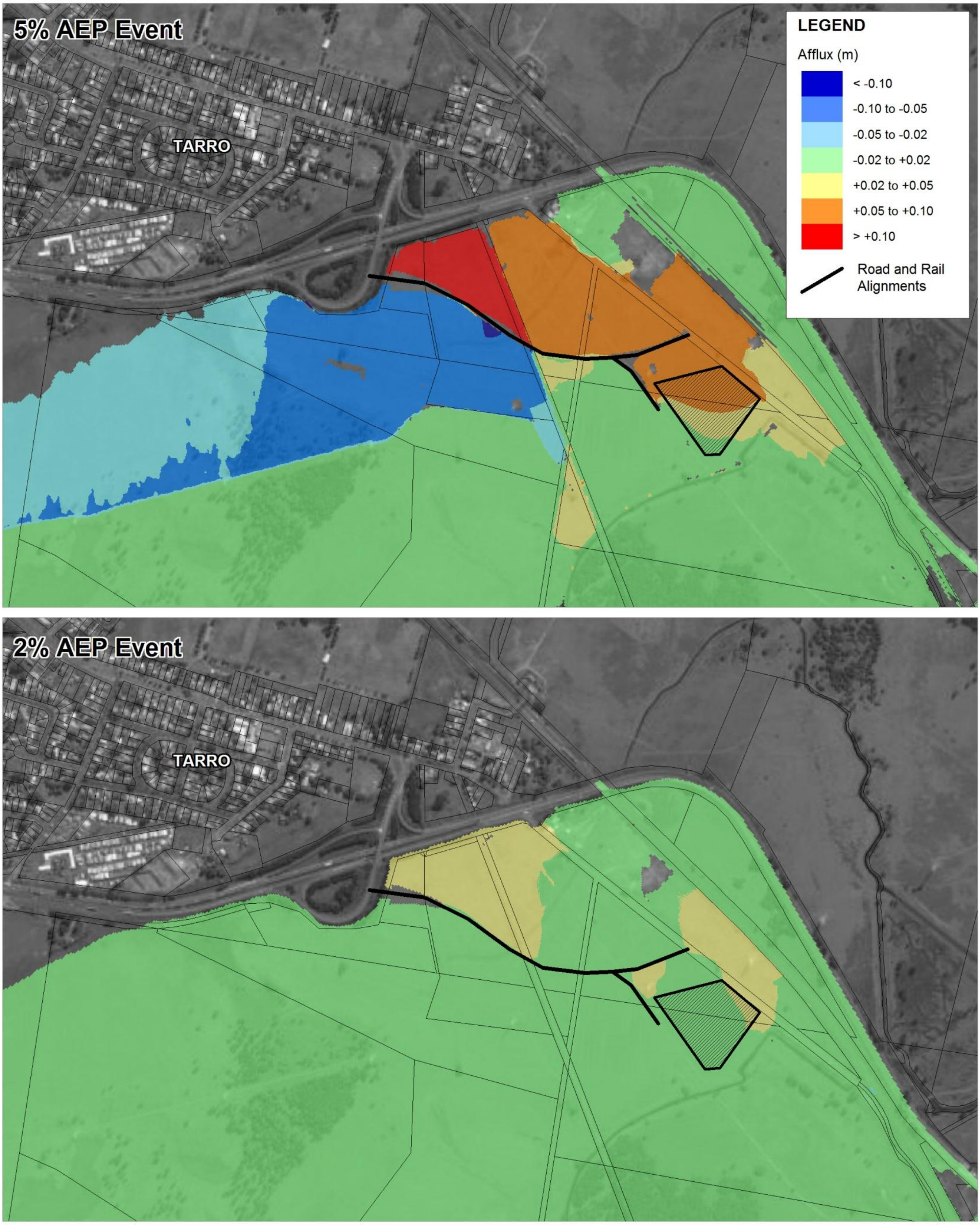


Title:

Impact of Temporary Access Works on Peak Flood Levels

Figure: 5-9

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 250 500m

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2335_QR_Hexham_Train_Support_Facility\MapInfo\Workspaces\DRG_060_130205_Temporary_Access_h_Impact.WOR

6 F3 UPGRADE

6.1 Description

The NSW Roads and Maritime Service (RMS) is proposing to upgrade the Pacific Highway from the F3 Freeway, south of John Renshaw Drive to the Raymond Terrace bypass, north of Heatherbrae. The freeway extension would be approximately 13 km long and follow a route that crosses the Hunter River and associated floodplain. A separate flood impact assessment has been undertaken by BMT WBM (2011) to determine the potential flood impacts associated with the proposed F3 upgrade. The focus of the current investigation is to assess the cumulative flood impacts of the proposed works and F3 Upgrade.

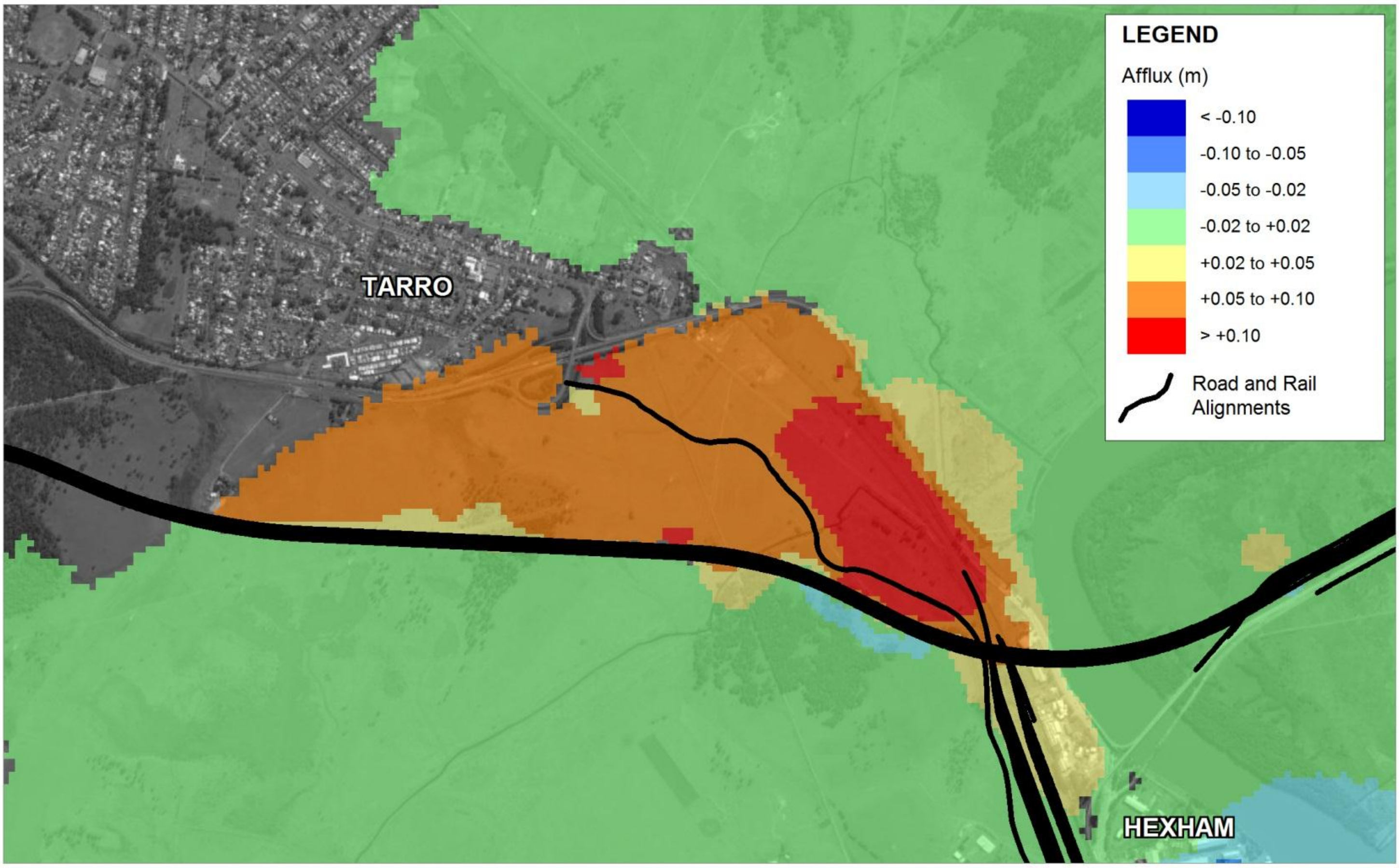
The design details for the preferred route option of the road upgrade were incorporated into the TUFLOW model of the Lower Hunter as part of the study for the Roads and Traffic Authority in 2011. The road levels have been designed to be flood free in the 5% AEP event, with flood impacts at the 1% AEP event reduced to acceptable standards through the provision of adequate flood flow cross drainage. The details of the design that were incorporated into the TUFLOW model for the 2011 study have also been included in this study to assess the cumulative impacts on regional Hunter River flooding. This includes road crest elevations, bridge and culvert details.

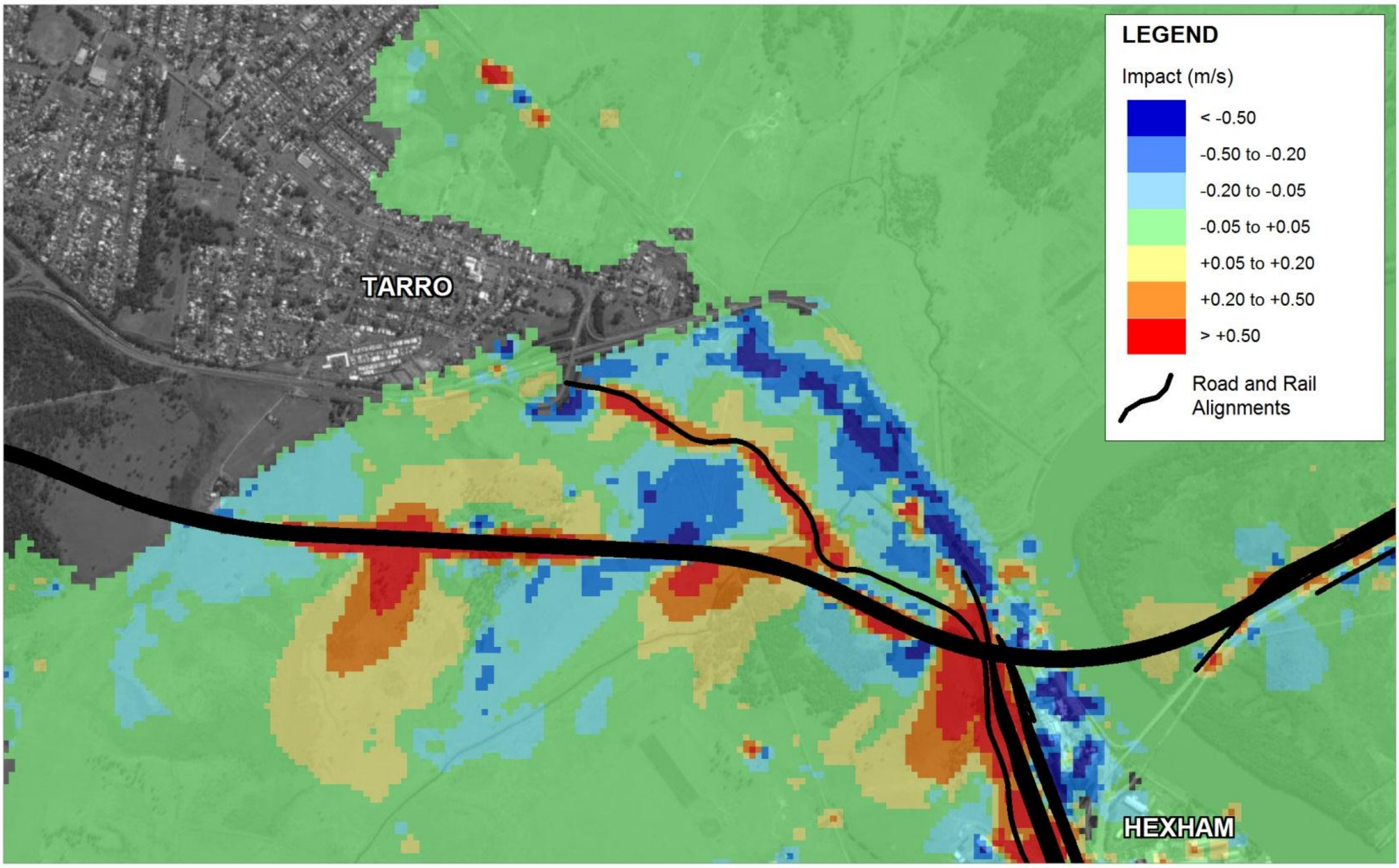
6.2 Cumulative Impacts

The cumulative flood impacts of the proposed works and the F3 upgrade have been modelled for the 1% AEP event. The cumulative impacts on peak flood level and velocity are presented in Figure 6-1.

The proposed F3 level sits higher than the proposed access road level, and accordingly it is the F3 embankment which becomes the critical control on peak flood levels upstream. The impact of the proposed access road is effectively drowned out, such that the increases in peak flood levels are largely attributed to the F3 embankment. This condition is evident when looking at the extent of afflux, which extends from upstream of the proposed F3 alignment.

The cumulative impacts of the proposed works and the F3 upgrade are expected to be refined in future design iterations of the F3 upgrade. In this regard, the F3 design would be anticipated to further consider the location of appropriate cross drainage to better align with the flow distribution through/across the access road and taking account of the local topographic controls. This may provide for further reduction in the relative flood impacts.





Title:

Cumulative Impact of Proposed Works and F3 Upgrade on Peak 1% AEP Flood Conditions with Flood Mitigation

Figure: **6-1**

Rev: **A**

N

0 0.5 1km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2335_QR_Hexham_Train_Support_Facility\MapInfo\Workspaces\DRG_058_130205_1%AEP_F3_Impact.WOR

7 CLIMATE CHANGE CONSIDERATIONS

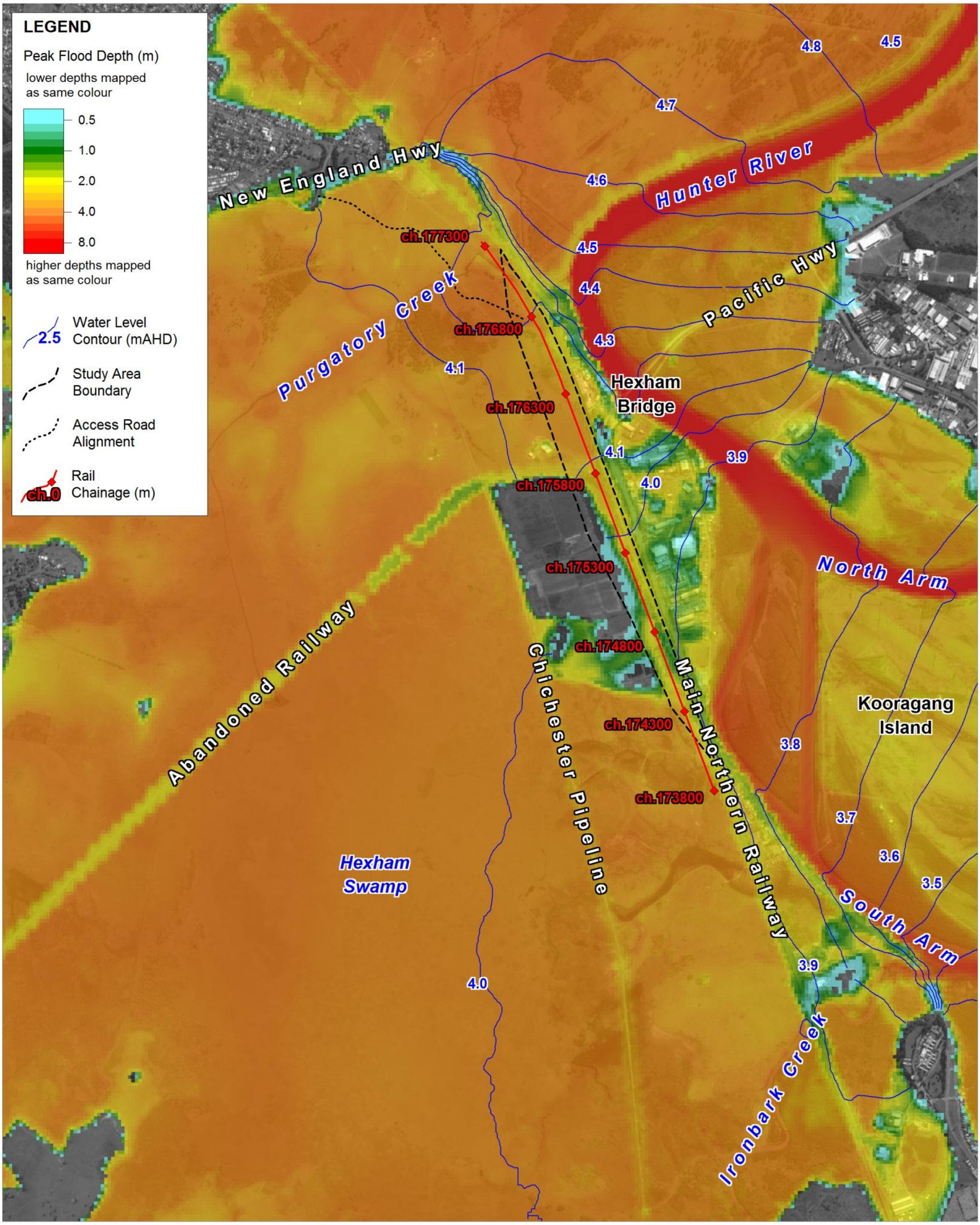
The NSW Government recently adopted sea level rise planning benchmarks to ensure consistent consideration of sea level rise in coastal areas of NSW. These planning benchmarks are an increase above 1990 mean sea levels of 0.4m by 2050 and 0.9m by 2100.

To assess the impact these sea level rise scenarios have on the proposed development a sensitivity test on the 1% AEP design event has been undertaken incorporating a 0.9m increase in water level conditions at Newcastle Harbour (model boundary).

Typically climate change sensitivity tests also consider increases in design rainfall intensity of 10%, 20% or 30% in accordance with DECCW Practical Consideration of Climate Change Guideline for Floodplain Risk Management (2007). An increased rainfall intensity of 10% has been considered for this study, represented as direct increases to the inflow hydrographs, to assess the potential impacts on flood conditions at the development site.

The baseline flood condition at the 2100 planning horizon is shown in Figure 7-1. Typically the increase in peak flood level local to the development site is over 0.4m, raising peak flood levels to around 4.1m AHD.

The proposed works would broadly have similar impacts under future flood condition scenarios incorporating climate change. The design mitigation solutions are such that they effectively maintain the same flow distributions as existing conditions across the full range of design events. The broad flood behaviour locally in the Hexham area will be similar under climate change scenarios, though the frequency of particular magnitude events may change. Nevertheless, in effectively maintaining existing flow distributions, the performance of the mitigated design solution holds across the full range of design events, including future events incorporating potential climate change impacts.



Title:

1% AEP Peak Flood Depths and Levels - 0.9m Sea Level Rise to 2100 and 10% Increase in Design Rainfall

Figure: 7-1

Rev: B

N

0 0.5 1km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2335_QR_Hexham_Train_Support_Facility\MapInfo\Workspaces\DRG_022_120814_1%AEP_CC2100_Depths.WOR

8 FLOOD EMERGENCY RESPONSE MANAGEMENT

A Flood Emergency Response Strategy was prepared for the site as part of the original Flood Impact Assessment by WorleyParsons (2011). This strategy has been reproduced in this section. However, certain elements of the original strategy have been modified where appropriate, due to the revised nature of the development and to be consistent with other information presented within this report.

As outlined in the preceding sections, the site that QR National plans to develop at Hexham is located within the floodplain of the lower Hunter River. As a result, there is potential for floodwaters to inundate the QR National site and the surrounding land. In severe floods the depth of inundation across surrounding lands can be substantial. In addition, floodwaters could be at elevated levels for several days. Hence, there is potential for future employees of the Train Support Facility, to be exposed to an increased risk during times of major flooding.

Employee numbers at the Train Support Facility are expected to increase from 10 to around 30 once fully operational. Accordingly, there is a need to recognise that major flooding of the Lower Hunter River and severe floods like the 1955 flood, could present emergency management issues for QR National. Although these developments will be above the predicted peak level for the 2% AEP flood, provisions will need to be made to cater for rarer floods up to the Probable Maximum Flood (PMF). The PMF is the largest flood that could conceivably occur and is of the order of the 0.001% AEP event or greater.

One way of reducing the flood risk is to develop and implement a Flood Emergency Response Plan (FERP). The primary objective of a FERP is to reduce the threat that floods pose to the safety of people living and/or working on or adjacent to flood affected land.

A flood emergency response plan typically consists of the following distinct processes:

- Identification of areas at risk to flooding;
- Forecasting the time, arrival and height of the flood peak;
- Dissemination of warnings to flood prone property owners;
- Flood awareness and education of staff;
- Evacuation of people from areas at risk from flooding; and
- Recovery in the flood aftermath.

From a floodplain and river-wide perspective, these processes are the responsibility of local Councils, the State Emergency Services (SES) and the Bureau of Meteorology.

However, where new development is proposed in areas exposed to high hazard, local and state governments are encouraging individual developers to act independently to minimise their risks due to flooding. Accordingly, it is appropriate for QR National to consider the risks that future employees of the Train Support Facility could be exposed to and to ensure that a mechanism is in place to reduce that risk.

8.1 Background Information

8.1.1 Flood Behaviour in the Hexham Area

Contemporary flood behaviour in the Lower Hunter Valley is influenced by the levees and structures that form part of the Lower Hunter Valley Flood Mitigation Scheme. Higher frequency floods up to the 20% AEP event are generally contained within the river's banks and the levees that form the flood mitigation scheme. As flood severity increases, floodwaters overtop the natural and man-made levees, discharging into low lying storage areas (i.e. backwater swamps) via levee spillways and control banks. During floods larger than the 20% AEP event, floodwaters discharge to floodplain storage areas across spillways located within the levee system.

Hexham is situated on the southern banks of the Hunter River between the main river channel and Hexham Swamp (refer Figure 1-1). During the notorious 1955 flood, floodwaters entered the Swamp across the New England Highway (then Maitland Road) between Hexham Bridge and Tarro. Computer based flood modelling has since confirmed that this flowpath is a major floodway during large floods. The distribution of floodwaters in the Hexham area during a 1% AEP flood (i.e. a 1955 type flood) is shown in Figure 2-2.

Although the New England Highway in the Hexham area has been raised over the last 50 years or so, this floodway has been maintained. Newcastle City Council has dedicated this low lying land between Hexham and Tarro as a flood reserve, classified as floodway in Council's City-wide Floodplain Risk Management Study and Plan (2012)

Nonetheless, floodwaters that overtop the river's banks are not necessarily contained within the defined floodway. In large floods, floodwaters spill out across the floodplain filling Hexham Swamp. In these circumstances, Hexham Swamp, Kooragang Island and Longbight Swamp resemble an inland sea, and most of the existing development in the Hexham area is likely to be at least partly inundated.

In major floods water levels remain in the overbank areas for at least 72 hours. In February 1955, floodwaters reached depths of 4 metres over the floor of the Australian Co-operative Foods plant at Hexham (also known as the Oak Milk Factory), and the Hexham area remained isolated for several days (Hawke, 1958).

8.1.2 Flood Levels

8.1.2.1 Historical Floods

As discussed, the Lower Hunter River, and in particular, the Hexham area, has a long history of flooding. The major floods that have occurred in the Hunter over the last 50 years are listed in Table 8-1, along with the corresponding peak water level at Hexham, and the estimated annual exceedance probability for each event.

The largest flood at Hexham since completion of the Lower Hunter Flood Mitigation Scheme occurred in 1978. This flood reached a peak water level at Hexham of about 2.0m AHD.

Table 8-1 Characteristics of Historical Floods at Hexham

Year of Flood	Peak Water Level at Hexham (m AHD)	Approximate Flood Probability at Hexham
1955	3.8	1% AEP
1971	1.6	>10% AEP
1972	1.6	>10% AEP
1977	1.8	10% AEP
1978	2.0	>5% AEP
1985	1.6	>10% AEP
1990	1.6	>10% AEP
2007	1.7	>10% AEP

8.1.2.2 Design Floods

Peak flood levels at Hexham for floods of varying degrees of severity are listed in Table 8-2.

Table 8-2 Design Flood Levels for Hexham

Design Flood	Peak Flood Level at Hexham Bridge (m AHD)
PMF	8.0
1% AEP	3.8
2% AEP	2.9
5% AEP	2.3
10% AEP	1.9

8.1.3 Potential Flooding Mechanisms

8.1.3.1 Historical Floods

Based on the history of flooding in the Hexham area, there are two potential flooding mechanisms that could cause inundation of the QR National development site. These are:

- Overtopping of the banks of the Hunter River upstream of Hexham Bridge and discharge across the New England Highway and into Hexham Swamp; and
- Backwater flooding due to filling of Hexham Swamp by floodwaters overtopping the Pacific Highway downstream of Hexham Bridge.

8.1.3.2 Bank Overtopping During Mainstream Flooding

Flooding at Hexham would typically be due to mainstream Hunter River floods overtopping the river bank upstream of Hexham Bridge. As discussed above, floodwaters from the Hunter River flow in a south-westerly direction towards the New England Highway where they cross the floodplain between Tarro and Hexham.

Investigations into the impact of raising the level of the New England Highway between Tarro and Hexham established that the road, which is higher than the general level of the floodplain, controls the discharge of floodwaters south from the Hunter River into Hexham Swamp. The Main Northern Railway, which is located about 100 metres west of the New England Highway in this area, acts as a secondary control on floodwaters entering the Swamp.

Longitudinal profiles of the New England Highway between Hexham and Tarro indicate that the low point in the road is located about 900 metres north of Hexham Bridge (see Figure 8-1). Available RTA drawings indicate that the road crest at this low point is at an elevation of around 2.1 mAHD.

Therefore, the Hunter River immediately upstream of Hexham Bridge, would begin to overtop the New England Highway once floodwaters reached an elevation of about 2.1 mAHD (see Figure 8-1).

Based on the design flood levels listed in Table 8-2, a flood slightly more severe than the 10% AEP event at Hexham would be required to cause overtopping of this section of the New England Highway. Nonetheless, for the purposes of emergency response planning, it can be conservatively assumed that a 10% AEP flood is required before overtopping of the highway upstream of Hexham Bridge, would occur.

8.1.3.3 Backwater Overtopping During Mainstream Flooding

Hexham Swamp can also be flooded when the Pacific Highway south of Hexham Bridge is overtopped. This would require the swampland between the Pacific Highway and the Great Northern Railway to fill and floodwaters to 'back-up' upstream, leading to inundation of the Hexham area.

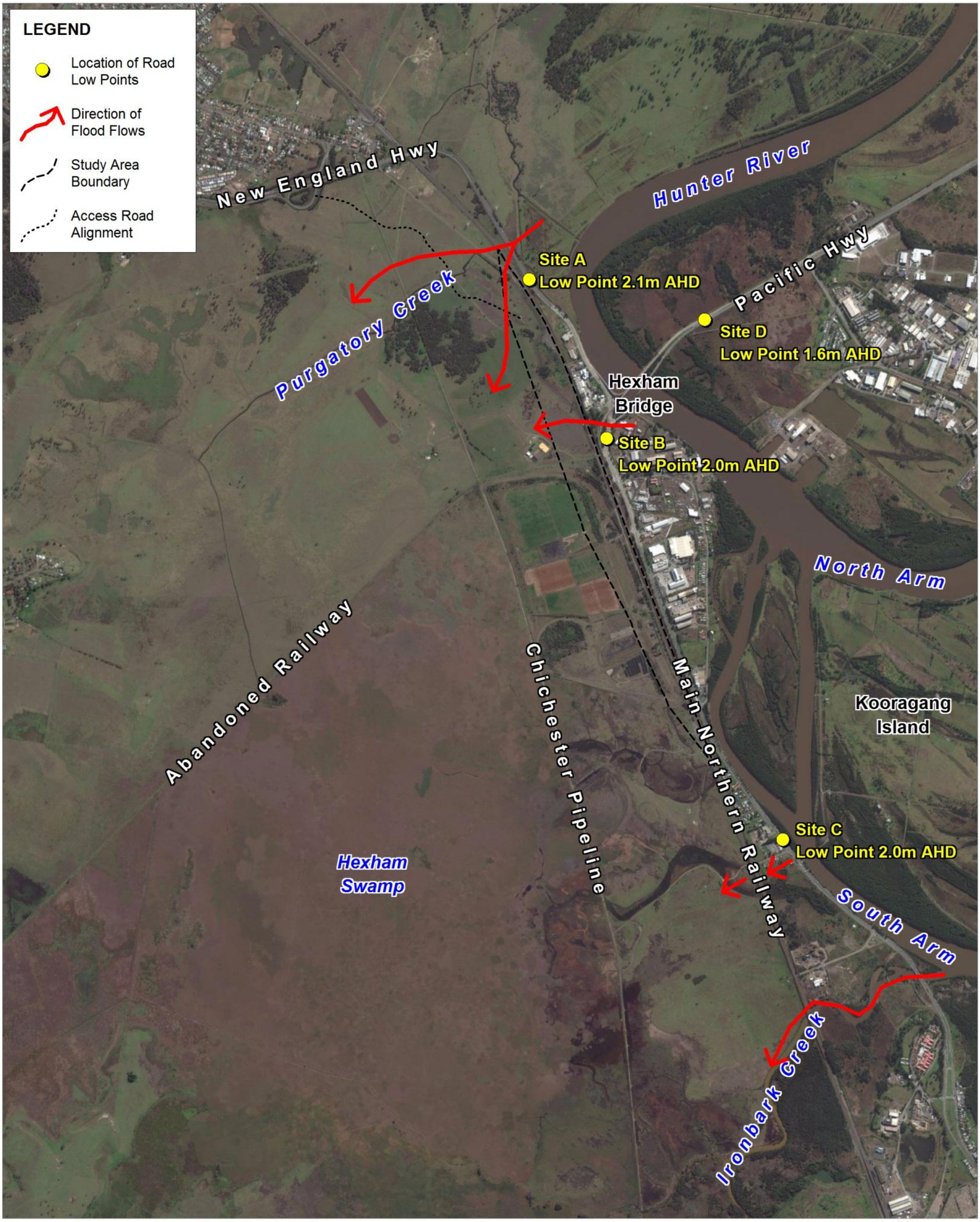
As shown in Figure 8-1 the Pacific Highway between Hexham Bridge and Sandgate forms a barrier between the South Arm of the Hunter River and Hexham Swamp. The road surface along this stretch of the highway is higher than most of Hexham Swamp. However, for drainage purposes, there are a number of low points along the road across which floodwaters can spill from the South Arm into the Swamp.

Available elevation information for this section of the highway indicate that low points occur at the locations listed in Table 8-3 and highlighted in Figure 8-1**.**

Table 8-3 Overtopping of the Pacific Highway Between Tarro and Sandgate

Low Point (see Fig 7-1)	Description of Low Point Location	Road Surface Level (m AHD)	Approximate Probability of Flood Required to Cause Overtopping
A	Along the New England Highway about 900m north of Hexham Bridge	2.1	10% AEP
B	Intersection of New England Highway & Pacific Highway (at Hexham Bridge)	2.0	5% AEP
C	Intersection of Pacific Highway & Shamrock Street	2.0	2% AEP

Based on this information, floodwaters would first overtop the Pacific Highway at Hexham Bridge (*i.e., Site B in* Figure 8-1). Floodwaters would need to reach a level of around 2.0 mAHD before overtopping would occur.



Title:

Potential Flooding Mechanisms in the Vicinity of Hexham

Figure: 8-1

Rev: B

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 0.5 1km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2335_QR_Hexham_Train_Support_Facility\MapInfo\Workspaces\MapInfo\Workspaces\DRG_027_120816_Mechanisms.WOR

Computer modelling shows that a flood of around a 5% AEP event would be required to cause flooding to this level in the vicinity of Hexham Bridge.

Overtopping of the Pacific Highway would next occur near the intersection with Shamrock Street (*i.e., Site C in* Figure 8-1). The road surface at this location is around 2.0 mAHD. Computer modelling shows that a flood of almost a 2% AEP would be required to cause flooding to this level at this location.

8.1.3.4 Critical Flooding Mechanism

The data presented above shows that around a 10% AEP flood is required to cause overtopping of the New England Highway immediately north of Hexham. A flood of greater severity is required to cause overtopping of the Pacific Highway downstream of Hexham Bridge.

Therefore, overtopping of the New England Highway will occur first, and be the critical flooding mechanism that would lead to the onset of flooding across the QR National Site.

8.1.4 Flood Warning Times

The issuing of flood warnings in the Hexham region is the responsibility of the Lower Hunter Division of the State Emergency Services (*SES*). At present flood warnings and estimates of the time of arrival of the flood peak are based on floodwater levels at gauges located upstream at Maitland and Greta. Typically, water levels at these gauges are communicated to the Lower Hunter headquarters of the SES, where they are compared with stage hydrographs for recorded floods. There is no telemetered flood forecasting and warning system in existence for the downstream reaches of the Lower Hunter.

In order to determine indicative flood warning times for the Hexham area, the lag time between flood peaks at key locations across the Lower Valley were determined for a range of recorded and 'design' floods. The lag times were estimated using the MIKE 11 flood model that was developed for the 1994 Flood Study and are summarised in Table 8-4.

These flood warning times can be used to estimate the time of arrival of the peak of a flood at Hexham. As outlined in the *Newcastle Flood Plan,* the SES conveys flood information via Flood Bulletins that are distributed to local radio and television stations. These bulletins advise the general severity of flooding, as well as the current and expected peak flood level at key locations such as Maitland and Raymond Terrace. Unfortunately, the SES does not give flood level projections for areas downstream of Raymond Terrace due to the potential influence of the tide on peak flood levels.

The data contained in Table 8-4 can be used to understand approximate lag times for the arrival of the flood peak at Hexham. It can be seen that for large flood events a lag time of around 20 hours or more can be expected between the flood peak passing Maitland and arriving at Hexham. Flood warnings issued by the Bureau of Meteorology (BoM) and the State Emergency Service (SES) are given 24 hours in advance for Singleton and Maitland. This provides sufficient warning of more than a day in advance of when Hexham Swamp is likely to be inundated by Hunter River flood waters. However, it should be recognised that no two floods are the same, and therefore, any interpretation of the data contained in Table 8-4 to predict the arrival of the flood peak should be superseded by advice from the SES, when received.

Table 8-4 Lag Time Before Modelled Peak Flood Level Reaches Hexham

Location	Lag Time (hrs)				
	1% AEP Event	2% AEP Event	5% AEP Event	10% AEP Event	1955 Flood *
Maitland (Belmore Bridge)	29	21	20	18	20 (31)
Hinton (Paterson confluence)	11	13	12	16	6 (9)
Green Rocks	6	7	8	8	5 (5)
Raymond Terrace	3	2	3	5	2 (1)

* The bracketed values represent actual recorded lag time for the 1955 flood. This shows that the computer modelling only provides indicative estimates of lag times and that contemporary flood behaviour may differ to that experienced during actual floods.

8.2 Flood Evacuation

Given the length of flood warning time of one or two days available at the site, evacuation from the site during a flood event should not be a likely situation to occur. When a major flood warning for the Lower Hunter River is issued by BoM or the SES then Train Support Facility staff should be advised not to enter the site. This would prevent the staff from being placed at risk from any potential flooding of the site. However, in the event of flood warning information not being communicated to staff or other potential visitors to the Train Support Facility site, it is necessary to understand how the site should be evacuated during the onset of flooding.

Although flooding at Hexham is not serious until floodwaters rise to above the level of the 2% AEP event, many of the potential evacuation routes from the area could be cut before this level is reached. Therefore, it is important for any Flood Emergency Response Plan for the QR National Site to consider the potential evacuation routes for safe independent evacuation of employees and visitors.

8.2.1 Potential Evacuation Routes

During major floods there are three vehicular routes available for independent evacuation from the Hexham area (see Figure 8-2). These evacuation routes all connect Hexham to 'high ground' with an elevation of at least 10 mAHD, which is well above the peak flood level estimated for the PMF. Each potential evacuation route is listed in Table 8-5 on the following page along with the distance to 'high ground'.

Although Woodlands Close and the proposed access road will have a road crest level that is relatively low, floodwaters cannot overtop the New England Highway and discharge along the Hexham Swamp floodway and across these routes until peak river levels reach at least 2.0 mAHD. Therefore, the low points along Woodlands Close or the proposed access road are not the critical control for evacuation from the QR National Site. Floodwaters must firstly overtop the New England Highway or the Pacific Highway at one of the low points identified in Figure 8-1 before floodwaters can inundate either site access route.

Table 8-5 Primary Vehicular Evacuation Routes

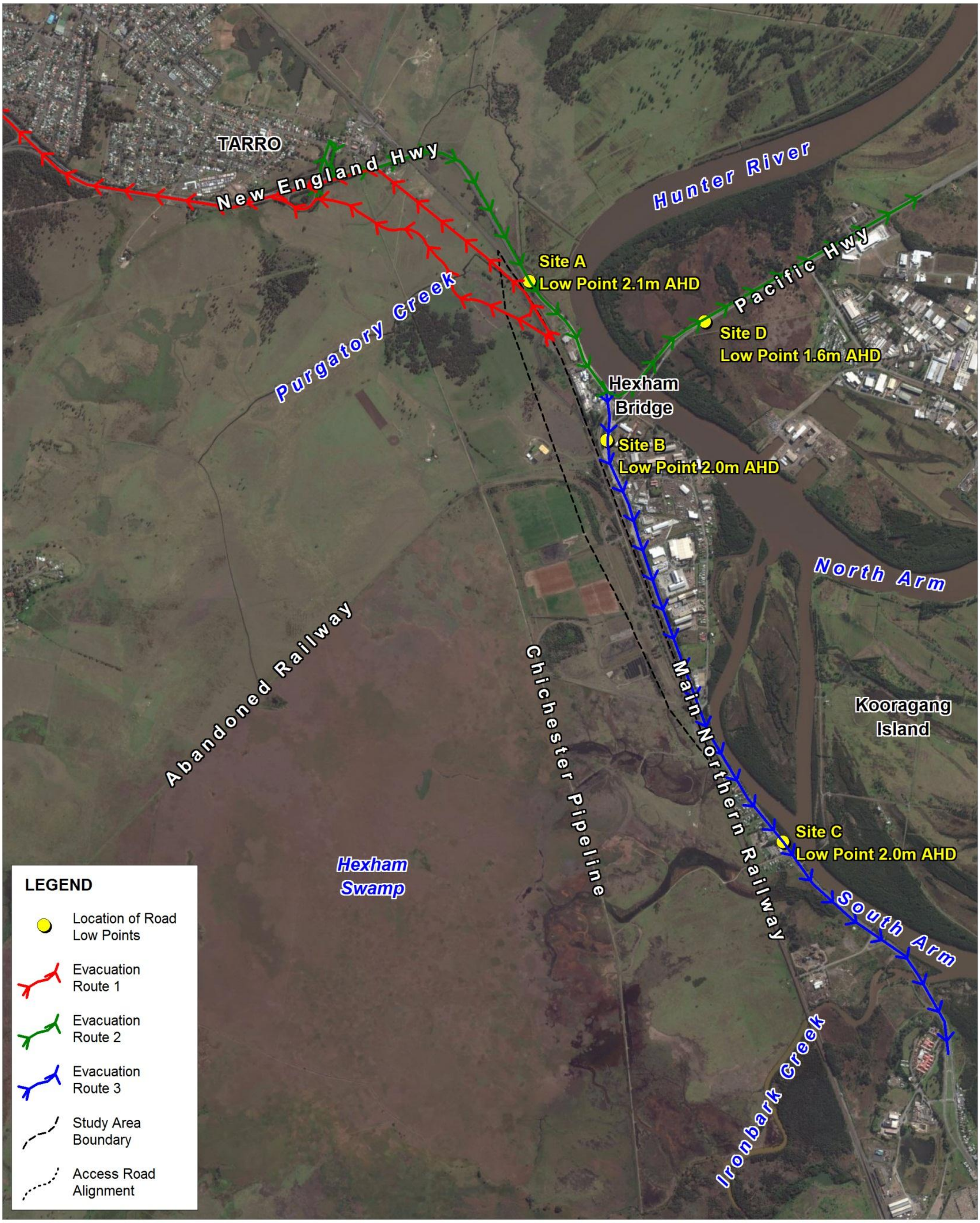
Route	Evacuation Route Description	Distance to 'High Ground' (km)	Lowest Point Along Route (m AHD)
1	Along Woodlands Close or the proposed access road to Tarro and then north-west along the New England Highway toward Thornton	3.5	1.1 (Woodlands Close or proposed access road)
2	Along Woodlands Close or the proposed access road to Tarro and then south along the New England Highway to Hexham and then along the Pacific Highway to Sandgate	9.0	1.1 (Woodlands Close or proposed access road) 2.0 (Pacific Highway)
3	Along Woodlands Close or the proposed access road to Tarro, then south along the New England Highway to Hexham, across the Hexham Bridge and then north-east along the Pacific Highway to Tomago	6.5	1.1 (Woodlands Close or proposed access road) 1.6 (Pacific Highway)

In a 10% AEP event floodwaters would largely not overtop the highways or would be at a shallow depth at each of Sites A, B and C (see Figure 8-1 and Figure 8-2) and would not impede vehicular traffic. In floods of 5% AEP, the water depths at sites A and B would be about 0.5m and 0.1m, respectively. Floodwaters are considered unsafe for vehicular traffic to negotiate once the product of the velocity (*v*) and depth (*d*) of floodwaters exceeds about 0.4. Computer modelling shows that floodwaters would be safe for vehicular traffic at site B, but unsafe for vehicular traffic at point A.

The Pacific Highway north-east of Hexham Bridge (*low point Site D*) would be covered by floodwaters to a depth of 0.4 metres in a 10% AEP flood. Computer modelling shows that when the river breaks its banks upstream of Hexham Bridge on the Tomago (*northern*) side, a portion of the flow travels overland and across the Pacific Highway between the northern bridge abutment and the high ground at Tomago. This evacuation route is therefore considered unsafe for evacuation once flood levels in the Hexham area reach 2m AHD and major flooding of Hexham Swamp begins.

8.2.2 Evacuation Timing

As discussed previously, at least a day or more of warning time should be available before the onset of flooding to the proposed development site. It is therefore unlikely that the situation should arise where an urgent emergency evacuation of the site is required. However, once the flood level in the Hunter River rises above the New England Highway at Hexham, the Swamp can fill to a level of over 2m AHD within a few hours and begin inundating the study site. It is therefore essential that if people are on the site at the onset of flooding to Hexham Swamp, that they begin evacuation immediately.



Title:
Potential Evacuation Routes from Hexham

Figure: 8-2

Rev: B

N

0 0.5 1km
Approx. Scale

BMT WBM
www.bmtwbm.com.au

Filepath : K:\N2335_QR_Hexham_Train_Support_Facility\MapInfo\Workspaces\MapInfo\Workspaces\DRG_028_120816_Evacuation.WOR

8.3 Suggested Emergency Response Measures

8.3.1 Procedures to Facilitate Evacuation

The response of the flood affected community to flood warnings is probably the single-most important factor that determines the effectiveness of a 'flood emergency response system' (*Australian Water Resources Council, 1992*). The successful implementation of emergency response measures is highly dependent on the flood awareness of the community resident in the floodplain and the local work force, and on their knowledge of the protocols that need to be followed during a major flood.

The information presented in the preceding sections indicates that there is sufficient time for the Train Support Facility workforce to relocate to higher ground or allocated flood refuge centres during the onset of a major flood.

Flood education and emergency response training will need to be undertaken for the Train Support Facility workforce. This should include the identification of flood wardens and staff responsible for relocating stock and equipment so that it is not damaged during a major Hunter River flood. Flood awareness workshops for employees should also be held at regular 6 month intervals to allow for staff turnover.

The key to ensuring the safety of the workforce in times of major flooding will be the dissemination of flood intelligence during the onset of a major flood so that they can take advantage of the warning time that is available. This can occur through interpretation of Bureau of Meteorology Flood Bulletins and SES flood warnings.

8.4 Procedures for Reducing Impacts and Potential Flood Damages on Development

The Train Support Facility will comprise buildings that are to be constructed with floor levels that are approximately equivalent to the predicted peak 2% AEP flood level. Accordingly, it is recognised that the Facility could be inundated during a major flood of the order of the 1955 flood and that there is potential for flooding of this magnitude to cause damage to components of the Facility.

However, as outlined in 5.2.5 of this report, velocity depth products across the Hexham floodplain during major flood events are typically low and are therefore, unlikely to result in structural damage to components of the Facility infrastructure. Furthermore, QR National plans to construct the Facility using flood compatible materials in accordance with the guidelines outlined in the NSW Government's *'Floodplain Development Manual'* (*2005*). This would include the siting of power facilities at a suitable freeboard above the design 1% AEP flood.

In addition, the analysis documented in the preceding sections indicates that a flood warning time of around one to two days is available. Accordingly, there would be ample time for Train Support Facility staff to relocate stock and equipment to areas above the predicted peak level of the oncoming flood. There would also be the potential for rolling stock to be relocated to higher ground further up the valley, such as between Lochinvar and Branxton.

9 HEXHAM SWAMP LOCAL CATCHMENT FLOODING

Hunter River flooding is the critical flood mechanism when assessing the impacts of the proposed works. However, there is also potential for impacts associated with a local catchment flood event in Hexham Swamp. Local catchment flood conditions in Hexham Swamp have been assessed to establish any potential flood impacts and to assist the design process of the proposed site access road.

9.1 Flood Modelling

In order to undertake an assessment of the local catchment flood conditions in Hexham Swamp a hydrological model of the catchment was developed. As the flood level in Hexham Swamp is principally a volume driven flood mechanism, a fairly simple hydrological model is adequate. However, as the swamp is drained to the Hunter River via a number of hydraulic structures, the timing of flood flows is still of significance. To ensure that the catchment response was adequately modelled a more detailed hydrological model of the Hexham Swamp catchment was developed.

The hydrological model was developed using XP-RAFTS and incorporates a total of 45 sub-catchments representing almost 120km^2, as shown in Figure 9-1. A PERN value (representing the response of the sub-catchments) of 0.03 was adopted for both swamp and suburban sub-catchments, whilst a value of 0.12 was adopted for the forested sub-catchments.

Being a volume driven system the adopted rainfall loss parameters are critical for determining peak flood levels within Hexham Swamp. The rainfall loss parameters that were adopted for the Hexham Swamp hydrological model are presented in Table 9-1.

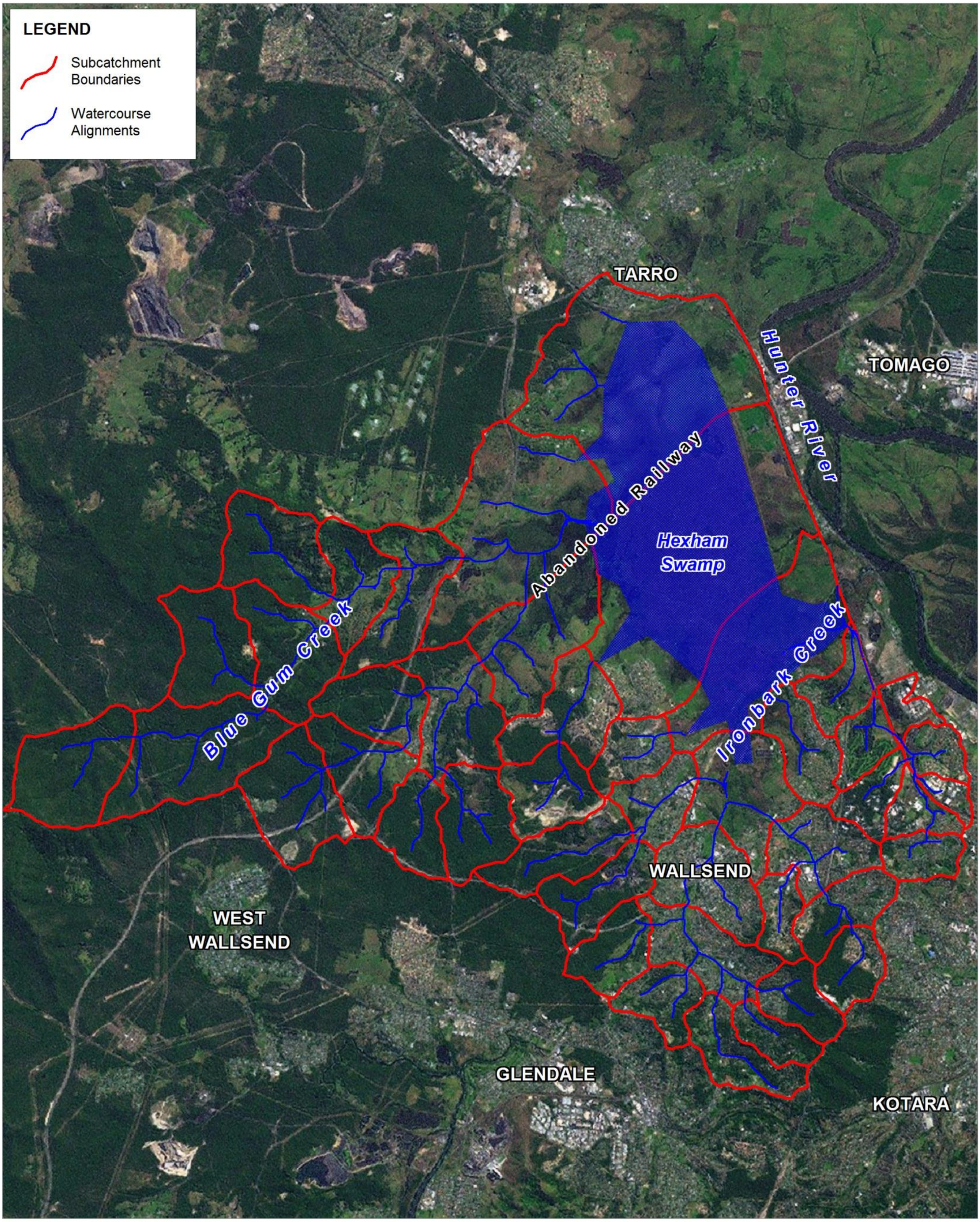
Table 9-1 Adopted Loss Parameters for the Hexham Swamp Hydrological Model

Sub-catchment Type	Initial Loss (mm)	Continuing Loss (mm/h)
Swamp	0	0
Suburban	5	1
Forested	15	2.5

Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in AR&R (2001). These curves provide rainfall depths for various design magnitudes (up to the 1% AEP) and for durations from 5 minutes to 72 hours.

A range of storm durations were modelled in order to identify the critical storm duration for design event flooding in the catchment. Design durations considered include the 18-hour, 24-hour, 36-hour, 48-hour and 72-hour durations.

The outputs from the hydrological model were input to the TUFLOW model of the Hunter River as model inflow boundaries. The tailwater in the Hunter River was set to a fixed level Mean High Water Springs (MHWS) tidal condition of 0.65m AHD. The initial water level within the swamp was set to 0.4m AHD, which represents a reasonably wet baseline condition.



Title:

Hexham Swamp Hydrological Model Sub-catchments

Figure: **9-1**

Rev: **A**

N

0 2 4km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : K:\N2335_QR_Hexham_Train_Support_Facility\MapInfo\Workspaces\MapInfo\Workspaces\DRG_029_121003_Hexham_Subcatchments.WOR

Following initial model simulations the critical duration for flooding in Hexham Swamp from a local catchment storm was found to be the 72-hour duration storm event. This duration event was then simulated for the 1% AEP, 2% AEP, 5% AEP and 10% AEP design events.

The model results provide peak flood levels that are broadly similar across the swamp. There is a small difference in peak flood levels in the northern and southern sections of the swamp, as separated by the abandoned railway. For all of the simulated design events the flood levels were typically around 20mm higher north of the abandoned railway than to the south. The peak flood levels for the northern section of the swamp are provided in Table 9-2 for the range of simulated events.

Table 9-2 Design Flood Levels in Hexham Swamp from a Local Catchment Event

Design Event	Peak Flood Level (m AHD)
10% AEP	1.18
5% AEP	1.30
2% AEP	1.44
1% AEP	1.56

When comparing these results to those in Table 2-1 it can be seen that the local catchment assessment provides slightly higher flood levels in Hexham Swamp for the 10% AEP and 5% AEP design events. This is due to the sensitivity of peak flood levels in the swamp to the adopted rainfall loss parameters and initial conditions. For the 2% AEP and 1% AEP design events the Hunter River flood conditions provide higher flood levels than the Hexham Swamp catchment flood.

Caution should be exercised however when interpreting design flood levels in Hexham Swamp from the Hunter River flooding condition for lower order events. When the swamp is filling with flood waters from the Hunter River it is highly sensitive to small changes in flow spilling over the New England Highway, as is the case for the 5% AEP and 2% AEP events. There is a greater level of uncertainty on modelled flood levels in Hexham Swamp for these events than for the 1% AEP event, when the Hexham Swamp floodplain is fully connected.

9.2 Flood Impacts

The flood modelling does not indicate any significant changes to peak flood levels or velocities. This is to be expected as the nature of the flooding is for the swamp to fill relatively slowly and at a uniform level. The rate of rise of flood waters in the swamp under local catchment flood conditions is no higher than around 0.05m per hour. This enables flood waters on either side of the proposed access road to quickly equalise (assuming cross drainage connectivity), minimising impacts on peak flood conditions. Flood impact mapping is provided in Appendix C for reference.

Although there are no impacts on local catchment peak flood conditions associated with the proposed works, there may be localised changes in flood progression and flow distribution. Where localised flow paths are important from a hydrological or ecological perspective, the existing conditions should be maintained through the provision of local cross-drainage infrastructure. Where possible, this should retain the capacity of existing local drainage within the swamp.

10 CONCLUSIONS

The objective of the study was to undertake a detailed flood impact assessment of the proposed cumulative development on Hunter River flood conditions. Central to this was the application of a two-dimensional hydraulic model of the Hunter River floodplain developed as part of the Williams River Flood Study (BMT WBM, 2009) and updated for the Williamtown / Salt Ash Flood Study Review (BMT WBM, 2011) for Port Stephens Council.

Specifically the modelling undertaken for the proposed cumulative development aimed to:

- Confirm existing flooding conditions across the site including flood levels, flows and velocities to establish baseline conditions for impact assessment;
- Identify the potential flood impacts of the proposed cumulative developments of the Hexham Train Support Facility, Relief Roads and access road for a range of design flood magnitudes;
- Consider the potential cumulative flood impacts of development with the RMS Pacific Highway upgrade from the F3 to Heatherbrae.

The modelling of the original road/rail designs as presented in previous submissions provided for unacceptable flood impacts. The flood impacts were principally as a result of the blocking of existing flow paths through the construction of elevated road and rail embankments. These obstructions provide for local redistribution flows and associated increases in local peak flood water levels. The proposed works has limited impact on regional flood behaviour, however, the localised impacts were of sufficient magnitude to require specific flood mitigations works.

Flood mitigation design solutions were tested with the overall objective to minimise flood impacts, particularly to property external to the development area. The design mitigation solutions incorporated lowering significant sections of the proposed road and rail embankments in order to maintain as best as possible the existing flow distributions. The proposed development with the mitigation provided for a significant reduction in flood impacts, and significantly almost no adverse impact to existing property and businesses.

The flood mitigation design solutions are such that they are effective across the full range of design events and would remain effective considering potential future changes to local flood conditions either through potential climate changes scenarios or significant infrastructure development such as the F3 upgrade.

Whilst the site may be subject to significant flood inundation in major events, consideration of appropriate flood emergency response measures provides for flood risk to be effectively managed. This is largely attributed to the available warning times available for major Hunter River flooding at this location and the corresponding opportunity to enact on-site floodplain risk management plans.

11 REFERENCES

BMT WBM (2009) *Williams River Flood Study*

BMt WBM (2011) *Hexham Relief Roads Flood Impact Assessment*

BMT WBM (2011) *Pacific Highway Upgrade – F3 to Heatherbrae: Flooding, Drainage and Water Quality Impact Assessment*

BMT WBM (2011) *Williamtown / Salt Ash Flood Study Review*

BMT WBM (2012) *Newcastle City-wide Floodplain Risk Management Study and Plan*

Department of Environment and Climate Change (DECC) (2007) *Floodplain Risk Management Guideline – Practical Consideration of Climate Change.*

PWD (1994) *Lower Hunter River Flood Study – Green Rocks to Newcastle*

WorleyParsons (2011) *Hexham Redevelopment Project Incorporating a Train Support Facility, Industrial Subdivision and Intermodal Facility – Flood Impact Assessment*

APPENDIX A: FLOOD MAPS FOR EXISTING CONDITIONS