# FLOODING AND HYDROLOGY

CHAPTER TWENTY-ONE

# 21 Flooding and hydrology

**This chapter provides an assessment of the potential impact on flooding and surface water as a result of the project, and identifies mitigation measures to minimise these impacts.**

## 21.1 Secretary's environmental assessment requirements

The Secretary's environmental assessment requirements relating to flooding and hydrology, and where these requirements are addressed in this Environmental Impact Statement, are outlined in Table 21-1.

**Table 21-1 Secretary's environmental assessment requirements –flooding and hydrology**

| Ref. | Secretary's environmental assessment requirements | Where addressed |
|---|---|---|
| **6. Flooding** | | |
| 6.1 | The Proponent must assess and model (where appropriate), taking into account any relevant Council-adopted flood model or latest flood data available from Councils, the impacts on flood behaviour during construction and operation for a full range of flood events up to the probable maximum flood (taking into account sea level rise and storm intensity due to climate change) including: | |
| 6.1(a) | any detrimental increases in the potential flood affectation of other properties, assets and infrastructure | Flood impacts are addressed in Sections 21.4.2 and 21.5.2. |
| 6.1(b) | consistency (or inconsistency) with applicable Council floodplain risk management plans | Flood impacts are addressed in Sections 21.4.2 and 21.5.2. |
| 6.1(c) | compatibility with the flood hazard of the land | Flood impacts are addressed in Sections 21.4.2 and 21.5.2. |
| 6.1(d) | compatibility with the hydraulic functions of flow conveyance in flood ways and storage areas of the land | Hydrology impacts are addressed in Sections 21.4.1 and 21.5.1. |
| 6.1(e) | downstream velocity and scour potential | Hydrology impacts are addressed in Sections 21.4.1 and 21.5.1. |
| 6.1(f) | impacts the development may have upon existing community emergency management arrangements for flooding. These matters must be discussed with the State Emergency Services and Council | Flood impacts are addressed in Sections 21.4.2 and 21.5.2.<br>Consultation with the State Emergency Service and Council is provided in Chapter 5 (Stakeholder and community engagement). |
| 6.1(g) | any impacts the development may have on the social and economic costs to the community as consequence of flooding. | Flood impacts are addressed in Sections 21.4.2 and 21.5.2. |

| Ref. | Secretary's environmental assessment requirements | Where addressed |
|---|---|---|
| **17. Water – Hydrology** | | |
| 17.1 | The Proponent must describe (and map) the existing hydrological regime for any surface and groundwater resource (including reliance by users and for ecological purposes) likely to be impacted by the project, including stream orders, as per the Framework for Biodiversity Assessment (FBA). | The hydrological regime for surface water is described in Section 21.3.<br>The hydrological regime for groundwater is described in Chapter 17 (Groundwater and geology). |
| 17.2 | The Proponent must assess (and model if appropriate) the impact of the construction and operation of the project and any ancillary facilities (both built elements and discharges) on surface and groundwater hydrology in accordance with the current guidelines, including: | |
| 17.2(a) | natural processes within rivers, wetlands, estuaries, marine waters and floodplains that affect the health of the fluvial, riparian, estuarine or marine system and landscape health (such as modified discharge volumes, durations and velocities), aquatic connectivity and access to habitat for spawning and refuge | Hydrology impacts are addressed in Sections 21.4.1 and 21.5.1.<br>Biodiversity impacts associated with hydrology are addressed in Chapter 20 (Biodiversity). |
| 17.2(b) | impacts from any permanent and temporary interruption of groundwater flow, including the extent of drawdown, barriers to flows, implications for groundwater dependent surface flows, ecosystems and species, groundwater users and the potential for settlement | Groundwater impacts are addressed in Chapter 17 (Groundwater and geology). |
| 17.2(c) | changes to environmental water availability and flows, both regulated / licensed and unregulated / rules-based sources | Chapter 18 (Soils, contamination and water quality). |
| 17.2(d) | direct or indirect increases in erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses | Hydrology impacts are addressed in Sections 21.4.1 and 21.5.1. |
| 17.2(e) | minimising the effects of proposed stormwater and wastewater management during construction and operation on natural hydrological attributes (such as volumes, flow rates, management methods and re-use options) and on the conveyance capacity of existing stormwater systems where discharges are proposed through such systems | Hydrology impacts are addressed in Sections 21.4.1 and 21.5.1. |
| 17.2(f) | water take (direct or passive) from all surface and groundwater sources with estimates of annual volumes during construction and operation. | Water take is addressed in Chapter 25 (Sustainability). |
| 17.3 | The Proponent must identify any requirements for baseline monitoring of hydrological attributes. | Mitigation measures are outlined in Section 21.6. |

# 21.2 Assessment methodology

## 21.2.1 Surface hydrology and drainage infrastructure

The methodology for assessment of surface hydrology and drainage involved:

- Compilation and review of background information (previous studies, survey and mapping data) relevant to the project to define the existing environment within potentially affected catchments
- Identification and assessment of construction and operational activities that may impact on the surface water hydrology of receiving environments
- Identification of potential impacts as a result of changes in surface water quantity, with respect to increases or decreases in stormwater runoff and the sensitivity of the downstream waters
- Identification of mitigation measures, including type of controls and design criteria required to manage potential impacts.

The following guidelines were considered during the preparation of the surface hydrology and drainage infrastructure assessment:

- *Managing Urban Stormwater: Soils and Construction Volume 1* (Landcom 2004)
- *Managing Urban Stormwater: Soils and Construction Volume 2* (Department of Environment and Climate Change, 2008a).

## 21.2.2 Flooding

The methodology for assessing potential flood impacts involved:

- Compilation and review of previous flood studies relevant to the project to define existing flood behaviour within potentially affected catchments
- Identification and assessment of potential flood impacts on the project and adjacent properties
- Identification of mitigation measures, including type of controls and design criteria required to manage potential flood impacts
- Flood modelling at the Marrickville dive site to identify any potential changes to flood levels, discharges, velocities, duration of flood inundation and flood hazards (see below).

The following guidelines were considered during the preparation of the flood assessment:

- *Floodplain Development Manual* (NSW Government, 2005b)
- *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* (Department of Environment and Climate Change, 2007b)
- *Floodplain Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (Department of Environment, Climate Change and Water, 2010c)
- *New guideline and changes to section 117 direction and EP&A Regulation on flood prone land,* Planning Circular PS 07-003 (NSW Department of Planning, 2007).

### Flood modelling at the Marrickville dive site (southern)

Two previous flood studies have been carried out for Marrickville Council within the catchment areas influenced by the Marrickville dive site:

- The *East Channel East Sub-catchment Flood Study* (Golders, 2010). The purpose of the *East Channel East Sub-catchment Flood Study* was to prepare a sub-catchment management plan, to allow Marrickville Council to apply sustainable water management to the East Channel East (ECE) sub-catchment
- The *Marrickville Valley Flood Study* (WMAwater, 2013). The purpose of the *Marrickville Valley Flood Study* was to define existing flood behaviour and provide a basis for a future Floodplain Risk Management Study and Plan (that is not yet finalised).

The *East Channel East Sub-catchment Flood Study* was used as an input into the *Marrickville Valley Flood Study*. Combined, these two flood studies cover the catchment area influenced by the Marrickville dive site.

To assess potential impacts of the project, the models for the above studies were obtained from Marrickville Council and adapted to create a new combined 1D-2D TUFLOW hydraulic flood model (the *Sydenham Flood Model*) that covers the project catchment. The *Marrickville Valley Flood Study* model was used as the basis for the *Sydenham Flood Model*; however elements of the *East Channel East Sub-catchment Flood Study* model and the *Marrickville Valley Flood Study* model have been incorporated into the *Sydenham Flood Model* as outlined in Table 21-2.

Table 21-2 Key parameters incorporated into the Sydenham Flood Model

| Model parameter | Application to the Sydenham Flood Model |
|---|---|
| **Hydrologic inputs** | For their respective study areas, 1D network hydrology from the *Marrickville Valley Flood Study* and the *East Channel East Sub-catchment Flood Study* were applied to the *Sydenham Flood Model.* |
| **TUFLOW version** | 2013-12-AE (latest version at the time of model creation). |
| **Topographic data** | As per the *Marrickville Valley Flood Study.* |
| **Roughness values** | For their respective study areas, roughness values from the *Marrickville Valley Flood Study* and the *East Channel East Sub-catchment Flood Study* were applied to the *Sydenham Flood Model* with the exception of the roughness co-efficient value for railway corridor areas, which was updated to 0.1 to ensure consistency across both models. |
| **Building footprints** | Building footprints have been applied as regions of high roughness (a roughness co-efficient of 10 has been applied) to ensure that velocities through the building footprints are reduced to be near zero. This approach produces results that are consistent with the modelling approach adopted by the *Marrickville Valley Flood Study* and the *East Channel East Sub-catchment Flood Study.* |
| **Events simulated** | Flood modelling has been carried out for the two year, five year, 10-year and 100-year average recurrence interval flood events, and the probable maximum flood event. |
| **Critical duration storm events** | Critical duration storm events have been applied as per the *Marrickville Valley Flood Study* (assumed to be two hours for the two year, five year, 10-year and 100-year average recurrence interval flood events and one hour for the probable maximum flood event. |
| **Climate change scenario** | A 30 per cent increase in rainfall combined with a 0.9 meter increase in sea level has been applied and is considered an appropriate worst case scenario. |

The *Sydenham Flood Model* was run to model an 'existing condition' scenario (that is, existing flood conditions without the project) and checked for consistency with the outputs generated by the *Marrickville Valley Flood Study* and the *East Channel East Sub-catchment Flood Study* for the respective areas covered by those models.

Once the *Sydenham Flood Model* was verified as consistent with outputs from previous models in the 'existing condition' scenario, the project design was incorporated into the model to create a 'project base-case' (that is, modelled flood conditions inclusive of the project 'without flood mitigation'). Based on the results of this model run it was found that flood mitigation would be required and various flood mitigation design scenarios were modelled (referred to as 'project mitigation' cases).

The 'existing condition' flood scenarios for the Marrickville dive site are discussed in Section 21.3.2, while potential construction phase flooding impacts are discussed in Section 21.4.2 and the operation phase 'project base case' and 'project mitigation' cases are discussed in Section 21.5.2.

# 21.3 Existing environment

## 21.3.1 Surface hydrology and drainage infrastructure

The project would be located within drainage catchments that ultimately drain to Middle Harbour, Sydney Harbour and Botany Bay. The catchments the project is located in, the receiving waters and associated drainage infrastructure are summarised in Table 21-3.

All drainage catchments across the project are highly urbanised, with large impervious surfaces created by roads, footpaths and buildings. These impervious surfaces are interspersed with pervious surfaces associated with parkland areas and other unsealed surfaces (such as vacant land and landscaped areas).

All natural watercourses have generally been replaced with constructed drainage systems (such as lined and unlined drainage channels, and sub-surface pit and pipe networks) that discharge into the downstream receiving environments (refer to Table 21-3).

Surface water is generally collected by developed stormwater networks, which consist of road kerb and guttering, lined and unlined drainage channels, and sub-surface pit and pipe networks. The majority of the drainage systems are owned and maintained by the local council, while a number of the larger trunk drainage systems are assets of Sydney Water. The existing drainage systems, as they would relate to project elements, are described in Table 21-3. Surface water catchments and watercourses are shown in Figure 21-1.

**Table 21-3 Existing drainage catchments, receiving waters and associated drainage infrastructure**

| Project location | Surface water catchment | Receiving waters | Drainage infrastructure |
|---|---|---|---|
| **Chatswood dive site (northern)** | Near the top of Scotts Creek and Flat Rock Creek catchments | Middle Harbour | Rail corridor runoff is collected by the rail drainage system and discharged into surrounding council stormwater systems within the Flat Rock Creek Catchment.<br><br>Runoff from the Chatswood dive site flows north into the Scotts Creek Catchment and is drained by a stormwater pipe that runs down Hammond Lane and crosses under the rail corridor at Chapman Avenue. |
| **Artarmon substation** | Flat Rock Creek | Middle Harbour | Runoff is collected by the drainage networks on Reserve Road and Gore Hill Freeway. |
| **Crows Nest Station** | Flat Rock Creek | Middle Harbour | Runoff is collected by road kerb and gutter systems and discharged into stormwater pits at the intersection of Oxley Street and Clarke Lane. |
| **Victoria Cross Station** | Milson Park | Sydney Harbour | Runoff is collected by road kerb and gutter systems and discharged east towards Kirribilli. |
| **Blues Point temporary site** | N/A | Sydney Harbour | Runoff drains directly into Sydney Harbour. |

| Project location | Surface water catchment | Receiving waters | Drainage infrastructure |
|---|---|---|---|
| **Barangaroo Station** | City Area (Sydney) | Sydney Harbour | Runoff is collected by a number of drainage pits and pipes on Hickson Road. The pipes discharge west directly into Sydney Harbour. |
| **Martin Place Station** | City Area (Sydney) | Sydney Harbour | Runoff is collected by the drainage system in Castlereagh Street, which discharges north toward Circular Quay and Sydney Harbour. |
| **Pitt Street Station** | City Area (Sydney) | Sydney Harbour | Runoff is collected by the road drainage systems, and drains north down Pitt Street and eventually discharges directly into Sydney Harbour. |
| **Central Station** | Darling Harbour (Sydney) | Sydney Harbour | Runoff is collected by the rail corridor drainage system and connects to larger pipe systems draining around and under the site. Rail corridor drainage in the northern half of the site connects to drainage in Eddy Avenue or a trunk drain under the site near Devonshire Street, both of which are part of the Darling Harbour catchment. Rail drainage in the southern half of the site connects to trunk mains under the site from Prince Alfred Park that are part of the Blackwattle Bay catchment. |
| **Waterloo Station** | Alexandra Canal | Botany Bay via the Cooks River | Runoff is collected by drainage systems in Botany Road and Cope Street. |
| **Marrickville dive site (southern)** | Marrickville Valley | Botany Bay via the Cooks River | Runoff is collected by the rail corridor drainage system or council stormwater system and discharged into the surrounding street and trunk drainage systems. The main drainage features comprise the Eastern Channel and the Sydenham Storage Pit located immediately north of the rail corridor. The Eastern Channel collects runoff from the areas of Enmore, Newtown and St Peters and discharges it south to the Cooks River and ultimately to Botany Bay.<br>A number of rail culverts between Sydenham Station and the Bedwin Road overbridge drain areas south of the rail line into the Eastern Channel. The Sydenham Storage Pit is a large detention basin that collects urban runoff from areas of Marrickville that is then pumped into Eastern Channel.<br>The Eastern Channel and Sydenham Storage Pit are both assets of Sydney Water. |

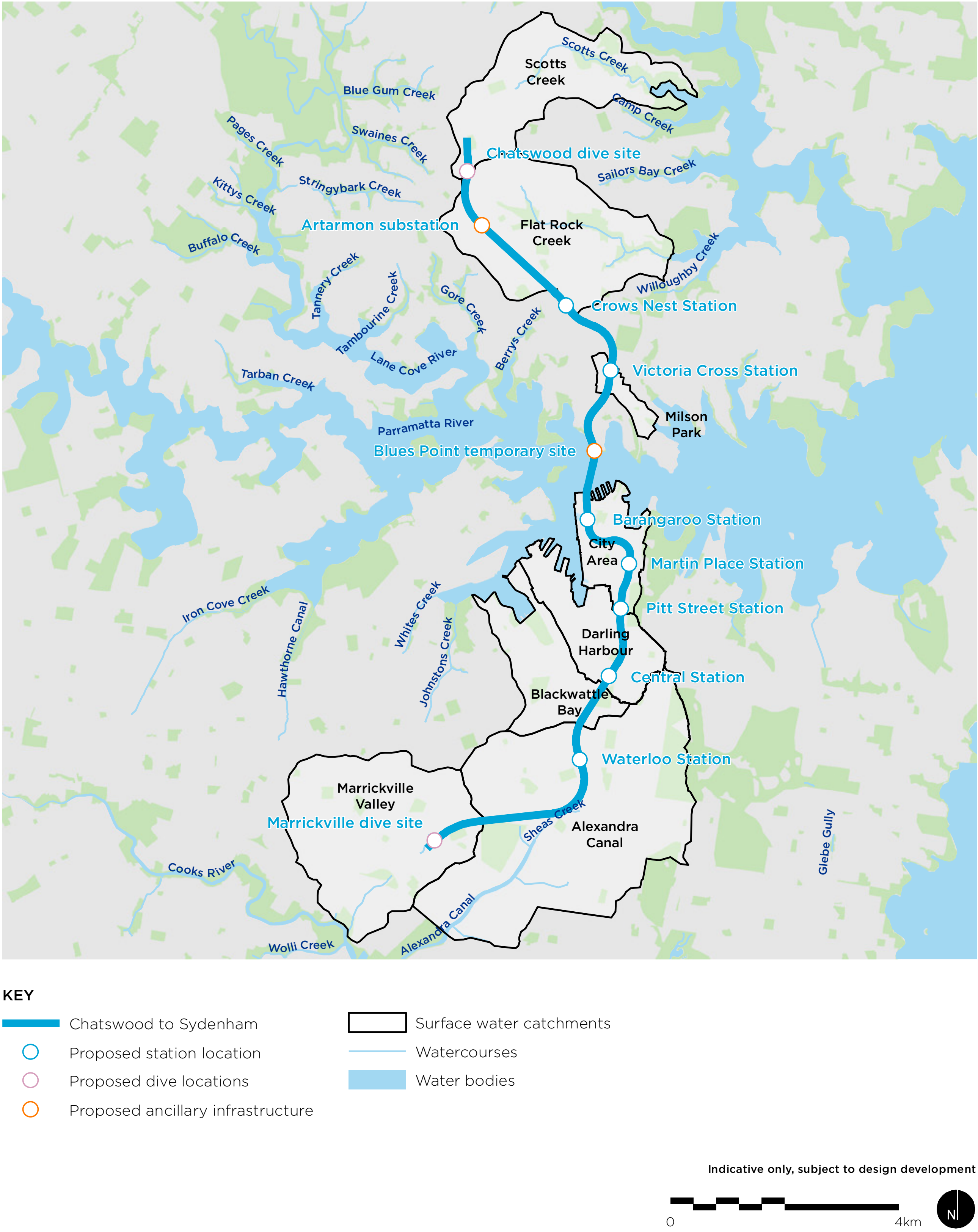



**Figure 21-1 Surface water catchments and watercourses**

### 21.3.2 Flooding

#### Background information

Due to the highly urbanised drainage catchments surrounding the project area, flooding behaviour is expected to be largely controlled by the capacity of stormwater drainage systems and roadways that form overland flow paths. Local councils have investigated flood behaviour to varying degrees. Relevant flood studies include:

- *Scotts Creek Flood Study* (Lyall and Associates Consulting Engineers, 2008)
- *Flat Rock Creek Flood Study* (Lyall and Associates Consulting Engineers, 2006)
- *Flat Rock Creek Updated Flood Study* (Lyall and Associates Consulting Engineers, 2011)
- *City Area Catchment Flood Study Final Report* (BMT WBM Pty Ltd, 2014a)
- *Darling Harbour Catchment Flood Study Final Report* (BMT WBM Pty Ltd, 2014b)
- *Eastern Channel East Subcatchment Management Plan Volume 1 – Management Study* (Golder Associates Pty Ltd, 2011)
- *Eastern Channel East Subcatchment Management Plan Volume 2 – Flood Study* (Golder Associates Pty Ltd, 2010)
- *Marrickville Valley Flood Study Final Report* (WMAwater, 2013)
- *Blackwattle Bay Catchment Flood Study Draft Report* (WMAwater, 2014)
- *Alexandra Canal Flood Study – Final* (Cardno Pty Ltd, 2014)
- *Cooks River Flood Study* (MWH+PB, 2009)
- *Cooks River Floodplain Risk Management Study and Plan* (WMAwater and Storm Consulting, 2015).

North Sydney Council is carrying out an overland flood study for the entire local government area. Flood modelling results from this study were not available at the time of writing.

#### Floodplain risk management

The *Floodplain Development Manual* (NSW Government, 2005b) identifies a floodplain risk management process that requires floodplain risk management studies and plans are developed based on relevant flood studies. As discussed in Section 21.2.2, the *Sydenham Flood Model* has been developed using the *Marrickville Valley Flood Study* model as a base, incorporating relevant elements of the *East Channel East Sub-catchment Flood Study* model. As such, the *Sydenham Flood Model* would be consistent with the flood studies informing a future floodplain risk management study and / or plan developed for the Marrickville Valley Catchment.

The *Cooks River Floodplain Risk Management Study and Plan* (2015) focusses on the Cooks River catchment and does not cover the area affected by the proposed Marrickville dive site. The Marrickville dive site (southern) is located within the Marrickville Valley Catchment and although no floodplain risk management study and / or plan is currently available for this catchment, the project is generally consistent with the *Eastern Channel East Subcatchment Management Plan* (Golder Associates Pty Ltd, 2011) and design development has considered, and does not preclude, potential future drainage improvement works proposed in this plan.

There would be ongoing consultation with Marrickville Council to review consistency of the project with any future floodplain risk management study and / or plan developed for the Marrickville Valley Catchment.

## Existing flood behaviour

Based on the above studies, the existing flood behaviour around the project sites is described in Table 21-4.

**Table 21-4 Description of existing flood behaviour**

| Location | Description of existing flood behaviour |
|---|---|
| **Chatswood dive site (northern)** | The Chatswood dive site is located near the top of the Scotts Creek and Flat Rock Creek drainage catchments. Localised flooding of the construction site and in the rail corridor has the potential to occur during high intensity rainfall events. |
| **Artarmon substation** | The site is located near the ridge between sub-catchments and would therefore not be affected by flooding. The main overland flow path near the site is on Reserve Road, which drains south before turning east along the northern side of the Gore Hill Freeway. |
| **Crows Nest Station** | The site is located at the top of the Flat Rock Creek catchment. During high intensity rainfall events, flows are carried away from the site by the existing road drainage infrastructure. |
| **Victoria Cross Station** | Urbanised areas of North Sydney drain towards the site. The main overland flow paths around the site are down Berry Street and Miller Street and there is a low point in Miller Street immediately north of the Pacific Highway intersection. The catchment upstream of the Miller Street low point covers about 17 hectares. Flood levels at the Miller Street low point, in the vicinity of the station site, are limited by the downstream level of the Pacific Highway. |
| **Blues Point temporary site** | This is a temporary site and would not be required for the full construction duration. It would be required to retrieve parts of the tunnel boring machines tunnelling from the Chatswood dive site and Barangaroo Station.<br><br>During high intensity rainfall events, the site may be impacted by overland flows that drain into the harbour via Blues Point Road and Henry Lawson Avenue. The site may also be at risk of flooding from elevated sea levels during storm events. A Sydney Harbour water level with a 100-year average recurrence interval is about 1.4 metres above the Australian Height Datum (*Fort Denison Sea Level Rise Vulnerability Study*, Department of Environment and Climate Change, 2008c). |
| **Barangaroo Station** | The site is located along a low-lying area of Hickson Road. The catchment draining toward Hickson Road extends about 200 metres east to Observatory Hill. When the stormwater system capacity is exceeded, floodwaters flow onto Hickson Road from a low point on High Street near Lance Lane. Ponding currently occurs on Hickson Road in the Barangaroo Station site area in events as frequent as the two-year average recurrence interval. Ponding depths of between 0.5 and 0.75 metres would occur in the probable maximum flood event.<br><br>There will be changes (improvements) to the existing flood environment in this location as a result of drainage infrastructure upgrade work proposed as part of the Central Barangaroo development. |
| **Martin Place Station** | The catchment falling towards the site extends about 200 metres east to Macquarie Street. The overland flow paths around the site are down Elizabeth, Castlereagh and Hunter streets. Overland flooding occurs during a five-year average recurrence interval event and flood depths of between 0.25 to 0.5 metres would occur in the probable maximum flood. High hazard flooding occurs in Hunter Street in flood events at or higher than the 20-year average recurrence interval. |
| **Pitt Street Station** | The site is located near the top of the City Area (Sydney) catchment. During high intensity rainfall events, flows would be carried by the surrounding roads and associated drainage networks and would not result in flooding in the vicinity of the Pitt Street Station site. |

| Location | Description of existing flood behaviour |
|---|---|
| **Central Station** | Urbanised areas of Surry Hills drain towards Central Station from the east.<br>The main overland flow paths that approach Central Station are from:<br>• Foveaux Street, where floodwaters continue west down Eddy Avenue toward George Street<br>• Devonshire Street and Prince Alfred Park, where floodwaters enter the Central Station site and pond in low-lying sections of the rail track next to Prince Alfred Park in events as frequent as the two-year average recurrence interval. |
| **Waterloo Station** | Urban areas of Redfern drain towards the site. Cope Street and Botany Road are the main overland flow paths around the site. Flood depths of up to one metre occur near the Cope Street and Wellington Street intersection in the 100-year average recurrence interval event. |
| **Marrickville dive site (southern)** | The Marrickville dive site would be located in low-lying terrain where flooding occurs. Areas to the north and south of the existing rail lines (T2, T3 and T4 rail lines) drain towards the Marrickville dive site and Eastern Channel. The main overland flow path from the north is down Murray Street before floodwaters enter the upstream section of Eastern Channel. Catchments from south of the rail corridor drain via a number of culverts under the rail line into Eastern Channel. These culverts flow full in flood events with an average recurrence interval of two years or more, causing floodwaters to flow over the rail line near the Bedwin Road overbridge and Sydenham Station.<br>Currently in a 10-year average recurrence interval event, overland stormwater flows mostly occur to the south of the rail corridor. From Grove and Sutherland streets, stormwater flows westward and across Unwins Bridge Road and through commercial properties before pooling mostly in low-lying areas on Bolton Street. Low-level flooding occurs within the rail corridor immediately to the north of Sydenham Station. Low to mid-level flooding also occurs on Murray Street.<br>Currently in a 100-year average recurrence interval event, overland stormwater flows follow similar flow paths to the one in 10-year annual recurrence interval event. Low to mid-level flooding occurs in Grove and Sutherland streets and Unwins Bridge Road and high-level flooding is predicted to occur in Bolton Street. Mid-level flooding (about 0.75 metres peak depth) is predicted to occur on Murray Street in this flood event. At Sydenham Station, flooding of the rail tracks between station platforms occurs with peak depths reaching about 0.5 metres. Low-level flooding of the rail corridor occurs to the north of Sydenham Station and also in the vicinity of Murray Street (south of Bedwin Road) in the 100-year average recurrence interval flood event.<br>Currently the modelled probable maximum flood event results in extensive flooding around the Marrickville dive site. The majority of the existing rail line between the Bedwin Road overbridge and Sydenham Station would be flooded with depths varying between 0.5 and 1.5 metres. Under current site conditions mid to high-level flooding is modelled to occur in the probable maximum flood event on Unwins Bridge Road, and high-level flooding to depths exceeding 1.5 metres is predicted to occur on Murray Street, Bolton Street and at Sydenham Station between the station platforms.<br>Existing flood extents around the Marrickville dive site are shown in Figure 21-2. |


**Figure 21-2 Marrickville dive site – existing 10-year ARI, 100-year ARI and Probable Maximum Flood events**

# 21.4 Potential impacts – construction

## 21.4.1 Surface hydrology and drainage infrastructure

Construction of the project has the potential to alter existing stormwater flows due to the introduction of additional areas of impervious surfaces, alterations (relocation and / or additions) to existing stormwater drainage infrastructure, dewatering activities, and the establishment of erosion and sediment control measures (to redirect stormwater runoff around the construction site and / or capture runoff in detention basins).

With the exception of widening work required in the T1 North Shore Line corridor, construction of the Artarmon substation and the Blues point temporary site all construction sites are currently impervious to infiltration and well-established drainage systems are already in place to cater for stormwater flows. At these sites construction activities would not result in any major increase in stormwater volumes or peak flow rates.

Construction activities may result in a minor redistribution of some surface water flows. However, it is unlikely that the redistribution of flows would affect the performance of downstream drainage infrastructure. For example, construction of the Marrickville dive site and southern services facility may require minor changes to existing stormwater infrastructure in Murray Street.

Construction within the T1 North Shore Line corridor, the Artarmon substation and the Blues Point temporary site may result in minor changes to existing localised surface water and / or stormwater flow regimes. At these sites it is unlikely that additional stormwater infrastructure would be required to manage any changes in flow regimes in the construction phase. Erosion and sediment controls, including the redirection and capture of construction site runoff, would be used to manage drainage on construction sites prior to discharge into existing drainage infrastructure (mitigation measures are outlined in Section 21.6).

## 21.4.2 Flooding

### Stations and ancillary infrastructure

As identified in Table 21-4, the Barangaroo Station, Martin Place Station and Waterloo Station sites are at risk of flooding during construction. Flooding of the construction sites could result in flood water entering the tunnels and excavations or stockpiles of construction materials (such as aggregate, fuels and other hazardous materials) and spoil being washed into nearby drainage lines and waterways.

Construction of the project also has the potential to alter local flood behaviour due to the obstruction of overland flow paths, loss of floodplain storage (for example, due to stockpiling construction materials and spoil) and the alteration to stormwater drainage infrastructure. Changes in existing flood behavior may have adverse effects on nearby properties or infrastructure by increasing flood levels or the likelihood of flooding.

Work at the Blues Point temporary site and at Martin Place and Waterloo station sites is expected to have minimal impacts on flooding.

As identified in Table 21-4, Barangaroo Station construction site would be located within Hickson Road that is currently subject to flooding. There will be changes (improvements) to the existing flood environment in this location as a result of drainage infrastructure upgrade work proposed as part of the Central Barangaroo development. Detailed construction planning for the Barangaroo construction site would consider flood risk at the site inclusive of any change to the flood environment as a result of the Central Barangaroo development.

### Tunnel dive structures

The Chatswood dive site would not be located in a flood prone area and because the site is not subject to inundation in flood events, any changes in levels at the site during construction of the project would not affect existing flood behaviour in the area.

As discussed in Table 21-4, the Marrickville dive site would be located within a flood-prone area and would be at risk of flooding during construction. The Marrickville dive site would cover an area bounded by Edinburgh Road, the existing rail line, Sydney Steel Road, and the Sydenham Storage Pit. Eastern Channel runs through the Marrickville dive site (southern).

Construction access within the Marrickville dive site (southern) area would require minor treatments (widening / reinforcement) to existing structures that span Eastern Channel. These treatments would not change the capacity of Eastern Channel in the construction phase.

Existing overland flow paths surrounding the Marrickville dive construction site include flows from the existing rail corridor and Edinburgh Road into Murray Street that then connect with Eastern Channel. Railway Parade and Edgeware Road also carry overland flows. Construction of the Marrickville dive site may obstruct other overland flow paths (that is, require diversion of overland flow) that may result in flooding of the construction site and / or adjacent properties.

The extent of flooding associated with the diversion of existing overland flow paths is currently unknown as detailed construction methods and sequencing have not yet been developed for this site. Potential flood impacts during construction would be managed through detailed construction planning, including the development of appropriate site layouts and staging of construction activities, to avoid or minimise obstruction of overland flow paths and limit the extent and duration of flow diversions required.

# 21.5 Potential impacts – operation

## 21.5.1 Surface hydrology and drainage infrastructure

The project has the potential to alter localised stormwater catchment flows and the operation of existing stormwater drainage networks due to:

- The introduction of additional drainage infrastructure or rerouting of existing drainage infrastructure (drainage infrastructure may need to be relocated and / or augmented to accommodate elements of the project such as station infrastructure)
- Increases to local drainage catchment areas
- Increases to impervious surface areas.

Potential impacts associated with increased local drainage catchment areas and increased runoff due to an increase in impervious surfaces may occur as a result of widening of the T1 North Shore Line corridor at Chatswood and at the Artarmon substation site. For example, widening of the T1 North Shore Line corridor to accommodate metro tracks would increase the drainage catchment within the corridor and increase the peak flow rate and volume of stormwater entering the existing drainage network.

At all other locations, the aboveground station infrastructure would be located within the footprint of existing development and would have a negligible impact on the existing surface hydrology. The runoff volume and flow rate would be similar to the existing conditions and there would be no impact to the capacity of the existing downstream stormwater infrastructure. All surface water from aboveground facilities and tunnel dive structures would also be collected by new drainage infrastructure and connected to existing stormwater systems.

Surface water from aboveground facilities and tunnel dive structures, including for the T1 North Shore Line corridor and at the Artarmon substation site, would be managed such that there would be no net increase in discharge rates from existing discharge locations into the downstream drainage system for all storm events. This management approach would not be required where it can be demonstrated that increased flow rates as a result of the project would not increase downstream flood risk.

On-site detention of stormwater would be introduced where surface water runoff rates are increased and where space for on-site detention is available. Where there is insufficient space for the provision of on-site detention, the upgrade of downstream infrastructure would be considered in the preparation of detailed design.

The southern services facility, located adjacent to the Marrickville dive site, would include a water treatment plant to treat all tunnel water prior to release into Eastern Channel. Conservatively, the rate of inflow of water into the tunnel has been estimated at about 12.5 liters per second. To accommodate treatment of this inflow and additional volumes of water (for example as a result of fire suppression) the water treatment plant design accommodates an inflow rate of up to 15 litres per second (470 megalitres per year).

The impact of this additional discharge on the performance of the stormwater channel is expected to be minimal as the additional flow would be negligible compared to the channel's existing capacity and the current volume of stormwater flows from the local catchment. There would be no potential erosion impacts as the receiving stormwater channel is fully concrete lined.

### 21.5.2 Flooding

#### Stations and ancillary infrastructure

As identified in Table 21-4 Barangaroo Station, Martin Place Station and Waterloo Station sites are at risk of flooding during operation. To avoid flooding impacts on project infrastructure, station entries aboveground rail system facilities would be located above the Probable Maximum Flood level and at least 0.5 metres above the 100-year average recurrence interval flood level, where feasible and reasonable. Where it is not feasible and reasonable to meet these design criteria, design would consider the need for sumps and pumps to manage any potential inflows into project infrastructure.

Aboveground stations and ancillary infrastructure would have a negligible impact on existing flood behaviour because the infrastructure would be located within the footprint of existing structures or located away from identified overland flow paths. The infrastructure would be compatible with the existing flood hazard and hydraulic function of the site and would have minimal impact to the community and emergency management response requirements given there would be minimal change to the existing flood behaviour.

#### Tunnel dive structures

To avoid inundation, the tunnel dive structures would be designed at or above the Probable Maximum Flood level for mainstream flooding. Drainage at the dive structures would be designed to manage flows for the 100-year average recurrence interval event.

No flooding impacts on, or as a result of, the project are anticipated at or surrounding the Chatswood dive site. To avoid flooding of the Marrickville dive structure, the metro tracks have been designed at a level of about 6.3 metres Australian Height Datum near the start of the dive structure, which is about 1.5 metres above the existing ground level. This design means that retaining walls for the dive structure and placement of metro tracks on new embankment material would be required within the floodplain at this location.

The flood hazard at this location in the 100-year average recurrence interval event is low, with high hazard areas being located at the Bolton Street low point (a flood storage location) and along Eastern Channel (a floodway). These flood storage and floodway areas would not be impacted by the design and hence the dive structure would not change the flood hazard at the site and would be compatible with the hydraulic function of the site.

The establishment of project infrastructure within flood-prone areas such as at the Marrickville dive structure has the potential to affect the existing flood behaviour surrounding the sites due to the loss of overland flow path capacity, loss of floodplain storage and change to local catchment boundaries (which could change the distribution of stormwater between existing drainage networks). Changes in existing flood behaviour may have adverse effects on nearby properties or infrastructure by increasing flood levels or the likelihood of flooding.

There are limitations to the design options available for the introduction of the Marrickville dive structure and associated metro tracks. The introduction of metro surface tracks on a viaduct-type structure (that allows stormwater to flow between the existing surface level and the underside of the viaduct) was considered, however this option was not viable because of the limited vertical clearance available, which is dictated by vertical clearance constraints under the station concourse and adjacent road bridge at Sydenham Station. As such, flood mitigation options considered are limited to drainage infrastructure treatments (see below).

Flood modelling at the Marrickville dive site was carried out to determine the potential impacts of the project on flood behaviour. As discussed in Section 21.3.2, the *Sydenham Flood Model* has been developed based on flood models provided by Marrickville Council and is consistent with the current available flood studies for the area. The following criteria, developed based on principles identified in the *Floodplain Development Manual* (NSW Government, 2005b), were used to assess the design:

- No additional private properties flooded, in events up to and including the 100-year average recurrence interval event
- Increases in flood levels during events up to and including the 100-year average recurrence interval are to be minimised, as far as practicable, particularly within private properties
- Any increase in flow velocity in a 100-year average recurrence interval event should not significantly increase the potential for soil erosion and scouring
- Running tunnels to be protected from inundation in the Probable Maximum Flood event.

The flood model considers the Chatswood to Sydenham project as well as elements of the Sydenham to Bankstown project located at and to the north of Sydenham Station. As such, the assessment at this location reflects the potential flooding impacts of both projects combined. The Sydenham to Bankstown Environmental Impact Statement would refine and update the flood modelling, if required, in the area between the Marrickville tunnel portal and Sydenham Station.

The design of the Marrickville dive structure was developed and incorporated into the flood model and was initially found not to comply with the above flood-related design criteria. Six flood mitigation options were developed and a preferred option selected for inclusion in the project design that best met the flood-related design criteria. Flood mitigation options considered are outlined in Table 21-5.

**Table 21-5 Flood mitigation options considered**

| Mitigation option | Number of grated inlets provided | Inlet spacing | Connection to Eastern Channel | Assumed blockage[1] |
|---|---|---|---|---|
| Option 1 | Five (about 3 x 1.2 metres) | About 50 metres | One culvert (about 1.2 x 0.9 metres) | 25 per cent |
| Option 2 | Six (about 3 x 1.2 metres) | About 25 metres | One culvert (about 1.2 x 0.9 metres) | 25 per cent |
| Option 3 | Six (about 3 x 1.2 metres) | About 10 metres | One culvert (about 1.2 x 0.9 metres) | 25 per cent |
| Option 4 | Six (about 3 x 1.2 metres) | About 10 metres | Two culverts (about 1.2 x 0.9 metres) | 25 per cent |
| Option 5 | 10 (about 3 x 1.2 metres) | About 10 metres | Two culverts (about 1.2 x 0.9 metres) | 10 per cent |
| Option 6 | 14 (about 3 x 1.2 metres) | About 10 metres | Two culverts (about 1.5 x 0.9 metres) | 10 per cent |

1 *'Assumed blockage' refers to an allowance made for reduced capacity performance of drainage infrastructure for modelling purposes*

As identified in Chapter 6 (Project description – operation), the preferred flood mitigation option is for the introduction of ten grated inlets (about 3 metres x 1.2 metres) at ten metre spacing on the eastern side of the proposed metro rail tracks, connected to Eastern Channel via two underground reinforced concrete box culverts (about 1.2 metres x 0.9 metres). On balance, mitigation option 5 best meets the assessment criteria and provides a realistic representation of the flood mitigation treatment that could constructed for the project in this location.

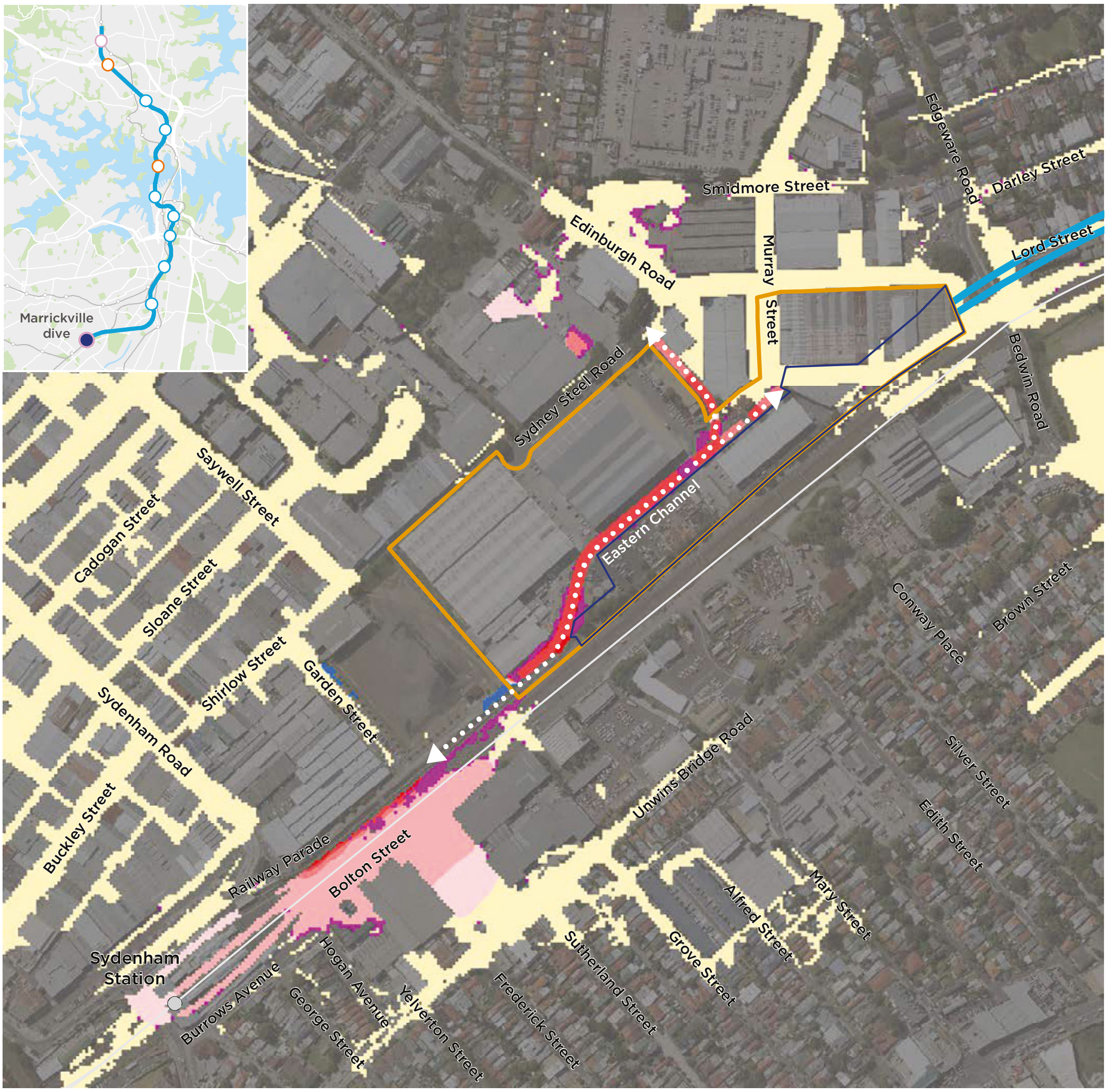
Table 21-6 identifies existing flood levels for the two year, five year, 10-year, 100-year and the probable maximum flood events at locations surrounding the Marrickville dive site and outlines the modelled changes in flood levels for those events with the project and inclusive of the preferred flood mitigation design treatment.

**Table 21-6 Flood depths for modelled flood events with and without the project**

| Flood event | | Location | | | | |
|---|---|---|---|---|---|---|
| | | Within private property (corner Hogan Ave and Bolton St) | Within road reserve (Bolton Street) | Within the Sydenham Station area | Generally within the rail corridor | Within rail corridor adjacent to proposed metro infrastructure |
| **Two year ARI event** | Existing flood depth | 430 mm | 1310 mm | 420 mm | 260 mm | 360 mm |
| | Increase with project | +20 mm | +20 mm | +70 mm | +70 mm | +260 mm |
| **Five year ARI event** | Existing flood depth | 510 mm | 1400 mm | 500 mm | 340 mm | 430 mm |
| | Increase with project | +20 mm | +30 mm | +80 mm | +80 mm | +320 mm |
| **Ten year ARI event** | Existing flood depth | 550 mm | 1450 mm | 530 mm | 390 mm | 450 mm |
| | Increase with project | +30 mm | +30 mm | +90 mm | +90 mm | +360 mm |
| **100 year ARI event** | Existing flood depth | 660 mm | 1570 mm | 640 mm | 580 mm | 570 mm |
| | Increase with project | +70 mm | +70 mm | +130 mm | +160 mm | +470 mm |
| **PMF event** | Existing flood depth | 800 mm | 1740 mm | 840 mm | 660 mm | 740 mm |
| | Increase with project | +380 mm | +380 mm | +420 mm | +570 mm | +600 mm |

In a 10-year average recurrence interval event, residual flood impacts have been modelled to include an increase in flood level within the rail corridor of between 90 and 360 millimetres (depending on location) and an increase of less than 30 millimetres in peak flood depth at the Bolton Street low point and at adjacent properties.

In a 100-year average recurrence interval event, there would be an increase of 70 millimetres in flood level within the Bolton Street low point and adjacent private property, and increases of 130 to 470 millimetres within the rail corridor. The changes in flood levels as a result of the project in the 100-year average recurrence interval event are shown in Figure 21-3.




KEY

- Chatswood to Sydenham
- Proposed operational area at surface
- Proposed construction site area
- Existing suburban rail
- Eastern Channel

100 year ARI event change in flood level (mm)

- > -20
- Negligible change
- 20 to 50
- 50 to 150
- 150 to 250
- 250 to 350
- 350 to 450
- 450 <
- Increase in flood extent

Indicative only, subject to design development

0 200 m

N

**Figure 21-3 Marrickville dive site – change in flood level as a result of the project in the 100-year average recurrence interval event**

In a probable maximum flood event, there would be increases in flood level of 150 to 250 millimetres on the southern side of the rail line on Bolton Street, Unwins Bridge Road, Sutherland Street, and Briar Lane, and increases greater than 450 millimetres on the northern side of the rail line at the intersection of Railway Parade and Sydenham Road.

The project would result in increased flood levels in areas that currently experience flooding (that is, no additional properties would be flood-affected as a result of the project in scenarios up to and including the 100-year average recurrence interval flood event). Flood levels would increase only in those parts of the road network and rail corridor that currently experience flooding (for example Bolton Street and the rail corridor from Bedwin road up to and including Sydenham Station). Bolton Street is currently not considered trafficable in the 100-year average recurrence interval event and there would be no additional sections of the rail corridor that experience 'above-rail' flooding as a result of the project.

Given that the increase in flood levels would only occur at areas already subject to flooding, the project would not require changes to existing community emergency management arrangements for flooding and there would not be increased social and / or economic costs to the community as consequence of flooding.

The frequency of disruptions to rail services in the area immediately north of Sydenham Station as a result of flooding is unknown, however given that there would be an increase in flood depth within the rail corridor there is a possibility that the frequency of flood-related disruptions to Sydney Trains operations in this area may increase. The design of this project and the Sydenham to Bankstown upgrade project would be reviewed with the intent of further reducing flood levels for events up to and including the 100-year annual recurrence interval, including at private properties, within the road reserve at Bolton Street and within the rail corridor around Sydenham Station. Consultation with Sydney Trains would be carried out during detailed design to ensure the frequency of rail service disruptions is not increased as a result of the project.

There would be no discernible change to flood velocities except within the Sydenham Station area where minor increases of up to 0.25 metres per second are predicted. There would also be no discernible change in flood duration in the area surrounding the Marrickville dive structure as a result of the project.

## 21.6 Mitigation measures

The mitigation measures that would be implemented to address potential impacts on hydrology and flooding are listed in Table 21-7 and Table 21-8.

**Table 21-7 Mitigation measures – flooding and hydrology – construction**

| Ref | Mitigation measure | Applicable location(s)[1] |
|---|---|---|
| **Flooding** | | |
| **FH1** | Detailed construction planning would consider flood risk at Barangaroo Station, Martin Place Station and the Waterloo Station construction sites. This would include identification of measures to avoid, where reasonable and feasible, construction phase flooding impacts on the community and on other property and infrastructure. | BN, MP, WS |
| **FH2** | The site layout and staging of construction activities at the Marrickville Dive site would avoid or minimise obstruction of overland flow paths and limit the extent of flow diversion required. | MDS |
| **FH3** | Overland flow diversions required during construction at the Marrickville dive site would meet the following criteria:<br>• Increases in flood levels during events up to and including the 100-year average recurrence interval would be minimised, particularly within private properties<br>• Any increase in flow velocity for events up to and including a 100-year average recurrence interval event would not increase the potential for soil erosion and scouring<br>• Dedicated evacuation routes would not be adversely impacted in flood events up to and including the probable maximum flood.<br>Construction planning for the Marrickville dive site would be carried out in consultation with the State Emergency Services and Marrickville Council. | MDS |

1 *STW: Surface track works; CDS: Chatswood dive site; AS: Artarmon substation; CN: Crows Nest Station; VC: Victoria Cross Station; BP: Blues Point temporary site; GI: Ground improvement works; BN: Barangaroo Station; MP: Martin Place Station; PS: Pitt Street Station; CS: Central Station; WS: Waterloo Station; MDS: Marrickville dive site; Metro rail tunnels: Metro rail tunnels not related to other sites (eg TBM works); PSR: Power supply routes.*

Table 21-8 Mitigation measures – flooding and hydrology – operation

| Ref | Mitigation measure | Applicable location(s)[1] |
|---|---|---|
| **Surface hydrology and drainage infrastructure** | | |
| **FH4** | Where feasible and reasonable, detailed design would result in no net increase in stormwater runoff rates in all storm events unless it can be demonstrated that increased runoff rates as a result of the project would not increase downstream flood risk. | STW, AS, MDS |
| **FH5** | Where space permits, on-site detention of stormwater would be introduced where stormwater runoff rates are increased. Where there is insufficient space for the provision of on-site detention, the upgrade of downstream infrastructure would be implemented where feasible and reasonable. | STW, AS, MDS |
| **FH6** | Detailed design would occur in consultation with Marrickville Council to ensure future drainage improvement works around the Marrickville dive site would not be precluded. | MDS |
| **FH7** | Consultation would be carried out with Marrickville Council to ensure flood-related outcomes of the project are consistent with any future floodplain risk management study and / or plan developed for the Marrickville Valley Catchment. | MDS |
| **FH8** | The frequency of Sydney Trains rail service disruptions due to flooding would not be increased in the vicinity of the Marrickville dive structure. | MDS |
| **FH9** | Design of the Marrickville dive structure would be reviewed to, where reasonable and feasible, further reduce flood levels for events up to and including the 100-year annual recurrence interval, including at private properties, within the road reserve at Bolton Street and around Sydenham Station.<br>Flood modelling to support detailed design would be carried out in accordance with the following guidelines:<br>• *Floodplain Development Manual* (NSW Government, 2005b)<br>• *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* (Department of Environment and Climate Change, 2007b)<br>• *Floodplain Risk Management Guide: Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments* (Department of Environment, Climate Change and Water, 2010c)<br>• *New guideline and changes to section 117 direction and EP&A Regulation on flood prone land, Planning Circular PS 07-003* (NSW Department of Planning, 2007). | MDS |

*1 STW: Surface track works; CDS: Chatswood dive site; AS: Artarmon substation; CN: Crows Nest Station; VC: Victoria Cross Station; BP: Blues Point temporary site; GI: Ground improvement works; BN: Barangaroo Station; MP: Martin Place Station; PS: Pitt Street Station; CS: Central Station; WS: Waterloo Station; MDS: Marrickville dive site; Metro rail tunnels: Metro rail tunnels not related to other sites (eg TBM works); PSR: Power supply routes.*