CrossRiverRail

14. Flood Management

Cross River Rail

CHAPTER 14

FLOOD MANAGEMENT

JULY 2011

Contents

14 Flood management

14.1 Introduction

This chapter addresses Section 3.5.3 of the Terms of Reference (ToR). The Project includes the construction of a range of surface infrastructure that has the potential to change the existing flood regime of waterways, drainage lines and overland flow paths in the study corridor. This includes permanent infrastructure such as surface stations, accesses for underground stations, ventilation and emergency access building, surface tracks and stabling facilities, bridges and elevated structures, as well as temporary infrastructure associated with construction activities, eg worksites.

This chapter assesses the potential changes to flooding in the study corridor due to the construction and operation of the Project. It describes the existing waterways and flood potential in the study corridor and assesses potential changes due to the Project. Measures are also proposed to mitigate potential impacts relating to flooding.

The following issues have been considered in this chapter:

- potential implications of climate change on surface water management
- potential impacts on the flow of surface waters during all phases of the Project
- effects on neighbouring landholders where bunds or stream diversions are proposed
- potential impacts of surface water flow on existing infrastructure
- proposed drainage structures for all aspects of the Project, including supporting facilities ie access roads
- flood mitigation structures.

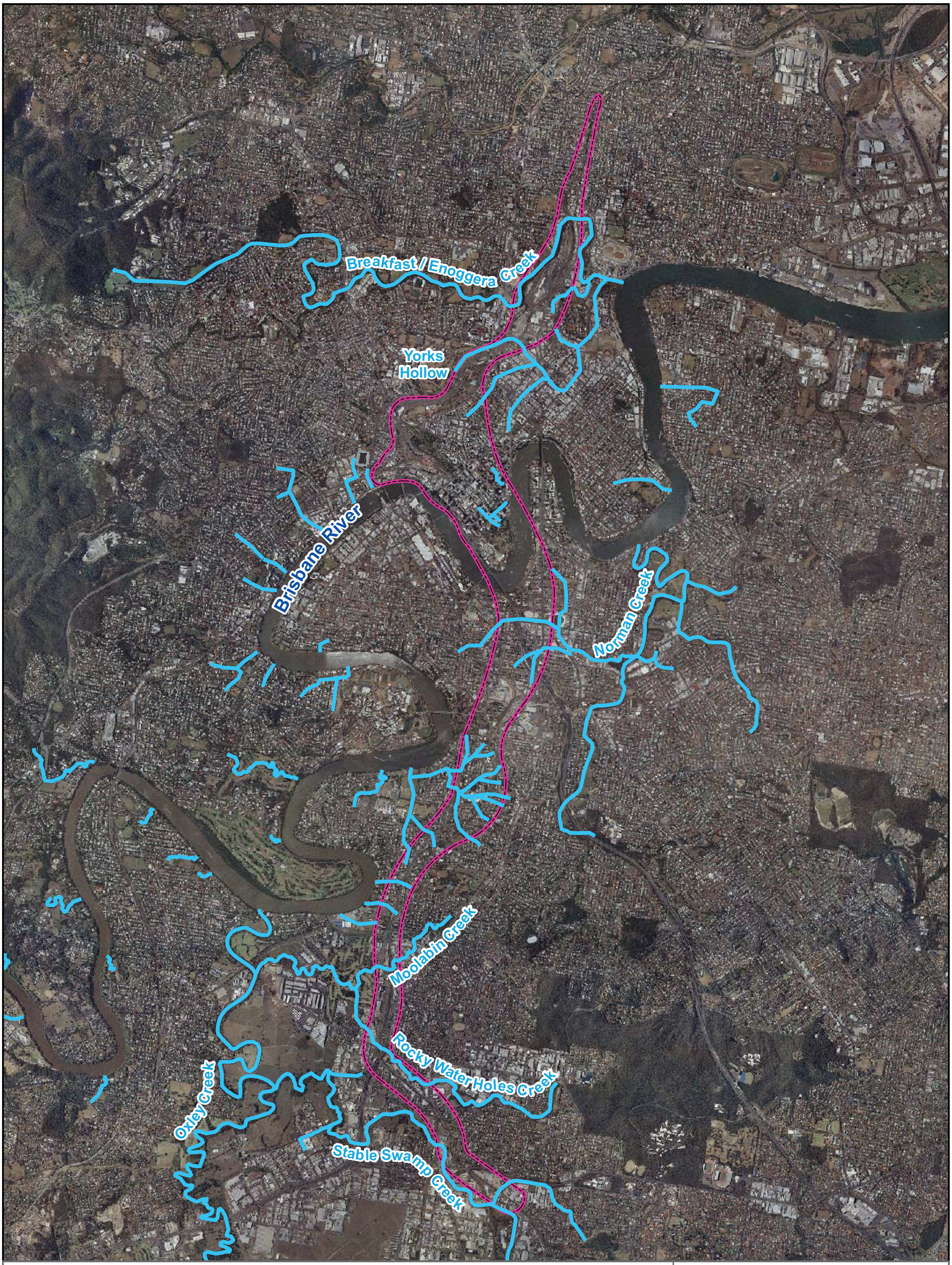
The potential impacts of the Project on surface water quality and strategies for protecting surface water quality are examined in **Chapter 13 Surface Water Quality**.

14.1.1 Methodology

The study area for this assessment includes that area of potential interaction between the Project and waterways and floodplains (refer **Figure 14-1**). In some locations, this extends beyond the study corridor for the EIS.

This assessment considers the potential for the Project to change the existing flood regime of the study area. The assessment involved:

- reviewing Queensland Government and Brisbane City Council (BCC) policies relevant to flooding in the study area
- understanding the existing flood regime in the study area by
  - reviewing previous studies undertaken for each of the waterways in the study area
  - assessing the general flood behaviour and flood history of rivers, creeks and overland flow paths in the study area
  - assessing the likelihood of flooding in the study area under existing conditions, including undertaking additional flood modelling where required
- undertaking flood modelling for a range of flood events up to the 1 in 100 Annual Exceedance Probability (AEP) flood event, to assess the potential impacts of the Project on the existing flood regime of the study area. The AEP is defined as the probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
- consideration of the Project with regard to the flooding which occurred in January 2011.



LEGEND
Study Corridor
Tributaries

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-1

Flood Management Study Area

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The potential for climate change to affect flooding within the study area was also considered. This used a standard methodology for each waterway. The methodology used is summarised in *Technical Report No.6 – Flood Study.* Climate change predictions incorporate climatic change that could influence a range of different parameters used in the hydrologic modelling of flood design. These changes may include:

- increased rainfall intensity during large to extreme events
- altered spatial variation of rainfall during rainfall events
- altered temporal variation of rainfall during rainfall events
- changes in mean seasonal and mean annual rainfall, impacting upon rainfall losses.

14.1.2 Policy framework

This section provides an overview of the regional and local flooding policy framework relevant to the Project.

State Planning Policy 1/03 Mitigating the Adverse Impacts of Flood, Bushfire and Landslide

State Planning Policy (SPP) 1/03 *Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* has been prepared to minimise the potential impact of natural hazards such as flood, bushfire and landslide on people, property, economic activity and the environment. The SPP is supported by *Guideline for SPP 1/03: Mitigating the Adverse Impacts of Flood, Bushfire and Landslide* which provides advice and information on interpreting and implementing the SPP 1/03.

The policy is relevant to areas across Queensland for flooding, including areas located near the Brisbane River, Breakfast Creek, Enoggera Creek and Oxley Creek.

The policy applies to community infrastructure that *"provide services vital to the wellbeing of the community",* including railway lines, stations and associated facilities. The policy does not specify recommended flood levels for rail lines, stations and associated facilities but states "*development proponents should ensure that the infrastructure is optimally located and designed to achieve suitable levels of service, having regard to the processes and policies of the administering government agency".*

Further information on SPP 1/03 is provided in **Chapter 9 Land Use and Tenure**.

South East Queensland (SEQ) Regional Plan 2009-2031

The *SEQ Regional Plan 2009-2031* provides a framework for managing growth, land use change and development in the region. The Plan outlines 12 regional policies to address growth and management of the region. Each regional policy is supported by desired regional outcomes, principles, policies and programs.

Sustainability and climate change is identified as a key policy, with the SEQ Regional Plan seeking to ensure the region grows and changes in a sustainable manner. This is to be achieved by increasing *"the resilience of communities, development, essential infrastructure, natural environments and economic sectors to natural hazards including the projected effects of climate change".*

Water management is also identified as a key policy for the SEQ Regional Plan. Principle 11.6 of the SEQ Regional Plan relates to overland flow and flood management. This seeks to *"provide necessary flood immunity for infrastructure and buildings, and resilience to potential climate change flooding, while seeking to maintain the natural flow regime".*

SEQ Regional Plan policies relevant to the Project include:

- 1.4.1 – reduce the risk from natural hazards, including the projected effects of climate change, by avoiding areas with high exposure and establishing adaptation strategies to minimise vulnerability to riverine flooding, storm tide or sea level rise inundation, coastal erosion, bushfires and landslides
- 1.4.2 – reduce the risk from natural hazards, including the projected effects of climate change, by establishing adaptation strategies to minimise vulnerability to heatwaves and high temperatures, reduced and more variable rainfall, cyclones and severe winds, and severe storms and hail
- 11.6.1 – avoid areas of unacceptable flood risk, including additional risks from climate change, and areas where development may unacceptably increase flood risk elsewhere
- 11.6.2 – achieve acceptable flood immunity through water sensitive movement and detention infrastructure that minimises alterations to natural flow regimes, including floodplain connectivity.

Brisbane City Plan 2000

The Brisbane City Plan 2000, including the associated planning codes, provides guidelines on development within flood affected areas. Planning codes relevant to the Project include:

- stormwater management code
- filling and excavation code
- waterway code.

The purpose of the stormwater management code is to ensure stormwater management achieves acceptable levels of water quality and quantity, and that stormwater run-off from development prevents or minimises adverse social and environmental impacts on the City's waterways, overland flow paths and drainage networks.

In relation to flood management, the filling and excavation code seeks to ensure that filling does not adversely impact on flooding of upstream, downstream and adjoining land.

The purpose of the waterway code is to keep waterways clear of development where possible, and to protect and enhance the values of the City's waterways relating to water flow, water quality, ecology and open space, and recreational and amenity.

The codes also support the BCC's *Subdivision and Development Guidelines and Environmental Best Management Practice for Waterways and Wetlands*.

14.1.3 Climate change

The ToR for this EIS requires consideration of impacts of climate change on flood levels (also refer to **Chapter 6 Climate Change and Sustainability**). This section describes relevant policy for assessing climate change impacts, flooding mechanisms that may be impacted by climate change and estimates for climate change impacts.

Background and approach

The Queensland Government has identified climate change as a key criterion for its decisions about large infrastructure projects and in July 2008, Cabinet released a new requirement for a climate change impact statement to be prepared for submissions to Cabinet and the Cabinet Budget Review Committee.

Potential climate change impacts which may influence flooding in the Brisbane River include changes to rainfall depths and ocean levels. Flood impacts could also be influenced by climatic changes that result in:

- increased rainfall depth and intensities during large to extreme events
- altered spatial variation of rainfall during rainfall events
- altered temporal variation of rainfall during rainfall events
- changes in mean seasonal and mean annual rainfall, impacting upon rainfall losses.

Impacts of climate change are currently incorporated into hydrologic modelling through consideration of changes to design rainfall depths and adopting spatial and temporal patterns and catchment losses based upon current conditions. These changes are described in detail in *Technical Report No.6 – Flood Study*.

Climate change also has the potential to impact on the behaviour of flooding of the Project through:

- increases to mean sea level (MSL)
- modified cyclonic activity resulting in changes to storm surge behaviour.

In November 2010, the Queensland Government released the *Increasing Queensland's Resilience to Inland Flooding in a Changing Climate: Final Report on the Inland Flooding Study* (DERM *et al* 2010). This report recommends increasing rainfall depth by 5% °C of global warming. This results in a 20% increase in rainfall depth for 2100.

Climate change estimates considered in the assessment of flood impacts are presented in **Table 14-1**. Given that the design life of the Project is 100 years, climate change estimates for "beyond 2070" have been adopted for this assessment. These are the longest range climate change projections currently available.

Given that the Project is likely to become operational in 2021 and have a design life of 100 years, it is recommended that climate change scenarios be further considered during detailed design of flood immunity aspects of the Project.

Table 14-1 Adopted climate change estimates

Climate change parameter	Climate change estimate
Temperature increase	4°C
Increased rainfall depths / intensities	20%
Sea level rise	0.49 m
Storm surge	0.5 m
Storm surge and sea level rise combined	0.99 m

Sources: DERM *et al* (2010) and Queensland Office of Climate Change and Environmental Protection Agency (2008)

14.1.4 Reference design flood protection measures

A range of flood protection measures are incorporated into the reference design to provide flood immunity to the tunnel in extreme, ie 1 in 10,000 AEP, riverine flood events. Flood immunity in local catchment flood events is considered concurrently with these events.

Design of the Albert Street Station, ventilation and emergency access building and southern portal provides flood protection measures for both local and extreme flood events (AECOM 2011d, 2011e. Design of the underground stations at the Gabba, Roma Street and Boggo Road provide protection for local flood events only as they are not impacted by extreme flood events.

Proposed flood protection measures include (refer to **Chapter 4 Project Description**):

- raised underground station entry points to protect against local flash flooding events and potential problems with the local stormwater network. Floodboards can be quickly and easily installed in case of intermediate flood events and provide up to one metre of additional protection above the raised entrances.
- dedicated automated flood gates at each of the entry points to the Albert Street Station and at the southern portal to protect against extreme flood events. A floodgate would be incorporated into the southern portal. The floodgate would comprise a hinged tilting gate operated by hydraulic rams.
- protection of potential flood entry points from local and extreme flooding by local topography and elevation of flood entry points such as vents.

The Project requires the extension of minor culvert cross-drainage infrastructure in some locations at the north and south of the study corridor to accommodate widened rail embankments.

These crossings have not been detailed as part of the reference design but would be designed in accordance with the appropriate standards such as the Queensland Urban Drainage Manual (DNRW 2007). The design principles to be followed would include:

- flood immunity of the existing rail lines would be maintained
- no flood impacts on adjacent private property and community infrastructure would occur.

The tunnel portals are situated well above the 1 in 100 AEP flood levels and would not impact on flood behaviour in the study area.

All worksites and Project surface structures are located outside of the 1 in 100 AEP flood extents except for:

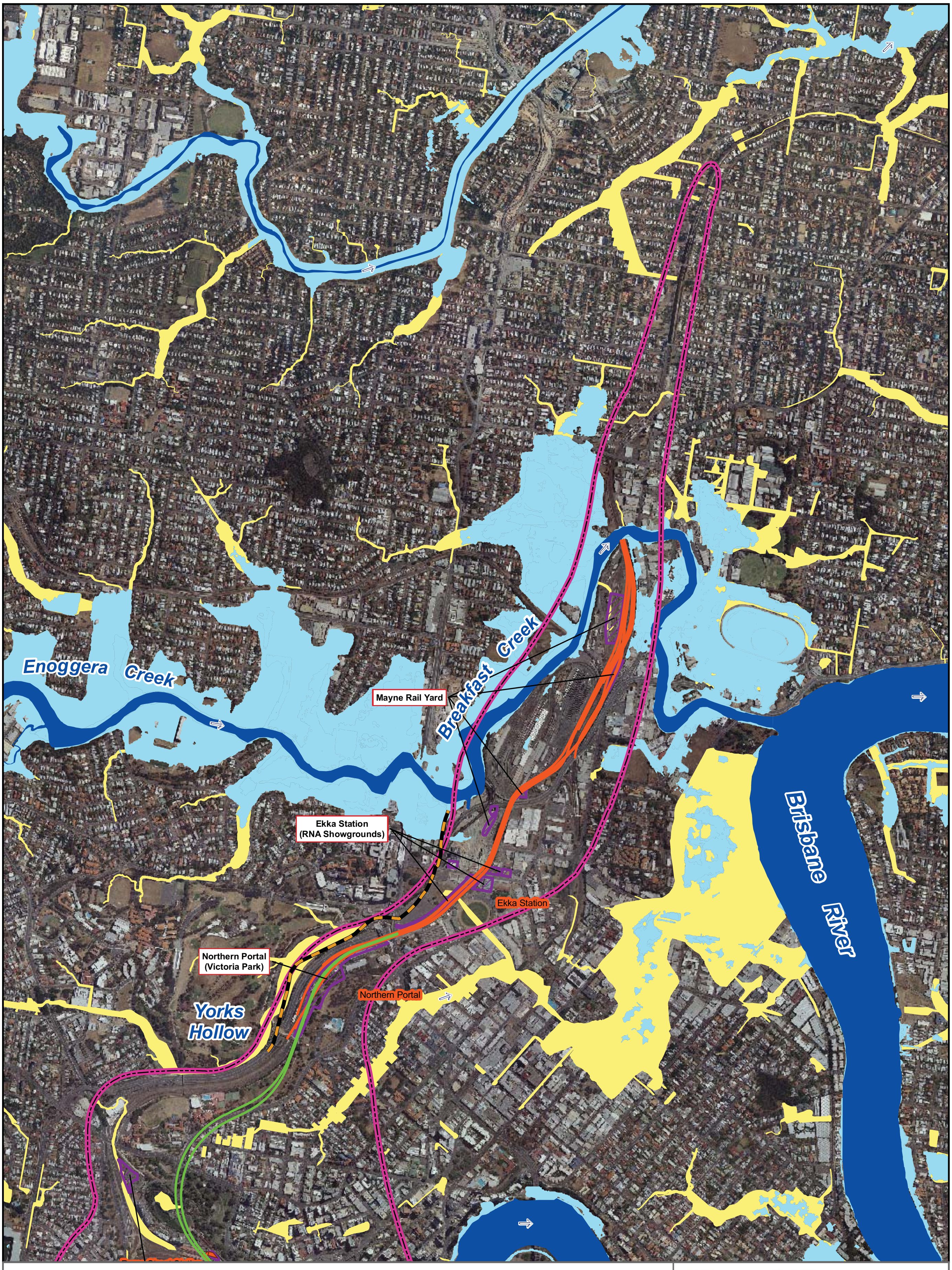
- culvert extension associated with southern surface works
- raising of Beaudesert Road Service Road, Salisbury
- Rocky Water Holes Creek bridge
- Clapham Rail Yard
- Moolabin Creek bridge
- Yeeroongpilly worksite
- ventilation and emergency access building
- Albert Street Station
- Ekka Station.

14.2 Description of environmental values

This section provides an overview of waterways in the study area and existing flood potential.

14.2.1 Waterways in the study area

Existing waterways in the study area, including overland flow paths, drainage lines and rivers and creeks, and extent of flood inundation for the Defined Flood Event (DFE) prior to the January 2011 flood are shown in **Figure 14-2** to **Figure 14-5** and are described as follows. A DFE is a flood event adopted by a local government for the management of development in a particular locality (SPP1/03 2003), In light of the January 2011 flood, BCC have released an interim DFE (BCC 2011). However, the previous DFE still provides a good overview of flood prone areas (BCC 2011).



LEGEND

- Study Corridor
- Flow Direction
- Waterways
- Overland Flow Path
- Creeks, River or Tidal Flooding
- Campbell St Drain

Alignment

- Above Ground
- Underground
- Worksites

Flood Flag Map Data Source: Brisbane City Council (2009)

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-2

Brisbane City Council Flood Flag Mapping (Northern Section)

0 200 400 600 800 1,000 m

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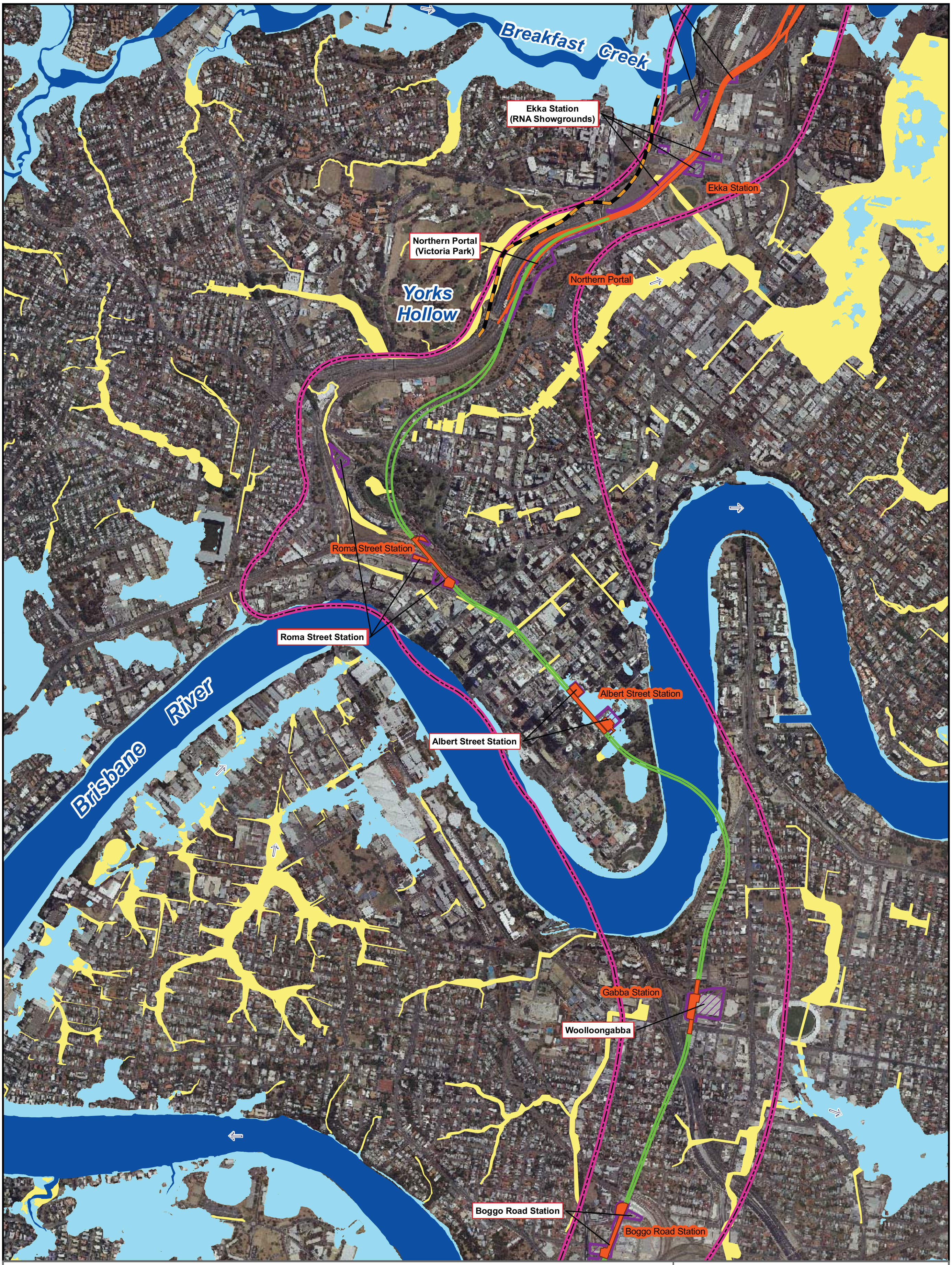

LEGEND

- Study Corridor
- Flow Direction
- Waterways
- Overland Flow Path
- Creeks, River or Tidal Flooding
- Campbell St Drain

Alignment

- Above Ground
- Underground
- Worksites

Flood Flag Map Data Source: Brisbane City Council (2009)

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-3

Brisbane City Council Flood Flag Mapping (Central Section)

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LEGEND

- Study Corridor
- Flow Direction
- Waterways
- Overland Flow Path
- Creeks, River or Tidal Flooding

Alignment

- Above Ground
- Underground
- Worksites

Flood Flag Map Data Source: Brisbane City Council (2009)

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-4

Brisbane City Council Flood Flag Mapping (Southern Section)

0 200 400 600 800 1,000 m

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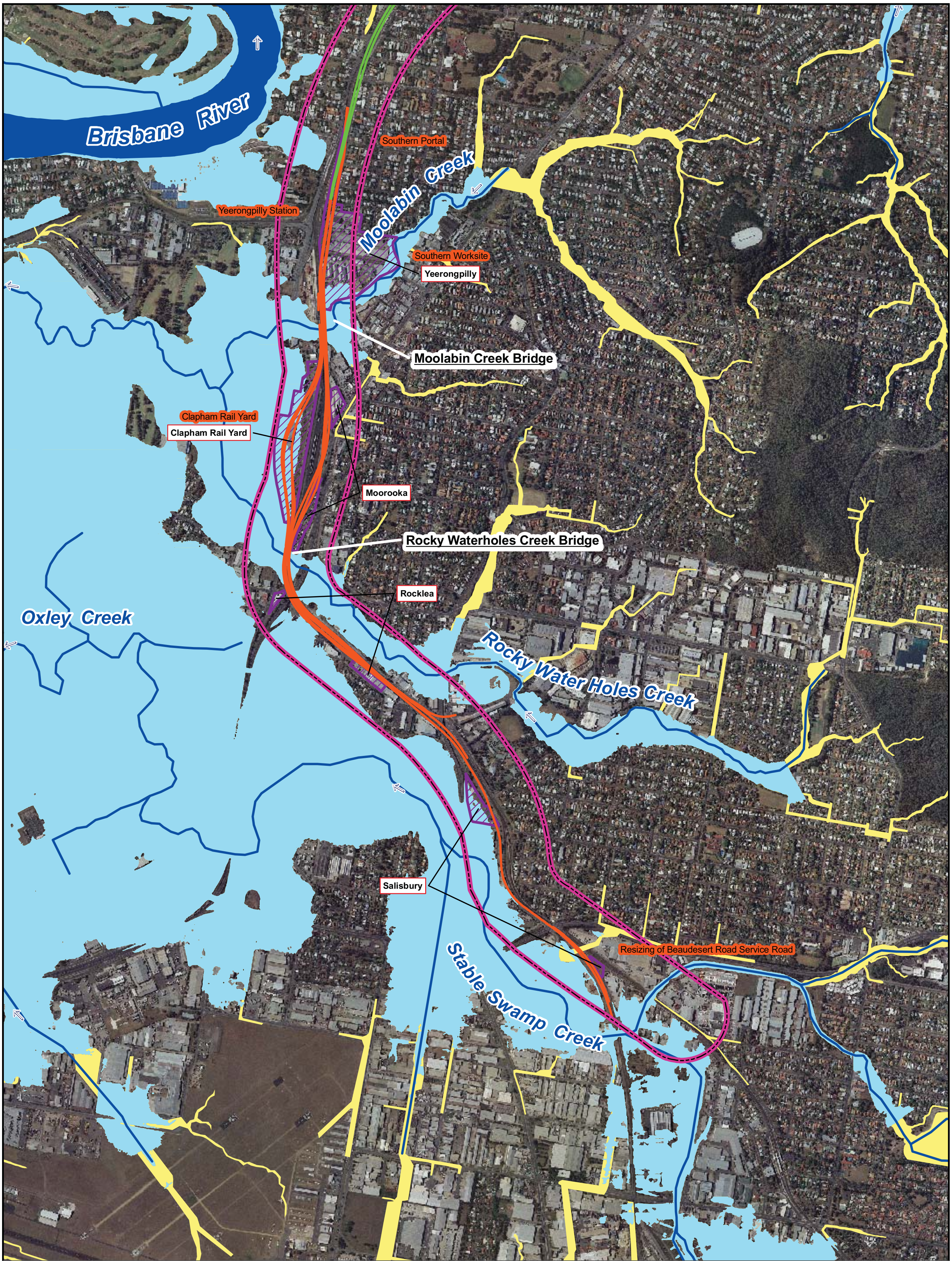

LEGEND

- Study Corridor
- Flow Direction
- Waterways
- Overland Flow Path
- Creeks, River or Tidal Flooding

Alignment

- Above Ground
- Underground
- Worksites

Flood Flag Map Data Source: Brisbane City Council (2009)

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-5

Brisbane City Council Flood Flag Mapping (Southern Section)

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More detailed mapping of the flood extent of major waterways for a range of flood events is included in *Technical Report No.6 – Flood Study*.

Overland flow paths

Numerous overland flow paths occur along the study corridor and interact with the Project. Overland flow paths are drainage lines that convey water that are not part of a creek, river or waterway. These are usually dry except in rainfall events. They are typically activated in short duration, high intensity rainfall events.

Breakfast/Enoggera Creek

Breakfast/Enoggera Creek is a tributary of the Brisbane River. It extends almost 39 km from the Brisbane Forest Park east to the Brisbane River at Newstead. Upstream of Three Mile Scrubs at Kelvin Grove, the waterway is known as Enoggera Creek, while the lower tidal reaches are known as Breakfast Creek. Flood studies were previously conducted for Breakfast Creek by BCC City Design in 1999 and 2007.

Breakfast Creek has a long history of flooding, affecting both residential and commercial properties. This has required regular dredging of the creek mouth to improve flood conveyance and lower flood levels.

Numerous bridges, elevated structures and surface works have recently been constructed, are being constructed or are proposed to be constructed in the Breakfast Creek floodplain upstream of the Brisbane River confluence. These are associated with the Inner City Bypass, Clem Jones Tunnel (formerly North-South Bypass Tunnel), Inner Northern Busway and Airport Link projects.

The proposed surface works for the Project would not impinge on the current floodplain of Breakfast Creek ie the inundated area of the DFE.

Campbell Street drain

The Campbell Street drain is a piped drainage system located west and east of the Inner City Bypass (ICB) (refer to **Figure 14-2**). The drain has a catchment area of approximately 1.5 km^2. The catchment incorporates the Victoria Park Golf Course and the suburb of Kelvin Grove. The channel drains to an underground network which conveys flow under the RNA Showgrounds, discharging into Breakfast Creek upstream of Horace Street.

The underground drainage network in this catchment accommodates flood events to a certain size/ frequency. For larger, rarer flood events, only the excess of flow from the RNA catchment would discharge through the RNA Showgrounds, flowing to the Brisbane River through Newstead. The catchment to the west of the RNA Showgrounds area would not result in overland flows through the RNA Showgrounds as flows are blocked by Bowen Bridge Road. The Ekka Station would span over the overland flowpath at the RNA Showgrounds as does the existing rail line.

Brisbane River

The Brisbane River runs through the centre of Brisbane. It intercepts the study corridor near the Brisbane Central Business District (CBD). The Brisbane River catchment upstream of the CBD covers an area of approximately 13,560 km^2 and includes both the Somerset and Wivenhoe dams.

The Brisbane River has a long history of flooding with records extending back to the 1840's. Brisbane's largest recorded flood was in 1841, with this having a recorded flood level in the CBD of 8.43 m AHD. Large flood events also occurred in 1844 and in the 1890s. More recently, the largest flood event was in January 1974. This flood had a recorded flood level in the CBD of 5.45 m AHD. The completion of Wivenhoe Dam in 1985 changed the storage characteristic of the upper Brisbane River catchment, resulting in lessening the effect of all subsequent Brisbane River floods.

The most recent floods which occurred in January 2011 recorded a flood level of 4.46 m AHD at the CBD flood gauge (BCC 2011). This flood level was higher than the 2009 DFE. The January 2011 flood was a Brisbane River flood caused by the rainfall in the Brisbane River catchment, rather than in Brisbane itself. Therefore, this event has been discussed in the context of Brisbane River flooding and has not been discussed at local creek level.

Numerous flood studies have been undertaken in recent years for the Brisbane River. These are listed in *Technical Report No.6 – Flood Study*. These studies were used as the basis for the flood models developed for the Project assessment.

Hydrologic modelling for the 1 in 100 AEP event was adopted from the model undertaken for BCC by Sinclair Knight Merz in 2004 (SKM 2004a).

A two-dimensional hydraulic model of the Brisbane River was developed for this assessment to represent regional Brisbane River flooding in the 1 in 20 AEP, 1 in 50 AEP and 1 in 100 AEP flood events. The model extended from the Centenary Bridge at Jindalee to the Sir Leo Hielscher Bridge (formerly the Gateway Bridge) at Eagle Farm.

Moolabin Creek

Moolabin Creek is a tributary of Oxley Creek (refer to **Figure 14-5**). It is located approximately 2 km upstream of the Brisbane River outlet for Oxley Creek. The creek intercepts the study corridor at Moorooka. Previous modelling of Moolabin Creek and Rocky Waterholes Creek has been undertaken by BCC City Design.

A combined one-dimensional and two-dimensional model of Moolabin Creek was created for this assessment. Based on the flood model results, peak 1 in 100 AEP flood levels through this area of Moolabin Creek vary from 8.6 m AHD to 6.7 m AHD.

Rocky Waterholes Creek

Rocky Waterholes Creek is a tributary of Oxley Creek (refer to **Figure 14-5**). It joins Moolabin Creek approximately 2 km upstream from the Oxley Creek outlet. The creek intercepts the study corridor at Rocklea.

A TUFLOW model was created for Rocky Waterholes Creek which extends from Beaudesert Road at Salisbury to 200 m downstream of Fairfield Road at Rocklea. The flood model representation of existing case flood behaviour (for a 1 in 100 AEP flood event) resulted in estimations on peak flood levels ranging from 6.4 m AHD at Fairfield Road to 6.8 m AHD at the Ipswich Motorway. The model also identified relatively high flood velocities near Muriel Avenue at Rocklea, with these being in the order of 1 to 2 m/s.

Stable Swamp Creek

Stable Swamp Creek is a tributary of Oxley Creek (refer to **Figure 14-5**). The creek intercepts the study corridor at Salisbury. Stable Swamp Creek has been modelled previously by BCC using a one-dimensional hydraulic model.

Oxley Creek

Oxley Creek is a major tributary of the Brisbane River (refer to **Figure 14-5**). The creek joins the river at Tennyson. Moolabin Creek, Stable Swamp Creek and Rocky Waterholes Creek are the main tributaries of Oxley Creek. Previous modelling of Oxley Creek undertaken for the Draft Oxley Creek Flood Study (BCC City Design 2006) has been reviewed for this assessment.

Flood extents for Oxley Creek do not intercept the extent of the proposed Project works.

14.2.2 Flood potential in the study area

The previous sections have assessed the waterways in the study area and their existing flood potential. This section provides an overview of how each of the Project elements (from north to south) interacts with flooding from creeks, rivers and overland flow paths.

North (Wooloowin to Bowen Hills)

The northern section of the study area extends from Wooloowin to Bowen Hills (refer to **Figure 14-2**). Flooding in this section of the study area is potentially affected by:

- Breakfast/Enoggera Creek
- Brisbane River flooding backing up into Breakfast Creek
- the Campbell Street drain
- local overland flowpaths.

Flood levels in that section of the corridor intercepted by Breakfast/Enoggera Creek are dominated by flood events in the Breakfast/Enoggera Creek catchment. BCC flood mapping identifies the peak flood level for the 1 in 100 AEP as 3.4 m AHD immediately upstream of the rail bridge across Breakfast/ Enoggera Creek (BCC Floodwise Property Search).

Flooding in the Breakfast/Enoggera Creek catchment generally results in relatively high velocity flows, with flooding typically occurring from rainfall events of much shorter duration than those that cause major flooding of the Brisbane River. As such, during flood events in the Breakfast/Enoggera Creek catchment, the Brisbane River is typically at a normal (tidal) level. This results in relatively steep flood gradients through the study corridor.

During major Brisbane River flood events, the Breakfast/Enoggera Creek floodplains act as a storage of floodwaters from the Brisbane River. These areas rise relatively slowly as the Brisbane River rises.

BCC flood mapping identifies the peak 1 in 100 AEP flood levels from the back-up of Brisbane River flood waters, as 2.6 m AHD in this part of the study corridor (BCC Floodwise Property Search).

The Project crosses the overland flowpath in the RNA Showgrounds.

Central (Spring Hill to Brisbane CBD)

The central section of the study area extends from Spring Hill to the Brisbane River, near the City Botanic Gardens (refer to **Figure 14-3**). Flooding in this part of the study area is potentially affected by the Brisbane River and local overland flow paths.

Flooding from the Brisbane River can result in inundation of parts of the Brisbane CBD, especially lower Albert Street. This can occur from the back-flow of floodwaters through the pipe drainage system surcharging into the City Botanic Gardens and surrounding area. During a Brisbane River flood event, rainfall on the CBD while the river is at or near peak levels can also result in ponding of water in the lower parts of the Brisbane CBD.

A number of local overland flow paths also traverse the study corridor in the CBD, which typically flow when the capacity of the underground pipe drainage system is exceeded. The frequency of overland flooding in the CBD is a function of the rainfall intensity, the degree of blockage of pits and the coincident tide level in the Brisbane River.

South (Kangaroo Point to Salisbury)

The southern part of the corridor extends from the Brisbane River to Salisbury (refer to **Figure 14-4** and **Figure 14-5**). Flooding in this section of the study area is potentially affected by:

- Brisbane River back-up causing inundation of floodplains
- Oxley Creek and tributaries
- local overland flow paths.

14.3 Potential impacts and mitigation

This section provides an assessment of potential impacts on flood behaviour from the construction and operation of the Project. The flood impact assessment has focussed on flood events up to and including the 1 in 100 AEP flood event. Changes to flood behaviour in the study area may result from:

- minor reductions of Brisbane River floodplain storage
- loss of flood conveyance and floodplain storage for Moolabin Creek, due to the worksite adjacent to the north bank of Moolabin Creek and construction of a new rail bridge across Moolabin Creek
- loss of flood conveyance for Rocky Waterholes Creek due to the construction of a new bridge across the creek
- loss of flood storage for Stable Swamp Creek due to raising of the Beaudesert Service Road.

As described in **Section 14.1.4**, the tunnel portals are situated well above the 1 in 100 AEP flood levels. All worksites and Project surface structures are located outside of the 1 in 100 AEP flood extents except for:

- culvert extension associated with southern surface works
- raising of Beaudesert Road Service Road, Salisbury
- Rocky Water Holes Creek bridge
- Clapham Rail Yard
- Moolabin Creek bridge
- Yeeroongpilly worksite
- Ventilation and emergency access building
- Albert Street Station
- Ekka Station.

Flooding has been considered in the design of these aspects of the Project and their potential impact on flooding assessed. Drainage structures are described in **Chapter 13 Surface Water Quality**.

Excess spoil from the Project is proposed to be transported to the Swanbank area and used to fill old mining voids. Spoil will not be placed in areas affected by flooding in the 1 in 100 AEP event and therefore will not impact on flooding behaviour in events up to and including the 1 in 100 AEP event.

14.3.1 Potential impacts

The following provides an assessment of potential impacts on flood behaviour of watercourses in the study area.

Breakfast/Enoggera Creek

Earthworks would be required in the Mayne Rail Yard for the construction of the new rail lines. Existing ground levels in this area are at least 4.0 m AHD. The 1 in 100 AEP flood levels in this area are approximately 3.4 m AHD for Breakfast Creek and 2.6 m AHD for the Brisbane River (BCC Floodwise Mapping).

The Project is not expected to change flood behaviour for Breakfast Creek during construction and operation, given that the proposed works for the additional rail embankment are above the 1 in 100 AEP flood level.

Under the adopted climate change scenario set out in **Section 14.1.3**, flood levels in Breakfast/ Enoggera Creek are predicted to increase by 0.8 m to 4.2 m AHD. Depending on the level of the infrastructure, this may result in a minor loss of flood storage in the 1 in 100 AEP flood event under the climate change scenario and is unlikely to result in any flood level increases or changes to flood behaviour. Detailed flood modelling would be required during the detailed design phase to ensure the Project infrastructure avoids potential flood impacts under the climate change scenario.

Campbell Street drain

The northern portal for the Project is located in an area with ground levels at approximately 19.5 m AHD and works are not proposed in the area subject to local flooding in the Campbell Street drain catchment.

The overland flow path of the Campbell Street drain catchment near to the northern portal has an elevation of approximately 14.5 m AHD and a width of more than 50 m. The depth of the overland flow path in a 1 in 100 AEP flood event is not expected to be more than 1 m. Surface works for the northern portal would not affect the overland flow path in this area during construction and operation.

Additional rail lines proposed adjacent to the current rail lines are also located well above the local overland flow path and so the flow path would not be adversely affected during construction and operation.

Within the RNA Showgrounds, the new rail bridge would cross a pedestrian underpass. The underpass is currently crossed by an existing rail bridge. The new rail bridge is proposed to be a similar height to the existing bridge above any potential overland flow through this pedestrian underpass. As such, the Project is not expected to impact on this overland flow path during construction and operation. The worksite within the RNA Showgrounds will include provision to maintain overland flows through the site.

The reconfiguration of O'Connell Terrace is not expected to affect the overland flow path because it is not located in a flood prone area.

The Campbell Street drain overland flow is also not expected to be affected under the climate change scenario set out in **Section 14.1.3**, as the Project will maintain the overland flow path currently in place.

Albert Street overland flow paths

The Project is not expected to change existing ground levels in lower Albert Street. As such, the Project would not affect the capacity or flood behaviour of overland flow paths in this area during construction and operation. Conveyance of the overland flow would also not be affected by the surface works in this area.

Tunnel

The tunnel would not change surface levels that are currently inundated by floodwaters in a 1 in 100 AEP flood event. Hence, the tunnel would not affect flood behaviour for flood events up to 1 in 100 AEP along the route.

Brisbane River

The Project would result in very minor reductions in the flood storage volume of large Brisbane River flood events at Rocklea, Clapham Rail Yard, Fairfield and Albert Street.

At Salisbury, filling would be undertaken to raise the Beaudesert Road Service Road north of Dollis Street to the level of Beaudesert Road. This is to allow emergency egress from the area during flood events via a gate to Beaudesert Road. Existing ground levels at this location vary between 6.1 m AHD and 10.6 m AHD. The Brisbane River flood level is approximately 7.2 m AHD. The filling of areas below 7.2 m AHD would remove a small volume of flood storage of the Brisbane River floodplain in the 1 in 100 AEP event.

At Rocklea, filling would be undertaken approximately 1 km south-east of Clapham Rail Yard where the rail alignment crosses the Brisbane River floodplain.

Existing ground levels at the western edge of the Clapham Rail Yard vary between 7.0 m AHD and 9.0 m AHD. The Project would require the rail yard to be raised to 9.5 m AHD. The Brisbane River flood level is approximately 7.0 m AHD in this area. The filling of land within the Clapham Rail Yard currently below 7.0 m AHD would remove a small volume of flood storage of the Brisbane River floodplain in the 1 in 100 AEP flood event.

A ventilation and emergency access building is proposed to be located between Sunbeam Street and Bledisloe Street in Fairfield. During construction and operation, the building would be designed to be protected from an extreme flood event ie 1 in 10,000 AEP flood event. This would remove a small volume from the available flood storage in a Brisbane River flood event.

While the entrances to the Albert Street Station would be raised, the Project is not expected to change existing ground levels in Albert Street.

Conveyance of the overland flow would also not be affected by the surface works in this area. The Albert Street Station would raise the station access points to 450 mm above street level to protect against local flooding. Any potential loss of floodplain storage would have minimal effect on flood levels.

The extent of inundation for smaller flood events such as the 1 in 20 AEP and 1 in 50 AEP flood events would not be affected by the Project. As such, this assessment is focussed on the 1 in 100 AEP flood event.

Changes to peak 1 in 100 AEP flood levels for the Brisbane River from a reduction in the flood storage area due to the Project, would not be greater than 0.01 m. In addition, the Project is not expected to affect flood velocities during a Brisbane River flood event, under the construction and operations phases.

A similar impact assessment was carried out for the 1 in 100 AEP Brisbane River flood event under the climate change conditions set out in **Section 14.1.3,** with higher rainfall intensities and higher sea levels. Under this scenario, the main area in the CBD which would experience an increase in flood level due to the Project would be the City Botanic Gardens, which would have an increase of up to 0.02 m. The filling of the Clapham Rail Yard and the rail embankment at Rocklea causes less than 0.01 m increase in flood level in their respective areas.

Oxley Creek

Project works are not located in the area subject to a 1 in 100 AEP flood event for Oxley Creek. As such, the Project would not change the flood behaviour for this creek during construction and operation.

An assessment of flood behaviour of Oxley Creek under the climate change conditions set out in **Section 14.1.3** was also undertaken. Works for the Project are not located within the flood extent for Oxley Creek under climate change conditions. Therefore, it would not change flood behaviour for this creek.

Moolabin Creek

The following provides an assessment of the Project's impacts on flooding in Moolabin Creek during the 1 in 5 AEP, 1 in 20 AEP and 1 in 100 AEP flood events.

Construction

Construction of the Project includes a bund at the Yeerongpilly worksite adjacent to Moolabin Creek to prevent floodwater in a 1 in 20 AEP flood event from entering the worksite. The bund would be located outside the waterway and on industrial land. For the purposes of this assessment, it is assumed that the bund at the Yeerongpilly worksite would be in place for the five and a half year duration of construction works. The bund would be removed following the completion of construction activities. Potential flood impacts from the construction of the bund at 1 in 5 AEP, 1 in 20 AEP and 1 in 100 AEP flood events are presented in **Figure 14-6**, **Figure 14-7** and **Figure 14-8** respectively.

Changes to flood levels in a 1 in 5 AEP flood event are expected to be negligible (less than 0.01 m). A 1 in 5 AEP flood event is likely to occur during the construction period given the duration of construction.

In a 1 in 20 AEP flood event, changes in flood levels are expected to be in the order of 0.04 m, while potential changes to flood levels would be in the order of 0.09 m in a 1 in 100 AEP flood event. The probability of experiencing a 1 in 100 AEP flood event during the construction period is approximately 5.5%.

Two commercial/industrial buildings are potentially affected by changes to flooding from the proposed construction bund. It is predicted that these properties would experience an increase in water level during a 1 in 100 AEP flood event of about 0.09 m. Changes in water level would be approximately 0.04 m during a 1 in 20 AEP flood event and 0.01 m during a 1 in 5 AEP flood event. Consultation would be undertaken to discuss mitigation options, such as compensation or a temporary relocation of the premises during construction.

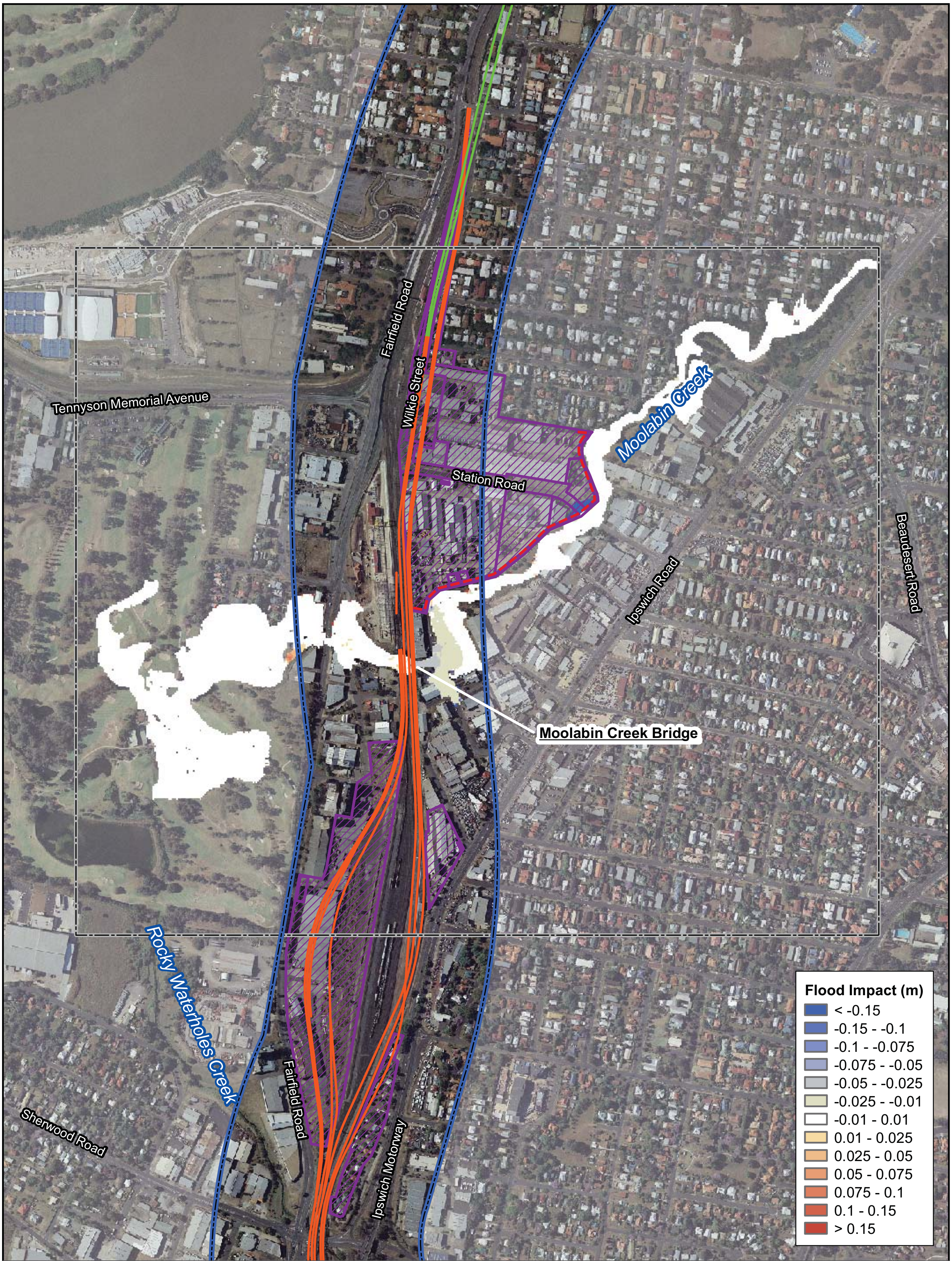
Flood velocities in Moolabin Creek are not expected to be affected during a 1 in 100 AEP flood event.

Section 11.3.4 of **Chapter 11 Nature Conservation** describes mitigation measures for the rehabilitation of Moolabin Creek following construction.

Operation

The assessment of potential flood impacts associated with the operation of the Project considered an additional 12 piers in the floodplain for a new rail bridge, of which one pier would be located in the waterway. The design level for the rail bridge is approximately 9 m AHD. An existing bridge would also be removed.

The additional piers are expected to have a negligible impact on peak flood levels for the 1 in 5 AEP, 1 in 20 AEP and 1 in 100 AEP flood events, with changes to peak flood levels expected to be less than 0.01 m. Modelling for the Project also suggests that changes to flood velocities from the Project would be negligible.



LEGEND

Study Corridor

Model Area

Construction Bund

Worksites

Alignment

Above Ground

Underground

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-6

Moolabin Creek Flooding 1 in 5 AEP Flood Event Construction Impacts

0 100 200 300 400 m

N

1:10,000 at A4

CrossRiverRail

SKM aurecon
CRR JOINT VENTURE

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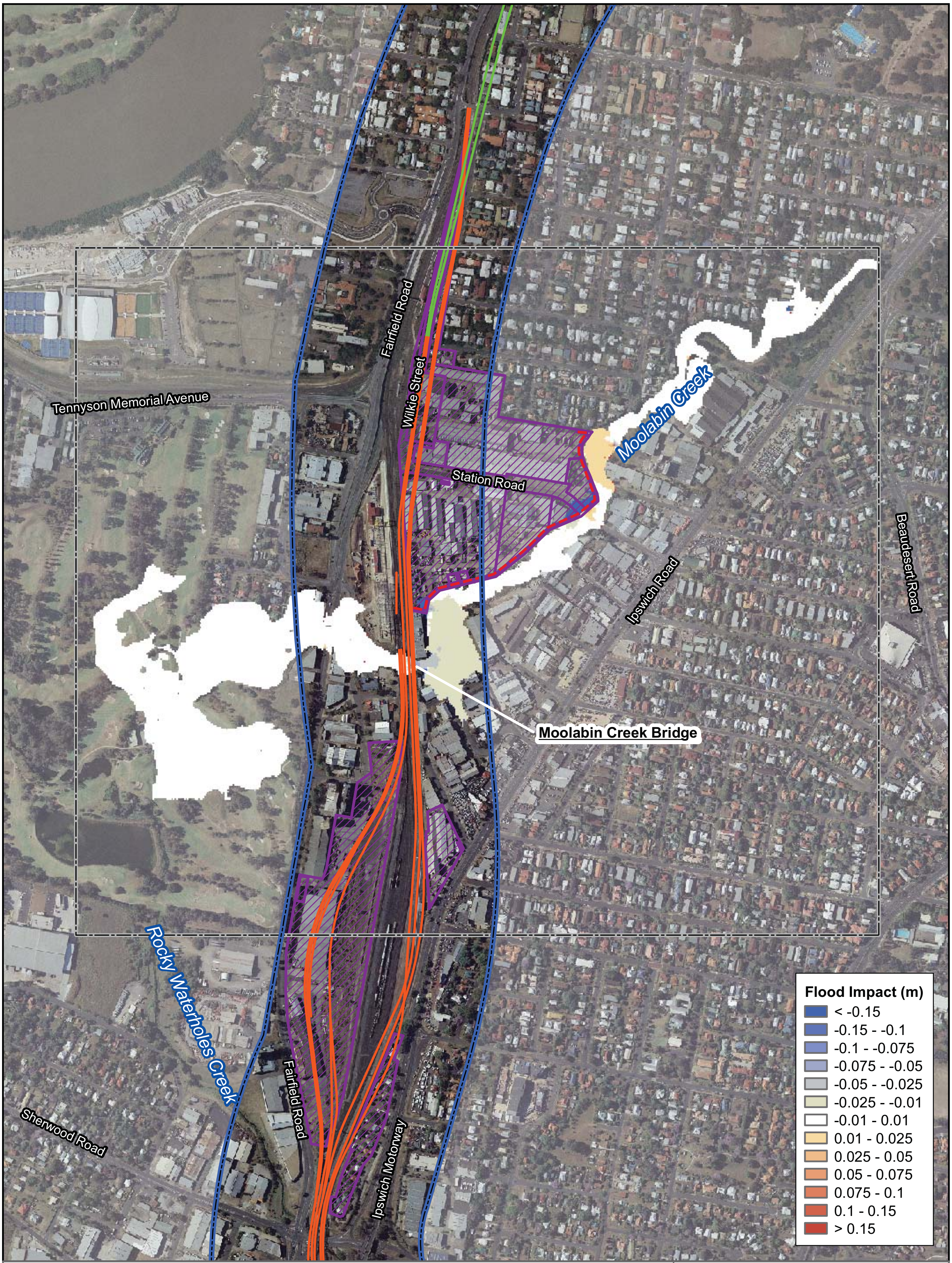

LEGEND

- Study Corridor
- Model Area
- Construction Bund
- Worksites

Alignment

- Above Ground
- Underground

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-7

Moolabin Creek Flooding 1 in 20 AEP Flood Event Construction Impacts

0 100 200 300 400 m

1:10,000 at A4

CrossRiverRail

SKM aurecon CRR JOINT VENTURE

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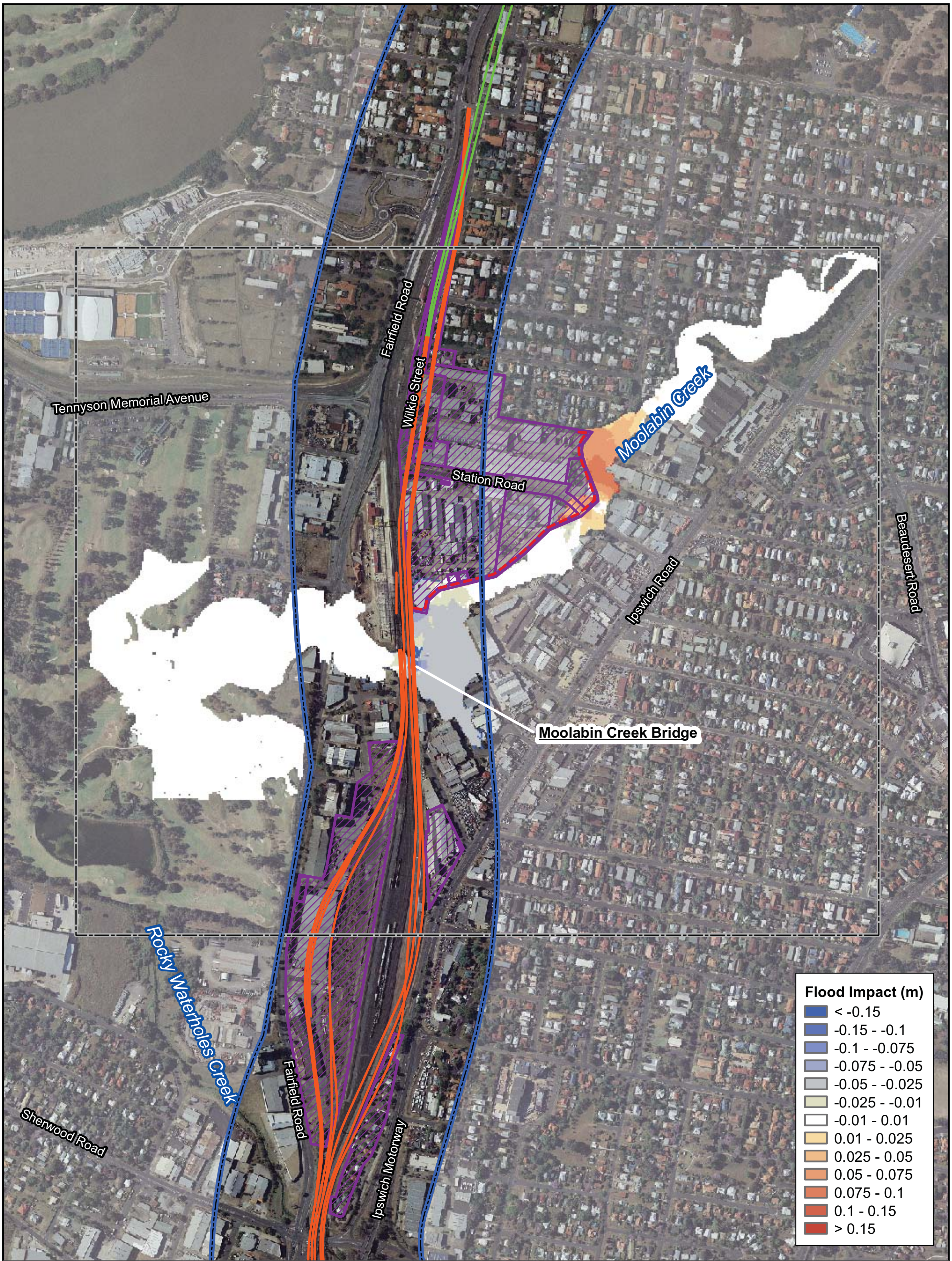

LEGEND

- Study Corridor
- Model Area
- Construction Bund
- Worksites

Alignment

- Above Ground
- Underground

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-8

Moolabin Creek Flooding 1 in 100 AEP Flood Event Construction Impacts

0 100 200 300 400 m

N

1:10,000 at A4

CrossRiverRail

SKM aurecon CRR JOINT VENTURE

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An assessment of flood behaviour of Moolabin Creek under the climate change conditions set out in **Section 14.1.3** was also conducted. There are not expected to be any impacts to flood depths under the climate change scenario.

An assessment was also undertaken to determine changes to velocities that may affect movement of aquatic fauna. This assumed a bank-full flood event for a 1 in 5 AEP flood event. As such, the change in pier area would be the change in waterway area. The increase in velocity resulting from the additional pier in the waterway is 1.6%. This would have a negligible impact on the movement of aquatic fauna.

Rocky Waterholes Creek

The Project would involve the construction of eight additional piers across Rocky Waterholes Creek for a new rail bridge. The design level of the bridge is approximately 10.7 m AHD.

Potential changes to peak flood levels for the 1 in 5 AEP, 1 in 20 AEP and 1 in 100 AEP flood events for Rocky Waterholes Creek are shown in **Figure 14-9**, **Figure 14-10** and **Figure 14-11** respectively.

It is predicted that the peak flood levels on Muriel Avenue would increase by 0.09 m in a 1 in 5 AEP flood event. In a 1 in 20 AEP flood event, flood levels on Muriel Avenue would increase by 0.08 m. The proportional reduction in flow area due to the Project (additional piers) would be larger in smaller events. Hence, the impacts to flood levels would be larger for smaller events.

These changes would result in an increase in peak flood levels of up to 0.015 m (15 mm) in a 1 in 5 AEP flood event and up to 0.02 m in a 1 in 20 AEP flood event for one private industrial property located east of Ipswich Road. This property currently experiences regular inundation, eg at least every five years. There are no structures currently located on the site.

During construction and operation, flood levels in Rocky Waterholes Creek are predicted to increase by up to 0.04 m at Muriel Avenue for a 1 in 100 AEP flood event under existing climate conditions, in comparison to 0.03 m under adopted climate change conditions set out in **Section 14.1.3**. The Project is not expected to increase flood levels on private property in this area for the 1 in 100 AEP or result in noticeable changes to flood velocities in the creek.

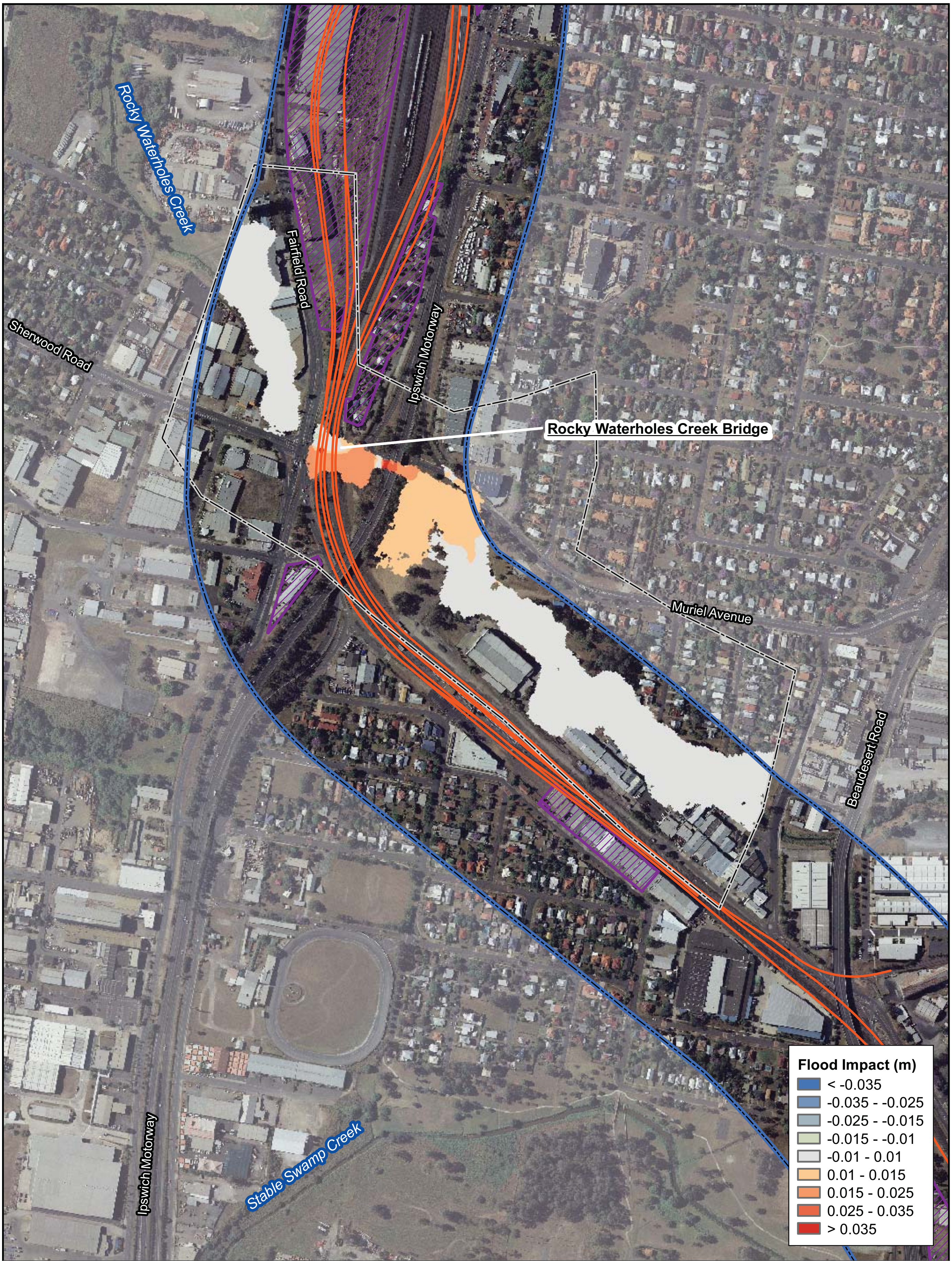
It is predicted that changes to the rate of rise and fall of floodwater is expected to be minimal during construction and operation. In the 1 in 100 AEP flood event, inundation at Muriel Avenue is expected to occur less than two minutes earlier with the Project, while the delay to re-opening the road on the recession of the floodwaters would also be less than two minutes. Overall, it is predicted that the Project would not change the duration of inundation of Muriel Avenue by more than three minutes.

An assessment was also undertaken to determine changes to velocities that may affect movement of aquatic fauna. This assumed a bank-full flood event for the 1 in 5 AEP flood event. With the Project, the change in waterway area would be limited to the change in area from the piers. The increase in velocity resulting from the additional eight piers in the waterway was 3%. This would have a negligible impact on aquatic fauna movement during the Project's construction and operation.

Stable Swamp Creek

At Salisbury, filling would be undertaken to raise the Beaudesert Road Service Road north of Dollis Street to the level of Beaudesert Road. This is to allow emergency egress from the area during flood events via a gate to Beaudesert Road. Existing ground levels along the proposed Service Road alignment vary between 6.1 m AHD and 10.6 m AHD.

The Stable Swamp Creek flood level is approximately 6.2 m AHD. Therefore, the Project will cause a minor reduction in floodplain storage in Stable Swamp Creek. It is not expected that this will change flood levels in this creek.



LEGEND

- Study Corridor
- Model Area

Alignment

- Above Ground
- Underground
- Worksites

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-9

Rocky Waterholes Creek Flooding 1 in 5 AEP Flood Event - Operational Impacts

0 100 200 300 m

1:7,500 at A4

CrossRiverRail

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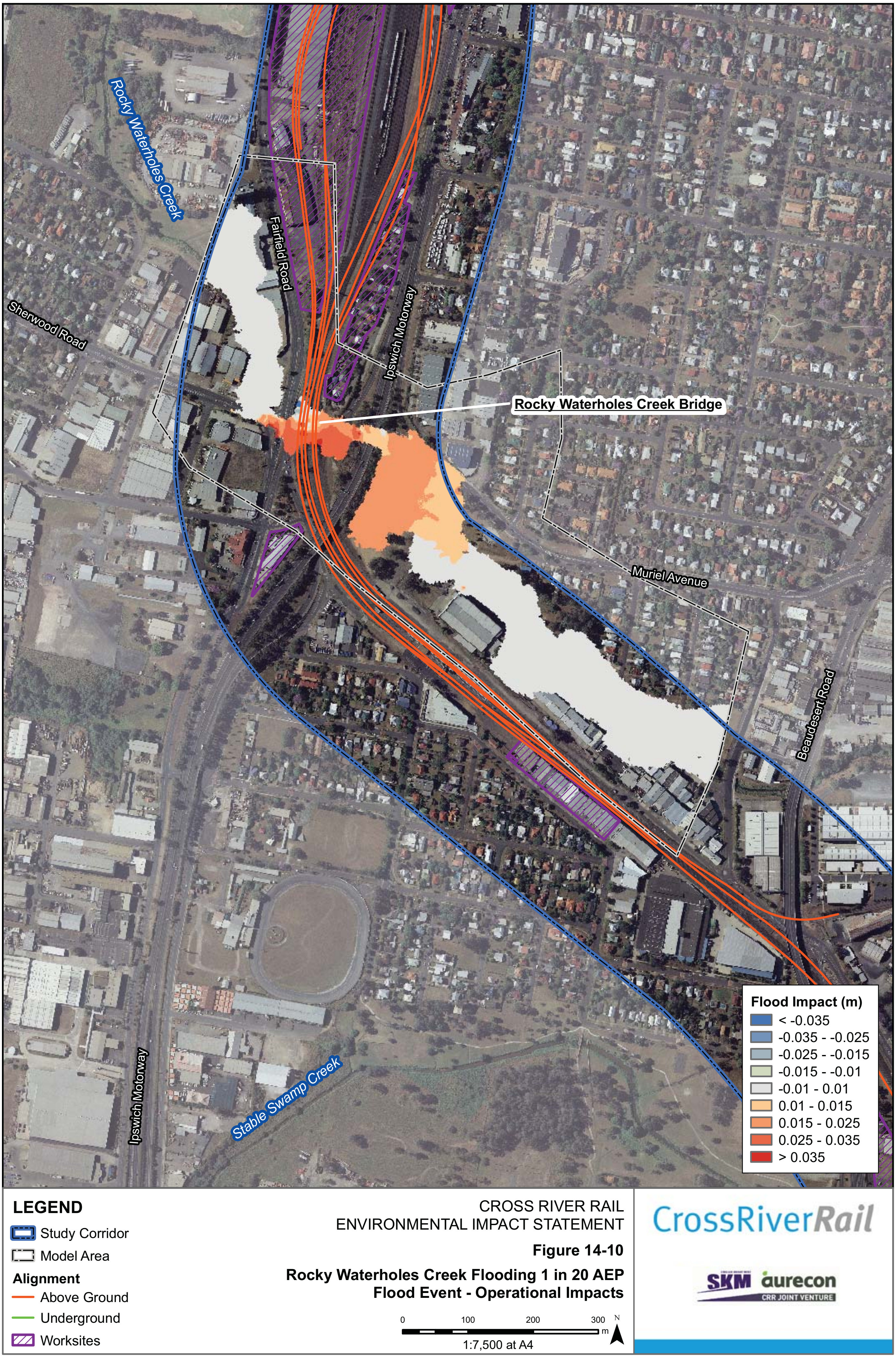

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-10

Rocky Waterholes Creek Flooding 1 in 20 AEP Flood Event - Operational Impacts

CrossRiverRail

SKM aurecon CRR JOINT VENTURE

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LEGEND

Study Corridor

Model Area

Alignment

Above Ground

Underground

Worksites

CROSS RIVER RAIL
ENVIRONMENTAL IMPACT STATEMENT

Figure 14-11

Rocky Waterholes Creek Flooding 1 in 100 AEP Flood Event - Operational Impacts

0 100 200 300 m

N

1:7,500 at A4

CrossRiverRail

SKM aurecon CRR JOINT VENTURE

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Minor culvert crossings

The Project would require the extension to minor culvert cross-drainage infrastructure in some locations at the north and south of the study corridor to accommodate the widened rail embankments. These crossings would be designed in accordance with the appropriate standards such as the Queensland Urban Drainage Manual (DNRW 2007). The design principles which would be followed include:

- maintaining flood immunity of the existing rail lines
- ensuring no flood impacts on adjacent private property and community infrastructure.

14.3.2 Mitigation measures

A number of mitigation measures are proposed to address potential impacts associated with changes to flooding in the study area. Only those Project components where there are possible impacts under construction and/or operation phases have been modelled or mapped.

The following is a summary of mitigation measures included in the reference design:

- where culverts are required to be extended to accommodate Project infrastructure and a wider rail corridor, these would be designed to ensure no increase in upstream flood levels
- where changes to the road network require changes to local roads, these would be designed to ensure no reduction in the floodplain storage.

In addition to these mitigation measures, the following measures are proposed relevant to specific waterways:

- consultation would be undertaken with the owners of two properties which are likely to experience flooding from Moolabin Creek due to the construction bund to discuss mitigation options temporary relocation of the business operations during construction. Appropriate mitigation measures would be developed and implemented informed by this consultation.
- consultation would be undertaken with the owner of the property expected to be affected in the 1 in 5 AEP and 1 in 20 AEP flood events for Rocky Waterholes Creek during construction and operation of the Project to discuss mitigation options. Mitigation measures would be developed and implemented informed by this consultation.

The reference design flood protection measures as set out in **Section 14.1.4** would provide flood immunity to the tunnel and stations for different flood events. **Chapter 24 Draft Outline EMP** describes measures to minimise impacts on the existing flood regime of waterways and flood monitoring during construction.

14.4 January 2011 Flood in Brisbane River

The Brisbane River experienced a major flood event in mid-January 2011. The January 2011 flood resulted in a peak flood level at the Port Office gauge of approximately 4.46 m AHD. This is higher than the flood level for the DFE (peak flow of 6.8 m^3/s), but is comparable with the DFE under a climate change scenario. This scenario is accommodated by the reference design.

In the January 2011 flood, there were some sections of the proposed alignment that flooded while the majority of the alignment was unaffected. The main areas affected were:

- the western portion of rail embankment at Clapham Rail Yard
- Moolabin Creek rail crossing and Yeerongpilly worksite
- Fairfield, including the vicinity of the ventilation and emergency access building in Railway Road
- Albert Street adjacent to the proposed station location.

The existing rail crossing of Moolabin Creek was affected by flood waters to an estimated level of 8.6 m AHD. The proposed crossing of Moolabin Creek is designed at a level of approximately 9.0 m AHD or about 0.4 m clear of the January 2011 flood event.

A part of the proposed Yeerongpilly worksite was flooded in the January 2011 floods in addition to the rail crossing of Moolabin Creek. The worksite would be developed to the height of the 1 in 20 AEP local creek flood level (10.47 m AHD), well above the estimated level for the January 2011 flood of approximately 8.6 m AHD.

The proposed Albert Street Station would have an entry level at RL 4.45 m and would incorporate floodgates in its design. The floodgates would be designed to withstand a 1 in 10,000 AEP event. Had the Albert Street Station been in place in January 2011, normal operating procedure would have required the floodgates to be activated before the peak levels were reached and would have protected the station from inundation. While the station entry would have been closed off in that event, the Project would have been protected from inundation and would have remained available for operation.

14.5 Summary

Detailed design

A range of flood protection measures have been incorporated into the reference design. These measures include flood immunity for the tunnel and underground stations for a range of flooding events. Other protection measures include dedicated automated flood gates at each of the major entry points to Albert Street Station and at the southern portal to protect against extreme flood events.

In addition to the flood protection measures included in the reference design, the detailed design would address potential impacts associated with flooding, including the appropriate sizing of culverts to ensure no increases in upstream flood levels.

The tunnel portals are situated well above the 1 in 100 AEP flood levels and would not impact on flood behaviour in the study area.

Construction

Proposed construction activities upstream of the existing rail bridge at Moolabin Creek are predicted to increase flood levels by about 0.09 m in a 1 in 100 AEP flood event and 0.04 m in a 1 in 20 AEP flood event. Potential changes to current flood levels during a 1 in 5 AEP flood event would be negligible.

Mitigation measures have been identified to minimise potential flooding risks during the construction phase and would be incorporated within the draft outline EMP. These include the construction of bunds or raising ground levels to protect worksites from flooding, thereby ensuring equipment, materials and storage areas are stored above the predicted flood levels. Construction of these bunds or raising of ground levels may cause temporary impacts on flooding. These impacts have been assessed in the EIS and generally found not to impact on private property or community infrastructure. Where there is a potential impact on private property, consultation would be undertaken to determine the mitigation strategy to be implemented.

Operation

At Rocky Waterholes Creek, the Project is predicted to result in minor increases in flood levels at Muriel Avenue. The maximum impacts on the road are up to 0.04 m in a 1 in 100 AEP event, 0.09 m in a 1 in 20 AEP, and 0.08 m in a 1 in 5 AEP flood event. One private property is affected by changes to flooding at Rocky Waterholes Creek, with impacts up to 0.02 m in the 1 in 20 AEP flood event and 0.015 m in the 1 in 5 AEP flood event. This property currently experiences regular inundation eg at least once every five years. There are no structures currently located on the site. With the Project, Muriel Avenue is predicted to be closed for an additional three minutes during a 1 in 100 AEP flood event.

Changes to peak 1 in 100 AEP flood levels for the Brisbane River from a reduction in the flood storage area due to the Project, would not be greater than 0.01 m. In addition, the Project is not expected to affect flood velocities during a Brisbane River flood event. Under climate change conditions, the minor reductions in floodplain storage would not result in increases to flood levels greater than 0.01 m, apart from part of the City Botanic Gardens which is predicted to experience impacts up to 0.02 m.

The remainder of the Project is not expected to have any discernable impact on flood behaviour.

The flood assessment has determined that the Project is not expected to significantly impact on the current flood behaviour of waterways in the study area. Changes in flood levels and velocities in waterways are predicted to be negligible. Under climate change scenarios, the impact of the Projects infrastructure on flooding would be similar to potential impacts under current climate conditions.

14.5.2 Residual effects

With mitigation, the residual effects of the Project during construction are predicted to be low over the short term. The residual effects on flood management during operation are also predicted to be low over the long term.

Flood modelling has been carried out in order to identify and quantify the impact of the Project on flood behaviour of watercourses in the study area. The potential for climate change to affect flood levels has also been examined.

The Project is not expected to significantly impact on current flood behaviour in the study area.