6. Water Resources

This section provides a summary of the hydrology (surface water) and hydrogeology (groundwater) investigations undertaken, and the potential impacts identified, in regards to the Project (Rail) during construction and operation. The assessment was undertaken in accordance with the requirements of the Terms of Reference (ToR) and a table cross-referencing these requirements is provided in Volume 4 Appendix C ToR Cross Reference Table. A detailed hydrology (surface water) report is included in Volume 4 Appendix AB Rail Hydrology Report. A detailed hydrogeology (groundwater) report is included in Volume 4 Appendix AC Rail Hydrogeology Report.

6.1 Hydrology

6.1.1 Introduction

6.1.1.1 Approach

The approach adopted for the surface water resource assessment comprised:

- Describing the catchments, beds, banks, water column and environmental values associated with waterways crossed by the Project (Rail).
- Identifying the environmental values against which the effects will be reported.
- Assessing the potential adverse effects on the nominated surface water environmental values from the construction and operation of the railway.
- Identifying suitable management and mitigation measures to reduce the risk of any such adverse effects to an acceptable level.

6.1.1.2 Legislation Policies and Guidelines

The description of the water resource environment and how it may be affected by the Project (Rail) has been conducted in the context of the environmental values and legislative and policy requirements defined in:

- *Water Act 2000* (Qld)
- *Environmental Protection Act 1994* (Qld) (EP Act)
- Environmental Protection (Water) Policy 2009 (EPP (Water))
- ANZECC (2000) Water Quality Guidelines
- Queensland Water Quality Guidelines(DERM, 2009)
- Water Resource (Burdekin River Basin) Plan 2007
- Water Resources (Fitzroy Basin) Plan 2011
- Burdekin Dry Tropics Natural Resource Management Plan (2005–2010)
- Social, Economic, Cultural and Environmental Values of Streams and Wetlands in the Burdekin Dry Tropics Region (Greiner and Hall, 2006)

- Environmental Protection (Water) Policy 2009 Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin (DERM, 2011a)
- National Land and Water Resource Audit 2000-2002 as part of the Australian Water Resources Assessment 2000 (Australian Natural Resource Atlas (ANRA) 2009)

6.1.1.3 Flood Flow Methodology

The methodology adopted for the flood flow and flood level assessments was based on preliminary concept level design and relied upon modelling and reports prepared by Golder Associates (2011), provided in Volume 4, Appendix AB Rail Hydrology Report. The following methodology was applied:

- Design flows were derived using flood frequency regression analysis applied to local or regional historic stream flow data for the larger named waterways such as the Belyando River and Mistake Creek. Flood estimates for the 2, 10, 50, 100 and 500 year Average Return Interval (ARI) events were determined.
- The Rational Method was used to estimate flood flows for minor watercourses using time of concentration calculated according to the Bransby Williams formula and runoff coefficients from DERM (2005) assuming medium density bushland with low permeability soils.
- At the time of the preliminary hydrology modelling no guidelines or current acceptable afflux limitations for similar infrastructure in the Project (Rail) region were available. As a result the afflux at the major waterway crossings (as defined in Section 6.1.2.1 and Figure 6-1) (catchment areas greater than 100 km^2) was simulated for several scenarios of discharge and crossing length using a 2D XP SWMM/TUFLOW model. The only exceptions to this were the crossings at Logan Creek and the unnamed waterway where qualitative comparisons were made to the other modelled crossings.

Minor waterway and overland flow paths are those with catchment areas less than 100 km^2. Eight minor bridge structures and 68 minor drainage structures likely to be reinforced with concrete box culverts and pipe culverts, respectively, are proposed.

Mitigation strategies were formulated for the potential adverse impacts of the construction and operation of the Project (Rail) on environmental values identified at a collective workshop held for that purpose. Mitigation and ponding impacts on surrounding land uses for minor waterways are discussed as part of this strategy in Section 6.1.3.1.

The methodologies and results of the preliminary modelling are currently being utilised as a base for further development and modelling during the engineering design that is currently taking place. Detailed engineering design will incorporate identified design criteria including acceptable afflux and criteria for passage of flows through the proposed railway line and embankment as well as 100 year ARI flood immunity required for the railway line.

6.1.2 Existing Environment

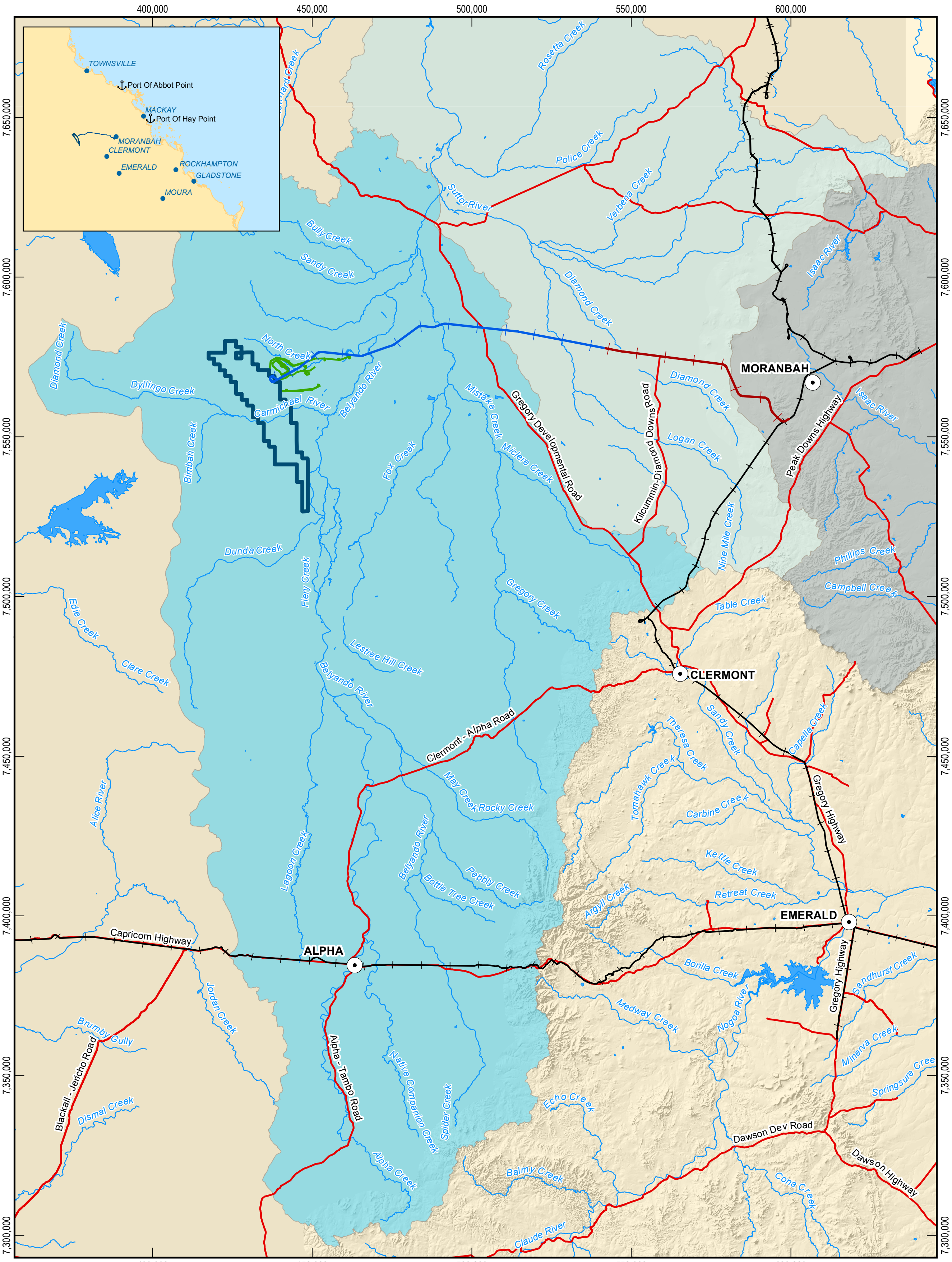
6.1.2.1 Stream and Catchment Characteristics

Overview

The landscape traversed by the rail corridor is characterised by relatively flat floodplains dominated by rivers and creeks which have reasonably well defined channels lying within wider floodplains that are inundated during flood events. Streams are largely ephemeral, reflecting the intermittent nature of rainfall in the area. Some base flow is retained from groundwater inflows in some streams. The vegetation within the corridor comprises dry savannah grassland under depleted secondary growth remnants of formerly extensive dry forests that are understood to have been cleared from the 1950s to the 1980s. Cattle grazing is the dominant land use of the area. The railway alignment is located predominantly within the Belyando River / Suttor River sub-catchments of the Burdekin River Catchment as shown in Figure 6-1. The first 40 km of the railway alignment (from the eastern extent) is located within the Grosvenor Creek sub-catchment of the Isaac River, which is a tributary of the Fitzroy River (142,665 km^2 catchment).

The Belyando River / Suttor River sub-catchments comprise the southern headwaters of the Burdekin River and occupy 60 per cent of the Burdekin River's 130,000 km^2 catchment area. Along with the Cape River and Upper Burdekin River, these catchments are the main contributors to the Burdekin Falls Dam, which lies 60 km downstream of the Project (Rail) corridor. This dam has no backwater influence on the flood levels of the Belyando or Suttor Rivers in the vicinity of the rail corridor.

Due to the relatively flat topography between channels, floodwaters from adjacent streams may join across the adjacent floodplain during large rainfall events. In these situations, the hydraulic modelling of the crossings (Golder Associates, 2011) has included more than one crossing within a single hydraulics model. Major waterway crossings which have been modelled are listed in Table 6-1.



LEGEND

Town	Rail (West)	Watercourse	River Basins
State Road	Rail (East)	Waterbody	Belyando River
Other Rail Network	Mine (Onsite)		Suttor River
	Mine (Offsite)		Isaac River

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0 10 20 30 40 50

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

Project (Rail)
Catchments and Watercourses

Job Number 41-25215
Revision C
Date 11-09-2012

Figure 6-1

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Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: DERM: River Basin (2009), State Road (2010); DME: EPC1690 (2010), EPC1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Locality, Rail, Watercourse (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA

Table 6-1 Major Waterways Traversed by the Project (Rail)

Number*	River Catchment	Waterway Name	Rail Corridor Chainage (km)	Catchment upstream of Project (Rail) (km^2)
1	Isaac River	Grosvenor Creek	18.5	128.4
2	Suttor River	Diamond Creek	62.7	1000
3	Suttor River	Logan Creek	82.7	2900
4	Suttor River	Unnamed Creek	90.2	109.7
5	Belyando River	Gowrie Creek	113.5	210
6	Belyando River	Mistake Creek	120.8	7,900
7	Belyando River	East Branch Belyando River	139.2	210
8	Belyando River	Belyando River Anabranch	149.0	22,000
9	Belyando River	Ogenbeena Creek (Lower crossing)	150.6	870
10	Belyando River	Ogenbeena Creek	153.0	850
11	Belyando River	North Creek	170.4	300
12	Belyando River	Eight Mile Creek	176.2	180

The morphological character of many of the waterways crossed by the Project (Rail) have changed as a result clearing of remnant vegetation for cattle grazing purposes. This has altered the original hydrological regimes. The research of Pettit (2002) shows that catchment responses to this land clearance include increased runoff, increased drainage density, and increased erosion and sediment yields within the catchment. In response to altered hydrological regimes, channel morphology changes can occur in the form of bank erosion, channel incision and floodplain scour. These effects are increasingly pronounced with distance downstream from the ephemeral headwaters to the main creek and river channels.

This is illustrated in Plate 6-1 which shows a channel of Eight Mile Creek near the Mine Site. Plate 6-2 shows the Belyando River and Plate 6-3 shows the eastern channel of the Belyando River and Mistake Creek with slumped, highly eroded banks and beds choked with loose sediment. This material is mobilised readily once there is appreciable flow. In the relatively flat topography, floodplains can be a kilometre or more wide in some localities about the main stem of the rivers.

Almost all of the waterways within the Project (Rail) area are ephemeral. Under normal conditions the main stem of the Belyando River maintains a small base flow during the dry season. Once storm flow reaches the rivers and creeks, they rapidly fill and overflow into floodplains where flooding can persist for several days and sometimes weeks at a time as illustrated in Plate 6-4. After the flooding recedes, the majority of waterway main channels become a series of waterholes sustained by a slow base flow. Farm dams (refer to Plate 6-5) are often dry by the beginning of the next wet season, unless maintained by pumped groundwater.

Plate 6-1 Eight Mile Creek

Source: GHD, August 2011. Location 10 Mile Road, Labona (S21° 59.878 E146°20.765).

Plate 6-2 Belyando River at Moray Downs Station

Source: GHD, August 2011 (S21°56.163 E146°37.869)

Plate 6-3 Mistake Creek at Elgin Downs Crossing

Source: GHD, August 2011 (S21°59.659 E146°55.623)

Plate 6-4 Belyando River Anabranch in Flood

October 2010, Moray Downs Station (S21°56.163 E146°37.869)

Plate 6-5 Farm Dam on Grosvenor Creek

Rugby Run Station (S22°7.860 E147°54.889)

Belyando River and Suttor River

There is currently no regulation of the Belyando/Suttor Surface Water Management Area (SWMA) under the Water Resources (Burdekin River Basin) Plan 2007. The Water Resource Plan focuses on water extraction for the irrigated farmlands in the lower Burdekin and Houghton River sub-catchments. The unreliability of the surface water resource in the Belyando and Suttor River catchments is principally due to the rainfall patterns and presents a problem for setting sustainable takes in these catchments (North Queensland Dry Tropics, 2001b).

Grosvenor Creek in the Isaac River Catchment

Grosvenor Creek drains to the Isaac River, which in turn is a tributary of the Fitzroy River.. The dominant land use in the Grosvenor Creek sub-catchment in the vicinity of the Project (Rail) is cattle grazing. In the wider catchment of the Isaac River, mining, dryland cropping and production forestry are also significant land uses.

Moranbah will soon supplement its domestic water supply from the Burdekin catchment via pipelines across the catchment divide from Burdekin Falls Dam and Eungella Dam. On the Isaac River, water for coal mining in the Goonyella area is supplied from the Burton Gorge Dam and Teviot Dam.

All of the other creeks and rivers crossed by the Project (Rail) ultimately drain to the Burdekin River.

Rainfall

The main influence on the hydrology of the waterways crossed by the Project (Rail) is the rainfall patterns. The catchment areas of these waterways comprise over 35,000 km^2. Monthly rainfall data has been plotted from the records at Moranbah, Alpha and Moray Downs. The locations of these rainfall gauges are shown on Figure 6-2. Rainfall characteristics include:

- Rainfall patterns, in terms of summer maxima, winter minima and annual totals are broadly similar across this relatively large area. The annual total depths for the three rain gauges are 588 mm, 559 mm and 521 mm. These totals are consistent with the BOM regional average of 550 mm.
- In any month of the year, including in the typical wet season months, there can be zero rainfall.

The monthly rainfall trends described above are reflected in the gauged daily river flows. Similarly, the pronounced annual variations in rainfall, including the persistence of both dry years and wet years, are evident in the annual discharges at St Annes (Belyando / Suttor Rivers) and Goonyella (Isaac River).

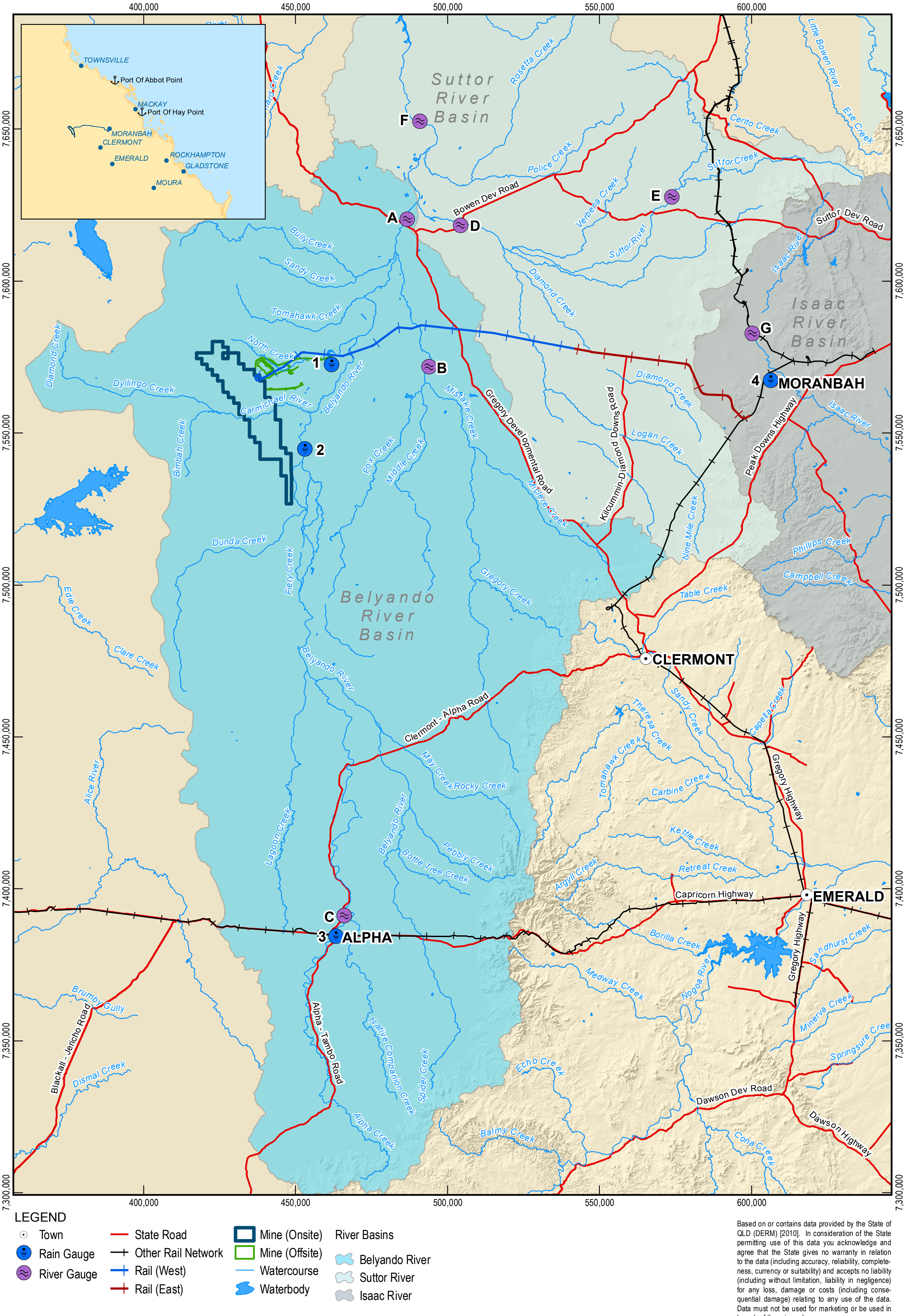
Stream Flow

The description of the existing conditions, flows, or hydrology, is informed by data published by the Bureau of Meteorology (BOM). There are three BOM flow depth recording sites, also referred to as river gauges, in the Belyando River, Suttor River and Isaac River. The locations of these river gauges are presented in Figure 6-2. Recorded water levels at these sites have been converted to flows based on a rating table that has benefited from actual flood flow gauging. In the Belyando River, the nearest river gauge to the Project (Rail) is at the Gregory Developmental Road crossing (refer to river gauge A Figure 6-2). There are no river gauges on Logan Creek, which has a catchment area of 3,372 km^2. There are two river gauges on the Suttor River, one at Bowen Development Road Weir and the other upstream at Eaglefield. There are no river gauges on Grosvenor Creek. On the Isaac River, the nearest gauge to the Project (Rail) is at Goonyella Creek, 30 km to the north of Moranbah. Derived daily flow records at the Gregory Developmental Road (river gauge A on the Belyando River), Twin Hills (river gauge B on Mistake Creek), Eaglefield (river gauge E on the Suttor River) and Goonyella (river gauge G on the Isaac River) river gauges is presented in Figure 6-3, Figure 6-4, Figure 6-5 and Figure 6-6, respectively.

The derived daily flows provide an overview of the flow regimes in the relevant catchments. These flow patterns mimic rainfall, and while there are more flow events in the wet season, there are also periods of zero flow in the same season.   Conversely flow events are variable and will also occur periodically throughout the dry season. Consequently recorded base flow is often zero or minimal and as such are generally not visible at the scale of the figures even though the catchment areas at the gauges are large (in the range 1,214 to 35,411 km^2). It should be noted it is not intended that these plots represent the flow at the intersection with the Project (Rail). Rather they indicate typical patterns of flow in the Study Area.

There is also variability from year to year. This variation in annual discharge volumes is presented in Figure 6-7 which plots the annual flow volumes recorded at St Annes (river gauge F) combining the Belyando and Suttor Rivers. The Isaac River at Goonyella shows a similar variation, refer to Figure 6-8, that is, a series of high flow years is often followed by a series of low flow years.

Low flow or dry periods have a high frequency despite the difficulty in prediction their occurrence and duration. However it is the episodic, low frequency events of short duration and high intensity that dominate the discharge regime and long term averages. These short-lived phenomena can occur at any time from November to May and tend to mask the seasonality of higher flows during summer.



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
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Flow Gauging Sites and Rain Gauges (after NQ Dry Tropics 2011b)

Figure: 6-2

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Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: DERM: River Basin (2009), State Road (2010); DME: EPC1690 (2010), EPC1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Locality, Rail, Watercourse (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA

Figure 6-3 Average Daily Flows in the Belyando River at Gregory Developmental Road Bridge

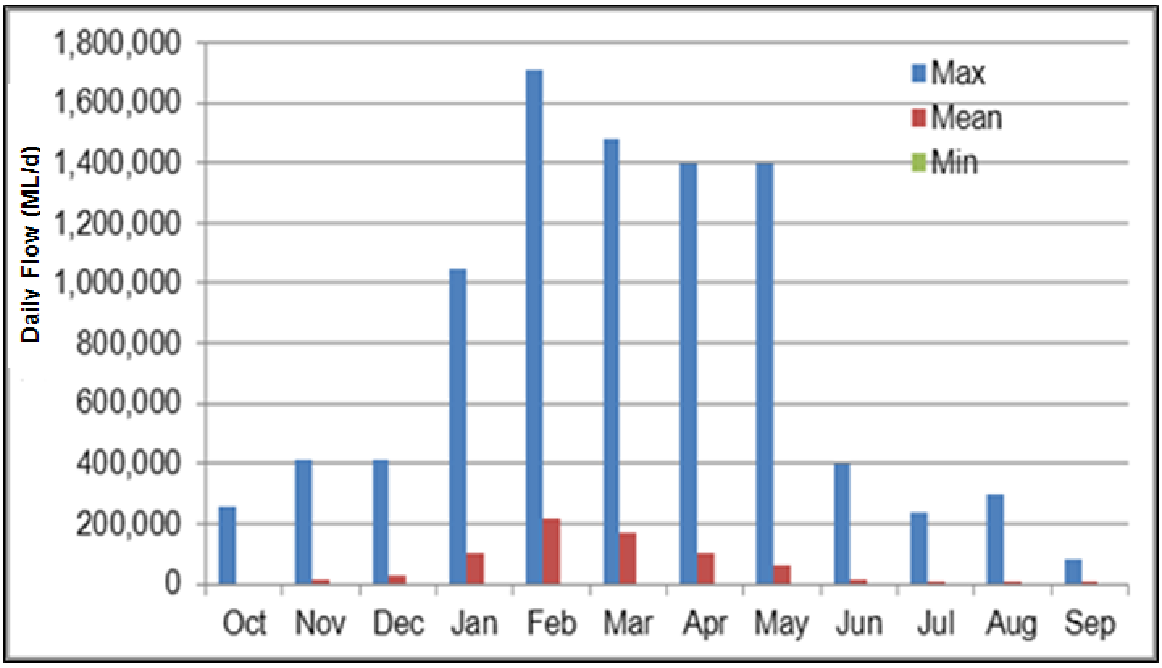


Figure 6-4 Average Daily Flows in Mistake Creek at Twin Hills

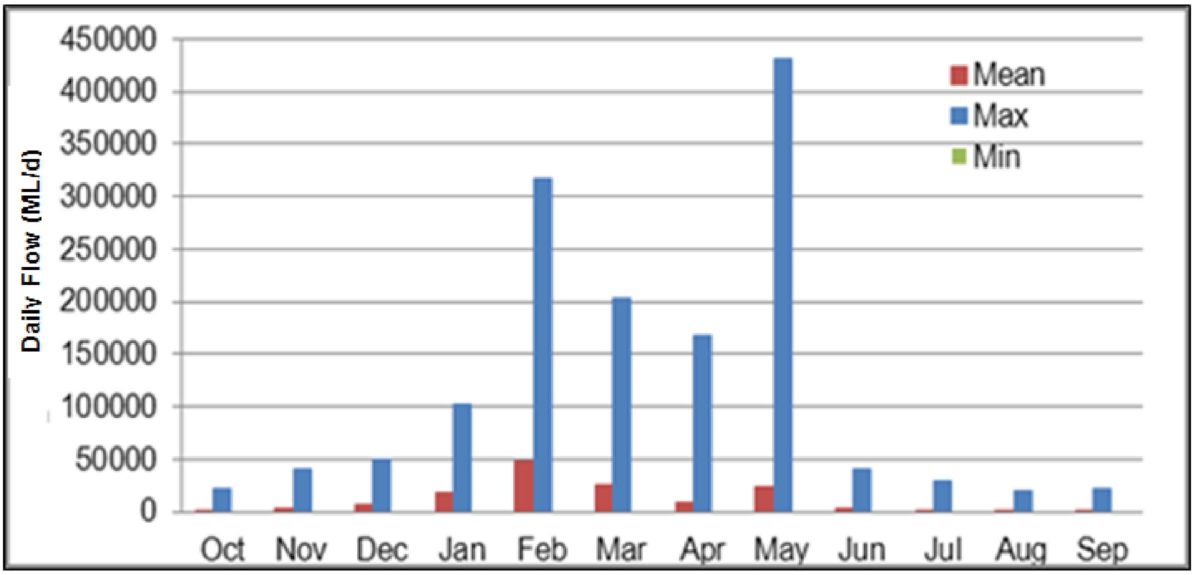


Figure 6-5 Average Daily Flows in the Suttor River at Eaglefield

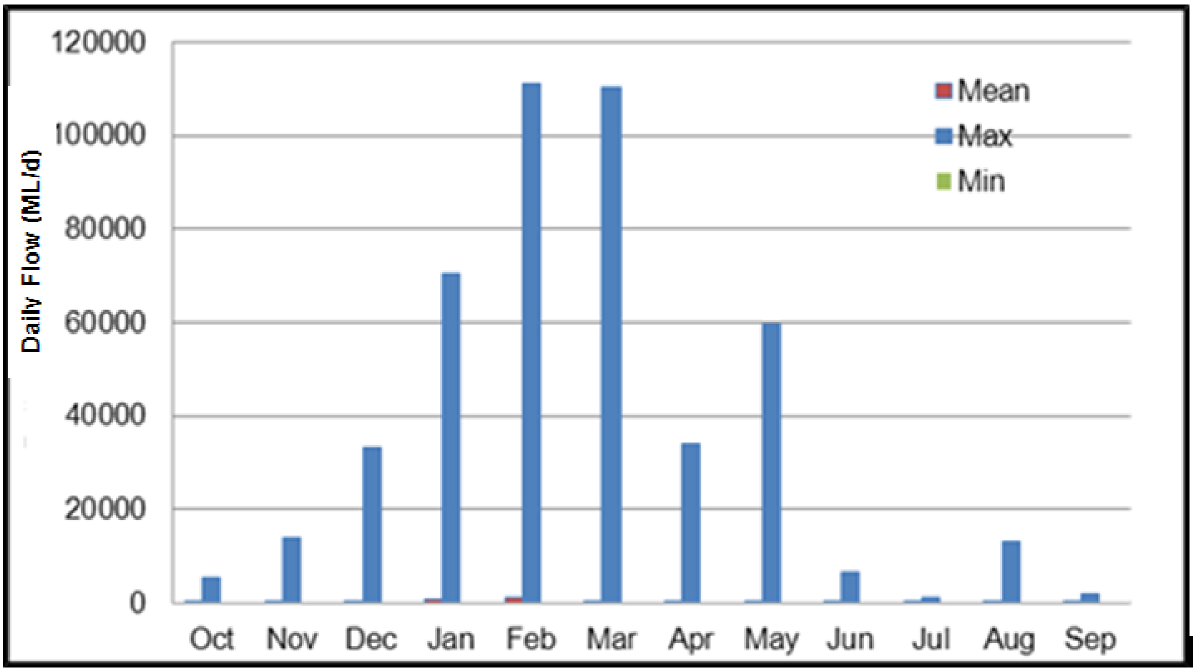


Figure 6-6 Average Daily Flows in the Isaac River at Goonyella

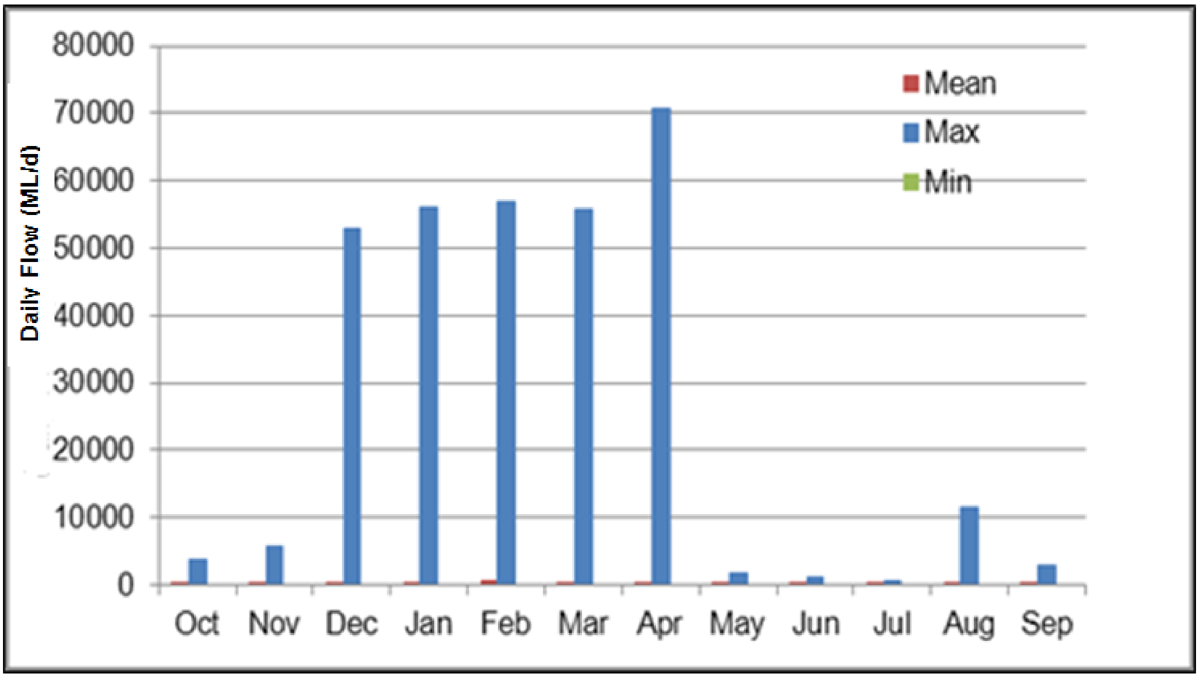


Figure 6-7 Annual Discharges at St Annes (Belyando/Suttor Rivers) (1967-2006)

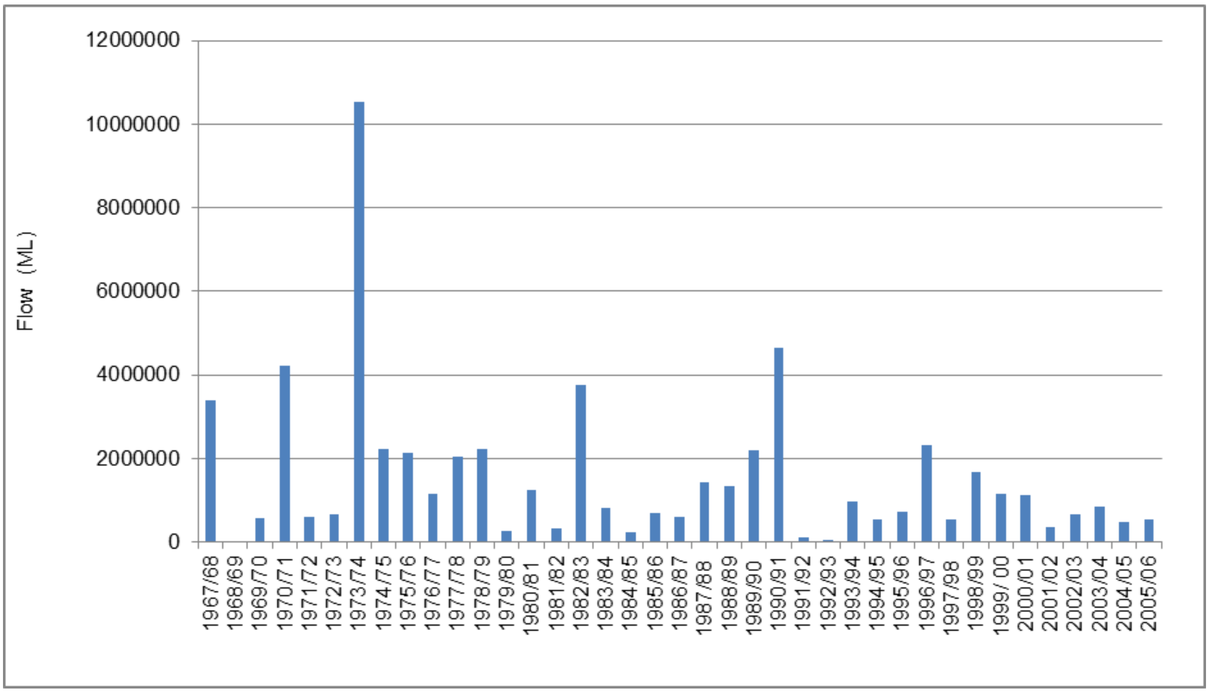


Figure 6-8 Annual Discharges at Goonyella (Isaac River) (1976-2010)

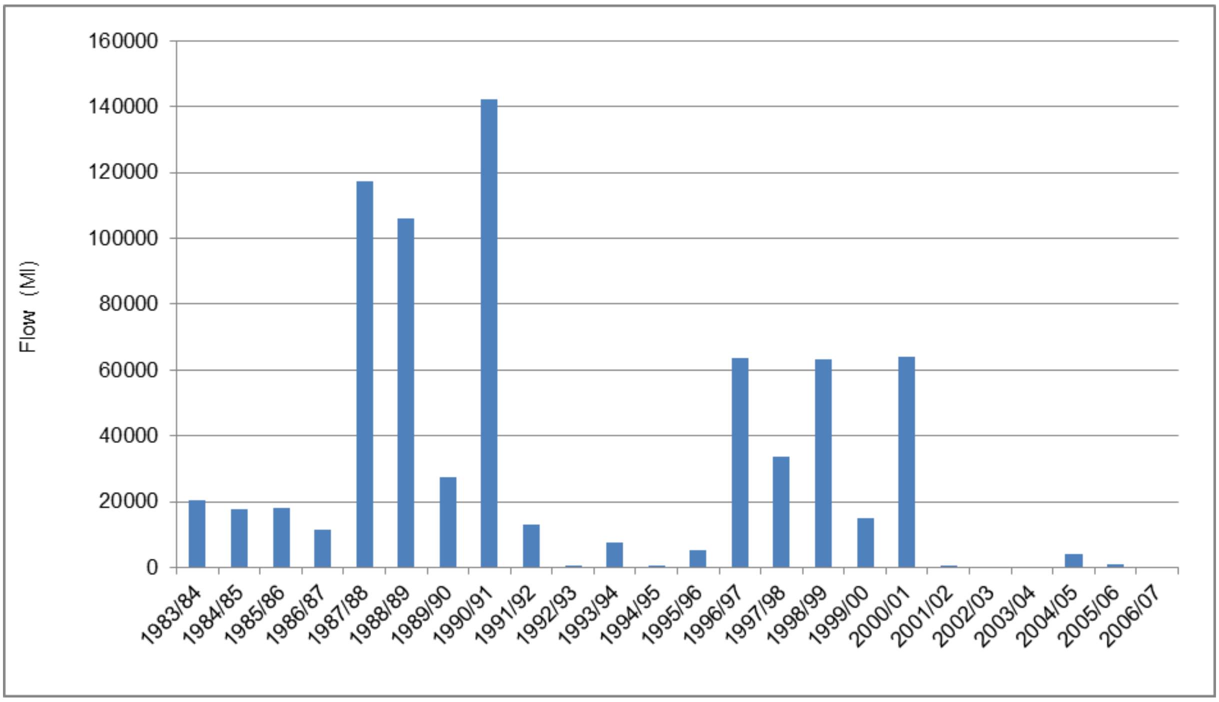


Table 6-2 presents the average catchment contributions to the Burdekin River at Clare. The table demonstrates that more than half of the total Burdekin River flow comes from the Upper Burdekin sub-catchment despite this sub-catchment representing only 28% of the Burdekin Basin. By contrast, the Belyando River and Suttor River sub-catchment contributes approximately half that of the Burdekin River yet occupies 57% of the Burdekin Basin (Pusey and Arthington, 1996).

Table 6-2 Average Catchment Contributions to the Burdekin River at Clare

Sub-catchment Area (km^2)	Area of Burdekin Basin upstream of Clare (%)	Sub-catchment annual contribution (ML/a)	Contribution to total flow (%)
Upper Burdekin (36,181)	28	4,067,000	52
Belyando/Suttor (73,828)	57	2,554,500	33
Bowen/Broken (9,413)	7	1,021,760	13
Lower Burdekin (10,028)	8	132,700	2
Total at Clare (129,450)	100	7,775,960	100

Source: Burrows, 1999

Flow Estimates

Peak flow water levels were estimated for the locations where the proposed Project (Rail) will traverse major watercourses. Table 6-3 shows the results of the interpolation of ARI for the peak flows recorded in the Belyando River at Gregory Developmental Road gauge (120301B) and Mistake Creek at the Twin Hills gauge (120309A) during three historic floods: May 1983, January 2008 and January 2011. The peak discharges at were then derived from a pro-rata increase/decrease in catchment area between the crossing and the gauges.

Table 6-3 Historic and Estimated Peak Flood Flows

	Belyando River	Mistake Creek
May 1983 (Cyclone Naomi)	**3 May**	**3 May**
Estimated ARI (Years)	20	10
Recorded Peak Flow at gauge (m^3/sec)	2,018	425
Estimated Flow at Rail Crossing (m^3/sec)	1,589	439
January 2008 (Cyclone Helen)	**23 January**	**21 January**
Estimated ARI (Years)	100	10
Recorded Peak Flow at gauge (m^3/sec)	4,114	451
Estimated Flow at Rail Crossing (m^3/sec)	3,240	466
January 2011	**1 January**	**1 January**

	Belyando River	Mistake Creek
Estimated ARI (Years)	10	5
Recorded Peak Flow at gauge (m^3/sec)	1029	318
Estimated Flow at Rail Crossing (m^3/sec)	810	329

In order to understand the behaviour of major waterways during flood events, design flows for statistically significant events were derived from existing streamflow data using a flood frequency regression analysis. Flood estimates for 2, 10, 50, 100 and 500 year ARI events were determined. Flood modelling then proceeded with the 100 year ARI flood flows as this was the selected design flood immunity for the proposed Project (Rail).

Flood flow estimates for the 12 major waterway crossings are presented in Table 6-5. These were then used for assessment of impacts presented in Section 6.1.3.4.

Table 6-4 Estimated Peak Flows for Major Waterways within the Project (Rail)

	Peak Flow m^3/sec		
Waterway	**50 yr ARI**	**100 yr ARI**	**500 yr ARI**
Grosvenor Creek	240	**341**	490
Diamond Creek	460	**682**	1100
Logan Creek	1000	**1452**	2100
Gowrie Creek	350	**488**	660
Mistake Creek	640	**3022**	800
Belyando River (East Branch)	310	**443**	630
Belyando River (Anabranch)	2600	**3727**	5400
Ogenbeena Creek (Lower Crossing)	550	**799**	1200
Ogenbeena Creek	550	**791**	1200
Combined branches of Belyando River and Ogenbeena Creek	2600	**3400**	5500
North Creek	370	**522**	740
Eight Mile Creek	230	**338**	530

Weather Systems

The summer rainfall maxima arise from prolonged eastward travelling monsoon depressions and intense short-term contributions from predominantly westward travelling tropical cyclones. According to Sturman and Tapper (2006), Australian tropical cyclones commonly originate in the Gulf of Carpentaria and in the Coral Sea between 9-19^o south.

An average of ten tropical cyclones per year develop over Australian waters, of which six cross the coast, mostly over north-western Australia and northeast Queensland. According to Watkins (2011), the frequency of cyclones in eastern Queensland is significantly correlated to the fluctuations in the El Niño-Southern Oscillation (ENSO), which is driven by variability on sea surface temperatures in the Pacific Ocean. A strong La Nina phase of the ENSO (cooler sea surface temperatures off eastern Australia) saw four tropical cyclones crossing Queensland over the 2010/11 summer including Cyclone Yasi on 2 February 2011.

Rainfall associated with monsoons and tropical cyclones in North Queensland is often of extreme intensity and while as much as 1,000 millimetres can fall in a few days at the coast, depths of 200 to 300 mm are more common inland as was evidenced during Cyclone Helen (8 January to 19 January 2008).

Although the Belyando River catchment appeared to miss the rainfalls of comparable depth over the summer of 2010/11, relatively high totals were still recorded including 92.1 mm at Moranbah and 196 mm at Barcaldine over the period 20 December to 27 December 2010 (BOM 2011).

The lower winter rainfalls typically experienced in the region coincide with the stalling of large stable anticyclones over central Australia that cause cool dry west to southwesterly airflow to predominate over Queensland. Rainfall in this season is associated with short southerly fronts originating in the southern oceans that affect the southern and eastern coasts of Australia.

Catchment Morphology

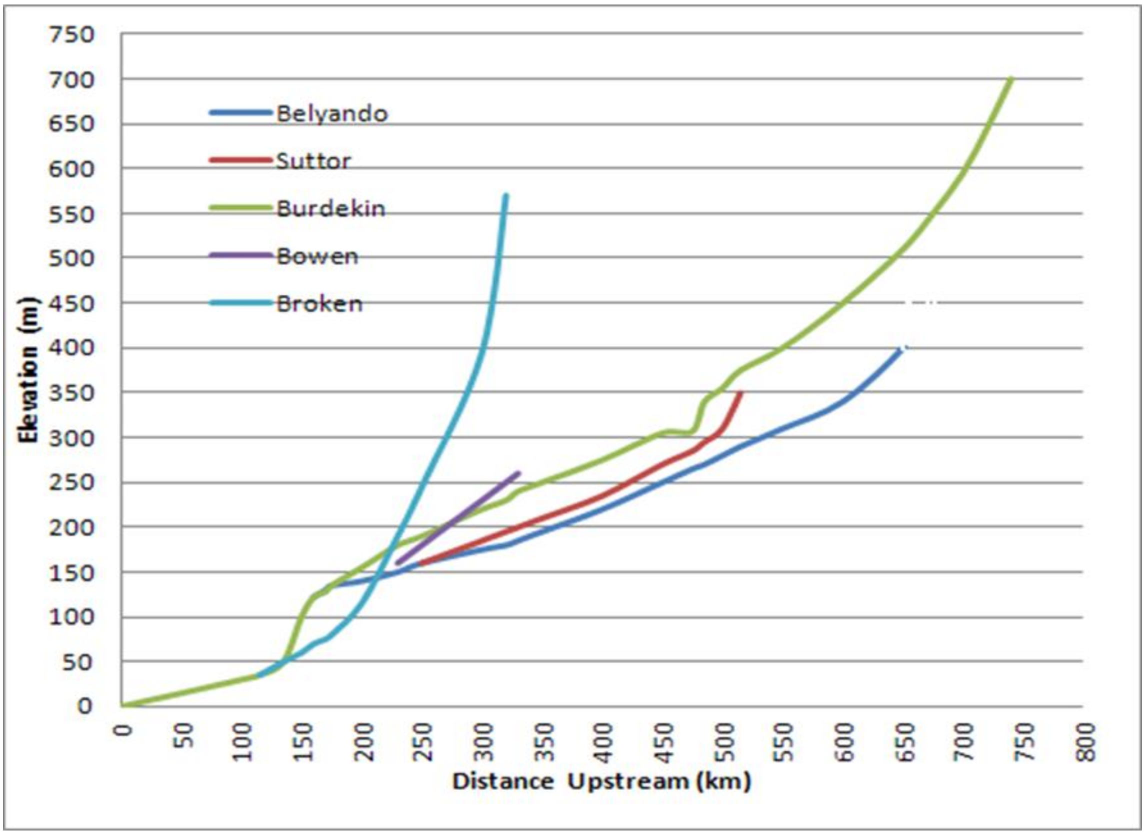
There is little significant topography along the lengths of the Belyando and Suttor rivers which extend more than 300 km. Both rivers occupy a long eroded plain which slopes from south to north with some uplands and minor isolated hills rising no more than a further 200 m higher than the average elevation of the plain. Elevation within the Suttor and Belyando catchments ranges from approximately 150 m AHD to 400 m AHD, as shown in Figure 6-9. Channel slope is a measure of the overall change in ground level along the length of a river, and influences flow and geomorphological characteristics. As shown by Figure 6-9 the channel slope of the Belyando River and Suttor River is similar to the Burdekin River but shallower than the other two Burdekin River tributaries.

Average channel slopes for watercourses in the vicinity of the Project (Rail) are as follows:

- 1 in 1,750 for the Belyando River
- 1 in 1,650 for Mistake Creek
- 1 in 1,400 for Logan Creek
- 1 in 375 for Grosvenor Creek

The long flat catchments of the three Burdekin Catchment waterways (Belyando River, Mistake Creek and Logan Creek) with their shallow channel gradients means that even when peak discharges are high the flow velocities are relatively slow. Flood waters therefore take a long time to travel through the catchment and prolong the duration of flooding. By contrast, flow velocities are higher on Logan Creek and Grosvenor Creek resulting in relatively shorter flood durations within their catchments.

Figure 6-9 Burdekin River Tributaries – Channel Slope



Source: after Pusey and Arthington (1996).

Channel Morphology

Within the study area, all of the rivers and indeed most of their tributaries have small, incised low flow channels. During episodic high flow events, flows exceed the low flow channels and inundate the flood plain. There is no braiding of channels but during flood conditions floodwaters from adjacent streams may join across the adjacent floodplain due to the flat topography between channels.

Soil

Soils within the study area are dominated by vertosols (cracking clays). For the majority of the year these soils shrink, opening deep cracks which can be as much as a metre deep. During the wet season, the soils swell to close the cracks and allow water to collect on the surface in the characteristic gilgai pattern. This pattern is characterised by small mounds and depressions in the soil. At this time, soil infiltration rates decline to near zero.

Substantial rainfall is thus absorbed and ponded before runoff and stream flow commences (Mckenzie *et al*, 2004). This initial ponding, and hence restriction of flow within the catchment, explains the nature of the Belyando/Suttor sub-catchment contribution to total flows within the Burdekin River.

Historic Floods

Historical flood data is shown in Figure 6-10 for the Gregory Developmental Road gauge (no data available between 1972 to 1976 or 2006 to 2010). Flooding on the Belyando River mirrors the frequency of summer monsoonal and cyclonic rain events. The severity of flooding is presented in Figure 6-11. The severity of flooding is likely to depend upon both the extent of any soil cracking as well as the volume of rainfall.

Figure 6-10 Flood Frequency on the Belyando River at Gregory Developmental Road Gauge (1949-2006)

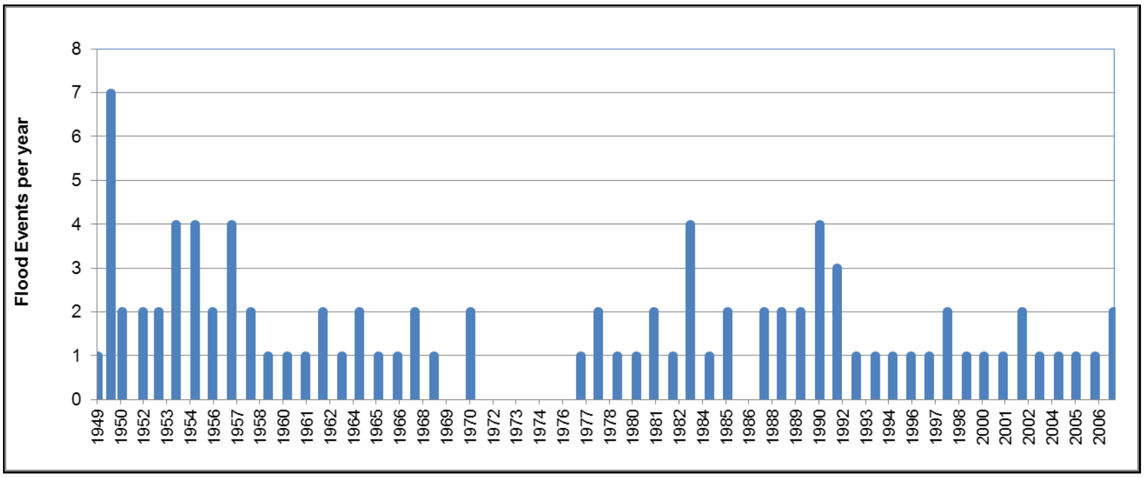
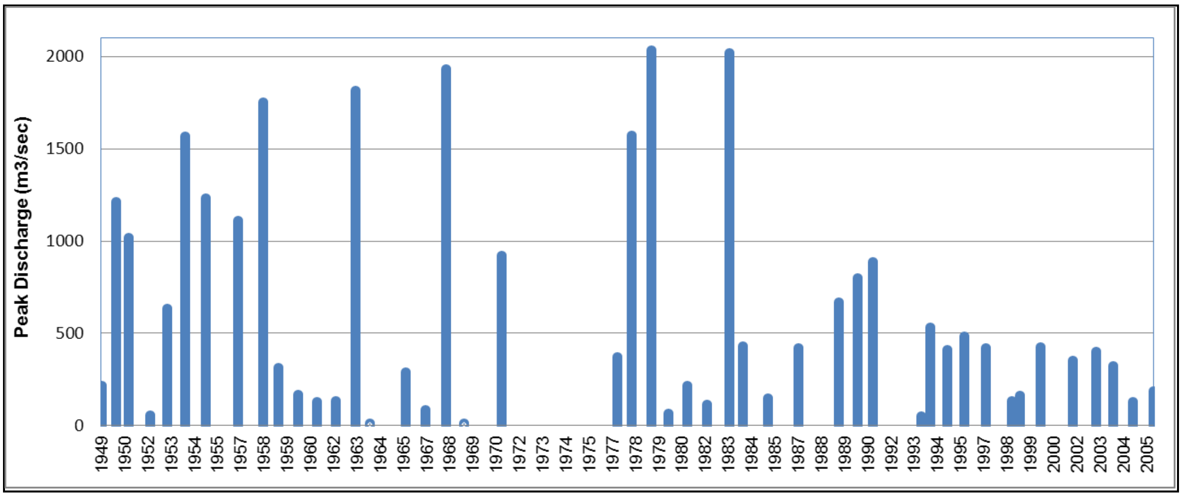


Figure 6-11 Annual Maximum Flood recorded on the Belyando River at the Gregory Developmental Road Gauge



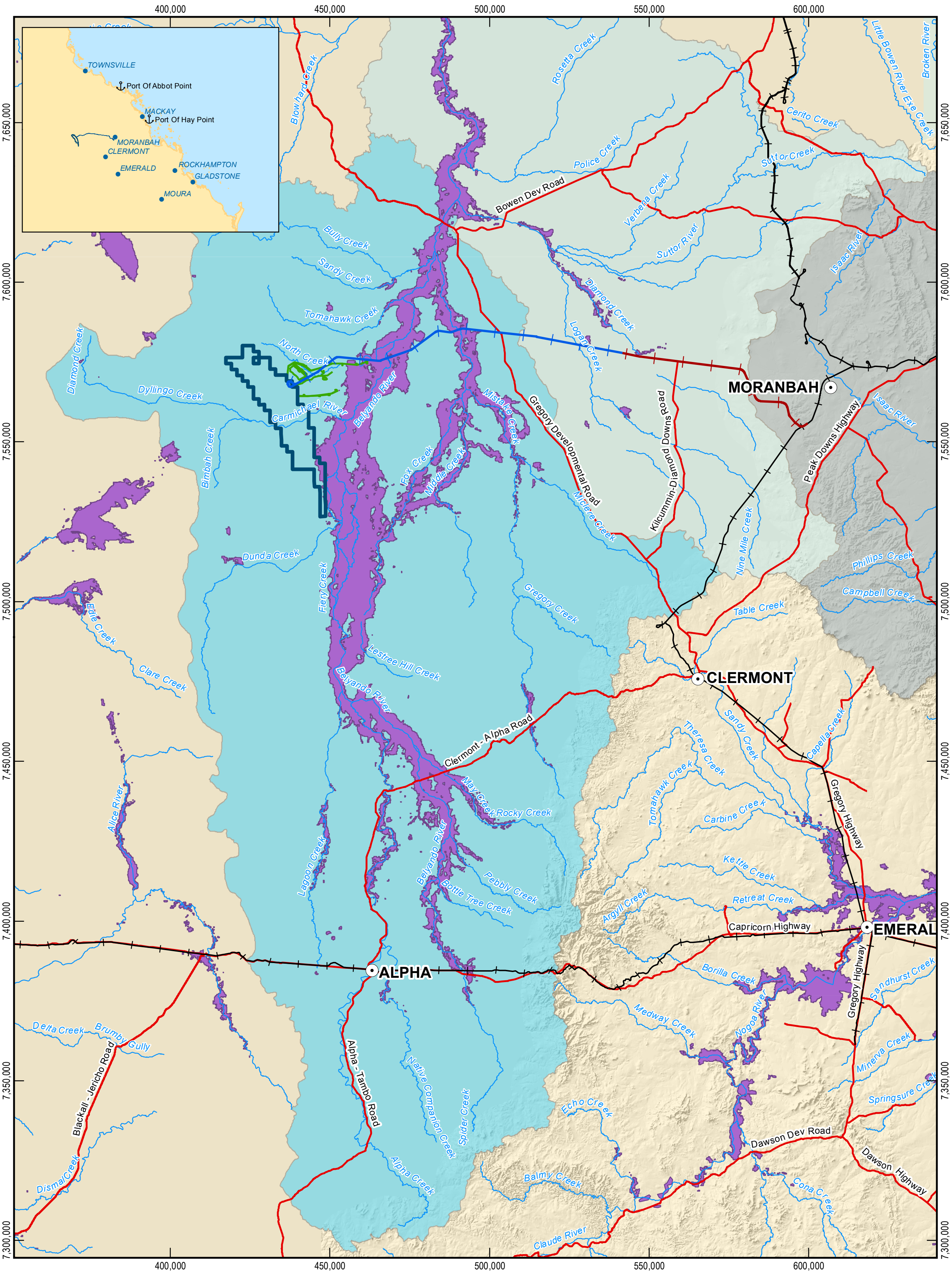
There have been two recent cyclones that have resulted in flood events in the study area namely Cyclone Yasi in December 2010 and Cyclone Helen in January 2008. Although the majority of rainfall during Cyclone Yasi fell to the north of the Belyando River catchment, river levels still reached a peak of 3.2 m on 27 December 2010 at the Gregory Developmental Road gauge. Concurrent BOM (Bureau station number: 035229) flood heights recorded at the Alpha gauge (70 km to the south of the Mine Site and 140 km to the east of Barcaldine) were the third highest on record and only one metre lower than the record peak of April 1990.

Cyclone Helen, which occurred between 8 January and 19 January 2008, produced 162 mm of rain at the Alpha rain gauge on 17 January 2008. This is the highest volume recorded and occurred within a six day total of 225 mm.

Flood frequency analysis shows that the 9.9 m recorded at Gregory Developmental Road was a 1 in 100 year event. Following the initial peak of this flood, flooding remained for more than two weeks. The lateral extent of this flooding is shown in Figure 6-12. During this event, 380,000 hectares were inundated. This included 59 properties. At Bygana Station 60 km upstream of Project (Rail) corridor on the Belyando River, 50 per cent of the property remained inundated for 32 days after the cessation of rain. Plate 6-6 shows the extent of the flooding at another Station, Laglan Station, located another 30 km upstream of Bygana Station.

Plate 6-6 Cyclone Helen (January 2008) - Flooding of the Belyando River at Laglan Station

Source: Isaac Regional Council, 2008



LEGEND

- Town
- State Road
- Other Rail Network
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Watercourse
- Cyclone Helen Flood Extent (2008)

River Basins

- Belyando River
- Suttor River
- Isaac River

Based on or contains data provided by the State of QLD (DERM) [2010]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:1,700,000 (at A4)

0 10 20 30 40 50

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

Cyclone Helen Flood Extent
Belyando River 20 Jan 2008

Job Number	41-25215
Revision	C
Date	11-09-2012

Figure: 6-12

G:\41\25215\GIS\Maps\MXD\500_SurfaceWater\41-25215_507_rev_c.mxd Level 4, 201 Charlotte St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: Dartmouth Flood Observatory: Cyclone Helen Flood Extent (2008); DERM: River Basin (2009), State Road (2010); DME: EPC1690 (2010), EPC1080 (2011); © Copyright Commonwealth of Australia - Geoscience Australia: Mainland, Locality, Rail, Watercourse (2007); Adani: Alignment Opt9 Rev3 (2012); Gassman/Hyder: Mine (Offsite) (2012). Created by: BW, CA

6.1.2.2 Description of Environmental Values

No environmental values or water quality objectives (WQOs) have been defined for the catchments of the Dry Tropics, including the Belyando River. It is understood that these will be available December 2013 (North Queensland Dry Tropics, 2011b). However, a list of draft environmental values has been proposed for the Belyando and Suttor Rivers by Greiner and Hall (2006). According to this study, the relevant environmental values for the Belyando River and Suttor River are described in terms of the following:

- Stock watering and farm supply/use
- Aquatic ecosystems
- Other values (Floodplain)

These are typical environmental values applied to surface water resources.

Grosvenor Creek is located within the Isaac Western Upland Tributaries sub-catchment for the setting of scheduled environmental values under the EPP (Water) for the Fitzroy River (DERM, 2011a). Of those values listed, the environmental values of relevance to the Project (Rail) are the same as those listed for the Belyando and Suttor River i.e. stock watering, farm supply/use and aquatic ecosystems.

Stock Watering and Farm Use

Data supplied by DERM lists 26 licenses to take surface water, either involving a diversion or extraction from a stream in the Belyando River catchment that includes various impoundments, direct pumped takes and irrigation for domestic supply, stock water and crop irrigation. There are no water licences issued on any of the properties intersected by the proposed Project (Rail), nevertheless there are an unknown number of unregulated takes constructed by local farmers to take advantage of the wet season surplus and any base flow. It is estimated by the Burdekin Dry Tropics Board (2005) that around 6,400 ha of cotton and grain crops are irrigated in the Belyando River catchment with about half of this area being located in the Mistake Creek sub-catchment. This irrigated land tends to be located in alluvial plains adjacent to the main stems of the river or its larger tributaries.

Within the Mistake Creek sub-catchment, farmland under irrigation most commonly produces cotton. Forage, maize, cereal crop and pasture (including lucerne) are currently the most commonly irrigated crops. While there is some pressure to expand irrigated agriculture, financial constraints within the farming industry may inhibit such development (BDTNRMP, 2005).

Aquatic Ecosystems

The Mistake Creek sub-catchment contains two areas that have been identified as containing High Ecological Value (HEV) waters (NQ Dry Tropics, 2011b). In particular, these waters correspond to: (i) Nairana National Park in the south of the sub-catchment; and (ii) Narrien Range National Park in the south-west of the sub-catchment. Spring-fed creeks are thought to originate in the Narrien Range and provide a very important source of water in an otherwise dry landscape. These areas are in excess of 160 km south-west of the Project (Rail).

The aquatic ecosystem values of Logan Creek and the remaining other parts of the Belyando/Suttor Rivers sub-catchment are considered to be Slightly to Moderately disturbed (SMD). This reduced value is a consequence of the cattle grazing. The extent of this disturbance was revealed by a vegetation assessment conducted by Kinsey-Henderson, *et al* (2007) which showed that as much as half of the entire Belyando River/ Suttor River sub-catchment has less than 50 per cent ground cover.

The water and remnant riparian vegetation of Grosvenor Creek is recognised as habitat for native animals and plants. Aquatic habitat within Grosvenor Creek is considered to be Moderately disturbed. There are a total of 107 Wetland Protection Areas that occur within 50 km of the Project (Rail) vicinity, as further described in Volume 4, Appendix AA Rail Ecology Report.

Other Values (Floodplain)

The floodplains within the study area are generally used for grazing beef cattle. An exotic grass species *Cenhrus ciliaris* (buffel grass) is a common species of grazing land pasture in the dry tropics. A consequence of the flooding associated with Cyclone Helen in 2008 was the widespread die off of buffel grass, followed by a proliferation of the toxic pest herb *Parthenium hysterophorus* (parthenium) which poses a threat to grazing cattle. Land use and other infrastructure present within the Project (Rail) area are discussed further in Volume 3 Sections 4 and 11.

6.1.3 Potential Impacts and Mitigation Measures

6.1.3.1 Flood Hydrology and Hydraulics

Design Flood Flow Estimates

Design flows for the major waterway crossings were derived using flood frequency regression analysis applied to local or regional historic streamflow data. Flood estimates for the 2, 10, 50, 100 and 500 year ARI event were determined. Flood modelling proceeded with the 100 year ARI flood flows.

Flood flow estimates for the 12 major waterway crossings are presented in Table 6-5.

Table 6-5 Estimated Peak Flows for Major Waterways within the Project (Rail)

	Peak Flow m^3/sec		
Waterway	**50 yr ARI**	**100 yr ARI**	**500 yr ARI**
Grosvenor Creek	240	**341**	490
Diamond Creek	460	**682**	1100
Logan Creek	1000	**1452**	2100
Gowrie Creek	350	**488**	660
Mistake Creek	640	**3022**	800
Belyando River (East Branch)	310	**443**	630
Belyando River (Anabranch)	2600	**3727**	5400
Ogenbeena Creek (Lower Crossing)	550	**799**	1200
Ogenbeena Creek	550	**791**	1200
Combined branches of Belyando River and Ogenbeena Creek	2600	**3400**	5500
North Creek	370	**522**	740
Eight Mile Creek	230	**338**	530

The Rational Method was used to determine design flows for the 76 minor waterways crossings, in accordance with the recommendations set out in the Queensland Urban Drainage Manual (DNRW 2007), as appropriate. Runoff coefficients were estimated using methods provided in DNRW (2005). It was assumed that the soils have low permeability and that the vegetation is light to medium bush and grass cover. Table 6-6 summarises the results of the Rational Method flood estimates.

Table 6-6 Summary of Design Flows for Minor Waterways within the Project (Rail)

	Catchment Area (ha)	50 yr ARI Design Flow (m3/sec)	100 yr ARI Design Flow (m3/sec)
Minimum	0.11	4	4.7
Average	9	39	44
Maximum	110	300	336

Estimation of Existing Flood Levels and Span Lengths at Waterway Crossings

Modelling considered the results for three “total bridge span scenarios” for each of the major waterway crossings. Initially bridge length was estimated using simplified methods. These provisional estimates were loosely based on a flow velocity through the openings of 2 m/s and are presented in Table 6-7.

Table 6-7 Summary of Watercourse Crossing Structures and Span Lengths (100 yr ARI Design Flood)

Waterway Name	Rail Corridor Chainage (km)	Estimated Length of Span (m)	Crossing Type
Grosvenor Creek	18.5	180	Multi span bridge
Diamond Creek	62.7	450	Major drainage structure
Logan Creek	82.7	400	Multi span bridge
Unnamed	90.2		Major drainage structure
Gowrie Creek	113.5	300	Multi span bridge + Drainage structure
Mistake Creek	120.8	600	Multi span bridge + Drainage structure
East Branch - Belyando River	139.2	2000 (combined structure for Belyando and Ogenbeena)	Major drainage structure
Belyando River - Anabranch	149.0	2000 (combined structure for Belyando and Ogenbeena)	Multi span bridge + Drainage structure
Ogenbeena Creek	150.6	2000 (combined structure for Belyando	Multi span bridge + Drainage structure

Waterway Name	Rail Corridor Chainage (km)	Estimated Length of Span (m)	Crossing Type
(Lower Crossing)		and Ogenbeena)	
Ogenbeena Creek	153.0	2000 (combined structure for Belyando and Ogenbeena)	Multi span bridge + Drainage structure
North Creek	170.4	300	Multi span bridge + Drainage structure
Eight Mile Creek	176.2	300	Multi span bridge + Drainage structure
5 minor crossings	-	100 to 250	Drainage structure
45 minor crossings	-	10 to 100	Drainage structure
15 minor crossings	-	<10	Drainage structure

Afflux Modelling

Hydraulic modelling of the 100 year ARI storm event using a 2-dimensional model was conducted for pre- and post- development conditions at the Belyando River and Mistake Creek crossings to determine the peak afflux (the maximum change in flood level compared to existing) of three bridge length scenarios.

The results for the pre-development conditions were transposed onto a LIDAR plot and calibrated against the satellite images of the historic floods. The modelled extent of the inundation in the Belyando River and Mistake Creek compared well with the 2008 Cyclone Helen inundation which was a 100 year ARI storm event. Table 6-8 and Table 6-9 show the modelled afflux results for the Belyando River and Mistake Creek, and Grosvenor Creek, Diamond Creek, Gowrie Creek and North Creek, respectively. Results are presented at three distances upstream of the railway, namely 0.5 km, 1 km and 2 km.

Further afflux modelling of the other major waterway crossings will be required as part of the engineering design process to determine the appropriate span lengths over those waterways and to determine the effect that any bridge configuration has on flood duration.

Table 6-8 Modelled Afflux for Crossings of the Belyando River and Mistake Creek.

			Modelled Afflux (m)		
	Span Length	Peak Afflux (m)	0.5 km upstream	1.0 km upstream	2 km upstream
Belyando River	6000 m	0.23 m	0.12	0.10	0.03
	2000 m	0.37 m	0.35	0.29	0.12
	800 m	1.95 m	0.71	0.61	0.33
Mistake Creek	4000 m	0.14 m	0.04	0.03	0.02

	1500 m	0.15 m	0.07	0.05	0.04
	800 m	0.28 m	0.20	0.13	0.09

Source: Golder Associates (2011).

Note that all proposed span lengths and resulting modelled values are obtained from Golder Associates (2011) and have not been adjusted for the EIS.

Table 6-9 Modelled Afflux for Crossings of Grosvenor Creek, Diamond Creek, Gowrie Creek and North Creek

		Modelled Afflux (m)			
	Span Length	Peak Afflux (m)	0.2 km upstream	0.5 km upstream	1 km upstream
Grosvenor Creek	240 m	0.36	0.04	<0.01	<0.01
	120 m	0.43	0.11	<0.01	<0.01
	60 m	1.00	0.54	<0.03	<0.01
Diamond Creek	680 m	0.23	0.23	0.26	0.19
	340 m	0.44	0.50	0.47	0.34
	200 m	0.60	0.79	0.70	0.52
Gowrie Creek	250 m	0.14	0.22	0.30	0.18
	125 m	0.34	0.31	0.34	0.20
	65 m	0.65	0.56	0.48	0.25
North Creek	520 m	0.11	0.08	0.01	<0.01
	260 m	0.16	0.10	0.10	<0.10
	130 m	0.47	0.42	0.23	<0.01
Eight Mile Creek	340 m	0.50	0.14	0.10	<0.01
	170 m	0.10	0.21	0.13	<0.01
	85 m	0.17	0.31	0.18	<0.01

Source: Golder Associates (2011).

Note that all proposed span lengths and resulting modelled values are obtained from Golder Associates (2011) and have not been adjusted for the EIS.

In general, there is no defined acceptance criterion for afflux caused by railways that applies uniformly to all projects. Achieving a zero afflux outcome is impractical and, normally, the final result is a compromise between minimising the effects of afflux (and flooding) and cost. It is considered that this is an iterative process that continues through the next design phase of the Project (Rail) until potential and predicted impacts associated with flooding are considered acceptable to stakeholders as well as achievable in terms of costs and engineering. The following observations may be useful to that decision making process:

- Longer bridges with less afflux cost more, but also provide some benefits in the form of lower flood levels (which influence the elevation of the railway), and slower flow velocities through the bridges and hence a lower risk of scour at bridge abutments.
- In areas where land values are high (e.g., industrial, commercial and residential property, intensive horticulture), and / or where there are many flood vulnerable assets such as sealed roads, lower levels of afflux are sought.
- In areas where land values are lower, and where the flood affected assets are sparse and of lower value (e.g. broad acre dry land farming, limited unsealed roads that are lightly trafficked), and where the lateral gradients are generally steeper (implying modest additional flooding area for a given rise in flood level) higher values of afflux may be appropriate.
- For a given floodplain value, where the duration of flooding is moderately long (say 12 hours to 3 days), and where the lateral slope of the floodplain is generally flatter, acceptable afflux values will be generally smaller, and vice versa.

Further investigations, including detailed identification and consideration of all afflux affected property and asset owners, is currently being undertaken as part of the engineering design and will progress as the detailed design progresses in order to determine afflux levels appropriately.

The levels shown in Table 6-10 have been adopted as preliminary allowable afflux levels for the base engineering design. These levels are based on what is considered to be current industry practice for this type of infrastructure project in the region however discussions will need to be held with stakeholders as part of the design development process to ascertain final limits.

Table 6-10 Preliminary Afflux Levels Adopted for Base Engineering Design

	Afflux Limit (m)
Critical Infrastructure	0.2 maximum
Housing Areas	0.1 maximum
Other Areas	Limited to 0.3 where practicable
Non-critical infrastructure / housing or uninhabited areas	0.5 maximum

A hydrological/hydraulic report will be prepared to identify drainage structure dimension requirements based on the proposed design basis including afflux limitations, velocity limitation and stakeholder requirements in order that the construction of the railway and associated infrastructure has an acceptable effect on the hydrological behaviour of the associated region in its current state. The report will include the following as a minimum:

- Design criteria and methodology
- A qualitative and quantitative description of each crossing

- The catchment area at each crossing location
- Details of the watercourse for the mainstream and its tributaries
- Longitudinal slope of the main stream and average land slope of the catchment from the contours
- Extent of vegetation (forest, pasture, cultivated, barren, etc.)
- Probable changes that may occur in the catchment characteristics and flow velocity forecasts
- Information from the rainfall records of local or nearby rain gauges
- Other climatic conditions (like temperature, humidity, etc.)
- Changes in the course of the channel
- The nature of the material through which the channel flows (whether it consists of boulder, gravel, sand, clay or alluvium) to the extent possible using available geotechnical information
- Design Flood Levels at each crossing (based on railway levels of optimised alignment)
- Flood inundation mapping, velocity profiles, peak water level afflux levels, etc.
- Embankment protection options along the alignment
- Scour depth based on estimated flood in the vicinity of the proposed bridge to the extent possible using available geotechnical information
- Full description of bridges including relief and overflow structures
- Waterway area, span length and number of spans (to be agreed by structural engineer)
- Pier orientation with consideration to alignment design
- Identification of debris classification for adoption by structural engineer
- Cross-section near the structure and direction of the current during floods
- Longitudinal drainage requirements associated with cross drainage waterway areas
- Photographs of past floods, main channels and flood plains where available
- A detailed map showing flood patterns, location of proposed bridge, spill openings, if any and alignment of piers

The methodology to produce the hydrological/hydraulic report will include:

- Field inspections of all major creek systems
- Mapping of the location of all waterway crossings for the proposed rail alignment
- Calculation of the catchment areas for each crossing
- Estimation of the design flood peak discharges for each crossing
- A detailed hydraulic investigation to provide the required waterway area to the immunity criteria for each crossing
- Determination of prospective water crossing structures (bridge or drainage structure) in consultation with the rail and structural designers
- Detailed assessment of afflux at each crossing and outline of resulting effects on properties, structures and infrastructure (both pre-developed and post-developed)

- Proposed modelling scenarios will be 20 year ARI, 50 year ARI and 100 year ARI of the 12 major river crossings. The 2000 year ARI will also be modelled for bridge serviceability design requirements
- Protection design (including erosion control) subject to the availability of input data for each water crossing structure and any other relevant areas of the rail line as required.

6.1.3.2 Stock Watering and Farm Use

Potential Impact

It is not expected that the construction phase of the Project (Rail) will adversely impact on water quantity associated with stock watering and farm use. It is understood water required for the construction phase (for earthworks, dust suppression, concrete batching plants, potable water, etc.) will be imported to construction sites. Where water is required to be sourced from rivers and creeks appropriate permits and licenses will be obtained.

With respect to water quality, there are potential impacts to stock watering and farm use associated with the potential for contamination and increased turbidity (through sedimentation and additional total dissolved solids (TSS)). Raised sediment levels, cement residues and hydrocarbon spillages diminish the value of the water as a farm supply. Potable use of these water supplies would require increased treatment. Irrigation lines can become clogged and downstream farm dams can silt up, diminishing capacity of seasonal storage. Good water quality is essential for successful stock production. Poor quality water is less palatable to animals leading to poor health and impaired fertility.

If river and / or creek flows are temporarily impounded by the construction phase embankments, this can potentially reduce the supply of downstream stock water and / or irrigation supply. Sediment liberated by scouring can potentially have adverse water quality effects, which may adversely affect stock.

The potential impacts to stock watering and farm use are expected to be limited during the operational phase because it is not intended that the railway will permanently divert, abstract or take water from any of the rivers and creeks.

There are unlikely to be any adverse effects on stock water and irrigation due to afflux. Potential impacts in relation to farm road and stock routes are covered in Section 6.1.3.4 under Other Values (Floodplain).

A description of the flood modelling work undertaken by Golders Associates (2011), including the afflux (rise in flood level) results is presented in Section 6.1.3.

Mitigation Measure

Mitigation measures to address the potential deterioration in water quality comprise:

- A comprehensive suite of erosion and sediment control measures will be incorporated into the construction phase works (refer Volume 3 Section 13 Environmental Management Plan).
- Construction methodology allowing for construction within watercourses to be undertaken during the drier periods, as far as is practicable.

6.1.3.3 Aquatic Ecosystems

Potential Impact

Water quality monitoring was not undertaken for the Project (Rail) as no concentrated discharges will be made to the waterways that are crossed.

Corridor establishment activities, such as vegetation clearance, topsoil stripping and earthworks in the floodplain and bed and banks of the low flow channel, temporarily create areas of exposed earth, which potentially leads to a degradation of water quality, and hence potentially impacts upon the aquatic ecosystem in the downstream waterways after a rainfall event.

Other construction activities can also lead to erosion and hence a degradation of water quality, i.e. an increase in turbidity and TSS concentrations.

Other potential sources of water pollution are:

- Spillages of concrete and cement residue, which can originate from wash down of boxing and equipment used for in situ casting of waterway crossing components.
- Fuel and lubricants from site machinery. Refuelling and lubrication maintenance activity on site carries the greatest risk.

Undersized culverts in a construction phase causeway may increase the flow velocities of the watercourse. This can adversely affect the upstream migration of aquatic animals. If there is a blockage causing loss of flow, there is a risk of habitat damage. Scouring of the channel bed can cause loss of habitat and the displaced sediment can degrade water quality for animals and plants as described above.

Potential degradation of water quality during the construction phase may include elevated sediment loadings/turbidity leading to covered stable natural substrates and a reduction in habitat availability. Suspended sediments can clog fish and invertebrate gills, decrease light availability for aquatic plants and reduce visibility for fish.

Furthermore, localised high sediment contamination can become a barrier to migration of some species that then decline in abundance due to restriction in range or loss of seasonal habitat above the contaminated reach (ANZECC, 2000). Over time aquatic ecosystem values change from those accommodating a high biodiversity of species characteristic of clean water such as fish, to a low biodiversity environment of silt tolerant worms and invertebrates (Williamson, 1993). In addition to this, there can be a further loss of animals such as fish eating birds that were dependent on the cleaner water food sources.

Although most minor oil and fuel spillages are unlikely to affect the aquatic environment (Williamson, 1993), polynuclear aromatic hydrocarbons (PAHs), which are known to adversely affect aquatic sediment-feeding animals (ANZECC, 2000 and Williamson, 1993), are a constituent of oil and fuel spillages. While the PAHs are only a small fraction of total oil discharge, it may have an effect far in excess of the volume of its contribution (Williamson 1993). PAHs typically become bound to fine particulate matter, which can be ingested by aquatic animals.

The development and operation of construction camps and concrete batching plants may potentially affect surface water resources through the potential discharges of:

- Runoff from the construction camps, concrete batching plants and stockpiling areas is likely to contain elevated levels of sediment plus concrete residues and hydrocarbons from vehicle movements fuelling and maintenance. Unimpeded run on water or floods would become contaminated if allowed to flow through the sites. This constitutes a potential impact to the aquatic ecosystems.
- Stormwater from the roofs and hardstand associated with the construction camps runoff may contain significant quantities of sediment from the coming and going of work parties and vehicles. The stormwater runoff from the concrete batching plants may contain high levels of sediment that may

have significant lime content from cement dust, spilled concrete product and equipment wash down. Some hydrocarbon residues may also be present in this latter runoff.

- Lime is a major component of cement and concrete. Spillages dissolve easily in water and readily overwhelm the buffering capacity of any stream. Receiving water becomes alkaline (pH in the range 11 to 13), which kills fish and other aquatic life.

Mitigation Measures

A comprehensive suite of control measures will be incorporated into the construction phase works. Details of these include:

- Complete the crossing constructions in drier periods when most waterways are dry or have minimal flow, as far as possible.
- Minimise any runoff and sedimentation from the construction to waterways. Before commencement of earthworks, install perimeter catch drains to prevent upslope clean water runoff from entering the site and bunding and basins downslope to confine dirty water within the site. Design and manage the installation of such controls in accordance with IECA guidelines (IECA 2008).
- Minimise the area of vegetation disturbance and bare ground within the floodplain and conduct rehabilitation of disturbed ground progressively as soon as construction activities are complete in any area.
- Use bridges in preference to causeways as temporary building platforms/vehicle access as they involve less disturbance to the bed of the low flow channel.
- Do not permit stockpiling of soil in the bed of the low flow channel or floodplain.
- Do not permit spillages of concrete or wash down to enter water courses.
- Do not permit refuelling or servicing of vehicles and plant within the low flow channel. Clean up spills immediately and dispose of contaminated soil and clean-up materials off site at an appropriate facility.
- Develop a surface water monitoring program for the Belyando River in accordance with the Australian Guidelines for Water Quality Monitoring and Reporting (NWQMS 2000). Include TSS, turbidity and pH in this program.

In addition to erosion and sediment controls described above, mitigation measures that apply to the construction camps, concrete batching plants and hard stand area include:

- Locate construction camps and concrete batching plants away from creeks and waterways and preferentially, at least 0.5 m above the 100 year ARI flood level.
- Minimise the area of vegetation disturbance and bare ground within the floodplain and conduct rehabilitation of disturbed ground progressively as soon as construction activities are complete in any area.
- Discharge to ground all campsite stormwater runoff.
- Contain all runoff from concrete batching plants within the plant footprint and incorporate it and wash down water into the process water supply recycling. Prevent spillages of concrete and wash down water from entering waterways.

- Do not permit refuelling or servicing of vehicles and plant outside designated areas. Clean up spills immediately and dispose of contaminated soil and clean-up materials off site at an appropriate waste disposal facility.

Potential Impact

During operation, faster flow velocities at the railway crossings may lead to the following effects:

- Potential scouring of the river bed at crossings and immediately downstream due to faster flow velocities. Scour is exacerbated by turbulence at piles or the edges of rail embankments. Any scour leads to an increase in the silt load. Scour can cause holes to develop around the piles of bridges and immediately downstream of bridges and culverts.
- Increased difficulties for the upstream migration of fish and native animals through bridges and culverts.

Mitigation Measures

Mitigation measures to be implemented would include:

- Select generally longer bridge length scenarios, which will tend to limit the increase in flow velocity.
- Incorporate into the detailed design scour protection measures at all locations where analysis of the in-situ material and modelled flow velocities suggest the potential for scour. Erosion prevention measures include: rip-rap pads, wing walls on embankments, shotcrete, rip rap and / or gabion bed protection.
- Setting the invert of culverts below the ground surface.

6.1.3.4 Other Values (Floodplain)

Potential Impacts

The construction of temporary bridge/causeways over the channel as a construction platform, or for vehicular access, is a potential barrier to waterway flows. This could potentially cause flooding if there is insufficient hydraulic capacity to convey the flood flows, or the waterway becomes blocked by debris.

Mitigation Measures

Construction phase activities within major watercourses are as far as is possible, likely to be limited to the drier periods and the risk of additional flooding of the floodplains is considered low. However, the following specific mitigation measures are proposed:

- Complete construction in dry periods to minimise the risk of flood occurrence
- If a causeway is used provide sufficient hydraulic capacity to allow the conveyance of natural flows with minimal increase in velocity or afflux.
- Keep low flow channel and any culverts through site clear of debris.
- Conduct a detailed scour assessment to determine the appropriate depth of cover or scour protection measures to be adopted at each crossing. The detail design of the creek crossings will incorporate works and measures to minimise the following:
  - The risk of damage to the creek banks during construction
  - Change in the sediment transport regime at the crossing

– The risk of creek bank collapse or erosion during flood events

Potential Impacts

It is noted that the Project (Rail) concept design considers a range of crossing openings (i.e. bridge lengths and/or culvert widths). As such, the magnitude of the afflux is not defined at this stage. It is considered however that while afflux will be unavoidable, predicted flood levels upstream of bridges and drainage structures will be assessed throughout the detailed design phase such that no existing buildings, structures or other infrastructure will be adversely affected by increased flood levels as a result of the Project (Rail). Further to this preliminary afflux, limits have been adopted for the base engineering design which is currently being completed.

Potential impacts arising as a result of afflux are described below:

- Graziers currently lose the use of grazing land for the duration of flooding. An increased afflux has the potential to lead to greater areas of lost grazing land being inundated during floods. Inundation may also present for longer. According to DEEDI (2010), five days full of inundation is sufficient to kill the exotic buffel grass. Buffel grass is a common species of grazing land pasture in the Dry Tropics. The estimated average flood duration only exceeds five days for the Belyando River so incremental loss of buffel grass is unlikely to be of concern.
- Widespread grass death caused by weeks of flooding in the Belyando River associated with Cyclone Helen in January 2008 (an estimated 100 ARI event) resulted in an invasion of the toxic pest herb parthenium. An increase in flood extent and duration will potentially increase the area at risk of invasion by parthenium.
- Infrastructure assets in the floodplain, such as roads and farm tracks, will most likely be affected by the increased depth and duration of flooding.
- In areas where land values are lower, and where the flood affected assets are sparse and of lower value (e.g. broad acre dry land farming, limited unsealed roads that are lightly trafficked), and where the lateral gradients are generally steeper (implying modest additional flooding for a given rise in flood level), higher values of afflux may be appropriate.
- For a given floodplain “value”, where the duration of flooding is moderately long (say 12 hours to 3 days), and where the lateral slope of the floodplain is generally flatter, acceptable afflux values will be generally smaller, and vice versa.

Mitigation Measures

Mitigation measures associated with potential impacts to the floodplain as a result of the operation of the Project (Rail) will consider the following:

- Continued and iterative flood modelling through detailed design will refine afflux values in association with refinement in bridge and culvert crossing design. The scope and methodology of this work is outlined in Section 6.1.3
- Further work will be undertaken to catalogue the impacts of afflux on the floodplain, properties, assets and infrastructure
- Ongoing consultation with affected landowners and asset owners to assist in further refinement of the project design and ongoing flood modelling

- Selectively raising farm roads, by placing fill material, will reduce the impact on farm roads subject to negotiations and agreements with landholders and asset owners
- Consideration of compensation to flood affected land and asset owners in relation to excessive afflux

6.1.4 Summary

The Project (Rail) traverses the western most extremity of the Fitzroy River catchment across the broad, flat Suttor and Belyando River sub-catchments of the Burdekin River to a looped terminus at Labona on the eastern side of the proposed Project (Mine).

The hydrological regime is characterised by a prolonged dry autumn, winter and spring with little or no flow and summers where large tropical rain systems and cyclones flood local creeks and rivers for weeks at a time across wide floodplains. Highly dispersive cracking clay soils in a recently deforested gilgai landscape absorb large amounts of rain before discharging highly turbid, sediment-charged runoff to the rivers and creeks.

Local land use is predominantly cattle grazing. Ecologically, the waterways are described as slight to moderately disturbed due to the loss of much riparian vegetation as a result of the land use.

Twelve major waterways and 76 minor waterways and overland flow paths are crossed by the railway. The major waterway crossings will comprise either a bridge or culvert or a combination of both depending on the predicted depth of the water. Crossings of the smaller waterways will also consist of either a bridge or culvert or a combination of both but will predominantly be culvert only.

Identified environmental values for the affected waterways include:

- Aquatic ecosystems
- Stock watering and farm use
- Other values (floodplain)

The main construction phase surface water effects on these values relate to the potential disturbance of watercourses for the crossings, which manifest as:

- Change and / or interruption to flows, particularly a rise in flood levels upstream of the railway (afflux)
- Degradation of water quality
- Barriers to movement of aquatic fauna

The main surface water environmental effects of railway during the operating (permanent) phase on the environmental values derive from long term changes to surface water flows and include:

- Increased depth and extent of flooding
- Possibly longer inundation periods
- Possibly altered drainage patterns
- Scouring and geomorphological changes

Conceptual flood modelling presents results for three bridge length scenarios as a preliminary step based on concept level design. Individual crossing structures will require further modelling as detailed design for the Project (Rail) progresses to determine exact afflux impacts and limits can be determined.

The principal effect of the operating railway crossings is likely to be changes to the flows of waterways and overland flow paths, and particularly the rise in flood levels (afflux). Further modelling of refined waterway crossings is being undertaken.

6.2 Hydrogeology

6.2.1 Introduction

6.2.1.1 Overview

An assessment of the potential impacts on groundwater resources for the Project (Rail) has been undertaken (Refer to Volume 4 Appendix AC Rail Hydrogeology Report). Volume 4 Appendix D Project Approvals and Assessment provides further detail on legislative requirements.

6.2.1.2 Legislation, Policies and Guidelines

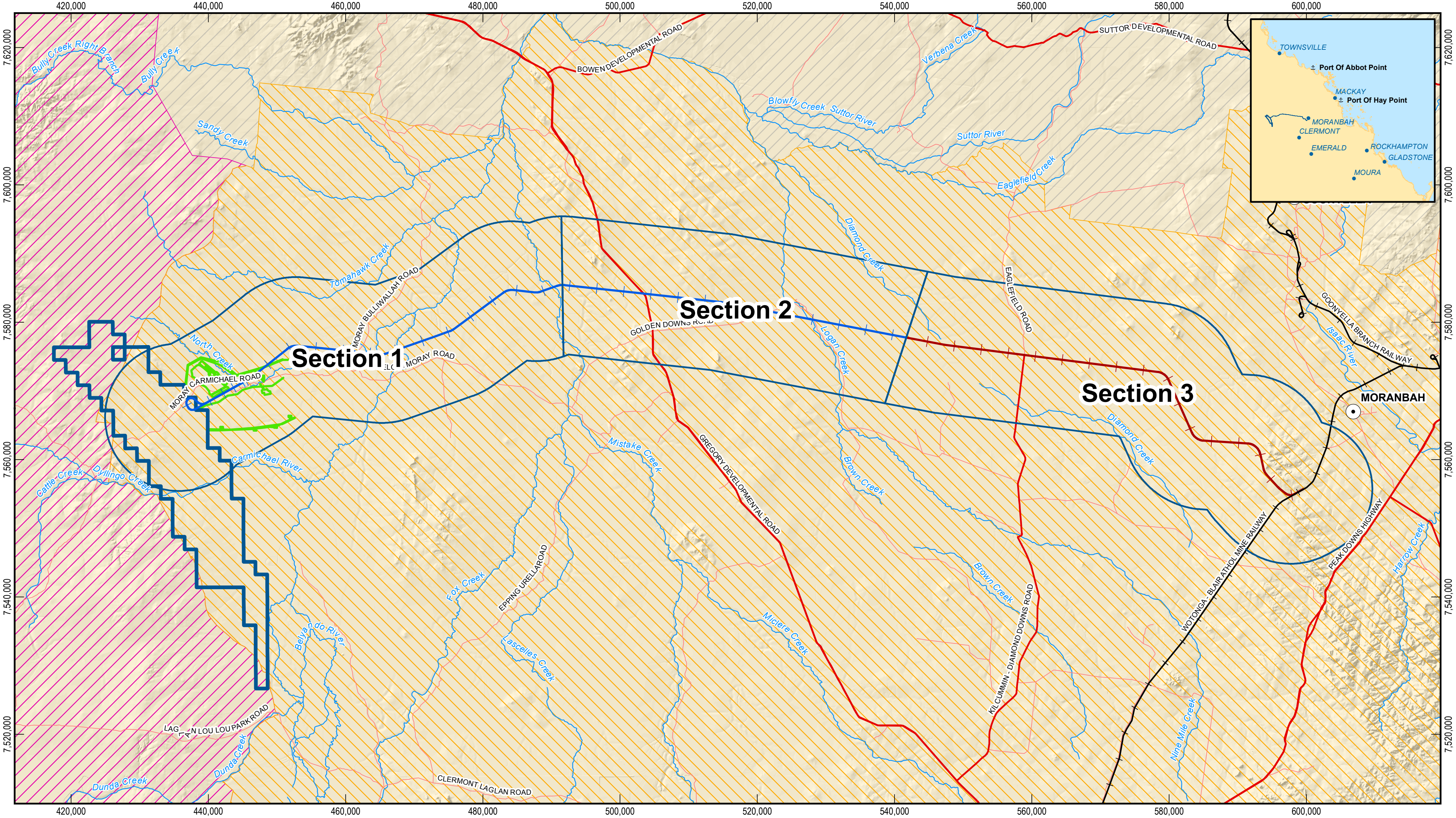
The following legislation, policies and guidelines are relevant to the assessment of impacts of the Project (Rail) on groundwater resources.

- *Water Act 2000*
- *Environmental Protection Act 1994* (EP Act)
- Environmental Protection (Water) Policy 2009 (EPP (Water))
- ANZECC (2000) Water quality guidelines
- Queensland Water Quality Guidelines (DERM, 2009)
- Water Resource (Burdekin River Basin) Plan 2007
- Water Resources (Fitzroy Basin) Plan 2011
- Burdekin Dry Tropics Natural Resource Management Plan (2005–2010)
- Social, Economic, Cultural and Environmental Values of Streams and Wetlands in the Burdekin Dry Tropics Region (Greiner and Hall, 2006)
- Environmental Protection (Water) Policy 2009 Isaac River Sub-basin Environmental Values and Water Quality Objectives Basin (DERM, 2011a)
- National Land and Water Resource Audit 2000-2002 as part of the Australian Water Resources Assessment 2000 (ANRA 2009)

6.2.1.3 Approach and Methodology

To define the groundwater environmental values for the Project (Rail) a desktop assessment was undertaken. The Groundwater Assessment Area was defined by a 10 km buffer around the Project (Rail) and divided into three sections based on geological and hydrogeological characteristics and the availability of groundwater data (refer to Table 6-11 and Figure 6-13).

A separate study to investigate construction water supply options was undertaken by Hyder Consulting. The purpose the study was to identify suitable water supply sources for the Project (Rail), whilst minimising impacts on stakeholders and the environment.



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Other Rail Network
- Watercourse
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Study Corridor

Declared Sub-Artesian Areas

- Great Artesian Basin
- Highlands
- Non Artesian Area

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Carmichael Coal Mine and Rail Project

Regional Hydrogeology
Groundwater Management Areas

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Revision	C
Date	11-09-2012

Figure: 6-13

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Data source: DERM: DEM (2008),Declared Sub-Artesian Areas (2009); DME: EPC1690 (2011), EPC1080 (2010); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads, Watercourses (2007); Adani: Alignment Opt9 Rev3 (2012); GHD: Study Corridor (2012), Gassman/Hyder: Mine (Offsite) (2012). Created by: AJ, CA

Table 6-11 Project (Rail) Groundwater Assessment Area Sections

Section	Location Name	Geological Setting	Number of Registered Bores (10 km radius)
1	Carmichael Coal Mine to Mistake Creek	Floodplain alluvium and Tertiary sediments overlying Permian sedimentary bedrock	24
2	Mistake Creek to Diamond Creek	Outcropping units of metamorphic, igneous and sedimentary bedrock with overlying colluvial and alluvial deposits in low-lying areas	10
3	Diamond Creek to Goonyella rail system tie in	Alluvium to the west and outcropping Tertiary / Permian sedimentary units to the east	9

6.2.2 Existing Environment

6.2.2.1 Existing Groundwater Resources

Bowen Unincorporated Area Groundwater Resources

The Project (Rail) falls entirely within the Highlands Sub-artesian Groundwater Management Area (refer to Figure 6-13) and is not expected to impact upon the Great Artesian Basin (GAB). The proposed Project (Rail) traverses the Bowen Unincorporated Area (UA), which is bound to the west by the Great Artesian Basin GMU and the Isaac River GMU to the north-west (Figure 6-14).

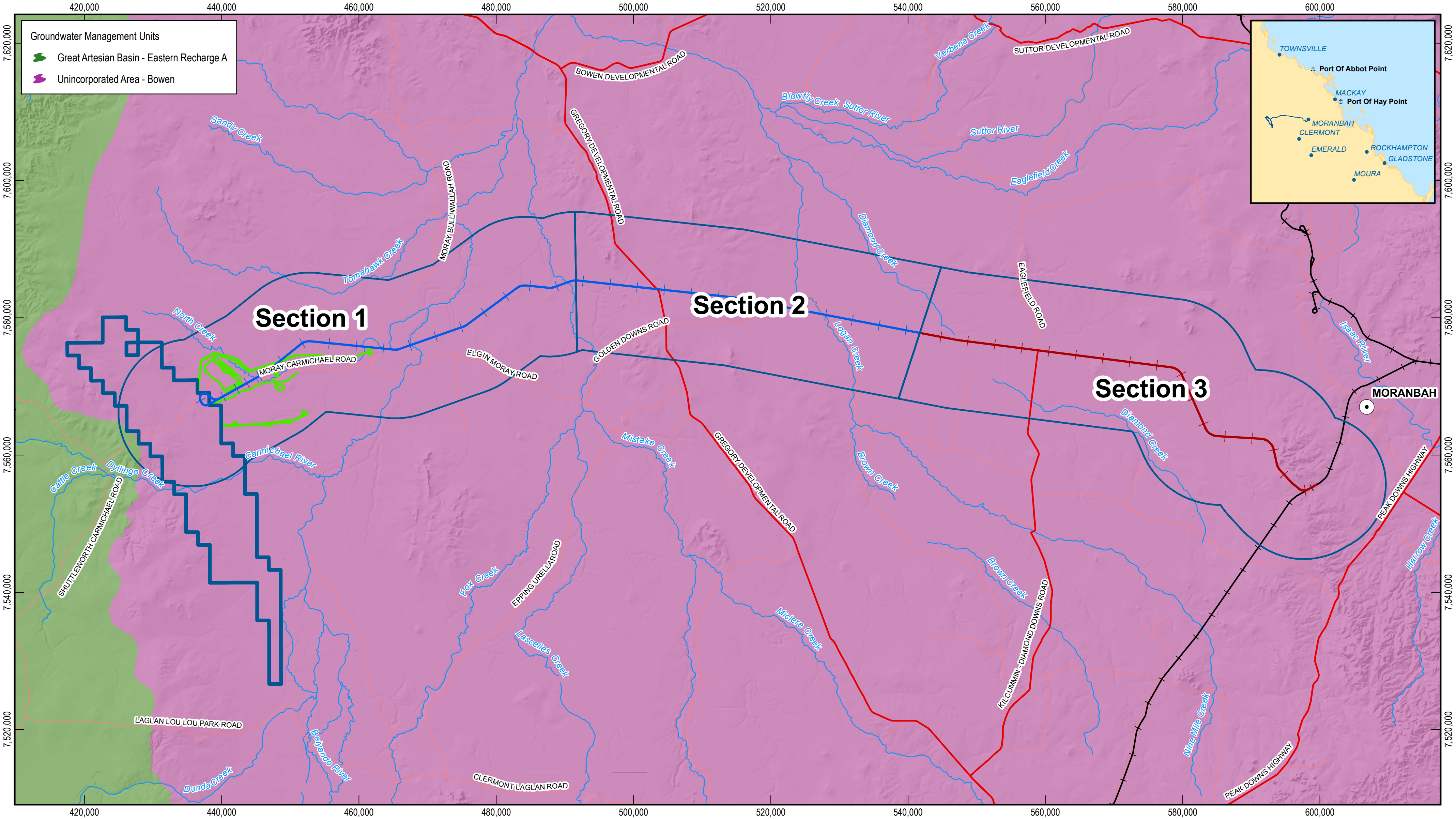
The Bowen UA consists of several groundwater resources that are being utilised to much less than their full potential (ANRA, 2009). The major aquifers within the Bowen UA are Quaternary-aged alluvium, the sand and gravel horizons of the Tertiary-aged sediments and the Tertiary-aged basalts. The achievable bore yields are generally below 5 L/sec and consequently most groundwater development would be limited to stock and domestic supplies.

The extent of groundwater resources within the Bowen UA is not well studied and limited information within the Project (Rail) area is available. A sustainable yield has not been assessed for the entire Bowen UA, however, preliminary estimates of the sustainable yield were calculated for the Bowen UA sub-catchments of Mackenzie, Nogoa, Comet and Isaac resulting in a total for all sub-catchments of 260,000 ML/yr, which was applied to the entire UA (ANRA, 2009).

Groundwater abstraction at the time of the audit was well under the calculated total sustainable yield. Predicted abstraction rates within the Bowen UA for 2020 and 2050 of 15,000 ML/yr and 20,000 ML/yr, respectively, remain well below the sustainable yield of 260,000 ML/yr (ANRA, 2009). Groundwater abstraction for stock and domestic use are generally not recorded, however the amount of groundwater take is considered to be low overall. The Audit determined that major abstractions are for agricultural and mining activities. While currently underexploited, demand for groundwater is increasing with the expansion of the coal mining industry within the Bowen and Galilee Basin.

Current and Potential Users

Forty-three registered bores occur within a 10 km radius buffer of the Project (Rail) as shown in Figure 6-15. The reported facility roles (or bore type) are detailed in Table 6-12.



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Kilometres

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Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

LEGEND

- Town
- State Road
- Local Road
- Other Rail Network
- Watercourse
- Rail (West)
- Rail (East)
- Mine (Onsite)
- Mine (Offsite)
- Study Corridor

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

Groundwater Management Units

Job Number	41-25215
Revision	C
Date	11-09-2012

Figure: 6-14

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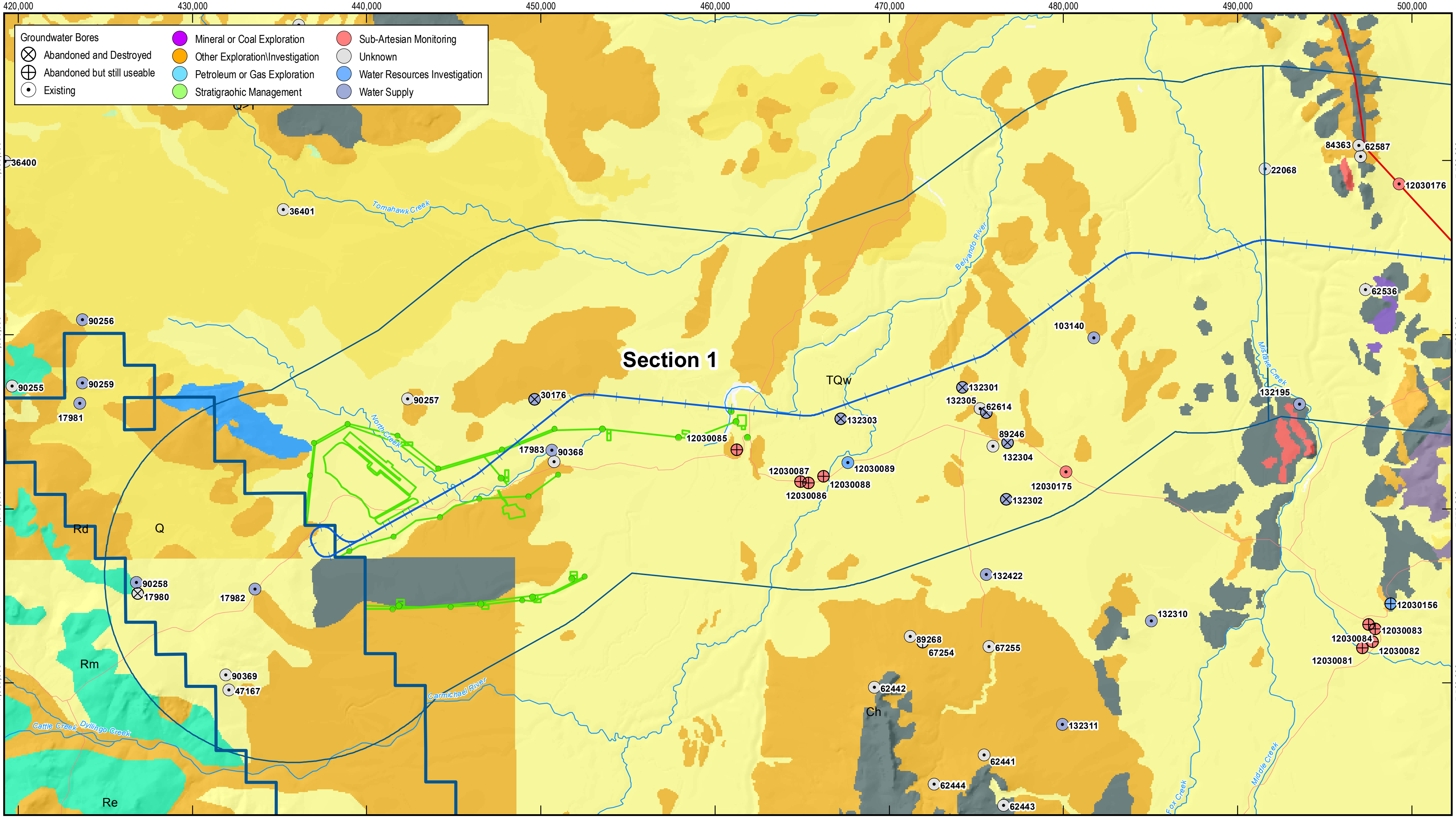
Data source: DERM: DEM (2008) Groundwater Management Units, Declared Sub-Artesian Areas (2009); DME: EPC1690 (2011), EPC1080 (2010); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads, Watercourses (2007); Adani: Alignment Opt9 Rev3 (SP1&2) (2012); Gassman/Hyder: Mine (Offsite) (2012); GHD: Study Corridor (2012). Created by: AJ, CA



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Existing Railway
- Watercourse
- Rail (West)
- Rail (East)
- Study Corridor
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

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Registered Groundwater Bores

Job Number	41-25215
Revision	C
Date	11-09-2012

Figure: 6-15
Sheet 1 of 4

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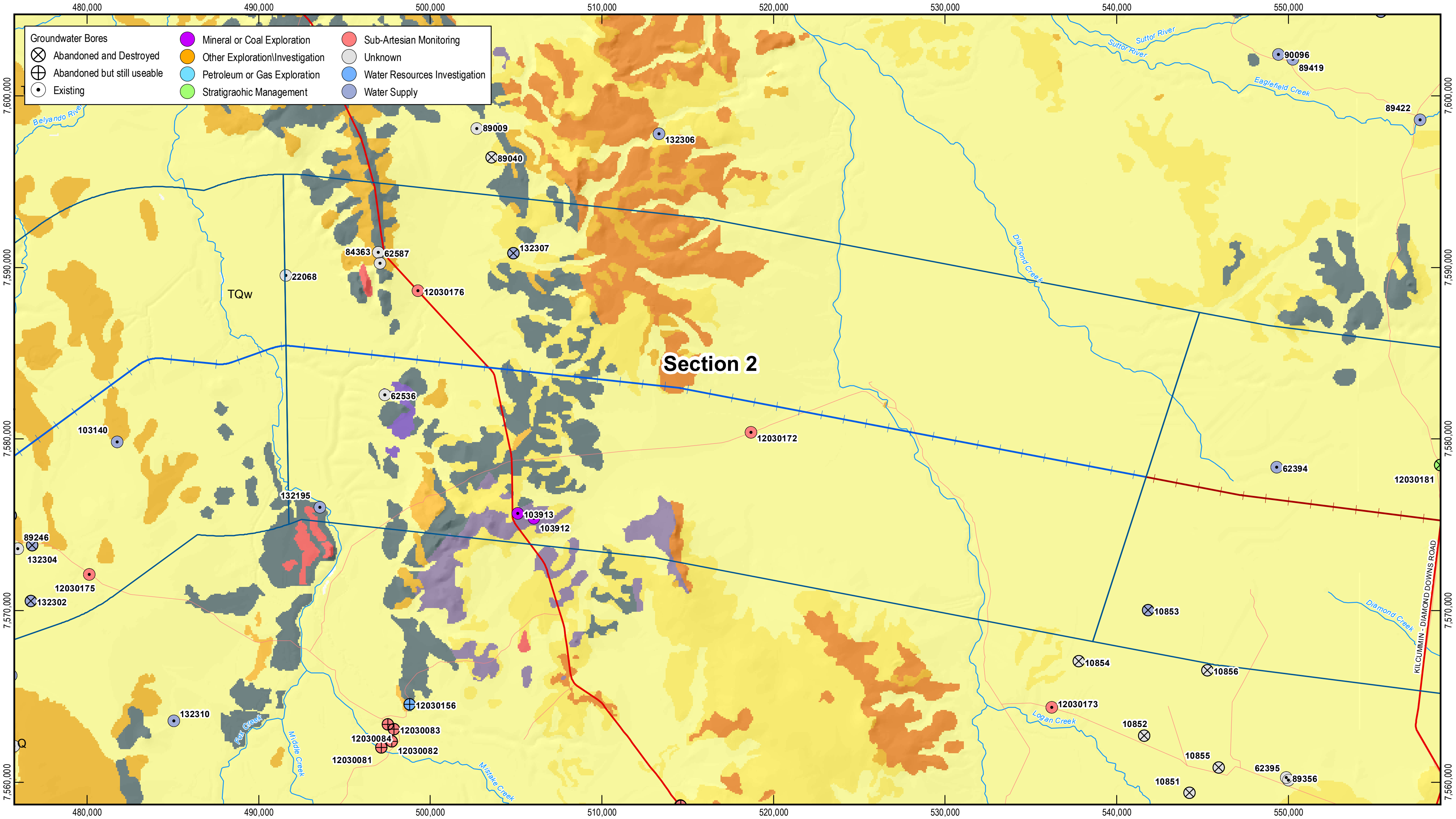
Data source: DERM: Groundwater Bores (2010); DME: EPC1690 (2011), EPC1080 (2010); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007), 100k Geology (2007), 250k Geology (2008); Adani: Alignment Opt9 Rev3 (SP1&2) (2012); Gassman/Hyder: Mine (Offsite); GHD: Study Corridor (2012). Created by: AJ, CA



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Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
- Existing Railway
- Watercourse
- Rail (West)
- Rail (East)
- Study Corridor
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

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Carmichael Coal Mine and Rail Project

Registered Groundwater Bores

Job Number	41-25215
Revision	C
Date	11-09-2012

Figure: 6-15
Sheet 2 of 4

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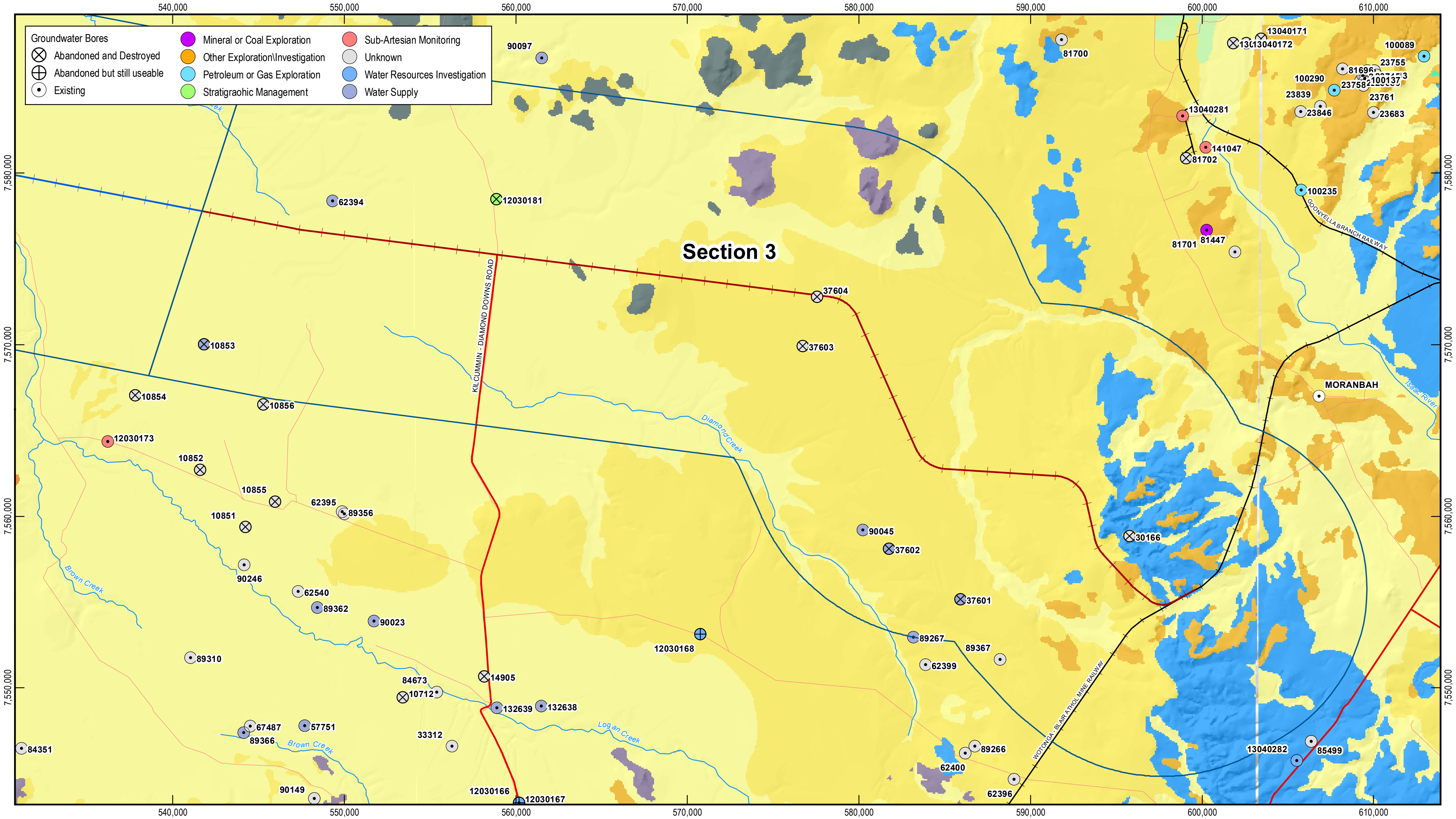
Data source: DERM: Groundwater Bores (2010); DME: EPC1690 (2011), EPC1080 (2010); © Commonwealth of Australia (Geoscience Australia): Localities, Railways, Roads (2007), 100k Geology (2007), 250k Geology (2008); Adani: Alignment Opt9 Rev3 (SP1&2) (2012); Gassman/Hyder: Mine (Offsite); GHD: Study Corridor (2012). Created by: AJ, CA



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0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Town
- State Road
- Local Road
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- Watercourse
- Rail (West)
- Rail (East)
- Study Corridor
- Mine (Onsite)
- Mine (Offsite)
- Mine (Offsite)

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Carmichael Coal Mine and Rail Project

Registered Groundwater Bores

Job Number	41-25215
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Figure: 6-15
Sheet 3 of 4

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- Qr>Pwj, QUATERNARY, Qr-8455>Rangal Coal Measures
- Qhh, HOLOCENE, Qhh-8454
- Qw, HOLOCENE, Qhw-QLD
- Qpa, PLEISTOCENE, Qpa-QLD
- Qpa>Cs, PLEISTOCENE, Qpa-QLD>Star of Hope Formation
- Qpa?, PLEISTOCENE, Qpa?-QLD
- Qa, QUATERNARY, Qa-QLD
- Qa\c, QUATERNARY, Qa\c-8354
- Qa\f, QUATERNARY, Qa\f-ANAKIE
- Qa\f>Qr\b, QUATERNARY, Qa\f-ANAKIE>Qr\b-ANAKIE
- Qa\f>Tb, QUATERNARY, Qa\f-ANAKIE>Tb-ANAKIE
- Qa\s, QUATERNARY, Qa\s-ANAKIE
- Qas, QUATERNARY, Qas-8454
- Qf, QUATERNARY, Qf-8554
- Ql, QUATERNARY, Ql-8554
- Qr, QUATERNARY, Qr-QLD
- Qr\c, QUATERNARY, Qr\c-8455
- Qr\c,Pwb, QUATERNARY, Qr\c-8455,Moranbah Coal Measures
- Qr\c>Pwt, QUATERNARY, Qr\c-8455>Fort Cooper Coal Measures
- Qr,Ch, QUATERNARY, Qr-8354,Mount Hall Formation
- Qr>CPgb, QUATERNARY, Qr-8455>Bluegrass Creek Granite
- Qr,Cs, QUATERNARY, Qr-8354,Star Of Hope Formation
- Qr,DCs, QUATERNARY, Qr-8354,Silver Hills Volcanics
- Qr\f, QUATERNARY, Qr\f-8455
- Qr\f>Ts,Pb, QUATERNARY, Qr\f-8455>Suttor Formation,Back Creek Group
- Qr>Pb, QUATERNARY, Qr-8455>Back Creek Group
- Qr,PLa, QUATERNARY, Qr-8354,Anakie Metamorphic Group
- Qr,PLa, QUATERNARY, Qr-ANAKIE,Anakie Metamorphic Group
- Qr,PLa?, QUATERNARY, Qr-8354,Anakie Metamorphics Group?
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- Qr>Rr, QUATERNARY, Qr-8455>Rewan Formation
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- Qr>Ts, QUATERNARY, Qr-8455>Suttor Formation
- Qr,Tu?, QUATERNARY, Qr-8354,Suttor Formation?
- Qr>Cb, QUATERNARY, Qr-QLD>Bulliwallah Formation
- Qr>Ch, QUATERNARY, Qr-QLD>Mount Hall Formation
- Qr>Cs, QUATERNARY, Qr-QLD>Star of Hope Formation
- Qr>Pb, QUATERNARY, Qr-ANAKIE>Back Creek Group
- Qr>Ts, QUATERNARY, Qr-QLD>Ts-QLD
- Qr?,PLa, QUATERNARY, Qr?-8354,Anakie Metamorphic Group
- Qr\b, QUATERNARY, Qr\b-ANAKIE
- Qr\b, QUATERNARY, Qr\b-QLD
- Qr\b>Tb, QUATERNARY, Qr\b-ANAKIE>Tb-ANAKIE
- Qr\s, QUATERNARY, Qr\s-8554
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- TQa\m, LATE TERTIARY - QUATERNARY, TQa\m-ANAKIE
- TQa\s, LATE TERTIARY - QUATERNARY, TQa\s-ANAKIE
- TQa>Ts?, TERTIARY - QUATERNARY, TQa-8554>Suttor Formation?
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- TQr>PLa, LATE TERTIARY - QUATERNARY, TQr-ANAKIE>Anakie Metamorphic Group
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- TQr>Ts?, LATE TERTIARY - QUATERNARY, TQr-ANAKIE>Suttor Formation?
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- TQr>Pb, TERTIARY - QUATERNARY, TQr-8454>Undivided Back Creek Group
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- Tb, TERTIARY, Tb-QLD
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- Td\q, TERTIARY, Td\q-QLD
- Td\q>Tu, TERTIARY, Td\q-8354>Suttor Formation
- Td\s, TERTIARY, Td\s-SEQ
- Tp, TERTIARY, Peak Range Volcanics
- Ts, TERTIARY, Suttor Formation
- Ts, TERTIARY, Ts-QLD
- Ts,Qr, TERTIARY, Ts-QLD,Qr-QLD
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- Ts>Pb, TERTIARY, Suttor Formation>Undivided Back Creek Group
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- Ts?, TERTIARY, Ts?-QLD
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- Tu?, TERTIARY, Duaringa Formation?
- Tu?, TERTIARY, Suttor Formation?
- Kgb, CRETACEOUS, Bundarra Granodiorite
- Kgg, CRETACEOUS, Gotthardt Granodiorite
- Ki, CRETACEOUS, Ki-8554
- Ki, CRETACEOUS, Ki-BBG
- Rm(w), MIDDLE TRIASSIC, Moolayember Formation(w)
- Rm, MIDDLE TRIASSIC, Moolayember Formation
- Re, TRIASSIC, Clematis Group
- Rm, TRIASSIC, Moolayember Formation
- Rr, TRIASSIC, Rewan Formation
- Rr, TRIASSIC, Rewan Group
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- Rw, TRIASSIC, Warang Sandstone
- Rw?, TRIASSIC, Warang Sandstone?
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- CPg, PERMIAN, CPg-8355
- Pa?, PERMIAN, Blair Athol Coal Measures?
- Pb, PERMIAN, Back Creek Group
- Pb, PERMIAN, Undivided Back Creek Group
- Pb,TQr, PERMIAN, Undivided Back Creek Group,TQr-8454
- Pwt,TQr, PERMIAN, Fort Cooper Coal Measures,TQr-8554
- Pbx, LATE PERMIAN, Exmoor Formation
- Pwb, LATE PERMIAN, Moranbah Coal Measures
- Pwj, LATE PERMIAN, Rangal Coal Measures
- Pwt, LATE PERMIAN, Fort Cooper Coal Measures
- Pb?, EARLY PERMIAN - LATE PERMIAN, Back Creek Group?
- Pjo?, EARLY PERMIAN, Jochmus Formation?
- Pb, EARLY PERMIAN - LATE PERMIAN, Back Creek Group
- CPjj?, LATE CARBONIFEROUS - EARLY PERMIAN, Jericho Formation?
- CPg, CARBONIFEROUS - EARLY PERMIAN, CPg-DRUM/BULG
- Ca,TQr, CARBONIFEROUS, Mount Rankin Formation,TQr-8454
- Cb, CARBONIFEROUS, Bulliwallah Formation
- Cb?, CARBONIFEROUS, Bulliwallah Formation?
- Cg/b, CARBONIFEROUS, Cg/b-DRUM
- Ci, CARBONIFEROUS, Ci-8354
- Cid, CARBONIFEROUS, Cid-Kennedy Province
- Cn, CARBONIFEROUS, Natal Formation
- Cn?, CARBONIFEROUS, Natal Formation?
- Cubb?, CARBONIFEROUS, Bobby Dazzler Rhyolite?
- Cubi, CARBONIFEROUS, Pinang Rhyolite
- Cubb, CARBONIFEROUS, Bobby Dazzler Rhyolite
- Cubl/b, CARBONIFEROUS, Locharwood Rhyolite/b
- Cubl/b,Cubl/c, CARBONIFEROUS, Locharwood Rhyolite/b,Locharwood Rhyolite/c
- Cubl/c, CARBONIFEROUS, Locharwood Rhyolite/c
- Cubl/c?, CARBONIFEROUS, Locharwood Rhyolite/c?
- Cubl/d, CARBONIFEROUS, Locharwood Rhyolite/d
- Cvb/rh, CARBONIFEROUS, Cvb/rh-8454
- Cvbl/b, CARBONIFEROUS, Locharwood Rhyolite/b
- Cvb/l, LATE CARBONIFEROUS, Bulgonunna Volcanic Group/l
- Ch, EARLY CARBONIFEROUS, Mount Hall Formation
- Ch?, EARLY CARBONIFEROUS, Mount Hall Formation?
- Cr, EARLY CARBONIFEROUS, Raymond Sandstone
- Cr?, EARLY CARBONIFEROUS, Raymond Sandstone?
- Cs, EARLY CARBONIFEROUS, Star of Hope Formation
- Cs?, EARLY CARBONIFEROUS, Star of Hope Formation?
- Cu, EARLY CARBONIFEROUS, Ducabrook Formation
- Ca, LATE DEVONIAN? - EARLY CARBONIFEROUS, Mount Rankin Formation
- DCg, LATE DEVONIAN - EARLY CARBONIFEROUS, DCg-ANAKIE
- DCir, LATE DEVONIAN - EARLY CARBONIFEROUS?, DCir-ANAKIE/DRUM
- DCs, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics
- DCs/ic, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/ic
- DCs/ij, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/ij
- DCs/ik, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/ik
- DCs/r, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/r
- DCs/r10, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/r10
- DCs/r11, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/r11
- DCs/r9, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/r9
- DCs/s, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/s
- DCs/se, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/se
- DCs/t1, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/t1
- DCs/t2, LATE DEVONIAN - EARLY CARBONIFEROUS, Silver Hills Volcanics/t2
- Dy, MIDDLE DEVONIAN - LATE DEVONIAN, Greybank Volcanics (undivided)
- Dy/c, MIDDLE DEVONIAN - LATE DEVONIAN, Greybank Volcanics/c
- PLEa, NEOPROTEROZOIC - CAMBRIAN?, Anakie Metamorphic Group
- PLEa,Qr, NEOPROTEROZOIC - CAMBRIAN?, Anakie Metamorphic Group,Qr-8354
- PLEa,Qr, NEOPROTEROZOIC - CAMBRIAN?, Anakie Metamorphic Group,Qr-ANAKIE
- PLEa>Qr, NEOPROTEROZOIC - CAMBRIAN?, Anakie Metamorphic Group>Qr-ANAKIE
- PLEa?, NEOPROTEROZOIC? - EARLY CAMBRIAN?, Anakie Metamorphic Group?
- PLEb/q(w), NEOPROTEROZOIC? - EARLY CAMBRIAN?, Bathampton Metamorphics/q (w)
- PLEm(w), NEOPROTEROZOIC? - EARLY CAMBRIAN?, Monteagle Quartzite (w)
- PLEm, NEOPROTEROZOIC? - EARLY CAMBRIAN?, Monteagle Quartzite

1:250,000 (at A4)

0 1 2 3 4 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project

Registered Groundwater Bores

Job Number	41-25215
Revision	B
Date	11-09-2012

Figure: 6-15
Sheet 4 of 4

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Data source: 250k Geology (2008); © Commonwealth of Australia (Geoscience Australia). Created by: A.J.

Table 6-12 Registered Bores and Facility Roles

Facility Role / Type	Existing	Abandoned (useable)	Abandoned and destroyed	Total
Unknown	11	-	4	15
Water supply	7	-	10	17
Stratigraphic investigation	-	-	1	1
Mineral or coal exploration	2	-	-	2
Sub-artesian monitoring	3	1	-	4
Groundwater investigation & sub-artesian monitoring	1	3	-	4
TOTAL	**24**	**4**	**15**	**43**

Abandoned bores total 19, of which 15 are reported as destroyed. The remaining 24 bores are assumed to be in use, seven of which are defined as 'water supply' bores and eleven of which are defined as having an 'unknown' use. It is possible that some or all of the 11 existing bores with an 'unknown' facility role may abstract groundwater for water supply.

Table 6-13 provides detail on each registered existing water supply bore located within 10 km of the Project (Rail), as discussed below:

- Groundwater Assessment Area Section 1 – Four existing water supply bores are situated within 8.2 km of the Project (Rail). Three of these bores are indicated to penetrate Tertiary-aged sedimentary bedrock. Bore RN 90258 is located 10 km from the proposed Project (Rail) and is screened within a Triassic –aged sedimentary aquifer at a depth of 75.0 to 79.3 m below ground level (bgl).
- Groundwater Assessment Area Section 2 – One registered bore (RN 132195) is recorded as an existing water supply facility within 4.6 km of the Project (Rail). This bore appears to abstract groundwater from weathered shale within the Star of Hope Formation.
- Groundwater Assessment Area Section 3 – Two registered bores (RN 62394 and RN 90045) are located 1.7 km and 9.8 km away from the Project (Rail). These bores abstract groundwater from the Suttor Formation and from fine sand within the Blenheim Subgroup, respectively.

Table 6-13 Registered Existing Water Supply Bores

Section	RN	Formation	Yield (L/s)	Distance from Project (Rail) (km)
1	17982	Sediments (interpreted Dunda Beds)	-	1.7
	90258	Undifferentiated (interpreted Dunda Beds)	1.89	8.2
	90368	Tertiary – Undefined	3.9	1.5

Section	RN	Formation	Yield (L/s)	Distance from Project (Rail) (km)
	103140	No lithology details (interpreted Tertiary Sediments	0.5	2.9
2	132195	Star of Hope Formation	0.75	9.1
3	62394	Suttor Formation	1.0	1.9
	90045	Blenheim Sub Group (Undifferentiated)	0.75	5.6

6.2.2.2 Hydrogeological Description

Analysis of the data extracted from the Queensland Groundwater Database (DERM, 2010) and the available 1:100,000 (100K) scale geological mapping indicates four distinct geology types present in the vicinity of the Project (Rail) subset of which are as follows:

- Major hydrogeological units:
  - Alluvium, colluvium and miscellaneous sediments (Quaternary to Tertiary)
  - Sedimentary units (Tertiary, Carboniferous and Permian)
- Minor outcropping units within the Project (Rail) area buffer:
  - Igneous units (Tertiary and Carboniferous to Late Devonian)
  - Metamorphic unit (Neoproterozoic to Cambrian)

Quaternary to Tertiary-aged alluvium and colluvium occur within the majority of the Project (Rail) area with some minor miscellaneous sediment. The alluvial sediments are most prevalent, particularly in low-lying areas and have been typically deposited by adjacent rivers, creeks and associated floodplains. The alluvium mostly consists of sand, silt, clay and gravel. Miscellaneous sediments typically occur distal to watercourses consisting of sand, silt, clay and gravel, originating from alluvial, colluvial and residual sources.

The low-lying Quaternary to Tertiary-aged alluvial, colluvial and miscellaneous sediments are typically underlain by Carboniferous-aged sedimentary bedrock units in Groundwater Assessment Area Section 1; Carboniferous-aged volcanic and Neoproterozoic to Cambrian aged metamorphic units in Groundwater Assessment Area Section 2; and Permian-aged sedimentary bedrock units in Groundwater Assessment Area Section 3.

Groundwater Assessment Area Section 1

Hydrogeological Units

Shallow Quaternary-aged alluvial hydrogeological units (Qa and Qpa) in Groundwater Assessment Area Section 1 are located in the vicinity of major rivers and creeks (refer to Figure 6-15) with depths ranging from 10.1 m bgl (RN 12030086) to 37.7 m bgl (RN 90368). Standing water levels (SWL) for bores within the Belyando River alluvium (total of five bores) have mostly been reported as dry (except for

RN 12030085), indicating that alluvial aquifers with significant groundwater resources is not typical of the region.

Aquifers within Groundwater Assessment Area Section 1 predominately occur in Tertiary-aged arenite and mudrock (Ts) with depth to top of the Tertiary aquifer ranging from 35.6 m bgl (RN 90369) to 60.0 m bgl (RN 89246) SWL for Tertiary-aged sediments is approximately 18.3 m bgl (RN 17983) to 39.6 m bgl (RN 90258).

Deeper bedrock aquifers also occur within Carboniferous-aged sandstone in some locations (possibly of the Mt Hall Formation) at a depth of ranging 39.0 m bgl (RN 12030175). The deeper bedrock aquifer reports SWL ranging from 27 m bgl (RN 90257) to greater than 153 m bgl (RN 132302 and RN 132304, which report as a dry hole).

Groundwater level hydrographs for all bores with recorded water level data in Groundwater Assessment Area Section 1 indicates that the alluvial bore is more responsive with a change in groundwater levels up to 3.7 m between the minimum and maximum. There appears to be no direct relationship with rainfall recharge.

Yields and Water Quality

No data is available on yields from the Tertiary aquifer. A yield of up to 11 L/sec was recorded from RN 30176 through possibly the Mt Hall Formation. Data for the alluvial aquifers suggests yields ranging from 0 L/s to 3.9 L/s (RN 90368).

Electrical conductivity (EC) of the groundwater is variable with values ranging from 373 µS/cm (RN 17980) in Tertiary sediments and up to 15,500 µS/cm (RN 12030175) in the Mt Hall Formation.

pH values range from slightly acidic to basic with pH levels of 6.7 (RN 17983) to 8.5 (RN 12030175), from Tertiary sediments and the Mt Hall Formation, respectively. No pH values are available for the alluvial sediments.

Groundwater Assessment Area Section 2

Hydrogeological Units

A number of outcropping volcanic, sedimentary and metamorphic bedrock units are present within the buffer zone of Groundwater Assessment Area Section 2. Colluvium is mapped on the slopes and toward the base of the outcropping units and alluvial deposits dominate the low-lying areas in the vicinity of Mistake Creek, Logan Creek and Diamond Creek.

Depth to top of the Carboniferous-aged bedrock aquifer ranges from 54.9 m bgl (Mt Hall Formation) to 96 m bgl (Star of Hope Formation). The Tertiary-aged sedimentary aquifer top is reported at 85 m bgl (RN103912).

There are four bores situated within the alluvial deposits of Mistake Creek, which are south of the 10 km study area. These bores range in depths of up to 13.6 m bgl and according to the Groundwater Database (DERM, 2010) records all have reported dry during monitoring, indicating that shallow alluvial groundwater resources are not extensive in the region.

Groundwater level hydrographs for all registered bores in Groundwater Assessment Area Section 2 and Groundwater Assessment Area Section 3 show that water levels in the Anakie Metamorphics (RN 12030172), the Mt Hall Formation (RN 12030176) and the Suttor Formation (RN 12030181) have remained relatively static and appear to not be subject to rainfall recharge. This lack of response indicates that there is limited hydraulic connection or a large response lag-time between surface waters and groundwater.

Yields and Water Quality

Bores within the Mistake Creek alluvium have remained dry therefore there is no yield data available for the shallow alluvial deposits. Yields of up to 3.43 L/s have been recorded in the Tertiary-aged sedimentary aquifer. Yields in the bedrock aquifers are typically lower and range from 0.4 L/s to 0.75 L/s of slightly brackish water (up to 2,000 µS/cm). Saline water was reported in two bores with EC values of 45,500 µS/cm (Anakie Metamorphic Group) and 53,100 µS/cm (Mt Hall Formation). Only RN 12030176 reported a pH with a value of 7.5.

Groundwater Assessment Area Section 3

Hydrogeological Units

Much of the Groundwater Assessment Area Section 3 is underlain by alluvium associated with Diamond Creek to the west and Late Tertiary- to Quaternary-aged unconsolidated sediments to the east. Outcropping Tertiary volcanics or durricrust and Permian sedimentary units (Back Creek Group) are also present towards the eastern limit of the search area.

There is very little information on aquifer properties within this area. The Groundwater Database (DERM, 2010) indicates that the top of the Blenheim Subgroup (part of the Back Creek Group) ranges in depths of 79.2 to 85.3 m bgl with SWL ranging 51.2 to 61.0 m bgl; and the top of the Suttor Formation from 36.6 to 55 m bgl with a SWL of 27.4 m bgl.

Yields and Water Quality

Information on groundwater yields is only available for two bores within Groundwater Assessment Area Section 3 and range from 0.75 L/s (Blenheim Subgroup) to 1.0 L/s (Suttor Formation). Limited water quality data are also available, with two bores reporting ‘brackish’ water and two bores reporting an EC with values of 9,600 µS/cm (Blenheim Subgroup) and 18,010 µS/cm (Suttor Formation), which may be characterised as saline. pH in the Suttor Formation was reported as slightly basic with a value of 8.0.

6.2.2.3 Groundwater Quality

Limited water quality data are available. Some pH, EC and/or total dissolved solids (TDS) data are available for up to 21 bores within the search area as summarised in Table 6-14, details the minimum, median (middle value) and maximum recorded value in each Groundwater Assessment Area Section.

Laboratory data is also available for major ions for some of the bores in Groundwater Assessment Area Section 1. A piper plot of the major ion data indicates that groundwater is typically a sodium/potassium-chloride type water (with the exception of RN 17982, which can be classified as sodium/potassium-bicarbonate type water). The same data are also shown on an expanded durov plot which suggests that the majority of the groundwater samples are end-product water meaning that the groundwater has long residence times and groundwater that is not actively recharged from rainfall or infiltration from surface water bodies.

Table 6-14 Groundwater Quality Data from Registered Bores on Project (Rail) Sections

Parameter	Statistical Parameter	Section 1	Section 2	Section 3
pH	Minimum	6.4	7.3	8.0
	Median	7.85	7.55	8.0
	Maximum	8.5	7.7	8.0
	Datum Count	12	4	1
EC (µS/cm)	Minimum	320	495	9600
	Median	2080	45,500	17,500
	Maximum	17,750	53,100	18,010
	Datum Count	20	9	3
TDS (mg/L)	Minimum	0	316	10,360
	Median	972	27,656	10,360
	Maximum	11,070	32,845	10,360
	Datum Count	12	3	1

Source: Queensland Groundwater Database (DERM, 2010).

6.2.2.4 Interaction between Groundwater and Surface Water

Other than the Belyando River, all the watercourses in the Project (Rail) search area are highly intermittent or ephemeral. The Belyando River typically sustains flow for several months after rainfall ceases. The remaining creeks, following heavy rainfall typically stop flowing and retract into a few small water holes within a few days to weeks. Peak surface water flow is likely to occur between November and May, with February producing the highest average flow.

The ephemeral nature of the watercourses within the Project (Rail) area suggests little to no significant groundwater base-flow during dry periods. The Belyando River sustains permanent water holes in some sections of the river, indicating that there is some base-flow, although this would be highly reduced during the dry season.

Recharge of alluvium underlying the creeks and rivers likely occurs during the wet season when surface water levels are highest. Recharge of Tertiary-aged aquifers is via rainfall recharge at outcrop areas and from percolation through alluvial deposits during peak flow of surface water. The underlying Permian and Cambrian aquifers are recharged through leakage from alluvial and Tertiary sediments and via direct recharge at outcrop areas.

6.2.2.5 Groundwater Flow Direction

Determination of groundwater flow direction allows the assessment of potential impacts on sensitive receptors (i.e. potential migration of any contaminants that may enter the groundwater, drawdown/flow-through extent etc.).

There is insufficient data to be able to definitively determine groundwater flow direction. However, groundwater will generally follow broad-scale topographical features. The low-lying topography of the Project (Rail) study area is dominated by the Belyando River basin and the Suttor River basin (refer to Volume 3 Section 5). A ridge of outcropping bedrock in the middle of the Project (Rail) study area forms a natural ridge between the Belyando and the Suttor basins. Groundwater is thought to flow toward the low-lying rivers and the ridge forming a possible groundwater divide.

6.2.2.6 Sensitive Receptors

Spring Complexes

According to the Springs of Queensland dataset (Environmental Protection Agency (EPA), 2005) there are no reported spring complexes within the Project (Rail) study area.

Groundwater Dependant Ecosystems

Much of the landscape surrounding the Study Area has experienced broad-scale vegetation clearing, and as such, remnant vegetation coverage is fragmented. Connectivity of remnant vegetation at a landscape level is maintained by tracts of remnant vegetation often associated with major watercourses including the Belyando River and Mistake Creek.

Open cleared land is the most common and widespread fauna habitat type within the study area. This habitat type typically provides a low diversity of suitable resources for fauna (including threatened species), as compared to the higher ecological value of remnant vegetation.

Flows in the major watercourses including the Belyando River and Mistake Creek are understood to be relatively persistent and even during extended dry periods these systems are thought to maintain a series of semi-permanent to permanent waterholes. This suggests that the major water courses and the associated remnant riparian vegetation are groundwater dependent to a degree. Consequently the fauna which are attracted to these areas are also thought likely to be dependent on groundwater to a degree, albeit indirectly.

Outside of the riparian areas associated with the main watercourses then groundwater dependant ecosystems (GDEs) are unlikely to be present within the Project (Rail) study area. The other minor creeks and rivers are typically ephemeral and are not associated with areas of remnant vegetation. This is understood to be related to elevated depths to water table away from the main river systems and little or no groundwater contribution to vegetation demands and/or river flows.

Groundwater Users

There are a number of existing water supply bores within the Project (Rail) study area (that is, within 10 km radius of the Project (Rail)) as discussed in Section 6.2.2. These bores are typically utilised for stock and domestic purposes.

All groundwater bores within the nominal 10 km radius are considered sensitive receptors for Project (Rail) construction activities, however, due to the nature of the proposed development the risk to groundwater supplies is considered low.

Groundwater bores located in close proximity to the Project (Rail) have the highest risk of being impacted (i.e. bores within 1 km of the construction zone). There are two registered bores (RN 37604 and RN 132303) within 1 km of the Project (Rail), both of which are reported to be abandoned and destroyed (DERM, 2012). Bores that are greater than 1 km from the Project (Rail) have a very low risk of being impacted from construction or operational activities.

6.2.2.7 Hydrogeology Conceptualisation

The Project (Rail) falls within an area for which there is little to no data on groundwater resources.

Assessing data obtained from the Groundwater Database (DERM, 2010), BOM long-term average rainfall data, stream flow data and considering the hot central Queensland climate during the wet season (i.e. elevated evaporation) it is likely that recharge to groundwater is low and limited to heavy rainfall periods during the wet season.

A number of water supply exploration bores were historically installed into the alluvium of Belyando River and Mistake Creek. Data from monitoring of these bores (DERM, 2010) show that the bores have remained dry during monitoring periods and the bores have subsequently been abandoned. This indicates that alluvial aquifers are not extensive nor a source for significant local groundwater abstractions. The majority of abstractions within the Project (Rail) study area are from the underlying Tertiary and Permian sedimentary units. Information on observed depth to groundwater in these bores suggests that groundwater is typically encountered between approximately 15 and 75 m below ground level. Interaction between surface water and groundwater resources in the project area is therefore likely to be limited to major watercourses including the Belyando River and Mistake Creek. Flows in these major river systems are relatively persistent and permanent to semi-permanent waterholes are maintained year-round suggesting a degree of groundwater support. This is supported by ecological data which confirms the presence of mature remnant riparian vegetation including River Red Gums and Paperbarks associated with these water courses. Conversely the remaining minor water courses are typically highly ephemeral and are not associated with mature riparian vegetation suggesting little or no groundwater support.

While some minor recharge of shallow aquifers may occur during the wet season, it is not likely to be significant, as indicated by the very low groundwater yields achieved in most bores (typically less than 1 L/s) and the brackish to saline quality of the groundwater. The piper and durov plots indicate that the groundwater is an ‘end-point water’ (i.e. is not actively recharged directly from surface waters and has a long residence time).

6.2.3 Potential Impacts and Mitigation Measures

6.2.3.1 Overview

The greatest potential for any impact to groundwater is in the vicinity of shallow alluvial aquifers, mostly found near major creeks and rivers and within quarry and borrow areas, which could be impacted by temporary dewatering for Project (Rail) construction activities.

Potential operational impacts have been identified and discussed on the basis of a desktop analysis. With regard to the Project (Rail) operational phase, embankment infrastructure may result in retention of water (pooling/ponding, water logging) thereby locally increasing groundwater levels.

Work on the rail will primarily consist of minor cut and fill activities and sourcing of construction materials (quarrying of rock and borrowing of sand). Deeper disturbances of the ground may occur at creek and river crossings where piles for bridge structures and culverts may be required and within quarry and borrow areas. Hence depending on the construction method temporary dewatering may be necessary. A number of quarry and borrow locations have been identified for investigation within and in the vicinity of the Project (Rail). Geotechnical investigations are underway to better determine the nature of the potential resource and the quantity of resource available. The number and size of pits developed within each borrow area will vary depending on the volume of borrow material required for each section of the railway formation. The final locations will be identified during detailed design as the results of onsite geotechnical and environmental investigations become finalised. Table 6-15 lists the major creek and river rail crossings, where the potential for interaction between surface and groundwater is likely to be the greatest.

Table 6-15 Major Creek and River Crossings along the Rail Corridor

Section	Approximate Chainage*	Watercourse Name	Status / Notes
1	170 km	North Creek	Ephemeral
	149 km	Belyando River – Western Branch	Ephemeral, maintains permanent waterholes
	146 km	Belyando River	Ephemeral, maintains permanent waterholes
2	122 km	Mistake Creek	Ephemeral
	83 km	Logan Creek	Ephemeral
3	63 km	Diamond Creek	Ephemeral; does not cross the rail corridor.

*East-west direction.

6.2.3.2 Civil Works, Track Construction, Quarries and Borrow Areas

Potential Impacts

Construction activities, such as civil works, including: earthworks, drainage construction, haul road and access track construction and maintenance, track laying, water extraction and excavation of quarry and sand materials, have the potential to adversely impact on groundwater resources.

Specifically, potential impacts on groundwater resources may include;

- The degradation of groundwater resources
- The intersection of groundwater resources
- A decrease in groundwater levels at a local scale

Storage of chemicals, fuels, machinery and waste has the potential to impact groundwater quality where significant spills and leaks could occur. Contaminants have the potential to enter groundwater through infiltration and/or runoff. If the spill/leak is up-gradient of a sensitive receptor (i.e. groundwater bore or GDEs) there may be potential for degradation of water quality and impact on groundwater users.

Excavations of construction material from borrow pits, quarries and sand pits have the potential to intersect groundwater resources. Potentially dewatering of pits and quarries may be required.

Excavation of construction materials is considered most likely to occur in bedrock area to provided ballast and/or fill material. The desktop study has shown that groundwater within the bedrock is relatively deep (greater than 30 m bgl) and hence is not likely to be intersected during extractive activities. Sourcing of sand is likely to be in alluvial areas and has the potential to impact on shallow aquifers.

Management Measures

Laydown areas for vehicles and machinery and storage areas for chemicals, oils and fuels will be contained in appropriately designed facilities. Containment may include: sealed/lined surfaces and hard stand areas; bunded areas; containerised storage. In addition, chemicals, oils, fluids and other hazardous substances will be stored in accordance with the specifications of the material safety data sheet, as appropriate. Containment and correct storage will prevent spills, leaks, infiltration and surface runoff and hence prevent contaminants from entering aquifers, waterways and the general environment.

Laydown and storage areas will not be placed in the vicinity of creeks or rivers or close-by to sensitive receptors (i.e. groundwater bores or GDEs).

Spill kits will be available to all personnel in the event of a spill or leak. Booms and spill kits will be on-site at refuelling facilities. Refuelling will only occur at designated sites away from watercourse and sensitive receptors. All machinery will have its own designated spill kit.

Where sources of sand are required, this will, as far as is practicably possible, be obtained from borrow pits where shallow aquifers are not present (e.g. older alluvial palaeochannels). Importing sources of construction materials will also be investigated where necessary.

Where dewatering of pits/quarries/excavations is required, opportunities for reinjection of the groundwater down-gradient will be explored. Engineered cut-offs for pits and excavations may also be an option; however this is dependent on the size of the pits and groundwater inflows.

During detailed design, fill and capping material details will be defined and water demand curves formulated. A range of water sources will be investigated and developed.

6.2.3.3 Construction Water Supply Options

Potential Impacts

A number of construction water supply options are available and have been investigated by Hyder Consulting (Hyder Consulting, 2012).These included groundwater and surface water (existing large storage dams, in line and offline storage and minor overland flow capture structures) options within 1-2 kms of the Project (Rail). The surface water options were discounted as primary water sources due to security of supply and regulatory risk and therefore groundwater is the preferred water supply option.

Overall water supply demands for construction activities including foundation preparation, material conditioning, haul road maintenance, earthworks, dust suppression, concrete batching, construction camp water and access track maintenance result in an estimated peak demand of 450 kL per day.

The water supply investigation identified existing possible supply points along the proposed rail alignment to minimise construction of new supply points. Twenty-nine registered existing groundwater bores were investigated (18 within 10 km of the alignment and 11 between 10 and 20 km of the alignment).

The estimated groundwater demand of up to approximately 450 kL per day will require a groundwater bore yield of about 8 L/s for 16 hours pumping over a period of 24 hours. This yield means that the groundwater bore will have to be within an aquifer having sufficient storage and recharge within the rock mass. In order to ascertain the expected yield, further assessment will be required including a groundwater exploration and development program. This may include further hydrogeological assessment and groundwater bore location assessment.

It is expected that with adequate mitigation measures and controls in place throughout construction, any adverse impacts on groundwater can be minimised and will be temporary and localised given the following:

- No long-term lowering of groundwater levels due to construction activities is anticipated
- The majority of the Project (Rail) area does not contain well developed or extensive alluvial aquifers. Groundwater in the area is therefore not considered threatened or vulnerable as a resource
- Outside of the main river corridors groundwater and surface water connectivity is thought to be limited (Appendix AC Rail Hydrogeology Report)
- The required yield for construction means that any groundwater bores will have to be within aquifers having sufficient storage and recharge within the aquifer.

Management Measures

Design Project (Rail) construction water extraction groundwater borefields with a focus on reducing potential impacts on any GDEs, and groundwater users by allowing for a suitable distance between the abstractions bores and any listed GDE sites or other user extractions points or sensitive environmental sites such as wetlands or watercourses.

The location of groundwater extraction bores will take into consideration the expected cone of influence associated with groundwater drawdown.

Groundwater extraction bore pumping times and desired flow rates will be managed around consideration of likely recharge times.

6.2.3.4 Watercourse Crossings Construction

Potential Impacts

Activities, such as drilling and piling, associated with the construction of bridges and culverts have the potential to adversely impact on groundwater resources. Potential impacts may include:

- Degradation of groundwater quality
- A decrease in groundwater levels

Drilling and piling operations have the potential to degrade the quality of groundwater as a result of direct contamination through the introduction of drilling muds, chemicals and machinery fluids.

Dewatering may be required to facilitate drilling and piling operations within and near creeks and rivers during the construction of bridge pylons and/or culverts. Dewatering has the potential to reduce shallow groundwater levels in the vicinity of creeks and rivers. However, given the short-term duration, expected low volumes and localised nature of potential dewatering, it is unlikely that significant or long-term impacts will result.

Management Measures

Any boring or similar activity during construction will utilise drilling fluids and chemicals that are environmentally neutral and biodegradable. Machinery and equipment will be maintained in accordance with manufacturer requirements and regularly maintained to minimise breakdown and decrease risk of contamination.

Dewatering of shallow groundwater, if required for bridge pylons and/or culverts construction, will be of a short duration and no long-term impacts are expected. However, if extended dewatering is identified during detailed design and major drawdown of the alluvial aquifer is expected, a groundwater management plan may be required. The management plan will include objectives and targets to be met and detail monitoring requirements.

6.2.3.5 Blasting

Potential Impacts

Blasting has the potential to impact on groundwater through fracturing of bedrock changing its permeability and altering localised groundwater regimes. This may impact on local groundwater users and/or discharge from local spring complexes, through the fracturing of rock. Fracturing of previously component rock may increase flow through the rock aquifer and potentially dewater adjacent aquifers.

Management Measures

Blasting during the construction of the Project (Rail) is not considered necessary at the present time, but will be determined following further geotechnical investigations. Blasting potentially associated with borrow (quarry) areas away from the Project (Rail) area will be assessed separately.

If blasting of rock is required for construction of the Project (Rail) (or for quarrying activities), a census (physically finding and detailing bore properties) of all existing groundwater bores and spring complexes within a one kilometre radius will be undertaken. A search of the Queensland Groundwater Database (DERM, 2010), the Department of Natural Resources and Mines (DNRM) Water Entitlement Registration Database, enquiries with the local council and liaison with local landholders will inform the census. Any bores and springs that are located will be monitored pre and post blasting to assess pre and post blasting impacts and determine any mitigation measures that may be needed. Measures may include make-good reparations, capture of water if there is increased flow etc.

6.2.3.6 Construction Camps

Potential Impacts

It is expected that four construction camps will be established for the Project (Rail), approximately evenly spaced along the alignment, with one camp combined with the Project (Mine) workers accommodation village.

Potable water use is estimated at 84,000 litres of water per day per camp.

A number of supply options exist for the provision of potable and non-potable water. This may include, extraction from creeks and rivers, water and rainfall harvesting, use of farm dams, recycling, etc.

There is potential for the development of water bores in the Project (Rail) area. It is not likely, however, that water usage will rely solely on groundwater sources. Further it is not likely that establishment of groundwater bores and abstraction of groundwater for construction purposes will result in a decrease in the local resource for other users.

Management Measures

Water supply and demand options are currently being investigation and will be further developed during the detailed design phase. The main purpose of the study is to identify suitable water supply sources to accommodate the water supply for construction purposes whilst minimising impacts on stakeholders and the environment.

6.2.3.7 Operation

Potential Impact

There is potential for localised increases in groundwater levels (i.e. water logging) as a result of pre-loading or construction of embankments, where the groundwater is close to the ground surface. This is particularly relevant in the vicinity of the Belyando River. Pre-loading of sediments reduces pore space within sediments, thereby decreasing any groundwater flow through the aquifer and decreasing recharge of the aquifer from surface waters.

Management Measures

Pylon structures, culverts and filling activities are designed and will be constructed to minimise the loading and compaction of alluvial sediments, which may alter shallow groundwater regimes and recharge.

The current design allows for openings in the embankment (through culverts and bridge spans) in the vicinity of creeks and rivers to facilitate flow.

If extensive loading or compaction of alluvium at watercourse crossings is required for construction, alternative design concepts will be explored to minimise this (e.g. piles).

It is anticipated that little impact to groundwater regimes is likely to result from pre-loading, since the area of the loading will be comparatively small and shallow alluvial aquifers are not extensive within the Project (Rail) study area.

6.2.4 Summary

Groundwater resources are likely to be most vulnerable to impact in the vicinity of major creeks/rivers and other areas characterised by relatively shallow depths to groundwater. Temporary construction dewatering may be required in such areas and there is therefore the greatest potential for both direct and indirect contamination and other impacts due to the lack of any significant saturated zone between the ground surface and water table. However, given the short-term duration, expected low volumes and localised nature of potential dewatering, it is unlikely that significant or long-term impacts will result. Based on the available data, such areas are likely to be limited to crossing points of the Belyando River and the Mistake, Logan and Diamond creeks.

In general therefore no significant impacts on groundwater resources and/or quality are anticipated based on:

- Available information on baseline groundwater conditions

- Current understanding of proposed rail construction and operational activities including the limited number of shallow cuttings included in the preliminary rail design
- Adoption of the mitigation measures outlined in Section 6.2.3.

Construction of new infrastructure such as culverts, cuttings, embankments and bridge structures has the potential to result in short-term, localised impacts on shallow groundwater, such as increases or decreases in groundwater levels, however no significant impacts on groundwater resources and groundwater quality are expected given:

- No long-term lowering of groundwater levels due to construction dewatering activities is anticipated
- The majority of the Project (Rail) area does not contain well developed or extensive alluvial aquifers. Groundwater in the area is therefore not considered threatened or vulnerable as a resource
- Outside of the main river corridors groundwater and surface water connectivity is thought to be limited

The preferred water supply option for the Project (Rail) construction is groundwater. It is expected that with adequate mitigation measures and controls in place throughout construction, any adverse impacts on groundwater can be minimised and will be temporary and localised given the following:

- No long-term lowering of groundwater levels due to construction activities is anticipated
- The majority of the Project (Rail) area does not contain well developed or extensive alluvial aquifers. Groundwater in the area is therefore not considered threatened or vulnerable as a resource
- Outside of the main river corridors groundwater and surface water connectivity is thought to be limited (refer to Appendix AC Rail Hydrogeology Report)
- The required yield for construction means that any groundwater bores will have to be within aquifers having sufficient storage and recharge within the aquifer.

Similarly, no significant long term impacts on groundwater resources and groundwater quality are anticipated during operation of the rail line given that:

- Only a small number of shallow cuttings are included in the preliminary rail design and hence no significant permanent lowering of groundwater levels due to drainage of cutting areas is anticipated
- River crossing points will be designed such that compaction of alluvial sediments and upstream ponding of surface water flow is minimised.