hydrologic models and as such, areal reduction factors (ARF) have been used. ARF's typically reduce the peak discharge of the subject catchment.

This process has been undertaken automatically in XP-RAFTS. The automated ARF values are then applied to adjust the rainfall intensities for each Average Recurrence Interval (ARI) and storm duration.

4.1.4 Design Rainfall Temporal Patterns

The design rainfall temporal patterns used for the respective hydrologic models for each catchment contributing to the major river crossings of the proposed rail alignment are Standard Zone 3 Pattern as described in AR&R Book 2.

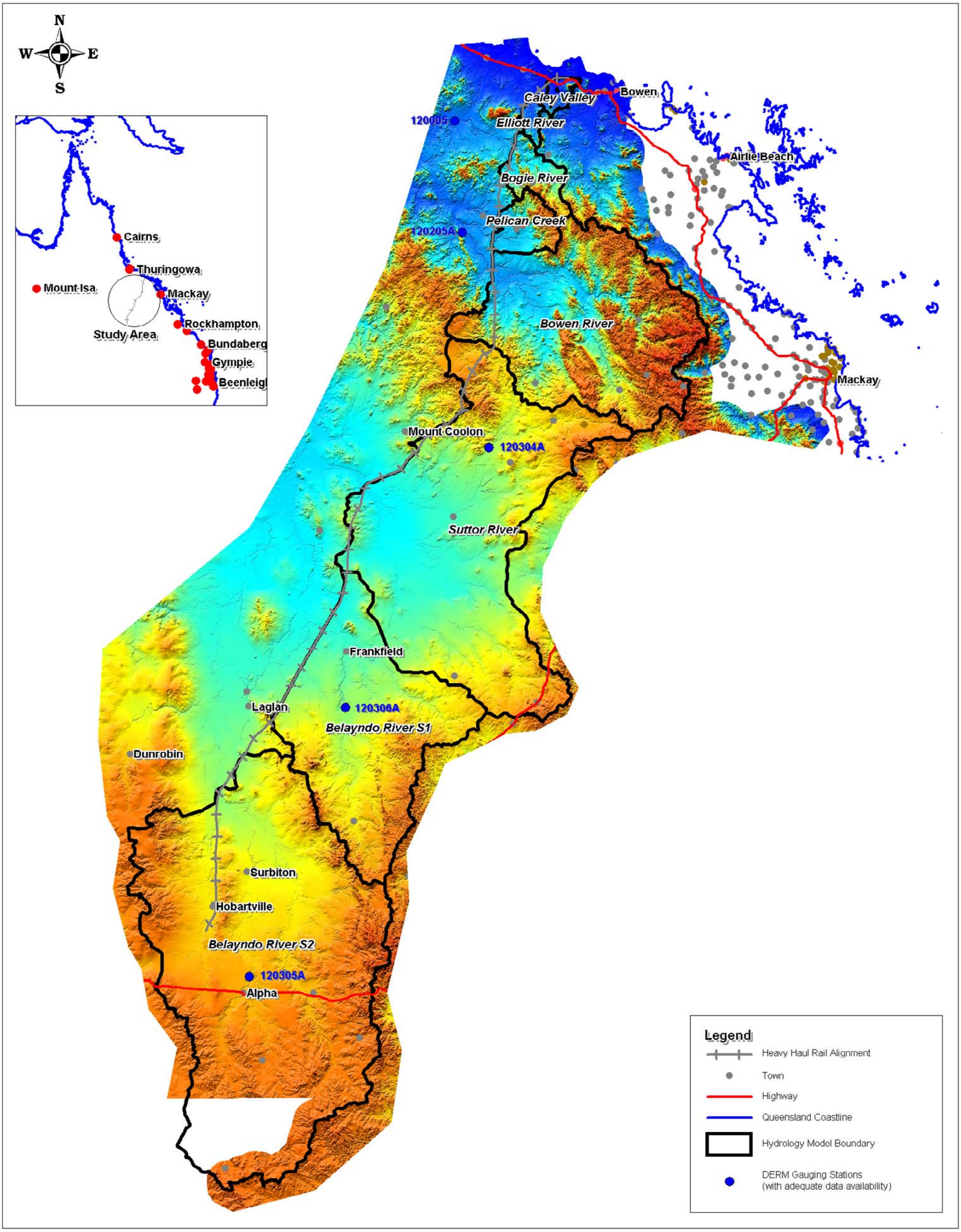

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Figure 4-1

Hydrology Model Locations & Boundaries

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4.2 XP-RAFTS Models

The nine (9) separate catchment areas were analysed in individual models utilising the XP-RAFTS software package.

XP-RAFTS is a robust runoff routing model that is used extensively throughout Australia and the Asia Pacific region for hydrologic analysis of storm water drainage and conveyance systems and has been used in the analysis, design, and management of both urban and rural watersheds and flood protection and river systems for over 30 years.

4.2.1 Catchment Delineation

Sub catchment delineation for the nine (9) separate hydrologic models was carried out using the DERM 25m DEM. This is discussed in more detail in Section 2.

Appendix A graphically represents the overall model layouts and associated sub-catchment breakdowns and for each of the hydrologic models.

4.2.2 Hydrologic Model Parameters

Rainfall Loss Model

Rainfall losses in each of the hydrologic models were applied using an initial and continuing rainfall loss model.

Design loss parameters for each of the XP-RAFTS models were based on values as described in AR&R (2001) and review of model results in comparison to flood frequency analysis results for a limited number of available stream flow gauges within the different catchment areas. A review of the works undertaken previously by WorleyParsons was also completed.

The adopted loss parameters applied to the different XP-RAFTS models are summarised in Table 4-3.

Table 4-3 Rainfall Loss Parameters

Model Name	Loss Type	Pervious Area	Impervious Area
Belyando River_S1	Initial loss (mm)	30	0
	Continuing loss (mm/hr)	2.5	1
Belyando River_S2	Initial loss (mm)	25	0
	Continuing loss (mm/hr)	2.5	1
Suttor River	Initial loss (mm)	0	0
	Continuing loss (mm/hr)	1	1
Caley Valley	Initial loss (mm)	0	0
	Continuing loss (mm/hr)	1	1
Elliott River	Initial loss (mm)	0	0
	Continuing loss (mm/hr)	1	1
Bogie River (North)	Initial loss (mm)	0	0
	Continuing loss (mm/hr)	1.2	1
Bogie River (South)	Initial loss (mm)	0	0
	Continuing loss (mm/hr)	1	1
Pelican Creek	Initial loss (mm)	0	0
	Continuing loss (mm/hr)	1.5	1
Bowen River	Initial loss (mm)	0	0
	Continuing loss (mm/hr)	1	1

Storage Coefficient (ßx factor)

Storage coefficient factors for each of the hydrologic models have been selected from recommended design values for vegetation types and review of model results and flood frequency analysis (FFA) outputs.

Based on the review of modelling results against FFA results, the following ßx values were adopted for each hydrologic model.

Table 4-4 Catchment Storage Co-efficient

Model Name	ßx Value
Belyando River S1	1.4
Belyando River S2	1.4
Suttor River	0.9
Caley Valley	1.0
Elliott River	1.0
Bogie River North	1.0
Bogie River South	1.0
Pelican Creek	1.0
Bowen River	1.0

Pervious 'n' (PERN), Percentage Impervious Values and Land Use Classification

Catchment details such as land use, and land use classification have been based on review of the QLUMP (1999) dataset and review of aerial imagery and site record.

Percentage impervious values for each land use type have been based on QUDM (2007) recommendations and review of site inspection notes and photographs. All impervious areas were assigned a PERN value of 0.015.

A summary of the adopted parameters for each land use type represented in the hydrologic models is presented in Table 4-5.

Table 4-5 Catchment land use parameters

Description	Impervious %	Pervious Manning's 'n'	Impervious Manning's 'n'
Native / thick vegetation	0	0.075	0.015
Cleared vegetation (farmland)	2	0.055	0.015

Channel routing / roughness coefficients

Catchment runoff has been routed between each sub catchment using the Muskingum-Cunge method within the XP-RAFTS software. Routing details such as routing channel shape and roughness values for both in channel and overbank areas have been derived from the DERM 25m DEM and review of aerial photography and site notes and photographic record. Based on the aforementioned data, Manning's n values between 0.07 and 0.1 were adopted for the routing links.

4.3 XP-RAFTS Model Validation

Due to the large catchments contributing to the Rail Corridor study area, using the Rational Method to validate predicted 100, 50 and 10 year ARI flows was not considered appropriate. The 'Queensland Urban Drainage Manual' (QUDM, 2007) and AR&R (1998) suggests a maximum catchment area of 2,500 hectares (25 km^2) be used for calculating flows using the Rational Method for rural catchments.

To provide verification of the adopted 100 year ARI flows within the Belyando River and Suttor River systems, a flood frequency analysis (FFA) has been undertaken at three gauging stations within these catchments. Previous reports including *Bungil Creek Flood Study*, Final Report, (EGIS, 2002), and *Final Report for Levee Construction Investigation for Charleville and Augathella*, (EGIS, 2001) was considered for determination of appropriate magnitudes of 100 year ARI flow for the neighbouring catchment areas along with previous FFA undertaken in *Flood Investigation and Mapping for the GLNG Upstream Development – Campsite and Hub Areas,* (Engeny, 2010) and *Australian Pacific LNG Project EIS – Volume 3, Chapter 11: Water Resources* (March 2010).

A FFA was undertaken on the three gauges and the results are summarised in Table 4-6 below. The annual peak flows were provided by DERM and the Log Pearson Type 3 (LPIII) distribution was fitted to the data as per Book 4 of AR&R. Refer to Figure 4-1 for the location of the gauging stations. Table 4.6 below summarises the years of recorded flow data and the number of low flows omitted to obtain a better fit of the LPIII distribution at higher flows. Refer to Appendix B for a plot of the FFA of the three gauging stations.

Table 4-6 LPIII Flood Frequency Summary for Available Gauging Stations

Gauge No.	Gauge Name	Year of Peak Flow Data	Number of low flows omitted	LPIII Estimated 100 Year ARI Peak Discharge (m^3/sec)		
				95% Confidence Limit	Adopted Value	5% Confidence Limit
120305A	Native Companion Creek at Violet Grove	43	5	607	1,077	2,375
120306A	Mistake Creek at Charlton	23	1	504	715	1,205
120304A	Suttor River at Eaglefield	38	1	1,958	3,303	6,746

To provide verification of the adopted 100 year ARI flows for the other 6 systems modelled (Caley, Elliot, Bogie North, Bogie South, Pelican and Bowen), a FFA was undertaken by WorleyParsons within their study *Waratah Coal Abbot Point Railway Corridor Preliminary Flood Investigation* (November 2009). WorleyParsons flood frequency analysis is summarised in Table 4.7 below.

Table 4-7 LPIII Flood Frequency Summary Undertaken by WorleyParsons

Gauge No.	Gauge Station Name	LPIII Estimated 100 Year ARI Peak Discharge (m^3/sec)
120205A	Bowen River at Myuna	18,000
120005	Bogie River at Strathbogie	5,000
120304A	Suttor River at Eaglefield	2,580
120305A	Native Companion Creek at Violet Grove	1,750

Review of the WorleyParsons results showed some vast discrepancies between their predicted Q100 flow rates and historical records at gauging station 120304. At least ten events of greater than 10,000 m^3/sec magnitude (peak event of 50,500 m^3/sec) have been recorded at this location, yet the flood frequency analysis undertaken by Worley Parsons predicted a Q100 flow of 2,859 m^3/sec. Flood frequency analysis results for gauge 120205A appeared to correlate well with the predictions of the XP-RAFTS models developed as part of this study for the Bowen River system, and as such model parameters were adjusted to best fit the FFA results.

4.4 XP-RAFTS Results

Table 4-8 below summarises the XP-RAFTS total flows at the major inflow boundaries to the TUFLOW hydraulic models. The critical duration for all inflows varied between 12 hours and 72 hours. The 96 hour duration storm event was also run to ensure the 72 hour event was the critical event.

Table 4-8 100 year ARI Peak Flow Summary

Hydrology Model Name	Hydraulic Model Inflow Location	10 year ARI Peak Flow (m^3/sec)	50 year ARI Peak Flow (m^3/sec)	100 year ARI Peak Flow (m^3/sec)
BELYA_S1	Mistake Creek	511	1,030	1,329
BELYA_S1	Lascelles Creek	60	122	158
BELYA_S2	Sandy Creek	346	717	926
BELYA_S2	Belyando River	1,439	2,589	3,267
BELYA_S2	Lestree Hill Creek	47	82	106
SUTTO	Upper Suttor River	291	455	530
SUTTO	Lower Suttor River	6,040	9,340	11,014
CALEY	Splitters Creek	668	937	1,083
ELLIOT	Elliot River	1,180	1,638	1,918
BOGIE NORTH	Bogie River	1,300	1,917	2,232
BOGIE SOUTH	Sandy Creek	440	632	742
PELICAN	Pelican Creek	1,628	2,403	2,780
BOWEN	Bowen River	11,179	16,165	18,501

5. HYDRAULIC MODELLING

The proposed rail alignment transects a significant number of creeks and river systems. Previous studies of the major river crossings undertaken by other consultants have been coarse in nature and utilised a one dimensional (1D) steady state modelling approach.

The purpose of this investigation is therefore to provide detailed analysis of flooding behaviour for the major waterway crossings along the rail route using the latest detailed ALS topographic dataset collected as part of this study. Engeny has constructed a series of eleven TUFLOW one dimensional (1D)/two dimensional (2D) hydrodynamic flood models to facilitate a detailed representation of flood behaviour in each modelling area.

All details concerning model development, baseline data, assumptions and parameters are detailed below.

5.1 Modelling Software

Hydraulic analysis of the study area was undertaken using the two dimensional finite difference model TUFLOW.

TUFLOW is an industry accepted software package that is highly suited to the investigation of flood behaviour in complex flow scenarios and is particularly suited to simulation of complex interaction between waterways that occurs in flat floodplain areas. The software was therefore considered the most appropriate modelling tool for all of the waterway crossing locations.

5.2 Hydraulic Model Construction and Parameters

The TUFLOW models constructed for the 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. Each of the model inputs and parameters used in this study is detailed below.

5.2.1 Two Dimensional Topographic Grid

The 2D model topography was created using the discrete 2m DEM’s constructed from the ALS data as supplied by Waratah Coal.

Given the variable nature of the floodplains in each of the eleven TUFLOW models, it was necessary to vary the model gird size for each model to both achieve the required level of modelling detail, whilst maintaining reasonable simulation times.

Through review of initial modelling results and simulation times, it was determined that generally a grid size of between 5m – 20m 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.

Table 5-1 summaries the adopted model grid for each of the eleven hydraulic models whilst Figure 5-1 illustrates each of the respective modelling areas.

Table 5-1 2D Model Grid Size

Model Name	Cell size (m)
Caley Valley	10
Elliott River	5
Bogie River	5
Pelican Creek	5
Bowen Tributaries	5
Bowen River	10
Sandy Creek	5
Belyando River & Lestree Hill Creek	20
Mistake Creek	10
Lascelles Creek	5
Lower Suttor River	10
Upper Suttor River	5

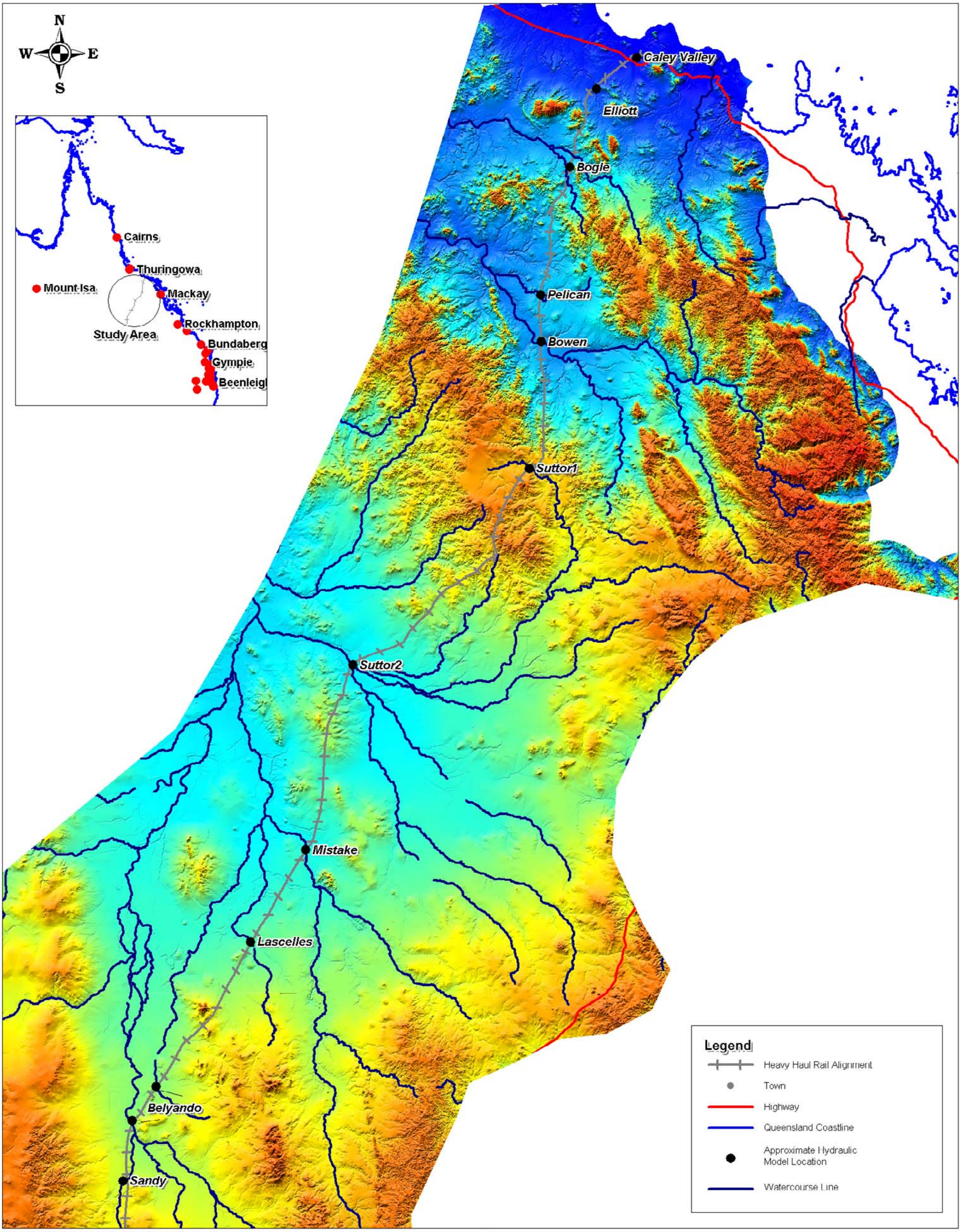

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Figure 5-1

TUFLOW Hydraulic Model Locations

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5.2.2 One Dimensional Hydraulic Structures

Small drainage structures such as culverts are often modelled in a 1D environment in TUFLOW to allow for increased accuracy in representation of the structure characteristics.

Most of the modelling areas were shown to be free of regional scale hydraulic structures that could impact on flood behaviour. However the Caley Valley model was shown to have a number of structures within the modelling area that given the surrounding topographic variation, could impact on flood behaviour. 1D model elements have therefore been introduced in this model to represent a number of these floodplain structures. Larger scale structures such as bridges have typically been modelled in the 2D domain.

A detailed summary of the 1D structure elements is provided in Table 5-2. Only a limited number of 'As Constructed' drawing was available for the hydraulic structures in the modelling area and as such most structure details such as approximate size and invert levels were interpolated by way of review of the surrounding topography based off the DEM created for this study, aerial photography, site notes and oblique site photographic record. The 'As Constructed' drawing provided by the Department of Transport and Main Roads are included in Appendix C.

Table 5-2 One Dimensional (1D) Hydraulic Structure Summary – Caley Valley

Structure ID	Location Description	Inlet Invert Level (mAHD)	Outlet Invert Level (mAHD)	Description
Culvert_2*	Bruce Highway	9.3	9.25	2/1500x600 RCBC
Culvert_3*	Bruce Highway	8.8	8.75	2/1500x600 RCBC
Culvert_4*	Bruce Highway	8.95	8.65	3/1500x600 RCBC
Culvert_5*	Bruce Highway	8.26	8.01	5/3000x2400 RCBC
Culvert_6*	Bruce Highway	7	6.72	6/3000x1500 RCBC
Culvert_7*	Bruce Highway	6.75	6.5	5/3000x1200 RCBC
Culvert_8*	Bruce Highway	6.7	6.6	2/3000x2400 RCBC
Culvert_9*	Bruce Highway	6.35	6.05	4/2400x600 RCBC
Culvert_10*	North Coast	4.6	4.55	2/3000x3000 RCBC

Structure ID	Location Description	Inlet Invert Level (mAHD)	Outlet Invert Level (mAHD)	Description
	Railway - Bowen to Bobawaba			
Culvert_11*	Bruce Highway	8.5	8.25	2/1500x600 RCBC
Culvert_12*	Bruce Highway	10.55	10.51	3/1800x450 RCBC
Culvert_13*	Bruce Highway	4.7	4.5	7/1800x600 RCBC
Culvert_14*	Bruce Highway	3.5	3.25	5/3000x1200 RCBC

*Denotes interpolated structure details

5.2.3 Two Dimensional Hydraulic Structures

Large scale structures such as major crossings on the Bruce Highway and a number of rail crossings within the Caley Valley model have been modelled using TUFLOW's layered flow constriction (2d_lfcsh) capability. Layered flow constrictions allow spatially varying blockage and form loss attributes to be applied to the structure (e.g. under obvert, bridge deck, above deck).

Table 5-3 specifies which structures in each hydraulic model have been descriptively modelled using this feature.

Table 5-3 Two Dimensional Hydraulic Structure Summary – Caley Valley

Structure ID	Location	Description
Splitters_Cr_Rail_2*	North Coast Railway - Bowen to Bobawaba	38m Span with 6/600mm Piers
Splitters_Cr_Rail_3*		61m Span with 10/600mm Piers
Splitters_Cr_Rail_1*		13.5m Span with 2/600mm Piers
Spring_Cr_Rail*		30.5m Span with 5/600mm Piers
Bridge_2_No221a*		Single 7.2m Span

Structure ID	Location	Description
Plain_Cr_Rail*		25m Span with 4/600mm Piers
Bridge_3_No218*		19.4m Span with 2/600mm Piers
Bridge_4*		20m Span with 3/600mm Piers
Bridge_5*		17m Span with 2/600mm Piers
Bridge_7_No220*		Single 7.2m Span
Bridge_8_No219*		Single 7.4m Span
Bridge_6_Road*	Bruce Highway	36m Span with 2/450mm Piers
Plain_Cr_Road	Bruce Highway	60m Span with 3/450mm Piers

*Denotes interpolated structure details

5.2.4 Model boundary conditions

Tailwater Boundaries

Most of the waterway systems modelled as part of this investigation are classified as non perennial with no significant standing water at the model outlets, and hence a normal depth boundary condition was adopted for most of 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 0.001m/m to 0.01m/m in the steeper coastal systems.

The model representing the Caley Valley Wetlands was the only hydraulic model with influence from tidal ingress. As the Caley Valley Wetlands and Abbot Point region is susceptible to Tropical Cyclone activity and storm surge effects, a review of literature was undertaken. A storm surge level of 2.52mAHD was predicted in *"The Frequency of Surge Plus Tide During Tropical Cyclones for Selected Open Coast Locations Along the Queensland East Coast"* (JCU, 2004). This level represents a 100 year ARI storm surge event including greenhouse effects (as best estimated at that time).

However review of the latest Queensland Government "Coastal Management Policy (Draft)" suggests planning for a 100 year sea level rise of 0.8m on top of the Highest Astronomical

Tide. This results in a level of 2.77mAHD at the subject site. This level was deemed conservative and was therefore adopted for the purposes of this study. Much of the study area in this location was shown to be above the adopted tail water level.

Inflow Boundaries

Inflow hydrographs for each TUFLOW model were derived from the XP-RAFTS models created for each contributing catchment area for each of the design flood events analysed (10, 50 and 100 year ARI events). These hydrographs were then directly applied to the representative TUFLOW 2D model domains for each major water system.

5.2.5 2D model roughness

Definition of the various floodplain roughness areas was undertaken using a combination of aerial imagery and site notes and photographic record.

The Manning's 'n' roughness parameters adopted in the model ranged from 0.015 for water bodies such as storage reservoirs through to 0.500 for immovable constructed objects and no flow areas (e.g. buildings). Table 5-4 summarises the Mannings 'n' roughness parameters assigned to each land use type identified in the study areas.

Table 5-4 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)	0.500

6. DESIGN EVENT MODELLING RESULTS

Hydraulic modelling of each major waterway crossing of the proposed Heavy Haul Rail alignment was performed for the 10, 50 and 100 year ARI design rainfall events.

Flood mapping has been undertaken for the 100 year ARI event based upon the ALS topographic data provided by Waratah Coal for the purposes of this study and are presented in Appendix D.

6.1 Existing Case

6.1.1 Model 1 - Caley Valley Wetlands

Caley Valley Wetlands lies to the south west of the Abbot Point Coal Terminal and is the most northern system modelled in this study. The area of interest is bisected by the Bruce Highway and the North Coast Railway and is extremely flat. The boundary adopted in the hydraulic model is some 2.5km from the outlet to Abbot Bay and is tidally affected with the invert of Splitters Creek being approximately 1.5mAHD. The other creeks modelled include Plain Creek, Tabletop Creek and Spring Creek.

Several bridge and culvert crossings have been identified and included in the hydraulic model. The low lying floodplain experiences wide spread inundation in the 100 year ARI flood event. The peak depths experienced in Plain and Splitters Creek are greater than 4m while there are large areas of the floodplain inundated up to 0.8m. Peak velocities around the major structures associated with the Bruce Highway and North Coast Railway are predicted to be greater than 2m/s while the peak velocities over the floodplain is generally less than 1m/s. Minor inundation of the Bruce Highway near the Caley Valley Wetlands is predicted to occur during events equal to or larger than the 50 year ARI design rainfall event. The adjacent North Coast Railway is also predicted to experience minor inundation during these larger rainfall events, however the depth of inundation was predicted to be typically less that 50mm.

Peak flows for the two watercourses that bisect the proposed coal terminal location are similar and vary from approximately 60m^3/s to 95 m^3/s for the 10 and 100 year ARI events respectively. It is noted that these peak flows are likely attenuated to some degree by the existing Bruce Highway and North Coast Railway crossings of these systems. These existing infrastructure features have not been included in the hydraulic model due to detailed design information for crossing structures not being available at the time of this investigation. As a result, flood behaviour estimates in the waterways downstream of the existing North Coast Railway and through the proposed coal terminal facility location are considered conservative.

Modelling results suggest peak flood depths in the minor waterways flowing through the proposed coal terminal location generally range from approximately 1.7m and 2m for the 10 and 100 year ARI events respectively. These depths are highly variable along the length of the watercourse due to the highly variable nature of the watercourse topography at this location. Flow depths dissipate to broader shallower inundation further downstream towards the Caley Valley Wetlands, where the topography is flatter and waterways less defined. Peak flow velocities are likewise highly variable across the coal terminal site, with the greatest flow velocity at the upstream end of the proposed terminal location being on average between 2m/s and 2.5m/s for the 10 and 100 year ARI events respectively. Again, these flow velocities reduce once flows enter the lower reaches of the waterways near the Caley Valley Wetlands.

Most of the study area in this location was shown to be above this adopted tail water level. Infrastructure located in areas below this level may be susceptible to inundation from storm surge or sea level rise effects. However the constructed “outer bund” on the Mount Stuart Creek outlet is likely to significantly reduce tidal influences in the wetlands.

6.1.2 Model 2 – Elliot River

The proposed crossing over the Elliott River is approximately 22km 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 while depths between 2 and 4m in the side tributary to the west of Elliot River. The predicted peak velocities within the Elliot River are in excess of 2m/s while 0.4 to 0.8m/s is experienced in the overbank areas. The tributary to the west of Elliot River experiences velocities in the main channel between 0.4 and 1.2m/s along the proposed rail alignment. Flow characteristics in the main watercourse reduce to approximately 8m in the 10 year ARI event, with velocities reduced to approximately 2m/s.

6.1.3 Model 3 – Bogie River

The proposed rail alignment bisects Bogie River in the north and runs along the meander of Sandy Creek to the south. The proposed crossing over Bogie River is some 70km upstream from the confluence with the Burdekin River. The surrounding topography is steep with a deep, well defined channel. Bogie River has medium to dense vegetation with consistent vegetation to the 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 6m in Bogie River and 8m in Sandy Creek, with depths of 4.8m and 7m respectively during the 10 year ARI event. The predicted peak velocities within the Bogie River are in excess of 2.5m/s and 2.2m/s for the 100 and 10 year ARI events while the peak velocities in Sandy Creek are approximately 2.2m/s and 1.7m/s for the 100 and 10 year ARI events.

6.1.4 Model 4 – Pelican Creek

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

Pelican River 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 Crush 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 10.5m and 9m for the 100 and 10 year ARI events respectively. Peak depths in the floodplain areas to the north along Crush Creek are predicted to be 0.4 to 0.8m deep with the main channel experiencing depths greater that 4m. The predicted peak velocities across Pelican Creek range from 1.5m/s in the 10 year ARI event up to 2.5m/s in the 100 year ARI event, whilst lower velocities of between 0.4 to 0.8m/s are predicted in the floodplain areas to the north around Crush Creek.

6.1.5 Model 5 – Bowen River

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 67km 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 17m and 6m in the main channel of the Bowen River for the 100 and 10 year ARI events respectively. Parrot Creek was also shown to have significant flood depths of approximately 12.5m and 11m during the 100 and 10 year ARI events respectively.

The predicted peak velocities within the main Bowen River waterway are predicted to be over 6m/s during the 100 year ARI event, with approximately 5.5m/s during the 10 year ARI event. Parrot Creek was predicted to have peak velocities in the order of 1m/s and 0.7m/s for the 100 and 10 year ARI events respectively.

6.1.6 Model 6 – Suttor River (Upstream)

The Suttor River is the main waterway within the Belyando Suttor Sub Basin. This model is located in the very upper reaches of the Suttor River, with the lower Suttor River Crossing occurring some 150km 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 8m in some areas. This is due to the well defined nature of the waterway at this location. Peak velocities are predicted to be approximately 1.5m/s with some discrete areas above 2m/s. Depths and velocities reduce to approximately 7m and 1.3m/s respectively during the 10 year ARI event.

Results suggest that the well defined nature of the waterway at this location results in deeper, more defined flood extents, with peak velocities maintained typically under 2m/s, possibly as a result of the thicker vegetation cover at this location.

6.1.7 Model 7 - Suttor River (Downstream)

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

The crossing is located in a rural / natural 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 5km 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 4m reducing to 3m for the 10 year ARI event. Localised channels within the floodplain experience depths of up to 6m during the 100 year ARI event. Peak velocities are predicted to be on average approximately 1m/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 1.5m/s for the 100 year ARI event.

Results suggest that the Suttor River's large flow rates result in expansive inundation and significant flow depths. Peak velocities would appear to be quite low given the high flow rates, and this is likely due to the flat gradient of the waterway system and the well vegetated nature of the floodplain areas.

6.1.8 Model 8 – Mistake Creek

Mistake Creek lies within the Belyando Suttor Sub Basin, and is a tributary of the Belyando River, which it joins some 19km downstream of the crossing location.

The crossing location is in a rural area with regions of cropping and associated dam storages present. This is shown in the flood mapping where a storage reservoir is represented in the topographic data and flood modelling results. Topographic data suggests the storage was near capacity when the ALS was collected, and for the purposes of this assessment it was assumed that the dam was at 100% capacity at the onset of the design rainfall events. 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.

Results predict that peak flood depths in the order of 5.5m and slightly under 5m for the 100 and 10 year ARI events respectively in the main Mistake Creek channel. Peak depths of around 2.5m and 2m for the 100 and 10 year ARI events occur in the local channels within the floodplain areas to the north of the main channel alignment. Peak velocities are predicted to be approximately 1m/s for the 100 year ARI event in the cleared floodplain areas where the limited vegetation cover enables faster flow rates. Within the main Mistake Creek channel, velocities are predicted to be in the order of 0.5m/s for the 100 year ARI event due to the thicker vegetation and flat waterway gradient.

Local catchment flows entering the storage facility were shown to overtop the dam and result in shallow expansive flow downstream of the storage, with depths adjacent to the constructed channel at this location in the order of 1m for the 100 year ARI event. As no bathymetry data for the storage dam was available for this analysis, depths within the dam itself are unknown. No flow release structures were modelled as part of this storage reservoir.

6.1.9 Model 9 – Lascelles Creek

Lascelles Creek lies within the Belyando Suttor Sub Basin, and is a tributary of Mistake Creek, which joins the Belyando River some 95km 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 30m in width that interconnect through the study area. Flood extents are therefore typically shallow and expansive due to the unremarkable nature of the topography.

Model predictions for the 100 and 10 year ARI event suggest peak depths to be in the order of 3m and 2.5m respectively in the main channel of the floodplain. Peak depths of up to 1m for the 100 year ARI event were evident in the overbank areas immediately adjacent to the main channel. Peak velocities are predicted to be approximately 0.5m/s in the cleared floodplain areas whilst within the main channel, velocities are predicted to be up to 1m/s during the 100 year ARI event. These velocities reduce to approximately 0.25m/s and 0.7m/s for the 10 year ARI event.

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.

6.1.10 Model 10 – Belyando River

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

The crossing location is in an area where flood behaviour is expansive and interconnects with the adjacent waterway systems (Letree Hill Creek).

Flood depths in the main channel regions of up to 7.5m and 6.5m for the 100 and 10 year ARI events respectively are predicted in the main Belyando River channels. Peak velocities within the main channel are predicted to be in the order of 2.5m/s during the 100 year ARI event reducing to approximately 2m/s for the 10 year ARI event. In the floodplain areas of the Belyando, depths of approximately 1.5m are predicted to occur with lower flow velocities of approximately 0.9m/s during the 100 year ARI event. Flow depths in the floodplain that links the Belyando to the Lestree Hill Creek system is predicted to have peak depths of over 2m in some instances with peak velocities of approximately 1m/s. It is noted these model results are likely to be influenced by the forced flow path in the modelling at this location. Due to the limited envelope of the detailed topographic data, and the significant differences in topographic data elevations shown at this location, extending the model using the DERM 25m DEM was not possible. Similarly, the poor channel definition within the DERM 25m DEM would limit confidence in the ability of this dataset to determine flow routing through this intricate interconnecting system. The forced flow path approach adopted as part of this study was based on review of all available data, including aerial photography and both topographic datasets and was considered to be a conservative approach.

Flows in the Lestree Hill Creek system were shown to be small compared to those entering the system from the Belyando River. Extremely small low flow channels are evident in this system and as such most of the catchment runoff is transferred through floodplain areas with depths varying from approximately 0.5 to 1.5m. Velocities are similarly low with peak velocities in the order of 0.75m/s due to the flat gradient of the system.

6.1.11 Model 11 – Sandy Creek

Sandy Creek lies within the Belyando Suttor Sub Basin, and is a tributary of the Belyando River, which it joins some 16km 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 4m in the main Sandy Creek channels, with depths of around 1.8m in the floodplain areas to the north of the main channel alignment. These depths reduce to approximately 3m and 1m respectively during the 10 year ARI event. During the 100 year ARI event, peak velocities are predicted to be approximately 2.5m/s in the cleared floodplain areas where the limited vegetation cover enables faster flow rates. Within the main Sandy Creek channel, velocities are predicted to be in the order of 1.25m/s due to the thicker vegetation present. Again, these velocities are reduced to 2m/s and 1m/s respectively during the 10 year ARI event.

Results generally suggest that for the larger scale events, both the main channel and the floodplain areas adjacent to the main channel carry significant amounts of the catchment discharge, with faster but shallower flow rates in the cleared floodplain areas.

6.2 Possible Impacts on Existing Case Flood Behaviour

It is likely that the filling within the floodplain required for the creation of the railway embankment and the crossings of the major waterways and associated infrastructure will impact on flood behaviour. These impacts may include but are not limited to scour in the immediate area of the crossing locations, as well as possible changes to flood levels both upstream and downstream of the rail crossing (afflux) as a result of either the railway embankment or impacts associated with drainage structure design (e.g. piers, abutments etc). Changes to flow regimes in the immediate areas adjacent to the rail embankment are likely due to the change of flow dynamics from the natural pre project environment to constructed crossing arrangements. These impacts are discussed in more detail for each crossing location below.

6.2.1 Caley Valley Wetlands

The majority of contributing catchment runoff within the Caley Valley Wetlands area are predicted to be shallow and expansive and natural flow regimes in this area are already impacted by the Bruce Highway and North Coast Railway.

The proposed rail alignment embankment will likely cause a barrier to the shallow sheet flows within the floodplain areas, and concentrate the catchment runoff through the various constructed culvert or bridge crossings.

The concentration of flow to these areas can create additional scour (localised erosion) potential, and can also alter the amount and timing of peak catchment flows entering the environment below the rail alignment.

6.2.2 Elliott, Bogie, Bowen, Upper Suttor Rivers & Pelican Creek

These waterways are well defined with significant flooding depths and velocities in some instances. It is likely that these crossings will be bridged, and as such and depending on the respective bridge designs, impacts from the rail alignment may be limited to scour potential around the bridge piers and abutments, and possible increases in flood levels upstream of the rail embankment due to the form losses and blockage associated with the bridge structure.

The effect of the bridges on flow rates downstream of the crossings is not likely to be as significant during lower order events due to the inherent flow transference capabilities of this style of crossing. However, some impact on peak flow rates during flooding events will occur if significant debris build up results in partial blockage of the structure during a flooding event. Blockage of the bridge structures is likely to occur to some extent given the surrounding natural environments at many of these crossings. Blockages of bridges can also lead to increased flood levels upstream as well as impacts on the timing of floodplain peaks within the overall drainage basins.

6.2.3 Mistake, Lascelles and Sandy Creeks & Belyando and Lower Suttor River

Waterways which are shown to experience more expansive, shallow inundation across a majority of the floodplain are likely to have a crossing incorporating both earth embankment and bridge/culvert structure. The extent of either the bridge or earth embankment components will be likely dependant on a detailed review of flow rates and flood behaviour at each crossing location.

The likely impact for these crossings is therefore highly dependent on the incorporated flow capacity of each structure, and the extent of earth embankment encroachment into the respective floodplain regions. It is likely that increased scour potential will occur around and through the bridge/culvert region. This is a result of increased velocities through the structure and around features such as piers and abutments. If the earth embankment encroaches into the floodplain significantly, it is likely increased water levels (and depths) upstream of the railway will occur, with a reduced water level downstream of the embankment. Accordingly, impacts on flow transference will occur, possibly resulting in reduced peak flow rates downstream of the rail embankments. This inherently may impact on timing of peak flood levels in regions further downstream in the respective drainage sub basins.

Again, some impact on peak flow rates during flooding events will occur if significant debris build up results in partial blockage of the structure during a flooding event. Blockage of the bridge structures is likely to occur to some extent given the surrounding natural environments at many of these crossings.

6.2.4 Cumulative Impacts

Impacts on the natural hydrologic response of each of the catchments crossed by the rail alignment have the potential to be amplified by similar projects in the catchment areas. Multiple rail alignment crossings of the same waterway systems may lead to increased impact on natural waterway flooding behavior and catchment response, and result in increased attenuation of catchment flows at each rail crossing. This will likely lead to an alteration to the time to peak flow levels from each respective contributing catchment, and may also impact on the timing of flood peaks downstream of the rail alignments within the respective drainage sub basins. The severity of these cumulative impacts will be highly dependent on the location of the proposed alignments within each catchment.

6.2.5 Mitigation Options

Whilst still in the conceptual stage of the project, mitigation of most perceived hydraulic impacts to natural waterways can be undertaken by:

- Appropriate design of waterway crossings by use of bridge and culvert structures to ensure any impacts on natural waterway behaviour are minimised;
- Incorporation of stream protection works during construction to minimise the likelihood of causing erosion within the watercourses; and
- Ensuring infrastructure are located clear of the predicted flood inundation extents (where practicable).

7. CONCLUSIONS & RECCOMENDATIONS

This study has been commissioned by Waratah Coal to provide a detailed assessment of flood behaviour at a number of discrete major waterway crossings along the proposed heavy haul rail route.

The flood analysis results as determined using the XP-RAFTS and TUFLOW models have been successful in quantifying flooding behaviour at these locations for the 10, 50 and 100 year ARI events.

Modelling results predict that the significant catchment areas and resultant peak flows that contribute to many of the waterway crossings lead to significant areas of inundation. This is especially true for the crossings of the Belyando and Suttor Rivers, where expansive flood extents are predicted due to the large contributing catchments. Other waterways with smaller contributing catchment areas were shown to have smaller regions of inundation, with generally shallower depths of inundation in floodplain areas and lower flow velocities. Systems closer to the coast such as the Elliott River and Bowen River were shown to have more concentrated flood extents, with model results predicting deeper and faster flowing flood behaviour in these locations.

It is recommended that during the design phase of the project, additional investigation be carried out for all minor stream crossings of the rail alignment. This may be undertaken by way of desktop analysis for smaller systems or for larger minor systems discrete 1D modelling may be appropriate. This will enable Waratah Coal to determine adequate culvert sizing requirements for the minor waterway crossings, and ensure that no impacts on natural flow regimes occur.

Detailed GIS mapping tasks have been undertaken to fully illustrate flooding behaviour at each crossing location for the 100 Year ARI event. These maps have included detailed flood heights, depths and velocities. All heights, depth and velocity GIS tables for all of the design rainfall events analysed as part of this study have been provided to Waratah Coal in the form of digital data to facilitate future interrogation of modelling results.

The outcomes from this study will provide important information to assist Waratah Coal in the progression of its detailed design of the Heavy Haul Rail system, and to support requirements of the Environmental Impact Statement (EIS) process.

8. 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. If any warranty would be implied whether by law, custom or otherwise, that warranty is to the full extent permitted by law excluded. 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.

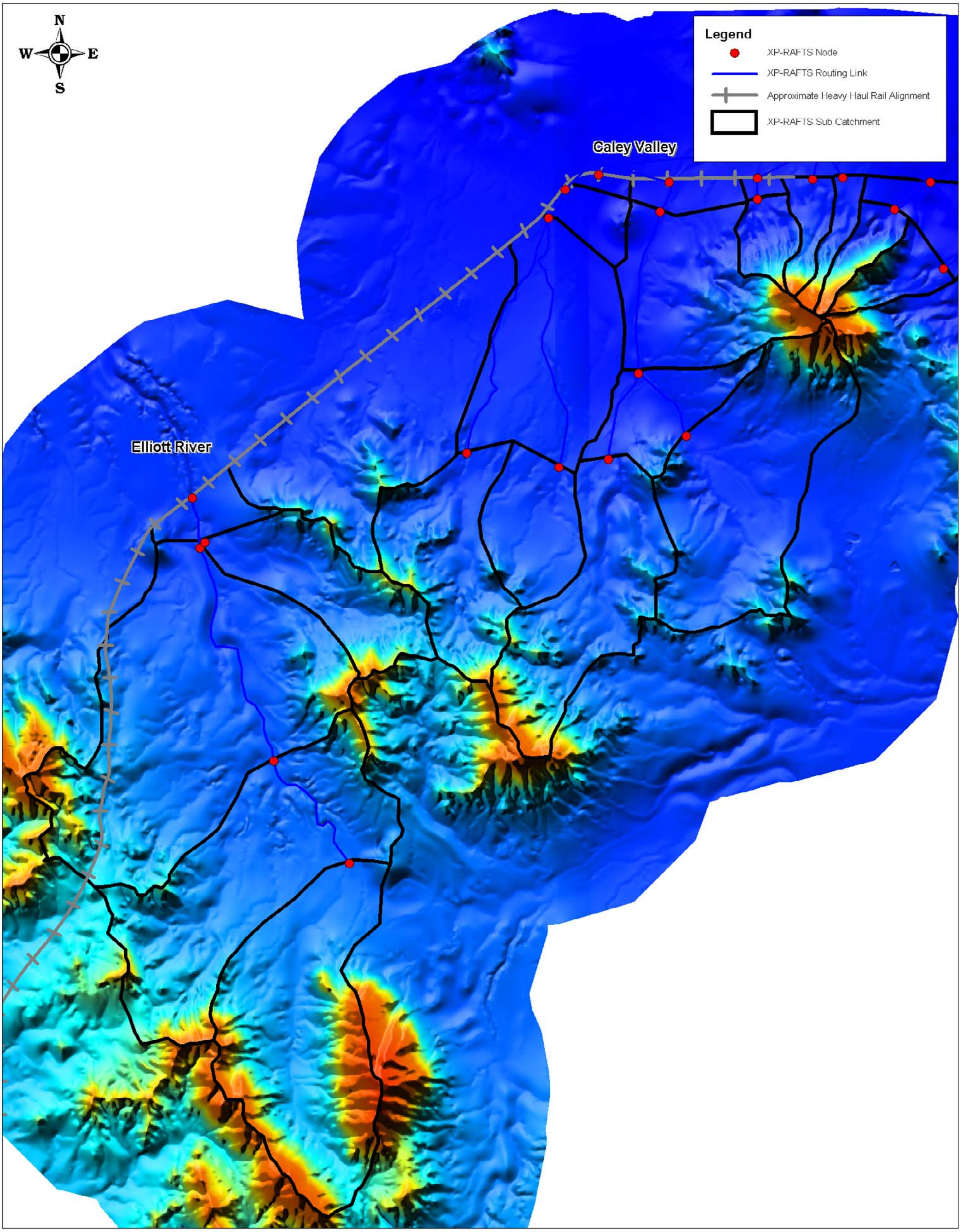
e. This document is for the use of the party to whom it is addressed and for no other persons. No information as to the contents or subject matter of this document or any part thereof may be disclosed to a third party in any form, without prior consent in writing from Engeny.

9. REFERENCES

1. WorleyParsons, 2009, *"Waratah Coal Abbot Point Rail Corridor – Preliminary Flooding Investigation"*
2. XP Software, 2008, *"XP-RAFTS Manual v.7"*
3. WBM BMT, 2008, *"TUFLOW User Manual"*
4. Queensland Department of Natural Resources and Water, 2007, *"Queensland Urban Drainage Design Manual, Volume 1 (2nd Ed)"*
5. James Cook University (JCU), 2004, *"The Frequency of Surge Plus Tide During Tropical Cyclones for Selected Open Coast Locations Along the Queensland East Coast"*
6. The Institute of Engineers Australia (IEA), 2001*, "Australian Rainfall and Runoff – A Guide to Flood Estimation Volumes 1 and 2"*
7. Queensland Government, *Draft Queensland Coastal Plan - Draft Guidelines Coastal Hazards*
8. *Bureau of Meteorology, 2010 (www.bom.gov.au)*

APPENDIX A

Hydrologic Model Layouts



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:100,000 (A3)

0 2 4
Kilometers

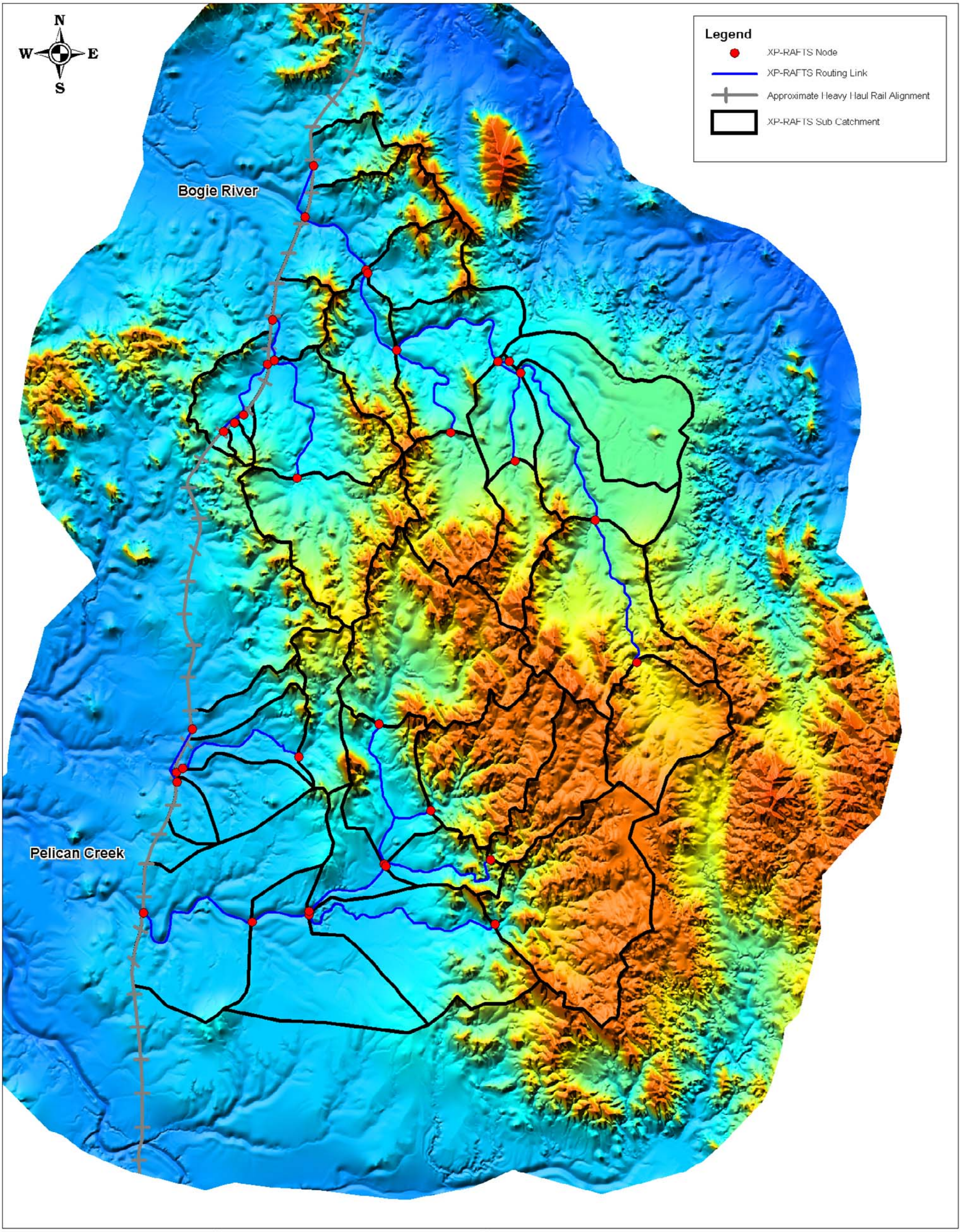
REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study

Appendix A

Elliott River & Caley Valley Hydrology Model Layouts

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

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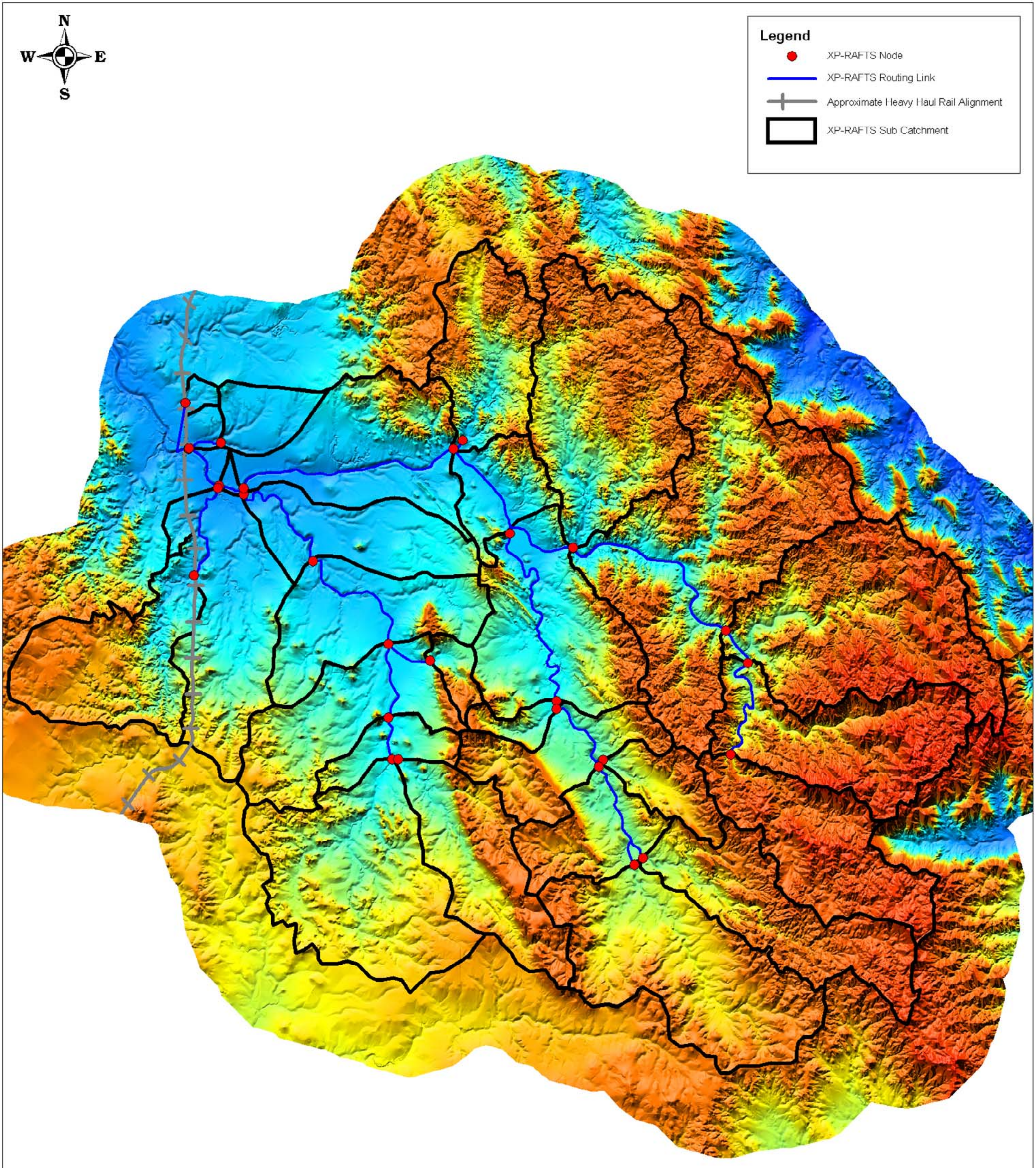
REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study

Appendix A

Bogie River & Pelican Creek Hydrology Model Layouts

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

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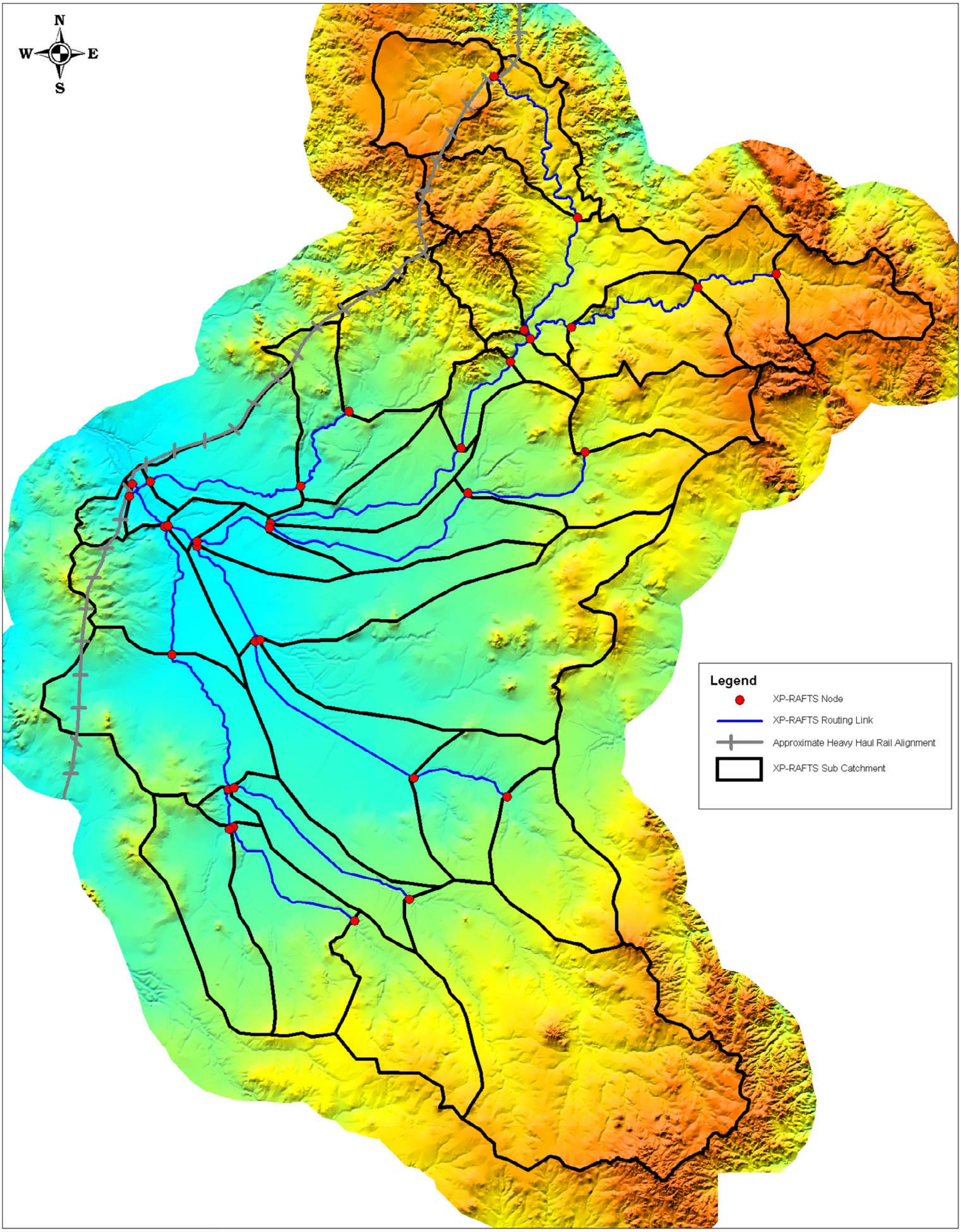
REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study

Appendix A

Bowen River Hydrology Model Layout

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:500,000 (A3)

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Kilometers

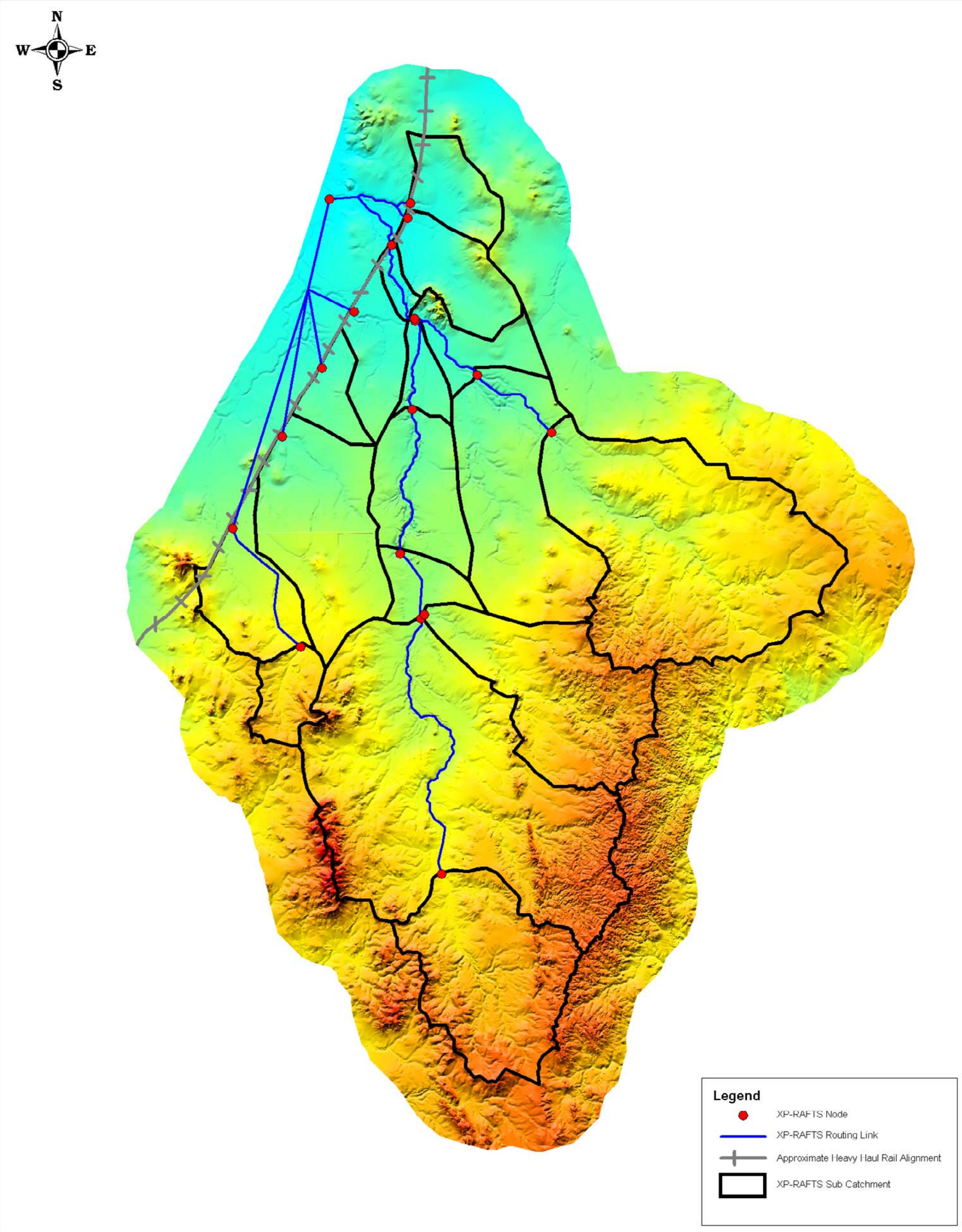
REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study

Appendix A

Suttor River Hydrology Model Layout

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:500,000 (A3)

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Kilometers

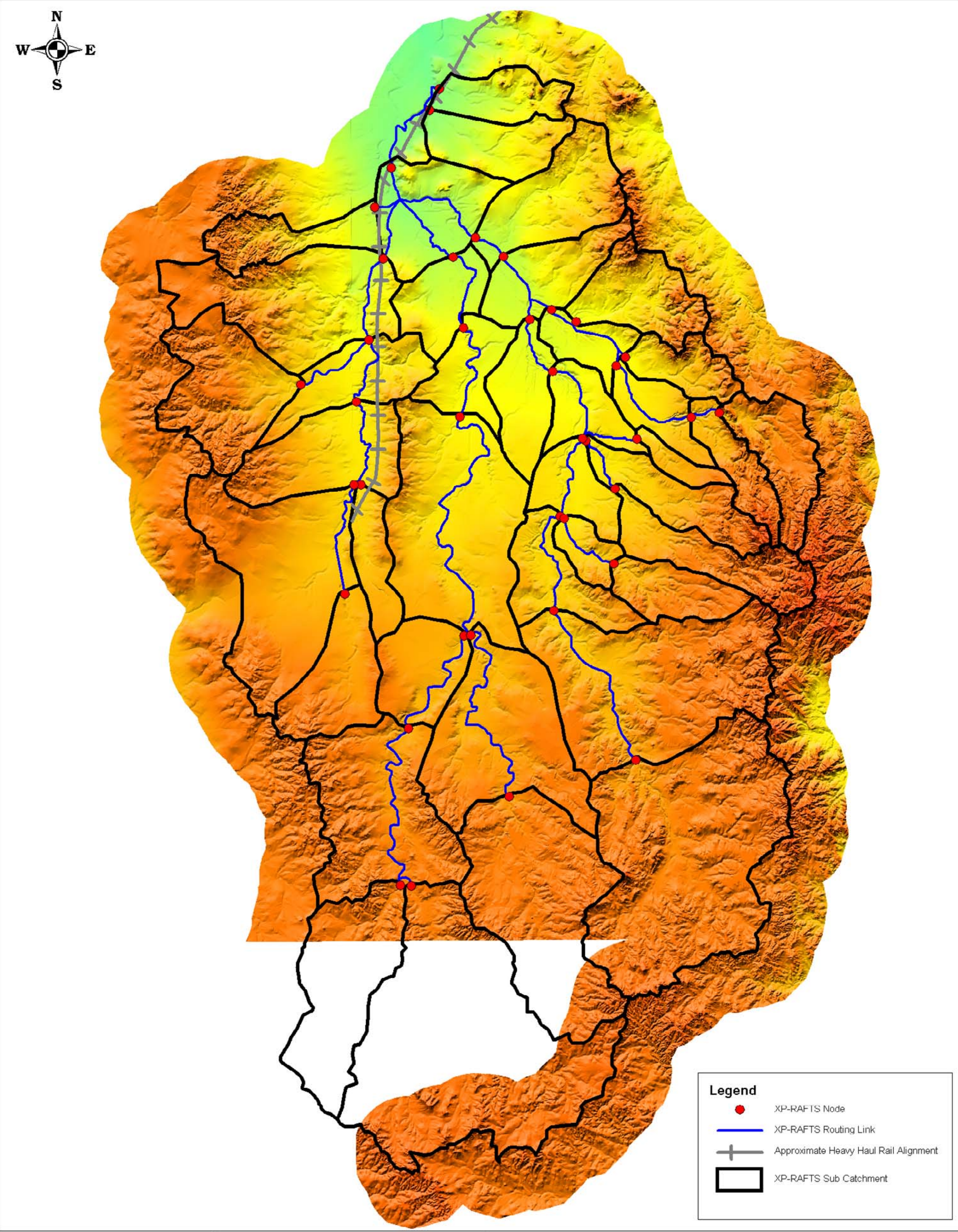
REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study

Appendix A

Belyando S1 Hydrology Model Layout

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:600,000 (A3)

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Kilometers

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study

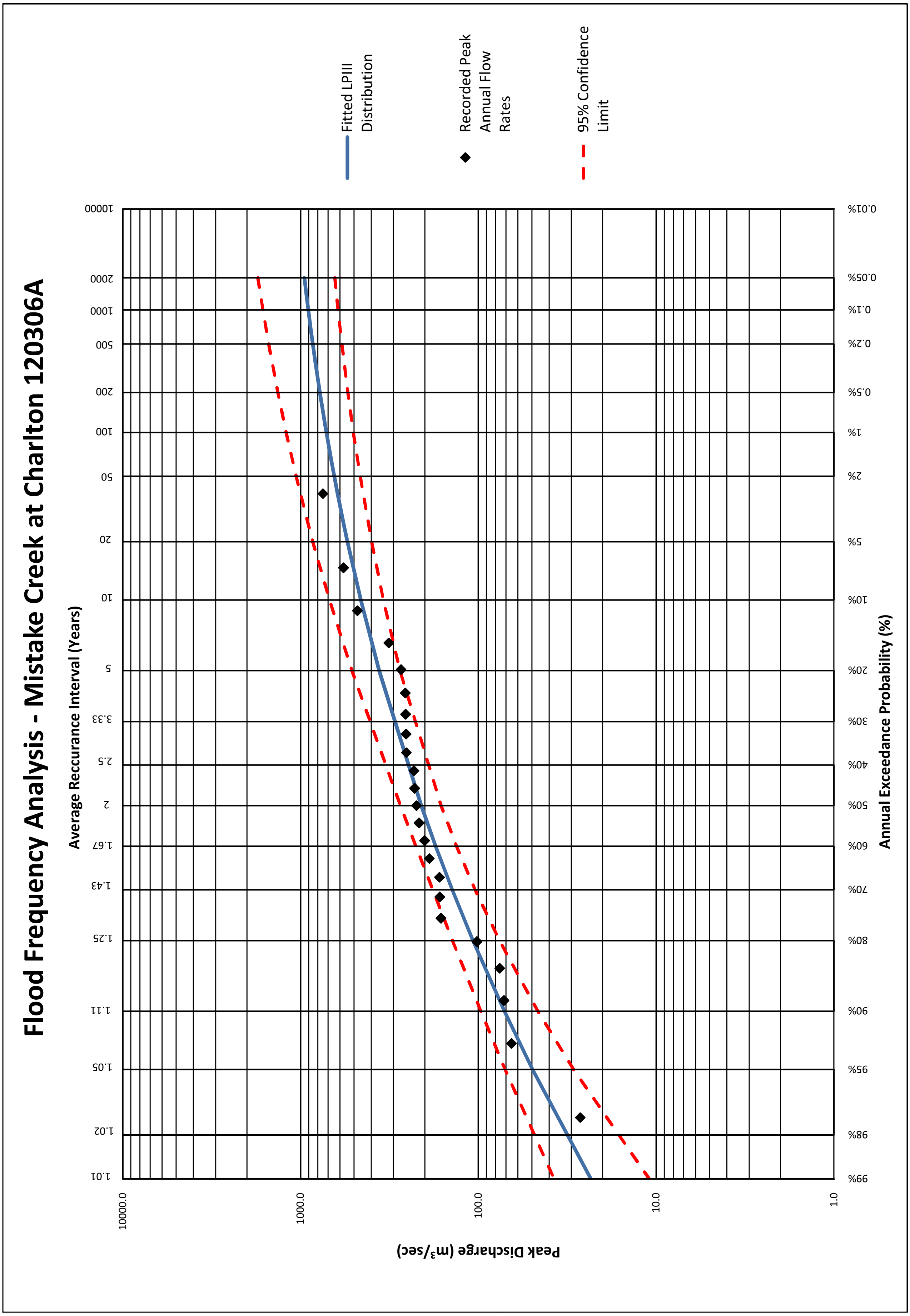
Appendix A

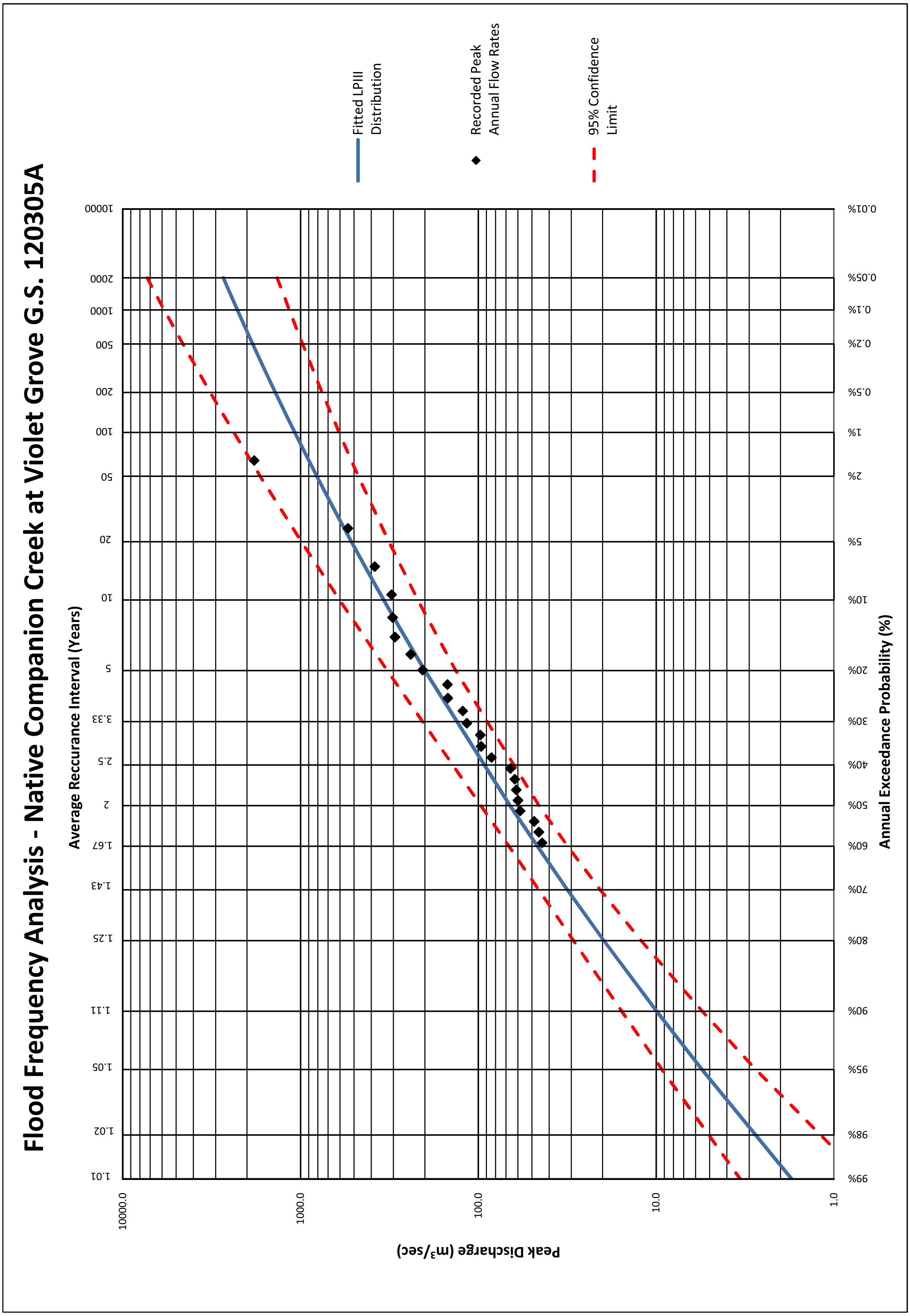
Belyando S2 Hydrology Model Layout

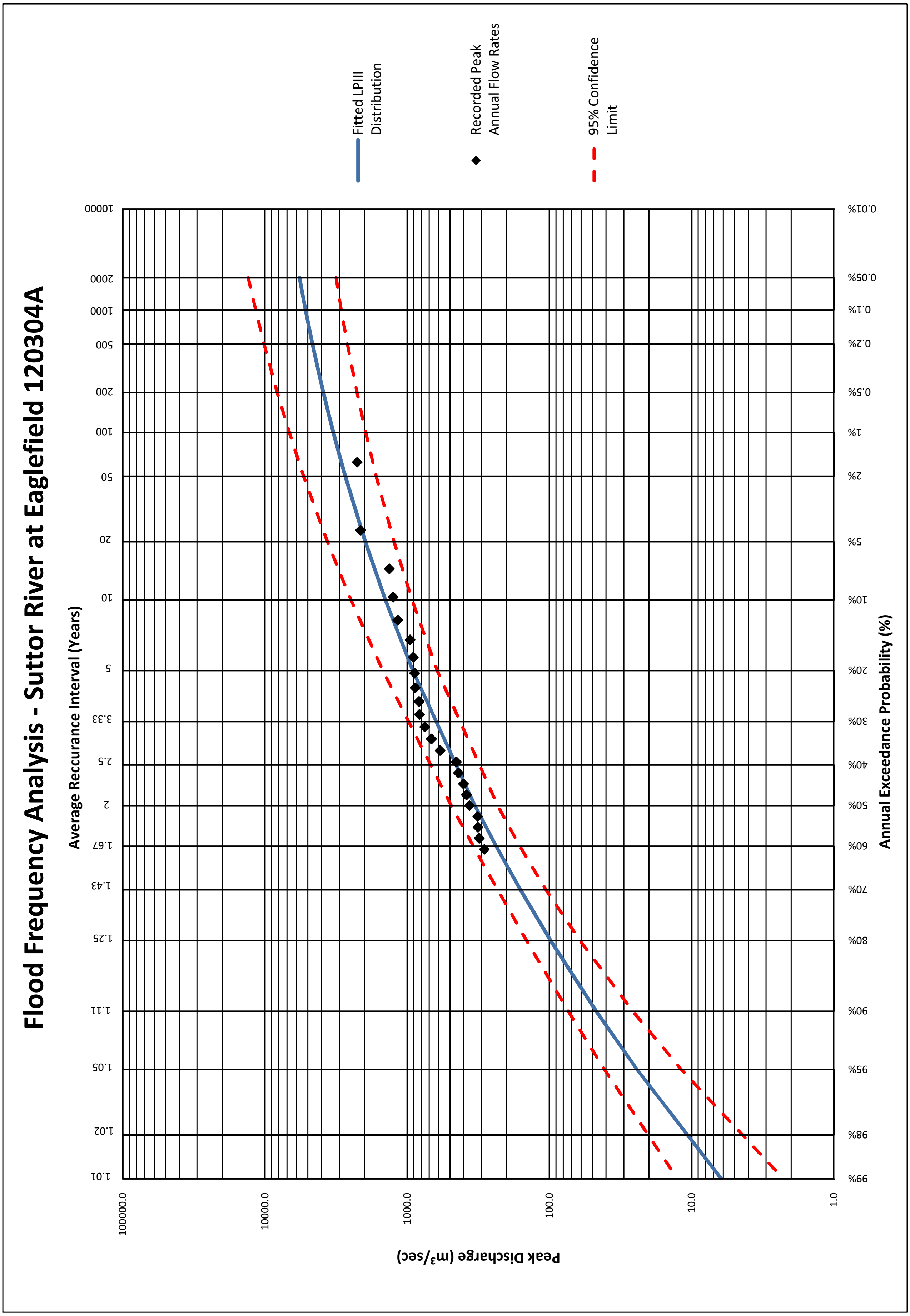
Waratah Coal

APPENDIX B

Flood Frequency Analysis Results

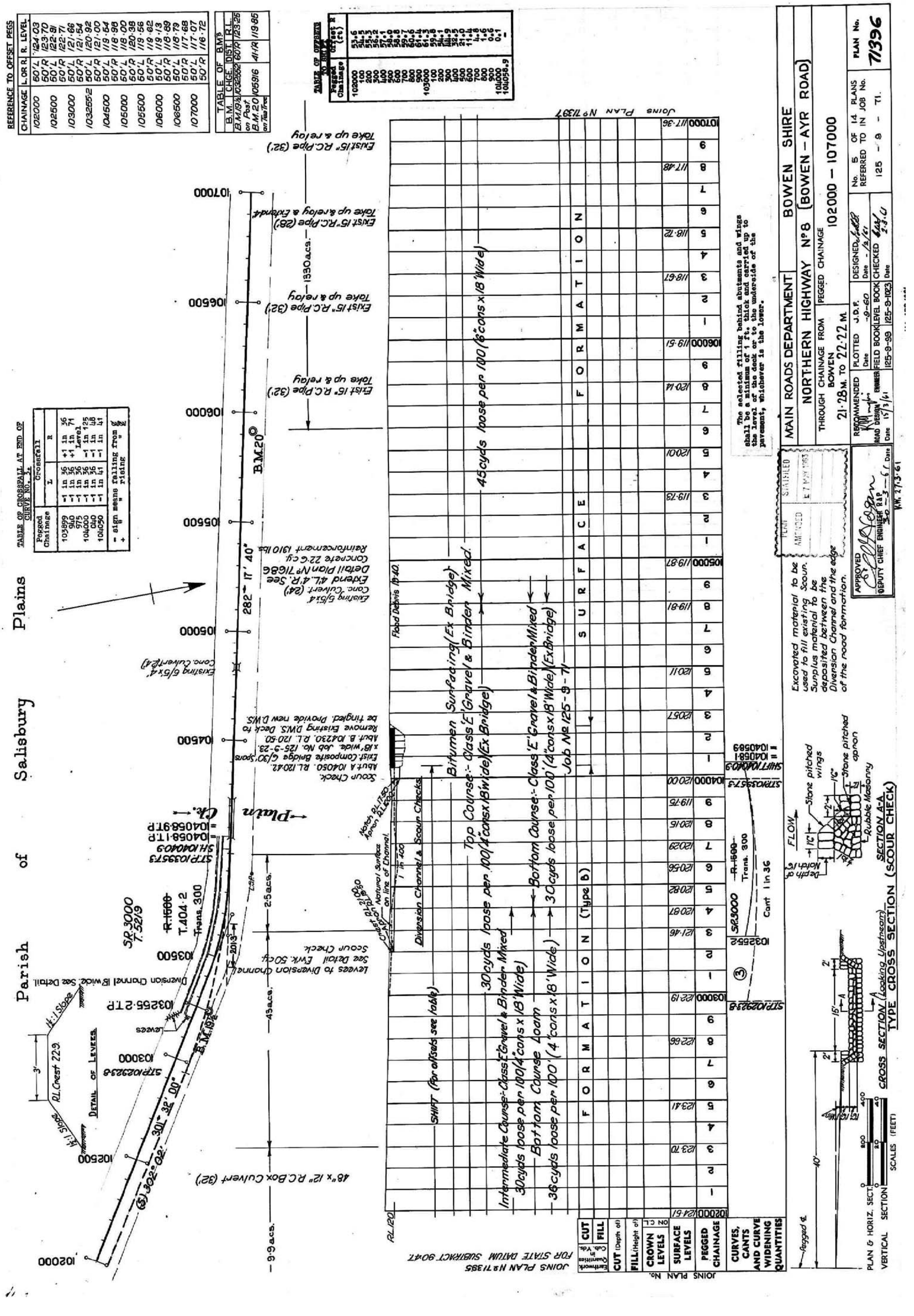

Flood Frequency Analysis - Mistake Creek at Charlton 120306A
Average Reccurance Interval (Years)
1.01
1.02
1.05
1.11
1.25
1.43
1.67
2
2.5
3.33
5
10
20
50
100
200
500
1000
2000
10000
Annual Exceedance Probability (%)
99%
98%
95%
90%
80%
70%
60%
50%
40%
30%
20%
10%
5%
2%
1%
0.5%
0.2%
0.1%
0.05%
0.01%
Peak Discharge (m3/sec)
10000.0
1000.0
100.0
10.0
1.0
Fitted LPIII Distribution
Recorded Peak Annual Flow Rates
95% Confidence Limit

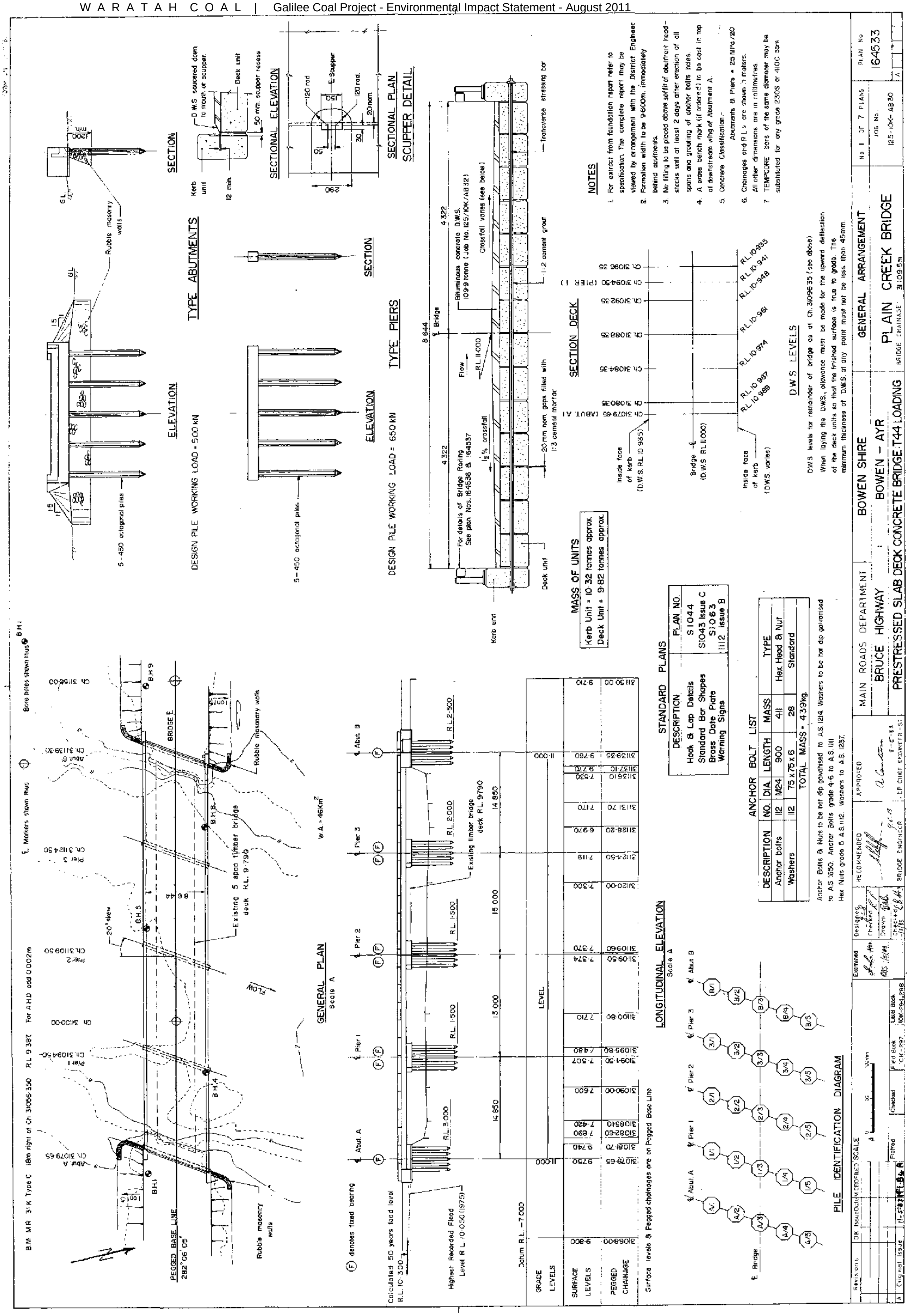

Flood Frequency Analysis - Native Companion Creek at Violet Grove G.S. 120305A
Average Reccurance Interval (Years)
1.01
1.02
1.05
1.11
1.25
1.43
1.67
2
2.5
3.33
5
10
20
50
100
200
500
1000
2000
10000
Annual Exceedance Probability (%)
99%
98%
95%
90%
80%
70%
60%
50%
40%
30%
20%
10%
5%
2%
1%
0.5%
0.2%
0.1%
0.05%
0.01%
Peak Discharge (m³/sec)
10000.0
1000.0
100.0
10.0
1.0
Fitted LPIII Distribution
Recorded Peak Annual Flow Rates
95% Confidence Limit

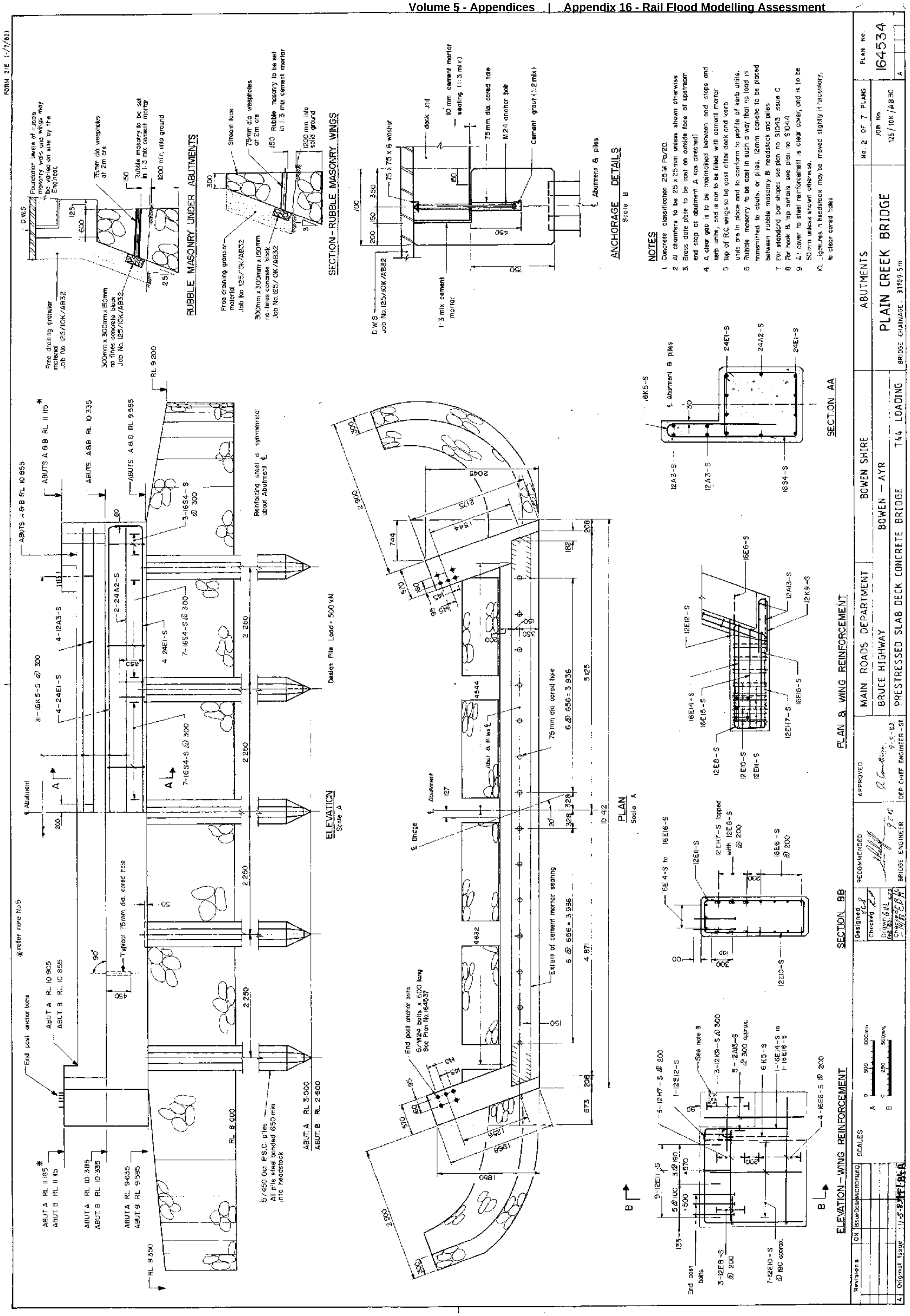

Flood Frequency Analysis - Suttor River at Eaglefield 120304A
Average Reccurance Interval (Years)
1.01
1.02
1.05
1.11
1.25
1.43
1.67
2
2.5
3.33
5
10
20
50
100
200
500
1000
2000
10000
Fitted LPIII Distribution
Recorded Peak Annual Flow Rates
95% Confidence Limit
100000.0
10000.0
1000.0
100.0
10.0
1.0
Peak Discharge (m3/sec)
99%
98%
95%
90%
80%
70%
60%
50%
40%
30%
20%
10%
5%
2%
1%
0.5%
0.2%
0.1%
0.05%
0.01%
Annual Exceedance Probability (%)

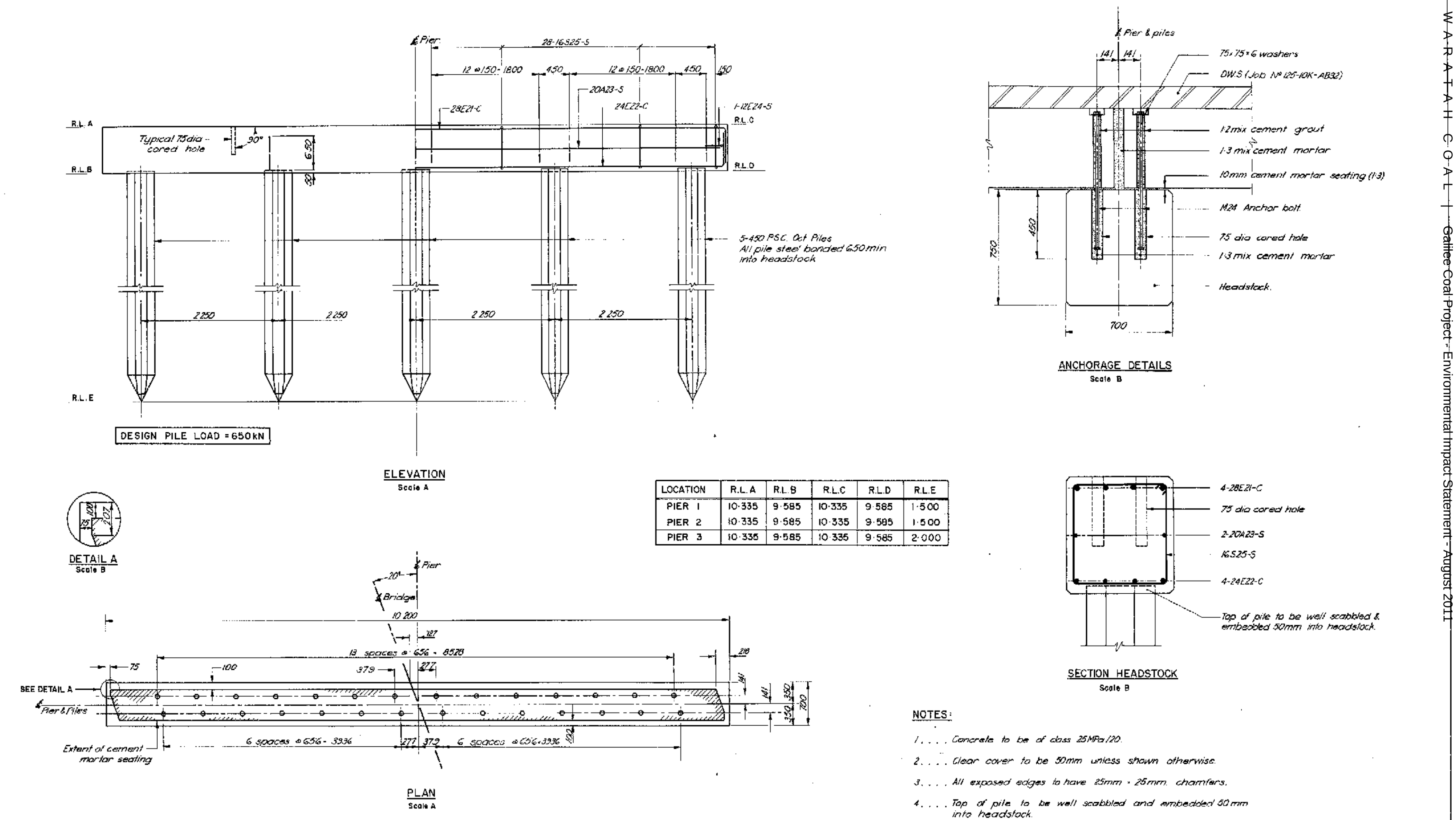
APPENDIX C

As Constructed Drawings


Parish of Salisbury Plains
MAIN ROADS DEPARTMENT
BOWEN SHIRE
NORTHERN HIGHWAY No 8 (BOWEN – AYR ROAD)
102000 – 107000
PLAN No. 7/396
REFERENCE TO OFFSET PEGS
TABLE OF B.M.s
DETAIL OF LEVEES
CROSS SECTION (Looking Upstream)
SECTION A-A
TYPE CROSS SECTION (SCOUR CHECK)
FORMATION
SURFACE
CUT
FILL
CROWN LEVELS
SURFACE LEVELS
PEGGED CHAINAGE
CURVES, CANTS AND CURVE WIDENING QUANTITIES


MAIN ROADS DEPARTMENT
BRUCE HIGHWAY
PRESTRESSED SLAB DECK CONCRETE BRIDGE T44 LOADING
BOWEN SHIRE
BOWEN – AYR
GENERAL ARRANGEMENT
PLAIN CREEK BRIDGE
PLAN No 164533
GENERAL PLAN
Scale A
LONGITUDINAL ELEVATION
Scale A
PILE IDENTIFICATION DIAGRAM
TYPE ABUTMENTS
DESIGN PILE WORKING LOAD = 500 kN
TYPE PIERS
DESIGN PILE WORKING LOAD = 650 kN
SECTIONAL PLAN
SCUPPER DETAIL
SECTIONAL ELEVATION
SECTION DECK
MASS OF UNITS
Kerb Unit = 10·32 tonnes approx.
Deck Unit = 9·82 tonnes approx.
STANDARD PLANS
ANCHOR BOLT LIST
NOTES
D.W.S. LEVELS


MAIN ROADS DEPARTMENT
BOWEN SHIRE
BRUCE HIGHWAY
BOWEN – AYR
PRESTRESSED SLAB DECK CONCRETE BRIDGE
T44 LOADING
ABUTMENTS
PLAIN CREEK BRIDGE
PLAN & WING REINFORCEMENT
BRIDGE CHAINAGE : 31103·5m
PLAN No. 164534
JOB No. 125/10K/AB3C
No. 2 OF 7 PLANS
ELEVATION
PLAN
SECTION AA
SECTION BB
ELEVATION – WING REINFORCEMENT
ANCHORAGE DETAILS
RUBBLE MASONRY UNDER ABUTMENTS
SECTION - RUBBLE MASONRY WINGS
NOTES
Design Pile Load = 500 kN
FORM 21E



LOCATION	R.L.A	R.L.B	R.L.C	R.L.D	R.L.E
PIER 1	10·335	9·585	10·335	9·585	1·500
PIER 2	10·335	9·585	10·335	9·585	1·500
PIER 3	10·335	9·585	10·335	9·585	2·000

NOTES:

1. . . . Concrete to be of class 25MPa/20.
2. . . . Clear cover to be 50mm unless shown otherwise.
3. . . . All exposed edges to have 25mm × 25mm chamfers.
4. . . . Top of pile to be well scabbled and embedded 50mm into headstock.
5. . . . All pile steel to be bonded 650mm into headstock.
6. . . . For details of reinforcing steel and hook, lap and bend details, refer to Plan Nºs 51043 (Issue C) and 51044.

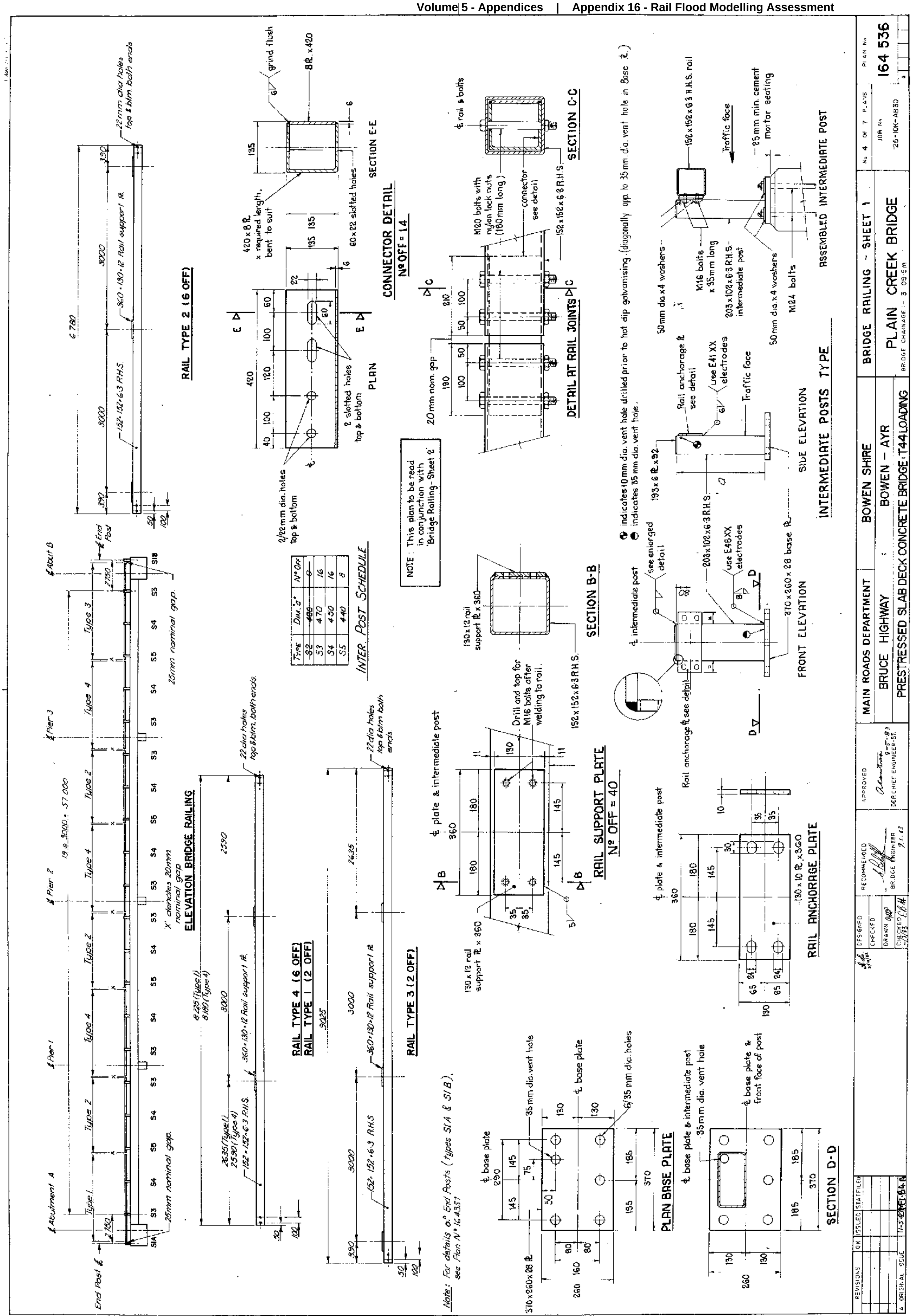
Revisions | Issue Date | M. CROFILED | SCALES A 0 500 1000 mm B 0 200 400 mm
A Original Issue 11-5-83 MF1-64 A

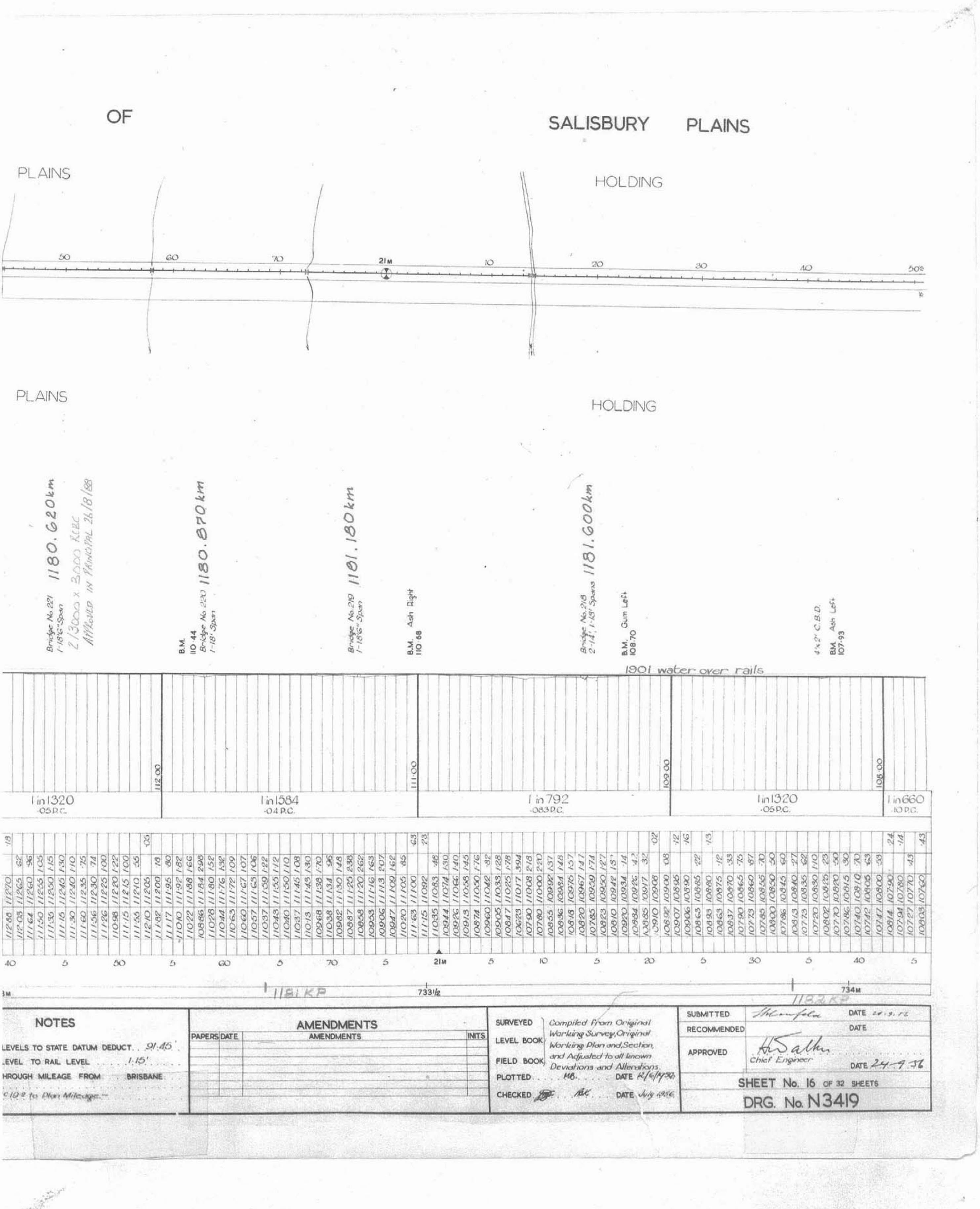
Field Book | Level Book | Designed | Drawn | Examined | Checked | Checking | RECOMMENDED | BRIDGE ENGINEER | APPROVED | 9-5-83 | DEPUTY CHIEF ENGINEER-ST.

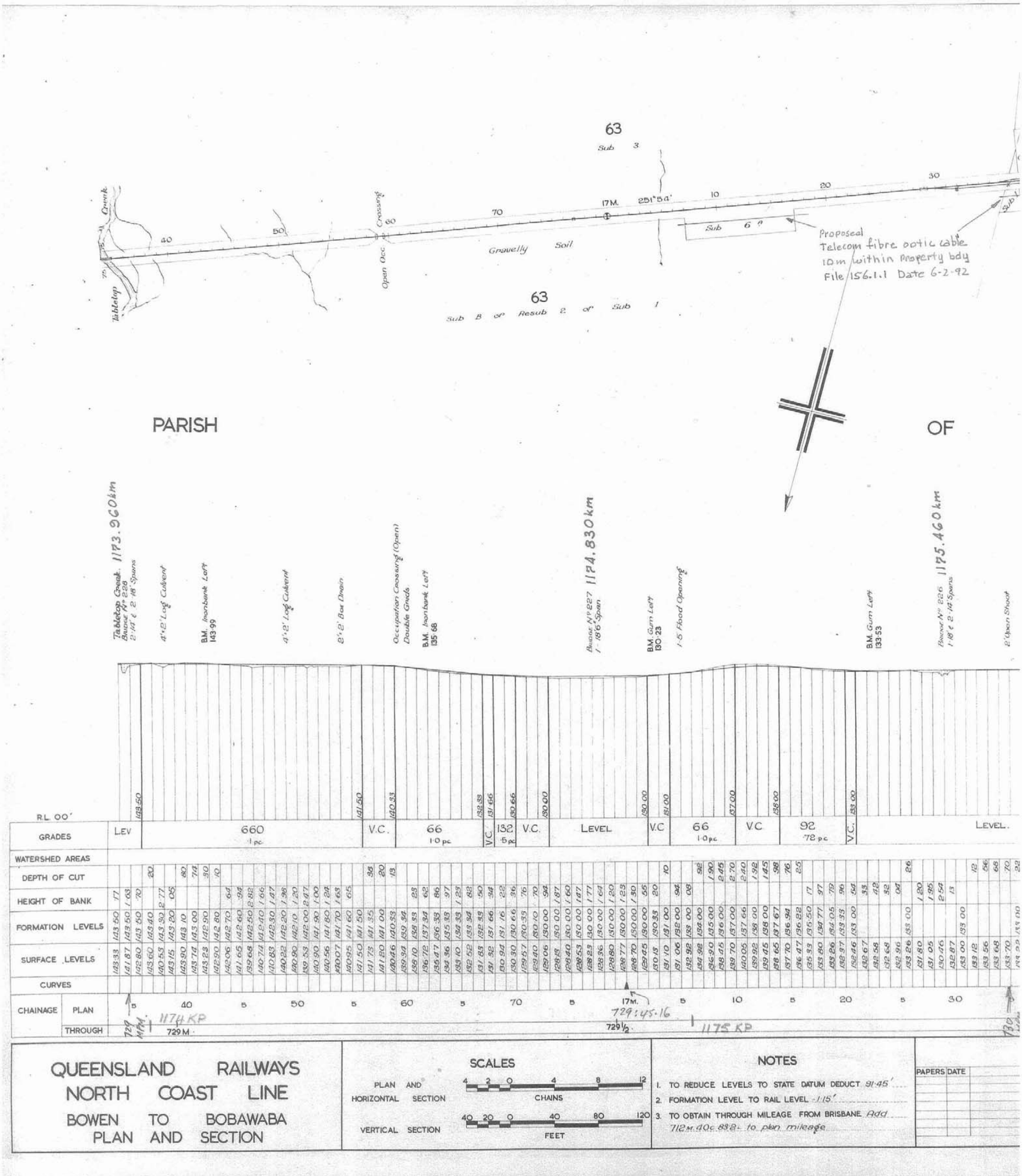
MAIN ROADS DEPARTMENT | BOWEN SHIRE
BRUCE HIGHWAY : BOWEN — AYR
PRESTRESSED SLAB DECK CONCRETE BRIDGE: T44 LOADING

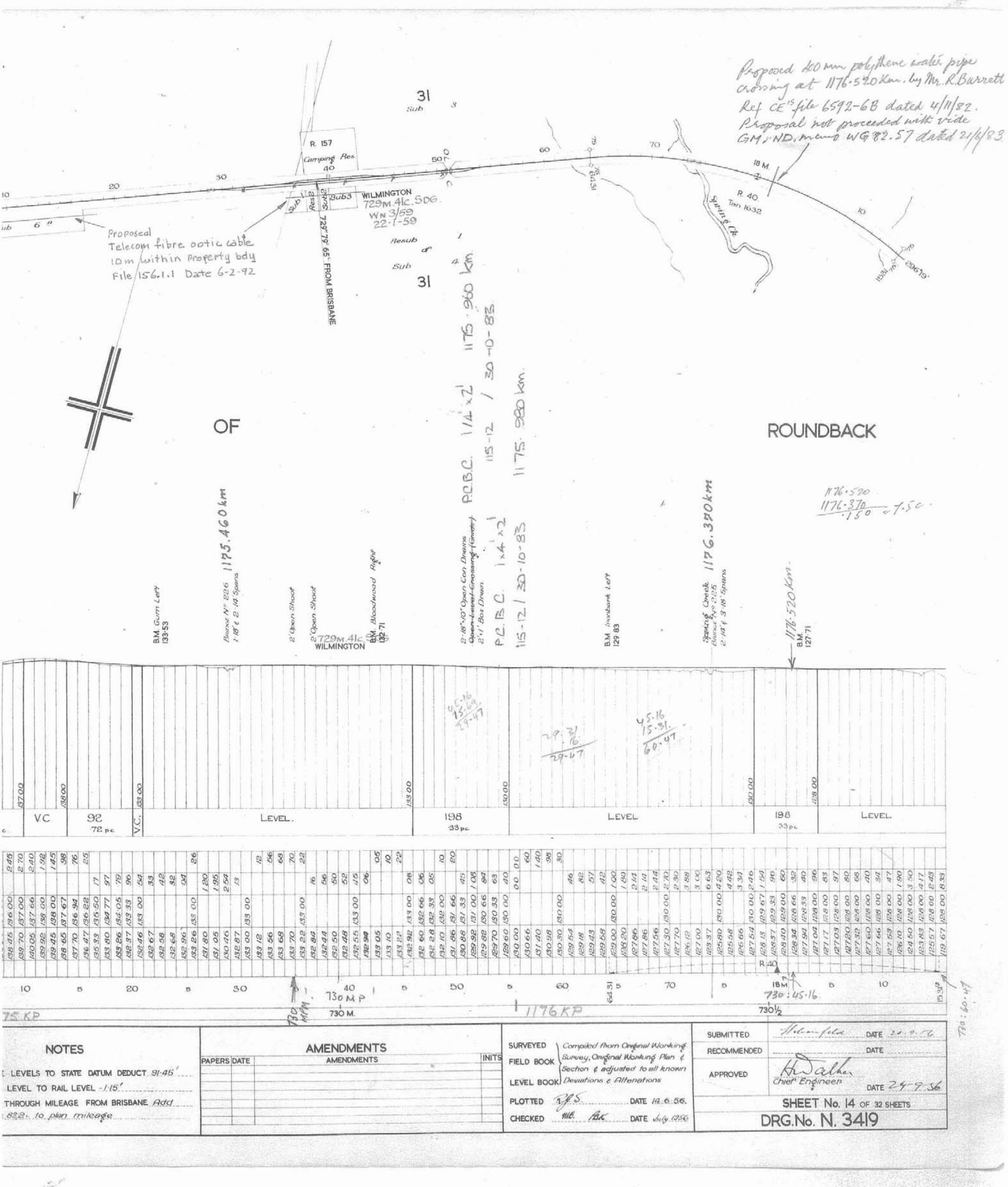
PIERS 1, 2 & 3
PLAIN CREEK BRIDGE
BRIDGE CHAINAGE: 31 109.5m

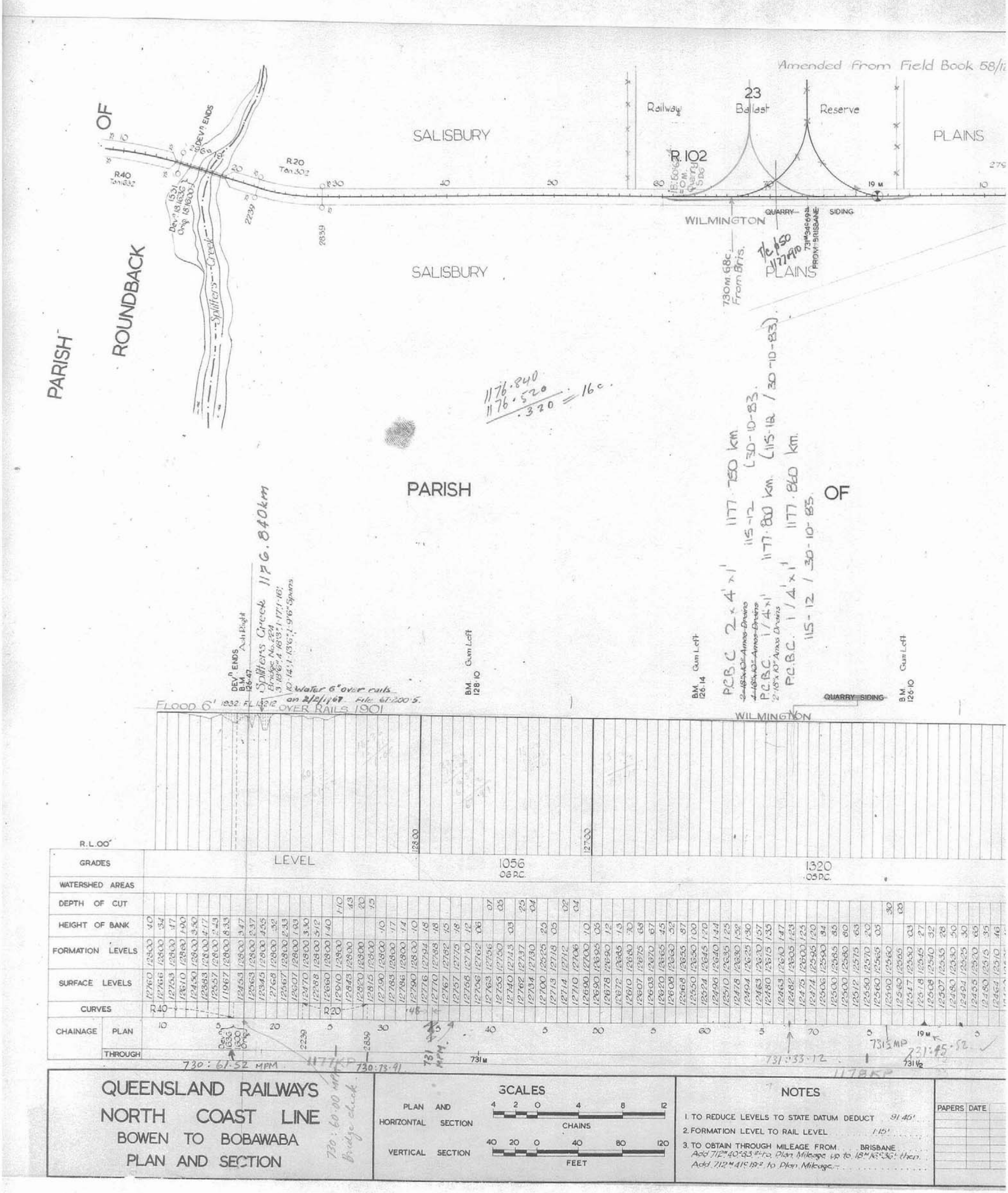
No 3 OF 7 PLANS
JOB No 125-10K-AB30
PLAN No. 164535

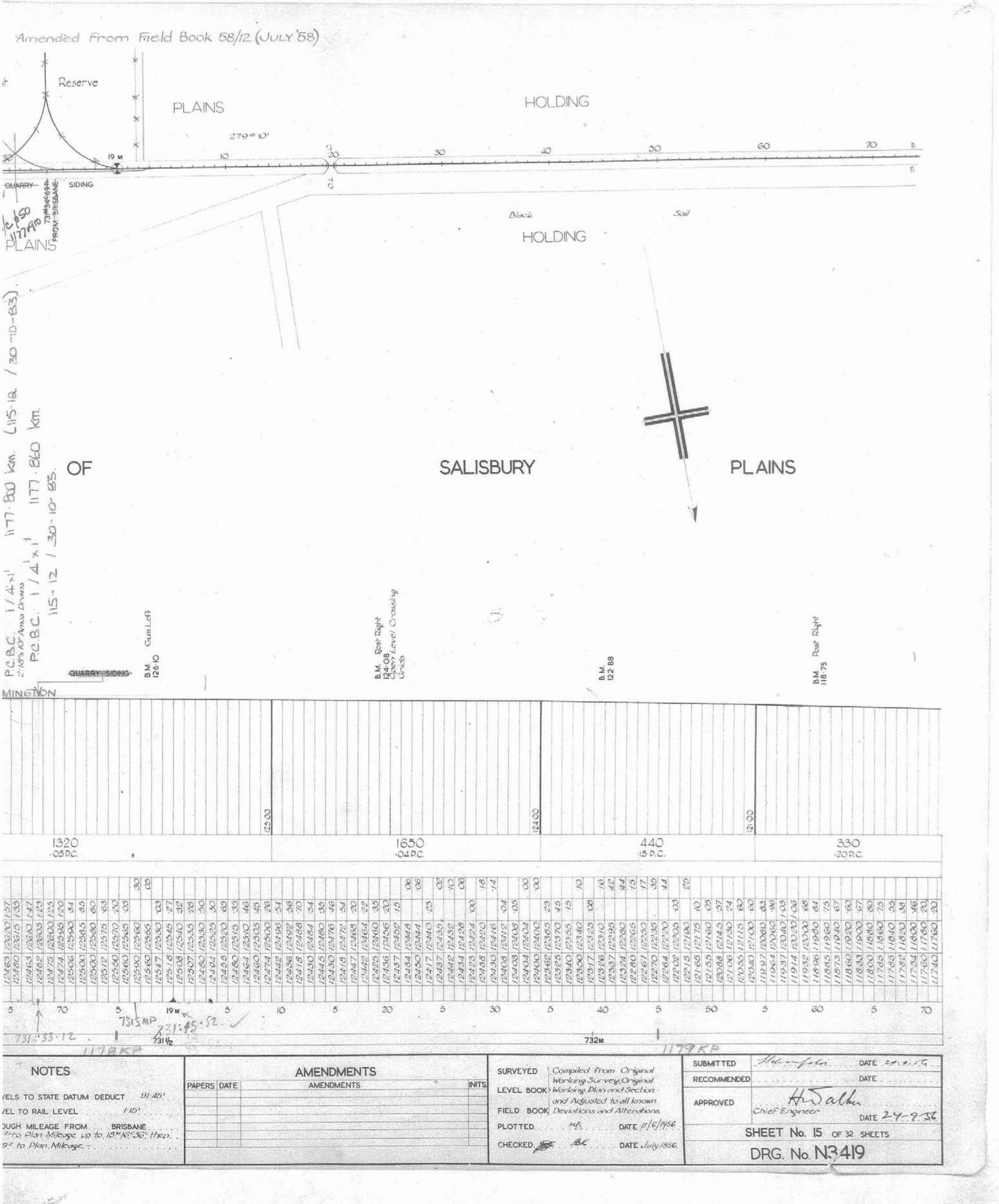

MAIN ROADS DEPARTMENT
BRUCE HIGHWAY
PRESTRESSED SLAB DECK CONCRETE BRIDGE: T44 LOADING
BOWEN SHIRE
BOWEN – AYR
BRIDGE RAILING – SHEET 1
PLAIN CREEK BRIDGE
164 536
ELEVATION BRIDGE RAILING
RAIL TYPE 2 (6 OFF)
RAIL TYPE 4 (6 OFF)
RAIL TYPE 1 (2 OFF)
RAIL TYPE 3 (2 OFF)
CONNECTOR DETAIL
Nº OFF = 14
SECTION E-E
SECTION C-C
DETAIL AT RAIL JOINTS
INTER. POST SCHEDULE
SECTION B-B
RAIL SUPPORT PLATE
Nº OFF = 40
PLAN BASE PLATE
SECTION D-D
RAIL ANCHORAGE PLATE
FRONT ELEVATION
SIDE ELEVATION
INTERMEDIATE POSTS TYPE
ASSEMBLED INTERMEDIATE POST
NOTE: This plan to be read in conjunction with 'Bridge Railing - Sheet 2'
Note: For details of End Posts (types S1A & S1B), see Plan Nº 164357

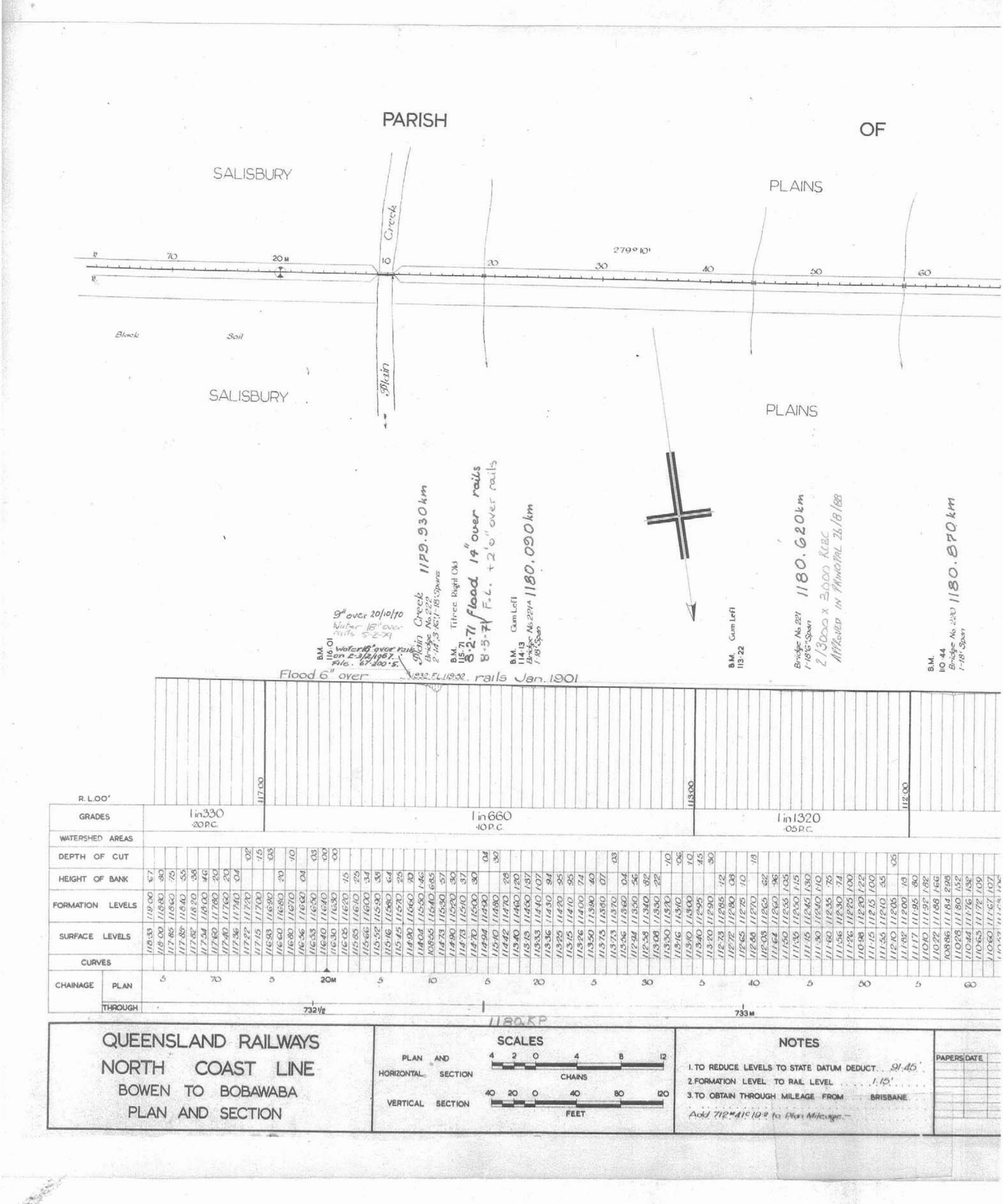

OF
SALISBURY PLAINS
PLAINS
HOLDING
PLAINS
HOLDING
Bridge No 221 1-18'6" Span 1180.620km
2/3000 x 3000 RCBC APPROVED IN PRINCIPAL 26/8/88
B.M. 110·44
Bridge No 220 1-18' Span 1180.870km
Bridge No 219 1-18'6" Span 1181.180km
B.M. Ash Right 110·68
Bridge No 218 2-14', 1-18' Spans 1181.600km
B.M. Gum Left 108.70
4"x2" C.B.D.
B.M. Ash Left 107·93
1901 water over rails
1 in 1320 ·05 P.C.
1 in 1584 ·04 P.C.
1 in 792 ·083 P.C.
1 in 1320 ·05 P.C.
1 in 660 ·10 P.C.
1181 KP
733½
1182 KP
734M
NOTES
LEVELS TO STATE DATUM DEDUCT 91·45'
LEVEL TO RAIL LEVEL 1·15'
THROUGH MILEAGE FROM BRISBANE
AMENDMENTS
PAPERS DATE AMENDMENTS INITS.
SURVEYED
LEVEL BOOK
FIELD BOOK
Compiled from Original Working Survey, Original Working Plan and Section, and Adjusted to all known Deviations and Alterations.
PLOTTED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
Chief Engineer
SHEET No. 16 OF 32 SHEETS
DRG. No. N3419


63
Sub 3
17M.
251°54'
Sub 6 ?
Gravelly Soil
Open Occ Crossing
Tabletop Creek
Proposed Telecom fibre optic cable 10m within property bdy File 156.1.1 Date 6-2-92
63
Sub 8 of Resub 2 of Sub 1
PARISH
OF
Tabletop Creek 1173.960km
Bridge No 228 2-14' & 2-18' Spans
4'x2' Log Culvert
B.M. Ironbark Left 143.99
4'x2' Log Culvert
2'x2' Box Drain
Occupation Crossing (Open) Double Grids
B.M. Ironbark Left 135.68
Bridge No 227 1-18'6 Span 1174.830km
B.M. Gum Left 130.23
1-5 Flood Opening
B.M. Gum Left 133.53
Bridge No 226 1-18' & 2-14' Spans 1175.460km
2' Open Shoot
R.L. 00'
GRADES
WATERSHED AREAS
DEPTH OF CUT
HEIGHT OF BANK
FORMATION LEVELS
SURFACE LEVELS
CURVES
CHAINAGE PLAN
THROUGH
1174 KP
729:45·16
1175 KP
729 M
QUEENSLAND RAILWAYS
NORTH COAST LINE
BOWEN TO BOBAWABA
PLAN AND SECTION
SCALES
PLAN AND HORIZONTAL SECTION
CHAINS
VERTICAL SECTION
FEET
NOTES
1. TO REDUCE LEVELS TO STATE DATUM DEDUCT 91·45'
2. FORMATION LEVEL TO RAIL LEVEL -1·15'
3. TO OBTAIN THROUGH MILEAGE FROM BRISBANE Add 712m 40c 83ℓ to plan mileage
PAPERS DATE


Proposed 400 mm polythene water pipe crossing at 1176.520 Km. by Mr. R. Barrett Ref CE's file 6592-6B dated 4/11/82. Proposal not proceeded with vide GM, ND. memo WG 82.57 dated 21/6/83
31
R. 157
Camping Res.
WILMINGTON
729M.41c. SDG
WN 3/59 22-1-59
Proposed Telecom fibre optic cable 10m within property bdy File 156.1.1 Date 6-2-92
729M 79' 65' FROM BRISBANE
R. 40
Tan 1632
OF
ROUNDBACK
1175.460 km
1176.390 km
1176.520 Km
1175.960 Km
1175.980 Km
P.C.B.C. 1/4' x 2' 115-12 / 30-10-83
P.C.B.C. 1x4'x2 115-12 / 30-10-83
B.M. Gum Left 133.53
B.M. Bloodwood Right 132.71
B.M. Ironbark Left 129.83
B.M. 127.71
Spring Creek
VC
92
72 pc
V.C.
LEVEL.
198
33 pc
LEVEL
198
33 pc
LEVEL
730 M P
730 M.
1176 KP
75 KP
730½
730:45.16
730:60.47
NOTES
LEVELS TO STATE DATUM DEDUCT 91.45'
LEVEL TO RAIL LEVEL -1.15'
THROUGH MILEAGE FROM BRISBANE Add 882. to plan mileage
AMENDMENTS
PAPERS DATE
AMENDMENTS
INITS
SURVEYED
FIELD BOOK
LEVEL BOOK
Compiled from Original Working Survey, Original Working Plan & Section & adjusted to all known Deviations & Alterations
PLOTTED
DATE 14.6.56.
CHECKED
DATE July 1956
SUBMITTED
DATE 24.9.56
RECOMMENDED
DATE
APPROVED
Chief Engineer
DATE 24.9.56
SHEET No. 14 OF 32 SHEETS
DRG.No. N. 3419

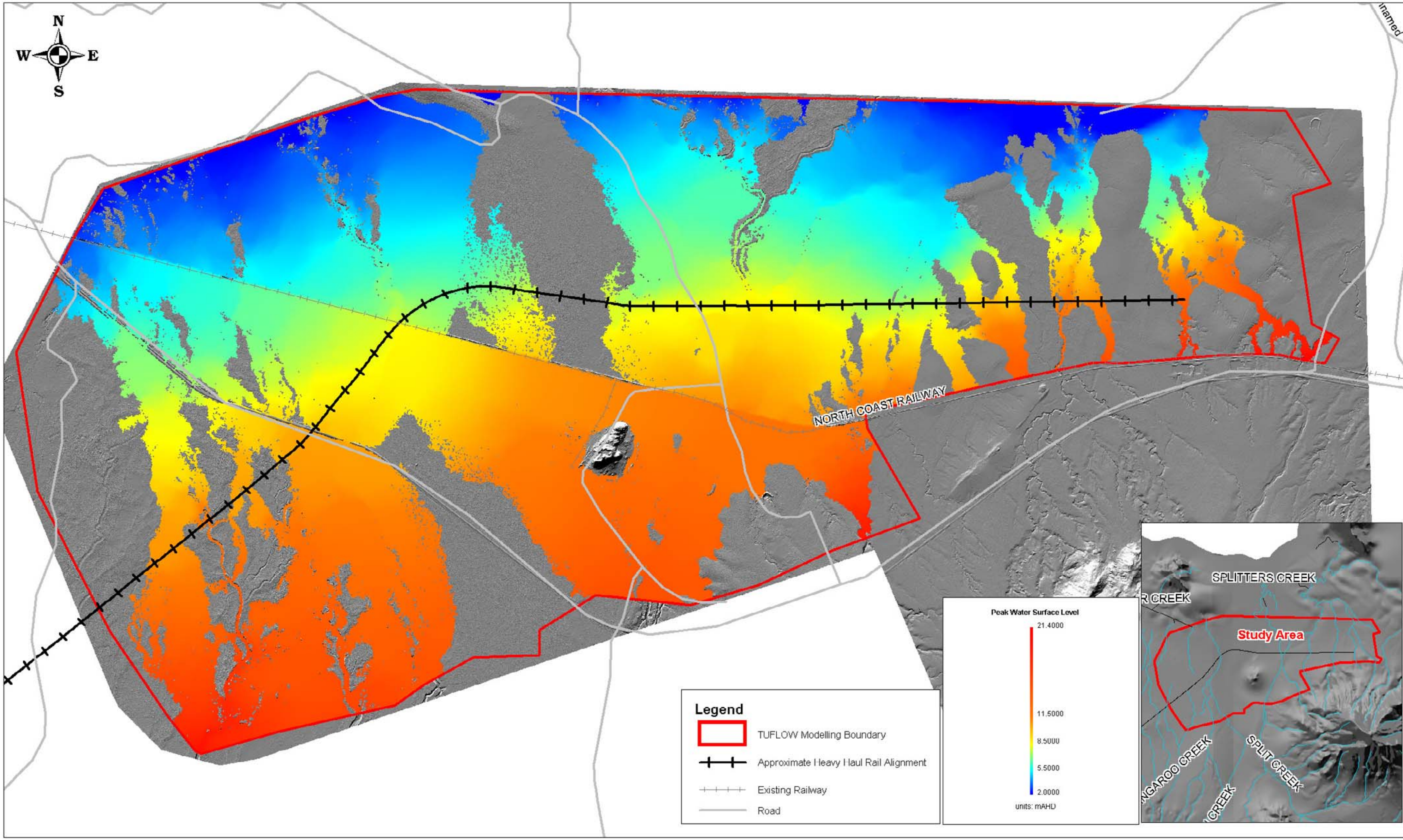

Amended From Field Book 58/
PARISH OF ROUNDBACK
SALISBURY
PLAINS
Railway Ballast Reserve
R.102
WILMINGTON
QUARRY SIDING
Splitters Creek
PARISH OF
1176·840
1176·520
·320 = 16c.
Splitters Creek 1176.840km
FLOOD 6' OVER RAILS 1901
Water 6" over rails on 2/2/1967
R.L.00'
GRADES
LEVEL
1056
1320
WATERSHED AREAS
DEPTH OF CUT
HEIGHT OF BANK
FORMATION LEVELS
SURFACE LEVELS
CURVES
CHAINAGE PLAN
THROUGH
730: 61·52 MPM
1177KP
1178KP
QUEENSLAND RAILWAYS
NORTH COAST LINE
BOWEN TO BOBAWABA
PLAN AND SECTION
SCALES
PLAN AND HORIZONTAL SECTION
CHAINS
VERTICAL SECTION
FEET
NOTES
1. TO REDUCE LEVELS TO STATE DATUM DEDUCT
2. FORMATION LEVEL TO RAIL LEVEL
3. TO OBTAIN THROUGH MILEAGE FROM BRISBANE
PAPERS DATE


Amended from Field Book 58/12 (JULY '58)
Reserve
PLAINS
HOLDING
QUARRY SIDING
Black Soil
HOLDING
PLAINS
OF
SALISBURY
PLAINS
QUARRY SIDING
1320
1650
440
330
NOTES
AMENDMENTS
SURVEYED
LEVEL BOOK
FIELD BOOK
PLOTTED
CHECKED
SUBMITTED
RECOMMENDED
APPROVED
Chief Engineer
SHEET No. 15 OF 32 SHEETS
DRG. No. N3419


PARISH
OF
SALISBURY
PLAINS
SALISBURY
PLAINS
Black
Soil
Blain Creek
279° 10'
1179.930 km
1180.090 km
1180.620 km
1180.870 km
9" over 20/10/70
Water 18" over rails 5-2-79
Water 18" over rails on 2-3/2/1967. File. 67-200-5.
8.2.71 flood. 14" over rails
8.5.71 F.L. +2'0" over rails
Flood 6" over rails Jan. 1901
B.M. 116.01
B.M. 115.71 Titree Right Ob
B.M. 114.13 Gum Left
B.M. 113.22 Gum Left
B.M. 110.44
Blain Creek Bridge No. 222
Bridge No. 221A 1-18' Span
Bridge No. 221 1-18'6" Span
2/1300D x 3000 RCBC APPROVED IN PRINCIPAL 26/8/88
Bridge No. 220 1-18' Span
R.L.00'
GRADES
1 in 330 ·20 P.C.
1 in 660 ·10 P.C.
1 in 1320 ·05 P.C.
WATERSHED AREAS
DEPTH OF CUT
HEIGHT OF BANK
FORMATION LEVELS
SURFACE LEVELS
CURVES
CHAINAGE PLAN
THROUGH
732½
733M
1180 KP
QUEENSLAND RAILWAYS
NORTH COAST LINE
BOWEN TO BOBAWABA
PLAN AND SECTION
SCALES
PLAN AND HORIZONTAL SECTION
CHAINS
VERTICAL SECTION
FEET
NOTES
1. TO REDUCE LEVELS TO STATE DATUM DEDUCT 91.46'
2. FORMATION LEVEL TO RAIL LEVEL 1.15'
3. TO OBTAIN THROUGH MILEAGE FROM BRISBANE
Add 712M 41C 19.9 to Plan Mileage.
PAPERS DATE

APPENDIX D

100 Year ARI Flood Maps



ENGENY

Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:30,000 (A3)

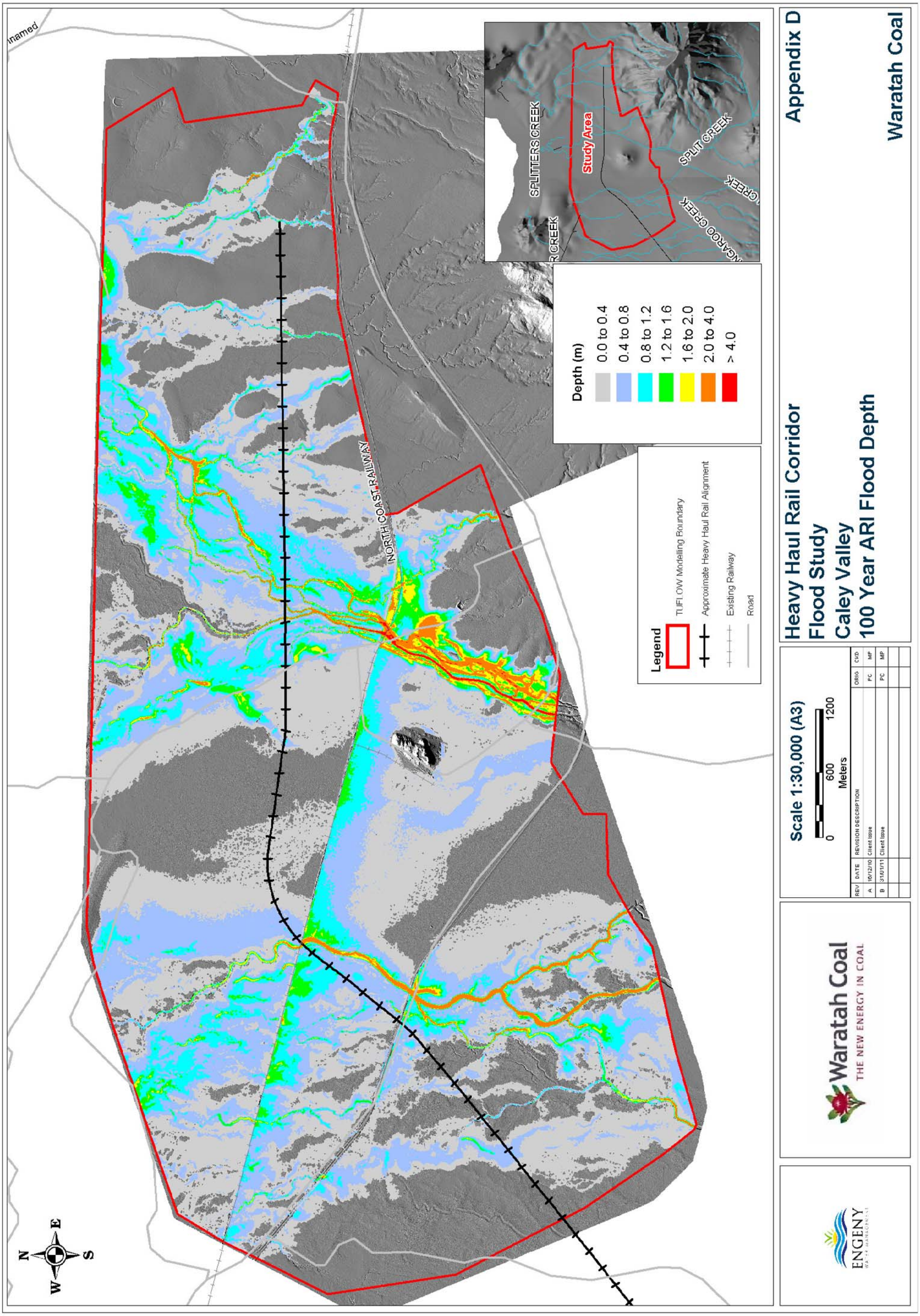
0 600 1200
Meters

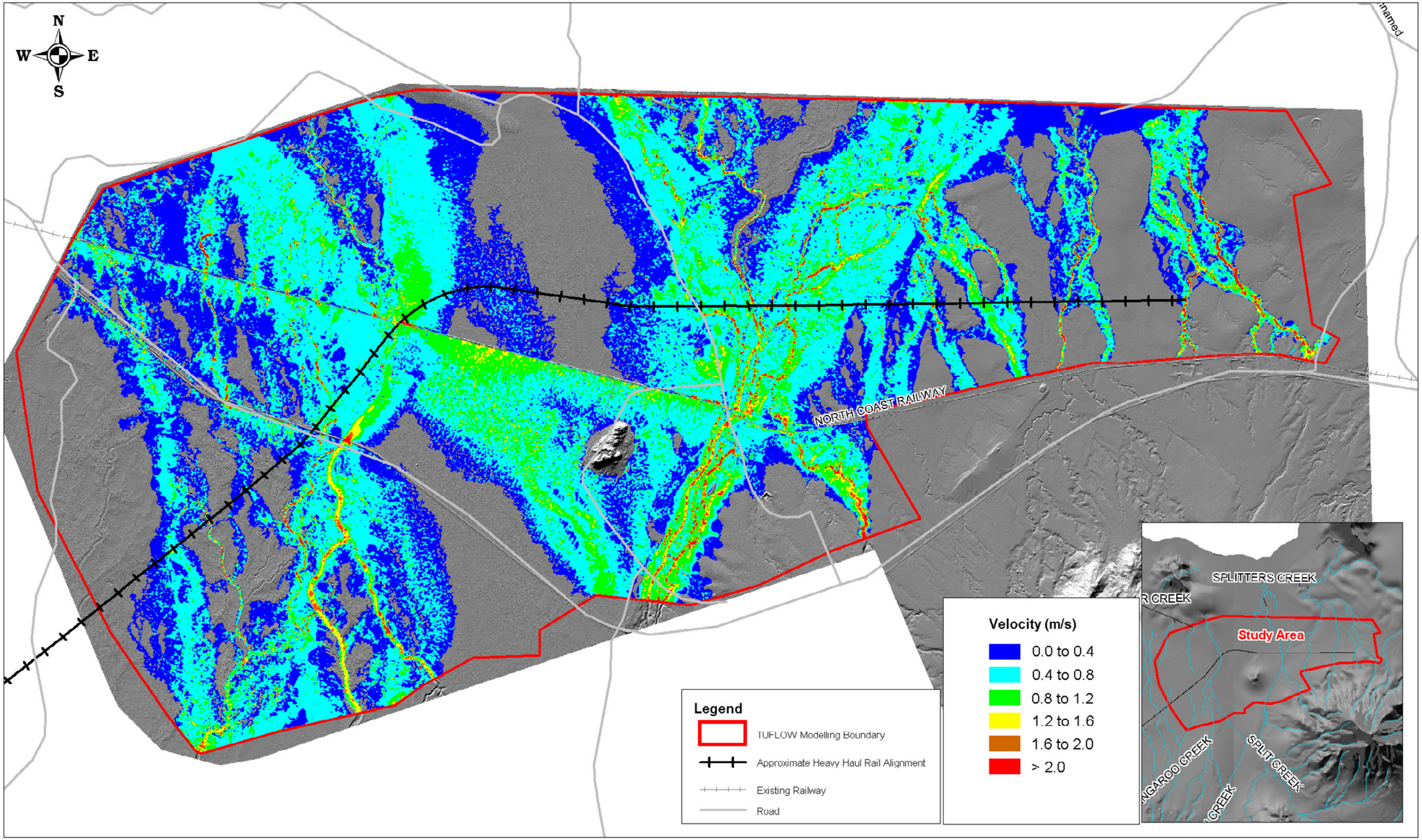
REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP
B	31/01/11	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Caley Valley
100 Year ARI Water Surface Level

Appendix D

Waratah Coal


Appendix D
Waratah Coal
Heavy Haul Rail Corridor
Flood Study
Caley Valley
100 Year ARI Flood Depth
Scale 1:30,000 (A3)
0
600
1200
Meters
Legend
TUFLOW Modelling Boundary
Approximate Heavy Haul Rail Alignment
Existing Railway
Road
Depth (m)
0.0 to 0.4
0.4 to 0.8
0.8 to 1.2
1.2 to 1.6
1.6 to 2.0
2.0 to 4.0
> 4.0
NORTH COAST RAILWAY
SPLITTERS CREEK
Study Area
SPLIT CREEK
REV DATE REVISION DESCRIPTION ORIG CKD
A 16/12/10 Client Issue PC MP
B 31/01/11 Client Issue PC MP
Waratah Coal
THE NEW ENERGY IN COAL
ENGENY
N
E
S
W



ENGENY

Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:30,000 (A3)

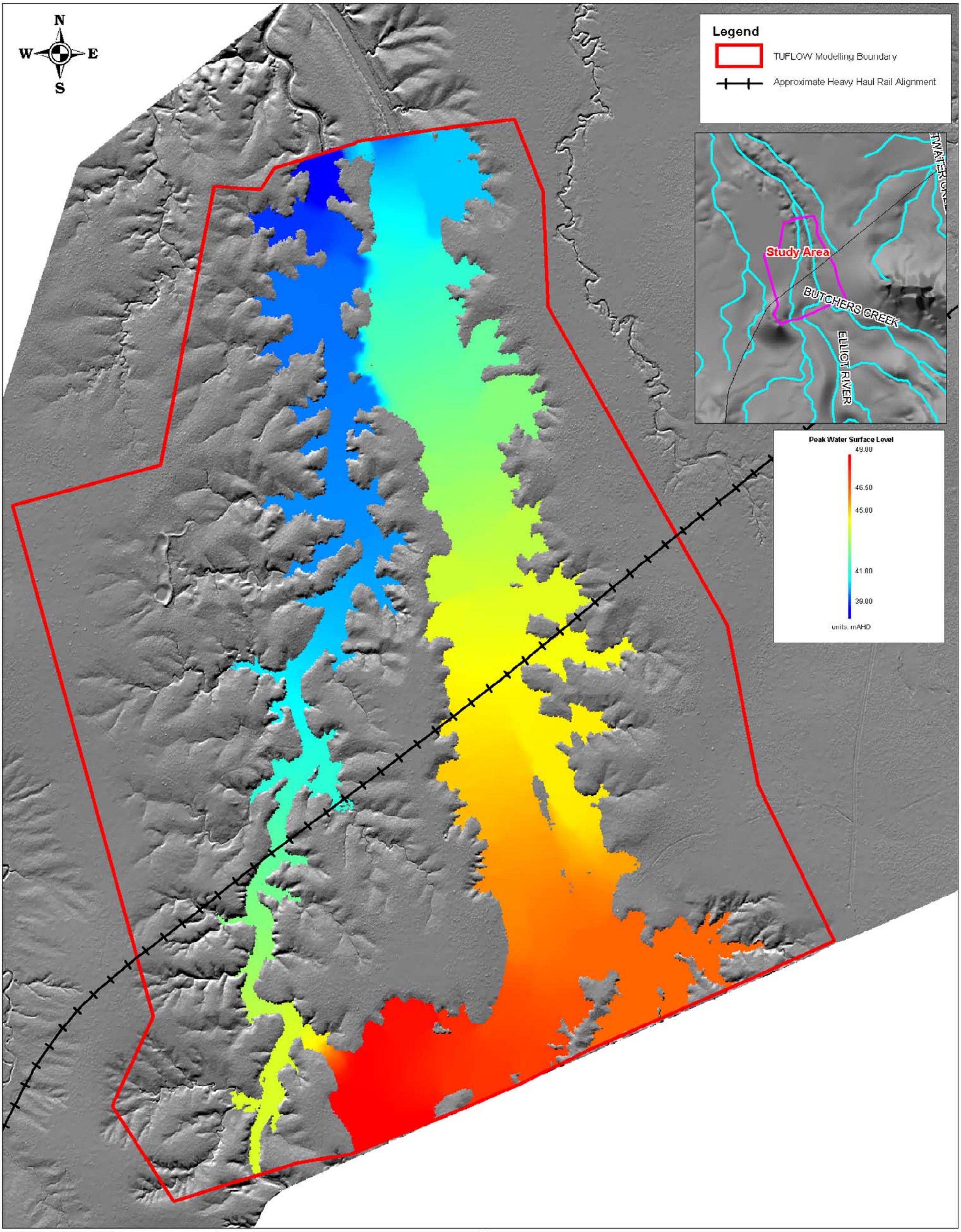
0 600 1200
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP
B	31/01/11	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Caley Valley
100 Year ARI Flood Velocity

Appendix D

Waratah Coal



ENGENY
WATER MANAGEMENT

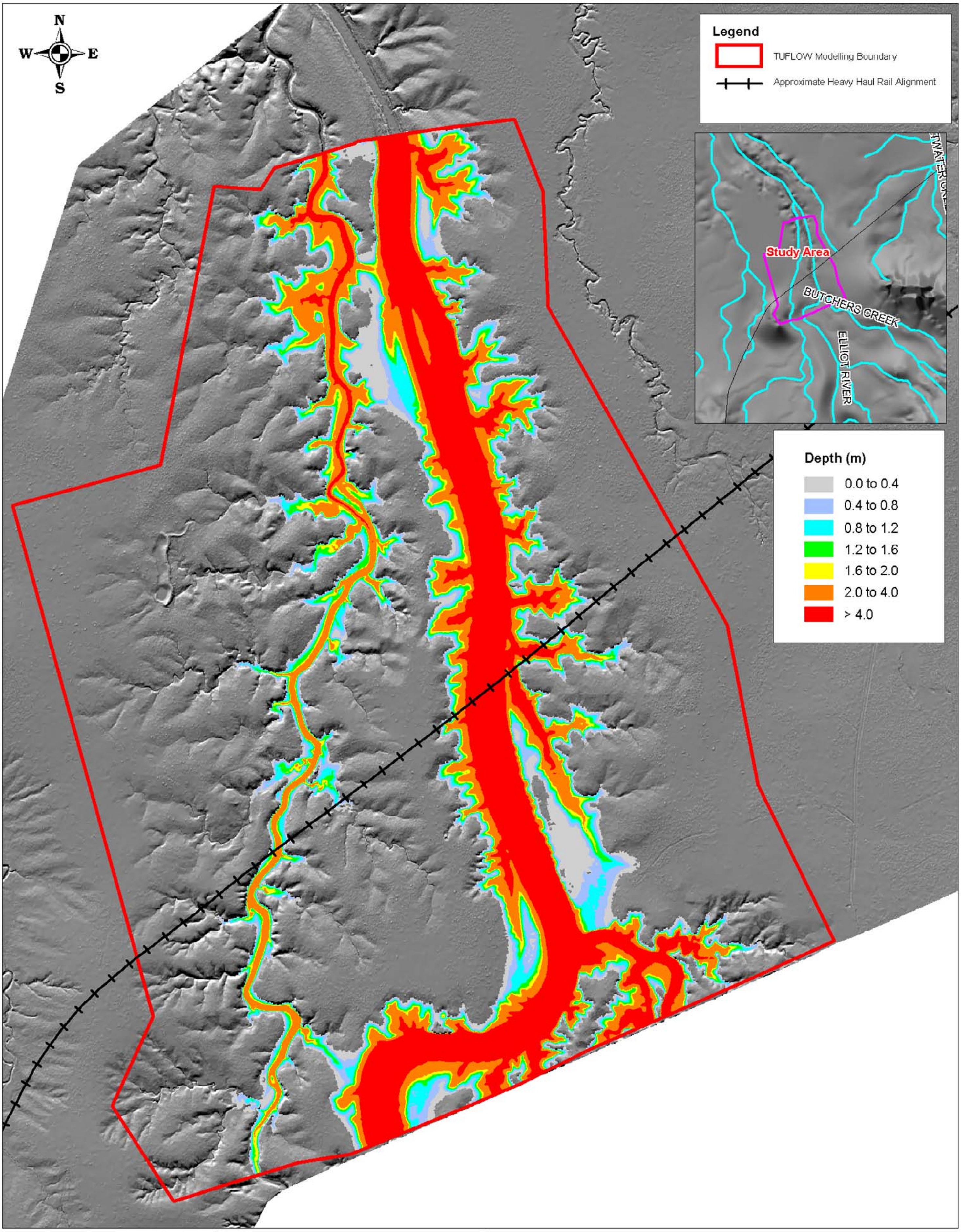
Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Appendix D
Flood Study
Elliot River
100 Year ARI Water Surface Level
Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

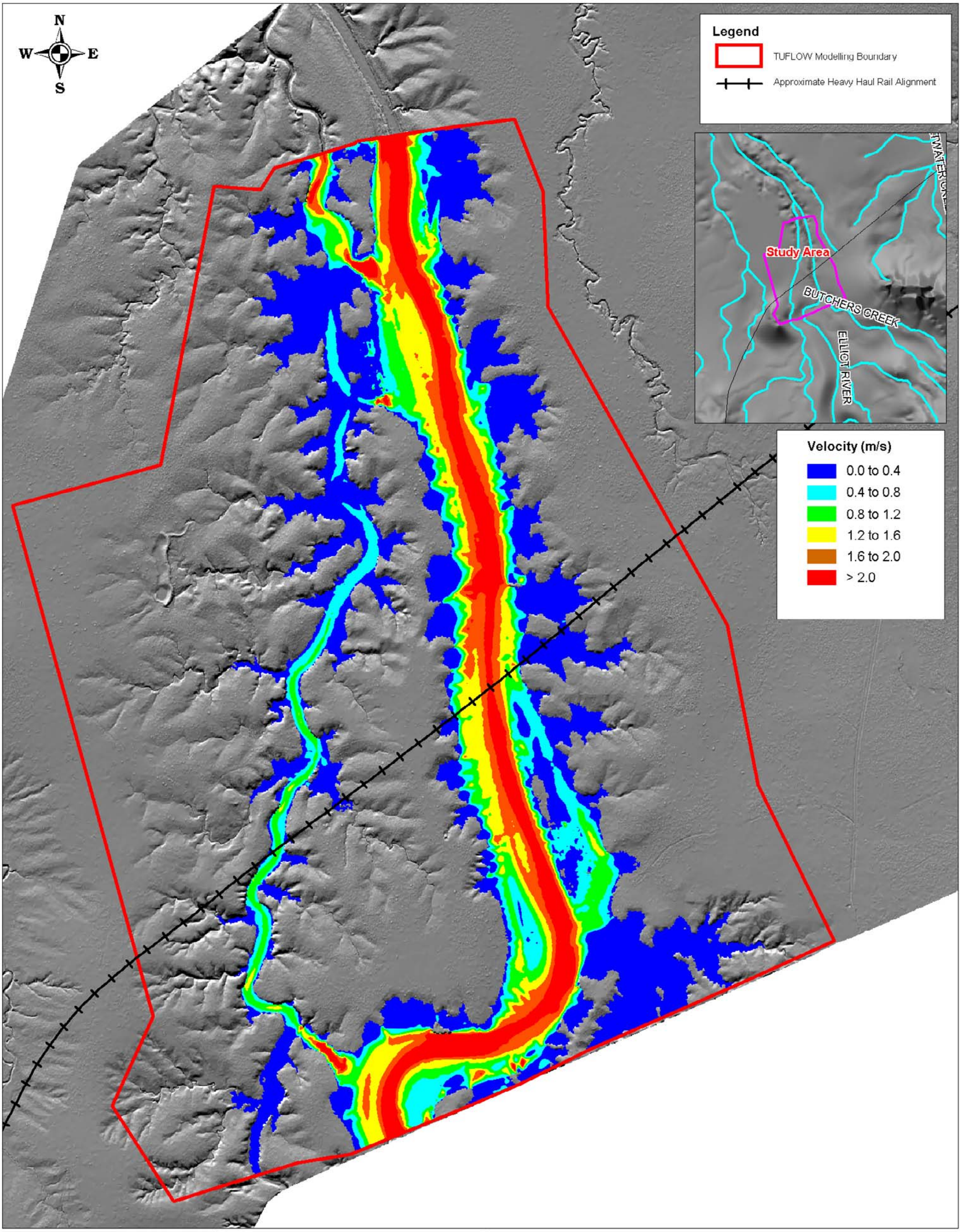
0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Elliot River
100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY
WATER MANAGEMENT

Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

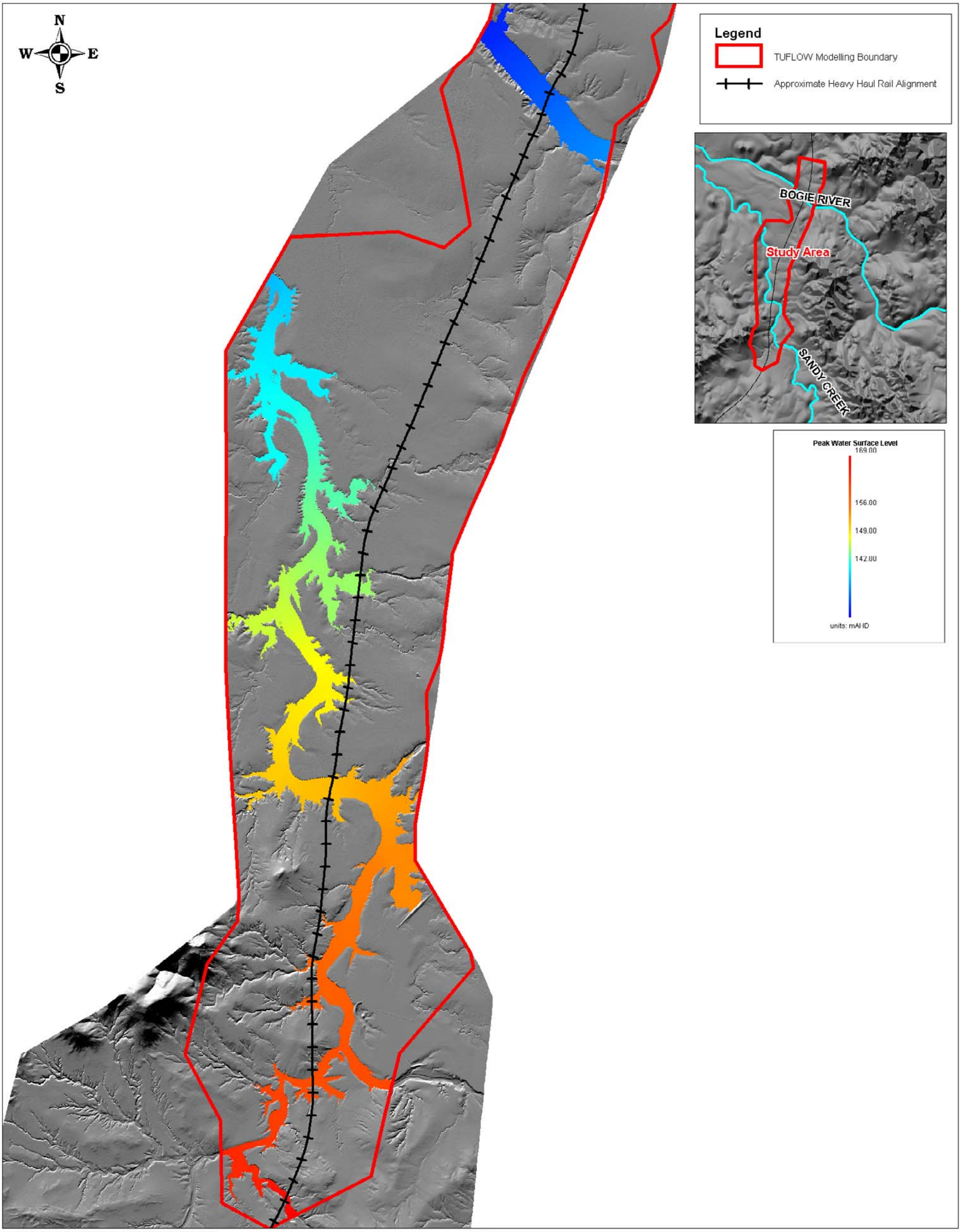
0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Elliot River
100 Year ARI Flood Velocity

Appendix D

Waratah Coal



ENGENY
WATER MANAGEMENT

Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:30,000 (A3)

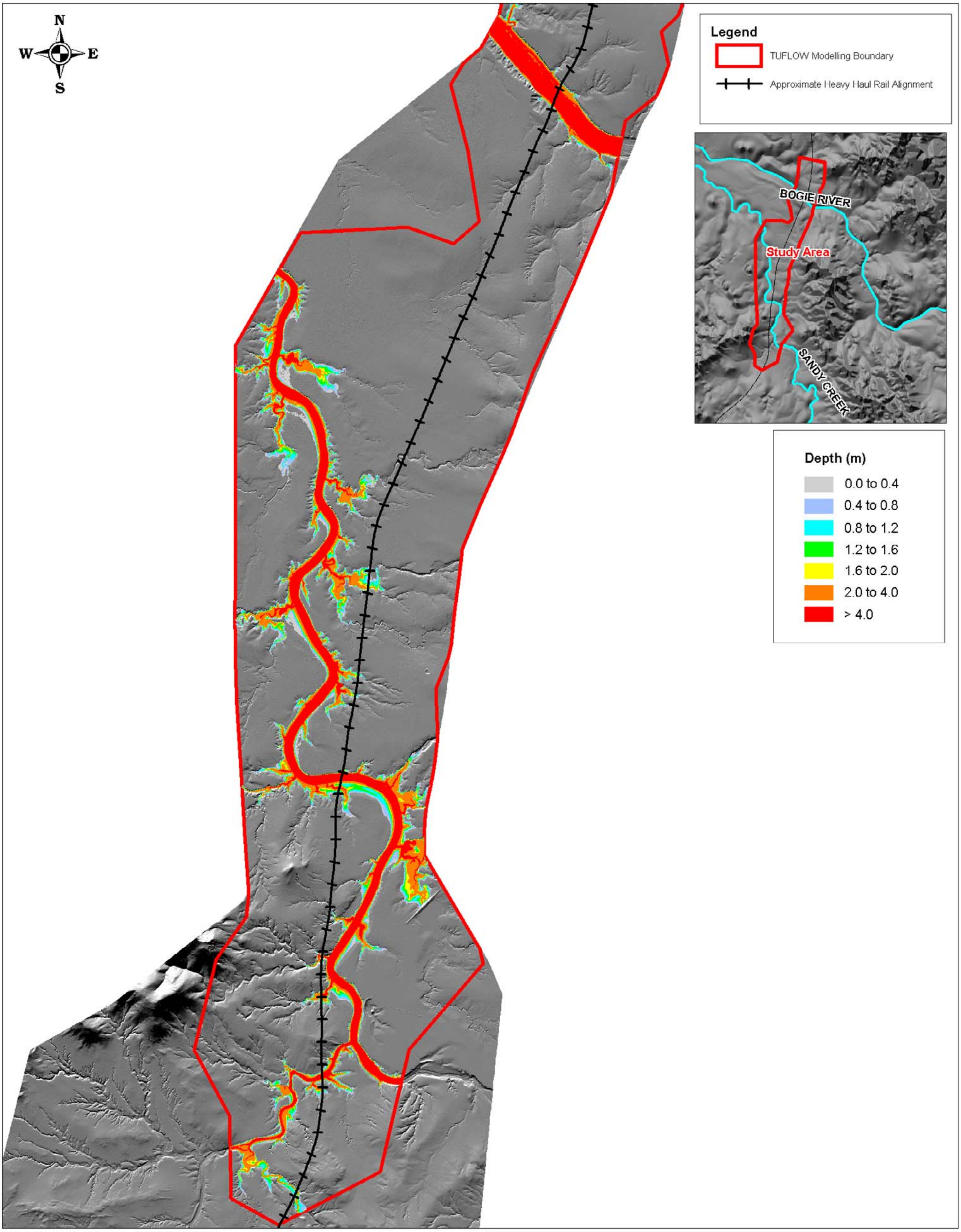
0 600 1200
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Bogie River
100 Year ARI Water Surface Level

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:30,000 (A3)

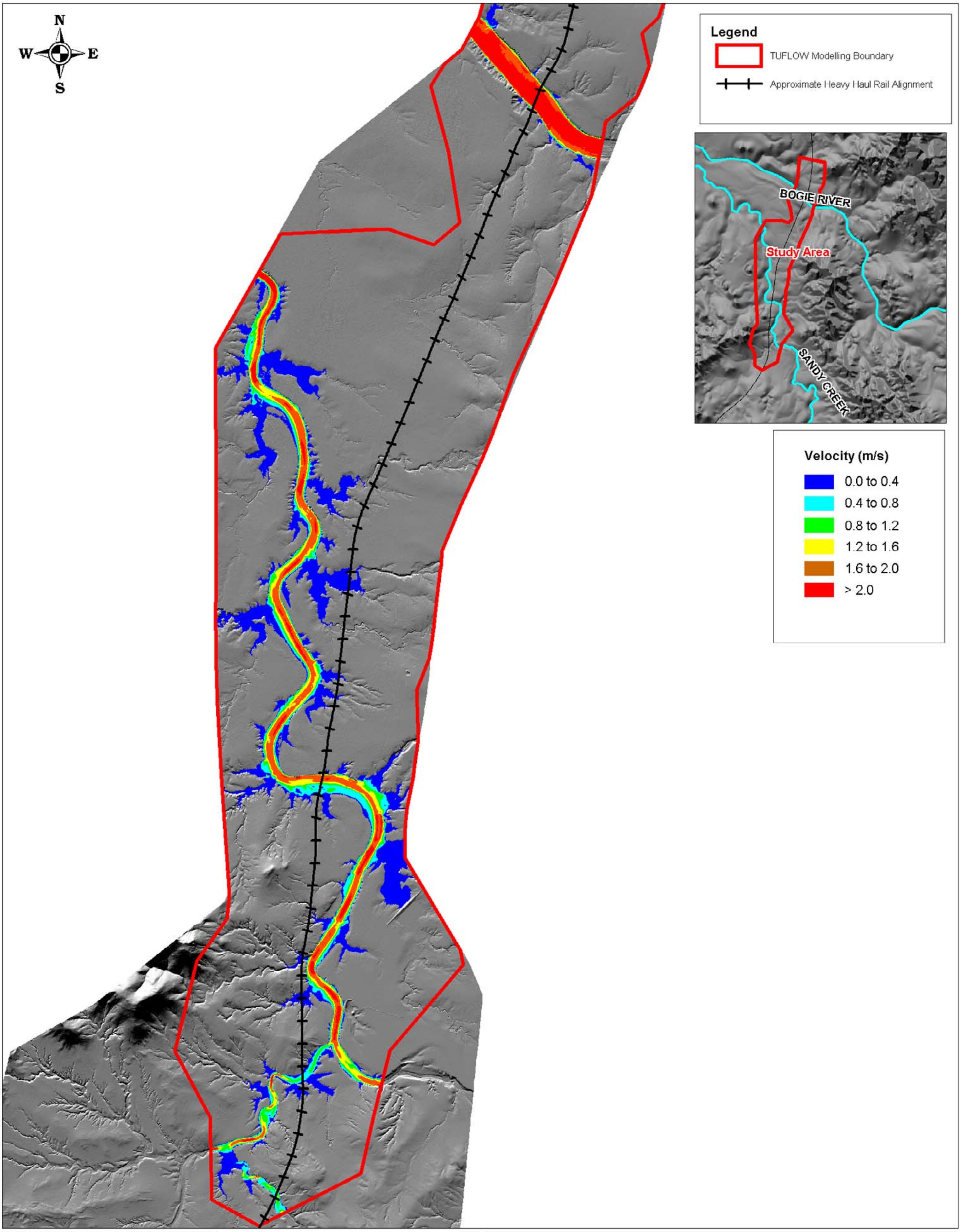
0 600 1200
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Bogie River
100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:30,000 (A3)

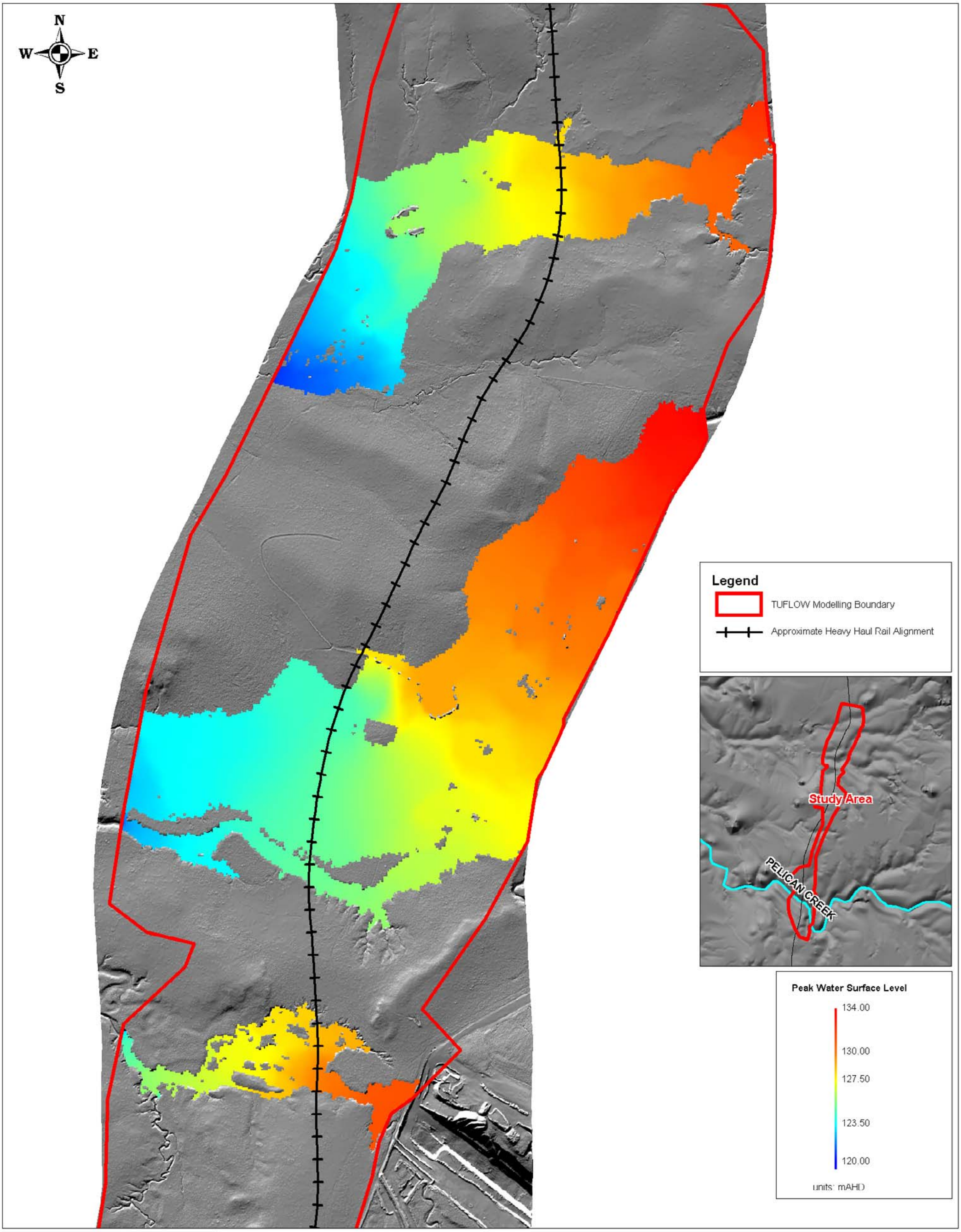
0 600 1200
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study
Bogie River
100 Year ARI Flood Velocity

Appendix D

Waratah Coal



Scale 1:12,500 (A3)

0 250 500
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

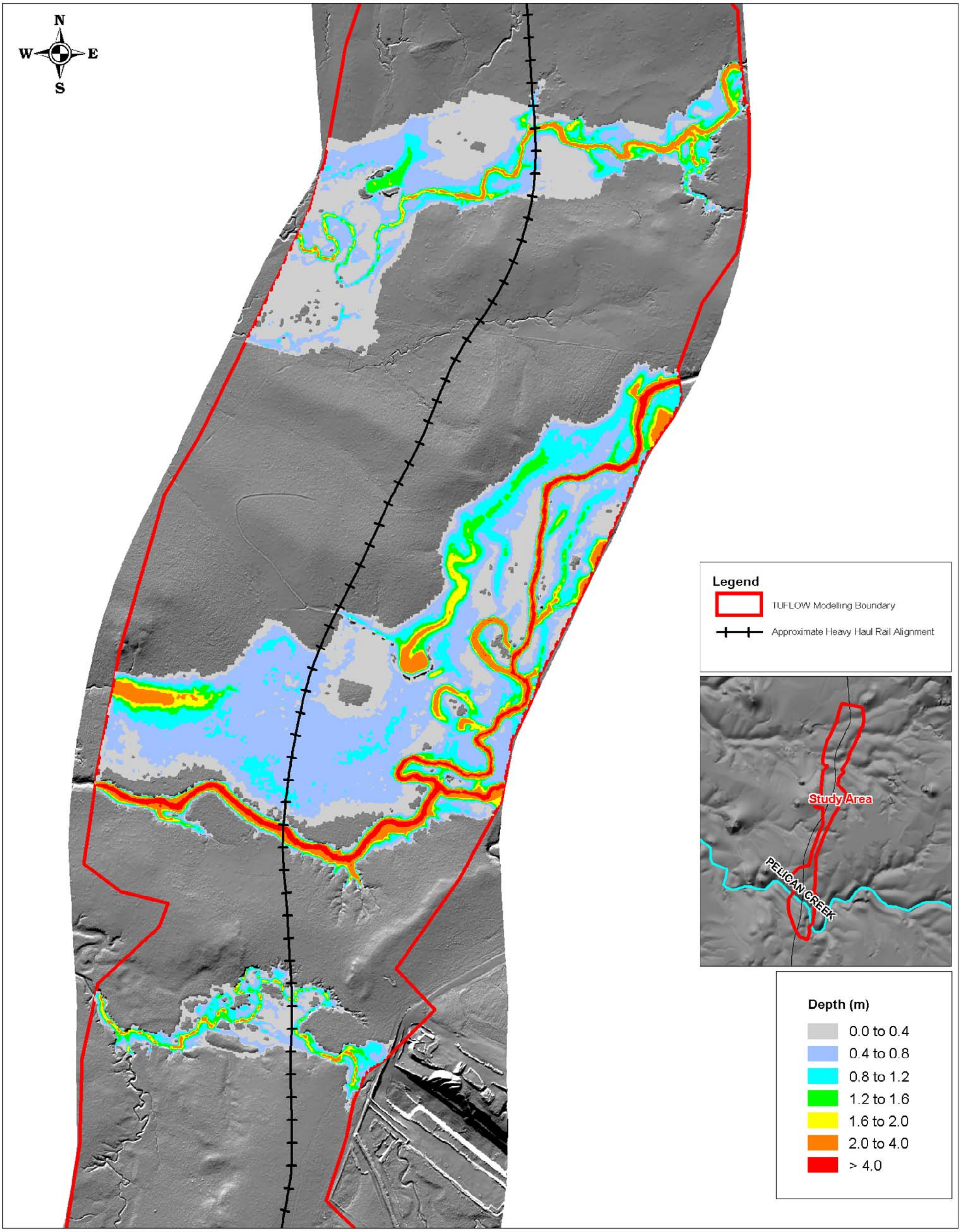
ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Heavy Haul Rail Corridor
Flood Study
Pelican Creek (Strathmore Creek)
100 Year ARI Water Surface Level

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:12,500 (A3)

0 250 500 Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

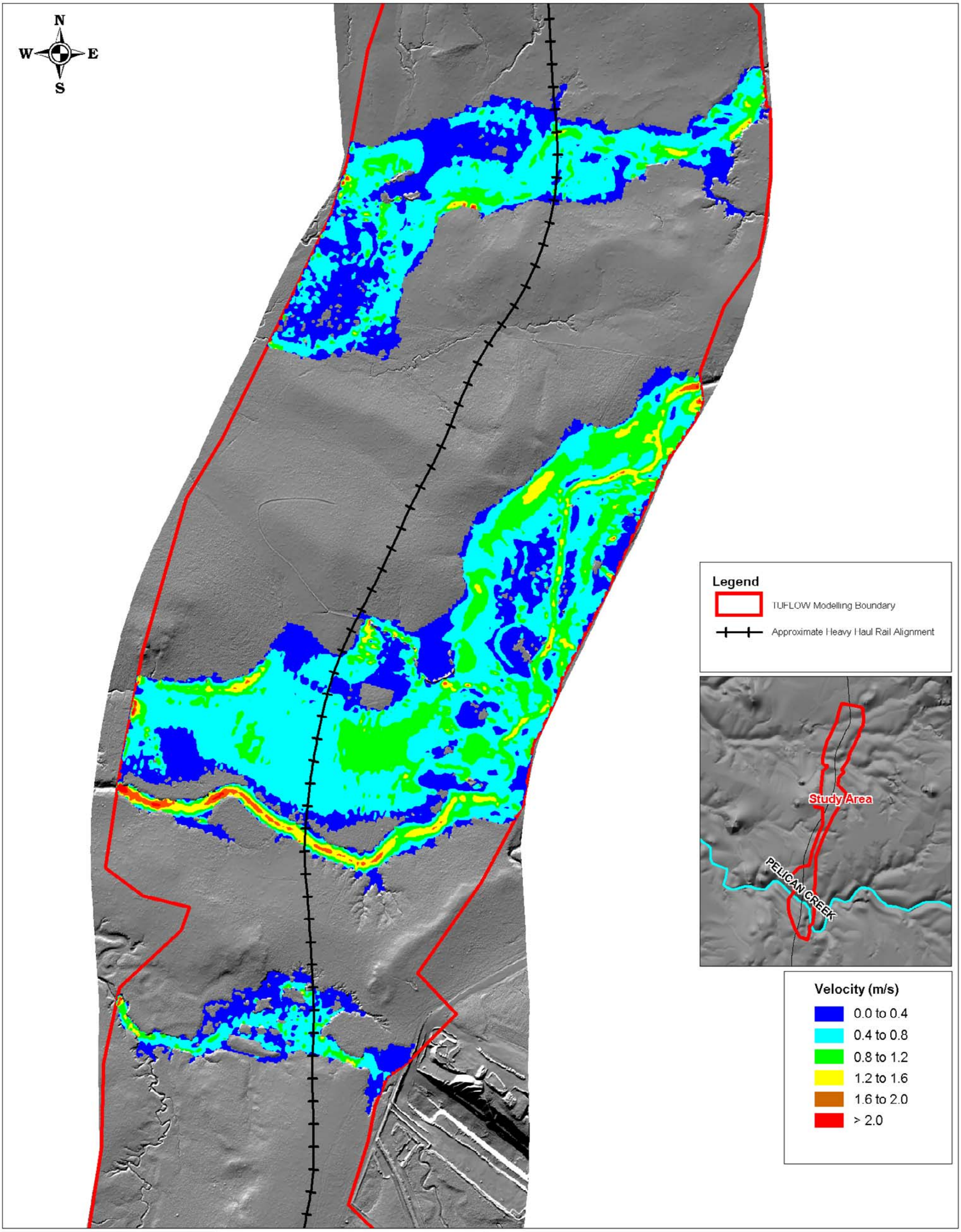
Heavy Haul Rail Corridor Flood Study

Pelican Creek North

100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:12,500 (A3)

0 250 500
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

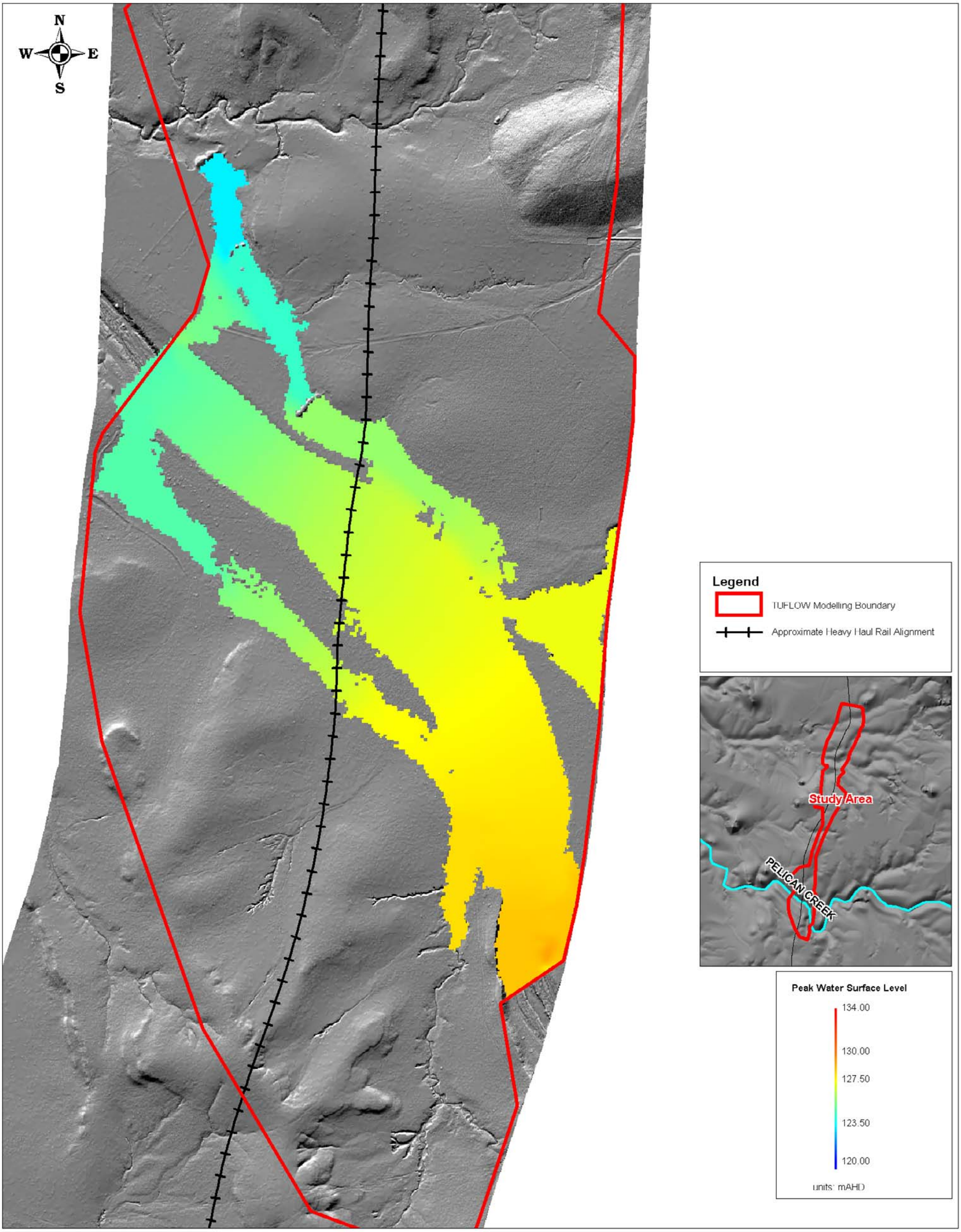
Heavy Haul Rail Corridor Flood Study

Pelican Creek North

100 Year ARI Flood Velocity

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

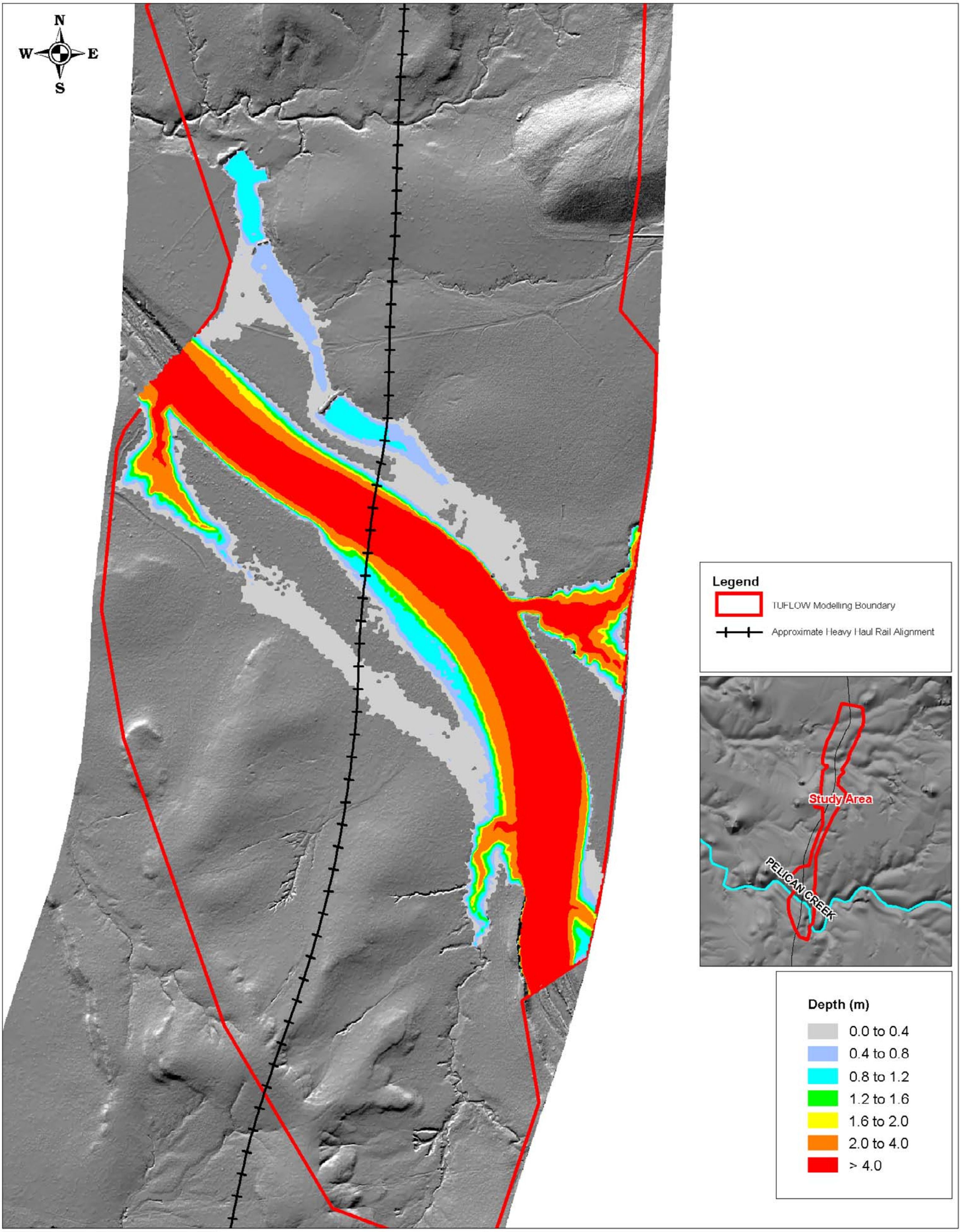
Heavy Haul Rail Corridor Flood Study

Appendix D

Pelican Creek

100 Year ARI Water Surface Level

Waratah Coal



ENGENY
WATER MANAGEMENT

Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

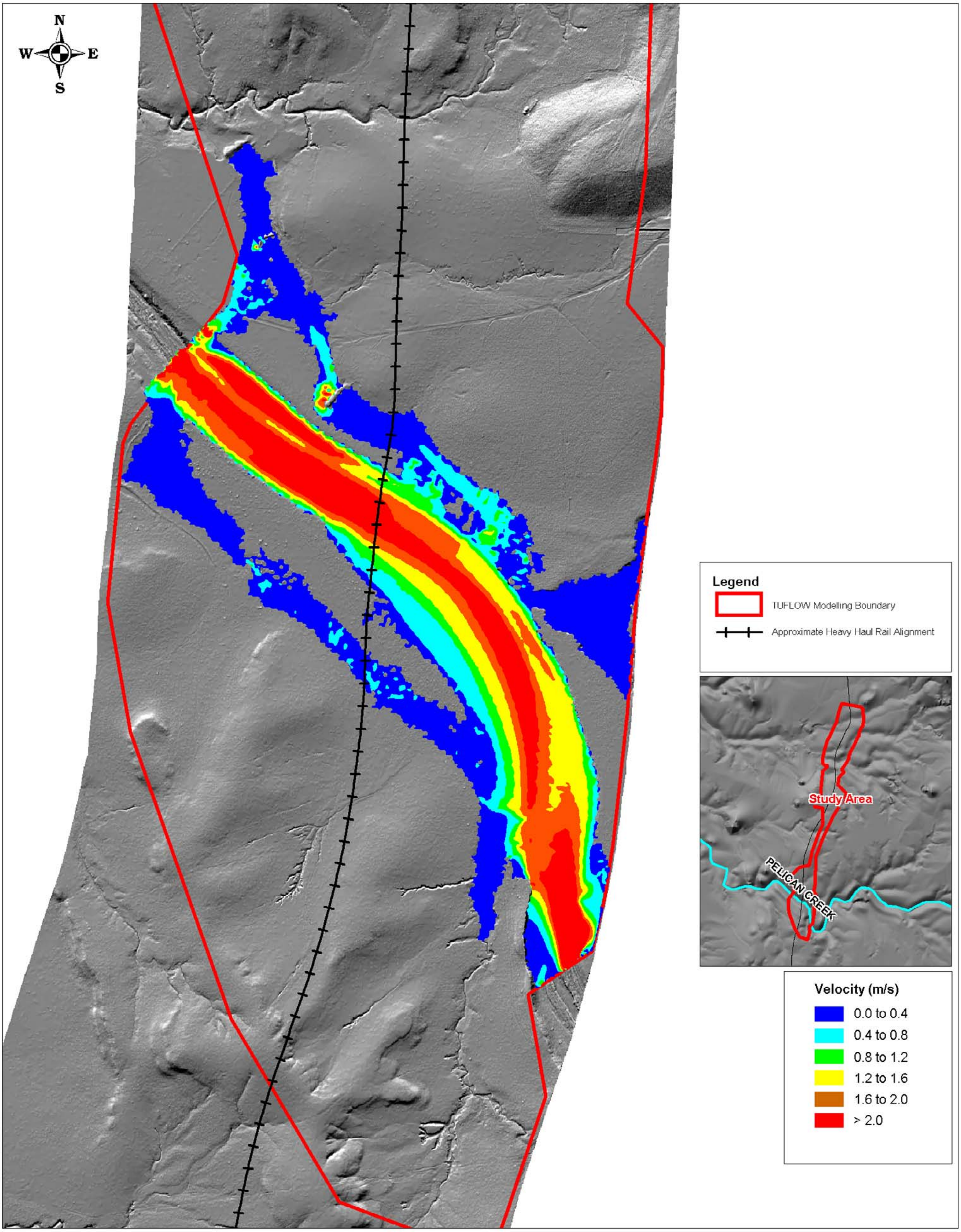
0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study
Pelican Creek
100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

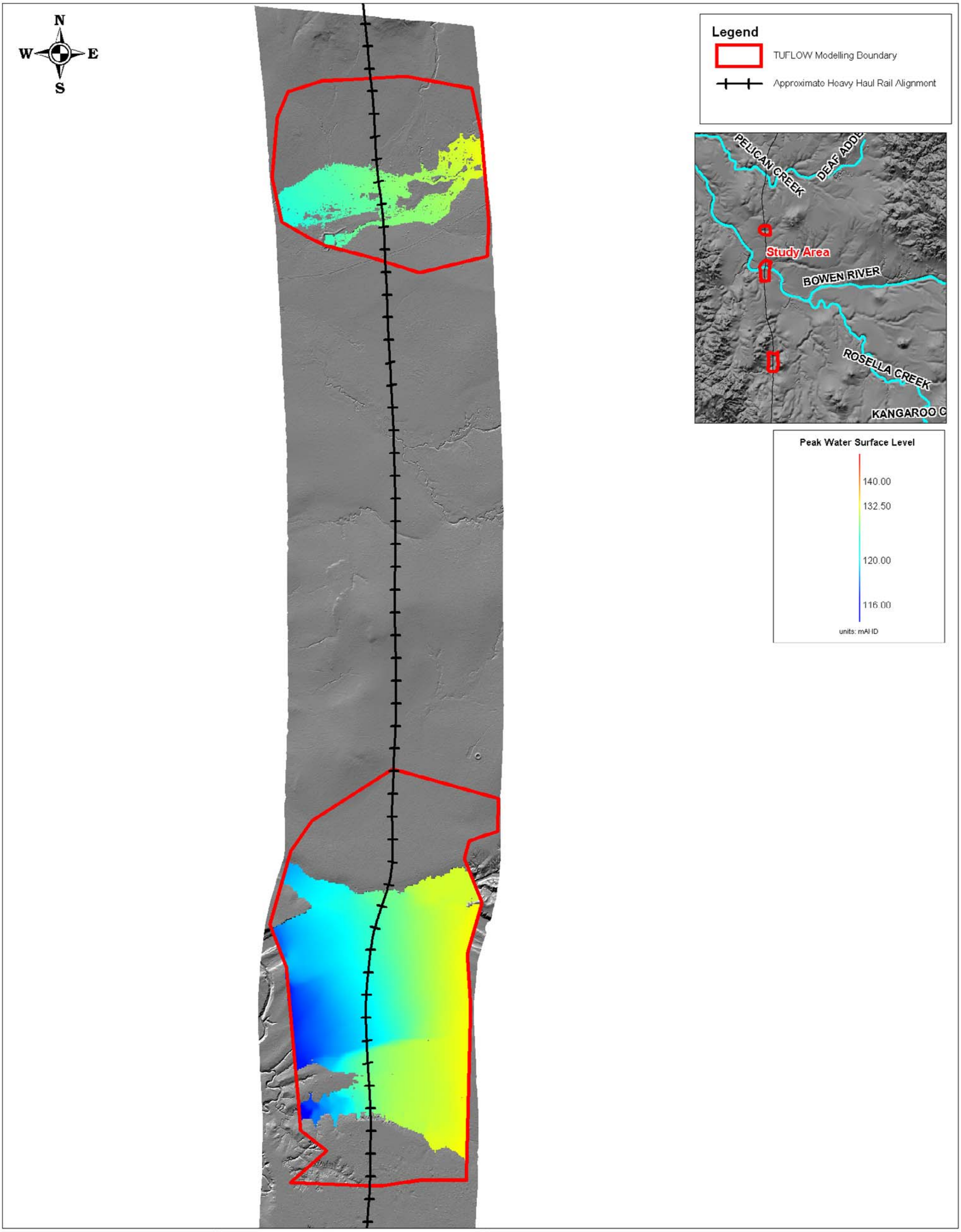
0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study
Pelican Creek
100 Year ARI Flood Velocity

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

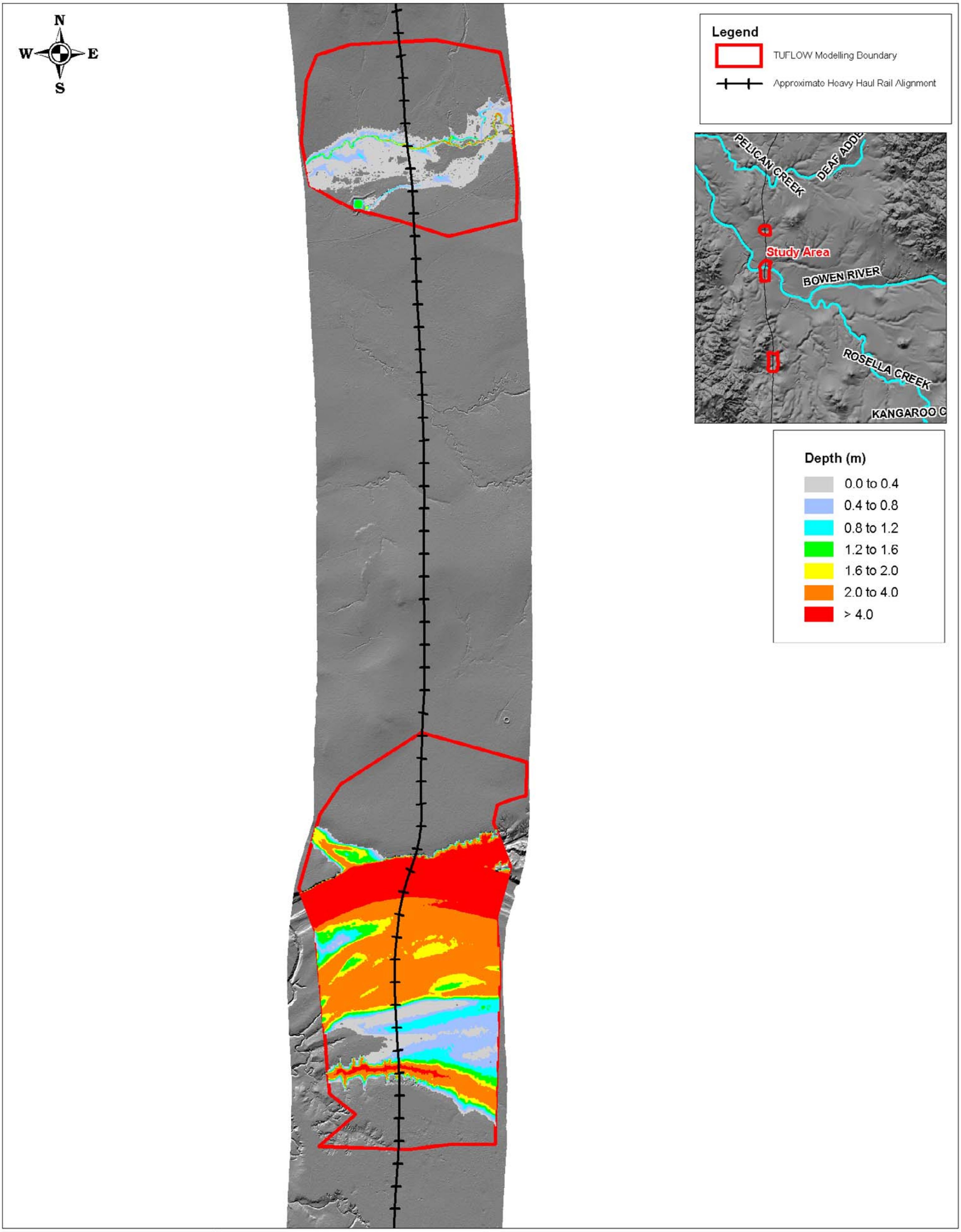
Waratah Coal THE NEW ENERGY IN COAL

Scale 1:25,000 (A3)

0 500 1000
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor **Appendix D**
Flood Study
Bowen River
100 Year ARI Water Surface Level
Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:25,000 (A3)

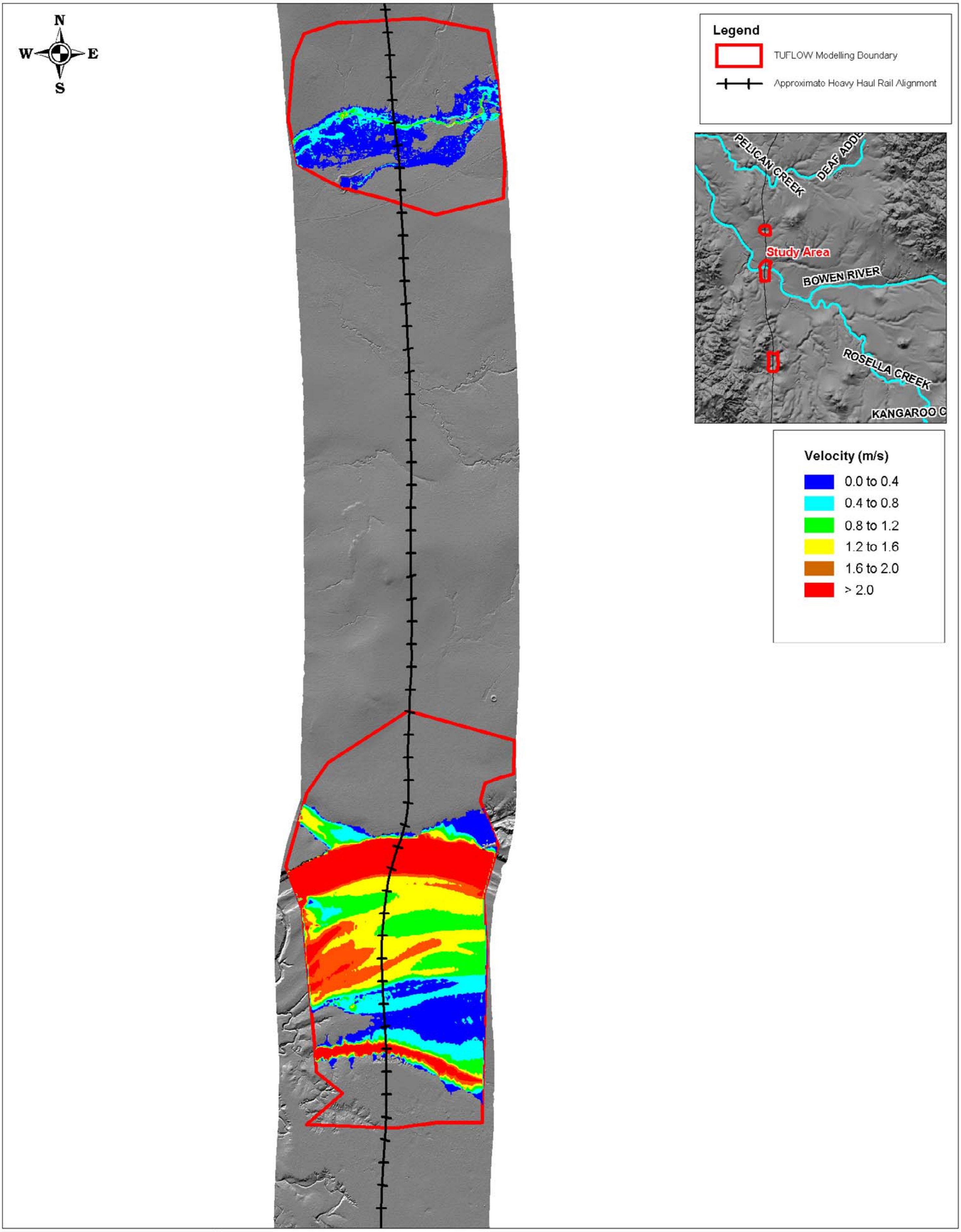
0 500 1000
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Bowen River
100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:25,000 (A3)

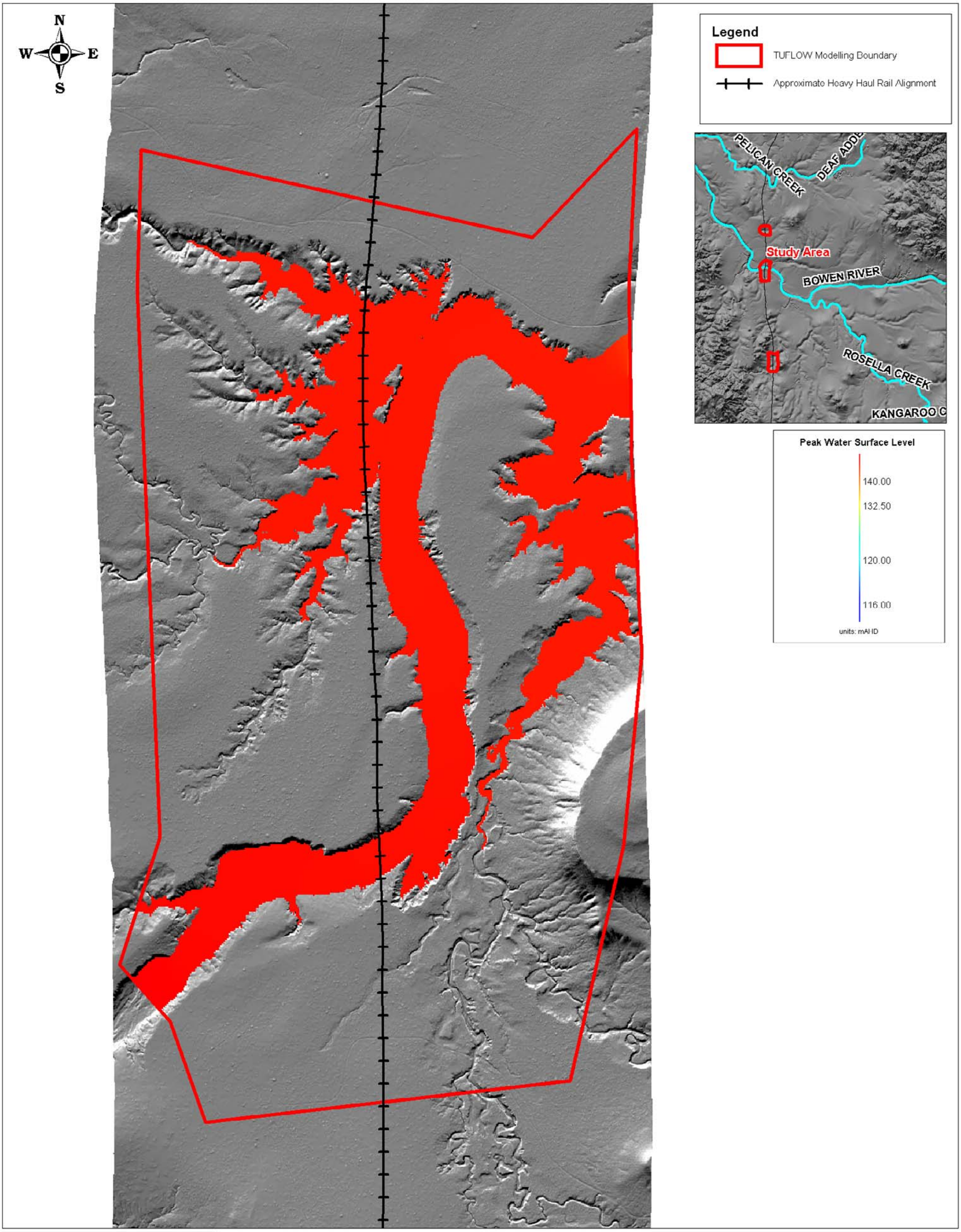
0 500 1000
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study
Bowen River
100 Year ARI Flood Velocity

Appendix D

Waratah Coal



ENGENY
WATER MANAGEMENT

Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

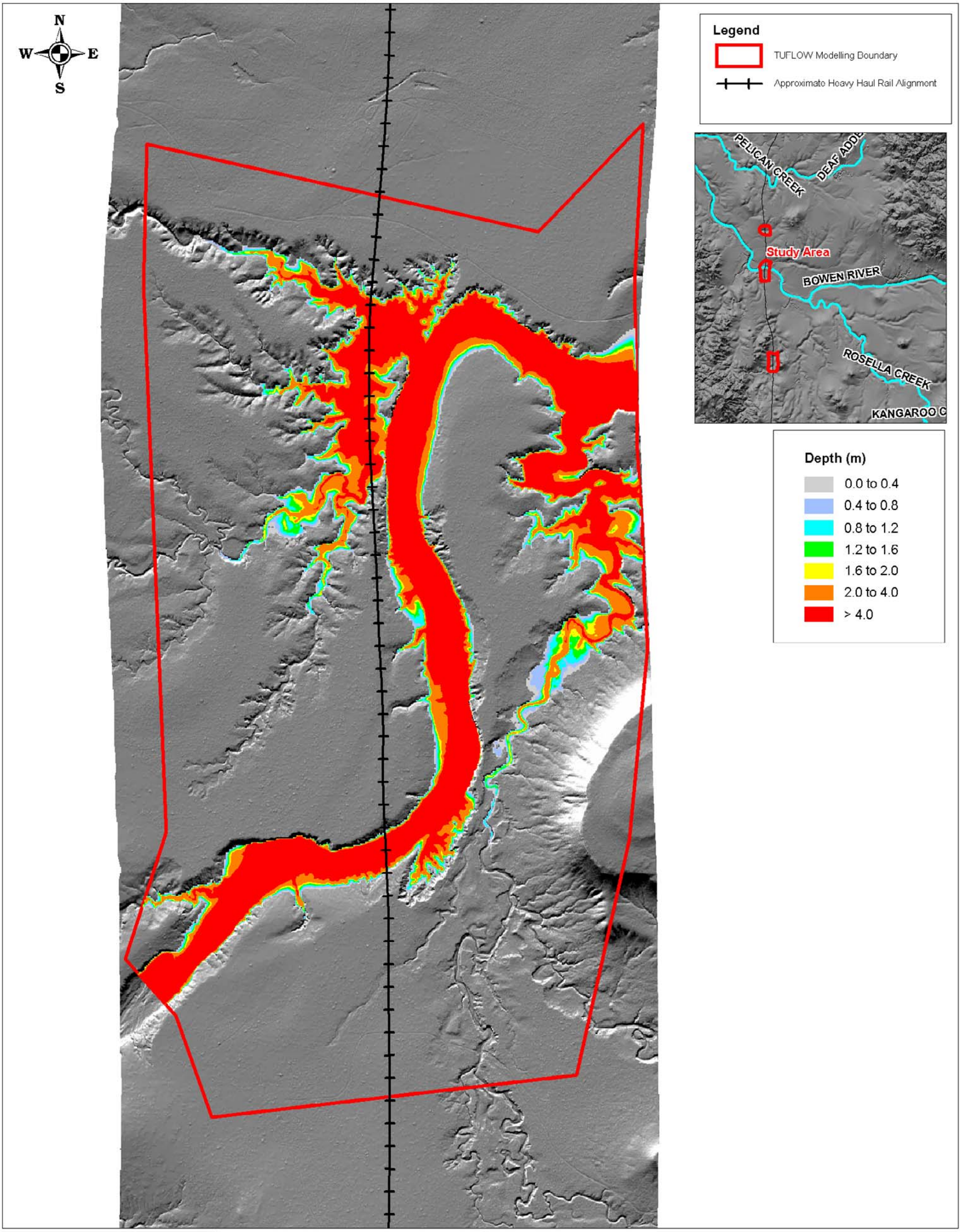
0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Bowen River South (Parrot Creek)
100 Year ARI Water Surface Level

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

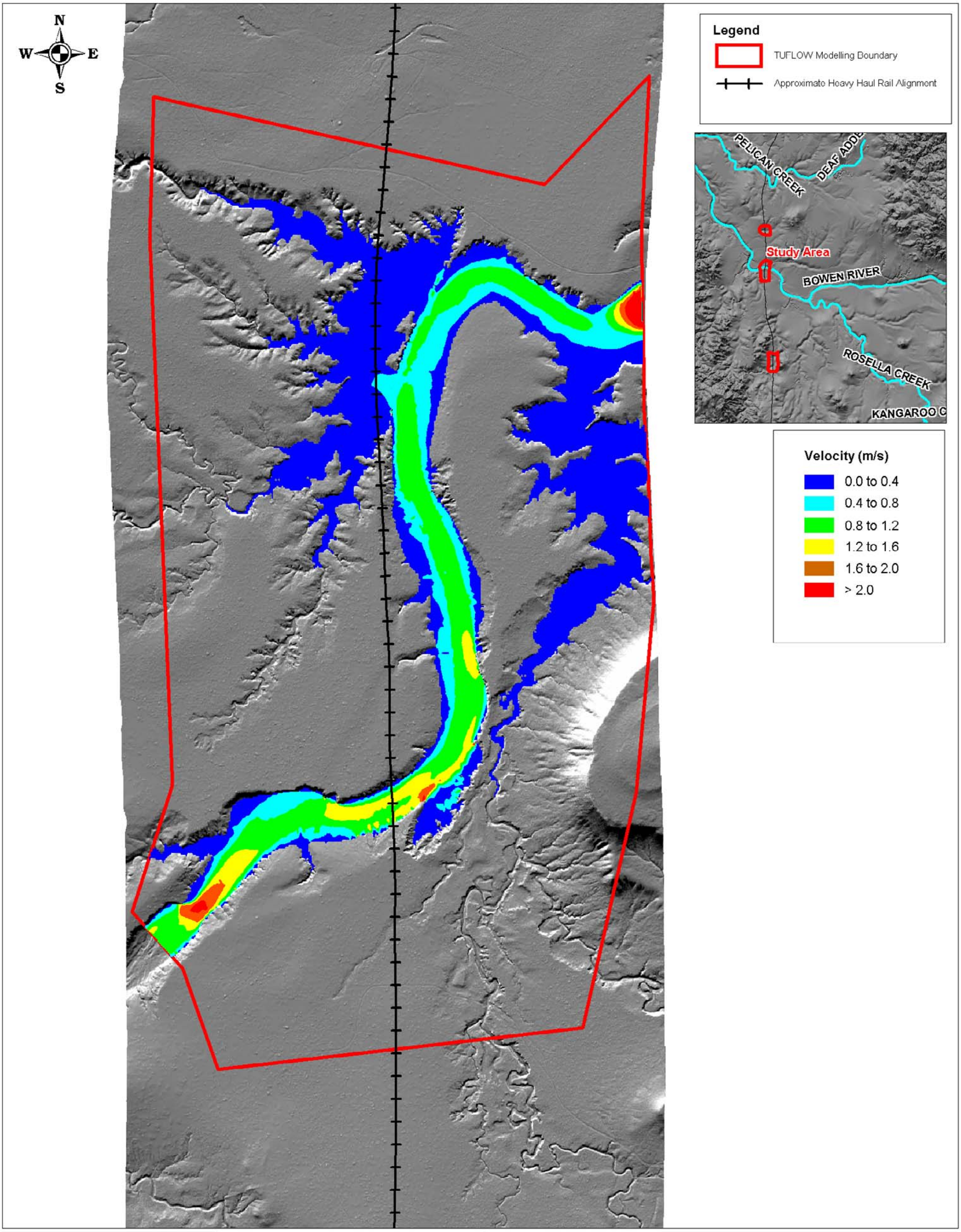
Heavy Haul Rail Corridor Flood Study

Appendix D

Bowen River South (Parrot Creek)

100 Year ARI Flood Depth

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

0 200 400 Meters

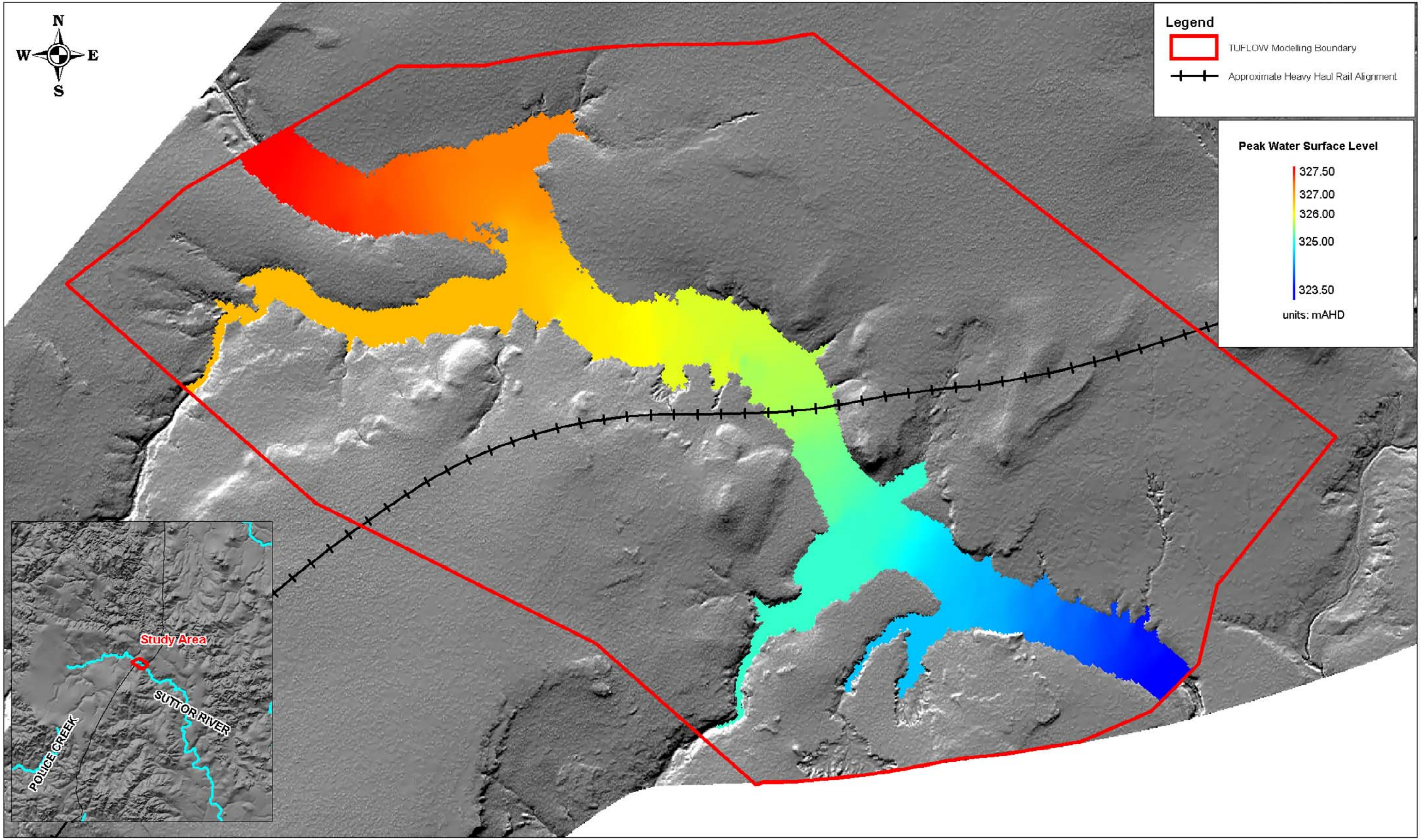
REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study **Appendix D**

Bowen River South (Parrot Creek)

100 Year ARI Flood Velocity

Waratah Coal



ENGENY

Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:7,500 (A3)

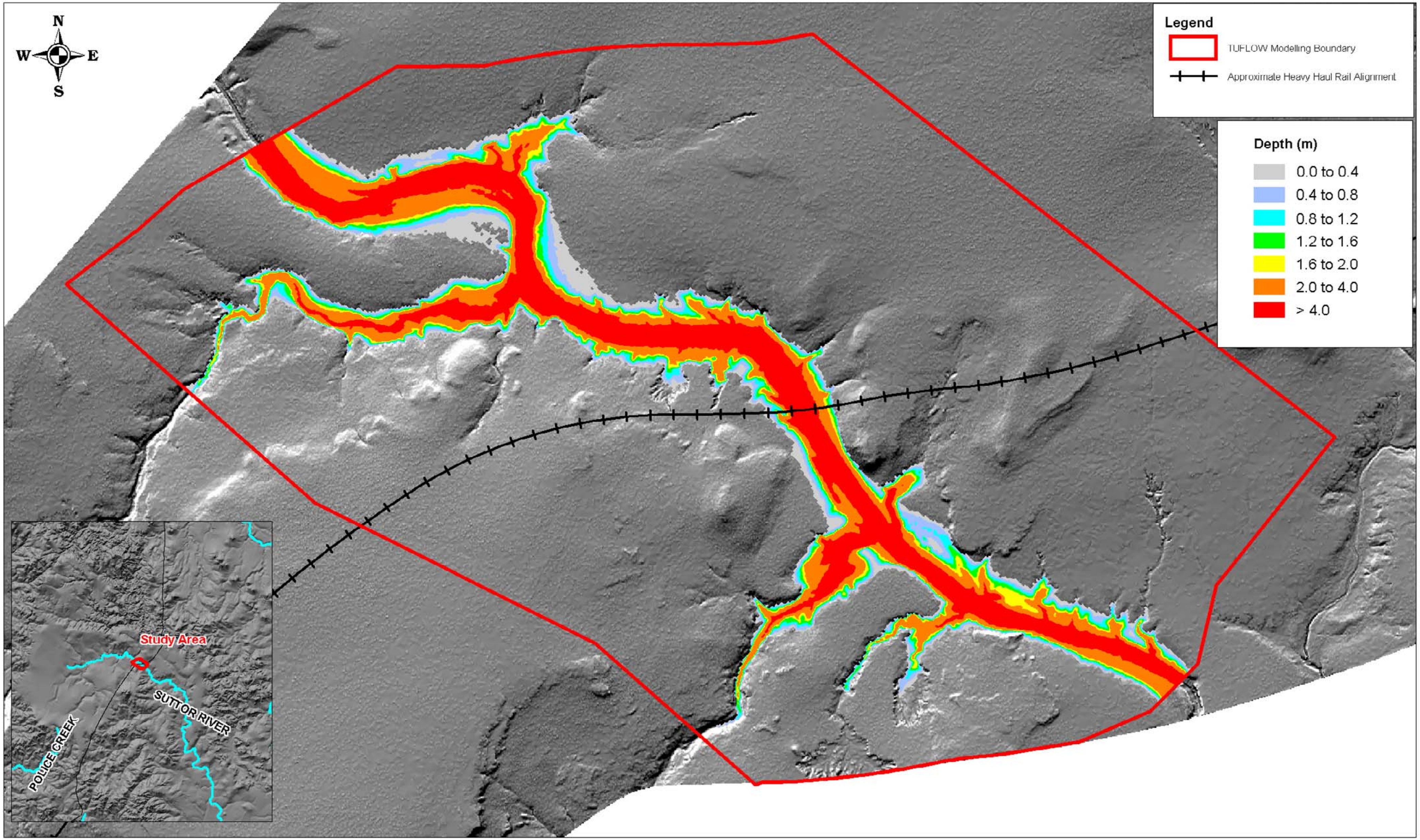
0 150 300
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Upper Suttor River
100 Year ARI Water Surface Level

Appendix D

Waratah Coal



ENGENY

Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:7,500 (A3)

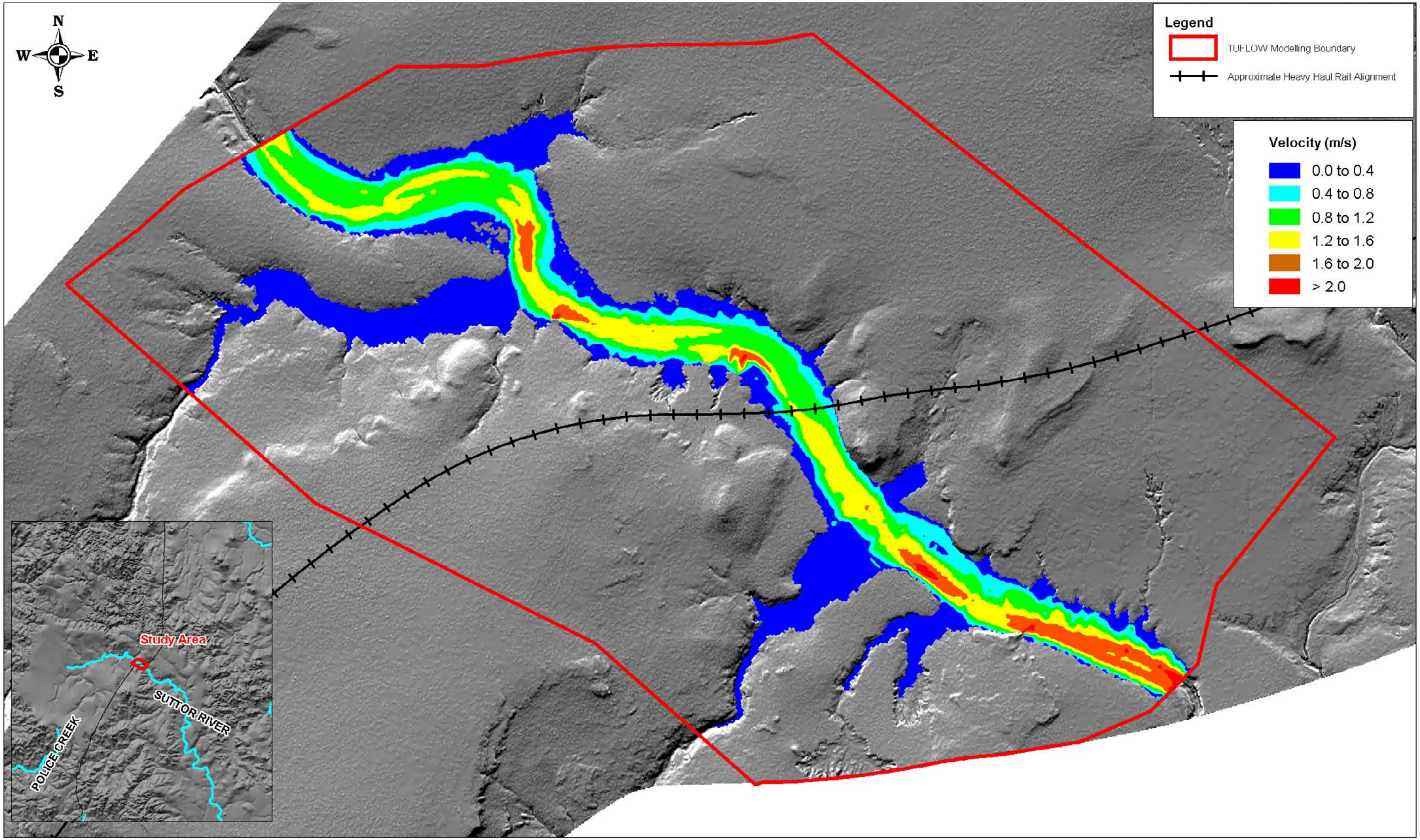
0 150 300
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Upper Suttor River
100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:7,500 (A3)

0 150 300

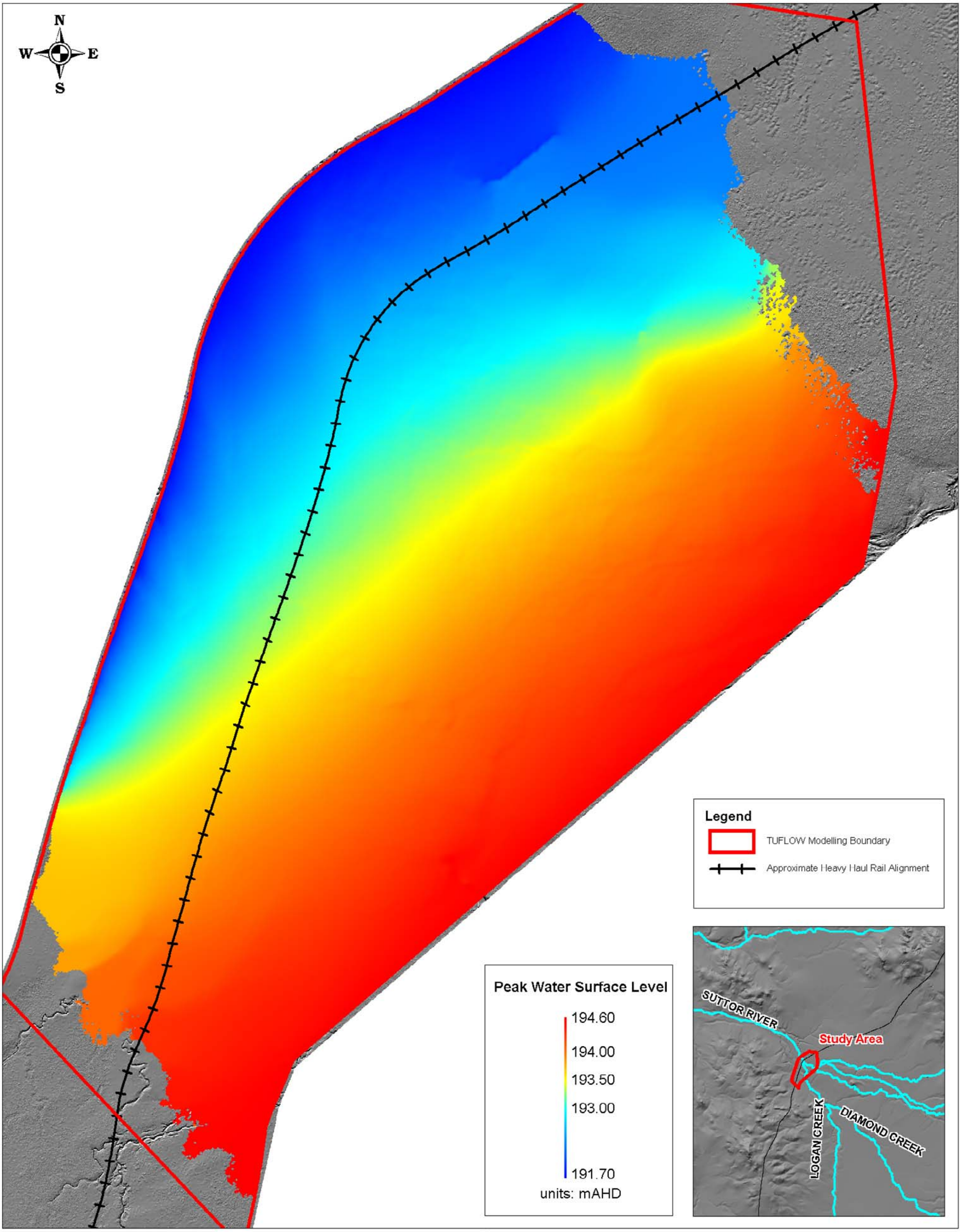
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Upper Suttor River
100 Year ARI Flood Velocity

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:17,500 (A3)

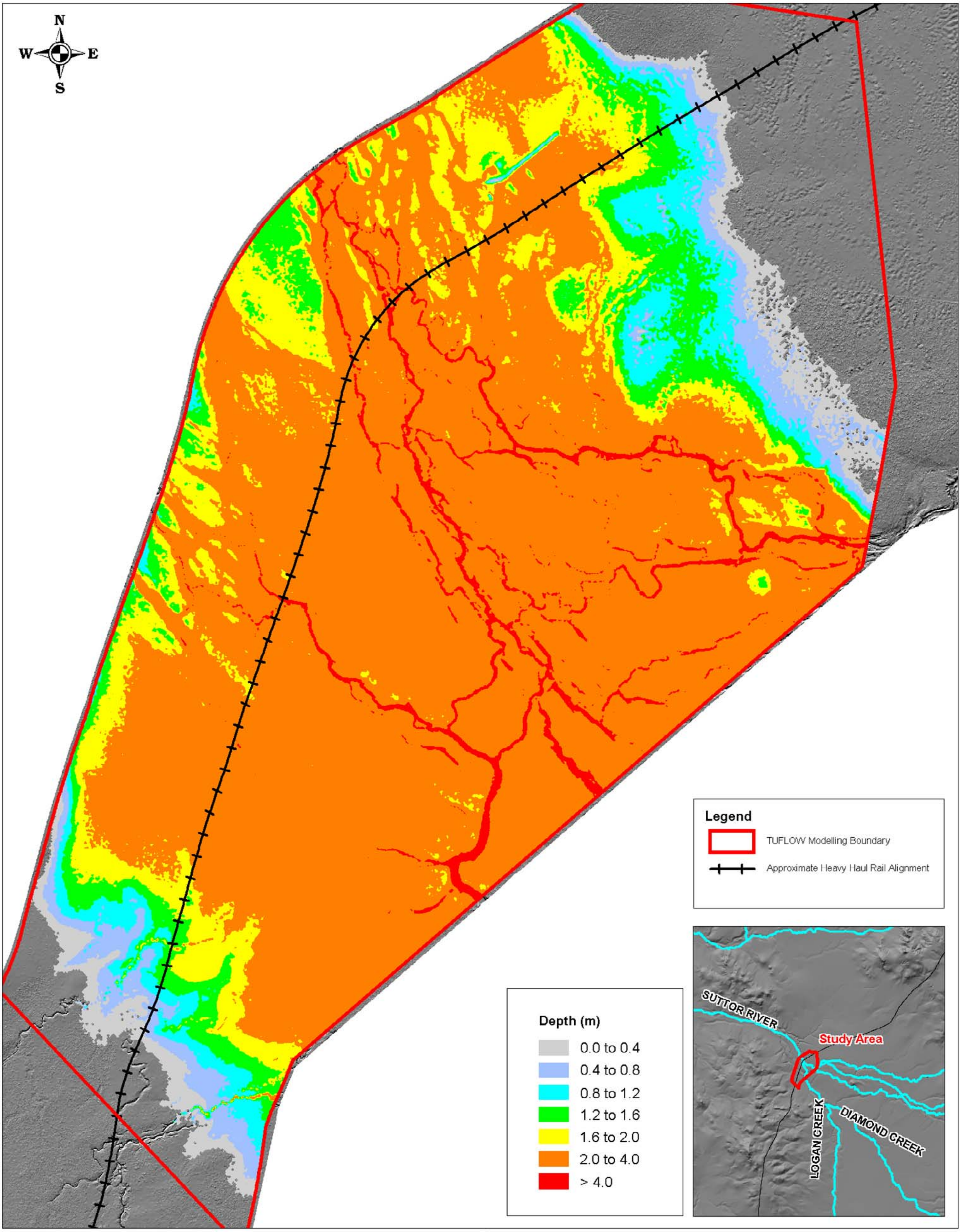
0 350 750
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study
Lower Suttor River
100 Year ARI Water Surface Level

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:17,500 (A3)

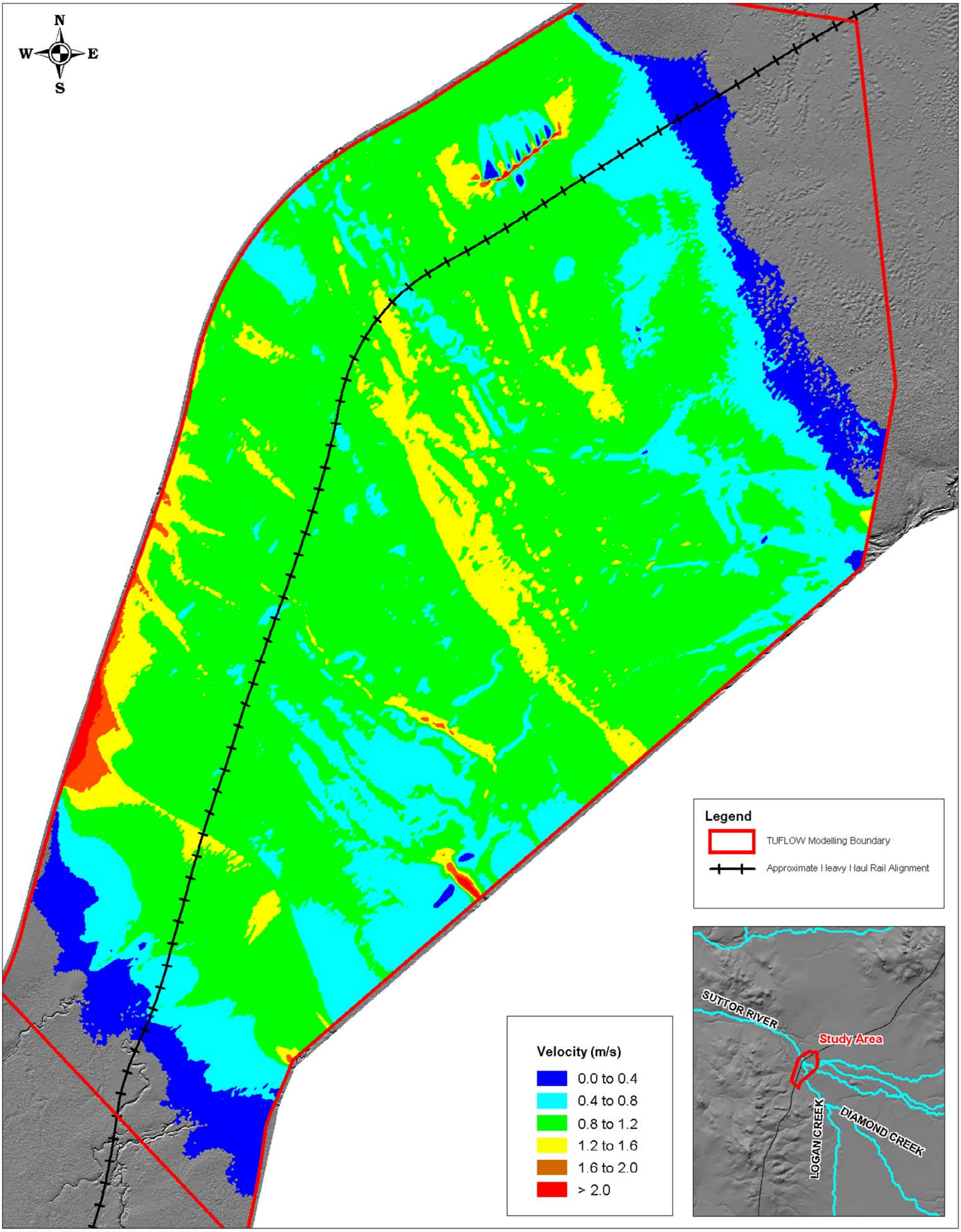
0 350 750
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study
Lower Suttor River
100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:17,500 (A3)

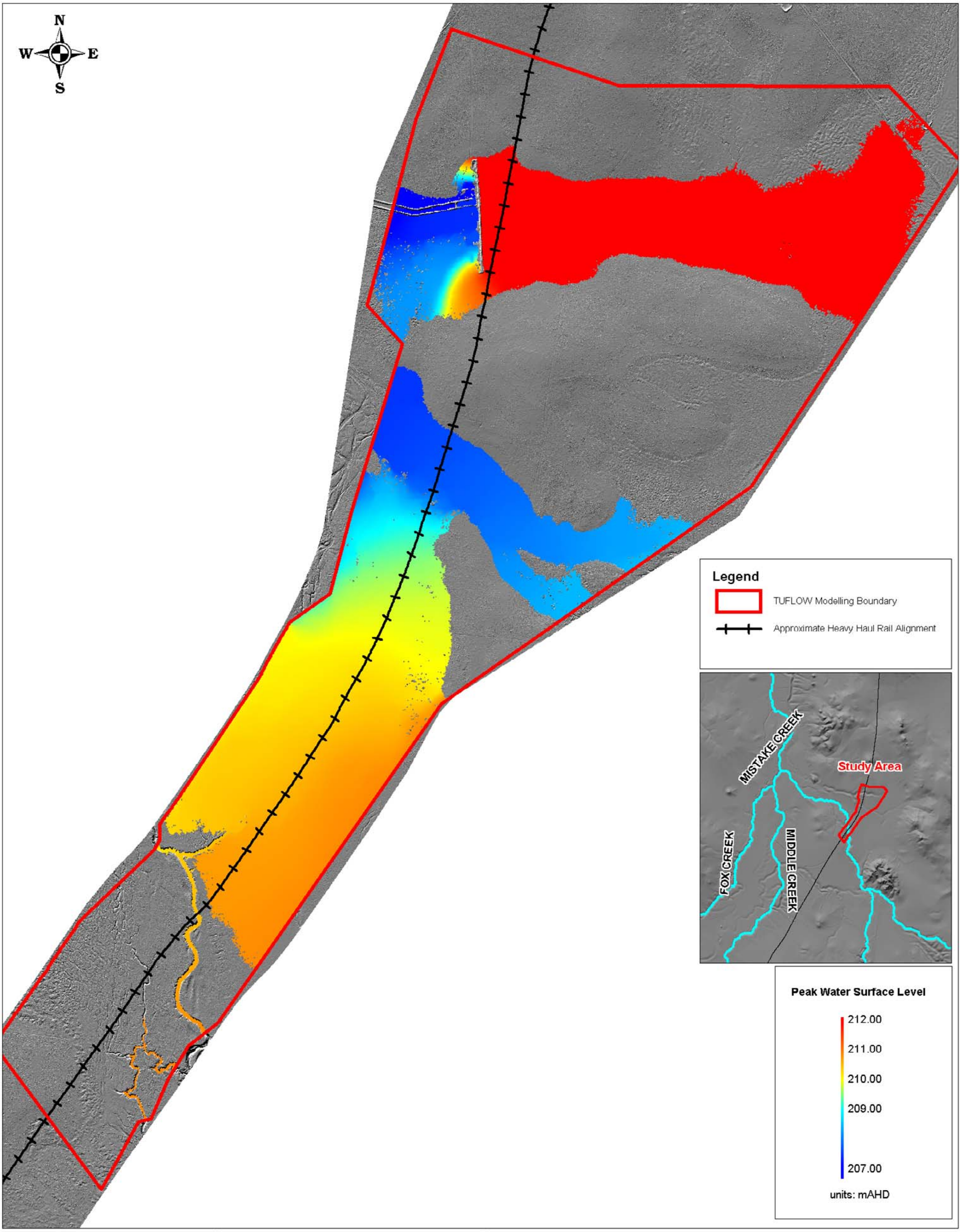
0 350 750
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Lower Suttor River
100 Year ARI Flood Velocity

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:30,000 (A3)

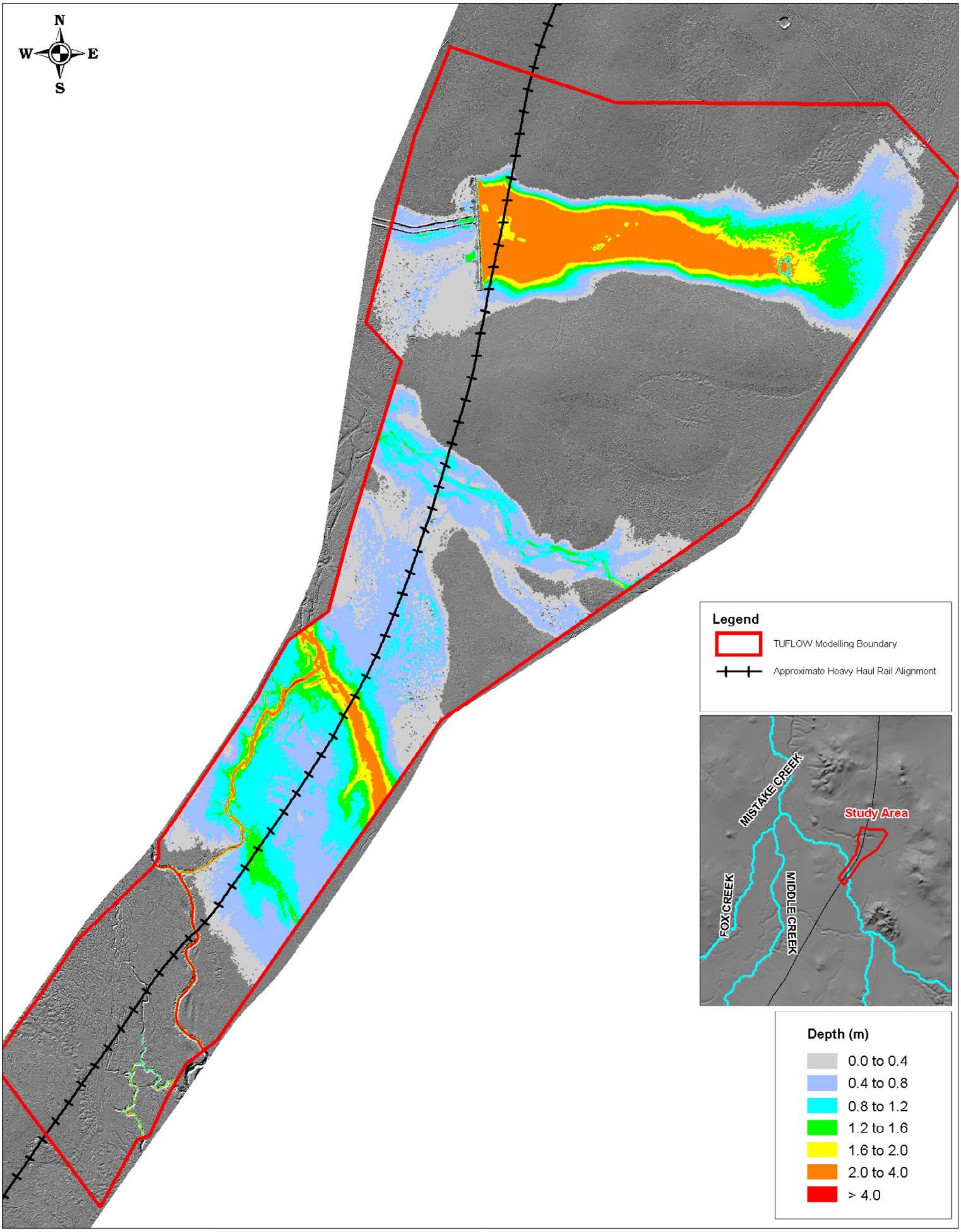
0 600 1200
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Mistake Creek
100 Year ARI Water Surface Level

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:30,000 (A3)

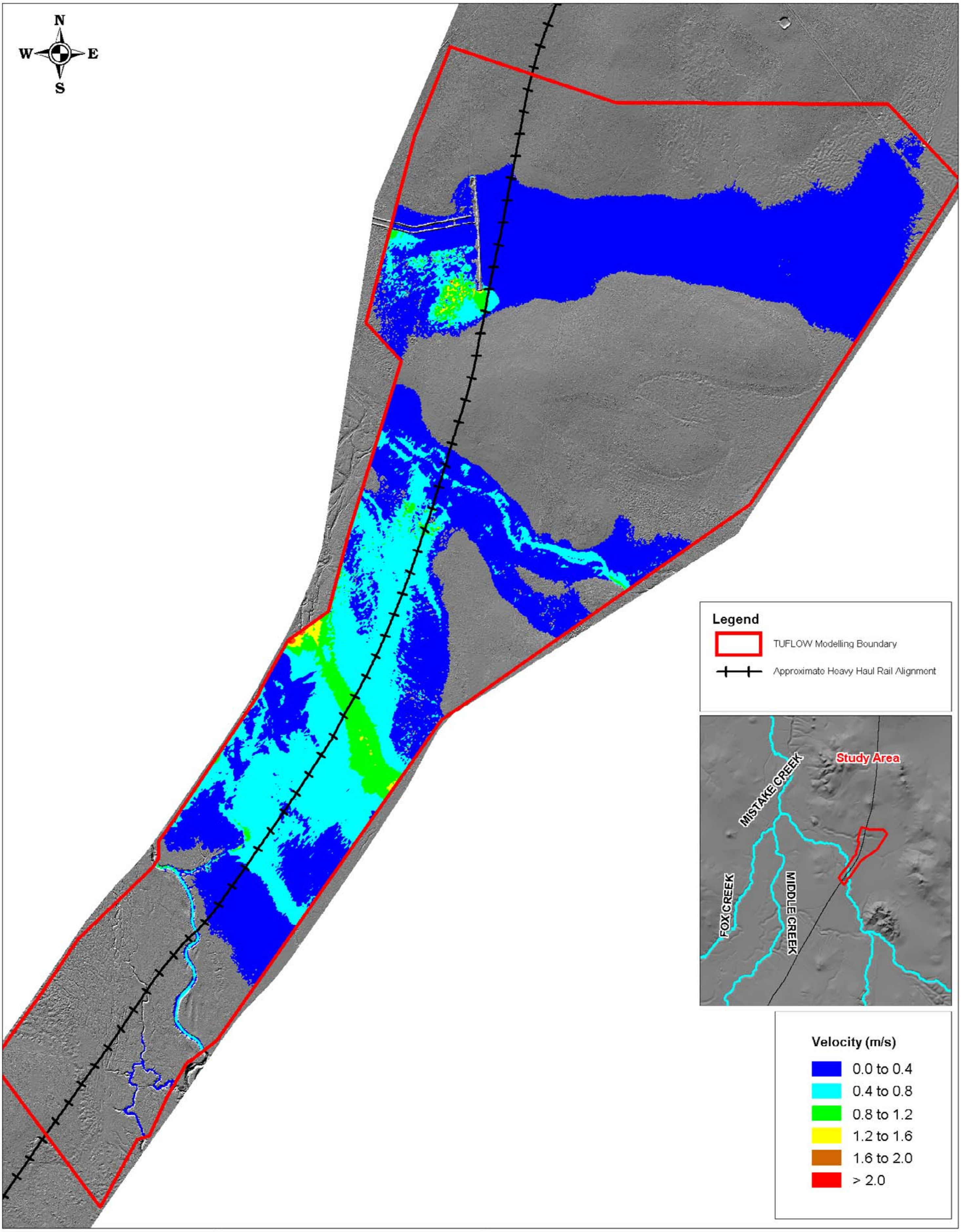
0 600 1200
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Mistake Creek
100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:30,000 (A3)

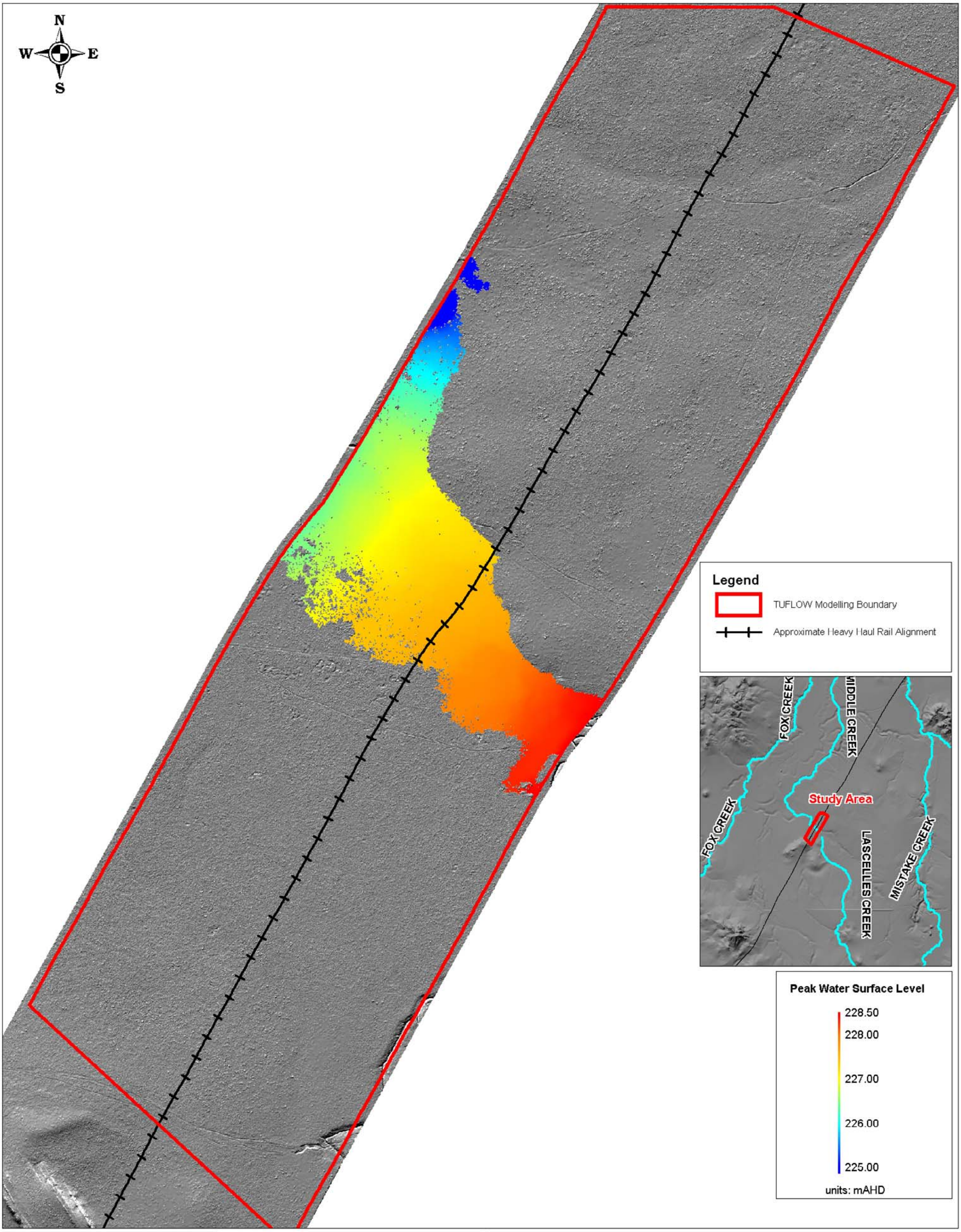
0 600 1200
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Mistake Creek
100 Year ARI Flood Velocity

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:15,000 (A3)

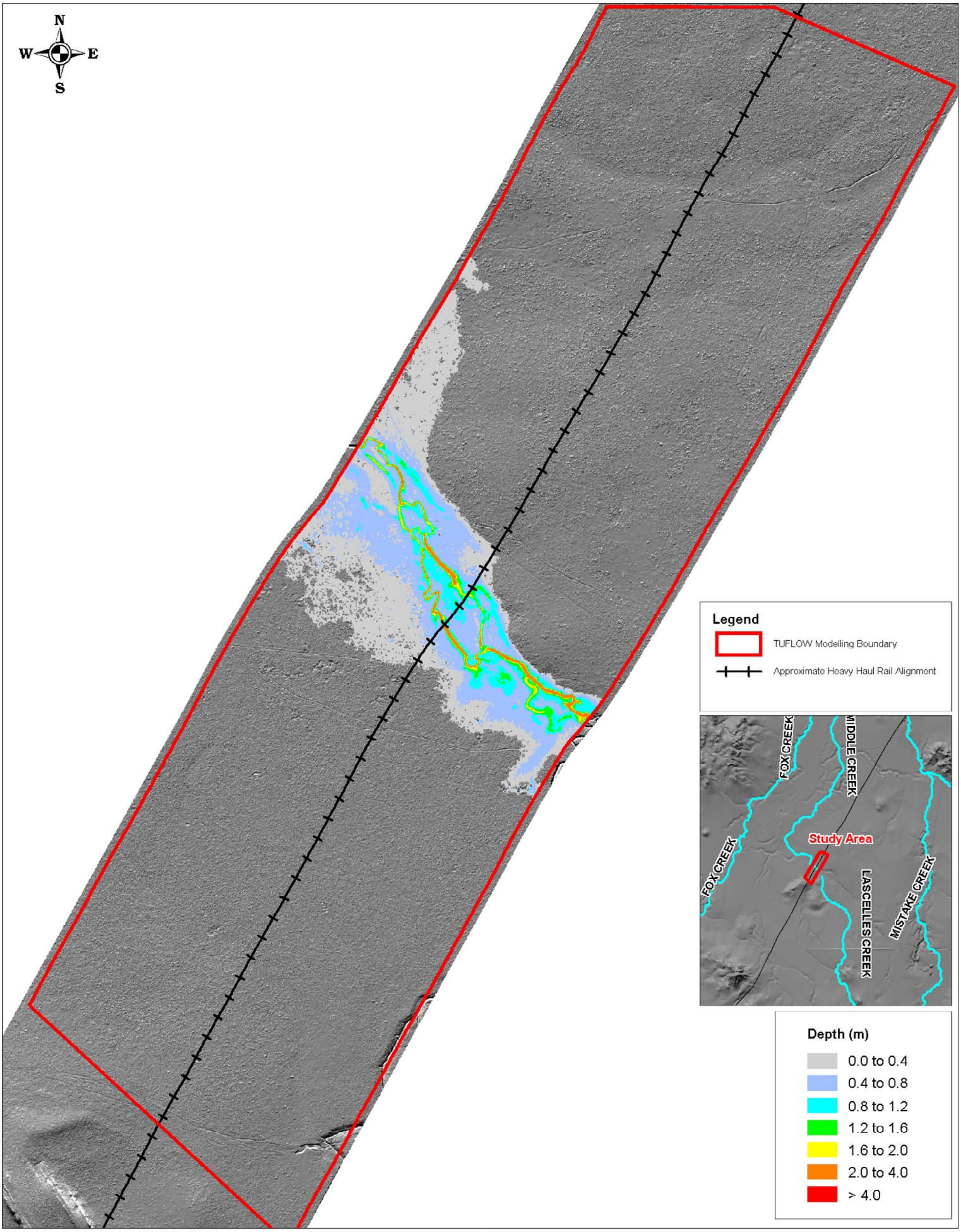
0 300 600
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study
Lascelles Creek
100 Year ARI Water Surface Level

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:15,000 (A3)

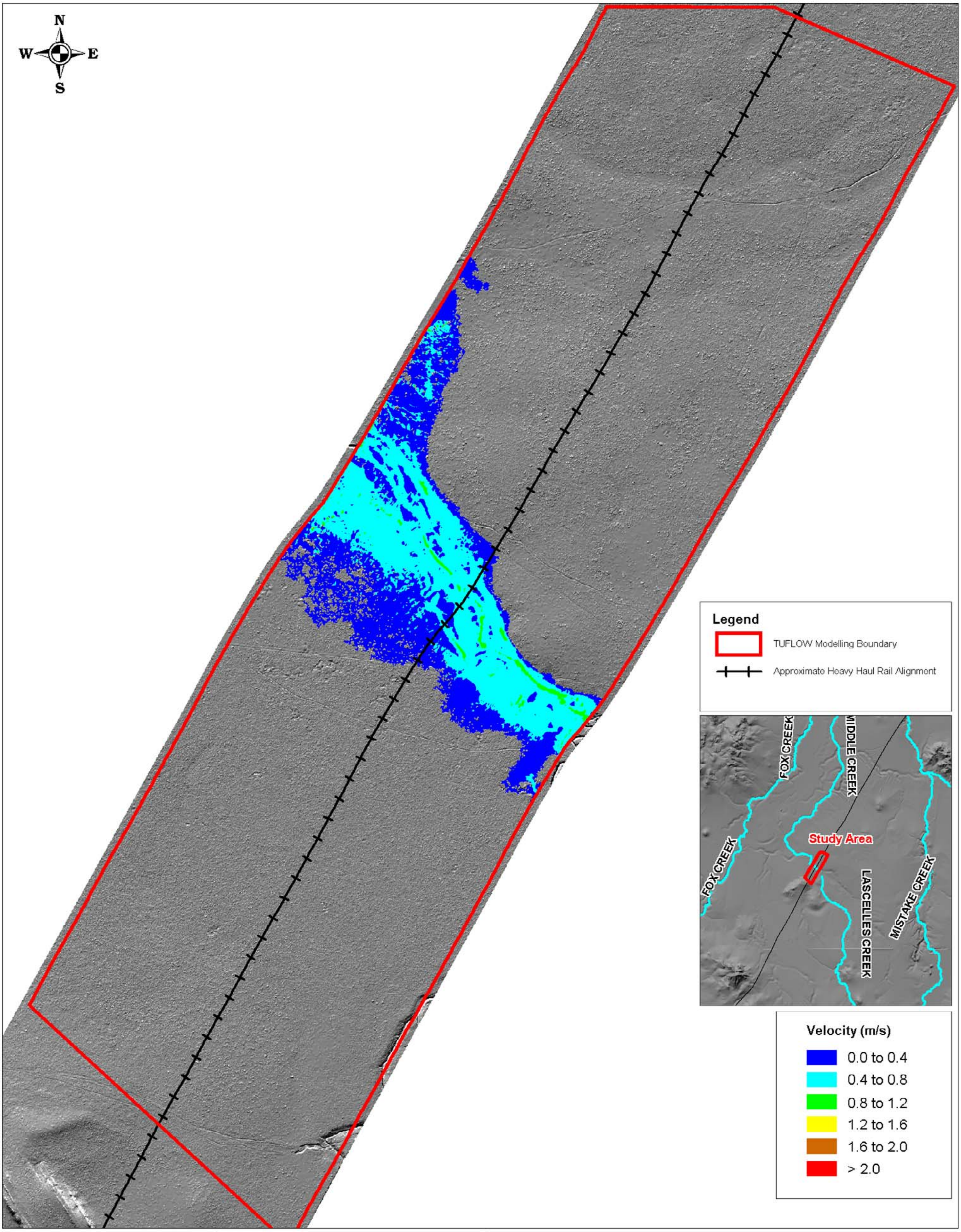
0 300 600
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study
Lascelles Creek
100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:15,000 (A3)

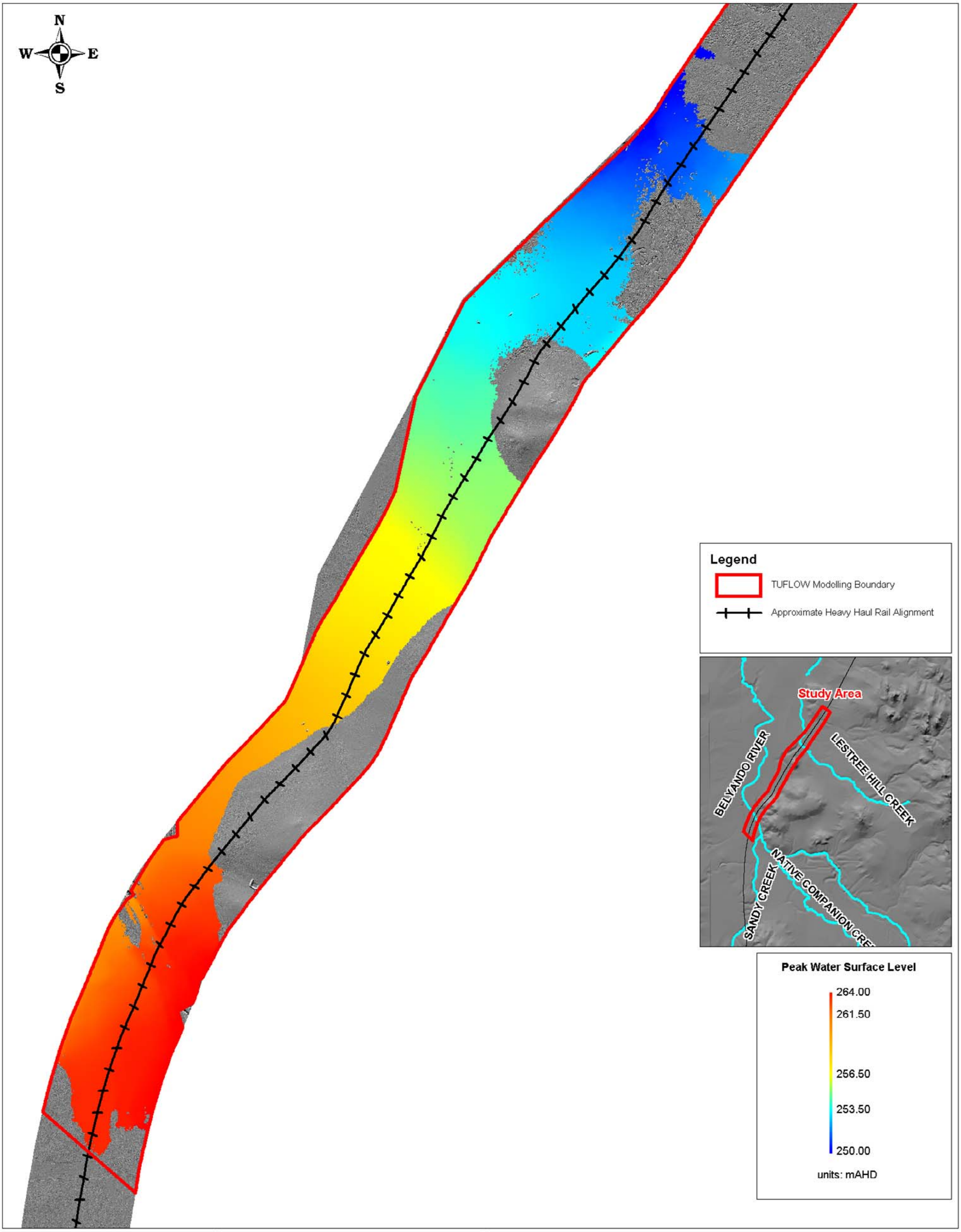
0 300 600 Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Lascelles Creek
100 Year ARI Flood Velocity

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:50,000 (A3)

0 1 2
Kilometers

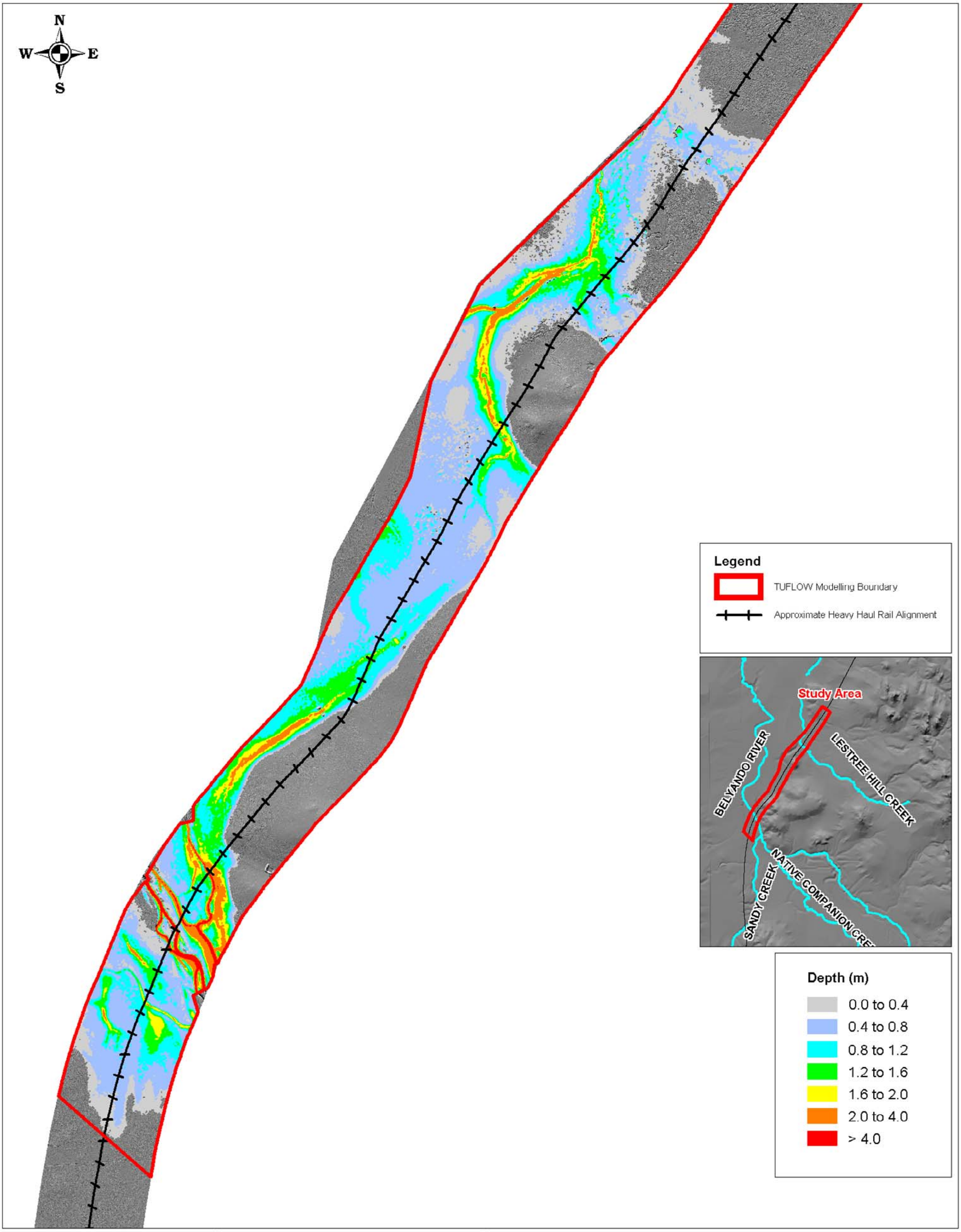
REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study **Appendix D**

Belyando River & Les Tree Hill Creek

100 Year ARI Water Surface Level

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:50,000 (A3)

0 1 2
Kilometers

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

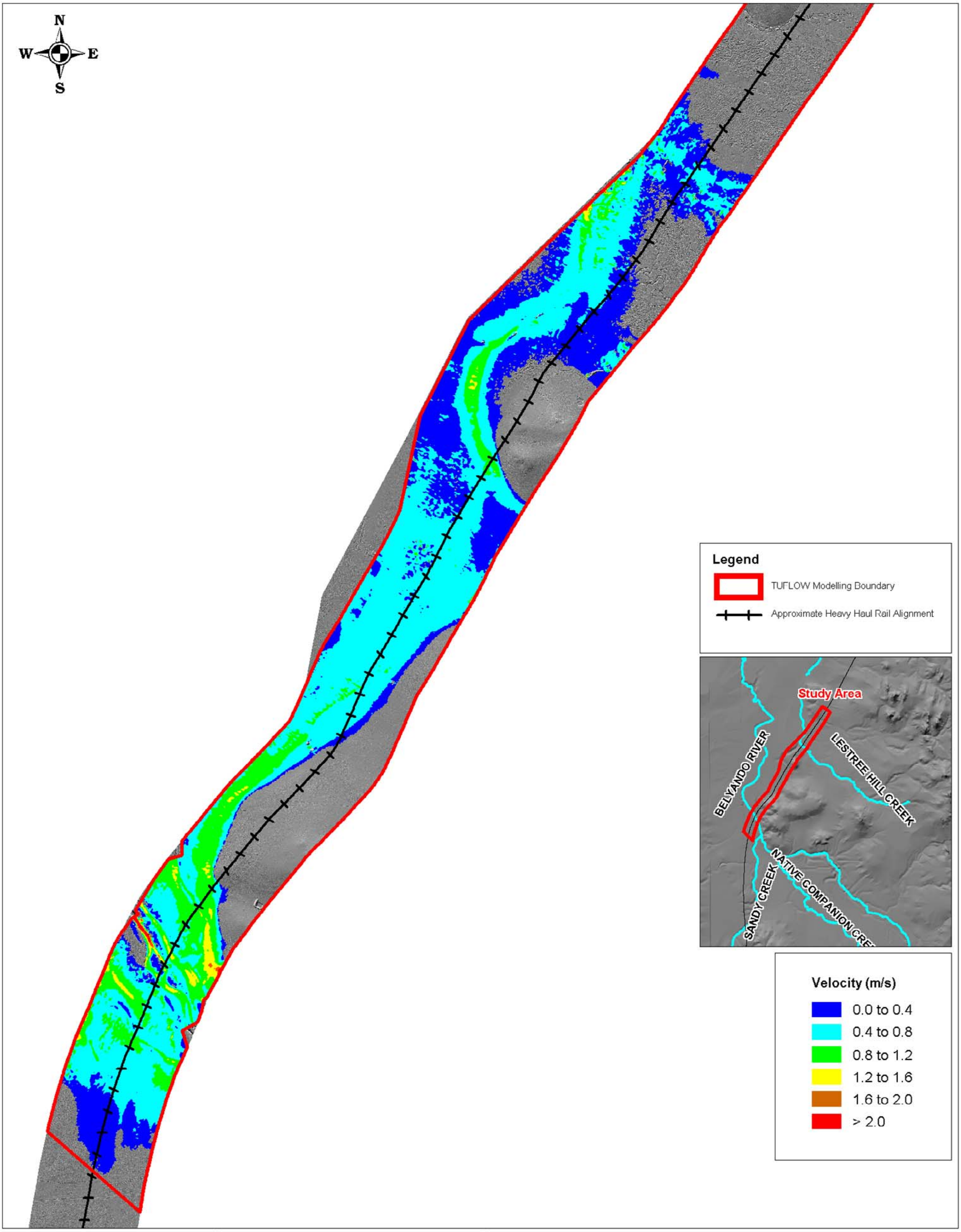
Heavy Haul Rail Corridor Flood Study

Belyando River & Les Tree Hill Creek

100 Year ARI Flood Depth

Appendix D

Waratah Coal



ENGENY
WATER MANAGEMENT

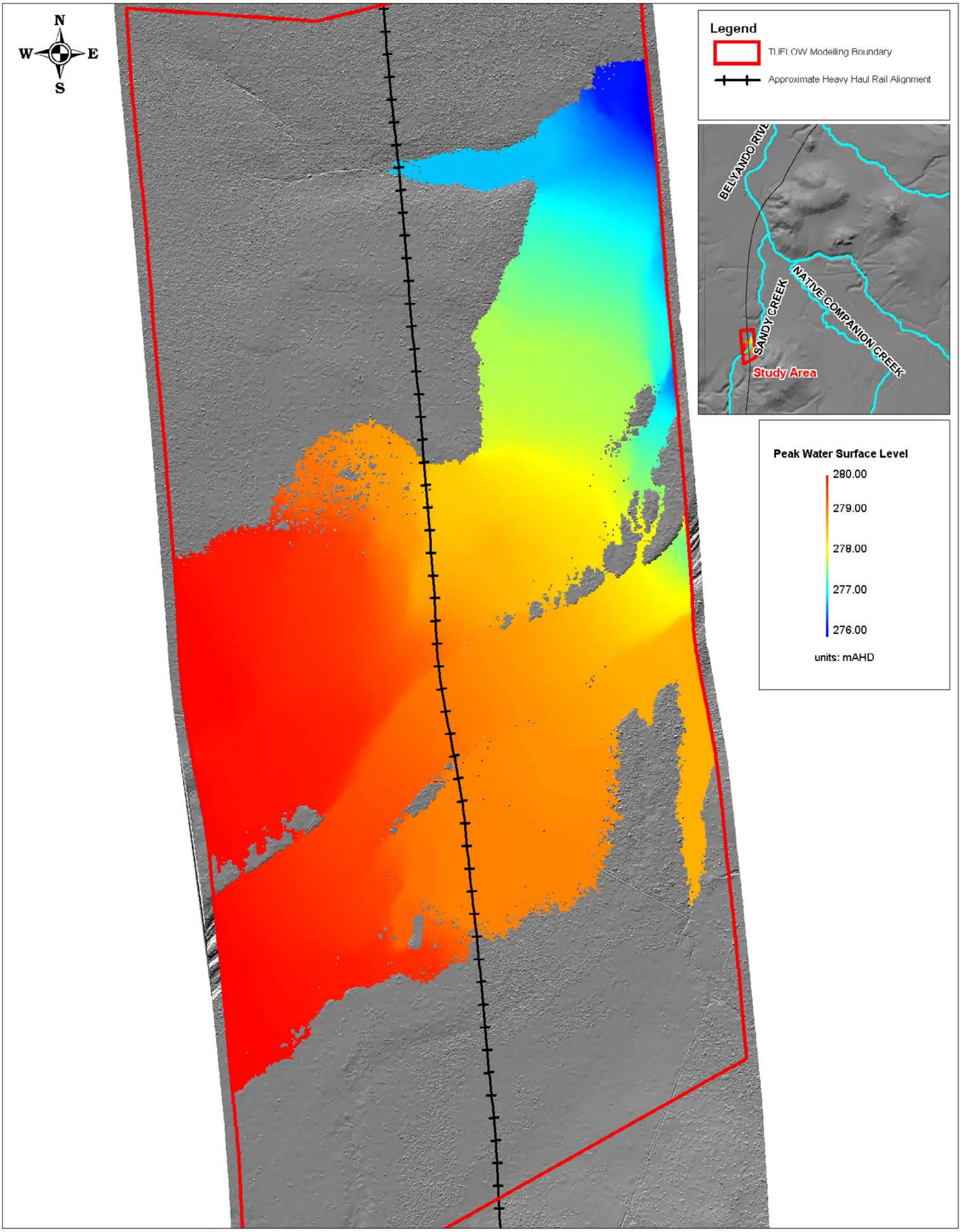
Waratah Coal
THE NEW ENERGY IN COAL

Scale 1:50,000 (A3)

0 1 2
Kilometers

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor **Appendix D**
Flood Study
Belyando River & Les Tree Hill Creek
100 Year ARI Flood Velocity
Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

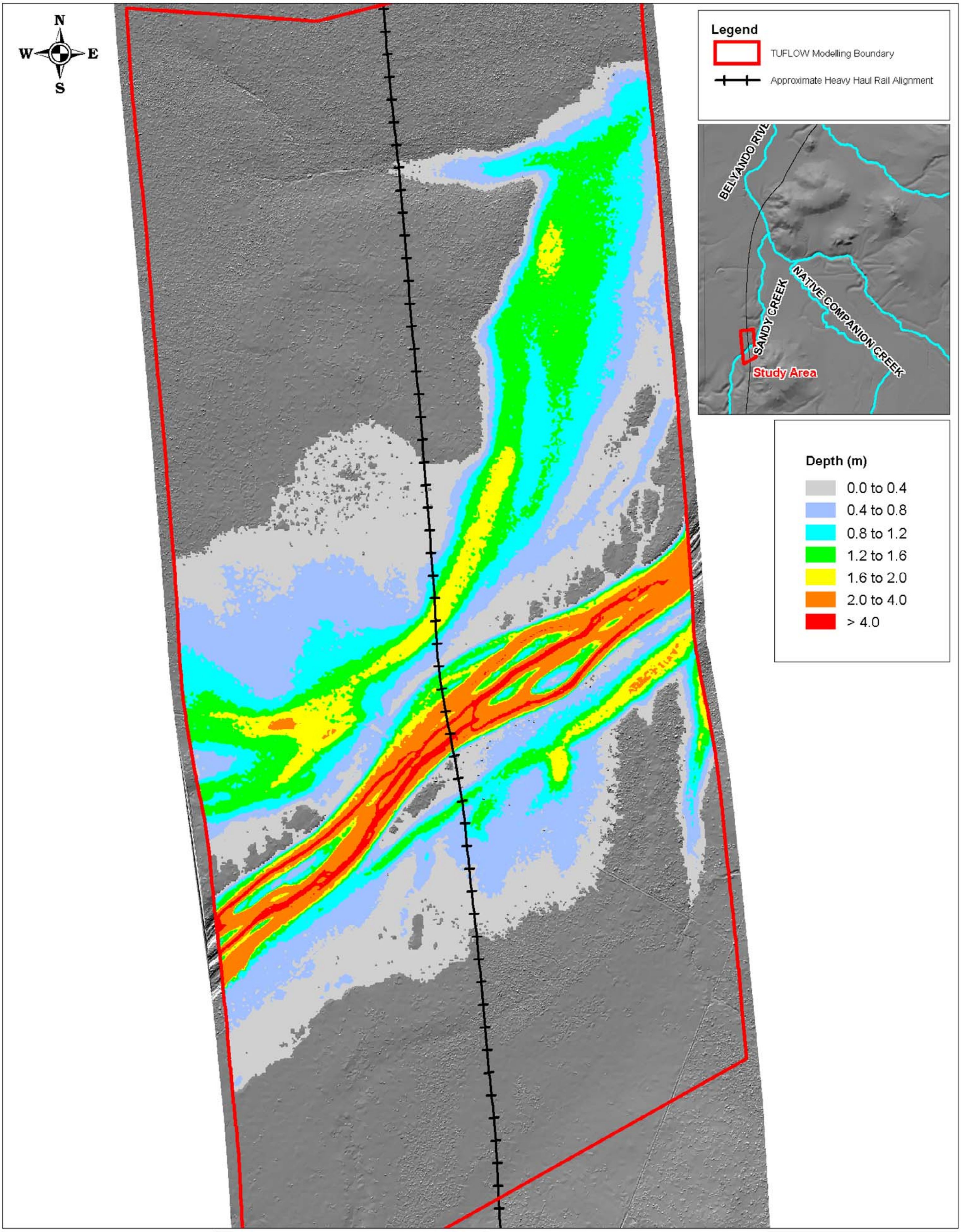
0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Sandy Creek Crossing
100 Year ARI Water Surface Level

Appendix D

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

0 200 400
Meters

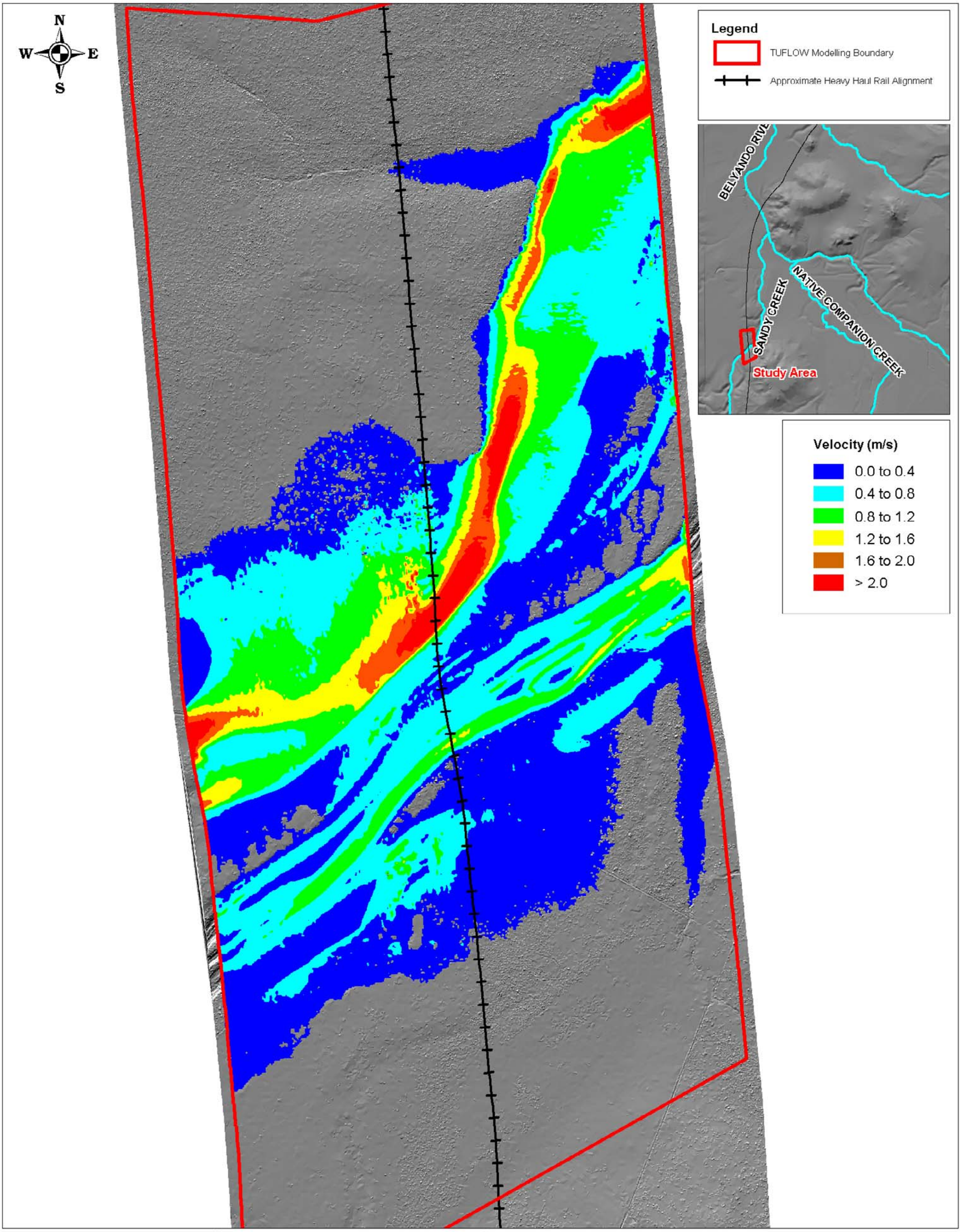
REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor Flood Study

Appendix D

Sandy Creek Crossing 100 Year ARI Flood Depth

Waratah Coal



ENGENY WATER MANAGEMENT

Waratah Coal THE NEW ENERGY IN COAL

Scale 1:10,000 (A3)

0 200 400
Meters

REV	DATE	REVISION DESCRIPTION	ORIG	CKD
A	16/12/10	Client Issue	PC	MP

Heavy Haul Rail Corridor
Flood Study
Sandy Creek Crossing
100 Year ARI Flood Velocity

Appendix D

Waratah Coal