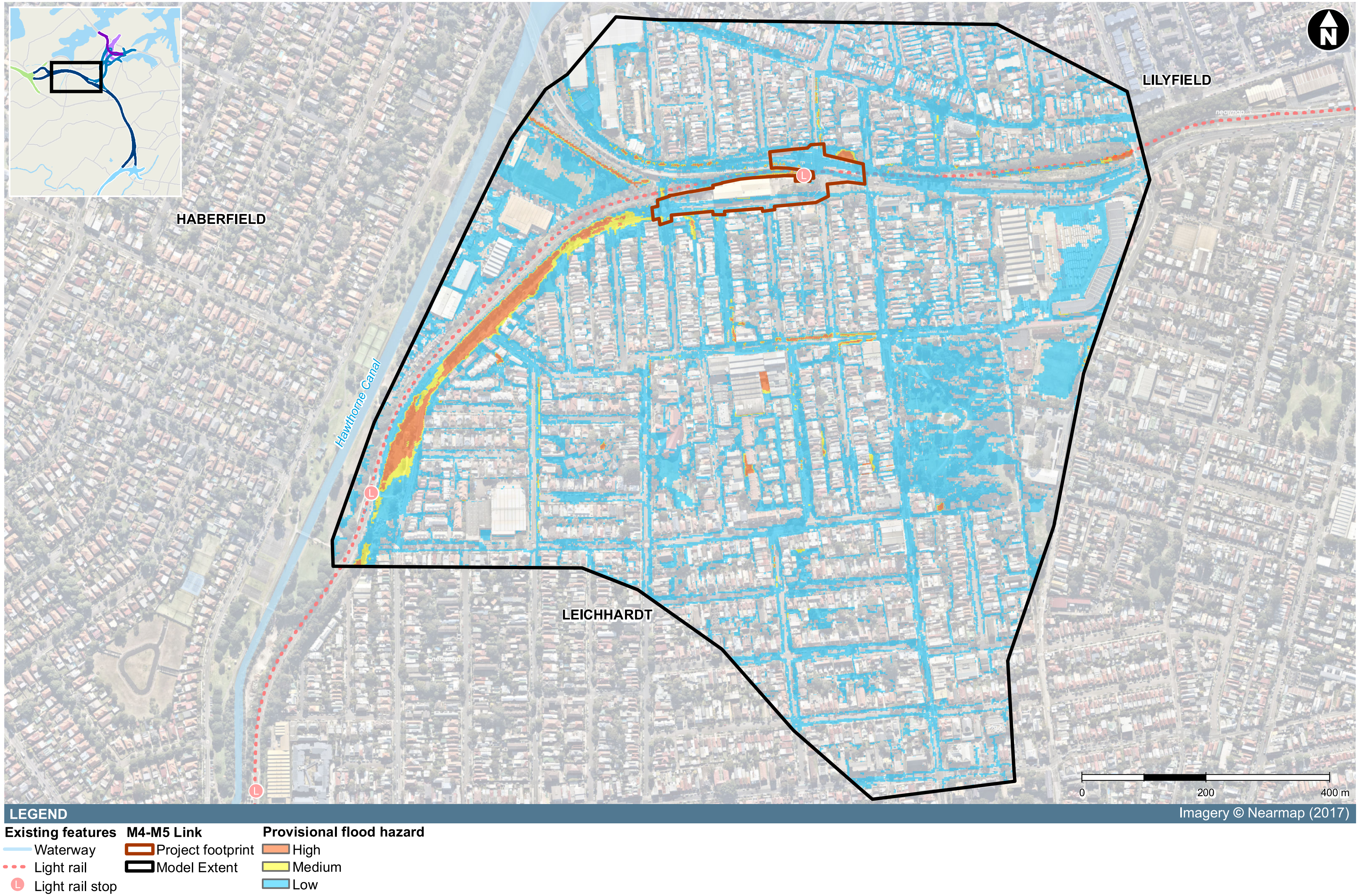

Figure 6-21 Proposed design conditions flood behaviour – Darley Road - provisional flood hazard (100 year ARI)

6.2.2 Potential impacts of future climate change

Future climate change could lead to sea level rise and potential increase in rainfall intensity and frequency. This could affect flood behaviour over the life of the project. An assessment of the potential impact of climate change on flood behaviour in the vicinity of the M4-M5 Link has therefore been undertaken and is discussed below:

- For the Wattle Street and St Peters interchanges, potential impacts of future climate change have already been considered in the design of the M4 East and New M5 projects. Climate change impact assessments are described in the design documentation for those projects (see **section 3.4.1**). Therefore no additional assessments with regards to climate change are required for these areas
- The Rozelle interchange is located in close proximity to Rozelle Bay and both sea level rise and potential increases in rainfall intensity could affect the flooding in the vicinity of the interchange
- Iron Cove Link is situated at a level that is well above the influence of any sea level rise associated with climate change. Therefore, only the influence of increases in rainfall intensities was considered
- Darley Road is located in proximity to Hawthorne Canal, which will be influenced by sea level rise as well as increased rainfall intensities and frequencies.

Rozelle interchange

Based on the guidelines set out in **section 3.2.8**, a number of different scenarios were adopted in the assessment of the potential climate change impacts at the Rozelle interchange over the design life of the project. These scenarios are summarised in **Table 6-2** and were based on a combination of:

- 200 year and 500 year ARI rainfall intensities, assumed to represent 10 per cent or 30 per cent increase in 2016 (present day) rainfall intensities, respectively
- A rise in sea level by 0.4 metres or 0.9 metres.

Table 6-2 Design flood scenario for assessment of climate change impacts at Rozelle interchange

Scenario	Local catchment flood	Tailwater boundary condition
R1	200 year ARI	2016 High High Water Solstice Springs (HHWSS) peak tide level plus 0.4 m (1.4 m AHD)
R2	500 year ARI	2016 HHWSS peak tide level plus 0.9 m (1.9 m AHD)
R3	500 year ARI	2016 Extreme tide peak storm tide level plus 0.9 m (2.8 m AHD)
R4	PMF[(1)]	2016 HHWSS peak tide level plus 0.4 m (1.4 m AHD)
R5	PMF[(1)]	2016 SS peak tide level plus 0.9 m (1.9 m AHD)

Notes:

[1]There are currently no guidelines which quantify the likely increase in probable maximum precipitation (PMP) associated with future climate change. By its definition, the PMP is the result of the optimum combination of the available moisture in the atmosphere and the efficiency of the storm mechanism in regards to rainfall production. On this basis no adjustment has been made to the PMP rainfall intensities for future climate change.

The flood model developed for the flood assessment around the Rozelle interchange was used to assess potential changes in flood behaviour under the various climate change scenarios. The climate change assessment has been based on the proposed design conditions. Peak flood levels at key locations for present day (2016) as well as for the assessed climate change scenarios are summarised in **Table 6-3**. Potential impacts are as follows:

- Potential increases in rainfall intensities by up to 10 per cent would lead to flood level increases of approximately 0.06 metres for areas that are not affected by sea level rise in the 100 year ARI event. Increases in rainfall intensities by up to 30 per cent would lead to flood level increases of up to 0.15 metres. This means that more properties could be affected by flooding or experience more frequent flooding under future climate change conditions

- At the new bridge over Whites Creek at The Crescent, sea level rise would lead to increases in peak flood levels of between 0.26 metres and 0.82 metres in the 100 year ARI event. This would reduce the freeboard to the underside of the bridge. This means that properties adjacent to Whites Creek, in particular along Railway Parade could experience much more frequent flooding under future climate change conditions
- At the tunnel portal the effect of sea level rise would be less pronounced than at The Crescent. Sea level rise would lead to increases in peak flood levels of between 0.1 metres and 0.67 metres in the 100 year ARI event. This would reduce the freeboard to the portal but peak flood levels would still be more than 0.5 metres below the PMF level
- At the new culverts under City West Link, sea level rise would lead to increases in peak flood levels of between 0.1 metres and 0.66 metres in the 100 year ARI event. Peak flood levels would still be more than 0.5 metres below the PMF level which would set the minimum level for the tunnel portal
- Neither potential increases in rainfall intensities nor sea level rise would lead to overtopping of The Crescent or City West Link in the 100 year ARI event
- At the tunnel portal sea level rise would lead to minor increases in peak flood levels of between 0.01 metres and 0.04 metres in the PMF. Peak PMF flood levels at the tunnel portal are therefore not very sensitive to a sea level rise of up to 0.9 metres.

Flood behaviour with potential increases in rainfall intensities and sea level rise in a 100 year ARI and PMF events are shown in **Figure 6-22** and **Figure 6-23**.

Table 6-3 Summary of peak flood levels – 2016 and future climate change conditions for the Rozelle interchange

Location	100 year ARI							PMF				
	2016 Conditions	Scenario R1		Scenario R2		Scenario R3		2016 Conditions	Scenario R4		Scenario R5	
	Level (m AHD)	Level (m AHD)	Change (m)	Level (m AHD)	Change (m)	Level (m AHD)	Change (m)	Level (m AHD)	Level (m AHD)	Change (m)	Level (m AHD)	Change (m)
The Crescent bridge at Whites Creek	2.75	2.90	+0.16	3.10	+0.35	3.40	+0.66	5.07	5.07	+0.0	5.08	+0.10
Western channel	2.33	2.41	+0.08	3.53	+0.19	3.04	+0.71	3.33	3.64	+0.03	3.67	+0.06
New culverts at City West Link	2.09	2.20	+0.11	2.36	+0.27	3.00	+0.91	3.61	3.36	+0.04	3.41	+0.08
CBD and South East Light Rail site	5.91	5.91	+0.0	5.91	+0.01	5.91	+0.01	6.09	6.09	0.00	6.09	0.00

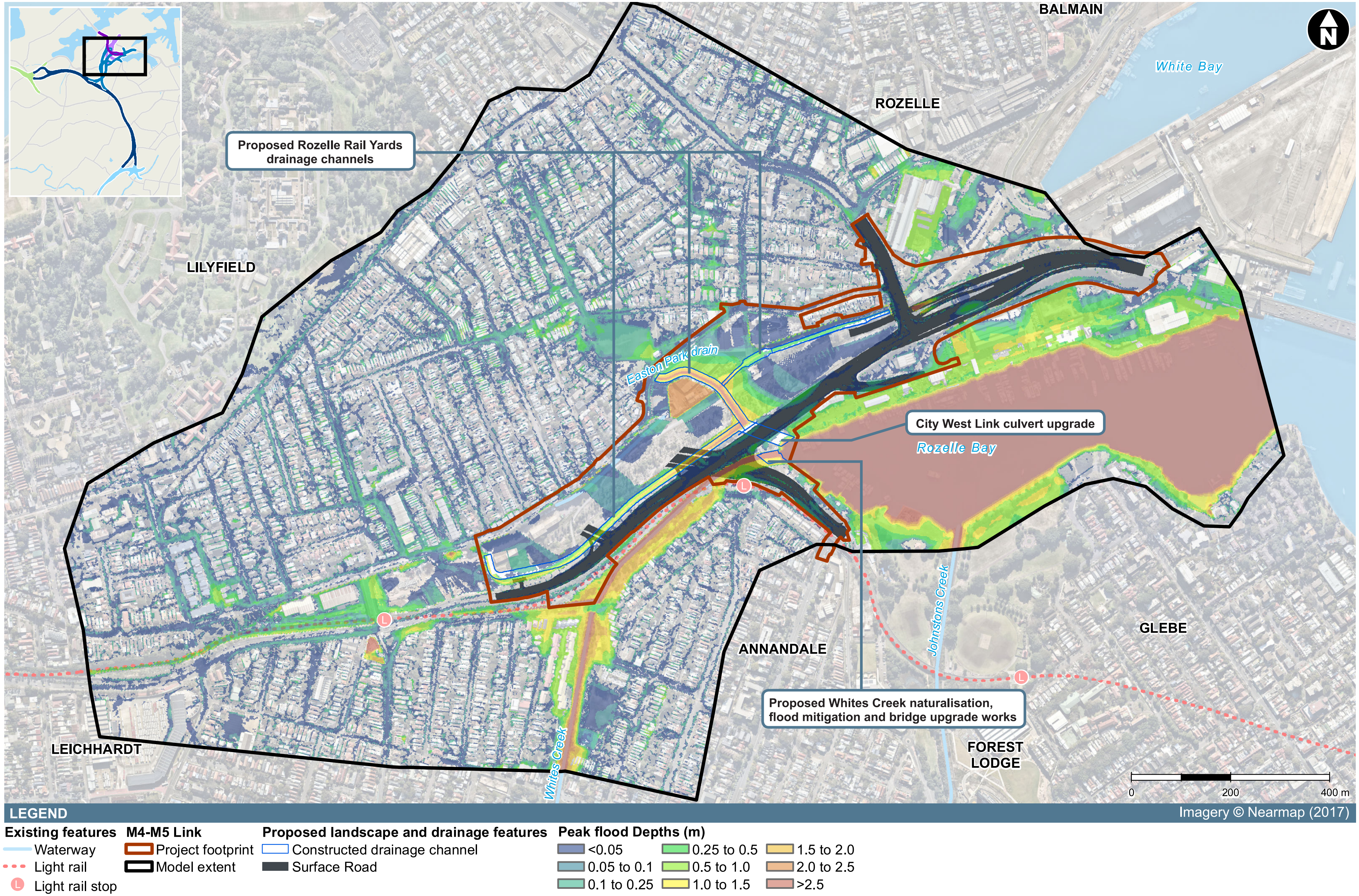

Figure 6-22 Potential climate change impact – Rozelle interchange - peak flood depths (100 year ARI)

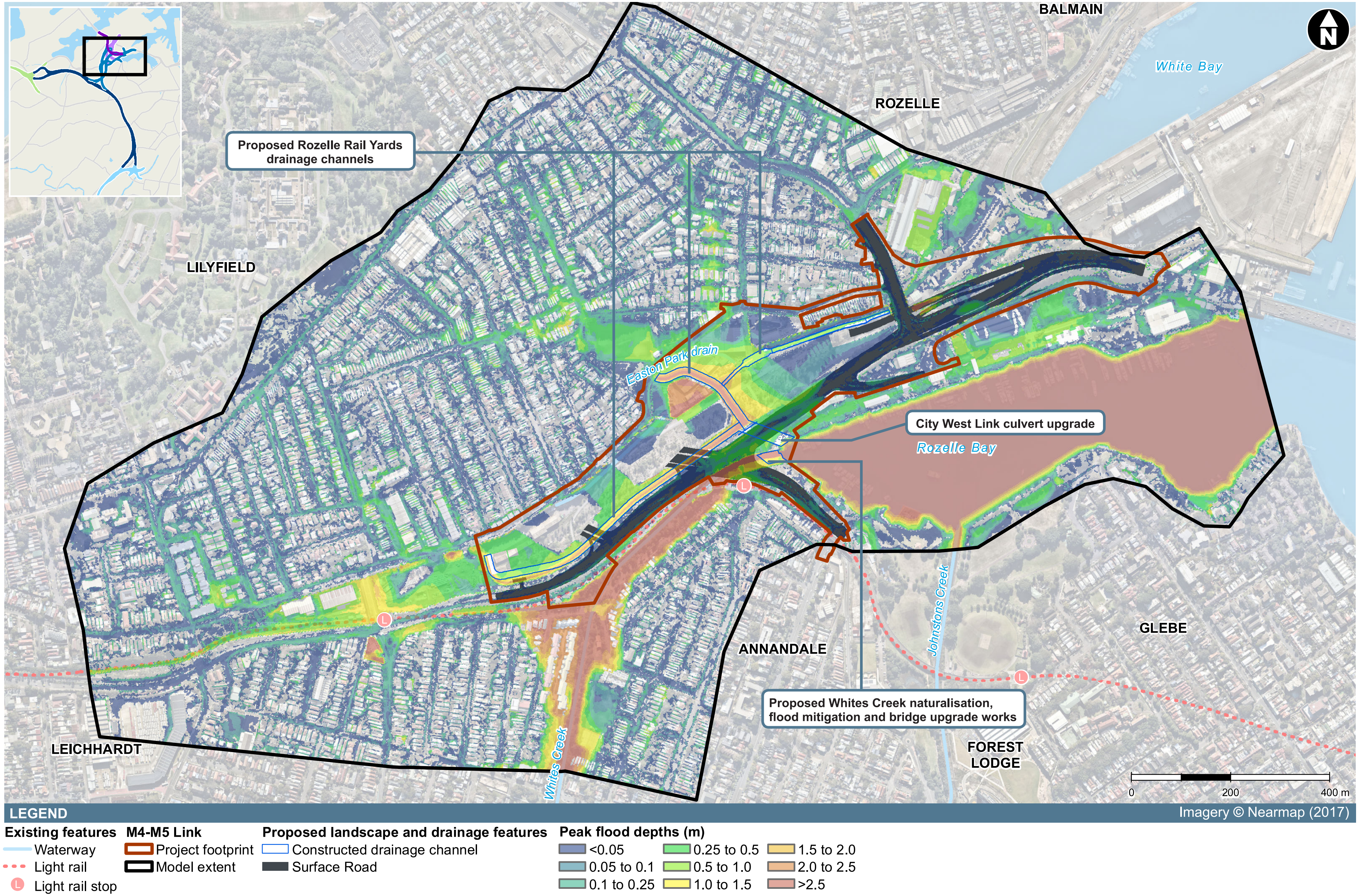

Figure 6-23 Potential climate change impact – Rozelle interchange - peak flood depths (PMF)

Iron Cove Link

The climate change assessment at Iron Cove involved determining the potential influence on flood levels as a consequence of higher rainfall intensity. Design rainfall intensities for the 200 and 500 year ARI events were adopted as being similar to the 100 year ARI design rainfall intensity being increased by 10 per cent and 30 per cent respectively.

The peak flood levels at Iron Cove Link or surrounding roads did not vary significantly under the higher rainfall intensity scenarios of the 200 year and 500 year ARI events (see **Table 6-4**). Along roads and other areas with reasonable hydraulic gradients and shallow depths the increase in flood level would only be between 0.01 and 0.05 metres.

Flood behaviour with potential increases in rainfall intensities and sea level rise in a 100 year ARI and PMF events are shown in **Figure 6-24** and **Figure 6-25**.

Table 6-4 Summary of peak flood levels – 2016 and future climate change conditions at Iron Cove Link

Location	100 year ARI	200 year ARI		500 year ARI	
	Level (m AHD)	Level (m AHD)	Difference (m)	Level (m AHD)	Difference (m)
Victoria Road near Iron Cove Bridge	17.86	17.89	+0.03	17.90	+0.04
Victoria Road near Crystal Street	25.72	25.73	+0.01	25.74	+0.02
Manning Street	3.61	3.63	+0.02	3.66	+0.05
Victoria Road near Callan Street	23.72	23.73	+0.01	23.75	+0.03
King George Park	3.15	3.17	+0.02	3.19	+0.04

Darley Road

The climate change assessment at Darley Road involved determining the potential influence on flood levels as a consequence of higher rainfall intensity. Design rainfall intensities for the 200 and 500 year ARI events were adopted as being similar to the 100 year ARI design rainfall intensity being increased by 10 per cent and 30 per cent respectively.

The peak flood levels at Darley Road did not vary significantly under the higher rainfall intensity scenarios of the 200 year and 500 year ARI events (see **Table 6-5**). Along roads and other areas with reasonable hydraulic gradients and shallow depths the increase in flood level would only be between 0.01 and 0.05 metres. In ponding areas flood levels could rise up to 0.16 metres under future climate conditions.

Flood behaviour with potential increases in rainfall intensities and sea level rise in a 100 year ARI and PMF events are shown in **Figure 6-26** and **Figure 6-27**.

Table 6-5 Summary of peak flood levels – 2016 and future climate change conditions at Darley Road

Location	100 year ARI	200 year ARI		500 year ARI	
	Level (m AHD)	Level (m AHD)	Difference (m)	Level (m AHD)	Difference (m)
Leichhardt North light rail stop	8.20	8.22	+0.02	8.25	+0.05
Darley Road near Charles Street	3.29	3.32	+0.03	3.45	+0.16
Darley Road near James Street	14.59	14.59	+0.0	14.59	+0.0

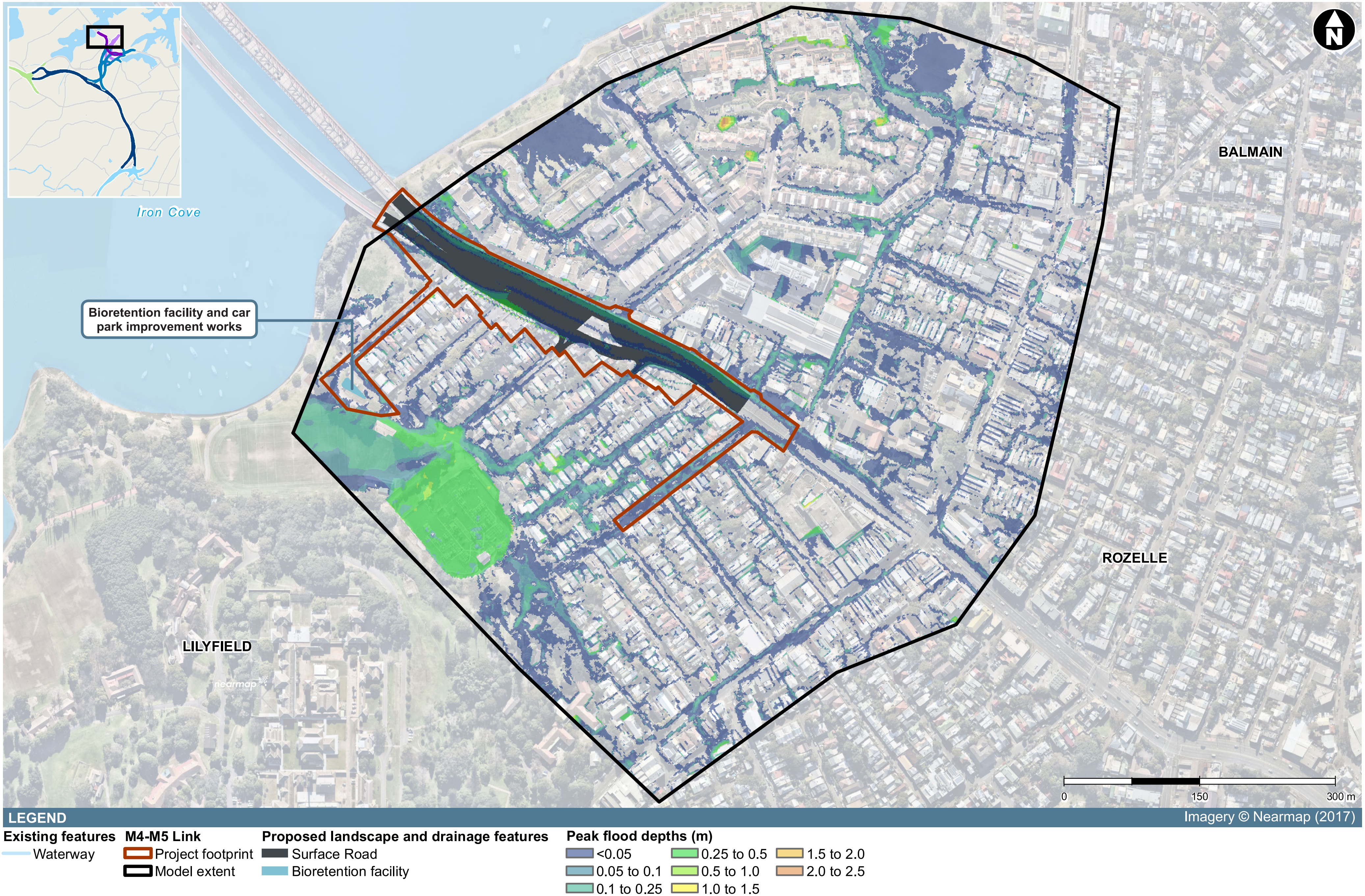

Figure 6-24 Potential climate change impact – Iron Cove Link - peak flood depths (100 year ARI)

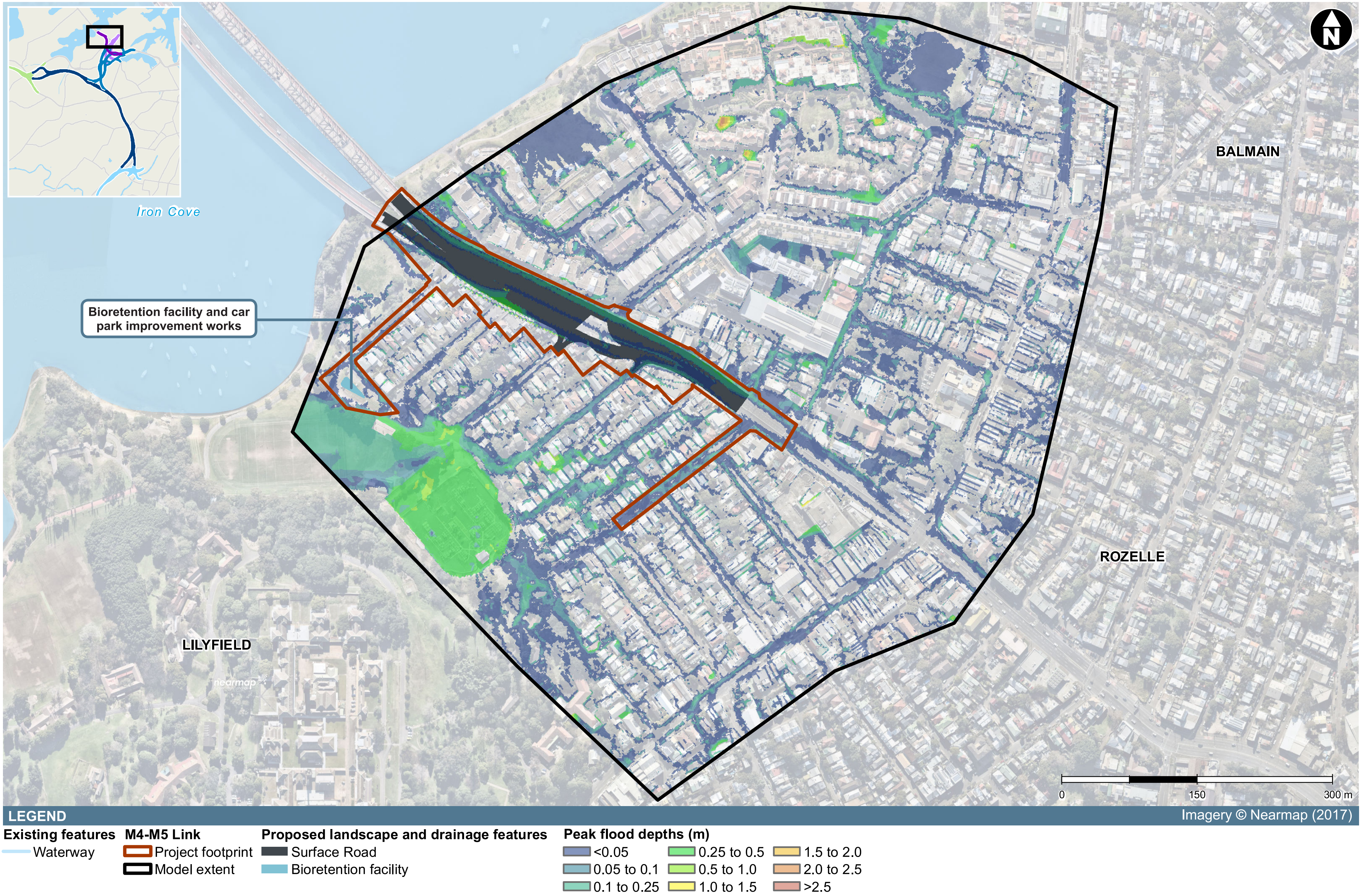

Figure 6-25 Potential climate change impact – Iron Cove Link - peak flood depths (PMF)

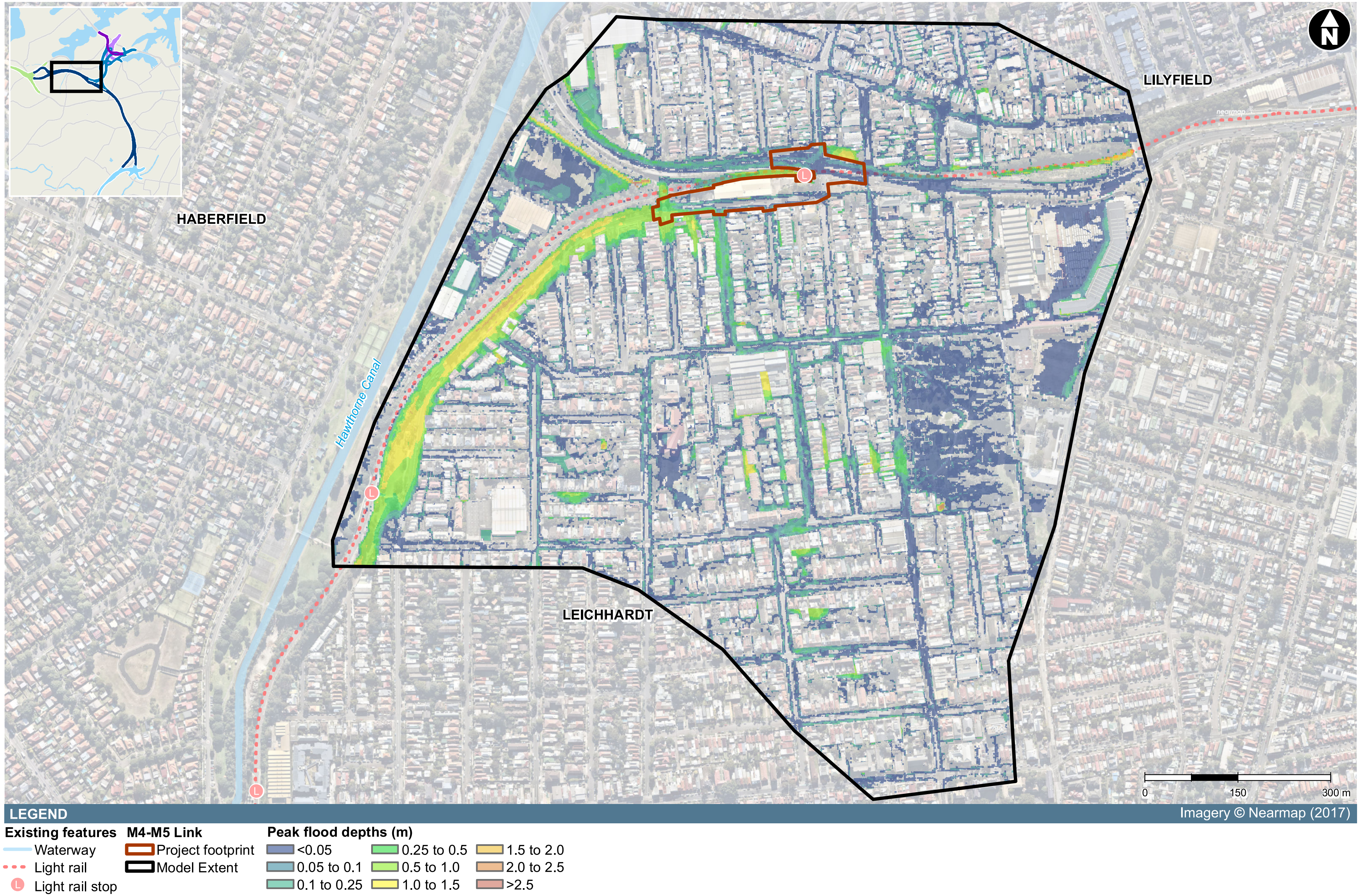

Figure 6-26 Potential climate change impact – Darley Road - peak flood depths (100 year ARI)

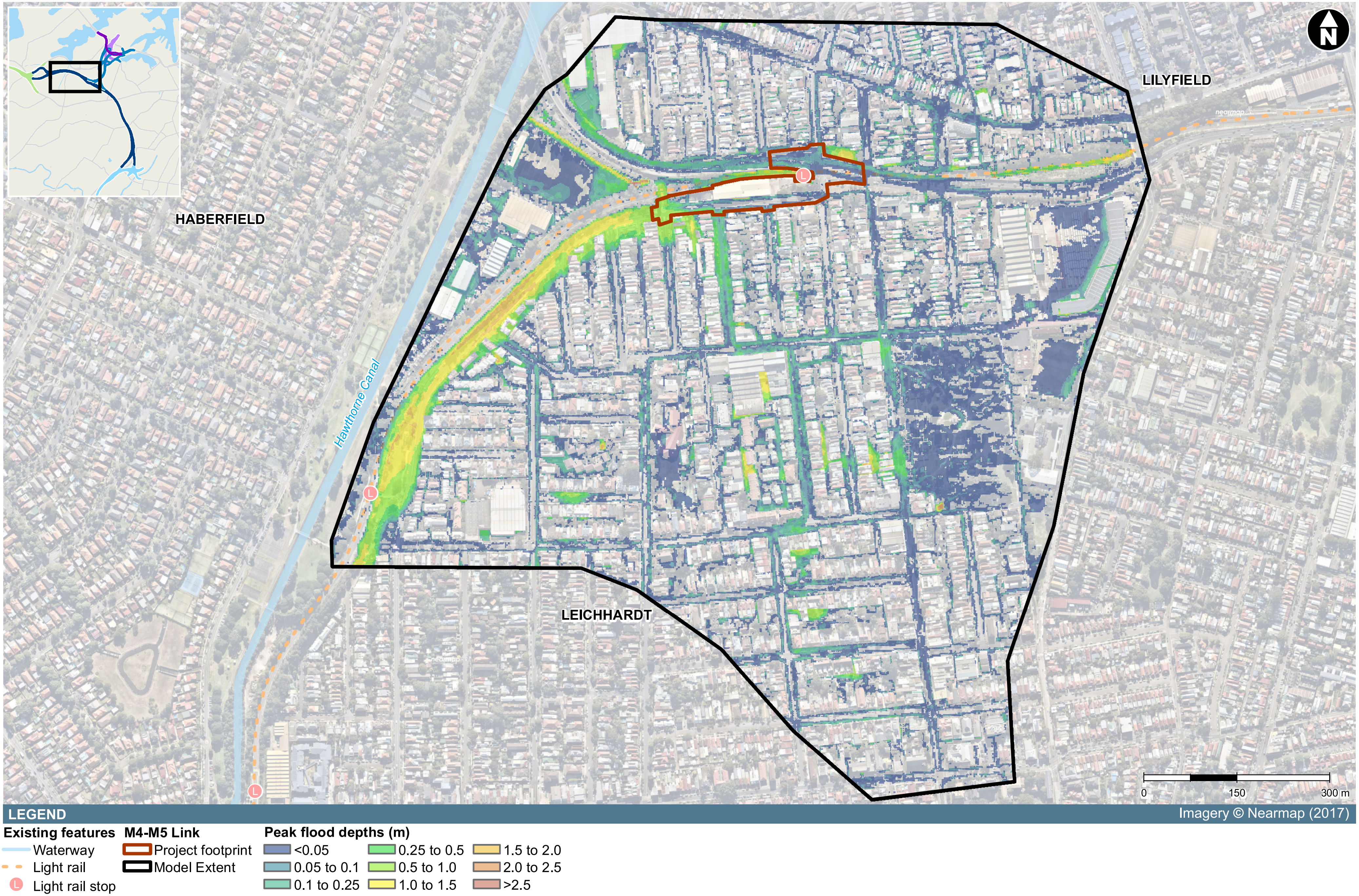

Figure 6-27 Potential climate change impact – Darley Road - peak flood depths (PMF)

6.2.3 Impact on existing drainage infrastructure

There is limited existing drainage infrastructure at many of the sites associated with the M4-M5 Link project that would be impacted or need to be modified. For the operational sites, the surface water runoff would be managed to minimise flood impacts on adjoining properties. Where the operational sites propose to connect directly into existing drainage infrastructure, flow rates from the sites would match existing flow rates where possible so as not to overload the existing drainage system or cause adverse flood impacts on adjoining properties.

6.2.4 Surface water balance

Stormwater runoff volumes generated within the project footprint would be increased as a result of an increase in impervious surfaces associated with surface road widenings, ramps and ancillary surface infrastructure. The change in effective impervious area, (see **section 3.4.3**) is provided in **Table 6-6**. The footprint included within the modelling is shown in **Annexure C**.

MUSIC modelling was undertaken to estimate changes in annual stormwater runoff volume to receiving waterways as a result of the project. The MUSIC modelling methodology is described in **section 3.4.3** (note that proposed public open space areas were not included within the modelling) and the impacts on annual runoff volume are provided in **Table 6-7**. A comparison of the stormwater discharges for the existing and post development scenarios is provided for each waterway in **Figure 6-28** to **Figure 6-32**.

The results indicate that annual runoff volumes would be increased as a result of the project with increases occurring to Rozelle Bay, Dobroyd Canal, White Bay and Whites Creek. A slight decrease in runoff volume would occur to Iron Cove as a result of the additional losses at the bioretention basin.

Design refinements made at The Crescent after MUSIC modelling was completed for this assessment would slightly increase the impervious area of the project. This very small increase would not significantly change the effective impervious area or water balance calculated for the project.

Table 6-6 MUSIC modelling - change in effective impervious area

Catchment	Total catchment area (ha)	Existing effective impervious area (ha)	Proposed effective impervious area (ha)	Increase (ha)
Total Project	11.2	8.4	11.2	2.8
Rozelle Bay	8.1	6.0	8.1	2.1
Iron Cove	1.9	1.8	1.9	0.1
White Bay	0.3	0.1	0.2	0.2
Whites Creek	0.5	0.2	0.3	0.3
Dobroyd Canal	0.4	0.3	0.1	0.1

Table 6-7 Mean annual runoff volume

Catchment	Existing conditions flow (ML/year)	Proposed conditions flow (ML/year)	Change (ML/year)
Total Project	125	145	20
Rozelle Bay	91.8	111	19.2
Iron Cove	20.8	20.7	-0.1
White Bay	3	3.2	0.2
Whites Creek	5.0	5.3	0.3
Dobroyd Canal	3.9	4.6	0.8

Treated tunnel water flows from the operational water treatment plants at Darley Road and at Rozelle would ultimately discharge to Hawthorne Canal and Rozelle Bay respectively, leading to an increase in base flow rate to those waterways. Indicative flow rates are provided in **section 2.4.2** for the respective tunnel waste water streams. Up to around 725 megalitres per year and 693 megalitres per year of treated groundwater would be discharged to Hawthorne Canal and Rozelle Bay respectively. Up to around 50 megalitres per year of tunnel drainage from approximately one kilometre of the northbound and 600 metres southbound tunnel would be captured by the New M5 drainage system and conveyed to the New M5 operational water treatment plant at Arncliffe, prior to discharge to the Cooks River.

A post development mean annual water balance based on the MUSIC modelling and incorporating treated tunnel water discharges is provided in **Table 6-8**.

The project would result in a negligible impact on the frequency and duration of stormwater discharges to Iron Cove, White Bay, Whites Creek and Dobroyd Canal. Discharges from the project footprint would be continuous to Rozelle Bay and Hawthorne Canal as a result of the treated tunnel water discharges.

The flow variability within the receiving waterways is dominated by tides at the discharge locations. Therefore the minor increases in storm flow within Rozelle Bay and White Bay and increase in base flow to Hawthorne Canal and Rozelle Bay would pose a negligible impact on the natural flow variability, environmental water availability or natural processes of the waterways. As detailed in **section 4.2**, given the waterways are hard lined, increased discharge volumes would not impact on bank stability of the waterways. Potential bed scour impacts are discussed in **section 6.3.4**.

The impacts associated with discharges from the Arncliffe operational water treatment plant were assessed as part of the New M5 EIS. The additional tunnel drainage flow (around 1.6 litres per second) associated with the M4-M5 Link would be negligible compared to flows within the Cooks River therefore impacts on levels and velocities in the Cooks River would be negligible. The existing scour protection and/or energy dissipation measures would minimise any sediment disturbance impacts near to the outlet.

Table 6-8 Surface water balance – post development

Catchment	Rainfall (ML / year)	Evapotranspiration (ML / year)	Infiltration (ML / year)	Water use (ML / year)	Stormwater discharge (ML / year)	Treated tunnel water discharge (ML / year)	Total discharge volume (ML / year)
Total Project	171.4	26.4	0	0	145	0	145
Rozelle Bay	132.2	21.2	0	0	111	725	836
Iron Cove	24.3	3.6	0	0	20.7	0	20.7
White Bay	3.7	0.5	0	0	3.2	0	3.2
Whites Creek	6.0	0.7	0	0	5.3	0	5.3
Dobroyd Canal	5.2	0.6	0	0	4.6	0	4.6
Hawthorne Canal	0	0	0	0	0	693	693

Note: See **section 3.4.3** for MUSIC modelling assumptions. It is noted that proposed public open space areas at Rozelle were not included within the MUSIC modelling

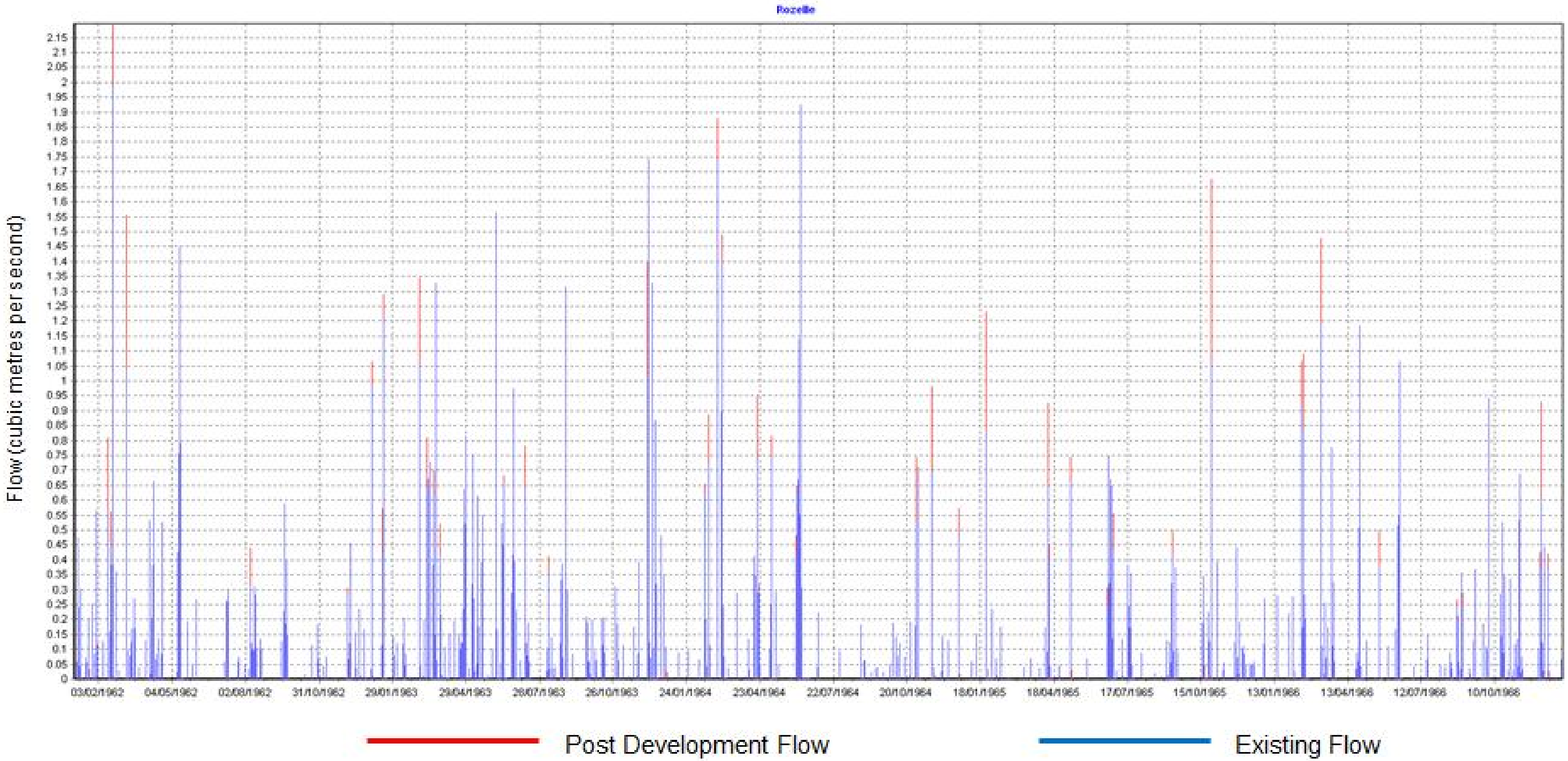

Figure 6-28 Stormwater discharges to Rozelle Bay

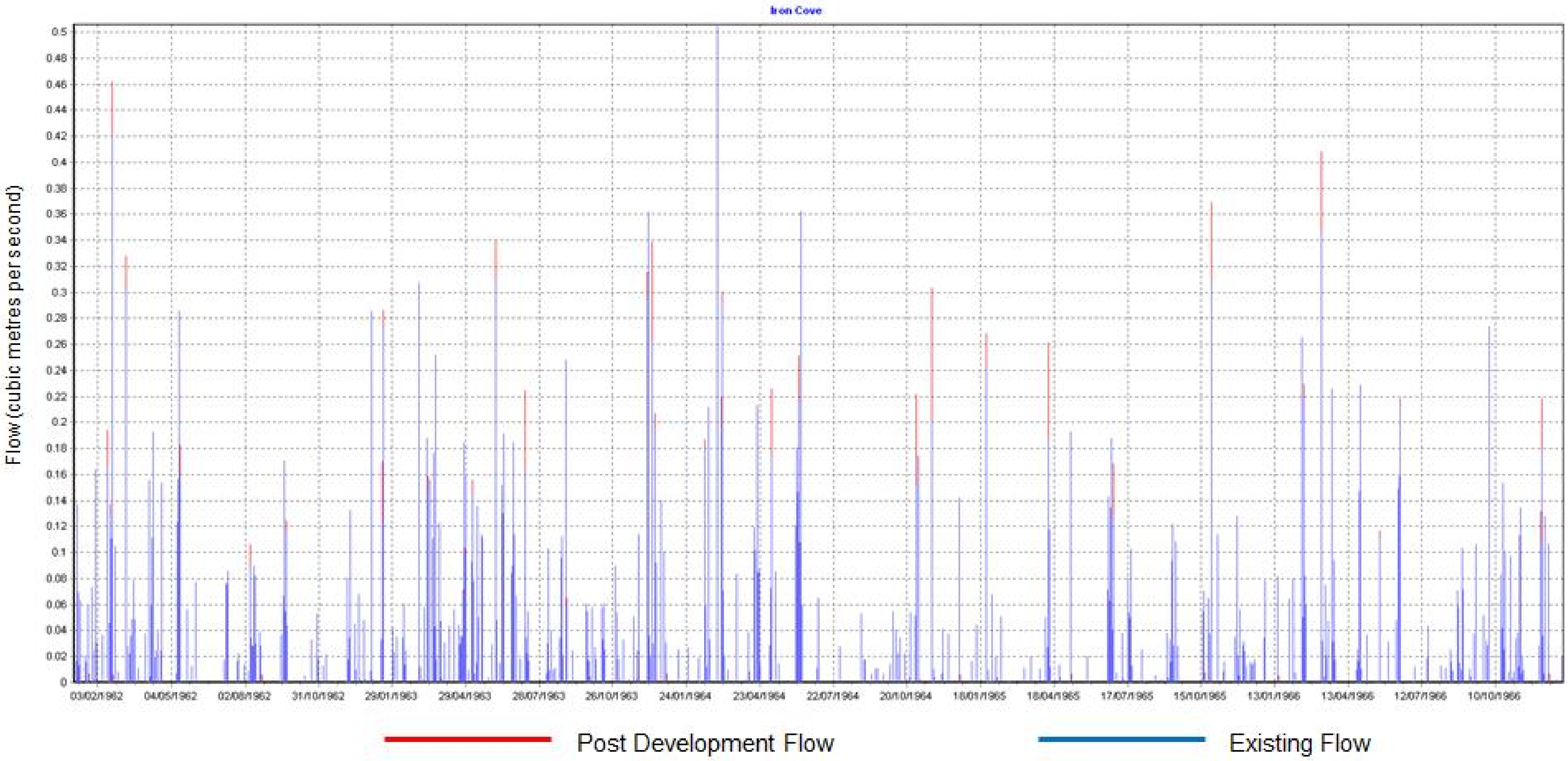

Figure 6-29 Stormwater discharges to Iron Cove

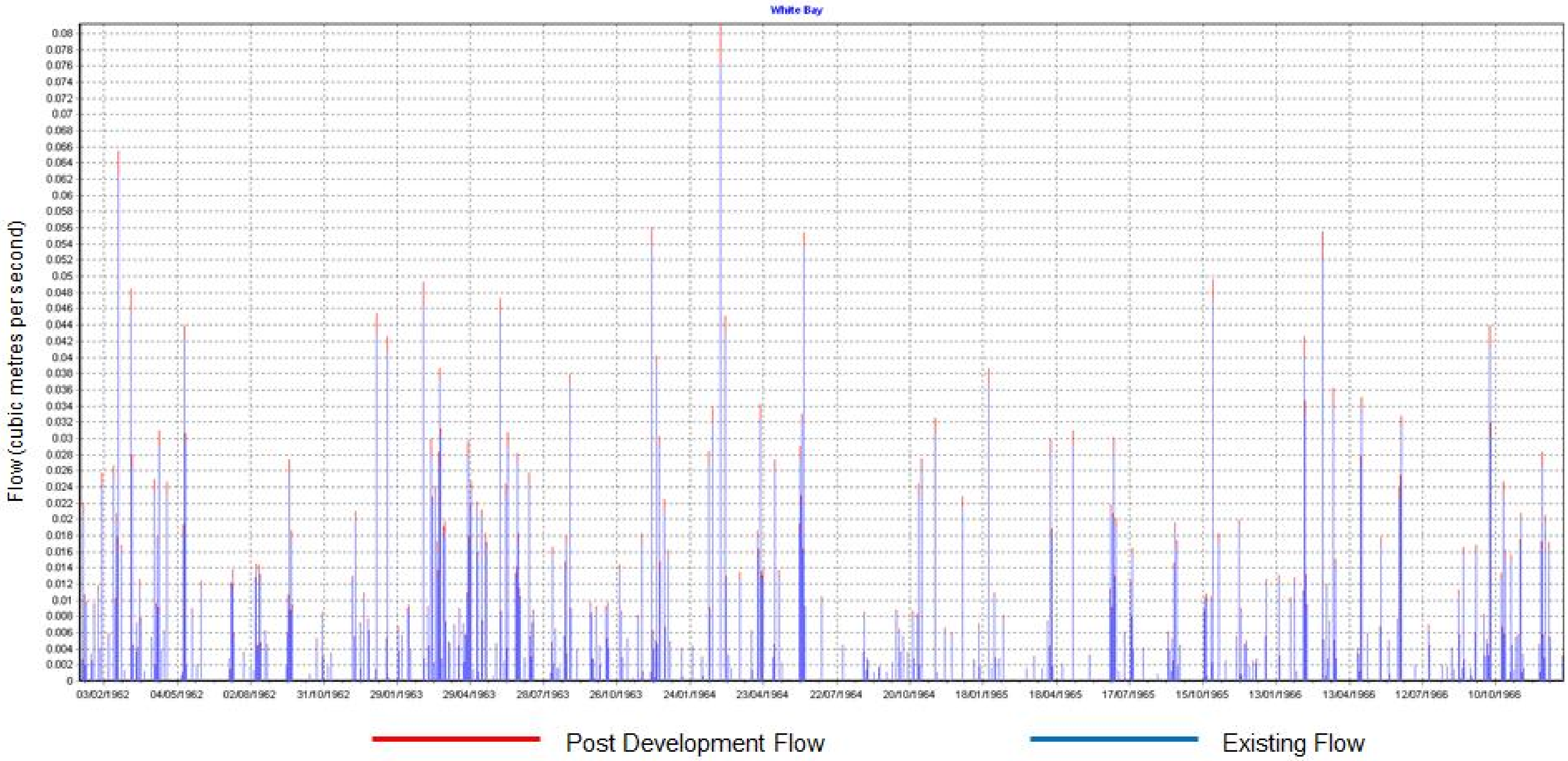

Figure 6-30 Stormwater discharges to White Bay

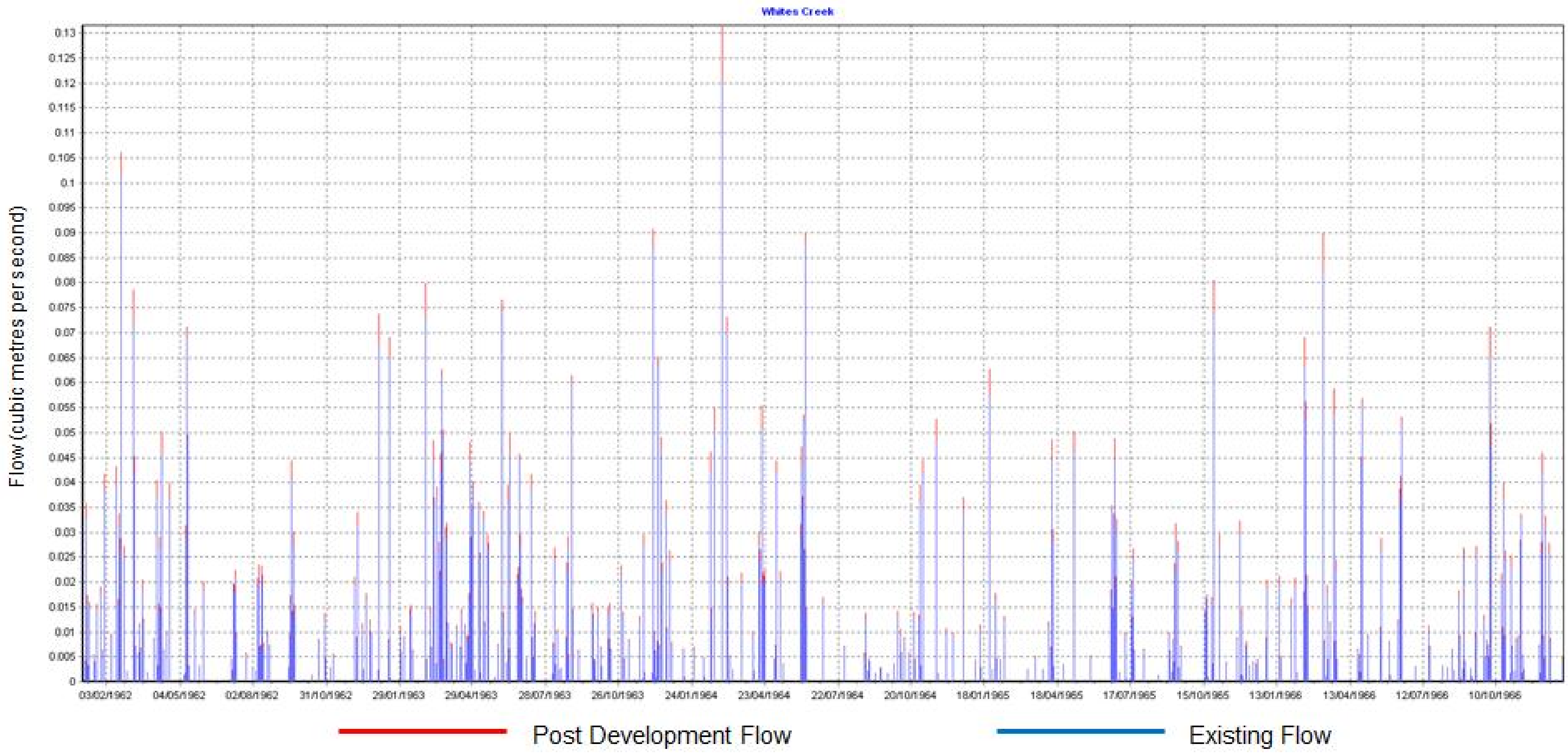

Figure 6-31 Stormwater discharges to Whites Creek

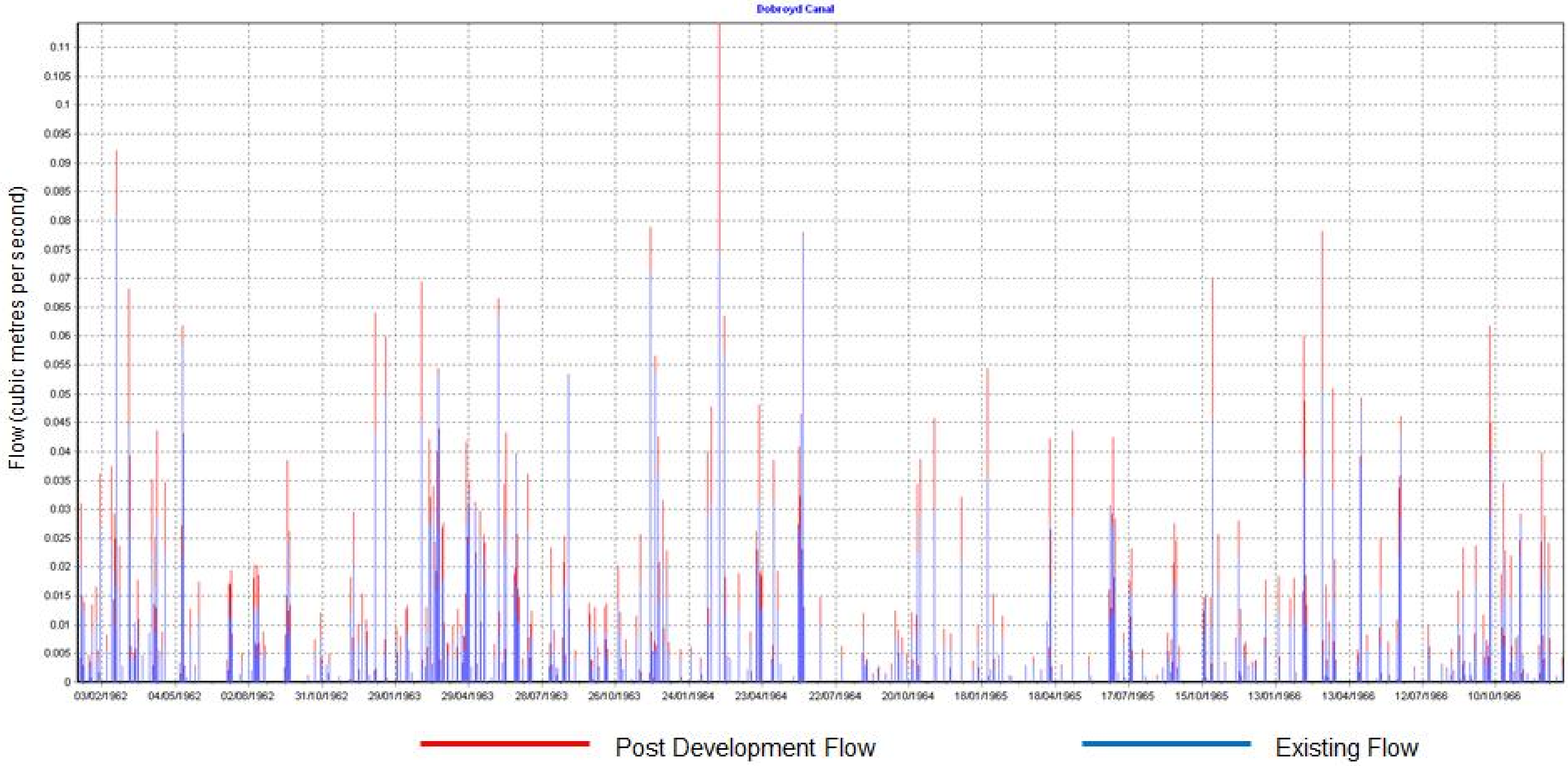

Figure 6-32 Stormwater discharges to Dobroyd Canal

6.3 Water quality

6.3.1 Potential operational impacts

The highest risk of impacts on water quality during operation of the project would be associated with:

- Increased stormwater runoff and associated increases in pollutant loading from roads
- Poor maintenance of stormwater quality treatment devices
- Spills or leaks of fuels and / or oils from vehicle accidents or from operational plant and equipment
- Discharges of poorly treated tunnel wastewater (eg groundwater ingress, stormwater ingress, tunnel wash-down water)
- Erosion of soft landscaped areas during the vegetation establishment period
- Scour / mobilisation of contaminated sediments at potential new outlet locations (i.e. Rozelle Bay and Iron Cove) and increased flow to existing locations (ie Alexandra Canal).

Discussion of the potential impacts on water quality associated with the operation of the project is provided in the following sections.

6.3.2 Stormwater discharge quality

The project is split into sections of above ground roadway, including interchanges with existing surface roads, and subsurface road through tunnels. New surface roadway, exposed to direct rainfall, is proposed at Rozelle interchange and Iron Cove Link. The Wattle Street ramps will also generate a minor amount of surface runoff. The project does not include any new surface roadways at St Peters interchange.

Increases in impervious area, such as road pavement, exposed to direct rainfall will contribute to an increase in runoff volume and associated increase in pollutant mobilisation. Runoff from road pavement would typically contain pollutants such as sediments, nutrients, oils and greases, petrochemicals and heavy metals, which result from atmospheric deposition, vehicle leaks, operational wear, road wear or spills of materials on the road. These pollutants could potentially impact on water quality when discharged to receiving waterways.

Pollutants from road surfaces (within above ground areas) are typically generated at a rate of about:

- TSS: 4,000 kilograms per year per hectare
- TP: Seven kilograms per year per hectare
- TN: 28 kilograms per year per hectare.

These rates were estimated from MUSIC stormwater quality modelling for a 100 per cent impervious catchment in Sydney. Stormwater pollutant loads generated by the project would be controlled by a stormwater quality treatment system designed in accordance with the project stormwater quality objectives (see **section 3.2.11**).

The proposed drainage system is indicatively shown in **Figure 2-3** to **Figure 2-5** and is described below. Indicative operational discharge points are shown in **Figure 2-6**. The assumed treatment for various catchments, as described below, is shown in **Annexure F**.

Subject to detailed design, a new discharge outlet would be constructed to Rozelle Bay to serve the majority of the Rozelle interchange. Portions of The Crescent, James Craig Road and City West Link unable to be drained to the Rozelle Rail Yards would likely drain via existing drainage connections to Rozelle Bay. Victoria Road northbound and southbound would likely drain to two separate outlets to Iron Cove. Either an upgraded existing discharge outlet or a new discharge outlet would be provided. Drainage from the Wattle Street ramps will discharge via a gross pollutant trap to sumps in the tunnel before being pumped to the surface, discharging to the surface drainage network, ultimately draining to Dobroyd Canal. City West Link adjacent to Whites Creek would utilise existing discharge outlets or a new discharge outlet would be provided. The portion of Victoria Road potentially draining to White Bay would drain via the existing surface drainage network. As detailed in **section 2.4.2**, operational stormwater quality treatment measures are proposed within the vicinity of Rozelle interchange and Iron Cove Link to treat stormwater prior to discharge.

MUSIC modelling was undertaken to assess the impact of the project and performance of the stormwater quality treatment measures with consideration to the SHPRC water quality objectives and the project pollutant load reduction targets as detailed in **section 3.2.11**. The modelling methodology is described in **section 3.4.3**. As discussed in **section 3.4.3**, the treatment strategy and associated modelling results are preliminary only and subject to detailed design.

The modelling results are summarised in **Table 6-9** for the main locations where stormwater will be discharged (Rozelle, Iron Cove, White Bay and Whites Creek) and for the project as a whole.

The modelling results indicate that:

- The project as a whole will generally reduce the mean annual stormwater pollutant loads being discharged to the Sydney Harbour and the Parramatta River estuary when compared to the existing conditions
- The project will generally reduce the mean annual stormwater pollutant load being discharged to the five receiving waterways when compared to the existing conditions, with the exception of total phosphorus loading to Dobroyd Canal which was slightly higher than the existing loading
- The stormwater mean annual pollutant load reduction targets (see **section 3.2.11**) were not quite achieved for the project or the individual catchments based on the treatment train measures that could practically or readily be implemented.

By decreasing the mean annual stormwater pollutant load when compared to existing conditions, the project would provide a beneficial effect in terms of reducing stormwater pollutant loads to the SHPRC. Further discussion on the projects overall impact on ambient water quality and the SHPRC water quality objectives, including other aspects of the project such as tunnel wastewater, is provided in **section 8.2.3**.

The pollutant load reduction targets were not achievable due to the modelling assumption that primary and secondary treatment proprietary devices would be utilised within highly constrained zones (see **section 3.4.3**) where implementation of vegetated WSUD or tertiary treatment devices is not considered feasible and/or reasonable. Oversizing other treatment measures to offset the reduced treatment within all the constrained zones was assessed and is not considered to be feasible and/or reasonable given that improvements in treatment performance diminish significantly with increasing footprint of the treatment devices.

Treatment performance could potentially diminish over time if the stormwater quality treatment devices (both vegetated WSUD and proprietary devices) are not adequately maintained during the operational phase. A maintenance plan would be developed during detailed design.

Table 6-9 MUSIC modelling results – water quality

Parameter	M4-M5 Link operation source load	M4-M5 Link operation residual load (following treatment)	% Reduction	Existing residual load	Impact compared to existing conditions
TOTAL PROJECT					
Total suspended solids (kg/year)	48600	8450	83%	33900	-25450
Total Phosphorus (kg/year)	81	39	52%	58	-19
Total Nitrogen (kg/year)	353	209	41%	271	-62
Gross pollutants (kg/year)	3520	242	93%	2530	-2288
ROZELLE BAY					
Total suspended solids (kg/year)	36500	5300	86%	24500	-19200
Total Phosphorus (kg/year)	61	28	55%	42	-15
Total Nitrogen (kg/year)	271	156	43%	202	-46
Gross pollutants (kg/year)	2710	108	96%	1860	-1752
IRON COVE					
Total suspended solids (kg/year)	7470	2170	71%	6680	-4510
Total Phosphorus (kg/year)	13	6	56%	11	-6
Total Nitrogen (kg/year)	51	31	39%	49	-18
Gross pollutants (kg/year)	501	103	80%	488	-385
WHITE BAY					
Total suspended solids (kg/year)	1130	240	79%	1080	-840
Total Phosphorus (kg/year)	2	1	27%	2	-0.4
Total Nitrogen (kg/year)	8	5	30%	7	-2
Gross pollutants (kg/year)	76	8	90%	72	-65
WHITES CREEK					
Total suspended solids (kg/year)	1850	395	79%	1650	-1255

Parameter	M4-M5 Link operation source load	M4-M5 Link operation residual load (following treatment)	% Reduction	Existing residual load	Impact compared to existing conditions
Total Phosphorus (kg/year)	3	2	27%	3	-1
Total Nitrogen (kg/year)	13	9	30%	12	-3
Gross pollutants (kg/year)	124	13	90%	115	-103
DOBROYD CANAL					
Total suspended solids (kg/year)	1600	343	79%	640	-301
Total Phosphorus (kg/year)	3	2	27%	1	1
Total Nitrogen (kg/year)	11	8	30%	8	-0.4
Gross pollutants (kg/year)	108	10.9	90%	92	-81

Target achieved
Target not achieved
Reduced load compared to existing conditions
Increased load compared to existing conditions

6.3.3 Tunnel discharge quality

As detailed in **section 2.4.2**, the tunnels will require drainage infrastructure to capture groundwater ingress, stormwater ingress at portals, spills, maintenance washdown water, fire suppressant deluge and other potential water ingress events.

The two tunnel drainage streams are expected to produce flows containing a variety of pollutants that require slightly different treatment before discharge to manage adverse impacts on the receiving environment. The pre-treatment water quality of each wastewater stream is expected to vary considerably, and consequently it is likely that the two streams would need to be collected and treated separately.

As detailed in **section 2.4.2**, operational water treatment plants would be provided for the Rozelle tunnels at the Rozelle interchange and for the mainline tunnels at Darley Road, Leichhardt. Groundwater would be collected and pumped to the water treatment plant. Sources other than groundwater that are captured by the tunnel drainage system will be collected in one of the tunnel sumps. Water in the sump will be tested and along with knowledge of its source (ie washdown or a spill) a determination will be made whether it can be pumped to and discharged at surface or will require removal directly from the sump by tanker for treatment and disposal elsewhere. The decision to pump to surface will need to consider the capacity of the water treatment facilities to accommodate and treat the additional flows.

Treated flows from the Rozelle plant would drain via a constructed wetland to Rozelle Bay. Treated flows from a plant at Darley Road would be discharged to Hawthorne Canal. A small portion (around 1.6 kilometres) of M4-M5 Link tunnel would also drain to the New M5 operational water treatment plant at Arncliffe. The combined mainline tunnel (23 litres per second) and Rozelle tunnels (22 litres per second) would generate up to 1,418 megalitres per year of treated groundwater. This is significantly more than the predicted mean annual stormwater runoff volume of around 121 megalitres per year.

Elevated metals and nutrients were recorded during groundwater sampling (see **Table 4-5** and Table 4-6).

The groundwater is also brackish and, subject to further investigation during detailed design, may be unsuitable in terms of the opportunity to reuse the water for irrigation of Blackmore Park or the Sydney Secondary College Leichhardt Campus oval, for example.

Metal, nutrient and ammonia loading to Hawthorne Canal and Rozelle Bay is likely to increase as a result of the continuous treated groundwater discharges. In order to prevent adverse impacts on downstream water quality within Rozelle Bay and Hawthorne Canal, treatment facilities will be designed so that the effluent will be of suitable quality for discharge to the receiving environment (see **section 8.2.3**).

The operational water treatment plant at Rozelle and Darley Road will treat iron and manganese (see **section 8.2.3**). The proposed constructed wetland at Rozelle will provide 'polishing' treatment to the treated groundwater flows removing a proportion of the nutrient (forms of nitrogen and phosphorus) and metal load. As no constructed wetland is proposed at Darley Road, opportunities to incorporate other forms of nutrient treatment (for example ion exchange or reverse osmosis) within the plant at Darley Road will be investigated during detailed design with consideration to other factors such as available space, increased power requirements and increased waste production.

A summary of the groundwater quality considering ANZECC (2000) guideline criteria, receiving water quality and proposed treatment measures is presented in **Table 6-10**. It is assumed there would be no nutrient treatment (as described above) at Darley Road. A qualitative assessment of the impacts on ambient water quality is provided below.

With consideration of groundwater quality and proposed treatment (see **Table 6-10)**, the concentration of the key constituents in the treated discharge to Rozelle Bay are unlikely to be significantly higher than the ambient concentration of the constituents in Rozelle Bay. Due to the mixing and dilution affect which would occur at the outlet to the receiving waters, impacts to ambient water quality are likely to be negligible and localised to near the outlet.

With consideration of groundwater quality and proposed treatment (see **Table 6-10)**, treated discharge concentrations of key constituents are unlikely to be significantly higher than concentrations in Hawthorne Canal. Due to the mixing and dilution affect which would occur at the outlet to the receiving waters, impacts to ambient water quality are likely to be negligible. Any minor impacts are likely to be localised and near to the outlet.

The impacts associated with discharge quality from the Arncliffe operational water treatment plant were assessed as part of the New M5 EIS. No adverse impacts are likely to occur as a result of the minor additional flow (1.6 litres per second) draining to the Arncliffe operational water treatment plant.

Table 6-10 Summary of tunnel groundwater pollutants of concern and treatment processes

Tunnel	Groundwater ingress to tunnel (L/s)	Receiving water body	Constituents which exceeded relevant ANZECC criteria[1]	Relative concentration[2]	Applicable treatment processes	Receiving environment
Rozelle	22	Rozelle Bay	Iron	High[3]	WTP[7] + Wetland Polishing	Estuarine bay
			Manganese	High[3]	WTP + Wetland Polishing	
			Ammonia	Medium[3]	Wetland Polishing	
			Total Nitrogen	Low[5]	Wetland Polishing	
			Total Phosphorus	Less than receiving[6]	Wetland Polishing	
			Reactive Phosphorus	Less than receiving[6]	Wetland Polishing	
Mainline	23	Hawthorne Canal	Iron	High[3]	WTP	Estuarine waterway
			Manganese	High[3]	WTP	
			Ammonia	Unknown	Further investigation into treatment during detailed design.	
			Total Nitrogen	Low[5]	Further investigation into treatment during detailed design.	
			Total Phosphorus	Low[3]	Further investigation into treatment during detailed design.	
			Reactive Phosphorus	Less than receiving[6]	Further investigation into treatment during detailed design.	

Notes:
[1] Constituent groundwater mean concentration exceeds ANZECC (2000) marine water 95 per cent species protection for toxicants and/or recreational water quality guideline level.
[2] Relative difference between constituent groundwater and receiving water body mean concentrations.
[3] Constituent groundwater greater than 10 times receiving water concentration.
[4] Constituent groundwater is between five and 10 times receiving water concentration.
[5] Constituent groundwater less than five times receiving water concentration.
[6] Constituent groundwater is less than the receiving water concentration.
[7] WTP = Assumes water treatment plant discharge criteria as per **section 8.2.3**.

6.3.4 Scour and channel geomorphology

There is potential for sediment to be scoured and mobilised where stormwater or wastewater is discharged to receiving waterways and bays including Rozelle Bay, Iron Cove, and Whites Creek. This could increase turbidity locally and lead to mobilisation of contaminants bound to sediments. Scour protection and energy dissipation measures will be assessed and provided as required at outlets (see **section 8.2.3**).

Stormwater discharges from the St Peters interchange were assessed as part of the New M5 EIS. The proposed ancillary facilities at St Peters interchange may slightly increase discharge volumes at the existing outlet. There is potential for localised disturbance of sediment to occur near to the existing outlet if appropriate scour protection and/or energy dissipation measures are not already in place (see **section 8.2.3**). Any minor increases in flow volume are unlikely to have a material impact on the mobilisation of contaminated sediments during flow events within other areas of Alexandra Canal given the minor surface area of the ancillary facilities in the context of the overall Alexandra Canal catchment.

The project includes widening and improvement works to the channel and bank at Whites Creek Annandale to manage flooding and drainage. The channel form would be naturalised with works extending back to the railway bridge to integrate with Sydney Waters proposed channel naturalisation works (see **section 4.2.1**). The naturalisation works would be finalised during detailed design but are likely to incorporate features such as sandstone blocks and vegetated benches to provide ecological benefits to the channel. The proposed channel bed and bank treatments would be hard lined therefore impacts on channel form and geomorphology are unlikely to occur once the works are complete. Any vegetated zones (eg benches) would be susceptible to erosion and should be protected during the vegetation establishment period.

6.3.5 Erosion and sedimentation

Once the construction phase of a project is completed, there is a period within the operational phase where recently disturbed soils are potentially susceptible to scour and erosion from stormwater runoff. This will be an issue in areas where soft landscaping is proposed for the project, including public open space areas at Rozelle interchange, cut batter or fill embankments and reinstatement of construction ancillary facilities where topsoil is settling and vegetation is establishing.

The potential for sediment transport and sedimentation issues to occur during operation of the project is influenced by factors such as severity of storm events, the slope and corridor of disturbance within an area, and the management controls that are implemented on site.

The erosion of landscaped areas during rainfall events could potentially cause sediment loads to enter into waterways through the stormwater pipe network. Landscaping at Rozelle interchange presents the greatest risk due to the extent of landscaping proposed.

Suitable stabilisation and management techniques would be deployed during the vegetation establishment period to minimise the potential for erosion within areas at risk. Provided appropriate controls are implemented, short term impacts during the establishment period are expected to be manageable with negligible impacts on receiving water quality.

6.3.6 Spills

Spills of oils, lubricants, hydraulic fluids and chemicals could potentially occur during the operation of the project due to vehicle or plant and equipment leakages or a vehicle crash. Any contaminant spill within the project footprint has the potential to pollute downstream waterways, as a result of being conveyed to waterways via the stormwater network. The severity of the potential impact depends on the magnitude and/or location of the spill in relation to sensitive receptors, emergency response procedures and/or management controls implemented on site, and nature of the receiving environment. Surface roads within close proximity to Rozelle Bay and Iron Cove are likely to present the greatest risk due to the short distance and time it would take contaminants to reach the receiving waters.

Spill control measures, as outlined in **section 8.2.3** would be required to reduce the potential for environmental impacts to occur at discharge points. Provided appropriate controls are implemented, there would be a low risk of impacts on receiving water quality.

6.4 Riparian corridors

Works may require removal of planted riparian vegetation adjacent to Whites Creek for the upgrade of the intersection of The Crescent and City West Link, refer to **Appendix S** (Technical working paper: Biodiversity) of the EIS. With consideration to the highly disturbed environment, the removal of the planted riparian vegetation is unlikely to impact on surface water quality or the stability of Whites Creek, a concrete channel. Although the upgraded road is likely to increase shade within the concrete channel, the reduction in light is unlikely to change the water temperature given the tidal water movement at this location.

7 Assessment of cumulative impacts

7.1 WestConnex projects

A summary of the key potential surface water and flooding impacts, mitigation measures and residual impacts identified through a review of EIS documents associated with the four other WestConnex projects are summarised in the following sections and in **Table 7-1**. The following WestConnex EIS documents were reviewed:

- Kings Georges Road Intersection Environmental Impact Statement, Appendix L, Flooding and drainage investigation (Lyall and Associates August 2014)
- M4 Widening Environmental Impact Statement (SMEC 2014)
- M4 East EIS, Surface Water: Flooding and Drainage (Lyall and Associates 2015a)
- M4 East Environmental Impact Statement, Appendix O, Technical Working paper: Soil and water quality assessment (GHD 2015)
- New M5 Environmental Impact Statement, Appendix N, Technical Working paper: Surface Water (AECOM 2015)
- New M5 Environmental Impact Statement, Appendix P, Technical Working paper: Flooding (Lyall and Associates 2015b).

7.1.1 M4 East

The M4-M5 Link project would connect directly to the M4 East at the Wattle Street interchange. Any potential cumulative surface water quality impacts could impact on the one common receptor, Dobroyd Canal and downstream environments (Iron Cove, Parramatta River Estuary).

The impacts of the M4 East project on surface water and flooding at the Wattle Street interchange were assessed as part of that EIS and subsequent detailed design. Management measures were identified to mitigate impacts on surrounding properties for both the construction and operational phases. The objective was to manage impacts on flood risk to an acceptable level where practicable and feasible, by working to achieve the requirements of the planning conditions.

As discussed in **section 4.4.1**, the M4-M5 Link connection to the Wattle Street interchange would not alter the surface layout or levels. Accordingly, there are no cumulative impacts on flooding in relation to the project anticipated at the Wattle Street interchange.

7.1.2 New M5

The M4-M5 Link project would connect directly to the New M5 at the St Peters interchange. Any potential cumulative surface water quality impacts could impact on the one common receptor, Alexandra Canal and downstream sensitive environments (Cooks River and Botany Bay).

The impacts of the New M5 project on surface water and flooding at the St Peters interchange were assessed as part of the EIS and ongoing design. Management measures were identified to mitigate impacts on surrounding properties for both the construction and operational phases of the New M5 project. The objective was to manage impacts on flood risk to an acceptable level, where practicable and feasible, by working to achieve the requirements of the planning conditions.

As discussed in **section 4.4.1**, the M4-M5 Link connection to the St Peters interchange would not significantly alter the surface layout or levels and the new ventilation facility would be located above the PMF flood level. The proposed ventilation facility would result in a negligible increase in runoff volume to Alexandra Canal. The potential for scour at the outlet would be controlled through appropriate mitigation as required. Accordingly, there are no cumulative impacts on flooding, water quality or geomorphology/scour in relation to the project anticipated at the St Peters interchange.

7.1.3 M4 Widening and King Georges Road Interchange Upgrade

M4 Widening project and Kings Georges Road Interchange Upgrade project have no common direct surface water receptors to the M4-M5 Link project but do have common downstream sensitive environments (Parramatta River Estuary, Cooks River and Botany Bay). There are unlikely to be cumulative impacts on the common sensitive downstream environments provided controls are implemented, maintained and monitored.

As the M4 Widening project and Kings Georges Road Interchange Upgrade project have no common surface catchments to the M4-M5 Link project there are no cumulative flood impacts anticipated.

7.1.4 Summary

Based on a review of the respective EIS documents that have been approved the M4 East, New M5, M4 Widening and King Georges Road Interchange Upgrade are considered unlikely to have a significant impact on receiving water receptors or sensitive environments provided the proposed management measures are implemented, maintained and monitored.

Therefore, with due consideration of the proposed management measures to be implemented as part of the M4-M5 Link project (see **section 8**) there are minimal adverse cumulative surface water quality or flooding impacts anticipated. The residual risk to common receptors and sensitive environments downstream would be low provided the proposed management measures are implemented, maintained and monitored.

7.2 Other projects

Cumulative impacts associated with other key projects proposed in the vicinity of the M4-M5 Link project footprint including the Rozelle Rail Yards Site Management Works, Transport for NSW CBD and South East Light Rail – Rozelle maintenance depot, The Bays Precinct, Sydney Water stormwater channel renewal / naturalisation works, Sydney Metro City and Southwest, and Western Harbour Tunnel and Beaches Link have been considered. A summary of the key potential surface water and flood impacts, mitigation measures and residual impacts related to these other key projects are summarised in **Table 7-1**.

Rozelle Rail Yards – Site Management Works

Roads and Maritime are carrying out a suite of site management works on part of the Rozelle Rail Yards. These works will be undertaken prior to the commencement of the M4-M5 Link project. *The Rozelle Rail Yards – Site Management Works Review of Environmental Factors* (Roads and Maritime 2016) indicates that stormwater runoff quality, drainage and flooding will be managed in accordance with legislation and good practice during construction and after completion of the site management works. After completion of the works, the ‘finished site’ would be managed and maintained to ensure that the surface cover and stormwater controls are operating effectively until commencement of the construction of the M4-M5 Link project. Therefore, no cumulative flood, drainage or water quality impacts are anticipated.

CBD and South East Light Rail

The CBD and South East Light Rail Rozelle maintenance depot is located immediately to the west of the Rozelle Rail Yards. This development has planning approval with design ongoing. Site clearance activities have been undertaken in 2016. Surface water from the Rozelle maintenance depot is discharged to the Rozelle Rail Yards. *The CBD and South East Light Rail Project Environmental Impact Statement* (Parsons Brinkerhoff 2013) indicates that stormwater runoff quality, drainage and flooding will be managed in accordance with legislation and good practice during construction and operation. Therefore no cumulative flood, drainage or water quality impacts are anticipated.

A review of preliminary designs and discussions with the project team for the CBD and South East Light Rail Rozelle maintenance depot shows a new drainage system to capture and manage surface water at the site. This will manage surface water from the proposed depot and maintenance area with two discharge points to the east of the depot. As there is no formal drainage system to discharge into, the Rozelle maintenance depot design proposes to discharge to the surface to then flow towards the Rozelle Rail Yards. The proposed discharge point from the Rozelle maintenance depot has been cumulatively considered in the M4-M5 Link project flood modelling. This included modifying the topography on the north western side of the Rozelle interchange design to enable the overland flows from the Rozelle maintenance depot and catchment to the west, to flow onto the site and be conveyed within a channel to Rozelle Bay. The detailed design for M4-M5 Link will need to consider the final detailed design for the Rozelle maintenance depot for stormwater drainage.

Sydney Metro City and Southwest

Waterloo Station, part of the Sydney Metro City and Southwest project is located within the Alexandra Canal catchment. Any potential cumulative surface water impacts could impact on Alexandra Canal and downstream sensitive environments (Cooks River and Botany Bay). The impacts of the Waterloo Station on surface water and flooding were assessed as part of that *Sydney Metro Chatswood to Sydenham Environmental Impact Statement* (Transport for NSW 2016). Surface water management measures were identified to mitigate impacts during construction. The aboveground station infrastructure would be located within the footprint of existing development and would have a negligible impact on the existing surface hydrology. Waterloo Station and ancillary infrastructure would have a negligible impact on existing flood behaviour during operation and minimal impacts during construction. Management measures were identified to mitigate impacts on surrounding properties for both the construction and operational phases.

The Marrickville dive site is proposed to be located to the west of the New M5 interchange, but is located in the Eastern Channel catchment, which drains directly to the Cooks River. The site is flood affected and flood mitigation measures to compensate for loss of overland flowpaths and flood storage have been designed to minimise flood impacts in and around Eastern Channel. No flood impacts were identified for the Cooks River as a result of the proposed works at the Marrickville dive site. Therefore no cumulative flood impacts with this project are anticipated. The Marrickville dive site has no common direct surface water receptors with the M4-M5 Link project but does have common downstream sensitive environments (Cooks River and Botany Bay). There are unlikely to be cumulative impacts to the common sensitive downstream environments provided controls are implemented, maintained and monitored.

The Bays Precinct, Sydney Water stormwater channel renewal/naturalisation and Western Harbour Tunnel

The Bays Precinct, Sydney Water stormwater channel renewal / naturalisation and Western Harbour Tunnel and Beaches Link projects are in their early planning stages, and as such no environmental assessments were available for review at the time of this assessment. Therefore, cumulative surface water impacts cannot be fully understood at this stage due to insufficient information available regarding the impacts, design and management of surface water flows and infrastructure associated with these projects. However, a preliminary qualitative assessment has been undertaken here.

The Bays Precinct Transformation Plan (UrbanGrowth NSW 2015) has set a high benchmark for controlling water quality and it is assumed that The Bays Precinct project would incorporate surface water and flood management measures during construction and operation in accordance with legislative requirements to prevent adverse impacts to the common receiving receptors of Whites Creek, White Bay and Rozelle Bay and flooding impacts to local properties. Similarly, it is assumed that management measures would be implemented during the construction works at Whites Creek and Johnstons Creek to manage potential impacts to the creeks and downstream environment from both a water quality and flood management perspective.

The greatest risk of the Sydney Water channel works in the common receptors of Whites Creek and Johnstons Creek relates to sedimentation of the waterways during earthworks. This would likely be managed by Sydney Water during construction using best practice techniques in accordance with relevant legislation. The works are also likely to be designed to avoid flooding impacts during operation. Therefore, no surface water and flooding cumulative impacts are anticipated. Consultation with Sydney Water would be undertaken throughout the detailed design process.

The Western Harbour Tunnel and Beaches Link contractor would manage a portion of the Rozelle civil and tunnel site near to the Western Harbour Tunnel entry and exit ramps north of the City West Link/The Crescent intersection when this area is no longer needed for construction of the M4-M5 Link project, extending the use of this construction site. Whilst no EIS for the proposed future Western Harbour Tunnel and Beaches Link is available for review it is assumed that construction activities and the operation of the proposed future Western Harbour Tunnel and Beaches Link would be undertaken with appropriate surface water management measures in place in accordance with legislative requirements to prevent adverse impacts to the common receiving receptor of Rozelle Bay as part of Sydney Harbour. No surface water and flooding cumulative impacts are therefore anticipated, however a cumulative impact assessment of these aspects would be undertaken by the environmental impact assessment for the proposed future Western Harbour Tunnel and Beaches Link project.

Accordingly, no adverse cumulative surface water quality impacts are anticipated with implementation of appropriate management measures as part of the project, and as such the residual risk to the environment would be low.

Table 7-1 Summary of potential impacts from other surrounding projects and their mitigation

Common receiving receptors	Common downstream sensitive receptors	Potential impacts on common receiving receptors during construction of M4-M5 Link	Construction mitigation measures	Potential impacts on common receiving receptors during operation of M4-M5 Link	Operational mitigation measures	Construction and operation residual impacts
M4 East						
Dobroyd Canal	Parramatta River estuary	Increased pollutant loading to Dobroyd Canal associated with stormwater runoff. Discharge of poorly treated tunnel water to Dobroyd Canal.	Soil and water management plan and associated measures in accordance with Blue Book. Staging of works Stockpile management Water Quality Monitoring Construction water treatment plant.	Increased pollutant loading to Dobroyd Canal. Impacts on drainage infrastructure capacity near to Wattle Street interchange. Flood impacts due to redirection of overland flows at Wattle Street interchange.	Drainage upgrades. Flood mitigation required for overland flow paths impacted by Wattle Street interchange. Stormwater quality treatment measures. Water quality monitoring. Operational tunnel water treatment plant.	Unlikely to be significant impacts on downstream receptors or sensitive receiving environments provided controls are implemented, maintained and monitored.
New M5						
Alexandra Canal	Cooks River and Botany Bay	Minor impacts on local overland flows and existing minor drainage paths. Increased sedimentation and pollutant loading to Alexandra Canal as a result of unmitigated construction discharges. Discharge of poorly treated tunnel water to Alexandra Canal. Negligible increase in	Where undesirable flood impacts are identified, appropriate mitigation will be implemented for overland flow paths impacted by construction works. Soil and water management plan and associated measures in accordance with Blue Book. Staging of works Stockpile management	Negligible increase in runoff volume and pollutant loading to Alexandra Canal associated with new ancillary facilities at St Peters interchange Increases in Alexandra Canal flow rate, velocities and water level would also be negligible. Potential for localised sediment disturbance if appropriate scour	Where undesirable flood impacts are identified, appropriate mitigation will be implemented for overland flow paths impacted at St Peters interchange. Stormwater quality treatment measures. Water quality monitoring. Operational tunnel water treatment plant Appropriate scour	Unlikely to be significant impacts on downstream receptors or sensitive receiving environments provided controls are implemented, maintained and monitored.

Common receiving receptors	Common downstream sensitive receptors	Potential impacts on common receiving receptors during construction of M4-M5 Link	Construction mitigation measures	Potential impacts on common receiving receptors during operation of M4-M5 Link	Operational mitigation measures	Construction and operation residual impacts
		baseflow to Alexandra due to construction wastewater discharges. Potential for localised sediment disturbance if appropriate scour protection / energy dissipation measures not already installed at existing outlet.	Construction water treatment plant Water quality monitoring. Appropriate scour protection and energy dissipation as required.	protection / energy dissipation measures not already installed at existing outlet. Flood impacts due to redirection of overland flows at St Peters interchange. Slight increase in tunnel wastewater discharging from Arncliffe operational water treatment plant to the Cooks River due to portion of M4M5 Link tunnel drainage draining to New M5 system.	protection and energy dissipation as required.	
King Georges Road Interchange Upgrade						
None	Cooks River and Botany Bay	No common receptors.	Soil and water management plan and associated measures in accordance with Blue Book. Spill kits and training.	No common receptors.	Upgrade of an existing water quality pond. Pavement drainage upgrades. Spill containment facilities.	No common receptors. Unlikely to be significant impacts on common sensitive receiving environments downstream provided controls are implemented, maintained and monitored.
M4 Widening						
None	Parramatta	No common receptors	Soil and water	No common receptors.	Swales.	No common receiving

Common receiving receptors	Common downstream sensitive receptors	Potential impacts on common receiving receptors during construction of M4-M5 Link	Construction mitigation measures	Potential impacts on common receiving receptors during operation of M4-M5 Link	Operational mitigation measures	Construction and operation residual impacts
	River Estuary		management plan and associated measures in accordance with Blue Book. Staging of works Stockpile management Managing disturbance and mobilisation of sediment within Duck River channel during in channel works. Water quality monitoring.		Spill management basins. Scour protection measures.	receptors. Unlikely to be significant impacts on common sensitive receiving environments downstream provided controls are implemented, maintained and monitored.
Rozelle Rail Yards site management works						
Easton Park drain, Whites Creek and Rozelle Bay	Sydney Harbour	Increased sedimentation and pollutant loading to receiving receptors as a result of unmitigated construction discharges. Increased temporary flows to drainage network. Impact to local overland flows and existing minor drainage paths.	Soil and Water management plan and associated measures (sediment and erosion controls) in accordance with Blue Book. Staging of works to minimise surface disturbance. Conveyance of flows from western external catchment through the site. Temporary drainage measures Storage of equipment and other obstructions	Not applicable as M4-M5 Link project will have commenced within the Rozelle Rail Yards.	Not applicable as M4-M5 Link project will have commenced within the Rozelle Rail Yards.	Unlikely to be significant impacts on common sensitive receiving environments downstream provided controls are implemented, maintained and monitored.

Common receiving receptors	Common downstream sensitive receptors	Potential impacts on common receiving receptors during construction of M4-M5 Link	Construction mitigation measures	Potential impacts on common receiving receptors during operation of M4-M5 Link	Operational mitigation measures	Construction and operation residual impacts
			to floodwater (e.g. stockpiles) on high ground. Protection of existing drainage infrastructure from surface water flows. Diversion of overflows from sediment basin to a low point onsite.			
CBD and South East Light Rail Rozelle maintenance depot						
Easton Park drain and Rozelle Bay	Sydney Harbour	Increased sedimentation and pollutant loading to receiving receptors as a result of unmitigated construction discharges.	Sediment basin and discharge of stormwater runoff onto Rozelle Rail Yards through a series of small outfalls to replicate overland flow.	Increased pollutant loading to receiving receptors. Concentrated flows (rather than overland flow) being discharged onto Rozelle Rail Yards.	Discharge of stormwater runoff onto Rozelle Rail Yards through a series of small outfalls to replicate overland flow. Treatment of stormwater runoff. Recycling of wash-down water.	Unlikely to be significant impacts on stormwater flooding or significant impacts on common receiving receptors provided controls are implemented, maintained and monitored.
The Bays Precinct						
White Bay, Rozelle Bay, Whites Creek	Sydney Harbour	Increased sedimentation and pollutant loading to downstream receptors as a result of unmitigated construction discharges. Impacts on flood risk	Unknown.	Increase in potable water demand. Increased pollutant loading to downstream receptors. Impacts on flood risk to surrounding properties.	Unknown.	Unknown.

Common receiving receptors	Common downstream sensitive receptors	Potential impacts on common receiving receptors during construction of M4-M5 Link	Construction mitigation measures	Potential impacts on common receiving receptors during operation of M4-M5 Link	Operational mitigation measures	Construction and operation residual impacts
		to surrounding properties.				
Sydney Water naturalisation projects						
Whites Creek Johnstons Creek	Sydney Harbour	Increased sedimentation and pollutant loading to Whites Creek and Johnstons Creek as a result of disturbance and mobilisation of sediments during construction works within and adjacent to the creeks. Impacts on flood risk to surrounding properties.	Unknown.	Alterations (improvement or reduction) to flood conveyance in Whites Creek and Johnstons Creek.	Unknown.	Unknown.
Western Harbour Tunnel						
Rozelle Bay	Sydney Harbour	Increased sedimentation and pollutant loading to downstream receptors as a result of unmitigated construction discharges from tunnel wastewater and stormwater runoff.	Unknown.	Increased pollutant loading to downstream receptors as a result of stormwater runoff and tunnel wastewater discharges.	Unknown.	Unknown.
Sydney Metro City and Southwest						
Alexandra Canal	Sydney Harbour, Cooks River	Waterloo Station site within the Alexandra Canal catchment is at	Erosion and sediment controls, including the redirection and capture	Waterloo Station site within the Alexandra Canal catchment is at	On-site detention as required and where space permits.	Unlikely to be significant impacts on stormwater flooding or

Common receiving receptors	Common downstream sensitive receptors	Potential impacts on common receiving receptors during construction of M4-M5 Link	Construction mitigation measures	Potential impacts on common receiving receptors during operation of M4-M5 Link	Operational mitigation measures	Construction and operation residual impacts
	and Botany Bay	risk of flooding during construction. Flooding of the construction site could result in floodwater entering excavations or stockpiles of construction materials and spoil being washed downstream to Alexandra Canal. Works at Waterloo station are expected to have minimal impacts on flooding. The proposed Marrickville dive site is within the Eastern Channel catchment and is at risk of flooding during construction. Works at the dive site would need to be carefully managed to minimise local flood impacts.	of construction site runoff, would be used to manage drainage on construction sites. Detailed construction planning for flood risk at Waterloo Station including identification of measures to avoid flood impacts during construction.	risk of flooding during operation. Waterloo Station and ancillary infrastructure would have a negligible impact on existing flood behaviour.	Station entries above ground rail system facilities at Waterloo Station to be located above PMF flood level or 0.5 metres above 100 year ARI flood level where necessary. The proposed Marrickville tunnel dive structure is to be protected from inundation in the PMF and drainage infrastructure has been designed to compensate for the loss of overland flowpaths and flood storage.	significant impacts on common receiving receptors or common sensitive downstream receptors provided controls are implemented, maintained and monitored.

8 Management of impacts

8.1 Flooding

Public safety is one of the driving factors for assessing and mitigating flood impacts. This is reflected in the hydrologic standards that have been set for both construction and operation of the project as set out in **section 3.4.4**. In terms of flooding, public interest and safety has specifically been taken into account by:

- Providing PMF flood immunity to tunnel portals and other critical infrastructure such as motorway control centres and substations
- Providing drainage channels within the Rozelle Rail Yards that have 100 year ARI capacity, leaving the overbank areas flood free up to the 100 year ARI and opening the area up to recreational uses
- Widening of Whites Creek which reduces 100 year ARI flood levels along Whites Creek
- Designing the tunnel drainage system to safely manage local runoff from the open tunnel dives, deluge flows and accidental spills.

Incidents in tunnels, including flooding, are covered in **Chapter 25** (Hazard and risk) of the EIS, together with the implementation of design features to minimise the potential for and manage incidents, the provision of emergency egress points/cross-passages to prevent people becoming trapped, and manage traffic flow during incidents.

Traffic management systems during the operation of the project will ensure that traffic is directed away from an incident (eg flooding) and avoid traffic moving toward floodwater.

8.1.1 Proposed flood mitigation strategy

A Flood Mitigation Strategy (FMS) will be prepared for flood prone or flood affected land within the project footprint prior to construction, to demonstrate that the existing flooding characteristics will not be exacerbated as a consequence of the project. The strategy will be prepared by a suitably qualified and experienced person in consultation with directly affected landowners, the NSW Office of Water, OEH, Sydney Water and relevant councils. It will include, but not be limited to:

- The identification of flood risks to the project and adjoining areas, including the consideration of local drainage catchment assessments, and climate change implications on rainfall, drainage and tidal characteristics
- Identification of design and mitigation measures that will be implemented to protect proposed operations and not worsen existing flood characteristics or soil erosion and scouring during construction and operation
- Identification of drainage system upgrades
- The 100 year ARI flood level will be adopted in the assessment of measures which are required to mitigate flood risk to the project, as well as any adverse impacts on surrounding property
- Changes in flood behaviour under PMF conditions will also be assessed in order to identify impacts on critical infrastructure and significant changes in flood hazards as a result of the project
- Consideration of limiting flooding characteristics to the following levels:
  - A maximum increase in inundation time of one hour in a 100 year ARI rainfall event
  - A maximum increase of 10 mm in inundation at properties where floor levels are currently exceeded in a 100 year ARI rainfall event
  - A maximum increase of 50 mm in inundation at properties where floor levels will not be exceeded in a 100 year ARI rainfall event
  - No inundation of floor levels which are currently not inundated in a 100 year ARI rainfall event
  - Or else provide alternative flood mitigation solutions consistent with the intent of these limits
- Consideration of the EIS documents.

The strategy will also need to consider any existing emergency response plans, with relevant information provided to SES and councils to assist in the preparation of new or necessary updates to relevant plans.

Sections 8.1.2 and **8.1.3** lists measures which should be considered during the preparation of the FMS in regards to the project-related flood risks and impacts.

Flood review report

A flood review report will be prepared after the first defined flood event affecting the project works for any of the following flood magnitudes – the five year ARI event, 20 year ARI event and 100 year ARI event - to assess the actual flood impact against those predicted in the design reports or as otherwise altered by the FMS. The Flood Review Report(s) must be prepared by an appropriately qualified person(s) and include:

- Identification of the properties and infrastructure affected by flooding during the reportable event
- A comparison of the actual extent, level, velocity and duration of the flooding event against the impacts predicted in the design reports or as otherwise altered by the FMS
- Where the actual extent and level of flooding exceeds the predicted level with the consequent effect of adversely impacting of property(ies), structures and infrastructure, identification of the measures to be implemented to reduce future impacts of flooding related to the M4-M5 Link project including the timing and responsibilities for implementation.

Flood mitigation measures will be developed in consultation with the affected property, structure and/or infrastructure owners, OEH and the relevant council(s).

8.1.2 Management during construction phase

During the construction phase, some of the works will occur within the extent of various flood event magnitudes as outlined in **section 5.2**. Flood management plans will be developed prior to construction of any temporary ancillary facilities, including construction ancillary facilities as part of the CEMP, to guide the design of construction ancillary facilities and thereby minimise potential impacts of flooding. This will be in line with minimising risk to the surrounding environment.

Further assessment of the construction ancillary facilities and measures to manage flooding onsite and mitigate flood impacts during construction will be undertaken during detailed design. Inherent flood risks will be managed through the following methods:

- Detailed flood modelling to understand the effects of likely rainfall events. Construction layouts will be finalised accordingly. This may include:
  - Allocating carparks in areas where floodwater storage occurs
  - Earthworks and stockpiles located outside the 20 year ARI flood extent, where possible
  - Site buildings or infrastructure vulnerable to flooding (such as ventilation facilities or water treatment works) located on higher ground or elevated, to raise floor levels above expected flood levels.
- Temporary bunding (including noise barriers) or flood protection barriers around parts of the site that will be adversely affected by floodwaters, such as tunnel dive shafts, portals and cut and cover sections. The flood level adopted for design of temporary protection will need to be informed by consideration of both mainstream and local overland flows, the potential risk to the environment, safety and the potential disruption and damage to project works
- Installation of breaks or flaps in fencing or site hoarding to allow existing overland flowpaths into and out of sites in a controlled manner, where appropriate. This is relevant to the Pyrmont Bridge Road tunnel site (C9) where there is an existing flow path on Bignell Road
- Where transverse drainage structures are to be upgraded or replaced during the project, existing transverse drainage structures will be left in place and remain operational during the process. If this is not achievable, temporary drainage and detention areas will be required. At the Rozelle civil and tunnel site (C5), it is recommended that the permanent floodwater conveyance solution is installed as soon as possible to manage risk during construction

- All mitigation works will be designed so as to not exacerbate impacts to surrounding property
- A contingency plan to manage flooding will be prepared and implemented where construction ancillary facilities and vulnerable temporary facilities (including fuel storages, water treatment plants and substations) are located in the 20 year ARI flood extent, including the development of suitable procedures for flood warning, emergency management, site evacuation and planning
- During construction of new bridge structures, such as at The Crescent over Whites Creek near Rozelle interchange, the construction approach should seek to minimise impacts associated with impeding the conveyance of flow. Temporary falsework and access road crossings over Whites Creek are to be designed and staged to minimise the impact of construction activities on flooding conditions in adjacent development. Temporary works or infrastructure are to be removed as soon as possible once no longer required
- Runoff generated will be managed using existing or temporary drainage arrangements. Where required, storage of runoff will be provided to mitigate risk of overloading the receiving drainage system
- Undertake regular inspection and maintenance activities, such as cleaning of pit grates, channels and sediment basins to minimise risk of waterway blockage
- Siphonic based water management systems implemented during construction are removed and, where applicable, replaced with an adequate permanent drainage system.

The FMS will need to include details and procedures to manage the risk of adverse flood impacts on surrounding properties. This will require a more detailed assessment into the impacts construction activities will have on the existing flood behaviour and also identify measures which are required to mitigate those impacts. This will be an iterative process to inform detailed site layouts and staging diagrams. Results from construction related flood impact assessments will be provided as input to any emergency management procedures developed as part of the CEMP.

Where a property is identified as potentially being impacted (i.e. potential increase in flood levels), a floor level survey will need to be undertaken to determine whether construction activities will increase flood damages in adjacent development.

The layout of construction sites will need to be designed to:

- Limit the extent of works located in high flood risk areas
- Divert overland flow either through or around work areas in a controlled manner
- Minimise adverse impacts on flood behaviour for adjacent development.

Measures to manage residual flood impacts will include:

- Staging the construction to limit the extent and duration of temporary works in the floodplain
- Developing flood emergency response procedures to make sure construction equipment and materials are removed from floodplain areas at the completion of each work activity or should a weather warning for impending flood producing rain be issued
- Providing temporary flood protection to properties identified as being at risk of adverse flood impacts during any stage of construction of the project.

Management measures for each construction ancillary facility are provided in **Table 8-1**.

Table 8-1 Construction ancillary facilities and potential flood mitigation measures

Construction ancillary facility	Specific mitigation measures
C1a Wattle Street civil and tunnel site (part of M4 East project footprint)	None required. Construction activities will not impact on the mitigation measures implemented as part of the M4 East project.
C2a Haberfield civil and tunnel site (part of M4 East project footprint)	None required.
C3a Northcote Street civil site (part of M4 East project footprint)	None required.
C1b Parramatta Road West civil and tunnel site	None required. No topographic changes are proposed for Parramatta Road, Bland Street and Alt Street as part of the construction activities. As such the overland flowpaths would not be affected.
C2b Haberfield civil site (part of M4 East project footprint)	None required.
C3b Parramatta Road East civil site	None required.
C4 Darley Road civil and tunnel site	The indicative site layout has taken into consideration flood risk and hazards, with car parking allocated to the western side of the site which is more vulnerable to flooding. Bunding to protect tunnel ramps and vulnerable infrastructure to prevent floodwater ingress. There might be some localised increases on water depths on Darley Road adjacent to the site. Surrounding properties are unlikely to be impacted due to the small volume of water that would be displaced as a consequence of water exclusion measures.
C5 Rozelle civil and tunnel site	The indicative site layout has taken into consideration flood risk and the requirements for the conveyance of flood water through the site. Where setback from flooded areas is not possible, bunding will be required to protect tunnel ramps and vulnerable infrastructure to prevent floodwater ingress. Alternatively floor levels could be raised above expected flood levels. Construction of the permanent conveyance system as early as possible during construction to enable flood risk to the project to be managed and to mitigate impacts on surrounding properties. Temporary drainage measures required whilst installing the permanent arrangement.
C6 The Crescent civil site	Local drainage flow paths will be taken into consideration to divert flows safely around the laydown area.

Construction ancillary facility	Specific mitigation measures
C7 Victoria Road civil site	None required.
C8 Iron Cove civil site	Bunding of ramps to prevent floodwater ingress to the tunnel dive structures. Temporary drainage works would be implemented to minimise impacts on existing development as far as practicable by managing runoff on Victoria Road.
C9 Pyrmont Bridge Road tunnel site	The indicative site layout has taken into consideration risk of flooding on Bignell Lane, which functions as a preferential flowpath through the site. Vulnerable uses, such as the tunnel dive structure is located away from flooding on Bignell Lane. The existing flow path on Bignell Lane will be retained by the installation of breaks or flaps in fencing or site hoarding, to allow the overland flow path into and out of site. The overland flow path will be managed and controlled along existing and proposed roads. Use of noise walls or other flood protection barriers around the perimeter of the site to prevent ingress of flood water from Parramatta Road to the south and Mallett Street to the east.
C10 Campbell Road civil and tunnel site (part of New M5 project footprint).	None required. Construction activities will not impact on the mitigation measures implemented as part of New M5 project.

8.1.3 Management during operational phase

The assessment of flood impacts associated with the project has provided an understanding of the scale and nature of the flood risk to the project infrastructure and its operation, as well as the risks for the surrounding environment.

The layouts of the different interchanges have been influenced by flood risk and drainage considerations. In addition to the site specific mitigation measures outlined in **section 8.1.3**, a broad outline of other measures to be implemented in order to manage the operational flood risks and impacts as part of the detailed design is provided as follows.

Tunnel portals and ancillary facilities

Tunnel entries and associated flood protection barriers are to be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater). The same hydrologic standard would be applied to tunnel ancillary facilities such as tunnel ventilation and water treatment plants where the ingress of floodwaters would also have the potential to flood the tunnels.

Emergency response facilities

Emergency response facilities including the motorway control centre, tunnel fire water tank, pump buildings and associated electrical substations are to be located above the PMF level or the 100 year ARI flood level plus 0.5 metres (whichever is greater).

Impacts of flooding on existing development

A 100 year ARI flood standard is to be adopted in the assessment of measures required to mitigate any adverse flood impacts attributable to the project. Changes in flood behaviour under PMF conditions are also to be investigated in order to identify potential impacts on critical infrastructure and significant changes in flood hazard as a result of the project.

Potential blockage of major hydraulic structures

When setting finished road level and flood wall heights during detailed design, consideration should be given to the effects that partial blockage of major hydraulic structures might have on flood behaviour.

Potential impacts of future climate change on flood behaviour

Further assessment would need to be undertaken during detailed design to determine the climate change related flood risks to the project and flood impacts from the project, and would confirm requirements for any management measures. The assessment should be undertaken in accordance with the *Practical Considerations of Climate Change – Floodplain Risk Management Guideline* (DECC 2007).

Management of adverse flood impacts on existing development

The assessment of impacts the project might have on flood behaviour for surrounding properties and the mitigation measures required to manage such impacts would be refined during detailed design, through a detailed hydrologic and hydraulic assessment.

Works within the floodplain would be designed to minimise adverse impacts on surrounding development for flooding up to the 100 year ARI event, for example at the Rozelle interchange. Potential impacts for events in excess of the 100 year ARI up to the PMF would also be considered in the context of impacts on critical infrastructure and flood hazards.

The assessment has shown that impacts to surrounding properties can be mitigated so as to not increase flood risk to adjoining properties. If impacts to properties are identified as the assessment is refined during detailed design, then a floor level survey in affected areas would need to be undertaken. This information would be used to determine whether the project would increase flood damages for adjacent development (i.e. properties where there are potential increases in peak flood levels for events up to 100 year ARI).

Where adverse flood impacts for existing properties and potential future development are identified during the detailed design phase, additional mitigation measures would need to be incorporated in the design to minimise these impacts.

Stormwater drainage systems

Further hydrological and hydraulic modelling based on the detailed design would be undertaken to determine the ability of the receiving drainage systems to effectively convey drainage discharges from the project once operational. The modelling must be undertaken in consultation with the relevant council(s). It would include, but not be limited to:

- Confirming the location, size and capacity of all receiving drainage systems affected by the operation of the project
- Assessing the potential impacts of drainage discharges from the project drainage systems on the receiving drainage systems
- Identifying all feasible and reasonable mitigation measures to be implemented where drainage discharge from the project is predicted to adversely impact on the receiving drainage systems.

8.2 Water quality

Except as may be provided by an Environment Protection Licence, the project will be constructed and operated to comply with section 120 of the POEO Act, which prohibits the pollution of waters. Specific management measures are detailed below.

8.2.1 Management of construction impacts

Soil and water management plan

A CSWMP will be prepared for the project. The plan will include the measures that will be implemented to manage and monitor potential surface water quality impacts during construction. The CSWMP will be developed in accordance with the principles and requirements in Managing Urban

Stormwater – Soils and Construction, Volume 1 (Landcom 2004) and Volume 2D (DECCW, 2008), commonly referred to as the 'Blue Book'.

Erosion and sediment control/waterway and riparian area protection

Erosion and Sediment Control Plans (ESCPs) will be prepared for all work sites in accordance with the Blue Book. ESCPs will be implemented in advance of site disturbance and will be updated as required as the work progresses and the sites change. A soil conservation specialist would be engaged for the duration of construction to provide advice regarding erosion and sediment control.

The following controls would be implemented as part of the ESCP to address potential erosion and sediment control issues:

- Surface runoff generated during construction would be captured in basins or low point sumps, tested (and treated if required) prior to reuse or discharge under a site specific arrangement
- The design, construction and management of sediment sumps/basins to capture stormwater runoff and sediment during the construction phase would be in accordance with The Blue Book (Landcom 2004). The number, location and size of these basins/sumps will be confirmed during detailed design and in accordance with the requirements of the relevant Environment Protection Licence. The Blue Book recommends that where receiving waters are sensitive, sediment basins should be sized for an 80th percentile or 85th percentile five day rainfall depth for disturbance periods of less than or greater than six months respectively
- Internal construction traffic would be restricted to access tracks, delineated through fencing before the start of construction and maintained until construction is complete
- Erosion and sediment controls would be implemented prior to soil disturbance. Lateral flow (i.e. stormwater) would be managed to avoid flow over exposed soils which may result in erosion and impacts to water quality
- Above ground stockpile sites would be located outside the 20 year ARI flood extent, where possible. Appropriate management control measures such as bunding would be in place where construction ancillary facilities are located in the 20 year ARI flood extent (see **Annexure D**)
- The extent of ground disturbance and exposed soil will be minimised to the greatest extent practicable to minimise the potential for erosion
- Disturbed ground and exposed soils will be temporarily stabilised prior to extended periods of site inactivity to minimise the potential for erosion
- Disturbed ground and exposed soils will be permanently stabilised and proposed landscaped areas will be suitably profiled and vegetated as soon as possible following disturbance to minimise the potential erosion
- Rainfall forecasts to be monitored daily and the site managed to avoid erosion and sedimentation and to minimise the impact of heavy rainfall and flood events
- Sealed surfaces to be provided within construction ancillary facilities where possible to minimise erosion
- Controls to minimise mobilisation of dirt onto roads would be implemented including, for example, a wheel wash or rumble grid systems installed at exit points
- A soil conservation specialist would be contracted to supervise construction in 'high risk' areas in accordance with the Roads and Maritime Erosion and Sedimentation Management Procedure
- Procedures and protocols to manage potentially contaminated fill, soil, and bedrock, acid sulfate soils and extracted groundwater would be detailed in the CEMP measures to minimise the disturbance of sediments during construction of new stormwater discharge outlets to Rozelle Bay and Iron Cove. Measures would be designed in accordance with *Controlled Activities – Guidelines for outlet structures* (NSW Office of Water 2010). Where practical, permanent scour protection measures required for the operational phase would be installed early in the construction phase
- Works within or adjacent to waterways to be managed in accordance with the *Controlled Activities on Waterfront Land Guidelines* (DPI 2012).

Water quality monitoring

A program to monitor potential surface water quality impacts due to the project will be developed and included in the CSWMP. The program will include the water quality monitoring parameters and the monitoring locations identified in **Annexure E**.

The monitoring program would commence prior any ground disturbance to establish appropriate baseline conditions and continue for the duration of construction, as well as for a minimum of three years following the completion of construction or until the affected waterways are certified by a suitably qualified and experienced independent expert as being rehabilitated to an acceptable condition (or as otherwise required by any project conditions of approval).

Samples would be taken monthly, including a range of wet and dry conditions, where possible. This would include upstream (control) and downstream measurement locations. Additional monitoring locations may be required as part of the CSWMP. As a minimum an additional monitoring location should be incorporated within or at a suitable discharge point to White Bay.

New crossings

The proposed bridge crossing and widening at Whites Creek including any temporary work platforms, waterway crossings and/or coffer dams, where feasible and reasonable, must be designed and constructed in a manner which is consistent with:

- *NSW Guidelines for Controlled Activities Watercourse Crossings* (DPI 2012)
- *Why do Fish Need to Cross the Road? Fish Passage Requirements for Waterway Crossings* (Fairfull and Witheridge 2003)
- *Policy and Guidelines for Fish Friendly Waterway Crossings* (NSW Fisheries February 2004)
- *Policy and Guidelines for Fish Habitat Conservation and Management* (DPI-Fisheries 2013).

Appropriate fish passage will be provided for crossings of fish habitat streams.

Construction water treatment

Temporary construction water treatment plants would be designed to treat wastewater including tunnel groundwater ingress, rainfall runoff in tunnel portals and ventilation outlets, heat and dust suppression water and wash down runoff.

The level of treatment provided would consider the characteristics of the waterbody, any operational constraints or practicalities and associated environmental impacts and be developed in accordance with ANZECC (2000) and with consideration to the relevant NSW WQOs.

With consideration to the 'highly disturbed' nature of all receiving waterways and temporary nature of the construction phase, an ANZECC (2000) species protection level of 90 per cent for toxicants is considered appropriate for adoption as a discharge criterion where practical and feasible. The discharge criteria for the treatment facilities will be finalised during the preparation of the CSWMP.

The design of the construction water treatment plants will be undertaken during detailed design. The treatment facilities may consist of:

- Primary settling tanks / ponds to remove sand and silt sediment fractions as well as oil and grease
- pH balance/metals oxidation tank with primary flocculation
- Secondary flocculation tank
- Clarifiers to remove sediment and residual oil
- Sediment dewatering processes
- Inline process and discharge turbidity and pH monitoring with diversion valves to divert out of specification water for retreatment.

Water reuse

As detailed in **section 2.4.1**, where available and practicable, and of appropriate chemical and biological quality, stormwater, recycled water or other water sources would be used in preference to potable water for construction activities, including dust control.

As a minimum, stormwater and groundwater inflows and reclaimed water shall satisfy the following water quality requirements prior to reuse onsite for non-potable uses:

- Workplace health and safety requirements
- Water showing signs of contamination, such as oil and grease, shall not be reused onsite
- pH levels are between 6.5 and 8.5
- Guidelines set out in the tip sheet *Use of Reclaimed Water* (RTA 2006b).

Contaminated runoff and spills

The following measures would be implemented to manage spills of contaminated fluids:

- Areas would be allocated for the storage of fuels, chemicals and other hazardous materials as far away as feasible and reasonable from drainage channels and areas that are unlikely to be flooded during a 20 year ARI event on an impervious, bunded area
- Facilities would be secured and bunded to levels in accordance with the NSW EPA guidelines
- Spills or contaminated runoff would be captured and disposed of at a licensed facility where necessary
- Activities such as re-fuelling, wash down and preparation of construction materials would be undertaken in bunded areas to mitigate risks in relation to spills or leaks of fuels/oils or other hazardous onsite construction material
- The application of good practice in the storage and handling of dangerous and hazardous goods would provide appropriate practical responses to minimise the risk of a spill occurring
- Potential discharges from construction sites such as accidental construction spills or leaks would be managed through the installation of sumps / basins (primarily designed for sediment capture but with capacity to contain the nominated spill volume) constructed in accordance with *Managing Urban Stormwater – Soils and Construction, Volume 1* (Landcom 2004). Captured contaminants resulting from spills or leaks would be treated and disposed of at a licensed facility where necessary
- Soil which has been contaminated with fuel, oils or other chemicals would be disposed as contaminated soil through the projects waste subcontractor.

8.2.2 Residual construction water quality impacts

The proposed surface water management measures aim to minimise short term impacts on the receiving waterways during construction. With the implementation of the management measures, and in the context of the overall catchment, any potential short term impacts are unlikely to have a material impact on ambient water quality within the receiving waterways.

Therefore, the project is likely to have a negligible influence on whether NSWWQOs are protected (if currently met) or achieved (if currently not met) during the construction phase.

8.2.3 Management of operational impacts

Stormwater runoff

Suitable treatment devices would be provided to treat stormwater runoff from impervious surfaces that result from the project. Treatment of stormwater runoff would target the stormwater quality objectives outlined in **section 3.2.11**. Stormwater treatment systems would be installed where space is available. In the case where space is unavailable, the treatment suite would more likely include proprietary stormwater treatment devices. Stormwater treatment systems would incorporate a high flow bypass for a minimum of a three month ARI flow, where practical and appropriate. This would enable treatment of the majority of runoff events whilst protecting treatment devices from scour or damage associated with larger rainfall events.

The final design of treatment trains would be informed by an assessment of the sensitivity of the receiving environments and supported by MUSIC modelling. This would be undertaken during detailed design. Potential opportunities to further reduce the projects annual stormwater pollutant loading through the treatment of external catchments, to achieve the project pollutant load reduction targets (see **section 3.2.11**), will be explored during detailed design. Proposed landscaped areas would be suitably profiled, vegetated and stabilised to control erosion.

A maintenance plan for the management of all stormwater treatment devices will be developed during detailed design. The maintenance plan would outline future maintenance responsibilities, maintenance frequency and specific tasks to be undertaken.

New discharge outlets would be designed with appropriate energy dissipation and scour protection measures as required to minimise the potential for sediment disturbance caused by the operation of new outlets. The design of the outlets, including discharge velocities and energy dissipation/scour protection measures would be informed by appropriate drainage modelling and confirmed during detailed design. The presence and suitability of energy dissipation and scour protection measures at existing outlets would also be assessed during detailed design and appropriate improvements incorporated as required.

Water quality monitoring

A program to monitor potential surface water quality impacts due to the project will be developed and included in the OEMP. The program will include the water quality monitoring parameters and the monitoring locations identified in **Annexure E**.

The monitoring program would continue for a minimum of three years following the completion of construction or until the affected waterways are certified by a suitably qualified and experienced independent expert as being rehabilitated to an acceptable condition (or as otherwise required by any project conditions of approval).

Spill controls

An assessment of risk of spills on the motorway, with emphasis placed on the receiving environment, would be undertaken. If warranted in areas of higher sensitivity, such as upstream of Rozelle Bay and Iron Cove, containment facilities would be provided. This would be determined during detailed design.

Spill management and emergency response procedures would also be documented in an OEMP.

Tunnel water treatment facilities

The tunnel operational water treatment facilities would be designed such that effluent will be of suitable quality for discharge to the receiving environment.

The level of treatment would consider the characteristics of the discharge and receiving waterbody, any operational constraints or practicalities and associated environmental impacts and be developed in accordance with ANZECC (2000) and with consideration to the relevant NSW WQOs.

With consideration to existing water quality within Hawthorne Canal and Rozelle Bay. NSW WQOs and the permanent nature of the tunnel water discharges the ANZECC (2000) 'marine' default trigger values for 95 per cent level of species protection may be appropriate for establishing discharge criteria for parameters which require treatment, where practical and feasible. As no 'marine' trigger value is available for the key toxicants which are likely to require treatment within the tunnel water (iron and manganese), alternative discharge criteria are provided in **Table 8-2**. The discharge criteria for the treatment facilities will be further developed and finalised within the OEMP.

Table 8-2 Indicative tunnel wastewater discharge criteria

Parameter	Discharge criteria	Reference	Comments
Iron	0.3 mg/L	ANZECC (2000) recreational water quality guideline value	No marine or fresh water trigger value available
Manganese	1.8 mg/L	ANZECC (2000) fresh water 95% species protection	No marine water trigger value available

The constructed wetland within the Rozelle interchange area would be designed to cater for the continuous treated groundwater flows from the water treatment plant. The wetland at Rozelle interchange would also be used to treat a portion of stormwater runoff from the project footprint.

Opportunities to incorporate other forms of nutrient/ammonia removal will be investigated during detailed design for the treatment plant at Darley Road, as required.

8.2.4 Residual operational water quality impacts

As detailed in **section 4.5** the receiving waterways currently do not achieve all the SHPRC water quality objectives with elevated levels of some heavy metals, nutrients, turbidity and pH recorded. The MUSIC modelling indicates that the project would reduce the stormwater pollutant loading to the receiving waterways when compared to the existing conditions.

Tunnel water will be treated and spill controls and water quality monitoring will be implemented to manage impacts to ambient water quality within the receiving waterways. Residual impacts to ambient water quality will generally be negligible with impacts localised to the zone near the outlet where discharges mix with receiving waters. In the context of the entire catchment draining to Sydney Harbour, the project is likely to have a negligible influence on achieving the SHPRC water quality objectives.

8.3 Management of cumulative impacts

An assessment of cumulative impacts associated with other projects in the vicinity of the M4-M5 Link, in particular other WestConnex projects, such as the M4 East and New M5 projects, has been carried out. The assessment also considered other projects such as the CBD and South East Light Rail and Western Harbour Tunnel and Beaches Link (see **section 7**). The projects currently under construction all incorporate surface water and flood management measures during construction and operation to prevent adverse impacts to the common receiving receptors and adjoining properties. Other projects that are still in the planning stages will likely be required to implement similar mitigation measures in accordance with legislative requirements to prevent adverse impacts.

Therefore, with due consideration of the proposed management measures to be implemented as part of the M4-M5 Link project as discussed in **sections 8.1** and **8.2**, there are minimal adverse cumulative surface water quality or flooding impacts anticipated. The residual risk to common receptors and sensitive environments downstream would be low provided the proposed management measures are implemented, maintained and monitored.

9 Conclusion

9.1 Flooding

The risk of flooding posed to the surface features of the M4-M5 Link project has been assessed, taking into account the likely impacts of climate change and cumulative impacts with other projects, as well as the potential impact that the project might have on surrounding properties.

Flood risk has been identified as a consideration at some of the construction sites, including Rozelle Rail Yards, Darley Road, Iron Cove Link and Pyrmont Road Bridge Road. The indicative layouts for the sites have considered the existing flood risk, by locating more vulnerable land uses away from areas of flooding or deeper water. Where this is not possible, a number of mitigation measures have been identified in order to protect the portals and sensitive infrastructure from inundation and minimise the potential to displace flood water.

The flood risk posed to the interchanges at the connection points to the M4 East and New M5 are being managed by the respective projects, therefore no further mitigation is considered to be required. The proposed site of the Rozelle interchange currently functions as an area of significant flood storage and a number of measures have been incorporated into the operational layout to enable floodwater to be conveyed through the site as well as protecting sensitive project infrastructure such as the portals, substations and ventilation facilities. At the Iron Cove Link and Darley Road sites, the proposed change to the road layout and levels and protection of the portals is not considered to have a significant impact on flood risk.

The potential flood risk impacts associated with the project are considered to be acceptable based on the mitigation measures identified. The assessment of flood risk and mitigation measures identified will need to be refined throughout the detailed design process.

9.2 Water quality

Potential impacts on surface water quality during construction of the project are considered minor and manageable with the application of standard mitigation measures.

The CEMP would control potential surface water quality impacts during construction. Construction water treatment plants would be established during the construction phase to treat water to a quality suitable for discharge to the environment.

A CSWMP would be prepared as part of the overall CEMP and a Water Quality Monitoring Program would be prepared and implemented to monitor and avoid or mitigate impacts on surface water quality during construction and operation.

During operation, there is potential for the project to impact surface water quality through discharges of poorly treated tunnel water. Two operational water treatment plants will be designed to treat tunnel flows to a suitable quality for discharge to the receiving environment. Treated flows from the Rozelle plant will be discharged to a wetland providing additional ‘polishing’ treatment prior to discharge. Opportunities to incorporate other forms of nutrient treatment within the treatment plant at Darley Road will be investigated during detailed design, as required.

During operation, there is potential for the project to impact surface water quality through increases in imperviousness that would lead to increases in pollutant loads associated with surface runoff. This would be managed through a range of treatment devices such as wetlands, bioretention systems, and good practice inline pollution control measures or proprietary treatment devices. Current provisions are sufficient to reduce the stormwater mean annual pollutant loading to Sydney Harbour when compared to existing conditions.

In the context of the entire catchment draining to Sydney Harbour, the project is likely to have a negligible influence on achieving the SHPRC water quality objectives.

9.3 Hydrology and geomorphology

The discharge of treated construction water would have a minor increase in base flow rates to receiving waterways. The flow variability within the receiving waterways is dominated by tides at the proposed discharge locations.

During operation, minor increases in storm flow to Rozelle Bay, Whites Creek, White Bay, Iron Cove, Alexandra Canal and Hawthorne Canal associated with an increase in impervious surface and the increase in base flow to Hawthorne Canal and Rozelle Bay associated with treated tunnel flows are considered to pose a negligible impact on the flow variability and hydrological attributes of the tidal waterways.

Given the majority of existing waterways are hard lined, increased discharge volumes will not impact on bed or bank stability during construction or operation. Negligible increases in discharge volume to Alexandra Canal during construction and operation are unlikely to have a material impact on the disturbance of bed sediments within the canal. Appropriate energy dissipation and scour protection will be assessed and provided as appropriate at outlet locations to minimise scour and mobilisation of contaminated sediments in the vicinity of the outlet. Naturalisation works on Whites Creek would incorporate surface treatments which provide suitable erosion protection once constructed and established. The naturalisation works would likely provide added ecological benefits to the waterway.

10 References

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Annexures

Annexure A Photographs

Photo 1 – Dobroyd Canal at Timbrell Park

Photo 2 – Hawthorne Canal at Blackmore Park

Photo 3 – Easton Park drain adjacent to Lilyfield Road

Photo 4 – Easton Park drain (culverts in foreground) and Whites Creek outlet (background) to Rozelle Bay

Photo 5 – Whites Creek at Brenan Street

Photo 6 – Iron Cove immediately downstream of Iron Cove Bridge

Photo 7 – Alexandra Canal downstream of Canal Road

Photo 8 – Steep embankments along Rozelle Rail Yards

Photo 9 – Median barrier along Victoria Road (Google Street View)

Annexure B Water Quality Data Summary

Table B-1 Dobroyd Canal surface water quality monitoring summary

Parameter	Units	Guideline Criteria		M4 East Dobroyd Canal monitoring[5] – Non–Tidal			M4 East Dobroyd Canal Monitoring[6] – Tidal			M4M5 Dobroyd Canal Monitoring[7] – Tidal		
		ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[2]	Min	Max	Med	Min	Max	Med	Min	Max	Med
Dissolved Oxygen (Field) (Filtered)	mg/L	-	-	9.02	13.1	10.8	4.43	15	10.86	1.7	20.83	7.95
Electrical Conductivity (Field)	µS/cm	125 – 2000[4]	-	230	2749	643.7	260	52630	25560	216	58650	21219
pH (Field)		6.5 – 8.0[4]	7 – 8.5[3]	7.9	9.07	8.545	6.98	9.15	7.85	5.67	10.3	8.1
Turbidity (Field)	NTU	6-50	0.5-10	10.6	549	50.4	2.5	187	14.4	1	111.6	12.1
Arsenic	mg/L	0.013[8]	-	0.001	0.007	0.003	0.002	0.003	0.0025	0.001	0.014	0.004
Cadmium	mg/L	0.0002	0.0055	-	-	-	0.0001	0.0001	0.0001	<0.0001	<0.001	0.0001
Chromium (III+VI)	mg/L	0.001[9]	0.0044[9]	0.002	0.006	0.0035	0.002	0.003	0.0025	0.0005	0.025	0.003
Copper	mg/L	0.0014	0.0013	0.005	0.051	0.013	0.004	0.028	0.01	0.003	0.113	0.019
Iron	mg/L	-	-	NS	NS	NS	NS	NS	NS	0.2	14.3	1.385
Lead	mg/L	0.0034	0.0044	0.003	0.024	0.0055	0.001	0.014	0.0045	0.002	0.136	0.011
Manganese	mg/L	1.9	-	NS	NS	NS	NS	NS	NS	<0.01	0.159	0.0255
Mercury	mg/L	0.0006	0.0004	NS	NS	NS	NS	NS	NS	<0.00004	0.0002	0.00005
Nickel	mg/L	0.011	0.07	0.001	0.006	0.002	0.002	0.007	0.004	<0.001	0.012	0.003
Zinc	mg/L	0.008	0.015	0.01	0.08	0.0405	0.021	0.074	0.033	0.015	0.474	0.0575
Ferrous Iron	mg/L			NS	NS	NS	NS	NS	NS	<0.05	10.5	0.175
TRH C10 - C40 (Sum of Total)	mg/L	-	-	0.48	0.48	0.48	-	-	-	<100	1540	50
C6 - C 9 Fraction	mg/L	-	-	-	-	-	-	-	-	<20	30	10
C10 - C36 (Sum of Total)	mg/L	-	-	0.43	0.43	0.43	0.05	0.05	0.05	<50	1190	25
Total BTEX	mg/L	-	-	NS	NS	NS	NS	NS	NS	<0.001	<0.001	0.0005

Parameter		Guideline Criteria		M4 East Dobroyd Canal monitoring[5] – Non–Tidal			M4 East Dobroyd Canal Monitoring[6] – Tidal			M4M5 Dobroyd Canal Monitoring[7] – Tidal		
	Units	ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[2]	Min	Max	Med	Min	Max	Med	Min	Max	Med
Phosphorus	mg/L	0.05[4]	0.03[3]	0.1	0.41	0.23	0.06	0.44	0.1	0.03	2.24	0.19
Reactive Phosphorus	mg/L	-	-	NS	NS	NS	NS	NS	NS	<0.01	0.38	0.04
Kjeldahl Nitrogen Total	mg/L	-	-	0.7	3.3	1.3	0.3	4.9	0.75	<0.2	12	1.25
Nitrate	mg/L	0.7	-	NS	NS	NS	NS	NS	NS	0.04	2.33	0.56
Nitrite	mg/L	-	-	NS	NS	NS	NS	NS	NS	<0.01	0.3	0.04
Nitrogen (Total Oxidised)	mg/L	-	-	1.22	4.23	2.06	0.03	2.35	0.485	0.04	2.39	0.61
Nitrogen (Total)	mg/L	0.5[4]	0.3[3]	2.1	6.4	4.2	0.4	5.2	1.25	<0.5	13.7	2.25
Total Suspended Solids	mg/L	-	-	7	200	22	12	66	39	NS	NS	NS

Notes:

[1] ANZECC (2000) *'freshwater'* default trigger values for 95 per cent level of species protection

[2] ANZECC (2000) *'marine'* default trigger values for 95 per cent level of species protection

[3] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[4] ANZECC (2000) *'lowland rivers'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[5] M4 East sampling conducted by GHD between June 2015 and May 2016 based on 12 samples collected from DOB1

[6] M4 East sampling conducted by GHD between June 2015 and May 2016 based on 11 samples collected from DOB2

[7] M4-M5 Link sampling conducted by AECOM between July 2016 and May 2017, based on 16 samples collected from SW8 and 16 samples collected from SW09

[8] Based on Arsenic (As V)

[9] Based on Chromium (Cr VI)

5.2 = Exceeds one or more relevant guideline criteria

NS = No sample collected

'-' = Sample collected but below detection limit

Table B-2 Hawthorne Canal surface water quality monitoring summary

Parameter	Units	Guideline Criteria		M4 East Hawthorne Canal Monitoring - Tidal[5]			M4M5 Hawthorne Canal Monitoring - Tidal [6]		
		ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[2]	Min	Max	Med	Min	Max	Med
Dissolved Oxygen (Field) (Filtered)	mg/L	-	-	3.94	13.83	9.34	1.05	51.81	5.115
Electrical Conductivity (Field)	µS/cm	125 – 2000[4]	-	267	40140	12072	3032	51650	42333.5
pH (Field)		6.5 – 8.0[4]	7 – 8.5[3]	6.81	8.38	7.885	5.35	7.88	7.605
Turbidity (Field)	NTU	6-50	0.5-10	4.3	425	31.1	0.1	51.3	8
Arsenic	mg/L	0.013[7]	-	0.001	0.008	0.003	0.0019	<0.01	0.005
Cadmium	mg/L	0.0002	0.0055	0.0002	0.0002	0.0002	<0.0001	<0.001	0.00035
Chromium (III+VI)	mg/L	0.001[9]	0.0044[8]	0.001	0.006	0.001	<0.0005	<0.01	0.005
Copper	mg/L	0.0014	0.0013	0.003	0.067	0.0065	<0.001	0.033	0.005
Iron	mg/L	-	-	NS	NS	NS	<0.1	3.91	0.34
Lead	mg/L	0.0034	0.0044	0.001	0.032	0.004	0.0016	0.056	0.005
Manganese	mg/L	1.9		NS	NS	NS	<0.01	0.062	0.018
Mercury	mg/L	0.0006	0.0004	NS	NS	NS	<0.00004	0.0001	0.00005
Nickel	mg/L	0.011	0.07	0.002	0.006	0.0035	0.0005	<0.01	0.004
Zinc	mg/L	0.008	0.015	0.015	0.127	0.032	0.01	0.124	0.026
Ferrous Iron	mg/L	-	-	NS	NS	NS	<0.05	1.45	0.075
TRH C10 - C40 (Sum of Total)	mg/L	-	-	-	-	-	<100	<100	50
C6 - C 9 Fraction	mg/L	-	-	-	-	-	<20	<100	10
C10 - C36 (Sum of Total)	mg/L	-	-	-	-	-	<50	<50	25
Total BTEX	mg/L	-	-	NS	NS	NS	<0.001	<0.005	0.0005
Phosphorus	mg/L	0.05[4]	0.03[3]	0.03	0.59	0.125	<0.02	6.82	0.07
Reactive Phosphorus	mg/L	-	-	NS	NS	NS	<0.01	0.1	0.03
Kjeldahl Nitrogen Total	mg/L	-	-	0.4	2	0.8	0.4	2	0.25
Nitrate	mg/L	0.7	-	NS	NS	NS	0.01	2.79	0.09

Parameter	Units	Guideline Criteria		M4 East Hawthorne Canal Monitoring - Tidal[5]			M4M5 Hawthorne Canal Monitoring - Tidal [6]		
		ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[2]	Min	Max	Med	Min	Max	Med
Nitrite	mg/L	-	-	NS	NS	NS	<0.01	0.05	0.005
Nitrogen (Total Oxidised)	mg/L	-	-	0.18	2.75	0.83	0.01	2.84	0.09
Nitrogen (Total)	mg/L	0.5[4]	0.3[3]	0.8	4.5	1.55	<0.5	4.8	0.25
Total Suspended Solids	mg/L	-	-	8	229	20.5	NS	NS	NS

Notes:

[1] ANZECC (2000) *'freshwater'* default trigger values for 95 per cent level of species protection

[2] ANZECC (2000) *'marine'* default trigger values for 95 per cent level of species protection

[3] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[4] ANZECC (2000) *'lowland rivers'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[5] M4 East sampling conducted by GHD between June 2015 and May 2016 based on 13 samples collected from DSW

[6] M4-M5 Link sampling conducted by AECOM between July 2016 and May 2017, based on 16 samples collected from SW5 and 16 samples collected from SW06

[7] Based on Arsenic (As V.)

[8] Based on Chromium (Cr VI)

5.2 = Exceeds one or more relevant guideline criteria

NS = No sample collected

'-' = Sample collected but below detection limit

Table B-3 Whites Creek surface water quality monitoring summary

Parameter	Units	Guideline Criteria ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[1]	M4M5 Whites Creek Monitoring[4] – Tidal Min	Max	Med	The Bays Whites Creek Monitoring[5] – Tidal Min	Max	Med[8]
Dissolved Oxygen (Field) (Filtered)	mg/L	-		4.97	35.43	11.855	NS	NS	NS
Electrical Conductivity (Field)	µS/cm	125 – 2000[2]		39.1	39785	1055	NS	NS	NS
pH (Field)		6.5 – 8.0[2]	7 – 8.5[3]	5.38	9.41	7.73	NS	NS	NS
Turbidity (Field)	NTU	6-50	0.5-10	-0.7	18.8	2.45	NS	NS	NS
Total suspended solids		-	-	-	-	-	5.10	16.18	10.00
Arsenic	mg/L	0.013[7]	-	0.0009	0.003	0.005	0.0012	0.0027	0.0013
Cadmium	mg/L	0.002		0.0001	0.0006	0.00035	NS	NS	NS
Chromium (III+VI)	mg/L	0.001[8]	0.0044[8]	0.0008	0.002	0.005	0.0005	0.0008	0.0006
Copper	mg/L	0.0014	0.0013	0.003	0.014	0.005	0.0025	0.0048	0.0036
Iron	mg/L	-	-	0.17	0.89	0.34	0.0370	0.2158	0.1403
Lead	mg/L	0.0034	0.0044	0.002	0.017	0.005	0.00008	0.00096	0.00044
Manganese	mg/L	1.9	-	0.006	0.06	0.018	NS	NS	NS
Mercury	mg/L	0.0006	0.0004	-	-	0.00005	-	-	-
Nickel	mg/L	0.011	0.07	0.001	0.003	0.004	0.0015	0.0019	0.0017
Zinc	mg/L	0.008	0.015	0.034	0.361	0.026	0.027	2.93	1
Ferrous Iron	mg/L	-	-	0.06	0.62	0.075	NS	NS	NS
Silicate		-	-	NS	NS	NS	0.63	4.15	1.98
TRH C10 - C40 (Sum of Total)	mg/L	-	-	-	-	50	NS	NS	NS
C6 - C 9 Fraction	mg/L	-	-	-	-	10	NS	NS	NS
C10 - C36 (Sum of Total)	mg/L	-	-	-	-	25	NS	NS	NS
Total BTEX	mg/L	-	-	0.002	0.002	0.0005	NS	NS	NS
Phosphorus	mg/L	0.05[2]	0.03[5]	0.04	0.48	0.07	0.068	0.18	0.089
Reactive Phosphorus	mg/L	-	-	0.01	0.12	0.03	NS	NS	NS

Parameter	Units	Guideline Criteria		M4M5 Whites Creek Monitoring[4] – Tidal			The Bays Whites Creek Monitoring[5] – Tidal		
		ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[1]	Min	Max	Med	Min	Max	Med[8]
Reactive Orthophosphate	mg/L	-	-	NS	NS	NS	0.010	0.039	0.026
Kjeldahl Nitrogen Total	mg/L	-	-	0.3	1.3	0.25	NS	NS	NS
Nitrate	mg/L	0.7	-	0.06	1.83	0.09	0.25	1.83	0.80
Nitrite	mg/L	-	-	0.01	0.14	0.005	0.005	0.077	0.049
Nitrogen (Total Oxidised)	mg/L	-	-	0.06	1.89	0.09	NS	NS	NS
Oxides of Nitrogen	mg/L		-	NS	NS	NS	0.256	1.881	0.863
Nitrogen (Total)	mg/L	0.5[2]	0.3[5]	0.5	2.4	0.25	0.73	2.87	1.56

Notes:

[1] ANZECC (2000) *'freshwater'* default trigger values for 95 per cent level of species protection

[2] ANZECC (2000) *'lowland rivers'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[3] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[4] M4-M5 Link sampling conducted by AECOM between July 2016 and May 2017, based on 16 samples collected from SW2

[5] The Bays sampling conducted by Sydney University between June 2016 and September 2016, based on five samples collected from SW2

[6] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[7]Based on Arsenic (As V)

[8]Based on Chromium (Cr VI)

5.2 = Exceeds one or more relevant guideline criteria

NS = No sample collected

'-' = Sample collected but below detection limit

Table B-4 Rozelle Bay surface water quality monitoring summary

Parameter	Units	Guideline Criteria ANZECC 2000 Marine[2]	M4M5 Rozelle Bay Monitoring[5] – Tidal			The Bays Monitoring - Tidal		
			Min	Max	Med	Min	Max	Med[6]
Dissolved Oxygen	mg/L	-	-0.16	66.2	5.6	64	89	85
EC	µS/cm	-	402.9	51100	46630.5	47788	51981	50859
pH		7 – 8.53	5.65	7.96	7.61	7.69	8.14	8.02
Turbidity	NTU	0.5-10	-1.4	15	2.35	0.20	3.40	1.40
Total suspended solids	mg/L	-	-	-	-	2.30	11.15	4.40
Arsenic	mg/L	-	-	-	0.005	0.0015	0.0019	0.0018
Cadmium	mg/L	0.0055	-	0.0018	0.0005	-	-	-
Chromium (III+VI)	mg/L	0.0044[7]	-	-	0.005	0.0005	0.0005	0.0005
Copper	mg/L	0.0013	0.002	0.015	0.005	0.0016	0.0052	0.0028
Iron	mg/L	-	0.027	0.67	0.23	0.0025	0.0094	0.0037
Lead	mg/L	0.0044	0.0009	0.015	0.005	0.00004	0.00029	0.00025
Manganese	mg/L	-	0.0068	0.061	0.0059	-	-	-
Mercury	mg/L	0.0004	-	-	0.00005	-	-	-
Nickel	mg/L	0.07	-	-	0.005	0.0017	0.0024	0.0019
Zinc	mg/L	0.015	0.019	0.503	0.0415	0.019	1.559	0.218
Ferrous Iron	mg/L	-	-	0.38	0.07	-	-	-
Silicate	mg/L	-	NS	NS	NS	0.05	1.11	0.27
TRH C10 - C40 (Sum of Total)	mg/L	-	-	-	50	NS	NS	NS
C6 - C 9 Fraction	mg/L	-	-	-	10	NS	NS	NS
C10 - C36 (Sum of Total)	mg/L	-	-	-	25	NS	NS	NS
Total BTEX	mg/L	-	-	0.004	0.0005	NS	NS	NS
Phosphorus	mg/L	0.03[3]	0.02	3.76	0.025	0.032	0.046	0.039
Reactive Phosphorus	mg/L	-	-	0.07	0.02	-	-	-
Reactive Orthophosphate			NS	NS	NS	0.013	0.054	0.016

Parameter	Units	Guideline Criteria	M4M5 Rozelle Bay Monitoring[5] – Tidal			The Bays Monitoring - Tidal		
		ANZECC 2000 Marine[2]	Min	Max	Med	Min	Max	Med[6]
Kjeldahl Nitrogen Total	mg/L	-	0.2	-	0.25	-	-	-
Nitrate	mg/L	0.7	0.01	0.9	0.085	0.01	0.94	0.14
Nitrite	mg/L	-	-	0.02	0.005	0.002	0.007	-
Nitrogen (Total Oxidised)	mg/L	-	0.01	0.92	0.085	-	-	-
Oxides of Nitrogen	mg/L		NS	NS	NS	0.008	0.951	0.140
Ammonia			NS	NS	NS	0.013	0.114	0.042
Nitrogen (Total)	mg/L	0.3[3]	0.3	1.3	0.25	0.256	1.430	0.416
Enteroccoci	CFU/100mL		NS	NS	NS	0	1300	28
Chlorophyll a	mg/L	0.003	NS	NS	NS	0.0007	0.0085	0.0032

Notes:

[1] ANZECC (2000) *'freshwater'* default trigger values for 95 per cent level of species protection

[2] ANZECC (2000) *'marine'* default trigger values for 95 per cent level of species protection

[3] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[4] ANZECC (2000) *'lowland rivers'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[5] M4-M5 Link sampling conducted by AECOM in 2016 between July 2016 and May 2017, based on 16 samples collected from SW1

[6] Where the median values is less than the limit of reporting, the median was assumed to be half of the value of the limit of reporting

[7] Based on Chromium (Cr VI)

5.2 = Exceedance of guideline criteria

NS = No sample collected

'-' = Sample collected but below detection limit

Table B-5 White Bay surface water quality monitoring summary

Parameter	Units	Guideline Criteria	The Bays Monitoring – Tidal[4]		
		ANZECC 2000 Marine[2]	Min	Max	Med
Dissolved Oxygen	mg/L	-	5.88	8.14	7.31
EC	µS/cm	-	NS	NS	NS
pH		7 – 8.5[3]	7.86	8.17	8.06
Turbidity	NTU	0.5-10	0.10	2.60	1.40
Total suspended solids	mg/L	-	2.00	33.49	3.12
Arsenic	mg/L	-	0.0015	0.0021	0.0019
Cadmium	mg/L	0.0055			
Chromium (III+VI)	mg/L	0.0044[5]	0.0005	0.0007	0.0006
Copper	mg/L	0.0013	0.0023	0.0037	0.0026
Iron	mg/L	-	0.0028	0.0083	0.0035
Lead	mg/L	0.0044	0.00001	0.00006	0.00002
Manganese	mg/L	-	NS	NS	NS
Mercury	mg/L	0.0004	-	-	-
Nickel	mg/L	0.07	0.0018	0.0018	0.0018
Zinc	mg/L	0.015	0.006	0.86	0.072
Ferrous Iron	mg/L	-	NS	NS	NS
Silicate	mg/L	-	0.048	0.93	0.21
TRH C10 - C40 (Sum of Total)	mg/L	-	NS	NS	NS
C6 - C 9 Fraction	mg/L	-	NS	NS	NS
C10 - C36 (Sum of Total)	mg/L	-	NS	NS	NS
Total BTEX	mg/L	-	NS	NS	NS
Phosphorus	mg/L	0.03[3]	0.024	0.11	0.036
Reactive Phosphorus	mg/L	-	NS	NS	NS
Reactive Orthophosphate			0.007	0.050	0.014

Parameter		Guideline Criteria	The Bays Monitoring – Tidal[4]		
	Units	ANZECC 2000 Marine[2]	Min	Max	Med
Kjeldahl Nitrogen Total	mg/L	-	NS	NS	NS
Nitrate	mg/L	0.7	0.007	0.791	0.093
Nitrite	mg/L	-	0.003	0.006	0.005
Nitrogen (Total Oxidised)	mg/L	-	NS	NS	NS
Oxides of Nitrogen	mg/L	-	0.007	0.796	0.093
Ammonia		-	0.003	0.105	0.019
Nitrogen (Total)	mg/L	0.3[3]	0.195	1.279	0.320
Enteroccoci	CFU/100mL		0	940	5
Chlorophyll a	mg/L	0.003	0.0005	0.0067	0.0018

Notes:

[1] ANZECC (2000) *'freshwater'* default trigger values for 95 per cent level of species protection

[2] ANZECC (2000) *'marine'* default trigger values for 95 per cent level of species protection

[3] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[4] The Bays precinct water quality sampling conducted by Sydney University between June 2016 and September 2016, based on 12 samples collected from BW2

[5] Based on Chromium (Cr VI)

5.2 = Exceedance of guideline criteria

NS = No sample collected

'-' = Sample collected but below detection limit

Table B-6 Johnstons Creek surface water quality monitoring summary

Parameter	Units	Guideline Criteria		M4M5 Johnstons Creek Monitoring[5] –Tidal			M4M5 Johnstons Creek Monitoring[6] – Non Tidal			The Bays Monitoring[7] – Non Tidal		
		ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[2]	Min	Max	Med	Min	Max	Med	Min	Max	Med
Dissolved Oxygen (Field) (Filtered)	mg/L	-	-	2.72	14.01	8.3	6.09	10.29	8.74	NS	NS	NS
Electrical Conductivity (Field)	µS/cm	125 – 2000[4]	-	103.6	50444	2945	73.6	6980	593	NS	NS	NS
pH (Field)		6.5 – 8.0[4]	7 – 8.5[3]	6.06	8.69	7.915	5.78	814	8.18	NS	NS	NS
Turbidity (Field)	NTU	6-50	0.5-10	0	119.7	10.65	10.6	222.7	28.65	NS	NS	NS
Total suspended solids				-	-	-	-	-	-	9.3	20.2	10.3
Arsenic	mg/L	0.013[8]	-	-	-	0.0028	-	0.012	0.003	0.0009	0.0013	0.001
Cadmium	mg/L	0.002	0.0055	-	-	0.00005	-	0.0023	0.0001	NS	NS	NS
Chromium (III+VI)	mg/L	0.001[9]	0.0044[9]	0.0009	-	0.001	0.0006	0.012	0.002	0.0008	0.0011	0.0009
Copper	mg/L	0.0014	0.0013	0.007	0.07	0.015	0.007	0.107	0.025	0.0042	0.01	0.0072
Iron	mg/L			-	4.07	0.935	0.41	5.36	1.96	0.020	0.45	0.069
Lead	mg/L	0.0034	0.0044	0.002	0.072	0.011	-	0.071	0.014	0.00009	0.0012	0.00064
Manganese	mg/L	1.9	-	-	0.102	0.031	0.003	0.174	0.042	NS	NS	NS
Mercury	mg/L	0.0006	0.0004	-	0.0001	0.00005	-	-	0.00005	-	-	-
Nickel	mg/L	0.011	0.07	-	0.016	0.002	-	0.008	0.002	0.0012	0.0022	0.0016
Zinc	mg/L	0.008	0.015	0.025	0.187	0.0665	0.021	0.252	0.08	0.0077	0.053	0.0088
Ferrous Iron	mg/L	-	-	-	0.4	0.12	-	0.77	0.19	NS	NS	NS
Silicate	mg/L	-	-	NS	NS	NS	NS	NS	NS	3.87	5.15	4.79
TRH C10 - C40 (Sum of Total)	mg/L	-	-	-	-	50	-	1700	50	NS	NS	NS
C6 - C 9 Fraction	mg/L	-	-	-	-	10	-	-	10	NS	NS	NS
C10 - C36 (Sum of Total)	mg/L	-	-	-	-	25	-	1430	25	NS	NS	NS
Total BTEX	mg/L	-	-	-	-	0.0005	-	-	0.0005	NS	NS	NS
Phosphorus	mg/L	0.05[4]	0.03[3]	-	0.5	0.19	0.11	1.49	0.32	0.13	0.22	0.18

Parameter	Units	Guideline Criteria		M4M5 Johnstons Creek Monitoring[5] –Tidal			M4M5 Johnstons Creek Monitoring[6] – Non Tidal			The Bays Monitoring[7] – Non Tidal		
		ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[2]	Min	Max	Med	Min	Max	Med	Min	Max	Med
Reactive Phosphorus	mg/L	-	-	-	0.16	0.08	-	0.71	0.11			
Reactive Orthophosphate		-	-	NS	NS	NS	NS	NS	NS	0.068	0.126	0.083
Kjeldahl Nitrogen Total	mg/L	-	-	0.2	2.5	0.95	0.6	11	2.2			
Nitrate	mg/L	0.7	-	0.03	4.84	1.23	0.08	3.48	2.18	2.04	2.5	2.20
Nitrite	mg/L	-	-	-	0.21	0.065	-	0.87	0.12	0.065	0.370	0.227
Nitrogen (Total Oxidised)	mg/L	-	-	0.03	4.95	1.315	0.08	3.6	2.38			
Oxides of Nitrogen	mg/L	-	-	NS	NS	NS	NS	NS	NS	2.29	2.57	2.48
Nitrogen (Total)	mg/L	0.5[4]	0.3[3]	-	6.4	2.8	1.3	14.1	4.7	3.25	3.78	3.48
Ammonia	mg/L	0.9	0.91	NS	NS	NS	NS	NS	NS	0.200	0.713	0.452
Enteroccoci	CFU / 100mL	-	-	NS	NS	NS	NS	NS	NS	4800	32000	4900
Chlorophyll a	mg/L	0.003	0.005	NS	NS	NS	NS	NS	NS	0.0019	0.0026	0.0020

[1] ANZECC (2000) *'freshwater'* default trigger values for 95 per cent level of species protection

[2] ANZECC (2000) *'marine'* default trigger values for 95 per cent level of species protection

[3] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[4] ANZECC (2000) *'lowland rivers'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[5] M4-M5 Link sampling conducted by AECOM between July 2016 and May 2017, based on 16 samples collected from SW3

[6] M4-M5 Link sampling conducted by AECOM between July 2016 and May 2017, based on 16 samples collected from SW4 and 9 samples collected from SW14

[7] The Bays precinct sampling conducted by Sydney University between June 2016 and September 2016, based on five samples collected from SW1

[8] Based on Arsenic (As V)

[9] Based on Chromium (Cr VI)

5.2 = Exceeds one or more relevant guideline criteria

NS = No sample collected

'-' = Sample collected but below detection limit

Table B-7 Easton Park drain surface water quality monitoring summary

Parameter	Units	Guideline Criteria ANZECC 2000 Marine[2]	M4M5 Easton Park drain Monitoring[5] –Tidal Min	Max	Med
Dissolved Oxygen (Field) (Filtered)	mg/L	-	1.94	11.35	8.215
Electrical Conductivity (Field)	µS/cm	-	29.7	30379	1633
pH (Field)		7 – 8.5[3]	5.87	10.06	7.44
Turbidity (Field)	NTU	0.5-10	-0.2	390.7	4.35
Arsenic	mg/L	-	<0.001	<0.01	0.00225
Cadmium	mg/L	0.0055	<0.0001	<0.001	0.0001
Chromium (III+VI)	mg/L	0.0044[6]	<0.001	<0.01	0.001
Copper	mg/L	0.0013	0.005	0.049	0.0135
Iron	mg/L	-	0.24	3.37	0.515
Lead	mg/L	0.0044	<0.001	0.164	0.01815
Manganese	mg/L	-	0.007	0.072	0.02705
Mercury	mg/L	0.0004	<0.00004	<0.0001	0.00005
Nickel	mg/L	0.07	0.001	0.013	0.00495
Zinc	mg/L	0.015	0.073	0.395	0.1905
Ferrous Iron	mg/L	-	<0.05	1.28	0.135
TRH C10 - C40 (Sum of Total)	mg/L	-	<100	150	50
C6 - C 9 Fraction	mg/L	-	<20	<20	10
C10 - C36 (Sum of Total)	mg/L	-	<50	110	25
Total BTEX	mg/L	-	<0.001	<0.001	0.0005
Phosphorus	mg/L	0.03[3]	<0.05	1.28	0.125
Reactive Phosphorus	mg/L	-	<0.01	0.23	0.045
Kjeldahl Nitrogen Total	mg/L	-	0.4	5.9	0.9
Nitrate	mg/L	0.7	0.29	2.92	1.57

Parameter	Units	Guideline Criteria	M4M5 Easton Park drain Monitoring[5] –Tidal		
		ANZECC 2000 Marine[2]	Min	Max	Med
Nitrite	mg/L	-	<0.01	0.11	0.025
Nitrogen (Total Oxidised)	mg/L	-	0.3	2.94	1.605
Nitrogen (Total)	mg/L	0.3[3]	0.8	6.3	2.7

Notes:

[1] ANZECC (2000) *'freshwater'* default trigger values for 95 per cent level of species protection.

[2] ANZECC (2000) *'marine'* default trigger values for 95 per cent level of species protection

[3] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[4] ANZECC (2000) *'lowland rivers'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[5] M4-M5 Link sampling conducted by AECOM between July 2016 and May 2017, based on 16 samples collected from SW7

[6] Based on Chromium (Cr VI)

5.2 = Exceeds one or more relevant guideline criteria

NS = No sample collected

'-' = Sample collected but below detection limit

Table B-8 Iron Cove surface water quality monitoring summary

Parameter		Guideline Criteria	M4M5 Iron Cove Monitoring[5] –Tidal		
	Units	ANZECC 2000 Marine[2]	Min	Max	Med
Dissolved Oxygen (Field) (Filtered)	mg/L	-	-1.22	9.71	6.66
Electrical Conductivity (Field)	µS/cm	-	465	52825	45057
pH (Field)		7 – 8.5[3]	6.56	8.29	7.96
Turbidity (Field)	NTU	0.5-10	-1.9	647	7.3
Arsenic	mg/L	-	0.0015	<0.01	0.005
Cadmium	mg/L	0.0055	<0.0001	<0.001	0.0005
Chromium (III+VI)	mg/L	0.0044[6]	<0.0005	0.013	0.005
Copper	mg/L	0.0013	0.003	0.022	0.005
Iron	mg/L	-	<0.1	5.43	0.395
Lead	mg/L	0.0044	0.0023	0.063	0.005
Manganese	mg/L	-	<0.01	0.068	0.0238
Mercury	mg/L	0.0004	<0.00004	0.0006	0.00005
Nickel	mg/L	0.07	0.0008	0.0502	0.005
Zinc	mg/L	0.015	0.015	0.306	0.026
Ferrous Iron	mg/L	-	<0.05	0.71	0.09
TRH C10 - C40 (Sum of Total)	mg/L	-	<100	<100	50
C6 - C 9 Fraction	mg/L	-	<20	<20	10
C10 - C36 (Sum of Total)	mg/L	-	<50	<50	25
Total BTEX	mg/L	-	<0.001	<0.001	0.0005
Phosphorus	mg/L	0.03[3]	0.03	0.77	0.025
Reactive Phosphorus	mg/L	-	<0.01	0.08	0.02
Kjeldahl Nitrogen Total	mg/L	-	0.4	<1	0.25
Nitrate	mg/L	0.7	<0.01	1.08	0.085

Parameter		Guideline Criteria	M4M5 Iron Cove Monitoring[5] –Tidal		
	Units	ANZECC 2000 Marine[2]	Min	Max	Med
Nitrite	mg/L	-	<0.01	0.02	0.005
Nitrogen (Total Oxidised)	mg/L	-	<0.01	1.1	0.085
Nitrogen (Total)	mg/L	0.3[3]	<0.5	1.5	0.25

Notes:

[1] ANZECC (2000) *'freshwater'* default trigger values for 95 per cent level of species protection

[2] ANZECC (2000) *'marine'* default trigger values for 95 per cent level of species protection

[3] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[4] ANZECC (2000) *'lowland rivers'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[5] M4-M5 Link sampling conducted by AECOM between November 2016 and May 2017, based on 10 samples collected from SW11 and 10 samples collected from SW12

[6] Based on Chromium (Cr VI)

5.2 = Exceeds one or more relevant guideline criteria

NS = No sample collected

'-' = Sample collected but below detection limit

Table B-9 Alexandra Canal and Sheas Creek surface water quality monitoring summary

Parameter		Guideline Criteria		New M5 Alexandra Canal Monitoring[5] –Tidal			M4M5 Sheas Creek Monitoring[6] –Tidal		
	Units	ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[2]	Min	Max	Med	Min	Max	Med
Dissolved Oxygen (Field) (Filtered)	mg/L	-	-	2.4	6.75	4.59	5.59	65.18	8.99
Electrical Conductivity (Field)	µS/cm	125 – 2000[4]	-	11483	44865	28091.5	111.2	4830	447
pH (Field)		6.5 – 8.0[4]	7 – 8.5[3]	7.27	7.97	7.46	5.78	9.79	7.78
Turbidity (Field)	NTU	6-50	0.5-10	0	256	6.3	4.6	46.5	10.25
Arsenic	mg/L	0.013[7]	-	0.001	0.003	0.005	<0.001	0.057	0.002
Cadmium	mg/L	0.002	0.0055	-	-	-	<0.0001	0.0014	0.00005
Chromium (III+VI)	mg/L	0.001[8]	0.0044[8]	-	-	-	<0.001	0.143	0.001
Copper	mg/L	0.0014	0.0013	0.003	0.054	0.005	0.008	0.493	0.015
Iron	mg/L	-	-	-	1.38	0.265	0.34	107	0.746
Lead	mg/L	0.0034	0.0044	0.001	0.03	0.005	<0.001	0.392	0.007
Manganese	mg/L	1.9	-	-	0.059	0.03	0.015	1.78	0.0447
Mercury	mg/L	0.0006	0.0004	-	-	-	<0.00004	<0.0001	0.00005
Nickel	mg/L	0.011	0.07	-	0.002	0.005	<0.001	0.277	0.00185
Zinc	mg/L	0.008	0.015	-	0.097	0.039	0.034	0.684	0.0715
Ferrous Iron	mg/L	-		-	0.26	0.055	<0.05	16.3	0.12
TRH C10 - C40 (Sum of Total)	mg/L	-	-	-	-	-	<100	100	50
C6 - C 10	mg/L	-	-	-	-	-	<20	<20	10
C10 - C36 (Sum of Total)	mg/L	-	-	NS	NS	NS	<50	<50	25
Total BTEX	mg/L	-	-	-	-	-	<0.001	<0.001	0.0005
Phosphorus	mg/L	0.05[4]	0.03[3]	0.04	0.19	0.065	<0.01	4.02	0.165
Reactive Phosphorus	mg/L	-	-	-	0.04	0.01	<0.01	0.57	0.055
Kjeldahl Nitrogen Total	mg/L	-	-	-	1.3	0.65	0.2	7.4	1.4
Nitrate	mg/L	0.7	-	0.08	4.69	0.25	0.33	3.17	2.06

Parameter		Guideline Criteria		New M5 Alexandra Canal Monitoring[5] –Tidal			M4M5 Sheas Creek Monitoring[6] –Tidal		
	Units	ANZECC 2000 Freshwater[1]	ANZECC 2000 Marine[2]	Min	Max	Med	Min	Max	Med
Nitrite	mg/L	-	-	0.01	0.03	0.02	0.03	0.2	0.085
Nitrogen (Total Oxidised)	mg/L	-	-	0.09	4.71	0.27	0.39	3.24	2.185
Nitrogen (Total)	mg/L	0.5[4]	0.3[3]	-	5.4	1.0	0.7	8.8	3.8

Notes:

[1] ANZECC (2000) *'freshwater'* default trigger values for 95 per cent level of species protection

[2] ANZECC (2000) *'marine'* default trigger values for 95 per cent level of species protection

[3] ANZECC (2000) *'estuaries'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[4] ANZECC (2000) *'lowland rivers'* default trigger values for physical and chemical stressors for south-east Australia for slightly disturbed ecosystems

[5] New M5 Link sampling conducted by AECOM between June 2015 and November 2015, based on eight samples collected from SW1

[6] M4-M5 Link sampling conducted by AECOM between July 2016 and May 2017, based on 16 samples collected from SW10

[7] Based on Arsenic (As V)

[8] Based on Chromium (Cr VI)

5.2 = Exceeds one or more relevant guideline criteria

NS = No sample collected

Annexure C Flood Model Development

This annexure details the hydrologic and hydraulic modelling undertaken to establish existing flood conditions and assess the potential flood risks associated with the project, as well as determining potential impacts on surrounding properties and appropriate mitigation requirements.

1. Rozelle interchange

1.1. Previous flood assessments

A number of previous flood assessment reports have been reviewed and used to inform the current investigation:

- Leichhardt Council, 2014, Leichhardt Flood Study (Cardno)
- Sydney Water, 1990, Whites Creek Catchment Management Study.

1.2. Approach

Based on the reported flooding mechanisms for the area originating from creeks and overland surface flows, the assessment approach has adopted a 1D-2D flood model using TUFLOW (Two-dimensional Unsteady Flow) software with direct rainfall on grid. This approach enables the identification of overland flow paths and accounts for floodplain storage within the 2D model.

1.3. Model extent

The extent of the model was influenced by the catchment extents to the north and west of the Rozelle Rail Yard site, as well as allowing for a sufficient length of the Whites Creek watercourse and catchment area.

1.4. Hydrology

Due to the nature of the study area, the hydrologic approach included a combination of deriving hydrographs for inflows to Whites Creek using a rainfall-runoff model, and applying the direct rainfall method to the remainder of the area defined in the TUFLOW hydraulic model.

Direct rainfall

Design rainfalls

Design rainfall hyetographs (graphical representation of the distribution of rainfall over time) were derived for the 5, 10, 20 and 100 year ARI storm events in accordance with Australian Rainfall and Runoff (AR&R) 1987. Design Intensity-Frequency-Duration (IFD) data were obtained for the catchment using the BoM website. An Areal Reduction Factor of one was applied due to the small size of the catchment and temporal patterns for Zone 1 were obtained from AR&R. Storm durations of between 15 minutes and two hours were assessed.

Probable Maximum Precipitation

The Probable Maximum Precipitation (PMP) was calculated using The Estimation of Probable Precipitation in Australia: Generalised Short Duration Method (BoM 2003). PMP rainfall was derived from depth-duration-area envelope curves, application of rough/ smooth factors, elevation adjustment factors and a moisture adjustment factor. The design temporal and spatial distribution was then applied to produce a hyetograph.

Rainfall losses

Rainfall losses were applied within the materials file of the TUFLOW model. An initial loss of 10 millimetres and continuing loss of 2.5 millimetres per hour were applied on permeable areas, in line with AR&R recommendations and values adopted in the *Leichhardt Flood Study* (Cardno 2014). An initial loss of 1.5 millimetres was used for impermeable areas.

Whites Creek hydrograph

In order to establish hydrographs for Whites Creek, a hydrologic model of the catchment was established using the WBNM software. The software is appropriate for use in urban catchments and was also adopted in the hydrologic assessment of the M4 East Design.

Flows were derived for Whites Creek for the five, 10, 20 and 100 year ARI design events as well as the PMF using the following process:

- The catchment and sub-catchments of Whites Creek were determined based on LiDAR, aerial photography and information available on the stormwater drainage systems. This catchment was then compared with the catchment areas delineated in the *Leichhardt Flood Study* (Cardno 2014)
- Percentage imperviousness was identified for each sub-catchment based on latest aerial photography
- A catchment lag parameter of 1.6 was used in accordance with the WBNM guidelines
- Stream lag coefficient of 0.4 was used due to the flow paths being a combination of concrete lined channels and overland flow paths
- An initial rainfall loss of 10 millimetres and continuing loss of 2.5 millimetres per hour were applied for permeable areas. A loss of 1.5 millimetres was applied for impermeable areas. No rainfall losses were included for the PMF event
- Inclusion of IFD parameters.

Hydrology validation

The rainfall and hydrograph boundaries were validated against the inputs and results extracted from the 2014 SOBEK model.

SOBEK model peak flows extracted from the same locations as the TUFLOW model inflows were found to be reasonably well aligned with those generated in WBNM. Differences of between two per cent and 10 per cent were found for the five, 10, 20 and 100 year ARI design events. The WBNM flows for the PMF were 14 per cent higher than those extracted from the SOBEK model. As the estimated peak flows are within 10 per cent to 15 per cent of those from the Leichhardt Flood Study, the hydrologic model parameters adopted for this investigation are considered acceptable. A comparison of the peak flows is provided in **Table C-1**.

Table C-1 Comparison of peak flows for Whites Creek (cubic metres per second)

Source	Event				
	5 year ARI 120 minutes	10 year ARI 120 minutes	20 year ARI 120 minutes	100 year ARI 60 minutes	PMF 30 minutes
Cardno SOBEK	28.2	32.1	39.3	58.3	186.0
WBNM	30.0	35.3	42.3	56.9	211.7

The hyetographs calculated for the application of direct rainfall to the TUFLOW model were also compared to the rainfall inputs from the SOBEK model. Based on the comparison of total rainfalls provided in **Table C-2** it is evident that the rainfall inputs in the Rozelle interchange flood study were marginally higher for the ARI design events. This is most likely a consequence of using slightly different IFD parameters from the BoM. The rainfall adopted for the current investigation is considered to be appropriate for use.

Table C-2 Comparison of total rainfall depths (millimetres)

Source	Event				
	5 year ARI 120 **minutes**	10 year ARI 120 **minutes**	20 year ARI 120 **minutes**	100 year ARI 60 **minutes**	PMF 30 **minutes**
Cardno SOBEK	60	70	83	94	240
TUFLOW Hyetographs	68	78	91	95	240

1.5. Hydraulics

Topography

The model grid was constructed based on LiDAR data, with some manipulation of topography based on site observations.

Pit and pipe network

The 1D component of the model incorporated some of the stormwater drainage network. These systems were embedded into the 2D domain enabling water to exchange between above ground and below ground flow paths. As the potential impacts of the project were being assessed against relatively large events (100 year ARI), only some of the pit and pipe network were included in the model (generally greater than 375 millimetre diameter). Various assumptions regarding pipe invert level and pit size were necessary due to the limited availability of data. This approach was considered sufficient for the inputs required as part of this assessment but will need to be improved (through survey) as part of the detailed design stage.

Boundary conditions

A rainfall boundary was applied to the entire model domain and a boundary was included at the top of Whites Creek to represent the inflow hydrographs.

A downstream boundary of one metre AHD was set for Rozelle Bay and corresponding initial water levels were applied to channels and the pipe network where appropriate. A level of 1 metre AHD was used as this is equivalent to the High High Water Solstices Springs (HHWSS) peak tide level. This is consistent with the levels adopted in the modelling for the *Leichhardt Flood Study* (Cardno 2014) and the modelling undertaken to inform the design of the M4 East.

As a direct rainfall approach had been used, boundaries were applied to the edge of the model domain to prevent 'glass-walling' whereby water ponds against the edges of the model.

Roughness

The roughness for the model has been defined using Manning's 'n' values as shown in **Table C-3**.

Table C-3 Manning's Roughness Values used in the TUFLOW Model

Surface	Manning's value
Roads	0.02
Well maintained grass	0.03
Reserves	0.045
Trees	0.08
Scrub	0.05
Fields	0.035
Buildings	10
Channel	0.02
Water (Harbour)	0.03

Development

Directly adjacent to the western side of the Rozelle Rail Yards, a new depot is being constructed for the CBD and South East Light Rail on behalf of Transport for NSW. This includes a Light Rail maintenance facility, with associated tracks and offices. The design for the site and drainage was not available to inform this Rozelle interchange model.

It is recommended that during the detailed design of the Rozelle interchange, the drainage design for the CBD and South East Light Rail Rozelle maintenance depot is obtained to understand the interfaces between the two sites and refine the mitigation measures as appropriate.

Hydraulic model validation

There are no known stage or flow gauges present on Whites Creek and it was therefore not possible to undertake a rigorous calibration of the hydraulic model. Calibration is the benchmarking of the model outputs against previous flood events with known flows or water levels.

The TUFLOW model was validated against the SOBEK model established for the *Leichhardt Flood Study*. The SOBEK model was also not calibrated, however it was validated against model results from the Sydney Water investigation (1990) as well as against data from some historical flood events.

Peak design flood levels from the TUFLOW hydraulic model representing the existing conditions have been compared to the results from the Cardno SOBEK model at key locations along Whites Creek as well as the Sydney Water model results (see **Figure C-1**). A summary comparison of 100 year ARI peak design flood levels is shown in **Table C-4**. Flood levels are generally slightly higher than the Cardno model, by about 0.25 metres, but are lower than the Sydney Water model results.

Table C-4 Comparison of Peak Flood Levels (metres AHD) along Whites Creek for 100 year ARI event

Location	Cardno SOBEK levels	Sydney Water levels	TUFLOW levels	Difference to Cardno (m)	Difference to Sydney Water (m)
P1	3.63	4.13	3.74	+0.11	-0.39
P2	3.70	4.13	3.72	+0.02	-0.41
P3	3.20	3.88	3.42	+0.22	-0.46
P4	3.12	3.58	3.38	+0.26	-0.20
P5	3.08	3.56	3.33	+0.25	-0.23
P6	1.63	1.63	2.84	+1.21	+1.21

Figure C-1 Location of comparison points as listed in Table C-4

In general the 100 year ARI peak flood levels from the TUFLOW model were comparable with those reported in the Leichhardt Flood Study along Whites Creek. Levels in the TUFLOW model were higher at the downstream extent of Whites Creek between the railway culvert and the culvert under The Crescent. However, investigations into the representation of the structures within the SOBEK model found that the railway culvert was undersized. This may explain the difference in water levels at this location.

A comparison of inundation depths within the Rozelle Rail Yards for the 100 year ARI event found that the TUFLOW levels were generally within 0.1 metres of those from the SOBEK model. These variations are within normal acceptable ranges and the parameters adopted in the established TUFLOW hydraulic model are therefore considered appropriate.

1.6. Sensitivity

As there is limited data for calibration a model sensitivity analysis was also carried out by increasing the roughness values applied in the model by 20 per cent as summarised in **Table C-3**. The results of that sensitivity analysis have shown that flood levels would only increase by up to 0.03 metres if roughness values were higher by up to 20 per cent. The model is therefore not considered to be very sensitive to model roughness values.

1.7. Post-development models

The following adjustments were made to the Rozelle interchange TUFLOW Model in order to assess the impact the operational phase would have on flooding behaviour and to also assess the flood risks to the project:

- The 3D concept design surface model for the Rozelle interchange was merged with the available LiDAR survey data

- The new channel and associated overland flow path for the Easton Park drain, western and eastern catchments to collect and direct water within and out of the interchange were incorporated into the 3D concept design surface. A typical cross-section for the proposed channels is shown in **Figure C-2**.
- Flood bunds around the dive structures to protect the portals from floodwater ingress from the PMF within the interchange area
- Inclusion of culverts under City West Link for the channel to discharge into Rozelle Bay. This includes 'low-flow' culverts (4 no. 1.05 metre diameter circular pipes) and culverts for high flows (10 no. 2.4 x 1.2 metres box culverts)
- New bridge structure over Whites Creek to represent the larger road junction at City West Link and The Crescent. To mitigate impacts of the larger structure on water levels in Whites Creek for the larger flow events, the new structure includes two 16 metre spans, one includes the existing Whites Creek channel (approximately nine metres wide). The second opening will provide an overland flow path for floodwater that has either spilled out of Whites Creek or unable to get into the channel as it is at capacity. The topography of land between the existing light rail bridge over Whites Creek and where it discharges into Rozelle Bay has been re-profiled to enable water to spill out of Whites Creek and flow overland and into Rozelle Bay in a controlled manner
- Amendments to the Manning's values to reflect different surfaces.

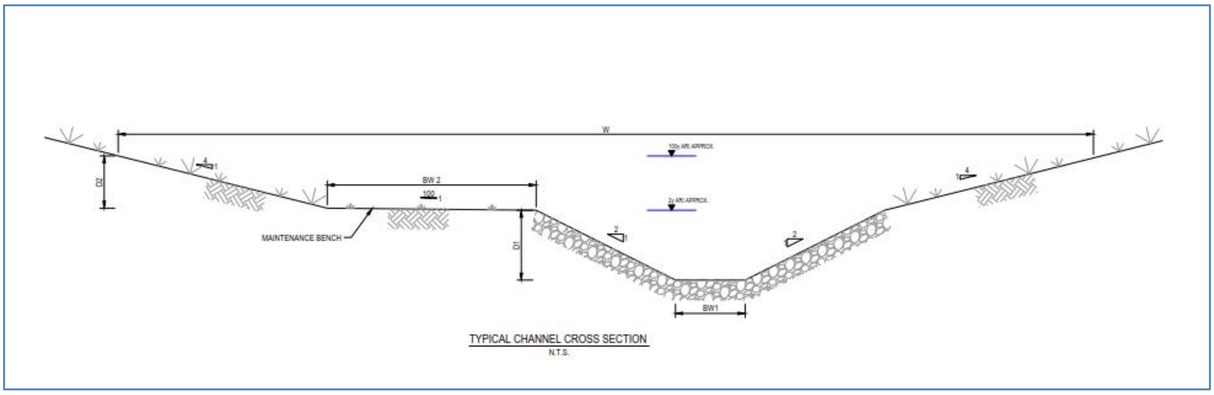


Figure C-2 Typical channel cross section

1.8. Consideration of blockage of waterway structures

The effect of blockage of waterway structures was also considered. *AR&R Project 11 - Blockage of Hydraulic Structures* (Engineers Australia, 2015) provides recommendations for the assessment of waterway blockage due to floating debris. Based on those recommendations, considering the size of the new waterway structures compared to the size of the channel as well as the size and availability of potential floating debris, appropriate blockage factors have been applied to the proposed waterway structures. See **Table C-5** for percentage blockage applied.

Table C-5 Summary of assumed blockage applied to waterway structures

Structure	Comment	Assumed blockage for 100 year ARI	Assumed blockage for PMF
The Crescent bridge at Whites Creek	New twin 16 metre span bridge	10%	20%
Culvert at City West Link	New four x 1.05 metre diameter pipes and 10 x 2.4 x 1.2 metre box culverts	20%	50%
Tunnel portal bridge	New 31 metre single span	10%	20%

Considering the waterway area of two new bridges and the size and availability of floating debris an assumed blockage of 20 per cent has been applied to both new bridges for the 100 year ARI event.

For the PMF a higher blockage was assumed as the potential for blockage during the PMF is considered higher than during more frequent events.

The results of the blockage assessment as summarised in **Table C-6** show that there would only be a minor increase in flood levels of up to 0.2 metres as a result of blockage of the new waterway structures. Blockage of between 10 and 20 per cent would reduce the freeboard at the bridges but would not cause floodwaters to overtop onto City West Link or The Crescent.

In a PMF event the greater potential for blockage at the culverts under the City West Link of up to 50 per cent could lead to an increase in peak flood levels of up to 0.4 metres to the north of City West Link. This increase in peak flood levels would not lead to overtopping of City West Link in the PMF. At The Crescent the increase in peak flood levels would be up to 0.18 metres with a 20 per cent blockage of the new bridge structure in the PMF.

Table C-6 Summary of results for waterway blockage assessment (metres AHD)

Structure	No blockage		With blockage			
	100 year ARI	PMF	100 year ARI	Difference (m)	PMF	Difference (m)
The Crescent bridge at Whites Creek	2.75	5.07	2.82	+0.08	5.25	+0.18
Culvert at City West Link	2.09	3.33	2.26	+0.17	3.73	+0.40
Western channel upstream of tunnel portal bridge	2.33	3.61	2.41	+0.08	3.86	+0.25

2. Iron Cove Link

2.1 Previous flood assessments

The following previous flood assessment reports have been reviewed and used to inform the current investigation:

- Leichhardt Council, 2014, *Leichhardt Flood Study*.

2.2 Approach

Based on the reported flooding mechanisms for the area and associated overland flow, the assessment approach has adopted a 1D-2D flood model using TUFLOW software with direct rainfall on grid. This approach enables the identification of overland flow paths within the 2D model.

2.3 Model Extent

The extent of the model was influenced by the catchment extents to the east of Victoria Road at Iron Cove.

2.4 Hydrology

Due to the nature of the study area, the hydrologic approach included applying the direct rainfall method to the catchment defined in the TUFLOW hydraulic model. The same hydrological inputs used for the Rozelle interchange were used for the Iron Cove Link model.

2.5 Hydraulics

Topography

The model grid was constructed based on LiDAR data, with some manipulation of topography based on site observations. For example, the traffic barrier was included on Victoria Road.

Pit and pipe network

The 1D component of the model incorporated some of the stormwater drainage network in the catchment of Iron Cove Link. These systems were embedded into the 2D domain enabling water to exchange between above ground and below ground flow paths. Information on the diameter and invert levels of the drainage network were extracted from the Dial Before You Dig dataset and the Cardno model.

Boundary Conditions

A rainfall boundary was applied to the entire model domain. As a direct rainfall approach had been used, boundaries were applied to the edge of the model domain to prevent ‘glass-walling’ whereby water ponds against the edges of the model.

A review of the topographic levels of the area of interest established that the model did not need to include Iron Cove as a downstream boundary condition. The elevations were significantly above the extreme peak storm tide level plus 0.9 metres for climate change allowance (2.8 metres AHD) and so would not be inundated or flood behaviour influenced under such conditions.

Roughness

The roughness for the model has been defined using Manning’s ‘n’ values as per those used in the Rozelle interchange model (see **Table C-3**).

Hydraulic Model Validation

As there are no watercourses present or historical data available it is not possible to undertake rigorous calibration of the hydraulic model.

The TUFLOW model was validated against the SOBEK model established for the *Leichhardt Flood Study*. The SOBEK model was also not calibrated for this area.

Peak design flood levels from the TUFLOW hydraulic model representing the existing conditions have been compared to the results from the Cardno SOBEK model at key locations near the Iron Cove Link (see **Figure C-3**). A summary comparison of 100 year ARI peak design flood levels is shown in **Table C-7**.

The peak water depths generated by the TUFLOW model were generally within 0.05 metres of those from the SOBEK model. These variations are within normal acceptable ranges and the parameters adopted in the established TUFLOW hydraulic model are therefore considered appropriate**.**

Table C-7 Comparison of peak flood depths (metre) around the proposed Iron Cove Link (100 year ARI event)

Location	Cardno SOBEK depths (m)	TUFLOW depths (m)	Difference (m)
P2	0.14	0.11	-0.03
P4	0.02	0.01	-0.01
P5	0.12	0.11	-0.01
P6	0.11	0.15	+0.04
P8	0.08	0.06	-0.02
P23	0.02	0.02	0.00
P25	0.04	0.02	-0.02
P34	0.03	0.06	+0.03
P37	0.03	0.02	+0.02

Figure C-3 Location of comparison points for Iron Cove Link model as listed in Table C-7.

2.6 Sensitivity

A sensitivity analysis was also carried out by increasing the roughness values applied in the model (as summarised in **Table C-3**) by 20 per cent. The results of that sensitivity analysis have shown that flood levels in and around Iron Cove Link increased by up to 0.03 metres. The model is therefore not considered to be sensitive to the assumptions made regarding model roughness.

2.7 Post-development models

The following adjustments were made to the Iron Cove Link TUFLOW model in order to assess the impact the operational phase would have on flood behaviour and to also assess the flood risks to the project:

- The 3D concept design surface model for Iron Cove Link was merged with the available LiDAR survey data
- Flood bunds around the dive structures to protect the portals from floodwater ingress
- Re-alignment of the stormwater drainage network to reflect the widening of Victoria Road to the south
- Changes to the extent of the traffic barrier on Victoria Road
- Amendments to the Manning's roughness values to reflect different surfaces.

2.8 Consideration of blockage of waterway structures

No assessment of blockage of structures was undertaken as there are no new proposed waterway structures in proximity to the Iron Cove Link.

3. Darley Road

3.1 Previous flood assessments

The following previous flood assessment reports have been reviewed and used to inform the current investigation:

- Ashfield and Marrickville Councils, 2013, Hawthorne Canal Flood Study, Final Draft (WMAwater)
- Leichhardt Council, 2014, Leichhardt Flood Study.

3.2 Approach

Based on the reported flooding mechanisms for the area and associated overland flows, the assessment approach has adopted a 1D-2D flood model using TUFLOW software with direct rainfall on grid. This approach enables the identification of overland flow paths within the 2D model.

3.3 Model extent

The extent of the model was influenced by the catchment extents to the east of the Darley Road civil and tunnel site.

3.4 Hydrology

Due to the nature of the study area, the hydrologic approach included applying the direct rainfall method to the catchment defined in the TUFLOW hydraulic model. The same hydrological inputs used for the Rozelle interchange were used for the Darley Road model.

3.5 Hydraulics

Topography

The model grid was constructed based on LiDAR data, with some manipulation of topography based on site observations.

Pit and pipe network

The 1D component of the model incorporated some of the stormwater drainage network. These systems were embedded into the 2D domain enabling water to exchange between above ground and below ground flow paths. Information on the diameter and invert levels of the drainage network was extracted from the Cardno flood model, which was based on a combination of Sydney Water asset information and survey.

Boundary conditions

A rainfall boundary was applied to the entire model domain. As a direct rainfall approach had been used, boundaries were applied to the edge of the model domain to prevent ‘glass-walling’ whereby water ponds against the edges of the model.

Roughness

The roughness for the model has been defined using Manning’s ‘n’ values as per those used in the Rozelle interchange model (see **Table C-3**).

Hydraulic model validation

As there are no watercourses present it is not possible to undertake rigorous calibration of the hydraulic model.

The TUFLOW model was verified against the SOBEK model established for the *Leichhardt Flood Study* (Cardno 2014). The SOBEK model was also not calibrated for this area.

Peak design flood levels from the TUFLOW hydraulic model representing the existing conditions have been compared to the results from the SOBEK model at key locations near the Darley Road site (see **Figure C-4**). A summary comparison of 100 year ARI peak design flood levels is shown in **Table C-8**.

Table C-8 Comparison of peak flood depths (m) near the Darley Road site (100 year ARI event

Location	Cardno SOBEK depths (m)	TUFLOW depths (m)	Difference (m)
1	0.09	0.07	-0.02
2	0.56	0.54	+0.02
3	0.24	0.29	+0.05
4	0.24	0.25	+0.01
5	0.97	0.94	-0.03
6	0.98	0.92	-0.06
7	0.11	0.09	-0.02
8	0.70	0.76	+0.06
9	0.18	0.13	-0.05
10	0.15	0.08	-0.07

Figure C-4 Location of comparison points for Darley Road model as listed in Table C-8

A comparison of inundation depths within the vicinity of the Darley Road site for the 100 year ARI event found that the TUFLOW levels were generally within 0.1 metres of those from the SOBEK model. These variations are within normal acceptable ranges and the parameters adopted in the established TUFLOW hydraulic model are therefore considered appropriate.

3.6 Sensitivity

Sensitivity analysis was also carried out by increasing the roughness values applied in the model by 20 per cent, as summarised in **Table C-3**. The results of that sensitivity analysis have shown that flood levels in and around Darley Road increased by up to 0.03 metres. The model is therefore not considered to be sensitive to the assumptions made regarding model roughness.

3.7 Post-development models

The following adjustments were made to the Darley Road TUFLOW Model in order to assess the impact the operational phase would have on flood behaviour and to also assess the flood risks to the project.

Flood bunds were included around the perimeter of the site, excluding the car park area to the west. This was considered a conservative assessment of the potential impact that protecting the portals from floodwater ingress from the PMF could have on surrounding properties.

Annexure D Step by Step Flood Risk Assessment

Table D-1 Flood risk assessment for construction and operational sites

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
	Is there an existing flood risk assessment available to inform the assessment on existing flood conditions?	Is the existing flood risk assessment at an appropriate level of detail to determine existing flood conditions?	Does the existing assessment show the area of interest being partially or fully at risk of flooding for events up the probable maximum flood?	Identify the mechanisms and characteristics of flooding (source, frequency, depths, velocity).	Determine whether flood risk is: · To the project – ie risk of infrastructure being flooded · Likely to be influenced by the project, having a detrimental impact on flood risk to sensitive receivers (surrounding properties)	For sites that are partially flooded, can sufficient easement from areas at risk of flooding be provided in the site layout and topographic changes avoided, so that development is not impacted by and does not impact on flood risk?
Construction						
C1a Wattle Street civil and tunnel site, C2a Haberfield civil and tunnel site, C3a Northcote Street civil site, C2b Haberfield civil site (part of M4 East project footprint)	M4 East EIS report and flood model (2015)	Yes - EIS approved. Assessed flooding for 5, 20, 100, 200 year ARI and PMF.	No - the post-development scenario was not shown to be affected by the PMF. Low risk from Iron Cove Creek and overland flow.	N/A	N/A	N/A
	M4 East Design (2016 draft)	Yes - refinement of EIS model to inform design.	No - proposed M4 East provides mitigation measures to manage risk at Wattle Street interchange portals for PMF. Low risk from Iron Cove Creek and overland			

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
			flow.			
C1b Parramatta Road West civil and tunnel site, C3b Parramatta Road East civil site	Dobroyd Canal Flood Study (WMAwater 2013)	Yes - Council approved flood study. Assessed 2, 5, 10, 20, 50, 100 year ARI and PMF.	No, the sites are notaffected by mainstream or overland flows in events up to the 100 year ARI and only sits on the fringe of the PMF. Low risk of flooding of the sites in the PMF.			
C4 Darley Road civil and tunnel site	Leichhardt Council Flood Study and flood model (Cardno 2014)	Yes - Council approved flood study. Assessed 5, 100 year ARI and PMF.	Yes -partially flooded in 100 year ARI event and PMF.	· Sources of flooding appear to be ponded water to the west of the site (junction of Darley Road and Canal Road/ Charles Street). · Floodwater seems to be spilling from Light Rail immediately north of the site, onto the western side of the site. · Ponded water from rain falling on the site. Water depths up to approximately one metre and flows of two metre per second	Flood risk posed to the western side of the site and localised ponding on the eastern side.	· The western edge of the site identified for car park use with the portals located on the eastern side of the site on higher ground away from floodwater. Flooding of the car park area is considered acceptable. The use of fencing to permit floodwater to pass onto the western side of the site, combined with minimal changes to topography, means that the development is not likely to have a significant impact in terms of displacing water. · The portals will need to be protected from water ingress from the PMF. This may include use of walls or bunds in small area of the eastern section of site and
	Hawthorne Canal Flood Study and flood	Yes - Council approved flood study. Assessed	Yes - partially flooded in 100 year ARI event and PMF.	· Source of flooding appears to be from ponded water as a	Flood risk posed to the western side of the site.	

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
	model for Ashfield and Marrickville Council (WMAwater, 2013)	flooding for 2, 5, 10, 20, 50, 100 year ARIs and the PMF.		consequence of overland flow. Localised flooding in southwest section of the site in 100 year ARI event (up to 0.4 metre), velocities <0.2 metres per second. · PMF shows depths of up to 1.2 metres on the western side of the site. Velocity generally <0.2 metres per second but >0.5 metres per second at edge of site.		re-profiling of topography (eg installation of a speed hump) at the entrance to the portal. · The infrastructure that has the potential to displace water (acoustic sheds, buildings) has been located on the eastern side of the site to minimise impacts. The existing site includes a large warehouse building. The majority of the proposed buildings are located within the footprint of the existing building.
C5 Rozelle civil and tunnel site	Leichhardt Council Flood Study and flood model (Cardno 2014)	Yes - Council approved flood study. Assessed 5, 100 year ARI and PMF.	Yes - significant flooding in the 100 year ARI event and PMF.	· The site is subject to overland flow inputs from catchments to the west and north. · Easton Park drain runs through an open section of channel in the northern section of the site before being culverted and discharging into Rozelle Bay. · Flooding from Easton Park drain may occur if the	· There is a risk posed to site infrastructure, with risk of flooding to the portals and other sensitive infrastructure. · Due to extensive flooding at the site during the 100 year ARI and PMF, there is potential for buildings and stockpiles to displace floodwater and impact on existing flood behaviour.	· The indicative site layout has taken into consideration flood risk and the requirements for the conveyance of flood water through the site, with an allowance for the permanent drainage arrangement that will be constructed. · Opportunities to locate portals and flood sensitive infrastructure outside of the 100 year ARI extent has been achieved for some of the facilities. · Where setback from flooded

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
				capacity of the channel is exceeded or the culvert surcharged. · During PMF events, water from Whites Creek spills over The Crescent road across City West Link and can flow onto the Rozelle Rail Yards. · Water depths of approximately <1 metre for 100 year ARI and >1 metre for the PMF.		areas was not possible, bunding would be used to protect tunnel ramps and vulnerable infrastructure to prevent floodwater ingress. Alternatively raising floor levels above expected flood levels would be considered. · The potential location of acoustic sheds and stockpile areas have been located as close to the southern boundary as possible, where ground levels are higher. This is to minimise potential impacts on the displacement of water. · The construction of the permanent conveyance system would occur as early as possible during the construction phase to enable flood risk to the project to be managed and to mitigate impacts to surrounding properties. Temporary drainage measures will be required whilst installing the permanent arrangement.
C6 The Crescent civil site	Leichhardt Council Flood Study and flood model (Cardno	Yes - Council approved flood study. Assessed 5, 100 year ARI	Yes – the site in events greater than the 100 year ARI	The site is subject to overland flow inputs from The Crescent and breakouts from Whites	There is a low flood risk to the site from local overland flows.	The site layout will consider that local overland flow ill need to be safely conveyed around the laydown areas.

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
	2014)	and PMF		Creek in the PMF.		
C7 Victoria Road civil site	Leichhardt Council Flood Study and flood model (Cardno 2014)	Yes - Council approved flood study. Assessed 5, 100 year ARI and PMF.	No - mapping suggests no flooding for 100 year and PMF. Low risk of flooding from overland flow sources.	N/A	N/A	N/A
C8 Iron Cove civil site	Leichhardt Council Flood Study and flood model (Cardno 2014)	Yes - Council approved flood study. Assessed 5, 100 year ARI and PMF.	Yes - potential inundation for sections of the sites between Toelle St and Springside in 100 year ARI and PMF.	· The site is subject to runoff from the north and east, from Victoria Road, Wellington Road, Crystal Lane and Terry Street. · Floodwater depths of up to 0.4 metres on Victoria Road north carriageway with peak velocities of 2-3 metres per second for the PMF.	Flood risk posed to the proposed portals and potential for displacement of water due to changes to the road geometry and levels.	· Iron Cove Link is fairly constrained spatially as it has to connect to the existing Victoria Road, so this restricts location of the portals. · Bunding of ramps to prevent floodwater ingress to the tunnel dive structures · Temporary drainage works would be implemented to minimise impacts to existing development as far as practicable by collecting and managing runoff on Victoria Road.
C9 Pyrmont Bridge Road tunnel site	Johnstons Creek Flood Study, City of Sydney (WMAwater 2013)	Yes - Council approved flood study. Assessed 5, 10, 20, 50, 100 year ARI and PMF.	Yes - potential inundation along Bignell Lane in 100 year ARI and PMF.	· Current high density building development concentrates all flows onto Bignell Lane, which acts as the only flowpath for overland flow. • Flood depths	· There is some risk posed to site infrastructure, with risk of flooding to the portals and other sensitive infrastructure (substation, offices), however the site is	· The indicative site layout has taken into consideration risk of flooding on Bignell Lane, which functions as a preferential flowpath through the site. Vulnerable uses, such as the tunnel dive structure is located away from the flooding at the

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
				generally only 0.1 to 0.2 metres. Ponding at the low point up to 1 metres for the 100 year ARI and PMF on Bignell Road	located towards the top of the catchment and flow rates are therefore not substantial. · The construction site would also demolish the existing buildings and replace with facilities of a smaller footprint, which would allow for less concentrated overland flows paths and would also reduce the potential to displace water and impact surrounding properties.	topographic low point on Bignell Lane. · Use of flood bunds or ramps to prevent ingress into the tunnel portals. · The existing flow path on Bignell Lane would be retained by the installation of breaks or flaps in fencing or site hoarding, to allow the overland flow path into and out of site. The overland flow path would be managed and directed along existing and proposed roads, using kerblines to try to retain flows within road areas and car parks. · The acoustic shed and offices have been located within the footprints of the existing buildings · Installation of noise walls or other flood protection barriers around the perimeter of the site to prevent ingress of flood water from Parramatta Road to the south and Mallett Street to the east.
	Leichhardt Council Flood Study and flood model (Cardno 2014)	Yes - Council approved flood study. Assessed 5, 100 year ARI and PMF.	Yes - potential inundation along Bignell Lane in 100 year ARI and PMF.	· Current high density building development concentrates all flows onto Bignell Lane, which acts as the only flowpath for overland flow. · Flood depths generally only 0.1 to 0.2 metres. Ponding up to one metre for the 100 year ARI on Bignell Road and peak velocity of approximately two metres per second.		
C10 Campbell Road civil and tunnel site (part of New M5 project	New M5 EIS and flood model (2015)	Yes - EIS approved. Assessed flooding for	No - the post-development scenario was not shown to be affected	N/A	N/A	N/A

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
footprint).		(20,100, 200 year ARI and PMF.	by the PMF. Low risk from overland flow .			
	M4 East Design (2016 draft)	Yes - refinement of EIS model to inform design.	No - New M5 provides mitigation measures to manage risk at St Peters interchange portals for the PMF. Low risk from overland flow .			
Operation						
Wattle Street (M4 East interface)	M4 East EIS report and flood model (2015)	Yes - EIS approved. Assessed flooding for 5, 20, 100, 200 year ARI and PMF.	No - the post-development scenario was not shown to be affected by the PMF. Low risk from Iron Cove Creek and overland flow .	N/A - operational site only includes sub-surface infrastructure	N/A	N/A
	M4 East Design (2016 draft)	Yes - refinement of EIS model to inform design.	No - M4 East provides mitigation measures to manage risk at Wattle Street interchange portals for PMF. Low risk from Iron Cove Creek and overland flow .			
Darley Road	Leichhardt	Yes - Council	Yes -partially	· Sources of flooding	Flood risk posed to the	· The western edge of the

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
	Council Flood Study and flood model (Cardno 2014)	approved flood study. Assessed 5, 100 year ARI and PMF.	flooded in 100 year ARI event and PMF.	appear to be ponded water to the west of the site (junction of Darley Road and Canal Road/ Charles Street). · Floodwater seems to be spilling from the light rail immediately north of the site, onto the western side of the site. · Ponded water from rain falling on the site. Water depths up to approximately one metre and flows of two metres per second.	western side of the site and localised ponding on the eastern side.	site identified for car park use with the portals located on the eastern side of the site on higher ground away from floodwater. Flooding of the car park area is considered acceptable. The use of fencing to permit floodwater to pass onto the western side of the site, combined with minimal changes to topography, means that the development is not likely to have a significant impact in terms of displacing water. · The portals will need to be protected from water ingress from the PMF. This may include use of walls or bunds in small area of the eastern section of site and re-profiling of topography (for example, installation of a speed hump) at the entrance to the portal. · The infrastructure that has the potential to displace water (acoustic sheds, buildings) has been located on the eastern side of the site to minimise impacts. The existing site includes a large warehouse building. The majority of the
	Hawthorne Canal Flood Study and flood model for Ashfield and Marrickville Council (WMAwater, 2013)	Yes - Council approved flood study. Assessed flooding for 2, 5, 10, 20, 50, 100 year ARIs and the PMF.	Yes - partially flooded in 100 year ARI event and PMF.	· • Source of flooding appears to be from ponded water as a consequence of overland flow. Localised flooding in southwest section of the site in 100 year ARI event (up to 0.4 metres), velocities <0.2 metres per second. · PMF shows depths of up to 1.2 metres on the western side of the site. Velocity	Flood risk posed to the western side of the site.	

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
				generally <0.2 metres per second but >0.5 metres per second at edge of site.		proposed buildings are located within the footprint of the existing building.
Rozelle interchange	Leichhardt Council Flood Study and flood model (Cardno 2014)	Yes - Council approved flood study. Assessed 5, 100 year ARI and PMF.	Yes - significant flooding in the 100 year ARI event and PMF.	· The site is subject to overland flow inputs from catchments to the west and north. · Easton Park drain runs through an open section of channel in the northern section of the site before being culverted and discharging into Rozelle Bay. · Flooding from Easton Park drain may occur if the capacity of the channel is exceeded or the culvert surcharged. · During PMF events, water from Whites Creek spills over The Crescent road across City West Link and can flow onto the Rozelle Rail Yards. · Water depths of	· There is a risk posed to site infrastructure, with risk of flooding to the portals and other sensitive infrastructure (ventilation facilities, substations). · Due to extensive flooding at the site during the 100year ARI and PMF, there is potential for permanent facilities to displace floodwater and impact on existing flood behaviour.	· The need for providing conveyance of floodwater through the site has significantly influenced the layout and design of the site. · The proposed site layout includes channels to carry the 2 year ARI flows and associated overland flowpaths to convey the 100 year ARI event. · Opportunities to locate portals and flood sensitive infrastructure (ventilation facilities and substations) outside of the 100 year ARI extent has been achieved for some of the facilities. · Where setback from flooded areas was not possible, bunding would be used to protect tunnel ramps and vulnerable infrastructure to prevent floodwater ingress. Alternatively raising floor levels above expected flood levels can be considered. · Road levels on City West

	Step 1 Existing Information		Step 2 Flood risk	Step 3 Flooding characteristics	Step 4 Flood risk to the project and potential impacts	Step 5 Proposed layout
				approximately <one metre for 100 year ARI and >one metre for the PMF.		Link have been raised to provide flood immunity to the Western Harbour Tunnel ramps.
Iron Cove Link	Leichhardt Council Flood Study and flood model (Cardno 2014)	Yes - Council approved flood study. Assessed 5, 100 year ARI and PMF.	Yes - potential inundation for sections of the sites between Toelle St and Springside in 100 year ARI and PMF.	· The site is subject to runoff from the north and east, from Victoria Road, Wellington Road, Crystal Lane and Terry Street. · Floodwater depths of up to 0.4 metres on Victoria Road north carriageway with peak velocities of 2-3 metres per second for the PMF.	Flood risk posed to the proposed portals and potential for displacement of water due to changes to the road geometry and levels.	· Iron Cove Link is constrained spatially as it is connecting to the existing Victoria Road, so this restricts location of the portals. · Bunding of ramps or profiling of road geometry to prevent floodwater ingress to the tunnel dive structures.
St Peters interchange (New M5 interface)	New M5 EIS and flood model (2015)	Yes - EIS approved. Assessed flooding for 20,100, 200 year ARI and PMF.	No - the post-development scenario was not shown to be affected by the PMF. Low risk from overland flow.	N/A - operational site only includes sub-surface infrastructure	N/A	N/A
	New M5 design (2016)	Yes - refinement of EIS model to inform design.	No - New M5 provides mitigation measures to manage risk at St Peters interchange portals for the PMF. Low risk from overland flow.			

Annexure E Water Quality Monitoring Program

Table E-1 Water quality monitoring parameters

In situ field parameters	Analytical sampling
Temperature (˚C) Dissolved Oxygen (mg/L) Electrical Conductivity (µS/cm) Reduction-Oxidation Potential (Redox)(mV) pH Turbidity (NTU).	Organics TRH (C6-C40) BTEXN – Benzene, Toluene, Ethylbenzene, Xylene and Naphthalene Nutrients - Total Nitrogen, TKN, NOx, NO2, NO3, Total Phosphorus and Filterable Reactive Phosphorus 8 Metals (Cu, Cr, As, Ni, Zn, Pb, Hg, Ni) and Manganese (total metals) Ferrous Iron, Total Iron

Table E-2 Monitoring locations

Site reference	Water course	Location	Easting[1]	Northing[1]	Monitoring purpose
Tidal Locations					
SW01	Rozelle Bay	Whites Creek outlet at City West Link/The Crescent, Rozelle	331068	6250619	Downstream of construction
SW02	Whites Creek	Whites Creek Valley Park, Railway Parade Annandale	330675	6250214	Downstream of construction
SW03	Johnstons Creek	Smith Park pedestrian bridge, Neilson Lane Annandale	331348	6249812	Downstream of construction
SW05	Hawthorne Canal	Hawthorne Canal Reserve, Canal Road, Leichhardt	328710	6249937	Upstream of construction
SW06	Hawthorne Canal	Canal Road (between City West Link and Lilyfield Road) Lilyfield	328944	6250424	Downstream of construction
SW07	Easton Park drain	Adjacent to 88-90 Lilyfield Road, Lilyfield	330816	6250769	Upstream of construction
SW08	Dobroyd Canal	Pedestrian bridge between Timbrell Park and Reg Coady Reserve, Dobroyd Parade, Haberfield	327694	6250353	Downstream of construction
SW09	Dobroyd Canal	West of Ramsey Road bridge at Dobroyd Parade, Haberfield	327295	6250337	Upstream of construction
SW11	Iron Cove	Under Iron Cove	TBC	TBC	Downstream of

Site reference	Water course	Location	Easting[1]	Northing[1]	Monitoring purpose
		bridge			construction
SW12	Iron Cove	King Georges Park	TBC	TBC	Downstream of construction
Non-Tidal Locations					
SW04	Johnstons Creek	Adjacent to playground, Chester Street,	331138	6249152	Downstream of construction
SW14	Johnstons Creek	Cruikshank Street	330955	6248607	Upstream of construction
SW10	Sheas Creek	South side of Huntley Street, Alexandria	332869	6246434	Up-stream of construction

An additional monitoring location will also be incorporated at White Bay.

It is noted that SW13 monitored as part of the contamination assessment was not included in the surface water assessment.

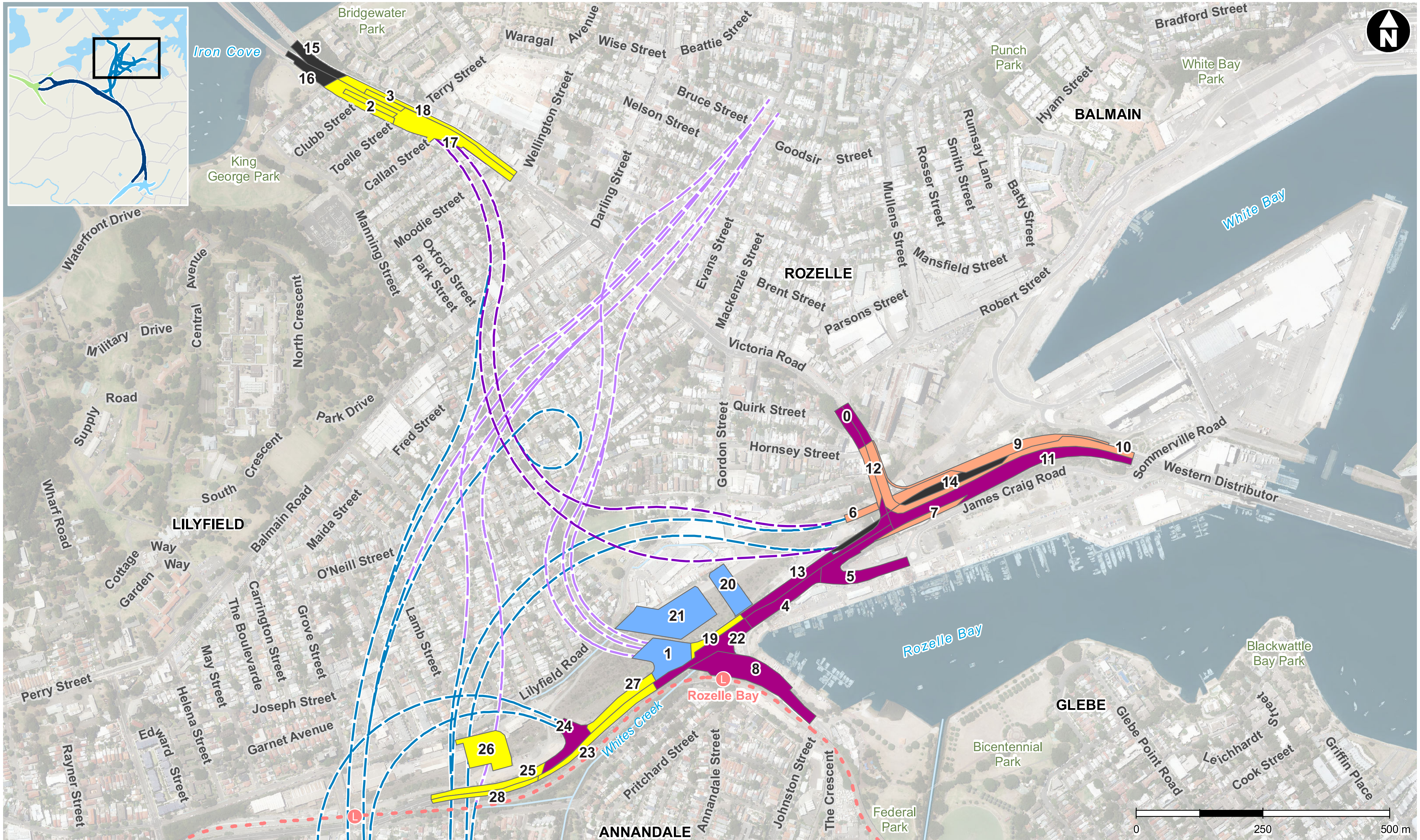
Annexure F Stormwater Quality Modelling Catchments

The catchment areas and corresponding treatment assumed in the MUSIC modelling is presented in **Table F-1** and **Figure F-1.**

Table F-1 MUSIC Modelling catchments and assumed treatment measures

Catchment ID	Catchment Description	Area (ha)	Existing treatment	Proposed treatment
0	Victoria Road north of crest	0.29	None	GPT + Hydrodynamic Separator
1	Western Harbour Tunnel ramps	0.55	None	GPT + Wetland
2	Iron Cove portal	0.11	None	GPT + Bioretention
3	Iron Cove portal	0.08	None	GPT + Bioretention
4	The Crescent westbound / culvert to James Craig Road	0.36	None	GPT + Hydrodynamic Separator
5	The Crescent westbound and James Craig Road	0.63	None	GPT + Hydrodynamic Separator
6	Anzac Bridge/M4 East ramp portal	0.30	None	Bioswale
7	Anzac Bridge/M4 East ramp portal	0.17	None	Bioswale
8	The Crescent Bridge	0.93	None	GPT + Hydrodynamic Separator
9	Victoria Road to Anzac Bridge eastbound ramp 1	0.52	None	Bioswale
10	Victoria Road to Anzac Bridge eastbound ramp 2	0.84	None	Bioswale
11	Anzac Bridge westbound ramp	1.17	None	GPT + Hydrodynamic Seperator
12	Victoria Road northbound, south of crest	0.14	None	Bioswale
13	The Crescent eastbound / culvert to Victoria Road bridge	0.52	None	GPT + Hydrodynamic Separator
14	Mousehole	0.38	None	Bioswale
15	Victoria Road southbound (to old outlet)	0.20	GPT	None
16	Victoria Road northbound (to old outlet)	0.19	GPT	None
17	Victoria Road northbound (to new outlet)	0.97	GPT	GPT + Bioretention

Catchment ID	Catchment Description	Area (ha)	Existing treatment	Proposed treatment
18	Victoria Road southbound (to new outlet)	0.35	GPT	GPT + Bioretention
19	City West Link eastbound Western Harbour Tunnel to CWL culvert	0.16	None	GPT + Hydrodynamic Separator
20	Water Treatment Plant and access	0.38	None	Wetland
21	Ventilation facilities	1.07	None	Wetland
22	City West Link westbound west of The Crescent 3	0.47	None	Bioretention
23	City West Link westbound west of The Crescent 2	0.38	None	GPT + Hydrodynamic Seperator
24	New M5 ramps	0.35	None	GPT + Hydrodynamic Separator
25	City West Link eastbound - west of New M5 ramps	0.28	None	Bioretention
26	Western substation, ventilation supply, water, access	0.57	None	Bioretention
27	City West Link eastbound – New M5 ramps to Western Harbour Tunnel ramps	0.27	None	Bioretention
28	City West Link westbound west of The Crescent 1	0.19	None	Bioretention



LEGEND

Existing features
- Waterway
- Light rail
- Light rail stop

M4-M5 Link

Rozelle interchange
- Surface road
- Tunnel

Iron Cove Link
- Surface road
- Tunnel

Proposed future WHTBL connections (civil construction only)
- Surface road
- Tunnel

Stormwater treatment catchments
- Bioretention
- Bioswale
- GPT and hydrodynamic separator
- None
- Wetland

Figure F-1 Stormwater treatment catchment plan

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Annexure G NSW Water Quality Objectives – Indicators and Criteria

Table G-1 NSW Water Quality Objective indicators and criteria (DECCW 2006)

Indicator	Numerical Criteria (Trigger Values)
Aquatic Ecosystems	
Total phosphorus	Lowland rivers: 25 µg/L for rivers flowing to the coast Estuaries: 30 µg/L
Total nitrogen	Lowland rivers: 350 µg/L for rivers flowing to the coast Estuaries: 300µg/L
Chlorophyll-a	Lowland rivers: 5 µg/L Estuaries: 4 µg/L.
Turbidity	Lowland rivers: 6–50 NTU Estuaries: 0.5–10 NTU
Salinity (electrical conductivity)	Lowland rivers: 125–2200 µS/cm
Dissolved oxygen	Lowland rivers: 85–110% Estuaries: 80–110%
pH	Upland rivers: 6.5–8.0 Lowland rivers: 6.5–8.5 Freshwater lakes & reservoirs: 6.5–8.0 Estuaries: 7.0–8.5
Temperature	See ANZECC 2000 Guidelines, table 3.3.1.
Chemical contaminants or toxicants	See ANZECC 2000 Guidelines, chapter 3.4 and table 3.4.1. 90% species protection level considered appropriate for construction. 95% species protection level considered appropriate for for operation.
Biological assessment indicators	This form of assessment directly evaluates whether management goals for ecosystem protection are being achieved (e.g. maintenance of a certain level of species diversity, control of nuisance algae below a certain level, protection of key species, etc). Many potential indicators exist and these may relate to single species, multiple species or whole communities. Recognised protocols using diatoms and algae, macrophytes, macroinvertebrates, and fish populations and/or communities may be used in NSW and interstate (e.g. AusRivAS).
Visual Amenity	
Visual clarity and colour	Natural visual clarity should not be reduced by more than 20%. Natural hue of the water should not be changed by more than 10 points on the Munsell Scale. The natural reflectance of the water should not be changed by more than 50%
Surface films and debris	Oils and petrochemicals should not be noticeable as a visible film on the water, nor should they be detectable by odour. Waters should be free from floating debris and litter.
Nuisance organisms	Macrophytes, phytoplankton scums, filamentous algal mats, blue-green algae, sewage fungus and leeches should not be present in unsightly amounts.
Secondary Contact Recreation	
Faecal coliforms	Median bacterial content in fresh and marine waters of < 1000 faecal coliforms per 100 mL, with 4 out of 5 samples < 4000/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month).
Enterococci	Median bacterial content in fresh and marine waters of < 230 enterococci per 100 mL (maximum number in any one sample: 450-700 organisms/100 mL).

Indicator	Numerical Criteria (Trigger Values)
Algae & blue-green algae	< 15 000 cells/mL
Nuisance organisms	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.
Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucous membranes are unsuitable for recreation. Toxic substances should not exceed values in tables 5.2.3 and 5.2.4 of the ANZECC 2000 Guidelines.
Visual clarity and colour	Use visual amenity guidelines.
Surface films	Use visual amenity guidelines.
Primary Contact Recreation	
Turbidity	A 200 mm diameter black disc should be able to be sighted horizontally from a distance of more than 1.6 m (approximately 6 NTU).
Faecal coliforms	Beachwatch considers waters are unsuitable for swimming if: the median faecal coliform density exceeds 150 colony forming units per 100 millilitres (cfu/100mL) for five samples taken at regular intervals not exceeding one month, or the second highest sample contains equal to or greater than 600 cfu/100mL (faecal coliforms) for five samples taken at regular intervals not exceeding one month. ANZECC 2000 Guidelines recommend: Median over bathing season of < 150 faecal coliforms per 100 mL, with 4 out of 5 samples < 600/100 mL (minimum of 5 samples taken at regular intervals not exceeding one month).
Enterococci	Beachwatch considers waters are unsuitable for swimming if: the median enterococci density exceeds 35 cfu/100mL for five samples taken at regular intervals not exceeding one month, or the second highest sample contains equal to or greater than 100 cfu/100mL (enterococci) for five samples taken at regular intervals not exceeding one month. ANZECC 2000 Guidelines recommend: Median over bathing season of < 35 enterococci per 100 mL (maximum number in any one sample: 60-100 organisms/100 mL).
Protozoans	Pathogenic free-living protozoans should be absent from bodies of fresh water. (Note, it is not necessary to analyse water for these pathogens unless temperature is greater than 24 degrees Celsius).
Algae & blue-green algae	< 15 000 cells/mL
Nuisance organisms	Use visual amenity guidelines. Large numbers of midges and aquatic worms are undesirable.
pH	5.0-9.0
Temperature	15°-35°C for prolonged exposure.
Chemical contaminants	Waters containing chemicals that are either toxic or irritating to the skin or mucus membranes are unsuitable for recreation. Toxic substances should not exceed the concentrations provided in tables 5.2.3 and 5.2.4 of the ANZECC 2000 Guidelines 2000.
Visual clarity and	Use visual amenity guidelines.

Indicator	Numerical Criteria (Trigger Values)
colour	
Surface films	Use visual amenity guidelines.
Aquatic Foods	
Algae & blue-green algae	No guideline is directly applicable, but toxins present in blue-green algae may accumulate in other aquatic organisms.
Faecal coliforms	*Guideline in water for shellfish:* The median faecal coliform concentration should not exceed 14 MPN/100mL; with no more than 10% of the samples exceeding 43 MPN/100 mL. *Standard in edible tissue:* Fish destined for human consumption should not exceed a limit of 2.3 MPN *E Coli* /g of flesh with a standard plate count of 100,000 organisms /g.
Toxicants (as applied to aquaculture activities)	Metals: Copper: less than 5 µgm/L Mercury: less than 1 µgm/L Zinc: less than 5 µgm/L Organochlorines: Chlordane: less than 0.004 µgm/L (saltwater production) PCB's: less than 2 µgm/L.
Physico-chemical indicators (as applied to aquaculture activities)	Suspended solids: less than 40 micrograms per litre (freshwater). Temperature: less than 2 degrees Celsius change over one hour.

Annexure H Tunnel water treatment plant options review

Table H-1 Summary of Treatment Options

	Option 1 – Primary Sedimentation	Option 2 – Primary Sedimentation + Biological Treatment (SBR)	Option 3 – Primary Sedimentation + Ion Exchange	Option 4 – Primary Sedimentation + Reverse Osmosis
Process description	· Buffer tank is aerated to precipitate dissolved iron and manganese. Primary sedimentation removes settleable solids through chemical precipitation and sludge removal. Water filtered prior to discharge	· Buffer tank is aerated to precipitate dissolved iron and manganese. Primary sedimentation removes settleable solids through chemical precipitation and sludge removal. · Biological treatment for nutrient removal. · Water filtered prior to discharge	· Buffer tank is aerated to precipitate dissolved iron and manganese. Primary sedimentation removes settleable solids through chemical precipitation and sludge removal · Ion exchange for nutrient removal · Water filtered prior to discharge	· Buffer tank is aerated to precipitate dissolved iron and manganese. Primary sedimentation removes settleable solids through chemical precipitation and sludge removal · Reverse osmosis for nutrient and TDS removal
Major infrastructure / equipment	· Balance tank (aerated) · Clarifier tank · Chemical dosing units (PAC, caustic, polymer) · Media filters · Sludge tank · Filter press	As per Option 1, plus: · Sequencing batch reactor tanks · Treated water tanks · Blowers · Additional chemicals – nutrients, antifoam	As per Option 1, plus: · Anionic and cationic ion exchange units · Additional chemicals – acid, caustic · Neutraliser waste tank · IX waste to trade waste (assume 5% flow)	As per Option 1, plus: · Reverse osmosis units · Additional chemicals – Acid/ antiscalant. Membrane cleaning · Waste brine to trade waste (approx. 20% flow)
Parameters targeted	· Iron, manganese, total suspended solids, pH	· Iron, manganese, total suspended solids, pH · Nutrients (nitrogen & phosphorous)	· Iron, manganese, total suspended solids, pH · Nutrients (nitrogen & phosphorous)	· Iron, manganese, total suspended solids, pH · Nutrients (nitrogen & phosphorous) · Total dissolved solids

Process performance	· Typical treatment for Sydney groundwater · Successful in meeting target water quality for iron, manganese, suspended solids, turbidity, pH	· In addition to Option 1, SBR will have limited additional nutrient removal. Requires input nutrients to maintain bioreactor viability · Low level nitrogen targets not achieved	· As per Option 1 · IX has high nutrient removal capacity · Requires strong chemical regeneration solutions for IX · Requires higher skilled operator	· As per Option 1 · RO removes all dissolved solids, including target nutrients · Membrane process has high power consumption · Membranes require chemical cleaning · Waste brine is approx. 20% of total treated water volume – requires trade waste disposal · Requires higher skilled operator
Other factors	· Dewatered sludge to be trucked off-site for disposal · Will not achieve ANZECC guidelines for nitrogen and phosphorus	· Large footprint requirement · Increased power requirement (due to aeration process) · Increased chemical dosing (nutrient dosing and antifoam) · Will not achieve ANZECC guidelines for nitrogen and phosphorus	· Increased power requirement for ion exchange plant · Produces chemical waste to be trucked off-site as trade waste	· High power requirement for membrane filtration process · Produces high volume of waste stream (brine), requires connection to sewer for trade waste · Treated water available for use as non-potable water

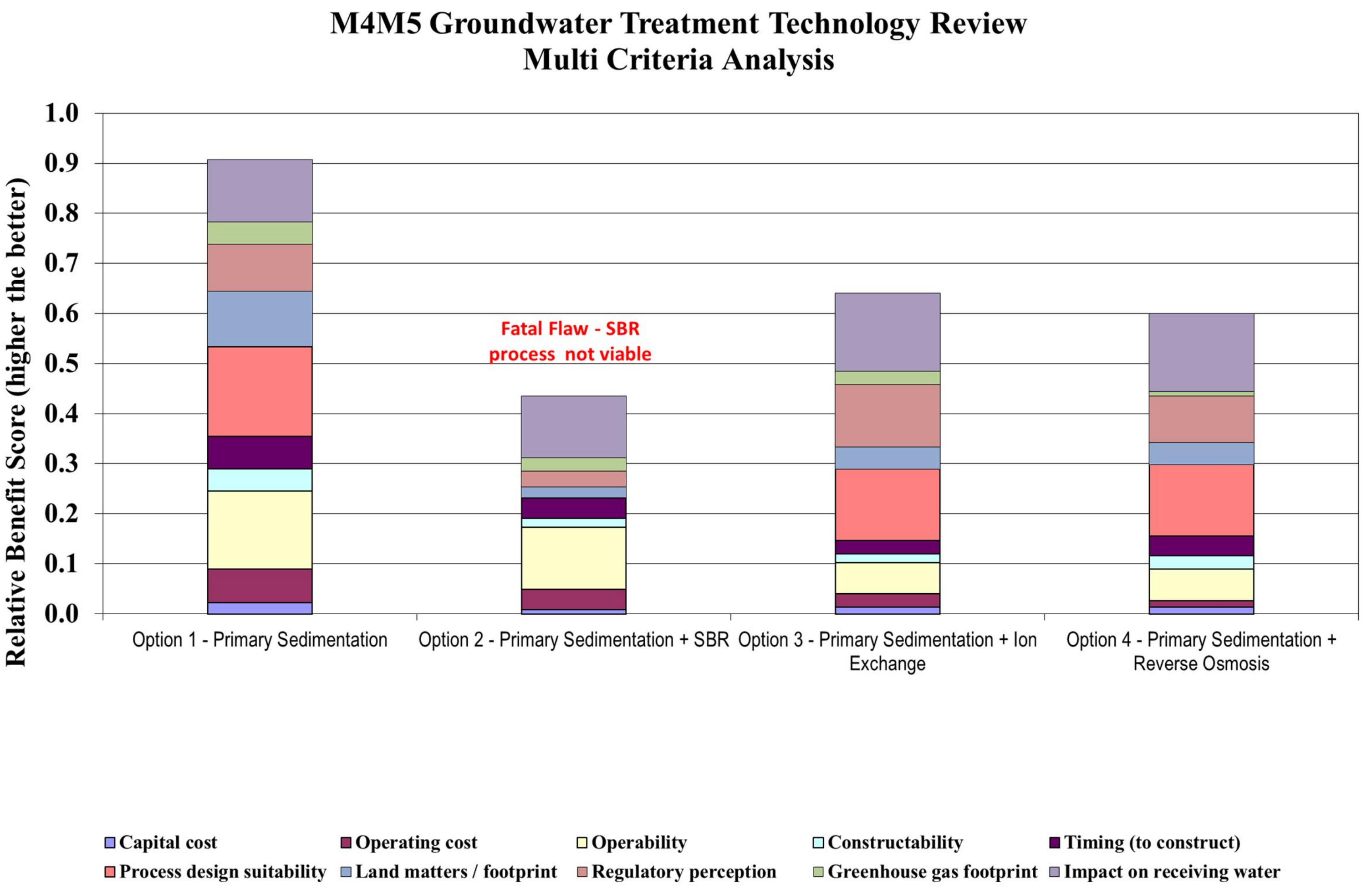

Figure H-1 MCA Comparison

Table H-2 MCA scoring and weighted criteria

Criteria	Description	Weight	Option 1 - Primary Sedimentation (Note 1)	Option 2 - Primary Sedimentation + SBR	Option 3 - Primary Sedimentation + Ion Exchange	Option 4 - Primary Sedimentation + Reverse Osmosis
Capital cost	Lowest capital cost	2.22%	5	2	3	3
Operating cost	Lowest operating cost: power, chemicals, labour, third party waste transporters, etc.	6.67%	5	3	2	1
Operability	Labour intensiveness, process complexity, etc.	15.56%	5	4	2	2
Constructability	Impact on adjacent community, construction requirements, noise, etc.	4.44%	5	2	2	3
Timing (to construct)	Will the solution have a long construction or commissioning period? Will the solution be constructed in the appropriate timeframe?	6.67%	5	3	2	3
Process design suitability	Will the process achieve the water quality targeted by the treatment process? (Note 2)	17.78%	5	0	4	4
Land matters / footprint	Is land available? Will procurement of easements be required?	11.11%	5	1	2	2
Regulatory perception	Will solution be accepted by the regulatory authorities long term, will the solution require NSW EPA negotiations?	15.56%	3	1	4	3

Criteria	Description	Weight	Option 1 - Primary Sedimentation (Note 1)	Option 2 - Primary Sedimentation + SBR	Option 3 - Primary Sedimentation + Ion Exchange	Option 4 - Primary Sedimentation + Reverse Osmosis
Greenhouse gas footprint	Does the solution have a low greenhouse gas footprint?	4.44%	5	3	3	1
Impact on receiving water	Will the discharge quality have any detrimental impacts on the receiving environment?	15.56%	4	4	5	5
		100.00%				
5= best						
1= worst						
Notes	1. This option reflects the accepted groundwater treatment process strategies for other Sydney transport and power tunnel infrastructure					
	2. Process design suitability considers the ability of the final process plant configuration to reliably achieve the parameters targeted for the respective treatment processes					

AECOM

Table H-3 Criteria Ranking

	Ranking/Scoring: AECOM Project team				Capital cost	Operating cost	Operability	Constructability	Timing (to construct)	Process design suitability	Land matters / footprint	Regulatory perception	Greenhouse gas footprint	Impact on receiving water	0	0	0	0	0			Relative Importance
Rank	Category	Criteria	Definition		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Comments		
10	Financial	Lowest capital cost	Capital cost	A		0	0	0	0	0	0	0	1	0								2.22%
6	Financial	Lowest operating cost: power, chemicals, labour, third party waste transporters, etc.	Operating cost	B	1		0	1	1	0	0	0	0	0								6.67%
2	Reliability	Labour intensiveness, process complexity, etc.	Operability	C	1	1		1	0	0	1	1	1	1								15.56%
8	Implementation	Impact on adjacent community, construction requirements, noise, etc.	Constructability	D	1	0	0		1	0	0	0	0	0								4.44%
6	Implementation	Will the solution have a long construction or commissioning period? Will the solution be constructed in the appropriate timeframe?	Timing (to construct)	E	1	0	1	0		0	0	0	1	0								6.67%
1	Reliability	Will the process achieve the specified treated water quality?	Process design suitability	F	1	1	1	1	1		1	1	1	0								17.78%
5	Implementation	Is land available? Will procurement of easements be required?	Land matters / footprint	G	1	1	0	1	1	0		0	1	0								11.11%
2	Implementation	Will solution be accepted by the regulatory authorities long term, will the solution require EPA negotiations?	Regulatory perception	H	1	1	0	1	1	0	1		1	1								15.56%
8	Implementation	Does the solution have a low greenhouse gas footprint?	Greenhouse gas footprint	I	0	1	0	1	0	0	0	0		0								4.44%
2	Reliability	Will the discharge quality have any detrimental impacts on the receiving environment?	Impact on receiving water	J	1	1	0	1	1	1	1	0	1									15.56%