6.2 Flooding and hydrology

The potential impacts of the proposal on flooding and hydrology are assessed in the *Hexham Straight Widening Flooding and Hydrology Assessment*, refer to **Appendix L**. The potential impacts and safeguards to mitigate impacts, are summarised in this section.

6.2.1 Methodology

Overview

The methodology for the flooding and hydrology assessment included:

- Undertaking a desktop assessment – A desktop assessment was carried out to assess the likely and potential impacts of the proposal on flooding and hydrology. The desktop review involved a collation of available literature, databases, aerial photography, topographic mapping and existing land use to aid in interpreting the existing hydrological conditions of waterways and floodplains within the respective study areas. Literature sources included:
    - Soil landscape and hydrological soil group mapping – eSPADE v2.0 interactive NSW Soil and Land Information mapping (DPIE, 2020)
    - Climate and rainfall data from the Bureau of Meteorology (BoM, 2020a, 2020b)
- Identification of sensitive receiving environments (SREs) – SREs are environments that have high conservation or community value, or support ecosystems/human uses of water that are particularly sensitive to changes in quantity of surface water and groundwater such as aquifers, groundwater users, GDE, and wetlands
- Developing detailed flood modelling – Detailed flood modelling was completed to inform the concept design and the environmental impact assessment. The model was developed using a TUFLOW two-dimensional flood hydraulic model of the Lower Hunter River. A detailed summary of the models parameters is provided in Section 3.3.3 of **Appendix L**
- Undertaking stormwater discharge modelling – Potential changes to the rates and volume of stormwater discharged from the proposal during the operational phase were assessed using 12D dynamic hydraulic modelling of the existing and operational phase drainage conditions. Discharges to the receiving environment were quantified at the downstream boundary to assess impacts to downstream drainage systems and natural areas. Where permanent water quality basins form part of the drainage flow path, the basins were conservatively modelled as drainage nodes with no storage capacity being considered in the modelling
- Assess construction flooding impacts – Flooding impacts associated with the construction phase of the proposal was represented and analysed in the TUFLOW model for the 20% and one per cent Annual Exceedance Probability (AEP)
- Assess operational flooding impacts – Flooding impacts due to the operation of the proposal were assessed using TUFLOW modelling by determining the flood level, flood depth, maximum velocities, flood hazard categories, and duration of inundation (hour) above 0.50 metres depth of flooding. Flooding impacts for the operational phase were assessed for the 63.2 per cent, 50 per cent, 20 per cent, 10 per cent, five per cent, two per cent and one per cent AEP and probable maximum flood events.

Study area

The flooding study area has been identified to assess the potential adverse impacts to flooding from the proposal and covers waterways connected to Hexham Swamp, including Ironbark Creek, and part of Kooragang Island. The flooding study area extends about 0.3 kilometres further north than the proposal, covering part of Purgatory Creek, one kilometre further in the west, covering part of Hexham Swamp, 0.3 kilometres further in the south, covering Sandgate and South Channel Hunter River, and up to three kilometres further in the east to cover North Channel Hunter River and a portion of Kooragang Island including Cobbans Creek.

Flood design criteria

The flood design criteria adopted for the proposal are outlined below:

- Minimise the increases in flood levels/depths, velocity, hazard and duration of inundation due to temporary and permanent infrastructure where reasonable and feasible during flood events up to an including the one per cent AEP event
- Major roads would not be adversely impacted in flood events up to and including the probable maximum flood.

Flood management design objectives

The flood management design objectives identified in **Table 6.11** have been adopted as the proposal's quantitative design limits. These objectives apply outside the proposal boundary, for events up to and including the one per cent AEP flood event.

Table 6.11 Quantitative flood management objectives

Parameter	Location or land use	Quantitative design objective
Afflux i.e. increase in flood level resulting from implementation of the proposal	Above floor flooding of habitable floors	50 mm
	Below flood flooding at habitable buildings	100 mm
	Other urban and recreational	100 mm
	Sensitive infrastructure: • Emergency services (e.g. hospitals, ambulance, fire, police stations) • Electricity substations • Water treatment plants.	50 mm
	Rural and forest	100 mm
	Named roads and railways	Less than 100 mm Less than 10% change in length of overtopping
Flood hazard i.e. increase in flood hazard resulting from implementation of the proposal	All areas outside the proposal	Minimise changes based on an assessment of risk with a focus on land use and flood sensitive receptors
Flood duration i.e. increase in duration of inundation resulting from implementation of the proposal	All areas outside the proposal	Less than 10% change in duration of inundation for flood depths above 0.5 metres

6.2.2 Existing environment

Catchment overview

The proposal is located in the lower portion of the Hunter River catchment in NSW. The Hunter River catchment is one of the largest in NSW covering an area of about 22,000 square kilometres. The Hunter River catchment is east of the Great Dividing Range, bound by the Manning and Karuah catchments to the north, and by the Lake Macquarie and Hawkesbury-Nepean catchments in the south. The catchment drains a total area of about 22,000 square kilometres. The headwaters of the Hunter River are located in the Liverpool Ranges, which flows generally in a south-easterly direction for about 450 kilometres, before reaching the Tasman Sea at Newcastle. Elevations across the catchment vary from over 1500 metres above sea level in the mountain ranges, to less than 50 metres above sea level on the floodplains of the lower valley. Four major rivers discharge into the Hunter River along its length – these are Pages River, Goulburn River, Williams River and Paterson River.

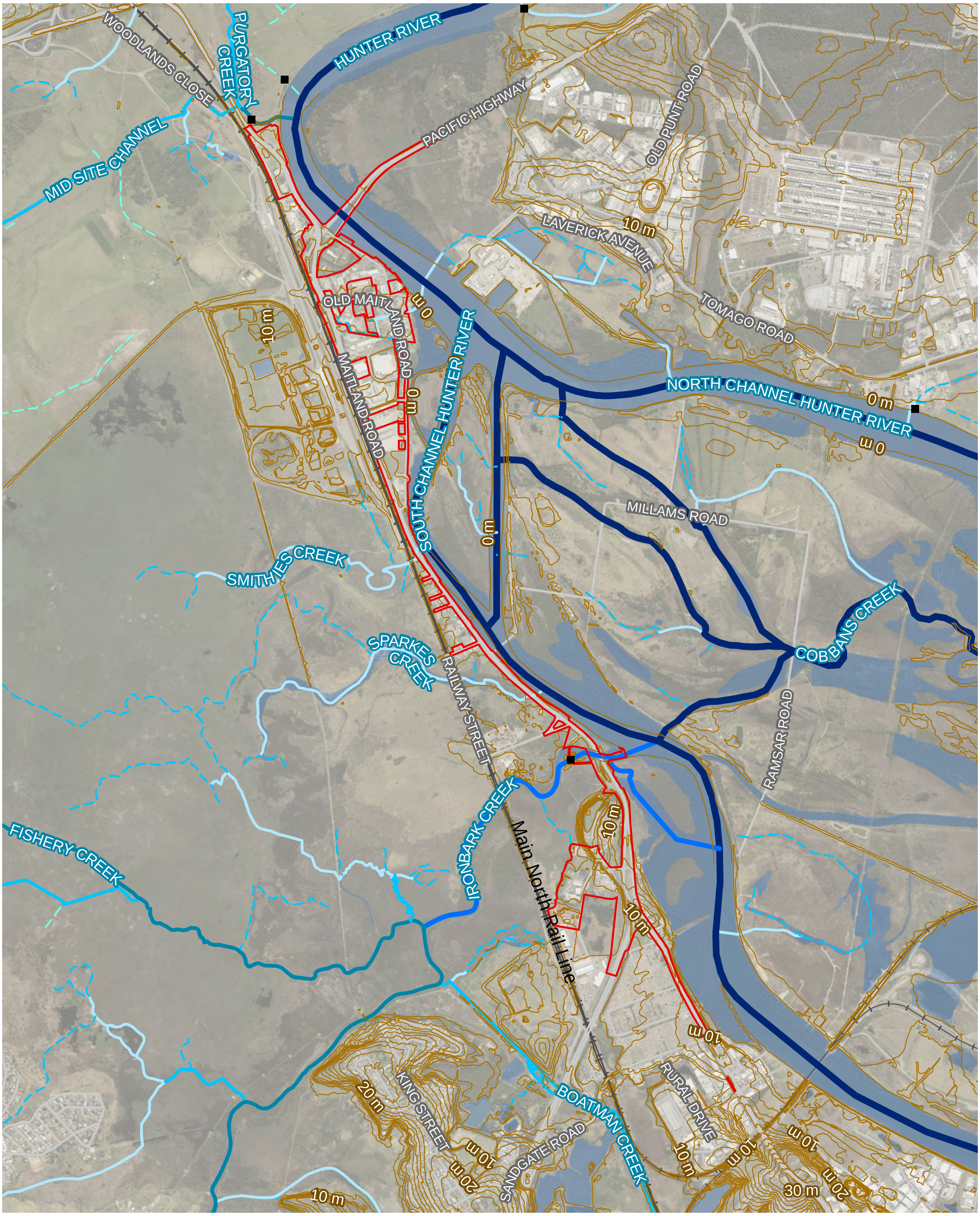
The lower reaches of the Hunter River extend about 64 kilometres inland to its tidal limits at Oakhampton (OEH, 2017). The Hunter Estuary has two main channel arms (identified as the North Channel Hunter River and the South Channel Hunter River) that diverge about 17 kilometres inland and reconverge before flowing to the mouth. The area surrounding the lower estuary is heavily urbanised with significant industrial, commercial and residential development and a major harbour port near the mouth of the estuary.

Waterways and wetlands

Key waterways, wetlands and drains within the surface water study area include:

- Hunter River and floodplain
- Ironbark Creek
- Unnamed drainage channel to the south of Ironbark Creek
- Hunter Estuary Wetlands Ramsar sites – Kooragang Nature Reserve and Shortland Wetlands
- Hexham Swamp Nature Reserve
- Unnamed Coastal Wetland (to the north and south of Ironbark Creek)
- Unnamed Coastal Wetland (to the west of the Hunter River and to the north of Millams Road and the Ash Island Bridge)
- Sparkes Creek
- Smithies Creek
- Unnamed Coastal Wetland (to the north of Hexham Bowling Club, between Old Maitland Road and the South Channel Hunter River)
- Unnamed Coastal Wetland (to the west of the Main North Rail Line at the northern end of the proposal)
- Unnamed Coastal Wetland (to the east of the Hunter River in Tomago)
- Mid Site Channel
- Purgatory Creek.

Waterways and drains are shown on **Figure 6.4** and the Coastal Wetlands and Ramsar wetlands are shown in **Figure 1.3**.



Date: 9/11/2021 Filename: IA301100_REF_F006_KeyWaterwaysAndDrainage_v2

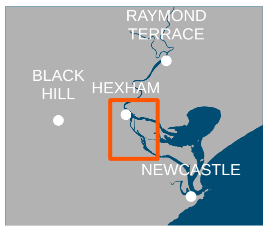
Legend

- REF area
- Contour (2m)
- Floodgates

Strahler Stream Order
- SSO 0
- SSO 1
- SSO 2
- SSO 3
- SSO 4
- SSO 5
- SSO 9

- Railway
- Road

0 200 400 m
Scale 1:35,000 at A4
GDA94 MGA56



Data sources:
Jacobs 2020
Department Finance, Services and Innovation 2020
DPIE 2020

Figure 6.4 Key waterways and drainage features

Drainage

Natural drainage on and around the construction area has been disrupted by the rail corridor, fill and the historical industrialisation of the western portion of the Hexham Swamp to the west of the proposal which includes Hexham Swamp Nature Reserve. Drainage of Hexham Swamp principally occurs through Ironbark Creek which discharges to the Hunter River in the southern portion of the REF area. Flood gates are present near the confluence of Ironbark Creek and the Hunter River however these are open to allow tidal flushing and improve water quality for Hexham Swamp Nature Reserve (NCC 2020). These gates are only closed during flood events. Hexham Swamp is also drained by Sparkes Creek and Smithies Creek which drain through culverts under the Main North Rail Line and Maitland Road into the South Channel Hunter River.

In the north of the proposal, there is also some surface water flow to the east through Mid Site Channel which directs surface water under Woodlands Close, the existing rail corridor and Maitland Road before discharging into Purgatory Creek and then into the Hunter River. In the north of the REF area, there is also some surface water flow to the east through a series of manmade drains which direct surface water via Mid Site Channel under Woodlands Close, the existing rail corridor and Maitland Road before discharging via Purgatory Creek to the Hunter River. Hydrological drainage features that drain stormwater within the REF area are described in **Section 2.2.4**. and shown in **Appendix B**.

Hydrological flow regimes

The Hunter River is subject to tidal influence as it traverses the flooding study area (as are all other waterways within the Hunter River catchment downstream of any existing floodgates that are in operation). Upstream of the tidally influenced reach, flow in the Hunter River is partially regulated by the operation of the Hunter Regulated Water Source which comprises two large water supply dams (Glennies Creek and Glenbawn).

Where waterways traverse the low-lying Hunter River floodplain a relatively permanent presence of water is found due to lack of streambed gradient, presence of floodgates and channel incision below the surrounding water table. Inflows from the upper catchment are likely to have long residence times resulting in prolonged inundation of the surrounding catchment after flood events.

Above the low-lying floodplain areas, the relatively small tributary catchment areas of Mid Site Channel, Smithies Creek, Sparkes Creek, Purgatory Creek and Ironbark Creek to the west of the study area would typically only generate episodic flows with stream flow recessing relatively quickly and restricted to periods during and immediately after rainfall events.

Flood conditions - existing

Flooding on the Lower Hunter River floodplain is a result of both main-stream flooding from the Hunter River, and local catchment runoff. The floodplain within the REF area varies in width from around 2.5 kilometres between Tarro and Tomago just north of the proposal, to up to 10 kilometres between the western reaches of Hexham Swamp and the North Channel Hunter River.

When the western side levee bank of the Hunter River is overtopped, a substantially large area of low-lying floodplains is inundated. This broad and wide floodplain extends as far as Thornton. To the east of the proposal just past the existing Hexham Bridge, the floodplain is constricted to about 1.5 kilometres wide before branching into the North Channel and South Channel of the Hunter River around Kooragang Island. The North Channel and South Channel of the Hunter River re-join downstream, between Tighes Hill and Stockton, with the main channel of the Hunter River running adjacent to the Newcastle city centre before discharging into the Pacific Ocean through the Port of Newcastle breakwalls.

The behaviour of flood waters from the Hunter River catchment within the REF area is influenced by the geomorphology surrounding the proposal which includes the raised linear features associated with the Main North Rail Line and Maitland Road which act as a levee controlling flood behaviour. During major flooding events, water ponds upstream of the Main North Rail Line in Hexham Swamp and drains to the Hunter River by Ironbark Creek. Under current conditions, sections of the Maitland Road are overtopped in the five per cent AEP flooding event.

Extent and depth of existing flooding behaviour - existing

The behaviour of floods within the proposal local area are influenced by the flood level in the Hunter River and the local catchment runoff arriving directly from the Hexham Swamp catchment. The extent of existing flood levels within the proposal occurs as a result of raised water levels from the Hunter River and Hexham Swamp. In general, high water depth occurs along and directly next to the Hunter River and Hexham Swamp, then spreads gradually to the floodplains. This can be attributed to the large catchment area of the Hunter River which contributes to high inflow into the main channel of the Hunter River.

Existing flood mapping has been included in Attachment B of the *Hexham Straight Widening Flooding and Hydrology Assessment* (refer to **Appendix L**). During low flood events with a high probability of occurrence (i.e. 63.2 per cent AEP (every year)) the flood extent is limited throughout the proposal and the surrounding road network and the Main North Rail Line are not overtopped. Some areas along Maitland Road may experience localised ponding of water, however the road is not subject to flooding.

A 20 per cent AEP event does not cause any overtopping of roads or railways within or directly next to the proposal. Similar to the 63.2 per cent AEP event, localised flooding occurs along Maitland Road in the 20 per cent AEP event.

During a 10 per cent AEP event, the A1 Pacific Highway is overtopped east of Hexham Bridge, to a depth of about 0.35 metres. The northern sections of Old Maitland Road, Hexham are overtopped by around 0.5 metres leading to pooling next to the road on the eastern edge of the proposal, up to a depth of 0.5 metres. Pooling occurs near Shamrock Street, Hexham resulting in inundation over it up to 0.5 metres. Maitland Road is also overtopped just north of the proposal, with flows from the Hunter River Floodplain north of the proposal entering Hexham Swamp in the area around Purgatory Creek. Modelling results of the existing flood levels indicate that two sections of south bound lanes of the proposal are inundated, while one north bound lane of the proposal is generally free from flooding in the 10 per cent AEP event.

In the five per cent AEP event, Clark Street, Merchant Street and Fenwick Street as well as Shamrock Street, are subject to a flood depth of about 0.7 metres. The Main North Rail Line is overtopped towards the southern extent of the proposal, east of the Newcastle Golf Practice Centre and north of the NICB.

In the two per cent AEP event, much of the existing alignment of Maitland Road throughout the REF area is inundated up to a depth of around 0.5 metres as well as other areas within the proposal. In the one per cent AEP event, most of the area within the proposal is inundated, with maximum depths up to 2.8 metres near the A1 Pacific Highway and Maitland Road intersection at the northern end of the proposal.

In the probable maximum flood (PMF), the proposal is almost completely inundated. During a PMF event, the model results show that the depth of flooding on Maitland Road is about 6.0 metres, and the Main North Rail Line located next to the REF area experiences complete inundation.

Flow velocity - existing

Flow velocities above 0.5 metres per second are typically confined to the Hunter River, South Channel Hunter River and Ironbark Creek in flood events smaller than 10 per cent AEP. In the 10 per cent AEP event, flow velocities of one metre per second occur during overtopping of the A1 Pacific Highway to the east of Hexham Bridge and Maitland Road to the north of the proposal.

In the two per cent AEP event, water begins to flow from Hexham Swamp back into Hunter River south of Hexham Bridge by first overtopping the abandoned Minmi Colliery Railway Line in Hexham Swamp, with velocities up to two metres per second, and then overtopping the Main North Rail Line and Maitland Road from the northern extent of the proposal to Ironbark Creek Bridge. These flows result in velocities of 1.5 metres per second over Maitland Road and 0.7 metres per second over the Main North Rail Line. Velocities do not increase noticeably during the one per cent AEP event. The PMF sees velocities up to four metres per second in Hunter River next to the proposal.

Flood hazard - existing

Existing flood hazard mapping has been included in Attachment B of the *Hexham Straight Widening Flooding and Hydrology Assessment* (refer to **Appendix L**). In events more frequent than the 10 per cent AEP event, hazard ratings remain low within or next to the REF area. During the 10 per cent AEP event, Maitland Road is overtopped at the northern end of the proposal near Hexham Bridge, and the A1 Pacific Highway is overtopped, east of the Hunter River within the Port Stephens Council LGA, resulting in high flood hazards at both locations across the existing roads. During the five per cent AEP event, these hazards increase further at Maitland Road, north of the proposal near Hexham Bridge, and on the A1 Pacific Highway, across Hexham Bridge within the Port Stephens Council LGA.

Overtopping of the Main North Rail Line near the southern end of the proposal and overtopping of Old Maitland Road north of Hexham Bowling Club result in high hazards. During the two per cent AEP event much of the proposal extent is inundated with high hazards. Overtopping of the A1 Pacific Highway, east of the Hunter River within the Port Stephens Council LGA, and overtopping at Old Maitland Road, just south of Hexham Bridge, results in an increased hazard category.

In the one per cent AEP event, high hazard category occurs within the proposal, including at the following areas:

- Residential properties on Old Maitland Road north of Hexham Bowling Club
- Residential properties located between Clark Street and Shamrock Street
- The rail maintenance facility located to the north-west of the proposal
- Areas near the Hexham Bridge A1 Pacific Highway intersection
- The area around Shamrock Street on Maitland Road.

In the PMF event, much of the proposal extent has a high flood hazard category This excludes an area of high ground at the southern extent of the proposal where the Calvary St Joseph's Retirement Community is located.

Duration of inundation - existing

Existing flood mapping for duration of inundation has been included in Attachment B of **Appendix L**. Areas within the proposal that experience inundation above 0.5 metres only occur during the 10 per cent AEP event and above. In the 10 per cent AEP event, the A1 Pacific Highway east of Hexham Bridge and the Hunter River is overtopped for a duration of around 12 hours and Maitland Road to the north of the proposal is overtopped for about 48 hours. In the five per cent AEP event, other areas within the proposal are inundated above 0.5 metres and include areas near Shamrock Street and along Old Maitland Road, north of Hexham Bowling Club for durations from zero to 36 hours. For the one per cent and two per cent AEP events, almost all of Maitland Road north of Ironbark Creek is inundated for over 24 hours. In the PMF event, the entire REF area, excluding the high ground at the southern end, is inundated for over 120 hours (5 days).

Inundation of buildings – existing

Surveyed floor levels of buildings near to the proposal was provided by City of Newcastle and was clipped to the flooding study area so that a total of 333 buildings was used to assess flooding impacts to buildings from the proposal. A summary on the number of buildings flooded above floor and depth of flooding floor is provided in **Table 6.12**. Details on location, floor level and flood level for each building are provided in Attachment J of **Appendix L**.

Table 6.12 Number of buildings flooded above floor in the existing case

Depth of flooding above floor (m)	63.2%AEP	20%AEP	10%AEP	5%AEP	2%AEP	1%AEP	PMF
0.0 – 0.2	-	-	6	5	15	13	5
0.2 – 0.5	-	-	-	9	37	7	4
0.5 – 1.0	-	-	-	2	30	26	9
1.0 – 2.0	-	-	-	-	23	82	22
> 2.0	-	-	-	-	-	14	204
Total	**-**	**-**	**6**	**16**	**105**	**142**	**244**

Flood evacuation

Local flood plans applicable for areas within the vicinity of the proposal include the *City of Newcastle Flood Emergency Sub Plan* (SES, 2013a), and *Port Stephens Flood Emergency Sub Plan* (SES, 2013b). Under current conditions there are locations on the major roads, including the New England Highway (Maitland Road) and NICB, which are unlikely to be trafficable during particular AEP events.

During the existing flood behaviours, potential flood impacts may result in access and evacuation routes becoming cut-off more frequently. At the rail maintenance facility, exceedance of a two per cent AEP event is likely to result in significant impacts to all evacuation routes, although a flood warning time of about 24 hours is available which would allow sufficient time to evacuate the facility site.

6.2.3 Potential impacts

Impacts avoided and minimised

The concept design for the proposal was developed using a multi-disciplinary process that identified and assessed the concept design and options against a range of engineering, environmental, social, land-use and economic criteria.

As a result of proposal development, the bridge over Ironbark Creek has been located to the east of the existing bridge and the overall vertical alignment o Maitland Road remains the same as the existing for the majority of the works. The adoption of this corridor has avoided:

- Adverse flooding impacts to Hexham Swamp and residential receivers between Shamrock Street and Clark Street Hexham
- Erosion and scour directly downstream of the proposal by providing rock transition aprons at the outlet of all culverts that are being upgraded.

Construction

Hydrology impacts

The proposal would potentially impact on the waterways located immediately next to and within the REF area and would include:

- Ironbark Creek
- The South Channel Hunter River alongside the REF area located to the north of EIS Area 2 and extending up to the southern side of EIS Area 2, then from the northern side of EIS Area 2 and extending up to the proposed U-turn facility at Old Maitland Road, Hexham to the north-east of Hexham Bowling Club.
- The Hunter River between Hexham Bridge and Compound 4
- The section of the waterway which receives discharge from the proposal drainage systems in the REF area which includes 31 systems comprised of Systems 3, 7, 10 to 13 and 22 to 46 but does not include the seven systems (1, 2, 4, 5, 6, 15 and 21) in the REF area that drain into CM SEPP areas, refer to **Appendix B**.

<u>Drainage design impacts</u>

Construction activities associated with drainage patterns and infrastructure within the REF area that have the potential to impact on sensitive receiving environments include:

- Cleaning of drainage pipes and culverts resulting in increased turbidity and rubbish reducing visual amenity of waterway
- Installation of new drainage pipes and culverts and relining of existing pipes (where required) resulting in a lack of positive drainage leading to an increased risk of flooding
- Temporary drainage resulting in changes in flows and velocities leading to scouring and erosion downstream
- Earthworks, cuttings or stockpiling resulting in erosion and sedimentation altering geomorphology of waterways and leading to algal blooms
- Dewatering resulting in discharges from construction sediment basins, mobilising sediments and contaminants and increase the turbidity of the receiving environments.

<u>Surface water hydrology</u>

Key activities during construction of the proposal that may impact the nature of surface water hydrology (volume, rate, timing, duration, velocity, etc.) associated with stormwater discharges include:

- Vegetation clearance (of trees, understorey and ground cover) and reduced infiltration associated with soil compaction and paving within the road corridor
- Temporary dewatering of groundwater ingress to construction excavations
- Temporary and permanent alteration or impedance of existing drainage paths and waterways which have the potential to result in localised increases in flow velocities around in-stream features. In particular:
  - The construction of the new twin bridges at Ironbark Creek including the temporary waterway structures and the permanent piers themselves
  - Demolition of the existing Ironbark Creek Bridge and piers
  - Adjustment of the drainage channel to the south-east of Ironbark Creek as well as temporary and permanent culverts

- Attenuated or delayed discharge of stormwater captured in temporary construction sediment basins and permanent water quality basins
- Reuse of stormwater captured in temporary construction sediment basins and permanent water quality basins.

Potential changes to the rates and volume of stormwater discharged from the proposal during the construction phase have not been assessed quantitatively. However, minor to moderate changes to rates of stormwater discharge, volume and velocity during construction may result as existing drainage infrastructure is cleaned out and new infrastructure is installed. These changes are not expected to result in a material impact to the receiving environment with the implementation of mitigation measures outlined in **Section 6.2.4**.

Impacts to waterway and riparian processes from changes in flow regime

The geomorphology of waterways within the study area are typically stable, low energy environments that show little evidence for lateral migration except during flood events and are generally considered low risk from stormwater discharges from the proposal. Unmitigated risks include:

- Reduced bank stability (scouring, undercutting, slumping, etc) immediately downstream of proposal discharge locations as a result of increased streamflow discharge and velocities
- Increased rates of removal and transport of eroded bed and bank material leading to downstream sedimentation and potential infilling of aquatic habitat features such as rocky holes or smothering of aquatic vegetation
- Increased water turbidity due to suspended material and subsequent reduction in light infiltration potentially impacting sensitive aquatic vegetation
- Potential for fish passage obstruction due to increased flow velocities, reduced water levels or physical obstructions caused by the realignment of the unnamed drainage channel to the south-east of Ironbark Creek and the installation of piers for the new Ironbark Creek Bridge.

The proposal seeks to minimise or avoid these impacts with the implementation of erosion and sediment controls, site-specific drainage design for REF areas and temporary and permanent erosion and scour protection as outlined in **Section 3.2.3**.

Flooding impacts

The 20 per cent and one per cent AEP events were assessed and the impacts to flooding for Stage 1, Stage 2 and Stage 3 of the construction phase were reviewed. The proposal is not subject to flooding under the existing condition in the 20 per cent AEP event and consequently no discernible impacts to flooding were identified for all three construction stages. Flood impact maps for the one per cent AEP event are mapped in Attachment C of **Appendix L**.

Flood levels

Afflux refers to the predicted change, usually in flood levels, between two scenarios. It is frequently used as a measure of the change in flood levels between an existing scenario and a proposed scenario.

The flood model indicates that three of the construction stages impact on Hexham Swamp, and this includes Hexham Swamp Nature Reserve with Stage 1 of construction having the greatest impact. The afflux in Hexham Swamp is up to 0.03 metres in Stage 1 while in Stage 2 and Stage 3 it is up to 0.02 metres (refer to Figure C-1 in **Appendix L**).

All of the three construction stages show a decrease in flood levels up to 0.05 metres downstream of Ironbark Creek and near Cobbans Creek, south of Ironbark Creek.

The afflux upstream of the Ironbark Creek Bridge and near Sparke Street intersection is about 0.10 metres in all three construction stages, except during Stage 2 when it is about 0.14 metres near Sparke Street intersection.

Surveyed floor levels of buildings provided by City of Newcastle have been used to assess potential flooding impacts to buildings. The properties between Shamrock Street and Clarke Street, Hexham experience an afflux ranging from 0.02 metres to 0.10 metres in Stage 1. The properties around Old Maitland Road, Hexham to the south of Hexham Bridge experience an afflux of about 0.02 metres both in Stage 1 and Stage 2 only. These buildings are currently flood affected.

The properties to the east of Maitland Road at Sandgate and north of the NICB experience an afflux up to 0.05 metres in construction Stage 1 and Stage 2 compared to Stage 3 when afflux is limited to 0.03 metres.

Flow velocities

During construction, there are no large areas with substantial changes in flow velocities across the floodplain during the three stages of construction, with the majority of changes in flow velocities being localised around the construction area.

Flow velocities are increased about 1.25 metres per second on the temporary platform in Stage 1 of the construction and flow velocities are decreased by about 0.5 metres per second in Ironbark Creek upstream of the new bridge. Flow velocities through Ironbark Creek are also increased by about 0.3 metres per second in Stage 2 and Stage 3 of the construction. A reduction in velocity, to a maximum of 0.45 metres per second, is observed within the proposal north of Hexham Bridge in Stage 3 (refer to Figure C-2 in **Appendix L**).

The flow velocities change around the Sparke Street intersection, are variable and show increases by 0.3 metres per second in some locations and decreases by 0.1 metres per second in other isolated patches in all three construction stages.

Flood hazard

The changes in hazard are expressed in terms of changes between dry, low hazard and high hazard condition, or no change.

The flood hazard changes to dry for areas of new bridges embankments in all three stages (refer to Figure C-3 in **Appendix L**). There are minor areas with changes to flood hazard of dry to low or low to high in all three stages in isolated patches near properties around:

- Old Maitland Road, Hexham to the south of Hexham Bridge
- Sparke Street, Hexham
- To the east of Maitland Road at Sandgate and north of the NICB.

Duration of inundation

Figure C-4 in **Appendix L** shows the change in duration inundation for Stage 1, Stage 2 and Stage 3 of the construction phase for the one per cent AEP event. The flood plain between the North Channel and South Channel of the Hunter River has an increase of three per cent in the duration of inundation in general with a maximum increase by about five per cent in isolated patches in all three stages of construction. The duration of inundation increases by a maximum of 10 per cent at the edges of the flood extent in Hexham Swamp with a maximum increase by about 20 per cent in isolated patches.

There is some change to the duration of inundation during Stage 2 of the construction phase. Some areas have a decrease in duration of inundation up to 10 per cent, same localised areas have an increase in duration of inundation. Impacts are lesser in the other two stages of construction.

The majority of properties near Old Maitland Road, Hexham south of Hexham Bridge have an increase in inundation duration of 10 per cent, with increase of more than 20 per cent in isolated patches for all three stages of construction. Sparke Street intersection and north of Sparke Street have an increase of more than 25 per cent in all three stages of construction. The areas around Sandgate Radio Transmission Tower (north of NICB) and Boatman Creek south of Sandgate Road have maximum increase of about 12 per cent for Stage 1 and up to 10 per cent for Stage 2 and Stage 3.

Flooding impacts to buildings

Surveyed floor levels of buildings near to the proposal was provided by City of Newcastle and was clipped to the flooding study area so that a total of 333 buildings was used to assess flooding impacts to buildings from the proposal. It is to be noted that the data provided by City of Newcastle does not include floor levels of all buildings located near to proposal.

The afflux was calculated separately for buildings which were flooded above floor and below floor. In addition, buildings newly flooded above or below floor due to the proposal have been identified and addressed separately as part of the discussion around additional number of buildings flooded.

The difference in building impacts between the baseline and construction cases is minimal for the AEPs modelled. The key metrics investigated were the afflux, as well as the change in the number of buildings flooded above and below floor surveyed floor levels. Modelling results have shown that no buildings are flooded above floor in the 20 per cent AEP event during the construction phase. However, buildings near to the proposal are flooded above the floor level during the one per cent AEP event during construction Stage 1, 2 and 3 and the number of buildings impacted for each stage is summarised in **Table 6.13**.

Table 6.13 Number of buildings flooded above floor during the one per cent AEP flood event for Stages 1-3

Afflux (m)	Stage 1	Stage 2	Stage 3
0.01 – 0.02	27	35	51
0.02 – 0.03	6	28	4
0.03 – 0.05	44	11	0
0.05 – 0.08	19	-	0
Total	**96**	**74**	**55**

In the one per cent AEP event two buildings are newly flooded above floor due to the proposal in construction Stage 1 and one building is newly flooded above floor both in Stage 2 and Stage 3 (refer Attachment J in **Appendix L**). It is to be noted that at all newly flooded buildings above floor is up to 0.04 metres.

Afflux below floor levels for all buildings is lower than 0.01 metres in the 20 per cent AEP event. A summary of afflux below floor levels for all buildings for the three construction stages in the one per cent AEP event is shown in **Table 6.14.**

Table 6.14 Number of buildings flooded below floor during the one per cent AEP flood event for Stages 1-3

Afflux (m)	Stage 1	Stage 2	Stage 3
0.01 – 0.02	5	6	12
0.02 – 0.03	-	6	-
0.03 – 0.05	11	-	-
0.05 – 0.08	-	-	-
Total	**16**	**12**	**12**

Site water balance

During construction of the proposal key water demands are anticipated for earthworks and dust suppression. Lesser demands are anticipated for potable usage at site offices. For earthworks it is anticipated that water would be required primarily for conditioning of fill material and conditioning of in-situ soils for foundation treatments (ripping and re-compaction).

Indicative estimates of water demands are provided in **Table 6.15** and are based on preliminary construction material estimates. Over the duration of the proposal construction, about 8 megalitres of water would be required, equivalent to an average daily demand of about 9.86 kilolitres (kL) or 0.23 litres per second for a 12 hour working day.

Table 6.15 Estimate of construction water demands

Water use	Requirements (kL)
Earthworks – fill conditioning	3,250
Earthworks – foundation treatments	570
Dust suppression	1,962
Potable	1,965
Total	**7,747**

Water demand during construction would be met through use of scheme water.

While there may be potential to opportunistically utilise water within sediment retention basins for uses such as dust suppression and fill conditioning. Water availability from the basins is only temporary and cannot be relied on for supply with a requirement to empty the basins within five days following a storm event. It is also noted that key water demands, such as dust suppression and fill conditioning would be reduced during periods of rain when the supply is available following storm events.

There is also potential to opportunistically utilise dewatering discharge produced through temporary construction dewatering for the sediment basins, however in this instance it is noted that dewatering is only likely to occur for a matter of weeks at each basin during construction, and dewatering is not considered to be a viable water source over the duration of the proposal.

Discharge of water from site would only occur from sediment retention ponds at approved discharge points. Discharge will be monitored and managed in accordance with the relevant EPL conditions.

Groundwater produced through temporary construction dewatering for sediment retention basins will be treated as required and discharged to local stormwater drainage system.

Operation

Hydrology impacts

An assessment of the impacts of the changes in drainage design and stormwater discharge from the proposal has been completed of the 26 drainage systems that drain to waterways surrounding the proposal and including the Hunter River, South Channel Hunter River and Ironbark Creek.

Table 6.16 provides a summary of the results of the 26 drainage systems assessed and estimated changes to flow rates and flow velocities, which are summarised as follows:

- Total catchment areas are not proposed to substantially change with a maximum increase of 27 per cent for the catchment (near the intersection of Sparke Street and Maitland Road) and a maximum reduction of -21 per cent for the catchment (near the intersection of Shamrock Street and Maitland Road)
- The relative change in percentage of impervious area within each catchment ranges from zero to five per cent as a result of the road development
- The results indicate that discharge rates would generally increase as a result of the proposal which is consistent with the increase in impervious area within each catchment
- Similarly, discharge volumes are typically predicted to increase as a result of the proposal
- Estimated velocities are also expected to increase.

The drainage modelling indicates that stormwater discharge rates, volumes and velocities are generally expected to increase as a result of the increased percentage of impervious area within each reporting catchment. These changes are not expected to result in a material impact to the receiving environment as:

- Increased discharges of stormwater from the proposal and dewatering of water quality basins would largely be consistent with variations in existing conditions and occur during or following naturally occurring flow events. Changes to the number, timing and duration of flow events in the receiving environment are likely to be minor and not of a material impact
- Where stormwater discharges are made from the proposal, drainage design includes appropriate mitigations including scour protection in the form of rock transition aprons at culvert outlets
- Estimated increases to discharge rates and velocities at the outlets are likely to be reduced as a result of stormwater attenuation provided by the water quality basins that were not included in the drainage modelling.

Table 6.16 Summary of estimated changes to stormwater discharges from the 26 culverts that were assessed

Storm event	Change	Change	
		Flow (m3/s)	Velocity (m/s)
50% AEP	Mean	0.02	-0.19
	Min	-0.03	-1.50
	Max	0.14	1.92
10% AEP	Mean	0.03	-0.18

Storm event	Change	Change	
		Flow (m3/s)	Velocity (m/s)
	Min	-0.04	-1.45
	Max	0.23	1.85
1% AEP	Mean	0.04	-0.08
	Min	-0.12	-0.77
	Max	0.34	0.62

Drainage design impacts

The proposal would potentially impact on the waterways located immediately next to and within the REF area and would include:

- Ironbark Creek
- The South Channel Hunter River alongside the REF area located to the north of EIS Area 2 and extending up to the southern side of EIS Area 2, then from the northern side of EIS Area 2 and extending up to the proposed U-turn facility at Old Maitland Road, Hexham to the north-east of Hexham Bowling Club.
- The Hunter River between Hexham Bridge and Compound 4
- The section of the waterway which receives discharge from the proposal drainage systems in the REF area which includes 31 systems comprised of Systems 3, 7, 10 to 13 and 22 to 46 but does not include the seven systems (1, 2, 4, 5, 6, 15 and 21) in the REF area that drain into CM SEPP areas refer to **Appendix B**.

The potential impacts to hydrology during operation of the proposal relate to the increase in impervious surface from introduction of the widening of the road, a change in surface flow paths associated within drainage lines across the proposal and the changes in stormwater discharge due to the frequency and intensity of the storm events.

The drainage design including the cross-drainage culverts and longitudinal drainage pipe systems have been developed to avoid drainage catchment diversion as far as practicable to minimise hydrology impacts. Overall, there is unlikely to be a significant change in hydrology and flow distribution across the broader catchment. However, there is the potential for localised changes in flow from one pavement sub-catchment to the next.

Culvert upgrades

The proposal work would require extension of the existing culverts to accommodate the widening of Maitland Road. Upgrade of the size of the existing culverts would also be required where the capacities of the existing culverts are inadequate to cater for flows. The catchment areas to the culverts have not changed, though there are minor changes to the catchment imperviousness. The design methodology adopted has minimised changes to peak flows and velocity as much as practical, and wherever localised changes would still occur, scour protection would be provided to prevent erosion.

Between the southern limit of works and Ironbark Creek, the existing drainage systems that drain the proposal and the upslope catchments on the western side through to the eastern side of Maitland Road, flow from the culvert outlet to intermediate open channels located perpendicular to the edge of the existing road reserve that then discharges water into the low lying swamp areas to the east of Maitland Road. One new reinforced concrete pipe would be provided as part of System

3 that connects System 2 with System 4 via Basin 2 and grassed swale 1 (refer to **Appendix B**), otherwise all the other culverts to the south of Ironbark Creek would not be upgraded, as the existing culverts meet the drainage criteria for the 10 per cent AEP standard and one lane free from inundation in the 10 per cent AEP storm events for the local catchment flows.

All other culverts have a smaller drainage capacity and drain the road pavement runoff from one side of the road to the other side. Where water is drained to the western side of Maitland Road to the north of Ironbark Creek there are some open channels within the road reserve corridor that drain to one of the two major culverts that are described in **Section 2.2.4**. System 10 would be upgraded as part of the proposal and one new reinforced box culvert (2 x 600mm x 300mm) would be provided at System 14 to the southern side of Shamrock Street (refer to **Appendix B**).

Where the existing culverts have been upgraded or extended to suit the new road embankment, scour protection would be provided.

The existing culvert system does not direct flow into the Hexham Swamp Nature Reserve. No adverse impacts to Hexham Swamp and Hexham Swamp Nature Reserve are anticipated from the drainage works that will be implemented as part of the proposal.

Longitudinal drainage pipe upgrades

The overall effect of the proposal on longitudinal drainage pipes is considered minor and generally limited to the relocation of the drainage pits on the median and outside lanes as a result of the road design changes.

Existing drainage pipes and the outlets within the proposal area have been retained as much as practical. New drainage pipes and pits (refer to **Appendix B**) have also been provided where required to drain the road surface runoff to the existing outlets in order to meet the proposal drainage design requirements,. System 7 would be removed as part of the removal of Ironbark Creek Bridge and new drainage systems would be constructed at the northern and southern sides of Ironbark Creek Bridge. The southern side of Ironbark Creek Bridge would discharge through Basin 3 and grassed swale 2 and the northern side of the bridge would discharge through Basin 4.

Where new pipes or pipe outlets have been provided, these have been designed with as low gradient as practical and sized to minimise the outlet velocities. Scour protection would be provided at all new pipe outlets to minimise potential risk of erosion.

Surface water hydrology impacts

Activities during operation of the proposal that may impact the nature of surface water hydrology (volume, rate, timing, duration, velocity, etc.) associated with stormwater discharges include:

- Road paving and soil compaction leading to reduced or effectively eliminated rates of infiltration
- Alteration or restriction of existing drainage paths and catchments
- Attenuated or delayed discharge of stormwater captured in water quality basins which have been designed to reduce the current annual average pollutant loads.

There would potentially be minor to moderate changes to rates of stormwater discharge, volume and velocity during operation as existing drainage infrastructure is cleaned out and new infrastructure is installed. These changes are not expected to result in a material impact due to the proposed drainage mitigation such as scour protection that will be implemented where required at culverts that will be upgraded for the proposal and permanent water quality basins, refer to **Appendix B**.

Impacts to waterway and riparian processes

As identified above, waterways across the study area are generally considered stable, low energy, show little evidence for lateral migration and are hence considered low risk from stormwater discharges from the proposal. However, during operation of the proposal impacts to waterway health and in-stream processes on the Hunter River, the South Channel Hunter River and Ironbark Creek may occur as a result of the increase in impervious surfaces associated with the widening of Maitland Road.

Impacts may extend beyond the immediate discharge location and include:

- Reduced bank stability (scouring, undercutting, slumping, etc) immediately downstream of proposal discharge locations as a result of increased streamflow discharge and velocities and this includes drainage systems that are located on river banks. Within the REF area this includes Systems 10 to 13, 15, 21 and 22 to 24 located on the banks of the South Channel Hunter River and Systems 37-46 located on the banks of the Hunter River
- Increased rates of removal and transport of eroded bed and bank material leading to downstream sedimentation and potential infilling of aquatic habitat features such as rocky holes or smothering of aquatic vegetation
- Increased water turbidity due to suspended material and subsequent reduction in light infiltration potentially impacting sensitive aquatic vegetation.

The proposal seeks to minimise or avoid these impacts by adopting permanent erosion and scour protection at culverts that are upgraded as part of the proposal and the inclusion of five permanent water quality basins , refer to **Appendix B**. The proposal would maintain existing water flow under Maitland Road to Hexham Swamp and no changes are expected from the proposal to the existing surface water hydrology including for sensitive receiving environments such as Hexham Swamp, the surrounding Coastal Wetlands, freshwater wetlands or Ramsar listed wetlands.

Flooding impacts

Impacts of flooding on the proposal

The majority of the main carriageway alignment, along Maitland Road, is immune to flooding in the five per cent AEP event. Flood mapping is included in the *Hexham Straight Widening Flooding and Hydrology Assessment* (refer to **Appendix L**).

The sections which are overtopped are identified below.

- A section of Maitland Road to the south of Hexham Bridge, next to the A1 Pacific Highway northbound onramp towards Raymond Terrace from Hexham
- A section of Maitland Road at the northern extent of the proposal
- A section of Maitland Road, near Shamrock Road
- A section of Old Maitland Road, Hexham at the northern end of the proposal.

In the two per cent AEP event, the majority the proposal is subject to flooding. Almost the entire proposal is subject to overtopping in the one per cent AEP event aside from the section of Maitland Road and Old Maitland Road, Sandgate next to the Calvary St Joseph’s Retirement Community, towards the southern extent of the proposal.

In a PMF event, the proposal would experience complete inundation, aside from areas surrounding the Calvary St Joseph’s Retirement Community and the intersection of Maitland Road and NICB.

Change in flood level

Figures D-1 to D-4 in **Appendix L** show change in flood levels (afflux) for the five per cent, two per cent and one per cent AEP events and the probable maximum flood event, respectively, for the operational phase. Afflux for the operational phase of the proposal is negligible for flood events smaller than the five per cent AEP event.

Changes in flood for the operational phase in the one per cent AEP event (refer to Figure D-3 in **Appendix L**) are much lower than the construction phase (refer to Figure C-1 in **Appendix L**). Changes in flood levels for the operational phase for the two per cent AEP event are more pronounced than the five per cent AEP, one per cent AEP and the probable maximum flood events.

In the five per cent AEP event, flood level is increased up to 0.25 metres (refer to Figure D-1 in **Appendix L**) at Aurizon Facility along the north-western boundary of the proposal, this is most likely related to the high profile redirective kerb and would be further investigated in detailed design. The localised increase in flood level results in a reduction of flood levels up to 0.10 metres on the southern side of Maitland Road. Changes in flood levels elsewhere are less than 0.01 metres.

In the two per cent AEP event, a localised increase in flood level up to 0.25 metres (refer to Figure D-2 in **Appendix L**) occurs in the vicinity of Smithies Creek along the western boundary of the proposal. The majority of the area located between Shamrock Street and Sparkes Street is subject to 0.1 metres increase in flood level with a maximum localised increase in flood level up to 0.25 metres along the western boundary of the proposal. Flood levels on the floodplain located to the west of the proposal, including Hexham Swamp are increased up to 0.03 metres. Flood levels are lowered up to 0.01 metres along the western boundary of the proposal at the Sparke Street intersection and downstream of the proposed bridge at Ironbark Creek.

Changes in flood levels in the one per cent AEP event (refer to Figure D-3 in **Appendix L**) are less extensive than the two per cent AEP event. A maximum increase in flood level up to 0.25 metres occurs in isolated areas within the proposal. Flood levels on the floodplain located to the west of the proposal are increased up to 0.03 metres due to the proposal.

In the case of the probable maximum flood changes in flood levels are confined to the floodplain located east of the Main North Rail Line as shown in Figure D-4 in **Appendix L**. Increase in flood levels up to 0.25 metres occurs in the vicinity of the new bridge due to the proposal, however this location is currently flood affected.

Change in flow velocity

There are no large areas with significant changes in flow velocities across the Hunter River floodplain and Hexham Swamp, and the majority of changes are localised around the operational footprint. Figures D5 to D-8 in **Appendix L** show the change in flow velocities for the five per cent, two per cent and one per cent AEP events and probable maximum flood event for the operational phase. Changes in flow velocities are negligible for flood events smaller than the five per cent AEP event.

In the five per cent AEP event, flow velocity changes show a decrease in velocity in the Hunter River, with changes around the eastern embankment of Hexham Bridge. Increases in velocity of up to 0.3 metres per second occur along Maitland Road, north of Ironbark Creek, near Sparke Street. Furthermore, increases in velocity are expected to occur along the Main North Rail Line next to the rail maintenance facility located at the north-western end of the proposal.

In the two per cent and one per cent AEP events, in addition to impacts similar to the 10 per cent and five per cent AEP events, there are areas of increased velocity of 0.1 to 0.2 metres per second and decreased velocity of 0.1 metres per second in the far northern part of Hexham Swamp. There are also increases of 0.3 metres per second around Clarke Street and Merchant Street, Hexham in addition to increases of 0.3 metres per second at the Sparke Street intersection and within Ironbark Creek adjoining the South Channel Hunter River.

In the probable maximum flood, there are numerous locations where flow velocities both increase and decrease, where the most prominent changes are located around where Ironbark Creek adjoins the South Channel Hunter River and between Shamrock Street and Clark Street, Hexham. Localised increases and decreases of up to 0.5 metres per second occur in these locations.

Flood hazard

Figures D-9 to D-12 in **Appendix L** show the change in flood hazard for the five per cent, two per cent and one per cent AEP and probable maximum flood events for the operational phase. Changes in flood hazard are negligible for flood events smaller than the five per cent AEP event. In the case of the other flood events, changes to flood hazard are generally minor and localised.

The one per cent and five per cent AEP events experience minor increases in flood hazard in areas of the northern extent of the proposal, an increase north of Ironbark Creek along Maitland Road to Shamrock Street and decreases directly north of the A1 Pacific Highway along Maitland Road within the REF area. There are not large increases in extent of the high hazard areas, which would indicate a new floodway or flow path being formed as a result of the operational phase.

In the probable maximum flood event, the flood hazard remains unchanged with the proposal.

Overall, the change in flood hazard for the operational phase is localised and as such does not have adverse impacts on flood conveyance, floodways, flow direction and flood storage.

Flood duration and inundation

Figures D-13 to D-16 in **Appendix L** show the change in duration in inundation for the five per cent, two per cent and one per cent AEP and probable maximum flood events for the operational phase. Changes in duration of inundation are negligible for flood events smaller than the five per cent AEP event.

In the five per cent AEP event there is a change in duration in inundation located around the rail maintenance facility, located to the north-west of the proposal, increasing in areas for up to 50 hours. Generally, in other areas of the proposal, the duration of inundation is relatively uniform in distribution and typically within +/- five per cent of existing conditions. Downstream of Hexham Bridge there are localised decreases in durations of 10 to 20 per cent where reductions in flood levels are expected.

In the two per cent and one per cent AEP events the changes in duration of inundation are similar to the 10 per cent and five per cent AEP events, with prominent differences around the Hexham Bridge interchange on the southern bank near the railway line, and north of Ironbark Creek to Shamrock Street, with a difference in flooding duration between one and 10 hours.

In the probable maximum flood event, the change in duration of inundation is again typically within +/- five per cent from the existing case across Maitland Road/Pacific Highway (A43) adjacent and just north of the Calvary St Joseph's Retirement Community, with decreases over 30 per cent.

Flooding impacts to buildings

Surveyed floor levels of 333 buildings provided by City of Newcastle have been used to assess flooding impacts to buildings. The difference in building impacts between the baseline and operational cases is minimal for the AEPs modelled. The key metrics investigated were the afflux, as well as the change in the number of buildings flooded above and below floor surveyed floor levels.

Details on location, floor level and flood level for each building are provided in Attachment J of **Appendix L**.

Table 6.17 Number of buildings flooded above during operation of the proposal

Depth of flooding above floor (m)	63.2%AEP	20%AEP	10%AEP	5%AEP	2%AEP	1%AEP	PMF
0.01 – 0.02	-	-	-	-	22	48	-
0.02 – 0.03	-	-	-	-	23	17	-
0.02 – 0.05	-	-	-	-	13	-	-
0.05 – 0.07	-	-	-	-	3	-	-
Total	**-**	**-**	**-**	**-**	**61**	**65**	-

Only one building is newly flooded above floor in the one per cent AEP event, refer to **Appendix L.** It is to be noted that the building is newly flooded 0.01 metres above floor.

Modelling results of the above floor impacts to the 333 buildings located near to the proposal during operation is summarised in **Table 6.18**.

Property surveys would be carried out during detailed design in order to confirm any adverse flooding impacts in consultation with landowners.

Table 6.18 Number of buildings impacted below floor during operation of the proposal

Depth of flooding above floor (m)	63.2%AEP	20%AEP	10%AEP	5%AEP	2%AEP	1%AEP	PMF
0.01 – 0.02	-	-	-	-	22	48	-
0.02 – 0.03	-	-	-	-	23	17	-
0.02 – 0.05	-	-	-	-	13	-	-
0.05 – 0.07	-	-	-	-	3	-	-
Total	**-**	**-**	**-**	**-**	**61**	**65**	-

Climate change impacts

The impact of climate change on flooding during the operational phase was assessed through modelling scenarios that had tidal levels set at expected future heights due to climate change. These expected future heights were for 2050 and 2100. Figure E-1 in **Appendix L** shows increases of flood depths of 0.05 to 0.1 metres in the one per cent AEP event across the entire flood extent within the vicinity of the proposal for the 2050 scenario, with the exception of South Channel Hunter River south of the proposal and an area in Kooragang Island adjacent to this increasing by 0.1 to 0.25 metres. The flood extent has scattered increases on edges of the existing flood extent, except South Channel Hunter River south of Ferry Road, Sandgate where flood extent increases by 130 metres into Kooragang Island.

In the 2100 scenario, flood depths increase by 0.1 to 0.25 metres in the one per cent AEP event (refer to Figure E-2 in **Appendix L**) across the flood extent within the vicinity of the proposal, with the exception of South Channel Hunter River south of Old Maitland Road, Sandgate and the area adjacent in Kooragang Island which increases by 0.25 to 0.4 metres and South Channel Hunter River south of Ferry Road, Sandgate which increases by over 0.4 metres. The flood extent similarly has scattered increases on edges of the existing flood extent with the exception of South Channel Hunter River south of Ferry Road, Sandgate where flood extent increases by 150 metres into Kooragang Island and 50 metres into Sandgate. The flood extent also increases by 350 metres near Kennington Drive.

Site water balance

There are no ongoing operational water demands for the proposal.

The construction sediment retention basins employed during the proposal construction would be retained as water quality basins during operation.

Discharge of water from site to the environment would only occur from sediment retention ponds at approved discharge points. Discharge will be monitored and managed in accordance with the relevant EPL conditions.

6.2.4 Safeguards and management measures

The environmental management measures that will be implemented to minimise hydrology and flooding impacts of the proposal within the REF area, along with the responsibility and timing for those measures, are presented in **Table 6.19.**

Table 6.19 Safeguards and management measures – hydrology and flooding

Impact	Environmental safeguards	Responsibility	Timing
Potential changes to flood impacts resulting from detailed design	Further flood investigations and detailed hydrological and hydraulic modelling will be carried out during detailed design to ensure the design objectives and performance criteria for the proposal are met.	Contractor	Detailed design
Flooding impacts on property	Landowners will continue to be consulted regarding any changes to flooding and hydrology impacts and mitigation measures in relation to individual properties.	Transport/ Contractor	Detailed design
Flooding impacts during construction	A Flood Management Plan (FMP) will be prepared as part of the CEMP for the proposal and will include: • Details on the processes for flood preparedness, materials management, weather monitoring, site management and flood incident management • Responsibilities for flood response (preparation of site upon receipt of flood warning, evacuation of site personnel) during and recovery following a flood event • Detailed construction planning such that construction phase traffic management and other construction area arrangements do not impact on flood evacuation route traffic capacity.	Transport/ Contractor	Prior to construction
Flooding impacts of bridges and culverts	Where possible, culvert and bridge design will be further developed to minimise upstream and downstream impacts to wetlands and other sensitive environments.	Contractor	Detailed design
	Where possible, detailed construction staging plans will be developed during detailed design so that bridges and	Contractor	Detailed design

Impact	Environmental safeguards	Responsibility	Timing
	culverts are constructed in a way that minimises flood risk.		
Impacts on existing drainage systems	Activities that may affect existing drainage systems during construction will be carried out so that existing hydraulic capacity of these systems is maintained where practicable. This will continue to be undertaken through appropriate design methodologies and considerations during detailed design. Drainage systems that are upgraded and require scour protection would also consider Roads and Maritime Services (2017) *Water Sensitive Urban Design Guideline* as part of detailed design.	Contractor	Construction
Impacts to riverbanks downstream of proposal discharge locations during construction	As part of the Construction Soils and Water Management Plan a measure will be included to monitor waterways (channels and banks) immediately downstream of proposal discharge locations during the construction phase to identify potential downstream impacts (e.g. sedimentation, scour, etc.). If impacts are identified, relevant corrective actions will be implemented to ensure stabilisation as part of the erosion and sediment control plan. Further to this, the requirement for remediative and additional preventative actions will be assessed. Physical controls to ensure the stabilisation and continuing integrity of watercourse geomorphic properties will be considered where reasonable and feasible.	Contractor	Construction
Unforeseen impact to surface water hydrology	A surface water and groundwater monitoring program will be implemented that includes the collection of baseline data and detailed monitoring during construction. Should unforeseen impacts arise that are not already addressed by the environmental management measures outlined in this table, appropriate responses and management measures will be developed in consultation with the relevant authority.	Transport	Construction